ECM ENGINE CONTROL AND MONITORING

NOxCAN* Module

(NOxCANt, NOxCANg, NOxCAN)

Instruction Manual

Important Note

Due to the nature of CAN instrumentation, you cannot just physically connect a measurement module to a bus and expect data from that module to be available. The NOxCAN* measurement module has to be set up to send the data required and the receiving device (ex. data acquisition software) has to know what is being sent. The setting up of modules and the production of a .dbc file used by the receiving device to interpret the data sent, is performed using the supplied Configuration Tool (i.e. software) which runs on a PC.

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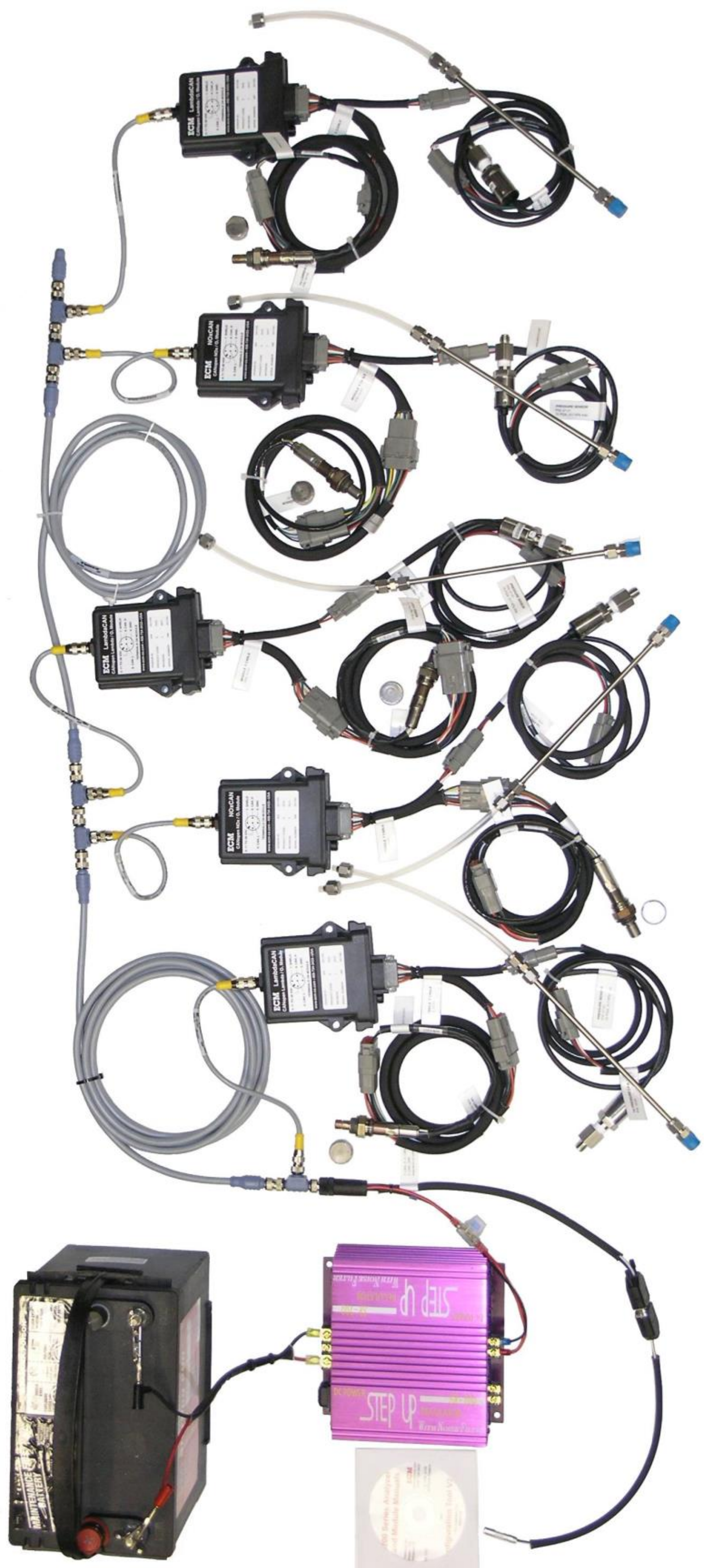


Complex measurement systems can be easily built with LambdaCAN*, NOxCAN*, and baroCAN modules. Here is a five-channel lambda, O_2, and NOx pressure-compensated in-vehicle system.

Introduction

ECM offers three NOx module kits: NOxCANt ("Type T"), NOxCANg ("Type G"), and NOxCAN (the original NOxCAN kit). The modules use different NOx sensors and must be matched to the correct module (i.e. a NOxCANt sensor cannot be used with a NOxCANg module). See Appendix A for kit contents. The specifications for the kits are as follows:

<u>NOxCANt Kit:</u>

Recommended for general-purpose NOx measurement for combustion processes that can be rich, lean, and stoichiometric (i.e. all Lambda. ex. spark ignition engines).

Ranges: **NOx:** 0 to 5000 ppm (wet), (For all λ)
λ (Lambda): 0.4 to 25
AFR: 6 to 364
%O2: 0 to 25% (wet)
Accuracies: **NOx:** ± 20 ppm (0 to 1000 ppm), ± 2% (elsewhere)
λ, AFR, φ: ± 0.8% (at stoichiometric), ± 1.8 (average, elsewhere)
%O2: ± 0.2% (absolute)
Response Times: **NOx:** Less than 1 sec., **λ, AFR, φ, O2:** Less than 150 ms
Sensor Mounting: 18mm x 1.5mm thread

<u>NOxCANg Kit:</u>

Recommended for NOx measurement for combustion processes that are only lean of stoichiometric (i.e. Lambda > 1. ex. diesel engines).

Ranges: **NOx:** 0 to 5000 ppm (wet), (For λ > 1 only)
λ: 0.4 to 25
AFR: 6 to 364
%O2: 0 to 25% (wet)
Accuracies: **NOx:** ± 15 ppm (0 to 1000 ppm), ± 1.5% (elsewhere)
λ, AFR, φ: ± 0.8% (at stoichiometric), ± 1.8 (average, elsewhere)
%O2: ± 0.2% (absolute)
Response Times: **NOx:** Less than 1 sec., **λ, AFR, φ, O2:** Less than 150 ms
Sensor Mounting: 20mm x 1.5mm thread

<u>NOxCAN Kit (The "Original" NOxCAN Kit):</u>

For all Lambda; however, recommend using NOxCANt or NOxCANg Kit for new applications.

Ranges: **NOx:** 0 to 5000 ppm (wet), (For all λ)
λ: 0.4 to 25
AFR: 6 to 364
%O2: 0 to 25% (wet)
Accuracies: **NOx:** ± 30 ppm (0 to 1000 ppm), ± 3% (elsewhere)
λ, AFR, φ: ± 0.8% (at stoichiometric), ± 1.8 (average, elsewhere)
%O2: ± 0.2% (absolute)
Response Times: **NOx:** Less than 0.7 sec. (NOx), **λ, AFR, φ, O2:** Less than 150 ms
Sensor Mounting: 18mm x 1.5mm thread

<u>For all Pressure-Compensated Kits:</u> 0 to 75 psia (517 kPa) range, ± 5.2 kPa (± 0.75 psia)

Setup and calibration of NOxCAN* kits is performed using the supplied PC software program called "The Configuration Tool". The Configuration Tool uses a CAN communication device to communicate with one or more ECM *CAN modules (i.e. NOxCAN*, LambdaCAN*, baroCAN, appsCAN) or analyzers (i.e. NOx 5210, Lambda 5220, EGR 5230). While the tool is being used with modules, just ECM modules set to stand-alone mode (see Appendix B) should be connected to the CAN bus. While the tool is being used with analyzers, just analyzers should be connected to the CAN bus. With analyzers, the Configuration Tool is just used to produce .dbc files. However with modules, the Configuration Tool replaces the analyzer's display head as the user interface so it must do much more. This document focuses on using the Configuration Tool with ECM's NOxCAN* modules.

The Configuration Tool supports four CAN communication devices: Kvaser, ETAS, Peak USB-to-CAN adapters, and the VectorCAN CAN adapter card. Driver software for one of these adapters must be installed prior to using the Configuration Tool. This software will be supplied with the adapter or be available on-line. ECM's Configuration Tool is delivered on a CD.

Once the adapter's driver and the Configuration Tool software are installed, and with the module(s) powered and connected to the CAN adapter, start the Configuration Tool software. Click on the "Modules" tab, select the CAN adapter, and click on the "START" button.

The software will identify the modules on the bus and display them in the "Module" field. If this does not happen, make sure that the CAN bus is properly terminated (i.e. resistors). Open the Module field to see all the modules on the bus. If a module is not listed, one reason could be that its Node ID is the same as another module. To resolve this, remove all modules except the "missing" one from the CAN bus, STOP then START the software, and change that module's Node ID. Another reason that a module is not listed could be that the module is in EIB mode instead of stand-alone mode. All modules must be in stand-alone mode.

To configure one of the modules (ex. change its Node ID) or to look at that module's data, you have to select that module in the "Module" field.

There are three things you can do with modules using the Configuration Tool:

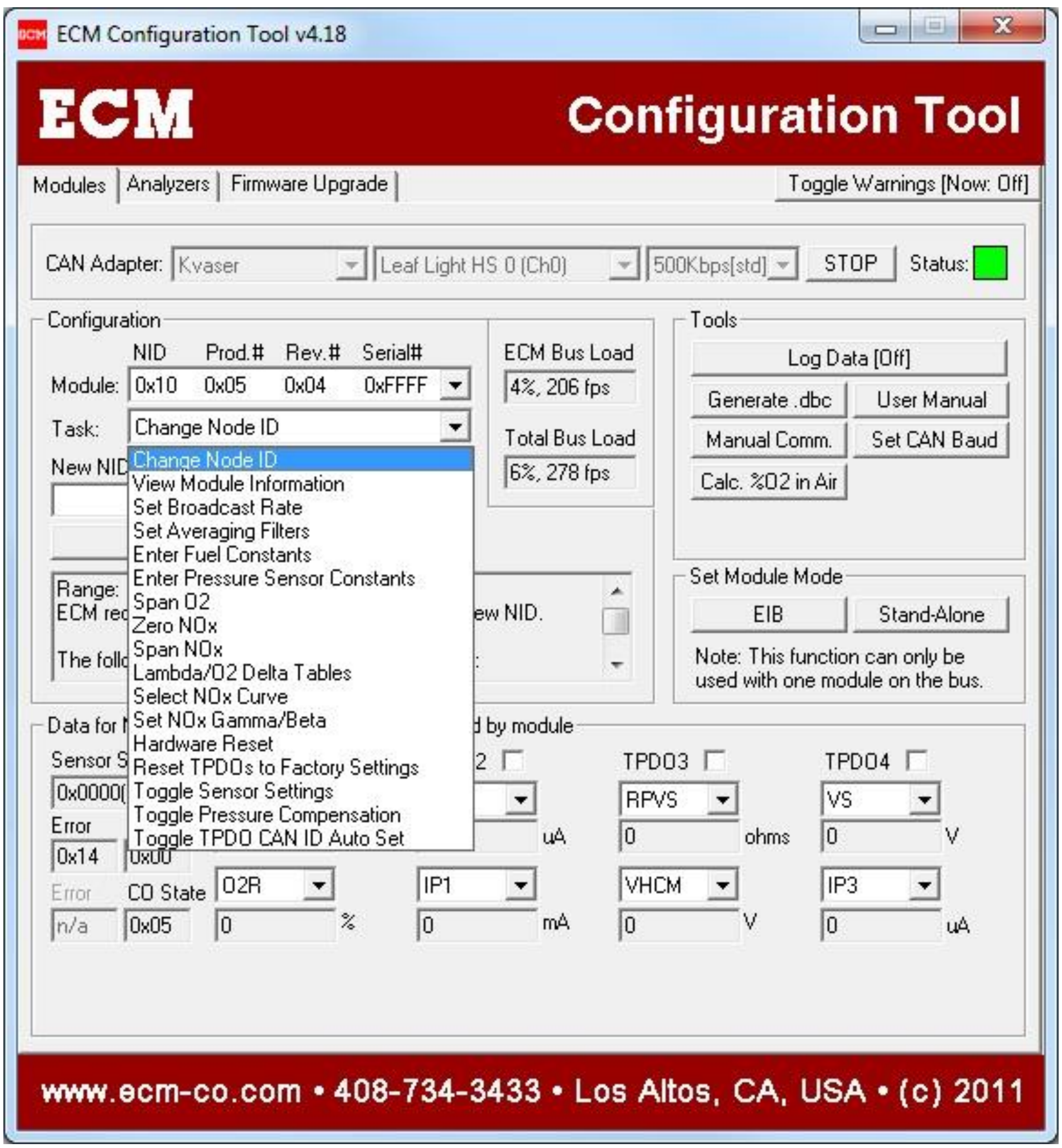
1. Configure a module. This includes calibrating a sensor attached to the module.
2. Look at data coming from that module in real-time and optionally log it.
3. Produce a .dbc file to be used by a device receiving module data.

Alternatively, 1. and 2. (above) can be performed by direct CAN communication with the NOxCAN* module using user-written software. For information on how to do this and detailed information about the modules, refer to the NOxCANt, NOxCANg, or NOxCAN Instruction Manual.

Configuring a Module

Normally, you will be configuring a module to be used in stand-alone mode. Stand-alone mode is used when the modules are connected to a CAN bus that goes directly to a data acquisition system. In stand-alone mode, a module's configuration is performed by selecting one of the tasks in the "Task" field. When a module is connected to a NOx 5210, Lambda 5220, or EGR 5230 Analyzer, it must be in EIB mode. In EIB mode, most of these tasks are performed using the analyzer. Appendix B describes how to configure a module to operate in one mode or the other.

The following assumes that the module is to be used in stand-alone mode. The tasks available for NOxCAN* modules are listed in Table 1.



Change Node ID: Allowable range 0x01 to 0x7F (hex). When you assign a Node ID (NID), the following CAN IDs **cannot be used** by any other devices on the bus: 0x00, 0x80 + NID, 0x180 + NID, 0x280 + NID, 0x380 + NID, 0x480 + NID, 0x580 + NID, 0x600 + NID, 0x700 + NID, 0x7E4, 0x7E5.

View Module Information: Manufacturer's Name, Hardware Version, Software Version

Set Broadcast Rate: All activated TPDOs are transmitted every "n" milliseconds. "n" can be programmed. 5 ms is the minimum. Default: 5 ms.

Set Averaging Filters: Before the data is transmitted by the module (at the broadcast rate), it can be averaged. There are three averaging filters (alphas): one for NOx (i.e. NOx, IP2, IP2X, IP2R, IP3), one for Lambda (i.e. O2R, IP1, IP1X, IP1R, LAMR, AFR, PHI, FAR, LAM, O2), and one for Pressure (i.e. PR16, PR10, PCF, P, PVLT, PKPA, P, PVLT, PKPA, PBAR, PPSI). Alphas can range from 0.001 to 1 and are used in the recursive averaging filter: $AvgData_t$ = alpha x $Data_t$ + (1-alpha) x $AvgData_{t-1}$.

Where: $AvgData_t$ is the transmitted data at time "t".

$AvgData_{t-1}$ is the previously transmitted data.

$Data_t$ is the raw data at time "t".

This formula is executed every 5 ms regardless of broadcast rate. Note that if alpha = 1, there is no averaging and the data taken at time "t" becomes the average value at time "t" and hence the broadcast value. Default Alpha values: 0.375.

Enter Fuel Constants: H:C, O:C, and N:C ratios or if the fuel is H2. Defaults: H:C = 1.85, O:C = 0, N:C = 0

Enter Pressure Sensor Constants: N and C are the gain and offset of the pressure sensor. N and C are written on a label attached to the pressure sensor. P (psia) = N x (V - C). V = voltage from sensor.

