Simtec EMS (MPi) : System overview

Introduction

The Simtec EMS was introduced by GM on the 1993 Astra F DOHC C18XE engine and subsequently fitted to other 1.8 and 2.0 litre Omega, Cavalier and Vectra vehicles. Simtec belongs to a class of GM systems designated ECOTEC and was designed as a modular system that was capable of controlling a range of engines utilising DIS ignition, sequential MPi and a catalytic converter. The engine is equipped with a digital CAS and the load sensor is a Hot Wire type AFS.

There are a number of variations to Simtec although essentially the system remains similar in most aspects. The original system fitted to the Astra F was designated Simtec 56.0 and other variations include Simtec 56.1 and 56.5. Simtec 56.1 sees the addition of EGR & pulse air and 56.5 includes a switched inlet manifold system. It is important to note that although the same ECM pin numbers are used for Simtec 56.0 and 56.1, a totally different set of pin numbers are used in 56.5.

The Simtec ECM is designed with three main areas of control. These are the ignition, fuel system and idle speed. The Simtec ignition point and injection duration are jointly processed by the ECM so that the best moment for ignition and fuelling are determined for every operating condition.

An ISCV, located in the throttle body, is provided for Idle control. The injection system is multi-point sequential and control of emissions is aided by the use of EGR and pulse air. A single 55 pin multiplug connects the ECM to the battery, sensors and actuators.

Basic ECM operation

Note 56.5 pins in brackets
Voltage is permanently applied to ECM pin 18 (55) from the system battery. Once the ignition is switched on, voltage is applied to the ignition coils, VSS and to ECM pin 47 (17). When the ECM senses ignition voltage, the main relay is driven to earth which energises the relay winding and so provides voltage output from terminal 87. Voltage is thus applied to ECM terminals 37 and 46 (35 and 44), the AFS, all the main actuators, the Pulse air pump relay, the OS heater and terminal 86 of the fuel pump relay.

The majority of sensors (other than those that generate a voltage such the CAS, KS, and VSS), are now provided with a 5.0 volt reference supply from a relevant pin on the ECM. When the engine is cranked or run, a speed signal from the ignition causes the ECM to apply voltage to the relay so that the fuel pump and injector valves will run. Ignition and injection functions are also activated. The injector circuit is completed by pulsing the relevant actuator wire to earth, and the ISCV regulates the idle speed under ECM control when the engine is at idle.

Reference voltage

Voltage supply from the ECM to the engine sensors is made at a 5.0 volt reference level. This ensures a stable working voltage unaffected by variations in system voltage.

The earth return connection for some engine sensors is made through an ECM pin and this pin is not directly connected to earth. The ECM internally connects these sensors to earth via an ECM earth pin that is directly connected to earth. However, in the Simtec system the majority of sensors are directly connected to earth.

Signal shielding

To reduce RFI, a number of sensors (ie CAS, CID, KS, AFS, TPS, and OS) use a shielded cable. The control signals for the ignition coils are also shielded.

Signal processing

Basic ignition timing is stored by the ECM in a three dimensional map and the engine load and speed signals determines the ignition timing. Engine load is determined from the Hot Wire AFS and engine speed is determined from the CAS.

Correction factors are then applied for starting, idle, deceleration and part and full-load operation. The main correction factor is engine temperature (CTS). Minor correction to timing and AFR are made with reference to the ATS and TPS signals.

The basic AFR is also stored in a three dimensional map and the engine load and speed signals determines the basic injection pulse value. Simtec calculates the AFR from the AFS and the speed of the engine.

The AFR and the pulse duration are then corrected on reference to the ATS, CTS, battery voltage and rate of throttle opening (TPS). Other controlling factors are determined by operating conditions such as cold start and warm-up, idle condition, acceleration and deceleration.

Simtec accesses a different map for idle running conditions and this map is implemented whenever the engine speed is at idle. Idle speed during warm-up and normal hot running conditions are maintained by the Idle control. The ECM makes small adjustments to the idle speed by advancing or retarding the timing, and this results in an ignition timing that is forever changing during engine idle.

