Signal Timing

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Signal Timing Introduction

A traffic signal controls traffic by assigning right-of-way to one traffic movement or several non-conflicting traffic movements at a time. Right-of-way is assigned by turning on a green signal for a certain length of time or an interval. Right-of-way is ended by a yellow change interval during which a yellow signal is displayed, followed by the display of a red signal. The device that times these intervals and switches the signal lamps is called a controller unit.

The objective of traffic signal timing is to assign the right-of-way to alternating traffic movements in such a manner to minimize the average delay to any group of vehicles or pedestrians and reduce the probability of accident producing conflicts.

Often, signals are installed to solve problems at an individual intersection without consideration to the system-wide implications. Traffic control must be set up and implemented on a system-wide basis. You must consider the system, route, and then intersection operations. Synchro is designed to assist you in considering the system-wide impacts created on an individual intersection and the system as a whole.

Some of the guiding standards to signal timing are as follows:

- Minimize the number of phases that are used. Each additional phase increases the amount of lost time due to starting delays and clearance intervals.
- Short cycle lengths typically yield the best performance in terms of providing the lowest overall average delay, provided the capacity of the cycle to pass vehicles is not exceeded. *The cycle length, however, must allow adequate time for vehicular and pedestrian movements*. Longer cycles are used during peak periods to provide more green time for the major street, to permit larger progression opportunities in the peak direction, and/or to reduce the number of starting delays. See the topic on **Optimize→Intersection-Cycle-Length** for information on how Synchro optimizes a cycle length.
- When signals are coordinated with adjacent intersections, they can provide for the continuous movement of traffic along a route at a given speed. The **Coordinatability Factor** in Synchro will assist you in determining if adjacent intersections should be coordinated.
- May reduce the occurrence of certain types of crashes, in particular, the right angle and pedestrian types.

Controller Types

A traffic signal controller is a device that controls the signal indications at an intersection. There are primarily two types of signal controller units in use today: the pretimed and the traffic actuated. Actuated controllers can be further defined as semi-actuated (coordinated or non-coordinated) and fully actuated.

In Synchro, you can set the Controller Type in either the TIMING window or the PHASING window.

Each type of control has it's own unique advantages and disadvantages. There is no optimum way to determine the best controller type for each intersection. Pretimed controllers tend to be less expensive and easier to maintain then actuated controllers. Actuated controllers usually reduce delay, increase capacity, and can be safer than pretimed controllers.

The majority of traffic signal controllers in use today are microprocessors. Generally, they can be categorized as NEMA or model 170 types.

National Electrical Manufacturers Association (NEMA) controllers are units that conform to a number of standards for a wide variety of equipment and devices. These standards govern the operation of TS1 type controllers, and more recently the TS2 type controller. The TS2 controller standard was developed to overcome some to the limitations of the TS1 standard.

The model 170 controller unit is a general purpose, microcomputer that is part of a standardized controller assembly. As manufactured, the model 170 is not capable of traffic signal control. To run, the 170 requires the user to provide a software program to be installed on the PROM module of the unit. When programmed with the appropriate software, the 170 can perform the same functions as the NEMA controller.

Pretimed Signal Control

Under these conditions, the signal assigns right-of-way at an intersection according to a predetermined schedule. The sequence of right-of-way (phases or splits), and the length of the time interval for each signal indication in the cycle is fixed, based on historic traffic patterns. No recognition is given to the current traffic demand on the intersection approaches unless detectors are used. The major elements of pretimed control are (1) fixed cycle length, (2) fixed phase length, and (3) number and sequence of phases.

Figure 1 shows the timing operation for a basic two-phase or two-traffic movement pretimed controller unit.

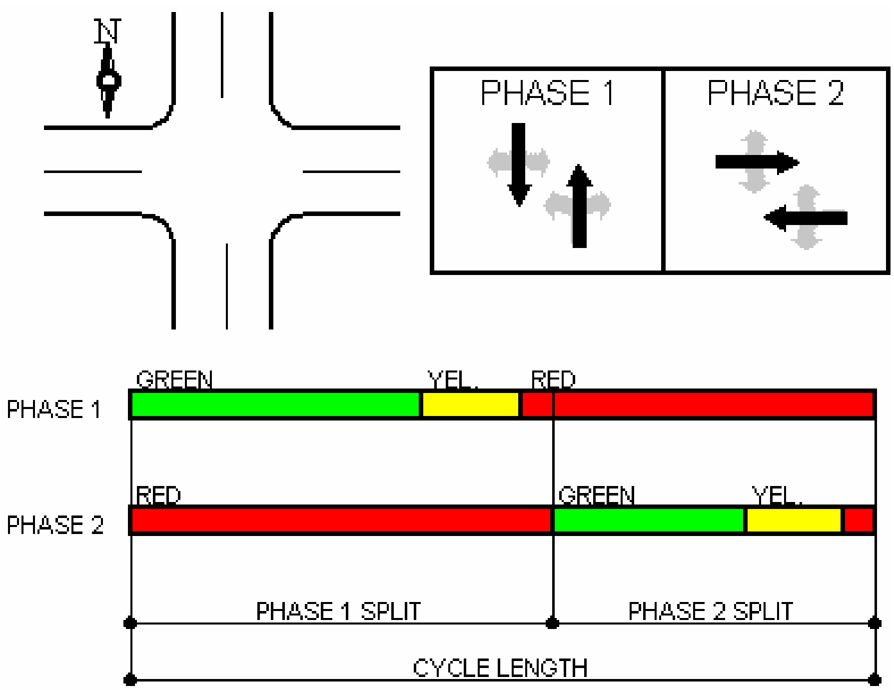


Figure 1 Pretimed Signal Operation

Traffic Actuated Signal Control

Traffic-actuated control of isolated intersections attempts to adjust green time continuously, and, in some cases, the sequence of phasing. These adjustments occur in accordance with real-time measures of traffic demand obtained from vehicle detectors placed on one or more of the approaches to the intersection. The full range of actuated control capabilities depends on the type of equipment employed and the operational requirements.

Traffic actuated signal control can further be broken into the following categories:

In semi-actuated control, the major movement receives green unless there is a conflicting call on a minor movement phase. The minor phases include any protected left-turn phases or side street through phases. Detectors are needed for each minor movement. Detectors may be used on the major movement if dilemma zone protection is desired.

In semi-actuated coordinated systems, the major movement is the "sync" phase. Minor movement phases are served only after the sync phase yield point and are terminated on or before their respective force off points. These points occur at the same point in time during the background signal cycle and ensure that the major road phase will be coordinated with adjacent signal controllers.

In semi-actuated non-coordinated systems, the major movement phase is placed on minimum (or maximum) recall. The major movement rests in green until a conflicting call is placed. The conflicting phase is serviced as soon as a gap-out or max-out occurs on the major phase. Immediately after the yellow is presented to the major phase, a call is placed by the controller for the major phase, regardless of whether or not a major phase vehicle is present.

Volume-density operation can be considered to be a more advanced form of full-actuated control. It has the ability to calculate the duration of minimum green based on actual demand (calls on red) and the ability to reduce the maximum allowable time between calls from passage time down to minimum gap. Reducing the allowable time between calls below the passage time will improve efficiency by being better able to detect the end of queued flow.

Controller Unit Elements

Cycle Length

The cycle length is the total time to complete one sequence of signalization around an intersection. In an actuated controller unit, a complete cycle is dependent on the presence of calls on all phases. In a pretimed controller unit, it is a complete sequence of signal indications.

One approach to determining cycle lengths for an isolated pretimed location is based on Webster's equation for minimum delay cycle lengths. The equation is as follows:

$$C_o = \frac{1.5\sum(tLi) + 5}{1.0 - \sum Xi}$$

Where,

C_o = Optimum cycle length in seconds

tLi = The unusable time per cycle in seconds (sum of lost times)

Xi = degree of saturation for Phase i (critical lane groups)

The equation above indicates that cycle lengths in the range of $0.75C_o$ to $1.5C_o$ do not significantly increase delay. The equation is valid when the sum of Xi is less than 1.0.

The equation is for isolated pretimed signal locations only. The determination of actuated cycle lengths or network cycle lengths is much more difficult. A detailed network optimization should be performed using Synchro for cycle length determination in a system.

In Synchro, the Cycle Length is set in either the TIMING window or the PHASING window.

Vehicle Green Time Intervals

The green time interval, or split, is the segment of the cycle length allocated to each phase or interval that may occur. In an actuated controller unit, split is the time in the cycle allocated to a phase. In a pretimed controller unit, split is the time allocated to an interval.

The primary considerations that must be given to vehicle split times are as follows:

1. The phase duration must be no shorter than some absolute minimum time, such as five to seven seconds of green. If pedestrians may be crossing with this phase, their crossing time must also be considered and should be included in the minimum phase length.
2. A phase must be long enough to avoid over saturating any approach associated with it. Too short a time will cause frequent cycle failures where some traffic fails to clear during its phase.
3. A phase length must not be so long that green time is wasted and vehicles on other approaches are delayed needlessly.
4. Phase lengths should be properly designed to efficiently balance the cycle time available among the several phases, not just "equitably" between, say, North-South and East-West.

In Synchro, the Total Split (current split) is set in the TIMING window

Phase Change Interval

The phase change interval timing advises drivers that their phase has expired and they should:

Come to a safe stop prior to the stop line, or; proceed through the intersection if they are too near the intersection to stop.

The following equation is generally used to determine the proper change interval:

$$Y + AR = T + \frac{V}{2a \pm 64.6gr} + \frac{w + L}{V}$$

where:

Y + AR = Sum of the yellow and all red time intervals

T = perception/reaction time of driver in seconds (typically taken as 1.0 second)

V = approach speed in feet per second

a = deceleration rate in feet per second (typically taken as 10 feet per second)

w = Width of intersection in feet

L = length of vehicle in feet (typically taken as 20 feet)

gr = approach grade, percent of grade divided by 100 (add for up-grade and subtract for downgrade)

It is common for many agencies to use the third term in the equation as the all-red time.

In Synchro, the Yellow Time and All Red Time are set in the PHASING window.

Pedestrian Timing Requirements

The pedestrian timing requirements include the:

- Walk interval, and
- Flashing don't walk interval

Walk: Under normal conditions, the walk interval is typically 4 to 7 seconds. This allows pedestrians to have adequate opportunity to leave the curb before the clearance interval is shown. Under special circumstances, such as at a school crossing with numerous pedestrians, walk times may need to exceed 7 seconds.

Flashing Don't Walk: The current Manual on Uniform Traffic Control Devices states that the flashing don't walk time (pedestrian clearance) needs to be of a duration to allow a pedestrian crossing in the crosswalk to leave the curb and travel to the center of the farthest traveled lane before opposing vehicles receive a green indication. The year 2000 update to the MUTCD will require that the FDW time is long enough to allow a pedestrian crossing in the crosswalk to leave the curb and travel to the far side of the farthest traveled lane before opposing vehicles receive a green indication.

The calculation of the flashing don't walk (pedestrian clearance) is:

$$FDW = \frac{W}{WS}$$

Where:

FDW = flashing don't walk (pedestrian clearance) time in sec;

W = walking (crossing) distance, as noted above; and

WS = the average walking speed in feet/sec (typically 3.5 to 4 feet/sec)

Many controllers do not time the yellow vehicle indication concurrent with the Flashing Don't Walk. The steady Don't Walk is displayed at the onset yellow to encourage any pedestrians still in the street to complete the crossing without delay. In some instances, it is allowed to use the yellow interval in the pedestrian clearance time (i.e., the pedestrian clearance time is equal to Flashing Don't Walk interval plus the yellow interval).

In Synchro, the Walk Time and the Flashing Dont Walk Time are set in the PHASING window.

Traffic Signal Phasing

A traffic signal phase, or split, is the part of the cycle given to an individual movement, or combination of non-conflicting movements during one or more intervals. An interval is a portion of the cycle during which the signal indications do not change.

The predetermined order of phases is the sequence of operation. This order is fixed in a pretimed controller, and under certain circumstances, may be variable with an actuated controller.

Consider Figure 2 for an example two-phase signal with pedestrian timing.

