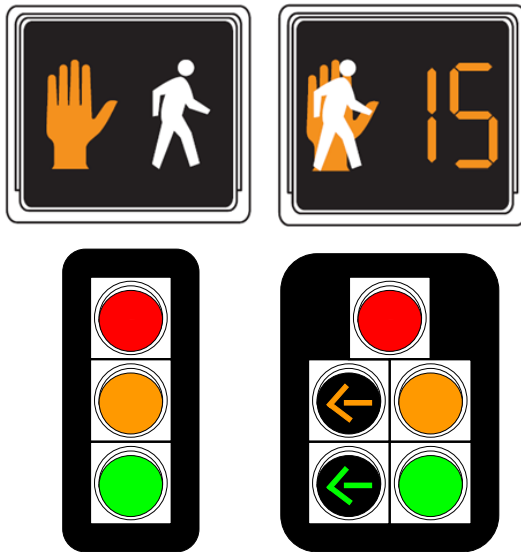


# Traffic Signal Design Guide & Timing Manual

June 2015



Alabama Department of Transportation

**TRAFFIC SIGNAL DESIGN GUIDE  
& TIMING MANUAL**

June 2015

*Prepared by:*

The University Transportation Center for of Alabama

Andrew Sullivan, P.E.  
Steven L. Jones, Ph.D.  
Elsa Tedla  
Ehsan Doustmohammadi

Steering Committee

Stacey Glass, P.E., ALDOT Maintenance Bureau  
Robert Blankenship, ALDOT Maintenance Bureau  
Tim Barnett, P.E., ALDOT Office of Safety Operations  
Stuart Manson, P.E., ALDOT Office of Safety Operations  
Gary Moore, ALDOT Traffic Design Section  
Kim Norton, ALDOT Traffic Design Section  
Preston Franklin, ALDOT Traffic Design Section  
Russell Dicks, ALDOT Traffic Design Section  
Menasse Kumlachew, ALDOT Maintenance Bureau

**DISCLAIMER**

**This manual provides guidelines and recommended practices for designing and timing traffic signals in the State of Alabama. This manual can not address or anticipate all possible field conditions that will affect a traffic signal design. It remains the ultimate responsibility of the design engineer to ensure that a signal design is appropriate for prevailing traffic and field conditions.**

# TABLE OF CONTENTS

1. Introduction	
1.1. Overview .....	1-1
1.2. Purpose .....	1-1
1.3. Scope and Organization.....	1-2
1.4. Organization.....	1-2
1.5. Terms and Definitions .....	1-3
1.6. Legend.....	1-3
1.7. Limitations.....	1-3
2. Traffic Signal Warrants and Justification	
2.1. Overview.....	2-1
2.2. MUTCD Warrant Guidelines.....	2-1
2.3. When a Traffic Study is Required.....	2-2
2.4. Submitting a Traffic Study to ALDOT.....	2-2
2.5. Preparing a Traffic Study for a Permit Signal.....	2-6
2.6. Right Turn Volume Adjustments.....	2-16
2.7. ALDOT Policy Regarding Warrants .....	2-18
2.8. Alternative Treatments .....	2-19
2.9. Access Management Considerations .....	2-21
2.10. Warrants for Removal of Traffic Signals .....	2-21
3. Signal Operation and Phasing	
3.1. Signal Phasing Definitions .....	3-1
3.2. ALDOT Typical Phase Numbering Scheme.....	3-4
3.3. Left Turn Phasing.....	3-4
3.4. Warrants for Left Turn Phasing .....	3-5
3.5. Types of Left Turn Phases .....	3-8
3.6. Protected-Permissive Phasing and Left Turn Traps .....	3-9
3.7. Lead-Lag and Lag-Lag Left Turn Phasing.....	3-11
3.8. Combining Permissive, Protected, and Protected-Permissive .....	3-11
3.9. Protected-Permissive Phasing for Dual Lefts .....	3-12
3.10. Split Phasing .....	3-12
3.11. Phase Overlaps .....	3-14
4. Signal Layout and Pole Placement	
4.1. Box Span .....	4-1
4.2. Z-Span .....	4-2
4.3. Suspended Box Span .....	4-3
4.4. Mast-Arm Installations .....	4-4
4.5. Pole Placement for Span Wire Designs .....	4-5
4.6. Computing Pole Heights for Span Wire Designs .....	4-8
4.7. Signal Pole Types for Span Wire Designs .....	4-11
4.8. Twin Mast-Arm Installations .....	4-14

5. Traffic Signal Heads	
5.1. Permissible Arrangements .....	5-1
5.2. Standard Head Sizes .....	5-4
5.3. LED Heads.....	5-4
5.4. Optically Programmed Heads .....	5-6
5.5. Louvers .....	5-7
5.6. Backplates .....	5-8
5.7. Signal Head Location .....	5-9
5.8. Offset Intersections .....	5-13
6. Vehicle Detection	
6.1. Inductive Loop Detectors.....	6-1
6.2. Video Detection .....	6-9
6.3. Microwave Detection .....	6-14
6.4. Magnetometers .....	6-15
6.5. Special Detection Circumstances .....	6-15
6.6. Summary .....	6-16
7. Pedestrian Features	
7.1. When to Provide Crosswalks .....	7-1
7.2. When to Provide Pedestrians Signal Heads.....	7-2
7.3. Pedestrian Phase Intervals .....	7-3
7.4. Actuated vs. Non-Actuated Ped Phasing.....	7-4
7.5. Pedestrian Signals and Channelizing Islands.....	7-5
7.6. Detection and Signs .....	7-6
7.7. Mounting Heights for Pedestrian Signals.....	7-6
7.8. Pedestrian Phasing .....	7-7
7.9. Countdown Pedestrian Displays.....	7-8
7.10. Handicap Accessible Pedestrian Signals .....	7-8
7.11. Pedestrian Hybrid Beacons.....	7-8
8. Power Service, Signal, Wiring, and Conduit	
8.1. Power Service.....	8-1
8.2. Signal Wiring.....	8-6
8.3. Conduit and Junction Boxes.....	8-13
8.4. Junction Boxes.....	8-18

9. Signal Pre-Emption	
9.1. Types of Signal Pre-Emption.....	9-1
9.2. Railroad Pre-Emption.....	9-1
9.3. Emergency Pre-Emption .....	9-9
9.4. Transit Pre-Emption .....	9-16
9.5. Pedestrian Pre-Emption .....	9-16
9.6. Pre-Emption Hierarchy.....	9-16
9.7. Operational Impacts of Signal Pre-Emption.....	9-16
10. Signal Interconnect and Coordination Methods	
10.1. Time-Based Coordination (no interconnect) .....	10-1
10.2. Hardwire Interconnect.....	10-2
10.3. Twisted Pair Interconnect.....	10-3
10.4. Advanced Interconnect Systems .....	10-4
10.5. Fiber Optic Interconnect.....	10-5
10.6. Spread Spectrum Radio Interconnect.....	10-16
10.7. Summary of Interconnect Types.....	10-18
11. Signing and Striping	
11.1. Regulatory Signs .....	11-1
11.2. Warning Signs .....	11-5
11.3. Advance Warning Flashers .....	11-7
11.4. Striping and Pavement Markings.....	11-12
12. The Controller Cabinet	
12.1. Cabinet Types and Dimensions .....	12-1
12.2. Cabinet Location and Mounting .....	12-2
12.3. Cabinet Hardware .....	12-4
12.4. Cabinet Foundations .....	12-10
12.5. Type 170 and 2070 Controllers .....	12-10
12.6. Uninterruptible Power Supply .....	12-12
13. Traffic Signal Quantities	
13.1. ALDOT Quantities.....	13-1
13.2. Units of Measurement.....	13-2
13.3. Miscellaneous Quantities .....	13-2

14. Signal Timing Concepts	
14.1. Pre-Timed vs. Actuated Signals .....	14-1
14.2. Timing Pre-Timed Signals .....	14-2
14.3. Yellow Clearance Interval .....	14-7
14.4. All-Red Interval .....	14-11
14.5. Timing for Actuated Signals .....	14-12
14.6. Semi-Actuated Signals .....	14-26
14.7. Other Controller Settings.....	14-26
14.8. Flashing Mode .....	14-27
14.9. Pedestrian Timing .....	14-28
15. Typical Plan Set	
15.1. Elements of a Plan Set .....	15-1
15.2. Sample Plan Set .....	15-9
Appendix A – Glossary of Terms .....	A-1

# ***Chapter 1***

## ***Introduction***

### **1.1 Overview**

Traffic signals are one of the most common forms of traffic control in use and offer potential benefits to intersection operations, capacity, and safety. However, traffic signals also have potential drawbacks and if not designed properly can have adverse impacts on motorist delay and safety. The purpose of this design guide is to present standard practices for the design and timing of traffic signals for the Alabama Department of Transportation (ALDOT). These standards include:

- Traffic signal justification
- Traffic signal design
- Traffic signal timing

The guidelines presented herein are to be applied to all traffic signals designed for ALDOT as well as all signals installed on state and federal routes. They shall also be used for all traffic signals designed as part of ALDOT sponsored projects.

In accordance with Alabama Law (Title 32-5A-36), all traffic control devices used on STATE, US, and Interstate routes within the State of Alabama shall be pre-approved prior to use to ensure they conform to state and federal regulations. This is accomplished through the ALDOT [“Materials, Sources, and Devices with Special Acceptance Requirements”](#) document, known as the APL (Approved Products List). This document is a listing of traffic related items that are approved for use within the State of Alabama. Equipment used on any project shall be pre-approved and found either on this listing or in ALDOT specifications.

### **1.2 Purpose**

This document, the *Alabama Department of Traffic Signal Design Guide and Timing Manual* (referred to herein as Signal Manual) is to serve as the official document to provide guidance for the design and operation of signalized intersections in the State of Alabama. It is to provide designers, and contractors with guidance on the physical design and specification of traffic signal timing parameters at signalized intersections on state-maintained roads throughout Alabama. It is intended to ensure consistency across the state in the implementation of new

installations and in the case of retrofit/redesign of existing intersections, safe and efficient traffic operations.

### 1.3 Scope and Organization

This Signal Manual applies to signalized intersection design and operation and should therefore be used in conjunction with other guidelines that relate to intersection design, namely:

- [Alabama Department of Transportation Access Management Manual](#)
- [AASHTO: A Policy on Geometric Design of Highways and Streets](#)
- [Manual of Uniform Traffic Control Devices \(MUTCD\)](#)

### 1.4 Organization

The Signal Manual is organized as follows:

Chapter 1 - **Introduction:** This chapter provides an introduction to the manual and discusses the scope and limitations to the guide.

Chapter 2 – **Traffic Signal Warrants and Justification:** This chapter provides an overview of ALDOT policies and criteria regarding the justification of traffic signals.

Chapter 3 – **Signal Operation and Phasing:** This chapter discusses traffic signal phasing and its relationship to signal operation and design. Standard phasing schemes employed by ALDOT are presented as well as discussions of their impacts on signal efficiency and safety.

Chapter 4 – **Signal Layout and Pole Placement:** This chapter discusses traffic various possible configurations of traffic signal layouts and provides guidance on the placement of traffic signal mounting poles.

Chapter 5 – **Traffic Signal Heads:** This chapter covers the permissible head types, arrangements, and location criteria.

Chapter 6 – **Vehicle Detection:** This chapter describes available vehicle detection technologies and provides guidance on their installation and use.

Chapter 7 – **Pedestrian Features:** This chapter discusses the applications of pedestrian phasing and features to signal designs in Alabama. All pedestrian features shall conform to the MUTCD, current ALDOT adopted edition.

Chapter 8 – **Power service, Signal, Wiring, and Conduit:** This Chapter presents ALDOT requirements for signal wiring and conduit. All power service, signal wiring, and conduit on state routes shall conform to Alabama DOT standards and specifications.

Chapter 9 – **Signal Pre-Emption:** This chapter presents guidelines for implementing the most common types of signal pre-emption.

Chapter 10 – **Signal Interconnect and Coordination Methods:** This chapter discusses techniques and technologies for interconnecting traffic signal systems to provide coordinated signal operations.



Chapter 11 – **Signing and Striping**: This chapter presents only the most commonly required signs and striping associated with traffic signals.

Chapter 12 – **The Controller Cabinet**: This chapter presents a brief discussion of the types, size, and location of a controller cabinet and the most common hardware found in it.

Chapter 13 – **Traffic Signal Quantities**: This chapter presents general guidelines for preparing traffic signal quantities for an ALDOT plan set.

Chapter 14 – **Signal Timing Concepts**: This chapter presents a discussion of the fundamentals of signal timing for isolated signals and signals in coordinated systems that may operate isolated during certain periods of the day.

Chapter 15 – **Typical Plan Set**: This chapter presents a typical ALDOT Traffic Signal plan set and describes the requirements for a complete submittal.

## 1.5 Terms and Definitions

A glossary of terms is provided in appendix of this document.

## 1.6 Legend

All symbols used in this document conform to ALDOT CAD and drafting standards. The most commonly used symbols are shown in Figure 1.1.

## 1.7 Limitations

The materials in this design guide are current at the time of publishing. ALDOT will update this manual as needed to reflect changing practices and new design standards. It is the responsibility of the designer to check the ALDOT website periodically for updates to this manual. ALDOT recommends that the designer check for updates prior to each new signal design.

**ⓘ This manual provides guidelines and recommended practices for designing and timing traffic signals in the State of Alabama. This manual cannot address or anticipate all possible field conditions that will affect a traffic signal design. It remains the ultimate responsibility of the design engineer to ensure that a signal design is appropriate for prevailing traffic and field conditions.**

ELECTRICAL BOXES		MISCELLANEOUS EQUIPMENT	
	EXISTING	EXISTING	REQUIRED
METALLIC PULL BOX	[PB]	□→	■→ (#)
FIBER OPTIC COMMBOX TYPE F1	[F1]	□→	■→ (#)
FIBER OPTIC COMMBOX TYPE F2	[F2]	↗	↗
TRAFFIC SIGNAL JUNCTION BOX	[J]	↗	↗
<b>CABLE IN CONDUIT</b>			
	EXISTING		REQUIRED
FIBER OPTIC CABLE IN CONDUIT (UNDERGROUND)	-- fo --	— —	— —
FIBER OPTIC CABLE IN CONDUIT (UNDERGROUND WITH CONCRETE)	-- fowc --	∪	∪
FIBER OPTIC CABLE IN CONDUIT (BRIDGE ATTACHED)	-- fo ● --	∪	∪ ●
FIBER OPTIC CABLE (AERIAL INSTALLATION)	-- ofo --	∪	∪
INTERCONNECT CABLE IN CONDUIT (UNDERGROUND)	-- ui --	∪	∪
INTERCONNECT CABLE (AERIAL INSTALLATION)	-- oi --	∪	∪
CONDUIT	-- c --	∪	∪
ENCASEMENT	[ ]	∪	∪
OVERHEAD ELECTRIC	-- oe --	∪	∪
BURIED ELECTRIC	-- be --	∪	∪
<b>VEHICULAR DETECTORS</b>			
	EXISTING		REQUIRED
TRAFFIC SIGNAL HEAD	□→	□→	■→ (#)
TRAFFIC SIGNAL HEAD WITH BACKPLATE	□→	□→	■→ (#)
PEDESTRIAN SIGNAL HEAD	↗	↗	↗
8 FOOT PEDESTAL POLE AND PEDESTRIAN SIGNAL HEAD	↗	↗	↗
PEDESTAL MOUNTED FLASHING WARNING SIGNAL WITH SIGN	∪	∪	∪
PEDESTAL MOUNTED ILLUMINATED SCHOOL ZONE SIGN	SCH ∪	SCH ∪	SCH ∪
SPAN/MASTARM MOUNTED SIGN	— —	— —	— —
OMNI DIRECTIONAL ANTENNA	∪	∪	∪
DIRECTIONAL ANTENNA	∪	∪	∪
EMERGENCY VEHICLE PREEMPTION SENSOR	EVP ∪	EVP ∪	EVP ∪
BLANKOUT MESSAGE SIGN	[B]	[B]	[B]
TRAFFIC CONTROL CENTER	[H]	[H]	[H]
HIGHWAY ADVISORY RADIO	[H]	[H]	[H]
HUB BUILDING	[H]	[H]	[H]
DYNAMIC MESSAGE SIGN (OVERHEAD)	∪	∪	∪
DYNAMIC MESSAGE SIGN (ROADSIDE)	∪	∪	∪
DYNAMIC MESSAGE SIGN (CANTILEVER)	∪	∪	∪

(NOTE: (#) INDICATES SIGNAL HEAD NUMBER)

Figure 1.1 – ALDOT standard legend

<u>VEHICULAR DETECTORS</u>		<u>POLES</u>	
	EXISTING		EXISTING
PRESENCE LOOP DETECTOR		METAL TRAFFIC SIGNAL POLE	
QUADRUPOLE LOOP DETECTOR		CONCRETE TRAFFIC SIGNAL POLE	
6' x 6' LOOP DETECTOR		METAL MASTARM TRAFFIC SIGNAL POLE	
VEHICLE DETECTION CAMERA		CLASS 3 WOOD SERVICE POLE WITH DISCONNECT	
VIDEO DETECTION ZONE		CAMERA POLE	
RADAR DETECTION UNIT		WOOD POLE	
		DOWN GUY	
		LUMINAIRE	
			REQUI RED

# ***Chapter 2***

## ***Traffic Signal Warrant & Justification***

### **2.1 Overview**

When properly designed and implemented, traffic signals can provide many benefits to traffic operations, such as:

- Improved intersection efficiency
- Improved intersection safety
- Reduced delays for many movements

It should be remembered, though, that unnecessary or unjustified traffic signals can have negative impacts on traffic operations. Traffic signals typically increase delays on the major thru movements and signals that are spaced too closely together can seriously impede traffic progression on arterial streets.

It is the goal of the Alabama Department of Transportation (ALDOT) that traffic signals be installed only when justified and only after other reasonable alternatives have been considered. This section provides an overview of ALDOT policies and criteria regarding the justification of traffic signals.

### **2.2 MUTCD Warrant Guidelines**

ALDOT follows the general guidelines for traffic signal warrants presented in the [Manual on Uniform Traffic Control Devices](#) (MUTCD, current ALDOT adopted version) published by the FHWA. The MUTCD presents 9 warrants for traffic signals:

1. Eight Hour Vehicular Volume
2. Four Hour Vehicular Volume
3. Peak Hour Volume
4. Pedestrian Volume
5. School Crossing
6. Coordinated Signal System
7. Crash Experience
8. Roadway Network
9. Intersection Near a Grade Crossing

**It should be noted that the satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.**

Warrants 1 and 2 are based on traffic volumes and are the most common warrants used to indicate that further study is required to determine the need for traffic signal installations. Warrants 3 through 9 consider unique volume, roadway, pedestrian, or accident characteristics and are evaluated by ALDOT on a case by case basis.

ALDOT has developed a detailed worksheet that includes all 9 warrants and must be submitted, along with all supporting data, when requesting formal approval for a traffic signal. A copy of the worksheet is provided in this section and can be downloaded from the ALDOT website at:

[http://www.dot.state.al.us/maweb/maintenance\\_bureau\\_pub.htm](http://www.dot.state.al.us/maweb/maintenance_bureau_pub.htm)

### **2.3 When a Traffic Study is Required**

ALDOT requires a traffic signal study for all traffic signals installed or modified under the following situations:

- Federally funded projects
- State projects using federal funds
- Permit applications (see description)

For traffic signals installed, modified, or encompassed under federally funded projects or state projects using federal funds, the designer shall submit a signal study according to the guidelines described in the following sections. A traffic signal study shall be submitted for each new signal installation in the project, and a warrant analysis for existing signals that will be modified or remain in place at the conclusion of the project.

For traffic signals installed or modified on a state or federal route under a permit application, the designer should first contact the Region/Area Traffic Engineer to discuss the appropriateness of a traffic signal at the desired location. The Region/Area Traffic engineer may arrange an inspection of the site and collect preliminary count information to determine if the site is a realistic candidate for signalization. If the Region/Area Traffic Engineer determines that a signal may be justified, the designer should then proceed with a formal Traffic Impact Study as described in Appendix A of the ALDOT Permit Manual.

For traffic signals installed or modified under state projects that do not use federal funds, ALDOT may require a traffic study; however this is determined on a case by case basis. The designer should contact the Region/Area Traffic Engineer to determine if a formal traffic study is required.

### **2.4 Submitting a Traffic Study to ALDOT**

ALDOT has established standards for the preparation and submission of traffic studies. All traffic studies shall conform to these guidelines or they will be returned by ALDOT without review.

### 2.4.1 Traffic Studies for Unsignalized Intersections

A traffic study for an unsignalized intersection shall contain the following information:

1. A minimum of 12 continuous hours of hourly approach counts for each approach to the intersection. The counts shall be for the same 12 hour time period and same day on each approach. Counts shall be taken on a typical day, unaffected by holidays or special events, preferably Tuesday through Thursday. Monday AM and Friday PM counts can be skewed in relation to the other days. **ADT counts shall not be used, nor will they be accepted, for existing intersections.**
2. Peak-hour turning movement counts for each approach of the intersection. At a minimum, this should cover the AM and PM peaks. It is preferred that these counts be taken on the same day as the approach counts, but counts collected on a day comparable to the day of the approach counts will be acceptable.
3. A detailed, geometric layout of the intersection. Each approach shall show the following where applicable: number of approach lanes, approach lane usage (left only, thru/left combined, etc.), lane width, turn lane length, channelization, dimensions, and sight distance limitations. Also included should be details of any medians or shared left-turn center lanes and any other intersection details that might be pertinent to the traffic study (driveways, median crossovers, etc). The distance to any downstream or upstream signal from any approach within ½ mile of the intersection shall be noted. **Note: This layout shall not show any proposed signals, but may show proposed roadway improvements.**
4. A completed 'Traffic Signal Warrant Worksheet'. This form can be found on the ALDOT website at: [http://www.dot.state.al.us/maweb/maintenance\\_bureau\\_pub.htm](http://www.dot.state.al.us/maweb/maintenance_bureau_pub.htm)

All eight pages of this worksheet shall be included for the intersection. **Note: Reports generated by analysis software are acceptable provided they show the status of all warrants and applicable data verifying a satisfied warrant.**

5. A vicinity map of the area where the intersection is located. The map shall provide enough detail to easily locate the intersection (scale: 1" = ½ mile or less).
6. Traffic signal timing and peak hour movement counts for any signalized intersection within ½ mile of the intersection in question. If the signalized intersections are part of a coordinated signal system and changes to existing timings are proposed, movement counts shall be provided for all intersections included in the system.
7. An intersection capacity analysis shall be included, to include any downstream and/or upstream signals within ¼ mile of the intersection. If engineering judgment dictates that downstream and/or upstream signals have no impact on the intersection in question, this shall be noted in the analysis for clarification. If these downstream and/or upstream signals are part of a coordinated signal system and changes to the existing timings are proposed, intersection capacity analysis shall be provided for all intersections included in the system.
8. If pedestrian signal heads are to be installed at the intersection in question, justification for these heads shall be in accordance with **Section 4, 'Application of Pedestrian Signal Heads'** in the currently adopted edition of the MUTCD and Section 7 of this manual. Data supporting the inclusion of pedestrian heads shall be included with this study or these warrants will be disqualified and the pedestrian heads will be removed from the installation.

9. All data and applicable information shall be provided for the justification of Warrants 6, 7, 8, and/or 9 being satisfied. Warrant 7, Crash Experience, requires an independent road safety assessment be completed in conformance with the [ALDOT Road Safety Assessment Guidance Manual](#). Simply marking boxes and inserting data without any supporting documentation will be grounds for not accepting these warrants.

#### 2.4.2 Traffic Studies for Signalized Intersections

On state projects utilizing federal funds, the designer is required to verify that any signals currently operating within the scope of the roadway work still satisfy signal warrants. For these instances, the following information shall be included when submitting traffic studies for existing signals.

1. A minimum of 12 continuous hours of hourly approach counts for each approach to the intersection. The counts shall be for the same 12 hour time period and same day on each approach. Counts shall be taken on a typical day, unaffected by holidays or special events, preferably Tuesday through Thursday. Monday AM and Friday PM counts can be skewed in relation to the other days. **ADT counts shall not be used, nor will they be accepted, for existing intersections.**
2. A detailed, geometric layout of the intersection. Each approach shall show the following where applicable: number of approach lanes, approach lane usage (left only, thru/left combined, etc.), lane width, turn lane length, channelization, dimensions, and sight distance limitations. Also included should be details of any medians or shared left-turn center lanes and any other intersection details that might be pertinent to the warrant study/analysis (driveways, median crossovers, etc). Any proposed changes to the intersection and approaches should be shown as well.
3. A completed 'Traffic Signal Warrant Worksheet' for each intersection studied. This form can be found on the ALDOT internet site at:

[http://www.dot.state.al.us/maweb/maintenance\\_bureau\\_pub.htm](http://www.dot.state.al.us/maweb/maintenance_bureau_pub.htm)

All eight pages of this worksheet shall be included for each intersection. **Note: Reports generated by analysis software are acceptable provided they show the status of all warrants and applicable data verifying a satisfied warrant.**

4. Should the intersection not meet any of the first three Warrants (1, 2, or 3), then some other valid documentation shall be required to maintain the signal, based on any of the other Warrants (4 through 9) at the intersection in question. If a traffic signal no longer satisfies any warrants for a given intersection, then the removal of the signal shall be accomplished in accordance to the guidance set forth in [MUTCD Section 4](#), 'Basis of Installation or Removal of Traffic Control Signals', current ALDOT adopted edition and Chapter 5.0 'Traffic Control Signal Removals' of the ITE Recommended Practice "[Guidelines for the Activation, Modification, or Removal of Traffic Control Signals](#)".

#### 2.4.3 Traffic Studies for Proposed Intersections

The following information shall be included when submitting a traffic study for the signalization of an intersection that currently does not exist.

### 2.4.3.1 New Intersection on Existing Roadway

This is applicable where a business or development will access an existing state or U.S. route, or Interstate ramp; any new streets/roads that are either re-located or extended to state or U.S. route, or Interstate ramp; or any work using federal or state funds, regardless of the classification of the road being intersected and signalized. A traffic study shall include the following information:

- a. A scaled drawing showing the following information where applicable: number of approach lanes, approach lane usage (left only, thru/left combined, etc.), lane width, turn lane lengths (storage), channelization dimensions, and sight distance limitations. Include any other intersection details that might be pertinent to the warrant study/analysis (driveways, median crossovers, etc). **Note: This layout shall not show any proposed signals for the proposed intersection.**
- b. A drawing noting any changes being proposed to the existing roadway(s) being intersected, including any changes to the current geometric layout, road details, medians, or shared left-turn lanes. The diagram shall also include driveways, median crossovers, etc that need to be considered in the analysis. Finally, the diagram shall note the distance to any downstream and/or upstream signal from any approach within  $\frac{1}{2}$  mile of the proposed intersection. **Note: This layout shall not show any proposed signals for the proposed intersection.**
- c. A minimum of 12 continuous hours of traffic counts for each direction of the **existing roadway** at or near the proposed intersection. The counts shall be for the same 12 hour time period and collected on the same day for each direction. These shall be taken on a typical day, unaffected by holidays or special events, preferably Tuesday through Thursday. Monday AM and Friday PM counts can be skewed in relation to the other days.
- d. For a development creating a new intersection or adding a leg to an existing one, a detailed trip generation study for the proposed development is required. The study shall include projected peak hour movement counts and their impact on the existing traffic volumes. The analysis shall also include percentage breakdowns for new and intercept traffic distributions along with the supporting rationale for these percentages.
- e. For streets/roads being extended, a detailed traffic study showing expected hourly traffic flow for a 12-hour continuous period on a typical day, denoting percentage breakdowns for traffic generation and turning movements. The analysis shall include supporting rationale for the distribution.
- f. Traffic signal timing and peak hour movement counts for any signalized intersection within  $\frac{1}{2}$  mile of the intersection in question. If the signalized intersections are part of a coordinated signal system and changes to existing timings are proposed, movement counts shall be provided for all intersections included in the system.
- g. An intersection capacity analysis shall be included, to include any downstream and/or upstream signals within  $\frac{1}{4}$  mile of the intersection. If engineering judgment dictates that downstream and/or upstream signals have no impact on the intersection in question, this shall be noted in the analysis for clarification. If these downstream and/or upstream signals are part of a coordinated signal system and changes to the existing timings are proposed, intersection capacity analysis shall be provided for all intersections included in the system.



- h. For streets/roads being re-located or re-aligned:
  - 1) A minimum of 12 continuous hours of hourly approach counts for each approach to the existing intersection.
  - 2) A detailed geometric layout of the existing intersection as denoted in section 2.4.3.1a above. If this intersection is currently signalized, showing the signal heads is required in this layout.
  - 3) Projected hourly approach counts for a minimum of 12 continuous hours for each approach to the new intersection. Also included should be percentage breakdowns for any traffic redistribution or generation and supporting rationale for these assumptions.

#### 2.4.3.2 New Intersection on New Roadway

This section applies to the construction or extension of state or U.S. route, or Interstate ramp where either exit ramps or connector roads are created to direct new traffic in an area. This will also apply to any routes and intersections constructed with federal and/or state funds, regardless of the classification of the road being constructed. A traffic study shall include the following information:

- a. A scaled drawing showing the relationship of the new road(s) to the existing roadway network.
- b. A detailed layout of the new road(s) showing the following where applicable: number of lanes, lane usage (left only, thru/left combined, etc.), lane width, turn lane lengths (storage), channelization dimensions, sight distance limitations, and distances between the new intersection and where the new road will tie in to any existing road(s). It should also include any other intersection details that might be pertinent to the warrant study/analysis (driveways, median crossovers, etc). **Note: This layout shall not show any proposed signals for the proposed intersection.**
- c. Projected ADT/AADT (Average Daily Traffic) counts are permissible for an initial review of the intersection to determine whether further study is required. This data will only be valid for a peak-hour computation for a possible Warrant 3 satisfaction. Rationale shall be provided for the choice of values and constants (D, K, etc.) used in the determination of the peak-hour volume(s).
- d. Should Warrant 3 appear to be satisfied in the above analysis, then a more detailed analysis of traffic generation is required. This analysis shall show percentage breakdowns of traffic generation and turning movements with supporting rationale for these assumptions.

## 2.5 Preparing a Traffic Study for a Permit Signal

The above guidelines apply to signals installed as part of an ALDOT project. Signals installed under ALDOT permit are those that are designed and installed by a municipality or private developer and maintained by a public entity other than ALDOT, generally referred to as the Maintaining Agency. In addition to satisfactorily completing a Traffic Impact Study as referred to in Section 2.4, the applicant for a permit signal shall also submit an Agreement for the Installation and/or Operation & Maintenance of Traffic Control Signals and/or Roadway Lighting.

Justifying and installing a traffic signal under an ALDOT permit is a more complex process than installing a signal as part of a State project and typically involves a much longer approval process. Some general guidelines for the permit process are as follows:

1. A Traffic Signal Agreement must be obtained for any signal installed on a State or U.S. route, or Interstate ramp that is not part of a State project. This includes signals installed by cities, counties, and private developers.
2. Traffic signals installed on non-State routes (e.g., county, city, or private roads) do not require an ALDOT signal agreement.
3. A permit signal must be operated and maintained by a public entity (county or municipal government). **ALDOT cannot enter into signal agreements with private entities, such as developers or property owners.** Signal agreements must therefore be executed by the local government that will ultimately operate and maintain the signal. Every signal agreement form shall be accompanied by a sealed and notarized resolution by the local government agency (typically a city or county council) stating they will assume operation and maintenance responsibilities for the signal once installed.
4. A signal agreement form shall be submitted whether the signal in question is a new installation or modification of an existing signal.

Following is the standard process for obtaining a traffic signal permit agreement. Typical time frames for each step are provided to give the designer a feel for the length of the process and ensure that enough time is allowed for securing a permit. Actual times will, of course, vary.

**Table 2.1 – Signal Permit Application Process**

Step	Typical Time Frame
1. Applicant contacts ALDOT Region/Area Traffic Engineer and arranges inspection of proposed signal location. If the Region/Area Traffic Engineer determines that the location may be a candidate for signalization, the applicant may proceed to Step 2.	1 week
2. Applicant submits Traffic Study to ALDOT Region/Area Traffic Engineer. Traffic Study shall conform to all requirements described in Section 2.3 and 2.4 of this manual.	varies
3. ALDOT Region/Area Traffic Engineer reviews traffic study.	3 weeks
4. Applicant submits the following items to the ALDOT Region/Area Traffic Engineer: <ul style="list-style-type: none"> <li>• sealed traffic signal design plans</li> <li>• completed traffic signal agreement form†</li> <li>• completion of applicable permit forms††</li> <li>• sealed copy of council resolution to assume maintenance responsibility for signal</li> </ul>	Design time varies  Council resolution and signatures typically require 4 weeks
5. Region/Area Traffic Engineer reviews signal plans, agreement, and permit forms and provides comments to applicant. Applicant submits revised plans, agreement, and permit forms as required.	4 weeks
6. Region/Area Traffic Engineer conducts final review and issues permit and agreement.	2 weeks
<b>Typical ALDOT Review Time (excludes study and design)</b>	10 weeks
<b>Typical Time Required for Complete Approval Process</b>	14 - 18 weeks

† The ALDOT Signal Agreement form can be obtained at the ALDOT Maintenance Bureau intranet (local) website, otherwise, contact the Region/Area Traffic Engineer. The form is formatted for 8-1/2" x 11" letter paper and shall be printed at that size.

†† The proper Permit form shall be obtained from the Region/Area Permit Engineer. The form is formatted for 8-1/2" x 11" letter paper and shall be printed at that size.

### TRAFFIC SIGNAL WARRANTS

City/Town: \_\_\_\_\_ Analysis Performed By: \_\_\_\_\_  
 County: \_\_\_\_\_ Date Analysis Performed: \_\_\_\_\_  
 Division: \_\_\_\_\_ Project Number if Applicable: \_\_\_\_\_  
 Data Date: \_\_\_\_\_ Weather Conditions: \_\_\_\_\_  
 Major Route: \_\_\_\_\_ Appr. Lanes: \_\_\_\_\_ Critical Approach Speed (mph): \_\_\_\_\_  
 Minor Route: \_\_\_\_\_ Appr. Lanes: \_\_\_\_\_

**Volume Level Criteria**

1. Is the critical speed of major street traffic > 70 km/h (40 mph) ?  Yes  No

2. Is the intersection in a built-up area or isolated community of <10,000 population?  Yes  No

If Question 1 or 2 above is answered "Yes", then use "70%" volume level  70%  100%

**WARRANT 1 - EIGHT-HOUR VEHICULAR VOLUME**

Warrant 1 is satisfied if Condition A or Condition B is "100%" satisfied. Satisfied:  Yes  No

Warrant is also satisfied if both Condition A and Condition B are "80%" satisfied, given adequate trials of other remedial measures have been tried.

Adequate trial(s) of other remedial measures tried:  Yes  No

*List Remedial Measures Tried (Required for 80% Combination of A & B)*

**Condition A - Minimum Vehicular Volume & Condition B - Interruption of Continuous Traffic**

100% Satisfied:  Yes  No

(Used if neither Condition A or B is satisfied) 80% Satisfied:  Yes  No

	(volumes in veh/hr)	Minimum Requirements		Eight Highest Hours									
		Approach Lanes		Volume Level		1		2 or more					
<b>W - 1A</b> 100%	Both Approaches on Major Street	500	350	600	420								
	Highest Approach on Minor Street	150	105	200	140								
<b>W - 1B</b> 100%	Both Approaches on Major Street	750	525	900	630								
	Highest Approach on Minor Street	75	53	100	70								
<b>W - 1A</b> 80%	Both Approaches on Major Street	400	280	480	336								
	Highest Approach on Minor Street	120	84	160	112								
<b>W - 1B</b> 80%	Both Approaches on Major Street	600	420	720	504								
	Highest Approach on Minor Street	60	42	80	56								

## TRAFFIC SIGNAL WARRANTS

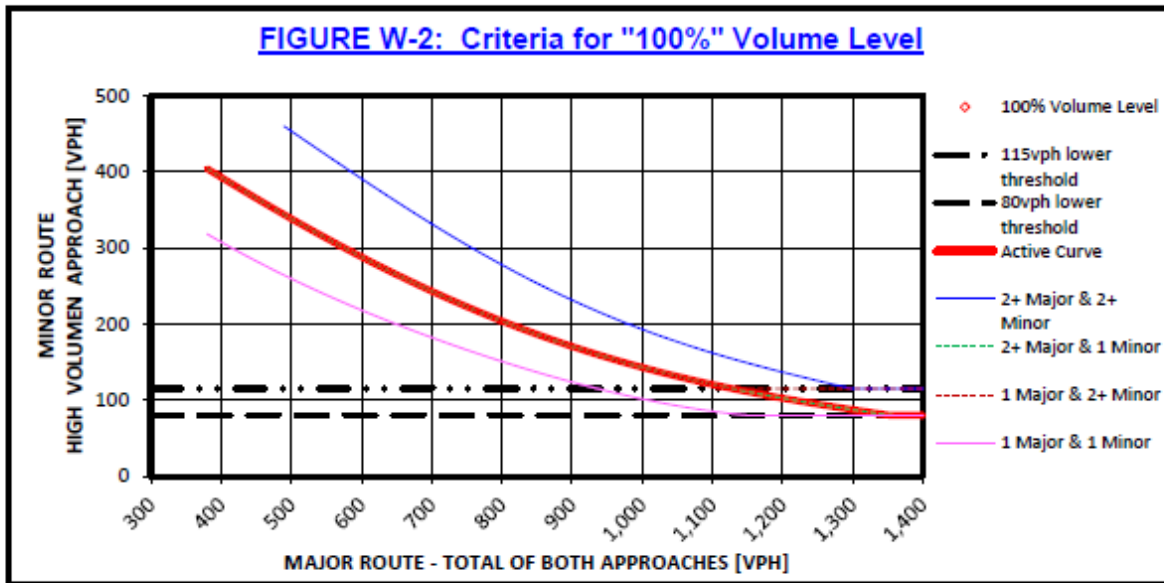
### WARRANT 2 - FOUR-HOUR VEHICULAR VOLUME

Satisfied:  Yes  No

*If all four points lie above the appropriate line, then this warrant is satisfied.*

(Volumes in veh/hr)	Four Highest Hours			
SUM of Both Approaches on Major Street				
Highest Minor Street Approach				

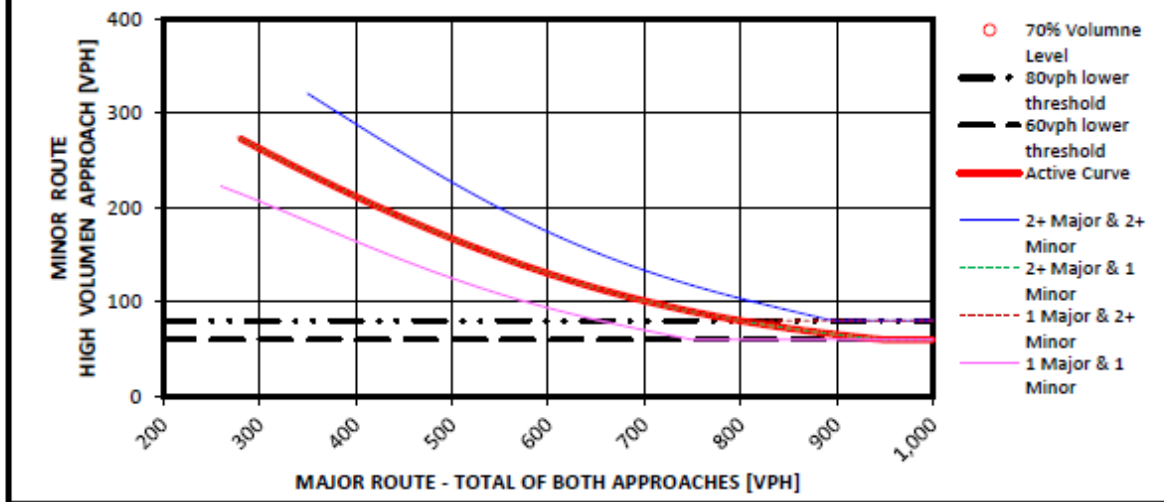
**FIGURE W-2: Criteria for "100%" Volume Level**



*\* Note: 115 vph applies as the lower threshold volume for a minor route approach with two or more lanes and 80 vph applies as the lower threshold volume threshold for a minor route approach with one lane.*

**FIGURE W-2: Criteria for "70%" Volume Level**

(Community less-than 10,000 population or speeds greater-than 70 km/hr [40 mph] on Major Street)



*\* Note: 80 vph applies as the lower threshold volume for a minor route approach with two or more lanes and 60 vph applies as the lower threshold volume threshold for a minor route approach with one lane.*

## TRAFFIC SIGNAL WARRANTS

### WARRANT 3 - PEAK HOUR VEHICULAR VOLUME

This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time period.

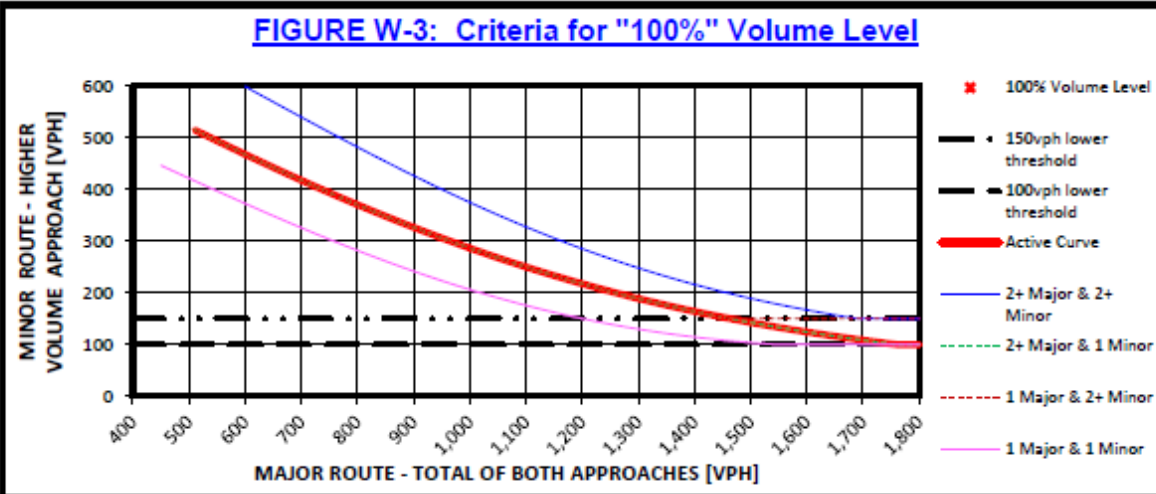
Signalization shall be considered if a point lies above the appropriate line or the Delay criteria is met.

Unusual case(s) justifying this Warrant:

Applicable:  Yes  No  
 Satisfied:  Yes  No

Peak Hour Data		
Peak Hour	Major Route	Minor Route

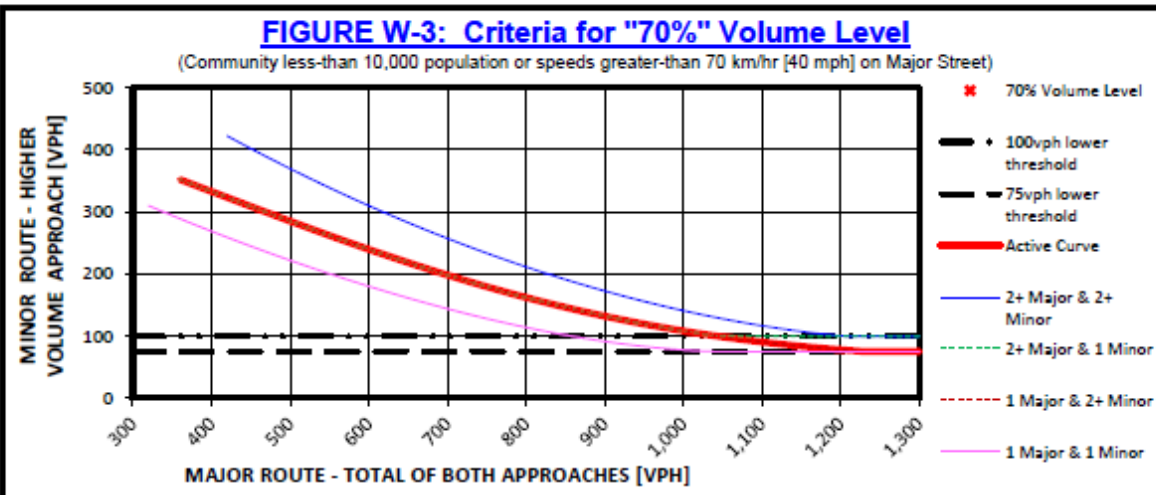
FIGURE W-3: Criteria for "100%" Volume Level



\* Note: 150 vph applies as the lower threshold volume for a minor route approach with two or more lanes and 100 vph applies as the lower threshold volume threshold for a minor route approach with one lane.

FIGURE W-3: Criteria for "70%" Volume Level

(Community less-than 10,000 population or speeds greater-than 70 km/hr [40 mph] on Major Street)



\* Note: 100 vph applies as the lower threshold volume for a minor route approach with two or more lanes and 75 vph applies as the lower threshold volume threshold for a minor route approach with one lane.

DELAY CRITERIA	1. Delay on Minor Approach (vehicle-hours)		2. Volume on Minor Approach (veh/hr)		3. Total Entering Volume (veh/hr)			
	Approaches	Lanes	Approaches	Lanes	Number of Approaches			
					3	4	4 or more	
	Approaches	Lanes	Approaches	Lanes	No. of Approaches	3	4	
	Delay Criteria:	4.0 5.0	Volume Criteria	100 150	Volume Criteria	650	800	
	Delay:		Volume:		Volume:			
	Fulfilled?	Yes NO	Fulfilled?	Yes NO	Fulfilled?	Yes NO		

## TRAFFIC SIGNAL WARRANTS

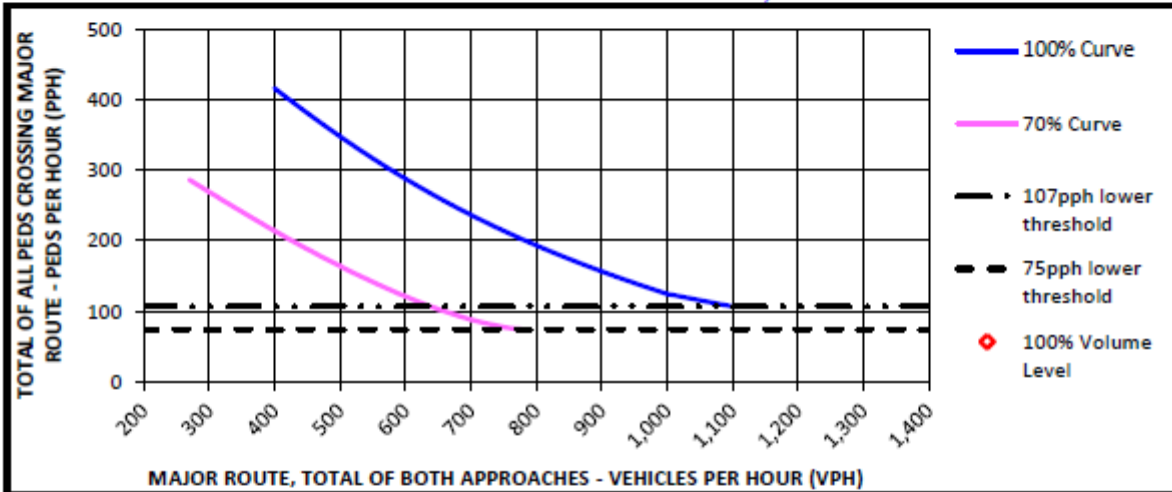
### WARRANT 4 - PEDESTRIAN VOLUME

Satisfied:  Yes  No

Pedestrian Signal Location Criteria		Fulfilled?	
		Yes	No
The nearest traffic control device (signal or STOP sign) controlling traffic on the major route is more than 90m (300 ft) away:	<input type="checkbox"/> Yes <input type="checkbox"/> No		
If no above, will this proposed signal restrict the progressive movement of traffic?	<input type="checkbox"/> Yes <input type="checkbox"/> No		

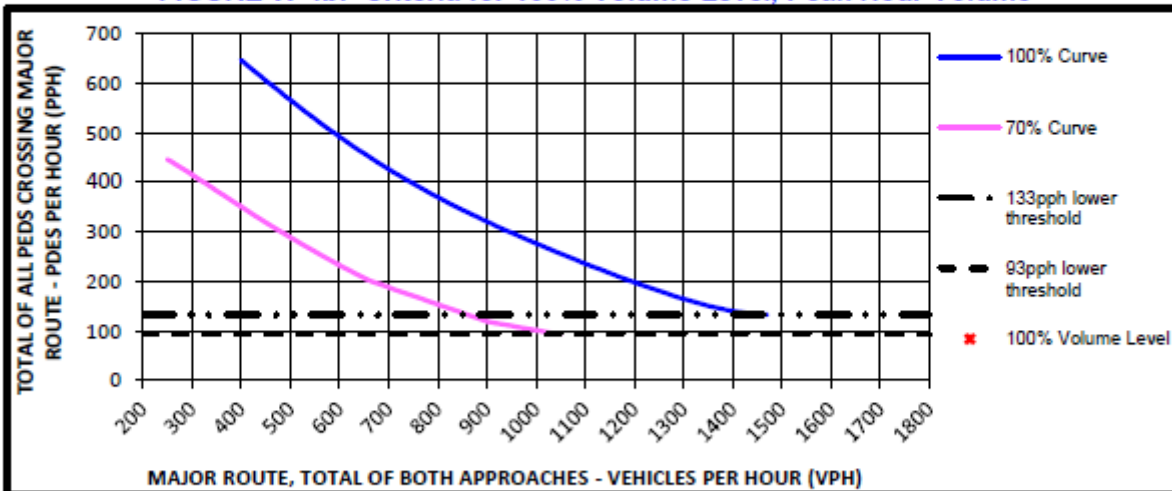
Vehicle volumes in veh/hr and Pedestrian volumes in ped/hr	Four Greatest Hours				Peak Hour
SUM of Both Approaches on Major Route					
Pedestrians crossing the Major Route					

**FIGURE W-4a: Criteria for 100% Volume Level, Four-Hour Volumes**



\* Note: 107 pph applies as the lower threshold volume for the 100% Volume Level.  
75 pph applies as the lower threshold volume for the 70% Volume Level.

**FIGURE W-4b: Criteria for 100% Volume Level, Peak Hour Volume**



\* Note: 133 pph applies as the lower threshold volume for the 100% Volume Level.  
93 pph applies as the lower threshold volume for the 70% Volume Level.

## TRAFFIC SIGNAL WARRANTS

### WARRANT 5 - SCHOOL CROSSING

Satisfied:  Yes  No

*This warrant is intended for application where the fact that schoolchildren crossing the major route is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word "schoolchildren" includes elementary through high school students. This warrant is satisfied if all three of the criteria below are fulfilled after remedial measures have been considered.*

Any remedial measures implemented in or around the intersection to improve the safety of the students as noted in Section 4C.06 **Warrant 5, School Crossing** in the MUTCD:

Criteria			Fulfilled?	
			Yes	No
1. Enter the number of schoolchildren crossing the major route along with the hour this occurs. The hour can be any 60 minute interval (ex 2:15 PM - 3:15 PM enter 2:15 - 3:15). Requires a minimum of 20 schoolchildren during the any hour.	Num. of Students	Highest Crossing Hour Period		
	-	-		
2. For both the morning (AM) and afternoon (PM) periods of operation, enter the number of adequate gaps observed for each period and the number of minutes each period lasted. Requires one period to operate with fewer gaps than the number of minutes in the period.	Period			
	Minutes	Gaps		
AM				
PM				
3. Is the nearest traffic signal along the major route more than 90m (300 ft) from this crossing? <input type="checkbox"/> Yes <input type="checkbox"/> No				
If the signal is within 90m (300 ft) of an existing signalize intersection, will it restrict progressive movement of traffic? <input type="checkbox"/> Yes <input type="checkbox"/> No				

### WARRANT 6 - COORDINATED SIGNAL SYSTEM

Satisfied:  Yes  No

*Progressive movement in a coordinated signal system sometimes necessitates the installation of traffic control signals at intersections that would not otherwise be considered in order to maintain proper platooning of vehicles. This warrant is satisfied if the below criteria is satisfied as follows: criteria 1 is satisfied and either criteria 2 or 3 is satisfied.*

Criteria		Fulfilled?	
		Yes	No
1. The inclusion of this proposed signal, into the coordinated system, does not result in a signal spacing of less than 305m (1,000 ft)?			
a. On a one-way street or a street that has traffic predominantly in one direction, are the adjacent traffic control signals so far apart that they do not provide the necessary degree of vehicular platooning?			
b. On a two-way street, do adjacent traffic control signals <u>not</u> provide the necessary degree of platooning and will the proposed and adjacent traffic control signals collectively provide a progressive operation?			

## TRAFFIC SIGNAL WARRANTS

### WARRANT 7 - CRASH EXPERIENCE

Satisfied:  Yes  No

*This warrant is intended for application where the severity and frequency of crashes are the principal reasons to consider the installation of a traffic control signal. The need for a traffic control signal shall be considered if an engineering study finds that criteria 1, 2, and 3 are met.*

Criteria			Fulfilled?	
			Yes	No
1. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency as shown below:				
2. How many crashes within the past 12 months? For this criteria to be met, five or more reported crashes, of types susceptible to correction by the installation of a traffic control signal, must have occurred.				
3. If Warrant 1A or Warrant 1B are 80 percent satisfied of the current values or if Warrant 4, 4-hour or peak, is met at the 80 percent values.			Met?	
			Yes	No
Warrant 1, Condition A, Minimum Vehicular Volume (80 percent satisfied):				
Warrant 1, Condition B, Interruption of Continuous Traffic (80 percent satisfied):				
Warrant 4, Four-Hour Volume (80 percent satisfied):				
Warrant 4, Peak Hour Volume (80 percent satisfied):				

### WARRANT 8 - ROADWAY NETWORK

Satisfied:  Yes  No

*This warrant is used to encourage the concentration and organization of traffic flow on a roadway network. This warrant is satisfied if one of the following 2 criteria is met and both routes meet at least one of the characteristics of a Major Route below.*

Criteria			Met?		Fulfilled?	
			Yes	No	Yes	No
1. Both of the criteria to the right are required in order to be met.	a. Please enter the total existing, or immediately projected, entering traffic volume during the peak hour of a typical weekday. Requires a minimum of 1,000 vehicles to be met.	Volume				
	b. Based on an engineering study, does the 5 year projected traffic volumes, for this location, meet one or more of Warrants 1, 2, or 3 during an average weekday? *					
2. Enter the total existing, or immediately projected, entering volume for each of any 5 hours of a non-normal business day. (Saturday or Sunday). 1,000 vph for each hour required.						
			← Hour			
			← Volume			

\* Supporting data required for verification of the projected 5 year traffic Warrants.

A major route, as used in this signal warrant, shall have at least one of the following characteristics:			Met?		Fulfilled?	
Characteristics of Major Routes			Yes	No	Yes	No
1. Is it a part of the street or highway system that serves as the principal roadway network for through traffic flow?	Major Route					
	* Minor Route					
2. Does it include rural or suburban highways outside, entering, or traversing a city?	Major Route					
	* Minor Route					
3. Does it appear as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study?	Major Route					
	* Minor Route					

\* This is a minor route, but for the purposes of this Warrant, shall be considered as the other major route.

**Note:** Supporting data shall be required to verify the routes meet one of the characteristics of a major route.



## TRAFFIC SIGNAL WARRANTS

### WARRANT 9 - INTERSECTION NEAR A GRADE CROSSING

Applicable  
 Yes  No

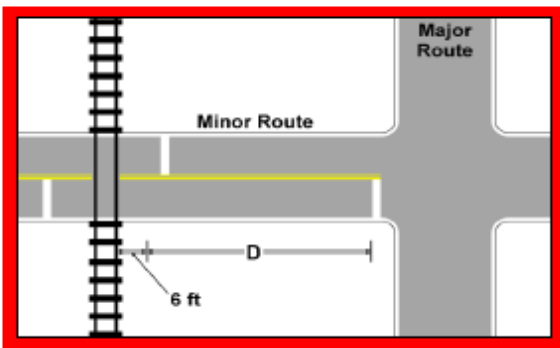
The need for a traffic control signal may be considered if an intersection that is controlled by a STOP or YIELD sign has a rail crossing within 140 feet of the stop/yield line and the highest Equivalent Minor Approach Traffic value lies above the curve represented on the graph below.

Minor Route Adjustment Factors - Enter the following:	
1. The number of occurrences of rail traffic/day:	
2. The percentage of "High-Occupancy Buses" crossing the track/day: <small>(A high-occupancy bus is defined as a bus occupied by at least 20 people)</small>	
3. The percentage of Tractor-trailer Trucks crossing the track/day:	

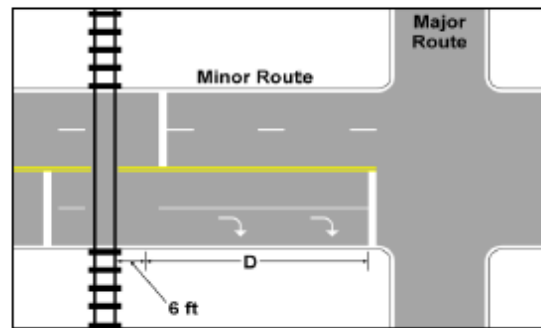
Satisfied:  Yes  No

Peak Hour Data		
Peak Hour	Major Route	Minor Route

Enter the distance value "D" from the STOP/YIELD bar to the track as shown below:  

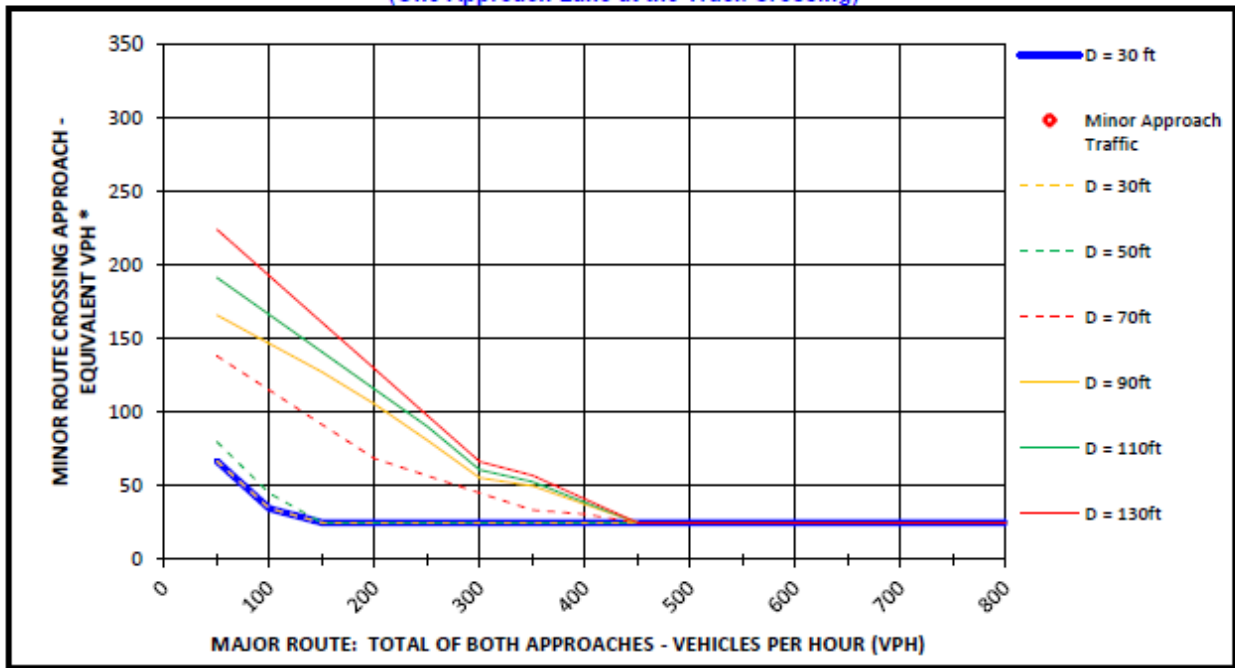


(One Approach Lane at the Track Crossing)



(Two or More Approach Lanes at the Track Crossing)

**FIGURE W-9: Intersection Near a Grade Crossing**  
 (One Approach Lane at the Track Crossing)



\* VPH after applying the adjustment factors for Rail, Bus, and Tractor-Trailer traffic  
 25 vph applies as the lower threshold volume

### TRAFFIC SIGNAL WARRANT SUMMARY

City/Town: \_\_\_\_\_ Analysis Performed By: \_\_\_\_\_  
 County: \_\_\_\_\_ Date Analysis Performed: \_\_\_\_\_  
 Division: \_\_\_\_\_ Project Number if Applicable: \_\_\_\_\_  
 Data Date: \_\_\_\_\_ Weather Conditions: \_\_\_\_\_  
 Major Route: \_\_\_\_\_ Appr. Lanes: \_\_\_\_\_ Critical Approach Speed (mph): \_\_\_\_\_  
 Minor Route: \_\_\_\_\_ Appr. Lanes: \_\_\_\_\_

---

**Warrant #1: Eight-Hour Vehicular Volume** **SATISFIED**  
 Yes  No

1A - Minimum Vehicular Volume:  Yes  No **80% Satisfied**  Yes  No **100% Satisfied**  
 1B - Interruption of Continuous Traffic:  Yes  No  Yes  No  Yes  No

*Any Remedial Measures Tried and their Outcome.*

**Warrant #2: Four-Hour Vehicular Volume**  Yes  No

**Warrant #3: Peak Hour**  Yes  No

*The Unusual Case(s) that Justifies the use of this Warrant.*

**Warrant #4: Pedestrian Volume**  Yes  No

**Warrant #5: School Crossing**  Yes  No

*Any Remedial Measures Implemented to improve the Safety of the Students.*

**Warrant #6: Coordinated Signal System**  Yes  No

**Warrant #7: Crash Experience**  Yes  No

*Other Alternatives that have failed to reduce crashes.*

**Warrant #8: Roadway Network**  Yes  No

**Warrant #9: Intersection Near a Grade Crossing**  Yes  No

---

**CONCLUSIONS** Warrants Satisfied:

Remarks:

## 2.6 Right Turn Volume Adjustments

When a signal is being considered for capacity reasons, it is customary to adjust minor street right turn volumes to allow for the fact that a certain percentage of vehicles can make right turns without the aid of a traffic signal. High volumes of right turns on the minor streets can skew a signal warrant analysis and indicate a possible need for a signal where one does not exist.

The MUTCD states that a signal warrant analysis “*should consider the effects of the right-turn vehicles from the minor-street approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count*” ([MUTCD Section 4](#)). This provides justification for reducing right turn volumes but does not provide guidance.

ALDOT requires justification for any right turn adjustments (or lack thereof). Right turn adjustments can be based on engineering judgment, field observation, or an accepted right turn adjustment methodology.

A formal right turn adjustment methodology has been developed by the Illinois Department of Transportation and can be used as a guide to estimate appropriate right turn adjustments. It is a two-step methodology that uses 1) a Minor Street Reduction Factor and 2) a Mainline Congestion Factor to estimate the portion of right turn volumes that should be discounted.

This process determines the amount of right-turning traffic to dismiss from the minor street approach for each hour of approach counts. Each approach hour generally produces a different reduction factor, so the right-turn reduction calculation shall be computed for each approach hour for all minor streets, when data is available.

The Minor Street Reduction Factor reflects whether minor street geometry and traffic volumes permit the free movement of right turns and reduces right turning volumes accordingly. The Mainline Congestion Factor adjusts the Minor Street Reduction Factor to account for the amount of congestion on the mainline. In essence, the Minor Street Reduction Factor considers what portion of vehicles can get to the intersection to make a right turn while the Mainline Congestion Factor determines whether there are enough gaps in mainline traffic to permit them to actually make that right turn. The adjusted right turn volume is computed as follows:

$$R_{adj} = R \times [1 - (f_{minor} - f_{main})]$$

**where:**

$R_{adj}$  = adjusted right turn volume (veh/hr)

$R$  = raw right turn volume (veh/hr)

$f_{minor}$  = minor street adjustment factor

$f_{main}$  = mainline congestion factor

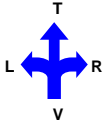
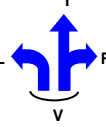
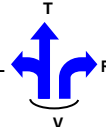
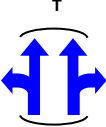

\*note: if  $(f_{minor} - f_{main}) \leq 0$  then  $R_{adj} = R$

Values for  $f_{minor}$  and  $f_{main}$  are shown in Tables 2.2 and 2.3.

The mainline volume used in Table 2.3 is always the stream into which the right turning vehicles are entering. The factor  $f_{main}$  is computed for the thru movement associated with the minor street approach used to compute  $f_{minor}$ . For a standard intersection with the mainline running east-west, the eastbound thru movement would be associated with the northbound minor street movement and the westbound thru movement would be associated with the southbound minor street movement.

If there is no mainline right turn lane the mainline right turn volumes are added to the thru volumes for the lane volume calculations. If a right turn lane is present, mainline right turn volumes are excluded from the calculations in Table 2.3.

**Table 2.2 – Right Turn Adjustment Factors (Source: Illinois DOT)**

Minor Street Adjustment Factor ( $f_{minor}$ )			
Case	Lane Configuration	Volume Condition	$f_{minor}$
1		$R > 0.7V$	0.60
		$0.7V \geq R > 0.35V$	0.40
		$R \leq 0.35V$	0.20
2		$R > 3T$	0.60
		$3T \geq R > T/3$	0.40
		$R \leq T/3$	0.20
3		Any configuration with an exclusive right-turn lane $\geq 500$ ft. long. (See note* for shorter right-turn lanes)	0.75
4		$R > (T+L)$	0.65
		$L > (T+R)$	Use Case 2
		$L \approx T \approx R (\pm 10 \text{ veh})$	0.40
		$L \approx T > 3R$	0.20
		$R \approx T > 3L$	0.50
		all other conditions	0.30
5		$R > T$	0.75
		$T \geq R > T/2$	0.50
		$T/2 \geq R > T/4$	0.30
		$R < T/4$	0.15

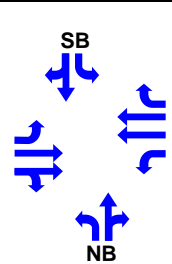
\* Note: ALDOT will accept a minimum right turn lane length of 150 ft. Shorter right-turn lanes should be considered 'exclusive' only if they permit right-turn traffic to flow freely past queued traffic.

**Table 2.3 – Mainline Congestion Factors (Source: Illinois DOT)**

Mainline Congestion Factor ( $f_{main}$ )			
Mainline volume per lane (veh/hr/lane)	$f_{main}$	Mainline volume per lane (veh/hr/lane)	$f_{main}$
0 - 399	0.0	1100 – 1199	0.40
400 – 499	0.05	1200 – 1299	0.45
500 – 599	0.10	1300 – 1399	0.50
600 – 699	0.15	1400 – 1499	0.55
700 – 799	0.20	1500 – 1599	0.60
800 – 899	0.25	1600 – 1699	0.65
900 – 999	0.30	1700 – 1799	0.70
1000 – 1099	0.35	1800 - 1899	0.75

**Example: Right Turn Volume Adjustment**

The following hourly traffic volumes were collected for the eastbound and northbound approaches at an intersection with the lane geometry shown. Compute the adjusted right turn volumes for the northbound minor street approach.

	EBL	EBT	EBR	NBL	NBT	NBR	$f_{minor}$	$f_{main}$	$1-(f_{minor}-f_{main})$	$NBR_{adj}$
	56	2156	141	41	15	88	0.60	0.40	0.80	70
	41	2405	166	58	9	106	0.60	0.45	0.85	90
	48	1881	101	38	11	74	0.60	0.30	0.70	52
32	1156	87	41	15	44	0.40	0.15	0.75	33	

The northbound minor street lane configuration corresponds to Case 2 in Table 2.2. For the first three hours  $R > 3T$  so a value of 0.60 is used for  $f_{minor}$ . In the last hour,  $3T \geq R > T/3$  so a value of 0.40 is used for  $f_{minor}$ . To compute  $f_{main}$ , the eastbound lane volumes are computed for each hour. Using the first hour:

$$\begin{aligned} \text{Mainline volume} &= 2156 \text{ thru} + 141 \text{ rights} = 2297 \text{ veh/hr} \\ \text{Lane volume} &= (2297 \text{ veh/hr}) / (2 \text{ thru lanes}) = 1148 \text{ veh/hr/lane} \\ \text{Mainline Congestion Factor } (f_{main}) &= 0.40 \text{ [from Table 2.3]} \end{aligned}$$

$$\begin{aligned} 1-(f_{minor} - f_{main}) &= 1 - (0.60 - 0.40) = 1 - (0.20) = 0.80 \\ R_{adj} &= 88 \text{ veh/hr} \times (0.80) = 70 \text{ veh/hr} \end{aligned}$$

If there was an eastbound right turn lane then the eastbound right turn volumes would not be included in the calculations.

It is recommended that right turn adjustments be determined for at least the AM and PM peak hours. If it is found that significant right turn volume reductions are necessary, the designer should consider collecting the necessary data and adjusting the remaining count volumes to reflect this. The reduction of minor street approach traffic due to right-turning traffic is only valid if turning-movement data was collected for every approach hour of traffic data. If no turning-movement data was collected, then right-turn adjustments cannot be computed. Also, if the only right-turning traffic collected was for the peak approach hours, this will not provide sufficient data to assume the percentage of right-turning traffic for the other hours of the day. Additional off-peak volume data must be collected.

When performing a traffic study for a future intersection, it is difficult to estimate the effects of right turning vehicles on minor street traffic flow. In these cases, engineering judgment should be used.

**2.7 ALDOT Policy Regarding Warrants**

Satisfying one or more of the MUTCD traffic signal warrants does not imply that a traffic signal should be installed at a given location or that ALDOT is in any way obligated to approve a traffic signal. Satisfying one or more signal warrants simply means that a traffic signal can be given consideration along with other design alternatives.

## 2.8 Alternative Treatments

Traffic signals are most often installed to address one of two conditions: 1) capacity deficiencies, particularly those which cause excessive side street delays, and/or 2) safety deficiencies, often related to poor sight distances or high mainline speeds.

### 2.8.1 Design Alternatives to Address Capacity Deficiencies

ALDOT requires engineers and planners to consider all reasonable design alternatives before requesting a traffic signal. Selected design alternatives to address capacity deficiencies are shown in Figure 2.1 and may include:

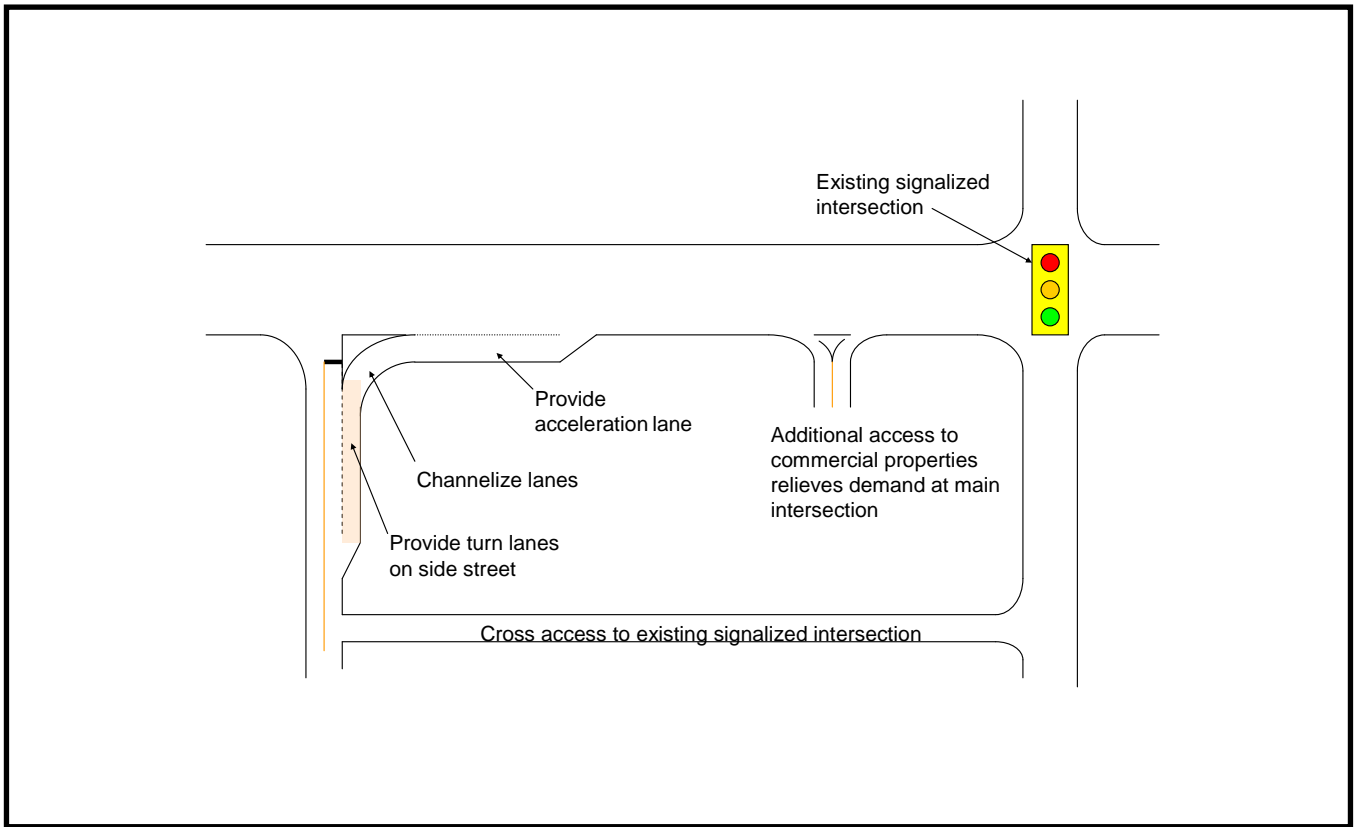
- Providing additional side street lanes
- Channelizing right turn movements
- Providing acceleration lanes
- Relocating streets or driveways
- Providing multiple driveways to commercial developments
- Providing cross access to an existing traffic signal
- Adding left-turn lanes and/or right-turn lanes

### 2.8.2 Design Alternatives to Address Safety Deficiencies

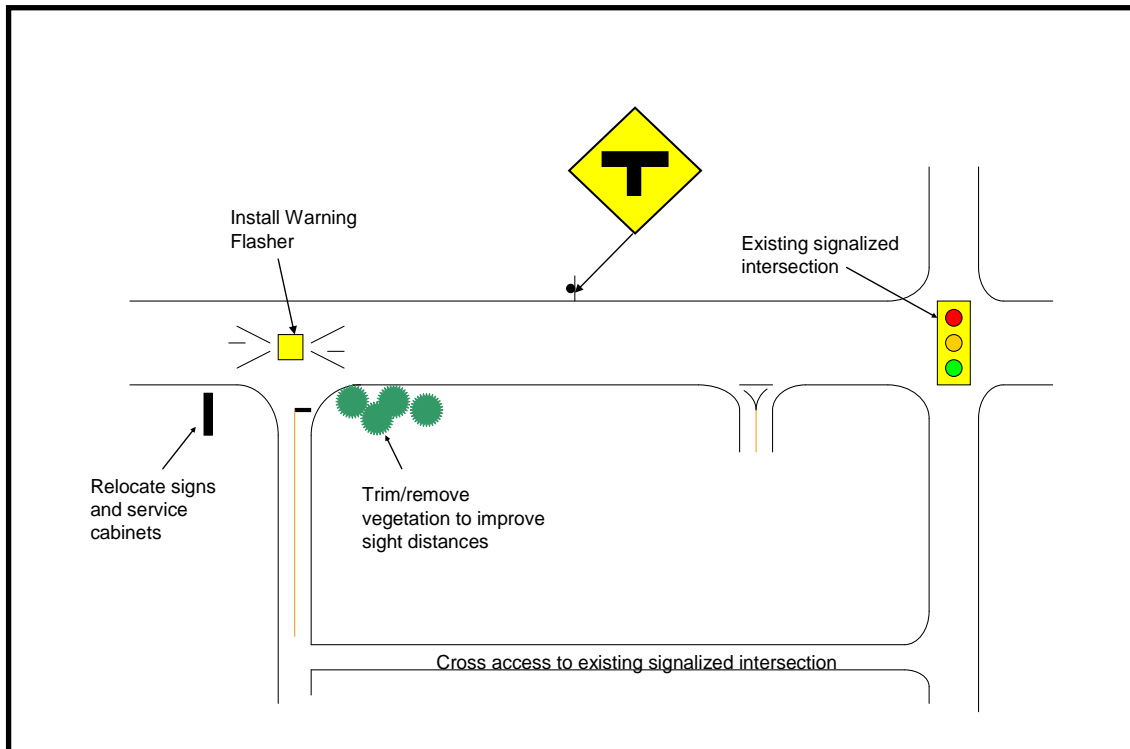
Design alternatives which address safety deficiencies are illustrated in Figure 2.2 and may include:

- Appropriate advance warning signs
- Trimming plants and trees to improve sight distances
- Relocating obstructions which limit sight distance
- Reducing speed limits (*if warranted; see the [ALDOT Speed Management Manual for guidance](#)*)
- Installing advance and/or stop beacons
- Providing acceleration and deceleration lanes
- Providing cross access to an existing traffic signal
- Constructing a roundabout
- Relocating stop lines to improve stopping sight distance
- Providing rumble strips
- Providing pedestrian median/refuge
- Improving roadway lighting if applicable
- Restricting turning movements (if alternate routes are available)
- Considering a multi-way stop warrant

Additional guidance may be found in the [NCHRP Report 500 series](#).



**Figure 2.1 – Alternative treatments to address capacity deficiencies**



**Figure 2.2 – Alternative treatments to address safety concerns**

## 2.9 Access Management Considerations

A traffic signal must operate in conjunction with the general access plan in a corridor. Specific guidance on the relationship between traffic signals and access management is provided in the [ALDOT Access Management Manual](#).

## 2.10 Warrants for Removal of Traffic Signals

Over time the conditions which originally justified a traffic signal may change. The closing of a large store, plant, or school may suddenly reduce traffic in the vicinity of a signal to the point that the signal no longer meets any warrants under the MUTCD guidelines. For this reason, ALDOT requires that a signal warrant analysis be performed for any existing traffic signal being modified as part of a federally funded state project. If a signal no longer meets any MUTCD warrants, serious consideration should be given to removing it. Guidelines for removing unwarranted traffic signals on federally funded projects can be found in the FHWA document, "[User Guide for Removal of Not Needed Traffic Signals](#)", FHWA-IP-80-12, in the [MUTCD Section 4](#), "Basis of Installation or Removal of Traffic Control Signals", and the ITE Recommended Practice "[Guidelines for the Activation, Modification, or Removal of Traffic Control Signals](#)".

ALDOT recognizes that removal of an existing signal can be a contentious issue, particularly for local governments. Because of this, the engineer may consider retaining an unwarranted signal if any of the following conditions are met:

- The signal is adjacent to a school, retirement home, or similar high pedestrian traffic area
- Sight distance or geometric conditions merit retaining the signal for safety reasons
- The observed traffic volumes satisfy at least 70% of the volume criteria for MUTCD Warrant 1 for at least 8 hours of the day
- Engineering judgment deems the signal necessary

If none of the above conditions are met the engineer should recommend removal.



# Chapter 3

## Signal Operation and Phasing

This Chapter discusses traffic signal phasing and its relationship to signal operation and design. Standard phasing schemes employed by ALDOT are presented as well as discussions of their impacts on signal efficiency and safety.

### 3.1 Signal Phasing Definitions

“Signal phase” refers to the complete sequence of green, yellow, and all red indications given to one movement. Each of the green, yellow, and all red periods that make up a phase is referred to as a “phase interval” (See Figure 3.1). A series of signal phases that service all possible movements at an intersection is a “cycle”. A cycle may comprise as few as two phases or as many as eight (or more) phases.

