DMS-11170, Fully Actuated, Solid-State Traffic Signal Controller Assembly

Overview


This Specification governs for a shelf-mounted, 16-phase, full-actuated, solid-state controller unit with internal time based coordination (TBC), railroad and fire (emergency vehicle) preemption (PE), diamond-intersection operation, and closed-loop secondary operation in a traffic signal controller assembly and cabinet assembly.

Supply the equipment type and options identified in the plans or the Invitation to Bid.

Bidders' and Suppliers' Requirements

To be accepted on bids, materials must have approved product codes or designations and be from prequalified producers. The Traffic Operations Division (TRF) of the Texas Department of Transportation (TxDOT) maintains the material producers list of approved producer product codes or designations. Use the following link to view this list: ftp://ftp.dot.state.tx.us/pub/txdot-info/gsd/pdf/to4048preq2.pdf.

The supplier's facilities must be of sufficient size and staffing that all warranty repairs to the cabinet assembly can be made on a timely basis. The interpretation of ‘timely return of equipment’ is no more 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 bids. Ship the controller cabinet enclosed in cardboard on 4 in. X 4 in. (100 mm × 100 mm) runners covered with 0.5 in. (12.5 mm) plywood to facilitate handling. Runners consisting of stacked 2 in. by 2 in. (50 mm × 50 mm) boards are not acceptable.

For ventilation purposes while testing, do not bubble wrap or package cabinet components in boxes when shipping.

Use polypropylene strapping material to secure all cabinet components for shipping. Secure all load switches and flash transfer relays, but glass filament tape may be used for these components. Other means of securing components are acceptable but require written approval by TRF Signal Operations Engineer.

Procurement and Payment

Payment for all materials under this Specification will be in conformance with provisions of the purchase order awarded by the Department or the conditions prescribed in the Contract awarded by the Department.
Prequalification

For prequalification, submit one signal controller cabinet assembly to the Texas Department of Transportation, Traffic Operations Division, 9500 Lake Creek Parkway, Austin, Texas 78717.

The Traffic Operations Division (TRF) tests samples for compliance with this specification and updates the list to include materials that meet the requirements of this specification. If materials fail to meet any of the requirements of this specification, the producer may not resubmit for prequalification until 1 yr. from original evaluation date. TRF may waive this time limit if provided with documentation from an independent testing facility stating that materials meet all requirements. TRF will enforce the 1-yr. time limit if, after retesting, the material again fails any of the requirements of this specification.

All materials submitted for prequalification tests will be at no cost to the Department.

Test and Acceptance

Signal controller cabinet assemblies must meet or exceed all applicable National Electrical Manufacturers Association (NEMA), Texas Manual on Uniform Traffic Control Devices (MUTCD) and Institute of Transportation Engineers Standards and these Specifications. In addition to testing of preshipment samples, complete testing of signal controller assemblies may be required at any time before acceptance.

Burn-in each controller cabinet assembly for a period of 48 hr. at a temperature of 60°C or for a period of 96 hr. at a temperature of 23°C. A certification must 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.

The Department may test any controller cabinet assembly under load in a shop environment for a period of at least 120 hr. During this time, the entire controller cabinet assembly will be inspected for compliance with the Specifications. During this time, the Department will inspect the entire controller cabinet assembly for compliance with the Specifications.

The Department may then perform any or all tests described in NEMA Standard Publication TS 2 1998 on 1 or more complete controller cabinet assemblies on a random sample basis. Environmental sampling and testing will be in accordance with "Tex-1170-T, Sampling and Environmental Testing of Traffic Signal Controller Assemblies: Traffic Signal Controllers and Conflict Monitors." Testing will be performed in the normal operating (i.e., nonflashing) range of 95–135 VAC. All traffic signal cabinet assembly components must operate normally at 95 VAC, just as the unit would operate at 120 VAC. If any of the assemblies fail any of the tests, the supplier will be permitted to make 1 complete repair of the order on a timely basis, which will be determined by the Department, and the testing will be redone. The supplier must reimburse the Department for any retesting required during acceptance. The Department will base the cost for each retest, estimated at $1,500 per test, on time and charges.
Minor discrepancies noted in sampling and test of this item received must be corrected within 30 days of written notice of the discrepancies or as stated in the notice. Major discrepancies that in the opinion of the Department will substantially delay receipt and acceptance of the item will be cause for cancellation of the purchase order. Correct any discrepancies found in partial shipments before the delivery of subsequent shipments.

The traffic signal controllers and cabinets must be identical to the approved preshipment sample. Submit any deviations from the approved sample for evaluation and approval before any shipment is accepted for payment.

Deviations from the approved sample after shipment of any parts of the order will be cause for rejection and nonpayment 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 nonpayment.

Date of acceptance will be date that TRF approves the controller cabinet assembly.

Provide TRF with closed-loop software, hardware, and cables needed to monitor controller operations during testing.

**Warranty**

All equipment must have no less than 95% of the manufacturer's standard warranty remaining on the date that the contractor submits equipment invoices for payment. The Department will not accept any equipment with less than 95% of its warranty remaining.

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

Software and firmware updates must be included as part of the warranty.

**Controller Unit**

The controller unit must meet the requirements of NEMA Standards Publication TS 2-1998 (TS 2), latest edition. Where a difference occurs, these requirements govern. The purchase document must identify either a TS 2 Type 1 interface or TS 2 Type 2 interface. This document specifies the cabinets for TS 2 Type 1 controllers. TS 2 Type 2 controller cabinets must use a cabinet specification identified in the bid document.

Each controller unit must have a unique serial number permanently and neatly displayed on the face of the unit. Affix an additional temporary label, neatly printed or typed, to the controller unit face if the serial number is not on the face of the unit.
Hardware Design Requirements — NEMA Controller

Provide a controller unit that is completely solid state and digitally timed. All timing must be referenced to the 60-Hz power line.

The dimensions of the controller unit must not exceed 12.2 in. (305 mm) H, 17.6 in (440 mm) W, and 12.2 (305 mm) D.

Supply both TS 2 Type 1 and TS 2 Type 2 controllers with Port 1 SDLC and Port 2 RS 232. The TS 2 specification defines the connectors. Port 3 must be capable of FSK communications with a 9-pin FSK connector, unless the plans specify radio communications. Provide a 9-pin RS 232 or 25-pin RS 232 connector, as appropriate, if the plans specify radio communications.

The controller unit must be built using 1 or more circuit boards. All printed circuit boards must be designed to plug into or out of a motherboard or harness within the unit. Requirement exceptions are the power supply, transformers, capacitors, and heat dissipating components.

The design must allow for removal or replacement of a circuit board without unplugging or removing other circuit boards.

The unit must be designed so that 1 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 1 circuit board at a time.

No more than 2 circuit boards may be attached to each other to constitute a circuit subassembly. Attaching hardware must use captive nuts or other approved method to secure the boards together. The boards must be designed so that the Department can test and operate the controller unit with the boards separated.

No circuit cuts will be allowed on circuit boards in any of the equipment supplied. Any wire jumpers included on circuit boards must 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.

All ICs with 16 or more pins must be mounted in machine-tooled sockets. To eliminate solder wicking, all sockets must have 2-piece, machined contacts and closed-end construction. The outer sleeve must be brass with tin or gold plating and tapered to allow easy IC insertion. Surface-mount devices are allowed. The inner contact must be beryllium-copper sub-plated with nickel and plated with gold. All sockets must have thermoplastic bodies meeting UL specification 94V-0. Other high-quality sockets may be acceptable but must have prior written approval of the TRF Signal Operations Engineer. Sockets meeting alternate Specifications must be submitted in writing with the bids. Zero-insertion-force sockets are not allowed.
Each of the following must be simultaneously displayed during standard NEMA dual-ring operation on the face of the unit:

♦ Phases in service (1 per ring)
♦ Phases next to be serviced (1 per ring)
♦ Presence of vehicle call (1 per phase)
♦ Presence of pedestrian call (1 per phase)
♦ Reason for green termination (1 per ring)
  • Gap-out
  • Maximum time-out
  • Force-off
♦ Pedestrian service (1 per ring)
♦ Max II in effect (1 per ring).

User programmed entries must be stored and maintained in nonvolatile memory. Battery power is not allowed for this application.

The controller unit must be designed to operate properly with the logic ground isolated from the AC neutral (common).

Provide a high-quality keyboard with a rated lifetime of $1 \times 10^6$ operations or keystrokes on the front panel of the controller unit. The keyboard will be used for programming all user-entered timings and settings. Provide an operator entry that enables and disables the audible sound output (default must be enabled).

