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| 16. Abstract This report describes the research conducted within a two-year study that developed an effective advance warning for end-of-green phase at high-speed traffic signals in Texas. High-speed signals are defined as having approach speeds of 45 mph or more. The Advance Warning of End-of-Green System (AWEGS) was developed in this research by the Texas Transportation Institute for the Texas Department of Transportation (TxDOT). AWEGS was deployed at two locations, one on a two-lane highway in Waco, Texas, and another on a four-lane highway in Brenham, Texas. Deployments at these two locations showed a reduction in average red-light running per day of approximately 40-45 percent. This report describes the installation and maintenance procedures for operating AWEGS. The details of ensuring proper installation of loops and W3-4 signs are illustrated. The connectivity of the input/output (I/O) devices and the flasher panel functionality are described. Finally some guidance is given on the programming necessary in both the traffic signal controller as well as the AWEGS controller to operate AWEGS. The report also describes the maintenance procedures necessary for AWEGS to perform efficiently. AWEGS will only work properly if these maintenance procedures are followed. | | | | | |
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SIGNAL TECHNICIAN'S INSTALLATION AND MAINTENANCE MANUAL FOR ADVANCE WARNING OF END-OF-GREEN PHASE AT HIGH SPEED TRAFFIC SIGNALS

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OBJECTIVE

The objective of the Advance Warning of End-of-Green System (AWEGS) is to provide an advance warning (approximately five seconds) to motorists approaching an isolated signalized intersection at the end-of-green. AWEGS provides this warning by flashing some beacons on a W3-4 sign as seen in [Figure 1](#). This warning by the sign located upstream of the intersection will enhance the dilemma zone protection at the intersection and reduce red-light running.

This report presents the installation and maintenance guidelines to signal technicians to implement and operate the AWEGS. Detailed findings from this study have been documented in a TTI research report ([1](#)). TTI has also developed a design guidelines manual ([2](#)) which provides additional background for the installation of AWEGS.



Figure 1. A Typical W3-4 Sign.

ADVANCE WARNING OF END-OF-GREEN SYSTEM

Figure 2 illustrates the layout of the AWEGS at an isolated intersection. The figure illustrates the location of dilemma zone detectors as per Nader's design guidelines (3) and the Signal Ahead Signs (W3-3) that are present at a typical intersection. The figure also shows the location of the advance detectors and the W3-4 sign on the approaches. Figure 3 illustrates the functionality of AWEGS and shows the various components.

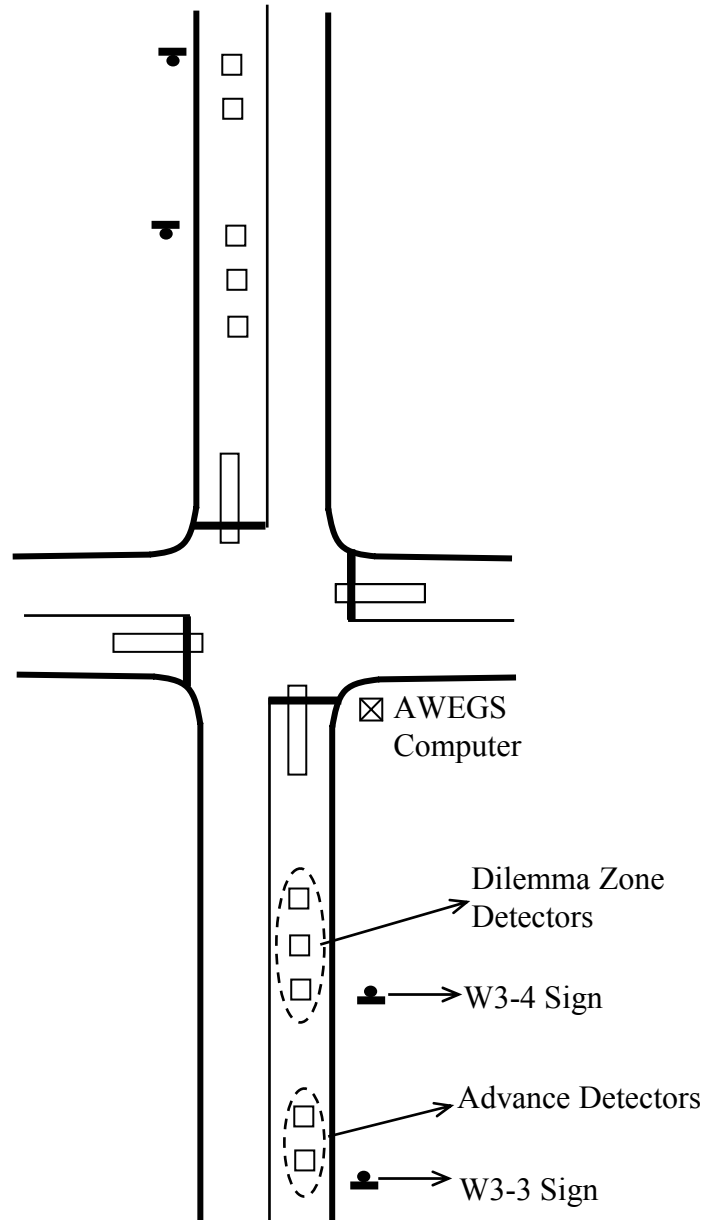


Figure 2. AWEGS Intersection Layout.

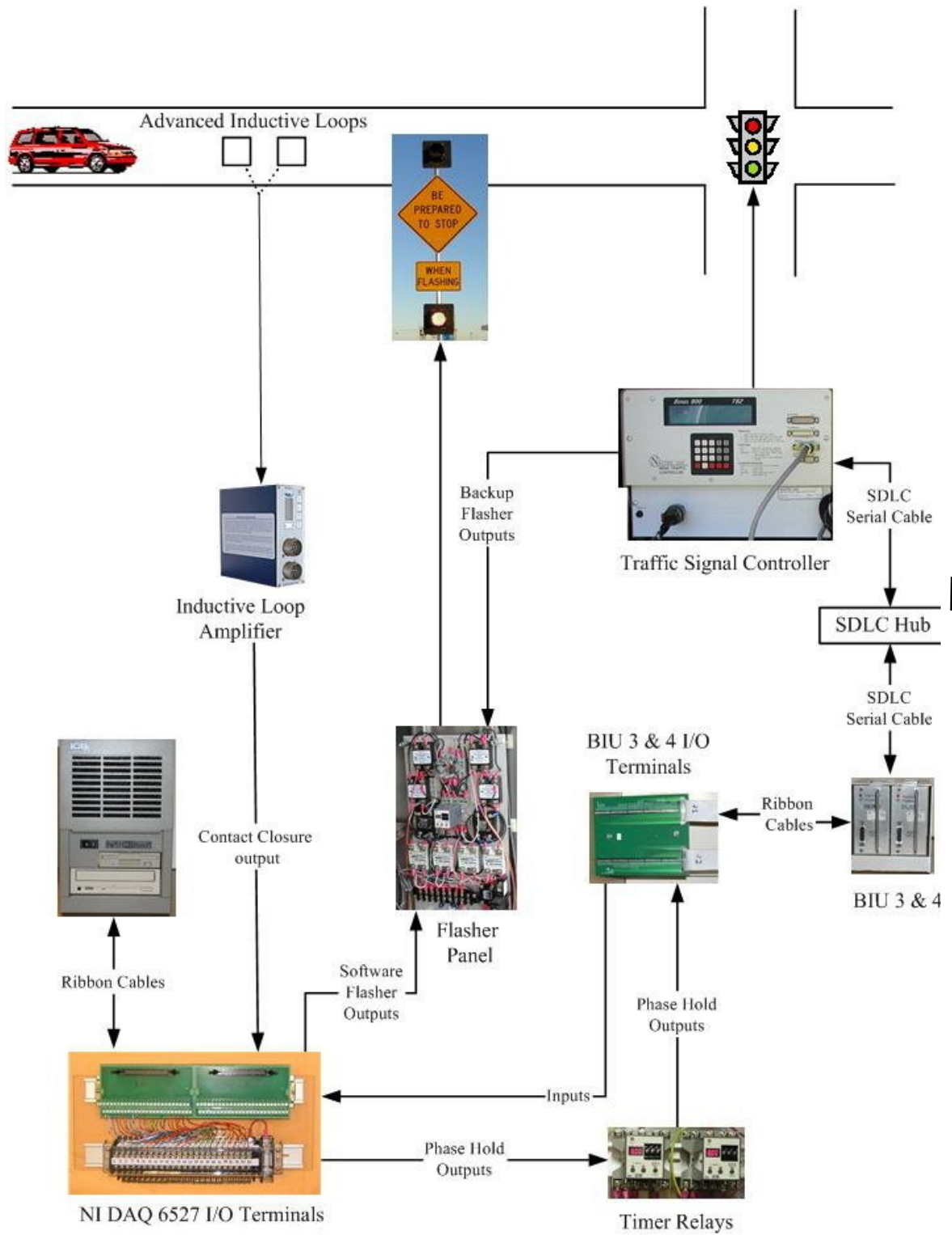


Figure 3. Functional Diagram of AWECS.

INSTALLATION GUIDELINES

This section details the installation of the advance loops, W3-4 signs, the interface of the industrial computer with the TS-2 cabinet, and the flasher panel. Guidelines are also provided to program the traffic signal controller and AWECS controller.

Advance Loops

Two advance inductive loops should be installed per lane for both the arterial approaches. [Figure 4](#) illustrates the configuration of the pair of loops in each lane where ADA and BDA are the names of the two loops.

