ECM ENGINE CONTROL AND MONITORING

XCM114

%O_2, Lambda, AFR Module

Instruction Manual

07/15/2014. P/N XCM114-4

Printed in the United States of America.

Safety Warnings

In the installation and use of this product, comply with the National Electrical Code and any other applicable Federal, State, or local safety codes.

Always wear eye protection when working near engines, vehicles, or machinery.

During installation, turn off the power and the engine and take all other necessary precautions to prevent injury, property loss, and equipment damage. Do not apply power or start the engine until all wiring is completed. Never work on a running engine.

Route and cable-tie all cables away from hot, moving, sharp, high energy (spark), and caustic objects. Take into consideration the movement of the engine, chassis, and wind buffeting.

Clear tools away from the engine before starting.

Operate the engine only in a well ventilated area.

The sensor is heated and you can burn yourself by touching it.

The sensor should not be used in an environment where an oxidizer and fuel exist because the sensor may ignite the mixture.

Important Operation Notes

1. Before installing the O_2 sensor, apply a small amount of non-lead containing antiseize compound to its threads. Do not get the compound on the sensor's tip.

2. **Do not operate an engine for more than three minutes with the O_2 sensor in the exhaust and the control module's power off. If the sensor is off in a running engine for a longer period, soot and water will condense in the sensor and may reduce its sensitivity.**

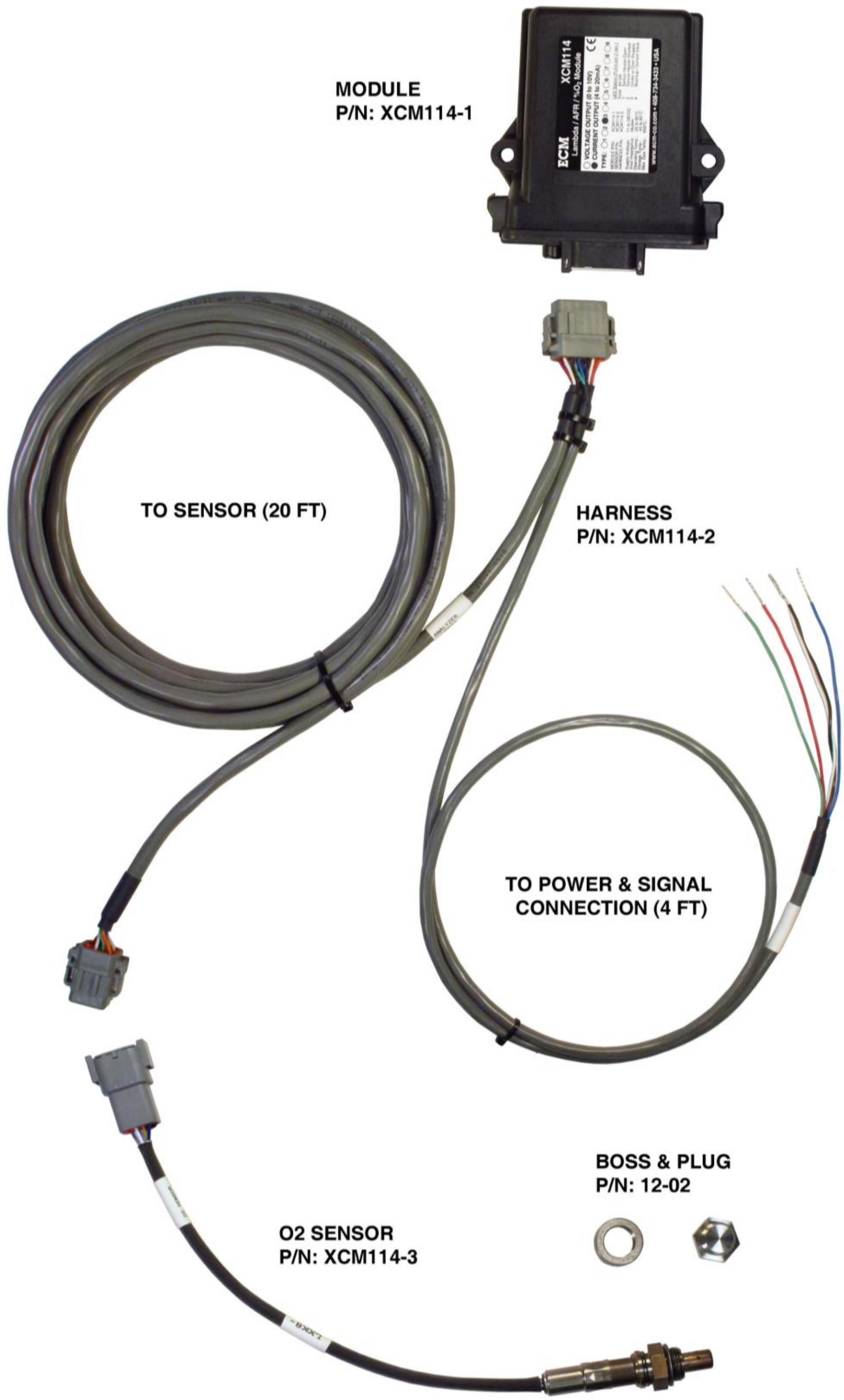
3. Do not put the O_2 sensor in a heavily sooting or oil-burning engine, or in exhaust systems in which water is sprayed into the exhaust.

