4. BASIC TYPES OF SIGNAL CONTROL

4.1 General

Traffic control signals may be installed at intersections or at mid-block locations. They may operate independently of any other traffic control signal ("isolated" operation) or their operation may be related to other traffic control signals ("coordinated" operation) forming a traffic control signal system.

All local traffic signal controllers that operate to control traffic at either intersection or mid-block locations have two basic components, a timer and a device used to switch the signal indications "on" and "off".

4.2 Types of Control

4.2.1 Pretimed Signal Control

Pretimed control directs traffic to stop or permits it to proceed according to a predetermined "fixed" cycle length and a division of the "fixed" cycle time between the various approaches to the intersection regardless of the actual vehicle demand. The sequence in which the signal indications are shown, and the time-relation of the signal to other signals are also pre-selected. Any or all of these features may be changed to accommodate specific needs.

In pretimed operation, signal sequence is controlled by signal plans, which define the order of the signal intervals that are displayed. The amount of time given to each interval in a signal plan is determined by a timing plan. The time of the day at which specific timing and/or signal plan programs begin or end may be predetermined locally or remotely by a time clock or equivalent device.

Pretimed control may be used at isolated intersections where traffic volumes are predictable, or where the installation is to be coordinated in the near future with adjacent intersections. However, traffic actuated signals may be preferable at most intersections due to their potential for being more efficient for such locations than pretimed signals.

4.2.1.1 Solid-State Pretimed

In the early 1980s, manufacturers began to produce pretimed controllers based on solid-state circuits. The dial motors and cam shafts of the electromechanical controllers were replaced with software driven equipment. Timings are accomplished through the use of timing plans, which are keyboard entered. Cam shafts were replaced with signal plans contained on a PROM, or Program Read Only Memory, chips which were burned in. Newer models of these controllers do not require that the PROM's be burned. The basic functions of the
4.2.2 Pretimed Actuated Control

Pretimed actuated control employs the same basic controller as described in the preceding section except that vehicle detection amplifiers can be wired into the controller circuitry. The controller will dwell in a specified phase until a vehicle is detected on one of the approaches having detection. This type of operation has the advantage of permitting the controller to dwell in a green condition, generally for the main street. A disadvantage is the controller must follow through the preset minimum signal intervals and does not easily permit the skipping of any intervals. With the solid-state controllers, signal plans as well as timing plans can be changed through the detection, which, with certain brands, closely mimics the operation of the fully actuated controller.

4.2.3 Fully Actuated Control

A fully actuated controller uses detection for all movements to determine the display and duration of vehicle and/or pedestrian movements at an intersection. The controller is able to "skip" those movements where no demand is present.

Fully actuated controllers are available in two primary types, the NEMA, National Electrical Manufacturers Association, or the Type 170. Both are keyboard entry and software driven machines. The NEMA controllers make up the bulk of the actuated controllers used in the state. The Type 170 controllers are used in the Springfield District and at those locations in Kansas City where we are interfacing with the city.

NEMA TS1 standards define the basic operating parameters of the controller as well as the inputs and outputs of the unit. This has led to the interchangeability of NEMA controllers between manufacturers. Most of the manufacturers have enhanced the operating software, adding many features that may be unique to that make and model. However, to be certified as a NEMA controller, the basic operating functions are identical.

The NEMA TS2 standard expands the features of the TS1 standard, providing a higher level of standardization and interchangeability of equipment. TS2 also defines many of the features that have evolved in the current NEMA controller technology.

The Type 170 controller defines the hardware of the controller and allows the user to choose the software to run the controller. This has led to a great and almost total interchangeability of the controller and cabinet hardware but has left the user to evaluate and standardize on the software to run the intersection. Most of the features of the software are similar to the NEMA parameters. The Springfield district is using the BiTrans software and the Kansas City area uses the Wapiti software.

All fully actuated controllers are able to respond to the traffic at the intersection. Minimum green times for called phases as well as extensions, when there continues to be traffic present, are programmable. There are also maximum
green times, when a phase must be terminated to serve other calls, as well as yellow change and red clearance intervals which are programmable. Walk and flashing don't walk change intervals are also available for those phases that require them. There are also other features which are available on a per phase basis such as added initial, maximum initial, minimum gap, time to reduce, time before reduction, minimum and maximum recalls. These features are what allow the fully actuated controller to serve the traffic, at the intersection, in the most efficient manner.

