ECM ENGINE CONTROL AND MONITORING

NOx 5210*

Single/Dual NOx Analyzer

Instruction Manual

* Note:

ECM's NOx analyzer can be either single or dual channeled. Each channel can use one of three NOx sensors: the Type T sensor, the Type G sensor, or the "Original" NOx sensor.

6/10/22

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Introduction

The NOx 5210

The NOx 5210 is a compact, ceramic sensor-based NOx and O_2 analyzer for the development of engines and their aftertreatment systems. Its features include:

- Single or dual channel NOx sensor operation
- Works with Type T, Type G, and the "Original" NOx sensors[1]
- NOx 5210 systems can be linked together for multi-cylinder monitoring
- Wide range of operation: NOx : 0 to 5000 ppm
  λ : 0.4 to 25.0
  AFR : 6.0 to 364.0
  Φ : 0.04 to 2.5
  $\%O_2$: 0.0 to 25.0
  FAR[2] : 27 to 1667
- Pressure compensation[3] for NOx, λ, AFR, Φ, $\%O_2$, and FAR
- Can specify any fuel type by H:C, O:C, and N:C ratios, including H_2
- Exhaust pressure measurement range[3]: 0 to 517 kPa (75 Psia)
- All sensor parameters available for display and output
- Calibration data for NOx sensor stored in sensor's connector
- Six programmable 0 to 5V or 0 to 1V analog outputs
- Simulated EGO (exhaust gas oxygen) sensor outputs
- CAN output and .dbc generation software
- Up to 100 m between NOx sensor and display possible
- "Lockout" feature for front panel of display
- Power on/off can be controlled by external "key" signal
- 11-28 VDC and 95-250 VAC[4] operation

The NOx 5210 analyzer can have one or two channels. Each channel uses one of three NOx sensors (and its corresponding control module). Type T NOx sensors are recommended for general-purpose NOx measurement for combustion processes that can be rich, lean, and stoichiometric (i.e. spark ignition engines). Type G NOx sensors are recommended for NOx measurement of combustion processes that are only lean of stoichiometric (i.e. diesel engines). The "Original" NOx sensor was the old "general-purpose" NOx sensor and has been replaced by the Type T. All NOx sensors have sensitivities to NH3 (ammonia).

[1] When supplied with matching NOxCANt, NOxCANg, or NOxCAN modules.

[2] FAR x 10000 is displayed. This is the most commonly used way to express FAR. For example, with an H:C=1.85 fuel, Lambda=1 is FAR=686.8.

[3] Optional.

[4] With optional P/N 04-01 AC/DC Power Supply.

NOx 5210 Kit Contents

The following items are included with a single-channel, NOx 5210 kit:

Item No.	Description	Part Number
1.	NOx 5210 Display Head	01-01
2.	NOxCANt Module (for Type T sensor), or NOxCANg Module (for Type G sensor), or NOxCAN Module (for "Original" sensor)	02-07 02-03 02-02
3.	NOx Sensor, Type T (18mm x 1.5mm thread), or NOx Sensor, Type G (20mm x 1.5mm thread), or NOx Sensor, Original (18mm x 1.5mm thread)	06-05 06-02 06-01
4.	Inconel Shield (2 required), Only installed on Original NOx sensor	12-09
5.	Eurofast 12 mm Cable, 4 m	09-01
6.	Eurofast 12 mm Cable, 2 m	09-02
7.	Flexi-Eurofast 12mm Cable, 0.3 m, (3 required)	09-04
8.	Eurofast "T", (4 required)	09-05
9.	Eurofast Termination Resistor, (3 required)	09-06
10.	Lambda/NOx Sensor Cable, 1 m	10-02
11.	DC Power Cable, Banana Plugs	11-16
12.	Female Eurofast to DB9F	11-05
13.	Key-on Cable, 2 m	11-08
14.	5200 Series Analyzer and Module Manuals and Configuration Software, CD	13-01
15.	Boss & Plug for Type G NOx sensor (20mm x 1.5mm), only supplied with Type G sensor	12-28

For pressure-compensation, these additional items are included (per NOx channel):

Item No.	Description	Part Number
1.	Pressure Sensor with ¼" tube fitting (USA), or Pressure Sensor with 6 mm tube fitting (Metric)	07-01 07-02
2.	Module Y Cable	10-21
3.	Pressure Sensor Cable, 1 m	10-04
4.	Pressure Line Assembly, 28", (USA), or Pressure Line Assembly, 711 mm, (Metric)	12-08A 12-11A

For a dual-channel kit, these additional items are included:

1.	NOxCANt Module (for Type T sensor), or NOxCANg Module (for Type G sensor), or NOxCAN Module (for "Original" sensor)	02-07 02-03 02-02
2.	NOx Sensor, Type T (18mm x 1.5mm thread), or NOx Sensor, Type G (20mm x 1.5mm thread), or NOx Sensor, Original (18mm x 1.5mm thread)	06-05 06-02 06-01
3.	Inconel Shield (2 required), Only installed on Original NOx sensor	12-09
4.	Eurofast 12mm Cable, 2 m	09-02
6.	Flexi-Eurofast 12mm Cable, 0.3 m	09-04
7.	Eurofast "T"	09-05
8.	Lambda/NOx Cable, 1m	10-02
9.	Boss & Plug for Type G NOx sensor (20mm x 1.5mm), only supplied with Type G sensor	12-28

Optional Items:

1. Lambda/NOx Sensor Cable, 2m or 3m 10-03 (2m) or 10-37 (3m)
2. Pressure Sensor Cable, 2m or 3m 10-05 (2m) or 10-40 (3m)
3. AC/DC Power Supply, Universal 24VDC @ 4.2A 04-01
4. Vboost Supply, 10-14VDC to 24VDC @ 14.5A 04-02
   (helps to avoid battery drop-out issues during cold starts)
5. Ceramic Sensor Heater Kit (recommended for original NOx sensor) BTU200

Safety Warnings

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

The NOx sensor is heated, gets hot, and can burn you.

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

During installation, turn off the power and take all other necessary precautions to prevent injury, property loss, and equipment damage. Do not apply power until all wiring is completed.

Never work on a running engine.

When installing the NOx 5210s cabling and sensor(s) on a stopped engine, it is best to think-out your moves before you make them.

Route and cable-tie all cables away from hot, moving, sharp, or high voltage (spark) objects.

Take into consideration the movement of the engine, chassis, and wind buffeting when instrumenting the engine.

Clear tools away from the engine before starting.

Operate the engine only in a well ventilated area and never when you or one of your co-workers is tired.

When operating the NOx 5210 in a moving vehicle, the operator should keep his or her eyes on the road.

One measure of professionalism is how much you and your co-workers can accomplish without an injury. Always be at your professional best. Think and act with safety in mind.

How to Use

Hooking up the NOx 5210

The NOx 5210 kit consists of 4 parts:

1. The display head
2. The module(s)[1]
3. The sensor(s)
4. Cabling

The NOx 5210 is unique in that it puts a control module close to the NOx sensor. There are several advantages of doing this; the main ones are: improvements in signal-to-noise ratio, multi-channel capability, simplified cabling, and an almost unlimited sensor-to-display head distance.

The cable between the display head and module(s) is called the EIB (ECM Instrument Bus) and carries signal and power. There must be a termination resistor at each end of the EIB. The EIB can be powered at either the module end (Figure 1) or the display head end (Figure 2). To minimize the power voltage drop on the EIB, it is preferable to power the EIB from the end closest to the module(s) because that is where most of the power is being consumed (by the NOx sensor).

Branches/drops to display head(s) and module(s) are made from tees attached to the EIB. Up to 32 display heads and modules (total) can exist on the same EIB. The EIB cable, tees, and termination resistors are industry-standard Eurofast 12 mm. The EIB can be extended to a length of 100 m.

The NOx 5210 can be turned on and off by the PWR button on the front of the display head or by a voltage signal (2.7 - 32 V) applied to the KEY connector on the back of the display head. The current requirements of this voltage signal are very low (100 μA).

After being turned on, the display head will test both displays and all leds and then show:

1. The display head's serial number
2. The version of the display head's software
3. The calibration date of the display head (MM.DD YYYY)
4. The serial number (see Figure B1) of the NOx module assigned to the upper channel and the serial number of the NOx module assigned to the lower channel.
   "…." means no NOx module has been assigned to the channel.
5. Parameter data from the NOx module assigned to that channel.

Figures 3 through 5 show details and part numbers of components in Figures 1 and 2. Optional components are also shown.

[1] Modules can be setup in EIB Mode or Stand-alone Mode. When the modules are used with a display head, they must be in EIB mode. See Appendix B for more information.