4. Use of the O_2 sensor with leaded fuels over time may reduce the sensitivity of the sensor.

5. Do not use the O_2 sensor in a location where the temperature is greater than 850 deg. C (1562 deg. F) or if the pressure is not between 0.8 to 1.3 atm (23.9 to 38.9 inches Hg, 81 to 132 kPa).

6. Do not drop the O_2 sensor onto a hard surface, expose to flammable substances, or attempt to wash with solvents or compressed air.

XCM114 Kit Contents



Not pictured: This instruction manual, P/N XCM114-4.

How to Use

General Information

The XCM114 is a ruggedized, environmentally-sealed, general-purpose O_2 sensor controller providing $\%O_2$ (Lambda, AFR) information. The O_2 measurement range is 0 to 22 %. The Lambda and AFR ranges depend on the module programming. See “Output Signal” section. The XCM114 is to be used with a XCM114-3 sensor and a XCM114-2 harness.

Power:	11 to 28VDC, 5A (max 1 min. surge), 1.2A (steady-state)
Module Dimensions (WxHxD):	4" x 3.5" x 1", 102mm x 89mm x 25mm
Module Weight:	5.6 oz., 160 gm.
Module Operating Temperature:	-20°C to +85°C
Module Storage Temperature:	-40°C to +85°C
Sensor Thread:	18mm x 1.5mm.
Max. Gas Temperature:	850 °C

Setting Up the XCM114

The XCM114 module comes preconfigured in terms of Mode (Voltage Output or Current Output), Current Output Power Source (Internal or External), and Type (1 through 9 giving different measurement-to-output scaling). The preconfiguration is written on labels stuck to the module. This manual contains information on changing the configuration.

The O_2 sensor should be located from 12" to 48” from the exhaust valve(s) of the engine. **Mount the O_2 sensor in a location where liquids (ex. condensed water) will not collect on the sensor.** Lightly coating its threads with a non-lead containing antiseize compound. Do not modify the wiring harness. Replace the wiring harness if it becomes damaged.

After powering-up the XCM114, it will take approximately 30 seconds for the control module to bring the O_2 sensor to its operating temperature.

Measure the output and calculate the $\%O_2$ (Lambda, AFR) using the tables on the “Output Signal” section. If output is greater than what is indicated as valid in the table, the sensor is broken and needs to be replaced.

In voltage output mode, the analog output ground (GRN wire) is electrically connected to the power ground (BLK & WHT wires) inside the module. Avoid ground loop problems by connecting harness power ground wires (BLK & WHT wires) directly to the power supply ground. Do not run a single wire from where the BLK and WHT wires join to the power supply ground. Contact ECM for harness modification questions.

