



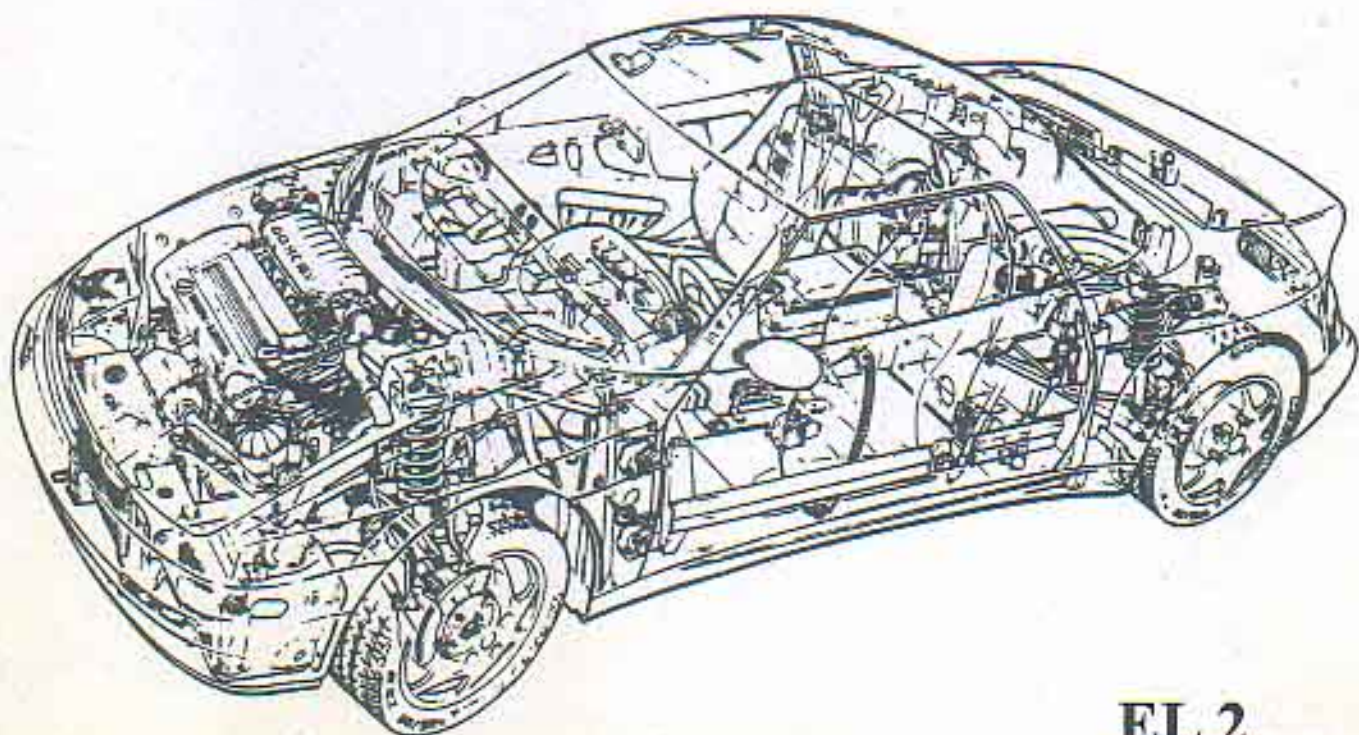
Training Centre

Course Notes

ELAN

NATURALLY ASPIRATED (N/A)

AND TURBO (O/L)



EL 2

LOTUS TRAINING

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1.0 INTRODUCTION

1.1 GENERAL DESCRIPTION

The Multipoint Fuel Injection (MPFI) systems used on the 1.6L LOTUS ELAN (Naturally Aspirated) and the 1.6L TURBO LOTUS ELAN are fully electronic processor controlled systems supplied by GM.

The main functions of the systems are:

- 1) Fuel Management
- 2) Spark Timing
- 3) Idle (Air) Speed Control

1) FUEL MANAGEMENT

The engine is equipped with 4 injectors, 1 for each cylinder. The injectors are solenoid

- driven and generally operated (pulsed) in pairs 1-3, 2-4 once every engine revolution on the TURBO
- fired all at the time once every engine revolution on the Naturally Aspirated (N/A)

The injectors are controlled by a processor called "Electronic Control Module" ECM. This calculates the amount of fuel required by the engine at all conditions from information supplied by a series of sensors.