The ECM is supplied in MT form and automatically adjusts itself to an AT or MT environment when first fitted to a particular motor vehicle. However, if the ECM is moved it should be manually reprogrammed to suit the new environment because automatic adaption only occurs at first fitting. This is also true of in-service replacements.

Self Diagnostic function

The Simtec system has a self-test capability that monitors the signals from the engine sensors and internally logs a code in the event of a fault being present. This code can be extracted from the serial port by a suitable Fault Code Reader.

Warning lamp

A warning lamp is provided in the instrument panel to warn that faults are present in the system. When the ignition is first switched on the warning lamp will illuminate and remain illuminated until the engine is started. It will then extinguish. If the ECM detects that a fault is present whilst the engine is running, pin 35 (52) is earthed and the warning lamp will light. The lamp will stay lit until the fault is no longer present.

If the fault clears, the internal fault code will remain logged in EEPROM until wiped clean with a suitable FCR. Disconnecting the battery will not clear the codes.

LOS (limp home)

In addition to the self-test capability, Simtec has a limp home facility. In the event of a serious fault in one or more of the sensors, the EMS will substitute a fixed default value in place of the defective sensor.

This means that the engine may actually run quite well with failure of one or more minor sensors. Since the substituted values are those of a hot engine, cold starting and running during the warm-up period may be less than satisfactory. Also, failure of a major sensor, ie AFS, will lead to a considerable reduction in performance.

Adaptive function

The ECM is adaptive to changing engine operating characteristics and constantly monitors the data from the various sensors. As the engine or its components wear, the ECM reacts to new circumstances by adopting the changed values as a correction to the basic Map. This process affects the idle and lambda functions in particular.

Non-volatile memory

The Simtec system stores adaptive and certain other values in non-volatile (EEPROM) memory. Consequently, a replacement ECM will need some time to re-learn the system parameters before proper idle control is restored. Re-programming with a suitable FCR is recommended whenever a new ECM is fitted.

Faults identified by the self-diagnostic function will also be stored in non-volatile memory and will remain there until erased by a suitable FCR. This allows the self-diagnostic function to retain data of an intermittent nature.

Adaptive idle measurements and fault codes retained in non-volatile memory cannot be lost - even if the vehicle battery is removed. If the ECM from one vehicle is transferred to another vehicle, the contents of non-volatile memory will also be transferred unless a FCR is used to erase the codes and the engine re-programmed to the new set-up.

Rogue Adaptive function

The danger with an adaptive function is that sometimes an erroneous signal may be adopted as a valid measurement and this may create an operating problem. If the erroneous signal remains within the system parameters a fault code will not be generated.

Where this problem is suspected, the sensors should be checked for correct operation within their own operating parameters. Any faults must be corrected and the ECM recalibrated as described above.

In some instances the ECM can become confused and the adaptive values could become corrupted. This may cause operational problems and a system check will reveal 'no fault found'. Re-programming the ECM as described above may effect a cure since the re-calibration will reset the ECM default base values.

VSS

The VSS is used to advise the ECM of vehicle speed. It operates upon the Hall-effect principle and can be mounted directly upon the gearbox or behind the dash.

A voltage of approximately 10 volts is applied to the VSS from the ignition switch when it is in the switched on position. As the speedometer cable turns, the hall switch is alternately turned on and off to return a square wave signal to the ECM. The frequency of the signal denotes the vehicle speed.

CAS (Primary Trigger)

The CAS consists of a toothed disk and an two coils (exciter and modulator). The disk is attached to the crankshaft and theoretically comprises 59 teeth set around its circumference. At a position 114° BTDC, one tooth is omitted as a reference to TDC and so a total of 58 teeth remain on the disk. A high frequency signal of between 120 and 180 khz is delivered to the exciter coil by the ECM.