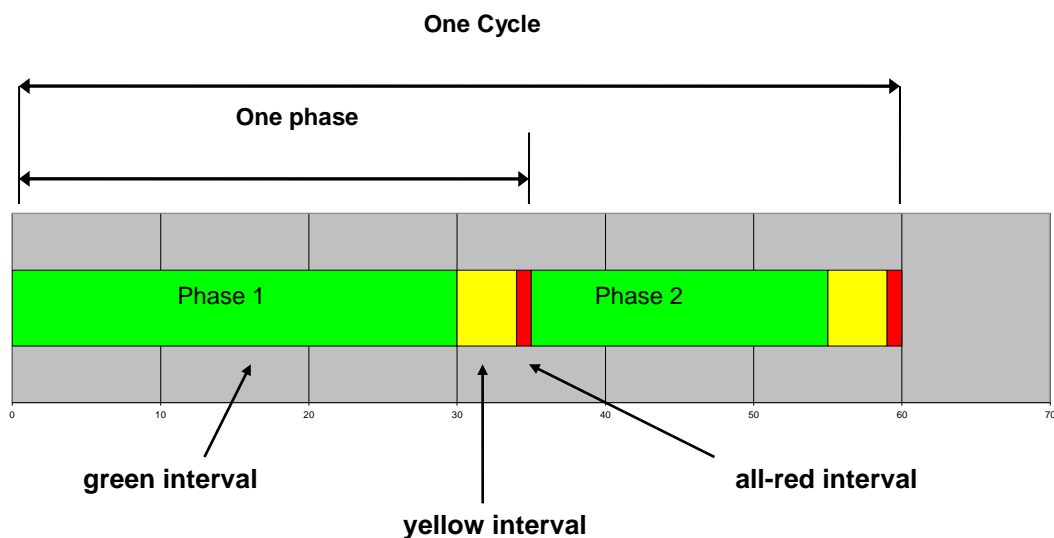
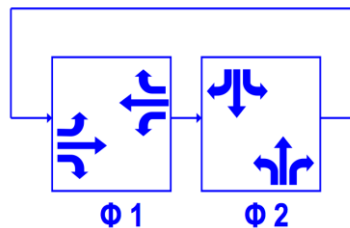


Figure 3.1 – Phase intervals for a two phase signal

### 3.1.1 Standard Two Phase Operation

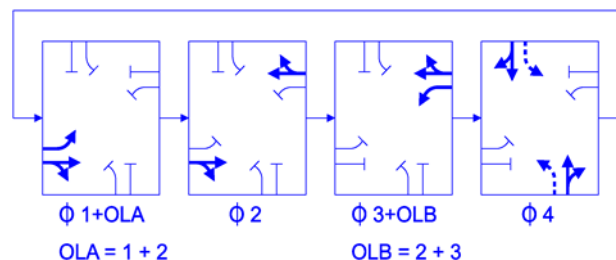
The simplest type of signal phasing is the standard two-phase operation. In it, the major street approaches to an intersection are served by one phase and the minor street approaches are served by the second phase, as shown in Figure 3.2. The two phase configuration is very efficient and operates well under low volume conditions but does not permit separate turn phases. Two phase signals are often seen in urban and rural areas where left turn volumes are low to moderate.



**Figure 3.2 – Two phase operation**

### 3.1.2 Standard Four Phase Operation

In order to provide separate left turn phases when left turn conditions warrant, the four phase signal controller was developed. In a four phase signal all phases are sequential, meaning no two phases can be active at the same time. It typically does not allow movements within a phase to be timed individually, or in other words, the signal cannot progress to the next phase until all movements within the current phase have either timed out or gapped out. Its overall structure is referred to as a 'ring' because after completing a cycle it returns to phase 1 and begins again. A typical four phase plan is shown in Figure 3.3.



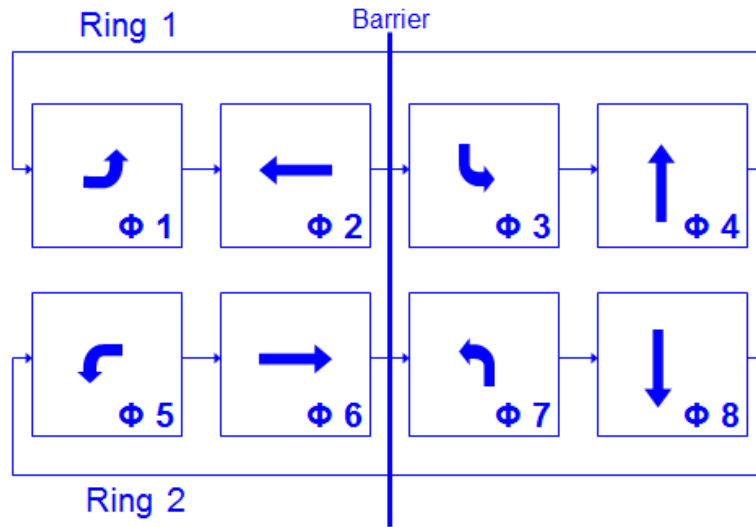
**Figure 3.3 – Four phase operation (one leading and one lagging main street left)**

### 3.1.3 Standard Eight Phase Operation

Four phase operation allows for separate treatment of left turns but does not permit each movement within a phase to be separately timed. This can be important in cases where opposing volumes within a phase are unbalanced and a four phase operation would hold a phase even though there was no longer any demand on one of the movements. Eight phase operation allows each movement to be timed separately for more efficient operation.

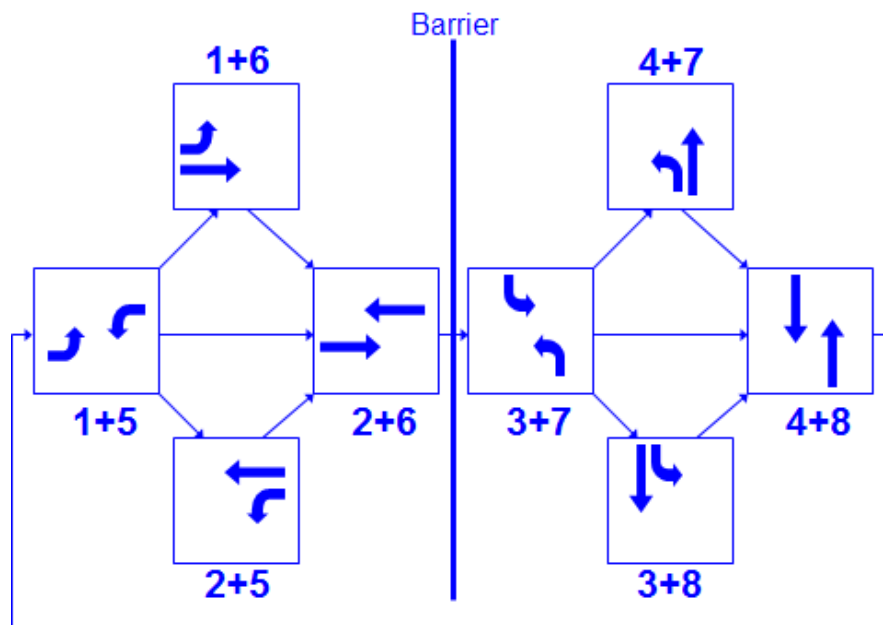
The eight phase controller acts like two four-phase controllers operating together. Phases 1-4, just as in a four phase controller, constitute one ring. Phases 5-8 constitute a second ring, and an 8-phase controller is therefore often referred to as a 'dual ring' controller. Each ring operates sequentially;

meaning only one phase in a ring can be active at any time, although phases can be skipped if there is no demand for them (see Figure 3.4).



**Figure 3.4 – Eight phase operation (protected lefts)**

A general rule when assigning movements to phases is that all phases in a given ring should be in conflict. Each ring operates separately with the only limitation being that both rings must cross the barrier together. Thus, any phase from Ring 1 left of the barrier (1 & 2) can come up with any phase from Ring 2 left of the barrier (5 & 6). The same holds true for the right side of the barrier. Under standard [National Electrical Manufacturers Association \(NEMA\)](#) operation, phases from opposite sides of the barrier can never be active at the same time. Standard NEMA eight-phase operation yields the possible phase combinations shown in Figure 3.5.



**Figure 3.5 – Possible phase combinations for an 8-phase controller**

### 3.2 ALDOT Typical Phase Numbering Scheme

The standard ALDOT phase numbering schemes are shown in Figure 3.6 below. Phase numbers can be adjusted as conditions warrant.

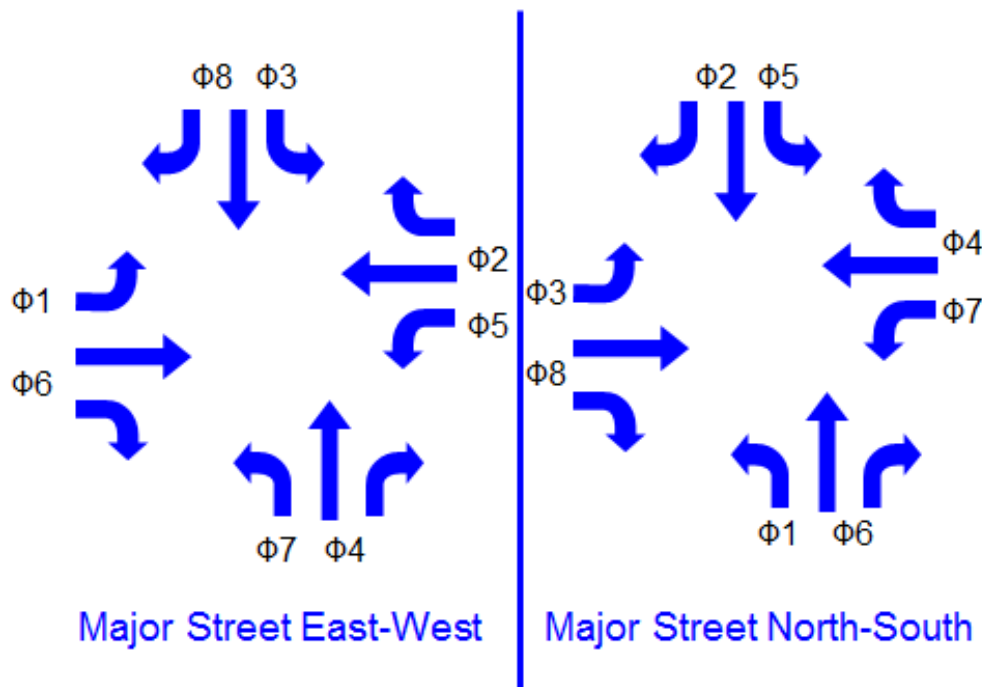


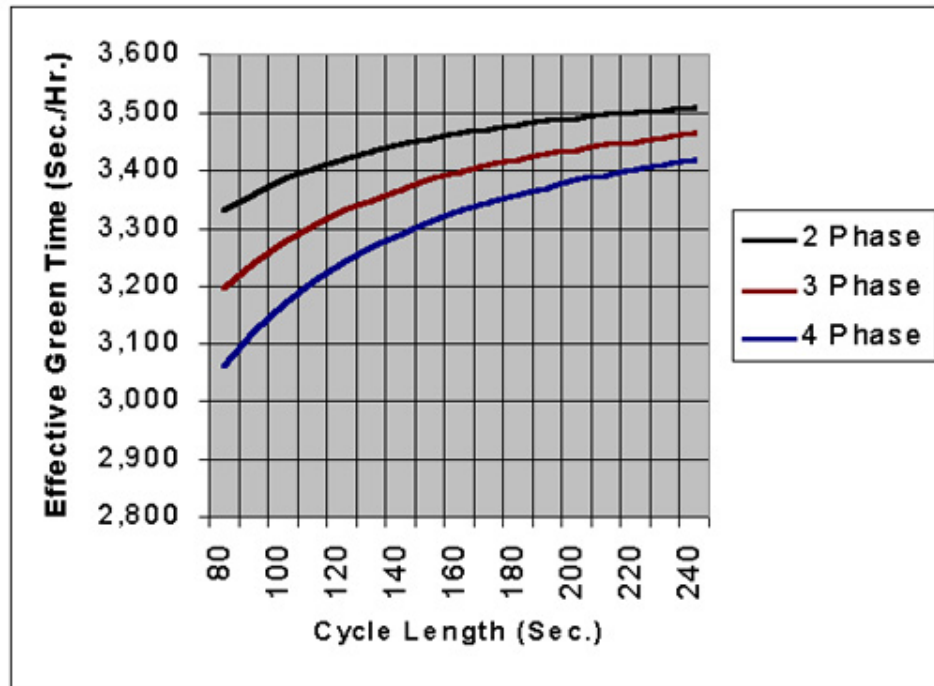
Figure 3.6 – Standard ALDOT phase numbering schemes

### 3.3 Left Turn Phasing

Left turn phases can improve intersection operation and reduce delays when:

- Left turn volumes are high
- Opposing thru volumes are too high to provide sufficient gaps for left turning traffic
- Sight distances are inadequate

However, it should be remembered that the provision of left turn phases can also reduce overall intersection capacity (see Figure 3.7). Every additional phase carries with it built in penalties in terms of start-up lost time and cycle time lost during yellow and all-red clearance intervals. The addition of left turn phases, while reducing delays for those movements, tends to reduce overall intersection capacity and increase delays for thru movements. Left turn phases should therefore be used only when necessary.



**Figure 3.7 – Impact of additional phases on overall intersection effective green time**  
(Source: CITE Training Course, 2003)

### 3.4 Warrants for Left Turn Phasing

When designing a new signal there is the temptation to “build it out”, meaning to provide left turn phasing on all approaches (if lane geometry permits). In fact, some municipalities will request that left turn phasing be provided on all approaches as a matter of policy. But because left turn phases tend to reduce overall intersection capacity ALDOT recommends a left turn warrant analysis.

ALDOT has adopted a set of warrants for determining whether left turn phasing should be provided on a given approach. These warrants are described in the following paragraphs and are summarized in a Left Turn Warrant Spreadsheet (Excel) available from the ALDOT Maintenance Bureau.

The warrants for left turn phasing fall into three general categories and are explained in detail in the following sections:

- Traffic volumes – left turn phasing is required for capacity reasons
- Geometric – left turn phasing is required due to insufficient sight distance or other geometric limitations
- Crash history – left turn phasing is required because of a high number of crashes related to left turns

#### 3.4.1 Volume Warrants for Left Turn Phasing

For a permissive left turn movement to function properly, sufficient gaps must be available in the opposing traffic stream to allow waiting vehicles to turn during the associated green phase. When the number of left turning vehicles exceeds the number of available gaps it creates a capacity deficiency. A left turn movement functioning over capacity will create queues and delays, and studies have shown

that drivers will take greater risks as delays increase. ALDOT has adopted a set of volume criteria for determining when a left turn phase is required for capacity reasons. It uses a methodology developed by the Texas Transportation Institute which considers left turn volumes, opposing thru volumes, and phase green time. The volume thresholds are presented in Table 3.1 below.

To determine the minimum left turn volume threshold for an approach the designer must know the peak hour left turn volume (vph), the opposing thru volume (vph) for the same hour, the lane configuration, and an estimate of the G/C ratio for that approach, where G = unprotected green time for those movements and C = total cycle time. In the planning stage the designer may need to estimate the values for G and C using HCM, SYNCHRO, or some other signal timing optimization program.

To use Table 3.1, the designer should follow these steps for each left turn movement:

1. Determine the number of lanes of opposing traffic. Consider a right turn lane an opposing lane unless it is channelized and does not affect the movement of left turning vehicles. Opposing left turn lanes are disregarded.
2. Compute the value of  $V/(G/C)$  where V is the opposing thru/right volume in veh/hr and determine the appropriate equation in Table 3.1 to use for the Left Turn Threshold.
3. Compute the Minimum Critical Left Turn Volume L using the appropriate equation in Table 3.1. This is the minimum peak hour left turn volume required to warrant left turn phasing.

The left turn volume threshold value should be computed separately for each approach.

**Table 3.1 – Threshold values for left turn phasing (Source: Texas Transportation Institute)**

Number of Opposing Lanes <sup>†</sup>	Opposing volume V adjusted by G/C	Minimum critical left turn volume L (vph)
1	$0 < V/(G/C) < 1000$	$764(G/C) - 0.634V$
	$1000 < V/(G/C) < 1350$	$484(G/C) - 0.348V$
2	$0 < V/(G/C) < 1000$	$855(G/C) - 0.500V$
	$1000 < V/(G/C) < 1350$	$680(G/C) - 0.353V$
	$1350 < V/(G/C) < 2000$	$390(G/C) - 0.167V$
3 <sup>‡</sup>	$0 < V/(G/C) < 1000$	$892(G/C) - 0.448V$
	$1000 < V/(G/C) < 1350$	$735(G/C) - 0.297V$
	$1350 < V/(G/C) < 2400$	$390(G/C) - 0.112V$

**Legend:** V = opposing volume (vph), G = unprotected green time (sec), C = cycle length (sec)

<sup>†</sup> Include thru and right turns when determining opposing lanes and volumes, unless the right turn lane is channelized and does not interfere with the movement of left turning vehicles. Opposing left turn lanes are disregarded.

<sup>‡</sup> For more than 3 opposing lanes, left turn phasing should be strongly considered.

### 3.4.2 Geometric Warrants for Left Turn Phasing

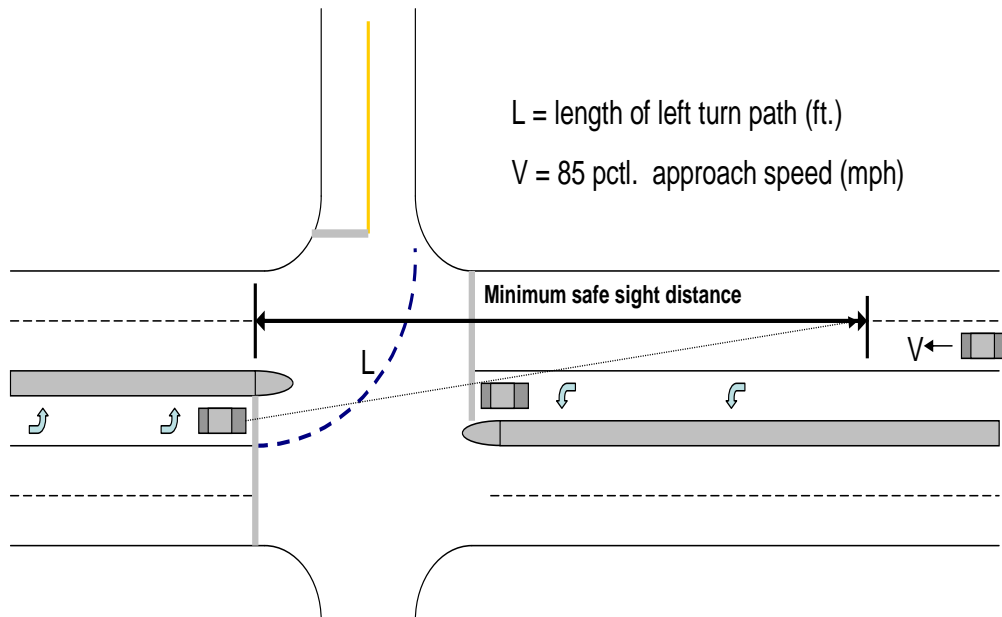
Certain geometric conditions automatically warrant left turn phasing. The most common are:

- Dual or triple left turn lanes
- Insufficient sight distances

Adequate sight distance is required for motorists to observe opposing traffic and decide whether a sufficient gap exists to make their turn. Minimum left turn sight distances are shown in Figure 3.8. If these minimum values cannot be achieved then left turn phasing must be provided.

### 3.4.3 Crash Warrants for Left Turn Phasing

Left turn phasing may be provided if there have been 5 or more crashes related to left turns within a 12 month period. The accidents must be related to left turns and be of a type not effectively addressed by other measures.



Length of turn path, L (ft)	85 <sup>th</sup> Percentile Approach Speed, V (mph)								
	25	30	35	40	45	50	55	60	65
40	250	290	330	375	415	455	500	540	580
60	315	365	420	470	520	570	620	670	720
80	375	435	495	550	610	725	725	785	845
100	430	495	560	625	690	825	825	890	955
120	480	550	625	695	770	910	910	985	1055
140	530	610	685	765	840	995	995	1075	1150
160	575	660	745	825	910	1075	1075	1160	1240
180	620	710	800	885	975	1150	1150	1240	1325

**Figure 3.8 – Minimum sight distances for permissive left turns (ft.)**

### 3.4.4 Other Warrants for Left Turn Phasing

ALDOT will consider left turn phasing for reasons other than those outlined above if the engineer can demonstrate that it is necessary for the proper operation of the intersection.

If left turn phasing is not warranted the designer may still provide for future left turn phases by including the following elements in the signal design:

- Wiring to accommodate future left turn heads
- Mast-arms long enough to accommodate future left turn heads
- An 8-phase controller

## 3.5 Types of Left Turn Phases

Left turn treatments are typically of three types: permissive, protected, or protected-permissive. Following is a discussion of each type and conditions for its use.

### 3.5.1 Permissive Left Turn Phasing

This can be the most efficient type of left turn treatment in terms of overall intersection capacity if turning volumes and/or opposing thru volumes are low. Under permissive phasing left turning vehicles must wait for gaps in opposing traffic to make their turn. There is no separate left turn phase. It is typically used under the following conditions:

- Sight distance is adequate (see Fig. 3.8)
- Turning volumes and/or opposing thru volumes are low enough that sufficient gaps exist to accommodate left turning traffic

### 3.5.2 Protected-Only Left Turn Phasing

Under protected-only phasing, left turns are permitted only under a green arrow. Turns are prohibited at all other times. This type of phasing is typically used under one or more of the following conditions:

- Poor sight distance limits visibility of opposing traffic
- Opposing traffic volumes are so high as to make unprotected left turns hazardous
- Speed of opposing traffic is high and makes unprotected left turns hazardous
- Dual or triple left turn lanes

### 3.5.3 Protected-Permissive Left Turn Phasing

When left turn phasing is required, protected-permissive phasing offers the best aspects of both permissive and protected-only phasing. It is typically used in situations where geometric conditions allow permissive left turns but traffic volumes are high enough that a left turn phase is required for capacity reasons. Under protected-permissive phasing, an initial (or lagging) left turn phase is provided to allow a portion of the left turning vehicles to make a protected turn. The remaining vehicles must then wait for gaps in traffic and make permissive turns. This arrangement is typically more efficient than protected-only left turn phasing because it devotes less green time to the left turning phases and allows more green time to be provided to the thru movements. ALDOT therefore encourages the use of protected-permissive left turn phasing wherever possible.

**i** In situations where left turn phasing is warranted, ALDOT encourages the use of protected-permissive phasing wherever possible. Protected-permissive phasing should be used unless protected-only phasing is warranted or is deemed necessary by the engineer.



### 3.5.4 When to Use Protected vs. Protected-Permissive Left Turn Phasing

In general designers should consider protected-permissive left turn phasing unless one or more of the following conditions for protected-only left turn phasing are met:

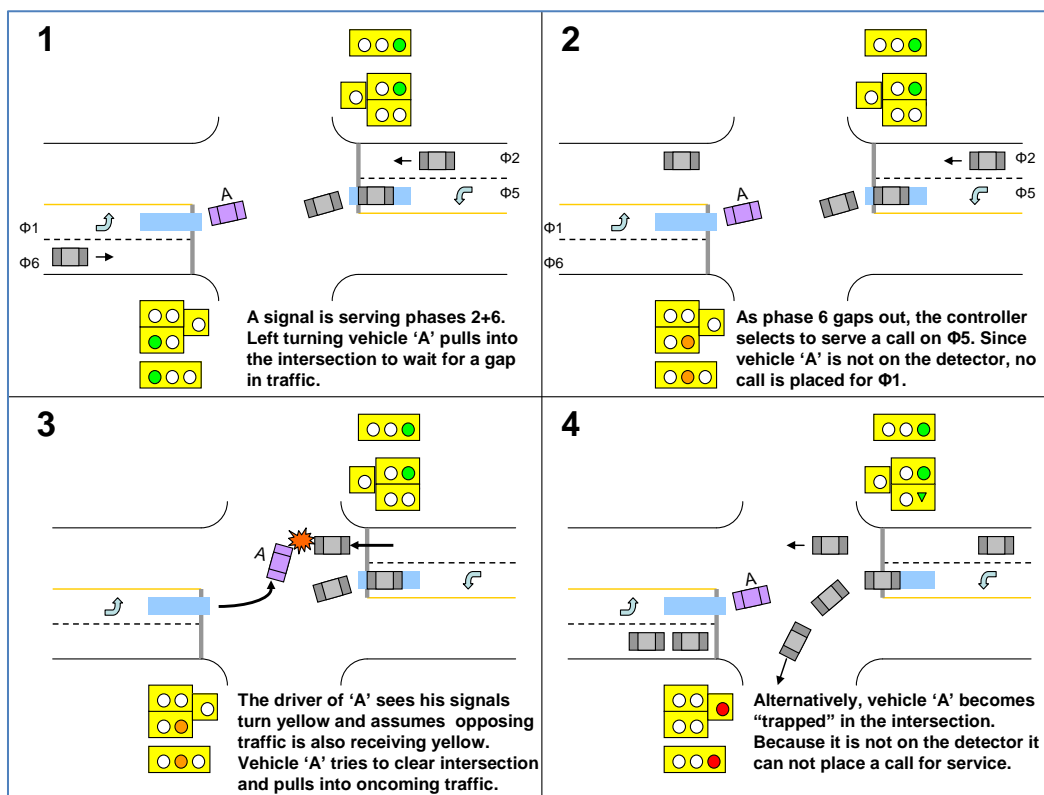
- Inadequate sight distance exists for permissive left turns
- Dual or triple left turn lanes are present
- The engineer determines that the combination of speeds, opposing lanes, and opposing volumes create an unsafe environment for permissive left turns
- An approach experiences 5 or more crashes in a 12 month period related to permissive left turns that cannot be addressed by other means
- Lead-lag left turn phasing is used (see section 3.7)

The left turn phase warrants and protected phasing warrants have been summarized in an Excel spreadsheet available from ALDOT. A copy of the summary sheet is shown in Figure 3.10.

### 3.6 Protected-Permissive Phasing and Left Turn Traps

When using protected-permissive left turn phasing the designer must ensure that he does not create a trap for left turning vehicles. A left turn trap occurs when a signal clears from a protected-permissive green ball (typically phases 2+6 or 4+8) to serve one of the left turn phases for the same roadway. It is illustrated in Figure 3.9.

To prevent a left turn trap from occurring, ALDOT does not permit signals using protected-permissive left turn phasing on the mainline to clear from phases 2+6 directly to phases 1+6 or 2+5. On side streets, if protected-permissive left turn phasing is used, phases 4+8 may not clear directly to phases 3+8 or 4+7. Options to prevent left turn trapping are described in Chapter 14.



**Figure 3.9 – Illustration of the left turn trap**

### ALDOT Left Turn Phasing Warrants Worksheet

Fill in all green shaded fields

	Major Street		Minor Street	
	EB	WB	NB	SB
<b>Geometry</b>				
Exclusive left turn lane provided (Y/N)?				
Number of left turn lanes				
Number of opposing thru/right lanes*				
Consider Left Turn Phasing?	No	No	No	No

\* Do not include right turn lane if channelized.

#### Volume Warrant

Peak hour left turn volume (vph)				
Opposing thru volume (vph)				
Estimated cycle time (s)	60	60	60	60
Green time for thru phase (s)	30	30	30	30
Computed minimum left turn volume (vph)				
Consider Left Turn Phasing?	N/A	N/A	N/A	N/A

#### Sight Distance Warrant

Min. required sight distance (ft) <i>(see Figure 3.8)</i>				
Available sight distance (ft)				
Consider Protected Left Turn Phasing?	N/A	N/A	N/A	N/A

#### Accident Warrant

No. of left turn related accidents in 12 month period				
Consider Protected Left Turn Phasing?	No	No	No	No

#### Summary

Consider Left Turn Phasing? Consider the Following Type	No Permissive	No Permissive	No Permissive	No Permissive
--	------------------	------------------	------------------	------------------

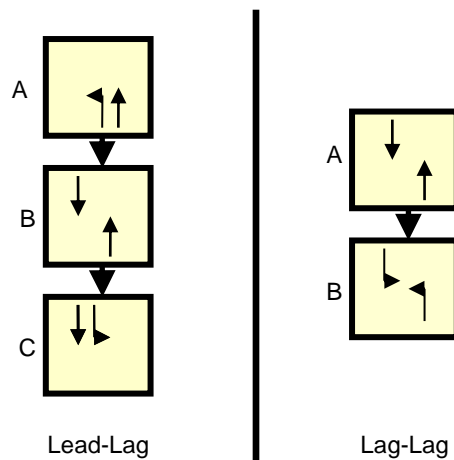
**Important:**

This worksheet provides typical phasing based on standard ALDOT guidelines. It is the responsibility of the engineer to verify that the phasing scheme is appropriate for the observed conditions.

Figure 3.10 – Left turn phasing worksheet

### 3.7 Lead-Lag and Lag-Lag Left Turn Phasing

Most left turn phases in Alabama operate as 'lead-lead', meaning both left turn phases on a given roadway precede the accompanying thru phases. In some cases a signal may operate more efficiently with 'lead-lag' or 'lag-lag' phasing, where one or both of the left turn phases occur after the thru phases, as shown in Figure 3.11.



**Figure 3.11 – Lead-Lag and Lag-Lag Phasing**

Lead-lag and lag-lag phasing are most commonly used in coordinated systems to enhance mainline progression or at interchanges where signals are closely spaced. They are rarely used at isolated signals except when special conditions dictate their use. Any proposed lead-lag or lag-lag phasing should be approved by the Region/Area Traffic Engineer in advance.

In cases where the left turn movements are protected, conventional signal heads and indications can be used for lead-lag phasing. In cases where the left turn movements operate in protected-permissive mode, the designer must specify flashing yellow arrow heads and operation in order to operate lead-lag phasing. This ensures that the lead-lag phasing will not create a left-turn trap (see section 3.6). A signal should not be operated lead-lag with conventional 5-section protected-permissive left turn heads. An exception to this is at interchanges or T-intersections where there is no opposing left turn movement and the left-turn trap can therefore not occur. Lag-lag phasing may be used with protected-permissive lefts but also requires flashing yellow arrow heads and operation.

### 3.8 Combining Permissive, Protected, and Protected-Permissive Left Turn Phasing

ALDOT recommends that the left turn phasing treatment used for opposing left turn movements be of the same type if possible. This means that opposing left turn movements should generally be either both permissive, both protected, or both protected-permissive, assuming these treatments are appropriate for both approaches. This is consistent with driver expectation and minimizes potential confusion, particularly with respect to permissive left turns. Combinations of protected, protected-permissive, and permissive left turn phasing may be specified with the approval of the Region/Area traffic engineer. Allowable combinations of left turn phasing are summarized in Table 3.2 below.

**Table 3.2 – Allowable Left Turn Phase Combinations on Opposing Movements**

Left Turn Treatment	Opposing Left Turn Treatment	Allowed?
Permissive	Permissive	Yes
Permissive	Protected	Yes <sup>1</sup>
Permissive	Protected-Permissive	Yes <sup>2</sup>
Protected	Protected	Yes
Protected	Protected-Permissive	Yes <sup>1</sup>
Protected-Permissive	Protected-Permissive	Yes <sup>2</sup>

<sup>1</sup> Flashing yellow arrow heads and operation required

<sup>2</sup> Detector switching or flashing yellow arrow heads and operation required (see Section 14).

### 3.9 Protected-Permissive Phasing for Dual Lefts

Under most conditions ALDOT discourages the use of protected/permissive left turn phasing for dual left turn lanes; however, ALDOT will consider protected-permissive left turn phasing for dual left turn lanes if **all** of the following conditions are satisfied:

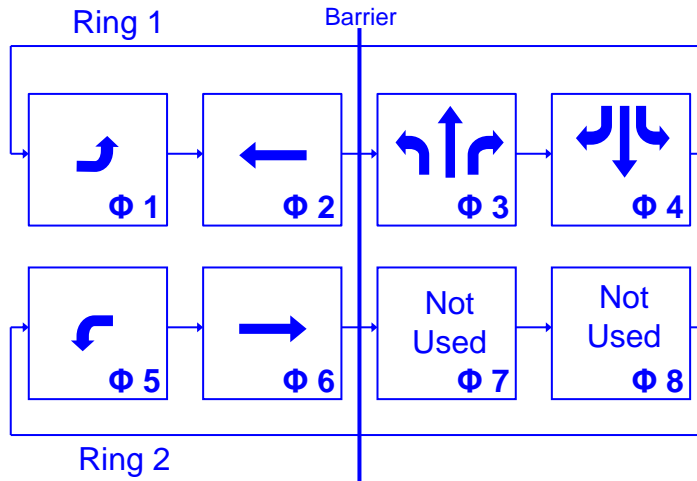
- Dual left turn lanes are on an approach where the 85<sup>th</sup> percentile speed does not exceed 35 mph
- Adequate sight distances exist
- This phasing will significantly enhance intersection operation

The designer should obtain approval for the use of dual protected-permissive left turn phasing from the Region/Area Traffic Engineer prior to plan submittal.

### 3.10 Split Phasing

In most cases, minor street approaches are assigned phases 4 and 8, with phases 7 and 3 assigned to left turn movements if they are present, as shown in Figure 3.4. This arrangement allows side street movements to operate simultaneously and is generally very efficient. There are situations, however, where it is desirable to run the side street approaches separately. This is most common when the side street approaches are offset and would conflict if run together, or in cases where there are shared left/thru lanes on one or both of the side street approaches that preclude the use of traditional left turn phasing.

To achieve split phasing one must assign the side street approach phases so that only one phase will be active at a time. This is easily achieved by assigning the minor street movements to the same ring (typically ring 1), since no two phases within a ring can be active at the same time. A standard phase assignment for side street split phasing is shown in Figure 3.12. As a general rule, it is good practice to assign phases so that the lower volume movement precedes the higher volume movement.

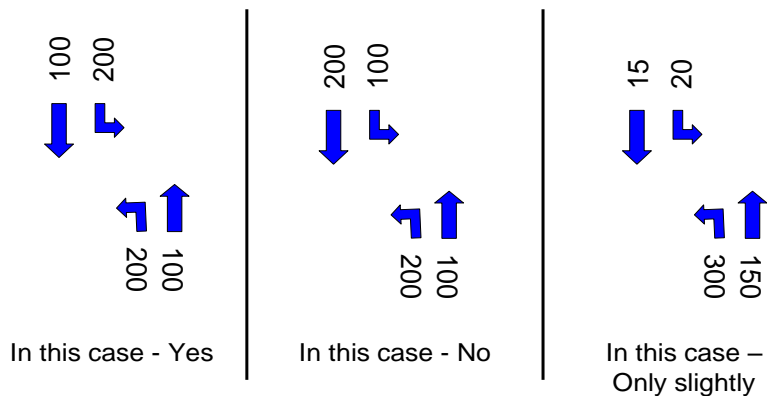


**Figure 3.12 – Typical phase assignments for side street split phasing**

There is a popular belief that split phasing is always less efficient than standard phasing. While this is true in many cases it is not always so. Split phasing will typically be less efficient in cases where all side street movements (lefts and thru’s) would otherwise run concurrently. However, in cases where separate left turn phasing would be required on the side street the relative efficiency of split phasing depends on the balance of traffic volumes. When opposing traffic volumes are fairly well balanced split phasing tends to be less efficient than standard 8-phase operation. However, in cases where one approach carries substantially more traffic than the other or where there are large volume differences between opposing turn movements (see Figure 3.13) then split phasing may not be significantly less efficient than a standard 8-phase operation.

When split phasing is required, it is recommended that the designer perform capacity analyses for both split-phasing and standard phasing options to determine whether the loss in efficiency resulting from split-phasing merits consideration of intersection improvements, such as additional lanes or re-alignment.

**Is Split Phasing Less Efficient than 8-Phase?**

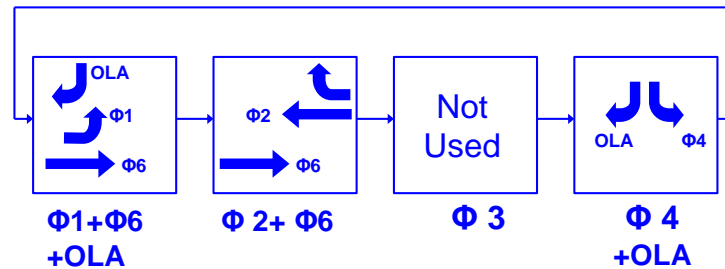


**Figure 3.13 – Comparison of split phasing to standard 8-phase operation**

### 3.11 Phase Overlaps

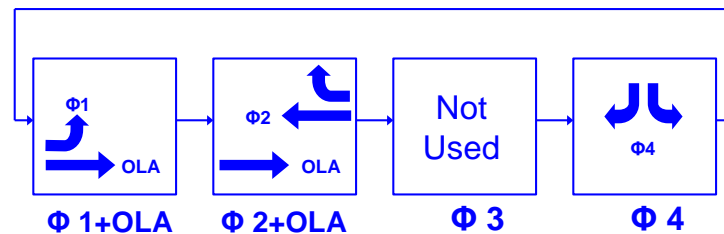
A phase overlap is a signal indication programmed to activate only when other specified phases are active. An overlap has no timing parameters of its own nor any detectors; it is instead entirely dependent on other phases for its activation and duration.

The most common type of overlap is the right turn overlap, where a green arrow is given to a heavy right turn movement while the cross-street left turn phase is active, as shown in Figure 3.14. This increases the capacity of the right turn movement.



**Figure 3.14 – Use of an overlap for right turns**

Another overlap type is commonly seen when a 4-phase controller is used at a 'T' intersection. In this case the indications for one mainline thru movement are designated Overlap A and assigned to phases 1 and 2 as shown in Figure 3.15. This allows the thru movement to be active both when the left turn movement is active and when the opposing mainline thru movement is active. It should be noted that if an 8-phase controller were used in this example the overlap would not be necessary.



**Figure 3.15 – Use of overlap for a T-intersection**

Overlap location and parent phases should be clearly defined on the signal layout, especially if the phasing doesn't conform to any of the standard signal operating plans.

# ***Chapter 4***

## ***Signal Layout and Pole Placement***

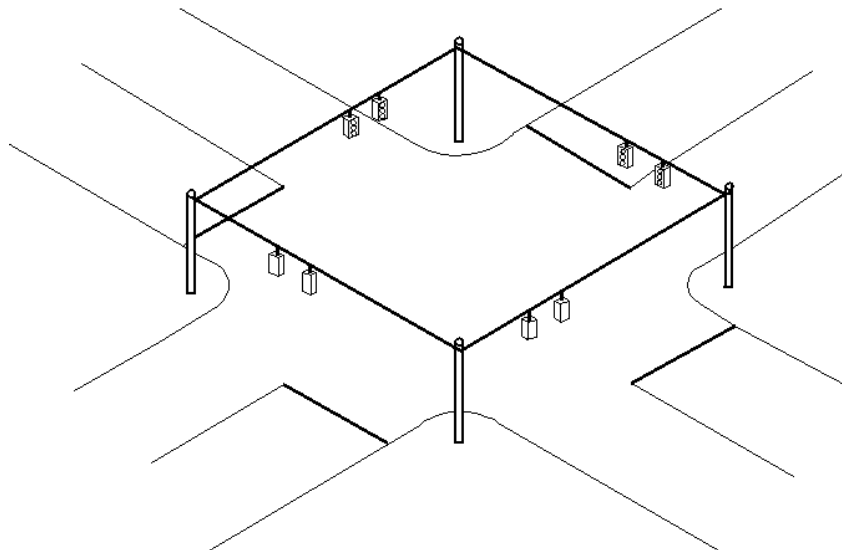
Traffic signal layouts generally follow four basic forms:

- Box span
- Z-span
- Suspended box span
- Mast-arm

Each type is described in detail below.

### **4.1 Box Span**

In a standard box span signal poles are placed in each of the four intersection quadrants with span wires strung between poles as shown in Figure 4.1. Signal heads are typically all mounted on the span wires. This arrangement has the following advantages and disadvantages:



***Figure 4.1 – Typical box span design***

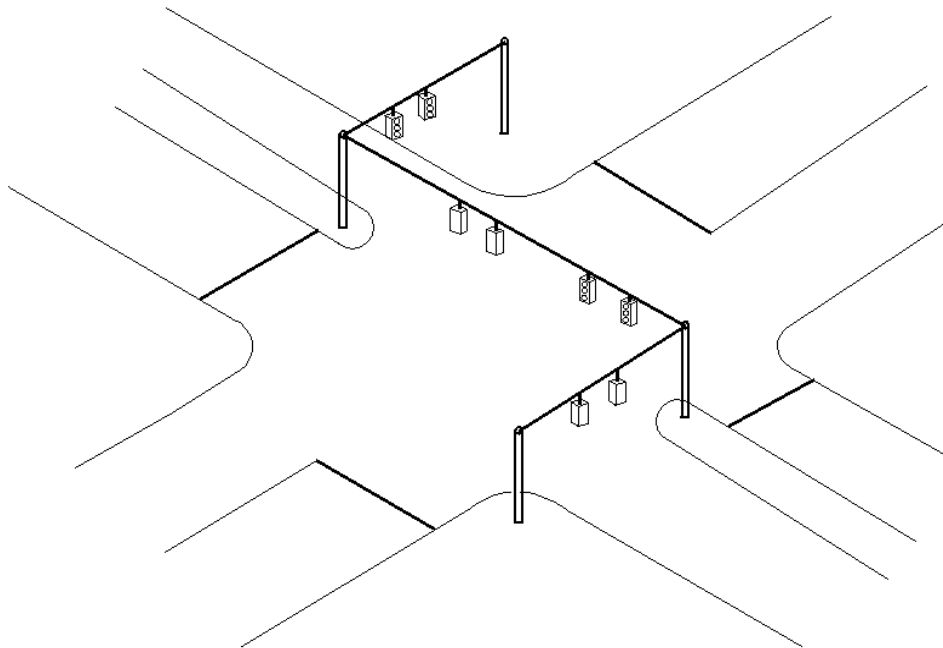
- ✓ Simple layout
- ✓ Provides good visibility to signal heads
- ✓ All wiring can be run across span wires
- ✗ Requires long spans for large intersections
- ✗ Signal heads may exceed distance limits
- ✗ Signal wiring exposed to elements

Because of its simplicity, visibility, and ease of maintenance, the box span is the most common layout type used by ALDOT. Box spans can be used for most standard signal installations.

## 4.2 Z-Span

In this arrangement, poles are placed in the median as well as two of the intersection corners, as shown in Figure 4.2. Z-Spans are sometimes used at large intersections to reduce the distances to signal heads. Advantages and disadvantages of this design are as follows:

- ✓ It reduces distances to heads at large intersections
- ✓ All wiring can be run across span wires
- ✗ It requires adequate median width for pole placement (min. 22 ft. if uncurbed or min. 6 ft. if curbed)
- ✗ Poles in the median may pose a collision risk
- ✗ Left turning vehicles waiting in the middle of the intersection may lose sight of the signal heads



**Figure 4.2 – Typical Z-span design**

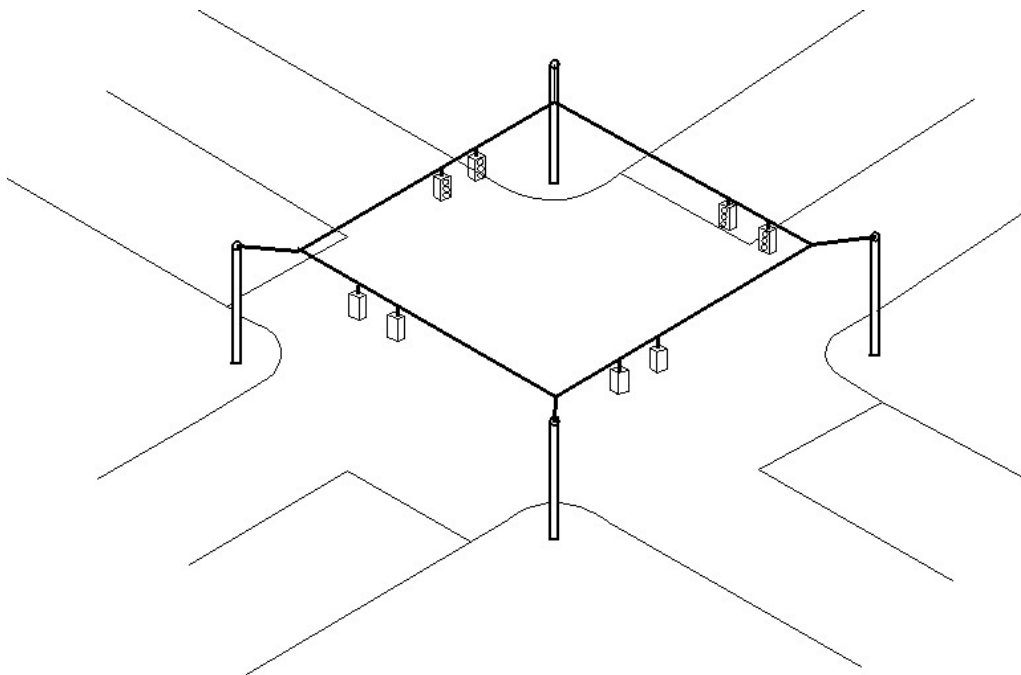


### 4.3 Suspended Box Span

This type of span is typically used when distances to the signal heads exceed maximum MUTCD standards (i.e., 180 ft.). In these cases, the box span is suspended out over the intersection using diagonal stringers as shown in Figure 4.3. This reduces the distances to the signal heads; however, it can also create maintenance issues. These types of spans can be prone to sag over time due to the increased load on the stringers. The pros and cons of the suspended box design are summarized below:

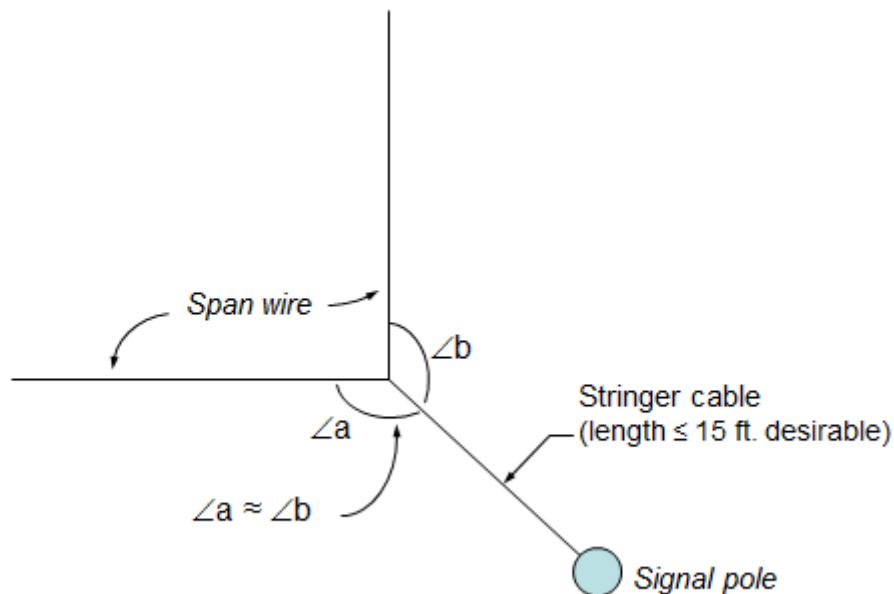
- ✓ It reduces distances to signal heads at wide intersections
- ✓ All wiring can be run across span wires
- ✗ It can be prone to sag over time
- ✗ Increased loads may require larger poles
- ✗ It can be difficult to adjust spans for proper signal head mounting heights

For these reasons, ALDOT recommends that designers explore other alternatives prior to recommending a suspended box span design.



**Figure 4.3– Typical suspended box design**

When a suspended box design is used, ALDOT recommends the length of the stringers be kept to a maximum of 15 ft. if possible. This helps to minimize span wire sag over time. A stringer length longer than 15 ft. can be used if necessary; however, it should be discussed with the Region/Area Traffic Engineer prior to plan submission. It is also recommended that the poles and box span be oriented so that each stringer bisects the angle created by the suspended box corner as shown in Figure 4.4.



**Figure 4.4 – Suspended box stringer design**

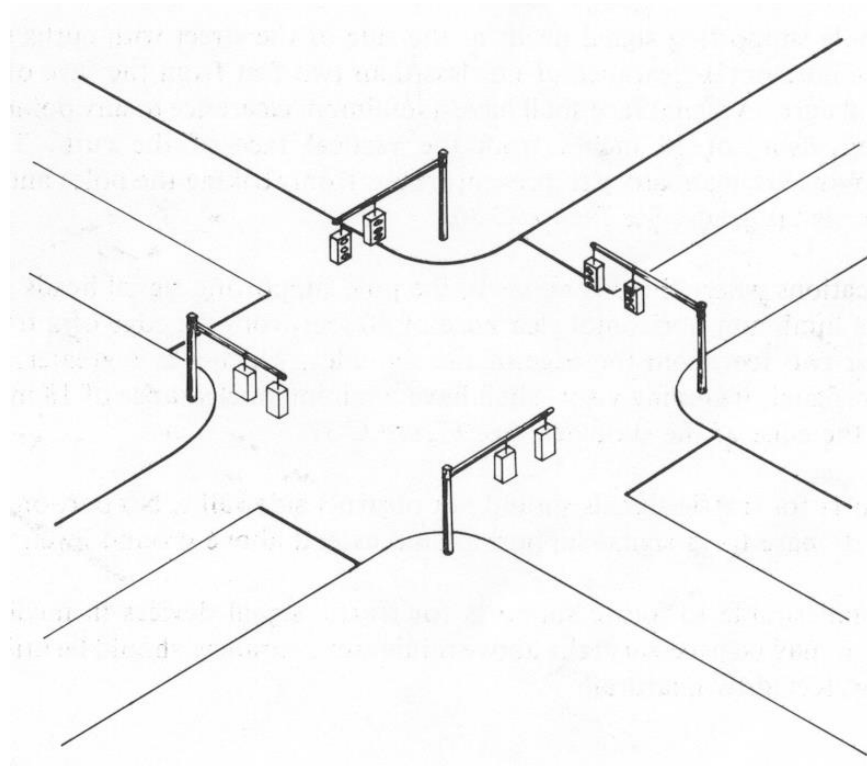
**i** The suspended box span should be used only when conditions dictate. ALDOT's preference is that span wires be attached directly pole-to-pole. Consider the following alternatives to a suspended box design first:

- adjust pole locations
- relocate stop lines
- use near-side indications

#### 4.4 Mast-Arm Installations

Mast-arm poles are used for a variety of installations (see Figure 4.5). They can be used for aesthetic purposes, in locations where high winds are likely (e.g., near the coast), or in locations where right-of-way or overhead utilities make standard pole placement difficult. Mast-arm installations are typically more expensive than span wire designs, so the designer is advised to obtain ALDOT approval for a mast-arm design prior to plan development. Mast-arm designs have the following advantages and disadvantages:

- ✓ Clean and aesthetically pleasing design
- ✓ Wiring is not exposed to weather
- ✓ Stable platform for heads, signs, and video cameras/detectors
- ✓ More durable in high wind areas
- ✗ Wiring must be placed in underground conduit
- ✗ Typically more expensive than span-wire designs ( $\approx 25\%$  or more)
- ✗ Large intersections can require very long arms, increasing installation costs significantly



**Figure 4.5 – Typical mast-arm design**

Mast-arm poles are required on all new signal installations south of I-10 in order to provide protection against hurricane damage. The concrete foundations for mast-arm poles (as well as for steel strain pole installations) shall be designed for the appropriate wind loads. Estimated wind loads in the State of Alabama are contained in the [ALDOT Standard and Special Drawings for Highway Construction](#) Book (current edition). The [ALDOT Standard Specifications for Highway Construction](#) requires the contractor to have a professional engineer design all poles and foundations per Sections 718 and 891.

#### **4.5 Pole Placement for Span Wire Designs**

The most common type of signal design used in Alabama is the span wire design, which includes box, Z-span, and suspended box layouts. There are a number of considerations involved in determining optimum signal pole locations:

- Right-of-way
- Utilities
- Signal head distances
- Roadway clearances

#### 4.5.1 Right-of-Way (ROW)

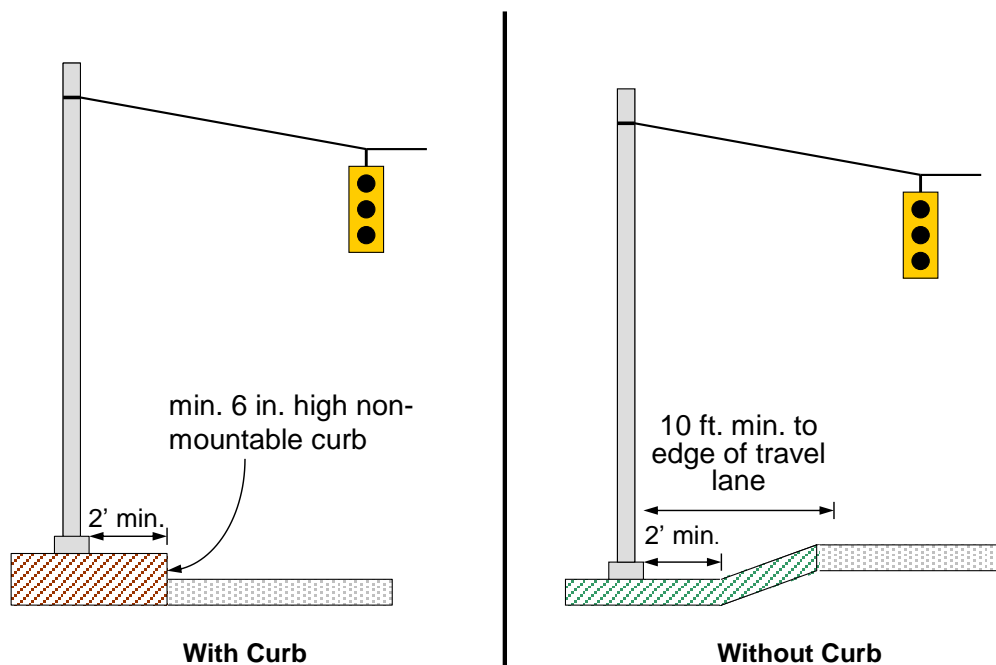
On state projects, all signal poles must be located within public right-of-way (ROW). Public right-of-way can include State or municipal right-of-way, as long as an agreement has been obtained from the municipality to locate signal poles on their ROW. Poles may not be located on private property on State projects.

For signals installed under permit, it is desirable to locate all poles within public ROW, however, a pole may be placed on private property if an easement is obtained. The designer should consider locating signal poles near the edge of ROW if it appears likely that a roadway will be widened in the future. Locating the poles at the edges of the ROW allows more flexibility for future intersection improvements, although it also creates longer spans and may increase installation costs.

#### 4.5.2 Roadway Clearances

In curbed areas, the face of the signal pole must be located a minimum of 2 ft. from the face of curb. The curbing should be a minimum of 6 in. in height and non-mountable. In areas without curbing, the face of the signal pole must be located a minimum of 10 ft. from the edge of the nearest travel lane. Shoulders are not considered travel lanes and can be considered part of the 10 ft. setback distance. These dimensions are summarized in Figure 4.6. See the [ALDOT Standard and Special Drawings for Highway Construction](#) Book (current edition) for additional details.

It should be noted that ALDOT does not require that clear zone distances be observed for traffic signal equipment (as described in the [AASHTO Roadside Design Guide](#)). If clear zone distances can be easily met then the designer may wish to incorporate them into his design; however, it has been found that clear zone requirements can result in excessively long signal spans.



**Figure 4.6 – Minimum pole setback distances**

### 4.5.3 Utility Clearances

All utilities, both underground and overhead should be shown on the design plans. Typical utilities include electricity, water, gas, cable tv, telephone, and fiber optic communications lines. If the exact locations of underground utilities are not known, a note shall be provided on the plans stating that the locations shown are approximate.

Minimum clearances must be maintained between all signal equipment (including poles, foundations, cables, and span wire) and utilities. Some typical minimum clearances are shown in Table 4.1:

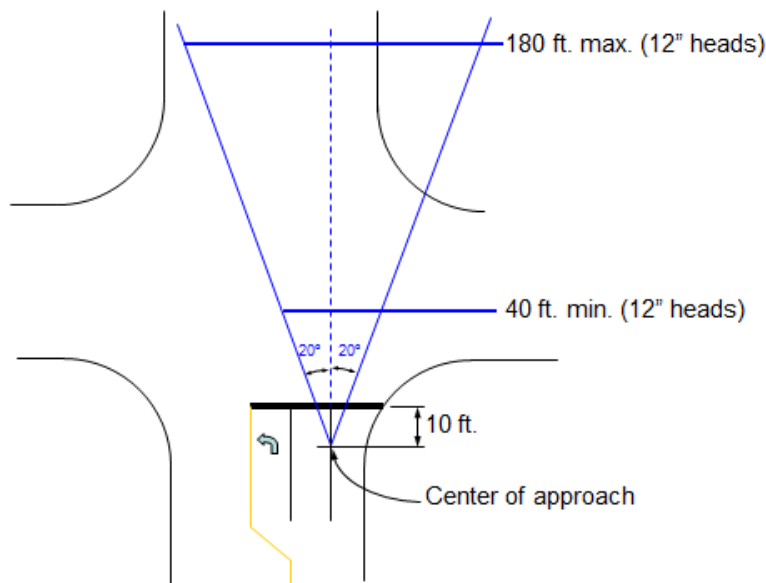
**Table 4.1 – Typical minimum utility clearances**

Utility Type	Min. Clearance
Electric (primary, >750V)	90 in. radius
Electric (secondary, uninsulated)	60 in. radius
Electric (secondary, insulated)	42 in. radius
Electric (underground)	30 in.
Telephone (overhead)	30 in.
Cable TV (overhead)	18 in.
All other underground	18 in. min. (varies)

Table 4.1 presents typical utility clearances; actual clearances will vary with local utilities. The designer is responsible for contacting all utilities prior to signal design to obtain local clearance requirements. Additional information can be found in the [National Electrical Safety Code \(NESC\)](#), current edition.

### 4.5.4 Signal Head Distances

MUTCD guidelines set maximum allowable distances from stop lines to signal heads (see Figure 4.7 and Section 5.7.1). If possible, signal poles should be located to facilitate meeting these distance requirements without requiring the use of near-side indications or suspended box designs. Standard signal heads used on ALDOT projects are 12 in. and the distances shown in Figure 4.7 are for 12 in. heads only.



**Figure 4.7 – Maximum distances from stop line to signal heads ([MUTCD Section 4](#))**

#### 4.5.5 Placing Poles in Channelizing Islands

ALDOT discourages placing signal poles or equipment in channelizing islands. Placing equipment in islands increases the risk of it being struck by errant vehicles, which is both a safety and maintenance issue. Every effort should be made to place poles outside of the roadway if possible. In cases where conditions dictate locating a pole in an island the following minimum criteria must be met:

- The island should have a minimum area of 100 ft<sup>2</sup> and must be curbed
- The face of pole should be located a minimum of 10 feet from all travel lanes
- Region/Area approval must be obtained

#### 4.5.6 Effects of Small Curb Radii

At intersections where curb radii are less than 25 ft. and there is significant truck traffic, there is a danger of large trucks (WB-50 or larger) jumping the curb when making right turns and damaging a signal pole. If an intersection has significant heavy truck traffic the designer should consider locating signal poles far enough back from the curb to eliminate the potential for truck damage. A safe distance can be estimated using a WB-50 truck turning template.

### 4.6 Computing Pole Heights for Span Wire Designs

It is the responsibility of the designer to specify pole shaft height. ALDOT uses three standard signal pole heights:

28 ft. Pole – Used for most standard installations that do not require luminaires (see Section 4.6.3). A 28 ft. pole provides enough shaft height to accommodate most slopes and spans. When used, the designer should check attachment heights to ensure the 28 ft. pole height is adequate.

37 ft. Pole – Used in most standard installations where 250W luminaires are required. The shaft height is usually sufficient to accommodate all slopes and spans.

47 ft. Pole – Used in special cases where a 400 watt luminaire is specified or in cases where extra pole height is required.

Other pole heights may be specified for special circumstances, but ALDOT standard pole sizes should be adequate for most applications. To determine the appropriate pole height the designer should consider the following factors:

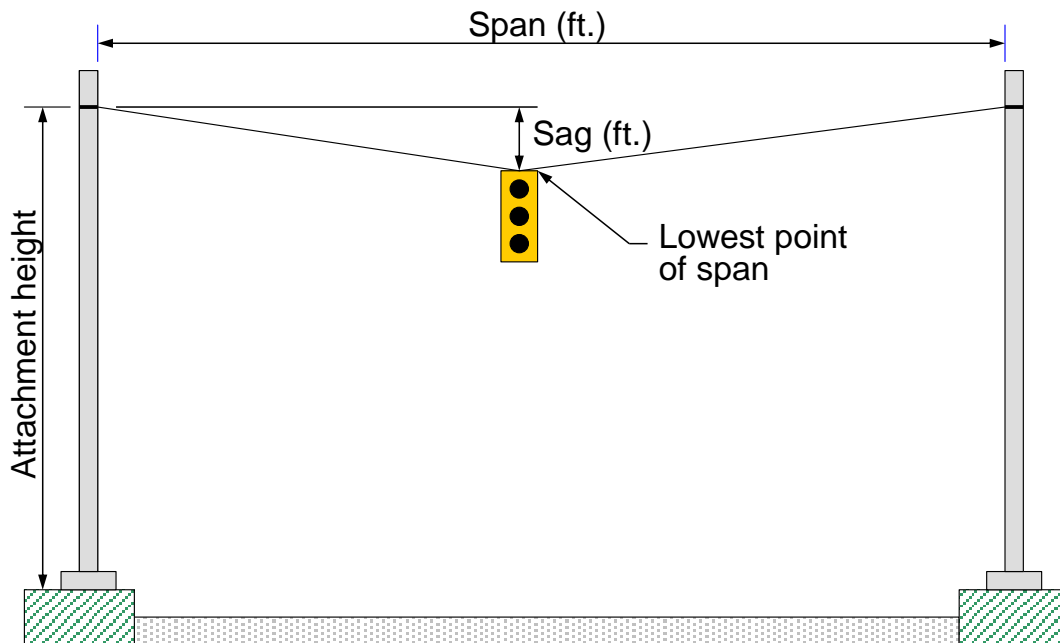
- Span wire sag and attachment height
- Effects of slopes
- Provision of luminaires

#### 4.6.1 Span Wire Sag and Attachment Height

On spans greater than 100 feet, the designer should check attachment heights to ensure that the specified pole heights are adequate for the span. ALDOT requires the sag in the span wire to be at least 3% but not more than 5%. Sag of less than 3% dramatically increases the stress on the signal poles. Sag in excess of 5% allows too much sway in the span wire and signal heads.

Span wire sag can be computed as:

$$\text{Percent sag} = (\text{sag}/\text{span}) \times 100 \text{ (see Figure 4.8)}$$



**Figure 4.8 - Computing span wire sag**

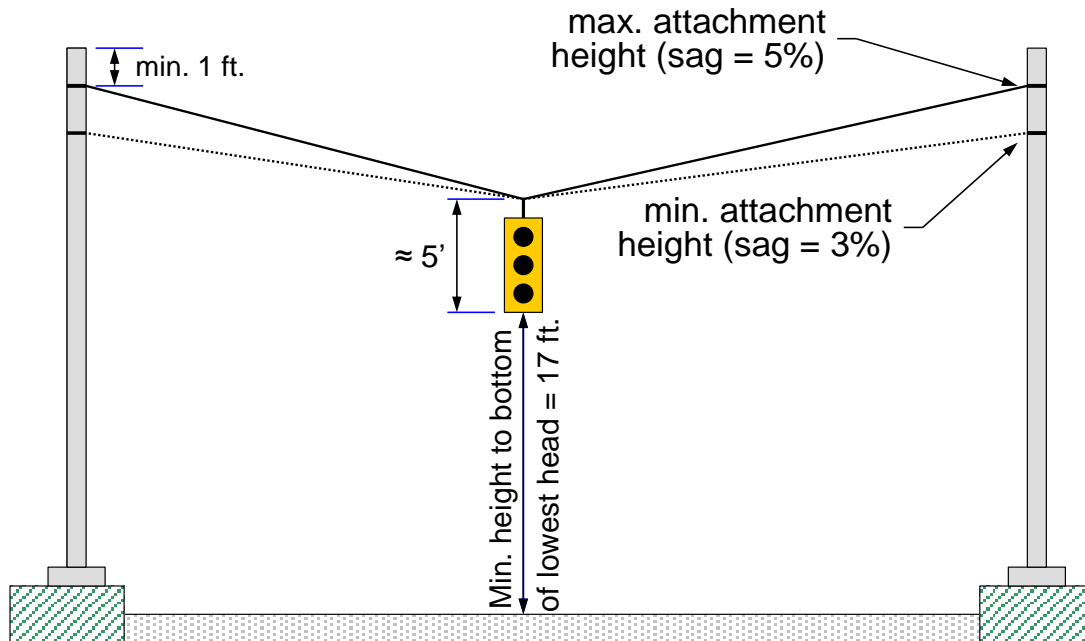
Based on sag and clearance requirements and assuming 5 ft. from the span wire to the bottom of a signal head, the maximum attachment height can be estimated as follows:

$$h_{\text{max}} (\text{ft}) = 25 + (\text{span length} / 20) \quad \text{[assumes 5\% sag]}$$

The minimum attachment height can be estimated as follows:

$$h_{\text{min}} (\text{ft}) = 22 + (\text{span length} / 33) \quad \text{[assumes 3\% sag]}$$

In general, the specified poles should be able to accommodate the maximum attachment height with at least 1 ft. remaining between the attachment point and the top of pole, as shown in Figure 4.9.



**Figure 4.9 – Maximum and minimum attachment heights**

#### 4.6.2 Effects of Slopes

If a signal pole is located on a slope the designer should account for the effect of the slope on pole height. The mounting height calculations presented in section 4.6.1 assume level terrain. If a pole is located on a slope, the designer must add to those calculations the additional shaft height necessitated by the slope, as shown in Figure 4.10. It is ultimately the responsibility of the signal contractor to verify pole heights and to adjust lengths accordingly, so the designer should place a note on the layout if it is obvious there is a considerable slope present.

#### 4.6.3 Provision of Luminaires

Luminaires provide additional lighting at an intersection to improve visibility and safety at night. They are typically mounted at the top of the signal strain poles and oriented to illuminate the stop lines and pavement markings at the intersection (see [ALDOT Standard and Special Drawings for Highway Construction](#) Book, current edition). Luminaires are recommended under the following conditions:

- Offset or skewed intersections
- Complex intersections (multiple turn lanes, lane shifts, etc.)
- Intersections which have channelized movements
- Intersections with pedestrian features



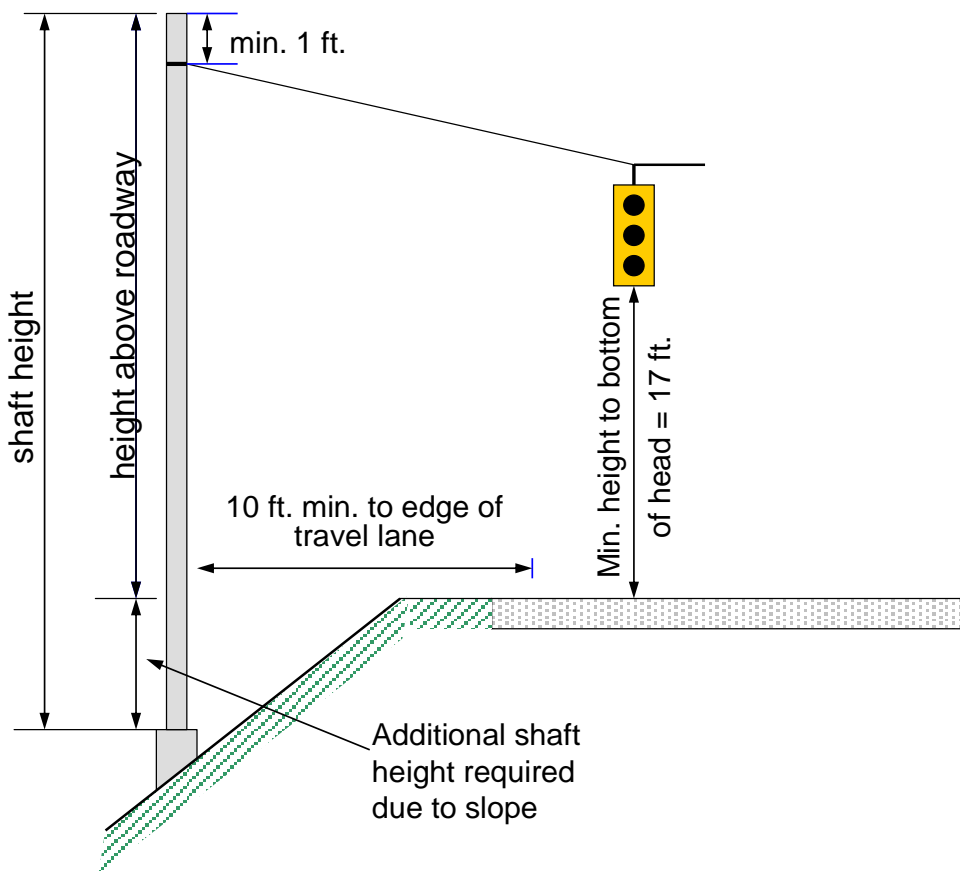


Figure 4.10 – Effect of slope on pole height

Luminaire power (wattage) depends on pole height. Standard ALDOT luminaire/pole height combinations are shown in Table 4.2. Using higher wattage luminaires than those specified for a given pole height will result in lighting that is too localized and intense. Typical luminaire orientations are shown in Figure 4.11. Typical arm lengths are 12 ft. and 15 ft.

Table 4.2 – Standard Luminaire/Pole Height Combinations

Pole Height	Luminaire Power
28 ft.	not used
37 ft.	250 watt
47 ft.	400 watt

#### 4.7 Signal Pole Types for Span Wire Designs

ALDOT uses three types of signal poles for span wire installations:

**Wood Poles** – Wood poles are typically not permitted for new or permanent installations. Wood poles may be used for temporary signal installations or in downtown CBD areas where they are replacing existing wood poles. Region/Area approval should be obtained before specifying wood poles. Details for wood poles are provided in the [ALDOT Standard and Special Drawings for Highway Construction](#) Book (current edition). When wood poles are used for signal installations they must be guyed, as shown in Figure 4.12.

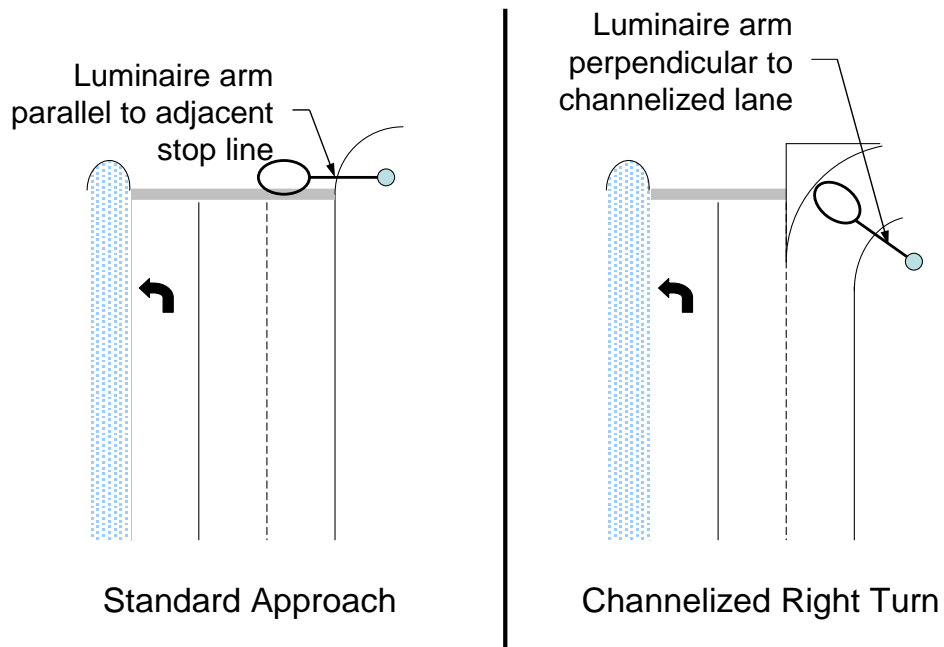


Figure 4.11 – Standard luminaire orientation

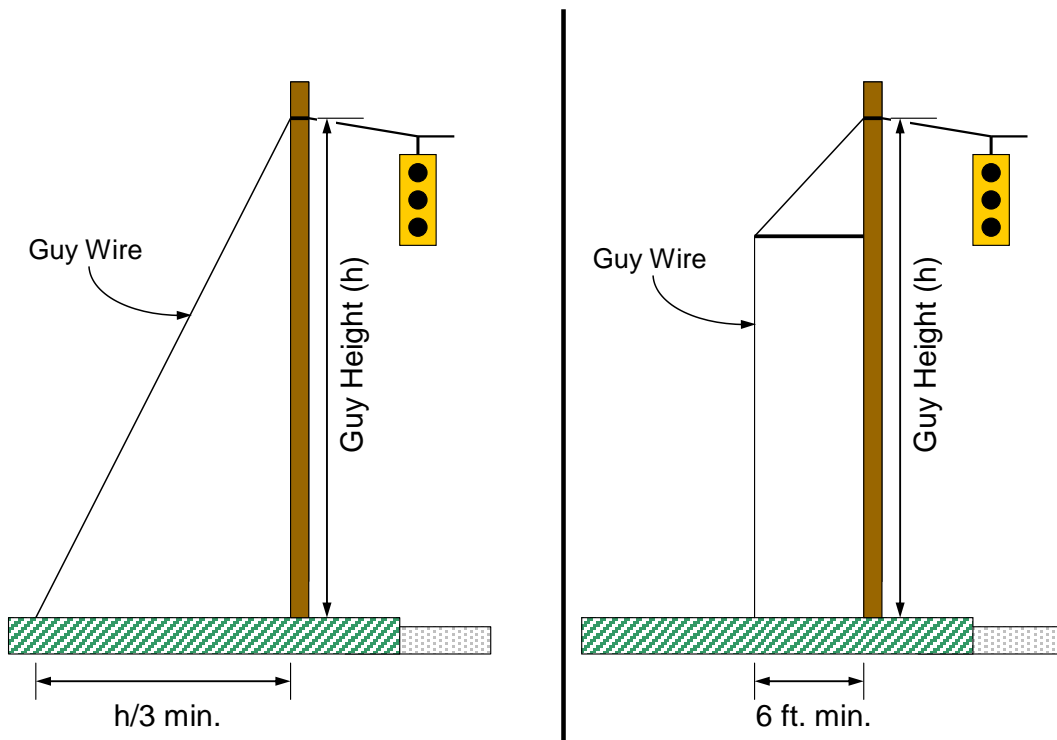


Figure 4.12 – Typical guy configurations for wood poles

**Steel Strain Poles** – Hollow steel tubes are the most commonly used pole type in Alabama. Standard heights range from 28 ft. to 47 ft. and they can be designed to carry most signal loads. Steel strain poles require ALDOT approved steel reinforced concrete foundations. When locating steel poles the designer should also account for the typical 3 foot diameter of the foundation.

**Concrete Strain Poles** – Consisting of spun concrete, they can be manufactured to standard heights from 28 ft. to 47 ft. Backfill may consist of soil, soil-aggregate, or concrete. Backfilling of concrete poles should be in accordance with the manufacturer's and/or engineer's recommendation. Under heavy loading, concrete poles may require guy wires.

#### 4.7.1 Retrofitting Existing Span Wire Installations

When upgrading an existing signal installation the question often arises whether the existing strain poles should be retained. In general, strain poles may be retained if the number and size of signal heads and signs mounted on the span wires remains the same. The greatest factors affecting pole design are span length and wind loading, and if either of these changes significantly the existing poles should be replaced, unless it can be shown that they meet currently adopted [AASHTO Standard Specifications for Structural Sign Supports, Luminaires, and Traffic Signals](#). Poles must also meet all criteria identified in the current ALDOT Standard Specifications.

The designer should consider replacing existing strain poles under the following conditions:

- Added signs and/or signal heads mounted on span wires increase the combined stress ratio (CSR)
- The length of the signal spans increases more than 10% due to one or more of the poles being moved
- Existing poles are damaged or deteriorated

The designer should also be aware that if an upgrade to an existing signal results in a significant increase in the number of conductors required to serve the signal components, the existing signal poles may need to be retrofitted with riser conduits to house some of the additional conductors.

#### 4.7.2 Span Wire

Standard span wire is 3/8 in. stranded steel cable.

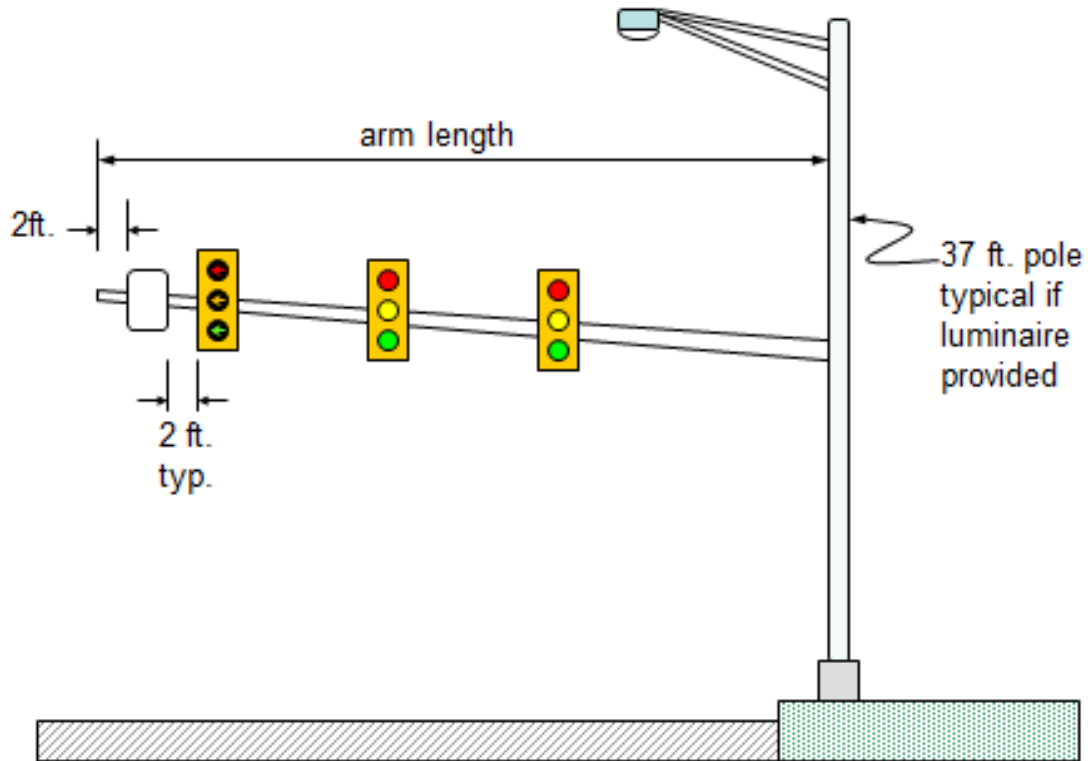
#### 4.7.3 Mast-Arm Installations

The same general guidelines for pole location and height outlined in sections 4.5 and 4.6 apply to mast-arm installations as well, with a few key differences. The cost to fabricate a mast-arm pole depends heavily on the length of the mast-arm. Although mast-arms as long as 80 ft. or more can be manufactured, a practical limit is 60 ft. Mast-arms longer than 60 ft. become cost-prohibitive and should be used only in special circumstances.

Because the cost of the pole depends on the length of the mast-arm, it is desirable to locate mast-arm poles as close to the intersection as possible in order to minimize the necessary arm length. The specified arm length should be long enough to accommodate all necessary signal heads and signs (see Chapter 5) plus an extra 2 feet, as shown in Figure 4.13.

Designers should keep in mind that signal pole locations are often adjusted in the field due to utility conflicts or the presence of other features such as ditches, trees, and plants. Mast-arm poles are far

more constrained than strain poles in this regard because the arm length is fixed and any major adjustments may leave inadequate room for proper signal head alignment on the arm. The designer should take special care to locate all possible conflicts and obstructions before computing mast-arm lengths and locations.



**Figure 4.13 – Computing mast-arm length**

#### 4.8 Twin Mast-Arm Installations

Twin mast-arms have two arms mounted on a single shaft. They are used to mount signal heads for two approaches on a single pole unit. They can be particularly useful when utility conflicts or ROW concerns make it difficult to locate a pole in one or more intersection quadrant. The total cost of a twin mast-arm installation can be less than the cost of two separate mast-arm installations but they typically require larger foundations. Because one of the arms will have to extend over opposing traffic lanes as well as the approach lanes, they are most effective on narrow streets or one-way streets.

