Operating Manual

EPC-50/50e AIR-FUEL CONTROLLERS

Form EPC-50/50e OM 2-20

HOERBIGER Engine Division

altronic
HOERBIGER Engine Division

1.0 SYSTEM DESCRIPTION

1.1 The Altronic EPC-50 is an air/fuel ratio controller designed for use on low-horsepower, carbureted natural gas-fueled engines. It employs microprocessor technology, allowing for a high level of sophistication in control strategy, ease of programming and diagnostic capability. The EPC-50 is designed for use on engines operating at or near a stoichiometric air/fuel ratio (lambda .95 - 1.05) and is ideally suited for application with 3-way catalytic converters. The EPC-50 is designed to be mounted in the engine/compressor control panel.

WARNING: DEVIATION FROM THESE INSTRUCTIONS MAY LEAD TO IMPROPER ENGINE OPERATION WHICH COULD CAUSE PERSONAL INJURY TO OPERATORS OR OTHER NEARBY PERSONNEL.

EPC-50E OPTION: TO TAKE ADVANTAGE OF THE EPC-50E FEATURES, THE FIRMWARE UPDATER MUST BE INSTALLED TO THE LOCAL PC AND LOADED INTO THE EPC-50. SEE SECTION 21

1.2 The single control output of the EPC-50 allows for its use on any engine application incorporating a single fuel gas regulator. An oxygen sensor is used in the exhaust stream to sense O_2 content, and a thermocouple input signals when proper exhaust temperature has been reached to allow for accurate sensor operation. The system fuel control valve installed in the fuel line to the carburetor is precisely adjusted by a stepper-motor under microprocessor control to maintain the correct O_2 content in the exhaust. The desired air/fuel ratio can be easily adjusted by changing the control target voltages through the sealed membrane keypad or through the use of a PC.

1.3 The EPC-50 has an alphanumeric LCD display which shows the target voltage, sensor voltage, operating temperature, stepper motor position, and diagnostic information.

1.4 Power requirement is 24 (10–30) Vdc, 1 amp. In remote areas, power can be provided by the Altronic 24Vdc Alternator Power Package. Refer to Altronic Form ALT.

1.5 The EPC-50 also incorporates a thermocouple input and a dedicated output for implementation of catalyst over-temperature protection. A second digital output is available for use as an alarm for diagnostics or uncontrolled operation.

2.0 SYSTEM COMPONENTS

2.1 One part from each group below is required for each installation:

PART NO.	DESCRIPTION	QUANTITY REQUIRED
EPC-50	Air/fuel controller	1 per engine
690153-1	Control Valve, .75" NPT	1 per engine
690154-1	Control Valve, standard 1.5" NPT	1 per engine
690154-2	Control Valve, low HP 1.5" NPT	1 per engine
690154-5	Control Valve, very low HP 1.5" NPT	1 per engine
690220-1	Control Valve, butterfly 2.0" NPT	1 per engine
690225-1	Control Valve, butterfly 2.5" NPT	1 per engine
690230-1	Control Valve, butterfly 3.0" NPT	1 per engine
693013-1	Cable, control valve, 30 ft.	1 per engine
693006-1	Cable, oxygen sensor, 25 ft.	1 per engine
693006-2	Cable, oxygen sensor, 50 ft.	1 per engine
610621	Oxygen sensor	1 per engine
**	"K" Thermocouple Probe (ungrounded w/thermowell)	1 per engine, plus 1 for Catalyst Out
**	"K" Thermocouple Ext. Wire	50 ft. per thermocouple
**	12-16 AWG Hook-up Wire	150 ft. per engine

** Not supplied in Altronic kits.

2.2 Accessory Kits

691305-1 Accessory Kit Includes:

610621	Oxygen Sensor
693013-1	Cable Assembly, Control Valve, 30 ft.
693006-1	Cable Assembly, O_2 Sensor, 25 ft.

691305-2 Accessory Kit Includes:

610621	Oxygen Sensor
693013-1	Cable Assembly, Control Valve, 30 ft.
693006-2	Cable Assembly, O_2 Sensor, 50 ft.

691306-KT EPC-50e Kit Includes:

691306-1	Enhanced Adaptor
609035-1	CD-ROM
610372	Screw Driver

2.3 See Figure 1 for general layout of EPC-50 components.

3.0 MOUNTING THE EPC-50

3.1 Operating temperature range is -40°F to 158°F / -40°C to 70°C. Humidity specification is 0-95%, non-condensing. Mount the EPC-50 inside a control panel, preferably off the engine, in such a manner as to minimize exposure to vibration. The Control Module should be mounted so that the display is at a convenient viewing height. See Figure 2 for mounting dimensions. A NEMA 3R housing (720004-1) is also available as an alternative mounting option, see Figure 3. Avoid mounting the LCD display and keypad in direct sunlight.

4.0 MOUNTING THE OXYGEN SENSOR

NOTE: A WELDMENT BOSS MAY BE REQUIRED FOR SENSOR INSTALLATION IN SOFT OR THIN WALL EXHAUST SYSTEMS.

4.1 The sensor should be installed in the exhaust system between the engine and the catalytic converter and/or muffler. The mounting location should be as close to the exhaust manifold of the engine as possible. The tip of the sensor should be exposed to the unobstructed flow of the exhaust gases from all cylinders of the engine. This means that the sensor should be mounted near, but still before, the exhaust stack. **DO NOT** locate the sensor in a coupling or in a location where the exhaust gas flow is uneven due to obstructions or sharp bends. The sensor location should allow easy access since sensor replacement may be required as often as every 2000 hours in some applications. The location should not subject the exterior shell of the sensor to an ambient air temperature greater than 350°F.

4.2 Drill, tap, and spot face a hole in the exhaust pipe at the selected location. A flat, smooth sealing surface is required to assure accurate readings since air or exhaust leaks will impact sensor operation. See Figure 4 for details

4.3 New sensors are packaged with an anti-seize compound applied to the threads. There is no need to apply additional anti-seize unless reinstalling a used sensor. If required, use high temperature anti-seize very sparingly and apply only to the sensor threads. Sensors should be torqued to 28-34 lb.-ft.

5.0 MOUNTING THE K-TYPE THERMOCOUPLES

5.1 An exhaust temperature thermocouple is used to monitor the temperature of exhaust gases near the exhaust oxygen sensor. It should be mounted as close as possible to the O_2 sensor. As with the O_2 sensor, the location should be easily accessible, and the tip of the probe, which should be enclosed by a thermowell, should be surrounded by unobstructed exhaust flow.

5.3 Catalyst protection thermocouple should be installed in the catalyst housing. Provision for thermocouple installation is normally incorporated in the design and manufacture of the catalyst. Installation of the thermocouple at the outlet of the catalyst provides two modes of protection: High Outlet Temp Shutdown and High Catalyst Temperature Rise Shutdown. Consult the recommendations of the catalyst manufacturer for required overtemp protection.

5.3 Only ungrounded thermocouple probes can be used with the EPC-50. Grounded type thermocouples will not function correctly. Resistance from either lead of the thermocouple to the probe shell should be 2 megohms or greater.

6.0 MOUNTING THE FUEL CONTROL VALVE

6.1 In order to control the air/fuel ratio, an electronically controlled valve is connected in series between each regulator and carburetor. The valve should be installed as close to the fuel inlet of the carburetors as possible. The distance from the valve to the carburetor inlet should not exceed 12 pipe diameters in length. The valve should be installed with the control cable connector facing upward to avoid the collection of condensation in the stepper motor.

NOTE: FOR DETAILED INSTRUCTIONS COVERING THE GAS CONTROL VALVE, SEE FORM GCV1 OM (690154 SERIES) OR GCV2 OM (6902XX SERIES).

6.2 If possible, connection piping should be of the same diameter as currently in use. The threaded connection to the valve body may require the use of thread adaptors. If adaptors are used, proper plumbing procedures must be followed.

6.3 The control valve is connected to the EPC-50 using the 693013-1 cable. The cable wires are color-coded and must be connected to the valve output terminal block of the EPC-50 according to color. This cable must not be run in the same conduit as the ignition primary or other O_2 sensor or thermocouple wires. A distance of 4 to 6 inches should be maintained between EPC-50 wiring and other engine wiring.

7.0 ELECTRICAL HOOK-UP

7.1 The power connections to the EPC-50 must be in accordance with the National Electrical Code. The EPC-50 is suitable for installation in Class I, Division 2, Groups C and D locations.

7.2 Although the input power has an internal protective fuse (3 amp), an external fuse (5 amp max.) near the power source is recommended.

7.3 The EPC-50 can be powered in one of the following ways:

- 24 volt battery with trickle charger (1 amp min. output).
- DC power supply capable of furnishing 12-30Vdc, 2 amps.
- Altronic 24Vdc Alternator Power Package – see form ALT.

NOTE: VOLTAGE AND CURRENT SUPPLIED MUST BE SUFFICIENT TO OPERATE ALL TRANSDUCERS USED IN THE INSTALLATION. IF A HEATED OXYGEN SENSOR IS REQUIRED, THE HEATER CURRENT MUST BE ADDED TO THE REQUIREMENTS SHOWN.

7.4 Power wiring and signal (transducers) wiring must be in separate conduits and conduit entries into the panel containing the EPC-50 to avoid undesired electrical interaction.

7.5 Input power supply wires (16 AWG minimum) should connect to the 24 volt supply terminals of the main terminal block.

NOTE: ENGINES USING POSITIVE GROUND DC ACCESSORIES OR STARTER MOTORS WILL REQUIRE A SEPARATE, DEDICATED, UNGROUNDED POWER SUPPLY FOR THE EPC-50.

7.6 The oxygen sensor is connected via shielded cable P/N 693006. This should be run in conduit only with the EPC-50 thermocouple connections. These cables should enter the panel containing the EPC-50 and connect to the main terminal block. The red wire should be connected to the O_2 sensor (red) terminal, and the black wire to the O_2 sensor (black) terminal. The shield wire should be cut short and not connected. The cable provided is terminated with weather-tight connectors which mate to the O_2 sensors provided by Altronic. The shield wire (green wire at connector end) must be connected to the exhaust piping near the sensor. This shield will assist in rejecting noise from other wiring which could affect the O_2 sensor signal. Refer to Figures 4 and 5.

7.7 The thermocouple (24 AWG min., type K extension) wires should be run in a conduit only with the EPC-50 O_2 sensor wires. The yellow wire should be connected to the T/C (yellow) terminal and the red wire to the T/C (red) terminal. Care should be taken to identify the two thermocouple wires (TC1 and TC2). Refer to Figure 5.

7.8 The Catalyst Temp Protection Shutdown Output is configured as a normally-closed output signal. Any of three protection shutdown diagnostic temperature thresholds can cause this output to open. Connect this output to the safety shutdown system in combination with a relay to result in an engine shutdown for the purpose of catalyst protection. This output is non-latching and is self-resetting upon the clearing of related protection conditions. (Solid State Switch Rated 30

Volts/0.5 Amps max.) The protection shutdown switch is labeled SW2 and a red LED indicator located below the terminal will turn on when the switch opens to indicate the shutdown condition.

7.9 The Alarm Output is configured as a normally-closed output signal. Any diagnostic relating to measured temperatures, O_2 sensor voltages, or rich or lean limit stepper positions will cause this output to open for identification of possible improper airfuel control system operation. This output is non-latching and is self-resetting upon the clearing of all the alarm conditions. (Solid State Switch Rated 30 Volts/0.5 Amps max.) The Alarm Shutdown Output is labeled SW1 and a yellow LED indicator located below the screw terminal will turn on when the switch opens to indicate an alarm or diagnostic condition.

7.10 Although the EPC-50 does not require a computer to be operated or installed, a serial port has been included which can be used for MODBUS RTU slave communications using an RS-485 connection. The port configuration is accomplished using the display and keypad as described in sections 12.12 and 12.13.

8.0 THEORY OF OPERATION

8.1 The primary task of the EPC-50 is to accurately control the exhaust air fuel ratio (AFR) of an engine. Control should be maintained through reasonable load and fuel BTU variations.

8.2 Three-way catalysts are used to oxidize CO and HC and to reduce NO_x. These processes require high temperature and correct AFR control. Catalysts perform best for all emissions when operated near the stoichiometric AFR.

8.3 The stoichiometric AFR is the AFR at which exactly the required amount of air (O_2) is present to completely burn all of the fuel. Because no engine can perform perfect combustion, typical emission by-products include O_2, HC, NO, and CO even though the engine is running at stoichiometry. The stoichiometric AFR is determined by the chemical composition of the fuel, thus they are different for each fuel, or BTU rating.

(e.g., Methane => 16.09 : 1 and Gasoline => 14.70 : 1)

8.4 Because the fuel type is not always known, it is often easier to specify the AFR target in terms of lambda. Lambda is an indicator of AFR normalized to the appropriate stoichiometric AFR.

(Lambda Actual AFR/Stoichiometric AFR)

Thus lambda for stoichiometric combustion would be 1.0, no matter what fuel is used.

Lambda > 1 = Lean, Lambda < 1 = Rich.

8.5 An O_2 sensor (lambda sensor) is used to provide exhaust AFR feedback to the EPC-50. This type of sensor uses a zirconia element which, when combined with a catalyzing outer surface, creates an output voltage used to indicate lambda. Characteristics of the sensor include: an output range of about 0.1 to 0.9 volts when above 650°F, a very high output impedance when cool, a very high sensitivity at stoichiometry, and a very low sensitivity away from stoichiometry. The output signal provides a very suitable means of controlling just rich of lambda 1.0, which is the AFR range required to obtain best catalyst efficiencies for methane-based fuels.

8.6 A type K thermocouple is used to assure that exhaust temperatures are high enough for correct operation of the sensor before closed loop control is enabled. An additional thermocouple is used to monitor outlet temperature. The EPC-50 was designed for use on small engines where the catalyst is assumed to be close to the engine. The engine out temperature is assumed to be representative of the catalyst in temperature. The three shutdown thresholds are Engine/CatIn temperature too high, CatOut temperature too high, and Catalyst temperature rise too high. Temperature limit setpoints are provided to create a catalyst protection shutdown capability.

8.7 An electronic valve is used to create a variable restriction between the fuel pressure regulator and the carburetor inlet. This restriction is used to adjust the effective inlet pressure seen by the carburetor and results in a mechanical adjustment of the air/fuel mixture delivered by the carburetor. A stepper motor adjusts the restriction by moving a plunger inside the valve. A stepper motor is a brushless motor consisting of a permanent magnet armature and a four-coil multi-pole stator. The armature is moved by sequentially pulsing the four stator coils. Coupled to a worm screw, the rotating armature of the motor provides very accurate linear positioning capability. The motor used provides 1700 steps of travel at .0005 inch/step for a total valve stroke of 0.85 inch.

8.8 The EPC-50 adjusts the stepper motor to maintain a specific input voltage from the O_2 sensor. When the sensor voltage is above the O_2 target voltage, the system is richer than desired, and the stepper position is increased to further restrict fuel flow to the carburetor. Conversely, when the sensor voltage is below the O_2 target voltage, the system is leaner than desired, and the stepper position is decreased to reduce the restriction of fuel flow.

8.9 Because the sensor voltage output is not linear with lambda, it would not be practical to adjust the system faster when the error from the set-point is greater. So, in order to maximize the control response, the motors are instead adjusted faster as the error persists longer. This method provides rapid response characteristics as well as control stability. Control target voltages must be determined with the use of an exhaust analyzer to locate the operating point of lowest stack emissions. These target values are adjustable in the EPC-50 through the keypad. The resulting system provides accurate and stable control of air/fuel ratio which results in high catalyst efficiencies and reduced stack emissions.

