SPECIFICATION

NEMA TS2 Fully-Actuated Traffic Controller

This specification is fully met by the following Econolite models:

ASC/2S-1000 Fully Actuated Controller
ASC/2S-2000 Fully Actuated Controller
ASC/2S-2100 Fully Actuated Controller

ECONOLITE
CONTROL PRODUCTS, INC.

Phone: (714) 630-3700 • Fax (714) 630-6349
3360 E. La Palma Avenue, Anaheim, CA 92806
P. O. Box 6150, Anaheim, CA 92816-6150

#80-10223M-00

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NEMA TS2 FULLY-ACTUATED TRAFFIC CONTROLLER

1. INTRODUCTION

This specification sets forth the minimum requirements for a shelf-mountable, two through twelve phase, fully-actuated, digital, solid-state traffic controller. The controller shall meet, as a minimum, all applicable sections of the NEMA Standards Publication No. TS2-1998. Where differences occur, this specification shall govern. Controller versions shall be available to comply with NEMA TS2 Types 1 and 2. Type 2 versions of the controller shall be capable of operating as a Type 1.

2. HARDWARE

2.1 Enclosure

2.1.1 The controller shall be compact so as to fit in limited cabinet space. It shall be installable on a shelf that is not more than 7" deep. External dimensions shall not be larger than 10" x 15 1/4" x 8 1/2" (H x W x D).

2.1.2 The enclosure shall be constructed of sheet aluminum and shall be finished with an attractive and durable protective coating. Model, serial number, and program information shall be permanently displayed on the top surface.

2.1.3 The enclosure shall open along a vertical stainless steel hinge so as to provide ready access to the electronics in case of service.

2.2 Electronics

2.2.1 The electronics shall be modular and shall consist of vertical circuit boards. Horizontal circuit cards are not acceptable.

2.2.2 A microprocessor shall be used for all timing and control functions. Continuing operation of the microprocessor shall be verified by an independent monitor circuit, which shall set an output to FALSE and indicate an error message if a pulse is not received from the microprocessor within a defined period.

2.2.3 In the interest of reliability, sockets shall only be used for the memory device used to store configuration and data entries. All other devices shall be directly soldered to the printed circuit board. Surface mount parts shall be used for the majority of the electronic components in the controller.

2.2.4 A built-in, high-efficiency switching power supply shall generate all required internal voltages as well as 24 VDC for external use. All voltages shall be regulated and shall be monitored with control signals. Fuses shall be mounted on the front of the controller for 120 VAC input and 24 VDC output.

2.2.5 Timing of the controller shall be derived from the 120 VAC power line. A 5-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 shall not be acceptable.

2.2.6 User-programmed settings and intersection configuration data shall be stored in an electrically erasable programmable read-only memory (EEPROM). Designs using a battery to maintain user data shall not be acceptable. Write-protection shall be provided for the portion of the EEPROM used to store intersection configuration data. To facilitate the transfer of data from one controller to another, the EEPROM shall be mounted on an easily removable sub-module, which shall be connected to the processor module via a DIN printed circuit board connector.

2.2.7 All controller software shall be stored in surface mount Flash Memory devices. The controller software shall be easily updated without the removal of any memory device from the controller. The use of PROMS or EPROMS shall not be acceptable. The controller shall include an option that allows updating software using a software installation utility running on a Windows based computer. This shall allow updating the controller software via Port 2 on the front of the controller. The controller shall also have an option for the direct transfer of software from a software installation module. It shall also be possible to transfer the current software in the controller to a software installation module to facilitate updating the software of other controllers.

2.2.8 The controller shall include the capability of adding optional software via an expansion memory module. This module shall be capable of being plugged into the controller and shall use Flash Memory devices. The software on this module shall be capable of being updated by the user without changing memory devices.

2.2.9 All printed circuit boards shall meet the requirements of the NEMA Standard plus the following requirements to enhance reliability:

a. All plated-through holes and exposed circuit traces shall be plated with solder.
b. Both sides of the printed circuit board shall be covered with a solder mask material.
c. The circuit reference designation for all components and the polarity of all capacitors and diodes shall be clearly marked adjacent to the component. Pin 1 for all through-hole integrated circuit packages shall be designated on both sides of all printed circuit boards.
d. All electrical mating surfaces shall be gold-plated.
e. All printed circuit board assemblies, except power supplies, shall be coated on both sides with a clear moisture-proof and fungus-proof sealant.

2.3 Front Panel

2.3.1 The front of the controller shall consist of a panel for the display and keyboard.

2.3.2 A 16-line by 40-character/line alphanumeric liquid crystal display (LCD) shall show program and status information. The display area shall have nominal measurements of 2 1/2" x 4 1/2" (H x W) or larger. For ease of viewing, backlighting by light emitting diodes and multiple levels of contrast adjustment shall be provided. Display contrast shall be adjustable with a small potentiometer (labeled as DISP ADJ) located on the bottom of the front panel.

2.3.3 Front-panel operator inputs shall be via clearly labeled and environmentally-sealed elastomeric keys. These shall include a 10-digit numeric keypad, eight function keys, an oversize ENTER key, and an oversize four-arrow cursor control key.

2.3.3.1 The eight function keys shall be clearly labeled and provide the following operation:

MAIN MENU - F1
Pressing the Main Menu key shall display the main menu.
NEXT SCREEN - F2
Pressing the Next Screen key shall display the next screen, thus allowing rapid advancement from screen to screen.
SUBMENU - F3
Pressing the SubMenu key from any data screen shall display the current submenu.
NEXT DATA - F4
Pressing the Next Data key shall search for the first non-zero data field, thus allowing rapid search for valid entries.
DISPLAY ADJUST - F5
This key is has no current use in this model of controller.
NEXT PAGE - F6

Pressing the Next Page key shall advance to the previous or next group of data entry screens in a submenu.

STATUS DISPLAY - F7

Pressing the Status Display key shall present the intersection status display.

HELP - F8

Pressing the Help key at any data entry field shall display a help screen about that field.

2.3.3.2 **SPECIAL FUNCTION**. A key marked "special function" shall be provided to allow secondary functions to be accessed by the numeric or function keys.

2.3.3.3 **CLEAR.** A key marked "clear" shall be provided to abort a data entry and restore the current value.