Provide a direct-reading, alphanumeric liquid crystal display with back lighting on the front panel of the controller unit. The display must be clearly readable in ambient light — including the cabinet light, full sunlight, or the absence of light — from a distance of 1.0 m at a 45° angle. The display must have an automatic time-out feature unless the display has an expected continuous life of 10 yr. or more, and must have an operating temperature range of $-34^\circ C$ to $+74^\circ C$. The display must blank out approximately 10 min. after the last keystroke is made.

The display must be a minimum 40-character × 4-line display. The bidder may be required to supply literature demonstrating that all display requirements of this Specification are met before the awarding of the bid. (If a LCD contrast adjustment is required for visibility at temperature extremes, then the control must be on the face of the controller unit, adjustable without the use of tools.)
Time Clock

The clock must use the 60-Hz power line frequency as time base when power is present. The clock operating voltage range must be 89 to 135 VAC over the temperature range of $-34^\circ C$ to $+74^\circ C$. A 10-yr. lithium battery must 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.

The time base clock must be maintained to within $\pm 0.005\%$ at $20^\circ C$ 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.

Clock-Calendar Programming Requirements

The clock must:
♦ be easily set to the year, month, day of month, day of week, hour, minute, and second and
♦ must store sequences of operations in the form of 255 entries and 15-day plans.

The keyboard must provide:
♦ automatic daylight-savings time entry and
♦ the capability for the user to program dates for fixed and floating holidays and special.

Calendar adjustments for leap years must be automatic.

<table>
<thead>
<tr>
<th>Schedules</th>
<th>Global Time Base Schedule</th>
<th>Actuated Traffic Signal Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>Months Dates of Mo Days of Wk. Day Plan</td>
<td>Time Base Actions</td>
</tr>
<tr>
<td>1</td>
<td>1–12 1–31 1–7 1–15</td>
<td>entry 1 actions</td>
</tr>
<tr>
<td>:</td>
<td>&quot; &quot; &quot; &quot;</td>
<td>:</td>
</tr>
<tr>
<td>255</td>
<td>&quot; &quot; &quot; &quot;</td>
<td>entry 255 actions</td>
</tr>
</tbody>
</table>

Structure and Interrelationship of Programs

The structure and interrelationships of each type of program must be in accordance with the following paragraphs.

A day plan must consist of the following:

$$\text{Hour} : \text{Minute} \quad \text{Action 1} \quad \text{(time to implement: action to implement)}$$

$$\text{Hour} : \text{Minute} \quad \text{Action 10} \quad \text{(time to implement: action to implement)}$$

where each action is unique. There must be a minimum of 10 actions per day plan.

There must be a minimum of 15-day plans.
Each action in a day plan must consist of a group of the following objects:

- pattern, consisting of:
  - cycle length
  - offset
  - split
  - MUTCD flash (on-off) and
  - 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 time of day)
- max II
- gap / extension II and
- phase omits.

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

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

An entry must consist of time period implemented: day plan, months, dates of the month, and days of the week.

A minimum of 255 entries must be programmable.

There must be a copy feature that allows the transfer of entries between day plans.

Other programming schemes that meet the functional intent are acceptable but require approval in writing by the TRF Signal Operations Engineer.

Program Requirements

Programming

Programming of the controller unit must be by the use of a keyboard and display on the front of the controller unit. Programming must require only simple keystrokes aided by full menu displays.
Ease of programming through a well-organized menu structure and ease in interpreting the display are required for acceptance. The menu structure must contain a main menu that contains options for all sections of the controller on 1 screen. Each option must be selectable by a numeric entry. Each subsequent menu must be a detailed breakdown of 1 of the previous menu options. Each menu option must be a descriptive name to prompt the user to the desired section for programming. All entries must be displayed and entered in plain English. Toggle-type entries must be set by entering YES-or-NO or ON-or-OFF responses. Non-alphanumeric symbols and abbreviations used to display information must be clear and unambiguous in meaning. Numeric entries must be in the Base-10 (decimal) number system. Entries in other number bases, such as hexadecimal or binary, are not acceptable.

A user-selectable, 4-digit (minimum) code must be available to secure access to timing and configuration of the unit. Display features must be available without the need to access the unit. The controller units must be supplied with the code preset to all zeros. Internal DIP switches may be used to establish codes.

Instructions for use of the access code must not be provided on the face of the unit.

A keyboard-entered, coded command (a series of commands or entries, not a single entry) must be provided setting all controller and TBC timings and entries to a default or inactive value. This coded command must allow new values to be entered without first deleting prior entries.

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

**Phase Operation**

In NEMA operating mode, the controller unit must provide a minimum of 16 possible phases and 8 possible overlaps. The overlaps must be designated as A, B, C, D, E, F, G, and H. All overlaps must be programmable through the keyboard and must function as specified by TS 2.

Each of the NEMA timing intervals must 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.

The controller unit must have a copying mode whereby the user after having programmed all intervals of 1 phase, may copy this information into all or selected remaining phases. Other versions of the copying process that meet the functional intent are acceptable.

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

♦ Soft Recall and
♦ Phase Omit.
The following configurations, as a minimum, must be programmable within the controller unit and be user selectable:

- 8-Phase NEMA
- 8-Phase Sequential
- NEMA phasing to the left of the barrier, sequential phasing to the right of the barrier (Quad Sequential)
- 4-Phase Diamond
- 3-Phase Diamond and

Separate Intersection (see 'Program Requirements' under 'Diamond Operation.')

The controller must have a configuration that allows user-programmable rings (compatibility lines, reference points to prevent concurrent selection and timing of conflicting phases). A minimum of 4 rings must be available in this configuration.

The controller must have programmable conflicting phase settings where simultaneous operation of compatible phases is not allowed.

Provide a dynamic maximum operation that increments the current maximum in programmable steps (dynamic max step) in seconds to a maximum limit (dynamic max limit) in seconds. The operation must function as defined by NEMA Standard Publication National Transportation Communications for ITS Protocol's (NTCIP) 1202:1996 (TS 3.5), "National Transportation Communications for ITS Protocol (NTCIP) Object Definitions for Actuated Traffic Signal Controller Units."

The TBC must select and coordinate reversible left-turn sequence operations (dual leading, leading and lagging, or lagging and leading left turns). It must be possible to transfer operation from 1 sequence to another at a preprogrammed time. Transfer must take place at T₀ during coordination (see 'Coordination' under 'Program Requirements' 2nd paragraph).

**Pedestrian Timing**

Actuated pedestrian movements must operate as follows:

- When no pedestrian calls are present, the normal phase timings will be effective for service of the intersection.

- 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 must return to coordination in the manner described in this Specification after the call is serviced.

The controller must rest in main street green and Don't Walk when no actuated pedestrian calls are present.
Coordination

Provide a minimum of 16 timing plans, each with a unique cycle length and split combination, in accordance with TS 2. Each of the 16 timing plans must have 3 unique offsets available. Each cycle length selection must be changeable from 30 to 255 sec. in 1-sec. increments. Split and offset selections must be adjustable from zero to 254 in 1-sec. increments.

The coordinator must reference a system-wide reference cycle timer (system cycle timer). The term T₀ will refer to the point in the local cycle timer when the first coordinated phase (or leading coordinated phase if the user selected a pair of coordinated phases) is scheduled on for the first time.

Note: This may not be the beginning of green in the case of early return. The offset must be the amount the local cycle timer is behind the system cycle timer. Example: If the offset is +10 sec., then T₀ (the point at which the local cycle timer is at zero will occur when the system cycle timer is at 10 sec.

There must be 2 modes of automatic coordination programming, fixed and floating force-off modes. The following information must be all that is required from the user to establish a pattern:

♦ basic NEMA controller timing
♦ cycle length in seconds
♦ phase sequence desired for the particular pattern
♦ total seconds of the cycle that a phase is to be active including green, yellow, and red clearance times when there is constant demand on all input detectors
♦ the coordinated phase or phases (from ‘Coordination’ and it’s associated paragraph below) and
♦ the offset of the first coordinated phase serviced in the sequence from the reference clock's T₀ in seconds.

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

♦ Guarantee the coordinated phase 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 must start at T₀.
♦ Calculate each phase's force-off point, which is the point at which a phase's green must terminate in order to not violate the following phases' programmed times.
♦ Calculate the beginning of each phase's permissive window, which is the point in the cycle when the coordination phase is allowed to yield to each corresponding phase.
♦ Calculate the end of each phase's vehicle permissive window, which is 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.

♦ Calculate the end of each phase's pedestrian permissive window, which is 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.

♦ 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.

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 noncoordinated 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.

