Haltech Wideband Controller
(HWC)
Manual

 **Warning!** 

The Oxygen Sensor used in this device gets very hot in operation. Do not touch the hot sensor. Do not let a hot sensor touch a combustible surface. Do not use the sensor with or near flammable liquids or gases. Failure to heed these warnings may result in severe burns, explosions or fires.

When installed in the exhaust, the oxygen sensor MUST be connected and operating whenever the car is running. An un-powered oxygen sensor will be quickly damaged when exposed to hot exhaust gases.

1. Overview

The HWC is a stand-alone Wideband Controller used to measure the Air/Fuel Ratio (AFR) or Lambda for an engine. For *gasoline*-driven engines, the theoretically optimal air fuel ratio is 14.7 pounds of air for every pound of fuel. At this ratio, theoretically, all available oxygen in the air combines with all available fuel. This ratio is called the stoichiometric ratio. Stoichiometric for different fuels are as follows:

Gasoline	14.7
LPG (Propane)	15.5
Methanol	6.4
Ethanol	9.0
CNG	17.2
Diesel	14.6

The measurement Lambda is the actual air fuel ratio over the stoichiometric ratio. A Lambda measurement of "1" equates to the air fuel ratio of 14.7 (for gasoline engines). When Lambda is less than 1 the engine runs "rich", i.e., unburned fuel exists in the exhaust stream. If lambda is greater than 1 the engine runs lean, i.e., free oxygen (0^2) is present in the exhaust. Depending on the engine, maximum power is typically delivered when the engine runs slightly rich (for example at lambda values of 0.8 to 0.9 for most engines). This instrument provides a means to measure the actual air fuel ratio or lambda in the engine in operation directly from the exhaust. For this a special wide-band oxygen sensor is used to measure the lambda value derived from the oxygen content (or lack thereof) of the exhaust gases.

2. The Haltech Wideband Controller (HWC)

The Haltech Wideband kit set contains the following parts:

2.1. The HWC Module

2.2 Included cables and devices

Oxygen Sensor:

3. Mounting and Connecting the Wideband Controller

1. Find a suitable location under your vehicle where the Controller body can be mounted. Using zip ties or other suitable method, fasten the body of the Controller device securely to the frame-rails or other mounting points as far away from the heat of the exhaust system as the sensor cable allows. DO NOT zip-tie the **HWC** by the cables.

2. Route the cables from the **HWC** (except sensor cable) into the car interior under the dash.

3. **HWC** Cable connections:

   3.1 Out of the HWC comes 3 cables:

   A. Interface and power cables with 6 stripped ends:

      a. Red 12V supply
      b. Blue Heater Ground
      c. White System Ground
      d. Yellow Analog out 1 (0-1v Output)
      e. Brown Analog out 2 (0-5v Output)
      f. Green Analog Ground
      g. Black Calibration wire

   B. Serial In connection, 2.5mm stereo (female) marked as IN
   C. Serial Out connection, 2.5 mm stereo (female) marked as OUT.

4. Connect the 12V supply wire to a switched 12V source in your car. A switched 12V source goes on as soon as the ignition on the car is on. Make sure the connection is fused with a fuse of minimum 5A.

5. Connect the Heater Ground wire to a chassis ground. Make sure it has a good ground connection.

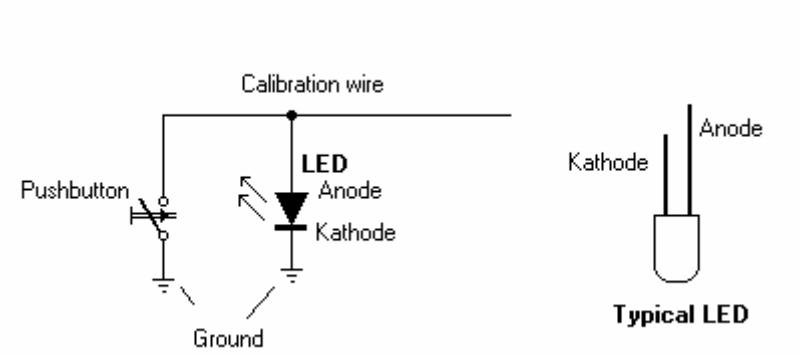
6. Connect the System Ground to where you will use the analog out signals. If you use the analog out signals as input for an ECU or datalogger, connect the system ground to the ground of the ECU or datalogger.