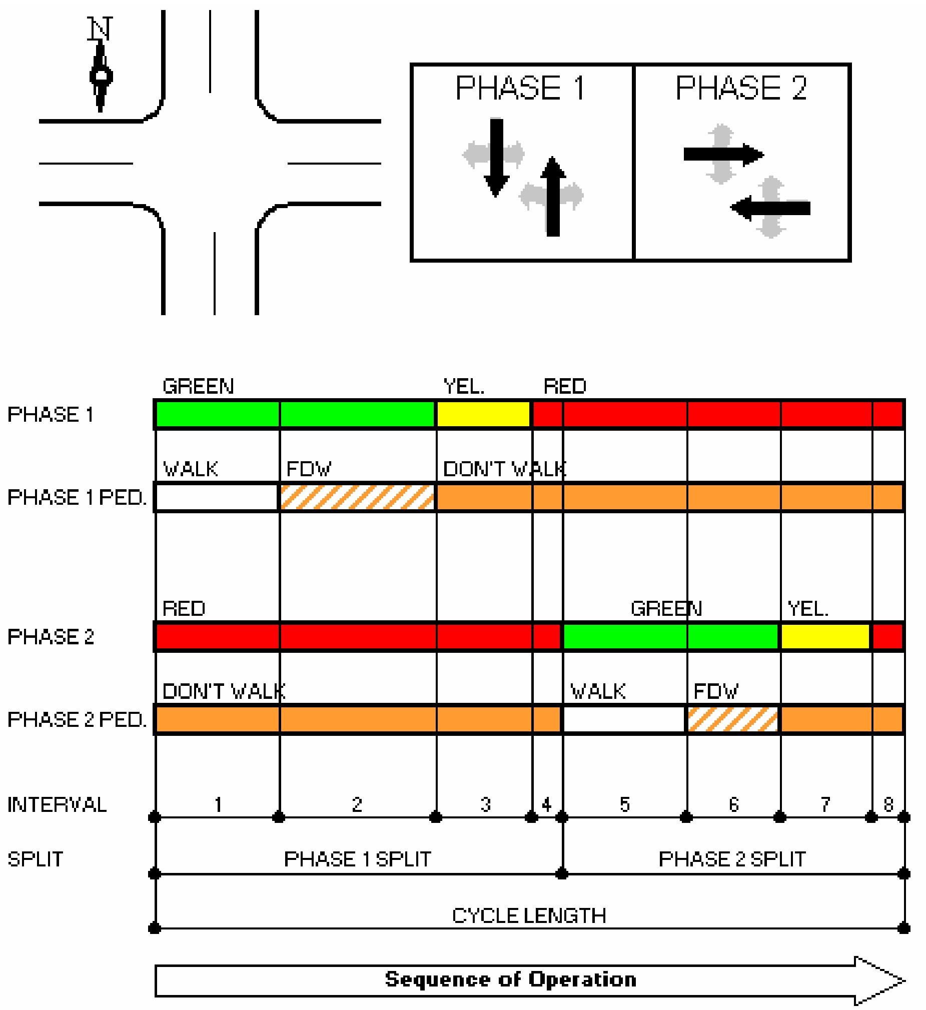


Figure 2 Traffic Signal Phasing

For Figure 2, there are eight intervals where the signal indications do not change. Notice that intervals 4 and 8 are all red periods (interval 4 is the phase 1 all red and interval 8 is the phase 2 all red). The phase 1 split is made up of intervals 1 through 4 and the phase 2 split is made up of intervals 5 through 8. The sum of split 1 and 2 is the cycle length.

Ring Structure

Ring

A ring is a term that is used to describe a series of conflicting phases that occur in an established order. A ring may be a single ring, dual ring, or multi-ring and is describe in detail below. A good understanding of the ring structure is a good way to understand the operation of multiphase controllers. In Synchro, the ring structure is defined using the Ring-and-Barrier-Designer in the PHASING window.

Barrier

A barrier (compatibility line) is a reference point in the preferred sequence of a multi-ring controller unit at which all rings are interlocked. Barriers assure there will be no concurrent selection and timing of conflicting phases for traffic movements in different rings. All rings cross the barrier simultaneously to select and time phases on the other side.

Phase Numbers

Phase numbers are the labels assigned to the individual movements around the intersection. For an eight phase dual ring controller (see definition of dual ring below), it is common to assign the main street through movements as phases 2 and 6. In addition, it is common to use odd numbers for left turn signals and the even numbers for through signals. A rule of thumb is that the sum of the through movement and the adjacent left turn is equal to seven or eleven.

Figure 3 illustrates a typical phase numbering scheme for an East/West arterial and a North/South arterial.

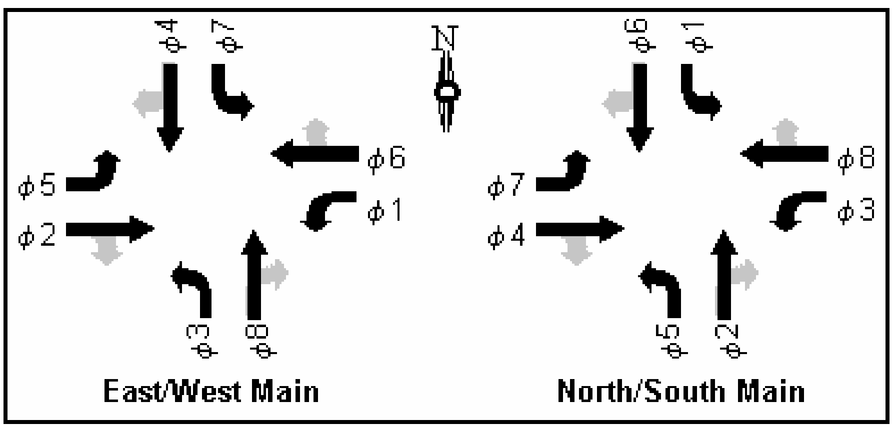


Figure 3 Typical Phase Numbering Schemes

Local standards may have the phases mirrored from that shown in Figure 3. In addition, Figure 3 is for dual ring control. Depending on the situation, unique phasing combinations may be required and the phase numbers shown in the figure are not applicable.

In Synchro, you can use the default Phase Templates to set up phase numbers matching the agencies standard phasing scheme.

Dual Ring Control

The traffic actuated controller usually employs a "dual ring concurrent" timing process. The NEMA, dual ring concept with the major route in the east/west direction is illustrated in Figure 4.

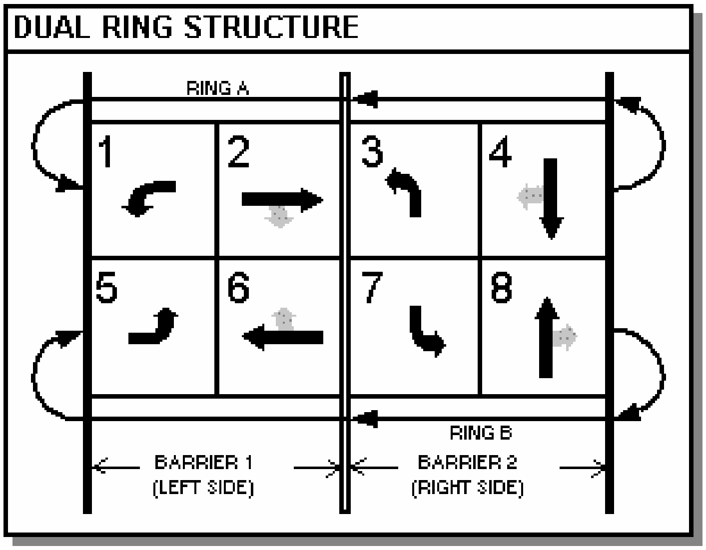


Figure 4 Dual Ring Concept (East/West Main Street)

The dual-ring controller uses a maximum of eight phase modules, each of which controls a single traffic movement with red, yellow and green display. The eight phases are required to accommodate the eight movements (four through and four left turns) at the intersection. Phases 1 through 4 are included in ring A, and phases 5 through 8 are included in ring B. The two rings operate independently, except that their control must cross the barrier (see definition of barrier above) at the same time.

If the movements to be controlled by these eight phases are assigned properly, the controller will operate without giving the right-of-way simultaneously to conflicting movements. All of the movements from one street (usually the major street) must be assigned to the left side of the barrier. Similarly, all movements from the other street must be assigned to the right side.

Figure 4 shows how the phases are arranged. At any given time, the controller will display one phase from Ring A and one phase from the Ring B. Both phases must be either from the left side of the barrier or from the right side of the barrier. Phase 1 can be displayed with phase 5 or 6 for example, but not with any other phase.

The dual-ring concurrent operation can be shown to maximize the operating efficiency at an intersection by eliminating the "slack" time on each cycle. This is illustrated with the possible phase sequence paths shown in Figure 5 for a quad-left eight-phase operation.

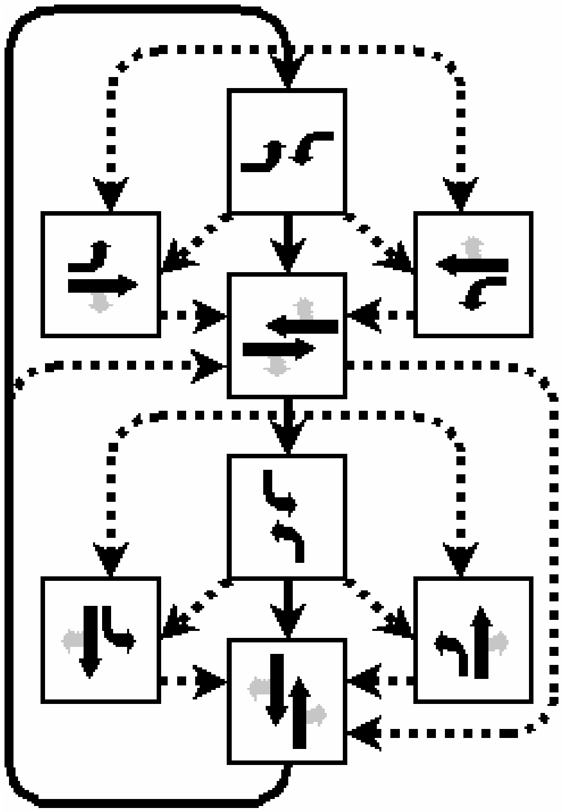


Figure 5 Quad-Left Eight Phase Operation

The vehicle demand (or lack of) determines the phase sequence for each movement. For instance, if the eastbound left has more demand than the westbound left, the operation is allowed to follow the path with the with phases 1-5, 2-5, then 2-6.

Single Ring (Sequential Phases)

Sometimes it is desirable to use a single ring and have the phases operate one at a time sequentially. Each phase is individually timed and can be skipped if there is no demand for it. This is called sequential or exclusive phasing. When using sequential phases on the left side of the barrier, phases 1-2-5-6 show in order. When using sequential phases on the right side of the barrier, phases 3-4-7-8 show in order.

Synchro will automatically use Sequential Phasing when split phasing is used. Synchro will also assume Sequential phasing if two approaches have left turn type permitted and use the same phase number.

Figure 6 is an example of a controller using Sequential phases. North and South traffic use split phasing, East and West share a phase.

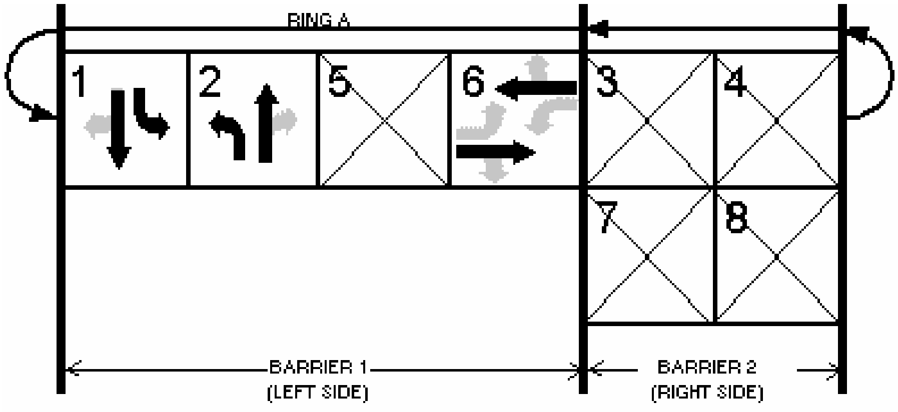


Figure 6 NEMA Phase Chart, with Sequential Phases

Some 170 controller software uses the order 1-5-2-6 when using sequential phases. Be sure to check for incompatibilities.

Sequential phasing can be activated or disabled by using the Ring-and-Barrier-Designer.

Multi-Phase

Modern controllers offer more flexibility in assigning traffic signal phases in order to control many complex or unique situations. TS2 controllers include four timing rings and up to sixteen vehicle phases and sixteen pedestrian phases. Each phase can be assigned to any ring. In addition, there are up to sixteen overlap assignments.

In Synchro, the Ring-and-Barrier-Designer allows up to 32 phases to be entered in one of 64 fields. This allows for the modeling of complex phasing strategies. Phase numbers are entered into the appropriate barrier, ring and position (BRP) fields in the four rings and four barriers.

Some possible examples of multi-phase controllers include:

- Group Control (see the example problem Multiple Intersections with One Controller).
- Intersections with 5 or more legs (see the example problem *Intersection with Five or More Legs*).
- Single ring controller with more than 4 phases (see the example problem *Single Ring Controller, More than Four Phases*)
- Diamond interchange (see the example problems on *Diamond Interchanges*).
- Intersections with more than 9 phases (see the example problem *Controller with More Than Nine Phases*).

Actuated Phasing Parameters

Some of the basic principles of timing the green interval in a traffic actuated controller unit is as follows:

There must be a minimum green time so that a stopped vehicle that receives a green indication has enough time to get started and partially cross the intersection before the yellow signal appears. This time is termed the minimum initial portion of the green interval.

Each following vehicle requires green time. This is called vehicle extension or gap. Gap refers to the distance between vehicles as well as the time between vehicles.

There must be a maximum time that the green interval can be extended if opposing cars are waiting – this is called the maximum or extension limit.

Figure 7 shows a timing diagram for one traffic-actuated phase. The other phases in the controller operate in the same manner.