The phases in an actuated controller can be assigned or grouped many ways to provide unique operations that best serve the intersection's needs. The most common configuration is the dual ring eight-phase quad. This arrangement allows for separate through and left turn phases for up to four approaches. The opposing left turns are typically on concurrently, either leading or lagging. When a leading left gaps out, the controller is then able to move to the through phase that would not be a conflict with the remaining left being serviced. Through the software, the phases can be repositioned to provide a lead-lag left operation if so desired. Another typical configuration is the sequential operation. In this method, only one phase at a time is serviced. This causes an increase in the overall delay at the intersection but is used where geometric or capacity considerations are restrictive. Combinations of the quad and sequential are also possible. Examples of typically used configurations are found in Appendix 6.3.

Efficient actuated operation is very dependent on the type and placement of the detectors. Poor detector placement can have a very serious impact on the delay and capacity of an intersection. Typically, stop bar presence detection is used for cross streets and left turn lanes. The common presence detector is the 6 foot by 30 foot quadrupole loop in the pavement. Main line through detection is accomplished with either back detectors located a distance from the stop bar based on the speed of approaching traffic, stop bar presence detectors or a combination of both. Back detectors are typically 6 foot by 6 foot loop detectors that operate in the pulse mode. A further discussion of detection can be found in Section 4.4.3.

Fully actuated control is typically used at an intersection where isolated operation is desired or possible in the future. Such control is also applicable to heavily used intersections requiring three or more phases and where the unused green time can be reassigned to another phase needing it.

4.2.4 **Semi-Actuated Control**

Semi-actuated intersection control refers to those intersections where a fully actuated controller is used but one or more phases are not actuated. Typically, the main line through phases are not actuated and the side streets and the main line lefts are fully actuated.

Timing for the non-actuated phases may be accomplished by setting the minimum green time and placing the phases on minimum recall. This will cause the controller to always service the phases for the specified time. Actuated extension of the non-actuated phases is not possible since there are no detectors available for those movements. The non-actuated phases will remain in green until there is a call from one of the other movements and the minimum green timer is expired.
The actuated phases work the same as in fully actuated control since vehicle detection is used to determine the need for the phase and the length of the green. The normal actuated parameters of minimum green, gap/extension, and maximum green are used for these phases.

Semi-actuated control of an isolated intersection is less expensive than fully actuated control because fewer vehicle detectors are required. They may, therefore, be used where the major street carries considerably greater traffic than the minor street, and pretimed control would result in very inefficient traffic operation. In such installations, the major street should be the non-actuated phase. To avoid or minimize unnecessary delay at isolated intersections fully actuated control is preferable to semi-actuated control. Semi-actuated control can be more easily coordinated than fully actuated control and therefore may be a better choice for individual intersection control in coordinated systems.

4.2.5 Features Common to Semi-Actuated and Fully-Actuated Control

Both semi-actuated and fully actuated controls have capabilities that enable them to be responsive to traffic and pedestrian needs. These capabilities include:

1. Minimum delay when used in isolated operation
2. Traffic density control
3. Demand control
4. Separate pedestrian-actuated timing control
5. Multi-phase interval sequences
6. Recall operation
7. Multiple maximums

4.3 Comparison of Pretimed and Actuated Control

4.3.1 Relative Adaptability to Normal Intersection Requirements

Each of the principal types of traffic signal control, pretimed and actuated, possess certain advantages not afforded by the other. The choice of equipment should be made only after a review of the relative merits and adaptability to the particular requirements of the location proposed for signalization. The following discussion is intended to bring out basic differences in the different types of control, as to their operating characteristics and suitability for various traffic requirements. It should be remembered that each type of control is capable of being modified in various ways for improved efficiency and flexibility.

With basic pretimed control, a consistent and regularly repeated sequence of signal indication is given to traffic. Pretimed control is best suited to intersections where traffic patterns are relatively stable or where the variations in traffic that do occur can be accommodated by a pretimed schedule without causing unreasonable delays or congestion. Pretimed control is particularly adaptable to intersections where it is desired to coordinate signal operation with existing or planned signal installations at nearby intersections.

The actuated controller differs basically from the pretimed controller in that signal indications are not of fixed length, but are determined by and conform within
certain limits to the changing traffic flow or to the background cycle from the master controller, if coordinated. The length of cycle and sequence of phases may or may not remain the same from cycle to cycle since phases will not be serviced ("skipped") unless there are detections from waiting vehicles or pedestrians.