7. Optionally connect the analog out signals to their intended devices.

8. Optionally connect a pushbutton switch between ground and the calibration wire.

9. Optionally connect an indication LED between the calibration wire and ground. The following diagram shows how to connect the pushbutton and indication LED.

3.1 Indicator LED and Calibration button hookup:



Any color LED can be used. A typical LED has 2 wires called Anode and Cathode. The Cathode side is the shorter of the 2 wires. It is connected to Ground. The Anode side will be connected to the calibration wire.

Pressing the pushbutton or connecting it quickly to ground starts a free air calibration process in the HWC. MAKE SURE THE SENSOR IS IN FREE AIR FOR THAT. See chapter 6 for details.

3.2 Mounting the sensor using a Bung.

Using a bung is the preferred method for mounting the O^2 sensor for both catalytic and non-catalytic cars.

On CATALYTIC CONVERTER equipped vehicles:

Install the oxygen sensor's bung upstream from the catalytic converter. Any decent muffler or exhaust shop can do this for you. The wide-band oxygen sensor is then installed into the bung to take a reading. (Insert the plug into the bung when not in use). **The bung must be installed in the exhaust pipe *at the side or on top, NOT on the bottom* of the exhaust pipe.** Best position is between 10:00 and 2:00 position.

On NON-CATALYTIC converter vehicles:

You have the option with non-catalytic cars to also use a Bung as described above. Use of a bung is the preferred method for mounting the 0^2 sensors for both catalytic and non-catalytic cars.

On TURBO CHARGED vehicles:

Install the bung downstream from the turbo before the catalytic converter. The high exhaust pressure before the turbo interferes with the lambda measurement and the high exhaust temperatures encountered there can damage the sensor.

 **Do NOT install the Bung below the 3 o'clock or 9 o'clock position. Condensation can form in the exhaust pipe and permanently damage the sensor. 6 o'clock is the absolute worst position to mount the sensor.**

 **Wide band oxygen sensors – like the one shipped optionally with the HWC – are designed to work with unleaded gasoline. Using them with leaded gasoline will significantly reduce the lifespan of the sensor. The reduction is directly proportional to the metal content of the fuel. In most cases, a wide band sensor will provide accurate measurements somewhere between 50 hours and 500 hours with leaded fuel.**

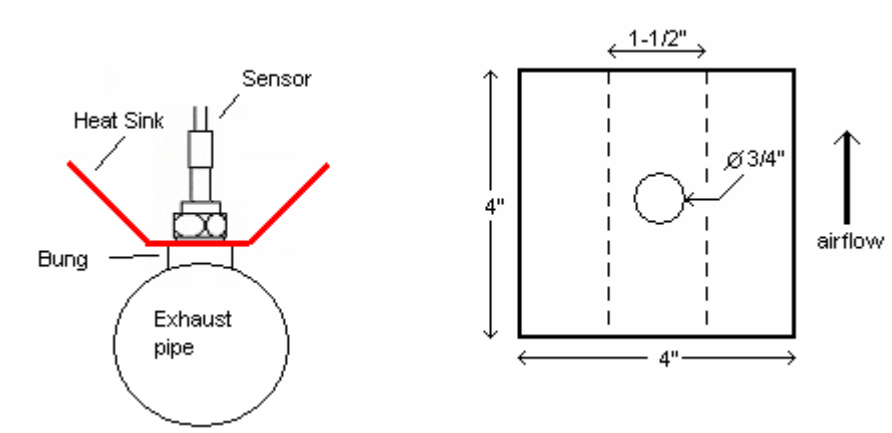
 **WHEN INSTALLED IN THE EXHAUST, THE OXYGEN SENSOR MUST BE CONNECTED AND OPERATING WITH THE HWC WHENEVER THE CAR IS RUNNING. AN UN-POWERED OXYGEN SENSOR WILL BE DAMAGED WHEN EXPOSED TO EXHAUST GAS.**

 **The maximum temperature of the sensor at the bung (the sensor hexagon) should not exceed 500 ^{o}C or 900 ^{o}F. If these temperatures are exceeded in your application you should either install a copper heat sink (see instructions below).**

 **It is NOT a good idea to connect the HWC permanently to 12V and switch it on with a separate switch before the vehicle is started. Depending on the climate and the sensor position in the exhaust, condensation water can form in the exhaust pipes. This condensation water could then be blown by the exhaust stream against the hot sensor when the car is started. The resulting heat shock can permanently damage the sensor.**

3.3 How to fabricate a copper heat sink

Use a 4” x 4” (10cm x 10 cm) sheet of copper sheet metal 14ga (1.5mm) thick. Drill a hole in the center with the same diameter of the oxygen sensor threads ~3/4” (19mm).
Fold the sides up 45 deg and mount it between the sensor and the bung like you would a big washer. Orient it such that the sides are exposed to good airflow.