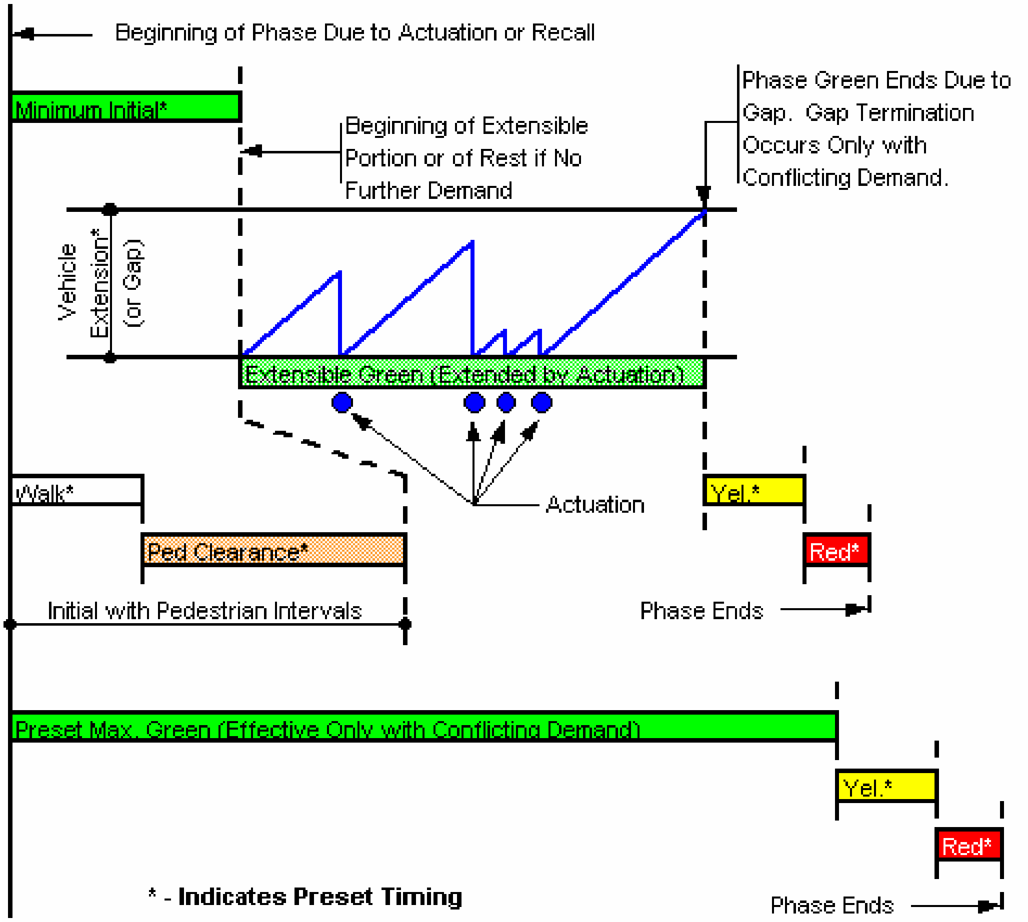


Figure 7 Actuated Phase Timing Diagram

The following topics further define the functions shown in Figure 7.

In Synchro, actuated phasing parameters are set in the PHASING window.

Minimum Initial

There must be a minimum green time so that stopped vehicles have enough time to get started and partially cross the intersection before the clearance interval appears. This time is often termed the minimum initial portion of the green interval. A typical value would be 4 seconds and could range from 2 to 30 seconds. This value is also called minimum green by some controllers.

The minimum initial (minimum green) can be further defined by the following, depending on the controller features:

Fixed Initial Portion: A preset initial portion that does not change and is sometimes referred to as the Minimum Initial Portion.

Computed (or Added) Initial Portion: This is a volume-density feature that is an initial green portion that is traffic adjusted. An increment of time is added to the minimum initial portion in response to vehicle actuation.

Maximum Initial Portion: This is a volume-density feature and is the limit of the computed (added) initial portion.

The minimum initial may also be the sum of the walk and pedestrian clearance time in the presence of a pedestrian actuation. Figure 7 shows the timing of the initial portion for a pedestrian operation.

In Synchro, the minimum initial value is set in the PHASING window. Synchro does not have settings for computed initial minimum times or maximum initial times. The Minimum Initial time should be set to the Minimum Initial or Minimum Green values. Synchro’s actuated calculations assume that the controller and detectors are set up correctly so that any initial queue beyond the extension detectors will be serviced.

Vehicle Extension

The vehicle extension (or gap) is the unit time extension for each vehicle actuation during the extensible portion as shown in Figure 7. The extensible green portion is that portion of the green interval of an actuated phase following the initial portion that may be extended, for example, by traffic actuation. Each detector actuation resets the vehicle extension timer. The green interval of the phase may terminate on expiration of the extension time.

With no opposing calls for other phases, the phase will rest in green. The vehicle extension will continue to time but will have no effect on the green interval. Upon receipt of an actuation on an opposing phase, the vehicle extension will check to see if the time between actuations is greater than the vehicle extension time. If so, the green will be terminated, the yellow interval will show, and the next phase in sequence with demand will be serviced. This is commonly referred to as "gap-out". These vehicles actuations (calls) can be received at the detector in either a locking or non-locking mode.

The vehicle extension time is typically set to allow an average speed vehicle to move from the detector to and through the intersection. This time can be reset by continuous vehicle actuation up to the maximum green time. Typical values of vehicle extension range from 0 seconds to 9 seconds.

In Synchro, the vehicle extension is set in the PHASING window.

Maximum

The maximum green time is the maximum limit to which the green time can be extended on a phase in the presence of a call on a conflicting phase. The maximum green is illustrated in Figure 7.

The maximum green time begins timing at the start of the green interval when there is a serviceable vehicle demand on a conflicting phase. The phase is allowed to "max-out" if the preset time is reached even if actuations are close enough in time to prevent gap termination. If the phase terminates due to reaching the maximum, a recall is placed on the phase and it is returned to at the earliest opportunity.

The maximum green time typically ranges in values from 0 to 99 seconds (or more in some cases).

In Synchro, you code the Maximum Split time, not the maximum green, in the PHASING window. The Maximum Split is the current split time, given in seconds and is the amount of green, yellow, and all-red time assigned for each phase.

Recall

In the absence of an actuation, a controller unit will normally rest on the current phase being serviced. A recall will force the controller to return to a particular phase's green interval, even with no demand.

Every phase has the capability of operation with the following types of recall:

Minimum Recall: When active and in the absence of a vehicle call on the phase, a temporary call to service the minimum initial time will be placed on the phase. If a vehicle call is received prior to the phase being serviced the temporary call will be removed. Once the phase is serviced, it can be extended based on normal vehicle demand.

Maximum Recall: With the maximum vehicle recall active a constant vehicle call will be placed on the phase. This constant call will force the controller to time the maximum green. Maximum recall is generally used to call a phase when local detection is not present or inoperative.

Pedestrian Recall: This feature provides vehicle green and pedestrian walk and clearance intervals. After that, normal green timing is in effect except that pedestrian calls will not recycle pedestrian intervals until opposing phases are serviced.

If Rest-in-Walk is enabled for the phase, the controller will rest in the walk interval in free operation until a conflicting call is received. During coordination, this feature insures that the end of pedestrian clearance occurs at the force-off point of the phase.

In addition, a phase has a vehicle call placed on it if it is terminated with some vehicle extension time remaining. This can happen with termination by maximum.

If all of the active phases of a controller unit are placed on recall, the controller unit will operate in a pretimed mode. It should be added that unless the detectors are disconnected from a phase, that phase's green interval could be extended beyond the preset minimum if the recall is set to minimum.

In Synchro, the Recall Mode is set in the PHASING window.

Volume Density Control

A more advanced controller operation is possible when using volume density traffic actuated control. A volume density controller uses the basic parameters previously discussed, such as minimum initial, vehicle extension and maximum, plus it adds two way of modifying the basic timing intervals. These added features include:

Added (or computed) initial: This is a means of extending the initial portion of the green interval. This is done based on the number of actuations above a preset number while the phase is displaying yellow or red. This extended initial provides additional green time for a queue of vehicles waiting, when the green signal appears, to clear the intersection if the detectors are set back a distance from the stop bar and there are no vehicles following. The limit of the added initial is the maximum initial setting.

Gap reduction: This is a means of reducing the extension (passage) time or gap based on the time that opposing vehicles have waited. In effect, it benefits the waiting vehicles by reducing the time allowed between vehicles arriving on the green phase before that phase is terminated.

Figure 8 shows a timing diagram for one phase of a volume density controller.

Minimum Gap: The minimum gap is the minimum value to which the gap is reduced at the end of the Time to Reduce.

Time Before Reduce: This is a preset time before the allowed gap begins to reduce.

Time to Reduce: This is the amount of time in which the allowable gap is reduced from the vehicle extension to the minimum gap after the Time Before Reduction.

In Synchro, the Minimum Gap, Time Before Reduce and Time to Reduce are all set in the PHASING window.

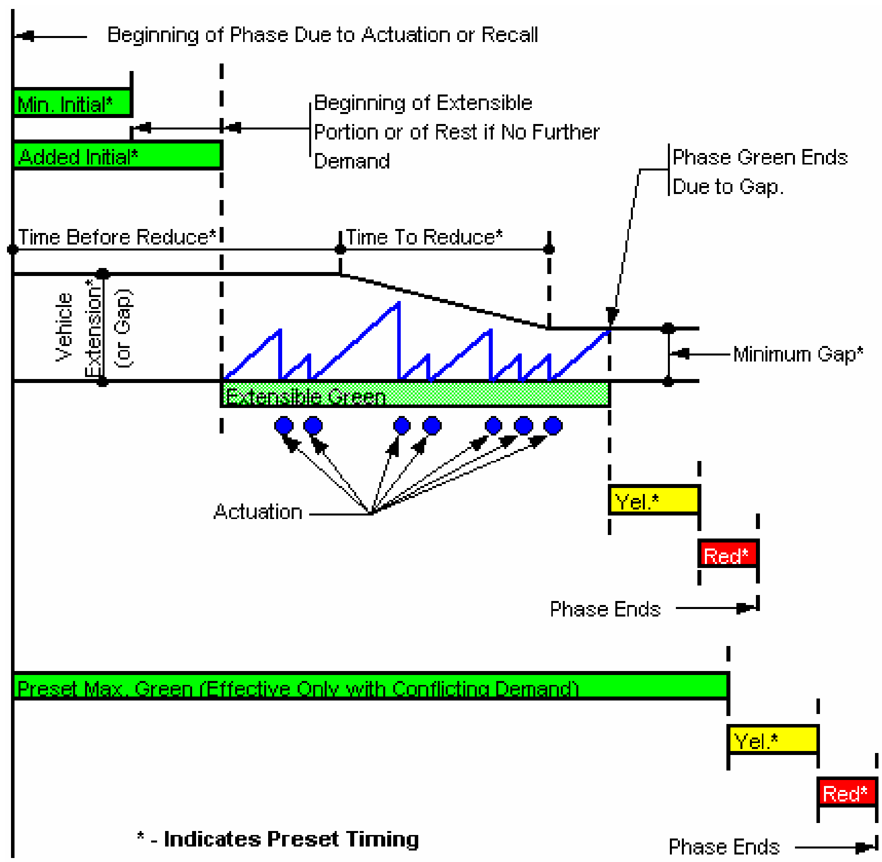


Figure 8 Volume Density Phase Timing Diagram

Additional Actuated Controller Functions

In actuated controllers, there are many additional features that are used. The following paragraphs define some of the more common actuated controller options that are in use.

Simultaneous Gap-Out: Simultaneous gap-out is the controller setting that specifies that ring A and ring B must cross the barrier at the same time. This can occur when both lag phases cross the barrier by gaping-out, forcing off or reaching maximum. If simultaneous gap-out is not set, one ring can gap-out and the other can max-out. In addition, if one phase gaps-out it, will stay in that condition, irrelevant of any future vehicle actuations until the phase in the opposite ring either gaps-out or maxes-out and then both phases cross the barrier.

Synchro will place a hold on any phase that gaps-out (simultaneous gap-out is in effect) if the concurrent phase requires additional time and both phases will cross the barrier at the same time.

Conditional Service: Conditional service is the controller setting that allows a left-turn phase to be serviced twice within the same controller cycle. Under a specific set of circumstances, conditional service allows the left to be serviced first as a leading phase and then as a lagging phase.

Dual Entry: Dual entry is a mode of operation (in a multi-ring controller unit) in which one phase in each ring must be in service. If a call does not exist in a ring when it crosses the barrier, a phase is selected in that ring to be activated by the controller unit in a predetermined manner.

For example, consider the ring structure shown in Figure 4. If there is a call for service on phase 2 but there are no other calls on phase 5 or 6, dual entry would automatically place a temporary call on phase 6. In Figure 4, compatible dual-entry phases are 1 and 5, 2 and 6, 3 and 7, and 4 and 8.

Single Entry: Single entry is a mode of operation (in multi-ring controller unit) in which a phase in one ring can be selected and timed alone if there is no demand for service in a non-conflicting phase on parallel ring(s).

Hold: The hold feature is a command that retains the existing green interval. A hold is internally set within the controller when simultaneous gap-out is set. This ensures that phases will simultaneously cross the barrier.

A hold can also be user defined for coordinated operation. During coordinated operation, a hold will prevent a phase from terminating before its force-off point is reached. This is desirable when lead-lag left-turn phasing combinations are used to maximize two-way progression. A hold on a lagging left turn phase prevents that phase from gapping-out. This prevents the concurrent through phase from terminating early and shortening the progression band in that direction. This is often referred to as *lag-phase hold.*

Synchro will place a hold on any phase that gaps-out (simultaneous gap-out is in effect) if the concurrent phase requires additional time and both phases will cross the barrier at the same time.

Force Off: A force off is a command to force the termination of the green extension in actuated mode or walk hold in the non-actuated mode of the active phase. Termination is subject to presence of a serviceable conflicting call.