Span O2: User enters displayed %O2 (TPDO data) and the actual %O2 of the span gas. This is how you calibrate the O2 (AFR, Lambda, PHI, FAR) measurement function of the NOx sensor.

Zero NOx: User enters displayed NOx value (TPDO data) and the actual NOx value of the "zero" gas. Zero gas does not necessarily have to be exactly zero. A non-zero value can be entered.

Span NOx: User enters displayed NOx value (TPDO data) and the actual NOx value of the gas. Preferentially Span near the upper NOx value to be measured.

Lambda/O2 Delta Tables: These tables are used to modify the calculated O2 and Lambda (and hence AFR, FAR, and PHI). There are two tables. The first, the Delta O2 Table, allows modification of the calculated %O2 via a user-entered look-up table. Delta O2 Table entries will not influence Lambda, AFR, FAR or PHI values. The second, the Delta Lambda Table, allows modification of the calculated Lambda (and hence AFR, FAR, and PHI) via a user-entered look-up table. The Delta Lambda table will not influence O2 values. See Appendix C.

Select NOx Curve (NOxCANg only): Match engine (wet) data or model gas data.

Set NOx Gamma/Beta (NOxCANg only): User enters parameters for O2 compensation.

Hardware Reset: Equivalent to powering the module down then up again.

Reset TPDOs to Factory Settings: These are the parameters displayed and transmitted. TPDO stands for Transmit Process Data Object.

Toggle Sensor Settings: Allows power to ceramic sensor to be turned on and off and enables rapid sensor warm-up scheduling (Default: On (fast)).

Toggle Pressure Compensation: Enable and disable pressure compensation of O2 (Lambda, AFR, FAR, PHI) and NOx data. Defaults: On.

Toggle TPDO CAN ID Auto Set: Enable and disable TPDO CAN ID Auto Set. Default: En.

Table 1: Task List for NOxCAN* Modules

Calibration of the NOx Sensors

Ceramic NOx sensors operate on a diffusion mechanism. Molecules leaving the combustion chamber diffuse through passages into the sensor where oxidation, oxygen pumping, and oxygen stripping occurs. Diffusion passages are like filters and can get clogged. In fact, it is impossible to avoid clogging when the sensor is being used. The clogging of diffusion passages is the main mechanism by which a sensor "ages" resulting in a calibration shift.

Sensors shipped with NOxCAN* modules have been calibrated (i.e. zeroed and spanned) before leaving the factory. It is recommended that they be calibrated periodically during use. How often can only be determined by your experience. Alternatively, sensors can be sent to ECM for recalibration.

Calibration information (both factory calibration and user calibration) for the NOx sensors is stored in a memory chip in the sensor's connector. Therefore, the sensor does not have to be used with the module it was calibrated with. Once calibrated, the sensor can be sent to another site to be used. After use, the sensor can be returned to the calibration center for recalibration thus compensating for any sensor aging. Centralization of calibration in this way improves measurement consistency and extends useful sensor life.

Calibration should be performed in this order: Span O2, Zero NOx, Span NOx. The sensor does not require the "Zero O2" task.

Span O2 for NOxCANt, NOxCANg, and the Original NOxCAN

The "Span O2" task in the Configuration Tool calibrates both the %O2 and Lambda (AFR, FAR, PHI) measurements of the sensor. To perform an O2 span:

1. The NOx sensor and pressure sensor (if so equipped) should on for at least 20 minutes.
2. Hang the NOx sensor and the pressure sensor (if equipped) in ambient, stationary air. The pressure is required during calibration if the sensor's %O2 and Lambda (AFR, FAR, PHI) measurements are to be pressure compensated.
3. Calculate the %O2 in the air. The %O2 in air with no humidity is 20.945. This percentage decreases with increasing humidity. To calculate the %O2 in non-zero humidity air, use the "Calculate %O2 in Air" tool in the Configuration Tool. 20.7 is a common number.
4. Select O2 as a TPDO parameter.
5. Select the Task "Span O2". Enter the displayed O2 (the TPDO parameter) and the actual %O2 (as calculated in 3 above), then click on "Span".

◆ Delta O2 Table and Delta Lambda Table

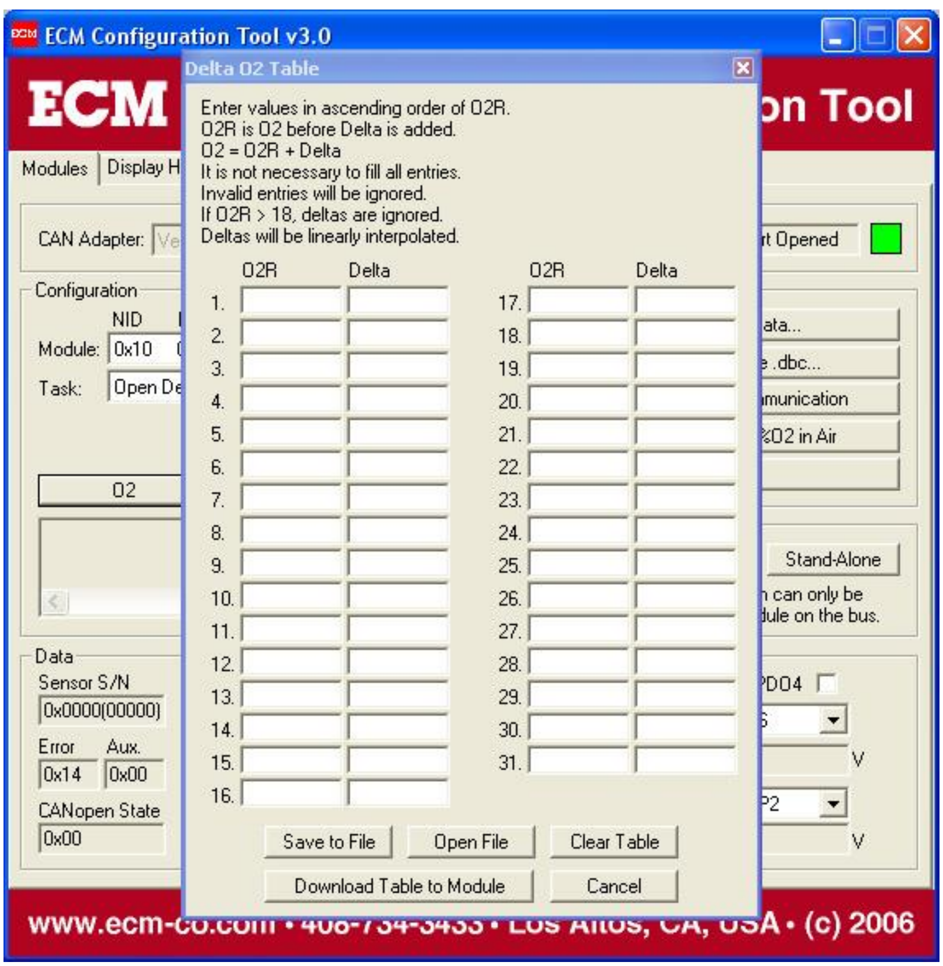
The %O2 calculated by NOxCAN* modules is denoted as "O2R" and is a wet (i.e. water taken into consideration in %O2 calculation), at chemical-equilibrium (i.e. not frozen-equilibrium) %O2 measurement (see Appendix C). The Lambda (AFR, FAR, PHI) calculated by NOxCAN* modules is denoted as "LAMR" and matches that calculated by mass flowrates of air and fuel entering the engine.

Sometimes users would like dry %O2 readings, or frozen-equilibrium %O2 readings, or dry frozen-equilibrium readings, or readings that match another instrument. For this purpose, the Delta O2 Table is used. The Delta O2 Table (found in the "Lambda/O2 Delta Tables" task) allows the user to add a number (a "delta") to the "O2R" calculated by the NOxCAN* modules giving the "O2" parameter:

O2 = O2R + Delta O2 Table value (interpolated from table)*

* except when O2R > 18 for which O2 = O2R, regardless of table data.

A Delta O2 Table can be created, edited, and saved as a text file (.txt) on your PC. The file must be downloaded into the NOxCAN* module for it to be used. Unlike the sensor calibration information (i.e. zero, span) which is stored in a memory chip in the sensor's connector, the Delta O2 Table is stored in the module.



Similarly, sometimes users would like Lambda (AFR, FAR, PHI) readings to match other instruments such as gas-bench analyzer calculated values (ex. via Spindt or Brettschneider) or company "heritage" Lambda measurement techniques. The Delta Lambda Table (found in the "Lambda/O2 Delta Tables" task) allows to user to add a number (a "delta") to "LAMR" calculated by the NOxCAN* modules giving the "LAM" parameter:

LAM = LAMR + Delta Lambda Table value (interpolated from table)

AFR, FAR, and PHI are calculated from "LAM". A Delta Lambda Table can be created, edited, and saved as a text file (.txt) on your PC. The file must be downloaded into the NOxCAN* module where it is used. File LA42.TXT (for LSU4.2 sensor) or file LA49.TXT (for LSU4.9 sensor) can be downloaded to make NOxCAN* modules match default ETAS LA4 data (see Appendix C). Unlike the sensor calibration information (i.e. zero, span) which is stored in a memory chip in the sensor's connector, the Delta Lambda Table is stored in the module.

Zero and Span NOx for NOxCANt and NOxCANg

The following applies to the calibration of the NOxCANt and NOxCANg kits only. For the calibration of the original NOxCAN kit, refer to the next section.

Calibration should be performed in this order: Span O2, Zero NOx, Span NOx.

It is important to realize that when in the exhaust of a running engine, the NOx sensor is seeing water vapor. Therefore it will report "wet" %O2 and NOx ppm numbers. Classical gas analysis equipment (ex. NOx Chemiluminescent Analyzer (CLA)) typically have the water removed from the gases before they reach the analyzer. Thus classical gas analysis equipment will report "dry" numbers which are greater than "wet" numbers. When comparing "wet" to "dry" numbers make sure to compensate for the removed water.

The Zero NOx and Span NOx tasks can be performed either using model gases or in a running engine. Model gases are mixtures of NOx, O2, and N2 from bottled tanks that have been bubbled through water before reaching the sensor.

◆ Calibrating Using Model Gases

When calibrating the NOx sensor using model gases, the recommended procedure is:

1. The NOx sensor and pressure sensor (if so equipped) should on for at least 20 minutes.
2. Hang the NOx sensor and the pressure sensor (if equipped) in ambient, stationary air. The pressure is required during calibration if the sensor's NOx measurements are to be pressure compensated.
3. (For NOxCANg Only): Select "Model Gas" in the task "Select NOx Curve".
4. (For NOxCANg Only): There are four O2 compensation parameters (two gammas, and two betas) that affect the calculated NOx. One set of gamma, beta is used for the engine NOx calculation and the other for the model gas NOx calculation. These

numbers are factory-set to nominal values, stored in the sensor's memory chip, and should not be changed without contacting ECM.

5. Perform the "Span O2" task if not performed earlier.
6. Perform the "Zero NOx" task with the NOx sensor and pressure sensor (if so equipped) hanging in ambient, stationary air (i.e. same condition as "Span O2"). **IMPORTANT NOTE**: Do not zero in pure N2 or N2 that has been bubbled through water! This will damage the NOx sensor.
7. Perform the "Span NOx" task with the NOx sensor mounted in a vessel. The pressure sensor should be measuring the pressure in the vessel if the NOx measurements are to be pressure compensated. Use the supplied pressure line assembly to avoid overheating the pressure sensor. Flow gases of the composition NO + O2 (approximately 20%) + N2 (balance) through a bubbler and through the vessel containing the NOx sensor. The NO concentration (ppm) should be close to the maximum ppm that is expected in the engine**.** **IMPORTANT NOTE**: Do not span in a mixture that contains less than 1% O2! Use approximately 20% O2 for best calibration. The flowrate should be less than 5 lpm.
8. Correct the span NOx ppm content of the gas for water vapor using the formula:

NOx (corrected) = NOx (before bubbler) x ((%O2 in air)/20.945)

where: "%O2 in air" is determined using the "Calculate %O2 in Air" tool with Rh=100%, the pressure in the bubbler, and the water temperature in the bubbler.

IMPORTANT NOTE: We have found that the best calibration is performed based on 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 model gas tanks to the sensor.

9. "Span NOx" when the displayed NOx (the TPDO parameter) is stable.
10. (For NOxCANg Only): Select "Engine" in the task "Select NOx Curve" before using the NOx sensor in an engine.

◆ Calibrating Using Engine Gases

When calibrating the NOx sensor using engine gases, the recommended procedure is:

1. Hold the powered NOx sensor and pressure sensor (if so equipped) in air for 20 minutes. Pressure information is required if the calibration is to be pressure compensated.
2. (For NOxCANg Only): Select "Engine" in the task "Select NOx Curve".
3. (For NOxCANg Only): There are four O2 compensation parameters (two gammas, and two betas) that affect the calculated NOx. One set of gamma, beta is used for the engine NOx calculation and the other for the model gas NOx calculation. These numbers are factory-set to nominal values, stored in the sensor's memory chip, and should not be changed without contacting ECM.
4. Perform the "Span O2" task if not performed earlier.
5. Perform the "Zero NOx" task with the NOx sensor and the pressure sensor sensing the exhaust of a running engine and in comparison to a CLA. The pressure sensor should be measuring the pressure in the exhaust if the NOx measurements are to be

pressure compensated. Use the supplied pressure line assembly to avoid overheating the pressure sensor. The NOx level doesn't have to be exactly zero for the zero process. To get a low NOx number, the engine should not be under load and EGR should be used. For example, if it is 12 ppm, the Configuration Tool will allow for this. Since water is in the gases that the NOx sensor is seeing, it is best to use a "wet" NOx number from the CLA. If you do not do this, you are putting an error into the measurement since %H2O, and hence the difference between a "wet" and "dry" measurement, changes with stoichiometry.

6. Perform the "Span NOx" with the NOx sensor in a running engine and in comparison to a CLA. Span at the upper range of NOx to be measured. To get a high NOx number, the engine should be under load with no EGR. Again, it is best to use a "wet" NOx number from the CLA.

Zero and Span NOx for the Original NOxCAN

The following applies to the calibration of the original NOxCAN kit only. For the calibration of a NOxCANt or NOxCANg kit, refer to the previous section. Note that the original NOxCAN kit has been replaced by the NOxCANt kit.

Calibration should be performed in this order: Span O2, Zero NOx, Span NOx.

It is important to realize that when in the exhaust of a running engine, the NOx sensor is seeing water vapor. Therefore it will report "wet" %O2 and NOx ppm numbers. Classical gas analysis equipment (ex. NOx Chemiluminescent Analyzer (CLA)) typically have the water removed from the gases before they reach the analyzer. Thus classical gas analysis equipment will report "dry" numbers which are greater than "wet" numbers. When comparing "wet" to "dry" numbers make sure to compensate for the removed water.

The NOx sensor in the original NOxCAN kit was designed to be used in a hot exhaust pipe. If it is mounted in a cold sample tube, the NOx measurement response will be very slow (i.e. hundreds of seconds). Also, the zero and gain of the NOx measurement is sensitive to changes in the exhaust pipe's temperature. To reduce this sensitivity, ECM offers a heated NOx sensor mount (the BTU200). With or without the BTU200, for best accuracy the NOx sensor should be calibrated in a mounting pipe and with the pipe temperature similar to that it will be used at.

The gases the NOx sensor is measuring must contain water. Since the combustion of hydrocarbon fuels produces approximately 2 to 12% water (depending on fuel type and Lambda), this is not a problem unless the sensor is placed after a water separator. Also, for best accuracy, the NOx sensor should be calibrated in gases with approximately the same amount of water vapor as is in the exhaust it will be measuring.

