

Bosch Motronic 4.1: GM Copyright Equiptech
Motronic 4.1 operation

The electronic system used to control the GM 8 valve engines (1987 to 1990) is labelled Motronic 4.1 and is a fully integrated EMS that controls primary ignition, fuelling and idle control from within the same ECU. In addition the ignition point and injection duration are jointly processed by the ECU so that the best moment for ignition and fuelling are determined for every operating condition. The injection function of the Motronic system is based on the well tried 'L' jetronic system, although a number of refinements have improved operation. A 35 pin connector and multi-plug connects the ECU to the battery, sensors and actuators.

Basic ECU operation

A permanent voltage supply is made from the vehicle battery to pin 18 of the ECU. This allows the self-diagnostic function to retain data of an intermittent nature. Once the ignition is switched on, a voltage supply to the ignition coil and to ECU pin 35 is made from terminal 87 of the main fuel injection relay.

The majority of sensors (other than those that generate a voltage such the CAS and OS), are now provided with a 5.0 volt reference supply from a relevant pin on the ECU. When the engine is cranked or run, a speed signal from the CAS causes the ECU to earth pin 20 so that the fuel pump will run. Ignition and injection functions are also activated. All actuators (Injectors, ISCV, FTVV etc), are supplied with nbv from the main relay and the ECU completes the circuit by pulsing the relevant actuator wire to earth.

Signal processing

Basic ignition timing is stored in a two dimensional map and the engine load and speed signals determines the ignition timing. The main engine load sensor is the AFS and engine speed is determined from the CAS signal.

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 TS signals.

The basic AFR is also stored in a two dimensional map and the engine load and speed signals determines the basic injection pulse value. Motronic calculates the AFR from the AFS signal and the speed of the engine (CAS).

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

Motronic accesses a different map for idle running conditions and this map is implemented whenever the engine speed is at idle. Idle speed during all warm-up and normal hot running conditions are maintained by the ISCV. However, Motronic 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.

Self Diagnostic function

The Motronic 4.1 system has a self-test capability that regularly examines the signals from engine sensors and internally logs a code in the event of a fault being present. This code can be extracted from the Motronic Serial Port by a suitable Fault Code Reader. When the ECU detects that a fault is present, it earths pin 17 and the warning lamp on the dash will light. The lamp will stay lit until the fault is no longer present. If the fault clears, the code will remain logged until wiped clean with a suitable FCR, or until the engine has been started for more than 20 times when the fault code is self initialising. An ECU that retains codes for faults of an intermittent nature is a valuable aid to fault diagnosis.

The codes emitted by the Motronic 4.1 ECU fitted to GM vehicles emit codes of the 'slow code' variety. This means that the codes can be extracted by connecting two pins in the SD (ALDL) plug together.

In addition to the self-test capability, Motronic 4.1 has full limp home facilities. 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 the AFS, will tend to make driving conditions less easy.

Reference voltage

Voltage supply from the ECU to many of the engine sensors is 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 ECU pin that is not directly connected to earth. The ECU internally connects that pin to earth via one of the ECU pins that are directly connected to earth.

Signal shielding

To reduce RFI, the CAS uses a shielded cable. The shielded cable is connected to the main ECU earth wire at terminal 27 to

reduce interference to a minimum.

CAS

The primary signal to initiate both ignition and fuelling emanates from a CAS mounted in proximity to the crankshaft at the front of the cylinder block. The CAS consists of an inductive magnet that radiates a magnetic field and a toothed disk. The disk is attached to the crankshaft or pull. The disk is attached to the crankshaft and theoretically comprises 60 teeth set at 3° intervals around its circumference; each tooth being 3° wide. At a position some distance BTDC, two teeth are omitted as a reference to TDC and so a total of 58 teeth remain on the disk. As the crankshaft spins, and the teeth are rotated in the magnetic field, an AC voltage signal is generated and delivered to the ECU to indicate speed of crankshaft rotation. In addition, as the engine spins, the missing teeth generate a variation of the signal that serves as a reference to TDC to indicate crankshaft position.

The peak to peak voltage of the speed signal (when viewed upon an oscilloscope) can vary from 5 volts at idle to over 100 volts at 6000 rpm. Because computers prefer their data as on/ off signals, the ECU utilises an analogue to digital converter (ADC) to transform the AC pulse into a digital signal.

