4-8-1 Vehicle Detection April 2025

DETECTOR/CONTROLLER FUNCTIONS

As it affects signal timing & operations, the signal designer *should* understand the modes of operation for both detectors and controllers. The scope of this manual does not cover guidelines for determining intersection signal timing; however, the following discussion provides a brief overview of various modes of operation, which are directly related to signal timing. The selection of the detector/controller mode of operation is dependent on the location and desired objective of the loop layout. It *should* be noted that certain loop layout strategies require specific detector/controller functions to be utilized.

DETECTOR BASED OPERATIONS

Pulse and Presence

There are two basic modes of vehicle detection, pulse and presence. In pulse detection, the detector amplifier sends a pulse call to the controller upon detection of a vehicle. This is a call of short duration, and it does not depend upon the speed of the detected vehicle, its length, its continued presence over the loop, or the length of the loop. In presence detection the detector amplifier issues a continuous call to the controller for as long as any portion of the vehicle remains over the loop. The length of the call is, therefore, dependent on the speed of the vehicle, the length of the vehicle, and the length of the loop. Default is to use presence-based detection.

Extension Stretch

Extension stretch is used when the passage interval feature is set at a low value. Extension stretch allows an increment of time to pass while a vehicle travels from one point of detection to some other position. The interval *may* be used to extend the green, allowing a vehicle to pass the dilemma zone, or allow a vehicle to enter or clear the intersection. The various detector placements have different passage and extension stretch intervals associated with them. The designer *should* select the passage intervals which fulfill the requirements of the loop detector layout selected.

Delayed Call

Using the delayed call mode, the output is deferred until the detection zone has been occupied for a preset time. This has two common uses. First: at near detection in shared through and right-turn lanes or right only lanes, vehicles turning right on red *may* occupy the near detection for a short period without unnecessarily calling the controller to the respective phase. Second, at near loops that *may* be driven over by cross street left turning vehicles, especially tractor-trailer combinations.

Detector Disconnect

The detector disconnect feature allows a chosen detector(s) to be disconnected when the indicated phase is active.

OTHER CONTROLLER MODES OF OPERATION

There are several other modes of operation related to detection, which can be programmed directly within the controller. Some more commonly used modes at signalized intersections include minimum green time, maximum green time, passage interval, non-locking detection memory, phase recall, etc. Phase recall is discussed below; other controller functions are included in the glossary.

Phase Recall Mode of Operation

Use of these features is common for major route intersections with heavy traffic or pedestrian volumes. The phase recall function allows a phase (vehicle or pedestrian) to be displayed during each cycle whether demand exists or not.

The MIN recall setting will force its respective PHASE NUMBER (column 1 of the Detector Logic Chart) to be serviced, each cycle, for the established minimum green time. The MAX recall setting will force its respective PHASE NUMBER to be serviced, each cycle, for its maximum green time. The SOFT recall setting will return to its respective PHASE NUMBER when the controller goes to green rest in all other phases. The PED recall setting will force its respective PHASE NUMBER pedestrian walk display to be serviced during each cycle.

At isolated intersections the mainline is generally put on MIN recall bringing the green back to dwell on the mainline phases.

Locking and Non-Locking Mode of Operation

All calling detectors can function as locking or non-locking. Locking detectors hold a call when a vehicle is at rest on the detector and after the vehicle passes over the detector when in the red interval. The non-locking detection mode requires the vehicle to occupy the detector for a call to be issued to the controller. The call would be dropped if the vehicle moves off the detector. All detectors for each phase must be set to locking or non-locking; controllers do not allow individual detector settings within a phase.

DETECTOR TYPES

Inherent to modern signal design and operations is vehicle detection. Proper consideration must be given to providing vehicle detection that will result in efficient and safe signal operations. The primary goal is to be able to detect vehicles and transmit this data back to the controller as input for controlling signal indications.

There are two general types of loop detector placements. The first type is referred to as "advance" or "far" detection and is used generally for mainline through traffic detection and side road extensions. It is located well in advance of the stop line. The second type is "near" or "stop line" detection. It is usually located near the stop line. Detectors are typically operated in presence mode, which means if a vehicle is within the zone of detection; it will continue to be detected, until it leaves the zone of detection.

It *should* be noted that efficient signal operations and timings are directly related to all detector placement strategies and methods. As with all traffic control devices, adjustments to loop placement and size *may* be necessary depending on actual field conditions and *should* be verified in the field by the maintaining authority prior to installation.

This section covers the various loop layout strategies, which can be used for left turn lanes, advance detection, and near detection. In addition, the loop types, inductance calculation, construction considerations, and detector/controller modes of operation are also discussed.

WisDOT generally recommends using standard inductive, loop detectors. These detectors are cost effective, reliable, require little maintenance and last indefinitely when installed properly. (See FDM Chapter 16, Standard Detail Drawings).

Any detection technology that is selected **shall** first be discussed with the Region Traffic Signal Engineer due to long term operations and maintenance considerations.

INDUCTIVE LOOP DETECTORS

The vast majority of State-owned signals are fully actuated and use inductive, in-pavement loop detection to adjust local timing at an intersection. This type of detection consists of a loop installed in the pavement, a separate lead-in cable, and a detector amplifier located in the controller cabinet. When energized, the loop configuration creates a magnetic flux field. When a vehicle passes over the loop it causes that flux to change, which the detector amplifier can sense. This disruption is interpreted as the presence of a vehicle and will generally place a call to the signal controller for a certain phase. Ultimately, programming in the controller dictates what actions *may* occur based on a vehicle call, but other functions *may* also include phase extensions, preemption, or other features.

Detector loops *may* be configured in many ways depending upon the application. This manual will discuss primarily rectangular loop configurations for all applications. The technology associated with today's modern loop detector amplifiers, particularly digital amplifiers, allows for a variety of motor vehicles to be detected successfully with typical rectangular configurations.

MICROLOOP

Microloops are small, cylindrical probes typically buried beneath the roadway surface. The installation time for Microloops is much shorter than for installation of standard loop detectors. Microloops *may* be wired or wireless, depending on the product used.

Microloops *may* be used on bridge decks where it is not practical to implement other loop types. Microloops for permanent installations are generally recommended only under special conditions such as poor pavement structure and bridge decks. Their use **shall** be discussed with the maintaining authority.

VIDEO DETECTION

Video detection makes use of a camera and video monitor to detect vehicles on the roadway. The camera is placed at a location above the intersection and directed toward the approach; typically, one camera is required for each approach. The image is transmitted onto a video monitor where the user graphically draws the detection zone(s). Different sizes of detectors can be selected, and detection zones can be placed anywhere within the camera's field of view. This detection method is very flexible in that the detector locations can be modified easily using the mouse and video monitor.

Video detection is expensive but *may* have benefits in temporary or construction applications. Their use *should* be discussed with the maintaining authority.

MICROWAVE/RADAR DETECTION

Radar detection is based on the Doppler principle. A transmitter directs microwave beams toward the roadway. Any vehicle passing through the beam reflects the microwaves back to an antenna at a different frequency. The detector senses the change in frequency.

