TR-2100
Multi - Function Recorder

Operation Manual

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Revision A

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Overview

The TR-2100 is a multi-function recorder that includes the features of many separate instruments for monitoring a power system. These include protection operations, system stability, and power quality. The voltages and currents on three phase lines are recorded via standard instrumentation transformers to 16-bit accuracy. The state of protection relays and switchgear can also be monitored via auxiliary switch contacts. Additionally, other transducers can be connected to the TR-2100 for monitoring a wide range of parameters.

By providing a complete range of functions from a single connection to the power network, the TR-2100 is a very cost effective instrument. Information from the recorder can be used by a range of departments within a utility. A flexible reporting scheme enables the right information to be sent to the right person at the right time. Because the TR-2100 can be locked to a universal time standard, differential phase triggering can be implemented and network wide state determinations can be made.

The TR-2100 can include the functions of any of the systems listed below.

- High speed multi-channel analogue and digital data recorder
- Transient fault recorder
- Protection monitor
- Generator monitor
- Sequence of events recorder
- Disturbance recorder
- Phasor measurement unit
- Stability monitor
- High speed logger
- Long term logger
- Dual channel recording frequency meter
- Multichannel recording power meter
- Vector meter
- Power quality monitor
- Harmonic analyser
- Flicker meter
- Oscilloscope
- Switchgear wear & performance monitor
- Station battery monitor
- Diagnostic & maintenance tool

Triggered Records

When an abnormal event is detected, the analogue inputs and the digital switch data are stored in the TR-2100's memory. The stored data includes a period of time starting before the event occurs, until after conditions have returned to normal. This data frame constitutes a data record that may be printed in a graphical form with some initial measurements of the transient event.

Loggers

The input voltages and currents to the TR-2100 are recorded as a maximum, minimum and average RMS value every minute. The maximum, minimum and average frequency of two selected channels is also recorded. The TR-2100 is fitted with a large hard drive and this log will save data for 52 weeks before the data is overwritten. Selected blocks of data can be downloaded from the TR-2100 for graphical display.

As an option, all the inputs values can be saved every other cycle (1/2 the system line frequency) in a disturbance logger. This provides a continuous record for the previous 2 weeks. Harmonic, imbalance and energy data are also recorded in separate logs. These can be recovered separately or together.

Power Quality Monitor

The TR-2100 can also record the harmonic profile of voltage or current inputs over a set interval. This is used to measure trends with time or compare harmonic distortion at different locations. There are a number of features as part of Display Station that allow harmonic and other power quality data to be viewed.

Voltage dips can be classified by depth and duration to provide a profile of substation performance. This can be used to compare performance at different sites, and show trends with time.

The TR-2100 has a sensitive THD trigger mode that allows very subtle voltage distortions to be recorded, which would otherwise be missed using normal triggering methods. This can indicate progressive faults before they cause a serious problem.

Transducers

The TR-2100 computes a wide range of values from the recorded voltages and currents. External transducers may be connected to the TR-2100 to extend the range of functions. These could include pressure, temperature & position etc.

Display Station

Display Station is a software application that runs on a standard Windows 95/98/NT based PC. This provides a communication link to all TR-2100, TR-100, and DL8000 monitors via an RS232 port, LAN, dial up modem, or WAN.

All the recorder parameters can be updated remotely, and the analogue signals and digital status can be viewed on line. Data records can be downloaded to the user's location, and partial information such as a profile or cameo can be viewed to reduce communications time.

Transient, logger and harmonic data can be displayed, analysed and printed using a range of functions. An Expert System is used to classify faults into a number of categories for ease of interpretation. Voltage Dip and Breaker Performance Analysis databases are updated for quality and maintenance scheduling.

1 Introduction

The TR-2100 substation monitor is designed using leading edge computer hardware and software techniques. The high speed, high resolution recording, flexible triggering modes, and long term recording modes make it ideal for capturing all forms of line transients, protection operations, power quality surveys, real time display of station values, stability monitoring, switchgear maintenance, sequence of events recording, metering, etc.

Input Connections

A maximum of 32 analogue inputs can be connected to standard protection voltage and current transformers. Any input can be configured as a voltage or a current input when the system is ordered. Changing the input range in the field requires a simple link selection. All system inputs are DC coupled with a frequency response of about half the sampling rate.

In addition to the analogue inputs, there are also a maximum of 160 digital inputs for reading the state of protection relays and switchgear. The digital inputs require a wetting voltage from a source external to the TR-2100. Four status relays with pre-defined functions are available. The power source can be AC or DC, and must be specified at the time of order.

The TR-2100 can be specified to have 8, 16, 24 or 32 analogue inputs and up to 160 digital inputs. The size of the cabinet depends on the combination of analogue and digital inputs requested.

Recording Functions

The TR-2100 provides multiple concurrent power monitoring functions in one system. This gives maximum functionality with minimum installation cost. Each of the recording modes works independently of the others. The functions include:

- **High Speed Transient Recorder**

The high speed option allows all analogue inputs to be sampled synchronously up to 384 samples per cycle (19.20 KHz at 50 Hz, or 23.04 KHz at 60 Hz). The digital inputs can also be sampled at this rate, although in most cases they would be recorded at an integer sub-multiple.

The high speed recorder is used for special applications like lightning studies, monitoring high speed switching in DC links, Static VAR compensators (SVCs) and Flexible AC Transmission Systems (FACTS).

- ## **Protection monitor**

The transient recorder is mostly used for monitoring protection operations. The VT & CT waveforms and auxiliary protection contacts are recorded before, during, and after the fault clearance. Expert System software can be used to analyze this data and report on any abnormalities. Other information can be extracted for Power Quality and system maintenance.

- ## **Disturbance recorder**

Longer term events are monitored by the Disturbance recorder. RMS and phasor information is stored twice per cycle per channel, and these are used to compute a variety of power system quantities. A wide range of trigger options is available for the Disturbance recorder including a flexible oscillatory power trigger.

This function is used for recording re-closer sequences and system stability events. It can also be used to extend the pre- and post-fault times of a Transient record. A continuous Disturbance logger can be added as an option that allows up to 2 weeks of recording time. This records the RMS, phasor and frequency information at half the cycle rate. The disturbance recorder is independent of the other recording modes.

- ## **Long term logger**

The input and computed quantities are logged as maximum, minimum and average quantities every minute. A 52-week log of data is saved by the system. This data can be retrieved at reduced sampling rates for trending and power quality analysis.

- ## **Power Quality monitor**

The parameters that define Power Quality are recorded by the TR-2100, and then processed and viewed by applications running on a PC. These include:
> Voltage & frequency profiles
> Voltage dips & surges
> Loss of supply
> Harmonic content
> Flicker
> Imbalance

Flexible display options allow this information to be shown in a wide range of styles. Refer to the Display Station manual for setup information.

- ## **Sequence of Events Recorder**

All transitions on the digital inputs of the TR-2100 are recorded and can be displayed with a disturbance or logger record. The time resolution is 1 ms. Input point and time filtering are available to limit the number of events displayed. Digital data is also available with transient records.

- ## **Stability Monitor**

A powerful feature of the TR-2100 is the optional ability to trigger and record differential phasor measurements. Because the inputs are sampled at regular intervals, the absolute angle of the positive sequence voltage vector can be computed very accurately. This value is compared with the angle from a remote location, normally the far end of a transmission line. Because the two TR-2100s can be time locked together, the difference in phase angle is used as a measure of system stability. The recorder communications conforms to IEEE 1344 - 1995.

As an alternative, individual disturbance records can be recovered and compared in Display Station Analysis. This allows voltages, power flow etc. to be compared at several points in a network. The TR-2000 can also communicate with other equipment that supports the IEEE 1344 – 1995 standard.

- ## **Real Time Metering & Monitoring**

As well as triggering and logging instruments, the TR-2100 includes the ability to view analogue and digital inputs and compute values in near real time. Measured values and waveforms can be seen locally or remotely. These can replace or act as back-up systems for:

> Waveform oscilloscope
> Panel meters
> Annunciation panel
> Vector displays

- ## **Fault Locator**

Based on the information in a transient record of a line fault and a model of the transmission line impedance, the distance-to-fault can be calculated. Source and remote end impedances, remote end in-feed and mutual coupling are used to compute a more accurate distance.

The source, remote and line impedances may be entered in sequence component, per phase or per unit (PU) form. The fault distance is computed several times during the period of the fault and the results averaged. The fault impedance is also returned.

The fault impedance can be used with a complex impedance model to locate the source of a fault in a distribution network.

- ## **On-line Switchgear & Battery Monitor**

Because the TR-2100 is attached to strategic protection equipment, it can be used for condition monitoring. Circuit breaker operations are recorded and analysed by the Expert System. The measurements from each operation are stored in a database and these are used in a number of programmable contact wear formulae.

The accumulated number of operations, arcing current and arcing time all contribute to wear of the main contacts. By selecting one of the three standard formulae, the service period for each piece of switchgear can be determined.

The TR-2100 can also monitor the breaker coil currents and battery voltage. This provides more information on the state of the switchgear and the state of the battery under load.

- ## **Energy Meter**

The real power values from the logger are used to compute energy demand over a variable interval. Peak demand and load profiles can be tracked to minimize energy costs.

- ## **Plant Commissioning Diagnostic Tool**

The extensive sets of functions within Display Station Analysis (DSA) allow it to be used for the installation and commissioning of a power plant. Test records can be taken either manually or automatically and analyzed with DSA to check for correct operation of switchgear, transformers, etc. These records can be archived and used for comparison during future diagnostic checks.

Hard Disk Storage

The TR-2100 is fitted with a hard disk drive. This provides a large non-volatile data storage capacity for transient and disturbance fault records. It also stores the disturbance and long-term logger data. The disturbance logger stores RMS and phasor information for every channel for up to 2 weeks. The long-term logger saves the maximum, minimum and average voltages, currents and frequency every minute. It also records certain power usage and power quality data. This log is 52 weeks long and requires approximately 8 Mbytes of storage for every 8 input channels.

Network Capability

The TR-2100 can be configured as part of an integrated monitoring network with multiple recorders at sub-stations within a region. Display Station can be located at the regional control center or headquarters. Communications between Display Station and the TR-2100s may be by dial-up modem on an internal or external phone system, or by a TCP/IP network connection on a company wide area network (WAN).

Printing

Transient fault records may be printed locally by the TR-2100 or remotely at Display Station. The local printer can be any type that can emulate an Epson FX80 or IBM Proprinter. Each record includes the location of the TR-2100, the time and date of the record, and the source of the trigger. This is followed by a profile of the record with actual signal levels, durations, and digital transition times measured from the data. The last section of a record contains a graphical representation of the voltage and current signals and auxiliary switch transitions.

Event Log

The TR-2100 maintains a log of event and error messages, which may be read by Display Station. If an internal error is detected during a self-test, a message is sent to the printer (if one is attached) and placed in the event log. The red 'Attention' LED and relay are then activated until the message is read by Display Station.

2 Hardware Description

The size of the rack mounting enclosure depends on the number of input boards fitted.
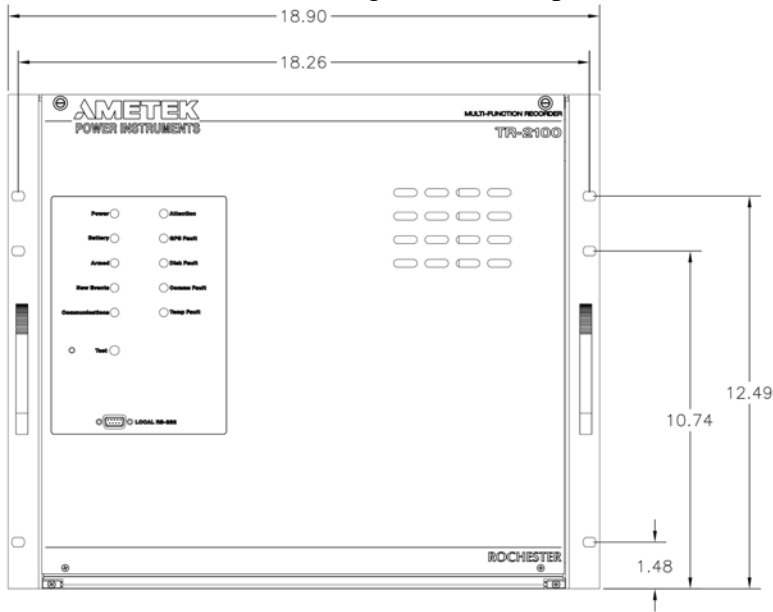
Figure 1 Front view of TR2100 with 4 analogue input boards and 2 digital-only input Boards.
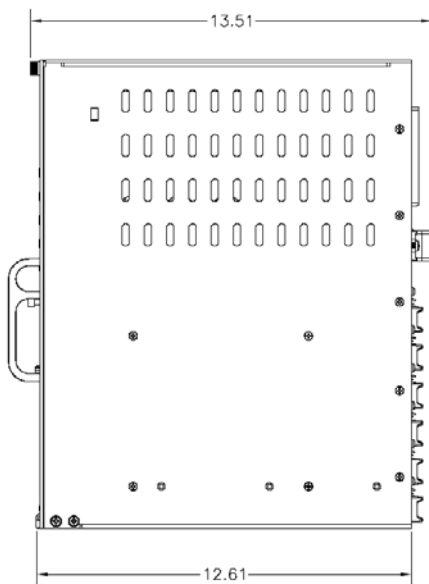
Figure 2 Side view of TR2100 with 4 analogue input boards and 2 digital-only input Boards.

The front panel of the chassis may be released by unscrewing the two screws at the top of the panel. When the panel is opened the internal architecture of the TR-2100 may be seen. The system is based on a number of horizontal steel trays that slide into tracks in two high-density polyethylene side plates, making service and maintenance of the TR-2100 very easy. The trays are locked in place with brackets that are screwed to the side plates.
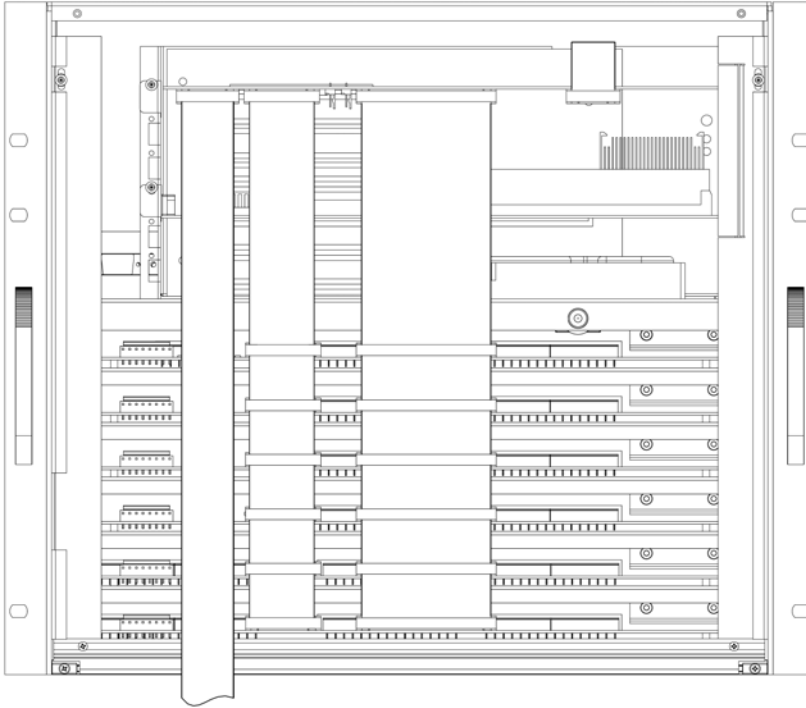
Figure 3 Internal view of TR2000

The top tray houses the processor and acquisition board and the power supply, while the bottom tray(s) holds the input conditioning board(s).

Top Tray

On the top (or processor) tray, the middle board is the Pentium processor board and the top board is the acquisition board. These boards are plugged into a six slot backplane and secured by a bracket at the left side of each board. A card guide supports the right side of each board. The spare slots in the backplane are assigned for options such as a data modem or network board.

The power supply is fitted at the rear of the tray with the power, printer, communications and auxiliary connectors mounted on the back flange of the tray. The main power switch is fitted to the front flange of the tray.

Bottom Tray

The bottom tray(s) hold the input boards, which contain the signal conditioning components for the analogue and digital input channels and the status relay outputs. It is connected to the acquisition board by two ribbon cables. The large central one is for the analogue and digital data signals, the smaller left hand one is for the status outputs and for programming the FPGAs on the input boards.

> Note: The top-most input board must be maintained in this position. This board contains the Status Output circuitry, and cannot be moved to any other position in the enclosure.

At the right rear of each input board is a strip of spring metal fingers. These slide against a bracket on the rear panel to make a connection for the protective earth ground. It is important to ensure that these contacts are kept clean. The signal input connectors are mounted directly on the rear of the input board with no interposing cables or boards. The actual configuration of voltage and current inputs is detailed in the Project Summary supplied with the unit.

Front Panel

Inside the front panel is a board that carries the status LEDs and test button. It is connected to the acquisition board via a 14-conductor IDC cable. Below this board is the serial port connector (used with Display Station), which is linked to the processor board via a 9-conductor cable.

Status LEDs

There are ten indicators on the front panel that display the system status. Four of these functions are also available as relay outputs on the rear panel. The ten LEDs have the following functions:

Power

This green LED is illuminated when the external power supply is present. The LED is connected to the internal +5V supply.

Battery

This option is not currently used.

On Line

At turn on, this green LED will remain off until the TR-2100 has completed its internal self-tests. If everything is satisfactory, the light will turn on and will stay on as long as the TR-2100 is acquiring data. To put the system off line, see 'Disarm Triggering' below.

Data Available

This amber LED shows that the TR-2100 has triggered and that a data record is available for downloading. After the directory with the new record is read by Display Station, the LED will be switched off.

The TR-2100 is fitted with a hard drive and this LED will flicker as data is being written to the drive.

Communications

During either local or remote communications, this amber LED is lit. This may be used by a local operator to indicate that a remote connection is active. Only one communications channel to Display Station can be active at any one time.

Attention

If the TR-2100 detects a problem during any of its regular internal self-tests, it will illuminate this red LED. If this is seen, Display Station must be connected to read the TR-2100's event log and find the source of the problem. There are four other LEDs that may be illuminated for specific faults. These are described below.

GPS Fault

The TR-2100 uses a GPS receiver as an accurate source of timekeeping. If the system detects a loss of satellites for more than 5 minutes, it will illuminate this LED. The TR-2100 will still operate normally on its internal oscillator, but the time reference may not be as accurate.

Disk Fault

The TR-2100 uses a 3½" IDE disk drive to store all of its data. The system RAM is used as a buffer area for fault data. When a record is complete, the data is transferred to the disk. The disturbance logger and standard logger data are saved directly to the hard disk. If the TR-2100 detects a problem with the hard disk, it will illuminate this LED.

Communications Fault

This LED is used to indicate that there is a problem with the remote communications channel. This is either a dial-up modem or a network connection. If a modem is supplied, it is checked regularly to ensure that it can communicate with the TR-2100.

Temperature Fault

The TR-2100 has a temperature sensor on each input board so that the system can automatically correct offset and gain errors due to temperature variation. There are three conditions where this LED is illuminated:

- The internal temperature has risen above 60°C

- The TR can't read a sensor
- There is a major difference between two sensors

Test Button

The 'Test' button on the front panel may be used at any time to check that the TR-2100 is operating correctly. When the button is pressed, a series of internal tests are performed and a manual trigger is performed. If a local printer is connected, the system configuration and record will be printed. Alternatively, Display Station can be connected to read and display the data. If the TR-2100 detects a fault during these tests, it will switch on the 'Attention' indicator. The cause of the problem can be found by reading the event log with Display Station.

Disarm triggering

The 'Test' button may also be used to disarm all triggering within the TR-2100. This may be required if maintenance is being performed on the monitored lines or transformers when extraneous triggering could occur. By pushing the 'Test' button for 5 seconds, the 'On Line' LED will go out, indicating that all triggering is disarmed. There is also a tone that changes from a low to high pitch when the triggers disarm.

To rearm the recorder, press the 'Test' button again briefly. Since the recorder is not yet armed, no test record will be generated. The Disarm function is also available in the Recorder Configuration window of Display Station. Messages are placed in the alarm log that indicates the time/date the system was disarmed and re-armed.

Status Outputs

The four solid-state status relay outputs are situated on the left of the lower input board. These are specified as normally open contacts. The power relay is held on by the main supply. The others are software controlled and switched on to indicate the designated function.

The four defined functions are as follows:

Power

Duplicates the function of the front panel LED.

On Line

Duplicates the function of the front panel LED.

Triggered

The relay is activated while the TR-2100 is triggered with a minimum on-time of 500 ms. This relay has a slightly different function if the recorder cross-triggering is enabled (see Section 2).

Attention

Duplicates the function of the front panel LED.

Printer

If a printer is connected to the TR-2100, it will report three separate events:

- All entries to the event log

- The system status will be printed with a test record when the Test button is pressed.

- A full data record with channel configuration, profile and graphical display of analogue and digital waveforms is printed when the recorder is triggered.

To enable the printer, see Chapter 4. To select the printer type, see the Display Station manual.

Printout Format

The TR-2100 logo is printed at the top, and then followed by the record header with the machine location, trigger type, and time/date. This is followed by the configuration of the analogue and digital channels and phase groups. The trigger levels for all enabled modes are also displayed.

Fax

It is possible to set the TR-2100 to automatically send a fax of the fault record when the system is triggered. This allows users that do not have direct access to Display Station (i.e. maintenance) to be made aware of the fault. This feature is functional if the data modem used for normal communication with Display Station is compatible with Group 3 fax transmission. The display format for the fax output is very similar to the printed output.

Transient and Disturbance Recording

For transient recording, all the inputs are sampled at up to 384 samples per cycle (19,200 samples per second at 50 Hz or 23,040 at 60 Hz) and stored in a circular memory buffer. The input levels are compared with defined values to check for an abnormal condition (e.g. an under voltage or an over current). If one is detected, the TR-2100 triggers and starts storing the sampled data in a separate post-fault buffer. After a fixed time, or after the inputs have returned to normal, the TR-2100 will stop saving data to the post-fault buffer and start a new circular buffer.

The data in the first circular buffer and the post-fault buffer form a data record that has saved data from the analogue and digital inputs before, during, and after the time the trigger condition was seen. This record may be printed or sent to Display Station for display and analysis.

Disturbance recording works in a similar way except that the RMS and phasor information is saved twice per cycle (100 samples per second at 50 Hz, or 120 samples at 60 Hz). The recording times for a disturbance record may be several minutes. The triggering modes are aimed at longer-term events such as system stability and some power quality parameters. Automatic printing of disturbance records is not available.

The transient and disturbance recorders may be cross triggered so that the disturbance record can act as extended pre- and post-fault data for the transient record.

To set the triggering conditions and read the data records, simply plug a portable computer (running Display Station software) into the program port on the front of the TR-2100. One computer can be used for many TR-2100s, thereby reducing costs and making the parameter and record data more secure. All the functions available from the front port are also available remotely via a modem or data network.

3 Installation

The TR-2100 is available in a rack mount, a wall mount or a portable enclosure. All main supply, input and output connections are via screw terminals at the rear of the case. Communications, printer and other auxiliary connectors are also on the rear panel. The only exception is the program plug, which is for temporary use and is on the front panel.
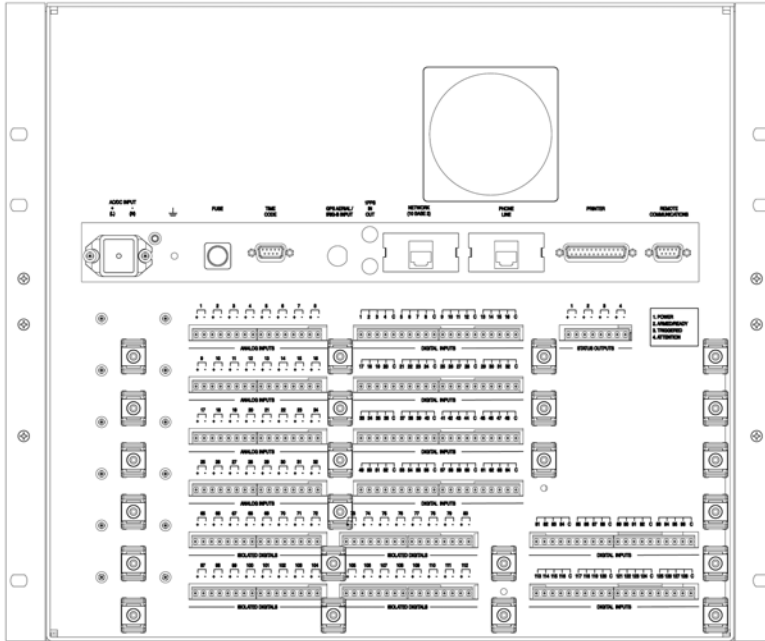
Figure 4 Rear view of TR2100 with 4 analogue input boards and 2 digital-only input Boards.