9.0 PRE-START INSTALLATION CHECKLIST

9.1 Before applying power to the EPC-50:

A. Measure the power supply voltage to assure voltage is within limits (12-30 volts). Leave unit unpowered.

B. With the terminal block disengaged, use an ohm meter to measure resistance between the black O_2 sensor wire and the earth ground of the panel. This should be less than 1 ohm. Also measure the resistance between earth ground and the common of the 24v power supply terminal to verify that it is less than 1 ohm.

C. With the main terminal block disengaged, measure voltage between yellow and red thermocouple wires. The voltage should be 0.80-1.50mV for temperatures 60-100°F. This verifies that thermocouple wires are terminated. If engine has been running, measurements will be higher, reflecting higher actual temperatures.

D. With the terminal block still disengaged, measure resistance between the red wire and the still-connected earth ground terminal. Resistance should be very high or open circuit. Repeat measurement between yellow wire and earth ground. This verifies that thermocouples are ungrounded and that wires are not shorted in conduit.

9.2 With the EPC-50 powered up and the engine not running:

A. Display should follow the power-up sequence described in section 11.0.

B. Display of O_2 sensor voltage should go to 0.5 volts. This may require a few minutes. Section 14.0 explains how to view data screens.

NOTE: IF ENGINE WAS RUNNING RECENTLY, TEMPERATURE WILL BE HIGHER.

C. Data display screen for exhaust temperatures should indicate ambient temperatures.

D. Control valve operation should be verified during a start position command. This can easily be done if the valves are not yet fully installed in the fuel line. Press ALARM ACK if the alarm LED is on. Then press F1 followed by START POS. During the start position activity, the left valve plunger should be fully retracted, then positioned near the middle of its travel. No movement, erratic movement, or movement in the wrong direction will result from incorrect wiring of the stepper cables.

NOTE: GROUND LOOPS COULD BE MORE SIGNIFICANT WHEN THE ENGINE IS RUNNING. THE ADDITION OF OTHER ELECTRICAL DEVICES MAY AFFECT EPC OPERATION WITH REGARD TO SIGNAL OFFSETS.

F. Return the setup values to the factory defaults. This can be done by slowly pressing the following keys in order: F1, F3, F2, F4. Then, once the screen indicates that you are in the setup mode, press F2 followed by F2 again to restore default setup values. Then press F4 to exit the setup mode. The default values are set as follows:

Gain Value	=	0.50
Left O_2 Target	=	0.80 volts
Left Default Position	=	1000 steps

G. Configure catalyst protection thresholds. Reasonable value ranges for protection thresholds are shown below. These max. temperature limit values should be configured based on the recommendations of the catalyst manufacturer. This can be done by slowly pressing the following keys in order: F1, F3, F2, F4, then F1 to view each successive setup parameter:

NOTE: SETTINGS SHOULD BE ESTABLISHED BASED ON THE RECOMMENDATION OF CATALYST MANUFACTURER.

Exh Temp Hi	=	(1000 to 1250°F)
Cat Out Hi	=	(1100 to 1250°F)
Cat Rise Hi	=	(100 to 300°F)

9.3 When all of these checks have been made successfully, move on to the Start-Up Procedure.

10.0 START-UP PROCEDURE

10.1 Before starting engine:

A. Check for fuel leaks where the fuel line was modified.

B. Verify that catalyst over-temp thermocouples and thresholds are in place and functional according to catalyst provider requirements and recommendations.

C. Press F1, then press START POS on the EPC-50 keypad to reset stepper position and enable the warm-up delay.

D. Be sure that the power screw adjustments on carburetors are fully open or fully rich. If these adjustments are not fully open, the control range of the stepper control valve will be limited.

E. If the alarm outputs of the EPC-50 are being used, temporarily disconnect or override these signals so that an alarm indication will not shut down the engine during setup.

F. Verify that the catalyst protection output is wired and functional to cause a shutdown in an overtemp condition.

G. Place EPC-50 controller in manual mode by pressing the LEFT MAN key.

H. Start and warm-up engine.

10.2 With the engine running:

A. Load engine to desired operating point.

B. Verify that the exhaust temperature data screen is displaying reasonable values, and that the temperatures exceed 650°F. Refer to section 14.0 for display key operation.

C. Enable automatic control by pressing the AUTO OPER key. The unit should begin adjusting the stepper valves, trying to control the engine air/fuel ratio. Use any diagnostic warnings which may occur to trouble-shoot the system. Rich or lean limit errors are a good indication that the pressure regulators need some adjustment.

D. Once the unit has gained control of the engine (O_2 sensor voltage very near the target voltage), adjust the fuel pressure regulators until the EPC-50 is controlling with the stepper valve positions near 1000 steps. This is approximately the middle of the valve's control range.

10.3 Fine tune the control setpoints:

A. Using an exhaust analyzer, determine the set-point voltage which results in the best emission performance. This can be done by incrementally adjusting the O_2 target voltage in the setup mode. Reference section 12.0 for an explanation of the setup mode. Alternatively, manual mode can be used to adjust the control valves to the positions which give the best emissions performance. Reference section 15.0 for an explanation of manual mode operation. The O_2 target voltages should be adjusted to match the actual sensor voltages using the setup mode.

B. The control gain rate and default stepper positions can also be adjusted, however, the default values represent the best typical values for these parameters.

10.4 Once the system is controlling at the best emissions point, the alarm output can be re-enabled.

10.5 The EPC-50 setup is now complete; the unit should be controlling the engine.

11.0 GENERAL: KEYPAD AND DISPLAY OPERATION

11.1 The EPC-50, or 50e (for enhanced), includes a front-mounted keypad and an LCD display which permits the monitoring and adjustment of various parameters and actions.

```
Altronic Inc.
EPC-50-1
```

OR

```
Altronic Inc.
EPC-50e-
```

11.2 The keypad and display function together as the user interface. Only one key on the pad should be pressed at a time. Some commands require a key sequence (a series of key presses, one followed by the next). Whenever possible, special messages indicate what is happening or why a command is not accepted.

11.3 With the engine not running (cool exhaust), when power is first applied to the EPC-50, the display will show an Altronic product description message, then perform an F1-Start function.

```
AutoWarmUp1000
```

11.4 After a few seconds, the display will indicate that the controller is in warm-up mode. This display indicates that the thermocouples are still reading temperatures too cool for the O_2 sensors to function correctly. The number at the end of the message indicates the current stepper valve position in steps. If the engine is not started this condition will persist for 10 minutes.

11.5 After 10 minutes with a cool exhaust, the display will begin rotating through the diagnostic messages for low exhaust temperature. All diagnostic messages include the **!** character for recognition. Diagnostics exist for several functions and are explained in detail in section 16. When any diagnostic condition is present, the status containing **!** will appear, then all of the appropriate descriptions will follow in rotation. O_2 sensor voltage and stepper valve position are also shown.

11.6 Press ALARM ACK. When a new alarm (ALM) or protection shutdown condition (PSD) is detected, the user keypad functions will be restricted until the user acknowledges the new condition. The message ALARMS MUST BE ACKNOWLEDGED! will be triggered by keypad presses until the ALARM ACK key is pressed to acknowledge the new condition. Pressing ALARM ACK does not affect any other indicators or outputs of the EPC-50. The display will indicate that the unit is responding to the ALARM ACK key press by showing the message WORKING.

The low temperature alarm has now been acknowledged and the EPC-50 will accept other keypad commands. When the alarm LED is on steady, no keypad commands will be accepted until the ALARM ACK key is pressed. The display will indicate that the unit is responding to this command with message WORKING.

```
!Auto!.802v1000
```

AND

```
!Auto!.802v1000
ALM! ExhTemp°LO!
```

12.0 SETUP MODE: KEYPAD AND DISPLAY OPERATION

12.1 Once any alarm is acknowledged, press F1, followed by F3, followed by F2, followed by F4. This is the setup mode entry key sequence. The display will indicate that the setup mode is now active.

```
$$$ SETUP $$$
F1=Next F4=EXIT
```

12.2 Press F2, then press F2 again to restore factory default parameters. This special command can be used only from this screen when the user wants to restore factory default values. A message will indicate that the default values have been restored, then will return to the main setup message. Default control values are in section 9.2. There is a second restore defaults command sequence: F3, then F2, that will reload all factory defaults with regard to diagnostic and PSD thresholds. These are kept separate to avoid changing protection settings for the catalyst.

NOTE: THE FACTORY DEFAULT PSD SETTINGS ARE VERY CONSERVATIVE AND WILL MOST LIKELY RESULT IN THE SHUTDOWN OF A LOADED ENGINE.

F2 **F2**

```
RESTORING
DEFAULT SETUP
```

THEN

```
$$$ SETUP $$$
F1=Next F4=EXIT
```

12.3 Press F1 to increment to the control gain setup screen. The factory default value for this parameter is 0.50 as shown on the display. This parameter determines the stepper valve adjustment rate when in automatic mode. The higher the value, the faster the controller will move the stepper in response to the O_2 sensor.

F1

```
$ F2=Up F3=Dn $
GAIN VALUE=0.50
```

12.4 Press F2 to increase the value for the gain parameter. The display will indicate that the value has been changed. The updated value will be used until the value is changed again.

F2

```
$ F2=Up F3=Dn $
GAIN VALUE=0.60
```

NOTE: ALL SCREENS IN SETUP MODE INCLUDE THE $ CHARACTER.

12.5 Press F3 to decrease the value. The value is decreased to the default value. The range for the gain value is limited to 0.1 to 2.0. The value cannot be moved beyond its limits.

F3

```
$ F2=Up F3=Dn $
GAIN VALUE=0.50
```

12.6 Press F1 to increment to the left O_2 target setup screen. The factory default value for this parameter is 0.80 volts as shown on the display. Like the gain value, the target can be increased and decreased with the F2 and F3 keys. The typical range is near 0.8 volts. The allowable range is 0.01 to 1.05; however, the output range of most sensors is limited to 0.1 to 0.9 volts.

F1

```
$ F2=Up F3=Dn $
 O2SetPnt=0.800v
```

12.7 Press F1 to rotate to the left default stepper position screen. The default position is used when any of the O_2 sensor or thermocouple diagnostics are active. The number on the right is the current default position. Because the temperature diagnostic is still active, the actual stepper position on the left is also 1000.

F1

```
$F2=chng L.dflt$
1000 ---> 1000
```

12.8 Press F2 to update the default position (on right) with the value of the current position (on left). Since both values are the same no change was actually made in this example. By using the manual mode described in section 15.0, the actual position can be adjusted to the desired position before entering the setup mode.

NOTE: MULTIPLE PRESSES OF THE KEY ARE REQUIRED TO CONTINUE INCREMENTING THE VALUE. IF THE KEY IS HELD, THE VALUE WILL BE ADJUSTED AT A PROGRESSIVELY FASTER RATE.

F2

```
UPDATING
DEFAULT POSITION
```

THEN

```
$F2=chng L.dflt$
1000 ---> 1000
```

12.9 Press F1 to rotate to the first temperature protection setup value. The Exhaust Temperature Hi setpoint represents the maximum permitted engine exhaust temperature as sensed by the left engine out thermocouple mounted near the O_2 sensors. High temperatures at this location may indicate engine overload or engine misfire. The Catalyst Temperature Protection Shutdown output switch will open if this threshold is exceeded, causing a protection shutdown.

F1

```
$ F2=Up F3=Dn $
ExhTempHI=1000°F
```

12.10 Press F1 to display the Catalyst-Out Hi temperature setpoint threshold. If the outlet temperature of the catalyst should exceed this setting, the Catalyst Temperature Protection Shutdown output switch, as well as the ALARM output switch, will open, causing a protection shutdown. Conditions of misfire or overload, or improper engine operation, may be identified by this test. Extreme temperature at the outlet of the catalyst indicates that the catalyst is being damaged by the operating conditions of the engine. Provision may be provided in the catalyst to mount a temperature probe at the catalyst element. This location may serve as an alternative to catalyst outlet temperature. Consult the catalyst manufacturer for the recommended outlet-temperature shutdown limits.

F1	$ F2=Up F3=Dn $ CatOutHI =1100°F

12.11 Press F1 to display the Catalyst Temperature Rise Hi setpoint threshold. The temperature difference outlet–inlet is compared to this setpoint to identify excessive temperature rise across the catalyst. The catalyst inlet temperature is assumed to be the same as the engine out exhaust temperature thermocouple. This condition of temperature rise is an indication that the catalyst is reacting to unburned air and fuel that may result from a misfire or poor combustion condition. If the temperature rise across the catalyst should exceed this setting, then the Catalyst Temperature Protection Shutdown output switch will open, causing a protection shutdown. Consult the catalyst manufacturer for the recommended temperature rise shutdown limits.

F1	$ F2=Up F3=Dn $ CatRiseHI= 100°F

12.12 Press F1 to display the ModBus Node ID setup screen. Valid node ID's are 0 to 255, permitting the communication system to incorporate multidrop communications to various ModBus slave devices.

F1	$ F2=Up F3=Dn $ ModBus ID=50

12.13 Press F1 to display the ModBus port setup screen. Various baud rates are supported by the EPC-50. The selections include baud rates of 600, 1200, 2400, 4800, 9600, 19200, 38400, and 57600.

F1	$ F2=Up F3=Dn $ BaudRate 9600n81

12.14 Press F1 to rotate to the main screen.

F1	$$$ SETUP $$$ F1=Next F4=EXIT

12.15 Press F4 to exit the setup mode. F4 can be used from any setup screen. All setup screens include the **$** character. Pressing F4 returns the display to the warning message which was caused by low exhaust temperatures.

F4	!Auto! .802v1000

AND

	!Auto! .802v1000 ALM! ExhTemp°LO!

NOTE: LOADING DEFAULT SETTINGS AS DESCRIBED IN SECTION 12.2 DOES NOT AFFECT SETTINGS RELATING TO THE CATALYST TEMP ALARM OUTPUT OR MODBUS CONFIGURATION.

13.0 ENGINE STARTUP: KEYPAD AND DISPLAY OPERATION

13.1 Press ALARM ACK to acknowledge alarms if alarm LED is ON.

13.2 Press F1, then press START POS to send the steppers to start position (stepper default position) and disable the alarm warnings due to a cold engine for 10 minutes. The controller will return each stepper to its start position and then display the warm-up screen. This procedure should ALWAYS be used when starting the engine.

F1

```
Moving Stepper
to Zero Pos.
```

```
Moving Stepper
to START Pos.
```

```
AutoWarmUp1000
```

13.3 Now the engine should be started, warmed up and loaded. Temperature requirements will be met before the 10 minute delay expires, and the controller will go into automatic control. Both the current O_2 sensor voltage, and the current stepper valve position are provided on the automatic display screen.

```
AUTO .812v1010
```

4.0 DATA VIEWING: KEYPAD AND DISPLAY OPERATION

14.1 Press DSPL SEL to display the first data view screen. The first data screen displays the current O_2 sensor voltages.

DSPL SEL

```
AUTO .625v 985
02Sensor=.625v
```

14.2 Press DSPL SEL again to display current O_2 target voltages.

DSPL SEL

```
AUTO .625v 985
02Target=.800v
```

14.3 Press DSPL SEL again to display the engine out exhaust temperature reading from thermocouple TC1 which is located near the O_2 sensor.

SINGLE BANK TC1

DSPL SEL

```
AUTO .625v 985
EXH TMP=1049°F
```

14.4 Press DSPL SEL again to display the catalyst inlet temperature which is assumed to be the same as engine out exhaust temperature as measured by TC1.