# Chapter 5

## Traffic Signal Heads

ALDOT uses a variety of traffic signal heads to provide indications to motorists and pedestrians. This section covers the permissible head types, arrangements, and location criteria.

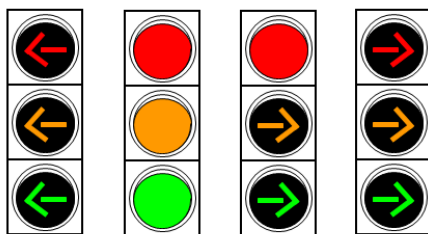
### 5.1 Permissible Arrangements

The MUTCD requires that there be at least two signal heads for each through movement, and at least one indication for each left turn lane if protected or protected/permissive left turn phasing is provided. A separate signal head/indication is not required if the left turn movement is permissive only. See Figures 5-21 through 5-25 at the end of this section to view a sample of minimum signal head arrangements. Number and arrangement of signal heads should be confirmed with ALDOT.

In Alabama, all standard signal heads are arranged vertically. Approval must be obtained from the Region/Area Traffic Engineer before using horizontally arranged signal heads. Permitted head arrangements are shown in Figure 5.1 through 5.8.

#### 5.1.1 3-Section Heads

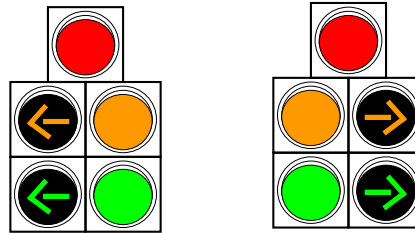
Standard 3-section head arrangements are shown in Figure 5.1. They are used for through movements, protected left turns, and protected right turns. Note that the standard configuration for a protected-only left turn or right turn head consists of red, amber, and green arrows. The red ball may be used in a protected turn head only in cases such as at a T-intersection where it makes clear that all traffic must stop.



**Figure 5.1 - Standard 3-section head arrangements**

### 5.1.2 5-Section Heads

Standard arrangements for 5-section heads are shown in Figure 5.2. These heads are typically used for protected-permissive left turns and right turn overlaps. These heads are only used when a phase shares the ball indications with the adjacent through movement.



**Figure 5.2 - Standard 5-section head arrangements**

### 5.1.3 Horizontal Head Arrangements

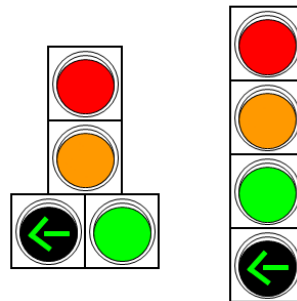
Horizontal head arrangements are typically used in cases where vertical clearance is constrained or there are high winds. They are typically mounted on mast-arms. Area/Region approval is required for use. Typical arrangements are shown in Figure 5.3.



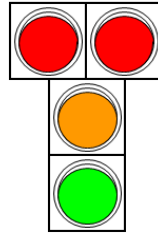
**Figure 5.3 - Horizontal arrangements**

### 5.1.4 4-Section Heads

Permissible 4-section head arrangements are shown in Figures 5.4 and 5.5. Heads with dual green indications are typically used for shared left-thru lanes. Heads with dual red indications are typically used in situations where extra visibility is desirable, such as at the first signal on a high speed route or in locations with limited visibility.



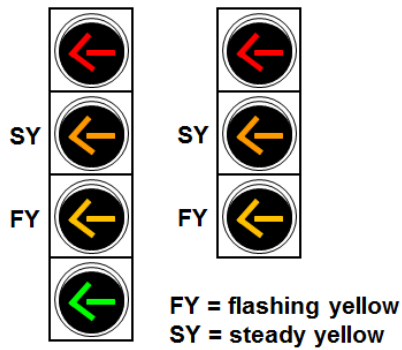
**Figure 5.4 – 4-section head arrangements  
(dual green indications)**



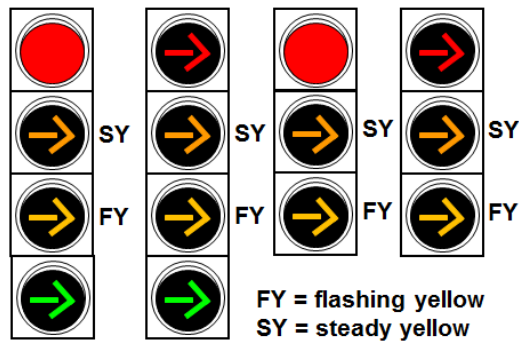
**Figure 5.5 – 4-section head arrangement (dual red indications)**

**5.1.5 Flashing Yellow Heads**

Figures 5.6 and 5.7 show permissible flashing yellow head arrangements. Additional details on flashing yellow operation can be found in the MUTCD.



**Figure 5.6 – Left-turn flashing yellow arrangements**



**Figure 5.7–Right-turn flashing yellow arrangements**

### 5.1.6 U-Turn Heads

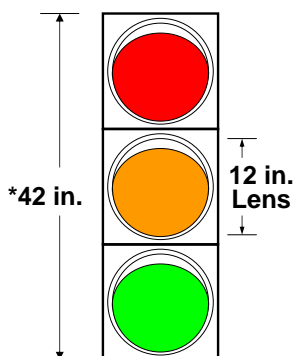
Figure 5.8 shows a typical u-turn signal head. These may be used for alternative intersection designs where left turn movements are replaced by u-turns either before or after the main intersection.



**Figure 5.8 – U-turn arrangement**

## 5.2 Standard Head Sizes

The standard sized signal head used on ALDOT projects contains three 12 in. lenses (see Figure 5.9). It is ALDOT practice to use 12 in. signal heads on all new projects because they provide the greatest visibility to motorists. All standard 12 in. heads shall use LED modules.



\* Height does not include mounting hardware

**Figure 5.9 – Standard head size**

## 5.3 LED Heads

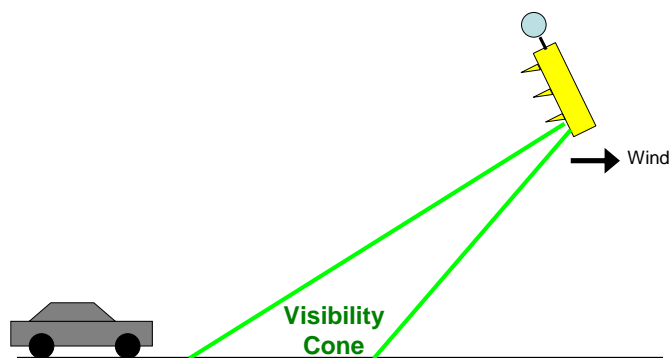
LED (Light Emitting Diode) heads have several advantages over conventional incandescent heads. These include longer service life and reduced power consumption. An LED head consumes about 1/10 the power of a conventional incandescent head and requires less maintenance. For these reasons, ALDOT requires LED heads on all new signal installations.

### 5.3.1 Visibility Issues with LED Heads

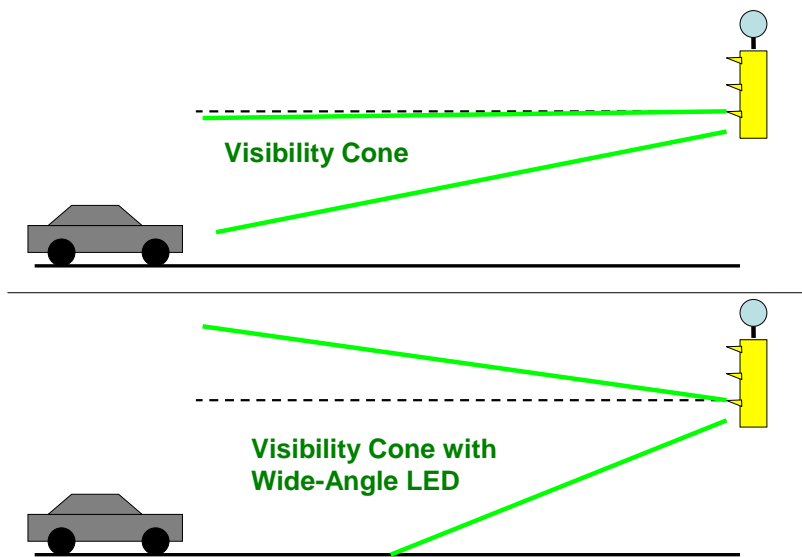
There can be visibility issues associated with LED heads. The cone of visibility for an LED head is smaller than for an incandescent head. This means that the brightness of an LED head can vary depending on the angle from which it is viewed, which can be a problem if wind causes the head to sway or if a head is simply improperly aligned, making it appear to “blank out” when the viewing angle



becomes too great (Figure 5.10). This problem can be countered through the use of wide angle LED's, balance adjusters, and tether. Wide angle LED's increase the cone of visibility (Figure 5.11) and are now included in the ALDOT standard specifications, so it need not be called out in the plans. ALDOT's List of Materials, Sources, and Devices with Special Acceptance Requirements specifies which of the approved LED products are restricted for mast arm or rigid mount only.



**Figure 5.10 – LED head appears to “blank out” when improperly mounted or swayed**



**Figure 5.11 – Effect of Wide-Angle LED on visibility**

Most ALDOT Regions/Areas require the use of balance adjusters on LED heads and their requirement should be clearly noted in the design plans. A balance adjuster is a piece of hardware used to mount signal heads to a span wire which allows the vertical aim of the head to be adjusted correctly. In most cases, a balance adjuster combined with wide angle LED's is enough to maintain proper visibility for LED heads. Balance adjusters should be installed according to the following guidelines:

- If an approach has a negative grade a balance adjuster is required. The entrance fitting should be turned to the front and pinned forward to hang perpendicular to the roadway. An approximate 4" vertical slot should be cut into the backplate to allow the entrance fitting to protrude through. The contractor should pull the signal cable down (drip loop) to the entrance fitting neck with a heavy duty plastic Ty-Rap to force the signal cable to form downward until the cable jacket hardens and the Ty-Rap falls off in time.
- If an approach has a level grade a balance adjuster is required. The entrance fitting should be turned to the back and pinned to hang perpendicular. The drip loop should be formed per standard procedure.
- If an approach has a low positive grade a balance adjuster may not be needed.
- If an approach has a high positive grade a balance adjuster is required. The entrance fitting should be turned to the back and for the drip loop formed per standard procedure.

Designers should note that the 2.5 degree tolerance may not be achieved if there is a very steep positive or negative grade.

### 5.3.2 Use of Tether Wire

In some cases, signal heads may require a tether wire running underneath the head to hold them in proper alignment (see Figure 5.16). These conditions can include high wind areas, areas with significant topography, or when programmed heads are used. Tether wire can become a maintenance issue over time, so its use should be restricted to cases where it is essential for proper head visibility.

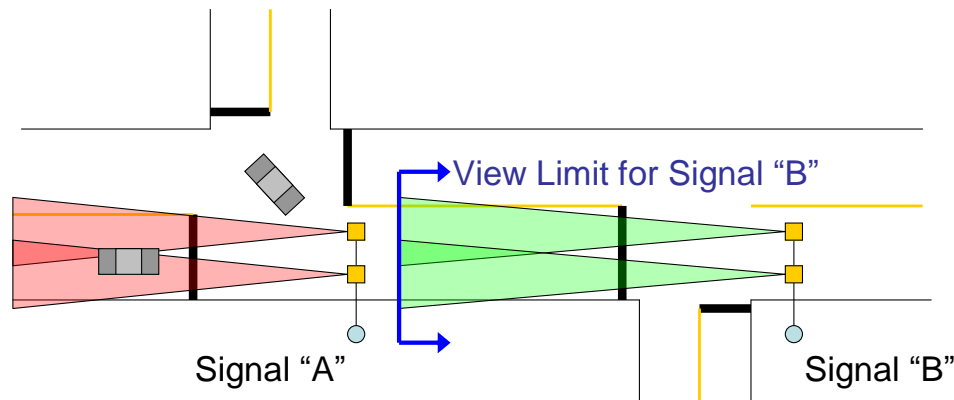
### 5.3.3 Retrofitting LED Heads

LED inserts can be retro-fitted to existing signal head housings. During upgrade projects it may be desirable to upgrade the signal faces with LED inserts in order to take advantage of their superior energy efficiency and longevity. The cost is lower than the cost of replacing an entire head but should only be specified if the signal head housings are in good condition.

Note that some municipalities upgrade only the red and green indications and leave the yellow indication incandescent. The reasoning behind this is that the yellow indication is typically on for only a very short duration compared to the red and green indications and therefore the energy savings will not justify the conversion cost. This may not be true, however, if the signal flashes yellow for long periods at night. It is recommended that the Region/Area Traffic Engineer be consulted about whether or not to retrofit all or just some of the signal faces.

## 5.4 Optically Programmed Heads

The previous sections discussed the potential issues that can arise from the LED head's restricted visibility cone and ways to address them. There are situations, however, where restricted visibility is desirable. Such a situation is shown in Figure 5.12. In cases where signals are placed very close to one another, such as at closely spaced or offset intersections, the conflicting indications can be confusing to drivers. In Figure 5.12, the green indications at Signal "B" might draw motorists through the red lights at Signal "A", so it is desirable that motorists stopped at Signal "A" not be able to view the indications at Signal "B". This can be achieved through the use of optically programmed heads, which use special lenses to significantly restrict visibility angles and distances.



**Figure 5.12 – Use of Optically Programmed Heads to Limit Visibility at Signal “B”**

In Figure 5.12, optically programmed heads would be used at signal “B” and conventional heads used at signal “A” (for traffic traveling in the opposite direction, conventional heads would be used at signal “B” while optically programmed heads would be used at Signal “A”). This would prevent motorists at signal “A” from viewing the indications at signal “B”. When using optically programmed heads, the designer must clearly specify them on the plan sheet and in the quantities, and clearly delineate their desired view limits on the plans (as done in Figure 5.12). Because programmed heads have highly restricted viewing angles (far more restricted than standard LED heads) they are very sensitive to movement and must be either rigidly mounted or tethered.

Finally, designers must keep in mind that because optically programmed heads restrict visibility distance they can also severely restrict stopping sight distance. Signal phasing must be chosen carefully so that the designer does not create a situation where motorists have inadequate warning of a red light. In the example of Figure 5.12, there should never be a case where the signal at “A” is green while signal “B” is red, because motorists passing through signal “A” would not have enough advance warning of the red indication at signal “B” to stop safely (the situation would be reversed for traffic traveling in the opposite direction). In this example, the optically programmed heads should operate on a “trailing green” (see Signal Timing Section) to allow all traffic to safely clear the intersection before turning red.

**! Optically programmed heads may reduce stopping sight distance.** When using optically programmed heads designers must choose signal phasing carefully so as not to create a situation where motorists have inadequate distance to stop for a red light.

## 5.5 Louvers

Another means of restricting the viewing angle and viewing distance for signal heads is the use of louvers. Louvers are vertical slats fitted to the tunnel visor designed to restrict lateral (side-to-side) visibility. Whereas optically programmed heads can restrict both longitudinal and lateral visibility, louvers restrict only lateral visibility and thus have limited applications. Louvers are most commonly used at intersections where the roads cross at oblique angles, as shown in Figure 5.13. In Figure 5.13, a vehicle approaching the intersection from roadway B would be able to see standard signal indications for both approaches and could find it confusing. Louvers restrict visibility to the view limits shown, thus eliminating potential confusion.

Designers should consider the use of louvers when the angle of intersection between two roadways is 35° or less. Louvers are typically cheaper than optically programmed heads and do not need to be tethered.

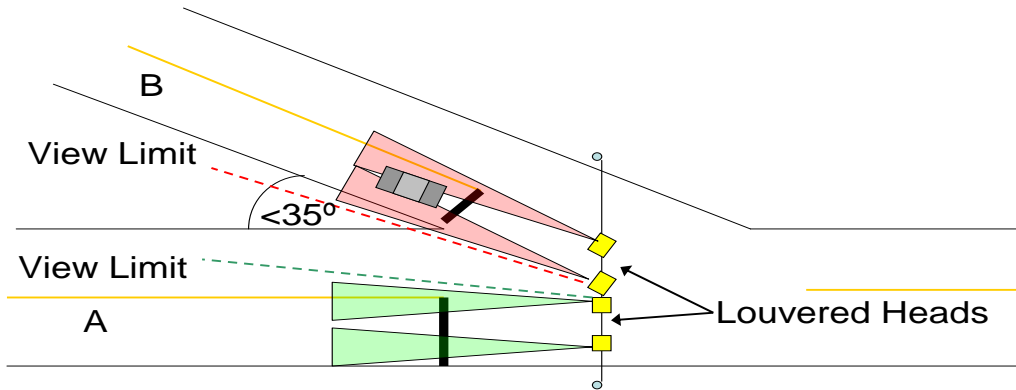


Figure 5.13 – Typical Application of Louvers

### 5.6 Backplates

Backplates can increase the visibility and conspicuity of a signal head, particularly when the signal is backlit by bright sunlight such as occurs during sunrise and sunset (see Figure 5.14). For this reason, ALDOT suggests that backplates be used on east-west approaches to an intersection. The designer should also note that some ALDOT Regions/Areas require backplates on all approaches, regardless of orientation, so the Region/Area Traffic Engineer should be consulted prior to design.

While backplates improve signal visibility they can also become maintenance problems over time. Backplates can crack or tear loose and they increase the wind loading on the signal, sometimes resulting in increased head sway. For this reason, some Region/Area Traffic Engineers prefer to limit the use of backplates. In some cases, it may be appropriate to use tethers to stabilize signals heads with backplates against wind loading. Such installations are subject to approval by ALDOT.

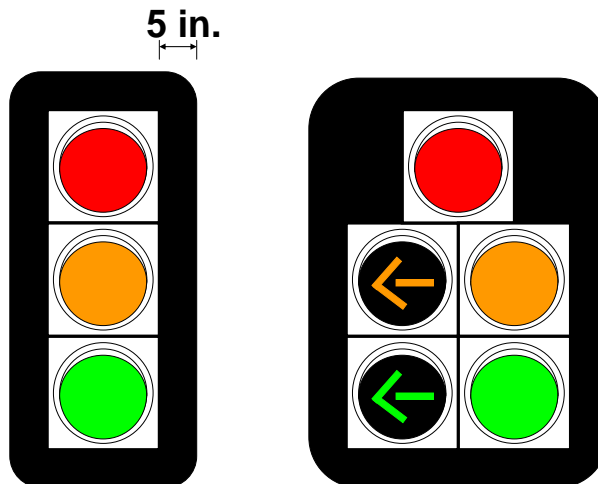


Figure 5.14 – Signal Heads with Backplates

## 5.7 Signal Head Location

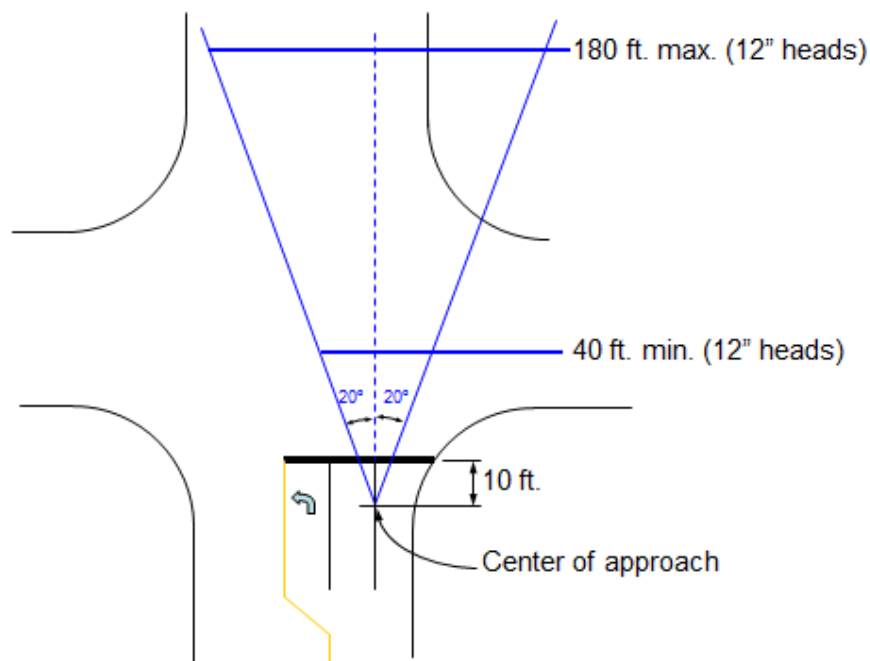
Signal heads must be mounted so as to be clearly visible to motorists. The following mounting guidelines reflect MUTCD (2009 edition) and Alabama DOT standards.

### 5.7.1 Signal Head Mounting Distances

In order to ensure proper visibility, signal heads must be mounted no less than 40 ft. and no more than 180 ft. from the stop line for the approach which they control. Maximum mounting distances from the stop line for 12 in. signal heads are shown in Figure 5.15. Signal heads placed closer than 40 ft. are difficult for drivers to see when stopped at the stop line. Signal heads farther than 180 ft. can be difficult to see and confusing with respect to which movements they apply.

### 5.7.2 Cone of Vision

At least one (and preferably two) signal heads must be located within a 40° cone of vision on each approach. The cone extends 20° to each side of a line projected from the midpoint of the approach lanes as shown in Figure 5.15 (parking lanes are typically excluded when determining the midpoint of an approach). Locating at least one head within this cone ensures that it will fall within a driver's normal field of view.



**Figure 5.15 – Minimum and maximum distances from stop line to signal heads**

### 5.7.3 Signal Head Mounting Height

Signal heads shall be mounted at heights which provide proper visibility to motorists. Signal heads shall be mounted so that the bottom of each signal head is at least 17 ft. but not more than 20 ft. above the roadway surface as shown in Figure 5.16. This ensures that the signal heads are easily visible to motorists stopped at the stop line.

A particular problem can occur when signal heads are located very close to the stop line (between 40 and 50 ft.). These heads can meet the minimum distance standards but still be difficult to see from the stop line if they are mounted at the upper limit of permissible mounting heights. In these cases, the maximum head mounting height should be specified on the plans based on Figure 5.17.

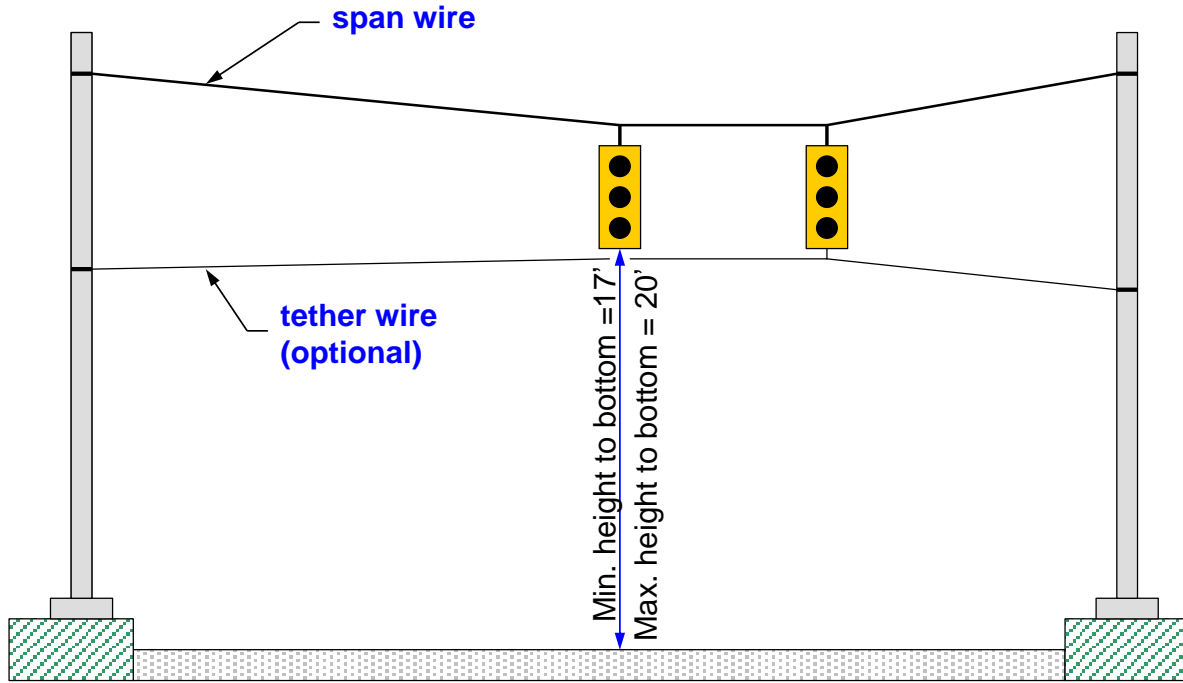


Figure 5.16 – Standard Signal Mounting Heights

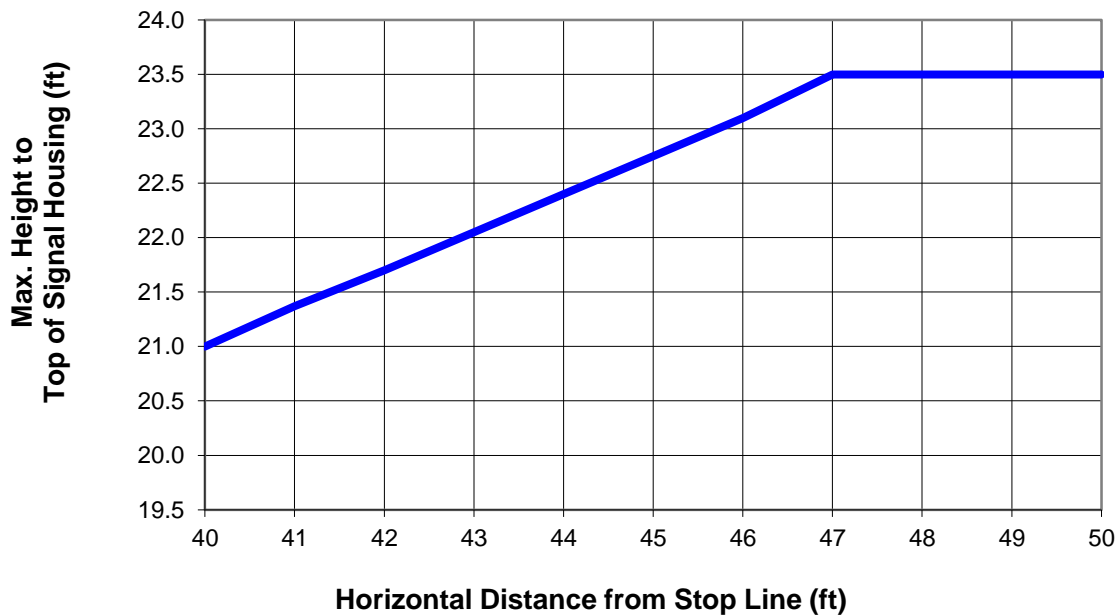


Figure 5.17 – Maximum head mounting heights for short horizontal distances (Source: [MUTCD Section 4](#))

#### 5.7.4 Signal Head Arrangements

Signal heads should be located on the span wire or mast-arm according to ALDOT guidelines. General guidelines include the following:

- Signal heads shall be spaced between 8 and 12 feet.
- If a signalized through movement exists on an approach, a minimum of two primary signal faces shall be provided for the through movement. If a signalized through movement does not exist on an approach, a minimum of two primary signal faces shall be provided for the signalized turning movement that is considered to be the major movement from the approach. At least one of these signal heads shall lie within a 40° cone of vision for the thru/major movement.
- Protected left turn movements shall have one signal head per turn lane. The signal head shall be centered over the turn lane.
- Protected/permissive left turn movements shall typically have a single indication (5-section) aligned with the line separating the left turn and thru lanes. In cases where a separate protected/permissive left turn head is required (such as when the left turn lane is offset), the designer shall specify a 4-section head with flashing yellow arrow for the protected/permissive phase. If dual protected/permissive left turn lanes are provided, the designer shall specify two 4-section flashing yellow arrow heads for the left turn lanes instead of the 5-section heads used for single left turn lanes. These heads shall be centered over each left-turn lane.
- Permissive left turns do not necessarily require a separate signal head, however, there can be cases when a separate head for a permissive left turn movement is desirable. In these cases the designer shall specify a 3-section, red arrow, steady yellow arrow, and flashing yellow arrow display head. This head is to be centered over the center of the left-turn lane.

Typical head arrangements for the most commonly encountered lane geometries are provided at the end of this section. This section does not present all possible configurations, so engineering judgment may be required.

Figure 5.21 – Simple phasing

Figure 5.22 – Protected left turns

Figure 5.23 – Protected/permissive left turns

Figure 5.24 – T-intersections

Figure 5.25 – Right turn overlaps

#### 5.7.5 Near-Side Indications

All signals should meet minimum visibility distance criteria, meaning a driver should be able to continuously view at least one signal head far enough in advance to stop safely if necessary. This minimum visibility distance for traffic signals is based on speed and grade and is summarized in Table 5.1 (note: visibility distance is measured from the vehicle to the stop line, not the signal head -- see Figure 5.19).

**Table 5.1 Minimum Visibility Distances (Source: [ITE Traffic Signal Timing Manual](#))**

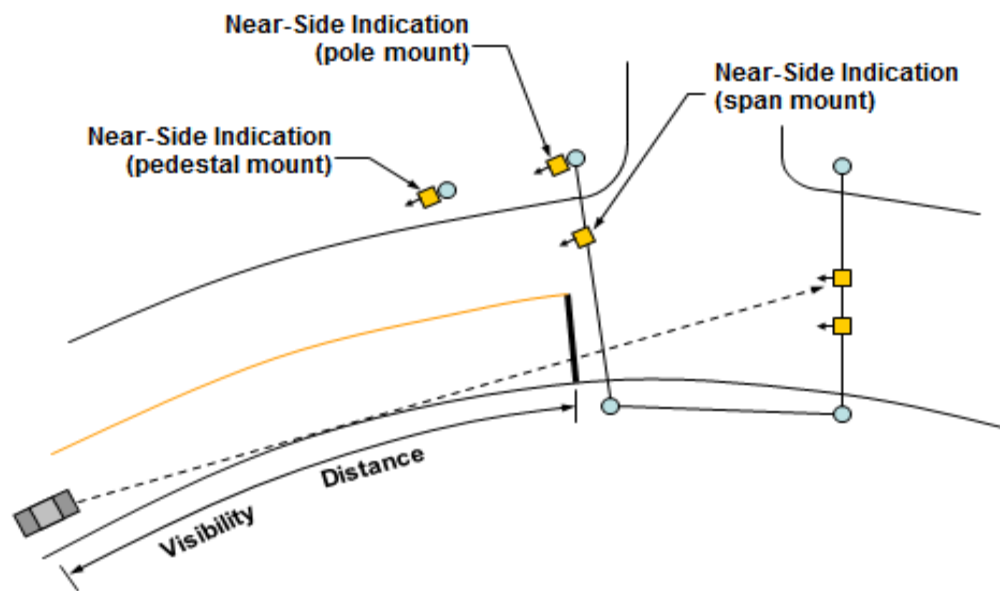
85 <sup>th</sup> percentile approach speed (mph)	Visibility Distance (ft)		Downgrade Adjustment (ft)		Upgrade Adjustment (ft)	
	Min	Desired	5%	10%	5%	10%
20	175	265	+5	+15	-5	-10
25	215	325	+10	+20	-10	-15
30	270	405	+15	+30	-10	-20
35	325	480	+20	+45	-15	-25
40	390	570	+30	+65	-20	-35
45	460	660	+40	+90	-30	-50
50	540	760	+50	+120	-35	-65
55	625	870	+60	+150	-45	-80
60	715	980	+70	+190	-55	-95

When minimum visibility distances cannot be met, one option is to provide near-side signal heads. These are supplemental heads installed either on the near side span and poles, or in advance of the intersection as shown in Figure 5.18. Near-side indications are typically 12 in. heads located to provide maximum visibility to motorists.

Examples of situations where near-side indications may be applicable include:

- positive grade approaches to a signal;
- approaches with curved horizontal alignments
- approaches with high percentages of truck traffic
- signals located near highway overpasses or other visual obstructions.

Supplemental near-side signal heads are often the most effective means of increasing signal visibility and providing advance warning to motorists. Supplemental signal heads are preferable to warning signs or flashers because they provide an indication of signal interval for that approach (red, yellow, or green) whereas signs and flashers do not. Warning signs and flashers may be considered in special cases but must be approved by ALDOT prior to design (see Chapter 11 for more details).

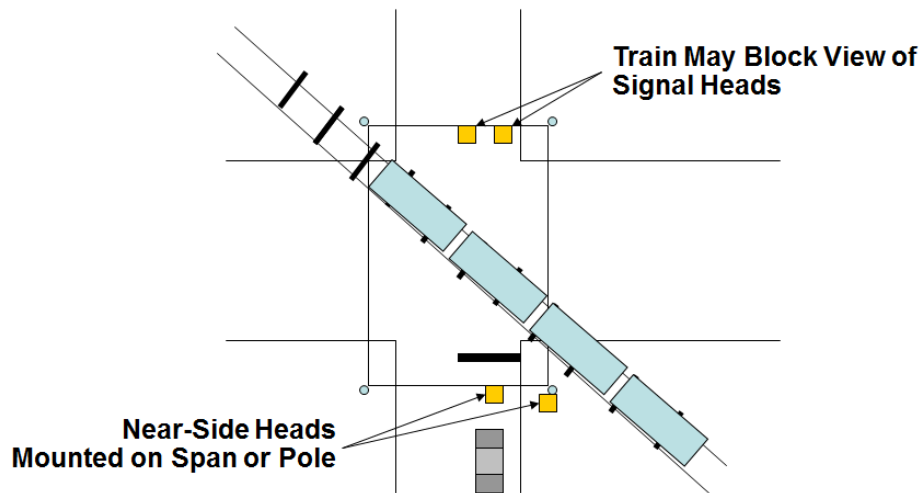


**Figure 5.18 – Minimum visibility distance and near-side indications**



### 5.7.6 Near-Side Indications at RR Crossings

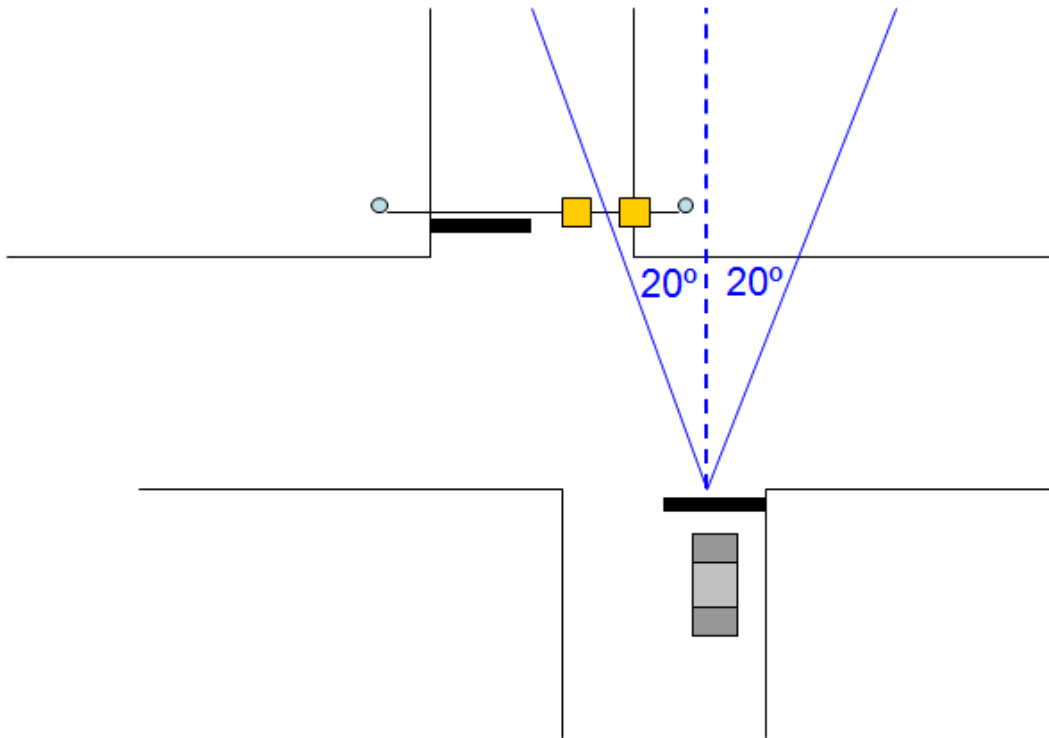
Other locations that may require near-side indications are traffic signals located at or near railroad crossings. At standard rail crossings normal signal visibility may be adequate, but under certain conditions a passing train may obscure the signal heads, which can be particularly dangerous at night. In these cases, the designer should consider providing near side indications as shown in Figure 5.19.



**Figure 5.19 – Use of near-side indications at RR crossings**

### 5.8 Offset Intersections

In cases where cross street approaches are offset, the question often arises whether the signal heads should be aligned with the approach lanes which they govern (for maximum visibility), or aligned with the destination leg in order to “draw” thru traffic across the intersection and into the proper lanes. There are no firm ALDOT guidelines on this and engineering judgment is required, however a general recommendation is that the signal heads be shifted as far as possible over the opposite (destination) lanes while retaining at least one head within the driver’s 40° cone of vision as shown in Figure 5.20. Such intersections should also be properly illuminated at night.



**Figure 5.20 – Shifting signal heads within cone of vision at offset intersections**

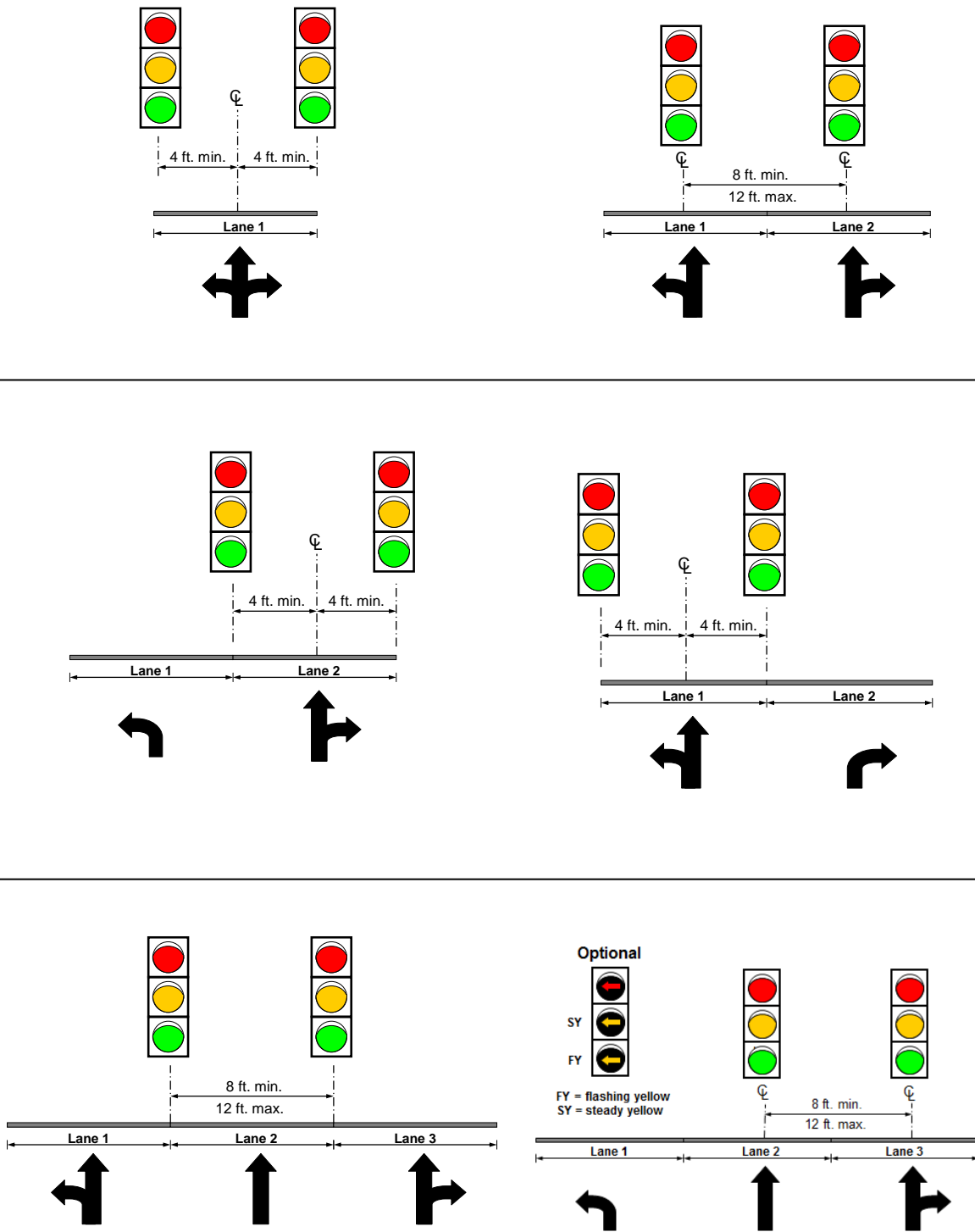
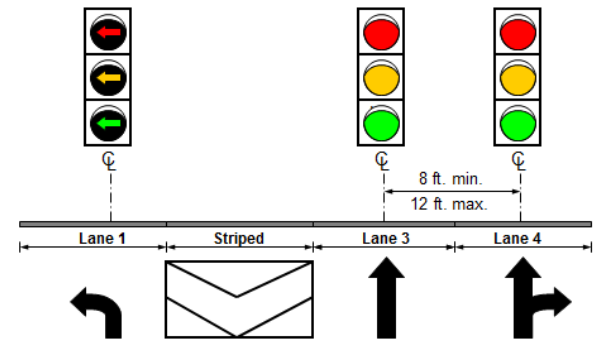
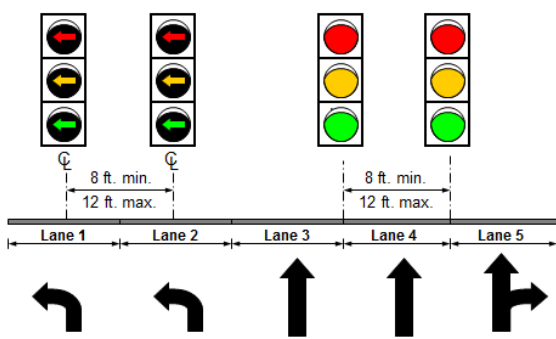
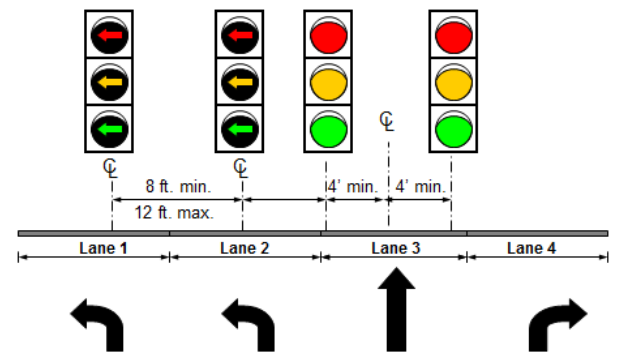
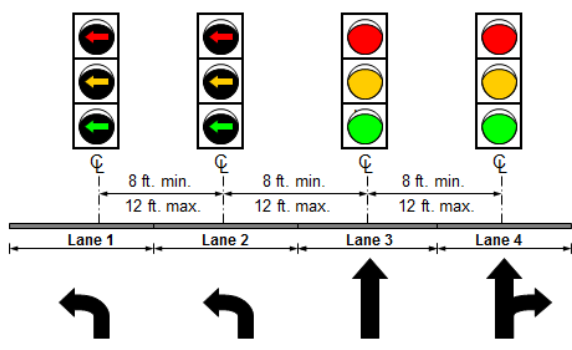
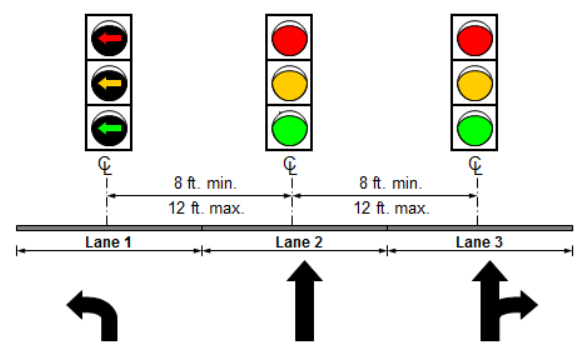
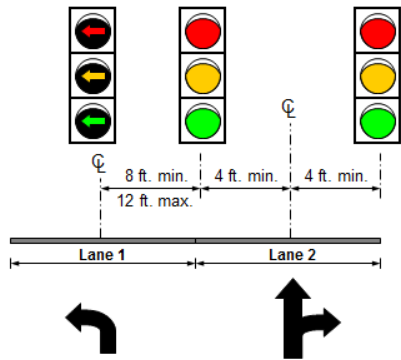


Figure 5.21 – Signal Head Alignments for Permissive Left Turn Phasing



Note: Over 45 mph consider using one head per thru lane

Figure 5.22 – Signal Head Alignments for Protected Left Turn Phasing

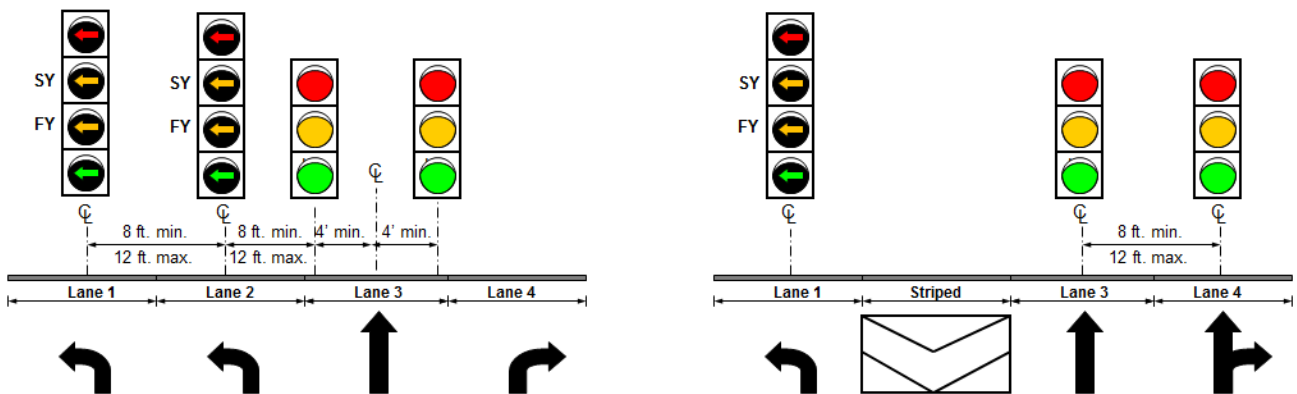
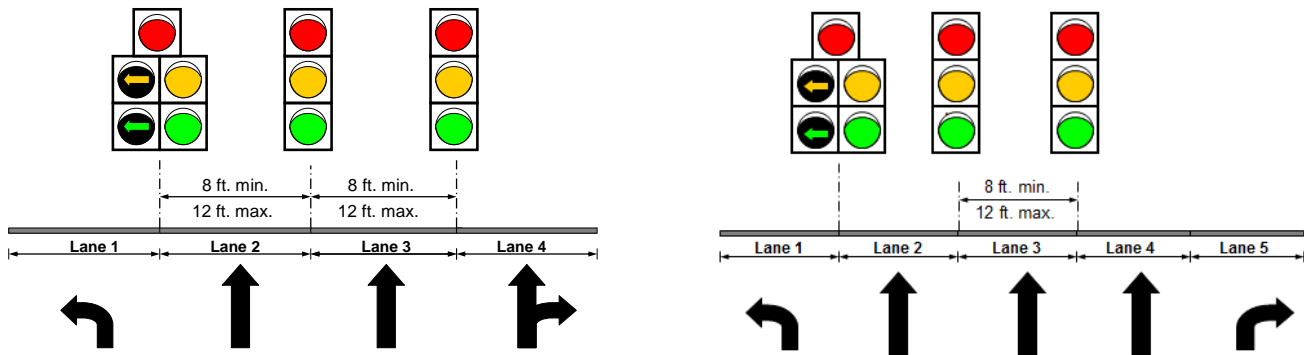
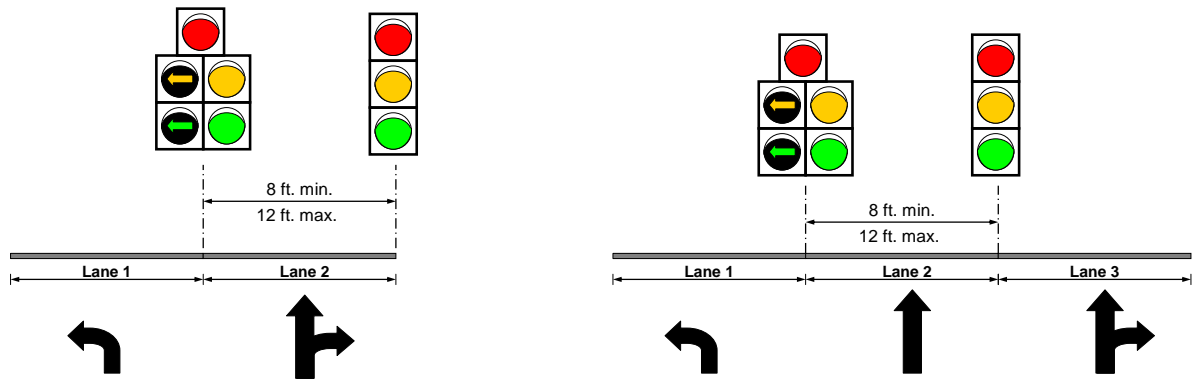
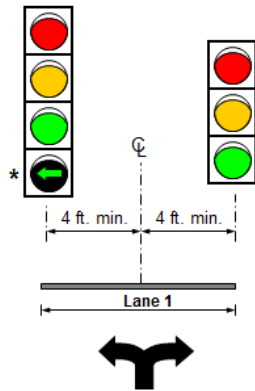
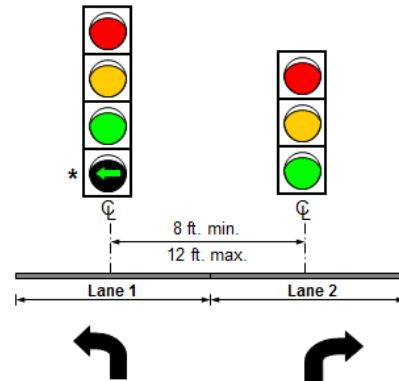


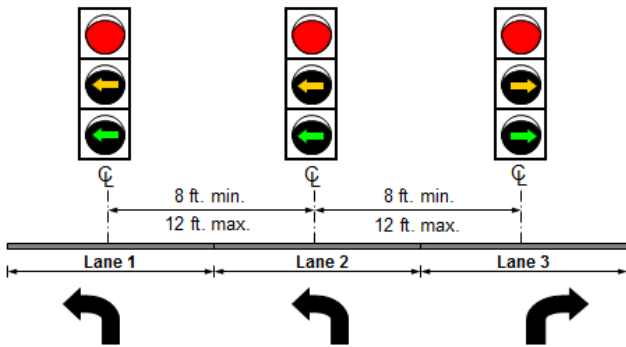
Figure 5.23 – Signal Head Alignments for Protected/Permissive Left Turn Phasing



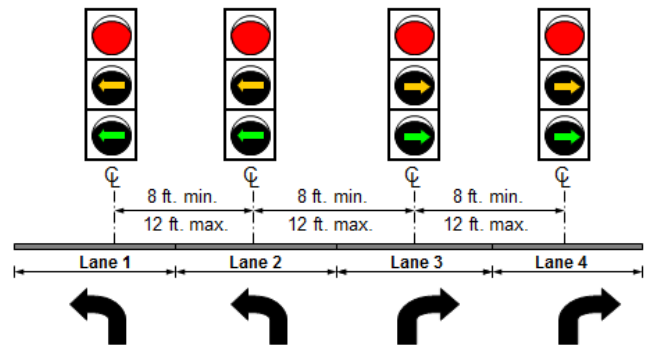
\* Left-turn green arrow section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.



\* Left-turn green arrow section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

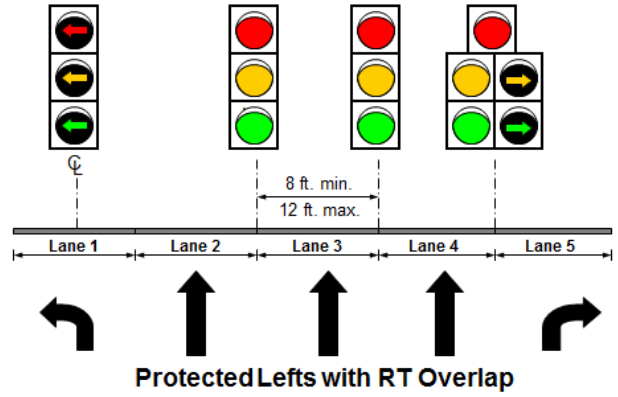
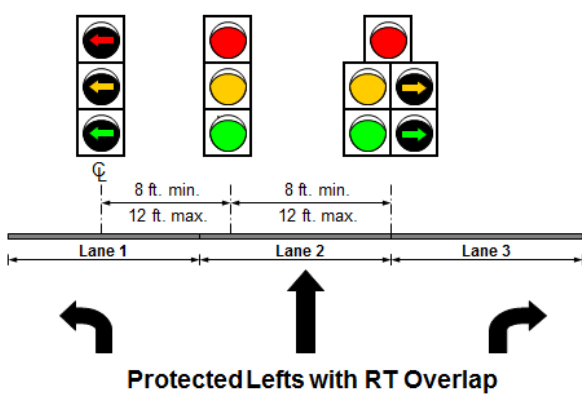
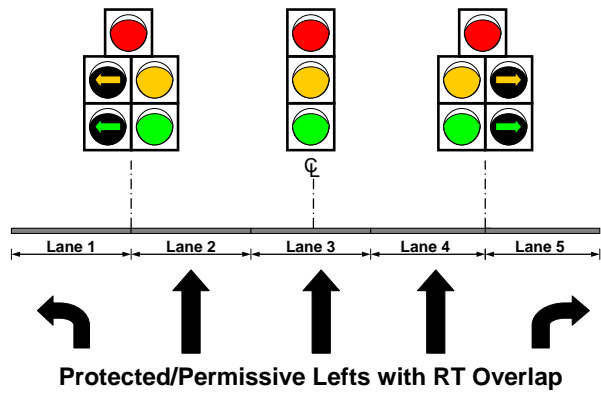
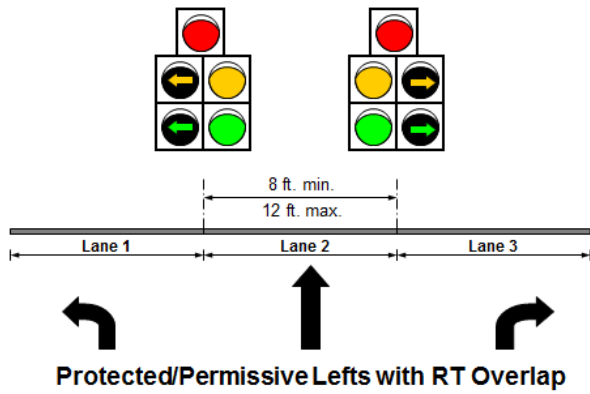
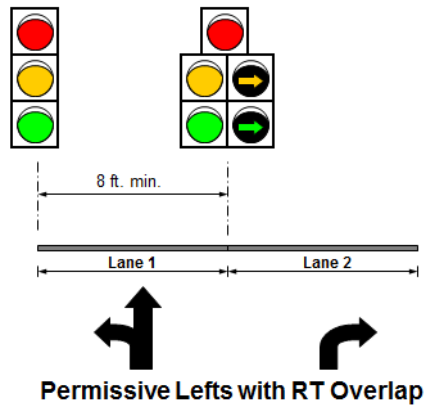


\*If there are vehicular or pedestrian conflicts with any of the turning movements, then use either Flashing Yellow Arrows for the turning movements or All Ball indications for approaches with conflicting movements.



\*If there are vehicular or pedestrian conflicts with any of the turning movements, then use either Flashing Yellow Arrows for the turning movements or All Ball indications for approaches with conflicting movements.

Figure 5.24 – Signal Head Alignments for T-Intersections



**Figure 5.25 – Signal Head Alignments with Right Turn Overlaps**

# ***Chapter 6***

## ***Vehicle Detection***

Actuated signals require vehicle detectors to determine when to activate individual phases. There are several types of vehicle detectors available on ALDOT's approved hardware list, including:

- Inductive loop
- Video
- Microwave
- Magnetometer

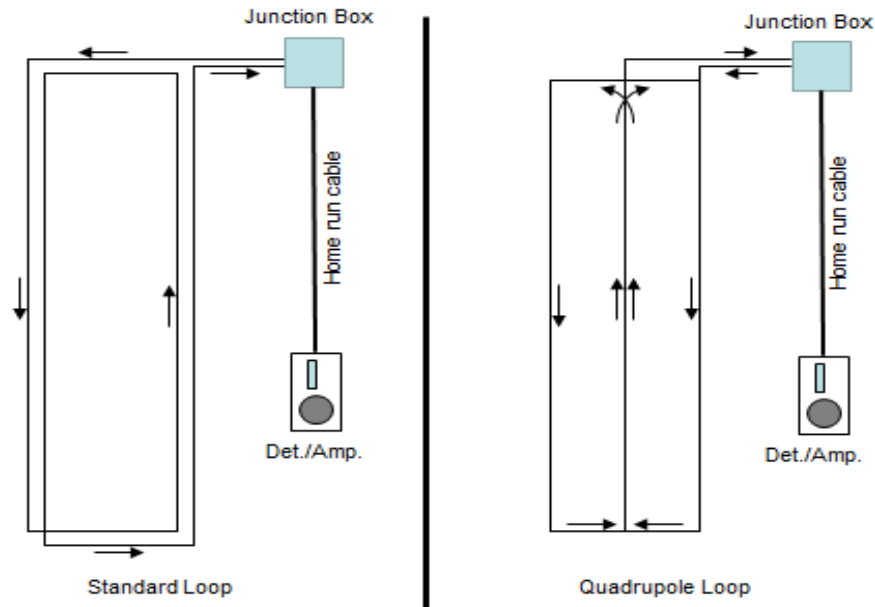
Each type of detector has pros and cons and is suitable for specific applications. Detailed discussion of each detector type follows. If ALDOT will not be maintaining the signal the designer should verify that the maintainer has the expertise and ability to maintain the designed detection equipment.

### **6.1 Inductive Loop Detectors**

A loop detector is a coil of wire embedded in the pavement which detects vehicles by measuring the change in the loop's inductance caused by the passing vehicle. Each loop consists of one continuous coil of wire connected to a vehicle loop detector (also known as a detector/amplifier) which contains an oscillator that sends an alternating current through the wire. This creates an electromagnetic field and an associated inductance in the loop, measured in micro-Henries ( $\mu\text{H}$ ). When a metal object passes over the loop (it does not have to be ferrous metal, it can be any conductive material), a weak current is induced in the object, which in turn creates its own magnetic field which acts in opposition to the field around the loop. The result is a net reduction in the inductance of the detector loop, a change that can be detected by the amplifier. When the amplifier detects a change in the loop inductance over a certain threshold value it sends a vehicle call to the controller.

The loop itself consists of multiple turns (2 to 4) of No.12 AWG wire embedded in slots cut into the pavement. The loop is one continuous run of wire (no splices are permitted) and the two ends are attached to the vehicle detector/amplifier or spliced to a home-run cable in a junction/pull box located several feet from the roadway using an ALDOT approved splice connector kit (see Figure 6.1).





**Figure 6.1 – Standard inductive loop layouts**

The size and sensitivity of the detection zone depends on the dimensions of the loop. Maximum detection height is roughly 2/3 the length of the shortest loop leg (e.g., the maximum detection height for a standard 6 ft. x 50 ft. loop would be approximately  $\frac{2}{3} \times 6 = 4$  ft.). The length of the loop determines the detection zone for the loop but also affects sensitivity. In general, the longer the loop, the less sensitive it is to any single vehicle passing over. For most applications, a 6x50 loop provides an adequate detection area with acceptable sensitivity. For detection of bicycles, smaller loops should be used.

**6.1.1 Number of Turns**

The number of turns of wire required per loop depends on the dimensions of the loop. Shorter loops require more turns of wire, longer loops fewer turns. Table 6.1 presents ALDOT standard guidelines for the number of turns required based on the perimeter of the sawcut (perimeter = (2 x length) + (2 x width)). Loops with an insufficient number of turns will not provide the sensitivity necessary to detect all vehicles.

**Table 6.1 – Standard number of turns for loops**

Saw Cut Dimensions	Number of Turns
6'x6' to 6'x24'	4
6'x30' to 6'x50'	2
Quadropole	2-4-2

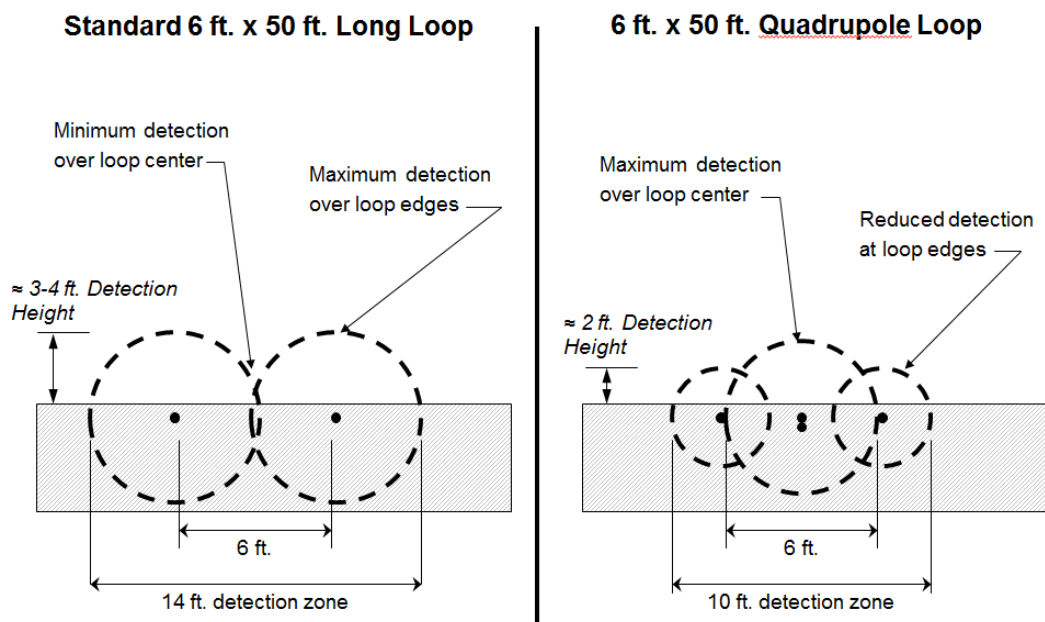
**6.1.2 Quadropole Loops**

A variant of the long loop is the quadropole loop. The quadropole looks like a standard long loop but has a third slot running the down the middle as shown in Figure 6.1. The quadropole is really two narrow long loops set side by side wound from a single wire in a figure '8' pattern. For instance, a 6 ft. x 50 ft. quadropole loop is essentially two 3 ft. x 50 ft. standard loops that share a common slot in the middle. This provides different detection properties than the standard loop.

One of the weaknesses of the conventional long loop is that its most sensitive detection areas are around its perimeter. The center of the loop by comparison has rather low sensitivity and may not detect smaller vehicles such as motorcycles. Also, having maximum detection around the perimeter means that the detection zones may “spill over” into adjacent lanes, making the loop susceptible to false calls caused by traffic in adjacent lanes or by left turning vehicles from cross streets. A standard 6 ft. x 50 ft. loop, for example, can have a detection area as wide as 14 ft.

The quadrupole has different detection properties than the conventional long loop, as shown in Figure 6.2. Because of its design, the maximum sensitivity in a quadrupole is at the center of the loop with reduced sensitivity at the perimeter. It creates an overall detection area that is both smaller than a conventional loop and more sensitive to vehicles in the center of the lane. ALDOT recommends using quadrupole loops in left turn lanes to improve detection and reduce false calls. An exception to this is in the case of dual or triple left turn lanes, where the designer may specify a quadrupole loop only in the outside left turn lane and use standard loops for the interior turn lanes. The main drawback to the quadrupole is that it requires additional saw cutting and almost twice as much loop wire.

**i** **ALDOT recommends using quadrupole loops in left turn lanes** to improve detection and reduce false calls. In cases where there are multiple left turn lanes, the designer may specify a quadrupole loop for the outside turn lane and standard loops for the interior lanes.



**Figure 6.2 – Detection properties of standard and quadrupole loops (longitudinal view)**

### 6.1.3 Multiple Inductive Loops

One drawback of long loops is that they are prone to breakage, particularly in cracked deteriorated pavement. One alternative is the use of multiple small loops instead of a single long loop. Typically multiple 6 ft. x 6 ft. loops are wired in series. This arrangement provides both advantages and disadvantages compared to long loops:

- ✓ less prone to breakage
- ✓ improved sensitivity in center of detection area
- \* requires more saw cutting and wire

ALDOT does not typically use multiple inductive loops unless pavement conditions warrant. Designers should consult the Region/Area Traffic Engineer before recommending them and consider other detection methods such as video or microwave.

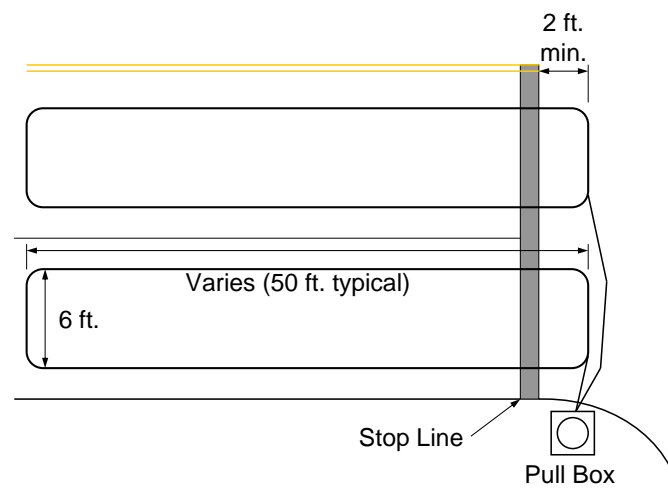
#### 6.1.4 Presence vs. Passage Detection

Most loops operate as either 'presence' or 'passage' detectors. Presence detectors are typically located at the stop line and detect the presence of vehicles as long as they are over the loop. Presence detection is typically used on low speed (25 mph or less) and side street approaches and is located at or near the stop line. Presence loops (typically 6 ft. x 50 ft.) place a call for green and then extend the green until the phase has timed out or the queue has been discharged. The advantage of the long loop (6 ft. x 40 ft. or more) is that it allows passage times to be set very low, providing "snappy" operation.

Passage detection is typically provided in advance of the intersection on approaches where speeds are 30 mph or greater. They are intended to extend the green to allow vehicles to pass from the loop to the stop line under green. Because passage detectors are designed to detect moving vehicles as they pass a specific point, smaller loops are used, typically 6 ft. x 6 ft. The small sized loop provides very good sensitivity.

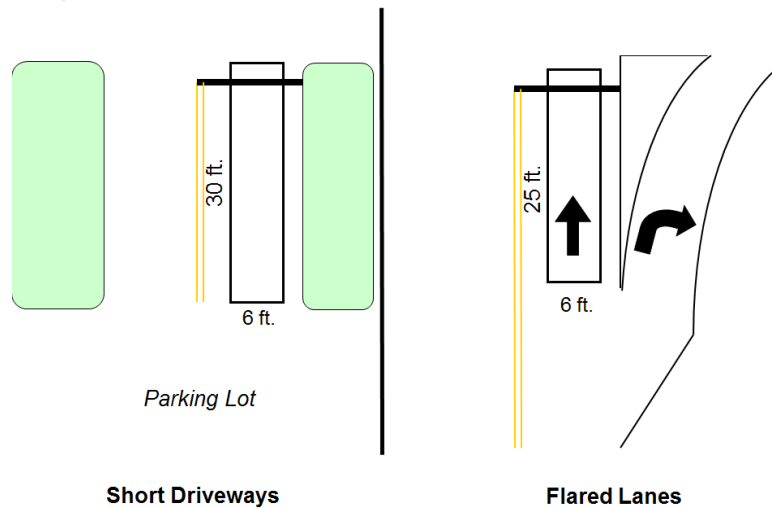
#### 6.1.5 Loop Location

On approaches where speeds are less than 30 mph, detector loops are located at the stop line to provide presence detection. A typical presence loop layout is shown in Figure 6.3. The 6 ft. x 50 ft. loop is the standard size used by ALDOT, but other dimensions may be used to conform to roadway geometry. Examples of conditions requiring shorter loops include driveways with short throats and turn lane flares, as illustrated in Figure 6.4. All presence loops should extend a minimum of 2 ft. beyond the stop line.



**Figure 6.3 – Typical presence loop layout**

The saw cuts which carry the loop wire from the loop to the pull box should be cut on the shortest and most direct route to the curb. In general, the designer should seek to minimize saw cutting wherever possible. Each loop shall require its own saw cut. Saw cuts shall not contain more than one loop wire set to the junction box or pole.



**Figure 6.4 – Examples or situations requiring non-standard loop sizes**

At speeds equal to or above 30 mph, detector loops are placed in advance of the intersection to provide passage protection. Advance loops are designed to extend the green phase when triggered by a passing vehicle. This provides dilemma zone protection and allows the vehicle to travel from the detector to the stop line under the green. Loop setback distances are based on safe stopping distances for a given speed. The equation below provides the distances for loop setbacks, with typical values summarized in Table 6.2.

$$\text{Loop Setback (ft)} = rV + \frac{V^2}{2d}$$

where: *r* = reaction time (1.0s)  
*V* = speed (ft/s)  
*d* = deceleration rate (10 ft/s<sup>2</sup>)

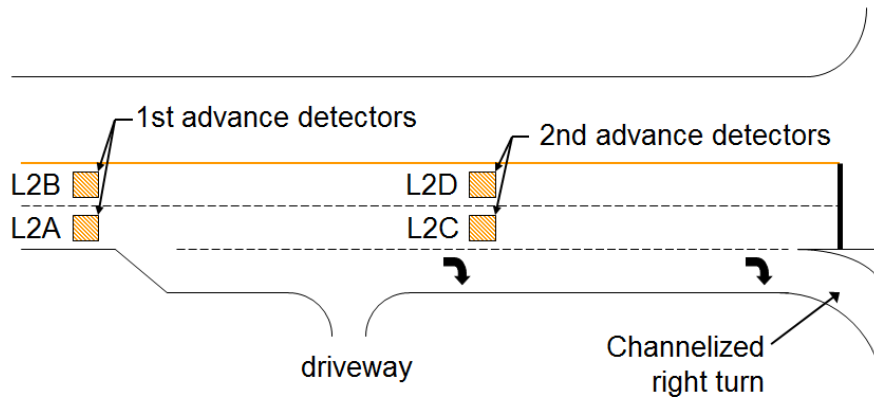
**Table 6.2 Loop Setback Distances**  
 (Source: [ITE Traffic Signal Timing Manual](#))

Approach Speed (mph)	Loop Setback (ft)	Passage Time (s)
30	140	3.1
35	185	3.6
40	230	3.9
45	285	4.3
50	340	4.6
55	405	5.0
60	475	5.4
65	550	5.8

It should be noted that the setback distances are measured from the trailing edge of the loop (nearest the stop line).

### 6.1.6 Multiple Setback Loops

There can be conditions where a setback loop will unnecessarily extend the green phase, especially on high speed approaches where passage loops are set back several hundred feet or more from the stop line. For example, a vehicle may activate a setback loop, but turn into a driveway located between the loop and the stop line, as illustrated in Figure 6.5. In this case it is not desirable to extend the green for vehicles that do not continue through the intersection, so a second loop can be placed just past the driveway and the extension times shortened.



**Figure 6.5 – Multiple setback loops**

The passage time for passage loops is typically set to allow the vehicle to travel from the loop to the stop line. When multiple setback loops are used, the passage times can be shortened to allow the vehicle to pass from the first loop to the second, and then from the second loop to the stop line. Should the vehicle not pass over the second loop before the passage time expires the phase will time out. Typical distances for multiple setback loops are shown in Table 6.3. These can be adjusted for roadway geometry but the passage times should also be adjusted accordingly.

Some agencies use multiple setback loops on all high speed approaches in order to keep passage times short, however, ALDOT typically recommends using single setback loops with volume-density timing (see Chapter 14, “Signal Timing”) unless there is a need for multiple setback loops. This minimizes the number of loops that must be installed and maintained by ALDOT. These preferences can vary by ALDOT Area/Region, however, so it is recommended that the Region/Area Traffic Engineer be consulted prior to plan preparation.

**Table 6.3 Multiple Loop Setback Distances (Source: [ITE Traffic Signal Timing Manual](#))**

Approach Speed (mph)	Loop #1 Setback (ft)	Loop #2 Setback (ft)
30	140	70
35	185	90
40	230	115
45	285	140
50	340	170
55	405	200
60	475	240
65	550	275

### 6.1.7 Loop Numbering Convention

On ALDOT plan sets each detector loop is given a unique identifier according to the phase to which it is assigned. The detector loop for phase 1 is designated “L1”, the detector for phase 2, “L2”. If there are multiple loops assigned to a given phase they are designated “L1A, L1B, L1C,...”, with the ‘A’ loop being closest to the near side curb. For multiple setback loops, begin numbering the loops farthest from the stop line and continue in. A typical setback loop numbering scheme is shown in Figure 6.5.

### 6.1.8 Detector Memory Settings

In standard NEMA controllers each detector has a memory function, which is set to either “locking” or “non-locking”. Detector memory determines whether the controller remembers vehicle calls on a loop even after a vehicle has passed.

When a loop is set to ‘Locking Memory’ the controller retains a vehicle call registered on that loop during the yellow or red intervals whether the vehicle remains over the loop or not. Once a vehicle has passed over the loop, the controller will “remember” the call and provide green to that phase even if the vehicle has since left the loop. This is important when passage loops are used because vehicles typically do not remain over passage loops but instead pass over them quickly. Without locking memory, vehicles could become stranded between the stop line and the setback loops during the red, unable to register a call. The memory lock function is therefore typically activated for setback loops.

When a loop is set to ‘Non-Locking Memory’ a controller will register vehicle calls only as long as a vehicle is actually over the loop. If a vehicle stops on a loop but then turns right on red, for instance, the controller will drop the call as soon as the loop is vacated. Presence loops are typically set in “non-locking” mode, to allow vehicles to turn right on red or make permissive left turns.

### 6.1.9 Vehicle Loop Detectors

Each loop must be wired to a separate vehicle loop detector/amplifier in the controller cabinet. ALDOT does not permit wiring multiple loops to a single vehicle loop detector. For most applications, single channel detectors which serve a single loop can be used (see Figure 6.6).

At large intersections, however, the number of loops can total 15 or more and the number of single channel detectors required can become unwieldy. In those cases the designer can specify multi-channel loop detectors. Multi-channel detectors have inputs for 2 or 4 separate loops on a single detector “card”. The cards are plugged into a “rack” that can accept multiple cards (typically 6). The controller cabinet must be specially wired with a card rack if multi-channel amplifiers are to be used, so a detector rack and number of required detector cards must be specified on the plan sheet and quantities.

If multi-channel vehicle detectors are specified, the designer should assign each loop to a specific card and channel and show that clearly on the plan sheet. (example: loop L1A assigned to Card 1/Channel 1, loop L1B assigned to Card 1/Channel 2, loop 2A assigned to Card 2/Channel 1, etc...).



Single channel amplifiers



Multi-channel detector cards

**Figure 6.6 - Single and Multi-Channel Detectors**

### 6.1.10 Loop Delay

In some cases, it may be desirable to delay a call from a loop to the controller. This is often the case when a loop is placed in a right turn lane and the designer wishes to allow vehicles the opportunity to make a right turn on red before placing a call to the controller. This can be accomplished by placing a delay on the loop, meaning there will be a user specified interval between the time a vehicle is detected and the time a call is actually placed to the controller (typically 8-14 seconds). The amount of delay provided for right turn or thru/right lanes should be evaluated and engineering judgment used.

Delay may also be used on a left turn lane where there is a problem with false calls created by vehicles from opposing left turn movements “clipping” the loops. A delay of 1-2 seconds will usually alleviate this problem and can often be programmed directly in the controller (i.e., no delay detectors required).

Delay can be input in two ways, either in the detector/amplifier or in the controller. In the first case, the delay is set on a special vehicle loop detector. In the second case, delay is programmed in the controller itself under the phase to which the loop is assigned. Because the controller will delay all calls on this phase, including calls from other loops (e.g. thru lanes), it can be limiting to the signal operation. For that reason, ALDOT recommends that loop delay be programmed in the detector amplifier itself.

**i** When specifying delay on a detector loop, the designer must also specify that a “detector amplifier with delay” is required. Not all amplifiers have a delay feature and the controller cabinet must be specially wired to accept an amplifier with delay.

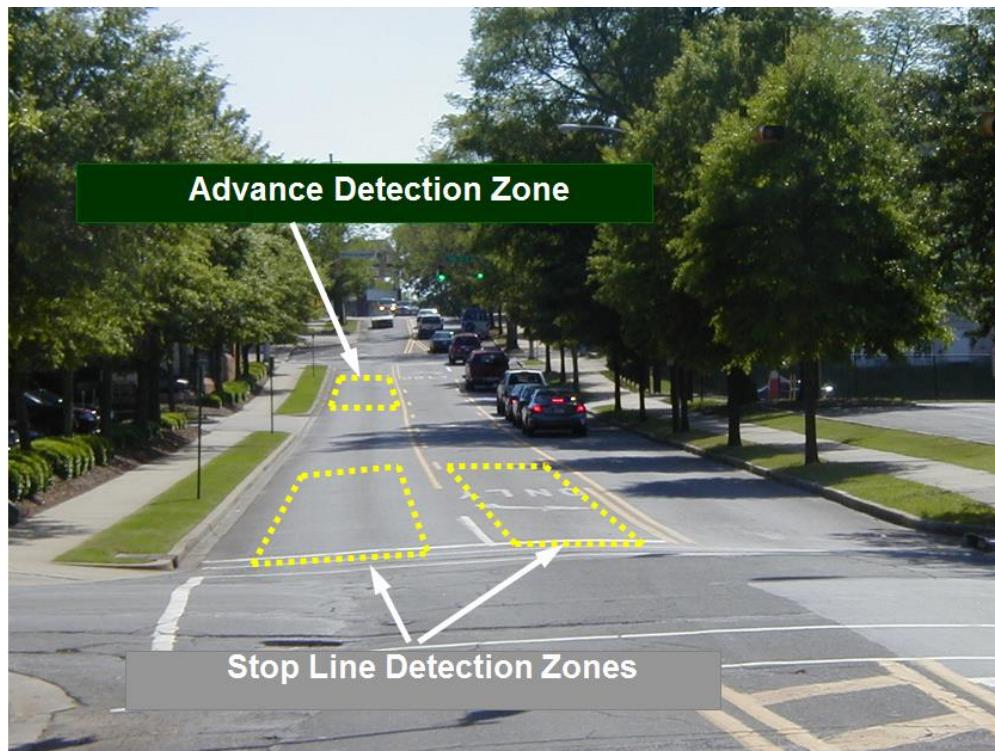
## 6.2 Video Detection

Video detection uses video cameras and image processing to detect the presence of vehicles and register calls to the controller. A video detection system (VDS) typically consists of one or more video cameras and an image processor located in the controller cabinet. A video camera is aimed at an intersection approach and the user designates detection zones within the image corresponding approximately to detection zones that would be defined by in-pavement loops (see Figure 6.7). When a vehicle passes over or through one of these defined zones, the image processor will place a call to the controller. With respect to inputs to the controller, video detection behaves much like conventional loops, so vehicle loops and video cameras can be combined at the same intersection (depending on controller type).