Like video detection, microwave detectors are expensive but *may* have benefits in temporary or construction applications. Their use *should* be discussed with the maintaining authority.

CONSTRUCTION CONSIDERATIONS FOR IN-ROADWAY LOOPS

The construction staging of road projects *may* have a direct influence on the loop size used for detection. For example, construction of a three-lane approach *may* be staged for the placement of two lanes first and the third lane in a different pour. Advance detector placement *may* be one 6’ x 20' loop covering the first construction stage and a single 6' x 6’ for the second construction stage. Loop placement *should not* cross asphalt to concrete, or concrete-to-concrete joints, unless detectors are placed in the base below the pavement. Construction staging *may* also make it practical to install other types of detection. The use of these other types of detection *should* be discussed with the maintaining authority.

In-Roadway Loops (including lead--in) *should* be placed below the pavement into the base course to avoid pavement joints that can cause loops to fail, to be out of conflict with pavement milling operations.

Loops *may* be installed in two general methods. See the Standard Detail Drawings in the FDM for the specific information on each type.

<u>Loops in Conduit:</u>

Pavement Overlaid Loops – Used anyplace where the entire loop will be within an area of new, overlaid, milled and replaced, or seal-coated pavement. The excavation and patching required are easily covered by the pavement work. When properly installed, loop failure is very minimal.

Saw cut Loops – Used if the loop or any part of the loop would end up in an existing pavement that will not be modified by any of the methods above. When properly installed, loop failure is minimal.

Below Pavement Loops – Used at locations where entire pavement is new or rebuilt construction. Loops are generally placed in base course.

<u>Loops Not in Conduit:</u>

Saw cut Loops – Loops are installed directly into saw cut and then sealed with an approved loop sealer. Loop life for this type of loop is shorter compared to the conduit encased loops. Although not recommended by WisDOT for long-term installations, signals under local jurisdiction *may* use saw cut loops. Uses of saw cut loops include temporary signals, intersections scheduled for reconstruction, and permanent signals under <u>local jurisdiction.</u>

ADVANCE OR FAR DETECTION

The methods associated with advanced detection design must be compatible with signal timing objectives and intended operations. Detector placement strategies which require high values of allowable gap for safety can affect efficiency. For example, a long allowable gap *may* cause unnecessary delay to waiting vehicles or routinely extend the controller to maximum green even under moderate traffic. Conversely, strategies that allow for lower values of allowable gap *may* not provide adequate dilemma zone protection.

Depending on vehicle speeds and roadway geometrics, advance detection *may* be augmented by the placement of intermediate and/or stop line detection. Additional near detection is commonly used on low volume side street approaches and main street approaches that do not use phase recall.

There are a variety of strategies that can be employed for advance detection. However, primarily there are two which provide the most efficient and safe operation. These are single point detection and dilemma zone detection.

SINGLE POINT DETECTION (FOR LOW-SPEED APPLICATIONS)

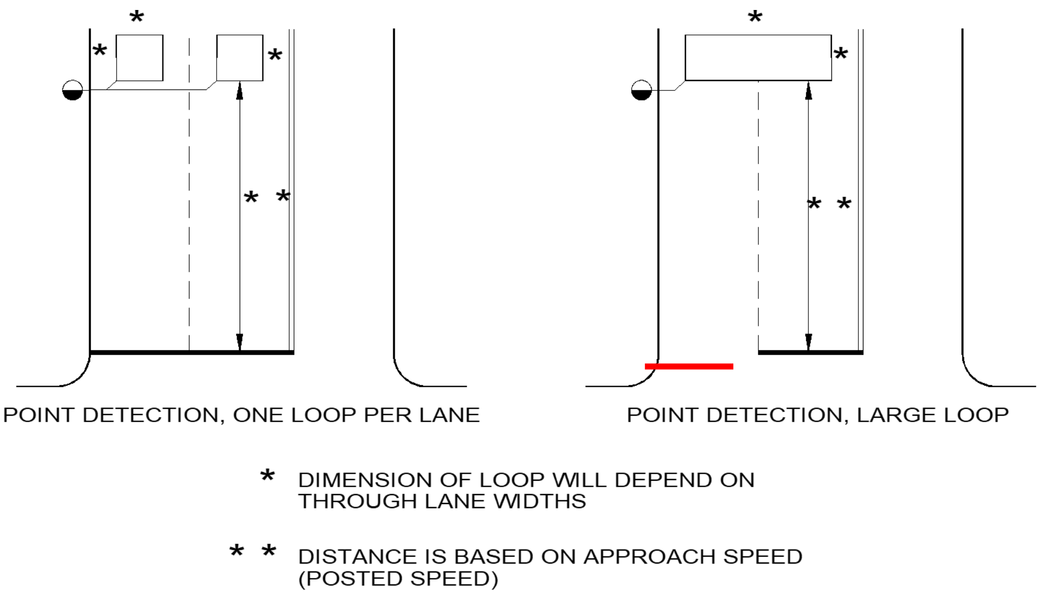
Single point detection consists of a single detection zone located two to five seconds of travel time in advance of the stop line. Single point detection is typically used where vehicle speeds are ≤35 mph or if the opposing volumes are such that it is inefficient to extend the green for sporadic arrivals.

Signal timing for this type of detector application is based on the distance from the stop line to the location of the advance detection. The minimum green time is commonly set for approximately 6 to 10 seconds. Variable initial time *may* be used to add green time beyond the minimum green value if the minimum green would not otherwise accommodate queue clearance back to the detector for additional extensions. While this type of detection can also be used for higher speeds, ≥35 mph, it is recommended that the second type, dilemma zone detection, be employed where speeds exceed 35 mph.

This loop layout *may* be used for extending the green time for a side street approach, and for left turn lanes. If extend only detection is installed without recall, it must be supplemented with near detection. This is required since extend only detection will not place a call from a passing vehicle when a red phase is being timed.

Figure 1.1 illustrates two commonly used layouts for Single Point Detection.

Figure 1.1. Advance Detection Loop Layout



DILEMMA ZONE DETECTION (FOR HIGH-SPEED APPLICATIONS)

The dilemma zone is defined as that portion of the roadway in advance of the intersection within which a driver is indecisive regarding stopping prior to the stop line or proceeding through the intersection at the termination of that approach's green interval. Detection designed to minimize driver decisions in this area is called dilemma zone detection.

The dilemma zone is generally identified in the area from 2- to 5-secs in advance of the intersection for a given speed. Empirical data suggest that at 2-secs from the intersection, it's 90% probable the vehicle will continue through. At 5-secs from the intersection, it's 90% probable the vehicle will stop. Based on kinematic principals, vehicles travelling at higher speeds will have a dilemma zone that physically begins further from the intersection than vehicles travelling more slowly.

For purposes of establishing the dilemma zone and advance loop placement, the 85th-percentile speed *should* be used. This value can be measured in the field using standard spot-speed study techniques, or it can be estimated by using the posted speed, plus 5-mph. In higher speed environments (≥55-mph), or locations were either greater speed variability or a higher percentage of heavy vehicles exist, consideration for placing advance detection at 6-secs from the stop line *should* be considered.

