M57X SERIES MEASUREMENT SYSTEM

Monitoring & Recording IED Manual

December 5, 2011
ML0032 Document Revision F

Bitronics ◆ D/3 ◆ Orion

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FIRMWARE VERSION

The following table provides the most recent firmware and software versions. For best results, the Configurator version used should match with the firmware version. A complete list of firmware and software versions is provided on the 70 Series Utilities CD.

NOTE: Host firmware version 3.01 requires 70 Series IEDs with 64 MB SDRAM. Do not attempt to upgrade older 70 Series IEDs with insufficient memory to v3.01.

Firmware Revisions & Version History						
Description	Bios Version	DSP Firmware	Host Firmware	Configurator	Utilities CD	Release Date
Mx7x Product Release, New Hardware supported Dual Bus, Analog I/O	3.00	1.21	2.05	2.31	2.43	03/24/06
Mx7x Updated Release	"	"	2.06	2.32	2.44	04/14/06
Mx7x Updated Release	"	1.24	2.12	2.39	2.50	10/01/06
Mx7x Updated Release	"	1.24	2.15	2.41	2.52	12/18/06
Mx7x Updated Release	"	1.29	2.15	2.41	2.54	06/04/07
M57x Product Release, transducer input, Modulated IRIG-B, fault location, adjustable waveform sample rate	3.40	1.30	2.17	2.43	2.56	12/21/07
M57x Product Release; Add Demand per phase for Watts ,VAr, & VA. Configurator & Biview improvements w/ modems. Change to Digital I/O default watchdog contact (Configurator setup; not firmware dependent).	3.40	1.30	2.18	3.00A	2.57	10/17/08
M57x Product Release: Improved poll rate from 500ms to 100ms for transducer input option. Fault distance configuration is changed. Time sync with respect to DNP master is changed from the DNP master jamming the time to asking the master what time to jam. Increased waveform recording limit from 999 post trigger for longer recording.	3.40	1.30	2.19	3.02	3.02	09/30/2009
Mx7x Product Release, IEC61850 & SNTP; Avg 3-Ph Amps and Avg 3-Ph Volts	3.40	1.30	3.01.0	3.01	3.01	1/30/2009

Firmware Revisions & Version History						
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M57x Product Release: Improved poll rate from 500ms to 100ms for transducer input option. Fault distance configuration is changed. Time sync with respect to DNP master is changed from the DNP master jamming the time to asking the master what time to jam. Increased waveform recording limit from 999 post trigger for longer recording.	3.40	1.30	3.02	3.02	3.02	09/30/2009
M57x Product Release: Added virtual I/O to DR. Added Peak Fault Current Measurement. Improved password security. Added support for control characters for SMS.	3.40	1.30	3.04	3.04	3.04	10/15/2010
M57x Product Release: Added support for dual peak current input range M572 (S56, S57), IEEE C37.232 naming convention, periodic triggering, and 4 IEC 61850 buffered reports.	3.40	1.32	3.05	3.05	3.05	2/28/2011
M57x Product Release: Increased pre and post trigger times for DR recorders, modified base memory to 1MB	3.40	1.32	3.07	3.07	3.07	11/11/2011

M57X MANUAL SET

ML0032	M57X User Manual
ML0022	70 SERIES UCA® Object Model
ML0025	70 SERIES Modbus Protocol
ML0026	70 SERIES DNP3 Protocol
ML0027	M870D Remote Display Manual
ML0033	M570Dx Remote Display Manual
ML0034	70 Series IEC61850® Protocol Manual

CERTIFICATION

Bitronics LLC certifies that the calibration of our products is based on measurements using equipment whose calibration is traceable to the United States National Institute of Standards Technology (NIST).

INSTALLATION AND MAINTENANCE

Bitronics LLC products are designed for ease of installation and maintenance. As with any product of this nature, installation and maintenance can present electrical hazards and should be performed only by properly trained and qualified personnel. If the equipment is used in a manner not specified by Bitronics LLC, the protection provided by the equipment may be impaired.

In order to maintain UL recognition, the following Conditions of Acceptability shall apply:

a) After installation, all hazardous live parts shall be protected from contact by personnel or enclosed in a suitable enclosure.

WARRANTY AND ASSISTANCE

This product is warranted against defects in materials and workmanship for a period of thirty-six (36) months from the date of their original shipment from the factory. Products repaired at the factory are likewise warranted for eighteen (18) months from the date the repaired product is shipped, or for the remainder of the product's original warranty, whichever is greater. Obligation under this warranty is limited to repairing or replacing, at our designated facility, any part or parts that our examination shows to be defective. Warranties only apply to products subject to normal use and service. There are no warranties, obligations, liabilities for consequential damages, or other liabilities on the part of Bitronics LLC except this warranty covering the repair of defective materials. The warranties of merchantability and fitness for a particular purpose are expressly excluded.

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SAFETY SECTION

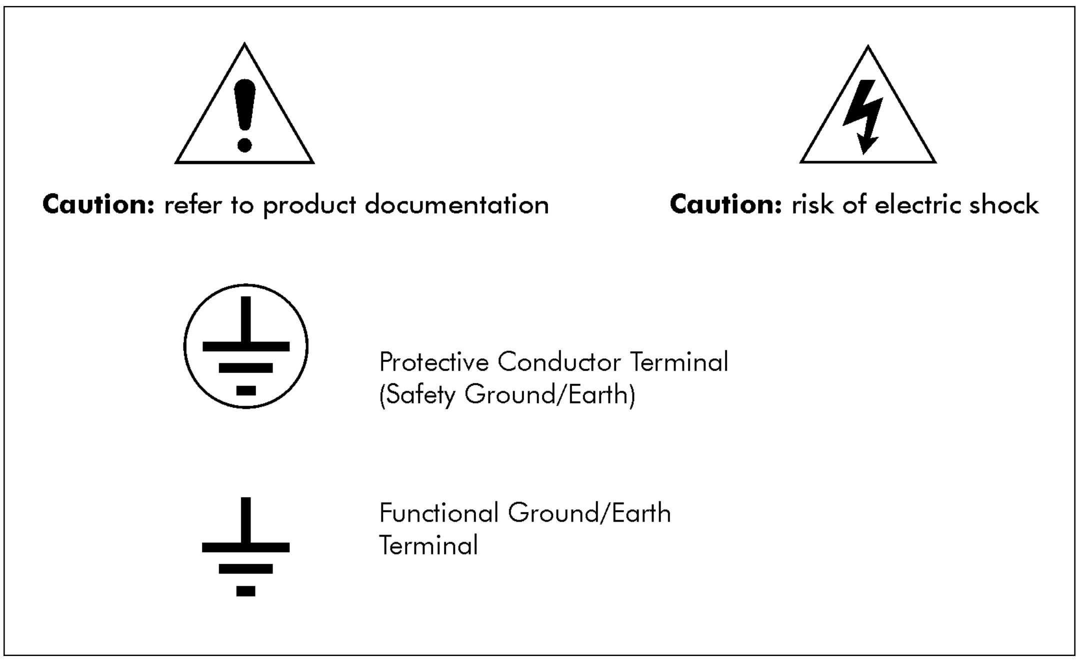
This Safety Section should be read before commencing any work on the equipment.

Health and safety

The information in the Safety Section of the product documentation is intended to ensure that products are properly installed and handled in order to maintain them in a safe condition. It is assumed that everyone who will be associated with the equipment will be familiar with the contents of the Safety Section.

Explanation of symbols and labels

The meaning of symbols and labels that may be used on the equipment or in the product documentation is given below.



Installing, Commissioning and Servicing

Equipment connections

Personnel undertaking installation, commissioning or servicing work on this equipment should be aware of the correct working procedures to ensure safety. The product documentation should be consulted before installing, commissioning or servicing the equipment.

Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

If there is unlocked access to the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections should be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety. To ensure that wires are correctly terminated, the correct crimp terminal and tool for the wire size should be used.

Before energizing the equipment, it must be grounded (earthed) using the protective ground (earth) terminal, or the appropriate termination of the supply plug in the case of plug connected equipment. Omitting or disconnecting the equipment ground (earth) may cause a safety hazard.

The recommended minimum ground (earth) wire size is 2.5 mm^2 (#12 AWG), unless otherwise stated in the technical data section of the product documentation.

Before energizing the equipment, the following should be checked:

Voltage rating and polarity

1. CT circuit rating and integrity of connections

2. Protective fuse rating

Integrity of ground (earth) connection (*where applicable*)

Equipment operating conditions

The equipment should be operated within the specified electrical and environmental limits.

Current transformer circuits

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation.

Battery replacement

Where internal batteries are fitted, they should be replaced with the recommended type and be installed with the correct polarity, to avoid possible damage to the equipment.
Internal Battery: 3v Lithium coin cell, Panasonic BR2330.

The battery supplies uninterruptible power to the real-time clock when the device is not powered normally. There are no other loads on the battery but the clock. When the unit is operating, the auxiliary power supply sources the clock, leaving the battery unloaded through the majority of its useable life except for brief intervals when the device is powered down (shipping, storage, etc.)

Maximum expected life is dictated by the manufacturer's advertised shelf life, about 10 years which is typical for Lithium batteries in this class. The minimum expected life is determined by the rated capacity of 255mAh, which can be expected to carry the full load of the clock if the unit remains unpowered for about three years or more.

If the auxiliary power to the device should be interrupted after the battery has fully discharged, the time and date settings will initially be lost when the power is restored.

However, if the device's clock is normally synchronized by an external source such as IRIG-B, the correct time and date will be restored by the first IRIG update following the power interruption. There are no other adverse effects resulting from eventual loss of the battery's charge.

There is no automatic provision to indicate the health of the battery. The status can be determined by cycling the power to the device then checking to determine if the clock has lost its time and date settings. Measuring the voltage of the battery, although effective, is not generally considered practical since it also requires powering the device down in order to gain access to the battery, thus providing no advantage over the recommended method.

Insulation and dielectric strength testing

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

Fiber optic communication

Where fiber optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

WARNING: EMISSIONS – CLASS A DEVICE (EN55011)

This is a Class A industrial device. Operation of this device in a residential area may cause harmful interference, which may require the user to take adequate measures.

DECOMMISSIONING AND DISPOSAL

1. Decommissioning

The auxiliary supply circuit in the equipment may include capacitors across the supply or to ground (earth). To avoid electric shock or energy hazards, after completely isolating the supplies to the relay (both poles of any dc supply), the capacitors should be safely discharged via the external terminals before decommissioning.

2. Disposal

It is recommended that incineration and disposal to watercourses is avoided. The product should be disposed of in a safe manner. Any products containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation may apply to the disposal of lithium batteries.

1.0 DESCRIPTION & SPECIFICATIONS

1.1 Introduction

The M57x IEDs with SubCycle™ technology combine an accurate and dependable measurement system with utility-proven innovations in data reporting. The M57x IEDs are based upon the M871, which has become a benchmark for measurement and control performance. The M57x IEDs were designed to provide the measurement and data power of an M871 in an economically priced package for applications not requiring the full functionality of the M871.

1.2 Features

- Extensive measurement set including two sets of voltages and currents with corresponding power and energy on some models
- Simultaneous support of multiple protocols over multiple physical links
- Two completely independent Disturbance Recorders
- Two separate Waveform Recorders
- Trend Recorder
- Sequence of Event log
- Voltage Fluctuation Table to use for sag and swell reporting
- Two options for analog inputs, 8 voltages with 3 currents or 8 voltages with 6 currents
- Two current ranges linear to 20A or linear to 100A
- 128 samples per cycle, 16 bit sampling.
- 32-bit floating point DSP, capable of 180 MFLOPS (Million Floating Point Operations Per Second). A 128-point complex Fast Fourier Transform (FFT) is performed in less than 50 microseconds.
- 486-class Host processor.
- Watchdog timer maximizes system reliability.
- 3 Configurable serial ports - Two RS232/RS485 ports and an RJ11 Display/RS232 port.
- Rugged all-aluminum housing.
- Optional - 4 Digital Inputs and 4 Digital outputs.
- Optional - ethernet 10/100 BASE-TX. Also may be ordered with either 10 BASE-FL or 100 BASE-FX fiber optic port as part of the Ethernet option.

1.3 Specifications

Power Supply Input Voltage

Nominal:	24-250Vdc, 69-240Vac (50/60Hz)
Operating Range:	21-300Vdc, 55-275Vac (45-65Hz)
Burden:	46VA max, 17W max

Input Signals		
CT Current Inputs (S51) M571	Configuration	4 Inputs. 3 Phase Currents.
	Nominal	5Aac
	Peak Current	Linear to 20A symmetrical (28A peak) at all rated temperatures.
	Overload	30Aac continuous. Withstands 400Aac for 2 seconds.
	Isolation	2500Vac, minimum.
	Burden	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz).
	Frequency	40-70Hz
CT Current Inputs (S50) M571	Configuration	4 Inputs. 3 Phase Currents.
	Nominal	5Aac
	Peak Current	Linear to 100A symmetrical (141A peak) at all rated temperatures.
	Overload	30Aac continuous. Withstands 400Aac for 2 seconds.
	Isolation	2500Vac, minimum.
	Burden	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz).
	Frequency	40-70Hz
CT Current Inputs (S53) M572	Configuration	6 Inputs. 3 Phase Currents from 2 Lines.
	Nominal	5Aac
	Peak Current	Linear to 100A symmetrical (141A peak) at all rated temperatures.
	Overload	30Aac continuous. Withstands 400Aac for 2 seconds.
	Isolation	2500Vac, minimum.
	Burden	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz).
	Frequency	15-70Hz
CT Current Inputs (S54) M572	Configuration	6 Inputs. 3 Phase Currents from 2 Lines.
	Nominal	5Aac
	Peak Current	Linear to 20A symmetrical (28A peak) at all rated temperatures.
	Overload	30Aac continuous. Withstands 400Aac for 2 seconds.
	Isolation	2500Vac, minimum.
	Burden	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz).
	Frequency	40-70Hz

Input Signals		
CT Current Inputs (S56) M572 with dual peak ranges 20A/100A	Configuration	6 Inputs. 3 Phase Currents from 2 Lines with different peak current ranges.
	Nominal	5Aac
	Peak Current	Linear to 20A symmetrical (28A peak)/linear to 100A symmetrical (141A peak) at all rated temperatures.
	Overload	30Aac continuous. Withstands 400Aac for 2 seconds.
	Isolation	2500Vac, minimum.
	Burden	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz).
	Frequency	15-70Hz
CT Current Inputs (S57) M572 with dual peak ranges 4A/20A	Configuration	6 Inputs. 3 Phase Currents from 2 Lines with different peak current ranges.
	Nominal	1Aac
	Peak Current	Linear to 4A symmetrical (5.7A peak)/linear to 20A symmetrical (28A peak at all rated temperatures.
	Overload	30Aac continuous. Withstands 400Aac for 2 seconds.
	Isolation	2500Vac, minimum.
	Burden	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz).
	Frequency	15-70Hz
VT (PT) Voltage Inputs	Configuration	8 Inputs, Measures 2 Buses, 3 or 4 Wire.
	Nominal	120Vac
	System Voltage	Intended for use on nominal system voltages up to 480V rms, phase-to-phase (277V rms, phase-to-neutral).
	Peak Voltage	Reads to 600V peak (425V rms), input-to-case (ground)
	Impedance	>7.5Mohms, input-to-case (ground)
	Voltage Withstand	2.5kV rms 1min, input-to-case (ground) 2kV rms 1min, input-to-input
	Frequency	15-70Hz

Sampling System		
Sample Rate	128 samples per cycle	
Data Update Rate	Amps, Volts	Available every ¼ cycle
	Watts, VAs, VARs, PF	Available every cycle
Number of Bits	16	

Accuracy	
Accuracies are specified at nominal Frequency and 25C, (unless otherwise noted). Unless noted, all values are true RMS and include Harmonics to the 63rd (minimum). See also Revenue Accuracy Standards (1.5.1).	
Voltage	AC: Better than 0.1% of reading (20 to 425V rms, input-to-case). (+/- 25ppm/DegC)
Current (S51, S54, S56 bus 1, S57 bus 2)	Better than 0.1% of reading +/- 100uA (0.5A to 20.0A, -10C to 70C)
	Better than 0.1% of reading +/- 250uA (0.05A to 0.5A)
Current (S50, S53, S56 bus 2)	Better than 0.1% of reading +/- 500uA (0.5A to 100.0A, -10C to 70C)
	Better than 0.1% of reading +/- 1mA (0.05A to 0.5A)
Current (S57 bus 1)	Better than 0.1% of reading +/- 20µA (0.1A to 4.0A),
	Better than 0.1% of reading +/- 50µA (0.01A to 0.1A).
Frequency	+/- 0.01 Hertz
Phase Angle (Volt-to-Volt)	+/- 0.2 Deg (-40C to 70C)
Phase Angle (Volt-to-Amp)	+/- 0.2 Deg (-10C to 70C)
Power	Better than 0.2% of reading (>20% of nominal inputs, 1PF to 0.7PF, -10C to 70C) (VARS are fundamental only)

Communication Ports	
Display P1	Display or RS232 service port
	Baud rate: 9600 – 38.4 kbps
Serial P2 & P3	RS232, RS485 or IRIG-B, Software configurable ports (IRIG-B specifications: See section 5.7.9)
	Baud rate: 9600 to 115.2 kbps
Ethernet (optional)	Single port; copper 10/100 Base-TX;, or, fiber 10Base-FL, or fiber 100Base-FX as ordered

Environmental	
Operating Temperature	-40C to 70C
Relative Humidity	0-95% non-condensing
Installation Category	IC III (Distribution Level) Refer to definitions below.
Pollution Degree	Pollution Degree 2 Refer to definitions below.
Enclosure Protection	IP20 to IEC60529:1989
Altitude	Up to and including 2000m above sea level
Intended Use	Indoor use; Indoor/Outdoor use when mounted in an appropriately rated protective enclosure to NEMA or IP protection classifications, as required for the installation. Class 1 equipment to IEC61140: 1997

Physical		
Connections	Current (CT)	10-32 Studs for current inputs. Recommended Torque: 12 In-Lbs, 1.36 N-m
	Voltage (VT) & (AUX PWR)	Terminal Block accepts #22-10 AWG (0.35 to 5mm^2) wire, or terminal lugs up to 0.375" (9.53mm) wide. Precautions must be taken to prevent shorting of lugs at the terminal block. A minimum distance of 1/8" (3mm) is recommended between uninsulated lugs to maintain insulation requirements. Recommended Torque: 9 In-Lbs, 1.02 N-m
	Display (Serial) Port P1	RJ11, 6 position modular jack; 50 ft , 15 m for RS232; 4000ft (1200m) for RS485 RJ11 to DB9 adapter used to connect as RS232 service port
	Serial Ports P2 & P3	6 position removable terminal blocks, accepts 26-14AWG solid or 26-12 AWG stranded wire. Recommended Torque 7 in-lbs, 0.79 N-m.
Optional Connections	Digital I/O	Status Inputs & Relay Outputs: 6 position removable terminal blocks, accepts 26-14AWG solid or 26-12 AWG stranded wire. Recommended Torque 7 in-lbs, 0.79 N-m.
	Ethernet	RJ45, 8 position modular jack, Category 5 for copper connection; 100m (328 ft.) STP (Shielded twisted pair) cable. ST connectors 62/125 um glass fiber; 2000m (6500 ft.), (412 m or 1350 ft. for 100Mb half duplex)
Weight (typical)	3.92 lbs (1.78 kg)	

Definitions:

Installation Category (Overvoltage Category) III: Distribution Level, fixed installation, with smaller transient overvoltages than those at the primary supply level, overhead lines, cable systems, etc.

Pollution: Any degree of foreign matter, solid, liquid, or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation.

Pollution Degree 2: Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

1.4 Digital I/O (optional)

1.4.1 Inputs

4 uni-directional inputs, including 1 isolated input. Input terminals have internal 510V clamp. Channels 1-3 share a common return, however, channel 4 has an independent return. The recommended torque ratings for the terminal block wire fasteners are listed in the Physical Specifications table (section 1.3).

Voltage Range:

Input Range:	0 to 250Vdc
Threshold Voltage:	18V dc +/-1V (at 25C)
Input Resistance:	33kohm

Input Channel-to-Channel Time Resolution: 200µs (maximum)

1.4.2 Outputs

4 outputs, 1 isolated, jumper selectable for Normally Closed (NC) or Normally Open (NO) operation and for energized or de-energized condition. Output terminals have internal 510V clamp. Channels 1-3 share a common return, however, channel 4 has an independent return. The recommended torque ratings for the terminal block wire fasteners are listed in the Physical Specifications table (section 1.3).

Output Maximum Switched Current (Resistive)

Voltage	Tripping (C37.90 Resistive)	Continuous Carry	Break (Inductive)
24Vdc	30A	5A	8A
48Vdc	30A	5A	700mA
125Vdc	30A	5A	200mA
250Vdc	30A	5A	100mA

Input De-bounce Time: Selectable, from 30us to 1s.
Output Operate Time (time from command by Host, does not include protocol delays)

Assert (Close time with "N.O." jumper):	8ms
Release (Open time with "N.O." jumper):	3ms

Input Delay Time (from terminals): <100µs

Indicator LEDs

Inputs:	Green, on when input voltage exceeds threshold.
Outputs:	Amber, on when relay coil is energized.

Isolation

I/O Terminals to Case:	2000Vac, 1min
I/O Channel to Channel:	2000Vac, 1min (channel 4 to other channels)

1.5 Standards and Certifications

1.5.1 Revenue

The M57x IEDs exceed the accuracy requirements of ANSI C12.20 and IEC 60687. The accuracy class of the instrument to each standard is determined by the Signal Input Type.

Type	Nominal Current	Certification
S50, S53, S56 bus 2	5A	ANSI C12.20, 0.5CA IEC 60687, 0,5S
S51, S54, S56 bus 1, S57 bus 2	5A 1A	ANSI C12.20, 0.2CA IEC 60687, 0,2S ANSI C12.20 0.5CA IEC 60687, 0,5S
S57 bus 1	1A	ANSI C12.20, 0.2CA IEC 60687, 0,2S

The M57x IEDs were tested for compliance with the accuracy portions of the standards only. The form factor of the M57x IEDs differs from the physical construction of revenue meters specified by the ANSI/IEC standards and no attempt has been made to comply with the standards in whole. Revenue accuracy requires firmware version 1.270 or higher. Contact customer service for more information.

1.5.2 Environment

UL/CSA Recognized, File Number E164178
UL61010-1, 2nd edition (July 12, 2004;
CAN/ CSA No. 61010-1-04 (2nd edition, dated July 12, 2004)

If applicable, the CE mark must be prominently marked on the case label.

European Community Directive on EMC 2004/108/EC (replaced former directive 89/336/EEC) amended by 92/31/EEC, 93/68/EEC, 98/13/EC) and Directive 91/263/EC [TTE/SES].

European Community Directive on Low Voltage 2006/95/EC (replaces former Directive 73/23/EEC).

Product and Generic Standards
The following generic standards were used to establish conformity:
Low Voltage Product Safety: EN 61010-1: 2001
EMC: EN 61326-1: 2006, EN 60255-26: 2006, EN 61000-6-2: 2005,
EN 61000-6-4: 2007

Radiated Emissions Electric Field Strength
EN 60255-25: 2000/ EN 55011: 2007/ A2: 2007
Group 1, Class A
Frequency: 30 - 1000 MHz

AC Powerline Conducted Emissions
EN 60255-25: 2000/ EN 55011: 2007/ A2: 2007
Group 1, Class A

Frequency: 150 kHz – 30 MHz

Electrostatic Discharge (ESD)
EN61000-4-2: 1995/ A1: 1998 / A2: 2001
Discharge voltage: ± 8 KV Air; ± 4 KV Contact (Additionally meets ± 6kv Contact)

Immunity to Radiated Electromagnetic Energy (Radio Frequency)
EN 61000-4-3: 2006/ A1: 2008, Class III (supersedes EN61000-4-3: 1996/ A1: 1998/ A2: 2001 and ENV 50204: 1996, on Immunity to Radiated Electromagnetic Energy – Digital Radio Telephones 900 MHz & 1890 MHz)
Frequency: 80 – 1000 MHz, Amplitude: 10.0 V/m, Modulation: 80% AM @ 1 kHz
Frequency: 1400 – 2000 MHz, Amplitude: 3.0 V/m, Modulation: 80% AM @ 1 kHz
Frequency: 2000 – 2700 MHz Amplitude: 1.0 V/m Modulation: 80% AM @ 1 kHz

Electrical Fast Transient / Burst Immunity
EN 61000-4-4: 2004 (supersedes EN 61000-4-4: 1995/ A1: 2001 /A2: 2001)
Burst Frequency: 5 kHz
Amplitude, AC Power Port ± 2 KV, Additionally meets ± 4 KV (Severity Level 4)
Amplitude, Signal Port: ± 1 KV, Additionally meets ± 2 KV (Severity Level 3)

Current/Voltage Surge Immunity
EN 61000-4-5: 2006 (supersedes EN 61000-4-5: 1995/ A1: 2001)
Open Circuit Voltage: 1.2 / 50 μs
Short Circuit Current: 8 / 20 μs
Amplitude, AC Power Port: 2 KV common mode, 1 KV differential mode
Amplitude, I/O Signal Port: 1 KV common mode; Additionally meets 2KV common mode

Immunity to Conducted Disturbances Induced by Radio Frequency Fields
EN 61000-4-6: 2007 (supersedes 1996/ A1: 2001)
Level: 3
Frequency: 150 kHz – 80 MHz
Amplitude: 10 V rms
Modulation: 80% AM @ 1 kHz

AC Supply Voltage Dips and Short Interruptions
EN 61000-4-11: 2004 (supersedes EN 61000-4-11: 1994/ A1: 2001)

Surge Withstand Capability Test For Protective Relays and Relay Systems
ANSI/IEEE C37.90.1: 2002

2.0 PHYSICAL CONSTRUCTION & MOUNTING

The M57X IEDs are packaged in rugged aluminum housings specifically designed to meet the harsh conditions found in utility and industrial applications.

The Front panel view and connector locations for all M57x versions are shown in Figure 1. The mechanical dimensions are shown in Figure 2.

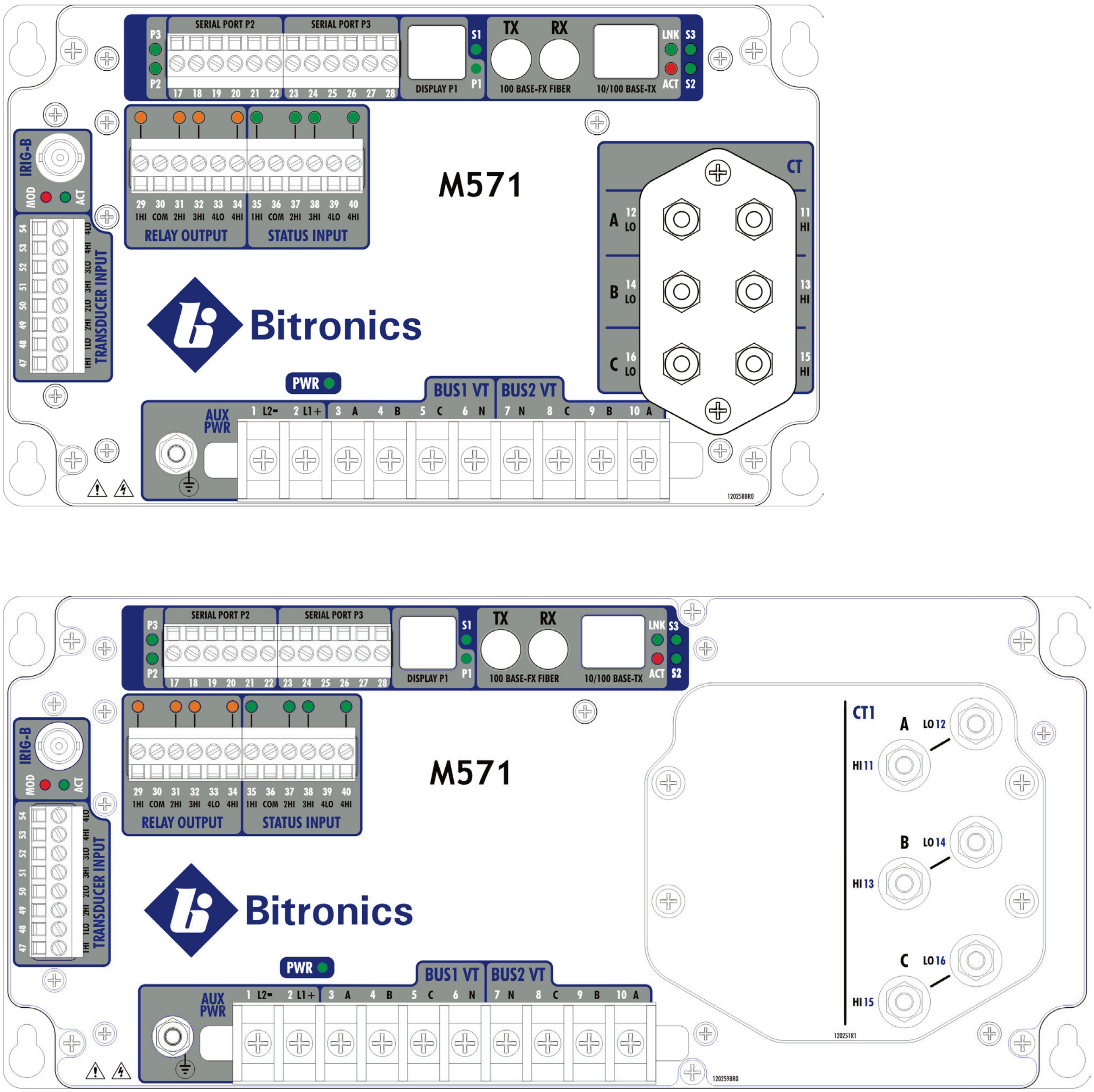


Figure 1 – M571 20A and 100A front view

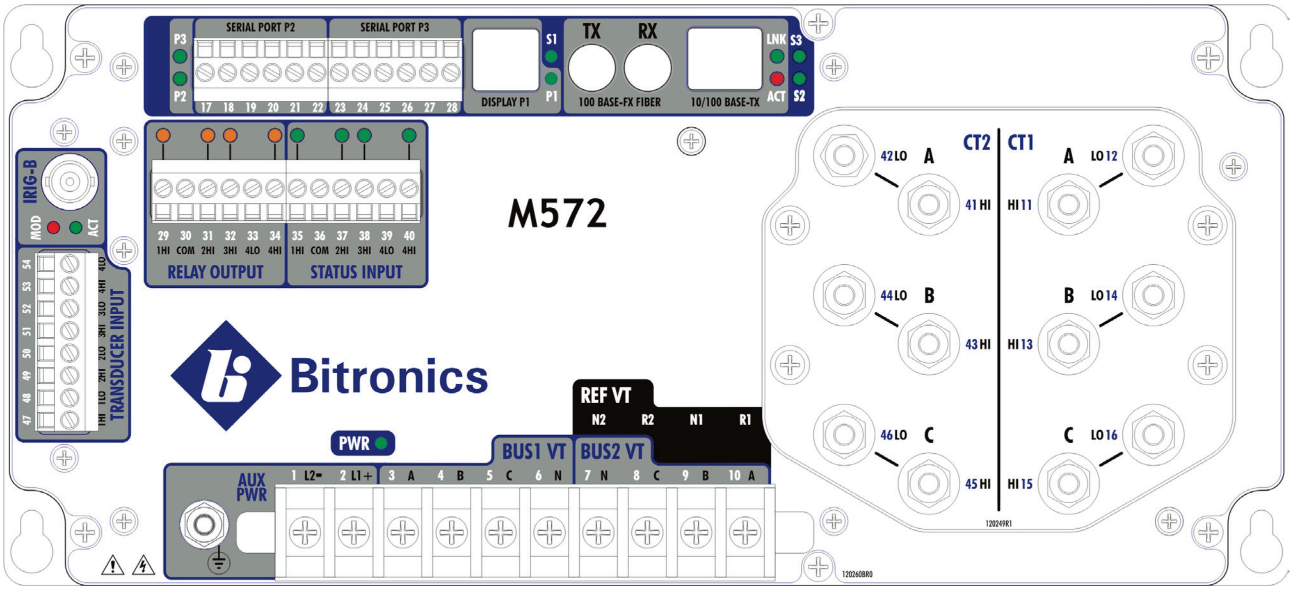


Figure 1 (continued) - Front View M572

Maintain 1-3/4” (44) minimum clearance top and bottom

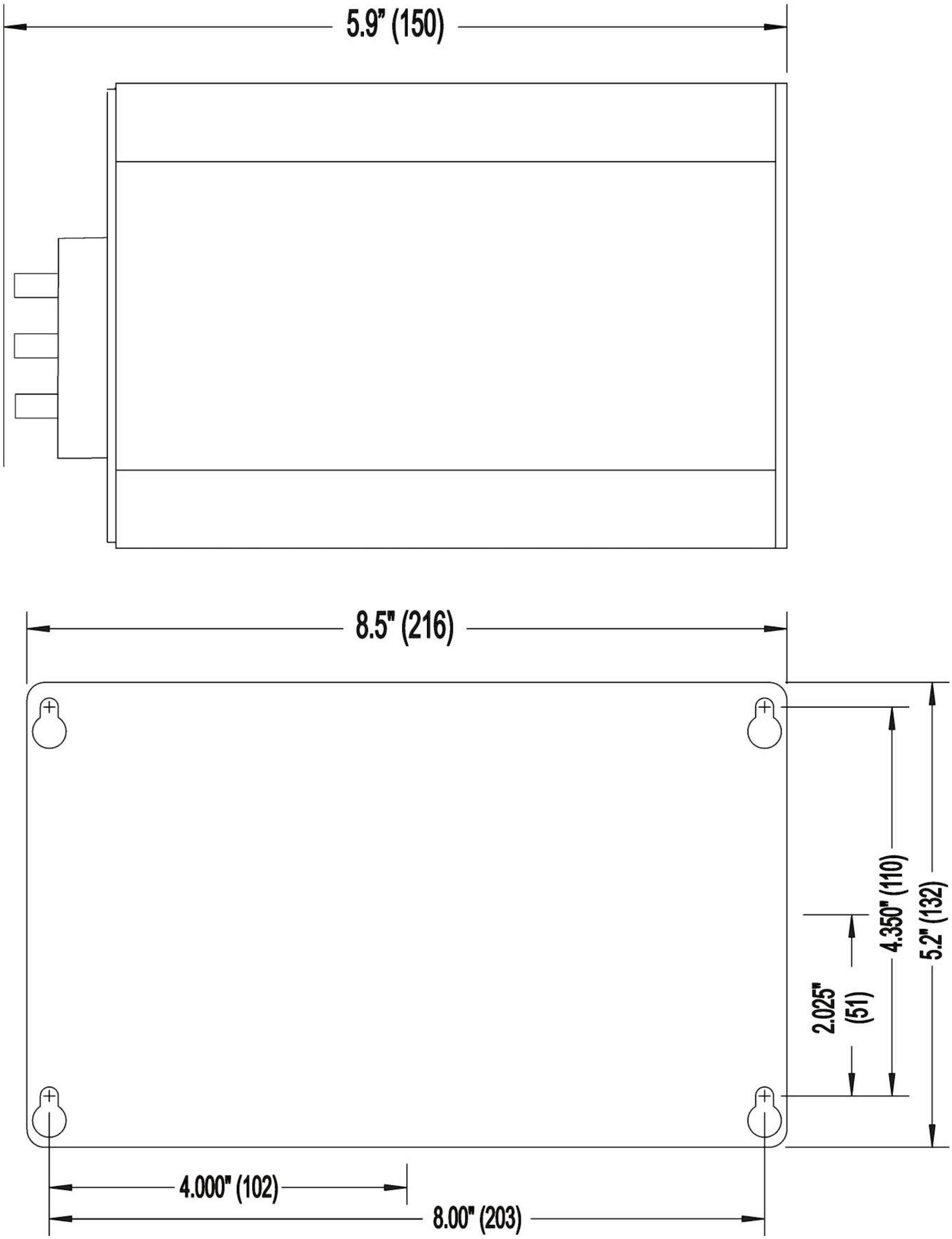


Figure 2 - Mounting and Overall Dimensions (M571 20A version)

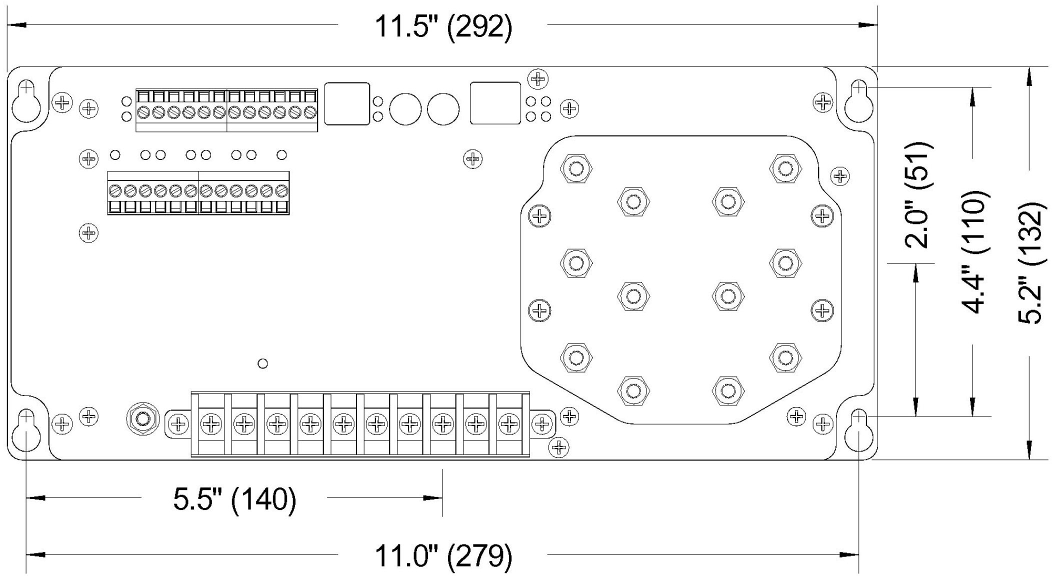


Figure 2 (continued) - Mounting and Overall Dimensions (M572/M571 100A version)

2.1 Installation

WARNING - INSTALLATION AND MAINTENANCE SHOULD ONLY BE PERFORMED BY PROPERLY TRAINED OR QUALIFIED PERSONNEL.

2.2 Initial Inspection

Bitronics instruments are carefully checked and "burned in" at the factory before shipment. Damage can occur however, so please check the instrument for shipping damage as it is unpacked. Notify Bitronics LLC immediately if any damage has occurred, and save any damaged shipping containers.

2.3 Protective Ground/Earth Connections

The device must be connected to Protected Earth Ground. The minimum Protective Ground wire size is 2.5 mm^2 (#12 AWG). Bitronics LLC recommends that all grounding be performed in accordance with ANSI/IEEE C57.13.3-1983.

2.4 Overcurrent Protection

To maintain the safety features of this product, a 3 Ampere time delay (T) fuse must be connected in series with the ungrounded/non-earthed (hot) side of the supply input prior to installation. The fuse must carry a voltage rating appropriate for the power system on which it is to be used. A 3 Ampere slow blow UL Listed fuse in an appropriate fuse holder should be used in order to maintain any UL product approval.