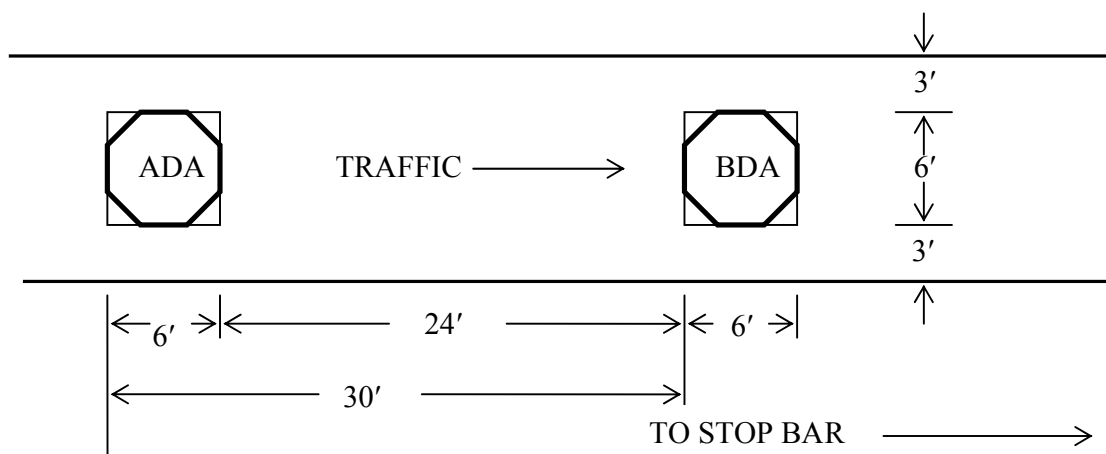


Figure 4. Advance Loop Configuration.

The approach speeds at each location will determine the location of ADA and BDA detectors from the downstream stopline. The initial location of the leading edge of the ADA detector can be adjusted ± 50 feet to avoid driveways and pavement problems, but the distance between the pair cannot be adjusted. It is essential that the clear spacing of 24 feet between the detectors (ADA and BDA) ALWAYS be maintained (see [Figure 4](#)). These advance detectors will measure the speeds of individual vehicles and also distinguish trucks from non-trucks. [Table 1](#) illustrates locations of the advance detectors for various approach speeds.

Table 1. Location of AWECS Advance Detectors for Level Grade.

| Design or Approach Speed, mph | AWECS ADA Detector, feet | AWECS BDA Detector, feet |
|-------------------------------|--------------------------|--------------------------|
| 45 | 595 | 565 |
| 50 | 683 | 653 |
| 55 | 776 | 746 |
| 60 | 875 | 845 |
| 65 | 979 | 949 |
| 70 | 1089 | 1059 |

Researchers recommend inductive-loop detectors for AWEGS applications as these detectors were found to be very accurate, reliable, and simple to implement. Both detectors should be 6-foot x 6-foot loops, with a minimum of four turns of #12 XHHW stranded copper wire per loop. Five or six turns may be needed on high-speed roads having very long home-runs to the cabinet. Since the cable home-run feed to the signal cabinet may be over 1000 feet, high-quality digital amplifiers should be used together with #12 detector shielded lead-in detector cable (e.g., a #12 AWG detector feeder cable → Belden 8718). Both detectors should operate in the presence mode of detection.

Some false detection may be observed in the detectors. This is because the detectors are very sensitive and detect traffic in the adjacent lanes (going in the opposite direction). It is recommended that loop installation is done properly, the actuations be carefully observed, and amplifiers be properly tuned to minimize these false calls.

AWEGS Signs

Passive W3-4 Advance Traffic Control signs as shown in [Figure 1](#) (See Section 2C.26 of the 2000 Manual on Uniform Traffic Control Devices [MUTCD],⁴) and the 2003 Texas MUTCD (⁵) supplemented by warning beacons were used by TTI researchers (¹) to provide the approaching motorists with the advance warning for end-of-green. TxDOT’s new Sign Crew Field Book (⁶) and the relevant sections in the national MUTCDs (⁴) and the 2003 Texas MUTCD (⁵) were consulted for official design requirements and guidance. If a site already has the beacons on W3-3 signs, it is recommended to turn them off upon implementation of AWEGS.

The location of the W3-4 sign is based on approach speeds and is usually located near the furthest dilemma zone detector. These locations are illustrated in [Table 2](#). Detailed design of the W3-4 signs is included in the AWEGS design report (²).

Table 2. Location of the W3-4 Signs.

| Design or Approach Speed, mph | W3-4 Sign, feet |
|-------------------------------|-----------------|
| 45 | 330 |
| 50 | 350 |
| 55 | 415 |
| 60 | 475 |
| 65 | 540 |
| 70 | 600 |

It is critical that the W3-4 signs and their beacons be aligned properly in the field. The target location shall be the centerline of the approaching roadway at the location of the ADA advance detector as illustrated in Figure 5. Field experience suggests that correctly targeting these beacons must be given *high priority*, and subsequent field inspection of their targeting during and after construction is imperative. Care should be taken to ensure proper alignment during installation at locations having an approach road curvature.

Light-emitting-diodes (LED) beacons tend to have a relatively narrow angle of view, and their apparent brightness will not be high or uniform unless they are always targeted at the same point on the approach roadway. This is especially true if two W3-4 signs are used per approach, one on each side of four-lane divided roadways as seen in Figure 5.

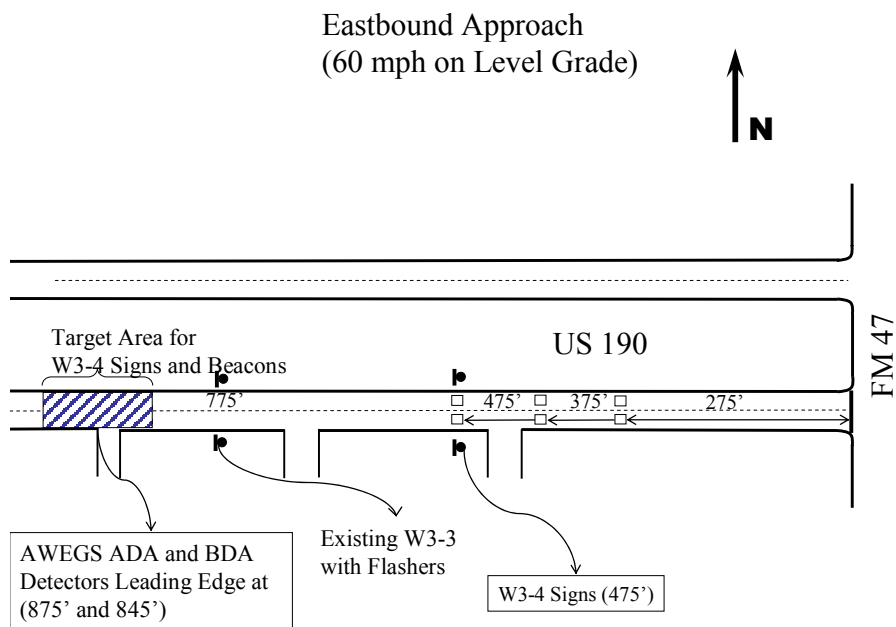


Figure 5. Location and Target of W3-4 Signs.

The electrical wiring of AWECS W3-4 signs is relatively simple. Power is only required to drive the low-power LED flashing beacons, which is provided from the signal cabinet by the AWECS computer/terminal switches. Thus, 120 volts AC electrical power and control of the sign beacons are combined using three-conductor #12 AWG signal cable. Since the sign is strategically located close to the existing dilemma zone detectors, electrical ground boxes and conduit should already be in place, which may expedite the cable run to the signal cabinet. Engineering judgment should be used to warrant any lightning arrestors for the W3-4 signs.

Since the cable home-run feed to the signal cabinet may be over 1000 feet, high-quality digital amplifiers should be used. Initial AWECS design by TTI used two-channel Model S series Reno detectors.

Hardened Computer

A field hardened industrial computer is currently used to run AWECS. The industrial computer used is manufactured by Kontron America and includes an Intel 850 MHz single-board computer, 40 gigabyte hard disk, and two National Instrument's digital I/O cards (Model # NIDAQ 6527) with 24 inputs and 24 outputs each. The NIDAQ cards are used to monitor the actuations of the advance speed-trap detectors. The NIDAQ cards are also used to monitor the status of the main street phases, stop-bar detectors, dilemma zone detectors, and the controller ring status bits (3 bits: A, B, and C per ring) through contact closure connections on the signal cabinet's backpanel. The large hard disk was necessary to store log files collected to evaluate and analyze the system performance during research development.

Input and Output Cards

The NIDAQ digital input/output card mentioned above consists of six ports. The ports are numbered 0, 1, 2, 3, 4, and 5. Ports 0, 1, and 2 are input ports, and ports 3, 4, and 5 are output ports. Each port consists of eight channels. The card provides a total of 24 input and 24 output channels. The 24 input channels are used to get the actuations of the advance detectors, intersection detectors, and phase status using the ring status bits (3 bits: A, B, and C per ring) from the cabinet's backpanel. Two output channels send a signal to hold the main street phases and flash the warning signal beacons. The [appendix](#) provides a listing of the digital I/O channels configuration by port for all the ports for a typical two-lane AWECS installation.