DSPL SEL

```
Cat Rise=+ 24°F
In=1098 Out=1125
```

14.5 Press DSPL SEL again to display TableA and TableB, Reg Val, X input and Y output (EPC-50e version only).

DSPL SEL

```
TblA= 503=+.000
TblB= 4773=+.000
```

14.6 Press DSPL SEL to display TableC, X input and Y output, Aux Input voltage and Max-units (EPC-50e version only).

DSPL SEL

```
TblC= 4773=0.000
AUX1=4.773=  5
```

OR

```
TblC= 2122=0.200
AUX1 O2SNS=.532v
```

NOTE: WHEN 40063=0, AUX INPUT IS ASSUMED TO BE AN O_2 SENSOR WITHOUT THE ADAPTOR. SEE SECTION 23.0.

14.7 Press DSPL SEL again to return to the automatic screen.

DSPL SEL

```
AUTO .811v1010
```

15.0 MANUAL MODE: KEYPAD AND DISPLAY OPERATION

15.1 Press MAN to enter the manual mode. The display will indicate WORKING and then return to manual mode. This mode can be used to help setup the controller, and to diagnose problems. Because no diagnostic alarms are present, it was not necessary to acknowledge alarms. Also, once in manual mode, diagnostic alarms are disabled. In manual mode, the alarm output SW1 will be open and the yellow LED will be on to indicate system is not in automatic control.

NOTE: BOTH THE ALARM LED AND THE ALARM OUTPUT RETURN TO THE NORMAL CONDITION WHEN THE SYSTEM FAULT IS CORRECTED.

LEFT MAN

```
MAN!  .811v1010
```

15.2 Press LEFT LEAN to increase the stepper position by 25 steps. A descriptive message will be displayed and then the modified position will be returned. Increasing the position causes the valve to close and the mixture to change in the lean direction.

LEFT LEAN

```
MOVING
STEPPER
```

THEN

```
MAN! .811v1035
```

15.3 Press LEFT FAST, then LEFT LEAN to increase the stepper position by 100 steps.

LEFT FAST   LEFT LEAN

```
MOVING
STEPPER
```

THEN

```
MAN! .811v1135
```

15.4 Press LEFT RICH to decrease the stepper position by 25 steps. Decreasing the position causes the valve to open and the mixture to change in the rich direction.

LEFT RICH

```
MOVING
STEPPER
```

THEN

```
MAN! .811v1110
```

NOTE: WHEN F1, THEN START, ARE PRESSED BEFORE STARTING THE ENGINE, THE EXHAUST TEMPERATURE DIAGNOSTIC WILL BE DELAYED 10 MINUTES, DISPLAYING THE WARM-UP SCREEN.

15.5 Press AUTO OPER to return to automatic mode. Whenever this key is pressed, automatic mode will be enabled for both banks.

AUTO OPER

```
AUTO .811v1110
```

15.6 POSITION UNCERTAIN — If power to the EPC-50 is interrupted, the display reads *Pos.UnCertain* and may or may not blink. This occured because the position was not saved automatically at the moment of power loss/interruption. Typically this would occur if the EPC-50 were powered up while the engine was running.

AUTO OPER

```
AUTO .811v1110
*Pos.UnCertain*
```

It is important to note that this is a temporary and resolvable condition. The EPC-50 is functioning properly and, if it is in AUTOMATIC mode, it will correct itself. If the EPC-50 is in MANUAL mode, the proper display setting can be restored by performing an F1 start.

16.0 DIAGNOSTIC DISPLAYS AND OPERATION

16.1 ALARM OUTPUT — The ALARM output is configured as a normally-closed output signal. Any system fault will open the alarm circuit, including loss of power, diagnostic warnings, etc. As described above, the alarm output will be in the fault condition (open) whenever an unacknowledged alarm or shutdown is present.

16.2 SYSTEM DIAGNOSTICS — The system diagnostics included in the EPC-50 are designed to identify conditions which are not considered normal operation. These diagnostic tests are performed continuously while the controller is in automatic mode. Each of the diagnostics will display a descriptive message and place the alarm output in the fault condition (open).

16.3 DIAGNOSTIC WARNING MESSAGES — Active diagnostic warning messages include the **!** character and are displayed in rotation, each message being displayed for about 1 second. The home screen uses the **!** character to indicate the status and that other diagnostics will follow in rotation.

```
!Auto!.765v1000
```

16.4 EXHAUST TEMPERATURE — The Exhaust Temperature diagnostic monitors the exhaust temperatures near the O_2 sensors, as measured with the thermocouples. If the temperature is below 650°F or above 1400°F, the EPC-50 displays the appropriate low or high message and activates the Alarm LED and Alarm output. Automatic control is also disabled and the stepper valves are positioned at the default stepper position. Thermocouple probe or thermocouple connection failures will also activate this diagnostic.

```
!Auto! .800v 982
ALM! ExhTemp°LO!
```

OR

```
!Auto! .800v 982
ALM! ExhTemp°HI!
```

16.5 SENSOR NOT READY — The Sensor Not Ready diagnostic is designed to identify problems with the O_2 sensor. The controller has a very high impedance pull up resistor to 0.5 volts in parallel with each exhaust sensor input. When the sensor is too cool or disconnected this will force the input to read 0.5 volts. If the controller sees that the sensor output is 0.5 volts for 10 or more seconds the EPC-50 will display the sensor not ready message and activate the Alarm LED and Alarm output. Automatic control is also disabled and the stepper valves are moved to the default stepper position. The sensor ready test is only performed if the exhaust temperature requirements of 16.4 are satisfied. Failure of this test indicates a cold, disconnected or failed sensor.

```
!Auto! .800v 1000
ALM! O2 NotRdy !
```

16.6 SENSOR INPUT VOLTAGE — The Sensor Input Voltage diagnostic is also designed to identify problems with the O_2 sensor. Normal input voltages should be between 0.1 and 0.9 volts. If the sensor input voltage is less than 0.1 volts, or more than 1.1 volts, the EPC-50 will display the appropriate low or high message and activate the Alarm LED and Alarm output. Automatic control is also disabled, and the stepper valves are moved to the default stepper position. Failure of this diagnostic test indicates shorted wiring or a failed sensor.

```
!Auto! .800v 1000
ALM! Exh O2v LO!
```

OR

```
!Auto! .800v 1000
ALM! Exh O2v HI!
```

16.7 LEAN AND RICH LIMIT — The Lean and Rich Limit diagnostic monitors the stepper positions. If the position of a stepper valve is at the minimum (0) or maximum (1700) travel limit, the EPC-50 displays the appropriate message and activates the Alarm LED and Alarm output. The rich limit warning indicates that the engine is too lean and the controller cannot open the valve any farther to enrich the mixture. The lean limit warning indicates that the engine is too rich and the controller cannot close the valve any farther.

```
!Auto! .800v  0
ALM! Rich Limit!
```

OR

```
!Auto! .800v 1700
ALM! Lean Limit!
```

16.8 ENGINE OUT EXHAUST OVER-TEMPERATURE — When the left or right bank exhaust temperature exceeds the setup threshold, the alarm output will open, the alarm LED will turn on, the Catalyst Protection Alarm output (PSD) will open, and the message below may be displayed.

```
 AUTO!WARN!1000
PSD! ExhTemp°HI!
```

16.9 CATALYST OUTLET OVER-TEMPERATURE — When the outlet temperature of the catalyst exceeds the setup threshold, the alarm output will open, the alarm LED will turn on, the Catalyst Protection Alarm output (PSD) will open and the message below is displayed.

```
 Auto!WARN!1000
PSD! CatTemp°HI!
```

16.10 CATALYST TEMPERATURE RISE — When the temperature from the inlet to the outlet of the catalyst exceeds the setup threshold, the alarm output will open, the alarm LED will turn on, the Catalyst Protection Alarm output (PSD) will open and the message below is displayed.

```
Auto!WARN!1000
PSD! CatTmpRise!
```

17.0 AUTOLOG FEATURE

17.1 Press F3 to display the first out AutoLog screen which provides the most recently detected cause for leaving normal automatic operation. The cause is logged to a modbus register and also presented as below on the screen using a text string. The example below indicates that, while the engine was running in automatic mode, the measured catalyst output temperature exceeded the PSD shutdown, triggering the snapshot of the AutoLog values as the engine was shutdown. The AutoLog values are updated on every transition out of fully-automatic control without alarms. The table of AutoLog causes is shown below.

```
AutoLOG Code  69
PSD! CatTemp°HI!
```

ALM! Exhtemp°LO!

ALM! ExhTemp°HI!

ALM! Exh O2v LO!

ALM! Exh O2v HI!

ALM! O2 NotRdy !

ALM! Lean Limit!

ALM! Rich Limit!

PSD! ExhTemp°HI!

PSD! CatTemp°HI!

PSD! CatTmpRise!

USER Left MANUAL

17.2 The following screens are viewed in rotation, each press of F3 displays the next screen.

```
AutoLOG EXHtemps
Eng1066°Cat1360°
```

Identifies the temperature at AutoLog event.

```
AutoLOG
AuxO2Sensr=.531v
```

Identifies O_2 voltage measurement at AutoLog event trigger.

```
AutoLOG Steppers
 ValvePos = 835
```

Identifies stepper position at AutoLog event trigger.

```
AutoLOG Supply V
 CJT 25.7°C 24.8v
```

Identifies internal and supply voltage at AutoLog event trigger (EPC-50e version only).

```
AutoLOG Aux 0-5v
1.198v= 771cnts
```

OR

```
AutoLOG
AuxO2Sensr=.531v
```

Identifies Aux input voltage value and register counts at AutoLog event trigger (EPC-50e version only).

NOTE: WHEN 40063=0, AUX INPUT IS ASSUMED TO BE AN O_2 SENSOR WITHOUT THE ADAPTOR. SEE SECTION 23.0.

18.0 ADDITIONAL DISPLAY SCREENS

18.1 Three additional screens exist which can be helpful in obtaining information about the version and supply voltage and temperature of the EPC-50. They can be viewed as follows.

Press F1 then DISP-SEL, to view the product description screen.

```
Altronic Inc.
EPC-50-1
```

OR

```
Altronic Inc.
EPC-50e-
```

Press F2 then DISP-SEL, to view the version and date information.

```
Version      1:  0
Date      02/14/09
```

OR

```
Version      2:  1
Date      07/25/12
```

Press F1 then F2 then DISP-SEL to view the supply voltage and temperature.

```
PWR Supply 24.8V
CJT Temp 26.0°C
```

19.0 TROUBLE-SHOOTING THE EPC-50 SYSTEM

19.1 Green PWR LED and LCD display backlight are dark; power is interrupted.

A. Check power supply voltage at EPC terminal block (10-30 volts), while still connected.

B. Replace EPC-50 unit.

19.2 LCD Display backlight is lit, but blank or not functioning properly.

A. Power-down unit for 1 minute. Re-power and check status of LCD display and green PWR LED.

B. LCD backlight is on with blinking PWR LED, indicates: Internal problem with terminal program. Replace EPC-50 unit.

19.3 Key pad entries do not generate a display response.

A. Verify connection of keypad ribbon connector at bottom of board inside unit.

B. Replace enclosure and keypad assembly.

19.4 EPC-50 will not move stepper valves during F1, then Start Pos. command.

A. Check stepper cable connections at EPC-50 and at stepper valve.

B. Test EPC-50 with a spare stepper valve assembly.

C. Test EPC-50 and stepper valve assembly, with a spare stepper cable. (Verify cable connections pin-to-pin.)

D. Replace EPC-50 unit.

19.5 High or low exhaust temp warnings persist.

A. Observe thermocouple readings for reasonable values using display select screens in section 14.0.
B. Compare observed readings to—and verify feasibility of—catalyst protection setpoints as described in section 9.2 (G).

C. If engine is not running, start and warm up engine.

D. Test the disconnected thermocouple reading at EPC-50 with an alternate thermocouple reading device.

E. Replace thermocouple or correct wiring if temperatures are incorrect. The life of thermocouple probes is highly dependent on the use of a thermowell and on corrosives in exhaust.

F. If low temperature is a problem during first installation, an alternate sensor and probe location may be required. Please contact the factory before pursuing any other action to raise sensor temperatures.

G. Replace EPC-50 unit.

19.6 Rich or lean limit warnings persist.

A. A misfiring engine can cause the system to shift in the rich direction. Check the engine for misfiring cylinders using a timing light or exhaust pyrometer.

B. Use an exhaust analyzer and the EPC-50 manual mode to adjust the %O_2 before the converter to around 1.0%. If the %O_2 cannot be manipulated in the manual mode, test to make sure the stepper valve is functioning as was done during installation.

C. If manual mode moves the %O_2 but cannot attain 1.0%, the fuel system may need to be readjusted. First, verify that the load screw adjustments on the carburetors are fully rich or fully open. If they are not fully open, the control range of the stepper valves will be limited. Second, adjust the fuel pressure regulators so that, when in automatic mode, the stepper valves are controlling near 1000 steps.

D. If the fuel system appears to be adjusting correctly, use an exhaust analyzer and the EPC-50 manual mode to sweep the %O_2 from around 3% down to 0.2% while watching the O_2 sensor voltage on the display. The voltage should move from around 0.2 volts toward 0.8 volts as the %O_2 is changed. If this is not the case, a new sensor should be tested.

E. If the EPC-50 O_2 sensor voltage display does not match the actual sensor voltage, test for ground loop problems.

F. Replace EPC-50 unit.

19.7 Setup values are lost at power-down; EEPROM memory has failed.

A. Replace EPC-50 unit.

20.0 EPC-50e ADVANCED CONTROL OPTIONS

20.1 In addition to the basic closed loop Lambda sensor control, it may be useful to apply additional automatic air/fuel ratio control trimming strategies. This might be done in an effort to secure more consistent exhaust emission levels across a wider range of operating conditions. The EPC-50e offers a number of advanced, user-customizable control options. For example, a dynamic adjustment of the pre-catalyst O_2 target setpoint based upon another measured engine operating parameter can be made. Some of the parameters which could be used are post catalyst O_2, engine load, or differential temperature across the catalyst. It is also possible to automatically adjust controller gain at various load levels or other measured operating conditions to maintain the best possible control stability. Under certain other conditions, a means of inhibiting automatic control on the basis of satisfying an external parameter such as load or temperature can be implemented. Selection of options is accomplished via a proprietary, high-level Windows™-based Modbus RTU Terminal Program included with each Altronic EPC-50e. Operation and configuration is essentially hidden from the casual user and therefore completely resistant to tampering or unauthorized adjustment.

20.2 The user can configure the EPC-50e system to automatically adjust the target O_2 setpoint or the controller gain (responsiveness) versus a variety of measured engine operating parameters. It is also possible to inhibit automatic control based upon a specified measured operating parameter, if necessary.

20.3 Enhanced control inputs and outputs include:

- Standard EPC-50 I/O
- AUX Input

These inputs and outputs, combined with the Terminal Program, offer the flexibility to meet specific control requirements for exhaust gas emissions levels. Specific control strategies that can be implemented by the user are almost limitless, with various control functions used simultaneously or in combination.

