

July 30, 2024

BOSTON TRANSPORTATION DEPARTMENT

Actuated Controllers - Addenda to Commonwealth of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges Dated 2021

Controllers purchased under this specification shall comply with the MassDOT Highway Division - Standard Specifications for Highways and Bridges Dated - 2021 supplemented by the following requirements. Where requirements of the addenda conflict with the standard specifications, these addendums shall govern.

Controllers (ATC) shall include coordinating features, and an internal remote communications unit (RCU) as defined herein. The “ATC” controller unit shall meet all requirements specified herein. The remote communication unit (internal to the ATC) shall provide for control via Boston's Central Computer System. Backup communication capability, as specified herein, is independent of central computer control and intended to be available as backup in the event of central computer or communication failure. No additional hardware, software items and/or subscription fees/costs shall be needed/allowed to satisfy the requirements as defined in these specifications.

1. ATC CONTROLLER UNIT

General

- A. The purpose of this specification is to describe the minimum acceptable and operating requirements for a solid state, microprocessor-based ATC with internal preemption.
- B. ATC unit shall meet NEMA TS-2 Type 2, 2021 requirements, including all amendments, for an actuated keyboard-entry ATC unit.
- C. The ATC unit shall contain ATC API operational software conforming to the ATC 5401 Standard v02.
- D. The ATC unit shall be configured to operate in a NEMA TS2/Type 2 (Mode 6) and ATCC 5301 v02 cabinet platform.
- E. The ATC unit shall be furnished with all licenses to support Connected Vehicle (CV) applications including Signal Phasing and Timing (SPaT) and other safety, environmental and mobility applications.
- F. The ATC unit shall be supplied with all necessary hardware and software elements needed to fully support Connected Vehicle (CV) operations utilizing dual mode DSRC/5G communications.

- G. The ATC unit shall all be furnished with all licenses necessary to support Signal Performance Measures (SPM).
- H. No additional hardware, software items and/or subscription fees /costs shall be needed / allowed to satisfy the requirements as defined in these specifications.
- I. The ATC unit shall be supplied with the appropriate version of the Linux operating system, Board Support Package (BSP) and internal processing levels necessary to support ATC local and system operations.
- J. The ATC unit shall be fully compliant with NTCIP 1201 and 1202 standards while also being in full compliance with existing BTDC UTCS communications protocols.
 - a. The ability of the ATC to support both NTCIP and BTDC/UTCS operations shall be contained within the same active ATC firmware version.
 - b. All mandatory and optional NTCIP objects shall be supplied with the ATC unit. The Contractor shall provide a list of all non-supported NTCIP objects included with the ATC unit.
- K. The ATC unit size (Maximum Dimensions) shall be 12 inches high, 18 inches wide, and 14 inches deep.
- L. The ATC unit shall be supplied with NEMA TS-2 ports 1, 2 and 3 and shall be software mappable as to pin functions. Port 2 shall be utilized for closed loop communication functions and port 3 shall be utilized for connections to the internal RCU which shall provide communications and interfacing to the Boston Transportation Department's Central UTCS computerized signal system (BTCS).
- M. The ATC unit shall include a minimum of 3 High Speed USB 2.0 ports.
- N. The ATC unit shall include a minimum of 3 10/100BaseT, RJ45 Ethernet connector ports.
- O. The ATC unit shall include a minimum of 2 SDLC ports.
 - a. The SDLC ports shall be fully functional and operate simultaneously with all other ports.
 - b. The SDLC ports shall support the following baud rates:
 - i. SDLC Port 1
 - 1. Asynchronous Rates (bps) 1200 / 2400 / 4800 / 9600 / 19.2k / 38.4k / 57.6k / 115.2k / 230.4k

ii. SDLC Port 2 (SIU)

1. Synchronous Rates (bps) 153.6k / 614.4k

- P. The ATC unit shall contain the ability for the user to alter the controller unit's internal database using a built-in front panel keyboard, using a computer connected to the controller unit with a USB cable or an Ethernet cable, and remotely using a central management system application. In addition, the ATC unit shall be supplied and configured with a remote access system using Telnet and/or HTTPS, this feature shall be included with the ATC unit at no additional cost.
- Q. The ATC unit shall include an internal database which stores all configurable parameters, including but not limited to phase timings, phase sequencing, overlaps, coordination parameters, preemption and priority parameters, time base parameters, communications parameters, detection parameters, flashing operation parameters, and security parameters.
- R. The ATC unit shall include detector failure algorithms that initiates user defined actions when user defined criteria are met.
- S. The ATC unit shall be supplied with the ability to generate user defined alarms and alerts.
- T. The ATC unit shall be supplied and installed to comply with the following software requirements:
 - a. Shall be supplied with programming documentation fully defining the coding (compiler and C libraries) used to create the ATC controller applications residing in the unit.
 - b. Shall be supplied with the source code used to produce and support the Linux kernel environment (Board Support Package).
 - c. Shall be supplied with a manufactures Software Development tool Kit (SDK) for supplied firmware version to allow for future system modifications/expansions.
- U. The ATC unit shall have connectors for all external input/output functions that are rigidly defined by the NEMA, ATC and NTCIP standards.
- V. The ATC shall be supplied with all necessary ATC hardware, software elements and instruction procedures needed to facilitate the extraction and processing of the SPM data.
- W. The ATC unit shall be able to backup and restore ATC programing data to a USB memory device connected to the front of the controller. No additional software shall be required to perform this function.

- X. The ATC unit shall be supplied with the ability to upgrade the ATC firmware via USB memory device connected to the front of the controller. No additional software shall be required to perform this function.
- Y. All controllers shall be supplied with the latest firmware. The use of older firmware shall not be allowed unless directed by the Engineer.
- Z. The ATC unit shall not utilize logic processing to directly control vehicle or pedestrian signal circuits.

2. FUNCTION

- A. The ATC unit shall provide actuated operation with a minimum of four overlaps and 12 internal preemption operations, and 12 priority operations provided.
- B. The ATC unit database shall be entered by using a front panel mounted keyboard and all database entries shall be retained without the use of internal battery backup.
- C. The ATC unit shall include provisions for backup, and time base coordination. An internal modem to allow communication with other devices via twisted pair cable using the NEMA TS-2 defined ports as specified herein shall be required only if called for on plans or in project specifications.
- D. The ATC unit shall be supplied, furnished, and configured to fully support Ethernet based communications via the RJ-45 front panel controller port to BTCS central computer or as directed by the Engineer. In addition, the ATC unit shall fully support BTM UTCS communications.
- E. The ATC unit shall be supplied, fully configured to communicate with an existing BTM backup system, BTCS central computer and NTCIP commands.
- F. The ATC unit shall contain real-time context sensitive HELP screens.
- G. The ATC unit shall include a time-of-day, day-of-week, week-of-year scheduler.
- H. The ATC unit shall include dedicated phase detection inputs, pedestrian detection inputs, and system detection inputs.
- I. The ATC unit shall support Flashing Yellow Arrow (FYA) and Flashing Red Arrow (FRA) operation with the ability to provide a minimum of 6 flashing pairs.

- J. The ATC unit shall be supplied and installed with the ability to collect, store, and report various measures of effectiveness (MOE's).
- K. The ATC unit shall collect and process all high-resolution enumerations as defined in the report entitled "Indiana Traffic Signal Hi Resolution Data Enumerations", dated 2019 and all amendments. This data will be processed in the controller and available via download from the controller USB Ethernet port or, if available, via system communications.

3. Maintenance Provisions

- A. The ATC unit power supply module shall contain test points, which will allow examination for appropriate output voltages and other points in the power supply. The power supply module shall contain all the power supply components including transformers, capacitors, regulators, and all other circuitry which are associated with the power supply. The power supply module shall be removable as a unit from the console chassis.

4. Electrical

- A. All database entries shall reside in a memory medium which does not require battery backup.
- B. Fuse protection for the ATC unit shall utilize fuses rated for the voltages present.
- C. No exposed 120 VAC points on the outside of the ATC unit shall be allowed.

5. Phase related parameters

- A. Each phase shall have identical control parameters which may be independently exercised for each phase.
- B. The following parameters shall be individually selectable per phase:
 - a. Phases used
 - b. Pedestrian features
 - c. Phases assigned to Non-Actuated input No. 1
 - d. Phases assigned to Non-Actuated Input No. 2
 - e. Enabling/disabling volume density features
 - f. Vehicle detector memory lock
 - g. Phase assignments for minimum, maximum, soft and pedestrian recall

- h. Display of which ring(s) have Max2 selected
- i. Actuated rest in walk
- j. Last car passage
- k. Dual entry
- l. Simultaneous Gap out
- m. MUTCD Flash (restricted use - see "Remote Flash Operation")

C. Initialization

It shall be possible to select for each ring which phase will start timing and whether the ATC unit is in green/walk, yellow or the red interval of that phase.