2.4 Connectors

2.4.1 All interface connectors shall be accessible from the front of the controller. Connector panels shall be offered to accommodate different controller versions, as follows:

a. NEMA TS2 Type 1.
b. NEMA TS2 Type 2 enhance (same data connectors as for TS2 Type 1, plus A, B, and C).
c. Connectors compatible with TS1 with expansion I/O plus telemetry port and D connector compatible with Econolite Model ASC-8000.

2.4.2 To facilitate special applications the controller shall have the capability of assignment of any input or output function to any input or output pin respectively on the interface connectors.

2.5 Serviceability

2.5.1 All electronic modules including the power supply shall be easily removable from the front of the controller using a screwdriver as the only tool. All power and signal connections to the circuit boards shall be via plug-in connectors.

2.5.2 The controller layout shall allow the removal and replacement of any circuit board without unplugging or removing other circuit boards. All boards shall be keyed to prevent improper installation. No more than two boards shall be attached together to form a circuit assembly.

2.5.3 The controller enclosure shall be designed so that one side of any circuit board is accessible for troubleshooting and testing while the controller is still in operation. This capability shall be accomplished without the use of extender cards or card pullers.

3. DISPLAYS

3.1 Dynamic Displays

3.1.1 The dynamic displays listed below shall be provided to show the operational status of the controller. Additional displays shall be offered for programming. It shall be possible to place vehicle, pedestrian and preemption calls from the keyboard while displaying status information.

3.1.2 An intersection status display shall indicate a summary of ring, phase, coordination, preemption and time-based control status.

3.1.3 A controller status display shall indicate current interval, pedestrian, density, maximum, and maximum extension timing by phase and ring. The status of vehicle and pedestrian signal outputs shall be displayed in combination with vehicle and pedestrian calls. The display shall also indicate the status and timing of each overlap.

3.1.4 A coordinator status display shall indicate the command source, current coordination pattern information, local/system cycle count, commanded/actual offset, offset correction, time-based control status, hold, force-off, permissive, and green band indications.

3.1.5 A preemptor status display shall indicate priority (railroad, fire, emergency) preemptors and bus preemptors with calls, preemptor active, inhibit, delay, and bus reservice timer status. When a preemptor is active, the display shall also indicate preemptor interval, timing, duration, and hold status. A portion of the display shall indicate the controller status during preemption including current status, interval, and timing by phase and ring and the status of vehicle and pedestrian signals for each phase.

3.1.6 A time base status display shall indicate the current time and date, the current day and week program, the active program step for both coordination pattern and time-of-day functions, the start time of the next program step, and the highest step used. The programmed selections of the active coordination pattern and time-of-day pattern shall also be displayed.

3.1.7 A telemetry status display shall indicate system detector call activity, status of mode and special function commands, telemetry address, transmit and valid data status, and speed trap velocities.

3.1.8 A detector status display shall indicate activity for up to 64 detectors. The display shall show detector calls as they are processed by the controller.

3.1.9 A flash/malfunction management unit (MMU) status display shall indicate flash status plus MMU channel, conflict, and monitoring function status.

3.2 Programming Displays

3.2.1 Programming displays in the form of menus shall aid the operator in entering data from the front-panel keyboard.

3.2.2 A main menu shall allow the user to select a major function of the controller. A submenu shall then be displayed to allow the user to select a sub-function within the major function. A four-arrow cursor key shall allow the user to scroll through all menus and submenus.

3.2.3 English language and traffic engineering terminology shall be used throughout to facilitate programming. The display organization shall allow traffic personnel to program the controller without using reference cards or manuals.

3.2.4 Programming entries shall consist of numerical values, YES/NO and ON/OFF entries. During program entry, the new data shall be displayed as it is entered. Entries shall only be validated and stored when the ENTER or cursor key is pressed.

3.2.5 The keyboard entry software shall include context sensitive help screens. Help information shall be accessed by placing the cursor on the data entry in question then pressing the HELP key. Help screens shall be provided for all keyboard entered data and shall include at a minimum range, description, and functional operation information for the data entry.

4. PROGRAMMING

4.1 Programming Methods
The methods listed below shall be available for controller programming. The manufacturer shall be able to provide as off-the-shelf items all of the firmware and software required to effect the listed programming methods and to implement network operation with system masters and host PC's.

a. Manual data entry via the front panel keyboard
b. Data downloading via telemetry from a system master connected to a host PC in a closed-loop system.
c. Data downloading from a portable PC-compatible computer via a modem cable.
d. Data downloading from a PC-compatible computer via modem.
e. Data downloading from one controller to another using a serial port on each controller.
f. Transfer of the EEPROM data module from one controller to another.

4.2 Programming Security
A minimum of three access levels shall be available to provide programming security. The highest or supervisor level shall have access to all programming entries including setting access codes. The second or data change level shall have access to all programming entries except access codes. The third or data display level shall only have access to displayed data. No access code shall be required to display data. User selectable, four-digit access codes shall be provided for the supervisor and data change access levels. Access codes shall initially be set to provide unrestricted access.

4.3 Programming Utility Functions

4.3.1 A copy function shall permit copying all timing data from one phase to another. It shall also permit copying all coordination pattern data from one pattern to another. This feature will facilitate data entry when programming any two or more phases with the same timing values and/or two or more coordination patterns with the same pattern data.

4.3.2 The controller unit shall contain a backup data base with user specified values stored in non-volatile memory. A copy function shall permit transferring the backup database to the active database.

4.3.3 A memory-clear function shall permit the user to clear data entries for the following controller functions, either individually or all at once:

a. Coordinator
b. Preemptor
c. Time base
d. Detectors
e. Diagnostic Enables

4.3.4 A print function shall allow the printing of controller unit data and detector count, detector failure, plus controller and MMU event logs. The controller shall be capable of interfacing with any printer with an RS-232 interface and capable of a minimum width of 80 columns. The communication rate shall be selectable from 1200 to 19,200 bps.

4.3.5 A sign-on message shall allow the user to view the controller software version number. This message shall be displayed upon power-up until a key is depressed. It shall also be possible to display the sign-on message by keyboard selection. The sign-on display shall allow a user-defined message of up to two lines with 38 characters per line.

4.3.6 The controller shall have the capability to output a memory image of the user programmed settings and intersection configuration data in Motorola S record format. This shall allow transferring the memory image data to another EEPROM device using appropriate programming equipment.