In the case of a detected failure, the output of the XCM114 will be encoded with a “pulsed” trouble code that will describe the failure. See “Troubleshooting” section.

Output Signal

Values for $\%O_2$, Lambda, and AFR (gasoline) can be determined using two methods. "Method #1" assumes an "as delivered" sensor from ECM. "Method #2" is for a sensor of unknown condition and requires a pre-calibration in air.

Method #1 (for new sensors):

1. Using the "Vout & Iout vs $\%O_2$" table and knowing the module "Type", determine the $\%O_2$. Negative $\%O_2$s should be interpreted as 0 (zero) $\%O_2$.

2. Use the $\%O_2$ calculated in step 1 to determine the Lambda and AFR in the "$\%O_2$ vs Lambda & AFR" table. Here negative $\%O_2$ numbers are used (meaning a rich mixture). The AFR numbers assume a gasoline fuel with an H:C ratio of 1.85:1.

3. Correct AFR, Lambda, or $\%O_2$ for pressure according to Equation 3a, b, or c.

Method #2 (for aged sensors):

1. Hold the sensor in quiescent air for at least 20 minutes. Measure Vout (or Iout) and determine the $\%O_2$ in the air from Appendix A. Denote this $\%O_2$ as $\%O_2$cal and the measured Vout (or Iout) as Vcal (or Ical).

2. While the sensor is in use, calculate the $\%O_2$ using the following if the output is a voltage:

   $$\%O_2 = \left((Vout - Offset) / (Vcal - Offset) \right) \times \%O_2cal \qquad \text{[Equation 1]}$$

   where: for Types 1, 4, 7: Offset = 1
   for Types 2, 5, 8: Offset = 3
   for Types 3, 6, 9: Offset = 4

   or if the output is a current, use:

   $$\%O_2 = \left((Iout - Offset) / (Ical - Offset) \right) \times \%O_2cal \qquad \text{[Equation 2]}$$

   where: for Types 1, 4, 7: Offset = 6
   for Types 2, 5, 8: Offset = 10
   for Types 3, 6, 9: Offset = 12

3. Use the $\%O_2$ calculated in 2 to determine the Lambda and AFR in the "$\%O_2$ vs Lambda & AFR" table. Here negative $\%O_2$ numbers are used (meaning a rich mixture). The AFR numbers assume a gasoline fuel with an H:C ratio of 1.85:1.

4. Correct AFR, Lambda, or $\%O_2$ for pressure according to Equation 3a, b, or c.

Vout & Iout vs %O_2

Vout (V)		0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
Iout (mA)		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Type																		
1			-6.967	0	6.967	13.93	20.9											
2							-6.967	0	6.967	13.93	20.9							
3									-6.967	0	6.967	13.93	20.9					
4		-5.219	-2.61	0	2.61	5.219	7.829	10.44	13.05	15.66	18.27	20.88						
5					-7.829	-5.219	-2.61	0	2.61	5.219	7.829	10.44	13.05	15.66	18.27	20.88		
6							-7.829	-5.219	-2.61	0	2.61	5.219	7.829	10.44	13.05	15.66	18.27	20.88
7		-5.098	-2.549	0	2.549	5.098	7.647	10.2	12.75	15.29	17.84	20.39						
8					-7.647	-5.098	-2.549	0	2.549	5.098	7.647	10.2	12.75	15.29	17.84	20.39		
9							-7.647	-5.098	-2.549	0	2.549	5.098	7.647	10.2	12.75	15.29	17.84	20.39

Note: A negative %O_2 in the above table should be interpreted as 0% (i.e. there are no O_2 molecules in the mixture). Negative values are given for use in calculating Lambda & AFR using the table below, where it indicates a rich mixture.