The TR-2100 is available in a wide range of configurations with a number of options. To check the actual specification of a particular system, consult the System Drawings in

Appendix V of this manual. Please confirm that the Serial number matches that on the Specification.

Power Supply Connection

The main power supply is connected to the terminal block at the lower left of the rear panel. If a DC supply is being used, the polarity must be observed. The actual voltage specified will be indicated in the System Drawings located in Appendix V of this manual. The specified voltage must be used, and damage may occur if an incorrect voltage is applied. The maximum wire size that the terminals will accept is 4 mm^2 (12 AWG).

There is one 6 mm earth stud at the rear of the TR-2100. The stud must be connected to a main system earth with a suitable braided ground cable. This is required to ensure the safe operation of the TR-2100.

Analogue & Digital Input Connections

The analogue input cables are connected to the orange strip connectors at the rear of the TR-2100. The sequence of voltage and current transformer inputs must follow the User Specification sheet. The maximum wire size for all analogue and digital inputs is 1.5 mm^2 (14 AWG). Smaller wire sizes can be accommodated using crimp terminations.

Voltage Inputs

The voltage inputs are connected directly to the standard 57 – 120V secondary windings of protection or metering VTs. The actual nominal and full-scale voltages are given in the System Drawings in Appendix V.

Phase to neutral connection   Phase to phase connection
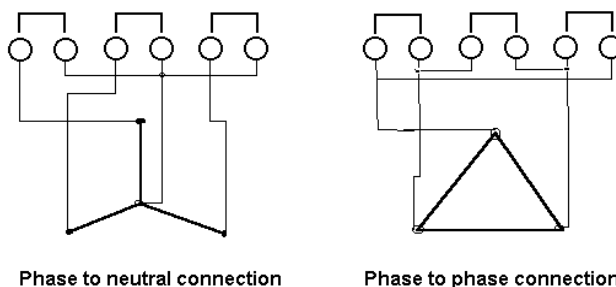
Figure 5 VT Wiring Options

Since all inputs are isolated from each other, either phase-to-phase or phase-to- neutral windings can be connected.

Current Inputs

The current inputs are derived from either a shunt resistor or an interposing CT connected in series with the 1 Amp or 5 Amp secondary winding of a protection CT. In the latter case, a burden resistor is fitted either inside the TR-2100 or on the CT module. The CT ratio and burden resistor value are chosen to suit the maximum short circuit current level and protection CT ratio. The actual nominal and full-scale values are given in the User Specification.

There are a number of options available for interposing CTs. The most common is the toroidal or 'wedding ring' type. Four of these are normally fitted to a DIN rail mounting assembly. This type requires either shorting (disconnect) switches or a line outage, so that the protection CT secondary can be wired to the interposing CT module.

The split-core and clamp-on CTs do not require an outage and are very simple to fit. These are most popular on portable systems. Clamp types are available with sensitivities down to 1.4 A.

Special Analogue Inputs

By special arrangement, other input ranges can be set to suit transducers and other sources. This ensures that the correct scaling and triggering values are used. To set special inputs, a component change may be required on the input board, along with recalibration of the unit.

Some examples of other inputs that have been used are:

> +/- 10 V industrial transducers
> 400 V for mains supply monitoring *
> 600 V for measuring rise in ground potential *
> 50 V – 150 V for recording tripping battery voltage
> 2V for Hall effect CT for monitoring battery current

* High voltage ranges require use of an external Voltage Divider Box, available from AMETEK.

For non-sinusoidal signals, a DC input can be specified in the Display Station configuration.

Digital Inputs

There can be between 16 and 160 digital inputs. These are normally used for monitoring the operation of protection relays and switchgear via auxiliary contacts.

The digital inputs must have a DC power supply connected externally and the voltage must be as specified in the System Drawings in Appendix V. When the contact being monitored is closed, approximately 3 mA DC will flow through the contact.

On the analogue cards each group of 4 inputs is isolated from each other group and has a common connection (marked C) for the field control voltage (FCV). This common connection may be wired to either the battery positive or negative terminal. On the digital-only cards there are 16 inputs arranged in isolated groups of 4, and there are 16 inputs individually isolated. The normal state of the input is defined in the recorder configuration in Display Station. The signal is displayed as being in the "Normal" or "Alarm" state.

Status Output Connections

The four status relay output circuits are available on the 16-terminal orange connector at the right of the rear panel. The relays outputs are normally open, dry contacts in the shelf (unpowered) state. The functions of these relays are described in the previous chapter.

Auxiliary Connections

Serial and Parallel Ports

If an external modem or local printer has been specified, they are connected to the 9-pin D and 25-pin D connectors at the right of the rear panel. The RS232 connectors may also be used for direct connection of a computer for Display Station communications (Display Station communications require hardware handshaking signals RTS & CTS).

The connectors conform to the IBM PC format for RS232 serial and Centronics parallel ports, respectively. There is also a front mounted 9-pin RS232 port available for serial connections. Both the front and rear RS232 communications ports have the following pin configurations:

Pin	Use
1	DCD
2	Rx
3	Tx
4	DTR
5	Gnd
6	DSR
7	RTS
8	CTS
9	RI

The data format is:

Baud rate	19200*
Parity	None
Data bits	8
Stop bits	1
Handshake	Hardware

* The actual baud rate is settable within Display Station

Serial Time Code Port

When a number of recorders are used at a single site, a single GPS receiver can be used to provide extremely accurate time synchronization between units. This requires connection of an external satellite antenna to one TR-2100 chassis, which we will call the "master" recorder. For time locking multiple recorders together, both the fiber optic and RS485 serial ports must be daisy chained between units.

Optical 1 PPS port

An accurate 1 pulse per second (1 PPS) signal is provided on the optical port at the rear of the TR-2100. The 1 PPS output from the master recorder is connected to all the others via low cost fiber optic cable to provide the time reference. A second port is also provided to allow daisy chaining several units.

To distribute the one second pulse, the optical cables are 'daisy chained' together. The 1 PPS optical Output from the master recorder (with the GPS receiver) is connected to the next recorder's Input. Its Output is connected to the next Input and so on. Any number of recorders can be linked in this manner.

RS485 Connection

The RS485 time code output can be daisy-chained directly from the master to drive up to 30 recorder "remotes" time code inputs. The polarity of the connections must be observed. The RS485 9-pin D connections are:

Pin	Function
1	Input +
2	
3	
4	
5	Output +
6	Input -
7	
8	
9	Output -

Connect the Output + and – pins on the master to Input + and – pins (respectively) on each remote.

A 120-ohm, ¼ W termination resistor must be installed at the beginning and end of the RS485 string. Insert the resistor in the cable connector across pins 5 and 9 at the master unit. Insert another resistor across pins 1 and 6 at the very last remote unit of the RS485 string. All units in-between do not require termination resistors.

GPS Antenna

The TR-2100 uses an internal GPS receiver as a very accurate source of time. This allows triggered transient and disturbance records to be given an accurate time tag. It also allows the absolute phase of the voltage and current signals to be measured. If two or more TR-2100s are located on a grid, accurate differential phase measurements can be made.

One of the most important factors affecting the continuous accuracy of the time and hence, phase in the TR-2100 is the adjustment of the antenna. This is a marine pole-mounted type and is designed for use outside in all weather.

The antenna should be located vertically at a place where it has the maximum view of the sky with no obstructions. If visibility is poor, it may take an extended period before the time output is locked to Universal co-ordinated time (UTC). Even then, accuracy will be lost if there are no satellites in view for more than 5 minutes. A good view of the sky is the requirement for long-term reliability.

To overcome losses in the co-axial cable and their connectors, there is an amplifier in the antenna module. Power for this is supplied up the same co-ax cable. The standard cable length supplied with the TR-2100 is 20 meters. If a longer cable is required, lower loss cable may need to be used with a higher gain antenna.
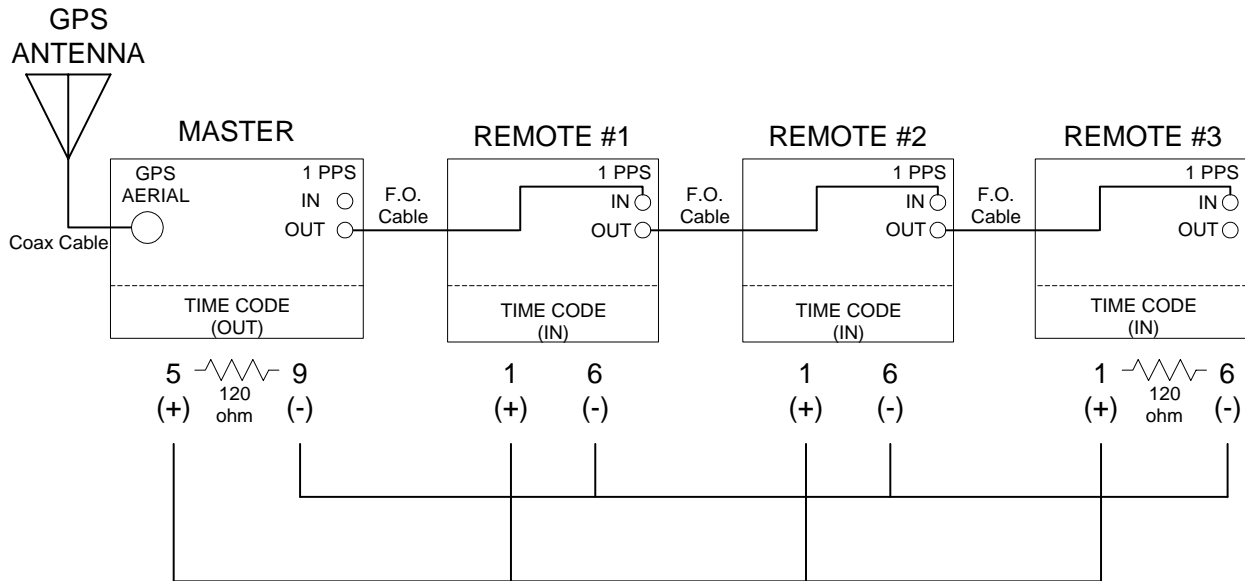
Figure 6 Time-Synchronization Connections for Multiple TR-2000 Chassis

Hardware Configuration

If the TR2100 is to be set up as a Master unit, then set SW1 switch 6 to ON (GPS receiver present) and SW1 switch 7 to OFF (Master). SW2 switch 1 should be set to OFF (serial clock on COM2 disabled).

If the TR2100 is to be set up as a Slave unit, then set SW1 switch 6 to OFF (GPS receiver not present) and SW1 switch 7 to ON (Slave). SW2 switch 1 should be set to OFF (serial clock on COM2 disabled).

Serial Clock on COM2

Connecting External Clocks

As an alternative to using a GPS signal for time synchronization, an external clock connected to the serial port COM2 can be used. Clocks which have an RS-232 interface and a time code format of either LER (RCC8000) or NGTS 3.7.9 can be connected directly to the external serial port on the rear of the chassis.

Clocks which have an IRIG-B format should be connected to the optional IRIG-B decoder board (1079-215). The clock is connected to a BNC connector located on the rear of the chassis. The IRIG-B decoder board then connects to the internal serial port COM2 located on the SBC. The external serial port COM2 may not be used when the IRIG-B decoder board has been fitted.

The IRIG-B decoder board can be set up for either the AC (modulated) or DC (non-modulated) formats by changing the position of jumpers on JP1 and JP2 on the IRIG-B decoder board. When both jumpers are placed on pins 1 and 2 of JP1 and JP2 then the board is set up for AC mode. When both jumpers are placed on pins 2 and 3 of JP1 and JP2 then the board is set up for DC mode.

Hardware Configuration

If an external clock is present on COM2, SW2 switch 1 should be set to ON (enable), and SW1 switch 6 should be set to OFF (GPS receiver not present) and SW1 switch 7 should be set to ON (Master). If an external clock is not present on COM2, SW2 switch 1 should be set to OFF (disable). Refer to Table 1 and Table 3.

Applying Power to the TR-2100

When all the relevant connections have been made, the system is switched on by first opening the front panel to expose the power switch. This is the toggle switch at the lower right of the enclosure. It is moved to the right to turn on the TR-2100.

When the TR-2100 is switched on, it performs a series of internal self tests to check the processor, the memory and the acquisition system. This takes about 30 seconds after which, if no fault is found, the TR-2100 will illuminate the green 'On line' lamp and start acquiring data. If a printer is attached, the parameter settings are printed.

The sampling rate, channel labels and scaling and other parameters may have been set at the factory. If these are to be changed, Display Station must be connected to the 'Program' plug on the front panel. Other parameters may also be changed over the remote connection. See the Display Station manual for details on programming the TR-2100.

Real Time Display

The real time display function in Display Station may be used to check that the signal levels reported by the TR-2100 are correct. The phase relationships of the voltages and currents may also be seen. The status of all the digital inputs is also shown. For more information on this, see the Display Station manual.

Test Record

To generate a local hard copy of the system configuration and signal inputs, the Test button may be used. This requires that a printer is attached locally. This is described in the previous chapter.

4 Hardware Configuration

The TR-2100 is available in many configurations with various user defined options. The values set for this machine at time of delivery can be found on the User Specification sheet and the System Drawings in Appendix V of this manual. The TR-2100 hardware configuration is set through two sets of 8 DIP switches on the acquisition board. The first bank (SW1) is the left hand of the two switch banks. It has the following functions:

Table 1

Switch	Function	Off	On
1	Digital-only cards	Yes	No
2	System frequency	50 Hz	60 Hz
3	No. of analogue cards – 1	See Table 2	
4	No. of analogue cards – 2		
5	Cross triggering	Disable	Enable
6	GPS receiver	Yes	No
7	Time code port	Master	Slave
8	(undefined)		

Table 2

Switch 3	Switch 4	Analogue Input Boards
Off	Off	1
Off	On	2
On	Off	3
On	On	4

* Default setting

The second bank (SW2) is the right one of the two banks. The functions of these switches may be altered. They have the following functions:

Table 3

Switch	Function	Off	On
1	Time code port	Disable	Enable
2	Program port – baud rate	See Table 4	
3			
4	Printer	No	Yes
5	Modem	No	Yes
6	Synchrophaser on rear COMM	No	Yes
7	No. of digital only cards - 1	See Table 5	
8	No. of digital only cards - 2		

Table 4

Switch 2	Switch 3	Baud Rate
Off	Off	1
Off	On	2
On	Off	3
On	On	4

Table 5

Switch 7	Switch 8	Digital Input Boards
Off	Off	1
Off	On	2
On	Off	3
On	On	4

Cross Triggering

Any number of TR-2100 recorders may be coupled together to form a system with any number of inputs (in multiples of 8, 16, 24, or 32 analogue inputs). This system uses the 'Triggered' status relay outputs and digital input 15 of each recorder. They are connected as follows:
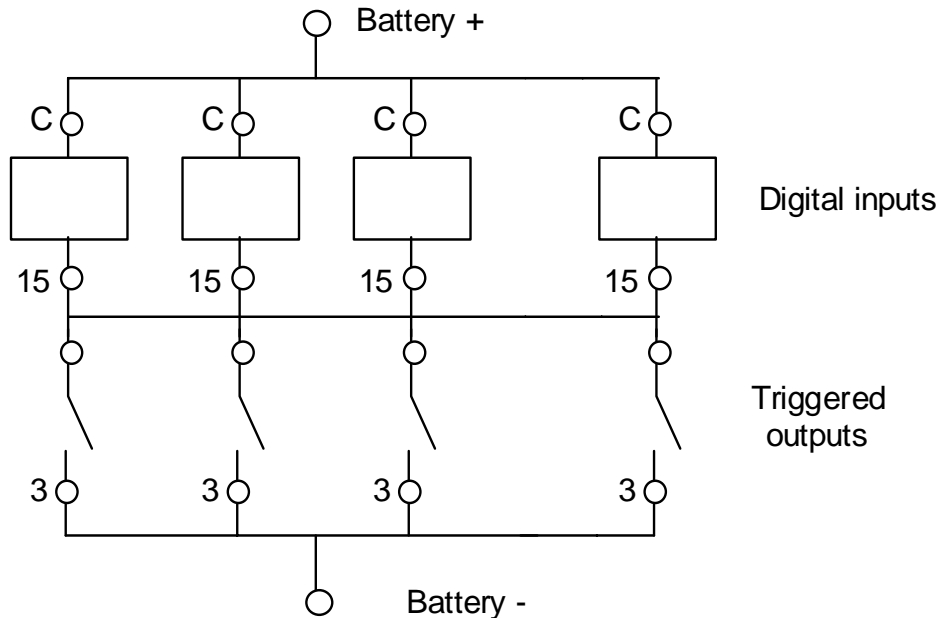
Figure 7 Cross-Triggering Wiring

Switch 5 in bank SW1 on the acquisition board must be ON for every machine connected together in this way. When this is done and the systems are switched on the channel labels for digital input 15 will become 'Cross-trigger'. The triggering for these channels must be enabled manually but are automatically set as level sensitive with profiling off.

Operation

When any of the connected recorders is triggered, its 'Triggered' status output relay will pulse immediately. This will cause digital input 15 on each recorder to go into the alarm state. When this happens, the recorders will trigger, but their status relays will not be activated. If a valid trigger is detected on a recorder other than that which started the process, its status relay will activate, thus extending the post fault period of all recorders if necessary.

The originating recorder will have a normal cause of trigger, but the others will show 'Cross-trigger' to identify the source of the original trigger.

When the fault records are downloaded to Display Station, they may be viewed and printed individually. The records can be aligned using the *normal* to *alarm* transition on each digital input 15 as a common time reference. The time, date, and cause of the composite record will be that of the recorder which started the process. Because the status relays have a switching time of up to 5 ms, the effective pre-fault period will be shorter than specified. This may be compensated for by increasing the pre-fault length by one cycle on all the connected recorders.
If cross triggering is enabled, a manual trigger (caused by pressing the 'Test' button or by selecting 'Manual trigger' from Display Station) will not cause the 'Triggered' relay to operate.

5 Calibration

Introduction

The system calibration should be checked annually using the real time display functions. If an error is found, a correction can be handled by one of two methods. Depending on the amount of the error, use the appropriate method as follows.

Calibration Method #1

If the error is less than 0.5%, the full-scale value of a channel can be corrected to adjust the value that is being read in the Real Time display, the Trigger section, or a Record. This can easily be done without recalibrating the unit. It is only a software change in the Configuration (Full Scale of any channel) of the TR-2100 unit. Note that the configuration must be downloaded before the change will take affect.

$$\frac{What\ the\ value\ on\ the\ screen/record\ should\ read}{Actual\ reading\ on\ the\ screen/record} \times Current\ Full\ Scale = New\ config.\ Full\ Scale\ Value$$

Calibration Method #2

If the error is more than 0.5%, then the channel in that unit should be recalibrated using the "*MFR Calibration*" software application that is available from AMETEK. The program allows simple calibration of the machine. Please note that the unit must be OFF LINE before running the Calibration program. This is very important, as the program will not work correctly if the unit is left on-line. It is recommended that the recorder be set to its working sampling rate before calibration, using Display Station 32 configuration software. Updating the calibration parameters will affect the internal system clock. The time should be reset *after* calibration, using DS32.

TR-2100 Input Boards

The TR-2100 has a separate analogue input board for each 8 analogue input channels; i.e. a 32-channel system has 4 analogue input boards. Each analogue input board contains a small non-volatile memory (EEPROM). This device is read when the TR-2100 is initialised. The calibration values for that board are read from the EEPROM and stored in the memory of the TR-2100. The calibration values are then used in all subsequent calculations performed by the TR-2100. The calibration program has the capability to read from and write to the chip. Once the program has set the calibration values, it will update the EEPROM.

The advantage of this scheme is that the calibration values are located on the input board. If the board ever has to be changed, its calibration factors will travel with it so the system will not need to be re-calibrated.

In the calibration program, each analogue input board is calibrated separately. The board is selected using 'radio' buttons at the top of the window under *Card selection*.

TR-2100 Calibration – Main Window

There are four options on the main window:

        Connect   - connect to a TR-2100
        Disconnect   - disconnect from a TR-2100
        Configure   - configure the baud rate and communication port
        Exit   - exit the program
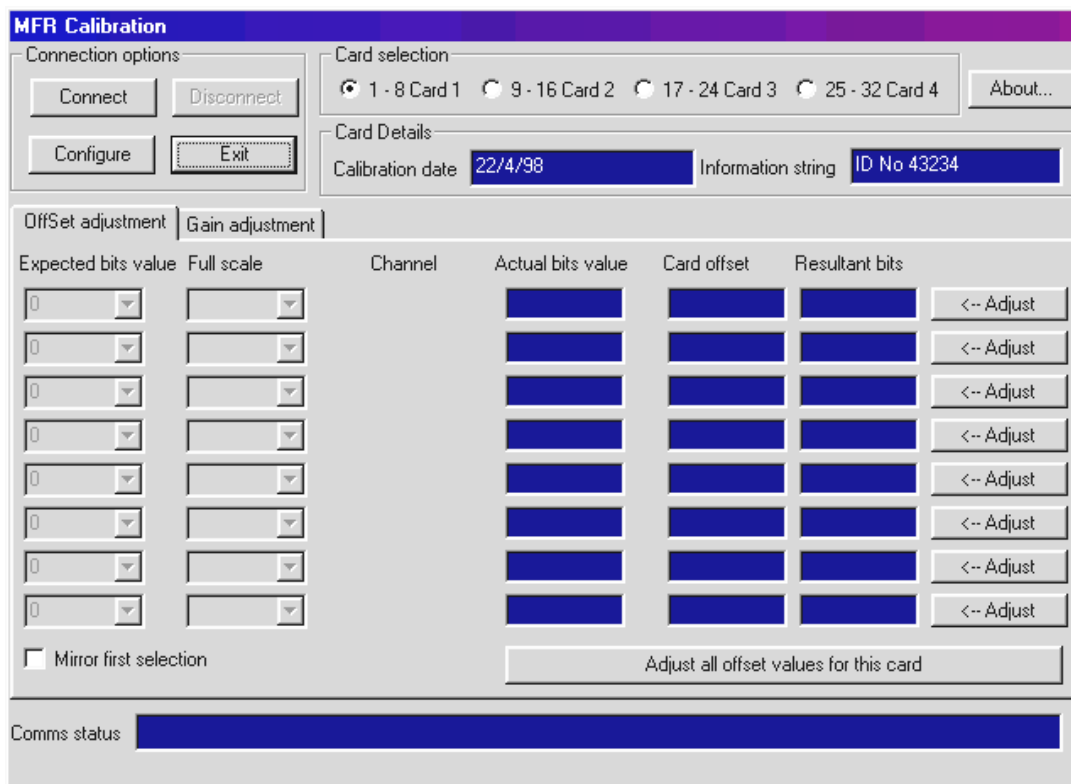
Communication Port Configuration

Ensure the communication port has been set up correctly before attempting to connect to a TR-2100. Use the Configure button to set up the parameters. The following window will be displayed:
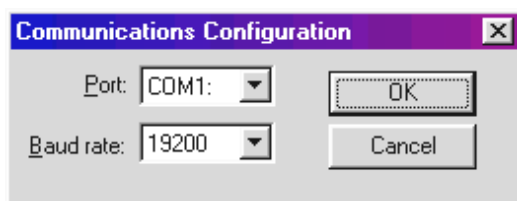
Select the communication port you are using on your PC. The baud rate must be the same as set in the recorder, which is determined by DIP switches in the TR-2100 (see chapter 4). Connect the Com port on the PC to the connector at the front left of the TR-2100 using the 'null modem' cable provided with the recorder.

TR-2100 Connection

To make a connection, click on the *Connect* button. The program will attempt a connection by looking for a CLI command prompt. If this is successful, it will attempt to read the EEPROM chip on the first board of the system. Once the values have been read from the board, the actual input values will start to be displayed. There are two main parts to the calibration process - offset and gain.

