programmable
flow processor
remote terminal unit

FP-93 Flow Processor
Operation & Maintenance Manual

FP-93

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ISO 9001 QUALITY SYSTEM CERTIFIED
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Section 1 - Installation

1.1 Mounting (Panel)

The panel mount version of the FP-93 is a device requiring a panel cutout 6.06" x 2.56", with 8" minimum clearance behind the panel if the DIN connector is used for the power supply connection or if the communication interface is used. Otherwise, the minimum clearance behind the panel is 6.5", which will allow 0.25" clearance behind the terminal block for wiring. The FP-93 is held in place using a spring clip, as shown in Figure 1.

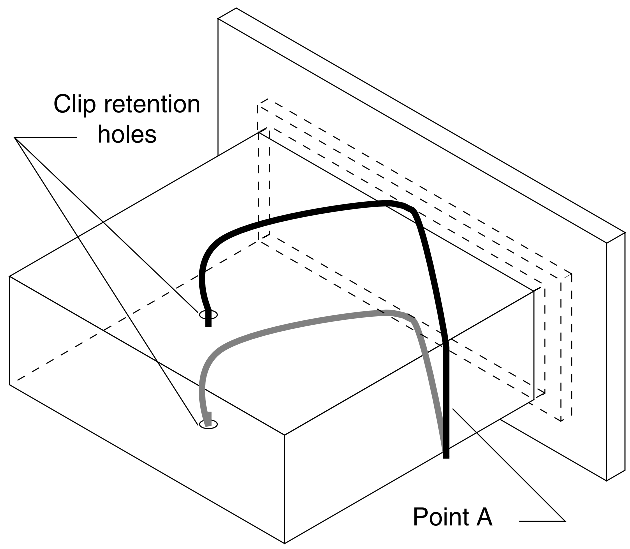


Figure 1. Panel Mount Installation

To install the FP-93, perform the following steps:

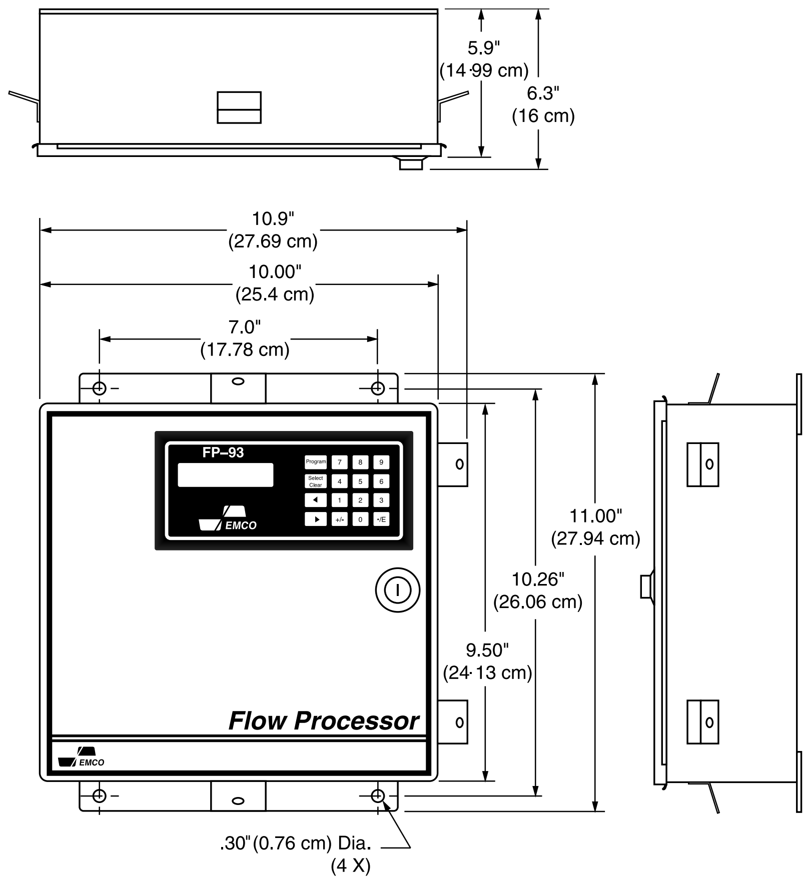
1. Insert FP-93 into the panel cutout.
2. Insert the ends of spring clip into the clip retention holes on the top and bottom of the unit. The spring clip may be installed on either side of the unit.
3. At point A, push the clip toward the side of the unit.

If the optional EMCO AC power supply is used, plug the DIN connector into the power jack on the rear panel of the FP-93. An external power supply may be connected using a 3-position 180° circular DIN connector, or simply by wiring to terminals 1 through 3 of the terminal block. If the DIN connector is used, the power supply and circuitry are protected by a 1/4 amp fuse inside the FP-93 (labelled F1 on the circuit board). Otherwise, no protection is provided by the FP-93.

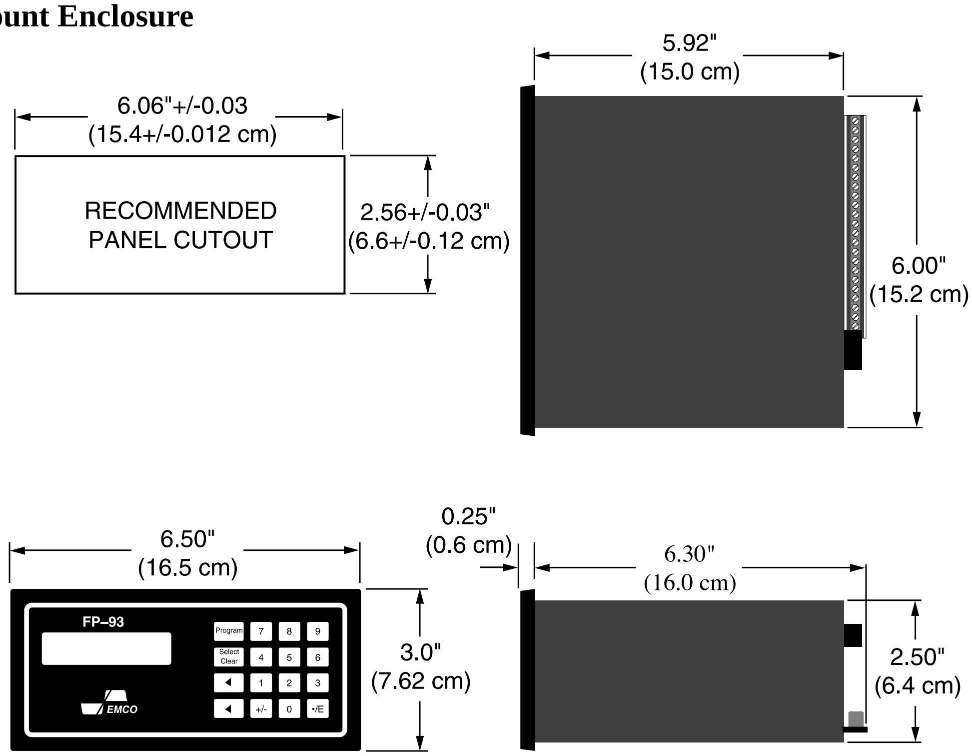
1.2 Mounting (NEMA)

The FP-93 NEMA enclosure is designed to be wall mounted, although other placements are possible. Secure the unit with 1/4" bolts using the four mounting holes located above and below the unit’s main housing. Mounting dimensions for both the NEMA and panel mount versions are shown on the following pages.

NEMA 4 Enclosure



Panel Mount Enclosure



Section 2-Operation

There are two modes of operation of the FP-93—*Display Mode and Program Mode.*

2.1 Display Mode

Display Mode is the normal state of operation, in which inputs, calculated flow rates, totalizers and outputs may be monitored on the display and accessed by the keypad. The displayed engineering units may be changed, the display intensity may be adjusted, and the statistical values, resettable totalizer, faults and alarms may be cleared. The unit is fully operational in Display Mode, processing inputs, calculating flow rates and updating the statistical values and totalizers while simultaneously responding to operator commands from the keypad and communicating with a computer or terminal.

Display Mode Operation

Accessing Variables:

*Disp*layed variables are accessed with the [▶] and [◀] keys. Only those variables which are selected for display (any variable may be turned on or off when the unit is programmed) are actually displayed.

[◀] displays the previous value
[▶] displays the next value

Changing Engineering Units:

If a value is displayed with changeable engineering units (temperature, density or a mass or volume flow rate), pressing the [1] key changes the displayed units. If the value is a flow rate, pressing the [2] key changes the flow rate time base. These changes affect the displayed values only. Communications units are still determined from the programmed units.

[1] changes engineering units
[2] changes time base

Changing the Scan:

The display can be set to scan through different display values such as flowrate, temperature, pressure, etc.

[3] Toggles the scan On and Off.

Changing the Resolution of a Displayed Variable:

The displayed values can be set so the resolution of a displayed variable can be increased or decreased. For example, a displayed value of 100.2631 can be displayed as 100.27 or 100.3 or 100.

[4] Changes the resolution of a displayed variable.

Changing Display Intensity:

The display intensity is adjusted by using the [+/–] and [•/E] keys. There are 16 levels of display intensity. When the intensity is set at the maximum limit, [+/–] has no further effect; likewise [•/E] has no effect when the intensity reaches the minimum level.

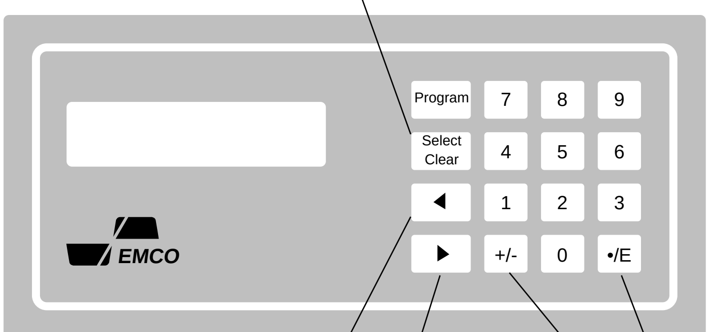
[+/–] increases display intensity
[•/E] decreases display intensity

Display Mode Key Summary

Functional Keys

0. N/A
1. Changes engineering units.
2. Changes time base.
3. Toggles the scan On/Off.
4. Changes the resolution of a displayed variable.
5. N/A
6. N/A
7. Initializes Modem
8. N/A
9. N/A

- Clears values or conditions.
- Resets the totalizer.
- Clears statistical values.
- Clears the faults or alarms.



Displays the previous value

Displays the next value

Decreases display intensity

Increases display intensity

Clearing Values, Alarms and Faults:

[Select Clear] is used to clear values or conditions in the FP-93. The effect of [Select Clear] depends upon the value displayed:

- If any statistical value is displayed, the FP-93 displays

    Clear stats?
    [Clear][ ]

All statistical values (average, minimum and maximum temperature, volume flows and mass flow) will be cleared by pressing the [Select Clear] key. Any other key will return to Display Mode without clearing the statistical values.

- If the *resettable totalizer is displ*ayed, the FP-93 displays

    Clear total?
    [Clear][ ]
    *Enter t*he 1 to 5-digit password

The resettable totalizer will be cleared by pressing the [Select Clear] key. Any other key returns to Display Mode without clearing the totalizer.

- If a *fault or alarm* message is displayed, the displayed fault or alarm is cleared.
- If any other value is displayed (other than a statistical value, the resettable totalizer or a fault or alarm message), the [Select Clear] key has no effect.

Setting Time and Date:

In order to set up time and date, the FP-93 has to be in the display mode. Use the [◄] or [►] to display time and date. The FP-93 displays time and date

    Tue 1 Jan 1980
    0 : 59 : 09

Press the [Program] key and the FP-93 will display

    Password

and a flashing cursor will appear on the second line of the display. Enter the 1 to 5-digit password **(the default password is 37540).** The FP-93 will display

    1 Jan 1980
    [0]: 59 : 09

Use the numeric keys to enter the correct date.

Use the [►] to move the cursor to the month. Now use the [+/–] or [·/E] to enter the correct month.

Use the [►] to move the cursor to the year. Now use the numeric keys to enter the correct digit and use the [►] to move cursor to next digit.

Use the [►] to move the cursor to the time. Now use the numeric keys to enter the correct hour and use the [►] to move cursor to the minutes and second.

2.2 Program Mode

Program Mode is used to access and change the configuration data in the unit. This allows the unit to be configured for your application. When entering Program Mode, the unit may be set to continue or to suspend calculations; communications are disrupted while in Program Mode. The proper password is required to make changes in the Program Mode. FP-93 configuration data which may be accessed include the following:

- Flow meter calibration
- Temperature input and calibration
- Fluid density vs. temperature relationship
- Totalizer and analog output assignments and scaling
- Relay output assignment and alarm setpoint
- Displayed variables and engineering units
- Communication interface setup and unit number
- User-changeable password (not accessible unless proper password was entered)
- Flow and analog input filter time constants
- A/D and D/A converter calibration values

Accessing Program Mode:

Program Mode is accessed by pressing the [Program] key. The FP-93 will display

Password

and a flashing cursor will appear on the second line of the display. Enter the 1 to 5-digit password (the default password is 37540). Passwords with fewer than five digits may be entered either by preceding the password with enough zeros to make a 5-digit number, or by pressing any non-numeric key after entering the 1 to 4-digit number. If an incorrect password is entered, the FP-93 displays

Data entry
Examine only

allowing the user to examine, but not change, the configuration data. All of the configuration data will be accessible for display except for the password itself. In this case, any attempt to change any of the data will result in an Examine only message. If the correct password is entered, the FP-93 displays

Stop calc?
[Prog][ ]

Pressing the [Program] key stops calculations during programming; any other key allows calculations to proceed. The FP-93 then displays

Data entry
Full access

followed by the display of the first column header

Column 1
Flow Calibration

The FP-93 is now in Program Mode.

Program Mode Operation

The configuration data are organized in columns as follows.

Column 1	*Application*	Select fluid type (steam, natural gas, etc.)
Column 2	*Flow Input*	Flow input and calibration
Column 3	*Analog Input*	Analog input(s) and calibration
Column 4	*Fluid Parameters*	Fluid density vs. temperature and other properties
Column 5	*Totalizer*	Totalizer(s) assignment and scaling
Column 6	*Analog Output*	Analog output assignment and scaling
Column 7	*Relay Output*	Relay output assignment and alarm setpoints
Column 8	*Displayed Values*	Select which values are displayed in Display Mode
Column 9	*Display Units*	Select engineering units for flow, temperature and pressure
Column 10	*System*	Communication setup, password, unit calibration

When Program Mode is entered, the first column header is displayed. Pressing the [▶] key displays the next column header, while the [◀] key displays the previous column header. Data within a column are accessed by pressing the [Select Clear] key. Program Mode is exited by pressing the [Program] key when a column header is displayed.

When a data value within a column is displayed, the [▶] key displays the next data value if not at the end of the column. If the last data value in the column is displayed, the [▶] key has no effect. Similarly, the [◀] key displays previous data value unless the first data value in the column is not displayed. The column header is displayed by pressing the [Select Clear] key. The data values may be one of three basic types:

- •*Floating point* numbers have approximately 7 digits of accuracy, and a range of approximately ±(10-38 to 10^{+38}). Virtually all numeric data programmed into the FP-93 are floating point numbers.
- •*Integer* numbers are 16-bit whole numbers with a range of 0 to 65535. Examples of integer data include the unit number and the password.
- •*Selector* data have two to eight selections which are sequentially accessed by pressing the [+/–] key.

If a floating point data value is displayed:

[•/E] toggles between normal display with engineering units and full precision (7-digit mantissa + 2-digit exponent) scientific format display without engineering units.

[+/–] or [0]…[9] initiates data entry. Once data entry is started, the floating point number may be entered, using [•/E] to enter a decimal point or an exponent of a number in scientific notation.

[+/–] changes the sign of the mantissa or exponent during data entry. [◀] deletes the last character entered. The number is stored by pressing either [Program] (displays current value) or [▶] (displays next value if not at the last value in the column). Data entry may be cancelled by pressing [Select Clear], reverting to the number which was previously programmed.

If an *integer* data value is displayed:

[0]…[9] initiates data entry. Up to 5 digits may be entered. [◄] deletes the last digit entered. The number is stored by pressing either [Program] (continues to display current value) or [►] (displays next value if not at end of column). Data entry is cancelled by pressing [Select Clear], reverting to the number which was previously programmed.

If a *selector* data value is displayed:

[+/–] selects next value. Selector data may have two or more values. If it has two values then [+/–] acts as a simple toggle; otherwise, each of the possible values for the selector data are displayed sequentially.

To exit *Program Mode*, a column header must be displayed. If a data value is displayed, press [Select Clear] to display the column header, then press [Program] to exit Program Mode. If any of the configuration data have been changed, the FP-93 displays

Save changes?
[Prg][ ][Clr][.]

[Program] saves all changes permanently in EEPROM (non-volatile permanent memory). The new data values will be in effect until changed again by reprogramming the unit. The FP-93 will display

Saving changes
(permanent)

and then returns to Normal Mode.

[Select Clear] cancels any changes made, and restores the values in effect prior to entering Program Mode.
[•/E] cancels the effect of pressing the [Program] key. The FP-93 momentarily displays

Cancelled

and then returns to Program Mode.
Any other key saves all changes temporarily in RAM. The FP-93 will display

Saving changes
(temporary)

and then returns to Normal Mode.

If the changed values were stored in RAM, the new values will be used only until the power is turned off; then the values formerly stored in EEPROM will be used. The values stored in RAM may be stored in EEPROM by entering Program Mode using a valid password, then immediately exiting Program Mode by pressing [Program]. Respond to the

Save changes?
[Prg][ ][Clr][.]

prompt by pressing [Program], and the values will be stored permanently in EEPROM.

Column Header Selector Data Data Value

FP-93 Programmed Constants

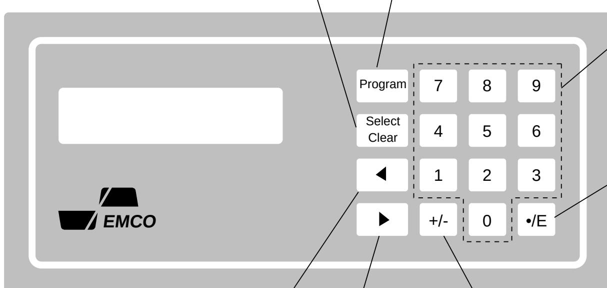
Column #1 Application	Column #2 Flow Input	Column #3 Analog input	Column #4 Fluid parameters	Column #5 Totalizer	Column #6 Analog Output	Column #7 Relay Output	Column #8 Displayed Values	Column #9 Display Units	Column #10 System
Fluid *Steam* *Water* *Water energy* *Liquid* *Air* *Natural gas* *Ideal gas* *Steam/cond*	Flow *Frequency* *4-20 mA* *Substitute* Flowmeter *Linear* *Non-linear* *Insertion* *Small turbine* *Large turbine* Interpolation *Linear* *Cubic Spline* Bidirectional *On/Off* Substitute freq Substitute flow Pipe diameter Obscuration Profile factor K-factor Full scale vel Diff press cal Frequency #1 Velocity #1 Frequency #2 Velocity #2 Frequency #3 Velocity #3 Frequency #4 Velocity #4 Frequency #5 Velocity #5 Frequency #6 Velocity #6 Frequency #7 Velocity #7 Frequency #8 Velocity #8	Temp input *None* *RTD* *4-20 mA* *Substitute* Sub temp #1 RTD #1 cal A RTD #1 cal B RTD #1 cal R Zero scale Full scale Temp Input #2 *None* *RTD* *4-20 mA* *Substitute* Sub temp #2 RTD #2 cal A RTD #2 cal B RTD #2 cal R Zero scale Full scale Pressure input *None* *4-20 mA* *Substitute* Sub pressure Zero scale Full scale Atm pressure	Density from *Temp. input #1* *Temp. input #2* Ref. density Specific gravity Mole frac CO_2 Mole frac N_2 Supercomp Viscosity Temperature #1 Density #1 Temperature #2 Density #2 Temperature #3 Density #3 Temperature #4 Density #4 Temperature #5 Density #5 Temperature #6 Density #6 Temperature #7 Density #7 Temperature #8 Density #8	Totalizer #1 *None* *Volume flow* *Comp flow* *Mass flow* *Energy flow* Scale factor Totalizer #2 *None* *Volume flow* *Comp flow* *Mass flow* *Energy flow* Scale factor	Analog output *None* *Temperature* *Temperature #2* *Dif temp* *Pressure* *Velocity* *Volume flow* *Comp flow* *Mass flow* *Energy flow* Zero scale Full scale	Relay output *None* *Temp alarm* *Temp #2 alarm* *diff temp alarm* *Pressure alarm* *Velocity alarm* *Vol flow alarm* *Comp flow alarm* *Mass flow alarm* *Energy flow alarm* *Forward total* *Reverse total* Alarm limit *Low* *High* Setpoint Hysteresis	Bar graph *Off/On* Density *Off/On* Temperature *Off/On* Temp Stats *Off/On* Pressure *Off/On* Pressure stats *Off/On* Line velocity *Off/On* Volume flow *Off/On* Vol flow stats *Off/On* Comp vol flow *Off/On* Comp vol stats *Off/On* Mass flow *Off/On* Mass flow stats *Off/On* Energy flow *Off/On* Energy flow stats *Off/On* Analog output *Off/On* Relay output *Off/On* Totals *Off/On* Clock/Calendar *Off/On* Verification *Off/On*	Velocity units *ft/sec* *cm/sec* *m/sec* Volume units *cubic feet* *cubic inches* *gallons* *barrels* *cubic cm* *liters* *cubic meters* Mass units *pounds* *tons* *grams* *kilograms* *metric tons* Energy units *Btu* *tons* *kJ* *kW* *MW* *GW* Flow time base */second* */minute* */hour* */day* Temp units *˚F* *˚R* *˚C* *˚K* Pressure units *psi* *atm* *bars* *kg/cm2* *mm Hg* Pressure display *absolute* *gauge* Density units *lb/ft3* *g/cc* *kg/m3*	Unit number Baud rate *38400* *19200* *9600* *4800* *2400* *1200* *600* *300* Data format *7 Even* *7 Odd* *8 None* Stop bits *1/2* Comm hand shake *None* *Hardware (CTS)* *XON/XOFF* *Both* Modem Comm *Off/On* Password Display scan Sync calc *Off/On* Temperature TC Pressure TC Flow TC A/D reference A/D int count D/A Zero count D/A span count

Programming Mode Key Summary

- Access the data within a column.
- Exits the data within a column.