Video detection offers both benefits and drawbacks compared to conventional detector loops:

- ✓ It is unaffected by pavement condition
- ✓ It offers potentially lower maintenance costs
- ✓ It can often be installed and serviced without disruption to traffic
- ✓ Detection zones can be easily modified
- ✓ It allows the user to collect additional data, such as speed and counts
- ✗ It may have higher installation costs, particularly at smaller intersections
- ✗ It provides reduced detection in fog or bad weather
- ✗ It is susceptible to vehicle occlusion
- ✗ It can place false calls based on shadows
- ✗ It requires luminaires to be installed in order to work effectively at night





**Figure 6.7 – Example of video detection zones**

Because video detection can be affected by fog or winter weather it is not recommended for fog prone areas. Video detection is typically more expensive to install than inductive loops so the additional costs should be weighed against the anticipated benefits. Some controller and cabinet types also limit the number of detection zones that can be used. Video detection should be discussed with the Area/Region Traffic Engineer prior to specifying it on plans.

Some situations in which video detection is commonly used include:

- During roadway construction or widening projects, so that detection zones can be easily modified and the detection remains unaffected by paving operations
- In poor pavement conditions, where cracking or rutting causes frequent loop failures.
- On a gravel or dirt road approach to an intersection where loops are impractical
- At large intersections where multiple detector loops make the installation costs of video detection competitive
- On bridges and overpasses where sawing into the bridge deck to install loops is not recommended

### 6.2.1 Locating Detection Cameras

Video can provide the same detection capabilities as conventional inductive loops, including presence and passage detection, advance detection, stop line detection, and system or count detection. The location of the cameras, however, is critical to their proper operation.

Video detection cameras require a stable mounting platform in order to function properly. Excessive camera movement can lead to false calls or missed calls, so cameras should be mounted on strain poles, mast-arms, or some other stable platform. Current technology has also made it possible to mount cameras on span wires. Factors that influence camera location include approach speeds,

terrain, and available mounting platforms. The exact placement of each camera will require engineering judgment and each approach should be considered individually to ensure that the cameras have proper fields of view. Some general mounting guidelines follow.

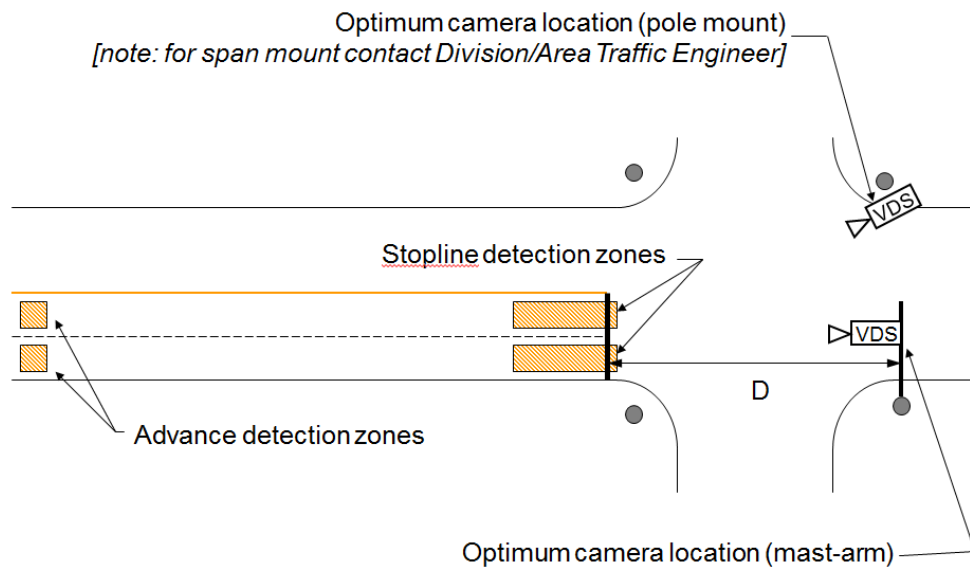
In general, the optimum location for a detection camera is on the far side of the intersection opposite the approach being monitored, as shown in Figure 6.8. Ideally, the camera would be placed in the middle of the approach it is detecting, or if left turns lanes are present, along the line separating the left turn lanes from the adjacent thru lanes, which is now possible with both mast-arm and span wire installations. If a traditional span wire installation is being used, the camera is typically mounted on the left side strain pole. These positions provide the best field of view for the camera. Cameras are typically not located on the near side of the intersection because their view becomes too constrained.

### 6.2.2 Camera Mounting Height

Mounting height should be set high enough that trucks and large vehicles do not create blind spots in the detection zones, as shown in Figures 6.9 and 6.10. In general, detection accuracy improves with camera height but there are practical limitations to how high a camera should be mounted. The typical range used by ALDOT is 30 ft. to 42 ft., depending on conditions. Cameras mounted below 30 ft. may have a constricted field of view and are prone to spray from passing vehicles. Cameras mounted more than 42 ft. high can be difficult to service with a standard bucket truck. Typical mounting heights are shown in Figure 6.11.

#### 6.2.2.1 Mounting Height for Stop Line Detection

When a video camera is to be used strictly for presence detection at the stop line the mounting height can be lower than that required for advance detection. If the camera is mounted near the center of the approach lanes (mast-arm) then a minimum mounting height of 30 ft. may be used. If an offset mounting is to be used (camera mounted on the right side pole or luminaire) then the recommended minimum heights shown in Table 6.4 should be used.



**Figure 6.8 – Optimum camera locations**

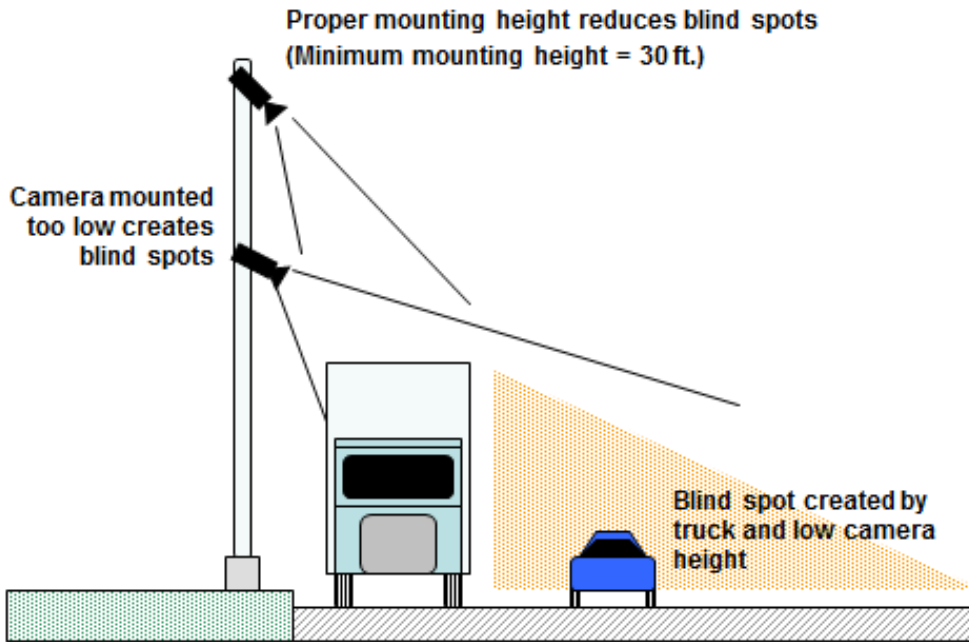


Figure 6.9 – Effect of camera height at stop line

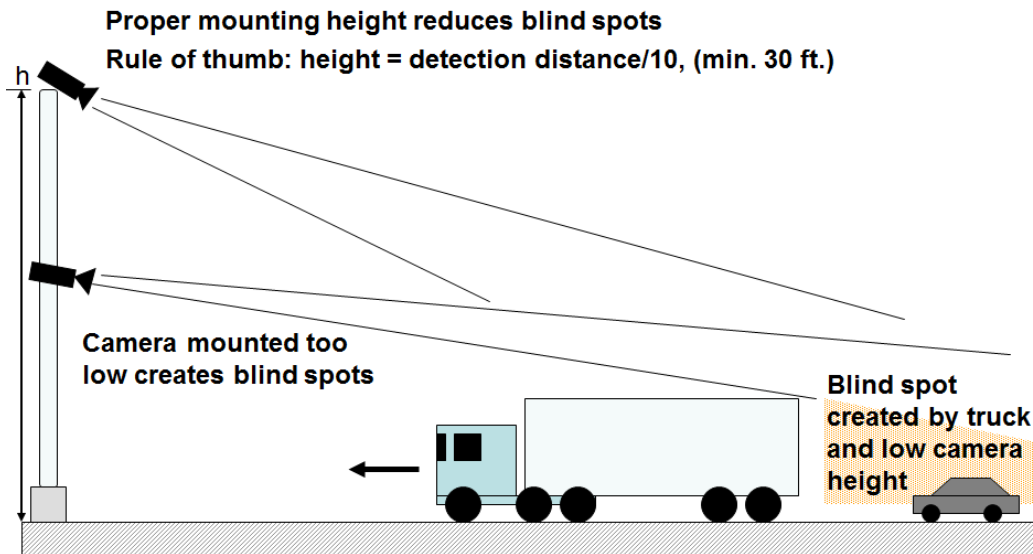
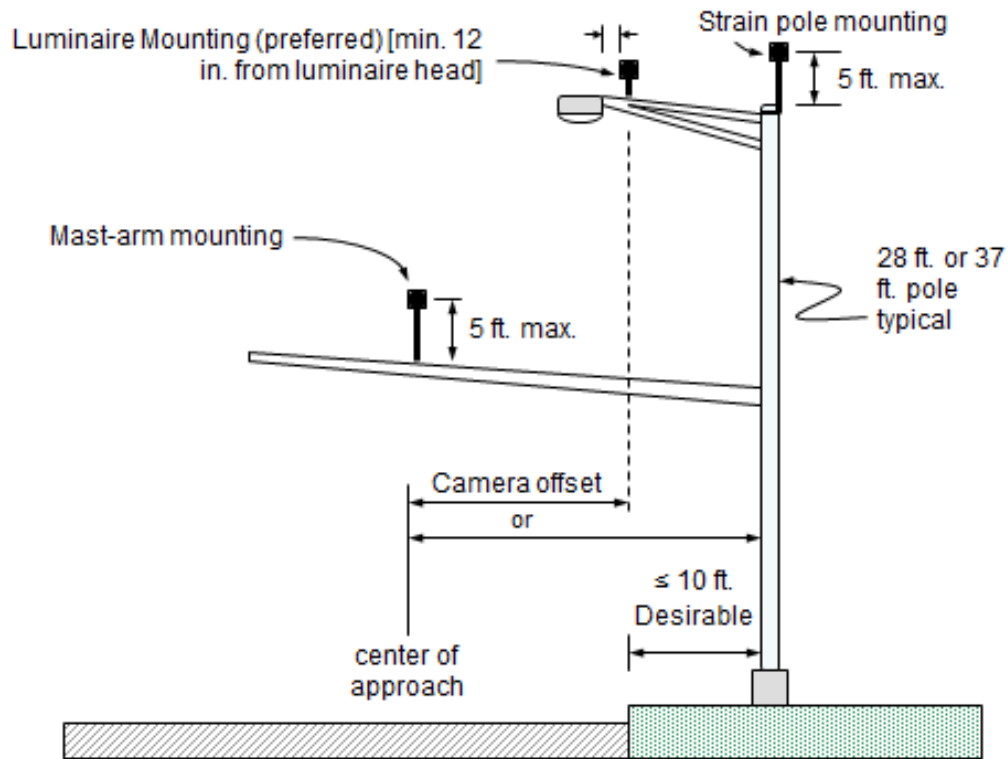


Figure 6.10 – Effect of camera height on advance detection



**Figure 6.11 – Camera mounting heights**

(note: for span wire camera installations, contact the ALDOT Region/Area Traffic Engineer)

**Table 6.4 – Recommended minimum camera heights for stop line detection**

Camera Mounting	Camera Offset	No left turn lanes thru + right lanes			1 Left turn lane thru + right lanes			2 Left turn lanes thru + right lanes		
		1	2	3	1	2	3	1	2	3
Mast-arm	-	30 ft. all cases			30 ft. all cases			30 ft. all cases		
Right Side	≤ 25 ft.	30 ft. all cases			30 ft. all cases			30 ft. all cases		
Strain Pole	26 – 35 ft.	30 ft.	30 ft.	30 ft.	30 ft.	33 ft.	38 ft.	24 ft.	29 ft.	33 ft.
	36 – 45 ft.	not recommended			not recommended			32 ft.	36 ft.	41 ft.

(Based on: ALDOT VDS Installation Detail and the [Video Detection Field Handbook](#), Texas Transportation Institute, 2002)

### 6.2.2.2 Mounting Height for Advance Detection

Video cameras can effectively detect vehicles at distances of 500 ft. or more (check manufacturer specifications for individual cameras) and can be effectively used to provide advance detection at an intersection. Proper mounting height is critical for advance video detection. A good rule of thumb is that 10 ft. of mounting height is required for each 100 ft. of distance between the camera and the advance detection zone, with a minimum height of 30 ft. This can, however, lead to very high mounting heights for distances greater than 400 ft. The maximum recommended camera mounting height is 42 ft., and detection distances greater than 450 ft. are not recommended. If detection distances greater than 450 ft. are desired, the designer could consider mounting the advance detection camera on a near-side pole or using traditional loop detectors. Table 6.5 presents minimum mounting heights for cameras used for advance detection.

**Table 6.5 – Minimum camera heights for advance detection**

Distance from camera to detection zone (ft)	Minimum camera height (ft)
≤ 300	30
350	35
400	40
450	42
> 450	not recommended

In cases where a camera is to be used for both stop line and advance detection, the designer should check minimum camera height requirements for both (Tables 6.4 and 6.5) and use the higher of the two values.

### 6.2.2.3 Specifying Video Detection Quantities

On ALDOT design plans, video detection is specified as a lump sum quantity per intersection. The lump sum pay item includes all equipment necessary for a complete functioning installation. The actual number of cameras and equipment will vary by intersection.

## 6.3 Microwave Detection

Microwave detection functions in a similar way to video detection. Microwave detectors use radar to detect the presence and/or speed of vehicles and fall into three main categories:

1. Doppler sensors – detect shifts in the reflected signal to measure vehicle speeds. Often used in ‘side-fire’ configurations they are used primarily for detecting speeds, not vehicle presence, and are therefore more frequently found in ITS applications.
2. Presence detectors – use a different type of signal processing to detect the presence of either moving or stationary vehicles. This is the type most commonly used for traffic signals.
3. Passive detectors – detect electromagnetic emissions from vehicles to determine presence. These are not used in Alabama.

Most applications of microwave detectors for traffic signals in Alabama involve presence detection, although Doppler sensors may be used for advanced ITS applications. Doppler sensors can also be used for passage detection on high speed approaches. In signal applications, microwave sensors are most commonly used for presence detection at the stop line. Typical mounting is overhead on a mast-arm or side-mounted on a strain pole. Typical mounting heights range from 16 – 22 ft., though specific mounting heights vary by manufacturer. Current models are also capable of providing advance detection from the intersection at distances up to 900 feet.

Early models of microwave detectors suffered from limitations in range and accuracy; however, newer generation detectors are available which can rival video detection in terms of accuracy and the ability to detect vehicles on multiple lane approaches. Their use should be discussed with the Region/Area Traffic Engineer prior to specifying them on plans.

## 6.4 Magnetometers

The magnetometer detects vehicles by measuring the disturbances they create in the earth's magnetic field. Magnetometers come in two basic types: inductive magnetometers, which can detect only moving vehicles, and two-axis fluxgate magnetometers, which can provide true presence detection. Magnetometers are installed in the pavement, but unlike inductive loops they are very small (typically a few inches long). One of their primary areas of use is in bridge decks, where traditional inductive loops cannot be installed.

Because they occupy a much smaller area in the pavement, magnetometers are less susceptible to stresses and pavement failures than are inductive loops. In fact some magnetic detectors can be placed in non-metallic conduit running underneath the roadway. It should be noted that magnetometers typically have very small detection zones and multiple sensors must be used to cover a single lane or to provide presence detection. With the use of repeaters, magnetometers can be used for advance detection as well.

Magnetometers can provide many benefits in terms of ease of installation and maintenance. They typically require less time to install than conventional loops, which requires less disruption to traffic. The designer should discuss their use with the Region/Area Traffic Engineer prior to plan submission.

## 6.5 Special Detection Circumstances

### 6.5.1 Motorcycle Detection

Standard vehicle detection methods typically work for motorcycles, though loop detectors may have trouble detecting smaller motorcycles. If high motorcycle traffic is expected, the designer should consider special detector designs for motorcycles. These can include inductive loop, video, or microwave. Magnetometer detectors typically do not function well for motorcycles.

### 6.5.2 Bicycle Detection

Standard loop detectors will not function for bicycles, however there are special loop detector designs that will detect bicycles. If heavy bicycle traffic is expected, the designer should consider video or microwave detection. Magnetometers should not be used to detect bicycles.

### 6.5.3 Pedestrian Detection

Pedestrian detection requires the use of either video or microwave detectors.

### 6.5.4 Detection for Adaptive Signal Systems

Designers should note that adaptive signal systems require special vehicle detection equipment and detection zones. The detection requirements for an adaptive system should be carefully reviewed with the system supplier.

## 6.6 Summary

A summary of the advantages and disadvantages of the various detection types is provided in Table 6.6.

**Table 6.6 – Comparison of detection methods**

Detector Type	Maintenance	Advance Detection?	Performance in Low Visibility Conditions	Changing Detection Zones	Bike/Ped Detection
Inductive Loop	Average loop service life is 5 -10 years, less in poor pavement. Repair requires closing travel lane. Overall costs can be high.	Yes, but requires long home-run cable and conduit back to the controller cabinet.	Unaffected by lighting or weather.	Loops must be replaced.	Yes for bikes, but special designs must be used. Standard vehicle detectors will not perform well for bikes.
Video	Several agencies have reported significantly lower maintenance costs for video detection compared to inductive loops. Minimal disruption to traffic when repairing cameras.	Yes, but most cameras have limited detection distances on the order of 300-400 ft. Check manufacturer specs. No home-run cable required, camera can be mounted at intersection.	Manufacturers claim good performance at night (cameras detect headlights), although studies have found some loss of efficiency. Performance in fog or snow questionable. Not recommended for fog prone areas.	Once installed detection zones can be easily modified.	Can detect bikes and peds.
Microwave	Lower maintenance costs than inductive loop. Minimal disruption to traffic when repairing or replacing detectors.	Yes, current models can provide detection from the intersection at distances up to 900 feet.	Unaffected by lighting or weather.	Once installed detection zones can be easily modified.	Can detect bikes and peds.
Magnetometer (micro-loop)	Less prone to pavement stress and wear than traditional loops.	Yes, but may require home-run cable back to the controller cabinet. Some newer models use wireless repeaters.	Unaffected by lighting or weather.	Detectors must be replaced or relocated.	Not suitable for bike or ped detection.

# ***Chapter 7***

## ***Pedestrian Features***

The Manual on Uniform Traffic Control Devices (MUTCD) states that engineering judgment should determine the need for separate pedestrian signal heads and accessible pedestrian signals (see [MUTCD Section 4](#)). In other words, the designer can accommodate pedestrians by either:

- Ensuring that the vehicular signal heads are easily visible and easily understood by pedestrians
- Providing pedestrian signal heads and phasing

In many cases in Alabama, and particularly in rural areas, pedestrians rely on the vehicular signal heads to determine when to cross the street, and this is adequate for most signalized intersections where pedestrian volumes are very low. In other cases, though, it is desirable to provide pedestrian signal heads and phasing to accommodate high pedestrian volumes or ensure pedestrian safety. This Chapter discusses the applications of pedestrian phasing and features to signal designs in Alabama. All pedestrian features shall conform to the MUTCD, current ALDOT adopted edition.

### **7.1 When to Provide Crosswalks**

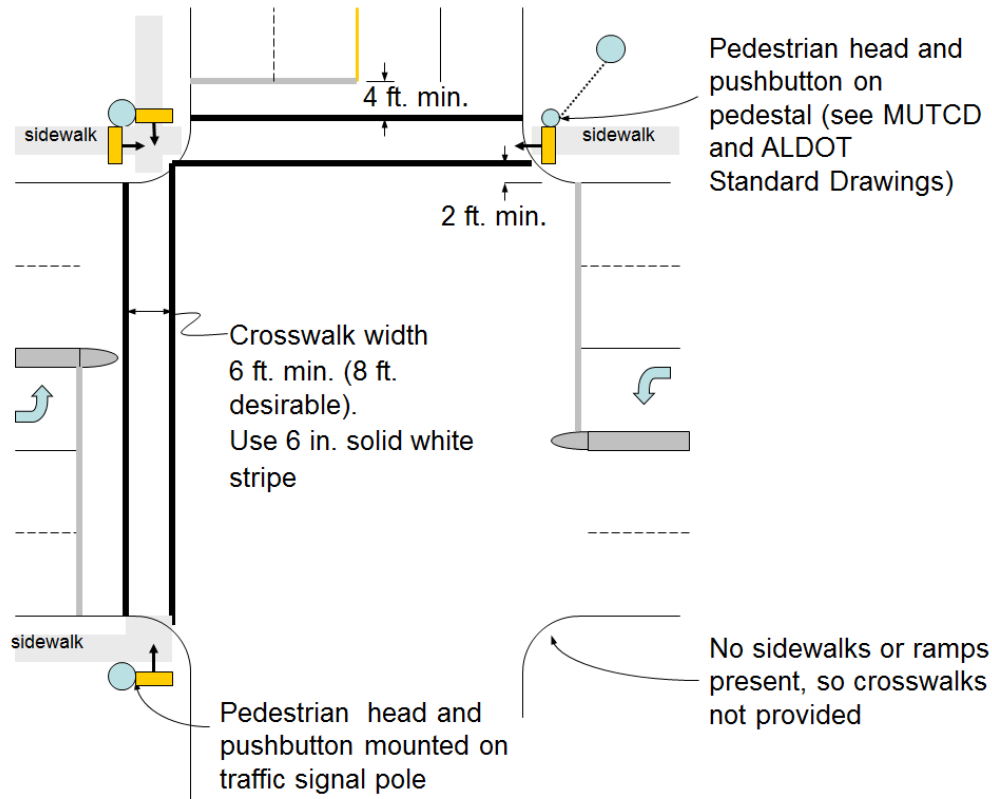
Crosswalks should be considered at any signalized intersection where sidewalks or other pedestrian facilities are present. They should also be considered at locations where pedestrian volumes exceed 20 persons per hour even if sidewalks are not present.

Crosswalks may be provided regardless of whether or not pedestrian signal heads are used. A standard layout for crosswalks is shown in Figure 7.1.

Crosswalks should be located at least 4 ft. from the stop line and a minimum of 2 ft. from adjacent thru lanes. See [ALDOT Standard and Special Drawings for Highway Construction](#) for crosswalk details.

The designer may elect not to provide crosswalks under circumstances where he wishes to discourage pedestrian traffic. These could include locations where pedestrian traffic is very low, where crossing conditions are hazardous, or where adequate pedestrian facilities are not available to accommodate people after they have crossed the intersection.





**Figure 7.1 – Typical pedestrian features**

## 7.2 When to Provide Pedestrian Signal Heads

If only vehicular heads are provided, the phase times can still be set to allow pedestrians enough time to safely cross the intersection. Pedestrian heads are required where significant pedestrian volumes exist.

According to MUTCD guidelines, pedestrian signal heads shall be provided under any of the following conditions:

1. If a traffic signal is justified by an approved Warrant Study (see Chapter 2) and meets either MUTCD Warrant 4 (Pedestrian Volume) or Warrant 5 (School Crossing);
2. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicle movements being stopped (i.e., an exclusive ped phase where all vehicle indications are red);
3. At an established school crossing at any signalized location;
4. Where engineering judgment determines that multiphase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular indications.

The above guidelines describe conditions where pedestrian signal heads shall be provided, but in most cases the decision to provide pedestrian signal heads is at the discretion of the design engineer.

ALDOT policy is that pedestrian heads should be provided only when one of the MUTCD warrants is met or when there is a demonstrated need. If there is little or no pedestrian activity at an intersection then pedestrian heads should not be provided. There are no firm volume criteria, but when pedestrian crossings exceed 20 per hour the designer should consider providing pedestrian heads.

Assuming that pedestrian traffic is present, the MUTCD offers some general guidance on providing pedestrian heads when not mandated by the above criteria ([MUTCD Section 4](#)):

- A. If it is necessary to assist pedestrians in deciding when to begin crossing the roadway in the chosen direction or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts
- B. If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval
- C. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications visible to pedestrians starting or continuing a crossing provide insufficient guidance for them to decide when it is reasonably safe to cross, such as on one-way streets, at T-intersections, or at multiphase signal operations.

Other cases where pedestrian heads may be warranted include signals located adjacent to parks, locations with high senior citizen pedestrian traffic, or large numbers of children. For intersections not meeting these criteria, vehicular signal heads may be sufficient to accommodate pedestrian traffic provided they are clearly visible and easily understood by pedestrians. However, designers should consider the following when relying on vehicular heads to govern pedestrian movements:

- The relevant vehicular heads must be visible at either end of the crosswalk and at least one head must remain clearly visible to the pedestrian throughout the crosswalk.
- Separate left turn phases can create confusion for pedestrians. Some pedestrians will begin crossing when the cross street traffic receives red, not realizing that protected left turn movements on the parallel street have right of way. If pedestrians are present and protected left turn phases are provided the designer should consider providing pedestrian heads.

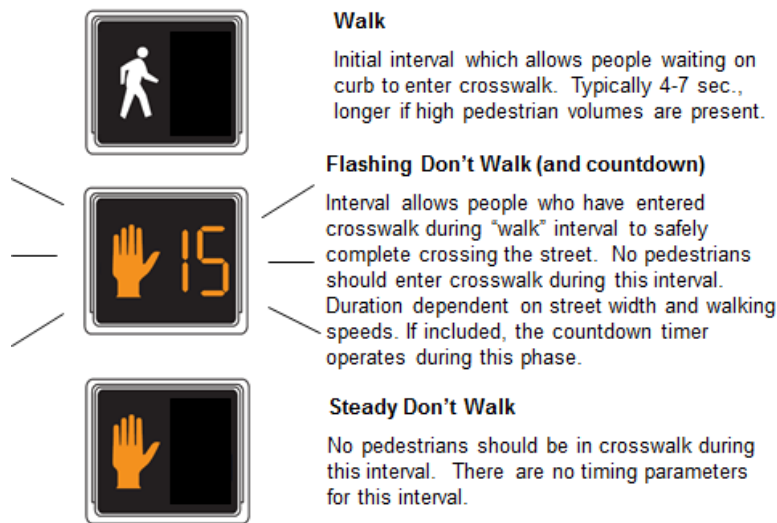
**i** ALDOT practice is that pedestrian heads should be provided only when there is a demonstrated need. If pedestrian heads are to be provided the designer should state the reasons for doing so and provide supporting data (e.g., pedestrian counts, projected demand, or summary of safety issues) with the plan submittal.

### 7.3 Pedestrian Phase Intervals

The standard pedestrian signal heads used by the Alabama DOT are shown in Figure 7.2. A countdown timer is required for any location with a pedestrian change interval (FDW) of more than 7 seconds. Pedestrian heads shall be LED and a minimum of 6 in. in height. Pedestrian phases comprise the three basic intervals shown in Figure 7.3, namely “walk”, “flashing don’t walk”, and “steady don’t walk”. For more information on timing pedestrian phases see Chapter 14 of this manual.



**Figure 7.2 – Standard pedestrian signal heads without (a) and with (b) countdown timer**



**Figure 7.3 – Standard pedestrian intervals**

### 7.4 Actuated vs. Non-Actuated Ped Phasing

When pedestrian phasing is provided, it can be either actuated or non-actuated. With non-actuated phasing, the pedestrian interval times are preset and are activated every time the associated vehicle phase is activated. This has advantages and disadvantages:

- ✓ Does not require pedestrian detectors,
- ✓ Well suited to urban locations with consistent demand,
- ✗ May cause inefficient operation, especially if ped demand is low or ped intervals are long,
- ✗ If the associated vehicle phase is actuated, pedestrians may wait for long periods until a vehicle calls up the vehicle/ped phases.

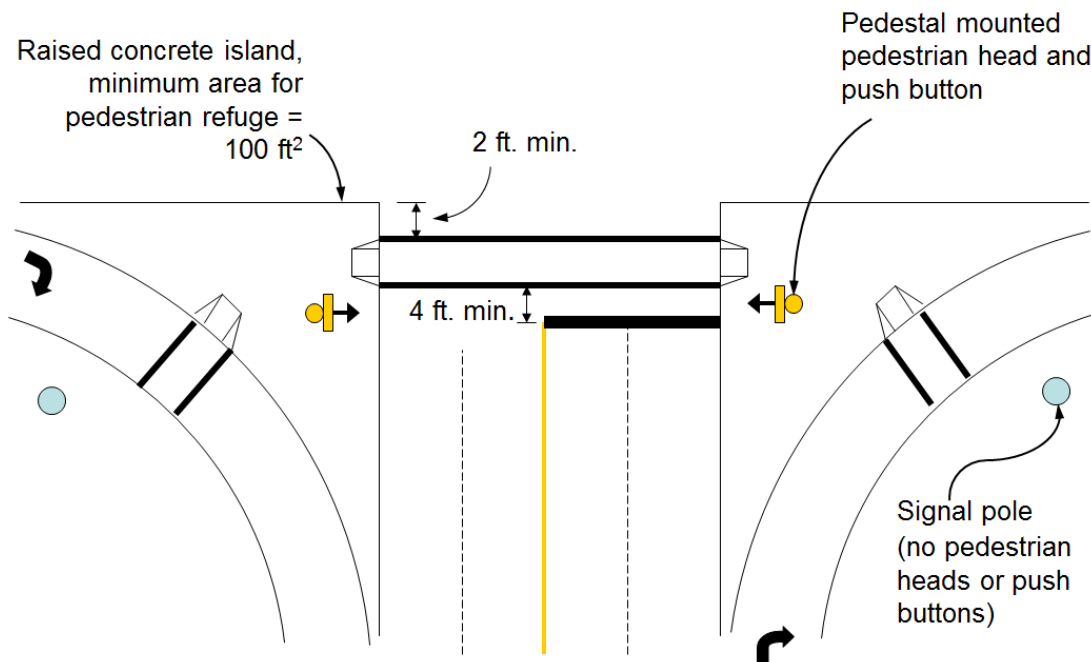
For these reasons, non-actuated ped phasing is recommended only if the signal is pre-timed or if the associated vehicle phase is on recall. If the associated vehicle phases are actuated then pedestrian pushbuttons should be provided.

In actuated signals, the pedestrian phase intervals are activated only when a call is placed on a pedestrian detector, typically a pushbutton. At all other times the ped heads remain in “Do Not Walk”. This is generally more efficient for overall intersection operation because pedestrian timings are activated only when needed.

### 7.5 Pedestrian Signals and Channelizing Islands

A special situation arises when pedestrian signals are provided at intersections where one or more of the turn movements are channelized. These channelized movements are typically right turns and they create a potentially dangerous situation for pedestrians who may not realize that turning traffic may not stop for red signals.

Placing pedestrian signals at either side of the intersection could create a false sense of security for pedestrians who believe they have right-of-way when in fact they do not. One way of dealing with this situation is shown in Figure 7.4. In this case the pedestrian signals are actually placed in the channelizing islands on pedestals, forcing pedestrians to cross the channelized lanes on their own before activating the pedestrian phases.



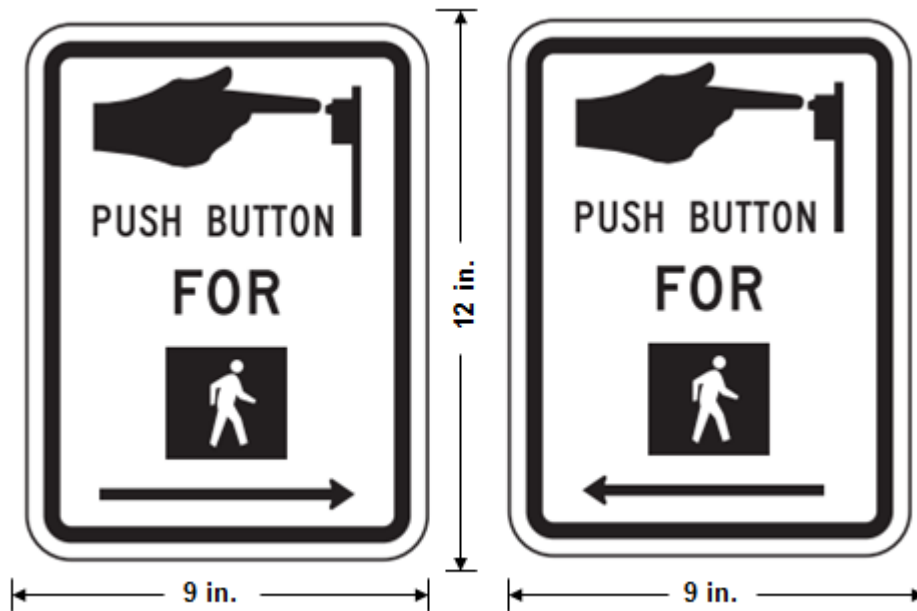
**Figure 7.4 – Pedestrian signals with channelizing islands**

The above treatment should only be used if a curbed island > 100 s.f. is present. When smaller islands or painted channelizing islands are present, the designer should work with ALDOT to develop a design that ensures pedestrian safety. Some options include:

- providing concrete islands
- requiring turning traffic to stop on red lights
- shifting pedestrian movements to other approaches

## 7.6 Detection and Signs

When providing actuated pedestrian phasing, each pedestrian movement shall have a detector (e.g., pushbutton). If a pushbutton is used, it shall also be equipped with a standard sign (see Figure 7.5) indicating the crosswalk to which it applies. The pushbutton and sign shall be located parallel to the crosswalk to which it applies and shall be not more than 5 ft. laterally from the crosswalk extended and 10 ft. from the adjacent curb, shoulder, or pavement (see Figure 7.6). See the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition) as well as [MUTCD Section 4](#) (current ALDOT adopted edition) for additional details.



**Figure 7.5 – Standard pedestrian R10-3 pushbutton signs**

## 7.7 Mounting Heights for Pedestrian Signals

Pedestrian heads shall be mounted so that the distance from the bottom of the housing to the sidewalk is no less than 7 ft. and no more than 10 ft., as shown in Figure 7.6. The height of the pushbutton shall be approximately 3.5 ft. but no more than 4 ft. above the sidewalk. The pushbutton shall be located no more than 5 ft. laterally from the crosswalk extended, and ideally 1.5-6.0 ft. but no more than 10 ft. from the edge of curb, shoulder, or pavement. For additional details and dimensions, see the [ALDOT Standard and Special Drawings for Highway Construction](#), current edition, and figures from [MUTCD Section 4](#) (current edition).

Pedestrian heads and pushbuttons can be mounted on a signal pole if the above location requirements can be met. If the signal pole is located too far from the intersection to meet the location requirements, the designer should consider mounting the pedestrian heads and pushbuttons on a pedestrian pedestal, as shown in Figure 7.6. See the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition) for details regarding pedestrian pedestals.

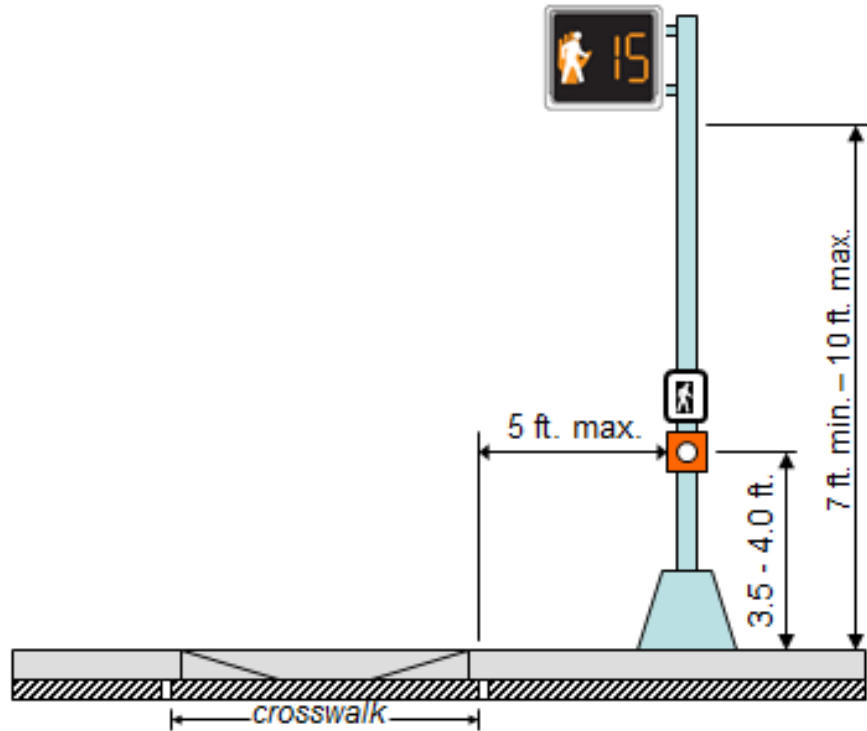


Figure 7.6 – Pedestrian signal mounting heights

### 7.8 Pedestrian Phasing

Pedestrian phases are generally run concurrently with the adjacent thru phase. No pedestrian movement should ever be given a “walk” indication at the same time that a conflicting vehicle movement receives a “green”. This includes adjacent left turns and cross street thru movements. Pedestrian movements in a standard NEMA 8-phase scheme are illustrated in Figure 7.7. Additional information on pedestrian phasing and timing can be found in Chapter 14 of this manual.

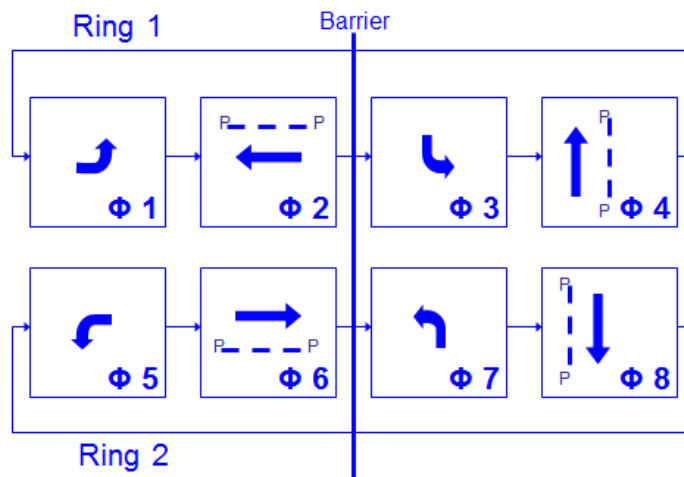


Figure 7.7 – Standard pedestrian phasing (8-phase)

## 7.9 Countdown Pedestrian Displays

Countdown pedestrian displays consist of an extra signal section that displays the amount of time remaining in the pedestrian change interval (Flashing Don't Walk). They are particularly useful on longer crossings to help pedestrians determine how much time they have remaining to complete their crossing. They are typically specified for high volume pedestrian crossings and their use should be discussed with the Region/Area Traffic Engineer prior to plan submittal.

When used, the countdown indication shall be located immediately adjacent to the Don't Walk indication. The countdown indication illuminates at the beginning of the Flashing Don't Walk (FDW) interval and displays the number of seconds remaining in the FDW interval. The indication goes dark at the beginning of the steady Don't Walk interval and remains dark during the Don't Walk and Walk intervals.

If used with a pedestrian signal head that does not have a concurrent vehicular phase, the FDW interval should be set to be approximately 4 seconds less than the required pedestrian crossing time and an additional buffer interval (during which the steady Don't Walk is displayed) should be provided prior to the start of the conflicting vehicular phase. In this case, the countdown display of the number of remaining seconds should be displayed only during the display of FDW interval, should display zero at the time when the FDW changes to the steady Don't Walk, and should be dark during the buffer interval prior to the conflicting vehicular phase.

Minimum height for a countdown indication is 6 in. For locations where the pedestrian enters the crosswalk more than 100 ft. from the countdown display, the numbers should be at least 9 in. in height. Additional information on the use of countdown displays can be found in the [MUTCD Section 4](#), current ALDOT adopted edition.

## 7.10 Handicap Accessible Pedestrian Signals

Persons with disabilities may require additional pedestrian features, such as audible tones and tactile pushbuttons. It is ALDOT practice to provide these features on an as needed basis. An engineering study should be submitted to ALDOT stating the need for special features and justifying their use. When used, ALDOT adheres to the design guidelines for accessible pedestrian features contained in the MUTCD (current ALDOT adopted edition) and ADA guidelines.

When modifying an existing signal that has handicap accessible pedestrian features, the designer should consider upgrading these features to meet current MUTCD and ADA requirements.

## 7.11 Pedestrian Hybrid Beacons

Pedestrian hybrid beacons (also sometimes known as HAWK beacons) are special signal treatments for standalone crosswalks, such as mid-block crossings, whereby vehicle traffic can be stopped to allow pedestrians to cross the street. The signal indications in a hybrid installation are activated only when there is a pedestrian call for crossing; at all other times the vehicle signal indications remain dark (the pedestrian indications remain active at all times). For more information about HAWK designs reference [MUTCD Section 4](#) and the FHWA publication "[Safety Effectiveness of the HAWK Pedestrian Crossing Treatment](#)".

# ***Chapter 8***

## ***Power Service, Signal Wiring, and Conduit***

This Chapter presents ALDOT requirements for signal wiring and conduit. All power service, signal wiring, and conduit on State routes shall conform to Alabama DOT standards and specifications.

### **8.1 Power Service**

Every signal installation (with the exception of solar powered beacons) requires a power service. Power may be run from a nearby power pole, an underground power vault, or even an adjacent signal. Specific ALDOT guidelines for power sources follow. Additional details may be found in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition).

#### *8.1.1 Locating the Power Source*

The location of the power source must be specified on the plans. It is recommended that the designer arrange a meeting with the local power company to identify the most appropriate source of power for the signal. This is particularly important when the power source is located underground. Since the location of the power source affects a contractor's bid price it should be shown as accurately as possible on the plans. If the power source cannot be readily shown on the plans, a note should be provided indicating direction and distance to the power source. In either case, the location of the power source shown on the plans is approximate. It remains the responsibility of the contractor to determine the exact location.

#### *8.1.2 Power Service Pole*

Above ground power service is typically run from the power source to a power service pole located near the controller cabinet, as shown in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition). The power service pole, service wire, weatherhead, disconnect switch, conduit from weatherhead to disconnect switch, and all ancillary hardware are paid for under the lump sum bid item 730C-XXX, "Furnish and Install Traffic Control Unit" so it is not necessary to compute the exact quantities of service wire. It is important, however, that the location of the power source and service pole be shown accurately on the plans and "Power" listed in the Estimated Equipment and Material Box shown on the layout.



In the field, the power company will run power to the top of the service pole. The power company will typically provide a 3-wire power drop, consisting of two 120V “hot” wires and 1 neutral. To obtain 120V power for the controller and luminaires, a single hot wire and neutral are run to the cabinet. To obtain 240V power for other applications (if needed), both hot wires and the neutral are used.

### 8.1.3 Electric Meters

Whether or not an electric meter is required depends on which agency will be maintaining the signal. In most cases, ALDOT has agreements with local power companies to pay flat rates per signal; however, if the signal is to be maintained by an agency other than ALDOT a meter may be required. The designer should check with the local power company to locate the most appropriate power source and discuss metering.

### 8.1.4 Conductors and Conduits for Power Service

Power service wire is run from the top of the service pole in 1 in. metallic conduit down to a disconnect switch and circuit breaker. From there, separate conduits carry conductors for luminaire power, controller cabinet power, and ground. ALDOT standard conductor sizes for providing power to a traffic signal are as follows:

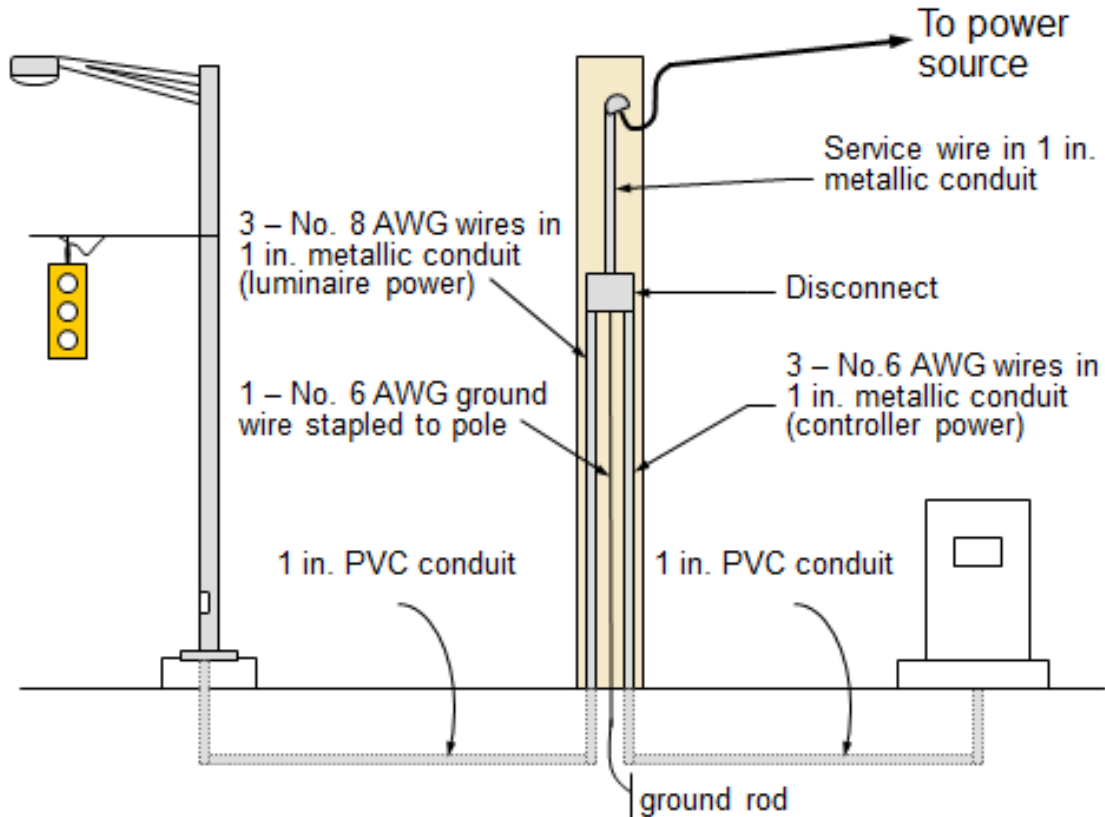
Controller Cabinet	No.6 AWG, 3-1/C	120V
Luminaires	No.8 AWG, 3-1/C	120V
Ground	No.6 AWG, 1/C	

All conductors must be contained in conduit and all exposed (above ground) conduit must be metallic. Figure 8.1 shows a standard configuration for conductors and conduit at a power service pole. If a signal installation does not include luminaries then the extra conduit and conductors would be omitted. Conduit running underground from the service pole to the controller cabinet or signal poles shall be PVC, as shown in Figure 8.1 (see also the [ALDOT Standard and Special Drawings for Highway Construction](#), current edition).

Quantities for the conduits required to provide power from the disconnect switch to the signal and luminaires must be computed and shown in the plan set (conductor quantities are included in the lump sum 730C-XXX pay item and are not computed). Figure 8.2 may be used as a guide to compute typical quantities for power service conduit.

### 8.1.5 Running Power Across Signal Spans

Often the nearest power source will be located across the street from the controller cabinet. In these cases power should be run directly from the source to the service pole and not attached to the signal span. ALDOT prohibits the practice of attaching power service to a signal span because maintenance personnel could shut off power to a signal without realizing that there is still live power running across the span. Power can be run across the street either overhead or in underground conduit.



**Figure 8.1 – Typical configuration for a power service pole**

Note: For underground service, remove the “Service wire in 1 in. metallic conduit” from the top of the “Disconnect Switch” and show the service coming up the pole, from below ground-level, to the bottom of the “Disconnect Switch”. An additional 1 in. metallic conduit will also need to be added when using Figure 8.2 for the quantities layout.

### 8.1.6 Accounting for Voltage Drop

The power company will ensure that proper voltage is provided to the power service pole and, if the service pole is fairly close to the traffic signal, standard No.6 AWG copper wire will be sufficient to provide power to the controller cabinet and No.8 AWG copper wire to the luminaires in most cases. In some cases, however, the designer may tap into an existing 120V electrical drop several hundred feet from the controller (at an adjacent signal for example) or the service pole may be located some distance from the controller. In these cases the designer should remember that line voltage decreases over distance due to wire resistance and that a heavier gauge conductor may be required to maintain adequate voltages to the signal.

The typical maximum operating range for a controller is 89V – 135V AC, however many conflict monitors will record a power loss at 95V, so for practical purposes the line voltage should not be allowed to drop below 100V AC. ALDOT policy is that power service conductors should be sized so as to limit any line voltage drop from the service pole to the controller to no more than 5%.

✘ Power service shall not be attached to signal spans. It should be run directly from the power source to the service pole.

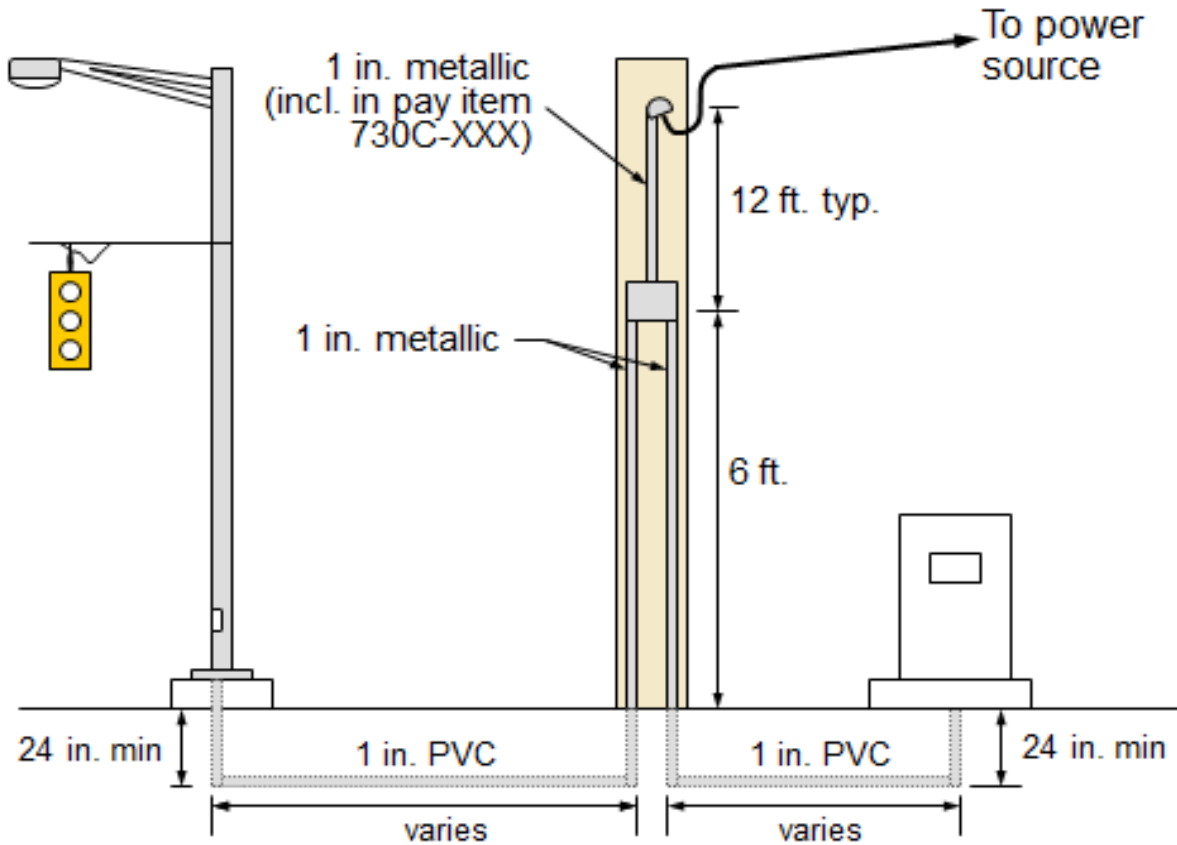


Figure 8.2 – Typical conduit quantities for power service

Voltage drop is a function of wire resistance, which is in turn a function of wire length and size. Voltage loss can be estimated as:

$$V_{\text{drop}} = I \times R \times d \times 2$$

where: I = current (amps)

R = resistance (ohms/100 ft.)

d = length of wire (100 ft.) x 2 (for 2 wires)

Average resistance values for standard gauges of copper wire are provided in Table 8.1.

Table 8.1 Typical Resistances for Copper Wire (Ohms/100 ft.)

Copper Wire Gauge (AWG)				
No.8	No.6	No.4	No.2	No.1
0.063	0.040	0.025	0.016	0.009

A conservative estimate is that a large signal installation will draw 25 amps of current at 120V. Assuming this, Table 8.2 presents some typical voltage losses per 100 ft. of distance to the power source (copper wire) as well as maximum distances over which various wire gauges should be used to provide power service. Designers should specify the smallest appropriate gauge, but at least No. 6 AWG for service to the cabinet or No. 8 AWG for service to luminaries.

**Table 8.2 Average Voltage Drop for Copper Wire (Volts/100 ft. @ 25 amps, 2-Wire)**

Copper Wire Gauge				
#8	#6	#4	#2	#1
3.2	2.0	1.2	0.8	0.5
Maximum Distance for Power Service				
190 ft	300 ft	480 ft	750 ft	1330 ft

**Example:** A designer plans to draw 120V power from an existing street light 350 ft. from the signal. Is standard No.6 AWG conductor appropriate to supply power to the cabinet?

**Solution:**

350ft. x 2.0V/100ft.= 7V drop (5.8% drop – unacceptable)

From Table 8.2: No.4 AWG service wire should be used

It can be seen from Table 8.2 that as long as the service pole or power source is located within 300 ft. of the controller No.6 AWG conductor should be adequate for power service to most installations. If the signal for some reason will draw unusually heavy current the designer should compute voltage losses manually. Some typical power consumption values for common signal components are listed in Table 8.3.

**Table 8.3 – Typical power consumption for signal components (@ 120V)**

Component	Power (W)	≈ Current (A)
Controller (local)	25	0.20
Controller (master)	25	0.20
Conflict monitor	5	0.04
Loop detector	1.5	0.01
Signal head (LED)	15	0.13
Ped head (LED)	6	0.05
Misc. cabinet (light, fan, modem, etc.)	250	2.10

**8.1.7 Luminaire Power**

Most luminaires provided on ALDOT signal projects operate at 120V. If luminaries are to be included at a signal the designer must specify 3 - No.8 AWG, 1/C cables for power to the luminaires. No.8 AWG cable is used to supply power from pole to pole between luminaires. There may be cases where a municipality uses high wattage luminaires that operate at 240V. In those cases, the designer must specify a 240V power source on the plans.

## 8.2 Signal Wiring

Traffic signal wiring generally consists of the following:

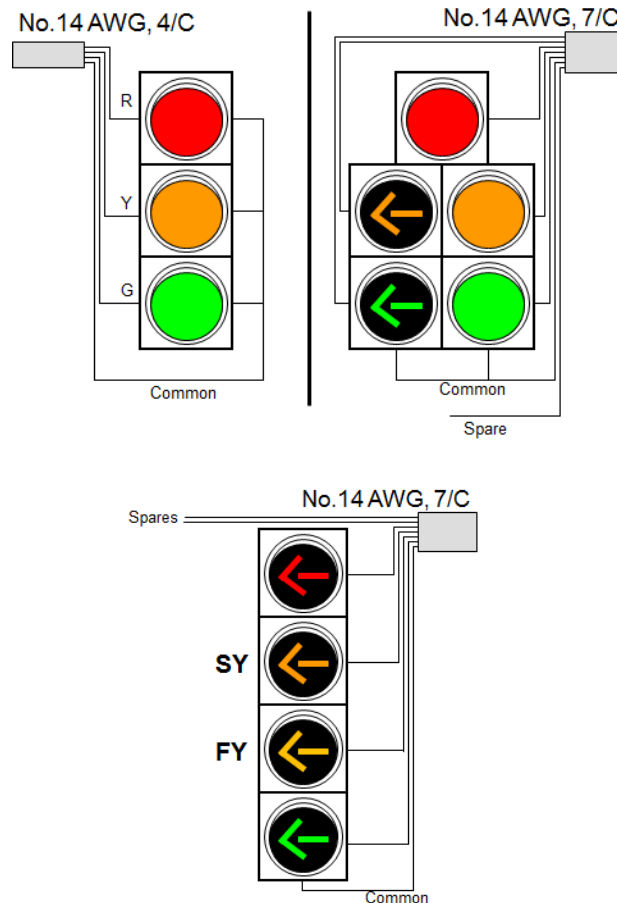
- Signal head wiring
- Pedestrian head & detector wiring
- Vehicle detector returns

The wiring requirements for each are discussed in the following section.

### 8.2.1 Signal Head Wiring

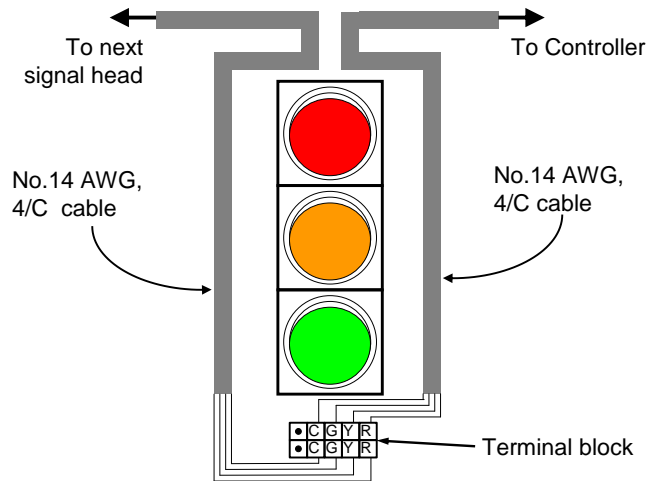
All signal head wiring shall be No.14 AWG and must conform to IMSA Specification 20-1. Signal head wiring must run from the controller cabinet to the signal heads without splices. Signal indications for different approaches may not be served by a common signal cable; each approach must be wired separately. Signal heads on the same approach, however, may share cable.

The number of conductors in each cable depends on the number and type of heads on each approach. Figure 8.3 shows standard 3-section and 5-section signal heads and the number of conductors required for each:



**Figure 8.3 – Standard wiring for 3, 4, and 5 section heads**

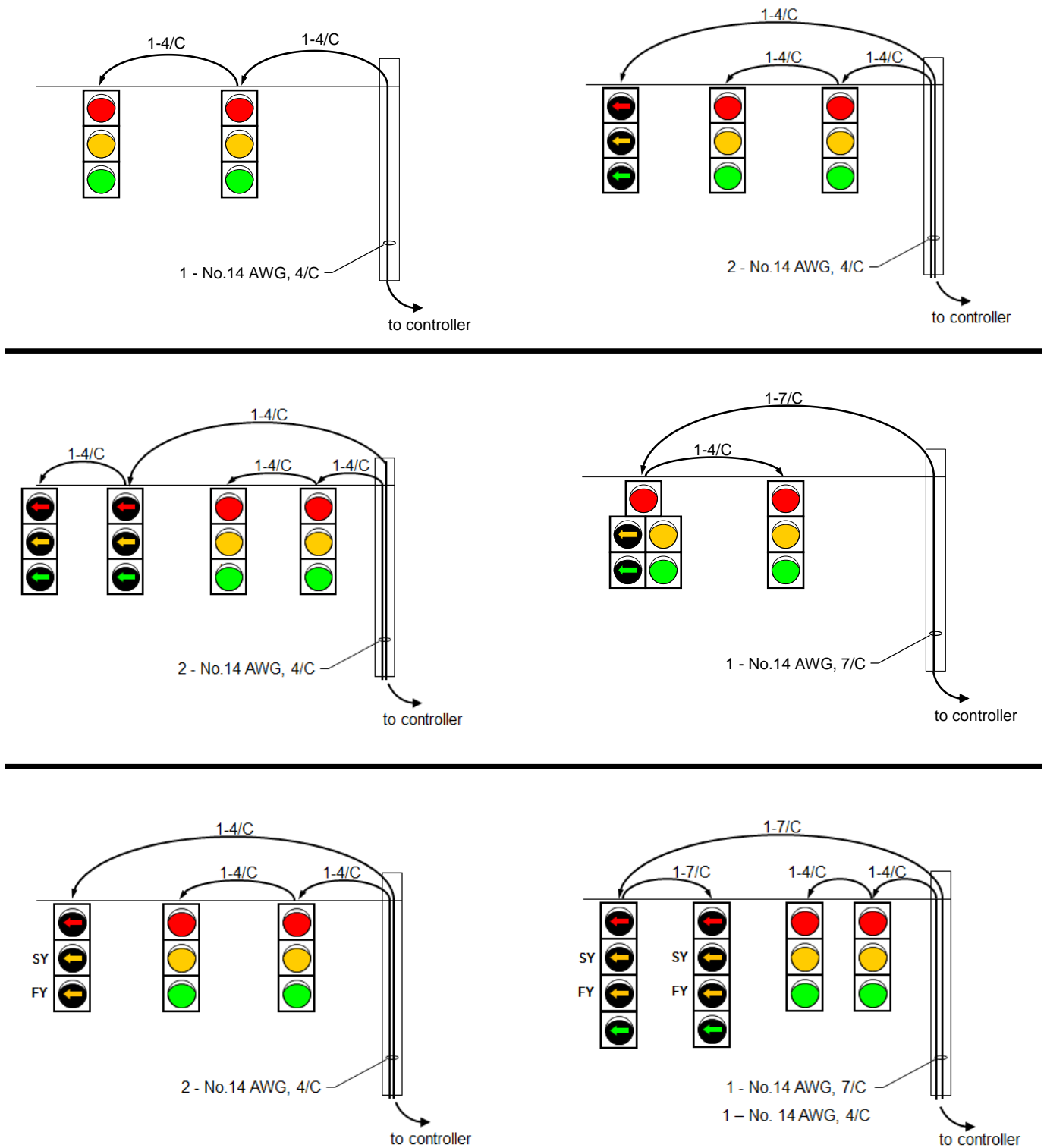
Standard ALDOT signal cable is No.14 AWG, 4 conductor (4/C) for 3-section heads and No.14 AWG, 7 conductor (7/C) for 4 and 5-section heads. Signal heads on the same approach typically share signal cable, meaning a single cable from the controller can operate several heads. Protected left turn and flashing yellow heads, however, are typically wired on a separate cable from the heads for the through movements. The signal heads are typically wired in parallel through a terminal block located in the bottom of each signal head as shown in Figure 8.4.



**Figure 8.4 – Wiring through the terminal block**

### 8.2.2 Common Wiring Configurations

Wiring configurations for some of the most commonly encountered signal head arrangements are shown in Figure 8.5.



**Figure 8.5 – Wiring configurations for common head arrangements**

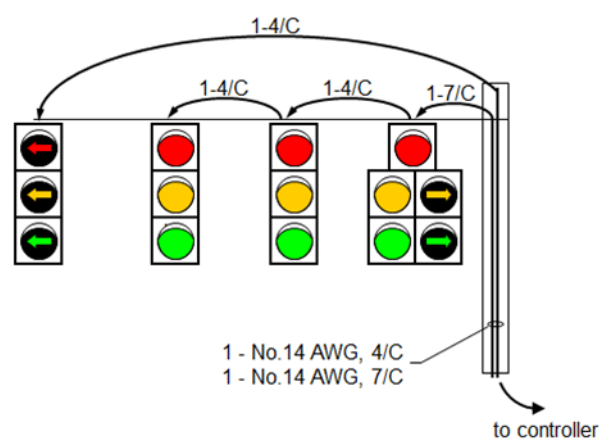
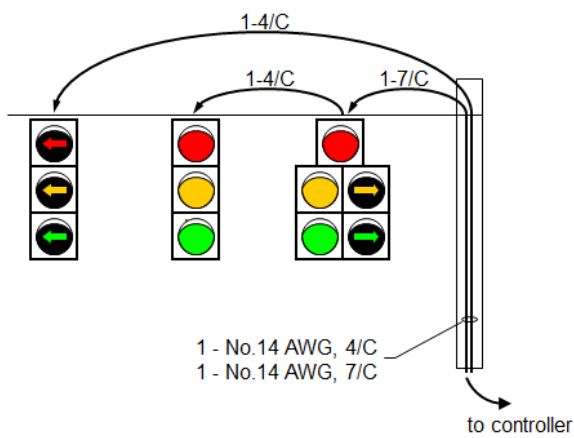
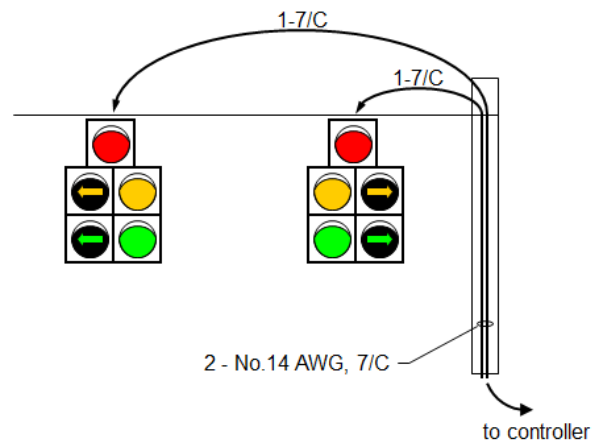
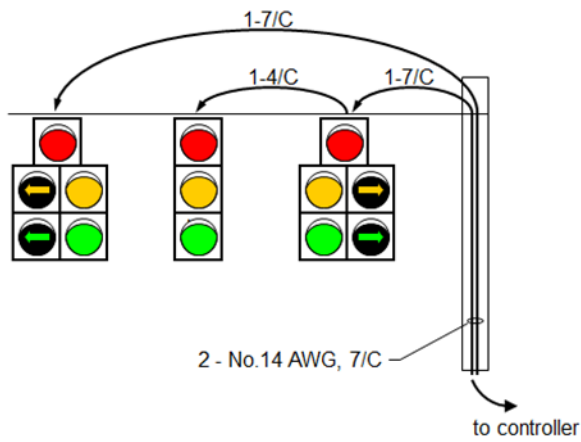
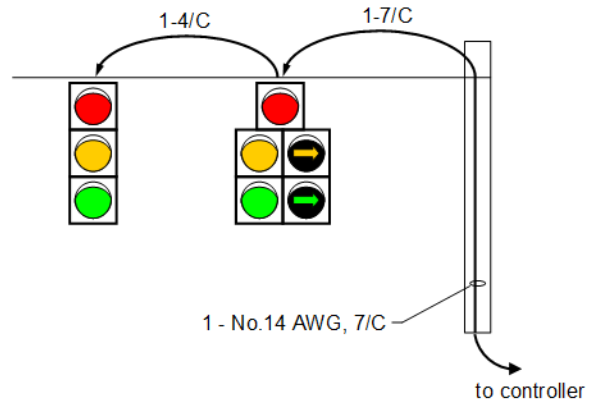
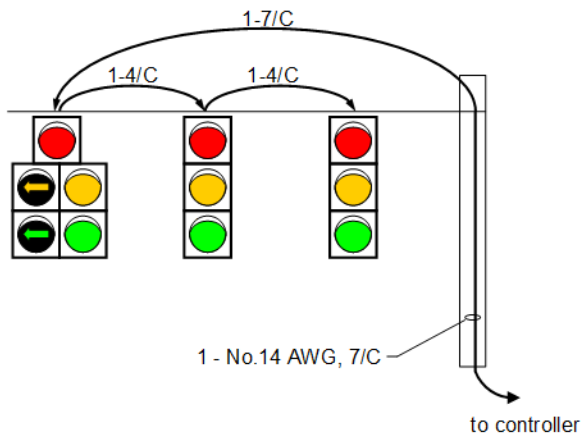


Figure 8.5 (continued) – Wiring configurations for common head arrangements



### 8.2.3 Computing Signal Cable Quantities

ALDOT does not require that signal cable quantities be computed for signal plan sets (all signal cable is covered under the 730C-XXX pay item). For signals installed under State permit, however, the designer will likely need to compute signal cable quantities in order to obtain contractor bids. This section presents guidelines for computing signal cable quantities.

A general procedure for computing signal cable quantities is shown in Figure 8.6. The following assumptions can be made:

- Assume the span wire mounting height to be 25 ft., unless otherwise noted
- Assume underground conduit is located 1.5 ft. below the surface, unless noted
- The terminal blocks into which the wire is connected are located at the base of most signal heads, therefore add a total of 10 ft. of slack plus connection wire at each intermediate signal head (from span wire down to terminal block, then back up and out to the next signal head) and 5 ft. of wire at each terminal signal head
- Note from Figure 8.5 that the terminal signal head is not always located at the end of a series of heads

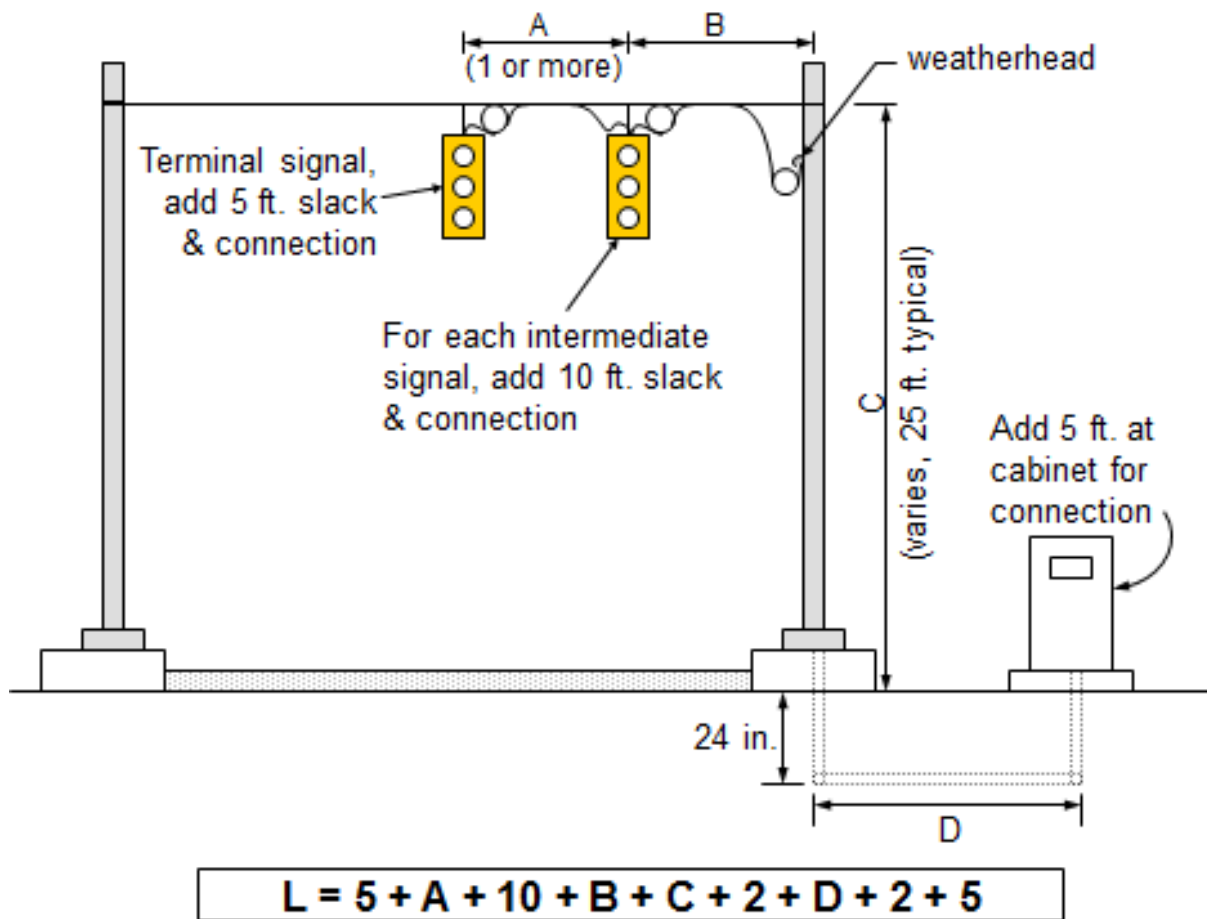
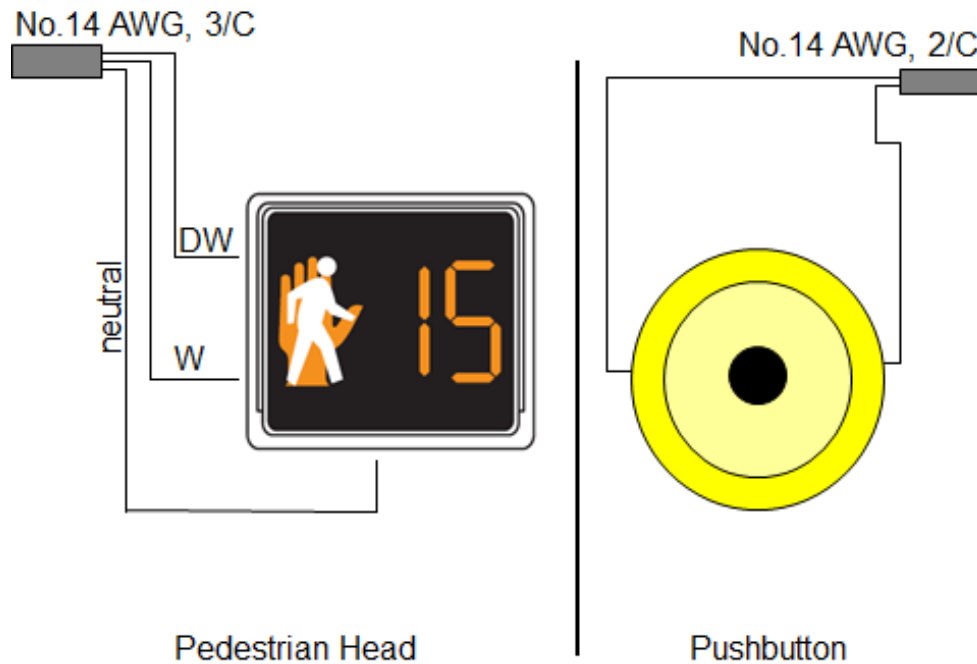


Figure 8.6.- Computing Signal Cable Quantities

### 8.2.4 Pedestrian Head and Pushbutton Wiring

Pedestrian signal heads and pushbuttons also require No.14 AWG, IMSA Specification 20-1 signal cable. Pedestrian heads utilize No.14 AWG, 3 conductor (3/C) signal cable and pedestrian pushbuttons utilize No.14 AWG, 2 conductor (2/C) signal cable as shown in Figure 8.7. A single No.14 AWG, 5 conductor (5/C) cable may be used to serve a pedestrian head and its associated pushbutton in place of two separate cables. Pedestrian heads for conflicting approaches are often located next to one another on the same signal pole; however, ALDOT does not allow pedestrian indications for conflicting approaches to share signal cable.



**Figure 8.7 – Wiring for pedestrian heads and pushbuttons**

Separate signal cables should always be used. Pedestrian heads also shall not share cable with vehicular signal heads.

As with signal cable, ALDOT does not require cable quantities for pedestrian features for signal plan sets (all pedestrian signal cable is covered under the 730C-XXX pay item). For permit plans, cable quantities for pedestrian features can be computed in a manner similar to that used to compute signal cable quantities. Figure 8.8 provides some basic guidance.

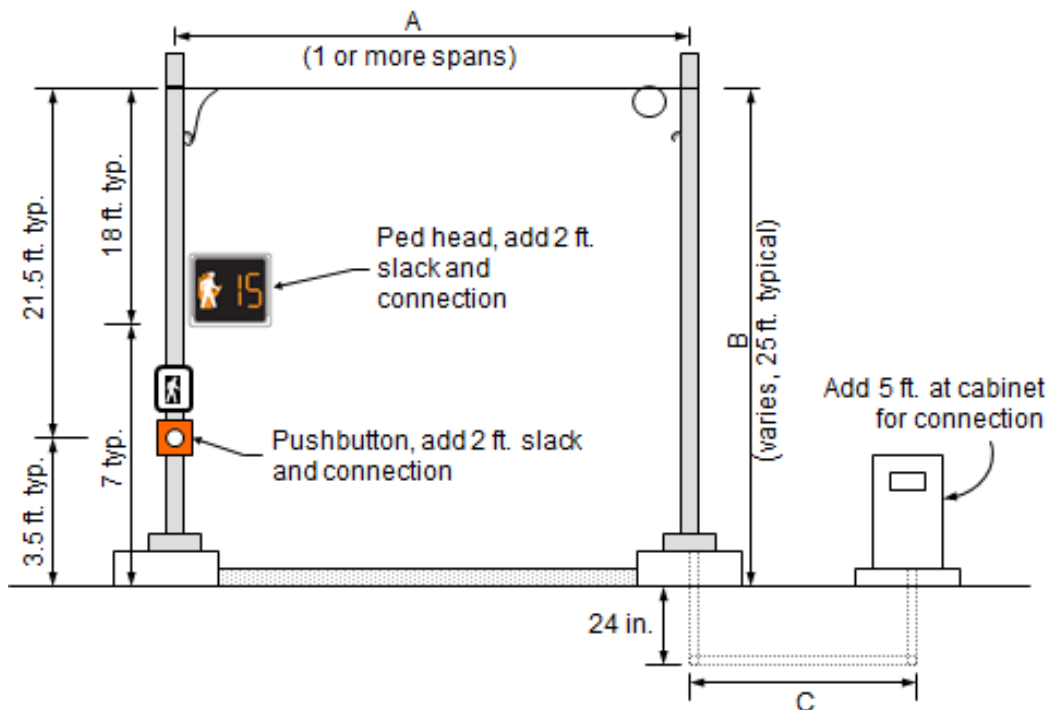
### 8.2.5 Loop Wire Quantities

Loop detector design is discussed in Chapter 6. All loop wire shall be No. 12 AWG, 7 strands, and conform to ALDOT Standard Specifications Section 890.13. A quantity for loop wire is required on all signal plan sets and is paid for under pay item 730H-001. Loop wire quantities for standard loop sizes are shown in Table 8.4.

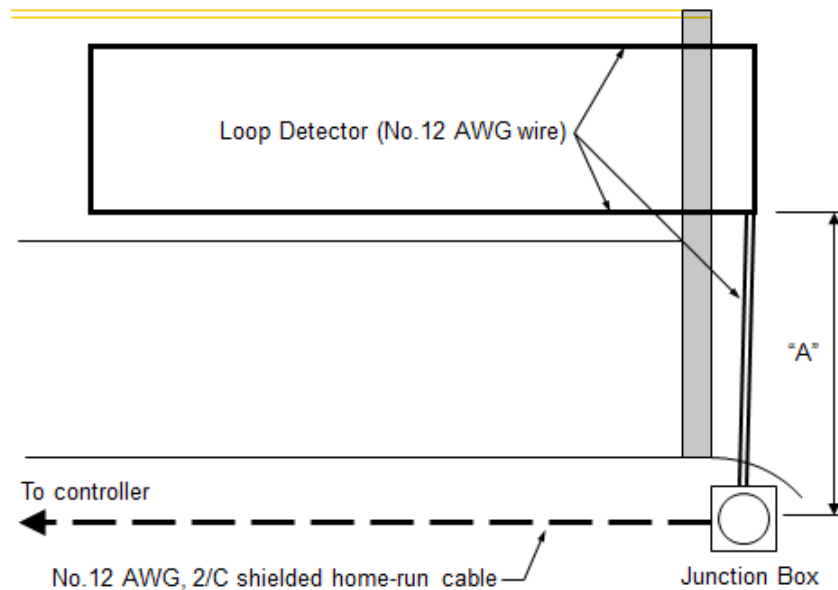
**Table 8.4 – Wire quantities for standard loops**

Detector Size	# turns	Loop Wire (ft.)
6 ft. x 6 ft.	4	96
6 ft. x 30 ft.	2	144
6 ft. x 40 ft.	2	184
6 ft. x 50 ft.	2	224
6 ft. x 40 ft. quadrupole	2-4-2	344
6 ft. x 50 ft. quadrupole	2-4-2	424

All detector loops consist of one continuous wire that begins and ends in a junction box as shown in Figure 8.9 or in the pole base or cabinet. The quantities shown above are for the loop detector only and do not include the wire from the loop detector to the junction box. The designer must add to the quantities shown in Table 8.4 a length of wire equal to 2 times the distance from the detector to the junction box (distance “A” in Figure 8.9) or to the cabinet.