%O_2 vs Lambda & AFR (Gasoline, H:C = 1.85)

%O2	Lambda	AFR
10.442	2.104	30.658
8.420	1.741	25.373
7.918	1.670	24.325
7.375	1.598	23.279
6.784	1.526	22.237
6.140	1.455	21.197
5.433	1.384	20.161
5.055	1.348	19.643
4.657	1.313	19.127
4.238	1.277	18.611
3.798	1.242	18.096
3.569	1.224	17.838
3.334	1.207	17.581
3.092	1.189	17.324
2.844	1.171	17.067
2.589	1.154	16.811
2.326	1.136	16.554
2.056	1.119	16.298
1.777	1.101	16.042
1.491	1.083	15.786
1.196	1.066	15.530
0.891	1.048	15.275
0.577	1.031	15.019
0.254	1.013	14.764
0.014	1.001	14.581
-0.109	0.994	14.488
-0.836	0.958	13.962
-1.509	0.927	13.507
-2.922	0.867	12.636
-4.424	0.811	11.818
-6.015	0.759	11.052
-7.696	0.709	10.337

Pressure Compensation Equation for AFR

$$AFR_{corrected} = (AFR_{measured} + B \times P) / (1 + C \times P) \quad \text{[Equation 3a]}$$

where:

$AFR_{corrected}$	= the AFR corrected for exhaust pressure.
$AFR_{measured}$	= the AFR output by the AFM.
B	= 0.009140 for AFR < 14.57 (rich).
B	= 0.012100 for AFR ≥ 14.57 (lean).
C	= 0.000627 for AFR < 14.57 (rich).
C	= 0.000830 for AFR ≥ 14.57 (lean).
P	= the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (760 mmHg for "Method #1"). Equation 3a is valid for -152 mmHg < P < 532 mmHg.

Pressure Compensation Equation for Lambda

$$Lambda_{corrected} = (Lambda_{measured} + B \times P) / (1 + B \times P) \quad \text{[Equation 3b]}$$

where:

$Lambda_{corrected}$	= the Lambda corrected for exhaust pressure.
$Lambda_{measured}$	= the Lambda output by the AFM.
B	= 0.000627 for Lambda < 1.0 (rich).
B	= 0.000830 for Lambda ≥ 1.0 (lean).
P	= the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (760 mmHg for "Method #1"). Equation 3b is valid for -152 mmHg < P < 532 mmHg.

Pressure Compensation Equation for %O2

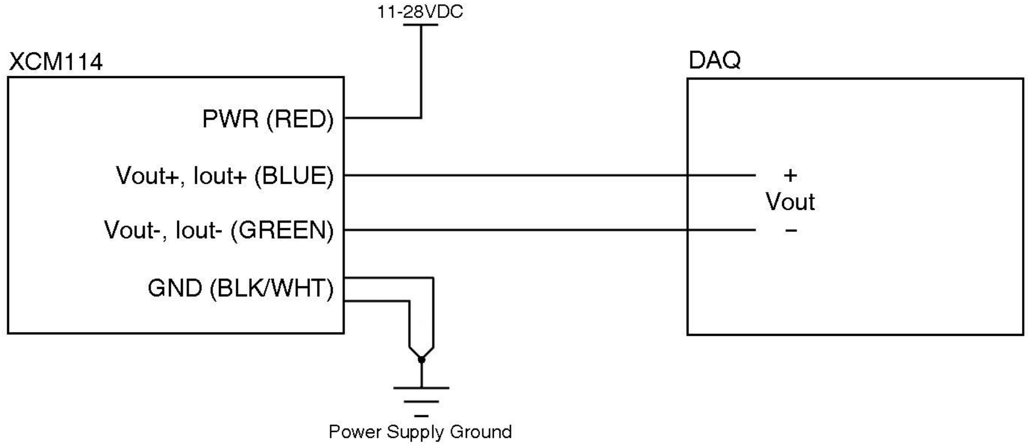
$$\%O_{2\ corrected} = \%O_{2\ measured} / (1 + B \times P) \quad \text{[Equation 3c]}$$

where:

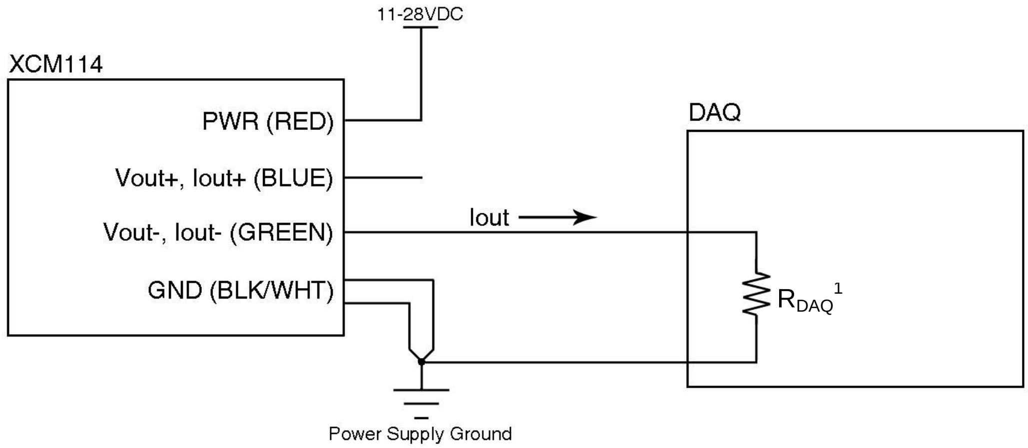
$\%O_{2\ corrected}$	= the %O2 corrected for exhaust pressure.
$\%O_{2\ measured}$	= the %O2 output by the AFM.
B	= 0.000830.
P	= the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (760 mmHg for "Method #1"). Equation 3c is valid for -152 mmHg < P < 532 mmHg.

Modes of Operation (Voltage Output or Current Output

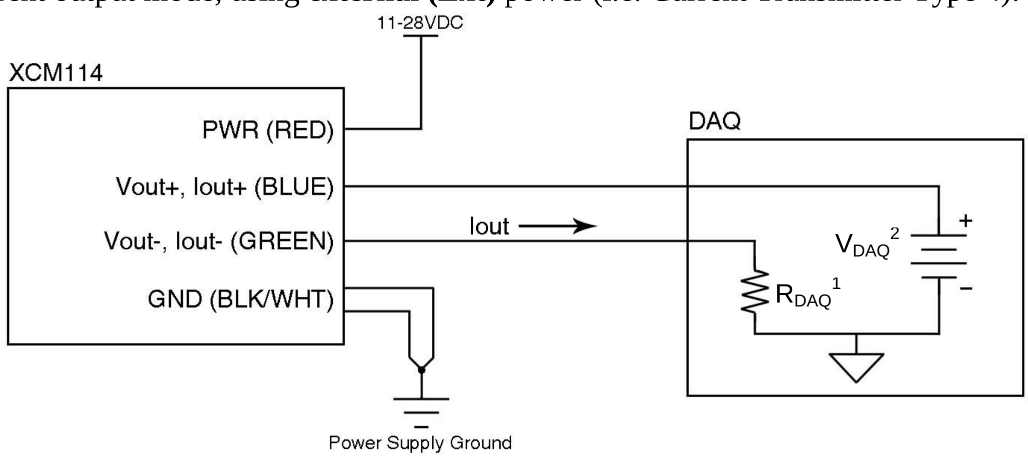
Voltage output mode (Vout- and GND are connected internally):



Current output mode, using **internal (Int)** power (i.e. Current Transmitter Type 3):



Current output mode, using **external (Ext)** power (i.e. Current Transmitter Type 4):



[1] R_{DAQ} in 4-20mA systems is typically 50Ω, 100Ω, 250Ω, or 500Ω.
[2] V_{DAQ} in 4-20mA systems is typically 12-24VDC.