No percentage inputs are allowed. Once the information for phase service is entered via the keyboard, the controller unit must 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 must show an error code indicating the problem. If the error is not corrected, the controller unit must run in free-operation mode whenever the erroneous plan is selected. If actuated pedestrian movements are programmed, the coordinator must ignore errors detected due to the pedestrian Walk and clearance times violating the phase split time for any actuated pedestrian.

The coordinator must 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 will determine which method and may program the longest permissible dwell times.

The controller unit's coordination program must be designed to be programmed from the front panel to emulate the operation of a pretimed controller by recall for applications where no vehicle detection is provided.

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 coordination phase exists. The coordinated phase or phase pair must be selectable from 1 of the individual phases or phase pairs shown in the following table:
Configuration

<table>
<thead>
<tr>
<th>Coordinated Phase(s)</th>
<th>8 Phase NEMA dual ring and 3Φ Diamond</th>
<th>Quad Sequential</th>
<th>8 Phase Sequential</th>
<th>4Φ Diamond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>—</td>
<td>4 or 8</td>
<td>2, 4, 6, or 8</td>
<td>—</td>
</tr>
<tr>
<td>Pairs</td>
<td>2 &amp; 6 or 4 &amp;8</td>
<td>2 &amp; 6</td>
<td>—</td>
<td>2 &amp; 5, 4 &amp;5, 1 &amp; 6, or 1 &amp; 8</td>
</tr>
</tbody>
</table>

Compatible phase pairs must not be forced to begin simultaneously.

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

The internal coordination and upload and download programs must not interfere with normal intersection operation except when changing ring structure in the controller or active phases. These operations (i.e., changing ring structure and active phases) must 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 must be programmed to occur only at points in the controller coordination cycles that do not alter the controller phase sequence. The controller unit may temporarily drop out of synchronization during the upload or download, but must continue to operate.

TBC

The internal reference sync pulse, from which the local offset is calculated, must resynchronize at midnight, or the resynchronization must be user programmable with a default to midnight. A pulse must 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, resync must be calculated from the programmed resync time. The power failure recovery routine must accommodate the case of a power failure at midnight.

Diamond Operation

Program Requirements

Phase numbers must be assigned to traffic movements as shown on the diamond intersection layout in the following figure. Overlap A (OL A) is defined as phases 1+2. Overlap B (OL B) is defined as phases 5+6.
There must be 6 additional user-programmable overlaps. All additional overlaps must be programmable through the keyboard and must function as specified by TS 2.

The controller unit must be programmable for 4-phase and 3-phase diamond operation as well as for 2 independent, 4-phase rings (separate intersection operation) as shown in the following figure.

The following modes must be available for each phase and for the intervals identified as special intervals in 3-phase and 4-phase operation:

- Maximum Recall
- Minimum Recall
- Pedestrian Recall
- Detector Locking and Non-Locking Memory
- Phase Omit.

The controller unit must be designed to provide pedestrian phasing with phases 2, 4, 6, and 8.

All timing entries and displays must be available for phases 3 and 7.

The operation of the controller unit as a 4-phase, 3-phase, or separate-intersection-operation diamond must be keyboard selectable. This must be overridden while under closed-loop system control or by TBC control.
**Four-Phase Operation**

The controller unit must perform the sequences for 4-phase and 6-phase diamond operation defined in the series of 6 figures captioned: “Four-Phase Operation Sequence.”

The normal 4-phase operation sequence must be 25 → 45 → 16 → 18. The 6-phase operation sequence must be 25 → 35 → 45 → 16 → 17 → 18.

The point at which operation may be switched from 4-phase to 3-phase operation must be at the clearance interval 2516B or 2518B to the 3-phase clearance interval 15.

**Concurrent Timing Requirements**

Refer to the series of 6 figures captioned: “Four-Phase Operation Sequence” for the following descriptions:

Intervals 4516B and 4516C must time concurrently with interval 16; however, interval 16 may not terminate green until interval 4516C has timed out.

Intervals 3516B and 3516C must time concurrently with interval 16; however, interval 16 may not terminate green until interval 3516C has timed out.

Intervals 1825B and 1825C must time concurrently with interval 25; however, interval 25 may not terminate green until interval 1825C has timed out.

Intervals 1725B and 1725C must time concurrently with interval 25; however, interval 25 may not terminate green until interval 1725C has timed out.

All left-to-right internal clearance times (intervals 4518B, 4517B, 3518B, 3517B, 2518B, 2517B, and 2516B) must use the same timing settings for minimum green, extension, maximum (max) green, yellow clearance, and red clearance.

All right-to-left internal clearance times (intervals 1845B, 1835B, 1745B, 1735B, 1645B, 1635B, and 1625B) must use the same timing settings for minimum green, extension, max green, yellow clearance, and red clearance.

Separate timing settings for minimum green, extension, max green, yellow clearance, and red clearance must be provided for each of the 4 external clearance intervals (1825B, 1725B, 4516B, and 3516B).
Figure 3. Four-Phase Operation Sequence — Clearance Intervals from Phase 25

Figure 4. Four-Phase Operation Sequence — Clearance Intervals from Phase 45
Figure 5. Four-Phase Operation Sequence — Clearance Intervals from Phase 18

Figure 6. Four-Phase Operation Sequence — Clearance Intervals from Phase 16
Diamond Detector Operation

The loop-detector layout for 3-phase, 4-phase, 6-phase, or separate-intersection diamond operation must be as shown in the following figure. The detector operation defined must be automatically loaded when any diamond sequences are selected.
Figure 9. Loop-Detector Layout for Diamond-Intersection Operation

The controller unit software must provide the logic for detector operation described in the following table:

<table>
<thead>
<tr>
<th>Detector</th>
<th>4- and 3-Phase Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In 4-phase operation:</td>
</tr>
<tr>
<td></td>
<td>♦ Must call phase 6 if Overlap A is not green and phase 7 is not called.</td>
</tr>
<tr>
<td></td>
<td>♦ Must call phase 6 if Overlap A is not green and phase 8 is not called.</td>
</tr>
<tr>
<td></td>
<td>♦ Extend intervals 2516B, 2517B, 2518B, 4517B, 4518B, 3517B, and 3518B.</td>
</tr>
<tr>
<td></td>
<td>In 3-phase operation:</td>
</tr>
<tr>
<td></td>
<td>♦ Must call and extend phase 1 (left turn).</td>
</tr>
<tr>
<td>5</td>
<td>In 4-phase operation:</td>
</tr>
<tr>
<td></td>
<td>♦ Must call phase 2 if Overlap B is not green and phase 3 is not called.</td>
</tr>
<tr>
<td></td>
<td>♦ Must call phase 2 if Overlap B is not green and phase 4 is not called.</td>
</tr>
<tr>
<td></td>
<td>♦ Extend Intervals 1625B, 1635B, 1645B, 1735B, 1745B, 1835B, and 1845B.</td>
</tr>
<tr>
<td></td>
<td>In 3-phase operation:</td>
</tr>
<tr>
<td></td>
<td>♦ Must call and extend phase 5 (left turn).</td>
</tr>
<tr>
<td>2, 3, 4, 6, 7, and 8</td>
<td>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 the figure titled 'Loop-Detector Layout for Diamond-Intersection Operation.' These detectors must have a 2-sec. delay set during red conditions of their parent phase. The detectors are used to extend the parent phase during green.</td>
</tr>
<tr>
<td>11, 12, 15, 16, 17, and 18</td>
<td>These detectors are stop bar detectors and are used to call the associated parent phases shown in the figure titled 'Loop-Detector Layout for Diamond-Intersection Operation.' The parent phase green plus a call for that phase plus a 0.2-sec. gap on the detector must disable the detector until the end of green.</td>
</tr>
</tbody>
</table>
9 and 10

In 4-phase operation:
- Must extend phase 2 if phase 3 is called
- Must extend phase 2 if phase 4 is called
- Must call phase 6 if Overlap A is not green and phase 7 is not called
- Must call phase 6 if Overlap A is not green and phase 8 is not called
- Extend intervals 2516B, 2517B, 2518B, 4517B, 4518B, 3517B, and 3518B

In 3 phase operation:
- Must 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

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In 4 phase operation:
- Must extend phase 6 if phase 7 is called
- Must extend phase 6 if phase 8 is called
- Must call phase 2 if Overlap B is not green and phase 3 is not called
- Must call phase 2 if Overlap B is not green and phase 4 is not called
- Extend Intervals 1625B, 1635B, 1645B, 1735B, 1745B, 1835B, and 1845B

In 3 phase operation:
- Must 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

**Three-Phase Operation**

The controller unit must be keyboard selectable for 3-phase diamond operation.

The controller unit must perform the sequences for 3-phase diamond operation defined in the figure titled ‘Three-Phase Diamond Operation’ and in the table titled ‘Three-Phase Diamond Sequence.’