Offset: Offset is the time relationship, expressed in seconds or percent of cycle length, determined

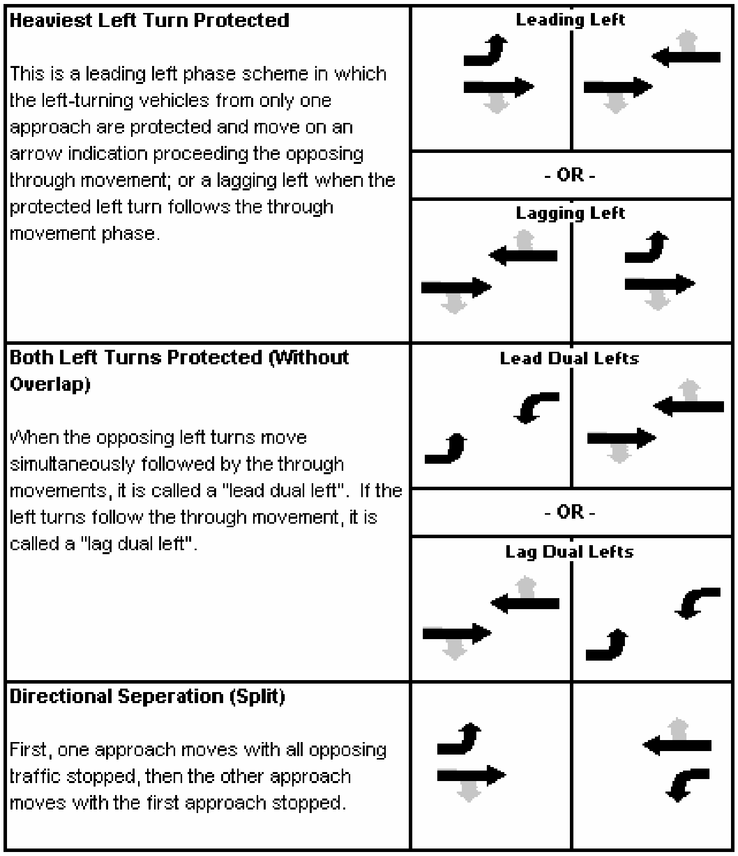
Overlap: An overlap is a green indication that allows traffic movement during the green intervals of and clearance intervals between two or more phases (parent phases). Often, an overlap is for a right turn phase.

In Synchro, a right turn overlap is set with the Turn Type selection in the TIMING window.

Left Turn Phasing

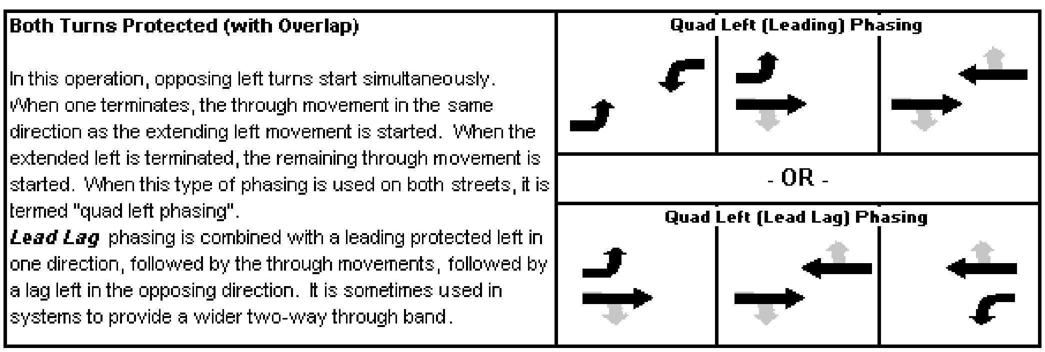
At certain signalized intersections, it may be necessary to provide left turn signal phasing to reduce the conflicts between the left turners and opposing traffic. This phasing can be in a protected only mode, a permitted mode or by directional split. These left turn phasing schemes will be discussed in the following topics.

There are additional considerations for determining the left turn phasing alternative as shown in Figure 9 and Figure 10.



Heaviest Left Turn Protected This is a leading left phase scheme in which the left-turning vehicles from only one approach are protected and move on an arrow indication proceeding the opposing through movement; or a lagging left when the protected left turn follows the through movement phase.	Leading Left - OR - Lagging Left
Both Left Turns Protected (Without Overlap) When the opposing left turns move simultaneously followed by the through movements, it is called a "lead dual left". If the left turns follow the through movement, it is called a "lag dual left".	Lead Dual Lefts - OR - Lag Dual Lefts
Directional Seperation (Split) First, one approach moves with all opposing traffic stopped, then the other approach moves with the first approach stopped.	

Figure 9 Left Turn Phasing without Overlap



Both Turns Protected (with Overlap) In this operation, opposing left turns start simultaneously. When one terminates, the through movement in the same direction as the extending left movement is started. When the extended left is terminated, the remaining through movement is started. When this type of phasing is used on both streets, it is termed "quad left phasing". ***Lead Lag*** phasing is combined with a leading protected left in one direction, followed by the through movements, followed by a lag left in the opposing direction. It is sometimes used in systems to provide a wider two-way through band.	Quad Left (Leading) Phasing - OR - Quad Left (Lead Lag) Phasing

Figure 10 Left Turn Phasing with Overlap

Whether or not separate left turn phasing should be provided is a decision that must be based on engineering analysis. This analysis may involve serious trade-offs between safety, capacity, and delay considerations.

- Separation of left turns and opposing traffic may reduce accidents that result from conflicts between these movements, and may increase left turn capacity. However, through traffic capacity may be reduced.
- Left turn phasing may reduce peak period delay for left turners, but may increase overall intersection delay. Off-peak left turn delay may also increase.

Protected and Permitted Left Turn Phasing

If a protected left turn phase is to be used (left turn made without conflicts with opposing traffic) left turns may or may not also be permitted on a circular green indication with opposing traffic.

In general, it is desirable to allow this permitted left turn movement unless there are overriding safety concerns that make such phasing particularly hazardous.

- Use of a permitted left turn can significantly reduce overall intersection delay as well as delay to left turners.
- Use of permitted left turn phasing may reduce the required length of left turn storage on the approach and allow an approach with substandard left turn storage to operate more efficiently.

Certain situations exist where safety considerations generally precluded the use of permitted left turns. In these cases, left turns should be restricted to the protected left turn phases. Such situations include:

- Intersection approaches where crash experience or traffic conflicts criteria are used as the basis for installing separate left turn phasing.
- Blind intersections where the horizontal or vertical alignment of the road does not allow the left turning driver adequate sight distance to judge whether or not a gap in on coming traffic is long enough to safely complete his turn.
- High-speed and/or multilane approaches may make it difficult for left turning drivers to judge gaps in on coming traffic. Such locations should be evaluated on an individual basis.
- Unusual geometric or traffic conditions may complicate the driver's task and necessitate the prohibition of permitted left turns. An example of such conditions is an approach where dual left turns are provided.
- When normal lead-lag phasing is used (due to left turn trapping).

Left Turn Trapping

The combination of a permitted left turn with lead-lag phasing leads to a situation commonly called the "left-turn trap". Consider Figure 11 for an eastbound leading scenario.

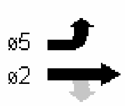
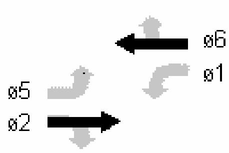
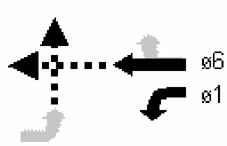
	**Interval 1:** Phase 5 eastbound shows protected left turn arrow while phase 2 eastbound through shows a green ball
	**Interval 2:** Phase 5 eastbound and phase 1 westbound show permitted left turn (green ball) while phase 2 and phase 6 through shows green ball. At the end of interval 2, phase 5 displays a yellow indication. Since the eastbound left sees the yellow on all facing displays, they may incorrectly presume that westbound left is likewise receiving a yellow ball and about to stop.
	**Interval 3:** Phase 1 westbound shows protected left turn arrow while phase 6 eastbound through shows green ball. Eastbound left may have assumed the westbound through was stopping creating a crash situation.

Figure 11 Left Turn Trapping

There is no real problem with the westbound situation here; these left turners are presented in interval 2 with a green ball after a period of obvious opposing flow. It is clear they must yield to the eastbound through traffic. In interval 3 this movement is protected and, again there is no problem. The transition is given by green ball direct to green arrow, but even if a yellow ball was displayed at the end of interval 2, there is no problem.

The problem is with the eastbound left turns. If this scenario was allowed, any left turner who had not been able to find a gap during the interval 2 green would be presented with a yellow ball at its end. Since these drivers see yellow balls on all facing displays (through and left), they may incorrectly presume that the westbound through is likewise receiving a yellow ball and is about to stop.

When the signal goes red, (eastbound) the turner will:

5. Be stuck (now illegally), in the middle of the intersection with nowhere to go, or
6. Commit the left turn thinking the opposition is stopping, creating a serious safety issue.

Four Section Flashing Yellow

A recent research report NCHRP 3-54 studied the best traffic signal display for protected/permitted left turn control. The resulting recommendation is to use a four section signal head with a flashing yellow arrow for the permitted left turn interval. This type of arrangement allows for the safe implementation of lead-lag permitted plus protected phasing. There is no need for special louvers or positioning of the signal heads. Information about NCHRP 3-54 is available in the July 2003 issue of Westernite. See http://www.westernite.org/newsletters/archive.htm.

Detectors

One of the advantages to actuated control is the ability to adjust timing parameters based on actual vehicle or pedestrian demand. Since this vehicle or pedestrian demand varies at different times of the day, a detector is placed in the path of approaching vehicles or at a convenient location for the use of pedestrians.

The actual operation of the signal is highly dependent on the operation of these detectors. The following sections identify some of the more common detector types and the various modes of operation employed. In addition, some detector strategies are documented in the topics Stop-Bar Detector and Initial Interval Strategies and Other Detector Strategies.

Types of Detectors

Some of the more common detectors in use today include:

Loop Detector: This is the most common detector type. It is a loop of wire imbedded in the pavement carrying a small electrical current. When a large mass of metal passes over the loop, it senses a change in inductance of its inductive loop sensor by the passage or presence of a vehicle near the sensor.

Microwave Radar Detector: A detector that is capable of sensing the passage of a vehicle through its field of emitted microwave energy. The principles of operation involve microwave energy being beamed on an area of roadway from an overhead antenna, and the vehicle's effect on the energy detected.

Video Detection: A detector that is responds the Video image or changes in the Video image of a vehicle.

Magnetic Detector: A detector that senses changes in the earth's magnetic field caused by the movement of a vehicle near its sensor.

Magnetometer Detector: A detector that measures the difference in the level of the earth's magnetic forces caused by the passage or presence of a vehicle near its sensor.

Infrared Detector: A detector that senses radiation in the infrared spectrum.

Light-Sensitive Detector: A detector that utilizes a light-sensitive device for sensing the passage of an object interrupting a beam of light directed at the sensor.

Pneumatic Detector: A pressure-sensitive detector that uses a pneumatic tube as a sensor.

Ultrasonic Detector: A detector that is capable of sensing the passage or presence of a vehicle through its field of emitted ultrasonic energy.

Detector Definitions

Some of the more common detector definitions are defined below.

Actuation: The operative response of any type of detector (call).

Call: A registration of a demand for the right-of-way by traffic at a controller unit.

Calling Detector: A registration of a demand during red interval for right-of-way by traffic (vehicles or pedestrians) to a controller unit.

Check: An output from a controller unit that indicates the existence of unanswered call(s).

Continuous-Presence Mode: This is a mode of operation where the detector output continues if any vehicle (first or last remaining) remains in the zone of detection.

Controlled Output: This is the mode of operation where the detector has the ability to produce a pulse that has a predetermined duration regardless of the length of time a vehicle is in the zone of detection.

Detector: A device for indicating the presence or passage of vehicles.

Extension Detector: A detector that is arranged to register an actuation at the controller unit only during the green interval for that approach so as to extend the green time of the actuating vehicles.

Limited-Presence Mode: This is a mode of operation where the detector output continues for a limited period of time if vehicles remain in zone of detection.

Locking and Non-Locking Mode of Operation: Vehicle actuations (calls) can be received at the detector in either a locking or non-locking mode. For the locking mode, the call is retained until the phase receives it's green interval. For non-locking mode, the call is retained only while vehicles are in the zone of detection.

Passage Detection: The ability of a vehicle detector to detect the passage of a vehicle moving through the zone of detection and to ignore the presence of a vehicle stopped within the zone of detection.

Presence Detection: The ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in its zone of detection.

Pulse Mode: This is a mode of operation where the detector produces a short output pulse when detection occurs.

Zone of Detection: The area or zone that a vehicle detector can detect a vehicle.

Detector Operations

Some of the more common detector operations are defined below.

Call and Extend: Upon actuation the detector immediately places a call on its associated phases at all times. The detector shall also immediately cause the controller unit to extend the green time for the actuating vehicle only during the green interval of that phase. The controller unit may be in Lock or Non-Lock mode.

Extend Only: The detector immediately registers actuation at the Controller unit only during the green interval for that phase thus extending the green time before the actuating vehicles. The controller unit may be in Lock or Non-Lock mode.

Call Only: Upon actuation the detector immediately places a call on its associated phase only during the red interval of that phase. This call remains active as long as the detector is actuated. The controller unit may be in Lock or Non-Lock mode.

Call Only Density: Upon actuation the detector immediately places a call on its associated phase only during the red interval of that phase. This call is inactivated when the controller unit outputs a check. This allows the use of density functions on this phase but necessitates the use of detector memory (lock) on the controller unit.