When the NOx sensor is off (i.e. cold) and is stored for a period longer than a few days, the sensor may adsorb water vapor. This results in a NOx measurement error until the water is evaporated off the sensor. When the sensor is used in an engine, this will occur quickly. However, if the sensor is held in air or is mounted in a cold pipe with slow moving gases, it may take up to eight hours for the water to evaporate off.

To minimize above-described effects, it is strongly recommended that the NOx zero and span be performed with the NOx sensor mounted in the exhaust of a running engine and in comparison to a CLA. It is not recommended that the NOx sensor be calibrated using the CLA's zero and span gases (i.e. "model gases") because the NOx sensor will be mounted in a cold tube during this calibration and water vapor will not be present in suitable quantities in the calibration gases.

Therefore, the recommended calibration procedure for the original NOxCAN and uses engine gases.

◆ Calibrating Using Engine Gases (Recommended for Original NOxCAN)

1. Hold the powered NOx sensor and pressure sensor (if so equipped) in air for eight hours. This is to remove any adsorbed water. Pressure information is required if the calibration is to be pressure compensated.
2. Perform the "Span O2" task if not performed earlier.
3. Perform the "Zero NOx" task with the NOx sensor and the pressure sensor sensing the exhaust of a running engine and in comparison to a CLA. The pressure sensor should be measuring the pressure in the exhaust if the NOx measurements are to be pressure compensated. Use the supplied pressure line assembly to avoid overheating the pressure sensor. The NOx level doesn't have to be exactly zero for the zero process. To get a low NOx number, the engine should not be under load and EGR should be used. For example, if it is 12 ppm, the Configuration Tool will allow for this. Since water is in the gases that the NOx sensor is seeing, it is best to use a "wet" NOx number from the CLA. If you do not do this, you are putting an error into the measurement since %H2O, and hence the difference between a "wet" and "dry" measurement, changes with stoichiometry.
4. Perform the "Span NOx" with the NOx sensor in a running engine and in comparison to a CLA. Span at the upper range of NOx to be measured. To get a high NOx number, the engine should be under load with no EGR. Again, it is best to use a "wet" NOx number from the CLA.

◆ Calibrating Using Model Gases (Not Recommended for Original NOxCAN)

If a NOx CLA is not available, the back-up calibration procedure for the NOx sensor used in the original NOxCAN is:

1. Hold the powered NOx sensor and pressure sensor (if so equipped) in air for eight hours. This is to remove any adsorbed water. Pressure information is required if the calibration is to be pressure compensated.
2. Perform the "Span O2" task if not performed earlier.
3. Mount the NOx sensor in a BTU200 heater or in a tube heated to the temperature of the exhaust pipe that the sensor will be used in.
4. Perform the "Zero NOx" task with the NOx sensor and pressure sensor (if so equipped) exposed to ambient, stationary air. **IMPORTANT NOTE**: Do not zero in pure N2 or N2 that has been bubbled through water! This will damage the NOx sensor.
5. Perform the "Span NOx" task with the NOx sensor mounted in a vessel and in the same heated condition as during "Zero NOx". The pressure sensor should be measuring the pressure in the vessel if the NOx measurements are to be pressure compensated. Use the supplied pressure line assembly to avoid overheating the pressure sensor. Flow gases of the composition NO + O2 (approximately 20%) + N2 (balance) through a bubbler and through the vessel containing the NOx sensor. The NO concentration (ppm) should be close to the maximum ppm that is expected in the engine**. IMPORTANT NOTE**: Do not span in a mixture that contains less than 1% O2! Use approximately 20% O2 for best calibration. The flowrate should be less than 5 lpm.

6. Correct the span NOx ppm content of the gas for water vapor using the formula:

NOx (corrected) = NOx (before bubbler) x ((%O2 in air)/20.945)

where: "%O2 in air" is determined using the "Calculate %O2 in Air" tool with Rh=100%, the pressure in the bubbler, and the water temperature in the bubbler.

IMPORTANT NOTE: We have found that the best calibration is performed based on 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 model gas tanks to the sensor.

7. "Span NOx" when the displayed NOx (the TPDO parameter) is stable.

The following conditions may result in inaccurate NOx readings:

1. If the NOx sensor is not held in air for eight hours (while powered) prior to calibration.
2. If a BTU200 is not used or if the pipe the sensor is mounted in during calibration is not heated.
3. If the calibration model gases are not bubbled through water.
4. If the calibration model gases change composition while flowing from the tanks to the sensor.
5. If the NOx sensor is subsequently used in an unheated sample line.
6. If the NOx sensor subsequently measures exhaust gases after these gases have passed through a water separator.

IMPORTANT NOTE: ECM has found it very difficult to accurately calibrate the original NOxCAN NOx sensor using model gases. Calibrate in an engine and in comparison to a NOx CLA if possible or send the NOx sensor back to ECM for calibration.

Selecting What Data is to be Sent (TPDOs)

Data send from NOxCAN* modules is packaged as TPDOs (Transmit Process Data Object). Each TPDO contains two pieces of data and each module can send up to four TPDOs. All selected TPDOs will be sent at the broadcast rate. For example, if the broadcast rate is 5 ms and four TPDOs were selected to be sent, then eight pieces of data would be transmitted every 5 ms. To avoid slowing down the effective data rate on the CAN bus, select the number of TPDOs to be sent and the broadcast rate sparingly. For the case of multiple modules sending multiple TPDOs on the same CAN bus, the minimum (i.e. fastest) broadcast rate is given by:

Minimum Broadcast rate (ms) = The total number of TPDOs for all modules x 0.3125

For example, if there are eight modules, each sending two TPDOs, the minimum broadcast rate is 5 ms.

The data transmitted is selected in the "Data" area of the Configuration Tool. Activate the number of TPDOs to be used by clicking in its box to put in a check mark. Select the data contained in each TPDO using the pull-down windows. The list of available parameters for the NOxCAN* module is given in Table 2.

Note that in the parameter list, there are two Lambdas: LAMR (Lambda Real) and LAM (Lambda).

LAMR is the Lambda value calculated by the module.

LAM is the Lambda value calculated by the module and modified by the Delta Lambda Table according to the relationship:

LAM = LAMR + Delta Lambda Table value (interpolated from table)

The modified LAM (Lambda) will also influence AFR, FAR, and PHI.

Similarly for O2R and O2:

O2 = O2R + Delta O2 Table value (interpolated from table)*

* except when O2R > 18 for which O2 = O2R, regardless of table data.

Parameter Name Displayed	**Full Parameter Name**	**Parameter Description**
NOX	NOx (ppm)	NOx
O2R	%O2real (%)	%O2 before addition of Delta O2 Table
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	VP1+ (V)	NOx sensor Ip1 pumping voltage
VP2	VP2 (V)	NOx sensor Ip2 pumping voltage
VSW	Vsw (V), not used for NOxCANg	Supply voltage measured at the module
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 pressure compensation correction factor x 10000
PCFE		ECM diagnostic parameter
O2E		ECM diagnostic parameter
IP1E		ECM diagnostic parameter
PE		ECM diagnostic parameter
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
IP1X	Ip1 non Pcomp (mA)	Non-pressure compensated NOx sensor Ip1 pumping current
PVLT	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), NOxCANg only	NOx sensor Ip3 pumping current
IP2X	Ip2 non Pcomp (µA), NOxCANg and NOxCANt only	Non-pressure compensated NOx sensor Ip2 pumping current
NCF	NOx Pressure Correction Factor, NOxCANg and NOxCANt only	NOx sensor Ip2 pressure compensation correction factor x 10000

Table 2: NOxCAN* Parameter List

Producing a .dbc File

A .dbc file describes to the device receiving data from one or more *CAN modules what is in the data packages. For each module, the packages will contain data for the parameters selected in the activated TPDOs and an error code. The Configuration Tool has a tool called "Generate .dbc…" that will generate a .dbc file for all the *CAN modules on a CAN bus. Make sure that each module is configured as desired and that all modules are on the bus before the "Generate .dbc…" button is pushed. Data package information from all the modules is stored in the one .dbc file produced.

Programs importing the .dbc file and applying it to the CAN data transmitted by the modules will see data, etc identified as follows:

Data: **name_nid[units]**

where: name = parameter name. See Table 2.
nid = node id of module in hex
units = units of parameter

for example: O2_0X01[%] which is the %O2 measured by module with nid 0X01

Error code: **ECM_Error_Code_nid**

where nid = node id of module hex
error code is in hex and given in Table 3

for example: ECM_Error_Code_0x11

Auxiliary: **ECM_Auxiliary _time[sec]**

where: time = decrementing countdown to module activation in hex

for example: ECM_Auxiliary_0X12[sec]

ECM ERROR CODE	LED ACTION	DESCRIPTION OF ERRORS
0x0000	Grn ON	All OK, (green led constantly on)
0x0001	Flash Grn 10Hz	Sensor warm-up period
0x0002	Grn/Both/Red 2s	Power on reset/ Init hardware
0x0011	Pulse Red 1x/2s	16b ADC failed to init
0x0012	Pulse Red 1x/2s	+Vsw shorted
0x0013	Red ON	Sensor turned off (red led constantly on)
0x0014	Pulse Red 1x/2s	HTR open
0x0015	Pulse Red 1x/2s	HTR shorted
0x0021	Pulse Red 2x/2s	1wire bus shorted
0x0022	Pulse Red 2x/2s	No 1wire present
0x0023	Pulse Red 2x/2s	CRC16 error
0x0024	Pulse Red 2x/2s	Invalid 1wire parameter (sensor type)
0x0025	Pulse Red 2x/2s	1-wire data format not compatible (old rev)
0x0031	Pulse Red 3x/2s	+Vsw < 6 for > 7sec
0x0032	Pulse Red 3x/2s	+Vsw > 30V
0x0041	Pulse Red 4x/2s	VS too high
0x0051	Pulse Red 5x/2s	RVS too high
0x0052	Pulse Red 5x/2s	(VHcommanded - VHactual) > 0.5V for > 10sec
0x0061	Pulse Red 6x/2s	VP+ > 6V
0x0062	Pulse Red 6x/2s	VP+ < 2V
0x0063	Pulse Red 6x/2s	VP2 out of range (NOxCAN* only)
0x0064	Pulse Red 6x/2s	0.15V > VS+ > 0.75V for 7.5 sec.
0x0065	Pulse Red 6x/2s	User data (span) in 1wire corrupted (user must set new span)
0x00A1	N/A	Invalid software state
0x00B1	N/A	CAN overrun
0x00B2	N/A	CAN passive mode
0x00B3	N/A	CAN heartbeat error
0x00B4	N/A	CAN recover bus off
0x00B5	N/A	CAN Tx CanId collision
0x00B6	N/A	Serial overrun
0x00FF	Both ON	Module powering down within 500ms
ECM AUX	N/A	Sensor Warm-up count down in seconds (active during ECM Error Code 0x0001)

Table 3: NOxCAN* Error Codes List

Using the dashCAN* Display

The dashCAN display (see cover and below) is a small (105 mm x 63 mm x 63 mm), display for CAN networks containing ECM *CAN modules. dashCAN+ is a slightly larger display (105 mm x 63 mm x 165 mm) with the addition of six programmable analog outputs. dashCAN* (i.e. dashCAN or dashCAN+) comes with a two meter cable and a "T" (P/N 09-05). Simply attach dashCAN* to the CAN bus and parameters from two ECM *CAN modules can be displayed and converted to analog outputs (dashCAN+ only). The top display and analog outputs 1, 2, and 3 can be assigned to one module and the bottom display and analog outputs 4, 5, and 6 can be assigned to the same or another module. Multiple dashCAN* displays can be attached to the CAN bus.

dashCAN* has two modes of operation: RUN (when measurements are displayed) and SYS (where dashCAN* is set-up). The SYS key toggles between the modes.

While in RUN mode:

i. If the ↑ button is pressed, the displays will show the serial numbers of the modules assigned to the displays (a module is assigned to the top display and analog outputs 1, 2, 3 and a module is assigned to the bottom display and analog outputs 4, 5, 6).
ii. If the ↓ button is pressed, the displays will show the parameter names assigned to the displays. See Table 2.
iii. If the ENT button is pressed, the displays will show the units of the parameters. "PCTG" is %. "dIM" means dimensionless (ex. for AFR, FAR, PHI, Lambda).

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

i. "ERR" and "####" where "####" is an error code. See Table 3.
ii. "…." which means that a module has not been assigned to that display.
iii. "----" which means that dashCAN* has an internal problem.
iv. "XXXX" which means that dashCAN* is not receiving any data from the module assigned to that display.

When first entering SYS mode, either "MOd" will be on the top display or "LOCK" will be on the bottom display. If "MOd" is displayed, the ↑ and ↓ keys will roll through the setup options (see Table 4). First the options for the module assigned to the top display are shown on the top display, followed by identical options for the module assigned to the bottom 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 dashCAN* has been locked and its setup cannot be changed until it is unlocked. Appendix F describes how to LOCK and unlock dashCAN*.

Setup Option	Level 1	Function
MOd		Select module s/n to be assigned to the display. Default is NONE.
RATE		Set parameter averaging rate. Range 0.001 to 1.000 Default is 1.000. 1.000 means no averaging.
AOUT (dashCAN+ only)		
	A1	Program analog output 1 from module assigned to top display
	A2	Program analog output 2 from module assigned to top display
	A3	Program analog output 3 from module assigned to top display
	A4	Program analog output 4 from module assigned to bottom display
	A5	Program analog output 5 from module assigned to bottom display
	A6	Program analog output 6 from module assigned to bottom display
dISP		Select parameter. Note: Parameters available are those contained in TPDOs programmed to be transmitted from the module (programmed using the Configuration Tool).
CONF	LEdS	Set display intensity. Default is 3333.
	LOCK	Lock and Unlock Display for Programming

MOd, RATE, AOUT, and dISP appear on the top display for the module assigned to the top display and then on the bottom display for the module assigned to the bottom display. CONF just appears on the bottom display and is for global dashCAN* setup. All entries must be followed by pressing the ENT key.

Table 4: Menu Tree for dashCAN*

MOd (Module) Setup Option

In MOd setup, the serial number of the module assigned to the top or bottom display is entered. The serial number is written on a label on the module. The module assigned to the top display will be assigned analog outputs 1, 2, and 3. The module assigned to the bottom display will be assigned analog outputs 4, 5, and 6. The same module can be assigned to both displays or different modules can be assigned to each display.

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

RATE Setup Option

Data is transmitted from modules at the broadcast rate and the programmed averaging that was programmed using the Configuration Tool. This transmitted data can then be further averaged before being displayed on the displays. Separate averaging can be programmed for the top display and the bottom display. RATE does not affect the analog outputs.

The averaging is programmed with values from 0.001 (heavy averaging) to 1.000 (no averaging). The default is 1.000. The averaging is performed as follows:

$$\mathbf{DisplayedValue_t = \alpha \times Parameter_t + (1 - \alpha) \times DisplayedValue_{t-1}}$$

where:

$DisplayedValue_t$ = the new displayed value

α = The user-programmable averaging.
Range: 0.001 (heavy averaging) to 1.000 (no averaging).

$Parameter_t$ = the latest value transmitted by the module

$DisplayedValue_{t-1}$ = the previous displayed value

AOUT (Analog Outputs) Setup Option (dashCAN+ Only)

The dashCAN+ display head has six 0 to 5V programmable analog outputs. The analog outputs are updated at the module Broadcast Rate (see Table 1). This can be as fast as every 5 ms. Keep in mind that the data may be averaged (see **Set Averaging Filters** in Table 1) before being broadcast by the module but it is not averaged by the display.