- D. A minimum of four (4) overlaps shall be provided internal to the ATC unit. A programming sheet with specific instructions on how to set up the required overlaps shall be supplied.
- E. The ATC unit shall be user programmable to operate in either a sequential, dual-ring, or quad turns mode. A third and fourth ring shall be provided for use in some applications. It shall be possible to modify the ring and barrier structure by keyboard programming to assign signal phasing/operation of each phase. The phase next and allowable concurrent phases shall also be programmable for each phase. Rings 1,2,3 and 4 shall be programmable as to which force off command it responds to.
- F. The ATC unit shall be configured to operate in compliance with TS 2, type 2 mode 6 input/output assignments as defined herein.

6. Preemption/Priority

- A. Twelve emergency preempt operations shall be provided. Response and activation of an active preemption call shall be from lowest to highest under the conditions stipulated below:
 - a. Clearance to preemption shall occur even if the ATC unit is actively clearing from a normally timed active phase. The normal phase(s) next in order shall be replaced by the preemption phase(s) or preemption clearance phases (s).
 - b. When the ATC unit is operating under BTM mode 6, pre-emption operation shall be available as allowed by defined inputs. Additional pre-emption operations, as defined by NEMA TS-2, shall be available internally for future use.

- c. Each emergency vehicle operation shall contain the following parameters:
 1. Locking preemption memory.
 2. An input delay timer which shall provide up to 255 seconds of delay between receipt of the preemption input and acknowledgement of its presence.
 3. Vehicle and pedestrian clearance times set in the individual phase timers shall not be violated.
 4. A Minimum Green period that the active phase must time prior to entering preemption.
 5. Assignment of which phase(s) will be on during preemption. One or more phases shall be permitted to be on during preemption.
 6. Permitted pedestrian movements during preemption.
 7. Permitted overlaps which may be on during preemption.
 8. Duration time for the preemption green. This shall be independent of max# 1 or max #2 timer unit settings.
 9. Return phase(s) to which the ATC unit will exit to following clearance from a preemption event.
- B. A display on the front panel of the ATC unit shall be provided which indicate which preemption operation is active and which routes are pending.
- C. At locations under BTCS computer control, which are specified to have fire pre-emption, the appropriate RCU return data bit shall be set prior to initiation of any pre-emption timing. This signal shall remain active until pre-emption green timing is completed. The pre-emption calls must be latched so that once an input to the central computer from the internal RCU has been sent, pre-emption shall occur.
- D. At locations specified to have firehouse pre-emption, pre-emption shall be initiated by application of 120VAC to an ATC cabinet input terminal. This input shall be isolated from local cabinet power so that the ATC can be used as part of a fire run. The input shall be fused and mounted separately from the interconnect inputs and clearly and permanently labeled "Pre-emption Input".

- E. All ATC units supplied and installed as part of this project shall be provided with Transit Signal Priority (TSP) operation without the need for additional software, hardware, data key device or any recurring licensing fees. The TSP algorithm shall be fully programmable to extend a phase or reduce a vehicle phase depending on user defined settings. This function shall be available for operation during both coordinated and free operation.
 - a. TSP shall support a minimum of twelve priority routines.
 - b. The TSP program shall be capable of extending the priority phase green time and truncating the non-priority phase(s) green when a priority call is received by the ATC unit.
 - c. TSP operation shall not cause the ATC unit to skip any phases that have active vehicle/pedestrian demand.
 - d. Emergency vehicle preemption (EVP) shall override TSP operation.
 - e. The TSP program shall have the ability to delay and/or extend priority calls.
 - f. The TSP program shall have the ability to support user defined time periods between servicing valid priority calls.
 - g. All TSP events shall be logged (time/date stamped) in the ATC unit.
 - h. The TSP algorithm shall allow for non-TSP phases to be conditionally truncated based on the absence of a concurrent pedestrian service of the non-TSP phase.
 - i. It shall be possible to user define in the ATC unit a minimum time between responses to priority calls.
 - j. TSP shall be disabled when the controller is operating from the BTM Central Computer System which provides an integrated TSP function.

- F. TSP Backup Coordinated Operation – Under backup coordinated operation using patterns stored in the ATC, the ATC unit shall modify existing signal operation to accommodate a priority call. This may include modification to per phase termination points established under normal coordinated control. During a priority event, per phase coordination modes shall remain in effect. Priority and non-priority phase duration shall be user programmable per coordination pattern.

- G. TSP Non-Coordinated (Free operation) – Upon receipt of a valid priority call, the ATC unit shall either extend the priority phase or reduce the non-priority(s). These settings for the adjusted green times shall be user defined, on a per phase basis, and adjustable on a time-of-day basis. This function will only be available on a controller not configured to operate from the BTDCentral computer system as the primary control mode.

7. Software Updates

- A. ATC unit software/firmware updates shall be furnished to the City for a period of 3 years after the date of acceptance at no additional cost.
- B. All software/firmware supplied to the City shall be of the most recent revision at the time of final acceptance. The Contractor shall provide to the agency all manufacturer software/firmware release notes.

Phase Assignments

The ATC unit shall be supplied with phases assigned sequentially as defined on the plans or in special provisions. Where letters are used, Phase #1 will be assigned as Phase A; Phase #2 as Phase B and so forth. If letter or number configurations are inconsistent with a NEMA architecture, the supplier shall request clarifications of the desired phase assignments from the Engineer.

Maximum #2 Feature:

Each phase shall be supplied with two (2) independent maximum settings, the second of which shall be selected when a "ground:" is applied to a control box back panel terminal or it is called for by the time base coordinator integral to the ATC unit.

Non-Detected Mode

A feature shall be provided to be activated by a ground applied to a control cabinet back panel input to maximize walk timing on Non-Exclusive concurrent pedestrian walk phases during coordinated or computer-controlled modes. This feature will cause each walk phase (except for the button activated exclusive pedestrian phase) to rest in walk until the appropriate force off signal from the computer or local coordinator. Under this operation, the momentary force off function will activate pedestrian clearances which shall be automatically followed by the corresponding vehicle clearance without further force off input.

Conflict Monitor (Malfunction Management Unit)

- a. The MMU shall meet all requirements of NEMA TS2 2003(R2008) standard including Amendment #4.

- b. The MMU shall support MUTCD Flashing Yellow Arrow PPLT operation and meet NEMA Standard MMU requirements of TS-2 Amendment #4-2012 providing modes for both TS-2 or TS-1 cabinet configurations.

Remote Flash Operation

Changes from flashing to stop and go operation and from stop and go to flashing operations shall occur as set forth in section 4D-29 of the "Manual on Uniform Traffic Control Devices" dated 2009. The flash operation shall be initiated by activation of a ground true input on a control cabinet back panel terminal(s). Input of the remote flash call shall apply vehicle calls as necessary to insure transfer to flash within a controller cycle (sum of max. times). The remote flash call shall not cause the exclusive pedestrian phase to service except for controllers operating a two-phase operation where there are no vehicle signals on Phase 2. This logic to provide the transition to/from flashing operation shall be internal to the controller.

The internal RCU shall contain logic which disables the "Conflict Monitor" input to the BTM UTCS Central Computer prior to implementing remote flash triggered either from the BTM UTCS Central Computer or from the back-up master. The input shall be restored when the ATC unit returns to stop and go operation.

This logic shall be designed so that the BTM UTCS Central Computer shall not fail the local ATC unit for conflict flash except when an actual conflict failure occurs.

The ability for the BTM UTCS Central Computer to distinguish between manual, back-up system, BTM Central system and conflict flash types shall be retained using appropriate logic in the internal RCU.

Load Switches:

- a. All load switches shall be the NEMA triple load switch type. No more than one (1) circuit on each load switch shall be energized at any one time.
- b. Each circuit shall be controlled by a sealed modular "cube".
- c. Each load switch shall be provided with LED indicators wired to the input of each circuit.
- d. Light coupling devices shall be used to isolate input circuits from output circuits.

Control Cabinet:

- a. Type CC cabinets shall be designed as specified on BTM Plan A3.4, latest revision. Type CB cabinets shall be designed as specified on Plans A3.1, A3.5, latest revision. Type CD cabinets shall not be allowed. Holes for anchor bolts

shall be elongated minimum one inch (1") beyond anchor bolt size front to back. See detail A3.5 for alternate height CB cabinet requirements.

A type CB cabinet (Type I) shall be supplied for a 4DW controller with an internal RCU unless otherwise specified on plans or in project specifications. A type CC cabinet shall be otherwise supplied.