As the crankshaft spins, and the teeth are rotated in the exciter coil field, a modulation occurs which is returned to the ECM to indicate speed of crankshaft rotation and a reference to TDC as an indication of crankshaft position. The ECM makes a digital comparison of both ECM and CAS output signals and registers a phase difference that is proportional to the CAS output.

If the CAS were to fail, the ECM logs a fault code and enters LOS mode utilising the signal from the CID sensor. If both sensors were to fail, ignition operation would be inhibited for safety purposes.

CID (camshaft sensor)

The camshaft sensor operates on the same principle as the CAS. The CID sensor consists of a disk with one segment and an exciter coil. The disk is attached to the camshaft. A high frequency signal of between 120 and 180 khz is delivered to the exciter coil by the ECM. As the camshaft spins, and the segment is rotated in the exciter coil field, a modulation occurs which is returned to the ECM to indicate the position of number one cylinder. The ECM makes a digital comparison of both ECM and CID sensor output signals and registers a phase difference that is proportional to the CID position.

If the CID sensor were to fail, the ECM logs a fault code and enters LOS mode utilising the signal from the CAS. If both sensors were to fail, ignition operation would be inhibited for safety purposes.

Ignition system

Data on engine load and engine speed are collected by the ECM, which then refers to a digital ignition map stored within its microprocessor. This map contains an advance angle for basic load and speed operating conditions. The advance angle is corrected after reference to engine temperature (CTS), so that the best ignition advance angle for a particular operating condition can be determined.

Amplifier

The amplifier contains the circuitry for switching the coil negative terminal at the correct moment to instigate ignition. The amplifier circuitry is contained within the ECM itself and the microprocessor controls the ignition dwell period for each condition of engine speed and battery voltage.

The ECM calculates the correct ignition dwell time and timing advance from data received from its sensors, and signals the amplifier which then switches the coil negative terminal. Dwell operation in Simtec is based upon the principle of the `constant energy current limiting' system. This means that the dwell period remains constant at about 3.0 to 4.0 ms, at virtually all engine running speeds. However, the dwell duty cycle, when measured in percent or degrees, will vary as the engine speed varies.

Ignition coils

The twin ignition coils utilise low primary resistance in order to increase primary current and primary energy. The amplifier limits the primary current to around 8 amps and this permits a reserve of energy to maintain the required spark burn time (duration). Each ignition coil requires a voltage supply from the ignition switch and a separate dwell connection to the ECM, so that the ECM can switch each coil individually.

The coil is switched on by the amplifier and a magnetic field builds-up in the primary coil windings during the dwell duration. On receiving the correctly timed ECM signal, the amplifier switches off the coil which collapses the magnetic field and induces a high voltage in the secondary coil windings. Secondary voltage is thus output from the coil tower and sent directly to the sparkplug.

DIS ignition

Although the ignition system is termed DIS, the basic operation is similar to models with conventional ignition. In a DIS or so called `wasted spark' system, a double ended coil is used to fire two plugs at the same time. This means that the system can only be used where two cylinders rise and fall together. Two double ended coils are therefore required to fire four sparkplugs in a four cylinder engine.

One cylinder will fire on the compression stroke and the companion cylinder will fire on the exhaust stroke where the spark is ` wasted'. Two pairs of coils are therefore required for a four cylinder engine. About 3 KV is still needed to fire the `wasted spark' plug, but this is far less than that required to bridge the rotor gap when a distributor is fitted.

Knock control

The optimal ignition timing (at engine speeds greater than idle) for a given high compression engine is quite close to the point of onset of knock. However, running so close to the knock point, means that knock will certainly occur on one or more cylinders at certain times during the engine operating cycle.

The KS is mounted on the engine block and consists of a piezoceramic measuring element that responds to engine noise oscillations. The KS converts these noise oscillations into a small AC output voltage. GM engines have a knocking frequency in the 8 kHz frequency band and noise signals in this band form the basis for the output signal.