4.3.2 Advantages of Pretimed Control

Among the advantages of pretimed control are the following:

1. Consistent starting time and duration of intervals facilitates coordination with adjacent traffic signals. It also provides more precise coordination than does actuated control, especially when coordination is needed with adjacent traffic signals on two or more intersecting streets or in a grid system. This capability can permit progressive movement through a system of several well-spaced traffic signals. Precise coordination of timing permits the operation of two or more very closely spaced intersections to operate at maximum efficiency.

2. For proper operation, pretimed controllers are not dependent on vehicle detectors. Thus, the operation of the controller is not adversely affected by such conditions as a stopped vehicle or construction work within the area.

3. Pretimed control may be more acceptable than actuated control in areas where large and fairly consistent pedestrian volumes are present, and where confusion may occur with the operation of pedestrian push buttons.

4.3.3 Advantages of Actuated Control

At intersections where traffic volumes fluctuate widely and irregularly, where traffic loads shift frequently, or where interruptions to main-street flow must be minimized, maximum efficiency in signal operation may be attained by the use of actuated control.

Among the special advantages of actuated control are the following:

1. Actuated control may provide maximum efficiency at intersections where fluctuations in traffic cannot be anticipated or programmed with pretimed control.

2. Actuated control may provide maximum efficiency at complex intersections where one or more movements are sporadic or subject to variation in volume.

3. Semi-actuated control will usually provide maximum efficiency at intersections of a major street and a minor street by interrupting the major-street flow only when required for minor-street vehicular or pedestrian traffic. Such interruptions should be restricted to the minimum time required.
4. Actuated control may provide the advantages of continuous signal control even in periods of light traffic without causing unnecessary delay to traffic on the major street.

5. Actuated control is particularly applicable at locations where traffic signal control is warranted for only brief periods during the day.

6. Actuated control tends to reduce problems associated with the arbitrary stopping of vehicles.

7. Actuated controllers have the flexibility of operating fully actuated, semi-actuated or pretimed. The type of operation may also be changed by time of day.

8. Actuated controllers are basically interchangeable between manufacturers because of NEMA or Type 170 standards.

4.3.4 **Other Factors Governing Selection of Type of Control**

In addition to the advantages of pretimed vs. actuated signals as a basis for selecting the appropriate type of traffic control, initial equipment cost, installation cost, and anticipated operating expenses need to be considered. Pretimed control is generally less expensive to install and maintain than other types of control. Attention should also be given to economic benefits or losses that may occur to motorists and pedestrians. Unnecessary stops and delays to traffic movement results in economic losses, and can accumulate to a significant total during the life of the traffic control equipment. In many cases, the reduction in motor vehicle operating costs will justify installation of signal control equipment which has a higher first cost but greater efficiency in handling traffic.

Crash potentials also should be considered. While signals are the most effective in reducing right-angle crashes, they tend to increase the frequency of rear-end crashes. Possible reduction of crashes through efficient operation of traffic signals frequently will offset added signal installation and maintenance costs.

Extreme care should be used in selecting traffic control equipment so that proper features for present and future operation will be obtained when controllers are purchased.

4.4 **Control Features for Isolated and Other Intersections**

4.4.1 **Isolated Operation**

With isolated operation of actuated signal controllers, the time cycle is composed of the sum of the green interval times of the various phases and their vehicle change and clearance intervals. Hence, the time cycle is variable and not readily adaptable to signal system coordination. Isolated actuated operation can effectively minimize traffic delays at locations where nearby signalized intersections are not a consideration.
4.4.2 Traffic Density Timing

The traffic density timing feature provides for the initial green interval and/or the allowable traffic gap that ends the green interval, to be automatically adjusted according to traffic flow variations.

The variable initial green interval setting provides a means for timing the length of the green interval according to the number of vehicle actuations received during the preceding red interval. The variable initial green control is intended for use where the shortest practical minimum green interval is not adequate for the traffic that can be stored between the back detectors and the stop bar. The initial part of the green interval, (minimum initial), remains short when few cars have arrived during the red interval, but it increases (added initial), a fixed amount per actuation during the red interval up to the maximum initial. With back detection only, vehicles need more time to enter the intersection before they lose the right of way.