The normal sequence of operation must be \( 4 + 8 \rightarrow 2 + 6 \rightarrow 1 + 5 \).

The point at which operation may be switched from 3-phase to 4-phase operation must be through the transition phase sequence to 4-phase interval 25 as indicated in the figure titled ‘Three-Phase Diamond Operation.’

The controller must 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 or phases to be serviced next conflict 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 must override this feature. The phases must not be allowed to advance to a green interval beyond the rest state that might override or defeat the simultaneous gap operation.
Texas Department of Transportation 20 08/04–10/08

Departmental Material Specifications
DMS-11170, Fully Actuated, Solid State
Traffic Signal Controller Assembly

Figure 10. Three-Phase Diamond Operation

♦ Three-Phase Diamond Sequence

<table>
<thead>
<tr>
<th>From Interval</th>
<th>IF Call On</th>
<th>AND No Call On</th>
<th>GO TO Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>2 and 6</td>
<td>----</td>
<td>2+6</td>
</tr>
<tr>
<td></td>
<td>2 or 6</td>
<td>1 or 5</td>
<td>2+6</td>
</tr>
<tr>
<td></td>
<td>1 and 6</td>
<td>2</td>
<td>1+6</td>
</tr>
<tr>
<td></td>
<td>2 and 5</td>
<td>6</td>
<td>2+5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1 or 2 or 6</td>
<td>4+5</td>
</tr>
<tr>
<td></td>
<td>1 and 5</td>
<td>2 or 6</td>
<td>1+5</td>
</tr>
<tr>
<td>45</td>
<td>8</td>
<td>----</td>
<td>4+8 if 4+8 Was Not Serviced Immediately Before 4+5</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1 or 2 or 6</td>
<td>4+8</td>
</tr>
<tr>
<td></td>
<td>2 and 6</td>
<td>8</td>
<td>2+6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>8 or 1</td>
<td>2+6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8 or 6</td>
<td>2+5</td>
</tr>
<tr>
<td></td>
<td>1 and 6</td>
<td>8 or 2</td>
<td>1+6</td>
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<td></td>
<td>1</td>
<td>8 or 2 or 6</td>
<td>1+5</td>
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<td>18</td>
<td>4</td>
<td>----</td>
<td>4+8 if 4+8 Was Not Serviced Immediately Before 1+8</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5 or 2 or 6</td>
<td>4+8</td>
</tr>
<tr>
<td></td>
<td>2 and 6</td>
<td>4</td>
<td>2+6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4 or 5</td>
<td>2+6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4 or 2</td>
<td>1+6</td>
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<tr>
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<td>4 or 6</td>
<td>2+5</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 or 2 or 6</td>
<td>1+5</td>
</tr>
</tbody>
</table>

Transition Phase to 4 Phase Operation
### Three-Phase Diamond Sequence

<table>
<thead>
<tr>
<th>From Interval</th>
<th>IF Call On</th>
<th>AND No Call On</th>
<th>GO TO Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>1 and 5 or 4 or 8</td>
<td>2 or 6</td>
<td>1+5</td>
</tr>
<tr>
<td>5</td>
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<td>2+5</td>
<td></td>
</tr>
<tr>
<td>2 and 5</td>
<td>6</td>
<td>2+5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 or 4 or 8</td>
<td>1+6</td>
<td></td>
</tr>
<tr>
<td>1 and 6</td>
<td>2</td>
<td>1+6</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>1 or 8</td>
<td>----</td>
<td>1+5</td>
</tr>
<tr>
<td>4</td>
<td>1 or 8</td>
<td>4+5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1 or 4 or 8</td>
<td>2+6</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>4 or 5</td>
<td>----</td>
<td>1+5</td>
</tr>
<tr>
<td>8</td>
<td>4 or 5</td>
<td>1+8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4 or 5 or 8</td>
<td>2+6</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>4 and 8</td>
<td>----</td>
<td>4+8</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>4+5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>1+8</td>
<td></td>
</tr>
<tr>
<td>2 and 6</td>
<td>4 or 8</td>
<td>2+6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4 or 6 or 8</td>
<td>2+5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2 or 4 or 8</td>
<td>1+6</td>
<td></td>
</tr>
</tbody>
</table>

### Coordination-Control Hierarchy

When the system switch is in the SYSTEM position, the controller unit must be under the control of the master controller or TBC.

In the absence of any on line closed-loop-system control by a master controller, the internal TBC must control the coordinated, free, and flash operation of the intersection when the system switch is in the SYSTEM position.

When a master controller brings the intersection on line, its control must supersede that of the internal time-base coordination.

When the system switch is in the FREE position, the controller unit must operate in a noncoordinated (free) mode.

### PE

The internal preemptor supplied must be easily programmable from the front panel for either railroad- or emergency-vehicle PE sequences.

Phases must be selectable such that a limited signal sequence may be operational during PE. It must be possible to add phases that are not in the intersection sequence to this special limited sequence. This must be accomplished without adding external logic.
The intervals shown in the following table must be provided as a minimum. Terminology may vary, but the meaning must be clear. Additional unspecified intervals that may lead to confusion must be programmable to zero. If abbreviations are used on the display, they must be defined on the front panel. While in PE, the display must clearly identify the intervals being timed as PE intervals. Yellow and red clearances from the phase timings may be used in place of the clearance intervals shown.

### PE Timing Interval Definitions

All intervals are sequential.

<table>
<thead>
<tr>
<th>Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. PE Delay</td>
<td>This time must start immediately when the PE command is received. It must 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) PE delay. If zero time is set, the interval must be omitted.</td>
</tr>
<tr>
<td>1. PE Minimum Duration</td>
<td>The PE sequence must not terminate until the PE input signal is removed and the Minimum Duration time has expired.</td>
</tr>
<tr>
<td>2. PE Minimum Green</td>
<td>Any vehicle signal that is green at the time this interval becomes active must not terminate unless it has been displayed for at least the time programmed in this interval. If zero time is set; the interval must be omitted.</td>
</tr>
<tr>
<td>3. PE Minimum Walk</td>
<td>PE Minimum Walk Time (in seconds). A PE-initiated transition must not cause the termination of a Walk before its display for this period.</td>
</tr>
<tr>
<td>4. PE Ped Clearance</td>
<td>At the time of PE call, walk-indications must immediately change to Pedestrian Clearance interval. The Pedestrian Clearance interval must not terminate unless it has been displayed for at least the time programmed in this interval. If zero time is set; the interval must be omitted.</td>
</tr>
<tr>
<td>5. PE Track Green</td>
<td>Signals programmed as track (or fire-lane) signals must remain green or be changed to green. All other signals must be red. This interval must be optionally programmable to zero during emergency-vehicle PE.</td>
</tr>
<tr>
<td>6. PE Dwell Green</td>
<td>Minimum Dwell Time (entered in seconds). This parameter controls the minimum timing for the dwell movement. The phases allowed during the dwell interval must be selectable to include all phases that do not cross the track. The dwell interval must not terminate before the completion of PE-duration time and PE-dwell time, and until the call is no longer present. Each signal must be keyboard-programmable for red, red flash, yellow flash, or green. As an alternative, a limited cycle must be programmable for use with railroad PEs.</td>
</tr>
<tr>
<td>7. PE Exit Ped Clear</td>
<td>PE Exit Pedestrian Clear Time (in seconds). This parameter controls the pedestrian clear timing for a walk signal transition to the exit phase or phases.</td>
</tr>
<tr>
<td>8. PE Exit Yellow</td>
<td>This interval must provide a solid yellow clearance for indications that were green or flashing yellow. Red and flashing red displays must display solid red.</td>
</tr>
<tr>
<td>9. PE Exit Red Clearance</td>
<td>This interval must be an all-red clearance in preparation for return to the normal cycle. Return phases must be programmable from the keyboard.</td>
</tr>
<tr>
<td>10. PE Max Call</td>
<td>This interval is the amount of time that a PE call may remain active and be considered valid. When the PE call has been active for this amount of time, the controller must return to normal operation. The PE call must be considered invalid until the call is no longer active.</td>
</tr>
</tbody>
</table>
The following table shows PE timing interval ranges:

<table>
<thead>
<tr>
<th>PE Timing Interval</th>
<th>Time (seconds)</th>
<th>Increments (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. PE Delay (Emergency vehicle PE)</td>
<td>0–999</td>
<td>1</td>
</tr>
<tr>
<td>1. PE Minimum Duration</td>
<td>0–999</td>
<td>1</td>
</tr>
<tr>
<td>2. PE Minimum Green</td>
<td>1–255</td>
<td>1</td>
</tr>
<tr>
<td>3. PE Minimum Walk</td>
<td>1–255</td>
<td>1</td>
</tr>
<tr>
<td>4. PE Ped Clearance</td>
<td>1–255</td>
<td>1</td>
</tr>
<tr>
<td>5. PE Track Green</td>
<td>1–255</td>
<td>1</td>
</tr>
<tr>
<td>6. PE Dwell Green</td>
<td>1–255</td>
<td>1</td>
</tr>
<tr>
<td>7. PE Exit Ped Clear</td>
<td>0–255</td>
<td>1</td>
</tr>
<tr>
<td>8. PE Exit Yellow</td>
<td>3.0–25.5</td>
<td>0.1</td>
</tr>
<tr>
<td>9. PE Exit Red Clearance</td>
<td>0–25.5</td>
<td>0.1</td>
</tr>
<tr>
<td>10. PE Max Call</td>
<td>0–999</td>
<td>1</td>
</tr>
</tbody>
</table>

The phases to be serviced following the PE sequence must be front-panel-keyboard programmable.