5. ACTUATED CONTROL FUNCTIONS

The controller shall provide all actuated control functions and operations required by the NEMA TS2 Standard. In addition, it shall provide the features described in the following paragraphs.

5.1 Phase Sequence

5.1.1 The phase sequence of the controller shall be programmable in any combination of twelve phases, eight concurrent groups and two timing rings.

5.1.2 Phase sequence information shall be changeable from the keyboard and stored in EEPROM data memory.

5.1.3 The standard phase sequence of the controller shall also be capable of being altered by coordination, time-of-day or external alternate sequence command. The alternate sequence commands shall allow reversing the normal phase sequence of each phase pair as shown below:

a. Command A reverses phases 1 and 2.
b. Command B reverses phases 3 and 4.
c. Command C reverses phases 5 and 6.
d. Command D reverses phases 7 and 8.
e. Command E reverses phases 9 and 10.
f. Command F reverses phases 11 and 12.

5.2 Timing Intervals

5.2.1 Timing intervals shall be programmable from 0-255 in one second increments or from 0-25.5 in one-tenth second increments, depending on the function.

5.2.2 Guaranteed minimum interval values shall be specified at the time of purchase and shall not be changed or overridden from the keyboard. Values shall be provided for the following intervals:

a. Minimum green
b. Walk
c. Pedestrian clearance
d. Yellow
e. Red
f. Red revert

5.2.3 Two vehicle extension intervals shall be provided for each phase. The active vehicle extension interval shall be selected by time-of-day.

5.2.4 Volume density intervals shall include actuations before added and cars waiting. Actuations before added shall provide a user-specified number of actuations that must occur before adding variable (added) initial time. Cars waiting shall provide a userspecified number of actuations, or cars waiting, that must occur before starting gap reduction. Gap reduction shall be initiated by either time before reduction or cars waiting, whichever reaches its maximum value first.

5.2.5 The controller shall be capable of dynamically extending the maximum green time for each phase based on vehicle demand. Three maximum green intervals shall be selectable per phase based on either time-of-day or external input. The initial interval shall be selectable as either Max 1 or Max 2. If the phase terminates due to max-out for two successive cycles, then the maximum green time in effect shall automatically be extended by a maximum green extension interval on each successive cycle until it is equal to Max 3. If the phase gaps out for two successive cycles, then the maximum green time shall return to the original Max 1 or Max 2 value.

5.2.6 Each phase shall include a detector failure maximum green time. This maximum green shall be selectable to be in effect whenever a detector assigned to the phase has been diagnosed as failed.

5.3 Overlaps

5.3.1 The controller shall provide four internally-generated overlaps (A,B,C,D). These shall be individually programmable as standard, protected/permissive or negative. The green, yellow and red intervals shall be individually programmable following termination of the parent phase. Programming flexibility shall permit assigning the overlap to lead, lag, or provide an advanced green time for a parent phase(s).

5.3.2 The controller shall be capable of an additional twelve standard overlaps by assigning each phase output to an overlap.

5.3.3 The controller shall provide the capability of pedestrian overlaps. These shall be capable of overlapping the pedestrian displays of any combination of phases with a pedestrian movement.

5.3.4 Overlap functions shall be programmable from the controller keyboard. As an option, the four internally-generated standard overlaps may be programmed with a NEMA overlap card.

5.4 Conditional Service

5.4.1 The controller shall provide a programmable conditional service feature. When selected, the controller shall service an odd-numbered phase once normal service to that phase has been completed and enough time for additional service exists on the concurrent even phase.

5.4.2 A conditional service minimum green time shall be programmable for each phase. This interval shall ensure a minimum green if the phase is conditionally served.

5.4.3 It shall be possible to program the controller to reservice the even phase after conditionally serving an odd phase. Once an even phase has been conditionally reserviced, the odd phase shall not be conditionally served again until returning to the concurrent group that is timing.

5.5 Additional Features

5.5.1 The following features shall be programmable for each phase:

a. Phase in use
b. Locking/non-locking detector memory
c. Vehicle recall
d. Pedestrian recall
e. Maximum recall
f. Soft recall
g. No-rest phase
h. Ped dark with no call

5.5.2 Soft recall shall return the controller to the programmed phase in the absence of other calls.

5.5.3 If a phase is designated as a no-rest phase the controller shall not rest in the phase.

5.5.4 The controller shall permit power start and external start to be individually programmed by phase and interval. Start intervals shall be green, yellow red, or yellow with overlaps forced yellow.

5.5.5 During a power start condition, the controller shall be capable of timing an all-red or flash interval before the power start phase(s) and interval are displayed.

5.5.6 The controller shall provide guaranteed passage operation on a per phase basis. When selected, this feature shall provide a full passage (vehicle extension) interval when a phase gaps out with a gap in effect less than the vehicle extension interval (preset gap).

5.5.7 The controller shall provide both single and dual entry operation. When selected, dual entry shall cause the controller to ensure that one phase is timing in each ring.

5.5.8 It shall be possible via keyboard selection to inhibit the service of a phase with other phase(s) within the same concurrent group.

5.5.9 The controller shall provide the following additional selectable pedestrian functions:

a. Actuated phase rest in WALK.
b. Flashing WALK output.
c. Pedestrian clearance protection during manual control.
d. Pedestrian clearance through yellow.
e. Pedestrian indications remain dark with no call.
f. Pedestrian timing shall be capable of being carried over from one phase to another.

5.5.10 Programming shall be provided to inhibit reservice of odd phases (left turns) within the same concurrent group.

5.5.11 The controller shall provide a programmable simultaneous gap termination feature. When programmed, phases in both rings shall gap out together in order to terminate the green interval and cross the barrier.

5.5.12 The controller shall provide automatic flash selection per the requirements of the MUTCD. Both the flash entrance and exit phases shall be programmable through the keyboard, and flashing shall be controlled by either setting the fault/voltage monitor output to be FALSE or by flashing through the load switch driver outputs. Automatic flash shall be selectable by external input, system command, or time of day.

5.5.13 The controller shall provide dimming for selectable load switch outputs. Dimming shall be accomplished by inhibiting the selected outputs for alternate half cycles of the 120 VAC line. Dimming shall be controllable by time of day and an external input; both functions must be TRUE for dimming to occur. Programming shall permit individual dimming of the Green/Walk, Yellow/Ped Clear, Red/Don't Walk outputs for each load switch.