Ignition

Data on load (AFS), engine speed (CAS), engine temperature (CTS) and throttle position (TS) are collected by the ECU, which then refers to a three dimensional digital map stored within its microprocessor. This map contains an advance angle for each operating condition, and thus the best ignition advance angle for a particular operating condition can be determined.

Amplifier

The Motronic amplifier contains the circuitry for switching the coil negative terminal at the correct moment to instigate ignition. The amplifier circuitry is contained within the ECU itself and the microprocessor contains a map containing the correct ignition dwell period for each condition of engine speed and battery voltage. One disadvantage of an internal amplifier, is that if the amplifier fails, the whole ECU must be renewed.

Dwell

Dwell operation in Motronic is based upon the principle of the 'constant energy current limiting' system. This means that the dwell period remains constant at around 4.0 to 5.0 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. A current limiting hump is not visible when viewing an oscilloscope waveform.

Ignition coil

The ignition coil utilises 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).

Distributor

In the Motronic system, the distributor only contains secondary HT components (distributor cap, rotor and HT leads) and serves to distribute the HT current from the coil secondary terminal to each spark plug in firing order.

Octane coding

It is not possible to adjust the ignition timing on the Motronic 4.1 system. However, an octane coding plug is provided to enable the ECU to adopt different characteristics to suit various operating conditions.

The ECU has been built with several different programs to cater for various circumstances, and selecting an alternative Octane Plug or setting will trigger a different program. The most obvious change is from leaded to unleaded fuel - or vice versa, when the ECU may alter the ignition timing and fuel map to cater for the changed conditions.

Simply turning the standard 95/98 Octane Plug to its alternative position will fulfill the alternative condition. Other conditions may be fulfilled by fitting an alternative octane plugs - such as the 95/91. A number of other octane plugs are also available and depending upon the Octane Plug chosen, will cause fuel enrichment during acceleration, overall fuel enrichment throughout the engine speed range, timing retard or an increase in idle speed. However, fitting alternative plugs should be approached with caution as the effects may be detrimental to good running and economy.

Fuel injection

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

The Motronic 4.1 system is a multi-point injection system and pulses all injectors at the same time - ie simultaneously and twice per engine cycle. Half of the required fuel per engine cycle is injected at each engine revolution. During engine start from cold, the pulse duration and number of pulses (frequency) are increased to provide a richer air/fuel mixture.

Fuel injectors

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The fuel injector is a magnetically operated solenoid valve that is actuated by the ECU. Voltage to the injectors is applied from the main relay and the earth path is completed by the ECU for a period of time (called pulse duration) of between 1.5 and 10 milliseconds. The pulse duration is very much dependant upon engine temperature, load, speed and operating conditions. When the magnetic solenoid closes, a back EMF voltage of up to 60 volts is initiated.

The fuel injectors are mounted in the inlet stubs to the engine inlet valves so that a finely atomised fuel spray is directed onto the back of each valve. Since the injectors are all pulsed simultaneously, fuel will briefly rest upon the back of a valve before being drawn into a cylinder.

Air Flow Sensor (AFS)

The AFS is located between the air filter and the throttle body. As air flows through the sensor it deflects a vane (flap). The vane is connected to a wiper arm which wipes a potentiometer resistance track and so varies the resistance of the track. This allows a variable voltage signal to be returned to the ECU.

Three wires are used by the circuitry of this sensor and it is often referred to as a three wire sensor. A 5 volt reference voltage is applied to the resistance track with the other end connected to the AFS earth return. The third wire is connected to the wiper arm.

From the voltage returned, the ECU is able to calculate the volume of air (load) entering the engine and this is used to calculate the main fuel injection duration. To smooth out inlet pulses, a damper is connected to the AFS vane. The AFS exerts a major influence on the amount of fuel injected.

ATS

The ATS is mounted in the AFS inlet tract and measures the air temperature before it enters the inlet manifold. 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. However, the ATS has only a minor correcting effect on ECU output.

The ATS operates on the NTC principle. A variable voltage signal is returned to the ECU based upon the air temperature. This signal is approximately 2.0 to 3.0 volts at an ambient temperature of 20°C and reduces to about 1.5 volt as the temperature rises to around 40°C.