Offset Adjustment

The offset should ALWAYS be adjusted first because it will affect the subsequent accuracy of the gain offset. To set the offset, it is important that no signal is going into the back of the recorder. The best way to ensure this is by using a shorting connector that links the positive and negative terminals of each analogue input.

At this point, the actual level that is being read by the recorder is shown in the **actual bits value** column. The **actual bits value** is what the analogue to digital converter has provided to the TR-2100. The actual value that the TR-2100 will end up reporting is the value in the **resultant bits** column. This is the value that is required to be as near as possible to 0. The value in the **card offset** field is the actual offset value which will be sent to the input board when it is updated.

The option is available to adjust the offset for all the channels at once, or the adjustment can be changed for each individual channel. The **resultant bits** field has two colors to reflect status. When the field is red, the **resultant bits** field is not 0. When the field is green, the **resultant bits** field is 0. This is a visual aid to help in determining that the offset adjustment is correct. However, even after adjustment some of the fields may flash between red and green. It may be necessary to adjust that channel in that case, however as long as all fields are displaying 0 or close to 0, it can be assumed that the offset has been calibrated.

Once any adjust button has been pressed, a command is sent to the TR-2100 that updates offset values in the memory of the TR-2100. Although the TR-2100 has its local values updated, the actual EEPROM has not been updated at this stage. The process of writing to the EEPROM is a slow process. Therefore, the EEPROM is only updated when the user switches to gain calibration or switches input cards.

Gain Adjustment

To start the gain calibration, click on the **Gain adjustment** tab. The system will first save any changes in offset calibration – see below. A good AC or DC signal generator is required, preferably one which generates a signal at least twice as accurate as the accuracy of the TR-2100. Alternately, the output of the generator can be measured with a meter that has at least twice the accuracy of the TR-2100. For AC calibration, the normal system frequency (50.00 or 60.00 Hz) should be used.

The user requires knowledge of the type of channels (voltage or current etc.) and their Full Scale Deflection (FSD) values. These are found in the User Specification Sheets that are located in Appendix V of this manual, and are specific to each individual instrument. The serial number of the instrument should be checked against the serial number on the User Specification sheet. The instrument serial number will be found on a label attached to the rear panel.

The channel types and FSDs can also be found by using Display Station to connect to the recorder and viewing the analog input configuration. The TR-2100 is normally calibrated using secondary units. As an example, for a voltage channel the full scale value is 212.132 V rms, and for a current channel the full scale value is 1.41421 V rms. For current channels, the TR-2100 may be calibrated using a current or voltage signal. If internal shunts are installed, a current signal can be used and is preferred since the correction will include the

shunt error. In this case, the test current can be found by dividing the shunt resistor value (found in the CT section of the User specification Sheet) into the equivalent test voltage:

Test voltage = 1.000V
Shunt = 130 ohms
Test current = 7.6923mA
Therefore, a test current of 8.000mA would be acceptable

The TR-2100 can be calibrated using a DC or AC signal. The input channels of a TR-2100 are defined as either AC (transformer) or DC (transducer). This indicates the type of input signal and NOT the type of coupling. The TR-2100 uses this information to determine if the FSD is an RMS value, and if the inputs must be scaled to accommodate the peak value.

Table 6

Channel Type	Calibration Type	Full Scale Deflection
DC	DC	As final value
AC	DC	(As final value) * $\sqrt{2}$
DC	AC	n/a
AC	AC	As final value
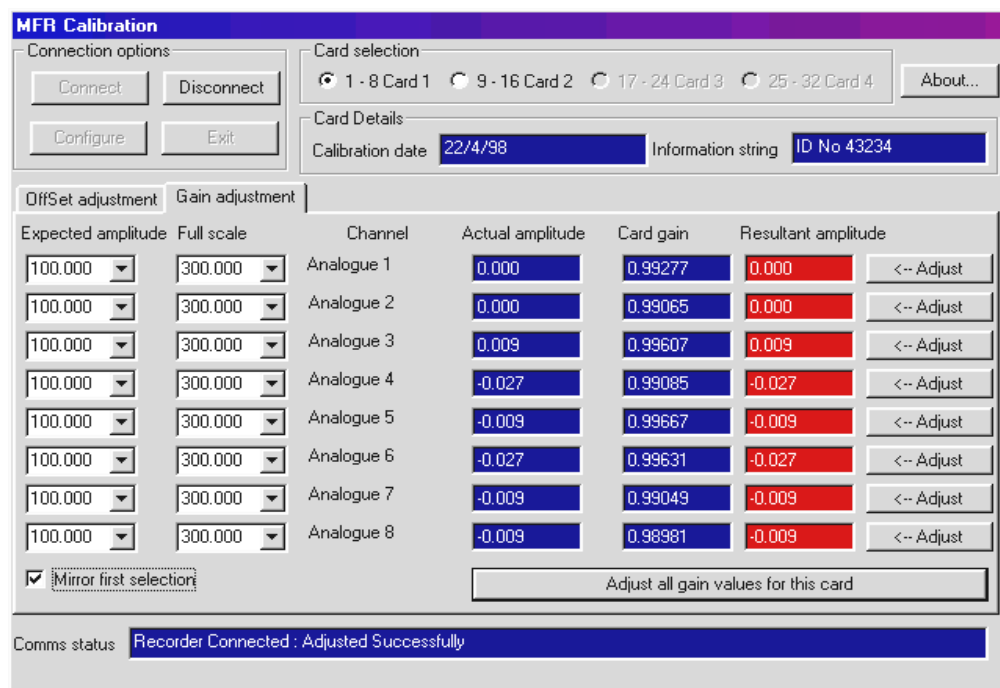
The value that is fed into the recorder should be at least half the Full Scale Deflection. 150.00 V ac is a good value for voltage inputs, and 1.0000 V ac is good for current inputs. For each channel, type in the FSD and the value being fed in to the input card. If all channels are setup with the same FSD and expected value, then the **Mirror First Selection** check box can be set. This will copy the first value and first FSD fields into all the boxes.

Once these values have been set up, the Calibration program displays will be giving relevant information. The **actual amplitude** field will display the value that the input card would report if no gain adjustment were applied. The **card gain** field gives a number between 0 and 2.0 that represents the gain applied to the actual amplitude. The **resultant amplitude** is the final value that will be reported by the TR-2100. This field should end up close to the expected amplitude.

Press the Adjust button to update the card gain values. This will produce a new resultant amplitude. The values are sent to the TR-2100 memory, however the EEPROM value has *not* been updated at this point.

When the field is red, the resultant amplitude is greater than 0.1% away from the expected value. When the field is green, the resultant amplitude is less than 0.1% away from the expected amplitude. This is a visual aid to help in determining that the gain adjustment is correct. However, even after adjustment some of the fields may flash between red and green or stay permanently at red. It is up to the user to determine if the resultant amplitude is accurate enough.

Once the user switches cards or switches tabs or disconnects, the gain values will be written to the EEPROM (see below).

Transducers
Inputs to be calibrated for transducers are performed in a similar way. If possible, the TR-2100 should be calibrated with the transducer in place so that any errors introduced by the transducer will be corrected. For 4 – 20 mA output devices, this must be done so that the 4 mA zero offset can be removed.

Updating Board Calibration Values
The Calibration program will automatically update the calibration parameters for a board when the user switches tabs, switches cards or disconnects from the recorder. Switching tabs refers to switching from offset adjustment to gain adjustment. Switching input cards refers to switching from button "1-8 Card 1" to button "9-16 Card 2" or "17-24 Card 3" or "25-32 Card 4".

Whenever any update of calibration values has occurred (e.g. offset adjustment), the EEPROM chip of the input card must have its calibration values updated. The program detects if the user has changed any value at the previous tab or input card. If a change has been made, a dialog box will pop up asking the user if he wants to update the EEPROM on the input card.
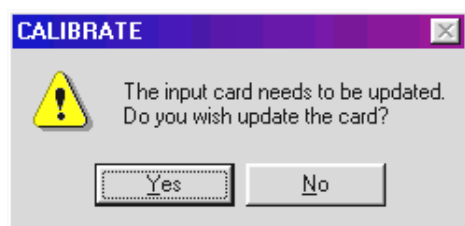
Answer "Yes" to this question if all the adjustments for the card have been made and the card has been successfully calibrated. The actual process of writing to the card will take approximately 90 sec for each input board. Once the values on the display start moving again, the card has been updated.

Disconnect

Disconnecting will prompt the user to update the EEPROM if any adjustments have been made. The connection to the recorder will be dropped and the program terminated.

CT Phase Correction

CT phase correction is not part of the calibrate program described above. Details are included here to complete the adjustment of the input scaling parameters of a TR-2100 to ensure maximum accuracy. The correction values are computed and set manually.

Inputs derived from interposing CTs and some other forms of transducer will normally suffer from phase shift error. This will affect the accuracy of derived parameters like power and impedance. This error can be corrected by adjusting the *phase correction* value in the *Analogue channel configuration* in Display Station. For more details on how to set the value, see the Display Station 32 manual.

To measure the phase shift for a particular input, first ensure that the *phase correction* value is set to zero using Display Station. Next, apply 50 or 60 Hz signals to the voltage input and interposing CT connected to a current input of the same phase. That is, inputs with the same phase designation as set in the line and phase group definitions. These two signals *must* be in phase. This requires a specialized test set that can generate voltage and current at the same time. Now, use the *real time display* option in Display Station to show the voltage and current vectors. The CT error can be seen by noting the difference between the voltage and current angles. Another method is to show the power values in the *real time display* and to compute the CT error from:

$$CTerror = Sin^{-1}\left(\frac{Q}{S}\right)$$

Where Q is the reactive power & S is the apparent power.

The CT *phase correction* value entered at Display Station is a phase lag. That is, if the current signal is seen to lead the voltage, then the correction is negative. Enter the value and *Setup* the TR-2100. Now, check that the angle difference is zero or that the reactive power (Q) is zero using the method described above.

Unfortunately, CT phase error is not fixed and varies with current magnitude. To maximize accuracy, the system should be phase corrected at a current value close to the normal working value. For a protection CT with a 5A secondary, the interposing CT should be calibrated at approximately 2 to 3A.

6 Maintenance

The TR-2100 is designed for the rigors of an industrial environment; however the unit requires a minimal amount of regular and preventative maintenance.

Fans

The system uses two cooling fans, one at the rear of the chassis and one at the front, which include mesh filters that should be checked regularly. The interval will depend on how dirty the environment is, but every 4 - 6 months is recommended. A build-up of dirt can be simply washed off the filter. The small fan located on the CPU board should be cleaned or at least checked, once a year. If the environment is dirty, it should be checked more often.

Batteries

The standard TR-2100 has 2 semiconductor packages that contain lithium batteries. These batteries have a life of ten years without any external power applied. These are the real time clock on the processor board which is a Dallas DS1287; and the parameter and profiles memory on the acquisition board which is a DS1245Y-07 at location U13.

Power Supply Adjustment

The internal power supply voltages should be checked on an annual basis, as aging and environment could affect critical voltage levels.

We recommend the complete reading and understanding of this procedure. Knowledge and familiarity with the TR-2100 and Display Station 32 Communication Software will be very helpful and is recommended. It is also recommended that two persons perform this procedure.

If you have any questions or encounter problems, please contact the AMETEK Transient Recorder Technical Support Department at the numbers listed in this manual.

RECOMMENDED TOOLS AND EQUIPMENT LIST:
- Computer with one unused RS-232 port
- AMETEK TR-2100 direct connect cable
- DVM / Digital Volt Meter for DC
- Basic technician hand tools, Phillips screwdriver, 5/16th Nut driver, etc.
- ESD protection equipment
- Several very small flat blade screwdrivers (one with a long length)

CAUTION:
**TR-2100 UNITS CONTAIN STATIC SENSITIVE ELECTRONIC DEVICES.
PROPER ELECTROSTATIC DISCHARGE (ESD) DAMAGE PREVENTION AND
HANDLING TECHNIQUES SHOULD BE FOLLOWED.**


Adjustment Procedure:
1. To open the front panel of the TR-2100 unit, use the two screws at the top. Locate the white connector on the CPU card, see Figure 9, this is where you will monitor your five volts DC. This white connector is located just to the right of the ribbon cable that goes to the hard-drive on the CPU board. Note the arrow in the middle of Figure 9 pointing to it. Attach a digital volt meter's positive connector to Pin #12 (located on the far left of the connector). Count five pins over to the right (including pin #12) and attach the meter's negative probe to pin #8. Set the DVM for Volts DC. If the voltage is already between 4.91 to 5.1 VDC, you can stop here and close the front panel. If the voltage is not between these specifications, then you must continue with this procedure.

2. Hook up your computer to the front RS232 port of the TR-2100 and set up communications to the unit using DS32 software. After you have established communications, make sure you know the current configuration of the TR-2100. Also, make sure that you have downloaded any events that you may want to save. This is not required, but is done just as a safety precaution. Now disconnect DS32 communications from the TR-2100 and remove the communications cable from the front port of the unit.

3. Setup your ESD protection. Open the front panel and turn the internal power switch to off. We also recommend removing the power source to the unit. You should not need to disconnect the power wiring at the rear of the TR-2100. Open the fuse or breaker that supplies power to the rear of the chassis, as these cables may be exposed to the chassis in the operation. Next, you need to remove any cables (except the input Power wiring) on the back of the CPU chassis. This may include the IRIG-B/GPS, Network, Printer, Phone and RS-232 cables, see Figure 8 later in this procedure.

4. Locate the two brackets located inside the TR-2100 on either side of the chassis, see Figure 9. Each bracket is held in position by one screw, located either in the top or centre of the white bracket. Remove the screw holding each bracket and remove both brackets that hold the chassis.

5. The ground braid that supports the Front Panel will need to be removed; one nut holds this inside on the left panel. Locate the two ribbon cables that go between the ACQ card and the Inputs Cards located above it. You will see a large and smaller ribbon cable that connects to all of the input cards. Remove these two cables from the ACQ card end. See Figure 9 for the cables.

6. Slide the CPU chassis out; the correct distance can be seen in Figure 10. Make sure that someone supports it as needed so it does not fall. Now check to make sure that the input Power wires on the back are not touching the chassis, *this is very important.*

7. If it is electrically safe, apply power back to the chassis INPUT Power connections. Turn on the internal switch (the small switch inside of the TR-2100 unit). The unit will start its normal boot up sequence once you turn the switch on.

8. Locate the White connector on the CPU card (see Figure 9). This is where you will monitor five volts DC. This white connector is located just to the right of the ribbon cable that goes to the hard-drive on the CPU board. Note the arrow in the middle of Figure 9 pointing to it. Set the Digital Volt Meter for Volts DC. Attach the meter's positive probe to Pin #12 (located on the far left of the connector). Count five pins over to the left (including pin #12) and attach the meter's negative probe.

9. Using a long, small, flat blade screwdriver, locate the Blue potentiometer on the Power supply. See   Figure 11 for the location. Adjust this potentiometer until the DVM reads 5.00 VDC, +/- 0.05 VDC.

10. Next, turn off the internal power switch and also turn off the power to the rear power connector. Remove the DVM from the white connector.

11. Reverse the order of the above procedures to reconnect all of the cables and close the front panel on the TR-2100 unit.

12. To verify proper operation, set up a direct connection using DS32 to the TR-2100. When connecting to the recorder, the program may prompt you to update the computer's/recorder's local configuration. Select to update the remote recorder's configuration. If possible, have the computer (running DS32/DSA32) call into the TR-2100 by modem, to verify that the TR-2100's modem has been initialized correctly.

13. Make sure that the unit still has the correct parameters, and will trigger and record a waveform on all channels that have voltage or current going into them.
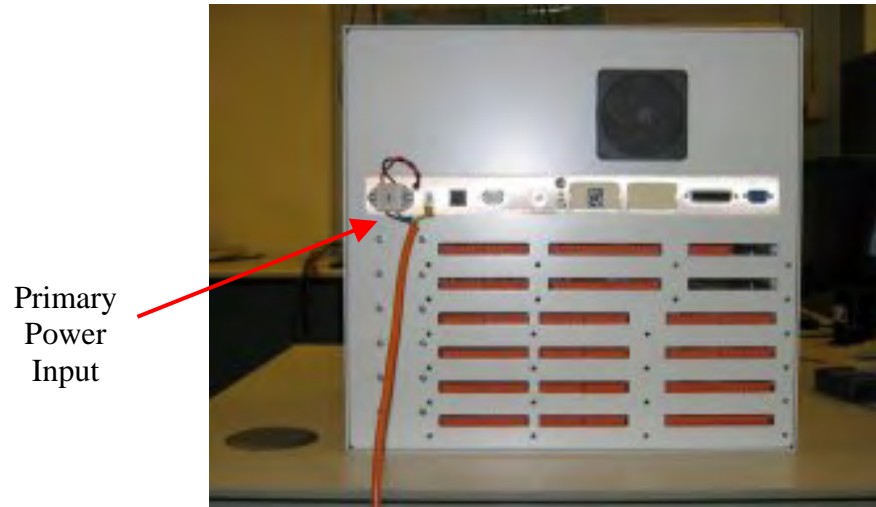
Figure 8 Primary Power Input

Primary
Power
Input

Bracket

White
Connector

Bracket

Ribbon
Cables
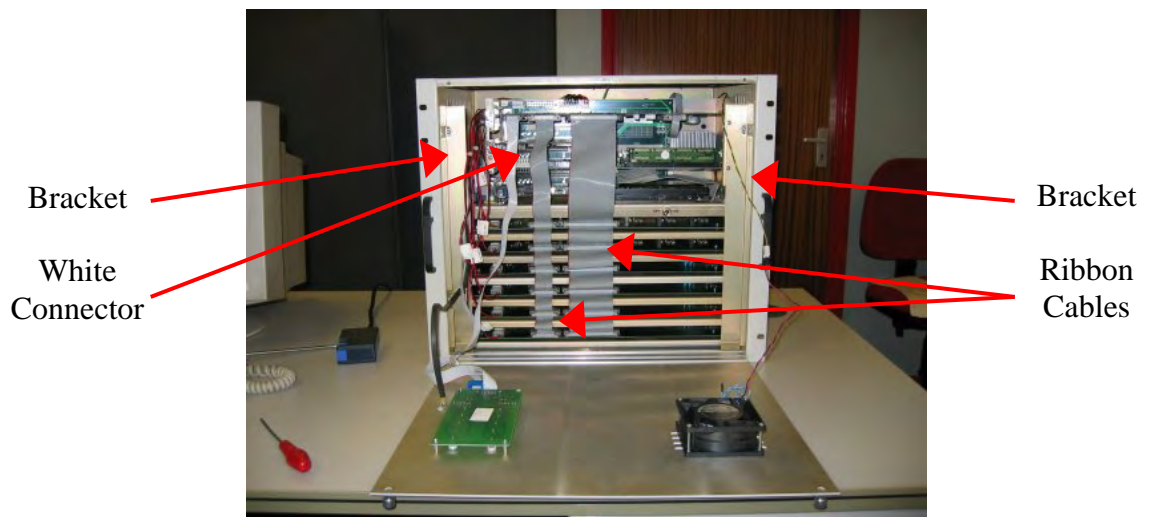
Figure 9 Chassis Internals
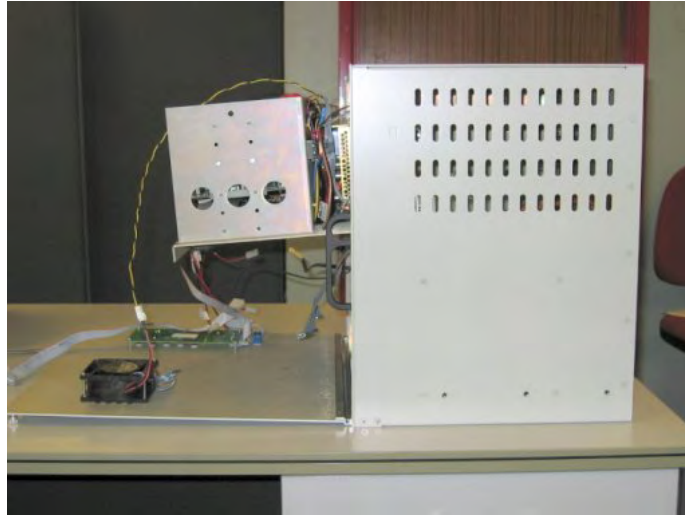
Figure 10 Sliding Out CPU Assembly
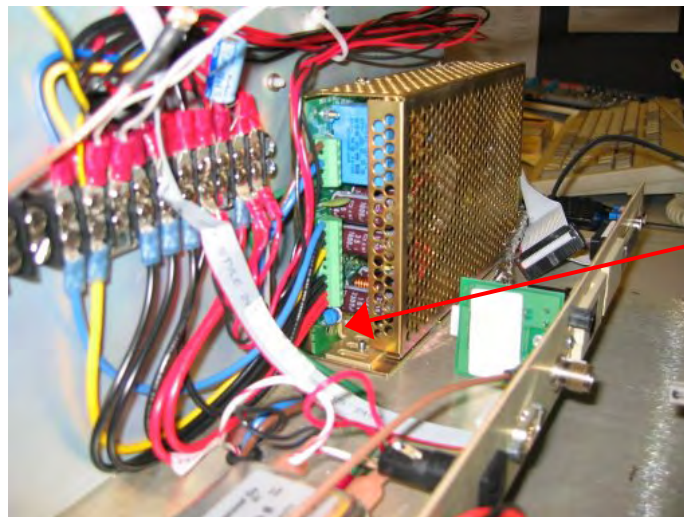
Potentiometer

Figure 11 PSU Potentiometer

Hardware Settings

Acquisition Board Configuration Switches

Set-up the acquisition board configuration switches as shown below. Reference the System Drawings for number of channels and options to be enabled.

Bank 1

Table 7

Switch	Function	Off	On
1	Digital-only cards	Yes	No
2	System frequency	50 Hz	60 Hz
3	No. of analogue cards – 1	See 8	
4	No. of analogue cards – 2		
5	Cross triggering	Disable	Enable
6	GPS receiver	Yes	No
7	Time code port	Master	Slave
8	(undefined)		

Table 8

Switch 3	Switch 4	Analogue Input Boards
Off	Off	1
Off	On	2
On	Off	3
On	On	4

* Default setting

Bank 2

Table 9

Switch	Function	Off	On
1	Time code port	Disable	Enable
2	Program port – baud rate	See 10	
3			
4	Printer	No	Yes
5	Modem	No	Yes
6	Synchrophaser on rear COMM	No	Yes
7	No. of digital only cards - 1	See 11	
8	No. of digital only cards - 2		

Table 10

Switch 2	Switch 3	Baud Rate
Off	Off	1
Off	On	2
On	Off	3
On	On	4

Table 11

Switch 7	Switch 8	Digital Input Boards
Off	Off	1
Off	On	2
On	Off	3
On	On	4

Digital Input Resistor Table

If necessary, the Digital Inputs can be changed to accept a different voltage level. For the Analogue Input boards the digital inputs use Resistors R9000 – R9015. For the Digital-only Input boards the digital inputs use resistors R1 – R32. Reference the Input Module schematics for resistor locations and change the value to match the Digital input voltage.

Table 12

Input VDC (Nominal)	Resistor	Description	Ametek Part No.
12V	3.6K	Carbon Composition Resistor (1W)	4716-130
24V	6.8K	Carbon Composition Resistor (1W)	4716-140
48V	15K	Carbon Composition Resistor (1W)	4716-152
125V	39K	Carbon Composition Resistor (1W)	4716-164
250V	82K	Carbon Composition Resistor (2W)	4716-180

Analogue Input Board Jumper Locations

Set the Input Board configuration jumpers per Table 13. Refer to Figure 12 for the location of each configuration jumper.

Table 13

Board No.	Analogue Channels	BRD SEL 0	BRD SEL 1
1	1-8	On	On
2	9-16	Off	On
3	17-24	On	Off
4	18-32	Off	Off

Input Board Analogue Input Range Selection Table
Set the Analogue Input Board range selection jumpers per Table 14. Refer to Figure 12 for the location of each range selection jumper.