6. COORDINATION

Coordination functions to control intersection cycle lengths, system offset relationships, and phase split percentages shall be provided as a standard feature, with no need for additional modules or software.

6.1 Coordination Patterns

6.1.1 A minimum of 64 coordination patterns shall be provided. Each pattern shall allow selection of an independent cycle length, offset and split. The coordination patterns shall be selected using telemetry (system), hardwire, or non-interconnected (time base) coordination commands.

6.1.2 The coordination patterns shall be selected by the coordination command using the following formats:

a. Plan - This format shall allow selecting the coordination patterns directly, that is, commanding Plan 1 selects Pattern 1. This format shall be the only format used for selecting non-interconnected coordination commands.
b. Standard - This format shall allow selecting the coordination patterns using a cycle offset-split command. Each pattern shall be assignable to a specific cycle-offsetsplit combination. The coordination pattern shall then be selected by matching the coordination command to the cycle-offset-split assigned to the pattern. The cycleoffset-split assignment shall allow pattern selection as a function of six cycles, five offsets, and four splits or one of 32 alternate plan commands. Alternate plan commands shall be selected by assigning the coordination pattern to cycle seven and the offset and split to correspond to the desired plan number. When an alternate plan command is in effect the coordinator shall operate in a time-based, non-interconnected coordination mode.
c. TS2 - This format shall allow selecting the coordination patterns as a function of Timing Plan and one of three offsets. With this format a minimum of 20 Timing Plans shall be available for selection of one of sixty coordination patterns.

6.1.3 The following functions shall be programmable in each coordination pattern: cycle length, offset, split interval for twelve phases, permissive timing, coordinated phase split extension, alternate-phase sequence, phase reservice, split demand pattern, crossing artery pattern, coordinated phases, phases to omit and phases to be placed on recall.

6.1.4 It shall be possible to omit selected phases during any coordination pattern. A phase shall also be omitted if the phase split value is zero for the current coordination pattern.

6.1.5 The following recall modes shall be selectable on a per phase basis for each coordination pattern:

a. Vehicle recall
b. Pedestrian recall
c. Maximum recall

6.2 Cycle Length

6.2.1 One cycle length shall be provided for each coordination pattern. The cycle shall be adjustable over a range of 30-255 seconds in 1-second increments.

6.2.2 The cycle length shall serve as the reference time for all coordination timing.

6.3 Synchronization

6.3.1 For systems with a single system sync pulse, coordination timing shall be synchronized to the leading edge of that pulse, which shall serve as the master zero reference for all offset timing.

6.3.2 For hardwire systems with multiple sync pulses, the coordinator shall lock onto the correct sync by trying different syncs and checking for reoccurrence during successive cycles.

6.3.3 After a valid system sync pulse has been received the coordinator shall check for the proper occurrence of the system sync pulse during each subsequent cycle. If a sync pulse does not occur, the coordinator shall self-sync and continue to operate with the last set of coordination commands for a programmable number of cycles from 0-255. If a sync pulse does not occur within the programmed period (or until the first sync pulse is received), the coordinator shall revert to the non-interconnected coordination mode.

6.4 Offset

6.4.1 Offset shall normally be defined as the time period from the system sync pulse to the beginning of the leading coordinated phase green (local zero). The coordinator shall also be capable of referencing the offset to either the beginning of the lagging coordinated phase green, coordinated phase yield or force off point.

6.4.2 Offsets shall be programmable using both percent and seconds. The range shall be from 0-99% of the cycle length in 1% increments or 0-254 seconds in 1-second increments.

6.4.3 Offset changes shall be achieved by adding or subtracting cycle time over a maximum of three cycle periods to allow a smooth transition to the new offset. Offset correction using dwell shall also be selectable.

6.5 Split

6.5.1 Each split shall provide a split interval for each of twelve phases. The split interval shall be programmable using percent or seconds. The range shall be from 0-99% of the cycle length in 1% increments or 0-254 seconds in 1-second increments.

6.5.2 Split interval settings shall determine the maximum time, including vehicle clearance (yellow and red), for a non-coordinated phase, or the minimum time for a coordinated phase. Phase termination shall be controlled by establishing a force-off point for each phase within the cycle. Except for the coordinated phases the force-off point shall be selectable to be a fixed point within the cycle or allowed to float. If floating force-offs are selected each phase shall time no more than its own split interval.

6.5.3 During coordination, it shall be possible to operate a coordinated phase as actuated or non-actuated. If a coordinated phase is actuated, vehicle detections shall permit the coordinator to extend a phase beyond the normal yield point. Extended coordinated phase green shall be selectable using the same range as split interval settings (percent or seconds). If actuated coordinated phases are used they shall be able to have actuated or non-actuated (walk rest) pedestrian movements.

6.6 Permissive Periods

6.6.1 Permissive periods shall be provided to control the time period during which coordinated phases are released to service calls on non-coordinated phases.

6.6.2 All permissive timing shall begin at the lead coordinated phase yield point. A yield point shall be automatically computed for the coordinated phase in each ring. The coordinated phase yield points shall allow the coordinated phases to yield independent of each other. The yield point shall be the point at which the coordinated phase is released to allow the controller to service calls on non-coordinated phases. The computation shall take into account the coordinated phase split interval plus pedestrian and vehicle clearance times.

6.6.3 Automatic permissive period operation shall be provided by automatically calculating a permissive period for each non-coordinated phase. The permissive period shall consist of a separate vehicle and pedestrian period computed from the phase split interval and the vehicle/pedestrian minimum time. The controller shall answer a call only during the associated phase permissive period. However, once the controller has been released to answer a call, all remaining phases shall be served in normal sequence.

6.6.4 Single permissive period operation shall be provided by defining a single time period per cycle beginning with the yield point during which the controller is allowed to answer phase calls for any phase. The duration of this period shall be selectable in each coordination pattern.

6.6.5 Dual-permissive period operation shall also be provided. During the first permissive period, the controller shall answer only vehicle or pedestrian calls on the phases following the coordinated phase. If the controller yields to a call during this period, calls on the remaining phases are served in normal rotation. During the second permissive period, the controller shall answer calls on all remaining phases except the first permissive phase. The duration of the two permissive periods and the time at which to start the second permissive period (displacement) shall be selectable in each coordination pattern.