Delay Call Density Only: When actuated during the red interval of its associated phase, the detector delays its output call for a pre-determined length of time during the extended actuation. This call is inactivated when the controller unit outputs a check and the time delay unit is not reset until after that phase has been served. This allows the use of density functions on this phase but necessitates the use of detector memory (lock).

Carry-Over Call and Extend: Upon actuation the detector immediately places a call on its associated phase at all times and continues to output the call for a pre-determined length of time. The detector shall also immediately cause the controller unit to extend the green time for the actuating vehicle during the green interval of that phase and shall continue its output for a pre-determined length of time following an actuation. The controller unit may be in Lock or Non-Lock mode.

Delay Call Only: When actuated during the red interval of its associated phase, the detector delays its output call for a pre-determined length of time during the extended actuation. After the time delay expires, the call remains active at the controller unit as long as the detector remains actuated. The controller unit may be in Lock or Non-Lock mode.

Type-3: These are detectors at the stop bar that place a call while the phase is red. These type-3 detectors also place extension calls for the first 4 to 10 seconds of green time. After this initial green time, the type-3 detectors are disabled.

Stop-Bar Detector and Initial Interval Strategies

Placing extension detectors at the stop bar can lead to the "unused green time" phenomenon. This occurs because the signal requires a full gap (vehicle extension) after the last vehicle leaves the last detector at the stop bar. During this time, no new vehicles are entering the intersection and the signal stays green. Synchro will detect for this time and add this unused green time to actuated phases. Here are four ways to reduce the unused green time.

Short Gap Time with Long Detection Area

In this strategy, a long detector (or several shorter ones) is placed from the stop bar to perhaps 50 or 100 feet (15 to 30 m) back as shown in Figure 12.

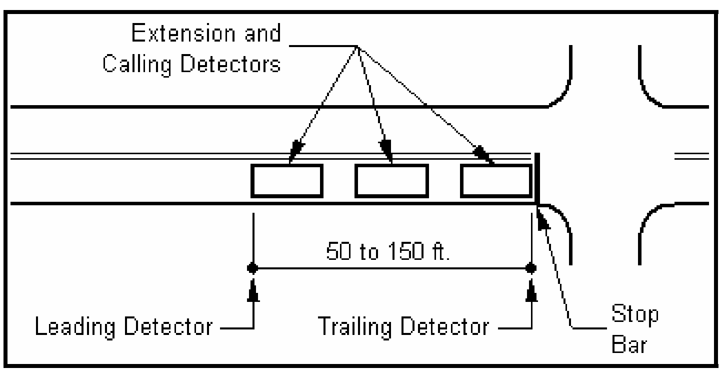


Figure 12 Long Detection Area

In conjunction with the long detection area, a short vehicle extension (gap time) is used, perhaps 0.5 seconds. When there are no more vehicles at the approach, the signal will gap out. This strategy works well at low speed approaches and approaches with limited space such as driveways and left turn bays. To use this type of detection in Synchro, use the following settings:

- Leading Detector: 50 to 100 ft (15 to 30m)
- Trailing Detector: 0 ft (0 m)
- Vehicle Extension: 0.2 to 1 s
- Minimum Gap: same as Vehicle Extension

No Detector at Stop Bar

In this strategy, no detectors are placed at the stop bar as shown in Figure 13.

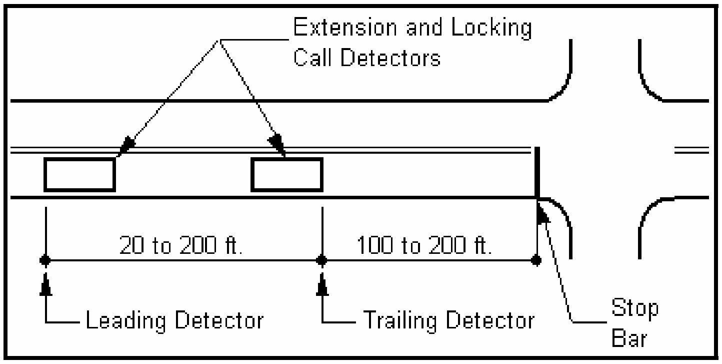


Figure 13 No Detector at Stop Bar

The advance detectors place a locking call to the controller during yellow and red times. The advance detectors also count the number of actuations on red and increase the initial interval in order to accommodate each counted vehicle after the last detector. This strategy works good at high-speed approaches and requires fewer detectors. To use this type of detection in Synchro use the following settings:

Leading Detector Location of most upstream detector

- Trailing Detector: Location of trailing edge or most downstream detector
- Minimum Initial: Set to minimum of initial interval
- (Synchro will automatically calculate the extension to initial interval.)
- Vehicle Extension: 2 to 5 s
- Minimum Gap: 2 to 5 s
- (Vehicle Extension times must be enough to carry vehicle from last detector into intersection.)

Calling-Only Detector at Stop Bar

In this strategy, the detectors at the stop bar place a call while the phase is red, see Figure 14.

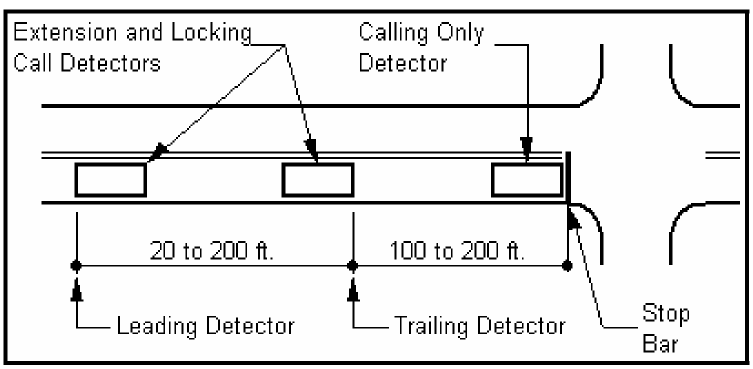


Figure 14 Calling Only Detector at Stop Bar

When the phase is green, the stop bar detectors are inactive. The advance detectors are extension detectors and extend the green by the gap time. The minimum initial interval must be long enough to clear all vehicles after the last extension detector. This strategy works well at high-speed approaches. To use this type of detection in Synchro use the following settings:

- Leading Detector: Location of most upstream detector
- Trailing Detector: Location of trailing edge of most downstream detector
- (Does not include stop-bar, calling-only detector)

- Minimum Initial: Set to initial interval
- (Initial interval must be enough to clear all vehicles after last extension detector.)
- Vehicle Extension: 2 to 5 s
- Minimum Gap: 2 to 5 s
- (Extension times must be enough to carry vehicle from last detector into intersection.)

Type-3 Detector at Stop Bar

In this strategy, the detectors at the stop bar place a call while the phase is red, see Figure 15.

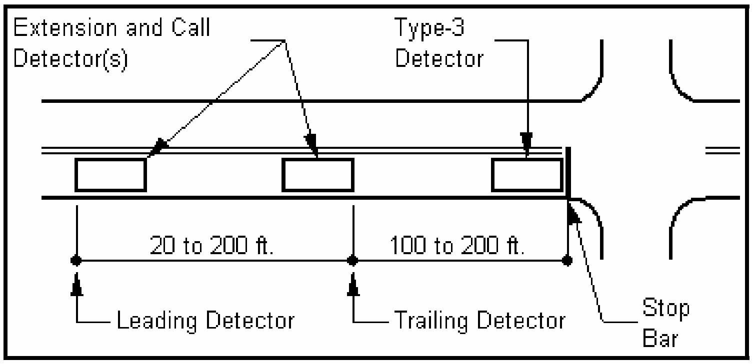


Figure 15 Type-3 Detector at stop bar

These type-3 detectors also place extension calls for the first 4 to 10 seconds of green time. After this initial green time, the type-3 detectors are disabled. The advance detectors are extension detectors and extend the green by the gap time. The type-3 detectors should be able to extend the signal to clear all vehicles after the last extension detector. This strategy works well at high-speed approaches. Type-3 detectors are commonly used in areas with lots of trucks, because trucks can take longer to accelerate. To use this type of detection in Synchro use the following settings:

- Leading Detector: Location of most upstream detector
- Trailing Detector: Location of trailing edge or most downstream detector
- (Does not include stop-bar type-3 detector)
- Minimum Initial: Set to minimum initial interval
- Vehicle Extension: 2 to 5 s
- Minimum Gap: 2 to 5 s
- (Extension times must be enough to carry vehicle from last detector into intersection.)

Other Detector Strategies

Series of Extension Detectors

With this detector layout, several detectors are placed in series in advance of the intersection as shown in Figure 16.

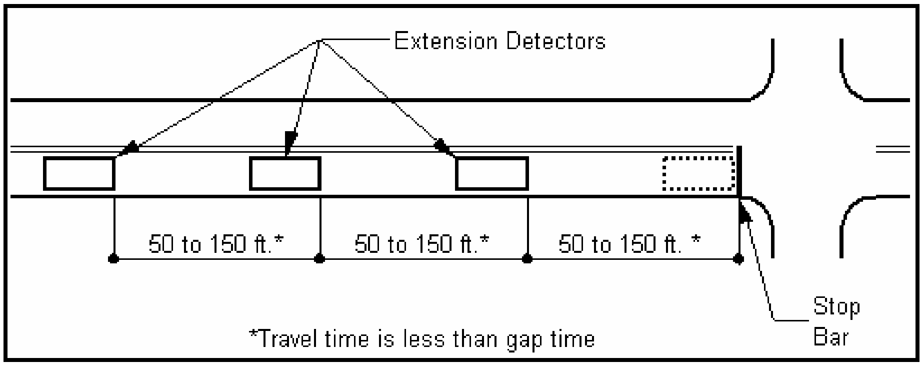


Figure 16 Series of Extension Detectors

Extension detectors might be placed at 400 ft, 300 ft, 200 ft, and 100 ft from the stop bar. The vehicle extension (gap time) is set so that each detector holds the signal green long enough for the vehicle to reach the next detector. In this example, if the speed is 40 mph or 59 ft/s, the gap time might be set at 2.0 seconds. With a series of detectors, a single vehicle can extend the green time several times. In this example, one vehicle can extend the green time for 7 seconds. This operation is somewhat sluggish and will give low v/c ratios. This type of operation should be avoided on side street approaches to congested intersections. This type of operation is good for high-speed approaches, because it holds the phase green while vehicles are in the dilemma zone.

In determining the time to gap-out, Synchro will use a longer "effective gap time" if there is a long distance between the first and last extension detectors. Synchro assumes that the Minimum Extension (minimum gap) time is long enough to carry a single vehicle between detectors. To use this type of detection in Synchro use the following settings:

- Leading Detector: Location of most upstream detector
- Trailing Detector: Location of trailing edge or most downstream detector
- (Does not include stop-bar type-3 detector or calling-only detector)
- Minimum Initial: Set to minimum initial interval
- Vehicle Extension: 2 to 5 s (actual controller gap time)
- Minimum Gap: 2 to 5 s
- (Extension times should be long enough to carry a vehicle between detectors and to the stop-bar.)

Volume-Density Controllers

With volume-density control, the gap time is reduced the longer the signal is green. This type of control is intended to make the signal snappier with higher volumes and more sluggish with lower volumes. A typical setting for a volume-density controller is to have the Vehicle Extension or Maximum Extension set to 5 seconds and the Minimum Extension set to 2 seconds.

NOTE: Volume-Density operation is not as effective when used with a series of extension detectors. As already discussed, the effective gap time when using a series of detectors might be 5 seconds more than the actual gap time. When volume density reduces the actual gap from 5 to 2 seconds, it may be reducing the effective gap time from 10 to 7 seconds. Volume-density works best with a single extension detector.

To use this type of control in Synchro use the following settings:

- Leading: Detector Location of most upstream detector
- Trailing: Detector Location of trailing edge or most downstream detector
- (Does not include stop-bar type-3 detector or calling-only detector)

- Vehicle Extension 3 to 7 s (this is also the maximum extension)
- Minimum Gap: 1.5 to 3 s
- (Extension times should be long enough to carry a vehicle between detectors and to the stop-bar.)
- Time Before Reduce: 0 to 20 s
- Time to Reduce: 10 to 30 s

Detector Extension Time or Carry Time

Modern traffic signal controllers allow individual detectors to place a call for an extended time. This is also sometimes called "carry-though" time. This detector extension time is in addition to the vehicle extension time associated with the phase. A typical configuration will have a 2-second detector extension time at the advanced detectors and none at the stop bar detectors. The vehicle extension is 1 second. This configuration allows calls at advanced detectors to keep the signal active while the vehicle moves between advanced detectors and while vehicles are queued at the stop bar. The signal will turn yellow 1 second after the last vehicle leaves the stop bar, allowing for snappy termination. To code this configuration, the trailing detector is at the stop bar and the vehicle extension includes the detector extension of the stop bar detector only.

Interchanges and Closely Spaced Intersections

This section covers the timing of freeway interchanges and groups of other closely spaced intersections.

Types of interchanges and intersections covered:

- Diamond interchange
- Partial Cloverleaf
- Two or more closely spaced intersections
- Arterial with median over 100 ft wide
- Multiple intersections using one controller (Group Control)
- Arterial with frontage road
- Diamond interchange plus frontage road

This section also contains a discussion about using Group Control (multiple intersections with one controller) versus Local Control.

See the topic on Setting up a Timing Plan in the Example Chapter for detailed steps on how to create a timing plan for an interchange or closely space intersection.

