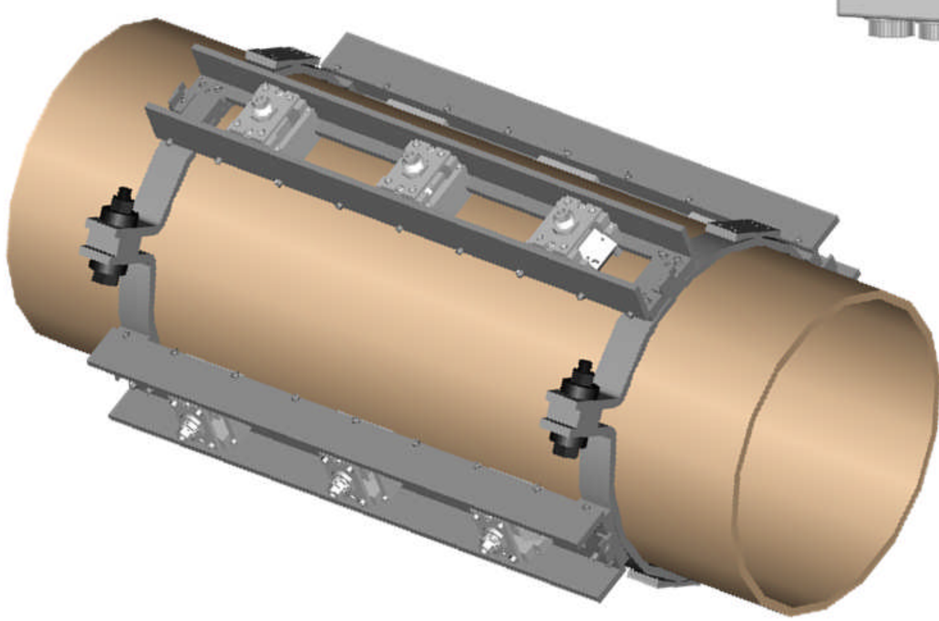
Rockwell Automation + Schlumberger

CALDON® ULTRASONICS

LEFM® 2010FE
Ultrasonic Flowmeter

User Manual



RECEIPT OF EQUIPMENT

Prior to uncrating, check outside packing case for visible damage. Notify local carrier at once if damage is present. Inspect unit for damaged or missing parts. Contact Cameron at (724) 273-9300 to report damage. Follow up with a written report to:

Cameron
Caldon Ultrasonics Technology Center
1000 McClaren Woods Drive
Coraopolis, PA 15108
USA

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INTRODUCTION

The Caldon LEFM 2010FE Ultrasonic Flow Transmitter is a highly sophisticated flow measurement system. It employs the ultrasonic transit time method to measure fluid velocity and flow rate. It contains advanced signal and data processing circuitry to achieve high accuracy and repeatability. It also contains an automatic self-checking system to continuously verify that it is performing properly and to initiate warnings and alarms when unsatisfactory conditions are detected. For ease of troubleshooting, it provides easy to interpret diagnostic information via Modbus®.

Important Safety Information

CAUTION

OPERATORS SHOULD NOT REQUIRE ACCESS TO THE INTERIOR OF THE ELECTRONICS. ONLY QUALIFIED PERSONNEL SHOULD SERVICE THE ELECTRONICS. DO NOT ATTEMPT TO DISASSEMBLE THE INSTRUMENT OR OTHERWISE SERVICE THE INSTRUMENT UNLESS YOU ARE A TRAINED MAINTENANCE TECHNICIAN.

If the equipment is used in a manner not specified by Cameron, the protection provided by the equipment's safety features may be impaired. Cameron is not responsible for damages or injuries sustained as a result of inappropriate use.

Before performing system verification and repair procedures, contact Sensia Measurement Systems.

For additional information or assistance on the application, operation or servicing, write or call the Sensia office nearest you or visit www.sensiaglobal.com

Terms Used in this Manual

WARNING

This symbol identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.

CAUTION

This symbol indicates actions or procedures which if not performed correctly may lead to personal injury or incorrect function of the instrument or connected equipment.

HOT SURFACE

This symbol indicates a particular surface maybe hot and touching this surface may lead to personal injury.

Note – Indicates actions or procedures which may affect instrument operation or may lead to an instrument response which is not planned.

1.0 EQUIPMENT SPECIFICATION

1.1 LEFM 2010FE Equipment

The LEFM 2010FE Flow Measurement System consists of two major pieces of equipment:

- LEFM 2010FE Transmitter
- LEFM 2010FE Metering Section

The LEFM 2010FE Metering Section typically includes the following:

- Diagonal Path and Cross Path Transducers
- High-Temperature Transducer Cables (to run between the Junction Box and Metering Section)
- Junction Box(es)
- Low-smoke Transducer Cables (to run between the Transmitter and Junction Box)
- Pressure and Temperature devices (optional)
- Transducer fixture that holds the transducers to the pipe surface

1.1.1 LEFM 2010FE Transmitter

The LEFM 2010FE Transmitter is a wall mount unit with the following special features:

- Standard Outputs:
  Flow Pulse (0-5 V standard, 0-12 V optional); the meter K factor is programmable (minimum frequency 3 Hz)
  RS-485 Serial Output (Modbus)

- Optional Analog Inputs:
  Temperature (100 Ohm P_T RTD, $\alpha = 0.00385$)
  Pressure (0,4-20 mA)

- Optional Analog Outputs (Select 1 if used):
  Density (0,4-20 mA)
  Specific Gravity (0,4-20 mA)
  Temperature (0,4-20 mA)
  Velocity of Sound – (0,4-20 mA)
  Flow – (0,4-20 mA)

- Display Screen indicating:
  Volume Flow or Mass Flow
  Temperature
  Acoustic Path Status
  System Density
  Totalized Flow

1.1.2 LEFM 2010FE Metering Section

The metering section contains the acoustic transducers that transmit and receive the ultrasonic pulses that pass through the fluid. It can be configured with either four ultrasonic measurement paths (two cross paths and two diagonal paths or all four diagonal paths) or eight ultrasonic measurements paths (four cross paths and four diagonal paths).

LEFM 2010FE Transmitter is programmed with the dimensions of the metering section (cross sectional area, distance between transducers, pipe wall thickness, etc.) in order to calculate flow from acoustic measurements made on the metering section. The LEFM 2010FE Transmitter is connected to the transducers via a shielded cable. Acoustic transit times through the fluid are measured to determine axial fluid velocity. The average cross path transit times (or diagonal paths if cross paths are not present) are used to calculate the fluid sound velocity and fluid temperature. The fluid temperature is used to calculate density and then used with the volumetric flowrate to determine the mass flowrate.

The transducer modules contain piezoelectric crystals. Each transducer transmits and receives ultrasonic pulses (typically 1.0 MHz). The LEFM 2010FE Transmitter operating frequency is matched to the transducers. Transducer cables are used to route electronic signals between the Transmitter and the transducers.

1.2 LEFM 2010FE Transmitter Part Code

As a member of the Cameron product family, each LEFM 2010FE Transmitter has a part code that completely defines the construction and features of the flow meter. Table 1-1 defines the part code.

Part Number	Power Supply	Frequency	Paths	Enclosure Material
9A-203B040G02	120 VAC	1.0 MHz	4 Path	Stainless Steel
9A-203B040G05	120 VAC	1.0 MHz	8 Path	Stainless Steel
9A-203B040G08	230 VAC	1.0 MHz	4 Path	Stainless Steel
9A-203B040G11	230 VAC	1.0 MHz	8 Path	Stainless Steel
9A-203B040G20	120 VAC	1.0 MHz	4 Path	Carbon Steel
9A-203B040G23	120 VAC	1.0 MHz	8 Path	Carbon Steel
9A-203B040G26	230 VAC	1.0 MHz	4 Path	Carbon Steel
9A-203B040G29	230 VAC	1.0 MHz	8 Path	Carbon Steel

Table 1-1 LEFM 2010FE Transmitter Part Code

LEFM 2010FE Specifications

1.2.1 *LEFM 2010FE Transmitter*

Material:

NEMA 4X	Stainless Steel
NEMA 4	Painted Carbon Steel

Wall Mount

Net Weight:	30 lbs. (13.6 kg) (See Figure 2-1 for dimensions)

Power Requirements

Voltage Supply Required:	120 VAC, 50/60 Hz or, 230 VAC, 50/60 Hz
Current Draw:	120 VAC – 0.8 Amps 230 VAC – 0.6 Amps
Power Consumption:	12W (80W with heaters active)

Cable Lengths

Standard:	25 feet (approximately 7.6 meters); lengths up to 100 feet (31 meters) can be ordered
Extended Range:	Special cables can be used for runs up to 1000 feet (310 meters). Contact the Cameron Engineering department to discuss the needs of the application.

Pulse Outputs/Communications

Pulse Output:	0-5 V (standard) or 0-12 V (optional)
Alarm Status:	+5V or +12V @ 20mA Normal, 0V Alarm
Serial Communications:	RS-485 Modbus Protocol (see Cameron Modbus Specification)

Analog Output:	4-20mA or 0-20mA (max load 650 Ohms)
Analog Inputs:	4-20mA, 0-20mA, and RTD

1.2.2 Environment

Indoor or Outdoor Use

Altitudes up to 3000 meters

Pollution – Degree 2

Power Supply ±10% of nominal voltages

Storage Temperature

Transducer Cable:	N/A
Transmitter:	-70°F (-57°C) to 158°F (70°C)

Operating Temperatures

Transmitter:	-40°F (-40°C) to 140°F (60°C)
Transducer Cable (High Temp):	-67°F (-55°C) to 392°F (200°C)
Transducer Cable (Low Smoke):	-22°F (-30°C) to 176°F (80°C)

CAUTION

Confirm that all other cables entering the transmitter (e.g., power, analog input, analog output, RS485 etc) that are supplied by the site installation team, are rated to 80 deg C. This rating allows cables to comply with the full temperature range of the transmitter.

Relative Humidity

Transmitter:	0 – 95% Relative Humidity (Internal)
	0 – 100% Relative Humidity (External)

EMI

According to EPRI standard TR-10323 Rev 3
EN Standards EN61326-1 (EN-61000)

2.0 INSTALLATION

The exact physical properties, acoustic properties, and calibration of the metering section are programmed into the transmitter as part of the commissioning activities. **When installing multiple units ensure that the transmitter is properly associated with the intended metering section. Also ensure that each group of transducer signal cables (all transducer cables routed from one transmitter to its specific metering section is considered a group) are physically separated from other groups of transducer signal cables.**

2.1 Transmitter and Terminations

The LEFM 2010FE meter is designed to be used under a wide variety of environmental conditions. Durable construction permits conventional installation practices. The transmitter should be installed in an environment consistent with the ratings of the enclosure. All wiring to and from the transmitter must be put in grounded metal conduit or equivalent. Mounting must use the mounting points indicated in Figure 2-1. No ventilation is required, other than that which is necessary to meet the ambient temperature requirements.

2.1.1 Transmitter Mounting

For installation, simply uncrate the delivered transmitter (please note the weight of your transmitter in Section 1.2.1 for proper handling). Use the indicated mounting points for mounting the units. Select bolts/hardware appropriate for the unit's weight. Consider site seismic requirements.

- Use 5/16 inch bolts/hardware (or equal) on at least the 4 top and 4 bottom mounting points for the LEFM 2010FE Transmitter and torque to 18 ft/lbs.
- The mounting hardware must be capable of handling 4 times the transmitter's weight or approximately 140 lbs (63.6 kg). This should be verified by the site installation team (EN61010).

The transmitter should be mounted at a convenient working height. (The recommended height is the bottom of the transmitter at about 4 feet (1.2 meters) from the floor.)

2.1.2 Field Terminations

The wiring should be routed to the transmitter in shielded conduit that meets site environment specifications. All terminations should be made according to Table 2-1 through Table 2-6.

For full environmental temperature range, all wiring (conductors) into and out of the transmitter should be rated as follows:

- Temperature range - minimum of 176°F (80°C).
- All supply wiring must be rated to 300 volts AC (18 AWG).
- Equipment must be installed by a licensed electrician, in accordance with NEC/CEC and local codes.
- As a minimum, a disconnect switch should be installed before and near the transmitter. The external disconnect device must be an approved device rated for the supply voltages and is rated to 3 Amps for 120 VAC or 240 VAC and provide a minimum of 3.0 mm spacing. This remote disconnect should be marked as the disconnect to the Transmitter.

Figure 2-1 illustrates the conduit connections for the LEFM 2010FE Transmitter and the transmitter layout. Transducer termination guide is defined in Table 2-1. Metering section transducers are defined in acoustic pairs, path 1 through path 8, and designated as upstream or downstream with respect to typical flow direction. Each transducer has a positive and negative lead and a shield wire.

2.1.2 RS-485 Communication

Serial communications is RS-485. Table 2-6 shows pin out for serial communications. The system also has the option for Ethernet connectivity using two RJ45 jacks. Each of the communication ports (Channel 1 and Channel 2) can be configured for either serial or Ethernet using the switches 1 and 2 located on the datalogger board.

2.1.3 Grounding/Earthing

The transmitter has grounding/earthing points available. Site guidelines are to be followed regarding grounding/earthing. Transducer cable shields are to be grounded in the transmitter, but not at the transducers. Shielding through the transmitter terminal blocks avoids undesirable ground loops. Note that some installations may use transformers to match other vendor's transducers (single ended transducers). In these installations, the shield termination may not be landed.

2.1.4 Digital Outputs

The LEFM 2010FE Transmitter is a bidirectional meter and has two digital output options that indicate direction. The first is quadrature pulse output to indicate direction of flow (reference Table 2-4). Quadrature output uses two pulse outputs (A and B). Pulse output A leading pulse output B by 90° indicates forward flow while pulse output B leading pulse output A by 90° indicates reverse flow with respect to the flow arrow of the nameplate. The second is a level indication that is driven by direction (output "Hi" for positive flow and "Lo" for negative flow).