6.7 Phase Reservice

6.7.1 If actuated coordinated phases are in use it shall be possible to reservice noncoordinated phases within the same cycle if sufficient time remains. A phase shall be reserviced only if the permissive period for the phase indicates there is sufficient time remaining in the cycle to service the phase.

6.7.2 Phase reservice shall be capable of being enabled/ disabled in each coordination pattern.

6.8 Transition Cycles

6.8.1 The controller shall provide a smooth and orderly transition when changing from free operation to coordinated operation and from one coordination command to another.

6.8.2 During a free-to-coordinated transition, the controller shall initiate a pick-up cycle beginning upon receipt of a sync pulse and a valid coordination command. The controller shall then enter coordination mode upon crossing a barrier or if resting in the coordinated phases.

6.8.3 Each coordination command shall select a cycle, offset and split. A command change shall be implemented concurrent with a sync pulse. Cycle, offset, and split changes shall not take effect until local zero.

6.9 Crossing Artery Control

6.9.1 The coordinator shall be capable of implementing dual coordination at an intersection where two arterials are under control of separate masters.

6.9.2 An external input shall enable dual coordination. Once enabled, the coordinator shall place a continuous call on the crossing artery phases so as to ensure that these remain green for their full split interval.

6.9.3 The coordinator shall output a crossing artery sync signal to indicate the beginning of the crossing artery phase split interval.

6.9.4 Dual coordination shall force a selectable crossing artery split plan to be used so as to allow a particular split to be optimized for dual coordination in each coordination pattern.

6.10 Local Split Demand

6.10.1 The coordinator shall provide a minimum of two split demand detector inputs, which shall allow the selection of a preferred split plan based on intersection demand.

6.10.2 If the split demand detector indicates continuous vehicle presence during a programmed monitoring period beginning with the onset of a selected phase green, the coordinator shall force a selectable split plan to be in effect during the next cycle. This split plan shall remain in effect for a selected number of cycles from 0-255. A specific split plan shall be capable of being selected in each coordination pattern.

6.11 Free Mode

6.11.1 The coordinator shall provide a free mode of operation, where all coordination control is removed.

6.11.2 Free mode operation shall be selectable by coordination commands, by external input or by keyboard entry.

6.11.3 The coordinator shall revert to the free mode when active controller inputs or functions would interfere with coordination. Such inputs or functions shall include the following:

a. Manual control enable
b. Stop time
c. Automatic flash
d. Preemption

6.11.4 The coordinator shall provide an active free mode, where coordination control is removed but the coordinator continues to monitor system sync so as to keep its timing in step with the system master.

6.12 Manual Control
The controller shall allow manual override of the current coordination command from the keyboard. The manual command shall allow selection of any coordination pattern to be in effect.

6.13 Interconnect Modes

6.13.1 The coordinator shall be capable of operating with any of the following interconnect types:

a. Non-interconnected coordination (time-based)
b. Telemetry
c. Hardwired

6.13.2 The coordinator shall be compatible with fixed-time interconnect, which provides the sync pulse superimposed on the offset lines. It shall also operate within an interconnected system using a separate sync line. The non-interconnected coordination mode shall serve as a backup when using telemetry or hardwired interconnect.

6.14 Master Coordinator
The coordinator shall output the coordination command, including sync pulse. This feature shall permit the controller to be used as a time-of-day master in a hardwired interconnected system.

7. PREEMPTION
The controller shall provide a minimum of six railroad-fire-emergency vehicle preemption sequences plus four bus preemption sequences. Preemption capability shall be standard and shall not require additional modules or software.

7.1 Railroad-Fire-Emergency Vehicle Preemption

7.1.1 The six railroad-fire-emergency vehicle preemptors shall be selectable as a priority or non-priority type. Priority preemptor calls shall override non-priority preemptor calls. Low-numbered

priority preemptors shall override higher-numbered priority preemptor calls. Non-priority preemptor calls shall be serviced in the order received.

7.1.2 Each preemptor shall provide a locking and non-locking memory feature for preemptor calls. If a preemptor is in the non-locking mode and a call is received and dropped during the delay time, the preemptor shall not be serviced.

7.1.3 Preemptor timing intervals shall be programmable from 0-255 in one-second increments or 0-25.5 in one-tenth second increments, depending on function.

7.1.4 A programmable delay time interval shall be provided to inhibit the start of the preemption sequence. This interval shall begin timing upon receipt of a preemption call.

7.1.5 An inhibit time shall be provided as the last portion of the delay time interval. During this time, phases that are not part of the preempt sequence shall be inhibited from service.

7.1.6 A programmable duration time shall be provided to control the minimum time that a preemptor remains active. This time shall be programmable from 0-999 in one second increments.

7.1.7 A programmable maximum time shall be provided to control the maximum time that a preemptor remains in the hold interval. The preemptor maximum time interval shall be inhibited if the preemptor is programmed as a priority preemptor.

7.1.8 Phases timing at the beginning of a preemption sequence shall remain in effect for a minimum time before the controller advances to the next sequential interval. If the phase has been timing for longer than the programmed preemptor minimum time, the controller shall immediately advance to the next sequential interval. Minimum times shall be programmable for the following intervals:

a. Green/pedestrian clearance
b. Yellow
c. Red

7.1.9 A phase shall advance immediately to pedestrian clearance if it has been timing a WALK interval at the beginning of a preemption sequence. It shall be possible to time the minimum pedestrian clearance through the yellow interval, or alternately to advance immediately to yellow. During preemption, pedestrian indicators shall be selectable as being a solid DONT WALK, OFF (blank) or fully operational.

7.1.10 If an overlap is in effect when the preemption sequence begins, it shall be possible to terminate the overlap so that it remains red for the remainder of the preemption sequence. Overlaps terminating or forced to terminate shall time the preemptor minimum yellow and red clearance times.

7.1.11 Each preemptor shall provide user-programmable green, yellow and red track clearance intervals. These shall begin timing immediately after the preemptor minimum red interval.

