Motronic 2.5 operation

Motronic 2.5 is an enhancement of the Motronic 4.1 EMS fitted to earlier Vauxhall and Opel vehicles. It was first fitted in the 1990 model year (late 1989) and is a fully integrated system that controls primary ignition, fuelling and idle control from within the same ECU. It is normally only fitted to 16 valve GM engines. The control unit contains three microprocessors for:

general control unit operation
sequential injection
knock control

The Motronic 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 55 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 27 is made from the ignition switch. This causes the ECU to connect pin 36 to earth, so actuating the main fuel injection relay. A relay switched voltage supply is thus made to ECU pin 37, from terminal 87 of the main fuel injection relay.

The majority of sensors (other than those that generate a voltage such the CAS, KS 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 3 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 calculated from the ignition map and engine load determines the basic injection pulse value. Correction factors are then applied for starting, idle, deceleration, part and full-load operation. The main engine load sensor is the AFS and the main correction factor is engine temperature.

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 most 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.

ECU coding wires (where fitted)
Some vehicles equipped with Motronic 2.5 have certain ECU pins allocated as coding earths. The open circuit voltage at these pins is either nbv or at 5.0 volt reference level. Connection of the pin to earth indicates to the ECU that the vehicle is equipped with certain equipment. The non cat vehicle has pin 20 connected to earth and the catalyst equipped vehicle has pin 20 open circuit. The vehicle with AT has pin 21 connected to earth and the vehicle with MT has pin 21 open circuit.

Signal shielding
To reduce RFI, a number of sensors (ie CAS, HES, KS, amplifier and OS) use a shielded cable. The shielded cable is connected to the main ECU earth wire at terminal 19 to reduce interference to a minimum.

CAS
The CAS consists of an inductive magnet that radiates a magnetic field and a toothed disk. The disk is attached to the crankshaft or pulley 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. When the throttle switch is closed, the ECU enters base timing mode and the timing is set at 10°.

Amplifier
The amplifier contains the circuitry for switching the coil negative terminal at the correct moment to instigate ignition. The signal received by the amplifier from the trigger is of an insufficient level to complete the necessary coil switching. The signal is thus amplified to a level capable of switching the coil negative terminal.

Unlike earlier Vauxhall/ Motronic systems (in which the amplifier was contained in the ECU itself), Motronic 2.5 utilises a separate amplifier mounted on a heat sink plate adjacent to the coil. The ECU thus calculates the correct ignition dwell time and timing advance from data received from its sensors, and sends a signal to the amplifier which then switches the coil negative terminal. The advantage of a separate amplifier, is that if the amplifier fails, it is less costly to renew than a new ECU.

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.

Knock sensor
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 point of knock occurrence, means that knock will certainly occur on one or more cylinders at certain times during the engine operating cycle.

Since knock may occur at a different moment in each individual cylinder, Motronic 2.5 employs the Knock Control unit - KCU (in the ECU) to pinpoint the actual cylinder or cylinders that are knocking. The Knock Sensor is mounted on the engine block and consists of a piezoceramic measuring element that responds to engine noise oscillations. This signal is converted to a voltage signal by the Knock Sensor and returned to the KCU for evaluation and action. Tests have shown that the 20XE & C20XE engines have a knocking frequency in the 15kHz frequency band.

The KCU will analyse the noise from each individual cylinder and set a reference noise level for that cylinder based upon the average of the last 16 phases. If the noise level exceeds the reference level by a certain amount, the KCU identifies the presence of engine knock.

Initially, timing will occur at its optimal ignition point. Once knock is identified, the Knock Control microprocessor retards the ignition timing for that cylinder or cylinders by 3ш. Approximately 2 seconds after knocking ceases (20 to 120 knock- free combustion cycles), the timing is advanced in 0.75ш increments until the reference timing value is achieved or knock occurs once more when the timing is retarded or 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 control sensor or wiring, an appropriate code will be logged in the self-diagnostic unit and the ignition timing retarded by 10.5ш by the LOS program.