- Access the program mode.
- Exit program mode when a column header is displayed.
- Save changes to program.
- Toggles between metric and english.

- 0-9 keys are used for numeric data entry.



- Decimal point entry.
- Exponent data entry.

- Displays the previous column header.
- Displays previous data value within a column.
- Deletes the last character entered during numeric data entry.

- Changes the selector data within a column.
- Changes the sign of mantissa or exponent during numeric data entry.

- Displays the next column header.
- Displays the next data value within a column header.

Section 3- Programming

3.1 Configuration Data

This section describes the configuration data programmed into the FP-93. This data is organized in ten columns as follows:

Column 1	*Application*	Select fluid type (steam, natural gas, etc.)
Column 2	*Flow Input*	Flow input and calibration
Column 3	Analog Input	Analog input(s) and calibration
Column 4	*Fluid Parameters*	Fluid density vs. temperature relationship and other properties
Column 5	*Totalizer*	Totalizer assignments and scaling
Column 6	*Analog Output*	Analog output assignment and scaling
Column 7	*Relay Output*	Relay output assignment and alarm setpoint
Column 8	*Displayed Values*	Displayed values
Column 9	*Display Units*	Temperature, density and flow engineering units
Column 10	*System*	Communication interface setup and unit number User-changeable password Synchronized calculation flag Flow and analog input filter time constants A/D and D/A converter calibration values Etc.

Column 1 - Application

Fluid

Steam	Saturated and superheated steam measurement
Steam/cond	Steam Supply - condensate return heat flow calculation
Water	Water flow measurement
Water energy	Water heat measurement (2 temperature inputs)
Liquid	Liquids (other than water) flow measurement
Air	Air flow measurement
Natural gas	Natural gas flow measurement
Ideal gas	Gas (other than air or natural gas) flow measurement

Column 2 - Flow Input

Flow input

Substitute	Substitute frequency value is used for flow calculations
Frequency	Frequency input is used for flow calculations
4-20 mA	Analog input is used for flow calculations

If *Substitute* is selected for flow input, this value will be used in flow calculations, and a Substitute freq alarm message will be displayed in Normal Mode.

Column 2- Flow Input (continued)

If frequency is selected for flow input, the frequency input will be used in flow calculations.
If *Analog* is selected for flow input, analog 4-20 mA input signal will be used in flow calculations.

Flow meter

Linear	Linear flow input. For inline flowmeters such as inline Vortex or Turbine with a single K-Factor, and EMCO insertion vortex. (EMCO's model PhD, TLS, TLG, PDH, PDP, V-Bar)
Non-linear	With frequency input, this allows the use of frequency/velocity pairs to characterize the flow input. This is used with inline flowmeters which have multiple point calibration including calibration points in their non-linear flow region. (EMCO’s model TLG, TLS, PDH, PDP) With analog input, this performs a square root calculation on the analog input.
Insertion	Used for non-EMCO insertion meters. This option allows the use of Schlicting theory to perform calculation on non-turbine insertion flowmeters.
Small turbine	Small EMCO Insertion turbine rotors. (series 100 (1") and G6 rotors).
Large turbine	Large EMCO Insertion turbine rotors . (series 150 (1.5"), G1 thru G5 and L1 rotors).

Interpolation

Linear	Linear curve fit for frequency/velocity pairs.
Cubic spline	Cubic spline curve fit for frequency/velocity pairs.

Bidirectional

On/Off	This allows the use of a bidirectional flowmeter with a directional input. If the flow transducer is not bidirectional this register must be turned *off.*

Substitute freq	Substitute frequency value entered as a constant and is used to verify flow calculations. This value can be entered only if *“Substitute”* is chosen under *Flow Input and Flow meter is non-linear, Insertion, Small Turbine or Large Turbine*.
Substitute flow	Substitute flow value entered as a constant velocity (ft/sec or m/sec) to verify flow calculations. This value can be entered only if *“Substitute”* is chosen under *Flow Input* and *Flow meter* is *Linear.*
Pipe diameter	Pipe inside diameter in inches or mm.

Column 2 - Flow Input (continued)

Obscuration — When using insertion type flowmeters, this number is either entered as a constant or calculated by the FP-93. Obscuration factor is a number used to compensate for the area of the pipe obscured by the insertion meter stem and rotor. If the flowmeter selected under column 2 is *linear,* the *obscuration* does not apply. If the *flowmeter* selected under column 2 is *non-linear,* the *obscuration must be entered as 1.0000*. If the *flowmeter* selected under column 2 is *insertion,* the proper value of *obscuration* must be entered. If the *flowmeter* selected under column 2 is *small turbine* or *large turbine,* the *obscuration* is automatically calculated by the FP-93.

Profile factor — When using insertion type flowmeters, this number is either entered as a constant or calculated by the FP-93. *Profile factor* is the number used to relate the point velocity to average velocity in the pipe. If the *flowmeter* selected under column 2 is *linear* or *non-linear,* the *profile factor* does not apply. If the *flowmeter* selected under column 2 is *insertion, small turbine* or *large turbine,* the *profile factor* is automatically calculated by the FP-93.

K-factor — If the *flow input* selected under column 2 is a *pulse* and the *flow meter* selected is *linear,* then the meter *K-factor* is the sole conversion factor the FP-93 uses for calculating actual volume flow from frequency. This calculation is done using the equation

$$Q = F / K \text{ (Actual cubic feet per second)}$$

Where Q = Flow rate in Actual cubic feet per second
F = frequency of pulse input, Hz
K = K-factor, pulses per cubic feet

NOTE: When using insertion vortex (V-Bar), the meter is shipped with a calibration factor of 1 pulse/ft. In this case, the K-factor equals:

$$K = \frac{1}{\text{area of the pipe } \left(ft^2\right)}$$

If your meter is provided with a K-factor in pulses per cubic feet (p/ft^3), then simply enter this number in the K-factor register; otherwise it will be necessary to convert from your meter calibration units to pulses per cubic feet. If the K-factor of your meter is in volumetric units, then calculate the new K-factor by dividing the K-factor of your meter (km), by the appropriate conversion factor A, from the following table, and enter this number in the K-factor register of the FP-93.

K = (km / A) pulses per cubic feet

Column 2 - Flow Input (continued)

Meter K-factor units	A
pulses/cubic inches	0.0005787
pulses/fluid ounce	0.0104439
pulses/gallon	0.1336805
pulses/cubic centimeter	0.0000353
pulses/cubic meter	35.314662
pulses/liter	0.0353146

Example: A meter with a K-factor of 830 pulses per gallon is used. The K-factor to be entered in the FP-93 is 830 / 0.1336805, or 6,208.833 pulses/cubic feet.

Full scale vel If the *Flow input* selected under column 2 is 4-20 mA analog and the *Flowmeter* selected in *Linear*, then the *Full scale velocity* must be entered in its register. Full scale (20mA) velocity in feet/sec is calculated from the meter calibration and preamplifier settings. For example, if a vortex meter with a *K-factor* of 11.12 pulses/feet is used with a preamplifier maximum frequency scaling of 1200 Hz, the full scale velocity is 1200/11.12 = 107.91 ft/sec.

Full scale freq If the *flow input* selected under column 2 is *4-20 mA* analog and the *flowmeter* selected is *insertion, small turbine* or *large turbine*, then the *full scale frequency* must be entered in its register. Full scale (20 mA) frequency in Hz (pulses/sec) is calculated from the meter calibration and preamplifier settings. For example, if an insertion turbine meter with a preamplifier setting of 1400 Hz (max frequency) is used, the full scale frequency is 1400.

Diff press cal If the *flow input* selected under column 2 is *4-20 mA* analog and the *Flowmeter* selected is *non-linear,* then the FP-93 will perform square law calculation on the analog input.

Square-Law Analog Input-Mass Flow

When programmed for a square-law analog input to perform mass flow calculations, the *Diff press cal* value is calculated based on the following equation:

$$\text{Diff press cal} = \frac{\dot{m}_{fs}}{A \bullet \sqrt{\rho_{fs}}}$$

Where: $= \dot{m}$ Full Scale Mass Flow, Pounds/Second

$$A = \frac{\pi d^2}{576}\,\text{ft}^2$$

$$\rho_{fs} = \text{density, pounds/ft}^3$$

Example: An orifice plate with differential pressure transducer is rated at 10,000 pounds per hour with saturated steam at 150 psia in a 6" schedule 40 pipe. *Calculate Diff press cal.*

Column 2 - Flow Input (continued)

$$A = \frac{\pi d^2}{576} ft^2 = \frac{\pi \bullet 6.065^2}{576} = 0.20063\, ft^2$$

From the ASME Steam Tables, the density of saturated steam at 150 psia is 0.3318 lbs/ft3, and the mass flow is given as 10,000 pounds/hour. The full scale volume flow must always be calculated in pounds/sec

$$\dot{m}_{fs} = \frac{10,000}{3,600} = 2.7777\, lbs/sec$$

Diff press cal is calculated from the equation

$$\text{Diff press cal} = \frac{2.7777}{0.20063 \bullet \sqrt{0.3318}} = 24.036$$

Square-Law Analog Input-Volume Flow

When programmed for a square-law analog input to perform volume flow calculations, the *Diff press cal* value is calculated based on the following equation:

$$\text{Diff press cal} = \frac{q_{fs} \bullet \sqrt{\rho_{fs}}}{A}$$

Where:

q_{fs} = Full Scale Volume Flow, ft^3/sec

$$A = \frac{\pi d^2}{576} ft^2$$

ρ_{fs} = density, pounds/ft^3

Example. An orifice plate with differential pressure transducer is rated at 150,000 ACFH with air at 100 psig and 140 °F in a 10" schedule 40 pipe. *Calculate Diff press cal*

$$A = \frac{\pi d^2}{576} ft^2 = \frac{\pi \bullet 10.02^2}{576} = 0.5476\, ft^2$$

The density of air is calculated from the ideal gas law:

$$\rho_{fs} = 0.0764 \bullet \frac{114.696}{14.696} \bullet \frac{519.67}{599.67} = 0.51672\, lbs/ft^3$$

The full scale volume flow must always be calculated in ft^3/sec

$$q_{fs} = \frac{150,000}{3,600} = 41.6666\, ft^3/sec$$

The *Diff press cal* is calculated from the equation

$$\text{Diff press cal} = \frac{q_{fs} \bullet \sqrt{\rho_{fs}}}{A} = \frac{41.6666 \bullet \sqrt{0.51672}}{0.5476} = 54.6956$$

Column 2 - Flow Input (continued)

If the *Flow input* selected under Column 2 is *pulse* and the *Flowmeter* selected is *Non-linear*, *Insertion*, *small turbine* or *Large turbine* , then 8 points of frequency v.s. velocity pairs can be entered in their registers in increasing order. If fewer than eight points are available, set the value of the last points to zero. For example if there are only six pairs of frequency v.s. velocity available, set frequency #7 and #8 and velocity #7 and #8 to zero. The same would apply as above if the *Flow input* selected is *4-20 mA* analog and the *Flowmeter* selected is *Insertion, Small turbine* or *Large turbine*.
Frequency #1
Velocity #1
Frequency #2
Velocity #2
Frequency #3
Velocity #3
Frequency #4
Velocity #4
Frequency #5
Velocity #5
Frequency #6
Velocity #6
Frequency #7
Velocity #7
Frequency #8
Velocity #8

Column 3 - Analog Inputs

Temp input -Selects the temperature input to the FP-93 for density and enthalpy calculations

None	No temperature input is used
RTD	Temperature is to be measured from the resistance of an RTD
4-20 mA	Temperature is to be measured from a 4-20 mA temperature transmitter
Substitute	Use substitute temperature value

If *None* is selected, and the application is for saturated steam, properties are calculated using the pressure input. If pressure input is none, then the substitute temperature is used.

If *Substitute* is selected, the substitute temperature value will be used in density calculations, and an alarm message indicating *Substitute temp* will be displayed in Normal Mode. The substitute value will also be used if an RTD fault is sensed or if the 4-20 mA input drops below 2.4 mA.
If RTD is selected, three RTD calibration factors may be accessed and entered:

RTD #1 Cal A	Default value = –6.018822 x 10-7
RTD #1 Cal B	Default value = 3.810188 x 10–3
RTD #1 Cal R0, Ohm	Resistance of RTD at 32 °F (0 °C) in Ohms, default value = 1000 Ohms

When used for **Water Energy** (two temperature inputs), Temp#1 always corresponds to the higher temperature line. In **Steam/Condensate** application, Temp #1 corresponds to the steam temperature.

If calibration information is not available for the RTD, the default values for the A and B coefficients may be used for a platinum RTD, and set the R_0 value equal to the nominal resistance of the RTD at 32 °F (0 °C). If calibration data are available, the A, B and R_0 values may be determined. If only one calibration point is supplied, it should be the resistance at 32 °F (0 °C), and this number should be entered for R_0. If two calibration points are known, use the default value for A (or the RTD vendors default value, if known), and calculate the values for B and R_0. If three calibration points are given, all three coefficients may be calculated.
Coefficients are calculated by solving two or three simultaneous equations of the form

$$R = R_0 \cdot (AT^2 + BT + 1)$$

for A, B and R_0.

If 4-20 mA temperature input is selected, the temperature transmitter zero and full scale calibration factors are accessible and may be entered.

Zero scale, °F	Temperature at which transmitter output is 4.0 mA. Pressing the [Program] key allows the zero scale temperature value to be entered in °C metric units.
Full scale, °F	Temperature at which transmitter output is 20.0 mA. Pressing the [Program] key allows the full scale temperature value to be entered in °C metric units.

Column 3- Analog Inputs (continued)

Temperature conversion chart for converting to °F

Temperature Units	Multiply by	then add
°F	1.0	0.0
°R	1.0	-459.67
°C	1.8	32.0
°K	1.8	-459.67

Temp input #2 Used only for **Water Energy** or **Steam/Condensate** heat calculations. For water Energy calculations, Temp input #2 always corresponds to the lower temperature line. In Steam/Condensate heat calculations, Temp input #2 corresponds to the condensate temperature. The temperature input #2 must be programmed in the same manner as for temperature input #1 except the values entered must correspond to RTD#2 or temperature transmitter #2.

Pressure input Selects the pressure input to the FP-93 for density and calculations
- *None* No pressure input is used
- *4-20 mA* Pressure is to be measured from a 4-20 mA pressure transmitter
- *Substitute* Use substitute pressure value

If *None* is selected, saturated steam properties are calculated using the temperature input.
If *4-20 mA* is selected, the pressure input is used to calculate the steam properties. If a temperature input is also selected, superheated steam properties are calculated.

If *Substitute* is selected, the substitute pressure value will be used in density calculations, and an alarm message indicating *Substitute press* will be displayed in Normal Mode. The substitute value will also be used if the 4-20 mA pressure input drops below 2.4 mA.

Sub pressure Substitute pressure value in psi. Pressing the [Program] key allows the substitute pressure to be entered in “bar” metric units.

Zero scale Pressure (psig) at which the transmitter output is 4 mA. Pressing the [Program] key allows the zero scale pressure value to be entered in “barg” metric units.

Full scale Pressure (psig) at which the transmitter output is 20 mA. Pressing the [Program] key allows the full scale pressure to be entered in “barg” metric units.

Pressure conversion chart for converting to psi

PressureUnits	Multiply by
psi	1.0
bar	14.5038
kg/cm^2	14.2233
Kpa	0.145

Column 3- Analog Inputs (continued)

Atm pressure Atmospheric pressure in psia. Pressing the Program key allows the atmospheric pressure to be entered in metric units (bara).

Absolute pressure is used in the calculation of steam properties, and is calculated by adding either substitute pressure or transducer pressure to the atmospheric pressure constant. If an absolute pressure transmitter is used, set the atmospheric pressure constant to zero.

Column 4 - Fluid Parameters

The values programmed in the *Fluid parameters* column are based on the type of fluid measured. The following is a listing of these parameters based on the fluid type selected in *Column 1*.

<u>Steam , Steam/cond</u>

Ref density	For steam applications, accept the default value of reference density. This does not affect the mass flow computation for steam.

<u>Water</u>

Ref density	For water applications, the *Reference density* has two purposes. If the unit is programmed for no temperature input (Temp input selector is set to none), then this is used as a constant density for water. Otherwise, the *Reference density* is used by the FP-93 to calculate temperature compensated volume flow. For example, if the required flow calculations for water is standard gallons at 60°F, then the density (lbs/ft^3) of water at 60°F must be entered.

<u>Water energy</u>

Density From *Temp input #1* *Temp input #2*	In water energy applications, the mass flow is computed using the density from the temperature sensor located in the same pipe (Supply or Return) in which-the flow transducer is located. If the *Temperature #2* sensor is located in the same pipe as the flow transducer, push the [+/-] Key to choose Density from *Temp input #2*.
Ref Density	The *Ref density* has the same functions as described above for water.

<u>Liquid</u>

Ref density	For liquids other than water, the *Ref density* would have the same functions as described for water above.
Viscosity	Viscosity is measured in centipoise (cP) of the liquid at the nominal operating temperature.
Temperature #1, °F	degrees Fahrenheit
Density #1, Lbs/ft^3	pounds per cubic foot
Temperature #2, °F	
Density #2, Lbs/ft^3	
Temperature #3, °F	
Density #3, Lbs/ft^3	
Temperature #4, °F	
Density #4, Lbs/ft^3	
Temperature #5, °F	
Density #5, Lbs/ft^3	
Temperature #6, °F	
Density #6, Lbs/ft^3	

Column 4 - Fluid Parameters (continued)

Temperature #7, °F
Density #7, Lbs/ft^3
Temperature #8, °F
Density #8, Lbs/ft^3

If a temperature input is selected, up to eight points (each consisting of a temperature/density pair), may be entered to define the density/temperature relationship. These points are used by the FP-93 to calculate the coefficients for a density/temperature curve using a cubic spline curve-fit and interpolation algorithm. The points must be entered in increasing order of temperature. If fewer than eight points are used, set the temperature value of the point following the last one to a lower value than the last temperature.

AIR

Ref density — The *Ref density* can be used to compute temperature/pressure compensated volume flow (Scfm, Scfh, Ncfm, etc.,) for air at standard conditions. The value of the *Reference density* of air at standard conditions is calculated using the equation:

Ref density = (2.7 x 14.696 x SG) / 519.67

Where: SG = 1.0 (Specific gravity of air)

Example: FP-93 is used with a flow transducer measuring air at 70 psig and 100°F. To compute compensated volume flow at standard conditions (Scfm, Scfh, etc.), the *Ref density* is calculated as

(2.7 x 14.696 x 1.0) / 519.67 = 0.076354 lbs/ft^3

Enter this value in the *Ref density* register. Note: (The actual conditions of 70 psig and 100°F do not affect the *Ref density* value.) If the standard conditions are considered different than 14.696 psia and 60 °F, then a new *Ref density* value must be calculated. For example, if standard conditions are considered at 14.7 psia and 70°F, then the new *Ref density* is calculated as

(2.7 x 14.7 x 1.0) / (70 + 459.67) = 0.07493 lbs/ft^3.

The *Ref density* is particularly important in metric units, where the standards in calculating normal or standard conditions may be different in various countries.

Ideal gas

Ref density — The *Ref density* for ideal gases other than air is calculated using the same equation used for air. The only difference is that the appropriate specific gravity of the ideal gas must be used.

Specific gravity — The *Specific gravity* of the ideal gas at standard conditions. This is the same value used in calculating the Ref density value above.

Column 4 - Fluid Parameters (continued)

Compressibility The *compressibility* value of the ideal gas. If this is not available, the default value is 1.0000

Viscosity *Viscosity* in centipoise (cP) of the ideal gas at nominal operating temperature. The default value is 0.016 cP.

Natural gas
Ref density The *Ref density* can be used to compute temperature and pressure Compensated volume flows (SCFM, SCFH, etc.) for natural gas at standard conditions. The value of the Reference density of natural gas at standard conditions is calculated using the equation:

Ref density = (2.7 x 14.73 x SG) / 519.67
Where SG = Specific gravity of natural gas

Example: FP-93 is used with a flow transducer measuring natural gas with a specific gravity of 0.667 at 70 psig and 100 °F. To compute temperature/ pressure compensated volume flow at standard conditions (SCFM), the Ref density is calculated as

(2.7 x 14.73 x 0.667) / 519.67 = 0.051046 lbs/ft^3.

Enter this value in the *Ref density* register. Note: (The actual conditions of 70 psig and 100°F do not affect the *Ref density* value). If the standard conditions are considered different than 14.73 psia and 60°F, then a new *Ref density* value must be calculated. For example if standard conditions are considered at 14.7 psia and 70°F, then the new *Ref density* is calculated as
(2.7 x 14.7 x 0.667) / (70 + 459.67) = 0.04998 lbs/ft^3.
The *Ref density* is particularly important in metric units, where the standards in calculating normal or standard conditions may be different in various countries.

Specific gravity The *specific gravity* of natural gas. This is the same value used in calculating the *Ref density* above.

Mole Frac C02 % mole fraction of $C0_2$ in natural gas. If not available, use the default value.

Mole Frac N2 % mole fraction of N_2 in natural gas. If not available, use the default value.

Supercomp Supercompressibility of natural gas at nominal operating temperature and pressure.

Column 5 - Totalizer

Total # 1

None	Totalizers are not assigned
Volume flow	Totalizers accumulate actual volume flow
Comp flow	Totalizers accumulate Compensated volume flow
Mass flow	Totalizers accumulate mass flow
Energy flow	Totalizers accumulate energy flow

Scale factor #1
If *None* is selected, no further programming is necessary for totalizer #1. Otherwise, the scale factor #1 may be accessed and changed. This number is the volume, mass or energy represented by one count of the totalizer. For example, if the totalizer is configured to accumulate mass flow, and the scale factor is set to 100.0 lb, then each increment of the totalizers represent 100 pounds of fluid. Both resettable and non-resettable totalizers use the same scale factor.

If *Volume flow* or *Comp flow* is selected, the scale factor units are **cubic feet** or **standard cubic feet respectively**. (abbreviated in the display as ft^3). If Mass flow is selected, the scale factor units are **pounds** (lb). The units for energy flow are **British thermal units** (Btu).