Group Control versus Local Control

Group Control has multiple intersections using a single controller as shown in Figure 17. Group control is useful with tightly spaced intersections and interchanges to prevent blocking problems. With Group Control, the interchange can operate fully actuated with a floating cycle length yet still maintain coordination within the interchange. Group Control can also be used with fixed cycle lengths and Group Control maintains coordination when transitioning between timing plans.

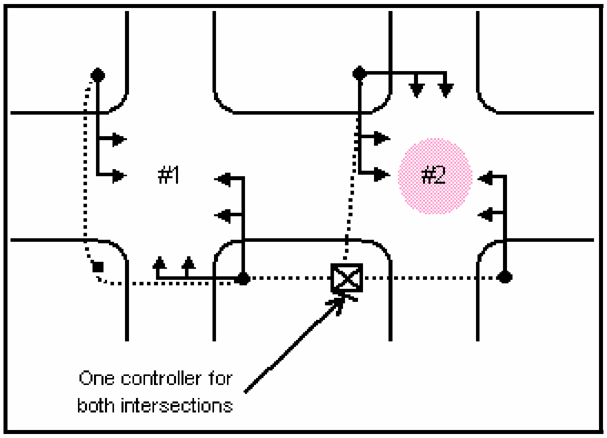


Figure 17 Group Control

With Group Control, each intersection typically has one ring of sequential phases as shown in Figure 18. In some cases, an intersection may have two rings. Normally a phase or ring is not used for more than one intersection. The phasing for Group Control can be quite complex and certain phase sequences may not be supported by all controllers. When implementing Group Control, work closely with an expert for your controller types to insure that the desired phasing is possible.

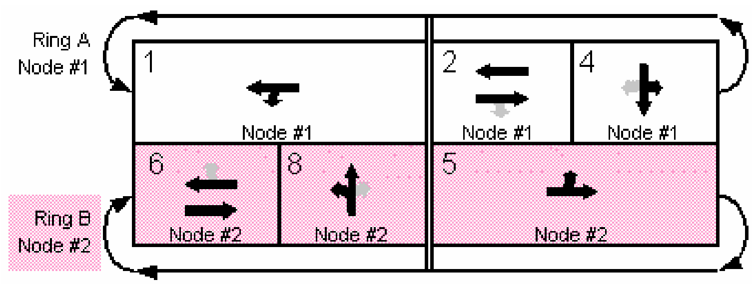


Figure 18 Phasing for Group Control

Local Control gives each intersection its own controller as shown in Figure 19. Local Control requires a fixed cycle length to maintain coordination. Local control may offer more flexibility to meet conditions at each intersection.

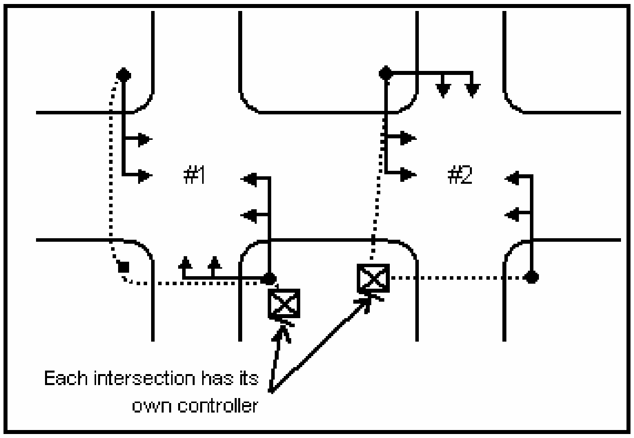


Figure 19 Local Control

Fixed Cycle Length versus Floating Cycle Length

A Floating Cycle Length is used when a controller is operating fully actuated. A Floating Cycle Length allows Group Control to handle multiple changing traffic patterns with a single timing plan. A Floating Cycle length will not provide coordination with surrounding signals.

A Fixed Cycle Length can provide coordination with adjacent intersections. To handle varying traffic patterns, multiple timing plans with splits, cycle lengths, and offsets must be developed. For more information, see Table 1.

In many cases the decision whether to use Local or Group control will depend on the existing equipment. Unless you are working on new construction or a major update, the timing plans must be generated to match the existing equipment.

If coordination with adjacent signals is needed, a fixed cycle length is required.

Table 1 Comparison of Interchange Control Methods

Control Type	Group	Group	Local	Local
Cycle Length	**Fixed**	**Floating**	**Fixed**	**Floating**
Coordination within Group	Yes	Yes	Yes	No
Coordination with other signals	Yes	No	Yes	No
Eliminates Internal Blocking	Yes	Yes	Mostly	No
Spacing < 200 ft	Yes	Yes	No	No
Requires Multiple Timing Plans	Yes	No	Yes	No
Responds to fluctuating traffic	No	Yes	No	Yes
Snappy under low volume	No	Yes	No	Yes
Many changing traffic patterns	Maybe	Best	Maybe	Maybe
Smooth transitions between plans	Yes	Yes	No	No

Sometimes there are institutional barriers to coordination. If the interchange is controlled by the state and the adjacent intersections are controlled by the city, coordination may not be possible due to agency communication problems. In this case, a floating cycle length for the interchange may be an appropriate solution.

The Critical Left Turns

A diamond interchange has four critical left turn movements, see Figure 20. These movements are critical because none of these movements require coordination on both sides of the interchange and no two of these movements can move together simultaneously at both intersections. It is possible to serve two movements at one intersection for short periods of time, but with longer time periods, lockup may occur, see Figure 21.

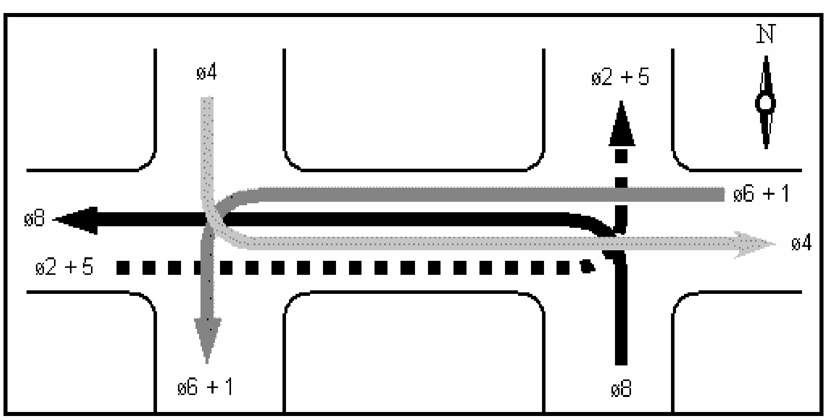


Figure 20 The Critical Left Movements

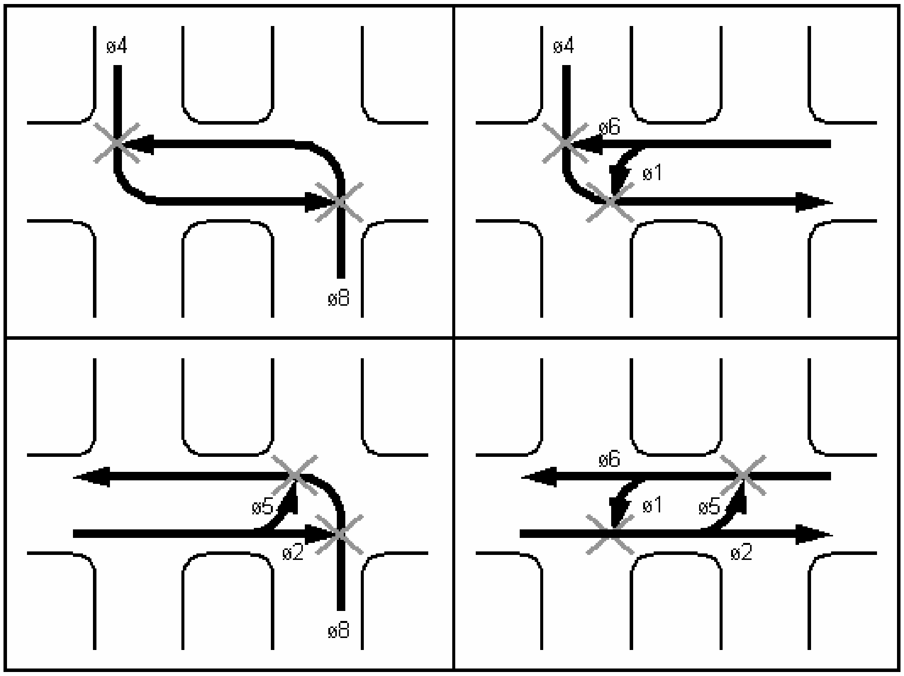


Figure 21 Critical Lane Blocking

When timing diamond interchanges, care must be taken to insure that blocking doesn't occur. This can be handled by using shorter cycle lengths, giving priority to the heaviest movements, building adequate storage space, or using creating signal phasing.

The Case for Lagging Left Turns

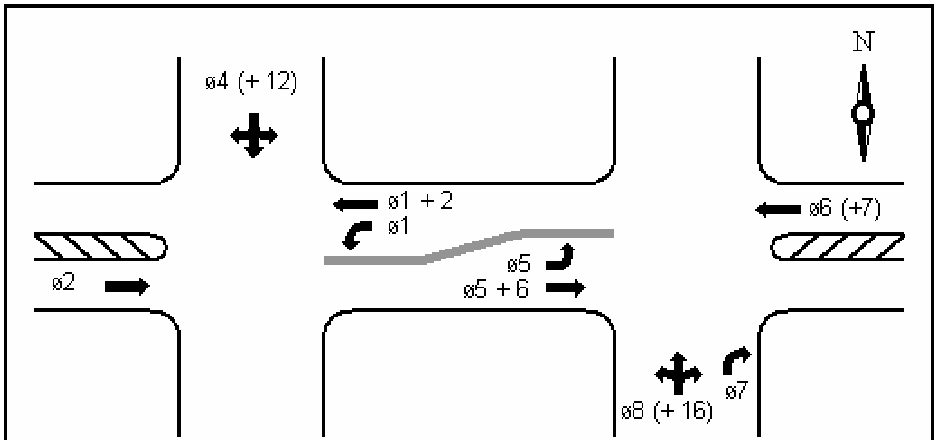
The use of lagging left turns can offer tremendous benefits within an interchange or other system of closely spaced intersections. Left turns within an interchange often cause blocking problems. The appropriate use of lagging left turns can reduce the waiting time and queue lengths of internal left turn movements. Lagging left turns also have the ability to reduce delays for all movements and improve coordination.

Many agencies are reluctant to consider lagging left turns. When timing diamond interchanges, this often leads to the poorly operating Simultaneous Leading Sequence discussed below. The Simultaneous Lagging Phasing also discussed below offers significantly better operation.

Diamond Interchange Timing Plans

This section will present four types of phasing used with diamond interchanges. There are other variations possible, but these present some of the common timings.

Refer to Figure 22 to see phase assignments for the interchange used in this discussion.



Phase assignments for diamond interchange. Phases 12, 16 and 7 are not used in all examples.

Figure 22 Diamond Interchange Phase Assignments

See the topic on Setting up a Timing Plan in the Example Chapter for detailed steps on how to create a timing plan for an interchange or closely space intersection.

Leading Alternating

Figure 23 shows a diagram of diamond interchange phasing using leading left phasing with the main cross street phases alternating between the off-ramp phases. This phasing is also sometimes called 4 Phase plus overlap or TTI Phasing. The term "4 Phase plus overlap" is misleading, the timing actually uses 8 phases, and the use of the word overlap is not used in the normal way. An overlap normally means a movement served by two or the more phases. The TTI description is also misleading because this type of phasing has been used in California for years before the Texas Transportation Institute "invented" it.

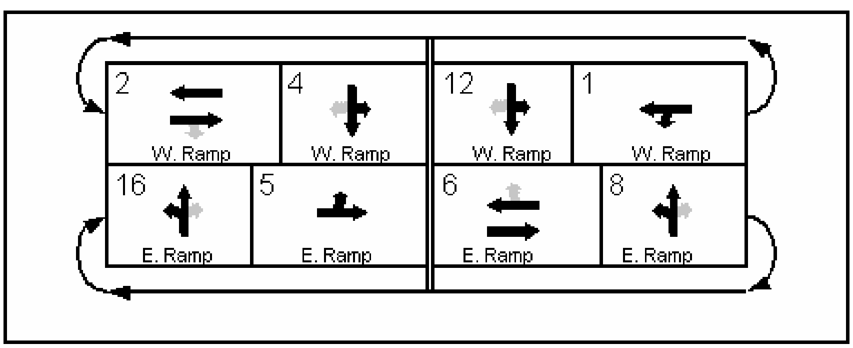


Figure 23 Leading Alternating Phasing

Figure 24 and Figure 25 are diagrams of the Leading Alternating in operation.

The Leading Alternating offers several significant benefits including:

Benefits

- Eliminates stops for almost all movements within the interchange.
- The four critical left movements are all timed independently.
- Can handle large volumes for all movements without blocking.

- Scales to low cycle lengths with low volumes
- Works well for intersections less than 200 feet apart

Disadvantages

- Does not provide as much time to cross street through traffic simultaneously.
- Loss in efficiency because each of the four movements control the entire interchange.

It should be noted that the Leading Alternating sequence does not provide good coordination for vehicles making a two left turns or a U turn on the freeway.

