

**TEXAS DEPARTMENT OF TRANSPORTATION
DEPARTMENTAL SPECIFICATION
TO-4048
FULL-ACTUATED SOLID STATE CONTROLLER UNIT (TS-2)
WITH DIAMOND, TBC, PREEMPT, AND CLOSED LOOP OPERATION; AND
BASE-MOUNTED TS-2 CABINET ASSEMBLY**

1.0 SCOPE

- 1.1 This specification sets forth the minimum requirements for a shelf-mounted 16 phase full-actuated solid state controller unit with internal Time-Based Coordination (TBC), railroad/fire (emergency vehicle) preemption, diamond intersection operation, and closed loop secondary operation in a traffic signal controller assembly and cabinet assembly.
- 1.2 Appendix A identifies the equipment type and options available in this specification. Equipment supplied shall be according to the selections made in Appendix A.

2.0 CONTROLLER UNIT

- 2.1 The controller unit shall meet the requirements of NEMA Standards Publication TS-2 2003 V2.06 or latest revision. The controller/cabinet unit shall meet all current AASHTO and ANSI standards applicable to the industry. The controller/cabinet unit shall comply with all current and applicable National Transportation Communications for ITS Protocol (NTCIP) standards. The controller/cabinet unit shall comply with all the criteria of this specification. Where a difference occurs between this specification (TO-4048) and another specification or standard the requirements of this specification (TO-4048) shall govern. The purchase document shall identify either a TS-2 Type 1 interface or TS-2 Type 2 interface. The cabinets for TS-2 Type 1 controllers are specified in this document. TS-2 Type 2 controller cabinets shall use a cabinet specification identified in the solicitation document.
- 2.2 Each controller unit shall have a unique serial number that is permanently and neatly displayed on the face of the unit. If this serial number is not on the face of the unit, then an additional temporary label that is neatly printed or typed shall be affixed to the controller unit face.

2.3 Hardware Design Requirements - NEMA Controller

- 2.3.1 The controller unit shall be completely solid state and digitally timed. All timing shall be referenced to the 60 Hz power line.
- 2.3.2 The dimensions of the controller unit shall not exceed 305 mm high, 440 mm wide, and 305 mm deep.

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- 2.3.3 Both TS-2 Type 1 and TS-2 Type 2 controllers shall be supplied with Port 1 SDLC and Port 2 RS 232 connectors as defined by the TS-2 specification. Port 3 shall be capable of FSK communications with a 9 pin FSK and 25 pin RS 232 connector provided on the front face of the unit. The controller shall have an Ethernet port on the front face of the unit
- 2.3.4 The controller unit shall be built using one or more circuit boards. All printed circuit boards shall be designed to plug into or out of a mother board or harness within the unit. Power supply, transformers, capacitors, and heat dissipating components are exempted from the above requirements.
- 2.3.5 The design shall allow for removal or replacement of a circuit board without unplugging or removing other circuit boards.
- 2.3.6 The unit shall be designed so that one side of each board can be completely accessible for troubleshooting and testing the unit while it is still operating. This may be accomplished with extender boards or cables. This need apply to only one circuit board at a time.
- 2.3.7 No more than two circuit boards shall be attached to each other to constitute a circuit sub-assembly. Attaching hardware shall use captive nuts or other acceptable method to secure the boards together. The boards shall be designed so TxDOT can test and operate the controller unit with the boards separated.
- 2.3.8 No circuit cuts shall be allowed on circuit boards in any of the equipment supplied. Any wire jumpers included on circuit boards shall be placed in plated through holes specifically designed to contain them. Jumpers that are tack soldered to circuit traces or are added to correct board layout errors are not acceptable.

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- 2.3.9 Each of the following shall be simultaneously displayed during standard NEMA dual ring operation on the face of the unit:
1. Phase(s) in service (one per ring)
 2. Phase(s) next to be serviced (one per ring)
 3. Presence of vehicle call (one per phase)
 4. Presence of pedestrian call (one per phase)
 5. Reason for green termination (one per ring)
 - (1) Gap-out
 - (2) Maximum time-out
 - (3) Force-off
 6. Pedestrian service (one per ring)
 7. Max II in effect (one per ring)
- 2.3.10 User programmed entries shall be stored and maintained in non-volatile memory. Battery power will not be allowed for this application.
- 2.3.11 Controller unit shall be designed to operate properly with the logic ground isolated from the AC neutral (common).
- 2.3.12 High quality keyboard with a rated lifetime of 1×10^6 operations/key shall be provided on the front panel of the controller unit. The keyboard shall be used for programming all user-entered timings and settings. An operator entry shall be provided that will enable/disable the audible sound output (default shall be enabled).
- 2.3.13 Direct-reading alphanumeric liquid crystal display (LCD) with back lighting shall be provided on the front panel of the controller unit. The display shall be clearly readable in ambient light including the cabinet light, in full sunlight, or in the absence of light from a distance of 1.0 meters at a 45 degree angle. The display shall have an automatic time-out feature unless the display has an expected continuous life of 10 years or more, and shall have an operating temperature range of -34°C to $+74^{\circ}\text{C}$. The display shall blank out approximately 10 minutes after the last keystroke is made.
- 2.3.14 Display shall be a minimum 40 characters X 4 line display. The respondent may be required to supply literature which demonstrates all display requirements of this specification are met prior to the awarding of the purchase order. If a LCD contrast adjustment is required for visibility at temperature extremes, then the control shall be on the face of the controller unit, adjustable without the use of tools.

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2.4 Time Clock

- 2.4.1 The clock shall use the 60 Hz power line frequency as time base when power is present. The clock operating voltage range shall be 89 to 135V AC over the temperature range of -34°C to +74°C. A 10 year lithium battery shall maintain the time-of-day clock and digital data during a power outage lasting up to 30 days. Lead-acid, nickel-cadmium, or alkaline batteries are not acceptable.
- 2.4.2 The time base clock shall be maintained to within $\pm 0.005\%$ at 20°C and to within a $\pm 0.02\%$ over the specified operating temperature range as compared to coordinated universal time (WWV) standard for a period of 30 days during periods when AC power is not applied.

2.5 Clock/Calendar Programming Requirements

- 2.5.1 The clock shall be easily set to the year, month, day of month, day of week, hour, minute, and second.
- 2.5.2 Automatic daylight savings time shall be available by keyboard entry.
- 2.5.3 The dates for fixed and floating holidays and special events shall be keyboard programmable by the user.
- 2.5.4 Calendar adjustments for leap years shall be automatic.
- 2.5.5 The clock shall store sequences of operations in the form of 255 entries and 15 day plans.

Global Time Base Schedule					Actuated Traffic Signal Schedule
Entry	Months	Dates of Month	Days of Week	Day Plan	Time Base Actions
1	1-12	1-31	1-7	1-15	entry 1 actions
:	"	"	"	"	:
255	"	"	"	"	entry 255 actions

- 2.5.6 The structure and interrelationships of each type of program shall be in accordance with the following paragraphs:

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2.5.6.1 A day plan shall consist of the following:

Hour : Minute	Action 1	(time to implement: action to implement)
:	:	:
Hour : Minute	Action 10	(time to implement: action to implement)

Where each action is unique, there shall be a minimum of ten actions per day plan.

There shall be a minimum of 15 day plans.

2.5.6.2 Each action in a day plan shall consist of a group of the following objects:

- pattern (consisting of):
 - cycle length
 - offset
 - split
 - MUTCD flash (on/off)
 - free operation
- sequence
- special functions 1-8 (on/off)
- auxiliary functions 1-3 (on/off)
- mode of operation (a means of changing operating modes by T.O.D.)
- max II
- gap/ext II
- phase omits

Any or all of these may be selected within a single action.

Transfer into and out of flash shall be in accordance with the Texas MUTCD. It shall be possible to program each phase and overlap to flash either yellow or red via the front panel of the controller unit. This shall be accomplished by flashing the load switch driver outputs simultaneously.

2.5.6.3 An entry shall consist of time period implemented: day plan, month(s), date(s) of month, and day(s) of week.

2.5.6.4 A minimum of 255 entries shall be programmable.

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- 2.5.6.5 There shall be a copy feature that allows the transfer of entries between day plans.
- 2.5.6.6 Other programming schemes meeting the functional intent are acceptable but require approval in writing by the Traffic Operations Division Signal Operations Engineer.

2.6 Program Requirements

2.6.1 Programming

- 2.6.1.1 Programming of the controller unit shall be by the use of a keyboard and display on the front of the controller unit. Programming shall require only simple keystrokes aided by full menu displays. It shall be possible for the controller to interface with a laptop and using compatible software, upload, download, and save data to a database
- 2.6.1.2 Ease of programming through a well-organized menu structure and ease in interpreting the display shall be required for acceptance. The menu structure shall contain a main menu that contains options for all sections of the controller on one screen. Each option shall be selectable by a numeric entry. Each subsequent menu shall be a detailed breakdown of one of the previous menu options. Each menu option shall be a descriptive name to prompt the user to the desired section for programming.

All entries shall be displayed and entered in plain English. Toggle type entries shall be set by entering YES/NO or ON/OFF responses. Non-alphanumeric symbols and abbreviations used to display information shall be clear and unambiguous in their meaning. Numeric entries shall be in the base 10 (decimal) number system. Entries in other number bases, such as hexadecimal or binary, are not acceptable.

- 2.6.1.3 A user selectable 4 digit (minimum) code shall be available to secure access to timing and configuration of the unit. Display features shall be available without the need to access the unit. The controller units shall be supplied with the code preset to be all zeros (0000). Internal DIP switches may be used to establish codes.
- 2.6.1.4 Instructions for use of the access code shall **not** be provided on the face of the unit.
- 2.6.1.5 A keyboard entered coded command (a series of commands or entries, not a single entry) shall be provided which will set all controller and TBC timings and entries to a default or inactive value. This coded command shall allow new values to be entered without first deleting prior entries.

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2.6.1.6 With the intersection display active, a keyboard command shall enable the keyboard for the user to place a call to each phase individually.

2.6.2 Phase Operation

2.6.2.1 In NEMA operating mode, the controller unit shall provide as a minimum, 16 possible phases and 8 possible overlaps. All overlaps shall be programmable through the keyboard and shall function as specified by TS-2.

2.6.2.2 Each of the NEMA timing intervals shall be programmable for a minimum of 8 phases at a time from the same display screen in a spreadsheet format. The display may be rolled or paged down to display additional intervals or information.

2.6.2.3 The controller unit shall have a copying mode whereby the user, after having programmed all intervals of one phase may copy this information into all or selected remaining phases. Other versions of the copying process that meet the functional intent are acceptable.

2.6.2.4 In addition to the modes defined by TS-2, the following modes shall be available on a per phase basis:

1. Soft recall
2. Phase omit

2.6.2.5 The following configurations, as a minimum, shall be programmed within the controller unit and be user selectable:

1. 8 phase NEMA
2. 8 phase sequential
3. NEMA phasing to the left of the barrier, sequential phasing to the right of the barrier (quad sequential).
4. 4 phase diamond
5. 3 phase diamond
6. Separate intersection (see Paragraph 2.8.1.3)

2.6.2.6 The controller shall have a configuration which allows user programmable rings (compatibility lines, reference points to assure there shall be no concurrent selection and timing of conflicting phases). A minimum of 4 rings will be available in this configuration.