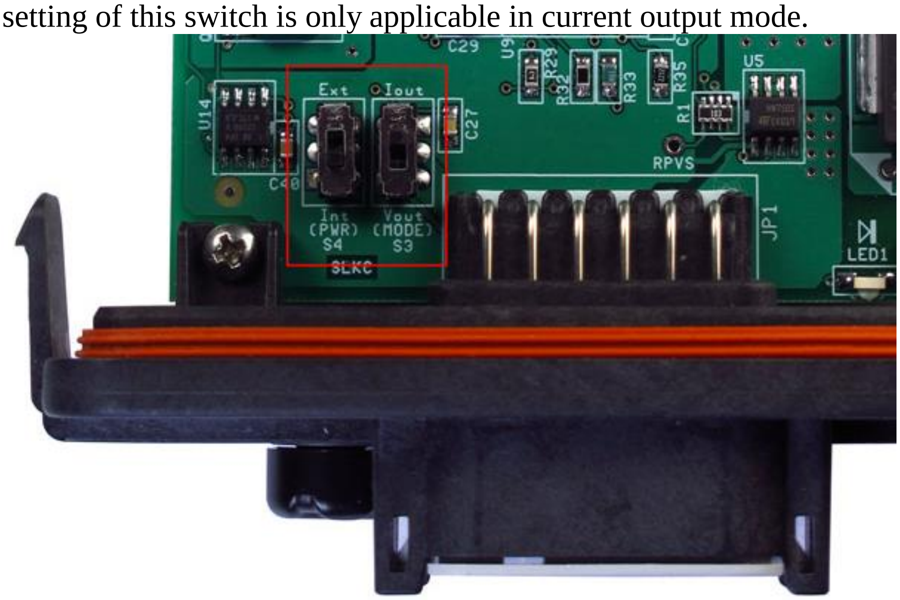
Changing Modes, Current Output Power Sources, and Types

The modes and current power sources are set by two toggle switches inside the module. The type is set by an 8-position dip switch inside the module. To modify:

1. Disconnect the module from its harness.

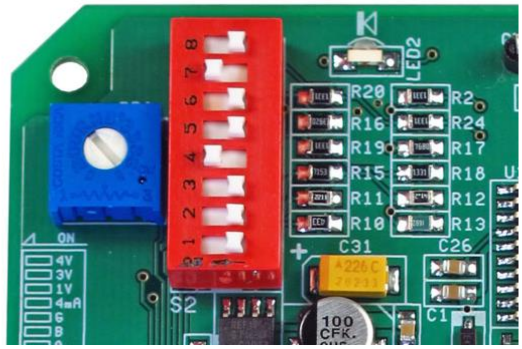
2. Release the two tangs on each side of the module and slide the PCB out of the enclosure.

3. The switches for mode and current output power source are located on the lower left of the board labeled S3 & S4. Set the position of the switch according the label directly adjacent to it.
   - S3 selects between voltage output mode (Vout) and current output mode (Iout).
   - S4 selects the power source in current output mode to internal (Int) or external (Ext). The setting of this switch is only applicable in current output mode.



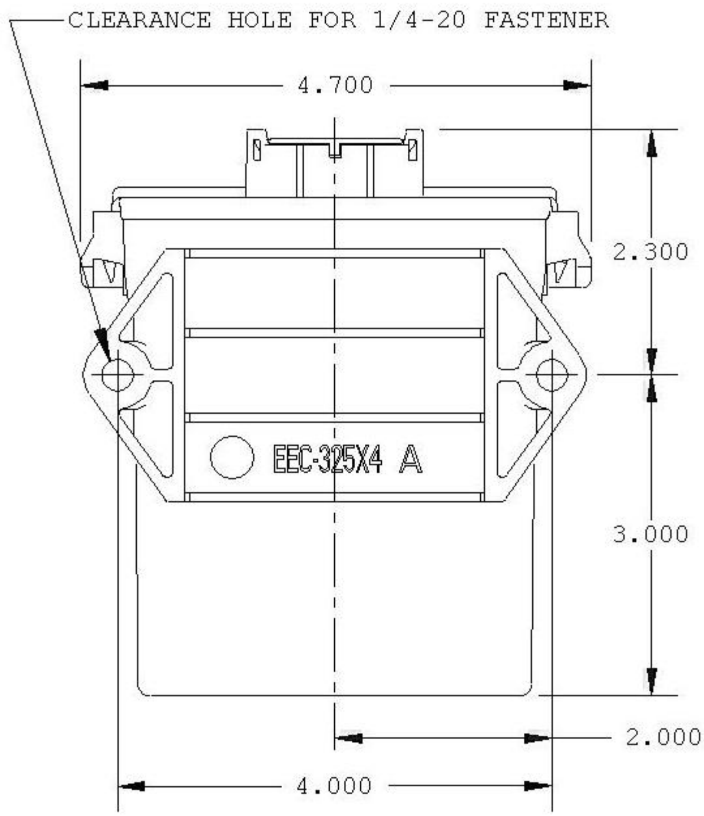
4. The switch for type settings is located on the upper left of the board labeled S2. Set the positions of the switches according to the table below. Note that only the switches listed for each type should be set to on, all others are off. The on position is with the switches flipped to the left. Do not change the blue potentiometer adjacent to it.

