**RUG9 SPECIFICATION, v 6.50**

## REMOTE TERMINAL UNITS

## OVERVIEW

The remote controllers shall be fully integrated microprocessor based units specifically designed for unattended operation in unconditioned environments having wide temperature ranges, wide humidity ranges, high electrical noise, high audible noise and high vibration. They shall include optically isolated analog, digital and communications interfaces to interface directly with all standard transducers, actuators, and communications equipment without the need for intervening conditioning devices. An integral operator interface shall be provided such that normal operations such as device enabling/disabling, on/off control, mode changes, setpoint changes, etc. shall be accomplished with English language prompting and shall not require any programming, command code memorization, or reference to any operating instructions. The units shall require no cooling fans and shall be resistant to dust, water and insects.

## GENERAL ARRANGEMENT

Each RTU shall consist of at least one card cage having a CPU card, a mother board, and up to 8 I/O cards as required by the I/O functional requirements. If the RTU requires more I/O than can be accommodated in one card cage, then up to 7 additional card cages shall be connected to the base card cage to increase the I/O capacity. Cards shall slide in to the card cages from the front. No more than one fastener shall need to be removed to change an I/O card. Each card cage shall be powered by nominal 12 VAC or 12-15 VDC.

## PROGRAMMING

The RTU shall not require procedural programming in the usual sense. Instead, the unit shall be equipped with pre-programmed modules enabling the programmer to configure the unit using a manufacturer supplied Windows compatible support software program. With that program, the programmer shall be able to design his control strategies, displays, telemetry formats, etc. by interconnecting the pre-programmed modules using a technique of pointing, clicking and dragging on the Windows screens. He shall then command the support software to send the configuration file to the RTU, where it shall begin running automatically.

## SUPPORT SOFTWARE

Support software shall be Windows 7/8/10/11 compatible. The software shall be self-contained and complete in that it shall not require any equipment or software other than Windows running on a PC along with a serial cable to define the RTU program and load it into the RTU and start it running. It shall enable the programmer to configure the unit by identifying and naming pre-programmed modules for installation into the overall control strategy without the need for any procedural programming.

## SUPPORT SOFTWARE UPGRADES

The latest support software revision shall be available at any time from the manufacturer’s web site for download at no charge. No registration, product code or password shall be required to obtain any revision.

## OPERATING SYSTEM UPGRADES

The RTU operating system (OS) shall be contained in flash memory in the RTU. It shall be reloadable serially from the support software. The RTU OS shall be included with the support software and shall be available from the manufacturer’s web site for download at no charge. No registration, product code or password shall be required to obtain any OS revision.

## SUPPORT HARDWARE

The RTU shall not require any support hardware other than a power supply and a serial cable for loading and running programs. Special hardware such as special purpose programming panels or dongles shall not be required.

# RTU ELECTRONIC CHARACTERISTICS

Units shall be designed to operate reliably in high electrical noise, wide temperature range environments without external cooling or noise suppression equipment. All components and subassemblies shall be new and of recent manufacture. The design shall be conservative in that all components shall operate at no more than 50% of rated thermal dissipation in worst case conditions. There shall be 30% timing margin in all critical timing paths.

## LOGIC FAMILY

Unit electronics shall be constructed entirely using the high noise immunity, low power CMOS logic family. No NMOS, TTL or bipolar components shall be used.

## MICROPROCESSOR

The microprocessor shall be a 32-bit pipelined design that shall employ a 24-bit address bus and 16-bit external data bus. Clock rate shall be 16 MHz.

## MEMORY

### FLASH

Electrically erasable programmable FLASH memory shall be employed to contain the operating system, background scanning software, communications software and all software specifically written and installed for this project. No batteries shall be required to maintain the contents of this memory for up to 20 years of power outage. The FLASH shall be partitioned to allow installation of the operating system as well as the application specific code without affecting any other FLASH contents. Boot loader code shall be contained in a section of the FLASH that is protected from erasure other than at the factory. A total of 512K bytes of contiguous FLASH memory shall be installed in each unit, which shall include at least 20% spare capacity in each of the boot loader, operating system and application areas.

### EEPROM CALIBRATION STORAGE

All analog channel calibration constants shall be set at the factory and installed in EEPROM devices on the individual I/O cards such that no field calibration will be required on initial installation or whenever an I/O card is replaced.

### RAM

Static random access memory (RAM) shall be employed for data bases, communications buffers, and to store temporary variables, totalizations, logged data, and any other data specifically used for this project that changes momentarily. A minimum of 256K bytes of contiguous battery backed up RAM shall be installed in each unit. Lithium battery backup shall power the RAM for a minimum of 3 years of power outage cumulative over a 20 year period. A holding capacitor shall be installed so that the battery can be replaced without loss of RAM data.

### WRITE PROTECTION

FLASH memory sectors allocated for operating system and user program storage shall be protected from writing whenever the program is running. It shall also be protected for at least 1.7 seconds following power application, watchdog timer timeout, or brownout detection. Boot loader program shall be protected from field alteration.

### BATTERY BACKUP

RAM memory and the realtime clock shall be powered during primary power outages by a lithium battery whose capacity over a 20 year period shall be sufficient to power the memory and clock for accumulated outages of at least 3 years. It shall be possible for project personnel to replace the battery without the use of a soldering iron, and without loss of memory contents.