Parameter information from the module assigned to the top display (see MOd) can be sent to analog outputs 1, 2, and 3. Parameter information from the module assigned to the bottom display can be sent to analog outputs 4, 5, and 6. Only parameters selected as active TPDOs for that module (using the Configuration Tool) can be output.

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

1. Press the SYS key so that "MOd" appears on the top display.
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 ↓ key until the parameter (see Table 2) that will drive A2 is displayed. Then press the ENT key.
5. 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.
6. When 5V 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 on analog output 2.
7. When "AOUT" is displayed, press SYS to return to RUN mode.

If in the above example analog output 4 was being programmed, AOUT, A4, 0V, 5V, and your entries would be shown on the bottom display.

dISP (Display) Setup Option

The dashCAN* display head has two displays, the top display and the bottom display.

In dISP setup, a parameter from the module assigned to the display (see MOd) can be shown on the display. Only parameters selected as active TBDOs for that module (using the Configuration Tool) can be displayed.

Here is an example of setting the parameter to be displayed on the top display:

1. Press the SYS key so that "MOd" is displayed.
2. Press the ↓ key until "dISP" is on the top display. Then press the ENT key.
3. Press the ↑ and ↓ key until desired parameter name is displayed. See Table 2. Then press the ENT key.
4. Press SYS to return to RUN mode.

CONF (Configure) Setup Option

CONF setup appears at the end of the setup list on the bottom display. To enter CONF, press the SYS key so that "MOd" appears on the top display, press the ↓ key until "CONF" appears on the bottom display, and then press the ENT key. CONF is for global dashCAN* setup.

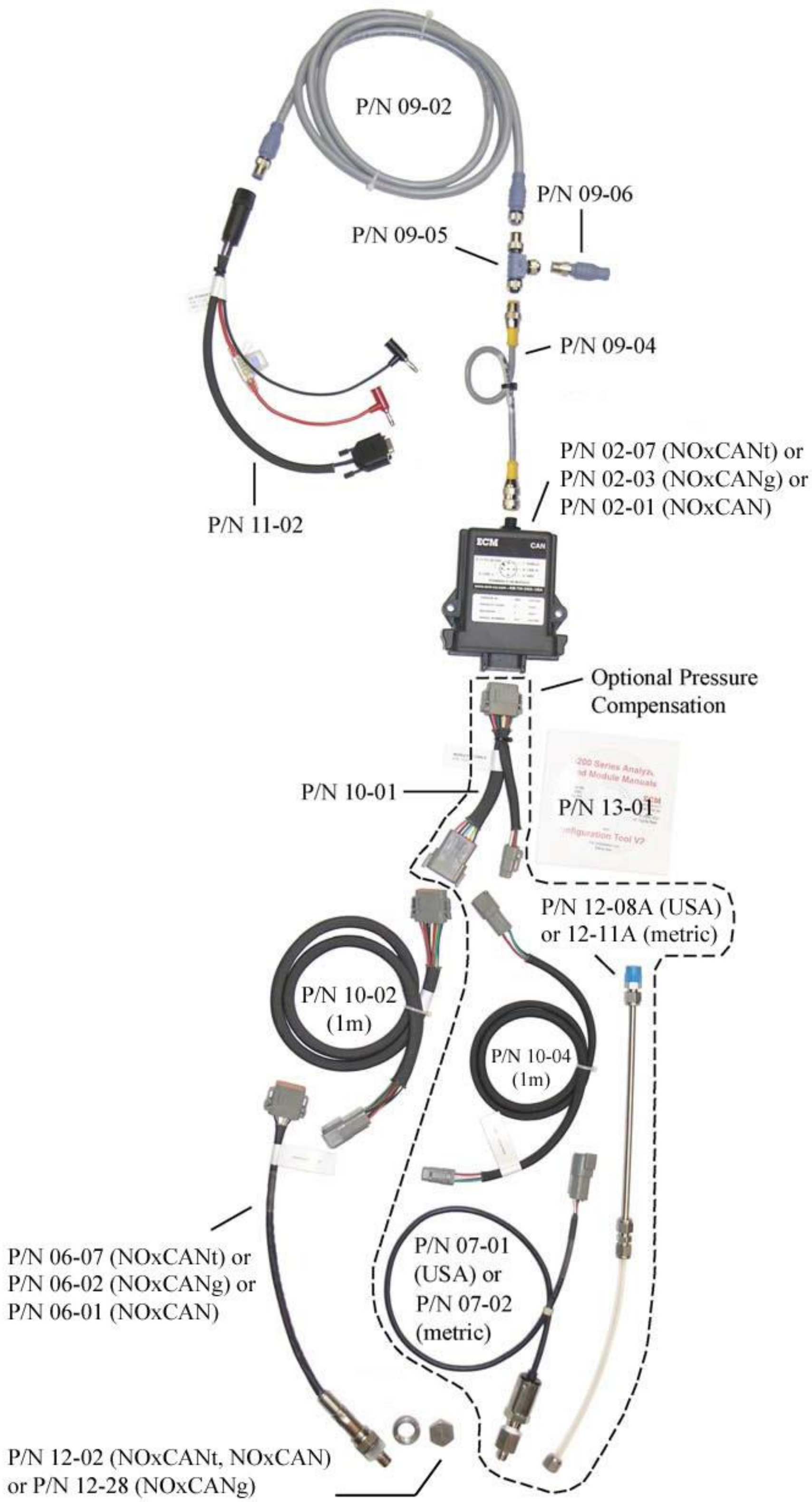
◆ **LEdS**

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

◆ **LOCK**

"LOCK" locks the MOd, RATE, AOUT, dISP, and LEdS setup. This stops unauthorized modification of the display. Refer to Appendix F for more information.

Appendix A: NOxCAN* Kit Contents



The NOxCAN* (NOxCANt, NOxCANg, or the Original NOxCAN) Kit consists of:

	Description	P/N	Quantity
1.	NOxCANt Control Module or	02-07	1
	NOxCANg Control Module or	02-03	
	NOxCAN Control Module	02-02	
2.	NOxt Sensor or	06-05	1
	NOxg Sensor or	06-02	
	Original NOx Sensor	06-01	
3.	Inconel shield (installed on 06-01 sensor only)	12-09	2
4.	NOx Extension Cable	10-02 (1m)	1
5.	Flexi-Eurofast Cable	09-04 (0.3m)	1
6.	Eurofast “T”	09-05	1
7.	Eurofast Terminating Resistor	09-06	1
8.	2m Eurofast 12mm Cable	09-02	1
9.	DC Power Cable, DB9F, Banana	11-02	1
10.	NOxt, NOx Sensor Boss & Plug (18mm x 1.5mm) or	12-02	1
	NOxg Sensor Boss & Plug (20mm x 1.5mm)	12-28	
11.	Manuals and Configuration software CD	13-01	1

Optional Pressure Compensation (add /P to kit part number):

1.	Pressure Sensor, 0-75 psia, 517 kPa	07-01 (USA) or 07-02 (metric)	1
2.	Pressure Sensor Tubing	12-08A (USA) or 12-11A (metric)	1
3.	Pressure Extension Cable	10-04 (1m)	1
4.	Module Y Cable	10-21	1

Optional Cables:

1.	NOx Cable	10-03 (2m)	1
2.	Pressure Cable	10-05 (2m)	1
3.	DC Power Cable, DB9F, Spades	11-01	1

Optional Power Supplies, Heater, and CAN-to-USB Adapter:

1.	AC/DC Power Supply, Universal 24VDC @ 4.2A (requires P/N 11-17 Deutsch DTM3M to DB9F Cable)	04-01	1
2.	Vboost Supply, 10-14VDC to 24VDC @ 14.5A	04-02	1
3.	Ceramic Sensor Heater Kit (for Orig. NOxCAN only)	BTU200	1
4.	Kvaser Leaf Light CAN Adapter	13-02	1

Appendix B: Module Stand-alone Mode and EIB Mode

CAN data from *CAN modules (ex. NOxCAN, LambdaCAN) can either be taken directly from the modules themselves or from the CAN port of display heads connected to the modules. When data is taken directly from one or more modules, each module must in Stand-alone mode. When data is taken from one or more display heads of an EGR 5210, Lambda 5220, or EGR 5230 analyzer, each module must be in EIB mode.

Therefore, the module must be properly configured in Stand-alone mode or EIB mode depending on how it will be used. When *CAN modules are sold alone, they are delivered in Stand-alone mode. When *CAN modules are sold as part of a NOx 5210, Lambda 5220, or EGR 5230 analyzer, they are delivered in EIB mode.

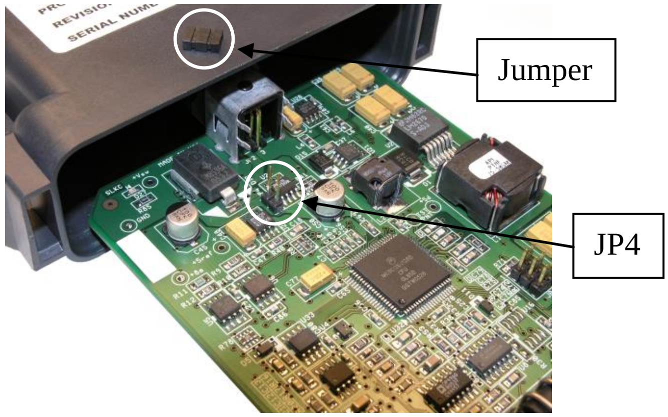
To convert from one mode to the other requires software reprogramming of the module (using the Configuration Tool) followed by the installation (to set to Stand-alone) or removal (to set to EIB) of a jumper inside the module.

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

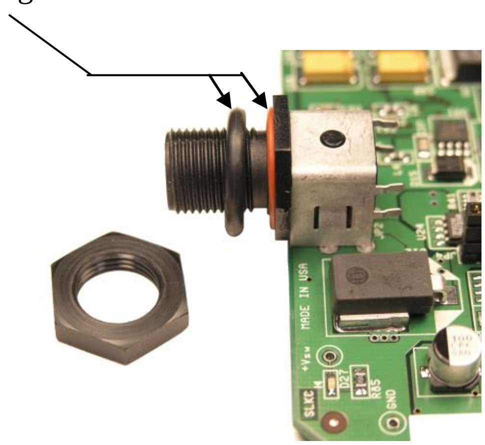
1. Take the nut off the end of the module. Use an 18mm socket without the wrench.

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

3. Slide the PCB out. Install a jumper on JP4.



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



5. Slide the PCB into the enclosure until the two tangs "click".

6. 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.

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

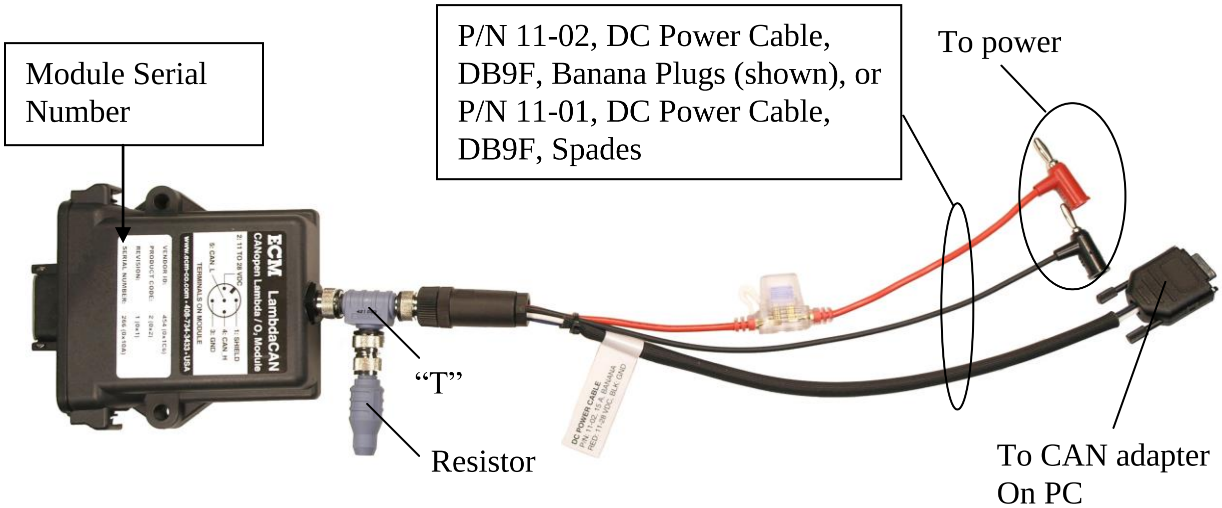
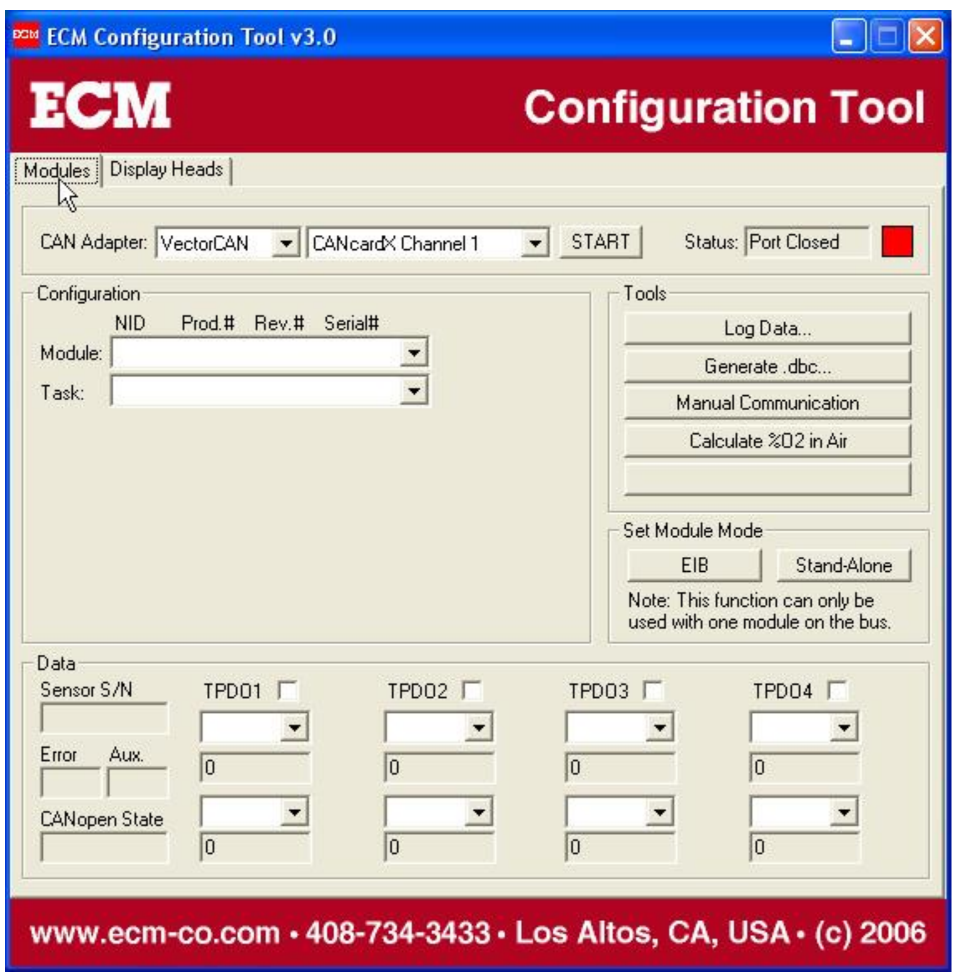


Figure A1: Module prepared for Reprogramming

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



10. Click on the “Set to Stand-Alone Mode”. Wait for “Done” Message.
    Stop communication and exit program. The module is in Stand-alone mode.