The interface circuit consists of a double-layer terminal strip with 24 individual terminals ([Figure 3](#)). A bus connecting all 24 bottom level terminals supplies all 24 16K ohm resistors with 24 volts DC. The supply to the bus is fused by a 0.2 amp fuse to protect the output of the traffic signal controller. The current flowing through each resistor is approximately 1mA (milli-amps) when the output from the traffic signal controller is active low on a particular output. Each input for the NIDAQ card requires 1mA for the NIDAQ card's optical isolator's LED to work reliably. The path the current flows is from the 24 volts DC supply through the fuse, then the resistor into the NIDAQ optical isolator and then out of the NIDAQ and into the output of the traffic signal controller. Current sinks into the output only when the output of the traffic signal controller is active low.

Flasher Panel

An AWECS requirement is that the flasher must always display a "full on" period within 0.2 seconds of the time the system detects a vehicle at the ADA detector. No off-the-shelf flasher could be found in the signal industry that could reliably provide this desired feature. Only expensive microprocessor-based programmable timers could be found. Thus, the AWECS computer is routinely used to "drive the flashers," i.e., the system uses a software flasher to get the desired initial "full on" flash. [Figure 6](#) shows a photograph of the fully functional flasher panel developed in this project. [Figure 7](#) illustrates the circuit diagram of the same flasher panel.

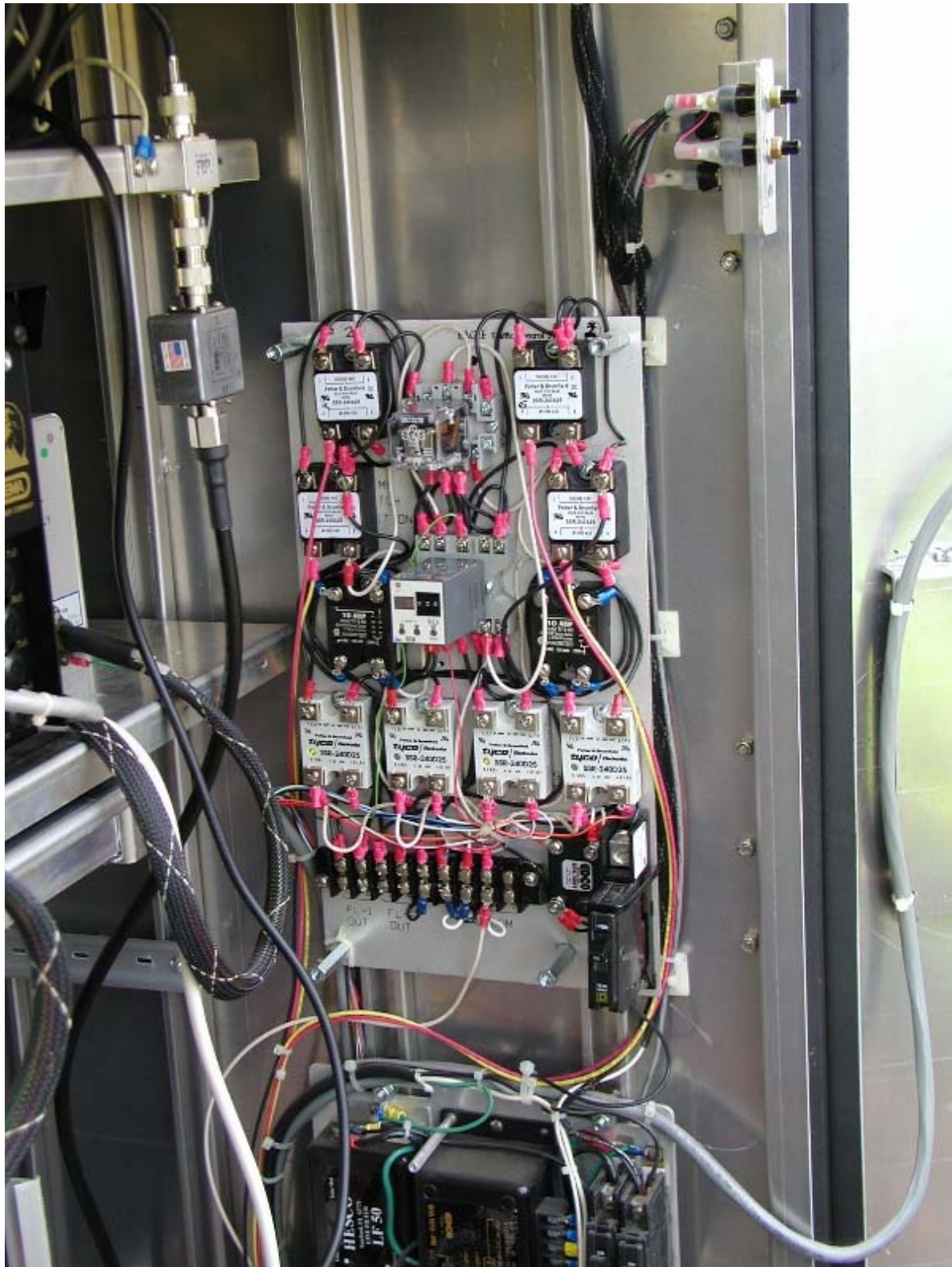


Figure 6. Fully Functional AWEGS Flasher Panel.

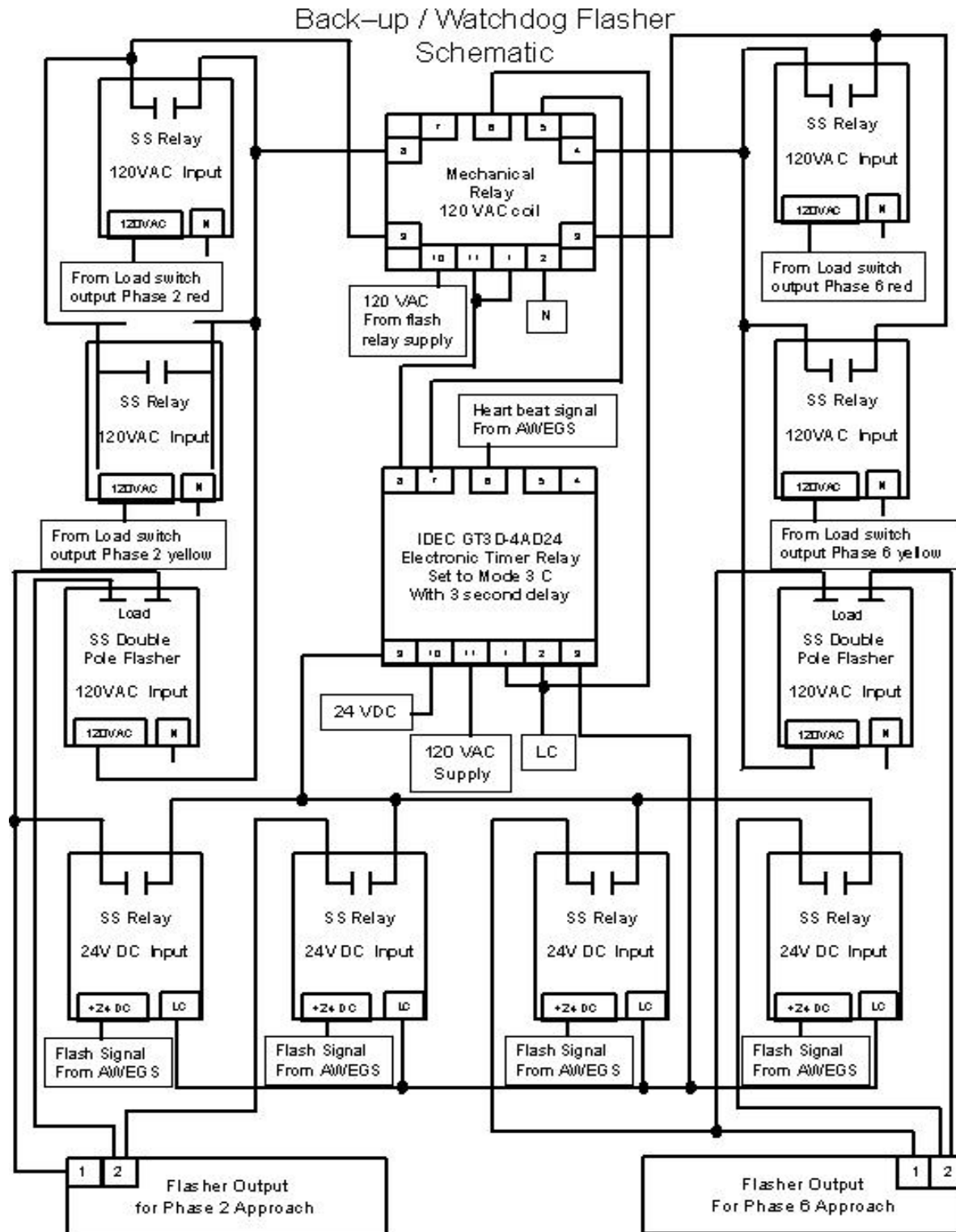


Figure 7. Flasher Panel Circuit Diagram.

Software Flasher System

The software flasher system uses four solid-state relays whose input signal is controlled by AWECS. When AWECS turns on one of the four outputs, 24 VDC is supplied to the optically isolated input of a solid-state relay, causing the output of that relay to supply 120 VAC to a particular beacon. By precisely switching the relays alternately on and off, AWECS creates a software flasher with a 50 percent duty cycle, 0.50 second on and 0.50 second off.

Local conditions may desire a flashing pattern from an alternate flashing top/bottom arrangement of beacons to a simultaneous flashing side-by-side beacon arrangement. This is accomplished by changing the wire connections on the flasher output to the beacons as seen in [Figure 7](#). For simultaneous operation, both beacons for a particular approach beacon are connected to flasher output 1. For alternating flashing operation, one beacon is connected to flasher output 1, and one beacon is connected to flasher output 2.