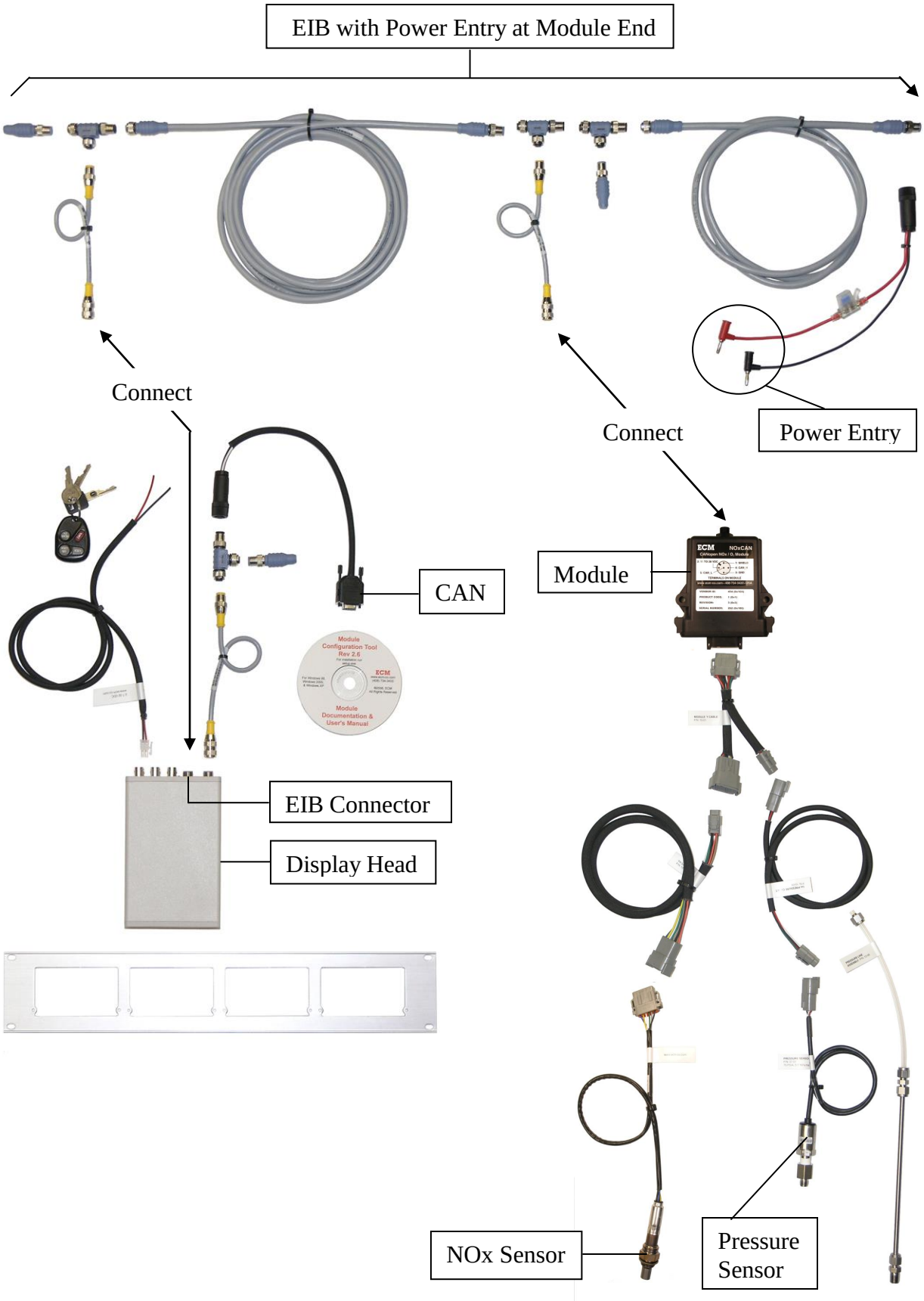


Figure 1: NOx 5210 with Power Entry at Module End

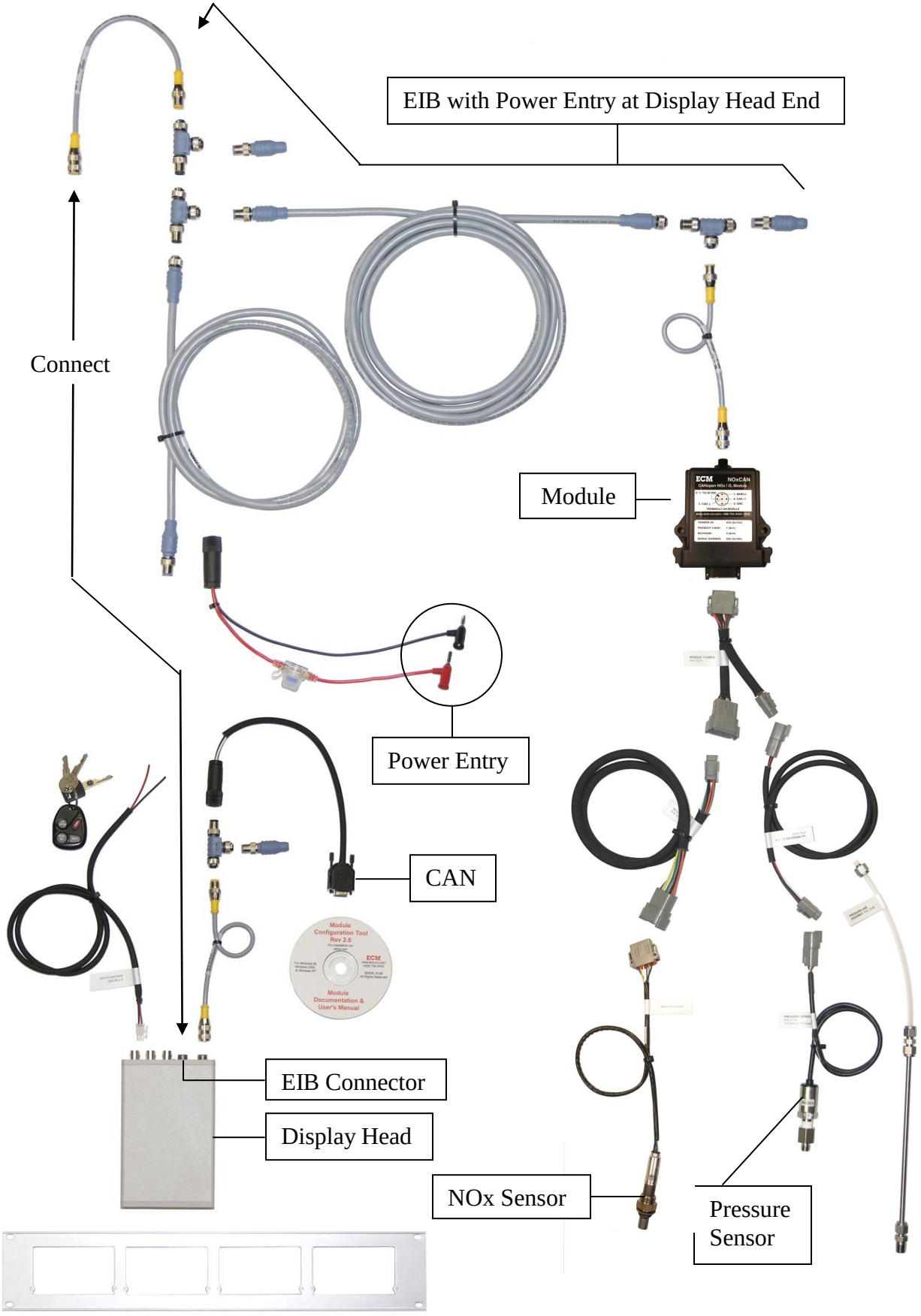


Figure 2: NOx 5210 with Power Entry at Display Head End

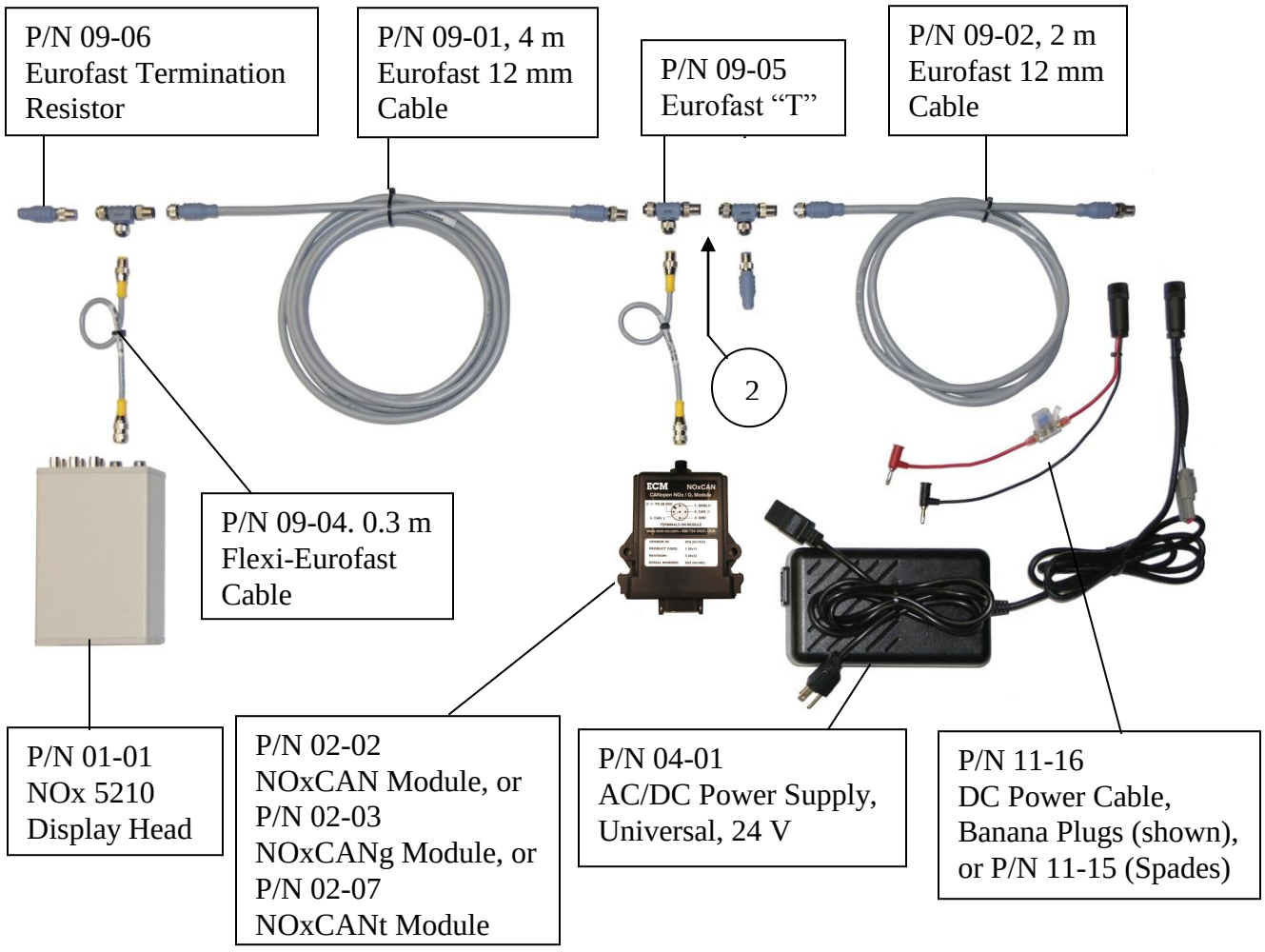


Figure 3a: Part Numbers of Components on EIB

Figure 3b: Add above in Location "2" for Second NOx Channel

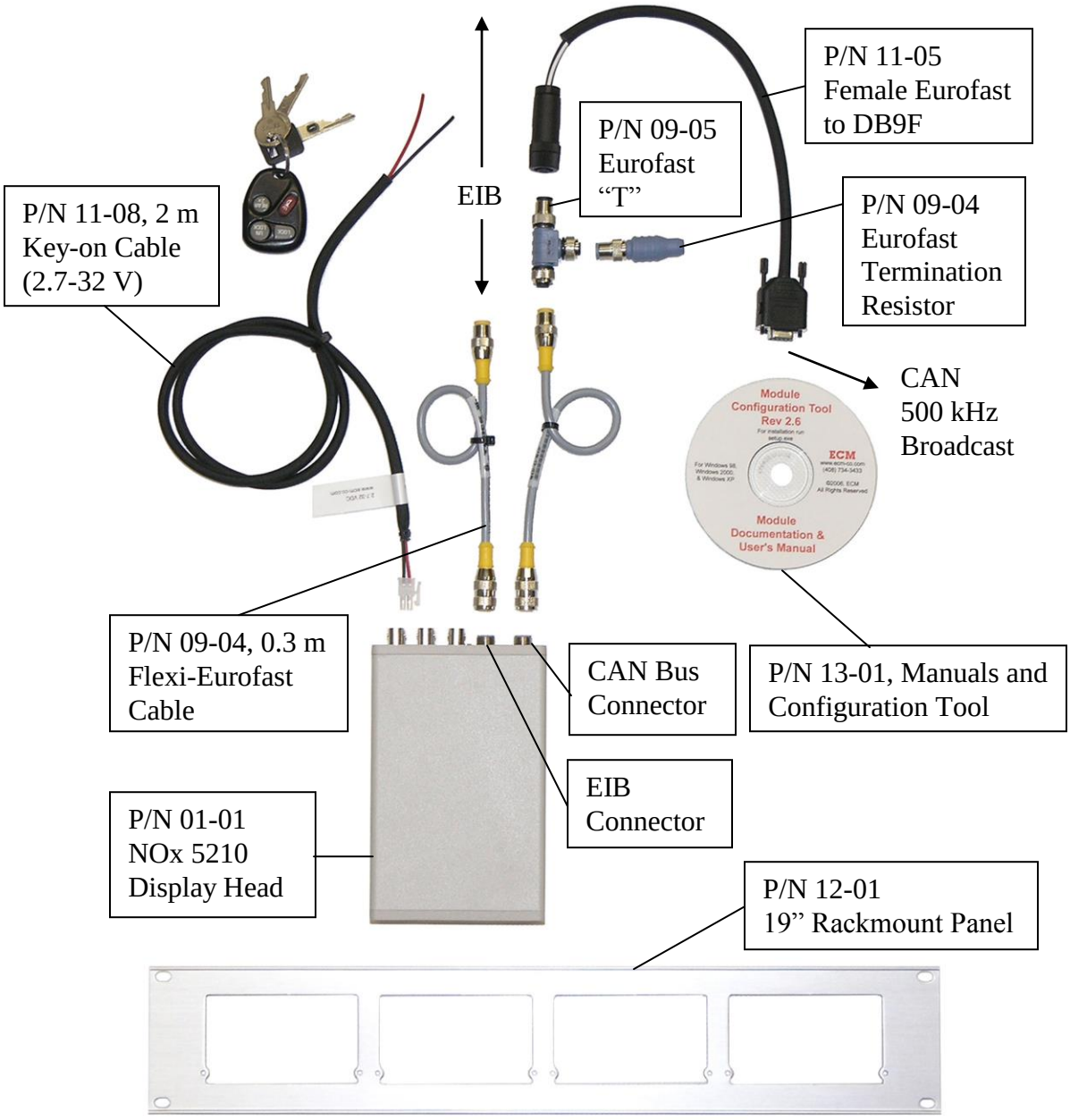


Figure 4a: Part Numbers of Components near Display Head

Figure 4b: Front and Back of Display Head

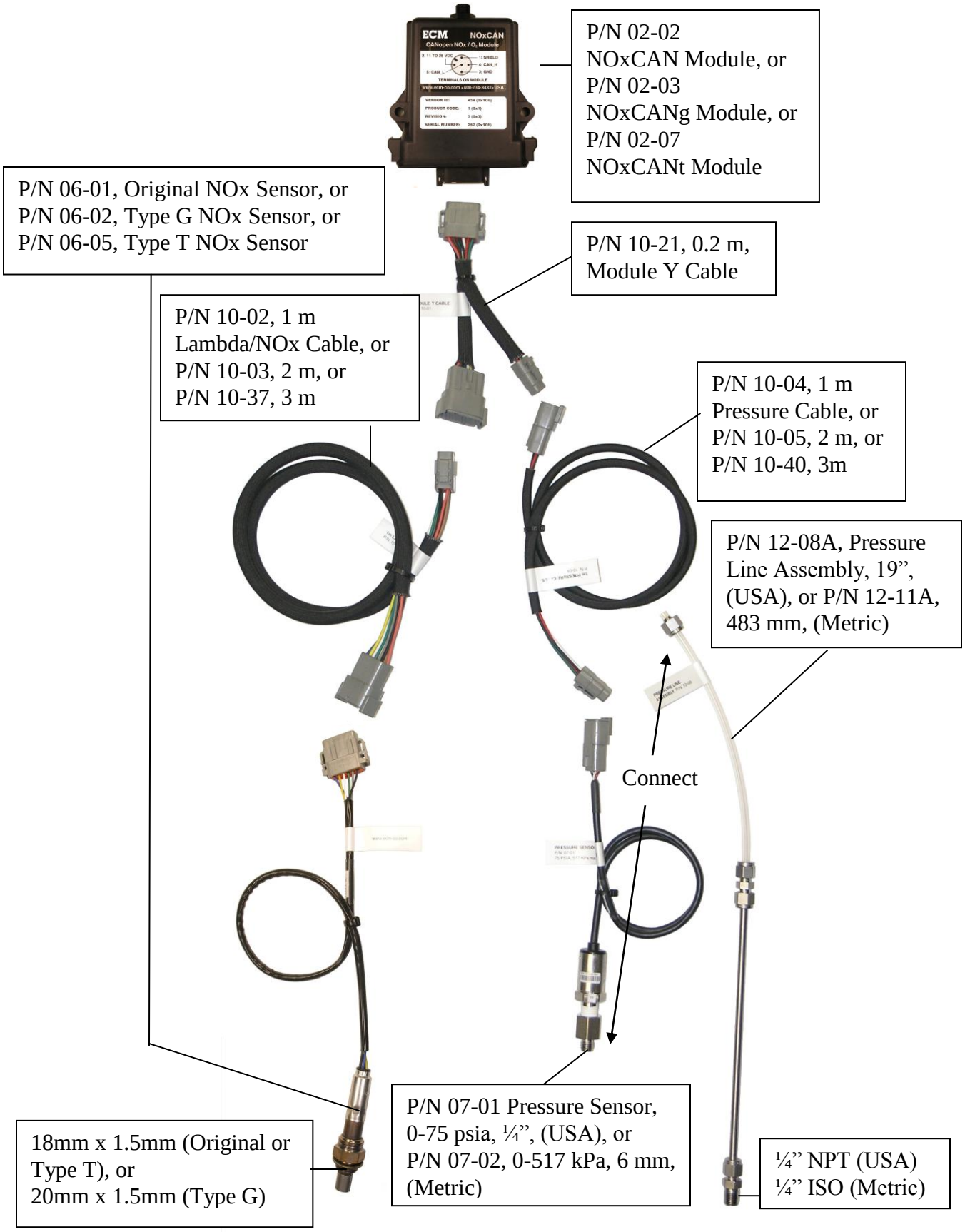


Figure 5: Part Numbers of Components near Module

Mounting the NOx Sensor and Pressure Sensor

◆ NOx Sensor

- Thread is 18mm x 1.5mm (Original and Type T Sensor) or 20mm x 1.5mm (Type G Sensor)
- Mount between 300 mm from exhaust valve and ten exhaust diameters upstream of exhaust end. Preferentially mount downstream of turbocharger and upstream of exhaust catalyst.
- Do not exceed 850 °C exhaust gas temperature at location of sensor.
- Mount where condensed material will not collect on the sensor.
- Run tap into thread in exhaust before screwing in sensor.
- Put antiseize on threads and lightly tighten sensor.
- Occasionally run tap through mounting boss to clean threads.
- Occasionally clean threads on sensor with small metal brush.
- Do not operate engine with NOx sensor not being powered.
- Route NOx sensor cable away from hot, moving, sharp, or high voltage (spark) wires.

