MOTOROLA

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MOSCAD

Motorola SCADA

System Planner

R4-11-03E
June 1996

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Initial Printing: December 1991
Updated: July 1992
Updated: January 1993
Updated: Auguest 1993
Updated: October 1994
Major Rewrite: June 1996

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MOSCAD System Overview

The purpose of a MOSCAD system is typically to provide some degree of automatic operation to a new or existing customer process. The process may be found in water pump stations, sewage lift stations, communication system monitoring, security, public notification control, electrical substation monitoring, distribution automation, demand-side management, automated meter reading, or other applications. This automation is provided by a mixture of hardware.

RTU: The field sites are equipped with MOSCAD RTUs that collect data from on-site sensors, add data from off-site sources, and use this data aggregate to make decisions regarding how the process is operating. Changes to the local process may be made; messages may be initiated that send data elsewhere to influence the operation of off-site equipment or to advise the SCADA Manager of some important change. The RTU is thoroughly discussed in Chapter 2.

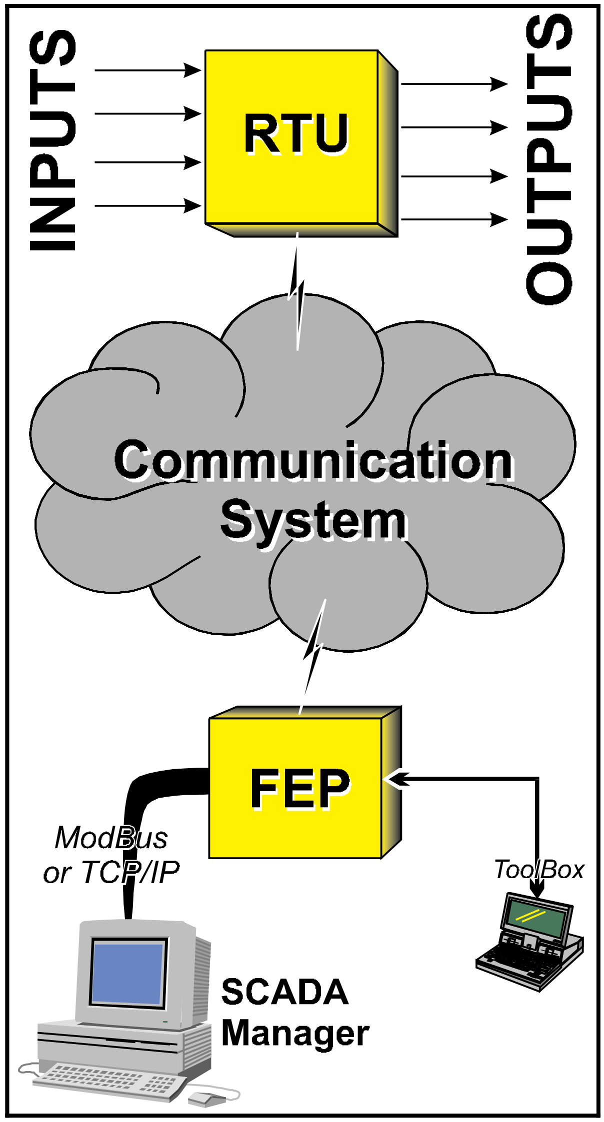


Figure 1. MOSCAD System Overview

Communications: The multiple sites in the system may communicate among themselves by utilizing a variety of communication choices: two-way conventional, trunked, or MAS radio plus wire-line, fiber, microwave, and satellite networks. MDLC is the signalling protocol employed by MOSCAD, is based on the 7-layer OSI recommendation, and is designed to be totally functional on all of these communication media.

MDLC includes a *store-&-forward* capability that permits different communication media links to be incorporated into the total system, i.e. conventional radio *and* trunked radio *and* microwave radio *and* wireline all interconnected by MOSCAD into a single communication system. Data may be passed from any site to any other site in the system (peer-to-peer) either directly or by multiple hops through intermediate MOSCAD sites. This peer-to-peer communication capability enables system designs that use a distributed-intelligence operating philosophy; central-intelligence-only systems may also be implemented if the load on the communication system permits it. More is said about the communication capability of MOSCAD in Chapter 3.

FEP: The Front End Processor is used at the central site(s) to provide a two-way path to the communication system and the distant RTUs from the SCADA Manager hardware & software. The FEP converts MDLC protocol data from the RTUs to a protocol used by the SCADA Manager vendor: when the ModBus protocol is used, the FEP will maintain a local database of all the data from the multiple in-field sites; when TCP/IP is used, the FEP is simply a gateway between the two different protocols. The FEP always acknowledges all RTU-initiated messages. The FEP also provides a two-way path between the MOSCAD Programming ToolBox and the field RTUs for those functions unique to MOSCAD that are not provided by the SCADA Manager software (over-the-air programming download, diagnostics upload, more). The FEP is discussed in Chapter 4.

SCADA Manager: The SCADA Manager provides the operator with the display and report tools necessary to view and manage the associated process(es). The SCADA Manager obtains data from the FEP according to its needs and typically presents that data on custom-created display formats; control messages may also be initiated from these custom screens. Security is typically implemented via permission levels activated by the operator's sign-on password. Microsoft Windows is becoming the operating system of choice because it easily supports the desired graphic symbols used on the custom screens. The report capability may be provided by the SCADA software or a data export to Microsoft Excel or equivalent may be utilized. The end result is an easy to use pictorally-described representation of the field status of key equipment items plus the means to make changes in how those pieces of equipment operate. See Chapter 4 for more information.

ToolBox: The MOSCAD Programming ToolBox is a collection of software programs that allow the system engineer to define and maintain the MOSCAD system in accordance with system-specific requirements. The ToolBox pc computer may be connected to any RTU or FEP in the system and connectivity established with any other site through the store-&-forward capability of the MDLC protocol; all the capabilities available during a local connection may then be enjoyed by the remotely-connected system engineer: the communication network topography may be defined; the application(s) for each site may be created and downloaded into the RTUs; run-time and diagnostic data may be uploaded. Refer to Chapter 5 for additional information on the Programming ToolBox.

MOSCAD RTU

The MOSCAD RTU is a universal device that may serve as an RTU, a PLC, or as the system FEP. It is placed at the system's field sites to collect data from on-site sensors, add data from off-site sources, and use this data aggregate to make decisions regarding how some process is operating. The RTU may make changes to the local process; messages may be initiated that send data elsewhere to influence the operation of off-site equipment or to advise the SCADA Manager of some important change.

The RTU consists of a mounting plate containing a motherboard, power supply/charger, battery, Series 300 CPU module, communications interface, communications device (radio or modem), and space for numerous Input/Output (I/O) modules. The RTU is normally packaged inside a steel NEMA-4 enclosure although several options exist to change the size and/or material of the enclosure or to convert the model to a 19" rackmount configuration. Refer to Physical Configurations for more details.

Figure 2. The MOSCAD RTU

CPU Module

The MOSCAD CPU module contains the majority of the product's intelligence. It has a Motorola 68302 16/32-bit CMOS processor, RAM, ROM, and Flash memory, lithium backup battery, a real-time clock, plus the interfaces to the I/O and communication aspects of the RTU. The CPU module may be programmed, using the Programming ToolBox, providing it with the capabilities expected of a PLC.

Three different CPU modules are available:

» The Series 300 CPU module contains a versatile memory management system that accepts the download (see Figure 25) of ModBus and other third-party protocol drivers and compiled 'C' functions as created by the user; it is the CPU module included with all MOSCAD RTUs.

» The Series 200 CPU module (V424 option) contains a bit less total memory and a memory management system that does not accept the download of 'C' functions, ModBus drivers, etc. The Series 200 CPU may be used in the RTU when these download functions are not required and when the application program and in-module data storage requirements are small.

» The Series 400 CPU module (V426 option) uses Flash memory instead of EPROMs: upgrades to the operating system are easily downloaded into the Flash memory, and more Flash memory is available than on the Series 300 CPU module to store larger compressed source code files—see the ToolBox chapter for more

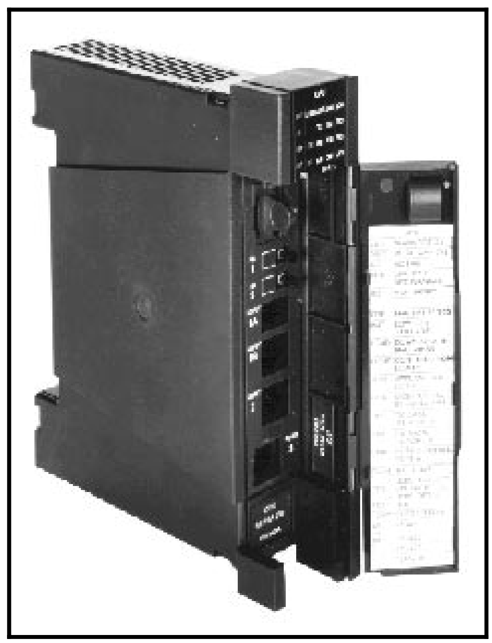


Figure 3. The MOSCAD CPU Module

details. The Series 400 CPU accepts the download of ModBus and other drivers, of compiled ‘C’ functions, etc; it must be used in Europe for compliance with the standards on emissions and magnetic susceptability. See Appendix B for a thorough comparison of the CPU modules.

An additional 1.2 Mbyte of RAM (V449 option) or a math coprocessor (V445 option) or both (V446 option) may be added to any CPU module; the RAM addition is recommended when large amounts of collected or calculated data is to be stored within the CPU module, and the math coprocessor addition is recommended whenever the application requires math-intensive operations, i.e. AGA8, etc.

A real-time clock chip is located on the CPU module and provides year (including leap year), month, day, date, hour, minute, second, and milliseconds support to the application. Diagnostic or error messages contain the time of the occurence; input events may be time-tagged; time-sensitive application tasks may be created. The clocks within the RTUs may be synchronized by a manual time download from the ToolBox, an automatic time download from the SCADA Manager, or via an automatic message from another RTU having a GPS receiver.

Each CPU module contains three data ports with different capabilities.

» Port 1 provides either RS-485 (2-wire multidrop) or a partial RS-232 (data but no RTS, CTS, DTR, etc.) communications to other CPU modules, to the Programming ToolBox, or to the SCADA Manager computer according to the port definition loaded from the ToolBox.

» Port 2 provides a full RS-232 communications and may be configured by the ToolBox as either DTE or DCE for data connectivity under the control of the loaded application or configured as a system port for local or remote (dial-in) ToolBox use.

» Port 3 is normally the communications port and contains a plug-in communication interface appropriate to the medium used; it may also be provided with a second full RS-232 capability when appropriate.

All modules include 20 LEDs that provide information regarding the operation of the module. The LEDs on the CPU module include the availability of a configuration and application in Flash memory, communications with the ports, etc.

Communications Interface

Each MOSCAD RTU is identified by the communication device it contains, normally the type and power level of the internal two-way radio device. The CPU module in the RTU contains the communication interface board most commonly used with the included radio although other types of interface boards may generally be substituted.

Wireline communications may replace radio communications. Two separate pieces of hardware are added to the RTU: a line interface plug-in board *(internal modem*) in the CPU module that replaces the radio interface board and a line interface box that replaces the radio. It is mechanically impossible for simultaneous radio and wireline communications to exist in one CPU module (except for the special case when an *external modem* is connected to Port 2 and some radio interface exists on Port 3).

Refer to the Communications chapter for a thorough discussion of radio, wireline, and other communication alternatives

Figure 4. Wireline Communications

Multiple CPU Modules

The standard RTU contains a single CPU module that controls all activities in the RTU. Some critical sites may require a spare CPU module that is seamlessly activated should a failure be detected. The MOSCAD RTU provides a Dual CPU module mode of operation: the normal CPU module is installed in the left-most position in a standard motherboard and a second CPU module installed in the immediately adjacent position; each module is downloaded with essentially identical application programs. In the normal state the second CPU module is off-line (connected to the I/O modules but not controlling them). The active CPU module periodically sends an *I'm OK* message to the secondary CPU module; if the secondary CPU module ever fails to receive the *I'm OK* message within the allotted time, it will assume control of the I/O modules and begin all communication tasks. The RTU may, following such a switch, send an advisory message to the SCADA Manager or elsewhere to notify Maintenance that a service call is required.

There are other times when multiple CPU modules are required within a single RTU. The number of required RS-232 connections may exceed what a single CPU module may support, the amount of data through the several RS-232 connections may place an excessive time-burden upon a single CPU module, or multiple radios and/or wirelines may need to be connected to the RTU. Multiple CPU modules are clearly a solution: the CPUs may be interconnected via the RS-485 2-wire multidrop ports and exchange data using the MDLC protocol's store-&-forward capability. The rackmount configuration is the recommended approach: special motherboards are available that allow multiple CPU modules with one CPU collecting data from associated I/O modules and sharing that data with the other CPU modules. Refer to the rackmount discussion in the Physical Configuration section for more details.

The RS-232 Multiplexer (Mux) is available to expand a single full RS-232 port on the CPU module to four ports. The Mux obtains operating power from the power supply/battery and may be installed within the standard NEMA configuration or in the rackmount configuration but not in the small NEMA configuration (no space for the Mux). The Mux operates under the control of Port 2 (or Port 3 when an Async interface is present) on the CPU module and may be set for broadcast CPU-to-device with first-come-first-served response or set for directed CPU-to-device input/output; the Mux may also be set to echo characters received from some device back to the device. All connected devices must support the RTS/CTS/DTR mode of operation.

Dual Power Source

The MOSCAD RTU uses a dual source of operating power. The primary power source is a power supply connected to the ac power mains. The primary power source provides a nominal 12 Vdc operating voltage to the modules, the communication device, and to other active elements within the RTU. A rechargable battery is also present that will power the modules, communication device, and certain other active elements of the RTU when ac main power fails. The battery is connected to these elements through the power supply; the power supply acts as the battery charger. The power supply/battery interface provides zero-transfer-transient performance.

Low-current and high-current power supplies are available. The low-current power supply provides 3 amps at 12 Vdc and is included in MOSCAD RTU models that have no radio or low-power radios. The high-current power supply provides 8 amps at 12 Vdc and is included in MOSCAD RTUs with high-power radios or in the model with an interface to an external radio. The V261 option will replace the 3 amp power supply with it's 8 amp equivalent when the extra current capacity is needed. The V274 option replaces the power supply and battery with a cable that may be connected to a clean external source of 12 Vdc power; the V251 option changes the input voltage from 117 Vac 50/60 Hz to 230 Vac 50/60 Hz.

The battery capacity is 5 A-h and is recharged by the power supply. The V326 option adds a second battery to achieve 10 A-h capacity. Battery life is dependent upon transmitter usage, etc; refer to Chapter 3 for a discussion of current drain & battery life. A lithium battery is also provided in the CPU module that is active only when ac main power fails and the backup battery disconnects. The lithium battery keeps the RAM and real-time clock circuits functioning to help achieve an effortless RTU restart following voltage reconnect.

The power supply contains a low voltage disconnect circuit that prevents the battery from an over-discharge condition which would destroy the battery. If a disconnect should occur following an ac power failure, the power supply will maintain the disconnect state following power restoration until a minimum level of battery recharge has occurred (provide the full output of the power supply to the battery). The power supply provides an ac fail signal to the CPU module; this signal may initiate an ac fail message to be sent to the SCADA Manager and may cause some RTU startup activities to occur following reconnect.

The CPU module and the rackmount Expansion module both contain a 5 volt power source that can supply up to 2 amps to the 1-to-15 I/O modules in the module rack. Refer to Appendix A for help in calculating the current drain from the 5 volt supply.

Physical Configurations

The MOSCAD RTU is normally provided in a 20" x 20" x 8.4"(50 x 50 x 21 cm) steel NEMA-4 enclosure. This enclosure is suitable for either indoor or outdoor use and protects the electronics from dust and incidental damage. The standard configuration provides one Series 300 CPU module, space for up to five plug-in I/O modules, plus the power supply/charger, battery, and communication device. One RS-232 Mux may be installed within this enclosure. The V89 option will replace the steel NEMA-4 enclosure with a stainless steel NEMA-4X enclosure, and the V231 option deletes the enclosure totally. Refer to the Installation section for details on the size of these enclosures.

Other ordering options are available that change the size and/or configuration of the MOSCAD RTU. The V214 option changes the RTU to a smaller size (15" x 15" x 8.4"; 38 x 38 x 21 cm) that provides one Series 300 CPU module, space for up to two plug-in I/O modules, plus the power supply/charger, battery, and communication device all in a steel NEMA-4 enclosure. The RS-232 Mux may not be added to this small configuration. The V405 option may also be ordered to further specify a stainless steel NEMA-4X enclosure. The V228 option also changes the RTU from the large to small size but uses a plastic enclosure rated NEMA-4X whereas the V229 option changes from the large to small size but supplies no enclosure.

The V051 rackmount option changes from the NEMA configuration to one that allows direct installation on 19" equipment racks. The rackmount configuration provides one 19" x 12.2" (48 x 31 cm) panel containing one Series 300 CPU module and space for up to seven plug-in I/O modules; a second 19" x 12.2" panel provides space for two power supplies, two batteries, and two communication devices. Two RS-232 Mux, or one RS-232 Mux and one RS-485 Junction Box, may be added to the power supply panel also. See Figure 5 for details.

The rackmount configuration permits expansion beyond the basic seven I/O module capability. The V026 option adds a panel with space for eight additional plug-in I/O modules. The V120 option is used in conjunction with the V026 and provides even more expansion space; an Expansion module is included in Slot 0 to provide 5 Vdc power for the modules on the Rack and to provide Rack addressing switches. Refer to Figures 6 and 7 for details on these options. Note that these three options permit up to 67 I/O modules (1-V051, 4-V026, and 4-V120 maximum; see Table 27). Please calculate the total module plus radio current drain in larger configurations with expansion chassis—see Appendix A for details

When large I/O counts at any single site are required, the rackmount configuration with one CPU module supporting multiple I/O modules may not be the best solution. Depending upon anticipated I/O activity and the amount of calculations, etc. required to process the data, the application execution time may become unsatisfactory at larger sites. Consider instead multiple rackmount RTUs, each with its own CPU module, and distributing the total I/O and processing task among these several RTUs; interconnect the CPU modules with the RS-485 junction box and use the store-&-forward capability of the MDLC protocol to exchange data as appropriate. The

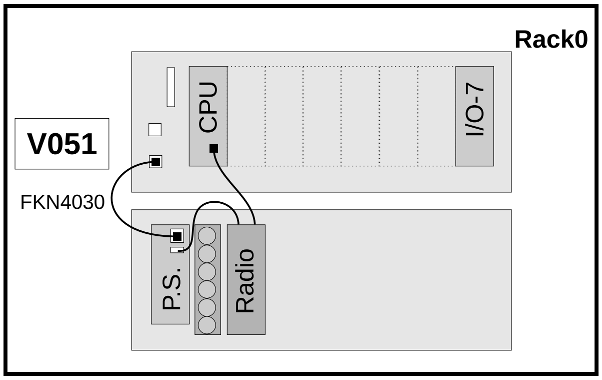


Figure 5. Basic Rackmount Configuration

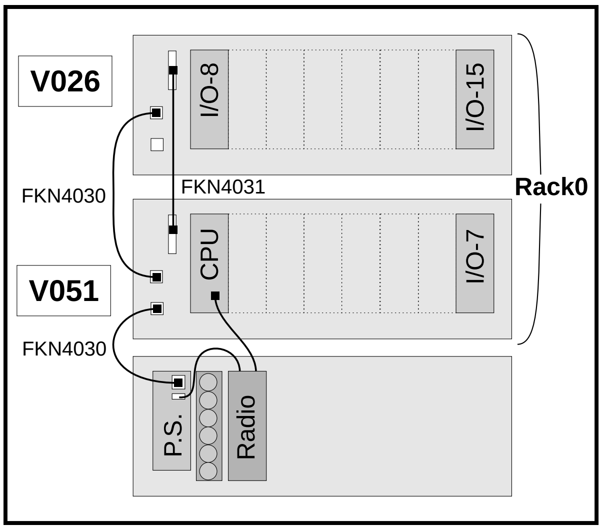


Figure 6. Rackmount Expanded to 15 I/O

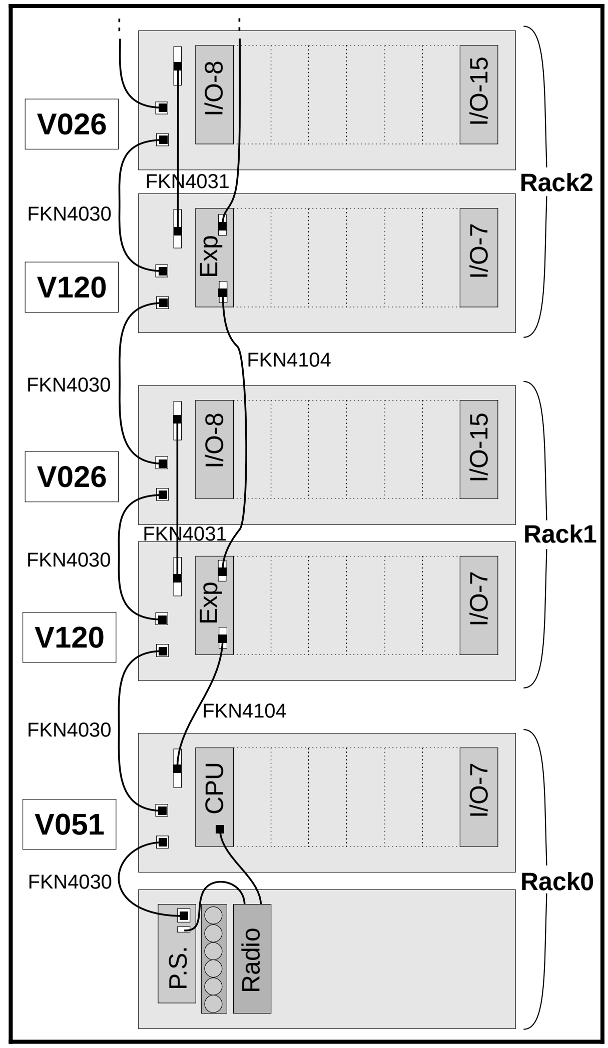


Figure 7. Rackmount Expanded Beyond 15 I/O

benefits include reducing the application execution time and reducing the impact of any single CPU module failure.