Backup/Watchdog Flasher System Logic

The flasher panel has been designed to include a watchdog functionality to monitor the heartbeat of AWECS and provide a backup function if necessary. When AWECS is operational, the system changes the state of output on the digital output interface every 2 seconds from high to low voltage. The (digital output) heartbeat is connected to the reset terminal of the timer relay that is set to countdown to 3 seconds. The heartbeat signal causes the timer relay to reset its countdown time back to zero whenever the state changes to low. Whenever the heartbeat is not present for 3 seconds, the timer disconnects the software flasher system and connects the backup flasher system.

During the backup flasher system, beacons on the approaches continue flashing independently during the yellow and red indications of phases for those approaches. The optically isolated inputs of the four 120 VAC input solid-state relays constantly monitor the status of the load switches for the yellow or red indications of those phases. When the backup system is activated, the timer relay's normally closed contact powers the 120 volts AC output supply voltage of the solid-state relays monitoring the load switches. When any one of the four solid-state relay's inputs is supplied 120 volts AC from a load switch, the relay supplies 120 volts AC to the appropriate solid-state double pole flasher that is connected to the flasher beacon associated with that particular phase. When the heartbeat is restored, the timer relay disconnects the backup flasher system power supply and connects the AWECS software flashers with 120 volts AC power supply and logic common connection.

The backup system will also flash the beacons when the cabinet is in cabinet flash, when the Malfunction Management Unit (MMU) detects a malfunction, or if the power to the flash transfer relay's input is not present for any reason. The mechanical relay's 120 volts AC input is supplied from the same source as flash transfer relay's input source. When 120 VAC input is not present on the relay's input due to a fault condition or loss of power, the normally closed contacts in the mechanical relay power both solid-state two-pole flashers. The backup flasher system's control logic was created by combining the inputs and outputs of four solid-state relays with one mechanical relay and one timer relay.

Timer Relay for Phase Holds

Two electronic timer relays (IDEC GT3D-4AD24) are used to monitor the phase hold signal from AWEGS in case of a malfunction in the system. The timer relay is set to mode 3C on the operation mode selector and 8 seconds of delay on the time setting digital switch. In this mode, the relay starts counting down when a phase hold signal is applied. The phase hold signal passes through closed contacts in the timer relay. If the phase hold signal continues longer than 8 seconds, the timer relay times down from 8 seconds to zero and opens the contacts, dropping the phase hold. If the phase hold signal does not last for more than 8 seconds, then nothing happens. The relay resets back to 8 seconds whenever AWEGS drops the phase hold signal. There are two timer relays that work independently for each phase hold. Figure 8 illustrates the layout of the timer relay for phase holds.

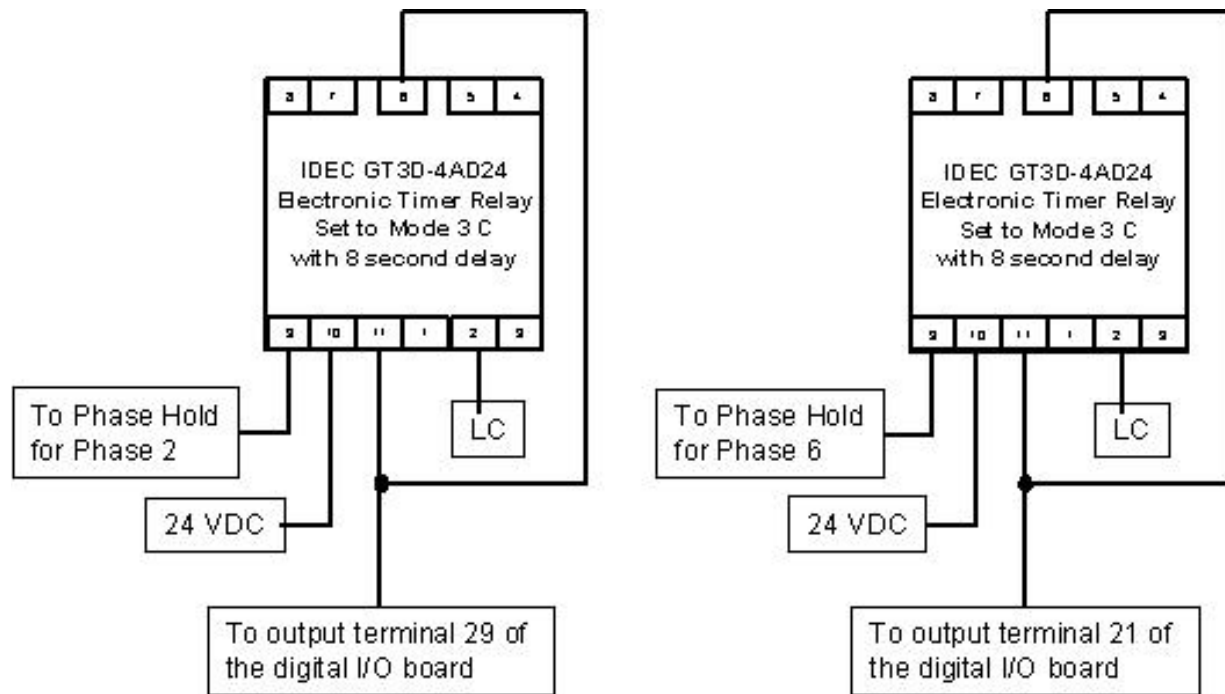


Figure 8. Timer Relay for Phase Hold.

Traffic Signal Controller Programming

AWEGS algorithm requires some signal controller parameters to predict the operation of the traffic signal controller. These include main street phase numbers, phasing sequence (ring structure), phase minimums, phase maximums, and passage times. AWEGS functions under the assumption that Nader's guidelines (3) are used in the placement of the dilemma zone detectors. Nader's guidelines also recommend the passage times to be used. TTI researchers have recommended some modifications in the passage times. These modifications are based on the probability of premature gap-outs for passage gaps by detector design. Figure 9 illustrates the probability of premature gap-outs for passage gaps by detector design for no speed change, i.e.,

when the observed approach speed is the same as the design speed adopted for the original detector layout.

It is illustrated in Figure 9 for approach speeds of 45 mph and 50 mph that a passage gap of about 2.8 seconds is needed and for higher speeds that a passage gap of about 1.6 seconds is necessary to avoid premature gap outs. However when approach speeds differ from design speeds, these probabilities change. This implies that attention should be given to the actual approach speeds and engineering judgment applied in the selection of passage gaps. However, a large passage time should not be used. A large passage time will prevent the phase from gapping out resulting in frequent max outs, which is not desirable.

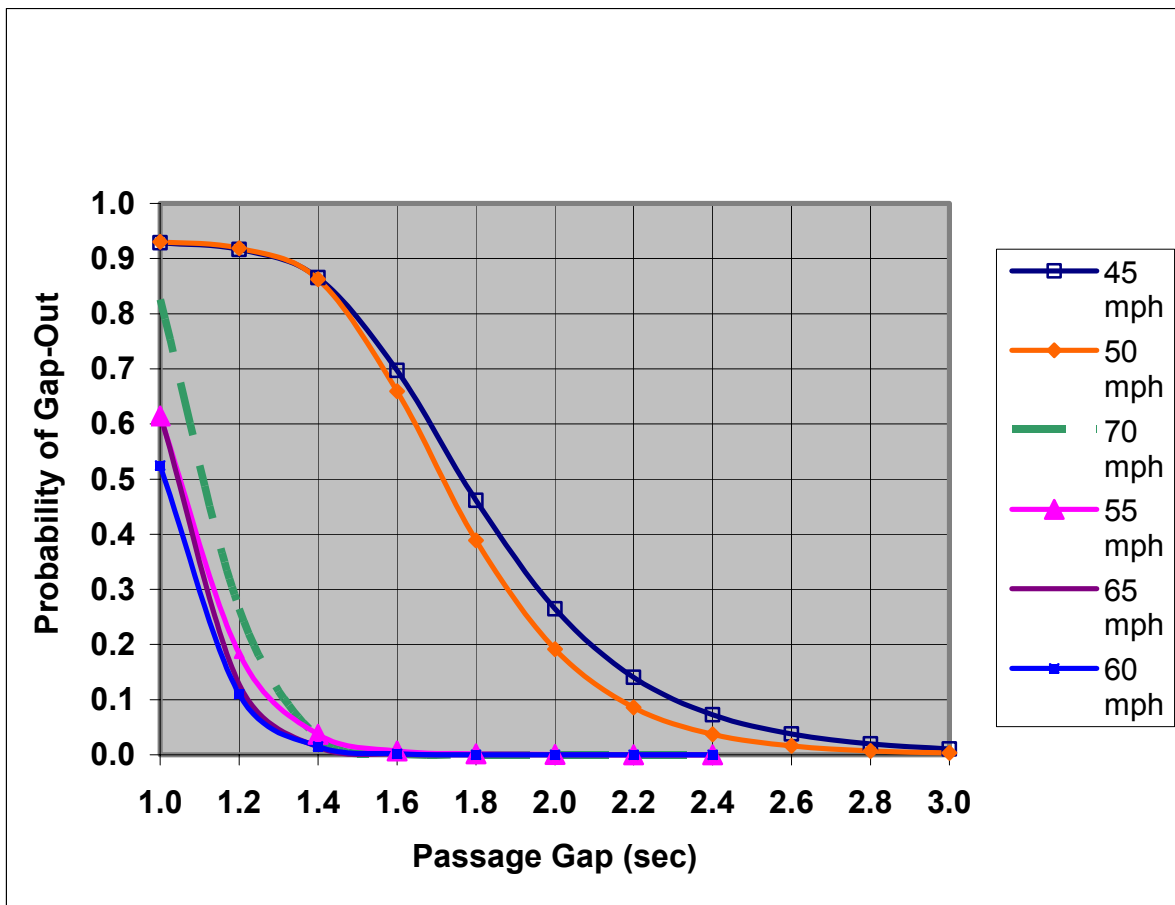


Figure 9. Probability of Premature Gap-out for Passage Gaps for No Speed Error.