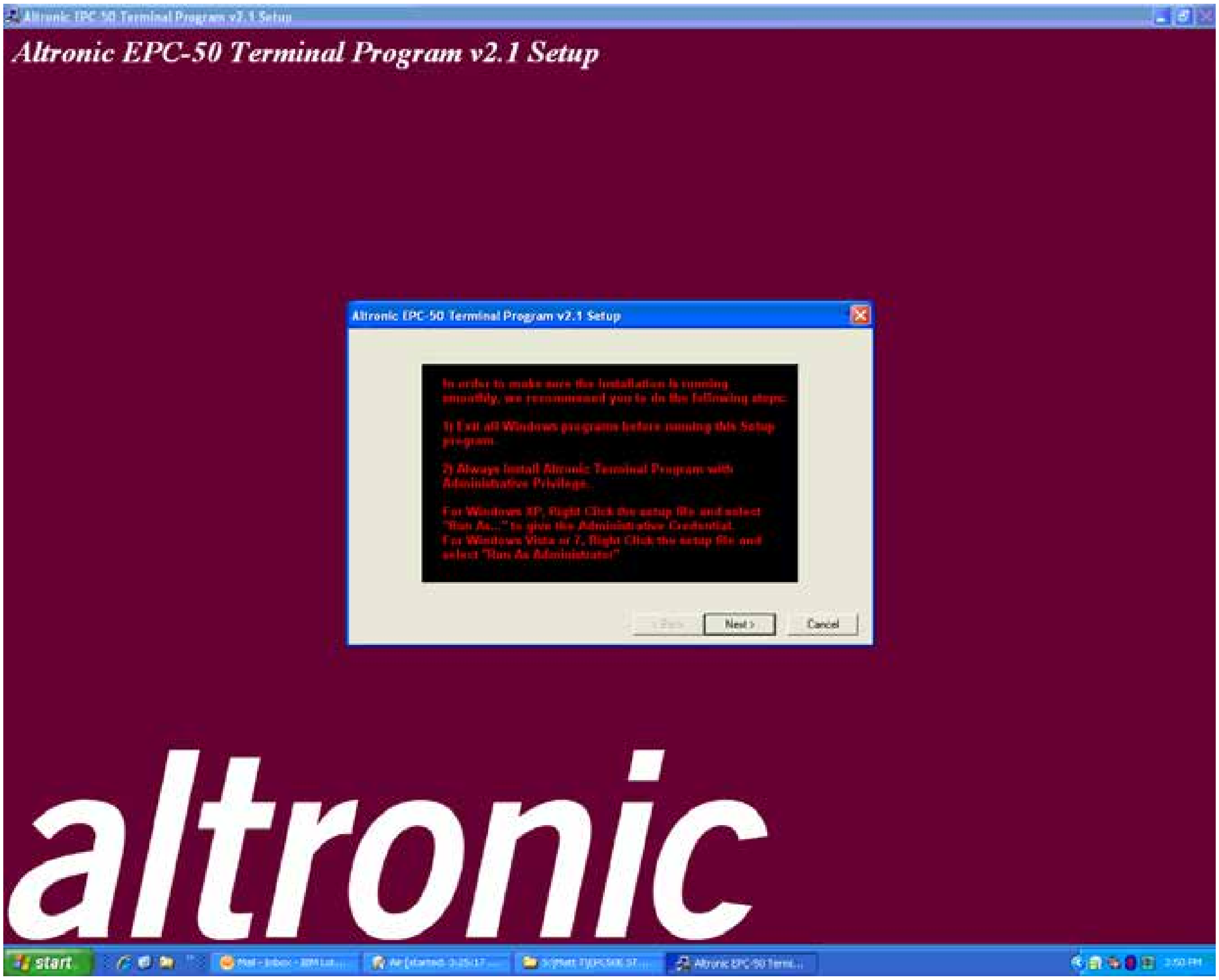
Examples include:

- Dynamic adjustment of the O_2 setpoint versus post-catalyst O_2, or load, catalyst differential temperature, post-catalyst NOx, ambient temperature, engine RPM, fuel flow, or other parameters.
- Adjustment of the controller gain (responsiveness) versus post-catalyst O_2, load, catalyst differential temperature, fuel BTU, post-catalyst NO_x, ambient temperature, engine RPM, fuel flow, or other parameters.
- Inhibiting automatic control based on post-catalyst O_2, load, catalyst differential temperature, fuel BTU, post-catalyst NOx, ambient temperature, engine RPM, or other parameters.
- Shutting down the engine or alarming based on post-catalyst O_2, fuel flow, catalyst temperature, NO_x emissions, catalyst differential temperature, catalyst differential pressure, or other parameters.

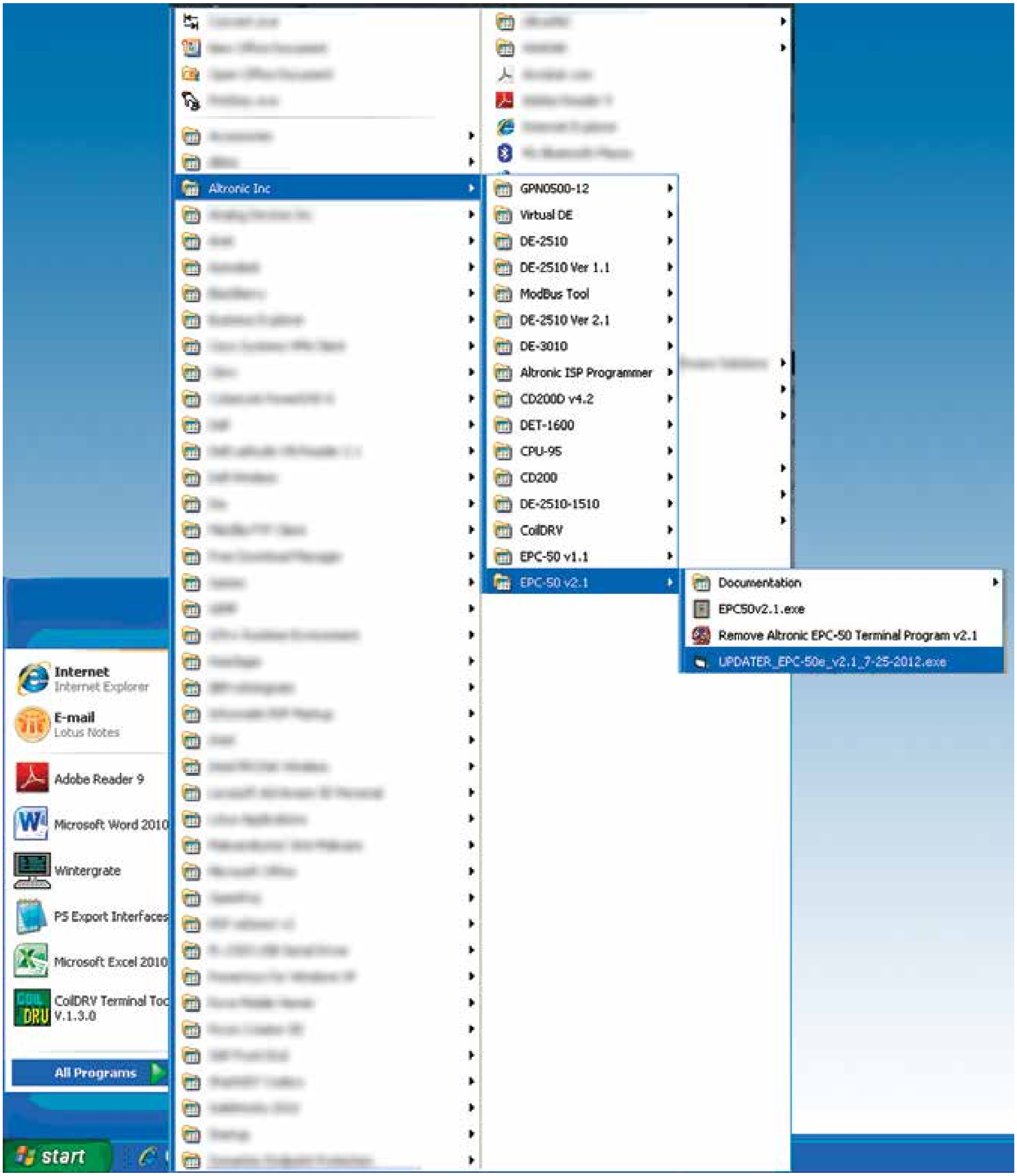
21.0 SETTING UP THE FIRMWARE UPGRADE AND TERMINAL PROGRAM

21.1 The standard EPC-50 has the ability to become the EPC-50e with the installation of the firmware updater to the EPC followed by the installation, and use of the terminal program on a PC. A CD-ROM has been provided in the kit that contains all of the necessary equipment. If the CD-ROM is not available, the software is available via the internet. See Figure 1 for the proper wiring to connect the EPC-50E system to a Personal Computer. The computer must have an operating system of Windows™ 95 or above.

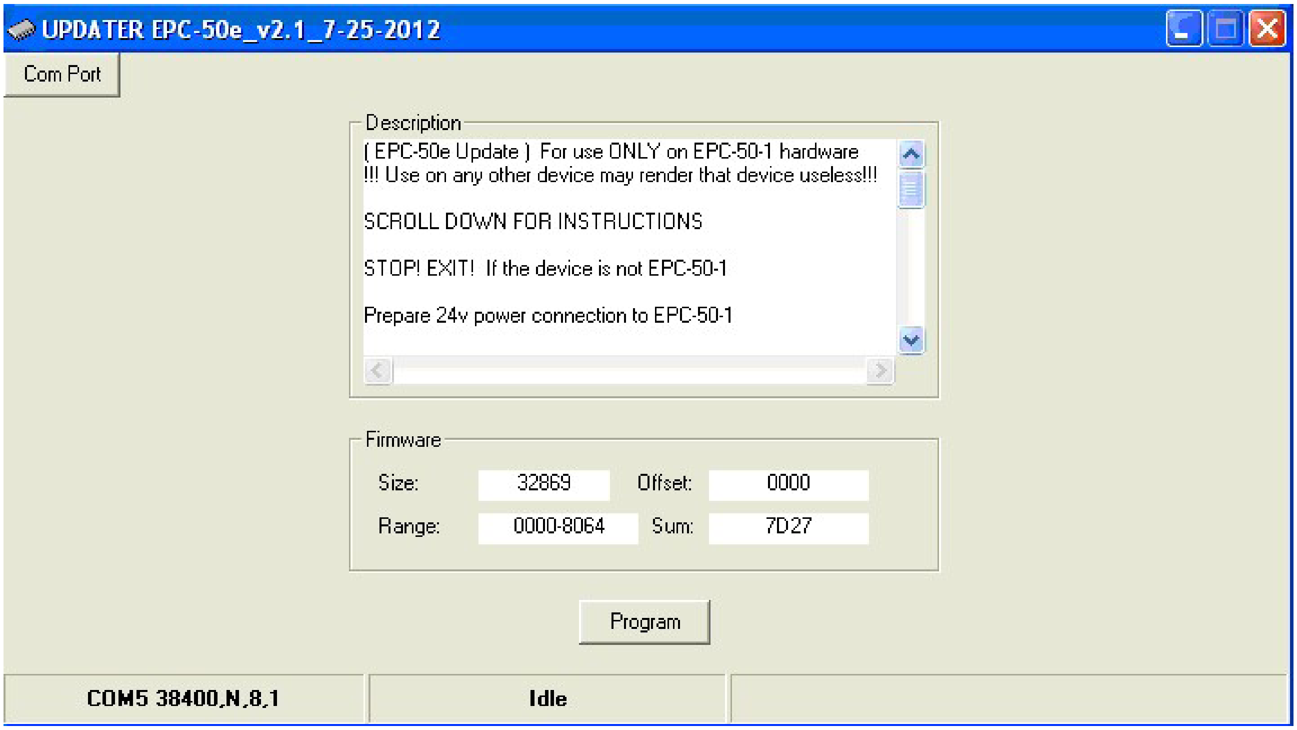
21.2 The CD-ROM has an auto-install feature that will prompt the contents of the CD to be installed immediately after loading the disk into the PC.



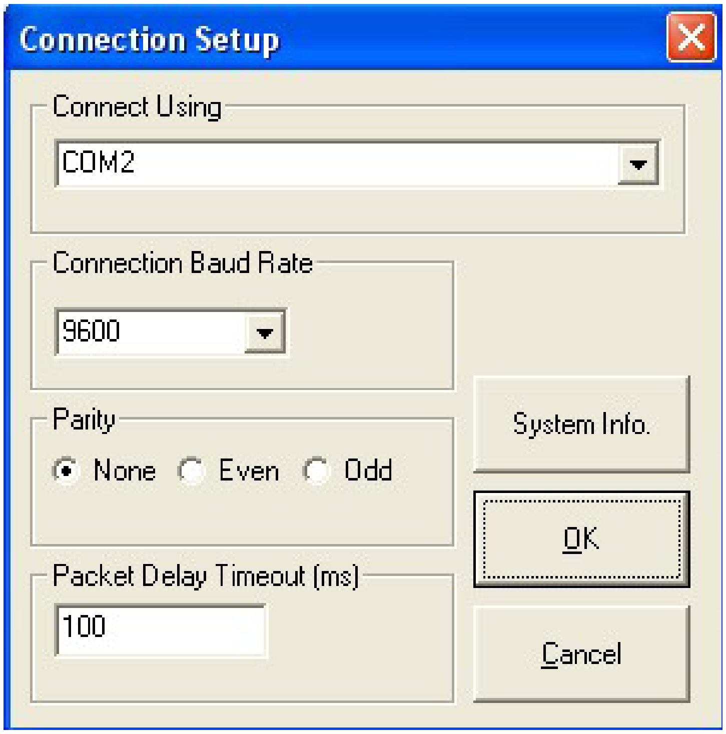
When using the default settings during the installation, the contents of the CD will install to a default directory on the *All Programs Start Menu* of the PC. It will be located under the new *Altronic* tab. First, select the UPDATER_EPC-50e_v2.1_7-25-2012.



Follow the instructions that load directly within the updater window for comm. port setup and procedure.



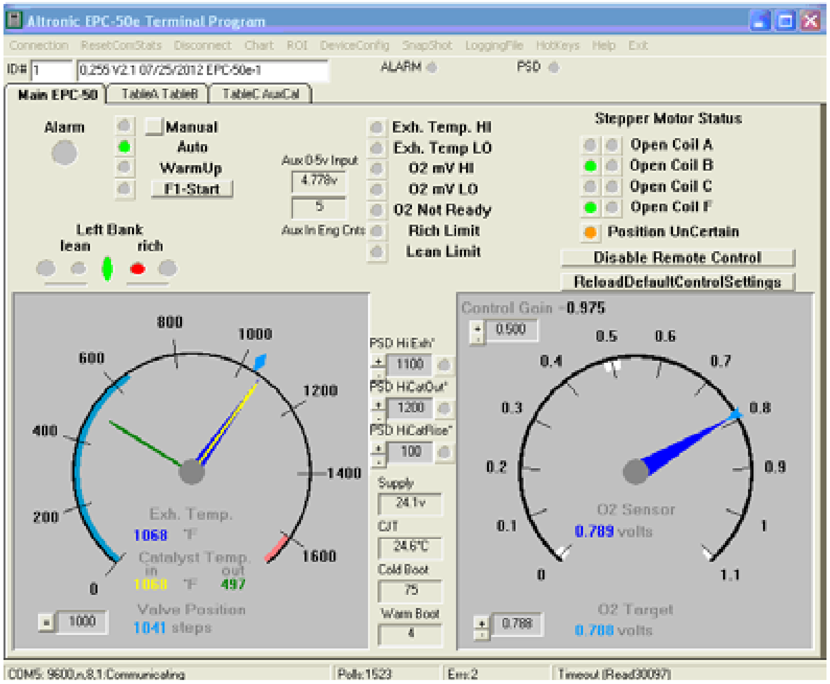
21.3 Open the Terminal Program Version 2.1 or greater, which is located under the *All Programs Start Menu*. The communications link to the EPC-50e must be set up, and differs from the communication setup for the updater file. Click on the word *Connection* on the top toolbar to open the connection dialog box shown below. Select an available comm. port on your computer and configure the Modbus port settings. The default communication settings for the RS-485 EPC-50e are 9600, N, 8, 1. The default NODE address is 50.



22.0 IMPLEMENTING THE ADVANCED CONTROL OPTIONS

22.1 With version 2.1, or later, of the Terminal Program installed on a PC connected to an EPC-50e unit which has been updated to 2.1, or later, the user will see the main, or legacy, screen which shows the current operating conditions.