Another feature of density control provides automatic variation in the allowable interval, or gap between traffic actuations, which, if exceeded will end the green after the initial time is completed. When using variable gap or gap reduction timings the allowable gap is automatically reduced by the passage of time during which traffic is moving on the green signal, and other traffic is waiting for a red signal on another approach to the intersection. The maximum gap is in effect for a predetermined interval (time before reduction). When this interval times out the allowable gap begins to decrease during the time to reduce. The allowable gap will continue to decrease until the programmed minimum gap is reached. The gap will remain at this level until the controller either gaps out or maxes out. Gap reduction timings are normally used on the main line through movements where the side street volumes are also significant. Reducing the allowable gap on the main line traffic provides for a more critical look at the traffic flow as the queue begins to clear and "free" flow on the approach starts. Use of these timings will allow the controller to move on to another phase when the traffic begins to stretch out and the overall efficiency declines. Gap reduction timing can increase the efficiency of the intersection and reduce the delays on the side streets.

4.4.3 Demand Control

The advantage of demand control is that it allows a more direct response by the controller system to the characteristics of traffic flow in the intersection or system.

To utilize demand control, a presence type, long loop detector (50 to 100 feet long) should be placed on the intersection approach beginning approximately at the edge of the cross street. The non-locking memory feature of the controller is utilized and the initial and extension controls are turned to a low or "off" setting. A second pulse detector placed a standard distance back from the intersection can allow use of density features. It can act as a calling detector to transfer the green prior to a vehicle entering the second loop, thus making it unnecessary for the vehicle to stop if there is no demand on other phases.
It is advantageous to supplement the long loop with a 6 foot by 6 foot booster or "header" in front of the long loop near the stop bar. Such an addition insures detection of motorcycles and high-bodied trucks that may be lost in turning a long loop. A booster wired separately also provides backup for the long loop in case of damage. The quadrapole loop can also be used to sense motorcycles and other vehicles that are hard to detect.

The principal advantage of demand control is to provide a quicker response to traffic for transfer of green. At the end of an approaching platoon, the green can be instantaneously shifted to yellow in preparation for the next phase being called. This minimizes wasted green time. A very simple preemption of phases can be provided by having the preemptor turn off the loop of the phase to be skipped. The controller will also respond directly to slow platoon start up (a high density low volume situation) from such condition as inclement weather, a severe grade, or a crash.

Care should be taken to insure an adequate minimum green for the prevailing conditions. Controller settings for minimum green should consider sight distance, prevailing speeds and other characteristics common to the intersection. Special attention should be given to pedestrian demand and the possible need for pedestrian detectors and indications.

The disadvantage of this type of control is the need to maintain the long loops in the pavement. Experience has shown when joints in the pavement are crossed by the loop the likelihood of a failure is greatly increased. Two or more loops up to 6 foot by 30 foot may be used. The disadvantage of this is the additional cost of more lead-in cables and detector amplifiers.

4.4.4 Pedestrian Control

Where pedestrian activity exists on a regular basis at a signalized intersection and it is reasonable to cross, pedestrian indications and marked crosswalks should be provided. It is important that consistency be provided in pedestrian control to enhance the understanding of and conformance to traffic signals by pedestrians. Where a more appropriate pedestrian facility exists nearby, i.e. pedestrian overpass or tunnel, adjacent intersection with better pedestrian facilities, etc., pedestrian signals and crossings should not be provided.

4.4.4.1 Separate Pedestrian Actuated Timing Control

Separate pedestrian actuation can be furnished for any actuated phase. Actuation of a pedestrian detector increases the vehicle minimum green interval by an amount that, together with the vehicle change indication, provides the time required for a pedestrian to cross. If pedestrian indications are used, the increased minimum green interval is divided into a walk interval and a pedestrian clearance period. As described herein, the duration of pedestrian clearance extends from the end of the walk interval until opposing vehicles receive a green indication. This includes the previously described pedestrian clearance period, plus the vehicle change interval(s).

The use of separate pedestrian actuation permits the vehicle minimum green interval to be set at a lower value than required for pedestrian crossing, thus reducing waiting time for other traffic in the absence of
pedestrians. Pedestrian actuation should be provided whenever low or moderate volumes of pedestrians are to cross wide streets.

Pedestrian actuation may also be used with low or medium pedestrian volumes to minimize the traffic delays caused by exclusive pedestrian intervals at locations where no other practical way can be found to provide for pedestrian crossing. Adding pedestrian indications and detectors at intersections that have controllers capable of handling the actuations is encouraged when there is a request for pedestrian crossings.