Preempt sequences must be selectable using external inputs. Preempt priority must be assigned with #1 being the highest. If a higher-priority PE input is received during a PE sequence, the controller unit must immediately transition to the new sequence subject to the constraints of PE Minimum Green and PE Minimum Walk. The transition must take place in a safe manner from any point in the sequence and must meet all Texas MUTCD requirements. Provisions must be made to clear 2 conflicting track phases from a single PE input. This may be provided by 2-track clearance phases for a single PE or by combining 2 PEs.

PE 1 must be reserved for a priority railroad PE. If more than 2 PEs are provided, it must be possible to delete the priority override for all but the railroad PE. If a nonpriority PE is activated during another PE cycle, the one in progress must continue through its entire cycle. If the second PE input is still active when the first one is completed, the controller unit must immediately go to all-red flash or initiate the nonpriority PE. When all PE inputs are removed, the controller unit must proceed through the normal sequence to Return Red Clearance (interval 9).

Once the controller unit has entered the first timed interval following Preempt Delay (interval 1), the sequence must continue to the end, even if the PE call is dropped. If the call returns, the Minimum Preempt Duration (interval 1) the controller unit should reinitiate track green and complete the PE sequence.
The controller unit must be programmable to be in flash or in limited sequence during interval 6. If flash is specified, the phases must flash yellow or red as programmed from the front panel. Flash must be implemented by simultaneously flashing the appropriate load-switch driver outputs. If limited sequence is selected, all phases must be programmable even if not normally used in the intersection sequence.

In the event of a power interrupt as defined by TS 2, if the PE command is present when power is restored, the controller unit must power up in cabinet flash operation and remain there until the PE command is removed.

Overlap phases must 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 must display a minimum of 3 sec. of yellow and a minimum of 1 sec. of red clearance.

Don't Walk must be displayed throughout the PE sequence unless a limited cycle is run. During a limited cycle (interval 6) the pedestrian heads may be programmed to be dark.

Preempt routines must have priority over all controller functions.

The controller must be programmable to allow multiple track clearance phases either within a single PE sequence or by mapping multiple PEs together in all modes of operation including 3-phase and 4-phase diamond modes.

Closed-Loop Operation and Monitoring Software (CLS)

The controller software must either be capable of implementing the 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, must be provided internal to the timer. All necessary cables and communication ports needed for operation in a closed-loop-system cabinet must be provided. The modems must meet TS 2 environmental requirements for traffic signal equipment.

Window-based CLS software must be provided (with a minimum of 5 licensed users per copy), according to the plans or the Invitation to Bid, that allows the monitoring, setup, and programming of all controller unit timing entries, functions, and features. These functions and features must include but not be limited to the following:

♦ monitoring signal indications, detectors, alarms, and time-base functions
♦ controller-database error checking
♦ coordination parameters
♦ remote resetting of coordination errors
♦ toggle-special function outputs from the controller
♦ ability to receive reports and alarms generated from the controller.

♦ 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) must be provided.

All controller-keyboard capabilities must also be available remotely through the computer interface through a telephone modem connection. The software must not require that the controller unit be connected while making entries until the actual download-upload process.

Personal data assistants (i.e., Palm Pilot®™, IPAC's®™, etc.) must also be provided according to the plans or the Invitation to Bid. All necessary cables and hardware to upload and download intersection-timing programs must be provided.

A cable must be supplied to direct-connect the controller to a PC in order to upload and download data as well as monitor the controller operation.

The controller must have a minimum of 8 detector inputs per intersection for use with closed-loop-system operation. The system must 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 must be made for a minimum of 8 system detectors at any local controller, in addition to any local detectors.

NTCIP Compliance

The controller software must comply with the referenced NTCIP Standards when installed. The software must comply with the versions of the relevant NTCIP standards that are current at the date of this document or a later version.

The software must comply with NEMA Standard Publication TS 3.2-1996 (TS 3.2), "The Simple Transportation Management Framework," and must meet the requirements for Conformance Level 2. The software must comply with NEMA Standard Publication TS 3.3-1996 (TS 3.3), "The Class B Profile," and must include both an EIA/TIA 232-E and an FSK modem interface for NTCIP-based communications.

The software must implement all mandatory objects of all mandatory conformance groups as defined in "Global Object Definitions," NEMA Standard Publication NTCIP 1201:1996 (TS 3.4):

♦ Configuration Conformance Group and Actuated Signal Controller Object Definitions, NEMA Standard Publication NTCIP 1202:1996 (TS 3.5)

♦ Phase Conformance Group

♦ Detector Conformance Group.
The software must implement all mandatory objects of all optional conformance groups as defined in "Global Object Definitions," NTCIP 1201:1996:

♦ Database Management Conformance Group
♦ Time Management Conformance Group
♦ Time Base Event Schedule Conformance Group
♦ Report Conformance Group
♦ STMF Conformance Group
♦ 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.

The software must also implement the following optional objects as defined in the "Global Object Definitions," NTCIP 1201:1996:

♦ globalSetIDParameter
♦ dbMakeID
♦ eventLogOID
♦ eventConfigAction and
♦ eventClassDescription.

The software must also implement the following optional objects as defined in the "Actuated Signal Controller Object Definitions," NTCIP 1202:1996:

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

All objects required by these procurement Specifications must support all values within their standardized ranges, unless otherwise approved by the Project Engineer. A size, range, or enumerated listing indicated in the object's SYNTAX field or through descriptive text in the object's DESCRIPTION field of the relevant standard defines the ‘standardized range.’ The following table provides the current listing of known variances for this project:

### Object Range Values for Actuated Signal Controllers

<table>
<thead>
<tr>
<th>Object</th>
<th>Minimum Project Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NTCIP 1201:1996:</strong></td>
<td></td>
</tr>
<tr>
<td>moduleType</td>
<td>Value 3</td>
</tr>
<tr>
<td>dbCreateTransaction</td>
<td>All Values</td>
</tr>
<tr>
<td>dbErrorType</td>
<td>All Values</td>
</tr>
<tr>
<td>globalDaylightSaving</td>
<td>Values 2 &amp; 3</td>
</tr>
<tr>
<td>maxTimeBaseScheduleEntries</td>
<td>255</td>
</tr>
<tr>
<td>maxDayPlans</td>
<td>15</td>
</tr>
<tr>
<td>maxDayPlanEvents</td>
<td>10</td>
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<tr>
<td>maxEventLogConfigs</td>
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<tr>
<td>eventConfigMode</td>
<td>Values 2 thru 5</td>
</tr>
<tr>
<td>eventConfigAction</td>
<td>Values 2 &amp; 3</td>
</tr>
<tr>
<td>maxEventLogSize</td>
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<td>maxEventClasses</td>
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<td>maxGroupAddress</td>
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<td><strong>NTCIP 1202:1996:</strong></td>
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<tr>
<td>maxPhases</td>
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<td>phaseStartup</td>
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<td>phaseOptions</td>
<td>All Values</td>
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<td>Object Range Values for Actuated Signal Controllers</td>
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<tr>
<td>---------------------------------------------------</td>
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</tr>
<tr>
<td><strong>Object</strong></td>
<td><strong>Minimum Project Requirements</strong></td>
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<td>maxVehicleDetectors</td>
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<td>vehicleDetectorOptions</td>
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<tr>
<td>maxPedestrianDetectors</td>
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<tr>
<td>unitAutoPedestrianClear</td>
<td>All Values</td>
</tr>
<tr>
<td>unitControlStatus</td>
<td>All Values</td>
</tr>
<tr>
<td>unitFlashStatus</td>
<td>All Values</td>
</tr>
<tr>
<td>unitControl</td>
<td>All Values</td>
</tr>
<tr>
<td>maxAlarmGroups</td>
<td>1</td>
</tr>
<tr>
<td>maxSpecialFunctionOutputs</td>
<td>8</td>
</tr>
<tr>
<td>coordCorrectionMode</td>
<td>Values 2 thru 4</td>
</tr>
<tr>
<td>coordMaximumMode</td>
<td>Values 2 thru 4</td>
</tr>
<tr>
<td>coordForceMode</td>
<td>Values 2 &amp; 3</td>
</tr>
<tr>
<td>maxPatterns</td>
<td>48</td>
</tr>
<tr>
<td>patternTableType</td>
<td>Either 2 or 3</td>
</tr>
<tr>
<td>maxSplits</td>
<td>16</td>
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<tr>
<td>splitMode</td>
<td>Values 2 thru 7</td>
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<tr>
<td>localFreeStatus</td>
<td>Values 2 thru 11</td>
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<td>maxTimebaseASCActions</td>
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<td>maxPreempts</td>
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<tr>
<td>preemptControl</td>
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<tr>
<td>preemptState</td>
<td>Values 2 thru 9</td>
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<td>maxRings</td>
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<td>maxSequences</td>
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<td>maxChannels</td>
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<tr>
<td>channelControlType</td>
<td>Values 2 thru 4</td>
</tr>
<tr>
<td>channelFlash</td>
<td>All Values</td>
</tr>
<tr>
<td>channelDim</td>
<td>All Values</td>
</tr>
<tr>
<td>maxChannelStatusGroups</td>
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<td>maxOverlaps</td>
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<tr>
<td>overlapType</td>
<td>Values 2 &amp; 3</td>
</tr>
<tr>
<td>maxOverlapStatusGroups</td>
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</tr>
<tr>
<td>maxPort1Addresses</td>
<td>255</td>
</tr>
<tr>
<td>port1Status</td>
<td>Values 2 &amp; 3</td>
</tr>
</tbody>
</table>