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- 2.6.2.7 The controller shall have programmable conflicting phase settings where simultaneous operation of compatible phases is not allowed.
- 2.6.2.8 A dynamic maximum operation which increments the current maximum in programmable steps (dynamic max step) in seconds to a maximum limit (dynamic max limit) in seconds shall be provided. The operation shall function as defined by NEMA Standard Publication NTCIP 1202:1996 (TS 3.5) Object Definitions for Actuated Traffic Signal Controller Units, or latest revision.
- 2.6.2.9 The TBC shall select and coordinate reversible left turn sequence operations (dual leading, leading and lagging, or lagging and leading left turns). It shall be possible to transfer operation from one sequence to another at a preprogrammed time. Transfer shall take place at T_0 during coordination (see Paragraph 2.6.4.2).

2.6.3 Pedestrian Timing

- 2.6.3.1 Actuated pedestrian movements shall operate as follows:
1. When NO pedestrian calls are present, the normal phase timings shall be effective for service of the intersection.
 2. When a pedestrian call is present, the call will be serviced by extended phase timings that account for pedestrian crossing times and override the normal phase timings. If the intersection is coordinated, it may drop out of coordination when servicing the pedestrian call if the pedestrian times exceed the vehicle splits. The controller shall return to coordination in the manner described in this specification after the call is serviced.
- 2.6.3.2 The controller shall rest in main-street green and Don't Walk when no actuated pedestrian calls are present.

2.6.4 Coordination

- 2.6.4.1 A minimum of 16 timing plans, each with a unique cycle length and split combination, shall be required as per TS-2. Each of the 16 timing plans shall have 3 unique offsets available. Cycle length selections are to be each changeable from 30 to 255 seconds in one second increments. Split and offset selections adjustable from 0 to 254 in 1 second increments.

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2.6.4.2 The coordinator shall reference a system-wide reference cycle timer (system cycle timer). The term T_0 shall refer to the point in the local cycle timer when the first coordinated phase (or leading coordinated phase if a pair of coordinated phases was selected by the user) is scheduled on for the first time. NOTE: This may not be the beginning of green in the case of early return. The offset shall be the amount the local cycle timer is behind the system cycle timer.

Example: If the offset is +10 seconds, T_0 (the point at which the local cycle timer is at 0) will occur when the system cycle timer is at 10 seconds.

2.6.4.3 There shall be two modes of automatic coordination programming, fixed and floating force off modes. The following information shall be all that is required from the user to establish a pattern.

1. Basic NEMA controller timing.
2. Cycle length in seconds.
3. Phase sequence desired for the particular pattern.
4. Total seconds of the cycle that a phase is to be active including green, amber, and red clearance times when there is constant demand on all input detectors.
5. The coordinated phase or phases (from Paragraph 2.6.4.9).
6. The offset of the first coordinated phase serviced in the sequence from the reference clock's T_0 in seconds.

2.6.4.4 Using the above information in fixed force-off mode, the coordinator must perform the following functions for each pattern.

1. Guarantee the coordinated phase(s) programmed time will be serviced in its entirety to achieve coordination between intersections (when not correcting). The programmed time of the first coordinated phase in the phase sequence shall start at T_0 .
2. Calculate each phase's force off point (the point at which a phase's Green must terminate in order to not violate the following phases' programmed times).
3. Calculate the beginning of each phase's permissive window (the point in the cycle when the coordinated phase is allowed to yield to each corresponding phase).
4. Calculate the end of each phase's vehicle permissive window (the point preceding a phase's force off point by its minimum time and the prior phase's clearance time). Any phase receiving a vehicle call before the end of vehicle permissive window will be serviced during the current cycle.

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5. Calculate the end of each phase's pedestrian permissive window (the point preceding a phase's force off point by pedestrian Walk and pedestrian clearance times and the prior phase's clearance time). Any pedestrian call received by a phase before the end of pedestrian permissive window will be serviced during the current cycle up to the beginning of the phase vehicle green.
6. Guarantee that each phase's programmed time be serviced in full if a call was received before the beginning of permissive window and the phase does not terminate due to Gap out.

2.6.4.5 Using the same information in floating force-off mode, the coordinator must operate in the same manner as fixed force-off mode except that if a non-coordinated phase is entered early, it will remain active only for the time programmed in the split time. Automatically setting the max timer in each split to accomplish this function is acceptable.

2.6.4.6 No percentage inputs are allowed. Once the information for phase service is entered via the keyboard, the controller unit shall test the plan to insure that the plan does not violate any minimum times based on the specified numbers and cycle length. If a faulty plan is detected, the controller unit shall show an error code indicating the problem. If the error is not corrected, the controller unit shall run in free operation mode whenever the erroneous plan is selected. If actuated pedestrian movements are programmed, the coordinator shall ignore errors detected due to the pedestrian Walk and clearance times violating the phase split time for any actuated pedestrian.

2.6.4.7 The coordinator shall be programmable to seek offsets by short-way (lengthening or shortening the cycle length up to 20%) and by dwell in the coordination phase awaiting the proper offset. The user shall determine which method and may program the longest permissible dwell times.

2.6.4.8 The controller unit coordination program shall be designed to be programmed from the front panel to emulate the operation of a pre-timed controller by recall for applications where no vehicle detection is provided.

2.6.4.9 For each configuration a coordinated phase must be selected from Ring 1. A coordinated phase must also be selected from other rings if a compatible phase with the Ring 1 coordinated phase exists. The coordinated phase or phase pair shall be selectable from one of the individual phases or phase pairs shown in the following table:

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CONFIGURATION				
Coordinated Phase(s)	8 Phase NEMA dual ring and 3 ϕ Diamond	Quad Sequential	8 Phase Sequential	4 ϕ Diamond
Individual	--	4 or 8	2, 4, 6, or 8	
Pairs	2 & 6 or 4 & 8	2 & 6	--	2 & 5, 4 & 5, 1 & 6, or 1 & 8

Compatible phase pairs shall not be forced to begin simultaneously.

2.6.4.10 When establishing its offset from the reference point the coordinator shall reference only the leading edge of the sync pulse, regardless of its width.

2.6.4.11 The internal coordination and upload/download programs shall not interfere with normal intersection operation except when changing ring structure in the controller or active phases. These operations (changing ring structure and active phases) shall require a confirmation and put the controller in a flash condition and a restart sequence. The implementation of revised timing parameters loaded into the timer shall be programmed to occur only at points in the controller coordination cycles which do not alter the controller phase sequence. The controller unit may temporarily drop out of synchronization during the upload/download, but must continue to operate.

2.7 Time-Based Coordinator (TBC)

2.7.1 The internal reference sync pulse, from which the local offset is calculated, shall re-sync at midnight, or the re-sync shall be user programmable with a default to midnight. A pulse shall be generated whenever the time-of-day clock shows a time that is an exact multiple of the current cycle length after this resynchronization. In case of a power failure, re-sync shall be calculated from the programmed re-sync time. The power failure recovery routine shall accommodate the case of a power failure at midnight.

2.8 Diamond Operation

2.8.1 Program Requirements for Diamond Operation

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2.8.1.1 Phase numbers shall be assigned to traffic movements as shown on the diamond intersection layout of Figure 1. Overlap A (OL A) is defined as phases 1+2. Overlap B (OL B) is defined as phases 5+6.

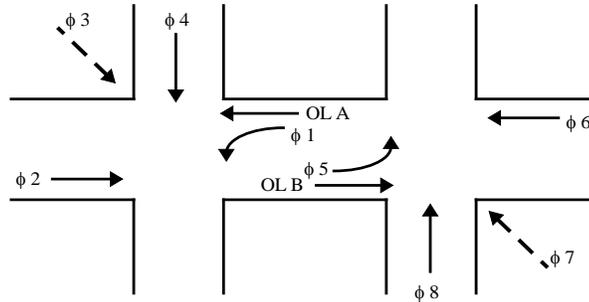


Figure 1

2.8.1.2 There shall be 6 additional user programmable overlaps. All additional overlaps shall be programmable through the keyboard and shall function as specified by TS-2.

2.8.1.3 The controller unit shall be programmable for 4 phase and 3 phase diamond operation as well as 2 independent 4 phase rings (separate intersection operation) as defined in Figure 2.

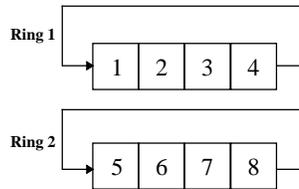


Figure 2

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- 2.8.1.4 The following modes shall be available for each phase and for the intervals identified as special intervals in 3 phase and 4 phase operation:
1. Maximum recall
 2. Minimum recall
 3. Pedestrian recall
 4. Detector locking and non-locking memory
 5. Phase omit
- 2.8.1.5 The controller unit shall be designed to provide pedestrian phasing with phases 2, 4, 6, and 8.
- 2.8.1.6 All timing entries and displays shall be available for phases 3 and 7.
- 2.8.1.7 The operation of the controller unit as a 4 phase, 3 phase, or separate intersection operation diamond shall be keyboard selectable. This shall be overridden while under closed loop system control or by TBC control.

2.8.2 Four Phase Operation

- 2.8.2.1 The controller unit shall perform the sequences for 4 phase and/or 6 phase diamond operation defined in Figures 3a to 3f.
- 2.8.2.2 The normal 4 phase operation sequence shall be 25 → 45 → 16 → 18. The 6 phase operation sequence shall be 25 → 35 → 45 → 16 → 17 → 18.
- 2.8.2.3 The point at which operation may be switched from 4 phase to 3 phase operation shall be at the clearance interval 2516B or 2518B to the 3 phase clearance interval 2648.

2.8.3 Concurrent Timing Requirements

Refer to Figures 3a - 3f for the following descriptions:

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- A. Intervals 4516B and 4516C shall time concurrently with interval 16, however interval 16 may not terminate green until interval 4516C has timed out.
- B. Intervals 3516B and 3516C shall time concurrently with interval 16, however interval 16 may not terminate green until interval 3516C has timed out.
- C. Intervals 1825B and 1825C shall time concurrently with interval 25, however interval 25 may not terminate green until interval 1825C has timed out.
- D. Intervals 1725B and 1725C shall time concurrently with interval 25, however interval 25 may not terminate green until interval 1725C has timed out.
- E. All left to right internal clearance times (intervals 4518B, 4517B, 3518B, 3517B, 2518B, 2517B, 2516B) shall use the same timing settings for minimum green, extension, maximum green, yellow clearance, and red clearance.
- F. All right to left internal clearance times (intervals 1845B, 1835B, 1745B, 1735B, 1645B, 1635B, 1625B) shall use the same timing settings for minimum green, extension, maximum green, yellow clearance, and red clearance.
- G. Separate timing settings for minimum green, extension, maximum green, yellow clearance, and red clearance shall be provided for each of the 4 external clearance intervals (1825B, 1725B, 4516B, 3516B).