4.4.4.2 Green Indications For Pedestrian Control

Green indications may be used for pedestrian control as a short-term accommodation until pedestrian indications, required equipment and cross walks can be provided. These locations should be scheduled for the necessary improvements as soon as workloads and/or funding allow. The following are required when green indications are used for pedestrian control:

1. Green indications associated with the pedestrian crossing shall be visible on the far side of both sides of the crosswalk.

2. Sufficient green time is guaranteed for pedestrians at any time pedestrians may be present. Green time is the same as if pedestrian signals were present (G + Y = Walk + Pedestrian Clearance).

3. For an actuated pedestrian associated phase, a pedestrian detector should be provided with sign R10-3 "PUSH BUTTON FOR GREEN LIGHT". Minimum green is set for pedestrian timing regardless of whether the phase is called by a vehicle or a pedestrian. This is necessary since an approaching pedestrian has no way of knowing if the phase was called by a vehicle or a pedestrian. Where pedestrian activity is only during a limited time of day, a pedestrian recall by time of day may be used. Use this method only with caution, since unnecessary calls to the side street may result.

4.4.5 Recall Operation

Each phase of an actuated controller is equipped with a recall feature. With recall off, the phase responds only to its detectors. With recall on, the controller will always service that phase. This is accomplished by the controller placing a single call back to the phase when the clearance interval is initiated.

Recall comes in several variations and has different uses. Minimum recall is normally used on the main line through phases. Minimum recall guarantees the timing of the minimum green for the phase selected with additional green available through actuations. Using this feature on the main line through is advantageous since during periods of light activity the controller will rest with the main street green indications on. Maximum recall guarantees the timing of the maximum green interval for the phase selected. This feature is normally used when the detection for a phase has been disabled due to failure or removal.

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Care should be used with this feature, as the phase will always be serviced for the maximum green interval programmed that should be adjusted accordingly. Many actuated controllers also have a feature called "soft" recall that allows the selected phase to be serviced only if there are no other valid calls. This feature can be used on the main street during periods of light traffic. The advantage over minimum recall is the controller can skip servicing the main street, if no real calls exist, and move on to the next called phase. This can provide a snappier response during the periods of light traffic.

4.4.6 Multiple Maximums

Normally, one "maximum" interval timing per traffic phase will be adequate. However, there are times when the peak-hour or special traffic demands on a given phase are so much heavier than during off-peak periods that a single maximum interval will not operate efficiently for both conditions. To handle this situation, two different maximum interval timings can be provided and controlled by time clock, so that the peak hour maximum green interval can be long and the off-peak maximum short. Selection of multiple maximum is normally done on a per ring basis and will also affect the selection of the "max II" timings for the other phases in the ring. In some controllers, selection of multiple maximums can be done on a per phase basis.

4.5 Controller Assembly Components

4.5.1 General

There are a number of parts that are contained in the signal controller assembly that are important to the operation of the signals.

4.5.2 Controller Unit

The controller unit (CU) is typically a solid-state pretimed or traffic actuated unit. The CU interfaces with a number of low voltage (logic level) input and output functions to control signal lamps, receive inputs from detectors, to operate in interconnect systems, etc. Additional information on types of control is found in Section 4.2.

4.5.3 NEMA TS2

The NEMA TS2 standard replaces much of the discrete cabinet wiring with high speed serial communications interfaces. In addition, the communications allows the CU, malfunction management unit (MMU), backpanel, and detector rack to exchange information on a regular basis, performing redundant checks on each other.

The TS2 Type 1 standard uses EIA-485 serial communications interfaces and Synchronous Data Link (SDLC) communication protocol to link the major cabinet components. The serial data is converted to analog inputs and outputs in the backpanel and detector rack by a buss interface unit (BIU).

4.5.4 Backpanel (Solid-State Pretimed and NEMA TS1 Controllers)

All solid-state controllers need a backpanel for the termination of the controller inputs and outputs. All of the primary functions of the controller have terminals

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4.5.5 Backpanel (NEMA TS2 Type 1 Controllers)

The TS2 cabinets also use a backpanel for the termination of controller inputs and outputs. Load switch drivers and other functions of the controller have terminals on the backpanel that are used to interface with the other devices in the cabinet and to display the indications on the street. The backpanel is linked to the CU through one or more BIUs. Load switch assignments and other backpanel functions are configured through the controller software. Discrete wiring is still provided between the back panel and the MMU to monitor load switch outputs.