The current dynamic operating conditions are displayed on cockpit-style gauges and the numeric values of temperature, stepper position, and oxygen sensor voltage are shown in the bottom center of the gauge face. The numeric value of each of the parameters is color matched to the appropriate gauge needle. For example, the LEFT exhaust temperature is the BLUE 1068 on the left-hand gauge display shown below. On the right hand gauge display, the BLUE 0.789 is the left bank O_2 sensor voltage which matches the setpoint voltage of 0.789 shown on the outside of the gauge scale by a LIGHT BLUE ARROW point.

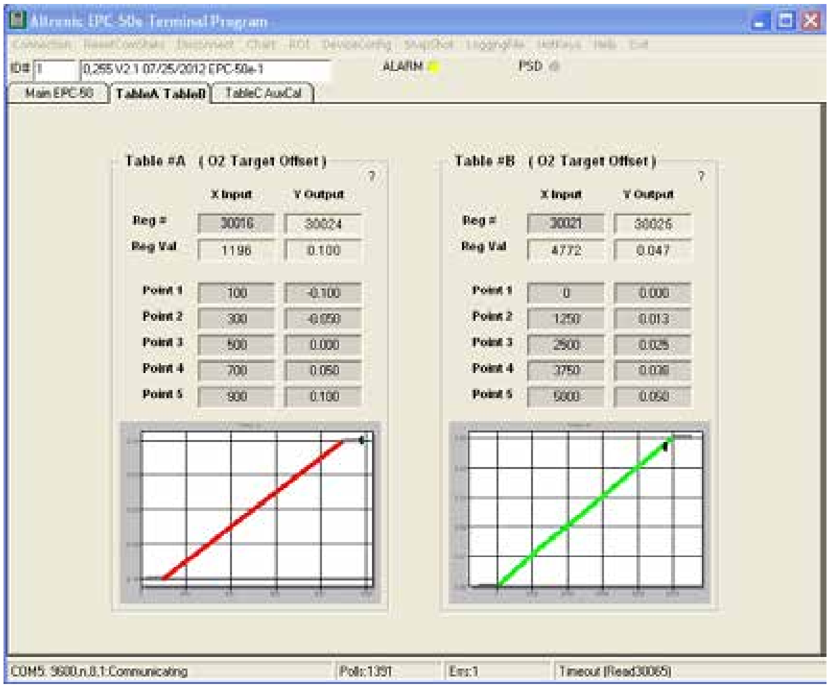


In addition to these operating values, the status of the standard EPC-50e alarms for exhaust temperature, O_2 sensor voltage, rich or lean limit, and so on are also displayed. The status flag for each of these turns RED, whenever that particular alarm is activated. On status flags which are user selected or which are normally changing during operation a GREEN status flag is used to show that a particular condition is active and in the normal range of operation.

Throughout the EPC-50e terminal program Windows Tool Tips have been provided to help guide the user. By placing the mouse indicator over a particular item any hidden tool tips will be revealed. Typical tips would include the Modbus register address attached to a flag and its description. On user-adjustable values a suggested range would also be included.

22.2 The Terminal Program on the PC is the Graphical User Interface (GUI) of the system and uses the Modbus RTU address structure to simplify the process of configuration. In general, the user creates custom control functions by entering the Modbus register number (address) assigned to a particular engine parameter into a pre-configured control function block. First, the selection of a specific input parameter to be used as a control variable (engine manifold pressure, exhaust temperature, post-catalyst O_2, or other) is made. Next, the controller can be configured to bias the O_2 setpoint to make a gain adjustment. Multiple means of control versus various monitored parameters can be used simultaneously or under different operating or ambient conditions. Specific examples of the advanced capability of this control system will follow, but these are examples only. The specific relationships and values required for best emissions performance must be developed for each application.

22.3 Offsetting the pre-catalyst Lambda sensor setpoint being used by the controller for closed loop control can be accomplished with the EPC-50e. This control approach is often used when a post-catalyst O_2 sensor, or an engine load sensor, is added for feedback trim. Selecting the TableA TableB tab displays the following PC screen.



Tables A and B are designed to dynamically change the O_2 target offset. Each table creates a five-point schedule, by which the O_2 target level would be offset relative to the input of another parameter. The schedules can be utilized independently or collaboratively, whereby the bias (offset) generated by each of the tables would be summed to determine the offset value. Each table has an input and an output, labeled X and Y respectively. The input is determined by a user-selected Modbus register that can be used to control the output. The selected parameter is placed in the Reg # position of the table. The output Reg # is predetermined and non-adjustable. In order to see real-time feedback from the registers in the Reg # position, a Reg Val position is available. Points 1 through 5 in the X value are based on the independent variable, and must be entered in ascending order, and the Y value of points 1 through 5 are the dependent variable for the O_2 offset (stored in Modbus register 30024). Once the table is populated, the value in the Reg Val Y position will contain the value to be added to, or subtracted from, the original O_2 target. The Y value can be negative or positive in sign. As values are entered into the table they appear in RED. When the values are accepted by pressing the ENTER key on the computer, they turn BLACK and the resultant graph on the programmed function will appear below the table. Remember to use the Tool Tips by placing the cursor on the item of interest. There is also additional help available by clicking the **?**.

EXAMPLE 1: The following explanation refers to Table A (page 25). Using an exhaust gas analyzer, the user has determined that he can minimize engine emissions by incorporating an automatic adjustment of the normally fixed pre-catalyst O_2 setpoint as a function of the signal from a post-catalyst O_2 sensor. From the Modbus register address list included with these instructions (section 25.0), the register which contains the post-catalyst sensor voltage is 30016, this number is entered for the X input REG#. The user has determined that the optimum catalyst performance on a given engine occurs when the post-catalyst O_2 sensor is reading about 500mV. On initial setup of the engine, the best emissions were found to occur with the pre-catalyst sensor setpoint at 720mV, this also corresponded to a post-catalyst sensor voltage of 500mV. In order to maintain this operating relationship over time, the post-catalyst O_2 sensor will be allowed to influence the pre-catalyst sensor setpoint by a maximum of ±100mV. If the post-catalyst sensor voltage is outside its normal operating range of 100 to 900mV, it has no effect. The current values of the X and Y variables are shown directly below the Modbus register address number. The actual offset value coming from the programmed function is also displayed as the small black bar on the graph.

NOTE: IN THIS EXAMPLE, THE BEST RELATIONSHIP WAS NOT LINEAR, SO A BREAKPOINT AT X EQUALS 2000 WHEN Y EQUALS 30 MILLIVOLTS WAS USED.

EXAMPLE 2: In reference to Table B (page 25), using an exhaust gas analyzer, the user has determined that he can minimize engine emissions by incorporating an automatic adjustment of the target O_2 setpoint as a function of engine load. Using a transducer monitoring engine intake manifold pressure (as a representation of engine load), the user has determined that the optimum O_2 sensor setpoint should range between 750mV and 700mV from zero to full load. Thus, the baseline O_2 sensor setpoint could be established at 700mV with an offset adjustment of +50mV being made for light engine load conditions.

NOTE: THE PERMANENTLY-CONFIGURED ENGINEERING UNIT VALUES FOR EACH OF THE PREDEFINED MODBUS REGISTERS IS INCLUDED IN THE MODBUS REGISTER LISTING. THE AUX. ANALOG INPUTS HAVE SEPARATE MODBUS REGISTER LOCATIONS FOR THE MEASURED VOLTAGE AND FOR USER-DEFINED ENGINEERING UNITS. EITHER OF THESE REGISTER LOCATIONS MAY BE USED TO ADD AN OFFSET, BUT THE DATA NEEDS TO BE ENTERED ACCORDINGLY. IT IS RECOMMENDED THAT THE ACTUAL INPUT VOLTAGE BEING MEASURED BE USED WHENEVER POSSIBLE IN ORDER TO SIMPLIFY BASIC TROUBLESHOOTING.

This example would be implemented by adding a 0-50psi transducer (Altronic P/N 691204-50) to the engine intake manifold and wiring it to EPC adaptor. The user would then enter the Modbus RTU value for that transducer (in this case, 30021 for AuxIn 1, 0-5 ratiometric, 1mv/cnt) into Table B under Reg# for the X input. This configures the system to accept the input of that transducer as the biasing input for the O_2 target value offset. To provide the EPC-50e with the schedule for when, and by what value, to offset the target value, the user enters the X value in transducer mV (0 to 5000mV for 0 to 5 volts) and the offset voltage in O_2 sensor mV (in this case, 0 to 50mV).

These examples are intended only to illustrate the optional capabilities of the EPC-50e. Among the concepts with the potential to improve long-term emissions may also be using the relative activity of the on-engine catalyst as indicated by the current temperature rise across the converter, or the use of a wide band oxygen or No_x sensor post-catalyst. Likewise the use of the engine intake manifold pressure is an example of a means to sense the current engine load and offset the O_2 setpoint, but this could also be done using a KW sensor, a throttle position sensor or fuel flow signal.

In as much as the generated offset values for Tables A and B are additive, utilizing both tables simultaneously permits the user to allow for the complex interaction of operating parameters.

22.4 Selecting the TableC Auxcal tab displays the following PC screen.

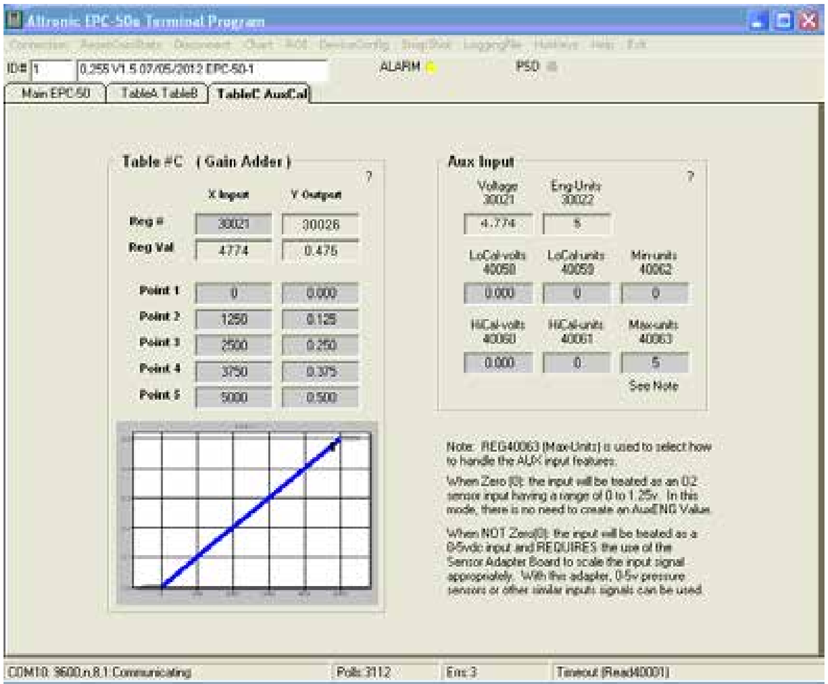
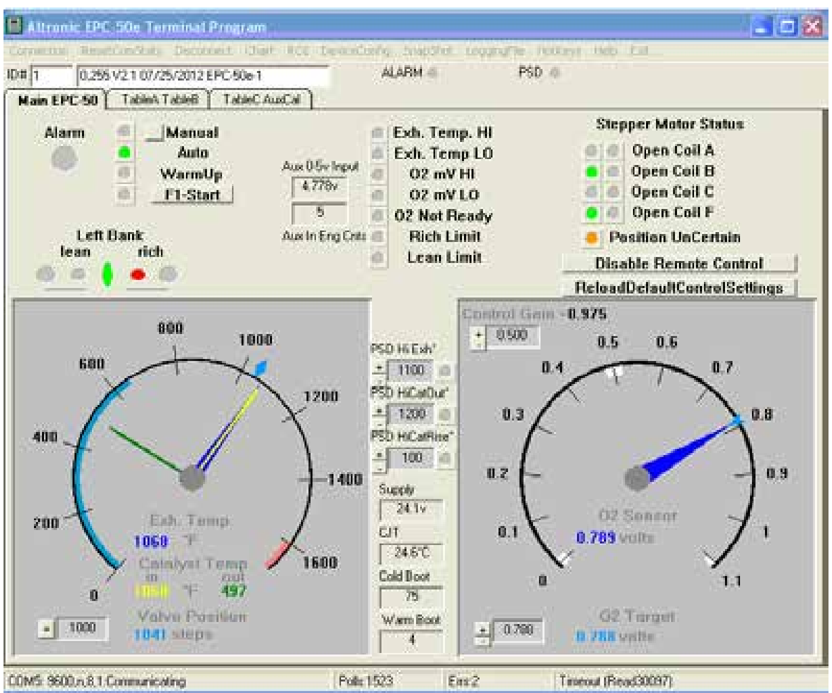


Table C is designed to dynamically change the gain setting (degree of response) of the EPC-50e controller. This table functions in the same manner as Tables A and B, but the value in Reg Val is added or subtracted from the original control gain. This can be viewed as shown below in the Main EPC-50 tab.

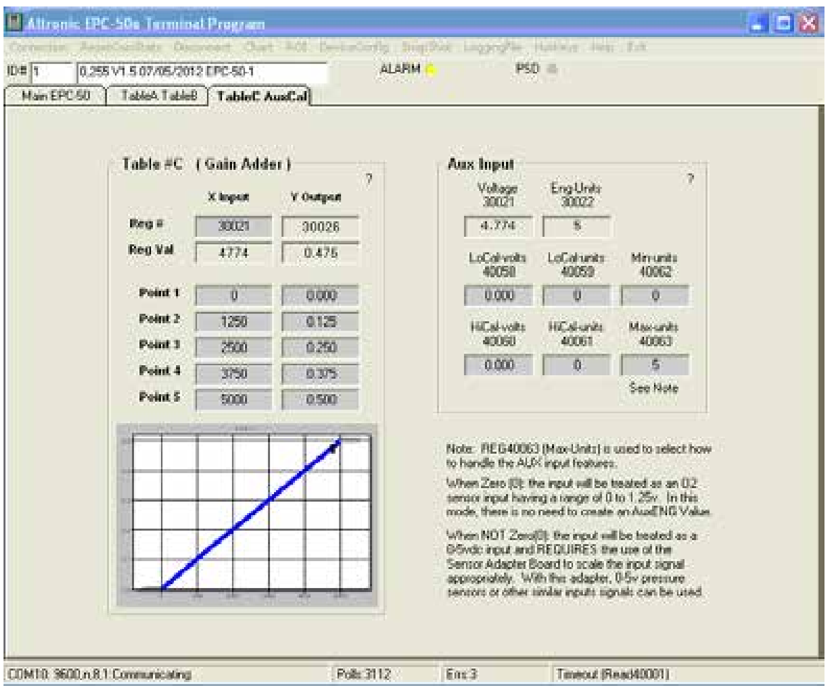


EXAMPLE (illustrated above): The basic fixed gain adjustment of the EPC-50e should always be optimized for the typical operating conditions of the engine. When the engine is operated at “off design” conditions, the normal gain setting may not be responsive enough to minimize variations in the emissions. In this example, the register address selected for the X Input (30021) is for the analog value connected to AuxIn 1 with an adaptor board. A pressure sensor measuring intake manifold pressure senses engine load. The values entered into the table result in a higher gain at lighter loads, which is often desirable because as fuel flow drops at lighter loads, the "leverage" of the flow control valve over the flow is reduced requiring a greater response to maintain control.

23.0 AUX INPUT ENG UNITS CONVERSION

23.1 The Aux Input section is independent of the TableC function, and offers a means of calibrating an input voltage to an engineering unit range. LoCal and HiCal volts are the low and high input voltage range of the sensor respectively, while the LoCal Units and HiCal Units are the low and high values associated with what the sensor detects.