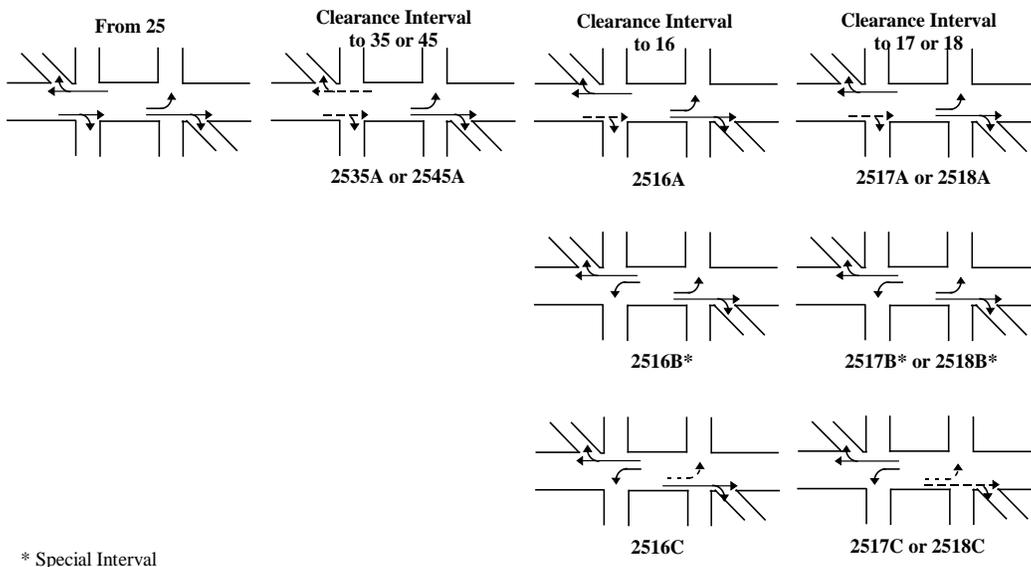


Figure 3a

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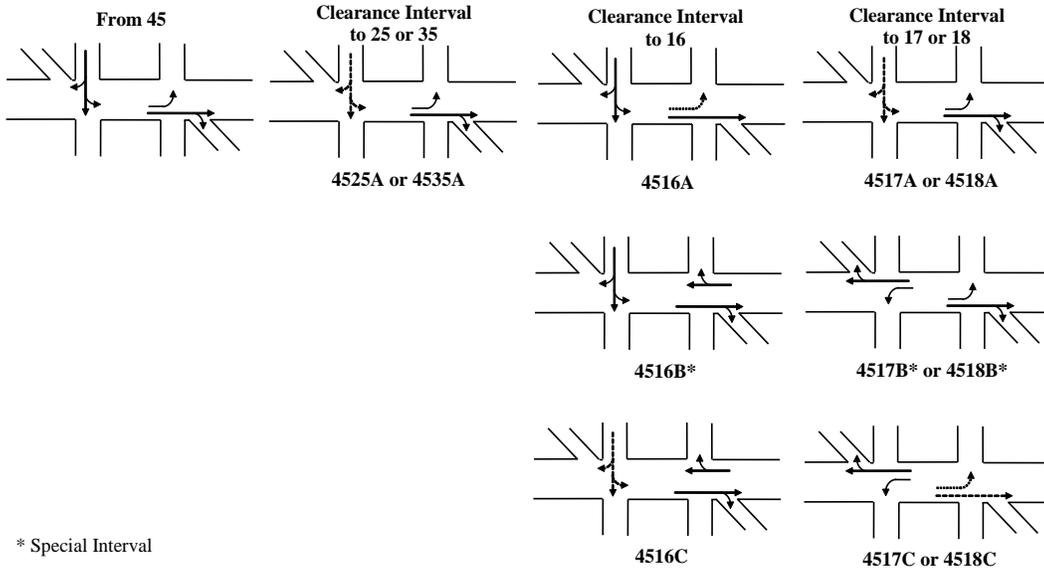


Figure 3b

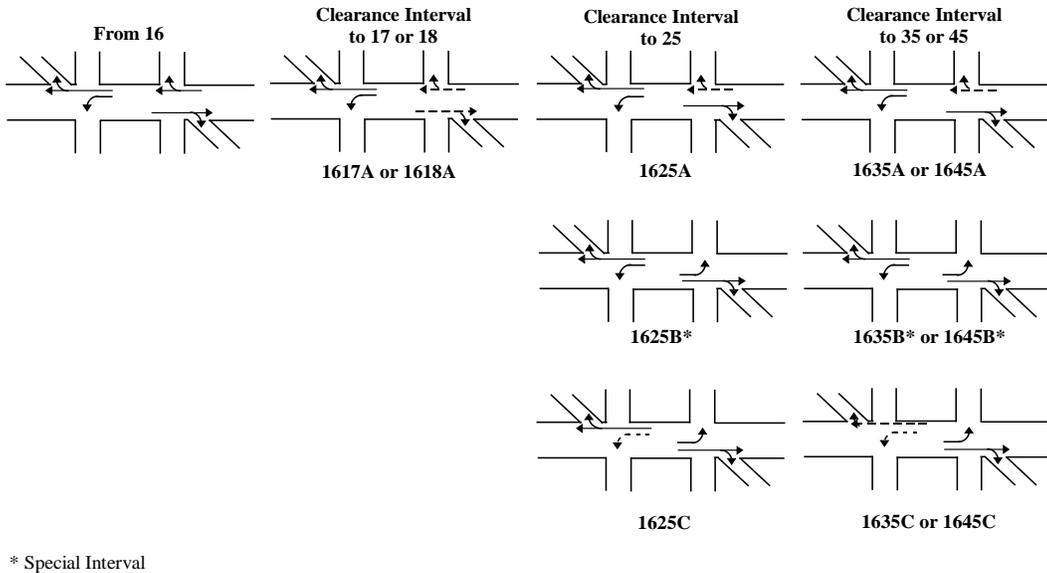


Figure 3c

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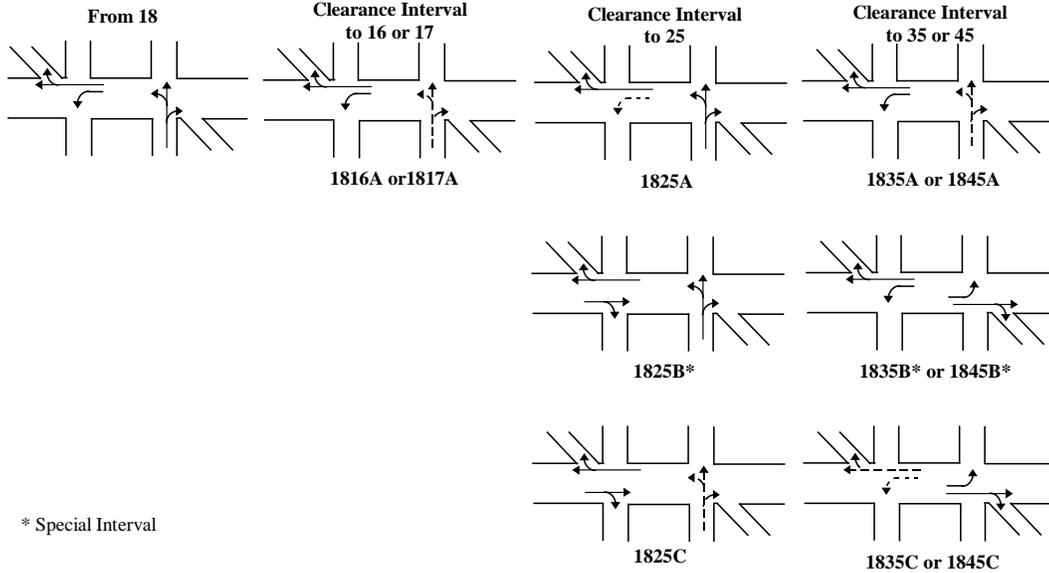


Figure 3d

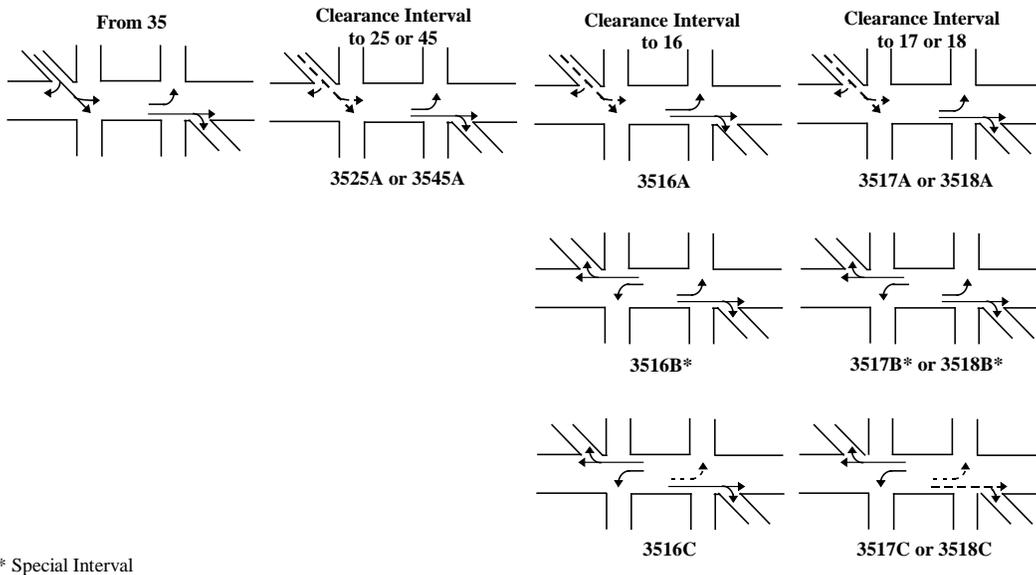


Figure 3e

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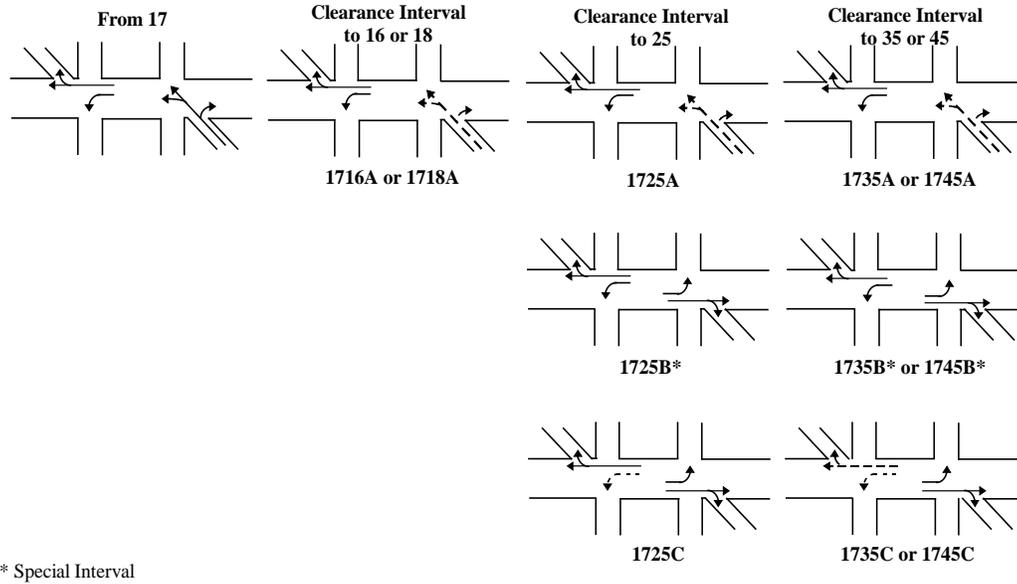


Figure 3f

2.8.4 Diamond Detector Operation

2.8.4.1 The loop detector layout for 3 phase, 4 phase, 6 phase, or separate intersection diamond operation shall be as defined in Figure 4. The detector operation defined shall be automatically loaded when any diamond sequences are selected.