4.5.6 Rack Assemblies (Type 170 Controllers)

Cabinets for Type 170 Controllers use a 19” rack assembly to secure equipment. The controller unit and a number of cabinet assemblies are attached to the racks. Cabinet assemblies consist of the power supply assembly, power distribution assembly (PDA), input file, and output file. The power supply and PDA provide power, circuit protection, and surge suppression for cabinet equipment. The PDA houses the flasher and auto/flash switch. The input file houses card rack detectors, isolators and other input devices. The output file houses load switches, flash transfer relays and the monitor. Other auxiliary equipment can be rack mounted or mounted by other means. Terminations for wiring are made on the back of associated cabinet assemblies.

4.5.7 Conflict Monitor Unit / Malfunction Monitor Unit

All solid-state controllers have a conflict monitor unit (CMU) or a malfunction monitor unit (MMU) to supervise the operation of the traffic signals. The primary purpose of this unit is to guarantee that conflicting signal indications are not displayed on the street. If such a conflict is detected, the unit will automatically put the intersection into a flashing condition. The intersection will remain in flash until the monitor unit is reset and the problem that caused the failure is corrected.

These monitors also have the ability to monitor the absence of signal indications on the street. The absence of a load on the output side of the load switch when that output is turned on will cause the monitor to put the intersection into a flashing condition. This occurs when all of the bulbs of the same color on a particular phase are burned out or when a wiring failure causes loss of power to the bulbs. For phases with only one signal head (i.e. a left turn phase), MoDOT standards require that the outputs be "satisfied" with load resistors so that a single bulb outage will not cause the intersection to go to flash.
Each conflict monitor has a program card that is unique for that intersection. On the program card, jumpers are installed to tell the unit which movements, or channels, are considered compatible. Those positions not having jumpers are considered as conflicts and will trip the monitor. It is very important that the monitor cards for each intersection be reviewed periodically to be sure the jumpers are assigned correctly.

The monitors also watch the overall "health" of the controller. If power is lost to the controller or if the internal 24-volt DC voltage of the controller is lost, the monitor will trip the intersection to flash. Some of the newer conflict monitors available exceed the minimum specifications set out by NEMA.

In NEMA TS2 cabinets, communications between the MMU and the CU allow the ability to monitor for fault conditions between the major cabinet components. Certain fault conditions will cause the intersection to flash. Some examples of these faults are the loss of serial communications, incompatibility between MMU program card and CU phase sequences and discrepancies between load switch outputs and CU phase outputs.

In no case shall a solid-state controller be operated without a monitor unit.

4.5.8 Load Switches

As previously mentioned, the operating voltages of the solid-state controller are 24 volts DC. This voltage must be converted to 120 volt AC in order to drive the signal bulbs and provide the indication on the street. The load switch is a solid-state device that converts the 24-volt DC output from the controller to the 120-volt AC needed by the bulbs. Each load switch is able to handle three circuits. Normally, one switch is assigned for each phase and it is able to handle the green, yellow and red outputs. A separate load switch is used to control pedestrian indications, if they are used.

4.5.9 Auxiliary Interfaces

Other auxiliary interfaces may also be needed in the controller cabinet. Examples of these include hardwire interconnect interfaces, closed loop system interfaces and preempt interfaces. These typically consist of a panel or unit that brings external inputs, outputs and communications into the CU.

4.5.10 Detector Interface

The detector interface provides connections between the CU and detection devices. In solid-state pretimed and NEMA TS1 controllers, the connections are made through the back panel. In NEMA TS2 controllers, the detector inputs and outputs are linked to the CU through a BIU. In type 170 cabinets, the input file serves as the detector interface.
4.6 Detectors

Detectors are the devices that provide the inputs the controller uses in determining the phasing and timing needs of the intersection. There are many types of detectors currently in use and more are being developed. Detectors range from the pedestrian push button installed on a post to video imaging systems that are being refined. But no matter how simple or sophisticated the technology, the basic goal of a detector is to provide a valid input to the controller unit of the need to provide service.

There are two primary types of detection, pulse (or passage) and presence. In pulse detection the detector provides to the controller an instantaneous call that demand is there and then the call is dropped. Presence detection is able to register that demand is present and will retain the call as long as the demand, normally a vehicle, is in the zone of detection.