For example (shown below) a 0-5psi pressure transducer, "0" being the LoCal-units and "5" being the HiCal-units. If the input voltage is higher than, or lower than, the specified range, the Minunits and Maxunits are provided as a means to bound the engineering unit values. Because only integer math is used here, the engineering values converted, as the voltage input varies, will be discrete values of 1, 2, 3, 4, and 5. By placing two zeros after the value of "5" (becoming 500), there is now a theoretical decimal point after the five that gives two places worth of resolution. The engineering values converted as the input voltage varies would be 1–500, representing .01 to 5.00psi. The fixed values shown directly below the stated labels are the associated Modbus registers that store the associated values.



23.2 Note: REG40063 (Max-Units) is used to select how to handle the AUX input features.

When Zero (0): the input will be treated as an O_2 sensor input having a range of 0 to 1.25v. In this mode, there is no need to create an AuxENG Value.

When NOT Zero(0): the input will be treated as a 0-5vdc input and REQUIRES the use of the Sensor Adapter Board to scale the input signal appropriately. With this adapter, 0-5v pressure sensors or other similar inputs signals can be used.

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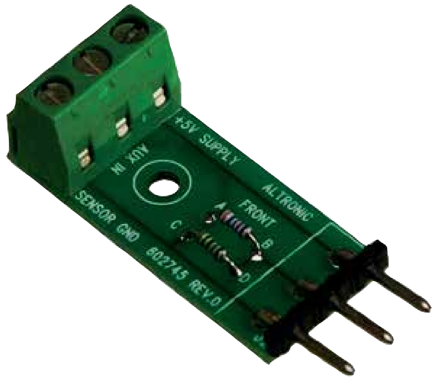
24.0 SENSOR ADAPTOR



A hardware sensor adaptor, P/N 691306-1, has been provided to allow the EPC-50e to accept sensors that use 5Vdc references. When using the adaptor and the functions of the additional firmware incorporated into the enhanced version of the EPC-50e, advanced configurations of the control gain and target O_2 offset are possible. This is accomplished by utilizing the parameters of the TableA TableB and TableC AuxCal tabs with the Modbus registers associated with the AuxIn input. There are three terminals on the back that are normally not connected, terminals 10, 11, and 12. Plugging the adaptor in with adaptor terminal strip face up, tighten the EPC-50 terminal strips. If the sensor adaptor is not used, the secondary O_2 sensor can be applied to terminals 11 and 12.

25.0 EPC-50E MODBUS REGISTER LIST

The EPC-50e incorporates a half-duplex RS-485 or RS232 port which is Modbus RTU slave compliant. The protocol used follows the Modicon Modbus RTU standard. A complete listing of the Modbus registers is included on the EPC-50e Terminal program CD along with a PC-based Modbus-compatible monitoring program. The default configuration for the port is 9600 baud N81 with a NODE ID of 50. The Modbus communications will allow the EPC-50e to meet the needs of continuous emissions monitoring should it be required.

REGISTER	BINARY REGISTER VALUES
00001	F1-START
00002	ALARM ACKNOWLEDGE
00003–08	Spare
00009	MOVE LEFT LEAN FAST +100
00010	MOVE LEFT LEAN SLOW +25
00011	MOVE LEFT RICH SLOW -25
00012	MOVE LEFT RICH FAST -100
00013–16	Spare
00017	L-Manual
00018	Spare
00019	DUAL-BANK
00020	Display Temps 0F 1C
00021–128	Spare

The 10xxx registers are read-only binary and support Modbus standard function 1. These registers are read in multiples of 8 (1 byte) addressed at each 8 bit boundary (10001-10008, etc.). A single Boolean read from registers 10001 to 10064 can be made which will return all 64 values as a group of 8 bytes. These registers also support an Altronic custom function 101 which will return a descriptive label for each specific register. The custom label function can be used to reduce the need for the Modbus master to maintain a current listing of all of the register labels for each unit.

REGISTER	BINARY REGISTER VALUES
10001	Save Position
10002	Low Supply Voltage
10003	Warmup Mode
10004	Spare Status
10005	Stepper Resetting Now
10006	Spare Status
10007	Spare Status
10008	Unacknowledged Alarm Preset
10009	Exh Temp Low
10010	Exh Temp High
10011	O2 Signal Low
10012	O2 Signal High
10013	aux auto inhibit
10014	O2 Sensor Not Ready
10015	Stepper Lean Limit
10016	Stepper Rich Limit
10017–28	Spare Status
10029	Step Coil Open Pin A
10030	Step Coil Open Pin B
10031	Step Coil Open Pin C
10032	Step Coil Open Pin F
10033	Auto Control is Active
10034	Getting Richer
10035	Very Rich >512mv
10036	Rich
10037	----ONTARGET---- +/-5mv
10038	Lean
10039	Very Lean >512mv
10040	Getting Leaner
10041–52	Spare Status
10053	Step Coil Drive A
10054	Step Coil Drive B
10055	Step Coil Drive C
10056	Step Coil Drive F
10057	Left Valve Position Uncertain
10058–64	Spare Status
10065	TC ENG LEFT HiTemp PSD
10066–68	Spare Status
10069	TC CAT OUT HiTemp PSD
10070–72	Spare Status
10073–74	Spare

The 30xxx registers are read-only, 16 bit, analog values. The Modbus standard function 4 is supported. These registers also support an Altronic custom function 104 which will return a descriptive label for each specific register.

REGISTER	16-BIT INPUT REGISTER VALUES
30001	Input Bit Mirror 10016-10001
30002	Input Bit Mirror 10032-10017
30003	Input Bit Mirror 10048-10033
30004	Input Bit Mirror 10064-10049
30005	Input Bit Mirror 10080-10063
30006	Input Bit Mirror 10096-10081
30007	Input Bit Mirror 10112-10097
30008	Input Bit Mirror 10128-10113
30009	SUPPLY INPUT VOLTAGE .1v/cnt
30010	CJT DEG C signed 0.01degc/cnt
30011	EXH TEMP ENG-OUT 1degf/cnt
30012–13	Reserved
30014	EXH TEMP CAT-OUT 1degf/cnt
30015	EXH O2 VOLTAGE-1 1mv/cnt
30016	EXH O2 VOLTAGE-2 1mv/cnt
30017	SMP1C
30018	Reserved
30019	SMP1M
30020	Reserved
30021	AUX1 0-5000
30022	AUX1_ENG
30023	Reserved
30024	LOOKUP TABLE A RESULT
30025	LOOKUP TABLE B RESULT
30026	LOOKUP TABLE C RESULT
30027	Reserved
30028	LEFT BANK O2 DYNAMIC TARGETmV
30029–30	Reserved
30031	CATALYST TEMP RISE (CATOUT-IN)
30032–37	Reserved
30038	CONTROL GAIN VALUE

The 40xxx registers are read/write, 16-bit, analog values and they support the Modbus standard functions 3, 6 and 16. These registers may have new values written to them in order to make setpoint adjustments from a remote location. They also support a custom function 103 which will return a label describing each specific register.

REGISTER	16-BIT READ/WRITE REGISTER VALUES
40001	CoilBits 00016-00001
40002	CoilBits 00032-00017
40003	CoilBits 00048-00033
40004	CoilBits 00064-00049
40005	CoilBits 00080-00063

REGISTER	16-BIT READ/WRITE REGISTER VALUES
40006	CoilBits 00096-00081
40007	CoilBits 00112-00097
40008	CoilBits 00128-00113
40009	LEFT BANK O2 BASE TARGET mV
40010	Reserved
40011	LEFT BANK START POS steps
40012	Reserved
40013	CONTROL GAIN RATE value/40
40014	EXH TEMP HI ALARM SETTING degF
40015	EXH TEMP LO ALARM SETTING degF
40016	EXH O2 HI ALARM SETTING mV
40017	EXH O2 LO ALARM SETTING mV
40018	EXH O2 READY HI SETTING mV
40019	EXH O2 READY LO SETTING mV
40020	TC ENGOUT HI PSD degF
40021	TC CAT OUT HI PSD degF
40022	TC CAT DELTA HI PSD degF
40023–57	Reserved
40058	AUX1 ENG. UNITS CAL POINT 1.X
40059	AUX1 ENG. UNITS CAL POINT 1.Y
40060	AUX1 ENG. UNITS CAL POINT 2.X
40061	AUX1 ENG. UNITS CAL POINT 2.Y
40062	AUX1 ENG. UNITS MINIMUM
40063	AUX1 ENG. UNITS MAXIMUM
40064	TABLE C INPUT REGNUMBER 30XXX
40065	TABLE C POINT 1.X
40066	TABLE C POINT 1.Y
40067	TABLE C POINT 2.X
40068	TABLE C POINT 2.Y
40069	TABLE C POINT 3.X
40070	TABLE C POINT 3.Y
40071	TABLE C POINT 4.X
40072	TABLE C POINT 4.Y
40073	TABLE C POINT 5.X
40074	TABLE C POINT 5.Y
40075–81	Reserved
40082	ENUMERATED CAUSE OF NOT AUTO
40083	SUPPLY INPUT VOLTAGE .1v/cnt
40084	CJT DEG C signed 0.01degc/cnt
40085	EXH ENGINE OUT 1degf/cnt
40086	Reserved
40087	EXH TEMP CAT IN 1degf/cnt
40088	EXH TEMP CAT OUT 1degf/cnt

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REGISTER	16-BIT READ/WRITE REGISTER VALUES
40089	EXH O2 VOLTAGE 1mv/cnt
40090	AUX INPUT VALUE 1mv/cnt
40091	STEPPER POSITION
40092	AUX ENG VALUE counts
40093	TABLE A INPUT REGNUMBER 30XXX
40094	TABLE A POINT 1.X
40095	TABLE A POINT 1.Y targ O2 ofst
40096	TABLE A POINT 2.X
40097	TABLE A POINT 2.Y targ O2 ofst
40098	TABLE A POINT 3.X
40099	TABLE A POINT 3.Y targ O2 ofst
40100	TABLE A POINT 4.X
40101	TABLE A POINT 4.Y targ O2 ofst
40102	TABLE A POINT 5.X
40103	TABLE A POINT 5.Y targ O2 ofst
40104	TABLE B INPUT REGNUMBER 30XXX
40105	TABLE B POINT 1.X
40106	TABLE B POINT 1.Y
40107	TABLE B POINT 2.X
40108	TABLE B POINT 2.Y
40109	TABLE B POINT 3.X
40110	TABLE B POINT 3.Y
40111	TABLE B POINT 4.X
40112	TABLE B POINT 4.Y
40113	TABLE B POINT 5.X
40114	TABLE B POINT 5.Y
40115–119	Reserved
40120	REG40126 MSB=BAUD LSB=NODEID
40121	Warm Boot (reset) Count
40122	Cold Boot (powerup) Count
40123	Spare-volatile
40124	Spare-volatile
40125	Spare-volatile
40126	REMOTE MAN MOVE SIGNED STEPS
40127	Reserved-volatile
40128	MODBUS KEY COMMAND

Detailed below are the command values which can be written to the Modbus Key Command Register (40128).

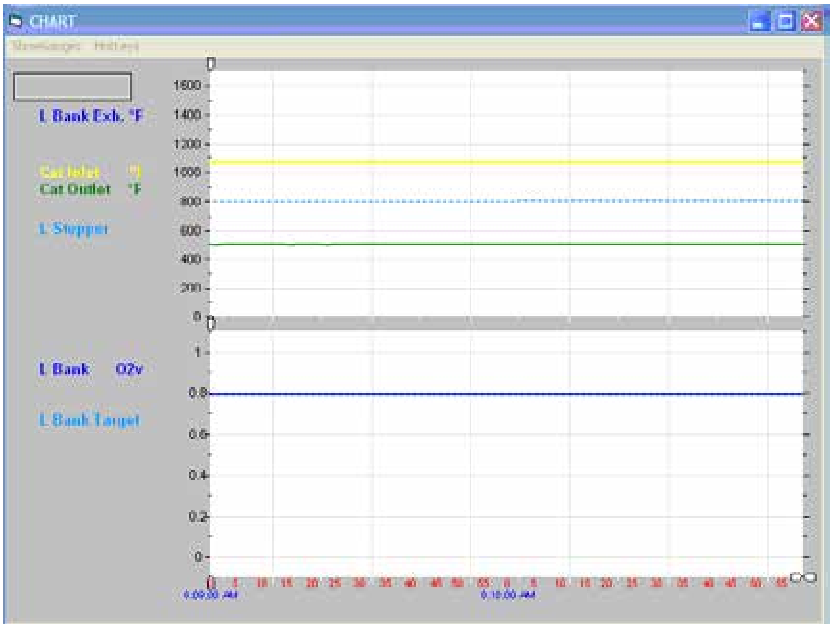
1.	Reg(40128)	00510	Select auto mode for both banks
2.	Reg(40128)	00765	Select manual mode for left bank
3.	Reg(40128)	01275	F1-Start stepper reset
4.	Reg(40128)	01530	Alarm acknowledge
5.	Reg(40128)	01785	Decrement left O2 target
6.	Reg(40128)	02040	Increment left O2 target
7.	Reg(40128)	02295	Decrement right O2 target
8.	Reg(40128)	02550	Increment right O2 target
9.	Reg(40128)	02805	Decrement control gain rate
10.	Reg(40128)	03060	Increment control gain rate
11.	Reg(40128)	03315	Reload calibration defaults
12.	Reg(40128)	03570	Update left start position with current pos
13.	Reg(40128)	03825	Update right start position with current pos
14.	Reg(40128)	05355	Manual move left stepper rich (-25)
15.	Reg(40128)	05610	Manual move left stepper lean (+25)
16.	Reg(40128)	05865	Manual move left stepper rich (-100)
17.	Reg(40128)	06120	Manual move left stepper lean (+100)

The EPC-50e unit also supports a Modbus function 17 which will return the unit information including the Version, Date and Name.

18.	Reg(40128)	07905	decrement Hi Exhaust Temp Threshold
19.	Reg(40128)	08160	increment Hi Exhaust Temp Threshold
20.	Reg(40128)	09435	decrement Hi Catalyst Temp Out Threshold
21.	Reg(40128)	09690	increment Hi Catalyst Temp Out Threshold
22.	Reg(40128)	09945	decrement Hi Catalyst Rise Temp Threshold
23.	Reg(40128)	10200	increment Hi Catalyst Rise Temp Threshold
24.	Reg(40128)	51118	autolog reset

26.0 CHARTING THE VALUES OF THE MEASURED VARIABLES

26.1 The EPC-50e Terminal Program allows the user the option of displaying the measured variables in a strip chart form as shown below. This type of display can be very useful to analyze large amounts of data quickly or to detect operating trends over time. To turn this display on, click on the word CHART on the top toolbar. Scales can be expanded or compressed using the mouse to "drag" the small white boxes on each axis.



27.0 ROI – THE REMOTE OPERATING INTERFACE

27.1 ROI (Remote Operating Interface) provides the user of the terminal with a direct interface to the EPC-50e keypad and display, just as if they were at the location. When using the ROI option, any function normally available at the keypad will execute and display in same manner as if the local keys were actually pressed. At the site where the EPC-50e unit is operating, the ROI function will appear to be keypad operation by an invisible operator.

NOTE: DO NOT ATTEMPT TO MODIFY COMMUNICATIONS SETUP VALUES USING ROI OR COMMUNICATIONS WILL BE LOST UNTIL THE COMPUTER IS RESET TO THE NEW VALUES.

28.0 OTHER TOOLBAR OPTIONS

28.1 There are some additional toolbar functions not covered elsewhere in this document, the operation of each of these is explained below.