Table 3 illustrates the location of the detectors and the passage times recommended by Nader’s guidelines (3) as well as TTI recommended passage times.

Table 3. Nader’s Guide on Detector Installation with TTI’s Recommended Passage Times.

| Approach Speed, mph | Distance from Head of Detector to Stopline at Intersection, feet | | | Stopline Area Detector ^a feet | Passage Gap ^a , sec | TTI Rec. Passage Gap ^b , sec |
|---------------------|--|-------|-------|--|--------------------------------|---|
| | CDA 1 | CDA 2 | CDA 3 | | | |
| 45 | 330 | 210 | --- | 6 x 40 | 2.0 | 2.8 |
| 50 | 350 | 220 | --- | 6 x 40 | 2.0 | 2.8 |
| 55 | 415 | 320 | 225 | 6 x 40 | 1.2 | 1.6 |
| 60 | 475 | 375 | 275 | 6 x 40 | 1.4 | 1.5 |
| 65 | 540 | 430 | 320 | 6 x 40 | 1.2 | 1.6 |
| 70 | 600 | 475 | 350 | 6 x 40 | 1.2 | 1.7 |

a – Nader’s guide

b – Minimum recommended gap

Figure 9 illustrates the need for the proper selection of passage times. It is crucial that appropriate passage times be used, as it will have an impact on AWECS operations. AWECS works on the assumption that Nader’s detector guidelines are followed for installation of detectors, and appropriate passage times are used to ensure safe and efficient intersection operations.

It is also crucial that the engineers and technicians verify the location of the dilemma zone detectors and ensure that the correct controller settings are coded in AWECS. To predict the controller operations, users will have to make the following minor changes to the detector delay.

Detector Delay

It is necessary to program a delay of 1-3 seconds on the arterial left-turn phases and all side-street phases in the controller. This delay, which is only effective during red, is necessary for two reasons. A delay of 1 second placed in the controller will provide vehicle presence data to the AWECS algorithm before the signal controller detects it. Hence, AWECS has an opportunity to respond to the call on the side street or arterial left turn by flashing the beacons if necessary.

Secondly, AWECS may sometimes start flashing the beacons because of false actuations. These false actuations occur when arterial left-turn vehicles actuate the side-street detector or when left-turn vehicles from the side street actuate the arterial left-turn detector. Placing a delay on these detectors minimizes the occurrences of the traffic signal controller and AWECS responding unnecessarily to these false calls.

Table 4 illustrates the detector delays recommended in the signal controller to use AWECS on phase 2 and phase 6 at an example intersection. Delays recommended in the table should be programmed *in the traffic signal controller*. However, as mentioned in the section on input/output cards, and elaborated on in the appendix, AWECS is monitoring the detector status.

The algorithm is monitoring the detector status on the detector panel. Thus, AWECS detects the presence of the vehicle as soon as the vehicle actuates the detector. However, by introducing the delay in the controller, the controller does not detect these vehicles until the delay has expired. This time lag permits AWECS to function appropriately by flashing the beacons if necessary. This time lag also prevents the controller from reacting to unnecessary actuations like permitted arterial left turns that turn on a green ball, false actuations, and right turns on red. Reduction in the controller reacting to these unnecessary actuations improves intersection operations as well as AWECS performance.

Table 4. Recommended Detector Delays for a Typical Intersection.

| Phase Number | Movement Type | Condition | Delay, seconds | Purpose |
|--------------|---------------------------|---|----------------|--|
| 1 and 5 | Arterial left – protected | If no false actuations from side-street lefts | 1 | To have advance warning before controller |
| | | If side street lefts actuate arterial left-turn detectors | 3 – 4 | To filter false calls and have advance warning before controller |
| | Arterial left - prot/perm | None | 3 – 4 | To filter permitted arterial left-turn traffic |
| 3 and 7 | Side street left | If no false actuations from arterial lefts | 1 | To have advance warning before controller |
| | | If arterial lefts actuate side-street left-turn detectors | 3 – 4 | To filter false calls |
| 4 and 8 | Side street through | If side street right-turn traffic actuates the detectors | 7 – 8 | To filter right-turn-on-red vehicles |

AWECS Programming

AWECS algorithm requires some input parameters for the system to start functioning. These parameters include signal controller data, intersection detector location data, advance detector location data, and the location of AWECS signs from the stop bar. The signal controller data includes phase numbers, phasing sequence (ring structure), phase minimums, phase maximums, and passage times. Size of the detectors is also necessary as an input parameter for AWECS. [Figure 10](#) illustrates the AWECS Intersection Status Screen that shows or displays the intersection, ring, and detector gap status. The [appendix](#) details the instructions about programming AWECS.

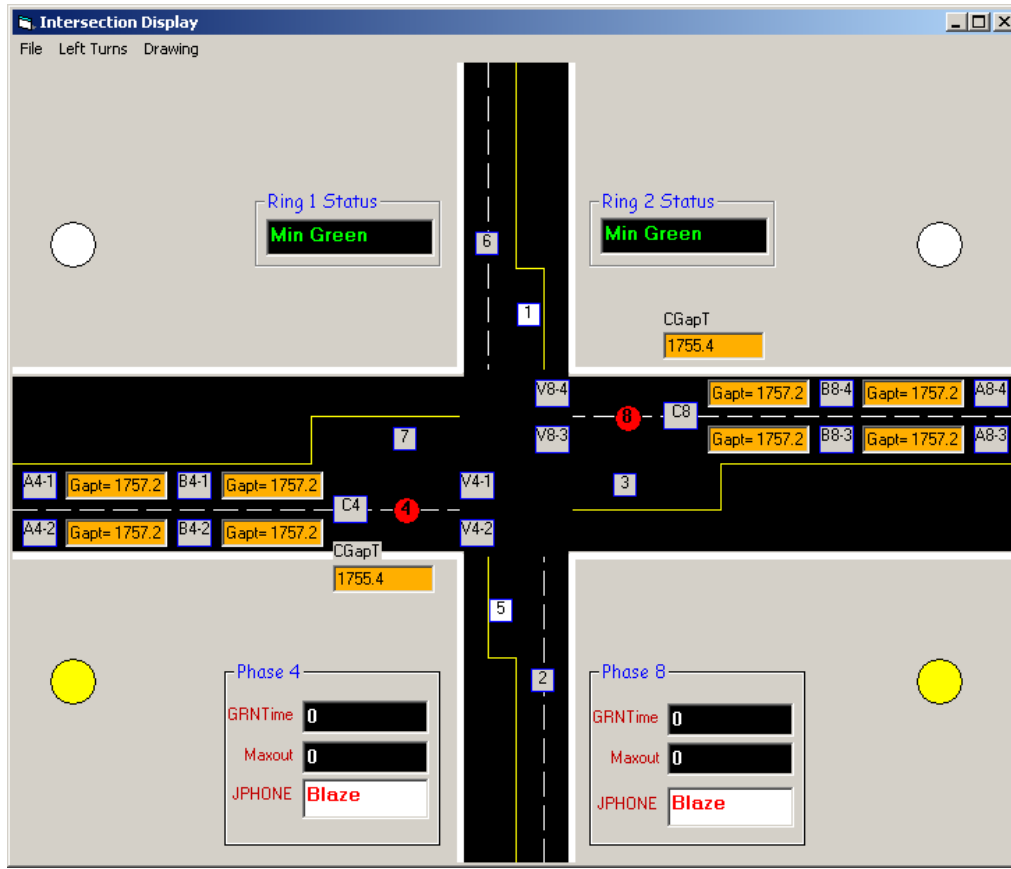


Figure 10. AWEGS Intersection Status Screen.

MAINTENANCE GUIDELINES

Maintenance of various components needs to be given careful attention to properly operate AWEGS. These components are listed below.

Beacons and Signs

The alignment of W3-4 signs and LED beacons should be maintained as specified. They should always target the road at driver eye height near the advance detectors. Signs and beacons can rotate due to high winds and lose the orientation if they are not tightened properly. The beacons should also be verified to ensure that the LED beacons continue to provide the necessary illumination and provide acceptable flashing operation.

W3-4 sign assemblies (signs and beacons) should also be frequently checked for damage due to vandalism. These W3-4 sign assemblies have an important function by providing motorists with critical information about signal indication changes. Hence, efforts should be made to ensure continuous functionality of these assemblies.

Traffic Signal Controller

It is essential that AWECS uses the data residing in the traffic signal controller. Any change made in the signal controller settings also needs to be made in the AWECS database. Failure to do so could result in AWECS not performing properly. The signal controller data to be verified includes phasing sequence (ring structure and/or alternate sequence), phase minimums, phase maximums, passage times, yellow times, all-red times, and phase detector delays.

Detectors

Properly functioning detectors are critical for AWECS functionality. These include the intersection detectors (including dilemma zone detectors) as well as the advance detectors. Regular inspection for the functionality of these detectors is essential. Detector amplifiers should also be checked for their settings and confirmed in the AWECS database.

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6. *Sign Crew Field Book*. 2nd Edition. Traffic Operations Division. Texas Department of Transportation, April 1998.