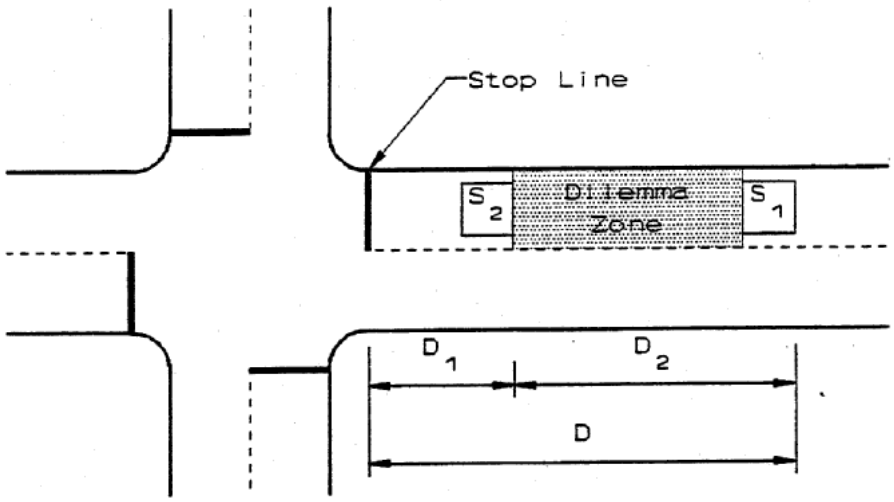
Any new or reconstructed WisDOT-owned, permanent signals located on ≥40 mph facilities **shall** incorporate considerations for dilemma zone protection. While there *may* be other ways of accommodating dilemma zone protection, the techniques discussed here are traditional methods.

The three primary dilemma zone detection methods described below are: 1) green extension system, 2) extended call detector system, and 3) single point. It *should* be noted that regardless of the method employed, vehicles *may* still be caught in the dilemma zone if traffic conditions, or timing parameters cause the respective phase to max out.

1) GREEN EXTENSION SYSTEM

The green extension system utilizes two loops per lane. The concept is to detect a vehicle as it enters the dilemma zone and then extend the green until the vehicle clears the dilemma zone. The advance loop (S_1) acts to extend the green time for a vehicle to reach the near loop (S_2). The near loop maintains the green time long enough to allow the vehicle to enter or clear the intersection. Figure 1.2 illustrates the Green Extension Detector system layout.

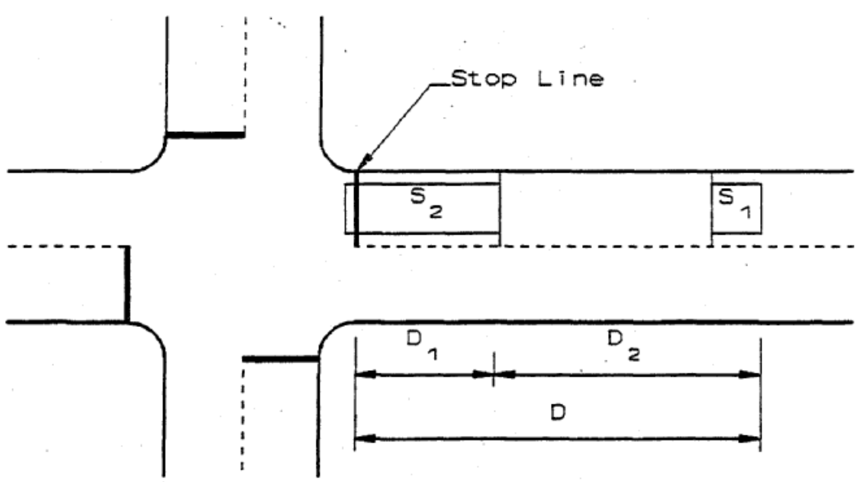
Figure 1.2. Green Extension System



2) EXTENDED CALL SYSTEM

The extended call detector system also utilizes two loops. However, under this method a long loop or series of long loops is placed at or near the stop line for presence detection, and a single extended call detector loop is placed upstream of the stop line. The advance loop (S_1), located at the beginning of the dilemma zone, extends the green time, allowing a vehicle to reach a point just prior to the stop line, but through the dilemma zone. The stop line loop (S_2, presence loop) ensures that vehicles queued at the intersection can enter the intersection without triggering a premature gap out in the case there are no subsequent calls from vehicles on the advance loops. Modern signal controllers allow for varied detector functions that can extend for the queued vehicles and shut off, such that the phase can be extended from approaching vehicles only, lending to more efficient gap reduction. Figure 1.3 illustrates the Extended Call Detector system layout.

Figure 1.3. Extended Call Detector System



3) SINGLE POINT DETECTION

One of the most straight forward conventional designs for “high-speed” approaches uses a controller with a volume-density mode. Based on a single advance point detector (S1) with the controller set on “Min Recall” and in “Locking Memory” this actuated operation can count waiting vehicles beyond the first because of the “Added Initial” feature. It also includes a timing adjustment to reduce the allowable gap based on the time vehicles have waited on the red on a conflicting phase. More efficient operation can be achieved with this controller mode than is possible with the normal full-actuated control because of these features and because detection is further back on the approaches (Up to and over 400-ft is possible when over 50 mph).

The basic concept for dilemma zone protection with this detection / controller strategy is to have the single advance detector (S1) detect a vehicle just prior to it entering the dilemma zone. Early in the cycle the detector would use the full passage time and would extend vehicles all the way to the stop line. Further into the cycle, after full “Gap Reduction”, the lowest extension setting would be timed to just clear the vehicle through the defined dilemma zone (Defined by the 90% GO Curve). If vehicles are separated by more than this Minimum Gap, then the phase will “Gap Out” at that point.

The Single Point Detection System layout is similar that shown in Figure 1.3 above but will have different spacing for the intersection.

REFERENCE CHARTS

There have been several tables published regarding the dilemma zone location for various design speeds. For the purpose of providing guidance, Chart 1.1 and Table 1.1 have been reprinted from a Northwestern University Traffic Institute course manual. Table 1.1 shows the dilemma zone response curves by vehicle speed and distance from intersection. The 90% Go and 90% Stop probability ranges have been marked for reference during design. Table 1 shows passage distances based on speed and time. The numbers shown in Table 1 are directly related to the curves shown in Chart 1.1. Chart 1.2 has been reprinted from the Federal Highway Administration Detector Manual. This chart shows various dilemma zone response curves by vehicle based on vehicle speed and percentage probability of stopping. The 90% and 10% probability ranges have been identified for reference during design. Chart 1.3 *may* be used to determine passage times for advance detection. Using the design speed and proposed passage distance, the passage time can be determined. It is the responsibility of the signal designer to determine the appropriate passage distance. The passage time *should* allow the vehicle to enter into the intersection; however, each case *should* be evaluated separately. Table 1.2 indicates loop placement options for the Green Extension System described above.

These tables and charts are provided only as a reference. In all cases the signal designer is responsible for selecting the appropriate design speed, passage time, and percentage probability of stopping.