**Figure 8.8 – Computing pedestrian cable quantities**



**Figure 8.9 – Loop detector wiring**

### 8.2.6 Loop Detector Returns

Generally, each loop detector will require a separate “home-run” cable to the controller cabinet. All loop home-run cable shall be shielded No.12 AWG and shall conform to IMSA 50-2 standards (shielded cable has a layer of metallic mesh in the insulation). Home-run cable is spliced to the detector wire in the junction box (see Figure 8.9) via an ALDOT approved splice kit and then run back to the controller in underground conduit and/or over the signal spans. Multiple loop detectors may not be spliced to the same home-run cable and each home-run cable shall be wired to a separate detector amplifier.

Loop detector home run cable quantities (pay item 730I-000) must be computed for the complete signal installation and shown in the plan set. General guidelines for computing loop return quantities are shown in Figure 8.10. Quantities for every detector loop should be included in the total.

## 8.3 Conduit and Junction Boxes

All signal wiring and cable run underground or attached to poles must be in conduit. This section presents ALDOT requirements for conduit, conduit encasement, conduit boring, and junction boxes. Additional details can be found in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition).

### 8.3.1 Metallic Conduit

All conduit exposed above ground must be rigid metallic and conform to ALDOT Specification 890.16. The most common applications of metallic conduit are on power service poles, risers on wood poles, and conduit attached to bridge decks. Due to its higher cost, ALDOT requires the use of metallic conduit only for above-ground applications.

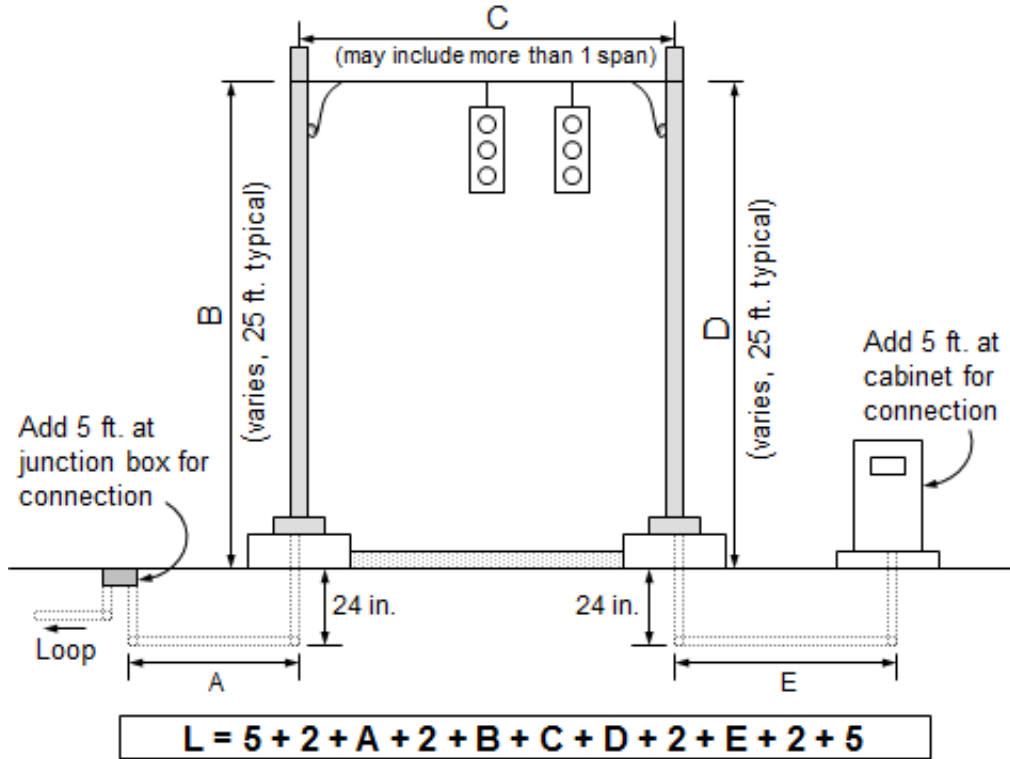


Figure 8.10 – Computing loop return quantities

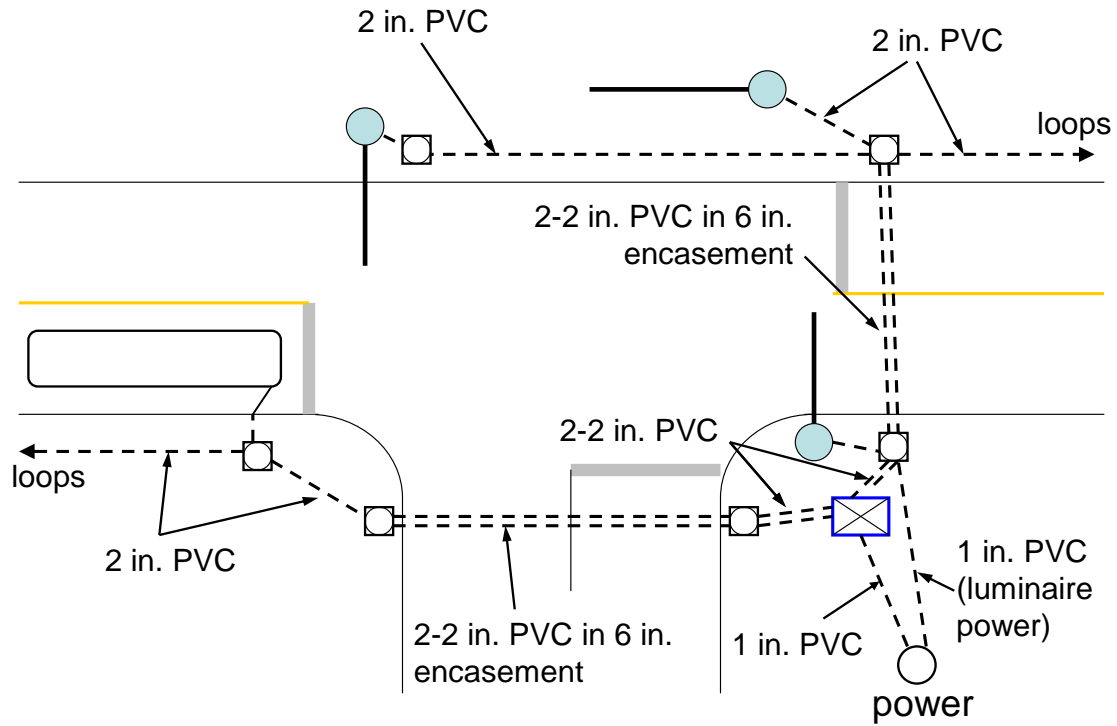
8.3.2 PVC Conduit

ALDOT specifies Type II, Schedule 40, PVC conduit for standard underground applications. All non-metallic conduit shall conform to ALDOT Specification 890.16. In cases where metallic conduit is run above ground it should transition to PVC conduit once underground. Standard conduit sizes used by ALDOT are 1 in. PVC for signal power applications and 2 in. PVC for signal cable and loop returns. Because the incremental cost of installing larger conduit is minimal, 2 in. conduit should be specified for signal cable and loop returns even if a smaller conduit would suffice. Typical conduit applications are summarized in Table 8.5.

Table 8.5 – Typical conduit applications

Location	Application	Conduit Type
Above Ground	service wire	1 in. metallic
	ground wire	¾ in. metallic
	controller power	1 in. metallic
	luminaire power	1 in. metallic
	signal cable (riser)	2 in. metallic
	loop return (riser)	2 in. metallic
	interconnect (riser)	2 in. metallic
Below Ground	controller power	1 in. PVC
	luminaire power	1 in. PVC
	signal cable	2 in. PVC
	loop returns	2 in. PVC
	interconnect	2 in. PVC
	under driveway	2 in. PVC encased
	under roadway	2-2 in. encased





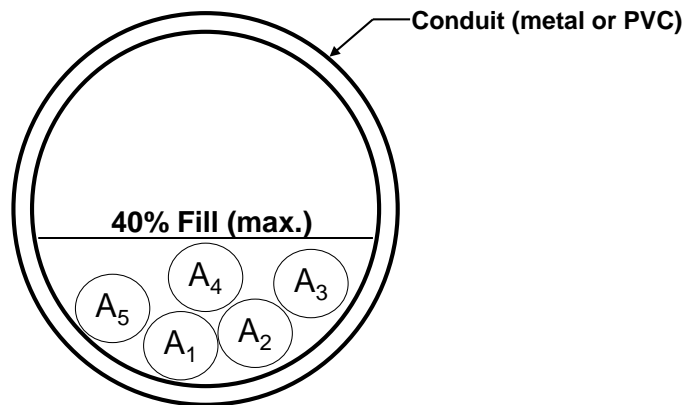
**Figure 8.12 – Typical conduit layout for mast-arm installation**

**8.3.3 Conduit Fill Limits**

When conduits are filled to even 50% of capacity with cables it becomes difficult to pull additional cables through. ALDOT therefore requires that conduits be filled to no more than 40% of capacity, as shown in Figure 8.13, with 25% fill preferred. The percent conduit fill is computed as:

$$\text{Fill \%} = [(A_1 + A_2 + A_3 + \dots + A_n) / C] \times 100$$

where:  $A_i$  = cross sectional area of cable  $i$  (in<sup>2</sup>)  
 $C$  = cross sectional area of conduit (in<sup>2</sup>)



**Figure 8.13 – Maximum conduit fill**

Cross-sectional areas for standard conduit sizes are shown in Table 8.6, as well as 40% fill areas. Cross-sectional areas for standard ALDOT conductors and cables are shown on Table 8.7.

**Table 8.6 - Conduit area and 40% fill  
(Metallic and Schedule 40 PVC Conduit)**

Conduit Size	Total Area (in <sup>2</sup> )	40% Fill Area (in <sup>2</sup> )
1 in.	0.78	0.31
1½ in.	1.78	0.71
2 in.	3.15	1.26
2½ in.	4.90	1.96
3 in.	7.08	2.83
4 in.	12.58	5.03
5 in.	19.63	7.85

Fill levels should be checked for all conduits. If the fill exceeds 40% an additional conduit should be provided. Since much of the cost of installing underground conduit is related to trenching/boring the incremental cost of adding an additional conduit is usually minimal.

**Table 8.7 – Cross-sectional areas for standard signal cable**

Cable	Cross-Sectional Area (in <sup>2</sup> )			
	quantity			
	1	2	3	4
No.8 AWG, 1/C	0.06	0.12	0.18	0.24
No.6 AWG, 1/C	0.08	0.15	0.22	0.30
No.14 AWG, 2/C	0.13	0.26	0.40	0.53
No.14 AWG, 3/C	0.15	0.29	0.44	0.58
No.14 AWG, 5/C	0.17	0.35	0.52	0.70
No.14 AWG, 7/C	0.18	0.36	0.54	0.72
No.12 shld, 2/C	0.14	0.28	0.42	0.56
No.12 shld, 4/C	0.20	0.40	0.60	0.80
No. 14 AWG, 9/C	0.36	0.73	1.09	1.46
No.19 AWG, 6 pair	0.22	0.44	0.66	0.88

### 8.3.4 Conduit Encasement

When conduit is run under driveways or roadways it must be encased to protect it from being damaged by the weight of vehicles above. Encasement is simply a larger rigid metallic pipe through which PVC conduits are run. Required encasement sizes for common conduit combinations are shown in Table 8.8. As a general rule of thumb, the encasement diameter should be at least 2 inches greater than the sum of the conduit diameters that will run through it.

**Table 8.8 – Common encasement sizes**

Conduits	Encasement
1 – 1 in.	2 in.
2 - 1 in.	4 in.
1 - 2 in.	4 in.
2 – 2 in.	6 in.
3 – 2 in.	8 in.



### 8.3.5 Conduit Boring

When conduit must be run under driveways or roadways, directional boring should be used. Trenching requires excavating a narrow trench across the driveway or roadway, installing the conduit, and repairing the roadway surface afterwards. Because trenching damages the roadway surface it should not be used to run conduit under roadways. The use of trenching should be limited to conduit runs under gravel roadways and gravel driveways.

Directional boring is a horizontal directional drilling method. The boring does not disturb the roadway surface and has minimal impact on the adjacent landscape. A Type 5 directional bore is recommended for most ALDOT projects. Additional boring details can be found in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition).

The designer should be aware that in order to bore under a roadway there must be a clear area on at least one side of the planned bore and within State or construction R.O.W. where the boring machine can operate. A boring machine requires an area approximately 20 ft. x 20 ft. in which to operate. When specifying bored conduit in the signal plans the designer should confirm that a clear boring area exists. If such an area does not exist the designer can move the bore location or seek a construction easement.

## 8.4 Junction Boxes

Traffic signal junction boxes are placed periodically along conduit runs in order to facilitate pulling cable or to provide space for splicing loop returns. Junction boxes are required in the following situations:

- Adjacent to detector loops. A junction box shall be installed at all loop locations. The junction box should be installed as close to the roadway edge as possible in order to minimize the length of the detector lead-ins. Home-run cable shall be spliced to the detector leads only in a junction box.
- At ends of major conduit bores. Whenever a conduit bore under a roadway exceeds 50 ft. or the encasement contains multiple conduits, junction boxes shall be provided at each end of the bore. Junction boxes are not required for bores under driveways or less than 50 ft.
- Adjacent to signal poles. A junction box shall be provided at each signal pole location with a minimum of one 2 in. conduit running to the signal pole.
- On conduit runs greater than 200 ft. junction boxes shall be provided at maximum intervals of 200 ft. If the conduit run exceeds 200 ft. but is less than 400 ft., the junction box shall be placed at the midpoint of the conduit run.

Details for the standard size junction box are provided in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition).

# ***Chapter 9***

## ***Signal Pre-Emption***

Signal pre-emption interrupts the normal operating cycle of a signal to give priority to irregular but urgent movements. Pre-emption can be used to enhance the safety of an intersection or to facilitate the movement of emergency and transit vehicles through a signal. This Chapter presents guidelines for implementing the most common types of signal pre-emption. For additional information on railroad crossings and pre-emption, see Chapters 4 and 8 of the Manual on Uniform Traffic Control Devices ([MUTCD](#), current ALDOT adopted version) as well as [“Preemption of Traffic Signals Near Railroad Crossings”](#) by ITE.

### **9.1 Types of Signal Pre-Emption**

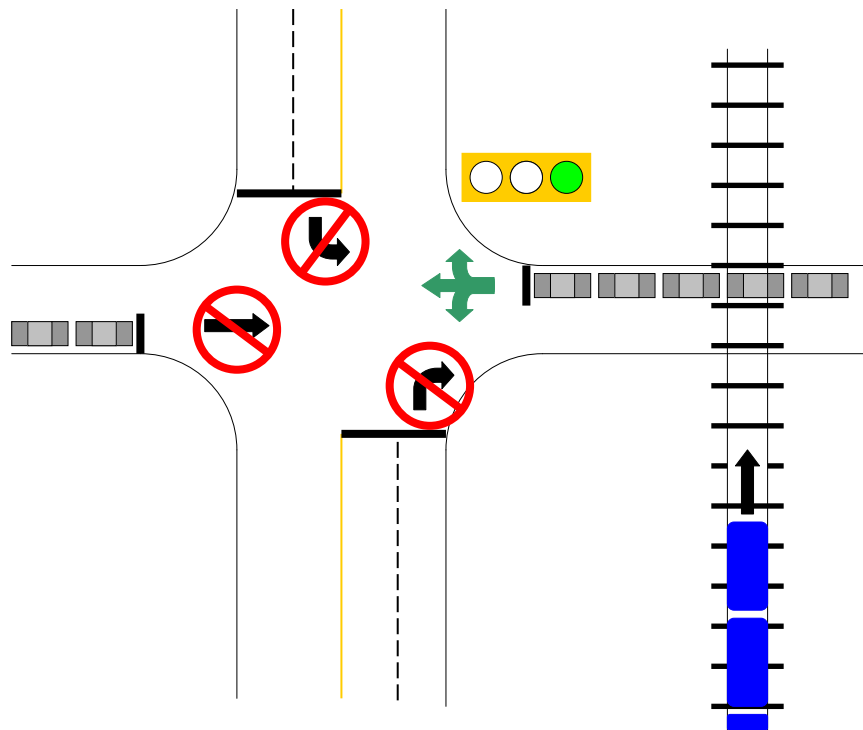
The most common types of signal pre-emption are:

- Railroad pre-emption - Designed to allow traffic to safely clear an intersection/railroad crossing before the passage of a train
- Emergency pre-emption - Designed to give priority phasing to emergency vehicles and allow them to pass through a signalized intersection with little or no delay
- Bus/transit pre-emption - Typically designed to extend a green phase or shorten cross street phases in order to reduce transit vehicle delays
- Pedestrian pre-emption - In some cases, pedestrian movements can be served with pre-emption rather than standard pedestrian phasing.

Each type is discussed in the following sections along with guidelines for developing phase intervals and timings.

### **9.2 Railroad Pre-Emption**

Railroad pre-emption is used when a signalized intersection is located near enough to a railroad crossing to affect vehicle movements and queues at the intersection. Railroad pre-emption serves two primary purposes: 1) to allow vehicles that may be queued near the track area to clear before a train arrives, and 2) to prohibit certain movements at the intersection while the train is passing. An illustration of a case where railroad pre-emption would be beneficial is shown in Figure 9.1.



**Figure 9.1 – Illustration of railroad pre-emption**

In the example shown in Figure 9.1, a train approaches a crossing located near a signalized intersection. As the train approaches, it is necessary to immediately clear all vehicles queued across the tracks, regardless of where the signal is in its cycle. A pre-emption call will terminate any conflicting phases and immediately give right-of-way to the approach crossed by the railroad tracks. Once that has been accomplished, the second function of pre-emption will be to prohibit vehicles from entering the approach (potentially queuing from the crossing back into the intersection) until the train has passed. Railroad pre-emption may be used whether the rail crossing is signed, signalized, or gated.

#### 9.2.1 When to Provide Railroad Pre-Emption

The Manual on Uniform Traffic Control Devices (MUTCD, current ALDOT adopted version) states that railroad pre-emption should be provided whenever the distance between a rail crossing and traffic signal is 200 ft. or less. This represents the minimum requirement for pre-emption in Alabama but should not be considered the only requirement. There are many cases where the 200 ft. requirement is not adequate for prevailing traffic conditions and the designer should carefully evaluate any signal near a rail crossing to determine if pre-emption is required. Warrants for railroad pre-emption include:

- A signal is located within 200 ft. of an active rail crossing
- Analysis indicates that vehicle queues from the traffic signal have the potential to extend into or past the rail crossing
- Analysis indicates that vehicle queues caused by a passing train have the potential to extend into the signalized intersection and obstruct traffic flow

It is recommended that the designer estimate the maximum (95%) queue expected on the approach to determine whether it will extend into the track area. If the estimated maximum queue will extend to within 8 feet of the nearest rail, pre-emption should be provided. A detailed procedure for estimating the maximum expected vehicle queue is presented in the document [“Preemption of Traffic Signals Near Railroad Crossings”](#) by ITE.

## 9.2.2 Railroad Pre-Emption Operation

A standard railroad pre-emption sequence includes the following intervals:

- Right-of-way Transfer Time - The time required to receive the train detection signal, terminate the active signal phases, and all vehicle and pedestrian clearance intervals on conflicting approaches. This can vary from 0 seconds if the track clearance phase is already active to some maximum time based on programmed clearance intervals.
- Track Green Interval – Time provided for the green interval to clear vehicles from the track area.
- Track Yellow + All Red – Standard yellow plus all red intervals following track clearance phase.
- Track Passage – Period during which train is passing through crossing. During this interval, the signal dwells in or cycles through designated phases.
- After Train Passage – Signal clears to specified phases and resumes normal operation.

A typical railroad pre-emption sequence is illustrated in Figure 9.3, along with guidelines for computing the minimum interval times.

### 9.2.2.1 Computing Right-of-Way Transfer Time

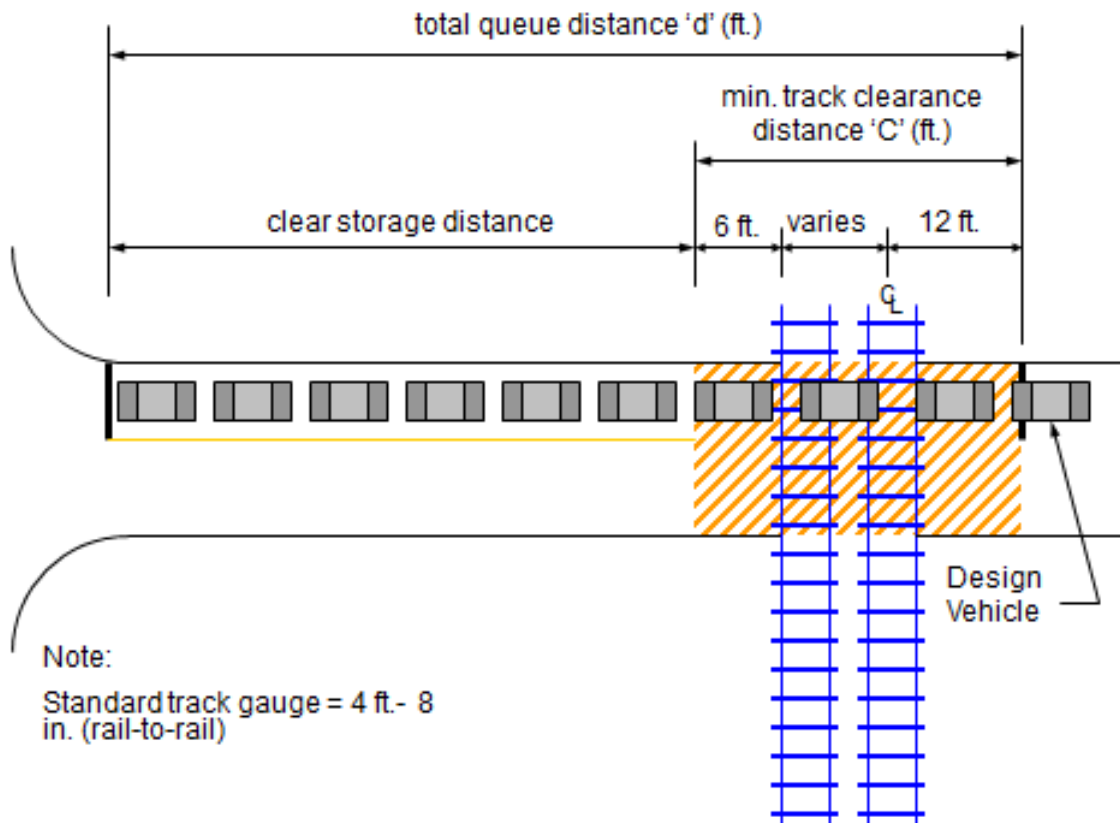
Railroad pre-emption timings are based on a worst-case scenario, meaning the longest possible times required for each interval are used. The right of way transfer time consists of three distinct elements:

- Equipment response time – The time required for the train detection equipment to detect an approaching train, send a pre-emption call to the signal controller, and have the controller initiate the pre-empt sequence. It can vary from 0 seconds to some maximum time determined by the railroad. A value of 5 seconds is typically assumed for pre-emption calculations. The train detection equipment is owned and operated by the railroad, so coordination may be required to determine this value.
- Pedestrian clearance time – If pedestrian phases are present, upon receipt of the pre-empt signal any conflicting active walk phase is immediately terminated and the clearance (FDW) interval is initiated. Under normal circumstances, the full pedestrian clearance interval will time out. If the pedestrian clearance interval is so long as to create unreasonable delays, it may be shortened with ALDOT approval. However, this is an undesirable situation that could leave pedestrians unprotected in a crosswalk. The pedestrian clearance time is usually assumed to be equal to the longest conflicting pedestrian clearance (FDW) interval.
- Vehicle clearance time – After the pedestrian clearance is complete, any conflicting vehicle phase is terminated. There is a pre-emption parameter “minimum green before pre-empt” that determines the minimum green that must be displayed on a conflicting phase before it will be terminated during pre-emption. This differs from the standard “min. green”, which is overridden during pre-emption. In most cases the “minimum green before pre-empt” is set to 0 seconds. If it is not zero, the programmed value must be included in the total vehicle clearance time. After the phase is terminated, normal yellow and all red intervals are timed. Vehicle clearance times may not be shortened during pre-emption.

### 9.2.2.2 Computing Track Green Interval

The Track Green interval is designed to clear any vehicles that may be queued in the vicinity of the railroad tracks before the train arrives. Specifically, it is designed to clear any vehicles stopped within the Minimum Track Clearance Distance, as illustrated in Figure 9.3. No vehicles should be within the Minimum Track Clearance Distance when the train arrives. For the purpose of calculating the minimum track green interval, the worst case scenario is that a vehicle will be queued with its nose just inside the Minimum Track Clearance Distance. The track green will have to provide enough time for the design vehicle to cross the tracks and completely exit the Minimum Track Clearance Distance before the train arrives.

The minimum track green interval has three components: 1) the time required for the queue ahead of the design vehicle to begin moving, 2) the time for the design vehicle to cross the tracks and completely exit the Minimum Track Clearance Distance (see Figure 9.2), and 3) a separation time to provide an extra measure of safety between the time the vehicle clears the tracks and the time the train arrives.

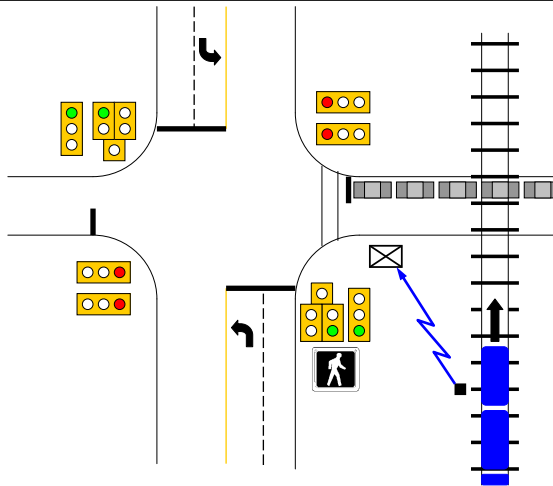


**Figure 9.2 – Track clearance distances**

**1. Right-of-Way Transfer**

**1a. Equipment Response**

Detection equipment operated by the railroad detects approaching train and sends call to signal controller.

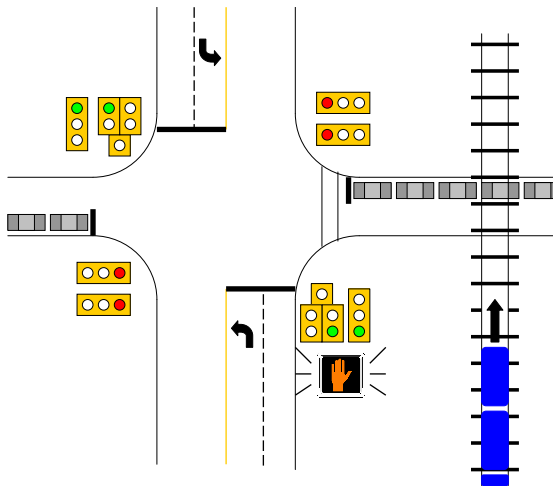


**Calculation**

Assume equipment response time = 5 seconds unless railroad reports otherwise.

**1b. Pedestrian Clearance**

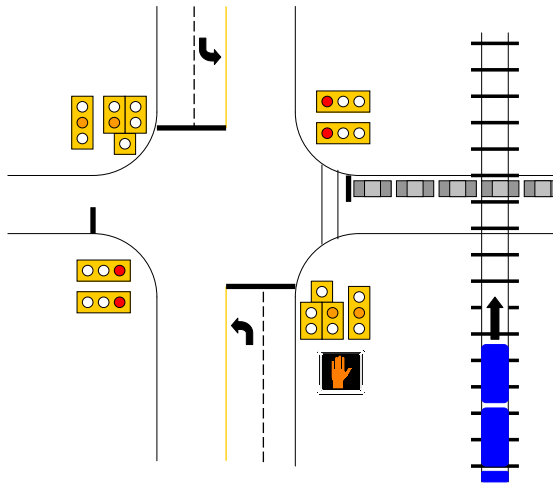
If present, pedestrian walk phase is terminated and flashing "Don't Walk" clearance interval is initiated. Pedestrian clearance interval will time its full length unless specially programmed.



Assume the pedestrian clearance time equals the pedestrian flashing don't walk (FDW) interval programmed for the active phase. If the pedestrian clearance interval is very long and will create unacceptable delay it may be shortened during pre-emption but only with the approval of ALDOT.

**1c. Vehicle Clearance**

Active vehicle phase (if not pre-empt phase) is terminated and normal vehicle clearances (yellow + all red) are initiated.



Vehicle clearance equals the sum of the yellow and all red for the conflicting phase. Vehicle clearance times may not be modified for pre-emption. If the 'minimum green before pre-empt'<sup>1</sup> for the conflicting phase has not finished timing out, the clearance interval will include remainder of minimum green + yellow + all red.

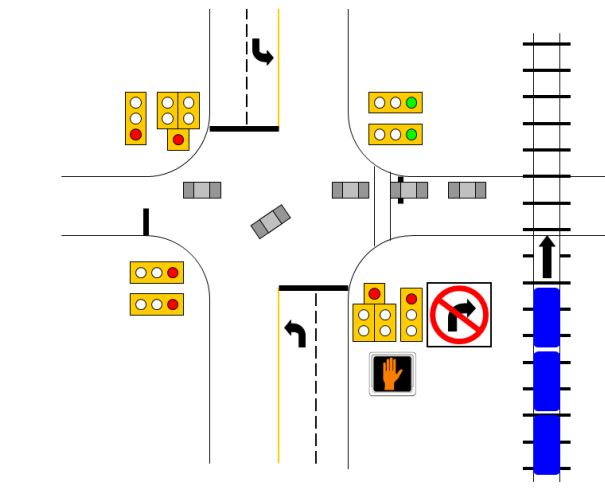
<sup>1</sup> Note: 'Minimum green before pre-empt' is different from normal min. phase green. Min. green before pre-empt is a pre-emption setting and typically set to 0 seconds.

**Figure 9.3 – Typical railroad pre-emption sequence**

**2. Track Clear Interval**

**2a. Track Green**

A green indication is given to clear queued vehicles from tracks before train arrival. If distance from stop line to crossing is  $\leq 200$  ft. then track green should be long enough to clear all vehicles from tracks through intersection.

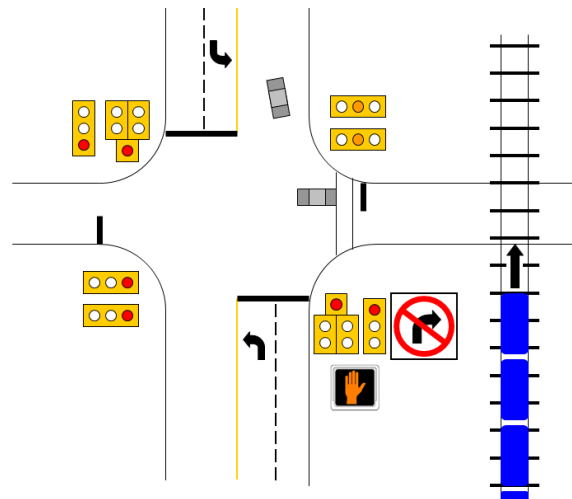


**Calculation**

See section 9.2.2.2 for method to compute minimum track green.

**2b. Track Green Clearance**

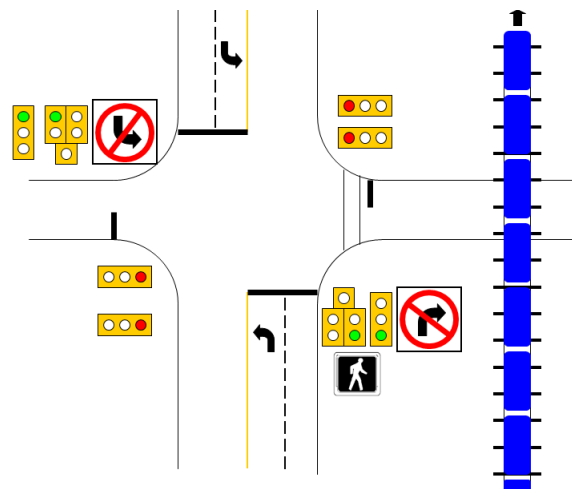
Yellow plus all red for track clear phase.



Track green clearance equals yellow plus all red times for track clear phase.

**3. Track Passage**

During train passage, signal cycles through designated phases. Phases for turn movements onto track approach are omitted. Other vehicle movements to track approach are prohibited using blank out signs.

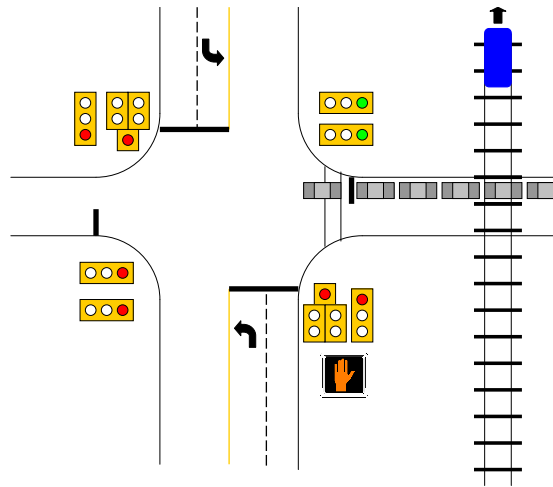


Duration determined by train passage.

**Figure 9.3 – Typical railroad pre-emption sequence (continued)**

#### 4. After Track Passage

Signal clears active phase and exits pre-emption to specified phase. Signal resumes normal operation.



#### Calculation

Exit phase is typically one of the phases omitted during the Track Passage period.

**Figure 9.3 – Typical railroad pre-emption sequence  
(continued)**



The time required for the queue ahead of the vehicle to begin moving can be computed as:

$$t_1 = 2 + 1.4n \quad (1)$$

where:  $t_1$  = time to move (sec)

$n$  = the number of vehicles queued in front of design vehicle

The value for  $n$  can be estimated as the total queue distance ( $d$ ) divided by 20 feet per vehicle, as shown in Figure 9.2.

The time required for the design vehicle to cross the tracks and exit the Minimum Track Clearance Distance can be computed as:

$$t_2 = \sqrt{2(L + C) / a} \quad (2)$$

where:  $t_2$  = crossing time (sec)

$L$  = length of the design vehicle (ft)

$C$  = Minimum Track Clearance Distance

$a$  = accel. rate for design vehicle (1.6 ft/sec<sup>2</sup>)

The acceleration rate of 1.6 ft/sec<sup>2</sup> is for heavy trucks and represents a worst case scenario. If no trucks are expected, an alternate rate of 4.4 ft/sec<sup>2</sup> can be used for passenger cars or 2.5 ft/sec<sup>2</sup> for single unit trucks. The total green interval equals  $t_1 + t_2$ .

An additional time, called the *separation time*, may be added to the track green interval for additional safety. The separation time is a fixed time interval, typically 5-8 seconds, between the time the design vehicle clears the Minimum Track Clearance Distance and the time the train arrives. For computation purposes, a minimum separation time of 5 seconds should be assumed. Thus, the total track green interval equals:

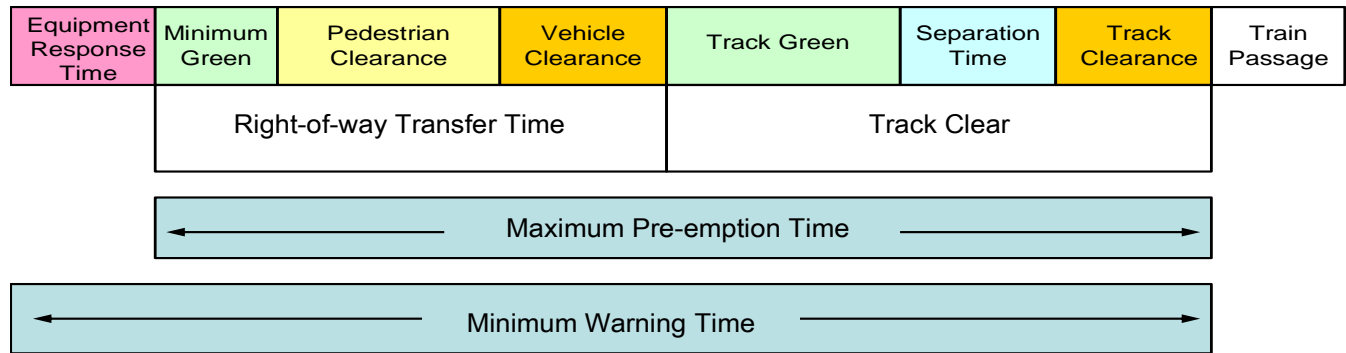
$$\text{Track Green (sec)} = t_1 + t_2 + \text{separation time}$$

### 9.2.2.3 Computing Track Clearance

The clearance intervals after the Track Green interval are the standard clearance intervals for that phase. The clearance times may not be modified for pre-emption.

### 9.2.2.4 Total Railroad Pre-Emption Warning Time

The sum of the (1) right-of-way transfer time, (2) Track Green interval, and (3) track clearance interval equal the total pre-emption warning time. This is the minimum amount of advance warning time required before a train arrives at the crossing. The designer must ensure that the railroad can provide this minimum warning time or the pre-emption may not function safely. If the actual warning time is less than the computed minimum, the designer shall work with the railroad to upgrade the train detection equipment and provide the appropriate warning time. The minimum advance warning time is illustrated in Figure 9.4



**Figure 9.4 – Illustration of pre-emption warning time**

### 9.3 Emergency Pre-Emption

Emergency pre-emption is typically used on routes where a fairly regular amount of emergency vehicle traffic is expected. Its purpose is to reduce delays for emergency vehicles traveling through the signal by providing green or holding a green indication on the pre-empted approach. Emergency pre-emption may be used for fire, police, rescue, or any other type of emergency vehicle. The need for emergency pre-emption should be discussed with the Region/Area Traffic Engineer prior to design.

#### 9.3.1 Hardware Requirements

The three most common types of pre-emption systems are a) optical pre-emption, b) acoustic pre-emption, and c) GPS pre-emption. Which system is selected depends on many factors, including terrain, roadway geometry, nearby obstructions, cost, and available hardware on the emergency vehicles. The type of pre-emption system selected should be discussed with Region/Area Traffic Engineer as well as local emergency agencies, if applicable. A brief description of each system type follows.

Optical pre-emption systems use a combination of optical emitters mounted on the emergency vehicles and optical sensors located at the signal. Coded light pulses from the emitters are detected by the optical sensors and initiate the pre-emption sequence. The sensors may be mounted on a span wire, mast-arm, or signal pole but must have a clear line-of-sight for the approach being served. Advantages of this type of system include the ability to encode the optical signal to prevent misuse and keep a log of each vehicle that has triggered a pre-emption. A disadvantage is that it requires a clear line of sight between vehicle and detector and requires hardware both on the vehicle and at the traffic signal.

Acoustic pre-emption operates on the same principle as optical pre-emption, except that it uses a sensor to detect the sound of the vehicle siren to activate a pre-emption sequence. An advantage is that while it requires a sensor at the traffic signal, it does not require any emitter or additional hardware on the vehicle itself. A disadvantage is that sensors can be susceptible to false activations, either from reflected sound waves or from vehicles on adjacent streets.

For both optical and acoustic systems, each intersection approach requires a separate sensor, although not every approach must be equipped for pre-emption. Often only the mainline approaches are equipped for pre-emption, with the side street approaches equipped only if regular emergency traffic is expected.

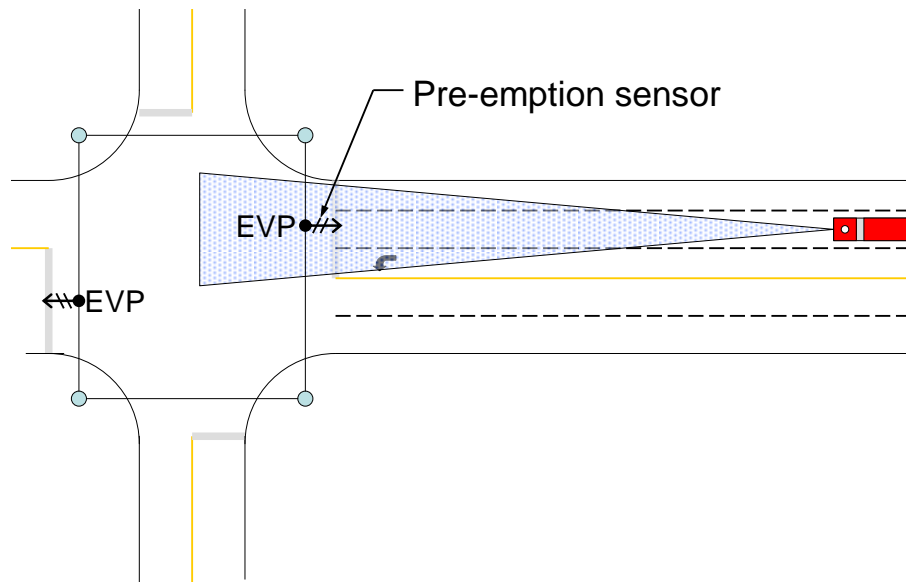
The third type of system uses GPS receiver and communications equipment on the emergency vehicle to transmit a pre-emption request to the signal. Equipment in the controller cabinet uses the GPS information sent from the vehicle to determine when and on what approach a pre-emption activation is needed. Advantages include the reduced probability of false activations and the ability to encode signals for specific vehicles and vehicle types. Disadvantages relate primarily to the possibility of loss of GPS signal (and therefore location information) in areas with tall buildings, overpasses, or other obstructions.

In all systems, the sensors at the traffic signal are wired to a phase selector mounted in the controller cabinet. The phase selector receives signals from the sensors and requests the appropriate pre-empt sequence from the controller based on the approach activated. The designer may specify either a 2-channel or 4-channel phase selector depending on the number of sensors used. Typically each sensor requires a separate channel. A typical optical sensor and phase selector are shown in Figure 9.5.



**Figure 9.5 – Typical optical pre-emption sensor (left) and phase selector (right)**

Optical and acoustic pre-emption sensors are typically mounted on the near-side span or mast-arm in order to provide the greatest advance detection capability, as shown in Figure 9.6. GPS sensors are typically mounted on the controller cabinet or on a signal pole near the cabinet.



**Figure 9.6 – Location of Pre-Emption Sensors**

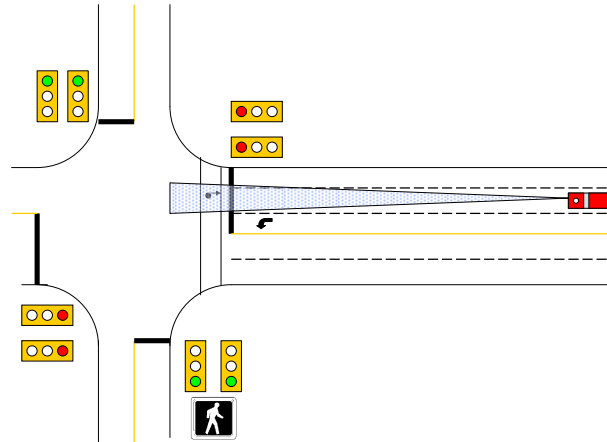
### 9.3.2 Emergency Pre-Emption Operation

A typical emergency pre-emption sequence is illustrated in Figure 9.7. It includes the following intervals:

- **Activation** – the emergency vehicle emits a coded signal that is detected by a sensor at the intersection. Because the signal is light, there must be a clear line-of-sight from the vehicle to the sensor. Activation distance will depend on the alignment of the sensor and roadway geometry.
- **Pedestrian Clearance Interval** – if present, any active pedestrian “walk” phase will be immediately terminated and the “Flashing Don’t Walk (FDW)” clearance interval initiated. The “FDW” interval will time to its full value.
- **Vehicle Clearance Interval** – Upon completion of the pedestrian clearance interval, any active conflicting phases will be terminated. There is a pre-emption parameter “minimum green before pre-empt” that determines the minimum green that must be displayed on a conflicting phase before it will be terminated during pre-emption. This differs from the standard “min. green”, which is overridden during pre-emption. In most cases the “minimum green before pre-empt” is set to 0 seconds. If it is not zero, the programmed value must be included in the total vehicle clearance time. After the phase is terminated, normal yellow and all red intervals are timed. Vehicle clearance times may not be shortened during pre-emption.
- **Pre-Empt Green** – The controller will initiate and hold green on the pre-empted approach as long as a signal is received from the emergency vehicle.
- **Dwell/Extend** – As the emergency vehicle enters the intersection the sensors will lose the signal from the emitter (due to angle or the vehicle passing under the sensor). The controller will continue to hold green on the pre-empted approach for a specified ‘dwell’ or ‘extend’ time to allow the vehicle to safely pass through the intersection. Typical dwell times range from 4-8 seconds.

**1. Activation**

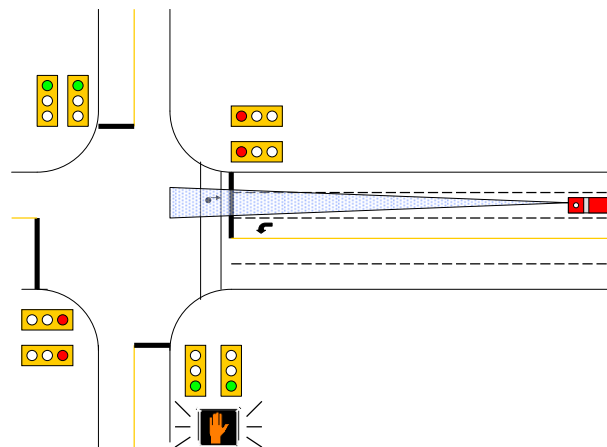
An emitter located on an emergency vehicle activates the pre-emption sequence through a detector mounted on the signal.

**Calculation**

Detection distance can be adjusted in the field.

**2. Pedestrian Clearance**

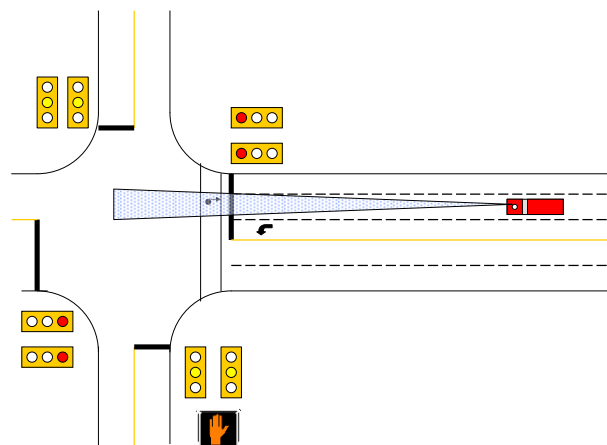
If present, the pedestrian walk phase is immediately terminated and the flashing "Don't Walk" clearance interval is initiated. The pedestrian clearance interval will time its full length unless specially programmed.



Assume the pedestrian clearance time equals the pedestrian flashing don't walk (FDW) interval programmed for the active phase. If the pedestrian clearance interval is very long and will create unacceptable delay it may be shortened during pre-emption but only with the approval of ALDOT.

**3. Vehicle Clearance**

Active vehicle phase (if not pre-empt phase) is terminated and normal vehicle clearances (yellow + all red) are initiated.



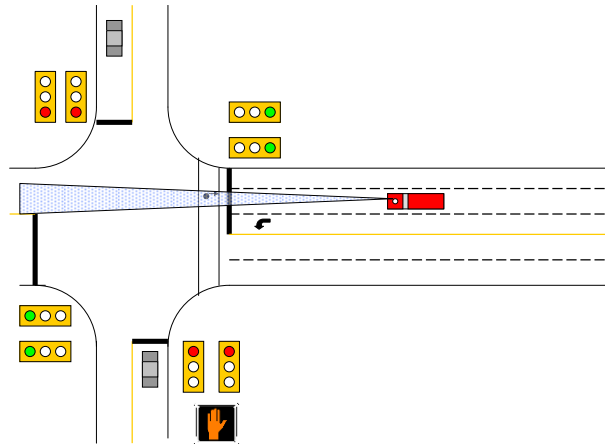
Vehicle clearance equals the sum of the yellow and all red for the conflicting phase. Vehicle clearance times may not be modified for pre-emption. If the 'minimum green before pre-empt'<sup>1</sup> for the conflicting phase has not finished timing out, the clearance interval will include remainder of minimum green + yellow + all red.

<sup>1</sup> Note: 'Minimum green before pre-empt' is different from normal min. phase green. Min. green before pre-empt is a pre-emption setting and typically set to 0 seconds.

**Figure 9.7 – Typical emergency pre-emption sequence**

#### 4. Pre-Empt Green

Signal provides green indications on pre-empt phase(s). As long as the pre-empt detector receives a signal from the emergency vehicle it will hold the green for the pre-empt phase.

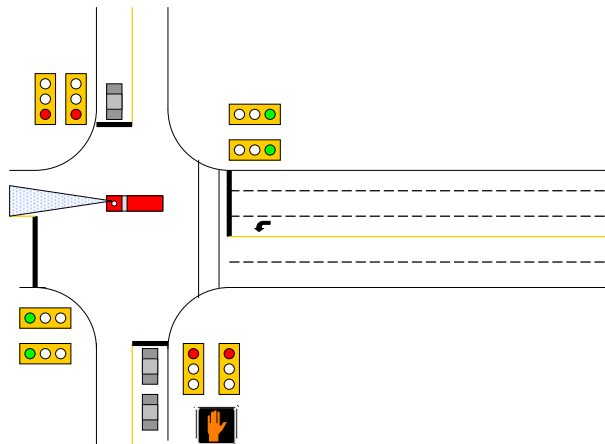


#### Calculation

Duration of pre-empt green depends on emergency vehicle passage time.

#### 5. Dwell/Extend

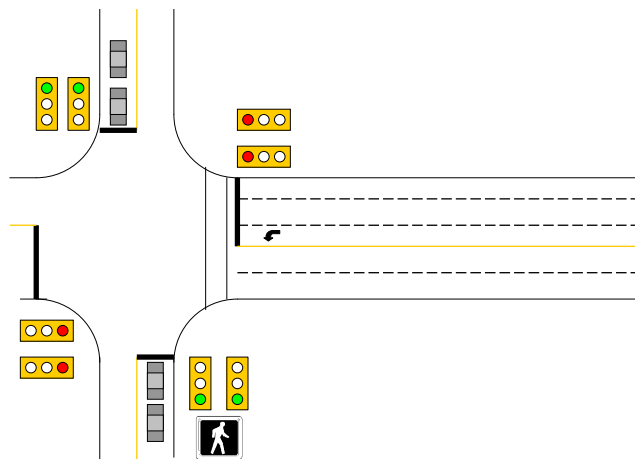
As the vehicle approaches and enters the intersection, the pre-empt detector loses the signal from the vehicle. The controller holds the pre-empt green for a specified 'dwell' time to allow the vehicle to safely pass through the intersection.



Dwell/Extension is set to allow the emergency vehicle to pass through the intersection. Typically 5 – 10 seconds.

#### 6. Exit Phase

After the dwell has expired the signal clears to the exit phase(s), typically one of the non-pre-empted phases.



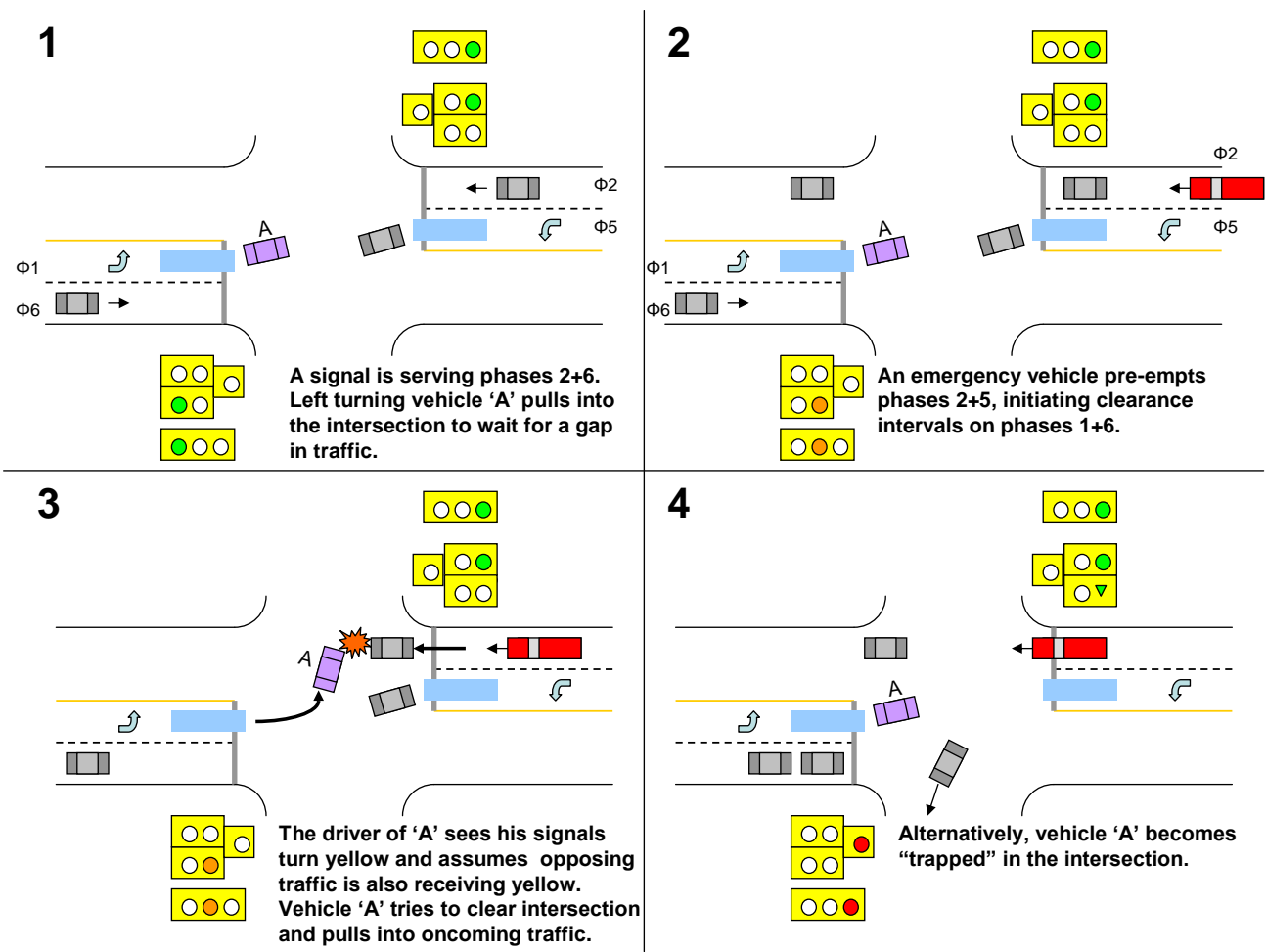
**Figure 9.7 – Typical emergency pre-emption sequence (continued)**

### 9.3.3 Emergency Pre-Emption Phasing

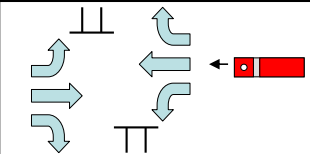
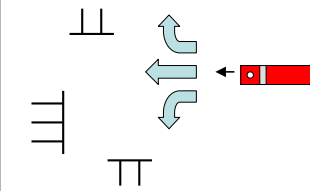
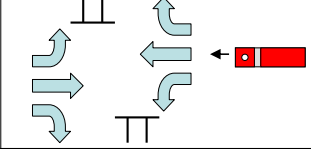
For each approach on which pre-emption equipment is installed, the designer must specify the pre-emption phasing, i.e., what phases will be called when pre-emption is activated. While it is desirable to provide green only to the approach being activated, thereby giving the emergency vehicle unimpeded freedom to turn left, thru, or right at the intersection, the designer must choose the pre-emption phasing carefully. Section 3.6 presents a discussion of the Left Turn Trap that can occur when protected-permissive phasing is used. The designer should be aware that the same principles apply during signal pre-emption.

**ⓘ The designer should remember that the principles of the ‘Left Turn Trap’ apply to signal pre-emption.**

The potential danger of providing green to only the pre-empted approach when protected-permissive left turn phasing is used is illustrated in Figure 9.8. For this reason, ALDOT does not permit providing exclusive green to the pre-empted approach when permissive or protected-permissive left turn phasing is present. ALDOT recommends the pre-emption phasing shown in Figure 9.9 when left turn phases are present.



**Figure 9.8 – Illustration of the Left Turn Trap and Emergency Pre-Emption**

Left Turn Phasing	Pre-Emption Phasing
Permissive	 2+6 or 4+8
Protected	 1+6, 2+5, 3+8, 4+7
Protected-Permissive Or Mixed	 2+6 or 4+8

**Figure 9.9 – Recommended Pre-Emption Phasing When Left Turn Phases are present**

#### 9.3.4 Emergency Pre-Emption Design Parameters

When emergency pre-emption is specified, ALDOT requires that the following timing parameters be specified for each pre-empt sequence as shown in Table 9.1 below.

**Table 9.1 – Emergency Pre-Emption Parameters (Sample)**

Phase	Approach	Max. Call (sec)	Max. Hold (sec)	Extend Time (sec)	Pre-Empt Phasing
1+6	EB	120	60	8	2+6
2+5	WB	120	60	8	2+6
4	NB	80	60	6	4
8	SB	80	60	6	8

- Phase/Approach – Normal phases serving approach being pre-empted
- Max. Call – The maximum time the controller will register a pre-emption call from the vehicle. Settings typically range from 60-120 seconds. This is designed to prevent excessive pre-emption calls when, for instance, an emergency vehicle stops in advance of a signal to serve a crash and leaves the emitter on
- Max. Hold – The maximum time the controller will hold pre-empt green for a given approach.
- Extend Time – The additional time the controller will hold the pre-empt green after the signal is lost from the emergency vehicle
- Phasing – The phases that are to be active (green) during pre-emption



## 9.4 Transit Pre-Emption

Signal pre-emption can also be used to reduce delays for transit vehicles by extending green indications to allow transit vehicles to pass. At this time, ALDOT does not have any standards for transit pre-emption. Details of any proposed transit pre-emption systems should be discussed with the Region/Area Traffic Engineer.

## 9.5 Pedestrian Pre-Emption

There are cases where it may be desirable to treat a pedestrian movement as a pre-emption rather than through standard pedestrian phase settings. This is most commonly seen in cases where a) pedestrian volumes are very low, and b) pedestrian crossing times are very long, such as at very wide streets. Long pedestrian crossing times result in long Maximum Green times for the associated vehicle phase, because Maximum Green phase settings must be long enough to accommodate associated pedestrian Walk and Flashing Don't Walk intervals. The Max Green times can sometimes be so long that they give excessive amounts of green time to side streets or reduce the efficiency of the intersection. In these cases, designers will sometimes treat a pedestrian call as a pre-emption rather than a standard pedestrian phase, allowing them to keep Max Green times low and activating the pedestrian features only when needed. It tends to be most effective when pedestrian volumes are very low. This type of treatment should be discussed with the Region/Area Traffic Engineer prior to implementation.

## 9.6 Pre-Emption Hierarchy

When multiple pre-emption types are present at an intersection, pre-emption calls shall be serviced in the following order:

1. Railroad
2. Emergency
3. Bus/transit
4. Pedestrian

## 9.7 Operational Impacts of Signal Pre-Emption

Traffic signal pre-emption is a necessary and beneficial design element; however, there are a number of operational impacts that should be considered when designing a pre-emption plan:

- Pre-emption disrupts coordinated systems. In order to serve a pre-empt call a controller operating in a system must drop out of coordination mode. Once the pre-empt has been served the controller will return to coordination mode but will usually be out of step with the rest of the system. It can take up to 4 cycles for the controller to “catch up” to the rest of the system, and if long cycle times are being used this can mean the controller will be out of step for intervals of 10 minutes or more. Furthermore, consider the impact of an emergency vehicle traveling the length of a coordinated system, pre-empting each signal as it goes. The combined effects can disrupt progression for significant periods of time.
- Pre-emption can create long vehicle queues. When railroad pre-emption prohibits a certain turn movement for an extended period, long vehicle queues can form that disrupt traffic flow in adjacent lanes. Similarly, after a coordinated signal has been pre-empted by an emergency vehicle, the controller will often cut short or skip phases for minor movements in order to quickly get back into step with the system. This can create unexpected queues on side streets and left

turn movements that are difficult to clear. These should be accounted for, to the extent possible, in the signal design.

- Pre-emption generally increases delay for other movements. Even at isolated intersections a pre-emption call will cut short opposing phases and increase delays on non-pre-empted movements.

If pre-emptions are an infrequent occurrence, then the issues described above may be acceptable for short periods. If, however, pre-emptions are a frequent occurrence, such as at a busy railroad crossing or in the vicinity of a fire station, the designer may consider modifying their design. Possible steps include:

- Consider shorter cycle times. If it is expected that a coordinated system will experience frequent pre-emptions, shorter cycle times may allow it to return to normal operation more quickly after each event. This would of course have to be carefully weighed against trade-offs to capacity and progression.
- Set phase times on affected movements to accommodate sudden queues. Phase times are typically set based on 'average' conditions, but phase times may need to be set higher on affected movements to help clear post pre-empt queues.
- Increase storage lengths on affected movements. If it is expected a signal will be frequently pre-empted and that a pre-emption will result in significant vehicle queues, it may be worthwhile to increase vehicle storage on affected movements to improve traffic flow in adjacent lanes. This is most applicable to railroad pre-emption

# ***Chapter 10***

## ***Signal Interconnect and Coordination Methods***

Interconnect links individual traffic signals so that they can be operated in coordination. Interconnect provides communication between individual signals, allowing designers to coordinate the operation of adjacent signals and providing various functions such as keeping clocks synchronized and reporting malfunctions. Signal coordination can be achieved at varying functional levels with different types of interconnect, including:

- Time-based coordination (no interconnect)
- Hardwire
- Twisted-pair
- Fiber-optic
- Spread Spectrum Radio

Each type of interconnect has pros and cons and is suitable for specific applications. Detailed discussion of each type follows. If fiber optic cable is used to interconnect signalized intersections the designer should coordinate with the Region/Area Traffic Engineer.

### **10.1 Time-Based Coordination (no interconnect)**

The simplest form of coordination can be achieved through the use of time based coordination, which does not require any interconnect at all. Time-based coordination (TBC) uses very accurate clocks installed in each controller to keep signals synchronized. In some systems the clocks are tied to the 60Hz frequency of the AC power supply, so that even if there are fluctuations in the 60Hz signal (as frequently happens), the clocks will theoretically drift in unison and maintain synchronization.

In practice, TBC is limited in function and requires frequent maintenance. It provides no communication between controllers so its only function is to keep the controller clocks in synch. Over time the clocks can degrade or malfunction and begin to drift, and even a drift as small as one second per week can cause the signals to be badly out of coordination within a few months.

Because TBC provides no communication between controllers, each controller clock must be periodically reset in the field by hand. This may be acceptable for small systems of two or three signals, but for large systems it can become very time consuming. For this reason ALDOT typically

does not specify TBC as the primary form for coordination on new systems. TBC is, however, a very useful backup in interconnected systems that can temporarily keep signals in synch when communications between controllers fail. ALDOT therefore requires that all controllers in coordinated systems be equipped with TBC for backup purposes. The advantages and disadvantages of TBC can be summarized as follows:

- ✓ It is a low cost method of coordination
- ✓ It requires no interconnect
- ✓ It is an effective backup to other forms of interconnect
- × It does not provide communication between controllers
- × Clocks can drift over time, creating long-term maintenance problems

## 10.2 Hardwire Interconnect

Hardwire is the simplest form of signal interconnect and has been in use for decades. It employs a No. 14 AWG, 9/C cable run between each controller cabinet to keep the controllers in synch. Although there is communication wire connecting each signal, the actual “communication” between signals is limited. In this type of system, one controller is designated the local system supervisor and energizes either none or combinations of conductors within the interconnect cable with a 120V current depending on which time-of-day (TOD) plan is active. The combination of the conductors energized determines which time-of-day plan the other controllers will run, ensuring that they are all running the same plan together. A separate conductor also carries a periodic synchronizing pulse to keep all the controllers synchronized.

The simplicity of this method allows different types and makes of controllers to be interconnected into one system. Hardwire can be used to interconnect modern solid state controllers with old electro-mechanical controllers, and multiple makes and models of controllers can all be tied together. It does not, however, permit communications between controllers beyond synchronization and time of day plans.

Designers may encounter older systems of this type. If a new signal is to be added to an existing system then No.14 AWG, 9/C cable may be used as interconnect. The designer should also be aware that if a hardwire system is used, one local controller must be designated the system supervisor (no master is required) and a hardwire interconnect panel must be installed in that cabinet. The interconnect panel is responsible for energizing the various conductors in the interconnect cable. A typical hardwire panel is shown in Figure 10.1 and it can be seen that it requires significant space within the cabinet. The designer should confirm that there will be adequate cabinet space to accommodate the panel, particularly if a pole-mounted cabinet is used. The remaining controllers in the system use relays to process the interconnect signals. Relays typically do not require significant space within the cabinet.

Because it requires a heavy gauge cable and additional hardware in the cabinets, ALDOT typically does not specify hardwire interconnect for new signal installations. If major modifications are being made to an existing hardwire interconnect system then it may be advisable to replace the hardwire interconnect with a more advanced type.



**Figure 10.1 – Typical hardwire interconnect panel**

In summary, hardwire interconnect has the following advantages and disadvantages:

- ✓ Simple interconnect method allows all types of controllers to be tied together in one system
- ✓ Does not require a master controller
- × Requires interconnect panel for local system supervisor cabinet
- × 120V power requires large conductors (No. 14 AWG) be used to minimize voltage loss

### **10.3 Twisted Pair Interconnect**

Another form of interconnect is twisted-pair copper wire. It is run between signals, just as hardwire is, but uses a lighter No.19 AWG,6 pair cable for more sophisticated communications (the pairs of wire are twisted to minimize external interference). Whereas hardwire interconnect simply energizes individual conductors to keep signals synchronized, twisted-pair uses interconnect communications boards installed in each controller to provide data transmission between controllers.

In its simplest form, twisted pair interconnect connects multiple signal controllers and keeps them synchronized in a manner similar to hardwire. As with hardwire, one local controller is designated the system supervisor and transmits data to the other controllers to keep them in step. The communications involved are not complex, so different makes/models of controllers can be interconnected, although twisted pair does not allow communication/coordination with older electro-mechanical controllers.

Twisted pair interconnect does not require an interconnect panel or relays in the cabinets, so its installation is usually simpler than for hardwire. Use of a lighter interconnect cable also reduces installation costs. Like hardwire interconnect, there is still only limited communication between controllers. The supervisor can transmit data to the other locals but there is no flow of data from the locals back to the supervisor for error checking or system monitoring. The advantages and disadvantages can be summarized as follows:

- ✓ Different makes/models of NEMA controllers can be tied together
- ✓ Small gauge interconnect cable (No.19 AWG/6 pair) reduces installation costs
- ✓ Does not require a master controller
- ✗ Each controller requires an internal interconnect board
- ✗ Does not provide error checking or system monitoring
- ✗ Interconnect is vulnerable to lightning

#### 10.4 Advanced Interconnect Systems

Conventional interconnect allows only one way communication from the system supervisor to the other local controllers. A closed loop interconnect system utilizes communication between controllers but includes two additional elements: 1) sophisticated closed-loop communication boards in each controller, and 2) a master controller to monitor the entire system. A 'closed loop' system derives its name from the fact that it allows communication from the master to the local controllers, and from the locals back to the master, thus 'closing the communication loop'. The actual communication can be via twisted-pair copper wire, fiber optic cable, or wireless interconnect.

The purpose of a master controller is to monitor system operation and coordinate the operation of local controllers. The master selects the appropriate coordination plan, either from a TOD plan or traffic responsive settings, and transmits that information to all locals. The master then verifies that all locals are running the correct plan and checks for any local malfunctions. In a closed-loop system, each signal still requires a local controller and the master is simply housed in one of the local cabinets. The combination of a master and communications boards in each local allows sophisticated two-way transmission of data and system monitoring. Some of the functions allowed by closed-loop operation include:

- Resetting of local clocks
- Overriding of local TOD plans
- Detection of system malfunctions
- Error logging and reporting
- Data input to any local via the master
- Monitoring the entire system via modem and central computer

The trade-off for this sophistication is that all controllers must be of the same make and have compatible communication boards. Mixing controllers of different makes typically is not permitted, so if an existing system is being upgraded to a closed loop system then all of the controllers must be upgraded. The general advantages and disadvantages of a closed loop system can be summarized as follows:

- ✓ Allows extensive system control and monitoring
- ✓ System can be remotely monitored via phone line
- ✗ Requires a master controller
- ✗ All controllers must be compatible (i.e., same make)
- ✗ Typically more expensive than conventional interconnected systems

A closed-loop system can utilize the same No.19 AWG/6 pair communication cable described in section 10.3, but with more sophisticated closed loop communication panels. Its main disadvantages are that it can be expensive when long distances are involved and it is susceptible to lightning and other electromagnetic interference. For these reasons, ALDOT typically specifies fiber optic interconnect for new installations.

## 10.5 Fiber Optic Interconnect

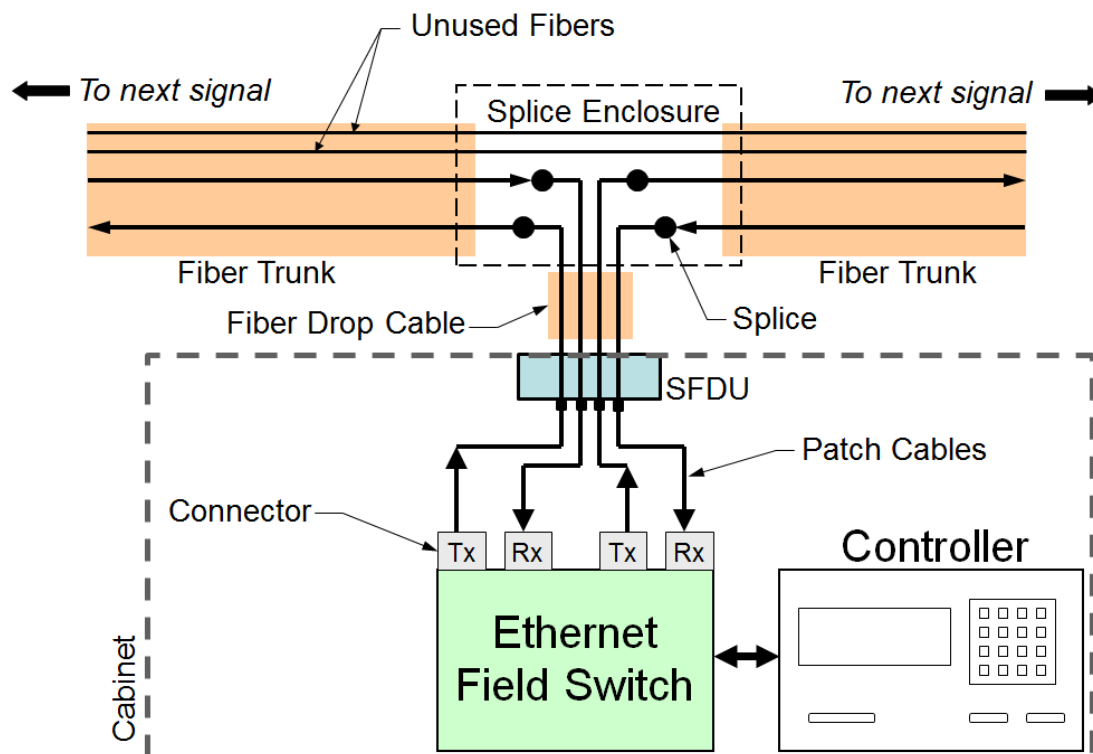
New closed loop systems typically use fiber optic interconnect for communications between controllers. The primary benefits of fiber optic cable are higher data transmission rates and the fact that it is not susceptible to lightning or electromagnetic interference. The higher data transmission rates are not usually a direct benefit to closed-loop systems because the amount of data transmitted between controllers is generally small and therefore does not require high speed fiber optics. However, fiber optic cable is very useful for video cameras and other high bandwidth ITS functions that often accompany new signal systems. The designer should note that the incremental cost of installing extra fibers (e.g., 24 or 36 fibers vs. 12 fibers) is minimal so future capacity needs should be discussed with the Region/Area Traffic Engineer prior to specifying a fiber count.

### 10.5.1 Fiber Optic Operation – Daisy Chain

The majority of fiber optic interconnect systems installed by the State utilize a daisy chain method of communication. In this type of system, the fiber optic interconnect utilizes a pair of fibers within the trunk cable to transmit data. One fiber carries data transmitted in one direction while the other carries data transmitted in the opposite direction (the fibers are sometimes referred to as ‘inbound’ and ‘outbound’). The individual traffic signals within the system are ‘daisy chained’ together using these two fibers and a series of drop cables along with fiber modems (Ethernet field switches or fiber transceivers). At each signal, the fiber pair is cut and a fiber optic drop cable is spliced in as shown in Figure 10.2.

The drop cable carries all data down to a secondary fiber distribution unit (SFDU) and then to a fiber modem located in the controller cabinet. Transmissions intended for that signal are read and relayed to the controller. Data intended for other signals is simply re-transmitted down the line to the next modem. In this way all data are relayed from signal to signal, eventually reaching the intended controller. This means that a problem in one modem can disrupt data transmission to all other signals farther down the line.

Although only two fibers are used in the fiber trunk, a fiber optic drop cable requires four fibers to carry transmissions from the trunk to the switch and back up to the trunk. A minimum of 4 splices are therefore required, along with four fiber connectors at the SFDU as shown in Figure 10.2.



**Figure 10.2 – Fiber optic ‘daisy chain’ configuration**

### 10.5.2 Fiber Optic Operation – Dual Rotating Self-Healing Ring

Another type of fiber optic interconnect system used in Alabama is the dual rotating self-healing ring. It is sometimes used in larger systems because it provides improved resiliency over the standard daisy chain configuration. In a dual rotating ring, the ends of the fiber optic trunk are joined to form a continuous ring. This allows data to be sent from the master to any controller on the ring in two different directions. If there is a faulty modem or if the fiber trunk is severed at any one location, data can be re-routed in the opposite direction so that communications will not be disrupted to the other local controllers.

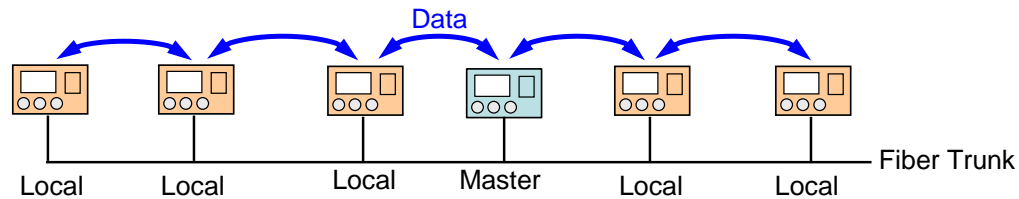
A special form of the dual rotating ring is known as a “collapsed ring”. In this configuration, a dual rotating ring is formed within a single trunk segment by splicing the ends of the two primary fibers to two additional fibers within the same cable to form a continuous ring. This offers improved resiliency over a standard daisy chain configuration, especially with respect to modem failures. It will also provide resiliency in instances of breaks in individual fibers. Unlike the full dual rotating ring, however, it is not likely to provide resiliency in cases where the entire trunk cable is severed. Examples of various fiber optic interconnect system configurations are summarized in Figure 10.3

### 10.5.3 Aerial vs. Underground Fiber Interconnect

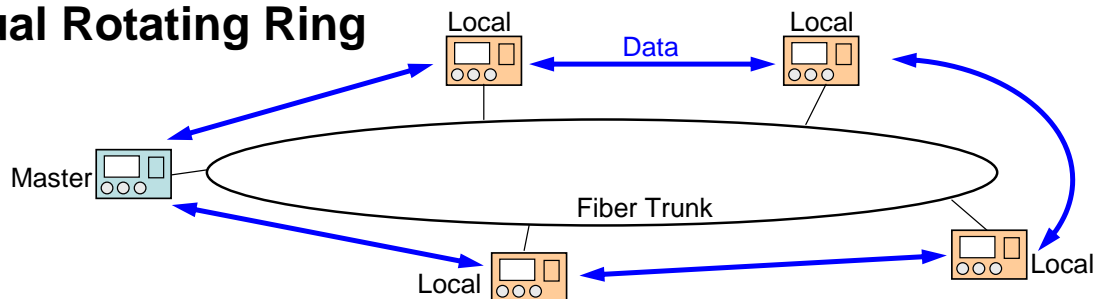
Fiber optic interconnect may either be run above ground on utility poles and messenger wire or run underground in conduit. There are advantages and disadvantages to both methods relating to cost and ease of installation. General design considerations for each are described below.



## Daisy Chain



## Dual Rotating Ring



## Collapsed Dual Rotating Ring

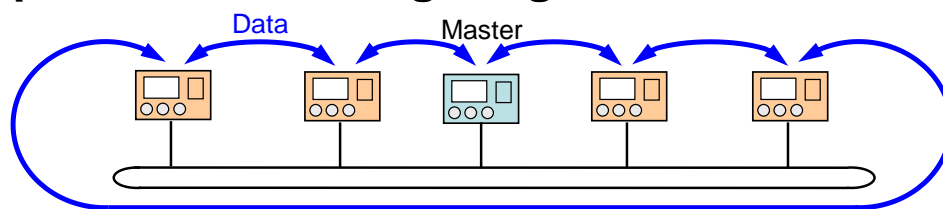


Figure 10.3 – Typical fiber optic interconnect configurations

Aerial fiber optic interconnect considerations:

- Installation costs are cheaper than for underground interconnect. Typical costs range from \$8-\$12 per foot installed if utility poles are available
- Fiber is exposed to elements, possibly reducing lifespan
- ALDOT must obtain permission to co-locate interconnect on utility poles. The designer should be aware that this can be a lengthy process
- Designer must verify that there is sufficient space on the utility poles to accept interconnect. Interconnect shall meet NESC requirements as well as minimum clearances. Attachment heights for the cable must be shown on the plans
- Fiber optic trunk lines should not attach to signal poles or span wire for any portion of their run
- If fiber is replacing an existing interconnect cable, consider lashing the fiber optic cable to the existing interconnect to reduce installation costs

Underground fiber optic considerations:

- Installation costs are typically more expensive than for aerial interconnect, on the order of \$15-\$20 per foot installed
- Fiber is not exposed to elements

- Fiber is run in 2 in. HDPE conduit (a second 2 in. HDPE conduit should always be provided as a spare). No other cabling shall be run in a fiber optic interconnect conduit. Because fiber cannot be detected by conventional utility spotting equipment, detectable tape with a tone wire must be installed
- Fiber optic cable and electrical cables in the same trench must be separated by at least 12 in. per NESC code

#### 10.5.4 Minimum Bending Radii and Splices Enclosures

Fiber optic cable cannot be bent the same way that copper interconnect can, imposing limitations on how fiber can be routed to the controller cabinet. Sharp bends in fiber optic cable can lead to signal loss or even damaged fibers. Every fiber optic cable therefore has a minimum bending radius that must not be exceeded. A good rule of thumb is that the minimum bending radius is approximately twenty (20) times the outside diameter of the cable when it is under tension, and ten (10) times the outside diameter when not under tension. For most cables used in interconnect applications this yields a bending radius of approximately 6 in.

This minimum bending radius limits how drop cables in particular can be routed. A standard 12F cable cannot make the sharp bend into a standard weatherhead or the sharp turn through a signal pole foundation. If the drop cable is to be routed through the signal pole then a 6F fiber must be used. A 12F drop cable must be routed through a metallic riser attached to the signal pole as shown in Figure 10.4.

When the fiber trunk is run aerially, an alternative drop cable arrangement is to run the fiber through underground conduit directly to the controller (see Figure 10.5) rather than overhead to a signal pole. This eliminates some of the tight turns through a weatherhead or pole foundation.

When fiber is run underground, a 12F fiber drop is spliced into the trunk in an F2 comm box as shown in Figure 10.6. An underground splice enclosure is used. The fiber drop is then run to the controller cabinet in 2 in. HDPE conduit.