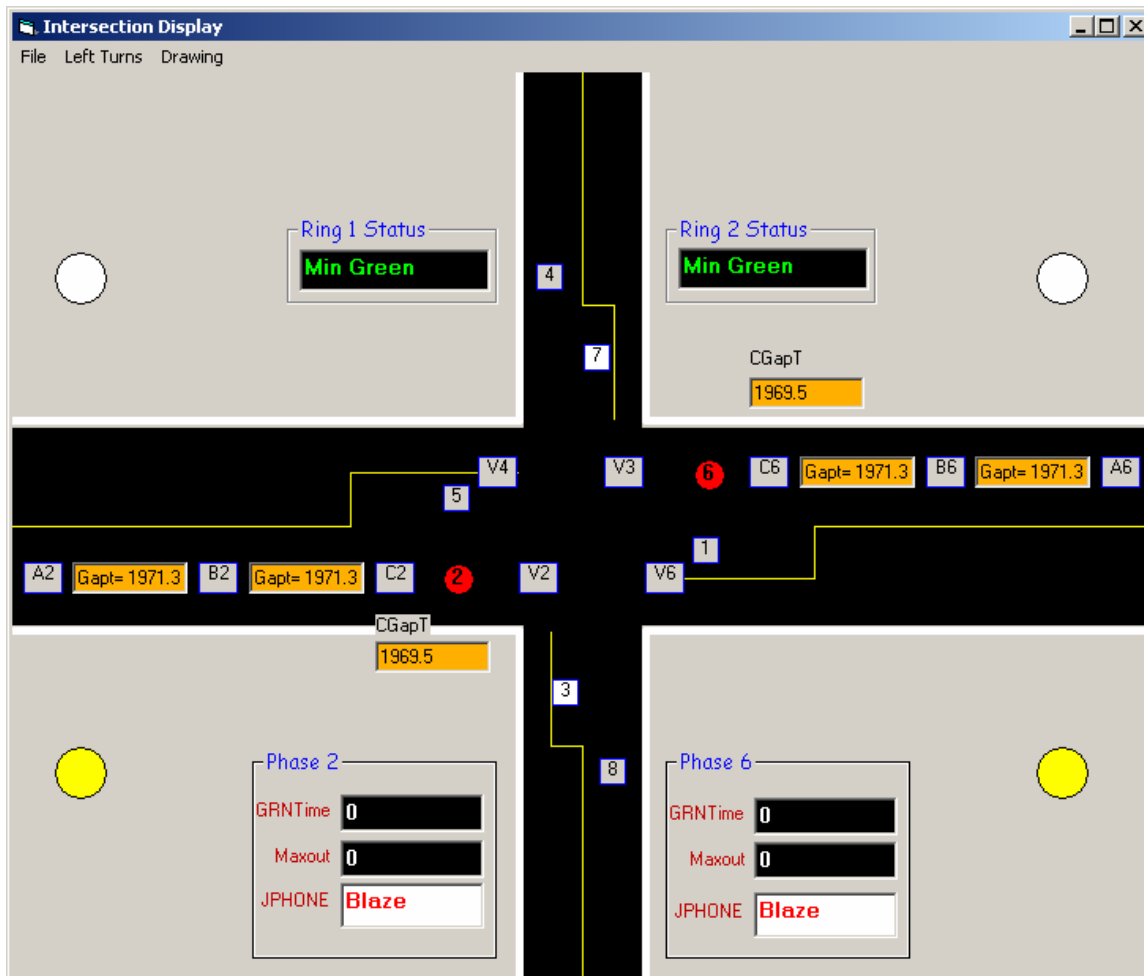
**APPENDIX PRODUCT 4 - TRAFFIC SIGNAL OPERATIONS (PHASING
AND OPERATION)**

AWEGS Graphical User Interface

The AWEGS Graphical User Interface (GUI) consists of a number of screens that enable the user to configure, control, and monitor AWEGS. The following sections provide descriptions of each of the AWEGS GUI screens.

Intersection Display Screen

The intersection display screen provides the user with real-time information about the status of the intersection like main street phases status (green, yellow, red), stop-bar detector status, dilemma zone detector status, advance detector trap status, ring status, warning sign beacon heads status, and the current decision made by AWEGS whether to start flashing the advanced warning signs or not. By observing the intersection display, the user can determine if AWEGS is performing properly or not.



Phase Settings Screen

AWEGS is installed at intersections using standard NEMA TS-1 and TS-2 controllers. The phase settings screen enables the user to customize AWEGS phase settings to match the settings in the controller at the installation site. These settings include the minimum green (MinGrn), maximum-green-1 (Max#1), and passage gap (Passage) for main street phases as they are entered in the controller. Other settings include whether a phase is a main street phase, minor street phase, arterial left phase, and whether the arterial left phases are lagging or leading. Some of the other settings, like the Beta, TAU, XPRange, and Hold interval of a phase will be calculated by AWEGS based on other inputs instead of being entered by the user in future system updates.

Phase Configuration

Phase Settings

| Phase | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----------------|--------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| MIN GRN | 0 | 7 | 7 | 30 | 0 | 7 | 7 | 30 |
| MAX #1 | 0 | 20 | 35 | 50 | 0 | 20 | 35 | 50 |
| PASS | 0 | 3 | 3 | 2 | 0 | 3 | 3 | 2 |
| TAU | 0 | 0 | 0 | 4.93 | 0 | 0 | 0 | 5.72 |
| Hold Interval | 0 | 0 | 0 | 2.8560 | 0 | 0 | 0 | 4.83 |
| Beta | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0.05 |
| XPRange | 0 | 0 | 0 | 0.1768 | 0 | 0 | 0 | 0.1768 |
| SS Det Delay | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C3 to SL Dist | 0 | 0 | 0 | 356 | 0 | 0 | 0 | 356 |
| Direction | | | | EB | | | | WB |
| Phase Chckck | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| Phase On | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| Main Phase | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| Minor Phase | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Art Left Phase | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| Lagging Left | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |

Exit Update Phase Settings

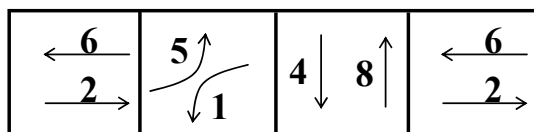
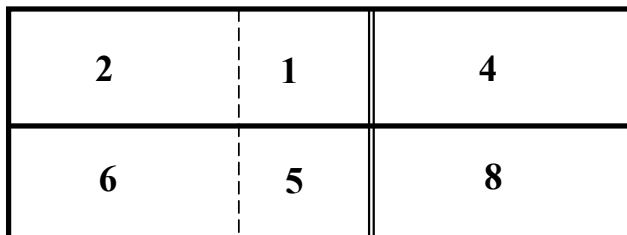
Ring Structure Screen

The ring structure screen allows the user to specify the ring that a phase belongs to and other phases that are concurrent with a phase. The ring information is used to determine the status of the main street phase. The concurrent phase data are used to determine the conflicting arterial left and side street calls for a certain main street phase. The ring structure window below illustrates the phasing sequence operating in Waco, Texas, which is also illustrated below.

The screenshot shows a software window titled "Ring Structure". Inside, there is a section labeled "Concurrent Phases" with a grid of 8 rows and 8 columns. Each cell in the grid contains a checkbox and a dropdown menu. To the right of the grid is a "Ring Number" section with four radio buttons labeled 1, 2, 3, and 4. Below the grid is a checkbox for "Simultaneous Gap-Out" and two buttons: "Exit" and "Update Ring Structure".

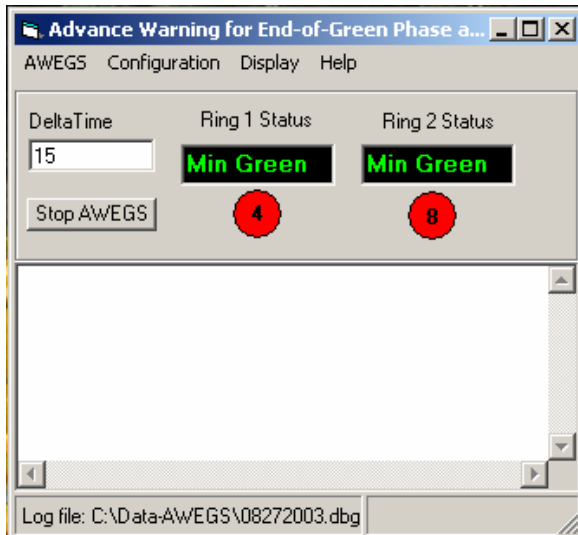
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | NXT PHS | Ring Number |
|---|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|---------|--|
| 1 | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | NA | <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input checked="" type="radio"/> 4 |
| 2 | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 3 | <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input checked="" type="radio"/> 4 |
| 3 | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | 4 | <input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 |
| 4 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | 1 | <input checked="" type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 |
| 5 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 6 | <input type="radio"/> 1 <input type="radio"/> 2 <input checked="" type="radio"/> 3 <input type="radio"/> 4 |
| 6 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 7 | <input type="radio"/> 1 <input type="radio"/> 2 <input checked="" type="radio"/> 3 <input type="radio"/> 4 |
| 7 | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | 8 | <input type="radio"/> 1 <input checked="" type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 |
| 8 | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | 5 | <input type="radio"/> 1 <input checked="" type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 |

Waco Phasing Sequence



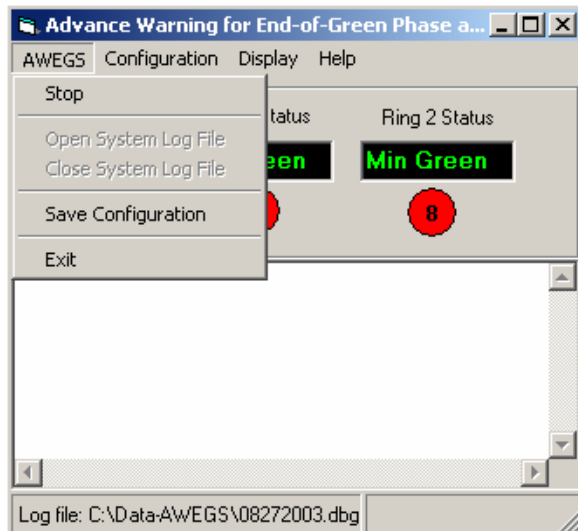
AWEGS Main Screen

The AWEGS main screen provides the user with the ability to start and stop AWEGS. The AWEGS main screen also allows the user to configure AWEGS and monitor its operations through a series of menus accessible from the main screen. The main screen window is also used by AWEGS to display error messages to alert the user to any problems with AWEGS operation and display the real-time status of the main-street phases (green/yellow/red).