4.6.1 Induction Loop Detectors

Induction loop detectors consist of wire that is placed in the pavement that senses the passage or presence of metal objects (i.e. vehicles). The detectors are tuned to a background frequency that is based on the number of turns of wire in the saw cuts in the pavement. The passage or presence of an iron mass changes the inductance and therefore the frequency of the loop. The detector amplifier is able to measure this change in inductance and, when set thresholds are exceeded, a detection is registered.

4.6.1.1 Loop Configuration

The most common arrangement of the loop detector is the quadrapole. See Appendix 4.1 for comparison of Induction Loop Detector Designs. This layout, a rectangle with an additional cut down the middle, provides the greatest sensitivity of detecting small vehicles while reducing the occurrence of cross talk between loops in adjacent lanes and false calls from adjacent lanes. The typical quadrapole loop is 6 feet wide by 30 feet long located at the stop bar in each lane. Quadrapole detectors are also used in lengths less than 30 feet, particularly where there are full depth joints.

Another widely used loop configuration is the 6-foot by 6-foot square loop. This loop, which is centered in the lane, is typically used for detection in advance of the stop bar. This layout is more susceptible to cross talk and false detections but, with proper adjustments of the amplifier, good performance can be achieved. This loop configuration is also typically used for vehicle counting and where speed traps are needed. A variation of this loop is a diamond shaped loop. By turning the square loop 45 degrees, the more sensitive corners can be centered on the lane.

There are additional loop layouts, such as the skewed loop, round loops and other variations being evaluated to overcome some of the deficiencies of the "typical" layouts described above. A resource for information on alternate loop designs and many other aspects of detectors is the FHWA Traffic Detector Handbook (also available through ITE).
4.6.1.2 **Induction Loop Detector Amplifiers**

Induction loop detector amplifiers are installed in the controller cabinet and are available in shelf mount and rack mount configurations. The shelf mount units are self contained and are connected to the controller backpanel through a wiring harness. Rack mount units are installed in a card rack with separate power supplies. Type 170 and NEMA TS2 controllers use only rack mount detectors. The TS2 detectors have additional diagnostics that are linked to the CU through the serial communications.

4.6.2 **Micro-loops**

Micro-loops are point detectors that consist of a probe that is installed in the pavement with a continuous lead in to the controller cabinet. They operate on a similar principal to a conventional loop detector.

Micro-loops are typically used at those locations where the pavement is not able to support the cutting of a loop or right of way is limited. Installation in pavement is normally done by drilling a hole in the pavement for the probe and saw cutting for the lead in.

The principal draw back of Micro-loops is they are only a point detection. Through the use of several probes in an array, they can closely simulate a long detector. Micro-loops typically cost more than loop detectors.

4.6.3 **Microwave (Radar)**

Microwave detectors consist of an emitter/sensor, mounted either above or adjacent to the pavement, which by measuring the Doppler shift in the microwave frequency used, and is able to detect the passage of a vehicle. Simple microwave units are designed to place a call if an approaching vehicle is sensed for one lane or the entire approach. More advanced microwave detectors are capable of defining multiple zones of detection with one unit and can measure speeds. Microwave detectors are also directional; they can distinguish if a vehicle is approaching or leaving the detector.

A big advantage of microwave detectors is that they do not need to be installed in the pavement. This can allow for greater flexibility in installation as well as avoiding the problems associated with being in the pavement. The major disadvantage of microwave detectors is that they typically cannot provide presence detection.

4.6.4 **Ultrasonic**

Ultrasonic detectors use ultrasonic ranging to detect the presence of a vehicle. Ultrasonic detectors are also mounted above or adjacent to the roadway. The primary advantage of ultrasonic detectors is that they do not need to be installed in the pavement. The primary disadvantage of ultrasonic detectors is a very narrow detection zone and a short range.
4.6.5 **Video Detection**

Video detection consists of a video camera mounted above or adjacent to the pavement and a unit that processes the video signal to generate vehicle calls and other information. The processing unit uses sophisticated software to "draw" zones of detection on the video output. Video detection units are capable of detecting both presence and passage, measuring speed and occupancy and classifying vehicles.

Video detection typically has a higher initial cost, but offers the advantages of being completely out-of-pavement and allowing considerable flexibility in detector placement and configuration. Video detection usually requires several cameras to be effective and requires a rigid mounting location for the cameras. Higher mounting locations will provide more effective detection.