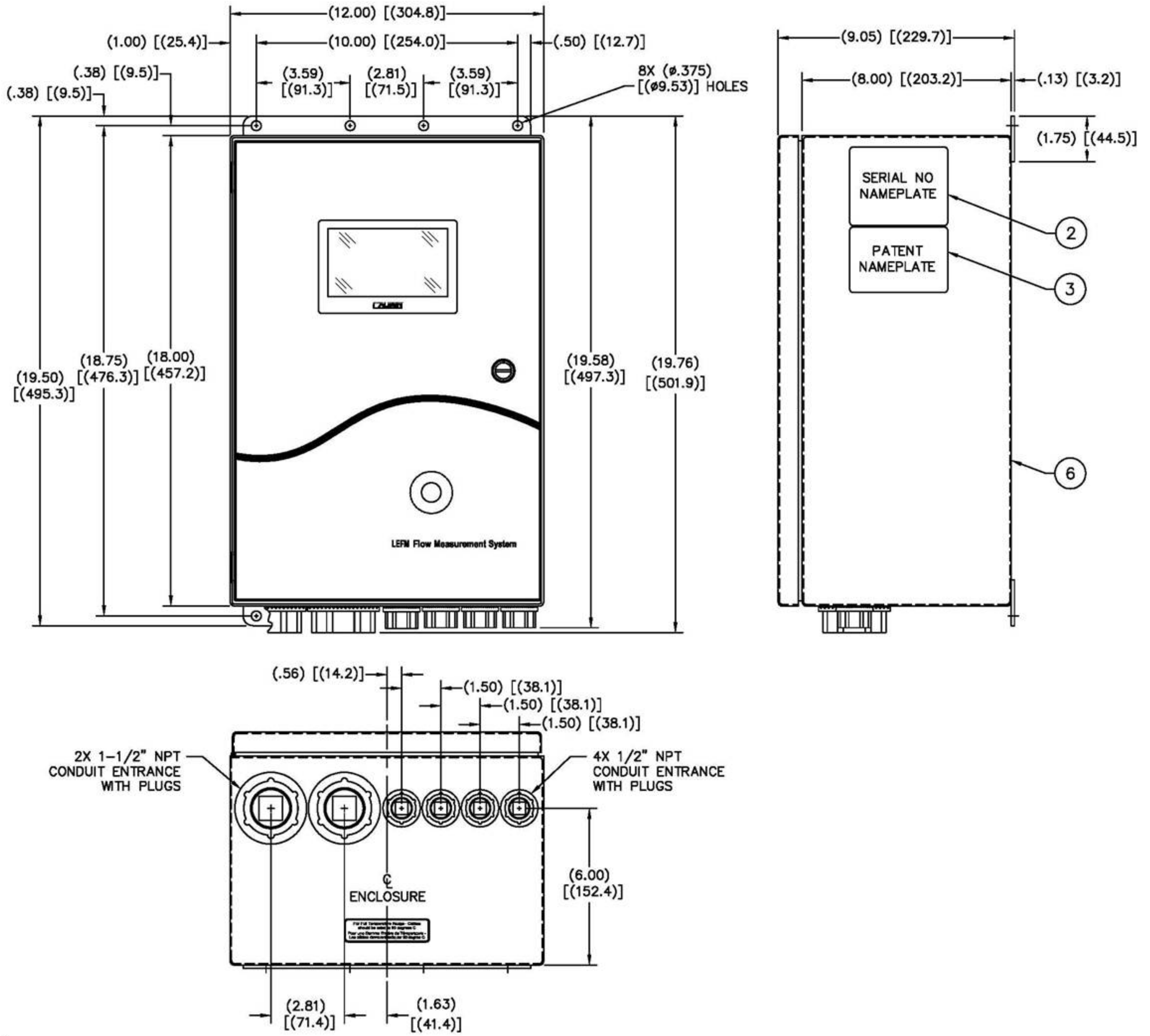


Figure 2-1: Transmitter Enclosure (units in inches, [mm])

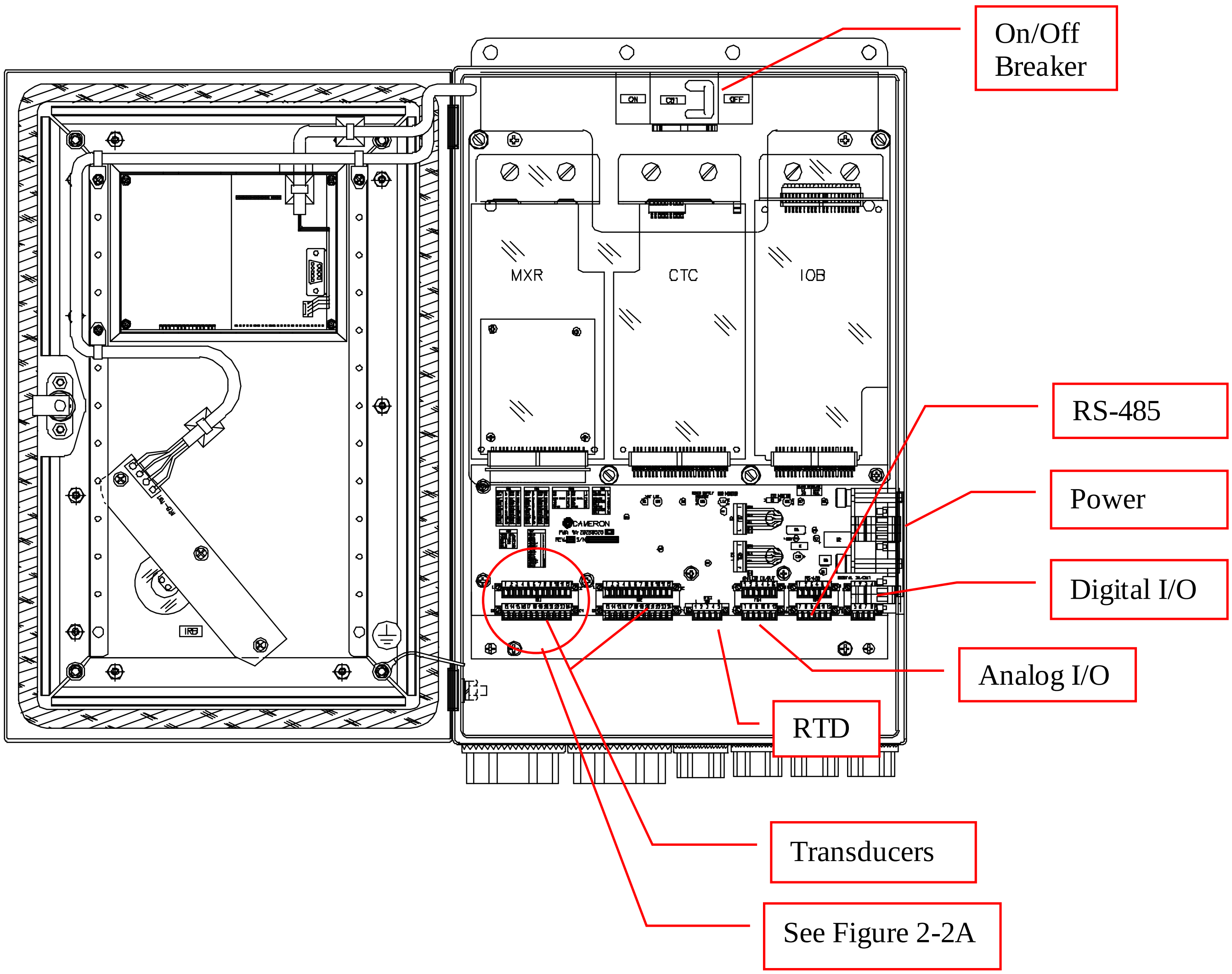
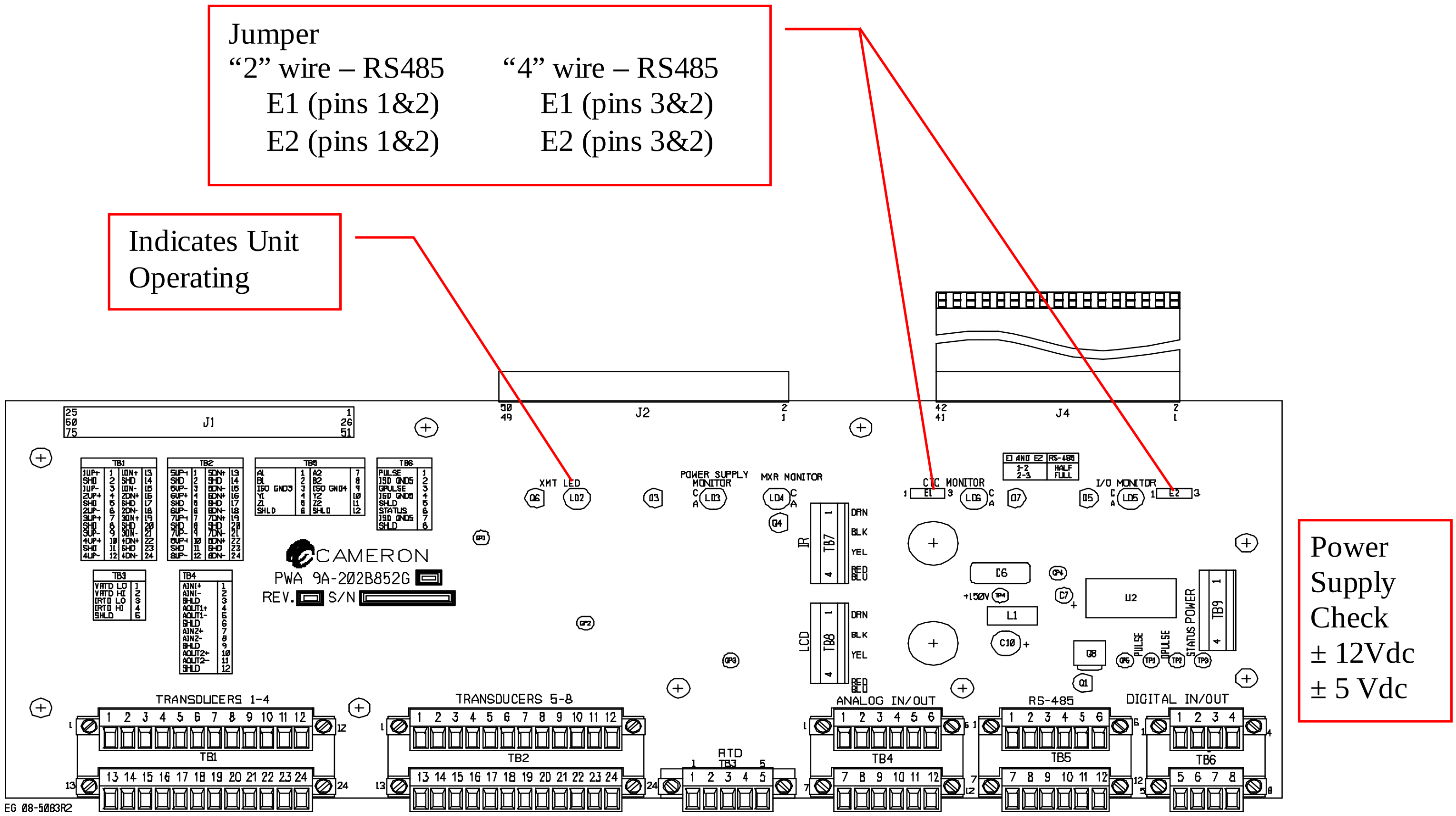


Figure 2-2: Electronics with Door Open

Circuit Breaker – ON to the LEFT, OFF to the RIGHT



Top View

Figure 2-2a – Transmitter Assembly Board

Transducer Path Name	Cable Identification	Transmitter Termination	
	Wire Name	Device	Terminal
Diagonal Path 1 UP	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	1 2 3
Cross Path 1 UP	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	4 5 6
Diagonal Path 2 UP	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	7 8 9
Cross Path 2 UP	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	10 11 12
Diagonal Path 1 DN	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	13 14 15
Cross Path 1 DN	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	16 17 18
Diagonal Path 2 DN	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	19 20 21
Cross Path 2 DN	+ Shield -	BPL-TB1 BPL-TB1 BPL-TB1	22 23 24
Diagonal Path 3 UP	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	1 2 3
Cross Path 3 UP	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	4 5 6
Diagonal Path 4 UP	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	7 8 9
Cross Path 4 UP	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	10 11 12
Diagonal Path 3DN	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	13 14 15
Cross Path 3 DN	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	16 17 18
Diagonal Path 4 DN	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	19 20 21
Cross Path 4 DN	+ Shield -	BPL-TB2 BPL-TB2 BPL-TB2	22 23 24

Table 2-1: LEFM 2010FE Transducer Terminations
(For 8 acoustic paths)

Transducer Path Name (when using DPs)	Transducer Path Name (when using DPs & CPs)	Cable Identification	Transmitter Termination	
		Wire Name	Device	Terminal
Diagonal Path 1 UP	Diagonal Path 1 UP	+	BPL-TB1	1
		Shield	BPL-TB1	2
		-	BPL-TB1	3
Diagonal Path 2 UP	Cross Path 1 UP	+	BPL-TB1	4
		Shield	BPL-TB1	5
		-	BPL-TB1	6
Diagonal Path 3 UP	Diagonal Path 2 UP	+	BPL-TB1	7
		Shield	BPL-TB1	8
		-	BPL-TB1	9
Diagonal Path 4 UP	Cross Path 2 UP	+	BPL-TB1	10
		Shield	BPL-TB1	11
		-	BPL-TB1	12
Diagonal Path 1 DN	Diagonal Path 1 DN	+	BPL-TB1	13
		Shield	BPL-TB1	14
		-	BPL-TB1	15
Diagonal Path 2 DN	Cross Path 1 DN	+	BPL-TB1	16
		Shield	BPL-TB1	17
		-	BPL-TB1	18
Diagonal Path 3 DN	Diagonal Path 2 DN	+	BPL-TB1	19
		Shield	BPL-TB1	20
		-	BPL-TB1	21
Diagonal Path 4 DN	Cross Path 2 DN	+	BPL-TB1	22
		Shield	BPL-TB1	23
		-	BPL-TB1	24

Table 2-2: LEFM 2010FE Transducer Terminations
(For 4 acoustic paths)

Analog Input Source	**RTD Connections**		**0, 4-20mA Connection**	
	Description	**Terminus**	**Description**	**Terminus**
Analog Input 1			0, 4-20mA +	BPL-TB4-1
			0, 4-20mA -	BPL-TB4-2
			Chassis Ground	BPL-TB4-3
Analog Input 2			0, 4-20mA +	BPL-TB4-7
			0, 4-20mA -	BPL-TB4-8
			Chassis Ground	BPL-TB4-9
Fluid Temperature	RTD -	BPL-TB3-1		
	RTD +	BPL-TB3-2		
	RTD -	BPL-TB3-3		
	RTD +	BPL-TB3-4		
	Chassis Ground	BPL-TB3-5		

Table 2-3: Analog Input Customer Connection Locations (Located on Backplane)

Note: TP4 on the IOB can be used to verify analog input value

Typical Analog Output*	Signal Description	Terminus
Analog Output 1 Flow (0)	4,0-20 mA + (high)	TB4-4
	4,0-20 mA – (low)	TB4-5
	Shield	TB4-6
Analog Output 2 Flow (38)	4,0-20 mA + (high)	TB4-10
	4,0-20 mA – (low)	TB4-11
	Shield	TB4-12

Table 2-4: Analog Output Customer Connection Locations (Located on Backplane)

*Note: Other variables can be mapped to the analog outputs (reference Cameron Modbus manual).