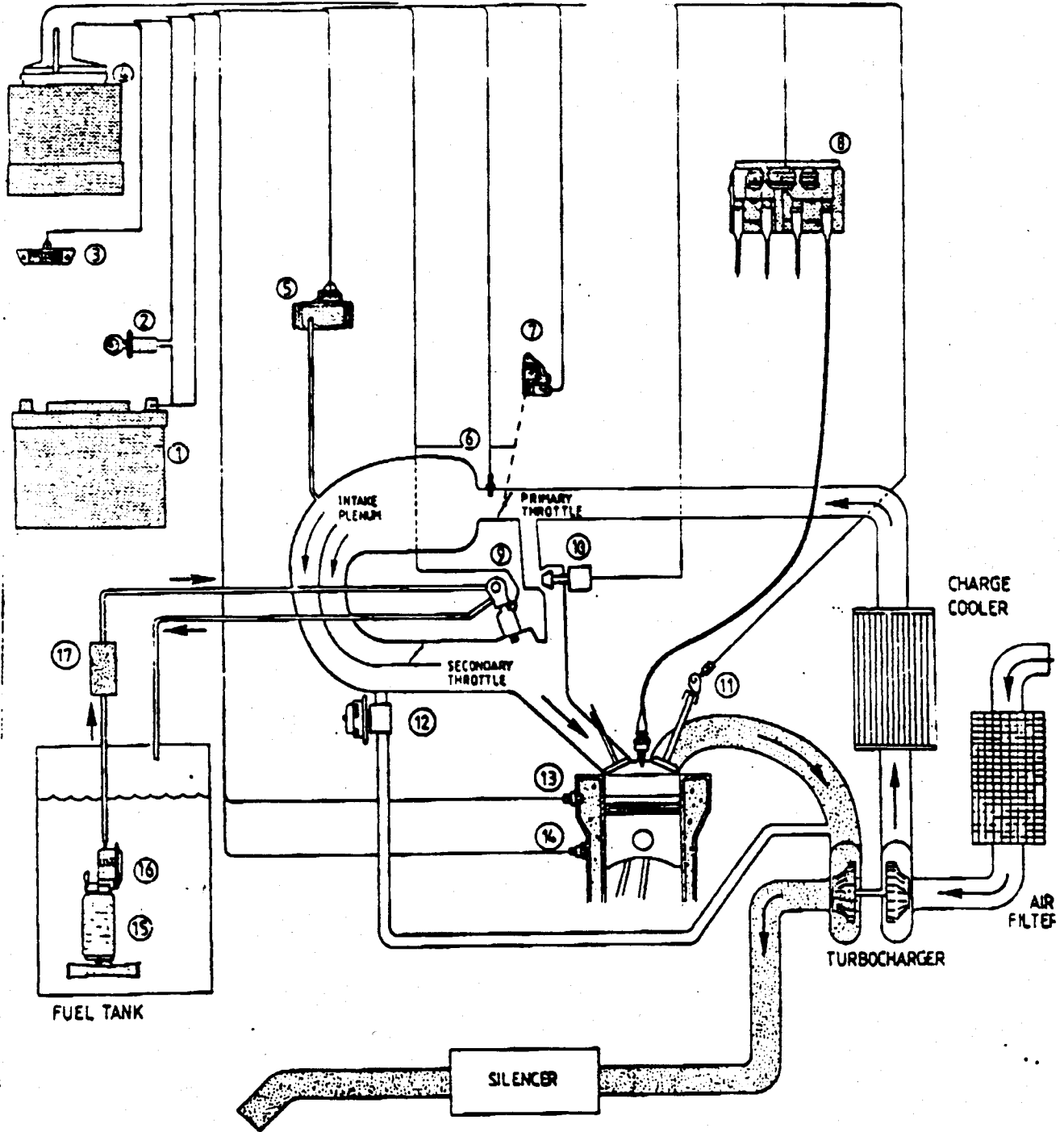
2) SPARK TIMING

- The TURBO engine has a "Direct Ignition" system which is a distributorless type of system. It contains an ignition module, 2 coils and a cam angle sensor to determine engine position. The ignition module receives and processes the signal from the cam angle sensor, interfaces with the ECM, and controls the primary current in the coils. Each coil drives two spark plugs.
- The N/A uses a distributor. The distributor generates "reference pulses", triggers the ignition coil under certain conditions, interfaces with the ECM and distributes the high ignition voltage.