Chart 1.1. Dilemma Zone Response Curves

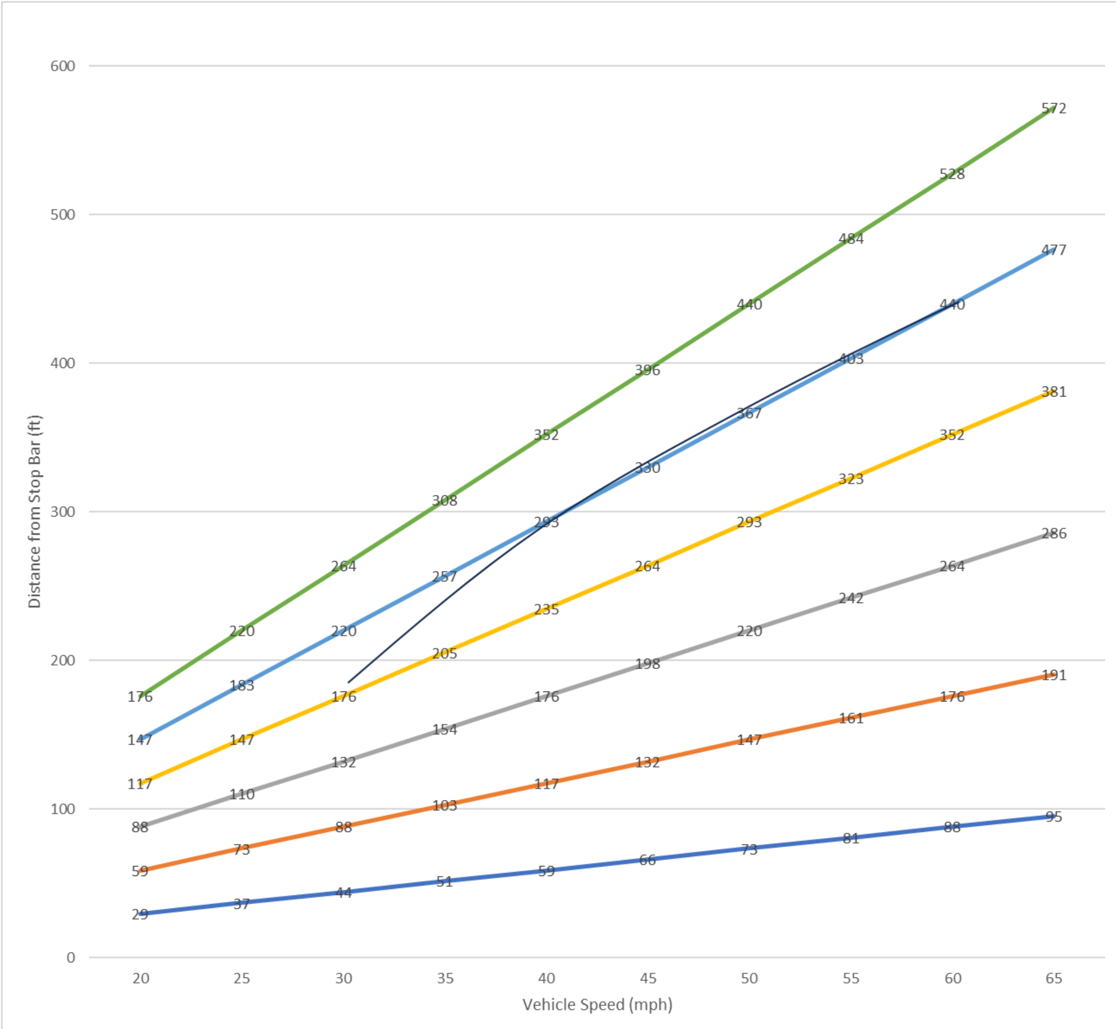


Table 1.1. Dilemma Zone Values

Passage/Travel Time from Detector to Stop Bar (Seconds)

Approach Speed (Miles per Hour)	1	2	3	4	5	6	7	8	9	10	11	12
20	29	59	88	117	147	176	205	235	264	293	323	352
25	37	73	110	147	183	220	257	293	330	367	403	440
30	44	88	132	176	220	264	308	352	396	440	484	528
35	51	103	154	205	257	308	359	411	462	513	565	616
40	59	117	176	235	293	352	411	469	528	587	645	704
45	66	132	198	264	330	396	462	528	594	660	726	792
50	73	147	220	293	367	440	513	587	660	733	807	880
55	81	161	242	323	403	484	565	645	726	807	887	968
60	88	176	264	352	440	528	616	704	792	880	968	1056
65	95	191	286	381	477	572	667	763	858	953	1049	1144

Density values (for reference) (columns 6–12)