### REMOVABLE FLASH MEMORY CARD

An up to 2GB removable flash memory card and interface shall be available for storing archived data, text messages, and other data. No batteries shall be necessary to maintain card data contents indefinitely. It shall be possible to remove and re-install the flash cartridge while power is applied to the unit and the program is running without corruption of stored data. The cartridge and interface card shall conform to the Compact Flash standard. Data stored on the card shall be in the form of ASCII text files compatible with commercial spreadsheet programs and readable as DOS files using any PC compatible computer with a PCMCIA interface.

## DISPLAY

Each unit shall be equipped with an LED backlit graphics compatible dot matrix type liquid crystal display (LCD) having at least 40 characters by 20 lines capacity. With the display, it shall be possible to present values, statuses, engineering units, alarm messages, trend plots and prompts to project personnel. The display shall provide the full ASCII character set plus necessary graphics to support trending and bargraph presentation. Multiple display pages shall be possible, limited only by available flash memory capacity. Display contrast shall be adjustable by key entry on the front panel keyboard or from the serial port on the CPU card. Display backlight shall turn on whenever a key is pressed and turn off after a time designated by the configuration file.

### DISPLAY TREND GRAPHICS

The display shall be capable of presenting trend information of up to ten analog or digital variables simultaneously versus time. Display resolution shall be 240 vertical pixels by 320 horizontal pixels. The plot window shall be adjustable such that the plot occupies the display above and to the right of the cursor location where the trend function is invoked. It shall be possible to mix user defined alphanumeric and trend data on the same display page. The plot pattern (solid, dashed, dotted, etc.) of each analog variable shall be selectable by the configuration file. Horizontal grid lines shall be located as specified in the configuration file. A time tag function shall be provided that shall plot a single vertical line with an alternating dot pattern at user defined time ticks imbedded in the raw data file. The vertical scale and horizontal time scale engineering units shall be calculated and presented automatically by operating system software. Depending upon the size of the database driving each trend plot, multiple pages of trend data shall be presentable by hitting the up or down arrow keys to move forward or backward in time. In addition, a time compression function shall provide for expanding or contracting the trend time base by sample decimation based upon an input to the configuration file.

### DISPLAY BARGRAPH GRAPHICS

It shall be possible to simultaneously display up 20 analog variables in horizontal bargraph form, with a resolution of 320 pixels.

## KEYBOARD

An integral numeric keyboard of at least 16 keys shall be provided for use by project personnel to change setpoints, acknowledge alarms, control devices, trigger printed reports, and in general interact with the unit in a prompted English language dialogue that requires no memorization of command codes. The keyboard shall be a sealed, membrane type with tactile feedback that shall be impervious to water or dust. The keyboard shall have numeric keys so that key functions can be designated on the display for easy, one keystroke invocation. As a minimum, the following keys shall be provided:

Numeric 0 to 9

(-) minus sign

(.) decimal point

Up arrow

Down arrow

ENTER

CLEAR

## REALTIME CLOCK/CALENDAR

A realtime clock/calendar shall be provided which shall provide the following time values:

Seconds Day Day of week

Minutes Month

Hours Year

These values shall be available to the operating program for time-based event and report triggering, and logged data time tagging. Software shall be provided for convenient and accurate time setting in English language format. The clock shall have a rate accuracy of +/-.005%. It shall include a lithium battery backup to assure clock running over accumulated power outages of at least 3 years over a 20 year period.

## SPEECH SYNTHESIZER/AUTODIALER

An integral solid state analyzer/synthesizer board shall be available that shall accept, digitize and store user spoken speech or other sounds in a minimum 4 Mbyte flash memory for later playback through the synthesizer. The board shall provide high quality, natural sounding storage and playback of speech in any language. At least 12 minutes of 4 Khz bandwidth audio storage shall be possible. Speech compression methods that degrade speech quality shall not be employed. A minimum of 254 individual messages shall be addressable, with any message length possible from 0 seconds up to the remaining capacity of the dialer. Individual messages shall be erasable and recordable without affecting other recorded messages. Integral software shall be supplied to organize the spoken messages efficiently in memory by user defined message number, prompt the user during the recording process, tag the messages, and enable the messages to be concatenated to form long messages from recorded phrases. System software shall efficiently manage the flash sectors to avoid wasting flash capacity. With user defined speech, it shall be possible for the unit to repeat previously entered spoken alarm messages and to verbally report analog values and associated engineering units in easily understandable language familiar to the operator. A touch tone detector shall be provided to enable the unit to respond to tones entered on any touch tone phone. With this capability and appropriate supplied software, it shall be possible for operators to acknowledge alarms, change setpoints, enter security keywords, control equipment operation, and trigger spoken reports of station status including spoken reporting of analog values such as tank levels, pressures, temperatures, etc. The dialer shall be able to report any status or analog value present in the RTU, including those received from remote RTU’s. Alarm acknowledgment shall require touch tone entry of a security code unique to each operator. The dialer shall also be able to dial into a pager system and issue a touch tone code to indicate an alarm condition. Dialer parameters including phone numbers, paging codes, security codes, redial delays, keystroke waiting periods, retry attempts and others shall be installed as fixed numbers or as table entries, at the programmer’s discretion, to enable a highly flexible dialer design with virtually unlimited size operator lists.

## OPERATIONAL SECURITY

### WATCHDOG TIMER

A hardware watchdog timer shall be provided that shall require correct operation of both the operating application program and background interrupt software. The timer shall timeout and restart the program within 0.5 seconds of program failure.