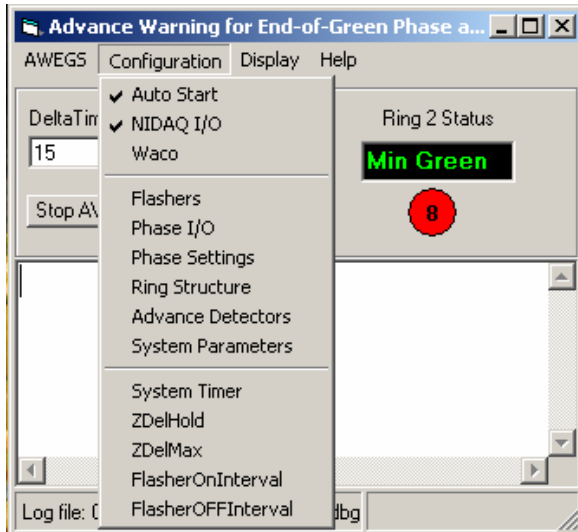
AWEGS Main Menu

The AWEGS main menu screen allows the user to start/stop AWEGS, update the AWEGS configuration file by saving the current configuration into a file, or exit AWEGS.



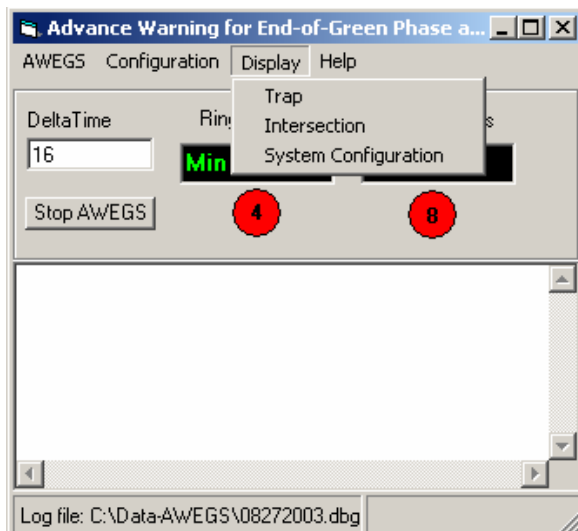
AWEGS Configuration Menu

The AWEGS configuration menu provides the user with access to the flashers, phase I/O mapping, phase settings, ring structure, advance detectors, system parameters, system timer, flasher on interval, flasher off interval, and other screens that enable the user to customize AWEGS configuration to a specific installation site.



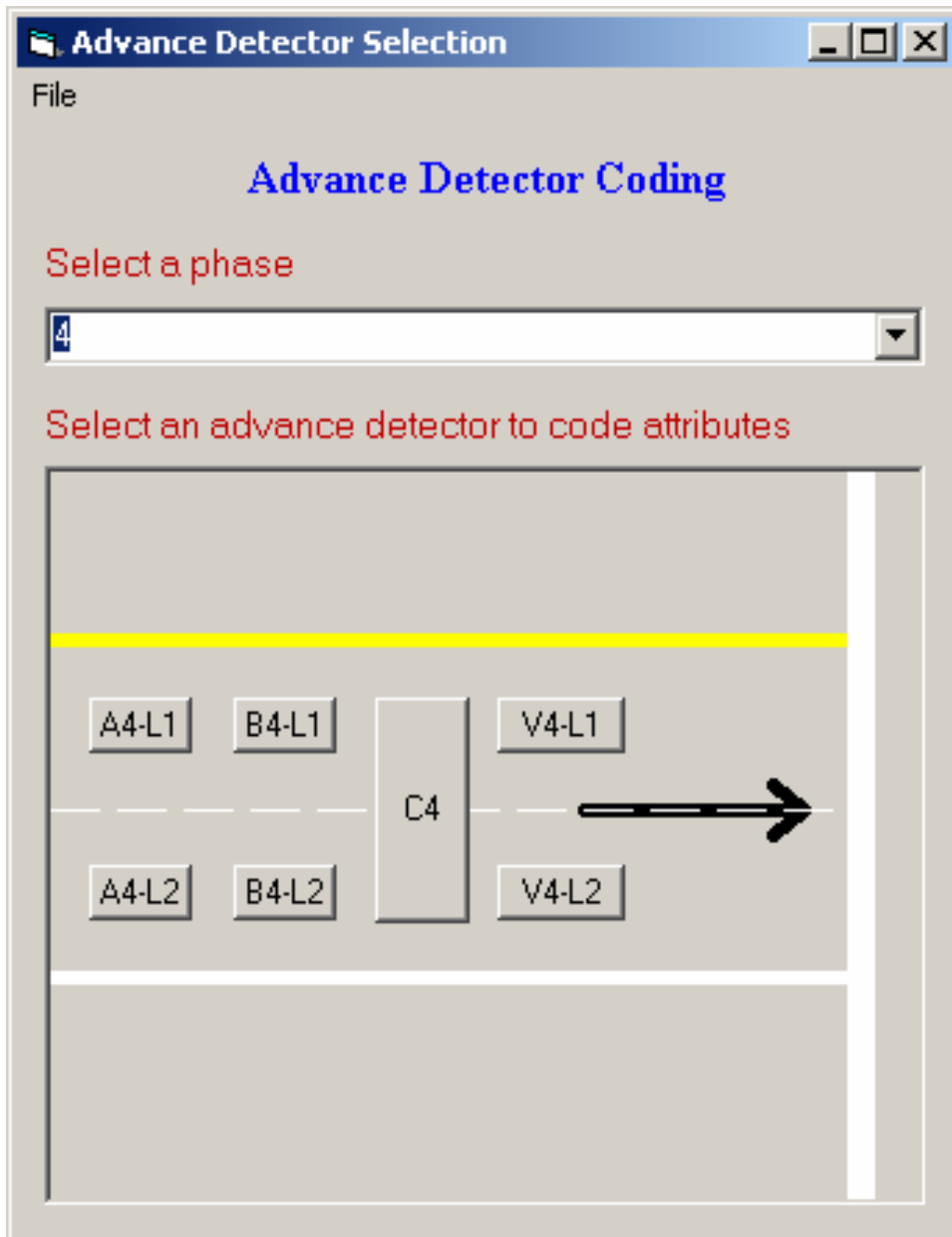
The AWEGS Display Menu

The AWEGS display menu provides the user with access to the intersection display and the trap display screens that enable the user to monitor AWEGS operation.



Advance Detector Screen

The advance detector screen allows the user to configure the advance detectors A, B, and C settings. The ADA and BDA advance detectors are the trap detectors used by AWEGS to detect vehicles upstream of the intersection, classify the vehicles (car/truck), and calculate the time needed by the vehicle to clear the intersection. The advance CDA1 detector represents the furthest detector from the intersection of the existing dilemma zone detectors installed at the intersection. The V_i detectors shown below should be ignored.



Advance Detector ADA Screen

The AWECS advance detector ADA screen allows the user to enter the distance from the leading edge of the detector to the stop bar, the length and width of the detector in feet, the gamma value, gap value in seconds, and the port and channel on the digital I/O card where the ADA detector lead-in is connected.

The screenshot shows a software window titled "Advanced Detector Configuration" with a close button (X) in the top right corner. The window content is titled "Settings for Phase 4, Lane 1, AD A detector". It contains several input fields and radio button groups:

- Length (ft):** Input field containing the value "6".
- Width (ft):** Input field containing the value "6".
- Gamma:** Input field containing the value "0.63".
- Gap (secs):** Input field containing the value "5.19".
- Distance to Stop Bar (ft):** Input field containing the value "1035".
- Distance to C Detector (ft):** Input field containing the value "429".
- I/O Device:** Input field containing the value "1".
- I/O Port:** A group of radio buttons labeled 0 through 5. The radio button for "2" is selected.
- I/O Channel:** A group of radio buttons labeled 0 through 7. The radio button for "0" is selected.

At the bottom of the window, there are two buttons: "Exit" on the left and "Update AD" on the right.

Advance Detector BDA Screen

The AWECS advance detector BDA screen enables the user to set advance detector BDA settings. The advance detector B is the trailing detector of the advance detector trap. In addition to the settings required by the advance detector ADA, the advance detector BDA requires the 85th percentile speed and 50th percentile speed values as collected from a spot-speed study.