- b. Cabinet door handle shall control a three (3) point latching system. Size of the shaft connecting the handle to the latching mechanism shall be minimum 1/2" diameter. If square, the shaft shall have a minimum dimension of 1/2" across the flat surface on each side.
- c. Cabinet door handle shall be supplied with a slot for a padlock.
- d. The control cabinet door shall be equipped with a heavy duty, sealed pushbutton wired to the appropriate remote communication unit harness input.
- e. The fan blade shall be provided with a safety screen on the inside of the cabinet. The fan shall be provided with a manually adjustable thermostat.
- f. Cabinet shall include a full extension sliding drawer with flip up cover approximately 16" wide by 14 inches deep mounted approximately 2" below the ATC unit shelf. The drawer shall be suitable for document storage and as a station for a laptop computer.
- g. The cabinet shall include a lightweight aluminum washable permanent air filter (11.75" X 15.75" X 1").
- h. The control cabinet shall be painted aluminum color.
- i. All components not mounted in sub-assemblies within the control cabinet shall be mounted on terminal strips. Mounting shall be done so that diodes leads are not stressed. This may preclude installation of a diode between adjacent terminals on a terminal block in some cases. All diode logic shall be located in the same area of the back panel. No components (such as diodes) shall be connected in line with wiring.
- j. Police panel location and size for type CB cabinets:

A police panel shall be supplied which shall be of such a size and located such that it will not interfere with space reserved for control equipment. In order to maximize available space, switches shall not be mounted at back of police panel.
- k. Cabinets shall be designed with a sloped roof without vents in the roof of the cabinet. Venting shall be provided from the underside of a roof protrusion over the cabinet front.

1. For type CC cabinets:

Cabinet shelf layout shall be designed to accommodate the maximum dimensions for conflict monitor size as specified by NEMA. The shelf space reserved for the controller unit shall be as follows:

Height 13", width 19"; and total depth (shelf plus space) shall be 15" to allow for M.S. connectors. The ATC unit shelf shall be a minimum of 12" deep and shall be constructed so that no noticeable deflection occurs when the ATC unit and auxiliary equipment are installed on this shelf.

- m. The cabinet door will be equipped with a mechanism to hold it open while servicing the controller. The mechanism shall be permanently secured to both the cabinet and the door.
- n. The cabinet shall include a rectangular LED Light mounted inside the top of the cabinet to illuminate the cabinet interior when the door is open. A second LED light panel shall be supplied and installed under the lower shelf and also illuminate when the door is open.

Electric Meter Socket:

An electric meter socket (Milbank 125 Amp 4 terminal Ringless Type UG model U7487-O-TG) shall be supplied, appropriately mounted. The meter shall be wired immediately after the main circuit breaker.

Circuit Breaker

The main power circuit breaker shall be 30 amps unless the load is defined and will exceed National Electric Code Requirements.

Auxiliary Equipment Power Supply

A 24 VDC power supply external to the timer unit shall be supplied per requirements of NEMA TS-2.

Switches

The following switches shall be provided:

1. Police panel:
 - a. Flash - auto switch which puts controller on flash and inputs stop timing to controller unit.
 - b. Power on-off which shuts off controller and field circuits. This switch must control power indirectly as the input to a back panel relay or relays.

2. Technician panel (on cabinet side wall):
 - a. Controller on-off.
 - b. Flash - auto switch which allows controller to cycle while flashing.
 - c. Signals on-off - allows controller to cycle with heads dark.
 - d. Stop time - normal - on - inputs a stop time when in "on" position.

Flasher:

- a. The field load shall be evenly distributed between all vehicle circuits (including overlaps).
- b. If intersection layout is defined, the number, type and wiring of flasher(s) shall be such that the field load shall not exceed 80 percent of the rated capacity on any circuit. In some cases, this will require that a second flasher be installed.

Load Bay

An eight (8) position load bay shall be supplied for a 4DW controller, and a sixteen (16) position load bay shall be supplied for an 8DW controller unless otherwise specified.

NEMA Connectors

For a type 4DW cabinet in addition to connectors required by NEMA and MassDOT, the NEMA "C" connector shall be supplied wired to a side panel terminal strip unless otherwise specified.

Controller Preliminary Testing:

Prior to installation in the street, the controllers, cabinet assembly, cabinet wiring and associated equipment shall be locally shop tested by the Contractor in the presence of the Boston Transportation Department Engineer.

The Contractor shall provide a test facility within twenty (50) miles of Boston. In order for the Contractor's facility to be acceptable for testing, it must be clean, heated and have test lights and other equipment needed for simultaneous testing of at least three (3) controllers. If directed by the BTM Engineer, the Contractor shall deliver the controller to the BTM Signal Shop at 12 Channel St, South Boston St. for testing.

The Contractor shall set up the controller to operate in its fully expanded mode with his own test lights on all circuits. For example, a four-phase controller shall be wired

for at least 4 vehicle phases, one pedestrian phase and three overlap phases regardless of the number of phases initially used. If the specified sequence requires additional pedestrian or overlap circuits, these shall also be wired to test lights. When the testing is complete, the contractor shall prepare the controller for operation as called for on the plans including timer settings as shown on plans or as directed by the Engineer. The Contractor shall notify the BTD Engineer to schedule the testing. A copy of controller timing shall be supplied to the BTD Engineer on a USB drive or other media approved by the BTD Engineer.

Prints

a. Delivery Schedule

One (1) complete set of prints, operating manuals and maintenance manuals shall be supplied prior to the testing of the equipment. This set will be left in the cabinet. The remaining two (2) sets of documentation shall be supplied before acceptance of the equipment. In addition to the required hard copy, the cabinet wiring diagram shall be provided in an "AutoCAD" compatible format on a CD or other media approved by the BTD Engineer. Quality of the drawings shall be such that when reproduced, all line work and characters are clearly visible.

b. Contents

Three (3) complete sets of prints, three (3) operating manuals and three (3) maintenance manuals shall be supplied with each controller. The prints shall include all circuitry within the cabinet including that in any modules or sub-assemblies. Detail in prints shall be down to the component level. Numbering of all terminals and components shall be unique and consistent. All wires on terminals must be labeled on the print.

Standard schematic packages which include schematics not specifically for equipment supplied at a given location shall have pages which do not apply so marked.

Operating manuals and maintenance manuals shall include the following:

- a. Full description of how all circuitry works (theory of circuit operation).
- b. Block diagram(s) defining interrelationships between various boards and components.
- c. Testing procedures for various failure symptoms including measurements to be found with a particular failure.
- d. Instructions for programming of all front panel, internal switches and internal function matrices such as conflict monitor programming.
- e. Step by step instructions for keyboard controller unit database setup, including sample programs, shall be provided. Included shall be Max#2 and flash programming for isolated locations and timing plan data for locations to operate in a coordinated system.
- f. Data sheets (8 1/2" x 11") shall be provided documenting the initial programming provided at the time of installation. Data sheets shall be provided for all menu screens including those initially unused. Unused screen programs shall indicate why they are not applicable and how their functions are disabled.

- g. A complete, labeled, pictorial parts layout for each P.C. board.
- h. Assignment of a specific system and local detectors to RCU input numbers.
- j. A complete parts list including part numbers appropriate for ordering replacement modules, sub-assemblies or components. Component parts lists shall include a cross reference to at least two other manufacturer's name and part number.

All manuals and schematics shall be supplied for the latest revision of equipment supplied. Documentation shall include the location where revision numbers for modules are stamped. All manuals and schematics shall be clearly readable in order to be acceptable.

Replacement Parts

Integrated circuits which are of such special design that they preclude the purchase of identical components from any wholesale electronics distributor or component manufacturer shall not be allowed in the design of any equipment, with the exception of micro-processor chips.

Equipment containing components no longer manufactured will not be acceptable.

Encapsulation of two or more discrete components into new design circuit modules shall be prohibited.

Wiring Termination

1. All wires in harnesses shall be terminated on terminal strips.
2. Connectors shall be supplied with wiring to all pins unless otherwise specified in plans or specifications.

Detector Rack and BIU

BIU slots and detector rack terminals shall be supplied for each initially actuated approach and each system sensor if the intersection is defined on the plans. The minimum cabinet configuration shall include a BIU with 8 slots for two channel loop amplifiers and a corresponding detector rack with wiring and terminals for 16 input channels.

CONTROLLER COORDINATION OPERATION SPECIFICATIONS

The purpose of coordinated operation is to guarantee the start of the arterial green interval at a specific point in a background cycle for progression of traffic. The coordinated operation shall also provide separate control of minimum arterial green and maximum times for non-arterial phases on each timing plan.

Coordinated operation shall control the point in the background cycle where it is permissible to leave the coordinated phase to service a specific phase. This feature shall allow the user to add time to the end of the coordinated phase when specific non-arterial phases lack calls. The controller unit shall remain in the coordinated phase(s) except during user programmed permissive periods when non-arterial phase demand exists. The co-ordination shall be designed so that time not required by a particular non-arterial phase shall be returned to the coordinated phase.