### BROWNOUT DETECTOR

A hardware brownout detector shall detect sagging power or impending power loss and halt the processor in advance of loss of regulated power to assure orderly shutdown and restart in conditions of

fluctuating primary power. It shall employ 10% hysteresis to eliminate the possibility of multiple restarts on power application.

### AUTOBOOTING

Upon power application or upon restarting after a watchdog timer timeout, the unit shall test the operating system and then test the application program. If both are intact, the unit shall restart the application program. If either is not intact, the operating system or boot loader shall prompt the user on the CPU serial port to reload the corrupted code. There shall be no loss of memory, loss of temporary storage contents, or loss of clock/calendar function due to power outages of up to 3 years.

## SLEEP MODE

For low power applications, it shall be possible using an add on sleep board, under software control, to put the unit to sleep, whereby the unit ceases normal computing operations and enters a low power mode, drawing less than 4.0 ma. Entering the sleep mode shall be under software control.

### PROCESSING DURING SLEEP MODE

While asleep, the sleep processor shall perform the following functions and wake the unit if any enabled conditions cross their wakeup threshold:

* Count time
* Count digital input state changes (tips)
* Compare analog inputs with high and low alarm setpoints
* Calculate wind speed and compare against a high alarm setpoint
* Compare encoder inputs against high and low alarm setpoints

### WAKING FROM SLEEP MODE

The sleep mode shall be terminated, i.e., the unit shall awaken upon

any one of the following:

* Timeout of the sleep mode internal timer (1 to 32768 seconds)
* Pulse detected on any of the sleep board digital inputs
* Pressing the sleep board wakeup button
* Sleep board analog input value exceeding or falling below user defined setpoint
* Sleep board encoder input value exceeding or falling below user defined setpoint
* Incoming ring signal from phone line
* Incoming touchtone sequence from radio

# I/O INTERFACES

## GENERAL OPTICAL ISOLATION AND SURGE PROTECTION

Each analog input, analog output and digital input shall be equipped with minimum 2500 V optical isolation to isolate the channel from the rest of the RTU. Each analog or digital input shall be equipped with circuitry to protect the input from surges in accordance with IEEE surge withstand guidelines. Additionally, analog inputs shall employ noise filters, current limiting resistors and zener clamps per channel to limit voltage excursion to within the A/D converter's operating range. Digital outputs shall employ relays with minimum 2500 V coil to contact isolation. Analog output boards and analog input, digital input and digital output boards designated ‘ISO’ shall additionally implement 2500 V channel to channel isolation.

## ANALOG INPUTS

### ANALOG INPUT BOARD 12-BIT RESOLUTION

Each board shall provide 8 analog inputs for measuring external analog values from standard 4-20 ma or 0-5 VDC transducers. Inputs shall be optically isolated from the computer bus. Analog to digital conversion shall employ 12-bit sigma-delta technique at a sample rate of 10 samples per second. Inputs shall be individually jumper selectable as either 4-20 ma. current loop or 0 to 5 VDC voltage compatible. In current loop mode, the input shall be able to measure down to zero milliamps. Input impedance shall be nominal 220 ohms for current loop channels, and 10 megohms for voltage channels. Power for electronics on the field side of the optical interface shall be provided by the RTU using transformer isolation. Power shall not be taken from the analog signal. Linearity, zero and full-scale error shall each be less than +/- 0.5 LSB over the range of -40 to+85 degrees C. Reference temperature drift shall be less than 0.1 mv/deg.C. Reference aging drift shall be less than 0.02 mv. Over or under voltage inputs shall not effect other input measurement accuracy. A/D conversion techniques such as integrating types that allow out of range inputs to effect other channels shall not be acceptable. Background software shall sample the analog inputs continuously and hold raw values for use by the analog input modules. The analog input modules shall apply low pass filtering and engineering units conversion as specified by the configuration file, and then transfer the samples to the floating point data base for use by other modules. Each board shall hold factory calibration for both 4-20 ma and 0-5 V in onboard EEPROM that shall be read during boot up so that field calibration will be unnecessary.

### ANALOG INPUT BOARD 16-BIT RESOLUTION

Each board shall provide 4 optically isolated analog inputs for measuring external analog values from standard 4-20 ma transducers. Optical isolation shall provide channel-to-computer and channel-to-channel isolation of at least 2500 volts. Analog to digital conversion shall employ 16 bit delta-sigma technique at a sample rate of 10 samples per second. Input impedance shall be nominal 91 ohms. Linearity, zero and full-scale error shall each be less than +/- 0.5 LSB over the range of -40 to+85 degrees C. Reference temperature drift shall be less than 0.1 mv/deg.C. Reference aging drift shall be less than 0.02 mv. Over or under voltage inputs shall not effect other channel input measurement accuracy. A/D conversion techniques such as integrating types that allow out of range inputs to effect other channels shall not be acceptable. Background software shall sample the analog inputs continuously and hold raw values for use by the analog input modules. The analog input modules shall apply low pass filtering and engineering units conversion as specified by the configuration file, and then transfer the samples to the floating point data base for use by other modules. Each board shall hold factory calibration in onboard EEPROM that shall be read during boot up so that field calibration will be unnecessary.

### ANEMOMETER INPUT

One analog input on each sleep board shall amplify, clip, digitize and count a nominal +/-

20 mv anemometer AC signal to obtain wind speed and wind run values.