4. First Time Use

1. **Do not connect the sensor yet.**

2. Switch 12V supply to the **HWC** on and wait for 10 seconds.

3. Switch the 12V supply off after 10 seconds.

4. Connect the sensor to the sensor interface connector. **The sensor must be exposed to air for the first time calibration.**

5. Switch the **HWC** on and wait for 2 minutes.

If you connected a LED to the calibration button, you will at first see the LED blink slowly and steadily. If it blinks for a fixed number of pulses, then switches off for 2 seconds and then repeats, you have an error code. See chapter X for details.

Slow and steady blinking indicates that the sensor is warming up to its optimum operating temperature. The warm-up period will last for about 30 seconds for a cold sensor, depending on the sensor type used.

After the sensor is warmed up the meter automatically calibrates the sensor heater controller to the particular sensor. During this 20-second period the **HWC** collects and calculates sensor specific data required to quickly reach operating temperature in the future. After the first time use the meter will use these values to regulate the sensor's temperature. During the heater calibration the optional LED will blink fast and steady.

After that period the **HWC** will automatically perform a free air calibration. During this 2-second period a connected LED will go off. The **HWC** will now calibrate itself by using air as a reference gas with known oxygen content.

After the free air calibration is finished the LED should light up steady and continuously, indicating correct operation of the **HWC**.

5. Calibration

There are two types of calibration for the **HWC**: free air calibration and sensor heater calibration. Sensor heater calibration and first free air calibration is automatically performed the first time a new sensor is used, while free air calibration should be executed frequently.

5.1 Free air calibration

To achieve maximum precision, the **HWC** and its sensor needs to be recalibrated frequently.

The sensor MUST be operated in free air for calibration.

If the wide-band sensor is installed in a vehicle, wait 6-8 hours after running the engine so that all exhaust gas is dissipated from the exhaust tract of the vehicle. Better yet, disengage the oxygen sensor and expose the sensor to air (away from the exhaust) for calibration purposes:

1. Connect the **HWC** to 12V from the vehicle and switch it on.
2. After the sensor has warmed up, either press the pushbutton or connect the calibration wire to ground for a brief period.
3. After the calibration is complete, switch the **HWC** off and wait for 30 seconds before you start the car.

If a LED indicator is connected to the calibration wire, it will be off during free air calibration.

5.2 Sensor heater calibration

If you change the sensor – either with a replacement sensor or a new type of sensor --, the heater circuit of the **HWC** needs to be recalibrated as well. (See steps in chapter 4 'First Time Use'). The heater calibration data in the **HWC** will be reset when the device is operated from 12V without a sensor connected for at least 5 seconds. You can force a reset by doing this, and then recalibrate by turning the unit off, reconnecting the sensor, and turning the unit on.

After the sensor is warmed up the meter automatically calibrates the sensor heater controller to the particular sensor. During this 20-second period the **HWC** collects and calculates sensor-specific data required to quickly reach operating temperature in the future.

Note: When using the Bosch Sensors the HWC may perform multiple calibration passes. This is normal and need not cause concern. When it completes, the HWC also will perform a free air calibration. Make sure the sensor is operating in free air for the heater and free air calibration.

6. Remote display and recording of Lambda and/or AFR

In many applications it may be desirable to monitor the air-fuel data remotely using a dash-mounted instrument. The **HWC** provides two options for that application.

6.1 Analog Lambda/AFR instrument.

There are many analog lambda/AFR displays on the market. They are essentially voltmeters for a voltage between 0 and 1 V and measure the analog voltage of a narrow band oxygen sensor. Some are true analog instruments while others provide a LED bar. Because of the very limited sensing range of a narrow band sensor they are essentially useless as true AFR meters. With the **HWC**, connecting these meters to the second analog output of the **HWC** allows them to be used as true remote AFR meters, provided the **HWC** analog output is programmed to the characteristics of the used meter. The **HWC** 's analog output 2 is factory programmed to provide a linear output between 0V and 5V for an AFR of 10 to 20, allowing a digital voltmeter to be used as the AFR display.