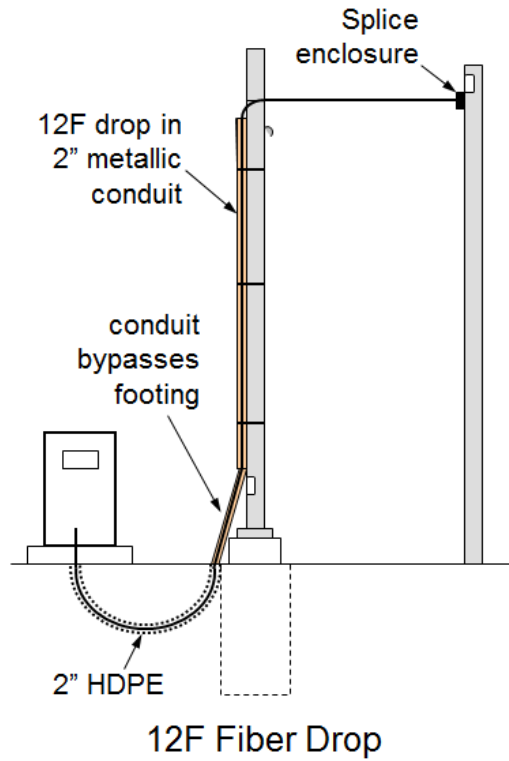


Figure 10.4 – Aerial fiber drops to signal poles

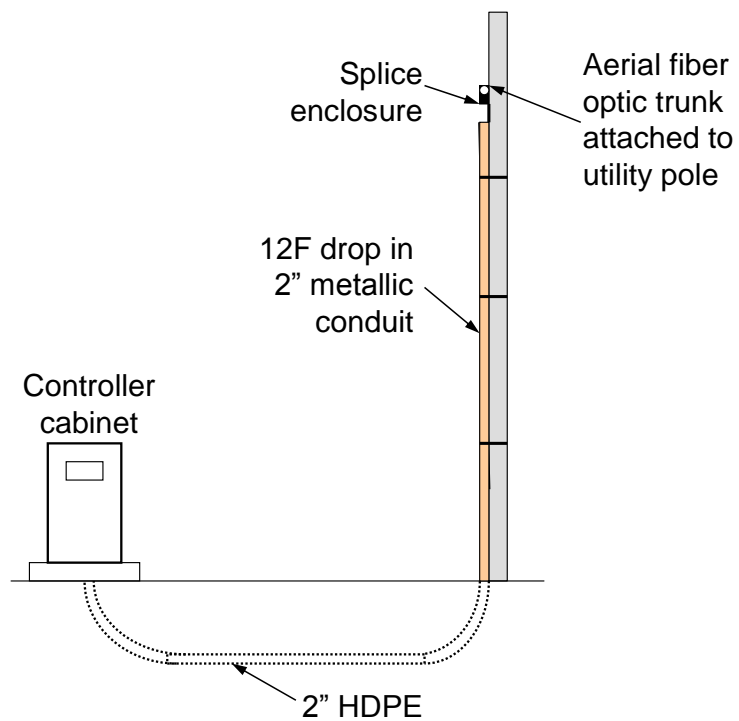
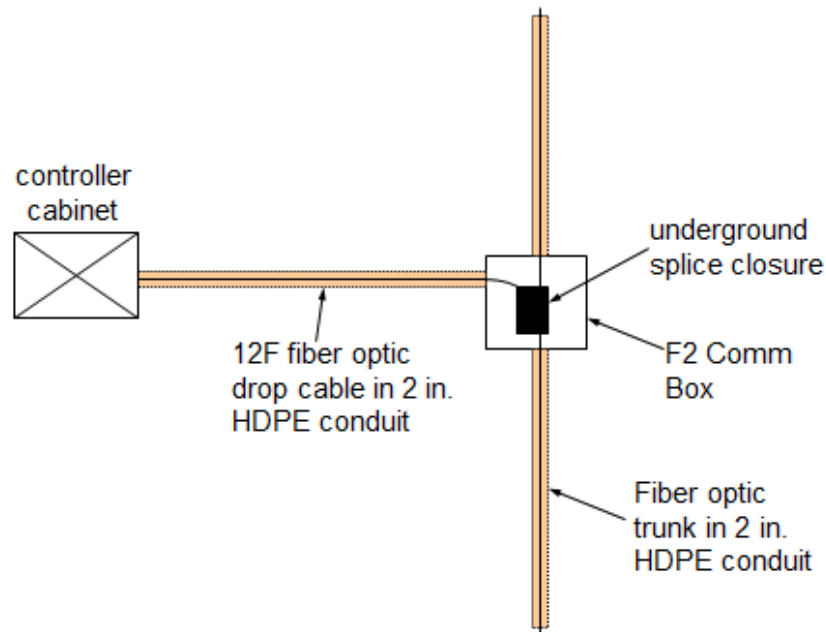


Figure 10.5 – Underground fiber drop from aerial interconnect



**Figure 10.6 – Fiber drop for underground interconnect (top view)**

#### 10.5.5 Maintenance Coil Requirements for Fiber Optic Interconnect

ALDOT requires that maintenance coil be provided in every fiber optic installation. Maintenance coil is additional cable coiled at regular points along the interconnect that can be used in the event of future repairs or minor relocations. ALDOT requires that a minimum 100 ft. of maintenance coil be provided every 1000 ft., but this can vary by Region/Area and by project. The cable is either coiled on a fiber storage rack (aerial) and lashed at regular intervals for aerial installations or coiled in an F2 comm box for underground installations as shown in Figure 10.7. A minimum of 100 ft. of maintenance coil shall be provided even if the total interconnect length is less than 1000 ft.

Additional maintenance coil requirements are as follows:

- 50 ft. coil at F1 comm boxes (min. at all locations)
- 100 ft. coil at F2 comm boxes (min. at all locations)
- Comm boxes with splice closures include 50 ft. maintenance coils on each side of splice
- 50 ft. maintenance coil per drop cable at controller cabinet
- 100 ft. maintenance coil at hub buildings and TMC's

#### 10.5.6 Fiber Optic Conduit and Comm Boxes

As with standard signal cabling, underground fiber optic interconnect requires that comm boxes be located at regular intervals to facilitate cable pulling, maintenance coil storage, and splices. An F2 comm box is required every 1000 ft. for maintenance coil storage, at each signal cabinet for splicing the drop cable, and at any reel end splice points. If a 1000 ft. interval falls near a planned splicing location, then a single F2 comm box can be used to serve both functions.

When fiber is run through directional bores a single F1 comm box is placed at one end of the bore and shall include a 50 ft. maintenance coil. In cases where there may be an extremely long bore (which is unusual and case by case) then two F1 comm boxes may be used. In cases where a bored conduit comes to the surface and makes a turn before continuing, a second F1 comm box would be installed at the turn location.

### 10.5.7 Fiber Optic Splices

Every splice made in a fiber optic cable results in signal loss, so splices should be kept to a minimum. In general, ALDOT permits splices only at drop cables or at reel end locations. Fiber optic interconnect is typically available in reels up to 16,000 ft. For interconnect runs greater than 16,000 ft. multiple fiber cables will have to be spliced together. The designer must include these reel end splice points in the estimated quantities. Whereas for a drop cable only four splices are needed (the spare fibers remain un-spliced for future use), at a reel end splice all fibers in the cable are spliced, not just the fibers being used. The number of splices at a reel end splice point will equal the number of fibers in the cable.

All fiber optic splices must be fusion splices and contained within a splice closure. Contained within each enclosure is a splice tray which holds the spliced fibers. Splice trays come in different sizes and the designer should specify a tray that will accommodate the total number of fibers contained in the cable. For example, if a 12F drop is being used, the splice tray should accommodate at least 12 fibers, even if only 4 splices are being made at the time of installation.

When designing a fiber optic interconnect, the designer shall compute the loss budget. The loss budget ensures that sufficient signal power is available from the transmitter so that the signal can be read at the receiver end. Typically a 5 dB system performance margin is provided for a fiber interconnect system. It is particularly important that the designer perform the loss budget calculations for interconnect that runs for long distances and/or may have numerous splice or connector points.

When computing the loss budget the designer should consider the following parameters:

- transmitter power – minimum signal output from the transceiver
- receiver sensitivity – minimum signal strength that can be read by a transceiver
- connectors – signal loss caused by connectors (typically associated with drop cables)
- splices – signal loss caused by reel end and drop cable splices
- cable attenuation – signal loss in a fiber over distance
- potential future repairs – system design should allow for accidental cuts and future repairs

A sample worksheet for calculating the loss budget and system performance margin is available from ALDOT and is shown in Figure 10.8. Similar worksheets are available from fiber optic cable and hardware manufacturers and may be used with ALDOT approval.

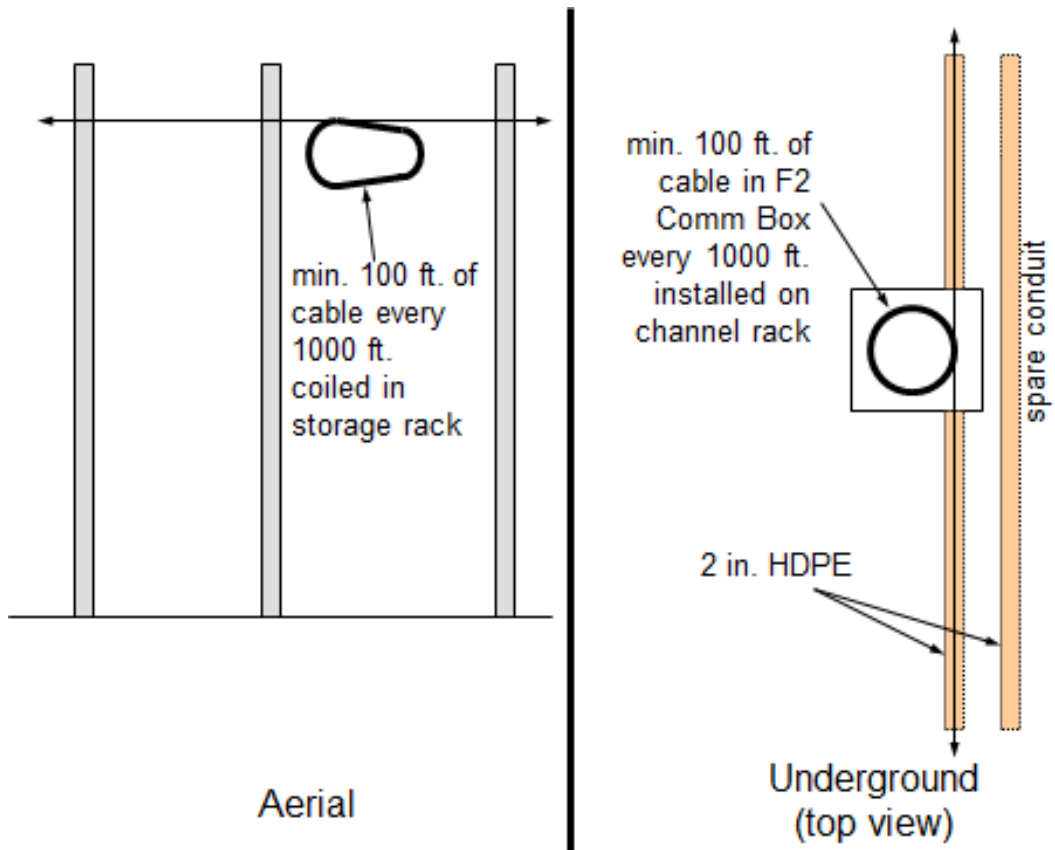


Figure 10.7 – Maintenance coil requirements

Fiber System Budget				
<b>1. Fiber Loss</b>				
Total cable length		ft		
Signal loss per ft <sup>1</sup>		dB/ft	<sup>1</sup> Obtain from cable manufacturer	
<b>Total fiber loss =</b>	<b>0.00</b>	dB		
<b>2. Splice Losses</b>				
Max allowable loss/splice <sup>2</sup>		dB	<sup>2</sup> Max value of 0.3 dB/splice recommended	
Number of splices per fiber <sup>3</sup>			<sup>3</sup> This is the number of splices per fiber, not total for a cable	
<b>Total splice loss =</b>	<b>0.00</b>	dB		
<b>3. Connector Losses</b>				
Max allowable loss per connector pair <sup>4</sup>		dB	<sup>4</sup> Max value of 0.75dB per pair recommended	
Number of connector pairs <sup>5</sup>			<sup>5</sup> Does not include connectors that plug into end equipment	
<b>Total connector loss =</b>	<b>0.00</b>	dB		
<b>4. Losses for Other Components</b>				
Optical bypass switch loss <sup>6</sup>		dB	<sup>6</sup> Loss values should be obtained from component manufacturer	
Optical splitter loss <sup>6</sup>		dB		
Other component loss <sup>6</sup>		dB		
<b>Total loss for other components =</b>	<b>0.00</b>	dB		
<b>5. System Gain</b>				
Average transmitter output <sup>7</sup>		dBm	<sup>7</sup> Obtain from manufacturer	
Minimum receiver sensitivity <sup>7</sup>		dBm		
<b>System gain =</b>	<b>0.00</b>	dB		
<b>6. Power Penalty/Repair Margin</b>				
Power penalty <sup>8</sup>		dB	<sup>8</sup> Obtain from manufacturer. If not available, assume 2.0 dB	
Repair margin <sup>9</sup>		dB	<sup>9</sup> Value of 0.6 dB typical	
<b>Total Power Penalty =</b>	<b>0.00</b>	dB		
<b>7. System Performance Margin</b>				
Link Loss Budget (5 - 6)	0.00	dB		
System Attenuation (1 + 2 + 3 + 4)	0.00	dB		
<b>System Performance Margin*</b>	<b>0.00</b>	dB	<b>* Minimum of 5 dB recommended by ALDOT.</b>	

Figure 10.8 – Fiber budget worksheet

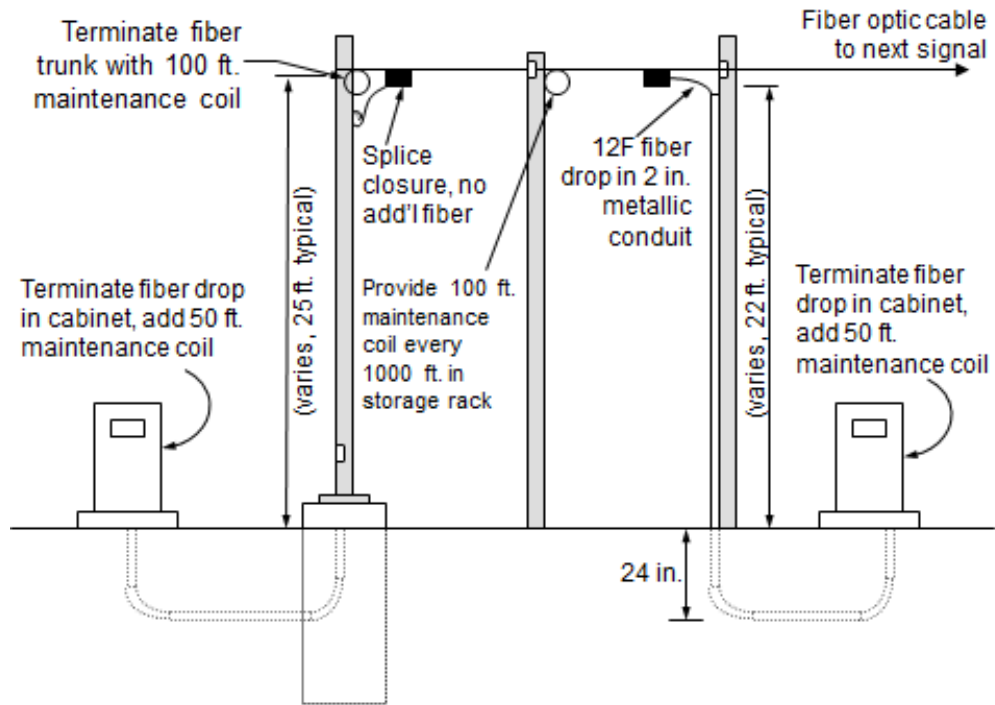


Figure 10.9– Computing fiber optic cable quantities

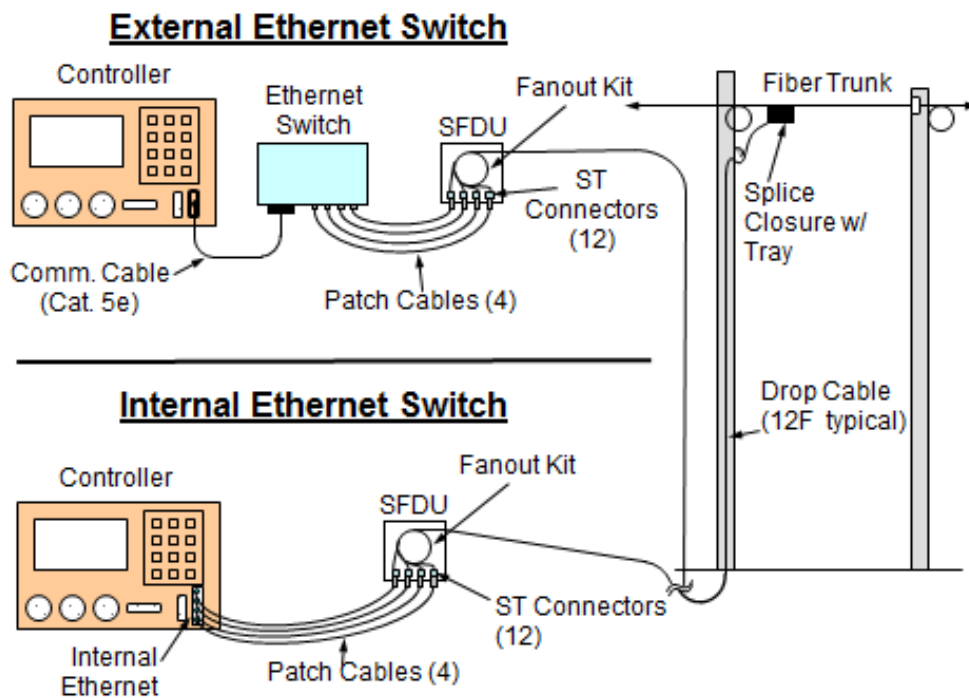


Figure 10.10 – Typical fiber optic interconnect configuration



### 10.5.8 Computing Fiber Optic Quantities

Figure 10.9 provides a general guide for computing quantities of fiber optic cable. Figure 10.10 illustrates the typical hardware components of a fiber optic interconnect installation. For a standard plan set with fiber optic interconnect, the designer must provide the following estimated quantities:

- Fiber trunk (# fibers, aerial/underground), lin. ft.
- Fiber drop cable (# fibers), lin. ft.
- Number of splices (drop and reel end)
- Number of ST connectors
- Number of internal fiber transceivers
- Number of external ethernet switches
- 2 in. HDPE conduit, lin. ft., and 2 in. HDPE for spare
- Splice Closures
- Splice trays (size and number)
- Patch cables and RS-232 cables
- Detectable tape and tone wire
- Marker post (spaced at maximum intervals of 500 ft. or at 45 degree or greater change in fiber optic cable)

Typical fiber optic interconnect system quantities and their descriptions are shown in Table 10.1.

**Table 10.1 – Typical fiber optic quantities**

<b>Fiber:</b>	
Min. fiber count (trunk – major arterial)	60F SM
Min. fiber count (trunk – minor arterial)	36F SM
Min. fiber count (trunk – collector)	24F SM
Drop cable (typical)	12F SM
Aerial interconnect type	lin. ft.
Underground interconnect type	lin. tt.
<b>Splices and Connectors:</b>	
Splices per reel end	# of fibers in cable
Connectors per drop	12
Splice closure	1 per drop/1 per reel
Splice tray	varies with # of fibers
Standard connector type	ST
Number of splices per drop	
- intermediate signal	4
-signal at end of system (daisy chain)	2
-signal at end of system (rotating ring)	4
<b>Conduit and Junction Boxes:</b>	
Conduit for fiber trunk	2-2 in. HDPE (one for fiber/one spare)
Conduit for drop cable	2 in. HDPE
Box type for reel end splices	F2 comm box
Box type for drop splices	F2 comm box
Box type for slack loops	F1 or F2 comm box.
<b>Miscellaneous:</b>	
Maintenance coil requirement	100 ft. min. every 1000'
Marker post	1 every 500'
Detectable tape and tone wire	lin. ft.
Fiber optic modem	1 per drop

When determining connector quantities, the designer may encounter legacy equipment that utilizes FC or other types of connectors. More recent projects utilize ST connectors. Therefore it is important that the designer field verify connectors when existing SFDU's and equipment are being retained.

## 10.6 Spread Spectrum Radio Interconnect

Radio interconnect uses radio transceivers located in each cabinet to transmit data between the master and local controllers. A typical radio interconnect installation includes a transceiver located in the cabinet and an antenna mounted on one of the signal poles, as shown in Figure 10.11. The radio transmits and receives using spread spectrum technology, meaning it transmits small pieces of data over multiple frequencies. This makes the radio transmissions less susceptible to interference and more secure from unauthorized access.



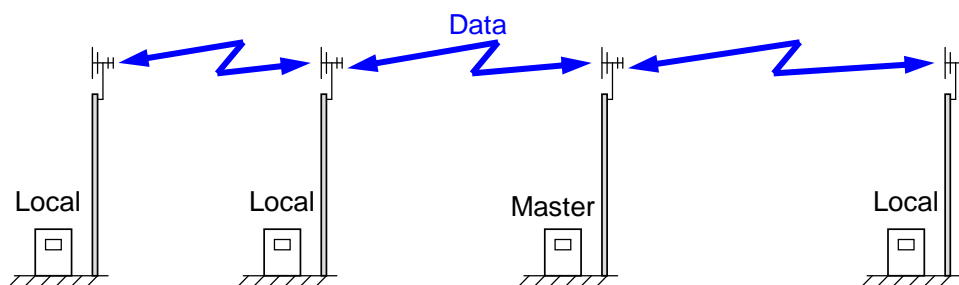
**Figure 10.11 – Radio transceiver (left) and antenna (right)**

A radio interconnect system can operate either in a daisy chain configuration or in a 'star' configuration. In a daisy chain configuration, data are relayed directly from one signal to the next one in line. As with fiber optic systems, a failure of a transceiver at one signal can disrupt communications to the remaining signals down the line.

In a star configuration, the master transmits directly to each controller in the system. This type of configuration eliminates the possibility of a communication failure at one intersection affecting communications to other intersections. It is effective only if all intersections in the system are located within communication distance of the master. It may also require a more complex antenna installation at the master. The daisy chain and star configurations are illustrated in Figure 10.12.

Hybrid versions of the star and daisy chain can also be specified, using a star configuration for portions of the network and a daisy chain configuration for outlying signals. The maximum effective transmission distance between signals in either the daisy chain or star configuration is on the order of 2 miles, depending on environmental conditions.

## Daisy Chain Configuration



## Star Configuration

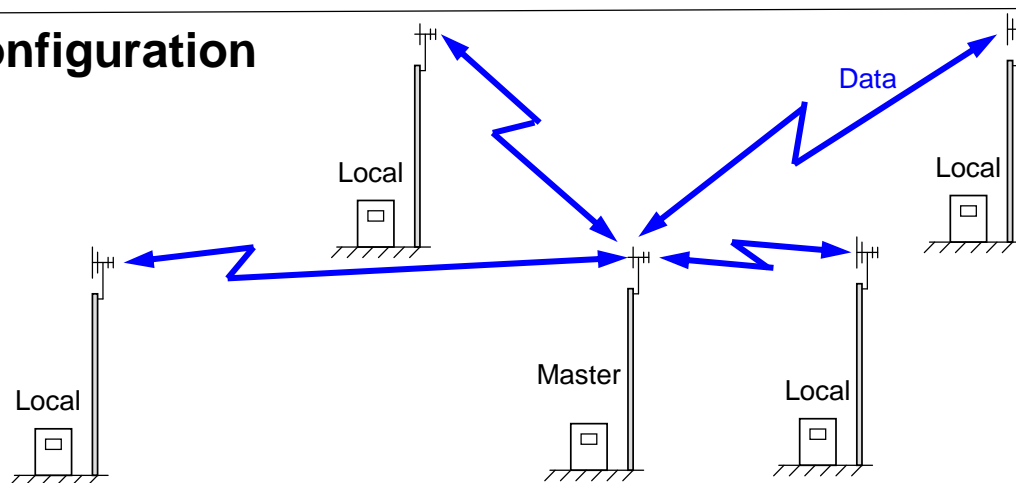


Figure 10.12 – Daisy chain and star configurations for radio interconnect

### 10.6.1 Advantages and Disadvantages of Radio

Radio has both advantages and disadvantages compared to copper wire or fiber optic interconnect. Its main advantage is cost, especially when used in very large systems. The cost to install a transceiver and antenna at one intersection averages about \$3,000 - \$6,000. The cost to install fiber optic interconnect, by comparison, can run as much as \$20 per foot and copper wire can run even higher. When distances between intersections are long, radio interconnect can be highly cost effective.

There are, however, disadvantages as well. The radio signals are highly directional and require a clear line of sight between antennas. The radio signals cannot transmit over hills or through buildings and can even be disrupted by thick stands of trees. To accommodate topography, 'repeater' stations may be used between intersections but this adds significantly to installation costs. Spread spectrum is also more susceptible to interference and data loss than are fiber or copper wire, so transmission rates are usually much lower.

Nonetheless, radio interconnect can be a cost effective solution in cases where utility poles do not exist to run aerial interconnect and underground interconnect would be prohibitively expensive due to utility conflicts or limited R.O.W. Radio can also be combined with other forms of interconnect on the same system, for example providing communications to a single outlying intersection on a system that is otherwise interconnected by fiber.

### 10.6.2 Hardware Requirements

The hardware requirements for radio interconnect are fairly simple and require only the following at each intersection:

- Radio transceiver
- Power supply
- Radio antenna and coax cable
- Noise filter (located between antenna and radio transceiver)

The radio transceiver, noise filter, and power supply are installed in the controller cabinet. The radio antenna is typically mounted to the top of one of the signal poles. When practical, it should be mounted on the pole that gives it the clearest line of sight to the adjacent signals. In most cases, a 28 ft. pole height is sufficient for antenna mounting.

For signal quantities, ALDOT uses a single lump sum pay item for radio interconnect that includes all hardware.

## 10.7 Summary of Interconnect Types

Table 10.2 presents a summary of the characteristics of each interconnect type.

**Table 10.2 – Summary of interconnect types**

Interconnect Type	Coordination	System Monitoring	Remote Data Input	Susceptible to Interference?	Maintenance
Hardwire (9c/#14 AWG)	Yes	No	No	Minimal	Low – very simple system
Twisted Pair (6-pair/#19 AWG)	Yes	No	No	Yes	Cable and panels highly susceptible to lightning
Closed Loop – Twisted Pair	Full	Yes	Yes	Yes	Cable and panels highly susceptible to lightning
Closed Loop – Fiber Optic	Full	Yes	Yes	No	Cables low maintenance (unless cable cut), modems moderate
Closed Loop – Radio	Full	Yes	Yes	Yes – radio interference	Moderate

# ***Chapter 11***

## ***Signing and Striping***

Traffic signals often require supplemental signing and striping to provide positive guidance to motorists. This section presents only the most commonly required signs and striping associated with traffic signals. Guidance for additional signing and striping may be found in Chapter 2 of the [Manual on Uniform Traffic Control Devices](#) (current ALDOT adopted edition).

Signing for traffic signals is generally of three types:

- Regulatory signing, often mounted on the span
- Advance warning signing
- Advance warning flashers

The most commonly used signing for traffic signals are described in the following sections.

### **11.1 Regulatory Signs**

#### ***R10-5, “Left On Green Arrow Only”***

This sign is optional for use with protected left turn heads. When used, one R10-5 sign shall be used for each left-turn signal head. Typical dimensions are 30 in. x 36 in. as shown in Figure 11.1 and are appropriate for all applications. The R10-5 sign is always located to the left of the associated signal head as shown in Figure 11.2.

#### ***R10-12, “Left Turn Yield on Green”***

The R10-12 sign may be used when a protected/permmissive signal head is provided in order to clarify control. The R10-12 sign is not required, but it can be specified under the following conditions:

- Its use is directed by ALDOT
- There have been a significant number of crashes related to permmissive left turns
- The intersection geometry or phasing is potentially confusing to drivers
- It is deemed appropriate by the design engineer

Standard dimensions for these signs are 30 in. x 36 in. as shown in Figure 11.1, which are appropriate for all applications. When used, one sign shall be provided for each protected/permmissive left turn head. The R10-12 sign is located to the left of the left turn head as shown in Figure 11.2.

**“Left Turn Yield on Flashing Yellow Arrow” Sign**

ALDOT has developed a standard sign for use with flashing yellow left turn operations. The sign, shown in Figure 11.1, is required for all flashing yellow arrow applications. It should be located adjacent to the applicable signal head similar to R10-5 and R10-12 signs as shown in Figure 11.2. Standard dimensions are 30 in. x 36 in. as shown in Figure 11.1.

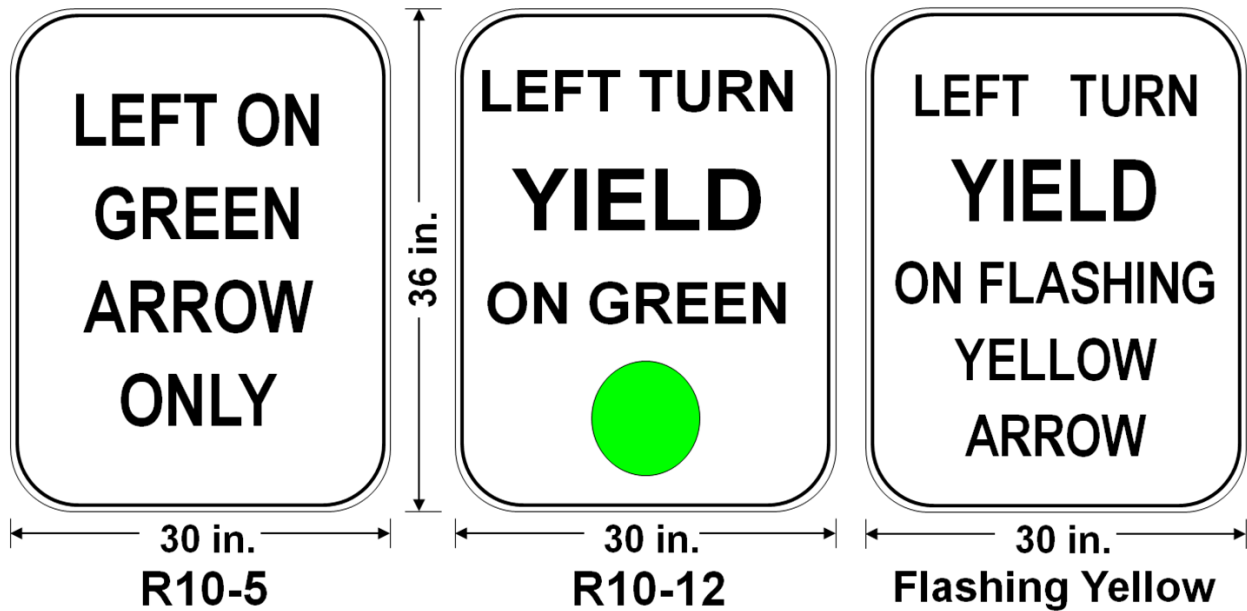


Figure 11.1 – R10-5, R10-12, and flashing yellow arrow signs

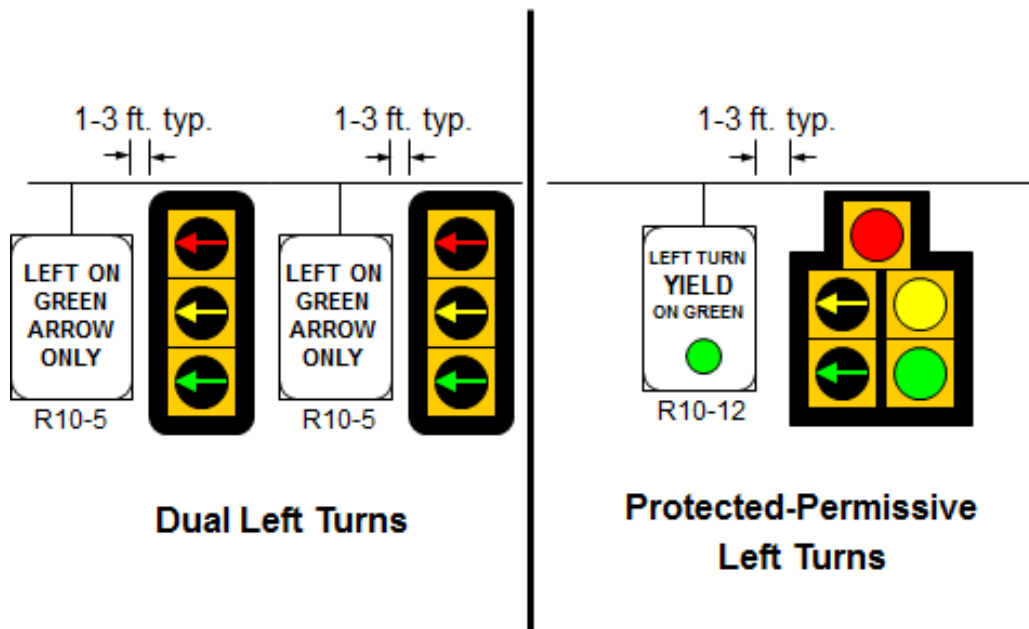


Figure 11.2 – Location of R10-5 and R10-12 signs

**R3-2, “No Left Turn”**

The R3-2 sign shall be erected on approaches where left turns are prohibited. Standard dimensions are 24 in. x 24 in. for single lane roads or 36 in. x 36 in. for multi-lane roads, as shown in Figure 11.3. The R3-2 is typically mounted on the far side span wire or mast-arm, to the left of the signal heads, opposite the left-most approach lane.

**R3-4, “No U-Turn”**

The R3-4 sign shall be provided on approaches where U-Turns are prohibited. An R3-4 sign shall be provided in cases where a right-turn overlap is provided on an adjacent side street. Standard dimensions are 24 in. x 24 in. for single lane roads or 36 in. x 36 in. for multi-lane roads, as shown in Figure 11.3. It is typically located on the far span opposite the left turn lane.

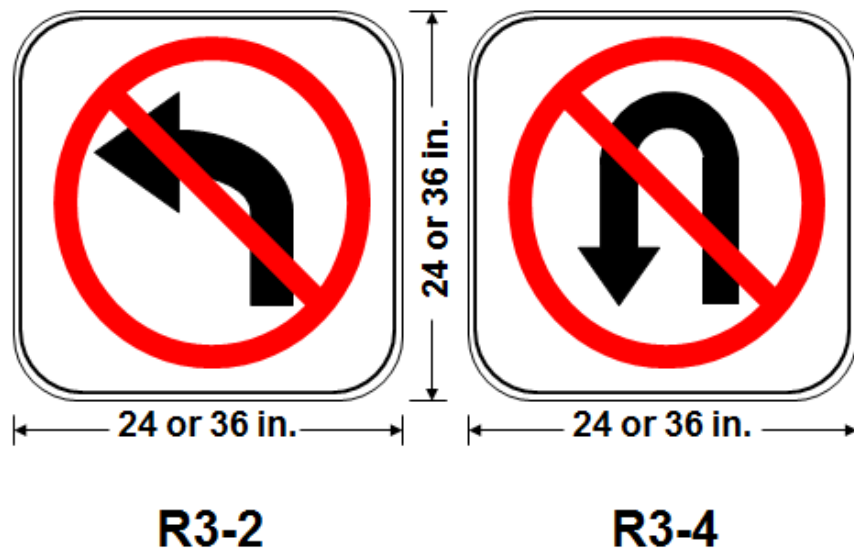


Figure 11.3 – R3-2 and R3-4 signs

**R10-3, “Push Button for Walk”**

The R10-3 sign shall be provided whenever a pedestrian pushbutton detector is installed. It shall be mounted on the signal pole or pedestal above the pedestrian pushbutton. Standard dimensions are 9 in. x 12 in., as shown in Figure 11.4.

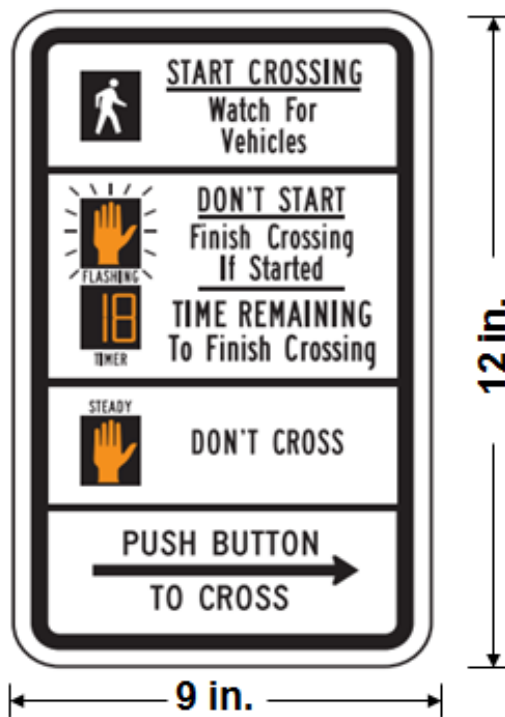
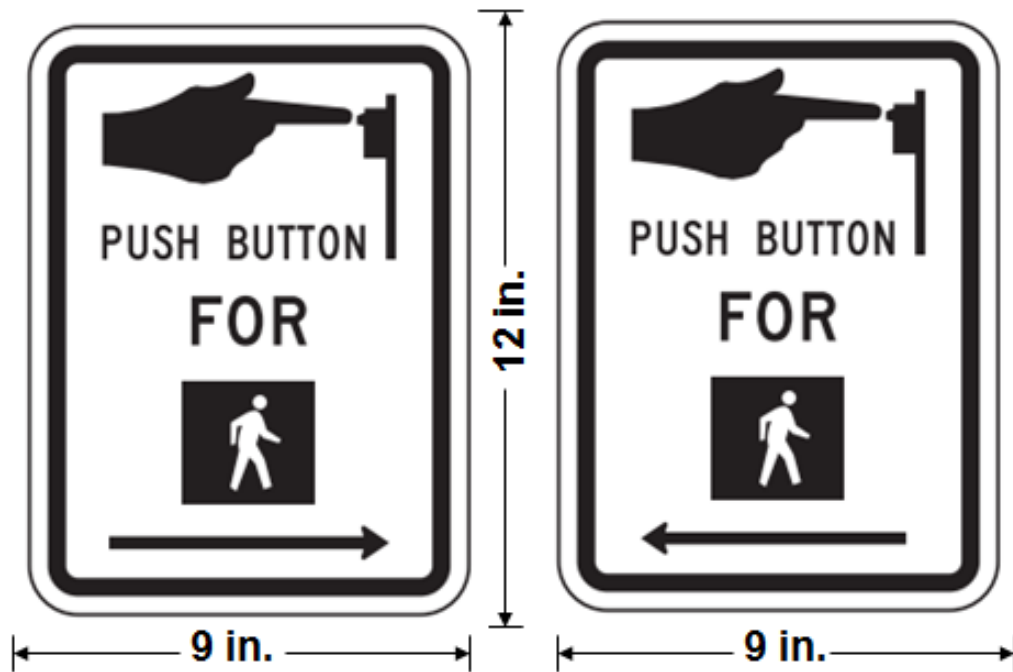


Figure 11.4 – R10-3 & 3e signs



**R10-7, “Do Not Block Intersection”**

The R10-7 sign shall be provided at intersections where vehicle queuing or spillback frequently blocks the intersection. Standard dimensions are 24 in. x 30 in., as shown in Figure 11.5, and typical mounting is on the center of the far signal span, centered over the approach.

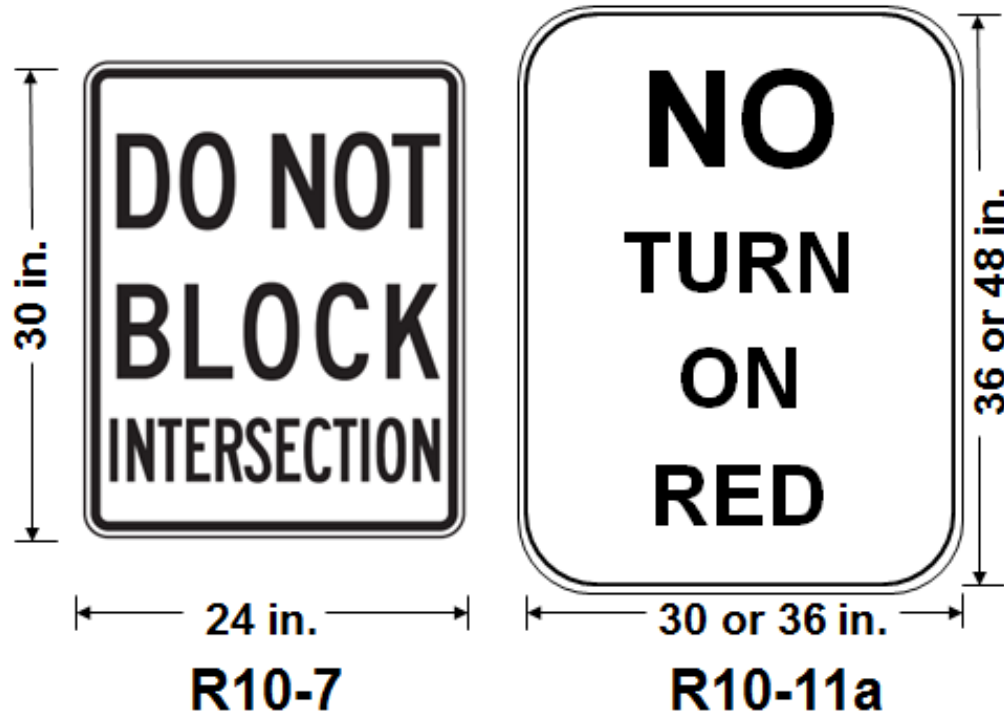


Figure 11.5 – R10-7 and R10-11a signs

**R10-11a, “No Turn on Red”**

The R10-11a sign shall be provided on approaches where right turns on red are prohibited. Standard dimensions are 30 in. x 36 in. on single lane roads and 36 in. x 48 in. on multi-lane roads, as shown in Figure 11.5. Typical mounting is on the far signal span aligned with the right-most lane.

**11.2 Warning Signs**

Warning signs can be placed in advance of a traffic signal to warn motorists of upcoming or unexpected conditions. The most commonly used warning signs are discussed in this section. Additional guidelines for warning signs are presented in the MUTCD (current ALDOT adopted edition).

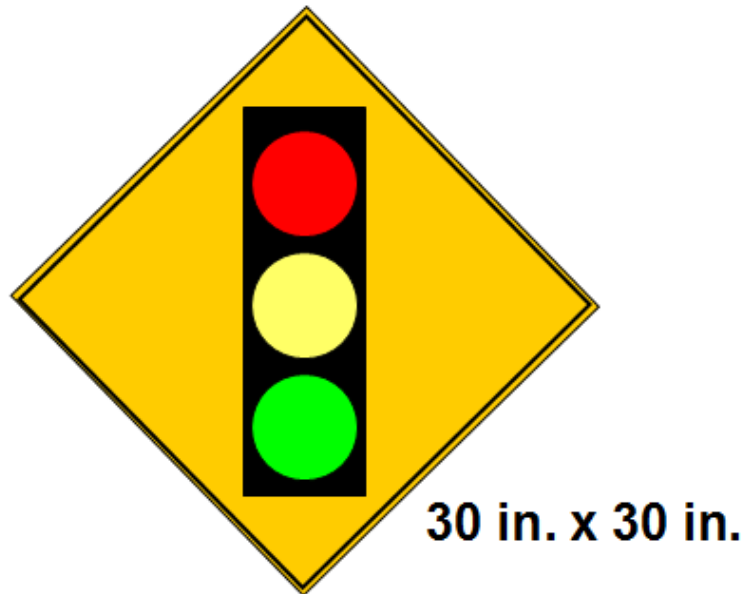
**W3-3, “Signal Ahead”**

The W3-3 sign is placed in advance of the intersection to alert drivers to an upcoming signal. It is typically used when a signal is unexpected or when horizontal or vertical curves limit sight distance to the signal. A W3-3 sign should be considered when minimum visibility distances to the signal are less than those shown in Table 11.1 and other methods of addressing the sight distance limitation, such as near-side indications, have been explored (see section 5.7.5).

**Table 11.1 Minimum Visibility Distances (Source: ITE Manual of Traffic Signal Design)**

85 <sup>th</sup> percentile approach speed	Visibility Distance (ft) Min.	Downgrade Adjustment (ft)		Upgrade Adjustment (ft)	
		5%	10%	5%	10%
20	175	+5	+15	-5	-10
25	215	+10	+20	-10	-15
30	270	+15	+30	-10	-20
35	325	+20	+45	-15	-25
40	390	+30	+65	-20	-35
45	460	+40	+90	-30	-50
50	540	+50	+120	-35	-65
55	625	+60	+150	-45	-80
60	715	+70	+190	-55	-95

Standard dimensions for the W3-3 sign are 30 in. x 30 in., as shown in Figure 11.6. The signs are mounted in advance of the intersection based on approach speed. Recommended location distances, measured from the stop line, are shown in Table 11.2. On single lane and undivided roadways, the W3-3 sign shall be mounted on the right side of the roadway. On multilane divided roadways, the signs shall be gate-posted (i.e., one on the right side of the roadway and one in the median).



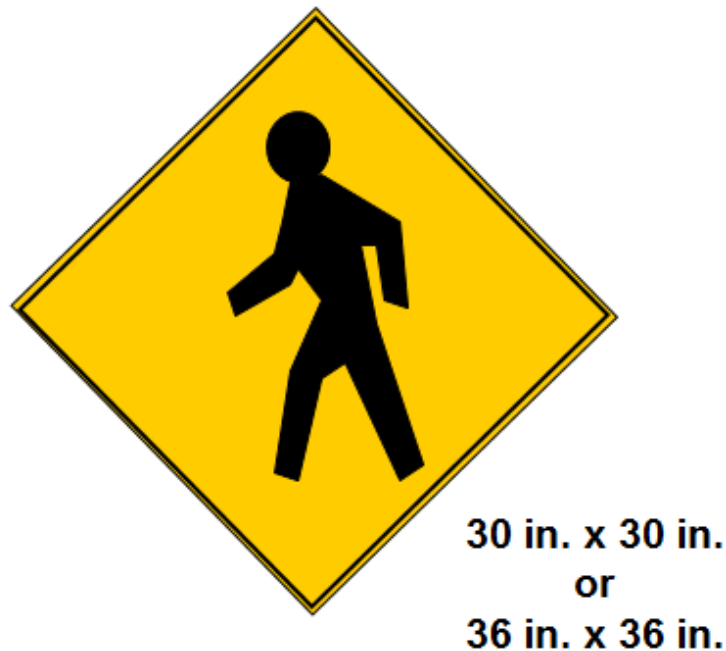
**Figure 11.6 – W3-3 sign**

**Table 11.2 – Placement distances for W3-3 advance warning signs & flashers (Source: [MUTCD Section 2](#))**

Approach Speed (mph)	Distance from Stop Line (ft.)
30	100
35	100
40	125
45	175
50	250
55	325
60	400
65	475
70	550
75	650

**W11-2, “Pedestrian Crossing”**

The W11-2 sign warns of an upcoming pedestrian crossing. The W11-2 sign is recommended for approaches with channelized right turns where a pedestrian movement is also provided. Because motorists do not typically stop for channelized movements there is an increased risk for pedestrian conflicts. Typical dimensions are 30 in. x 30 in. for single lane roads and 36 in. x 36 in. for multi-lane roads as shown in Figure 11.7. W11-2 signs should be located between 100 to 150 feet in advance of the crosswalk. The W11-2 sign is not required for standard signal-controlled pedestrian movements.



**Figure 11.7 – W11-2 sign**

**11.3 Advance Warning Flashers**

Section 11.2 discussed the use of the W3-3 “Signal Ahead” sign when minimum sight distances cannot be met. In some cases it is desirable to provide additional warning in the form of an advance warning flasher. The advance warning flasher is designed to increase driver awareness of an upcoming signal through the use of supplemental flashers. The advance warning flasher comes in two forms: 1) passive

warning flashers, and 2) active warning flashers. Passive warning flashers flash continuously to warn motorists of an obscured or unexpected signal. Active warning flashers flash only when the upcoming traffic signal is red and motorists need to prepare to stop.

Passive warning flashers should be considered under the following conditions:

- Isolated or unexpected signals
- Sight distances do not meet minimum standards shown in Table 11.1

Active warning flashers should be considered under the following conditions:

- Sight distances do not meet minimum standards shown in Table 11.1
- High number of crashes associated with a failure of motorists to recognize and stop for signal
- Truck volumes greater than 15% and a grade of 3% or greater

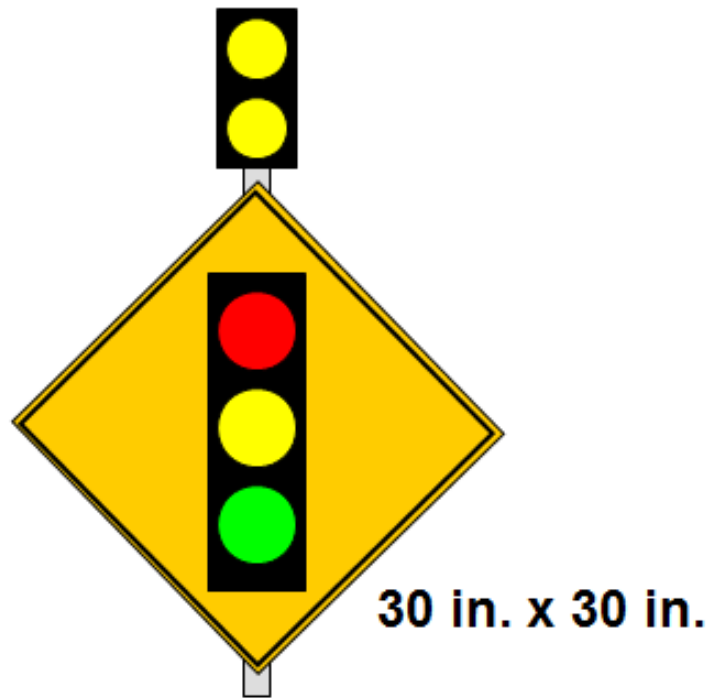
### 11.3.1 Passive Warning Flashers

The passive warning flasher consists of a W3-3 warning sign mounted on a standard warning flasher (See Figure 11.8). Details of a standard advance warning flasher are provided in [ALDOT Standard and Special Drawings for Highway Construction](#), TSD-730-7. Standard dimensions for the W3-3 sign are 30 in. x 30 in. Passive warning flashers are located in advance of the intersection according to location distances shown in Table 11.2.

On single lane and undivided roadways the advance warning flasher shall be located on the right side of the roadway. On multi-lane divided highways they shall be gate-posted, meaning one shall be located on the right side of the roadway and another in the median.

Power for an advance warning flasher can be drawn from an adjacent power source, from the power service pole at the signal, or from a solar panel provided as part of the installation. If power is drawn from an adjacent power source a separate power service pole may be required. Standard conductor size shall be 3/C No.14 AWG. At the low currents required for an LED flasher, voltage losses are minimal up to distances of 1500 feet, so 3/C No.14 AWG should be adequate for all applications, even if power is being drawn from the signal. The conductor shall be run in 1 in. metallic (above ground) or PVC (underground) conduit.

If solar power is provided, see TSD-730-7 in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition) for details on acceptable solar panel mounting methods.



**Figure 11.8 – Passive warning flasher with W3-3 sign**

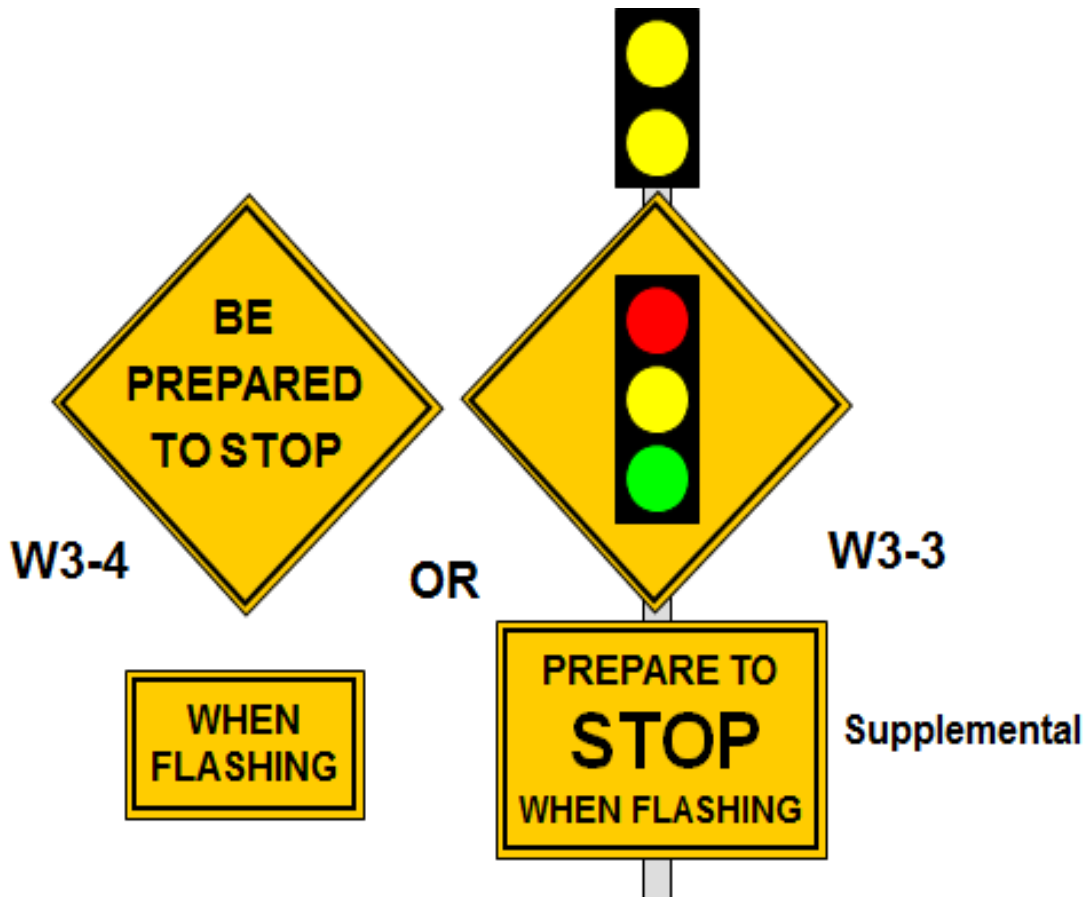
**11.3.2 Active Warning Flashers**

Active warning flashers consist of a warning sign mounted to a standard warning flasher as shown in Figure 11.9. Unlike a passive warning flasher, the lights on an active warning flasher flash only when the upcoming traffic signal is red or about to turn red. This is intended to provide motorists with advance warning of an upcoming stop condition.

Details of a standard advance warning flasher are provided in the [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition). Standard sign dimensions are 30 in. x 30 in. for the W3-3, 36 in. x 36 in. for the W3-4, and 30 in. x 24 in. for the supplemental plate. Suggested distances for locating active warning flashers are shown in Table 11.3.

**Table 11.3 – Location of active warning flasher (Source: [MnDOT Traffic Signal Design Manual](#))**

Approach Speed (mph)	Distance From Stop Line (ft)	Leading Flash (sec)
40	560	8.0
45	560	7.0
50	700	8.0
55	700	7.0
60	850	8.0
65	850	7.5



**Figure 11.9 – Active warning flasher with sign and supplemental plate**

On single lane and undivided roadways the active warning flasher shall be located on the right side of the roadway. On multi-lane divided highways they shall be gate-posted, meaning one shall be located on the right side of the roadway and another in the median.

The warning lights on an active warning flasher are powered through a load switch in the controller cabinet. Standard conductor size from the cabinet to the flasher shall be 3/C No.14 AWG. At the low currents required for an LED flasher, voltage losses are minimal up to distances of 1500 ft., so 3/C No.14 AWG should be adequate for all applications. The conductors shall be run in 1 in. metallic (above ground) or PVC (underground) conduit.

An active warning flasher begins flashing a preset time before the signal itself turns yellow. This is the “leading flash” and warns motorists of an impending clearance interval. For motorists who may not yet be able to see the signal it allows them to begin slowing down. The lights will continue to flash through the duration of the yellow and red phases and will cease flashing when the signal turns green.

To accomplish this, the active warning flasher is wired to the controller thru the approach phase yellow and red outputs, typically phase 2 or 6. The signal heads for the thru phase are wired as an overlap assigned to the thru phase but with a ‘trailing green’. Trailing green is a controller function that allows an overlap to remain green for a specified time after its associated phase turns yellow. In this case, the trailing green time is set to the ‘leading flash’ time specified in Table 11.3.

When the approach phase gaps or times out and clears to yellow, the warning flasher is immediately activated. The signal heads, however, remain green for the programmed trailing green interval before changing to yellow and then red. The flasher continues to flash as long as the output for the thru phase is yellow or red. An example is provided in Figure 11.10.

The designer should note the following design considerations for active warning flashers:

- The signal phasing must be designed so that the opposing thru movements clear to yellow and red at the same time. This means that the signal heads for both thru movements must be wired as overlaps with the same trailing green interval regardless of whether warning flashers are provided in both directions. Failure to do so will create a left turn trap.
- Yellow and all red intervals for the mainline thru movements (typically phases 2 & 6) should be computed and programmed normally.
- Loop detector distances are computed and designed as for a standard signal. Loop setback distances are not affected by an active warning flasher.

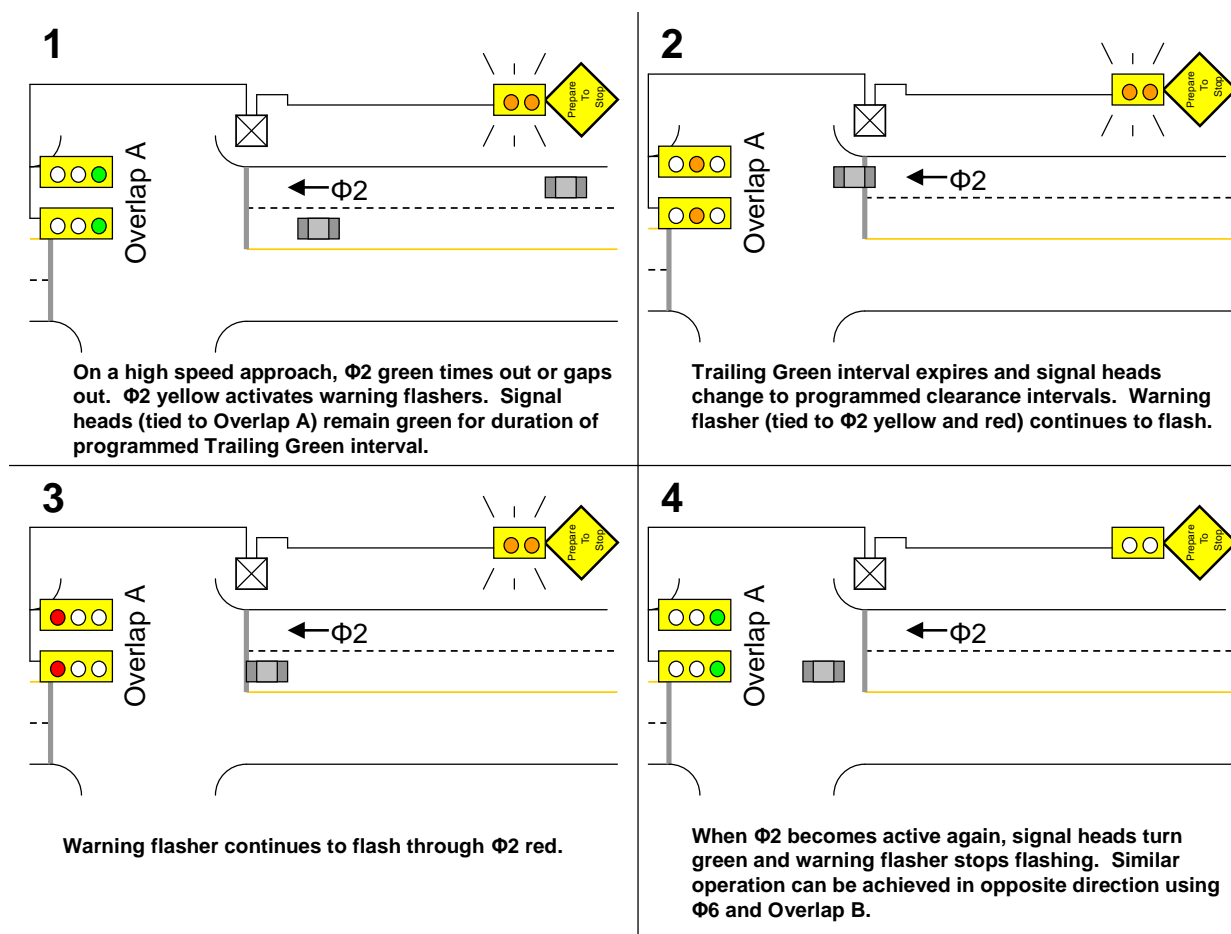


Figure 11.10 – Illustration of an active warning flasher

## 11.4 Striping and Pavement Markings

New traffic signals require additions or modifications to existing traffic striping. This section presents some of the most common striping associated with traffic signals. It includes:

- Stop lines
- Pavement markings and legends
- Pavement striping

Additional information on striping and pavement markings can be found in [ALDOT Standard and Special Drawings for Highway Construction](#) (current edition).

### 11.4.1 Stop Lines

Stop lines shall be provided on all approaches to a signalized intersection. Stop lines are 24 in. white thermoplastic. Stop lines are typically located at the radius point, although when the curb radius exceeds 50 ft. the stop line can be moved forward to minimize crossing distances (see Figure 11.11).

All stop lines should be checked with a WB-50 truck turning template to ensure that there is adequate clearance for all turning movements. Stop bars for left turn lanes may be staggered from thru lanes (See Figure 11.12) if necessary but multiple left turn lanes should not be staggered relative to one another (i.e., they should share a common stop bar). The maximum stagger between stop lines for left turn lanes and thru lanes should not exceed 25 ft.

### 11.4.2 Markings for Left Turn Lanes

Markings for a standard left turn lane are shown in Figure 11.13. Typical markings for creating a left turn lane from a two-way-left-turn (TWLT) lane are also shown.

### 11.4.3 Extension Lines

When dual left turn lanes are present or when turning paths for opposing movements are tight the designer should consider providing extension lines to guide vehicles through the intersection. Typical extension lines are illustrated in Figure 11.14.



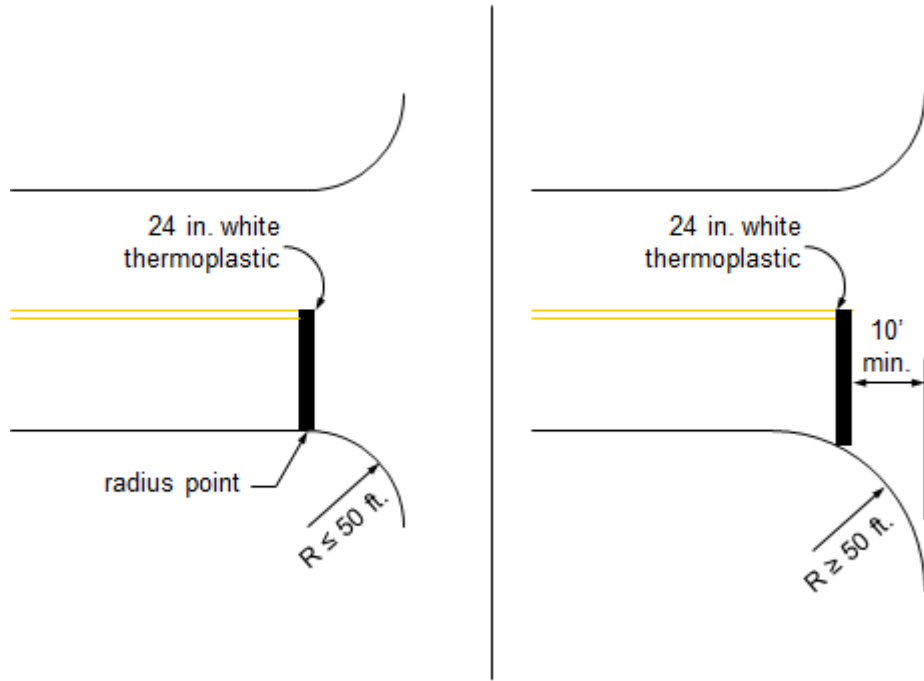


Figure 11.11 – Location of stop lines

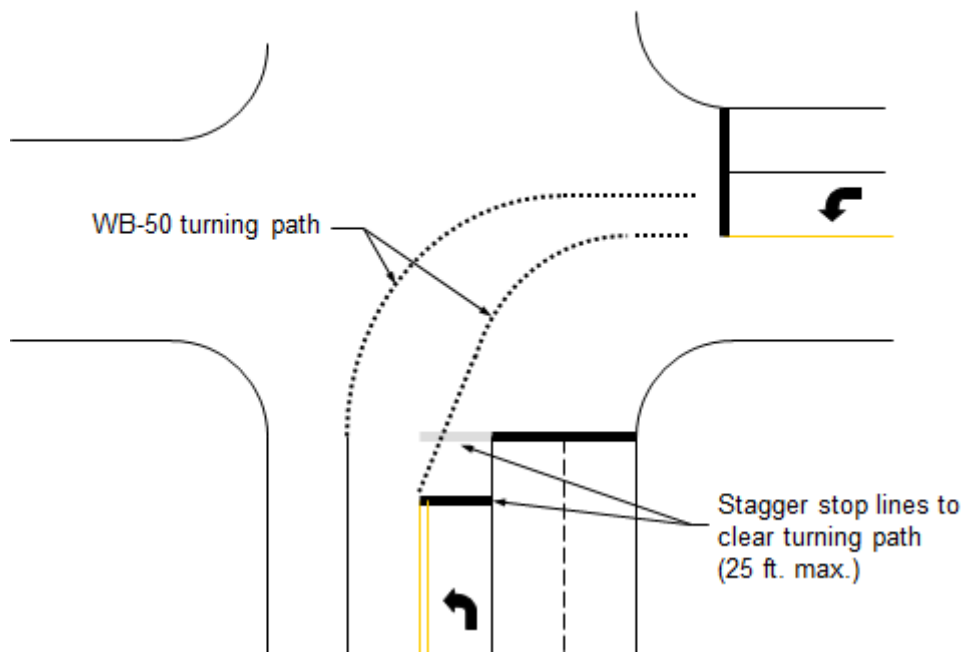


Figure 11.12 – Adjusting stop lines for turning paths

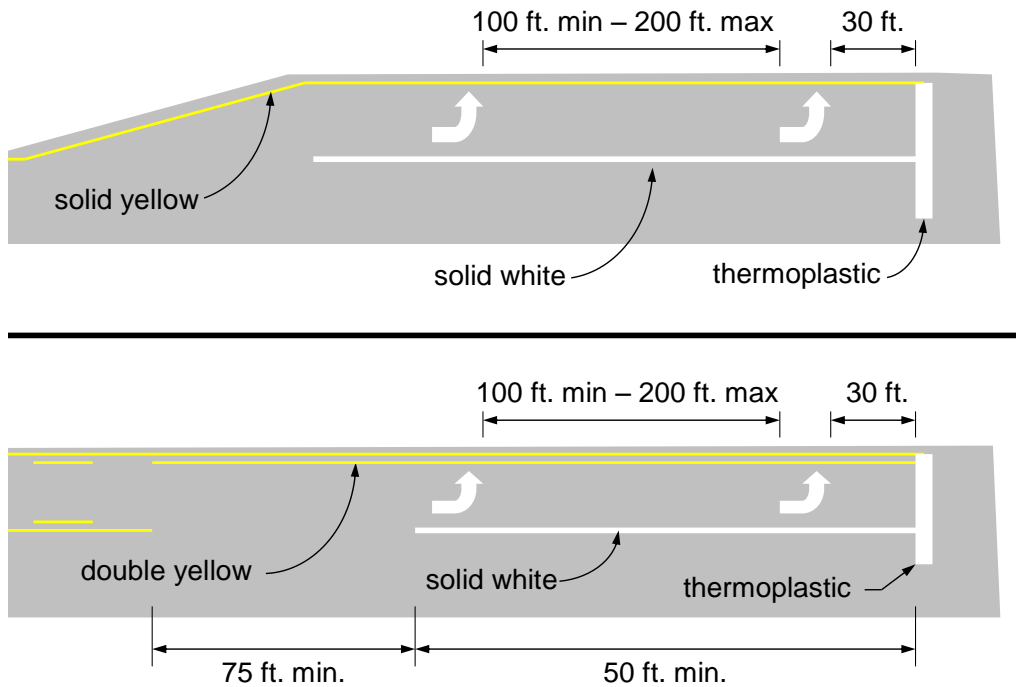


Figure 11.13 – Typical markings for standard left turn lanes (top) and TWLT lanes (bottom)

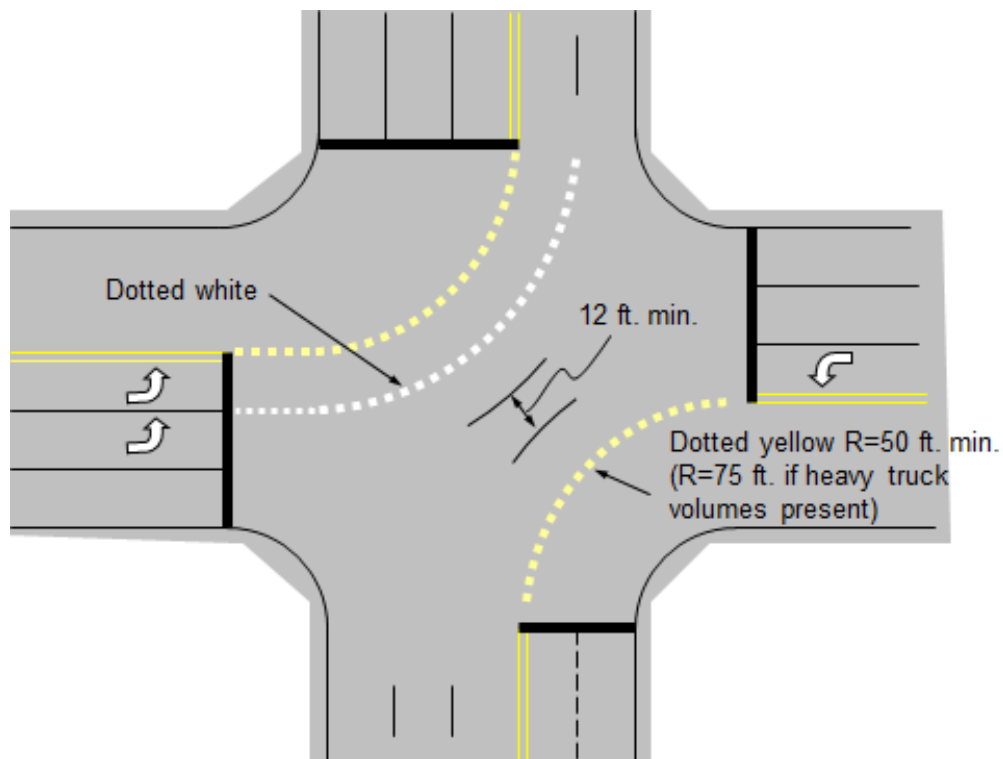


Figure 11.14 – Intersection extension lines

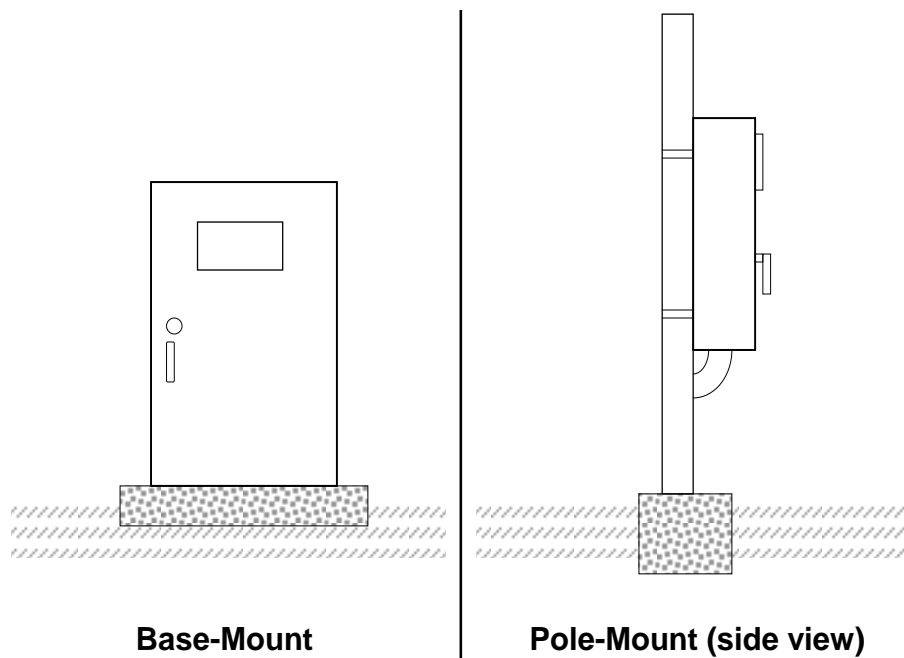
# ***Chapter 12***

## ***The Controller Cabinet***

This Chapter presents a brief discussion of the types, size, and location of a controller cabinet and the most common hardware found in it.

### **12.1 Cabinet Types and Dimensions**

Controller cabinets can either be base-mounted or pole-mounted, as shown in Figure 12.1. Base-mounted cabinets are larger and easier to access and are therefore the standard cabinet type used by ALDOT. A base-mounted cabinet should be specified unless conditions require a pole-mounted cabinet.



***Figure 12.1 – Base and pole-mounted cabinets***

Typical situations where a pole-mounted cabinet may be used include:

- Limited R.O.W.
- Urban or downtown areas where a base-mounted cabinet would obstruct sidewalks
- Location where slopes make a base-mounted cabinet impractical
- Utility conflicts prevent the use of a base-mounted cabinet
- Topography would make base-mounted cabinet susceptible to flooding

Standard dimensions for pole and base-mounted cabinets are shown in Table 12.1. A local cabinet is one that houses a local controller and associated hardware. A master cabinet houses both a local and master controller. Because of their smaller size it is generally not recommended that a pole-mounted cabinet be used as a master cabinet.

**Table 12.1 – Minimum cabinet dimensions**

Cabinet Type	Minimum Dimensions
<b>NEMA Type</b>	
Base-Mount (local)	54in. H x 38in. W x 16in. D
Base-Mount (master)	75.5in. H x 40 in. W x 27in. D
Pole-Mount (local)	41in. H x 28in. W x 16in. D
<b>Model 2070 Type</b>	
Base-Mount (332)	66in. H x 24in. W x 30 in. D
Pole-Mount (336)	36in. H x 24 in. W x 22in. D

## 12.2 Cabinet Location and Mounting

ALDOT Traffic Signal Standard Drawings provide details for both base and pole-mounted cabinets. The following guidelines should be used to select a location and mounting for the controller cabinet.

### 12.2.1 Base-Mounted Cabinets

A base-mounted cabinet should be located so that it provides an unobstructed view of the intersection and the cabinet interior at the same time. A technician should be able to make adjustments within the cabinet and easily observe their effects on the intersection without leaving the cabinet area. In addition to this, the following criteria should be considered when locating the cabinet:

- Proximity to power source
- Ease of access
- Topography/drainage
- Protection from vehicle collisions
- Effect on intersection sight distance

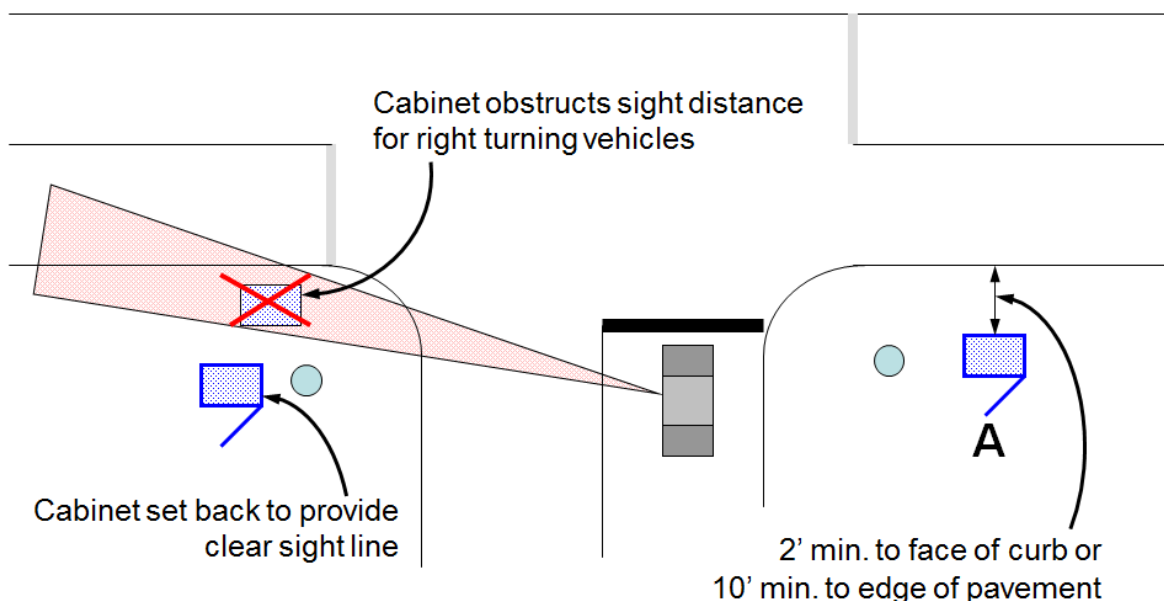
**Proximity to power source** – The controller should be located near the power source or service pole if possible, preferably on the same side of the road as the power source. This eliminates the need to run power across the road or use excessively long service runs.

**Ease of access** – The cabinet should be easily accessible to field technicians. It should be in an open area free from obstructions. Cabinets should not be located on steep slopes, difficult terrain, or in areas with dense vegetation. The location should also provide adequate room for the cabinet door to open freely and for a technician to work comfortably and observe the intersection without obstructing vehicle or pedestrian traffic.

**Topography/Drainage** – Cabinets should not be located in low lying areas such as ditches, gullies, or flood plains that would make them susceptible to flooding.

Protection from Vehicle Collisions – Vehicle collisions are one of the most common causes of damage to controller cabinets. In general, the cabinet should be located as far back from the roadway as possible, but at a minimum 2 ft. from the face of curb or 10 ft. from the edge of travel way in uncurbed areas. Where guardrail is present, the designer should consider locating the cabinet behind it if other location criteria can also be satisfied. When locating a cabinet behind guardrail, it should be located a minimum of 4 ft. from the back of the posts.

Effect on Intersection Sight Distance – The cabinet should be located so that it does not obstruct intersection sight distances. This is particularly important with respect to vehicles turning right from side streets. The cabinet should be located so that right turning vehicles have a clear line of sight to their left, as shown in Figure 12.2. For this reason, base-mounted cabinets are often located on the 'right' side of an intersection (as seen from a side street approach) as denoted by 'A' in Figure 12.2. Each proposed cabinet location should be visually inspected in the field for potential sight distance conflicts.