Type	Switches On	Vout Range	Iout Range
1	2,6	0.5 to 2.5 V	5 to 9 mA
2	2,7	2.5 to 4.5 V	9 to 12 mA
3	2,8	3.5 to 5.5 V	11 to 15 mA
4	4,6	0 to 5 V	4 to 14 mA
5	4,7	1.5 to 7 V	7 to 18 mA
6	4,8	2.5 to 8 V	9 to 20 mA
7	3,4,6	0 to 5 V	4 to 14 mA
8	3,4,7	1.5 to 7 V	7 to 18 mA
9	3,4,8	2.5 to 8 V	9 to 20 mA



5. Slide the PCB back into the enclosure until both tangs click into place securely.

Dimensions and Mounting Points



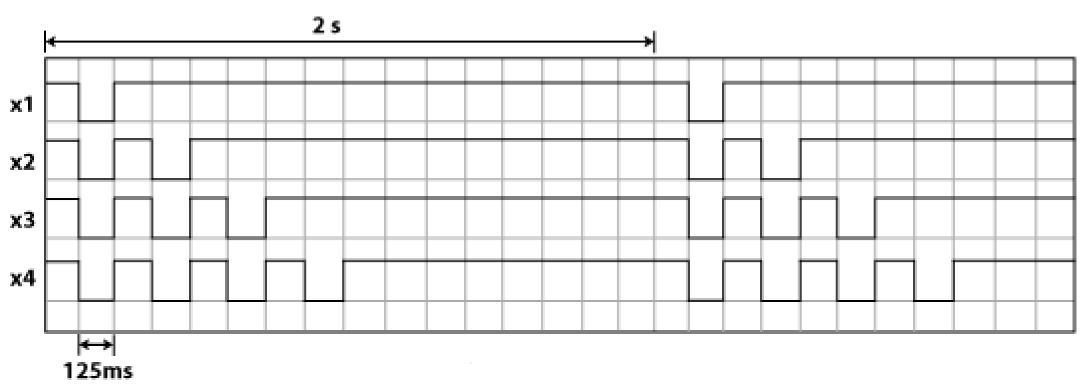
ALL DIMENSIONS IN INCHES

Troubleshooting

Trouble codes are output as LED flashes and as signal output pulses. The pulses are active low, so the signal will be pulled low for each pulse. In voltage output mode, 0V indicates a low state. In current output mode, 4mA indicates a low state. This allows for both visual indication as well as indication for the integrated diagnostic system.

Failure Mode	**Judgment Condition**	**Action After Failure Condition**		
		Heater	**Stop**	**Code**
Heater Open	-	Off	1	x1
Heater Shorted	-	Off	1	x2
Under or over Vbat	Vbat<11V or Vbat>28V	Off	1	x3
Vs too high	VVS>3.7V(Vs>1.7V)	On	1	x4

Codes: The codes represent the number of times the output is pulled low.
For example:
x1 – One 125ms pulse every 2 seconds
x2 – Two 125ms pulses every 2 seconds
x3 – Three 125ms pulses every 2 seconds
x4 – Four 125ms pulses every 2 seconds
See figure below for the code waveform diagram.