Table 14

Input Range	Jumper	Resistor Selected
0-2 Vpk (Current)	None	None
0-300 Vpk (Voltage)	JP0	Rx06 (909 Ohm)
0-12 Vpk	JP1	Rx07 (26.7 KOhm)
TBD	JP2	Rx08 (TBD)
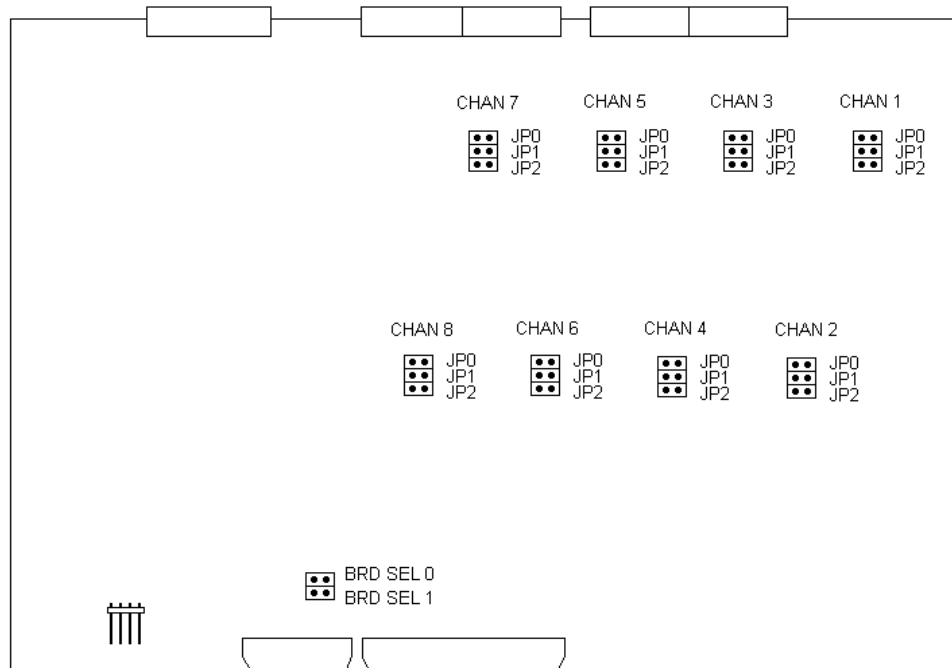
Figure 12 Analogue Input Board Jumpers

Digital-only Input Board Jumper Locations

Set the Digital-only Input Board configuration jumpers per Table 15. Refer to **Error! Reference source not found.** for the location of each configuration jumper.

Table 15

Board No.	Extra Digital Channels	DIG BRD SEL 0	DIG BRD SEL 1
1	1-32*	On	On
2	33-64*	Off	On
3	64-96*	On	Off
4	97-128*	Off	Off

* Channel number as reported in Display Station will depend on the number of analogue boards fitted.
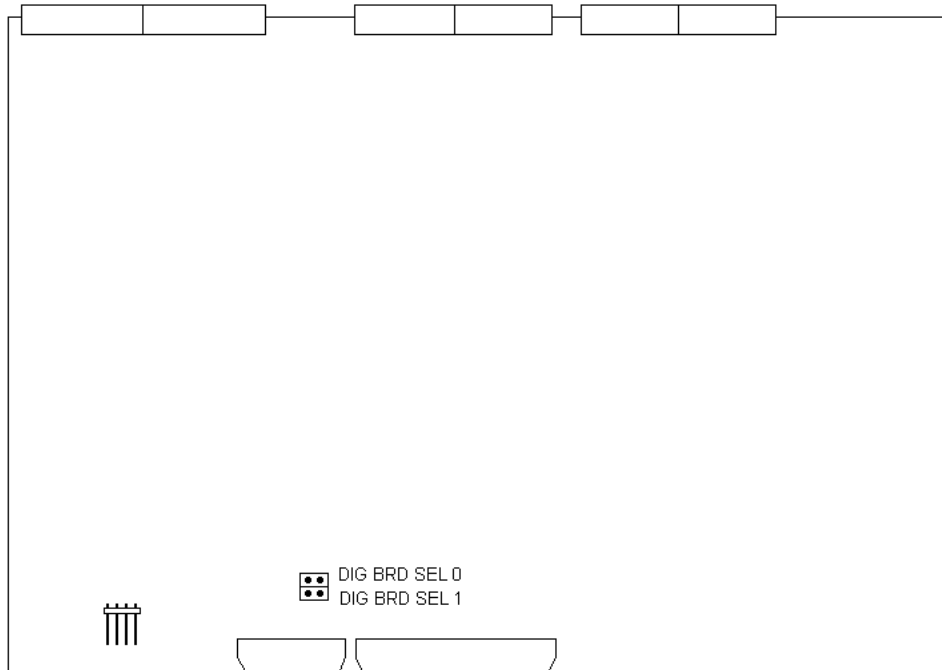
Figure 13 Digital-only Input Board Jumpers

Hard Drive Format Procedure

> **WARNING!**
> Only authorized personnel with computer service experience should perform this procedure. Contact the factory if there are any questions.

The   TR-2100 has an internal CLI program that will allow you to format the system's internal hard drive. This will require the use of a Terminal program (such as Win95's HyperTerminal, Qmodem, Telix, ProComm Plus, etc.) that can send data in ASCII format.

RECOMMENDED EQUIPMENT LIST:
1.   Computer with:
        - MS Windows™ 95 or better
        - Display Station32
        - HyperTerminal or equivalent
        - Unused 9 pin RS-232 port
        2.   TR-2100 direct connect cable
        3.   TR-2100 User Manual
        4.   Display Station32 Instruction Manual

IMPORTANT NOTE: The TR-2100 Event Directory will be deleted. Before beginning the hard drive format procedure, retrieve all events, harmonic files, and trend logger files.

Setting Up the Terminal Program

The TR-2100 Local RS-232 port can be set for 57600 or 11500 baud by switch SW2-3 on the master acquisition module. If the switch is off, the Local RS-232 port is set for 57600 baud. If the switch is on, the port is then set for 57600 baud. The factory default is 57600.

HyperTerminal™ is a Terminal program that comes standard with Win95 (or higher); therefore, this procedure will reference it. If you decide to use another Terminal program, use the following parameters: 57600 baud (or as needed, see above), no parity (N), eight data bits (8), one stop bit (1), and Hardware Flow control (Software Flow control is not used).

Format Procedure

1. Verify that all events at the TR have been retrieved. If not, retrieve them before proceeding. This includes Harmonic Logs, Trend Logs, and the standard TR events.
2. Attach one end of the TR-2100 direct connect cable (AMETEK P/N 1077-271) to the computer's unused RS-232 port and the other end to the TR-2100's Local RS-232 port (found on the front panel).
3. Turn on the computer and start Win95.
4. Open Comms Manager from the System menu, and note the port and port baud rate settings.
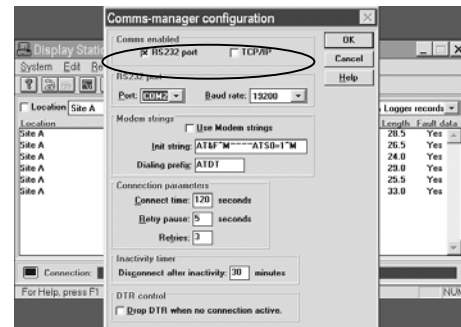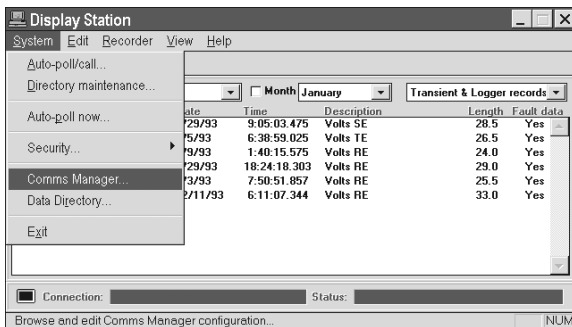
5. Exit the DS program now (close the program). Do not just minimize the program.
6. HyperTerminal™ can be found by clicking on the "Start" button in the Windows Taskbar, then clicking on Programs / Accessories / HyperTerminal, (or Programs / Accessories / Communications / HyperTerminal for Win98). If the program is not there, you will need to install it from your Windows CD-ROM. This will open a window similar to one of the ones detailed below.
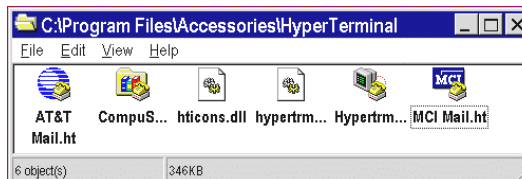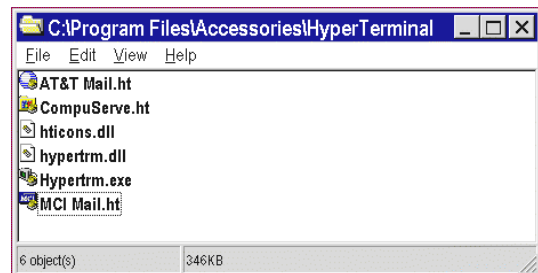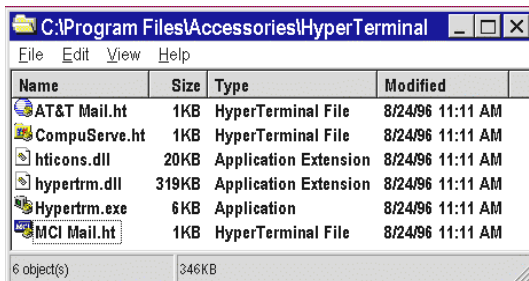
7. Double click on the file "Hyperterm.exe" and the screen depicted below will appear.
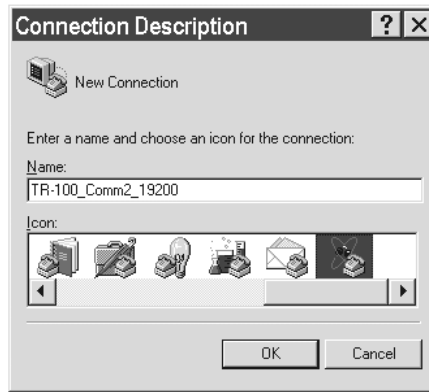
8.   Enter any name you desire. For example in this procedure, we will use "TR-100_Comm2_19200". Select the "OK" button when done and the screen depicted below will appear.

9.   Set "Connect using" to "Direct to Com*", where * is the number of the RS-232 port on the computer that is connected to the TR-2100. For our example, we have it set for Comm port 2 (This could also be Direct to Com1, Direct to Com3, or Direct to Com4). Select the "OK" button when done and the screen shown below will appear.
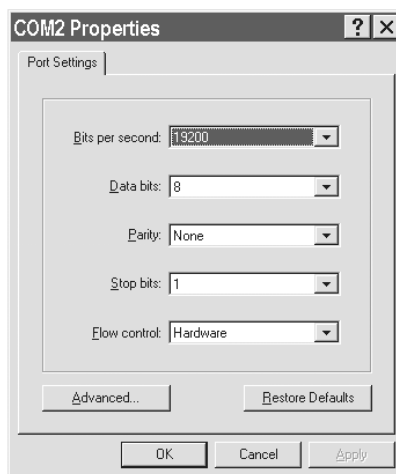
10.   This screen is where the computer's RS-232 port properties are entered. Set "Bits per second" to 57600. Set "Data bits" to eight (8). Set "Parity" to none (N). Set "Stop bits to one (1). Set "Flow control" to Hardware. Select the "OK" button when done and the following screen will appear.
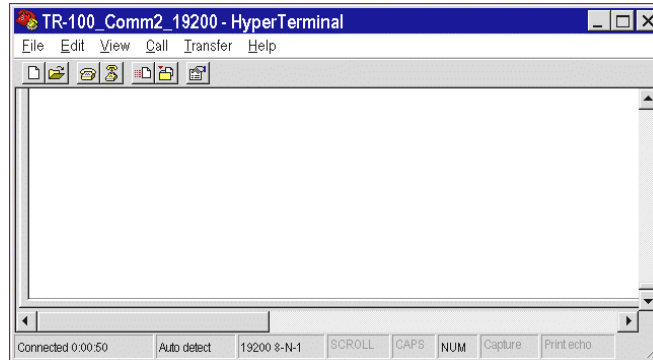
11.   Exit HyperTerminal. You will get a message saying, "You are still connected. Are you sure you want to disconnect now?" Select the "Yes" button. You will get the following message; "Do you want to save session *<Name you entered>*?" For our example, the message is "Do you want to save session TR-2100_Comm2_57600?" Select the "Yes" button.

12.   Re-enter HyperTerminal by selecting (double clicking) the connection name you just defined. For our example, the name is "TR-2100_Comm2_57600". This should open a screen similar to the one shown below.
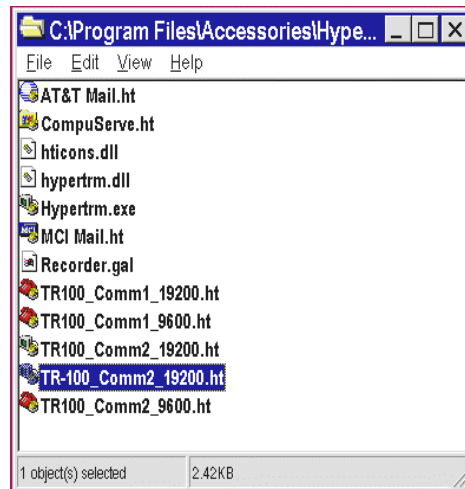
13.   Establish communications to the TR by pressing the computer's ENTER key three times. You will get a reply that will contain a complete configuration of the system, followed by a CLI> prompt from the TR-2100 if a connection is made (see the following screen). ***If you do not get a response, then your baud rate is incorrect, the wrong cable is being used, you have an internal***

PC conflict, or a failed port. Please call Technical Support for additional information or help.

```
TR-100_Comm2_19200 - HyperTerminal                          _ □ ×
File  Edit  View  Call  Transfer  Help

 ▢ ⍐ ▢▢ ▢▢ ⍐

Connection established (COM PORT 1)
Connected at 20:04:33 on 22/11/1998

TR-100(T) Transient Recorder.   [ American ]
(C) Copyright 1993-1996, Leading Edge Research Ltd.

MachineType        "TR-100(T) Transient Recorder"
SWRevision         2.08
CPUSupport         386+ (DOS4GW)
Analogues          32
Digitals           64

MainsFreq          60 Hz
Samplerate         192 samples per cycle
Cards              4
PGroups            8
CrossTriggered     No
Printer            No
Modem              No
TimeSync           No
IRIGBCard          Yes
DCF77Card          No
Battery            No
Disk               Yes  (ACTIVE)
DNP                No
Harmonics          No
RCC8000            No
NGTS               No
Logger             No
NetworkSupport     No
Hub                No
AnyIPConnections   No

CLI>

CLI>_

Connected 0:02:02   Auto detect   19200 8-N-1   SCROLL  CAPS  NUM  Capture  Print echo
```

14.   Now you will perform the following command to format the Hard drive. At the CLI> prompt, type in **system formatdisk** and press the Enter key. Formatting will take 30 minutes or longer to complete. See the example below. Once the process is complete, a message will appear telling you that the format was successful.
                     Example: CLI>**system formatdisk**

15.   At the CLI> prompt type in the word **QUIT** and press the enter key. The recorder will respond that it has disconnected. Exit (close) your Terminal program now. **Do not just minimize the program.**

16.   The rest of this procedure is not mandatory, but should be followed to make sure the unit is working correctly. Start DS32 and establish a connection to the TR-2100. Go into the Configuration window. The program may prompt you to update the Recorder or Local configuration (next screen). Select "Update the RECORDER configuration".
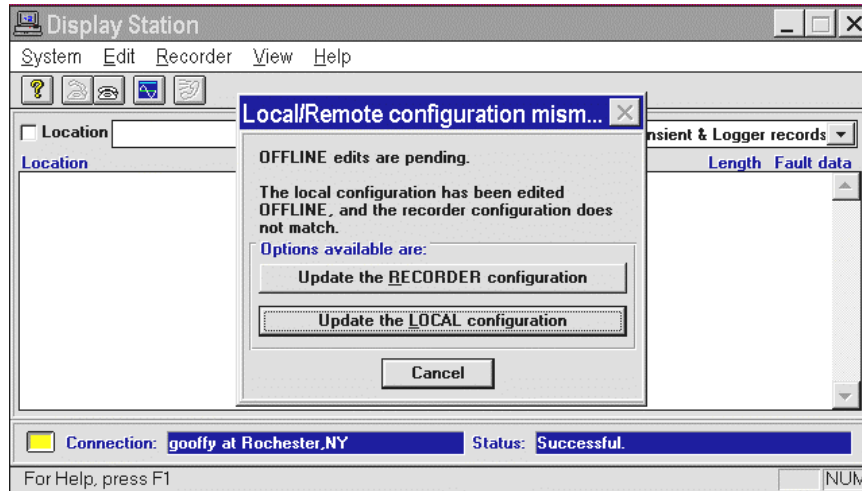
17.   Create an event and retrieve it.
18.   If possible, have the computer call into the TR-2100 and retrieve an event.

Installing NE2000 Compliant Network Cards

1. Make sure you have the appropriate network connectors available at the back panel of the TR-2100 unit, depending whether you need RJ-45 or Coaxial. If you don't see what you need on the back panel, it is recommended that you call Ametek Technical Support.

2. The network card must first be installed in a PC to be setup. It is recommended that the PC not already have a network card installed. You will need to run the Setup program for the network card, which is usually found on the accompanying diskette packaged with the Network card.

3. Once you have the Setup program on the screen, set up the network card for both coaxial and twisted pair. Next set the IRQ for 11 and Hex address for 360.

4. Save the setup information and the card is ready to install in the TR-2100. Remove the card from the PC.

5. To install the Network card, you will need to remove the left white vertical bracket, one screw holds it in place. To locate this bracket, open the front panel and look on the internal left hand side of the case.

6. Once the bracket is removed, the network card must be installed in one of the two bottom slots. Make sure to remove the retaining screw at the top of the chosen slot, before installing the Network card. Install the card in the slot, and then replace the retaining screw to hold the Network card in place.

7. Before re-installing the left white vertical bracket, make sure to plug in your coaxial or RJ-45 connector, and then replace the bracket.

Acquisition Card Change-Out Procedure

REQUIRED EQUIPMENT LIST
1.   Computer with one unused RS-232 port
2.   TR-2100 direct connect cable
3.   Update package
4.   TR-2100 User Manual
5.   Basic technician hand tools
6.   ESD protection equipment

CAUTION:
TR-2100 UNITS CONTAIN STATIC SENSITIVE ELECTRONIC DEVICES.
PROPER ELECTROSTATIC DISCHARGE (ESD) DAMAGE PREVENTION
AND HANDLING TECHNIQUES MUST BE FOLLOWED.

Change-out Procedure
1.   Hook up your computer to the front port of the TR-2100 and connect to the unit using DS32. After communications is set up, make sure you have a current configuration of the TR-2100. Also, make sure that you have downloaded any events that you may need. Now disconnect DS32 communications from the TR-2100 and remove the communications cable from the front port of the unit.

2.   Set up your ESD protection. Open the front panel using the two screws at the top, and then turn the Power Switch to OFF. We recommend also turning off the power feed to the unit. You will not need to disconnect the power wiring to the rear of the TR-2100. Leave the front panel open.

3.   Locate the Acquisition Card in the chassis. It will be the top-most board in the chassis. Note that it has six cables attached to it, four are ribbon cables, one is a white connector and one is a small round black fiber optic cable.

4.   Remove all six cables from the ACQ card:
    LED Board Cable (1077-259)
    Digital Ribbon Cable (1081-995)
    Analogue Ribbon Cable (1081-999)
    PPS Time Sync Cable (white connector with 2 red and 2 black wires)
    Time Code ribbon cable (1082-098) GPS Fiber Optic Cable (1082-110)

5.   Next, locate the large Phillips screw that holds the ACQ board in place, which is located on the left hand side. Remove this screw, and then remove the ACQ board from the unit.

6.   Locate the GPS Receiver unit on the ACQ board. This is located on the right hand side of the board and has four screws, washers, and nuts holding it on. It will be about two inches square and has the plug for the Black GPS Fiber Optic

Cable (small round black cable) that you just removed. Remove the four screws that hold the GPS receiver and place the GPS receiver onto the new ACQ board in the correct location. Make sure that the GPS Receiver's connector is pointing towards the edge of the new ACQ board. Now put the four screws, washers, and nuts in place to hold the GPS receiver in place on the new ACQ board. Make sure not to over-tighten the nuts or you will damage the ACQ board.

7.   Place the new ACQ board into the same slot that the old ACQ was located. Replace the Phillips screw on the left side of the ACQ board.

8.   Re-install all the cables that were removed in step 4, and close the front panel on the unit.

9.   Set up a direct connection using DS32 software on your computer to the front port of the TR-2100. When setting up communications, the program may prompt you to update the Computer's / recorder's local configuration. If so, select "Update the Remote's configuration".

10.   If possible, have the Master Station computer (running DS/DSA) call into the TR-2100 by modem, to verify that the TR-2100's modem has been initialized correctly.

11.   Make sure that the unit still has the correct parameters, and will trigger and record a waveform on all channels that have voltage or current going into them.

Converting an Analog Channel from V/I or I/V

If a channel in the TR-2100 is to be changed from voltage to current, current to voltage, (or other) the following information should be noted.

- Voltage channels have a maximum input of 212.12 Volts AC RMS, 300 Volts Peak, or 300 Volts DC. If jumper JP0 for that channel is ON both posts, then the channel is set for voltage. (Note that 50% will be 106.06 V AC RMS, which will be used later.)

- Current channels have a maximum input of 1.414 Volts AC RMS, 2 Volts Peak, or 2 Volts DC. If jumper JP0 for that channel is OFF both posts, then the channel is set for current. (Note that 50% will be .707 V AC RMS, which will be used later.)

- Special channels have a maximum input of 12 Volts DC. If the jumper is removed from JP0 and placed ON JP1, then the channel is set for a 12 volts DC input.

Procedure

1. Noting the above information, next we will need to locate the correct board and the associated jumper to change. Analogue channels (when viewing the unit from the front) start on the lowest card with channels one (1) through eight (8). Channel one (1) is to the right hand side of the lowest Analogue Input card. Figure 15 shows this in detail, including the locations of each jumper.

2. In the picture below, note the white holding bars on either side of the front of the unit. Also, note the gray ribbon cables including the power cables on the left side of each input board. These will all have to be removed before the input card can slide out of the unit. **Not shown in this picture are the orange plugs in the back of each card. Remove all plugs from the card to be changed before attempting to remove the card.**
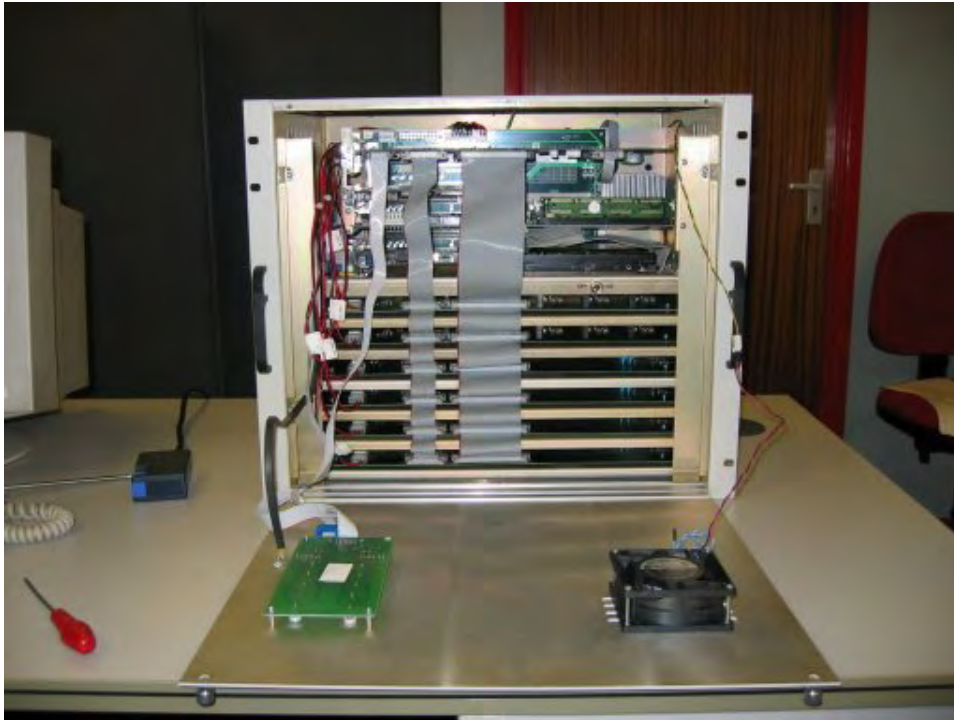
Figure 14

3. Open the front panel of the TR-2100 unit using the two top screws, and then turn the power switch (located in front of the Hard drive) OFF.