2.5 Supply/Mains Disconnect

Equipment shall be provided with a Supply/Mains Disconnect that can be actuated by the operator and simultaneously open both sides of the mains input line. The Disconnect should be UL Recognized in order to maintain any UL product approval. **The Disconnect should be acceptable for the application and adequately rated for the equipment.**

2.6 Instrument Mounting

The instrument may be mounted on a 19" Rack panel if desired. Two M571 20A units will fit side by side on a standard 5.25" high (3U) panel. See Figure 2 (pg. 11 -12) for dimensions. The unit should be mounted with four #10-32 (M4) screws. *Make sure that any paint or other coatings on the panel do not prevent electrical contact.*

2.7 Cleaning

Cleaning the exterior of the instrument shall be limited to the wiping of the instrument using a soft damp cloth applicator with cleaning agents that are not alcohol based, and are nonflammable and non-explosive.

3.0 FRONT PANEL & WIRING

The M571 20A view is shown below. The M572 has identical wiring for voltages, power supply, serial ports and digital inputs and outputs. It has an additional set of 3-phase currents (see Appendix A1 for detailed wiring diagrams and section 2.0 for other front panel views).

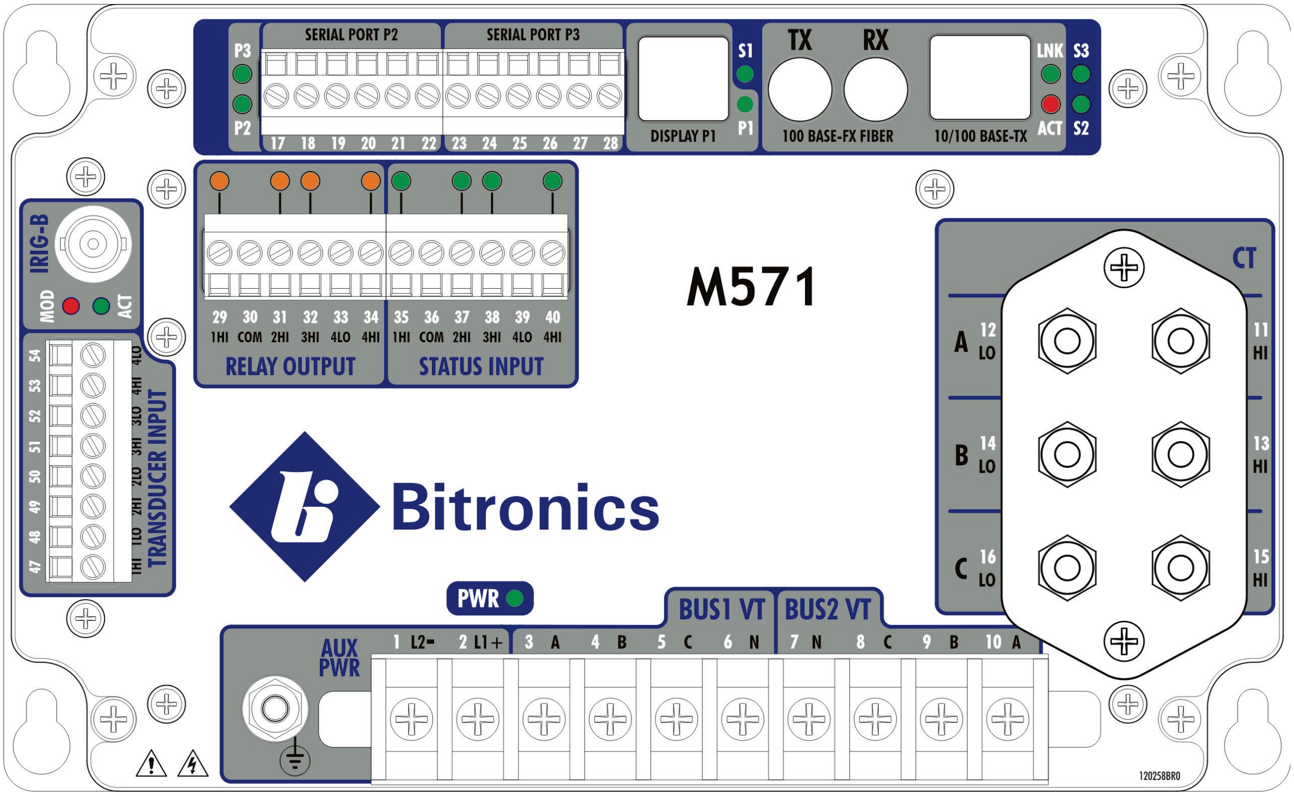


Figure 3 – Front panel view M571 20A

3.1 Auxiliary Power

The M57X IEDs are powered by connections to L1(+) and L2(-).

3.1.1 Specifications

Input (Auxiliary) Voltage

Nominal: 24-250Vdc, 69-240Vac (50/60Hz)

Operating Range: 21-300Vdc, 55-275Vac (45-65Hz)

3.2 VT Inputs (See Appendix A1)

The M57x IEDs are capable of monitoring two voltage buses, designated as Bus 1 (Terminals 3-6) and Bus 2 (Terminals 7-10). Voltage signals are measured using a 7.5Mohm resistor divider with a continuous voltage rating of 7kV. This ideal impedance provides a low burden load for the VT circuits supplying the signals. Grounding of VT &

CT signals per ANSI/IEEE C57.13.3-1983 is recommended. The polarity of the applied signals is important to the function of the instrument.

3.3 CT Inputs (See Appendix A1)

Current inputs are made to terminals (11-16 for M571 and 11-16 and 41-46 for M572). The current input terminal block features 10-32 terminals to assure reliable connections. This results in a robust current input with negligible burden to ensure that the user's external CT circuit can never open-circuit, even under extreme fault conditions. The instrument can be connected directly to a current transformer (CT). Grounding of CT signals per ANSI/IEEE C57.13.3-1983 is required.

3.4 Serial Ports (See section 4.2)

The M57x IEDs are equipped with three completely independent serial ports. The Display port (P1) is an RJ11 connection that can be used to connect a 70 series display or used as a service port. P2 and P3 are software (user) configurable for RS-232. RS-485 or IRIG B mode. The RS-232 drivers support full and half duplex modes. See Figures 4-7 (pg. 22-26) for signal assignments. Section 5.7.10 (pg. 54) indicates wiring instructions for IRIG-B connections.

3.5 Digital Inputs/Outputs (optional)

Connection to the 4 digital input ports is made to terminals (35-40). The digital outputs are accessed via connection to terminals (29-34). To change the output states for the relay outputs, refer to Appendix A3.

The high speed Digital I/O section features 3 inputs that share a common return and 1 fully isolated input. The 4 outputs consist of 3 outputs sharing a common return and 1 fully isolated output. Digital Input transition times are time-stamped. Outputs can be turned on or off based on commands received over communication links or by internal states generated by energy pulses, recorders, etc.

3.6 Ethernet (Optional)

The M57x IED Ethernet options meet or exceeds all requirements of ANSI/IEEE Std 802.3 (IEC 8802-3:2000) and additionally meet the requirements of the EPRI Substation LAN Utility Initiative "Statement of Work" version 0.7. The device also meets the requirements of IEC 61850, part 3 and part 8-1 TCP/IP T-profile for physical layer 1 (Ethernet copper interface) and physical layer 2 (100 Megabit fiber interface). These documents define an interface designed to inter-operate with other devices with little user interaction ("Plug-and-Play").

M57x instruments are offered with three Ethernet options. The first features a 10/100 Megabit (Mb) RJ45 (copper) interface (10BASE-T and 100BASE-TX) which automatically selects the most appropriate operating conditions via auto-negotiation. Option 2 has the features of the copper-only option plus a 10 Mb fiber-optic port (10BASE-FL) operating at 820 nm (near infra-red) using ST connectors. The final option offers the features of the first, plus a 100 Mb fiber-optic port (100BASE-FX) operating at 1300 nm (far infra-red) using ST connectors. All interfaces are capable of operating either as half-duplex (compatible with all Ethernet infrastructure) or full-duplex interfaces (which allow a potential doubling of network traffic). Note that only one port may be connected to a network at one time.

This product contains fiber optic transmitters that meet Class I Laser Safety requirements in accordance with the US FDA/CDRH and international IEC-825 standards.

The 70 Series IEDs come preconfigured for TCP/IP interface with an IP address, a SUBNET mask, and a ROUTER (GATEWAY) address. They also have a preconfigured NSAP address for an OSI network. It is very important that the network have no duplicate IP or NSAP addresses. Configuration of these addresses may be accomplished by using UCA, by using the 70 Series Configurator, or via a front panel serial port using a terminal emulator such as HyperTerminal™ or ProComm™. Please refer to sections 4.1 and 5.5.2 that provide additional information and commands for changing these addresses.

If using the IEC61850 protocol the IP address may be configured from either the 70 Series Configurator software or from the IEC61850 IED Configurator software. A user radio button selection is provided on the 70 Series Configurator Identity page, giving a user the flexibility to decide which software tool will control the IP address configuration setting, which is loaded upon reboot. IP address configuration settings will be stored in either the INI file or MCL file. The INI files are loaded by the 70 Series Configurator and the MCL file is loaded by the IEC61850 IED Configurator.

The units are pre-configured for TCP/IP with an IP address/subnet mask/gateway address of:

192.168.0.254 / 255.255.255.0 / 192.168.0.1

and for OSI with an NSAP of:

49 00 01 42 49 09 01 01

The 70 Series IEDs use the following port numbers for each type of protocol:

PROTOCOL	PORT NUMBER
DNP	20000 (TCP, UDP)
FTP (recommend passive mode)	20, 21 (TCP)
Modbus	502 (TCP)
MMS (UCA & 61850)	102 (TCP)
SMTP (electronic mail)	25 (TCP)
SNTP (network time sync)	123 (UDP)
Telnet	23 (TCP)

3.6.1 Indicators

The Ethernet interface has 2 LEDs for use by users. The "LNK" LED indicates a link with an Ethernet network. The "ACT" LED indicates network activity (send/receive).

A troubleshooting guide is found in Appendix A2.

4.0 OPERATION

4.1 Display Port (P1)

The Display Port can be used to connect to a PC running a terminal emulation program. Upon startup, the M57x default configuration sets P1 for 9600 baud, 8 data bits, no parity, 1 stop bit and no flow control handshaking. A small number of messages are sent to P1 and the M57x then outputs system messages. Enter the command mode by pressing the ENTER key until the system outputs a prompting message. Allowable commands are listed below.

Display (Service) Port\ZMODEM Commands			
c:	dir	receive	type
cd	exit	reset	trigger dr1
chp1	getlog	router	trigger dr2
chp2	Goose*	send	trigger wv1
d:	ip	serial	trigger wv2
date	mac	setlog	ver
del	nsap	subnet	whoami
dio point	password	software	vio point
display on	pulse	status	
display off	reboot	time	

Note: *This command is for UCA Goose only and is now referred to as GSSE.

Type “help <command>” to find out more about a particular command. The more commonly used commands are:

ip - Set Internet Protocol (IP) address information in "dotted decimal" format. The IP address defaults to "192.168.0.254".

subnet – Set the Subnet mask. The Subnet mask defaults to "255.255.255.0".

router – Set the Gateway (Router) address. The Gateway (Router) address defaults to "192.168.0.1".

nsap - Set the OSI network address (NSAP) in "space delimited octet string" format. The default address is "49 00 01 42 49 09 01 01" which is a local address not attached to the global OSI network.

The correct value for your network should be obtained from the network administrator. The default values are valid for a device that is attached to a local intranet with optional access via a router (such as a device within a substation).

time - Set the time as 24-hour UTC time. Time is entered as HH:MM:SS. The factory default is set to GMT.

date – Set the date. Date is entered as MM/DD/YYYY.

serial - Display M57x serial number

exit - Exit command line mode and return to logging mode. If no commands are received for five minutes the device will revert to logging mode.

Transient Voltage Suppressor (TVS) clamp devices are used on the Display P1 port as the method of protection. The Display P1 port signal lines are clamped to a voltage of 33V max (24V nominal) rated for a peak pulse current of 12A min. The Display P1 port DC output voltage is clamped to a voltage of 15V nominal, 24V max. The clamp across the DC output voltage is rated for a peak pulse current of 24.6A max.

4.2 Standard Serial Ports (P2, P3)

These ports can be set to RS-232 or RS-485, and support baud rates up to 115200. Set-up of the Serial Ports can be accomplished by using the 70 Series Configurator. The default configuration for the serial ports is:

Serial Port Default Settings					
Port	Protocol	Parity	Baud	IED	Physical Media
P1	ZMODEM/Display/L	None	9600		RS-232
P2	DNP 3.0	None	9600	1	RS-232
P3	Modbus	Even	9600	1	RS-232

The configuration of these ports is stored internally in the "**COMM.INI**" file (Section 5.2). If for any reason the configuration of the serial ports is erroneously set, the factory default settings can be restored by using FTP. The file "**COMM.INI**" can be deleted, which will return all ports to the factory default setting. The settings can then be changed by using the 70 Series Configurator.

Serial cable requirements for RS485 connection (Ports P2 and P3):
Tie RS-485 cable shields (pin 18 and pin 24) to earth ground at one point in system.

The recommended torque ratings for the terminal block wire fasteners (ports P2, P3) are listed in the Physical Specifications table (section 1.3).

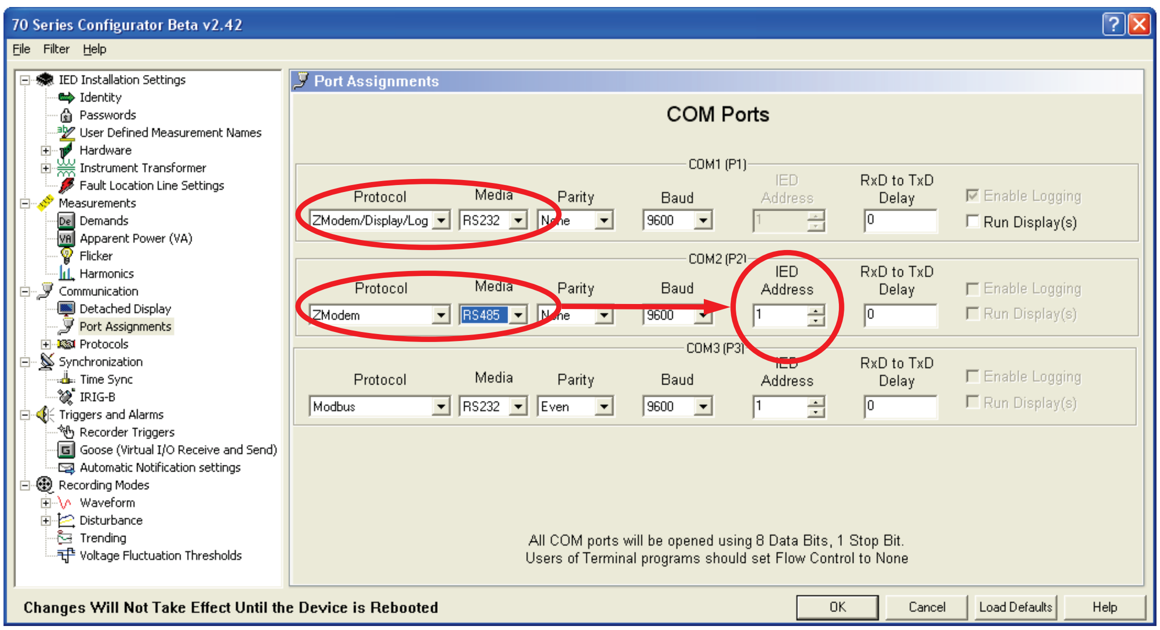
Transient Voltage Suppressor (TVS) clamp devices are used on the serial ports, P2 and P3, as the method of protection. The serial ports (P2, P3) are clamped to a voltage of 24V nominal, 33V max. The clamps are rated for a peak pulse current of 12A min.

4.2.1 RS485 Connections

Note that various protocols and services have different port connection requirements. When making connections to serial ports for Modbus or DNP3 over RS485, 2-wire half duplex is required. This is because it is imperative to maintain a minimum time period (3 1/3 characters) from the time the transmitter shuts off to the next message on the bus in order to guarantee reliable communications. However, when using ZMODEM or connecting to the remote display, asynchronous 2 way communications are required, and therefore a 4-wire full duplex (technically RS422) connection is needed. See figure 6 below for RS485 cable wiring diagrams showing both 2 and 4 wire.

There are special considerations for multi-drop ZModem connections. ZModem protocol was developed for RS232 point-to-point connections so it does not support any standard convention for addressing. Therefore, it does not facilitate multi-drop communications buses. In order to make it possible to use one modem to establish remote communications with multiple 70 Series devices when the Ethernet option (preferred) is not fitted, the following proprietary convention is employed.

When using HyperTerminal or a dial-up modem with RS485, the port on the IED must be configured for "ZModem" protocol, *not for "ZModem/Display/Log".* This is done with the pull-down menu in the Configurator program, see illustration below. Selecting ZModem also enables an address to be set for the selected com port. When daisy-chaining multiple devices on RS485, each device must have a unique address.



Type the command "connect 01" (use the *actual* address assigned) to establish communications with the device in ZModem protocol using RS485. *This command will not be echoed back as you type it.* After striking the enter key, the device will return a command prompt (for example c:\>, e:\data>, c:\config>, etc.) Once communications are established, you can now use the command-line interface, exactly as you would with a direct RS232 connection, to control the device (services supported by ZModem protocol include: download recording files, control digital outputs, reset demands, set time and date, etc.). In order to disconnect from one device and connect to another on the same bus, type the command "exit" to end the session then type “connect 02” (or whatever address you want to connect to).

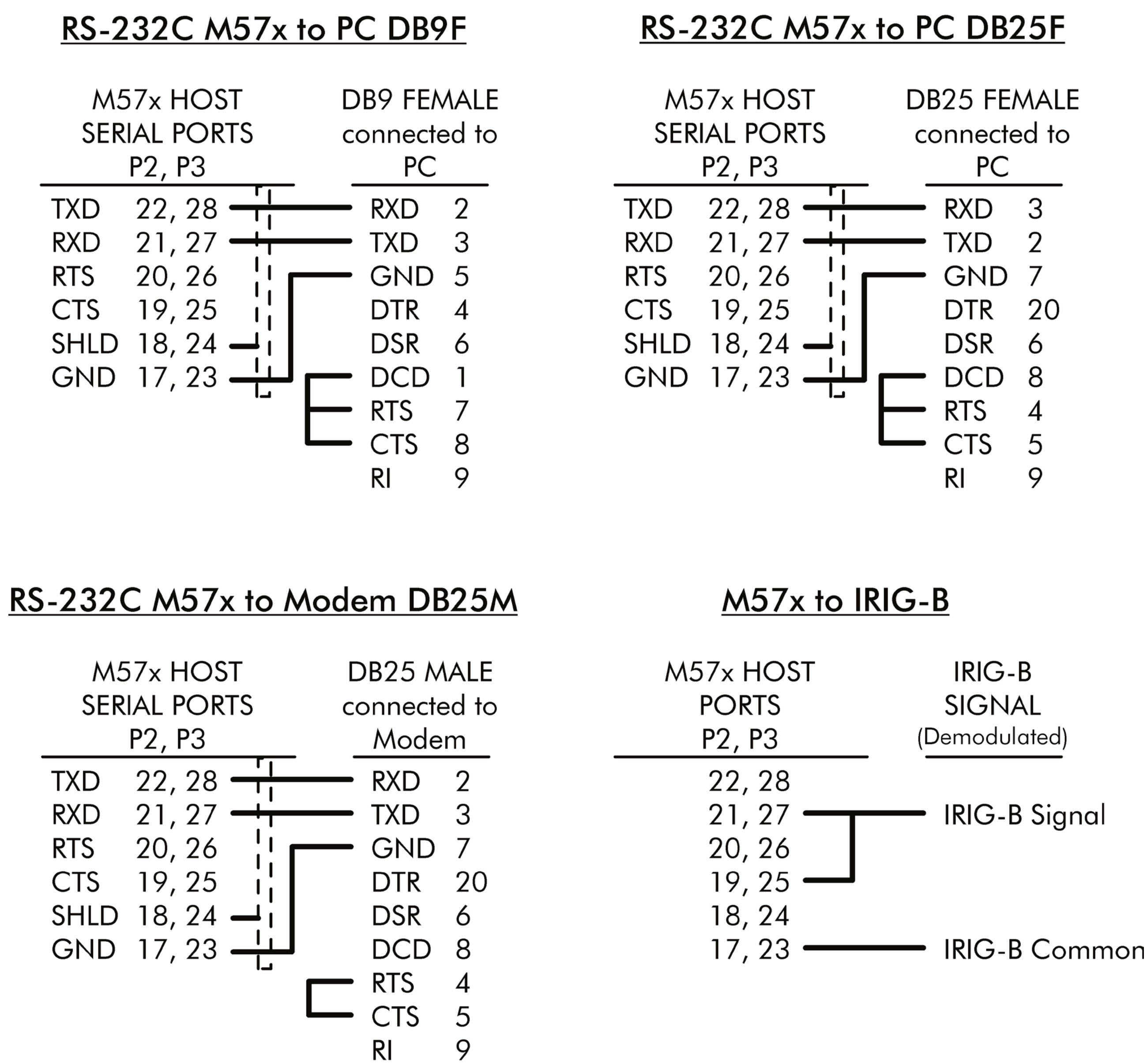
4.3 Diagnostic Status LED’s (S1, S2, S3)

There are three LED’s on the front panel: S1, S2, and S3. They perform the following functions:

LED	Description

LED	Description
S1	On while flash memory is being written to, otherwise off.
S2	Flashes every 5 power-line cycles, indicates DSP operating properly.
S3	On while CPU is busy. Intensity indicates CPU utilization level.

M57x RS-232 & IRIG-B Cable Connections



The cable should be Belden 9842 or equivalent.
The maximum cable length for RS-232 is 50 ft (15m).

Figure 4- Typical RS-232 & IRIG-B Cable Wiring

M57x RS-232 Adapter Cable Connections

Adapter - M57x RJ11 (P1) to DB9 Female

RJ-11 connected to M57x P1			DB9F PORT (to PC)	
TXD	3	—	RXD	2
RXD	4	—	TXD	3
GND	5	—	GND	5
+15V	2	—	DSR	6
CTS	6	—	RTS	7
RTS	1	—	CTS	8

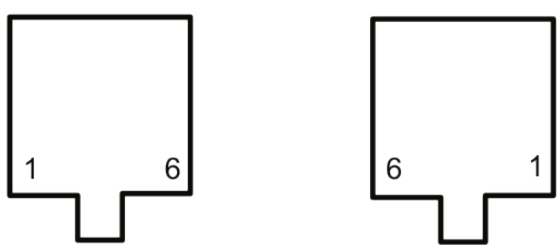
Part no.: M570-RJ11DB9F

Parts List:
Newark Electronics Kit Part No. 50F9354 or Unicom Electric Part No. DEM-25F, Connector Housing kit
Digi-Key H1662-07ND, 7 ft. 6 conductor RJ11 modular flat cable.

For RS232 Serial Port connection, the P1 port of the M57x and the PC must be set to matching baud rate and parity.

A straight through cable is required between the DB9 connector of the Adapter cable and the PC COM port.

Pin Designations for RJ11



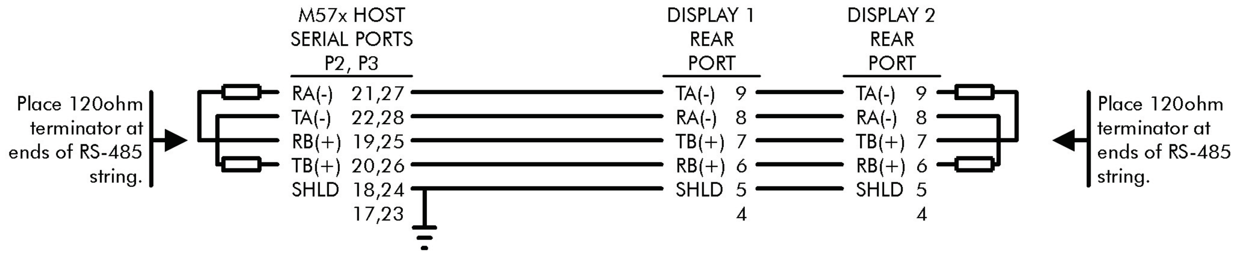
RJ11 Socket RJ11 Plug

RDS Wiring 232 adapter.cdr 11/3/05

Figure 5 – Display P1 Adapter cable - RJ11 to DB9

M57x RS-485 Cable Connections

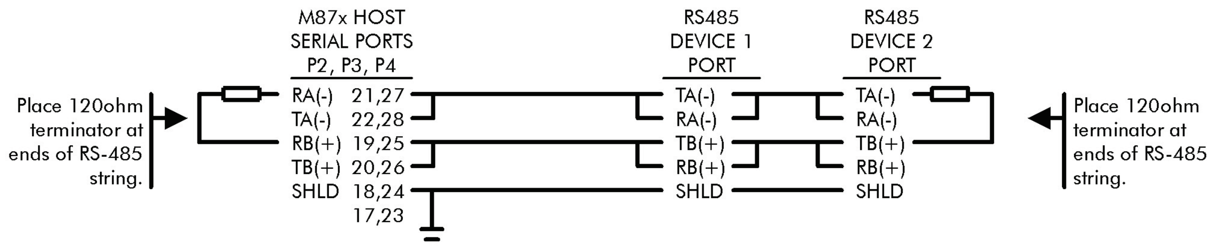
M57x Ports to M870D Display Rear Port (4-Wire, Full Duplex)
ZMODEM, Display Protocols



The rear port of the M870D and the Host port of the M57x must be set to RS-485, matching Baud rates and parity, and Display protocol.

The cable should be Belden 9842 or equivalent. The maximum cable length for RS-485 is 4000 ft (1200m).

M57x Ports to Generic RS485 Device (2-Wire, Half Duplex)
Modbus, DNP3 Protocols

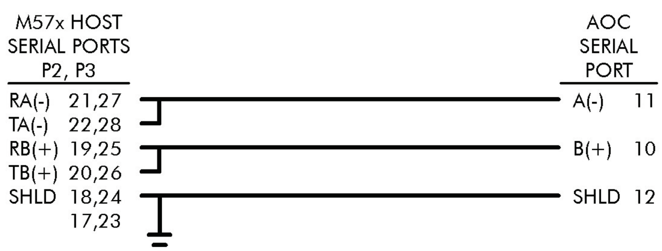


The rear port of the M870D Display and the Host port of the M87x must be set to RS-485, matching Baud rates and parity, and Display protocol.

The cable should be Belden 9841 or equivalent. The maximum cable length for RS-485 is 4000 ft. (1200m)

M57x RS-485 Cable Connections

RS-485 M57x to AOC



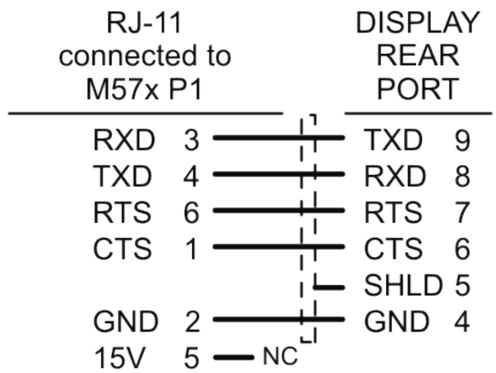
Refer to text for information on port configuration.

The cable should be Belden 9841 or equivalent. The maximum cable length for RS-485 is 4000 ft. (1200m)

Figure 6 - Typical RS-485 Cable Wiring

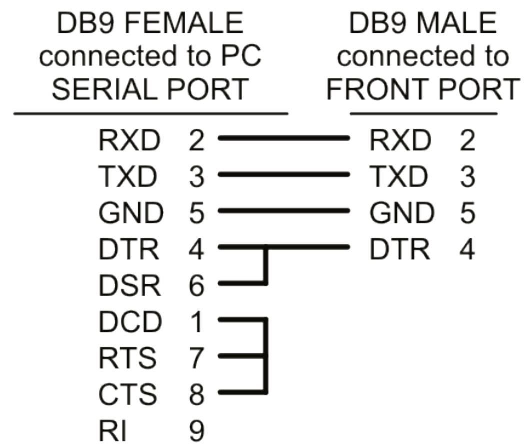
M870D RS-232 Cable Connections

M870D Rear Port to M57x RJ11 (P1)



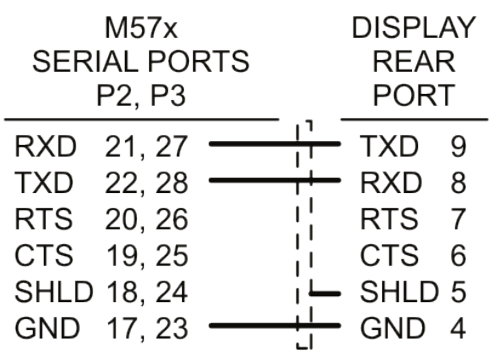
6 conductor RJ11 flat cable - RTS & CTS are required for file downloads when connecting a PC thru the M870D Front port. Otherwise, 4 conductor RJ11 flat cable will suffice for display operation.

M870D DB9F Front Port to PC DB9M

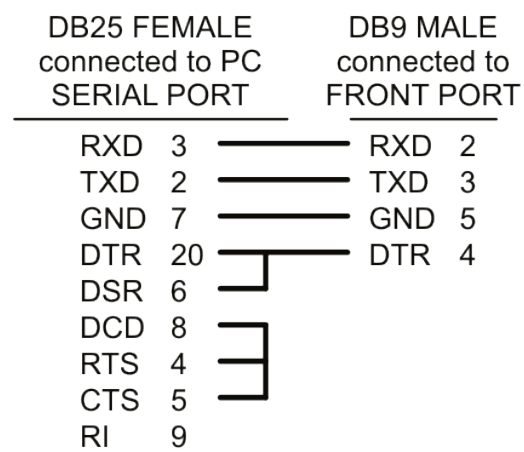


The RS232 Front (Service) port can be connected using a PC COM port to download files from an M57x to a PC.

M870D Rear Port to M57x Serial Ports



M870D DB9F Front Port to PC DB25M



The RS232 Front (Service) port can be connected using a PC COM port to download files from an M57x to a PC.

The rear port of the M870D Display and the port of the M57x must be set to RS-232, matching Baud rates and parity, and Display protocol.

The cable should be Belden 9842 or equivalent, unless otherwise specified.
The maximum cable length for RS-232 is 50 ft (15m).

RDS Wiring 232 r2.cdr 11/3/05

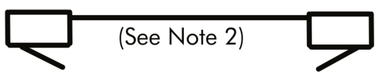
Figure 7 – Detached Display: M870D RS-232 Cable Wiring Diagram

M570D Display RS-232 Cable Connections

M570D Display Rear Port to M57x Port P1

M570D REAR PORT RJ11-6 Pos. (RJ12)	Pin	Wire	M57x Display P1 PORT RJ11-6 Pos. (RJ12)	Pin
CTS	1	TP1 Wire 1	RTS	6
GND	2	TP1 Wire 2	GND	5
RXD	3	TP2 Wire 1	TXD	4
TXD	4	TP2 Wire 2	RXD	3
+15V	5	TP3 Wire 1	+15V	2
RTS	6	TP3 Wire 2	CTS	1
N.C. (Cut back)		TP4 Wire 1	(Cut back) N.C.	
N.C. (Cut back)		TP4 Wire 2	(Cut back) N.C.	
Drain (Shield)		Screen	(Shield) Drain	

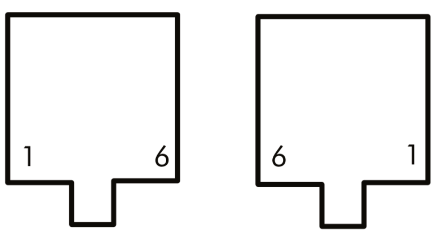
Cat 5e Shielded Cable - 8 Position



RJ11-6 Pos. IDC Plug with metal housing (RJ12)

RJ11-6 Pos.IDC Plug with metal housing (RJ12)

Pin Designations for RJ11-6 Position (RJ12)



RJ11-6 Pos. Socket (RJ12)

RJ11-6 Pos. Plug (RJ12)

M570D-DB9F Front Port to PC DB9M

DB9 FEMALE connected to PC SERIAL PORT	Pin	DB9 MALE connected to FRONT PORT	Pin
RXD	2	RXD	2
TXD	3	TXD	3
GND	5	GND	5
DTR	4	DTR	4
DSR	6		
DCD	1		
RTS	7		
CTS	8		
RI	9		

The cable should be Belden 9842 or equivalent.

M570D-DB9F Front Port to PC DB25M

DB25 FEMALE connected to PC SERIAL PORT	Pin	DB9 MALE connected to FRONT PORT	Pin
RXD	3	RXD	2
TXD	2	TXD	3
GND	7	GND	5
DTR	20	DTR	4
DSR	6		
DCD	8		
RTS	4		
CTS	5		
RI	9		

The cable should be Belden 9842 or equivalent.

1. The rear port of the M570Display and the Host port of the M57x must be set to RS-232, matching Baud rates, parity, and Display protocol.

2. The cable should be 5e screened 100 ohm 26AWG patch cord, Quabbin Datamax 2900 or equivalent. The maximum cable length for RS-232 is 50 ft. (15m). Drain wire must solder to the metal housing on RJ11-6 pos. (RJ12) connectors at each end of the cable. Cut back the unused wire pair to coincide with end of the cable jacket. Datacomm Cables, Inc., 800-422-2531, is a source for custom length cables. Datacomm Cables P/N 1212-7/SH is 7 feet in length.

M570D_RDSCablesR2-232.cdr, 31MAR06

Figure 8 – Detached Display: M570D Cable Wiring Diagram

4.4 Digital I/O (optional)

The high speed Digital I/O section features 3 inputs that share a common return and 1 fully isolated input. The 4 outputs consist of 3 outputs sharing a common return and 1 fully isolated output. Digital Input transition times are time-stamped. Outputs can be turned on or off based on commands received over communication links or by internal states generated by energy pulses, recorders, etc.

The M57x circuitry reads the state of the digital inputs every time it samples the analog inputs, and the sample rate of the digital inputs is tied to the frequency of the analog inputs. The Waveform and Disturbance Recorders may be configured to record the status of the digital inputs.

Consult the appropriate Protocol manual for information on reading the digital inputs or setting the digital outputs.

4.4.1 Debounce Time Setting

The Digital Inputs can be filtered to compensate for “chattering” relays, etc. The debounce time may be set using the 70 Series Configurator software, via the various protocols. An input transition is not recognized until the input remains in the new state for a time longer than the debounce time. Values between 30 μs and 1 second are acceptable.

An event triggered from the digital inputs will be subject to the debounce time setting for the digital input. Digital input traces in the Waveform and Disturbance files are the instantaneous status of the inputs, and DO NOT reflect any debounce time settings. If a long debounce time is set, it is possible to see an event on the digital input that does not cause a trigger.

5.0 FUNCTIONAL DESCRIPTION

5.1 Passwords

The M57x IEDs utilize the standard Bitronics password scheme. There are three different access levels:

Level 0: This access level provides read-only access to all settings and data, thus preventing modification of information that affects system security. The factory default password for level 0 is 'AAAA'; this is the same as entering no password.

Level 1: This access level includes the read access of level 0. In addition, the user is permitted to delete recorder files, and reset energy and demand values. The factory default password for level 1 is 'AAAA'; this is the same as entering no password.

Level 2: This access level includes all lower level functionality. The user is also granted full read/write/delete access on all files in the M57x, including the configuration files. The factory default password for level 2 is 'AAAA'; this is the same as entering no password.

NOTE: The factory default is to allow level 2 access with no password. For the password scheme to take affect, the user must change the passwords with the 70 Series Configurator.

5.2 Configuration

Setup of the M57x IEDs is most easily performed using the 70 Series Configurator. This software runs on a PC and allows the PC to communicate to the M57x using a serial port or Ethernet connection. The M57x configuration is stored internally by means of several configuration files, located in the M57x "c:\CONFIG\" directory shown in the following table. Most of these are ASCII text files, and may be saved, copied, and deleted by any of the various methods of file manipulation, such as FTP, ZMODEM, and the 70 Series Configurator.

If using IEC61850 protocol, the configuration of the IP and SNTP addresses will be determined based upon a selection the user makes by way of the radio button selections found on the 70 Series Configurator Identity page. The radio buttons provide the user with the flexibility to decide which software tool will control the IP and SNTP address configuration settings. Configuration settings are loaded upon reboot from either the Initialization (INI) files or the Micom Configuration Language (MCL) files, depending upon the radio button selected during configuration. The IP and SNTP addresses will be loaded either from the respective address settings stored in the INI file by the 70 Series Configurator or from the address settings stored in the MCL file by the IEC61850 IED Configurator. Addresses written into the MCL file will be written back into the INI file when the unit reboots. It is only possible to synchronize the addresses by reading the address information written into the MCL file back into the INI file upon reboot. (The IP and SNTP Addresses are rewritten to the INI file though the 70Series Configurator upon reboot since the IEC61850 IED Configurator does not have the ability to rewrite information once the configuration is written to the MCL file). There is a mechanism to automatically sychronize these addresses upon rebooting the M57x, so that the current IP address for the M57x will be updated on the 70 Series Configurator Identity page. For the case when the radio button is selected as “IEC61850 IED Configurator (MCL file)” the IP networking information will appear in grey indicating the IEC61850 IED Configurator is the active tool. Only the 70 Series Configurator allows the user to select which configurator tool loads the IP and SNTP addresses.

The configuration files are stored in the M57x directory c:\Config. The 70 Series Configurator will generate the IED Capability Description (ICD) file and automatically store it on the M57x in directory c:\Config. If using IEC61850 protocol 2 additional files, an MCL file and an MC2 file, will be generated by the IEC61850 IED Configurator and will be stored on the M57x in the c:\Config directory. The MCL files are the Micom Configuration Language files and contain the information pertaining to the IEC61850 Configuration. The MCL file is stored as the active bank and contains the IEC61850 configuration and the MC2 file becomes the inactive bank, containing the previous IEC61850 configuration.

Filename	Directory	Description
COMM.INI	c:\CONFIG\	Contains serial port information.
DEMANDS.INI	c:\CONFIG\	Contains demand intervals.
DIO.INI	c:\CONFIG\	Contains Digital I/O data, i.e. the Digital I/O debounce time.
DISPLAY.BIN	c:\CONFIG\	Contains setup information for communicating with a remote display
DNP.BIN	c:\CONFIG\	Contains DNP configurable register information
DR1.INI	c:\CONFIG\	Contains setup information for Disturbance Recorder 1
DR2.INI	c:\CONFIG\	Contains setup information for Disturbance Recorder 2
DSP.INI	c:\CONFIG\	Contains CT/VT ratios, user gains and phase, harmonic denominators, and VA calculation
IDENTITY.INI	c:\CONFIG\	Contains Identity info, i.e. device name of M871, IP address, NSAP address.
MODBUS.BIN	c:\CONFIG\	Contains Modbus configurable register information
PROTOCOL.INI	c:\CONFIG\	Contains Modbus, Modbus Plus, and DNP protocol setup information.
SBO.INI	c:\CONFIG\	Contains UCA2.0 Select Before Operate parameters
SCALEFAC.INI	c:\CONFIG\	Contains integer-to-floating point scale factor info for UCA.
TR1.INI	c:\CONFIG\	Contains setup information for TR1 recorder.
VIO.INI	c:\CONFIG\	Contains Virtual Input/Output setting information.
WR1.INI	c:\CONFIG\	Contains Waveform Recorder 1 Configurator parameters
WR2.INI	c:\CONFIG\	Contains Waveform Recorder 2 Configurator parameters
TRIGGER.INI	c:\CONFIG\	Contains all trigger configuration info
MEASUSER.INI	c:\CONFIG\	Contains user defined measurement names
VFT.INI	c:\CONFIG\	Contains Voltage Fluctuation Table configuration
COM.BIN	c:\PERSIST\	Password file
HARDWARE.INI	c:\CONFIG\	Contains configured hardware info
SYS_CNFG.INI	c:\PERSIST\	Contains hardware found by unit

There are also several ".BIN" files in the "c:\CONFIG\" directory which contain information on the protocol register configuration for Modbus, Modbus Plus and DNP. These files are written by the 70 Series Configurator and are not editable by the user.