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

1. Use the Configuration Tool to “Set to EIB Mode”.
2. Remove the jumper on JP4 in the lambda module.

Appendix C: Interpreting NOxCAN* Modules

◆ Comparing to Spindt and Brettschneider Calculations

NOxCAN* calculates Lambda, AFR, FAR, and PHI numbers comparable to those determined by mass flowrates of air and fuel into the engine. Lambda calculations based on gas-bench analyzer data (i.e. measurements of CO, CO2, etc) do not always give these same values. This fact is well documented in the literature.

However, some organizations prefer to call their specific (and often unique) Spindt or Brettschneider calculations of Lambda the "true" values. To satisfy such needs, ECM has provided the Delta Lambda Table and Delta O2 Table features.

◆ Before and After Catalyst Measurements

The NOx sensors operate on a diffusion mechanism. Molecules leaving the combustion chamber (O2, CO, CO2, H2O, H2, HC, NOx, N2, etc) diffuse into the sensor where oxidation, oxygen liberating, and oxygen pumping occurs. O2, Lambda, AFR, FAR, and PHI are determined from the oxygen pumping rate and assumptions about the combustion products entering the sensor. One such assumption is that the exhaust exists in a certain chemical composition. Exhaust gases entering and exiting a catalytic converter have different chemical compositions. NOxCAN* assumes that the gases are engine-out (not catalyst-out). Therefore measurements made at the exit of a catalyst will require a Delta O2 Table and a Delta Lambda Table correction to be accurate. This is sometimes called "H2 Correction".

◆ Wet versus Dry Measurements

Percentages of components in the exhaust of an engine are expressed as percentages (molecule count or volume) or ppm. The numerator used to calculate these percentages and ppm contains the molecule-of-interest count and the denominator contains the total number of molecules in the sample containing the "count". One of the molecules produced by the process of combustion, and in significant quantities, is H2O. The percentage H2O depends on the fuel composition and Lambda but typically ranges from 2 to 12%.

Percentages and ppm calculated by NOxCAN* consider the water molecules in the denominator and are called "wet" percentages (or ppm). This only makes sense since the sensors are directly in the exhaust where the H2O is present. In contrast to this, classical gas-bench analyzers almost always remove the water before the gas sample reaches the analyzers. This is because the analyzers cannot tolerate condensed water. Therefore, gas-bench analyzers will report O2 percentages and NOx ppms as "dry" percentages (or ppm) (i.e. without H2O molecules counted in the denominator).

Therefore, when comparing “wet” (or “true”) O2 and NOx data from NOxCAN* to “dry” O2 and NOx data from gas-bench analyzers, realize that the dry percentages and ppm will be 2% to 12% higher than the wet (or true) readings. To convert from wet to dry percentages use the formula:

$$\text{Dry percentage (or ppm)} = \text{Wet percentage (or ppm)} / (1 - \%H_2O/100))$$

This formula assumes a 100% removal of water before the dry measurement.

For a given fuel composition, %H2O changes with Lambda (or %O2). The maximum is at stoichiometric (Lambda = 1).

◆ **Equilibrium versus Non-Equilibrium O2**

Gases exiting the combustion chamber of an Otto or Diesel cycle engine are not at chemical equilibrium. As the exhaust valve opens, the gas temperature and pressure drop so quickly that many chemical reactions still occurring are slowed down or “frozen” at non-equilibrium values (for the specific temperature and pressure they are at). This degree of chemical non-equilibrium is affected by exhaust valve timing and ignition timing. The NOx sensor is hot and highly catalytic and will bring the exhaust they sample closer to chemical equilibrium. The result of this is that the %O2 measured by the NOx sensor will be close to equilibrium levels (typically 0.5% lower than actual engine-out). For example, at Lambda = 1 conditions, the %O2 reported by the NOx sensor will be 0 (the chemical equilibrium %O2 value) as opposed to the actual frozen equilibrium %O2 value of approximately 0.5%. Keep this in mind when comparing gas-bench measured %O2 with NOx sensor-measured O2. This difference can be corrected for by a Delta O2 Table.

◆ **Lambda Sensor-Measured O2 versus NOx Sensor-Measured O2**

Both the Lambda sensor and the NOx sensor will report %O2. However, the NOx sensor will not measure %O2 (and hence Lambda, AFR, FAR, and PHI) as accurately as the Lambda sensor. This is because in the Lambda sensor, the electrodes measuring %O2 are pure platinum. Pure platinum electrodes give best %O2 measuring performance. In the NOx sensor, the %O2 measuring electrodes have some gold in them which keeps the electrodes from destroying the NOx in the exhaust. NOx is measured in a second set of electrodes downstream of the %O2 measuring electrodes. If the first set of electrodes were pure platinum, the NOx would not reach the second set.

◆ **Pressure**

The main source of error influencing O2 (Lambda, AFR, FAR, PHI) measurements is exhaust pressure. This error is more significant the further from Lambda = 1 the exhaust stoichiometry gets. Pressure compensation (P-comp) data is stored in the memory chip of every NOx sensor. All that is required is the addition of a calibrated pressure sensor to the module and the entering of the correct pressure sensor constants to activate the pressure compensation. It is highly recommended that pressure compensation be used with any lean burn, HCCI, or diesel engine.

◆ Comparing to an ETAS LA4 Meter

Many ETAS meters with new sensors will not correctly show the %O2 when the sensor is held in air. The actual %O2 in air depends on the humidity and will be almost always less than 20.945%. Since the measurement of %O2 is the fundamental mechanism by which the wideband sensor determines Lambda, the effect that this error has on meter accuracy is obvious. This %O2 measurement error will have a negligible effect at Lambda=1 but the effect on Lambda will increase the further Lambda gets from Lambda=1.

All lambda meters should read the correct %O2 when the sensor is held in air. Due to sensor aging and changes in ambient pressure (due to weather and altitude changes), this may not be the case. However, NOxCAN*'s "Span O2" feature allows to user to restore the system's accuracy.

The O2 span is performed by holding the sensor in air and entering the actual %O2 in air. However, if you are comparing a NOxCAN* to an ETAS meter and you want the NOxCAN* to match the ETAS meter, then you must span the NOxCAN* to whatever the ETAS meter says the %O2 is in air – even if it is wrong.

Therefore, if you want a NOxCAN* to match an ETAS meter, whether or not the ETAS meter reads the correct %O2 in air, do the following:

1. Make certain that the "LA42.TXT" (for the LSU4.2 sensor) or "LA49.TXT" (for the LSU4.9 sensor) curve is downloaded to the NOxCAN* module as the "Delta Lambda Table". This is for the case of matching the "Default Curve" in the ETAS meter. Other curves are available and the user can create his own curve.

2. Turn on the ETAS meter and hold the sensor in air. Read the %O2 on the ETAS meter. This value should be 20.945 or less since 20.945 is pure air with no humidity. We have seen values of over 22%.

3. O2 span the NOxCAN* to the %O2 given on the ETAS meter even if it is wrong.

This procedure is to be used only if you want the NOxCAN* to match a specific ETAS meter and sensor combination. Normally, the NOxCAN* are spanned to the correct %O2 in air.

Appendix D: Setting Up ETAS INCA for ECM Modules

Hardware Setup: Using ETAS ES591.1

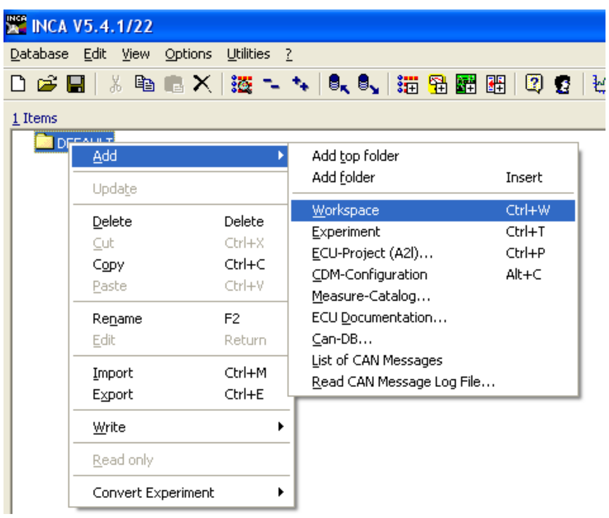
1. Connect the power port to a power source between 6V and 32V.
2. Connect the Ethernet port directly to the Ethernet port on your PC. This port does not use an internet/intranet connection like a router.
3. Connect either the CAN1 or CAN2 port to a CAN network (i.e. ECM modules or display heads).

Software Setup: Using ETAS INCA V5.4.1, Hotfix 22, GM Install

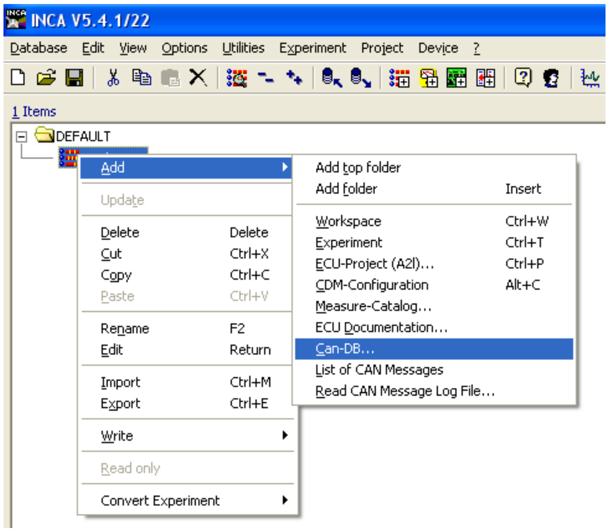
1. Double click the INCA V5.4 icon to open the software.

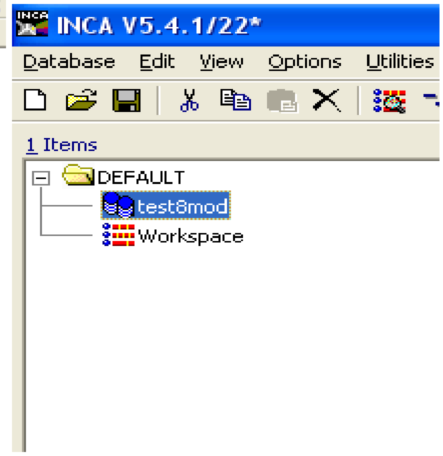
2. **Create a new Database**. In the Database menu, select New. Give your database a name (i.e. a folder name). In INCA, a Database means the current working directory. Each project is created in a unique directory. When INCA is opened, it will default to the last Database that was used.

3. **Add a new Workspace**. Right click on the "DEFAULT" folder icon, select Add > Workspace. You can rename it to whatever you want.

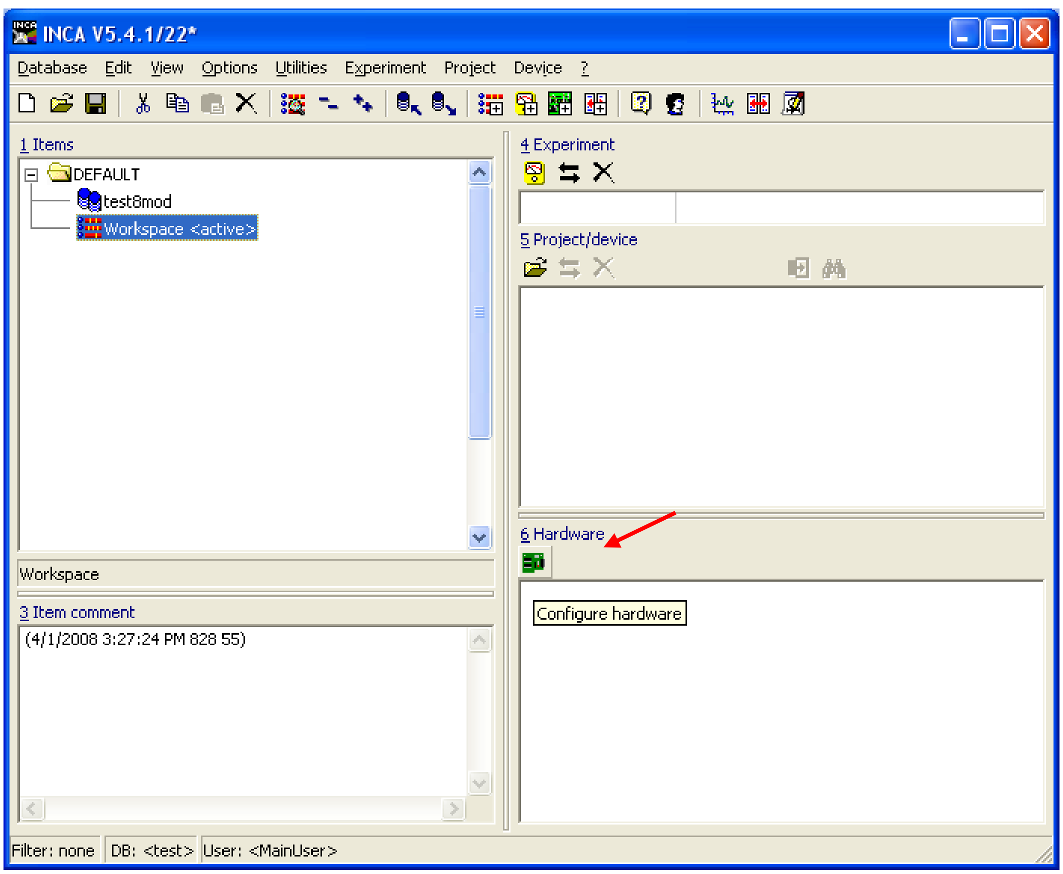


4. **Add a new dbc file for your project.** Right click on the workspace you created in step 3, select Add > Can-DB. Browse to your dbc file and click open. In this example, we are using a file named test8mod.dbc. An INCA log window will pop up. You can ignore this.

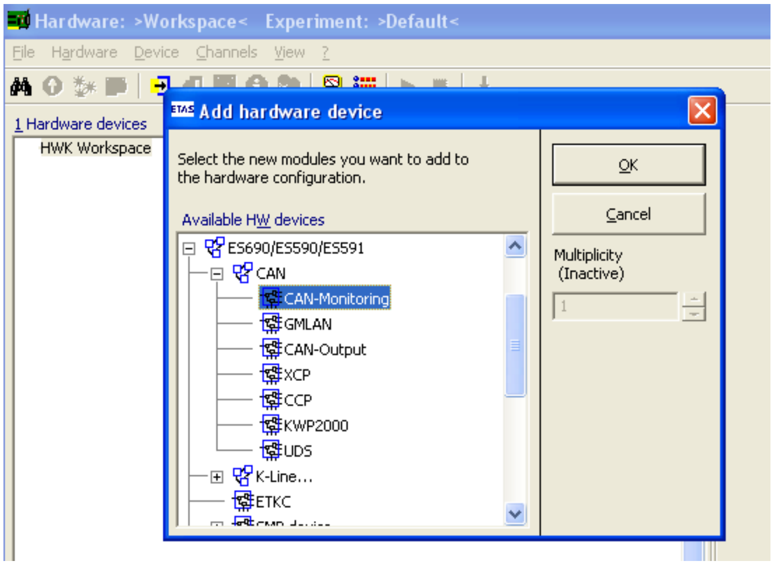




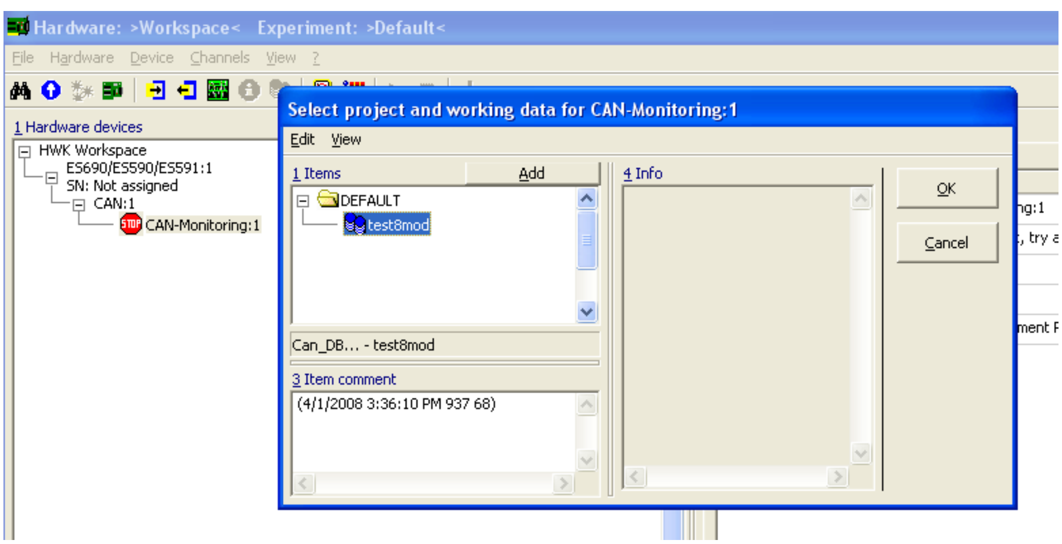
5. **Configure the hardware.** Click on the icon for the workspace you created in step 3. Open the Hardware Configuration icon under the section text "6. Hardware". A hardware configuration window will open.