The coordination offset and cycle transfer logic shall be compatible with that used in existing Boston Transportation Department coordinated systems.

Coordinated operation settings shall include the logic necessary to provide the specific yields and force offs described on the plans and in this specification.

Co-ordination settings shall be via a keypad controlling menu driven inputs. Settings shall be retained in controller memory.

General operation of the co-ordination logic during coordinated operation shall be as follows:

- A. Timing for each phase on each split including clearance times shall be input for each phase. The coordinator shall automatically calculate the required permissive periods in order to allow the user set maximums on each non-arterial phase to be timed. Where detector inputs are received by the controller unit after the start of the permissive period, the phase shall only be serviced if it is still possible to time vehicle and where appropriate pedestrian minimum periods without changing max times programmed for other non-arterial phases or the offset point for the coordinated phase.
- B. Refer to other portions of this specification for additional information relative to the required operation.
- C. Coordinated operation shall be an integral part of the controller unit.
- D. No connectors other than those defined in NEMA TS-2 shall be used to connect controller unit inputs or outputs to cabinet wiring.

The "time base reset" input shall, when enabled, reset the internal time base co-ordination zero references. A constant input on this line shall be ignored by the time base coordinator. The reset shall only occur when the input is first enabled.

Internal time base co-ordination shall be provided which can be programmed to be active or inactive when coordinated operation is not in effect. When coordinated operation is in effect, the time base co-ordination will be disabled.

During coordinated operation, the ATC unit shall use maximum #2 and shall guarantee return to the coordinated phase. During free operation, the ATC unit shall operate on maximum #1 and rest in any appropriate phase. Provisions shall be made so that a pedestrian phase concurrent with the coordinated phase can be programmed to rest in Don't Walk or in Walk. It shall be possible to program other phases to rest in Walk when operated in a non-actuated mode. This feature shall be available under coordinated or free operation.

Once yield to a phase has occurred, all other non-arterial phases shall be serviced except as limited by force off, force to or skip functions. These inputs shall be generated by the internal controller coordinated operation during coordinated operation but may be generated by a pre-emption device in some instances.

Force off functions shall not force off the arterial phase or cause its concurrent pedestrian phase to recycle unless specified.

For up to five (5) sequential phase sequences at least five (5) functions shall be supplied regardless of the number of functions specified on the plans. The following functions shall be included unless they are in conflict with those required by the plans:

- a. Phase one (arterial phase) yield to phase 2 only (not phase 3, 4, or 5).
- b. Phase one yield to phase 3, 4 or 5 (not phase 2).
- c. Force off phase 2 only.
- d. Force off phase 3 only.
- e. Force off phase 2, 3, 4, or 5, recycle ped concurrent with phase 1 if there is pedestrian demand.

Coordinated o operation shall be designed to allow use of any ATC unit phase in "non-lock" or "locking" memory as desired.

In addition to other prints, operations and maintenance data required by the plans and specifications a detailed description shall be provided for programming of coordination operation programming. functions. Several sample programs shall be provided to allow the user to easily utilize all available coordination functions.

When coordination is active in a controller, it shall be capable of operating in a dual (multiple) ring configuration for non-arterial phases, the following shall apply:

- a. Dual entry operation shall be programmed to operate during coordinated operation to call a selected phase in each ring when calls are not present for at least one phase in each ring.
- b. The dual entry logic shall not cause a phase to extend where there is no actual vehicular or pedestrian demand.

Terminal Blocks for Communication Cables:

R66 type terminal blocks shall be provided for a minimum of 3, 30 pair cables. If the existing / proposed cabinet does not include twisted pair copper communications cable, the R66 terminal shall not be required. These blocks shall be split type 6 clips wide isolated between three (3) separate two (2) slot clips. Cabinet wall space shall be reserved to allow connection of the cables. Bridge clips shall be provided to connect the three sets of clips for all terminals included spares. Labeling strips shall be provided and marked with system functions and cable destinations.

Ethernet Switch:

Each cabinet shall include a field hardened Ethernet switch DIN rail mounted on the interior side wall of the cabinet.

The ATC unit shall include TS-2 mode 6 with the following pin assignments:

A-Cable Mode 6

<u>Pin #</u>	<u>Signal Dir.</u>	<u>Mode #6</u>	<u>Pin #</u>	<u>Signal Dir.</u>	<u>Mode #6</u>
A	O	Fault Monitor	AA	I	10 V Det
B	O	+24VDC	BB	I	WRM
C	O	Volt Monitor	CC	O	Stat Bit A
D	O	1 Red	DD	O	Free/Coord
E	O	1 Dwk	EE	I	Dimming
F	O	2 Red	FF	I	Ped Rcyl R1
G	O	2 Dwk	GG	I	Max II R1
H	O	2 Pclr	HH	I	Mode Bit C
J	O	2 Wk			
K	I	2Vdet			
L	I	2 Pdet			
M	I	2 Hold			
N	I	Stop Time R1			
P	I	Inh Max R1			
R	I	Ext Start			
S	I	Int Advance			
T	I	Ind Lamp Cont			
U	*	AC Neutral			
V	*	Earth ground			
W	*	Logic ground			
X	O	FL LogicOut			
Y	O	Stat Bit C R1			
Z	O	1 Yel			
a	O	1 Pclr			
b	O	2 Yel			
c	O	2 Grn			
d	O	2 check			
e	O	auto/flash			
f	I	1 Vdet			
g	I	1 Pdet			
h	I	1 Hold			
i	I	Force Off R1			
j	I	Ext Min Rcl			
k	I	MCE			
m	I	CNA1			
n	I	9 V Det			
p	*	AC+117V			
q	I	Mode Bit A			
r	O	Stat Bit B R2			
s	O	1 Grn			
t	O	1 Wk			
u	O	1 check			
v	I	Auto flash			
w	I	Reserved			
x	I	Reserved			
y	I	Mode Bit B			
z	I	CNA II			

B Cable Mode 6

<u>Pin #</u>	<u>Signal Dir</u>	<u>Mode #6</u>	<u>Pin #</u>	<u>Signal Dir.</u>	<u>Mode #6</u>
A	O	Pre Stat 2	AA	O	OLA Grn
B	I	Preempt 2	BB	O	OLB Yel
C	O	Pre Stat 1	CC	O	OLB Red
D	O	3 Grn	DD	O	OLC Red
E	O	3 Yel	EE	O	OLD Yel
F	O	3 Red	FF	O	OLC Grn
G	O	4 Red	GG	O	OLB Grn
H	O	4 Pclr	HH	O	OLC Yel
J	O	4 Dwk			
K	O	4 Check			
L	I	4 Vdet			
M	I	4 Pdet			
N	I	3 Vdet			
P	I	3 Pdet			
R	I	3 Omit			
S	I	2 Omit			
T	I	Offset 1			
U	I	1 Omit			
V	I	TBC on line			
W	I	Preempt 1			
X	I	Time Plan C			
Y	O	3 Wk			
Z	O	3 Pclr			
a	O	3 Dwk			
b	O	4 Grn			
c	O	4 Yel			
d	O	4 Wk			
e	O	TBC Aux 2			
f	O	4 Next			
g	I	4 Omit			
h	I	4 Hold			
i	I	3 Hold			
j	I	Time Plan A			
k	I	Offset 2			
m	I	Offset 3			
n	I	MMU FL Stat			
p	O	OLA Yel			
q	O	OLA Red			
r	O	3 Check			
s	O	TBC Aux 1			
t	O	3 Next			
u	O	OLD Red			
v	I	Time Plan D			
w	O	OLD Grn			
x	I	Time Plan B			
y	I	Free/No Coord			
z	I	Max II R2			

C-Cable Mode #6

<u>Pin #</u>	<u>Signal Dir.</u>	<u>Mode #6</u>	<u>Pin #</u>	<u>Signal Dir.</u>	<u>Mode #6</u>
A	O	Stat Bit A R2	h	O	6 Yel
B	O	Stat Bit B R2	i	O	5 Grn
C	O	8 Dwk	j	O	5 wk
D	O	8 Red	k	O	5 Check
E	O	7 Yel	m	I	5 Hold
F	O	7 Red	n	I	5 Omit
G	O	6 Red	p	I	6 Hold
H	O	5 Red	q	I	6 Omit
J	O	5 Yel	r	I	7 Omit
K	O	5 Pclr	s	I	8 Omit
L	O	5 Dwk	t	I	6 Vdet
M	O	Offset 3	u	I	Reserved
N	O	Time Plan A	v	I	Zero Reset
P	I	5 Vdet	w	O	8 Pair
R	I	5 Pdet	x	O	8 Grn
S	I	6 Vdet	y	O	7 Dwk
T	I	6 Pdet	z	O	6 Dwk
U	I	7 Pdet	AA	O	6 pclr
V	I	7 Vdet	BB	O	6 check
W	I	8 Pdet	CC	O	Time Plan B
X	I	8 Hold	DD	O	Time Plan C
Y	I	Force Off R2	EE	I	7 Hold
Z	I	Stop Time R2	FF	O	8 Check
a	I	INH Max R2	GG	O	Offset 2
b	I	11 V Det	HH	O	TBC Aux 3
c	O	Stat Bit C	JJ	O	7 Wk
d	O	8 Wk	KK	O	7 Pclr
e	O	8 Yel	LL	O	6 Walk
f	O	7 Grn	MM	O	7 Check
g	O	6 Grn	NN	O	Offset 1
			PP	O	Time Plan D

INTERNAL REMOTE COMMUNICATIONS UNIT

The internal RCU shall meet requirements contained in the following separately numbered section of this specification:

Internal Remote Communication Features

General

The internal remote communication (RCU) unit shall provide communications and interface equipment required at local intersections for the transfer of data between the Boston Traffic Control Computer Center and the signalized intersections. This unit shall be an integral part of the NEMA TS-2 timing unit.