AFTER WRITING THE CONFIGURATION FILES, THE M57X IED MUST BE RESTARTED (REBOOTED) BEFORE THE NEW CONFIGURATION WILL TAKE EFFECT.

5.3 Triggering

Triggers can be configured in the 70 Series to initiate several different actions:

Waveform Recorders
Disturbance Recorders
Digital Outputs
Virtual Outputs
SOE Entries
Resetting of various measurements (Demands, Energy, etc.)

Up to 120 triggers can be specified, of the following types:

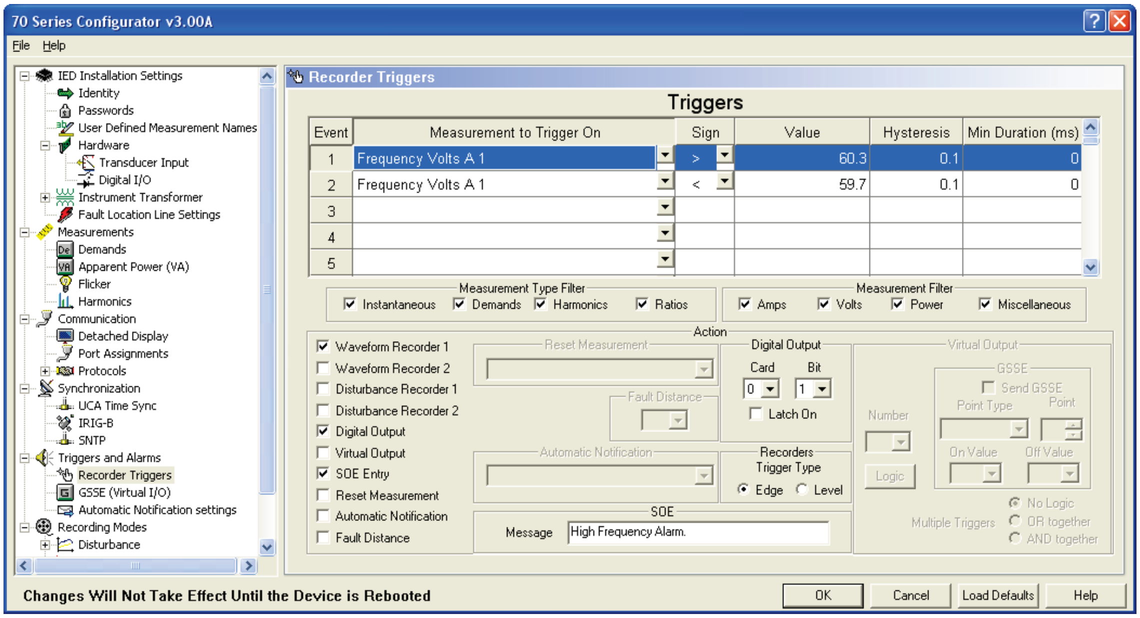
5.3.1 Threshold Trigger

Any measurement can be used to trigger a Waveform Recorder or Disturbance Recorder, or create an entry in the SOE log. Configuring multiple triggers will cause a logical "OR" to be applied to the list of triggers. The trigger thresholds are defined by the 70 Series Configurator. The user specifies the measurement to use, the threshold value, the arithmetic function of the trigger, and the hysteresis value.

If the measurement is an analog value (such as volts or amperes), the user may choose to trigger on values greater than or less than the threshold. Additionally, the user may choose a rate-of-change trigger greater than, less than, or equal to the threshold value. Rate-of-change intervals are calculated over the interval since the measurement was last updated.

5.3.1a Trigger Hysteresis

Hysteresis is used to prevent chattering of contacts or unintended repeat-triggering of recorders when a measurement fluctuates near the value where the action is intended to occur. Refer to the Hysteresis column on the Recorder Triggers page of the 70 Series Configurator program (below). The hysteresis setting is used to make the trigger occur and re-initialized at different values. In the example below, since 60.3 Hz - 0.1 = 60.2 Hz, the action takes place when frequency exceeds 60.3 Hz and re-initializes below 60.2 Hz. When hysteresis is set to zero (default) the action triggers and resets at the same value.



Configuration of Hysteresis Settings

For example: Suppose an alarm contact is intended to close when the frequency exceeds 60.3 Hz. Frequency is generally regulated very tightly about 60 Hz, so except for the significant transients that the setting is intended to capture, it would not be unusual for the frequency to dwell for a prolonged time near 60.3 Hz, fluctuating by only an insignificant amount but crossing the threshold many times (see illustration below, on the right half of the trace). To eliminate this chatter, the user might configure the hysteresis to be 0.1 Hz, as shown above. Then if the frequency were to rise from normal to the high frequency alarm range as illustrated below, the contact will close exactly as it passes 60.3 and it will remain closed until the frequency decreases below 60.2, when the contact opens.

The hysteresis function operates symmetrically when used with measurements that trigger below a threshold. So for Event 2 shown in the *70 Series Configurator* screen above, a trigger would occur when the frequency drops below 59.7 Hz, and reset above 59.8 Hz.

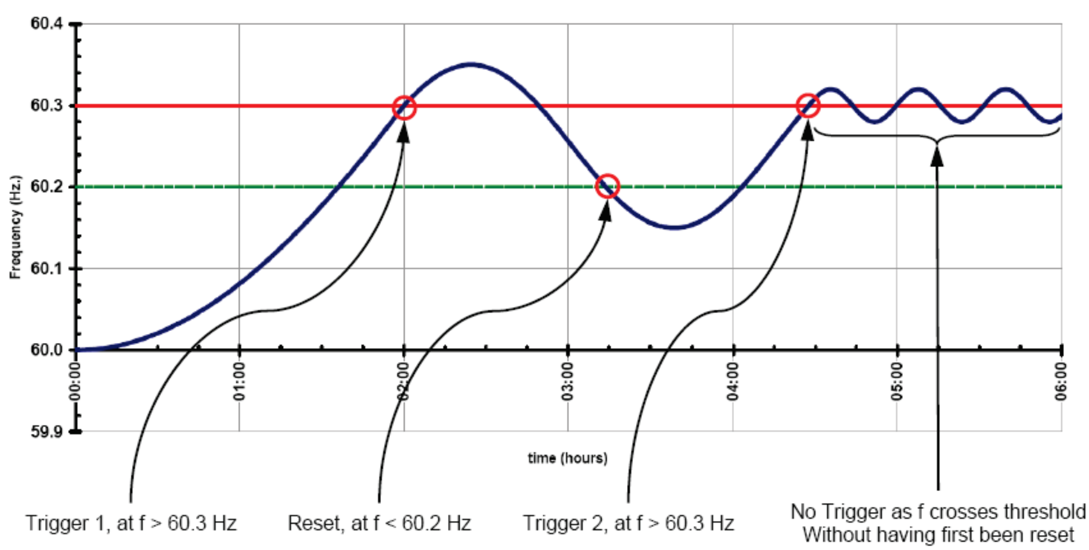


Illustration of Trigger and Reset (or Operate and Release) when using Hysteresis

Hysteresis may be used to constrain chatter in any of the Actions listed on the *Recorder Triggers* page (i.e. recorders, contacts, GOOSE messages, SOE Log entries, etc.) It may also be combined with a setting in the “Min Duration (ms)” column to prevent triggering on short-duration transients when a trigger might only be desired in connection with steady-state events; tap-changing for voltage control for example.

5.3.2 Digital Input Trigger

A waveform or disturbance record or an SOE log entry can be triggered by using any of the digital inputs on the Digital Input/Output Module (Section 4.4). Any or all of the digital inputs can be used to trigger a record. Each input can be independently set to trigger on a state transition. Assigning the digital inputs to initiate a record MUST be performed by using the 70 Series Configurator.

An event triggered from the digital inputs will be subject to the debounce time setting for the digital input. Digital input traces in the Waveform Recorder files are the instantaneous status of the inputs, and do not reflect any debounce time settings. If a long debounce time is set, it is possible to see an event on the digital input that does not cause a trigger.

5.3.3 Edge and Level Triggers

The user can select between Edge and Level Triggers.

An Edge trigger exists for only an instant in time. The time before the trigger is defined the Pre-trigger period, and the time after the trigger is the Post-trigger period.

A Level trigger has duration in time. The trigger is valid as long as the trigger condition is met. The time before the trigger is still defined the Pre-trigger period, but the Post-trigger period does not begin until after the trigger condition is no longer valid.

5.3.4 Manual Trigger

Refer to the appropriate protocol manual for information. Manual Triggers may also be activated through BiVIEW using Telnet, ZMODEM, or under Modbus or DNP3 protocols (depending on what register set/ point list is chosen). When a manual trigger is initiated, it bypasses the standard trigger setup, and directly intitiates the action specified by that command.

5.3.5 Logical Combinations of Triggers

Triggers can be logically combined in groups to perform actions. Each trigger is assigned to the same Virtual Output in the Configurator, and the type of logic function (AND or OR) is selected. That Virtual Output is then configured as a new trigger, with the appropriate action assigned. If "No Logic" is selected, then only one trigger can be assigned to a particular Virtual Output.

5.3.6 Cross Triggering Multiple 70 Series Units

Under certain circumstances, it is advantageous that a 70 Series device that captures a record, also functions in a capacity to send out a pre-determined trigger condition. That trigger condition, which is based on values measured by the instrument, can be used for the purpose of cross triggering (also referred to as inter-triggering) other 70 Series devices. Cross triggering is an essential requirement for synchronizing the equipment in a substation, where it is necessary that multiple instruments sense the occurrence of particular conditions

There are a number of ways to accomplish cross triggering across 70 Series devices. The cross triggering mechanism can be accomplished by way of a physical interconnection using Digital I/O, or by way of virtual messaging, which is communicated over an Ethernet network connection. Refer to Appendix A4 for examples of setting up cross triggering through either Digital I/O connections, GSSE messaging [through UCA], or GOOSE messaging [through IEC61850].

The Digital I/O option is necessary to set up cross triggering using a Digital I/O interconnection method. An Ethernet option is necessary in order to set up either GSSE messaging [through UCA] or GOOSE messaging [through IEC61850].

Units may both send and receive cross triggers from and to multiple other units.

5.3.7 Fault Distance Triggers

Fault distance calculations are initiated as an action from the configurable Triggers. For a chosen trigger, select the Fault Distance checkbox, and then the associated phase from the dropdown box. A simple limit trigger such as RMS Amps A 1 > 2000 can be set to calculate an A1 fault. Similarly, the Digital Inputs can be used to drive the calculations when connected to the outputs of a protection device. More complex conditions can be specified with the use of logic functions. For example:

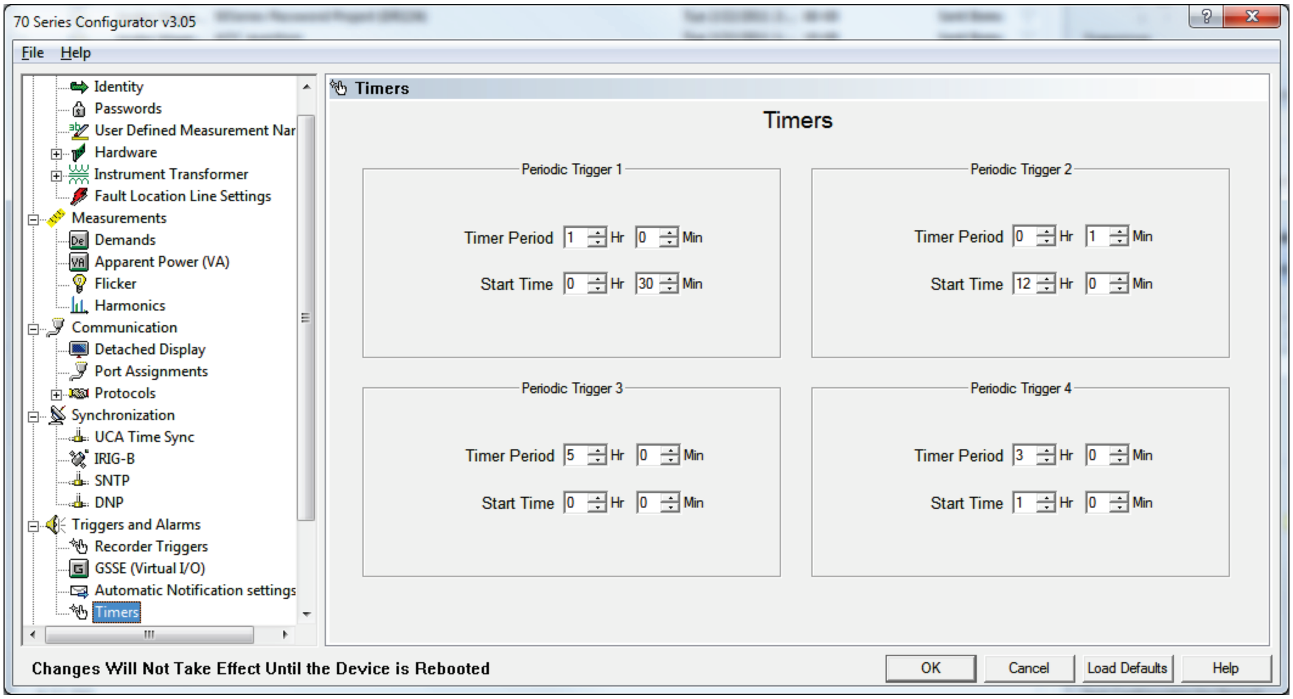
Triggers

Event	Measurement to Trigger On	Sign	Value	Hysteresis	Min Duration (ms)
1	RMS Volts B 1	<	260,000	0	0
2	RMS Amps B 1	>	2,000	0	0
3	Phase Angle Volts to Amps B 1	dt >	10	0	0
4	Virtual Output 2	=	1	N/A	0

Where the first three conditions are logically "anded" together to drive Virtual Output 2, which in turn is configured to initiate a fault distance calculation on B1. Line to line fault distances are calculated when more than one of the A1, B1, C1 events are triggered.

5.3.8 Periodic Triggers

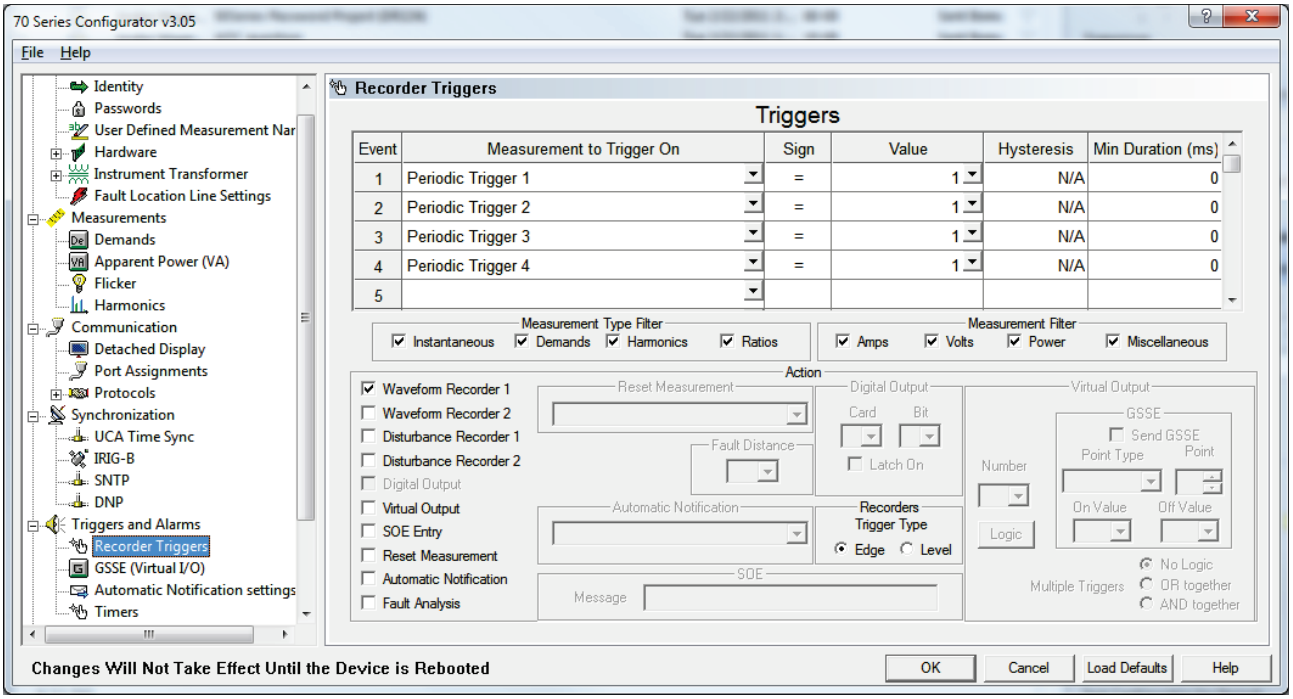
Four independent periodic triggers are available that can be used to initiate all of the actions listed in section 5.3 above. The timers for these triggers are configured to individually set the period and start time for each trigger on the Timers page of the 70 Series Configurator as shown below:



The period can be set in increments of minutes up to a maximum of 24 hours. Likewise, the time of day for the timer to start can be specified in increments of one minute.

Note that if the number of minutes in a day is not evenly divisible by the configured period, then the start time has little impact except at boot up. For example, if the period is configured for 7hrs and the start time is 0430hrs then the first day after the device starts the timer will activate at 0430hrs, 1130hrs, 1930hrs. And then on the second day, it will activate at 0230hrs, 0930hrs, 1630hrs, 2330hrs., etc.

The activation status of the timers is available as a binary point in the list of 'Measurements to Trigger On' in the Recorder Triggers page (see screen below). The point will transition from 0 to 1 at the timers scheduled activation. It will hold at 1 briefly and then return to 0. These 'Periodic Trigger' points can then be used to trigger any of the actions selected.



5.4 Recording

The M57x has five different methods of recording data. High-speed samples of the input signal are captured and stored by the two Waveform Recorders, slower-speed measurement data is stored by the two Disturbance Recorders, long-term load-profile data is stored by the Trend Recorder, and a voltage fluctuation table (VFT) and a sequence of event (SOE) log can be created as well.

The Waveform Recorders save the actual samples from the input channels, as well as from the Digital I/O modules. The two Disturbance Recorders log values at a user configurable rate of 1-3600 cycles. The Trend Recorder logs values at a user configurable rate of 1 minute -12 hours. The VFT file records voltage values when pre-selected thresholds are passed, and the SOE file creates a summary of events in the order they occur.

The Waveform and Disturbance records and the VFT and SOE files are created based on event conditions. Unlike these other recorders, the trend recorder is not based on triggered conditions but instead runs constantly when selected to record.

5.4.1 Waveform Recorder

A waveform recorder can be triggered by a measurement exceeding an upper or lower threshold, by a manual protocol command, or by a digital or virtual input channel changing state. When a trigger condition is met, a record is created that contains samples from the input channels. The waveform record normally contains 20 cycles of pre-trigger and 40 cycles of post-trigger information. The pre- and post- trigger times are configurable by the user. If additional triggers occur within the post-trigger period, the waveform record will be extended for the selected number of post-trigger cycles. Optionally, the user can choose to disable re-triggering.

There is a limit of 2000 cycles (approximately 33.3 seconds at 60Hz) for each waveform record. The M57x will continue to record waveforms until the memory allocated for the Waveform Recorder is full. Regardless of the number of records stored, if sufficient memory exists for the designated number of pre-trigger cycles the M57x will create a new record, although it may not be full-length.

When selecting the COMTRADE File Type for the Configuration settings in the Waveform Recorder, the user should be aware that certain processing limitations may be encountered that can result in data loss for a waveform record.

If the host processor encounters large amounts of data due to creating long length waveform records and is otherwise overloaded with performing other tasks, the data in the queue may be overwritten before it could be written onto the Flash drive. This is a possibility that may be encountered when attempting to handle an excessive volume of data, which may not be handled adequately by the host processor. To reduce the possibility of this occurring especially during the processing of large amounts of data, it is a good practice to tailor the selection of the COMTRADE File Type based on the desired length of the file to be recorded. As a guideline when configuring the waveform recorder, the following are useful recommendations: a Binary COMTRADE File Type used along with a lower sample rate is better for recording longer length waveform files; an ASCII COMTRADE File Type is better suited for recording short length waveform files. Binary format will generate smaller data files then ASCII format. A higher sample rate can be more useful when recording short files. Use the lowest sample rates possible when capturing long waveform records.

If the post-trigger times appear to be truncated in the COMTRADE file, that would suggest that the user adjust the waveform recorder's configuration settings, accordingly. This will usually alleviate the issues associated with recording long length waveform files.

The Waveform Recorders share storage space with the Disturbance Recorders and the Trend Recorder. The 70 Series Configurator allows the user to select the maximum available memory for each recorder function. **Note that if the user wishes to change the allocation of memory among the recorders after recordings have already been made, it is necessary to first remove the existing files from memory before making any change.**

Waveform records are presented in industry standard (IEEE C37.111-1999) Comtrade files which are stored as compressed .zip files. Waveform records may be retrieved and deleted from the instrument using the available communications protocols. Please refer to the specific protocol manual or section 5.5 (ZMODEM and FTP) for details. A file cannot be deleted while being read by another device.

The following table shows the signals that are included in the waveform record. The user can select a sampling rate of 32, 64 or 128 samples per cycle for all signals on all Mx7x models. An additional, higher sampling rate of 256 samples per cycle is available when using the M571 or the M871 models (excludes M572 and M872). Please note, however, that selecting the 256 sample per cycle sampling rate disables all measurements associated with bus 2 voltages (Volts A2, B2, and C2). Because the sampling rate is synchronized with the system frequency, the sample rate (in samples per second) will vary with frequency.

Comtrade Trace Label	WYE Definition	DELTA Definition (shown with Phase) B reference)
Volts 1 A	Voltage Bus 1 Phase A to Neutral	Voltage Bus 1 Phase A to B[1]
Volts 1 B	Voltage Bus 1 Phase B to Neutral	Always = 0[1]
Volts 1 C	Voltage Bus 1 Phase C to Neutral	Voltage Bus 1 Phase C to B[1]
Amps 1 A	Amps 1 Phase A Current	Amps 1 Phase A Current
Amps 1 B	Amps 1 Phase B Current	Amps 1 Phase B Current
Amps 1 C	Amps 1 Phase C Current	Amps 1 Phase C Current
Volts 2 A	Voltage Bus 2 Phase A to Neutral	Voltage Bus 2 Phase A to B[1]
Volts 2 B	Voltage Bus 2 Phase B to Neutral	Always = 0[1]
Volts 2 C	Voltage Bus 2 Phase C to Neutral	Voltage Bus 2 Phase C to B[1]
Amps 2 A (M572)	Amps 2 Phase A Current	Amps 2 Phase A Current
Amps 2 B (M572)	Amps 2 Phase B Current	Amps 2 Phase B Current
Amps 2 C (M572)	Amps 2 Phase C Current	Amps 2 Phase C Current
Dig In 1 (optional)	Digital Input 1	Digital Input 1
Dig In 2 (optional)	Digital Input 2	Digital Input 2
Dig In 3 (optional)	Digital Input 3	Digital Input 3
Dig In 4 (optional)	Digital Input 4	Digital Input 4

[1]When the M57x is used on a DELTA (2-element system), one of the Phase Voltage inputs will be connected to the Neutral Voltage input, and that Phase-to-Neutral voltage will then be zero. The remaining two Phase-to-Neutral voltages then become Phase-to-Phase voltages. The reference phase does not have to be Phase B.

5.4.1a Default Frequency Setting for Waveform Recorder

The Nominal System Frequency should be selected appropriately for the system in the “Instrument Transformer Ratio” page (previously named the "Advanced" tab) of the Configurator. Normally the unit will modify the sample rate to track the frequency of any CT or VT signal present. However, if there are no signals available for frequency tracking, the unit will default to the Nominal System Frequency setting.

5.4.1b Indicating Waveform Records with Digital Outputs (optional)

Any of the outputs on the Digital Input / Output Module can be configured to indicate the status of the recorder. Recorder status includes: Recorder Started, Recorder Completed, Recorder Memory Low, and Recorder Active. When a waveform record is created, the assigned output relay will be energized. When an output relay is assigned to indicate the presence of a waveform record, it can no longer be controlled via protocol commands. ***If power is removed from the M57x, the relay will revert to the default state.*** Assigning the digital outputs to indicate that a waveform record has been created must be performed by using the 70 Series Configurator. See Section 4.4 and Appendix A3 for information concerning output "Normally Open" and "Normally Closed" settings.

The indication of the status of a waveform record will persist until cleared, except for Recorder Active, which will reset when the recording is finished. Refer to the appropriate protocol manual for instructions

5.4.1c Retrieving and Deleting Waveform Recorder Files

Waveform records may be retrieved and deleted from the instrument using the available communications protocols. Please refer to the specific protocol manual or section 5.5 (ZMODEM and FTP) for details. A file cannot be deleted while being read by another device.

5.4.2 Disturbance Recorders

The M57x includes two individually configurable Disturbance Recorders. The most common method of triggering a disturbance event is by using the 70 Series Configurator to set an upper or lower threshold on one of the measurements. A disturbance record can also be initiated by a digital input or by a protocol-specific manual command. (See protocol manual for details on available commands.)

The Disturbance Recorder will archive samples of up to 64 user-selected measurements. Any measurement made by the device may be selected, allowing the user a great deal of flexibility in configuring the system. Additionally, the user may configure the Disturbance Recorder to calculate the min/max/avg of the selected measurements over the interval, or store only the present value at the end of the interval.

The number of disturbance records that can be stored is dependent on the number of measurements to record, the measurement type, and the number of pre- and post-trigger s*amples* selected.

Please note how the convention for determining time resolution in oscillography records (WR1, WR2) in samples per cycle is not relevant to long-time disturbance records (DR2, DR2), where RMS values are plotted using a sample rate measured in an integer number of cycles for each sample.

If the number of cycles/sample is set to 1, each entry in the Disturbance Record will reflect data collected over one cycle. The factory default setting provides 20 samples of pre-trigger recording and 40 samples post-trigger. The pre- and post- trigger times are configurable by the user, as is the number of cycles per sample. The maximum pre-trigger time is 1800 samples, while the maximum post-trigger time is 300,000 samples. If additional triggers occur within the post-trigger period, the disturbance record will be extended by the selected number of post-trigger samples. Optionally, the user can choose to disable re-triggering. The default cycles/sample setting is 0, which disables the recorder.

The Disturbance Recorders shares storage space with the Waveform Recorder and the Trend Recorder. The 70 Series Configurator allows the user to select the maximum available memory for each recorder function, but any record files already made should be removed before reallocating the memory as mentioned above in the Waveform Recorder section.

Disturbance records are presented in industry standard (IEEE C37.111-1999) Comtrade files stored as compressed .zip files. Disturbance records may be retrieved and deleted from the instrument via a network and protocol (refer to the specific protocol manual for details), or by using the serial ports and ZMODEM (Section 5.5.2).

5.4.2a Indicating Disturbance Records with Digital Outputs (optional)

Any of the outputs on the Digital Input / Output Module can be configured to indicate the status of the recorder. Recorder status includes: Recorder Started, Recorder Completed, Recorder Memory Low, and Recorder Active. When a waveform record is created, the assigned output relay will be energized. When an output relay is assigned to indicate the presence of a disturbance record, it can no longer be controlled via protocol commands. ***If power is removed from the M57x, the relay will revert to the default state.*** Assigning the digital outputs to indicate that a disturbance record has been created must be performed by using the 70 Series Configurator. See Section 4.4 and Appendix A3 for information concerning output "Normally Open" and "Normally Closed" settings.

The indication of the status of a waveform record will persist until cleared, except for Recorder Active, which will reset when the recording is finished. Refer to the appropriate protocol manual for instructions.

5.4.2b Retrieving and Deleting Disturbance Recorder Files

Disturbance records may be retrieved and deleted from the instrument using the available communications protocols. Please refer to the specific protocol manual or section 5.5 (ZMODEM and FTP) for details. A file cannot be deleted while being read by another device.

5.4.3 Trend Recorder

The M57x stores the values of a user-configurable set of up to 230 parameters every log interval. The default setting of this interval is 0 minutes, *which disables the Trend Recorder*. This interval can be changed from 1 to 720 minutes (12 hrs.) in 1-minute increments. Once the log file has reached its maximum length, it will wrap around to the beginning and overwrite the oldest entries in the file. The log file is stored in non-volatile memory, allowing for retrieval of a complete log file even after power has been cycled to the instrument.

The user may select between recording the instantaneous values only, or storing the minimum, maximum, and average values recorded during the previous interval. The recorded values are based on measurements that are updated every cycle.

Trend Recording is always started at the closest time that is an integral multiple of the log interval.

Example:
If the trend interval is set to 15 minutes and the M57x system clock time is 9:18, the first entry will occur at 9:30. Subsequent entries will be made at 15-minute intervals. If the trend interval is changed to 5 minutes at 9:37, the next entry will occur at 9:40. Subsequent entries will occur at 5-minute intervals.

For intervals less than 60 minutes, it is recommended that the trend interval be set to a number that will evenly divide 60 minutes. If the interval is greater than 60 minutes, it should evenly divide 24 hours.

Recommended intervals:
1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 minutes
1, 2, 3, 4, 6, 8, 12 hours

NOTE: *If the System Clock setting is to be changed backwards, it is recommended that all trend recorder files be retrieved, the time changed, and the trend recorder file be deleted. If this is not done, the file will effectively contain a section that shows time going backwards! This will cause problems with the Comtrade file format.*

5.4.3a Retrieving Trend Records

The trend file is stored on the unit in a proprietary data format. BiView or the Retriever program (supplied on the Utilities CD) is required to download & convert the raw trend file stored on the unit into an industry standard Comtrade file. When downloading the raw file via BiView or Retriever, the trend file on the unit will automatically be deleted; however both programs will preserve a copy of the raw trend file on the PC and append the new data every time the trend file is downloaded.

5.4.4 Comtrade Format

Waveform and Disturbance Records are available in Comtrade file format (C37.111-1999) and Trend Records can be converted into this format when retrieved using BiVIEW or Retriever software programs. These are user-selectable binary or ASCII format files. The files are stored as compressed .zip files to increase storage and decrease user download times. These files may be retrieved and deleted from the instrument using the available communications protocols. Please refer to the specific protocol manual or section 5.5 (ZMODEM and FTP) for details. A file cannot be deleted while being read by another device.

The Waveform Recorder file "**WR1_nnnn.CFG**" or "**WR2_nnnn.CFG**" will contain the event parameters including the names of the channels, time of start of file, time of trigger, and sampling frequency for each cycle. The file "**WR1_nnnn.DAT**” or "**WR2_nnnn.DAT**" contains the time of each sample and the data. The data values are integers and can be scaled back to primary units using the scale factors in the .CFG file. The file name format, **"WR1_nnnn.CFG"** and **"WR1_nnnn.DAT"**, indexes automatically from **"WR1_0001.xxx"** to **"WR1_9999.xxx"**. Similarly, Waveform Recorder 2 files will be stored as "**WR2_nnnn.CFG**" and "**WR2_nnnn.DAT**".

Upon power-up (or re-boot), the M57x notes the highest index number in memory, and will increment by one for the next file. If there are no waveform records, the next one will be WR1_0001. If there is a WR1_0034 in memory upon re-boot, the next file will be WR1_0035. Note that if the stored files are deleted, but the M57x is not re-booted, it will continue to index in sequence as if the files were still there.

The Disturbance Recorder stores files in the same manner as the Waveform Recorder. Files from Disturbance Recorder 1 will be saved as "**DR1_nnnn.CFG**" and

"**DR1_nnnn.DAT**", with the same indexing sequence as the waveform files. Similarly, Disturbance Recorder 2 files will be stored as "**DR2_nnnn.CFG**" and "**DR2_nnnn.DAT**".

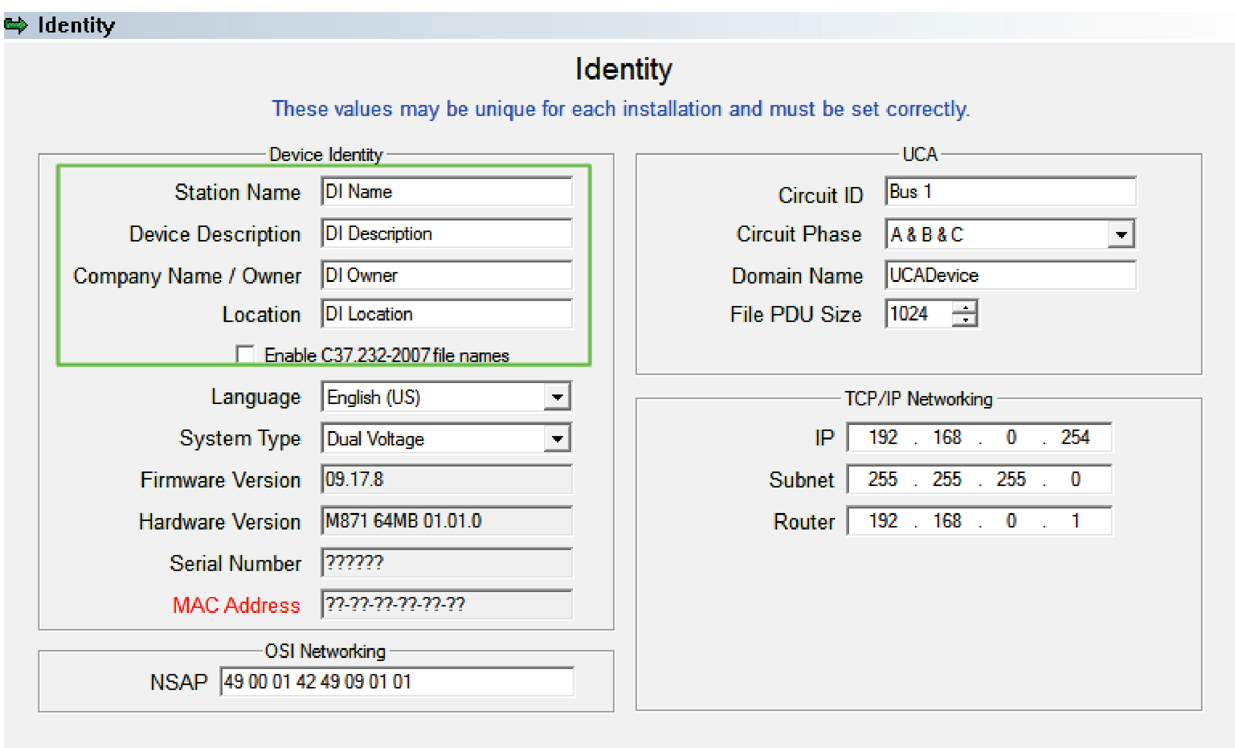
The Trending file "**TR1.CFG**" will contain the event parameters, including the names of the channels, time of start of file, and trend interval for each measurement. The file "**TR1.DAT**" contains the time of each sample and the data. The data values are integers and can be scaled back to primary units using the scale factors in the .CFG file.

5.4.4a Comtrade ZIP Files

The .CFG and .DAT files are combined into a single .ZIP file, which is placed in the c:\DATA\ or e:\DATA directory (see section 5.5). This file may be retrieved using FTP, ZMODEM, or protocol specific file transfer methods. Note that the .ZIP file may take up to 1 minute to appear in the c:\DATA\ directory after the records are created.

5.4.5 IEEE Long File Naming Convention

The 70 Series IEDs are capable of creating record files that meet the IEEE C37.232-2007 standard for file names. The long filename feature is enabled and configured on the Identity Page of the 70 Series Configurator. The Identity Page is shown below with factory default values. Settings relevant to long filename configuration are highlighted in green.



When the long filename feature is enabled, the Disturbance Recorder and Waveform Recorder functions of the IED will create IEEE C37.232-2007 compatible names for all generated Comtrade files. Note, that in all cases the IED compresses and stores Comtrade files within a Zip file. Generation of Comtrade files for the Trend Recorder function is handled by the BiView software application. BiView retrieves the Trend Recorder data and the Identity configuration from the IED and then converts to a Comtrade file. BiView will use the long filename configuration obtained from the IED.

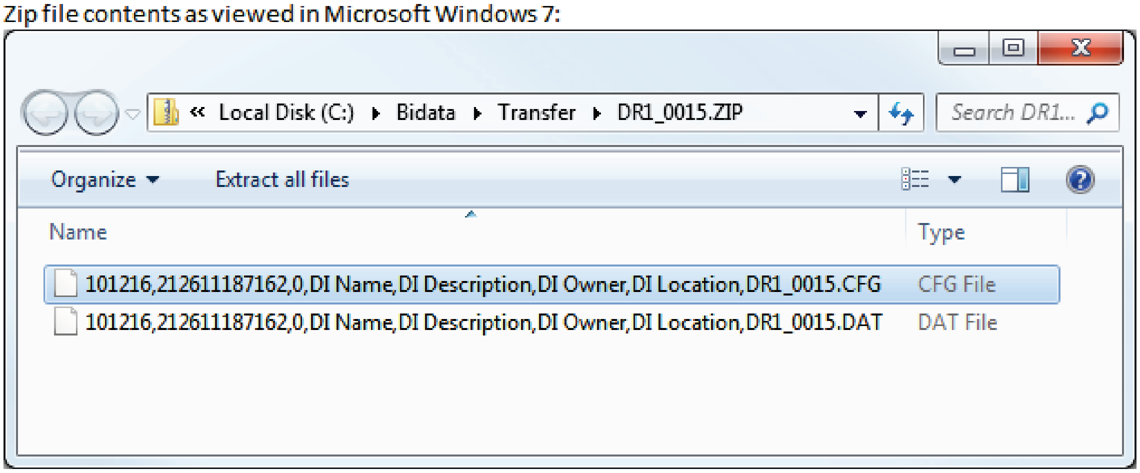
IEEE C37.232-2007 defines the following disallowed characters: ? “ / \< > * | : ; [ ] $ % { } (i.e., question mark, quotation mark, forward slash, backward slash, less than, greater than, asterisk, pipe, colon, semi-colon, brackets, dollar sign, percent, and braces). The 70 Series Configurator permits the use of these characters on the Identity Page, but they will be replaced with an underscore (_) in the resulting long filename. Note, the use of periods (.) and commas (,) while permitted by IEEE C37.232-2007 and properly handled by the 70 Series Configurator, may produce unexpected results when interpreted by a third party software application.