◆ Pressure Sensor

- Do not mount pressure sensor directly to exhaust. Always use the supplied stainless steel/teflon pressure line assembly between the engine's exhaust system and the pressure sensor. The stainless steel end goes towards the engine.
- Do not modify the length or diameter of the pressure line assembly.
- Thread on pressure line assembly is ¼" ISO (Metric) or ¼" NPT (USA).
- Measure pressure within 50 mm of NOx sensor.
- Locate pressure sensor where temperature is between -20 and 80 °C.
- Do not allow condensed material to collect in pressure line assembly.
- Run tap into threads in exhaust before screwing in pressure line assembly.
- Put antiseize on threads.
- Route pressure sensor cable away from hot, moving, sharp, or high voltage (spark) wires.

Front Panel and the "SYS" Key

The NOx 5210 display head can be thought of as two single-channel display heads in one package. One NOx module can be assigned to the upper display, upper four leds, and analog outputs 1, 2, 3 (i.e. the upper channel) and a second NOx module can be assigned to the lower display, lower four leds, and analog outputs 4, 5, 6 (i.e. the lower channel). Or one NOx module can be assigned to both channels. If no module is assigned to a channel, "…." appears on that channel's display. More than two NOx modules can exist on the EIB but a given display head can only show data from two of them. Adding another display head to the EIB will allow data from another two NOx modules to be displayed.

The display head has two modes of operation: RUN (when measurements or error codes are displayed) and SYS (where the instrument is set-up). The SYS key toggles between the modes.

When in RUN mode, the parameter being displayed is indicated by leds to the right of the display. There are four leds for each display and each led can be red or green. Five parameters (NOx, $\%O_2$, λ, AFR, Φ) are fixed and three (P1, P2, P3 or P4, P5, P6) are programmable from the list of parameters in Table 2. The ↑ and ↓ keys select which of the eight parameters are displayed (unless the display is LOCKed, see below).

While in RUN mode, pressing the ENT key will toggle between the ↑ and ↓ keys changing parameters on one channel's display to changing parameters on the other channel's display.

In RUN mode, four things other than data can be displayed:

1. "ERR" and "####" where "####" is an error code. See **Appendix C**.
2. "…." which means that a NOx module has not been assigned to that channel. See **MOd Setup Option**.
3. "----" which means that the display head has an internal problem.
4. "XXXX" which means that the display is not receiving any data.

When first entering SYS mode, either "MOd" will be on the upper display or "LOCK" will be on the lower display. If "MOd" is displayed, the ↑ and ↓ keys will roll through the setup options (see Table 1). First the options for the upper channel are shown on the upper display, followed by identical options for the lower channel on the lower display, ending with the global CONF (Configuration) setup. Pressing the ENT key will select the displayed setup option and allow its programming.

If "LOCK" is displayed, the display head has been locked and neither the parameters displayed nor the instrument setup can be changed until it is unlocked. Appendix E describes how to LOCK and unLOCK the display head.

Setup Option	Level 1	Level 2	Level 3	Function
MOd				Select module s/n [NONE]
RATE				Set display update rate [FAST]
FUEL				Program fuel H:C,O:C,N:C and if H_2 [1.85,0,0,NO]
AOUT	A1 (upper channel)			Program analog output 1 [NOx,0,2000]
	A2 (upper channel)			Program analog output 2 [O2,-25.00,25.00]
	A3 (upper channel)			Program analog output 3 [LAM,0.400,25.00]
	A4 (lower channel)			Program analog output 4 [NOx,0,2000]
	A5 (lower channel)			Program analog output 5 [O2,-25.00,25.00]
	A6 (lower channel)			Program analog output 6 [LAM,0.400,25.00]
dISP	P1 (upper channel)			Program upper display parameter P1 [FAR]
	P2 (upper channel)			Program upper display parameter P2 [P]
	P3 (upper channel)			Program upper display parameter P3 [O2]
	P4 (lower channel)			Program lower display parameter P4 [FAR]
	P5 (lower channel)			Program lower display parameter P5 [P]
	P6 (lower channel)			Program lower display parameter P6 [O2]
CAL	O2	SPAN		Calibrate NOx sensor (O_2 measurement function)
		FACT		Reset NOx sensor to factory calibration for O_2
		AGEF		Show age factor for NOx sensor
		EXIT		
	NOX	ZERO		Calibrate NOx sensor zero (NOx measurement function)
		SPAN		Calibrate NOx sensor span (NOx measurement function)
		FACT		Reset NOx sensor (zero and span) to factory calibration for NOx
		CURV		(for Type G NOx sensor only) NOx reading to match engine (wet) data or model gas data (ENGW or MODL), [ENGW]
		GAMM	ENGW	(for Type G NOx sensor only) O2 compensation coefficients for engine NOx numbers [GAMMA = 0, BETA = 0]
			MODL	(for Type G NOx sensor only) O2 compensation coefficients for model gas NOx numbers [GAMMA = 1, BETA = 0.2]
		EXIT		
	P	UNIT		Choose pressure units [KPA]
		N, C		Enter pressure sensor calibration numbers
	AVG	ILAM		Program Ip1,%O_2,λ,AFR,Φ,FAR averaging [0.375]
		PLAM		Program P (pressure) averaging [0.375]
		I2NX		Program Ip2, NOx averaging [0.375]
	SKEW	NOx		Program gain and offset modifier [1,0]
		P		Program gain and offset modifier [1,0]
		AFR		Program gain and offset modifier [1,0]
		PHI (Φ)		Program gain and offset modifier [1,0]
		FAR		Program gain and offset modifier [1,0]
		LAM (λ)		Program gain and offset modifier [1,0]
		O2		Program gain and offset modifier [1,0]
CONF	LEdS			Set display intensity [3333]
	1V4V			Check analog outputs at 1V and 4V
	CAN	IdS		Program CAN addresses and produce .dbc file [1~5]
		RATE		Program CAN transmit rate [5 ms]
		BAUd		Program CAN baud rate [500k]
	MOdE			Select parameter list [ENHd] and lock display
	FACT	RST		Reset all but FUEL, N, C, ILAM, PLAM, I2NX and …
		EXIT		NOx sensor user calibration to factory defaults

MOd ~ CAL appear on the upper or lower display for the upper or lower channel. CONF is for global setup. All entries must be followed by pressing the ENT key. Default values shown in square parentheses.

Table 1: Menu Tree for NOx 5210

MOd (Module) Setup Option

In MOd setup, the serial number of the NOx module assigned to the upper or lower channel is entered. The serial number is written on a label on the module (see Figure B1). The module assigned to the upper channel will send information to the upper display and the analog outputs 1, 2, and 3. The module assigned to the lower channel will send information to the lower display and the analog outputs 4, 5, and 6. The same module can be assigned to both channels.

After entering MOd (i.e. press ENT when "MOd" is displayed), the serial numbers of the available modules on the EIB will displayed. Select using ↑ and ↓ followed by the ENT key.

RATE Setup Option

Different display update rates can be assigned to the upper and lower displays. The selected display update rate does not affect the analog output update rate, the CAN transmission rate.

FUEL Setup Option (H:C, O:C, N:C, H2)

Fuel H:C, O:C, and N:C ratios and whether or not the fuel is H_2 can be programmed. This can be different for the module assigned to the upper channel and the module assigned to the lower channel (unless the same module is assigned to both channels). The ENT, ↑, and ↓ keys are used for programming. If you get into trouble when programming, press the SYS key twice to exit and re-enter setup to try again. Fuel H:C, O:C, and N:C ratios and whether or not the fuel is H_2 is information stored in the NOxCAN module.

AOUT (Analog Output) Setup Option (A1 to A6)

The display head has six programmable analog outputs. Each output can be programmed as 0 to 5V, 0 to 1V, or as an EGO (exhaust gas oxygen) sensor simulated output. The analog outputs are updated every 5 ms based on information sent to it by a NOx module every 5 ms. 5 ms is the maximum rate and is not programmable. The module averages the data before it is sent at this 5 ms rate. There is one programmable averaging filter for Ip1, λ, AFR, Φ, $\%O_2$, FAR (ILAM), one for pressure (PLAM), and one for Ip2, NOx (I2NX). See **CAL Setup Option** (AVG Suboption) for more information.

Parameter information from the module assigned to the upper channel can be sent to analog outputs 1, 2, and 3. Parameter information from the module assigned to the lower channel can be sent to analog outputs 4, 5, and 6.

The parameter selected to drive an analog output can be anything from Table 2 if the CONF MOdE has been set to ENHd (see **CONFIG Setup Option**) or a subset of Table 2 if the CONF MOdE has been set to STNd.

Here is an example of setting the analog output 2 (i.e. A2):

1. Press the SYS key until "MOd" is displayed.
2. Press the ↓ key until "AOUT" is on the top display. Then press the ENT key.
3. Press the ↓ key until "A2" (analog output 2) is on the display. Then press the ENT key.

4. Press the ↑ and ↓ keys until the parameter (see Table 2) that will drive A2 is displayed. Then press the ENT key. Keep in mind that if CONF MOdE is set to STNd, only a subset of Table 2 will be available.
5. Press the ↑ and ↓ keys to select 0V to 5V, 0V to 1V, or EGO sensor simulated output. Then press the ENT key. EGO sensor simulation is only available on λ, AFR, Φ, $\%O_2$, FAR parameters.
6. When 0V is displayed, press ENT. Using the ↑, ↓, and ENT keys, set the parameter value that you want to result in an analog output voltage of 0V on analog output 2. The first time you do this, it may be a little tricky. You are setting one digit at a time and for some numbers, the display will shift to the left so you can set the right-most digits. If you get into trouble when programming, press the SYS key twice to exit and re-enter setup to try again.
7. When 5V (or 1V) is displayed, press ENT. Using the ↑, ↓, and ENT keys, set the parameter value that you want to result in an analog output voltage of 5V (or 1V) on analog output 2.
8. If you want the EGO sensor simulated output, when EGO is displayed, press ENT. Using the ↑, ↓, and ENT keys, set the parameter value that you want the lean-to-rich (0V-to-1V) transition to occur at. 0V will be output when lean of the programmed value and 1V will be output when rich of the programmed value.
9. When "AOUT" is displayed, press SYS to return to RUN mode.

For analog outputs 4, 5, and 6, your entries will be shown on the bottom display.

Name	Full Parameter Name	Parameter Description
NOx	NOx (ppm)	NOx
O2R	%O2real (%)	%O2 before addition of Delta O2 curve
IP1	Ip1 (μA)	Pressure-compensated Ip1 sensor pumping current
IP2	Ip2 (μA)	Pressure-compensated Ip2 sensor pumping current
RPVS	RPVS (ohms)	NOx sensor internal VS cell resistance
VHCM	VH Commanded (V)	Desired heater voltage commanded by the module
VS	VS (V)	NOx sensor internal VS cell voltage
VP1P	VP1P (V)	NOx sensor Ip1 pumping voltage
VP2	VP2 (V)	NOx sensor Ip2 pumping voltage
VSW	Vsw (V), n/a for Type G	Supply Voltage at the module. Not available for Type G.
VH	VH Measured (V)	Actual heater voltage at the module
TEMP	Circuit Board Temp (°C)	Temperature of the module circuit board
IP1R	Ip1raw (bits)	NOx sensor Ip1 pumping current (unsigned integer format)
IP2R	Ip2raw (bits)	NOx sensor Ip2 pumping current (unsigned integer format)
ERFL	Error bit flags (bits)	Module error flags (unsigned long format)
ERCd	ECM CANOpen Error Code	ECM CANOpen Error Code
PR10	Praw10 (bits)	10 bit Pressure sensor output voltage (unsigned integer format)
PCF	Pressure Correction Factor	NOx sensor Ip1 Pcomp correction factor (x 10000)
PCFE, O2E		ECM diagnostic parameters
IP1E, PE		ECM diagnostic parameters
P	P (mmHg)	Pressure sensor measured pressure (absolute) in mmHg
LAMR	LAMBDAreal	Lambda before addition of Delta Lambda Table
AFR	Air-Fuel Ratio	Air-Fuel ratio calculated using LAMBDA (see below)
PHI	PHI	PHI = 1/LAMBDA
FAR	FAR*10000	FAR = (1/AFR) * 10000
LAM	LAMBDA	Lambda after addition of Delta Lambda Table
O2	O2 (%)	%O2 after addition of Delta O2 Table
IPX	Ip1 non Pcomp (mA)	Non-pressure compensated NOx sensor Ip1 pumping current
PVLP	P (V)	Raw volts from pressure sensor
PKPA	P (kPa)	Pressure sensor measured pressure (absolute) in kPa
PBAR	P (bar)	Pressure sensor measured pressure (absolute) in bar
PPSI	P (psi)	Pressure sensor measured pressure (absolute) in psi
IP3	Ip3 (μA) (Type G only)	NOx sensor Ip3 pumping current
IP2X	Ip2 non Pcomp (μA) (Type G and T only)	Non-pressure compensated NOx sensor IP2 pumping current
NCF	NOx Pressure Correction (Type G and T only)	NOx sensor Ip2 pressure compensation correction factor x 10000

Table 2: Parameter List for the NOx 5210

dISP (Display) Setup Option (P1 to P6)

Parameter information from the NOx module assigned to the upper channel can be displayed as parameters P1, P2, and P3. Parameter information from the NOx module assigned to the lower channel can be displayed as parameters P4, P5, and P6.

The parameter selected as P1, P2, etc can be anything from Table 2 if the CONF MOdE has been set to ENHd (see **CONFIG Setup Option**) or a subset of Table 2 if the CONF MOdE has been set to STNd.