6.2 Connection to Haltech ECU's

The addition of the **HWC** to the Haltech Engine Management System will allow for far greater tune ability and functionality. The **HWC** will allow the AFR to be monitored and logged in real time, making it possible for accurate tuning to be done anywhere. All Haltech ECU's require the use of the Analog output 2 (0-5v signal).

For E8 and E11v2: Using the **Brown** wire (Analog output 2), the **HWC** can be connected to either the O2A wire (**Pin 12** on the 26Pin ECU Connector), or any of the Spare A/D channels. Alternatively for easy installation, the **HWC** can be connected into the Spare A/D 2 (Trim connector found near the ECU connector), using the 4-pin connector.
For software setup please see the ECU instruction manual.

For E6X, F10X and E6GMX: Using the **Brown** wire (Analog output 2), the **HWC** can be connected to the O2 wire (**Pin 2** on the ECU Connector). Alternatively for easy installation, the **HWC** can be connected into the **Trim** or **Spare A/D** connectors found near the ECU connector), using the 4-pin connector.
For software setup please see the ECU instruction manual.

6.3 Haltech Digital Display (HDD)

1. Connect the Serial OUT connection (unmarked) to the Serial IN connection of the **HDD1** (marked) with the included 2.5mm to 2.5mm cable.

2. Connect the terminator plug (2.5mm male plug with no cable) into the Serial IN connection of the **HWC**.

8. Tips, Tricks and Troubleshooting

8.1 General measurement requirements

The **HWC** measures the air-fuel-ratio by measuring the amount of oxygen in the exhaust (for lean conditions) or the amount of unburned or partially burned fuel (for rich conditions). You should correct for the following in order to get optimum results from the **HWC**

1) An exhaust leak will allow oxygen to enter the exhaust stream and therefore will measure leaner than the engine is actually running. For correct measurement, air-leaks in the exhaust MUST be prevented under all circumstances.
2) Missing ignitions (where the air-fuel mixture does not ignite) also pump unburned oxygen into the exhaust and cause the **HWC** to measure lean.
3) The only circumstance where the **HWC** will measure richer than the engine is running is if the pressure in the exhaust tract is excessive (and the engine is running on the rich side to begin with).

8.2 Vehicles with 'smog-pumps'

Older fuel injected vehicles with a 'smog-pump' actually inject air into the exhaust stream to aid their catalytic converter in the burn-up of unburned or partially burned fuels. This additional air will make the exhaust look leaner than the engine is running. For an accurate measure, install the **HWC** sensor up-stream of the outputs of the smog-pump. If this is not possible, temporarily disable the smog-pump by removing its drive belt.

8.3 Measuring at the tail-pipe

On non-catalytic converter equipped vehicles it is possible to measure the air-fuel-ratio at the tail-pipe. Without it too much outside air may enter the exhaust, especially at idle, to prevent correct measurements and leading to a lean measurement. Sticking the sensor itself into the exhaust pipe can yield inconsistent results because the sensor will not have outside air available as a reference gas and its reaction time becomes so slow that the **HWC** will report a sensor timing error. The oxygen sensor needs to have the back part of the sensor (where the wires enter the sensor) exposed to outside air.

8.4 Single Cylinder Engines

These kinds of engines are difficult to measure at the tail-pipe. The oscillations of the exhaust gas are so large that a lot of outside air enters the exhaust and prevents correct measurement. Sometimes it helps to just wrap a piece of heat resistant cloth around the exhaust clamp to prevent outside air from entering the exhaust.

8.5 Diesel Engines

Diesel Engines and gas turbines run at wide open throttle at all times. They do not have a throttle but regulate power by the amount of injected fuel. The **HWC** can still be used, but measurements at idle will read as lean.

8.6 Reference cell or Pump cell circuit open or shorted errors

Under some rare circumstances it is possible that the heater calibration data in the **HWC** can become partially destroyed. This can manifest in the above-mentioned errors. Follow the steps in chapter 4 'First time use' to reset the heater calibration data.

8.7 Sensor Timing Errors

These errors are typically encountered when the sensor does not have outside air available as reference gas. If you encounter this error, restart the **HWC** and operate the sensor in free air. If you still encounter this error, the sensor may be bad and needs to be replaced.

Replacement sensors are available from your nearest VW dealer under the VW part-number 021-906-262-B or direct from Haltech.

Sensor timing errors are also common when the sensor overheats. Relocate the sensor further downstream in the exhaust and/or install a heat sink.