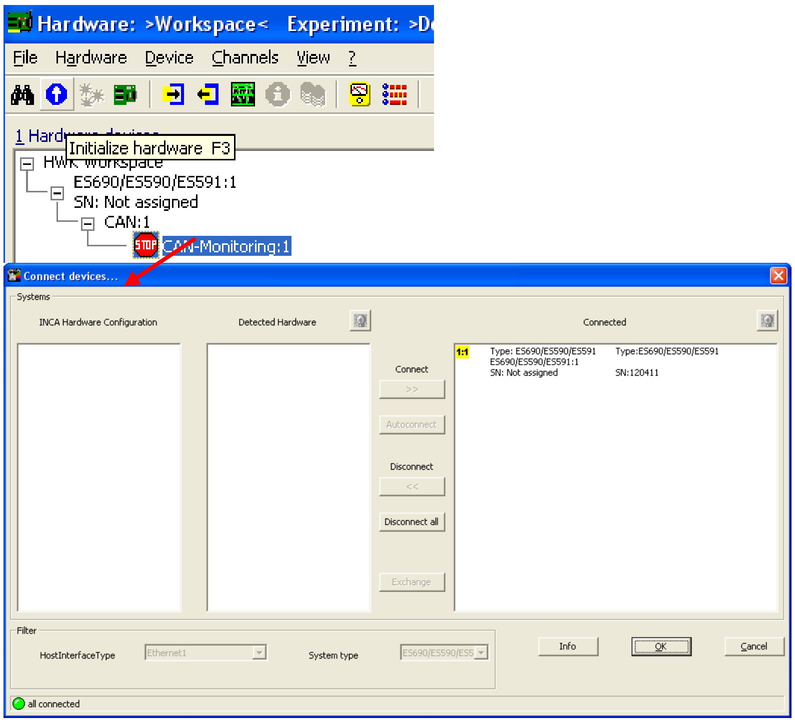
6. **Select the hardware.** In the hardware configuration window, right click the "HWK Workspace" listed under the section text "1. Hardware Devices", and select Insert. Select the ETAS device you wish to use. In this example, we are using an ETAS ES591.1. Expand the selection tree by clicking the "+" next to the hardware device model. Expand the CAN selection and select CAN-Monitoring. Click OK.



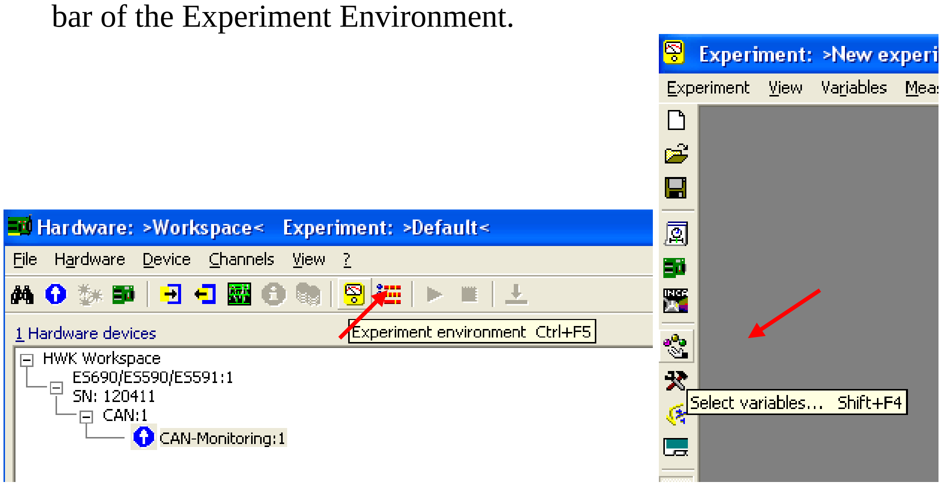
7. **Associate the dbc.** When you clicked OK in the last step, another window will pop up that will allow you to select a dbc that you have added to your workspace from step 4. Expand the selection tree, select your dbc file, and click OK.



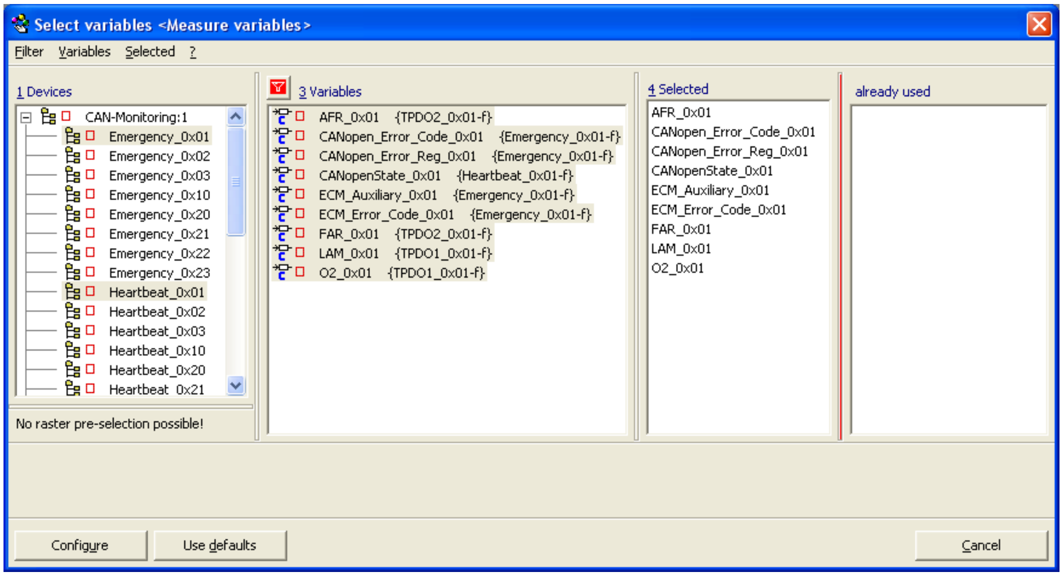
8. **Initialize hardware.** The hardware is currently stopped, as indicated by the red stop sign icon next to the selected hardware. You must initialize it before you can use it to collect data. Click on the Initialize Hardware button on the upper tool bar and wait for the hardware to complete its initialization. Another window will pop up to confirm the device to connect to. Click OK.



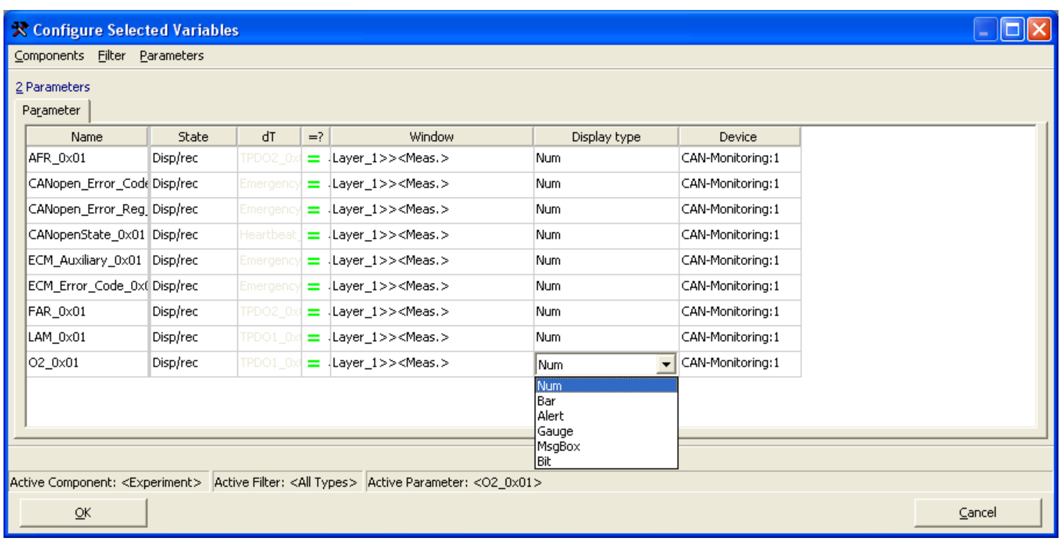
9. **Open an Experiment Environment.** Click on the Experiment Environment button on the upper tool bar to open an Experiment Environment. The Experiment Environment is where you can setup the monitoring of the CAN bus. By default, the Experiment Environment will be blank. You must select the variables from the dbc file that you wish to monitor. Click on the Select Variables icon in the left hand tool bar of the Experiment Environment.



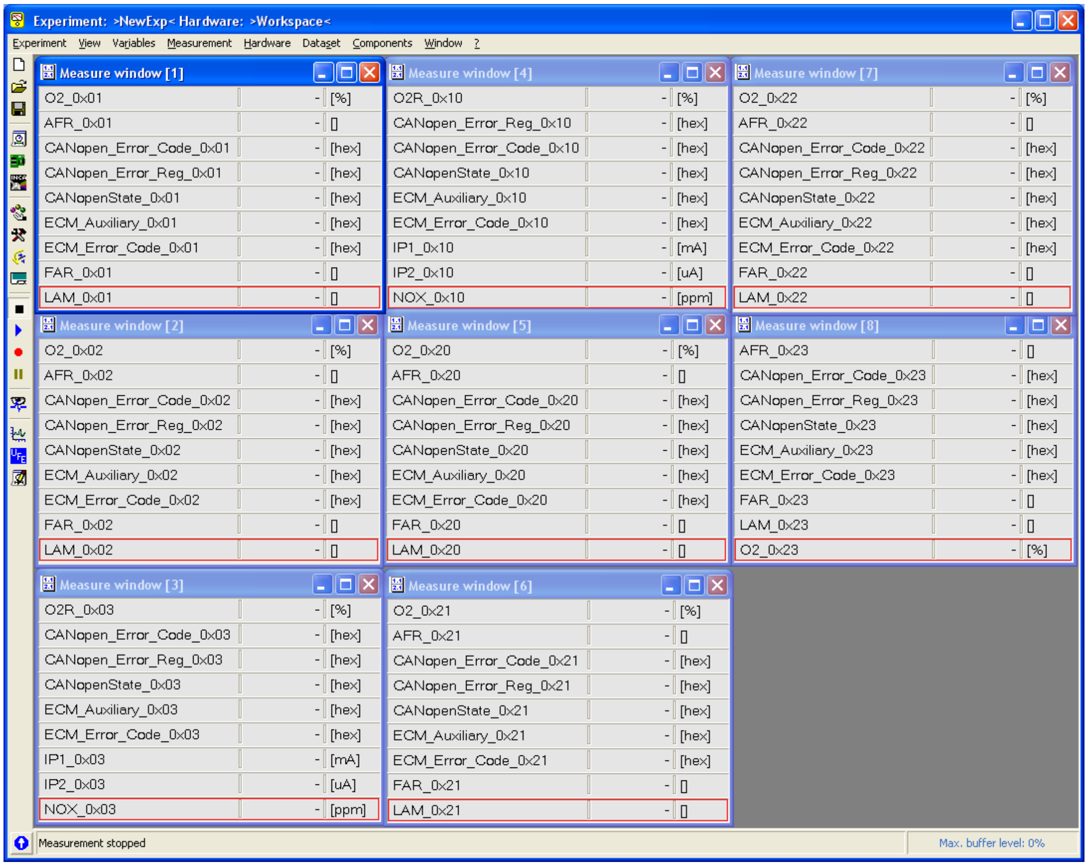
10. **Select and Configure Variables.** Select the variables that you wish to monitor in the Experiment Environment. These variables names are based on the data found in the dbc file. Click Configure.



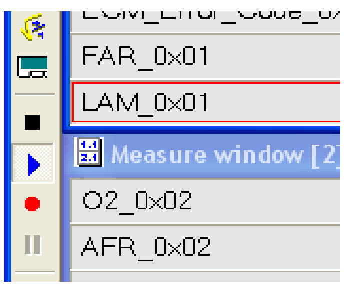
11. Another window will pop up to configure each selected variable. You can configure, for each variable, whether to record or simply display the data, how the data will be displayed (graphs, charts, gauges, numeric, etc.). When complete, click OK. We have left all configurations at default for this example.



12. A new sub-window will be added to the Experiment Environment. You do not need to select all the variables you want to monitor all at once. You can click on the Select Variables icon again at a later time to add more variables. Each set of variables you add will be placed in a new sub-window unless it is configured to join an existing sub-window. In this example, we have created a sub-window for each of the eight modules in the dbc file.



13. **Start CAN monitoring.** Right now there is no data displayed. That is because the CAN monitoring is stopped. To begin CAN monitoring, click on the Start Visualization icon (blue triangle) on the left hand tool bar. To stop CAN monitoring, click the Stop Measuring icon (black square) on the left hand tool bar. To begin recording the data, click on the Start Recording icon (red circle) on the left hand tool bar.



Appendix E: Setting Up ATI Vision for ECM Modules

NOTE: While shown here for a single LambdaCAN module, the same procedure applies for any of ECM's CAN-based devices (ex. NOxCAN) as well as for multiple modules simultaneously connected on the same bus.

Introduction

Connecting ECM LambdaCAN hardware to ATI VISION software is simple and does not require any third-party software interface. Using the ECM Configuration Tool software to produce a .dbc database file, and the ATI VISION CANMonitor interface, any available hardware CAN interface can be used to read LambdaCAN data.

Hardware Setup

A typical hardware configuration is shown in Figure 1. In this example, a Kvaser Leaf Light CAN-USB adapter is used. Other supported adapters have a similar procedure. Connect the DB9 CAN connector of the LambdaCAN to the PC to CAN adapter. Supply 11-28V DC (5A min. supply) to the LambdaCAN.