Initially, timing will occur at its mapped optimal ignition point. Once knock is identified, the ECM retards the ignition timing for that cylinder or cylinders by a predetermined number of degrees. Once knock ceases, timing is advanced until the reference timing value is achieved or knock occurs once more when the timing is again retarded. This procedure continually occurs so that all cylinders will consistently run at their optimum timing.

If a fault exists in the Knock Control processor, Knock Sensor or Knock Sensor wiring, an appropriate code will be logged in the self-diagnostic unit and the ignition timing retarded (12°) by the LOS program.

Due to the sophistication of timing and knock control in the Simtec system, the octane coding plug is redundant for engines equipped with this system.

Fuel injection system

The Simtec system pulses the injectors sequentially - ie in firing order and once per engine cycle. Each injector is connected to the ECM via a separate ECM pin. A camshaft phase sensor (CID), mounted in proximity to the camshaft, identifies the position of number one cylinder for correct injector sequential timing.

The ECM contains a three dimensional fuel map with an injector opening time for basic conditions of load and speed. Information is then gathered from engine sensors such as the AFS, CAS, CTS, and TPS. As a result of this information, the ECM will look-up the correct injector pulse duration right across the engine rpm, load and temperature range.

The amount of fuel delivered by the injector is determined by the fuel pressure and the injector opening time - otherwise known as the pulse duration. The ECM controls the period of time that the injector is held open and this determined by the signals from the various sensor inputs. During engine start-up from cold, the pulse duration is increased to provide a richer air / fuel mixture.

Fuel injector

The fuel injector is a magnetically operated solenoid valve that is actuated by the ECM. Voltage to the injectors is applied from the pump relay and the earth path is completed by the ECM for a period of time (called pulse duration) of between 1.5 and 10 milliseconds. When the magnetic solenoid closes, a back EMF voltage of up to 60 volts is induced.

Deceleration fuel cut-off

A reduction in the injection pulse is implemented during engine over-run conditions to improve economy and emissions.

CO adjustment

There is no provision for CO adjustment on any of the models in this range.

Hot-film Air mass meter (AFS)

Simtec utilises a Hot-film Air Flow Sensor to measure the mass of air entering engine. From the air mass, an accurate fuel injection pulse can then be calculated. Hot-film is a very accurate method of calculating the engine load (air input). The absence of moving parts improves reliability and lessens maintenance requirements.

Essentially, the hot-film is so called because a heated resistor (hot-film sensor) is placed in the air intake. The ECM applies current so that the resistor is maintained at a constant temperature that is much higher than the temperature in the air intake. As air passes over the resistor it has a cooling effect and the ECM adjusts the current flow to maintain the resistor at its original temperature. As airmass increases or decreases according to engine load, the current flow also increases or decreases and the current flow measurement is in direct proportion to the mass of air flowing into the engine.

By measuring the change in current flow, the ECM is able to determine the mass air flow. As the current varies on the signal wire, so does the voltage and an indication of load can be assessed by measuring the variable voltage signal. Voltage is applied to the sensor from the system relay. A honeycomb element and grid is provided in the air intake area of the AFS to smooth the flow of air past the sensor. In addition, the ECM individually corrects each signal to iron out inconsistencies created by manufacturing tolerances.

If a fault exists in the Hot Wire AFS or wiring, an appropriate code will be logged in the self-diagnostic unit and a substitute value provided by the LOS program.

ATS

The ATS is mounted between the air filter and the AFS and measures the air temperature in the inlet tract. Because the density of air varies in inverse proportion to the temperature, the ATS signal allows more accurate assessment of the volume of air entering the engine.

The ATS contains a variable resistance that operates on the NTC principle. When the air temperature is cold, the resistance is quite high. Once the engine is started and begins to warm-up, the air temperature in the engine bay becomes hotter and this causes the resistance of the ATS to diminish. A variable voltage signal is thus returned to the ECM based upon the air temperature.