Cylinder Identification
In earlier Motronic systems the ECU does not recognise number one cylinder or indeed even the firing order. This is because it is actually unnecessary. When the crankshaft or distributor provides a timing signal, the correct cylinder is identified by the mechanical position of the crankshaft, camshaft, valves and ignition rotor. In systems where the injectors fire simultaneously, then the fuel will sit upon the back of an inlet valve until the valve opens.

Since fuel injection occurs on an individual cylinder basis in Motronic 2.5, the ECU must be informed on which stroke a cylinder is actually on. This is achieved by a cylinder identification sensor attached to the distributor and which works on the Hall-Effect principle. The sensor identifies number one cylinder, and returns a signal to the ECU from which the identification of all the other cylinders can be calculated. The distributor is attached to the exhaust camshaft (the engine is DOHC in configuration) .

Octane coding
Because of the sophistication of the KCU and timing control an octane coding plug is not considered necessary for the 20XE & C20XE engines. Octane adjustment is automatically selected according to operating conditions. Motronic 2.5 is programmed with two different timing maps. These are Low Octane Number Map (more retarded timing) and High Octane Number Map (more

advanced dwell angle). The KCU selects the appropriate map according to the following conditions. Once knocking combustion of more than 50 have occurred, the KCU switches to the Low Octane Map. Once approximately 8.5 minutes of knock-free operation have passed, the KCU switches to the High Octane Map.

Fuel injection
The ECU or vehicle computer is programmed with a basic injector map. 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.

Fuel injection
The Motronic 2.5 system is a multi-point injection system and pulses the injectors sequentially - ie in firing order and once per engine cycle. Each injector is connected to the ECU via a separate ECU pin). Earlier Motronic systems (ie 4.1 and 1.5) pulse all injectors at the same time - ie simultaneously and twice per engine cycle.

During engine start from cold, the pulse duration and number of pulses (frequency) are increased to provide a richer air/fuel mixture.

Fuel injectors
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.

Hot Wire Air mass meter (AFS)
Motronic 2.5 also uses a Hot Wire airflow sensor to measure the mass of air entering engine. From the air mass, an accurate fuel injection pulse can then be calculated. Hot Wire is a very accurate method of calculating the engine load (air input) and excludes the need for additional sensors to measure air temperature and air pressure. Automatic compensation for altitude is thus provided. The absence of moving parts improves reliability and lessens maintenance requirements.

Essentially, the hot wire is so called because a heated wire is placed in the air intake. As air passes over the wire it has a cooling effect in proportion to the mass of air. As airmass increases or decreases according to engine load, the ECU adjusts the current flow to maintain the wire at its original resistance and temperature. By measuring the change in current flow, the ECU is able to determine the mass of air flow into the engine. 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.

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.

Hot wire burn-off
Over a period of time, deposits tend to build-up upon the hot wire and this can lead to contamination of the hot-wire. This is avoided with a `burn-off' function controlled by the ECU during engine shutdown. Approximately four seconds after the engine has been switched off, the ECU rapidly pulses the hot-wire terminal 4 of the AFS for 1.5 seconds. Burn-off will not occur if the engine speed has not exceeded 1000 rpm and the coolant temperature is under approximately 30° C.

CO pot
The CO pot mixture adjuster is a three wire 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. 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 normal idle and during engine warm-up. 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 increase the idle speed. When the load is removed, the ECU 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.

Relays relay diagram
The Motronic electrical system is controlled by a single system relay with dual contacts. A permanent voltage supply is made to relay terminals 30 and 86 from the battery positive terminal. When the ignition is switched on, the ECU earths terminal 85 through ECU terminal number 36 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. A voltage supply is thus output at terminal 87. Terminal 87 supplies voltage to the injectors, ECU terminal 37, 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 3. 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 approximately one second, 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 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 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.

Self Diagnostic function
The Motronic 1.5 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.

In addition to the self-test capability, Motronic 1.5 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.

Catalytic Converter and emission control
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 are 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.

Testing
Because of the difficulty in access to many of the sensors, a BOB is deemed necessary to make voltage, resistance, duty cycle and oscilloscope tests.

< END >