IEEE C37.232-2007 Field	Source	Notes
Start Date	Comtrade 'Start Time'	from CFG file
Start Time	Comtrade 'Start Date'	from CFG file
Time Code	Always zero	No time zone offset
Station ID	Identity page 'Station Name'	Limited to 32 characters
Device ID	Identity page 'Device Description'	Limited to 32 characters
Company Name	Identity page 'Company Name / Owner'	Limited to 32 characters
User 1	Identity page 'Location'	Limited to 64 characters
User 2	Original Zip file name	Such as DR1_0010 or WR2_0003
Extension	CFG or DAT	

Example long filename from Disturbance Recorder 1 using default configuration for fields:

```
101216,212611187162,0,DI Name,DI Description,DI Owner,DI Location,DR1_0015.CFG
101216,212611187162,0,DI Name,DI Description,DI Owner,DI Location,DR1_0015.DAT
```

Zip file contents as viewed in Microsoft Windows 7:



5.4.6 Voltage Fluctuation Table (VFT) File

The 70 Series IEDs are capable of creating a VFT file, which is used in conjunction with an external software package for monitoring Sags and Swells.

The raw data for each voltage channel is derived from 1 cycle RMS values that are updated each quarter cycle.

Each table contains one bus of voltages, phases A, B, & C
For units that have two buses of volts, two separate tables will be created. This currently includes M871, M571, M872 Breaker & a Half, and M572 Breaker & a Half.
Reference voltages will not be recorded in the table; therefore the M872 Dual Feeder & M572 Dual Feeder will only have 1 table.
The 70 series will maintain the minimum and maximum value for each voltage channel.
When the voltage for a channel crosses a user configured threshold an entry will be made in the table. The user can configure up to 30 thresholds but a minimum of 3 thresholds must be configured. The default configuration for the thresholds are :

- 110% of Nominal
- 90% of Nominal
- 1% of Nominal

A fixed value of 1% of nominal will be used for the hysteresis.
For Dips & Interruptions, the threshold is passed going down on the value the user specifies. On the way up, the threshold is passed at the value + 1% nominal.
For Swells, the threshold is passed going up on the value the user specifies. On the way down, the threshold is passed at the value – 1% nominal.

The Voltage Fluctuation Table consists of 2 files:

- VFTn.DAT
- VFTn.INI

Where n is the number of the bus. Currently n may be 1 or 2.
The DAT file is a text file with one entry per line. Each data value is separated by a semicolon. The order of the data values is

- Entry Number
- Time Tag seconds
- Time Tag milliseconds
- Phase Code
- Minimum Value
- Maximum Value
- Current value, that has passed threshold
- Voltage Ratio
- Ratio Offset

An example of 1 line
1803;351009204;335;20001002;55.734;55.734;79.932;1.0;0.0

The DAT file will be allowed to grow to 100K. This will result in proximally 1700 entries.

Due to flash drive limitations, the M57x can only have a finite number of entries. To prevent the file from growing too large, and ensure the newest data is always available, the M57x overwrites the oldest entry as needed.
Because the DAT file will be circular it will have a virtual end of file marker, thus making it easy to see where the oldest entry is. The end of file marker will be "**** End of File ****"

with out the quotes, and it will be on a line by itself.

A new “Voltage Fluctuation Thresholds” page in the 70 Series Configurator was created that allows the user to configure the Voltage Fluctuation Table. The user has the following options for each bus:

Enable/Disable the Voltage Fluctuation Table
Set the nominal voltage in primary units
Set the thresholds (can have 3-30 thresholds) entered in % of nominal

The files for the Voltage Fluctuation Table are available to download via Ethernet or Serial ports using BiView, Retriever, Internet Explorer, and HyperTerminal, ZModem, FTP. The files are not available via Modbus File Transfer.

5.4.7 Sequence Of Events (SOE) File

The M57x creates a record, in chronological order, of all events that occur, including:

Triggers
Health Check status errors
Change of state of status inputs and outputs
Creation of files
Change of configuration
Setting of clock
Record of Boot up

The SOE.LOG file is an ASCII text format file, and typically can be up to 5000 lines.

5.5 M57x File System

Files are stored in the M57x on internal drives labeled "c:" and "d:". Optional compact flash memory is accessible as drive "e:" Both FTP and ZMODEM may be used to access any drive. All other user accessible .files will be stored on the c: drive unless the unit is equipped with the optional compact flash memory. In this case these files are stored on the e: drive. The following directories are relevant to the user:

Directory	Function
c:\config	Location of Configuration files
c:\upload	Location of restart.now file
c:\data or e:\data	Location of recorder compressed ZIP files
d:\data	Location of trend recorder files

5.5.1 FTP Server

The M57x incorporates an internet-compatible FTP (File Transfer Protocol) data server. This allows user access to any program or data file that exists on the M57x. It has the following primary uses:

1. Allows remote software updates to be written to the M57x.
2. Allows determination of the time of last software update.

3. Allows configuration ".INI" files to be written, copied, and deleted from the M57x.
4. Allows Comtrade files to be read and deleted from the M57x.

The M57x can support up to 50 simultaneous FTP connections.

5.5.1a Introduction to FTP

FTP protocol is a standard component of the Internet protocol suite and is used to transfer files between computer systems. Every Windows/Unix/Linux operating system contains an FTP Client program that allows simple access to FTP Servers such as the M57x. FTP is accessed from the command prompt (sometimes referred to as the DOS prompt). A (simplified) sample session appears on the screen as:

> C:\windows> FTP 192.168.0.254
> M57x server, enter user name: **anonymous**
> Enter password: BITRONICS (Any password will work)
> FTP> binary

Some Operating Systems default to ASCII mode for FTP. Entering "binary" ensures that the FTP connection will be in the binary mode necessary for communicating with the M57x.

As shown above, the user specifies the IP address of the server, enters a username and password, and then is presented with the FTP prompt awaiting commands. The following table lists commands useful for communicating with the M57x.

Command	Function
BINARY	Changes FTP to binary mode
CD..	Change current directory to parent directory
CD directoryname	Change current directory to directyname
DELETE filename.ext	Delete file from Server
DIR filename.ext	List directory contents
GET source file destination file	Read file from M57x
PUT source file destination file	Write file to M57x
QUIT	Exit FTP server and return to command prompt

Refer to your local operating system documentation for more details.

5.5.1b M57x FTP Implementation

The M57x FTP server has three privilege levels that determine the allowed FTP operations.

Description	Username	Password
Read files within the C:\DATA directory	“anonymous” or “guest”	Any
Read files on any drive or directory	Drive\directory	Level 0
Read, Write, or Delete files on any drive or directory	Drive\directory	Level 2

Access to Levels 1 and 2 require the user to enter the starting (root) directory as the "User Name". For this purpose, the drive name is treated as a directory. The entire "c" drive would be accessed by entering a User Name of "c" and the appropriate password. Access to a subdirectory, for example the configuration files, is obtained by entering a User Name of "c:\config" and the password. Note that the FTP protocol does not allow access above the root directory.

The M57x will remotely restart if the file "c:\upload\restart.now" is written. Restart begins about 10 seconds after the file has been created.

It is recommended that FTP be operated in passive mode. The port number assignments are 20 and 21 (TCP)

Please consult customer service for information on using FTP for updating the M57x firmware or BIOS.

5.5.2 ZMODEM, TELNET, and Command Line Interface

M57x files may be written, read, and deleted by use of ZMODEM and the front panel serial ports. Using the 70 Series Configurator, make sure the serial port you wish to use is set to ZMODEM. By default, port P1 is set to ZMODEM @ 9600 Baud. Connect a terminal, or the serial port of a PC running a terminal emulator program (such as HyperTerminal™), to the serial port of the M57x configured for ZMODEM. Make sure the terminal emulator is set-up to connect directly to the serial port of the PC, and that the baud rate matches that of the M57x port. Allowable commands are:

Service Port/ZMODEM Commands			
c:	display off	receive	type
cd	exit	reset	trigger dr1
chp1	getlog	router	trigger dr2
chp2	Goose*	send	trigger wv1
d:	ip	serial	trigger wv2
date	mac	setlog	ver
del	nsap	software	vio point
dio point	password	status	whoami
dir	pulse	subnet	
display on	reboot	time	

Note: *This command is for UCA Goose only and is now referred to as GSSE.

NOTE 1: When connected to the M57x with a terminal emulator program, remember that the commands you type are operating on the M57x, not the PC. The terms "RECEIVE" and "SEND" are therefore from the perspective of the M57x.

NOTE 2: The location of files to be sent to the M57x from the PC must be set in the terminal emulator program.

NOTE 3: The RECEIVE command must be used before telling the terminal emulator program to transfer a file to the M57x.

NOTE 4: Some terminal emulator programs cannot transfer more than one file using the "RECEIVE" command.

NOTE 5: For a complete list of commands, type “help” at the command prompt. For help with a specific command, type “help” followed by the command (i.e. “help send”).

5.6 Assigning Pulse Outputs to Energy Values

Any of the relay outputs can be set up to operate as a pulse output, and assigned to any of the four energy values. Assigning the digital outputs to perform a pulse-output function MUST be done by using the 70 Series Configurator program. Additionally, Digital Outputs assigned to operate as a pulse output can be set for Energy per Pulse (in KWh/KVARh per pulse).

5.7 IRIG-B

5.7.1 Overview

There is a great need in many power measurement and power quality applications for synchronizing numerous instruments from various manufacturers to within fractions of a second. These applications include failure analysis, sequence of event recording, distributed fault recording, and other synchronized data analysis. One means of synchronizing various instruments to the same clock source is to connect them to a master time device that generates a standard time code. This scheme can be expanded upon such that two devices half a world apart could be synchronized to within fractions of a second if each is connected to an accurate local time master.

There are several vendors who manufacturer these master time devices and there are many standardized time synchronization protocols. IRIG-B is one of the more commonly supported standard time code formats.

5.7.2 Introduction to IRIG Standards

IRIG (InteRange Instrumentation Group) standards consist of a family of serial pulse time clock standards. These standards were initially developed for use by the U.S. Government for ballistic missile testing. There are several Time Code Formats within the family such as A, B, E, G, and H. Each Time Code Format has its own unique bit rate.

There are sub-variations within each Time Code Format that specify the Format Designation, the Carrier/Resolution, and the Coded Expression formats. All standard IRIG serial time standards use the IRIG B000 configuration.

The first letter following IRIG specifies the Time Code Format and Rate Designation. The first number following the letter specifies the Format Designation, the second number specifies the Carrier/Resolution, and the third number specifies the Coded Expressions.

The M57x’s IRIG interface recognizes and decodes the following standard IRIG formats: IRIG B000, IRIG B002, and IRIG B003.

5.7.2a Time Code Format (Rate Generation)

There are six different IRIG Time Code Formats. The M57x supports Time Code Format B. Time Code Format B specifies a 100-bit frame and a 1 second time frame (10 milliseconds per bit). The 100 bits consist of:

1 - time reference bit,
7 - BCD bits of seconds information,
7 - BCD bits of minutes information,
6 - BCD bits of hours information,
10 - BCD bits of days information,
27 - optional control bits,
17 - straight binary bits representing seconds of day information
15 - index bits
10 - position identifier bits

5.7.2b Format Designation

There are two IRIG Format Designations:

0 - Pulse Width Coded
1 - Sine Wave, Amplitude Modulated.

The Pulse Width Coded format is essentially the envelope of the Amplitude Modulated format. The base M57x supports the Pulse Width Coded format on serial ports P2 and P3. When the M57x is ordered with the modulated IRIG-B option both IRIG formats are supported on the dedicated port.

5.7.2c Carrier/Resolution

There are six IRIG Carrier/Resolutions:

0 - No Carrier/Index Count Interval
1 - 100 Hz/10 ms
2 - 1 kHz/1 ms
3 - 10 kHz/0.1 ms
4 - 100 kHz/10 us
5 - 1 MHz/1 us

The base M57x supports only the No Carrier/Index Count IRIG Carrier/Resolution. When the optional modulated IRIG-B receiver is installed the M57x additionally supports the 1kHz/1ms IRIG Carrier/Resolution.

5.7.2d Coded Expressions

There are four IRIG Coded Expressions:

0 - BCD, CF, SBS
1 - BCD, CF
2 - BCD
3 - BCD, SBS

The M57x only uses the BCD portion of the expression and as a result can accept any of the standard IRIG Coded Expressions.

5.7.3 M57x IRIG-B Implementation

The M57x receives the IRIG-B serial pulse code via the serial ports on the Host CPU module or the dedicated IRIG-B port (optional). The IRIG-B signal is decoded by the Host CPU, and the resulting IRIG time is compared to the M57x's time. The M57x processes the time errors and corrects its local time to coincide with the IRIG time.

5.7.3a M57x IRIG-B Receiver

As previously mentioned, the M57x receives the IRIG-B signal via the standard serial ports located on the M57x front panel. Port P2 or P3 can be configured to accept IRIG-B. The ports can be configured via the 70 Series Configurator software utility. If the modulated IRIG-B option is installed there is a dedicated BNC connection to accept the IRIG-B signal. This port can be set up in the 70 Series Configurator to accept either amplitude modulated or pulse width coded signals. When configured for an amplitude modulated signal, the MOD light on the front panel next to the BNC connector is illuminated. When a signal is detected on the port the ACT light is illuminated.

5.7.3b M57x IRIG-B Decoder

The M57x IRIG Decoder parses the bit stream from the IRIG Receiver into registers that represent the number of days, minutes, and seconds since the beginning of the present year. The control bits and straight binary seconds portion of the IRIG pulse stream are ignored. The M57x transducer compares its present time to the IRIG time and stores the delta time error. These errors are calculated every IRIG frame (every second) and are accumulated into a sample buffer until the sample buffer is full. Once the buffer is full, the buffer is passed to the IRIG Time Qualifier.

5.7.3c M57x IRIG-B Time Qualifier

The M57x IRIG-B Time Qualifier processes the sample buffer of time errors from the IRIG-B Decoder. If the IRIG-B Time Qualifier detects several sequential time errors greater than 3 seconds, the IRIG-B Time Qualifier forces the M57x to immediately “jam” its clock to the present IRIG-B time.

If the time errors are less than 3 seconds, the IRIG-B Time Qualifier examines all the errors in the sample buffer. The error data is subjected to various proprietary criteria to determine an accurate time offset. If the sample buffer does not meet the qualifying criteria the sample buffer is discarded and no clock correction is performed. The IRIG-B Time Qualifier continues to examine and discard sample buffers from the IRIG-B Decoder until it finds one that meets the accuracy qualifications.

Once a sample buffer is qualified, the IRIG-B Time Qualifier calculates a clock correction value and slews the M57x's clock to match the IRIG-B time. The slew time depends on the magnitude of the clock correction. The time required to slew the M57x's clock to match the IRIG time is approximately 30 times the clock correction value.

Slewing the clock ensures that time always moves forward. The clock may speed up or slow down to attain proper synchronization, but it never moves backward. This ensures that the ordering of events is always preserved while changing the clock. Ordering of events cannot be guaranteed when the clock is jammed.

The IRIG-B Decoder does not sample the IRIG bit stream and build a sample buffer while the M57x clock is slewing. All IRIG frames received during the M57x's clock slew are ignored until the slew has completed.

5.7.4 Determining the Correct Year

The IRIG-B standard provides days of year, minutes of day, and seconds of minute information. The IRIG standard does not provide any year information. IEEE-1344 specifies a bit pattern that is encoded into the IRIG control bit steam that specifies year information. The M57x IRIG driver is capable of decoding the IEEE-1344 year information from the control bits when connected to an IEEE-1344 compatible IRIG master. If the IRIG master that is connected to the M57x is not IEEE-1344 compatible, the IEEE-1344 compatibility configuration switch in the M57x comm port configuration should be turned off. This will prevent the M57x from incorrectly interpreting the control bits as year information.

If the IRIG master is not IEEE-1344 compatible, the M57x assumes that the year stored in its non-volatile battery backed-up CMOS clock is correct. If the M57x battery fails or the M57x's year is incorrectly set, the IRIG-B Driver will assume that the year is the year reported by the M57x's CMOS clock.

If the M57x is connected to an IRIG master that is not IEEE-1344 compatible and the year reported by the M57x's CMOS clock is incorrect, the IRIG Driver may also set the M57x's day incorrectly (due to leap year) when it tries to synchronize the device time to the IRIG time. The time, however, will still synchronize correctly. As a result, if the M57x's battery fails (or the year was not set correctly), any data time-stamped by the M57x or any waveform captures stored may have the wrong year and day but will have the correct time accurate to several microseconds. This data can still be synchronized to other events from other devices by simply adding the correct day and year offsets to the time.

5.7.5 Methods of Automatic Clock Adjustments

The automated clock adjustments controlled by the IRIG interface include “jamming” the clock and “slewing” the clock. Depending on the magnitude of the M57x's absolute clock error the clock adjustment algorithms will either jam the clock by directly writing a new value into the clock registers or slew the clock smoothly by adding or subtracting small adjustments to the clock registers over a period of time.

5.7.6 Types of M57x Clock Synchronization

There are various degrees (or states) of time synchronization. Upon power up, the device relies on the value stored in the battery backed-up CMOS clock to set the correct time, and the crystal frequency correction constant stored in non-volatile memory to correct the crystal's frequency. The M57x will keep time starting from the values read from the CMOS clock. There will be an accumulated time error based upon the frequency error of the Real Time Clock crystal. The crystal frequency correction constant provides a means for correcting for this error. If the M57x was never synchronized to an external source (i.e. IRIG-B or network synchronization protocol), the M57x will not have a value for the crystal frequency correction constant and the crystal error will be the M57x's clock error.

5.7.6a Frequency Adjustments and Free Wheeling

The M57x has the capability to add a correction factor to compensate for the crystal's effective frequency error rate. This frequency adjustment is accomplished by first determining the crystal's error rate and then correcting the clock to reflect that error. The IRIG-B interface serves as an external accurate time source to determine the crystal's typical error rate. The frequency error is calculated and stored in non-volatile memory.

When an M57x is connected to an IRIG-B source, it will automatically calculate and store the crystal's error. M57x transducers utilize this constant to maintain a more accurate clock. If the IRIG-B source is removed the M57x will no longer receive time corrections from the IRIG-B source, but the device clock will keep much better time due to the frequency correction constant. This mode of operation is referred to as "Free Wheeling."

Although "Free Wheeling" with constant frequency compensation provides a more accurate M57x clock, it will still drift and is less accurate than having a constant IRIG-B source connected to the M57x. The frequency error of the crystal will change with time and temperature. Having a permanent real time IRIG-B clock source allows for constant minute adjustments to the M57x clock.

5.7.6b Permanent IRIG-B Source Connection

Having a permanently connected IRIG-B source provides the most accurate M57x clock. In addition to correcting the frequency for the crystal error, the M57x will constantly receive corrections to compensate for any drift that may still occur. This provides for a typical clock error of less than 10 microseconds.

5.7.7 Stages of IRIG-B Synchronization and Accuracy

There are four basic stages of synchronization with an IRIG-B source: power-up, time lock, frequency lock, and final lock.

5.7.7a Power-Up Stage

Upon Power-up, the M57x obtains the time from its non-volatile battery backed-up CMOS clock. This clocks resolution is limited to seconds. Therefore, even if the clock was error free when it was turned off, the M57x could have an error of up to one second when it is powered-up. As mentioned previously, the typical crystal error rate is about 50 microseconds per second (50ppm). Therefore, if we assume that the M57x clock was keeping perfect time before it was reset (or powered down), it would typically be in error by:

(50 microseconds) x (number of seconds off) + 0.5 seconds after power is restored.

The M57x would start with this error and continue to drift by the frequency offset error. If the M57x were never connected to an IRIG-B source (or other clock synchronizing source), the drift would be equal to the crystal's frequency error. If the M57x previously stored a frequency correction constant in non-volatile memory, the device will include the compensation and drift by a smaller amount equal to the true crystal frequency error minus the correction constant.

5.7.7b Time Lock Stage

Once the M57x begins to receive IRIG-B frames, validates a sample buffer, and calculates a clock correction value, it will enter the Time Lock Stage of synchronization. If the clock correction value exceeds 120 seconds, the clock is jammed with the present IRIG-B time. Otherwise, the M57x clock is slewed to match the IRIG-B time.

The accuracy of this initial slew depends on whether a frequency correction constant was previously stored in non-volatile memory, and if so how accurate the constant is. The M57x will use this constant in the slew calculation to approximate the rate to change the clock to adjust to the specified IRIG-B correction error.

The M57x will remain in the Time Lock Stage for approximately five minutes plus the time required to perform the initial clock slew. The clock slew requires approximately 30 times the clock correction value. For example, if the initial clock correction error was 1.5 seconds, the Time Lock Stage would require approximately 6 minutes (5 minutes plus 45 seconds to slew).

The M57x enters the Frequency Lock Mode after completing the first IRIG-B clock correction. The M57x's clock is typically synchronized to within 1 millisecond of the true IRIG-B time after the Time Lock Stage is completed.

5.7.7c Frequency Lock Stage

The M57x enters the Frequency Lock Stage of synchronization when it receives the third valid clock correction value from the IRIG-B interface. At this time the M57x calculates a crystal frequency correction constant based on the clock correction value. The crystal frequency correction constant is stored in non-volatile memory to provide improved clock accuracy during "Free Wheeling." The crystal frequency correction constant along with the clock correction value is used to slew the clock to synchronize to the IRIG-B source.

The Frequency Lock Stage requires approximately five minutes. Once the M57x slews its clock with the correct crystal frequency correction constant, the M57x's clock is typically synchronized to within 50 microseconds of the IRIG-B time source. The M57x then enters the Final Lock Stage of synchronization.

5.7.7d Final Lock Stage

In the Final Lock Stage of synchronization, the M57x typically receives clock correction values from the IRIG-B interface every five minutes. The M57xcontinues to make slight adjustments to its crystal frequency correction constant to accommodate for small frequency drifts due to age and temperature. At this point, the M57x clock is typically synchronized to within less than 10 microseconds of the IRIG-B source.

5.7.8 Notes On Operation

A new crystal frequency correction constant will be written to non-volatile memory every four hours while a valid IRIG-B connection exists.

The battery backed-up CMOS clock will be corrected every hour while a valid IRIG-B connection exists.

Network Time Synchronization requests are refused while a valid IRIG-B connection exists.

5.7.9 IRIG-B Electrical Specifications

Pulse Width Coded Signal

Absolute Maximum Input Voltage:	-25 Volts to +25 Volts
Receiver Input Threshold Low:	0.8 Volts (min)
Receiver Input Threshold High:	2.4 Volts (max)
Receiver Input Hysteresis:	0.6 Volts (typical)
Receiver Input Resistance:	5 kohms (typical)

Amplitude Modulated Signal

Input impedance: >10K ohm

Input Format :IRIG-B120, B123,
1kHz modulated sine wave, amplitude 3Vpp – 10Vpp,
modulation ratio 3:1

Time skew: 600 uSec (Program this offset in Configurator)

5.7.10 IRIG-B Port Wiring Instructions (Pulse Width Coded, IRIG-B master, Demodulated)

The IRIG-B master can be connected to port P2 or P3 of the M57x when IRIG-B signals of format IRIG B000, IRIG B001, or IRIG B003 are used. The selected port must be configured for IRIG-B via the 70 Series Configurator software utility. To connect the IRIG-B master to a port (Figure 4, p 23):

- Connect the IRIG-B signal to terminals 19 and 21 (P2), or 25 and 27 (P3).
- Connect the IRIG-B signal common to terminal 17 (P2) or 23 (P3).
- Terminal 18 (P2) or 24 (P3) provides a connection to earth ground via a 100 ohm resistor for shielding.

5.7.11 IRIG-B Port Wiring Instructions Modulated IRIG-B Option

Connect IRIG-B signal from the master using a standard BNC cable. Use the 70 Series Configurator to set the port for either an Amplitude Modulated or Pulse Width coded signal (see figure 9). If Amplitude Modulated is selected go to the IRIG-B page and set the Absolute Time Offset to 620 usec. (This offset value includes the 600 usec time skew attributed to the demodulator circuit). The number used for the Absolute Time Offset may need to be increased, depending on time skew contributed by clock source and cable lengths. The remaining items on the IRIG-B page can initially be left at the default values. If there are problems with acquiring synchronization with the IRIG-B source, turning on the debug messages may help in diagnosing the problem. (Refer to section 4.1; Debug messages are turned on when service port P1 is running in logging mode). Depending on the installation it may be necessary to relax some of the qualifying parameters to achieve synchronization. If necessary, first increase the Max Skew setting from 5 usec to 8 – 10 usec. If this does not help it may be necessary to reduce the Quality Factor from 0.7 to 0.5 or less.

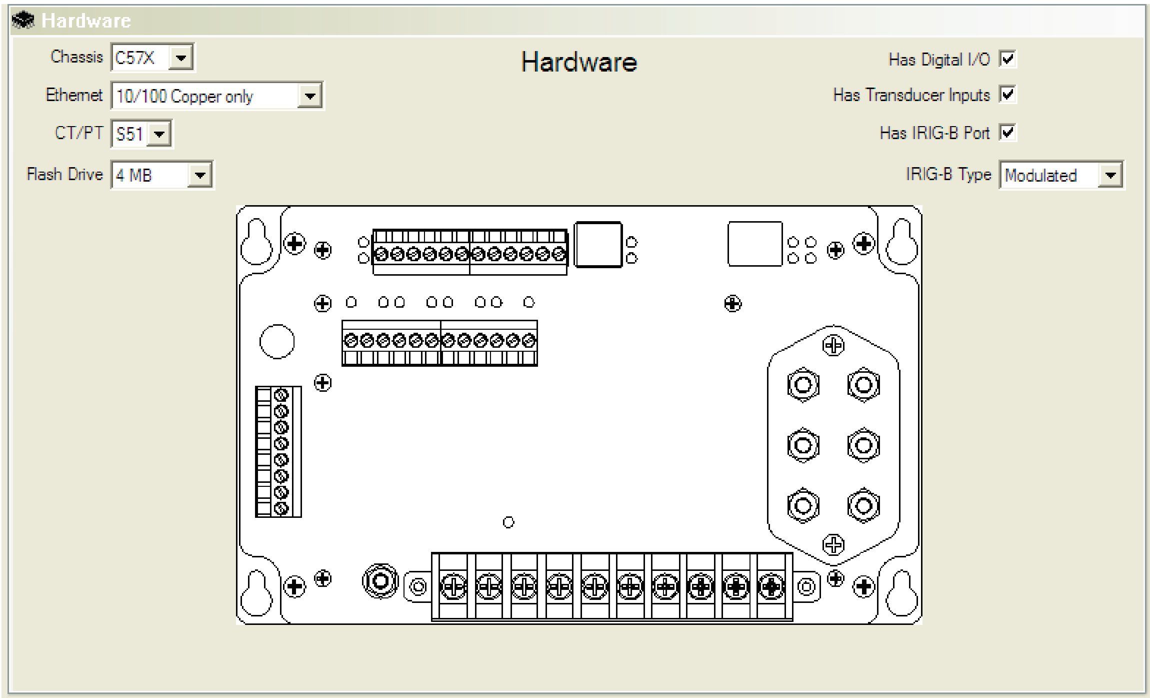


Figure 9 – IRIG-B Type Selection in 70 Series Configurator

5.8 Time Sync & Setting

The 70 Series IED utilizes an on-board clock to time stamp communications, SOE Log entries, and data samples in the Waveform, Disturbance, and Trend Recorders. A variety of external references may be used to synchronize the on-board clock to either local or Universal Coordinated Time (UTC) with a high degree of accuracy.

5.8.1 Time Sync Status Registers

Pre-defined status registers indicate the current state for each of the various time synchronization methods used in 70 Series IEDs
The following time sync registers will return status values of ‘0’ if a time sync master is inactive and ‘1’ if a time sync master is active:

Status Registers
IrigB Time Sync
Network Time sync *(UCA)*
SNTP Time Sync
DNP Time Sync

The 70 Series DNP and Modbus manuals define the status register locations within Appendix B for these time sync status points.

5.8.2 Manual time setting by Command-Line instruction

The command-line instruction is the manual method for setting the IED clock through service port P1. The “time” instruction in the command-line interface is used to set time for the IED’s internal clock. Refer to section 4.1 in order to set the IED clock.

5.8.3 Unsolicited DNP Time set (DNP master sets the IED clock)

DNP Time set is supported by the 70 Series IED. The IED clock simply free-wheels at its characteristic rate between DNP time updates. Each DNP set-time instruction simply "sets" the clock as it is received. Setting the clock via DNP supersedes any other time-sync method that might be in use.

5.8.4 IRIG-B Time sync (time-synchronization via dedicated IED port)

Detailed information on IRIG-B time sync can be found starting in section 5.7. IRIG-B is expected to produce the greatest accuracy relative to other time sync methods currently supported. A status bit, named ‘IrigB Time Sync’, is set to indicate the IED is being synchronized via IRIG-B as long as the IED continues to receive valid IRIG updates. While this bit is set, time-sync signals received from *(UCA)* Network Time Sync, SNTP, and Requested DNP are ignored.

It should be noted that the IED host is not able to distinguish between the Modulated and Unmodulated IRIG-B signals applied to the input port. Demodulation is accomplished by a dedicated circuit. The host processor makes no determination as to which type of external IRIG-B signal is applied. Unmodulated IRIG-B would provide a slightly more accurate time signal then Modulated IRIG-B, due to additional time latency that is introduced in the de-modulation process.

5.8.5 *(UCA)* Network Time Synchronization – time synchronization over Ethernet

The M57x real-time clock may be synchronized to a UCA2 network time-sync master. The network time sync functions as described in IEEE TR-1550 Part 2 Appendix B and is roughly analogous to the IRIG-B described in Section 5.7, in that the M57x continually "trains" it's internal clock to eliminate errors. An algorithm progressively adjusts the on-board clock to improve its accuracy with subsequent time updates received from the master. This allows the M57x to "Free Wheel" accurately in the event the UCA network time-sync master is unavailable.

5.8.6 SNTP (Simple Network Time Protocol) - time synchronization over Ethernet

Time synchronization is supported using SNTP (Simple Network Time Protocol); this protocol is used to synchronize the internal real time clock in substation devices , (i.e., control systems, relays, IEDs). Up to 2 SNTP servers, using optional many-cast (or any-cast) mode of operation, are supported, along with configurable polling times. SNTP servers can be polled for configurable time, but only one at a time.

The SNTP page in the 70Series Configurator software tool allows the user the option of selecting which tool will be used to load the SNTP (and IP) settings. Radio buttons are provided for that purpose. SNTP (and IP) settings can be loaded from either the 70Series Configurator (INI file) or the IEC61850 IED Configurator (MCL file). When using the 70Series Configurator, the initial default configuration will load SNTP settings from the 70Series Configurator (INI file). If IEC61850 protocol is used, it is possible for the user to change the radio button selected in order to indicate that the IEC61850 IED Configurator (MCL file) be used to load these settings instead. If the settings on the 70Series Configurator SNTP page grey out, it is an indication that the SNTP server addresses may have been set through the other Configurator's software.

Additionally, on the SNTP page of the 70 Series Configurator software, the user may specify that an offset from the SNTP server time be applied when synchronizing. A common use for this feature is to allow the 70 Series device to operate in local time when synchronizing with an SNTP server operating in UTC time. To further support local time, the application of Daylight Savings adjustments may also be configured.

5.8.7 DNP Time sync (slave requesting DNP time be set)

A slave may request that DNP time be set in order to have the DNP master set the DNP time.

5.9 Using the M57x with a Bitronics Analog Output Converter

The M57x may be used with any of the Bitronics AOC units (NAO8101, NAO8102, NAO8103, or NAO8104). The AOC may be connected to either port P2 or P3. The serial port must be configured for the appropriate protocol and register set for the AOC that will be connected. Setting up the serial ports is accomplished by using the 70 Series Configurator. AOC units will only function with the M57x configured for the Bitronics Legacy register set. When using AOCs that communicate via Modbus (NAO8101 and NAO8103) the M57x comm port must be set for an RxD to TxD Delay of 10ms for proper operation. A separate AOC may be connected on each serial port. Serial port and connection information is shown below and in Figure 6 (pg. 24). As stated previously, the AOC address must match the protocol address assigned to the M57x communications port.

Protocol	Baud	Parity	Media
DNP	9600	NONE	RS485
Modbus	9600	EVEN	RS485

5.10 Automatic Event Notification

The 70 Series is capable of sending an Automatic Notification via email, or over a serial port. The action of automatic notification may be selected in response to any of the available triggers, similar to triggering a recording or activating an output contact. The type of notification (email or serial) is selected in the 'Automatic Notification settings" page of the Configurator.

5.10.1 Email Notifications

A valid SMTP (email) server IP address must be entered. This server must exist on the local network in order for emails to be sent. Email addresses can then be entered for up to 3 users.

5.10.2 Serial Notifications

The 70 Series can be configured to send text strings out a serial port P2 or P3. These text strings can be used for various purposes, including operating a modem. This could be used to send a page to a numeric pager, for example.

5.10.3 Data Sent

The 70 Series meter will send the user-configured string out the specified COM port. It is the user’s responsibility to ensure the string is properly formatted to communicate through any port switches, modem switches, and/or modems. The user is also responsible for ensuring the string specified is meaningful to the user or device that will be receiving it.

If the 70 Series meter is not configured to have a COM port send notifications, then no serial notifications will be sent.

If the 70 Series meter has multiple COM ports configured to send notifications, then the notifications will be sent out each port configured for notifications.

5.10.4 Error Recovery

There is no provision to confirm that a message has been successfully transmitted to an end user or device. There may be a busy signal, an answering machine may take the call, or another device may be using the phone line.

5.10.5 Example

Here is an example of a string that can be configured to send the numeric message 123 to a pager with the phone # 610-555-1212, and then hang up:

ATDT6105551212,,,,,,,,123,,,,ATH<cr>

Note that it is typically important to enter the <cr> (carriage return character) for the string to be properly recognized by the modem. Information on modem control characters is available from your modem manufacturer.

5.10.6 Control Characters

Control characters can be entered in the Configurator by typing "\x" followed by the hexadecimal representation of the ASCII code for the desired character. For example, the control-Z character is represented by a hexadecimal 1A; therefore, "\x1a" should be entered into the serial data string where a control-Z is desired.

If the characters "\x" are desired to appear in the serial data string rather than a control character, then this special sequence can be escaped by entering "\\x". The characters "\x" will appear in the serial data string.

6.0 MEASUREMENTS

Basic measurement quantities are calculated and updated every 1/4 cycle. These quantities include RMS Amperes and RMS Volts. Watts, VARs, VAs, Power Factor, all harmonic-based measurements (such as fundamental-only quantities), Energy, Frequency, and Phase Angle are updated every cycle.

Note: For all of the following measurements, it is important to keep in mind that the specific protocol used to access the data may affect the data that is available, or the format of that data. No attempt is made here to describe the method of accessing measurements - always check the appropriate protocol manual for details.

6.1 Changing Transformer Ratios

The M57x has the capability to store values for Current Transformer (CT) and Potential Transformer (VT) turns ratios. The VT and CT values are factory set to 1:1 CT and 1:1 VT. These values can be entered into the M57x over the network or via the 70 Series Configurator Software, and will be stored in internal non-volatile memory located on the Signal Input Module. All measurements are presented in primary units, based on these ratios. Refer to the appropriate protocol manual for information on changing transformer ratios.

6.1.1 User (External Transformer) Gain and Phase Correction

It is possible to correct for both gain and phase errors in external current and voltage instrument transformers connected to the M57x when these errors are known. These Correction Factors can be entered via a protocol or by using the 70 Series Configurator Software.

User Gain Correction is a multiplier (from -2 to +2) that can be used to adjust for known gain errors in the system. User Gain Correction is "1" by default. For example, a gain correction of 1.01 would increase the effective ratio by 1%. Entering a negative number will reverse the phase of an input.

User Phase Correction is used to adjust for known phase errors in the system. User Phase Correction is measured in degrees from -180 to 180. The default value is "0". When a User Phase Correction is entered, it will have an effect on Watts and VARs, Fundamental Watts and VARs, PF and Displacement PF, and the phase angles reported for fundamental values. It will have no effect on the magnitudes of phase-to-phase Fundamental Volts.

6.2 Current (1/4-Cycle Update)

The M57x has three (M571) or 6 (M572) current inputs, with an internal CT on each channel. These inputs can read to $20A_{RMS}$ (symmetrical), or $28.2A_{PEAK}$ (S51 or S54 option) or to $100A_{RMS}$ (symmetrical), or $141A_{PEAK}$ (S50 or S53 option) under all temperature and input frequency conditions. No range switching is used, allowing a high dynamic range.

The current signals are transformer coupled, providing a true differential current signal. Additionally, a continuous DC removal is performed on all current inputs. Instrument transformer ratios can be entered for each current input, as described above. This can be accomplished via a network and protocol (refer to the specific protocol manual for details) or by using the 70 Series Configurator.

When used on 2-element systems, if there are only 2 currents available to measure, a "0" can be written to the CT Ratio for the missing phase current. This will cause the M57x to fabricate the missing phase current from the sum of the other 2 phase currents. This feature is not recommended for WYE connected systems.

The average of the 3 current phases ((Ia + Ib + Ic)/3) is also available. The Average 3-phase Amps for bus 1 and bus 2 (M572) are calculated and made available on a per cycle basis.

6.2.1 Residual Current (1/4-Cycle Update)

The M57x calculates the vector sum of the three phase currents, which is known as the Residual Current. The Residual Current is equivalent to routing the common current return wire through the neutral current input on systems without separate current returns for each phase, with the exception that individual Harmonics are not measured on Residual Current.

6.3 Voltage Channels (1/4-Cycle Update)

The M57x uses a unique voltage connection method, which is combined with simultaneous sampling to provide an extremely flexible voltage measurement system. All voltage inputs are measured relative to a common reference level (essentially panel ground). See Appendix 1 for input connection information. Because all signals are sampled at the same instant in time, common mode signals can be removed by subtraction of samples in the DSP, instead of the more traditional difference amplifier approach. This greatly simplifies the external analog circuitry, increases the accuracy, and allows measurement of the Neutral-to-Ground voltage at the panel. The 7kV input divider resistors are accurate to within +/- 25ppm/DegC, and have a range of $600V_{PEAK}$, from any input to panel ground. Each sample is corrected for offset and gain using factory calibration values stored in non-volatile memory on the board. Additionally, a continuous DC removal is performed on all inputs.

The M57x calculates voltages in PRIMARY units, based on the VT Ratios entered. There are separate VT Ratios for each input. Ratios can be entered via a network and protocol (refer to the specific protocol manual for details) or by running the 70 Series Configurator.

The advantages of this method of voltage measurement are apparent when the M57x is used on the common 2, 2-1/2, and 3 element systems (refer to Section 6.5). The M57x is always calculating Line-to-Neutral, Line-to-Line, and Bus-to-Bus voltages with equal accuracy. On 2 element connections, any phase can serve as the reference phase. Further, the M57x can accommodate WYE connections on one Bus, and DELTA connections on the other Bus.

On 2-1/2 element systems, one of the phase-to-neutral voltages is missing, and the M57x must create it from the vector sum of the other two phase-to-neutral voltages. In order to configure the M57x for 2-1/2 element mode and which phase voltage is missing, a "0" is written to the phase-to-neutral VT Ratio for the missing phase voltage.

The average of the 3 voltage phases ((Va + Vb + Vc)/3) is also available. The Average 3-phase Volts for bus 1 and bus 2 are calculated and made available on a per cycle basis.