Here is an example of setting displayed parameter P2:

1. Press the SYS key until "MOd" is displayed.
2. Press the ↓ key until "dISP" is on the top display. Then press the ENT key.
3. Press the ↓ key until "P2" is on the display. Then press the ENT key.
4. Press the ↑ or ↓ key until the parameter (see Table 2) that will be P2 is displayed. Then press the ENT key. Keep in mind that if CONF MOdE is set to STNd, only a subset of Table 2 will be available.
5. When "dISP" is displayed, press SYS to return to RUN mode.

If in the above example, displayed parameter P4 was being programmed, dISP, P4, and your entries will be shown on the bottom display.

CAL (Calibrate) Setup Option for Type T and Type G NOx Sensors

This section is for Type T (uses NOxCANt module) and Type G (uses NOxCANg module) NOx sensor applications only. For "Original" NOx sensor applications (uses NOxCAN module), see the next section.

NOx sensors supplied with the NOx 5210 are factory calibrated. This calibration is stored in a memory chip inside the sensor's connector. With use, NOx sensors can age requiring recalibration to maintain measurement accuracy. Recalibration can be performed by the user or by sending the sensor back to ECM.

There are two parts of the NOx sensor: the O_2 (Lambda, AFR, FAR, PHI) measuring part and the NOx measuring part. Recalibration consists of one ZERO and two SPANs. They should be performed in the following order:

1. SPAN the O_2 measurement (see **CAL, O2, SPAN Option**)
2. ZERO the NOx measurement (see **CAL, NOX, ZERO Option**)
3. SPAN the NOx measurement (see **CAL, NOX, SPAN Option**)

It is important to realize that when in the exhaust of a running engine, the NOx sensor is seeing H_2O as just another gas. Therefore, it will report "wet" $\%O_2$ and NOx ppm numbers. Classical gas analysis equipment (ex. NOx chemiluminescent analyzer (CLA)) typically (but not always) has the water removed from the gases before they reach the analyzer. Thus classical gas analyzers will report "dry" numbers which are always greater than "wet" numbers. When comparing "wet" to "dry" numbers, make sure to correct for the removed water.

◆ O2

The O2 SPAN function is for the recalibration of the NOx sensor's $\%O_2$, λ, AFR, Φ, and FAR measurements. This recalibration is stored in the sensor's memory chip and is used instead of the factory calibration. The FACT function cancels the user calibration resulting in the factory calibration being used.

SPAN (for $\%O_2$, λ, AFR, Φ, and FAR measurements)

To perform an O_2 span:

1. A span should be performed after the NOx sensor has been on for at least 20 minutes.
2. Put the NOx sensor and pressure sensor (if so equipped) in ambient, stationary air. Pressure during NOx sensor calibration is required if the calibration is to be pressure compensated.
3. Calculate the $\%O_2$ in air. The $\%O_2$ of air with no humidity is 20.945. This percentage decreases with increased humidity. To calculate the $\%O_2$ in non-zero humidity air, use the Configuration Tool Software or refer to Appendix D. 20.7 is a common number.
4. Press the SYS key until "MOd" appears.
5. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
6. With "O2" on the display, press the ENT key.
7. With "SPAN" on the display, press the ENT key.
8. Using the ↑ and ↓ keys, change the display to show the $\%O_2$ in air determined in 3 (above). Press the ENT key.
9. When "CAL" is displayed, press SYS to return to RUN model. See **AGEF** (below).
10. The user calibration is written into the memory chip in the NOx sensor's connector and will be used to calculate $\%O_2$, λ, AFR, Φ, and FAR. If the NOx sensor is removed and installed on another module, this user calibration will be used with the new module.

FACT (return to factory $\%O_2$, λ, AFR, Φ, and FAR calibration)

To return to the factory calibration of $\%O_2$, λ, AFR, Φ, and FAR for the NOx sensor:

1. Make sure the NOx sensor is attached to the module.
2. Press the SYS key until "MOd" appears.
3. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
4. With "O2" on the display, press the ENT key.
5. Press the ↓ key until "FACT" is on the display. Press the ENT key. The user O2 SPAN calibration of the NOx sensor is erased and the factory calibration will be used to calculate $\%O_2$, λ, AFR, Φ, and FAR. The NOx sensor age factor (AGEF) will be reset to "1.00".

AGEF (NOx sensor age factor)

After the NOx sensor has had its O_2 measurement spanned, data from this span is compared to data from the sensor when it was new. From this, a parameter (AGEF) is calculated that indicates the relative sensitivity of the sensor compared to when it was new. If AGEF is 1.00, the sensor's sensitivity has not changed. AGEF goes down with use. When the AGEF is 0.75 or below, it is recommended that the NOx sensor be replaced. AGEF is reset to "1.00" after the FACT option (see above) has been executed.

◆ NOx

The NOx ZERO and SPAN functions are for the recalibration of the NOx sensor's NOx measurements. This recalibration is stored in the sensor's memory chip and is used instead of the factory calibration. The FACT function cancels the user calibration resulting in the factory calibration being used.

The calibration of the NOx measuring portion of the NOx sensor can be performed either in the exhaust of an engine or using model gases. Model gases are mixtures of NOx, O_2, and N_2 that come from tanks, are mixed, and then bubbled through water before being passed by the sensor. The ZERO should be performed before the SPAN.

ZERO (for NOx measurement)

To perform a NOx zero:

1. A zero should be performed after the NOx sensor has been on for at least 20 minutes.
2. (For Type G Only) If the NOx sensor is being zeroed in air, make sure the "CURV" function is set to "MODL" (for matching a model gas mixture). If the NOx sensor is being zeroed in an engine, make sure the "CURV" function is set to "ENGW" (for matching wet NOx numbers from an engine). To set the "CURV" function, see the "CURV" section (in a few pages).
3. Put the NOx sensor and pressure sensor (if so equipped) in ambient, stationary air or in the exhaust of a running engine (at low NOx levels as determined by a CLA). Pressure during NOx sensor calibration is required if the calibration is to be pressure compensated. **IMPORTANT NOTE**: Do not zero in pure N_2 or pure N_2 bubbled through water! This will damage the sensor.
4. Press the SYS key until "MOd" appears.
5. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
6. Press the ↓ key until "NOx" appears. Then pressure the ENT key.
7. With "ZERO" on the display, press the ENT key.
8. Using the ↑ and ↓ keys, change the display to read 0 ppm. Note: In the case of zeroing in a running engine, the actual NOx may not be 0 ppm (ex. 10 ppm). In that case, use the arrows to get the display to read the actual ppm NOx (ex. 10 ppm) measured by a NOx CLA. The zero function supports "off zero" zeroing. Press the ENT key when the display reads the correct NOx value. When performing a zero using exhaust gases, wet NOx numbers should be used.
9. (For Type G Only) Program the "CURV" function as "ENGW" before measuring NOx in an engine.

10. Press SYS to return to RUN mode.
11. The user calibration is written into the memory chip in the NOx sensor's connector and will be used to calculate NOx. If the NOx sensor is removed and installed on another module, this user calibration will go with the sensor and be used with the new module.

SPAN (for NOx measurement)

To perform a NOx span:

1. A span should be performed after the NOx sensor has been on for at least 20 minutes.
2. (for Type G only) If the NOx sensor is being spanned using model gases, make sure the "CURV" function is set to "MODL" (for matching a model gas mixture). If the NOx sensor is being spanned in an engine, make sure the "CURV" function is set to "ENGW" (for matching wet NOx numbers from an engine). To set the "CURV" function, see the "CURV" section (in a few pages).
3. To span in the exhaust, put the NOx sensor and pressure sensor (if so equipped) in the exhaust of a running engine. Using a NOx CLA, determine the wet NOx in the exhaust. Go to step 6 (below).
4. To span using model gas, put the NOx sensor and pressure sensor (if so equipped) in an enclosed vessel fed by a NO + O_2 (approximately 20%) + N_2 mixture that is first bubbled through water. For a vessel of 50mm diameter, the flowrate should be about 5 lpm. Pressure during NOx sensor calibration is required if the calibration is to be pressure compensated; however, during the span try to keep the pressure within 7 kPa (1 psi) of atmospheric. **IMPORTANT NOTE**: Do not span in a mixture that contains less than 1% O_2! Use approximately 20% O_2 for best calibration.
5. Calculate NOx ppm that the NOx sensor is exposed to (NOx_{actual}). Since the NO + O_2 + N_2 mixture is being bubbled through water, this value is reduced from the concentration in the tank of gas.

$$NOx_{actual} = NOx_{tank} \times ((P - P_{ws})/P) \qquad \text{[Equation 1]}$$

where:

NOx_{actual} = actual NOx ppm the NOx sensor is exposed to

NOx_{tank} = NOx ppm in the tank NOx + O_2 + N_2 mixture

P = the absolute pressure in the vessel

P_{ws} = the saturated water vapor pressure. See Appendix D.
Use the temperature of the water to enter the table.

IMPORTANT NOTE: We have found that the best calibration is performed based on using measured NOx data from a NOx CLA sampling from the vessel holding the NOx sensor (i.e. not using the above formula). We believe that this is because of reactions that occur in the lines from the tanks to the sensor.

6. Press the SYS key until "MOd" appears.
7. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
8. Press the ↓ key until "NOx" appears. Then press the ENT key.

9. Press the ↓ key until "SPAN" appears. Then press the ENT key.
10. Using the ↑ and ↓ keys, change the display to read NOx_{actual} calculated above (or from a NOx CLA if available). Press the ENT key when the display reads the correct NOx value. When performing a span using exhaust gases, wet NOx numbers should be used.
11. (for Type G Only) Program the "CURV" function as "ENGW" before measuring NOx in an engine.
12. Press SYS to return to RUN mode.
13. The user calibration is written into the memory chip in the NOx sensor's connector and will be used to calculate NOx. If the NOx sensor is removed and installed on another module, this user calibration will go with the sensor and be used with the new module.

FACT (return to factory NOx calibration)

To return to the factory calibration for the NOx sensor:

1. Make sure the NOx sensor is attached to the module.
2. Press the SYS key until "MOd" appears.
3. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
4. Press the ↓ key until "NOx" appears. Then press the ENT key.
5. Press the ↓ key until "FACT" is on the display. Press the ENT key. The user NOx ZERO and SPAN calibration of the NOx sensor is erased and the factory calibration will be used to calculate NOx.

CURV (for Type G only)

The "CURV" function must be programmed as "ENGW" when the NOx sensor is measuring NOx in the exhaust of an engine, or programmed as "MODL" when the NOx sensor is measuring NOx in a model gas. To program "CURV":

1. Press the SYS key until "MOd" appears.
2. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
3. Press the ↓ key until "NOx" appears. Then press the ENT key.
4. Press the ↓ key until "CURV" is on the display. Press the ENT key.
5. Press the ↓ and ↑ keys until "ENGW" or "MODL" is displayed. Press the ENT key.
6. Press SYS to return to RUN mode.

GAMM (for Type G only)

The NOx-measuring portion of the Type G NOx sensor has a sensitivity to oxygen. To compensate (i.e. correct) for this sensitivity, the "GAMM" function was added. The oxygen compensation is different if the NOx sensor is in the exhaust of a running engine or if it is in model gases. Thus, there are two "GAMM" coefficients (GAMMA, BETA) used when the sensor is in an engine (entered under "GAMMA", "ENGW") and two different "GAMM" coefficients (GAMMA, BETA) used when the sensor is in model gases (entered under "GAMMA", "MODL"). ECM factory sets these numbers for each NOx sensor and they should only be modified after consultation with ECM.

CAL (Calibrate) Setup Option for Original NOx Sensor

This section is for "Original" NOx sensor applications only. This sensor uses a NOxCAN module. For Type T (uses NOxCANt module) and Type G (NOxCANg module) NOx sensor applications, see the previous section.

NOx sensors supplied with the NOx 5210 are factory calibrated. This calibration is stored in a memory chip inside the sensor's connector. With use, NOx sensors can age requiring recalibration to maintain measurement accuracy. Recalibration can be performed by the user or by sending the sensor back to ECM.

There are two parts of the NOx sensor: the **O_2** (Lambda, AFR, FAR, PHI) measuring part and the NOx measuring part. The recalibration consists of one ZERO and two SPANs. They should be performed in the following order:

1. SPAN the O_2 measurement (see **CAL, O2, SPAN Option**)
2. ZERO the NOx measurement (see **CAL, NOX, ZERO Option**)
3. SPAN the NOx measurement (see **CAL, NOX, SPAN Option**)

It is important to realize that when in the exhaust of a running engine, the NOx sensor is seeing H_2O as just another gas. Therefore, it will report "wet" $\%O_2$ and ppm NOx numbers. Classical gas analysis equipment (ex. NOx CLA) typically (but not always) has the water removed from the gases before they reach the analyzer. Thus classical gas analyzers will report "dry" numbers which are always greater than "wet" numbers. When comparing "wet" to "dry" numbers, make sure to compensate for the removed water.

◆ O2

The O2 SPAN function is for the recalibration of the NOx sensor's $\%O_2$, λ, AFR, Φ, and FAR measurements. This recalibration is stored in the sensor's memory chip and is used instead of the factory calibration. The FACT function cancels the user calibration resulting in the factory calibration being used.

SPAN (for $\%O_2$, λ, AFR, Φ, and FAR measurements)

To perform an O_2 span:

1. A span should be performed after the NOx sensor has been on for at least eight hours (hanging in air). This is to remove any adsorbed water which can be an issue with the Originals NOx sensor.
2. Put the NOx sensor and pressure sensor (if so equipped) in ambient, stationary air. Pressure during NOx sensor calibration is required if the calibration is to be pressure compensated.
3. Calculate the $\%O_2$ in air. The $\%O_2$ of air with no humidity is 20.945. This percentage decreases with increased humidity. To calculate the $\%O_2$ in non-zero

humidity air, use the Configuration Tool Software or refer to Appendix D. 20.7 is a common number.