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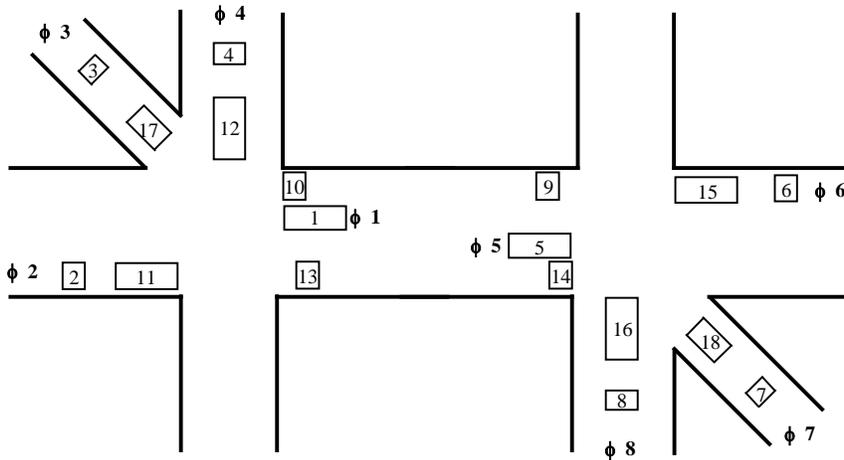


Figure 4

2.8.4.2 The controller unit software shall provide the logic for detector operation described below:

Detector 1

In 4 phase operation:

1. Shall call phase 6 if overlap A is not green and phase 7 is not called.
2. Shall call phase 6 if overlap A is not green and phase 8 is not called.
3. Extend intervals 2516B, 2517B, 2518B, 4517B, 4518B, 3517B, and 3518B.

In 3 phase operation: call and extend phase 1 (left turn)

Detector 5

In 4 phase operation:

1. Shall call phase 2 if overlap B is not green and phase 3 is not called.
2. Shall call phase 2 if overlap B is not green and phase 4 is not called.
3. Extend intervals 1625B, 1635B, 1645B, 1735B, 1745B, 1835B, and 1845B.

In 3 phase operation: call and extend phase 5 (left turn)

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Detectors 2, 3, 4, 6, 7, and 8

These setback detectors (or detector sets) belong to the parent phases with the same number (e.g. detector 2 belongs to phase 2) as shown in Figure 4. These detectors shall have a 2 second delay set during red conditions of their parent phase. The detector(s) are used to extend during green.

Detectors 11, 12, 15, 16, 17, and 18

These detectors are stop bar detectors and are used to call the associated parent phases shown in Figure 4. The parent phase green plus a call for that phase plus a 0.2 second gap on the detector shall disable the detector until the end of green.

Detectors 9 and 10

In 4 phase operation:

1. Shall extend phase 2 if phase 3 is called.
2. Shall extend phase 2 if phase 4 is called.
3. Shall call phase 6 if overlap A is not green and phase 7 is not called.
4. Shall call phase 6 if overlap A is not green and phase 8 is not called.
5. Extend intervals 2516B, 2517B, 2518B, 4517B, 4518B, 3517B, and 3518B.

In 3 phase operation: shall function as a phase 1 calling detector during phase 3 or 4 and as a phase 1 extending detector when a phase 3 or 4 call exists.

Detectors 13 and 14

In 4 phase operation:

1. Shall extend phase 6 if phase 7 is called.
2. Shall extend phase 6 if phase 8 is called.
3. Shall call phase 2 if overlap B is not green and phase 3 is not called.
4. Shall call phase 2 if overlap B is not green and phase 4 is not called.
5. Extend intervals 1625B, 1635B, 1645B, 1735B, 1745B, 1835B, and 1845B.

In 3 phase operation: shall function as a phase 5 calling detector during phase 7 or 8 and as a phase 5 extending detector when a phase 7 or 8 call exists.

2.8.5 Three Phase Operation

2.8.5.1 The controller unit shall be keyboard selectable for 3 phase diamond operation.

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- 2.8.5.2 The controller unit shall perform the sequences for 3 phase diamond operation defined in Figures 5a to 5b.
- 2.8.5.3 The normal sequence of operation shall be 4+8 → 2+6 → 1+5.
- 2.8.5.4 The point at which operation may be switched from 3 phase to 4 phase operation shall be through the transition phase sequence to 4 phase interval 2516 as indicated in Figure 5a.
- 2.8.5.5 The controller shall be programmable for simultaneous gap operation for phases 4 and 8 in 3 phase operation to allow a phase to extend out of a green rest state. When the phase(s) to be serviced next conflicts with both phases being serviced, both concurrent phases must reach a green rest state together before they terminate. Termination of the max timer or application of a force off shall override this feature. The phases shall not be allowed to advance to a green interval beyond the rest state which might override defeat the simultaneous gap operation.

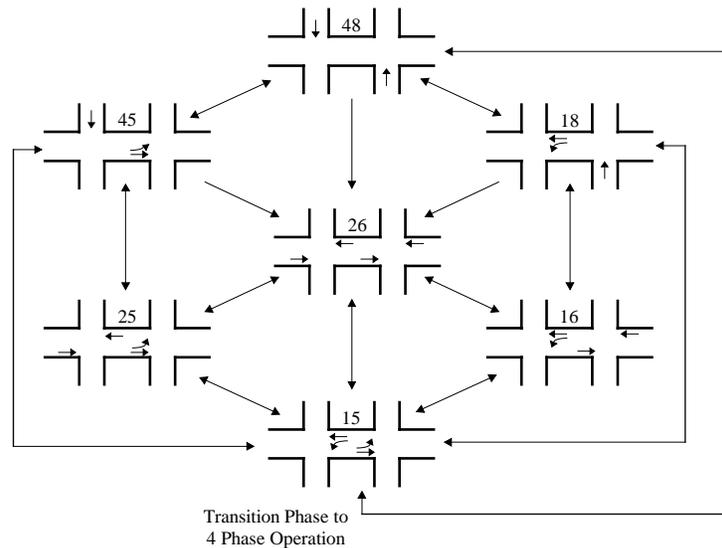


Figure 5a

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**3 Phase Diamond Sequence
Figure 5b**

From Interval	IF Call On	AND No Call On	GO TO Interval
48	2 and 6	----	2+6
	2 or 6	1 or 5	2+6
	1 and 6	2	1+6
	2 and 5	6	2+5
	5	1 or 2 or 6	4+5
	4 and 5	8	4+5
			if min. time of 5 can be serviced before max. time of 4
	1	2 or 5 or 6	1+8
	1 and 8	4	1+8
			if min. time of 1 can be serviced before max. time of 8
	1 and 5	2 or 6	1+5
45	8	----	4+8
			if 4+8 was not serviced immediately prior to 4+5
	8	1 or 2 or 6	4+8
	2 and 6	8	2+6
	6	8 or 1	2+6
	2	8 or 6	2+5
	1 and 6	8 or 2	1+6
1	8 or 2 or 6	1+5	
18	4	----	4+8
			if 4+8 was not serviced immediately prior to 1+8
	4	5 or 2 or 6	4+8
	2 and 6	4	2+6
	2	4 or 5	2+6
	6	4 or 2	1+6
	2 and 5	4 or 6	2+5
5	4 or 2 or 6	1+5	

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From Interval	IF Call On	AND No Call On	GO TO Interval
26	(1 and 5) or 4 or 8	2 or 6	1+5
	5	6 or 4 or 8	2+5
	2 and 5	6	2+5
	1	2 or 4 or 8	1+6
	1 and 6	2	1+6
25	1 or 8	----	1+5
	4	1 or 8	4+5
	6	1 or 4 or 8	2+6
16	4 or 5	----	1+5
	8	4 or 5	1+8
	2	4 or 5 or 8	2+6
15	4 and 8	----	4+8
	4	8	4+5
	8	4	1+8
	2 and 6	4 or 8	2+6
	2	4 or 6 or 8	2+5
	6	2 or 4 or 8	1+6

2.9 Coordination Control Hierarchy

- 2.9.1 When the system switch is in the system position, the controller unit shall be under the control of the master controller or TBC.
- 2.9.2 In the absence of any on-line closed loop system control by a master controller, the internal TBC shall control the coordinated, free, and flash operation of the intersection when the system switch is in the system position.
- 2.9.3 When a master controller brings the intersection on-line, its control shall supersede that of the internal time base coordination.
- 2.9.4 When the system switch is in the free position, the controller unit shall operate in a non-coordinated (free) mode.

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2.10 Preemption (PE)

- 2.10.1 The internal preemptor supplied shall be easily programmable from the front panel for either railroad or emergency vehicle preemption sequences.
- 2.10.2 Phases shall be selectable such that a limited signal sequence may be operational during preempt (PE). It shall be possible to add phases to this special limited sequence, which is not in the intersection sequence. This shall be accomplished without adding external logic.
- 2.10.3 The following intervals shall be provided as a minimum. Terminology may vary but the meaning must be clear. Additional unspecified intervals that may lead to confusion shall be programmable to zero. If abbreviations are used on the display, they shall be defined on the front panel. While in preemption, the display will clearly identify the intervals being timed as preempt intervals. Yellow and red clearances from the phase timings may be utilized in place of the clearance intervals shown.

2.10.3.1 Preemption Timing Interval Definition

All intervals are sequential.

- 0. **PE Delay** - This time shall start immediately when the preempt command is received. It shall not affect the normal operation of the controller unit until the delay time out occurs. This interval may be used for emergency vehicle (fire lane) preemption delay. If 0 time is set, the interval shall be omitted.
- 1. **PE Minimum Duration** - The preempt sequence shall not terminate until the preempt input signal is removed and the minimum duration time has expired.
- 2. **PE Minimum Green** - Any vehicle signal that is green at the time this interval becomes active shall not terminate unless it has been displayed for at least the time programmed in this interval. If 0 time is set the interval shall be omitted.
- 3. **PE Minimum Walk** - Preempt minimum walk time in seconds. A preempt initiated transition shall not cause the termination of a Walk prior to its display for this period.
- 4. **PE Pedestrian Clearance** - At the time of preempt call, Walk indications shall immediately change to pedestrian clearance interval. The pedestrian clearance interval shall not terminate unless it has been displayed for at least the time programmed in this interval. If 0 time is set, the interval shall be omitted.
- 5. **PE Track Green** - Signals programmed as track (or fire lane) signals shall remain green or be changed to green. All other signals shall be red. This interval shall be optionally programmable to zero during emergency vehicle PE.

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6. **PE Dwell Green** - Minimum dwell time in seconds. This parameter controls the minimum timing for the dwell movement. The phase(s) allowed during the dwell interval shall be selectable to include all phases that do not cross the track. The dwell interval shall not terminate prior to the completion of preempt duration time, preempt dwell time, and the call is no longer present. Each signal shall be keyboard programmable for red, red flash, yellow flash or green. As an alternative, a limited cycle shall be programmable for use with railroad preempts.
7. **PE Exit Pedestrian Clear** - Preemption exit pedestrian clear time in seconds. This parameter controls the pedestrian clear timing for a Walk signal transition to the exit phase(s).
8. **PE Exit Yellow** - This interval shall provide a solid yellow clearance for indications that were green or flashing yellow. Red and flashing red displays shall display solid red.
9. **PE Exit Red Clearance** - This interval shall be an all red clearance in preparation for return to the normal cycle. Return phases shall be programmable from the keyboard.
10. **PE Max Call** - This interval is the amount of time that a preempt call may remain active and be considered valid. When the preempt call has been active for this amount of time, the controller shall return to normal operation. The preempt call shall be considered invalid until the call is no longer active.