The open circuit supply to the sensor is at a 5.0 volt reference level and the earth path is through the sensor return.

CTS

The CTS is immersed in the coolant system and contains a variable resistance that operates on the NTC principle. When the engine is cold, the resistance is quite high. Once the engine is started and begins to warm-up, the coolant becomes hotter and this causes a change in the CTS resistance. As the CTS becomes hotter, the resistance of the CTS reduces (NTC principle) and this returns a variable voltage signal to the ECM based upon the coolant temperature.

The open circuit supply to the sensor is at a 5.0 volt reference level and this voltage reduces to a value that depends upon the resistance of the CTS resistance. Normal operating temperature is usually from 80° to 100° C. The ECM uses the CTS signal as a main correction factor when calculating ignition timing and injection duration.

TPS

A TPS is provided to inform the ECM of idle position and rate of acceleration. The TPS is a potentiometer with three wires. A 5 volt reference voltage is supplied to a resistance track with the other end connected to earth. The third wire is connected to an arm which wipes along the resistance track and so varies the resistance and voltage of the signal returned to the ECM.

ISCV

The ISCV is a solenoid controlled actuator that the ECM uses to automatically control idle speed during normal idle and during engine warm-up. The ISCV is directly located in the throttle body.

When an electrical load, such as headlights or heater fan etc are switched on, the idle speed would tend to drop. The ECM will sense the load and rotate the ISCV against spring tension to increase the air flow through the valve and thus increase the idle speed. When the load is removed, the ECM will pulse the valve so that the air flow is reduced. Normal idle speed should be maintained under all cold and hot operating conditions. If the ISCV fails it will fail in a fail-safe position with the aperture almost closed. This will provide a basic idle speed.

Induction Switchover Solenoid Valve (ICSV) wiring diagram operation

Under all operating conditions, air flows into the induction manifold through the throttle valve in the throttle body. However, on GM vehicles equipped with Simtec 56.5, a variable induction system is utilised to improve the flow of air into the engine at both low and high engine speeds.

At low engine speeds, airflow is comparatively slow and this can lead to inefficient fuel atomisation when the inlet port to the inlet valve is large. Ideally the port should be small which leads to higher air speeds and much better atomisation and a more efficient engine. The condition is accentuated in 16 valve engines which tend to be sluggish at low engine speeds.

Conversely, at high engine speeds the volume of air into the engine needs to be high which demands a larger inlet port. A small port at high engine speeds would restrict engine performance - particularly in 16 valve engines which are more efficient at higher engine speeds. For effective engine operation over the entire engine rpm range then, a variable inlet port would seem to be required.

Traditionally, engines equipped with a carburettor overcame this particular problem with the aid of a twin venturi air inlet. A number of fuel injected engines have used a similar arrangement in the throttle barrel. However, Simtec uses a somewhat different solution.

Each cylinder is provided with its very own inlet manifold. The inlet port to each set of inlet valves is divided into two ports. In addition, the manifolds are curved so that the outer inlet path is long. The secondary inlet curves inside the long inlets to give a short path - which improves the air flow at high speed. The shorter secondary inlet is provided with its own throttle valve whilst the longer inlet remains permanently open.

A centrally located shaft protrudes through each manifold where it is is attached to a secondary butterfly valve located in each short induction path.

Voltage is applied to the ISSV from the main relay and the earth path is completed through the ECM. When engine rpm is generally above 3600 rpm the ISSV is switched 'on' by the ECM so that the shaft is rotated and the butterfly valve will open.

.The diameter is large enough to satisfy engine demand at high engine speeds and air will pass into the engine through both inlet ports

When engine speed lies in the lower range, the ECM switches the ISSV 'off' so that the shaft will return to its rest position and the secondary butterfly throttle will close. The engine thus receives the correct volume of air for all operating conditions of speed and load.