4. Next, remove the two white holding bars on either side of the unit. Continue by removing the gray ribbon cables attached to the Analogue input cards. Now remove the power cables found on the left hand side of the input cards. Finally, remove the orange input plugs from the back of each Analogue input card.

5. The Analogue input cards are now ready to be removed. As noted previously, the upper two boards are the analogue input boards on a 16-channel unit. If the unit is a 32-channel recorder, there would be four analogue boards (the picture above show a 16 channel unit with two analogue input boards and four digital-only input boards), but the format will remain the same. The bottom or lowest of the boards is where to start counting. Channel #1 is located to the right hand side of the top board. Channel #8 can be found on the top board on the left hand side. Channel #9 can be located on the 2nd board from the top, right hand side. Channel #16 can be located on the 2nd board on the left hand side. Now you should be able to locate the correct board to remove from the unit.

6. Once the board has been removed, refer to Figure 15 for jumper locations. In Figure 15, you will see the Voltage and Current jumpers located across the input board. The lowest number channel will be located on the right, while the higher number channel will be on the left.

7. Locate the correct jumper and move it ON or OFF as needed to set up the channel correctly.
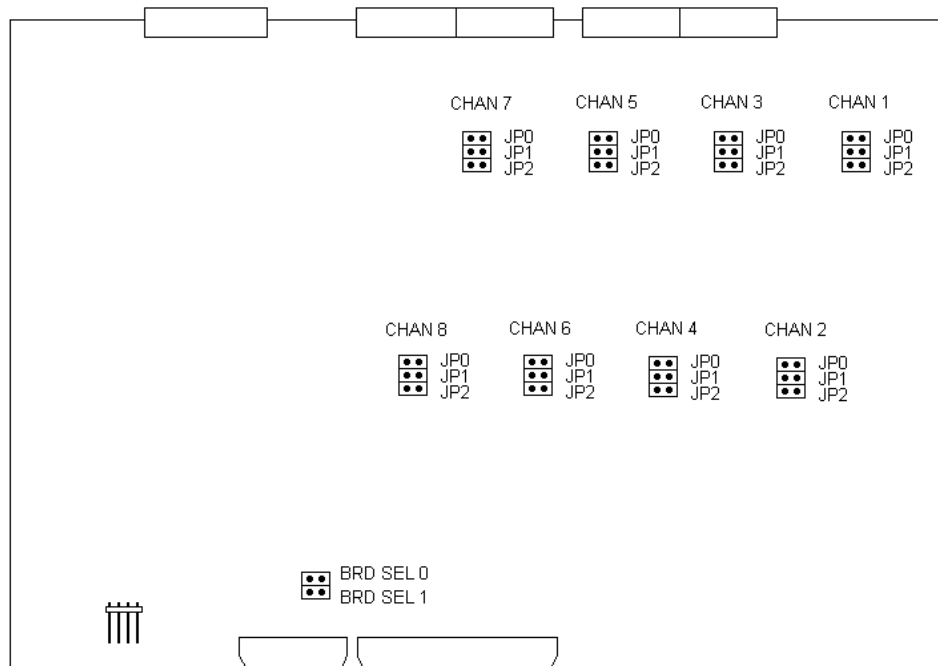
Figure 15 Analogue Input Board Jumpers

Jumper References

For Voltage input (212.12 V AC RMS) jumper is fitted in position JP0.
For Current input (1.414 V AC RMS) jumper is not fitted.
For the special input (12 V DC) the jumper is fitted in position JP1.
Position JP2 is unused.

8. Now that the channel is set up as needed for Voltage, Current, or Special input, change any other channels/cards as needed at this time also.

9. Once all jumpers are set correctly, make sure all the boards are properly reseated. Next, the two white brackets should be reinstalled, followed by the gray ribbon cables and power cables. The orange input plugs can now be inserted back into the rear of the input cards.

10. Turn the internal power switch to the ON position, and close the front cover of the unit.

11. Wait at least two (2) minutes for the unit to power up. Once the POWER, ON LINE, and ATTENTION LED's are on, the unit has powered up and you can continue.

Accuracy Verification

12. The accuracy of the changed channel should now be checked with a stable input source. This can be done quickly by setting the Full Scale Value (if voltage or current) to any level you wish to use. To calculate your Full Scale Values, use the following two formulas.

Voltage:

$$PT\ Ratio\ \times\ 212.12\ V\ AC\ RMS\ =\ Full\ Scale\ Value$$

Current:

$$No\min al\ Shunt\ Value\ \times\ 20\ \times\ CT\ Ratio\ =\ Full\ Scale\ Ratio$$

13. To test the accuracy of the channel, input .707 V AC RMS into a Current input or 106.06 V AC RMS into a Voltage Channel (directly into the back to the recorder). Note that these values are fifty percent of the maximum input we can put into the channels. The value you read under Real Time Values (in the DS32 Configuration screen) should be within 0.10% of the required value. The required value should be 50% of whatever you calculated for your Full Scale Value.

14. If the error is less than 0.5%, the full-scale value of a channel can be corrected to adjust the value that is being read in the Real Time display, the Trigger section, or a Record. This can easily be done without recalibrating the unit. Using DS32 software, change the Configuration (Full Scale of any channel) of the TR-2100. Note that the new configuration change must be downloaded before it will take affect.

$$\frac{What\ the\ value\ on\ the\ screen/record\ should\ read}{Actual\ reading\ on\ the\ screen/record} \times Current\ Full\ Scale = New\ config.\ Full\ Scale\ Value$$

15. If the error is more than 0.5%, then the channel in that unit should be recalibrated using the MFR CALIBRATION program. Refer to Chapter 5 of this manual for details about this procedure. Please note that the unit must be OFF LINE before running the Calibrate program. This is very important, as the program will not work correctly if the unit is left on-line.

Appendix I - TR-2100 Specifications

Inputs

No. of channels 8, 16, 24 or 32 Analogue
16 - 160 Digital
Unlimited number of channels by cross-triggering
systems

Voltage inputs 57 – 120V RMS typical
Other options available

Current inputs 1A or 5A RMS typical
Inputs via shunts or CTs
CT phase lag correction

Over range 212V RMS (voltage)
Selectable for current (x1 - x20)

Input burden 0.06 VA (voltage)
<0.014 VA (current)

Transducer inputs Any analogue input may be scaled for standard
transducers to record AC or DC quantities

Frequency response DC - 1/2 sampling rate, +0dB, -3dB.

Accuracy Better than 0.1% of full scale
Inputs are temperature compensated and can be auto-
calibrated (no pots required)

Digital inputs 24 / 48 / 125 / 250 Vdc
Contacts settable as normally open or closed

Digital debounce 1 - 10ms in 1ms increments

Recording (Transient)

Recording resolution   16 bits (65536 levels)

Dynamic range   96.3 dB

Recording accuracy   +/- 1 LSB

Sample rate   Up to 19,200 per sec. at 50 Hz
Up to 23,040 per sec. at 60 Hz
COMTRADE rates supported
Analogues and digitals can have different rates

Pre-fault time   2 - 500 cycles

Post-fault time   Fault length will extend as long as a trigger condition exists
Minimum is 8 - 100 cycles

Safety window   Recording time after trigger: 4 - 16 cycles

Maximum record length   1 - 30 sec. (This prevents memory filling with a continuous trigger)

Synchronization   All analogue channels sampled together and time tagged to better than +/- 100 ns (if GPS option is used)

Programmable Features   Sample rates
Pre, max & min post fault times
Safety window
Maximum record length
Trigger level and polarity
Trigger enable
Time and date
Channel labels
Local time offset

Configuration Switches   Number of analogue channels
Number of digital channels
System frequency (50/60)
Printer connected
Modem connected
Network connected
Cross trigger enabled

Fault Profile (Transient)

Measured Values   Fault duration, triggered channel
                                        Pre, during and post fault values per channel
                    Maximum & minimum values per channel
                              Selected digital channel timing

Recording (Disturbance)

Sample rate   2 x supply frequency (100/120 Hz)

        Pre-fault   10 sec. to 10 min.

        Post-fault time   Fault length will extend as long as a trigger condition
                                   exists.
                      Minimum value is 30 sec. - 5 min.

Safety window   Recording time after fault
                30 sec. - 5 min.

        Maximum record length   1 - 30 min.

        Recorded values   Fundamental voltages / currents (amplitude and angle)
                    RMS voltages and currents
                        2 frequency channels
                    Digital data in SER format

Computed values (in DSA)   Apparent, real & reactive power
                    Phase angle & power factor
                        Positive, negative & zero sequence components
                        Imbalance
                        Phasors
                    Load impedance, X/R ratio
                  Differential phasor

           (All measurements corrected for variations in system frequency)

Recording (Logging)

Storage interval   1 minute - Data can be recovered at up to 60 min
                              intervals.

Record length   52 weeks (circulating buffer)

        Recorded values   Maximum, minimum & average RMS voltages &
                                currents, 2 x frequency
                    Digital data in Sequential format

Harmonic log	Maximum, minimum & average amplitude and phase angle per channel up to 64th harmonic
Flicker log	Pst value per phase for 1 line group every 10 minutes, to IEC 1000-4-15
Imbalance log	Maximum, minimum & average imbalance (NPS/PPS*100%) for every line group, every 10 minutes
Power log	Maximum, minimum & average import or export power per line group, every 1 minute (energy computed at the PC)

Triggering (Transient)

Analogue channels	Over & under RMS level (or DC) with hysteresis Rate of change of level Positive, negative & zero phase sequence THD
	Cross trigger from disturbance recorder
Accuracy	Better than 0.5%
Digital channels	Normal to alarm state and return to normal state Edge or level sensitive
Programmability	Triggering on any number of analogue or digital channels.
Cross trigger	Allows unlimited number of recorder channels with precise time sync.

Triggering (Disturbance)

Analogue channels	Under & Over level
	Rate of change of real, reactive power
	Power Factor
	Frequency, rate of change of frequency (ROCOF) and frequency difference
	Power and frequency oscillation (0.1 - 15 Hz)
	Differential phase angle
Imbalance & impedance	
Cross trigger from transient recorder	

System Timing

Time source	Internal Global Positioning Satellite (GPS) receiver with 1 PPS output for sample clock
Oscillator source	Conditioned 16 MHz oscillator
Accuracy	Normally better than +/- 50 ns
Back up clocks	Dual 32,768 Hz. crystal oscillators
Range	Time and date (including leap year and day of the year)
Synchronization	1 pulse per second on optical port
	Any number of systems can be linked together
Serial time code	Time code input or output for synchronization of linked systems
Time setting	Automatic via GPS. Local time offset & daylight saving set via comms port
Y2K	The clock is Y2K compliant

Communications

Serial ports	Up to (4) RS232 type
Default setting	57600 baud, 8 bits, 1 stop, no parity Rates settable up to 115 kbaud
Serial port 1	Uses:
	Local programming Data retrieval Real time data display Software updates
Serial port 2	Uses:

	Remote programming
	       Data retrieval from remote
	       computer systems
	Real time data display
	Software updates

Serial port 3	Uses:
	IED/SCADA interface. Differential synchrophasor input/output
Serial port 4	Uses:
	RS485 Time code input/output (proprietary format)
Modem	Hayes compatible type internal or external, fax compatible
Phone line sharing	External unit to share a single phone line with a station phone and multiple recorders or IEDs
Network connection	10Base2 (50 R Coax & BNC) 10BaseT (twisted pair & RJ45)
Network protocol	TCP/IP

Data Storage

Buffer storage   30 Mbytes RAM (up to 128 Mbytes optional)

Program storage   4 Mbytes flash ROM (up to 64 Mbytes optional)

Permanent storage medium   3.5" Hard disk

    Capacity   12 Gbytes

Interface standard   Enhanced - IDE

Printer (optional)

Printer port   Centronics type

Output reports   System configuration
                  Transient record header
                  Transient record profile
                  Graphical display of transient record
                  Diagnostic and error reports

Front Panel Display

LED indicators   Power OK (Green)
                  Battery OK (Green)
                  System on line (Green)
                  Data available (Amber)
                  Comms. in progress (Amber)
          Attention (Red)
          Loss of time sync (Red)
          Disk fault (Red)
          Comms fault (Red)
          Temperature fault (Red)

Status Relays

Type	Solid State
Number of outputs	4
Contact rating	1 Amp max
	400 V dc / 280 Vac max
	Power & on line are N/C
	Attention & triggered are N/O
Indication	Power OK
	System on line
	Attention
	System Triggered
Isolation	Input to output - 2500 V ac
	Contact to contact - 600 V dc

Power Supply

Input voltage options	88 - 370 V dc, 85 - 264 V ac
	24 / 48 V dc optional
Power requirement	120 VA Max.
Backup batteries	Internal batteries for real-time clock and parameter memory
Cooling	Long life fans on rear panel & processor

Voltage Withstand

Isolation	2.5 kV RMS for 1 minute, Channel to channel, channel to ground. (per IEC 255-5)
	2.15 kV dc for PSU (Power Supply Unit)
Impulse voltage withstand	5 kV, 1.2/50 μs. 0.5 Joule
	(per IEC 255-5)
Surge withstand	2.5 kV, 1 MHz damped sine wave
	(per IEC 255-22-1; IEEE/ANSI C37.90.1-1989)
RFI	(per IEC 801 -3 & IEC 801-6 & IEEE/ANSI C37.90.2)
ESD	(per IEC 801-2)

Enclosure

Cabinet	Steel 19" rack mounting cabinet

Wall mount and portable options
8 & 16 channel units - 6U high
24 & 32 channel units- 8U high

Rack mount size   480 mm wide (including flanges)
                         267 mm high (6U)
                         356 mm high (8U)
                         350 mm deep (including handles)
                         6U – 18.9"W x 10.5"H x 13.8"D
                         8U – 18.9"W x 14.0"H x 13.8"D

Rack mount weight   13.7 Kg. (30.2 lbs) 16 channel
                         18.0 Kg. (39.7 lbs) 32 channel

Environment

Operating temperature   -10 to 55 °C
                                 14 to 131 °F

Relative humidity   10 - 97% non condensing

AMETEK reserve the right to change this specification without notice

Appendix II – Parameter calculations

Introduction

The Multi Function Recorder (TR-2100) is a very high performance monitoring instrument that can implement the functions of over 12 different systems concurrently. These can be configured and interrogated locally or remotely over a dial up modem or corporate WAN.

Inputs are connected to standard VT and CT secondaries as well as relay and switchgear auxiliary contacts. For the CT signals, an interposing shunt resistor, 'wedding ring' or clamp type CT can be used. Derived quantities (frequency, sequence components, power etc.) are computed internally and no external transducers are required. External transducers can be used for other, non derived, quantities such as temperature, pressure, generator rotor angle, etc.

Up to 32 analog inputs are synchronously sampled at regular intervals up to 195,000 samples per second, at 16 bits per sample. The sample clock is derived from a conditioned oscillator, which is phase locked to a 1 PPS signal from a GPS receiver. It is organized such that the TR-2100 will always take a sample at the exact second marker.

Conventions

The TR-2100 uses mostly fundamental calculations due to the differing techniques for computing derived quantities (especially power), and the lack of world wide accepted standards (such as parameters computed from the current and voltage vectors at the present system frequency). Therefore, power factor is actually displacement power factor (not true power factor) in most cases.

Reactive power into an inductive load (current lagging voltage) is treated as positive.

Exported real power (voltage and current in phase) is treated as positive.

Phase to neutral vectors are shown pointing outwards from the neutral point. Phase to phase vector Vab is shown pointing from a to b; i.e. It is the resultant vector of Vb - Va.

Three voltage or current channels can be defined as a phase group. These are listed in positive sequence order and the first channel is the reference phase. One voltage and one current phase group can be defined as a line group. These groups are used when defining the sources for sequence component, power & impedance calculations, etc.

Time Measurement

The TR-2100 uses the GPS navigation system as a source of absolute time. This generates UTC (universal co-ordinated time), which is the modern version of GMT (Greenwich Mean Time). This ensures that the time reference for each triggered event is accurate to better than 100 ns. A 1 pps (pulse per second) output from the receiver is used to synchronize a temperature compensated crystal. This in turn is used to derive the recorder's sampling clock. This means that all the TR-2100s in the world sample at exactly the same time to better than 50 ns. Not only is the acquisition engine phase-locked to the GPS, but it is arranged such that a sample is taken at the exact second marker. The outcome of this is that any phase information computed from this data is related to an exact point in time.

Frequency Measurement

The TR has two frequency channels that are calculated from two defined voltage channels. This allows split bus and generator synchronization to be recorded. The TR-2100 can be triggered by a frequency difference measurement.

The TR-2100 uses the zero crossing method for extracting frequency. The signal is first filtered with a recursive IIR filter to remove non 50 Hz or 60 Hz components. The exact position of each zero crossing is found using similar triangles to determine the sub sample position. Both positive and negative crossings are measured. The four period measurements over two cycles are averaged. The inverse is taken to yield the frequency. Any measurements that fall outside the fundamental frequency +/- 5 Hz are ignored.

Vector Measurement

The Cartesian vectors for every channel are generated twice per cycle. The angle is corrected for 180° inversion. This form can be converted into the polar notation for calculation of the derived parameters.

The data for one cycle are multiplied by sine and cosine tables to give the Cartesian co-ordinates. Since the sample clock is locked to the 1 PPS signal from the GPS receiver, the derived vector angle is related to absolute time. The reported angle is that at the left hand end of the data window. The amplitudes are divided by $\sqrt{2}$ to give the equivalent RMS value.

RMS Measurement

The true RMS value for every channel is generated twice per cycle. The data for one cycle are squared and summed. The square root is taken of this value divided by the number of samples per cycle. The number of samples per cycle will vary with the sample rate.

$$V_{rms} = \sqrt{\frac{\sum_{n=1}^{96} V_n^2}{96}}$$

Frequency Correction

Because the system frequency varies by small but finite amounts during normal operation, uncorrected RMS and vector measurements will have an error that is a function of frequency deviation. Since the TR-2100 measures the system frequency, it corrects for these errors.

For a frequency of 49.9 Hz the uncorrected errors are:

Amplitude error = 0.01%
Phase error = 0.7°

Calculation of Derived Parameters

A range of fundamental quantities may be computed from the fundamental voltage and current vectors.

Sequence components

$$3\bar{V}_{+1} = \bar{V}_a + a\,\bar{V}_b + a^2\bar{V}_c \qquad \text{Positive}$$

$$3\bar{V}_0 = \bar{V}_a + \bar{V}_b + \bar{V}_c \qquad \text{Zero}$$

$$3\bar{V}_{-1} = \bar{V}_a + a^2\bar{V}_b + a\,\bar{V}_c \qquad \text{Negative}$$

$\bar{V}_a$ represents the vector form of the a phase voltage

(operator **a** rotates the vector by 120°)

Power (fundamental)

Apparent

$$S_f = V_f * I_f$$

Real

$$P_f = V_f * I_f * Cos\Phi$$

Reactive

$$Q_f = V_f * I_f * Sin\Phi$$

For delta VTs real power is computed using the two wattmeter method.

Displacement power factor

$$PF = Cos\Phi$$

Impedance (fundamental)

$$Z_f = V_f / I_f$$

Imbalance

$$I_m = V_{-1} / V_{+1} * 100\% \qquad \text{(Ratio of NPS to PPS)}$$

Phasor Measurement

The TR-2100 acquisition system is organized so that a sample is taken at the second marker. The computed absolute phase angle from a Discrete Fourier Transform (DFT), using a 1 cycle window starting with this sample, will yield the angle of the vector at the exact second.

The synchrophasor output from the TR-2100 is compatible with IEEE 1344 - 1995. This defines the absolute angle of the positive sequence voltage vector relative to a time standard. A second of century time code is used to compare phase angles from different locations.

Harmonic Measurement

A single cycle window is used to calculate the harmonic content of voltages and currents. A standard Discrete Fourier Transform (DFT) technique is used to calculate the amplitude and angle of each component. A minimum of 4 samples per cycle is required to extract a harmonic component accurately. A number of samples are taken over the integrating interval (10 mins for EN50160) and averaged.

The maximum, minimum and average amplitude is stored every 10 minutes. The phase angles are also stored at the 10 minute boundary. Data for the fundamental and up to the 64th harmonic are recorded. THD, thd, TDD and K factor are computed on the host PC.

Flicker

Flicker is measured using the technique defined in IEC1000-4-15. This corrects some errors that were in the original standard IEC60868. The sub-synchronous spectrum is extracted and weighted using the defined curves. This instantaneous flicker value is recorded for 10 minutes and a statistical average is taken (as defined in the standard). This short term flicker value - Pst, is recorded in a separate long term log every 10 minutes.

Real Power

True power is computed by multiplying individual current and voltage samples and then averaging over one cycle. The actual number of samples per cycle will vary with the sample rate.

$$P = \frac{1}{96}\sum_{n=1}^{96}V_n * I_n$$

Real power for a circuit with a delta wound VT is derived using the two wattmeter method. This makes two power measurements using two of the line currents. It can be proved that the sum of the two powers is same as the total circuit power:

$$P = V_a I_a + V_b I_b + V_c I_c \quad \text{Total circuit power}$$

$$I_a + I_b + I_c = 0 \qquad \qquad \text{Currents sum to 0}$$

Substituting the second equation into the first and collecting terms yields:

$$P = \left(V_a - V_b\right)I_a + \left(V_c - V_b\right)I_c$$

The total circuit power can be measured using two wattmeters on the phase-to-phase voltages. Note that the phasing of the VTs is important.

Apparent Power

Apparent power is computed from the RMS voltage and current.

$$S = V_{rms} * I_{rms}$$

Reactive Power

Reactive power is derived from the apparent and real powers.

$$Q = \sqrt{\left\langle S^2 - P^2 \right\rangle}$$

Power Factor

True power factor is the ratio of real to apparent power.

$$PF_{True} = \frac{P}{S}$$

Total Harmonic Distortion (THD)

The THD for an input is derived from the RMS and vector magnitude (V)

$$\%THD = \frac{\sqrt{RMS^2 - V^2}}{V} x100$$

This is the IEEE form of THD. In DSA32, the calculation of THD can be selected from either the IEEE or ANSI standard. Refer to the DSA help file for a complete explanation of the differences.

Appendix III – DNP Protocol

Introduction

Distributed Network Protocol (DNP Version 3.0) is an industry standard specification for SCADA communications between Master Stations, Host computers, Remote Terminal Units, and Intelligent Electronics Devices (such as the TR-2100 Transient Recorder). It is a public domain, non-proprietary protocol based on the IEC-870 standards, and is intended primarily for use in SCADA-like systems.

DNP as a protocol provides efficient, robust data communications through a system of data link CRCs (Cyclical Redundancy Checks) and confirmation messages. However, DNP is much more than an error-detection-and-correction scheme. A DNP-compliant device, from the protocol's point of view, is considered a group of data "objects", each of which contains one or more "points". The DNP protocol specification defines the allowable object types and what constitutes a "point" for that object type.

DNP is *not* intended to be a general-purpose two-way communications link. Rather, it is highly optimized for SCADA and automation applications involving relatively small amounts of near-real-time data that is often read by the DNP master once every several seconds. In the case of the TR-2100, it is *not* used as a means of controlling or reconfiguring the recorder.

The TR-2100 is able to communicate with Remote Terminal Units (RTUs) using the Distributed Network Protocol (DNP). The available functions defined in V3.0 include reading of:

1. Instantaneous RMS voltage or current levels of the Analogue Inputs
2. Analogue profile values; four points per analogue channel
3. Digital contact inputs; alarm or normal state
4. Recorder status events

The level of DNP support, data formats and data object types are contained in the Device Profile Document. The interface uses the serial port at the rear of the recorder. This assumes that an internal modem is installed in the recorder. Baud rates of 300 to 19,200 are supported.

Note that the DNP refresh rate of the TR-2100 is 5 seconds. This means that the status of a DNP point may not change for up to 5 seconds after its real-time occurrence. The DNP Master should be instructed to read DNP data from the TR-2100 at a proportionate rate.