2.10.3.2 Preempt Timing Interval Ranges

TIMING INTERVAL	TIME (Seconds)	INCREMENTS (Seconds)
0. PE Delay (emergency vehicle preempt)	0-999	1
1. PE Minimum Duration	0-999	1
2. PE Minimum Green	0-255	1
3. PE Minimum Walk	0-255	1
4. PE Pedestrian Clearance	0-255	1
5. PE Track Green	0-255	1
6. PE Dwell Green	1-255	1
7. PE Exit Pedestrian Clear	0-255	1
8. PE Exit Yellow	3.0-25.5	0.1
9. PE Exit Red Clearance	0-25.5	0.1
10. PE Max Call	0-999	1

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- 2.10.4 The phases to be serviced following the preempt sequence shall be front panel keyboard programmable.
- 2.10.5 Preempt sequences shall be selectable using external inputs. Preempt priority shall be assigned with number 1 being the highest. If a higher priority preempt input is received during a preempt sequence, the controller unit shall immediately transition to the new sequence subject to the constraints of PE minimum green and PE minimum walk. The transition shall take place in a safe manner from any point in the sequence meeting all Texas MUTCD requirements. Provisions shall be made to clear two conflicting track phases from a single preempt input. This may be provided by two track clearance phases for a single preempt or by combining two preempts.
- 2.10.6 Preempt 1 shall be reserved for a priority railroad preempt. If more than two preempts are provided it shall be possible to delete the priority override for all but the railroad preempt. If a non-priority preempt is activated during another preempt cycle, the one in progress shall continue through its entire cycle. If the second preempt input is still active when the first one is completed, the controller unit shall immediately go to all red flash or initiate the non-priority preempt. When all preempt inputs are removed, the controller unit shall proceed through the normal sequence to return red clearance (interval 9).
- 2.10.7 Once the controller unit has entered the first timed interval following preempt delay (interval 1), the sequence shall continue to the end even if the preempt call is dropped. If the call returns, the minimum preempt duration (interval 1) the controller unit should reinitiate track green and complete the preempt sequence.
- 2.10.8 The controller unit shall be programmable to be in flash or in limited sequence during interval 6. If flash is specified, the phases shall flash yellow or red as programmed from the front panel. Flash shall be implemented by simultaneously flashing the appropriate load switch driver outputs. If limited sequence is selected, all phases shall be programmable even if not normally used in the intersection sequence.
- 2.10.9 In the event of a power interrupt as defined by TS-2, if the preempt command is present when power is restored, the controller unit shall power up in cabinet flash operation and remain there until the PE command is removed.

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- 2.10.10 Overlap phases shall begin and terminate with the parent phases as described in TS-2. If the PE call occurs during yellow or red displays between parent phases, the overlap phase shall display a minimum of 3 seconds of yellow and a minimum of 1 second of red clearance.
- 2.10.11 Don't Walk shall be displayed throughout the preempt sequence unless a limited cycle is run. During a limited cycle (interval 6) the pedestrian heads may be programmed to be dark.
- 2.10.12 Preempt routines shall have priority over all controller functions.
- 2.10.13 The controller shall be programmable to allow multiple track clearance phases either within a single preemption sequence or by mapping multiple preempts together in all modes of operation including 3 phase and 4 phase diamond modes.

2.11 Closed Loop Operation and Monitoring Software (CLS)

- 2.11.1 The controller software shall either be capable of implementing NTCIP or be downward compatible with CLS masters supplied by the same manufacturer since January 1992 and provide all necessary components to upgrade to NTCIP, as specified by the plans. Short haul FSK modems, necessary to operate the controller as a closed loop system secondary, shall be provided internal to the timer. All necessary cables and communication ports needed for operation in a closed loop system cabinet shall be provided. The modems shall meet TS-2 environmental requirements for traffic signal equipment.
- 2.11.2 Window-based CLS software shall be provided (with a minimum of 5 licensed users per copy) according to the solicitation, that will allow the monitoring, setup, and programming of all controller unit timing entries, functions, and features. These functions and features shall include but not be limited to the following:
 - 1. Monitoring signal indications, detectors, alarms, and time base functions.
 - 2. Controller database error checking.
 - 3. Coordination parameters.
 - 4. Remote resetting of coordination errors.
 - 5. Toggle special function outputs from the controller.
 - 6. Receive reports and alarms generated from the controller.
 - 7. Setting up the dial-up modem for the traffic signal controller needed to accomplish the remote operation through the controller or the PC software. The setup strings for Hayes compatible modems (including Hayes, US Robotics, and Computer Peripherals modems as a minimum) shall be provided.

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All capabilities from the controller keyboard shall be capable remotely through the computer interface through a telephone modem connection. The software shall not require that the controller unit be connected while making entries until the actual download/upload process.

- 2.11.3 A cable shall be supplied to direct connect the controller to a PC in order to upload and download data as well as monitor the controller operation.
- 2.11.4 The controller shall have a minimum of 8 detector inputs per intersection for use with closed loop system operation. The system shall report volume and occupancy counts based on a user-selectable time period for each detector. Storage of this data may take place at either the local controller or on-street master. Allowances in the software shall be made for a minimum of 8 system detectors at any local controller, in addition to any local detectors.

2.12 NTCIP Compliance

- 2.12.1 The controller software shall comply with the referenced NTCIP standards when installed. The software shall comply with the versions of the relevant NTCIP standards that are current at the date of this document, or latest revision.
- 2.12.2 The software shall comply with NEMA Standard Publication TS-3.2 2003 (TS-3.2), or latest revision, the Simple Transportation Management Framework, and shall meet the requirements for Conformance Level 2. The software shall comply with NEMA Standard Publication TS-3.3 2003 (TS 3.3), or latest revision, the Class B Profile, and shall include both an EIA/TIA 232-E and an FSK modem interface for NTCIP based communications.
- 2.12.3 The software shall implement all mandatory objects of all mandatory conformance groups as defined in Global Object Definitions, NEMA Standard Publication NTCIP 1201:1996 (TS 3.4), or latest revision:
- Configuration Conformance Group and Actuated Signal Controller Object Definitions, NEMA Standard Publication NTCIP 1202:1996 (TS 3.5), or latest revision.
 - Phase Conformance Group
 - Detector Conformance Group

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2.12.4 The software shall implement all mandatory objects of all optional conformance groups as defined in Global Object Definitions, NTCIP 1201:1996, or latest revision:

- Database Management Conformance Group
- Time Management Conformance Group
- Time Base Event Schedule Conformance Group
- Report Conformance Group
- STMF Conformance Group
- PMPP Conformance Group and Actuated Signal Controller Object Definitions, NTCIP 1202: 1996, or latest revision.
- Volume Occupancy Report Conformance Group
- Unit Conformance Group
- Special Function Conformance Group
- Coordination Conformance Group
- Time Base Conformance Group
- Preempt Conformance Group
- Ring Conformance Group
- Channel Conformance Group
- Overlap Conformance Group
- TS-2 Port 1 Conformance Group

2.12.5 The software shall also implement the following optional objects as defined in the Global Object Definitions, NTCIP 1201:1996, or latest revision:

- globalSetIDParameter
- dbMakeID
- eventLogOID
- eventConfigAction
- eventClassDescription

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2.12.6 The software shall also implement the following optional objects as defined in the Actuated Signal Controller Object Definitions, NTCIP 1202:1996, or latest revision:

- unitRedRevert
- phaseDynamicMaxLimit
- phaseDynamicMaxStep
- phaseControlGroupTable
- ringControlGroupForceOff
- vehicleDetectorQueueLimit
- vehicleDetectorFailTime
- vehicleDetectorReportedAlarms
- alarmGroupTable
- specialFunctionOutputTable
- preemptMinimumGreen
- preemptMinimumWalk
- preemptEnterPedClear
- preemptState
- preemptControlTable
- ringControlGroupMax2
- ringControlGroupMaxInhibit

2.12.7 All objects required by these procurement specifications shall support all values within its standardized range, unless otherwise approved by the Project Engineer. The standardized range is defined by a size, range, or enumerated listing indicated in the object's syntax field and/or through descriptive text in the object's description field of the relevant standard. The following provides the current listing of known variances for this project:

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TABLE 2.1 OBJECT RANGE VALUES FOR ACTUATED SIGNAL CONTROLLERS

OBJECT	MINIMUM PROJECT REQUIREMENTS
NTCIP 1201:1996	
moduleType	Value 3
dbCreateTransaction	All Values
dbErrorType	All Values
globalDaylightSaving	Values 2 & 3
maxTimeBaseScheduleEntries	255
maxDayPlans	15
maxDayPlanEvents	10
maxEventLogConfigs	255
eventConfigMode	Values 2 thru 5
eventConfigAction	Values 2 & 3
maxEventLogSize	255
maxEventClasses	7
maxGroupAddress	2
NTCIP 1202:1996	
maxPhases	16
phaseStartup	Values 2 thru 6
phaseOptions	All Values
maxPhaseGroups	2
maxVehicleDetectors	32
vehicleDetectorOptions	All Values
maxPedestrianDetectors	8
unitAutoPedestrianClear	All Values
unitControlStatus	All Values
unitFlashStatus	All Values
unitControl	All Values
maxAlarmGroups	1
maxSpecialFunctionOutputs	8
coordCorrectionMode	Values 2 thru 4
coordMaximumMode	Values 2 thru 4
coordForceMode	Values 2 & 3
maxPatterns	48
patternTableType	Either 2 or 3

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OBJECT	MINIMUM PROJECT REQUIREMENTS
maxSplits	16
splitMode	Values 2 thru 7
localFreeStatus	Values 2 thru 11
maxTimebaseASCActions	255
maxPreempts	6
preemptControl	All Values
preemptState	Values 2 thru 9
maxRings	4
maxSequences	16
maxChannels	16
channelControlType	Values 2 thru 4
channelFlash	All Values
channelDim	All Values
maxChannelStatusGroups	16
maxOverlaps	8
overlapType	Values 2 & 3
maxOverlapStatusGroups	8
maxPort1Addresses	255
port1Status	Values 2 & 3

- 2.12.8 The controller shall be able to implement all NTCIP messages called for in the specification without any additional vendor specific/proprietary statements.
- 2.12.9 The software shall be supplied with full documentation, including a CD-ROM disk and/or other approved storage media containing ASCII versions of the following MIB files in ASN.1 format:
- the relevant version of each official NEMA standard MIB module referenced by the device functionality; and
 - if the device does not support the full range of any given object within a NEMA standard MIB module, a manufacturer specific version of the official NEMA standard MIB module with the supported range indicated in ASN.1 format in the Syntax field of the Object-Type macro. The filename of this file shall be the same as the standard MIB filename with the extension “.man”.

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- 2.12.10 The software shall be supplied with full documentation, including a CD-ROM disk or other approved storage media containing ASCII versions of any and all manufacturer-specific objects supported by the device in ASN.1 format in a manufacturer-specific MIB with accurate and meaningful description fields and supported ranges indicated in the syntax field of the object-type macros.
- 2.12.11 The manufacturer shall not place any restrictions as to the passage of any and all of this documentation to any portion of TxDOT.
- 2.12.12 The manufacturer shall provide a copy of the following table that has been completed to describe the operation of their controller including which objects are used and the procedures that are done with these objects to implement the functions listed using NTCIP.

Table 2.2

Function	Objects	Procedures to Implementation
<i>Example: Function X</i>	Object T Object Y Object Z	Get object T then send objects Y and Z if T>0.
Change split time in an active coordination plan		
Change ring structure		
Change minimum Green in an active coordination plan		
Change alternate sequence in an active coordination plan		

- 2.13 **Flashing Yellow Arrow Operation. Provide a Flashing Yellow Arrow (FYA) routine that:**
 - is programmable in the controller unit,
 - provides as a minimum for operation of up to 4 FYA left turn signal displays per the MUTCD,
 - uses data entries in the controller unit to define when the signal face displays the protected (green arrow) and the permissive (flashing yellow arrow),

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- can be programmed for permissive only, permissive-protected, or protected only operation by time of day, transition from FYA permissive-protected operation to protected only operation must be accomplished after concurrent termination of both the FYA and the associated opposing through movement..