The rackmount configuration provides one additional capability, namely to replace the standard motherboard (one CPU module and up to seven I/O modules) with motherboards that support multiple CPU modules. One CPU module adjacent to the I/O modules controls those I/O module; the remaining CPU modules are available to connect to external RS-232 sources. The RS-485 junction box and store-&-forward capabilities are used to interconnect the several CPU modules. Figure 8 lists the available rackmount motherboards. These optional motherboards do not contain expansion connectors and may

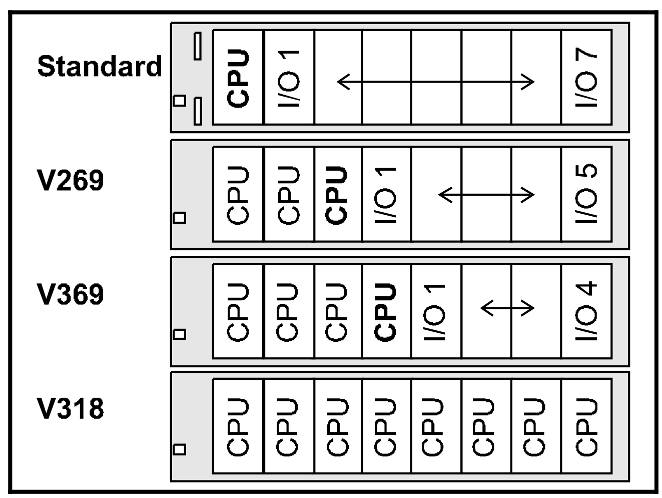


Figure 8. Available Rackmount Motherboards

	16DI	16 Voltage In
Screw	Function	Function
1	Counter 1	Input 1 (+)
2	Counter 2	Input 2 (+)
3	Input 1	Input 3 (+)
4	Input 2	Input 4 (+)
5	Input 3	common 1-4
6	Input 4	Input 5 (+)
7	Input 5	Input 6 (+)
8	Input 6	Input 7 (+)
9	Input 7	Input 8 (+)
10	common	common 5-8
11	Input 8	Input 9 (+)
12	Input 9	Input 10 (+)
13	Input 10	Input 11 (+)
14	Input 11	Input 12 (+)
15	Input 12	common 9-12
16	Input 13	Input 13 (+)
17	Input 14	Input 14 (+)
18	Input 15	Input 15 (+)
19	Input 16	Input 16 (+)
20	common	common 13-16

Table 1. 16DI and 16 Voltage Input Connections

Function	Terminal
Input 1	1C (+), 1A (-)
Input 2	2C (+), 2A (-)
Input 3	3C (+), 3A (-)
Input 4	4C (+), 4A (-)
Input 5	5C (+), 5A (-)
Input 6	6C (+), 6A (-)
Input 7	7C (+), 7A (-)
Input 8	8C (+), 8A (-)
Input 9	9C (+), 9A (-)
Input 10	10C (+), 10A (-)
Input 11	11C (+), 11A (-)
Input 12	12C (+), 12A (-)
Input 13	13C (+), 13A (-)
Input 14	14C (+), 14A (-)
Input 15	15C (+), 15A (-)
Input 16	16C (+), 16A (-)
Input 17	17C (+), 17A (-)
Input 18	18C (+), 18A (-)
Input 19	19C (+), 19A (-)
Input 20	20C (+), 20A (-)
Input 21	21C (+), 21A (-)
Input 22	22C (+), 22A (-)
Input 23	23C (+), 23A (-)
Input 24	24C (+), 24A (-)
Input 25	25C (+), 25A (-)
Input 26	26C (+), 26A (-)
Input 27	27C (+), 27A (-)
Input 28	28C (+), 28A (-)
Input 29	29C (+), 29A (-)
Input 30	30C (+), 30A (-)
Input 31	31C (+), 31A (-)
Input 32	32C (+), 32A (-)

Table 2. 32dcDI Module Connections

Fctn	Term	Fctn	Term
In1	1C	In2	1A
In3	2C	In4	2A
In5	3C	In6	3A
In7	4C	In8	4A
In9	5C	In10	5A
In11	6C	In12	6A
In13	7C	In14	7A
In15	8C	In16	8A
com	9C		
		In17	9A
In18	10C	In19	10A
In20	11C	In21	11A
In22	12C	In23	12A
In24	13C	In25	13A
In26	14C	In27	14A
In28	15C	In29	15A
In30	16C	In31	16A
In32	17C	com	17A
In33	18C	In34	18A
In35	19C	In36	19A
In37	20C	In38	20A
In39	21C	In40	21A
In41	22C	In42	22A
In43	23C	In44	23A
In45	24C	In46	24A
In47	25C	In48	25A
com	26C		
		In49	26A
In50	27C	In51	27A
In52	28C	In53	28A
In54	29C	In55	29A
In56	30C	In57	30A
In58	31C	In59	31A
In60	32C	com	32A

Table 3. 60DI Module Connections

not be used when expansion beyond the I/O module count listed is required.

I/O Modules

A variety of digital and analog input and output modules, plus some very special modules, are available to collect data from and send commands to other physical devices located at the site. The paragraphs that follow discuss each of these modules.

Digital Input Modules

Four different Digital Input (DI) modules are available. All modules connect to digital (binary) sensors to obtain the status/state of that sensor (door open or closed; motor running or stopped; temperature hot or normal). The CPU module then scans these DI modules to transfer the collected data into the application process.

The **16DI module** (V115 option) provides 16 dry-contact (sensor not connected to any voltage including ground) inputs plus two high-speed counter inputs (range 0-32,767). Any of the 16 dry-contact inputs may be used as low-speed counters under application control. The module provides an isolated current so the open/closed state of the sensor may be determined. Each of the inputs are opto-isolated from the remaining circuitry on the module to provide maximum input surge immunity. All connections to the module are via plug-in screw terminals (see Table 1). Refer to Appendix B for a complete listing of the performance specifications.

The **16 Voltage Input module** provides 16 inputs that may be connected to sensors that provide ac or dc voltages. The V329 option handles inputs in the 10-28 Vac/dc range whereas the V379 option handles 20-56 Vac/dc inputs. Any of the inputs may be used as low-speed counters under application control. Each input is opto-isolated from the remaining circuitry on the module to provide maximum input surge immunity. All connections to the module are via plug-in screw terminals (see Table 1). Refer to Appendix B for a complete listing of the performance specifications.

The **32dcDI module** provides 32 independent inputs that may be connected to sensors providing dc voltages. The V355 option handles inputs in the 10-28 Vdc range, the V480 option handles inputs in the 20-56 Vdc range, and the V481 option handles 35-80 Vdc inputs. Any of the inputs may be used as low-speed counters under application control. Each input is opto-isolated from the remaining circuitry on the module; however the addition of surge protection at the connection points into the module is recommended to provide maximum input surge immunity. All connections to the module are via a 64 pin plug; a mating cable is available in different lengths for connection to connection points within the equipment being monitored (see Table 2). Refer to Appendix B for a complete listing of the performance specifications.

The **60DI module** (V380 option) provides 60 dry-contact inputs for use at high-density sites; any of the inputs may be used as low-speed counters under application control. The module provides an isolated current so that the open/closed state of the sensor may be determined. Each of the inputs are opto-isolated from the remaining circuitry on the module to provide maximum input surge immunity. All connections to the module are via a 64 pin plug; a mating cable is available in different lengths for connection to connection points within the equipment being monitored (see Table 3). Refer to Appendix B for a complete listing of the performance specifications.

Digital inputs also are present on some of the modules that are available for specialized use. Refer to the Mixed I/O and Special Module sections for a discussion of those modules.

Digital Output Modules

Three different Digital Output (DO) modules are available. All modules connect to the digital (binary) devices to be controlled. The CPU module scans the control command into the DO modules to make some change in the associated process.

The **16DO module** provides 16 low-current relay outputs; twelve of the relays have Form A contacts and four relays have Form C contacts—their current switching capability appears in Figure 9. The V516 option provides a module having all magnetically-latched relays (each relay has separate set and reset coils; a momentary current in either coil changes the relay and a small internal magnet keeps the relay in the changed state). The V616 option provides a module having all electrically-energized relays (a single coil relay; pass current continuously through the coil to activate the relay). Magnetically-latched relays should be used in systems that require long operation from

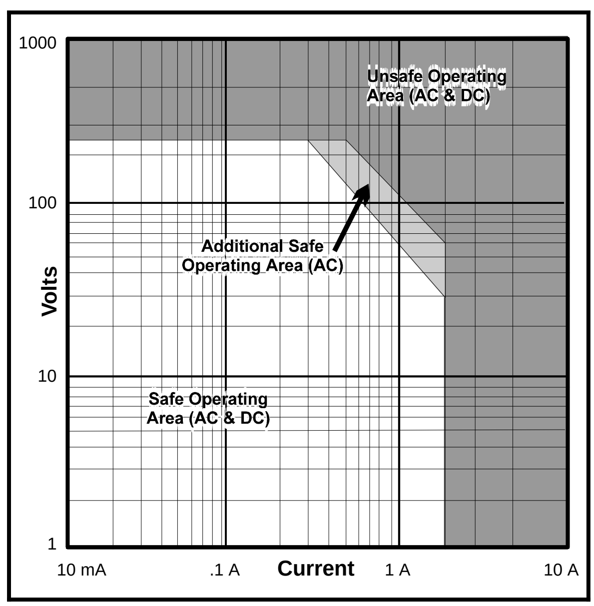


Figure 9. 16DO & Mixed I/O Relay Contact Rating

Screw	Function
1	K1 NO
2	K1 NC
3	K2 NO
4	K2 NC
5	K3 NO
6	K3 NC
7	K4 NO
8	K4 NC
9	com K1-4
10	K5 NO
11	K6 NO
12	K7 NO
13	K8 NO
14	com K5-8
15	K9 NO
16	K10 NO
17	K11 NO
18	K12 NO
19	com K9-12
20	K13 NO
21	K14 NO
22	K15 NO
23	K16 NO
24	com K13-16

Table 4. 16DO Module Connections

Function	Terminal
Out 1	1C (+), 1A (-)
Out 2	2C (+), 2A (-)
Out 3	3C (+), 3A (-)
Out 4	4C (+), 4A (-)
Out 5	5C (+), 5A (-)
Out 6	6C (+), 6A (-)
Out 7	7C (+), 7A (-)
Out 8	8C (+), 8A (-)
Out 9	9C (+), 9A (-)
Out 10	10C (+), 10A (-)
Out 11	11C (+), 11A (-)
Out 12	12C (+), 12A (-)
Out 13	13C (+), 13A (-)
Out 14	14C (+), 14A (-)
Out 15	15C (+), 15A (-)
Out 16	16C (+), 16A (-)
Out 17	17C (+), 17A (-)
Out 18	18C (+), 18A (-)
Out 19	19C (+), 19A (-)
Out 20	20C (+), 20A (-)
Out 21	21C (+), 21A (-)
Out 22	22C (+), 22A (-)
Out 23	23C (+), 23A (-)
Out 24	24C (+), 24A (-)
Out 25	25C (+), 25A (-)
Out 26	26C (+), 26A (-)
Out 27	27C (+), 27A (-)
Out 28	28C (+), 28A (-)
Out 29	29C (+), 29A (-)
Out 30	30C (+), 30A (-)
Out 31	31C (+), 31A (-)
Out 32	32C (+), 32A (-)

Table 5. 32DO Module Connections

Screw	Function
1	K1 NO
2	K1 com
3	K1 NC
4	K2 NO
5	K2 com
6	K2 NC
7	K3 NO
8	K3 com
9	K3 NC
10	K4 NO
11	K4 com
12	K4 NC
13	K5 NO
14	K5 com
15	K5 NC
16	K6 NO
17	K6 com
18	K6 NC
19	K7 NO
20	K7 com
21	K7 NC
22	K8 NO
23	K8 com
24	K8 NC

Table 6. 8DO Module Connections

the backup battery when the mains power fails; electrically-energized relays should be used when it is mandatory that the relays open following loss of power or when the module is removed from the RTU. Each relay has an internal feedback contact that the application may use to verify that the relay is open or closed. All connections to the relays are made via plug-in screw terminals on the module (see Table 4), and all relays have surge arresting devices installed. Refer to Appendix B for a complete listing of the performance specifications.

The **32DO module** (V318 option) provides 32 solid-state (FET) outputs that may be used to control direct-current loads, such as interpose relays or lamp panels, not exceeding 0.5 amp at 30 Vdc. Termination panel accessories, with eight relay sockets, are available; magnetically-latched or electrically-energized relays may be added to the termination panel(s) as required. Each output from the module has a diode-isolated feedback that the application may use to verify the state of the output. All connections to the module are made via a 64-pin connector; a mating cable in different lengths is available for direct connection to the accessory termination panels or directly to connection points within the equipment being controlled (see Table 5). Refer to Appendix B for a complete listing of the performance specifications.

The **8DO module** (V508 option) provides 8 high-current (10 amp @ 277 Vac/30 Vdc) Form C relay outputs. Each output on the module has an internal feedback contact that the application may use to verify that the relay is open or closed. All connections to the relays are made via plug-in screw terminals on the module (see Table

6), and all relays have surge arresting devices installed. Refer to Appendix B for a complete listing of the performance specifications.

Digital outputs also are present on some of the modules that are available for specialized use. Refer to the Mixed I/O and Special Module sections for a discussion of those modules.

Screw	Function
1	Analog 1 (+)
2	Analog 1 (-)
3	Analog 2 (+)
4	Analog 2 (-)
5	P. gnd
6	n/c
7	Analog 3 (+)
8	Analog 3 (-)
9	Analog 4 (+)
10	Analog 4 (-)
11	Analog 5 (+)
12	Analog 5 (-)
13	Analog 6 (+)
14	Analog 6 (-)
15	P. gnd
16	n/c
17	Analog 7 (+)
18	Analog 7 (-)
19	Analog 8 (+)
20	Analog 8 (-)

Table 7. 8AI Connections

Screw	Function
1	Vout1 (+)
2	com1
3	Iout1 (+)
4	Vout2 (+)
5	com2
6	Iout2 (+)
7	n/c
8	Loop V(+)
9	Loop V(-)
10	P. gnd
11	Vout3 (+)
12	com3
13	Iout3 (+)
14	Vout4 (+)
15	com4
16	Iout4 (+)
17	n/c
18	Loop V(+)
19	Loop V(-)
20	P. gnd

Table 8. 4AO Connections

Analog Input Modules

Six different Analog Input (8AI) modules are available. All modules connect to analog (value) sensors to obtain *how much* information (how much fluid is in a tank; what is the speed of a motor, etc). The CPU module then scans these AI modules to transfer the collected data into the application process.

The modules differ in the active voltage/current input range and the associated input resistance. The V276 option provides eight 4-20 ma input; the V459 option provides eight ±1 ma inputs; the V461 option provides eight ±2 ma inputs; the V461 option provides eight ±1 Vdc inputs; the V460 option provides eight ±2.5 Vdc inputs; and the V437 option provides eight ±5 Vdc inputs. Each of the 8 inputs, plus ground and temperature, are opto-switched into a precision A-to-D converter; ground is measured so short-term drift may be cancelled and temperature is measured so that the temperature drift associated with all silicon-based chips may be negated. The result is 13 bit resolution of the analog input; simply put, there are 8000 steps over the total range with an accuracy of ±0.05%. All of the modules utilize the total range as their active range except for the 4-20 ma module which uses only 40% (3200 steps) of the total range (see Figure 10).

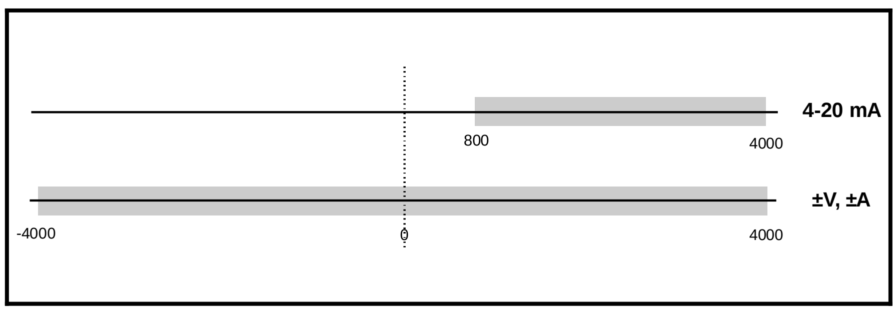


Figure 10. Analog A/D Ranges

There are two types of 4-20 ma sensors/transmitters, namely 2-wire and 4-wire. The 2-wire transmitters require a serial power feed for the current loop, whereas 4-wire transmitters have a separate power supply connection. As a result, with 4-wire transmitters a single power supply may be used to provide power to several sensors; Figure 11 shows the connection of the 4-wire transmitter to the MOSCAD analog input.

In contrast to the 4-wire sensor, each 2-wire sensor/transmitter requires a separate power supply. Figure 12 shows the connection of the 2-wire transmitter to the MOSCAD analog input.

All connections to the modules are via plug-in screw terminals as shown in Table 7. Refer to Appendix B for a complete listing of the performance specifications.

Analog inputs also are present on some of the modules available for specialized use. Refer to the Mixed I/O and Special Module sections for a discussion of those modules.

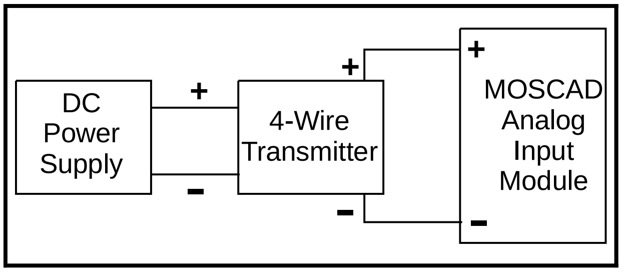


Figure 11: 4-Wire 4-20 ma Sensor Connection

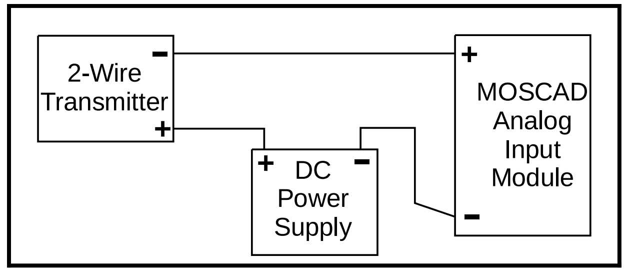


Figure 12: 2-Wire 4-20 ma Sensor Connection

Analog Output Module

The **Analog Output module** (V118 option) has four output channels that may be either 4-20 ma or 1-5 Vdc. The digital-to-analog converter on the module supports 12 bit data; this provides 1600 steps in the active output range with an accuracy of ±0.1%. The output current loop requires connection to an external voltage source. When the internal MOSCAD power supply/battery is utilized, the module will drive a load of up to 250 ohms but when an external 24Vdc power source is provided, the module will drive a load up to 750 ohms. The current drain on this power source will continue during ac mains failure unless handled specifically by the application; the backup battery life will be shortened if it is used as the loop power source. All wire connections to the module are via plug-in screw terminals (see Table 8). Refer to Appendix B for a complete listing of the performance specifications.

Mixed I/O Module

The **Mixed Input/Output** (I/O) modules are part of the special module collection that deserve special mention. They provide a combination of features that satisfy the needs of many smaller sites. The Mixed I/O module provides eight digital inputs that are identical to those found on the 16DI module. There are also two 4-20 ma analog inputs that are quite similar to those found on the 8AI module, the difference being that 12 bit A/D converters are used which provide 1600 steps in the 800-4000 active range with ±0.1% accuracy (see Figure 10). Four relay outputs are also provided: two of the relays have Form A contacts and two relays have Form C contacts. The V245 option provides a module with three magnetically-latched and one electrically-energized relays whereas the V436 option provides a module with four electrically-energized relays. Both modules provide plug-in screw terminals for connection of the associated wires (see Figure 9). Refer to Appendix B for a complete listing of the performance specifications.

Screw	Function
1	Analog1 (+)
2	Analog1 (-)
3	Analog2 (+)
4	Analog2 (-)
5	P. gnd
6	DI 1
7	DI 2
8	DI 3
9	DI 4
10	DI 5
11	DI 6
12	DI 7
13	DI 8
14	com DI1-8
15	K1 NC
16	K1 NO
17	K1 com
18	K2 NC
19	K2 NO
20	K2 com
21	K3 NO
22	K3 com
23	K4 NO
24	K4 com

Table 9. Mixed I/O Connections

Special Modules

Two additional special modules have been developed for specific markets but that may have applicability is other applications and markets as well.

The **AC Analyzer** module (V464 option) directly measures the three phase voltage and current of the ac mains 32 times each cycle and uses this data to calculate apparent power (V-A), real power (W), reactive power (VAR), and phase angle. This data is made available to the CPU module for use in the overall application: a phase loss that could damage large three phase motors can quickly be determined; a fault on a power distribution line may be determined and power rerouting actions begun; an adverse power factor condition on a power distribution line may be determined and correcting capacitors added or removed. The option consists of two parts: the plug-in module and a termination panel. All wire connections are made to screw terminals on the termination panel.

Two auxiliary analog inputs, eight digital inputs (10-28 Vdc) are provided as are 8 digital output relays (four with 2 amp contacts, four with 8 amp contacts; two of each contact type are magnetically-latched and the other two of each type are electrically energized). Refer to Appendix B for a complete listing of the performance specifications.

The **4DI/16DO** module (V316 option) was created for irrigation systems that require the control of multiple ac-operated valves. The module requires 24 Vac operating power, not supplied by MOSCAD, to power the output triac switching devices and the input sense current source. All wire connections are made to screw terminals on the termination panel.

Communications

The MOSCAD family facilitates the establishment of a highly sophisticated hybrid data communication network for SCADA that utilizes a variety of radio and/or line communication links. Radio links may include conventional (VHF, UHF, 800 & 900 MHz), trunked, and both analog and digital microwave radio technologies. Line links may include point-to-point, Public Service Telephone Network (PSTN) voice/data via dial-up modems, and Local Area Networks (LAN).

Multiple data signalling speeds are available to accommodate the particular need of these links. Lower data speeds are used when the bandwidth of the link is reduced either by their design or by laws in the user's country, or when data speed is sacrificed to achieve greater communication range. The higher data speeds (up to 9600 bps) typically usable, combined with the optimized-for-radio MDLC data protocol, ensure high network throughput even if the network is spread over a large geographical area.

MDLC Protocol

The MDLC protocol is a Motorola SCADA protocol that is based on the Open System Interconnection (OSI) model recommended by the International Organization for Standardization. MDLC utilizes all seven layers of the OSI model. This protocol is designed for optimum operation in SCADA systems which operate with diverse communication media such as two-way radio, line, LAN, etc. Each RTU, FEP, or ToolBox has all seven layers of the MDLC protocol available to them. The functions of the seven layers are summarized in Table 10.

The MDLC protocol is intended for operation in point-to-multipoint links, such as two-way radio or multidrop wireline, as well as in point-to-point communication networks. The protocol facilitates communications among all sites in the system, including extensive diagnostic messaging. MDLC is transparent and liberates the system engineer from the technical constraints and complexities of network operations thus allowing the intended application to be the item of focus.

MDLC uses a semi-synchronous data format on two-way radio and a asynchronous format on wirelines. It is not correct to refer to message size in byte notation because of the 16-bit architecture; the data may not be sent in asynchronous format—no start and stop bits—but it is not true synchronous either because there is no single network-provided clock signal. Instead, each CPU has a clock that is entirely adequate to provide the synchronize signal for data transfer up to 19.2 kbps. It is therefore better to refer to MDLC in terms of *data words* where each word may be variable in length, consist of both header and body components, and contain up to 80 16-bit variables within the body. A physical message may consist of a single word or may consist of a concatenated series of words (packets), each word addressed to one or more destination sites with some or all words requiring subsequent store-&-forward operation by the recipient site(s). The concatenated data words may be any combination of the supported functions, i.e. data upload to the SCADA Manager, error logger data to the ToolBox, etc.

The lower three layers of the MDLC protocol stack are commonly known as Network Services. These layers only are used when communicating with intermediary sites which makes it possible to pass any data through the system and not require the total system to know the details of the data. Each layer adds (removes) data to what was received and thereby communicates with equivalent layers in the destination (source) site—see Figure 13.

RTU-to-RTU communications supress the Presentation, Session, and Transport layers; all layers are present for SCADA Manager-to-RTU communications and for communications with the ToolBox.

MOSCAD Data Transfer Methods

Three messaging methods may be used by the MOSCAD RTU: Contention (transmission upon change-of-state; also called *burst*), Polling (interrogation), and Report-by-Exception. The Contention method has the RTU

Layer	Function
Layer 1: Physical	This layer caters to communications over conventional radio, trunked radio, data radio, serial data channels, modems, or telephone lines. The layer is also responsible for channel access and collision control on shared media.
Layer 2: Link	This layer ensures proper communications over a physical link. The layer arranges the data in variable-length frames and attaches addresses, frame sequence numbers, and Cyclic Redundancy Code (CRC) to the frames.
Layer 3. Network	This layer is responsible for the establishment of end-to-end communication paths in a network. This is necesary since communications may take place on more than one link and a message may travel through several nodes before reaching the final destination.
Layer 4. Transport	This layer ensures end-to-end integrity of the information flow between two nodes in the network. This is achieved by remote-end acknowledgement that data has been received completely and passed in the correct order to the next layer.
Layer 5. Session	This layer allows the definition of any number of entities capable of conducting simultaneous sessions with an equivalent entity in some remote unit. This enables transparent communications among multiprocessing machines without interference in their applications.
Layer 6. Presentation	This layer structures the information to/from various applications. This layer may also perform format conversion, data authentication, etc. if implemented.
Layer 7. Application	This layer interfaces to the various applications such as data transfer, configuration downloading, application software monitoring, remote diagnostics, etc.

Table 10. MDLC Seven Layer Summary

report upon a change-of-state (COS) of conditions/values without waiting for a poll from the SCADA Manager. The RTU recognizes a COS and reports relevant data to the SCADA Manager or to another site as soon as the shared communication medium becomes available. The RTU will repeat the data message until confirmation of reception is received. The RTU listens to the shared communication medium before sending a message and then uses a slotted channel acquisition method to avoid synchronized message collisions. This is the messaging method most often used by MOSCAD because it properly uses the shared communication medium.