Name	Signal Description	Terminus
Pulse A	+V, Indicates forward flow	BPL-TB6-1
GND5	Signal Ground	BPL-TB6-2
Pulse B or Direction	+V, Pulse 90 degrees phase shift to Pulse A If phase lags (positive flow) - if phase leads (negative flow) Direction: +V indicates reverse flow, 0 Indicates positive flow	BPL-TB6-3
GND5	Signal Ground	BPL-TB6-4
GND	Chassis Ground	BPL-TB6-5
Status	+0V, Indicates alarm condition +V, Indicates normal operation	BPL-TB6-6
GND5	Signal Ground	BPL-TB6-7
GND	Chassis Ground	BPL-TB6-8

Table 2-5: Pulse and Digital Output Wiring

Note: +V can be either 5 volts or 12 volts by moving the jumper E1 on the IOB board. When positions 1 & 2 are jumpered the output is 5 volts, when positions 2 & 3 are jumpered the output is 12 volts.

Power Connectivity	Description	Terminus
120 VAC	LINE	XMT-TB2-1
	Neutral/Return	XMT-TB2-2
	Ground/Earth	XMT-TB2-3
24 VDC	+24 VDC	XMT-TB2-1
	24 VDC Return	XMT-TB2-2
	Ground/Earth	XMT-TB2-3
240 VAC	LINE 1	XMT-TB2-1
	LINE 2	XMT-TB2-2
	Ground/Earth	XMT-TB2-3

Table 2-6: Power Connections
(Only one type of power should be connected)

Port Name	Termination	RS-485 Full Duplex* E1, E2 Jumpered 2-3	RS-485 Half Duplex* E1, E2 Jumpered 1-2
COM1	BPL-TB5-1	A, Noninverting Receive (+Rx)	
	BPL-TB5-2	B, Inverting Receive (-Rx)	
	BPL-TB5-3	Signal Ground	
	BPL-TB5-4	Y, Noninverting Transmit (+Tx)	Y, Noninverting Transmit/Receive (+Data)
	BPL-TB5-5	Z, Inverting Transmit (-Tx)	Z, Inverting Transmit/Receive (-Data)
	BPL-TB5-6	Chassis Ground	
COM2	BPL-TB5-7	A, Noninverting Receive (+Rx)	
	BPL-TB5-8	B, Inverting Receive (-Rx)	
	BPL-TB5-9	Signal Ground	
	BPL-TB5-10	Y, Noninverting Transmit (+Tx)	Y, Noninverting Transmit/Receive (+Data)
	BPL-TB5-11	Z, Inverting Transmit (-Tx)	Z, Inverting Transmit/Receive (-Data)
	BPL-TB5-12	Chassis Ground	

Table 2-7: RS-485 Serial Communications

* Jumpering E1 (COM1) and E2 (COM2) on the transmitter backplane board to positions 1-2 selects half duplex mode. Jumpering E1 (COM1) and E2 (COM2) on the transmitter backplane board to positions 2-3 selects full duplex mode (reference Figure 2-2A).

2.2 Meter Installation Check-Out

The following steps are recommended to checkout a meter's installation. See Section 5 and 6 for troubleshooting and maintenance. Also reference Cameron procedure EFP-54.

Step 1: Verify all field terminations have proper continuity and isolation from each other and earth. Verify connections are good with respect to insulation.

Step 2: Verify electronics turn on when CB1 (input power breaker) is closed (Display lights up on front panel). Reference Figure 2-2.

CAUTION

The circuit breaker is ON (power applied) when the switch is to the LEFT and OFF (electronics off) when the switch is to the RIGHT.

Step 3: Verify Modbus communications (Use Caldon LEFM Link 2G software or plant computer to communicate). Verify meter operation according to Section 5.

Step 4: Verify Analog Output, preferably using LEFM Link to force outputs (current and pulses). Forcing outputs verifies connections to site instruments. Verify observed forced outputs are within 0.1% on current and 0.01% on pulse frequency. Return meter to normal operation.

Step 5: If pipe is full of liquid, verify acoustic signals have Rejects < 5% and SNR (signal to noise ratio) > 15:1.

3.0 OPERATION

3.1 Measuring Flow

The LEFM 2010FE uses pairs of ultrasonic transducers (Reference Figure 3-1) mounted externally on the pipe, typically in a bounce path configuration, to send acoustic pulses to one another along a measurement path. The measurement path is at an angle to the fluid flow. The acoustic pulses transit time depends upon both the speed of sound in the fluid and the velocity of the fluid along the path. The transit time will be shorter for pulses that travel downstream with the flow than for the pulses which travel upstream against the flow.

$$T_D = \frac{l_P}{C_f + V_P}$$

$$T_U = \frac{l_P}{C_f - V_P}$$

where

T_D	=	downstream transit time
T_U	=	upstream transit time
l_p	=	path length
C_f	=	speed of sound in fluid
V_p	=	flow velocity along the ultrasonic path
V	=	flow velocity along pipe axis

When pulses travel upstream and downstream during the same time, the above equations may be treated as simultaneous, and solved for the two unknowns, C_f and V_P.

Solving for V_P and taking into account path angle ϕ_f (angle in fluid)

$$V = \frac{l_P}{2Sin\phi_f} \bullet \frac{T_U - T_D}{T_D T_U} \qquad (1)$$

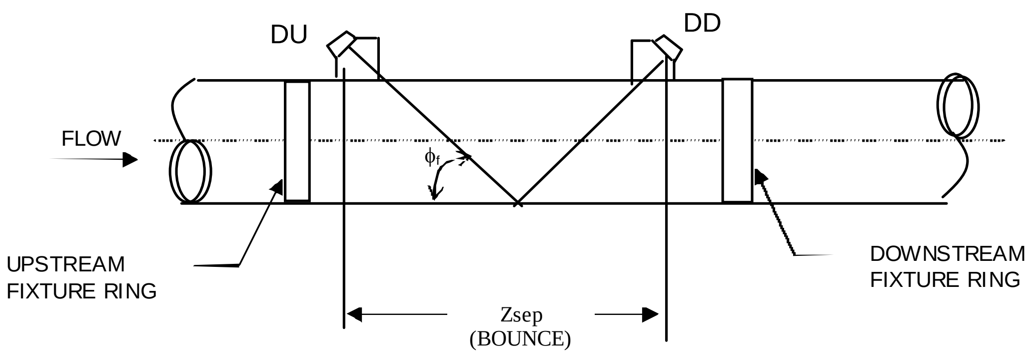


Figure 3-1: External Diagonal Transducer Bounce Path

The path angles in the pipe wall and fluid are determined by Snell's Law.

$$\frac{Sin\phi_W}{C_W} = \frac{Sin\phi_P}{C_P} = \frac{Sin\phi_f}{C_f} \qquad (2)$$

Where	C_f	=	Fluid sound velocity
	C_P	=	Pipe shear sound velocity
	C_W	=	Wedge sound velocity
	ϕ_f	=	Fluid Path angle
	ϕ_P	=	Pipe wall path angle
	ϕ_W	=	Wedge path angle

The fluid path length depends on the fluid path angle and pipe internal diameter.

$$l_P = \frac{N^* \cdot ID}{Cos\phi_f} \qquad (3)$$

* N = 2 for bounce path
N = 1 for direct across the pipe

By combining equations 1, 2, and 3, flow velocity along the pipe axis can be written as:

$$V_{\text{axial}_i} = \frac{C_f^{\,2}\,(\Delta T_i)}{2(N+1)(OD-2ap)\tan\phi_{f_i}} \qquad (4)$$

where:

$v_{\text{axial } i}$	=	Velocity on Diagonal Path i
ΔT_i	=	Measure delta t diagonal path i
$\tan\phi_{fi}$	=	Tangent of angle in fluid

The volumetric flowrate is calculated from the velocity as:

$$Q = PF\left(\frac{\sum_{i}^{\text{diagonal paths}}(V_{axial_i})}{\text{No.of Diagonal Paths}}\right)\cdot A \qquad (5)$$

Where	PF	=	Profile factor that corrects for velocity profile variations
	A	=	Pipe area
	V	=	Flow velocity along pipe axis

Mass flow is calculated by multiplying volume flowrate by the fluid's density.

$$M = Q \cdot \rho$$

ρ = Density

3.2 LEFM 2010FE Transmitter

The LEFM 2010FE Transmitter contains four major functional units, the digital board (CTC), the analog board (MXR), the Backplane where all wiring connections are made, the IOB which handles all inputs and outputs from the installation site and has protection circuitry, and the power supply.

The CTC/MXR boards perform all control and timing for the generation and measurement of acoustic pulses. It is designed to achieve high sampling rates, stable ultrasonic signals, and no zero drift. The CTC board has a microprocessor programmed to perform the following functions:

- Excite ultrasonic transducers to transmit sound in the upstream and downstream direction with respect to flow.
- Process received electronic signals generated by the ultrasonic transmission.
- Cycle through the ultrasonic path cycles and test cycles.
- Provide Gain Control for each ultrasonic path.
- Compute flow, temperature, and density.
- Provide Modbus communications for software interaction.
- Provide Display with updated flow, temperature, status, and density.

Setups to the CTC are provided by a Modbus serial link through the backplane connection.

3.3 Temperature-Density Determination

The temperature and density correlation with velocity of sound for water is well known and documented. The LEFM 2010FE Flow Measurement System accurately measures the velocity of sound of water and calculates temperature. From fluid temperature, density is determined based upon the ASME Steam Tables, Fifth Edition, 1983.

3.4 Remote Data Communications

The LEFM 2010FE has two RS 485 communication ports using the Modbus protocol. See the Modbus Manual for more detail. Another serial port located on the electronics door is dedicated to the IR serial interface.

4.0 DISPLAY OPERATION

4.1 Definitions

SNR – Signal to Noise Ratio

Gain – Required gain to amplify signal

Rejects – Percentage of data rejected by one or more of the System Quality Tests

VOS – Velocity of Sound

IOB – Input Output Board

CTC – Control and Timing Card

MXR – Multiplexer, Transmitter and Receiver Card

4.2 Normal Operating Conditions

If the LEFM is properly installed, the display will begin working when power is supplied to the unit. The display will provide a readout of flow total, flow rate, fluid properties and basic acoustic diagnostic information. If more detailed diagnostic data is needed beyond what is available via the display, consider accessing transmitter diagnostic data via the LEFM Link 2G software.

WARNING

Except when troubleshooting, do not remove the enclosure covers from the transmitter. The diagnostic information is easily read from the display with the covers in place.

4.3 Infrared Interface

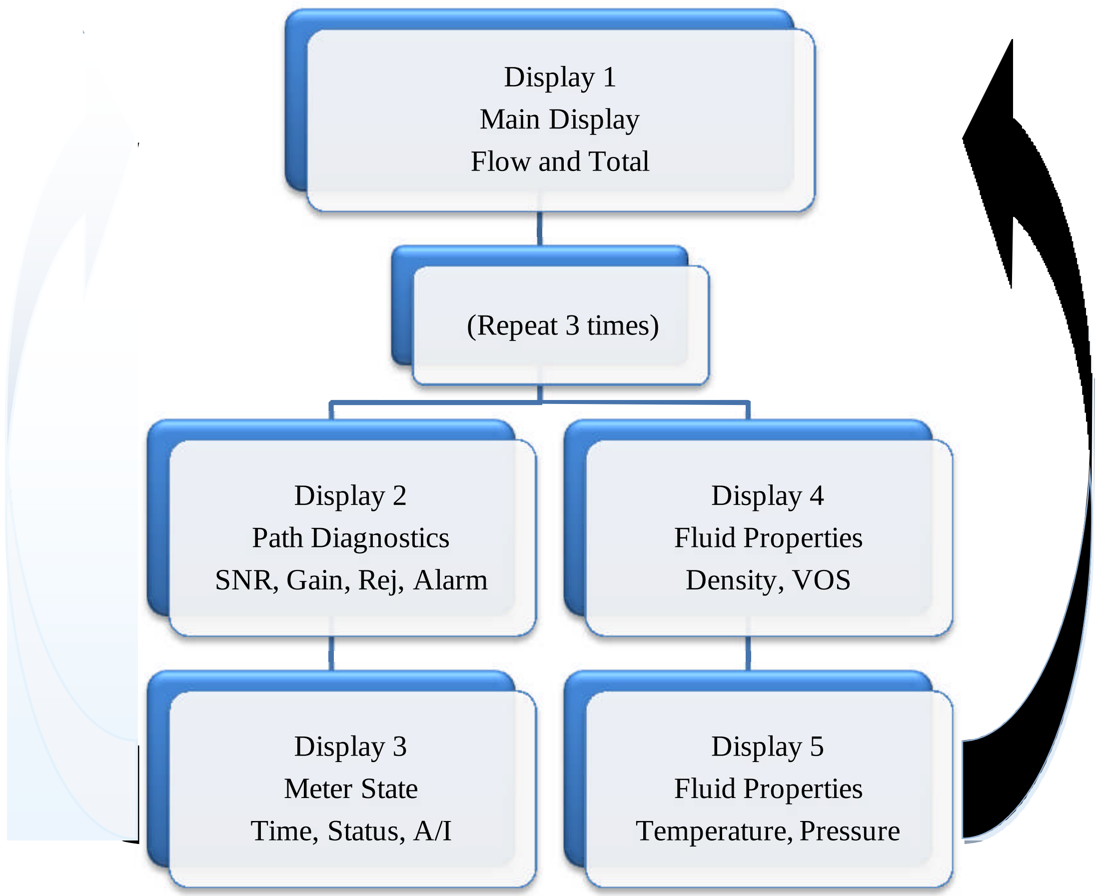
An infrared port is also mounted inside the display window for accessing the LEFM 2010FE via a Pocket PC running PocketLink software or other device operating with a Modbus protocol. LEFM Link software allows the user to interface with the transmitter via Modbus using a Pocket PC or a PC. For details, see the LEFM Link manual.

4.4 Display

The transmitter has a graphics display. The display shows the meter's indicated flow, totalized flow, fluid properties, and diagnostics data. The transmitter repeatedly cycles through all display parameters.