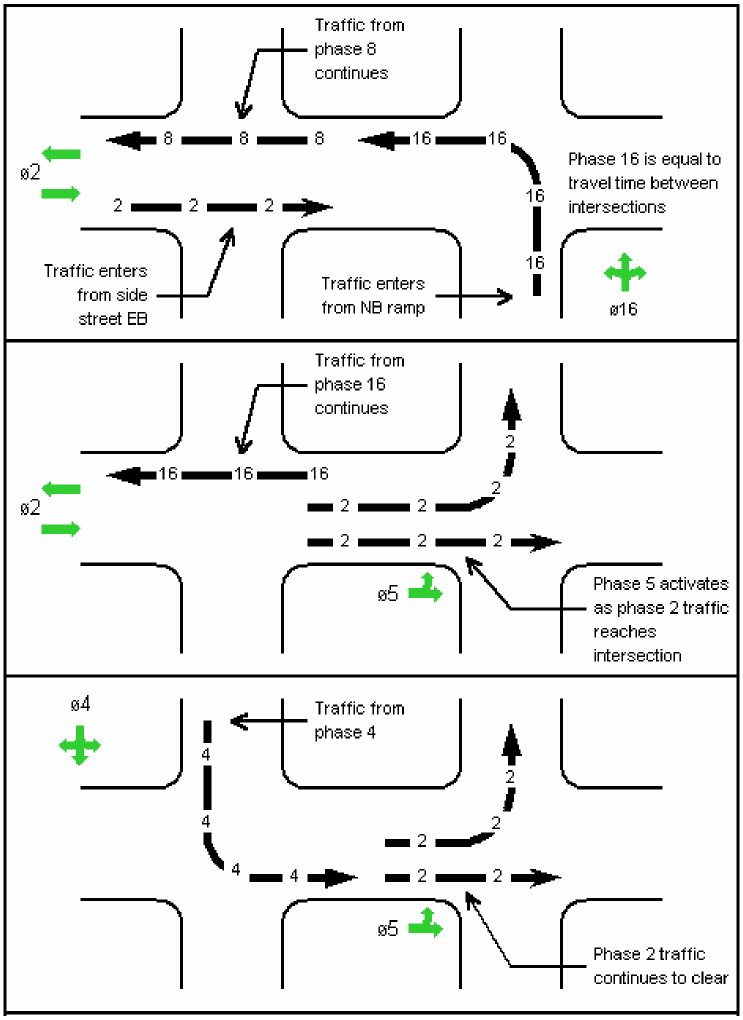


Figure 24 Leading Alternating Operation –1

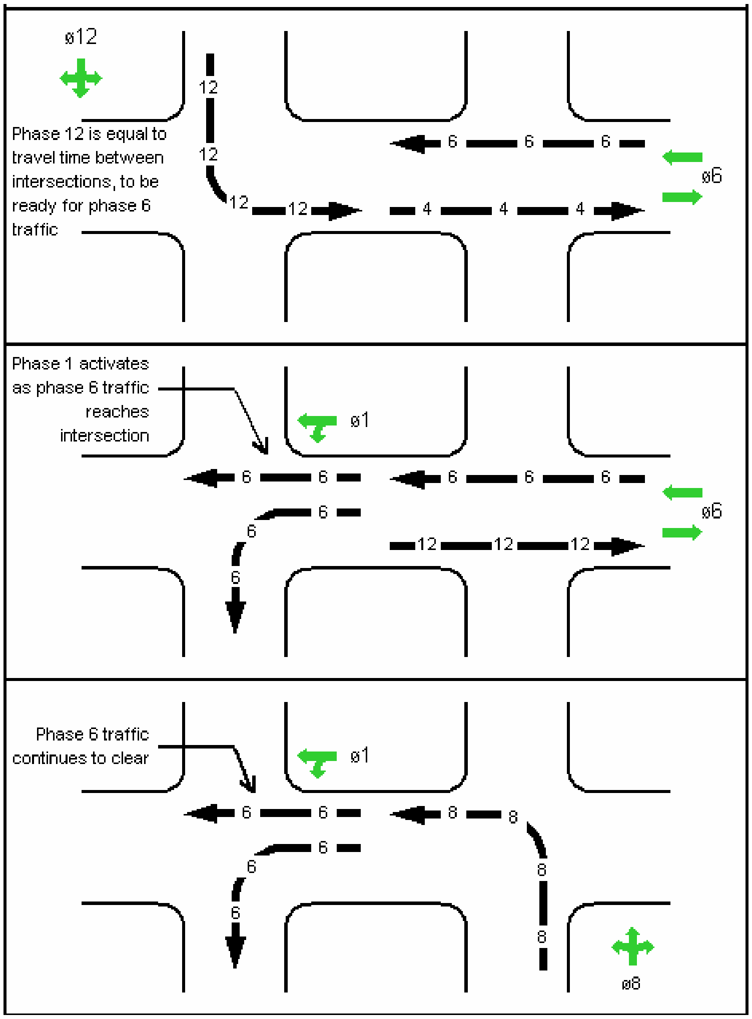


Figure 25 Leading Alternating Operation –2

The Leading Sequential plan shown here uses extra phases 12 and 16. The splits for their phases are limited to the travel time between the interchanges. During phase 12 and 16, traffic for two critical movements are entering the interchange simultaneously. Without these special phases, the interchange would essentially operate with 4 sequential phases. The Leading Alternating plan has 4 main stages while the simultaneous plans have 3 main stages. This makes the Leading Alternating plan a bit less efficient.

Leading Simultaneous

Figure 26 shows a diagram of diamond interchange phasing using leading left phasing with the main cross street phases showing simultaneous. This phasing is also sometimes called 3 Phase Leading. The term "3 Phase Leading " is misleading because the timing actually uses 6 phases. Leading Simultaneous phasing provides terrible coordination for the on ramp lefts (1 and 5), and mediocre coordination for the cross street through traffic (2 and 6).

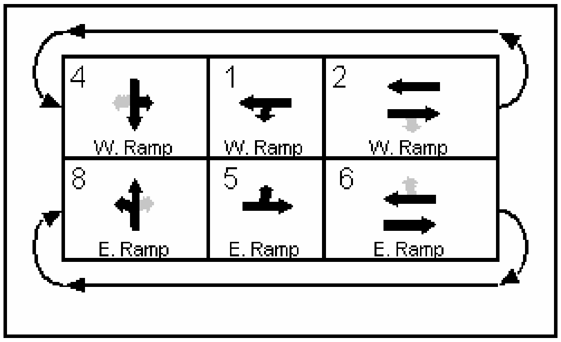


Figure 26 Leading Simultaneous Phasing

Trafficware believes that Leading Simultaneous Phasing should not be used under any circumstance. Leading Simultaneous is common because many agencies are prejudice against using lagging left turns and they also are attempting to get the widest through band on the cross street.

Figure 27 gives a diagram of the Leading Simultaneous in operation.

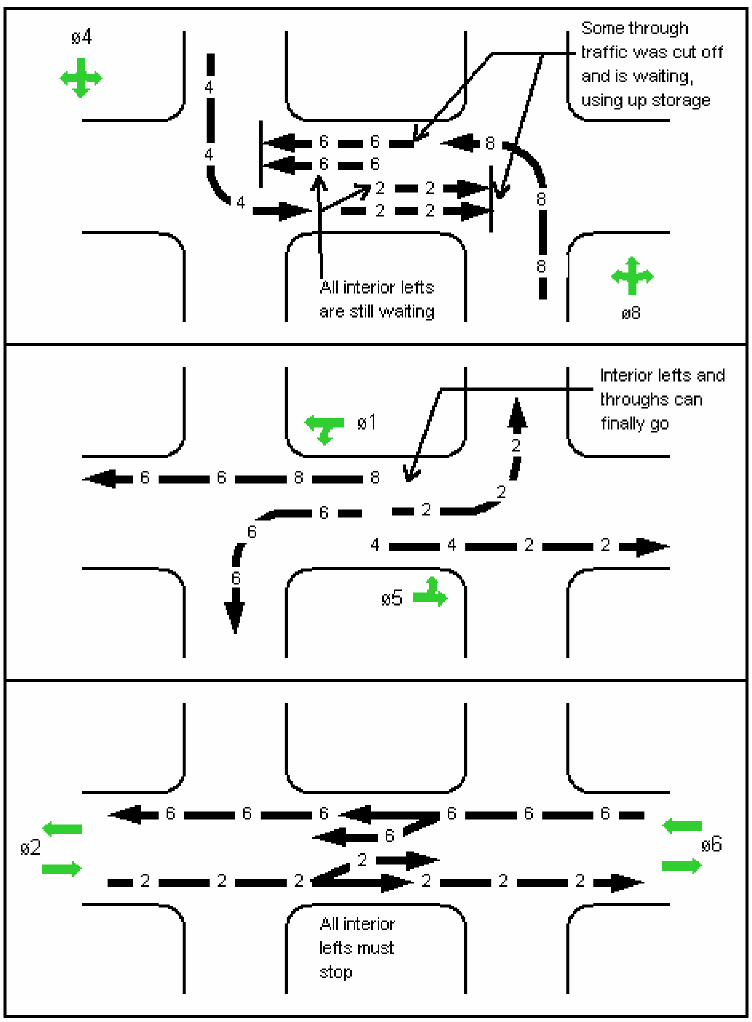


Figure 27 Leading Simultaneous Operation

Benefits

- None

Disadvantages

- Maximum delays to internal left turns (1and 5).
- Some through traffic (2 and 6) will stop twice and wait the maximum time.
- Internal left volume per cycle is limited to the amount of internal left storage space.
- Cannot service very large volumes from both off ramps (4 and 8).
- Requires at least 300 feet between intersections to provide storage

Step by step instructions for setting up phasing for Leading Simultaneous are show in the topic, Setting up a Timing Plan in the Example chapter.

Lagging Simultaneous

Figure 28 shows a diagram of diamond interchange phasing using lagging left phasing with the main cross street phases showing simultaneous. This phasing is also sometimes called 3 Phase Lagging. The term "3 Phase Lagging " is misleading because the timing actually uses 6 phases. Lagging Simultaneous phasing provides good coordination for all movements and is a bit more efficient than the Leading Alternating at allocating green time.

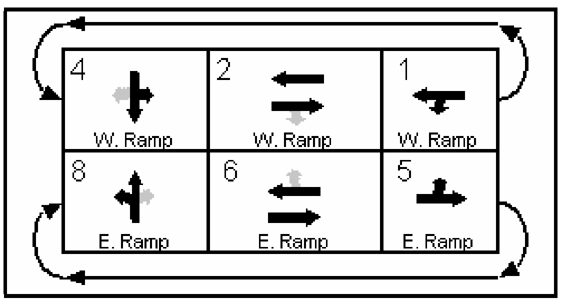


Figure 28 Lagging Simultaneous Phasing

Figure 29 is a diagram of the Leading Alternating in operation.

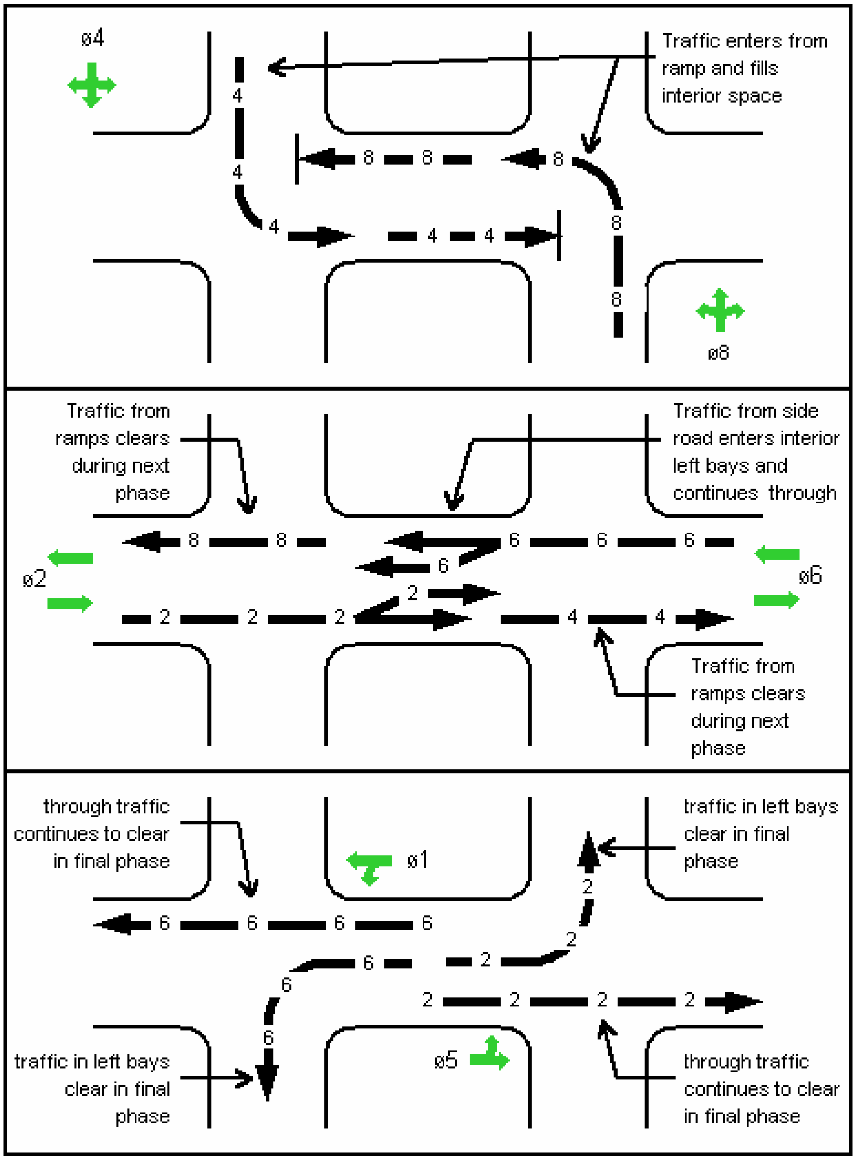


Figure 29 Lagging Simultaneous Operation

Benefits

- Provides good coordination for all movements
- A bit more efficient than Leading-Alternating at allocating green time

Disadvantages

- Internal left volume per cycle for one, but not both movements is limited to the amount of internal left storage space (1 and 5).
- Can not service very large volumes from both off ramps (4 and 8).
- Requires at least 300 feet between intersections to provide storage

Diamond with Heavy Right Turns

Figure 30 shows a diamond interchange with a special phase to accommodate heavy right turn traffic. In the example shown, most interchange traffic is between the freeway and the East side of the interchange. The phases serving the west side including 8 and 2 can be kept very short because they will experience low traffic volumes. Phase 8 is not critical because the NBR traffic is carried by phase 7.