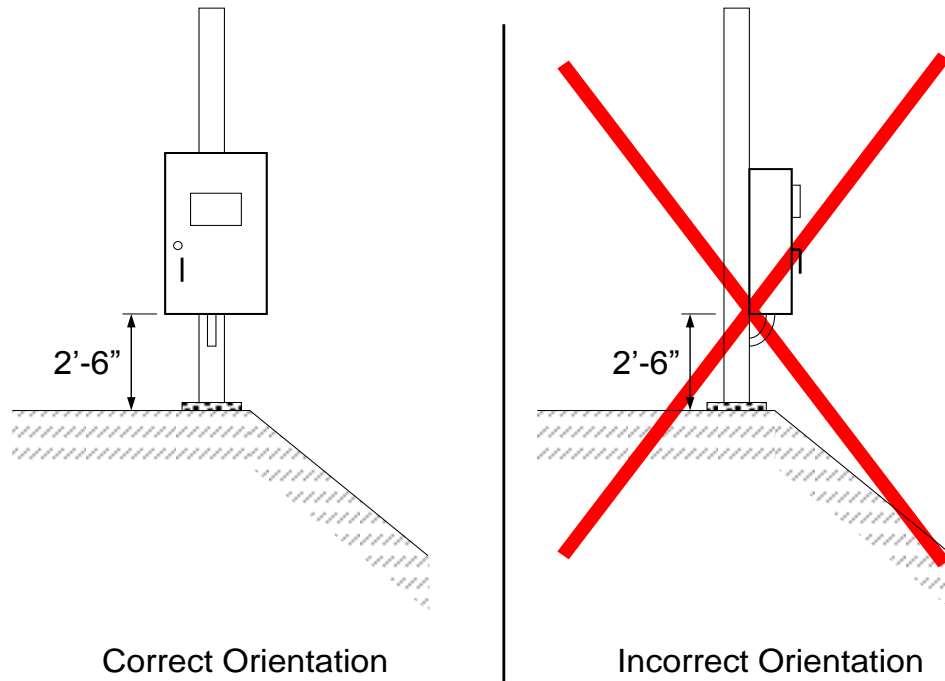


**Figure 12.2 – Locating a base-mounted cabinet to minimize sight distance impacts**

### 12.2.2 Pole-Mounted Cabinets

The same general criteria used to locate a base-mounted cabinet apply to a pole-mounted cabinet. Pole-mounted cabinets are typically attached to one of the signal poles, although in some cases they can be mounted on stand-alone pedestals (this should be discussed with the Region/Area Traffic Engineer prior to design).

Ease of access is an important consideration when locating a pole-mounted cabinet, particularly if the cabinet is located on or near a slope. Improperly positioned pole-mounted cabinets can make it very difficult for technicians to access all of the equipment inside. A pole-mounted cabinet shall be mounted so that the distance between the bottom of the cabinet and the ground is 2 ft.-6 in. (see [ALDOT Standard and Special Drawings for Highway Construction](#), current edition) allowing easy access without use of a step ladder. When the pole is located on a slope the designer should orient the cabinet so that it is not facing the slope, as this can make it very difficult to reach the cabinet (see Figure 12.3).



**Figure 12.3 – Correct orientation of a pole-mounted cabinet located on a slope**

### 12.3 Cabinet Hardware

This section provides a brief description of some of the hardware commonly found inside the controller cabinet. It does not provide an exhaustive explanation of how each unit functions but is instead intended to familiarize novice designers with controller cabinet equipment.

Figure 12.4 presents a picture of a master cabinet and a description of each of the pieces of hardware within. While this is typical of a master cabinet on a major arterial, other cabinets will vary in terms of size and hardware present. A brief description of each of the hardware types follows.

- A. Local controller – The local controller controls the signal operation at an intersection. It controls the operation of the signal heads, signal flashing, phase sequencing, pre-emptions, and all other signal functions. All signal timing data is input into the local controller.

ALDOT uses NEMA controllers on all state projects except in locations where Type 170 or 2070 controllers are already in use. Standard local controllers come in 2, 4, and 8 phase models, although ALDOT typically designs for an 8 phase model (see Chapter 3 discussion of signal phasing).

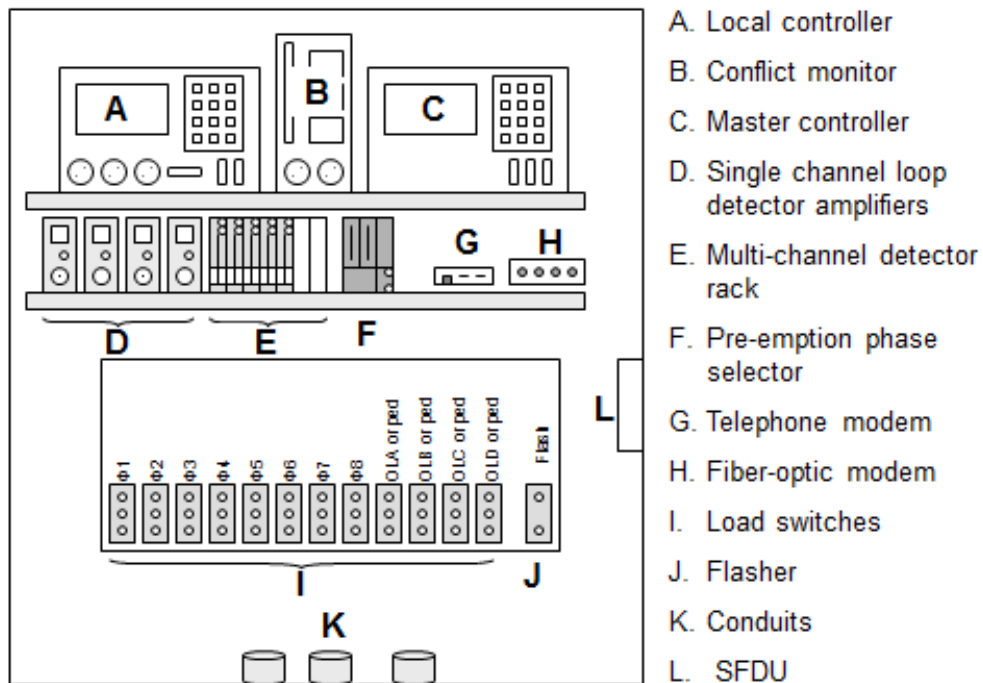
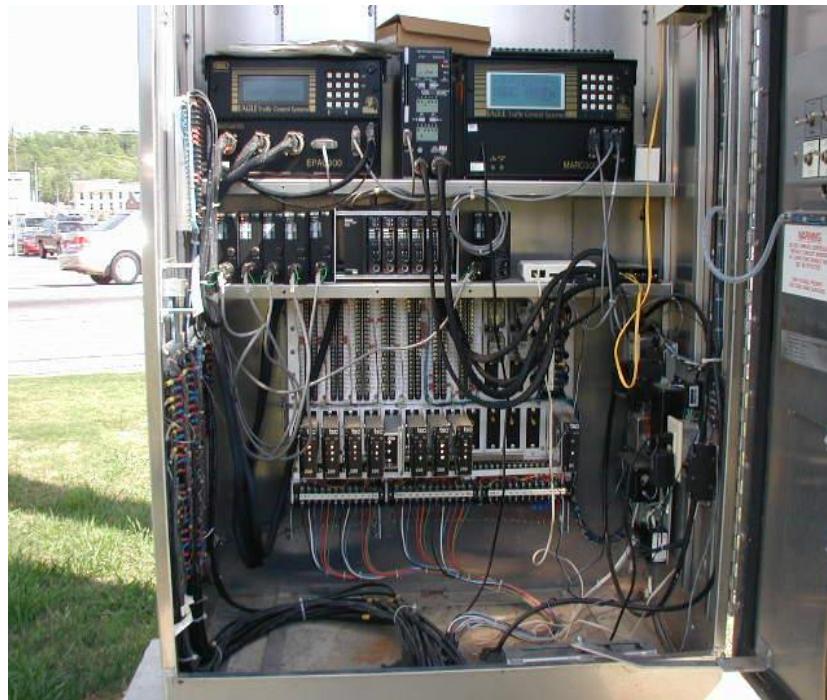


Figure 12.4 – Master cabinet and hardware

- B. Conflict monitor – The purpose of the conflict monitor is to ensure that a malfunctioning (or incorrectly programmed) local controller never gives simultaneous green indications to conflicting movements. It ‘monitors’ the outputs from the local controller to the signal heads and detects conflicting indications. If a conflict is detected the signal is immediately put into flashing mode.

Permissible (i.e., safe) phase combinations are hardwired into the conflict monitor on a removable circuit board. If the controller attempts any phase combination not wired into this circuit board the conflict monitor will trip and put the signal into flash. This is important to note if modifications are being made to an existing signal. If the designer is specifying non-standard phase combinations or modifying the ring structure he must also specify a new circuit panel for the conflict monitor or the signal will not function. These settings can not simply be reprogrammed in the field. An example of a typical conflict monitor is depicted in Figure 12.5.

❗ A traffic signal should never be operated without a conflict monitor, nor should the conflict monitor ever be disconnected from the controller, even briefly, while the signal is running.



**Figure 12.5 – Typical conflict monitor**

- C. Master controller – The function of the master controller is to coordinate the operation of local controllers within a system. Although it looks similar to a local controller, the master does not perform any local signal functions. The master communicates with the locals to ensure that all clocks are in synch, that all signals are running the proper timing plan, and to monitor the



system for malfunctions. The master can also be set to monitor traffic conditions through vehicle detectors and select appropriate timing plans.

The master can communicate with an external computer via modem to relay error messages and report system status. In fact, masters can be configured to automatically report any system errors to a central computer or pager.

Because it performs no local signal functions, the master can be briefly disconnected from the system without impacting the operation of signals within the system. When communication with the master is lost the local controllers revert to 'Backup' mode, using internal clocks and time-of-day (TOD) plans to maintain coordination. If the master is disconnected for extended periods, however, local clocks will tend to drift and system coordination will be affected.

The master can be housed in any one of the local cabinets (its location within the system is typically not important), although it is usually placed in an oversized 'master cabinet' to accommodate the extra equipment.

- D. Single-channel vehicle loop detector – A vehicle loop detector sends a current through the loop wire and monitors any changes in inductance that would indicate the presence of a vehicle (see Chapter 6). If a vehicle is detected, it sends a call to the controller for that phase. Single channel vehicle loop detectors (Figure 12.6) serve a single loop, meaning each loop in the pavement must have a corresponding vehicle loop detector in the cabinet.



**Figure 12.6 – Single channel vehicle loop detectors**

Most vehicle loop detectors have settings for sensitivity (low-med-high) that can be adjusted in the field. Sensitivity may be adjusted lower to avoid false calls or higher to detect smaller vehicles.

- E. Multi-Channel Vehicle Loop Detector Rack – Multi-channel vehicle loop detectors (Figure 12.7) perform the same function as single channel vehicle loop detectors but can handle multiple loops per detector. Because the number of single channel detectors can become unwieldy at large intersections, multi-channel detectors capable of handling 2 or 4 loops each are a useful alternative. Multi-channel vehicle loop detectors come in the form of circuit cards that are mounted in a card rack. All loops are wired to the rack so there are no visible cables as with single channel amps.



**Figure 12.7 – Multi-channel card rack & vehicle loop detectors (2-channel detector/amplifiers shown)**

- F. Pre-Emption Phase Selector – Receives signals from the pre-emption detectors and places an appropriate pre-emption call to the controller, which is discussed in more detail in Chapter 9. Pre-emption hardware may not be present at all signals.
- G. Telephone Modem – Typically present in closed-loop systems, the telephone modem allows an operator to communicate with the master controller through a remote computer. It operates just as a standard computer modem does and typically has a baud rate of 56Kbs. If a designer is specifying a closed loop system he should include a telephone modem for the master cabinet in the estimated equipment box on the plan sheet.
- H. Fiber Optic Modem – When fiber optic interconnect is used, a fiber optic modem is required for the master to communicate with each of the local controllers. The modem can either be external, as shown in Figure 12.8, or an internal panel in the master or local controllers. A fiber optic modem is required for each controller cabinet in the system. In the master cabinet, the master communicates directly with the local controller via a patch cable, so only one fiber optic modem is required.



**Figure 12.8 – Fiber optic modem (external)**

- I. Load Switches – The signal outputs from the controller are 24V DC and insufficient to power a traffic signal head. The controller outputs are therefore fed to load switches, which provide 120V AC power to the signal heads based on the controller outputs. Load switches mount to a plug-in rack in the cabinet and can be easily removed or replaced. Each signal phase has a separate load switch, as does each overlap or pedestrian phase.

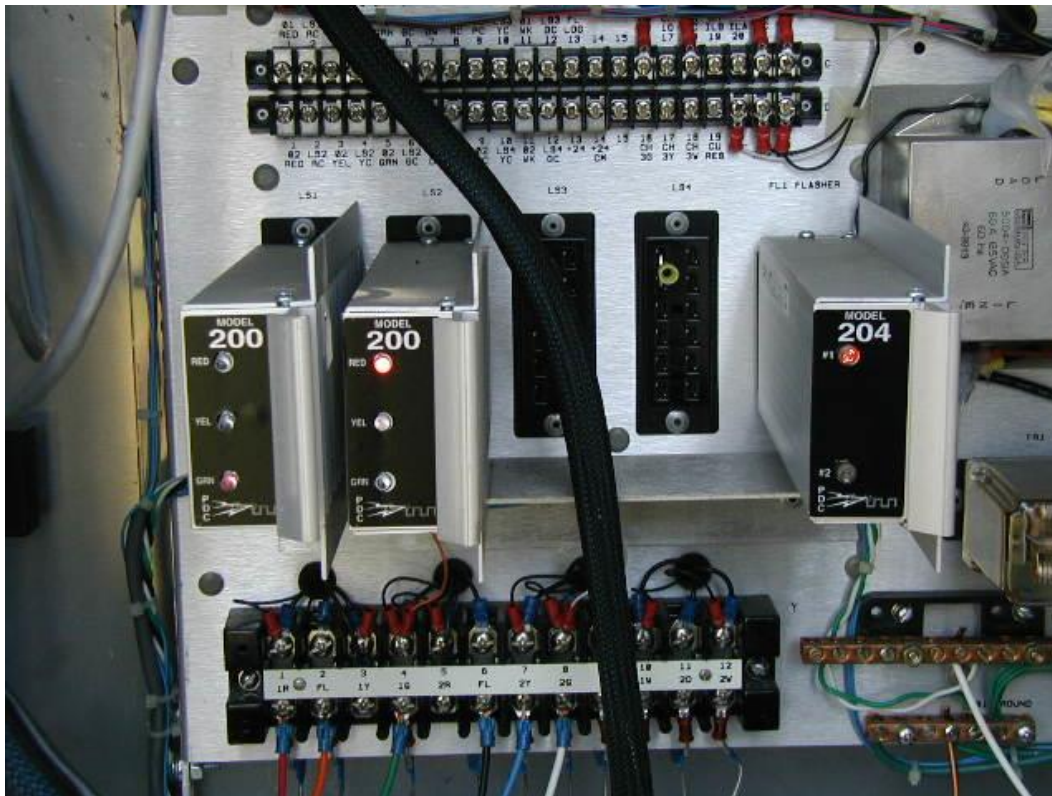
Load switches are only provided for active phases. Load switch bays corresponding to unused phases are left empty. The number of load switch bays provided in a cabinet depends on the type of local controller being used. A cabinet for a 2 phase controller, as depicted in Figure 12.9, must have a minimum of 4 load switch bays ( $\Phi 1$ ,  $\Phi 2$ , and 2 bays for pedestrian or overlap phases). Table 12.2 provides the minimum number of load bays required for each controller type.

**Table 12.2 – Minimum number of load switch bays by controller type**

Controller Type	Phases	Peds or Overlaps	Total Bays
2 Phase	2	2	4
4 Phase	4	4	8
8 Phase	8	4	12*

\* Up to 16 load bays may be specified if needed

When adding phases to an existing signal the designer should verify that there are enough load switch bays to accommodate the new phases. In most cases, if a two or four phase controller is being upgraded to an eight phase controller then the entire cabinet will need to be replaced. If additional phases are being added to an existing eight phase controller (e.g., left turn phases or pedestrian phases) then the designer must include in the quantities an additional load switch for each new phase.



**Figure 12.9 – Two phase cabinet with load switches, load switch bays, and flasher**

- J. Flasher – The flasher looks like a standard load switch except with two outputs instead of three. It controls the signal heads when the signal is in flashing mode and operates continuously even when the signal is not in flashing mode. In most cases, mainline thru heads will flash yellow and side street thru heads will flash red. Any protected left turn, whether on the mainline or side street, will flash red.
- L. Secondary Fiber Distribution Unit (SFDU) – The SFDU is where an incoming fiber optic cable is separated and its component fibers terminated into connectors. Patch cables connect the SFDU to the controllers or external modems.

## 12.4 Cabinet Foundations

A base-mounted cabinet sits atop a concrete foundation (see ALDOT Special and Standard Highway Drawings, current edition). A minimum of three 2 in. conduits shall be run through the foundation to carry signal and loop return cables. When upgrading a controller cabinet the foundation and conduits may be re-used, however the designer must verify that the existing foundation will accommodate the new cabinet.

## 12.5 Type 170 and 2070 Controllers

The above information relates to NEMA cabinets and controllers, which are the standard type used by ALDOT. In some parts of the State, Type 170 and 2070 controllers are also used. The Type 170 and 2070 differ from NEMA controllers in several key respects:

- Type 170/2070 utilizes an open architecture design whereas NEMA architecture is proprietary. The operating software in Type 170/2070 controllers can be modified by the user for special applications, whereas it is largely fixed in NEMA controllers. Some feel this gives 170/2070 controllers greater operating flexibility.
- The components contained in a Type 170/2070 cabinet are usually rack-mounted. A Type 170/2070 cabinet is usually smaller and more modular.
- A Type 170/2070 controller must usually be accessed using a laptop computer, whereas changes can be manually input in NEMA controllers.

Type 170/2070 controllers require different cabinets than those used for NEMA controllers. A picture of a typical Type 170 cabinet is shown in Figure 12.10.



Figure 12.10 – Typical 170 Cabinet

It can be seen that some of the components, such as load switches and vehicle loop detectors, are the same as those found in NEMA cabinets. Other components, such as the controller and conflict monitor are unique to the Type 170 design.

In general, a NEMA controller will require a larger cabinet and concrete base than will a Type 170/2070 controller. When upgrading from a NEMA cabinet to a Type 170, the cabinet foundation can be re-used but an adapter will usually be required.

## 12.6 Uninterruptible Power Supply

An uninterruptible power supply (UPS) is a backup battery source that provides continuous signal operation during temporary AC line failures or voltage drops. It can be installed as part of any signal equipped exclusively with LED heads, though it is most commonly used on high volume intersections where maintenance of signal operation during power outages is critical to traffic flow.

There are three basic types of UPS: standby, line interactive, and on-line. All of them provide power through batteries and inverters, but during “normal operation” when power is provided by the local power authority they handle power very differently. Following are brief descriptions of each.

### 12.6.1 Standby UPS

Standby UPS has a transfer switch that switches from AC power to the battery / inverter in 1 – 5 milliseconds in the event of an AC Line failure. The signal controller equipment will have to be able to hold through this interruption in order for it to function properly. Some units include a ferrous transformer to reduce the effect of this interruption.

### 12.6.2 Line Interactive UPS

Line interactive UPS during normal operation smoothes and regulates the AC power with a filter and multi-tap transformer. The inverter/ charger uses some of the line input to maintain the batteries. When the power fails a transfer relay disconnects the AC line and the batteries/ inverter provide power.

### 12.6.3 On-Line UPS

On line UPS during normal operation delivers all or part of the power through the inverter to the load. There are two major types of on line UPS systems: Double Conversion and Delta Conversion.

Double Conversion: Continually processes all the power through an AC to DC rectifier / charger then to an AC inverter to power the load.

Delta Conversion: Has the addition of a delta converter which sends part of the power to the load and part to the rectifier/ inverter. This allows for higher efficiency and power factor correction.

Designers should consult the Alabama DOT APL for a list of acceptable UPS systems.

### 12.6.4 Installation Requirements

ALDOT requires a separate cabinet to house a UPS unit (see Figure 12.11). This cabinet is to include the inverter, batteries, transfer switch, and generator hookups. Power is to be routed to this cabinet then to the controller cabinet. This cabinet can be mounted to the signal cabinet, however, there shall

be no pass-through port between these cabinets, as the possible danger of battery fumes corroding the electronics in the signal cabinet.



**Figure 12.11 – Typical installation of UPS in separate cabinet**

# ***Chapter 13***

## ***Traffic Signal Quantities***

This Chapter presents general guidelines for preparing traffic signal quantities for an ALDOT plan set. Quantities may be presented differently for a permit plan set (i.e., a plan set prepared by a private party for a permit application) but the same principles apply.

### **13.1 ALDOT Quantities**

Every ALDOT traffic signal plan set must include a comprehensive tabulation of quantities for bidding purposes. The quantities should be as accurate as possible to ensure meaningful bids and avoid costly change orders during construction.

Tabulation of quantities in ALDOT plan sets are typically broken down into three categories:

- Traffic signal equipment
- Fiber optic equipment
- Striping and signing

Each item specified in the plan set has a corresponding pay item number established by ALDOT. A complete list of all ALDOT pay item numbers can be obtained at the [ALDOT website](#).

Sample pay item quantity sheets are provided in the sample plan set in this manual. Some general guidelines for filling out the pay item sheets are as follows:

- Pay item numbers and descriptions must be listed ***exactly*** as they appear in the ALDOT pay item list (no exceptions).
- Totals must be checked for accuracy. Quantity summaries that contain errors will be rejected by ALDOT.
- Every quantity must be assigned a unique ALDOT pay item number. If a pay item number does not exist for a material or piece of equipment included in the plan set, excluding miscellaneous quantities, the designer must contact ALDOT to obtain a number.

The following pages are provided to illustrate common traffic signal pay items along with descriptions of their appropriate use and items covered under each pay item. **Note: The information contained in the following tables is a sample of information contained in the Alabama Standard Specifications for traffic signals, Sections 730 and 890. Designers are advised to review the [ALDOT Standard Specifications for Highway Construction](#) (current edition) for complete details about what is included under each pay item number. In the event of a conflict between the information**



contained in this manual and the Alabama Standard Specifications, the Alabama Standard Specifications shall govern. Section 734 is governed by Special Provision and will not be included in the specification book.

### 13.2 Units of Measurement

Most pay items used in traffic signal design are measured in one of three ways:

- Lump sum
- Each
- Linear foot

Lump Sum pay items include all materials necessary for the complete installation of a specific piece of equipment. For these pay items, it is not necessary to list any subsystems, peripheral hardware, or wiring. Some common lump sum pay items include removal of an existing signal, installation of video detection equipment, installation of pre-emption equipment, and installation of flashing beacons.

Lump sum pay items always have a quantity of '1' and a separate pay item must be used for each occurrence within a project. For example, if signal pre-emption equipment is to be installed at three signals within a project, the designer must specify a separate pay item for each installation (e.g., 730S-003, 730S-004, and 730S-005), each with a quantity of '1'. In this case, the designer should **not** specify a single pay item with a quantity of '3'.

Pay items measured as Each can group multiple occurrences of a hardware unit under a single pay item. For example, all signal heads on a project, even at multiple intersections, can be grouped under a single 730P-XXX pay item number. Common pay items measured this way include signal poles, signal heads, vehicle loop detectors, and controller assemblies.

Pay items measured by the Linear Foot can also group multiple occurrences of a material under a single pay item number. For example, all conduit on a project, even at multiple intersections, can be grouped under a single 730L-XXX pay item number. Common pay items measured this way include conduit, loop wire, loop detector lead-in cable, and interconnect.

### 13.3 Miscellaneous Quantities

There are several common pieces of traffic signal equipment that do not have an ALDOT pay item number. These are grouped under "Estimated Equipment and Material" and covered under the 730C-XXX "Furnishing and Installing Traffic Control Unit" pay item. Items grouped under "Estimated Equipment and Materials" include:

- 3/8 in. messenger cable
- 1/4 in. tether wire
- #14 signal cable
- Power source (specify 120V or 240V)
- Miscellaneous hardware
- Span mounted signs with hardware (e.g., R10-12, R10-10, etc.)
- Backplates with hardware

The above items should be listed in a box on the layout sheet titled "Estimated Equipment and Material Schedule (Lump Sum)", as shown in the sample plan set. Since they are part of a lump sum pay item, it is not necessary to compute quantities for any of the items such as span wire or signal cable. The lump sum designation covers all occurrences of these items in a design. The designer should ensure, however, that only items actually used in the signal layout appear in the estimated equipment box.

<b>Traffic Signal Pay Items</b>				
Pay Item Number	Description	Unit of Measurement	Pay Item Includes	Comments
730A-000 thru 730A-011 & 730A-037 thru 730A-051	Removal of Existing Traffic Control Unit ( <i>Intersection Name</i> )	Lump Sum	The cost of all labor, equipment, and materials associated with the complete removal of an existing traffic signal including all equipment such as controller, poles, span wire, and signal heads. Also includes grinding of foundations.	Should be used whenever a complete removal is required. If only some equipment is being removed, use pay item 730A-12 through 730A-32. Each signal to be removed within a project requires a separate pay item number, i.e., 730A-000, 730A-001, 730A-002... Multiple signal removals should <u>not</u> be lumped under a single pay item.
730A-012 thru 730A-032 & 730A-060 thru 730A-065	Removal of Existing Traffic Control Unit (Partial) - ( <i>Intersection Name</i> )	Lump Sum	The cost of all labor, equipment, and materials associated with the removal of any part of an existing traffic signal, such as controller, poles, or signal heads.	The 730A-012 pay item should be used if any part (but not all) of an existing signal installation will be removed, even if it is just a single head or pole. If a complete removal is required, use the 730A-000 pay item instead. Each partial removal of a signal within a project requires a unique pay item number, i.e., 730A-012, 730A-013, 730A-014... Multiple signal removals should <u>not</u> be lumped under a single pay item.
730A-053 thru 730A-056	Removal of Existing Traffic Control Unit (Temporary) - ( <i>Intersection Name</i> )	Lump Sum	The cost of all labor, equipment, and materials associated with the removal of a temporary traffic signal.	Temporary traffic signals are often associated with construction activities. This pay item covers the removal of a temporary signal. Since some signal equipment could be retained for a permanent installation (i.e., controller or detection equipment) this pay item does not imply a complete removal. Each temporary signal to be removed within a project requires a separate pay item number, i.e., 730A-053, 730A-054, etc... Multiple temporary signal removals should <u>not</u> be lumped under a single pay item.
730C-000 thru 730C-275	Furnishing and Installing Traffic Control Unit - ( <i>Intersection Name</i> )	Lump Sum	The cost of all labor, equipment, and materials required for a complete or partial signal installation. Items include labor, power service, signal cable, span wire, clamps, hardware, signs, and any hardware not covered under other pay items. These should be listed in the Estimated Equipment and Material box on the layout.	The 730C pay item should be used for all signal equipment installations, whether partial or complete. Each signal installation within a project requires a separate pay item number, i.e., 730C-000, 730C-001, 730C-002... Multiple signal installations should <u>not</u> be lumped under a single pay item.  Temporary traffic signals are also furnished and installed under the 730C pay item.
730E-000	Metal Traffic Signal Pole Foundation	Each	The cost of all labor, equipment, and materials required for a steel strain pole foundation	Each steel strain pole or mast-arm pole must include a quantity for a concrete foundation unless it is re-using an existing foundation. Multiple pole foundations may be included under this single pay item.

<b>Traffic Signal Pay Items</b>				
Pay Item Number	Description	Unit of Measurement	Pay Item Includes	Comments
730F-000 Thru 730F-008	Metal Traffic Signal Pole With ( <i>specify arm length</i> ) Mast Arm Assembly	Each	The cost of all labor, equipment, and materials required for the installation of a steel mast-arm assembly.  <u>Does not</u> include foundation.	This pay item is used for steel mast-arm poles (use 730G for steel strain poles). Pay item description should include length of mast arm, e.g., "Metal Traffic Signal Pole With 34 ft. Mast Arm". Multiple poles may be included under a single pay item if the mast arm lengths are the same. Mast arm poles with different mast arm lengths require separate pay items.
730G-001	Metal Traffic Signal Strain Pole	Each	The cost of all labor, equipment, and materials required for the installation of a steel strain pole.  <u>Does not</u> include foundation.	730G-001 specifies that a steel strain pole be provided. All metal strain poles required on a project, including poles of different shaft heights, are included under this single pay item.
730G-002	Concrete Traffic Signal Strain Pole	Each	The cost of all labor, equipment, and materials required for the installation of a concrete strain pole.  A concrete strain pole does not require a foundation.	730G-002 specifies that a concrete strain pole be provided. All concrete strain poles required on a project, including poles of different shaft heights, are included under this single pay item.
730G-004	Metal Traffic Signal Strain Pole (State Furnished)	Each	The cost of all labor, equipment, and materials required for the installation of a steel strain pole.  <u>Does not</u> include foundation.	Use this pay item only if metal strain poles are being furnished by the State. On most projects, strain poles will be furnished by the contractor.
730H-001	Loop Wire	Linear Foot	The cost of all labor, equipment, and materials required to furnish and install in-pavement loop wire..	The 730H-001 pay item is for in-pavement #12 AWG loop wire only. It should be measured from the junction box through the loop turns and back to the junction box. See Section 8.2.5 and Table 8.4 for guidance on computing loop wire quantities.
730I-001	Loop Detector Lead-In-Cable	Linear Foot	The cost of all labor, equipment, and materials required to furnish and install loop detector lead-in cable from junction box to controller cabinet. <u>Does not</u> include cost of installing conduit.	The 730I-001 pay item is for 2c/#12 shielded loop returns only. It should be measured from the loop splice point in the junction box to the controller cabinet. See Section 8.2.6 and Figure 8.10 for guidance on computing loop return quantities.

<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730J-010	Vehicle Loop Detector	Each	The cost of all labor, equipment, and materials required to furnish and install a loop detector/amplifier	The 730J-010 pay item is for any type of loop detector/amplifier, whether it be single channel or multi-channel rack mount. The quantity should be the total number of single channel amplifiers required or the number of channels required for a detector rack. If a detector rack is specified it should be clearly noted on the plan sheet.
730K-000	Traffic Signal Junction Box	Each	The cost of all labor, equipment, and materials required for a complete junction box installation.	The 730K-000 pay item is for a standard 20 in. x 29 in. fiberglass junction box. This type of junction box is suitable for most signal applications, including loop splices and intermediate conduit pull boxes. This type of junction box should <u>not</u> be specified for fiber optic applications.
730L-000	¾", Metallic, Conduit	Linear Foot	All labor and materials required to install ¾ in. metallic conduit.	¾ in. metallic conduit is used primarily for above-ground power service applications, namely to carry service wire from the weather head to the circuit breakers and to carry the ground wire from the circuit breaker to the ground rod (see Section 8.1.4 for guidance on computing quantities).
730L-001	¾", Non-Metallic, Conduit	Linear Foot	All labor and materials required to install ¾ in. non-metallic conduit.	¾ in. non-metallic conduit may be used only for underground applications. Not typically required for signal installations.
730L-002	1", Metallic, Conduit	Linear Foot	All labor and materials required to install 1in. metallic conduit.	1in. metallic conduit is used primarily for above-ground power service applications, namely to carry power cables from the circuit breakers on the service pole to the controller or luminaries. 1in. metallic conduit should be used only above ground; once below ground non-metallic conduit should be used (see Section 8.1.4 for guidance on computing quantities).
730L-003	1", Non-Metallic, Conduit	Linear Foot	All labor and materials required to install 1in. non-metallic conduit.	1in. non-metallic conduit is used primarily for below-ground power service applications, namely to carry power cables from the circuit breakers on the service pole to the controller or luminaries. 1in. non-metallic conduit should be used only below ground and through foundations; once above ground metallic conduit should be used (see Section 8.1.4 for guidance on computing quantities).

<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730L-004	2", Metallic, Conduit	Linear Foot	All labor and materials required to install 2 in. metallic conduit.	2 in. metallic conduit is used for most above-ground signal applications not related to power service. It should be used for all risers carrying signal cable, loop returns, and interconnect. It should also be used for all conduit attachments to bridges. 2 in. metallic conduit should only be used above ground; once below ground non-metallic conduit should be used (see Section 8.3 for guidance on computing quantities).
730L-005	2", Non-Metallic, Conduit	Linear Foot	All labor and materials required to install 2 in. non-metallic conduit.	2 in. non-metallic conduit is used for most underground signal applications not related to power service. It should be used for signal cable, loop returns, and interconnect (except fiber optic). 2 in. non-metallic conduit should only be used below ground or through foundations; once above ground metallic conduit should be used (see Section 8.3 for computing quantities).
730L-006	3", Metallic, Conduit	Linear Foot	All labor and materials required to install 3 in. metallic conduit.	3 in. metallic conduit is used only for special above-ground signal applications. It should be used for risers only when 2 in. conduit is inadequate (see Section 8.3.3 for computing conduit fill limits). 3 in. metallic conduit should only be used above ground; once below ground non-metallic conduit should be used (see Section 8.3 for guidance on computing quantities).
730L-007	3", Non-Metallic, Conduit	Linear Foot	All labor and materials required to install 3 in. non-metallic conduit.	3 in. non-metallic conduit is used for special underground signal applications. It should be used only when 2 in. conduit is inadequate for the number of cables required (see Section 8.3.3 for computing conduit fill limits). 3 in. non-metallic conduit should only be used underground; once above ground metallic conduit should be used.
730M-015	Interconnect Cable, Aerial Self-Supporting, #14 AWG, 9 Conductors, IMSA 20-1	Linear Foot	All labor and materials required to install a 9c/#14 self-supporting aerial interconnect cable.	This pay item is for a self-supporting aerial hardware interconnect. Self-supporting cable contains an internal span wire that supports the cable between poles and should be used unless the new cable is being lashed to an existing cable. See Section 10.3 for guidance on computing quantities.

<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730M-016	Interconnect Cable, Aerial Lashed, #14 AWG, 9 Conductors, IMSA 20-1	Linear Foot	All labor and materials required to install a 9c/#14 lashed aerial interconnect cable.	This pay item is for a lashed aerial hardwire interconnect. It is not self-supporting and should be used only if the new cable is to be lashed to an existing cable or a signal span wire. It can not be suspended on its own. See Section 10.3 for guidance computing quantities.
730M-017	Interconnect Cable, Underground, #14 AWG, 9 Conductors, IMSA 20-1	Linear Foot	All labor and materials required to install a 9c/#14 underground interconnect cable. Does not include conduit.	This pay item is for underground hardwire interconnect. It is intended for systems where the interconnect trunk is run underground. It should not be used if an aerial interconnect is run for short distances underground to a controller. See Section 10.3 for guidance computing quantities.
730M-020	Interconnect Cable, Aerial Self-Supporting, #19 AWG, 6 Pair, REA PE-38	Linear Foot	All labor and materials required to install a 6-pair/#19 self supporting aerial interconnect cable.	This pay item is for a self-supporting aerial twisted pair interconnect. Self-supporting cable contains an internal span wire that supports the cable between poles and should be used unless the new cable is being lashed to an existing cable. See Section 10.3 for guidance on computing quantities.
730M-021	Interconnect Cable, Aerial Lashed, #19 AWG, 6 Pair, REA PE-22	Linear Foot	All labor and materials required to install a 6-pair/#19 lashed aerial interconnect cable.	This pay item is for a lashed aerial twisted pair interconnect. It is not self-supporting and should be used only if the new cable is to be lashed to an existing cable or a signal span wire. It cannot be suspended on its own. See Section 10.3 for guidance computing quantities.
730M-022	Interconnect Cable, Underground, #19 AWG, 6 Pair, REA PE-39	Linear Foot	All labor and materials required to install a 6 pair/#19 underground interconnect cable. Does not include conduit.	This pay item is for underground twisted pair interconnect. It is intended for systems where the interconnect trunk is run underground. It should not be used if an aerial interconnect is run for short distances underground to a controller. See Section 10.3 for guidance computing quantities.
730N-000 thru 730N-012	Luminaire Extension Assembly, <i>specify arm length</i>	Each	All labor and materials for installing a luminaire extension assembly on a signal pole. Includes arm, luminaire, and wiring.	Must specify arm length (12 ft. is standard), e.g., "Luminaire Extension Assembly, 12 Foot". Multiple assemblies of the same length are included under a single pay item. Assemblies with different arm lengths require separate pay items.

<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730P-020	Vehicular Signal Head, 12 inch, 1 Section, Type LED	Each	All labor and materials for installing a signal head, including head, lenses, and mounting hardware.	Standard 1-section head with 12 in. lens and LED bulbs. Includes all 1-section heads of this type regardless of indication. If head includes strobe it should be clearly noted in the plans.
730P-021	Vehicular Signal Head, 12 inch, 2 Section, Type LED	Each	All labor and materials for installing a signal head, including head, lenses, and mounting hardware.	Standard 2-section head with 12 in. lenses and LED bulbs. Includes all 2-section heads of this type regardless of indications. Typically used for warning flashers.
730P-022	Vehicular Signal Head, 12 inch, 3 Section, Type LED	Each	All labor and materials for installing a signal head, including head, lenses, and mounting hardware.	Standard 3-section head with 12 in. lenses and LED bulbs. Includes all 3-section heads of this type regardless of indications.
730P-023	Vehicular Signal Head, 12 inch, 4 Section, Type LED	Each	All labor and materials for installing a signal head, including head, lenses, and mounting hardware.	Standard 4-section head with 12 in. lenses and LED bulbs. Includes all 4-section heads of this type regardless of indications (left turn or right turn).
730P-024	Vehicular Signal Head, 12 inch, 5 Section, Type LED	Each	All labor and materials for installing a signal head, including head, lenses, and mounting hardware.	Standard 5-section head with 12 in. lenses and LED bulbs. Includes all 5-section heads of this type regardless of indications (left turn or right turn).
730P-030	Vehicular Signal Head, 12 inch, 3 Section, Optically Programmed	Each	All labor and materials for installing a signal head, including head, lenses, mounting hardware, and tether hardware.	Optically programmed 3-section head with 12 in. lenses. Includes all 3-section heads of this type regardless of indications. If span mounted, head requires tether, which should be noted on plans and included under miscellaneous quantities.
730P-031	Vehicular Signal Head, 12 inch, 4 Section, Optically Programmed	Each	All labor and materials for installing a signal head, including head, lenses, mounting hardware, and tether hardware.	Optically programmed 4-section head with 12 in. lenses. Includes all 4-section heads of this type regardless of indications. If span mounted, head requires tether, which should be noted on plans and included under miscellaneous quantities.
730P-032	Vehicular Signal Head, 12 inch, 5 Section, Optically Programmed	Each	All labor and materials for installing a signal head, including head, lenses, mounting hardware, and tether hardware.	Optically programmed 5-section head with 12 in. lenses. Includes all 5-section heads of this type regardless of indications. If span mounted, head requires tether, which should be noted on plans and included under miscellaneous quantities.

<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730Q-011	Pedestrian Signal Head, Type LED	Each	All labor and materials for installing a pedestrian signal head, including head, lenses, and mounting hardware. Does not include pedestal, pole, or pushbutton.	Standard 17.5 in. x 16.875 in. pedestrian signal head with LED lights. If required, pedestal pole and pushbutton should be noted on plans and included under miscellaneous quantities.
730R-020	Controller Assembly, Type III, 2 Phase	Each	Includes controller, cabinet, foundation, conflict monitor, load switches, wiring, and miscellaneous equipment and hardware. Does not include loop detectors, detection equipment, external modems, or pre-emption systems.	Standard NEMA 2 phase local controller. TBC panel is included if coordinated operation is specified, but should be clearly noted on the plans. Additional features, such as an internal fiber modem or hardwire interconnect panel, must be clearly noted on the plans if they are to be covered under this pay item. If a new cabinet is not to be provided, i.e., the controller will be installed in an existing cabinet, it must be clearly noted on the plans.
730R-021	Controller Assembly, Type III, 4 Phase	Each	Includes controller, cabinet, foundation, conflict monitor, load switches, wiring, and miscellaneous equipment and hardware. Does not include loop detectors, detection equipment, external modems, or pre-emption systems.	Standard NEMA 4 phase local controller. TBC panel is included if coordinated operation is specified, but should be clearly noted on the plans. Additional features, such as an internal fiber modem or hardwire interconnect panel, must be clearly noted on the plans if they are to be covered under this pay item. If a new cabinet is not to be provided, i.e., the controller will be installed in an existing cabinet, it must be clearly noted on the plans.
730R-022	Controller Assembly, Type III, 8 Phase	Each	Includes controller, cabinet, foundation, conflict monitor, load switches, wiring, and miscellaneous equipment and hardware. Does not include loop detectors, detection equipment, external modems, or pre-emption systems.	Standard NEMA 8 phase local controller. TBC panel is included if coordinated operation is specified, but should be clearly noted on the plans. Additional features, such as an internal fiber modem or hardwire interconnect panel, must be clearly noted on the plans if they are to be covered under this pay item. If a new cabinet is not to be provided, i.e., the controller will be installed in an existing cabinet, it must be clearly noted on the plans.
730R-030	Controller Assembly, Type III, Master	Each	Includes master controller, local controller, cabinet, foundation, conflict monitor, load switches, wiring, and miscellaneous equipment and hardware. Does not include loop detectors, detection equipment, external modems, or pre-emption systems.	Standard NEMA master controller. This pay item includes master and local controller in a master cabinet. Do not specify a separate local controller pay item at the same intersection. Master cabinet dimensions and type of local controller (2, 4, or 8 phase) should be clearly noted on the plans.



<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730R-051	Controller Assembly, 170, 4 Phase	Each	Includes controller, cabinet, foundation, conflict monitor, load switches, wiring, and miscellaneous equipment and hardware. Does not include loop detectors, detection equipment, external modems, or pre-emption systems.	Standard model 170 4-phase local controller. Should be specified only for municipalities or systems currently using model 170 controllers. Additional features, such as an internal fiber modem, must be clearly noted on the plans if they are to be covered under this pay item.
730R-052	Controller Assembly, 170, 8 Phase	Each	Includes controller, cabinet, foundation, conflict monitor, load switches, wiring, and miscellaneous equipment and hardware. Does not include loop detectors, detection equipment, external modems, or pre-emption systems.	Standard model 170 8-phase local controller. Should be specified only for municipalities or systems currently using model 170 controllers. Additional features, such as an internal fiber modem, must be clearly noted on the plans if they are to be covered under this pay item.
730S-002 thru 730S-064	Furnishing and Installing Emergency Vehicle Preemption System ( <i>Intersection Name</i> )	Lump Sum	All equipment required to install a functioning emergency preemption system. Includes detectors, cable, phase selector, power supply, and misc. hardware. Does not include vehicle emitters.	Complete optical pre-emption system (does not include emitters). A separate 730S pay item should be used for each signal installation within a project where pre-emption is being used, i.e., 730S-003, 730S-004, 730S-005, etc..
730S-100	Furnishing and Installing Emergency Vehicle Optical Emitter System	Lump Sum	All equipment and labor required for a complete vehicle optical emitter installation.	On-board vehicle emitter. Each vehicle emitter installation requires a separate 730S pay item number.
730T-000	Wood Pole	Each	Pole, guy wire, hardware, excavation, and installation.	Can be used for either power service poles or signal poles. Type of pole should be clearly shown on plans.
730U-015 thru 730U-035	Video Detection System	Lump Sum	Video cameras, wiring, video processor, mounting hardware including extensions, and misc. hardware required for a complete installation.	The 730U pay item includes all equipment for a complete intersection installation. It may include multiple cameras and mountings. Each intersection installation requires a separate 730U pay item, i.e., 730U-005, 730U-006, 730U-007, etc...
730W-000	Monotube Signal Structure ( <i>specify length</i> )	Each	The cost of all labor, equipment, and materials required for the installation of a monotube signal structure.  <u>Does not</u> include foundation.	Monotube signal structures are used only in special cases in the State. Their use should be discussed with ALDOT prior to specifying them in plans.
730Y-000 thru 730Y-020 & 730Y-300 thru 730Y-320	Furnishing and Installing Pedestal Pole and Foundation with Flashing Beacon	Lump Sum	Pole, foundation, flashing beacon, signs, power source, and wiring.	Standard flashing beacon installation (see ALDOT Std. Dwg. TSD-730-13). Each flashing beacon requires a separate 730Y pay item.

<b>Traffic Signal Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
730Y-040 thru 730Y-060	Removal of Pedestal Pole And Foundation with Flashing Beacon	Lump Sum	Removal of pole, flasher, foundation, sign, and power source.	Each flashing beacon removal requires a separate 730Y pay item.
730Y-140 thru 730Y-160	Removal of Pedestal Pole and Foundation With Illuminated School Zone Sign	Lump Sum	The cost of all labor, equipment, and materials required for the removal of an illuminated school zone speed limit sign, including foundation and pedestal.	This pay item should be used for removal of pedestal mounted illuminated school zone signs. Each pedestal removal requires a separate pay item number.
730Y-600 thru 730Y-610	Furnishing And Installing Pedestal Pole And Foundation With LED Pedestrian Signal Head	Lump Sum	The cost of all labor, equipment, and materials required for the installation of a pedestal pole and LED pedestrian signal head, including foundation.	This pay item should be used for pedestal mounted pedestrian signal heads. Each pole requires a separate pay item number.
730Z-000	Computer Equipment, Desktop	Lump Sum	Computer, monitor, modem, keyboard, and all peripheral equipment.	Typically specified as a central monitoring computer for closed loop systems. Check bid specs to make sure computer has not already been specified under miscellaneous equipment.
730Z-001	Computer Equipment, Laptop	Lump Sum	Computer, modem, and all peripheral equipment.	Typically specified as a central monitoring computer for closed loop systems. Check bid specs to make sure computer has not already been specified under miscellaneous equipment.
756A-0XX	__in. Electrical Conduit, __ Line(s), Type __ Installation	Linear Foot	<p>Cutting, trenching, conduit, encasement, and backfill.</p> <p>Type 1 Installation = Open trench with concrete encasement.**</p> <p>Type 2 Installation = jack and bore with steel pipe encasement.</p> <p>Type 3 Installation = open trench with bituminous backfill.</p> <p>Type 4 Installation = open trench with steel pipe encasement and backfill.</p> <p>Type 5 Installation = directional bore with HDPE encasement.**</p> <p>**Note: ALDOT typically uses Type 5 and Type 1 installations.</p>	<p>Pay items for encased conduit under roadways and driveways. Size refers to diameter of encasement. See Section 8.3 for discussion of encased conduit.</p> <p>Type 1 installations are typically used in earth or under dirt or gravel driveways.</p> <p>Type 2 is a standard jack and bore encasement for underneath roadways and paved driveways, but has generally been superseded by the Type 5 installation.</p> <p>Type 3 utilizes an open trench cut in a roadway surface. It is generally used in cases where physical constraints make boring impractical or where a very small quantity of encasement makes boring uneconomical. Boring under State highways is preferred in most cases.</p> <p>Type 4 is similar to Type 1 except uses steel encasement instead of concrete. Typically used in earth or under dirt or gravel driveways.</p> <p>Type 5 is a precision directional bore. It is the preferred method for installing conduit under pavement.</p>

<b>Fiber Optic Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
734A-008 thru 734A-017	Cable OSP, Loose Tube, ___F SM	Linear Foot	Fiber optic cable and installation.	18F through 144F single mode fiber optic trunk cable. Minimum recommended fiber count for interconnect is 24F. Consult ALDOT for fiber count prior to plan preparation.
734A-100	Messenger Wire	Linear Foot	Messenger wire and installation.	Messenger wire is required for aerial fiber optic cable installations unless the cable is to be lashed to an existing cable or messenger wire. This pay item should not be used for traffic signal span wire.
734B-004 thru 734B-007	Drop Cable OSP ___F SM Central Core	Linear Foot	Drop cable and installation. Does not include splices or splice closure.	4 through 12 fiber, single mode cable. Standard drop cable is 12F SM, but it can not be routed through a standard weatherhead. 6F SM can be routed through a weatherhead but approval should be obtained before specifying 6F drops.
734E-000	Detectable Tape System	Linear Foot	Detectable tape installed (includes tone wire). Does not include conduit.	Fiber optic cable in non-metallic conduit is not detectable above ground. Detectable tape must be applied to all non-metallic conduit carrying fiber. Quantity typically equals conduit quantity.
734E-014 thru 734E-027	Buried Duct HDPE SDR11 ____ Inch	Linear Foot	Complete conduit installation. Should be used for fiber optics only.	Standard conduit for new fiber installation is 2 x 2 in. HDPE. Designer should also specify detectable tape system (see 734E-000). To be used for fiber optics only. For standard signal conduit, see 730L- ).
734E-028 thru 734E-039	Conduit PVC Schedule 40 ____ Inch	Linear Foot	Complete conduit installation	Not for general traffic signal fiber optic use.

\* Note: OSP refers to "Outside Plant", meaning fiber optic cable suitable for external use. Loose tube means the fibers are free to move within the cable sheathing. All traffic signal fiber should be OSP and loose tube.

<b>Fiber Optic Pay Items</b>				
<b>Pay Item Number</b>	<b>Description</b>	<b>Unit of Measurement</b>	<b>Pay Item Includes</b>	<b>Comments</b>
734G-002	Connector FC Terminator SM	Each	Terminator and installation	Standard terminator for single mode (SM) fiber. A terminator is a fitting attached to the end of a fiber that allows it to be plugged into a modem. See section 10.4 for guidance on the number of terminators to specify.
734G-001 734G-004	Connector ST Termination SM Connector SC Termination SM	Each	Terminator and installation	These terminators are no longer used for new installations but may be required for modifications of older interconnect systems. Single mode (SM) and multi-mode (MM) fibers require different terminators. See section 10.4 for guidance on the number of terminators to specify.
734G-005	Splice Closure, Aerial With Trays	Each	Aerial mounted splice closure, splice tray, and installation. Does not include splices.	Each aerial splice point must have an aerial splice closure. Size of tray to be determined by contractor.
734G-006	Splice Closure	Each	Closure and installation. Does not include tray or splices.	Generic splice closure. In most cases the designer should specify either 734G-005 (aerial) or 734G-100, 120, or 140 (undergrade).
734G-009	Splicing, Fusion	Each	Labor and materials to fusion splice two fibers.  Does not include splice closure or tray.	Each drop cable and reel end junction requires splices. See Section 10.4 for guidance on the number of splices required. A drop cable typically requires 4 splices. For reel end splices, the number of splices equals the number of fibers in the cable.
734G-010	Splicing, Mechanical	Each	Labor and materials to mechanically splice two fibers.	This splicing method is not used for signal applications.
734G-100 734G-120 734G-140	Splice Closure, Undergrade, 12 Fiber Splice Closure, Undergrade, 72 Fiber Splice Closure, Undergrade, 144 Fiber	Each	Splice closure, splice tray, and labor to install. Does not include splices.	Used for underground splices points. Specify smallest enclosure appropriate for fiber count. 12F closure is adequate for most drop cables. 72F and 144F closures are typically used for reel end splices.
734J-000	Comm Box F1	Each	Complete installation.	
734J-001	CommBox F2	Each	Complete installation.	
734J-003	Pull Box (24 In x 24 In x 12 In) Alum	Each	Complete installation.	
734J-004	Pull Box (36 In x 36 In x 24 In) Alum	Each	Complete installation.	
734N-001	Fiber Optic Transceiver, Remote SM, Data	Each	Transceiver and power supply. Does not include connectors.	A transceiver (fiber modem) is required for each fiber drop when an Ethernet switch is not used. This type of data-only modem is sufficient for most traffic signal applications.

# ***Chapter 14***

## ***Signal Timing Concepts***

This Chapter presents a discussion of the fundamentals of signal timing for isolated signals and signals in coordinated systems that may operate isolated during certain periods of the day. This manual does not cover coordinated signal system timing, which is more complex and will be covered in a separate manual. Suggested references for coordinated signal timing are provided at the end of this Chapter.

### **14.1 Pre-Timed vs. Actuated Signals**

Isolated traffic signals may operate either pre-timed, in which case they run a set timing pattern regardless of traffic conditions, or actuated, meaning they vary phase times based on traffic demand. There are advantages and disadvantages to each mode of operation.

Pre-timed (or non-actuated) signals have the benefit of being relatively inexpensive to install because they have no vehicle detectors, which can account for 25% or more of signal installation costs. They are also much cheaper to maintain, since vehicle detectors are one of the primary sources of maintenance costs, and in particular in-pavement detector loops. Fixed-time signals are also easier to time in coordinated systems because their phase times are fixed and predictable.

Pre-timed signals are most commonly used in areas where traffic volumes are fairly consistent, such as in downtown areas or low volume roads. They are also common in dense urban signal networks where the cost of installing and maintaining detectors can be prohibitive.

Actuated signals are more costly to install and maintain than non-actuated signals but can improve intersection capacity and operation, particularly when there is large variability in vehicle demand. Actuated signals will call a phase only when there is demand for that phase. They can also vary the amount of green time provided to each phase according to demand, so there is less “wasted” time providing green to a phase when no vehicles are present.

The majority of signals installed by ALDOT are actuated, although pre-timed signals are still installed under certain conditions. The designer should consult with the Region/Area Traffic Engineer to determine the type of signal required. The general principles of signal timing are similar for both pre-timed and actuated signals, but the two cases will be discussed separately because of the additional complexity associated with actuated signal timing.

## 14.2 Timing Pre-Timed Signals

Because they run on constant cycle lengths and splits, pre-timed signals require fewer input parameters than actuated signals. All pre-timed signals will, as a minimum, require the following settings:

- Cycle length
- Green time for each phase
- Yellow clearance interval for each phase
- All-red clearance interval for each phase

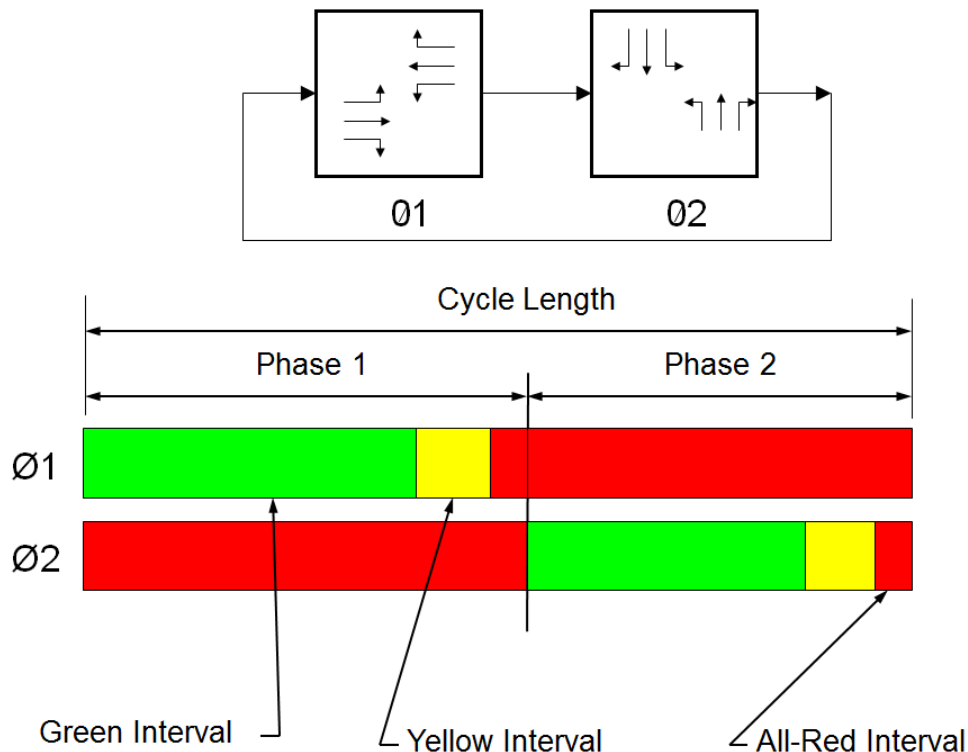
Each of these settings is described in the following sections.

### 14.2.1 Terminology

Four basic concepts in signal timing are interval, phase, cycle, and split. They are defined as follows:

- Interval – An individual green, yellow, or red indication
- Phase – A complete set of green, yellow, and all red intervals serving a single movement or a set of concurrent movements
- Cycle – The time required for a signal to run through all programmed phases
- Split – The portion of a cycle used by a single phase, expressed as a percent (phase time)/(cycle time), or in seconds (phase time).

These are illustrated for a simple two phase signal in Figure 14.1.



**Figure 14.1 – Illustration of cycle length, phase, and interval**

### 14.2.2 Cycle Length (Pre-Timed)

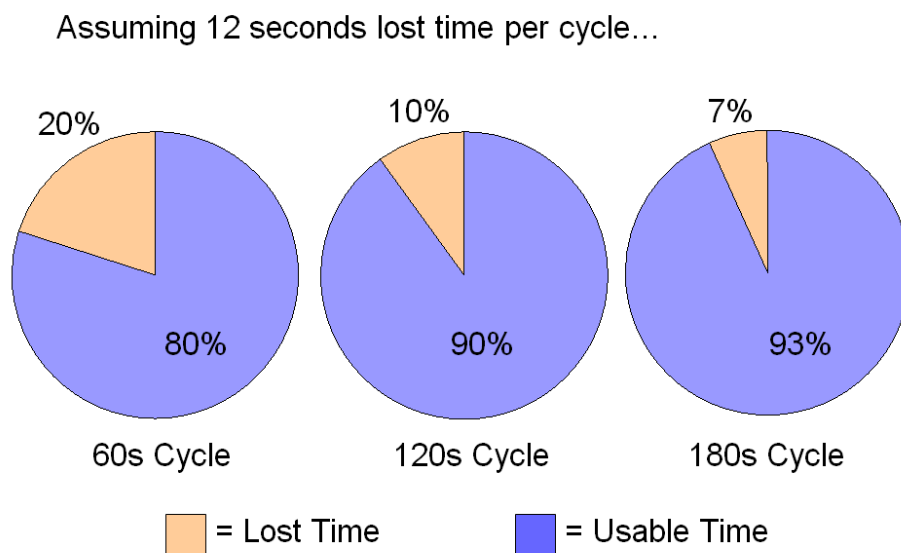
Cycle length is important to the function of an intersection and has a significant impact on intersection capacity and vehicle delays. The cycle length should therefore be chosen carefully. The following sections discuss the effects of cycle length on intersection capacity, vehicle queues, and vehicle delays.

#### 14.2.2.1 Cycle Length and Capacity

As a general rule, intersection capacity increases as the cycle length increases. This is because for every phase there is an associated “lost time” that is fixed regardless of cycle length. Lost time refers to time within a phase that is not used for vehicle movements. It includes:

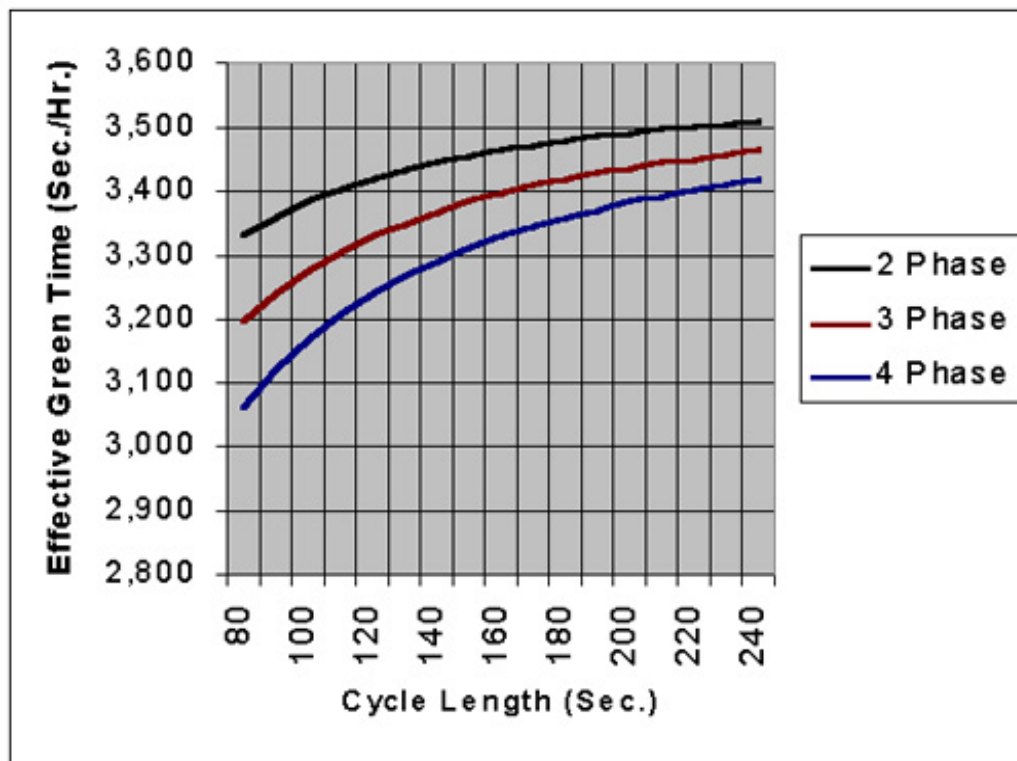
- Startup lost time – The time required by the initial vehicles in a queue to respond to a green indication and begin accelerating through the intersection. Typically 3-4 seconds per phase.
- Yellow clearance time – Typically half of the yellow clearance interval is assumed to be lost time.
- All-red clearance time – All of the all-red clearance interval is assumed to be lost time.

For a typical signal, there may be 6-8 seconds of lost time per phase, which significantly reduces capacity because that time is not being used to move vehicles through the intersection. For even a simple two phase signal with a low cycle length, this can comprise a significant portion of the total cycle length. Because lost time is generally fixed regardless of cycle length, lower cycle lengths will have a larger percentage of the total cycle time consumed by lost time than higher cycle lengths. Figure 14.2 provides an illustration of a simple two phase signal where the lost time is assumed to be 6 seconds per phase, or a total of 12 seconds per cycle. If the cycle is set to 60 seconds the lost time will account for 20% of the total cycle time. If, however, the cycle length is set at 120 seconds, the lost time is only 10% of total cycle time, allowing a greater percentage of the total cycle to be used moving vehicles through the intersection.



**Figure 14.2 – Illustration of lost time vs. cycle length**

It can be seen in Figure 14.2 that the impact of increasing the cycle length on the percent lost time diminishes as the cycle lengths increase. In fact, as Figure 14.3 illustrates, the gains in intersection capacity begin to diminish significantly as cycle lengths increase above 120 seconds. Above 180 seconds, increasing the cycle length will generally result in only minor increases in capacity.



**Figure 14.3 – Effect of cycle length on intersection capacity**  
(Source: CITE Training Course, 2004)

At high cycle lengths other factors such as vehicle queuing begin to have a greater influence on intersection capacity than does lost time, and the net result is that intersection capacity will usually begin to decrease above some threshold cycle length.

#### 14.2.2.2 Cycle Length and Queuing

As cycle lengths increase, average queue lengths also increase, due to the fact that there are fewer cycles per hour and therefore more vehicles must be served during each cycle. These increased queues can affect intersection operation in several ways. First, they increase the probability that vehicle queues will exceed the capacity of storage bays and block travel lanes. Second, they can create 'spillback', where a vehicle queue at one intersection affects operations at an adjacent intersection. Third, very long vehicle queues (in excess of several hundred feet) often do not discharge as efficiently as shorter queues, so gains in capacity resulting from reducing lost time may be offset by more inefficient queue discharge.

Selection of a cycle length should consider not only capacity and delay but also the impact the cycle length will have on vehicle queues. It is recommended that the designer use an analysis package such as Highway Capacity Software or Synchro to estimate 95<sup>th</sup> percentile queues on all movements and compare those estimates to available storage lengths and intersection spacing. If it appears that spillback or overflow is likely, the designer should consider adjusting the cycle length.



### 14.2.2.3 Cycle Length and Delay

Cycle lengths directly influence vehicle delays at intersections. Generally, in order to minimize delays shorter cycle lengths are preferred. However, increasing intersection capacity often requires higher cycle lengths. Thus, capacity and delay requirements are often in conflict.

Generally, the shortest cycle length that will satisfy capacity requirements should be used. The designer should note that while higher cycle lengths will typically increase intersection capacity and reduce delay for major movements, they will often significantly increase delay for minor movements.

### 14.2.2.4 Computing the Optimum Cycle Length

A general equation for manually computing the optimum cycle length to minimize delay is provided by Webster:

$$C = \frac{1.5L + 5}{1.0 - Y_i}$$

where: C = optimum cycle length (sec)  
L = sum of lost time per cycle  
Y<sub>i</sub> = critical lane volume (phase i, vph)/S  
S = saturation flow rate (vph)

For calculation purposes, the value of L can be assumed to be the sum of all yellow and all-red intervals per cycle. S can be assumed to be 1800 vph. Y<sub>i</sub> is the ratio of the critical lane volume to the saturation flow rate for each phase. Note that when concurrent phases occur, the value of Y<sub>i</sub> is computed for the highest critical lane volume among those phases, not for each individual phase. More details of the Webster method can be found in the [ITE Traffic Signal Timing Manual](#).

One weakness of the Webster method is that the equation is sensitive to the accuracy of the lost time and saturation flow values, values that are not easily measured in the field. The equation also tends to yield cycle lengths that are shorter than necessary and does not readily incorporate pedestrian timings into the calculation. For these reasons, ALDOT recommends that designers use either capacity analysis software, such as HCM, or signal timing optimization software such as Synchro or Transyt to obtain an optimum cycle length. These software packages are themselves not without weakness and also tend to yield cycle lengths that are too short, but they readily incorporate pedestrian phases into the calculations and provide other useful measures of effectiveness, such as vehicle queuing, that can aid the designer in selecting an appropriate cycle length.

In reality, it is difficult to determine a precise optimum cycle length because of uncertainties in driver behavior and variability in traffic volumes. The designer is really attempting to select an approximate optimum for a period that will often extend over several hours. Research indicates that intersection delay typically increases more rapidly as the cycle length falls below optimum than it does above optimum. This is illustrated in Figure 14.4. What Figure 14.4 suggests is that when the optimum cycle length is in question it is generally better to err on the high side than the low side.

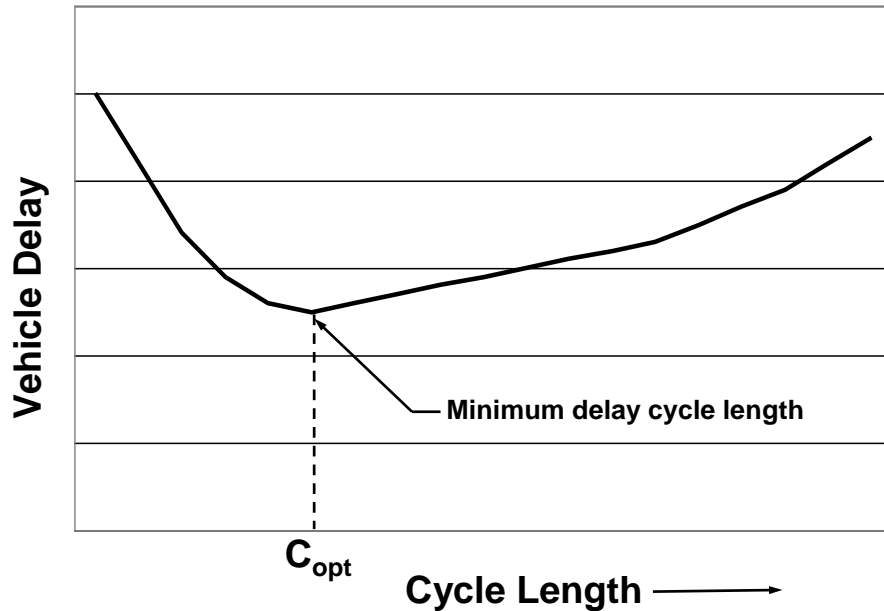


Figure 14.4 – Intersection delay vs. cycle length (typical)

Generally, as the number of phases used increases so does the optimum cycle length. This is due to the amount of lost time associated with each additional phase. Some useful rules of thumb for checking the reasonableness of a cycle length relate to the number of phases used. Cycle lengths typically should not fall below the values shown in Table 14.1.

Table 14.1 – Minimum recommended cycle lengths

Number of phases used	Min. cycle length
2	45
4	60
8	80

The maximum recommended cycle length depends on a number of factors, such as degree of saturation at an intersection and whether or not it is part of a coordinated system. In most cases where the intersection volume/capacity (V/C) ratio is less than 0.80, satisfactory operation can be achieved with cycle lengths less than 130 seconds. In cases where the V/C ratio exceeds 0.90, cycle lengths of up to 180 seconds may be required. Some very general guidelines regarding typical cycle length ranges are shown in Table 14.2.

Table 14.2 – Typical cycle length ranges

Traffic Volumes	Typical Cycle Length Range
low	50 – 90 sec.
moderate/high	90 – 130 sec.
congested	130 - 180 sec.

The cycle lengths shown in Table 14.2 are intended as a simple reference against which to check the reasonableness of a cycle length. Optimum cycle lengths may well fall outside of these ranges. ALDOT generally does not recommend cycle lengths in excess of 180 seconds unless the intersection is part of a coordinated system and then only after careful analysis. The designer should always select the lowest cycle length that affords reasonable operation.

### 14.2.3 Computing Green Interval (Pre-Timed)

Once a cycle length has been selected, the green interval for each phase can be computed. For a fixed time signal, the green interval will time to its full duration every cycle, so the designer should attempt to select values for the green intervals that accommodate most variations in demand without providing excessive green to any one phase.

The most common method of determining green times is to apportion the cycle time in proportion to the critical lane volume for each phase. The green time for phase  $i$  would therefore be computed as:

$$G_i = C \left( \frac{Y_i}{\sum_i Y_i} \right) - Y_{el_i} - AR_i$$

where:  $G_i$  = green time for phase  $i$  (sec)

$C$  = cycle length (sec)

$Y_i$  = critical lane volume for phase  $i$   
(vph)

$Y_{el_i}$  = yellow interval for phase  $i$  (sec)

$AR_i$  = all-red interval for phase  $i$  (sec)

The designer should check all green times to ensure that they can accommodate any pedestrian movements present (see section 14.9.1). The designer should also check the computed green times against the minimum recommended green times for different movement types shown in Table 14.3. The purpose of these minimums is to ensure that the green times are not so short that they violate driver expectancy. If the computed greens are less than the minimums shown, the green times should be increased and the cycle length recalculated. If signal optimization software is being used, these minimum green times should be coded before computing the optimum cycle length.

**Table 14.3 – Minimum green intervals for pre-timed signals**

Movement Type	Initial Green Time
Major Street Thru ( $\geq 45$ mph)	20 sec.
Major Street Thru ( $< 45$ mph)	15 sec.
Major Street Left Turn	6 sec.
Minor Street Thru	8 sec.
Minor Street Left Turn	6 sec.

### 14.3 Yellow Clearance Interval

The purpose of the yellow clearance interval is to alert drivers that the green interval is being terminated and that right of way is being assigned to another movement. The yellow interval should provide drivers with adequate time to either stop before entering the intersection, or if close enough, to proceed through the intersection before the light turns red. By Alabama law, a vehicle may be in the intersection during the red interval as long as it has crossed the stop line prior to the light turning red.

The yellow interval is critical to intersection safety and should be set very carefully. In some municipalities a designer may encounter 'rules of thumb' whereby yellow intervals are set to standard values such as 3 or 4 seconds regardless of prevailing conditions, however, failure to account for speed

and geometric conditions can create unsafe operating conditions and generic 'rules of thumbs' should not be used. ALDOT standards for yellow clearance intervals are discussed in the following sections.

### 14.3.1 Discussion of the Dilemma Zone

When computing the yellow clearance interval the designer must be careful not to create a dilemma zone for drivers. A dilemma zone is created during a yellow interval when a vehicle has neither enough yellow time in which to reach the stop line nor enough distance in which to safely stop. A dilemma zone is the result of an improperly set yellow clearance interval and should be avoided.

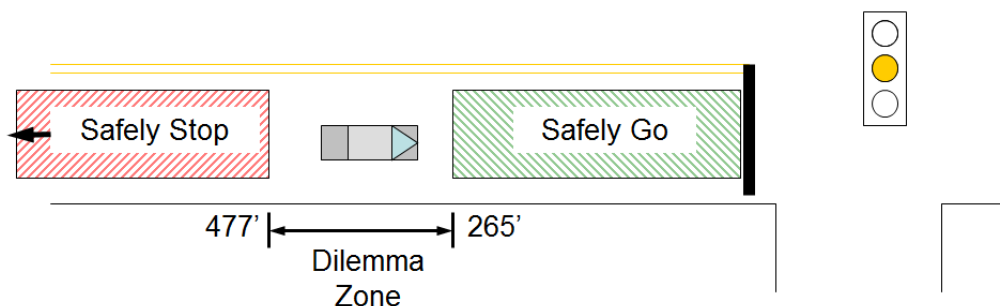
The dilemma zone can be illustrated in the following example. Vehicles traveling at 60 mph approach an intersection where the yellow interval has been arbitrarily set to 3.0 seconds. When the light turns yellow, each driver must decide whether he should a) continue through the intersection or b) stop for the light. In the first case, Alabama law states that a vehicle may enter an intersection (i.e., cross the stop line) at any point during the yellow interval, so in order to continue through the intersection a vehicle must be able to reach the stop line during the yellow interval. A vehicle traveling at 60 mph covers  $60 \times 1.47 = 88.2$  ft/sec. During the 3 seconds of yellow in this example, a vehicle will be able to travel  $88.2$  ft/sec  $\times$   $3.0$  sec = 265 feet, so any vehicle within 265 feet of the stop line when the light turns yellow will be able to safely proceed through the intersection at its current speed, as shown in Figure 14.5.

For drivers choosing to stop, they will need to have sufficient distance to brake at a safe rate and stop before the stop line. The minimum braking distance equals the reaction distance plus the deceleration distance and can be computed as follows:

$$S = rV + \frac{V^2}{2(a + Gg)}$$

where: S = minimum braking distance (ft)  
 r = reaction time (assume 1 sec)  
 V = vehicle speed (ft/sec)  
 a = deceleration rate (10 ft/sec<sup>2</sup>)  
 G = grade (expressed as decimal)  
 g = accel. due to gravity (32.2 ft/sec<sup>2</sup>)

Assume: V = 60 mph  
 Yellow = 5.4 sec.  
 Grade = 0%

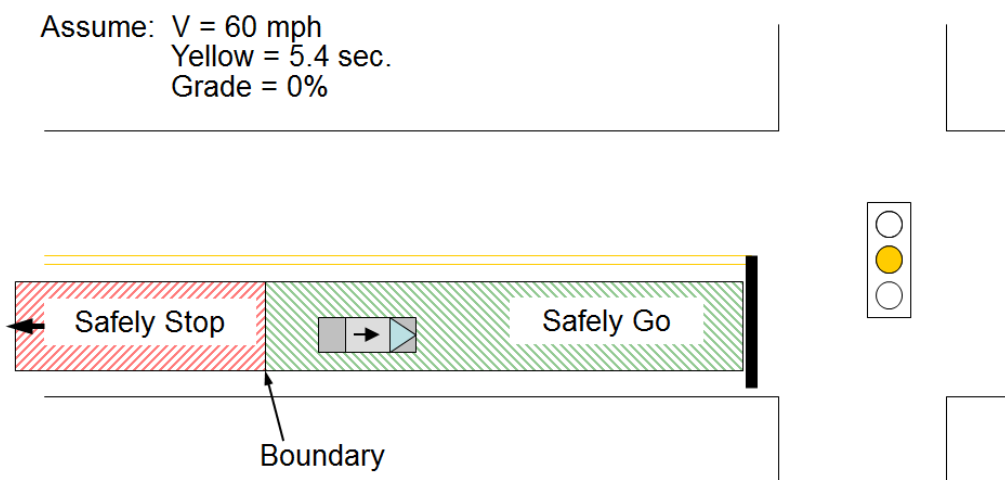


**Figure 14.5 – Illustration of the dilemma zone**

In this example where the grade = 0%, the minimum braking distance equals:  $(1)(88.2) + [(88.2)^2/(2)(10)] = 477$  ft. Vehicles which are 477 ft or more from the stop line when the light turns yellow can safely stop before entering the intersection, as shown in Figure 14.5. But Figure 14.5 also illustrates that there is an area between 265 ft and 477 ft from the stop line where vehicles are too far from the stop line to pass through on the yellow but too close to the stop line to safely stop. This is the 'dilemma zone'. Motorists caught in the dilemma zone have three choices: 1) accelerate to clear the stop line before the light turns yellow, 2) brake hard in order to stop before the stop line, or 3) continue at their present speed and simply run the red light. None of these choices is desirable from a safety standpoint.

By incorrectly setting the yellow interval in this example to 3 seconds the designer has created a dilemma zone where motorists are forced into unsafe driving decisions. It would be desirable instead to set the yellow interval so that there was no such dilemma zone. This can be accomplished by setting the yellow interval so that the distance traveled by a vehicle during the yellow is equal to the braking distance, or  $\text{Yellow (sec)} = \text{Braking Distance (ft)} / \text{Speed (ft/sec)}$

In this case, the yellow interval should equal to  $(477 \text{ ft}/88.2 \text{ ft/sec}) = 5.4$  sec. Setting the yellow interval to 5.4 seconds eliminates the dilemma zone for vehicles traveling at 60 mph, as shown in Figure 14.6.



**Figure 14.6 – Yellow interval set to minimize dilemma zone**

In the above example the dilemma zone was theoretically eliminated through the proper setting of the yellow interval, but in reality the dilemma zone can never really be eliminated. Variations in vehicle speeds mean there will always be a dilemma zone for some drivers. However, by computing the yellow interval as described above the designer can minimize the dilemma zone for drivers. In general it is recommended that the yellow interval be based on the 85<sup>th</sup> percentile approach speed of the roadway. When such measurements are not available, the posted speed limit may be used but the designer should verify that there is not significant variation from the posted speed.

#### 14.3.2 Computing the Yellow Clearance Interval

The yellow clearance interval is computed as follows:

$$Y = t + \frac{1.47 * V_{85}}{(2d + 64.4G)}$$

where: Y = yellow interval (sec)  
 t = reaction time (assume 1.4 sec)  
 $V_{85}$  = 85<sup>th</sup> percentile speed (mph)  
 d = deceleration rate (10 ft/sec<sup>2</sup>)  
 G = grade (expressed as decimal)

**Table 14.4 – Recommended Minimum Yellow Clearance Intervals (seconds)**

Approach Speed (mph)	Approach Grade								
	Downhill				-2% to 2%	Uphill			
	-5%	-4%	-3%	> -2%		>+2%	+3%	+4%	+5%
25	3.6	3.5	3.4	3.4	3.2	3.1	3.1	3.0†	3.0†
30	4.0	3.9	3.8	3.8	3.6	3.5	3.4	3.4	3.3
35	4.5	4.4	4.2	4.1	4.0	3.8	3.7	3.7	3.6
40	4.9	4.8	4.7	4.5	4.3	4.2	4.1	4.0	3.9
45	5.3	5.2	5.1	4.9	4.7	4.5	4.4	4.3	4.2
50	5.8	5.6	5.5	5.3	5.1	4.9	4.8	4.7	4.6
55	6.0‡	6.0‡	5.9	5.7	5.4	5.2	5.1	5.0	4.9
60	6.0‡	6.0‡	6.0‡	6.0‡	5.8	5.5	5.4	5.3	5.2
65	6.0‡	6.0‡	6.0‡	6.0‡	6.0‡	5.9	5.8	5.6	5.5

† Yellow clearance intervals less than 3.0 seconds shall not be used.

‡ Contact the ALDOT Region/Area Traffic Engineer before using yellow clearance intervals in excess of 6.0 seconds.

**Table 14.5 – Recommended Minimum All Red Clearance Intervals (seconds)**

Approach Speed (mph)	Intersection Width (feet)										
	20	30	40	50	60	70	80	90	100	110	120
25	1.1	1.4	1.6	1.9	2.2	2.4	2.7	3.0	3.3†	3.5†	3.8†
30	0.9	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.9	3.2†
35	0.8	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.7
40	0.7	0.9	1.0	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4
45	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1
50	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6	1.8	1.9
55	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7
60	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6
65	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.3	1.4	1.5

† Contact the ALDOT Region/Area Traffic Engineer before using all-red clearance intervals in excess of 3.0 seconds.

Table 14.4 presents minimum yellow clearance intervals for a range of approach grades and speeds. The designer should also note the following guidelines:

- Yellow intervals less than 3.0 seconds shall not be used
- It is generally recommended that yellow clearance intervals for opposing thru movements be equal
- For intersections that lie on a grade, e.g., one approach is a downgrade and the opposing approach is an upgrade, use the longer computed yellow clearance interval for both opposing thru movements
- Yellow intervals longer than 5.0 seconds may encourage red light running. The designer may wish to investigate ways to lower approach speeds if computed yellow intervals are in excess of 5.0 seconds. Yellow intervals greater than 6.0 seconds shall not be used without the approval of the Region/Area Traffic Engineer

## 14.4 All-Red Interval

The purpose of the all-red interval is to allow any vehicles that entered the intersection during the yellow interval to safely clear the intersection before a green indication is given to a conflicting movement. The all-red interval is computed by dividing the width of the intersection plus the average length of a vehicle by the vehicle speed.

$$\text{All Red (sec)} = (W+L) / (V*1.47)$$

where: W = intersection width (ft, see Fig. 14.7)  
 L = average vehicle length (assume 20 ft.)  
 V = approach speed (mph)

The intersection width should be computed as shown in Figure 14.7. Table 14.5 presents all red intervals computed for a range of approach speeds and intersection widths. These calculations assume a 20 foot passenger vehicle. If the traffic stream contains a very high percentage of large trucks the value of L in the formula above can be increased. All red intervals in excess of 3.0 seconds shall not be used without the approval of the Region/Area Traffic Engineer.