The Polling (interrogation) method is a periodic activity used to confirm the proper operation of the normally silent RTUs and/or to update the SCADA Manager database at specified intervals or when manually instructed by the operator. The Report-by-Exception method has the RTU report only the conditions/values that have changed since the last poll. The SCADA Manager retains all data conditions and values in a local database for instant use.

Radio Communications

The MOSCAD RTU is designed to operate with many Motorola radio transceivers (see Table 11) which are installed within the NEMA enclosure or upon the power supply/radio panel in the rackmount configuration. The radios in the table are not the standard voice models but are adapted for data operation.

Trunked radio is particularly advantageous in systems that use the distributed intelligence capability of MOSCAD to limit the number of radio transmissions. In a trunked radio system, any unit that needs to send a message requests, and is assigned to, a channel by the trunking system controller. The MOSCAD RTUs are typically clustered into a single trunked *data group* and are managed by the trunking system controller as a single entity. Therefore, any RTU that requests a channel causes all RTUs to switch to the assigned channel so that all units hear, decode, and may appropriately respond to the data transmitted. Two way data transfer among many RTUs may occur following a single channel request/assignment. Also, trunked systems provide an infrastructure

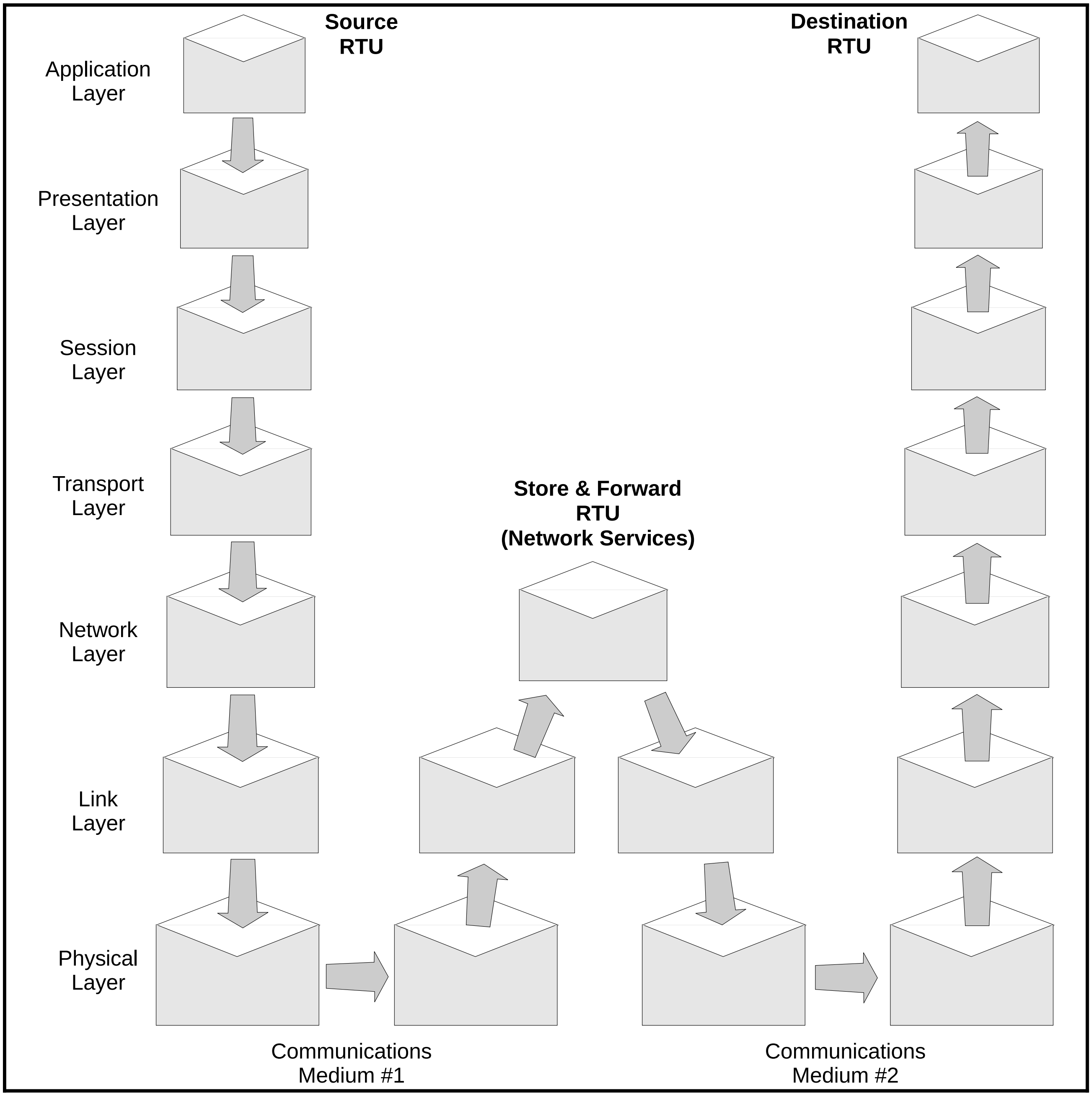


Figure 13. Data Transfer with MDLC

that is inherently redundant—if one base station should fail, the trunked system automatically assigns communications to a remaining station. *SCADA system data and trunked radio systems are very compatible!*

The physical interface to the radio is through a plug-in interface board on the CPU module; the characteristics designed into the interface board determines the emission characteristics of the radio. The data may directly modulate the FM transceiver's oscillator to most effectively use the radio bandwidth. Motorola refers to this modulation technique as DFM; in the U.S. this is also described by the FCC as an *F1* emission. Figure 14 shows the modulation sideband created by DFM. FCC licenses specifically state when F1 emission may be used and only radios having an F1 emission designator may be used in those licensed systems. No F1 emission is suitable

	Radio Type	RF Power	Radio Interface	Rule Part	Emission Designator	Type Acceptance
Conventional	MT-2000, 136-174 MHz	5 W (1-5)	FSK* DPSK	22, 74, 90	16K0F3E 20K0F1E 20K0F2D	AZ489FT3768
	MaxTrac, 150-174 MHz splinter channel	20 W (4-25)	DPSK*	90	5K60F1D 5K60F2D	AB492FT3002
	MaxTrac, 136-142 MHz, 142-174 MHz	20 W	DFM* FSK DPSK	90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT3712
	MC-900, 136-174 MHz (For Europe only)	20 W (1-25)	FSK* DPSK	n/a	n/a	None
	MT-2000, 403-470 MHz	4 W (1-4)	FSK* DPSK	22, 80, 90	16K0F3E 20K0F1E 20K0F2D	AB489FT4780
	MaxTrac, 403-420 MHz, 450-470 MHz	20 W	DFM* FSK DPSK	90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT4713
	MaxTrac LPI, 450-470 MHz	2 W (1-10)	DFM* FSK DPSK	90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT4765
	Spectra, 450-470 MHz, 470-512 MHz	15 W (8-15)	FSK* DPSK	90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT4736
	MC-900, 450-470 MHz (For Europe only)	20 W (10-25)	FSK* DPSK	n/a	n/a	None
	MaxTrac, 800 MHz	15 W (1-15)	DFM FSK* DPSK	90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT5677
Trunked	MaxTrac, 136-142 MHz, 142-174 MHz	20 W	DPSK*	90	10K0F1D 11K0F2D 11K0F3E	AB492FT3002
	MaxTrac, 403-430 MHz, 450-470 MHz	20 W	DPSK*	90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT4713
	MaxTrac, 806-869 MHz (not 821 MHz)	15 W (1-15)	FSK DPSK*	15, 90	15K0F2D 16K0F1D 16K0F3E	ABZ89FT5677
	Spectra, 806-869 MHz	15 W (8-15)	FSK DPSK*	90	11K0F1D 11K0F2D 14K0F3E 15K0F2D 16K0F1D 16K0F3E	ABZ89FT5712
	MaxTrac, 896-902 MHz	12 W (1-15)	DPSK*	90	10K0F1D 11K0F2D 11K0F3E	ABZ89FT5728
	DARCOM 9000 HR2, 928-960 MHz MAS	5 W	Async FSK* Sync	94	12K5F1D 12K5F2D 12K5F9W 16K0F1D 16K0F2E	ABZ9QCT6619
		* Denotes factory default Others are optional				

Table 11. Radio Availability & FCC Licensing Data

when intermediate amplifiers (voice/RT repeaters) are present and should not be used with PL/DPL, but F1 emissions are fully compatible with MOSCAD's store-&-forward operation.

The data may instead modulate a tone oscillator to produce a variable tone or variable phase output; this tone output then modulates the FM transceiver's oscillator. Motorola refers to this modulation technique as FSK (variable tone) or DPSK (variable phase); in the U.S. this is described by the FCC as an *F2* emission. Figures 15 and 16 show the modulation sidebands created by FSK and DPSK. FCC licenses stipulate when F2 emissions may/must be used in their licensed systems. F2 emission must be used whenever any intermediate amplifier (voice/RT repeater: conventional or trunked) is present; DPSK must be used when any degraded bandwidth condition (notch filters, etc.) exist and is the only emission allowable on the U.S. VHF *splinter* channels. FSK and DPSK are also fully compatible with store-&-forward operation.

MOSCAD also supports the Intrac 2000 modulation technique. Intrac is an older line of radio signalling hardware that share the common Intrac 2000 protocol. This protocol uses a two-tone (F2) emission so the restrictions previously listed for F2 emission apply here also. Note that while MOSCAD supports the Intrac protocol, the Intrac protocol does not support the full capabilities of MOSCAD. Therefore MOSCAD with the plug-in Intrac interface option is operating in a function-degraded mode.

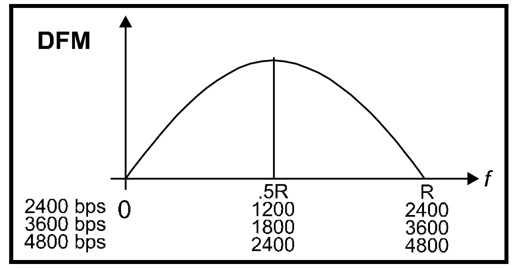


Figure 14. DFM Modulation Sidebands

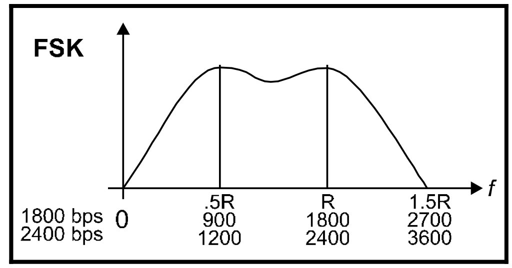


Figure 15. FSK Modulation Sidebands

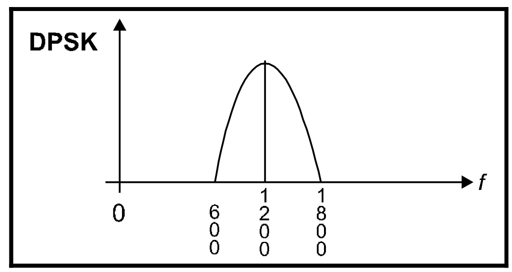


Figure 16. DPSK Modulation Sidebands

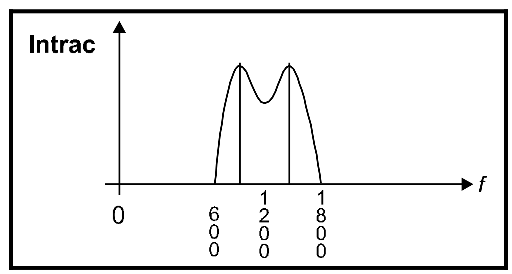


Figure 17. Intrac 2000 Modulation Sidebands

VHF *Splinter* Channels

In the U.S. the FCC has defined certain frequencies in the 154 MHz and 173 MHz bands for data operation—the *splinters*. The frequencies are few in number, have a 12.5 kHz bandwidth and a FCC-imposed deviation restriction, yet are very commonly used. In an attempt to insure that the transmitted emission stays within the assigned channel bandwidth, the FCC has stipulated that an F2 emission must be used and that the Sum of the Highest Modulating Frequency plus Deviation shall not exceed a stated maximum. For most channels, that maximum is 2800 Hz but on two frequencies[1] the maximum is 1700 Hz.

Modulation Technique	Data Speeds in bps (* = recommended)
DFM	4800 (*), 3600, 2400
FSK	2400 (*), 1800
DPSK	1200 (*)
Intrac 2000	600 (*)

Table 12. Radio Data Rates

MOSCAD, when using DPSK modulation, uses a 1200 Hz modulating tone; the legal allowable deviation on the "2800" channels is

1 These two frequencies are: 173.2100 and 173.3900 MHz

therefore 1.6 kHz whereas on the “1700” channels the legal deviation is only 500 Hz. The Intrac 2000 modulation uses 1500 Hz as the highest modulating tone; the legal allowable deviations are 1.3 kHz and 200 Hz respectively. FSK is theoretically usable but at a small deviation (300 Hz); DFM may not be used because it is not an F2 emission. PL/DPL must never be used because their deviation (750 Hz) must be subtracted from the data deviation which worsens an already marginal situation.

Therefore, DPSK modulation at 1.6 kHz and Intrac 2000 modulation at 1.3 kHz are the only legal emissions available for “2800” splinter frequency use; never use the “1700” frequencies and never use PL/DPL on a splinter frequency. Refer to the FCC rules or other applicable regulations to understand additional constraints on maximum Effective Radiated Power, antenna height, and antenna directivity.

PL & DPL

Private Line (PL) and Digital Private Line (DPL), also known as Continuous Tone-Coded Squelch System (CTCSS), was created for voice users of two-way radio to suppress activity from other co-channel users from being heard; it offered the illusion of a private channel. PL/DPL adds a decoder to the receiver that keeps the receiver muted until a signal having a specific low-frequency tone (PL) or slow data code (DPL) is received. All transmitters must encode the proper tone/code to open the protected receiver. Some repeaters, notably those in the UHF band, use PL or DPL to prevent unwanted access to the repeater system by co-channel users.

In the U.S. the FCC’s rules for Fixed Secondary Signalling and for Telemetry operations require data not to interfere with voice operations—the data message must wait until the voice message is finished. This is a practical matter also—if a data message were attempted simultaneously with any co-channel message, there is a high probability that the data would be corrupted and thruput would be zero. So why create the interference for no gain. Therefore the data equipment must listen to all on-channel activity; PL/DPL protection on the receiver is unwanted.

PL/DPL may be used in MOSCAD systems when it will operate through some existing voice repeater system that requires PL or DPL for repeater access, but the PL/DPL would be added to the transmitter and not the receiver. Note that PL/DPL should never be used on VHF splinter channels: the FCC limits the occupied channel bandwidth by severely limiting deviation; PL or DPL would consume too much of the authorized deviation to produce an effective system. Never use PL/DPL with DFM modulation.

Serial Communications

The MOSCAD CPU supports RS-485 2-wire multidrop communication through Port 1A, RS-232 communication less RTS/CTS/DTR support through Port 1B, and RS-232 communication with RTS/CTS/DTR support through Port 2. Note that either Port 1A or Port 1B but not both may be active at any time. Port 3 provides the opportunity of some communication flexibility. When the plug-in interface to a radio (see the Radio Communications section) is not required, an additional RS-232 plug-in board (with full RTS/CTS/DTR capability) or one part of the two-piece wireline modem shown in Figure 4 may be installed.

Port #	Data Type	Speed
1A	RS-485	2.4-19.2 kbps
1B	RS-232 (no DTR, etc.)	0.3-19.2 kbps
2	RS-232	0.3-19.2 kbps
3	RS-232 with V345 option	1.2-9.6 kbps

Table 13. Serial Data Speeds

The RS-485 port permits 32 2-wire RS-485 devices to be parallel-connected onto one pair of wires for the exchange of data. A typical MOSCAD use for RS-485 is the interconnection among multiple CPU modules: each CPU module is connected to specific sensory devices and is programmed to perform some subset of the total application at the site; data is exchanged among these CPU modules according to the needs of the total application. The V186 RS-485 Junction Box and FKN4400 cable are available to make this interconnection; or the installer may make the cables by using using the small handset-size connectors commonly found on modular telephones. The RS-485 port may operate at data speeds up to 19.2 kbps.

The RS-232 capability of Port 1B is limited. The data conforms to the normal RS-232D standard; the RTS/CTS/DTR capability commonly associated with RS-232 serial communications is not supported. This port is therefore suitable for connection to the Programming ToolBox, to a SCADA Manager using the ModBus protocol interface, or to other devices that work with this simple 3-wire interface. The 8-wire modular telephone connector, a.k.a. RJ-45, is used for connection to the port. The RS-232 Multiplexer may not be used on this Port.

The RS-232 capability of Port 2, and of Port 3 when the V345 RS-232 Async option is installed, provides full conformance to the RS-232D standard including the RTS/CTS/DTR capability. The port(s) may be programmed to function as a data terminal (DTE) or as a data modem (DCE); all of the devices suitable for Port 1B plus external terminal, modems, printers, and digital microwave may be connected. The 8-wire modular telephone connector, a.k.a. RJ-45, is used for connections to the port(s). The RS-232 Multiplexer may connected to, programmed from, and otherwise used on either port.

Port 3 may contain one radio interface board *or* one RS-232 interface board *or* one part of the two-piece modem. The RS-232 interface board may connect to on-site devices or to communications devices such as wireline modems, fiberoptic modems, cellular radio modems, satellite communication modems, digital micro-wave, or to the 4800 bps or 9600 bps modems that are optionally available when the 900 MHz DARCOM 9000 MAS radio model is ordered.

Wireline Modems

The wireline modem assembly shown in Figure 4 contains one piece that is installed in the Port 3 plug-in board location and a second piece that contains the physical connections to the line and installs where the two-way radio would normally install. *It is mechanically impossible to have both a two-way radio and the internal modem in a single RTU with one CPU module!* The rackmount RTU configuration with the Dual CPU capability makes two-way radio plus an internal wireline modem a possibility.

	1200 bps	2400 bps	PSTN	Multi drop	Pt-Pt	Notes
V104	X		X			
V219	X			X		half-duplex only
V285	X				X (*)	4-wire also
V226		X	X			
V404		X			X	4-wire also
			* For analog microwave system use			

Table 14. Wireline Modem Capabilities

A listing of the internal wireline modems and their option ordering numbers appear in Table 14. All modems provide full-duplex operation unless noted and operate on a 2-wire basis. They obtain operating power from the power supply/battery and therefore continue to operate during ac mains failure.

Working with Repeaters

A repeater extends the communications range of a single site. Radio repeaters are present in some systems to satisfy voice coverage requirements; MOSCAD may operate through those repeaters if the guidelines provided in the FSK and DPSK portion of the Radio Communications section are followed.

The MDLC protocol provides MOSCAD with its *store-&-forward* capability. Store-&-forward (S&F) is commonly used to extend the communication cability of single CPU modules and is therefore a repeater action. S&F is a Network Services function so any MOSCAD RTU may perform its intended application plus be an S&F node. Two or more S&F nodes may be interconnected in a linear, star, or combination thereof configuration to

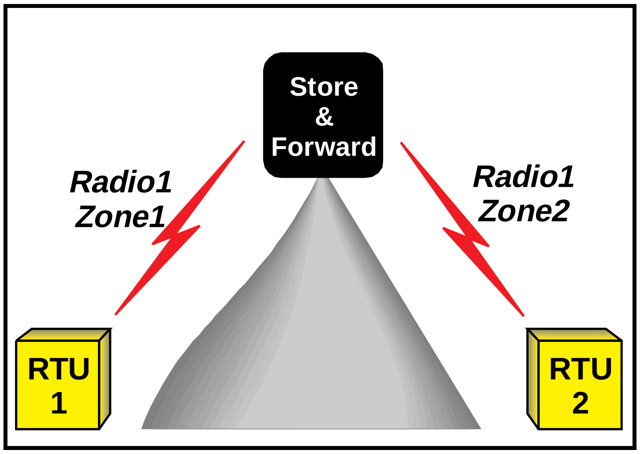


Figure 18. Store-&-Forward: Single Medium

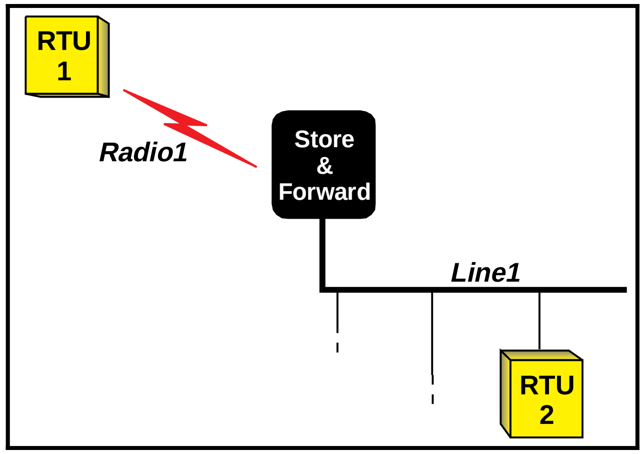


Figure 19. Store-&-Forward: Mixed Media

create an S&F network. Any MOSCAD RTU in the system may initiate a message to any other MOSCAD RTU in the system: the message initially goes to the local S&F node, is passed through the S&F node chain, and is ultimately delivered to the recipient. The contents of the message is not important because the Network Service layers are concerned only with data transport and not content.

On radio channels, S&F requires the single transceiver in the RTU to communicate in both the near and distant zones—see Figure 18. Simplex channelization (T=R) is mandatory; S&F through a repeater makes no sense. The rackmount RTU configuration permits two radios, power supplies, and CPUs; this combination may be used to create cross-channel or cross-band S&F nodes, or to extended a repeater system through a simplex radio link to more distant sites. A 202-T or other modem may be connected to Port 2 (and mechanically secured within the NEMA enclosure) to achieve a S&F node between the radio on Port 3 and the wireline modem on Port 2—see Figure 19.

Store-&-forward frees the system designer from most of the communication constraints otherwise encountered. Virtually every MOSCAD system, simple or complex, uses S&F somewhere in the system.

Fade Margin

MOSCAD systems typically require a minimum -100 dBm received signal strength (approximately 2 µV) for data speeds of 4800 bps or less. The path loss betweeen the transmitter and receiver is not constant, is affected by a variety of natural influences, and does vary widely. To assure that the minimum signal level is received it is necessary to include allowances for this path loss variation (*fade margin*). Systems should be designed with a fade margin of 30 dB or more to provide at least 99.9% channel availability. Figure 20 shows the relationship between fade margin and channel availability.

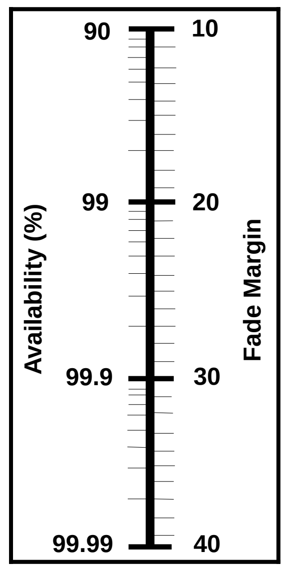


Figure 20. Fade Margin

Airtime Loading

According to the FCC (Title 47, Para 90.7), channel loading is defined as the number of (mobile) transmitters authorized to operate on a particular channel within the same service area. In a data system, this definition is typically extended to describe the number of data terminals that may operate on a single radio channel under a given set of conditions.

Traditional Radio Channels

Determining the number of data terminals (RTUs) requires first making some educated assumptions followed by some simple mathematics.

Air Time Loading (ATL) may be calculated by using the following equation:

ATL = N x [D + (16 x L/R)]

where:

ATL = Air Time Loading in seconds by a single RTU
N = Number of separate transmissions required in one communications session
D = Required radio channel access delay (PTT plus Unsquelch) in seconds
L = Length of the message (number of 16-bit variables)
R = Data signalling rate (bps)

The equation is not as awe-inspiring as Einstein's famous $E=MC^2$ but, without some explanation, is equally confusing. Therefore, an example is appropriate.