4. Press the SYS key until "MOd" appears.
5. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
6. With "O2" on the display, press the ENT key.
7. With "SPAN" on the display, press the ENT key.
8. Using the ↑ and ↓ keys, change the display to show the $\%O_2$ in air determined in 3 (above). Press the ENT key.
9. When "CAL" is displayed, press SYS to return to RUN model. See **AGEF** (below).
10. The user calibration is written into the memory chip in the NOx sensor's connector and will be used to calculate $\%O_2$, λ, AFR, Φ, and FAR. If the NOx sensor is removed and installed on another module, this user calibration will be used with the new module.

FACT (return to factory $\%O_2$, λ, AFR, Φ, and FAR calibration)

To return to the factory calibration of $\%O_2$, λ, AFR, Φ, and FAR for the NOx sensor:

1. Make sure the NOx sensor is attached to the module.
2. Press the SYS key until "MOd" appears.
3. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
4. With "O2" on the display, press the ENT key.
5. Press the ↓ key until "FACT" is on the display. Press the ENT key. The user O2 SPAN calibration of the NOx sensor is erased and the factory calibration will be used to calculate $\%O_2$, λ, AFR, Φ, and FAR. The NOx sensor age factor (AGEF) will be reset to "1.00".

AGEF (NOx sensor age factor)

After the NOx sensor has had its O_2 measurement spanned, data from this span is compared to data from the sensor when it was new. From this, a parameter (AGEF) is calculated that indicates the relative sensitivity of the sensor compared to when it was new. If AGEF is 1.00, the sensor's sensitivity has not changed. AGEF goes down with use. When the AGEF is 0.75 or below, it is recommended that the NOx sensor be replaced. AGEF is reset to "1.00" after the FACT option (see above) has been executed.

◆ NOx

The NOx ZERO and SPAN functions are for the recalibration of the NOx sensor's NOx measurements. This recalibration is stored in the sensor's memory chip and is used instead of the factory calibration. The FACT function cancels the user calibration resulting in the factory calibration being used. The ZERO should be performed before the SPAN.

IMPORTANT NOTE: The calibration of the NOx measuring portion of the Original NOx sensor should only be performed in the exhaust of a running engine and in comparison to a NOx CLA (chemiluminescent analyzer). This is because the Original NOx sensor's calibration is very sensitive to mounting (i.e. exhaust pipe) temperatures and it is difficult to

simulate these temperatures in a model gas apparatus. In addition, it is recommended that a BTU200 (ceramic sensor heater) be used.

ZERO (for NOx measurement)

To perform a NOx zero:

1. A zero should be performed after the NOx sensor has been on for at least eight hours (hanging in air). This is to remove adsorbed water which can be an issue with the Original NOx sensor.
2. Put the NOx sensor and pressure sensor (if so equipped) in the exhaust of a running engine. Pressure during NOx sensor calibration is required if the calibration is to be pressure compensated. **IMPORTANT NOTE**: Do not zero in pure N_2 or N_2 bubbled through water! This will damage the sensor.
3. Press the SYS key until "MOd" appears.
4. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
5. Press the ↓ key until "NOx" appears. Then pressure the ENT key.
6. With "ZERO" on the display, press the ENT key.
7. Using the ↑ and ↓ keys, change the display to read 0 ppm. Note: In the case of zeroing in a running engine, the actual NOx may not be 0 ppm (ex. 10 ppm). In that case, use the arrows to get the display to read the actual ppm NOx (ex. 10 ppm) measured by a NOx CLA. The zero function supports "off zero" zeroing. Press the ENT key when the display reads the correct NOx value. When performing a zero using exhaust gases, wet NOx numbers should be used.
8. Press SYS to return to RUN model.
9. The user calibration is written into the memory chip in the NOx sensor's connector and will be used to calculate NOx. If the NOx sensor is removed and installed on another module, this user calibration will go with the sensor and be used with the new module.

SPAN (for NOx measurement)

To perform a NOx span:

1. A span should be performed after the NOx sensor has been on for at least eight hours (hanging in air) or immediately following a zero.
2. To span, put the NOx sensor and pressure sensor (if so equipped) in the exhaust of a running engine. Using a NOx CLA, determine the wet NOx in the exhaust.
3. Press the SYS key until "MOd" appears.
4. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
5. Press the ↓ key until "NOx" appears. Then press the ENT key.
6. Press the ↓ key until "SPAN" appears. Then press the ENT key.
7. Using the ↑ and ↓ keys, change the display to read the wet NOx. Press the ENT key when the display reads the correct NOx value.
8. Press SYS to return to RUN mode.
9. The user calibration is written into the memory chip in the NOx sensor's connector and will be used to calculate NOx. If the NOx sensor is removed and installed on

another module, this user calibration will go with the sensor and be used with the new module.

FACT (return to factory NOx calibration)

To return to the factory calibration for the NOx sensor:

1. Make sure the NOx sensor is attached to the module.
2. Press the SYS key until "MOd" appears.
3. Press the ↓ key until "CAL" is on the display of the channel to be calibrated. Then press the ENT key.
4. Press the ↓ key until "NOx" appears. Then press the ENT key.
5. Press the ↓ key until "FACT" is on the display. Press the ENT key. The user NOx ZERO and NOx SPAN calibration of the NOx sensor is erased and the factory calibration will be used to calculate NOx.

CAL (Calibrate) Setup Option (P, AVG, SKEW)

◆ P

Pressure sensor calibration numbers (N and C) and displayed pressure units can be programmed. The "N" and "C" values must match those written on a label on the pressure sensor. The pressure sensor cannot be user calibrated.

The programmable pressure units are PSIA, KPAA, MMHG (mmHg), BAR, and KGCM (kg/cm^2). All pressures shown are absolute (i.e. not gauge).

◆ AVG

Raw data is sampled from the NOx sensor and pressure sensor every 5 ms. This data is averaged by the NOx module every 5 ms before being sent to the display head every 5 ms. For the parameters Ip1, $\%O_2$, λ, AFR, Φ, and FAR, the averaging filter (also called recursive averaging filter or digital low-pass filter) is ILAM. For Ip2 and NOx, the averaging filter is I2NX. For pressure, the averaging filter is PLAM. How the averaging filters are used is shown by Equation 2. The averaging filters are user-programmable and can be assigned values from 0.001 (heavy averaging) to 1.000 (no averaging).

$$ParameterAverage_{t+5ms} = \alpha \times Parameter_{t+5ms} + (1 - \alpha) \times ParameterAverage_{t} \quad [Equation\ 2]$$

where:

$ParameterAverage_{t+5ms}$ = the parameter average at time "t+5ms"

α = ILAM (for Ip1, %O2, λ, AFR, Φ, FAR) or
I2NX (for Ip2, NOx) or
PLAM for pressure.

These user-programmable filters range from 0.001 (heavy averaging) to 1.000 (no averaging).

$Parameter_{t+5ms}$ = the parameter value at time "t + 5ms"

$ParameterAverage_t$ = the parameter average at time "t"

The default averaging filter values are given within square parentheses in Table 1. These values and the length of the pressure line assembly should not be modified without first consulting ECM.

◆ **SKEW**

SKEW allows the parameters NOx, P, AFR, Φ, FAR, λ, and $\%O_2$ each to be modified by a programmable transform of the form:

$$ParameterSkewed = M \times Parameter + B \quad [Equation\ 3]$$

where:

ParameterSkewed = NOx, P, AFR, Φ, FAR, λ, or $\%O_2$ value after being skewed.

Parameter = NOx, P, AFR, Φ, FAR, λ, or $\%O_2$ measurement before being skewed.

M = Skewing gain. The default values for M are 1.000.

B = Skewing offset. The default values for B are 0.000.

The skewed parameters are displayed and output (i.e. analog outputs, CAN).

CONF (Configure) Setup Option (LEdS, 1V4V, CAN, MOdE, FACT)

CONF setup appears at the end of the setup list for the lower channel. To enter CONF, press the SYS key until "MOd" appears on the upper display, press the ↓ key until "CONF" appears on the bottom display, and then press the ENT key. CONF relates to display head (as opposed to NOx module or sensor setup).

◆ **LEdS**

The display intensity is programmable. Press the ENT key when "LEdS" appears on the lower display, press the ↑ or ↓ keys until the display intensity is suitable, press ENT, and press SYS to return to RUN mode.

◆ **1V4V**

This feature commands a 1 V (when "1V" is on lower display) or 4 V (when "4V" is on lower display) output on all six analog outputs. This feature is useful when troubleshooting the interface with an external data acquisition device.

◆ **CAN**

Figure 4a shows cabling connected to the back of the display head for CAN communication. Depending on where the display head appears in your CAN bus, the termination resistor may have to be present or removed.

The CAN data communicated is:

1. What is being sent to analog output 1
2. What is being sent to analog output 2
3. What is being sent to analog output 3
4. What is being sent to analog output 4
5. What is being sent to analog output 5
6. What is being sent to analog output 6
7. What is being sent to the upper display (but not averaged by display)
8. What is being sent to the lower display (but not averaged by display)
9. An error code for the upper channel. See **Appendix C**.
10. An error code for the lower channel. See **Appendix C**.
11. An auxiliary code for the upper channel.
12. An auxiliary code for the lower channel.

It is important to note that if a parameter that is being displayed is changed (by pressing the ↑ or ↓ key), the CAN data will also be changed to that newly displayed parameter for 7 or 8 (above). Similarly for an analog output. LOCKing the display head can be used to avoid this problem.

The CAN data is broadcast at 500 kHz in the following format:

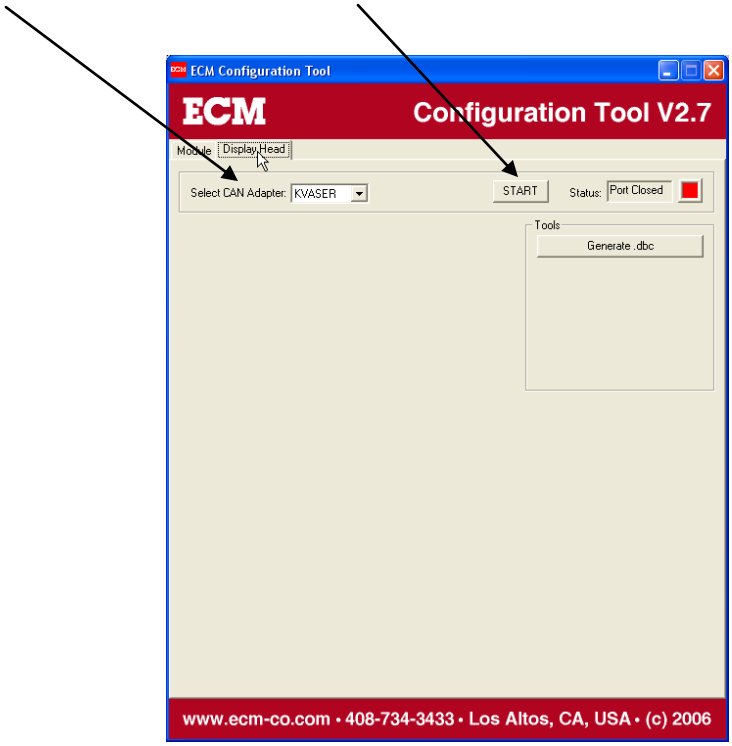
CANid	**byte 0**	**byte 1**	**byte 2**	**byte 3**	**byte 4**	**byte 5**	**byte 6**	**byte 7**
CANid1	What is being sent to analog output 1				What is being sent to analog output 2			
CANid2	What is being sent to analog output 3				What is being sent to analog output 4			
CANid3	What is being sent to analog output 5				What is being sent to analog output 6			
CANid4	What is being sent to upper display				What is being sent to the lower display			
ERCd	Error code for upper display/channel				Error code for lower display/channel			
	Error Code Low	Error Code High	Aux. Code	N/A	Error Code Low	Error Code High	Aux. Code	N/A

Each of the eight parameters in CANid1 to CANid4 is a single-precision 32 bit floating point number that conforms to the IEEE-754 standard. All eight of these parameters are transmitted on the CAN bus least significant byte first (Intel format). Parameters 1 through 8 (everything except error codes) sent on the CAN bus are averaged ("AVG"d, see **CAL Setup Option**).

Error codes are transmitted with address ERCd. The error codes are 16 bit integers that refer to those listed in Appendix C. The error codes are transmitted on the CAN bus least significant byte first (Intel format). The auxiliary code is the countdown number appearing on the channel's display. If there is no error or active countdown, an error message is not broadcast.

Addresses CANid1 through CANid4 and ERCd are user programmable. To program them: enter SYS mode, ↓ down to "CONF", press the ENT key, ↓ down to "CAN", press the ENT key once (while displaying "CAN"), press the ENT key again (while displaying "IdS"), and enter them (CId1, CId2, CId3, CId4) one by one (enter number then press the ENT key). After entering ERCd, ".dBC" will appear on the display. If the CAN port of the NOx 5210 is connected directly to a PC via a CAN adapter, pressing the ENT key will result in data for the .dbc file for the current NOx 5210 setup being sent to the PC. This .dbc file can be used with programs accepting the VectorCAN .dbc format. How to get this .dbc file is explained in more detail below:

1. Configure the analog outputs and displays as desired. The parameters assigned to the analog outputs and displays are what will be broadcast on the CAN bus.
2. Connect the NOx 5210 display head directly to the CAN adapter connected to the PC. There should be nothing else on the CAN bus. Just the display head and the PC.
3. Start the Configuration Program and click on the "Display Head" tab. Select the CAN adapter being used. Then start the communication.



The rate at which CAN data is sent can also be programmed via the "RATE" parameter under "CAN". To program how often the CAN data is to be sent: enter SYS mode, ↓ down to "CONF", press the ENT key, ↓ down to "CAN", press the ENT key, ↓ down to "RATE", press the ENT key, then enter the rate in ms. The allowable range is 5ms to 9999ms with 5ms being the default.

The CAN baud rate is programmed via the "BAUd" parameter under "CAN".

4. Click on the "Generate .dbc" button on the PC's screen. Enter the filename and directory for the .dbc file.

5. Get to the CAN setup in the display head and enter the desired CAN addresses for CANid1 to CANid4 (CId1, CId2, CId3, CId4), and ERCd. Then when ".dBC" is shown on the display, press the ENT key. Within a second, the .dbc file for that particular NOx 5210 analyzer setup will be sent to the PC. It is a good idea to LOCK the display head after this (see "MODE" below) since changing a new displayed parameter or new analog out parameter will change the data transmitted via CAN to that of the new parameter.