The display provides information for each of the meter's paths. The display cycle when in Normal Mode is shown below in Figure 4-1:

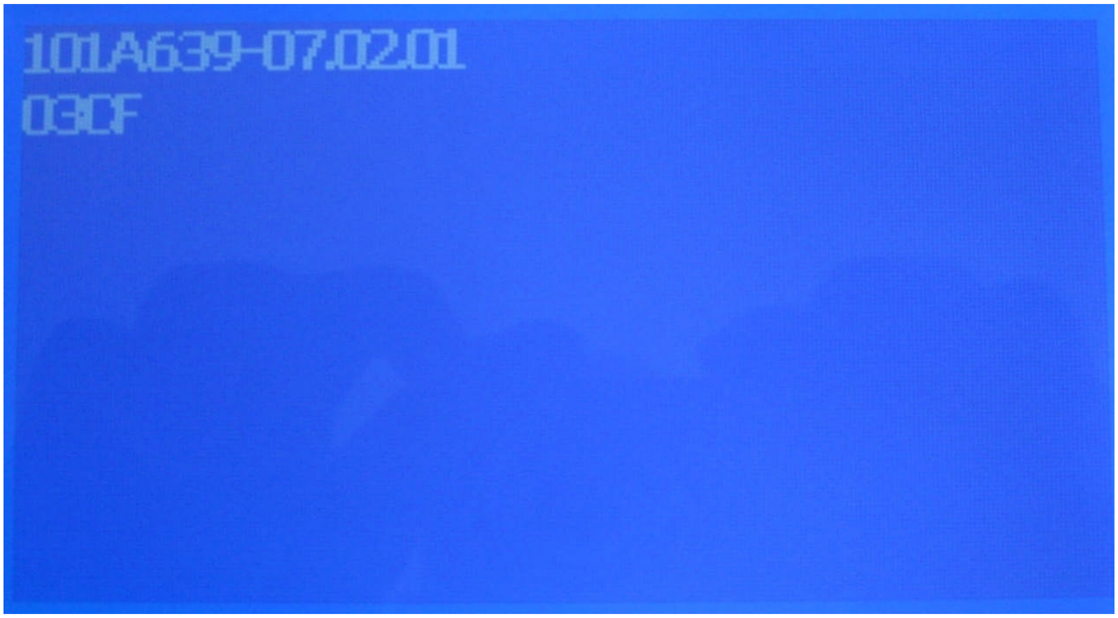
Figure 4-1: Display Screens in Normal Operation



Note that Display 2 will only display four path's information at one time. The first time through the display cycle, Paths 1-4 will be displayed; the second time, Paths 5-8 (for an 8 path meter only) will be displayed.

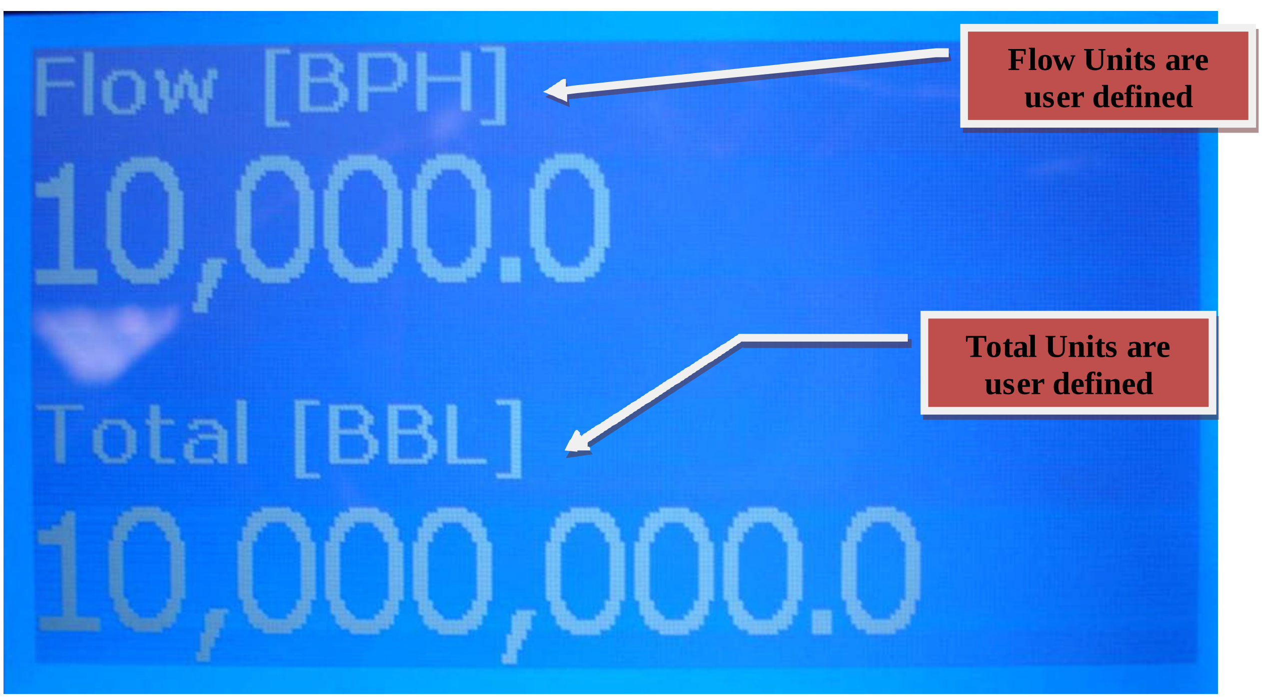
4.4.1 Boot up and Normal Operational Screens

On power up and boot up, a "splash screen" will appear displaying the part number and the checksum for the executable program (see below).



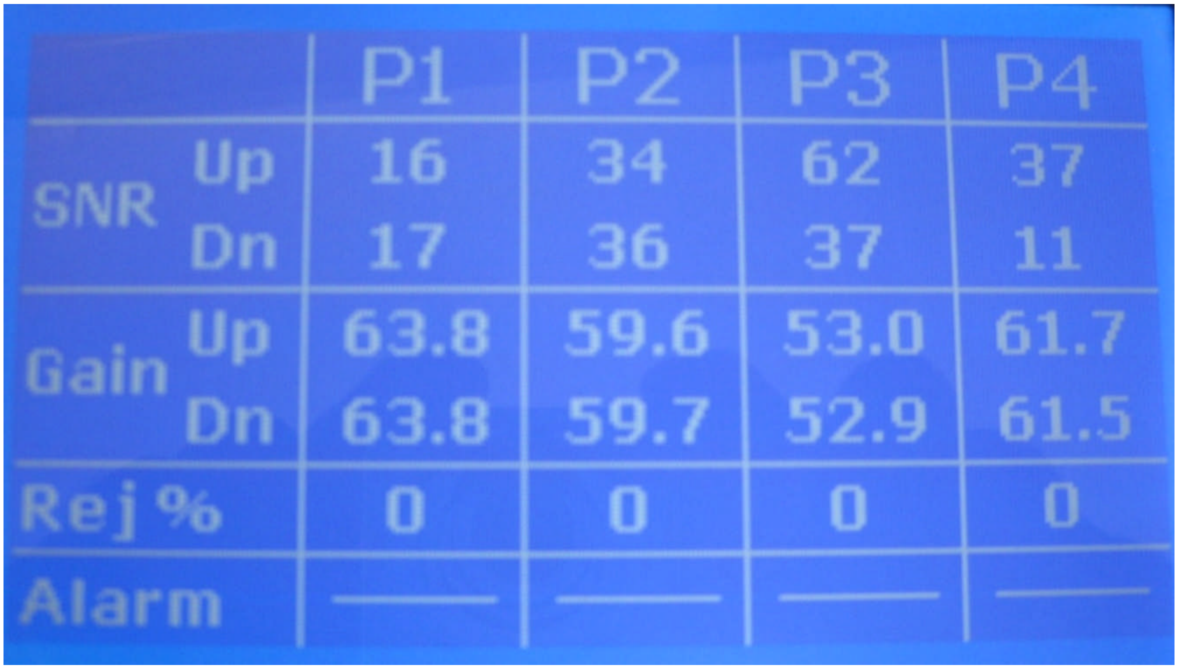
Boot up and Normal Operation Display Screen

Approximately 5 seconds after powering on the transmitter, the following Main Display screen appears displaying the total accumulated volume and the current flow rate. This screen will repeat three times.



Display 1—Main Display Data (repeats 3 times by default)

The second screen in the display cycle contains acoustic path diagnostic data. Information for Paths 5-8 (for an 8 path meter only) will be displayed on the next cycle through the screens.

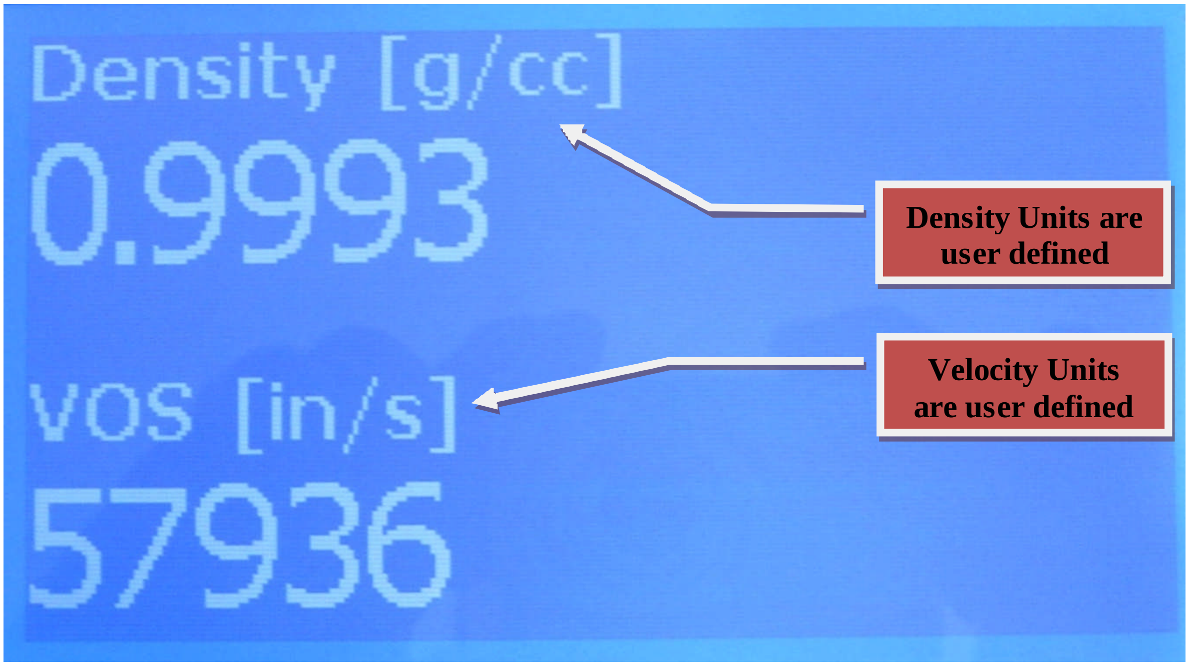


Display 2 - Acoustic Path Diagnostic Data (Four Paths at a Time)

The third screen to appear displays Meter level diagnostic data.

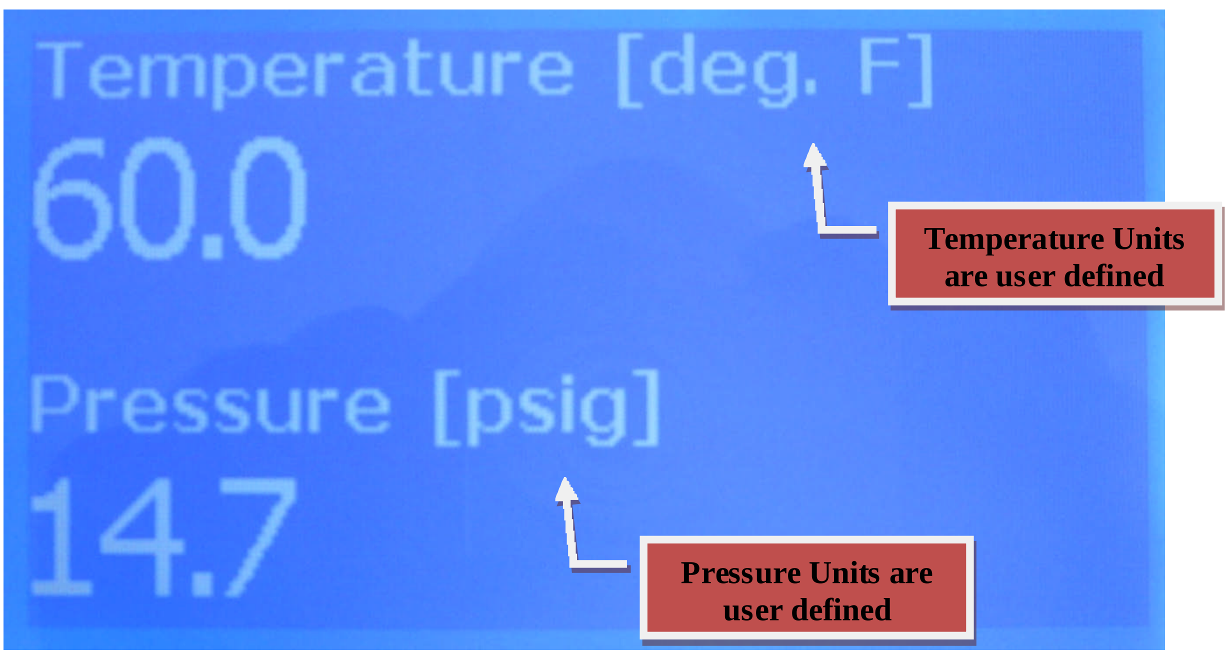
Display 3 – Meter State Display

Following Display 3, the Main Display screen will be displayed and repeat three times. Next will follow the first Fluid Properties screen which displays Density and Velocity of Sound (VOS).



Display 4 – Density and Velocity of Sound

The last screen to appear is the second Fluid Properties screen, which displays Temperature and Pressure.



Display 5 – Fluid Temperature and Pressure

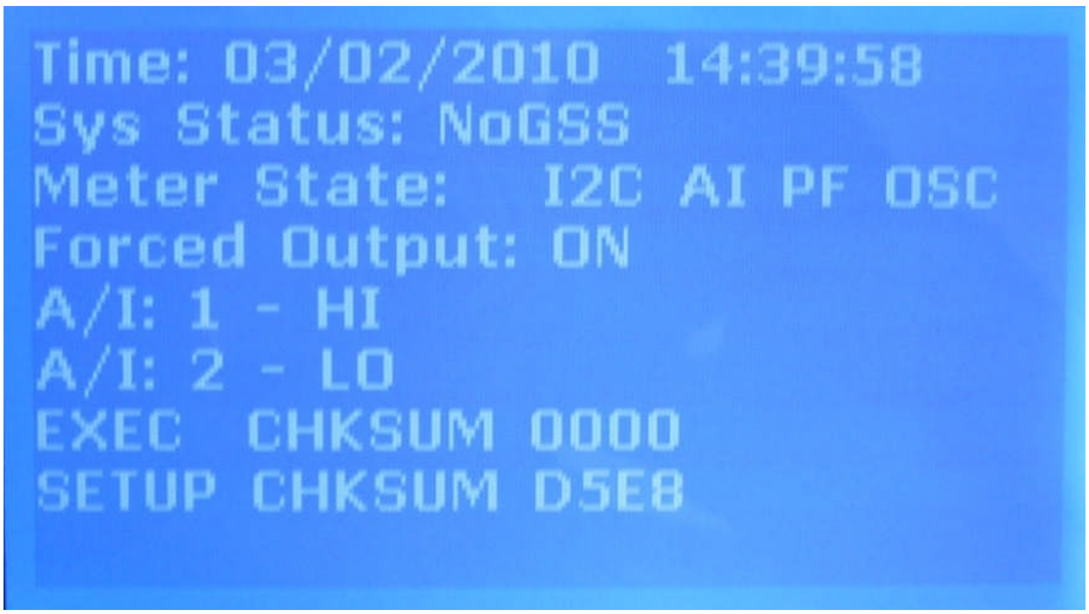
4.4.2 Path Level Alarm Display Screens

When in a Path Level Alarm condition, Display 6 will replace Display 1 (the displays will continue to cycle as in Figure 4-1). The display will contain alarm data on the bottom for each path and will alternate between displaying a flow or a totalizer value at the top. Note Alarm details are handled in Section 6.2.