7.1.12 Up to two permissive phases shall be selectable as track clearance phases. During the track clearance period, the selected phases shall time the track clearance green, yellow and red intervals once, and then advance to the hold interval. If track clearance phases are not selected the track clearance interval shall be omitted from the preempt sequence. Controller interval timing shall be used if track clearance interval times have been programmed as zero.

7.1.13 The preemption hold interval shall begin immediately after track clearance. It shall remain in effect until the preemptor duration time and minimum hold times have elapsed and the

preemptor call has been removed or the preemptor maximum time has been exceeded. During the preemption hold interval, any one of the following conditions shall be selectable:

a. Hold phase green
b. Limited phase service
c. All red
d. Flash

7.1.14 Any valid phase, except a track clearance phase, shall be selectable as a hold phase. If hold phases are not selected, the controller shall remain in all red during the hold interval. If flash is selected for the hold interval, up to two permissive phases shall be selectable to flash yellow, and the remaining phases shall flash red. Overlaps associated with the phases flashing yellow shall also flash yellow unless they have been forced to terminate, in which case they shall remain red.

7.1.15 Each preemptor shall provide a user-programmable green, yellow and red hold interval, during which the hold phase(s) shall operate normally, except that the minimum green interval time shall equal the hold green time. At the completion of the hold green interval, the controller shall time the hold yellow and red clearance intervals prior to transfer to the exit phases.

7.1.16 Up to two permissive exit phases shall be selectable to time after the preemption sequence has been completed. These shall serve as transition phases to return the controller to normal operation. It shall also be possible to place calls on selected phases upon exiting preemption.

7.1.17 Each preemptor shall provide a user-programmable exit maximum time. Upon exiting the preemption sequence, this time shall serve as the maximum green time in effect for one controller cycle for all phases except hold phases.

7.1.18 Preemptor linking shall permit preemption sequences, where lower-priority preemptors may call the higher-priority preemptors from their preemption sequence.

7.1.19 Preemptor active outputs shall be provided for each of the preemptors. The output shall be set to ON when the preemption sequence begins and shall remain ON for the duration of the sequence. It shall also be possible to program preempt active outputs to be ON only during preempt hold intervals. Additionally, it shall be possible to program the non-active, non-priority preemptor outputs to flash while another preemptor is active.

7.1.20 Preemptors shall normally override automatic flash. It shall be possible to inhibit this feature for each preemptor.

7.2 Bus Preemption

7.2.1 Four bus preemptors shall provide control for bus or other low-priority vehicles. Bus preemptors shall have low priority and shall be overridden by railroad-fire-emergency vehicle preemptor calls.

7.2.2 A 6.25 pulse-per-second signal with a 50% duty cycle shall identify a bus preemptor call. Bus preemptor calls shall be capable of preemptor call memory and shall be served in the order received.

7.2.3 Bus preemptor timing intervals shall be programmable from 0-255 in one second increments or 0-25.5 in one-tenth second increments depending on the function.

7.2.4 A reservice time shall be provided to avoid excessive utilization of the same bus preemptor. If a call is received before the reservice time has elapsed, the bus preemptor shall not be

reserviced. If reservice time has not been entered then all phases with a call when leaving the bus preemption sequence shall be serviced before the bus preemptor may be served again.

7.2.5 Bus preemptors shall provide delay, inhibit, and maximum time functions similar to those for railroad-fire-emergency vehicle preemptors described above.

7.2.6 Bus preemptors shall provide the following entrance intervals:

a. Green/pedestrian clearance
b. Yellow
c. Red

7.2.7 At the completion of the entrance red clearance, the bus preemptor shall advance to the hold green interval. During this interval, up to two permissive phases shall be selectable to remain green until the minimum hold time has elapsed and the bus preemptor call has been removed or the preemptor maximum time has been exceeded.

7.2.8 It shall be possible to program the controller to allow concurrent phases to be serviced for a bus preemptor with only one phase selected as the hold interval phase.

7.3 Preemption Safeguards

7.3.1 If a preemptor call is active when power is restored to a controller, the fault/voltage monitor output shall be set to FALSE, placing the intersection in flash. Similarly, if external start is applied during a preemption sequence, the intersection shall be set to flash. Intersection flash shall remain in effect until the preemptor call has been removed and the preemptor duration time has elapsed.

7.3.2 An input shall be provided to stop timing of the current active preemptor under control of the MMU/CMU.

7.3.3 A preemptor safety interlock shall be provided to cause the intersection to go into flash whenever the controller has been removed or has not been programmed for preemption. This shall be achieved with an appropriate signal to the MMU/CMU.

8. TIME-BASED CONTROL & NON-INTERCONNECTED COORDINATION
The controller shall include time-based control. This capability shall be a standard feature and shall not require additional modules or software.

8.1 Clock/Calendar Functions

8.1.1 The controller shall provide a time-of-day (TOD) clock, which shall be used for all time-based control functions. The only required clock settings shall be the current time (hour, minute and second) and date (month, day and year). Day of week and week of year shall be automatically computed from the date setting.

8.1.2 During normal operation, the TOD clock shall use the power line frequency as its time base. When power is removed, the time shall be maintained by a crystal oscillator for up to 30 days. The oscillator shall have a timing accuracy of +/- 0.005% over the entire NEMA temperature range as compared to the Universal Coordinated Time Standard.

8.1.3 In addition to entering time and date via the keyboard, it shall be possible to download the information from another controller, a computer or a system master.

8.1.4 The controller shall include a time reset input. This feature shall reset the TOD clock to 03:30 whenever the time reset input is TRUE.

8.1.5 The TOD clock shall automatically compensate for leap year and shall be programmable to automatically switch to daylight savings time.

8.2 Time-Based Control

8.2.1 Time-based control shall utilize a yearly program format. The year program shall consist of 53 programmable weeks, each assignable to one of ten week-programs. For each week-program, one of sixteen day-programs shall be capable of being assigned for each day of the week. Each day program shall consist of a variable number of program steps which define a program for the entire day.

8.2.2 There shall be a minimum of 36 holiday or exception day programs, which override the normal day program. Holiday programs shall be capable of being set as floating (occurs on a specific day and week of the month) or fixed (occurs on a specific day of the year). It shall be possible to program a fixed holiday so that it automatically repeats in the following year.

8.2.3 Separate program step control shall be provided for non-interconnected coordination (NIC) and TOD functions.

8.2.4 It shall be possible to manually force any of the non-interconnected or TOD program steps to override the current program step. The forced step shall be entered from the keyboard and shall remain in effect until removed.