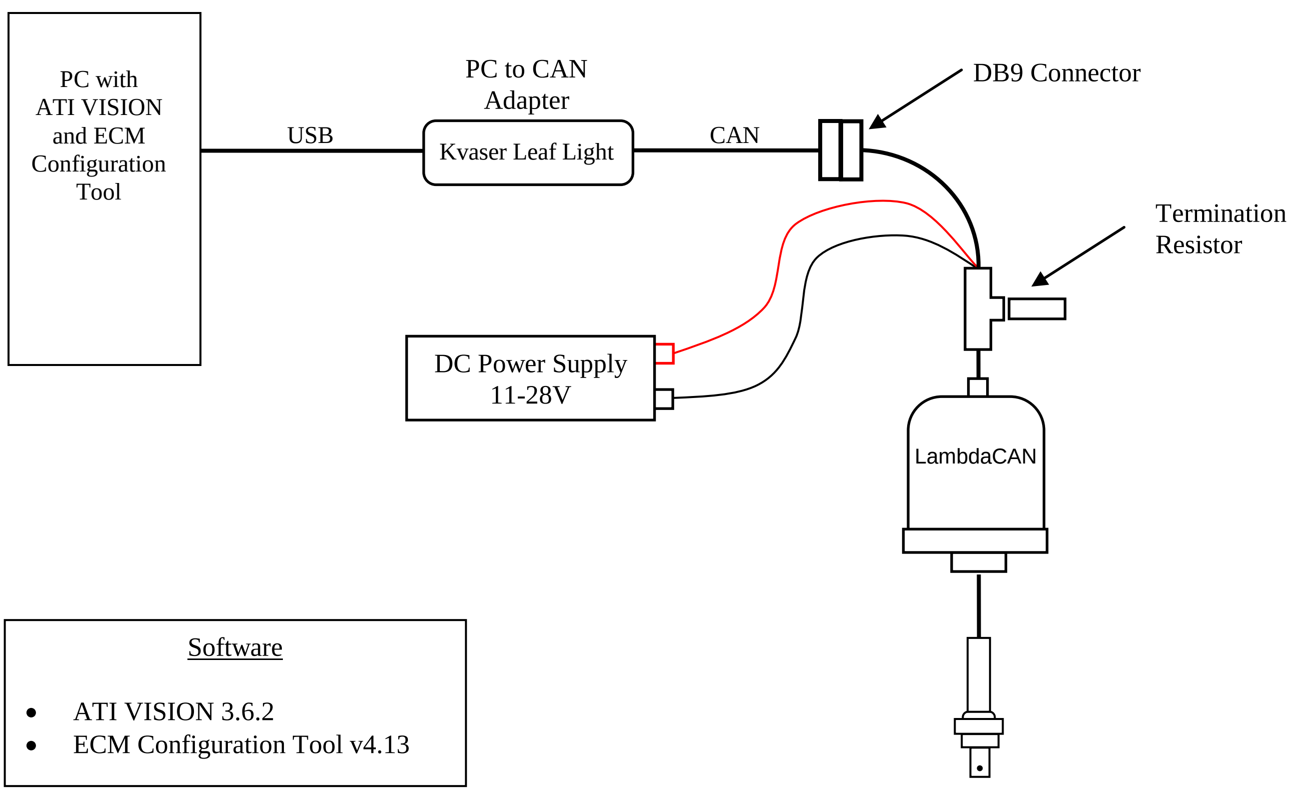


Figure 1: Equipment Schematic Layout

Creating a .dbc File

The ECM Configuration Tool is used to create a .dbc database file for describing the CAN messages broadcast from the LambdaCAN. All ECM products with a CAN interface use the CANopen protocol at 500kHz by default. To generate a .dbc file using ECM Configuration Tool:

1. Connect hardware as shown in Figure 1. Ensure LambdaCAN bi-color LED indicator near sensor connector is visible (green during normal operation, flashing red without sensor attached).
2. Run ECM Configuration Tool software, and select the Modules tab (or the Analyzers tab if connecting to 5200 series analyzers).
3. Select CAN adapter from drop down menus as shown in Figure 2, and click START.
4. After LambdaCAN module(s) have initialized, select desired parameters to transmit from the TPDO drop down menus for each module.
5. Click Generate .dbc, and save this file in a location such as the VISION Projects folder.
6. Click STOP to end CAN connection.

NOTE: Whenever TPDO's are modified, a new .dbc file must be created.

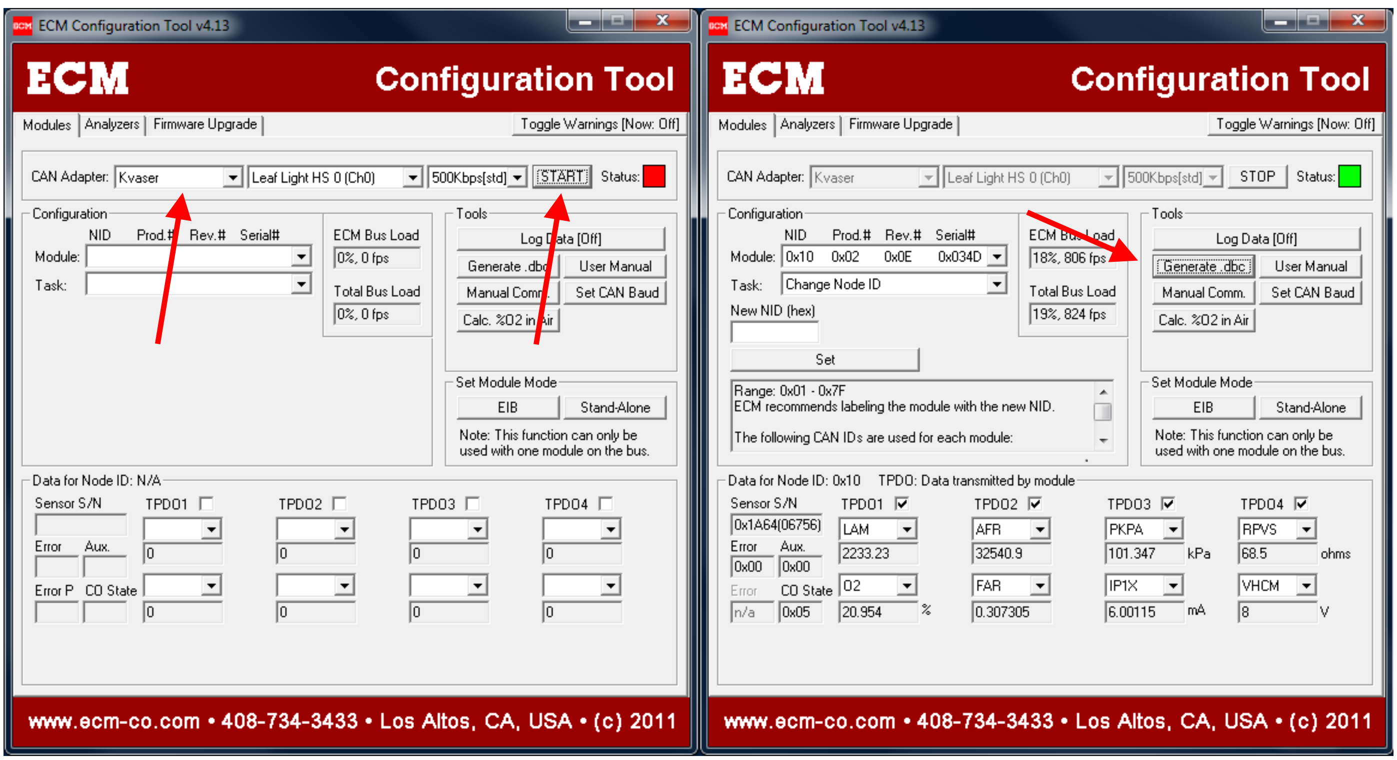
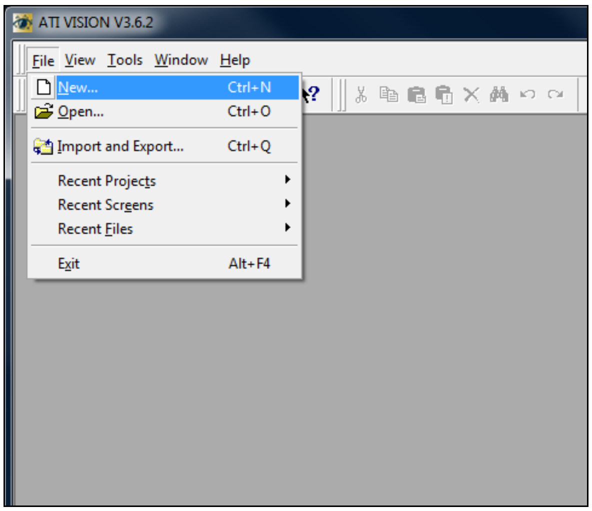


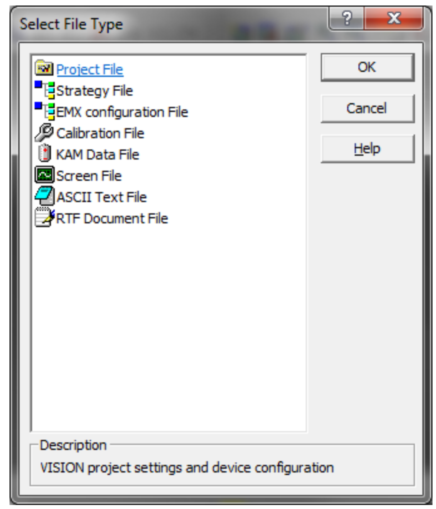
Figure 2: ECM Configuration Tool

Setup CANMonitor using ATI VISION

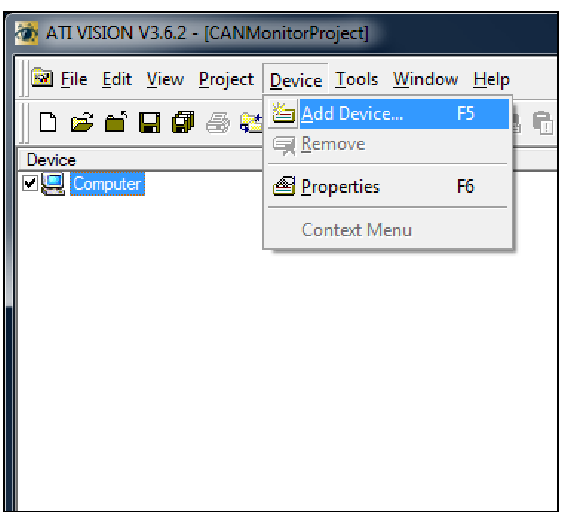
ATI VISION CANMonitor provides a method of reading general purpose information from any available CAN channel. The .dbc file generated by the ECM Configuration Tool is used to describe the format of the information available to VISION. To setup a CANMonitor in ATI VISION:

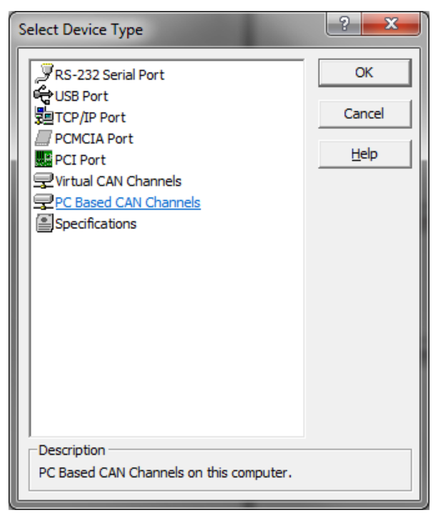
1. Run ATI VISION and open an existing Project File or create a new one by clicking File > New > Project File. In this example the Project has been named CANMonitorProject.



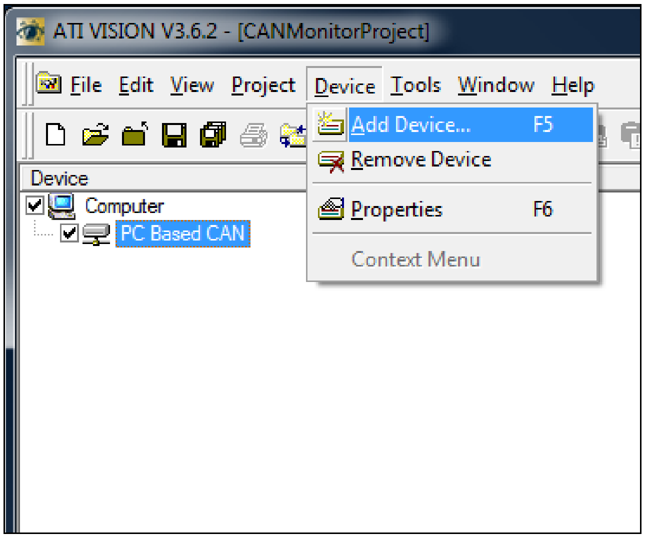


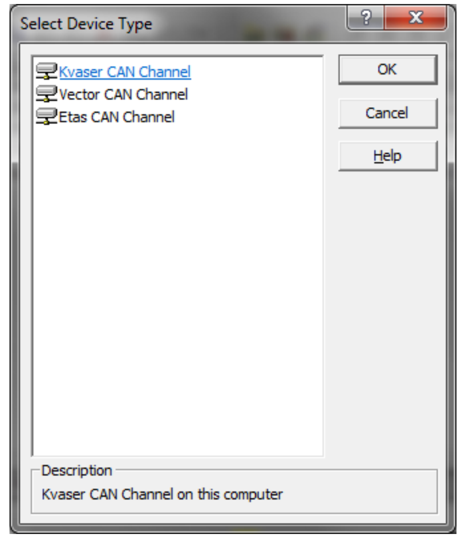
2. Add a Device by clicking Device → Add Device, select PC Based CAN Channels from the list.



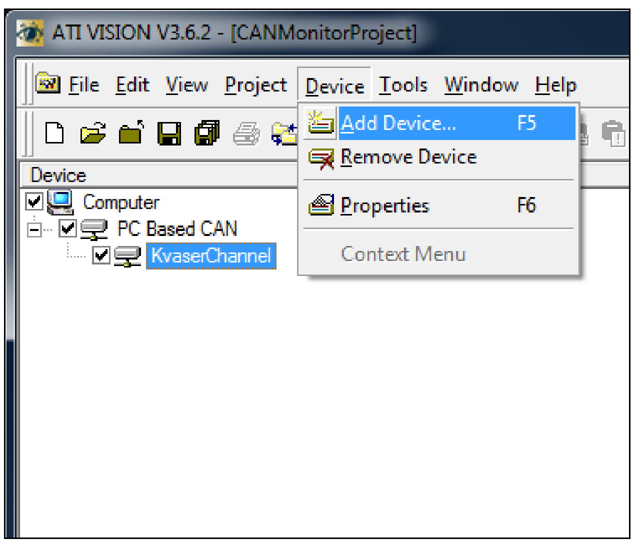


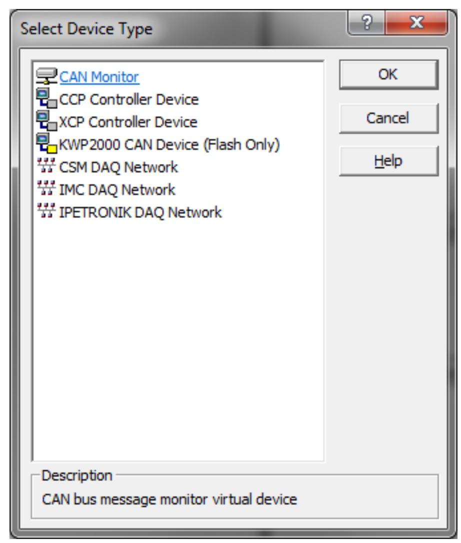
3. Add a physical hardware device by clicking Device → Add Device, and select Kvaser CAN Channel.