6.4 Power Factor (1-Cycle Update)

The per-phase Power Factor measurement is calculated using the "Power Triangle", or the per-phase WATTS divided by the per-phase VAs. The Total PF is similar, but uses the Total WATTS and Total VAs instead. The sign convention for Power Factor is shown in Figure 10 (pg. 65). Note that the Total PF calculation depends on the Total VA calculation type chosen.

6.5 Watts / Volt-Amperes (VAs) / VARs (1-Cycle Update)

On any power connection type (2, 2-1/2, and 3 element), the M57x calculates per-element Watts by multiplying the voltage and current samples of that element together. This represents the dot product of the voltage and current vectors, or the true Watts. The per-element VAs are calculated from the product of the per-element Volts and Amps. The per-element VARs are calculated from fundamental VARs.

In any connection type, the Total Watts and Total VARs is the arithmetic sum of the per-element Watts and VARs. The sign conventions are shown in Figure 10 (pg. 65).

When used on 2-element systems, the reference phase voltage (typically phase B) input, is connected to the Neutral voltage input, and effectively causes one of the elements to be zero. ***It is not required to use any particular voltage phase as the reference on 2-element systems. When used on 2-element systems the per-element Watts, VARs, and VAs have no direct physical meaning***, as they would on 2-1/2 and 3 element systems where they represent the per-phase Watts, VARs, and VAs.

When used on 2-1/2 element systems, one of the phase-to-neutral voltages is fabricated, as described in Section 6.3. In all other respects, the 2-1/2 element connection is identical to the 3 element connection.

The M57x may be configured to calculate Total VAs in one of several different ways. The calculation method may be selected either by sending a command to the M57x via a network and protocol (refer to the specific protocol manual for details) or by using the 70 Series Configurator. The three methods, Arithmetic, Geometric, and Equivalent (both for WYE and DELTA), all yield the same results when used on balanced systems with no harmonics present. The differences are illustrated below:

6.5.1 Geometric VA Calculations

$$GEOMETRIC\ VA_{TOTAL} = \sqrt{Watts_{TOTAL}^{\ 2} + VARs_{TOTAL}^{\ 2}}$$

This is the traditional definition of Total VAs for WYE or DELTA systems, and is the default method for Total VAs calculation. The value of Total VAs calculated using this method does not change on systems with amplitude imbalance, relative to a balanced system.

There is also a relationship to the Total Power Factor, which is described in Section 6.4. Total Power Factor calculations using the Geometric VA method will still indicate a "1" on a system with phase amplitude imbalance, or canceling leading and lagging loads.

For example, on a system with a lagging load on one phase and an equal leading load on another phase, the Geometric VA result will be reduced relative to a balanced system but the Total Power Factor will still be "1".

6.5.2 Arithmetic VA Calculations

$$ARITHMETIC\ VA_{TOTAL} = \left(V_{A-N} \times I_A\right) + \left(V_{B-N} \times I_B\right) + \left(V_{C-N} \times I_C\right)$$

The Arithmetic VA calculation is not applicable to DELTA connected systems. The value of Total VAs calculated using this method also does not change on systems with amplitude imbalance, relative to a balanced system. The value of Arithmetic VAs will not change on a system with canceling leading and lagging loads.

There is also a relationship to the Total Power Factor, which is described in Section 6.4. Total Power Factor calculations using the Arithmetic VA method will still indicate a "1" on a system with phase amplitude imbalance, but not with canceling leading and lagging loads.

For example, on a system with a lagging load on one phase and an equal leading load on another phase, the value of the Arithmetic VAs will not change relative to a balanced system, but the Total Power Factor will be less than "1". The Total Power Factor calculated with Arithmetic VAs will "see" the reactive elements in this system, while the Total Power Factor calculated with Geometric VAs will not.

6.5.3 Equivalent VA Calculations

$$EQUIVALENT\ WYE\ VA_{TOTAL} = \sqrt{V_{A-N}^2 + V_{B-N}^2 + V_{C-N}^2} \times \sqrt{I_A^2 + I_B^2 + I_C^2}$$

$$EQUIVALENT\ \ DELTA\ VA_{TOTAL} = \frac{\sqrt{V_{A-B}^2 + V_{B-C}^2 + V_{C-A}^2} \times \sqrt{I_A^2 + I_B^2 + I_C^2}}{\sqrt{3}}$$

The Equivalent VA calculation has not been as commonly used as other approaches, but has been discussed extensively in technical papers. It is also referred to as "System Apparent Power". This approach to the VA calculation may yield results which are surprising to those used to more traditional methods. A system with amplitude imbalance will yield a greater value of Equivalent VAs than a balanced system.

There is also a relationship to the Total Power Factor, which is described in Section 6.4. Essentially, Total Power Factor calculations using the Equivalent VA method will not indicate a "1" on any system unless the loads are purely resistive, and the amplitudes are balanced. Further, the Equivalent VA method may yield better results in the presence of harmonics, where Total Power Factor will also be reduced from "1". Refer to industry standards for more information.

6.6 Energy (1-Cycle Update)

Separate values are maintained for both positive and negative Watt-hours, positive and negative VAR-hours, and VA-hours, for each feeder. These energy quantities are calculated every cycle from the Total Watts, Total VARs, and Total VAs, and the values are stored into non-volatile memory every 15 seconds. Energy values may be reset. All values are reset simultaneously. Refer to the appropriate protocol manual for details.

6.7 Frequency (1-Cycle Update)

Frequency is calculated every cycle for every input. The M57x monitors the change in Phase Angle per unit time using the Phase Angle measurement for the fundamental generated by the FFT. The System Frequency is the frequency of the input used for synchronizing the sampling rate.

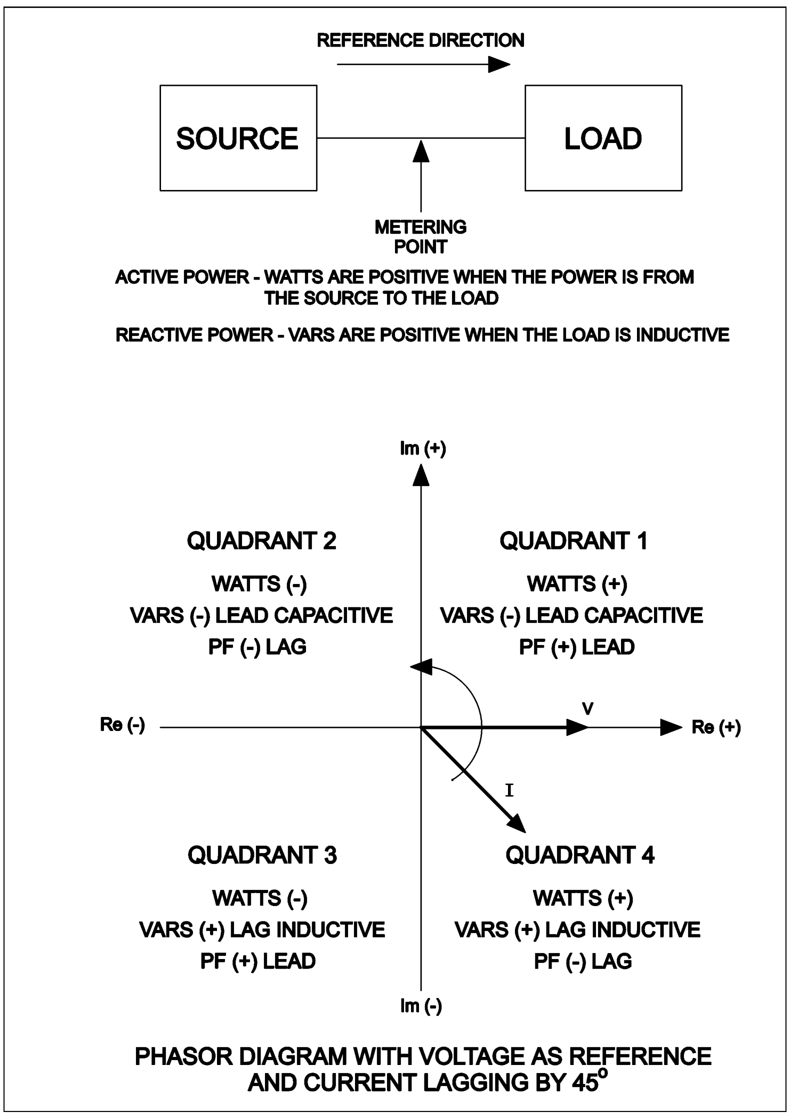


Figure 10 - Sign Conventions for Power Measurements

6.8 Demand Measurements (1-Second Update)

The traditional thermal demand meter displays a value that represents the logarithmic response of a heating element in the instrument driven by the applied signal. The most positive value since the last instrument reset is known as the maximum demand (or peak demand) and the lowest value since the last instrument reset is known as the minimum demand. Since thermal demand is a heating and cooling phenomenon, the demand value has a response time T, defined as the time for the demand function to change 90% of the difference between the applied signal and the initial demand value. For utility applications, the traditional value of T is 15 minutes, although the M57x can accommodate other demand intervals (Section 6.8.7).

The M57x generates a demand value using modern microprocessor technology in place of heating and cooling circuits, it is therefore much more accurate and repeatable over a wide range of input values. In operation, the M57x continuously samples the basic measured quantities, and digitally integrates the samples with a time constant T to obtain the demand value. The calculated demand value is continuously checked against the previous maximum and minimum demand values. This process continues indefinitely, until the demand is reset or until the meter is reset (or power removed and reapplied). The demand reset and power-up algorithms are different for each measurement. These routines are further described in following paragraphs. The maximum and minimum demand values are stored in non-volatile memory on the Host Processor module.

NOTE: Changing VT or CT ratios does NOT reset demand measurements to zero.

Demand Quantity	Phase Reference	Function
Amperes (1 & 2)	Phase, Residual	Present, Max
Fundamental Amperes	Phase, Residual	Present, Max
Volts (Bus 1 & 2)	Phase - Neutral, Phase - Phase	Present, Max, Min
Total Watts (1 & 2)		Present, Max, Min
Total VARs (1 & 2)		Present, Max, Min
Total VAs (1 & 2)		Present, Max, Min
THD Volts (Bus 1 & 2)	Phase - Neutral, Phase - Phase	Present, Max
TDD Amperes (1 & 2)	Phase, Residual	Present, Max

6.8.1 Ampere and Fundamental Ampere Demand

Present Ampere Demands are calculated via the instantaneous measurement data used to calculate the per-phase Amperes.

Upon power-up, all Present Ampere Demands are reset to zero. Maximum Ampere Demands are initialized to the maximum values recalled from non-volatile memory. Upon Ampere Demand Reset, all per-phase Present and Maximum Ampere Demands are set to zero. When Ampere Demands are reset, Fundamental Current Demands are also reset.

6.8.2 Volt Demand

Present Volt Demands are calculated via the instantaneous measurement data used to calculate the per-phase Volts. Upon power-up all Present Volt Demands are reset to zero. The Maximum Volt Demands and Minimum Volt Demands are initialized to the minimum and maximum values recalled from non-volatile memory. In order to prevent the recording of false minimums a new Minimum Volt Demand will not be stored unless two criteria are met. First, the instantaneous voltage for that particular phase must be greater than $20V_{rms}$ (secondary). Second, the Present Demand for that particular phase must have dipped (Present Demand value must be less then previous Present Demand value). Upon Voltage Demand Reset, all per-phase Maximum Voltage Demands are set to zero. Minimum Voltage Demands are set to full-scale.

6.8.3 Power Demands (Total Watts, VARs, and VAs)

Present Total Watt, VAR, and VA Demands are calculated via the instantaneous measurement data. The Total VA Demand calculation type is based on the instantaneous Total VA calculation type (Section 6.5)

Upon power-up, all Present Total Watt, VAR, and VA Demands are reset to the average of the stored Maximum and Minimum values. The Maximum and Minimum Demands are initialized to the minimum and maximum values recalled from non-volatile memory. Upon a demand reset, the Maximum and Minimum Demands are set equal to the Present Total Watt, VAR, and VA Demand values. A demand reset does not change the value of the Present Total Watt, VAR, and VA Demands.

6.8.4 Voltage THD Demand

Present Voltage THD Demands are calculated via the instantaneous measurement data used to calculate the per-phase and phase-to-phase Voltage THDs (Section 6.9.1). Voltage THDs are calculated for both Bus 1 and Bus 2. By applying a thermal demand to the THD measurement, the M57x provides a more effective method of determining the severity of a harmonic problem.

Upon power-up, all Present Voltage THD Demands are reset to zero. Maximum Voltage THD Demands are initialized to the maximum values recalled from non-volatile memory. Upon Harmonic Demand Reset, all per-phase Present and Maximum Voltage THD demands are set to zero.

6.8.5 Current TDD Demand

Present Current TDD Demands are calculated via the instantaneous measurement data. By applying a thermal demand to the TDD measurement, the M57x provides a more effective method of determining the severity of a harmonic problem.

Upon power-up, all Present Current TDD Demands are reset to zero. Maximum Current TDD Demands are initialized to the maximum values recalled from non-volatile memory. Upon Harmonic Demand Reset, all per-phase Present and Maximum Current TDD demands are set to zero.

6.8.6 Demand Resets

The demand values are reset in four groups: current, voltage, power, and harmonics. This can be accomplished via a network and protocol (refer to the specific protocol manual).

6.8.7 Demand Interval

The M57x uses 15 minutes as the default demand interval, however it can be changed. Four separate, independent demand intervals may be set for current, voltage, power, and harmonics. The range of demand intervals is 5 to 3600 seconds (1hr). This can be accomplished via a network and protocol (refer to the specific protocol manual for details) or by using the 70 Series Configurator. While the Demand Interval is stored internally as a 32-bit number, some protocols may place further restrictions on the Demand Interval due to limitations on numerical format. Please refer to the appropriate protocol manual for details.

6.9 Harmonic Measurements (1-Cycle Update)

M57x instruments continually sample all inputs at 128 samples per cycle, and compute a 128-point Fast Fourier Transform (FFT) every cycle for each input. When combined with high dynamic-range input of up to $28A_{PEAK}$ or $141A_{PEAK}$ and $600V_{PEAK}$, this allows the M57x to make extremely accurate measurements of harmonics, regardless of crest factor. All harmonic and harmonic-based values are calculated every cycle. Both magnitude and phase of each harmonic are provided. In the following sections, Harmonic 0 indicates DC, Harmonic 1 indicates the fundamental, and Harmonic N is the nth multiple of the fundamental.

6.9.1 Voltage Distortion (THD) (1-Cycle Update)

Voltage Harmonic Distortion is measured by phase in several different ways. The equation for Total Harmonic Distortion (THD) is given in Equation 1. For Odd Harmonic Distortion, the summation only uses harmonics where h is odd. For Even Harmonic Distortion, the summation only uses harmonics where h is even. Note the denominator is the fundamental magnitude. For Individual Harmonic Distortion there is no summation, only one component is used in the numerator.

$$\%THD = \frac{\sqrt{\sum_{h=2}^{63} V_h^2}}{V_1} \times 100\%$$

Equation 1 – Voltage

6.9.2 Current Distortion (THD and TDD) (1-Cycle Update)

Current Harmonic Distortion is measured by phase in several different ways. The first method is Total Harmonic Distortion (THD). The equation for THD is given in Equation 2. For Odd Harmonic Distortion, the summation only uses harmonics where h is odd. For Even Harmonic Distortion, the summation only uses harmonics where h is even. Note the denominator is the fundamental magnitude.

$$\%THD = \frac{\sqrt{\sum_{h=2}^{63} I_h^2}}{I_1} \times 100\%$$

Equation 2 – Current

Alternatively, Current Harmonic Distortion can be measured as Demand Distortion, as defined by IEEE-519/519A.

$$\%TDD = \frac{\sqrt{\sum_{h=2}^{63} I_h^2}}{\quad} \times 100\%$$

Equation 3 – Current

Demand Distortion differs from traditional Harmonic Distortion in that the denominator of the distortion equation is a fixed value. This fixed denominator value is defined as the average monthly peak demand. By creating a measurement that is based on a fixed value, TDD is a "better" measure of distortion problems. Traditional THD is determined on the ratio of harmonics to the fundamental. While this is acceptable for voltage measurements, where the fundamental only varies slightly, it is ineffective for current measurements since the fundamental varies over a wide range. Using traditional THD, 30% THD may mean a 1 Amp load with 30% Distortion, or a 100 Amp load with 30% Distortion. By using TDD, these same two loads would exhibit 0.3% TDD for the 1 Amp load and 30% TDD for the 100 Amp load (if the Denominator was set at 100 Amps). In the M57x, Current Demand Distortion is implemented using Equation 3. The TDD equation is similar to Harmonic Distortion (Equation 2), except that the denominator in the equation is a user-defined number. This number, I_L, is meant to represent the average load on the system. The denominator I_L is different for each phase and neutral, and is set by changing the denominator values within the M57x. Refer to the appropriate protocol manual for specific information.

Note that in Equation 3, if I_L equals the fundamental, this Equation becomes Equation 2 - Harmonic Distortion. In the instrument this can be achieved by setting the denominator to zero amps, in which case the instrument will substitute the fundamental, and calculate Current THD. For Odd Harmonic Distortion, the summation only uses harmonics where h is odd. For Even Harmonic Distortion, the summation only uses harmonics where h is even. For Individual Harmonic Distortions there is no summation, only one component is used in the numerator.

Note that there is a separate, writeable denominator for each current input channel. The TDD Denominator Registers are set by the factory to 5 Amps (primary), which is the nominal full load of the CT input with a 1:1 CT. These writeable denominators can be used in conjunction with the distortion measurements to obtain the magnitudes of harmonics, in other words, convert from percent to amps. This is simply done by multiplying the percent TDD by the TDD Denominator for that phase, and the result will be the actual RMS magnitude of the selected harmonic(s). This technique can also be used if the THD mode (denominator set to zero) is used, by multiplying the percent THD by the Fundamental Amps for that phase.

6.9.3 Fundamental Current (1-Cycle Update)

Fundamental Amps are the nominal component (50/60 Hz) of the waveform. The M57x measures the magnitude of the fundamental amps for each phase. These measurements can be used in conjunction with the distortion measurements to obtain the magnitudes of harmonics, in other words, convert from percent to amps. As was mentioned previously, this is simply done by multiplying the percent THD by the Fundamental Amps for that phase (which is the denominator), and the result will be the actual RMS magnitude of the selected harmonic.

6.9.4 Fundamental Voltage (1-Cycle Update)

Fundamental Volts are the nominal component (50/60 Hz) of the waveform. The M57x measures the magnitude of the fundamental phase-to-neutral and phase-to-phase volts. These measurements can be used in conjunction with the distortion measurements to obtain the magnitudes of harmonics, in other words, convert from percent to volts. This is simply done by multiplying the percent THD by the Fundamental Volts for that phase (which is the denominator), and the result will be the actual RMS magnitude of the selected harmonic.

Fundamental Volts and Amps can be used in conjunction to obtain Fundamental VAs, and when used with Displacement Power Factor can yield Fundamental Watts and Fundamental VARs.

6.9.5 Fundamental Watts / Volt-Amperes (VAs) / VARs (1-Cycle Update)

Fundamental Watt, VAR, and VA Demands are calculated analogous to the True Watts / Volt-Amperes (VAs) / VARs of Section 6.5, but contain only information about the fundamental. The Fundamental Total VA calculation type is the same as the True Total VA calculation type.

6.9.6 K-Factor (1-Cycle Update)

$$K-Factor = \frac{\sum_{h=1}^{63} I_h^2 \times h^2}{\sum_{h=1}^{63} I_h^2} \times 100\%$$

Equation 4 - K-Factor

K-Factor is a measure of the heating effects on transformers, and it is defined in ANSI/IEEE C57.110-1986. Equation 4 is used by the M57x to determine K-Factor, where "h" is the harmonic number and "I_h" is the magnitude of the h^{th} harmonic. K-Factor is measured on each of the three phases of amps, however there is no "Total" K-Factor. K-Factor, like THD and PF, does not indicate the actual load on a device, since all three of these measurements are ratios. Given the same harmonic ratio, the calculated K-Factor for a lightly loaded transformer will be the same as the calculated K-Factor for a heavily loaded transformer, although the actual heating on the transformer will be significantly different.

6.9.7 Displacement Power Factor (1-Cycle Update)

Displacement Power Factor is defined as the cosine of the angle (phi) between the Fundamental Voltage Vector and the Fundamental Current Vector. The sign convention for Displacement Power Factor is the same as for Power Factor, shown in Figure 9 (pg. 59).

The Total Displacement Power Factor measurement is calculated using the "Power Triangle", or the three-phase Fundamental WATTS divided by the three-phase Fundamental VAs. The per-phase Fundamental VA measurement is calculated from the product of the per-phase Fundamental Amp and Fundamental Volts values. The three-phase Fundamental VA measurement is the sum of the per-phase Fundamental VA values (Arithmetic VAs).

6.9.8 Phase Angle (1-Cycle Update)

The Phase Angle is calculated for the Bus 1 to Bus 2 per-phase Fundamental Voltages and Fundamental Voltage to Fundamental Current. It is the Bus 1 Fundamental Voltage angle minus either the Bus 1 Fundamental Current or Bus 2 Fundamental Voltage angle for a given phase. Values are from -180 to +180 Degrees.

6.9.9 Resistance, Reactance, Impedance (1-Cycle Update)

These measurements are calculated for each phase from the fundamental values of voltage and current. The Impedance value, combined with the voltage-to-current phase angle, gives the polar form of the impedance. The Resistance and Reactance represent the rectangular form of the Impedance.

6.9.10 Slip Frequency (1-Cycle Update)

The Slip Frequency is the difference in the Frequency of a phase of Bus 1 Voltage to Bus 2 Voltage. Values are + when Bus 1 Frequency is greater.

6.9.11 Individual Phase Harmonic Magnitudes and Phase Angles (1-Cycle Update)

The M57x measures individual Harmonic Magnitudes and Harmonic Phase Angles for all Currents, Line-to-Neutral Voltages, and Line-to-Line Voltages. The magnitudes are reported in units of Amperes or Volts, not in percent. The Harmonic Phase Angles are in degrees, and all are referenced to the Bus 1 $V_{A\text{-}N}$ Voltage, which places all Harmonic Phase Angles in a common reference system. Values are from -180 to +180 Degrees.

6.10 Temperature (1-Second Update)

The M57x measures the internal temperature of the unit. Values are reported in increments of 0.5C.

6.11 Symmetrical Components (1-Cycle Update)

For each three phase input, Voltage and Current, the M57x generates the positive-sequence, negative-sequence, and zero-sequence vectors relative to phase A. These vectors represent the symmetrical components of their respective busses. The sequence component vectors are calculated by applying the vector operator a to the fundamental vectors of each phase according to the following set of well-known equations:

Zero-sequence component (vector) $E0 = (Ea + Eb + Ec)/3$

Positive-sequence component (vector) $E1 = (Ea + a * Eb + a * a * Ec)/3$

Negative-sequence component (vector) $E2 = (Ea + a * a * Eb + A * Ec)/3$

Where $a = \cos(120°) + j * \sin(120°)$ and *Ea*, *Eb*, and *Ec* are the fundamental vectors of a given bus.

The configuration parameter **phase rotation**, swaps the positive and negative sequence components to accommodate installations with "CBA" phase rotation.

6.12 Supply Voltage and Current Unbalance (1-Cycle Update)

The supply voltage unbalance is evaluated from the symmetrical components, according to EN6100-4-30:2003. In addition to the positive sequence component, under unbalance conditions there also exists at least one of the following components: negative sequence component u2 and/or zero sequence component u0.

$$Uu(\%) = \frac{U_2}{U_1} x100\%$$

The current unbalance is calculated similarly using the current components.

6.13 Flicker

Flicker measurements are measured and evaluated according to IEC61000-4-15. Specific settings for Flicker are found on the “Flicker” page (previously named "Power Quality" tab) of the Configurator. The Nominal System Frequency should be selected appropriately for the system in the “Instrument Transformer Ratio” page (previously the "Advanced" tab) of the Configurator.

6.14 Fault Analysis

Fault location and fault type are determined using a single-ended impedance calculation that is based upon an algorithm using measured values. Following below are the required line parameters needed to be entered as well as the outputs obtained in the SOE log and for protocols. Information on triggering and recording for fault location can be found in section 5.3.7.

6.14.1 Line Parameters

Line parameters for Bus 1 and Bus 2 may be entered independently in the Fault Location Line Settings area of the 70 Series Configurator (version 2.43 and later). The magnitude and phase angle of the direct line impedance, Z_d (positive sequence), and the residual compensation factor, k_{Z0} are required, where Z_d is measured in ohms and $k_{Z0} = (Z_0 – Z_d) / 3Z_d$. The zero sequence impedance, Z_0, is needed when doing the calculation. In addition, the user may specify the line length and their preferred units of measure, in place of per unit values (p.u.), for reporting distance in the SOE log.

6.14.2 Peak Current

When the Fault Analysis module is triggered, it will scan for the maximum fundamental current values in the 10 cycles before and 20 cycles after the trigger point. The maximums for each of Phase A, Phase B, Phase C, and Residual current are saved. The results are made available in the SOE log and protocol registers as noted below. Additionally, the maximum of the three phase (A, B, C) maximums is saved separately and made available via protocol.

6.14.3 Status Indication and Reset

The availability of measurement points indicating status and which ones can be reset are indicated as follows:

Fault Type: One point representing the fault type is available on Mx71 (Two points on Mx72 models). The user is able to select Fault Type if it is of interest when creating a user-configurable point list. The index number will be determined by where the point falls within the point list. The Fault Type point value represents a set of packed bits. Bit0 represents A-Phase Involved, Bit1 represents B-Phase Involved, Bit2 represents Phase-C Involved. All other bits (Bit3 – Bit15) always equal Zero. In that way:

(1) A-G fault is indicated by binary value of 1 (0001)
(2) B-G is binary 2 (0010)
(3) A-B is binary 3 (0011)
(4) C-G is binary 4 (0100)
(5) A-C is binary 5 (0101)
(6) B-C is binary 6 (0110)
(7) ABC is binary 7 (0111)

Targets: Four points representing targets are available on Mx71 (Eight points on Mx72 models). The user will be able to select any of the points that are of interest when creating a user-configurable point list. Index numbers will be determined by where the points fall within the point list. Target Points: Fault Completed is set when the module has completed analysis. Fault Target A, Fault Target B, and Fault Target C are set when their associated phases are involved in the fault. Target points are single bit binaries. Possible values are 0 and 1.

Fault Counter: One point (Two points on Mx72 models) is available representing the number of times the fault location algorithm has been triggered. The user will be able to select Fault Count if it is of interest when creating a user-configurable point list. The index number will be determined by where the point falls within the point list. The Fault Count point may be read as a counter change object. This is intended to facilitate notification (via event polling) that the value of the peak fault current has been freshly updated. The Fault Count Point simply increments until it rolls over; it cannot be reset.

Target Resets: The above-mentioned Fault Completed point is available to permit the user to reset targets once all data associated with a fault has been read. The user will be able to select Reset Targets when creating a user-configurable point. The index number will be determined by where the point falls within the point list. When the point is reset by writing a zero to it, the Fault Type point and the Fault Target A,B,C points will be automatically set to zero as well.

Related points for Bus1, Mx72 model Bus2 points are similar:

6.14.4 SOELOG Output

The soelog will report the fault type and fault distance. Distance will be shown as per unit, and in terms of the users preferred length units. For example, if the line length is defined as 100km:

```
24 30-Jul-2007 01:10:51.300206 Fault AB1 at 0.4949 of line or 49.49 km
```

6.14.5 Protocol Output

Configurable registers in Modbus and DNP may be used to view the results of the fault analysis calculations and the peak fault current. The following measurements have been added:

Measurement	Modbus	DNP3
Fault Type Bus 1	Modbus register	DNP Analog Input
Fault Distance XAN1	Modbus register	DNP Analog Input
Fault Distance XBN1	Modbus register	DNP Analog Input
Fault Distance XCN1	Modbus register	DNP Analog Input
Fault Distance XAB1	Modbus register	DNP Analog Input
Fault Distance XBC1	Modbus register	DNP Analog Input
Fault Distance XCA1	Modbus register	DNP Analog Input
Fault Type Bus 2	Modbus register	DNP Analog Input
Fault Distance XAN2	Modbus register	DNP Analog Input
Fault Distance XBN2	Modbus register	DNP Analog Input
Fault Distance XCN2	Modbus register	DNP Analog Input
Fault Distance XAB2	Modbus register	DNP Analog Input
Fault Distance XBC2	Modbus register	DNP Analog Input
Fault Distance XCA2	Modbus register	DNP Analog Input
Peak Fault Current IA1	Modbus register	DNP Analog Input
Peak Fault Current IB1	Modbus register	DNP Analog Input
Peak Fault Current IC1	Modbus register	DNP Analog Input
Peak Fault Current IR1	Modbus register	DNP Analog Input
Peak Fault Current Bus1	Modbus register	DNP Analog Input
Peak Fault Current IA2	Modbus register	DNP Analog Input
Peak Fault Current IB2	Modbus register	DNP Analog Input
Peak Fault Current IC2	Modbus register	DNP Analog Input
Peak Fault Current IR1	Modbus register	DNP Analog Input
Peak Fault Current Bus2	Modbus register	DNP Analog Input
Fault Target A1		DNP Binary Output
Fault Target B1		DNP Binary Output
Fault Target C1		DNP Binary Output
Fault Completed Bus1	Modbus register	DNP Binary Output
Fault Count Bus1	Modbus register	DNP Analog Input
Fault Target A2		DNP Binary Output
Fault Target B2		DNP Binary Output
Fault Target C2		DNP Binary Output
Fault Completed Bus2	Modbus register	DNP Binary Output
Fault Count Bus2	Modbus register	DNP Analog Input

The ‘fault type’ registers are a bit-field representation of which phases were driven by the event system, and are the same information used to generate the faulted phase strings in the soelog. Bit0 is A, Bit1 is B, Bit2 is C. The ‘fault distance’ registers are integer representations of the per-unit distance, in DIV1000 or DIV100 format pending exact configuration implementation.

6.15 List of Available Measurements & Settings

Please note that not all measurements are available in every M57x model (second set of current measurements and corresponding power, energy, etc. only in M572)

Available Measurements	
Accrued Digital IO Module #0-6, Input 1-16	K-factor Amps A (1 and 2)
Accrued Digital IO Module #0-6, Output 1-4	K-factor Amps B (1 and 2)
Accrued DR1/DR2 Active, Completed, Started	K-factor Amps C (1 and 2)
Accrued Pulse KWH, KVARH Positive (Bus 1 and 2)	K-factor Amps Residual (1 and 2)
Accrued Pulse KWH, KVARH Negative (Bus 1 and 2)	Log Interval
Accrued Virtual IO, Inputs 1-32, Outputs 1-32	Meter Type
Accrued WR1/WR2 Active, Completed, Started	Misc. Packed Bits
Amps A, B, C, Residual (Feeder 1 and 2)	Network Time Sync
Any Recorder Active	Peak Fault Current Amps A, B, C, Residual, Bus (1 and 2)
Any Recorder Memory Full	Phase Angle Amps A Harmonic (1…63 for 1 and 2)
Any Recorder Stored	Phase Angle Amps B Harmonic (1…63 for 1 and 2)
Any Recorder Triggered	Phase Angle Amps C Harmonic (1…63 for 1 and 2)
Avg. 3-phase Amps (1 and 2)	Phase Angle Volts A Bus1-Bus2
Avg. 3-phase Volts (1 and 2)	Phase Angle Volts A Harmonic (1…63)
Best Clock	Phase Angle Volts AB Harmonic (1…63)
Class 0 Response Setup	Phase Angle Volts B Bus1-Bus2
CT Scale Factor	Phase Angle Volts B Harmonic (1…63)
CT Scale Factor Divisor	Phase Angle Volts BC Harmonic (1…63)
Demand (Max.) Amps A, B, C, Residual (1 and 2)	Phase Angle Volts C Bus1-Bus2
Demand (Max.) Fund. Amps A, B, C, Residual (1 and 2)	Phase Angle Volts C Harmonic (1…63)
Demand (Max.) TDD Amps A, B, C, Residual (1 and 2)	Phase Angle Volts CA Harmonic (1…63)
Demand (Max.) THD Volts Bus1 AN, BN, CN, AB, BC, CA	Phase Angle Volts to Amps A (1 and 2)
Demand (Max.) THD Volts Bus2 AN, BN, CN, AB, BC, CA	Phase Angle Volts to Amps B (1 and 2)
Demand (Max.) VARs A, B, C, Total (1 and 2)	Phase Angle Volts to Amps C (1 and 2)
Demand (Max.) VAs A, B, C, Total (1 and 2)	Power Factor A, B, C, Total (Bus 1 and 2)
Demand (Max.) Volts Bus1 AN, BN, CN, NG, AB, BC, CA	Power Factor Total Arithmetic (Bus 1 and 2)
Demand (Max.) Volts Bus2 AN, BN, CN, NG, AB, BC, CA	Power Factor Total Equivalent L-L (Bus 1 and 2)
Demand (Max.) Watts A, B, C, Total (1and 2)	Power Factor Total Equivalent L-N (Bus 1 and 2)
Demand (Min.) THD Volts Bus1 AN, BN, CN, AB, BC, CA	Power Factor Total Geometric (Bus 1 and 2)
Demand (Min.) THD Volts Bus2 AN, BN, CN, AB, BC, CA	Protocol Version
Demand (Min.) VARs A, B, C, Total (1 and 2)	PT Scale Factor
Demand (Min.) VAs A, B, C, Total (1 and 2)	PT Scale Factor Divisor
Demand (Min.) Volts Bus1, AN, BN, CN, NG, AB, BC, CA	Pulse Status- Negative VArHrs (1 and 2)
Demand (Min.) Volts Bus2, AN, BN, CN, NG, AB, BC, CA	Pulse Status- Negative WHrs (1 and 2)
Demand (Min.) Watts A, B, C, Total (1 and 2)	Pulse Status- Positive VarHrs (1 and 2)
Demand Amps A, B, C, Residual	Pulse Status-Positive WHrs (1 and 2)
Demand Fundamental Amps A, B, C, Residual	Pulse VAR-Hrs Normal (1 and 2)
Demand TDD Amps A, B, C, Residual	Pulse VAR-Hrs Reverse (1 and 2)
Demand THD Volts Bus1 AN, BN, CN, AB, BC, CA	Pulse Watt-Hrs Normal (1 and 2)
Demand THD Volts Bus2 AN, BN, CN, AB, BC, CA	Pulse Watt-Hrs Reverse (1 and 2)
Demand VARs A, B, C, Total	Reactance A, B, C (1 and 2)
Demand VAs A, B, C, Total	Resistance A, B, C, (1 and 2)
Demand Volts Bus1 AN, BN, CN, NG, AB, BC, CA	Slip Freq. Volts A Bus1-Bus2
Demand Volts Bus2 AN, BN, CN, AB, BC, CA	Slip Freq. Volts B Bus1-Bus2
Demand Watts A, B, C, Total	Slip Freq. Volts C Bus1-Bus2
Digital IO#0 Debounce Time	SNTP Time Sync
Digital IO#0 Input Point 1-4	Symmetrical comp. of Bus 1 voltage (mag. and

Available Measurements	
	angle)
Digital IO#0 Output Point 1-4	Symmetrical comp. of Bus 2 voltage (mag. and angle)
Digital IO Module #0-6 Status Output Point 1-4	Symmetrical comp. of current (mag. and angle, 1 & 2)
Displacement Power Factor A, B, C (1 and 2)	System Frequency
Displacement Power Factor Total (1 and 2)	Tag Register
Displacement Power Factor Total Arithmetic (1 and 2)	TDD Amps A, B, C, Residual (1 and 2)
Displacement Power Factor Total Equivalent L-L (1 & 2)	TDD Denominator A, B, C, (1 and 2)
Displacement Power Factor Total Equivalent L-N (1 & 2)	TDD, Even, Amps A, B, C, Residual (1 and 2)
Displacement Power Factor Total Geometric (1 & 2)	TDD, Odd, Amps A, B, C, Residual (1 and 2)
DNP Time Sync	Temperature
DR 1 Active	THD Volts Bus1 AN, BN, CN, AB, BC, CA
DR1 Memory Full	THD Volts Bus2 AN, BN, CN, AB, BC, CA
DR1 Record Count	THD, Even, Volts Bus1 AN, BN, CN, AB, BC, CA
DR1 Stored	THD, Even, Volts Bus2 AN, BN, CN, AB, BC, CA
DR1 Triggered	THD, Odd, Volts Bus1 AN, BN, CN, AB, BC, CA
DR2 Active	THD, Odd, Volts Bus2 AN, BN, CN, AB, BC, CA
DR2 Memory Full	Time Sync Error (usec, msec, sec)
DR2 Record Count	Trigger Derivative 1-120
DR2 Stored	Unbalance Volts (1 and 2)
DR2 Triggered	Unbalance Amps (1 and 2)
DSP Version	User Gain Amps A, B, C, Residual (1 and 2)
Factory Version Hardware	User Gain Volts Bus1 A, B, C, N
Factory Version Software	User Gain Volts Bus2 A, B, C, N
Fault Completed (Bus 1, Bus 2)	User Gain Volts Bus2 Aux1-Gnd, Aux2-Gnd, Aux1-Aux2
Fault Count (Bus 1, Bus 2)	User Phase Correction Amps A, B, C, Residual (1 and 2)
Fault Distance AN, BN, CN, AB, BC, CA (Bus 1, Bus 2)	User Phase Correction Volts Bus1 AN, BN, CN, NG, AB, BC, CA
Fault Target (A, B, C, Bus 1 and Bus 2)	User Phase Correction Volts Bus2 AN, BN, CN, NG, AB, BC, CA
Fault Type (Bus 1, Bus 2)	User Phase Correction Volts Bus2 Aux1-Gnd, Aux2-Gnd, Aux1-Aux2
Flicker Short (PST VAN, VBN, VCN Bus 1 and 2)	VA/PF Calc. Type (1 and 2)
Flicker Long (PLT VAN, VBN, VCN Bus 1 and 2)	VA-Hrs (1 and 2)
Frequency Amps A, B, C, Residual (1 and 2)	VAR-Hrs Lag (1 and 2)
Frequency Volts Bus1 A, B, C	VAR-Hrs Lead (1 and 2)
Frequency Volts Bus2 A, B, C	VARs A, B, C, Total (1 and 2)
Fund. Amps A, B, C, Residual (1 and 2)	VAs A, B, C, Total (1 and 2)
Fund. VAs Tot. Arith (1 and 2).	VAs Tot. Arith. (1 and 2)
Fund. VAs Tot. Equiv. L-L (1 and 2)	VAs Tot. Equiv. L-L (1 and 2)
Fund. VAs Tot. Equiv. L-N (1 and 2)	VAs Tot. Equiv. L-N (1 and 2)
Fund. VAs Tot. Geom. (1 and 2)	VAs Tot. Geom. (1 and 2)
Fund. VAs Total (1 and 2)	Virtual Input Point 1-32
Fund. Volts Bus1 AN, BN, CN, AB, BC, CA	Virtual Output Point 1-32
Fund. Volts Bus2 AN, BN, CN, AB, BC, CA	Volts Aux1-Gnd, Aux2-Gnd, Aux1-Aux2
Harmonic, Individual, Amps A, B, C, (1…63 for 1 & 2)	Volts Bus1 AN, BN, CN, NG, AB, BC, CA
Harmonic, Individual, Bus1, Volts A (1...63)	Volts Bus2 AN, BN, CN, NG, AB, BC, CA
Harmonic, Individual, Bus1, Volts AB (1...63)	Watt-Hrs Normal (1 and 2)
Harmonic, Individual, Bus1, Volts B (1...63)	Watt-Hrs Reverse (1 and 2)
Harmonic, Individual, Bus1, Volts BC (1...63)	Watts A, B, C, Total (1 and 2)
Harmonic, Individual, Bus1, Volts C (1...63)	Waveform Status

Available Measurements	
Harmonic, Individual, Bus1, Volts CA (1...63)	WV1/WV2 Active
Harmonic, Individual, Bus2, Volts A (1...63)	WV1/WV2 Memory Full
Harmonic, Individual, Bus2, Volts AB (1...63)	WV1/WV2 Record Count
Harmonic, Individual, Bus2, Volts B (1...63)	WV1/WV2 Stored
Harmonic, Individual, Bus2, Volts BC (1...63)	WV1/WV2 Triggered
Harmonic, Individual, Bus2, Volts C (1...63)	Xfmr Ratio Amps A, B, C, Residual (1 and 2)
Harmonic, Individual, Bus2, Volts CA (1...63)	Xfmr Ratio Future Use
Health	Xfmr Ratio Volts Bus1 A, B, C, N
Heartbeat	Xfmr Ratio Volts Bus2 A, B, C, N
Impedance A, B, C (1 and 2)	Xfmr Ratio Volts Bus2 Aux1-Gnd, Aux2-Gnd, Aux1-Aux2
IrigB Time Sync	

6.16 Calibration

Routine re-calibration is not recommended or required. A field calibration check every few years is a good assurance of proper operation.