An existing Central Communications Unit (CCU) and the central computer system have been interfaced as part of the BTCS (Boston Traffic Computer System).

The communications for the command and return data is accomplished by means of a polled Time Division Multiplexing (TDM) technique using four wire unconditioned lines. The internal RCU shall be designed so that no changes to central communications or system software are required. The FSK modem for the internal RCU may be shelf mounted with connections to the timer unit via a NEMA TS-2 port. Since most new installations will utilize IP based communications, the FSK modem is not required unless otherwise directed by the plans or specifications.

Functional Requirements

Communications Network

The remote communications unit shall be capable of transmitting data at distances of up to eight (8) miles over user owned twisted wire pairs. The existing system is expandable to 800 RCU's. Each four-wire circuit (2 pairs) will service a maximum of eight RCU's.

All CCMs and RCUs have been specified as presenting 600 ohms (average) impedance to the communications interconnect.

However, it is recognized that with up to 8 RCUs attached to Central, that the effective load impedance presented to the wire pairs is substantially less than 600 ohms. Over distances less than 3-4 miles between the control center and the controller cabinets (with the RCUs) it is customary to operate in this manner without any additional line conditioning, balancing or impedance matching. Wherever this is the method of implementation in the BTCS communications system it shall in no way compromise the performance and quality of the communications. All subject performance specifications shall be strictly adhered to.

Twenty-four (24) bits of the command data are generated by the computer and transferred to the CCU. Four of these bits representing RCU address are actually transferred to the CCU as zeroes. Actual addresses are then appended to the command data by the CCU. The CCU adds a check-sum character (8 bits) and formats this data into four bytes. Each of these data bytes is appended with a start bit, a stop bit and a parity bit. These additional bits are utilized by the RCU as and aid in detecting bad

transmissions. As an additional aid, the last eight bits of the 32-bit command message constitute a check-sum character. Utilization of both of these categories of error checking results in a system having the ability to detect communications errors in the command messages to the field. A 32-bit command message is then sent to each RCU in the field.

Start, stop and parity bits are also appended to the eight bytes of return data generated in the RCU. These additional bits are used by the CCU to perform error checking on the return data. The eighth byte is a check-sum character.

Each CCM has the following requirements:

Data Rate:

Serial 1312 BAUD modulation.

Modulation:

Frequency Shift Keying (FSK)

Operation:

Asynchronous

Line and Signal Requirements:

Type 3002 Voice Grade

Tone Carrier Frequencies:

1200 HZ mark - 2200 Hz Space

Transmitting Output Signal Level:

+6, +2, 0, -2, -4, -6, -8, -10 dbm continuous, switch or strap selectable. If continuous, means to lock the adjustment shall be provided.

Received Level Sensitivity:

0 to -40 dbm

Receiver Bandpass Filter:

Minimum of 20 db attenuation at frequencies outside of operating band.

Error Rate:

Not to exceed 1 bit in 100,000 bits with a signal to noise ratio of 16db with noise flat weight over a 300 to 400 HZ band.

Transmit Noise:

Less than -50 db across 1600 ohm resistive load within the frequency spectrum of 300 to 3000 HZ at maximum output.

Network:

Full duplex (four wire) system operation.

Indicators:

Have LED type indicators for Carrier Detect, Transmit Data, Receive Data, and Request to Send.

Multipoint Requirements:

Have turn around characteristics (CTS delay, Carrier Response Time, Soft Carrier Turn-Off Time) to allow a one second period polling of eight drops where each drop received four eleven bit "bytes" and transmits eight eleven bit "bytes".

INTERNAL Remote Communications Units (RCU's)

Each RCU will be connected to a 4-wire circuit, with a maximum of 8 RCU's sharing any circuit. The RCU will receive digital coded command data on one pair in bit serial form, decode the address portion, perform data validity tests and convert the received command data into parallel control signals. If the decoded address matches its assigned address and the comparison of the data check character at the end of the command data shows no errors, the RCU will output the command portion of the received data to its associated intersection ATC unit. Each time the RCU receives commands from Central, it will transmit back to central eight 8-data-bit bytes in bit serial form on the second wire pair. This return data includes ATC unit status, system and trolley sensor data, stop line detector status, pedestrian pushbutton status, and a check-sum character as defined herein.

In addition to providing the interface between the communication lines and the ATC units, the RCU will perform system sensor data processing. Each RCU shall be capable of processing and transmitting data from as many as eight (8) system sensors. The RCU shall also contain the Controller Adapter which serves as the interface between the communications media and the controller.

Specifications for Remote Communication Unit

Communications System Operation

All communications between the CCU and the computer are performed once per second. A buffer of commands is written to the CCU, and a buffer of responses is read from the CCU. Each buffer is sized for 56 CCMs and 8 RCU per CCM. The data is arranged in the buffer by CCM and then by each RCU associated with that CCM. The output data is sized at 4 bytes per RCU and the input data at 8 bytes per RCU. The sequence of communications is as follows:

- o The DMA portion of the I/O channel between the computer and the CCU is initialized with the start and end addresses of the output buffer.
- o A reset command is sent to the CCU.
- o A write command is sent to the I/O channel.
- o After transmission of the output buffer terminates the DMA portion is initialized with the start and end addresses of the input buffer.
- o A reset command is sent to the CCU.
- o A reset command is sent to the I/O channel.
- o After reception of the input buffer terminates the input data is processed.

The CCMs shall receive their respective command data words and addresses from the CCU. Start, stop and parity bits are appended in the CCU to each byte of data.

As noted above, the CCMs transmit the command message in bit serial form. The eight (8) successive command messages to each of the eight (8) RCU's on a channel are time division multiplexed by the CCMs, where the timing of this process is controlled by the CCU.

As the return data is received by each CCM, they will demodulate these signals. The CCU will calculate a check-sum character based on the first seven bytes of data and compare it to the eighth byte transmitted by the RCU. A substitute eighth byte is transferred to the computer from the CCU which consists of an analysis of the error checking performed by the CCU on the RCUs response.

The BTDC UTCS central computer provides both transmit and receive data transfers at the rate of one (1) per second \pm 10 milliseconds. All other interim timing is accomplished by the CCU such that the data transfer to and from the RCUs is repeated at the rate of one (1) per second.

Specifications for Remote Communication Unit

Data Format

The command and return data format at the central computer to CCU I/O Interface are shown herein. The data format in parallel bit form is shown for both the Command and Return message to a single RCU.

The last byte of data consists of a check-sum character created by the CCU. The RCU also computes a check-sum character based on the first three bytes received and compares it to the CCU generated character. If there is a match, then the RCU uses the data. If not, then the data is ignored and the RCU does not transmit.

The CCM receives return data in byte form and checks the start, stop and parity bits. It then presents the data to the CCU. The computer then reads the data in half word form as shown.

In the RCU return data format; byte 1 contains all of the Phase Greens; byte 2 contains two Spare bits, a Controller Repair, Pre-empt, System Flash, Flash, Conflict Monitor, and cabinet Door Open bits; byte 3 comprises the check bits of 8 phases of actuated controllers; byte 4 contains the bits for the eight (8) stop line sensors; byte 5 contains the bits for the eight (8) pedestrian pushbuttons at an intersection.