Volume conversion chart for converting to ft^3

Volume units	multiply by
cubic feet	1.0
gallons	1.33681e-1
barrels	5.61458
cubic centimeters	3.53147e-5
liters	3.53147e-2
cubic meters	35.3147

Mass conversion chart for converting to pounds

Mass units	multiply by
pounds	1.0
tons	2000.0
kilograms	2.20462
metric tons	2204.62

Total # 2 — The same or different variables shown above for *Total #1* above can be assigned to a second totalizer .

Scale factor #2 — The scale factor for the *Totalizer #2* is calculated using the same procedure explained above for *Totalizer #1*.

NOTE: For bidirectional applications, totalizer assignment and scale factor #1 are the same for forward and reverse flow. In this case, *Totalizer #1* represents forward total and *Totalizer #2* represents reverse total.

Column 6 - Analog Output

Analog output

None	Analog output is not assigned (actual output is set to 4.0 mA)
Temperature	Analog output represents temperature #1
Temp #2	Analog output represents temperature #2
Diff temp	Analog output represents differential temperature
Pressure	Analog output represents pressure
Density	Analog output represents density
Velocity	Analog output represents velocity
Volume flow	Analog output represents actual volume flow
Comp flow	Analog output represents temperature-compensated volume flow
Mass flow	Analog output represents mass flow
Energy flow	Analog output represents energy flow

Zero scale Zero scale (4 ma) analog output in appropriate engineering units

Full scale Full scale (20 mA) analog output in appropriate engineering units

If None is selected, no further programming is necessary in this column. Otherwise, the zero and full-scale values may be accessed and changed. The zero-scale value is the value of the assigned variable at which the output will be 4.0 mA, while the full-scale value is the value at which the output will be 20.0 mA.

If Volume flow or Comp flow is selected, the zero- and full-scale units are **cubic feet per second** or **Standard cubic feet per second** respectively (abbreviated in the display as ft^3/s). If Mass flow is selected, the units are **pounds per second** (lb/s). Temperature units are **degrees Fahrenheit** (°F).

Temperature conversion chart for converting to °F

Temperature units	multiply by	then add
°F	1.0	0.0
°R	1.0	-459.67
°C	1.8	32.0
°K	1.8	-459.67

Volume flow conversion chart for converting to cubic feet per second. Multiply by:

Volume flow units	/second	/minute	/hour	/day
cubic feet	1.0	1.66667e-2	2.77778e-4	1.15741e-5
gallons	1.33681e-1	2.22801e-3	3.71335e-5	1.54723e-6
barrels	5.61458	9.35764e-2	1.55961e-3	6.49836e-5
cubic centimeters	3.53147e-5	5.88578e-7	9.80963e-9	4.08735e-10
liters	3.53147e-2	5.88578e-4	9.80963e-6	4.08735e-7
cubic meters	35.3147	5.88578e-1	9.80963e-3	4.08735e-4

Column 6 - Analog Output (continued)

Mass flow conversion chart for converting to pounds per second. Multiply by:

Mass flow units	/second	/minute	/hour	/day
pounds	1.0	1.66667e-2	2.77778e-4	1.15741e-5
tons	2000.0	33.3333	5.55556e-1	2.31481e-2
kilograms	2.20462	3.67437e-2	6.12395e-4	2.55165e-5
metric tons	2204.62	36.7437	6.12395e-1	2.55165e-2

Energy flow conversion chart for converting to Btu/second. Multiply by:

Energy flow units	/second	/minute	/hour	/day
Btu	1.0	1.66667e-2	2.77778e-4	1.15741e-5
kJ	0.947817	1.5797e-2	2.63283e-4	1.09701e-5
kCal	3.96832	6.61387e-2	1.10231e-3	4.59296e-5
MCal	3968.32	66.1387	1.10231	4.59296e-2

Power conversion to Btu/second

Power units	Multiply by
Refrigeration tons	3.33333
kW	0.947817
MW	947.817
GW	947817

Pressure conversion chart for converting to psi

Pressure Units	Multiply by
psi	1.0
bar	14.5038
kg/cm^2	14.2233
Kpa	0.145

Column 7 - Relay Output

Relay output

None	Relay output is not assigned (output is off)
Temp alarm	Relay output is controlled by temperature
Temp #2 alarm	Relay output is controlled by temperature #2
Diff temp alarm	Relay output is controlled by differential temperature
Pressure alarm	Relay output is controlled by pressure
Density alarm	Relay output is controlled by density
Velocity alarm	Relay output is controlled by velocity
Vol flow alarm	Relay output is controlled by actual volume flow
Comp flow alarm	Relay output is controlled by compensated volume flow
Mass flow alarm	Relay output is controlled by mass flow
Energy flow alarm	Relay output is controlled by energy flow
Total # 1	Relay output pulses with each increment in the non-resettable totalizer #1
Total # 2	Relay output pulses with each increment in the non-resettable totalizer #2

Alarm limit

Low	Relay output turns on when value drops below (setpoint – hysteresis) and turns off when value exceeds (setpoint + hysteresis)
High	Relay output turns on when value exceeds (setpoint + hysteresis) and turns off when value drops below (setpoint – hysteresis)
Setpoint	Center of "dead band"
Hysteresis	Half of the total width of the "dead band"

If *None* or *Total* is selected, no further programming is necessary. Otherwise, the alarm setpoint and hysteresis may be accessed and changed. The setpoint and hysteresis determine the value at which the relay output changes state. If configured as a high limit alarm, the output will turn on when (setpoint + hysteresis) is exceeded, and will turn off when the value drops below (setpoint – hysteresis). The units for the setpoint and hysteresis are degrees Fahrenheit (°F) for temperature, pounds per square inch (psi) for pressure, pounds per cubic foot (lb/ft^3) for density, cubic feet per second (ft^3/s) for volume flow, pounds per second (lb/s) for mass flow and British thermal units per second (Btu/s) for energy flow.

If the relay output is assigned to one of the setpoint alarms, the status of the relay output may be displayed as one of the display variables.

If the relay output is assigned to the totalizer (*Total*), the output will turn on for 50 milliseconds, then off again, with each increment of the internal non-resettable totalizer. The maximum pulse

Column 7 - Relay Output (continued)

repetition rate of the relay output is 10 pulses per second. If this rate is exceeded, an alarm is set, and excess pulses are stored. The actual relay pulse rate will not exceed 10 pulses per second.

Volume flow conversion chart for converting to cubic feet per second. Multiply by:

Volume flow units	/second	/minute	/hour	/day
cubic feet	1.0	1.66667e-2	2.77778e-4	1.15741e-5
gallons	1.33681e-1	2.22801e-3	3.71335e-5	1.54723e-6
barrels	5.61458	9.35764e-2	1.55961e-3	6.49836e-5
cubic centimeters	3.53147e-5	5.88578e-7	9.80963e-9	4.08735e-10
liters	3.53147e-2	5.88578e-4	9.80963e-6	4.08735e-7
cubic meters	35.3147	5.88578e-1	9.80963e-3	4.08735e-4

Mass flow conversion chart for converting to pounds per second. Multiply by:

Mass flow units	/second	/minute	/hour	/day
pounds	1.0	1.66667e-2	2.77778e-4	1.15741e-5
tons	2000.0	33.3333	5.55556e-1	2.31481e-2
kilograms	2.20462	3.67437e-2	6.12395e-4	2.55165e-5
metric tons	2204.62	36.7437	6.12395e-1	2.55165e-2

Energy flow conversion chart for converting to Btu/second. Multiply by:

Energy flow units	/second	/minute	/hour	/day
Btu	1.0	1.66667e-2	2.77778e-4	1.15741e-5
kJ	0.947817	1.5797e-2	2.63283e-4	1.09701e-5
kCal	3.96832	6.61387e-2	1.10231e-3	4.59296e-5
MCal	3968.32	66.1387	1.10231	4.59296e-2

Power conversion to Btu/second

Power units	Multiply by
Refrigeration tons	3.33333
kW	0.947817
MW	947.817
GW	947817

Pressure conversion chart for converting to psi

Pressure Units	Multiply by
psi	1.0
bar	14.5038
kg/cm^2	14.2233
Kpa	0.145

Column 8 - Display Values

Bar graph, On/Off	Analog output bar graph display
Density, On/Off	Calculated fluid density
Temperature, On/Off	Temperature calculated from 4-20 mA input or RTD resistance
Temp stats, On/Off	Average, minimum and maximum temperature
Pressure, On/Off	Pressure calculated from 4-20 mA input
Pressure stats, On/Off	Average, minimum and maximum pressure
Line velocity, On/Off	Line velocity
Volume flow, On/Off	Actual volume flow
Vol flow stats, On/Off	Average, minimum and maximum actual volume flow
Comp vol flow, On/Off	Compensated volume flow
Comp vol stats, On/Off	Average, minimum and maximum Compensated volume flow
Mass flow, On/Off	Mass flow
Mass flow stats, On/Off	Average, minimum and maximum mass flow
Energy flow, On/Off	Energy flow
Energy stats, On/Off	Average, minimum and maximum energy flow
Analog output, On/Off	4-20 mA analog output current
Relay output, On/Off	State of relay output if assigned to setpoint alarm
Totals, On/Off	Resettable and non-resettable totalizers
Clock/calendar, On/Off	Time and date
Verification, On/Off	Additional engineering information, including RTD resistances, analog multiplexer input currents, input frequency, fluid viscosity, profile factor, obscuration factor and fluid enthalpy.

The selectors in this column determine whether certain variables will be displayed or not. You may customize your FP-93 to display only the variables of interest to you by turning On those variable displays, and setting any undesired displays to Off.

Column 9 - Display Units

The selector data in this column are used to select the Display Mode engineering units for temperature, density, actual volume flow, compensated volume flow and mass flow. The flow time base selector applies to all of the flow rate variables; for example, it is not possible to configure the unit for volume flow in gallons/minute and mass flow in pounds/hour. Note that these units apply only to the Display Mode variables, and have no effect on the units used for the configuration data in the other columns.

Velocity units
ft/sec
cm/sec
m/sec

Volume units	Applies to actual and compensated volume flow
cubic feet	
cubic inches	
gallons	
barrels	1 barrel = 42 gallons
cubic cm	
liters	
cubic meters	

Mass units
pounds
tons
grams
kilograms
metric tons

Energy units
Btu
ton
kJ
kW
MW
GW
KCal
MCal

Column 9 - Display Units (continued)

Flow time base	Applies to all flow variables
/second	
/minute	
/hour	
/day	
Temp units	
°F	degrees Fahrenheit
°R	Rankine
°C	degrees Celsius
°K	degrees Kelvin
Pressure units	
psi	
atm	
bars	
kg/cm2	
mm Hg	
Pressure display	
absolute	
gauge	
Density units	
lb/ft3	pounds per cubic foot
g/cc	grams per cubic centimeter
kg/m3	kilograms per cubic meter

Column 10 - System

Unit number
The *unit number* is used for communication purposes to identify individual units in a network. This number may be set to any value between 0 and 65535.

Baud rate	This selector data determines the data transmission rate of the FP-93, and may be set to any of the following values:
38400	Data format must be set to 8 None for reliable communications at this rate
19200	
9600	
4800	
2400	
1200	
600	
300	

Data format	This selector data determines the data format used for communication, and may be set to any of the following values:
7 Even	7 data bits, even parity
7 Odd	7 data bits, odd parity
8 None	8 data bits, no parity

Stop bits	This selector data determines the number of stop bits used in communications,
1	and may be set to 1 or 2.
2	

Comm handshake	This selector data determines the communication handshaking means used by the FP-93, and may be set to any of the following values:
None	CTS input and received data are both ignored
Hardware	(CTS) CTS input must be high for the FP-93 to send data
XON/XOFF	XOFF character (ASCII DC3) stops transmission, any other character starts again
Both	Combined Hardware and XON/XOFF handshaking

Modem Comm	This enables a ATTENTION command to the hayes compatible modem in the
On	format of AT E0S0=1
Off	AT sets the Data format, Stop bits, Baud rate of the modem
	E0 turns the Echo Off
	S0=1 Answers on 1 ring.

Column 10 - System (continued)

Password
The user changeable password is used to control access to the configuration data in the FP-93. If an incorrect password is entered when attempting to access Program Mode, then the configuration data may be examined but not changed. This number may be set to any value between 0 and 65535. Note that if it is set to 6811 (the diagnostics access password), then the Diagnostic Mode will not be accessible.

Display scan, sec
The FP-93 may be configured to scroll the display variables. This entry determines the rate of the scrolling in seconds. Setting this value to 0 disables the scrolling.

Sync calc, On/Off
The FP-93 may be configured to perform calculations at a one-per-second rate synchronized to the CPU clock (Sync calc On), or to perform calculations asynchronously, as fast as possible (Sync calc Off). This option must be on for the FP-93 to measure frequency at the specified accuracy, and for the greatest accuracy in calculating average flow rates and temperature.
It may be desirable to configure the FP-93 to update at a faster rate, with some loss of accuracy. This may be done by turning Sync calc Off. The update rate in this case is dependent only upon the time necessary to convert the inputs and perform the calculations (the update rate may also be affected by communication). It will typically be about 4 updates per second.
The actual calculation interval may be observed as one of the displayed variables.

Temperature TC, sec	A/D converter filtering time constant; default = 2.0 seconds
Pressure TC, sec	A/D converter filtering time constant; default = 2.0 seconds
Flow TC, sec	Flow input filtering time constant; default = 0.0 seconds

The analog inputs and flow inputs may be smoothed by applying a filtering time constant to their values. These filters act as a first-order filter with an exponential response by averaging the last actual input value with a percentage of the previous filtered value. The time constant is the time required for the filtered value to change to approximately 63% of the input value change.

A/D reference, volts	Factory calibration for A/D converter

The A/D (analog to digital) converter reference voltage is the voltage measured between TP1 and TP2 on the PC board. The value entered here is used in calculation of the 4-20 mA analog input current and the RTD current. Since the resistance measurement is done by ratio of A/D counts, the A/D reference voltage has no effect on resistance measurements. This voltage should be between 1.210 and 1.260 volts. This is a factory set value, and need not be changed by the user unless the A/D converter needs to be recalibrated.

Column 10 - System (continued)

A/D int count Default value = 30720

The A/D converter integration count is a 16-bit integer which determines the duration of the A/D (analog to digital) converter integration period. The FP-93 uses a dual-slope integrating A/D converter. With this technology, it is possible to greatly reduce the effects of AC line noise by selecting the integration period to be an even multiple of one cycle of the power line frequency. The A/D integration count is the integration period in CPU clock cycles, and the frequency of the CPU clock is nominally 614400 Hz. To set the integration to a multiple of the power line frequency, the following values may be used. The resistance ranges are the worst case maximum ranges which do not exceed 0.05% and 0.10% resolution (percentage of reading). The resolutions for the 4-20 mA current input are listed for those values with sufficient range for the maximum current.

Frequency Hz	A/D Integration Count	Resistance Range, Ω .05%	.1%	Current Resolution, μA
60	10240	—	100-2100	1.2
	20480	100-4160	32-4160	0.6
	30720 (default)	47-2000	19-2000	0.4
	40960	32-1210	14-1210	•
	51200	24-870	11-870	•
	61440	19-670	9-670	•
50	12288	—	68-2700	1.0
	24576	68-3310	25-3310	0.5
	36864	36-1440	16-1440	0.3
	49152	25-920	11-920	•
	61440	19-670	9-670	•

Increasing the value of the A/D integration count results in improved resolution and accuracy. The upper limit is determined by the application, as follows:

- If used for a 4-20 mA input, the count should be set to 30720 if the power line frequency is 60 Hz, or 36864 for 50 Hz. Higher values may result in A/D converter out of range faults.
- If used for measuring the resistance of an RTD, the value should be set to the highest value which will give the desired resistance range. For example, if the resistance of the RTD will not exceed 670Ω, then set the A/D integration count to 61440 with either 50 or 60 Hz power line frequency. If a 1000Ω (nominal resistance at 0°C) RTD is used, setting the A/D integration count to 30720 will give the greatest accuracy at 60 Hz, but will restrict the maximum resistance to 2000Ω. If a higher limit is required, set the count to 20480.

D/A *zero count* *Def*ault value = 700

D/A *span count* *Def*ault value = 2800

These values are used to calibrate the D/A (digital to analog) converter for the 4 to 20 mA analog output. They are factory set values, and need not be changed by the user unless the analog output needs to be recalibrated.

Section 4 — Monitoring Data

4.1 Display Values

Bar graph	The bar graph display follows the analog output, and displays the value of the assigned variable as a percentage of full scale. Each line in the bar represents approximately 2% of full scale.
Density	Calculated fluid density in selected density units.
Specific volume	Calculated specific volume. (Inverse of Density)
Temperature	Calculated temperature in selected temperature units.
Avg temperature	Average temperature in selected temperature units.
Min temperature	Minimum temperature in selected temperature units.
Max temperature	Maximum temperature in selected temperature units.
Temperature #2	Calculated temperature #2 in selected temperature units. (Water BTU application)
Avg temp #2	Average temperature #2 in selected temperature units. (Water BTU application)
Min temp #2	Minimum temperature #2 in selected temperature units. (Water BTU application)
Max temp #2	Maximum temperature #2 in selected temperature units. (Water BTU application)
Diff temp	Water energy (BTU) differential temperature in selected temperature units.
Superheat	Calculated degrees of steam superheat. (For superheated steam application)
Pressure	Calculated pressure in selected pressure units. (Steam or gas application)
Avg Pressure	Average pressure in selected temperature units. (Steam or gas application)
Min Pressure	Minimum pressure in selected temperature units. (Steam or gas application)
Max Pressure	Maximum pressure in selected temperature units. (Steam or gas application)
Line Velocity	Measured line velocity in selected velocity units.
Volume flow	Actual volume flow of the fluid in selected volume flow units.
Avg vol flow	Average actual volume flow of the fluid in selected volume flow units.
Min vol flow	Minimum actual volume flow of the fluid in selected volume flow units.
Max vol flow	Maximum actual volume flow of the fluid in selected volume- flow units.
Comp flow	Temperature-compensated volume flow for liquids or Temp/Pressure compensated volume flow for gases at standard conditions (relative to the programmed reference density) in selected volume flow units.
Avg comp flow	Average compensated volume flow in selected volume flow units.
Min comp flow	Minimum compensated volume flow in selected volume flow units.
Max comp flow	Maximum compensated volume flow in selected volume flow units.
Mass flow	Mass flow of the fluid in selected mass flow units.
Avg mass flow	Average mass flow of the fluid in selected mass flow units.
Min mass flow	Minimum mass flow of the fluid in selected mass flow units.
Max mass flow	Maximum mass flow of the fluid in selected mass flow units.
Energy flow	Energy flow of the fluid in selected energy flow units.
Avg energy flow	Average energy flow of the fluid in selected energy flow units.

*Display Values (co*ntinued)

Min energy flow	Minimum energy flow of the fluid in selected energy flow units.
Max energy flow	Maximum energy flow of the fluid in selected energy flow units.
Analog output	Actual analog output current in mA.
Relay output	Status of the relay output if assigned to a setpoint alarm.
Total #1 (reset)	Resettable value for totalizer #1.
Total #1	Non-resettable value for totalizer #1.
Total #2 (reset)	Resettable value for totalizer #2.
Total #2	Non-resettable value for totalizer #2.
Clock/Calendar	System time and date.
Resistance #1	Measured resistance of RTD#1 in ohms.
Resistance #2	Measured resistance of RTD#2 in ohms. (Water BTU application)
Analog input #1	Analog multiplexer channel 1 voltage divided by 100, in mA.
Analog input #2	Analog multiplexer channel 2 voltage divided by 100, in mA.
Analog input #3	Analog multiplexer channel 3 voltage divided by 100, in mA.
Analog input #4	Analog multiplexer channel 4 voltage divided by 100, in mA.
Frequency	Flow input frequency in Hz.
Raw Velocity	Actual measured point velocity in selected units.
Viscosity	Calculated fluid viscosity in cP.
Reynolds #	Calculated Reynolds number. (Dimensionless)
Profile factor	Calculated Profile factor. (Insertion type flowmeters)
Obscuration	Obscuration factor. (Insertion type flowmeters)
Enthalpy	Calculated fluid enthalpy in selected units.
Enthalpy #2	Calculated fluid enthalpy from temperature input #2 in selected units. (water BTU applications)
Calc interval	Actual time in seconds to perform the last calculation. If Sync calc is on, this should nominally be 1.000 seconds; otherwise, the calculation interval will typically be about 0.40 to 0.45 seconds.

Fault and alarm messages

There are several diagnostic and operational range tests that are performed by the FP-93. These tests fall into three categories:

Power-on diagnostics
Operational range tests
Power failure

As soon as a fault or alarm condition occurs, the display will immediately show an appropriate message. Pressing [Select Clear] while the message is displayed will clear the message. In the case of power-on tests, the power should be turned off, then back on to determine if the fault still exists. With the possible exception of the battery backup fault, the unit will probably have to be returned to the factory for repair if the fault recurs.

Power-on diagnostic fault messages

*CONFIG = nn. This f*ault occurs if the 68HC11 configuration register is not programmed to the correct value. The unit will not be operable, and must be returned to the factory for repair.

*RAM read/write fault. This f*ault is caused by a failure to read back a value written to the RAM (Random Access Memory). A test of the RAM is performed each time the power to the FP-93 is turned on. If the fault occurs, the unit may continue to function, or may behave erratically.

*ROM checksum fault. Each t*ime the power is turned on to the FP-93, the program memory stored in ROM is tested. If the checksum of the ROM is incorrect, a component failure on the printed circuit board is indicated. If the fault occurs, the unit may continue to function, or may behave erratically.

*EEPROM checksum fault. The co*nfiguration data in EEPROM are checked using a CRC checksum each time the power is turned on. Check the programmed configuration data values if this fault occurs. The checksum for the configuration data is calculated and stored each time the unit is programmed and the data saved in EEPROM. If the fault recurs after reprogramming the EEPROM, the unit should be returned to the factory for repair.

*Battery backup fault. Each ti*me the power is turned on, two bytes in the battery backed-up RAM are checked for correct contents. If the values are not correct, the battery has probably discharged, and this fault will occur. Statistical values, totals and fault indicators will be cleared and the correct check values stored if this fault has occurred. The time required for a full charge on the battery is two weeks; the unit should maintain statistical values and totals for at least one month with the power off after the battery has been fully charged. If the fault recurs after sufficient time has been allowed for charging the battery, the unit should be returned to the factory for repair.