6.17 Instantaneous Measurement Principles

The M57x measures all signals at 128 samples/cycle, accommodating fundamental signal frequencies from 15 to 70 Hz or 40 to 70 Hz depending on model. Samples of all bus signals are taken at the same instant in time, using a 16-Bit A/D converter, effectively creating 128 "snapshots" of the system voltage and current per cycle.

6.17.1 Sampling Rate and System Frequency

The sampling rate is synchronized to the frequency of any of the bus voltage or current inputs, prioritized as follows: $V1_{A\text{-}N}$, $V1_{B\text{-}N}$, $V1_{C\text{-}N}$, $V2_{A\text{-}N}$, $V2_{B\text{-}N}$, $V2_{C\text{-}N}$, I1A, I1B, I1C, I2A, I2B, I2C. This is the frequency reported as the "System Frequency". The AUX voltage inputs and Neutrals are not used to synchronize the sampling. The sampling rate is the same for all channels.

The default system frequency may be set in the Configurator to either 50 or 60 Hz. This will have no effect on the frequency that is reported, or the sample rate when signals are present. It is used to set the default sample rate when the unit cannot detect any applied signal.

7.0 TRANSDUCER INPUT OPTION

7.1 Introduction

The Transducer Input option features 4 separate inputs each with two terminals, one which provides a unique return path for each input. This permits the inputs configured as current inputs to be series connected to multiple transducer input devices and inputs configured as voltage inputs to be parallel connected to multiple transducer input devices. The input terminal assignments are shown in figure 11.

The inputs are jumper-selectable for three different transducer input formats. The inputs can be jumpered for either 0–1 mA or 4-20 mA current inputs or for 0–10V voltage inputs. Both the 0-1 mA and 0 -10 V formats are bipolar (bi-directional) such that they span (-)1mA to (+)1mA and (-)10V to (+)10V respectively. Each format allows for input over-range such that inputs exceeding the normal range can still be reported accurately. The reportable range for each input type is approximately: (+/-) 2.5 mA for 0-1mA inputs; (+/-) 12.5V for the 0-10V inputs; and 0 to 25mA for 4-20mA inputs.

Each transducer input can be independently configured for any of the three input formats. This permits one Transducer Input option to be used to read four analog inputs with any mix of the three standard current and voltage formats. The Transducer Input option can only be ordered pre-configured for one standard input type (all inputs are pre-configured at the factory for one input type), however, each input on every Transducer Input Module is calibrated to support all format types. Changing an input's type is easy and only requires changing that input's jumper setting. The jumper settings are documented in section 7.6.1, below.

Each transducer input is sampled by a 24-Bit delta sigma analog to digital converter, adjusted by a factory set pre-stored gain and offset calibration constant, and then converted to a 16-Bit integer value. The Host Processor Board updates the transducer input values in the floating point database every 500msec by reading each input's 16-Bit integer value and converting it to a floating point value. By default the floating point value represents the actual current (in mA) or voltage (in volts) present at the input. The Host Processor can be configured (via the 70 Series Configurator software) to independently scale each transducer input's floating point value. The scaling is accomplished by assigning a floating point value to the extreme values of the transducer input's format. Input scaling is described in detail in section 7.6.2, below.

Consult the appropriate Protocol manual for information on reading the transducer inputs and the available calculation types. In order to be read, the transducer input measurements need to be added into one of the available configurable register/point sets.

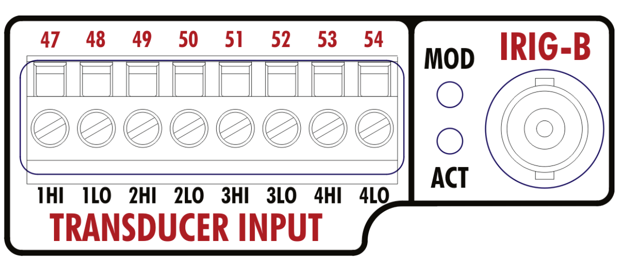


Figure 11 - Terminal Assignment

7.2 Features

- Each input has jumper selectable ranges for support of 0 to (+/-)10 volt, 0 to (+/-)1mA, and 4-20mA transducer input formats.
- All input terminals protected with internal transient limiting devices and spark gap protection.
- Design includes local microcontroller with 24-bit sigma delta analog-to-digital converter.
- Robust local microcontroller design incorporates local watchdog and continuously monitors offset and gain calibration constants integrity via checksum calculation.
- Removable terminal block for ease of installation

7.3 Specifications

Inputs: 4 bi-directional, jumper selectable for voltage or current range. Input terminals have internal transorb clamp and 90V spark gap protection.

0 – 10V Voltage Range

Overload Range:	-12.5 V to +12.5 Vdc
Resolution:	0.381 mV
Input Resistance:	10K ohm

0 – 1mA Current Range

Overload Range:	-2.5 mA to +2.5 mA
Resolution:	0.0763 uA
Input Resistance:	500 ohm

4 – 20mA Current Range

Overload Range:	0 mA to +25 mA
Resolution:	0.381 uA
Input Resistance:	50 ohm

Common Mode Input Range: +/- 9V, Input to Chassis

Common Mode Error

Vcm DC:	0.3% of FS @ 9Vp Common Mode
Vcm 50/60Hz AC:	0.1% of FS @ 9Vp Common Mode

Accuracy: 0.25% of Full Scale Input

Data Update Rate (poll rate): 100ms minimum

Input Capacitance, any Terminal to Case: 470pF

7.5 Physical

Connections: Removable Terminal Blocks, accepts #16-28AWG (1,4-0,09mm) wire. Recommended Torque Rating is 2.2 In-Lbs, 0.25 N-m. Standard 0.200" (5,08mm) header socket accepts other standard terminal types.

Recommend Wire:	Twisted pair, either solid core wire (preferred) or stranded wire with the use of "bootlace ferrules", where these are available.

7.6 System Design Considerations

7.6.1 Input Type Jumper Settings

The Transducer Input option is ordered by specifying an input type and the M57x is shipped from the factory with all inputs configured for that specified transducer input type. The input type configuration is determined by jumper settings and can easily be re-configured in the field. Each transducer input can be independently configured to support either the 0 to 1mA, 4 to 20mA, or 0 to 10V transducer input formats. To gain access to the jumpers follow the procedure outlined below:

1. De-energize all circuits connected to the M57x.
2. Disconnect wiring connected to the M57x
3. Remove the screws shown in Fig 12
4. Carefully slide front panel assembly away from chassis exposing circuit boards.
5. Locate analog input module and jumpers as shown in Fig 13.
6. Modify jumper settings as required. See jumper explanation below.
7. Reassemble.

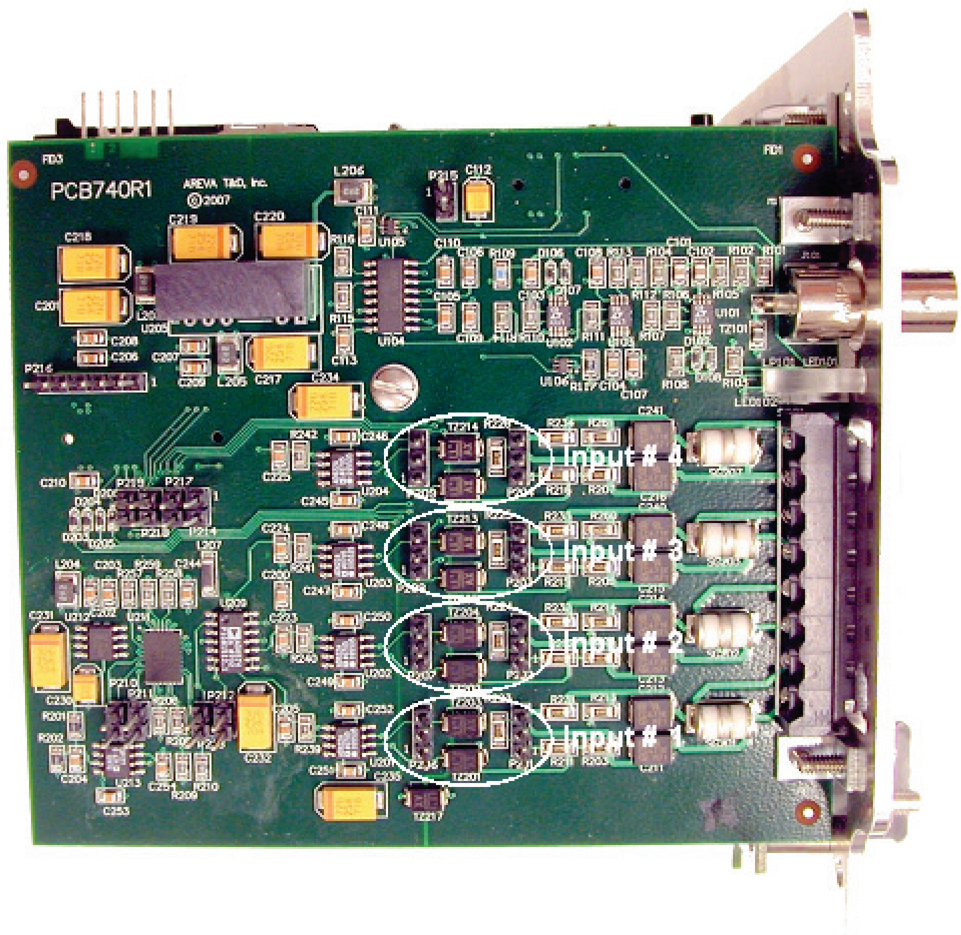


Figure 12 – Analog Input Type Jumper Locations

Each input has two configurable jumper blocks. One jumper block configures the hardware (the actual input circuitry), the other jumper control block configures the firmware and software driver (informs drivers of the status of the hardware selection). It is extremely important that when reconfiguring any input, that both the hardware jumper setting and firmware jumper setting for that input match (select the same input type).

Figure 12 (Analog Input Type Jumper Locations) shows the location of each input's jumper block pair. Each jumper block pair consists of two three pin headers and each header is shipped with a shorting block. The position of the shorting block on the header determines the input type configuration. Figure 13 (Transducer Input Type Jumper Configuration) demonstrates the shorting block positions for the three valid input configuration options.

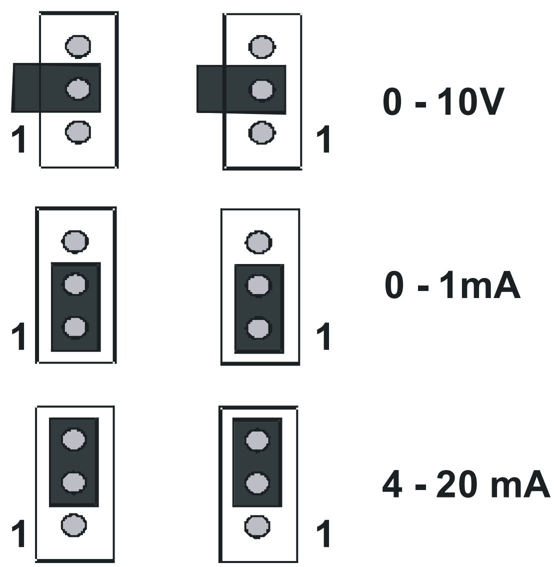


Figure 13 – Transducer Input Type Jumper Configuration

7.6.2 Transducer Input Scaling Configuration

The floating point values for the Transducer Input points on all present Transducer Input Modules will appear in the M57x floating point database. By default, values for Transducer Inputs configured as voltage inputs will be in volts and values for Transducer Inputs configured as currents will be in milliamps. Database points for which there are no corresponding Transducer Input points will report as zero.

The 70 Series Configurator software provides for gain and offset scaling for each Transducer Input. This permits transducer inputs to appear in primary units. The 70 Series Configurator allows the user to enter two specific primary values for the associated transducer input values and automatically calculates the correct offset and gain corrections. See Figure 14 (70 Series Configurator Software Transducer I/O Configuration Screen).

In the screen snap shot shown in the Figure 14, the first Transducer Input card has the first input configured for type 0-1mA, input 2 configured for type 4-20mA input, and the remaining two inputs configured as type 0-10V inputs. All inputs will appear in the database in default units (milliamps for inputs 1,2 and volts for inputs 3,4).

7.6.3 Setting the Data Update Rate (Poll rate) for P40 Transducer Inputs

The poll rate is now settable through the Transducer Input page. Poll rate has been added as a settable value starting with the release of Configurator v3.02. A poll rate as low as 100 ms can now be set. See Figure 14, which shows an example of settings made using the 70 Series Configurator Software on the Transducer Input page.

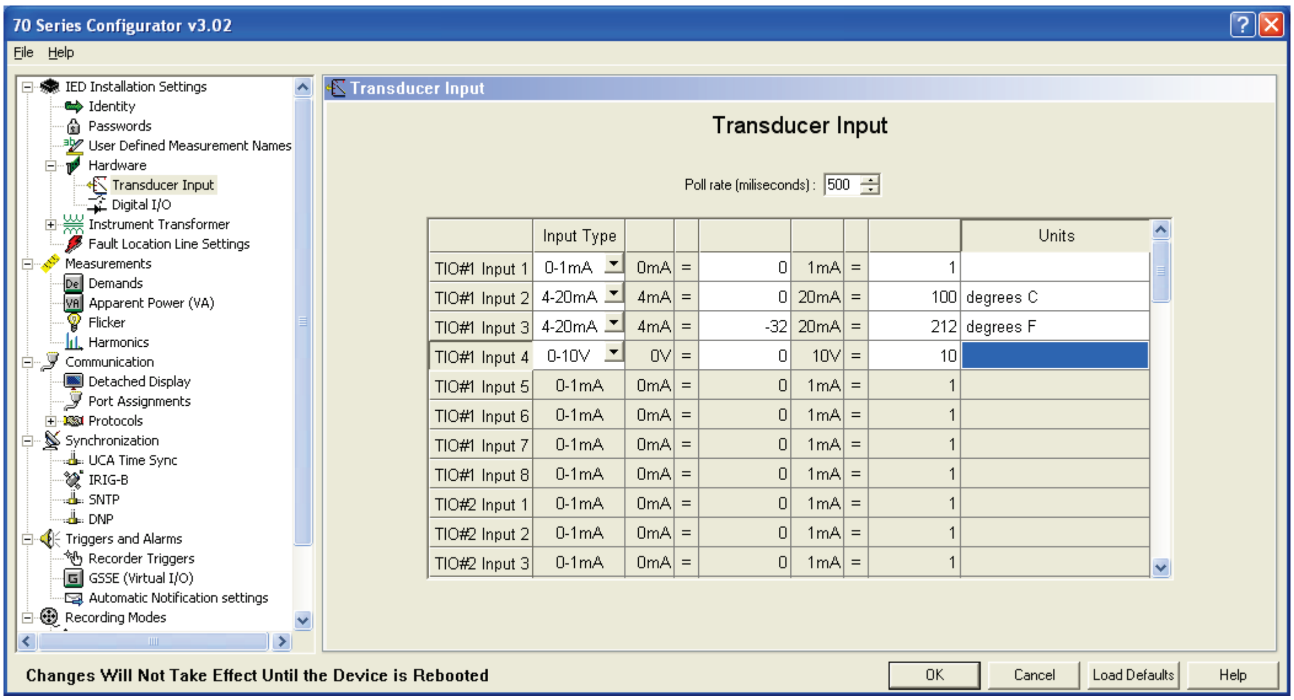
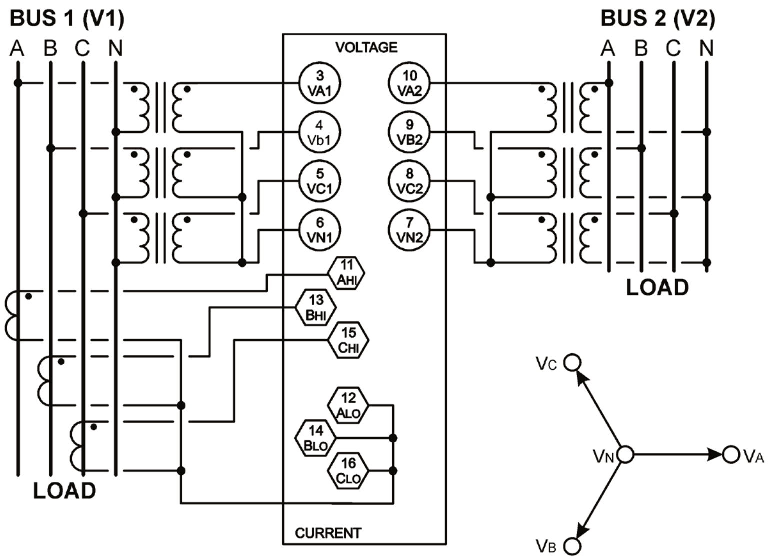


Figure 14 – 70 Series Configurator Software Transducer Input Configuration Screen

Suppose the device connected to input 2 is a temperature transducer with an output range from 4 to 20mA that corresponds to a temperature of 0 to 100 degrees C. Configuring the 4mA setting to report as 0 and the 20mA setting to report as 100 will scale the value in the M57x database to the primary units of the transducer.   If this same transducer is connected to input 3 with the scalings changed to -32 and 212 respectively, the value will appear in the M57x database in degrees F.

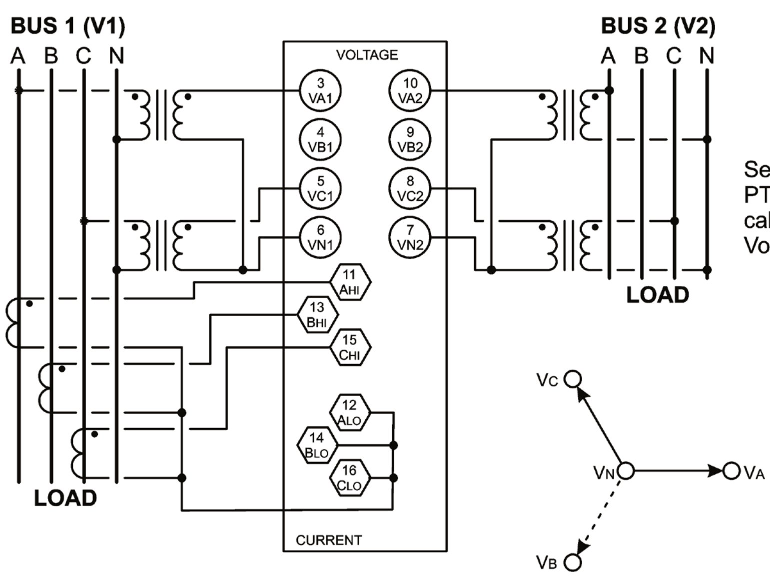
A1 CT/VT Connection Diagrams

3 Element, 4 Wire, WYE Connection



CT's and PT's SHOULD BE GROUNDED PER ANSI/IEEE C57.13.3

2-1/2 Element, 4 Wire, WYE Connection (Shown with Phase B Voltage Missing), without Neutral CT

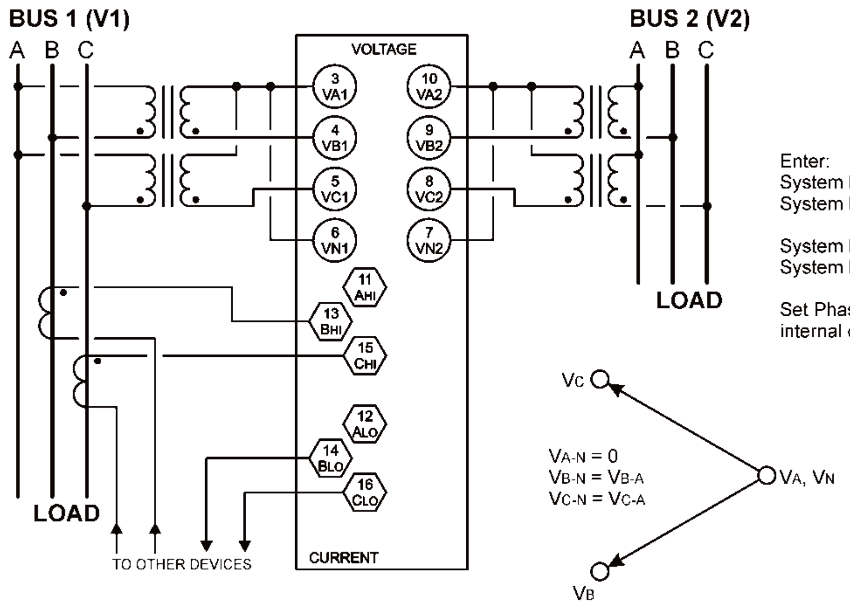


Set Bus 1 and Bus 2 B-N PT Ratios to 0 to force internal calculation of Phase B-N Voltages on both Busses.

M571 Wire SCH1.CDR 12-13-04

Figure 15 - Signal Connections – M571

2 Element, 3 Wire, DELTA Connection (Phase A Reference Shown).
Two Phase CT s Shown w/o Common Return, Phase A Current Calculated Internally.



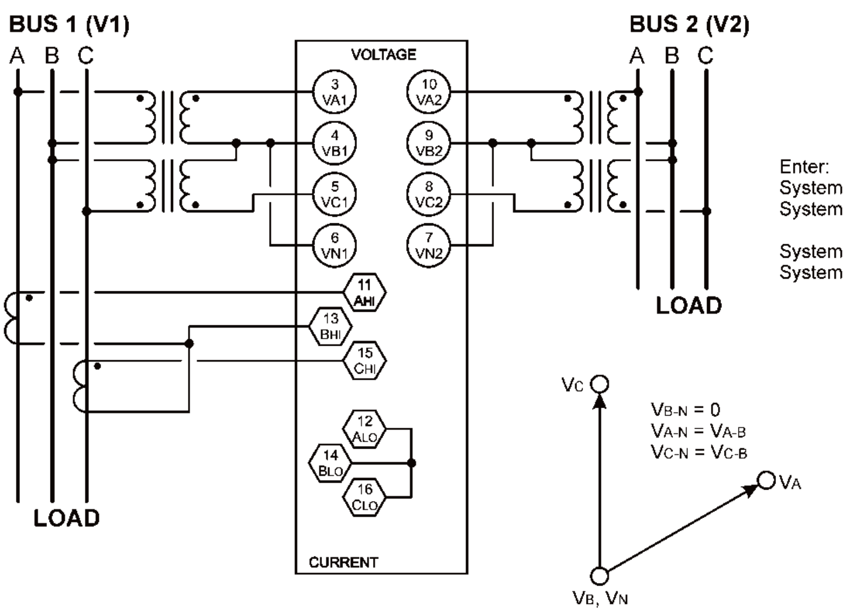
Enter:
System Bus 1 B-A PT Ratio as Bus 1 B-N PT Ratio
System Bus 1 C-A PT Ratio as Bus 1 C-N PT Ratio

System Bus 2 B-A PT Ratio as Bus 2 B-N PT Ratio
System Bus 2 C-A PT Ratio as Bus 2 C-N PT Ratio

Set Phase A CT Ratio to 0 to force
internal calculation of Phase A Amperes.

CT's and PT's SHOULD BE GROUNDED PER ANSI/IEEE C57.13.3

2 Element, 3 Wire, DELTA Connection (Phase B Reference Shown).
Two Phase CT s Shown, Phase B Current Measured in CT Return Path.

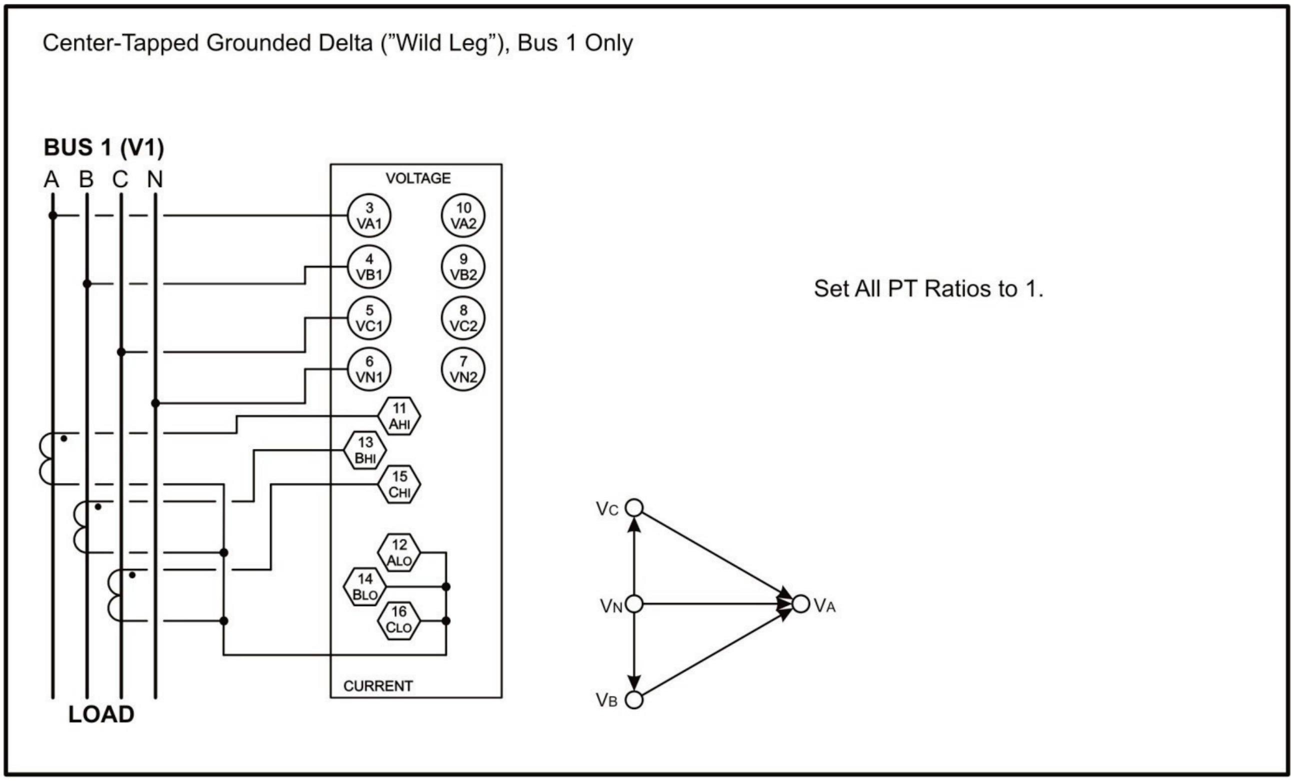


Enter:
System Bus 1 A-B PT Ratio as Bus 1 A-N PT Ratio
System Bus 1 C-B PT Ratio as Bus 1 C-N PT Ratio

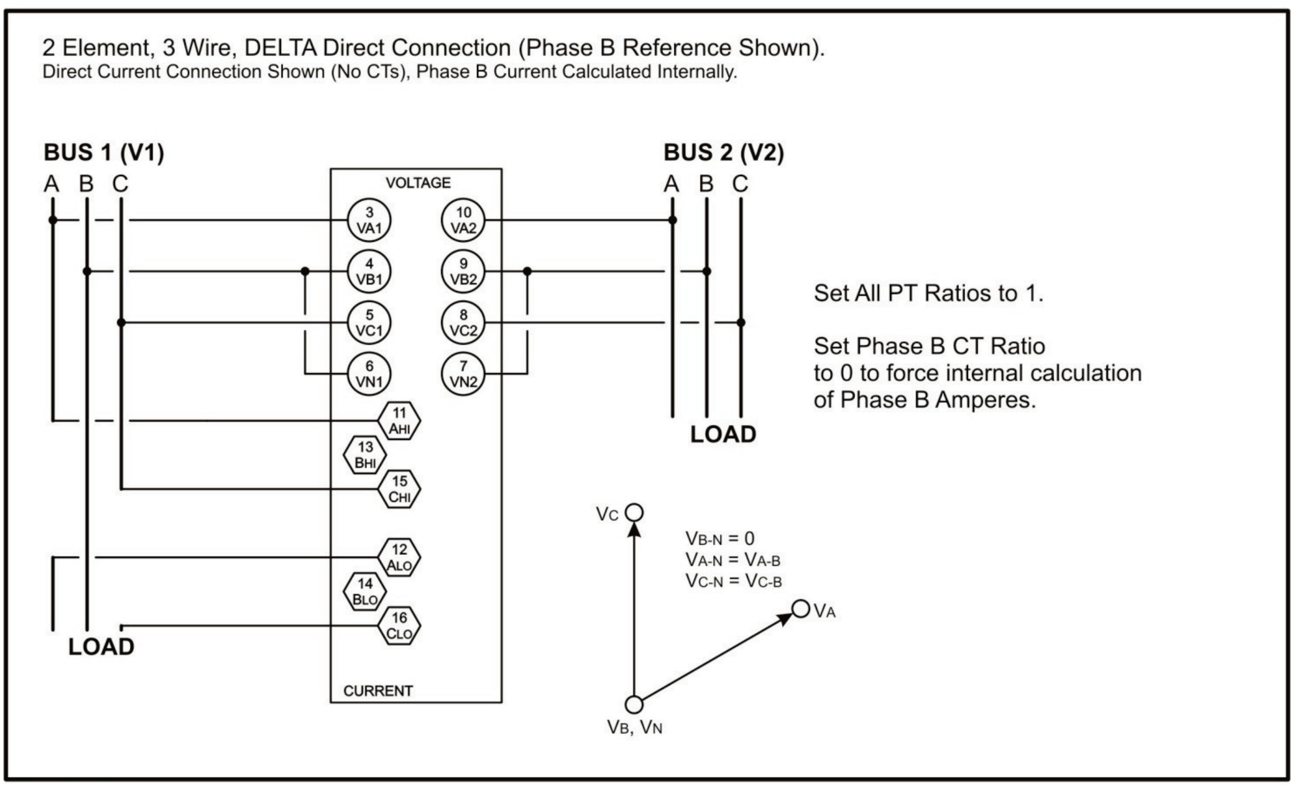
System Bus 2 A-B PT Ratio as Bus 2 A-N PT Ratio
System Bus 2 C-B PT Ratio as Bus 2 C-N PT Ratio