Display 6 – Main Display with Alarm (for an 8 path meter)

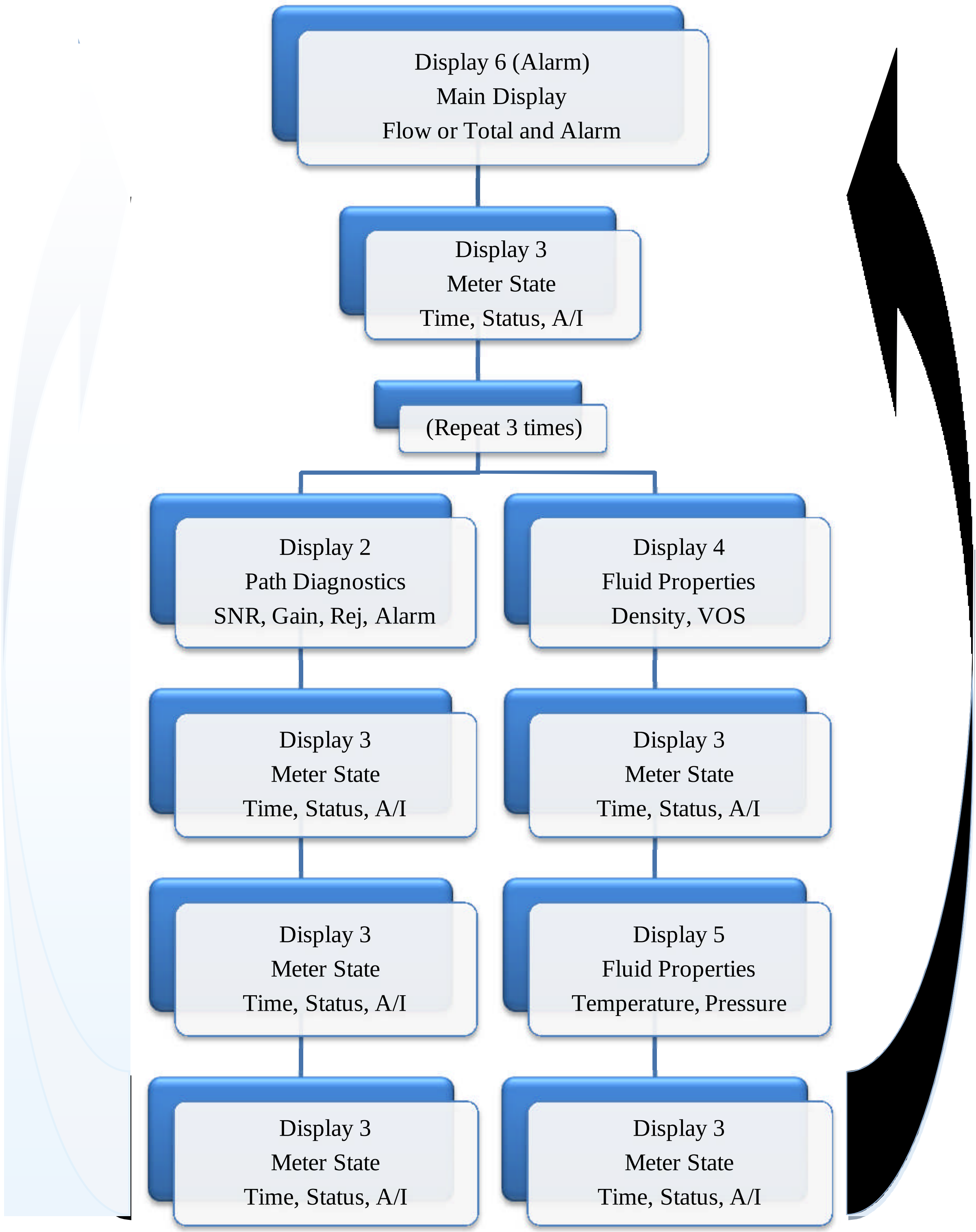
4.4.3 Meter State Alarm Display Screens

If a Meter State alarm condition exists, the displays will cycle as shown in Figure 4-2 with Display 3 (Meter State Display) appearing between every display change.



Display 3 – Meter State Display with Alarm

Figure 4-2: Display Screens in Meter State Alarm Mode



Note that Display 2 will only display four path's information at one time. The first time through the display cycle, Paths 1-4 will be displayed; the second time, Paths 5-8 (for an 8 path meter only) will be displayed.

4.5 Output Test Mode

For test and/or validation purposes, an operator can temporarily override the output of the LEFM 2010FE and set the output to a fixed value using the Output Test mode. The user places the instrument in the Output Test mode using the LEFM Link software. The words "Forced Outputs" will appear on the display during this test.

4.6 Bad Setup File

During boot-up, if the instrument's operational setup becomes corrupted such that the instrument cannot trust its configuration data, or the executable checksum is faulty, the transmitter will wait for a new setup file to be sent. Typically, the configuration data must be reloaded into the instrument to return the instrument to normal operation. While waiting for a new setup file, the transmitter's communication parameters will default to a baud rate of 9600 and a Modbus address of "1". The display is as follows:

Bad Setup File Display Screen

4.7 Switch Forced Setup

If CTC dip switch SW1-8 (see Table 5-2) is set in the UP position during boot-up, the transmitter will wait for a new setup file to be sent before running. While waiting for a new setup file, the transmitter's communication parameters will default to a baud rate of 9600 and a Modbus address of "1". The display is as follows:

Switch Forced Setup Display Screen

5.0 MAINTENANCE

WARNING: NO OPERATOR ACCESS IS PERMITTED IN THE UNIT. SERVICE SHOULD ONLY BE PERFORMED BY QUALIFIED PERSONNEL.

5.1 Introduction

This section provides procedures for troubleshooting and maintenance tasks which personnel can perform on the LEFM 2010FE Transmitter. These procedures may be incorporated into a plant's standard maintenance program.

This section includes procedures for maintaining the LEFM 2010FE Transmitter that are designed for a trained maintenance technician to perform. These procedures may require the maintenance person to reference schematics, system connection diagrams, and construction outlines in Section 1.0.

5.2 General Inspections - Preventative Maintenance Procedures

WARNING

Never open the transmitter or the meter body manifold when the instrument is energized. Before inspecting components, open the power supply circuit breaker. Failure to do so may result in electrical shock.

CAUTION

Wear an ESD protective wrist strap to avoid damaging any components.

HOT SURFACE

Underneath the main chassis, there are heaters that are enabled when the ambient temperature is below 50°F (10°C). Allow heaters to cool whenever disassembling the transmitter.

5.2.1 Enclosure Inspection

Perform the following inspections on each enclosure:

a. Verify electronic unit enclosure has not suffered structural damage. Report any damage to the proper maintenance supervisor.

b. Remove dust, dirt, and other soiling from the enclosure. If necessary, remove power to the LEFM 2010FE by opening circuit breaker CB1.

c. Inspect access cover gaskets. Clean gaskets and mating surfaces on enclosure with water if they are dirty; remove any corrosion from mating surfaces. Verify gaskets compress when the cover is installed and fastened to the enclosure.

d. Inspect door latch mechanism.

e. Lubricate door hinges with lubricant specified on enclosure.

f. Inspect enclosure mounting and fastening hardware.

5.2.2 Internal Electronics Inspection

a. If necessary, remove power to the LEFM 2010FE by opening circuit breaker CB1.

b. Put on an ESD (Electrostatic Discharge) protective wrist strap. Connect ESD protective wrist strap to a known ground; any part of enclosure structure is an acceptable ground.

c. Inspect all cable entry points to assure that the cable insulation is undamaged. Inspect cables that cross hinges to assure that the cable insulation is undamaged.

d. Inspect all cable connections for tightness. Clean the connections if fouled or corroded with electronic contact cleaning fluid.

e. Inspect all internal connections and terminals for tightness. Clean connectors and terminals if fouled or corroded with electronic contact cleaning fluid.

f. Inspect fuses to assure that they are not damaged or discolored. Replace any damaged or blown fuses.

g. Inspect all circuit boards for damage. Check that the printed circuit boards are properly seated. Check that devices are securely mounted. Clean dust and grime from the surface of all components using compressed air or a PC parts cleaner.

h.  **<u>Caution:</u> Heater located behind the top metal panel, allow surface to cool before removing panels.**

i. Clean dust and grime from all surfaces of the enclosure interior walls using compressed air or a PC parts cleaner.

5.3 Power Supply Voltage Troubleshooting and Maintenance

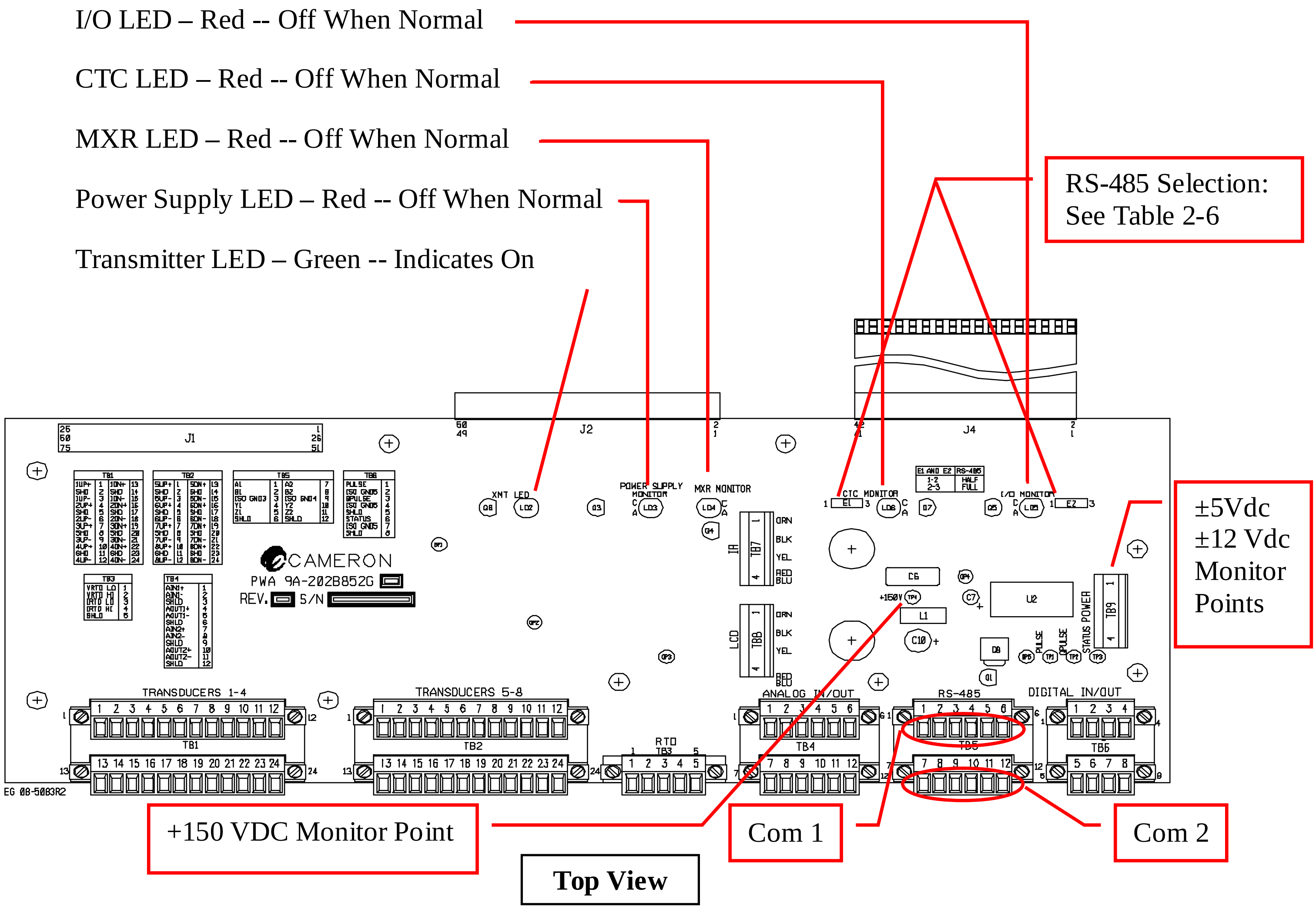


Figure 5-1: Transmitter Assembly Board

If the Power Supply Voltage light is on, check the AC voltage input and then the backplane DC voltage (see terminal block on Figure 5-1, see Table 5-1). If any of the DC power supplies are not functioning properly, then the power supply should be tested and possibly replaced. If any other lights are on, then the applicable board fuses should be inspected and replaced as necessary. The fuse locations are identified in Figures 5-2, 5-3, and 5-4.

The following table provides the specified backplane voltage.