- ResetComStats: Clears the Modbus communications error counter to zero. This can be very useful when troubleshooting communication problems.
- Connect/Disconnect: Connects/disconnects the computer from the EPC-50e.
- Snapshot: Creates a snapshot of the current screen display on the computer to be saved in a *.jpg file. This captures the gauge or the chart display, whichever one is active.
- LogFile: Allows for the selection of automatic data logging on the computer connected to the EPC-50e. Datalogs are Excel compatible, CSV type (Comma Separated Values).
- HotKeys: Gives access from any screen to turn Chart display on, or to enable remote control via Modbus.
- Help: Displays software version and dates.
- Exit: Disconnects EPC-50e from computer and exits this program.

FIGURES SECTION:

FIGURE 1 EPC-50, GENERAL INSTALLATION LAYOUT: SINGLE BANK

(CAPABLE OF SINGLE BANK ENGINE APPLICATION ONLY)

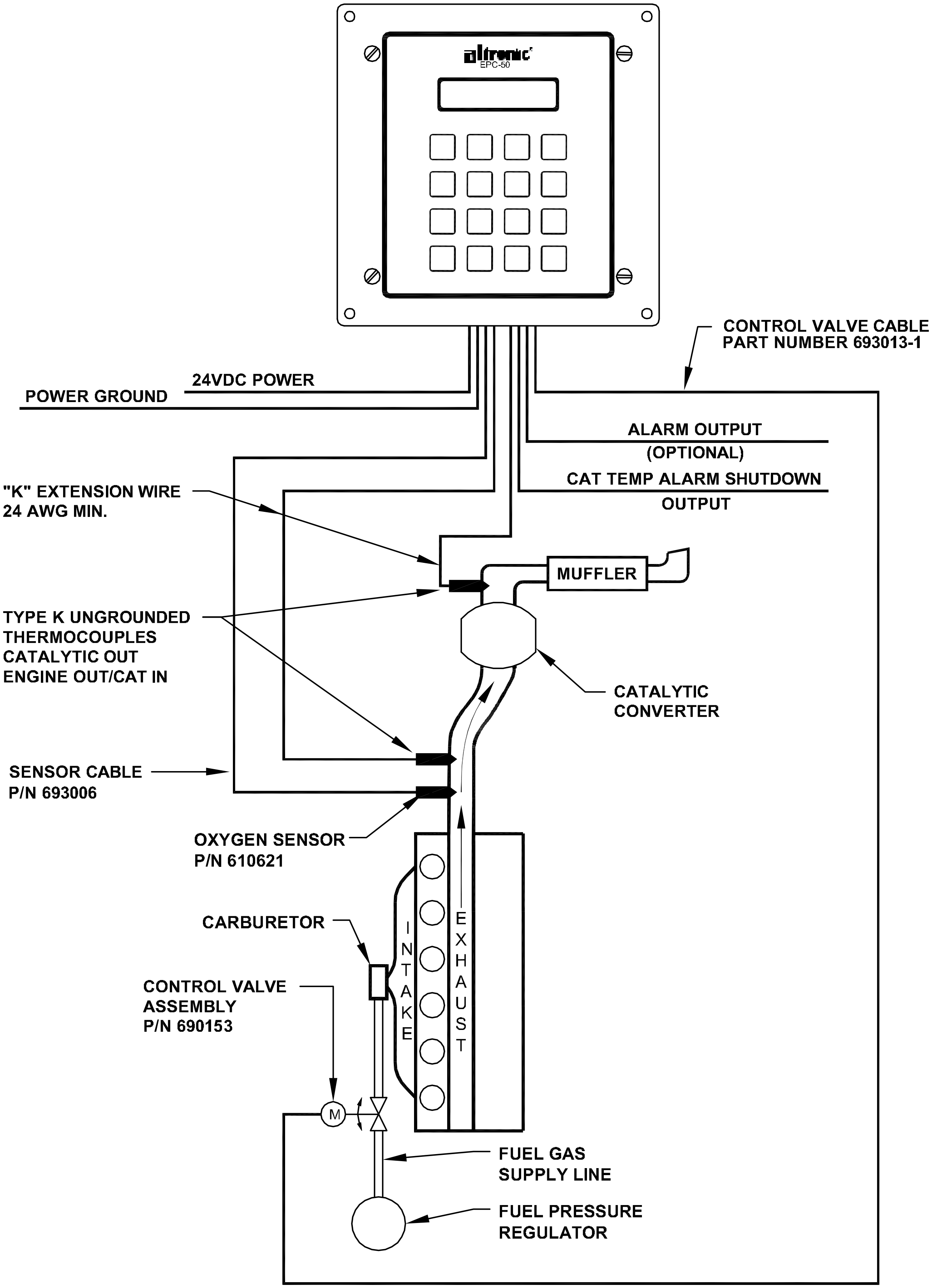


FIGURE 2 EPC-50, MOUNTING DETAIL

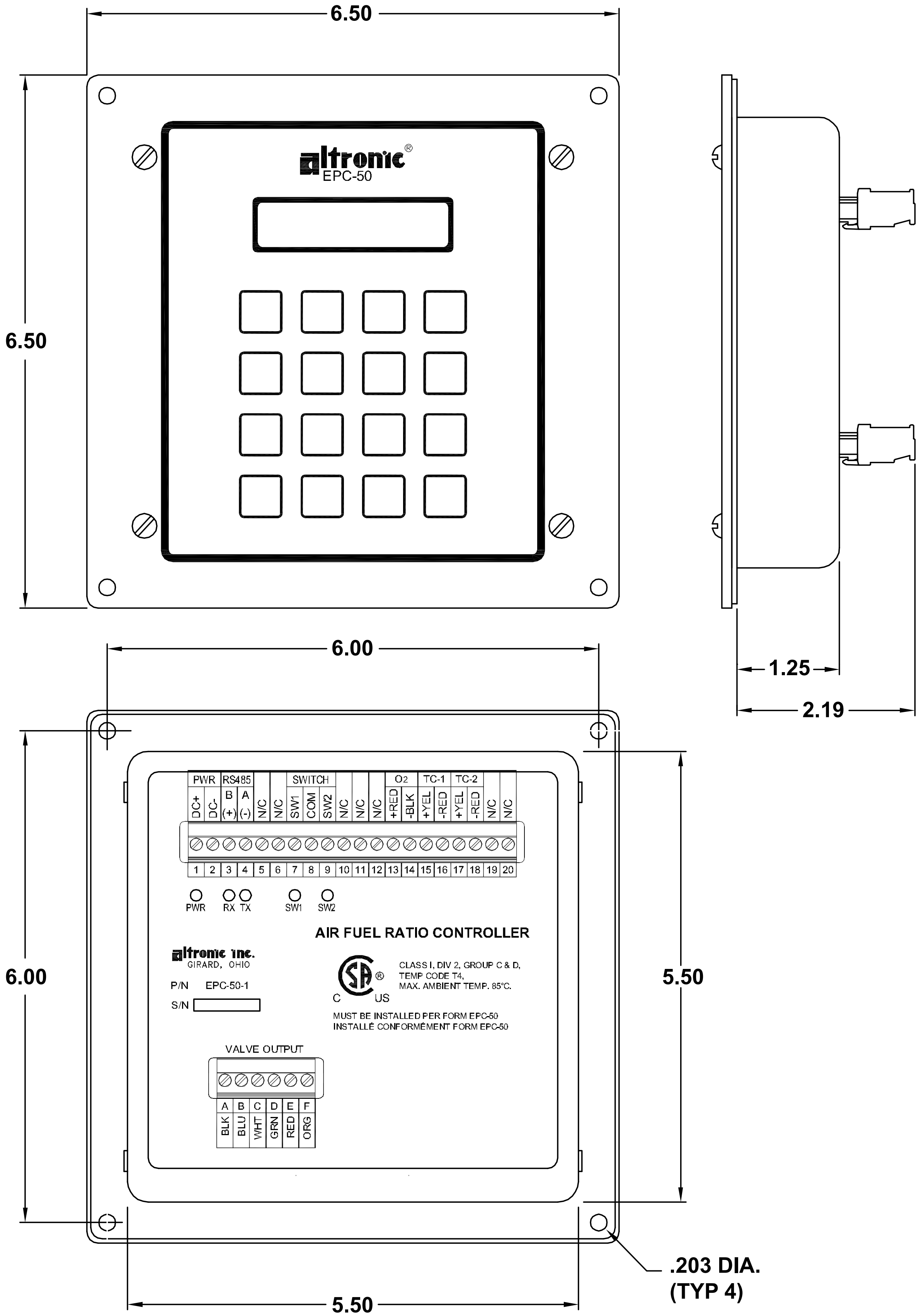


FIGURE 3 NEMA 3R ENCLOSURE MOUNTING DIMENSIONS

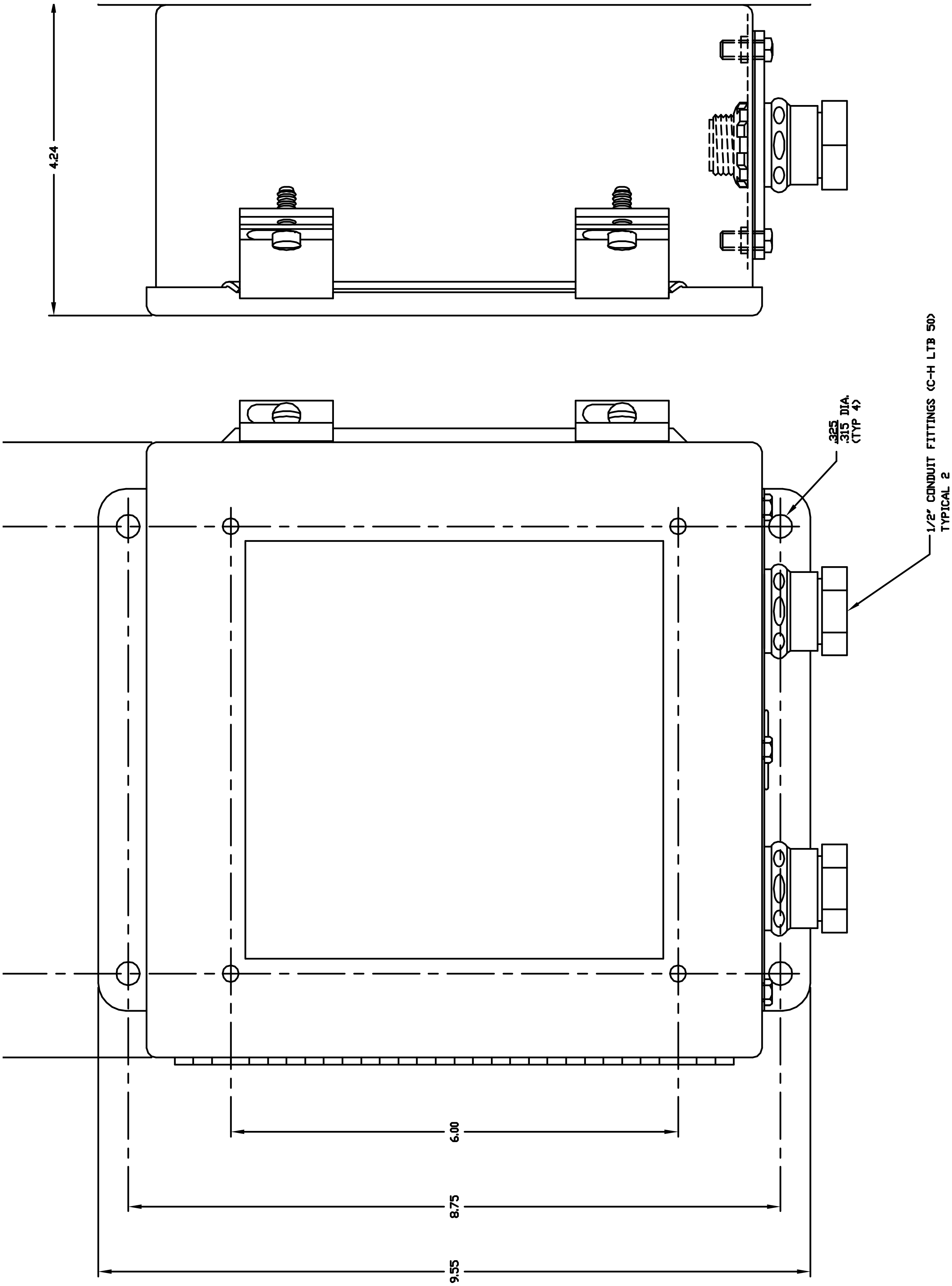
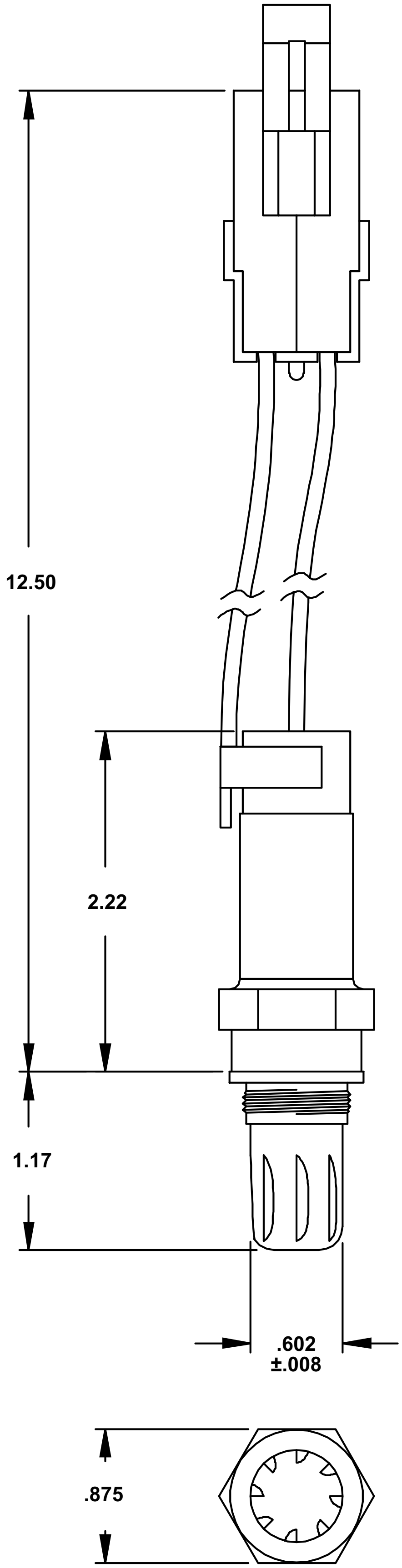
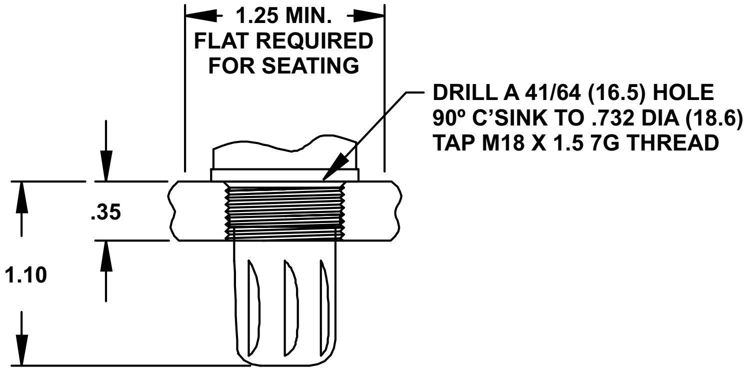