8.3 Non-Interconnected Coordination

8.3.1 A minimum of 200 non-interconnected coordination program steps shall be available for the day-programs. These shall not have to be entered in any special sequence. It shall be possible to add and delete steps from a day-program without affecting any other day-program. Each of the program steps shall permit selection of the following functions:

a. Day program assignment
b. Start time
c. Coordination pattern
d. System override

8.3.2 Selection of system override shall allow the coordination pattern selected by the program step to override the current telemetry or hardwire system commanded coordination pattern.

8.3.3 When operating in the non-interconnected coordination mode the synchronization point for all cycles shall be referenced to a user selected reference time (sync reference), last event or last sync as selected from the keyboard. The sync reference time is that time at which all cycles shall be reset to zero.

8.3.4 If the sync reference time is selected, the synchronization point for the cycle selected by the current program step, shall be computed using the present time, sync reference time, and cycle length. The synchronization point shall occur whenever the present time is such that an even number of cycle length periods have occurred since the sync reference time.

8.4 Time-of-Day Functions

8.4.1 A minimum of 100 TOD program steps shall be available for the day-programs. These program steps shall be separate from the non-interconnected coordination program steps described above. TOD program steps shall not have to be entered in any special sequence. It shall be possible to add and delete steps from a day-program without affecting any other day-program. Each of the TOD program steps shall permit selection of the following functions:

a. Day program assignment
b. Start time
c. Automatic flash
d. Red Rest
e. Dimming
f. Alternate vehicle extension interval
g. Detector logging
h. Detector diagnostic plan
i. Alternate phase sequence
j. Control of eight special functions
k. Control of the following by phase functions: Max 2, Max 3, Vehicle Recall, Max Recall, Pedestrian Recall, Condition Service, and Phase Omit.

9. DETECTORS

9.1 Detector Functions
The controller shall provide a minimum of 64 vehicle detector inputs. Each input shall be assignable to any phase and be programmable as to detector function. Extend and delay timing shall be provided for each detector. Each detector shall be capable of operating in a lock or non-lock mode. The controller shall also be capable of providing 12 pedestrian detector inputs. Each pedestrian detector shall be assignable to any phase.

9.2 Detector Cross Switching
The controller shall provide detector cross switching, which permits all vehicle detectors to alternately place calls on their assigned phases and their assigned crossswitch phases. If the assigned phase is not green and the cross-switch phase is green, the detector shall place calls on the cross switch phase. If the assigned phase is omitted for any reason, the detector shall place calls on the cross switch phase.

9.3 Detector Types

9.3.1 Each vehicle detector shall be user-programmable to operate as one of the following 9 detector types:

a. **Type 0** - Detector shall operate as a standard detector providing one call per actuation.
b. **Type 1 Extend/Delay** - Detector shall operate as follows: When the phase is green and a call is detected then dropped (indicating passage of a vehicle), the extend timer shall begin timing and the call shall be held for the length of the extend time. When the phase is not green and a call is detected, the call shall not be acknowledged by the controller until the delay time has elapsed.
c. **Type 2 Extend/Delay Call** - Detector shall operate as follows: When the phase is green and a call is detected then dropped (indicating passage of a vehicle), the extend timer shall begin timing and the call shall be held for the length of the extend time. If a gapout occurs further calls shall not be placed on the controller until the delay time has elapsed. When the phase is not green the detector shall operate as a Type 0 detector.
d. **Type 3 Stop Bar** - Detector shall operate as follows: Vehicle calls shall be accepted only when the phase is not green. When a call is detected, it shall be held until the detection area is empty. Once the detection area is empty no further calls shall be accepted until the phase is again not green.
e. **Type 4 Stop Bar** - Detector shall operate as follows: Vehicle calls shall be accepted only when the phase is not green. When a call is detected, it shall be held until the detection area is empty. The extend timer shall begin timing with the phase green. Once the extend timer times-out OR the detection area is empty, no further calls shall be accepted until the phase is again not green.
f. **Type 5 Stop Bar** - Detector shall operate as follows: Vehicle calls shall be accepted only when the phase is not green. When a call is detected, it shall be held until the detection area is empty. The extend timer shall begin timing with the phase green. If a call is received before the extend

timer has timed-out, the timer shall be reset. Timer reset shall occur until a gap between the calls is large enough to allow the extend timer to time-out. Once time-out has occurred, no further calls shall be accepted until the phase is again not green.
g. **Type 6 Calling** - Detector shall accept one call while the phase is red.
h. **Type 7 Bicycle** - Detector shall operate like a Type 0 detector except that it shall enable a bike minimum green interval on the assigned phase.
i. **Type 8 Dilemma Zone** - Detector shall use two detectors and shall operate as follows: While the phase is green a vehicle entering the first detection zone shall start the extension timer of the first detector. If the vehicle enters the second detection zone before the first extension time expires, a call shall be placed on the phase and extended by the second detector extension time period. If the vehicle arrives at the second detection zone after the first extension timer expires, a call shall not be placed on the phase until after the delay time of the first detector has expired. When the phase is not green the first detector shall place no calls and the second detector shall act as a Type 0 detector.

9.4 System Detectors

9.4.1 Each detector input shall be capable of functioning as one of 16 system detectors.

9.4.2 Vehicle detectors shall be capable of being assigned to a minimum of 16 speed detectors. Speed shall be detected using both one and two detector configurations. Speed shall be computed using a keyboard entered average vehicle length and loop length for a one-detector configuration. When using two detectors, speed shall be calculated using a keyboard entered distance between detectors and travel time between detectors.

10. SYSTEM COMMUNICATIONS

10.1 On-Street Master Communications

10.1.1 The controller shall be capable of communicating with an on-street system master. This capability shall be provided by a separate telemetry module, which shall be included in the controller when required by the plans and specifications. The telemetry module shall receive system master commands and data transmissions. In addition, it shall transmit the controller status, data base and system detector information to the system master.

10.1.2 System Commands

10.1.2.1 The telemetry module shall allow the controller to receive, as a minimum, the following commands:

a. Cycle, offset, and split (coordination pattern)
b. System sync
c. Special function commands (minimum of four)
d. Free and flash mode commands
e. Time and date
f. Request for local status
g. Recall to Max

10.1.2.2 All commands must occur more than once in any three-second period in order to be recognized.

10.1.2.3 All mode and special function commands shall be cleared after 20 minutes of loss of communication between controller and system master.