COMMAND DATA FORMAT - COMPUTER TO CCU

4 BYTE DATA WORD

<u>BYTE</u>	MSB..... LSB
								
1	F01	HOLD	DIAL REL	HOL	*	*	*	*	
2	SP1	SF3	SF2	SF1	CALL ALL	PED CALL	FLASH	FO2	
3	SP7	SP6	SP5	SP4	SP3	SP2	FREE	PHASE OMIT	
4	*	*	*	*	*	*	*	*	

NOTES:

1. Total number of bytes transferred is equal to 1792 (4 bytes x 448 RCU's).
2. The asterisks in Byte 1 are reserved for the address bits which are generated by the CCU. The computer transfers "zero's" in these bit locations.
3. The asterisks in Byte 4 are reserved for the check-sum character which is generated by the CCU. The computer transfers "zero's" in these bit locations.
4. Abbreviations: FO = Force-Off; SP = Spare; SF = Special Function; HOL = Hold On Line.

RETURN DATA FORMAT

8 BYTE DATA WORD

<u>BYTE</u>	MSB.....	LSB
1	GREEN PHASE 1	GREEN PHASE 2	GREEN PHASE 3	GREEN PHASE 4	GREEN PHASE 5	GREEN PHASE 6	GREEN PHASE 7	GREEN PHASE 8
2	SP2	SP1	CONT REP	PREEMPT	SYS FLASH	FLASH	CONF MON	DOOR
3	CHECK PHASE 1	CHECK PHASE 2	CHECK PHASE 3	CHECK PHASE 4	CHECK PHASE 5	CHECK PHASE 6	CHECK PHASE 7	CHECK PHASE 8
4	LOC DETECTOR PHASE 1	LOC DETECTOR PHASE 2	LOC DETECTOR PHASE 3	LOC DETECTOR PHASE 4	LOC DETECTOR PHASE 5	LOC DETECTOR PHASE 6	LOC DETECTOR PHASE 7	LOC DETECTOR PHASE 8
5	PED BUTTON PHASE 1	PED BUTTON PHASE 2	PED BUTTON PHASE 3	PED BUTTON PHASE 4	PED BUTTON PHASE 5	PED BUTTON PHASE 6	PED BUTTON PHASE 7	PED BUTTON PHASE 8
6	OCC 1	EOV 1	<u>SYSTEM</u> OCC 2	<u>SENSORS</u> EOV 2	OCC 3	OV 3	OCC 4	EOV 4
7	OCC 5	EOV 5	<u>SYSTEM</u> OCC 6	<u>SENSORS</u> EOV 6	OCC 7	EOV 7	OCC 8	EOV 8
8	1	----	----	----	0	CKE	NR	BE

NOTES:

1. Byte 8 contains error information as interpreted by the CCU. The eighth byte transmitted by the RCU consists of a check-sum character.
2. CKE represents a check-sum error. NR represents a no-response. BE represents a byte error such as framing, parity or overrun as generated by the UART.
3. For a normal RCU response the last byte would be a Hex "FO"; no-response is a Hex "D2".
4. EOV represents the end of vehicle bit.

Command Data

The command data to the RCU consists of four eight-bit characters. The first twenty-four bits are the actual command bits. The last eight bits are a "data check" character. Pre-timed and Actuated controller functions are intermixed below. Function assignments for the various bits are as follows:

<u>Byte</u>	<u>Bit</u>	<u>Function</u>
2	0	Spare bit to control spare NEMA ground true output circuit.
2	1-3	Special Functions (if required). Controls isolated Form C relay outputs.
2	4	The output from Bit 4 is to be used to place steady vehicle calls (NEMA ground true circuits) on all actuated phases. Use of this bit enables the system to operate actuated controllers in a fixed-timed (phase release) mode, extending all phases until a force-off command is received from the system. Exclusive Pedestrian phases are not to be called by this bit.
2	5	Output controlled by the PedCall bit is to be used to place steady pedestrian calls to those phases having concurrent or exclusive pedestrian movements. The RCU output consists of 4 NEMA ground true circuits and one AC ground true output.
2	6	The Flash bit is used to command the intersection to flashing operation. This bit operates in conjunction with MUTCD Flash.
2	7	These two bits are used to force-off Ring 2
1	0	and 1 respectively, of a dual ring actuated controller. Single ring controllers will require only Bit 0 of Byte 1 for control. They are NEMA ground true outputs.
1	1	Bit 1 controls the release or yield period of the coordinated phase or phases of the actuated controller. This bit works with the H.O.L. command as follows. When the H.O.L. command is received, phase HOLD signals are sent to the controller. Dropping off Bit 1 interrupts the HOLD signals to release the coordinated phase. Note that one bit is used to control the yield, even in dual ring controllers.

BTCS Data Format - ExplanationCommand Data (cont.)

<u>Byte</u>	<u>Bit</u>	<u>Function</u>
1	2	<p>Bit 2 is used to control the "release" of the System Dial in a pre-timed ATC unit. The output controlled by this bit becomes active when the phase release "System" dial has been selected and is interrupted to allow this "System" dial to advance the controller into the next phase. This bit usually operates with an unused offset circuit (Reset 2) on the system dial (Dial 2) to attain control.</p>
1	3	<p>Bit 3 is the "Hold online" (H.O.L.) command. When it is received at any intersection, standby coordination commands (where present) are to be totally disabled so that control of the intersection may be transferred to the BTDC UTCS central computer. This is accomplished by the fact that the Call Free RCU outputs are also enabled with the HOL bit. This control is enabled by the H.O.L. command at both pretimed and actuated controllers. Response to the command shall be as follows:</p> <p>When this command is received, the RCU is to place demand for minimum vehicle service on the coordinated phase or phases and remove local detector calls from that phase(s). After service has been initiated on the coordinated phase (s), pedestrian service is to be inhibited on the coordinated phase(s) until the phase HOLD input signal is removed by the RCU during periods of yield. Pedestrian service may only be initiated at the beginning of the phase(s) or during yield periods.</p> <p>The H.O.L. command must also be utilized to provide the following commands to the controller:</p> <ul style="list-style-type: none"> - Walk Rest Modifier - Inhibit Maximum Timer - Enable Coordinated Phase Hold Inputs

BTCS Data Format - ExplanationCommand Data (cont.)

<u>Byte</u>	<u>Bit</u>	<u>Function</u>
1	4	Not used.
1	5-7	These three bits are used to give the RCU and address number from 0 to 7. There are 8 RCU "drops" on a line. The RCU address is inserted in the command byte block by the CCU.
4	0-7	These are an 8-bit data check word generated by the Traffic System central Processor Unit. They constitute a check sum character. When an invalid message is received (as determined by an incorrect data check character) the RCU will re-use the data from the last transmission. Receipt of more than three such incorrect messages will cause the RCU to go "Off-Line" and drop all control of the associated intersection ATC unit.
3	0-5	Spares. These bits are to control spare ground true output circuits from the RCU. These output circuits are to be active when the associated bit is active. The output circuit is to be as defined in NEMA standard TS2-1998.
3	6	The Call Free bit, when active, disables the standby system at pre-timed or actuated ATC units connected to a standby system. All standby functions affecting controller operation except fire run are to be disconnected or disabled.
3	7	This bit is to control a Phase omit input. When this bit is used in conjunction with the call-all (Bit 4, Byte 2), the Hold/Yield (Bit 1, Byte 1) and the Force-Off (Byte 2, Bit 7 and Byte 1, Bit 0) commands via the TCS system, an ATC unit can be commanded to a pre-selected phase directly.

Return (Monitor) Data

Return data is synchronized by receipt of the command data. Return data consists of eight eight-bit characters. For some return functions additional logic may be required to bring back the data for actuated controller interfaces. Function assignments are as follows:

<u>Byte</u>	<u>Bit</u>	<u>Function</u>
1	0-7	These bits indicate the green status of phases 1-8 (1G-8G) respectively. Exclusive pedestrian phases, pre-timed or single ring actuated, will return the "walk" as phase 2 green. Dual Ring actuated controllers will return the Exclusive pedestrian phase "walks" as greens to be determined by the Engineer.
2	0-1	Spare bits to be active when a ground true signal as defined in NEMA standard TS2-1998 is applied to their associated input circuits.
2	2	Bit 2 is to be active when a technician selects the appropriate ATC unit menu item to indicate to the system that a repair has been made to the ATC unit. This bit shall also be driven by a Latch circuit which operates when a recognizable power failure occurs, and which resets after three seconds of return transmission of data.
2	3	The PRE-EMPT monitor bit is to be active when the intersection is pre-empted for any reason, such as manual control or fire-run.
2	4	Bit 4 is to be active when the intersection is operating on flash because of a standby system command for flash.
2	5	Bit 5 is to be active when the intersection is operating on flash for any reason.
2	6	Bit 6 is active when the intersection conflict monitor (MMU) has "tripped" indicating a conflict or other abnormal situation.
2	7	Bit 7 is to be active when the controller cabinet door is open for any reason.