6. The analog parameters are called A#_sn where "#" is the analog output number and "sn" is the serial number of the display head (ex. A1_45405300). The serial number is the first thing that is displayed on startup on the display head. The display parameters are called TopDisp_sn, and BtmDisp_sn. The error codes are called TopErr_sn, TopAux_sn, BtmErr_sn, and BtmAux_sn. During NOx sensor warm-up when the display is counting down, TopAux_sn or BtmAux_sn will contain the countdown number.

7. See Appendix F for additional information.

◆ **MOdE**

"ENHd" and "STNd" refer to whether the full list in Table 2 (for ENHd) or a subset (for STNd) will be available to assign to an analog output (A1 to A6) or a displayed parameter (P1 to P6).

"LOCK" locks the selection of displayed parameters and instrument setup. When locked, the display head can just be turned on and off. It cannot be modified unless unlocked. Refer to Appendix E for more information.

◆ **FACT**

"FACT" (in the **CONF Setup Option**) resets the display head to the default setup. The default setup is shown [in square parentheses] in Table 1. "FACT" (in the **CONF Setup Option**) does not reset FUEL, pressure sensor calibration numbers N and C, averaging filters ILAM and PLAM, nor does it cancel a user calibration of a NOx sensor. To cancel a user calibration of a NOx sensor use "FACT" (Twice: once for O_2 and once for NOx) in the CAL Setup Option.

Specifications and Limits

Measurements and Accuracies

Parameter	Range	Response Time	Accuracy
NOx (Type T)	0 to 5000 ppm[1]	< 1 s[6]	±20 ppm (0 to 1000 ppm) ±2.0% of reading (elsewhere)
NOx (Type G)	0 to 5000 ppm[2]	< 1 s[6]	±15 ppm (0 to 1000 ppm) ±1.5% of reading (elsewhere)
NOx (Original)	0 to 5000 ppm[1]	< 700 ms[6]	±30 ppm (0 to 1000 ppm) ±3% of reading (elsewhere)
Lambda (λ)	0.4 to 25	< 150 ms[7]	±0.8% (at λ=1) ±1.8% (elsewhere)
AFR	6 to 364[3]	< 150 ms[7]	±0.8% (at 14.56 AFR) ±1.8% (elsewhere)
Equivalence Ratio (Φ)	0.04 to 2.5	< 150 ms[7]	±0.8% (at Φ=1) ±1.8% (elsewhere)
FAR	27 to 1667[3,4]	< 150 ms[7]	±0.8% (at 687 FAR) ±1.8% (555<FAR<833)
$\%O_2$	-25 to 25%[5]	< 150 ms[7]	±0.2 (absolute)
Pressure	0 to 517 kPa, 75 Psia	< 50ms[8]	±5.2 kPa ±0.75 Psia

[1] NOx measurement at all stoichiometries (i.e. λ < 1, λ = 1, λ >1).
[2] NOx measurement for only lean stoichiometries (i.e. λ >1).
[3] AFR and FAR range given above for a fuel with an H:C ratio of 1.85, however all fuel types supported by analyzer and programmable by H:C, O:C, and N:C ratios.
[4] FAR x 10000 is displayed. This is the most commonly used way to express FAR. For example, with an H:C=1.85 fuel, Lambda=1 is FAR=686.8.
[5] For stoichiometries richer than Lambda=1 (i.e. λ < 1), negative $\%O_2$s are displayed. This novel convention is used by some researchers for lean-burn engines.
[6] The response time is affected by averaging filter I2NX (for Ip2, NOx) See **CAL Setup** for more information.
[7] The response times are affected by averaging filter ILAM (for Ip1, $\%O_2$, λ, AFR, Φ, FAR). See **CAL Setup** for more information.
[8] The response times are affected by averaging filter PLAM (for P). See **CAL Setup** for more information.

Sensor Limits and Specifications

◆ **NOx Sensor**

Exhaust Gas Temperature Range: 0 - 850 °C, 32 - 1562 °F
Maximum Exhaust Temperature: 950 °C, 1742 °F
Maximum Rate of Temperature Change: 50 °C/s, 122 °F/s

Fuel Composition:

H:C ratio range: 1.00 - 10.00, or Hydrogen (H_2)
O:C ratio range: 0.00 - 10.00
N:C ratio range: 0.00 - 1.00

gasoline: 1.70 < H:C < 2.10, O:C=0.0, N:C=0.0, (1.75 or 1.85 are commonly used)
methanol: H:C=4.0, O:C=1.0, N:C=0.0
ethanol: H:C=3.0, O:C=0.5, N:C=0.0
propane: H:C=2.67, O:C=0.0, N:C=0.0
methane: H:C=4.0, O:C=0.0, N:C=0.0

Maximum allowable levels of fuel "Impurities":

Lead: 0.012 gm/gal., 0.003 gm/ltr.
Phosphorous: 0.0008 gm/gal., 0.00027 gm/ltr.
Sulfur: 0.035% by weight

Do not use the NOx sensor in a heavily-sooting or crankcase-oil-burning engine because these conditions will shorten the life of the sensor.

Thread Size: 18mm x 1.5mm (Type T and Original NTK). 20mm x 1.5mm (Type G),
Lightly coat with non-lead containing antiseize compound.

The Type T and Original NOx sensor's thread size is identical to that of the exhaust gas oxygen sensors used in production automobiles with 3-way exhaust catalysts.

Hex Size: 22 mm

Tightening Torque: 40 ±4 Nm, 30 ±3 ft-lbf

◆ **Pressure Sensor**

Note: Must attach to engine via ECM-supplied pressure sensor tubing only!
Do not directly attach to the exhaust or pressure sensor damage will result.

Diaphragm Material: Stainless steel

Maximum Pressure: 200 Psia, 1379 kPa (absolute)

Operating Temperature Range: -40 to 105 °C

Thread on Pressure Sensor: ¼" NPT

Fitting on Pressure Sensor: Swagelok SS-400-7-4 to mate with ¼" tube (USA) or
Swagelok SS-6MO-7-4 to mate with 6 mm tube (Metric)

◆ **Pressure Sensor Tubing**

Note: Stainless steel end of tubing towards engine. Teflon end towards pressure sensor.

Mating Thread with Engine: ¼" NPT (USA) or ¼" ISO tapered (Metric)

Tubing Assembled Length: 19" (USA) or 483 mm (Metric)

Tubing Diameter: ¼" (USA) or 6mm (Metric)

Nut, Front Ferrule, Back Ferrule at Pressure Sensor end of Tubing:
Swagelok SS-402-1, SS-403-1, SS-404-1 (USA) or
Swagelok SS-6M3-1, SS-6M4-1, SS-6M2-1 (Metric)

Union between Stainless Steel and Teflon Tubing: Swagelok SS-400-6 (USA) or
Swagelok SS-6MO-6 (Metric)

Fitting on Engine End of Tubing: Swagelok SS-400-1-4, ¼" tube to ¼" NPT (USA) or
Swagelok SS-6MO-1-4RT, 6 mm tube to ¼" ISO tapered (Metric)

Output Specifications

◆ **Analog Outputs**

Output Range (linearized in displayed units): 0 to 5V, 0 to 1V, 20 mA max.

Output Impedance: 2.66 kΩ

Bits Resolution: 12 bits

Update Rate: 5 ms

Isolation: Electrically isolated from power supply ground.
All analog output grounds common.

◆ **CAN**

Protocol: Broadcast.

Broadcast Rate: Programmable 5 to 9999ms. 5ms default.

Speed: Programmable, 500 kHz default.

Isolation: Electrically isolated from power supply ground.

General Specifications

◆ **Power**

DC: 11 to 28 VDC

Current Draw: 0.5 A (display), 1.2 A steady-state (NOx sensor and module),
On start-up, NOx sensor and module may draw as much as 4 A for 30 s.

Case Ground: The NOx 5210 display head case is connected to power ground via a 2.15 kΩresistor.

◆ **Key-on Signal**

"ON" Voltage Level: 2.7 to 32 VDC

Current Draw: 100 μA

◆ **Environment**

Display Head: -40 to 85 °C, 100% humidity non-condensing, display head is not sealed

Module: -55 to 125 °C, 100% humidity, module is sealed, IP67

◆ **Dimensions and Weight**

Display Head: 108 mm x 64 mm x 178 mm, 4 ¼" x 2 ½" x 7", (W x H x D)
676 gm, 24 oz

Module: 120 mm x 37 mm x 143 mm, 4 ¾" x 1 ½" x 5 ¾", (W x H x D)
244 gm, 8.7 oz

Appendix A: 5200 Series Instruments Parts List

01 Display Heads (Just display head. Must add cables, etc.)

01-01 NOx 5210 (just head, no module, no cable, no sensor)
01-02 Lambda 5220 (just head, no module, no cable, no sensor)
01-03 EGR 5230 (just head, no module, no cable, no sensor)
01-04 dashCAN (includes cable and T)
01-05 dashCAN+
01-06 dashCANc

02 CAN Modules (just module)

02-01 LambdaCAN (just module, no sensor, no cables)
02-02 NOxCAN (for original sensor, just module, no sensor, no cables)
02-03 NOxCAN-G (for "G" sensor just module, no sensor, no cables)
02-04 LambdaCANc (just module, no sensor, no cables)
02-05 appsCAN (just module, no cables)
02-06 baroCAN (just module, no sensors, no cables)
02-07 NOxCAN-T (for "T" sensor, just module, no sensor, no cables)
02-08 LambdaCANp (just module, no sensor, no cables)
02-09 LambdaCANd (just module, no sensor, no cables)
02-10 gpCAN (just module, no cables)
02-11 COCO2CAN (just module, no sensor, no cables)

03 Simulators, Heater

03-01 LambdaCAN Sensor Simulator (just module, no cable)
03-02 NOx Sensor Simulator (just module, no cable)
03-03 Ceramic Sensor Heater (just module, no cable)
03-04 NOxg Sensor Simulator (just module, no cable)
03-05 NOxt Sensor Simulator (just module, no cable)
03-06 LambdaCANp Sensor Simulator (just module, no cable)

04 Power Supplies

04-01 AC/DC Power Supply, Universal, 24V
04-02 Vboost Supply, 10~14VDC to 24VDC @ 14.5A
04-03 30A AC/DC Power Supply, 15V, 120VAC
04-04 15A AC/DC Power Supply, 15V, 120VAC
04-05 60A AC/DC Power Supply, PWR 60, 15V, 120VAC

05 Linear O2 (Lambda) and CO/CO2 Sensors

05-01 NTK 6 mA
05-02 Bosch LSU4.2
05-03 Bosch LSU4.9
05-04 NTK 4 mA
05-05 Bosch LSU4.2, Type P

05-06 Delphi OSL
05-07 NTK 4mA Cofired (ZFAS-U2)
05-08 Bosch LSU4.9, Type P
05-09 Bosch ADV
05-10 NTK, 6mA, Type P
05-11 Bosch LSU4.2, Type PI (Intake)
05-12 CO, CO2

06 NOx and NH3 Sensors

06-01 NOx Original (use with NOxCAN)
06-02 NOx Type "G" (use with NOxCANg)
06-03 Calibrate NOx Sensor
06-04 Cal Sheet with NOx Sensor
06-05 NOx Type "T" (use with NOxCANt)

07 Sensors

07-01 Pressure, 0-75 psia, 1/4", (USA)
07-02 Pressure, 0-517 kPa, 6mm, (Metric)
07-03 Pressure, Type P, 0-75 psia, 1/4", (USA)
07-04 Pressure, Type P, 0-517 kPa, 6mm, (Metric)
07-05 Pressure, Type KP, 0-100 psia, 1/4", (USA)
07-06 Pressure, Type KP, 0-689 kPa, 6mm, (Metric)
07-07 RH (Humidity) Sensor, ¼" NPT
07-08 Pressure (Lp,C,bCAN only), 0-75 psia, 1/4", (USA)
07-09 Pressure (Lp,C,bCAN only), 0-517 kPa, 6mm, (Metric)
07-10 Pressure (Lp,C,bCAN only), Type KP, 0-75 psia, 1/4", (USA)
07-11 Pressure (Lp,C,bCAN only), Type KP, 0-517 kPa, 6mm, (Metric)

08 Actuators

08-01 Ceramic Sensor Heater Mount for 05-01, 05-04, 05-07, 05-10, 06-01, 06-05, 06-07 Sensors

09 Eurofast Cables, Ts, Term. Resistors, Connectors

09-01 4m Eurofast 12mm Cable
09-02 2m Eurofast 12mm Cable
09-03/n "n"m, Eurofast 12mm Cable
09-03/10 10m, Eurofast 12mm Cable
09-03/20 20m, Eurofast 12mm Cable
09-04 Flexi-Eurofast Cable, 0.3m
09-05 Eurofast "T"
09-06 Eurofast Termination Resistor
09-07 Eurofast Male Connector
09-08 8 Channel Eurofast Hub Block
09-09 Termination Resistor for Hub Block

10 Sensor Cables

10-01 Module Y Cable (Superceded by -21)
10-02 1m L/N/C/bCAN Cable, (12 term.)
10-02/25' L/N/C/bCAN Cable, (12 term., teflon)
10-03 2m L/N/C/bCAN Cable, (12 term.)
10-04 1m Pressure Cable (LCAN, NCAN, not Lp,C,bCAN), (4 term.)
10-05 2m Pressure Cable (LCAN, NCAN, not Lp,C,bCAN), (4 term.)
append suffix SD to cable for Teflon (Severe Duty) Version

10-09 Adapter to use P/N 05-01 with AFM1000, M1200, etc

10-12 Adapter to Pressure Sensor Wires

10-14 Adapter to use P/N 2400E-1 sensor (CPC) with LCAN

10-16 Adapter to use P/N 2400E-1S sensor (Fischer) with LCAN
10-17 Adapter to use P/N 1001A-2 (Deutsch) with LCAN
10-21 Module Y Cable (for all except Lp, C, and bCAN)

10-26 1m Humidity Cable (bCAN), (6 term.)
10-27 2m Humidity Cable (bCAN), (6 term.)