Sometimes it's possible to encounter Error 08 when the exhaust gas suddenly gets too rich. Normally the **HWC** will display a 'too rich' indication if the exhaust gas is too rich. If the mixture gets rich very suddenly, the **HWC** cannot distinguish between a too rich condition and a sensor timing error.

8.8 Calibration tricks and hints

If the outside air-pressure changes dramatically (for example from sea-level to 10 000 ft) the sensor calibration will be off. Recalibrate the **HWC** at the new altitude and then tune your engine to the same AFR as on sea level. This insures the same AFR as determined at the different altitude is used by the engine to maximize performance.

Note: The following tricks can only be performed on EFI equipped engines, not carbureted or CIS engines.

Sometimes it is inconvenient to remove the sensor from the exhaust pipe for recalibration. On EFI equipped vehicles the following trick can be used:
EFI systems usually shut the injectors off during coast-down conditions (throttle closed and RPM typically greater than 1500 RPM). In this situation the engine just acts as a car-driven air-pump and fills the exhaust system quickly with pure air. In this situation the sensor can be recalibrated. If you need to step on the throttle while a calibration is in progress, you MUST repeat the calibration.

To quickly clear out remaining exhaust gas from the exhaust tract, it also helps to rev the car up in neutral, then at high RPMs shut the engine off while holding the throttle fully open. While the engine rotates to a stop it will act as air-pump. Holding the throttle fully open (WOT) minimizes pumping losses and allows the engine to pump a maximum of air without the need to suck it past the throttle plate.

8.9 Analog Output tricks/hints

Sometimes there is a ground offset between the device that receives the analog output voltage and the **HWC**. This can be specially true if the System ground is not connected to the same ground as the measurement device using the analog out. Both devices reference different grounds and therefore see different voltages. So to compensate for the ground offsets the analog output voltage points have to be shifted by the ground offsets. To measure what the real ground offset is, you can program the analog outputs temporarily to output a flat line voltage by entering the same voltage in both fields for the two analog out programming points. This way the analog output voltage will be fixed, independent of current AFR and can therefore be measured and compensated for easily

 ***Note:***
The analog outputs are NOT designed to power other devices or sensors. So using the flat-line setting at 5V and expecting to power a sensor from it will not work and can damage the HWC.

9 Advanced Topics

9.1 Connecting the HWC to simulate a narrow band oxygen sensor.

It is possible to install the wide-band sensor in place of the OEM oxygen sensor. In this case the meter's analog output signal will replace the OEM oxygen sensor's signal to the fuel injection computer. EFI equipped cars typically incorporate a narrow band oxygen sensor. These sensors are typically 1, 2, 3 or 4 wire sensors.

The analog output 1 of the **HWC** can simulate the operation of a narrow band sensor while the wide-band oxygen sensor is installed in place of the OEM narrow-band sensor. Factory equipped Analog output 1 of the **HWC** is programmed to simulate a narrow band sensor. Some vehicles are equipped with oxygen sensors that do not produce an output voltage but change their resistance depending on exhaust gas content. These sensors **cannot** be simulated. They are used in less than 1% of all vehicles. Refer to your vehicles specifications if you think that your vehicle may be in this category. The same is true for vehicles already factory equipped with a wide-band oxygen sensor. These **cannot** be simulated either.

Some EFI-computers will create a fault when the heater power wires of the oxygen sensor are disconnected. In this case mount the old oxygen sensor in a safe place (but not necessarily in the exhaust) and connect the heater wires to it to keep the EFI-computer happy.

 **Be careful where you mount the stock sensor, as heated sensors will get hot.**

To connect the **HWC** to the EFI-computer, first determine what kind of narrow band sensor is used, then follow the instructions below (you will need a digital multimeter to determine correct OEM sensor wires):

a. Vehicle has a 1-wire sensor:
Wire analog output 1 directly to the wire.

b. Vehicle has a 2-wire sensor:
While the engine is off determine which of the 2 wires has a low resistance between the wire and the sensor body. This is the heater power for the sensor. Wire analog output 1 directly to the other wire. Leave the heater power wire unconnected but make sure it cannot ground itself or see above.

c. Vehicle has a 3-wire sensor:
Typically the 3 wires are: heater power, Ground, and sensor element connection.
Generally they have 1 black wire and 2 white wires. Connect the black wire from the EFI computer to analog output 1 of the meter. Leave the other wires unconnected but make sure they cannot contact any metal parts or see above. If the wiring colors are different, then heater power can simply be determined by measuring the voltage on the wires when the engine is running. The wire showing 12V or more is the heater power. The sensor element connection voltage fluctuates around 0.45V when the car is warmed up. Wire analog output 1 directly to this wire. The Ground connection has low resistance to chassis ground (less than 1 Ohm). Measure while the engine is off.

d. Vehicle has a 4-wire sensor
Typically the 4 wires are: heater power, heater ground, sensor ground, and sensor element connection. Proceed as for the 3-wire sensor.