BTCS Data Format - ExplanationCommand Data (cont.)Return (Monitor) Data (cont.)

<u>Byte</u>	<u>Bit</u>	<u>Function</u>
3	0-7	Phase call status (one bit/phase) connected to controller phase check output (up to 8 phases for actuated ATC units can exist). All exclusive pedestrian phases, pre-timed or actuated, will return a phase 2 check bit when a call is placed.
4	0-7	Bits 0-7 are to return an indication of activity on the stop line detectors (up to eight). These bits are to be driven by latch circuits which operate when the stop line detector is actuated, and which reset after return transmission of data.
5	0-7	These bits are to return an indication of activity on the pedestrian button (PB) inputs to phases 1-8 respectively. These bits are to be driven by latch circuits which operate when the PB is actuated, and which reset after every return transmission of data. Pre-timed "exclusive-ped" pushbuttons are returned as phase 2 pedestrian button.
6	0,2,4,6	Each bit indicates and "overflow" of a system sensor occupancy counter. When such bit is set, the counter will be reset to "0" to allow the continued accumulation of occupancy counts. Each bit represents 32/30 second of occupancy (Sys. Sensors 1-4).
6	1,3,5,7	Each bit indicates a system sensor end of vehicle. The counter is decremented to allow the continued accumulation of end of vehicle counts. Each bit represents a single end of vehicle (Sys. Sensors 1-4).
7	0,2,4,6	Same as bits 0,2,4,6, Byte 6 for Sensors 5-8.
7	1,3,5,7	Same as bits 1,3,5,7, Byte 6 for Sensors 5-8.

Bytes 6 and 7 contain the bits for the eight (8) system sensor return data, with 2 bits per system sensor. The first bit indicates a vehicle occupancy "overflow" and the second bit is used for an end-of-vehicle "overflow".

The eighth byte transmitted between the RCU and CCU consists of a check-sum character. The CCU utilizes this byte for error checking of the return data. A substitute eighth byte is transferred from the CCU to the computer. This byte consists

of error codes which inform the computer of the status of the last transmission received. Based on this error status, the computer decides how to process the incoming data.

The function of each data bit is explained herein.

Data Validity

Command Data to RCU's

The system, in addition to the timing (synchronizing) bits, generate a parity bit at the end of each 8 bit data byte to be used for parity error detection at the RCU.

Address Encoding and Error Detection in RCU

The RCU shall have a preset address code as specified by its particular intersection and 4-wire circuit (data channel). The RCU shall decode its assigned address (0-7). Programming of the address for the RCU may be accomplished via wire jumpers on a terminal within the controller cabinet. This terminal strip and wiring shall be external to the RCU. Address information shall be wired from the cabinet to the timer unit via TS-2 Port3. Port 3 Pin #3 shall be utilized for address bit 3, Pin #7 shall be used for address bit #1 and Pin #8 shall be used for address bit #2. If software programming for RCU address is available in timing unit programming, this programming method may be used in place of cabinet jumpers.

Prior to decoding and programming, the RCU receiver/transmitter section (following data demodulation) shall determine whether any parity, framing or overrun errors exist in any of the 8-bit data bytes. If such errors are detected, these bytes will be rejected and the commands which are transferred from RCU to controller shall be held at their current state.

After the address decoder recognizes its proper address, the command data shall be latched into the RCU command decoding logic. At this point, the RCU's check character decoder will analyze the preceding command words. If no errors are detected, the command data shall be transferred to the controller interface circuits.

If errors are detected, all command data shall be stopped and the data in the controller interface registers shall be held at the previous valid commands.

Timing and Parity Bits

One start bit at the beginning of each 8-bit byte and one parity bit at the end of the byte followed by one stop bit shall be used in the RCU communications circuit design.

RCU Turnaround Time

The time interval allowed between the end of the command data (check character) and start of the return data received by the CCMs at Central shall be 10 milliseconds minimum.

This permits communication from the central transmitter to settle down completely before the central receiver starts to receive response data from the RCU.

Transmit and receive data timing shall allow for up to 20 milliseconds turnaround-time.

Operational Performance

Data Rates

All command data to all intersections by the CCMs to the RCUs and return data received by the CCMs shall be transmitted within one (1) second interval.

The bit data rate in both directions shall be 1312 bits per second.

Error Rate

The probable undetected bit error rate of the communication system with 8 multipoint drops (RCUs) sharing one 4-wire circuit of up to 8 miles of common cable shall be no greater than one (1) part in 10^{+E8} at an 18 dB signal-to-noise ratio (white noise) and worst case conditions of message circuit noise and impulse noise defined in Bell System Technical Reference "Data Communications" PUB 41004, Section 4.3.

The probable throughput (percent of transmitted words accepted as errorless by the receiver), shall be no less than 99.95% under the worst-case conditions.

Transmission signal characteristics shall be such that self-induced noise on the cable does not cause probable error rates in excess of one part in 10^{+E8} or probable throughput less than 99.99% under the worst-case conditions.

Signal Levels

The output of the CCM and the RCU transmitters shall be a minimum of 0 dBm out at an average impedance of 600 ohms in the frequency range of 200-300 Hz. The output level shall be selectable from +6 to -10 dBm using switches, straps or a lockable continuous adjustment.

The receiver sensitivity of the RCUs shall be 0 to -40 dBm (minimum sensitivity).

Computer Failure; Standby Mode

The CCU is equipped with a +24 VDC relay which, when de-energized, positively disables and inhibits all CCM communication with all field (RCU) equipment. This

relay is de-activated by the watchdog circuitry in the control panel equipment when a computer system malfunction is detected.

Field response to such a cessation in communications is a drop of the "Hold online" along with all other commands from the RCU. This automatically causes all controllers to revert to the standby mode. In this mode all controllers are placed under the control of their respective standby master controllers.

Remote Communication Unit Interfacing

RCU/Communication Lines

There shall be an isolation transformer in the output/input circuit of each RCU. Appropriate surge protection shall be provided for the RCU inputs and outputs which connect to field circuits.

RCU/Controller Interfacing

The controller interface circuitry (adapter) shall be an integral part of the RCU.

The interface circuitry shall provide the necessary logic to provide data to and from the controller unit and cabinet wiring to and from the BTM UTCS central computer in a format compatible with the existing BTM central software and communications system.

It shall be possible to use a timer unit with an internal RCU as specified herein at any intersection without modification.

RCU/System Sensor Interfacing

Preprocessing logic shall be used in the RCU to encode both the volume and occupancy data returned to the CCU. This logic will operate as follows:

1. Volume - Each End of Vehicle (EOV) bit (of 8) shall indicate one of the counts of the system sensor (EOV) counter. When the counter reaches a count greater than 0, it shall set the appropriate EOV bit to a logic "1" and shall decrement the counter to allow continued EOV counting. The counter is incremented each time an end of vehicle is sensed. The counter shall hold up to 7 end of vehicle indications. The EOV counter is decremented when status is requested and sent to the CCU.
2. Occupancy - Each occupancy bit (of 8) shall indicate an "overflow" of a system sensor Occupancy counter which shall count up to thirty-two (32) in thirtieths of a second when the detector loop is occupied. When this counter reaches thirty-two, it shall set the

occupancy bit to a "1" and then it shall reset the counter to "0" once status is requested by and sent to the Control Computer.

Pedestrian Push Button Status

The RCU return data logic shall latch in a logic "1" when a pedestrian push button is actuated in a given phase (at pretimed or actuated controllers). The latch logic shall be reset to "0" at the end of the turn data message for that particular RCU. This affects the PB status bits (0-7) of the 5th return byte.

Door Open Status

A door switch installed in the ACT unit cabinet door shall activate Bit 7 of the 2nd return byte when the door is open. The door switch shall utilize Pin "T" (Harness A) defined by NEMA TS-2 as "IND LAMP CONT".

ATC Unit Repaired Status

"ATC Unit Repaired," status Bit 2 of the 2nd return byte shall show a logic "1" for the next returned word when the appropriate menu selection is manually actuated (by a technician) to indicate that the ATC unit has been repaired. This ATC unit repaired bit shall remain at logic 1 state for the next three seconds after activation before it resets to logic 0. Additionally, the UTCS interface return data logic shall include the capability to indicate logic "1" for this bit when the RCU power is restored after either a power failure, or from power being manually shut down for that ATC unit cabinet. This latched circuitry shall be supplied as part of the ATC unit and the circuitry shall be reset three seconds after initial return transmission of data to the CCU.

Stop Line Detector Status

The RCU return data logic shall latch in a logic "1" when a stop line detector is activated. The latch logic shall be reset to "0" at the end of the return data message. This affects the stop line detector status bits (0-7) of the 4th return byte.