Each RTU connects DI and AI data locally and makes appropriate DO decisions to control local devices plus notifis either the SCADA Manager or other RTUs of those control actions.

Assume:

1. Five percent of the RTUs initiate a transmission each minute.
2. Every transmission is acknowledged after the first transmission.
3. The typical RTU consists of 8 DI and 4 AI.
4. The system uses 20 watt MaxTrac radios on a UHF frequency (secondary signalling).
5. The data signalling speed is 2400 bps.
6. The average message length is 60 dibytes (1 dibyte = 16 bits, the size of the MOSCAD data variables). Similarly, the acknowledge message is 14 dibytes. *Note that this assumption eliminates any need for multiple transmission by a single RTU to complete a single message as would occur during an application download or large database upload.*
7. Half of the available time each minute is allocated for message/acknowledge activity.

Let us now calculate the message air time:

(16 x L/R) = 16 x 60/2400 = 0.4 second [*assumptions 5 & 6*]
D = 0.15 second (100 msec PTT, 50 msec unsquelch) [*assumption 4*]
N = 1 transmission [*assumptions 2 & 6*]
ATL_{msg} = 0.55 second

Similarly, the acknowledge message air time is:

(16 x L/R) = 16 x 14/2400 = 0.093 second
D = 0.15 second
N = 1 transmission
ATL_{ack} = 0.243 second

The total time required is the sum of the individual ATLs, namely

ATL_{tot} = 0.793 second

Per assumption 7, 37 RTUs (30/0.793) may communicate each minute. And since these 37 RTUs constitute 5% of the total system [*assumption 1*], then the total system size may include 740 RTUs.

The analysis completed above does not include any interrogation (polling) activity from the SCADA Manager. Therefore, a second analysis is appropriate to include this expected activity.

Assume:

8. The interrogation message length is the same as the responding data message length.
9. The SCADA Manager will interrogate the RTUs "continuously."

The *logical* interrogation message activity is:

Interrogation by SCADA Manager;
Acknowledge by RTU;
Response by RTU
Acknowledge by SCADA Manager.

However, MDLC allows the MOSCAD RTU and FEP to concatenate different logical messages to one or more destinations into a single physical transmission. Therefore, the *physical* message activity becomes:

Interrogation by SCADA Manager;
Acknowledge + Response by RTU;
Acknowledge + Next Interrogation by SCADA Manager; etc.

The Air Time Loading of each of these segments is the same [*assumption 8*]:

(8 x L/R) = 8 x (60 + 14)/2400 = 0.493 second
D = 0.15 second
N = 1 transmission
ATL_{ea} = 0.643 second

The per-RTU air time is 2 x ATL_{ea} = 1.286 seconds.

In the U.S., the FCC when defining secondary signalling by a SCADA Manager station has preserved the 10 seconds per minute for automatic activity rule. Therefore up to 15 RTUs (10/0.643) may be interrogated each minute (constant interrogation). Those 15 RTUs will consume 19.3 seconds (15 x 1.286) each minute. If half of the remaining time in the minute, namely 20.3 seconds (half of (60-19.3)), is used for RTU-initiated data activity (*assumption 7*] then 25 RTUs (20.3/0.793) will initiate messages each minute. So the system size (*assumption 1*] may include 500 RTUs. And each RTU will be interrogated every 33.3 (500/15) minutes.

SUMMARY:

System Type = UHF with Secondary Signalling
Data Signalling Rate = 2400 bps
System Size = 500 RTUs
Time of One Interrogation Cycle = 33.3 minutes
Each RTU Originates One Message every 20 minutes

Air Time Loading:
For Interrogations: 19.3 seconds each minute
For RTU-originated messages: 19.8 seconds each minute
Total: 39.1 seconds each minute

Point-to-Multipoint

Another analysis style is appropriate for those frequency bands, notably 900 MHz Point-to-Multipoint, and countries that have no restriction on the amount of time automatic data activity may occur on the channel.

MDLC uses a patented non-persistent Slotted Carrier Sense Multiple Access with Acknowledge procedure. An RTU that senses a busy channel will wait until the data transmission and associated link-layer acknowledgements are completed. The RTU will not transmit immediately after sensing that the channel is free but will wait a certain period of time to avoid synchronized data collisions with other RTUs also waiting to use the channel. The waiting time is a function of multiple parameters of the radio and the system with an average value of:

$$\text{Wait Time} = 12 \times D$$

where D is the required radio channel access delay (PTT plus Unsquelch) in seconds.

The channel access procedure must be recognized when designing a mixed polling and contention system. If polling occurs too often the RTU waiting to transmit will find the channel consistently busy and be unable to send its messages.

Use the following definitions:

- n = Number of RTUs in the system
- M = Message rate in messages per minute per RTU
- P = Polling rate in polls per minute per RTU

Then the message air-time consumption, including channel access, for all RTUs is:

$$\text{Message Time} = n \times M \times (ATL_{tot} + 12 \times D)/60 \text{ seconds/second}$$

The polling air-time consumption, including channel access, for all RTUs is:

$$\text{Polling Time} = n \times P \times (ATL_{ea} + 12 \times D)/60 \text{ seconds/second}$$

The total air-time consumption for both messages and polling is the sum of these two equations, namely:

$$T = [n \times M \times (ATLtot + 12 \times D) + n \times P \times (ATLea + 12 \times D)]/60 \text{ seconds/second}$$

For stable system operation it is necessary to guarantee that T<1. Therefore

$$\mathbf{n \times M \times (ATLtot + 12 \times D) + n \times P \times (ATLea + 12 \times D) < 60}$$

This equation has linked all system variables and may be used to predict whether a system can withstand the expected activity. Please note that this equation is based on statistical averages; variances may cause some reductions in actual results.

Assume a DARCOM 9000 system with 9.6 kbps modem, and assume that one message is sent by each RTU every 5 minutes (M=0.2). For this DARCOM 9000 system, D=20 msec.

From before:

$$\mathbf{ATL = N \times [D + (8 \times L/R)]}$$

Therefore:

ATL_{tot} = [0.02 + 8 x 60/9600] + [0.02 + 8 x 14/9600] = 0.163 seconds

ATL_{ea} = [0.02 + 8 x (60 + 14)/9600] = 0.143 seconds

Substituting and solving for P produces:

$$P < (114.077/n) - 0.154 \text{ polls/minute}$$

One equation with two variables has no single solution but has instead a family of solutions that can best be understood graphically. Figure 21 shows the relationship between the number of RTUs (n) and the Average Time Between Polls (1/P) in this assumed system.

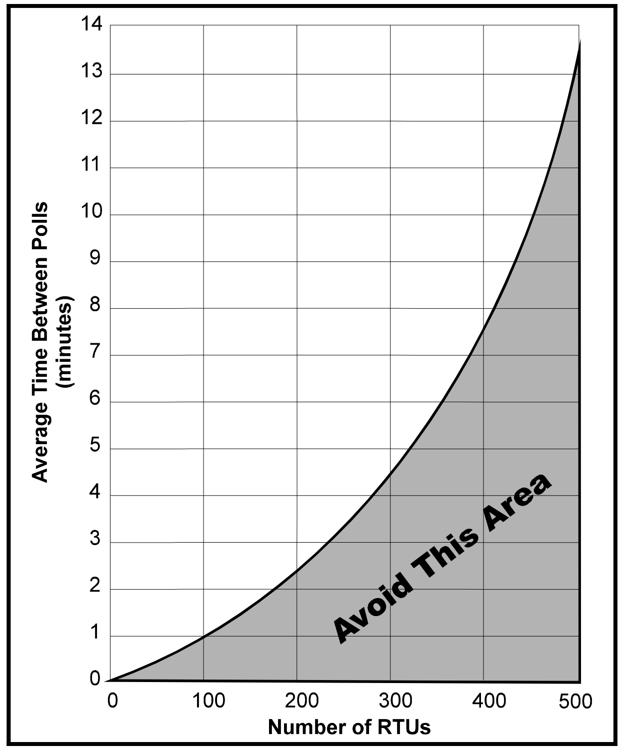


Figure 21. Minutes per Poll for Multipoint Example

SCADA Manager

Supervisory Control And Data Acquisition (SCADA) originally described a monitor and control process wherein all intelligence resided in a central computer (the *SCADA Manager*). The human operators would manage the system by observing the data as presented on the computer's terminal(s). Communications between the computer and its field units normally occurred on dedicated wireline circuits, one field terminal per wireline, under the full control of the computer—polling. The field units didn't have to be smart—that was the central computer's job—they only had to collect data and wait for the computer to request the data.

Computers aren't as big or expensive today as before—the MOSCAD CPU is a computer—and they don't require environmentally-controlled environments—the MOSCAD CPU is designed for field use. The application previously resident only in the central computer may now be distributed among all the field processors (distributed intelligence), with each processor managing its portion of the total system. The communication task has changed also: it is no longer necessary to continuously ask for data when the distributed processors may initiate communications when there is something new to report. This has relieved the communications burden and SCADA systems now function quite well on shared media.

A very noticable change has occurred at the central computer. The high-power mini-computer and associated attendants have yielded to the upper-tier desktop pc computer. The software no longer requires thousands of lines of custom code—off-the-shelf industry-standard packages are available that only require configuration files and display screens to be created. These software packages support the usual wire polling protocols plus the newer connectivity standards such as TCP/IP.

The FEP

The SCADA Manager correctly consists of the pc computer, the software package on that computer, the configuration files/screens created for the system, and an interface assembly between the computer system and the radio system—this interface is the Front End Processor (FEP). Commonly, the FEP is isolated and the term SCADA Manager used instead to describe the computer/software/etc.; that convention will be used hereafter.

The SCADA Manager typically does not support the MDLC protocol; the SCADA Manager might not support conventional, trunked, or MAS radio; it might not support microwave or satellite or cellular radio communications. The FEP provides this support and passes data to the SCADA Manager. The SCADA Manager thinks it is communicating with the field units but is truly communicating only with the FEP (see Figure 1). The technology used within the FEP is necessarily different according to the connectivity available in the SCADA Manager.

ModBus

ModBus is a wireline protocol in common use in SCADA markets. It is supported by many SCADA Manager vendors and is often used in MOSCAD systems at the central. ModBus drivers typically expect prompt communications between the computer and the field units; they don't tolerate well the random delays encountered when a shared communication medium is used. The MOSCAD Communications Processor for ModBus (MCP-M) was designed to interface ModBus to both MDLC and the shared media; it is the FEP of choice in this configuration.

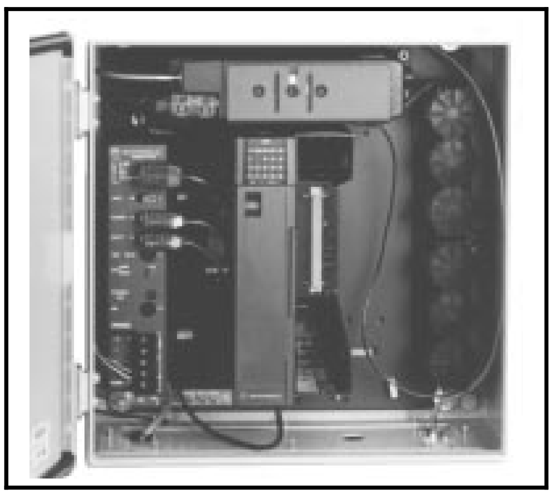


Figure 22. The MCP-M

The MCP-M contains a Series 400 CPU module with the RAM expansion board and a special FEP program. The MCP-M is packaged in the small NEMA-4 enclosure, contains the 8 amp power supply/charger, battery, and communications device (radio or wireline modem) according to the needs of the system. The FEP program retains the communication ports but does not support any I/O modules. A serial data cable connects between either Port 1B or Port 2 (or both—the MCP-M supports two simutaneous ModBus sessions) on the CPU module and the appropriate COM port on the pc computer; ModBus data typically at 19.2 kbps exists on this connection.

The MCP-M maintains an internal database of all the reportable data from all of the MOSCAD RTUs in the system. A System Builder software program is provided with the MCP-M to ease this task: it reads the export file created by the Programming ToolBox for each of the many RTUs' applications and prompts the system engineer to identify which data items are to be collected and which are not. Each identified data item has an equivalent ModBus address according to some very simple yet rigorous rules; therefore, the database in the MCP-M may easily be read, or written to, by the SCADA Manager. The MCP-M's database is kept accurate by any combination of the communication modes discussed in the Communication chapter. If the SCADA Manager should change the contents of any database items defined as outbound (a control), that change will automatically be sent to the associated RTU.

The MCP-M may be configured to periodically interrogate (poll) one or more RTUs to collect some or all of the reportable data in those RTUs and to update the MCP-M database accordingly. Multiple interrogation schedules may be defined: short time intervals for the sites with more interesting data and less often for the other sites.

TCP/IP

TCP/IP is a protocol in common use on Ethernet data highways such as the World Wide Web and others. This protocol is finding increased use in larger computer systems to connect multiple servers to many, many users. Connecting SCADA data to this Ethernet data distribution system is becoming a strong goal of the managers of these large systems. The MOSCAD Communications Processor for TCP/IP (MCP-T) was created to provide this very connectivity.

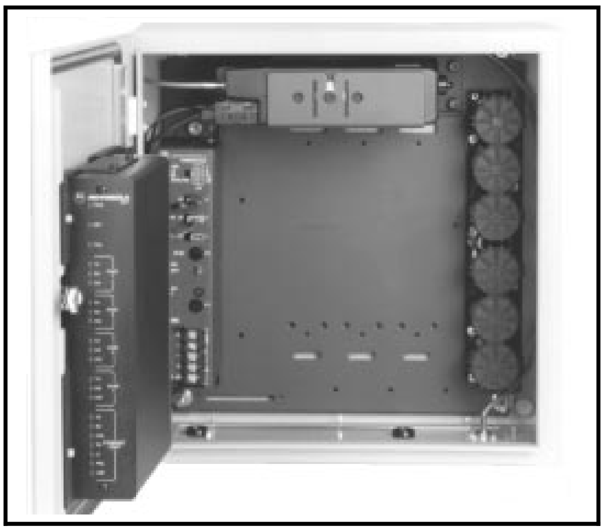


Figure 23. The MCP-T

The MCP-T contains a very special CPU that is quite different from the Series 300 CPU module. The MCP-T is packaged in the small NEMA-4 enclosure, contains the 8 amp power supply/charger, battery, and communication device (radio or wireline modem) according to the needs of the system. The MCP-T module has communication ports similar to those on the Series 300 CPU but no motherboard connection; it does not support any I/O modules. Both twisted-pair and AIX connectors are available to connect the MCP-T to the 10 Mbps Ethernet LAN.

The MCP-T is a gateway—a real-time protocol converter—that connects MDLC on its communication medium to TCP/IP. It does not contain a database. It is configured by simply assigning an MDLC and an IP address for their respective system's use; a configuration software program is provided with the MCP-T to ease this task. An API is also provided which the system engineer must use to develop a driver between the programs in the server that require data from the MCP-T and the MCP-T itself. Contact your Motorola Data Specialists to determine if a driver is already available for the host hardware/software being used.

The SCADA Manager

As used herein, the SCADA Manager is the pc computer hardware plus an industry-standard software package that is used to collect field data and present that data to the system's human operators. High-tier pc hardware is generally selected because humans become impatient when waiting for slow computers to present the data. See Table 15 for the current recommended pc hardware configurations. The amount of information presented on the typical display screen requires the use of a 1024 x 768 display mode; choose a video monitor for this requirement—a 17" monitor is great, smaller monitors may present icons too small for those with visual impairments to see, and larger monitors may spread the information so widely as to be hard to find. All but one of the serial and parallel ports on the computer are normally used by the basic accessories, i.e. ModBus connection on one serial data port, a line printer on one parallel data port, and a page printer on the second parallel port. A digiboard or equivalent serial port expander that manages its own interrupts must be added when additional serial ports are required; avoid those expander boards that provide COM3 and COM4 connectors but share the same interrupts as COM1 and COM2.

Equipment	Workstation (Windows NT)	Workstation (Windows for Workgroups)
Platform	Micron Millennia Plus or Dell Optiplex DGX (or approved equal)	Micron Millennia or Dell Optiplex GX (or approved equal)
CPU Type	Intel™ Pentium®	
Clock Speed	133 MHz minimum	100 MHz minimum
RAM	32 Mbyte minimum	16 Mb minimum
Floppy Disk Drive	One, 1.44 Mbyte, 3.5"	
Hard Disk Drive	One, 1 Gbyte SCSI-2 minimum	One, 500 Mbyte EIDE minimum
CD-ROM Drive	4x speed SCSI-2 minimum	4x speed EIDE minimum
Sound Card	Soundblaster 16	
Operating System	Windows NT v3.51 or later	Windows for Workgroups v3.11 and DOS v6.22
Required Software	Microsoft Excel v7.0	Microsoft Excel v5.0
Mouse	Microsoft mouse v2.0	
I/O Ports	2 serial, 2 parallel	
Video Adapter	64 bit PCI bus with 2 Mb VRAM minimum	
Video Monitor	15", 17", or 21" SVGA color (72 Hz minimum at 1024 x 768)	
Network Adapter (1)	3Com 3C509 Etherlink III combo (10BaseT, 10Base5, 10Base2)	
Printer	Dot matrix for alarms, laser for reports, color printer for graphics	
(1): For networked systems only (NetBIOS support required).		

Table 15. SCADA Manager Hardware Requirements

A single pc computer may serve as the SCADA Manager. Or several pc's may be connected through a computer LAN to share data, including SCADA, among them. One computer would be connected to and handle all communication tasks with the FEP. The other computers would obtain data from, or through, the main computer. Each computer on the LAN would have an Ethernet network support card, the appropriate software drivers, plus NetBIOS and other network-support software; the network cards would interconnect through coax or twisted-pair cables.

The SCADA software lets the system engineer customize the SCADA Manager to the unique requirements of the system. In the U.S., two different industry-standard software packages are normally used; other packages will be used when they provide some unique capability required by a particular system. These packages are THE FIX® from Intellution and InTouch® from WonderWare. Both packages operate under Windows for Workgroups or Windows NT and provide a graphical interface to the system. Both packages support the ModBus protocol and are used with the MCP-M FEP.

THE FIX software provides a database of all system data in the SCADA Node computer—this computer provides the ModBus connection to the FEP. Multiple time-functions ares used to control all ModBus read/write activity, to redraw the screens, etc.—these time-functions insure that all this activity occurs at intervals set by the system engineer. Therefore the SCADA Node computer must have a fast, powerful processor with plenty of RAM to properly and promptly service these many support tasks. When a LAN is present, the additional computers are known as View Nodes: they obtain data from the database in the SCADA Node according to their needs; they indirectly interrogate RTUs by triggering the SCADA Node to do the actual interrogation and send the results to all the View Nodes. THE FIX is the software to use when any regulatory agency requires that all actions consistently occur within established time periods.

InTouch software operates in an asynchronous manner by requesting data from the field units (in a MOSCAD system, from the database in the MCP-M) any time a display screen update is required. Any change in the MCP-M's database via MDLC activity is automatically passed to InTouch to properly update the display screen. InTouch provides a polling mechanism to request data updates either automatically or manually. When a LAN is present, all computers act in parallel: if any computer changes a display screen or otherwise requests data, that data is obtained from the MCP-M and passed to all computers where it is displayed appropriately.

Both software packages provide very similar drawing packages to create the display screens; the results from either package can be made to look quite similar although the effort required to achieve this look may be very different. Multiple display screens are cascaded so the human operator may step from a macroscopic view of the entire system down to a detailed view of a single site. The overview screen typically contains a map of the entire system; "hot spots" may be present on the map that change color and blink to advise the operator that somthing has occurred at a site that requires further examination. Buttons may be present that, when clicked on with the mouse, cause some other screen to appear. Individual site screens may have graphical symbols (icons) that change shape or color according to the normal/abnormal state of the associated real-world event: a door icon may open or close; a motor icon may change color; a circuit breaker icon may flash; etc.

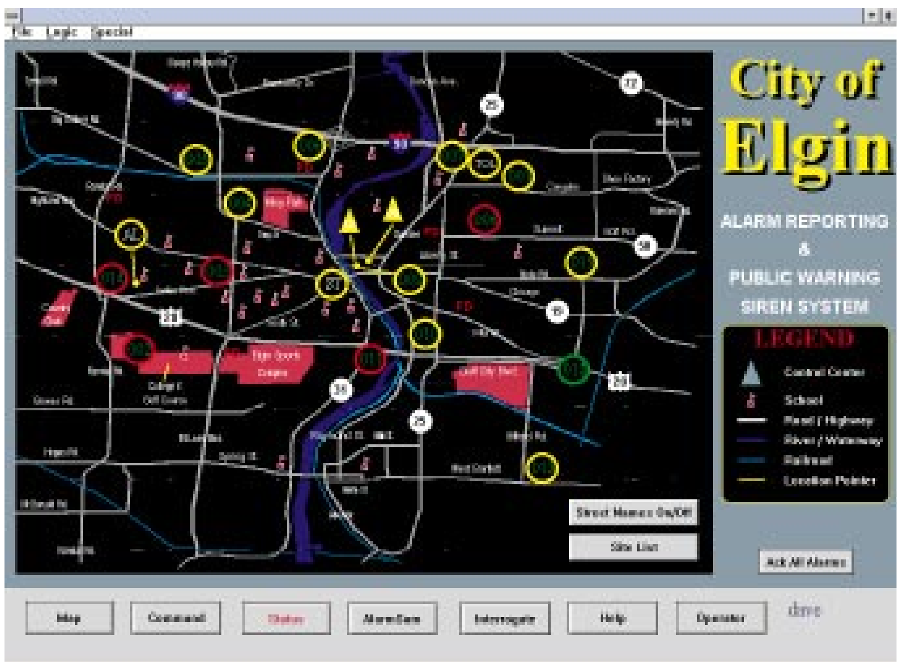


Figure 24. Typical System Overview Display

System-level display screens may also be present. A communication statistics screen is commonly provided to assist the operator determine both the state (available vs. failed) and the quality (1000 tries with 4 retries, etc.)

of communications with a given site. Communications to the sites may be enabled or disabled. An operator signon screen may be created that grants priviledges according to the password entered.

Both software packages provide basic report preparation capabilities. Both packages also support Direct Data Exchange (DDE) so that collected data may be sent to predefined applications within Microsoft Excel that automatically create row-column reports and/or charts. Reports may be automatically prepared and printed each morning so that the system manager may easily view a summary of overnight operations. The SCADA Manager should have two printers: a line printer for a journal record of the events as they occur and a page printer for the reports and charts.

The SCADA Manager may also connect to paging encoders so that off-site personnel may be automatically advised when some critical event is reported. This is advantageous when the on-duty operator is frequently required to be away from the control room or when the control room is not staffed on a 24/7 basis. The on-call operator may then use a laptop computer and modem and the correct SCADA software to call into a modem at the SCADA Manager site and thereby become a remote operator. Or an on-call maintenance person may use a laptop computer and modem with the Programming ToolBox software to call a modem connected to the FEP and access, through the communication system, any site to diagnose suspected problems.

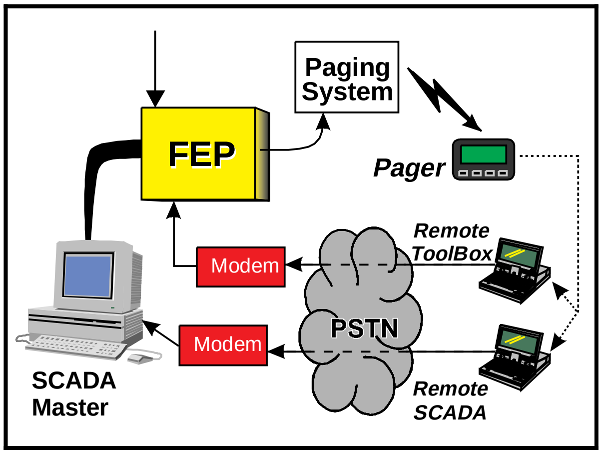


Figure 25. Notification of Problem by Pager

Other industry-available software programs have been evaluated with THE FIX and InTouch. WIN-911 may be used with InTouch to monitor selected data points; it will prepare and send an alphanumeric paging message via an available COM port on the computer through a modem to a paging system. Or, if a voice synthesizer card is added to the computer, WIN-911 will dial a telephone number, prompt the answerer to enter a password, and after receipt of a correct password deliver a predefined voice message that describes the alarm. The voice message is a concatenated selection of sound bytes, i.e. "Station" + "4" + "Power" + "Fail". The answerer is then prompted to enter an acknowledge code. All actions are logged for accountability purposes.