Legend: [box] Variable Initial only; Dilemma Zone

Chart 1.2. Dilemma Zone Response Curves

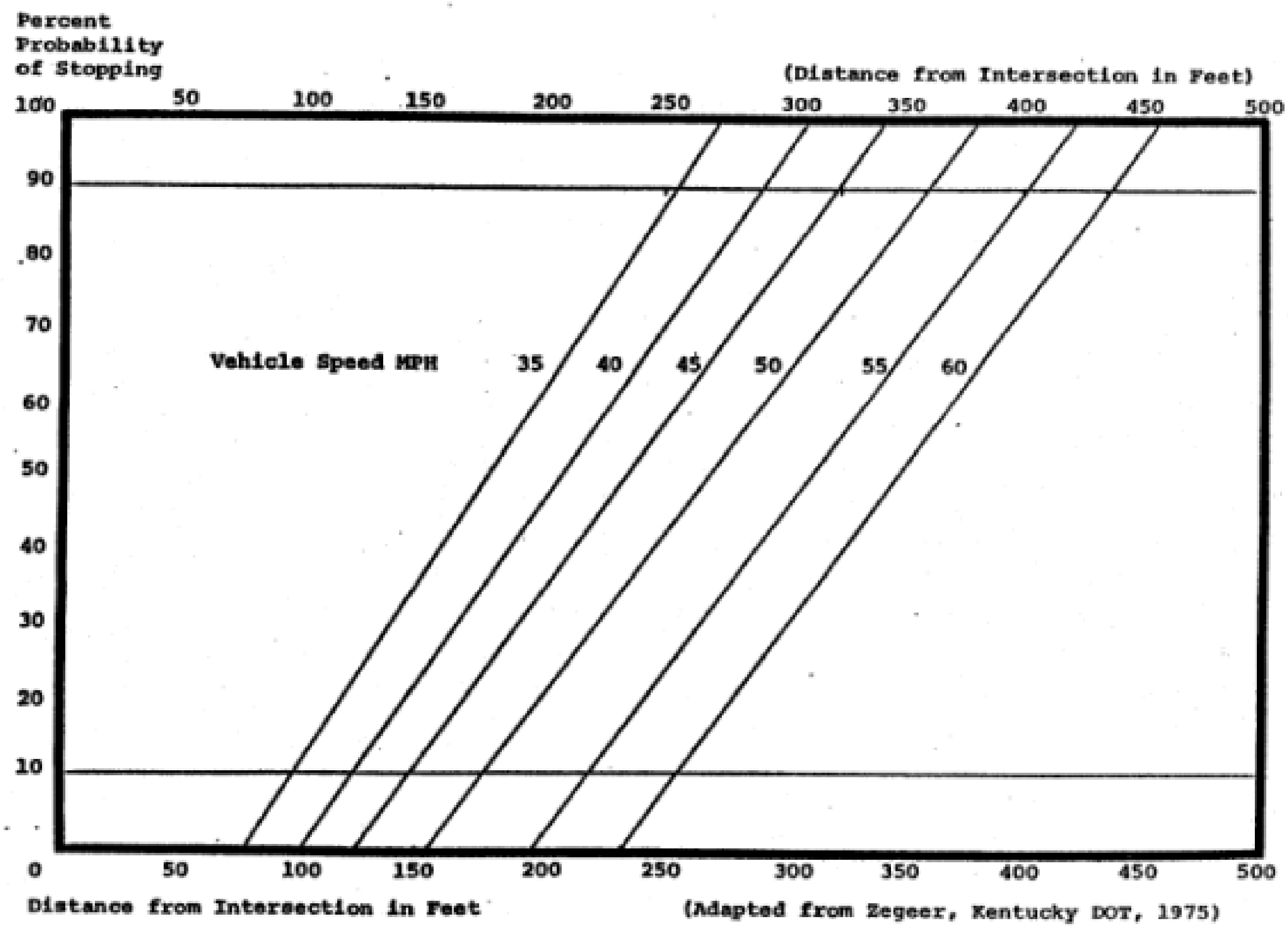
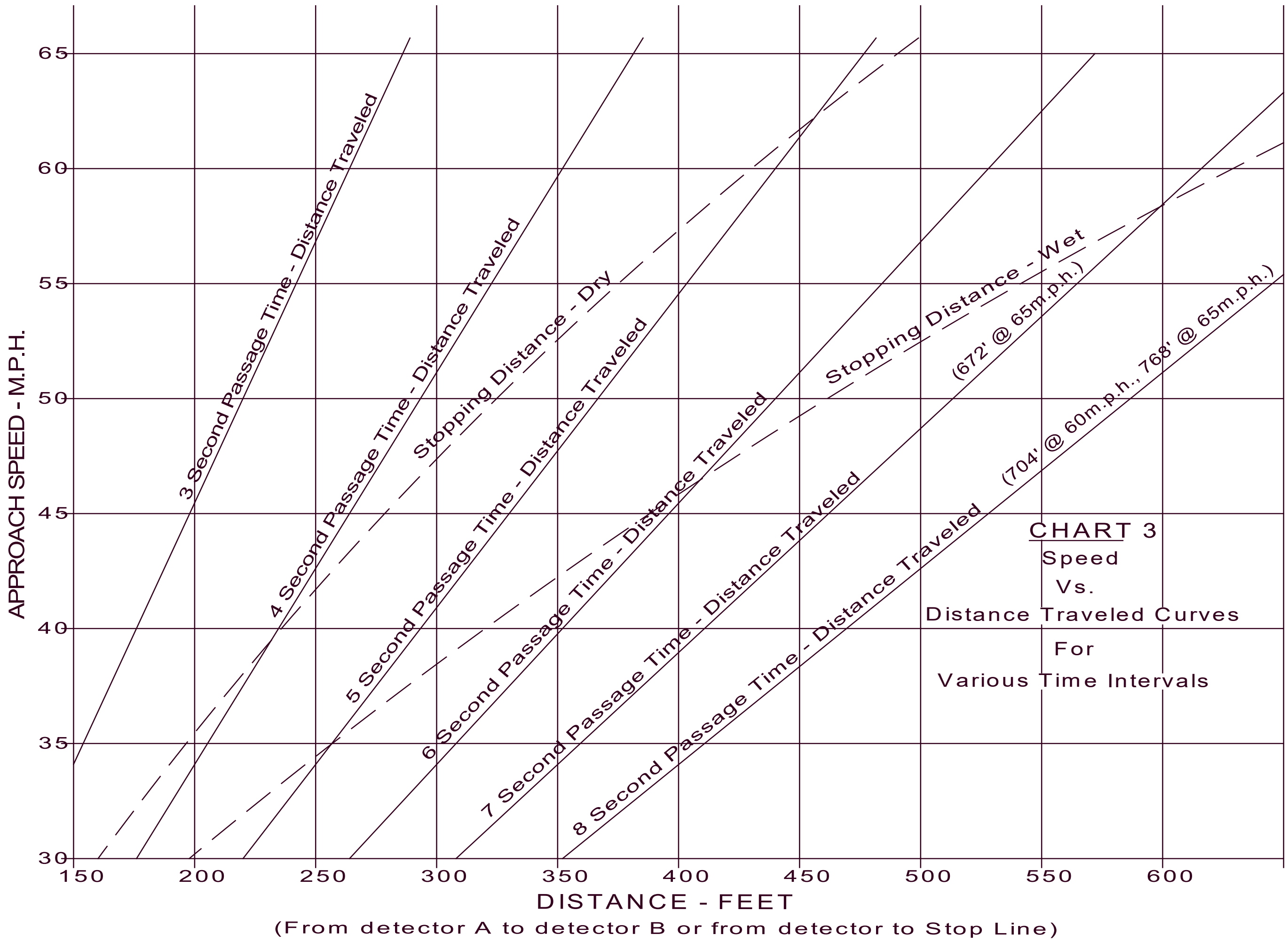


Table 1.2. Green Extension System Loop Placement Options

Advanced Detector Placement based on 90% Stop Probability (Measured from front of detector to near right signal)			
Vehicle Speed		Advance	Near
25-mph	37-fps	185-ft	---
30-mph	44-fps	220-ft	---
35-mph	51-fps	255-ft	---
40-mph	59-fps	295-ft	120-ft
45-mph	66-fps	330-ft	130-ft
50-mph	74-fps	370-ft	150-ft
55-mph	81-fps	405-ft	160-ft
60-mph	88-fps	440-ft	175-ft