Construction

The RCU 1312 baud modem included as part of the internal RCU shall be modular to allow for future baud rate changes.

NEMA TS-2 Port 3 Requirements

<u>PIN</u>	<u>FUNCTION</u>
1.	Transmit ring
2.	Transmit tip
3.	Address bit #3
4.	Receive ring
5.	Receive tip
6.	Logic ground
7.	Address bit #1
8.	Address bit #2
9.	Earth ground (to cable shield)

NEMA TS-2, Port #3 shall be utilized for RCU connections to the interconnect cable and for ATC unit cabinet back panel programming of the RCU address. Pins 3, 6, 7, and 8 shall be connected to a cabinet panel terminal strip where jumpers are to be added by the Contractor when the modem assignment is defined. Pins 5, 4, 2 and 1 shall be connected in order from bottom of a six (6) interconnect fuse strip with 1/4"x 1 1/4" glass tube type fuses. These fuses shall be clearly and permanently labeled with the functions listed above for port #3. Transient protection as specified herein shall be supplied from each of these four lines to ground and across receive pair and transmit pair. These surge suppression devices shall be of a heavy-duty two-stage balanced surge protector intended for use on data or communication pairs. The device shall consist of a primary and a secondary protector. During a surge, both signal leads shall be grounded simultaneously through the stud mounting where a solid earth ground is required. Units shall be EDCO model SRA64C-030X or approved equal.

Peak Surge Current	10,000 AMPS (8 X 20us)
Surge Clamp Voltage	30 Volts
Temperature	-20 to +85 Degrees Celsius
Construction	Epoxy Encapsulated
Stud Size	10 X 32 X 0,5"

Construction Requirements and Materials

Remote Communication Unit

Construction

All connectors, including cable and edge-board connectors, shall be supplied with gold plated contacts.

Plug-In Modules

RCUs shall be of modular construction.

New RCUs supplied on this job must be interchangeable with existing RCU's supplied by others.

Electrical Requirements

The equipment shall be designed to operate satisfactorily from a power source of 90 to 135 volts, 60 Hz, single phase, alternating current.

Some installations may require that the 120 VAC return, safety ground and logic signal ground be connected together. The design of the RCU shall allow these grounds to be connected without affecting the performance of the RCU, other connected RCUs or central modems. The RCUs shall be provided with all three grounds isolated.

RCU Special Output Requirements

The following outputs must be conditioned by the HOL command bit such that they will be active only when the HOL bit is also active (logic "1").

- o "Dial Rel"
- o "HOLD/YIELD"
- o "FO1"
- o "FO2"
- o "PHASE OMIT"

The HOL command bit shall generate a continuous HOL output. This output under normal conditions will be maintained by transmitting the HOL command bit continuously. Loss of the HOL bit or valid data for more than 3.0 seconds shall cause the RCU to terminate the HOL output.

Status Display

The status of the following functions shall be displayed when the appropriate menu selection is made. The display shall update in real time as functions change state.

1. "HOL"
2. "HOLD"
3. "FO1"
4. "FO2"
5. "CALL ALL"
6. "DIAL REL"
7. "PED CALL"
8. "P OMIT"
9. "RTS"
10. "CD"
11. "FREE"
12. "SFI"
13. "SF2"
14. "FLASH"

The Request to Send (RTS) indicator shall be turned on when the RCUs transmitter is active and the "clear to send" signal is active.

RCU Interference Filtering

The RCU input/output interface to the communication 4-wire circuits and the 115V power lines must include adequate transient and RFI filtering to prevent electro-mechanical controller switching transients, or any other source of electrical noise and voltage transients, from interfering with the proper operation of each RCU. The RCU shall comply with the High Frequency Interference requirements and tests specified in NEMA TS2-1998 Section 2, Controller Unit Tests.

Surge and Transient Protection

The RCU shall include adequate surge and transient protective devices in their 4-wire I/O interfaces, as well as for each 115V line to status monitors and power supply interface, to meet all subject Voltage Transient and Surge Tests defined in NEMA TS2-1998, Section 2.

Remote Communication Unit

Compatibility Test

The Contractor shall perform compatibility tests for the RCU or ATC unit supplied. This test shall ensure that the new equipment is interchangeable with its counterpart provided under previous contracts.

Each RCU supplied must be capable of satisfactorily operating at any actuated controller location. No functional differences will be noted between the existing RCU cabinets and the new internal RCU cabinets.

The RCU shall be compatible with existing communications test units (CTU). No functional difference shall be observed when operating the CTU with the RCU to be supplied under this specification.

Prints and Manuals

Three (3) schematics and 3 operating/ maintenance manuals shall be supplied with each RCU. The manual(s) shall include a complete parts list. The parts list shall include a cross reference to at least one other manufacturer's name and part number for each item. The manual(s) shall include detailed theory of operation and troubleshooting procedures.

Fiber Optic Patch Panel

Under this Item the Contractor shall furnish and install a fiber optic patch panels within the traffic signal controller cabinets as shown on the plans.

Materials -The Fiber Optic Patch Panels shall meet the following requirements:

1. This work shall consist of furnishing, installing, and testing Fiber Optic Patch Panel within field Cabinets, as well as all ancillary equipment necessary to provide a complete system.
2. The Contractor shall furnish, install, and test Fiber Optic Patch Panels that meet the following requirements:
3. The Fiber Optic Patch Panels shall be a stand-alone unit manufactured for outdoor field cabinets.
4. The Fiber Optic Patch Panels shall be wall or shelf mountable as required by the specific location. The splice panel shall be securely fastened in place in the field cabinet as recommended by the manufacturer.
5. The Fiber Optic Patch Panels shall be large enough to retain the number and size of splice trays capable of holding 24 splices as noted on the plans.
6. The Fiber Optic Patch Panels shall have a sufficient number of entry ports to accommodate the number of fiber optic cables needed for the specific application, as shown in the Plans.
7. The Fiber Optic Patch Panels shall be capable of housing and protecting 24 individual single mode fiber optic splices as noted on the plans.
8. The Fiber Optic Patch Panels shall include splice trays meeting the following requirements:
 - a) Each Fiber Optic Patch Panels shall contain a splice tray organizer capable of holding the required number of splice trays.
 - b) The splice trays in the Fiber Optic Patch Panels shall be capable of holding 24 48 individual single mode fiber optic splices.
 - c) The splice trays shall incorporate a system to retain and provide strain relief to the fiber optic buffers tubes, the fiber optic strands, and the protective sleeves used to house the fiber optic splices.
 - d) The splice trays shall incorporate grooves where the fiber optic splice can be held in place.
 - e) Each splice tray shall incorporate a clear snap on lid.

9. As described in the Boston Transportation Department document entitled “*Specifications for Fiber Optic Interconnect System*”:
 - a) Fiber optic cable strands shall be spliced using fusion splicing methods only.
 - b) After all installation and splicing is complete, the Contractor shall test the Fiber Optic Patch Panel.
 - c) Fiber optic splices shall exhibit 0.1 dB of optical loss, maximum, when measured with an Optical Time Domain Reflectometer (OTDR).
10. The Fiber Optic Patch Panels shall include a restraining system to hold the splice trays securely in place.
11. The Fiber Optic Patch Panels shall incorporate cable guides that maintain fiber strands and fiber buffer tubes bending radius greater than the minimum allowed by the fiber manufacturer.
12. The Fiber Optic Patch Panels shall incorporate a restraining and strain relief mechanism to securely retain and hold the fiber optic cables’ central members and outside jackets.

Type Testing/Approval

No equipment or accessories specified herein will be accepted unless type tested and approved by the BTM Engineer prior to the date of the proposal. The Contractor/supplier shall demonstrate to the satisfaction of the BTM Engineer that the controller and communications equipment will operate reliably under central real time control both at the BTM UTCs central computer site and at remote locations designated by the BTM Engineer. A controller which interferes with existing devices which utilize the same communications channel will not be acceptable. All approvals will be conditional and BTM reserves the right to withdraw its approval at any time of equipment or accessories. Reason for withdrawal of approval include but are not limited to equipment or accessories with abnormal maintenance and performance records or delivery of equipment which do not meet specifications.

Operation and Maintenance Training

The Contractor shall provide instructional time and furnish all materials and services necessary to train experienced BTM engineering and maintenance personnel in the operation, maintenance and repair, to the component level, of the following systems equipment and approximate duration:

ATC units 8 hours

Training sessions shall be conducted at the facilities in Boston. Eight (8) hours of training during periods to be approved by the BTM shall be provided for up to 15 trainees.

Training sessions shall only take place after all syllabi and proposed instructor(s) are submitted and approved by the BTD Engineer.

A single training session shall be required for orders of 5 or fewer ATC units or controllers. For orders in excess of 5 controllers, two (2) eight-hour training sessions shall be required.