DNP Data Objects

The DNP format divides data into several types of information called "Objects". The specific information elements are uniquely identified by their *object point number*. This may be thought of as the index into an array of objects. As well as being identified as a particular *object* number, the data is identified as being a particular *variation*. The variation identifies the type of data, e.g. 16-bit analogue input or 32-bit analogue input, etc. The application can choose to read a particular point as any variation it chooses. For the TR-2100, we are primarily interested only in Object 30, Variation 04 (Analogue Inputs, 16-Bit, Signed without flag), and Object 01, Variation 01 (Digital Status Values, Single bit binary input).

The data returned from the recorder is located as follows:

5. Digital Status values   Object 01   indices 101-103 inclusive
6. Digital Input Status   Object 01   indices 1-160 inclusive
7. Analogue Voltage values Object 30   indices 1-32 inclusive
8. Analogue Profile values   Object 30   indices 110-429 inclusive

The Digital Status values signify three Status types:

1. Recorder faulty – this is set for any alarm condition other than "Disk nearly full". The conditions are watchdog, modem, printer, time sync, Real Time Clock battery, memory, GPS fault, disk memory, disk not useable, and comms fault.
2. Disk nearly full – the disk is 85% full
3. New event – indicating a new record is available

The Analogue Voltage values (Object 30) are indexed 1 through 32, corresponding with the TR-2100 Analogue Input channels 1 through 32.

The Analogue Profile values are arranged in groups of ten per channel, thus:

9. 110-119   profile data for Analogue Input channel 1
10. 120-129   profile data for Analogue Input channel 2
    through ...
11. 420-429   profile data for Analogue Input channel 32

For each analogue channel, the ten data values indicate:

xx0	Pre-fault
xx1	Immediate
xx2	Final
xx3	Post-clearance
xx5-xx9	Not used

DNP v3.00 Device Profile Document

The purpose of this document is to describe the specific implementation of the **D**istributed **N**etwork **P**rotocol (DNP) 3.0 within the TR-2100 Transient Recorder. This document, in conjunction with the DNP 3.0 Basic 4 Document Set, and the DNP Subset Definitions Document, provides complete information on how to communicate with the TR-2100 via the DNP 3.0 protocol.

The TR-2100 uses the Triangle MicroWorks™, Inc. DNP 3.0 Slave Source Code Library Version 2.19. This implementation of DNP 3.0 is fully compliant with DNP 3.0 Subset Definition Level 1.

The following sections, in conjunction with the Device Profile Document, provide a complete interoperability/configuration guide for the TR-2100:
- The Implementation Table
- The Point List Tables
- Configuration methods

DNP V3.00

DEVICE PROFILE DOCUMENT

Vendor Name:	**AMETEK Power Instruments**
Device Name:	**TR-2100 Digital Transient Recorder, using the Triangle MicroWorks, Inc. DNP 3.0 Slave Source Code Library, Ver 2.19**

Highest DNP Level Supported:	Function:
For Requests: **Level 1**	☐ Master
For Responses: **Level 1**	☒ **Slave**

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

For static (non-change-event) object requests, request qualifier code 06 (no range – or all points) is supported.

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted: **292**	Transmitted: **2048**
Received **292**	Received: **2048**

um Data Link Re-tries:	Maximum Application Layer Re-tries:
urable from 0 to 255 via Display Station32	**None**

es Data Link Layer Confirmation:
urable as: Never, Only for multi-frame messages, or Always via DS32

es Application Layer Confirmation:
sending multi-fragment responses
mes

DNP V3.00

DEVICE PROFILE DOCUMENT

Timeouts while waiting for:

Data Link Confirm:	**Configurable via DS32**
Complete Appl. Fragment:	**None**
Application Confirm:	**Configurable via DS32**
Complete Appl. Response:	**None**

Others:

Transmission Delay:	**Configurable, via DS32**
Inter-character Timeout:	**1 sec.**
Need Time Delay:	**Configurable, via DS32**
Frozen Counter Event scanning period:	**FIXED AT 5 seconds**

Sends/Executes Control Operations:

WRITE Binary Outputs	**Never**
SELECT/OPERATE	**Never**
DIRECT OPERATE	**Never**
DIRECT OPERATE – NO ACK	**Never**
Count > 1	**Never**
Pulse On	**Never**
Pulse Off	**Never**
Latch On	**Never**
Latch Off	**Never**
Queue	**Never**
Clear Queue	**Never**

Reports Binary Input Change Events when no specific variation requested: **Never**	Reports time-tagged Binary Input Change Events when no specific variation requested: **Never**
Unsolicited Responses: **Never**	Static Data in Unsolicited Responses: er options are permitted.
Counter Object/Variation: **Default Object:** 30 t **Variation:** 4 by-point list attached	rs Roll Over at: **Value: 999,999,999** by-point list attached
Multi-Fragment Responses:	

The TR-2100 Implementation

The TR-2100 DNP implementation conforms to the standard for a Level 1 slave device. Implementation consists of the following **static** objects:

- (3) Single-bit Binary Input without flag (Object 01 Variation 01)
- (32) 16-bit Analogue Voltage values without flag points (Object 30 Variation 4)
- (128) 16-bit Analogue Profile values without flag points (Object 30 Variation 4)

IMPLEMENTATION TABLE

The following table identifies the variations, function codes, and qualifiers supported by the TR-2100 in both request messages and in response messages.

For static (non-change-event) objects, request qualifier code 06 (no range – or all points) is supported.

OBJECT			REQUEST (Library will parse)	RESPONSE (Library will respond with)	
Object Number	Variation Number	Description	Function Codes (decimal)	Function Codes (decimal)	Qualifier Codes (hex)
1	1	Binary Input	1 (read)	129 (response)	00, 01 (start-stop)
30	4	16-Bit Analog Input without Flag	(read)	--	--

Point List

The following tables identify all the individual data points provided by the implementation of DNP 3.0 in the TR-2100.

Digital Inputs

The Digital input points (Object 1) represent such things as:
- Recorder faulty – see previous definition of faults
- Disk nearly full (over 85% full)
- New event – indicates a new record is available
- Contact input alarm/normal status (alarm=1, normal=0)

Point Index	Binary Input Name/Description
101	Record Faulty
102	Disk nearly full
103	New event available
001	Contact Input 1 status
002	Contact Input 2 status
003	Contact Input 3 status
004	Contact Input 4 status
	Through
063	Contact Input 63 status
064	Contact Input 64 status

Analogue Inputs

Analogue Inputs are implemented as Object 30 Var 4 (16-bit analogue input without flag) points. A total of 160 points are implemented, which represent:

- Analogue Voltage values, 1 per analogue channel
- Analogue Profile values, 4 per analogue channel (Pre-fault, Immediate, Final, Post-Clearance)

The Analogue Voltage and the Analogue Profile points use different formulae to calculate actual engineering units.

Analogue Voltage Point Indices

The 32 Analogue Voltage inputs (Point Indices 1 through 32) are scaled so that 32,768 bits represent the recorder's full-scale input value. To convert the DNP output to actual engineering units, use the following formula.

$$\text{Actual Primary Units} = DNP\,raw\,value \quad x \quad \frac{(FSDx\sqrt{2})}{32768}$$

Where:

- **DNP raw value** is the number output from the DNP port
- **FSD** is the full scale primary RMS value (voltage or current)

Example:

The raw value read from Analogue Channel 1 is 19640, and your FSD is 345 kV. Multiply 345000 by square root 2 to obtain the peak voltage, then divide by 32768 bits to obtain Units Per Bit. Multiply the Units Per Bit by 19640 to obtain the actual primary voltage reading.

$$\frac{345000x\sqrt{2}}{32768}x19640 = 292432.47volts$$
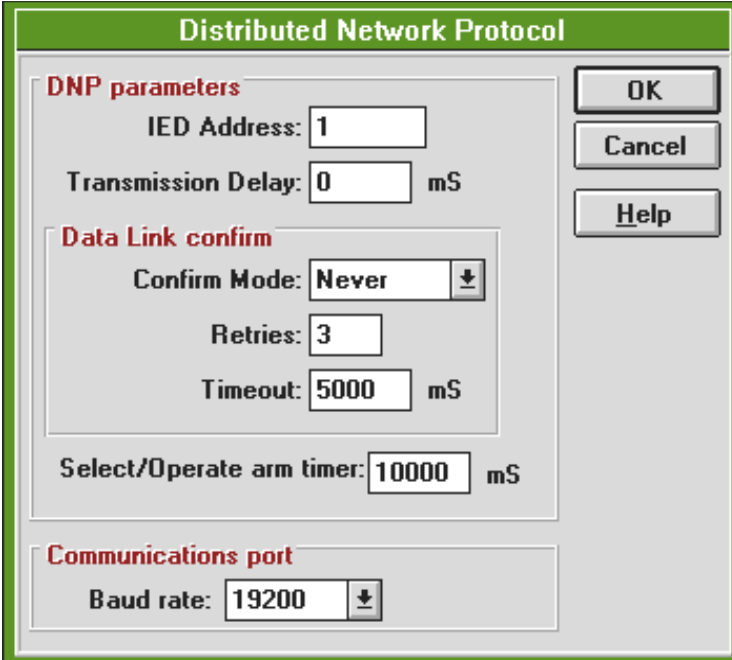
Analogue Profile Point Indices

The Analogue Profile points (Point Indices 110 through 429) are scaled so that 16,384 bits represent the full-scale value. To convert the DNP output to actual engineering units, use the following formula.

$$\text{Actual Primary Units} = DNP\,raw\,value \quad x \quad \frac{FSD}{16384}$$

Point Index	Analog Input Name/Description	Point Index	Analog Input Name/Description	Point Index	Analog Input Name/Description
1	Analog Channel 1	162	Channel 6 Final	300	Channel 20 Pre-fault
2	Analog Channel 2	163	Channel 6 Post-Clearance	301	Channel 20 Immediate
3	Analog Channel 3	170	Channel 7 Pre-fault	302	Channel 20 Final
4	Analog Channel 4	171	Channel 7 Immediate	303	Channel 20 Post-Clearance
5	Analog Channel 5	172	Channel 7 Final	310	Channel 21 Pre-fault
6	Analog Channel 6	173	Channel 7 Post-Clearance	311	Channel 21 Immediate
7	Analog Channel 7	180	Channel 8 Pre-fault	312	Channel 21 Final
8	Analog Channel 8	181	Channel 8 Immediate	313	Channel 21 Post-Clearance
9	Analog Channel 9	182	Channel 8 Final	320	Channel 22 Pre-fault
10	Analog Channel 10	183	Channel 8 Post-Clearance	321	Channel 22 Immediate
11	Analog Channel 11	190	Channel 9 Pre-fault	322	Channel 22 Final
12	Analog Channel 12	191	Channel 9 Immediate	323	Channel 22 Post-Clearance
13	Analog Channel 13	192	Channel 9 Final	330	Channel 23 Pre-fault
14	Analog Channel 14	193	Channel 9 Post-Clearance	331	Channel 23 Immediate
15	Analog Channel 15	200	Channel 10 Pre-fault	332	Channel 23 Final
16	Analog Channel 16	201	Channel 10 Immediate	333	Channel 23 Post-Clearance
17	Analog Channel 17	202	Channel 10 Final	340	Channel 24 Pre-fault
18	Analog Channel 18	203	Channel 10 Post-Clearance	341	Channel 24 Immediate
19	Analog Channel 19	210	Channel 11 Pre-fault	342	Channel 24 Final
20	Analog Channel 20	211	Channel 11 Immediate	343	Channel 24 Post-Clearance
21	Analog Channel 21	212	Channel 11 Final	350	Channel 25 Pre-fault
22	Analog Channel 22	213	Channel 11 Post-Clearance	351	Channel 25 Immediate
23	Analog Channel 23	220	Channel 12 Pre-fault	352	Channel 25 Final
24	Analog Channel 24	221	Channel 12 Immediate	353	Channel 25 Post-Clearance
25	Analog Channel 25	222	Channel 12 Final	360	Channel 26 Pre-fault
26	Analog Channel 26	223	Channel 12 Post-Clearance	361	Channel 26 Immediate
27	Analog Channel 27	230	Channel 13 Pre-fault	362	Channel 26 Final
28	Analog Channel 28	231	Channel 13 Immediate	363	Channel 26 Post-Clearance
29	Analog Channel 29	232	Channel 13 Final	370	Channel 27 Pre-fault
30	Analog Channel 30	233	Channel 13 Post-Clearance	371	Channel 27 Immediate
31	Analog Channel 31	240	Channel 14 Pre-fault	372	Channel 27 Final
32	Analog Channel 32	241	Channel 14 Immediate	373	Channel 27 Post-Clearance
110	Channel 1 Pre-fault	242	Channel 14 Final	380	Channel 28 Pre-fault
111	Channel 1 Immediate	243	Channel 14 Post-Clearance	381	Channel 28 Immediate
112	Channel 1 Final	250	Channel 15 Pre-fault	382	Channel 28 Final
113	Channel 1 Post-Clearance	251	Channel 15 Immediate	383	Channel 28 Post-Clearance
120	Channel 2 Pre-fault	252	Channel 15 Final	390	Channel 29 Pre-fault
121	Channel 2 Immediate	253	Channel 15 Post-Clearance	391	Channel 29 Immediate
122	Channel 2 Final	260	Channel 16 Pre-fault	392	Channel 29 Final
123	Channel 2 Post-Clearance	261	Channel 16 Immediate	393	Channel 29 Post-Clearance
130	Channel 3 Pre-fault	262	Channel 16 Final	400	Channel 30 Pre-fault
131	Channel 3 Immediate	263	Channel 16 Post-Clearance	401	Channel 30 Immediate
132	Channel 3 Final	270	Channel 17 Pre-fault	402	Channel 30 Final
133	Channel 3 Post-Clearance	271	Channel 17 Immediate	403	Channel 30 Post-Clearance
140	Channel 4 Pre-fault	272	Channel 17 Final	410	Channel 31 Pre-fault
141	Channel 4 Immediate	273	Channel 17 Post-Clearance	411	Channel 31 Immediate
142	Channel 4 Final	280	Channel 18 Pre-fault	412	Channel 31 Final
143	Channel 4 Post-Clearance	281	Channel 18 Immediate	413	Channel 31 Post-Clearance
150	Channel 5 Pre-fault	282	Channel 18 Final	420	Channel 32 Pre-fault
151	Channel 5 Immediate	283	Channel 18 Post-Clearance	421	Channel 32 Immediate
152	Channel 5 Final	290	Channel 19 Pre-fault	422	Channel 32 Final
153	Channel 5 Post-Clearance	291	Channel 19 Immediate	423	Channel 32 Post-Clearance
160	Channel 6 Pre-fault	292	Channel 19 Final		
161	Channel 6 Immediate	293	Channel 19 Post-Clearance		

DNP Configuration

To set the DNP communications format, open the *Display Station32* Communications software, select 'Configuration' in the 'Recorder' menu, and then click on 'DNP Parameters'. The following setup screen will appear.

Note: Since the present implementation of DNP is on an RS232 link, some of the parameters are not used.

The IED address
This can be set from 1 to 65534. Number 65535 is reserved for the broadcast address.

Transmission delay
This is the time to disable the Master transmitter on an RS485 network and is not currently used.

Confirm Mode
This can be set as Never/Sometimes/Always. The default value is Never.

Retries
This is the number of times that a Data Link will attempt to be established. Valid numbers are 0 - 255. 0 disables retries.

Timeout
This is the time the IED will wait for a Data Link confirmation. Valid numbers are 0 -
65535.

Select/Operate arm timer
This is the time period after the select command is received when the operate command will
be performed. Valid values are 0 - 65535 ms. This is not currently used.

Baud rate
This is the speed of the DNP serial port. Values from 300 - 19200 baud can be set. In most
cases, this is the only parameter that will need to be set up.

IMPORTANT Notes Relative to DNP Usage

1. Only the most recent channel data is available at the DNP port. If a channel
   triggers multiple times (before being read by DNP), only the last one is
   retrievable with DNP.
2. Once data is read via Display Station software, the event log is cleared and the
   data will not be available at the DNP port. This applies to "New Event" and
   "Recorder Faulty" status bits also. The event could still be active, but will not
   appear at the DNP port once the event log is cleared.

Appendix IV – Troubleshooting

The first indication that a TR-2100 is not functioning correctly is normally that it will not make a remote connection. Before going on site, it is worth checking the phone line by ringing the TR-2100's number and listening for the phone to be answered by the modem, followed by a series of tones. If these are heard, then the phone line and modem are OK and there is power to the TR-2100. If a data switch or DTMF switch is being used, then the phone may be answered but no tones will be heard.

If this is successful, contact the TR-2100 using a terminal package such as Hyperterminal™ in Windows™. After the modem has issued a 'CONNECT' message, press <Enter> 3 or 4 times. The TR-2100 should return with a list of configuration parameters. If this is successful, the fault may be with the Comms Manager set up of Display Station. To disconnect from the TR-2100 using a terminal, type "quit" then press <Enter>.

Off-Site Checks

Problem: Modem doesn't answer.
Things to check: Correct phone number?
                              Telecom wiring at substation?
                              If a data switch is used is it powered up?
                              Is TR-2100 powered up? (see below)
                              Is initialization string at TR-2100 correct? (S0=1)

Problem: Modem answers but is unable to communicate with TR-2100.
     Things to check: Are initialization strings at Display Station & TR-2100
                                   correct?
                              Is TR-2100 active? (see below)

Recommended initialization string for Pace modems:

             AT&F^M~~~~ATS0=1^M

Recommended initialisation string for US Robotics modems:

             AT&F1^M~~~~ATS0=1&G2&W^M

All Hayes compatible commands must begin with 'AT'. The ^M symbols are interpreted as if the <Enter> key has been pressed. The ~ symbol is interpreted as a short delay.

On-Site Checks

Start with test 1). Follow the test numbers depending on the result of each test. After a change is made start with test 1) again.

1)   Is the green 'Power' light on?   Yes 2) No 5)

2)   Press the 'Test' button for 1 second. Does the buzzer sound and the yellow 'Data available' light come on after a number of seconds?   Yes 3) No 4)

The TR-2100 is working correctly. The fault is with the modem, data switch or phone line.

3)   Is the internal modem board seated correctly? (This is the short board near the bottom of the unit with the grey phone connection.)
                                                                                          Yes 8) No 11)

4)   Is the red light on the processor board on. (This is the board at the centre of the TR-2100)   Yes 7) No 11)

5)   Is the power switch on? This is the toggle switch found at the bottom right of the bottom tray behind the front panel.   Yes 10) No 6)

6)   Switch system on   1)

7)   Restart the TR-2100 by switching off the supply waiting a few seconds then switching it on again. The processor should 'beep' several times as it checks its memory. After this there is short delay then the 'On line' light will be illuminated. The red 'Attention' light will also come on which is normal. This may be cleared by pressing the 'Test' button. This, in turn, will cause the 'Data available' light to be illuminated since a test record has been generated. Did this work correctly?   Yes 8) No 14)

8)   Ring the person with Display Station and ask them to contact the TR-2100. The phone should ring once then the modem should answer. If line share device is being used then an 'M' should be displayed on its front panel. The modem will respond with a number of tones followed by a 'hash' sound (like an AM radio not tuned to a station). This should end and a few seconds later the TR-2100 'Communications' light will come on. This indicates a valid connection. Was the connection completed?   Yes 20) No 13)

9)   Connect a laptop computer running Display Station to the front of the TR-2100. Check the 'Comms Manager' settings. The port should be COM1 or COM2 and the speed should be 9600, 19200, 34800 or 57600. The actual values will depend on the computer in use and the speed set on the internal DIP switches in the TR-2100. Make a 'Direct' connection. Is the connection successful?   Yes 3) No 15)

10)   There is no power to the TR-2100. Check the incoming supply and the fuse at the rear of the unit. There is also a fuse inside the power supply which is at the left rear of the bottom tray. Was everything correct?   Yes12)No 16)

11)   Check that all the boards on the processor tray are seated correctly and all the ribbon cables are in place. If boards need to be re-seated switch the system off first.   7)

12)   There is a fault in the power supply or supply wiring. Replace and re-test.   1)

13)   If the modem did not answer, the fault may be with the initialization string (see above). If this is correct there is a fault with the modem. Replace it and re-test.   1)

14)   There is a fault with the processor board. Replace it and re-test.   1)

15)   There is a fault with the wiring to the front port. Check that the ribbon cable is plugged into the processor board.   1)

16)   Replace fuse, etc. and re-test.   1)

20)   The TR-2100 is OK.

Check for Intermittent Resetting

Measure the +5 volt supply on the acquisition board with a multimeter. The acquisition board is the top one in the bottom tray. The test points are at the extreme left hand side of the board. The +5 volt point is to the back of the board and ground is to the front. The value should be 5.0 +/- 0.1 volts.

If the voltage is low the fault may be with the power supply, connectors or wiring.

Appendix V – System Drawings

PROPRIETARY

16.90 [429.26MM]
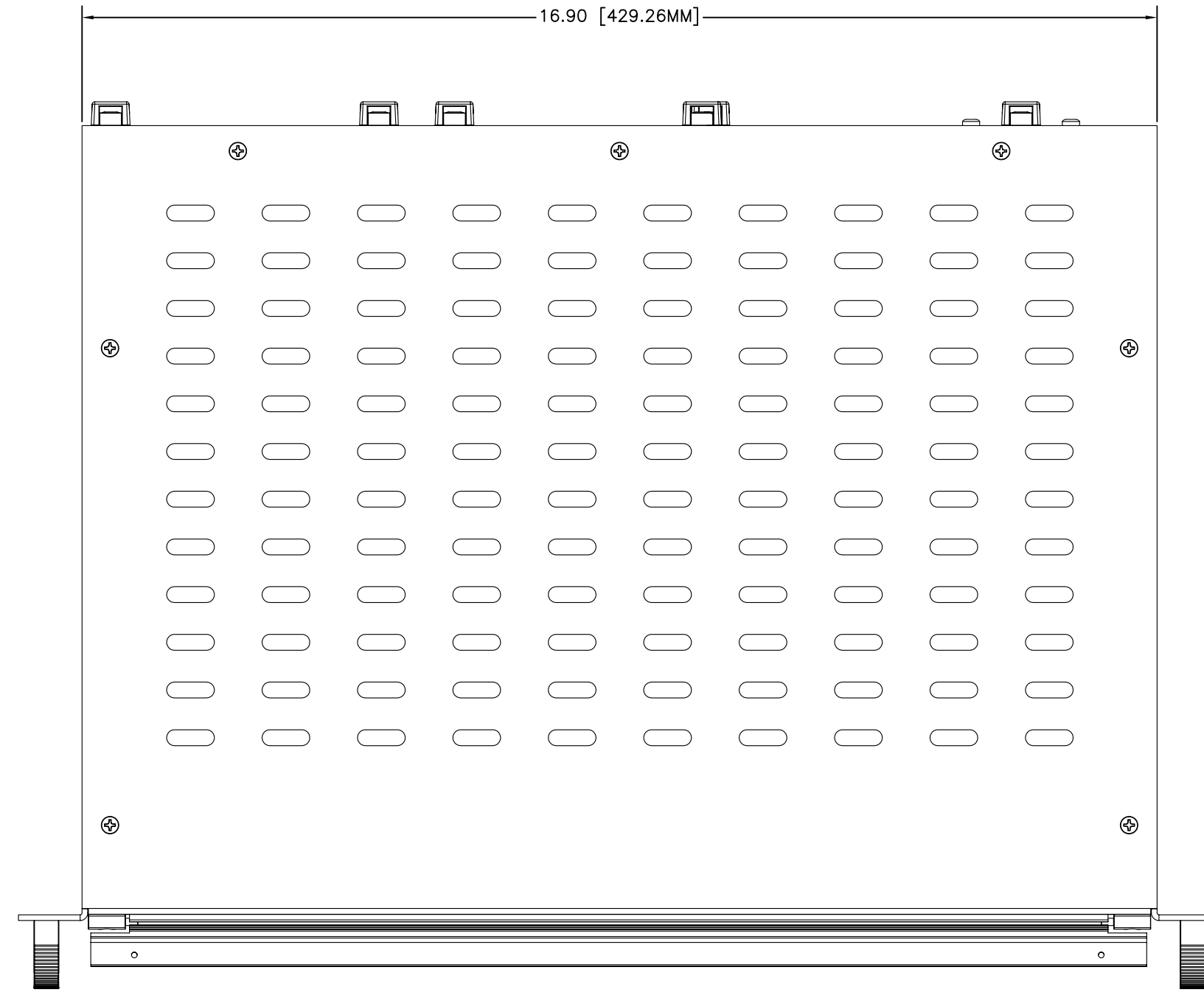
NOTES:
1. TRANSIENT RECORDER DIMENSIONS WILL VARY DEPENDING ON OPTIONS CHOSEN. SEE CHART FOR CHASSIS SIZES.
2. FOR REAR PANEL CONNECTIONS, SEE PAGE 2 & 3.
3. FOR MODEL CODES AND DESCRIPTIONS SEE PAGE 4.