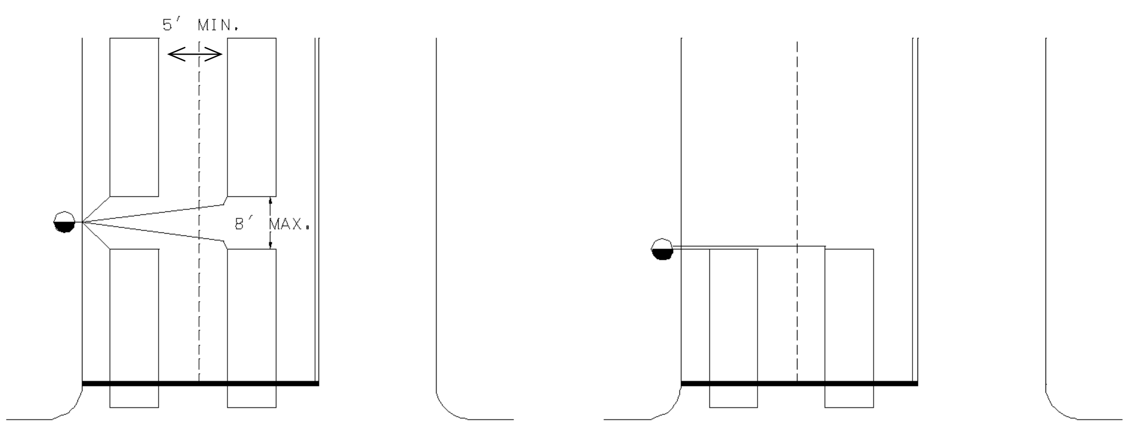
Chart 1.3. Passage Time Design Curves



NEAR DETECTION

Unless physical or operational characteristics are atypical, near detection for through movements *should* be placed at the stop line. The detector amplifier mode *should* be set to presence detection. However, detectors in the right lane and detectors that *may* be driven over by left turning vehicles *should* be set to a delay mode to allow those movements to occur without registering false calls. Figure 1.4 below illustrates common near detection layouts.

Figure 1.4. Near Detection



In many cases a set of loops is installed to provide a larger detection area and for redundancy in case of detector failure. This is especially important for detection on a single lane approach where loop failure (if only one loop is installed, and the phase is not set for recall) *may* cause failure of the corresponding phase.

Historically, motorcycles, bicycles, and/or small vehicles *may* have had problems with not being properly detected by large (≥ 6' x 20') loops at certain locations. While modern loop amplifiers have remedied issues related to missed calls, if concerns or issues at specific locations persist, other loop configurations *may* be considered. For example, smaller 6’ x 6’ loops turned 45-deg can result in increased sensitivity in locations where smaller vehicles need to be detected. Careful consideration *should* be given to using smaller detection zones due to their restricted ability to detect high bed trucks. WisDOT does not typically use quadrupole loops.

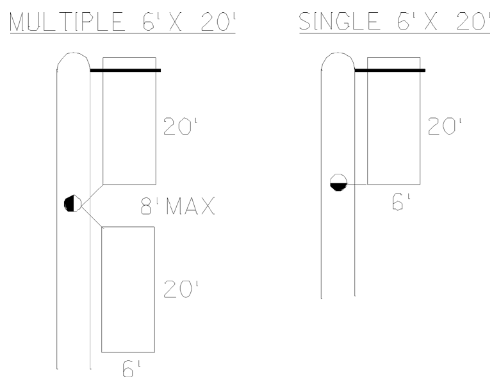
LEFT-TURN DETECTION

Several variations of detection *may* be used for left turn lane detection. The specific type of configuration that *should* be used is dependent upon many factors, including signal phasing, geometrics, vehicle classification, and turning volumes. All these factors must be considered when designing the detection scheme.

Alternative No. 1: Protected only or protected/permissive operation.

Detector loops are placed beginning at the stop line to call and extend the phase. This *may* be used for protected only or protected/permissive left turn operations. The detector amplifier is set to presence mode and controller logic to nonlocking memory. This allows for more efficient operation in that once a vehicle leaves the zone of detection the call is dropped, and the controller can begin to service other calls. This type of operation is often used for left turns where the opposing through volume is relatively high, and the left turn demand is constant. Figure 1.5 below illustrates two commonly used layouts.

Figure 1.5. Protected-Only or Protected/Permissive Left Turn Loop Layout



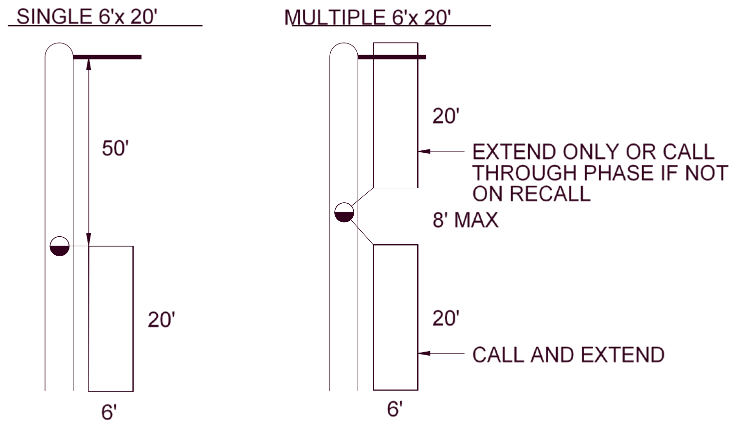
Alternative No. 2: Third vehicle detection. Protected/permitted operation only.

The detector is placed in advance (upstream) of the stop line such that the first one or two vehicles in the left turn lane will not place a call in the protective phase. This *should* not be used for protected only left turn operation. Figure 1.5 illustrates two commonly used layouts.

Sufficient gaps, particularly during non-peak hours, are usually available to permit vehicles to turn on a green ball. This alternative *may* be used only for approaches with minimum recall or approaches with stop line detection. The detector amplifier is set to presence mode and controller logic to non-locking memory. This type of operation allows for more efficient use of the green time for mainline traffic.

Detector layouts illustrated in Alternative 1 *may* be used for third-vehicle detection by programming the front loop for extend only. This layout allows for the flexibility of changing operations from third car to protected detection.

Figure 1.6. Third-Vehicle Detection Loop Layout



Alternative No. 3: Left-turn extension detection.

Long left turn lanes or high left turn volumes *may* require the use of advance detection for extending the green. Generally, an advance loop installed in the left turn lane *may* extend the left turn phase, the through movement, or both. Loop layout for left turn lane extension *should* follow the guidelines outlined in this subject.

Figure 1.7. Left Turn Extension Detection

INDUCTANCE CALCULATIONS

The ability to detect vehicles is primarily a function of the loop's inductance and sensitivity, not its shape. The advent of digital detector amplifiers and electronics has eliminated many problems associated with older loop detector amplifiers. These problems included splash over, crosstalk, and difficulty in detecting smaller vehicles with standard detector configurations.

The total inductance of loop detector systems is related to loop size, the number of turns in the loop and the length of lead-in cable. These elements will influence inductance associated with them. As a rule, the actual loop *should* have approximately twice the inductance as the lead-in cable to ensure good detection efficiency. Lead-in cable has approximately 23 microHenries of inductance per 100 feet. For the detector loop to have a 2:1 ratio of inductance compared to the lead-in cable, the loop must have a certain number of turns. The longer the lead-in the greater the number of turns. A commonly used formula for determining the loop inductance is shown below.

Inductance = $(N^2 \times 5 \times P) / (10 + N)$ Where: N = Number of turns in loop

P = Perimeter of loop

If two or more loops are wired in series, their inductances are additive (total inductance: $L = L_1 + L_2 + ... + L_n$). When several loops are installed, maximum inductance is obtained by wiring the loops in series. The total inductance for a single detector amplifier *should* not exceed 800 to 1000 mH.