M571 Wire SCH2 CDR 12-13-04

Figure 15 (Continued) - Signal Connections – M571

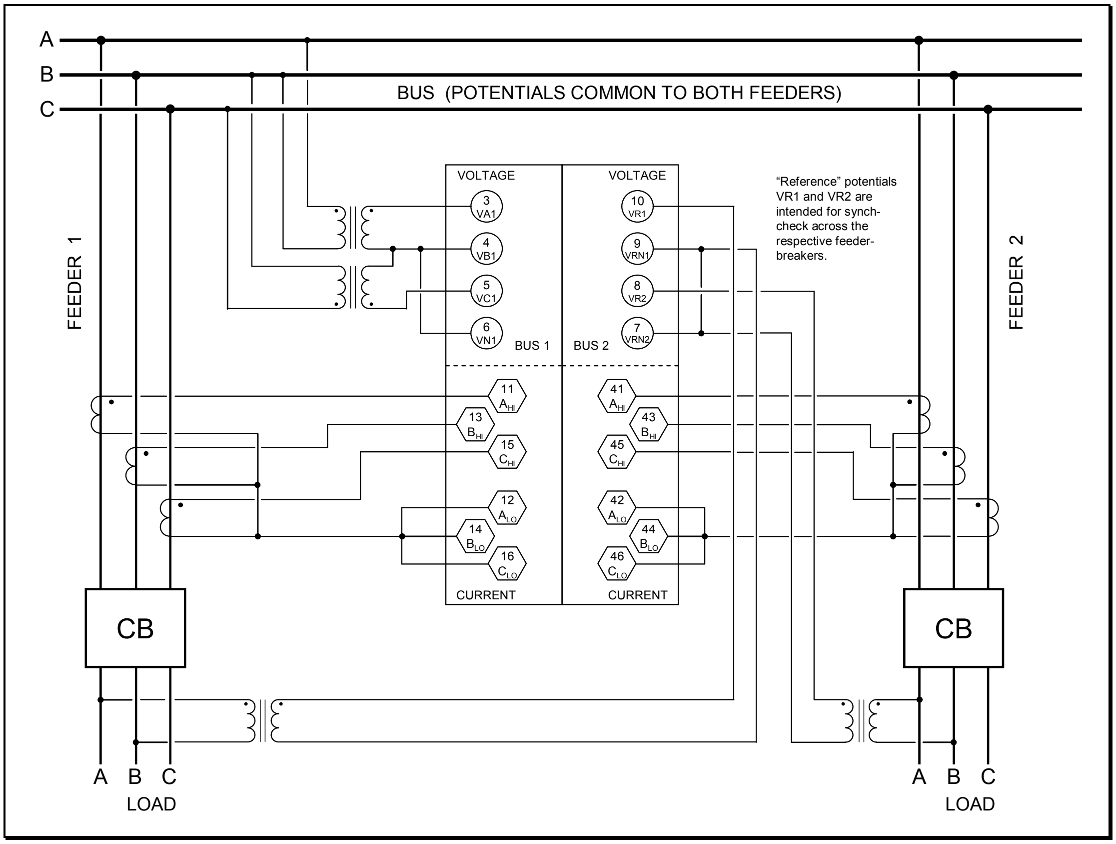


CT's and PT's SHOULD BE GROUNDED PER ANSI/IEEE C57.13.3

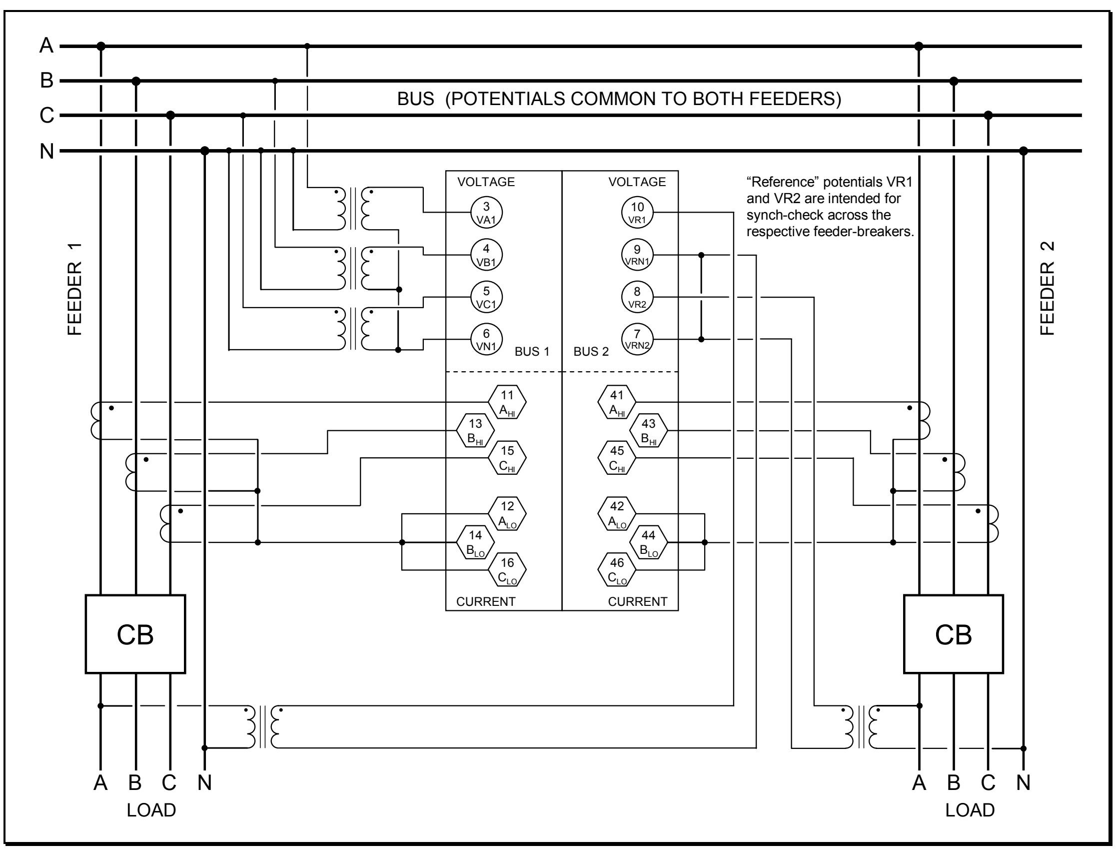


M571 Wire SCH3 r1.CDR 11-02-05

Figure 15 (continued) - Signal Connections – M571

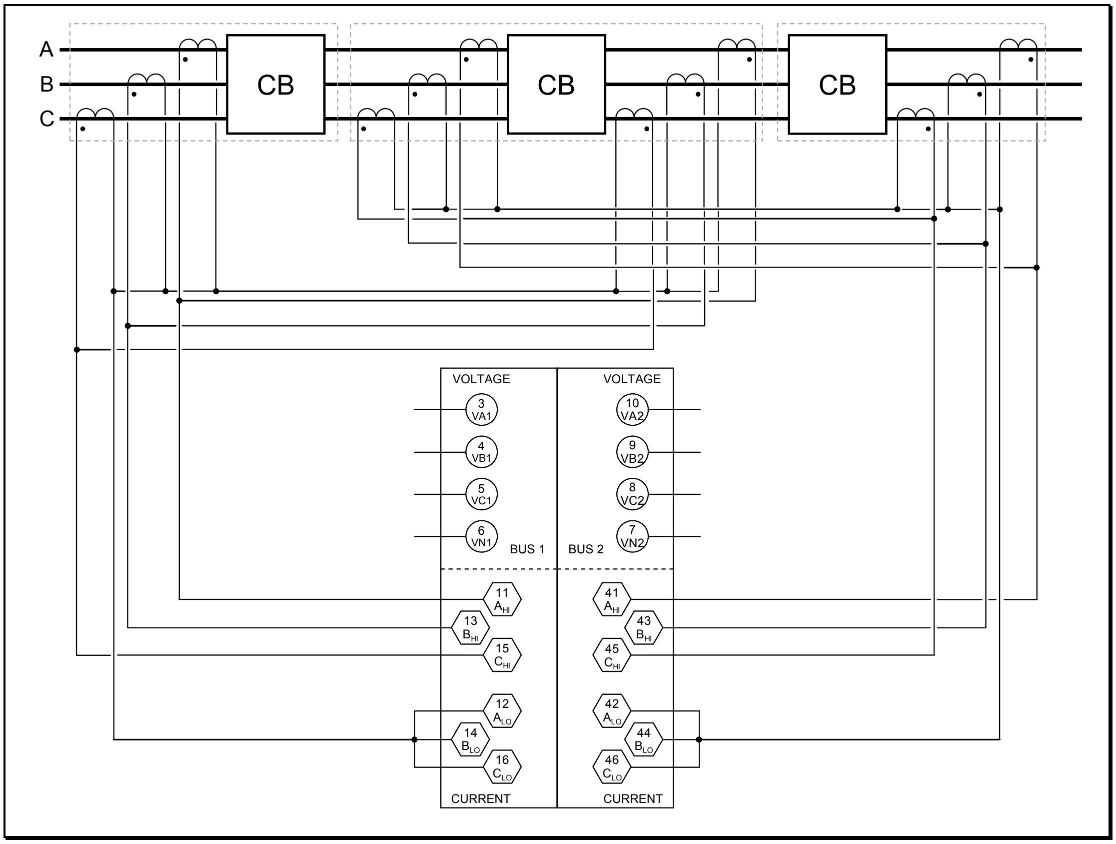


2-Element 3-Wire (Delta) configured for Dual Feeder Common Bus

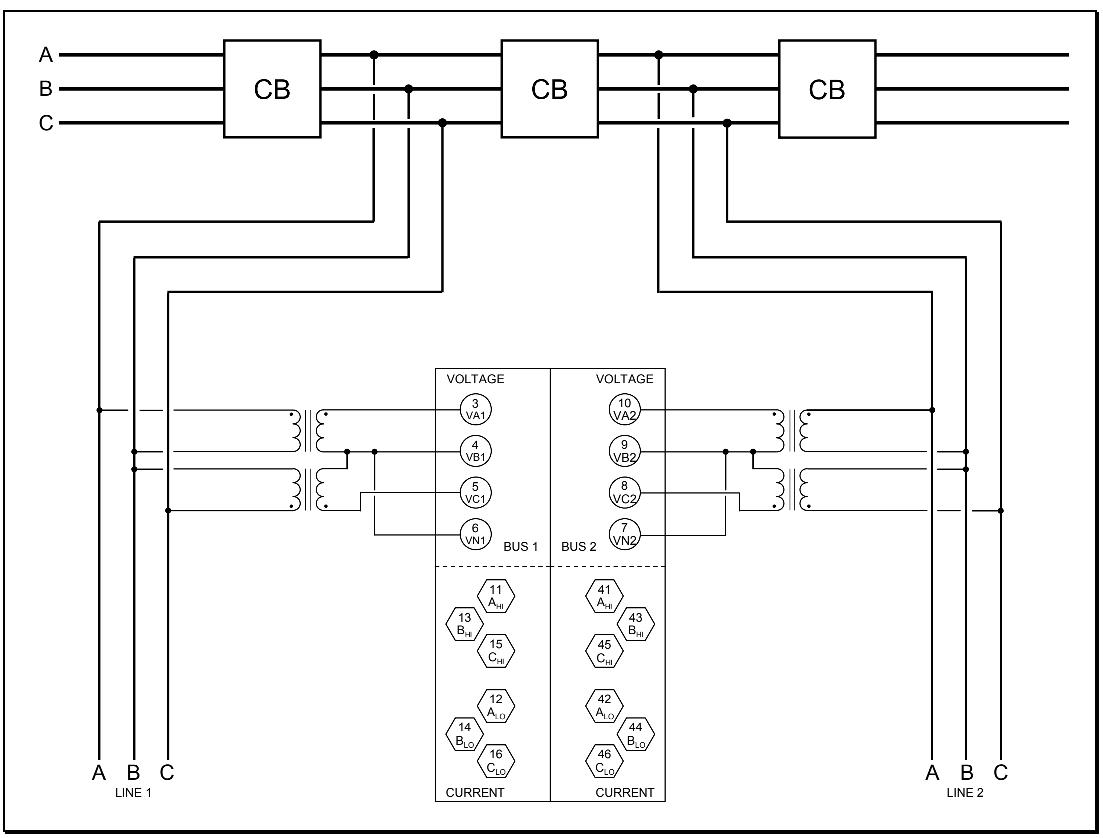


3-Element 4-Wire (Wye) configured for Dual Feeder Common Bus

Figure 16 - Signal Connections – M572

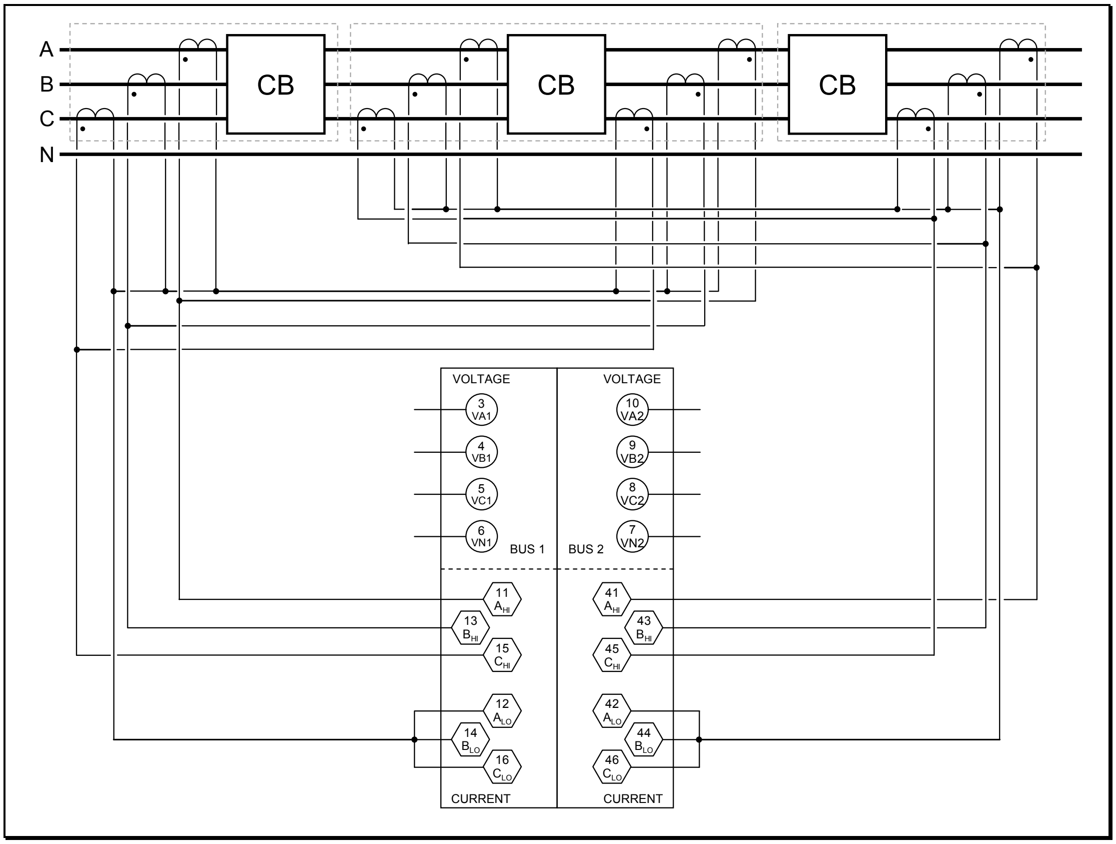


2-Element 3-Wire (Delta) configured for Breaker-and-a-Half (current connections shown)

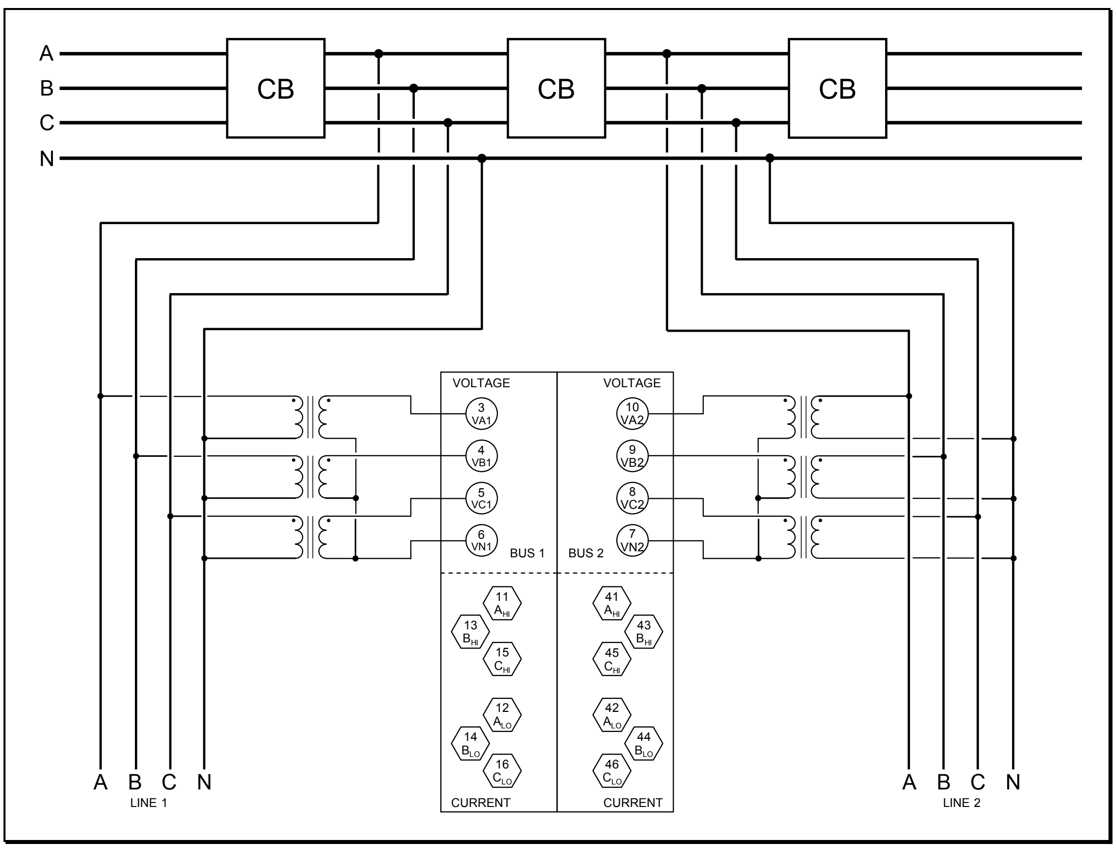


2-Element 3-Wire (Delta) configured for Breaker-and-a-Half (voltage connections shown)

Figure 16 (Continued) - Signal Connections – M572

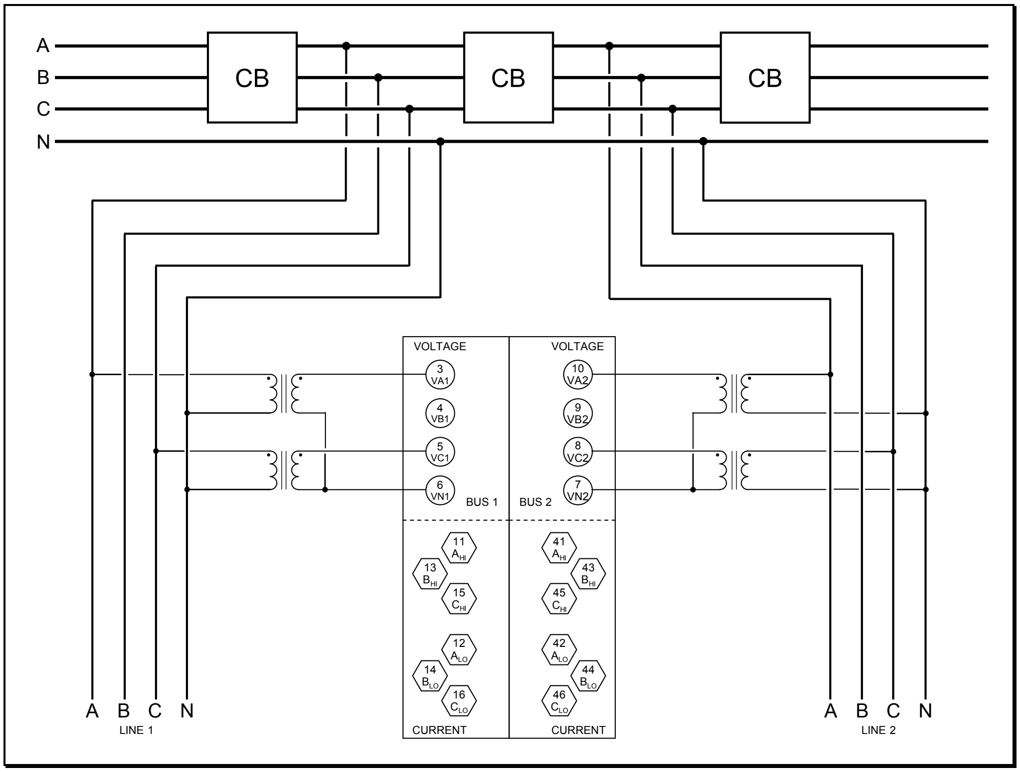


3-Element 4-Wire (Wye) configured for Breaker-and-a-Half (current connections shown)

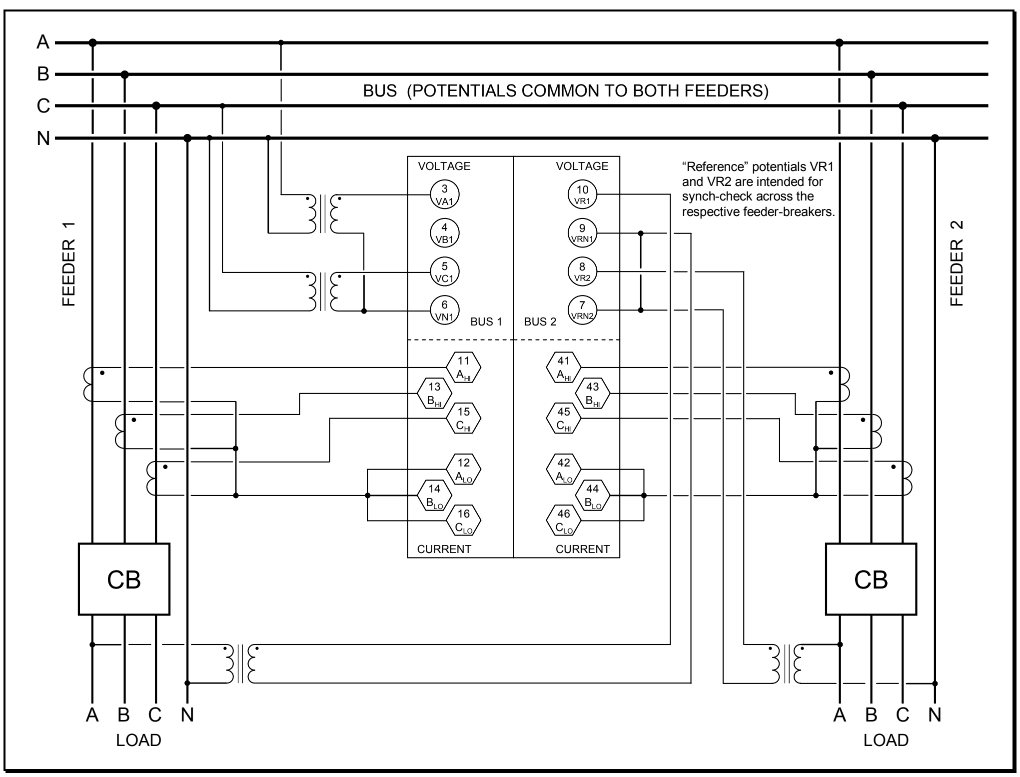


3-Element 4-Wire (Wye) configured for Breaker-and-a-Half (voltage connections shown)

Figure 16 (Continued) - Signal Connections – M572



2½ Element (Wye) configured for Breaker-and-a-Half (voltage connections shown, with B-phase missing)
Current connections are the same as for 3-element 4-wire (wye) shown on the preceding page.
When configuring the unit, set the VT ratio for the missing phase equal to 0. This will cause the M572 to calculate the voltage of the missing phase from the vector sum of the two phases present (assumes balanced voltage).



2½ Element (Wye) configured for Dual Feeder Common Bus (shown with B-phase missing).
When configuring the unit, set the VT ratio for the missing phase equal to 0. This will cause the M572 to calculate the voltage of the missing phase from the vector sum of the two phases present (assumes balanced voltage).

Figure 16 (Continued) - Signal Connections – M572

A2 Ethernet Troubleshooting

If the Link LED fails to illuminate, this is an indication that there is trouble with the connection and communication will not proceed without solving the problem. If a copper connection is used between the M57x and the hub/switch, check the following items:

- Verify that the connectors are fully engaged on each end.
- Verify that the cable used is a "straight-through" cable connected to a "normal" port. Alternatively, a "cross-over" cable *could* be connected to an "uplink" port (this could later cause confusion and is not recommended).
- Verify that both the M57x and hub/switch are powered.
- Try another cable.
- If a long CAT-5 cable is used, verify that is has never been kinked. Kinking can cause internal discontinuities in the cable.

If a fiber-optic connection is used:

- Verify that the hub/switch matches the Ethernet card port. A 100BASE-FX port will NEVER inter-operate with the 10BASE-FL port (fiber auto-negotiation does not exist).
- Try swapping the transmit and receive connector *on one end*.
- Verify that the hub/switch uses the proper optical wavelength (10BASE-FL should be 820 nm and 100BASE-FX should be 1300 nm). Note that the Ethernet card may take up to 12 seconds before it enables the 10BASE-FL transmitter, but it leaves the transmitter on for about 5 seconds before giving up.

If a copper connection is used to an off-board fiber converter:

- Verify that the LINK LED on the converter is lit on at least one side. Both sides need to be lit for a valid connection to be established.
- At least one brand of converters will not output an optical idle unless it receives a forced 10 Mb copper link pulse (for some reason, auto-negotiation pulses confuse it). Some hubs/switches will not output an optical idle unless they receive an optical idle. This then inhibits the converter from outputting a copper link pulse enabling the M57x to link. In this condition, no device completes the link.
- Follow the suggestions for the all copper and all fiber system troubleshooting.

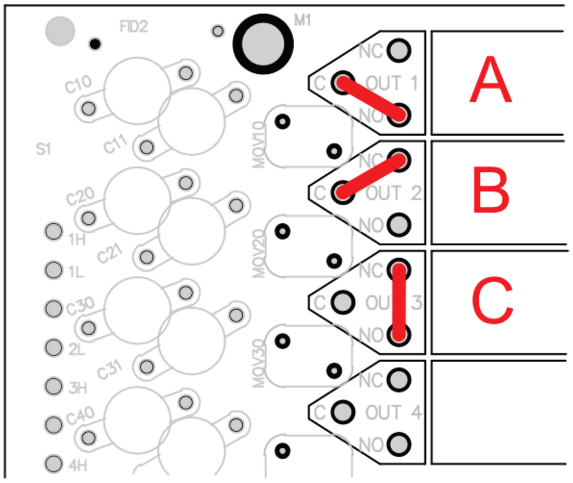
A3 Setting Digital I/O Jumpers

The Digital I/O jumpers described below are accessible by removing the four corner screws on the front panel of the M57x. Carefully remove the front panel assembly from the case. The jumpers can be found on the left side of PCB729, where it joins the front panel.

The M57x has jumper blocks (P4005) to set the output relay power-up configuration, which is the state (coil energized or de-energized) at which the relays go to when power is first applied to the module. The actual contact state is determined by the relay Normally Open (NO) or Normally Closed (NC) jumper (see below). By default, no jumpers are installed at the factory, which sets the output contact state to de-energized (open when configured for NO), which should be sufficient for most applications. If it is necessary to change the power-up configuration, jumpers may be installed as follows:

Power Up Configuration					
Jumper	**Function**	**ON**	**OFF**	**Output Relay NO**	**Output Relay NC**
P4005	PUC1		X	Output 1 set to OPEN	Output 1 set to CLOSED
P4005	PUC1	X		Output 1 set to CLOSED	Output 1 set to OPEN
P4005	PUC2		X	Output 2 set to OPEN	Output 2 set to CLOSED
P4005	PUC2	X		Output 2 set to CLOSED	Output 2 set to OPEN
P4005	PUC3		X	Output 3 set to OPEN	Output 3 set to CLOSED
P4005	PUC3	X		Output 3 set to CLOSED	Output 3 set to OPEN
P4005	PUC4		X	Output 4 set to OPEN	Output 4 set to CLOSED
P4005	PUC4	X		Output 4 set to CLOSED	Output 4 set to OPEN

The relay outputs can be set for Normally Open (NO) or Normally Closed (NC) operation. To enable Normally Open operation, which is the factory setting, place the jumper from "C" (common) to "NO". To enable Normally Closed operation, place the jumper from "C" to "NC". The relay outputs can be disabled if desired by placing the jumper vertically, from the "NC" to the "NO" contacts, or by removing the jumper entirely.



A - Normally Open
B - Normally Closed
C- Relay Disconnected (Storage)

Figure 17- Relay Output Configuration Jumper

Health Status Digital Output Setting (Optional assignment of Digital Output 1)

Digital Output 1 may be assigned to operate when the value of the Health variable is <1. To set up Digital Output 1 in this manner, it is necessary that the Relay Output 1 Connnection Jumper be set for Normally Closed operation (see Setting Digital I/O jumpers section which is included in this Appendix A3). Therefore, during normal operation, the unit is actively holding the contacts of the output relay open (no alarm). If an erroneous operation is detected, or there is a power supply failure, the contacts of the output relay will close (alarm).

The function of this output may be assigned for Health status by using the 70 Series Configurator along with the Normally Closed jumper connection installed for Relay output 1.

A4 Cross Triggering

There are many possible uses for the Input / Output functions available from 70 Series Recorders, but Cross-Triggering deserves special attention since it is prerequisite to the application of distributed recording.

Intelligent Electronic Devices (IEDs) like microprocessor-based relays or 70 Series Recorders are generally used to measure the electrical parameters associated with a particular load, such as a feeder for example. In contrast, most dedicated Sequence-of-Events (SOE) Recorders or Digital Fault Recorders (DFRs) collect measurements from all points of interest throughout an entire substation or load center. Those devices generally produce recordings that include the activity of all points in a single document facilitating analysis by showing everything on a common time scale. A consolidated document like that can be produced by time-synchronized distributed IEDs by combining files captured by each of the recorders.

In order to consolidate all the recordings from IEDs distributed throughout a substation, all the IEDs must first be made to trigger simultaneously whenever an event of interest is sensed by any one unit in the substation. That mechanism is referred to as Cross-Triggering. Recordings are then downloaded and combined by software designed for that purpose (described elsewhere). This appendix will concentrate on methods available for cross-triggering distributed IEDs.

70 Series Recorders support two mechanisms for cross-triggering one another. These mechanisms are vendor-independent so may be used in combination with protective relays and other IEDs to the extent that status and control points are available or that protocols are supported by the other devices.

1. **Hard-wired, using discrete digital I/O.** Contacts wired in parallel on a dedicated cable pass a voltage signal to the status inputs on each IED when an event is sensed. The status input on each device can then be configured to trigger a recording.

2. **Ethernet:**
   a. **using GOOSE.** Status points are communicated across an Ethernet LAN using the IEC-61850 standard. The principal advantage of GOOSE messaging is that it does not require a separate dedicated control cable for physical contacts.
   b. **using GSSE.** Status points are communicated across an Ethernet LAN. The principal advantages of GSSE are interoperability with legacy equipment and simplicity of configuration. All 70 Series firmware released from April 2004 to June 2008 supported UCA. The term "GOOSE" when used in the UCA context is equivalent to GSSE as defined by IEC-61850. GSSE messaging can be set up with the 70 Series Configurator alone. The IED Configurator is not required for GSSE.

The 70 Series Recorder provides considerable flexibility in how a user could customize these methods to fit the constraints of any particular application. An exhaustive description of all possible variations is not practical, but it is useful to provide an example of each method in a typical application.

Example 1. Discrete Digital I/O:

Please refer to Figure A1 for wiring, Figure A2 through A4 for configuration, Section 1.4 and Figure 3, Section 3.0 for the pin-out of the Digital I/O points that are not shown in Figure A1.

Note: Digital Input 4 and Digital Output 4 have been selected in this example because they are fully isolated from other I/O points. Digital Inputs 1, 2, and 3 and Digital Outputs 1, 2, and 3 are all wired internally to common return pins.

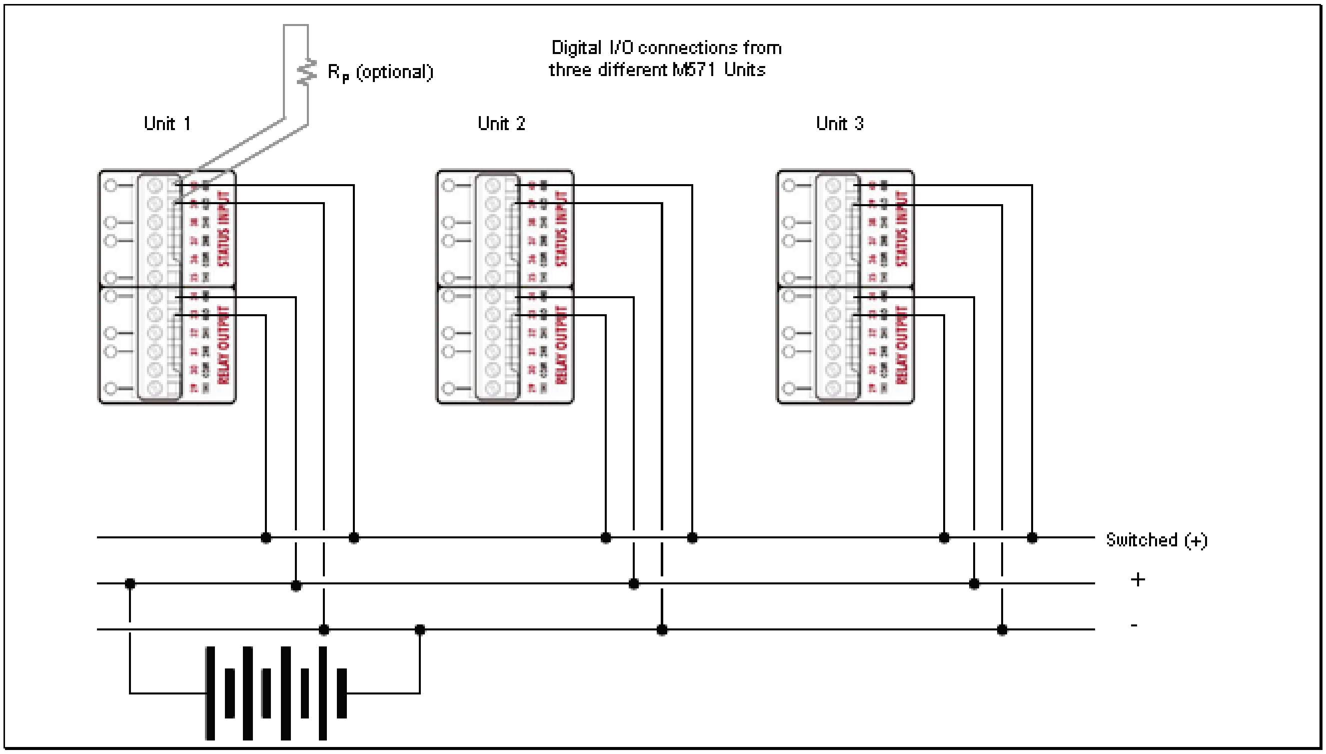


Figure A 1

<u>Wiring</u>:

Figure A1 illustrates one digital output pins 33 and 34 from each of three M571 units wired in parallel. Closing the Output 4 contact on any M571 will energize the switched conductor. Pins 39 and 40, are digital inputs wired in parallel between the switched and negative conductors. All three units will sense a status change on Input 4 whenever the switched conductor is energized or de-energized. All digital inputs on the M571 incorporate an internal current limiting resistor of approximately 33kΩ so no external resistor is required to prevent shorting (+) to (-) when digital outputs operate. It may be advisable, however, to place one pull-down resistor (R_P, in Figure A1) between the switched and negative conductors to prevent chatter on the inputs. Acceptable values for R_P depend on the application, but something in the 100kΩ to 500kΩ range should generally be safe in most cases.

Configuration:

Figure A2 illustrates a typical configuration that will initiate an oscillography recording and an SOE Log entry when the current exceeds a threshold on any of the three phases.

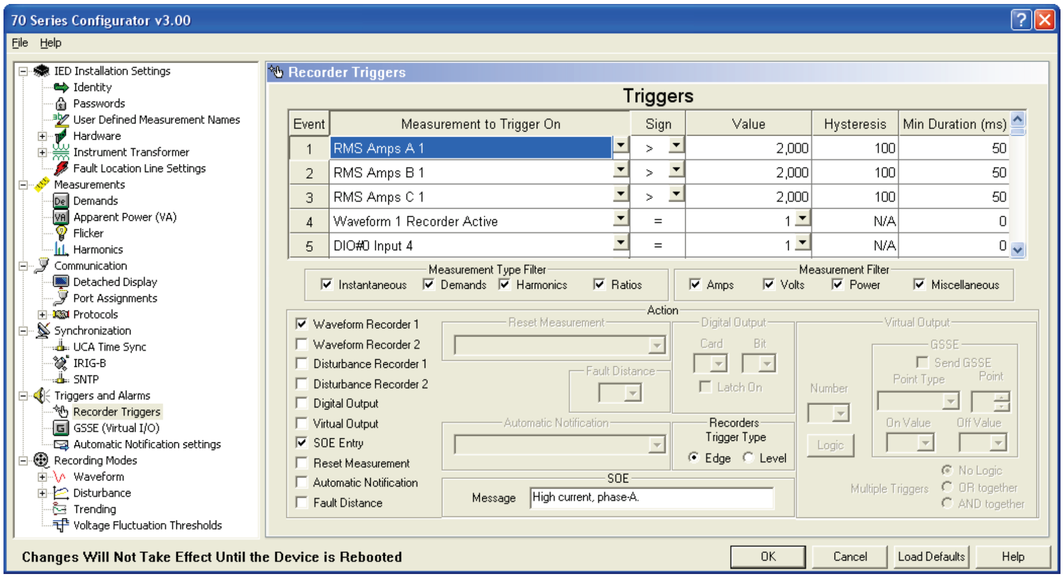


Figure A 2

Since a high current on one feeder would not normally be sensed by any other IEDs in a substation, a cross-trigger is necessary to initiate the oscillography recorders on all other IEDs. Figure A3 shows how any condition that triggers Waveform Recorder 1 also operates Digital Output 1 which initiates the cross-trigger. In this example, the contact dwells in the closed position for the length of time that Waveform Recorder 1 is running. (The characteristics of WR1 are set on a different page of the 70 Series Configurator.)

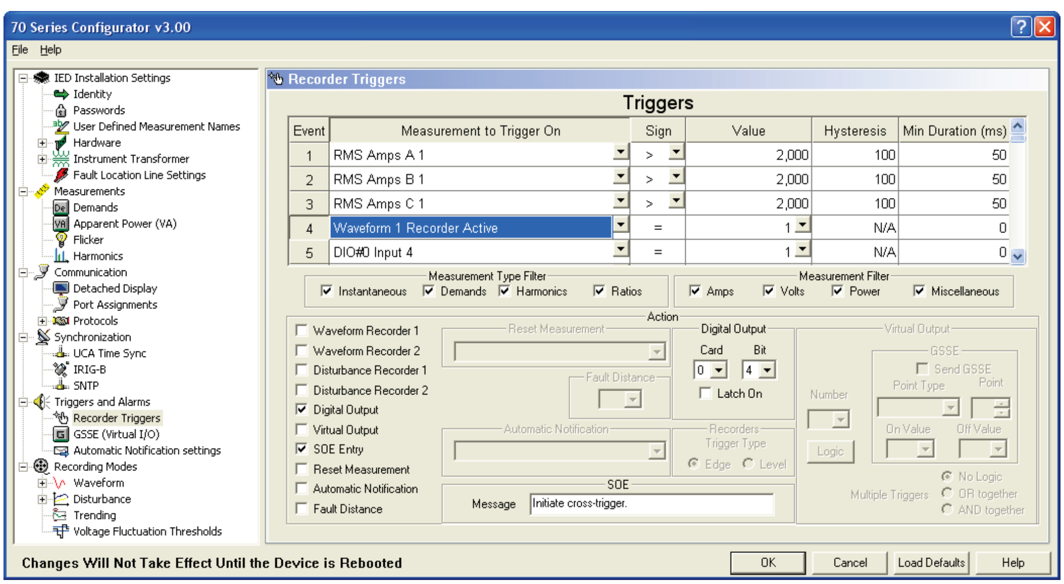


Figure A 3

Figure A4 shows the action taken when a cross-trigger on Digital Input 4 is sensed. In general, receiving a cross-trigger from another device should have the same effect as triggering on something sensed directly by the IED.

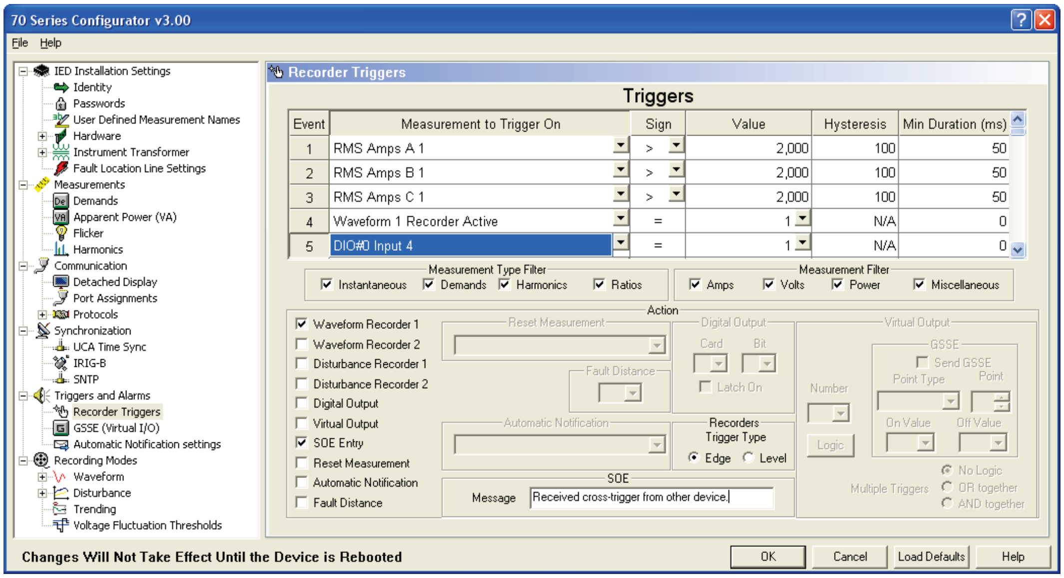


Figure A 4

Example 2. Ethernet, using GOOSE:

GOOSE is a function defined within the context of the IEC-61850 standard but there is no requirement to make use of any other aspect of 61850 just to use GOOSE for cross-triggering 70 Series IEDs. Due to the level of multi-vendor support for IEC-61850, cross-triggering between 70 Series IEDs, microprocessor based relays, and other devices may be an advantage of using GOOSE for cross-triggering. If a broader use of IEC-61850 is not intended, however, the user may find cross-triggering via GSSE (see Example 3) just as effective and somewhat simpler to set up.

In a broader application of IEC-61850, GOOSE could be used for much more than what is described in this example, but when applied simply for cross-triggering, it can be envisioned as a method to communicate a binary status over an Ethernet medium, exactly analogous to status and control performed by discrete I/O points (see Example 1). GOOSE messages are reliable enough to be used for controlling interlocks and protective relay blocking schemes, and can be propagated even faster than discrete digital contacts because of the time that it takes for moving mechanical parts to operate.

GOOSE operates by means of publication and subscription to unsolicited, unacknowledged, multicast (sometimes anycast) messages on an Ethernet LAN, so GOOSE messages can not pass through a router into another network. In its simplest form, such a network could consist of as little as an Ethernet switch and the inter-triggered IEDs connected via conventional Cat. 5 cables. There is no need to uplink into any wider LAN or to operate with any other clients or servers on the network (except for the purpose of configuring the IEDs). So in a substation, security could be accomplished easily just by restricting physical access to the network.

Otherwise, when used in a secure general purpose network, GOOSE messaging can coexist unobtrusively with other network traffic including file transfer services useful for collecting the recordings captured by the IEDs.

Connection:

The M57x must be manufactured with one of the available Ethernet options and be connected to a Local Area Network (LAN). The minimum hardware requirement for an M57x to support 61850 is 64MB SDRAM on the Host Processor. Older units built with 16MB SDRAM do not support any mechanism for RAM to be upgraded, so cross-triggering can only be accomplished via GSSE (see Example 3).

Configuration:

As implemented on the 70 Series IED, IEC-61850 requires two separate software programs to configure. These are the *IED Configurator* (used to set up functions specific to 61850, like defining Datasets, GOOSE publication and subscription, etc.) and the *70 Series Configurator* (for trigger logic, recorder settings, and other legacy functions). Both programs are supplied at no cost with the M57x and are also available for download from the company's public FTP site.

The following steps illustrate a typical configuration:

1. In the *70 Series* Configurator, Figure A5 shows how any event of interest measured directly by an M571 is configured to initiate an oscillography recording and make an SOE Log entry. (Only Phase-A Amps is shown, but the Trigger window scrolls vertically and can hold up to 120 separate independent events.)

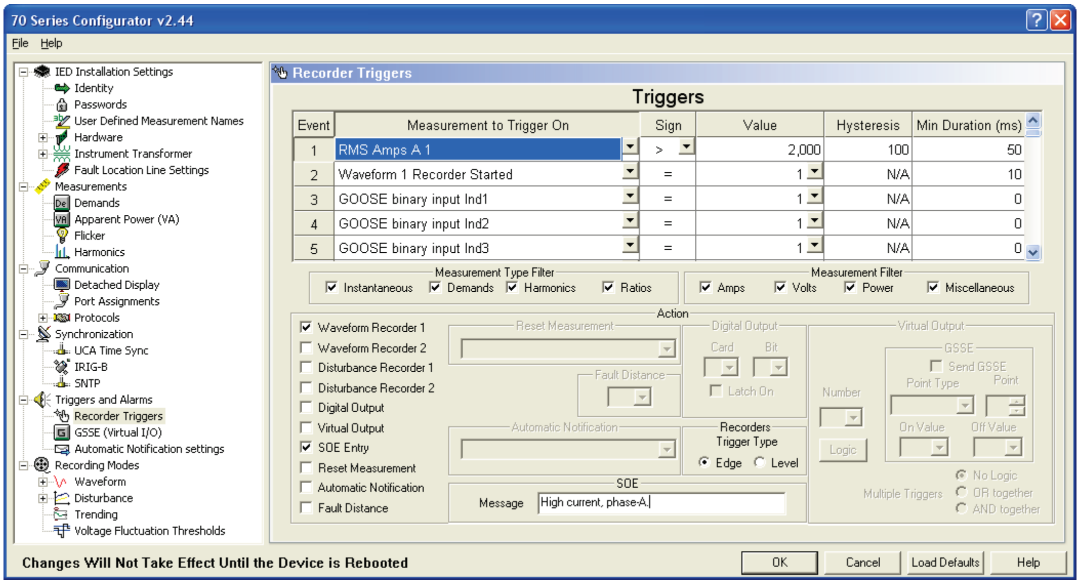


Figure A 5

2. The condition "Waveform Recorder 1 Started" is represented by a soft bit which is an element in the IEC-61850 Object Model (Records/WrxRDRE1.ST.RcdStr.stVal). Other soft bits are available to represent recorders WR2, DR1 and DR2 as needed (see 70 Series IEC-61850 manual, MICS document). The *IED* Configurator will be used in steps 4 and 5 below to make the M571 publish a GOOSE message when this bit changes status. The bit is set when WR1 begins recording. It remains set until it is re-initialized.