Terminal	Name	Requirement
TB9-1	5 Volts	5 ±0.1 Volts
TB9-2	+12 Volts	+12 ±0.5 Volts
TB9-3	-12 Volts	-12 ±0.5 Volts
TB9-4	Ground	Electrical Ground, 0V

Table 5-1: Required Backplane Test Voltages

5.4 CTC Troubleshooting and Maintenance

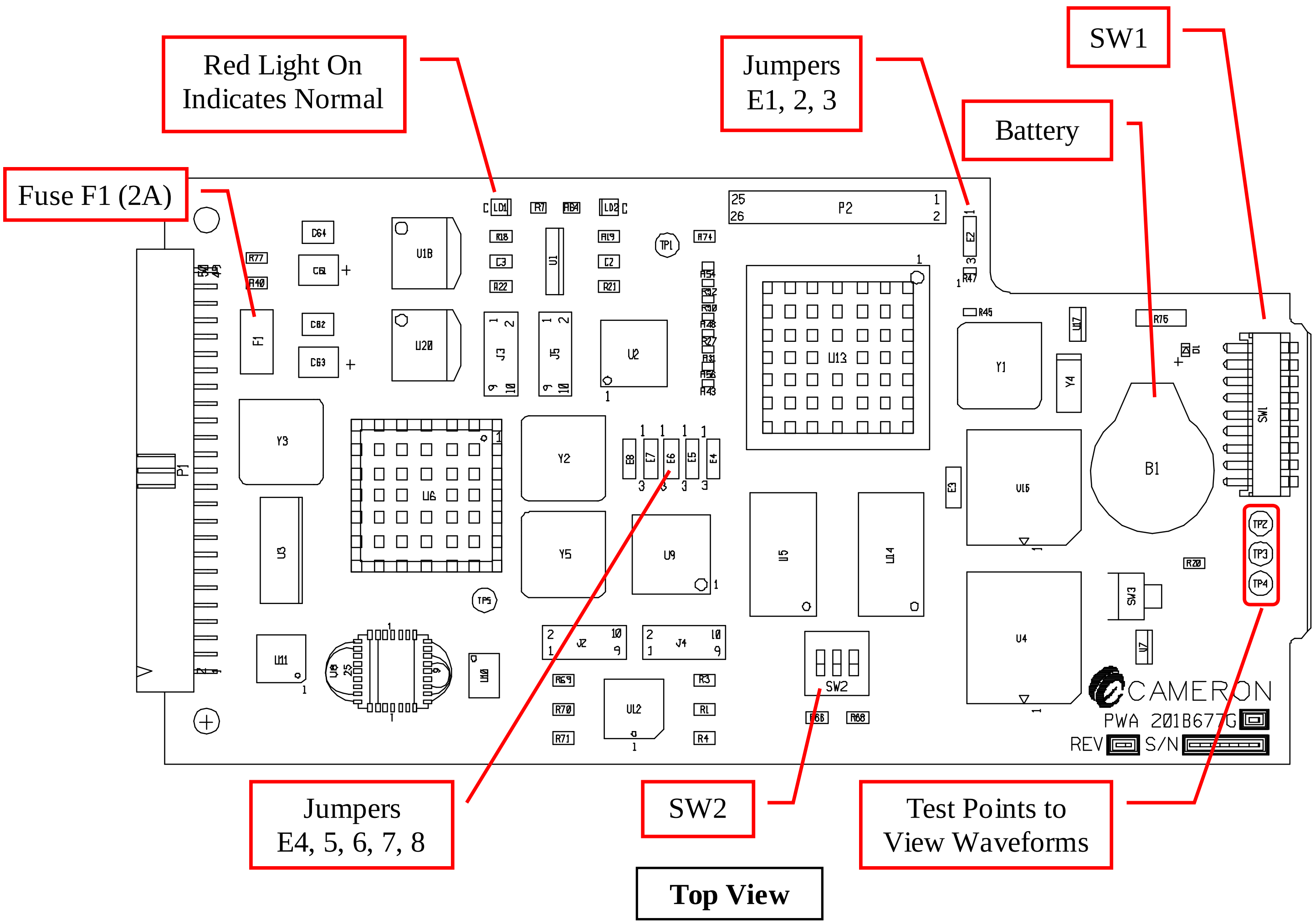


Figure 5-2: CTC Fuse, Switch, and Jumper Locations

The CTC has a battery (B1) in Figure 5-2. The battery (Panasonic CR1632) is used to backup the time and date on the device as well as variables used when acoustic paths fail. Cameron does NOT recommend changing the battery without consultation. It is recommended that the CTC card itself be replaced at that time.

The CTC has DIP switches that can be used to control the board. Typically, the only one ever needed is DIP Switch number 8. This is used if the configuration has been corrupted, putting the CTC into a safe state to have a new setup sent. DIP switches 3, 4 and 5 can be used to set up the oscilloscope test points (which path to select); however, it is recommended to use the LEFMLink 2G software to control test points (reference the LEFMLink 2G manual).

Switch Number Start at Right Side	**Name**	**Function (TRUE = 1 or Up FALSE = 0 or Down)**
1	Plane Select	If TRUE then select Plane B If FALSE then select Plane A
2	Impedance /Acoustic Measurement	If TRUE, the Impedance cycle is triggered for a path If FALSE, the Acoustic cycle is triggered for a path
3 and 4	Path Select	Binary Representation of the path number on the board. The MSB is switch 3. <u>34 – Path x</u> 00 – Path 1 01 – Path 2 10 – Path 3 11 – Path 4
5	Up/Down Select	If TRUE, the Triggering Path is the down transducer transmitting If FALSE, the Triggering Path is the up transducer transmitting
6	Echo or Direct	If TRUE, the Triggering Path is an echo signal If FALSE, the Triggering Path is a pitch-catch signal
7	Analog Mode	If TRUE, the software bypasses the digitization steps and runs off analog mode data. If FALSE, software is in normal mode
8	Wait for Setup	If TRUE, the hardware waits for a setup before running. Modbus address is 1, RTU mode and Baud rate is 9600. If FALSE, software starts running with existing setups.
9	Field Burn	If TRUE, and ALL other switches true – Field Burn Mode If FALSE, Normal Mode ADDITIONALLY – If TRUE, the Altera Watchdog Reset is DISABLED, else the Altera Watchdog Reset is ENABLED. When debugging, this switch should be TRUE.

Table 5-2: Dip Switch (SW1) Settings

The CTC dip switch (SW1) settings are described in Table 5-2.

5.5 MXR Troubleshooting and Maintenance

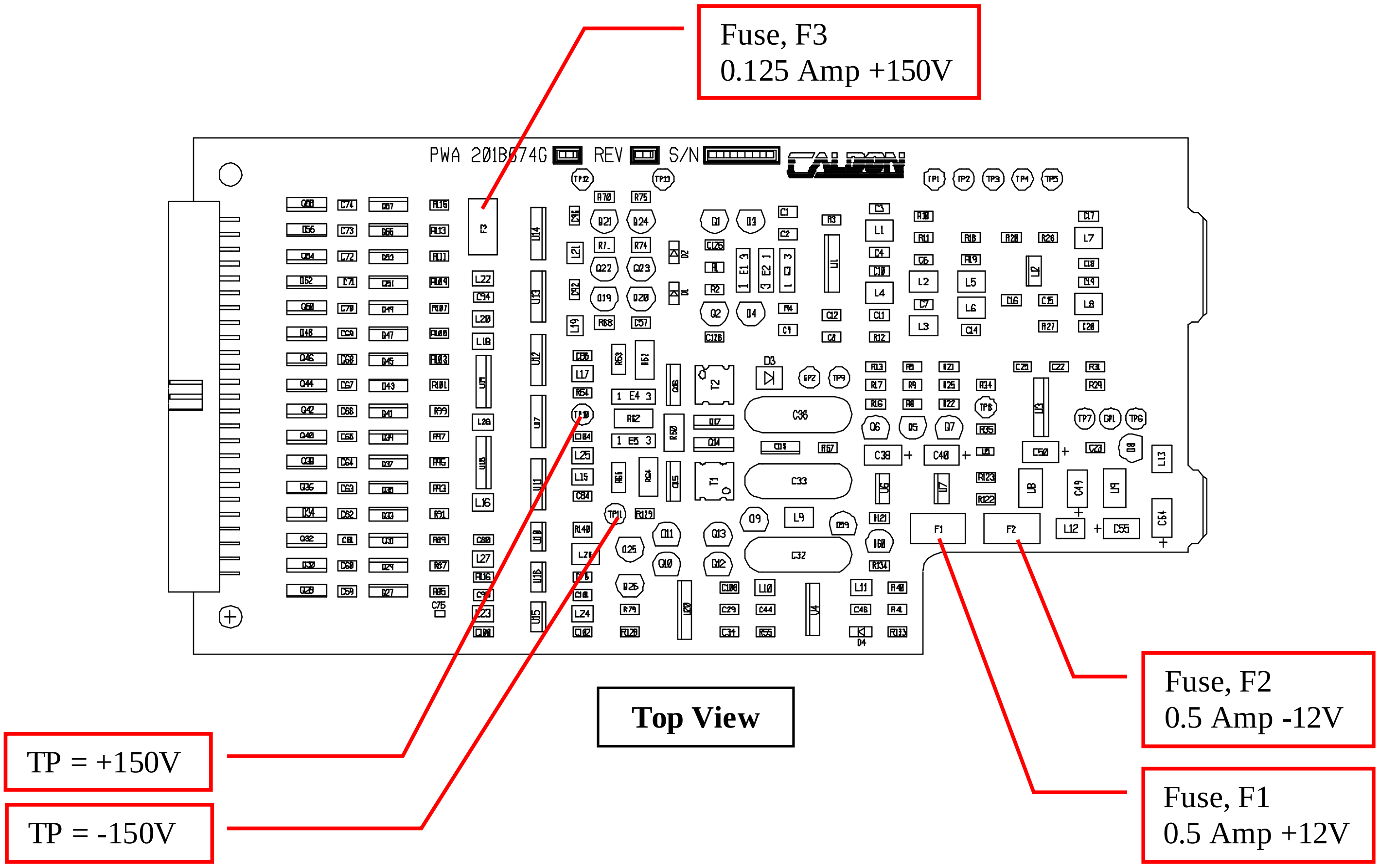


Figure 5-3: MXR Fuse Location

5.6 IOB Troubleshooting and Maintenance

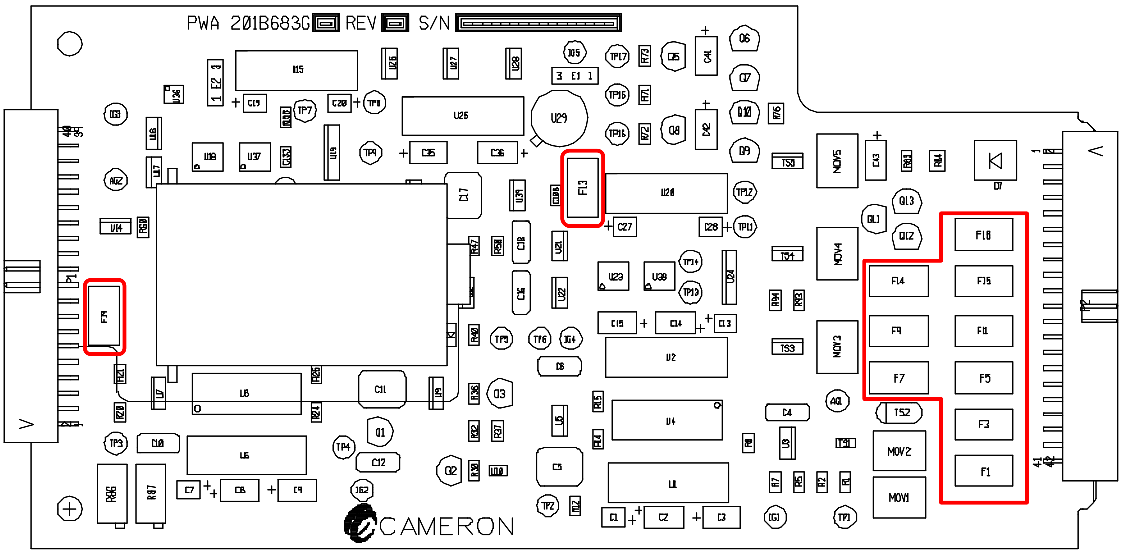


Figure 5-4A: IOB Fuse Location – Top View

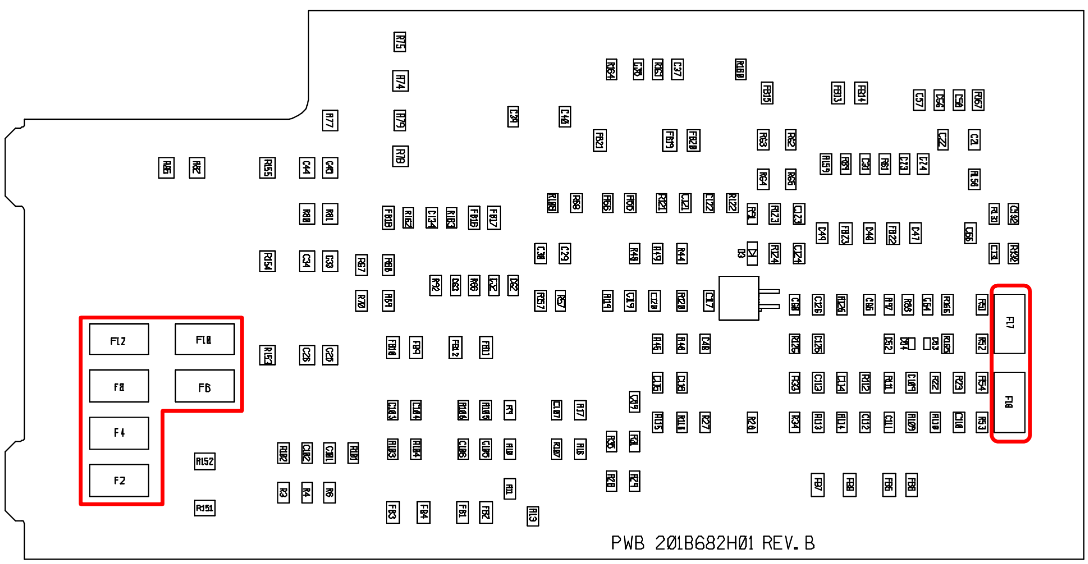


Figure 5-4B: IOB Fuse Location – Rear View

Fuse	Side	Rating (mA)	Purpose
F1	Front	125	Analog Input
F2	Back	125	Analog Input
F3	Front	125	Analog Output
F4	Back	125	Analog Output
F5	Front	125	RS485 A1
F6	Back	125	RS485 B1
F7	Front	125	RS485 Y1
F8	Back	125	RS485 Z1
F9	Front	125	RS485 A2
F10	Back	125	RS485 B2
F11	Front	125	RS485 Y2
F12	Back	125	RS485 Z2
F13	Front	125	Pulse Output (ALL)
F14	Front	125	Pulse Output (Pulse)
F15	Front	125	Pulse Output (QPulse)
F16	Front	125	Pulse Output (Status)
F17	Back	500	+12V Monitor
F18	Back	2000	+5V Monitor
F19	Front	500	-12V Monitor

Table 5-3: IOB Fuse Location and Rating

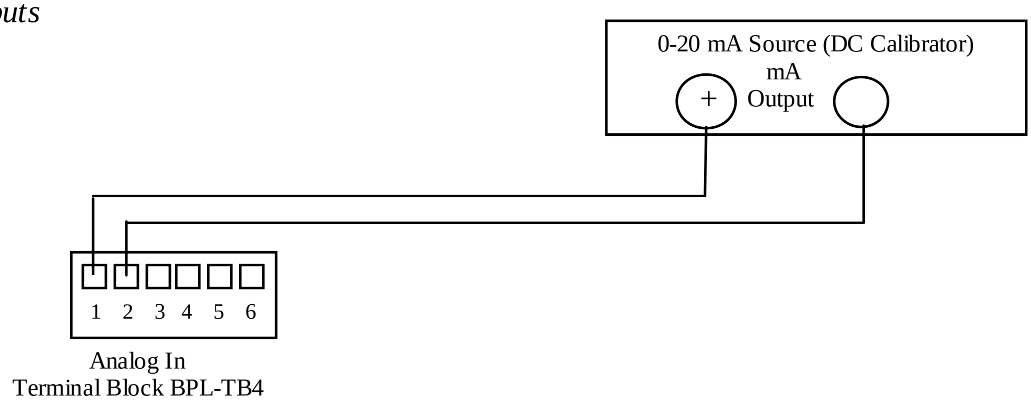
5.7 Analog Input/Output Verification Procedure

This procedure tests the analog inputs and outputs of the LEFM 2010FE Transmitter. The Transmitter, through the use of an input/output board (IOB), converts an isolated analog input signal (current) into a voltage readable by the CTC board. The IOB accepts an input (0 – 20 mA) and produces a DC output (0 – 5V). The IOB's analog output converts a voltage produced by the CTC board (0 to 5 VDC) into an isolated current (0 – 20mA). These signals are routed to and from the CTC board through the backplane (BIB).