3.0 MALFUNCTION MANAGEMENT UNIT (MMU)

- 3.1 This specification sets forth the minimum requirements for a shelf-mountable, 16 channel, solid-state MMU. The MMU shall meet as a minimum, Section 4 of the NEMA Standards Publication TS-2 2003, or latest revision. Where differences occur, this specification shall govern.
- 3.2 No circuit cuts shall be allowed on circuit boards in any of the equipment supplied. Any wire jumpers included on circuit boards shall be placed in plated through holes that are specifically designed to contain them. Jumpers that are tack soldered to circuit traces or that are added to correct board layout errors are not acceptable
- 3.3 All ICs with 16 or more pins shall be mounted in machine tooled sockets or surface mounted. All sockets shall have two-piece, machined contacts and closed end construction to eliminate solder wicking. The outer sleeve shall be brass with tin or gold plating and tapered to allow easy IC insertion. The inner contact shall be beryllium copper sub-plated with nickel and plated with gold. All sockets shall have thermoplastic bodies meeting UL Specification 94V-0. Other high quality sockets may be acceptable but must have prior approval of the Traffic Operations Division Signal Operations Engineer. Surface mount devices will be allowed. Sockets meeting alternate specifications shall be submitted in writing with the solicitation. Zero insertion force sockets will not be allowed.
- 3.4 The design shall allow for removal or replacement of a circuit board without unplugging or removing other circuit boards.
- 3.5 The unit shall be designed so that one side of each board can be completely accessible for troubleshooting and testing the unit while it is still operating. This may be accomplished with extender boards or cables. This need apply to only one circuit board at a time.
- 3.6 One set of extender boards (if required to meet Paragraph 3.5 above) for every 10 MMUs ordered or portion thereof shall be provided with the purchase order.

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- 3.7 No more than two circuit boards shall be attached to each other to constitute a circuit assembly. Attaching hardware shall use captive nuts or other acceptable method to secure the boards together. Alternate methods shall be submitted in writing with the solicitation. The boards shall be designed so TxDOT can test and operate the controller unit with the boards separated.
- 3.8 If this specification is used to support the purchase of a complete controller assembly, the unused red circuits shall be connected to the AC Line in the controller cabinet.
- 3.9 The MMU shall be pre-programmed according to Table 3-1.

Table 3-1

Channel	Load Switch	Phase
Channel 1	Load Switch 1	Phase 1 Vehicle
Channel 2	Load Switch 2	Phase 2 Vehicle
Channel 3	Load Switch 3	Phase 3 Vehicle
Channel 4	Load Switch 4	Phase 4 Vehicle
Channel 5	Load Switch 5	Phase 5 Vehicle
Channel 6	Load Switch 6	Phase 6 Vehicle
Channel 7	Load Switch 7	Phase 7 Vehicle
Channel 8	Load Switch 8	Phase 8 Vehicle

- 3.10 Provide an MMU that displays by LCD or other approved graphics display, the active or inactive state of each circuit on all 16 channels. An icon must be used representing the red (Don't Walk), yellow, and green (Walk) circuit for each channel.
- 3.11. The MMU must be compatible with the controller and capable of monitoring FYA operation as defined by the MUTCD and still provide standard NEMA TS-2 monitoring functions.
- 3.12 Each MMU shall have a unique serial number that is permanently and neatly displayed on the face of the unit. If this serial number is located elsewhere on the unit then an additional temporary label that is neatly printed or typed shall be affixed to the MMU face.
- 3.13 Provide the MMU with an Ethernet port on the front face of the unit.

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4.0 TS-2 CABINET ASSEMBLY

4.1 This specification describes the minimum acceptable requirements for a TS-2 cabinet assembly to house a NEMA TS-2 Type 1 solid state full-actuated controller unit. The assembly shall include the cabinet, flasher, card rack(s), a MMU, an external power supply, and 6 flash transfer relays. For cabinet assemblies of configuration 4 (16 position), the assembly shall include 16 load switches and for cabinet assemblies of configuration 3 (12 position), the assembly shall include 12 load switches. All cabinets shall include appropriate mounting hardware.

4.2 Cabinet Design Requirements

4.2.1 The cabinet shall be constructed using unpainted sheet aluminum with a minimum thickness of 3.2 mm. No wood, wood fiber products or other flammable material shall be used in the cabinet. All welds shall be neat and of uniform consistency.

4.2.2 The size of the cabinet shall be size 5 or size 6 as defined by TS-2 Clause 7.3 of the NEMA Standard Publication TS-2 2003, or latest revision, as specified by the plans. The load bay shall be configuration 3 (12 position) or configuration 4 (16 position) as defined by TS-2 Clause 5.3, as specified by the plans.

Cabinet Options	Size of Cabinet	Backpanel Configuration	Size of Load Bay
Option 1	Pole Mount TS-2 Size 5	Configuration 3	12 position load bay
Option 2	Base Mount TS-2 Size 5	Configuration 3	12 position load bay
Option 3	Base Mount TS-2 Size 6	Configuration 3	12 position load bay
Option 4	Base Mount TS-2 Size 6	Configuration 4	16 position load bay

4.2.3 Two aluminum-lifting eyes or ears shall be attached to the cabinet with a single carriage bolt or dual carriage bolts each to permit lifting the cabinet with a sling. The corners of each eye or ear shall be rounded and in the down position when shipped.

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- 4.2.4 Vertical shelf support channels shall be provided to permit adjustment of shelf location in the field. The channels shall have a single continuous slot to allow shelves to be placed at any height within the cabinet. Channels with **fixed notches** or **holes** are **not acceptable**.
- 4.2.5 Each cabinet shall be equipped with an extra set of unistrut channels or a keyhole panel on either side of the front section of the cabinet to permit mounting of additional equipment as necessary.
- 4.2.6 Shelves shall be at least 330 mm deep and be located in the cabinet to provide a 12.5 mm clearance between the back of the shelf and the back of the cabinet. A 38 mm drawer shall be provided in the cabinet, mounted directly beneath the controller support shelf. The drawer shall have a hinged top cover and shall be capable of storing documents and miscellaneous equipment. This drawer shall support to 22.5 kg in weight when fully extended. The drawer shall open and close smoothly. Drawer dimensions shall make maximum use of available depth offered by the controller shelf and be a minimum of 600 mm.
- 4.2.7 Two shelves shall be provided in the cabinet and shall be at minimum 305 mm apart in height. There shall be sufficient shelf space to accommodate a controller unit 330 mm high, an MMU, one 8 position card rack and external power supply. An additional space at least 305 mm high, 325 mm wide, and 305 mm deep shall be provided. The controller unit, MMU, card racks, and power supply shall be placed on the shelves in such a manner that sufficient ventilation is provided to all components. Labels showing the proper placement of each component shall be provided along the shelves to ensure proper placement.
- 4.2.8 The cabinet shall be vented and cooled by 2 thermostatically controlled fans. The fans shall be a commercially available model with a capacity of at least 2.7 m³/minimum. The thermostats shall have an adjustable range of 20°C to 43°C. A press-to-test switch shall be provided to test the operation of the fans.
- 4.2.9 The cabinet shall be provided with a unique 5 digit serial number which shall be stamped directly on the cabinet or engraved on a metal or metalized mylar plate, epoxied or riveted with aluminum rivets to the cabinet. The digits shall be minimum 5 mm in height and located on the upper right sidewall of the cabinet near the front.

4.3 Cabinet Door

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- 4.3.1 The cabinet shall be provided with one door in front that will provide access to the cabinet. The door shall be provided with 3 hinges with non-removable stainless steel pins, or a full-length piano hinge with stainless steel pins spot welded at the top of the hinge. The hinges shall be mounted so it is not possible to remove them from the door or cabinet without first opening the door. The bottom of the door opening shall extend at least to the bottom level of the back panel. The door and hinges shall be braced to withstand a 74 kg per vertical meter of door height load applied to the outer edge of the door standing open. There shall be no permanent deformation or impairment of any of the door or the cabinet body when the load is removed.
- 4.3.2 The cabinet door shall be fitted with a Number 2 Corbin lock and a cast aluminum or chrome plated steel handle with a minimum 16 mm diameter shaft (or equal cross-sectional area for a square shaft) and a 3 point latch. The lock and latch design shall be such that the handle cannot be released until the lock is released. One key shall be provided for each cabinet. A gasket shall be provided to act as a permanent dust and weather resistant seal at the controller cabinet door facing. The gasket material shall be of a nonabsorbent material and shall maintain its resiliency after long term exposure to the outdoor environment. The gasket shall have a minimum thickness of 6.25 mm. The gasket shall be located in a channel provided on the cabinet or on the door(s). An "L" bracket is acceptable in lieu of this channel if the gasket is fitted snugly against the bracket to insure a uniform dust and weather resistant seal around the entire door facing. Any other method is subject to written purchaser approval during inspection of an order.
- 4.3.3 A locking auxiliary police door shall be provided in the door of the cabinet to provide access to a panel that shall contain a signal shutdown switch, a signal flash switch, a manual-automatic switch, and a manual advance push-button switch on a 6 foot retractable cord. Manual control of the controller unit from the police door shall override any external control (external logic, etc.) in effect when the manual-automatic switch is in the manual position. Each actuation of the manual advance push-button switch shall advance the controller to the next interval. Manual control shall not override any calls for preemption. The police door shall be gasketed to prevent entry of moisture or dust and the lock shall be provided with one brass key.

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4.3.4 The intake for the vent system shall be filtered with a permanent air filter. The minimum filter dimensions shall be 406.4 mm wide X 304.8 mm high X 25 mm thick. The filter shall be securely mounted so that any air entering the cabinet must pass through the filter. The cabinet opening for intake of air shall be large enough to use the entire filter. The air intake and exhaust vent shall be screened to prevent entry of insects. The screen shall have opening no larger than 8.1 mm². The total free air opening of the exhaust vent shall be large enough to prevent excessive back-pressure on the fan.

4.4 Wiring

4.4.1 All wiring within the cabinet shall be neat and routed such that opening and closing the door or raising or lowering the back panel will not twist or crimp the wiring. All wiring harnesses shall be braided, sheathed in nylon mesh sleeving, or made of PVC or polyethylene insulated jacketed cable. Wiring leading to the cabinet door shall be sheathed in nylon mesh sleeving or be PVC jacketed cable only. All SDLC cabling shall be Belden 7203A or approved equal.

4.4.2 Size

A. All conductors between the main power circuit breakers and the signal power bus shall be a minimum size 10 AWG stranded copper. All conductors carrying individual signal lamp current shall be a minimum size 16 AWG stranded copper. All AC service lines shall be of sufficient size to carry the maximum current of the circuit or circuits they are provided for. Minimum cabinet conductor wire size shall be 22 AWG stranded copper. All wiring and insulation shall be rated for 600V or greater.

B. Conductors for AC common shall be white. Conductors for equipment grounding shall be green. All other conductors shall be a color different than the foregoing.

4.4.3 A barrier terminal block with a minimum of three compression fitting terminals designed to accept up to a number 4 AWG stranded wire shall be provided for connection of the AC power lines. The block shall be rated at 50A.

4.4.4 All terminals shall be permanently identified in accordance with the cabinet wiring diagram. Where through-panel solder lugs or other suitable connectors are used, both sides of the panel shall have the terminals properly identified. Identification shall be permanently attached and as close to the terminal strip as possible and shall not be affixed to any part which is easily removable from the terminal block panel.