Some of the remote computer access programs available on the market, such as LapLink and pcAnywhere, have been tried with limited success. System designers are urged to contact their Motorola data representative for the latest update on these programs before incorporating them into their designs.

The ToolBox

The F2316 MOSCAD Programming ToolBox (a.k.a. ToolBox) is a collection of software tools that the system engineer uses to create configuration and application files, and to download those files into the MOSCAD RTU. A set of utility programs is provided to read/set the RTU's date & time, upload error logger files, and view the results of diagnostic tasks within the RTU. The ToolBox may be connected directly to the RTU being monitored, or connected to any RTU to monitor the activity within any other RTU. The ToolBox initially operated in a DOS environment (pc computer with the minimum capability listed in Table 16 is required) and has recently been moved to a Windows environment.

Upon entrance into the DOS ToolBox, or before attempting certain operations in the Windows ToolBox, the user is prompted for a password. This password does not control access into the ToolBox; instead, the password gets encoded into certain files that are downloaded into the RTU. Future access by the ToolBox to the RTU must be made with the same password. There is no password decryption utility, so choose a password that isn't obvious to everyone but not so exotic as to be forgotten.

Equipment	Requirement
Hardware Platform	IBM-type pc computer
CPU Type	Intel™ 386SX or better
Clock Speed	Any (faster is better)
RAM	8 Mbyte minimum
Floppy Disk Drive	One, 1.44 Mbyte, 3.5"
Hard Disk Drive	One, 40 Mbyte minimum
CD-ROM Drive	not supported
Sound Card	not supported
Operating System	DOS version: DOS v3.3 , v5.0, or v6.x; Windows version: Windows v3.1
Mouse	Any
I/O Ports	1 serial, 1 parallel
Video Adapter	not required
Video Monitor	LCD, CGA, EGA, or VGA
Network Adapter	not supported
Printer	Any printer supported by DOS/Windows

Table 16. Requirements for ToolBox Computer

Site Configuration

The Site Configuration program allows the system engineer to create a configuration file that defines certain core aspects of the RTU; this file is analogous to the CONFIG.SYS file in DOS—any change to this configuration file requires the RTU to reboot. Which I/O modules are present in the RTU and where they are placed in the module rack is defined by the site configuration program. The function of each port on the CPU module may be defined: is Port 1 set for RS-232 or RS-485; is Port 2 set as system-controlled (for ToolBox, etc. use) or as application-controlled (for DTE or DCE, etc. use); is Port 3 set for conventional radio or trunked radio or modem operation. The Port 3 parameters (PTT, channel monitor, etc.) for each radio type are also set. Names for each communication link on all three ports are selected.

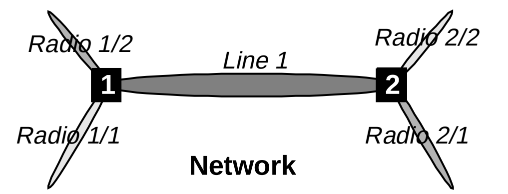
Finally, the address attribute of the RTU may be defined. The address consists of two parts: the system address which is an offset from zero that is shared by all RTUs in any given system, and the site address which is a sequential assignment beginning with one. The sum of these two parts is the true address and may not exceed 2^{16} (65,536). Select a non-zero system address to avoid unwanted duplication between different systems that may share the frequency: a system address of 65,000 still permits 500+ RTUs.

Download the finished configuration file into the RTU; a successful completion message will be received and the RTU will reboot. It is recommended that the download of the site configuration be only done to the locally-connected RTU, that an over-the-air site configuration download be avoided.

Network Configuration

Each MOSCAD RTU that is to act as a store-&-forward (S&F) repeater must be listed in the Network Configuration file. This file identifies the communication chain using the names assigned to each communication link during the site configuration process. The application “thinks” that direct end-to-end communications occurs whereas individual communication sessions among the several S&F nodes actually occurs.

The Network Configuration worksheet resembles a spreadsheet. The site address of each S&F RTU is listed one-per-row; the link names associated with each of these sites is then entered into the remaining columns in the associated row. When complete, this worksheet contains a mapping of the entire S&F network. This configuration file *must* be loaded into each S&F repeater during the application download process; it may be loaded into all sites in the system without harm.



Node	Link	Link	Link	Link	Link
1	Radio1/1	Radio1/2	Line1		
2	Line1	Radio2/1	Radio2/2		

Network Configuration

Figure 26. Network Configuration

Application Programmer

The application that each RTU must execute is created with the Application Programmer. This is a collection of software tasks that build an organized database of required data variables, constructs the lines (rungs) of ladder-logic programming code, links the I/O variable names to physical I/O on the different modules, compiles the above items into a downloadable ‘S-code’ format, and downloads the S-code along with any network file created by the Network Configuration program into the RTU. At the end of the download the ToolBox will provide the opportunity to set the RTU’s clock; application execution begins immediately thereafter.

Most programming languages, including ToolBox, require the variables that will be used be defined as to their type and size before use. The database builder further permits these variables to be organized into collections to facilitate data transfer from site to site and to help the system engineer find the data during application debug and system monitoring sessions. Up to 127 tables (collections) of variables may be created, each table resembling a spreadsheet. In each table there may appear up to eight columns and up to 250 rows of data. All the data in any column will be of like-type, i.e. all DI, all DO, all integer parameters, etc. Other tables are predefined and available to the application; these tables include that transmit and receive buffers, the date/time variables, etc. Still other tables contain the ASCII characters and more. The system engineer creates as many tables (within the maximums stated) and as many data variables as are needed.

The actual programming is accomplished by using ladder-logic. This is a totally graphical language with each icon representing some test (is some bit-variable true; is some value-variable greater than some parameter; etc.) or representing some action (set a relay; send a series of characters to a user port; etc.) Unlike older versions of ladder-logic where each logic statement must occupy a single line, MOSCAD’s version of ladder-logic permits up to 6 branches within each statement and each branch may contain up to eight icons. Most logic expressions may be coded within a single statement which is truly helpful during the debug process.

The *Main* process is automatically executed at RTU startup; additional processes may be created and treated as subroutines: the application may jump to and return from these many processes at will. It is recommended that Main be used as a task executive to test some variable and then jump to a subprocess to execute whatever actions are appropriate for that test. Refer to any textbook on ladder-logic programming for more details, and see also the ToolBox Explained publication (separately as Motorola document RO-11-57; included with the ToolBox since version 3.9).

The link process associates the physical inputs and outputs on the I/O modules with the DI, DO, etc. variables in the tables. The link process begins by the system engineer declaring which site configuration file is to be used with the application. Each table is then examined for DI, DO, etc. variables and all incomplete linkages identified. The system engineer gets to choose from a list of physical inputs/outputs that are appropriate for the variable-type being linked. The process is repeated until all the tables show a link-complete state.

Finally, the database, program, and link files are compiled into a format that may be downloaded directly into the RTU. This downloadable file is in the Motorola ‘S’ format which was created originally for programming EPROMs. The download process creates a virtual EPROM in Flash memory which the CPU then executes. The download process may occur into the directly-connected RTU or through that RTU to any other RTU in the system through any number of intermediate store-&-forward RTUs (true over-the-air programming).

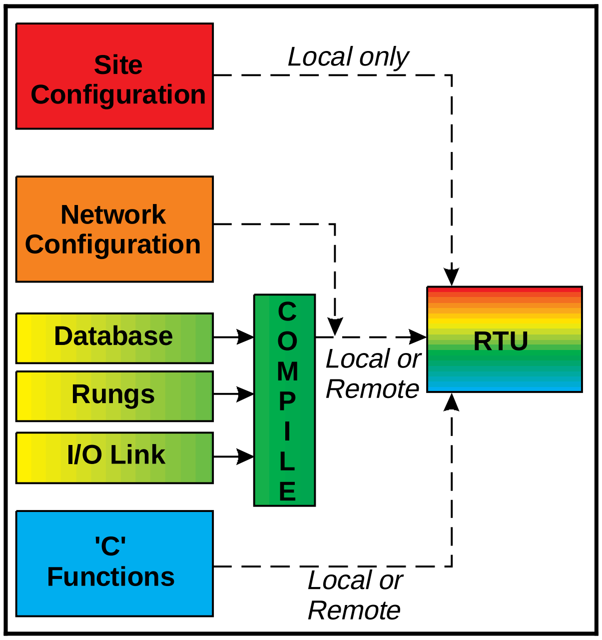


Figure 27. ToolBox Overview

The system engineer also has the capability to create functions using the ‘C’ programming language and to compile them into a downloadable format. This capability is supported by a ‘C’ programming toolkit (consisting of a diskette with programs, a set of debug EPROMS, and an instruction manual) which provides the required header file plus full instructions on the function calls supported by the header. The ‘C’ source code must include this header file and observe the protocols associated with the supported calls. The RAM expansion board for the CPU module will also be useful during the development and debug phases. The system engineer must use a specific Microtek linker, compiler, and debugger, and use either the ‘C’ toolkit or the ToolBox to download the ‘C’ function(s) into the CPU. Please note that the ‘C’ capability does not replace ladder-logic. The Main process will be run at startup; rungs must be created to call the ‘C’ function(s) as appropriate, and program execution must periodically return to ladder to prevent a watch-dog timer error. Contact your Motorola data specialist for more information on this capability.

Motorola has some ‘C’ function libraries available that support some special I/O modules or that provide tested and proven functions in common use in certain industries. The V377 option to the ToolBox provides the drivers required to use ModBus, Allen Bradley PLC5, and some other third-party protocols with the Series 300 CPU module. This driver is a ‘C’ function that is downloaded into the CPU module, using the Downloader capability of the ToolBox, after the Site Configuration, Network Configuration, and Application downloads have been completed. The V378 AC Analyzer option to the ToolBox adds the function calls to the Series 300 CPU module necessary to properly scan data to/from that module. A ‘C’ function is provided that is downloaded into the CPU module, using the Downloader capability of the ToolBox, after the Site Configuration, Network Configuration, and Application downloads have been completed. The V284 AGA-8 option adds to the ToolBox all the of the 51 table definitions, and proves a tested ‘C’ function for the Series 300 CPU module that performs the actual math, according to requirements for AGA-8 gas flow calculations. With this ‘C’ function downloaded in the CPU module by the Downloader capability of the ToolBox, the MOSCAD RTU provides a tested platform that fully conforms to existing AGA-8 gas flow calculation requirements. Note that the CPU module must also have the math coprocessor option if data from more than one meter run is being handled, and that the RAM expansion option is strongly recommended to store up to 35 days of collected data.

The application running in the CPU may be monitored via data upload from the RTU. The communication path may be via direct connection or over-the-air from a distant RTU through any number of intermediate store-&-forward RTUs. The rungs of the application or individual tables in the database may be monitored. The data being viewed may be updated manually by the system engineer or automatically by the ToolBox. Conditions may be defined that, when true, force an update of the viewed data.

An OUT file may be created for use with the MCP-M during it’s configuration process. This OUT file contains an image of the application’s database; the MCP-M’s configuration program reads that image file before prompting the system engineer to specify which tables to include or exclude. The process is quick and easy, and transcription errors are totally eliminated.

Utilities

Some additional diagnostic tools, beyond the application monitoring capability described above, are also present. The error logger file maintained by the RTU may be uploaded into the ToolBox, by direct connection or over-the-air, and later examined. Problems may be studied and corrective actions taken. Similarly, the diagnostics file maintained by the RTU may be uploaded into the ToolBox, directly or over-the-air, and examined. This capability provides access to the in-RTU communication monitor (number of initial messages, number of retries, number of received messages, more). The ToolBox includes a MDLC protocol analyzer utility for those who really encounter a problem involving data transfer, and a utility to set the data/time within the RTU.

The application’s source code, as created by the Application Developer task prior to compiling, must be retained by the system engineer. This code will be reused when the application is monitored or modified. Beginning with ToolBox v3.9, the source code may be compressed and downloaded into a Series 300 CPU module with firmware v3.7 or later *provided* that the CPU module has sufficient Flash memory available for the download. Anyone working on the system may later upload the file, uncompress it, and perform whatever actions are required. A backup disk copy of the source code, properly stored and protected, is always a great plan!

The ToolBox provides the system engineer with a complete suite of tools that define, program, monitor, and otherwise manage the MOSCAD RTUs. Most functions are available for over-the-air use from the safety of system engineering headquarters.

Installation Guidelines

The MOSCAD RTU is supplied in a steel enclosure that is rated NEMA–4. The enclosure can be omitted and the RTU wall mounted or the RTU ordered in a multiple-panel rackmount configuration. The physical dimensions (in millimeters and inches) of the MOSCAD RTU in various enclosures are summarized in Figures 28-31.

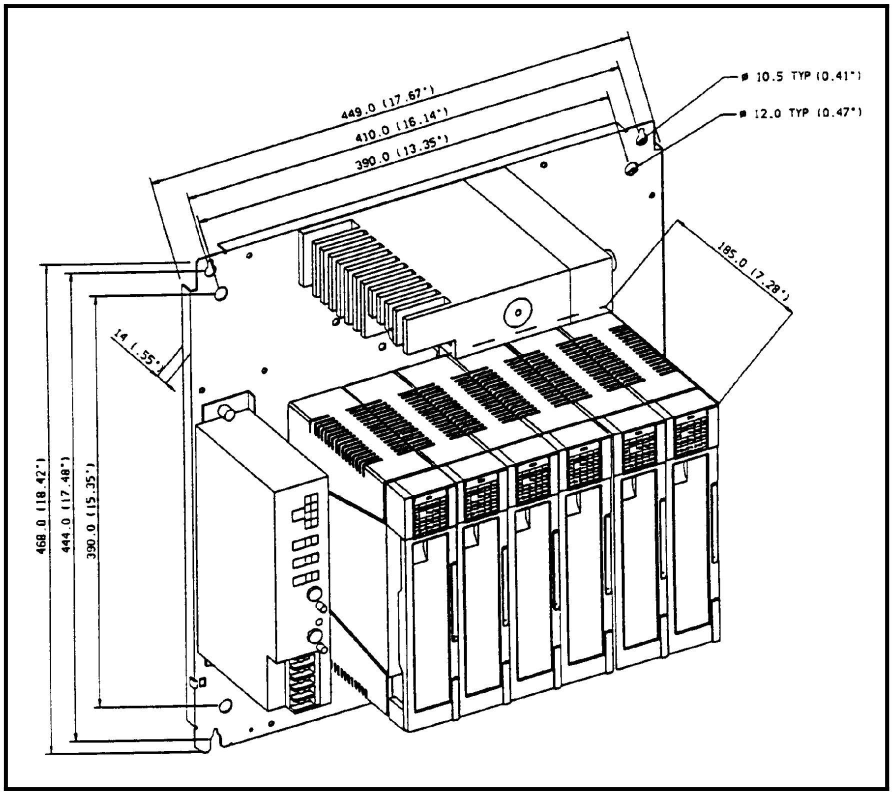


Figure 28. Wall Mount Details for 6-Slot

Power Requirements

The MOSCAD RTUs include either a 3 amp or an 8 amp power supply depending on the internal radio transceiver. This supply provides operating power for the entire RTU plus charges the internal battery. The MOSCAD unit operates on two internal DC voltages:

» 12 V for relays, drivers and LED displays.

» 5 V for digital circuits. The CPU module provides stabilized 5 Vdc @ up to 1.5A that is derived from the external 10.5 to 16 Vdc input. The rack Expansion module (see Figure 7) also provides 5 Vdc @ 1.5A and should be used in large rackmount configurations that exceed the maximum current available from

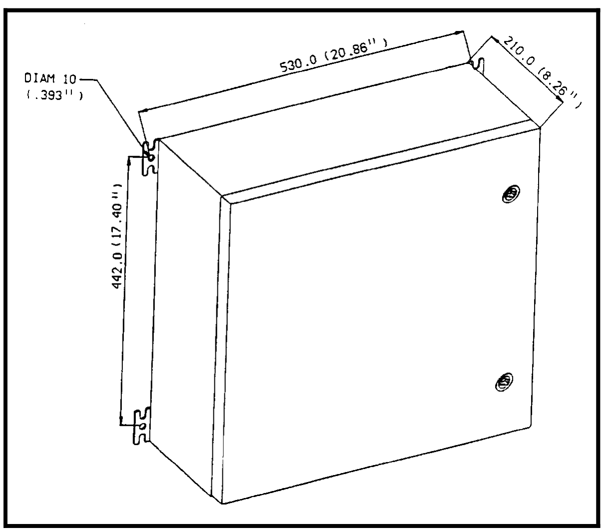


Figure 29. Mounting Details for Large Enclosure

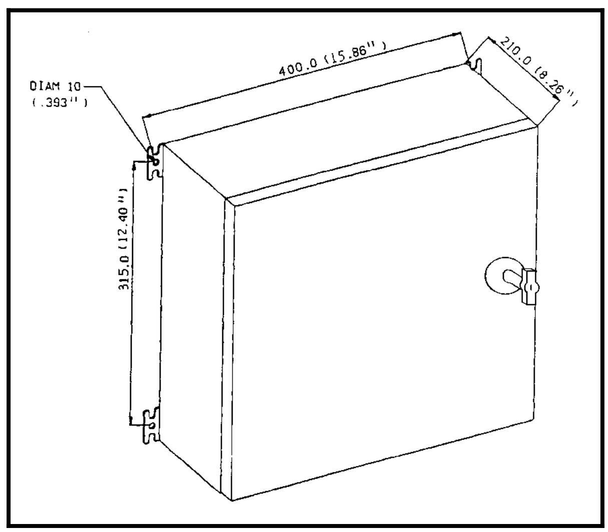


Figure 30. Mounting Details for Small Enclosure

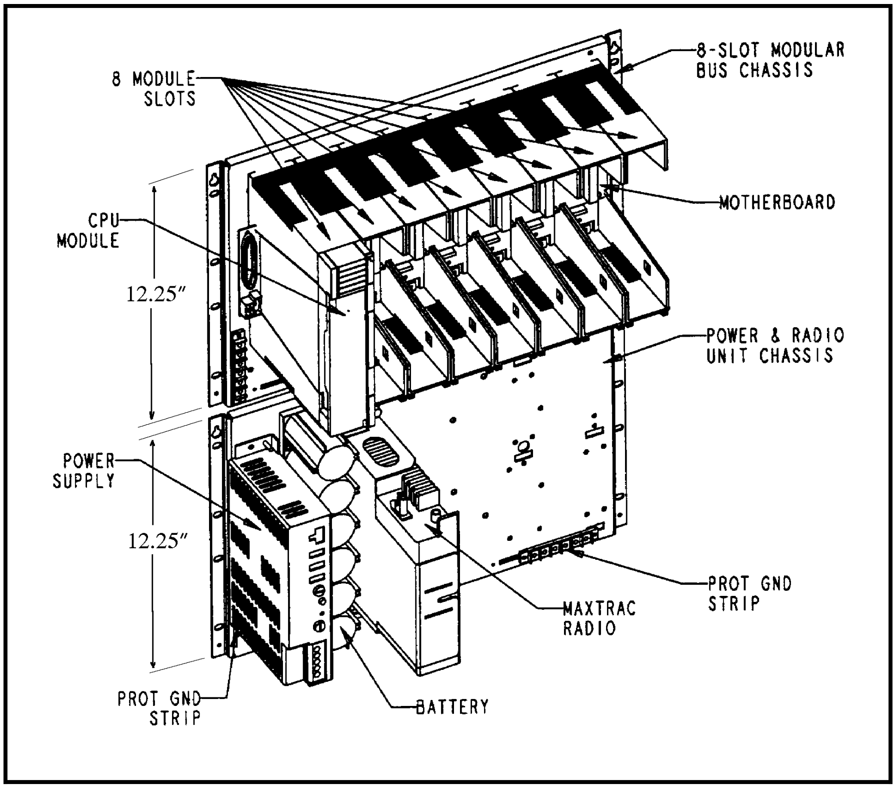


Figure 31. 19" Rackmount Details

the CPU module alone.

The MOSCAD power consumption from the 14.1 Vdc supply for the internal radio and for each module is listed in Appendix A.

Solar Power

It is possible to operate a remotely located MOSCAD RTU with a solar panel as the primary power source. This is a great convenience when commercial power is not available at the particular site. Before selecting the solar panel, the exact current consumption of the RTU must be established.

The RTU with radio has three operating modes:
(1) Transmit mode with the maximum power consumption;
(2) Receive mode with moderate power consumption;
(3) Stand-by mode with the minimum power consumption.

The power consumption should be based on a worst-case average calculation. On quiet radio channels, the RTU normally is in a stand-by mode whereas it may, on busy channels, be in the receive mode most of the time. The duty cycle for the remainder of the time should be calculated from system activity estimations.

For example, and using again the system calculations from Chapter 5, each RTU is interrogated once every 33.3 minutes thereby transmitting 2.32 sec/hr (1.286*60/33.3) and initiates one COS transmission every 20 minutes thereby transmitting an additional 2.38 sec/hr (0.793*60/20), for a total transmit time of 4.70 sec/hr. The RTU hears all other activity which uses 2341 sec/hr (39.1*60-4.7). The RTU can be in the standby state for the remaining 1254 sec/hr (3600-2341-4.7) if no other on-channel activity occurs (this variability can be eliminated if the RTU radio’s speaker amplifier is kept at minimum power so that receive-current = standby-current). The total current consumption is the sum of each individual time element plus the current consumption of the I/O modules:

Transmit time current drain	= 0.004 A-h (2.8A*4.7/3600)
Receive time current drain	= 0.260 A-h (0.4*2341/3600)
Standby time current drain	= 0.139 A-h (0.4*1254/3600)
CPU300 current drain	= 0.170 A-h
16DI current drain	= 0.065 A-h
16DO current drain	= 0.045 A-h
TOTAL	= 0.623 A-h

A suitable solar panel, voltage regulator, and larger batteries—from BOSS in Scottsdale, AZ, Sun Wize Energy Systems in Orland Park, IL, or equivalent—must be added.

Cables

Table 17 lists the cables used to connect the MOSCAD CPU ports to external devices. The connection of MOSCAD to the modem or to the terminal is by means of standard 8-pin to 8-pin connector cable plus a suitable 8-pin to DB25 connector adapter. These assemblies may be ordered as an Adapter Cable Kit.

Order	Description	From	To
FLN6457	RS-232 Async Terminal Cable	CPU RS-232 port	External computer
FLN6458	RS-232 Async Modem Cable	CPU RS-232 port 2 or port 3 w/Async intfc.	External async modem
FLN6407	RS-232 Sync Modem Cable	CPU port 3 w/Sync intfc.	External sync modem
Darcom Master + V431 or V432 + V390	DFM Interface w/cable	CPU RS-232 port 2 or port 3 w/Async intfc.	DARCOM master radio
Darcom Master + V356	FSK or DPSK Interface w/cable	CPU port 3 w/FSK or DPSK intfc.	DARCOM master radio
Darcom Master + V131	Sync Interface w/cable	CPU port 3 w/Sync intfc.	DARCOM master radio

Table 17. Serial Data Cables

The CPU modules in two co-located RTUs may be connected together in one of two ways:

1. Use one each FLN6457 and FLN6458 cables. The DB25 connectors are plugged together and the two 8-pin connectors are then inserted into port 1B or 2 on the CPU modules. The associated CPU ports are configured as an RS-link.
2. Connect the FKN4400 RS-485 cable either directly to, or connect through the RS-485 Junction Box (V186 option), ports 1A on the CPU modules; configure these ports as an RS-link.

Appendix D lists the specifications for different grades of leased communication lines commonly available throughout the world. Or use the information in Table 18 as an approximation when proprietary wire pairs must be installed to provide the communication service. To use Table 18, determine the maximum allowable difference between send level and receive level (in dB). Divide this differential by the dB/km [dB/mi] factor for the selected wire size—the result will be the approximate wire length between sites.