   Note: No self-initializing bits are defined by the 61850 object model so an entry must be made in the 70 Series Configurator to re-initialize the bit a short time after it is set. Event 2 in Figure A6 illustrates that instruction. The choice of a particular duration (Event 2, far right column) as the dwell time before the bit is reset is more-or-less arbitrary, but should generally be shorter than the run-time of the recorder. No new cross-trigger can be sent via GOOSE until the bit is re-initialized and WR1 has completed recording.

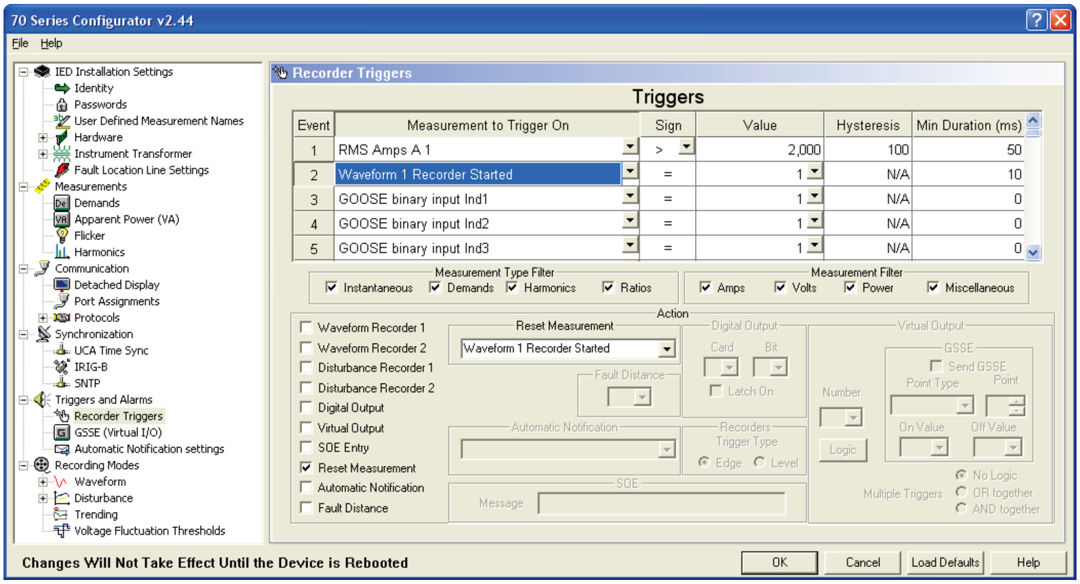


Figure A 6

3. When a cross-trigger is received from another unit, it comes in the form of a GOOSE subscription (set up in the *IED* Configurator in step 7, below). GOOSE subscriptions are represented in the *70 Series* Configurator by binary inputs that can be used to trigger WR1 and make an entry in the SOE Log. In this example, events 3, 4, and 5 shown in Figure A7 are the binary inputs received by subscribing to the GOOSE messages published by three other M571s on the network. This completes the settings that are made in the *70 Series* Configurator.

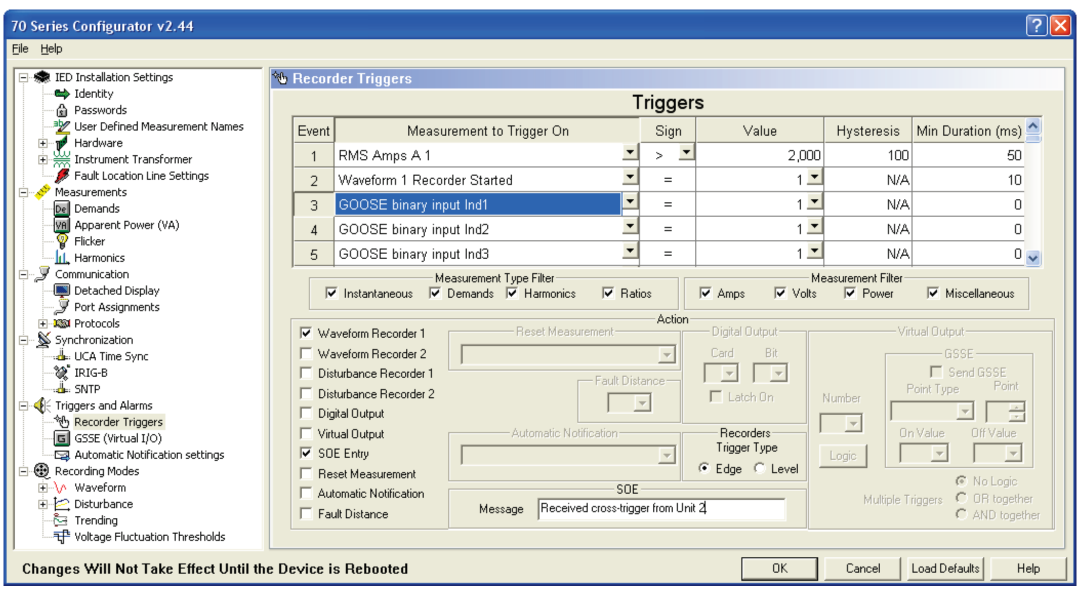


Figure A 7

4. The following settings must be made in the *IED* Configurator: Configuring an M571 to publish a GOOSE is a two step process. Figures A8 and A9 illustrate the first step, defining a Dataset that includes the soft bit described in step 2, above (Records/WrxRDRE1.ST.RcdStr.stVal).

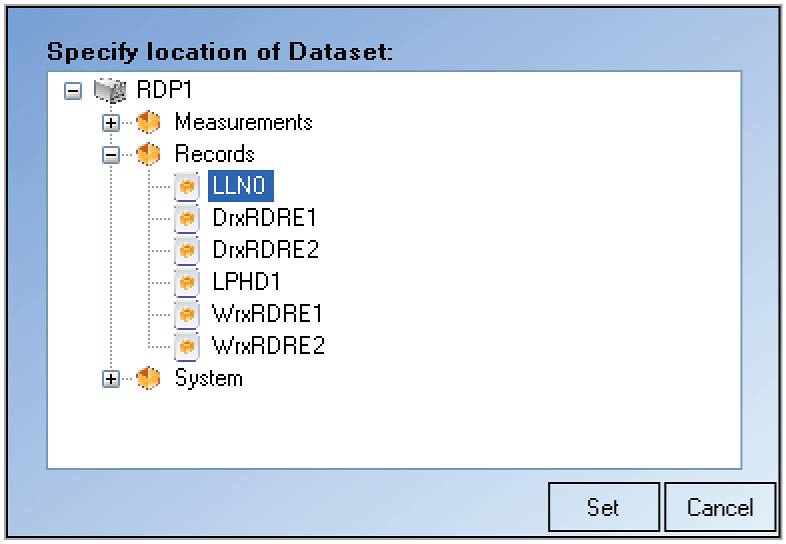


Figure A 8

Note: In order to be used for GOOSE publication, the Dataset must be defined under System\LLN0 as shown in Figure A9.

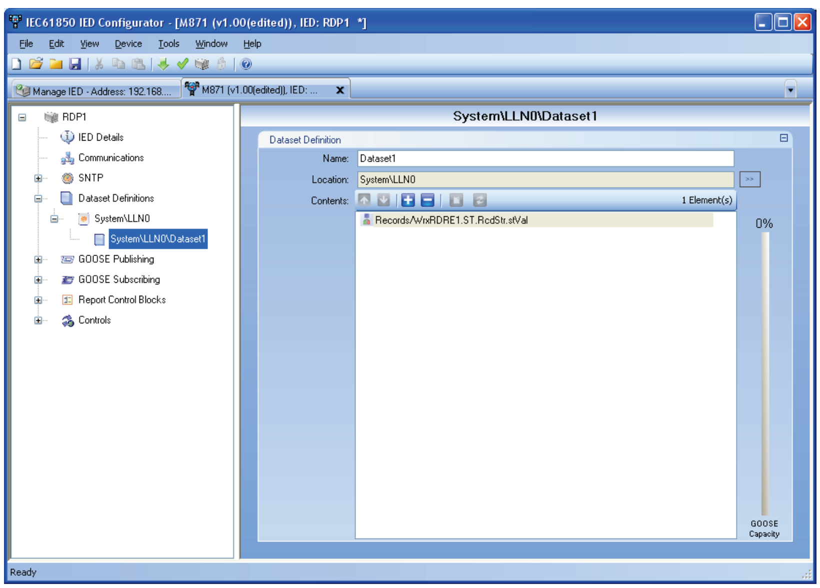


Figure A 9

5. The second step in publication is the defining a GOOSE message, Figure A10. Up to eight independent GOOSE publications may be defined for each device. Only one is required for cross-triggering any number of other devices. In this example, System\LLN0\gcb01 is used. All default entries shown in Figure A10 should generally be used in most cases, but the user must select the dataset defined in step 4, above, from the pull-down menu in the box Dataset Reference. Then the Configuration Revision must be incremented to at least 1 (usually incremented automatically by the IED Configurator). This Revision number must match the corresponding GOOSE subscription settings on all the other inter-triggered IEDs on the network (see step 7, below).

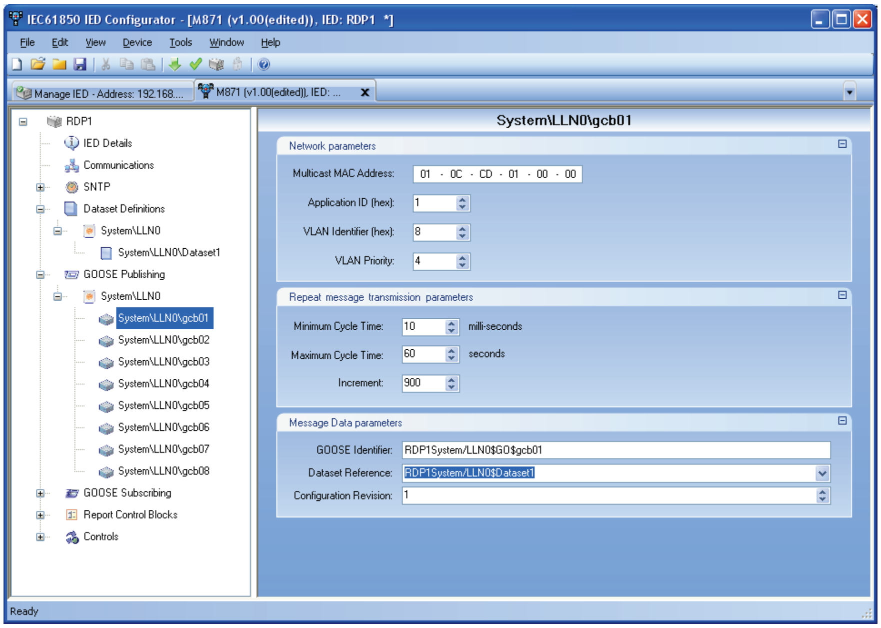


Figure A 10

6. Each IED only needs to publish one GOOSE to cross-trigger any number of other devices. When setting up subscriptions, however, the device must subscribe to every other device from which a cross-trigger may be expected. For example, in a substation with four inter-triggered M571 units, each unit would publish one and subscribe to three GOOSE messages. Up to thirty-two separate status points may be defined for each device. These status points correspond to elements in the Dataset transmitted by the GOOSE message.

   Refer to the points named **System\GosGGIO1\Ind1.stVal** through **System\GosGGIO1\Ind32.stVal** in Figure A11. These are the points in the *IED* Configurator that correspond to the points in the *70 Series* Configurator which were described in step 3, above. In the 70 Series Configurator these points are named **GOOSE binary input Ind1** through **GOOSE binary input Ind32**. See Figure A7, Events 3, 4, 5, etc.

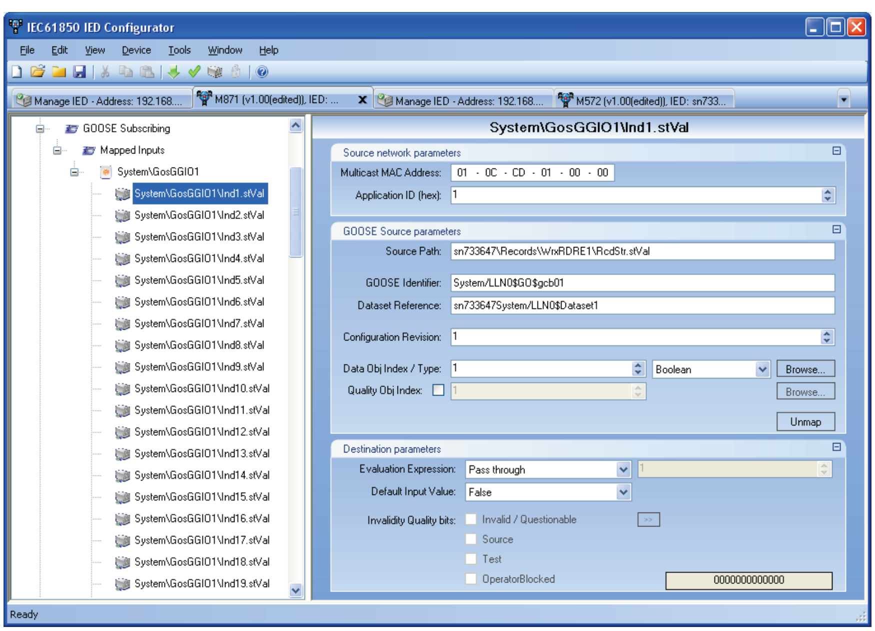


Figure A 11

7. The IED Configurator makes it relatively simple to configure subscriptions when the MCL files for all devices are open at the same time and the GOOSE publications have already been configured on each of the other devices. See Figure A12. By clicking on the Browse button, a window appears allowing the user to select the status point (green dot shown in Figure A12). Selecting the point (**Records/WrxRDRE1.ST.RcdStr.stVal**) causes a subscription to be configured for the GOOSE message that contains that status point. After selecting that point, next click on **System\GosGGIO1\Ind2.stVal** (see left side of Figure A11) and repeat step 7 selecting the same status point from the second M571 for the second subscription, and again with **System\GosGGIO1\Ind3.stVal** for the third subscription, etc. until a subscription has been made to each of the other IEDs on the network.

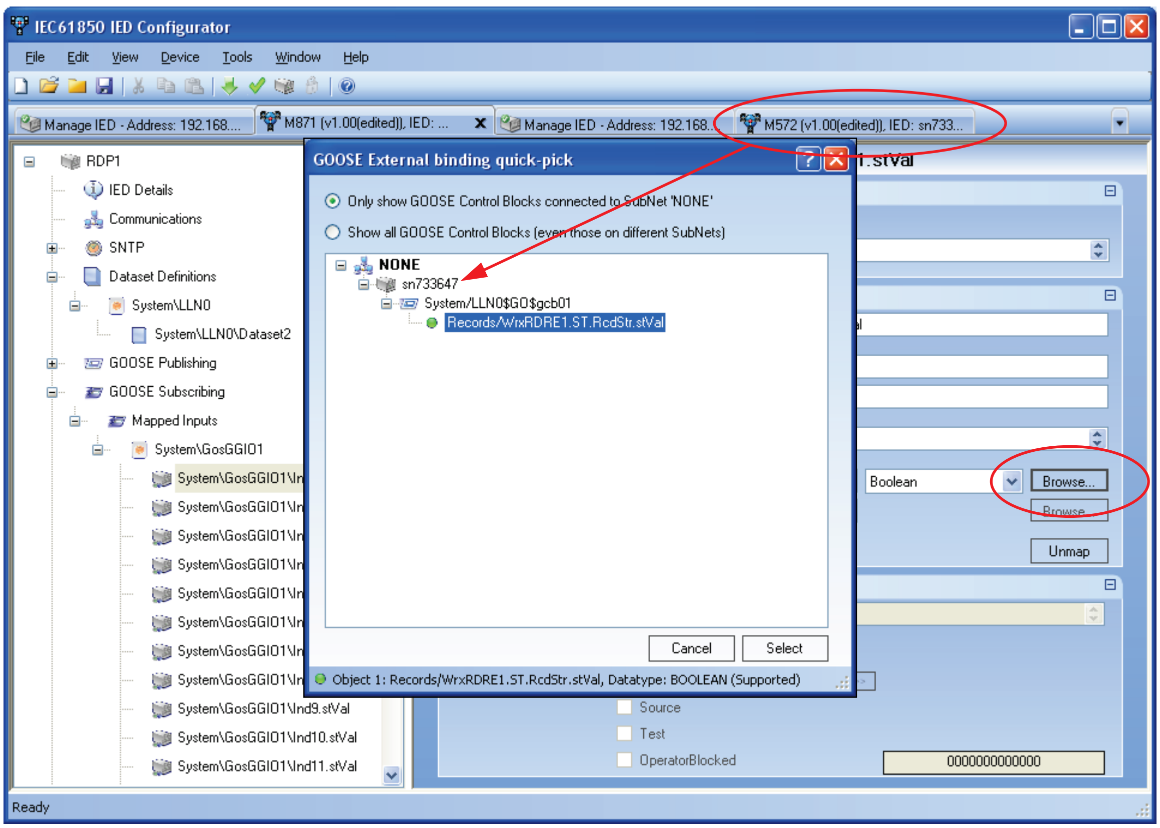


Figure A 12

8. Under **Destination Parameters** (see Figure A11 near bottom) verify that the pull-down menu labeled **Evaluation Expression** indicates **Pass through**. This completes the configuration settings for GOOSE subscription.

Example 3. Ethernet, using GSSE:

The GSSE service, as defined by IEC-61850, is identical to what has been called GOOSE in connection with UCA2.0 in past years. In order to reduce confusion as far as possible, all previous references to GOOSE in the UCA context have been replaced by the expression GSSE in 70 Series documentation because IEC-61850 supersedes UCA as a communications standard.

The use of GSSE to perform cross-triggering carries all the practical advantages of GOOSE and is simpler to set up, but has much narrower multi-vendor support. It is, however, available on all 70 Series IED firmware versions released since April 2004, so GSSE may be a better choice when it is either unnecessary to trigger other devices, or when triggering other vendors' devices might as easily be accomplished with discrete digital I/O while using GSSE among the 70 Series IEDs installed.

As with GOOSE, there is no need to make use of any other aspect of 61850 or UCA protocols just to use GSSE for cross-triggering.

GSSE can generally be envisioned as a way to communicate a binary status over an Ethernet medium, exactly analogous to status and control performed by discrete I/O points (see Example 1). GSSE messages are reliable enough to be used for controlling interlocks and protective relay blocking schemes, and can be propagated even faster than discrete digital contacts because of the time that it takes for moving mechanical parts to operate.

GSSE operates by means of transmitting and receiving unsolicited, unacknowledged, multicast messages on an Ethernet LAN, so GSSE messages can not pass through a router into another network. In its simplest form, such a network could consist of as little as an Ethernet switch and the inter-triggered IEDs connected via conventional Cat. 5 cables. There is no need to uplink into any wider LAN or to operate with any other clients or servers on the network (except for the purpose of configuring the IEDs). So in a substation, security could be accomplished easily just by restricting physical access to the network.

Otherwise, when used in a secure general purpose network, GSSE messaging can coexist unobtrusively with other network traffic including file transfer services useful for collecting the recordings captured by the IEDs.

<u>Connection</u>:

The M57x must be manufactured with one of the available Ethernet options and be connected to a Local Area Network (LAN). There is no other minimum hardware requirement for an M57x to support GSSE. Older units that support UCA but not 61850 can exchange cross-triggers via GSSE from newer units that support 61850.

<u>Configuration</u>:

All settings required for cross-triggering with GSSE are made in the 70 Series Configurator. The following steps illustrate a typical configuration:

1. In the 70 Series Configurator, Figure A13 shows how any event of interest measured directly by an M571 is configured to initiate an oscillography recording and make an

SOE Log entry. (Only Phase-A Amps is shown, but the Trigger window scrolls vertically and can hold up to 120 separate independent events.)

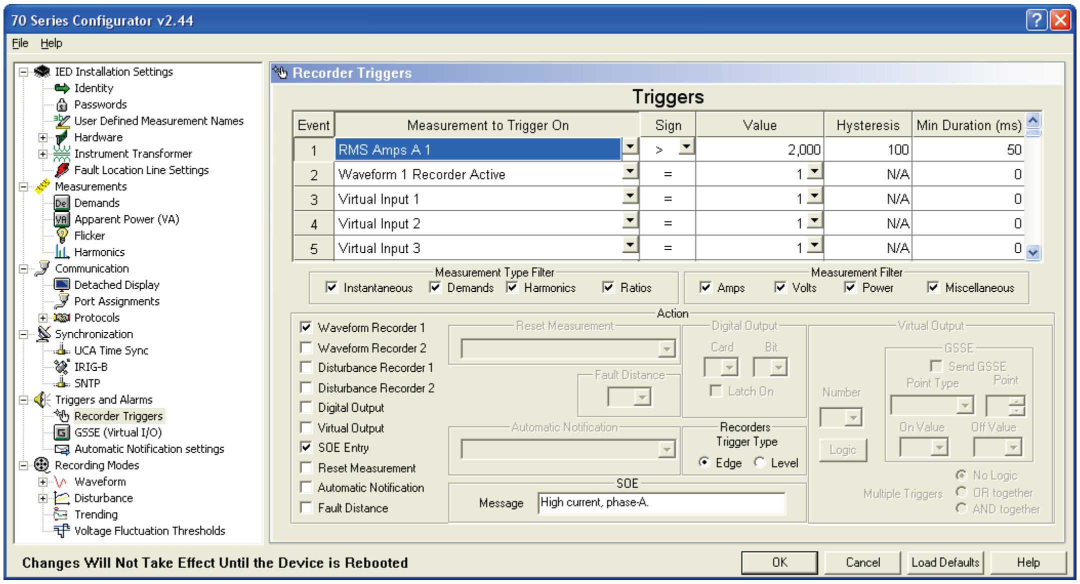


Figure A 13

2. The condition "Waveform Recorder 1 Active" is used to drive a Virtual Output that is linked to a GSSE message as illustrated in Figure A14. A Virtual Output can be driven by individual conditions (like RMS Amps A1 > 2000, in this example) or it could be the result of a combination of several conditions defined through rudimentary triggering logic.

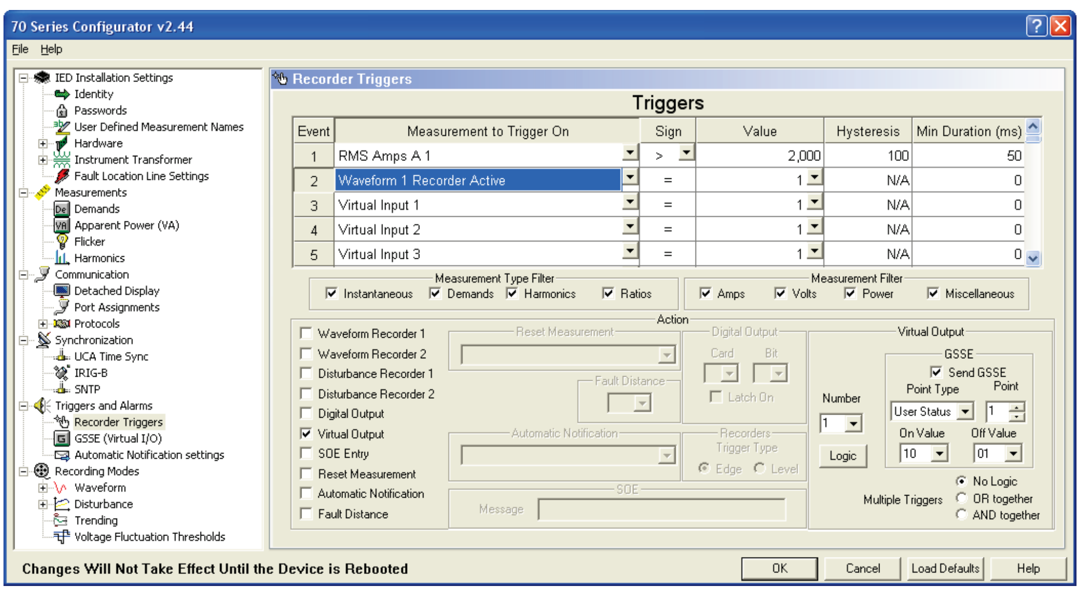


Figure A 14

Note: "Waveform Recorder 1 Active" can be considered to be a self-initializing condition since it transitions from 0 to 1 when the recorder starts then returns to 0 (its initialized state) when the recording is completed. Therefore, no deliberate step is necessary to re-initialize a soft bit, as was required for “Waveform Recorder 1 Started” in step 2 of Example 2.

3. On the GSSE (Virtual I/O) page, define a GSSE Tx Name (“Unit_1” in this example) which is unique to the device sending the GSSE message as illustrated near the bottom of Figure A15.

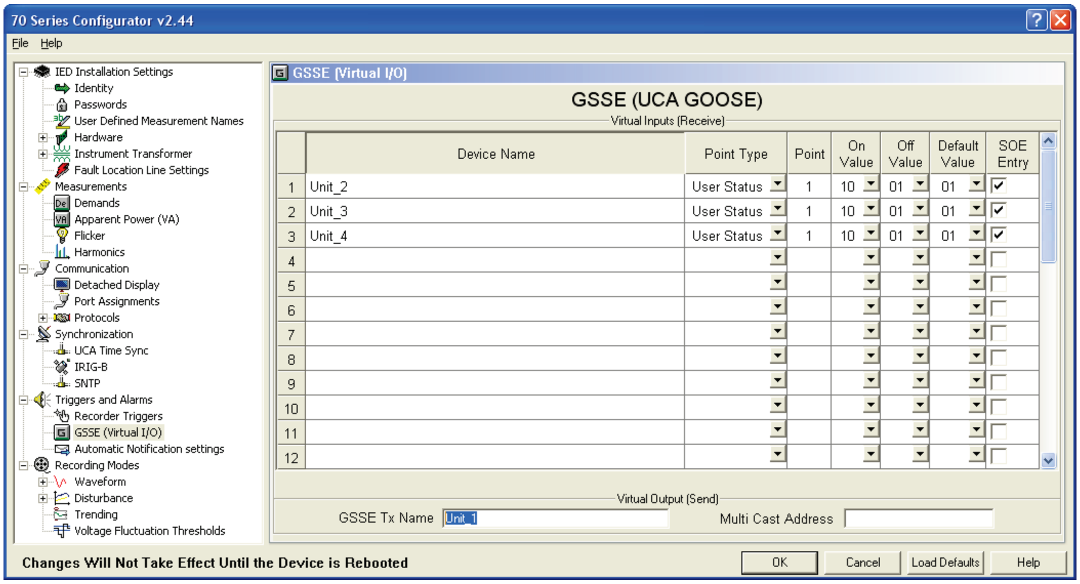


Figure A 15

4. When a cross-trigger is received from another unit, it comes in the form of a GSSE message. Each unique GSSE message must be associated with a specific numbered Virtual Input as seen on the top half of the GSSE (Virtual I/O) page of the 70 Series Configurator shown in Figure A15. Each device only needs to transmit one GSSE to cross-trigger any number of other devices. When setting up for receiving a cross-trigger, however, the device must be configured to receive GSSE messages from every other device from which a cross-trigger may be expected. For example, in a substation with four inter-triggered M571 units, each unit would transmit one GSSE and be configured to receive GSSE messages from all three other units. Up to thirty-two separate Virtual Inputs may be defined for each device.

5. On the Recorder Triggers page of the 70 Series Configurator, each of the Virtual Inputs defined in step 4, above, is then used to initiate the oscillography recorder and make an entry in the SOE Log. See Figure A16. This completes the configuration settings for cross-triggering by means of GSSE.

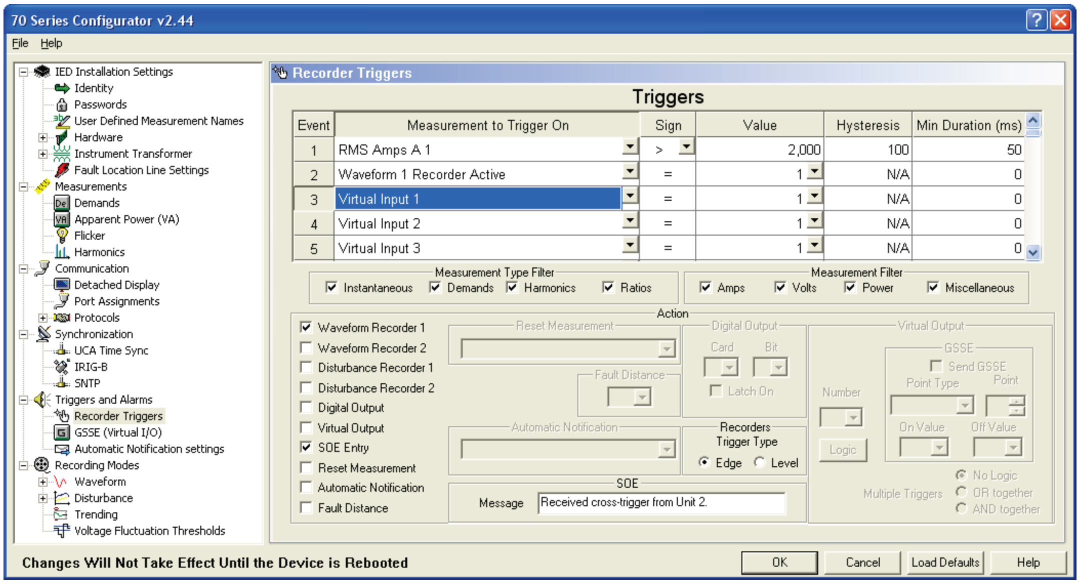

70 Series Configurator v2.44
File Help
IED Installation Settings
Identity
Passwords
User Defined Measurement Names
Hardware
Instrument Transformer
Fault Location Line Settings
Measurements
Demands
Apparent Power (VA)
Flicker
Harmonics
Communication
Detached Display
Port Assignments
Protocols
Synchronization
UCA Time Sync
IRIG-B
SNTP
Triggers and Alarms
Recorder Triggers
GSSE (Virtual I/O)
Automatic Notification settings
Recording Modes
Waveform
Disturbance
Trending
Voltage Fluctuation Thresholds
Recorder Triggers
Triggers
Event
Measurement to Trigger On
Sign
Value
Hysteresis
Min Duration (ms)
1 RMS Amps A 1 > 2,000 100 50
2 Waveform 1 Recorder Active = 1 N/A 0
3 Virtual Input 1 = 1 N/A 0
4 Virtual Input 2 = 1 N/A 0
5 Virtual Input 3 = 1 N/A 0
Measurement Type Filter
Instantaneous
Demands
Harmonics
Ratios
Measurement Filter
Amps
Volts
Power
Miscellaneous
Action
Waveform Recorder 1
Waveform Recorder 2
Disturbance Recorder 1
Disturbance Recorder 2
Digital Output
Virtual Output
SOE Entry
Reset Measurement
Automatic Notification
Fault Distance
Reset Measurement
Digital Output
Card
Bit
Latch On
Fault Distance
Automatic Notification
Recorders Trigger Type
Edge
Level
SOE
Message
Received cross-trigger from Unit 2.
Virtual Output
Number
Logic
GSSE
Send GSSE
Point Type
Point
On Value
Off Value
No Logic
Multiple Triggers
OR together
AND together
Changes Will Not Take Effect Until the Device is Rebooted
OK
Cancel
Load Defaults
Help

Figure A 16

Bitronics
A NovaTech Company

Measurement Products

Change of Company Name / Ownership

Product Technical Compliance, Type Test Certificates & Declarations of Conformity

Areva's Transmission & Distribution Measurement Unit based in Bethlehem Pennsylvania, USA was purchased by NovaTech LLC on July 1, 2008, and henceforth continues to operate as an affiliate of NovaTech LLC under the company name of:

Bitronics LLC
261 Broadhead Road
Bethlehem, PA 18017, USA

The change of ownership and company name at the Bethlehem location has resulted in the Measurement organization and it's operations remaining substantially the same. In regards to product technical compliance and performance claims, the following points indicate business continues as usual for the Bethlehem site:

- Technical Staff have been retained.
- Instruments will continue to be designed in Bethlehem.
- Production processes are unchanged.
- Measurement products are retained.
- A revision on product labels to indicate Bitronics as the company name shall be implemented.
- A strategic partnership agreement has been entered with Areva T&D, such that Bitronics LLC will manufacture products to be globally distributed under the AREVA T&D MICOM brand. A revision to product labels is anticipated.

Continuing to the subject addressing some of the necessary technical documentation, which is relied upon, the intent is to utilize existing product Type Test Certificates and Declarations of Conformity. The change of company name will not be implemented retroactively on these types of documents. Instead the change of company name to Bitronics will appear on new documents moving forward, that are created after July 1, 2008. Existing product approvals will be relied upon.

André Wagner

Andre Wagner – R&D Manager

Date: Oct 2, 2008

Issue 1

Bitronics
A NovaTech Company

EC Declaration of Conformity

We, the undersigned:

Manufacturer:	**Bitronics LLC** 261 Brodhead Road Bethlehem, PA 18017-8698 USA **T** +610.997.5100 **F** +610.997.5450 **E** bitronics@novatechps.com	**Authorized Representative in the European Union:**	**NovaTech Europe BVBA** Kontichsesteenweg 71 2630 Aartselaar Belgium **T** +32.3.458.0807 **F** +32.3.458.1817 **E** info.europe@novatechps.com

hereby declare that the following product(s) :

Product type :	M570 series
Description :	M57x Compact Monitoring and Recording IED
Models :	M571, including models with Current Transformers (CTs) rated to peak currents of 20A or 100A, with Digital I/O option D4, Ethernet options E1, E2, E3, Transducer input option, and IRIG-B input option. M572, including models with Current Transformers (CTs) rated to peak currents of 20A or 100A, with Digital I/O option D4, Ethernet options E1, E2, E3, Transducer input option, and IRIG-B input option.

Conform(s) with the protection requirements of the following directive(s) :

1. European Community Directive on EMC 2004/108/EC, and Directive 91/263/EC [TTE/SES].
2. European Community Directive on Low Voltage 2006/95/EC

The following route(s) were used to establish conformity :

1. **2004/108/EC:** In accordance with Article 7 Annex II (internal production control supported by a Technical File).

Technical Construction File No. :	TF B003
Date Revised :	9-April-2009 (original issue dated 23-Nov-2005)
Conformity Assessment Body : (C.A.B.)	Underwriters Laboratories, Inc., Melville Division 1285 Walt Whitman Road, Melville, NY 11747-3081 USA
Compliance Certificate / Test Report:	E164178, 05ME06115, M571, MA/EMC; E164178, 743668, M57x w/transducer & IRIG-B inputs, EMC 07ME09604; E164178, 1001052984, M87x, M57x, M870D, M570Dx EMC 09CA09082.

2. **2006/95/EC:** Self Certification supported by a Technical File.

Technical File No. :	TF B003
Date Revised :	9-April-2009 (original issue dated 23-Nov-2005)

Reference Number : DOC B003 **Issue :** E

Date of issue : 13-April-2009

Form BIDOC_B

The following standards were used for reference and to establish conformity :

EN 61010-1: 2001 **UL 61010-1, 2nd edition (July 12, 2004)** **CAN/CSA C22.2 No. 61010-1-04 (July 12, 2004)**	Safety requirements for electrical equipment for measurement, control, and laboratory use. Part 1: General requirements
EN 61326-1: 2006	Electrical Equipment for measurement, control and laboratory use – EMC requirements
EN60255-25: 2000	Electrical relays, Electromagnetic emissions tests for measuring relays and protection equipment
EN60255-26: 2005	Electrical relays, Electromagnetic compatibility requirements for measuiring relays and protectiion equipment
EN 61000-6-4: 2007	Electromagnetic compatibility Part 6-4: Generic emission standard – Industrial environment.
EN 61000-6-2: 2005	Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for Industrial environments.
EN 55011: 2007 / A2: 2007, **Group 1 Class A**	Radiated Emissions Electric Field Strength, AC Powerline Conducted Emissions
EN 61000-4-2: 1995 / A1:1998 / A2:2001	Electrostatic Discharge (ESD)
EN 61000-4-3: 2006 / A1: 2008 **Class III**	Immunity to Radiated Electromagnetic Energy (Radio Frequency)
EN 61000-4-4: 2004, **Severity Level 4**	Electrical Fast Transient / Burst Immunity
EN 61000-4-5: 2006, **Installation Class 3**	Surge Immunity
EN 61000-4-6: 2007 **Level 3**	Immunity to Conducted Disturbances Induced by Radio Frequency Fields
EN 61000-4-11: 2004	AC Supply Voltage Dips and Short Interruptions

Signed on behalf of the Company :	Andre Wagner, R&D Manager André Wagner Bitronics, LLC

CE Marking Year 2005, 2006, 2007, 2009

Reference Number : DOC B003 **Issue :** E

Date of issue : 13-April-2009

Form BIDOC_B back

Revision	Date	Changes	By
A	01/30/2009	Update Bitronics Name, Logo	E. DeMicco
B	05/01/09	Updated logos and cover page	MarCom
C	9/25/2009	Updates per New Firmware release: Updated standards in 1.4.2; Updated Transducer input poll rate specification in 7.3, 7.6.3, & Figure 13. Increased waveform recorder limit in 5.4.1 from 999 to 2000 cycles (or from 16.7 to 33.3 seconds at 60Hz). Added several paragraphs to address processing limits associated with generating long length waveform recorder COMTRADE files and recommendations to alleviate loss of data in long WR files. Removed paragraph entitled "5.4.2c Using the Disturbance Recorder for Fault Distance" and in 6.14 removed the reference to 5.4.2c. Moved Network Time Synchronization from Section 5.8 to 5.8.5. Moved SNTP from section 5.8.1 to 5.8.6. Rewrote section 5.8 through 5.8.7 to summarize Time sync methods. Added the ability for a DNP slave to send a request for time to the DNP master in order to periodically set the DNP time. Added SNTP Time Sync, DNP Time Sync and Best Clock to 6.15 List of available measurements.	R. Fisher
D	10/15/2010	Updates per new firmware release: Modifications to add section 5.13.6 for SMS control characters, modifications in fault analysis section 6.14 including adding Peak Fault Measurement, updated Measurement table in 6.15	E. DeMicco
E	2/28/11	Updates per new firmware release: inserted new section 5.4.5 covering IEEE long file naming convention, 5.3.8 Periodic Triggering and updated signal input and accuracy and revenue accuracy sections for dual peak range current options.	E. DeMicco
F	12/5/11	Updates per new firmware release: Note regarding reallocation of memory for recording and change to length of pre- and post-trigger time in DR in section 5.4	E. DeMicco

Bitronics • D/3 • Orion

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