When computing the all-red interval for a left turn phase, the intersection width 'W' is the outside length of the left turn arc as shown in Figure 14.7. If the turning arc is circular with a radius 'r' then this value is typically  $W = \pi r/2$ . If the arc is not circular (i.e., elongated) it should be measured manually. For standard left turn configurations the designer should assume a turning speed of 25 mph. For skewed intersections or tight turns, a turning speed of 15 mph should be used.

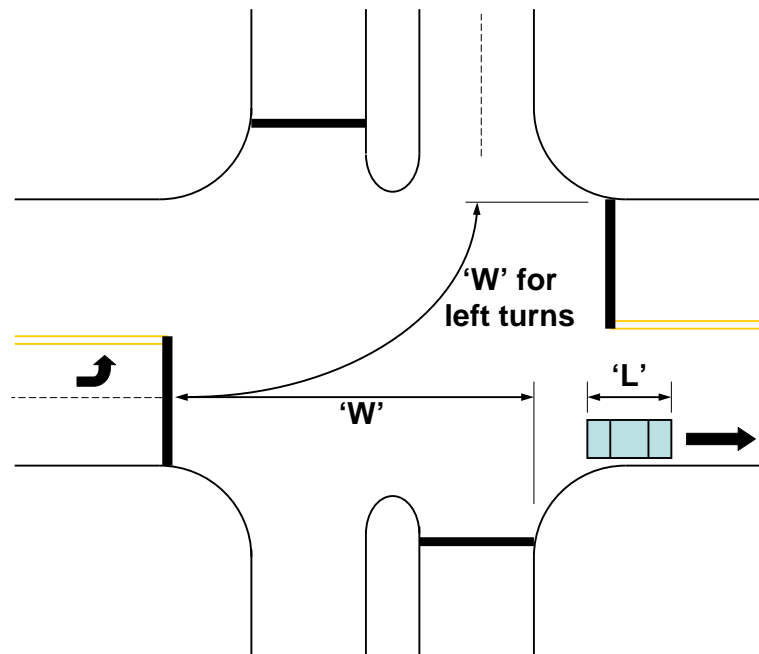


Figure 14.7 – Measuring intersection width for the all-red clearance interval

## 14.5 Timing for Actuated Signals

Actuated signals require more complex inputs than do pre-timed signals. As a minimum, an actuated signal requires the following timing parameters:

- Cycle length (min and max)
- Minimum green
- Maximum green
- Passage time
- Volume-density settings (when active)
- Yellow clearance interval
- All-red clearance interval

### 14.5.1 Cycle Length (Actuated Signals)

The concept of cycle length is slightly different for actuated signals than it is for pre-timed signals. Because an actuated signal will activate a phase only if there is demand and can terminate a phase in the absence of demand, the cycle length will typically vary between a minimum and maximum value. This minimum and maximum cycle length is determined by the minimum green interval, maximum green interval, and clearance intervals. When activated, each phase will display green for the minimum green time regardless of demand. After the minimum green has expired, the green phase can be extended by detector calls up to the maximum green, after which the green will be terminated regardless of demand. The period between the minimum green and the maximum green is known as the variable green, as illustrated in Figure 14.8.

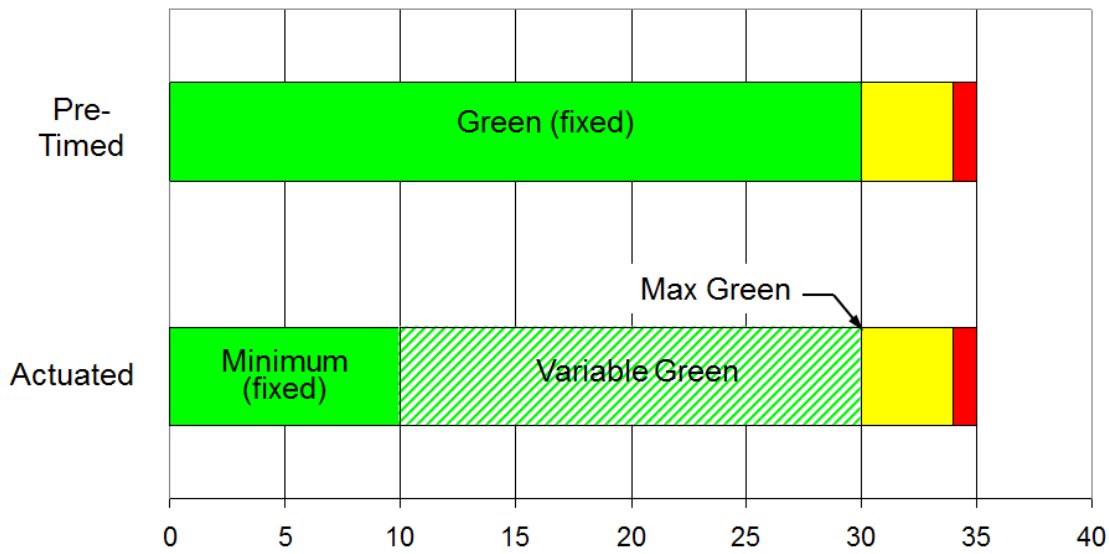
The minimum cycle length equals the sum of the minimum green time, yellow time, and all red time for each phase. This assumes that each phase is called during the cycle; if one or more phases is omitted then the cycle length will be even shorter. The maximum cycle length is the sum of the maximum green time, yellow time, and all-red time for each phase. (Note: for eight phase operation, compute the minimum/maximum cycle length for phases 1-4 and then for phases 5-8 and use the lower/higher of the two). Figure 14.9 illustrates the minimum and maximum cycle lengths for a simple two phase signal.

### 14.5.2 Minimum Green (Actuated Signals)

The minimum green interval (sometimes called the initial green interval) can serve several functions:

- When setback loops are used, it provides time for vehicles queued between the stop line and setback loops to startup and clear the stop line.
- When presence loops are used, it provides a small amount of time to allow queued vehicles to start up and begin moving before the detectors are relied on to extend the green phase.
- At intersections where separate pedestrian phases are not provided, it can be used to ensure the necessary amount of green to allow pedestrians to safely cross an approach. See section 14.9.1 for further discussion.





Note: Yellow & all-red times are constant for both fixed-time and actuated operation.

Figure 14.8 – Fixed-time vs. actuated phases

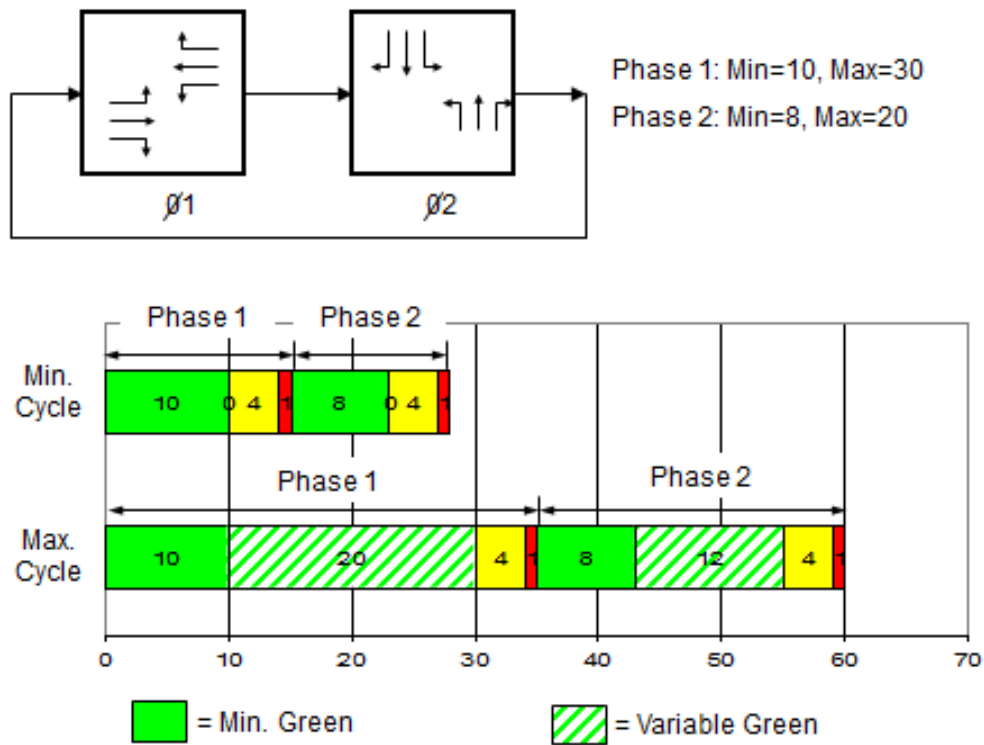
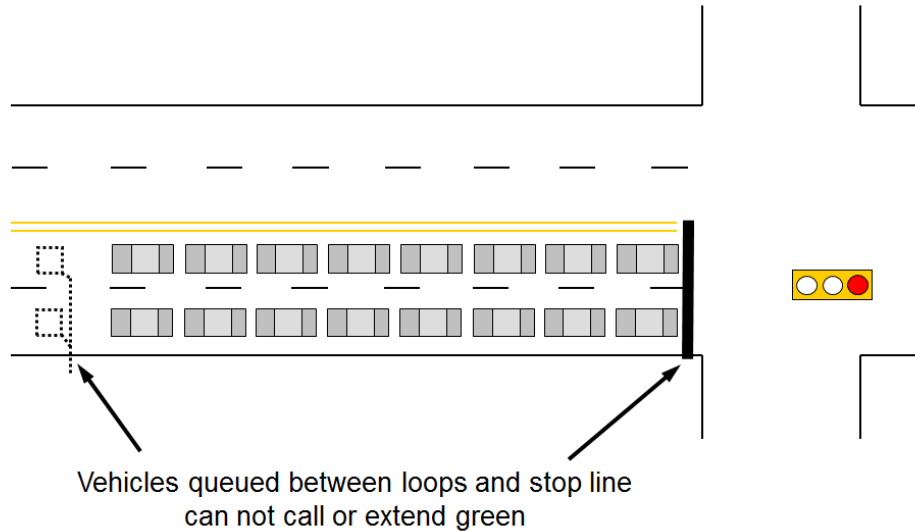


Figure 14.9 – Example of min and max cycle lengths

### 14.5.2.1 Minimum Green for Setback Detectors

When setback detectors are used, vehicles will queue between the stop line and the setback detectors during the red interval. Since they are queued past the detectors, these queued vehicles have no means of either calling or extending the green phase, as illustrated in Figure 14.10.



**Figure 14.10 – Setback loops and vehicle queues**

The minimum green interval is used to provide enough time to clear any vehicles that may be queued between the detectors and stop line. The minimum green interval can be computed for a given detector setback distance as follows:

$$G_{\min} = [(D/L) \times 2.1] + 3.7$$

where:  $G_{\min}$  = minimum green time (sec)  
 D = detector setback distance (ft)  
 L = avg. vehicle length (assume 25 ft)

In Alabama, setback loops are typically used when the approach speeds on the mainline are at least 30 mph (corresponding to a loop setback distance of 140 feet), however, there may be existing cases where a setback loop is located closer to the stop line. Table 14.6 presents typical minimum green values for various detector setback distances. When setback distances are greater than or equal to 140 feet, the designer should use volume-density settings.

**Table 14.6 – Min. Green settings vs. detector setback**

Detector Setback (ft from stop line)	Min. Green (sec)
40	7
60	9
80	11
100	12
120	14
≥ 140	use volume-density settings

#### 14.5.2.2 Minimum Green for Presence Detectors

When presence detectors are provided at the stop line, the minimum green interval need only provide enough time to allow the vehicle queue to begin moving so that there is not premature gap out due to slow vehicle start up. Minimum green times on left turns and minor movements are therefore typically set fairly short. For the major thru movement it is recommended that the minimum green time be set to a minimum of 15 seconds when approach speeds are less than 45 mph and 20 seconds when approach speeds are 45 mph or greater.

Minimum green times may be set higher on minor movements if conditions exist which may impede vehicle startup and lead to premature gap out. Such conditions can include:

- Approach is on an upgrade of 4% or more, causing slow vehicle startup and increased lost time for queued vehicles
- Approach has a high percentage of heavy truck traffic, resulting in slower vehicle startup

A summary of recommended minimum green times is presented in Table 14.7.

**Table 14.7 – Recommended minimum green times**

Movement	Initial Green Time
Major Street Thru (≥45 mph)	20 sec.
Major Street Thru (<45 mph)	15 sec.
Major Street Left Turn	4 sec.
Minor Street Thru	6 sec.
Minor Street Left Turn	4 sec.

#### 14.5.2.3 Minimum Green Times for Pedestrian Timing

See section 14.9.1 for details of setting minimum green times when pedestrian detectors are not provided.

#### 14.5.3 Maximum Green Time/Max Green 2

With actuated signals, the Maximum Green time is the maximum amount of time the controller will allow a given phase to remain green when there is a call on a conflicting phase. Because a phase can be terminated in the absence of vehicle demand, the maximum green times can be set higher for actuated signals than for pre-timed signals without adversely affecting intersection performance. Maximum green times can be set high enough to accommodate brief spikes in demand without making signal operation sluggish during off-peak periods. Some key points concerning the maximum green setting:

- The maximum green interval does not begin timing until a call is received on a conflicting phase. If the minimum green interval expires but there is no call on a conflicting phase, the signal will 'rest' in green until a conflicting call is received.
- Under ideal conditions with a signal operating below capacity, a phase should rarely reach maximum green ('max out'). The maximum green should be set high enough that a phase will typically 'gap out' before reaching max green. This ensures there is excess green time to accommodate variations in demand.
- As a signal approaches capacity, phases will tend to 'max out' more often. At capacity, most phases 'max out' every cycle and the signal will essentially operate pre-timed.

When computing maximum green times for signal phases, the designer should first have a good idea whether the signal will be operating well below capacity ( $V/C$  ratio  $\leq 0.80$ ), near capacity ( $V/C$  ratio between 0.81 and 0.90), or at capacity ( $V/C$  ratio greater than 0.90). This affects how the max green times should be computed.

In the first case where a signal is expected to operate well below capacity, the maximum green time can be computed in much the same manner that green times are computed for pre-timed signals (see Section 14.2). Once an optimum cycle length has been determined the computed green times for each phase are typically multiplied by a factor of 1.5 to provide max green values. Under most conditions, the phases should 'gap out' near the computed green time and the signal should operate somewhere around the optimum cycle length, but setting the max green = (1.5 x computed green) ensures there will be excess green time to accommodate variations in demand when they occur.

When a signal is operating near capacity, the same method is used to compute the max green, only the factor used to multiply the computed green is smaller, typically around 1.2. Because phases will 'max out' more often as a signal approaches capacity, the max green should be set closer to the computed green in order to keep the signal operating somewhere near the optimum cycle length.

When a signal is expected to operate at capacity, individual phases will 'max out' frequently and the signal will effectively operate pre-timed. The max green times should therefore be set equal to the computed green times (i.e., the factor used to multiply the computed green = 1.0). This will ensure that the signal will operate near the optimum cycle length. Many designers will use signal timing optimization software to develop maximum green settings. It should be noted that these programs often attempt to maximize green times on major movements at the expense of minor movements. The result can be green settings on minor movements that are too short to properly serve traffic. When reviewing green times generated by software packages, the designer should make sure the times are reasonable, particularly on minor movements and left turns. Table 14.8 provides a brief summary of the maximum amount of green time required to discharge  $n$  vehicles per lane per cycle. The max greens should be checked against these values to ensure that they can adequately meet demand.

A designer will sometimes encounter situations where there is a distinct change in vehicle demand during certain parts of a day. An example could be a signal located near a school, where there are very large peaks in demand in the morning and afternoon but very little demand at other times of the day. Other examples could include signals located near hospitals or manufacturing plants where traffic dramatically spikes around shift changes. In these cases, the off-peak max green settings may not be sufficient to accommodate peak demand while maintaining efficient operation during off-peak times. The Max Green 2 setting (often called MAX2) allows a second set of maximum green settings to be used during certain periods of the day. The Max Green 2 settings are computed in the same manner as standard max green setting and invoked using a time of day plan.

**Table 14.8 – Green time required to discharge  $n$  vehicles (single lane)**

Vehicles per Cycle	Green Time Required (sec)
1	4.0
2	7.0
3	10.0
4	12.0
5	14.0
6	16.0
...	...
N	$2.1n + 3.7$

#### 14.5.4 Passage Time

The passage time is designed to provide a vehicle with time to travel from the detector to the stop line. When a vehicle passes a detector, the controller extends the variable green phase by a preset passage time in order to allow the vehicle to safely travel to the intersection. This serves two functions: 1) it extends the green phase to accommodate vehicle demand, and 2) it enhances safety by allowing vehicles to travel out of the dilemma zone before the green phase is terminated.

The passage timer will remain set at the passage time as long as a loop or detector is occupied by a vehicle. When the detector is vacated, the timer begins counting down from the passage time to zero. If the timer reaches zero before another vehicle activates the detector then the green interval has 'gapped out' and is terminated. If, however, a vehicle activates the detector before the timer has reached zero the timer is reset to the passage time and begins counting down again once the loop is vacated. The green will be extended either until the timer gaps out or the maximum green is reached.

The designer should note that the passage time extensions are not cumulative, meaning the green is not extended by one passage time interval for each detector actuation. A vehicle actuation simply resets the passage timer to the passage time and extends the green until the timer expires (or max green is reached). Figure 14.11 illustrates the function of a passage timer under both 'gap out' and 'max out' scenarios.

##### 14.5.4.1 Passage Time for Setback Detectors

Passage time is programmed for both setback (passage) detectors and presence detectors, but serves a slightly different purpose for each and should be set accordingly. For setback detectors, the passage time should be long enough to allow a vehicle to travel from the detector to the stop line before the green interval terminates. Passage times for setback loops are therefore based on approach speed and setback distance. Passage time for a setback detector can be computed as follows:

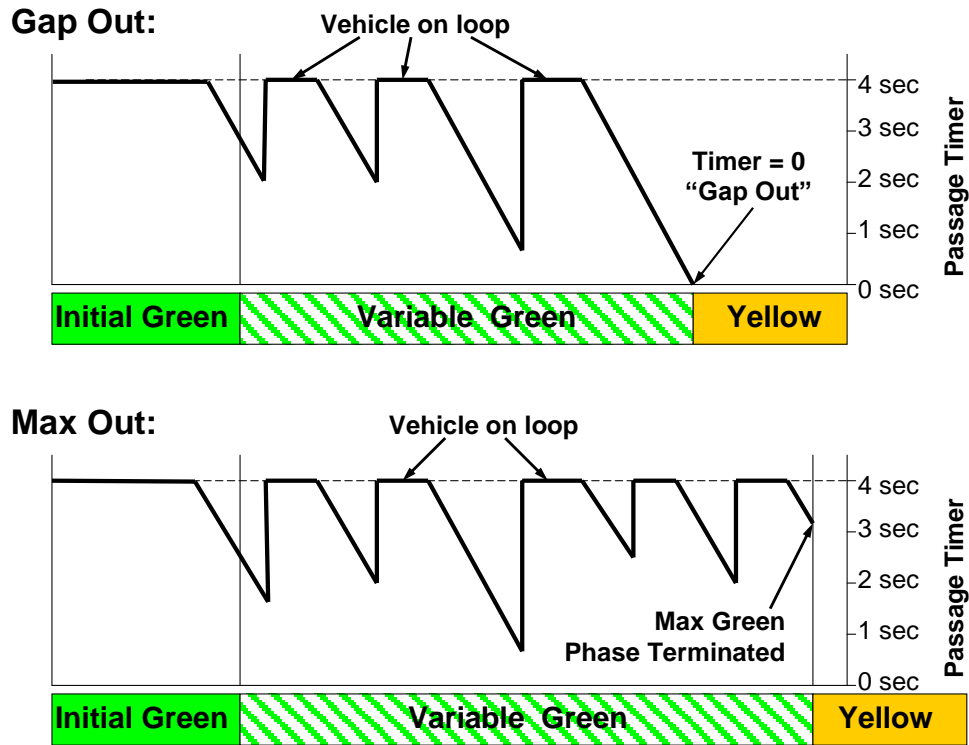


Figure 14.11 – Illustration of the passage timer under ‘gap out’ and ‘max out’ scenarios (passage time = 4.0 sec)

$$P = D / (V \times 1.47),$$

where:  $P$  = passage time (sec)  
 $D$  = detector setback from stop line (ft)  
 $V$  = 85<sup>th</sup> pcntl. approach speed (mph)

If the 85<sup>th</sup> percentile approach speed is not available, the posted speed limit may be used but the designer should verify that approach speeds do not vary significantly from the posted speed. Passage times for standard setback/approach speed combinations are summarized in Table 14.9 below.

Table 14.9 Standard passage times for setback detectors

Approach Speed (mph)	Loop Setback (ft)	Passage Time (sec)
30	140	3.1
35	185	3.6
40	230	3.9
45	285	4.3
50	340	4.6
55	405	5.0
60	475	5.4
65	550	5.8

Source: [ITE Traffic Signal Timing Manual](#)

#### 14.5.4.2 Passage Time for Presence Detectors

Passage times for presence detectors located at the stop line are set to the maximum gap between vehicles the controller will allow before terminating the green phase. There is often misunderstanding about how long passage times for presence detectors should be set. To maintain ‘snappy’ operation, the designer should try to set passage times as short as possible. The goal is to set the passage time short enough that the controller will not needlessly hold the green interval for stragglers, but long enough that it will not gap out too quickly and strand vehicles waiting in the queue.

The primary benefit of installing a long presence loop (e.g., 40 ft. long or more) at the stop line is that it allows the passage time to be set very low and therefore yields ‘snappier’ signal operation. The controller will extend the green phase as long as the detector is occupied, and with a long loop as one vehicle vacates the loop the trailing vehicle should either be already on the loop or approaching the back edge of the loop. The longer the loop, the more likely the trailing vehicle will already be on it when the lead vehicle exits and the shorter the passage time can be set. Theoretically, if the loop is long enough the passage time can be set to zero. The standard 6 ft. x 50 ft. presence loop used by ALDOT easily allows passage times of 1.0 – 2.0 seconds to be used.

Instead, what one often finds in the field is that a long loop (e.g., 6 ft. x 50 ft.) has been used but the passage time has been set to 4.0 or 5.0 seconds. Unless there is a special reason for doing so, the high passage time negates the benefits of using a long loop and yields inefficient signal operation. A 50 ft. loop combined with a 5.0 second passage time is likely to hold the green interval too long for stragglers at the expense of other movements. There are cases where the designer may wish to employ long loops and high passage times to favor a particular movement, the mainline thru for example, but for left turns and minor street movements the designer should consider shorter passage times. A summary of typical passage times for presence detectors is presented in Table 14.10. The designer should note that these are only typical values and that passage times should be adjusted for prevailing conditions.

**Table 14.10 Typical passage times for presence detection (sec)\***

Approach	Movement	Range	Detector Length			
			30'	40'	50'	60'
Major Street	Left	1.0 - 4.0	2.5	2.0	2.0	1.5
	Thru	1.0 – 6.0	3.5	3.0	3.0	2.5
Minor Street	Left	1.0 – 4.0	2.5	2.0	2.0	1.5
	Thru	1.0 – 5.0	3.0	2.0	2.0	2.0

\* Note: Table assumes approach speeds < 30 mph. For speeds ≥30 mph setback loops should be used for thru movements.

Conditions that can require longer passage times than those shown in Table 14.10 include the following:

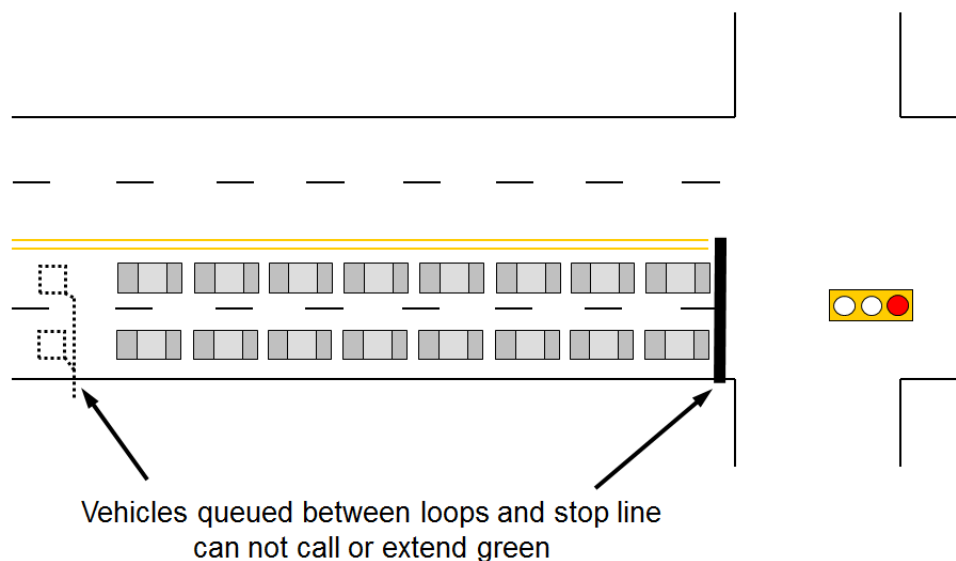
- Approach is on a steep grade that may retard vehicle startup and create longer gaps between vehicles
- A high percentage of heavy trucks slows vehicle startup and creates longer gaps between vehicles
- The designer wishes to favor a certain movement, such as the mainline thru, and sets passage times high to hold the green longer
- The designer wishes to ensure that a critical queue, such as for a left turn movement, clears every cycle to prevent storage overflow or spillback.

The designer should also consider using detector delay for side street approaches in order to allow vehicles to turn right on red without calling the side street phase. Detector delay can be used for right turn and shared lanes on the minor street approaches. Delay should not be used for exclusive left turn or thru lanes. Typical delay values range from 3-10 sec., with 7 sec. a commonly used value for minor street right turn lanes. See section 6.1.10 for additional information.

#### 14.5.5 Volume-Density Timing

When setback detectors are used, there will typically be vehicles queued between the detectors and the stop line when the green interval is activated (see Figure 14.12). These vehicles can not activate the detectors to place a call for green or extend the green to allow the queue to clear. To address this and prevent vehicles from becoming stranded between the detectors and the stop line, the designer typically places the phase on minimum recall and sets the minimum green interval long enough to allow any vehicles queued between the detectors and the stop line to clear.

If passage loops are located on a side street approach, the designer must either place the associated phase on minimum recall or provide secondary presence loops at the stop line that are switched off while the phase is green. The latter option allows the phase to operate in a non-recall mode.



**Figure 14.12 – Setback loops and vehicle queues**

This method generally functions well in cases where the loop setback distance is less than 150 feet, but when setback distances are greater it can create very long minimum green times and lead to inefficient operation. As an example, consider a signal approach with a 55 mph approach speed. The standard loop setback distance is 405 feet, and assuming an average vehicle length of 25 feet and the values shown in Table 14.7, a minimum green value of 38 seconds would be required to ensure that a queue stretching from the stop line to the detectors could clear. This would mean the green interval would time to at least 38 seconds every cycle, even if no vehicles were queued when the light turned green. This would cause very inefficient operation, particularly during off-peak periods.

Another problem encountered with long detector setback distances is that they require proportionately long passage times, as long as 5.0 or 6.0 seconds in some cases. These long passage times allow vehicles to travel from the detector to the stop line under green, but they have the secondary effect of



holding the green for excessively long periods and allowing it to be extended by stragglers at the expense of other movements.

To address the issues of excessive minimum green times and long passage times, ALDOT requires the use of volume-density timing for all detectors set back 140 ft or more from the stop line. When the volume-density function is activated, it serves two purposes:

- It counts the number of vehicles stored between the detectors and stop line and adjusts the minimum green interval according to demand;
- After a pre-set interval, it adjusts the passage time to a lower value so that the green will not be held for stragglers, but still ensures that the last vehicle before gap out will receive the full passage time to clear the stop line.

Volume-density timing requires values for the following parameters, each of which is discussed in the following sections:

- Minimum green
- Added initial
- Maximum initial
- Passage time
- Time before reduction (TBR)
- Time to reduce (TTR)
- Minimum gap

#### 14.5.5.1 Minimum Initial Green (Volume-Density)

The minimum green for volume-density timing should be set according to Table 14.6,. Since setback loops are typically used only on mainline thru approaches, the minimum green is usually set to 15.0 seconds if the approach speed is 45 mph or less, or 20.0 seconds if the approach speed is greater than 45 mph.

#### 14.5.5.2 Added Initial (Volume-Density)

When the thru phase clears to yellow, the volume-density module counts the number of vehicle actuations until the phase receives green again (these are the vehicles that will queue between the stop line and the detectors). The module then computes the minimum green time required to clear the resulting queue, often referred to as the 'computed initial' time. The module starts the computed initial time at zero and adds a preset amount, called the 'added initial', for each vehicle actuation. When the phase receives green, the controller uses the higher of the 'minimum green' and 'computed initial' as the minimum green interval. If the computed initial is less than the programmed minimum green interval, then the minimum green interval is used regardless of demand. If the computed initial is higher, however, the computed initial is used.

A value of 2.0 seconds per actuation is typically used for the added initial on single lane approaches. For multi-lane approaches, a value of 1.5 seconds per actuation is typically used.

### 14.5.5.3 Maximum Initial (Volume-Density)

The volume-density module will continue to increase the value of the computed initial with each vehicle actuation up to a preset maximum, called the 'maximum initial'. The maximum initial is the green time required to clear a hypothetical queue that extends from the stop line to the vehicle detectors. This value can be computed as:

$$MI = [(D/L) \times 2.1] + 3.7, \text{ where:}$$

*MI = maximum initial (sec)*

*D = detector setback distance (ft)*

*L = average vehicle length (assume 25 ft)*

Because of uncertainties associated with lane usage on multi-lane approaches, the standard added initial values are conservative. The maximum initial keeps the controller from calculating an excessively high computed initial interval.

### 14.5.5.4 Passage Time (Volume-Density)

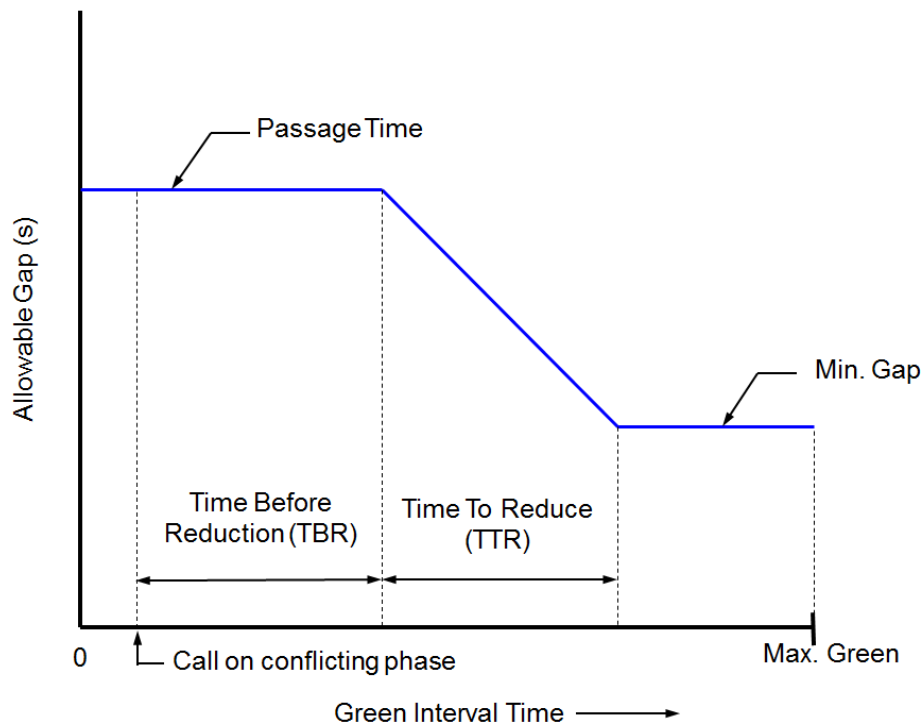
In volume-density timing, the passage time is active during the first part of the green phase and is computed as a normal passage time for setback loops. Values for the passage time should be based on detector setback distance and approach speed and can be found in Table 14.8. Ideally, the passage time should remain active until traffic has passed the start-up period and reached free-flow conditions.

### 14.5.5.5 Time Before Reduction – TBR (Volume-Density)

Once traffic has reached free flow conditions it is desirable to begin shortening the passage time so that the green is not extended for excessive periods. The Time Before Reduction (TBR) is the minimum time period that the controller will maintain the passage time at its programmed value before allowing it to be reduced. Note that the TBR period does not begin timing until a call is received on a conflicting phase (see Figure 14.13). If no conflicting call is received, the controller will hold the passage time at its programmed value indefinitely. The value for the TBR is typically set at 1/3 of the maximum green value (in seconds). This reserves the first third of the green interval for vehicle start-up and queue clearance. If conditions indicate that queue clearance will take longer than this, the TBR may be set to ½ the maximum green or higher.

### 14.5.5.6 Time to Reduce – TTR (Volume-Density)

When the TBR period has expired, the volume-density module will begin to reduce the passage time to a preset minimum linearly over a set period of time. The period of time over which the passage time is reduced is called the Time To Reduce, or TTR. Note that the passage time is adjusted gradually over this period of time, rather than all at once, so that preference is still given to the thru movement, although the allowable gap becomes shorter as vehicles on conflicting movements wait longer. The value of the TTR is typically set to 1/3 of the maximum green.



**Figure 14.13 – Adjusting the passage time using volume-density timing.**

#### 14.5.5.7 Minimum Gap (Volume Density)

The passage time is gradually adjusted down to a preset minimum called the ‘minimum gap’. This is the maximum allowable gap between vehicle actuations before the controller will terminate green and clear to another phase. It should be set fairly short so that the green is not extended for stragglers. Typical values range from 2.5 seconds on a single lane approach to 2.0 seconds on a multi-lane approach.

#### 14.5.5.8 Last Car Passage

Designers will note that if the passage time is decreased to a minimum gap value well below the computed passage time, the detectors will no longer provide dilemma zone protection. This is true but can be remedied by using the ‘last car passage’ function. The last car passage setting, when activated, will ensure that the last car to pass the detector prior to gap out will receive the full computed passage time. Once the minimum gap timer has expired the last car passage function will hold the green for an additional period equal to the difference between the passage and the minimum gap before initiating the yellow clearance interval. When using volume-density timing, the designer should also specify that the last car passage function be activated.

#### 14.5.5.9 Summary of Volume-Density Settings

Typical volume-density settings used by ALDOT are summarized in Table 14.11. These are typical values only and can be adjusted by the designer as necessary.

**Table 14.11 – Typical Volume-Density Settings**

Parameter	Range	Typical Values
Initial Green	15s– 25s	15s (< 45 mph) 20s (≥ 45 mph)
Added Initial	1.0s – 3.0s	2.0s (single lane) 1.5s (≥ 2 lanes)
Maximum Initial	15s – 40s	= $[(D/25) \times 2.1] + 3.7$ , where: D = loop setback (ft)
Passage Time	1.0s – 8.0s	= $D/1.47S$ , where: D = detector setback (ft) S = approach speed (mph)
Time Before Reduction (TBR)	10s – 30s	Max. Green/3
Time To Reduce (TTR)	10s – 30s	Max Green/3
Minimum Gap	1.0s – 4.0s	2.5s (single approach lane) 2.0s (≥ 2 approach lanes)
Last Car Passage	Active/Inactive	Active

#### 14.5.6 Detector Switching and Phase Omits for Protected/Permissive Phases

Section 3.6 discussed the left turn trap and the potential safety concerns associated with protected/permissive left turn phasing. ALDOT consequently does not permit a signal to clear directly from phases 2+6 to either 1+6 or 2+5 (or on side streets, from phases 4+8 to either 3+8 or 4+7) if protected/permissive left turn phasing is being used. Preventing this can be accomplished through the use of either ‘detector switching’ or ‘dynamic phase omits’. The detector switching function re-routes detector calls from the left turn phase to another phase after the left turn phase has expired. To prevent the phase backtracking described above, the detector for a protected/permissive left turn is rerouted or ‘switched’ to the opposing thru phase once the left turn phase has expired.

As an example, assume that a protected-permissive left turn is assigned to phase 1 as shown in Figure 14.14. While the mainline phase is red, the left turn detector will place vehicle calls to phase 1. When the left turn phase is green, the left turn detector will continue to place vehicle calls to phase 1, extending the green as necessary. Once phase 1 has expired and the opposing thru movement has been given green, the left turn detector is switched and will place all subsequent vehicle calls to phase 2. Any calls from left turning vehicles will have the effect of extending the mainline green phase rather than placing a call for left turn phase 1. Since the left turning vehicles can turn permissively, this is acceptable. Once the mainline phases have expired, the left turn detector is returned to phase 1. When requiring detector switching on a signal design the designer should include a note for each detector requiring switching: “Switch detector from Phase (A) to Phase (B) when Phase (B) is green”.

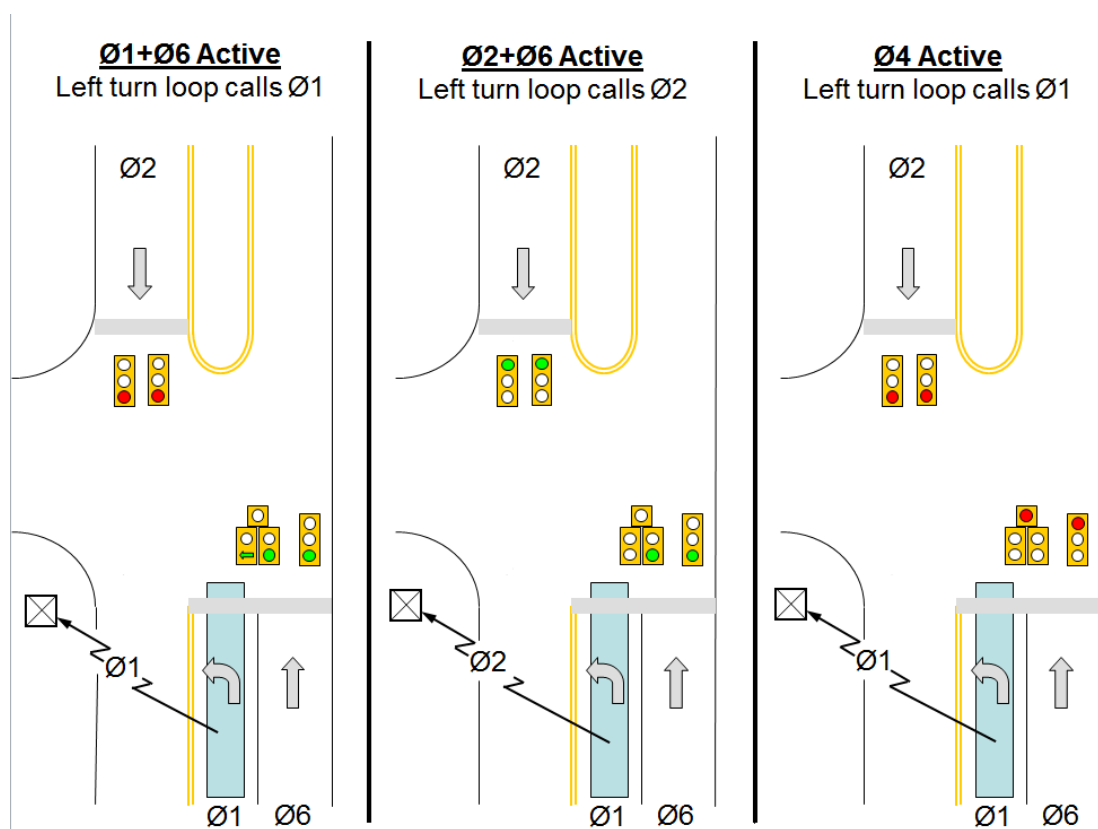
A dynamic phase omit is a controller setting that can be used to omit a left turn phase when the opposing thru movement is green. The controller will therefore not recognize any calls for the left turn while the opposing thru movement is green and there will be no opportunity for backtracking.

A summary of when detector switching is required is presented in Table 14.12. Note that detector switching should never be used on protected left turn phases, since the vehicles waiting to turn left can not turn permissively and would therefore only be delayed by extending the mainline green phase. Care should be taken when using detector switching on the side street thru phase when recall is not being used.

**Table 14.12 – Conditions requiring detector switching or phase omits**

Left Turn Phasing	Opposing Left Turn Phasing	Detector Switching/Phase Omits Required?
Protected-Permissive	Permissive	Yes <sup>†</sup>
Protected-Permissive	Protected	Yes <sup>†</sup>
Protected-Permissive	Protected-Permissive	Yes
Protected	Protected	No

<sup>†</sup> Left turn phasing combination may be used only on minor street approaches and only if main street thru movements have been placed on recall (see Section 3.8 for further discussion).



**Figure 14.14 – Illustration of detector switching**

① When protected-permissive left turn phasing is used, the designer must specify either detector switching or dynamic phase omits to prevent backtracking and creation of a left turn trap.

## 14.6 Semi-Actuated Signals

An alternative to pre-timed and actuated signals are semi-actuated signals. Semi-actuated signals are typically used at intersections with high mainline volumes and low side street volumes. In semi-actuated operation, vehicle detectors are provided only on the minor street approaches. After providing an initial minimum green interval, the signal will rest in mainline green until a call is received on one of the minor street approaches. Upon serving the minor street call, the signal will immediately return to mainline green. The mainline minimum green is typically set very high (higher than for a fully actuated signal) to keep traffic moving on the mainline.

Semi-actuated signals can provide efficient operation under certain conditions and have the advantage of requiring fewer detectors than fully actuated signals. Because they lack mainline detection, however, they can not provide passage and dilemma zone protection as fully actuated signals can and therefore are not recommended for general use by ALDOT. ALDOT requires that all new actuated signals be fully actuated (i.e., have both major and minor street detection).

Designers may note that when operating in a coordinated system most signals in effect operate in semi-actuated mode, since termination of main street green is determined by force-off settings and not by mainline detectors. This is true, but the provision of mainline detectors allows for dilemma zone protection when the signal is operating in non-coordinated mode, such as frequently occurs during overnight hours. Mainline detection is therefore required even when a signal will operate as part of a coordinated system.

## 14.7 Other Controller Settings

There are a number of other controller settings that the designer may encounter when installing the timings in the field. These are discussed briefly in this section.

### 14.7.1 Recall

A recall function automatically places a call on a phase regardless of whether a vehicle/pedestrian is present. Its purpose is to activate a phase every cycle regardless of demand. It is most commonly used on major street thru phases, causing the signal to 'rest' in main street green in the absence of demand on other phases. In most cases where main street volumes are significantly higher than minor street volumes the major street thru phases (typically phases 2 and 6) should be placed on minimum recall. There are several types of recall:

- **Minimum Recall** – Automatically places a call on a phase every cycle and times the minimum green interval. After the minimum green has expired, the green interval may then be extended by detector calls or terminated if there is no more demand for that phase and there is a call on a conflicting phase. Minimum recall is most commonly used for main street thru phases.
- **Maximum Recall** – Automatically places a call on a phase every cycle and holds the green for the maximum green interval regardless of demand. The green will then be terminated when a call is received for a conflicting phase. An actuated signal can be made to operate 'pre-timed' by placing all phases on maximum recall.
- **Soft Recall** – Automatically places a call on a phase only if there are no calls on conflicting phases. Use of this function is typically discouraged by ALDOT.

- Pedestrian Recall – Places a call on a pedestrian phase every cycle regardless of demand and activates the full ‘Walk’ and ‘FDW’ intervals. Typically used if pushbuttons are not provided.
- Rest in Red – When activated, this function causes the signal to rest with all phases red in the absence of demand. In normal operation, a signal will rest in green on the last phase called until a call is received on a conflicting phase. When a conflicting call is received, the signal must then proceed through the yellow and all-red clearance intervals before providing green on the called phase, resulting in some vehicle delay. Rest in red causes all phases to clear to red once demand has been served and passage time has expired. The signal is then able to respond more quickly to demand when a vehicle call is received. Rest in Red is typically used at low volume intersections where vehicle demand is roughly equal on all approaches (i.e., there is no favored movement).

## 14.8 Flashing Mode

During periods of low demand (e.g., late night and early morning) a signal may be placed in flashing mode in order to minimize vehicle delay. There are no set guidelines for when a signal should be placed into flashing mode, but some rules of thumb are presented in Table 14.13.

**Table 14.13 – Suggested mainline threshold volumes for flashing operation**

# of mainline thru lanes (two-way)	Maximum two-way volume (vph)
2	200
4	250
6	300
> 6	Not recommended

The above threshold volumes are general guides only. The designer should also incorporate geometric conditions and field observation in his decision to use flashing operation. Furthermore, flashing operation can be considered only if all of the following conditions are met:

- Minimum sight distances are satisfied for all approaches and movements. If minimum sight distance requirements are not met for even one movement, the signal must remain in standard operation at all times
- The signal was not installed to address crash or safety issues
- Traffic volumes do not satisfy the minimum volume criteria for either MUTCD Signal Warrants #1 or #2. Flashing operation will not create undue delays for minor movements
- Left turn lanes, when present, are single lane only. Intersections with dual left turn lanes should generally not be placed in flashing mode
- The number of mainline thru lanes (two-way) is 6 or less

When operating in flashing mode, the following conventions shall be observed:

- Signals for mainline thru and right turn movements shall flash yellow
- Signals for mainline protected left turns shall flash red
- Signals for mainline protected/permissive left turns (5-section head) shall flash yellow ball only
- Signals for all minor street movements shall flash red
- Signals shall not be set up to flash red on all approaches (i.e., all-way stop). If the designer feels this is necessary, then the signal should remain in standard operation

Flashing mode is also used prior to placing a new signal into service. A new signal must be placed in flashing mode prior to being placed into normal operation. Typically a new signal is flashed for a minimum of 7 days prior to being placed into normal operation, but this should be confirmed with the Region/Area Traffic Engineer.

## 14.9 Pedestrian Timing

Pedestrians may be accommodated at a signalized intersection in one of three ways ([ITE Traffic Signal Timing Manual](#)):

1. No pedestrian signals provided – pedestrians cross on the vehicle green indications
2. Separate pedestrian signals supplement vehicle indications – pedestrian movements controlled by walk/don't walk indications
3. Exclusive pedestrian phase provided – all vehicle movements are stopped to allow pedestrian crossings

Methods 1 and 2 are the most commonly encountered at signalized intersections. Method 3, exclusive pedestrian phasing, is normally reserved for situations when very high pedestrian volumes are present and potential conflicts require that pedestrian and vehicle movements be completely separated.

The principles of timing signals for pedestrians are the same whether separate pedestrian indications are provided or not. Pedestrians should always cross with the parallel thru movement and must never cross when a conflicting vehicle movement has been given the right-of-way. When separate pedestrian indications are not provided, pedestrians should cross when a green indication is given to the parallel thru vehicle movement. Table 14.14 illustrates standard pedestrian phases/movements and the appropriate concurrent vehicle phase.

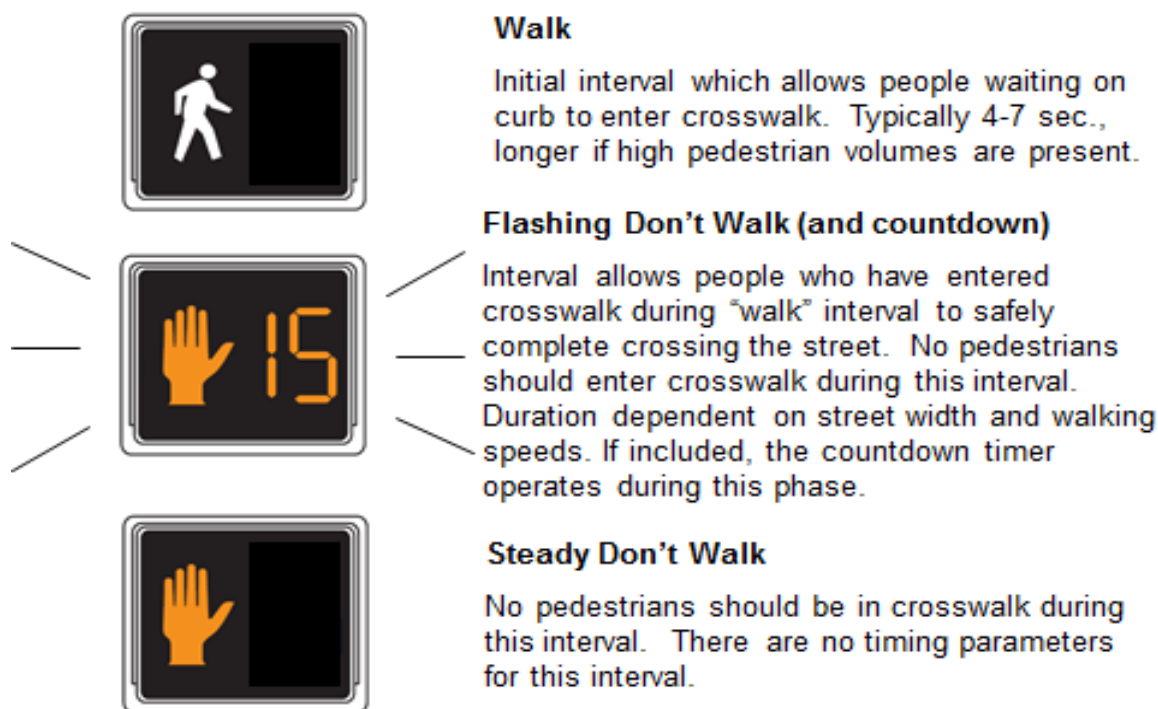


**Table 14.14 – Pedestrian Phases and Concurrent Vehicle Phases**

# Vehicle Phases	Vehicle and Pedestrian Phases	Ped Phase/Movement	Concurrent Vehicle Phase
2		P9	Ø1
		P10	Ø2
5		P9	Ø2
		P10	Ø6
		P11	Ø4
8		P9	Ø2
		P10	Ø6
		P11	Ø4
		P12	Ø8

**14.9.1 Timing when Pedestrian Signals are Present**

When pedestrian signals are provided, the designer must determine the appropriate values for the “Walk” and “Flashing Don’t Walk (FDW)” intervals. These intervals serve the following functions:



During the Walk interval the pedestrian must have enough time to observe the signal indications, recognize it is safe to cross, and step off the curb into the crosswalk. During the 'Flashing Don't Walk/Countdown' interval the pedestrian must have time to safely cross the street at a normal walking rate. The timing of each interval is discussed in the following sections.

#### 14.9.1.1 Computing the "Walk" Interval

ALDOT follows MUTCD guidance on appropriate timings for the Walk interval. Studies have shown that 4 seconds is a sufficient walk interval if there are fewer than 10 pedestrians per cycle (per direction). If there are between 10 and 20 pedestrians per cycle per direction, 7 seconds is the recommended minimum. If there are more than 20 pedestrians per cycle per direction, such as on a college campus or urban intersection, the designer should make field observations to confirm that a 7 second walk time will be adequate. Recommended Walk intervals are summarized in Table 14.15 below.

**Table 14.15 – Recommended Minimum "Walk" Intervals**

Pedestrians per Cycle (one direction)	Min. Walk Interval (sec)
< 10	4
$10 \leq x \leq 20$	7
> 20	*field observation

\* "Walk" times for heavy pedestrian movements should be based on field observations or HCM capacity analysis.

### 14.9.1.2 Computing the “Flashing Don’t Walk” Interval

The Flashing Don’t Walk (FDW)/countdown interval should provide the pedestrian, having already entered the crosswalk, with enough time to safely cross the street at a reasonable walking speed. The minimum FDW interval required for a pedestrian to cross a street is computed as:

$$FDW = (L-6)/S$$

where:

*FDW* = flashing don’t walk interval (sec)

*L* = crosswalk length (ft)

*S* = walking speed (ft/sec)

ALDOT follows MUTCD guidelines which recommend using a walking speed of 3.5 ft/sec for an average adult. If the crosswalk is located in a school zone or in an area where one would expect large numbers children or strollers (such as near a park) then the designer should consider a walking speed of 3.0 ft/sec. If the crosswalk is in an area where one would expect large numbers of elderly or handicapped users, the designer should consider using a walking speed of 3.0 ft/sec. Minimum FDW intervals for various crosswalk lengths and walking speeds are summarized in Table 14.16.

The designer should note that in the formula for computing the FDW interval, 6 feet is subtracted from the crosswalk length. For computational purposes, the pedestrian need only walk to the middle of the farthest lane before the FDW interval expires. It is assumed that he/she can walk the final 6 feet during the yellow vehicle clearance interval. This is accounted for in Table 14.16. **Note: “Flashing Don’t Walk” times greater than 7 seconds require the use of the Countdown indicator.**

**Table 14.16 – Minimum “Flashing Don’t Walk (FDW)” Intervals by Walking Speed (sec)**

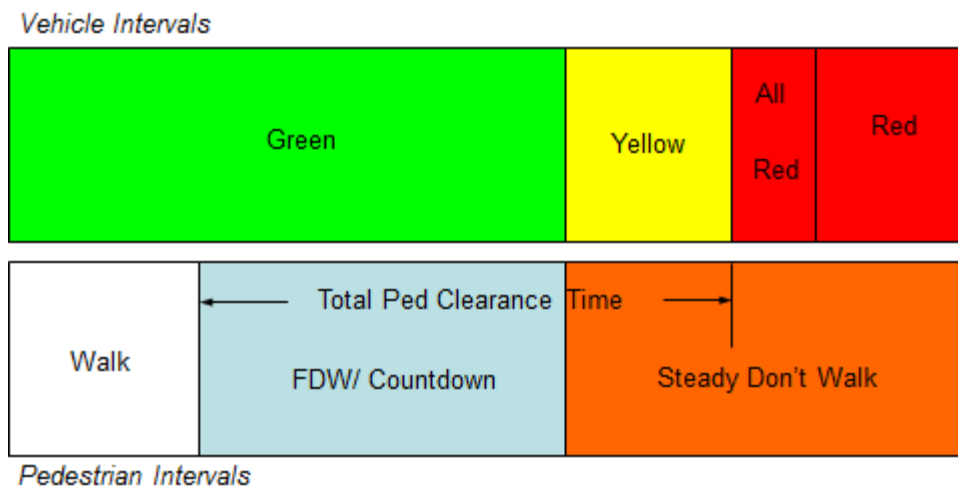
Crosswalk Length (ft)*	Walking Speed	
	3.0 ft/sec	3.5 ft/sec
20	5	4
30	8	7
40	11	10
50	15	13
60	18	15
70	21	18
80	25	21
90	28	24
100	31	27
110	35	30
120	38	33

\* Use full crosswalk length. Calculations include 6' reduction.

ALDOT recommends that the designer consider the entire crosswalk length in these calculations, even when parking lanes are present at either end. Cars may not always be parked in parking lanes, and in those cases motorists frequently use them as turn lanes.

### 14.9.2 Relationship of Pedestrian and Vehicle Phases

On state traffic signals, the “Walk” and “FDW/Countdown” intervals time concurrently with the associated vehicle green interval and must terminate before the vehicle yellow is activated. This means that the green time for the concurrent vehicle phase must be long enough to accommodate both the “Walk” and “FDW/Countdown” intervals, as shown in Figure 14.15.



**Figure 14.15 – Relationship of signal and pedestrian intervals**

This is accomplished in a slightly different manner for pre-timed and actuated signals:

- **Pre-Timed Signals** – the vehicle and pedestrian intervals are fixed and are activated every time the vehicle phase is activated. There are no pedestrian pushbuttons. The vehicle green time must be greater than or equal to the sum of the Walk and FDW intervals. In cases where the vehicle green exceeds the sum of the minimum Walk and FDW intervals, the Walk interval is typically increased so that  $Walk + FDW = Vehicle\ Green$ .
- **Actuated Signals** - If a signal is actuated and pedestrian phasing is provided it is recommended that pushbuttons also be provided. Providing pedestrian phases without pushbuttons means the pedestrian phases will not be activated unless a vehicle calls the associated vehicle phase. This can result for long delays for pedestrians.

An alternative to pushbuttons at an actuated signal is to place the pedestrian phases on recall, meaning they will be activated every cycle whether pedestrians are present or not. In practice, this is very inefficient and defeats the purpose of making the signal actuated. It is not recommended practice unless a constant pedestrian demand is present.

When active, the pedestrian phases will automatically extend the vehicle green in order to accommodate the Walk and FDW intervals. The Maximum Green for the vehicular phase must therefore be set greater than or equal to the sum of the Walk and FDW intervals. The Minimum Green should be set as normal. If the pedestrian phases are not called, the pedestrian heads will display a steady Don't Walk for the duration of the vehicle green.

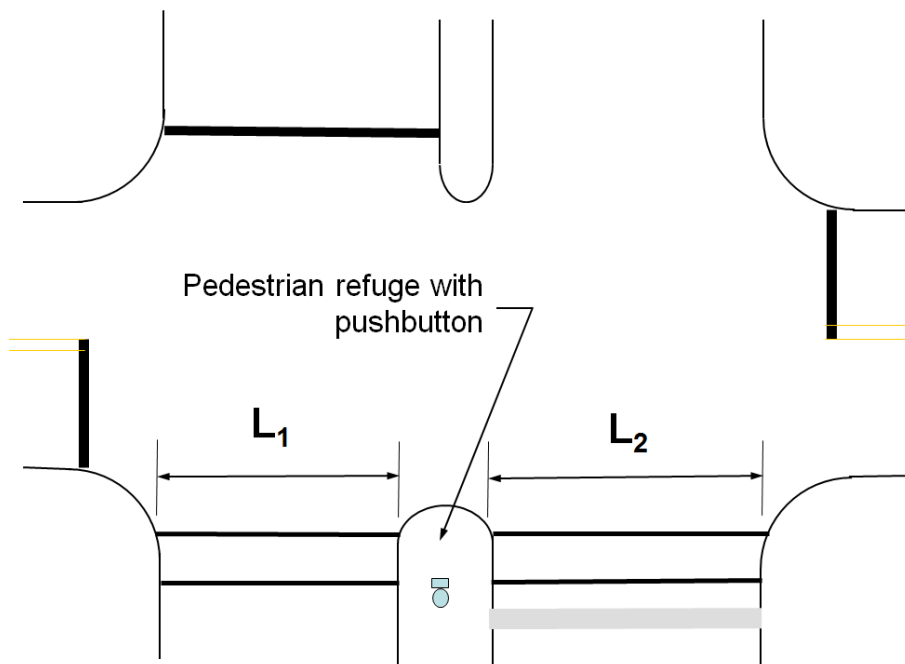
### 14.9.3 Crossing Divided Roadways

Pedestrian intervals at median divided roadways can be very long due to the time required to cross both the roadway and median. In some cases, the crossing times can be so long as to adversely affect intersection operation. In these cases, the designer may consider providing a split crossing plan, meaning the pedestrian intervals allow pedestrians just enough time to cross from the curb to the median. There the pedestrians wait until the next cycle, when the pedestrian intervals will allow them enough time to complete their crossing. Several conditions must be met in order for this type of system to be used:

1. The median must be a minimum of 8 feet wide and provide adequate refuge from vehicular traffic.
2. If the pedestrian intervals are actuated, a separate pushbutton must be provided in the median to allow pedestrians to complete their crossing.
3. The refuge area must be clear of visual obstructions such as signs, barriers, or vegetation and must provide an unobstructed view of vehicular traffic in all directions.

It is the preference of ALDOT that pedestrians be able to make a complete crossing during a single pedestrian interval. Split crossing schemes should be used only when there is a significant benefit to intersection operation.

For split crossing schemes, Walk and FDW intervals should be computed as discussed in sections 14.9.1.1 and 14.9.1.2. The crosswalk length 'L' used to compute the FDW interval should be the longer of the two crossing distances,  $L_1$  and  $L_2$  as shown in Figure 14.16.



**Figure 14.16 – Crossing divided roadways  
(use longer of  $L_1$  and  $L_2$  to compute FDW interval)**

#### 14.9.4 Timing without Pedestrian Signals

Even if separate pedestrian signals are not provided, the designer must ensure that adequate provisions are made to accommodate pedestrians. If pedestrian traffic is expected at an intersection then the signal timings should be set to allow enough time for a pedestrian to safely cross the street during the concurrent green interval. The same timing principles described in Section 14.9.1 apply to signals without pedestrian phases; the green interval must be set long enough to allow pedestrians to safely cross. Recommended timings are provided in Table 14.17.

**Table 14.17 – Recommended Timing without Separate Pedestrian Signal Heads**

Signal Type	Timing
Pre-timed, no pedestrian activity expected	Green interval should be set to optimize vehicle movements. No special considerations for pedestrians required.
Pre-timed, pedestrian activity possible or expected	Green time should be greater than or equal to the sum of the minimum Walk interval (Table 14.14) and the minimum FDW interval (Table 14.15).
Actuated, no pedestrian activity expected	Green interval should be set to optimize vehicle movements. No special considerations for pedestrians required.
Actuated, pedestrian activity possible or expected	Pedestrian pushbuttons must be provided, even if pedestrian heads are not. Maximum Green must be greater than or equal to the sum of the minimum Walk interval (Table 14.14) and the minimum FDW interval (Table 14.15).

# ***Chapter 15***

## ***Typical Plan Set***

This Chapter presents a typical ALDOT Traffic Signal plan set and describes the requirements for a complete submittal.

### **15.1 Elements of a Plan Set**

A standard (stand-alone) ALDOT traffic signal plan set must include the following elements:

1. Title Sheet
2. Index Sheet
3. Traffic Signal/ITS Legend
4. Traffic Signal Note Sheet
5. ITS Note Sheet (if needed)
6. Traffic Control Plan Note Sheet
7. Summary of Quantities
8. Traffic Signal Quantities Box Sheets
9. Fiber Optic Box Sheet(s) (if needed)
10. Signs and Pavement Markings Box Sheet
11. Traffic Signal Layout Sheet(s)
12. Interconnect Layout Sheet(s)
13. Traffic Control Plan Sheet(s)
14. Project Detail Sheets (if needed)
15. ITS/Signal Splice Table Index (if needed)
16. Fiber Allocation Chart (if needed)
17. Optical Fiber Cable Routing Diagram (if needed)

The above elements are required for a stand-alone plan set. If the traffic signal design plan is part of a larger highway plan set then items 1, 2, 6, and 10 will be replaced by sheets from the overall plan set. Each element is briefly described in the following sections.

#### *15.1.1 Title Sheet*

The designer must use the standard ALDOT title sheet template. The title sheet must contain:

- Project number, name, and location
- Vicinity map with project limits clearly shown, major roads labeled, county or city population noted, and directions to major cities shown
- North arrow
- Note referencing ALDOT standard specifications under which plans were developed
- Project number, fiscal year, and total number of plan sheets shown in block at upper right

### 15.1.2 Index Sheet

The index sheet clearly lists the contents of the plan set. Each plan sheet must be listed and each title must exactly match the corresponding title shown on the sheet itself. The plan set must end with a whole numbered sheet without a letter suffix (e.g., Sheet 46 rather than Sheet 45B).

The index sheet also contains a list of all relevant Special and Standard Drawings from the current [ALDOT Standard and Special Drawings for Highway Construction](#) Book. Each drawing must be listed by index number and standard/special drawing number and include the sheet title exactly as it appears in the Standard Drawings Book.

### 15.1.3 Traffic Signal/ITS Legend

Legend sheet showing standard ALDOT symbols for traffic signal equipment. All symbols used in the plan set must appear in the legend and must conform to ALDOT standards. The current Traffic Signal/ITS Legend can be obtained from ALDOT.

### 15.1.4 Traffic Signal Note Sheet

The standard traffic signal note sheet should be obtained from ALDOT. Notes relevant to the project should be circled while those not applicable should not. It is the responsibility of the designer to ensure that he is using the current signal note sheet.

The note sheet shall contain the project number and county and a note reading "In the event conflicts occur between the project traffic signal notes and the MUTCD (current adopted edition), the MUTCD will govern".

### 15.1.5 ITS Note Sheet

If fiber optic equipment is specified in the plan set then the fiber optic note sheet must be included. It is a standard sheet that can be obtained from the ALDOT Design Bureau. Notes relevant to the subject project should be circled while those not applicable should not. It is the responsibility of the designer to ensure that he is using the current fiber optic note sheet.

### 15.1.6 Traffic Control Plan Note Sheet

If traffic control plans are included in the plan set then the traffic control plan note sheet must also be included. It is a standard sheet that can be obtained from ALDOT. Notes relevant to the subject project should be circled while those not applicable should not. It is the responsibility of the designer to ensure that he is using the current traffic control plan note sheet.

### 15.1.7 Summary of Quantities

The Summary of Quantities sheet lists pay items and quantities for all materials required for the project. The quantities listed on this sheet must match exactly the quantities shown in the corresponding box sheets. It is the designer's responsibility to ensure that all pay items are correct and that totals have been computed correctly. Plan sets submitted with tabulation errors may be returned without review.

Every pay item listed in the box sheets must appear on the Summary of Quantities. Pay items measured as 'EACH' and 'LIN FEET' will show the total quantities for the entire project. 'LUMP SUM' pay items must always show a quantity of '1'.



### 15.1.8 Traffic Signal Quantities Box Sheet

Summary of traffic signal quantities by location. Each location must be listed separately. For further explanation of pay item numbers and quantities, see Chapter 13. Note that some lump sum pay items, such as 730A and 730C, can be presented in a separate tabulation box if table width dictates the need to do so.

Standard and Special Drawings relevant to each project location must also be shown in the table.

### 15.1.9 Fiber Optic Quantities Box Sheet

Summary of fiber optic quantities by location (if applicable). If fiber optic equipment is not specified then this box sheet can be omitted. For further explanation of pay item numbers and quantities see Section 13.

### 15.1.10 Signing and Striping Quantities Box Sheet

Summary of signing and striping quantities by location (if applicable). If signing and striping are not specified this box sheet can be omitted.

### 15.1.11 Traffic Signal Layout Sheets

Typical scale for a layout sheet is either 1 in. =30 ft or 1in. =20 ft. Scale should be clearly noted on each sheet. Each layout sheet **must** contain the following information as a minimum:

- Project number and county
- Scale and scale bar
- North arrow
- All utilities, both overhead and underground
- Right-of-way
- Edges of pavement and existing lane markings
- Street names clearly marked
- Project stationing (if used)

The layout sheet should clearly show all existing and required signal equipment using ALDOT standard symbols (see Signal Legend Sheet). This includes poles, signal heads, controller, detectors, conduit, conduit encasement, and junction boxes. Signal heads and detectors should be numbered according to ALDOT standard convention (see Chapters 5 and 6 of this manual).

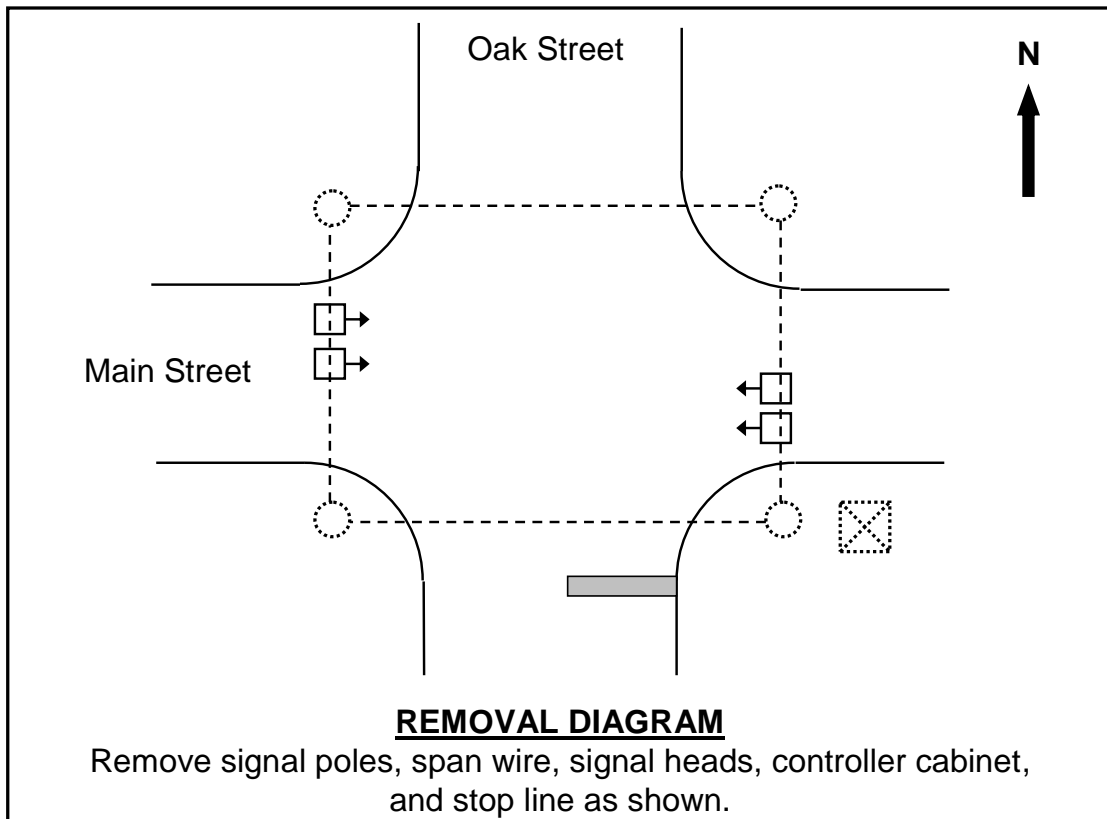
A typical layout sheet may also include the following:

- Removal diagram
- Required signal heads box
- Required signs box
- Conduit and conductor schedule
- Estimated equipment and materials schedule
- Supporting structures box
- Suggested timings chart
- Intersection-specific layout notes

Each of these items is discussed briefly below.

**Removal Diagram**

A removal diagram is required when there is existing signal equipment to be removed as part of the project. The removal diagram should contain a sketch of the intersection including street names, a north arrow, and show only equipment and striping that is to be removed as part of the project. Equipment and striping to be removed must be shown using ALDOT standard symbols for existing equipment. The removal diagram does not need to be drawn to scale. A typical removal diagram is shown in Figure 15.1. Note that if a removal diagram is shown, there must be a corresponding 730A-XXX pay item shown in the quantity sheets.



**Figure 15.1 – Typical removal diagram**

**Required Signal Heads**

This box displays the types of signal heads to be used at the intersection. Each type should be shown along with the signal phase number which it serves. Should a phase use multiple head configurations, then affix an alphabetic letter to the phase number, beginning with A. A typical required signal heads box is shown in Figure 15.2.

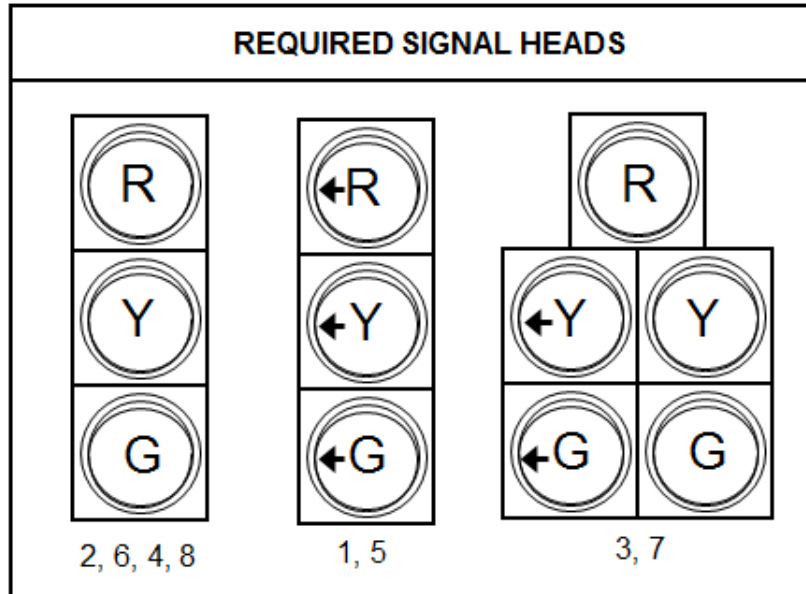


Figure 15.2 – Typical required signal heads box

**Required Signs Box**

This box displays any signs to be provided as part of the installation. It shows all post or span-mounted signs along with their dimensions and MUTCD designation. Each sign must also be clearly shown on the layout sheet. A typical required signs box is shown in Figure 15.3.

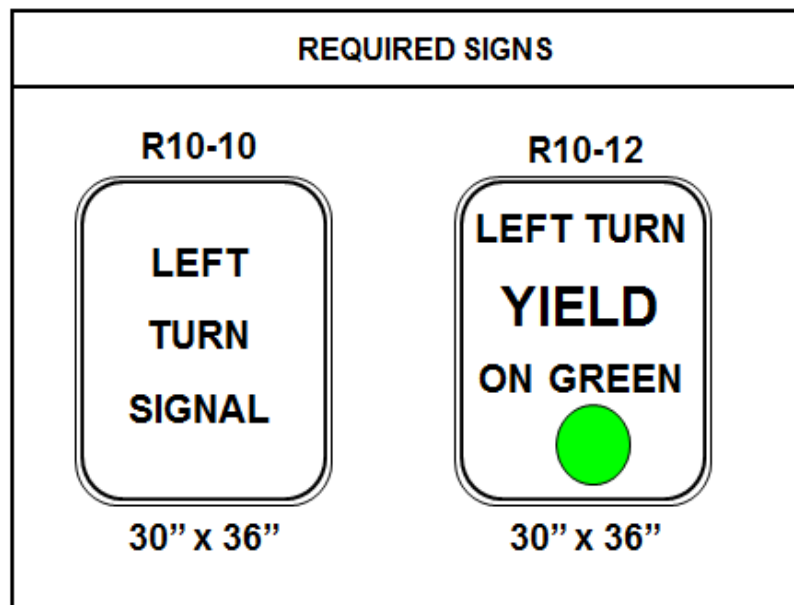


Figure 15.3 – Typical required signs box

**Conduit and Conductor Schedule**

The conduit and conductor schedule lists the wire and conduit runs required for the installation. All wiring and conduit must be listed, including:

- power service
- loops and loop returns
- signal wire
- interconnect

Existing conduit should be listed as ‘Existing’ while required conduit must specify the number and size for each run. The wiring contained in each conduit should be listed alongside under ‘Conductor’, specifying number, size, and number of conductors for each run. If the conductor is not to be run in conduit (e.g., signal wire across a span) the conductor column should be left blank. The ‘From’ and ‘To’ columns specify the start and end points of each run.

Requirements for wiring and conduit are discussed in Chapter 8 of this manual. Signal cable is typically #14 AWG IMSA 20-1. Loop detector wire is typically #12 AWG wire run from the junction box out to the loop and then back to the junction box. Loop lead-ins are typically #12 AWG shielded IMSA 50-2 cable. A sample conduit and conductor schedule is presented in Figure 15.4.

**Estimated Equipment and Materials Schedule**

This box lists all materials and equipment incidental to the signal installation that are included under the 730C-XXX lump sum pay item number. Items included in this box do not have pay items and do not require quantities. Typical equipment listed in this box is shown in Figure 15.5. Only materials specified on the layout sheet should be listed

CONDUIT AND CONDUCTOR SCHEDULE			
CONDUIT	CONDUCTOR	FROM	TO
1-1 in.	1-3c/No. 6 AWG	Disconnect	Controller
1-1 in.	1-3c/No. 8 AWG	Disconnect	Pole #4 (Luminaires)
1-2 in.		Junction Box	Junction Box
1-2 in.		Junction Box	Signal Poles
3-2 in.		Controller	Pole #4
	2c/No. 12 AWG Shld IMSA 50-2	Controller	Junction Box for Each Loop
	No. 12 AWG	Junction Box	Loop Back to Junction Box
	7c/No.14 AWG IMSA 20-1	Controller	Signal Heads 2 & 4
	4c/No.14 AWG IMSA 20-1	Controller	Signal Heads 3
	4c/No.14 AWG IMSA 20-1	Controller	Signal Heads 7

**Figure 15.4 – Typical Conduit and Conductor Schedule**

PAY ITEM 730C-000 ESTIMATED EQUIPMENT AND MATERIALS SCHEDULE (LUMP SUM)	
3/8 in. Messenger Cable	
1/4 in. Tether Cable	
Power Source (specify 120 or 240 Volt)	
R10-10 Signs w/ Hardware	
R10-12 Signs w/ Hardware	
Backplates w/ Hardware	
No.14 AWG Signal Cable	
Miscellaneous Hardware	

**Figure 15.5 – Typical Estimated Equipment and Materials Schedule**

Supporting Structures Box

If new signal poles are specified, they must be listed in the supporting structures box with their height, location, and size of any luminaire arm. A sample Supporting Structures Box is shown in Figure 15.6. If stationing is not being used, the designer may list “See Layout” under station and offset, but the pole locations must be clearly dimensioned on the layout sheet.

SUPPORTING STRUCTURES					
TRAFFIC SIGNAL POLE					
Pole Number	Pole Length (ft)	Mast-Arm (ft)	Luminaire Arm (ft)	Station	Offset (ft)
1	37	28	12	5+ 01.30	L 46
2	37	32	12	5+ 61.90	L 38
3	28	-	-	5+ 70.10	R 46
4E	Existing	-	-	4+ 97.40	R 46

**Figure 15.6 – Sample Supporting Structures Box**

Required Detector Schedule

All vehicle detectors shall be listed in the detector schedule, which will include information on each detector number, phase assignment, amplifier assignment, size, operation type, and location. A sample detector schedule is shown in Figure 15.7. This schedule should be used for all vehicle detector types, including inductive loop, video, microwave, and magnetometer. For non-loop detectors the number of loop turns should be omitted but the size and location of each detection zone should be specified.

Recommended Timings Chart

The designer must provided suggested timings for each signal installation in the plan set. ALDOT has five standard timing charts that are used based on the type of operation planned. They are:

- Figure 15.8 – Pre-timed, isolated
- Figure 15.9 – Pre-timed, coordinated
- Figure 15.10 – Actuated, isolated, no volume-density
- Figure 15.11 – Actuated, isolated with volume-density
- Figure 15.12 – Actuated, coordinated

Discussions of how to complete each field are presented in Chapter 14 of this manual.

### 15.1.12 Interconnect Layout Sheet

The interconnect layout sheet shows the location of all overhead and underground conduit and cable to be installed as part of the project. Each interconnect layout sheet should include the following information as a minimum:

- Scale and scale bar
- North arrow
- Edges of pavement and street names
- Right-of-way
- Utilities
- Required conduit
- Required interconnect cable
- Sheet-specific layout notes

The scale can be adjusted to best fit the drawing but should be no smaller than 1in. = 100 ft. All conduits should be labeled for size, number of runs, and cables included.

### 15.1.13 Signal Operating Plans

A plan set must include copies of the ALDOT Standard Operating Plans that pertain to each signal installation. The Standard Operating Plans (SOP) are found in the [ALDOT Standard and Special Drawings for Highway Construction](#) Book (current edition).



RECOMMENDED TIMINGS (all times in seconds)											
Phase	Movement	Min Grn	Passage	Max Grn I	Max Grn II	Yellow	All Red	Walk	FDW	Recall	Non Lock
1										Min	Yes
2										Max	No
3										Soft	
4										[blank]	
5											
6											
7											
8											

Figure 15.10 – Timing chart for actuated, isolated signals without volume-density settings

RECOMMENDED TIMINGS (all times in seconds)																
Phase	Min Initial	Density Active?	Added Initial	Max. Initial	TTR	TBR	Min Gap	Passage	Yellow	All Red	Max I	Max II	Walk	FDW	Recall	Non Lock
1		Yes														
2		No														
3																
4																
5																
6																
7																
8																

Figure 15.11 – Timing chart for actuated, isolated signals with volume-density settings

RECOMMENDED TIMINGS (all times in seconds)																Coordination			
Phase	Min Initial	Density Active?	Added Initial	Max. Initial	TTR	TBR	Min Gap	Passage	Yellow	All Red	Max I	Max II	Walk	FDW	Recall	Non Lock	AM	MID	PM
1		Yes													Min	Yes			
2		No													Max	No			
3															Soft				
4															[blank]				
5																			
6																			
7																			
8																			
																Cycle			
																Offset			

Figure 15.12 – Timing chart for actuated, coordinated signals with volume-density settings