Conductor Size mm^2 [Ga.-AWG]	Attenuation dB/km [dB/mile]	Loop DC Resistance per km [mi]
0.4 [26]	2.11 [3.40]	274 [442]
0.5 [24]	1.65 [2.66]	169 [273]

Table 18. Twisted-Pair Cable Attenuation

Field Wiring

The connectors on the MOSCAD modules are sized to accept up to a 14 ga. wire. This does not mean that every wire should be 14 gauge!

Installers are urged to adopt a wiring plan that separates the wiring by function: keep the small signal digital input (DI) and analog input (AI) wires in one bundle; keep the large signal digital output (DO), etc. wires in a different bundle. Keep AC power wires (to the power supply or the AC Analyzer termination panel) in an even different bundle. Use small gauge wires for the small signal inputs/outputs; this physical difference is helpful when keeping the power wires away from the signal wires. Route these wire bundles separately, in different pieces of conduit. The intention is to prevent noise and transients on the AC power wires, or on the DO wires, from cross-coupling into the DI and AI wires. Physical separation is an excellent start.

Consider the addition of surge suppressers on the AC lines. The power supply and the modules have an excellent surge rejection capability. Nevertheless, if the surges can be eliminated outside the enclosure, then the opportunity to create harm will never occur and the equipment will surely operate better. It’s simply anticipating trouble and eliminating it before it can occur.

Grounding! It’s a topic that everyone understands the importance of, yet–too often–is not properly addressed. A good connection to a good earth ground is mandatory. The surge protective devices all shunt the surge energy to ground, away from the equipment. If the ground connection is poor or missing, then the surge protective devices cannot function and the opportunity for damage persists. Anticipate the problem and take corrective actions in advance.

Don’t put the antenna on the MOSCAD enclosure. Doing so means that the enclosure becomes part of the total antenna system. RF energy will surround the modules and the service technician. Unwanted equipment performance has been documented and traced to these large RF energy fields enough times to warrant a blanket warning: put antennas on a pole, up in the air where antennas are meant to go.

Another word about antennas. Use directional antennas whenever possible. Directional antennas focus the radio energy toward the receiving site thereby providing more energy (signal) to the receiving site. This translates directly to better fade margins, reduced opportunity for interference from off-axis radio equipment, and better signal thruput. Use omni-directional antennas only at those sites that must communicate with many other widely separated sites.

Make the installation *look* good: clean, shiny connections; wiring planned and organized; enclosures mechanically secured to a wall; etc. These all increase the probability that the installation will indeed be a good one!

MOSCAD System Maintenance and Reliability

Reliability of electronic equipment is a complicated and confusing issue. This section is intended to clarify some issues and myths in this field. The following reliability terms are commonly used:

System reliability R(t) is defined as the probability that a given system or component operates without failure for a given time when used under specified environmental conditions. This term is complementary to the failure distribution function F(t), which is defined as the unreliability of the system at time t. Consequently R(t) = 1 - F(t).

MTBF (Mean Time Between Failures) is a common way of specifying system reliability. However MTBF is usually badly defined and misused. MTBF is the mean of all time periods when a system or equipment is in an operative state, over an infinite length of time.

MTTR (Mean Time to Repair) is the counterpart of MTBF, and is defined as the mean of all time periods taken to restore the failed system or equipment to an operative state, over an infinite length of time.

The mathematics behind MTBF and R(t) is quite complex as it involves different distribution functions and is best treated by means of complicated mathematical modelling. It is sufficient to say that the most applicable and usable reliability term is a combination of MTBF and MTTR, namely System Availability A(t), defined as the probability that the system will be operational at any point in time.

$$A(t) = \frac{MTBF}{MTBF + MTTR}.$$

System availability is a function of a large number of parameters such as:

» Operational and storage environment (temperature, humidity, vibrations, etc.)

» Maintenance procedures (periodic, preventive, etc)

» System configuration and topology

It is accepted practice to include temperature and vibration as environmental factors when specifying the reliability of a system. In actual use, a system will, however, experience a wide range of additional hazards and stresses. As a result, the actual or “field” reliability may be considerably lower or higher than that experienced in testing or established by calculations. In real life it may often occur that a calculated 10,000 hours MTBF is found to be a field MTBF of 1,000 hours or vice versa.

Motorola MTBF figures are calculated from Accelerated Life Test (ALT) of actual equipment, simulating six years of field operation. The ALT is performed by an independent Quality Assurance Department. This clearly is closer to actual field figures than calculated MTBF.

There are many other reliability prediction methods, of which the most notable are FMEA and FTA.

» Failure Modes and Effects Analysis (FMEA) is not utilized because, while particularly effective in analog circuits, it has little relevancy in digital circuits that can have a practically limitless number of logic state combination. This type of detailed component level analysis is usually applied to an analog Military Standard equipment.

» Fault Tree Analysis (FTA) is a complementary *system* engineering technique applied during the design of systems where safety and/or operational failure modes are of concern. This technique provides an organized, illustrative approach to the identification of the high risk areas. The FTA is usually used in development of Military Type systems.

General confusion in the area leads to a chaotic situation where various vendors provide different reliability figures, some of them artificially “treated” to fit the customer requirement. The figures from various vendors can not be readily compared as there are many methods of defining the reliability figures. The proliferation of various reliability standards does not help, and creates even more uncertainties.

Reliability figures for the MOSCAD RTU, obtained from ALT tests, show MTBF to be in excess of ***20 years*** (>175,000 hours) for a typical configuration consisting of one 8A power supply, one CPU module, and one each 16DI, 16DO, and 8AI module. MTTR cannot be predicted here but should have little impact on A(t). It should be emphasized, however, that MOSCAD based SCADA systems include the SCADA software and the system-specific user application software. Total system reliability calculations must include these software items in addition to the reliability of the MOSCAD RTU hardware.

Calculating Spare Part Availability

The availability A(t) equation previously cited shows that availability is largely dependent upon the maintenance philosophy and not only on equipment design. For this reason careful planning of maintenance centers, logistics, spare inventory, etc. is required.

Spares consist of plug-in modules, boards, antennas, etc. The quantity of each on hand depends on several factors:

» MTBF of the unit;
» Probability that the spare part is available in inventory when required;
» Transportation time from inventory to the equipment site;
» Time to make the repair on-site;
» Time to repair the defective part in a repair depot and return the part to inventory.

Exact calculation of the quantity of each part is based on the cumulative Poisson distribution. For practical purposes the number of spares may be estimated from the graph shown in Figure 30.

To use Figure 30, first establish the requirements:

n = Number of units in the system

T = Total time to transport, install, repair, and return the part to inventory

P = Probability of the spare being in inventory.

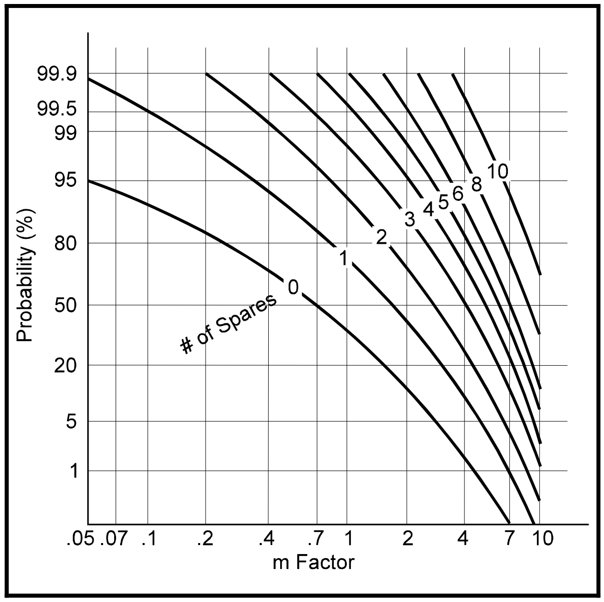


Figure 32. Calculating Spares Inventory

Then calculate:

$$m = \frac{n \times T}{MTBF}$$

and determine from the graph the number of spare parts necessary to achieve the stated Probability goal.

As an example, assume that the customer wishes to maintain their own spare parts inventory and has a system with:

n = 100 MOSCAD RTUs (MTBF approximately 175,000 hours each);

T = 8 days (192 hours) to obtain, install, and repair the spare part;

P = 99% probability of the spare part being in inventory when needed.

The *m*-factor calculates as 0.073. From Figure 30 one can see that one (1) spare part is needed for 99% part availability.

Another example: a Service Depot will maintain a spares inventory for many different customers with a total of 2,500 MOSCAD RTUs. They will use an overnight delivery service to ship parts to their customers and anticipate the return and repair time to total 16 days (384 hours). They calculate the *m*- factor as 3.65; Figure 30 then shows that eight (8) of each part should be obtained to provide 99% part availability.

Environmental Conditions

The mounting plate (less housing option) of the MOSCAD RTU is designed for installation in buildings, in equipment room or in office environment. Use the MOSCAD RTU in its NEMA 4 enclosure whenever outdoor installation is required. Use the plastic or stainless steel enclosure option when corrosive atmospheres are anticipated.

Operating Temperatures

The RTU operates as specified over an ambient temperature range of –30°C to +60°C with a relative humidity of up to 95% @ +50°C according to EIA standard RS-204B and RS-152B, intermittent duty specifications. The allowable temperature gradient is 2°C/minute.

Part	Description	Number
Power Supply	Power supply 117 Vac/13.6 Vdc @ 3A Power supply 230 Vac/13.6 Vdc @ 3A Power supply 117 Vac/13.6 Vdc @ 8A Power supply 230 Vac/13.6 Vdc @ 8A	FPN5123 FPN5223 FPN5128 FPN5228
Batteries	5 A-h standard battery pack 3V lithium battery for CPU module	FLN4666 60-08261C04
10 A-h battery expansion kit	Second 5 A-h battery pack Hardware kit for 10 A-h battery	FLN4666 FRN5528
Power Cables	P.S. to motherboard (NEMA) P.S. to motherboard (rackmount) P.S. to battery (3-slot NEMA) P.S. to battery (6-slot NEMA; rackmount) P.S. to pigtails (80 cm length) P.S. to 2 pin Molex	FKN5931 FKN4030 FKN4047 FKN5930 FKN4068 FKN4090
Radio power cable	P.S. to MaxTrac, MC900, Spectra radio P.S. to MT2000 radio	FKN5932 FKN5933
DARCOM HR2 cables	P.S. to DARCOM HR2 radio DARCOM radio adapter board w/o VF Interface DARCOM radio adapter board with VF Interface	FKN4017 FLN6594 FLN6796
Serial data cables	RS-232 modem adapter cable Terminal / ToolBox adapter cable	FLN6458 FLN6457
Radio interface cables	CPU to Radio communication cable MaxTrac radio adapter board MT2000 radio interface board MT2000 radio interface connector kit CPU to External Radio cable	FKN5953 FLN6433 FRN5751 FRN5733 FKN4091
Fuses	3 amp slow-blow 3*20 (on motherboard) 1.6 amp slow-blow 5*20 (on CPU)	65-03069C34 65-02069C35

Table 19. Replacements Parts

Packaging

The RTU in its standard shipping carton withstands a packaging test consisting of one hour of bouncing with maximum vibration frequency of 5 Hz. It can also withstand a drop test from a height of 1 meter.

Replacement Parts

Table 19 lists some of the replacement parts for MOSCAD.

Diagnostics

The RTU I/O modules are continuously tested by the CPU module software. Several levels of special Built-In-Test (BIT) circuitry is provided in each module for these tests. A 20 LED matrix is provided on both the CPU and on each module for fault identification and system diagnostics.

It is possible to test the MOSCAD unit remotely by using the Programming Toolbox software with a PC connected to any RTU in the system. The error log list in the CPU will provide a comprehensive list of errors, including date, time, software or hardware entity name, and full error description.

The logic circuitry may be removed from the module's housing without changing any wiring. All logic units are interchangeable between RTUs at the module level.

Test Equipment

Table 20 lists the minimum recommend test equipment, beyond the normal hand-tools and voltmeter, required to service a MOSCAD RTU.

Description	Model Number	Used For
PC or Laptop computer	See Table 16	Monitoring of the application and database in the field; downloading 'C' function blocks
MOSCAD Programming ToolBox software	F2316	
Motorola R2600 Communication system analyzer	R2600	Test of the radio equipment

Table 20. Recommended Test Equipment

Ordering Guide

The information provided herein summarizes the ordering process and offers some helpful material regarding the selection of models, options, and accessories for the MOSCAD RTU and FEP. It is important to have a thorough understanding of the intended application, of the connectivity requirements to on-site sensors, and of the communication medium that will be used as the choices to be made depend upon that knowledge. The models, options, and accessories being ordered must appear on the order form in a very specific manner. The order input system will check each entry on the order against an established set of compatibilities; problems will be identified which will delay order acceptance until resolved.

Choose the Model

MOSCAD RTU models are structured according to the communication device included within the model. Table 21 lists the current model choices; the basic model includes a Series 300 CPU module and expansion slots for five I/O modules. Refer to Chapter 2 for a listing of other items included within each model and to Chapter 3 for a discussion of the capabilities of the communication devices. Models must appear on the order writeup as an item and may never be included within other items. The quantity ordered may be greater than one provided that each RTU has identical option types and quantities.

	Freq. Range Radio Type	No Radio	VHF 136-142 MHz 142-174 MHz	UHF 403-430 MHz 450-470 MHz	800 MHz	900 MHz
	No Radio Ext. Radio	F6900 (3A PS) F6909 (8A PS)				
Conventional	MT-2000		F6953 5 W (var. to 1) 3 amp P.S.	F6954 4 W (var. to 1) 3 amp P.S.		
Conventional	MC-900 (Europe only)		F6963 20 W (1-20) 8 amp P.S.	F6964 20 W (1-20) 8 amp P.S.		
Conventional	MaxTrac		F6973 20 W 8 amp P.S.	F6974 20 W 8 amp P.S.	F6975 15 W 8 amp P.S.	
Conventional	Spectra			F6976 450-512 MHz 20 W 8 amp P.S.		
Conventional	DARCOM					F6956 928-960 MHz 5 W 3 amp P.S.
Trunked	MaxTrac		F6983 20 W 8 amp P.S.	F6984 20 W 8 amp P.S.	F6985 15 W 8 amp P.S.	F6986 896-902 MHz 12 W 8 amp P.S.
Trunked	Spectra				F6993 15 W 8 amp P.S.	

Table 21. Available MOSCAD RTU Models

odels are structured according to the communication device included within the model. Table 21 lists the current model choices; the basic model includes a Series 300 CPU module and expansion slots for five I/O modules. Refer to Chapter 2 for a listing of other items included within each model and to Chapter 3 for a discussion of the capabilities of the communication devices. Models must appear on the order writeup as an item and may never be included within other items. The quantity ordered may be greater than one provided that each RTU has identical option types and quantities.

Option	1200 bps	2400 bps	PSTN	Multi drop	Pt-Pt
V104	X		X		
V219	X			X	
V285	X				X
V226		X	X		
V404		X			X

Table 22. Wireline Modem Options

The model with no radio may have an internal wireline communication option added—see Table 22 and the Wireline discussion in Chapter 3.

Choose the Options

Options are ordering conveniences that may Add capability, Delete capability, or Enhance an existing capability. Options must be ordered as sub-items to a model item; option quantities may be greater than one provided they are also multiples of the model's quantity—see example in Table 23.

Item	**Qty**	**Model**	**Description**	
An incorrect example:				
1	3	F6973	RTU VHF 20W	Three RTUs being ordered
1a	6	V115	16DI module	OK: 6 is a multiple of 3
1b	5	V616	16DO module	Wrong: 5 is not a multiple of 3
1c	1	FRN6457	RS-232 cable	Wrong: an accessory may not be a sub-item
The example corrected:				
1	2	F6973	RTU VHF 20W	The first two RTUs
1a	4	V115	16DI module	OK
1b	4	V616	16DO module	OK
2	1	F6973	RTU VHF 20W	The third RTU
2a	2	V115	16DI module	OK
2b	1	V616	16DO module	OK
3	1	FRN6457	RS-232 cable	The cable accessory

Table 23. Use of Option Quantities

The many I/O modules that are described in Chapter 2 are summarized in Table 24. Select one or more I/O modules according to the needs of the application and as supported by the associated on-site sensors. Each module occupies one I/O slot; the AC Analyzer module also includes a termination panel and the 32DO module may require a relay accessory panel, neither of which will be installed within the model by the factory. Refer also to Appendix B for the specifications for the I/O modules. Other useful options are summarized in Table 25.

Communication interface options are also available which may be ordered when the product and communication design permits. Refer to Table 11 for a listing of which communication interface is standard for each

Digital Inputs	Digital Outputs	Analog Inputs	Analog Outputs	Combinations
V115 16DI + 2 counters	V516 16DO Mag Latch	V278 8AI 4-20 ma	V118 4AO	V245 Mixed I/O 8 DI 4 DO: ML & EE 2AI: 4-20 ma
V329 16DI 10-28 Vac/dc	V616 16DO Elect Engrzd	V437 8AI ±5 V		
V379 16DI 20-56 Vac/dc	V314 32DO (FET)	V459 8AI ±1 ma		V436 Mixed I/O 8 DI 4 DO: EE 2AI: 4-20 ma
V355 32dcDI 10-28 Vdc	V508 8DO (10 amp)	V460 8AI ±2.5 V		
V480 32dcDI 20-56 Vdc		V461 8AI ±2 ma		V464 A.C. Analyzer
V481 32dcDI 35-80 Vdc		V462 8AI ±1 V		V318 4DI/16DO (24 Vac required)
V380 60DI				

Table 24. Available I/O Module Options

	Option	Description
All Models	V424	Replace CPU300 with CPU200
	V426	Replace CPU300 with CPU400
	V445	Add math co-processor
	V446	Add math co-processor and 1.2 Mbyte RAM
	V449	Add 1.2 Mbyte RAM
	V450	Replace v3.7x firmware in Series 300 CPU with v3.47 firmware
	V451	Replace v3.7x firmware in Series 300 CPU with v3.01
	V223	Replace v2.74 firmware in Series 200 CPU with v2.04
	V184	Add RS-232 Multiplexer—includes one cable
	V186	Add RS-485 Junction Box—includes one cable
	V251	Replace 8 amp 117 Vac P.S. with 230 Vac equivalent
	V261	Replace 3 amp 117 Vac P.S. with 230 Vac equivalent
	V274	Delete power supply and battery
	V326	Replace 5 A-h battery with 10 A-h
F6956 only	V083	Replace standard IF with Wide IF for 9600 bps operation
	V085	Replace 24 MHz T/R separation with 76 MHz
	V406	Replace 24 MHz T/R separation with 9 MHz
	V484	Replace 24 MHz T/R separation with 31 MHz
	V110	Add network management @ 2400 bps
	V427	Add network management @ 4800 or 9600 bps

Table 25. Other Useful Options

radio and which interface(s) are compatible; specify an optional communication interface from Table 26 when appropriate.

Choose the Accessories

Accessories support additional functionality within the MOSCAD family. Accessories are not installed within the RTU by the factory and therefore require some field labor for installation, cabling, and testing. Refer to the pricebook for a list of available accessories. Accessories are always items (never sub-items.)

	Option	Description
All except F6900, F6909 and, F6956	V356	Replace DFM or DPSK with FSK
	V370	Replace DFM or FSK with DPSK
	V390	Replace DPSK or FSK with DFM
	V393	Replace DFM, DPSK, or FSK with Intrac
F6900 only	V340	Add RS-232 Synchronous
	V345	Add RS-232 Asynchronous
F6956 only	V127	Replace FSK with 4800 bps Sync
	V360	Replace FSK with 4800 bps Async
	V431	Add 4800 bps Asynchronous on Port 2
	V430	Replace FSK with 9600 bps Sync
	V387	Replace FSK with 9600 bps Async
	V388	Add 9600 bps Asynchronous on Port 2

Table 26. Communication Interface Options

Choose the Physical Configuration

The size and material used in the enclosure provided with the RTU may be changed by using the proper option—see Chapter 2. The motherboard included in the RTU depends on the size of the enclosure; the number of I/O modules supported is dependent upon the motherboard. The rackmount configuration permits considerable flexibility to substitute different motherboards, that support multiple CPU modules, or to add additional module panels for when the I/O

	Order Qty Shown	Maximum Number of I/O Modules Supported by Motherboard(s)												
		0	2	4	5	7	15	22	29	37	44	52	59	67
NEMA	Std. or V89 or V231				1									
	V214 or V226 or V229		1											
Rackmount	V051 + V269 (Note 1)				1 1									
	V051 + V369 (Note 1)			1 1										
	V051 + V318 (Note 1)	1 1												
	V051 + V120 + V026					1 0 0	1 0 1	1 1 1	1 2 1	1 2 2	1 3 2	1 3 3	1 4 3	1 4 4
		Note 1: V269 supports 3 CPU modules plus 5 I/O modules V369 supports 4 CPU modules plus 4 I/O modules V318 supports 8 CPU modules and no I/O modules												

Table 27. Motherboards and Number of I/O Modules

	Freq. Range Radio Type	No Radio	VHF 136-142 MHz 142-174 MHz	UHF 403-430 MHz 450-470 MHz	800 MHz	900 MHz
	No Radio Ext. Radio	F4x00 (3A PS) F4x09 (8A PS)				
Conventional	MC-900 (Europe only)		F4x63 20 W (1-20) 8 amp P.S.	F4x64 20 W (1-20) 8 amp P.S.		
Conventional	MaxTrac		F4x73 20 W 8 amp P.S.	F4x74 20 W 8 amp P.S.	F4x75 15 W 8 amp P.S.	
Conventional	DARCOM					F4x56 928-960 MHz 5 W 3 amp P.S.
Trunked	MaxTrac				F4x85 15 W 8 amp P.S.	
		x = 2 for MCP-M x = 3 for MCP-T				

Table 28. Available MOSCAD FEP Models

module count is large—see Table 27. Please be sure that the number of options and accessories being added to the RTU is consistent with the size of the ordered enclosure and/or the style of motherboard selected.

Choose the FEP

Two FEP models are currently available, one for a ModBus interface to a SCADA Manager and a second for a TCP/IP interface to a host computer as specified by a replacable character within the model number—see Table 28. Like the MOSCAD RTU, the FEP is further classified according to the type of communication device it contains. The FEP will accept no I/O module options although some communication interface options are available. MCP-M users should also order the FLN6457 computer-to-MCP-M cable.

At least one copy of the Programming ToolBox should be ordered (as an item) with every MOSCAD system. The V377 ModBus protocol option must be ordered as a sub-item to the ToolBox if the SCADA system uses the MCP-M FEP model.

Model Number	Description
T5737	InTouch Development software
T5738	InTouch RunTime with I/O software
T5739	Intouch RunTime without I/O software
T5740	The FIX for Windows SCADA Node software
T5741	The FIX for Windows VIEW Node software
T5742	Microsoft EXCEL
T5743	FEP Application (*Generic FIU*) for MOSCAD RTU

Table 29. Available SCADA Manager Software

SCADA Manager

The SCADA Manager consists of computer hardware—see Table 13—which may be obtained by the user directly from some distributor or through Motorola. A SCADA software package is also required—see Table 29.

Writing the Order

The equipment being ordered may all be placed on one large order or spread across multiple smaller orders. The large single order provides the factory with the best visibility to the total system requirement; the multiple small orders facilitate the identification by site of boxed equipment for warehousing, staging, and transportation purposes.

Item	Qty	Model	Description	Tx Frequency	Rx Frequency
1	6	F6973	RTU VHF 20W	173396.25	173396.25
1a	6	V115	16DI module		
1b	6	V516	16DO module		
1c	6	V214	Small NEMA-4 enclosure		
1d	6	V370	DPSK modulation		
2	1	F4273	MCP-M	173396.25	173396.25
2a	1	V370	DPSK modulation		
3	1	F2316	Programming ToolBox		
3a	1	V377	ModBus driver		
4	1	FLN6457	RS-232 Async cable		
5	1	T5737	InTouch Development software		
?	1	?	Computer hardware		
10	7	?	Antenna	173396.25	
11	7	?	Line Kit		
12	1	?	Surge Supressor		

Table 30. Small System Sample Order Writeup

All items with radios must have the transmit and receive frequency(ies) listed properly on the order except for items with a trunked radio which are programmed on-site with the specific trunked system parameters by using Motorola RSS software (not included). Models with an MT-2000 radio require a special RSS software (FVN4403); all other models use the standard RSS for that type of radio. VHF models that are to operate on a splinter channel must have the full seven or eight digit frequency entered so as to receive the correct radio. Items ordered with the PL/DPL option must have the desired PL or DPL code listed.