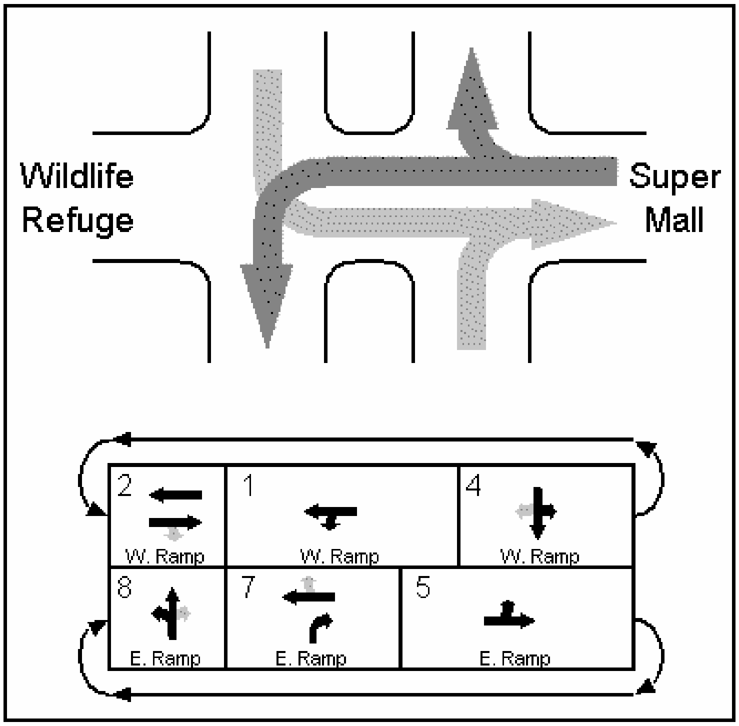


Figure 30 Diamond with Heavy Right Turns

Figure 31 and Figure 32 are diagrams of the Diamond with heavy rights in operation.

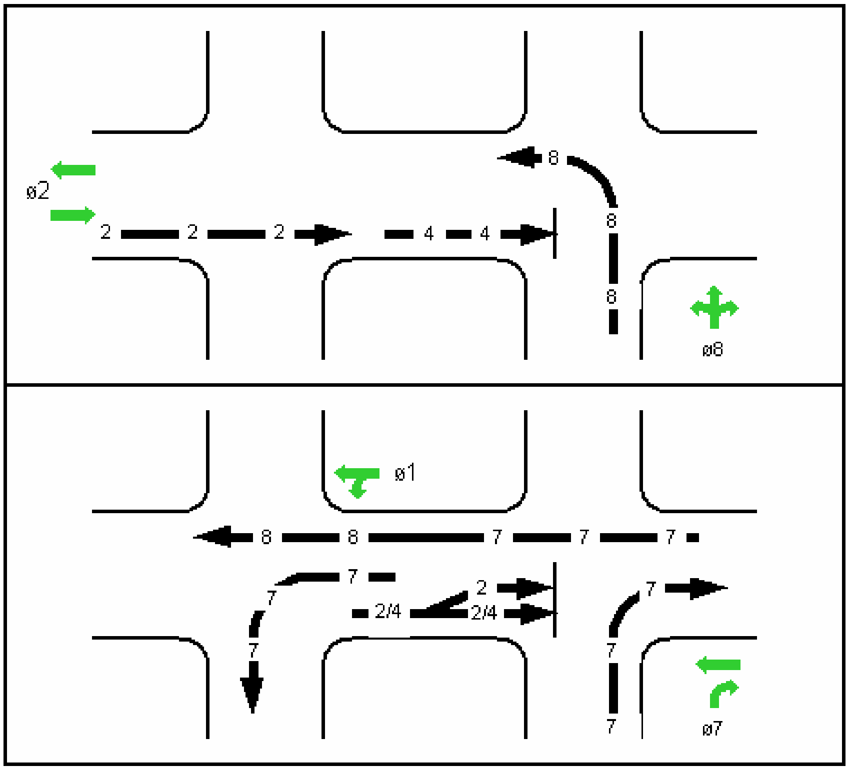


Figure 31 Diamond with Heavy Right Turns Operation–1

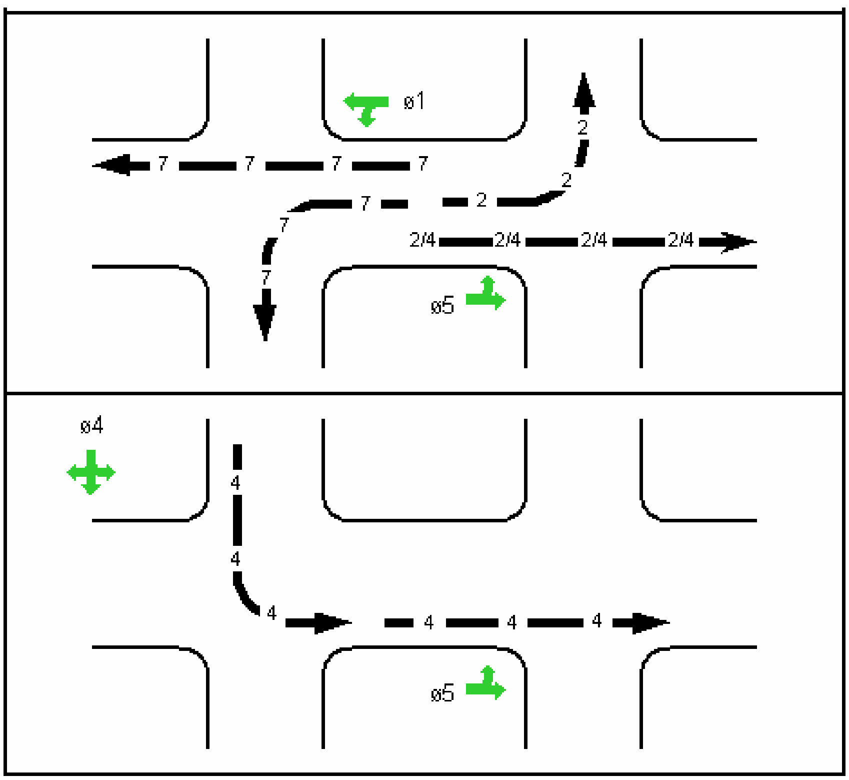


Figure 32 Diamond with Heavy Right Turns Operation–2

Benefits

- Provides high efficiency to the major movements when interchange traffic is mostly destined to one side of the interchange.
- Provides mostly good coordination to the major movements.
- No storage problems for the major movements

Disadvantages

- Only serves high volumes for one side of the interchange.
- Poor coordination for Eastbound through (phase 2).
- Some vehicles from movement 4 will get cut off.

Narrow Median Arterial or Interchange

If the distance between intersections is less than 200 feet, special care must be taken to prevent blocking with spill-back between intersections. The Leading Alternating plan can provide good service without blocking, however there is a loss in efficiency with short distances. The transition phases, 12 and 16 allow two critical movements to be served at once while traffic travels between intersections. Phases 12 and 16 are normally limited to the travel time between intersections. With a short spacing, these transition phases will be limited to less than 5 seconds. The phasing essentially becomes 4 sequential phases, one for each approach. Refer to Figure 33.

Since split time must be divided among 4 conflicting movements, this is generally an inefficient operation.

The Simultaneous timing plans are generally not acceptable because there is very little storage space between the intersections. With light volumes, it may be possible to implement a simultaneous type plan with permitted left turn phasing.

If faced with this geometry, alternative geometric designs should be considered, see Figure 34. If this is a wide median arterial, consider using flared left turn bays so that the left turn movements can move simultaneously. If this is a freeway, this type of geometry would require expensive structures and is called a single point urban interchange. With flared left turn bays, this interchange can be timed as though it is a single intersection.

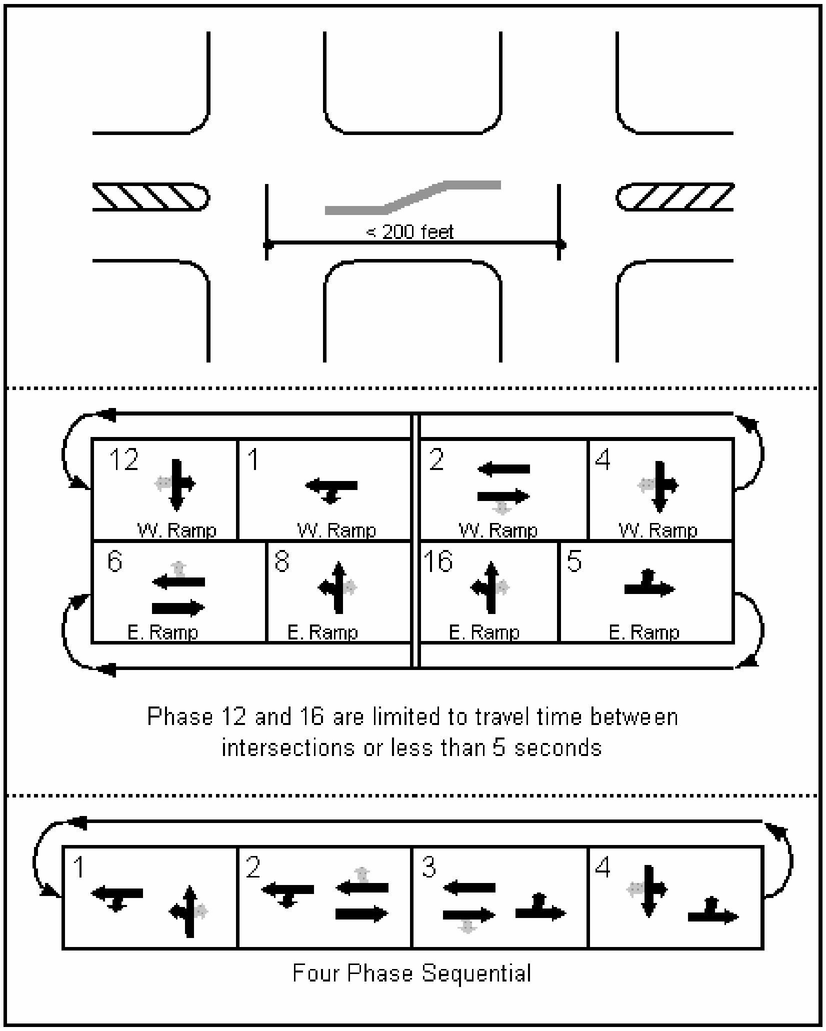


Figure 33 Diamond Phasing for Narrow Median

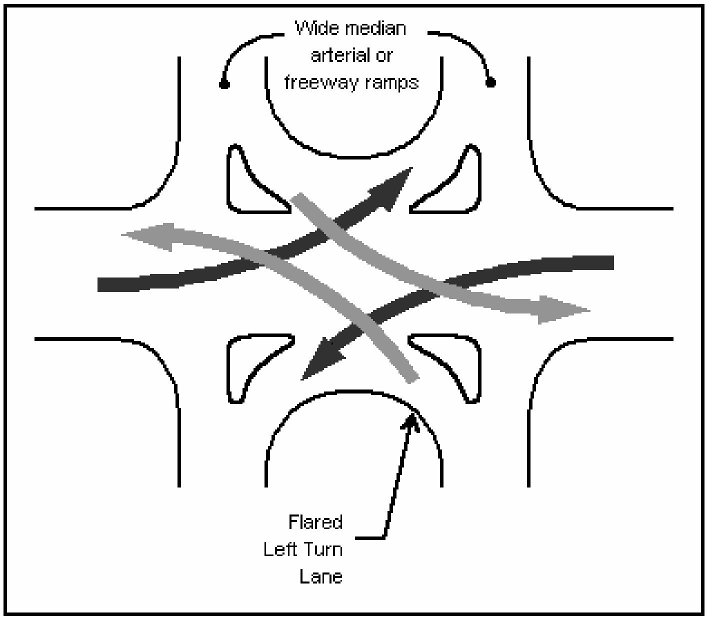


Figure 34 Flared Left Turns

Other considerations are to prohibit left turns. The state of Michigan prohibits left turns at many wide arterials and requires motorists to turn right and then a U-turn.

Many other agencies are installing loop on-ramps to eliminate the problems with internal left turns. Of course, if there is space for a loop on-ramp, there is probably also space for some left turn storage.