Operational range alarm messages

*Substitute flow, temp, press. Provid*es warning that substitute value(s) are in use.

*A/D converter out of range. This a*larm will occur if the actual voltage input to the A/D converter exceeds its maximum range (approximately 2.5 volts with the default A/D integrator count).

*Temperature input out of range or Temperature input #2 out of range. With a*n RTD temperature input, this alarm will occur if an open circuit is detected. If a 4-20 mA temperature input is used, the alarm will occur if the input current drops below 2.4 mA, or exceeds 21.6 mA.

Pressure input out of range. This alarm will occur if the input current drops below 2.4 mA, or exceeds 21.6 mA.

Flow input out of range. This alarm will occur if the analog flow input current drops below 2.4 mA, or exceeds 21.6 mA.

Analog output out of range. If the assigned value for the analog output drops below the zero-scale value, or exceeds the full-scale value, this alarm will occur. The actual output will not drop below 4 mA or go above 20 mA.

Relay output > 10 pulses/sec. If the relay output is assigned to the totalizer, and the totalizer scale factor is set too low, this alarm will occur.

Power failure messages

Power failure. This message appears normally after power has been restored to the FP-93.

Power dropout. This message is displayed when the power supply voltage drops below the power failure sensor voltage (approximately 10 volts DC). When displayed, the unit is inoperable. Normal operation will continue when the power supply voltage rises above the sensor voltage.

Section 5 — Communications

The FP-93 communicates with a computer or terminal through an RS-232 port using the ASCII protocol defined in this chapter. All calculated data and fault flags, as well as displayed units strings and totalizer assignment and scale factors, are accessible through individual data registers, which are listed on pages 46 thru 49. Information about the unit, such as model number, program code and version number, may also be obtained. In addition, there are special commands for clearing faults, resetting totalizers, clearing statistical values and resetting the data changed flag (set when any of the configuration data are changed from the front panel).

Programming of individual constants in the configuration data is not permitted with this protocol. The unit may be programmed with a single block transfer of all configuration data. These data are transmitted in hexadecimal ASCII format, and represent the actual binary data in the internal data structure of the FP-93. There are three types of data in this structure, defined in terms of the C programming language — unsigned char (8-bit, value between 0 and 255), unsigned int (16-bit, value between 0 and 65535) and float (32-bit IEEE single precision floating point format). The organization of this data structure is subject to change—the data structure defined here is for version 0.53 of the FP-93 firmware. The transmission of the data structure from the FP-93 will be preceded by a block containing information about the unit, such as model, program, version and number of bytes in the data structure. The last two bytes in the data structure are the CRC (Cyclic Redundancy Check) word, an integer containing the CRC of the data structure (the actual data in the structure, not the ASCII hexadecimal transmitted data), using the CCITT CRC polynomial X16 + X12 + X5 + 1. If the modulo-256 checksum of the data transmission is incorrect, or if the number of bytes in the received data block is incorrect, or if the CRC checksum of the data block is incorrect, an error message will be returned.

To request transmission of a data register:

:nnnnn#mm<cr>

where nnnnn is the 1 to 5-digit unit number

mm is the data register number (1 or 2 digits)

If the data request is valid, the FP-93 returns the message:

:nnnnn#mmxdata,cs<cr><lf> (no faults)
:nnnnn#mmxdata!cs<cr><lf> (faults are present)

where nnnnn is the unit number (1 or 2 leading zeroes if nnnnn < 100, no leading zeroes otherwise)

x is the data type:

a - floating point (%.5e printf format)

e - long integer (%lu printf format - 1 to 10 digits)
h - hexadecimal (%04X printf format - fault flags)
x - string

cs is the ASCII hexadecimal modulo-256 checksum of the entire transmission, including the colon and the comma or exclamation mark.

<cr> is an ASCII carriage return
<lf> is an ASCII line fees

Configuration data block transmissions to the FP-93 are of the form:

:nnnnn*data,cs<cr> (store data in permanent memory)
:nnnnn=data,cs<cr> (store data in RAM)

where data is the ASCII hexadecimal representation of the binary data structure (%02X printf format) including a 16-bit CRC checksum of the data. If there is an error in the received data, the FP-93 will respond with an error message. Otherwise, the FP-93 will respond with one of the following messages:

:nnnnn@,cs<cr><lf> (no faults)
:nnnnn@!cs<cr><lf> (faults are present)

To request transmission of the configuration data block from the FP-93:

:nnnnn@<cr>

The FP-93 will respond with a data block transmission in the form:

:nnnnn@header*data,cs<cr><lf> (no faults)
:nnnnn@header*data!cs<cr><lf> (faults are present)

where *header* is the unit information block:

mmmm-pppp-vv.vv-nnn

mmmm - model code
pppp - program code (1 to 4 digits)
vv.vv - version number
nnn - number of bytes in data structure, including CRC bytes (3 digits)

For example, the unit information block for the FP-93, program 1, version 0.53 is:

FP93-1-0.53-182

If there is an error in the received message, the FP-93 returns the message:

:nnnnn*e,cs<cr><lf> (no faults)
:nnnnn*e!cs<cr><lf> (faults are present)

where e is the error number (errors 5-7 apply only to configuration data block transmission):

0 - Data communication error (parity, overrun, framing or noise)
1 - Syntax error (invalid character or message format)
2 - Non-existent register number
5 - Message checksum error
6 - Data block CRC checksum error
7 - Incorrect number of bytes in data block

The C language function used in the FP-93 for calculation of the CRC of the data structure follows. This function may be used to check the CRC of the data structure after reception (the CRC of the entire data structure, including the CRC word, should be zero), or to generate the CRC word of the data structure prior to transmission.

```
#define CRC_POLY 0x1021                /* CCITT CRC polynomial                  */

/*
        crc() calculates the CRC of n bytes of data pointed to by its
        second argument, using the CRC polynomial CRC_POLY.
*/

unsigned crc(int n, char *data)
{
        unsigned i, accum = 0;
        static void calc_crc( unsigned, unsigned * );

        for (i=0; i<n; i++)
                calc_crc( (unsigned)*data++, &accum );

        return accum;
}

/*
        calc_crc() is based upon the routine crchware() in the C Programmer's
        Guide to Serial Communications by Joe Campbell, First Edition, 1987,
        Howard W. Sams & Company, pp 537-539.
*/
```

```
static void calc_crc( unsigned data, unsigned *accum )
{
	int i;

	data <<= 8;					/* data to high byte			*/
	for ( i=0; i<8; i++ ) {
		if ( (data ^ *accum) & 0x8000 )	/* if msb of (data XOR accum) is	*/
		  *accum = (*accum << 1) ^ CRC_POLY;	/* non-zero, shift and subtract	*/
		else				/* polynomial.				*/
		  *accum <<= 1;			/* otherwise, transparent shift		*/
		data <<= 1;			/* move up next bit for XOR		*/
	}
}
```

There are two reports which may be requested from the FP-93—the configuration data report, and the calculated variables report. These may be accessed as follows:

:nnnnn&c<cr>(configuration data)
:nnnnn&v<cr>(calculated variables)

These reports may take several seconds to prepare, during which calculations are not updated (totalizers are updated as soon as transmission of the report starts—accuracy of totalizers and flow calculations is not affected).

FP-93 Communication Registers

Register	Type	C print f format or unit string	Description
1	float	%.5e	RTD #1 resistance, Ω
2	float	%.5e	RTD #2 resistance, Ω
3	float	%.5e	Analog input #1 current, mA
4	float	%.5e	Analog input #2 current, mA
5	float	%.5e	Analog input #3 current, mA
6	float	%.5e	Analog input #4 current, mA
7	float	%.5e	Frequency, Hz
8	long	%lu	Flow direction (1 = forward, 0 = reverse)
10	float	%.5e	Temperature #1
11	float	%.5e	Average temperature #1
12	float	%.5e	Minimum temperature #1
13	float	%.5e	Maximum temperature #1
14	float	%.5e	Temperature #2
15	float	%.5e	Average temperature #2
16	float	%.5e	Minimum temperature #2
17	float	%.5e	Maximum temperature #2
18	float	%.5e	Differential temperature (temp #1 - temp #2) or superheat
19	string	deg F • deg R • d g C • K	Temperature units
20	float	%.5e	Pressure
21	float	%.5e	Average pressure
22	float	%.5e	Minimum pressure
23	float	%.5e	Maximum pressure
24	string	psi • atm • bars • kg cm^2 • mmHg	Pres ure units
25	float	%.5e	Density
26	string	lb/ft^3 • g/cc • kg/m^3	Density units
27	float	%.5e	Specific volume
30	float	%.5e	Volume flow
31	float	%.5e	Average volume flow
32	float	%.5e	Minimum volume flow
33	float	%.5e	Maximum volume flow
34	float	%.5e	Temperature compensated volume flow
35	float	%.5e	Average temperature compensated volume flow
36	float	%.5e	Minimum temperature compensated volume flow
37	float	%.5e	Maximum temperature compensated volume flow
38	string	ft^3 • gal • bbl • cc • l • m^3 /s • /m • /h • /d	Volume flow units

Register	Type	C print f format or unit string	Description
40	float	%.5e	Mass flow
41	float	%.5e	Average mass flow
42	float	%.5e	Minimum mass flow
43	float	%.5e	Maximum mass flow
44	string	lb • ton • g • kg • mt /s • /m • /h • /d	Mass flow units
45	float	%.5e	Energy flow
46	float	%.5e	Average energy flow
47	float	%.5e	Minimum energy flow
48	float	%.5e	Maximum energy flow
49	string	Btu • kJ • cal • kcal • Mcal /s • /m • /h • /d ton • kW • MW • GW	Energy flow units (power units)
50	float	%.5e	Calculation interval, seconds
51	float	%.5e	Analog output current, mA
52	long	%lu	Non-resettable totalizer #1 (forward)
53	long	%lu	Resettable totalizer #1 (forward)
54	long	%lu	Non-resettable totalizer #2 (reverse)
55	long	%lu	Resettable totalizer #2 (reverse)
56	long	%lu	Totalizer #1 assignment: 0 none 1 volume flow 2 compensated volume flow 3 mass flow 4 energy flow
57	float	%.5e	Totalizer #1 scale factor
58	long	%lu	Totalizer #2 assignment
59	float	%.5e	Totalizer #2 scale factor
60	float	%.5e	Raw velocity
61	float	%.5e	Profile factor
62	float	%.5e	Obscuration factor
63	float	%.5e	Line velocity
64	float	%.5e	Viscosity
65	float	%.5e	Reynolds number
66	float	%.5e	Compressibility factor
67	float	%.5e	Supercompressibility factor
68	float	%.5e	Enthalpy
69	float	%.5e	Enthalpy (temperature #2)
70	long	%lu	Current time - seconds since 12:00 midnight, 1/1/80

Register	Type	C print f format or unit string	Description
71	long	%lu	Time changed flag set
72	long	%lu	Time statistical values last cleared
73	long	%lu	Time totalizers last cleared
74	long	%lu	Time of power failure
75	long	%lu	Time of relay output rate alarm
76	long	%lu	Time of analog output alarm
77	long	%lu	Time of flow input out of range alarm
78	long	%lu	Time of temperature input out of range alarm
79	long	%lu	Time of temperature input #2 out of range alarm
80	long	%lu	Time of pressure input out of range alarm
81	long	%lu	Time of A/D converter overrange alarm
82	long	%lu	Time of battery fault
83	long	%lu	Time of EEPROM checksum fault
84	long	%lu	Time of ROM checksum fault
85	long	%lu	Time of RAM read/write fault
90	hex	%04X	Fault flags:
91	hex	%04X - previous fault flags	Clear faults and changed flag

Fault flags (register 90):

Bit	Fault
0	Changed flag is set
1	Communications fault (parity, overrun, noise)
2	Power failure
3	Relay output > 10 pulses/second
4	Analog output out of range
5	Flow input out of range
6	Temperature input #1 out of range
7	Temperature input #2 out of range
8	Pressure input out of range
9	A/D converter overrange
10	RAM battery fault
11	EEPROM checksum fault
12	ROM checksum fault
13	RAM read/write fault
14	Unused (always zero)
15	Substitute input(s)

Register	Type	C print f format or unit string	Description
92	long	always 0	Clear statistical values
93	long	previous value of forward totalizer	Clear resettable totalizers
94	string	mmmm-pppp-vvvv-nnn	Unit information block: mmmm - model number pppp program code (1-4 digits) vv.vv version number nnn number of bytes in data structure, including the two CRC checksum bytes (3 digits)

Example: FP93-2-0.53-374

Further information about the programming data structure is available from the factory.

Section 6 — Diagnostics and Calibration

The FP-93 is shipped from factory fully calibrated. The following section describes the procedures to recalibrate the FP-93.

Diagnostic Mode

Entering the special diagnostics password, 6811, when accessing Program Mode, enables a special Diagnostic Mode. All calculations are suspended, and communications are not allowed unless one of the communications tests are accessed. There are 13 diagnostic tests, accessible by pressing one of the numeric keys, as follows. The Diagnostic Mode is exited by pressing the [Program] key.

[1] simultaneous display of all four A/D converter counts.

[2] simultaneous display of all four A/D converter input voltages.

[3] locks A/D multiplexer onto a single channel, displaying the channel number, A/D counts and voltage for that channel. Change channels with the [+/–] key.

[4] tests the 68HC11 internal watchdog. The FP-93 should reset approximately 4 seconds after pressing the [4] key if no subsequent keys are pressed.

[5] tests the external watchdog timer. The FP-93 should reset approximately 2 seconds after pressing the [5] key if no subsequent keys are pressed.

[6] enables the keypad test, displaying keys as they are pressed, as follows. The [•/E] key terminates the keypad test.

Key	Display	Key	Display	Key	Display	Key	Display
[0]	0	[4]	4	[8]	8	[◄]	<
[1]	1	[5]	5	[9]	9	[►]	>
[6]	2	[6]	6	[Program]	P	[+/–]	-
[7]	3	[7]	7	[Select Clear]	S		

[7] provides a communications test. The first line of the display shows the unit number, baud rate, number of data bits, and parity. The second line shows the first 16 characters of the received message as they are received. The message must be started with a colon for the characters to be displayed. The unit will respond with a formatted message as soon as a carriage return is received.

[8] provides a data block reception test. If no message has been received, or if the last message received was not a data block, the first line of the display will show ‘Waiting’, and the second line will display the CRC of the internal data structure. If the last message received was a data block transmission, the first line will show Checksum: xx yy, where xx is the calculated checksum of the received message, and yy is the transmitted checksum. The second line shows the CRC of the received data block.

[9] outputs a formatted report of all of the displayed variables to the RS-232 port. The display will show ‘Printing’ while the report is being formatted, and will revert to the A/D converter count display as soon as actual printing starts.

[0] outputs a formatted report of the configuration data to the RS-232 port. The display will show ‘Printing’ while the report is being formatted, and will revert to the A/D converter count display as soon as actual printing starts.

[◄] allows adjustment of the D/A converter zero count. The count is adjusted by pressing [+/–] (to increase) or [•/E] (to decrease) while observing the output current with a current meter. Adjust so that the output current is 4.00 mA.

[►] allows adjustment of the D/A converter span count. The count is adjusted by pressing [+/–] (to increase) or [•/E] (to decrease) while observing the output current with a current meter. Adjust so that the output current is 20.00 mA.

[Select Clear] enters a special mode for calibration of the Bell 202 modem option. The display will show

Modem set

and the transmit data to the modem will be a square wave. The unit must be set to 1200 baud, with 1 stop bit for this function to be used for modem adjustment. The square wave is generated by sending continuous ‘U’ characters to the transmit data port, and may be useful for testing communications with other devices than the Bell 202 modem.

Calibration

Calibration of the FP-93 is a simple procedure of checking the frequency accuracy, and setting three constants for the analog to digital (A/D) converter and digital to analog (D/A) converter.

Frequency Input Test. Apply a 10 kHz pulse input with a 5 to 30 volt amplitude between the pulse input terminal (15) and the Supply Common terminal (17) on the terminal block of the panel mount FP-93. For the NEMA type FP-93, apply the pulse input between the pulse input terminal (10) and the Supply Common terminal (9) on the terminal block. Select the frequency display. If the unit is configured for synchronized calculations (see page 36), the display should read 10000±2 Hz; otherwise, the display should read 10000±10 Hz.

Analog Input Calibration. Using a 4-1/2 digit, 0.01% DC voltage accuracy digital voltmeter, measure the A/D reference voltage between test points TP1 and TP2 on the circuit board. This voltage should be 1.210 to 1.260 volts dc. Program the measured value into the A/D reference register (see page 36). Check the accuracy of the analog input circuit by applying a current to the Analog In 1 terminal (7). The displayed value should agree with the actual input current within 20 µA.

Analog Output Calibration. Perform the following steps:

a. Enter the Diagnostic Mode by pressing the [Program] key and entering the diagnostics password, 6811.

b. Press the [◄] key. The FP-93 will display:

Zero count   700
Span count 2800

with a cursor over the last position in the zero count. Note that the actual values displayed will probably be different. Press the [+/−] key to increase the count and the [·/E] key to decrease the count until the analog output current is exactly 4.00 mA. Holding the key down will cause the count to increase or decrease at a rate of 5 counts per second.

c. Press the [►] key. The cursor will move to the last position of the span count. Press the Kin key to increase the count and the [·/E] key to decrease the count until the analog output current is exactly 20.00 mA.

d. The new values are now stored in RAM. To make the changes permanent (assuming that the values have changed), exit the Diagnostic Mode by pressing the [Program] key. Enter Program Mode by again pressing the [Program] key and entering the correct password. Exit Program Mode by pressing the [Program] key and respond to the Save changes? prompt by again pressing the [Program]. The new calibration values will be stored in permanent memory.

Section 7 - Panel Mount Wiring

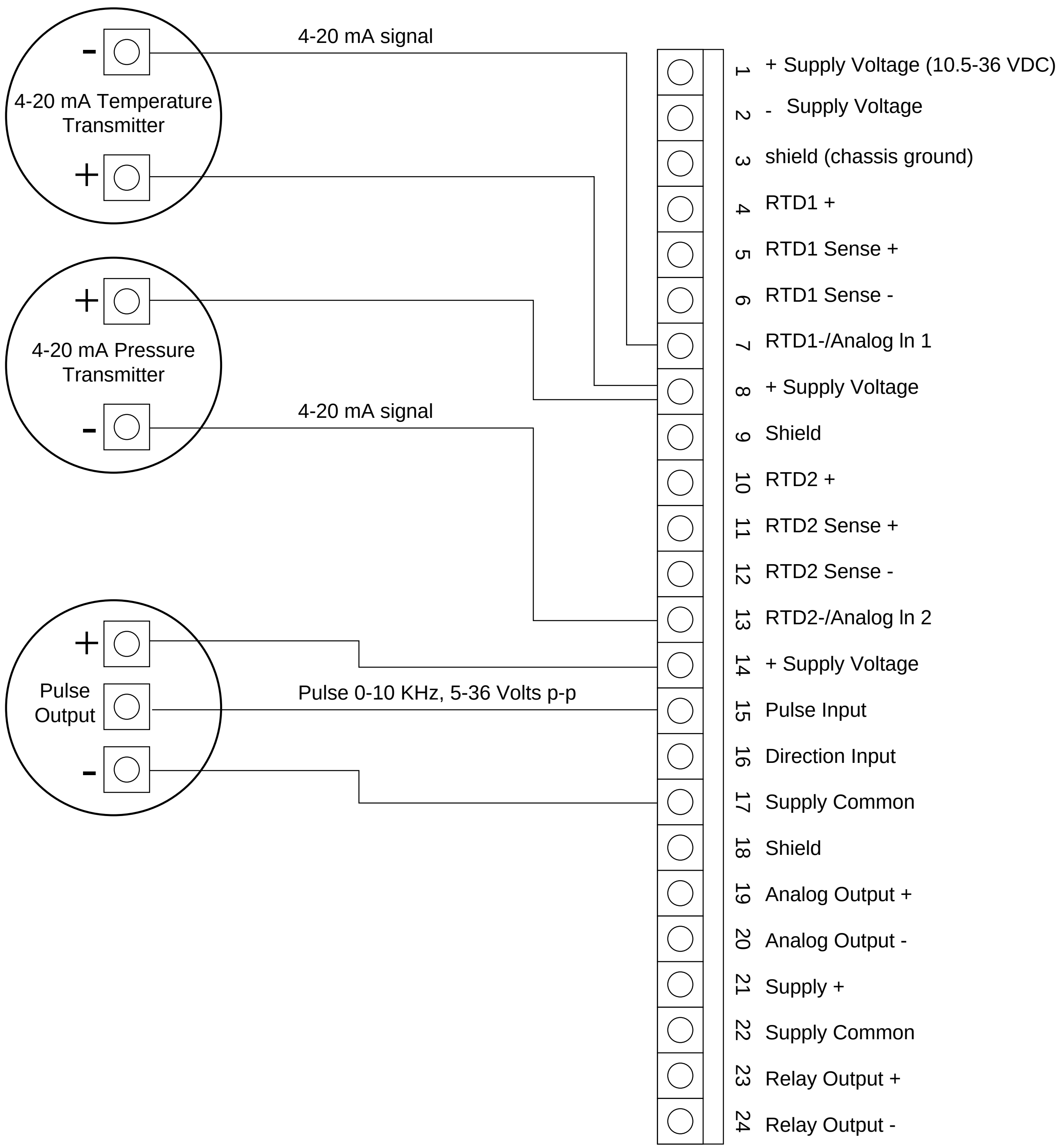
Input and output signals are wired through the-24 position terminal block on the rear panel of the FP-93. The signals at this terminal block are listed in table 1. For convenience in wiring external transmitters, extra terminals for power supply voltage, power supply common and chassis ground (used for cable shields) have been provided on the terminal block.

Good quality shielded cable (22 or 24 AWG copper wire size is satisfactory for most installations with runs of less than 300 feet) should be used for greatest accuracy and noise immunity. The cable shields should be connected to any of the shield terminals (3,9, or 18) on the terminal block.