10-30 Module Y Cable (for bCAN only)
10-31 1m Extension Cable for 12 terminal Deutsch
10-32 2m Extension Cable for 12 terminal Deutsch

10-34 Module Y Cable (for Lp and CCAN only)
10-35 1m Pressure Cable (Lp,C,bCAN only), (8 term.)
10-36 2m Pressure Cable (Lp,C,bCAN only), (8 term.)
10-37 3m L/N/C/bCAN Cable, (12 term.)
10-38 3m Pressure Cable (Lp,C,bCAN only), (8 term.)
10-39 1-to-4 Pressure Sensor Adapter (for /P kits only. Not for /PB kits)
10-40 3m Pressure Cable (LCAN, NCAN, not Lp,C,bCAN), (4 term.)

11 Cables

11-01 DC Power Cable, DB9F, Spades
11-02 DC Power Cable, DB9F, Banana Plugs
11-03 DB9M to CSM Lemo F Adapter (CSM Upstream)
11-04 DB9M to ETAS Lemo Adapter
11-05 Female Eurofast to DB9F
11-06 Male Eurofast to CSM Lemo F Adapter (CSM Downstream)
11-07 In-Line Power Entry Cable
11-08 2m Key-on Cable
11-09 2m Heater Cable
11-10 2m Hub Power/Eurofast Harness
11-11 Simulator (SIM300, 400, 500, 600, 700, 800) Cable

11-14 BNC to Banana Cable
11-15 DC Power Cable, Spades
11-16 DC Power Cable, Banana Plugs
11-17 Deutsch DTM3M to DB9F
11-18 3m DB9 Cable, M-F
11-19 EIB Power Tap to Ceramic Sensor Heater Controller
11-20 25' DB9 M-F Cable
11-21 SIM-200 Calibration Kit
11-22 Left (gray) appsCAN Connector with 300mm Pigtail Wires
11-23 Right (blk) appsCAN Connector with 300mm Pigtail Wires
11-24 Connector Kit: 2 connectors, 24 terminals, 12 plugs
11-25 Male Eurofast to Braided Shield Ground
11-26 Boom Box Cable for CAN Products (80' CAN, 30' Power)
11-27 Boom Box to Hub Springy Cable (1m relaxed, 2m stretched)
10-28 Male Eurofast to DB9F
11-29 Simulator Power Cable
11-30 Simulator LSU4.9 Adapter Cable
11-31 Lemo to Eurofast Adapter Cable for LCANc
11-32 M-F Eurofast Panelmount Connector
11-33 1m CSM F Lemo to DB9F
11-34 1m CSM Power Lemo to Male Eurofast
11-35 Termination Resistor for in F Lemo Package

12 Mounting Panels, Bosses, Probes, and Hardware

12-01 19" Rackmount Panel. Holds up to 4 Displays
12-02 18mm x 1.5mm MS Boss and SS Plug
12-03 18mm x 1.5mm SS Boss and SS Plug
12-04 18mm x 1.5mm Tall Al Boss, Cu Gasket, Al Plug
12-05 1/4" NPT MS Boss and Brass Plug, (USA)
12-06 1/4" NPT SS Boss and Brass Plug, (USA)
12-07 1/4" NPT Al Boss and Brass Plug, (USA)
12-08 Pressure Line Assembly, 1/4" dia, 19", (USA)
12-08A Pressure Line Assembly, 1/4" dia, 28" (USA)
12-09 Inconel Shield

12-10 18mm Cu Gasket
12-11 Pressure Line Assembly, 6mm, 483mm, (Metric)
12-11A Pressure Line Assembly, 6mm, 711mm (Metric)
12-12 1/4" ISO tapered MS Boss and Brass Plug, (Metric)
12-13 1/4" ISO tapered SS Boss and Brass Plug, (Metric)
12-14 1/4" ISO tapered Al Boss and Brass Plug, (Metric)
12-15 15A Fuse
12-16 Bifurcated Intake Sample Probe, 8mm
12-17 Replacement Bifurcated Tube, 8mm
12-18 Aluminum Sensor Mounting Block, 18mm
12-19 Individual Cylinder Exhaust Probe, 18mm Sensor (USA)
12-20 Individual Cylinder Exhaust Probe, 18mm Sensor (Metric)
12-21PS Rolling Cart to Support 8 LCAN or NCANs (Pwr & Suc)
12-22 Sampling-Type Exhaust Probe (USA)
12-23 Sampling-Type Exhaust Probe (Metric)
12-24 Small Heated Aluminum Sensor Heater Block, 18mm
12-25 1/4" UNC Module Stacking Standoff
12-26 Small Aluminum Sensor Mounting Block, 18mm
12-27 Cu Gasket for 20mm x 1.5mm Boss and Plug
12-28 20mm x 1.5mm SS Boss and SS Plug for NGK NOx
12-29 18mm x 1.5mm (male) to 1/4" NPT (female)
12-30 Carrying Case, Medium
12-31 Aluminum Sensor Mounting Block, 20mm & 18mm
12-32 Small Aluminum Sensor Mounting Block, 20mm & 18mm
12-33 Pressure Line Assembly (for baroCAN), 1/4", (USA)
12-34 Presure Line Assembly (for baroCAN), 6mm, (Metric)
12-35 Carrying Case for SIM300
12-36 Carrying Case for SIM400
12-37 Carrying Case for SIM500
12-38 Carrying Case for SIM600
12-39 Carrying Case for SIM700
12-40 Individual Cylinder Exhaust Probe, 20mm Sensor (USA)
12-41 Individual Cylinder Exhaust Probe, 20mm Sensor (Metric)
12-42 Aluminum Mounting Plate for 8-ch Block and Modules
12-43 Carrying Case for SIM800
12-44 Multi-channel Cart

13 Software, CAN Adapters, and Manuals

13-01 5200 Series Manuals and Config Software (CD)
13-02 Kvaser Leaf Light CAN Adapter
13-Product Name (Manual)

14 Tools

14-01 18mm x 1.5mm Tap
14-02 18mm x 1.5mm Die
14-03 1/4" NPT Tap
14-04 1/4" ISO Tapered Tap
14-05 Antiseize

14-06 Metal Brush
14-07 Lambda Sensor Calibration System
14-08 20mm x 1.5mm Bottoming Tap

Appendix B: Module EIB Mode and Stand-alone Mode

The NOxCAN module can be used in conjunction with a display head (EIB mode) or on its own (Stand-alone mode). When delivered to be used with a display head, the module is setup in EIB mode. When delivered to be used alone, the module is setup in Stand-alone mode.

In EIB mode, the module communicates to the display head via a special high-speed communication protocol. The module must be EIB mode when on the EIB with a display head. When in Stand-alone Mode, the module communicates via the common 500 kHz CAN broadcast protocol.

The module must be properly configured in EIB mode or Stand-alone mode depending on how it will be used.

To convert from one mode to the other requires software reprogramming of the NOx module (using the Configuration Tool) followed by the removal (set to EIB) or installation (set to Stand-alone) of a jumper inside the module.

◆ **To convert a module from Stand-alone to EIB Mode**
(Note: Lambda module shown in pictures but procedure for NOx module is identical)

1. Connect the NOx module to a power supply and a PC (via a CAN communication adapter) using the cabling shown below. A sensor does not have to be connected to the module. Note that only one module is connected and the display head is not involved.

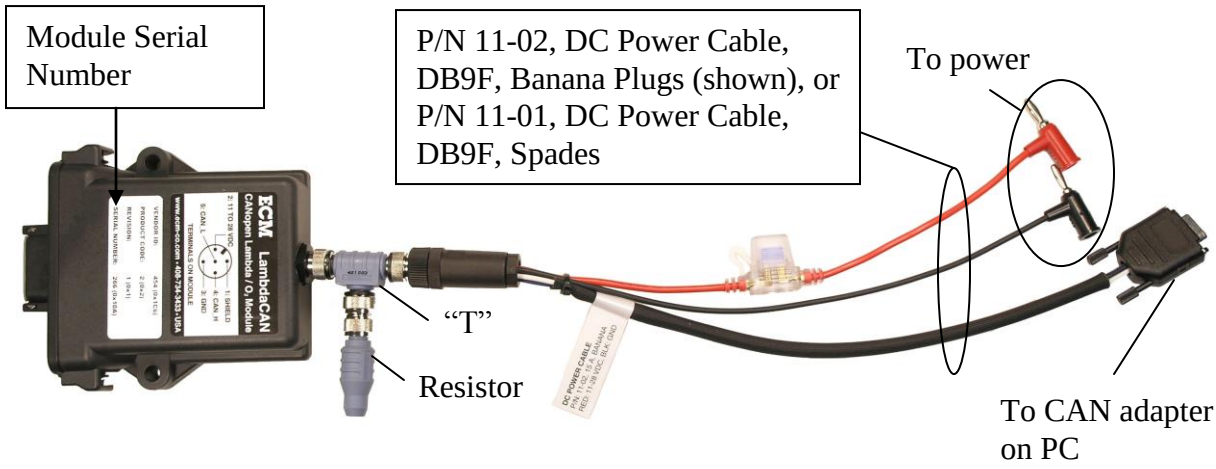
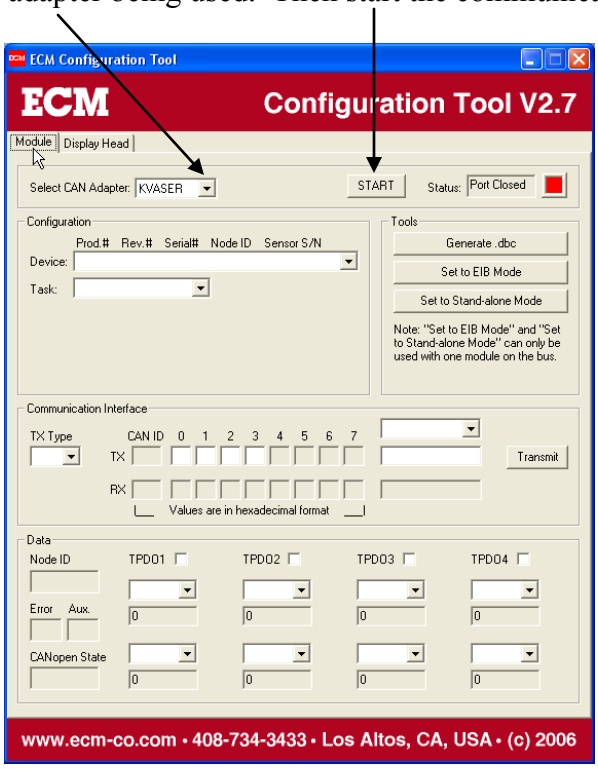
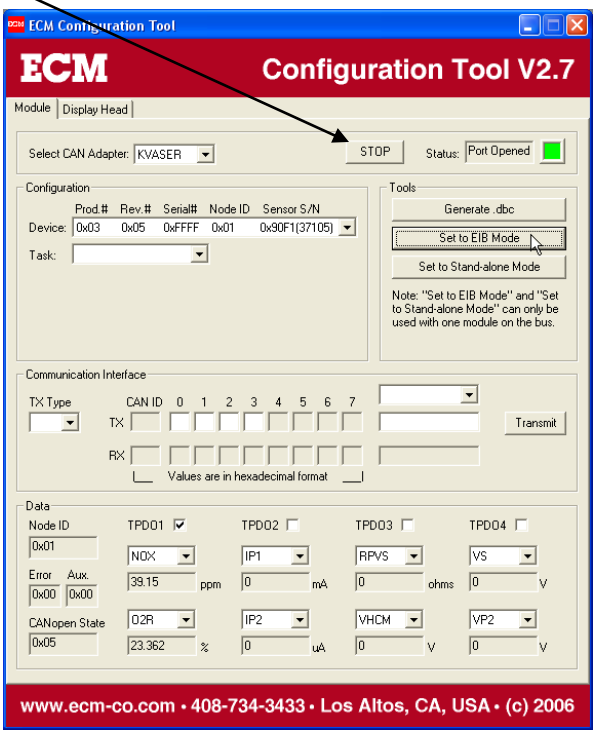


Figure B1: NOxCAN Module prepared for Reprogramming

2. Install and start the Configuration Tool (software). Click on the "Module" tab. Select the CAN adapter being used. Then start the communication.



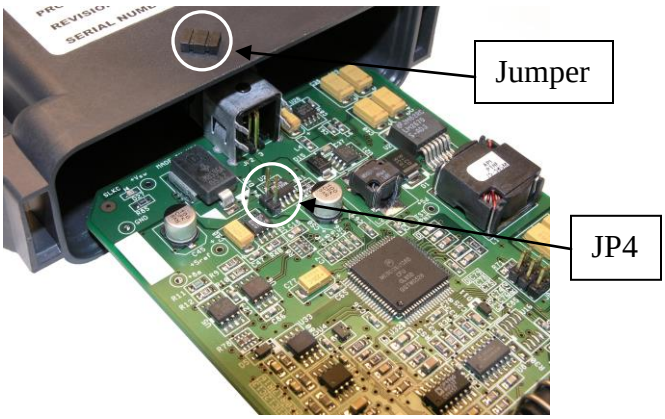
3. Click on the "Set to EIB Mode". Wait for "Done" Message. Stop communication and exit program.



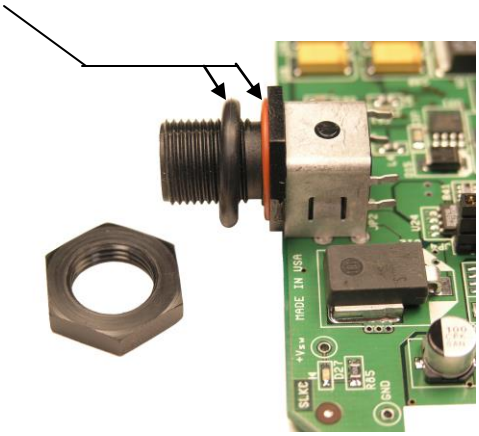
4. Take the nut off the end of the module. Use an 18mm socket without the wrench.