If two or more loops are wired in parallel, the combined inductance is reduced (total inductance: $1/L = 1/L_1 + 1/L_2 + ... + 1/L_n$). When using parallel connections, the designer *should* calculate the total loop inductance to be sure it is approximately two (2) times that of the lead-in cable inductance. Often a combination of parallel and series connections is used to keep the total inductance below 800 to 1000 mH and to aid in installation.

An effort *should* be made to avoid installing loops of equal size, side by side with the same number of turns. Such installations are potential sources of trouble (cross-talk, false calls). If, for example, one loop (closest to the cabinet) has 3 turns, then the farther one *should* have 4 turns.

Table I can be used as a quick reference for single loop inductance for various loop sizes. Inductance for this table is determined by the formula stated above.

It is the responsibility of the signal designer to determine the proper loop size and number of turns. The designer is not restricted to the loop sizes shown in the following table.

However, loops with greater than 5 turns are generally not easily constructed or maintained in 1” conduit. If loops need 5 or more turns in accommodate 2:1 inductance relative to lead-in cable, 1-1/2” conduit *should* be considered.

Table 1.3. Single-Loop Inductance Calculations

Loop Size	INDUCTION					
	1 turn	2 turns	3 turns	4 turns	5 turns	6 turns
2’ x 6’	7.3	26.7	55.4	91.4	133.3	180.0
2’ x 8’	9.1	33.3	69.2	114.3	166.7	225.0
2’ x 10’	10.9	40.0	83.1	137.1	200.0	270.0
2’ x 12’	12.7	46.7	96.9	160.0	233.3	315.0
2’ x 14’	14.5	53.3	110.8	182.9	266.7	360.0
2’ x 16’	16.4	60.0	124.6	205.7	300.0	405.0
2’ x 18’	18.2	66.7	138.5	228.6	333.3	450.0
2’ x 20’	20.0	73.3	152.3	251.4	366.7	495.0
3’ x 6’	8.2	30.0	62.3	102.9	150.0	202.5
3’ x 8’	10.0	36.7	76.2	125.7	183.3	247.5
3’ x 10’	11.8	43.3	90.0	148.6	216.7	292.5
3’ x 12’	13.6	50.0	103.8	171.4	250.0	337.5
3’ x 14’	15.5	56.7	117.7	194.3	283.3	382.5
3’ x 16’	17.3	63.3	131.5	217.1	316.7	427.5
3’ x 18’	19.1	70.0	145.4	240.0	350.0	472.5
3’ x 20’	20.9	76.7	159.2	262.9	383.3	517.5
4’ x 4’	7.3	26.7	55.4	91.4	133.3	180.0
4’ x 6’	9.1	33.3	69.2	114.3	166.7	225.0
4’ x 8’	10.9	40.0	83.1	137.1	200.0	270.0
4’ x 10’	12.7	46.7	96.9	160.0	233.3	315.0
4’ x 12’	14.5	53.3	110.8	182.9	266.7	360.0
4’ x 14’	16.4	60.0	124.6	205.7	300.0	405.0
4’ x 16’	18.2	66.7	138.5	228.6	333.3	450.0
4’ x 18’	20.0	73.3	152.3	251.4	366.7	495.0
4’ x 20’	21.8	80.0	166.2	274.3	400.0	540.0
4’ x 30’	30.8	113.5	235.7	388.8		
5’ x 6’	10.0	36.7	76.2	125.7	183.3	247.5
5’ x 8’	11.8	43.3	90.0	148.6	216.7	292.5
5’ x 10’	13.6	50.0	103.8	171.4	250.0	337.5
5’ x 12’	15.5	56.7	117.7	194.3	283.3	382.5
5’ x 14’	17.3	63.3	131.5	217.1	316.7	427.5
5’ x 16’	19.1	70.0	145.4	240.0	350.0	472.5
5’ x 17’	20.0	73.3	152.3	251.4	366.7	495.0
5’ x 18’	20.9	76.7	159.2	262.9	383.3	517.5
5’ x 20’	22.7	83.3	173.1	285.7	416.7	562.5
5’ x 30’	31.8	116.7	242.3	400.0	583.3	787.5

Table 1. Single-Loop Inductance Calculations (continued)

Loop Size	INDUCTION					
	1 turn	2 turns	3 turns	4 turns	5 turns	6 turns
6’ x 6’	10.9	40.0	83.1	137.1	200.0	270.0
6’ x 7’	11.8	43.3	90.0	148.6	216.7	292.5
6’ x 8’	12.7	46.7	96.9	160.0	233.3	315.0
6’ x 10’	14.5	53.3	110.8	182.9	266.7	360.0
6’ x 12’	16.4	60.0	124.6	205.7	300.0	405.0
6’ x 14’	18.2	66.7	138.5	228.6	333.3	450.0
6’ x 15’	19.1	70.0	145.4	240.0	350.0	472.5
6’ x 16’	20.0	73.3	152.3	251.4	366.7	495.0
6’ x 17’	20.9	76.7	159.2	262.9	383.3	517.5
6’ x 18’	21.8	80.0	166.2	274.3	400.0	540.0
6’ x 20’	23.6	86.7	180.0	297.1	433.3	585.0
6’ x 22’	25.5	93.3	193.8	320.0	466.7	630.0
6’ x 24’	27.3	100.0	207.7	342.9	500.0	675.0
6’ x 25’	28.2	103.3	214.6	354.3	516.7	697.5
6’ x 26’	29.1	106.7	221.5	365.7	533.3	720.0
6’ x 28’	30.9	113.3	235.4	388.6	566.7	765.0
6’ x 30’	32.7	120.0	249.2	411.4	600.0	-
6’ x 32’	34.5	126.7	263.1	434.3	633.3	-
6’ x 34’	36.4	133.3	276.9	457.1	666.7	-
6’ x 36’	38.2	140.0	290.8	480.0	700.0	-
6’ x 38’	40.0	146.7	304.6	502.9	733.3	-
6’ x 40’	41.8	153.3	318.5	525.7	766.7	-
6’ x 42’	43.6	160.0	332.3	548.6	800.0	-
6’ x 44’	45.5	166.7	346.2	571.4	-	-
6’ x 46’	47.3	173.3	360.0	594.3	-	-
6’ x 48’	49.1	180.0	373.8	617.1	-	-
6’ x 50’	50.9	186.7	387.7	640.0	-	-
6’ x 60’	60.0	220.0	456.9	754.3	-	-
6’ x 70’	69.1	253.3	526.2	-	-	-
6’ x 80’	78.2	286.7	595.4	-	-	-
7’ x 16’	20.9	76.7	159.2	262.9	383.3	517.5
7’ x 18’	22.7	83.3	173.1	285.7	416.7	562.5
7’ x 20’	24.5	90.0	186.9	308.6	450.0	607.5
8’ x 8’	14.5	53.3	110.8	182.9	266.7	360.0
8’ x 10’	16.4	60.0	124.6	205.7	300.0	405.0
8’ x 12’	18.2	66.7	138.5	228.6	333.3	450.0
8’ x 14’	20.0	73.3	152.3	251.4	366.7	495.0
8’ x 16’	21.8	80.0	166.2	274.3	400.0	540.0
8’ x 18’	23.6	86.7	180.0	297.1	433.3	585.0
8’ x 20’	25.5	93.3	193.8	320.	466.7	630.0

ASCT & TR DETECTION CONSIDERATIONS

Some traffic signal designs *may* need to include considerations for Adaptive Signal Control Technologies (ASCT) and/or Traffic Responsive (TR). ASCT allows for near real-time changes to coordinated signal offset and splits settings. TR allows for changes between timing plans (i.e,. cycle length and sequencing adjustments). Both forms of control require communication back to a central system, as well as an increased amount of detection.

