Exhaust Gas Analysis with Lambda Sensor

DTM4007 Air/Fuel Ratio Meter (actual size)

For decades measuring exhaust gas as a means of analysing the air/fuel ratio of the internal combustion engine has caused headaches for the serious engine builder or tuner. Until recent years the only reliable method was to use an infra-red carbon monoxide gas analyser, however because of the slow reaction time of this equipment, up to eight seconds, it can be difficult to interpret the results when an engine is at speed, and this can lead to damage at leaner mixtures.

With the development by motor manufacturers of the oxygen, or lambda sensor for use on cars fitted with catalytic converters, we now have available an economical sensor to measure exhaust gas oxygen content. At exhaust temperatures between 350 and 500 degrees C this is directly proportional to air/fuel ratio, and the sensor outputs a voltage which we can display on the DTM4007 Air/Fuel Ratio Meter using the LED display.

The DTM4007 Air/Fuel Ratio Meter has nineteen LEDS, seven red lights for lean mixtures, five orange lights for mid range mixtures around the stoichiometric or chemically correct air/fuel ratio of 14.7:1, and seven green lights for rich mixtures. Of most interest to high performance and race engine tuners is the area of the green lights. The term lambda is defined as "Actual air/fuel ratio divided by 14.7", therefore stoichiometry, the point at which the most energy can be obtained from a given amount of fuel, is 14.7 / 14.7 = 1. Richer mixtures are lambda less than one, leaner mixtures are lambda greater than one. Race engines give the most power running with an air/fuel ratio of less than 14.7:1, or lambda < 1 , whereas road going engines require a mixture of lambda = 1, or even lambda > 1 to achieve the required low emissions that enable catalytic converters to work, and give maximum fuel economy.

Mixture adjustment for racing engines

It is generally accepted that race engines give the most power at lambda = 0.9 to lambda = 0.8 , depending on engine type and conditions. At these air/fuel ratios the DTM4007 Air/Fuel Ratio Meter will display between the first and third green light under full load at full throttle. When accelerating more green lights should be seen to indicate that the acceleration enrichment part of the fuel system is calibrated correctly. The display should read lean on over-run and in feathered throttle conditions.

Mixture adjustment for road engines

If the vehicle is fitted with a catalytic converter the air/fuel ratio should never be richer than lambda = 1 to prevent damage to the catalytic converter. In fact the vehicle will have an inbuilt system to prevent this from happening. If the tuner has over-ridden this system, and the mixture has gone richer than lambda = 1 the catalytic converter may cease to function. This will not damage the engine. In cruise conditions the central orange light should be lit, and with all but the highest performance road engines the last orange light should be lit at full throttle for maximum fuel economy, or the first or second green light for maximum power.

Fitting the sensor

The sensor should be fitted into the exhaust system as close to the engine as possible, before the catalytic converter if fitted, just behind the collector. In the case of turbocharged engines, because of the high temperature created in the exhaust system the sensor should be at least 1.5 metres from the engine Care should be taken to ensure that the sensor cannot be cooled significantly by air or water passing under the car as it is driven. The display should be mounted on the dash were it can easily be seen whilst driving, or in the dyno control room.

Wiring

From the sensor the two white wires should be placed across a 12 volt supply capable of delivering 1 amp. These wires supply the inbuilt heater and are not polarity sensitve. The grey wire, if the sensor has one, is the earth return for the signal and should be connected to the 0 volt black wire from the display. If the sensor does not have a grey wire the earth return path is through the body of the sensor and the exhaust, engine, and chassis, in this case care must be taken that there is a good earth return path from the sensor body to the black wire from the display, as some exhausts or engine mounts can insulate the sensor body from earth. The black wire from the sensor is the signal wire and should be connected to the pink wire from the display. The red wire from the display should be connected to the +12 volt DC supply, and the black wire from the display connected to chassis ground.

Data Acquisition

The DTM4007 Air/Fuel Ratio Meter has an output of 0-5 volts to enable lambda readings to be logged along with all the other data collected. This is accessed by using the white wire and ground.

Used by leading engine builders;

Swindon Race Engines
Terry Hoyle Limited
Zytek
Mountune
Peugeot Talbot Motorsport
Racetech Electronics
General Engine Management Systems
DTW Engines
John Wilcox Engines
Terry Drury Race Cars
Lumenition
Raceparts

Racing Solutions
Mistral Engineering

Use of the sensor

The use of leaded fuel with the sensor will dramatically reduce its life. If you have to use leaded fuel, use the sensor to set up the engine and then replace it with a bung. If the display reads leaner and leaner with a constant mixture, either the sensor has cooled below its operating temperature, or it has become contaminated with lead. New sensors are available,

Other fuels

The DTM4007 Air/Fuel Ratio Meter will operate with most fuels, and has been tested with methanol, alcohol, butane, propane, nitrous oxide, hydrogen, and two stroke petrol (We are currently working on diesel). The numerical air/fuel ratio will differ from one fuel type to another, but the relationship of lights to stoichiometry for each fuel will remain the same.