5. Release the two tangs at each side of the module.

6. Slide the PCB out. Remove the jumper from JP4. You can hang it on one pin of JP4 when "off".



7. Make sure both O-rings are on the threaded connector.



8. Slide the PCB into the enclosure until the two tangs “click”.
9. Put the nut on and tighten ONLY ½ turn from where it is seated. If this nut is tightened too much, the connector will crack and the enclosure will not be sealed.
10. The NOx module is now in EIB mode and can be on the EIB with a display.

◆ To convert a module from EIB to Stand-alone Mode

The process is similar to the previously-described procedure. Note that in EIB mode, the module will not show up in the device list of the configuration program.

1. Use the Configuration Tool (software) to “Set to Stand-alone Mode”.
2. Install the jumper on JP4 in the NOx module.
3. In Stand-alone Mode, the module will continuously broadcast data via 500 kHz CAN. For more information, refer to the NOxCAN Module Instruction Manual.

Appendix C: Error Codes and Troubleshooting

If one of the NOx 5210's displays flashes "ERR" followed by "####" (the Error Code), an error has been detected in that channel's module (or attached sensors). The below table lists the errors. The errors are also flashed on the module's LED.

Error Code	Module LED Action	Description of Error
NONE	Green ON	All OK (green light constantly on)
0001	Flash Green, 10 hz	Sensor warm-up period (not really an error)
0002	Green/Both/Red 2s	Power on reset / Init hardware
0011	Pulse Red 1x/2s	16 bit ADC failed to init. Internal module error. Contact ECM.
0012	Pulse Red 1x/2s	+Vsw shorted. Internal module error. Contact ECM.
0013	Red ON	Sensor turned off (red led constantly on)
0014	Pulse Red 1x/2s	NOx sensor heater open / NOx sensor not connected.
0015	Pulse Red 1x/2s	NOx sensor heater shorted. Bad NOx cable or sensor.
0021	Pulse Red 2x/2s	Memory chip in NOx sensor's bus shorted. Bad cable or sensor.
0022	Pulse Red 2x/2s	No memory chip in NOx sensor detected. Bad cable or sensor.
0023	Pulse Red 2x/2s	CRC16 error. Bad cable or sensor.
0024	Pulse Red 2x/2s	Invalid NOx sensor memory chip parameter. Wrong sensor.
0025	Pulse Red 2x/2s	Non-compatible NOx sensor memory chip format (old Rev.)
0031	Pulse Red 3x/2s	Vsw < 6 for > 7 sec. Supply voltage too low.
0032	Pulse Red 3x/2s	Vsw > 30 V. Supply voltage too high.
0041	Pulse Red 4x/2s	VS too high. Bad NOx sensor or cable.
0051	Pulse Red 5x/2s	RPVS too high. Sensor too cold, bad, or battery voltage too low.
0052	Pulse Red 5x/2s	(VH Commanded – VH Measured) > 0.5 V for > 10 sec. Battery voltage too low.
0061	Pulse Red 6x/2s	VP+ > 6 V. Bad NOx cable or cracked sensor (common).
0062	Pulse Red 6x/2s	VP+ < 2 V. Bad NOx cable or cracked sensor (common).
0063	Pulse Red 6x/2s	VP2 out of range
0064	Pulse Red 6x/2s	0.25 V > VS+ > 0.75 V for 7.5s. Bad NOx sensor.
0065	Pulse Red 6x/2s	User data (span) in NOx sensor memory chip corrupted. User must reperform NOx sensor span.

The two most common problems are a damaged NOx sensor and a low supply voltage (less than 11 V). When the NOx sensor is damaged, it must be replaced. It cannot be repaired. The NOx sensor should be considered an expendable component and a spare kept.

Three other displays of interest are:

1. "…." which means that a NOx module has not been assigned to that channel. See **MOd Setup Option**.
2. "----" which means that the display head has an internal problem.
3. "XXXX" which means that the display is not receiving any data. The NOx module is disconnected, dead, or the EIB cable is broken.

Appendix D: Calculating the $\%O_2$ in Air

The Configuration Tool Software has a routine to calculate the $\%O_2$ in air. If the software is not available, the below may be used.

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

Appendix E: LOCKing and unLOCKing Display Head

When the display head is locked, the parameters displayed and instrument setup cannot be modified. The display head can just be turned on and off.

◆ **To LOCK the display head**

1. Press SYS until "MOd" is displayed.
2. Press ↓ until "CONF" is displayed. Then press ENT.
3. Press ↓ until "MOdE" is displayed. Then press ENT.
4. Press ↓ until "LOCK" is displayed. Then press ENT.
5. "50" will be displayed. Press ↑ until "60" is displayed. Then press ENT. Display is now LOCKed.

◆ **To unLOCK the display head**

1. Press SYS until "LOCK" is displayed. Then press ENT.
2. "50" will be displayed. Press ↑ until "60" is displayed. Then press ENT. Display is now unLOCKed.

If an unauthorized person learns that 60 is the key number, contact ECM.

Appendix F: Using the Configuration Tool Software

The ECM Configuration Tool with be used with analyzers (i.e. NOx 5210, Lambda 5220, EGR 5230). One or more analyzers can be connected to the same CAN bus using the CAN connector on the back of the analyzers. Make sure that the CAN bus is properly terminated.

The Configuration Tool can be used for the following:

To produce a .dbc file for one or more analyzers on the same CAN bus.
Real-time display of data from analyzers. Only one analyzer's data is shown at a time.
Log data from one or more analyzers.

Once the analyzers are connected to the CAN bus and turned on, start the Configuration Tool, select the "Analyzers" tab, select the CAN Adapter, and then press the start button. "Status:" should change to "Port Opened".

◆ Producing a .dbc File

Devices receiving CAN messages from one or more analyzers must understand the format of the messages. A .dbc file is used to describe the format. Using the Configuration Tool, a .dbc file describing the format of messages from one or more analyzers on the same CAN bus can be created.

Each analyzer communicates eight pieces of data, two error codes, and two auxiliary codes. The eight pieces of data are: what is being sent to the six analog outputs and what is sent to the upper and lower displays. Before producing a .dbc file for the analyzer(s), each analyzer on the CAN bus should have its displays and analog outputs programmed for the desired data.

Once the analyzer(s) have been programmed, send (one analyzer at a time) each analyzer's message format to the Configuration Tool.

To do this:

In the software, press "Add Device"
On an analyzer, press SYS, arrow down to CONF, press ENT, arrow down to CAN, press ENT, and with "IdS" on the display, press ENT.
Five CAN ids need to be entered: one each for CID1, CID2, CID3, CID4, and ERCd. These are entered in decimals. The allowable range is 1 to 2047. If analyzers and modules are on the same CAN bus (not EIB bus), be careful to avoid using the CAN ids used by the modules. The CAN ids used by the modules are: 0x00, 0x80 + Module NID, 0x180 + NID, 0x280 + NID, 0x380 + NID, 0x480 + NID, 0x580 + NID, 0x600 + NID, 0x700 + NID, 0x7E4, and 0x7E5. Note that these module CAN ids are given in hex. CID1 is the CAN id for the data going to analog outputs 1 and 2. CID2 is for analog outputs 3 and 4. CID3 is for analog outputs 5 and 6. CID4 is for the upper and lower displays. ERCd is for the error codes and auxiliary codes. After entering the CAN id for ERCd, ".dBC" will appear on the

display. Press ENT and the format of the messages for that analyzer will be sent to the Configuration Tool.

Each analyzer's serial number will appear in the "Device:" window list (open window to see all present) after its message format has been received by the Configuration Tool. When an analyzer's serial number is in the "Device:" window, its data will appear at the bottom of the Configuration Tool's screen.

After the last analyzer on the CAN bus has sent its message format to the Configuration Tool, that list of analyzers can be saved using "Save List" and later recalled using "Load List". This saves having to resend message formats to the Configuration Tool next time the tool is used.

A .dbc file for all analyzers in the "Device:" window list is produced by pressing "Generate .dbc".

◆ Real-Time Display

When an analyzer's serial number is in the "Device:" window, its data will appear at the bottom of the Configuration Tool's screen.

◆ Logging Data

Analyzers whose serial numbers are in the "Device:" window list can be data logged. Press the "Log Data" button and follow the instructions. Data is saved in .csv format.

Appendix G: The NOx Type F Sensor

The NOx Type F sensor (P/N 06-09) is a modified NOx Type T sensor where the exhaust gases have to pass through an NH3-adsorbing filter before reaching the sense elements inside the sensor. Therefore, instead of measuring NOx + NH3 (as any NOx sensor does), the NOx Type F sensor measures NOx only. The NOx Type T sensor is to be used with the NOx 5210 Analyzer.

The NOx Type F sensor was designed to measure tailpipe-out NOx. Three-way catalysts on spark ignition engines produce NH3 when running stoichiometric and rich and diesels with uera injection will sometimes have NH3 at the tailpipe. Therefore, unless the NH3 is removed, a NOx sensor at the tailpipe will measure NOx + NH3.

Typically, the filter will adsorb NH3 for 30 minutes to 1 hour. Fortunately, the filter is easy to replace. The maximum recommended temperature at the filter is 225 °C.

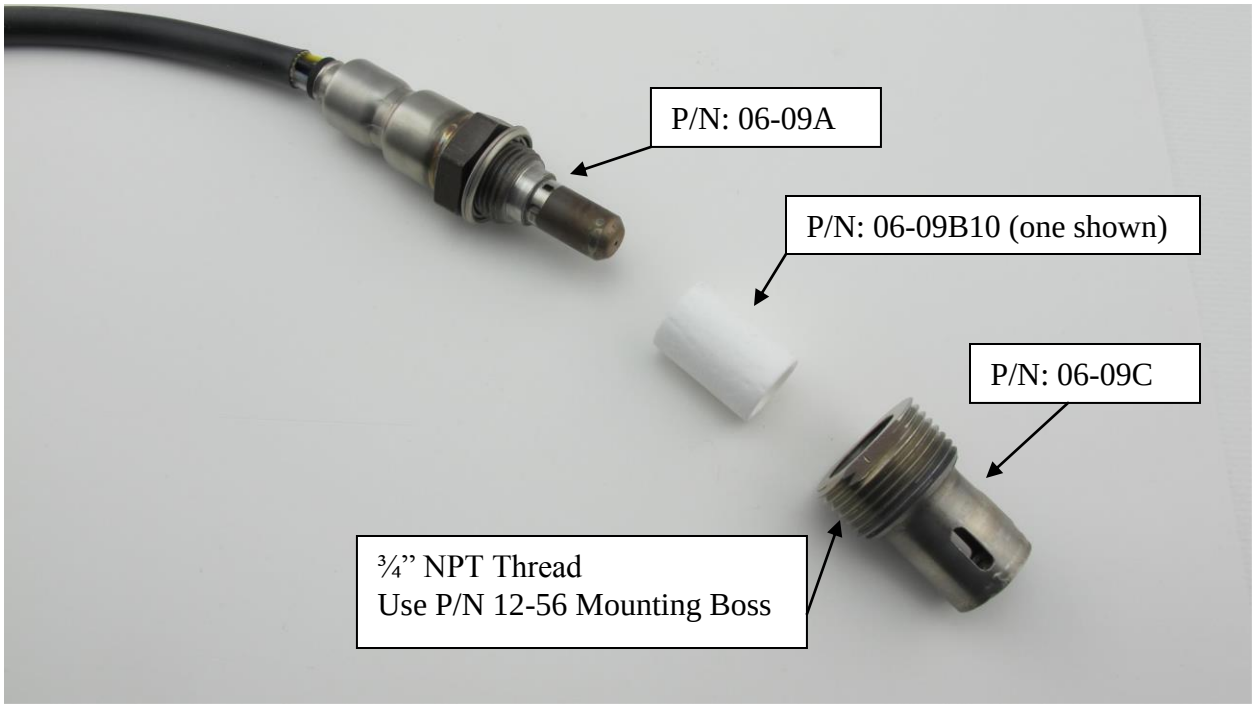


Figure G1: P/N: 06-09 is an assembly consisting of:
P/N: 06-09A Sensor Element
P/N: 06-09B10 Sensor Filter (package of 10)
P/N: 06-09C Cap

◆ **How to use the NOx Type F sensor**

1. Put antiseize on sensor thread

2. Put filter on sensor. Filter contains acid so use gloves.

3. Screw cap over sensor

4. Put antiseize on cap threads

5. Use P/N: 12-56 Mounting Boss (3/4” NPT)

6. Lightly tighten using hex on sensor

7. During removal, sometimes cap will remain in boss. Use flats to remove.

8. Typical application; mounted in tube attached to tailpipe

Warranty and Disclaimers

WARRANTY

The products described in this manual, with the exception of the NOx sensor and pressure sensor, are warranted to be free from defects in material and workmanship for a period of 365 days from the date of shipment to the buyer. Within the 365 day warranty period, we shall at our option repair 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 NOx sensor and pressure sensor are 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 display head is opened.

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.

ECM ENGINE CONTROL AND MONITORING

586 Weddell Drive, Suite 2
Sunnyvale, CA 94089-2134
USA
Phone: (408) 734-3433
FAX: (408) 734-3432
Email: sales@ecm-co.com
Web: www.ecm-co.com

EC DECLARATION OF CONFORMITY

We declare under our sole responsibility that the products:

AFM1540 Lambda Module
AFM1600 Lambda and O_2 Analyzer
DIS1000 Display Head
EGR 4830 Analyzer
Lambda 5220 Lambda Analyzer
NOx 5210 NOx Analyzer
EGR 5230 EGR Analyzer
LambdaCAN, LambdaCANc, LambdaCANd, LambdaCANp Lambda Modules
NOxCAN, NOxCANg, NOxCANt NOx Modules
NOx1000 NOx Module
baroCAN Module
dashCAN, dashCANc, dashCAN+
appsCAN
SIM300, SIM400, SIM500, SIM600, SIM700, SIM800
BTU200

To which this declaration relates are in conformity with the essential requirements of the following standards:
EN61326: 1997/A2: 2001 (Class A & Annex A)
EN61010-1: 2001 (Electrical Safety)

And therefore conform to the requirements of the following directives:
89/336/EEC Electromagnetic Compatibility (EMC)
72/23/EEC Low Voltage Directive (LVD)

Ronald S. Patrick
Vice President Sales
July 26, 2012

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