Detection for ASCT systems will need to include by-lane stop line detection on each intersection approach for split adjustments. While mainline advance detection *should* likely be accounted for within the design at some level, both advance and exit *may* be required for offset adjustments. Ideally, advance and exit detection for ASCT are also by-lane.

Detection needs for TR systems are not far beyond those required to operate an isolated intersection. The primary additional needs are likely limited to mainline exit detection for measuring system volumes associated with timing plan changes vs. running a similar set of plans via time-of-day schedule.

4-8-2 Detector/Controller Logic Chart April 2025

The Detector Logic Chart is located on the Sequence of Operations Sheet. There are several columns, which supply information regarding the detector location, mode of operation, and several other optional settings.

TS1 DETECTOR LOGIC CHART

A blank Detector Logic Chart for a TS1 signal cabinet with shelf-mounted loop amplifiers is shown below.

Figure 2.1. Detector Logic Chart

DETECTOR LOGIC

DETECTOR NUMBER	AMPLIFIER CHANNEL NUMBER	DETECTOR OPERATION			PHASE CALLED	PHASE EXTENDED	DETECTOR DISCONNECT PHASE	CALLING DELAY	EXTENSION STRETCH	LOOP SIZE	NUMBER OF TURNS
		CALLS & EXTENDS	CALLS ONLY	EXTENDS ONLY							
Column 1	2	3	4	5	6	7	8	9	10	11	12

Column 1: DETECTOR NUMBER - Indicate the detector number for all detectors at the signalized intersection. Detectors are numbered according to the phase they are associated with (first digit) and the order in which they would be encountered (second digit). Detectors adjacent to one another are numbered from the centerline to the outside.

Column 2: AMPLIFIER CHANNEL NUMBER - The second column indicates the amplifier channel corresponding to each detector or detector group. Every effort *should* be made to group detectors performing like functions. Do not wire more than two loops per amplifier channel.

Column 3-5: DETECTION OPERATION - Place an "X" in the cell to indicate a specific operation. Only one of the three columns *should* have an "X".

Column 6: PHASE CALLED - Indicate which phase is called when a vehicle arrives at a CALLS & EXTENDS or CALLS ONLY detector. This column must be filled out if the detector operation is set for CALLS & EXTENDS or CALLS ONLY: otherwise, it *should* be left blank.

Column 7: PHASE EXTENDED - Indicate which phase will be extended. This cell must be filled out if the detector operation is set to CALLS & EXTENDS or EXTENDS ONLY; otherwise, it *should* be left blank.

Column 8: DETECTOR DISCONNECT PHASE - Indicate which detectors use the detector disconnect feature by placing an "*" in the column. A note is also needed to explain when the detector(s) are disconnected.

Column 9: CALLING DELAY - Indicate which detectors use the calling delay feature by placing an "X" in the column.

Column 10: EXTENSION STRETCH - Indicate which detectors use the extension stretch function by placing an "X" in the column.

Column 11: SIZE - Enter the dimensions of the detector (e.g. 6'x 6').

Column 12: NUMBER OF TURNS - Indicate the number of turns required for the detector.

TS2 DETECTOR LOGIC CHART

A blank Detector Logic Chart for a single TS2 signal cabinet detector rack with rack-mounted loop amplifiers is shown below.

DETECTOR INPUT	3	1	7	5	11	9	15	13	Row 1
DETECTOR No.									2
PHASE CALLED									3
PHASE EXTENDED									4
CALLING DELAY									5
EXTENSION STRETCH									6
LOOP FUNCTION									7

DETECTOR INPUT	4	2	8	6	12	10	16	14
DETECTOR No.								
PHASE CALLED								
PHASE EXTENDED								
CALLING DELAY								
EXTENSION STRETCH								
LOOP FUNCTION								

Row 1: DETECTOR INPUT – NEMA defined assignment that corresponds to controller-based detector settings.

Row 2: DETECTOR NUMBER - Indicate the detector number for all detectors at the signalized intersection. Detectors are numbered according to the phase they are associated with (first digit) and the order in which they would be encountered (second digit). Detectors adjacent to one another are numbered from the centerline to the outside.

Row 3: PHASE CALLED - Indicate which phase is called when a vehicle arrives at a detector. This column must be filled out if the detector operation is set for CALLS & EXTENDS or CALLS ONLY: otherwise, it *should* be left blank.

Row 4: PHASE EXTENDED - Indicate which phase will be extended. This cell must be filled out if the detector operation is set to CALLS & EXTENDS or EXTENDS ONLY; otherwise, it *should* be left blank.

Row 5: CALLING DELAY - Indicate which detectors use the calling delay feature by placing an "X" in the column.

Row 6: EXTENSION STRETCH - Indicate which detectors use the extension stretch function by placing an "X" in the column.

Row 7: LOOP FUNCTION – Only intended to indicate the special or unique use of a detector. Data in this field *may* vary depending on the type controller. For example, some controller types allow detectors channels to be used to collect system data (such as volume and occupancy). Check with the Regional Traffic Signal Engineer for questions regarding specific locations.

CONTROLLER LOGIC CHART

The Controller Logic Chart is also located on the Sequence of Operations Sheet. The columns on this chart supply information regarding various controller operations. The designer **shall** show all phases in the controller logic box, and where appropriate, leave spaces for the unused phases (i.e. if phase 1 is not used, leave the first-row blank). A blank Controller Logic Chart is shown in Figure 2.2.

Figure 2.2. Controller Logic Chart

CONTROLLER LOGIC

PHASE NUMBER	PHASE LOCKING	DUAL ENTRY w / Ø	PHASE RECALL	PHASE ACTIVE
1				
2				
3				
4				
5				
6				
7				
8				
Column 1	2	3	4	5

Column 1: PHASE NUMBER - Enter the used phases associated with the controller logic settings.

Column 2: PHASE LOCKING - Indicate with an “X” which phases **shall** have locking memory.

Column 3: DUAL ENTRY - Enter which phase number will be permitted to be serviced concurrently with the phase number designated in column 1. This mode of operation requires two phases to be serviced concurrently even in the absence of vehicle demand. Single-entry operation will be programmed if no entry is made.

Column 4: PHASE RECALL - Indicate use of the phase recall function by listing MIN, MAX, or PED; otherwise, leave blank.

Column 5: PHASE ACTIVE - Indicate use of the phase active function. Dummy phases *may* be required in the case of EVP use with LC-8000 controllers and at T-intersection locations. The Regional Traffic Engineer **shall** be contacted regarding the use of the phase active function.