Appendix A: HWC Cable Pinouts

A1. Sensor Interface Connector (Standard DIN-5 female)

Lambda Meter	Signal	Wire Colors Bosch LSU4.2	Wire Colors NTK L1H1
1	Pump+	red	white
2	Sens+	black	red
3	Heater -	white	yellow
4	Pump-/Sens-	yellow	black
5	Heater +	gray	orange

Appendix B: LED blinking codes

1. Blinking steady about 2 times/second:	**Warming up**
2. Blinking steady at about 4 times/second:	**Heater calibration**
3. LED off	**No Power or free air calibration**
4. Blink sequence with 2 second pause	**Error indication**

Error indication details:

Count the number of fast flashes between 2 second pauses. The number of flashes indicates the error code as in

1 Flash	Error 1
2 Flashes	Error 2

And so on. See Appendix C for error code details.

Appendix C: HWC Error Codes and Troubleshooting Tips

Error Code	Error Message	Likely Root Cause	Fix
Error 1	Heater circuit shorted	1. Short in cable 2. Short in sensor	1. Repair/replace cable. 2. Replace sensor.
Error 2	Heater circuit open	1. Damaged sensor cable or Cable connector not fully seated	1. Verify Sensor connector is fully seated into unit. Repair/replace Sensor or cable.
Error 3	Pump cell circuit shorted	1. Short in sensor cable 2. Short in sensor 3. Sensor heater calibration incorrect 4. Sensor overheating 5. EGT >1700º F	1. Repair sensor cable. 2. Replace sensor. 3. Perform sensor heater recalibration. 4. Move your sensor bung as far downstream as possible OR add a heatsink to isolate the sensor from the pipe.
Error 4	Pump cell circuit open	1. Damaged sensor cable or sensor connector not fully seated 2. Sensor heater calibration incorrect	1. Verify sensor connector is fully seated into unit. Repair/replace cable. 2. Perform complete heater calibration (not just free air calibration). See section 4
Error 5	Reference cell circuit shorted	1. Short in sensor cable 2. Short in sensor	1. Repair sensor cable. 2. Replace sensor.
Error 6	Reference cell circuit open	1. Damaged sensor cable or sensor connector not fully seated 2. Damaged Sensor	1. Verify sensor connector is fully seated into unit. 2. Replace sensor
Error 7	General System error (typically a software error).	Typically a software error	Reboot **HWC** by cycling power. Re-flash unit if necessary.
Error 8	Sensor Timing error (typically a damaged sensor).	1. Sensor overheating. (The Bosch LSU4.2 is rated to operate at a sensor housing temperature of < 900 degrees (measured at the bung) for maximum accuracy and control. When this operating temperature range is exceeded, the sensor can no longer be accurately controlled.) 2. Sensor is damaged	1. a. Perform sensor heater recalibration; b. Move your sensor bung as far downstream as possible. Right before the cat, or 2-3 feet from the end of the tailpipe are good locations; c. Add a heatsink to isolate the sensor from the pipe. 2. Replace sensor.
Error 9	Supply Voltage too low	Supply voltage too low for sensor regulation	Check your 12V connection for corrosion.

Appendix C: Limited Warranty

LIMITED WARRANTY
Haltech stands behind the quality of its products. Haltech makes the following warranty to purchasers of its products: All new Haltech products carry a 90 day warranty from the date of purchase. If proof of purchase cannot be provided, warranty will be determined by date of manufacture.

When Warranty Void
This warranty shall terminate and Haltech shall have no obligation pursuant to it if (i) your Haltech product has been modified or repaired in a manner not previously authorized by Haltech in writing, (ii) the identification markings on your Innovate product have been removed, defaced, or altered; (iii) your Haltech product was subjected to accident, abuse, shipping damage, or improper use; (iv) your Haltech product was not used or configured as specified in the product manual; or (v) your Haltech product was subjected to operating conditions more severe than those specified in the product manual.

Exclusions From This Warranty
Oxygen Sensors are excluded from this warranty.

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Revision History

1.0 – 12/05/05
Initial release