The controller must be able to implement all NTCIP messages called for in this Specification without any additional vendor-specific proprietary statements.
The software must be supplied with full documentation, including 3.5-in. floppy disks or a CD-ROM containing ASCII versions of the relevant official NEMA standard MIB modules referenced by the device functionality. These must be in ASN.1 format. In addition, if the device does not support the full range of any given object within a NEMA standard MIB module, supply 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 must be the same as the standard MIB filename with ".man" as the extension.

The software documentation must also include 3.5-in. floppy disks or a CD-ROM containing ASCII versions of all manufacturer-specific objects supported by the device in ASN.1 format and in a manufacturer-specific MIB with accurate and meaningful DESCRIPTION fields and supported ranges indicated in the SYNTAX field of the OBJECT-TYPE macros.

The manufacturer may not place any restrictions on the dissemination of this documentation within the Department.

The manufacturer must provide a copy of the following table completed to describe the operation of their controller including which objects are used and the procedures performed with these objects to implement the functions listed using NTCIP.

<table>
<thead>
<tr>
<th>Controller Operation</th>
<th>Function</th>
<th>Objects</th>
<th>Procedures to Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example:</strong> Function X</td>
<td>Object T</td>
<td>Get object T then send objects Y and Z if T&gt;0.</td>
<td></td>
</tr>
<tr>
<td>Change split time in an active coordination plan</td>
<td>Object Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change ring structure</td>
<td>Object Z</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change Min Green in an active coordination plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change alternate sequence in an active coordination plan</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Malfunction Management Unit (MMU)**

This Specification sets forth the minimum requirements for a shelf-mountable, 16-channel, solid-state MMU. The MMU must meet, as a minimum, Section 4 of the NEMA Standards Publication TS 2-1998. Where differences occur, this Specification governs.

No circuit cuts are allowed on circuit boards in any of the equipment supplied. Any wire jumpers included on circuit boards must 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.
All ICs with 16 or more pins must be mounted in machine-tooled sockets. To eliminate solder wicking, all sockets must have 2-piece, machined contacts and closed-end construction. The outer sleeve must be brass with tin or gold plating and must be tapered to allow easy IC insertion. The inner contact must be beryllium-copper sub-plated with nickel and plated with gold. All sockets must have thermoplastic bodies meeting UL specification 94V-0. Other high quality sockets may be acceptable but must have prior approval of the TRF Signal Operations Engineer. Surface-mount devices will be allowed. Proposals for use of sockets meeting alternate Specifications must be submitted in writing with the bids. Zero-insertion-force sockets will not be allowed.

The design must allow for removal or replacement of a circuit board without unplugging or removing other circuit boards.

The unit must be designed so that 1 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 1 circuit board at a time.

If extender boards are required to meet the above requirement, provide 1 set for every 10 MMUs ordered or portion thereof with the order.

No more than 2 circuit boards may be attached to each other to constitute a circuit assembly. Attaching hardware must use captive nuts or other acceptable method to secure the boards together. Alternate methods may be submitted in writing with the bids. The boards must be designed so that the Department can test and operate the controller unit with the boards separated.

If this Specification is used to support the purchase of a complete controller assembly, the unused red circuits must be connected to the AC line in the controller cabinet.

Preprogram the MMU in accordance with the following table:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Load Switch</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel 1</td>
<td>Load Switch 1</td>
<td>Phase 1 Vehicle</td>
</tr>
<tr>
<td>Channel 2</td>
<td>Load Switch 2</td>
<td>Phase 2 Vehicle</td>
</tr>
<tr>
<td>Channel 3</td>
<td>Load Switch 3</td>
<td>Phase 3 Vehicle</td>
</tr>
<tr>
<td>Channel 4</td>
<td>Load Switch 4</td>
<td>Phase 4 Vehicle</td>
</tr>
<tr>
<td>Channel 5</td>
<td>Load Switch 5</td>
<td>Phase 5 Vehicle</td>
</tr>
<tr>
<td>Channel 6</td>
<td>Load Switch 6</td>
<td>Phase 6 Vehicle</td>
</tr>
<tr>
<td>Channel 7</td>
<td>Load Switch 7</td>
<td>Phase 7 Vehicle</td>
</tr>
<tr>
<td>Channel 8</td>
<td>Load Switch 8</td>
<td>Phase 8 Vehicle</td>
</tr>
</tbody>
</table>

Each MMU must have a unique serial number permanently and neatly displayed on the face of the unit. If this serial number is located elsewhere on the unit, affix an additional temporary label, neatly printed or typed, to the MMU face.
TS 2 Cabinet Assembly

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 must include the cabinet, flasher, card rack or racks, an MMU, an external power supply, and 6 flash-transfer relays. For cabinet assemblies of configuration 4 (16 position), the assembly must include 16 load switches; and for cabinet assemblies of configuration 3 (12 position), the assembly must include 12 load switches. All cabinets must include appropriate mounting hardware.

Cabinet Design Requirements

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

The size of the cabinet must be size 5 or size 6 as defined by TS 2, Clause 7.3, of the NEMA Standard Publication TS 2 - 1998, as specified by the plans. The load bay must be configuration 3 (12 position) or configuration 4 (16 position) as defined by TS 2, Clause 5.3, as specified by the plans. Provide the cabinet option shown on the plans with features and configuration in accordance with the following table:

<table>
<thead>
<tr>
<th>Cabinet Options</th>
<th>Size of Cabinet</th>
<th>Back Panel Configuration</th>
<th>Size of Load Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pole Mount</td>
<td>TS 2 Size 5</td>
<td>3</td>
<td>12 position</td>
</tr>
<tr>
<td>2 Base Mount</td>
<td>TS 2 Size 5</td>
<td>3</td>
<td>12 position</td>
</tr>
<tr>
<td>3 Base Mount</td>
<td>TS 2 Size 6</td>
<td>3</td>
<td>12 position</td>
</tr>
<tr>
<td>4 Base Mount</td>
<td>TS 2 Size 6</td>
<td>4</td>
<td>16 position</td>
</tr>
</tbody>
</table>

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

Vertical shelf support channels must be provided to permit adjustment of shelf location in the field. The channels must 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.

Each cabinet must 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 the Department to mount additional equipment as necessary.
Shelves must 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. Provide a 38-mm drawer in the cabinet, mounted directly beneath the controller support shelf. The drawer must have a hinged top cover and be capable of storing documents and miscellaneous equipment. This drawer must support to 22.5 kg in weight when fully extended. The drawer must open and close smoothly. Drawer dimensions must make maximum use of available depth offered by the controller shelf. The drawer width must be at least 600 mm.