TR MODEL	DIMENSION					ANALOG CHANNELS	DIGITAL CHANNELS
	U–SIZE	(A)	(B)	(C)	(D)		
TR-2108	6	10.47 [265.9mm]	1.75 [44.5mm]	5.75 [146.1mm]	1.57 [39.8mm]	8	16
TR-2108E	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	8	16
TR-2108-D1	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	8	48
TR-2108-D2	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	8	80
TR-2108-D3	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	8	112
TR-2108-D4	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	8	144
TR-2116	6	10.47 [265.9mm]	1.75 [44.5mm]	5.75 [146.1mm]	1.57 [39.8mm]	16	32
TR-2116E	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	16	32
TR-2116-D1	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	16	64
TR-2116-D2	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	16	96
TR-2116-D3	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	16	128
TR-2116-D4	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	16	160
TR-2124	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	24	48
TR-2124E	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	24	48
TR-2124-D1	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	24	80
TR-2124-D2	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	24	112
TR-2132	8	13.97 [354.8mm]	1.75 [44.5mm]	9.25 [234.9mm]	1.48 [37.6mm]	32	64
TR-2132E	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	32	64
TR-2132-D1	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	32	96
TR-2132-D2	9	15.72 [399.2mm]	1.75 [44.5mm]	11.0 [279.4mm]	1.48 [37.6mm]	32	128
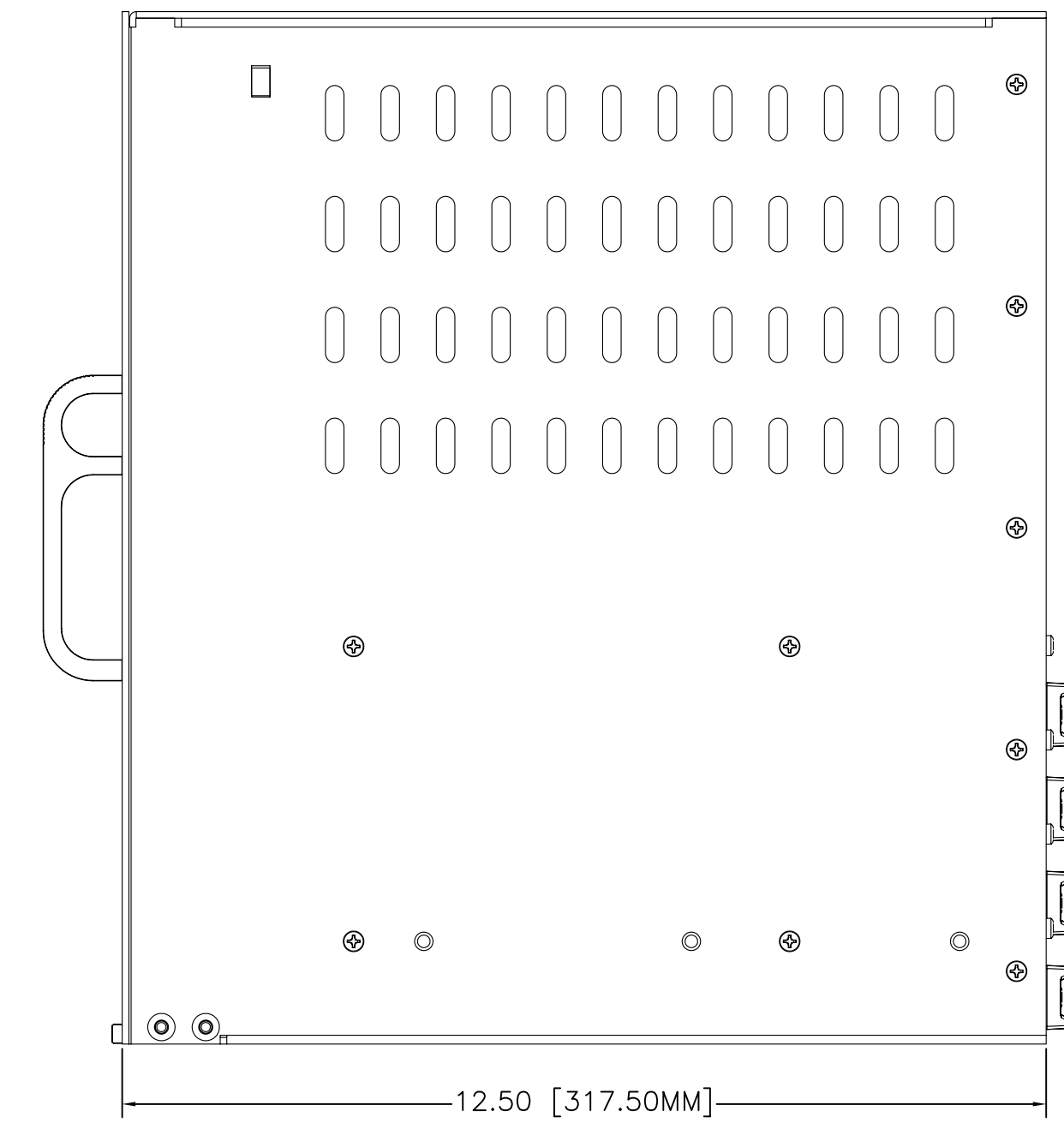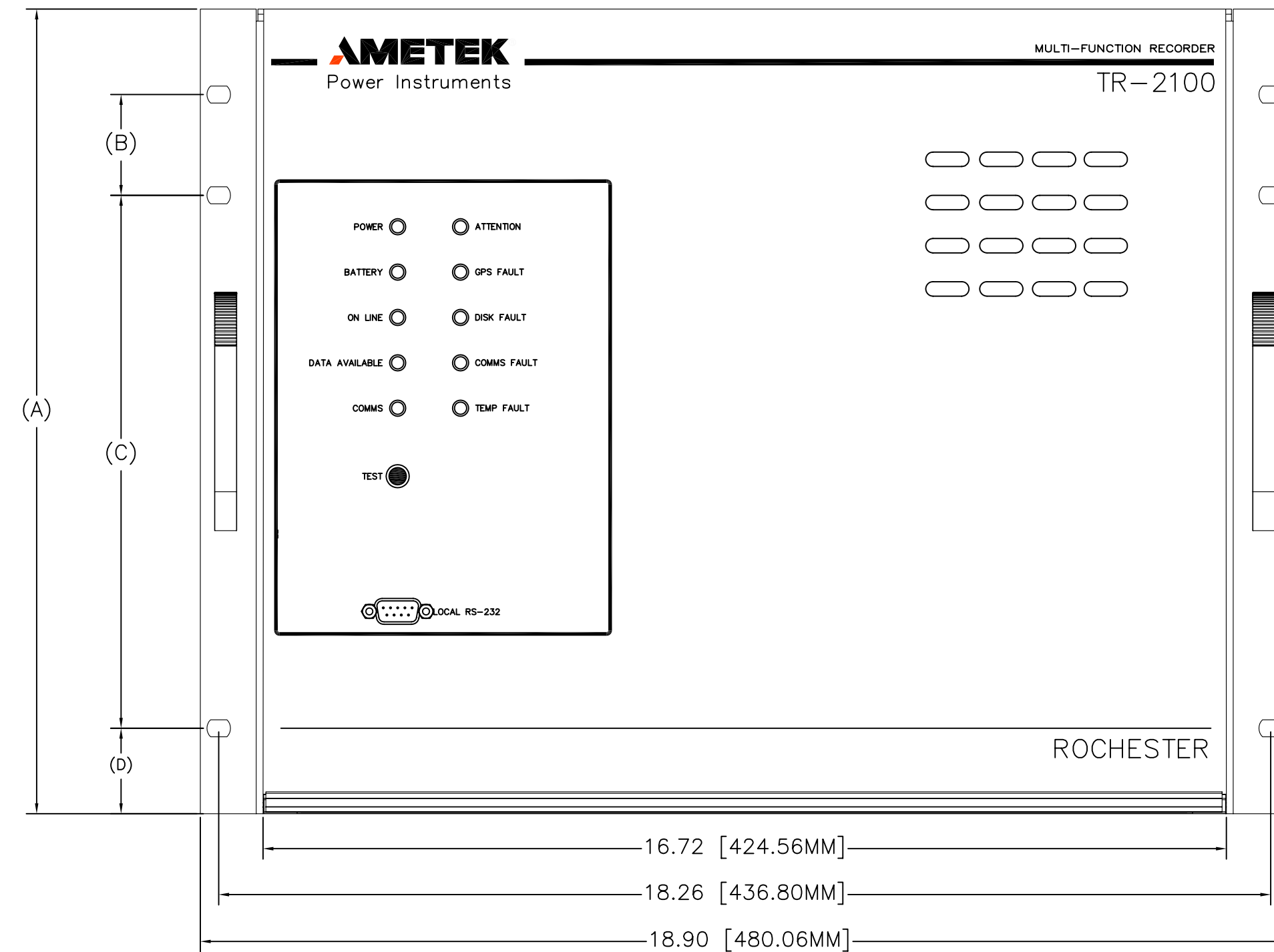
EXPANDABLE OPTION

ORIGINAL	MAY BE EXPANDED TO:				
TR-2108E	TR-2116	TR-2124	TR-2132	X	X
TR-2116E	X	TR-2124	TR-2132	X	X
TR-2124E	X	X	TR-2132	TR-2132-D1	TR-2132-D2
TR-2132E	X	X	X	TR-2132-D1	TR-2132-D2

OTHER EXPANDABLE OPTIONS FOR EXPANDED DIGITIALS REQUIRING REAR PANEL CHANGES ARE AVAILABLE CONSULT FACTORY FOR ADDITIONAL INFORMATION.

AMETEK
Power Instruments
MULTI-FUNCTION RECORDER
TR-2100

POWER
BATTERY
ON LINE
DATA AVAILABLE
COMMS

ATTENTION
GPS FAULT
DISK FAULT
COMMS FAULT
TEMP FAULT

TEST

LOCAL RS-232

ROCHESTER

(B)
(A)
(C)
(D)

16.72 [424.56MM]
18.26 [436.80MM]
18.90 [480.06MM]

12.50 [317.50MM]

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
[] ARE IN MILLIMETERS
TOLERANCES ON:
2 PL DECIMALS ± 0.02
3 PL DECIMALS ± 0.005
ANGLES ± 1°

	SIGNATURES	DATE
DRAWN	BAM	4/26/07
CHECK		

THIRD ANGLE PROJECTION

MATERIAL

FINISH

CAGE CODE 32582

SOFTWARE: 2005
AUTOCAD VER.

REV	DESCRIPTION	DATE	APPROVAL
A	NEW RELEASE		

REVISIONS

AMETEK
Power Instruments
255 North Union Street, Rochester NY 14605 USA

TITLE
TR-2100 DETAIL DRAWING
UNIT SIZES

TR

ROCHESTER SCIENTIFIC COLUMBUS

SIZE D   DWG NO 1086-940   REV A

SCALE NONE   FILE NAME 1086-940.dwg   SHEET 1 OF 4

TR-2100 REAR VIEW

(TR-2116-D2 SHOWN FOR REFERENCE)

PROPRIETARY
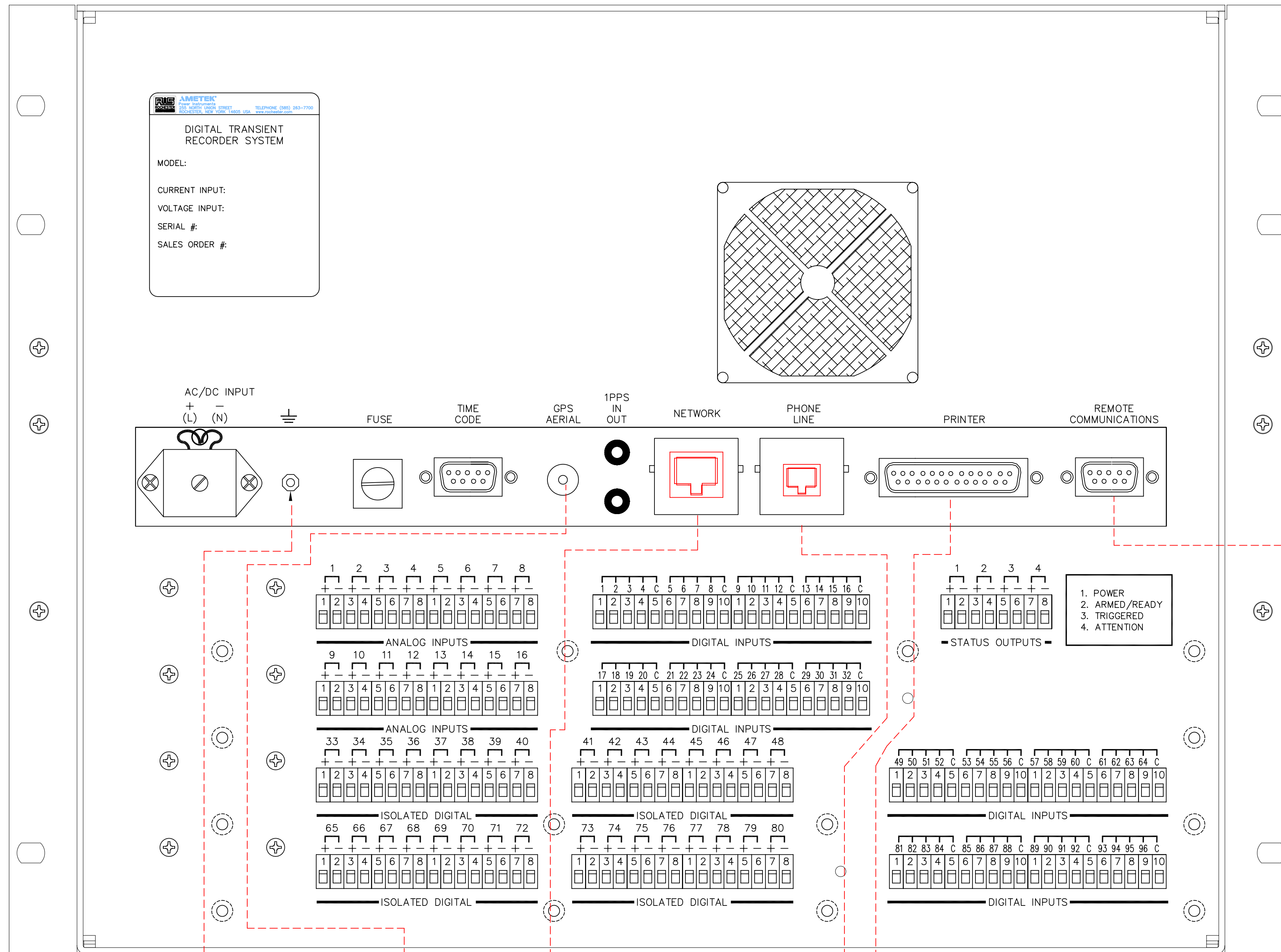
DIGITAL TRANSIENT RECORDER SYSTEM

MODEL:
CURRENT INPUT:
VOLTAGE INPUT:
SERIAL #:
SALES ORDER #:

AC/DC INPUT
+ −
(L) (N)

FUSE

TIME CODE
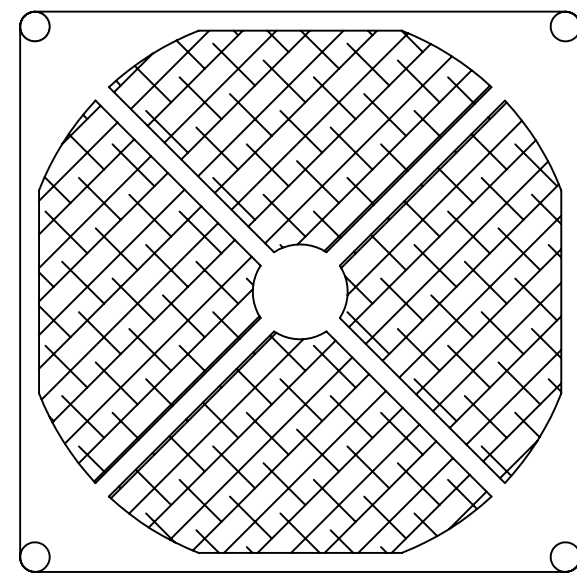
GPS AERIAL

1PPS IN OUT

NETWORK

PHONE LINE

PRINTER

REMOTE COMMUNICATIONS

1 2 3 4 5 6 7 8
ANALOG INPUTS

9 10 11 12 13 14 15 16
ANALOG INPUTS

33 34 35 36 37 38 39 40
ISOLATED DIGITAL

65 66 67 68 69 70 71 72
ISOLATED DIGITAL

1 2 3 4 5 6 7 8 C 9 10 11 12 13 14 15 16 C
DIGITAL INPUTS

17 18 19 20 C 21 22 23 24 C 25 26 27 28 C 29 30 31 32 C
DIGITAL INPUTS

41 42 43 44 45 46 47 48
ISOLATED DIGITAL

73 74 75 76 77 78 79 80
ISOLATED DIGITAL

1 2 3 4
1 2 3 4 5 6 7 8
STATUS OUTPUTS

1. POWER
2. ARMED/READY
3. TRIGGERED
4. ATTENTION

49 50 51 52 C 53 54 55 56 C 57 58 59 60 C 61 62 63 64 C
DIGITAL INPUTS

81 82 83 84 C 85 86 87 88 C 89 90 91 92 C 93 94 95 96 C
DIGITAL INPUTS

AMETEK RECOMMENDS THE USE OF A
HIGH FREQUENCY GROUND BRAIDED WIRE
FOR CONNECTION TO SUBSTATION GROUND

EITHER AMETEK SUPPLIED GPS ANTENNA
OR IRIG-B INPUT
(REFER TO MODEL #, SHEET 4)

TO CUSTOMER SUPPLIED NETWORK
(REFER TO MODEL #, SHEET 4)

SEE NOTE 5 FOR EXTERNAL MODEM OPTION.
SEE NOTE 7 FOR ADDED COMMUNICATIONS OPTION.

TO LOCAL PRINTER
THE FACTORY DEFAULT SET UP IS "OFF" (DISABLED).

TO TELEPHONE LINE
(REFER TO MODEL #, SHEET 4)

INSTALLATION NOTES:

1. CUSTOMER WIRING SHOWN DASHED
AMETEK FACTORY WIRING SHOWN SOLID

2. FIELD CONTACT VOLTAGE IS SUPPLIED BY CUSTOMER.
(FOR PROPER FCV REFER TO MODEL #, SHEET 3).

SERVICE NOTES:

1. FOR ANALOG CHANNEL ASSIGNMENTS REFER TO SERIAL TAG LOCATED AT THE
REAR SIDE OF THE TR-2100.
TO CHANGE A CHANNEL FROM CURRENT TO VOLTAGE OR VOLTAGE TO CURRENT
CHANGE THE JUMPER ON THE INPUT MODULE AND RE-CALIBRATE THE MODULE.
(REFER TO TR-2100 INSTRUCTION MANUAL)

2. STATUS VISUAL INDICATORS ARE ON THE FRONT PANEL. CONTACT OUTPUTS
FOR POWER ON, ARMED/READY, ATTENTION AND TRIGGERED ARE AVAILABLE
AT THE REAR OF THE TR-2100 CHASSIS. THE RELAYS ARE RATED 1.0A AC/DC,
280VAC/400VDC MAXIMUM VALUES.

3. POWER WIRING AND INPUT WIRING SHOULD BE ROUTED SEPARATELY FOR
NOISE IMMUNITY. CONTACT INPUTS SHOULD ALSO BE ROUTED SEPARATELY.

4. DIGITAL CHANNEL 15 IS USED TO CROSS-TRIGGER MULTIPLE RECORDERS.
THE STATUS RELAY "TRIGGERED" OUTPUT IS WETTED AND FED INTO
THE DIGITAL CHANNEL 15. THERE IS A HARDWARE SWITCH WHICH IS SET
TO CONFIGURE THE CHANNEL AS A CROSS TRIGGER CHANNEL.

5. WHEN AN INTERNAL MODEM IS USED, SWITCH 2 POSITION 5 ON ACQUISITION
CARD IS SET "ON", AND REMOTE COMMUNICATIONS PORT IS USED FOR ADDED
COMMUNICATIONS OPTIONS (Q1 & Q2, REFER TO NOTE 7).
WHEN AN EXTERNAL MODEM IS USED, SWITCH 2 POSITION 5 ON ACQUISITION
CARD IS SET "ON", AND REMOTE COMMUNICATIONS PORT IS USED FOR
COMMUNICATION TO AN EXTERNAL MODEM.
WHEN SWITCH 2 POSITION 5 IS IN THE "OFF" POSITION, REMOTE
COMMUNICATIONS PORT CAN BE USED FOR DIRECT COMMUNICATION TO A PC.

6. WHEN THE POWER IS APPLIED TO THE TR-2100 THEN UNDER NORMAL CONDITIONS:
POWER & ON LINE RELAYS ARE ENERGIZED (NORMALLY CLOSED).
TRIGGERED & ATTENTION RELAYS ARE DE-ENERGIZED (NORMALLY OPEN).