Fuel system relays

The Simtec electrical system is controlled either by a single system relay with dual contacts or two separate relays. Whichever method is used, the method of operation is very similar. A permanent voltage supply is made to relay terminals 30 and 86 from the battery positive terminal. When the ignition is switched on, the ECM earths terminal 85 through ECM terminal number 16 which energises the first relay winding. This causes the first relay contacts to close and terminal 30 is connected to the output circuit at terminal 87. Voltage is thus applied to ECM terminals 37 and 46, the AFS, all the main actuators, the Pulse air pump relay, the OS heater and terminal 86 of the fuel pump relay.

When the ignition is switched on. the ECM briefly earths relay contact 85b (or 85) at ECM terminal 15. This energises the second relay winding, which closes the second relay contact and connects voltage from terminal 30 to terminal 87b (or 87), thereby providing voltage to the fuel pump circuit. After approximately one second, the ECM opens the circuit and the pump stops. This brief running of the fuel pump allows pressure to build within the fuel pressure lines and provides for an easier start. The fuel pump circuit also applies voltage to the fuel injector valves.

The pump circuit will then remain open until the engine is cranked or run. Once the ECM receives a speed signal from the CAS, the second winding will again be energised by the ECM, and the fuel pump and injectors will run until the engine is stopped.

Pulse air pump relay

The Simtec pulse air pump is controlled by a single relay. A permanent voltage supply is made to the pump relay terminal 87 from the battery positive terminal.

When the engine is running, voltage is output from the main relay terminal 87 and applied to pulse air relay terminal 86.

The pulse air pump circuit is only actuated by the ECM during the first three to four minutes of engine running after a cold start. During this period the ECM earths the relay contact 85 at the appropriate ECM terminal which energises the relay winding and causes the pulse air pump relay contacts to close. Voltage is connected from terminal 87 (input) to terminal 30 (output) and a voltage is thus output to the pulse air pump circuit.

After three to four minutes the ECM switches off terminal 85 and the air pump ceases operation.

Fuel pressure system

The fuel system includes a fuel tank and a submerged fuel pump. The fuel pump draws fuel from the tank and pumps it to the fuel rail via a fuel filter.

The pump is of the 'wet' variety in that fuel actually flows through the pump and the electric motor. There is no actual fire risk because the fuel drawn through the pump is not in a combustible condition.

The fuel pump assembly comprises an outer and inner gear assembly termed a gerotor. Once the pump motor becomes energised, the gerotor rotates and as the fuel passes through the individual teeth of the gerotor, a pressure differential is created. Fuel is drawn through the pump inlet, to be pressurised between the rotating gerotor teeth and discharged from the pump outlet into the fuel supply line.

Once the engine is running, fuel is fed through a non-return valve and fuel filter to the multi-point injector rail. To prevent pressure loss in the supply system, a non-return valve is provided in the fuel pump outlet. When the ignition is switched off, and the fuel pump ceases operation, pressure is thus maintained for some time.

Fuel pressure regulator

Fuel pressure in the fuel rail is maintained at a constant 3.0 bar by a fuel pressure regulator. The fuel pump normally provides much more fuel than is required, and surplus fuel is thus returned to the fuel tank via a return pipe. In fact, a maximum fuel pressure in excess of 5 bar is possible in this system. To prevent pressure loss in the supply system, a non-return valve is provided in the fuel pump outlet. When the ignition is switched off, and the fuel pump ceases operation, pressure is thus maintained for some time.

The pressure regulator is fitted on the outlet side of the fuel rail and maintains an even pressure of 3.0 bar in the fuel rail. The pressure regulator consists of two chambers separated by a diaphragm. The upper chamber contains a spring which exerts pressure upon the lower chamber and closes off the outlet diaphragm. Pressurised fuel flows into the lower chamber and this exerts pressure upon the diaphragm. Once the pressure exceeds 2.5 bar, the outlet diaphragm is opened and excess fuel flows back to the fuel tank via a return line.