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- A. Each controller input and output function shall be distinctly identified with no obstructions, at each terminal point in the cabinet, with both a number and the function designation. The same identification must be used consistently on the cabinet wiring diagrams.
- B. Each load switch socket shall be identified by phase number, overlap number, and pedestrian phase number as applicable. No cabinet equipment, including the load switches themselves, may obstruct these identifications.
- C. Each flash transfer base and power relay base shall be properly identified with no possible obstructions.
- D. Each harness within the cabinet shall be distinctly identified by function on the connector end.
- E. The flasher socket shall be distinctly identified with no possible obstruction.
- F. All other sockets needed within the cabinet to fulfill the minimum requirements of the solicitation, or attachments thereof, shall be distinctly identified.

- 4.4.5 The controller unit harness (a plug) shall be long enough to reach any point 400 mm above the timer shelf. The MMU harness and any required auxiliary harness shall reach 600 mm from the MMU shelf.
- 4.4.6 An unused, spare terminal block providing 10 terminals shall be provided. This block shall be double 8-32 X 5/16 inch binder head screw design with shorting bars. These terminal strips shall be located on the lower third of either side of the cabinet.
- 4.4.7 Copper ground buses shall be provided for both the power supply neutral (common) and chassis ground. Each bus bar must provide a minimum of 10 unused terminals with 8-32 X 5/16 inch or larger screws. The AC neutral and chassis ground buses shall be jumpered together with a minimum number 10 AWG wire.
- 4.4.8 Two 15A and one 30A thermal type circuit breakers shall be mounted and wired in the cabinet. One 15A breaker shall protect the base light, trouble light, GFCI receptacle, modem duplex receptacle, and fans. The other 15A breaker shall be for the two-circuit flasher. The 30A breaker shall protect the signal load circuits, controller circuits, MMU, and card rack detector power supply. The breakers shall be Square "D" QUO 150 Series, or approved equal.
- 4.4.9 The circuit breakers shall be equipped with solderless connectors and installed on the right side wall (facing the cabinet) or lower right hand side of the back panel inside the cabinet. The breakers shall be easily accessible. The breakers shall be positioned so that the rating markings are visible.

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- 4.4.10 A ground fault circuit interruption (GFCI) type duplex receptacle shall be mounted and wired in the lower right side wall of the cabinet. An additional duplex receptacle (for use with communications modems) shall be mounted and wired in the upper left side of the cabinet behind the preempt/interconnect panel. These receptacles shall be wired on the load side of the 15A circuit breaker.
- 4.4.11 The above breakers are in addition to any auxiliary fuses that may be furnished with the controller to protect component parts, such as transformers, etc.
- 4.4.12 The cabinet shall include a surge protection device (SPD) on the AC service input that meets or exceeds the following requirements: The SPD shall be installed on the load side of the cabinet over current device. The SPD shall be equipped with a light or indicator to indicate when a failure has occurred in the surge protection circuitry and have NO/NC contacts for remote alarm. The SPD shall conform to the following:
- Withstand a peak surge current for an 8 X 20 microsecond waveform; minimum 20,000A for 15 occurrences at 3 minute intervals between surges without damage or degradation to the SPD (less than a 10% change in operating parameters).
 - Suppressed Voltage Rating as defined by UL 1449, 2nd edition or latest revision, shall be 400V maximum and Voltage Protection Rating as defined by UL 1449, 3rd edition, of 600V maximum.
 - Devices that are wired in series shall be rated for 30A maximum continuous operating current at 120V/60 Hz.
 - Nominal line or system voltage shall be 120V AC.
 - Minimum short circuit current rating shall be 20 kA.
 - Maximum continuous operating voltage (rms) shall be a minimum of 135V AC.
 - Rated to operate in ambient temperature range of -34°C to +74°C.
 - The SPD unit shall be tested by a nationally recognized test lab for compliance with current UL 1449, 2nd edition or latest revision. A copy of the test results shall be provided upon request.
 - Protected modes shall be L-G, L-N & N-G.

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- Be provided with documentation listing the following information: product/model number; circuit description; nominal operating voltage; maximum continuous load current; maximum continuous operating voltage, modes of protection, connection means, maximum surge current, and suppressed voltage rating, and installation instructions.
- Shall be provided in an enclosure suitable for the temperature range and outdoor environments.
- Shall be provided with mounting hardware, be surface mountable and fit into a space 6 inches long X 5 inches wide X 4 inches deep or less.
- Connections shall be either wire clamping box terminals, lugs, or minimum number 12 AWG wire. Connections for NO/NC contacts shall accept or be minimum stranded number 18 AWG wire.

- 4.4.13 The SPD ground connection shall be connected to the cabinet ground bus by means of a short, copper ground strap or minimum number 10 AWG insulated conductor.
- 4.4.14 If connected in series, the SPD shall be connected to the line filter. Number 10 AWG or larger wire shall be used for connections to the SPD, line filter and load switch bus.
- 4.4.15 A fluorescent light, with switch and rapid start ballast, or LED light with equivalent light quality shall be installed in the cabinet. This light shall turn on when the cabinet door is opened, and turn off when the cabinet door is closed. A MOV or other such transient suppression device shall be placed across the AC power input to the light.
- 4.4.16 A radio frequency interference (RFI) suppresser shall be provided and installed on the load side of the signal circuit breaker and shall be protected by the surge protector. This filter shall be rated at 50A and shall provide a minimum attenuation of 50 decibels over the frequency range of 200 Kz to 75 Mz.
- 4.4.17 Surge suppression devices shall be placed on the coil side of all relays in the cabinet. DC relay coils shall have, as a minimum, a reversed biased diode across the coil. AC relays shall have MOV's or equal suppression across their coils. RC networks are acceptable. One suppression device shall be supplied for each relay.

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- 4.4.18 Except where soldered, all wires shall be provided with lugs or other approved terminal fittings for attachment to binding posts. Insulation parts and wire insulation shall be insulated for a minimum of 600V.
- 4.4.19 The outgoing traffic control signal circuits shall be of the same polarity as the line side of the power source.
- 4.4.20 A switch shall be provided on the inside face of the cabinet door that shall be labeled “Test-Normal” When the switch is in the normal position, the call for flashing operation shall remove the power from the controller unit. When the switch is in the Test position, the call for flashing operation shall permit the controller unit to continue to run so that its operation can be observed.
- 4.4.21 A switch shall be provided near the “Test-Normal” switch to cause the controller unit, and any auxiliary equipment, to stop timing. It shall be labeled “Stop Timing”
- 4.4.22 The cabinet shall be wired so that activation of the MMU will cause the controller unit, and any auxiliary equipment, to stop timing.
- 4.4.23 Conflict and manual flash shall be wired for all red.
- 4.4.24 The cabinet shall be designed and equipped with enough transfer relays for changing any main street indications (movement TS-2, 6, and/or 1, 5) to amber for the conflict and/or manual flash operation on the face of the back panel or a side panel, using only simple tools.
- 4.4.25 Transfer relays shall be the plug-in type manufactured by Midtex (Part No. 136-62T3A1) or AEMCO (Part No. 136-4992), or approved equal. The relays shall have contacts a minimum of 3/8 inch diameter in size and shall be rated at a minimum of 30A/102/240V AC, 20A/28V DC.
- 4.4.26 The red enable and remote reset from the MMU shall be terminated on the face of the back panel.
- 4.4.27 A 75A, solid state relay shall be wired between the RFI filter output and the load switch power bus. The relay shall be controlled by the signal shutdown switch and the flash switch. The relay shall be mounted to a heat sink designed to allow maximum current flow at 74° C without damaging the relay.

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4.4.28 All exposed AC wiring points, including the RFI filter, surge suppresser, and solid state relay shall be covered with a clear non-conductive plastic cover to prevent accidental contact. Unless otherwise noted in this specification, wiring at terminal strips is exempt from this requirement.

4.4.29 The load switch outputs shall be brought out through posted 10-32 X 5/16 inch binder head screw terminals. Field wiring for the signal heads shall be connected at this terminal strip.

5.0 DETECTOR PANEL AND CARD RACK

5.1 The cabinet shall have a loop detector panel mounted on the left side of the cabinet. This panel shall provide for all connections between loops at the street and the detector amplifiers as described in the following sections.

5.2 Detector Card Rack

5.2.1 The card rack for cabinet configurations one, two, and three (12 position backpanel) shall be TS-2 detector rack configuration 2 and shall accommodate up to eight (8) two (2) channel or four (4) four channel TS-2 detector units. Two card racks, one TS-2 detector rack configuration 1 and one TS-2 detector rack configuration 2, shall be provided for cabinet configuration for (16 position backpanel) and shall accommodate up to twelve (12) two (2) channel or six (6) four (4) channel TS-2 detector units.

5.2.2 The detector card rack shall have a rigid frame and shall be fabricated from aluminum and shall have slots set in a modular fashion such that the PCB edge connectors shall plug into the rear while sliding between top and bottom card guides for each module. Mounting flanges shall be provided and be turned outward for ease of access. The detector card rack shall be bolted to a cabinet shelf. It shall be possible to unbolt the rack using simple tools.

5.2.3 All wiring to the rack shall be labeled and neatly run to other parts of the cabinet and detector termination panel. All loop inputs shall be wired with shielded twisted pair leads (Beldon 9451, 2 conductor, 22 AWG with 24 AWG drain wire, shielded cable or approved equal) to improve signal isolation. All grounds within the twisted pair leads shall be connected at the detector terminal panel.

5.2.4 The slots shall be numbered 1 to 8 left to right when viewed from the front of the rack. A flange shall be provided on the top and the bottom of the rack to label each individual channel.

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- 5.2.5 The detector DC supply shall be bussed to a common point and wired to the intersection detector panel.
- 5.2.6 The chassis ground shall be bussed to a common point and wired to the detector panel.
- 5.2.7 The logic ground shall be bussed to a common point and wired to the detector panel.
- 5.2.8 The data address for the detector channels shall be according to TS-2.

5.3 Detector Panel

- 5.3.1 The detector panel shall provide all connections between the detector loops and the detector amplifiers.
- 5.3.2 The panel shall be constructed of 3.2 mm aluminum.
- 5.3.3 The panel shall contain a 76 mm horizontal slot in each corner to accommodate 6.3 mm mounting bolts.
- 5.3.4 All inputs from the loops shall be brought through posted 10-32 X 5/16 inch binder screw terminals or 8-32 X 5/16 inch binder screw terminals.
- 5.3.5 Each loop pair shall be protected by lightning surge suppressers preapproved for use on loop detector inputs by TxDOT's Traffic Operations Division Signal Operations Engineer. The suppressers may be mounted either on the front or behind the panel.
- 5.3.6 The detector panel for cabinet configurations 1, 2, and 3 (12 position) shall provide the following connection points as a minimum for 16 detectors:

<u>Connection Point</u>	<u>Number of Connection Points</u>
External 24V Power Supply	1
Loop Inputs	32, 2 for each Detector
Logic Ground	1
Spares	6
Chassis Ground Bus	1 Bus

The detector panel for cabinet configuration 4 (16 position) shall provide the following connection points as a minimum for 24 detectors:

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<u>Connection Point</u>	<u>Number of Connection Points</u>
External 24V Power Supply	1
Loop Inputs	48, 2 for each Detector
Logic Ground	1
Spares	0
Chassis Ground Bus	1 Bus

- 5.3.7 A chassis ground bus bar shall be provided on the panel and connected to the cabinet by an insulated braided copper ground strap and shall be tied to the loop lead-in grounds. The strap shall be bonded to the cabinet.
- 5.3.8 An additional neutral bus bar shall be provided on the panel and tied to the pedestrian commons.
- 5.3.9 Toggle switches shall be provided to permit the user to input a vehicle or pedestrian call to the control unit. Switches will be provided as follows:
- 16 vehicle and 8 pedestrian switches shall be provided on 12 position cabinets.
 - 24 vehicle and 8 pedestrian switches shall be provided on 16 position cabinets.