## ANALOG OUTPUTS

Each analog output board shall provide 4 optically isolated analog outputs. Optical isolation shall provide channel-to-computer and channel-to-channel isolation of at least 2500 volts. The outputs shall be nominal 4-20 ma. current loop compatible, but shall operate linearly over a 3 ma to 25 ma range. Each output shall have a reverse voltage blocking diode to survive reverse connection. Each channel shall accommodate up to 48 V current loop supplies and shall require no more than 8 volts from the loop to function over its nominal 4-20 ma range. Conversion resolution shall be 12 bits. Linearity error shall be less than 0.1 ma. Scale temperature drift shall be less than 55 PPM/deg. C. Background software shall accept an engineering units input value from any data base and automatically transfer it to the designated analog output, properly scaled and calibrated based on user values held in the analog output module configuration file. Each board shall hold factory calibration in onboard EEPROM that shall be read during boot up so that field calibration will be unnecessary.

## DIGITAL INPUTS, 8 channels with common return

Each digital input board shall provide 8 optically isolated channels with a common return pin. They shall be 120 VAC compatible; or dry contact compatible using an onboard isolated loop power supply. Optical isolation shall provide channel-to-computer isolation of at least 2500 volts. Each digital input channel shall include an LED to annunciate the channel state and reverse polarity blocking diode along with current limiting resistor to protect the channel from mis-wiring and transients. Average LED current of 3 ma shall result in full LED illumination. How each channel functions depends upon the specific software module used to interface to them as defined below.

## DIGITAL INPUTS, 8 fully isolated channels

Each digital input board shall provide 8 optically isolated channels. They shall be 120 VAC compatible; or dry contact compatible using an onboard isolated loop power supply. Optical isolation shall provide channel-to-channel and channel-to-computer isolation of at least 2500 volts. Each digital input channel shall include an LED to annunciate the channel state and reverse polarity blocking diode along with current limiting resistor to protect the channel from mis-wiring and transients. Average LED current of 3 ma shall result in full LED illumination. How each channel functions depends upon the specific software module used to interface to them as defined below.

### STANDARD AC DIGITAL INPUTS

Inputs shall be sampled 250 times per second. If the input state switches at least once in 0.1 second, then the input shall be regarded as ON. Otherwise the input shall be regarded as OFF.

### STANDARD DC DIGITAL INPUTS

Whenever the digital input is sampled by a DC digital input module, the returned state shall be regarded as the state of the input.

### PULSE COUNTING

Pulses sensed by pulse counter modules shall be counted and stored in the integer data base, with a range of 0 to 2,147,483,648. Up to 125 pulses per second shall be counted per channel.

### MOMENTARY PUSHBUTTON DETECTION

Momentary pushbutton actuations on digital inputs shall be captured and saved by background software as triggers for use by other modules. The system shall detect any actuation greater than 10 milliseconds in duration.

### PULSE DURATION DETECTION

Background software shall measure and store the duration of digital inputs for interfacing with pulse duration type flow meters. The system shall provide 10 millisecond resolution.

## DIGITAL OUTPUTS

Each digital output board shall provide 8 normally open electromechanical relay output channels. They shall be 120 VAC/24 VDC compatible with 3 amp UL/CSA contact rating into a resistive load. Mechanical life shall exceed 10 million operations. Each digital output channel shall include an LED to annunciate the channel state, and a back EMF shunt diode. Relays shall require no more than 35 ma. to pull in. How each channel is used depends upon the specific software module used to interface to them as defined below. All relays shall remain off during the boot up process.

### STANDARD ON/OFF CONTROL

When a relay output module calls for the relay, the relay shall energize; when the module calls for it to turn off, it shall turn off immediately.

### ALARM OUTPUT CONTROL

When an alarm output module calls for an output to turn on from a steady off state, the output shall turn on flashing every half second and remain flashing until acknowledged. When acknowledged, the output shall assume a steady on or off state depending on the state of the alarm module’s alarm input state. When the module’s lamp test input is on, the alarm output shall turn on steady then return to its former state when the lamp test input turns off.

### PULSE DURATION OUTPUTS

It shall be possible to designate any digital output as a pulse duration output, and to generate pulses on such outputs with user defined cycle period and duty cycle with a range of 15 seconds and resolution of 10 milliseconds.

## SERIAL PORTS

It shall be possible to install serial port cards into any slot in the base card cage for a total of 8 cards with serial ports in addition to the serial port on the CPU card. Serial ports shall be independently configurable as to baud rate, word length, stop bits, parity, buffer length, communications protocol, etc., using the standard serial port settings. Configuration shall be by communications setup module in the configuration file. Communications protocols supported shall be RUG6, RUG9, ASCII, ALERT or MODBUS RTU protocol, minimum. Loading of any software or configuration files shall use the CRC secured RUG9 protocol and shall be possible on any serial port. Loading of the RUG9 operating system shall only be possible on the CPU serial port.

### CPU RS232 PORT

An RS232 port shall be provided on the CPU board for local terminal/printer control, program loading, operating system loading, logged data dumping, interfacing to a local computer, or for general communications with local serial devices. A standard DB9 connector shall be provided enabling the RS232 port to be connected to PC using a standard DB9 cable. A mini-USB shall be provided enabling the RS232 port to be connected to a PC using a standard mini-USB to USB cable.