The screenshot shows a software window titled "Advanced Detector Configuration" with a close button (X) in the top right corner. The window content is titled "Settings for phase 4, Lane 1, AD B detector" in blue text. Below the title are several input fields and radio button groups. The fields are arranged in a grid-like fashion. At the bottom, there are two buttons: "Exit" and "Update AD".

| Parameter | Value |
|-----------------------------|--------------|
| Length (ft) | 6 |
| Width (ft) | 6 |
| Gamma | 0.63 |
| Gap (secs) | 5.187412 |
| Distance to Stop Bar (ft) | 1010 |
| Distance to C Detector (ft) | 404 |
| Average Speed | 55.9 |
| I/O Device | 1 |
| 85% Speed | 62.7 |
| I/O Port | 2 (selected) |
| I/O Channel | 1 (selected) |

Advance Detector CDA Screen

The advance detector C screen allows the user to enter the settings for the furthest existing dilemma zone detector from the intersection. The information is used by the system to calculate the travel time of vehicles from the advance detector B to the first dilemma zone detector on the main street approaches.

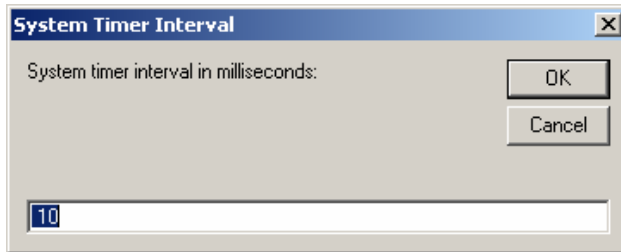
The screenshot shows a software window titled "Advanced Detector Configuration" with a close button (X) in the top right corner. The window contains the following settings for "Settings for phase 4, AD C detector":

- Length (ft):** 6
- Width (ft):** 6
- Gamma:** 5
- Gap (secs):** 2
- Distance to Stop Bar (ft):** 606
- I/O Device:** 1
- I/O Port:** Radio buttons for 0, 1, 2, 3, 4, 5. Option 1 is selected.
- I/O Channel:** Radio buttons for 0, 1, 2, 3, 4, 5, 6, 7. Option 6 is selected.

At the bottom of the window, there are two buttons: "Exit" and "Update AD".

System Timer Interval

The system timer interval enables the user to set the frequency in milliseconds that the system will sample the advance detector status, phase status, stop-bar detector status, and then make a decision based on the acquired data as to whether to flash the warning signs beacons to provide advanced warning to motorists or not. The lowest available setting is 10 milliseconds. TTI researchers recommend a setting between 10-20 milliseconds. Higher system timer values than these will result in longer sampling periods, and consequently, the system may not operate properly.



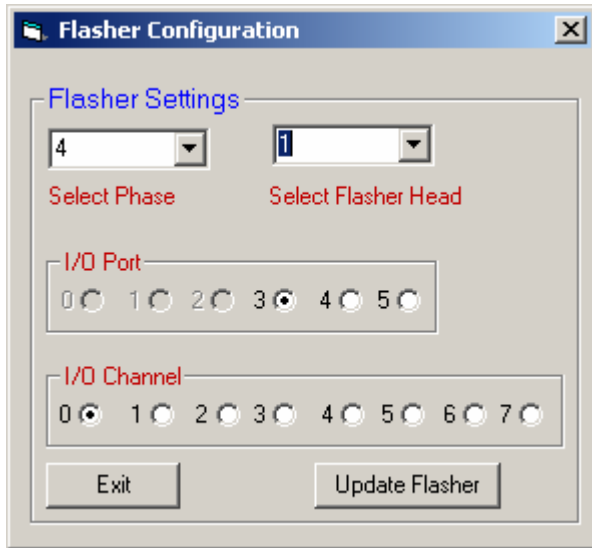
Flasher On Interval and Flasher Off Interval Screens

The flasher on/off interval screens enable the user to set the on/off intervals for the warning sign beacon heads when the beacons are flashing. AWECS controls the process of turning on/off the warning sign beacon heads. In the case of the two beacon heads per warning sign where the beacons flash alternating, the first beacon will be turned on and will stay on for the duration of the specified Flasher On Interval, followed by an off interval equal to the Flasher Off Interval where both beacons are dark (i.e., off). Then the second beacon head would be turned on and stays on for an interval equal to the Flasher On Interval, followed again by an off interval equal to the Flasher Off Interval when both warning sign beacons would be dark again. This sequence constitutes one cycle, and the cycle is repeated for the duration of the advanced warning period determined by AWECS. A 0.50 second (500 ms) on period followed by a 0.50 second (500 ms) off period are recommended.



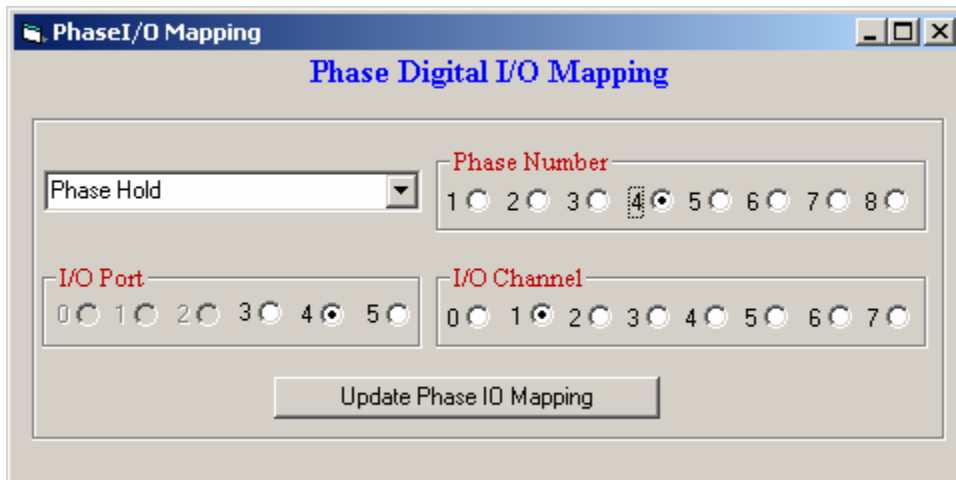
Flasher I/O Setting Screen

AWEGS provides advance warning of end-of-green to motorists by sending a signal to the warning sign beacons to start/stop flashing. The flasher configuration screen enables the user to map the digital I/O card output channels to the proper warning sign flashing beacon heads.



Phase I/O Screen

Among the inputs required by AWEGS are the main street phase status (green/yellow/red) and stop-bar detector status (on/off). The phase I/O screen enables the user to map the main street phase on and stop-bar detector connections on the cabinet's backpanel to the corresponding ports and channels on the digital I/O card, installed in the PC, and used by AWEGS to acquire the phase status and stop-bar detector status. The phase I/O screen is also used to map the digital I/O channels used by AWEGS to send a signal to hold main street phases to the proper phase-hold contact-closure connections on the cabinet's backpanel.



Digital I/O Details (Waco Site)

The NIDAQ digital input/output card consists of six ports. The ports are numbered 0, 1, 2, 3, 4, and 5. Ports 0, 1, and 2 are input ports, and ports 3, 4, and 5 are output ports. Each port consists of eight channels. The card provides a total of 24 input and 24 output channels. The 24 input channels are used to get the phase status and advanced loops and stop-bar detectors status from the cabinet's backpanel and detector panel, respectively. Two output channels are used to send a signal to hold the main street phases and flash the warning signal beacons. The following tables provide a listing of the digital I/O channels configuration by port.

Input Port 0

| | |
|-------------|----------------|
| Channel 0 - | Ring 1 – Bit A |
| Channel 1 - | Ring 1 – Bit B |
| Channel 2 - | Ring 1 – Bit C |
| Channel 3 - | Ring 2 – Bit A |
| Channel 4 - | Ring 2 – Bit B |
| Channel 5 - | Ring 2 – Bit C |
| Channel 6 - | Phase On – 2 |
| Channel 7 - | Phase On – 6 |

Input Port 1

| | |
|-------------|--------------------------------|
| Channel 0 - | Phase 1 Detectors |
| Channel 1 - | Phase 2 Dilemma Zone Detectors |
| Channel 2 - | Phase 3 Detectors |
| Channel 3 - | Phase 4 Detectors |
| Channel 4 - | Phase 5 Detectors |
| Channel 5 - | Phase 6 Dilemma Zone Detectors |
| Channel 6 - | Phase 7 Detectors |
| Channel 7 - | Phase 8 Detectors |

Input Port 2

| | |
|-------------|-------------------------|
| Channel 0 - | Advance Detectors A – 1 |
| Channel 1 - | Advance Detectors A – 2 |
| Channel 2 - | Advance Detectors B – 1 |
| Channel 3 - | Advance Detectors B – 2 |
| Channel 4 - | |
| Channel 5 - | |
| Channel 6 - | |
| Channel 7 - | |

Output Port 3

| | |
|-------------|----------------------------|
| Channel 0 - | Phase 2 Flasher – Beacon 1 |
| Channel 1 - | Phase 2 Flasher – Beacon 2 |
| Channel 2 - | Phase 6 Flasher – Beacon 1 |
| Channel 3 - | Phase 6 Flasher – Beacon 2 |
| Channel 4 - | |
| Channel 5 - | |
| Channel 6 - | |
| Channel 7 - | |

Output Port 4

| | |
|-------------|--------------|
| Channel 0 - | |
| Channel 1 - | Phase 2 Hold |
| Channel 2 - | |
| Channel 3 - | |
| Channel 4 - | |
| Channel 5 - | Phase 6 Hold |
| Channel 6 - | |
| Channel 7 - | |

Output Port 5

| | |
|-------------|------------------|
| Channel 0 - | System Heartbeat |
| Channel 1 - | |
| Channel 2 - | |
| Channel 3 - | |
| Channel 4 - | |
| Channel 5 - | |
| Channel 6 - | |
| Channel 7 - | |