Warranty and Disclaimers

WARRANTY

The products described in this manual, with the exception of the O_2 sensor, are warranted to be free from defects in material and workmanship for a period of one year from the date of shipment to the buyer. Within the one year warranty period, we shall at our option replace such items or reimburse the customer the original price of such items which are returned to us with shipping charges prepaid and which are determined by us to be defective. This warranty does not apply to any item which has been subjected to misuse, negligence or accident; or misapplied; or modified; or improperly installed.

The O_2 sensor is considered an expendable part and as such cannot be covered by a warranty.

This warranty comprises the sole and entire warranty pertaining to the items provided hereunder. Seller makes no other warranty, guarantee, or representation of any kind whatsoever. All other warranties, including but not limited to merchantability and fitness for purpose, whether express, implied, or arising by operation of law, trade usage, or course of dealing are hereby disclaimed.

The warranty is void if the control module is opened or the wiring harness is modified.

LIMITATION OF REMEDY

Seller's liability arising from or in any way connected with the items sold and/or services provided shall be limited exclusively to repair or replacement of the items sold or refund of the purchase price paid by buyer, at seller's sole option. In no event shall seller be liable for any incidental, consequential or special damages of any kind or nature whatsoever, including but not limited to lost profits arising from or in any way connected with items sold and/or services provided to buyer, whether alleged to arise from breach of contract, express or implied warranty, or in tort, including without limitation, negligence, failure to warn or strict liability. In no event shall the company's liability to buyer arising out of or relating to the sale of any product or service exceed the purchase price paid by buyer to the company for such product or service.

PRODUCT CHANGES

We reserve the right to discontinue a particular product or to make technical design changes at any time without notice.

Appendix A: Calculating the %O_2 in Air

The oxygen concentration in dry air (zero humidity) is 20.945 and decreases with increasing humidity. The %O_2 in air can be calculated from the barometric pressure (P_b, in mmHg), the relative humidity (Rh), and the saturated water vapor pressure (P_{ws}, in mmHg) by using the following formula:

$$\%O_2 = 20.945\% \times (P_b - P_{ws} \times (Rh/100)) / P_b$$

The saturated water vapor pressure (P_{ws}) is a function of the ambient temperature (T_a) and is given in the table below. For example, at 21 °C, P_{ws} = 18.65 mmHg.

T_a (°C)	0	1	2	3	4	5	6	7	8	9
	P_{ws} (mm Hg)									
0	4.579	4.926	5.294	5.685	6.101	6.543	7.013	7.513	8.045	8.609
10	9.209	9.844	10.518	11.231	11.987	12.788	13.634	14.530	15.477	16.477
20	17.535	18.650	19.827	21.068	22.377	23.756	25.209	26.739	28.349	30.043
30	31.824	33.695	35.663	37.729	39.898	42.175	44.563	47.067	49.692	52.442
40	55.324	58.34	61.50	64.8	68.26	71.88	75.65	79.60	83.71	88.02
50	92.51	97.2	102.09	107.2	112.51	118.04	123.80	129.82	136.08	142.60
60	149.38	156.43	163.77	171.38	179.31	187.54	196.09	204.96	214.17	223.73
70	233.7	243.9	254.6	265.7	277.2	289.1	301.4	314.1	327.3	341.0
80	355.1	369.7	384.9	400.6	416.8	433.6	450.9	468.7	487.1	506.1
90	525.76	546.05	566.99	588.60	610.90	633.9	657.62	682.07	707.27	733.24

1 mmHg = 0.01934 lbf/in2 = 1 torr

1 atm = 14.696 lbf/in2 = 760 torr = 101325 N/m2

ECM ENGINE CONTROL AND MONITORING
Los Altos, CA 94023-0040 • USA • (408) 734-3433 • Fax: (408) 734-3432
www.ecm-co.com