### MODEM/RS232 PORT

A serial port board shall be provided which shall be selectable under software control as RS232 or modem; and, when selected as modem, shall be selectable by jumper as 2-wire modem, or 4-wire modem. It shall be used for communicating with remotely located computers or other RTUs. The RS232 port shall be compatible with spread spectrum radios, radios with integral modems, and with external high baud rate phone line modems. The integral modem shall support 300/1200 baud using Bell 103/212 standards for use over phone lines or radio. Audio interfaces shall be transformer isolated with 600 ohm line impedance. An integral audio amplifier with a 3 to 1 potentiometer adjustment range shall be provided on the transmitter channel to accommodate highly attenuated lines. The 2-wire circuit shall have a touchtone generator, on/off hook relay, and optically isolated ring detector. A radio transmitter key circuit using an isolation relay shall also be provided. An LED shall indicate transmitter keying and on/off hook status. Connection to the modem shall be via removable screw terminals for the leased line and radio interfaces, and by modular jack for the 2-wire interface. The 2-wire phone line interface shall provide metal oxide varistor (MOV) and back-to-back zener diode lightning protection between tip and ring. The MOV shall be rated for 1200 amps surge current.

ALERT TONE COMPATIBILITY

In addition to the Bell compatible tone set, the unit shall be available with the ALERT compatible tone set.

### DUAL RS232/RS485 PORTS

Two ports, individually jumper configurable as either RS232 or RS485 shall be provided on the Dual Serial board for local terminal control, logged data dumping, interfacing to a local computer, HMI, serial radio communication or for general communications with local serial devices. Standard baud rates shall be supported up to 38,400. Communication settings shall be selectable under software control. LEDs indicating receive, transmit, clear to send, and ready to send status shall be provided for each independent channel. Two standard DB9 connectors shall be provided enabling the RS232 port to be connected to an external serial device using a standard DB9 cable.

## POWER INTERFACE

The unit shall operate from 12 VAC or 15 VDC. Input voltage tolerance shall be +/- 20%. An internal resettable fuse shall protect the unit from over current. Unit current draw shall be less than 150 ma. with all output relays off and loop supplies off. Current consumption in the SLEEP mode shall be less than 4 ma. An integral power failure and brownout detector shall be provided. Diode isolation and fuse shall be provided to protect against external battery reverse connection.

## I/O CHANNEL EXPANDABILITY

Each I/O type shall be expandable to at least the following. Up to 8 card cages shall be connectable to constitute a single RTU.

**CHANNEL TYPE CHAN/CAGE CHAN/RTU**

Digital inputs 64 channels 512 channels

Digital outputs 64 channels 512 channels

Analog inputs 64 channels 512 channels

Analog outputs 32 channels 256 channels

Serial ports 17 channels 17 channels

## I/O CONNECTIONS

All I/O connections shall employ individual screw type terminals using the rising cage clamp design capable of accepting 14 AWG wire. The terminals shall be removable in groups of 3 to 16 from PC board headers so that the unit can be changed out without removing field wires individually.

## ONBOARD DIAGNOSTICS

The Diagnostic/Loop supply/Charger board shall measure bus voltage, battery voltage and unit temperature with 12 bit resolution. Measurements shall be factory calibrated, requiring no field calibration for accurate measurements. Calibration shall be retained on EEPROM on the board and read at boot up. The bus voltage measurement shall enable the unit to detect AC power failure. The battery voltage measurement shall enable the unit to sense battery discharge before battery voltage falls below the brownout shutdown voltage. Database statuses shall be provided for AC power fail and battery undervoltage.

## LOOP SUPPLY

A fused switching type regulated 24 VDC optically isolated loop power supply shall supply up to 160 ma. for powering external 4-20 ma. transducers and digital input channels. The supply shall provide loop power when the unit is awake and powered by either AC or DC power.

## BATTERY CHARGER

A fused 160 ma. battery charger shall provide battery charging when AC power is present, and automatically switch to battery power when AC power fails. Reverse application of battery voltage shall not damage the unit.

# RTU SOFTWARE

## SECURITY SOFTWARE

Software shall be provided for verifying the integrity of the operating system and user configuration file on power application and immediately following file loading. Failure of the code to pass its check shall cause the unit to suspend operation of that software and issue a message through the CPU serial port prompting for software re-installation.

## SCANNING SOFTWARE

All I/O scanning shall be done by operating system software without need for programmer attention. Keyboard and serial port scanning shall use interrupts for fast response and to reduce scanning overhead. Keyboard multi-digit user entries shall be captured by background software without affecting the running program. Each entry shall be entered into a setpoint register immediately after the user hits the [ENTER] key at which time the new setpoint entry will take effect.

### VARIABLE TYPES AND RESOLUTION

The operating system shall support the following numeric types with the ranges specified:

TYPE RANGE

Status 0 to 1

Integer -2147483648 to 2147483647

Floating point 1.7E38 to 2.9E-39

## COMMUNICATIONS SOFTWARE

### PORT BUFFERING

Each serial port shall have separate receive and transmit buffers of length set by the compiler based on compiler’s detected use of the port. Printer port spooling buffers shall be set by the programmer in port setup modules. Interrupt driven background software shall accomplish buffer filling and emptying using a ring buffer structure to minimize the possibility of missing data. A continuous data rate of 9600 baud shall be supported. The speech board shall buffer 16 bytes of speech commands.

### SERIAL PORT PARAMETER SETTING

Serial port and printer port parameter settings shall be set by a port setup module per port. The following parameters shall be defined in the setup module:

Baud rate Word length Stop bits Parity

Tone use UART connection Address Mode

Tx delay Trigger to install Rings to answer Off hook max seconds

### CRC ERROR DETECTION

Background software shall accommodate message reception and transmission using CRC error checking. Each message shall consist of a fixed length header portion and an optional variable length data section. Background software shall generate CRC codes for outgoing messages, and shall check CRC codes for received messages. Any received message having invalid CRC codes shall be discarded and no reply sent.