6.0 PREEMPT/COMMUNICATION PANEL

- 6.1 A preempt/communication panel shall be provided that contains all interface circuits and wiring for preemption and communication functions. The panel shall be located on the left side of the cabinet interior.
- 6.2 Three input relay circuits, with 120V AC coil and contacts rated for the application, shall be provided on the preempt panel. These circuits shall be used to isolate the incoming preempt commands from the controller unit logic circuitry. The circuits shall be programmable to operate with either a normally open or normally closed relay contact by jumpers on a terminal strip. A barrier strip protected from accidental contact by service personnel shall be supplied to connect the external input. It shall be possible to use either a neutral or hot 120V AC input. Relays used shall be plug-in Potter Brumfield K10P series/Magnecraft W-78 series or interchangeable approved equal. The relays shall be mounted in relay sockets.
- 6.3 Adequate protection of the input relay circuits as well as the preemptor circuitry shall be provided to eliminate damage or false preempt commands caused by line transients or lightning surges. The devices shall have a minimum rating of 20 Joules.

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- 6.4 Three momentary test switches, one for each preempt circuit, shall be provided on the preempt panel. The operator shall not be exposed to hazardous voltages during operation of the test switches.
- 6.5 All necessary interconnection cables and mounting hardware shall be provided.
- 6.6 There shall be a switch on the preempt/communication panel which shall release the local controller to operate in an isolated, full-actuated manner, when necessary for maintenance purposes. The switch positions shall be labeled "System" and "Free".
- 6.7 Terminal connections for 2 twisted pair communication lines shall also be provided with a coordinated 4 stage electrical protection; including primary overvoltage protection, resettable over current protection, secondary clamping voltage protection, and fast transient filtering. The secondary overvoltage stage shall allow peak voltages of no more than 250V. The fast transient filtering stage shall provide no less than 40 dB/decade of attenuation to transients above the required pass band. The 4 stage protection shall be provided in an integrated closure with input/output terminations and ground connection.

7.0 POWER SUPPLY

- 7.1 The power supply shall be a shelf-mounted, enclosed, 24V DC power supply in accordance to Clause 5.3.5 of the NEMA Standards Publication TS-2 2003, or latest revision.
- 7.2 One power supply cable per power supply shall be furnished and installed in each cabinet. The wires shall be terminated to bus bars, terminals on the front of the back panel, detector panels, or connector as appropriate. The connections shall be with forked spade lugs or otherwise as needed. Each individual wire shall be cut to the length required to reach the point at which it is to be connected.
- 7.3 Electrical requirements for the power supply shall be in accordance with Clause 5.3.5 of the NEMA Standards Publication TS-2 1998 as stated above except that the minimum average continuous current capability shall be as shown below with DC voltages having less than 0.5 volts peak to peak ripple:

+12 VDC	5.0 Amps
+24 VDC	2.0 Amps
12 VAC	0.250 Amps

8.0 TWO CIRCUIT SOLID STATE FLASHER

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- 8.1 The solid state, two circuit flasher shall meet the electrical and physical characteristics described in Clause 6.3 of the NEMA Standards Publication TS-2 2003, or latest revision. The flasher shall be Type III (dual circuit rated at 15A per circuit) unit and so constructed that each component may be readily replaced if needed.
- 8.2 The two-circuit flasher shall be of solid state design and contain no electro-mechanical devices.

9.0 LOAD SWITCH

- 9.1 The solid state load switches shall meet the requirements set forth in Clause 6.2 of the NEMA Standards Publication TS-2 2003, or latest revision, and shall be "Triple-Signal Load Switch" type.
- 9.2 An indicator light for each circuit shall be provided in each load switch. The indicator light shall be on when a "Low Voltage Active" input to the load switch is present.

10.0 DOCUMENTATION

- 10.1 Each cabinet shall be provided with the following documentation:
- A. Three complete, accurate, and fully legible diagrams and one schematic for every electronic device. This shall include but not be limited to cabinet wiring, back panel, detector panel, power panel, preempt panel, flasher circuit, load switch, card rack power supply, bus interface unit, and power supply diagrams.
 - B. Complete parts list including names of vendors for parts not identified by universal part numbers such as JEDEC, RETMA, or EIA.
 - C. Manufacturer's specifications for cooling fans which includes the CFM rating of fans.
- 10.2 Each controller unit shall be provided with the following documentation:
- A. One service manual per unit which includes description of controller unit, description of its operation, and basic maintenance and troubleshooting information.
 - B. Two complete, accurate, and readable schematic diagrams for all circuitry in the controller unit. One set of these diagrams may be included in the service manual.
 - C. Complete parts list including names of vendors for parts not identified by universal part numbers such as JEDEC, RETMA, or EIA. This may be included in the service manual.

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D. Pictorial of components layout for each circuit board or individual component identification permanently printed on each circuit board. Regardless of which of the above is provided, each electronic component on the board will need to be clearly identified or labeled. This may be included in the service manual.

10.3 Each MMU shall be provided with one each of the following documentation:

- A. Complete and accurate schematic diagram.
- B. Complete parts list including names of vendors for parts not identified by universal part numbers such as JEDEC, RETMA, or EIA.
- C. Pictorial of component's layout on circuit board(s).
- D. One service manual per unit, which includes description of MMU unit, description of its operation and basic maintenance, and troubleshooting information.

10.4 Respondent shall be prepared to furnish NEMA certification for the complete cabinet assembly from an independent laboratory.

11.0 SOLICITATION REQUIREMENTS

11.1 The supplier's facilities shall be of sufficient size and staffing that any and all warranty repairs to the cabinet assembly provided shall be made on a timely basis. Timely return of equipment is interpreted as a period of time no longer than 18 calendar days from the date of receipt by the supplier to the return receipt of the equipment at the specified location. This requirement may be met by field service. Failure to meet these requirements may result in rejection of future solicitation.

11.2 The controller cabinet shall be delivered on 100 mm X 100 mm runners covered with 12.5 mm plywood to facilitate handling. Runners consisting of stacked 50 mm X 50 mm boards are not acceptable.

11.3 For ventilation purposes while testing, no cabinet components shall be packaged in boxes or bubble wrapped when shipped.

11.4 Polypropylene strapping material shall be used to secure all cabinet components for shipping. All load switches and flash transfer relays must also be secured, but glass filament tape may be used for these components. Other means of securing components are acceptable but require written approval by the Traffic Operations Division Signal Operations Engineer.

**TEXAS DEPARTMENT OF TRANSPORTATION
DEPARTMENTAL SPECIFICATION
TO-4048**

**FULL-ACTUATED SOLID STATE CONTROLLER UNIT (TS 2)
WITH DIAMOND, TBC, PREEMPT, AND CLOSED LOOP OPERATION; AND
BASE-MOUNTED TS 2 CABINET ASSEMBLY**

12.0 TEST AND ACCEPTANCE OF CONTROLLER CABINET ASSEMBLY

- 12.1 The supplier shall burn in each controller cabinet assembly for a period of 48 hours at a temperature of 60° C or for a period of 96 hours at a temperature of 23° C. A certification shall be included with or attached to each controller cabinet indicating the dates of the burn in period, number of hours, burn in temperature, and results.
- 12.2 TxDOT may test any controller cabinet assembly under load in a shop environment for a period of at least 120 hours. During this time, the entire controller cabinet assembly will be inspected for compliance with the specifications.
- 12.3 TxDOT may then perform any or all tests described in NEMA Standard Publication TS-2 2003, or latest revision on one or more complete controller cabinet assemblies on a random sample basis. Environmental sampling and testing shall be in accordance with the Traffic Operations Division Manual of Testing Procedures, Test Method TEX-1170-T, May 1999, or latest revision. Testing will be performed in the normal operating (i.e. non-flashing) range of 95-135V AC. All traffic signal cabinet assembly components shall operate normally at 95V AC as the unit would operate at 120V AC. If any of the assemblies fail any of the tests, the supplier will be permitted to make one complete repair of the order on a timely basis which will be determined by TxDOT and the testing will be redone. The supplier shall reimburse TxDOT for any retesting required during acceptance. The cost for each retest will be based on time and charges and is estimated at \$1,500.00 per test.
- 12.4 Minor discrepancies noted in sampling and test of this item received shall be corrected within a maximum of 30 days of written notice of the discrepancies or as stated in the notice. Major discrepancies that in the opinion of TxDOT will substantially delay receipt and acceptance of the item will be cause for cancellation of the purchase order. Discrepancies found in partial shipments shall be corrected prior to the delivery of subsequent shipments.
- 12.5 The traffic signal controllers and cabinets shall be identical to the approved pre-shipment sample. Any deviations from the approved sample shall be submitted for evaluation and approval before any shipment is accepted for payment.
- 12.6 Deviations from the approved sample after shipment of any parts of the order shall be cause for rejection and non-payment of the remainder of the order. Excessive delays or noncompliance by the vendor at any point in the approval process may be cause for cancellation and non-payment.

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12.7 Date of acceptance will be date that Traffic Equipment Systems Testing Group of the Traffic Operations Division approves the controller cabinet assembly.

12.8 The Traffic Equipment Systems Testing Group shall be provided closed loop software to monitor controller operations during testing.

13.0 MEASUREMENT

13.1 Measurement shall be made of each controller cabinet assembly with components required to make a complete assembly as specified in solicitation.

14.0 WARRANTY

14.1 The cabinet assembly including all contents shall be fully warranted for parts and labor for a minimum of 5 years from the date of acceptance.

14.2 Software/firmware updates shall be included as part of the warranty.

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Appendix A

Each table will designate the options and quantity for each type of cabinet and controller. Check only one box per section.

QUANTITY	<input type="checkbox"/>		
Controller Type			
	Type 1 - SDLC		
	Type 2 - SDLC <i>and</i> A, B, C connectors		
Cabinet Size			
	Size 5 Pole mount – Back panel Configuration 3 (12 position)		
	Size 5 Base mount – Back panel Configuration 3 (12 position)		
	Size 6 Base mount – Back panel Configuration 3 (12 position)		
	Size 6 Base mount – Back panel Configuration 4 (16 position)		
NTCIP			
	NTICP compliant		
	Downward compatible with existing system		

QUANTITY	<input type="checkbox"/>		
Controller Type			
	Type 1 - SDLC		
	Type 2 - SDLC <i>and</i> A, B, C connectors		
Cabinet Size			
	Size 5 Pole mount – Back panel Configuration 3 (12 position)		
	Size 5 Base mount – Back panel Configuration 3 (12 position)		
	Size 6 Base mount – Back panel Configuration 3 (12 position)		
	Size 6 Base mount – Back panel Configuration 4 (16 position)		
NTCIP			
	NTICP compliant		
	Downward compatible with existing system		

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Appendix A (continued)

Each table will designate the options and quantity for each type of cabinet and controller. Check only one box per section.

QUANTITY	<input type="checkbox"/>	
Controller Type		
	Type 1 - SDLC	
	Type 2 - SDLC <i>and</i> A, B, C connectors	
Cabinet Size		
	Size 5 Pole mount with mounting hardware- Back panel Configuration 3 (12 position)	
	Size 5 Base mount – Back panel Configuration 3 (12 position)	
	Size 6 Base mount – Back panel Configuration 3 (12 position)	
	Size 6 Base mount – Back panel Configuration 4 (16 position)	
NTCIP		
	NTICP compliant	
	Downward compatible with existing system	