A vacuum hose connects the upper chamber to the inlet manifold so that variations in inlet manifold pressure will not affect the amount of fuel injected. This means that the pressure in the rail is always at a constant pressure above the pressure in the inlet manifold. The quantity of injected fuel thus depends solely on injector opening time, as determined by the ECM, and not on a variable fuel pressure.

At idle speed with the vacuum pipe disconnected, or with the engine stopped and the pump running, or at WOT the system fuel pressure will be approximately 2.5 bar. At idle speed (vacuum pipe connected), the fuel pressure will be approximately 0.5 bar under the system pressure.

Catalytic Converter.

Since January 1993 all UK vehicles are required to be fitted with a catalytic converter.

A catalyst is something which promotes a reaction, but itself remains unaffected by the reaction. The catalytic converter consists of a stainless steel housing containing a ceramic monolith with a honeycomb of passages called cells.

There are 400 cells per square inch giving an internal surface area of 3.55 metres. The element is coated with a rough surfaced aluminium oxide washcoat and fired in a kiln to give a surface area of 1-2 football pitches (depending on catalyst size). The washcoat is coated with microscopically thin layer containing 2-3 grams of the precious metals platinum and rhodium.

A steel mesh blanket is used to protect the monolith from heat and road vibrations. Some form of heat shielding is placed between the vehicle underbody and exhaust and the passenger compartment is heat insulated.

The catalyst is like a secondary combustion chamber, and CO and HC are oxidised into HIO and COI. NOx is oxidised by a process known as reduction where oxygen and nitrogen are forced apart. The oxygen combines with CO to produce COI and NI.

A weak mixture with a high level of OI is good for the efficient oxidation of CO and HC. On the other hand a relatively rich mixture with some CO aids the reduction of NOx. A compromise is reached by adjusting the catalyst equipped engine to the stoichiometric ratio of 14:1. This means that the engine is perhaps adjusted slightly richer than desirable, and will therefore use more fuel.

A Catalyst needs to reach a minimum temperature of 300° C before it begins to work efficiently. A working temperature of 400-800° C is more desirable. As the temperature rises over 800-1000° C the precious metals will begin to breakdown. Above 1000° C the catalyst will melt. Excess fuel or misfires causes overheating. Leaded petrol and excessive oil residue also destroys the catalyst. Here the lead compounds clog the pores of the washcoat and coat the precious metals, thus reducing the conversion rate and eventually rendering it useless. The fuel filler pipe in a catalyst equipped vehicle is restricted to prevent the use of leaded petrol.

If the catalyst is to function at maximum efficiency with a life span of approximately 50,000 miles, the exhaust emission output from the engine must be strongly regulated. An engine with Catalytic Converter, operating in open loop control (without ECM and an OS) will convert a much lower percentage of emissions than an engine operating in closed loop control (with ECM and an OS). In the first instance the emission conversion rate will be approximately 50% and in the second instance the emission conversion rate is likely to be more than 90%.

When new the catalyst may emit HIS (Hydrogen Sulphide) gas. This smells like rotten eggs and is caused by the sulphur contained in petrol. Under deceleration when the AFR is lean, sulphur trioxide is stored in the catalyst. After deceleration, when the AFR enriches, this sulphur trioxide reacts with hydrogen in the exhaust to be emitted as HIS. Although HIS is toxic, the emission is considered to be quite safe. Generally, the smell becomes less pronounced after a few thousand miles.

Lambda control

The injection system fitted to Simtec equipped catalyst vehicles implements a closed loop digital control system so that exhaust emissions may be reduced. This systems is equipped with a Titanium oxide type oxygen sensor (OS) which monitors the exhaust gas for its oxygen content. A low oxygen level in the exhaust signifies a rich mixture and a high oxygen level in the exhaust signifies a weak mixture.