### COMMUNICATIONS WITH OTHER RTU’s

Upon reception of a message with correct unit address and correct CRC codes, background software shall take the action specified in the message and generate the proper response. This action shall be transparent to the running program, except that the message reception and message type shall be made available to the program in the form of triggers. Using built in message formats, it shall be possible to transfer analog measurements, setpoints, statuses, commands, totalizations, clock settings, etc. between a central computer and any or all remote units, and between remote units. It shall be possible for messages to contain a mix of 16 bit integers, 32 bit integers, statuses, and 32 bit floating point numbers. It shall also be possible to load a configuration file from a central computer to a remote unit. In addition to receiving messages having a unit’s address, it shall be possible for a unit to capture messages from one unit to another, both of which have different addresses than that of the receiving unit. In this case, no reply will be generated. A broadcast mode using address zero (0) shall be implemented whereby any unit having an array setup for address 0 shall capture data addressed to address 0 and not generate a reply.

### PEER TO PEER COMMUNICATIONS

It shall be possible for the unit to issue all commands supported by its formats except for memory loading and program run/stop commands by specifying destination unit address and message type. Background software shall take care of generating the message, accepting the response, and transferring data between the port buffers and the preassigned databases. Background software shall make message transfer status and result available to the program for use in accumulating statistics on link performance, and for notifying that requested data has been received. Using these messages it shall be possible to transfer analog values integers and statuses efficiently and securely between remote units.

### STORE AND FORWARD OPERATION

The system shall support message store and forward operation so that stations out of range or otherwise out of communications visibility shall be able to communicate using intermediary RTU's. The specific path each forwarded message is to take shall be specified at time of message initiation by the initiating station. The path shall be contained in the message so that any receiving station can determine whether it is to forward the message, and to which station it is to forward the message, based entirely upon the contents of the message. In this manner, the initiating station shall be capable of trying an alternate path to accommodate failed intermediary stations. The unit shall be capable of forwarding through a path of as many as 3 intermediary stations, and of retrieving a reply through the identical reverse path. In order that the a station shall be able to forward messages without a prior site visit or program change, it shall not be necessary for the programmer to include any code or modules other than normal communications setup for a unit to perform store and forwarding.

### PORT SWITCHING DURING FORWARDING

In order to accommodate differing channel types in a single system, the unit shall support port switching between a reception that is to be forwarded and the subsequent retransmission of the message such that a received message on one port shall be retransmitted on another port. Parameters such as baud rate, channel type (modem/RS232…), parity, etc. shall be set independently for the two channels involved in the forwarding function. An address range shall be set in the forwarding station to specify those destination addresses which are to involve port switching and those that are to be forwarded on the same port. The unit shall handle any reply message port switching in the reverse manner.

### UNIT ADDRESS RANGE

Each port shall have a one byte address kept in flash memory, enabling an address range of 1 to 255.

### GLOBAL SETPOINTS

In addition to local setpoints, the unit shall implement a global setpoint facility with which the programmer can implement setpoints that can be entered in any RTU in the system or the master site and be automatically sent to all RTU’s or the master as needed. The global setpoint shall include a system index to identify the setpoint to the system, and an age code so that only new setpoint entries will replace old ones. The system shall provide for queues in the RTU’s so that multiple setpoints can be captured and relayed to other units as communications permit.

## PREPROGRAMMED MODULES

Instead of programming in the usual sense, the RTU shall be configured using, as a minimum, the following modules by connecting the outputs of certain modules, contained in the databases, to the inputs of other module(s). All the modules listed below shall be included in the operating system and supported by the support software such that no additional software shall have to be purchased or downloaded in order to obtain these functions.