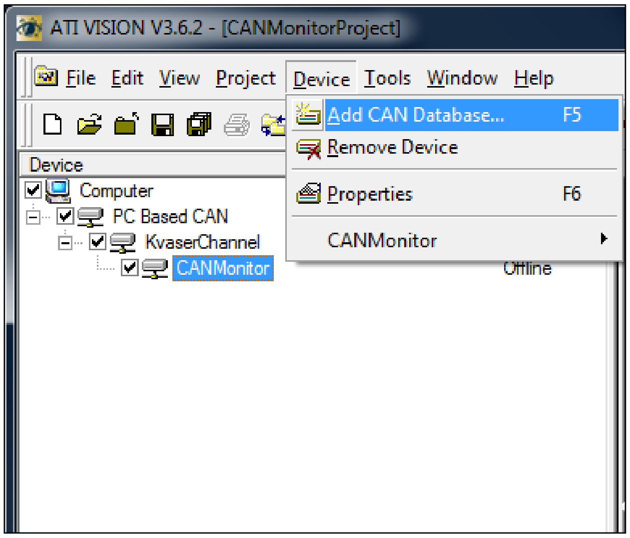


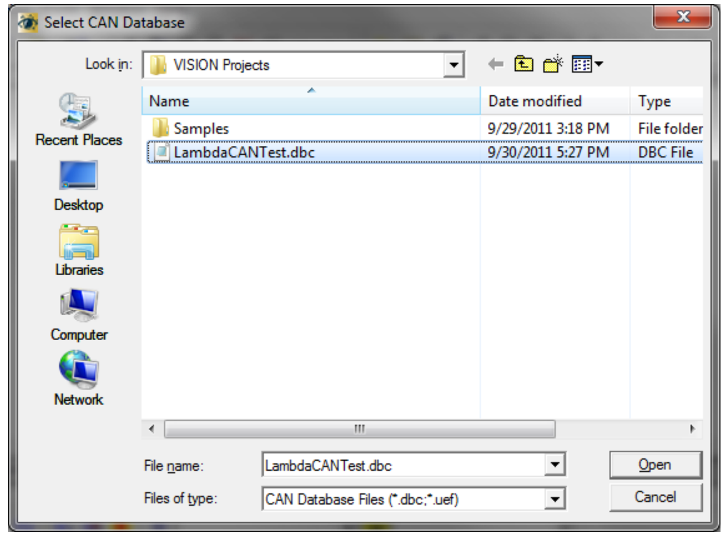
4. Select a CANMonitor device by again clicking Device → Add Device, and select CANMonitor.



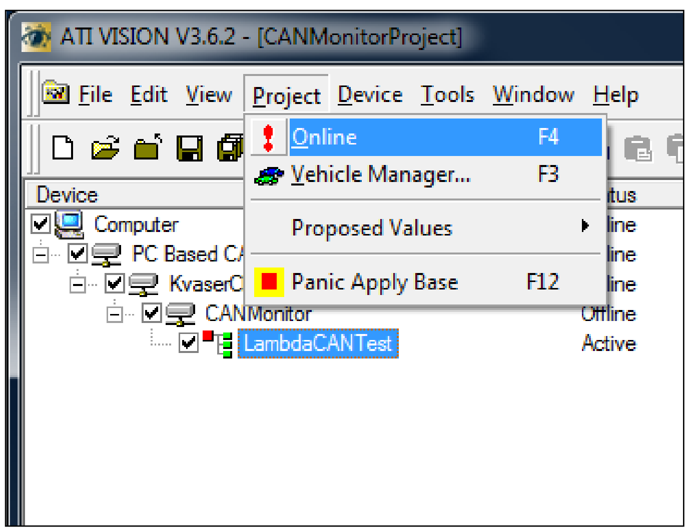


5. Add the .dbc file generated from the ECM Configuration Tool to CANMonitor by clicking Device → Add CAN Database and browsing to the previously created .dbc file.

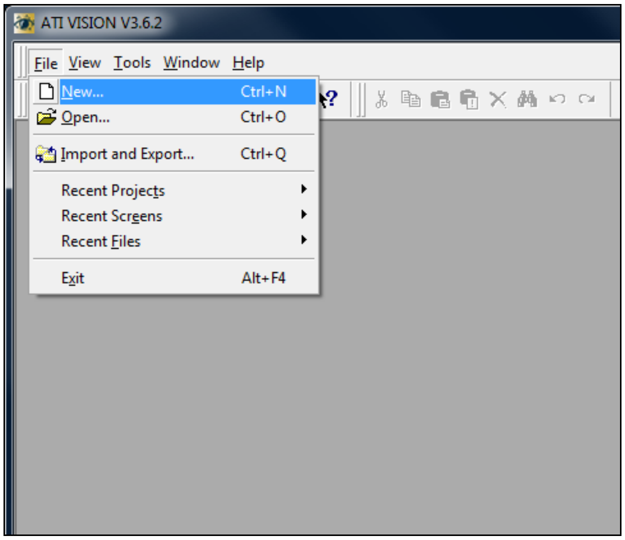


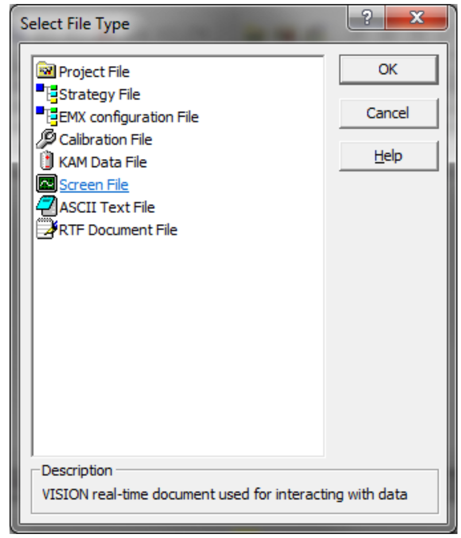


6. Enable the hardware by clicking Project → Online. The status of all of the devices should now show a Status of Online, and a value should appear in the Data Rate column of the Project window.

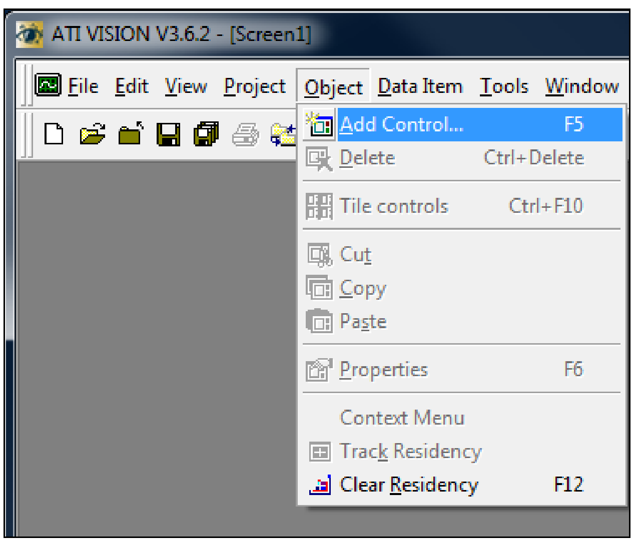


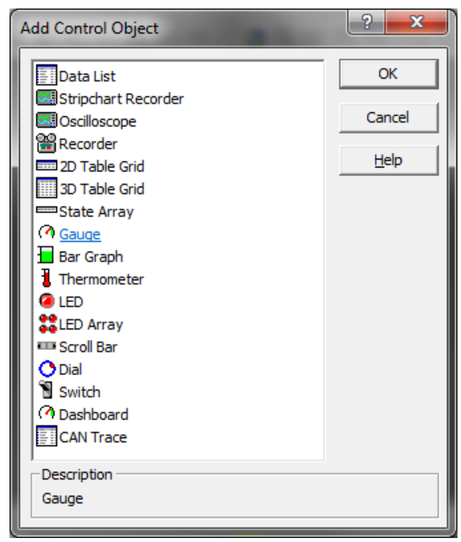
7. To view data, create a new Screen File and add a Control. Click File → New → Screen File



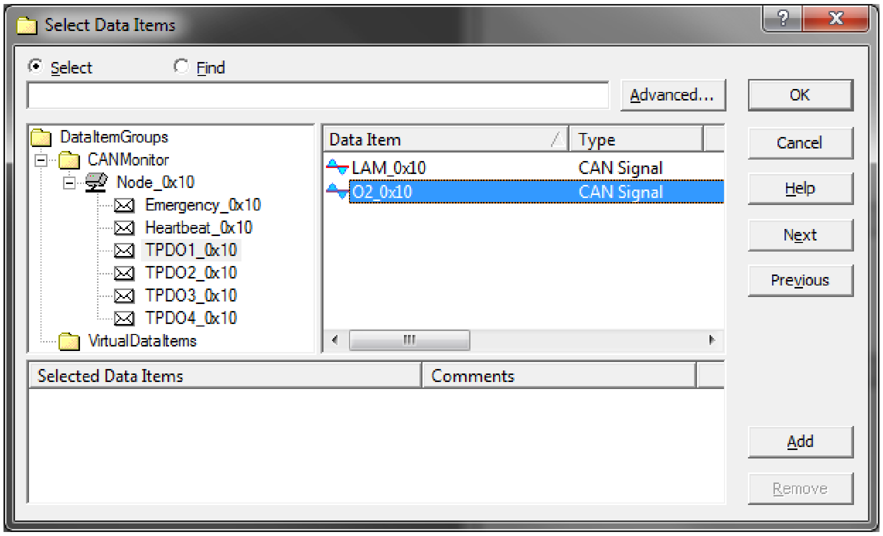


8. Select Object → Add Control → Gauge

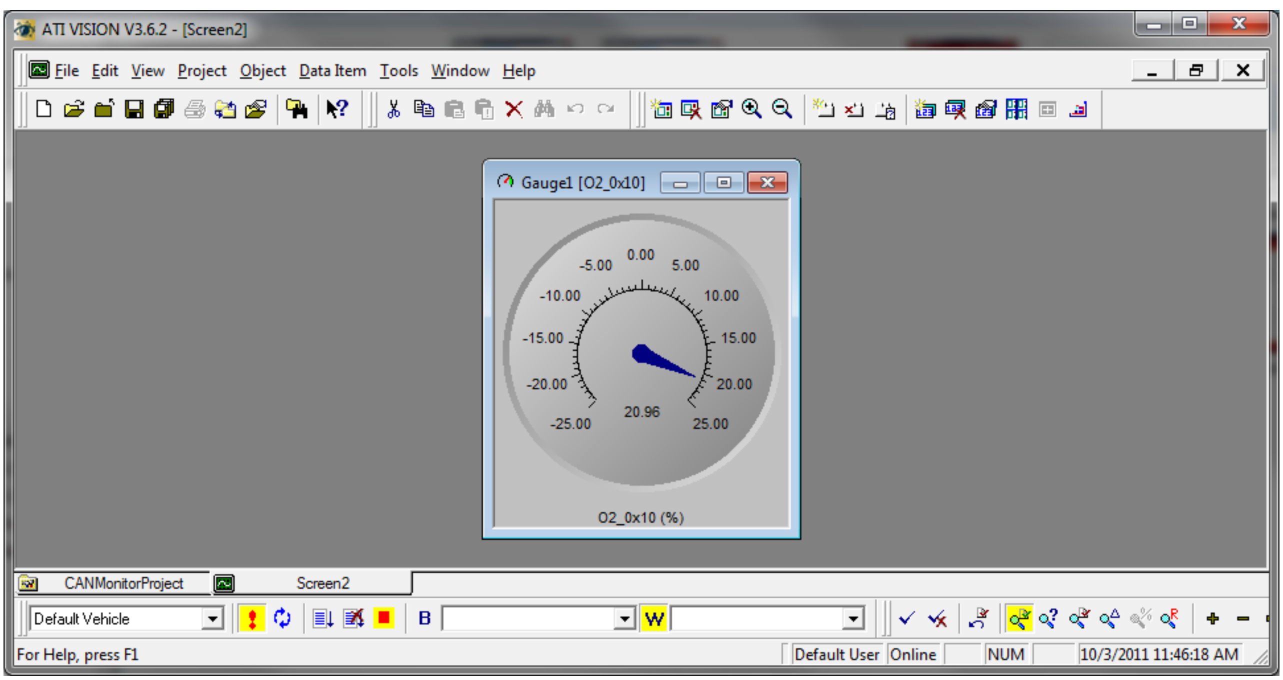




9. In the Select Data Items window open the CANMonitor file tree to view all of the available signals. Here the O2% from Node 0x10 has been selected. Click OK to add the Data Item to the Control.



10. Data should be visible on the gauge.



Appendix F: LOCKing and unLOCKing dashCAN*

When dashCAN* is locked, its setup cannot be modified.

◆ **To LOCK dashCAN***

1. Press SYS until “MOd” is displayed.
2. Press ↓ until “CONF” is displayed. Then press ENT.
3. Press ↓ until “LOCK” is displayed. Then press ENT.
4. “50” will be displayed. Press ↑ until “60” is displayed. Then press ENT. dashCAN is now LOCKed.

◆ **To unLOCK dashCAN***

1. Press SYS until “LOCK” is displayed. Then press ENT.
2. “50” will be displayed. Press ↑ until “60” is displayed. Then press ENT. dashCAN is now unLOCKed.

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

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 NOxCANt module.

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 ºC.

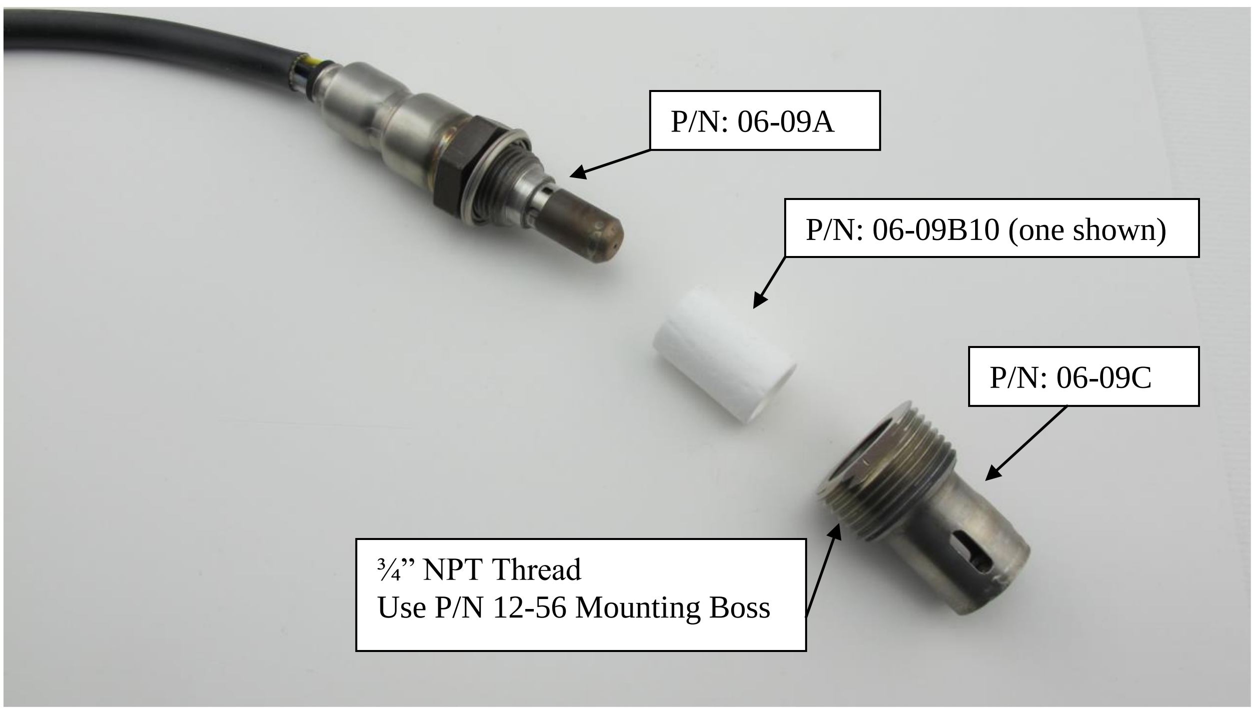


Figure G1: P/N: 06-09 is an assembly consisting of:
P/N: 06-09A Sensor Element
P/N: 06-09B10 Sensor Filter (package of 10)
P/N: 06-09C Cap

◆ 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

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
NOx 5210 NOx Analyzer
Lambda 5220 Lambda 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)

RSPatrick

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