CO pot

The CO pot mixture adjuster is a potentiometer that allows small changes to be made to the idle CO. A 5.0 volt reference voltage is applied to the sensor and connected to the AFS earth return circuit. The third wire is the CO pot signal.

As the CO pot adjustment screw is turned the change in resistance returns a voltage signal to the ECU that will result in a change in CO. The CO pot adjustment only affects idle CO. Datum position is usually 2.50 volts. On catalyst equipped models, the CO pot has no effect and the CO is thus non-adjustable.

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 ECU 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 ECU uses the CTS signal as a main correction factor when calculating ignition timing and injection duration.

Throttle switch

A throttle switch with dual contacts is provided to inform the ECU of idle position, deceleration, cruising and full-load (WOT) conditions. When the engine is at idle the idle contact is closed and the full-load contact is open. As the throttle is moved to the fully open position, the full-load contact closes and the idle contact becomes open. Under cruising conditions with a part-open throttle, both contacts are open. During full-load operation, the ECU provides additional enrichment.

During closed throttle operation above a certain rpm (deceleration), the ECU will cut-off fuel injection. Injection will be reintroduced once the rpm returns to idle or the throttle is opened.

ISCV

The ISCV is a solenoid controlled actuator that the ECU uses to automatically control idle speed during engine warm-up and idle at normal operating temperature. Irrespective of engine temperature or engine load, the engine idle speed should remain at an almost constant level. The ISCV is located in a hose that connects the inlet manifold to the air filter side of the throttle plate.

When an electrical load, such as headlights or heater fan etc are switched on, the idle speed would tend to drop. The ECU will sense the load and rotate the ISCV against spring tension to increase the air flow through the valve and thus maintain the idle

speed at its previous level. When the load is removed, the ECU will pulse the valve so that the air flow is reduced. Normal idle speed of 780 to 850 rpm 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.

Relay

The Motronic electrical system is controlled by a single system relay with dual contacts. A permanent voltage supply is made to relay terminal 30 from the battery positive terminal. When the ignition is switched on, a voltage supply is made to terminal 86 and this energises the first relay winding which is connected to earth. This causes the first relay contacts to close and terminal 30 is connected to the output circuit at terminal 87. A voltage supply is thus output at terminal 87. Terminal 87 supplies voltage to the injectors, ECU: t35, ISCV and the FTVV when fitted. In addition voltage is supplied to the second relay contact.

When the ignition is switched on, the ECU briefly earths relay contact 85b at ECU terminal 20. This energises the second relay winding, which closes the second relay contact and connects voltage from terminal 30 to terminal 87b, thereby providing voltage to the fuel pump circuit. After a second or so, the ECU 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 second circuit will then remain open until the engine is cranked or run. Once the ECU receives a speed signal from the CAS, the second winding will again be energised by the ECU, and the fuel pump will run until the engine is stopped.

Fuel pressure system

A roller type fuel pump, driven by a permanent magnet electric motor mounted close to the fuel tank, 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.

Mounted upon the armature shaft is an eccentric rotor holding a number of pockets arranged around the circumference - each pocket containing a metal roller. As the pump is actuated, the rollers are flung outwards by centrifugal force to act as seals. The fuel between the rollers is forced to the pump pressure outlet.

Fuel pressure in the fuel rail is maintained at a constant 2.5 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.

Fuel pressure regulator

The pressure regulator is fitted on the outlet side of the fuel rail and maintains an even pressure of 2.5 bar at the injectors during idle conditions. 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 ECU, 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

Versions with a Catalytic Converter will also be fitted with an oxygen sensor so that closed loop control of emissions can be implemented. The OS is heated so that it will reach optimum operating temperature as quickly as possible after the engine is started. The OS heater supply is made from the fuel injection relay terminal number 87b. This ensures that the heater will only operate whilst the engine is running.

An FTVV and activated carbon canister is also be employed to aid evaporative emission control. The carbon canister stores fuel vapours until the FTVV is opened by the EMS under certain operating conditions. Once the FTVV is actuated by the EMS, fuel vapours are drawn into the inlet manifold to be burnt by the engine during normal combustion.

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