Terminal	Description	Comments
1	+ Supply Voltage	10.5 to 36 volts DC power supply connections
2	– Supply Common	DC common
3	Chassis ground	Ground for shield purposes, not connected internally
4	RTD1+	Temperature input RTD source
5	RTD1 Sense +	RTD sense inputs
6	RTD1 Sense -	
7	RTD1– / Analog In 1	RTD return or temperature 4-20 mA input
8	+ Supply Voltage	Supply voltage for 4-20 mA transmitter
9	Shield	Connected to chassis ground
10	RTD2+	Temperature input #2 RTD source
11	RTD2 Sense +	RTD sense inputs, or flow 4-20 mA input
12	RTD2 Sense	
13	RTD2– / Analog In 2	RTD return, temperature or pressure 4-20 mA input
14	+ Supply Voltage	Supply voltage for flow meter
15	Pulse Input	Frequency input from flow meter
16	Direction	Pulse for Bi-directional flowmeters
17	Supply Common	Supply common for flow meter
18	Shield	Connected to chassis ground
19	Analog Output +	4-20 mA isolated analog output
20	Analog Output –	
21	+ Supply Voltage	
22	Supply Common	
23	Relay Output +	Solid-state relay output
24	Relay Output –	

Table 1. Panel Mount Terminal Block Connections

Panel Mount FP-93 General Wiring



Panel Mount FP-93 to RTD

The RTD temperature input is designed for use with a four-wire RTD connection (see Figure 2), which results in cancellation of all lead resistance effects. This circuit may be used with 100Ω or 1000Ω platinum RTDs, or with any other RTD whose resistance may be expressed as a quadratic function of temperature, and which has minimum and maximum resistance values in the range of 10 to 4000 ohms. The RTD may be used in either two-wire or three-wire configuration. For a two-wire connection, jumper terminal 4 to 5 and 6 to 7, then connect the RTD leads between 5 and 6. For the three-wire connection, jumper 4 to 5 and connect the single lead to 5, with the two common leads to 6 and 7.

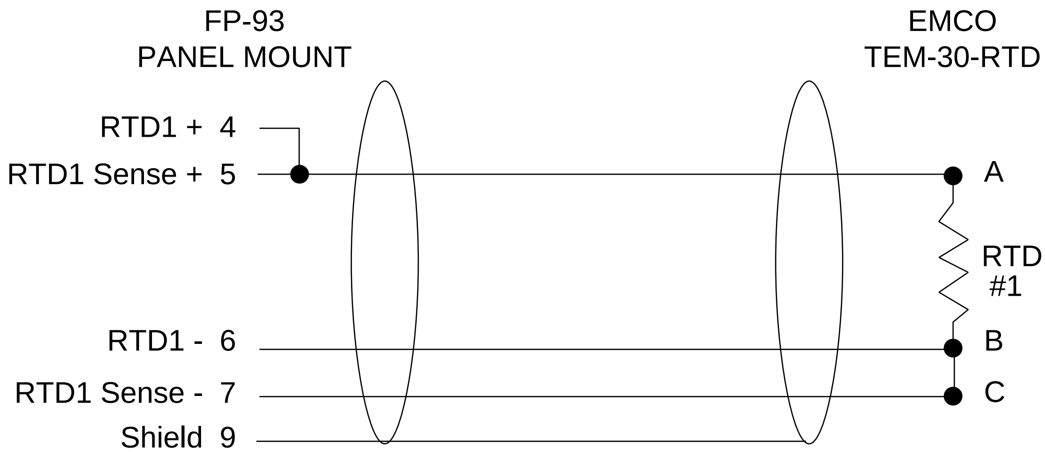


Figure 2. 4-wire RTD Temperature Input

For chilled and hot water energy flow measurements (BTUs), the RTD1 from the higher temperature line is connected to the FP-93 as shown in Figure 2 above. The RTD2 from the lower temperature line is connected to the FP-93 as shown in Figure 3 below. For a two wire connection jumper terminal 10 to 11 and 12 to 13, then connect the RTD leads between 11 and 12. For the three-wire connection jumper 10 to 11 and connect the single lead to 11, with the two common leads to 12 and 13.

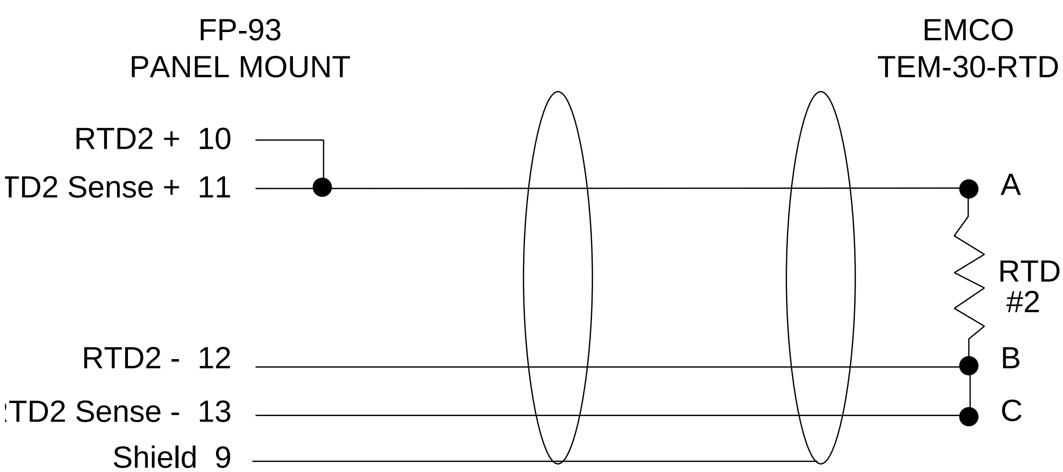
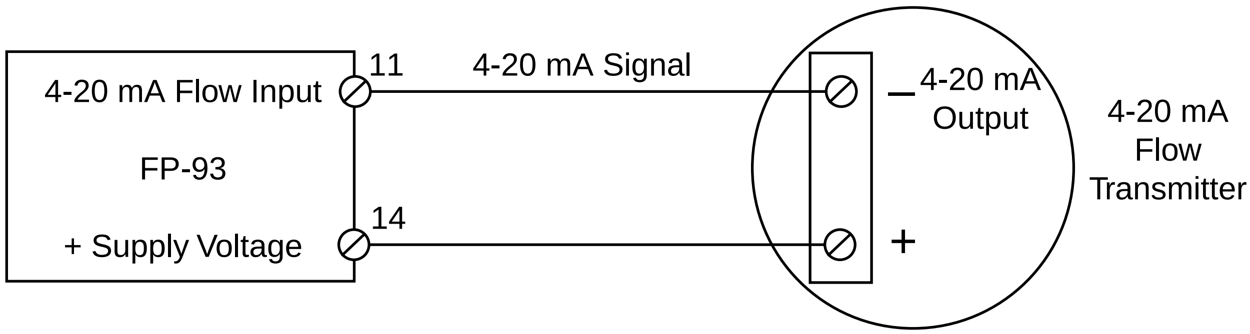


Figure 3. 4-wire RTD Temperature input for Energy flow measurement

Panel Mount Analog (4-20 mA) Flow Input

The flow input can also be a 4-20 mA analog signal. In this case the flow transmitter is connected to terminals 11 and 14 as shown below.



The FP-93 standard configuration is for pulse input. If the user has specified analog flow input prior to shipment, the unit is configured for analog input. Otherwise the user needs to configure the FP-93 for analog input using the following procedure:
1) Install W3 and W4 jumpers as shown in Figure 4 below.

2) Install R58 resistor . The value of the resistor is 100 ohms, 1/2 watt with accuracy of 0.05% or better.

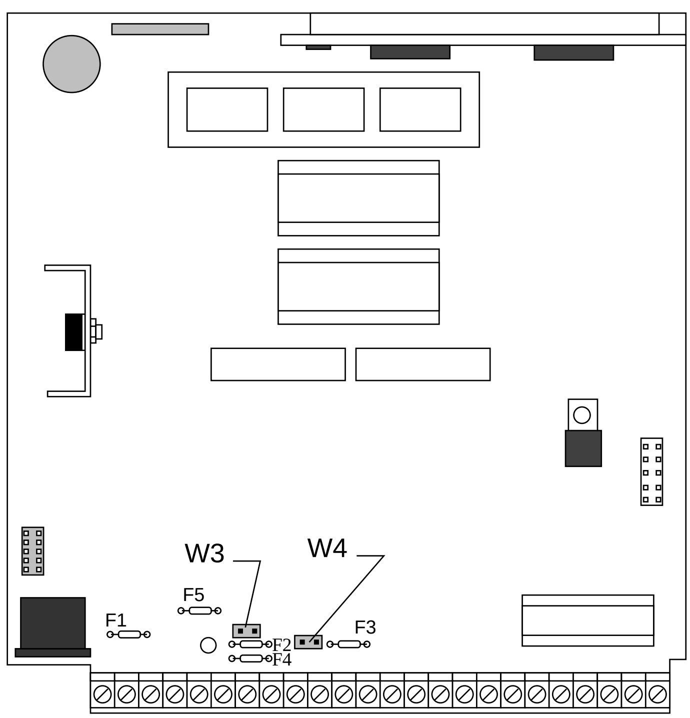
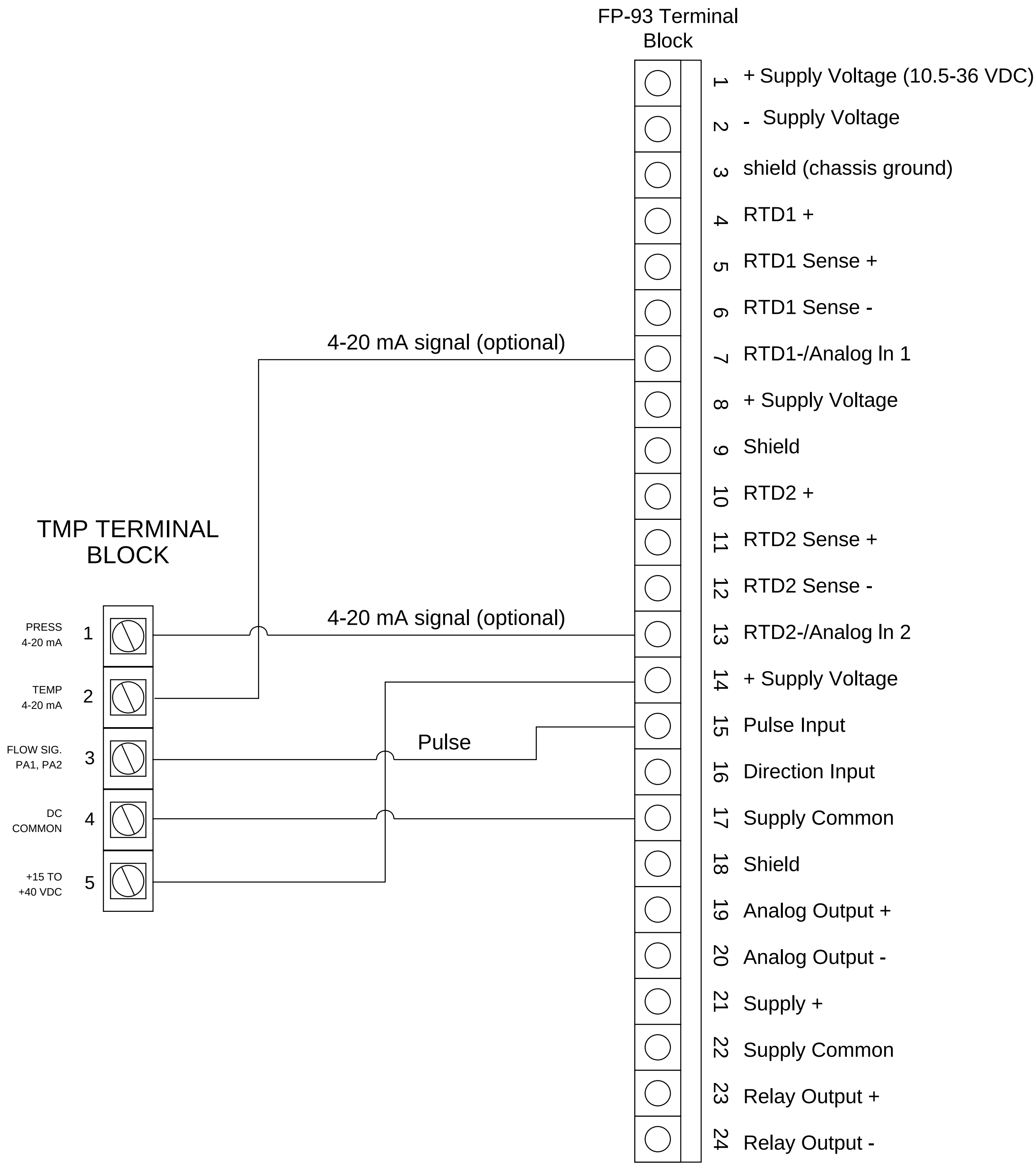
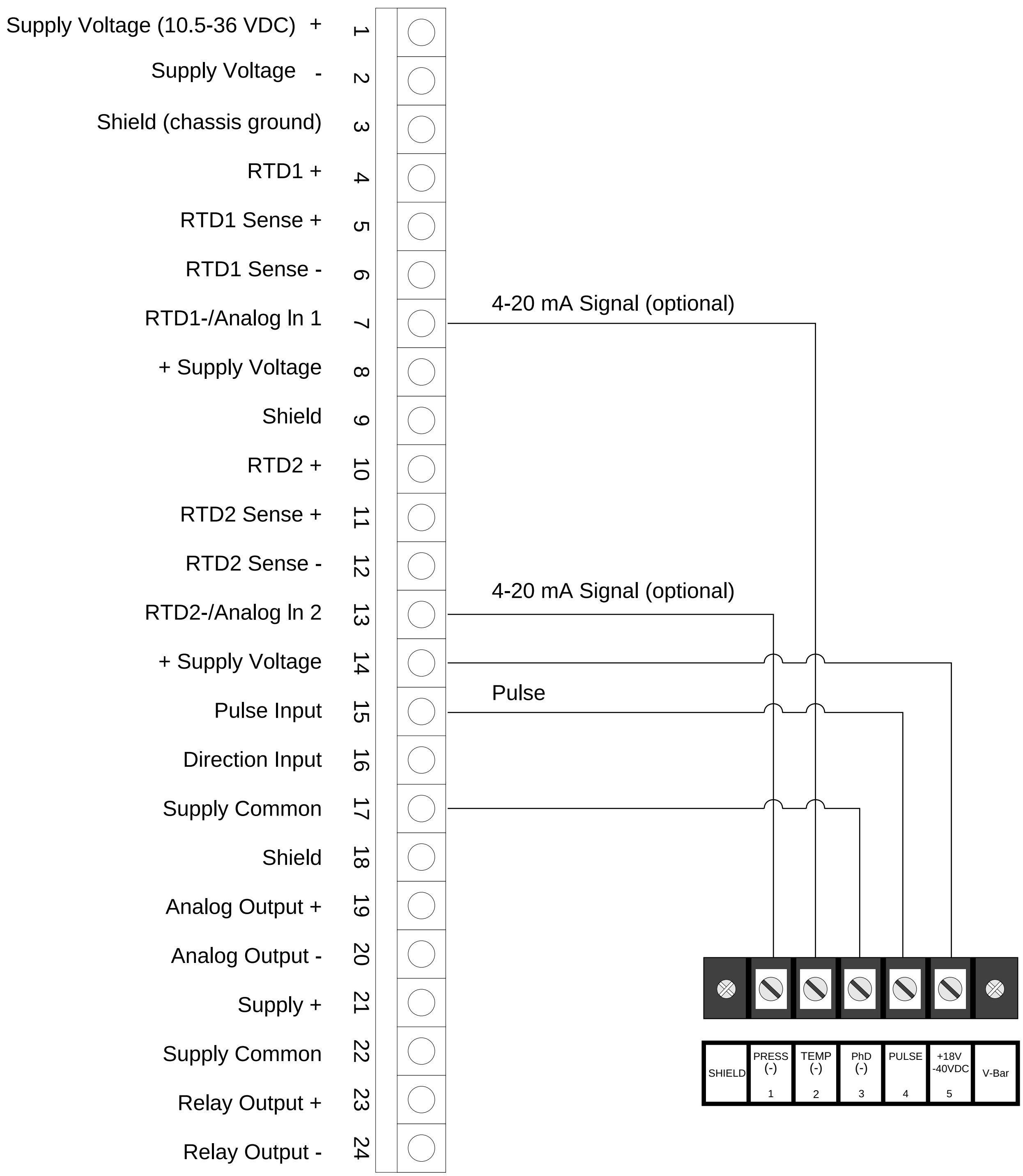


Figure 4. Analog Flow Input Configuration

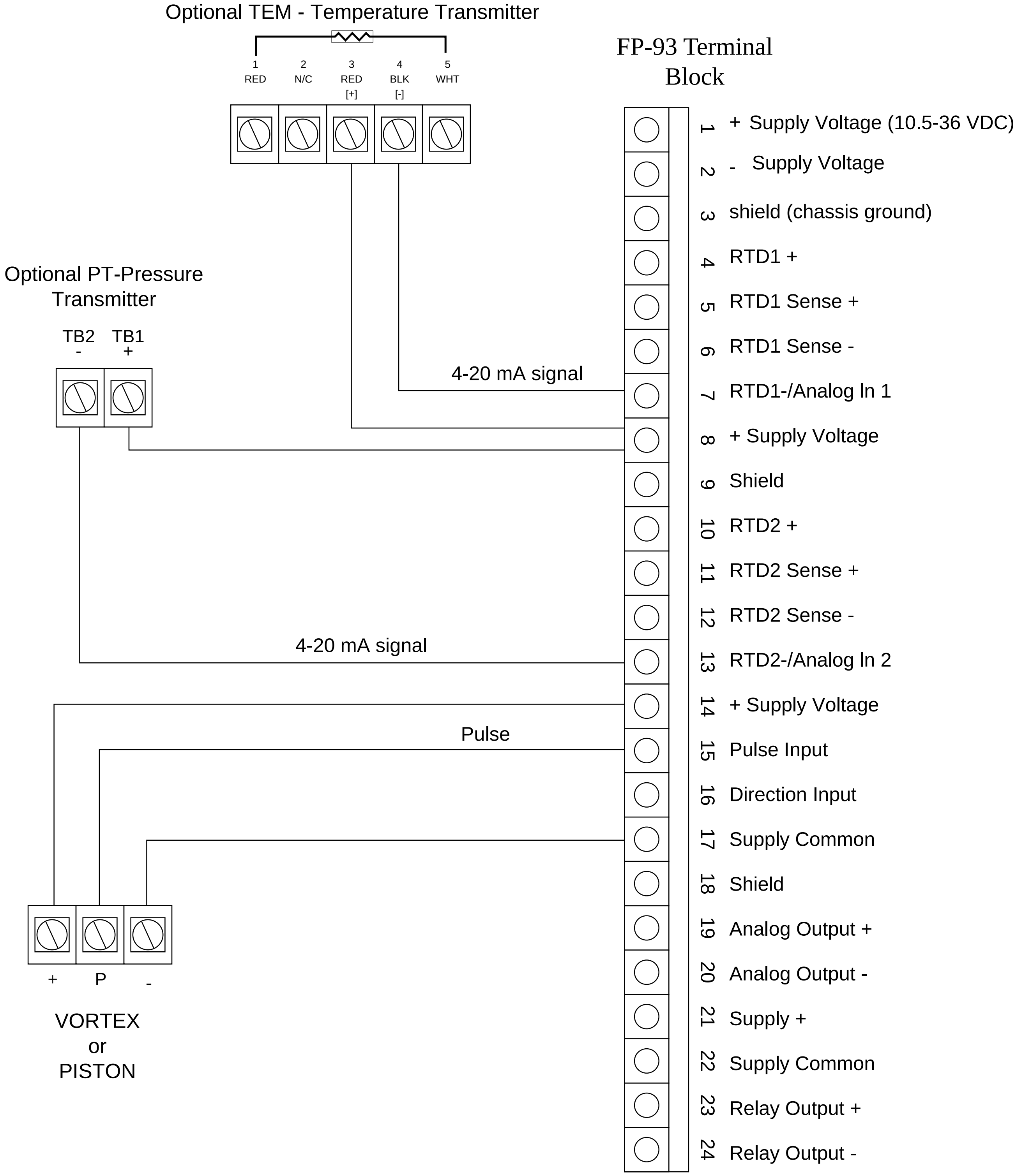
Panel Mount FP-93 to Insertion Turbine-TMP