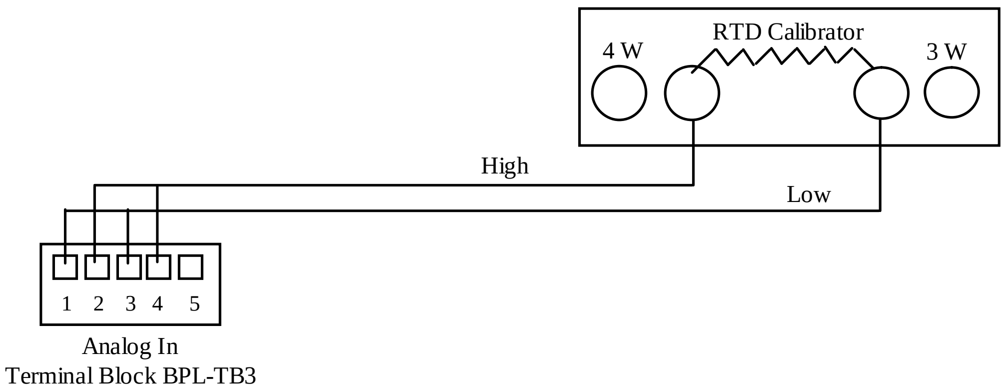
5.7.1 Current Inputs

Step 1: Connect the test equipment as follows:

Current Inputs



RTD Inputs



Analog Outputs

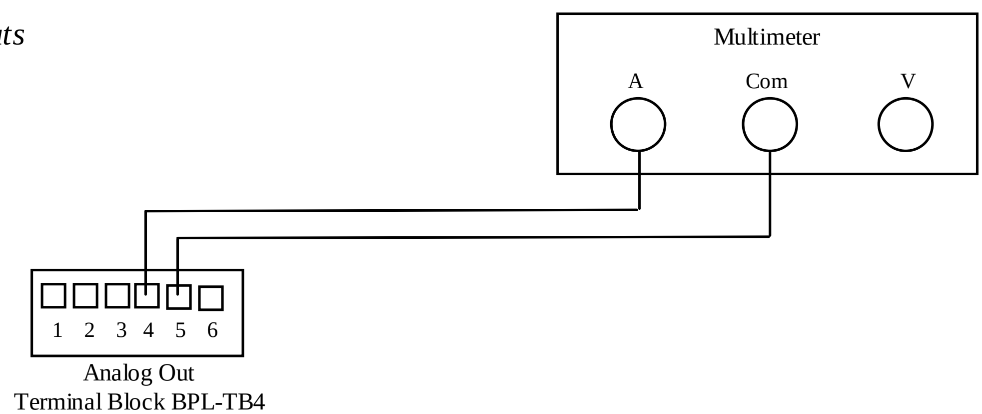


Figure 5-5: Analog Input/Output Connections

Refer to Table 5-3 for the specific connection terminals on EUA.

Analog Input				
A/D Channel	(+) Excitation	Positive Terminal	Negative Terminal	(-) Excitation
1	N/A	BPL-TB4-1	BPL-TB4-2	N/A
2	N/A	BPL-TB4-7	BPL-TB4-8	N/A
RTD	BPL-TB3-2	BPL-TB3-4	BPL-TB3-1	BPL-TB3-3
Analog Output				
D/A Channel		Positive Terminal	Negative Terminal	
1		BPL-TB4-4	BPL-TB4-5	
2		BPL-TB4-10	BPL-TB4-11	

Table 5-4: A/D Test, Terminals and Adjustments

Step 2: Establish communications with a PC that has the "LEFM Link" interface. Open the "LEFM Link" software interface and verify communication. Send a setup file with the analog input scaling determined during the system FAT. Under the "Update Scaling" tab, choose "Scale Analog Inputs". From the drop down list, select the appropriate choice (to test channel two choose "Temperature", to test channel one choose "Pressure", etc.). Scale the analog inputs appropriately (for RTDs these values will correspond to the minimum and maximum values in degrees F). Click "Accept" then view the converted values under "Temperature" on the main screen (reference the LEFM Link PC Interface Users Manual).

Step 3: Set the DC calibrator for 4.000 mA. Verify the analog input values (converted "Temperature" values on LEFM Link) correspond to those listed in Table 5-5. Record the analog input current.

Input
4.000 (±0.1 mA)
8.000 (±0.1 mA)
12.000 (±0.1 mA)
16.000 (±0.1 mA)
19.000 (±0.1 mA)

Table 5-5: Analog Test Values

Step 4: Confirm that each converted input value agrees within ± 0.1 mA of the expected value shown in Table 5-5.

5.7.2 RTD Inputs

Step 1: Connect the RTD calibrator as shown in Figure 5-5. Using LEFM Link, scale the analog inputs according to the specific RTD used. Using the RTD Calibrator, input five temperatures (equally separated and covering the range of the module).

Step 2: Verify that the converted value ("Temperature" on LEFM Link) agrees with the input temperature (RTD Calibrator) within ±0.5 degrees (F).

5.7.3 Analog Outputs

Step 1: Connect the test equipment as shown in Figure 5-5.

Step 2: Use LEFM Link to force the analog outputs. The output forcing requires a percent full scale value to be entered according to Table 5-5. Enter the value into LEFM Link Output forcing for the desired channel and click on "calibrate". After the transfer takes place, read the corresponding value from the multimeter. (Note: The acoustic path must be in "normal" analog output channel forcing to function properly. This is also dependent on the "path type" parameter in the setup file.

Step 3: Confirm that each converted output value agrees within ± 0.04 mA of the expected value shown in Table 5-6.

Percent Full Scale	Expected Output
20%	4.000 (±0.04 mA)
40%	8.000 (±0.04 mA)
60%	12.000 (±0.04 mA)
80%	16.000 (±0.04 mA)
95%	19.000 (±0.04 mA)

Table 5-6: Analog Output Values (0 to 5V / 0-20mA)

5.8 Analog Input Verification

The LEFM may have an analog input (for example, temperature, pressure, or density). The input signal is conditioned before it is converted to a digital input.

The input is scaled linearly to convert the user input of 4-20 mA (or 0-20 mA) to maximum and minimum values. Analog input ranges can only be adjusted via the LEFMLink software interface (see the LEFMLink manual for instructions).

Failed inputs result in readouts at their lowest range. For example, a 4-20 mA pressure input scaled to 0-1000 psig will go to 0 psig if the input is removed.

5.9 Analog Output and Pulse Output Verification

The digital output channels consist of an analog output and a pulse output. The current output channel has a 0-20 mA range. The pulse output has a range of 0 to 5V or 0 to 12V. There are no adjustments to be performed for the analog or pulse outputs. The analog output can be mapped to any Modbus input register for maximum flexibility. By default, the analog output is mapped to read flow.

5.9.1 Force Output (Analog)

The analog output is scaled linearly between its maximum and minimum values. Use the force output function of LEFMLink software to test the scaling of the analog output with input site devices. (See the LEFMLink Manual for detailed instructions).

5.9.2 Force Output (Pulse)

Similar to calibrating the analog outputs, a fixed frequency may be forced out of the transmitter pulse output. To verify the pulse output using a forced output, follow the instructions in the LEFMLink Manual.

5.9.3 Changing Digital Output Voltage

The pulse output and digital output can be configured for either 5 VDC or 12 VDC. This is done by changing jumper E1 on the IOB. See Figure 5-6 to locate jumper E1.

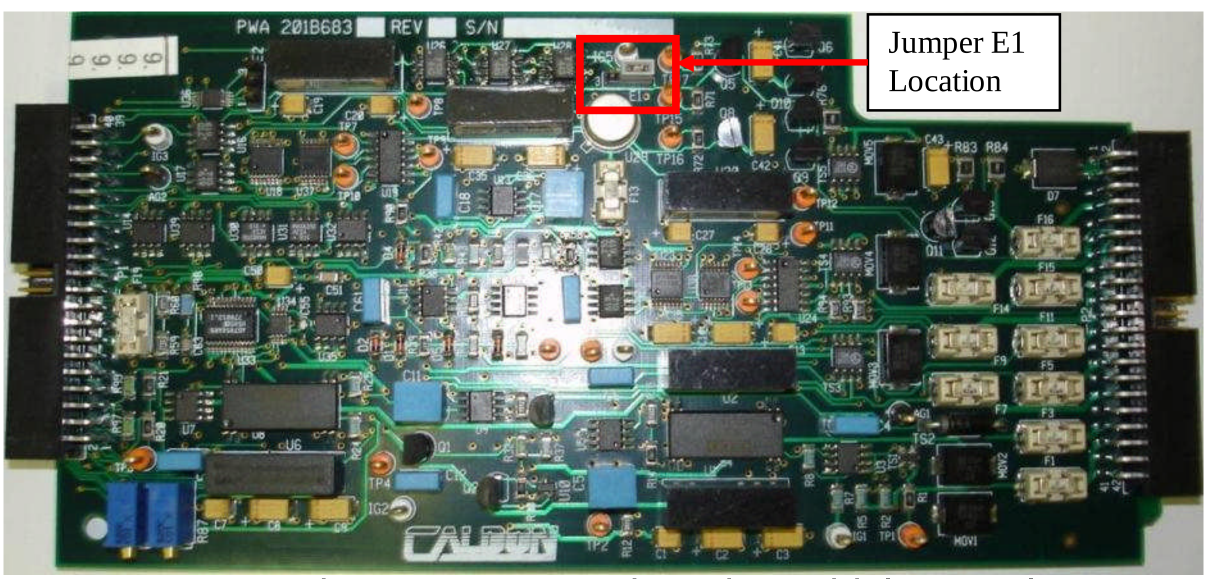


Figure 5-6: Jumper Location to change Digital Output Voltage

Table 5-7—Digital Output Voltage Jumper Positions

Jumper Position	Voltage
1-2	5V
2-3	12V

5.10 Metering Section and Transducer Cables

5.10.1 Metering Section Inspection

HOT SURFACE

Some steps in this procedure may require handling components at temperatures approaching 500°F (260°C) - if performed when the power plant is operating. Use insulated gloves to perform this procedure. Observe good safety practice to avoid burn injuries.

Perform the following inspection and maintenance tasks:

a. Inspect the metering sections(s) and verify it has not suffered any damage (rings, rails, the mounting hardware, etc.). If it appears to have suffered damage, contact Cameron.

5.10.2 Transducer Cable Inspection

Inspect transducer cables as follows:

a. Verify each transducer cable has not suffered any damage. Check connectors on cables at each end to verify each is undamaged. Clean connector with electronic contact cleaner if fouled or corroded. Replace any damaged cable or connector.

b. **Disconnect transducer cables from transducers.** Check continuity and isolation of cables.

c. If necessary, a meggar can be used to test the cables/transducers. If the cable/transducer impedance is less than 10 Megohms, then they may need to be replaced or repaired. DO NOT USE voltages over 250V.

d. Reconnect cables when inspection is complete.

5.11 Transducers

In the event of a poor transducer signal (or none at all), the transducers may need to be recoupled or replaced for that path (this procedure is detailed in EFP20). The system will require verification when a transducer is replaced or recoupled.

HOT SURFACE	**Some steps in this procedure may require handling components at temperatures approaching 500°F (260°C) - if performed when the power plant is operating. Use insulated gloves to perform this procedure. Observe good safety practice to avoid burn injuries.**

The transducer should be evaluated using the following steps:

Step 1: Power down the LEFM 2010FE transmitter (set circuit breaker to the right hand position) and remove the transducer assembly (see EFP20).

Step 2: Verify the transducer pad or wedge is clean and free from dirt. Remove any dirt or foreign material that may be present.

Step 3: Clean the pipe surface so that it meets the requirements of EFP27.

Step 4: Verify that the pipe side surface of the transducer pad or wedge is not cracked. A dye penetrant test can be done on the surface to identify any cracks that may affect the meter's performance.

Step 5: Replace the foil couplant with a new piece.

Step 6: Reinstall the transducer, energize the system, and verify the signal.

Step 7: If the signal is still not acceptable, remove and replace the transducer with a new one.

6.0 TROUBLESHOOTING AND DIAGNOSTICS FOR THE ULTRASONICS

6.1 Diagnostics

The LEFM 2010FE Transmitter interfaces via a serial port or infrared port to external devices. The Transmitter uses the Modbus protocol. Cameron provides PC (laptop) software, LEFM Link, to interface with the Transmitter via Modbus. Alternatively, the Cameron Modbus manual can be used to select the appropriate registers.

Note: Throughout the remainder of this manual, values such as path SNR (Signal to Noise Ratio), gain etc. are discussed as if the reader is using the Cameron provided LEFM Link software (Modbus register addresses will not be mentioned).

For detailed information on using LEFM Link-2G see the LEFM Link-2G User's Manual.

6.2 Alarm Conditions

The LEFM 2010FE's automatic fault detection system is specially designed to verify the performance of the transducers and transmitter electronics and to alert personnel when abnormal operating conditions are detected. It detects faults in three basic steps:

1. The fault detection system checks the data quality for ultrasonic paths and evaluates the data against thresholds. Data evaluation is based on signal to noise ratio (SNR), cross-correlation tests and signal statistics.
2. For each ultrasonic path, the transmitter determines if the path has failed.
3. If an ultrasonic path continues to fail, the meter will alert the operators to a potential problem by generating an "ALARM" status and an error code

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Note – Occasional rejected or bad data will not generate an alarm status; only a repetitious pattern of rejected or bad data will result in an alarm status.

The transmitter outputs the Meter status via the serial port and the digital output. The Meter status is also presented on the display screens as detailed in the next section.

6.3 Meter Troubleshooting

The following codes are used to indicate the Meter State alarms as shown on the Meter State Screen (reference Display 3 – Section 4.4.3):

Alarm	Description	Display Code	Modbus Code
Normal	All path are operating normally		0
Cross Path VOS	Cross path VOS measurements do not agree with the diagonal path VOS measurements	CPV	3
Internal Communication	Internal communication issue between the IOB and the display	I2C	4
Analog Input	An analog input has failed one of its tests. The inputs can fail for being out of range (HI or LO) and is shown on the Meter State display	AI	5
Path Failure	One or more of the paths are in fail	PF	6
Clock Failure	The 100 MHz clock is out of tolerance	OSC	8

Table 6-1: Meter Alarms

6.3.1 Cross Path VOS

This test compares the average cross path sound velocity to the average diagonal path sound velocity. If the measurements differ more than the threshold, the system will display this alarm and use the sound velocity as measured by the diagonal paths to determine system temperature.