**I/O MODULES**

**Analog input 4-20 ma**

#### Analog input 0-5v

**Analog output 4-20**

**Bargraph display**

**Clear memory**

**Diagnostics**

**Digital input counter fast**

**Digital input counter**

**Digital output alarm**

**Digital input AC**

**Digital input DC**

**Digital output**

**Get user value**

**Get string GP**

**Global setpoint**

**Message to display**

**Pulse duration input**

**Pulse duration output**

**Pulse to flow**

**Read calib. from EEPROM**

**Setpoint**

**Sleep**

**Sleep presets**

**Sleep read values**

**Sleep setpoints**

**System setup**

**Write cal to EEPROM**

**MATH**

**Arccosine**

**Arcsine**

**Arctangent**

**Bits to Numeric**

Characterization table

Constant

Constant list

**Cosine**

**Cotangent**

**Float to integer**

**Flow AGA3**

**Flow CipolletiRect**

**Flow container**

**Flow convert/dropout**

**Flow H flume**

**Flow Manning**

**Flow overshot gate**

**Flow Palmer-Bowlus**

**Flow Parshall**

**Flow Q=A\*(H+B)\*\*C**

**Flow trapez flume**

**Flow Vnotch weir**

**Gas flow AGA3**

**Limit value**

**Limit input value**

**Low pass filter**

**Mask integer**

**Numeric to bits**

**Numeric to string**

**Pack values**

**Polynomial Nth order**

**Power**

**Sine**

**Square root**

**Successive Sample Filter**

**Summing accumulated**

**Tangent**

**Trigger to numeric**

**Unpack to float**

**Unpack to int**

**Y=A\*B**

**Y=A+B**

**Y=A-B**

**Y=A\*B**

**Y=A/B**

**Y=A\*B\*C\*D\*E\*F\*G\*H**

**Y=A\*B+C\*D+E\*F+G\*H**

**Y=A+B\*C/D-E**

**Y=A+B\*exp\*\*(X+C)**

**Y=A+B\*rand(1)**

**Y=A+B+C+D+E+F+G+H**

**Y=A+B+C+D-E-F-G-H**

**Y=abs(X)**

**Y=Ln(X)**

**Y=Log10(X)**

**Y=MX+B**

**Y=sqrt(X)**

**Y=X^Z (power)**

**CONTROL**

**Alarm high**

**Alarm low**

**Alarm mismatch**

**Alternator**

**AND 2x8**

**AND gate**

**Counter**

**Counter stack**

**Count up dn rollover**

**Deadband**

**Delay timer**

**Exclusive OR**

**Event logger**

**Flip flop**

**Flip flop RS**

**HOA**

**HOA2**

**Intrusion**

**Latch 32 floats**

**Latch float value**

**Latch integer value**

**Latch on bit change**

**Latch string**

#### Lead lag sequencer

**Lead lag sequencer 4**

**Lookup switch**

**Mismatch Latch**

**Make string**

**Off delay**

**On delay**

**OR gate**

**OR gate latched**

**PID**

**Poke**

**Poke many**

**Pulse generator**

**Pump down controller**

**Pump up controller**

**Pump up/dn controller**

**Rate of change**

**Read realtime clock**

**Read table row float**

**Read table row integer**

**Read table row string**

**Select by value**

**Sequen batch**

**Sequencer timed #2**

**Sequencer timed**

**Sequencer up/down**

**Sequencer out (expander)**

**Set realtime clock**

**String switch**

**String switch by bits**

**String switch priority**

**Sync many values**

**Sync to RTC**

**Toggle**

**Trigger delay**

**Trigger every X minutes**

**Trigger every X seconds**

**Trigger generator**

**Trigger on bootup**

**Trigger on change**

**Trigger on change many**

**Trigger on keystroke**

**Trigger on keystroke many**

**Trigger on key log**

**Trigger on key log many**

**Trigger on realtime clock**

**Trigger on bit then clear**

**Value equal**

**Value test**

**Value test/value out**

**Write table row**

**STATISTICS**

**Average value**

**Data logger**

**Get from logger**

**Log many**

**Max value**

**Min value**

**Sliding average**

**Sliding rate**

**Totalize event**

**Totalize flow**

**Totalize time**

**COMMUNICATIONS**

**Alert receive analog**

**Alert receive status**

**Comm fail processor**

**Command serial device**

**Communications setup**

**Com watch**

**Decode binary message**

**Dial modem**

**Dump log to port**

**Dump log to flash disk**

**Encode binary message**

**Forward port switch**

**Get distant log many**

**Get string from port**

**Parse string**

**Parse string to float**

**Parse string to integer**

**Parse string to status**

**Poll**

**Poll Modbus**

**Poll sequencer**

**Printer setup/watch**

**Quiescent controller**

**Send ALERT data**

**Send string to port**

**Sequenced poller**

**Sequenced AT poller**

**Set display**

**Speech access**

**Speech dial/autoanswer**

**Speech record/play/delete**

**Speech dialing sequencer**

**String left/mid/right**

**String convert**

**Trigger on modbus write**

**Trigger on reception**

**MAJOR BLOCKS**

**BASIC language compiler**

**Display definition**

**Display trending**

**Event logger**

**Ladder logic**

**Modbus master & slave**

**R6/R9 CRC secure comm**

**Speech report setup**

**Table setup**

**Watch window debugger**

## LADDER LOGIC

The RTU shall enable the programmer to use ladder logic to implement any control strategies not covered by preprogrammed modules. Each rung shall have a minimum of 7 input contacts and a single coil output. The programmer shall be able to refer to contacts and coils by user defined names. Input contacts shall be designated as either normally open or normally closed. Each coil shall have independent ON delay and OFF delay entries that can be left blank for no delay, or may have either a constant or database variable to control the delay with tenth of a second resolution.

## EVENT TIMING

Events shall be timed by either the realtime clock with one second resolution, or by individual countdown registers that are decremented each 1/10 second.

## SLEEP TIMING

A timer shall run during SLEEP mode to accomplish a timed wakeup. The timer shall be initialized by the user's program and have a range of 1 to 32768 seconds. To accommodate software errors, the timer shall not allow the unit to sleep longer than 32768 seconds.

## FAULT TRAPPING

The unit shall test for potential math errors and as it executes the modules and return the most reasonable result (MAXVALUE or MINVALUE) instead of allowing run time errors. If any unrecoverable run time error occurs, the unit shall halt operation and allow the watchdog timer to reboot the system.

## CLOCK SETTING

Software shall enable personnel to examine and set the realtime clock/calendar using an English language query and response method. It shall also be possible using a global RTC command for one site to set all the realtime clocks in the system.

## DISPLAY CONTROL

Displays shall be accessed by hitting the [ENTER] key to traverse to the next display in the list of displays defined for the project. After the last display in the list is accessed, the list shall roll back to the first display in the list. At any time, the operator shall be able to hit the [-] key to obtain a menu of displays in the project from which he may choose the next one to be displayed. Displays shall be refreshed at a user specified time based upon a user designated trigger. The trigger can be a time tick, an event, a reception of a message, etc. A separate display list shall be kept for the LCD display and for each serial port in the project that is in ASCII mode.