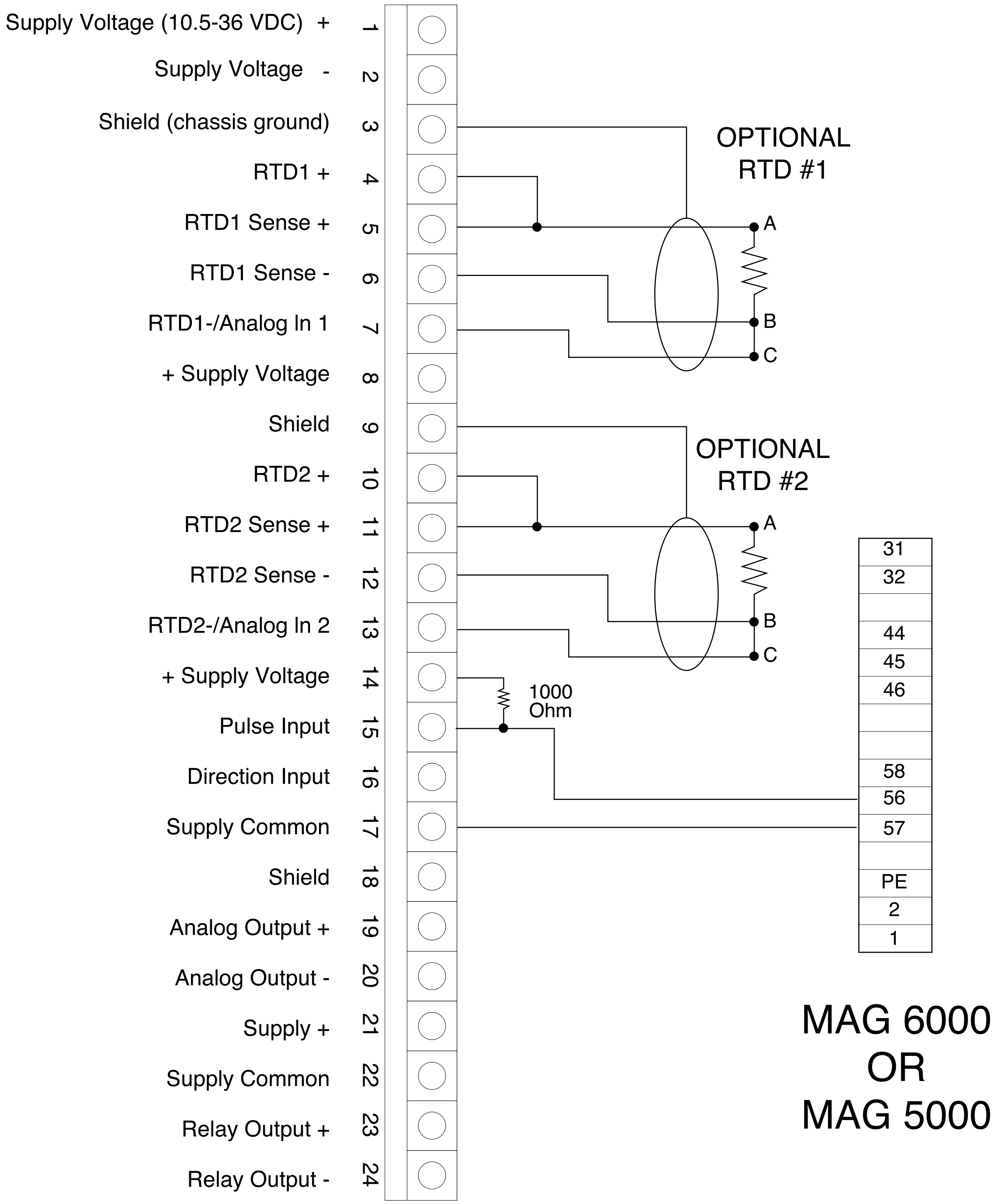
Panel Mount FP-93 to Insertion Vortex (V–Bar™) or Insertion Turbine (Turbo-Bar™)



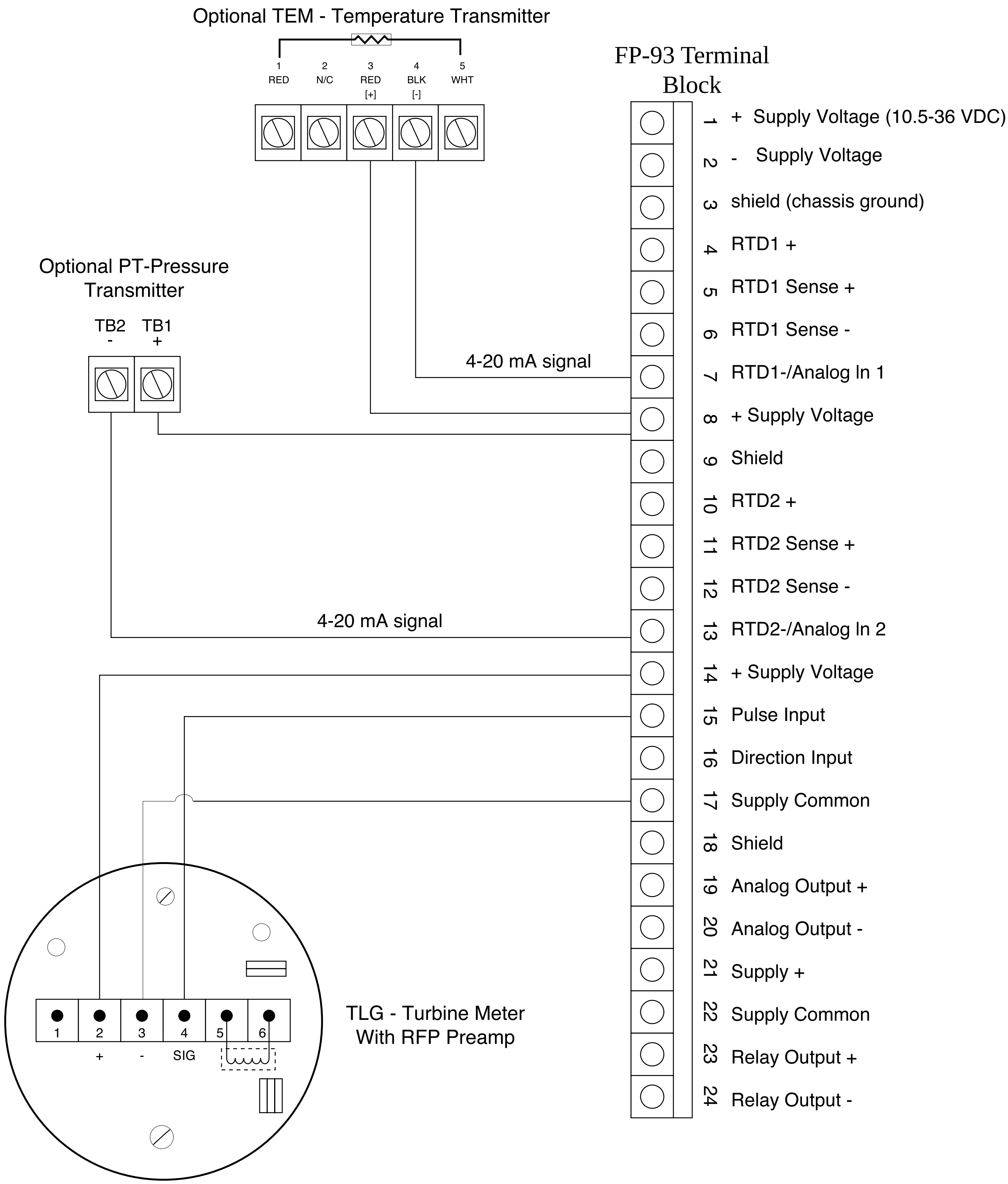
Panel Mount FP-93 to Inline Vortex-Vortex PhD or Piston-PDP



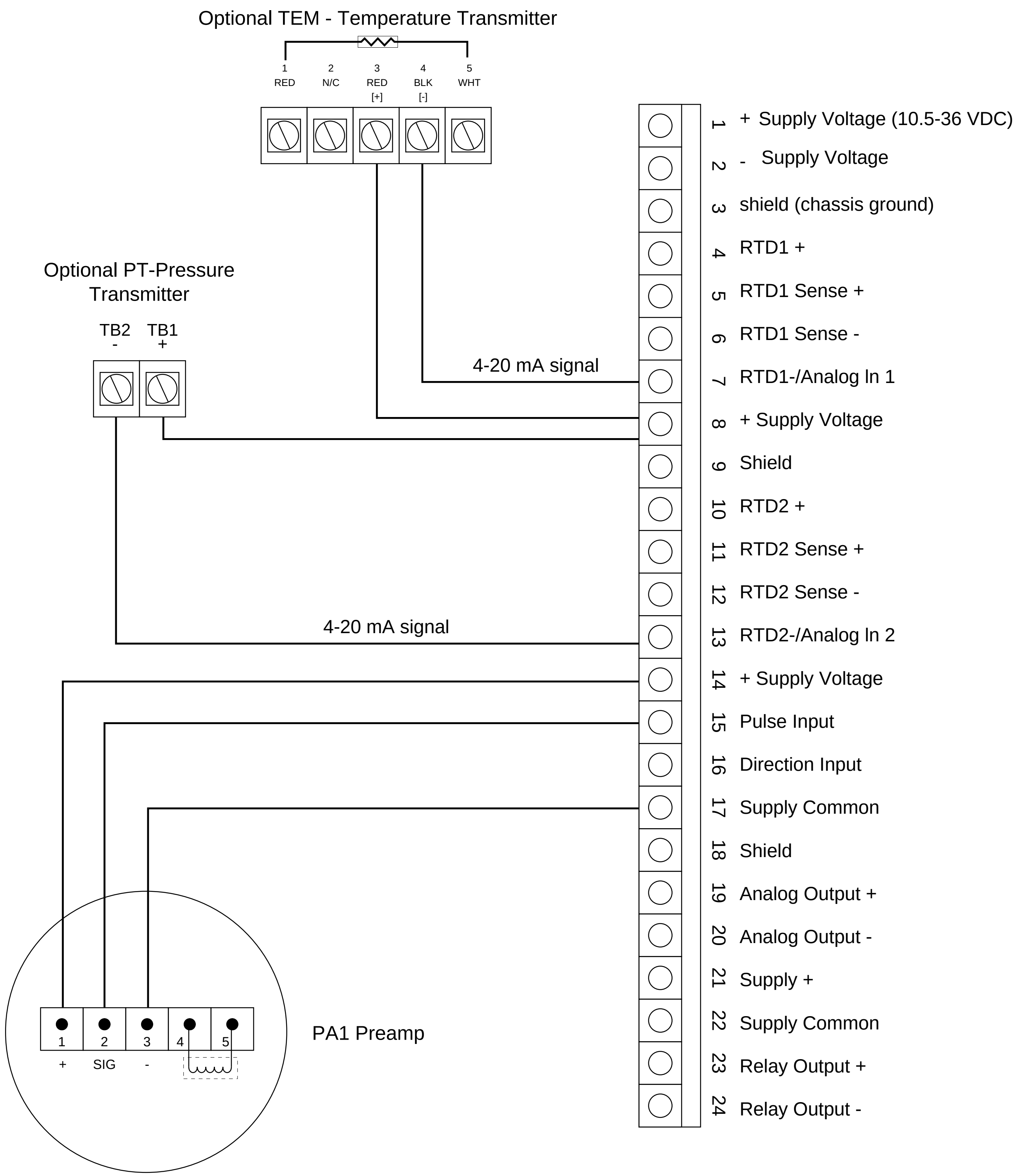
Panel Mount FP-93 to Electromagnetic-MAG 6000 or MAG 5000



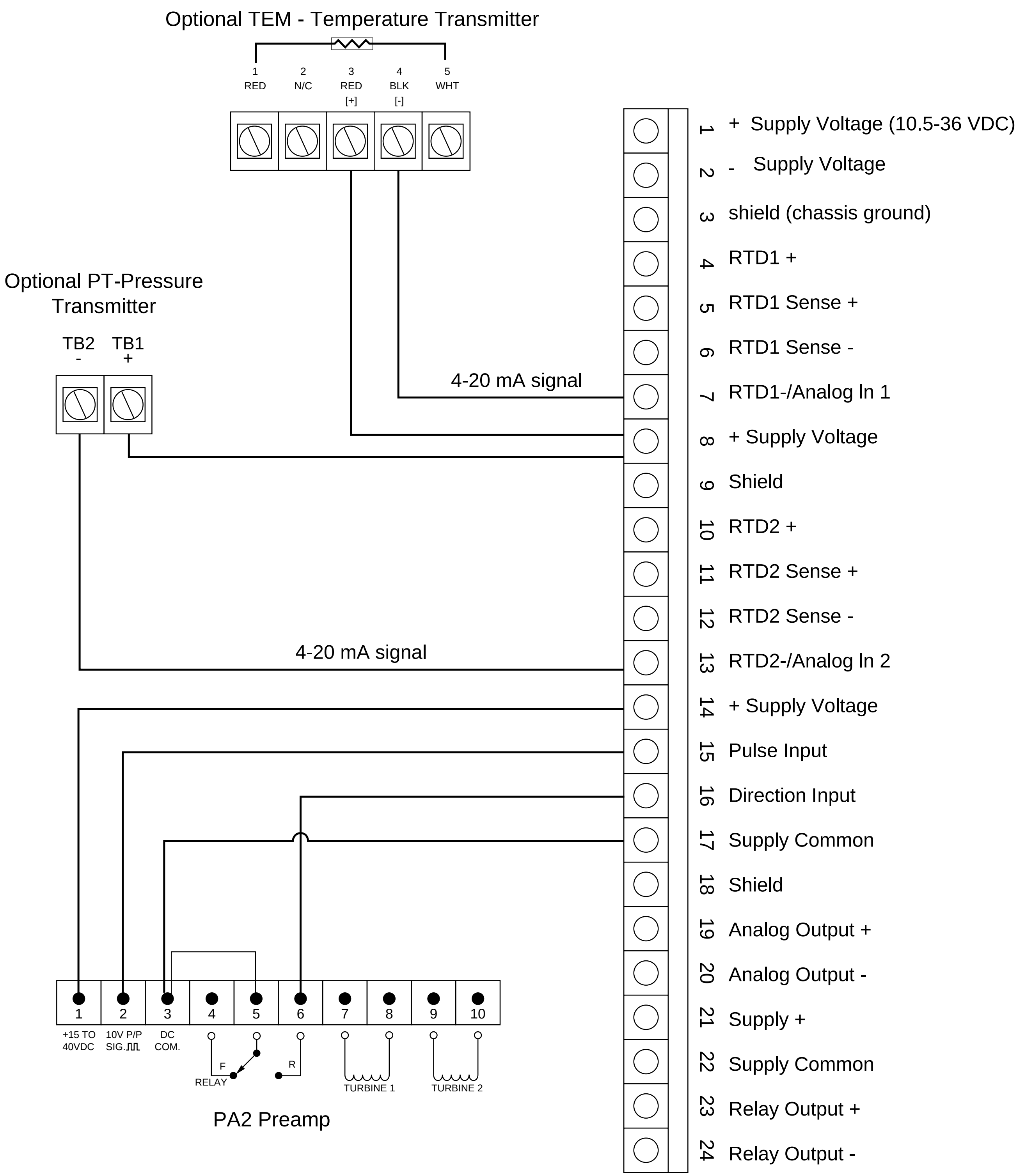
Panel Mount FP-93 to Inline Turbine -TLG-01 thru TLG-12



Panel Mount FP-93 to PA1 Preamplifier



Panel Mount FP-93 to PA2 Preamplifier



4-20 mA Analog Flow Output

The analog output is an optically isolated 4-20 mA output. It may be used to drive chart recorders or other devices with a signal that is proportional to the pressure, temperature, differential temperature, density, velocity, volume flow, mass flow or energy flow. The polarity of the wiring to the analog output is critical. It will not work if the connections are reversed. Based on the receiving electronics or control instrument, the wiring connections are made as shown in Figures 5 and 6.

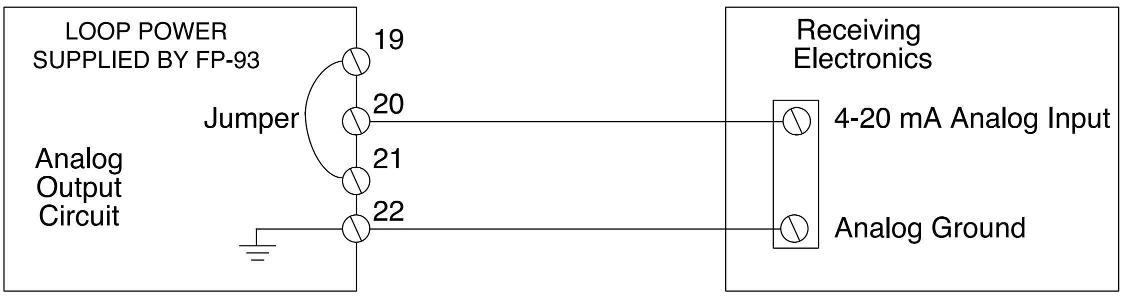


Figure 5. 4-20 mA Isolated Analog Output

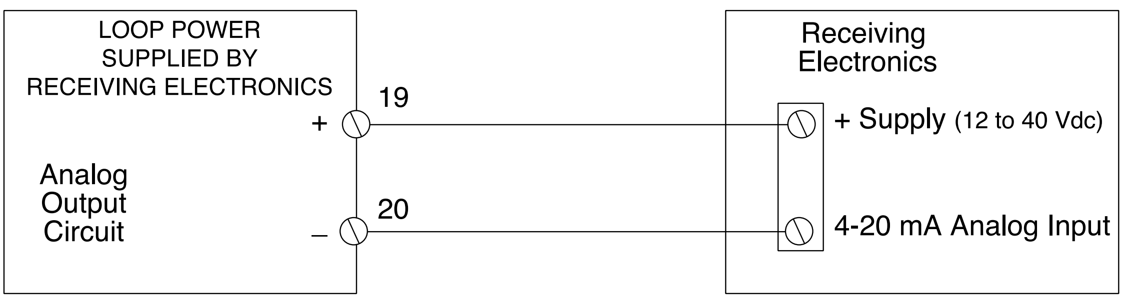
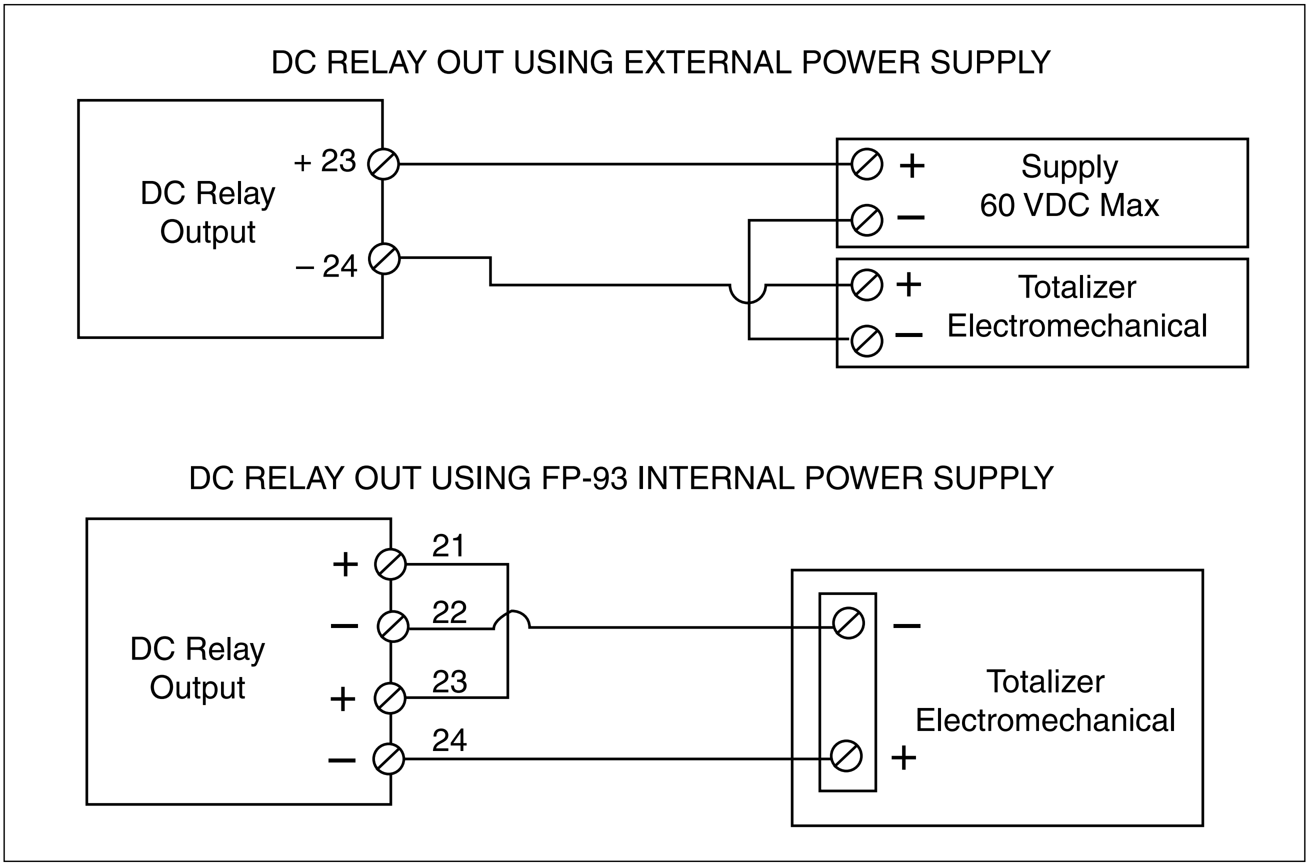
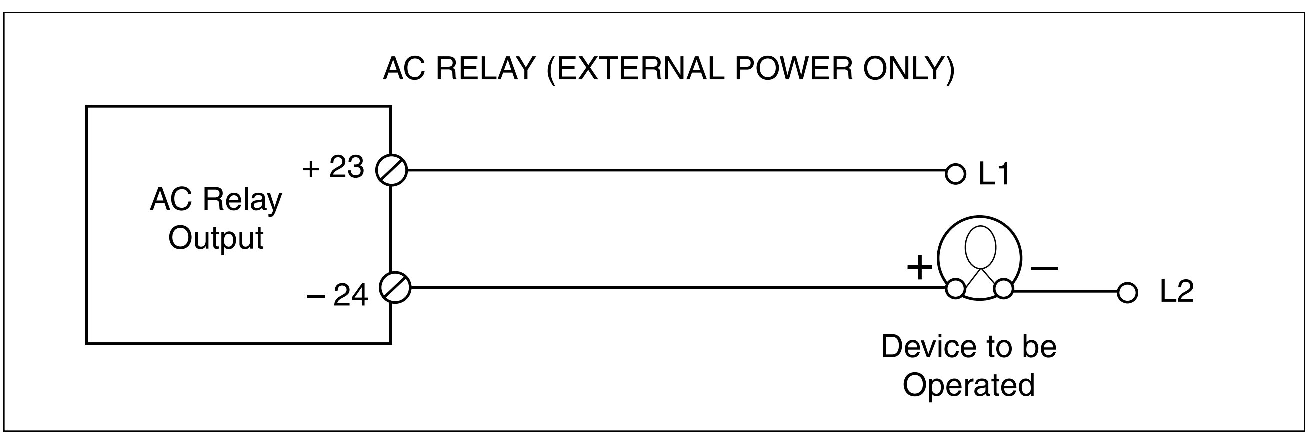


Figure 6. 4-20 mA Current Source Analog Output

Relay Output

The relay output is an optically isolated solid-state relay with current capacity of 1 ampere. Depending upon the model ordered, the relay may be a DC output, with the capability of controlling circuits with voltages of up to 60 volts DC, or an AC output, with a maximum voltage of 280 volts AC, or 500 volts peak. The polarity of the connections is critical if the DC relay option is installed.