Provide 2 shelves in the cabinet with a minimum height of 305 mm. There must be sufficient shelf space to accommodate a controller unit 330 mm high, an MMU, one 8-position card rack, and an external power supply. Provide an additional space at least 305 mm high, 325 mm wide, and 305 mm deep. The controller unit, MMU, card racks, and power supply must be placed on the shelves in such a manner that ventilation is sufficiently provided to all components. Provide labels showing the proper placement of each component along the shelves to ensure proper placement.

The cabinet must be vented and cooled by 2 thermostatically controlled fans. The fans must be a commercially available model with a capacity of at least 2.7 m³/min. The thermostats must be adjustable with a range of 20°C to 43°C. Provide a press-to-test switch for testing the operation of the fans.

Provide the cabinet with a unique 5-digit serial number 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 must be at least 5 mm in height and located on the upper right sidewall of the cabinet near the front.

**Cabinet Door**

Provide the cabinet with 1 door in front that will provide access to the cabinet. The door must have 3 hinges with nonremovable stainless-steel pins, or a full-length piano hinge with stainless-steel pins spot welded at the top of the hinge. The hinges must be mounted so that it is not possible to remove them from the door or cabinet without first opening the door. The bottom of the door opening must extend at least to the bottom level of the back panel. The door and hinges must 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 must be no permanent deformation or impairment of any of the door or the cabinet body when the load is removed.
The cabinet door must be fitted with a Number-2 Corbin lock and a cast-aluminum or chrome-plated steel handle with a 16-mm (minimum) diameter shaft (or equivalent cross-sectional area for a square shaft) and a 3-point latch. The lock and latch design must be such that the handle cannot be released until the lock is released. Provide one key for each cabinet. Provide a gasket to act as a permanent dust- and weather-resistant seal at the controller cabinet door facing. The gasket material must be of a nonabsorbent material and must maintain its resiliency after long-term exposure to the outdoor environment. The gasket must have a minimum thickness of 6.25 mm. The gasket must be located in a channel provided on the cabinet or on the door. 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 departmental approval during inspection of an order.

A locking, auxiliary police door must be provided in the door of the cabinet to provide access to a panel that must 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 must 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 must advance the controller to the next interval. Manual control must not override any calls for PE. The police door must be gasketed to prevent entry of moisture or dust and the lock must be provided with 1 brass key.

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

**Wiring**

All wiring within the cabinet must be neat and routed such that opening and closing the door or raising and lowering the back panel will not twist or crimp the wiring. All wiring harnesses must be braided, sheathed in nylon-mesh sleeving, or made of PVC or polyethylene-insulated jacketed cable. Wiring leading to the cabinet door must be sheathed in nylon-mesh sleeving or be PVC-jacketed cable only. All SDLC cabling must be Belden #7203A or approved equivalent.
Meet the following wire-size requirements:

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

♦ Conductors for AC common must be white. Conductors for equipment grounding must be green. All other conductors must be a color different from the foregoing.

Provide a barrier terminal block with a minimum of 3 compression-fitting terminals designed to accept up to a #4 AWG stranded wire for connection of the AC power lines. The block must be rated at 50 amperes.

All terminals must 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 must have the terminals properly identified. Identification must be permanently attached and as close to the terminal strip as possible and must not be affixed to any part that is easily removable from the terminal block panel.

Meet the following additional identification requirements:

♦ At each terminal point in the cabinet, each controller input and output function must be distinctly identified with both a number and the function designation and with no obstructions to visibility. The same identification must be used consistently on the cabinet wiring diagrams.

♦ Each load-switch socket must 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.

♦ Each flash-transfer base and power-relay base must be properly identified with no obstructions to visibility.

♦ Each harness within the cabinet must be distinctly identified by function on the connector end.

♦ The flasher socket must be distinctly identified with no obstruction to visibility.

♦ All other sockets needed within the cabinet to fulfill the minimum requirements of the plans or the Invitation to Bid or attachments thereof must be distinctly identified.

The controller unit harness (A plug) must be long enough to reach any point 400 mm above the timer shelf. The MMU harness and any required auxiliary harness must reach 600 mm from the MMU shelf.
Provide an unused, spare terminal block having 10 terminals. This block must be double-8-32×5/16-in., binder-head screw design with shorting bars. These terminal strips must be located on the lower third of either side of the cabinet.

Provide copper ground buses for both the power-supply neutral (common) and chassis ground. Each bus bar must provide a minimum of 10 unused terminals with 8-32×5/16-in. or larger screws. The AC neutral and chassis ground buses must be connected together (jumpered) with a minimum #10 AWG wire.

Two 20-ampere and one 50-ampere thermal-type circuit breakers must be mounted and wired in the cabinet. One 20-ampere breaker must protect the base light, trouble light, ground-fault-circuit-interruption (GFCI) receptacle, modem-duplex receptacle, and fans. The other 20-ampere breaker must be for the 2-circuit flasher. The 50-ampere breaker must protect the signal load circuits, controller circuits, MMU, and card-rack-detector power supply. The breakers must be Square "D," QUO-150 Series or approved equivalent.

The circuit breakers must be equipped with solderless connectors and installed on the right side wall (facing the cabinet) or lower-right side of the back panel inside the cabinet. The breakers must be easily accessible. The breakers must be positioned so that the rating markings are visible.

A GFCI type duplex receptacle must be mounted and wired in the lower-right sidewall of the cabinet. An additional duplex receptacle (for use with communications modems) must be mounted and wired in the upper-left side of the cabinet behind the PE-interconnect panel. These receptacles must be wired on the load side of the 20-amp circuit breaker.

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.

The cabinet must include a pluggable surge-protection unit on the AC service input that meets or exceeds the following requirement: EDCO SHA-1250 or equivalent using 12-pin and 2-guide-pin Beau connectors. The surge arrester must be a multi-stage, series, hybrid-type, power-line surge device. The surge arrester must be installed between the applied line voltage and earth ground. The unit must have 2 LED indicators for operational display status. The surge arrester must be capable of reducing the effect of lightning transient voltages applied to the AC line and provide filtering conforming to 50 kHz with a minimum insertion loss of 50 db. The arrester must conform to the following:

- Peak surge current for an 8×20 microsecond waveform: 20,000 A for 20 occurrences
- Clamp voltage at 20,000 A: 280 V maximum
- Maximum continuous operating current at 120 V/60 Hz: 15 A
- Series inductance: AC line/AC neutral — greater than 20 microhenries typical
- Response time: (< a nanosecond) Voltage never exceeds 280V during surge
- Temperature range: −40°C to +85°C
Departmental Material Specifications

DMS-11170, Fully Actuated, Solid State

Traffic Signal Controller Assembly

♦ Spike suppression for ±700-V spike: ±40-V deviation from sine wave all phase angles between 0° and 180°

♦ Terminals as follows:
  • main line (AC line first stage terminal)
  • main neutral (AC neutral input terminal)
  • equipment line in (AC line second stage input terminal, 10A)
  • equipment line out (AC line second stage output terminal, 10A)
  • equipment neutral out (neutral terminal to protected equipment) and
  • ground (GND) (earth connection).

♦ Arrestor encapsulation: flame-retardant material.

♦ Equipment line out that provides power to the controller.

The suppressor ground connection must be connected to the cabinet by a short, copper ground strap. The strap must be bonded to the cabinet.

The suppressor must be connected to the line filter as recommended by the manufacturer. Number 10 AWG or larger wire must be used for connections to the suppressor, line filter, and load switch bus.

A fluorescent light with switch and rapid-start ballast must be installed in the cabinet. This light must turn on when the cabinet door is opened, and turn off when the cabinet door is closed. An MOV or other such transient suppression device must be placed across the AC power input to the light.

A radio-frequency-interference (RFI) suppresser must be provided and installed on the load side of the signal circuit breaker and must be protected by the surge protector. This filter must be rated at 50 amperes and must provide a minimum attenuation of 50 db over the frequency range of 200 kHz to 75 MHz.

Transient suppression devices must be placed on the coil side of all relays in the cabinet. DC relay coils must have, as a minimum, a reversed-biased diode across the coil. AC relays must have MOVs or equivalent suppression across their coils. RC networks are acceptable. One suppression device must be supplied for each relay.

Except where soldered, provide all wires with lugs or other approved terminal fittings for attachment to binding posts. Insulation parts and wire insulation must be insulated for a minimum of 600 V.

The outgoing traffic control signal circuits must be of the same polarity as the line side of the power source.
A switch must be provided on the inside face of the cabinet door and labeled "TEST NORMAL." When the switch is in the NORMAL position, the call for flashing operation must remove the power from the controller unit. When the switch is in the TEST position, the call for flashing operation must permit the controller unit to continue to run so that its operation can be observed.

A switch must be provided near the "TEST NORMAL" switch to cause the controller unit and any auxiliary equipment to stop timing. This switch must be labeled "STOP TIMING."