FIGURE 4 OXYGEN SENSOR DETAIL



CONNECTOR PIN	WIRE COLOR	PIN AND WIRE CONNECTION
A	TAN	SENSOR (GROUND)
B	BLACK	OUTPUT

MATING CONNECTOR:
PACKARD ELECTRIC DIV. PART NO. 12010501

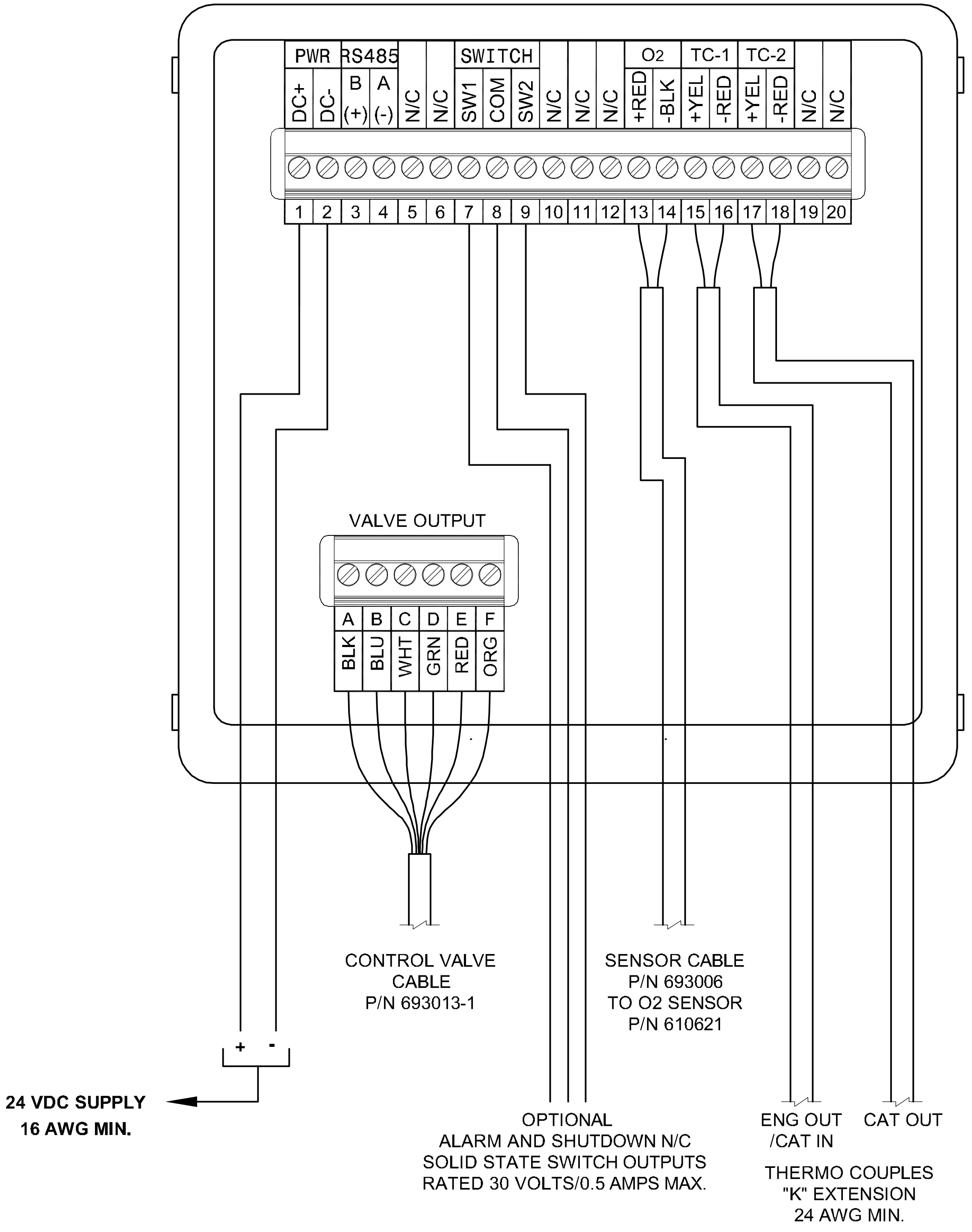


RECOMMENDED INSTALLATION DIMENSIONS

INSTALLATION INSTRUCTIONS:

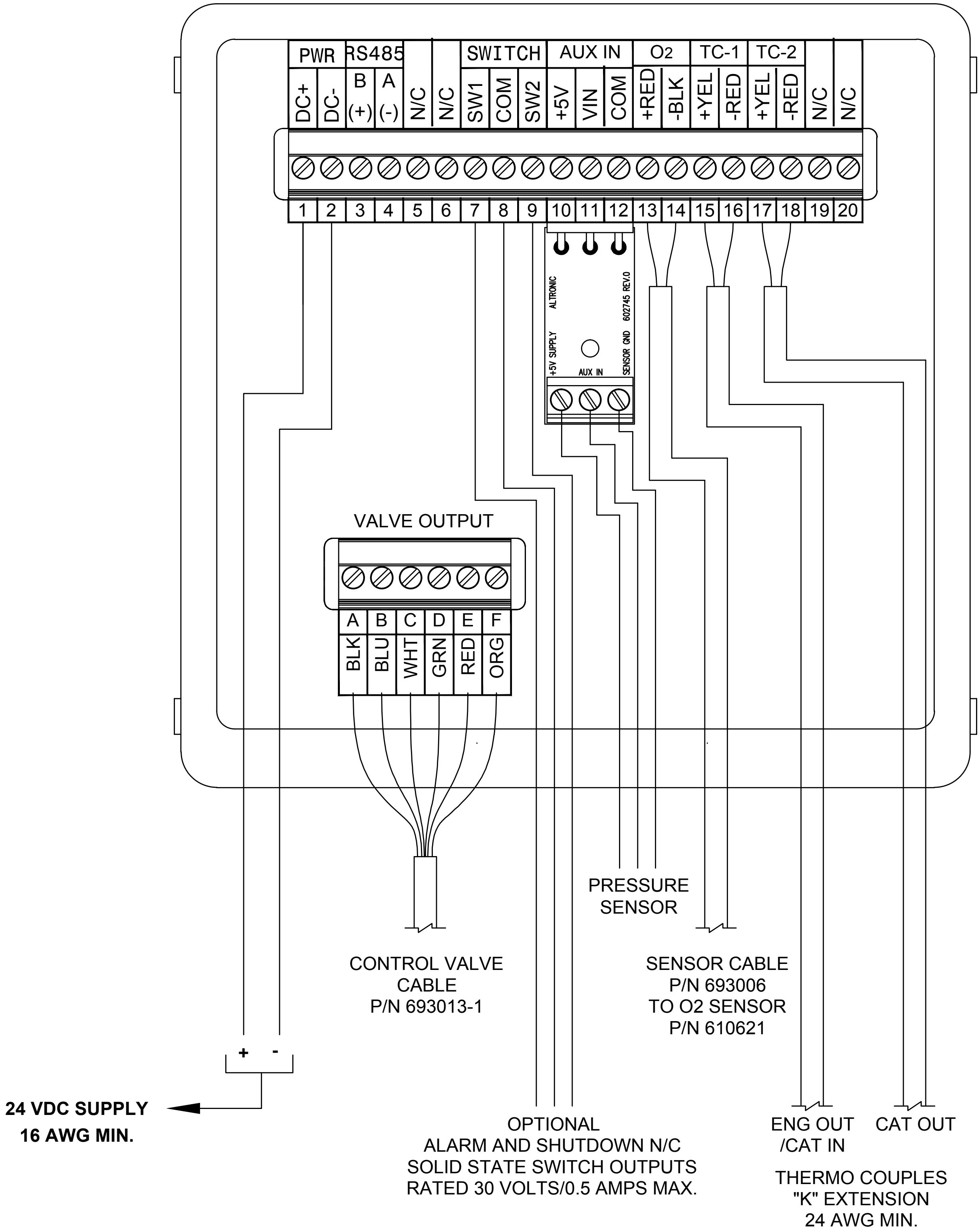
1. INSTALL IN THE APPROPRIATE MOUNTING HOLE TO A TORQUE OF 28-34 LB. FT.
2. USE A 7/8" WRENCH SIZE.
3. SENSORS ARE TO BE SUPPLIED WITH THREADS COATED WITH MS-0572 ANTISEIZE COMPOUND.
   CAUTION: DO NOT APPLY ANTISEIZE COMPOUND TO AREAS OTHER THAN THE MOUNTING THREADS.
4. FOR OPTIMUM RESISTANCE TO WATER INTRUSION, AC RECOMMENDS MOUNTING SENSORS SUCH THAT THE EXPOSED END (WIRE END) OF THE SENSOR IS ORIENTED AT OR ABOVE HORIZONTAL.
5. THIS SENSOR IS DESIGNED FOR WATER SPLASH RESISTANCE.

FIGURE 5 EPC-50, WIRE ROUTING DETAIL



NOTE: ROUTE WIRES SUCH THAT POWER INPUT AND VALVE OUTPUT SIGNALS ARE NOT IN COMMON CONDUIT WITH O_2 AND THERMOCOUPLE SIGNALS.

FIGURE 6 EPC-50e, WIRE ROUTING DETAIL



NOTE: ROUTE WIRES SUCH THAT POWER INPUT AND VALVE OUTPUT SIGNALS ARE NOT IN COMMON CONDUIT WITH O_2 AND THERMOCOUPLE SIGNALS.

FIGURE 7 EPC-50, MODBUS COMMUNICATION CONNECTIONS

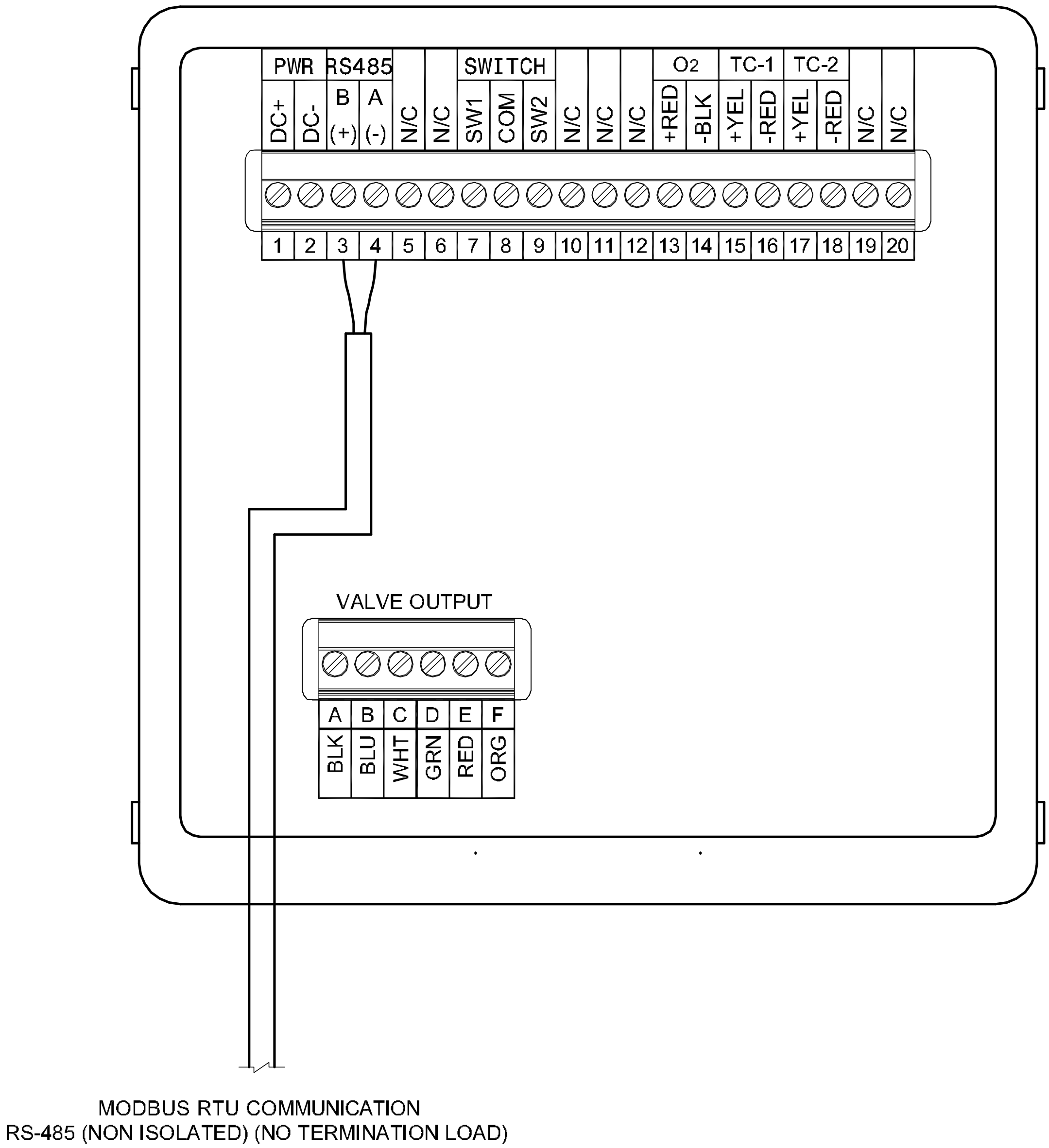
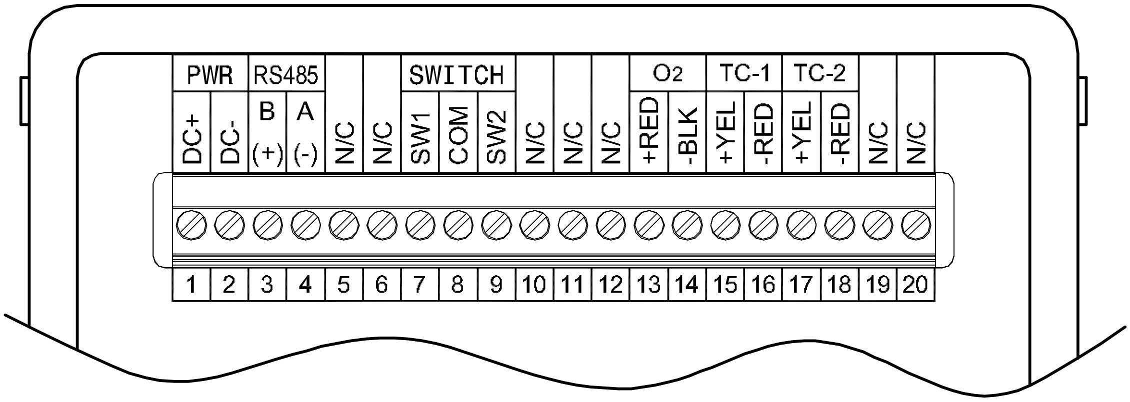


FIGURE 8 EPC-50/50E, TERMINAL LAYOUT



PIN 1 POWER SUPPLY +24 NOMINAL

PIN 2 POWER SUPPLY COMMON (ALSO ENGINE GROUND)

PIN 3 MODBUS RS485 SERIAL CONNECTION (+, B) SIGNAL

PIN 4 MODBUS RS485 SERIAL CONNECTION (-, A) SIGNAL

PIN 5 NOT USED

PIN 6 NOT USED

PIN 7 ALARM SWITCH OUTPUT (NORMALLY CLOSED)

PIN 8 COMMON/ENG. GND.

PIN 9 PROTECTION SHUTDOWN SWITCH (NORMALLY CLOSED)

PIN 10 NOT USED

PIN 11 NOT USED

PIN 12 NOT USED

PIN 13 ENGINE OUT OXYGEN SENSOR INPUT (0-1.25 V) (RED)

PIN 14 ENGINE OUT OXYGEN SENSOR INPUT (COMMON/ENG. GND.) (BLK)

PIN 15 ENGINE OUT/CATALYST IN EXHAUST TEMP INPUT (TYPE K TC) (YEL)

PIN 16 ENGINE OUT/CATALYST IN EXHAUST TEMP INPUT (TYPE K TC) (RED)

PIN 17 CATALYST OUT EXHAUST TEMP INPUT (TYPE K TC) (YEL)

PIN 18 CATALYST OUT EXHAUST TEMP INPUT (TYPE K TC) (RED)

PIN 19 NOT USED

PIN 20 NOT USED