Appendices

Appendix A: MOSCAD RTU Current Consumption Worksheet

Description	Current (maximum) in ma.			Qty	RTU Current in ma.	
	@5 Vdc	@ 13.6 Vdc			@5 Vdc	@13.6 Vdc
Communications: DARCOM HR2		*Receive* 70	*Transmit* 2500			*Transmit*
MaxTrax 2W UHF		400	6000			
MaxTrac 20W VHF or UHF		400	5500			
MaxTrac 15W 800 Trnk & Conv		500	5500			
MaxTrac 12W 900 Trnk & Conv		500	5500			
MC900 20W VHF or UHF Conv		450	6000			
MT2000 5W VHF or 4W UHF		47	850			
Spectra 15W UHF		500	6000			
Wireline Modem		6	6			
Modules: CPU Series 200		240	160			
CPU Series 300		240	170			
CPU Series 400		240	170			
16DI		15	65			
16 ac Voltage Input		20	50			
32DI		20	50			
60DI		15	65			
8DO		15	45			
16DO ML		5	300			
16DO EE		25	420			
32DO “Open Collector”		15	50			
8AI		15	65			
4AO (Note 1)		20	90			
Mixed I/O ML & EE		20	70			
Mixed I/O EE only		20	115			
AC Analyzer		530	490			
Total Current @ 5 Vdc. Maximum: 2000 ma unless V120 present						
Total Current @ 13.6 Vdc. Maximum: 3000 ma or 8000 ma depending upon P.S. present						

Note 1: Add 20 ma per output (@ 13.6 Vdc) if output current is obtained from MOSCAD power supply.

Appendix B: MOSCAD Specifications

General

Physical	NEMA-4 enclosure, 3 modules: 15" x 15" x 8.3" (38 x 38 x 21 cm) NEMA-4 enclosure, 6 modules: 19.7" x 19.7" x 8.3" (50 x 50 x 21 cm) Rackmount, 1-8 modules per panel: 19" x 12.2" x 7.87" (48 x 31 x 20 cm); second panel required for power supplies and radios.
Power	Dual: provides 14.1 Vdc @ 3 amp or 8 amp (depending upon model) from 117 Vac 50/60 Hz (230 Vac available), or from 12.6 Vdc internal battery
Environment	-30°C to +60°C; 90- 95% RH @ +50°C
Expansion	Maximum of 67 I/O modules in rackmount configuration; up to 4 Expansion modules
Indications	20 diagnostic LEDs per module. Current saved by automatic LED switch-off. Lamp On/Test controlled by a CPU pushbutton.

CPU Module

Processor	CPU200: Motorola 68302 (16/32 bit) CMOS; 16.6 MHz clock, ±100 ppm CPU300: Motorola 68302 (16/32 bit) CMOS; 16.6 MHz clock, ±30 ppm CPU400: Motorola 68302 (16/32 bit) CMOS; 16.6 MHz clock, ±30 ppm Math co-processor: Motorola 68882 on plug-in board
Memory	CPU200: 832 kByte (512 kByte EPROM, 64 kByte RAM, 256 kByte Flash) CPU300: 1536 kByte (1024 kByte EPROM, 256 kByte RAM, 256 kByte Flash) CPU400: 1536 kByte (1280 Flash, 256 kByte RAM) Expansion: additional 1.28 Mbyte RAM on plug-in board
Application Size	CPU200: approximately 10 kbyte CPU300: approximately 150 kbyte CPU400: approximately 150 kbyte
Memory Backup	Lithium battery: 3 months backup for RTC and RAM. Battery life: 10 years; low battery indication
RTC	Hardware real-time clock provides full calendar with leap year support
Gate Array	I/O bus support Watch-dog timer function Remote symbolic debugging support Early DC loss warning in case of AC failure for “clean” program and data recovery Plug-in communication board support Diagnostic LEDs, pushbutton, buzzer, and flash memory programming voltage support
Port 1	RS-485 serial data port (software controlled): 2.4-19.2 kbps 2-wire, *or* RS-232D serial data port: 0.3-19.2 kbps. Modem operation not supported.
Port 2	RS-232D: 0.3-19.2 kbps with full DTE/DCE support, transient protected
Port 3	Radio (half-duplex, synchronous), both conventional and trunked according to plug-in DFM or FSK or DPSK interface board, *or* Line communications according to plug-in interface and connections box, *or* RS-232D serial data (half-/full-duplex, synchronous or asynchronous); 0.3-19.2 kbps
Diagnostics	LED: power OK, AC failure, CPU failure, reset, communication and application diagnostics, LEDs test
Controls & Alarms	Pushbuttons: display control, self-test; On-board buzzer = 75 dBa
Protection	CPU400: Per IEC 801-2: air discharge = 15 kV, contract discharge = 8 kV Per IEC 801-3: radiation immunity = 10 V/m Per IEC 801-4: fast transient = 1 kV
Radiated Emission	CPU400: Per CENELEC EN55022, class B

16DI Module

Inputs	Sixteen (16) dry contact inputs + two high-speed counter inputs
Input Frequency	Without interrupt upon COS: 5 Hz maximum With interrupt upon COS: 50 Hz maximum
Source Resistance	Open: 70 kohm minimum; closed: 4 kohm maximum
Counter Frequency	Ten (10) kHz maximum
Counter Pulse Width	50 µsec minimum
Filtering	Software control of hardware filtering: 1-32 msec. Longer filtering possible under application control
Interrupt upon COS	Number of priorities = 255. Event time-tag resolution = 5 msec
Isolation	Per IEC 255-5: between user connection and logic = 1.5 kV; insulation resistance = 500 Mohm @ 500 V; insulation impulse = 5 kV
Protection	Per ANSI/IEEE C37.90.1-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV Per IEC 801-2: air discharge = 8 kV Per IEC 801-3: radiation immunity = 10 V/m Per IEC 801-4: fast transient = 500 V
Diagnostics	LEDs: 16 DI, 2 counter status, module failure, no clock

16 Voltage Input Module

Inputs	16; either AC (50/60 Hz) or DC voltages; may be low-speed counters
Input Signal	10-28 V module: <3 V for no input; >8 V for voltage input 20-56 V module: <6 V for no input; >16 V for voltage input
Input Resistance	10-28 V module: 2.2 kohm 20-56 V module: 4.4 kohm
Filtering	Off-to-On and On-to-Off: 35 msec
Interrupt upon COS	Number of priorities = 255
Isolation	Per IEC 255-5: between user connection and logic = 2.5 kV; insulation resistance = 500 Mohm @ 500 V; insulation impulse = 5 kV
Protection	Per ANSI/IEEE C37.90a-1974: oscillatory wave = 2.5 kV Per IEC 801-2: air discharge = 15 kV; contact dischage = 8 kV Per IEC 801-4: fast transient = 1 kV
Diagnostics	LEDs: 16 DI status, module failure, no clock

32 dcDI Module

Inputs	32 dc voltages; may be counters
Input Signal	10-28 V module: < 3.5 V for no input; >8 V for voltage input 20-56 V module: < 6 V for no input: >14 V for voltage input 35-80 V module: <10 V for no input; >28 V for voltage input
Input Resistance	10-28 V module: 2.2 kohm 20-56 V module: 4.4 kohm 35-80 V module: 7 kohm
Interrupt upon COS	Number of priorities = 255; event time-tagging resolution = 5 msec
Isolation without Termination Panel	Per IEC 255.5: between user connections and logic = 2.5 kV; insulation resistance = 500 Mohm @ 500 V; insulation impulse = 5 kV
Protection without Termination Panel	Per IEC 801-2: air discharge = 8 kV Per IEC 801-4: fast transient = 500 V
Protection with Termination Panel	Per ANSI/IEEE C37.90a-1994: oscillatory wave = 2.5 kV Per IEC 801-2: air discharge = 15 kV; contact discharge = 8 kV Per IEC 801-4: fast transient = 2 kV
Diagnostics	LEDs: 16 DI status; display mode; module failure, no clock

60DI Module

Inputs	60, dry contact; may be counters
Source Resistance	Open: 70 kohm minimum; closed: 4 kohm maximum
Filtering	Software control of hardware filtering: 1-32 msec. Longer filtering possible under application control
Interrupt upon COS	Number of priorities = 255. Event time-tag resolution = 5 msec
Isolation	Per IEC 255-5: between user connections and logic = 2.5 kV; insulation resistance = 500 Mohm @ 500 V
Protection with Termination Panel	Per ANSI/IEEE C37.90a-1974: oscillatory wave = 2.5 kV Per IEC 801-2: air discharge = 8 kV Per IEC 801-3: radiation immunity = 10 V/m Per IEC 801-4: fast transient = 2 kV
Diagnostics	LEDs: 16 DI, 2 display modes, module fail, no clock

8DO Module

Outputs	8 relays, electrically energized
Relay Contacts	SPDT
Contact Rating	Per UL: 10 amp @ 30 Vdc or 277 Vac. Minimum load required = 0.25 amp @ 24 Vdc
Isolation	Per IEC 255-5: between user connections and logic = 3.5 kV; insulation resistance = 100 Mohm @ 500 V
Output Protection	Per ANSI/IEEE C37.90a-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV Per IEC 801-2: air discharge = 8 kV Per IEC 801-3: radiation immunity = 10 V/m Per IEC 801-4: fast transient = 1 kV
Diagnostics	LEDs: 8 DO status, module failure, no clock

16DO Module

Outputs	16 relays, electrically energized or magnetically latched
Relay Contacts	12 SPST, 4 SPDT
Contact Rating	Per UL: 0.6 amp @ 110 Vdc or 125 Vac; 2 amp @ 30 Vdc
Isolation	Per IEC 255-5: Between contacts = 600 V, between user connections and logic = 1.2 kV; insulation resistance = 100 Mohm @ 500 V; insulation impulse = 1 kV
Protection	Per ANSI/IEEE C37.90a-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV Per IEC 801-3: radiation immunity = 10 V/m Per IEC 801-4: fast transient = 500 V
Diagnostics	LEDs: 16 DO status, module failure, no clock

32DO Module

Outputs	32 open-drain FETs
Output Rating	0.5 amp @ 30 Vdc (maximum)
Isolation	Per IEC 255-5: between contacts = 1 kV; between user connections and logic = 1.5 kV
Protection	Per ANSI/IEEE C37.90a-1974: oscillatory wave = 2.5 kV Per IEC 801-4: fast transient = 2 kV
Diagnostics	LEDs: 16 DO status, display mode, module failure, no clock

8AI Modules

Inputs	8: 4-20 *or* ±1 ma *or* ±2 ma *or* ±1 V *or* ±2.5 V *or* ±5 V
Input Resistance	4-20 ma: 226 ohm ±1 ma: 2.6 kohm ±2 ma: 1.4 kohm ±1 Vand ±2.5 V: 11.1 kohm ±5 V: 21.1 kohm
Resolution and Accuracy	13 bits (12 bits + sign) ±0.05% of full scale @ +25°C
Linearity	±1 LSB
Temp. Stability	±25 ppm/°C
Calibration	Automatic: software controlled hardware calibration
Isolation	Per IEC 255-5: between user connections and logic = 1.5 kV; insulation resistance = 500 Mohm @ 500 V; insulation impulse = 1 kV
Protection	Per ANSI/IEEE C37.90a-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV Per IEC 801-2: air discharge = 15 kV; contact discharge = 8 kV Per IEC 801-3: radiation immunity = 3 V/m Per IEC 801-4: fast transient = 500 V
Diagnostics	LEDs: 8 AI underflow; 8 AI overflow; module failure, no clock

Mixed I/O Modules

DIGITAL INPUT	8: dry contact; can be used for counters
Input Frequency	Without interrupt on COS: 5 Hz maximum With interrupt on COS: 50 Hz maximum
Source Resistance	Open: 70 kohm minimum; closed: 4 kohm maximum
Filtering	Software control of hardware filtering: 1-32 msec; longer filtering possible under application control
Interrupt upon COS	Numbr of priorities = 255; event time-tagging resolution = 5 msec
Isolation	Per IEC 255-5: between user connections and logic = 1.5 kV; insulation resistance = 500 Mohm @ 500 V
Protection	Per ANSI/IEEE C37.90a-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV
DIGITAL OUTPUT	Relays: 4 electrically energized *or* 3 magnetically latched + 1 electrically energized
Relay Contacts	2 SPST + 2 SPDT
Contact Rating	Per UL: 0.6 amp @ 110 Vdc or 125 Vac; 2 amp @ 30 Vdc
Isolation	Per IEC 255-5: between contacts = 1 kV; between user connections and logic = 1.5 kV insulation resistance = 500 Mohm @ 500 V
Protection	Per ANSI/IEEE C37.90a-1989: oscillatory wave = 2.5 kV; fast transient = 4 k
ANALOG INPUT	Two: 4-20 ma
Input Resistance	4-20 ma: 250 ohm
Filtering	Averaging: 1 or 2 or 4 or 8 samples
Resolution	12 bits (11 bits + sign)
Overall Accuracy	±0.05% of full scale @ +25°C
Linearity	±1 LSB
Temp. Stability	±100 ppm/°C
Calibration	Automatic: software control of hardware calibration
Isolation	Per IEC 255-5: between user connections and logic = 2.5 kV; insulation resistance = 500 Mohm @ 500 V
Protection	per ANSI/IEEE C37.90a-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV
GENERAL Diagnostics	LEDs: 8 DI status, 4 DO status, 2 AI underflow, 2 AI overflow, module failure, no clock

4AO Module

Outputs	Two: 4-20 ma *or* 0-5 V (suitable also for 1-5 V)
Load Resistance	4-20 ma: <250 ohm with 12 Vdc loop supply; <750 ohm with 24 Vdc loop supply
Resolution & Accuracy	12 bits (11 bits + sign) ±0.1% of full scale @ +25°C
Linearity	±1 LSB
Temp. Stability	±100 ppm/°C
Calibration	Automatic: software control of hardware calibration
Isolation	Per IEC 255-5: between user connections and logic = 2.5 kV; insulation resistance = 500 Mohm @ 500 V
Protection	Per ANSI/IEEE C37.90a-1974: oscillatory wave = 2.5 kV Per IEC 801-2: air discharge = 8 kV; contact discharge = 4 kV Per IEC 801-3: radiation immunity = 3 V/m Per IEC 801-4: fast transient = 500 V
Diagnostics	LEDs: 4 voltage AO, 4 current AO, 4 AO update, 4 AO uncalibrated, module uncalibrated, PROM failure, module failure, no clock

AC Analyzer Module

ANALOG INPUTS	3 AC voltage, 3 AC current, 2 auxiliary
AC Voltage AC Current	0-157 Vac, 50/60 Hz; 300 V max. 0.2-12.5 Aac; 20 A max.
Isolation	2 kV
Auxiliary	2: 0-5 Vdc
DIGITAL INPUTS	8: <3.5 Vdc for no input, >10 Vdc for voltage input; 28 Vdc maximum
DIGITAL OUTPUT	8 relays: 2 electrically energized @ 2 amp, 2 electrically energized @ 8 amp, 2 magnetically latched @ 2 amp, 2 magnetically latched @ 8 amp
Relay Contacts	SPDT
2 Amp Rating	Contacts: Per UL: 0.6 amp @ 110 Vdc or 125 Vac; 2 amp @ 30 Vdc Isolation: between contacts = 1 kVac, between contact sets = 1 kVac, between contacts and coil = 1.5 kV
8 AMP Rating	Contacts: Per UL: 8 amp @ 250 Vac; 5 amp @ 30 Vdc Isolation: between contacts = 1.2 kVac, between contact sets = 2 kVac, between contact and coil = 3.75 kVac
MEASUREMENTS	3 phase, Y-configured network parameters
Parameters	Per phase: RMS voltage, RMS current, real power, apparent power, reactive power, power factor, frequency, 1st harmonic phase angle, energy
Sampling Rate	32 samples per cycle per AC input
Averaging	1-64,000 cycles for voltage, current, real power, apparent power, reactive power, power factor
Resolution	11 bits + sign
Accuracy	Voltage = ±0.5%; Current = ±0.5%; Real Power = ±1%; Apparent Power = ±1%; Reactive Power = ±2% (*reference: 157 Vac, 12.5 Aac full scale @ +25°C*) Power Factor: 0.2-1 amp = ±4%; 1-12.5 amp = ±1% Phase Angle: 0.2-1 amp = ±4°; 1-12.5 amp = ±2°
GENERAL Protection	 Per ANSI/IEEE C37.90a-1974: oscillatory wave = 2.5 kV
Diagnostics	LEDs: 16 input/output status,display mode, run, module failure, no clock

Line Modem Board

General	
Receive Level	-47 to -3 dBm except Multidrop: -35 to -3 dBm (with Line Interface Assembly)
Dialing	DTMF or pulse
Diagnostics	Self-test LEDs on CPU module: TxD, RxD, CD
TYPE 1:	
Data Rates	Per CCITT V.21/Bell 103: 300 bps Per CCITT V.22: 0.6 or 1.2 kbps Per Bell 212A: 1.2 kbps
Send Level	-10 Dbm; DTMF dial-up = 0 dBm maximum (with Line Interface Assembly)
Handshake Signals	Generation: answer tone, guard tone Detection: call progress, carrier, answer tone, unscrambled mark
Special Features	Scrambling & descrambling
TYPE 2:	
Data Rates	Per CCITT V.21/Bell 103: 300 bps Per CCITT V.22: 0.6 or 1.2 kbps Per Bell 212A: 1.2 kbps Per CCITT V.22*bis*: 2.4 kbps
Send Level	-21 to -6 dBm user selectable; DTMF dial-up: 0 dBm max. (with Line Interface Assembly)
Handshake Signals	Generation: answer tone, guard tone, S1 pattern Detection: call progress, carrier, answer tone, unscrambled mark, S1 pattern, receive level & quality
Special Features	Scrambling & descrambling, adaptive line equalization

Line Interface Assembly

DIAL-UP	
Type	2-wire, full duplex
Isolation	Per IEC 255-5: between user connections and logic = 2 kV; insulation resistance = 500 Mohm @ 500 V
Protection	Per IEC 801-2: air discharge = 8 kV Per IEC 801-3: radiation immunity =3 V/m Per IEC 801-4: fast transient = 1 kV
LEASED LINE	
Type	2-wire or 4-wire, full duplex
Isolation	Same as for Dial-Up Interface
Protection	Same as for Dial-Up Interface
MULTI-DROP	
Type	2-wire, half duplex, self line-matching
Isolation	Same as for Dial-Up Interface *plus* insulation impulse = 5 kV
Protection	Per ANSI/IEEE C37.90.1-1989: oscillatory wave = 2.5 kV; fast transient = 4 kV Per IEC 801-2: air discharge = 8 kV Per IEC 801-3: radiation immunity = 10 V/m

FPN5522 & FPN5544 Power Supply

Input Voltage	105-132 Vac or 187-265 Vac @ 47-60 Hz
Output Voltage Temp. Coefficient	13.8 Vdc @ +25°C -27 mV/°C
Output Current	Continuous = 8 amp; @56% duty cycle = 10 amp
Load Disconnect	10.45 ± 0.35 Vdc battery voltage (following input voltage failure)
Load Reconnect	12.3 ± 0.4 Vdc battery voltage (following input voltage restoration)
Safety	Per UL E82633 Per CSA LR89572
Radiated Emission	Per FCC Part 15, class A
Protection	Per ANSI/IEEE C37.90a-1974: oscillatory wave = 2.5 kV; capacitive discharge = 50 µF @ 1.5 kV

FPN5123, FPN5128, FPN5223, FPN5228 Power Supply

Input Voltage	100-132 Vac or 187-276 Vac @ 45-65 Hz
Output Voltage Temp. Coefficient	14.1 Vdc @ +25°C -27 mV/°C
Output Current	8 amp models: continuous = 8 amp; @ 56% duty cycle = 10 amp 3 amp models: continuous = 3 amp
Load Disconnect	10.8 ± 0.2 Vdc battery voltage (following input voltage failure)
Load Reconnect	12.2 ± 0.2 Vdc battery voltage (following input voltage restoration)
Safety	Per UL/ULc 1950 Per TUV EN60950
Conducted/Radiated Emissions	Per FCC Part 15, class A Per CENELEC EN55022
Protection	Per IEEE 587 Per ANSI/IEEEC37.90.1-1989: oscillatory wave =2.5 kV; fast transient = 4kV Per IEC 801-2: air discharge = 15 kV; contact discharge = 8 kV Per IEC 801-3: radiation immunity = 10 V/m Per IEC 801-4: fast transient = 4 kV Per IEC 801-5: surge immunity = 1 kV

Appendix C: Ladder Diagram Language

This appendix details all elements, input and output, that are available in the Toolbox for programming the MOSCAD RTU.

INPUT ELEMENTS

Normally Open (N.O.) Contact
Normally Closed (N.C.) Contact
Comparator (Equal to, Less than, Not Equal to, Greater than)
Differentiator (Rising edge, Falling edge)

OUTPUT ELEMENTS

Relay (On, Off, Latch, Unlatch)
Timer (Delay on, Delay off, Retentive)
Counter (Up, Down)
Reset
Convert (to BCD, to Binary)
Jump within Process
Jump to Subprocess
Return from SubProcess
Run Process
Move Value or Low Byte
Move High Byte
Send (to RS232 User Port)
Scan physical and mapped I/O
Call a function (GetChr, GetDgt, SndFrm, AnsFrm, RcvFrm, TxEvnt, SetCOS, CALC, more)
Arithmetical Calculation (+, -, x, /)
Boolean Bitwise (AND, OR, XOR)
Logical Shift (Left, Right)
Arithmetical Shift (Left, Right)
Rotate (Left, Right)

LIBRARY FUNCTIONS

AGA3
AGA7 (Mass)
AGA7 (Volume)
PID

VALUE TYPES

Integers (-32768 to +32767)
Real (10^{-38} to 10^{+38})
Scaled (in Engineering Units)

Appendix D: Wireline Characteristics

The primary characteristics of various grades of point-to-point (leased) wirelines, as specified by Bell and CCITT, are listed below. The internal wireline modems are intended for operation over these lines which may be non-conditioned or conditioned depending on the data speed and distance. Carrier companies offer several types of channel conditioning which results in a higher transmission rate and/or reduction in data errors.

Although conditioning is usually necessary for data transmission at speeds above 2400 bps, the addition of conditioning, especially the D level, may give a modem the margin necessary to be less susceptible to some types of line impairments. For limited distances B conditioning, which removes load coils from the lines, may be necessary.

D conditioning improves several Type 3002 transmission parameters that are not improved by C1 conditioning. This is also called High Performance Data conditioning (HPDC) and is optional with point-to-point, leased 3002 channels with or without C conditioning.

Bell and CCITT Leased Line Specification

	Bell				**CCITT**
	Non-Conditioned 3002 channel	With C1 Conditioning	With C2 Conditioning	With C4 Conditioning	M1020 (Note 1)
Frequency Range	300 - 3000 Hz			300 - 3200 Hz	300 - 3000 Hz
Attenuation in dB, reference 1 kHz (reference 800 Hz for M1020)	-3 to +12 over range	-3 to +12 over range	-2 to +6 over range	-2 to +6 over range	-2 to +6 over range
	-2 to +8 @ 500-2500 Hz	-2 to +8 @ 300-2700 Hz	-1 to +3 @ 500-2800 Hz	-2 to +3 @ 500-3000 Hz	-1 to +3 @ 500-2800 Hz
		-1 to +3 @ 1000-2400 Hz			
Delay Distortion (msec)	<1750 @ 800-2800 Hz	<1750 @ 800-2800 Hz	<3000 @ 500-2800 Hz	<3000 @ 500-3000 Hz	<3000 @ 500-2800 Hz
		<1000 @ 1000-2400 Hz	<1500 @ 600-2600 Hz	<1500 @ 600-3000 Hz	<1500 @ 600-2600 Hz
			<500 @ 1000-2600 Hz	<500 @ 800-2800 Hz	<500 @ 1000-2600 Hz
				<300 @ 500-3000 Hz	
Maximum Impulse Noise	15 counts in 15 minutes				18 counts in 15 minutes
Type of Service	Point-to-point (PTP) or Multipoint			PTP	PTP only
Channel Mode	Half- or Full-duplex				Half or Full
Local Loop Termination	Two or four wire				Four wire
Maximum Frequency Error	±5 Hz				±5 Hz
Maximum Bit Error	Approximately 1 bit error per 100,000 (10^{-5})				Not specified
Note 1: According to the M1020 each PTT may have its own additional specifications.					