This alarm will be present if a failed cross path affects the average VOS measurement enough to exceed the threshold. Troubleshoot each cross path per Section 6.4 below.

6.3.2 Internal Communication

This is a test that checks the internal communication of the hardware. If this test is failed, replace the CTC board.

6.3.3 Analog Input

If an analog input is outside the minimum and/or maximum range, this alarm will be displayed.

Step 1) Check Input Instrument

If the analog input value outside the range (current is less than 4 mA or greater than 20 mA for pressure inputs or the resistance is less than 61 Ohms (-100°C) or greater than 224 Ohms (300 °C) for the RTD), troubleshoot the transmitting device and recalibrate or replace/repair as necessary.

Step 2: Check Power Supply

Verify the +5 VDC power supply at BPL-TB9-1. If the +5 VDC input is bad, then replace/repair power supply.

Step 3: Check the IOB

The analog input circuitry may be bad on the IOB, or a fuse may be blown. Check for any damaged fuses and replace if necessary. If none of the fuses are blown, then replace the IOB.

6.3.4 Path Failure

This alarm identifies that a path level alarm exists. See Section 6.4 for path level alarm details.

6.3.5 Clock Failure

The MXR board contains two highly accurate oscillators used in the timing and signal processing. A 100 MHz clock is used to measure the acoustic path timing (TDown and Tup) while a 5 MHz clock controls the path to path timing, range-gating, and other signal processing functions. This test compares the 100 MHz oscillator against the 5 MHz counter and compares the percent difference between them against a threshold.

If this alarm is displayed, the CTC board should be replaced.

6.4 Path Troubleshooting

The LEFM 2010FE System continuously checks the data quality of each acoustic path. Each time the signal is sampled, the MXR/CTC tests the signal as follows:

- Verifies path’s signal to noise ratio (SNR) is higher than its threshold value.
- Correlates the Upstream Signal with the Downstream Signal to test for “cycle skipping”. The MXR/CTC rejects data that does not pass this correlation test.
- Verifies the statistics of the computed transit time and Delta T are acceptable.

For the ultrasonic signals, the most frequently used diagnostic information will be the following:

- Rejects (%) Range: 0 – 100%, normal operation: 0 – 5%
- Gain (up/down) Range: 0 – 88dB, normal operation: 40dB – 70dB
- SNR Range: 0 – 100, normal operation: >15

The following codes (reference the LEFM Modbus manual) indicate the status of each acoustic path:

Alarm	Description	Display Code	Modbus Code
Normal	Path is operating normally		0
Rejects	Path is rejecting data due to low SNR, irregular statistics, or failing transit time tests	REJ	1
Calculation	Path has an input entry error	CALC	4
Iteration	Path dimensions do not agree with the timing measurements	ITER	5
Velocity of Sound	Path sound velocities are inconsistent with thresholds	VOS	6
Velocity Outlier	Path velocities are inconsistent (this test is for applications with low flow rates (~1 ft/sec))	↓↓↑↓	8
Impedance	Path fails an impedance self-test	OHMS	10

Table 6-2: Path Alarms

NOTE: Cameron interface software interprets these codes and displays a text message.

6.4.1 Path Reject Status

When the path status indicates that the Reject Test failed, it indicates that the percentage of data that has been rejected has exceeded the LEFM 2010FE System thresholds. The following troubleshooting sequence can be followed to pinpoint the root cause.

Step 1: Verify that the metering section is full of liquid.

Step 2: Verify continuity for all cables.

Step 3: Check all power supply voltages.

If the LED for any power supply is not lit on the top edge of the CTC card, then the fuse may be blown, or the power supply has failed (see Section 5.3).

Step 4: Check path gains (via Modbus or LEFM Link Interface Software). If the path gains are high (70db and higher), then the signals may be too weak to operate. Weak signals can be caused by any of the following (listed from most likely to least likely)

- Line is not full of liquid.
- Cable/wire from the meter to the transmitter is damaged or not landed properly
- Transducer coupling needs to be replaced
- Transducer has failed

Step 5: Determine Which Transducer Has Failed

Using the acoustic paths, follow these steps to determine which transducer to evaluate:

- Review the SNR (Signal to Noise Ratio) for each path (paths 1 through 8). The SNR should be greater than 15.
- Review the gains for each acoustic path (both upstream and downstream). The gains should be between 40dB and 70dB. Upstream and downstream gain should nominally be within 3 dB of each other.
- Review the percent rejected data for each path. The percent should be between 0 and 5%.
- If all paths are in fail, not just one, then either the meter has no liquid or an electronics hardware failure has occurred.
- If a path has 100% rejects it means the MXR/CTC cannot lock onto a signal. It is possibly a cable or transducer problem. Note: When rejects equal 100% then the MXR/CTC will always indicate SNR=0 for the path.

If an acoustic signal does not exist, or if SNR has degraded from installation, then follow checklist below:

- Verify the pipe is full of liquid.
- Check the impedance of the transducer cable. If cable impedance is less than 10 Megohms, then replace/repair cable.
- Check continuity of transducer cable. If transducer cable continuity impedance is infinite, then repair/replace cable.
- If a signal is present, the ultrasonic transducer may need to be reseated, or the acoustic coupling may need to be replaced.

Being able to view and understand the acoustic signals can be very helpful within the troubleshooting process.

- To observe the waveform from a received transducer signal, connect an oscilloscope to the "Receive" test point (TP04) on the front edge of the CTC card and connect the probe's ground to TP00 (reference Figure 5-2). Next, connect the oscilloscope's "external trigger" to the "trigger" test point (TP03) on the edge of the APU card. An external trigger level of 3-4 volts is appropriate for most oscilloscopes.
- With the oscilloscope vertical scale set to 1 volt/division and the timebase set to 2 μsec/div, the transducer signal waveform should be similar to that shown in Figure 6-1.

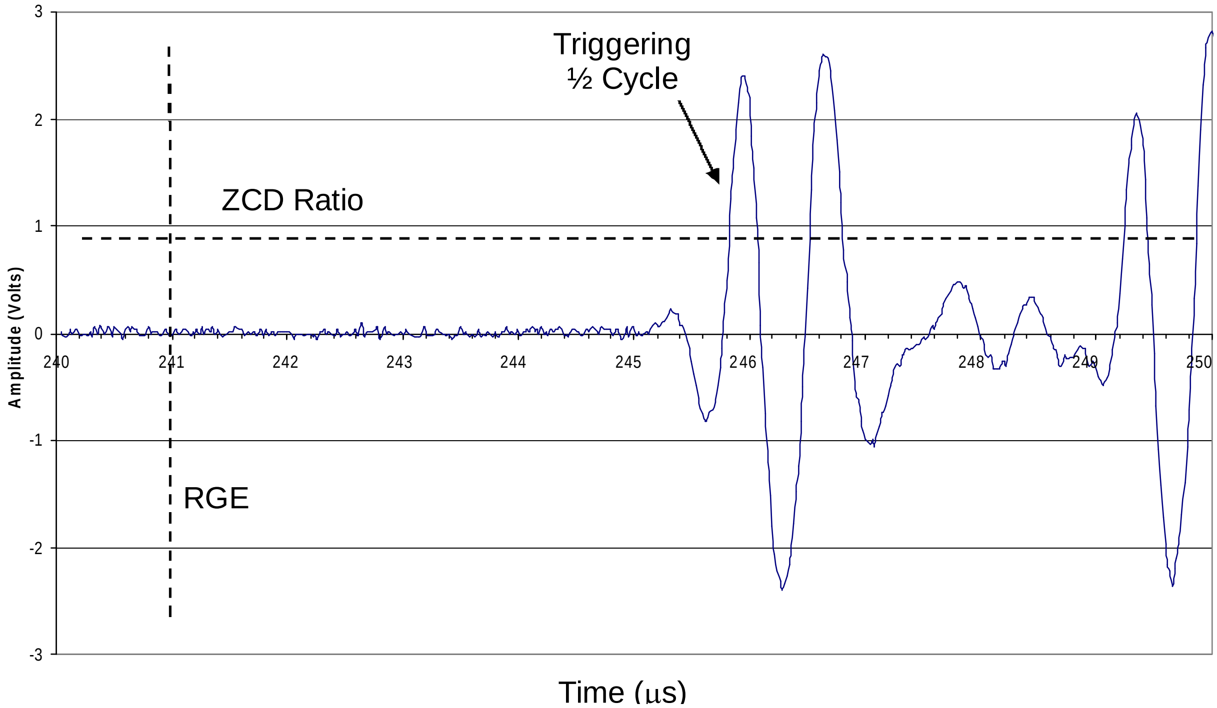

Figure 6-1: Example Transducer Waveform

- Individual acoustic path waveforms can be viewed by using the Dip Switches (SW1) on the front side of the CTC (reference Figure 5-2). Use Table 5-2 to determine the Dip Switch positions for the different paths.

If the transducer signal strength has decreased, or the level of coherent or random noise has increased, from the time of commissioning or last service a failure of that transducer path may be impending. Being able to measure and record these values is important.

- Measure the magnitude of the triggering half-cycle and the following negative half cycle (see sample waveform in Figure 6-1) using the averaging function (4 - 8 samples) of the oscilloscope. Calculate the signal strength as follows:

$$V_{signal} = V_{positive\ 1/2\ cycle} - V_{negative\ 1/2\ cycle}$$

- Use the oscilloscope averaging function (128 samples or greater) to measure the peak-to peak coherent noise magnitude, $V_{noise\ C}$, preceding the received signal. Calculate SNR_C as follows:

$$SNR_C = V_{signal} / V_{noiseC}$$

  The calculated SNR_C should be greater than 20:1 for diagonal paths and 10:1 for cross paths.

- Use the oscilloscope enveloping function (128 samples or greater) to measure the random noise magnitude, V_{noiseR}, preceding the received signal. Calculate SNR_R as follows:

$$SNR_R = V_{signal} / V_{noiseR}$$

  The calculated SNR_R should be greater than 5:1.

6.4.2 Calculation Error

This alarm alerts users to a computational failure within the LEFM 2010FE software. An illegal operation or attempting to divide a number by zero will trigger this alarm. Most often this alarm is displayed during the meter setup if a wrong value is entered. After the system is operational, this alarm should not occur.

6.4.3 Iteration Failure

This alarm occurs when the acoustic path timing data is not consistent with water's sound velocity/temperature characteristics. That is, given an acoustic path length, the measured path timing is inconsistent with water fluid properties. As with the above alarm, it is typically triggered by an input entry error and, after the system is operational, this alarm should not occur.

The exception is operation when the fluid temperature is between 140°F (60°C) and 220°F (104°C). In this range, the software has difficulty calculating the fluid temperature. For this, Cameron recommends an RTD input.

6.4.4 Velocity of Sound Failure

If all cross paths are operating in "digital mode" and are calculating path sound velocities, a speed of sound test is performed. In this test, each cross path's sound velocity is compared to the average cross path sound velocity and, if the difference exceeds the threshold, a path failure is produced.

The following troubleshooting sequence can be followed to identify the root cause.

Step 1: Review the performance of the failed path using LEFM Link and an Oscilloscope.

This step is to determine if a path failure, cycle skipping or cable polarity change is the root cause. While the data quality tests will typically detect cycle skips, in the case of a re-wired component (for example, a new transducer has been installed) a cycle skip may not be detected.

Using LEFM Link, review the acoustic path data quality (rejects, gain, SNR, etc.) and compare them with previous data. Using an oscilloscope, verify that a cycle skip is not occurring. Also, confirm that the signal polarity is consistent with the system documentation.

Step 2: Verify the Tau values are correct with commissioning documentation.

Upload the *.cal file from the transmitter and verify that the Tau values are consistent with the system documentation.

6.4.5 Velocity Outlier

This test is only performed at extremely low flows (~1 f/s) and is not performed at flow rates typical to nuclear power plant applications.

6.4.6 Impedance Failure

This test measures the impedance of the positive (+) and negative (-) polarity to ground on each transducer pair (+UP, -UP, +DN, -DN). A measured impedance less than the threshold results in this Fail state.

The following troubleshooting sequence can be followed to pinpoint the root cause(s). Note that if all paths are failing this test, then the problem most likely exists with the MXR board.

Step 1: Disconnect the transducer cables for the failed path from the transmitter. If this does not eliminate the Impedance failure, then the problem is most likely located in the MXR board and it should be replaced.

Step 2: If disconnecting the transducer cables for the failed path eliminates the impedance failure, then the problem is located in the cables or transducers. Reconnect the cables and disconnect the transducers. If the alarm returns, the cable will need to be replaced. If the alarm does not return, than the transducer will need to be replaced.

6.5 Reprogramming the Transmitter

While it is not likely, there may be a time that the transmitter may need to be reprogrammed.

This would typically occur when a CTC Board has been replaced with an inventory item, not specifically assigned to a given metering section. It is Cameron’s policy to provide a configuration file for each metering section. This configuration file includes:

- All pipe dimensions
- Transducer frequency
- Acoustic path lengths and angles
- Meter factor
- Alarm settings
- Analog input/output scaling

Cameron maintains records and configuration files for all Cameron commissioned metering sections. The simplest way to reprogram a transmitter is to use Cameron’s PC interface software. The procedure is as follows:

1) Select appropriate Modbus ID and Baud Rate (See Section 6.5.1)
2) Select the configuration file for the meter body
3) Send the Configuration File

Once these steps are complete, the transmitter is reprogrammed.

The transmitter may also be reprogrammed through Modbus using the site interface; however, it is not recommended to do the reprogramming this way. Given that there are many registers to load, the process will be tedious and prone to errors.

6.5.1 Modbus ID and Baud Rate

All Cameron transmitters are programmed with Modbus ID set to 1, Baud Rate at 9600 and in RTU Slave Mode. If the transmitter has been reprogrammed with a different setting and this setting is not known or lost, simply set Control Selector switch (DIP Switch) Number to 2 to up (TRUE) and toggle the reset switch. Resetting the transmitter in this mode forces the transmitter to operate with its default settings. In this mode the transmitter will wait for a new setup before restarting; **MAKE SURE YOU HAVE THE CORRECT SETUP FILE FIRST!**

7.0 RECOMMENDED SPARE PARTS

Qty: 5 F1 - Littelfuse 154.125 – 125mA fast acting (FF)

Qty: 1 F2 - Littelfuse 154.2 – 2000mA fast acting (FF)

Qty: 2 F7/F10 - Littelfuse 154.5 – 500mA fast acting (FF)

Qty: 1 CTC Board – 9A-201B677G02

Qty: 1 MXR Board – 9A- 202B874G04

Qty: 1 IOB – 9A-202B852G01

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Sensia LLC
200 Westlake Park Blvd
Houston, TX 77079
+1-866-773-6742
sensiaglobal.com

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Rockwell Automation + Schlumberger