The ECM provides a five volt reference to the OS. During engine operation the resistance of the OS varies with oxygen content in the exhaust gases so that a switching signal is returned to the ECM. The signal switches from weak (less than 400 mVolts) to rich (greater than 3.85 volts) at the rate of approximately 1 HZ (one pulse per second). Unlike Zirconia equipped OS systems, the Titania OS does not generate its own voltage.

When the engine is operating under closed loop control, the OS signal causes the ECM to modify the injector pulse so that the AFR is maintained close to the stoichiometric ratio. By controlling the injection pulse, during most operating conditions, so that the air/ fuel ratio is always in a small window around the Lambda point (ie Lambda = 0.98 to 1.04), almost perfect combustion could be achieved. Thus the Catalyst has less work to do and it will last longer with fewer emissions at the tail pipe.

Closed loop control is implemented during engine operation at normal operating temperatures. When the coolant temperatures is low, or the engine is at full load or is on the overrun the ECM will operate in open loop. When operating in open loop, the ECM allows a richer or leaner AFR than the stoichiometric ratio. This prevents engine hesitation, for example, during acceleration with a wide open throttle.

The OS only produces a signal when the exhaust gas, has reached a minimum temperature of approximately 300 degrees centigrade and an ECM controlled OS heater is implemented to quickly raise the exhaust temperature immediately the engine has started.

Evaporative emission control

A CFSV and activated carbon canister are also employed to aid evaporative emission control. The carbon canister stores fuel vapours until the CFSV is opened by the ECM under certain operating conditions. Once the CFSV is actuated by the ECM, fuel vapours are drawn into the inlet manifold to be burnt by the engine during normal combustion. Control of the CFSV by the ECM is coordinated with reference to Lambda control and Lambda adaption.

EGR system

typical diagram

Modern engine that run at high temperatures with high compression tend to produce a high level of NOx. NOx production can be reduced by recycling a small amount of exhaust gas into the combustion chamber. So long as the recycling of the exhaust gas is properly controlled, the engine operation will be little affected. The EGR system used in this version of the GM-Simtec equipped vehicles is controlled by the ECM according to signals received from the various sensors. Components used in this EGR control system include an EGR CS (EGR Control Solenoid) and a vacuum controlled EGR valve. The EGR CS is supplied with voltage from the fuel injection relay.

A passage connects the the inlet and exhaust manifolds and the EGR valve is located so that it controls the opening and closing of the passage. The EGR valve is normally held closed by a spiral spring. On receipt of a pulsed signal from the ECM, the EGR CS opens to allow vacuum to act upon the EGR valve which opens to allow a metered volume of exhaust gas into the inlet manifold. The opening time of the EGR valve is varied according to the control signal acting upon the EGR CS with a duty cycle that varies according to the degree of control required.

EGR is controlled by the ECM with regard to vehicle speed, coolant temperature and engine load. EGR must not occur during idle speed or full load conditions (at all temperatures) or during the cold start and engine warm-up period.

Pulse air system

typical diagram

It is important that the catalytic converter and OS reach their respective operating temperatures as soon after the engine is started as possible. Bleeding fresh air into the exhaust system allows the rich cold start mixture to continue burning. This raises the exhaust temperature and very quickly achieves the objective.

Fresh air from a secondary air pump is routed to the exhaust manifold via a pulse air valve (PAV). The air enters the exhaust manifold through a non-return valve. The air pump is actuated immediately after a cold start. Air is pumped into the exhaust manifold until the the OS reaches operating temperature and begins switching. This occurs within 3 to 4 minutes from a cold engine start.

Voltage is applied to the air pump from a relay that is controlled by the ECM. Once the OS begins switching, the ECM switches off the relay and the pulse air pump ceases operation.

In addition, the vacuum applied to the PAV is controlled by a Pulse Air Solenoid Valve (PASV). The PASV is also controlled by the pulse air relay or by the ECM relay driver pin.

Vacuum from the inlet manifold is routed to the PAV via the PASV. Immediately after the engine starts from cold, the ECM actuates the PASV which opens the air valve and air is thus introduced to the exhaust manifold.

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