Section 9 - NEMA Wiring

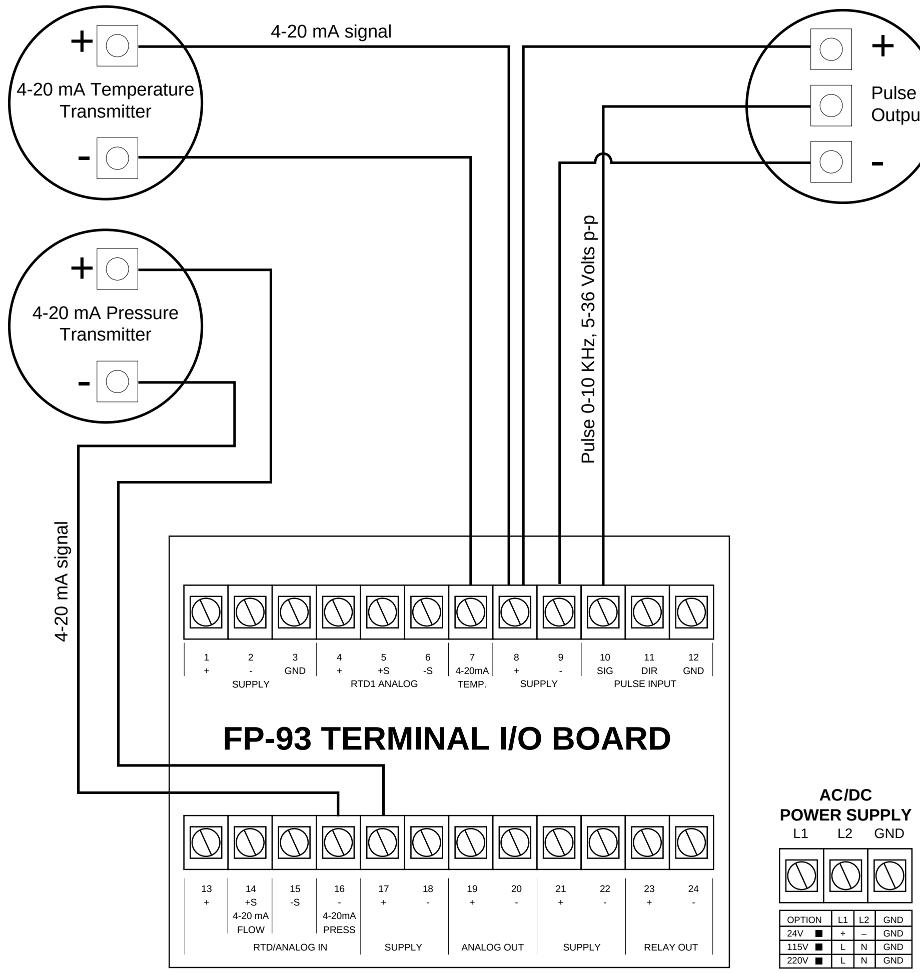
Input and output signals are wired through the two 12- position terminal block on the I/O board of the FP-93. The signals at this terminal block are listed in Table 2. For convenience in wiring external transmitters, extra terminals for power supply voltage, power supply common and chassis ground (used for cable shields) have been provided on the terminal block.

Good quality shielded cable (22 or 24 AWG copper wire size is satisfactory for most installations with runs of less than 300 feet) should be used for greatest accuracy and noise immunity. The cable shields should be connected to any of the shield terminals (3 or 12) on the terminal block.

Table 2. NEMA Mount Terminal Block Connections

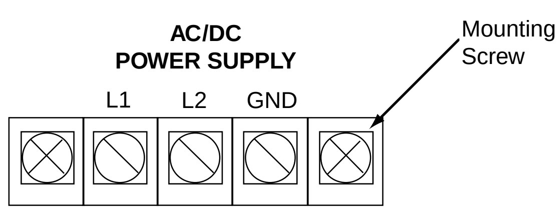
Terminal	Description	Comments
1	+ Supply Voltage	10.5 to 36 volts DC power supply connections
2	– Supply Common	DC Common
3	Chassis ground	Ground for shield purposes, not connected internally
4	RTD1+	Temperature input RTD source
5	RTD1 Sense +	RTD sense inputs, 4-20 mA flow input
6	RTD1 Sense -	
7	RTD1– / Analog In 1	RTD return or temperature 4-20 mA input
8	+ Supply Voltage	Supply voltage for 4-20 mA transmitter
9	Supply Common	Supply Common for flow meter
10	Pulse Input	Frequency input from flow meter
11	Direction	Pulse for Bi-directional flowmeters
12	Chassis ground	Ground for shield purposes, not connected internally
13	RTD2+	Temperature input #2 RTD source
14	RTD2 Sense +	RTD sense inputs, or flow 4-20 mA input
15	RTD2 Sense	
16	RTD2– / Analog In 2	RTD return, temperature or pressure 4-20 mA input
17	+ Supply Voltage	Supply voltage for flow meter
18	Supply Common	Supply common for transmitters
19	Analog Output +	4-20 mA isolated analog output
20	Analog Output –	
21	+ Supply Voltage	
22	Supply Common	
23	Relay Output +	Solid-state relay output
24	Relay Output –	

NEMA FP-93 General Wiring



CE Approval

To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to RTD

The RTD temperature input is designed for use with a four-wire RTD connection (see Figure 7), which results in cancellation of all lead resistance effects. This circuit may be used with 100Ω or 1000Ω platinum RTDs, or with any other RTD whose resistance may be expressed as a quadratic function of temperature, and which has minimum and maximum resistance values in the range of 10 to 4000 ohms. The RTD may be used in either two-wire or three-wire configuration. For a two-wire connection, jumper terminal 4 to 5 and 6 to 7, then connect the RTD leads between 5 and 6. For the three-wire connection, jumper 4 to 5 and connect the single lead to 5, with the two common leads to 6 and 7.

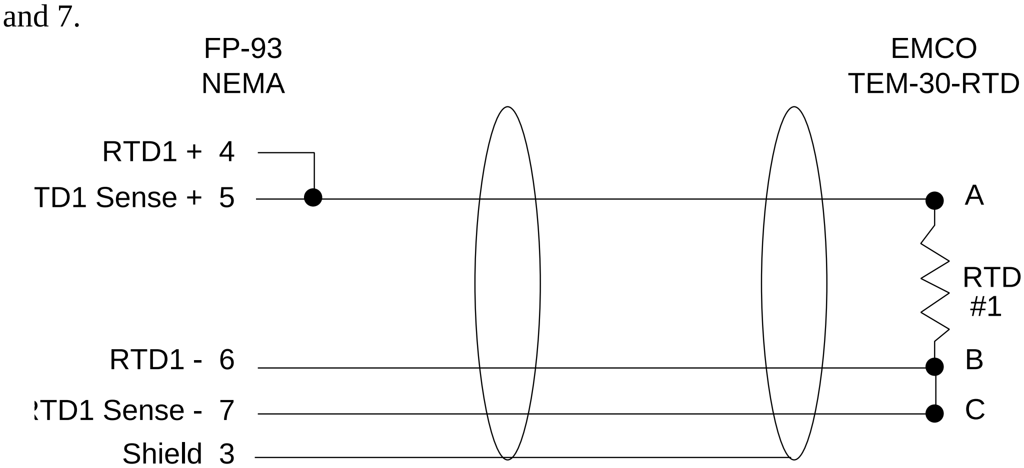


Figure 7. 4-wire RTD Temperature Input

For chilled and hot water energy flow measurements (BTUs), the RTD1 from the higher temperature line is connected to the FP-93 as shown in Figure 7 above. The RTD2 from the lower temperature line is connected to the FP-93 as shown in Figure 8 below. For a two wire connection, jumper terminal 13 to 14 and 15 to 16, then connect the RTD leads between 14 and 15. For the three-wire connection, jumper 13 to 14 and connect the single lead to 14, with the two common leads to 15 and 16.

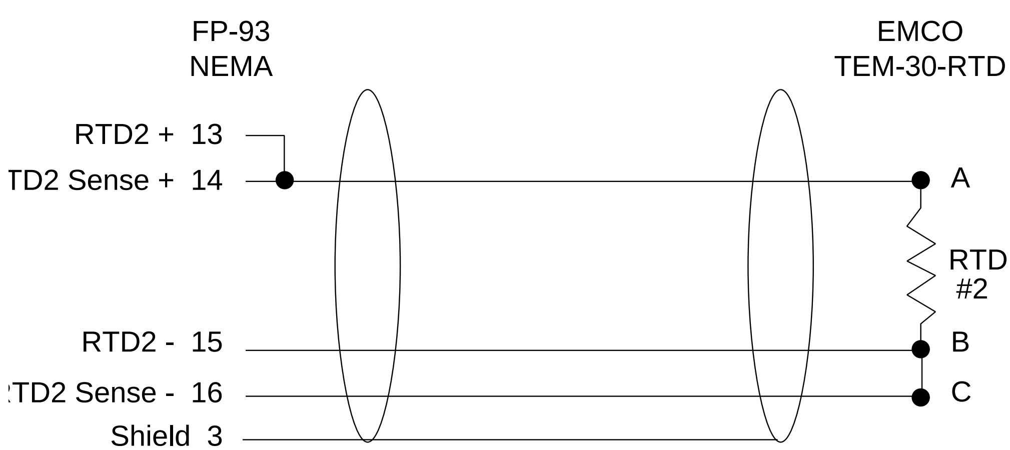


Figure 8. 4-wire RTD Temperature input for Energy flow measurement

NEMA Analog (4-20 mA) Flow Input

The flow input can also be a 4-20 mA analog signal. In this case, the flow transmitter is connected to terminals 8 and 14. The configuration of the FP-93 for analog flow input is the same for both panel and NEMA style as shown in Figure 4 on page 56

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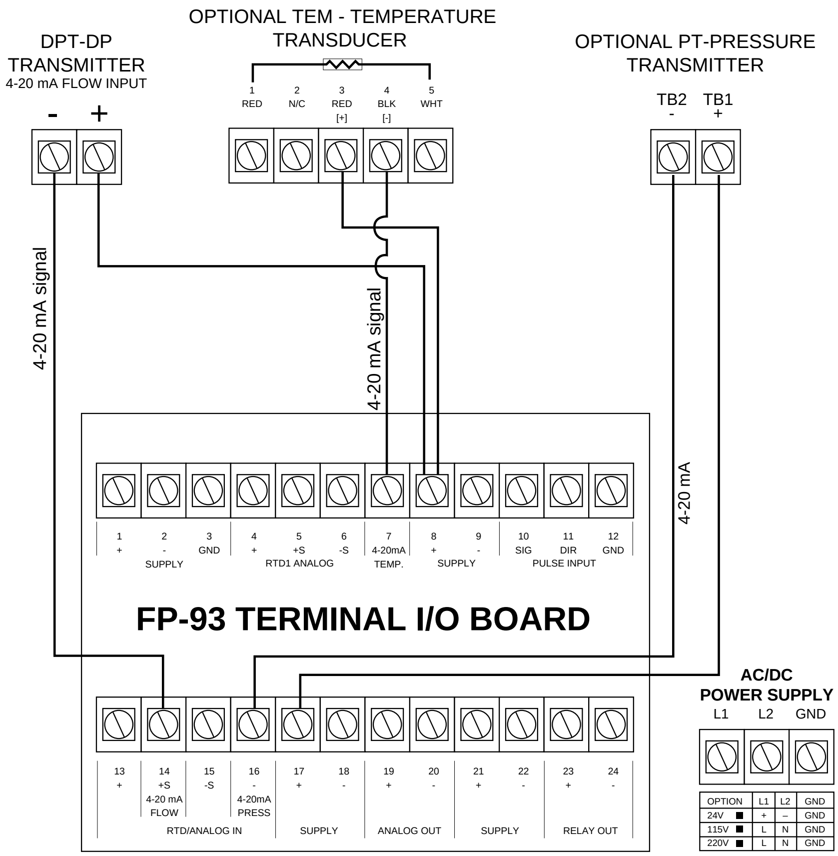
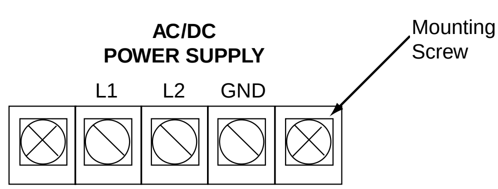


CE Approval

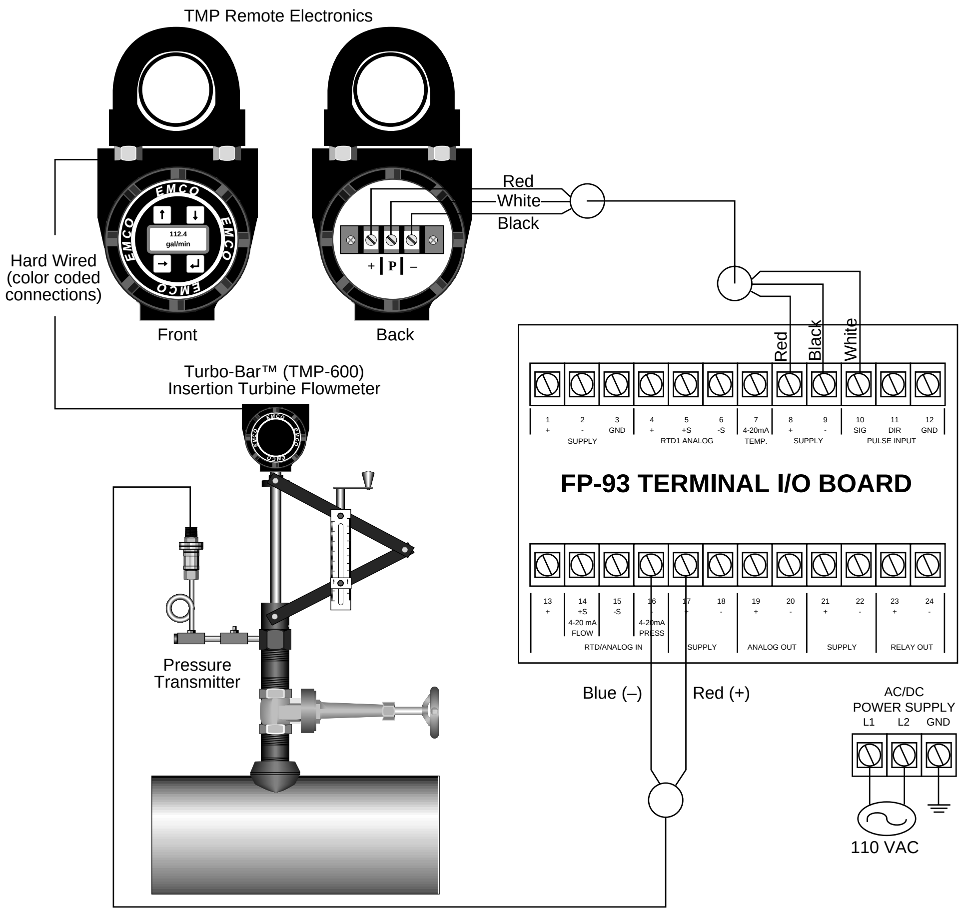
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

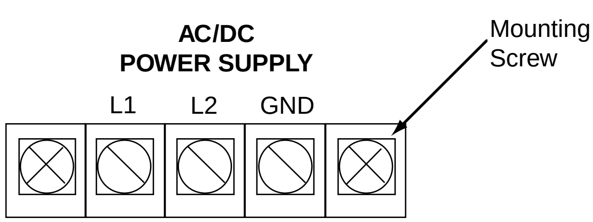
To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to Insertion Turbine-TMP or Turbo-Bar



CE Approval

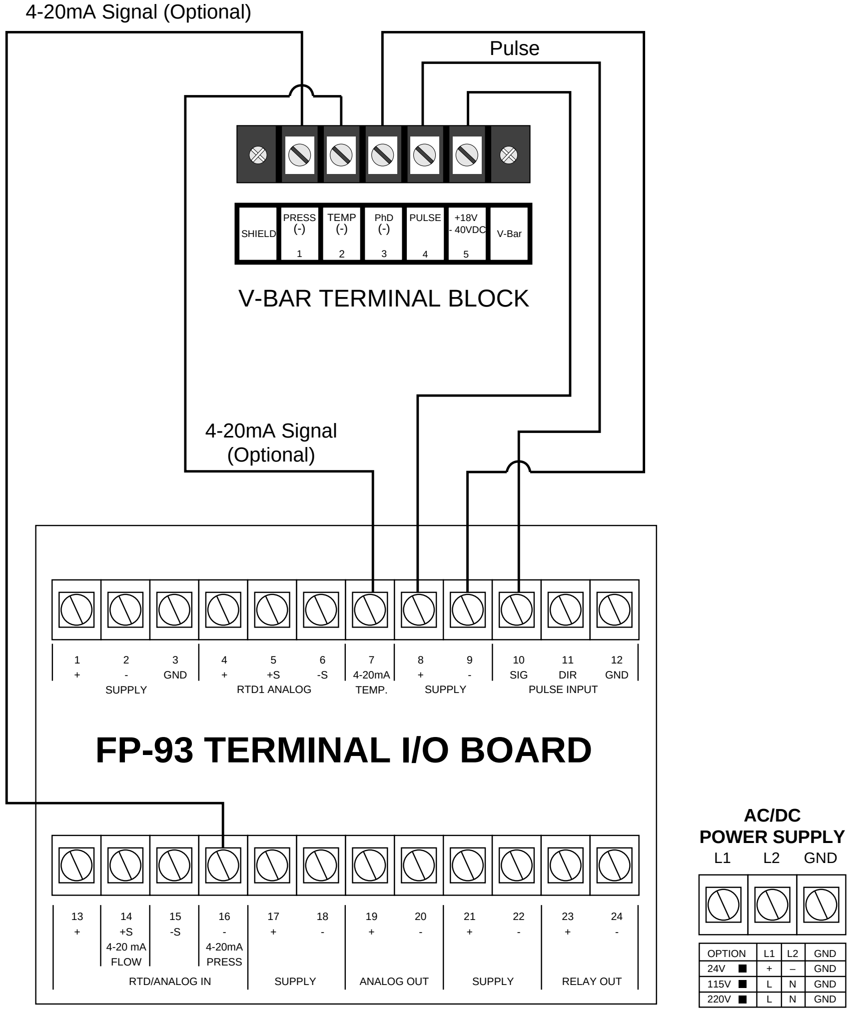
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



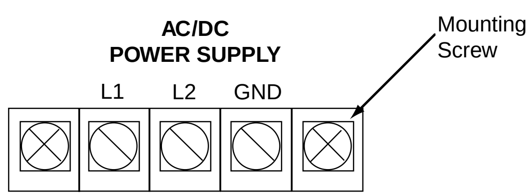
OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to Insertion Vortex-V–Bar or Insertion Turbine (Turbo-Bar)



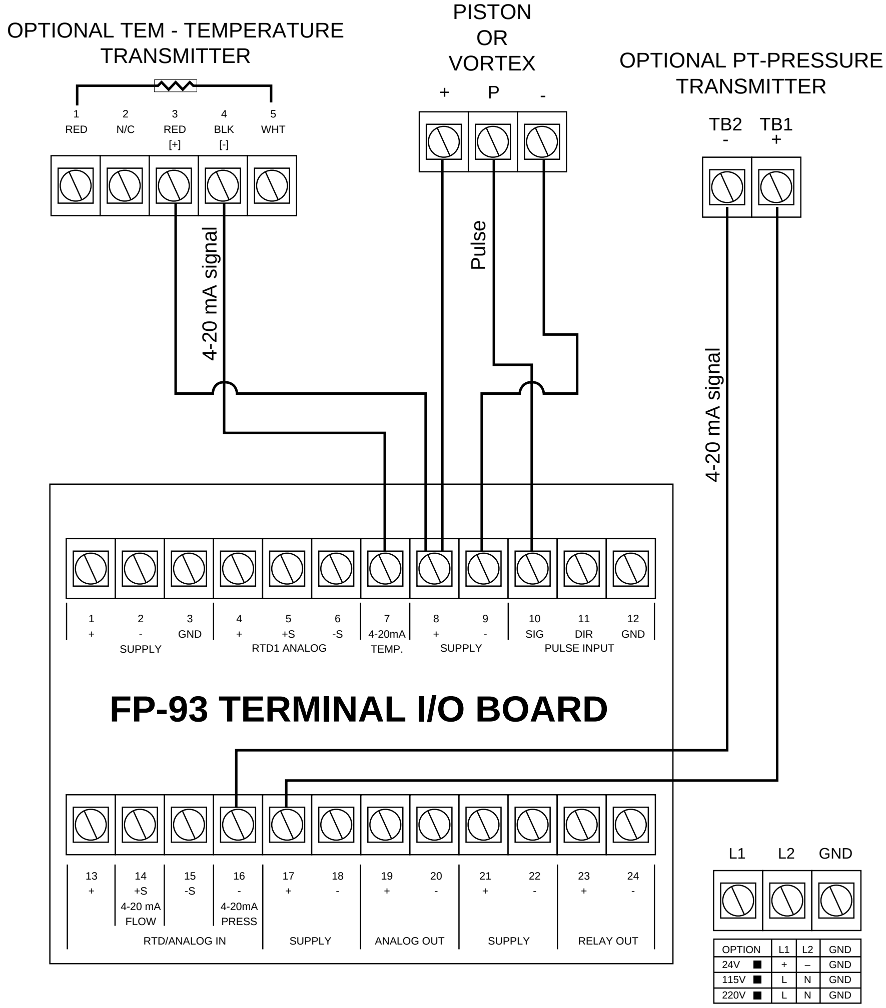
CE Approval
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

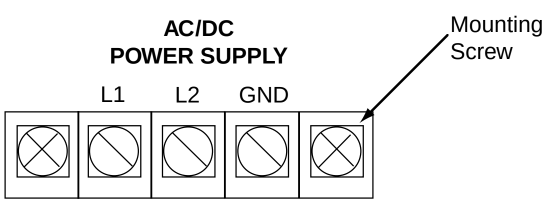
To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to Inline Vortex-Vortex PhD or Piston PDP