The cabinet must be wired so that activation of the MMU will cause the controller unit and any auxiliary equipment to stop timing.

Conflict and manual flash must be wired for all red.

The cabinet must be designed and equipped with enough transfer relays for the Department to change any main-street indications (movements 2, 6, 1, or 5) to yellow for either the conflict or manual-flash operation or both. Such changes must be feasible on the face of the back panel or a side panel using only simple tools.

Transfer relays must be the plug-in type manufactured by Midtex (Part No. 136 62T3A1) or AEMCO (Part No. 136 4992), or equivalent. The relays must have contacts a minimum of 3/8 in. in diameter and must be rated at a minimum of 30 amps 102/240 VAC, 20 amps 28 VDC.

The red enable and remote reset from the MMU must be terminated on the face of the back panel.

A 75-amp, solid-state relay must be wired between the RFI filter output and the load-switch power bus. The relay must be controlled by the signal-shutdown switch and the flash switch. The relay must be mounted to a heat sink designed to allow maximum current flow at 74°C without damaging the relay.

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

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

Detector Panel and Card Rack

The cabinet must have a loop-detector panel mounted on the left side of the cabinet. This panel must provide for all connections between loops at the street and the detector amplifiers as described in this segment.
**Detector Card Rack**

The card rack for cabinet configurations 1, 2, and 3 (12-position back panel) must be TS 2 detector rack configuration 2 and must accommodate up to eight 2-channel or four 4-channel TS 2 detector units. Two card racks, 1 TS 2 detector rack configuration 1 and 1 TS 2 detector rack configuration 2, must be provided for cabinet configuration for (16-position back panel) and must accommodate up to twelve 2-channel or six 4-channel TS 2 detector units.

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

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

Number the slots from 1 to 8 left to right when viewed from the front of the rack. Provide a flange on the top and the bottom of the rack to label each individual channel.

The detector DC supply must be bussed to a common point and wired to the intersection detector panel.

The chassis ground must be bussed to a common point and wired to the detector panel.

The logic ground must be bussed to a common point and wired to the detector panel.

The data address for the detector channels must be according to TS 2.

**Detector Panel**

The detector panel must provide all connections between the detector loops and the detector amplifiers.

Construct the panel of 0.125 in (3.2-mm) aluminum.

The panel must contain a 3 in. (76-mm), horizontal slot in each corner to accommodate 0.25 in. (6.3 mm) mounting bolts.

All inputs from the loops must be brought through posted 10-32×5/16-in. binder-screw terminals or 8-32×5/16-in. binder-screw terminals.
Each loop pair must be protected by lightning-surge suppressers pre-approved by the Departments' TRF Signal Operations Engineer for use on loop-detector inputs. Mount the suppressers either on the front or behind the panel.

The detector panel for cabinet configurations 1, 2, and 3 (12 position) must provide the following connection points as a minimum for 16 detectors:

<table>
<thead>
<tr>
<th>Connection point</th>
<th>No. of Connection Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>External 24-V Power Supply</td>
<td>1</td>
</tr>
<tr>
<td>Loop Inputs</td>
<td>32, 2 for each detector</td>
</tr>
<tr>
<td>Logic Ground</td>
<td>1</td>
</tr>
<tr>
<td>Spares</td>
<td>6</td>
</tr>
<tr>
<td>Chassis Ground Bus</td>
<td>1 bus</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Connection point</th>
<th>No. of Connection Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>External 24-V Power Supply</td>
<td>1</td>
</tr>
<tr>
<td>Loop Inputs</td>
<td>48, 2 for each detector</td>
</tr>
<tr>
<td>Logic Ground</td>
<td>1</td>
</tr>
<tr>
<td>Spares</td>
<td>0</td>
</tr>
<tr>
<td>Chassis Ground Bus</td>
<td>1 bus</td>
</tr>
</tbody>
</table>

Toggle switches must be provided to permit the user to input a vehicle or pedestrian call to the control unit. Provide switches as follows:

♦ 16 vehicle and 8 pedestrian switches on 12-position cabinets
♦ 24 vehicle and 8 pedestrian switches on 16-position cabinets.

**PE/Communication Panel**

A PE/communication panel must be provided that contains all interface circuits and wiring for PE and communication functions. The panel must be located on the left side of the cabinet interior.

Three input relay circuits, with 120-VAC coil and contacts rated for the application, must be provided on the PE panel. These circuits must be used to isolate the incoming PE commands from the controller-unit logic circuitry. The circuits must 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 must be supplied to connect the external input. It must be possible to use either a neutral or hot 120-VAC input.
Relays used must be plug-in Potter Brumfield K10P series, Magnecraft W 78 series, or interchangeable equivalent. Mount the relays in relay sockets.

Adequate protection of the input relay circuits and the preemtior circuitry must be provided to eliminate damage or false PE commands caused by line transients or lightning surges. The devices must have a minimum rating of 20 joules.

Three momentary test switches, 1 for each PE circuit, must be provided on the PE panel. The operator must not be exposed to hazardous voltages during operation of the test switches.

Provide all necessary interconnection cables and mounting hardware.

Provide a switch on the PE/communication panel that releases the local controller to operate in an isolated, full-actuated manner when necessary for maintenance purposes. The switch positions must be labeled "SYSTEM" and "FREE."

Also provide terminal connections for 2 twisted-pair communication lines with a coordinated, 4-stage electrical protection, including primary overvoltage protection, resettable overcurrent protection, secondary clamping-voltage protection, and fast transient filtering. The secondary overvoltage stage must allow peak voltages of no more than 250 V. The fast transient filtering stage must provide no less than 40 dB per decade of attenuation to transients above the required pass band. The 4-stage protection must be provided in an integrated closure with input-output terminations and ground connection.

**Power Supply**

The power supply must be a shelf mounted, enclosed, 24 VDC power supply in accordance with clause 5.3.5 of the NEMA Standards Publication TS 2-1998.

Furnish and install 1 power-supply cable per power supply in each cabinet. Terminate the wires to bus bars, terminals on the front of the back panel, detector panels, or connector as appropriate. The connections must be with forked spade lugs or otherwise as needed. Cut each individual wire to the length required to reach the point at which it is to be connected.

Electrical requirements for the power supply must 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 must be as shown below with DC voltages having less than 0.5 V peak-to-peak ripple:

<table>
<thead>
<tr>
<th>DC Voltage</th>
<th>Peak-to-Peak Ripple</th>
</tr>
</thead>
<tbody>
<tr>
<td>+12 VDC</td>
<td>5.0 amps</td>
</tr>
<tr>
<td>+24 VDC</td>
<td>2.0 amps</td>
</tr>
<tr>
<td>12 VAC</td>
<td>0.250 amps</td>
</tr>
</tbody>
</table>
Two-Circuit Solid-State Flasher

The solid state, 2-circuit flasher must meet the electrical and physical characteristics described in clause 6.3 of the NEMA Standards Publication TS 2 1998. The flasher must be Type III (dual-circuit rated at 15 amps per circuit) unit and so constructed that each component may be readily replaced if needed.

The 2-circuit flasher must be of solid-state design and contain no electro-mechanical devices.

Load Switch

The solid-state load switches must meet the requirements set forth in clause 6.2 of the NEMA Standards Publication TS 2 1998, and must be "triple signal load switch" type.

Provide an indicator light for each circuit in each load switch. The indicator light must be on when a "Low Voltage Active" input to the load switch is present.

Documentation

Provide each cabinet with the following documentation:

♦ three complete, accurate, and fully legible diagrams and 1 schematic for every electronic device (This must include but not be limited to cabinet-wiring, back panel, detector-panel, power-panel, PE-panel, flasher-circuit, load-switch, card-rack-power-supply, bus-interface-unit, and power-supply diagrams.)

♦ a complete parts list including names of vendors for parts not identified by universal part numbers such as JEDEC, RETMA, or EIA and

♦ manufacturer's specifications for cooling fans including the CFM rating of fans.

Provide each controller unit with the following documentation:

♦ one service manual per unit that includes description of controller unit, description of its operation, and basic maintenance and troubleshooting information

♦ 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)

♦ a 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); and

♦ a 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 must be clearly identified or labeled. This may be included in the service manual.)
Provide each MMU with 1 each of the following documentation:

♦ a complete and accurate schematic diagram
♦ a complete parts list including names of vendors for parts not identified by universal part numbers such as JEDEC, RETMA, or EIA
♦ a pictorial-of-components layout on the circuit boards and
♦ one service manual per unit that includes description of MMU unit, description of its operation and basic maintenance, and troubleshooting information.

Bidders must be prepared to furnish NEMA certification for the complete cabinet assembly from an independent laboratory.