## BASIC LANGUAGE

In addition to the preprogrammed modules and ladder logic programming, the unit and support software shall include the ability to write modules using the BASIC programming language. The BASIC language compiler shall be included in the support software without requiring purchase or downloading of any additional software. BASIC shall support integer, floating point, trigger, timer and string variable types and both local and global variable visibility. It shall support string concatenation and parsing, GOSUB and RETURN, If…THEN…ELSE , and full floating point math including trigonometry, logs and powers. With the BASIC compiler, the programmer shall be able to design a custom software module that is fully commented and reusable, and will interface with other preprogrammed modules and ladder logic through the databases.

## DISPLAY FORMAT DEFINITION

Displays shall be defined by typing in the data to be presented using the Windows compatible program that is used to configure the RTU. Data to be shown on the RTU’s LCD or ASCII serial port(s) shall be presented exactly as entered into the Windows configuration program. Where dynamic data are to be shown, the user shall only have to type in ‘@’ symbols to specify the size, format and location of the variable field, and then drag in the variable that is to be displayed in the specified field. The RTU shall present the variable data in real time in the format and location entered as example by the user.

## WATCH WINDOW DEBUGGING AID

The support software shall include a watch window that shall enable the programmer to drag up to 20 items from the RTU’s databases and observe their current values/states/string contents in real time with once per second automatic updates. He shall be able to double click on a value in the watch window to engage a poke mode whereby the programmer can jam a value into a variable in the running RTU in place of the result that would normally be present. In this manner, the programmer shall be able to substitute a value for any input or calculated result to observe the unit’s response without having to connect transducer simulators or other external signal generators.

## DOCUMENTATION GENERATOR

Support software shall include a documentation generator that, when triggered, will generate an ASCII file that completely documents the project’s design in easily read text. Items to be documented shall be selectively enabled and shall include at least the following:

* Operating instructions
* I/O setup by channel
* Software module setup
* Display formats
* Telemetry array formats
* Ladder logic setup
* Table setup
* Speech setup
* Database listings
* Database variable cross references

# PERFORMANCE

## I/O SCANNING

Background software shall scan analog and digital inputs at the rates specified above. For a nominal control application, the RTU shall accomplish all its scanning tasks in less than 0.1 second.

## COMMUNICATIONS RESPONSE TIME

The unit shall issue a response to a CRC secured message in less than 60 milliseconds. Provisions shall be made whereby the delay from transmission tone on to actual output of data is adjustable over the range of 10 to 3277 milliseconds in increments of 10 milliseconds to accommodate transmitter turnon delay, receiver acquisition time and receiving modem acquisition time. The specification of the tone turnon delay shall be specified in the communications definition module held in flash memory. Assuming a transfer of 16 digital inputs, the following response times shall be met, including time to request a transfer and receive and decode the transfer:

300 baud: 9 transfers in 10 seconds

9600 baud: 90 transfers in 10 seconds

Assuming a transfer of 8 analog inputs, the following response times shall be met:

300 baud: 6 transfers in 10 seconds

9600 baud: 67 transfers in 10 seconds

## COMMUNICATIONS SECURITY

The CRC error detection technique shall provide a probability of acceptance of an erroneous message of 1.0 E-14. It shall also reject all burst errors of 16 bits or less.

## KEYBOARD RESPONSE TIME

The unit shall respond to operator keystrokes in less than 20 milliseconds.

# ENVIRONMENTAL COMPATIBILITY

## ENCLOSURE

The unit card cage shall be constructed of 16 gauge steel with integral card guides capable of holding at least 9 circuit boards plus a mother board. Card cage size shall be no larger than 9.75 inches wide by 4.6 inches high by 4.1 inches deep. A steel display enclosure shall house the keyboard, LCD display, and support electronics, and shall be completely sealable with a single rear gasket to keep gases, fluids, dust, insects and other contaminants from corrupting the internal electronics. The display module shall be 8.5 inches wide by 4.7 inches high and 0.65 inches deep. The display module shall function as a front bezel with back facing mounting screws enabling front panel mounting. Alternatively, the display module shall be mountable, using a hinge kit, on the front of the RTU card cage. Both the display module and enclosure shall be powder coated for corrosion resistance.

## TEMPERATURE RANGE

The unit shall operate over an ambient temperature range of -40 to +85 degrees Centigrade. The display shall operate over a range of -20 to +65 degrees Centigrade and shall survive a range of -40 to +70 degrees Centigrade. No cooling fans or air circulation shall be required for normal unit operation over the temperature range specified.

# TESTING

Each unit shall be thoroughly tested at the factory before shipment to ascertain that all functions are operating normally. Each unit shall additionally be burned in for a minimum of 24 hours to reveal and correct infant mortality failures before shipment.

# DOCUMENTATION

Documentation shall be available for download at no charge from the manufacturer’s web site. The documentation shall include a complete technical manual of at least 300 pages that provides connection examples for all I/O connections and describes background software, communications formats, and the software modules.

# WARRANTY AND REPAIR

The unit shall be warranted for a period of 1 year from date of delivery, including parts and labor. The manufacturer shall guarantee that any failed unit shall be repaired and shipped within 24 hours of receipt by the factory.