7. REMOTE COMMUNICATIONS PORT IS USED FOR ADDED COMMUNICATIONS
OPTIONS (Q1 & Q2, REFER TO PAGE 4). SWITCH 2 POSITION 6 ON ACQUISITION CARD
SHOULD BE SET "ON" WHEN Q2 OPTION (PMU DATA OUTPUT) IS USED.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
[ ] ARE IN MILLIMETERS
TOLERANCES ON:
2 PL DECIMALS ± 0.02
3 PL DECIMALS ± 0.005
ANGLES ± 1°
MATERIAL
FINISH

AMETEK
Power Instruments
255 North Union Street, Rochester NY 14605 USA

TITLE
TR2100 DETAIL DRAWING
REAR PANEL CONNECTIONS
TR

SIZE D
DWG NO 1086-940
REV A

ROCHESTER SCIENTIFIC COLUMBUS

SCALE NONE
FILE NAME 1086-940.dwg
SHEET 2 OF 4

PROPRIETARY

TYPICAL INPUT CONNECTIONS

ANALOG INPUTS (CURRENT/CICT)

TYPICAL CICT

CT SECONDARY CURRENT

RED — L

BLACK — N

TYPICAL CUSTOMER SUPPLIED TEST SWITCH

mV SIGNAL

CH.1 — 8

TR-2100 ANALOG INPUT CONNECTOR

ANALOG INPUTS (CURRENT/SHUNT)

CT SECONDARY CURRENT

L

N

TYPICAL CUSTOMER SUPPLIED TEST SWITCH

TYPICAL CURRENT SHUNT

CURRENT

mV SIGNAL

CH.1 — 8

TR-2100 ANALOG INPUT CONNECTOR

ANALOG INPUTS (VOLTAGE)

300V PEAK FULL-SCALE VOLTAGE INPUT

L

N

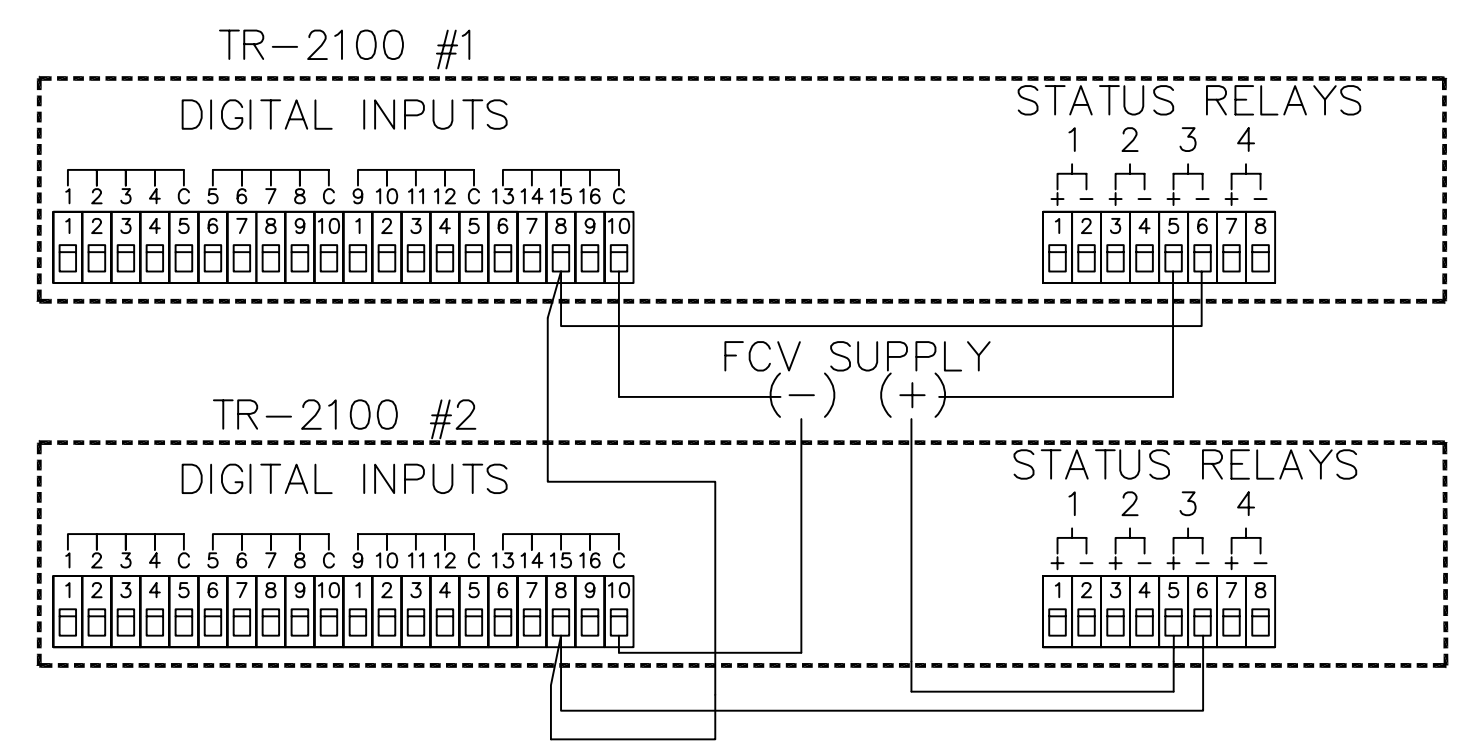TYPICAL CUSTOMER SUPPLIED TEST SWITCH

VOLTAGE SIGNAL
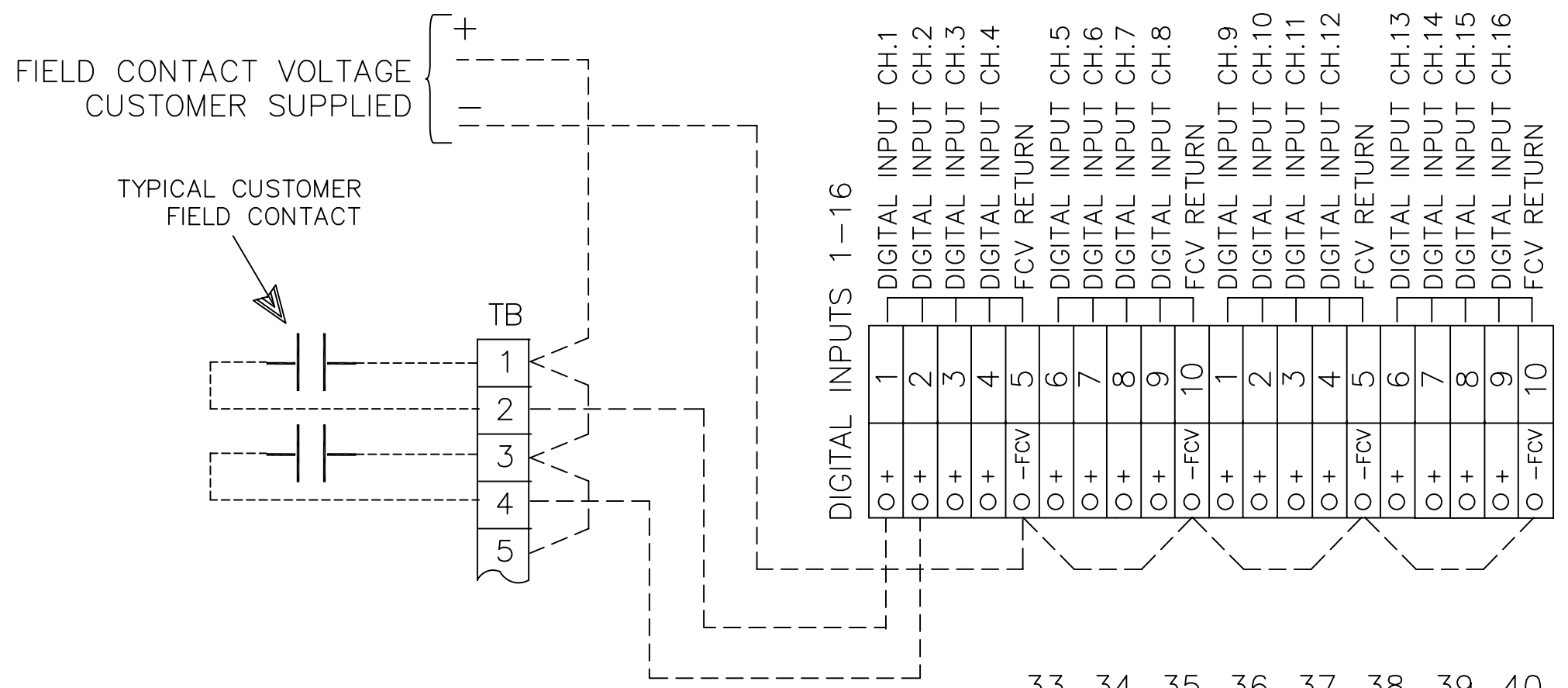
CH.1 — 8

TR-2100 ANALOG INPUT CONNECTOR
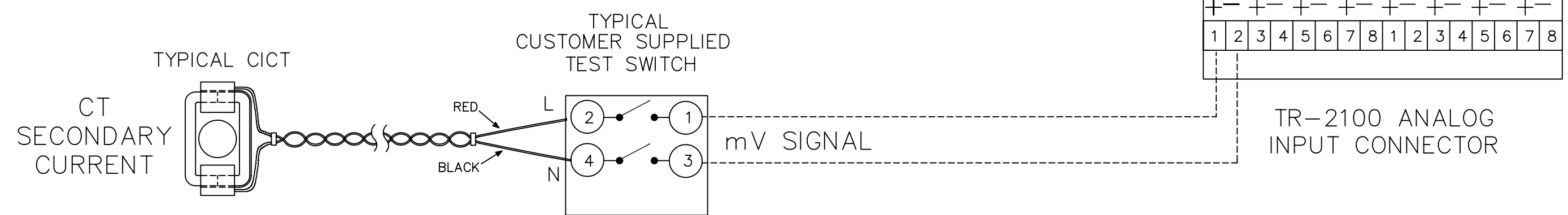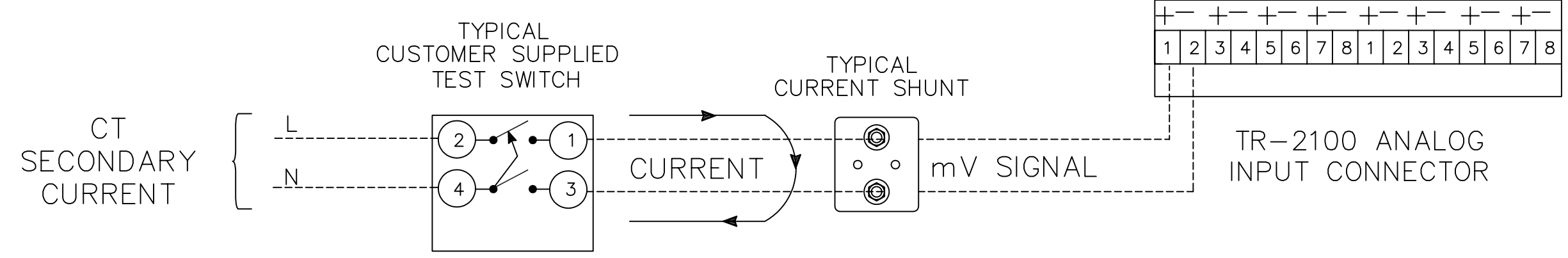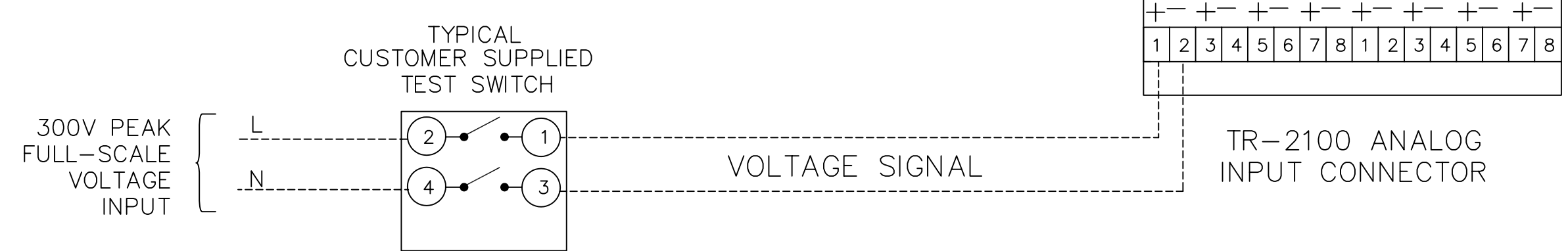
MULTIPLE SYSTEM CROSS TRIGGER SYNCHRONIZATION (TWO UNITS SHOWN)

STATUS RELAYS:
1. POWER
2. ON LINE
3. TRIGGERED
4. ATTENTIION

TR-2100 #1
DIGITAL INPUTS
STATUS RELAYS
1 2 3 4

FCV SUPPLY
(−) (+)

TR-2100 #2
DIGITAL INPUTS
STATUS RELAYS
1 2 3 4

DIGITAL INPUTS

FIELD CONTACT VOLTAGE CUSTOMER SUPPLIED

+
−

TYPICAL CUSTOMER FIELD CONTACT

TB
1
2
3
4
5

DIGITAL INPUTS 1-16

DIGITAL INPUT CH.1
DIGITAL INPUT CH.2
DIGITAL INPUT CH.3
DIGITAL INPUT CH.4
FCV RETURN
DIGITAL INPUT CH.5
DIGITAL INPUT CH.6
DIGITAL INPUT CH.7
DIGITAL INPUT CH.8
FCV RETURN
DIGITAL INPUT CH.9
DIGITAL INPUT CH.10
DIGITAL INPUT CH.11
DIGITAL INPUT CH.12
FCV RETURN
DIGITAL INPUT CH.13
DIGITAL INPUT CH.14
DIGITAL INPUT CH.15
DIGITAL INPUT CH.16
FCV RETURN

ISOLATED DIGITAL INPUTS

+ FCV
− FCV
+ FCV
− FCV

TB
1
2
3
4
5

ISOLATED DIGITAL INPUTS 33-40

33 34 35 36 37 38 39 40

SPLIT CORE
Current Isolation Current Transformer (CICT)
OUTLINE DRAWING

3.0"
1.25"
REMOVABLE HALF
CABLE TIE
0.80" DIA
1.75"
20 Ft.
6.0"
PRIMARY CORE
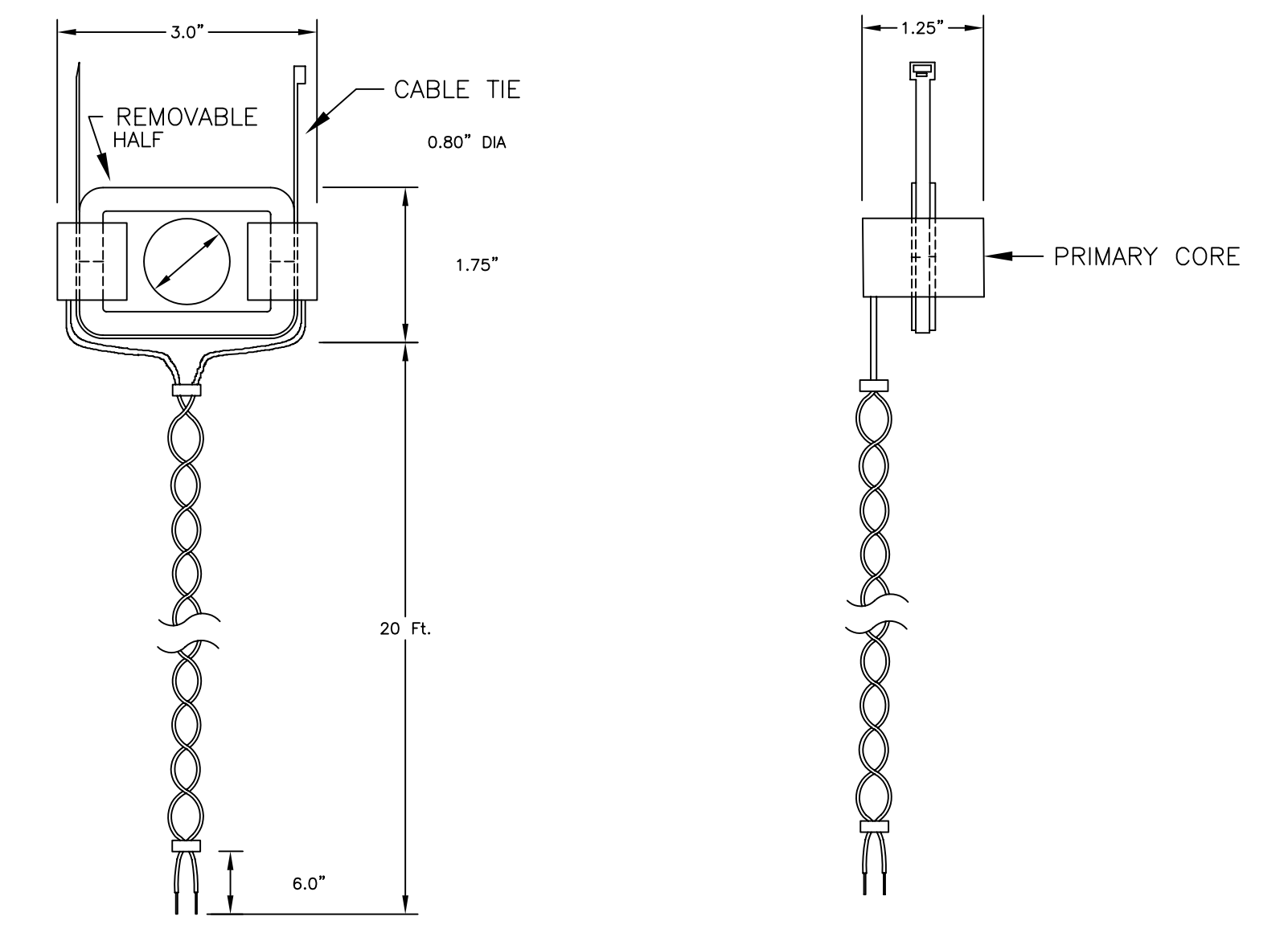
Notes:
1. Appropriate AMETEK P/N and Nominal current will be put on transformer in bold white letters. Markings will be on start side of transformer core (non-removable half) to indicate start of single turn (user-supplied) primary winding.
2. Top half of core is completely removable to allow customer insertion of primary wire (single turn) through core window. A cable tie is provided to secure both halves together for semi permanent mounting.

TRANSIENT RECORDER CURRENT SHUNT OUTLINE

2.25
0.90
2.00
1.75
BLACK
RED
6.00

PROPRIETARY

MODEL NUMBER: TR- XXXX - XX - XX - XX - XX - XX - XX - XX - XX - XX - XX

MASS STORAGE → MS1 (HARD DISK DRIVE)

EXPAMDED DIGITALS***
- D0 (NO ADDED DIGITAL INPUTS)
- D1 (32 ADDED DIGITAL INPUTS)
- D2 (64 ADDED DIGITAL INPUTS)
- D3 (96 ADDED DIGITAL INPUTS)
- D4 (128 ADDED DIGITAL INPUTS)

LANGUAGE ON CHASSIS
- E (ENGLISH ONLY)
- C (CHINESE AND ENGLISH)
- F (FRENCH AND ENGLISH)
- G (GERMAN AND ENGLISH)
- S (SPANISH AND ENGLISH)

FREQUENCY
- F50 (50 Hz OPERATION)
- F60 (60 Hz OPERATION)

ADDED COMMUNICATIONS
- Q0 (NONE)
- Q1 (DNP 3.0 OUTPUT)
- Q2 (PMU DATA OUTPUT)

COMMUNICATION OPTIONS
- C1 (STANDARD RS-232)
- C2 (HAYES COMPATIBLE INTERNAL MODEM)
- C3B (ETHERNET, 10BASE T)
- C4 (FAX OUTPUT, REQUIRES INTERNAL FAX MODEM)

TIME SOURCE
- T1 (INTERNAL CLOCK ONLY)
- T3 (IRIG-B, NO GPS)
- T5 (GPS RECEIVER ONLY, CUSTOMER SUPPLIED ANTENNA & CABLE)
- T5A (GPS SATELLITE ANTENNA AND 20M CABLE)
- T5B (HI-GAIN GPS SATELLITE ANTENNA AND 50M CABLE)
- T5C (GPS SATELLITE ANTENNA AND 20M CABLE AND IRIG-B, WITH IRIG-B ACTIVE)
- T5D (GPS SATELLITE ANTENNA AND 20M CABLE AND IRIG-B, WITH GPS ACTIVE)
- T5E (HI-GAIN GPS SATELLITE ANTENNA AND 50M CABLE AND IRIG-B, WITH IRIG-B ACTIVE)
- T5F (HI-GAIN GPS SATELLITE ANTENNA AND 50M CABLE AND IRIG-B, WITH GPS ACTIVE)
- T6 (OPTICAL TIME CODE TRANSMITTER, REQUIRES GPS RECEIVER)
- T7 (OPTICAL TIME CODE RECEIVER)

RECORDING OPTIONS
- R0 (NONE)
- R1 (DISTURBANCE LOGGER-2 WEEKS STORAGE)

FIELD CONTACT VOLTAGE
- F1 (250VDC)
- F2 (125VDC)
- F3 (48VDC)
- F4 (24VDC)

PRIME POWER
- P1 (100-300VDC OR 85-264VAC)
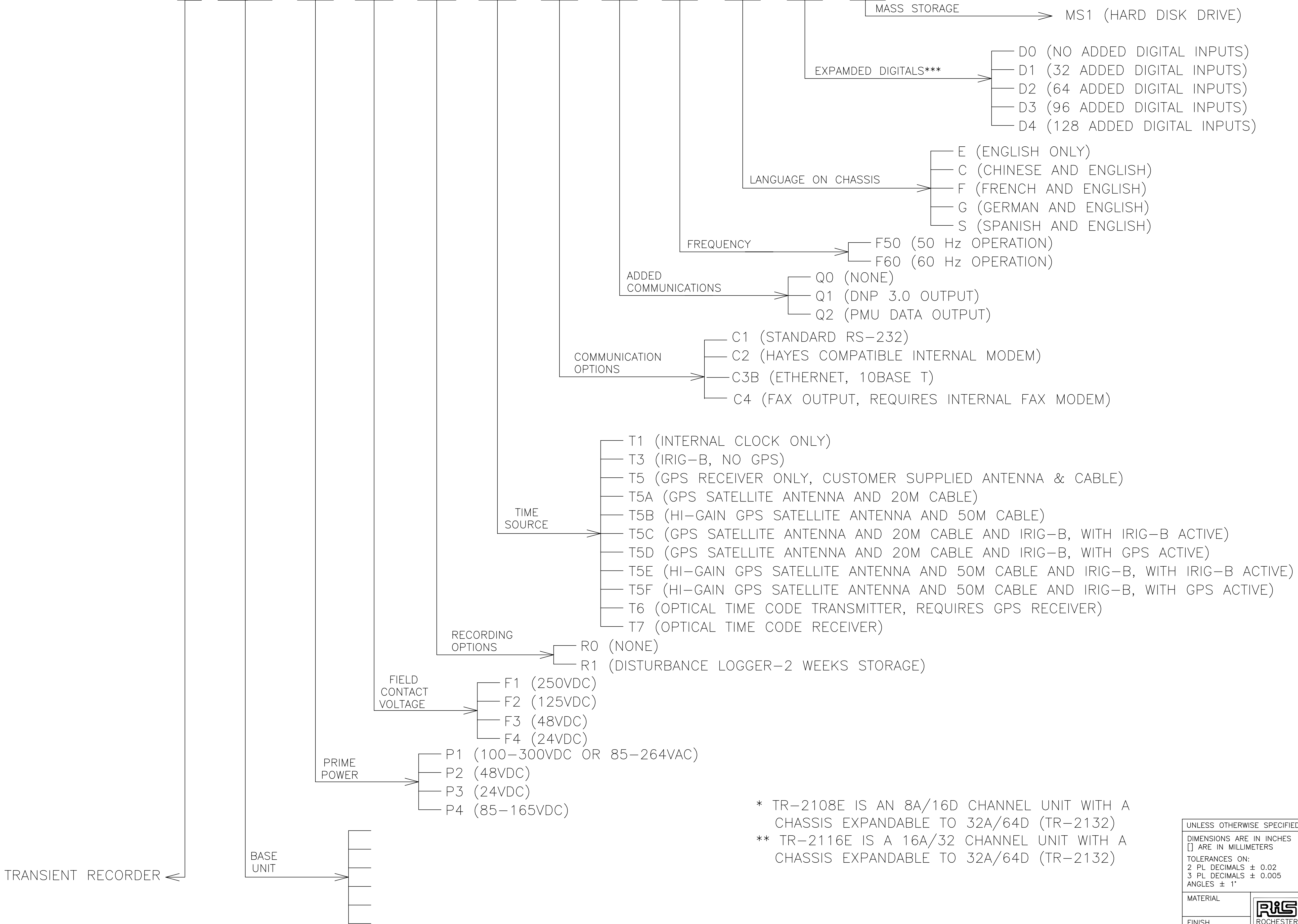- P2 (48VDC)
- P3 (24VDC)
- P4 (85-165VDC)

TRANSIENT RECORDER

BASE UNIT

* TR-2108E IS AN 8A/16D CHANNEL UNIT WITH A CHASSIS EXPANDABLE TO 32A/64D (TR-2132)
** TR-2116E IS A 16A/32 CHANNEL UNIT WITH A CHASSIS EXPANDABLE TO 32A/64D (TR-2132)

PROCEDURES FOR FACTORY REPAIR AND RETURN

A.   Obtain a Returned Material Authorization (RMA) number by calling the AMETEK
        Repair Department and giving the following information:

        1.   *Model* and *Serial Number* of the equipment.
        2.   Failure Symptom - **Be Specific**
        3.   Approximate date of installation.
        4.   The site name and address of the failed equipment.
        5.   Complete shipping information for the return of the equipment if
                other than the operating site.
        6.   Name and telephone number of person to contact if questions
        arise.

B.   Enclose the information with the equipment and pack in a commercially accepted
        shipping container with sufficient packing material to insure that no shipping
        damage will occur. Mark the outside of the container with the RMA number.
                Ship to the appropriate location:

                Attention: Repair Department

                AMETEK, INC.
                255 North Union Street
                Rochester, New York 14605 USA
                Telephone: (888) 222-6282
                Fax: (716) 238-4097

C.   Your equipment will be tested, repaired, and inspected at the factory. Normal
        factory turn-around is ten working days or less (excluding shipping time).

D.   For emergency service or repair status information, please contact the Repair
        Department at (716) 238-4993.

        WARRANTY — AMETEK warrants equipment of its own manufacture to be free
        from defects in material and workmanship, under normal conditions of use and
        service. AMETEK will replace any component found to be defective, upon its
        return, transportation charges prepaid, within one year of its original purchase.
        AMETEK will extend the same warranty protection on accessories that is extended
        to AMETEK by the original manufacturer. AMETEK assumes no responsibility,
        expressed or implied, beyond its obligation to replace any component involved.
        Such warranty is in lieu of all other warranties expressed or implied.