Appendix E: Industrial Enclosure Standards

The National Electrical Manufacturers Association (NEMA) defines in NEMA Standard 250 the standard enclosures for industrial indoor or outdoor use. The Underwriters Laboratories (UL 50, UL 508) and Canadian Standard Association (CSA C22.2) publishes similar standards. The IEC publishes a different standard (IEC 529) which defines an Index of Protection (IP classes). The tables that follow describe and correlate these standards.

Enclosure Standards

NEMA Type (Standard 250)	UL Type (UL 50, UL 508)	CSA Standard C22.2 Nr. 14, 40, and 94	Intended Use
1	1	1	Indoor use
2	2	2	Indoor use
3	3	3	Outdoor use
3R	3R	No CSA equivalent	Outdoor use
3S	3S	No CSA equivalent	Outdoor use
4	4	4	Indoor/Outdoor use
4X	4X	No CSA equivalent	Indoor/Outdoor use
No NEMA equivalent	No UL equivalent	5	Indoor/Outdoor use
6	6	No CSA equivalent	Outdoor use
6P	6P	No CSA equivalent	Indoor/Outdoor use
12	12	No CSA equivalent	Indoor/Outdoor use
13	13	No CSA equivalent	Indoor/Outdoor use

Enclosure Standards for Hazardous Locations

NEMA Standard 250 / UL 866	CSA Standard C22.2 Nr. 25
Type 9. Enclosures intended for use in indoor locations classified as Class II, Groups E or G defined in the National Electrical Code.	Enclosures for electrical equipment, other than lighting fixtures, intended for use in indoor locations classified as Class II, Groups E, F, and G hazardous locations in accordance with the Rules of the Canadian Electrical Code, Part I.

NEMA Enclosures for Indoor Non-Hazardous Applications

Provides a Degree of Protection Against the Following Environmental Conditions	Types of Enclosures												
	1	2	3	3R	3S	4	4X	5	6	6P	12	12 K	13
Indoor	X	X				X	X	X	X	X	X	X	X
Outdoor			X	X	X	X	X		X	X			
Limited amounts of falling dirt	X	X				X	X	X	X	X	X	X	X
Limited amounts of falling water		X											
Sleet			X	X	X								
Rain			X	X	X	X	X						
Waterblown dust			X		X	X	X						X
External ice formation			X	X		X	X		X	X			
Splashing water						X	X						
Hose-directed water						X	X		X	X			
Corrosion							X						
Operation of external mechanisms when ice laden					X								
Settling airborne dust								X					
Dripping noncorrosive liquids								X			X	X	
Entry of water during temporary submersion at a limited depth									X				
Entry of water during prolonged submersion at a limited depth										X			
Circulating dust											X	X	
Spraying of water, oil, and noncorrosive coolant													X

IEC IP Enclosure Standards: 1st Digit

First IP Digit	Degree of Protection (contact hazard & foreign body protection)
0	No special protection
1	Protection against penetration of solid objects larger than 50 mm in diameter (large objects) No protection against intentional access, e.g. by hand, but keeping larger parts of the body at a distance
2	Protection against entry of solid objects larger than 12 mm in diameter (medium size objects) Keeping out fingers and small objects
3	Protection against entry of solid objects larger than 2.5 mm in diameter (small size objects) Keeping out tools, wires, etc. larger than 2.5 mm in diameter
4	Protection against entry of solid objects larger than 1 mm in diameter (granular size objects) Keeping out tools, wires, etc., a thickness exceeding 1 mm
5	Protection against harmful dust deposits; ingress of dust is not totally prevented but dust does not enter in sufficient quantity to interfere with the satisfactory operation of the equipment (dust protected) Full contact hazard protection
6	Protection against ingress of dust (dust tight) Full contact hazard protection

IEC IP Enclosure Standards: 2nd Digit

Second IP Digit	Degree of Protection (contact hazard and foreign body protection)
0	No special protection
1	Protection against dripping water, falling vertically. Dripping water must not have any harmful effect.
2	Protection against dripping water, falling vertically. Dripping water must not have any harmful effect when the enclosure is tilted at any angle up to 15° from its normal position (obliquely dripping water).
3	Water falling as spray at any angle up to 60° from the vertical. The falling water shall not have any harmful effect.
4	Water splashed against the enclosure at any direction. The splashing water shall not have any effect.
5	Water projected by a nozzle against the enclosure at any direction. The water shall not enter the enclosure in harmful quantities (flooding).
6	Water from heavy seas or water rojected by powerful jets. The water shall not enter the enclosure in harmful quantities (flooding).
7	Ingress of water in a harmful quantity. Shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (immeresion).
8	The equipment is suitable for continuous submersion in water under conditions which shall be specified by the manufacturer (submersion). This protection normally signifies an airtight enclosure. However, water may enter certain equipment provided that it has no harmful effect.

1. With equipment of protection grades 1 thru 4, solid objects of regular or irregular shape with three dimensional squares to each other larger than the corresponding diameter values will be prevented from entering.
2. For protection grades 3, 4, and 5, the application of these tables to operating equipment with drainage holes or cooling air vents is the responsibility of the competent specialists committee.

NEMA-IEC Enclosure Cross Reference

NEMA Type	IEC 529 Index of Protection Rating (IP)										
	10	20-23	30	31-32	33	40-43	50-56	60-64	65	66	67
1	X	X									
2	X	X	X								
3	X	X	X	X	X	X	X	X			
3R	X	X	X	X							
3S	X	X	X	X	X	X	X	X			
4	X	X	X	X	X	X	X	X			
4X	X	X	X	X	X	X	X	X	X	X	
5	X	X	X	X	X	X	X	X	X	X	
6	X	X	X	X	X	X	X	X	X	X	X
12	X	X	X	X	X	X	X	X	X		
13	X	X	X	X	X	X	X	X	X		

Appendix F: Technical documents and Standards List

This appendix lists those technical documents that pertain in some manner to the MOSCAD product family. *Please note that the inclusion of a document herein does not imply or confer conformance to any or all aspects of the document*. The reader should refer to other sections within this System Planner for the appropriate description of MOSCAD operation.

MOSCAD Reference Documents

Document Name	Document Number	Available From
MOSCAD RTU Technical Description and Suggested Specification	R0-11-46	LDC (Literature Distribution Center)
Remote Terminal Unit catalog sheet Module catalog sheets MCP-M (for ModBus) catalog sheet MCP-T (for TCP/IP) catalog sheet	R3-11-78 R3-11-82 thru -93 R3-11-94 R3-11-95	LDC
MOSCAD Product Brochure Water Brochure Electric Utility Brochure	RC-11-09 RC-14-21 RC-11-12	LDC
MOSCAD System Planner	R4-11-03	LDC

MOSCAD Manuals

RTU Service Manual	68P02991G90	Motorola Parts Department
RTU Owner's Manual	68P02994G10	Motorola Parts Department
Rackmount Owner's Manual	68P02934C10	Motorola Parts Department
ToolBox Programming Manual	68P02445G10	Motorola Parts Department
MCP-M Manual	68P02943C25	Motorola Parts Department
MCP-T Manual	68P02930C95	Motorola Parts Department
Highband/UHF MaxTrac Radio	68P80102W84	Motorola Parts Department
800 MHz Trunked MaxTrac Radio	68P80102W84	Motorola Parts Department
DARCOM HR2 Radio	68P02997G55	Motorola Parts Department
MOSCAD/DARCOM Radio Links	68P02933C30	Motorola Parts Department
Adapting Spectra to MOSCAD	68P02932C30	Motorola Parts Department
Adapting MSF5000 to MOSCAD	68P02936C50	Motorola Parts Department

Electronic Industries Association (EIA)

Standard	Full Name
EIA RS-232D	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
EIA RS-422	Electrical Characteristics of Balanced Voltage Digital Interface Circuits
EIA RS-423	Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits
EIA RS-485	Standard for Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems
EA RS-152B	Minimum Standard for Land Mobile Communication FM or PM Transmitter
EIA RS-204C	Minimum Standard for Land Mobile Communication FM or PM Receiver
EIA RS-410	Standard for the Electrical Characteristics of Class A Closure Interchange Circuits

Serial Interface Correlation Matrix

Interface Type	Interface Definition	EIA Standard	CCITT Standard	ISO Standard
RS-232	Electrical	RS-232D	V.28	
	Functional	RS-232D	V.24	
	Connector	RS-232D	n/a	ISO 2110 (25 pin)
RS-485	Electrical	RS-485	None	
	Functional	RS-485	None	
	Connector	RS-485	None	ISO 2110 (25 pin)

Serial Interface Standards Comparison

Parameter	RS-232D	RS-422A	RS-485
Mode of Operation	Single-ended	Differential	Differential
# drivers and # receivers	1 driver, 1 receiver	1 driver, 10 receivers	32 drivers, 32 receivers
Maximum cable length	15 meters (50 feet)	1200 meters (2490 ft)	1200 meters (2490 ft)
Maximum data rate	20 kbps	10 Mbps	10 Mbps
Maximum common mode voltage	±25 V	+6 V, -0.25 V	+12 V, -7 V
Driver output	±15 V min, ±25 V max	±2 V min	±1.5 V min
Driver load	3-7 kohm	100 ohm min	60 ohm min
Driver slew rate	30 V/µsec max	n/a	n/a
Driver output short circuit current	500 ma to Vcc or Gnd	150 ma to Gnd	150 ma to Gnd; 250 ma to -8V or +12V
Receiver input resistance	3-7 kohm	4 kohm	12 kohm
Receiver sensitivity	±3 V	±200 mV	±200 mV

CCITT Standards

Standard	Full Name
V.10	Electrical Characteristics for Unbalanced Double-current Interchange Circuits for General Use with Integrated Circuit Equipment in the Field of Data Communications
V.21	300 bps Duplex Modem Standardized for Use in the General Switched Telephone Network
V.22	1200 bps Duplex Modem Standardized for Use in the General Switched Telephone Network
V.22*bis*	2400 bps Duplex Modem Using the Frequency Division Techniques Standardized for use in the General Switched Telephone Network and on Point-to-Point 2-Wire Leased Telephone Type Circuits
V.24	List of Definitions for Interchange Circuits Between Data Terminal Equipment and Data Circuit-terminating Equipment
V.40	Code Independent Error Control System (*16 bit CRC*)
M1020	Characteristics of Special Quality International Leased Circuits with Special Bandwidth Conditioning

Bell Standards

Standard	Full Name
PUB41106	Data Sets 103, 113C, 113D Type Interface Specifications
PUB41214	Data Set 212A Interface Specification
Bell 3002 Line	Non-conditioned Leased Telephone Lines
Bell C1 Line	Conditioned Leased Telephone Lines–Grade C1
Bell C2 Line	Conditioned Leased Telephone Lines–Grade C2
Bell C3 Line	Conditioned Leased Telephone Lines–Grade C3
Bell C4 Line	Conditioned Leased Telephone Lines–Grade C4
Bell D Line	Conditioned Leased Telephone Lines–Superior Grade

Other U.S. Standards

Standard	Full Name
FCC Rules, Part 15, Class A	Radiation Emission
FCC Rules, Subpart J, Par. 90.235 & 90.238	Non-voice and other Specialized Operations
FCC Rules, Subpart K, Par. 90.261 & 90.267	Standards for Special Frequencies or Frequency Bands
National Electrical Manufacturers Association (NEMA)	Enclosures for Industrial Controls and Systems

ANSI/IEEE Standards

Standard	Full Name
ANSI/IEEE C37.90.1.1989	IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
ANSI/IEEE C62.41-1980	IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits
ANSI/IEEE 754	Binary Floating Point Arithmetics

International Standards

Standard	Full Name
UL-611	Central Station Burglar Alarm System
UL-1076	Proprietary Burglar Alarm Unit and System
UL-508	Industrial Control Units
UL-1012	UL Recognition of FPN5522A and FPN5544A Power Supplies
CSA C22.2-107.1 CSA C22.2-107.2 CSA C22.2-223	Canadian standards for indoor power supplies
EN60590	European standard for electrical safety

Other International Standards

Standard	Full Name
IEC Publication 529	Classification of Degrees of Protection Provided by Enclosures (include Amendment No. 1)
ISO 2110	Data Communications–25 pin DTE/DCE Interface Connector and Pin Assignment
ISO 4903	Data Communications–37 pin and 9 pin DTE/DCE Interface Connector and Pin Assignment
ISO 7498	Reference Model for Open System Interconnection (OSI)

Appendix G: Radio Parameters

Use the Radio Service Software to set the radio parameters according to the information in the tables below.

MaxTrac Conventional

RF Power	20 Watt
Squelch	Coded
T-O-T	60 seconds
External Accessory: Pin 8 Pin 14	General I/O Output, CSQ detect, active high, no debounce Output, null, active high, no debounce
Rx/Tx Squelch	Carrier

MaxTrac Trunking

RF Power	15 Watt
Handset	Disable
Horn & Lights	Disable
Universal ID	Disable
External Accessory	General I/O
Private Call	Disable
Call Alert Decode	Disable
Call Alert Encode	Disable
Dynamic Regrouping	Disable
Trunked Options: Trunking T-O-T Synthesized	 Message 60 second Yes
Emergency Options: Call Alarm PTT-ID	 Disable Disable No

Spectra Trunking

RF Power	15 Watt
Tx Trunking Data	Invert
Rx Trunking Data	Normal
Scan Configuration	All disabled
Trunking Options: Trunking T-O-T TalkPermit Tone	 Message Enabled Disabled

MT2000 Conventional

RF Power	4 or 5 W (var to 1 W)
Switch Labels	All blank
Receive Only	Disabled
Direct/Talkaround	Disabled
T-O-T	60 seconds
Phone Operation	None
Signalling	None
Squelch Type	Rx: CSQ
Smart PTT	Disabled
Auto Scan	Disabled
Emphasis On	Tx and Rx
Tx Deviation	5.0 kHz
Mute/Unmute	Standard
Channel Spacing	25 kHz
Rx Mute Delay	0
Reverse Burst TOC	Disabled

MC900

Data Modem Applic.	Enabled
Phase Lock Special	Enabled
TX TOT Duration	52
User Selectable Output	Carrier Present
Power Level	High
Signalling Standard	ZVEI
Receive Squelch	Carrier

Special Trunked System Note:

The Channel Monitor Resolution setting in the CPU module and the Fade Timer setting in the Trunking Controller are inter-dependent. The Channel Monitor Resolution time is a function of the radio; 100 msec is recommended. The Fade Timer must be 20 or more times greater—2 seconds absolute minimum, 4 seconds recommended.

DARCOM I Master w/VF Interface

1. Connect Tx (J1-13) to Rx (J1-8)
2. Connect CM (J1-12) to PTT (J1-6)
3. Set the jumpers on the VF interface board:

JU1	TTL	1-2
JU2	GC	3-4
JU3	LEDs enable	1-2
JU4	D.D.	3-4
JU5|	TOT	1-2
JU6	O	1-2
JU7	O	1-2
JU8	N	2-3
JU9	LB	2-3
JU10	Data	2-3
JU11	Data	2-3
JU12	Data	2-3
JU13	H.D.	1-2

With 2.5 kHz deviation into receiver:
Adjust R8 for 1 Vp-p @ J1-13
Adjust R38 for 2.5 kHz transmitter deviation

DARCOM HR2

T-O-T	60 seconds
Soft Carrier Dekey	0
Sleep	No
Rx Mute	Upon Channel Monitor
Squelch	RSSI

DARCOM I Master w/Operator Module

1. Connect Tx (J2-3&4) to Rx (J2-1&2)
2. Connect CM (J2-7) to Ext PTT (J2-5)
3. Set the switches on the Operator Module:

S1-1	C
S1-2	O
S1-3	O
S1-4	C
S1-5	O
S1-6	C
S1-7	C
S1-8	O
S1-9	C
S1-10	O
S2-1	O
S2-2	O
S2-5	O
S2-6	O
S2-7	O
S2-8	C
S2-9	C
S2-10	O
S3-9	O
S3-10	C
JU11	C

With 2.0 kHz deviation into receiver:
Adjust R48 for 1.5 Vp-p @ J2-3
Adjust R22 for 2.0 kHz transmitter deviation

MOSCAD Glossary

AGA	American Gas Association. An organization that establishes metering procedures within the gas industry.
AI	Analog Input. A voltage or current, representing a physical value, generated by a sensor at a remote site. The MOSCAD RTU accepts 0-5V, 4-20 ma, 1 ma, 1 V from a field device.
AO	Analog Output. A voltage or current output, generated by an RTU to control a regulative valve, a motor speed drive, etc. The RTU outputs are 0-5V or 4-20 ma.
Async	Serial data communications format that is not synchronized to a common clock signal. Characterized by start and stop bits and sometimes a parity bit in addition to the seven or eight data bits.
Baud	Unit of signaling speed. The speed in baud is the number of discrete conditions or events per second. If each event represents only one bit condition, baud rate equals bps. When each event represents more than one bit (e.g. dibit), baud rate is less than bps.
Bit	Binary Digit. Contraction of “binary digit”, the smallest unit of information in binary systems; a one or zero condition.
Bps	Bits per second. Unit of data transmission rate.
Byte	A binary element string functioning as a unit, usually shorter than computer “word”. Eight-bit bytes are the most common. Also called a character.
Contention	An alarm reporting method, in which the remote station alarms are reported “as soon as they occur”, not just upon interrogation from the control center (see Interrogation).
COS	Change of State. Last reported change, sent from a remote station to the control center.
CPU	Central Processing Unit. Portion of the computer that directs the sequence of operations and initiates the proper commands to the computer for execution.
CT	Current Transformer. Used in electrical metering systems to reduce high currents to easily measured levels. See also PT.
DFM	See Direct FM
DI	Digital Input. A dry contact dual state sensor recognized by the MOSCAD RTU as < 4 kohm = closed and >70 kohm = open.
Dibyte	Two bytes (16 bits) treated as a single entity. All MOSCAD variables are one or more dibytes.
Direct FM	A baseband (unmodulated) transmission method of MOSCAD data via a radio set having such capability (“F1” emission).
DO	Digital Output. A dry contact relay output available from the RTU.
DPL	Digital Private Line. A slow speed digital code that modulates the transmitter along with the desired data system information. The DPL code is typically used to gain access to high powered repeater/base stations. See also PL.

DPSK	Dual phase shift keying. A frequency modulation technique in which the phase of a single frequency tone is changed between two states to represent the 1/0 status of the data. A form of “F2” emission.
Dry Contact	A switch or relay contact that is not connected to any voltage or to earth, that is devoid of any other circuit.
EEPROM	Electrically Erasable and Programmable Read Only Memory. A storage device that stores data unaffected by a power failure. The EEPROM is electrically erasable and programmable.
EPROM	Electrically Programmable Read Only Memory. A storage device that stores data not alterable by computer instruction or by a power failure. The EPROM is erasable by means of ultraviolet light and is electrically programmable.
F1 Emission	A FCC definition that applies to frequency modulated transmitters wherein the data source directly modulates the radio frequency.
F2 Emission	A FCC definition that applies to frequency modulated transmitters wherein the data source modulates a tone subcarrier with the subcarrier then modulating the radio frequency.
Fade Margin	Additional signal level included in radio system designs to insure adequate signal strength when a communication path degrades due to normal propagation factors.
FEP	Front End Processor. The interface between the SCADA Manager computer plus software and the communications network. The FEP is an independent processing unit, performing all the communication tasks via either radio or wireline links. Available with ModBus or TCP/IP connectivity to the SCADA Manager.
FIU	See FEP.
Flash Memory	Flash memory is a type of EEPROM memory technology.
FM	Frequency Modulation. Angle modulation in which the instantaneous frequency of a sine-wave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous value of the modulated wave.
FSK	Frequency Shift Keying. A frequency modulation technique in which one frequency represents a mark and a second frequency represents a space (“F2” emission).
Full Duplex	Simultaneous, two way, independent transmission in both directions over a data link.
Half Duplex	Transmission in either direction, but not simultaneously..
Interrogation	Polling method in which the control center requests update information from its subordinate RTUs. The process may be initiated automatically or manually.
INTRAC	One of the Motorola SCADA equipment families. The protocol used by all Intrac 2000 equipment..
ISO	International Organization for Standardization.
kb	1000 bits.
kB	kilo Byte, 1024 bits.
kbps	1000 bits per second.

LAN	Local Area Network. A data communication network confined to a limited geographical area (usually up to 10 km) with moderate (100 kbps) to high (100 Mbps) data rates. The area served may consist of a single building, a cluster of buildings or a campus-type arrangement. The LAN utilizes a common physical link (bus or ring topology) for the data transfer rather than switching technology.
LDC	Motorola Literature Distribution Center.
MB	Megabyte, 1,048,576 bytes.
MDLC	Motorola Data Link Control (protocol). Motorola's seven layer communication protocol designed according to the OSI reference model.
MIS	Management Information System.
MOSCAD	One of the Motorola SCADA equipment families as described in the MOSCAD System Planner.
MOSCAD FIU	MOSCAD Front-end Interface Unit; see FEP.
MTBF	Mean Time Between Failures. The average length of time that a system or component works without failure (not the formal definition).
MTTR	Mean Time To Repair. The average time it takes from failure to repair (not the formal definition).
NC	Normally Closed (Contact). A contact, the current carrying members of which are in contact when the operating unit is in normal position.
NEMA	National Electrical Manufacturers Association.
NO	Normally Open (Contact). A contact, the current carrying members of which are not in contact when the operating unit is in normal position.
OSI	Open System Interconnection. The theoretical reference model of ISO intended for the design of open systems.
PL	Private Line. A sub-audible precise tone that modulates the transmitter along with the desired data information. PL is normally used to gain access to high powered repeater/base stations. See also DPL.
PSTN	The Public Switched Telephone Network. The normal voice telephone service available through the world.
PT	Potential Transformer. Used in electrical metering systems to reduce high voltages to easily measured levels. See also CT.
PTP	Point-to-Point. A radio system concept wherein two sites on a radio channel communicate only between themselves and with no other site. Typically employed when the two sites exchange large amounts of information.
R/A Repeater	A radio system concept wherein two radios on different radio channels are connected back-to-back (receiver 1 connected to transmitter 2, etc.) to provide a communications bridge between the two channels. Typically one radio will also transmit (repeat) any message it receives on its channel as well as on the opposite channel.
Rackmount	The physical arrangement of MOSCAD to directly mount onto a 19" open or closed equipment rack. The lack of a physical enclosure permits expansion beyond the basic input/output constraints.

RAM	Random Access Memory. A storage device in which the access time is effectively independent of the location of the data.
RTU	Remote Terminal Unit. The generic industry name for a remote alarm and control unit.
SCADA	Supervisory Control and Data Acquisition. The utility industry name for monitoring and control operation.
SPDT	Single Pole Double Throw. Type of a three contact relay in which, as the first contact connects (make) to the common contact, the second contact disconnects (break) from the common contact.
SPST	Single Pole Single Throw. Type of two contact relay in which the switched contact connects to (make) or disconnects from (break) a common contact.
Store-&-Forward	A capability of the MDLC protocol wherein data is received, validated, and stored until the communication medium becomes available wherein it is then forwarded to the next site. Communication infrastructures may be thus created in linear or star arrangements utilizing a single or a mix of different media types.
ToolBox	A collection of software tasks and tools that permit the MOSCAD RTU to be assigned a site ID, modules configuration, application program created and downloaded into the RTU, and more.
UHF	Ultra High Frequency. Radio frequency range between 300 MHz and 3000 MHz.
VHF	Very High Frequency. Radio frequency range between 30 MHz and 300 MHz.
WAN	Wide Area Network. A data communication network over a large geographical area. The area served may be on a regional, national or even a global scale. The WAN utilizes private and national carrier links, and switching technology for the data transfer.
Wireline	The use of 600 ohm balanced wire link as a transmission path for telemetry data instead of radio link.

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