10.1.3 Status Data

10.1.3.1 The status of each of the following functions shall be transmitted to the system master in response to a local status request:

a. Green and yellow status for all phases and overlaps
b. Walk and pedestrian clearance status for all phases
c. Vehicle and pedestrian detector status
d. Phase termination status
e. Local time
f. Coordination status
g. Command source
(1) Sync or transitioning status of coordinator
(2) Conflict flash status
h. Local flash status
i. Preempt activity and calls
j. Volume and occupancy data from a minimum of 16 system detectors
k. Speed data from a minimum of two speed detectors
l. Maintenance required (cabinet door open) status
m. Status of two user-defined alarms

10.1.4 Split Reporting
The status of each of the following parameters shall be calculated on a per-cycle basis and transmitted to the system master:

a. Actual time spent in each phase
b. Time of day at end of cycle
c. Phases forced off during cycle
d. Type of coordination operation
e. Whether transitioning to new offset
f. Cycle, offset, and split in effect during last cycle
g. Flash status if operation is Free

10.1.5 Upload/Download Capability
The telemetry module shall provide the capability to upload/download the entire intersection database. Phase assignments for overlaps and preemptors shall not be downloaded to preclude unsafe controller operation. It shall be possible to inhibit downloading of phases in use and left-turn head control.

10.2 Telemetry

10.2.1 Telemetry shall utilize TDM/FSK data transmission at 1200 baud over two pairs of wires. These may be leased lines (Type 3002, voice grade, unconditioned) or dedicated cable. Optional fiber optic communications capability shall also be available.

10.2.2 The nominal transmitter output level shall be 0 dbm into a 600-ohm load. The receiver sensitivity shall be -34 dbm and shall be adjustable from -40 to +6 dbm.

10.2.3 Parity and error checking shall be employed to assure transmission and reception of valid data. Indicators shall be provided on the telemetry module to show telemetry activity as follows: transmit, receive carrier, and valid data.

10.2.4 In the event of a telemetry failure, the controller shall revert to the non-interconnected coordination mode after it has self-synchronized for a number of cycles, which shall be selectable from 0-255.

10.3 Communications Protocols
The controller shall have the capability of supporting communications with traffic management systems using industry standard protocols with the installation of appropriate optional software. At a minimum the controller shall have optional software to support the following protocols:

a. Caltrans AB3418
b. Caltrans AB3418+ including extensions for uploading and downloading of all controller data.
c. Computran Protocol 90‰ with full uploading and downloading capabilities.
d. NTCIP Level 1 as defined by Section 3.3.6 of NEMA TS2-1998. NTCIP capabilities shall include support for Class B communications, both SNMP and STMP, and at a minimum all objects defined for NTCIP Level 1 in TS2-1998. The controller vendor shall provide access to all controller data via vendor specific objects. These and all other objects supported by the controller shall be defined in a standard MIB file.

11. DIAGNOSTICS

11.1 General Diagnostics Features

11.1.1 The controller shall include both automatic and operator-initiated diagnostics. This capability shall be a standard feature and shall not require additional modules or software.

11.1.2 Automatic diagnostics shall verify memory, MMU compatibility programming, and microprocessor operation each time power is reapplied to the controller. After power has been applied, diagnostics shall continually verify the operation of essential elements of the controller including at a minimum: PROM, EEPROM, communications, and the microprocessor.

11.1.3 Operator initiated diagnostics shall allow the operator to verify proper operation of all controller input, output, communications, keyboard, and display functions. Both manual and automatic test modes shall be provided.

11.2 Detector Diagnostics

11.2.1 Time-of-day controlled detector diagnostics shall be provided that allow testing vehicle and pedestrian detectors for no activity, maximum presence, and erratic output.

11.2.2 A minimum of eight detector diagnostic plans shall be provided. These plans shall be selectable on a time-of-day basis. This shall allow varying the detector diagnostic intervals to correspond with changes in detector activity.

11.2.3 If a detector is diagnosed as failed, the associated phase shall be placed in one of the following keyboard selectable modes:

a. Minimum Recall
b. Maximum Recall
c. Maximum Recall using detector failure maximum green time

11.2.4 Diagnostics for NEMA TS2 detectors connected to the controller using a Bus Interface Unit (BIU) shall also include detection of watchdog, open and shorted loop, and excessive inductance change failures.

12. LOGGING
The controller shall be capable of logging and reporting detector activity, detector failures, and the occurrence of selected events or alarms. Logs shall be capable of being printed or displayed on the front of the controller.

12.1 Detector Logging

12.1.1 The controller shall include a detector log buffer capable of logging volume, occupancy and average speed for selected vehicle and speed detectors.

12.1.2 The detector-logging interval shall be keyboard selectable as 5, 15, 30, or 60 minutes.

12.1.3 Detector logging shall be capable of being enabled or disabled by time-of-day.

12.2 Detector Failure Logging

12.2.1 The controller shall include a detector failure log buffer capable of storing a minimum of 100 time and date-stamped detector failure events. Once logged, detector failure events shall remain in the log until cleared or the log buffer capacity is exceeded at which time the oldest detector failure events shall be overwritten.

12.2.2 All detector diagnostic failures shall be recorded in the detector failure log including: no activity, maximum presence, erratic output, watchdog failure, open loop, shorted loop, and excessive inductance change. If a detector recovers after a diagnostic failure, a detector on-line event shall be stored in the detector failure log.

12.2.3 Detector failure logging shall be capable of being disabled.

12.3 Event Logging

12.3.1 The controller shall include an event log buffer capable of storing a minimum of 200 time and date-stamped events or alarms. Once logged, events shall remain in the buffer until cleared or the log buffer capacity is exceeded at which time the oldest events shall be overwritten.

12.3.2 At a minimum the following events shall be logged: communication failures, coordination faults, MMU and local flash status, preempt, power ON/OFF, low battery, and status of a minimum of two alarm inputs. An on-line event shall be logged when an event or alarm returns to normal status.

12.3.3 Event logging shall be capable of being enabled or disabled for each category of event or alarm.