CE Approval

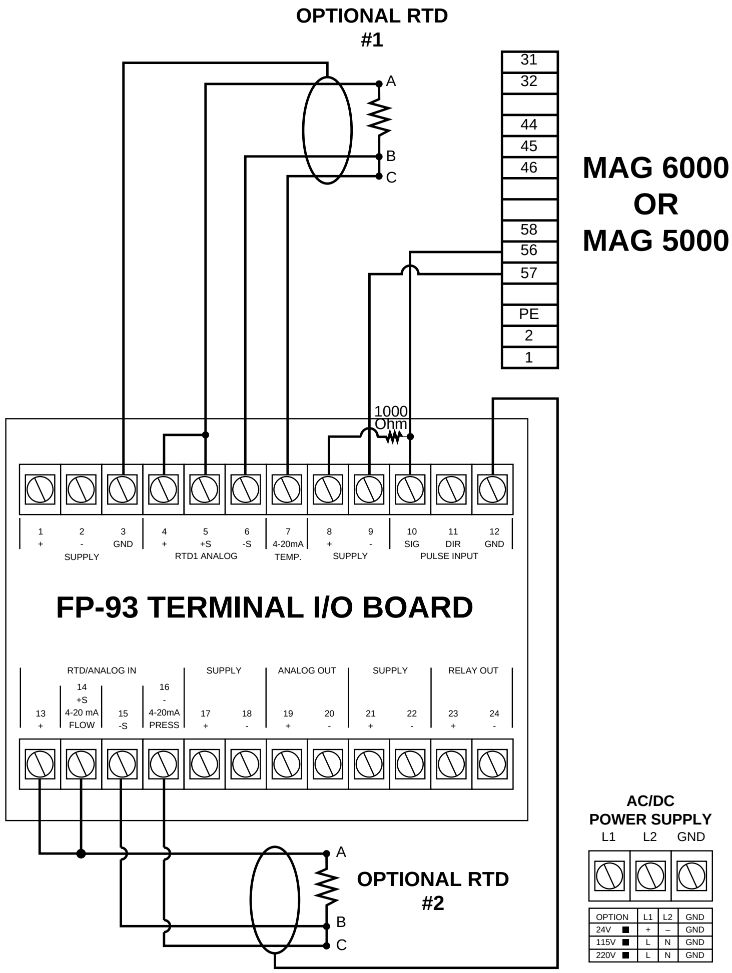
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

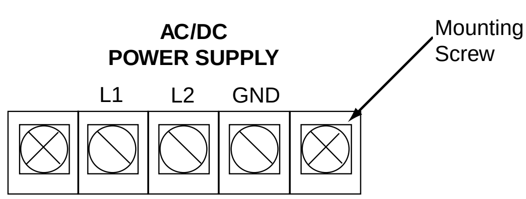
To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to Electromagnetic-MAG 6000 or MAG 5000



CE Approval

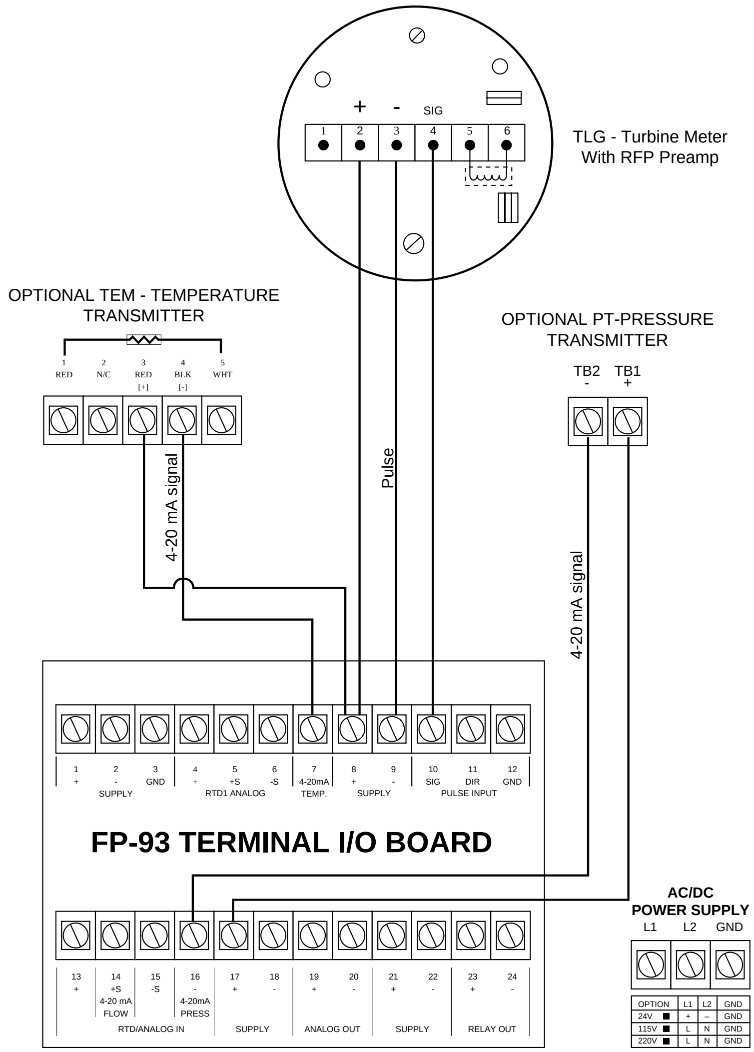
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

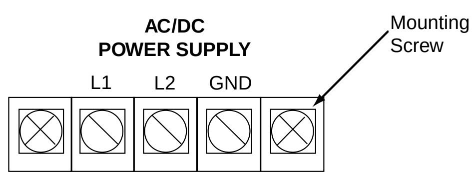
To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to InlineTurbine-TLG-01 thru TLG-12



CE Approval

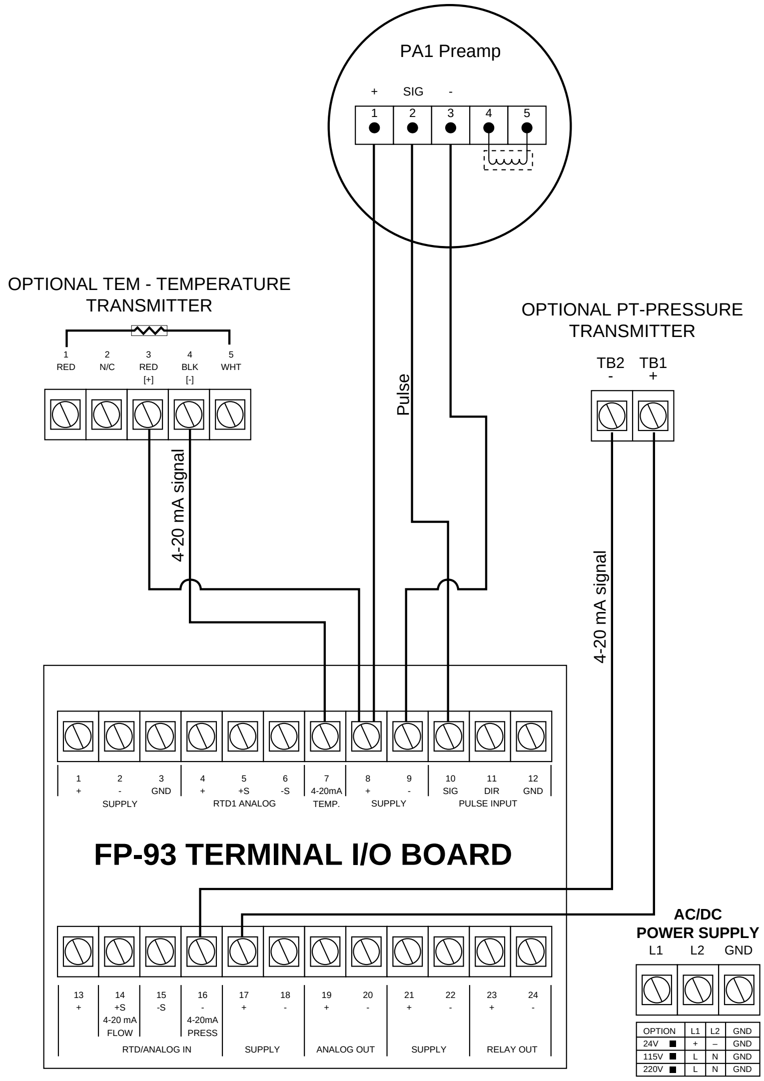
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

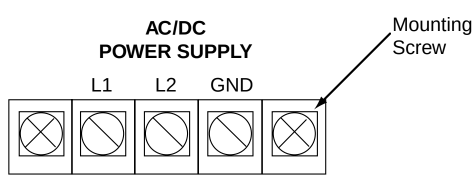
To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to PA1 Preamplifier



CE Approval

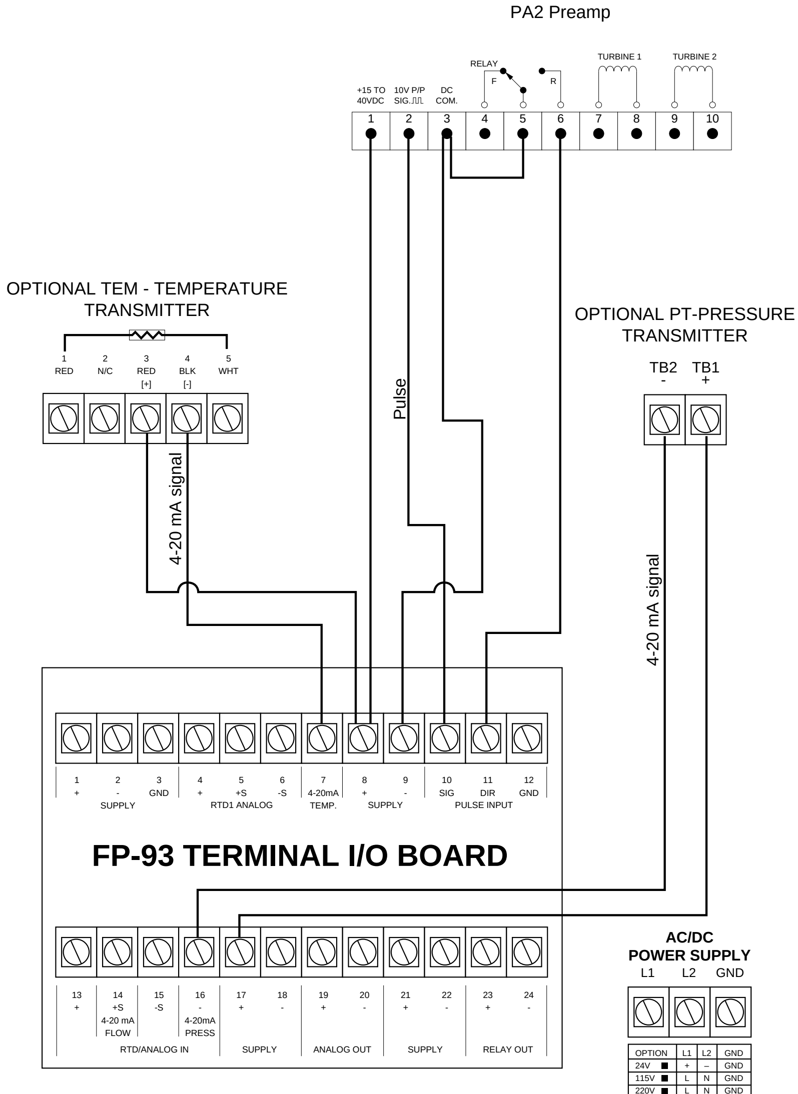
To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

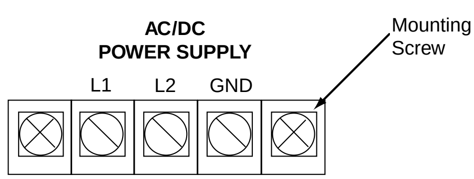
To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

NEMA FP-93 to PA2 Preamplifier



CE Approval

To comply with CE requirements, a NEMA FP-93 powered by an **external** approved 24-volt DC power suppy must have the supply connected to chassis ground. This can be accomplished at the DC input connector with a jumper from the GND terminal to the unmarked mounting screw to the right of the AC/DC power supply terminal strip illustrated below.



OPTION	L1	L2	GND
24V ☐	+	–	GND
115V ☐	L	N	GND
220V ☐	L	N	GND

To comply with CE requirements, a NEMA FP-93 powered by an **internal** approved 24-volt DC power supply (115v or 230v option) must have the DC supply connected to chassis ground. This can be accomplished at the top terminal strip with a jumper from the GND terminal (#3) to the (-) terminal (#2).

4-20 mA Analog Flow Output

The analog output is an optically isolated 4-20 mA output. It may be used to drive chart recorders or other devices with a signal that is proportional to the pressure, temperature, differential temperature, density, velocity, volume flow, mass flow or energy flow. The polarity of the wiring to the analog output is critical. It will not work if the connections are reversed. Based on the receiving electronics or control instrument, the wiring connections are made as shown in Figures 9 and 10.

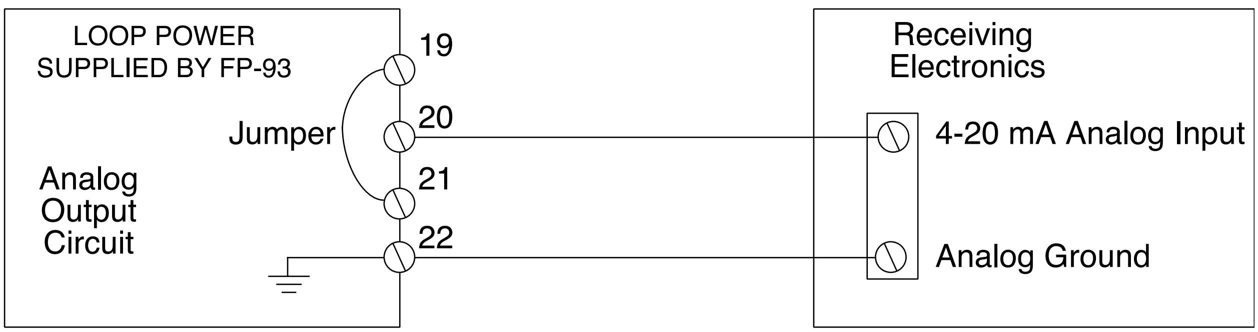
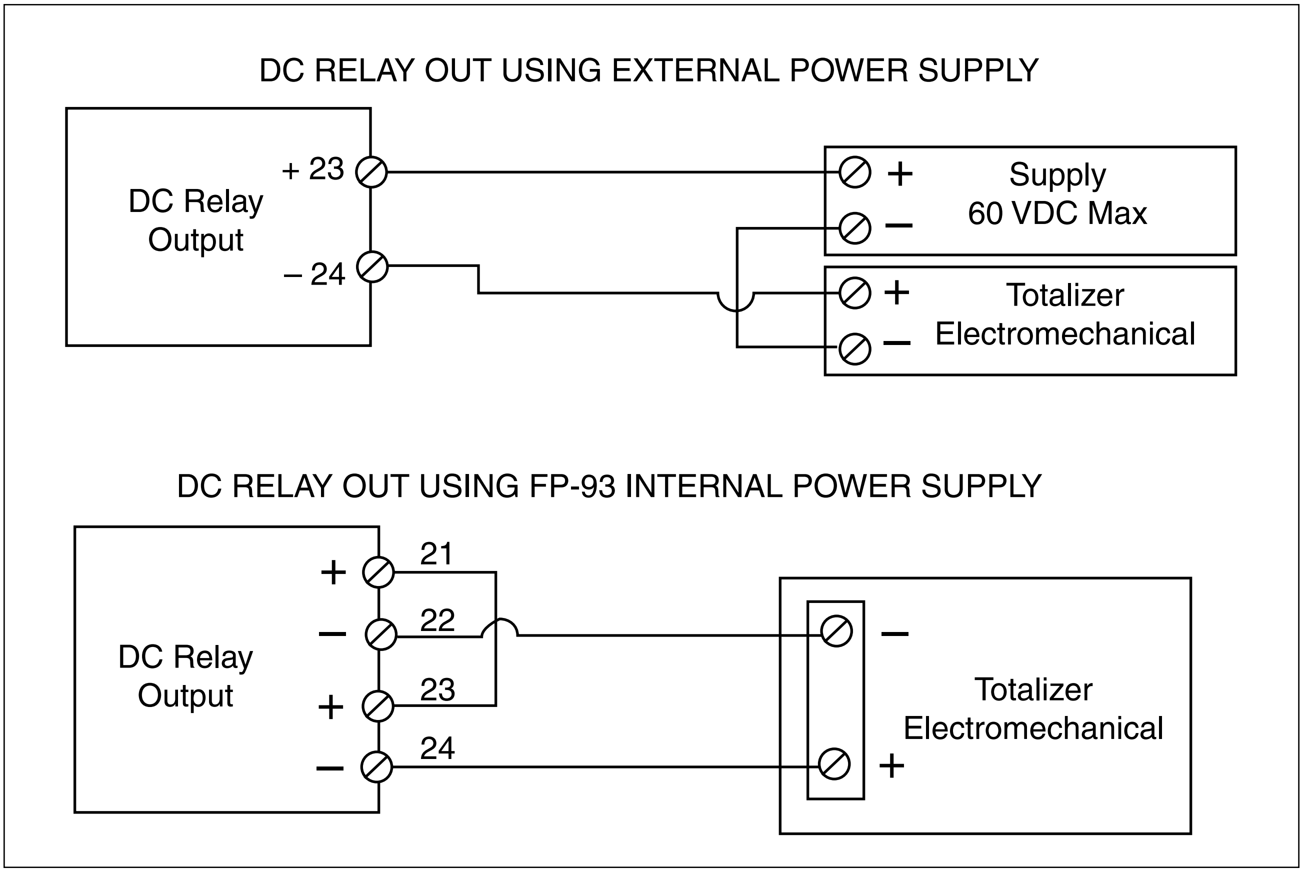


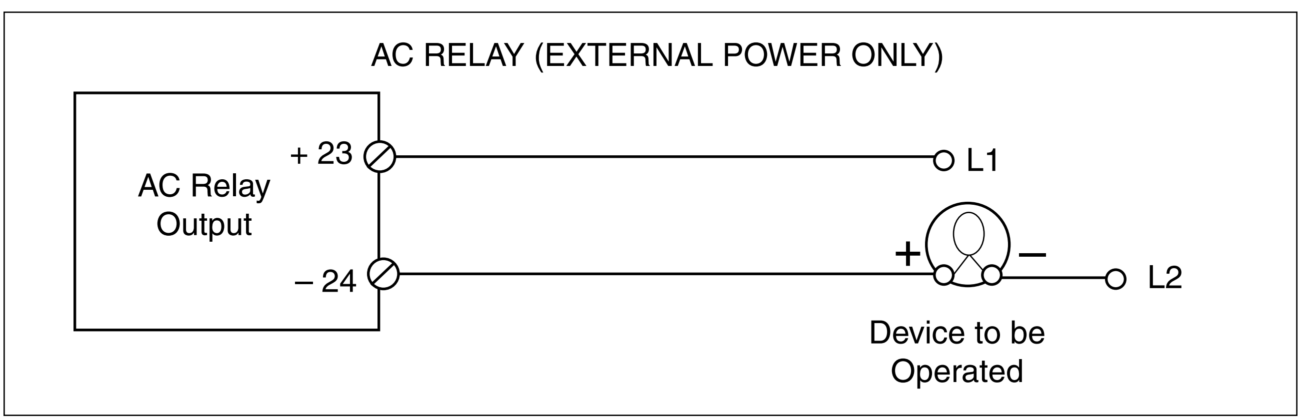
Figure 9. 4-20 mA Current Source Analog Output

Figure 10. 4-20 mA Isolated Analog Output

Relay Output

The relay output is an optically isolated solid-state relay with current capacity of 0.5 ampere. Depending upon the model ordered, the relay may be a DC output, with the capability of controlling circuits with voltages of up to 60 volts DC, or an AC output, with a maximum voltage of 280 volts AC, or 500 volts peak. The polarity of the connections is critical if the DC relay option is





Communication Interface

Connections for the communication interface are made through the 9-pin D-subminiature RS-232C connector. The signals at this connector are shown below. The connector on the FP-93 is a male connector, requiring a female connector on the interface cable.

Terminal	Signal	Type	Description
1	—	—	(no connection)
2	RxD	Input	Data from computer or terminal
3	TxD	Output	Data to computer or terminal
4	DTR	Output	Data Terminal Ready - always on when the FP-93 is transmitting data (high impedance state when the FP-93 is idle or receiving data)
5	GND	—	Signal ground
6	—	—	(no connection)
7	RTS		Output Request To Send - always on when the FP-93 is transmitting data (high impedance state when the FP-93 is idle or receiving data)
8	CTS		Input Clear To Send - handshaking input
9	—	—	(no connection)

The communication interface utilizes a driver/receiver integrated circuit which conforms to the EIA RS-232C standard. In addition, the driver outputs are disabled when the FP-93 is not transmitting data, so that multiple units may be wired together to a single port on a computer or terminal. To do this, connect the transmit data from the computer to all of the receive data inputs of the FP-93s, and the transmit data lines from the FP-93s to the receive data input to the computer. All of the ground terminals for the FP-93s and the computer should be wired together. If handshaking is required by the computer, connect the computer handshaking line to all of the FP-93 CTS input lines.
The FP-93 DTR and RTS outputs are set to a high impedance state when the FP-93 is not transmitting data, and are thus not usable as handshaking for the computer output; these lines are intended to be used for half-duplex modem control purposes.

The FP-93 may be configured for a variety of handshaking methods, including hardware handshaking (CTS), in which the CTS input on pin 8 must be at the EIA high level for the FP-93 to transmit data, and XON/XOFF handshaking, which relies on control characters transmitted to the FP-93 for data transmission control.

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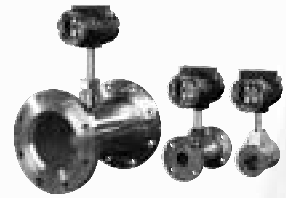
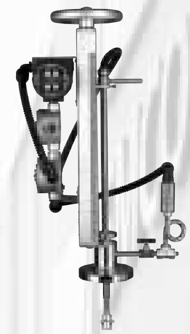


Vortex PhD™ Inline Vortex

V-Bar™ Insertion Vortex



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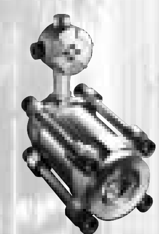

PDH Helix

PDP Piston

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