3) IDLE (AIR) SPEED CONTROL

The ECM also controls idle speed by means of an "Idle Air Control" (IAC) motor. It provides control of bypass air around the throttle plate. If RPM is lower than desired, the actuator pintle of the motor is retracted and more air diverted around the throttle plate to increase RPM; if RPM is too high the motor is extended.

1.2 SYSTEM OVERVIEW

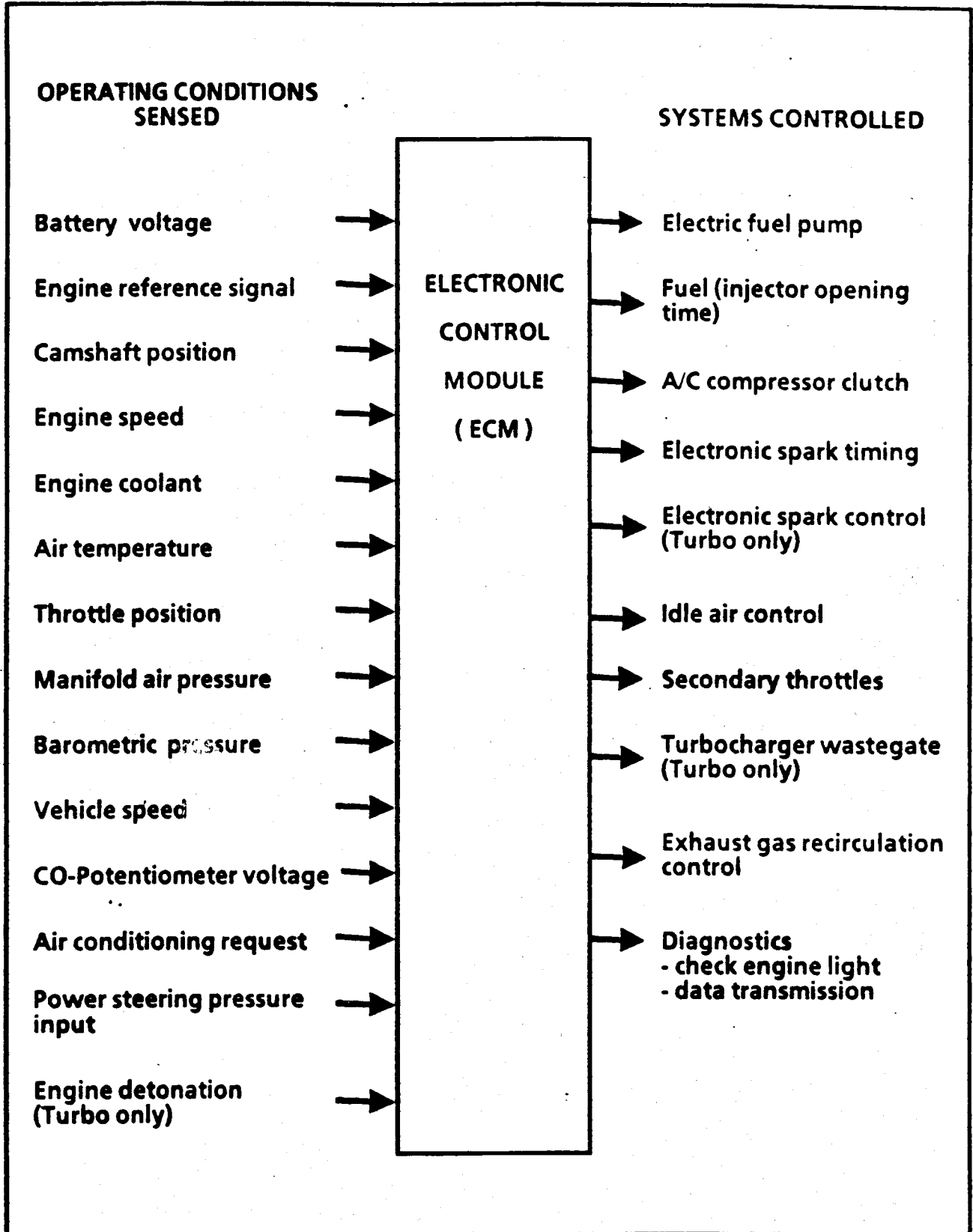


Key to Schematic Diagram

- | | |
|--|---|
| 1. Battery | 9. Fuel injector (4 off) |
| 2. Ignition switch | 10. Idle Air Control (IAC) valve |
| 3. Assembly Line Diagnostic Link (ALDL) | 11. Cam angle sensor |
| 4. Electronic Control Module (ECM) | 12. Exhaust Gas Recirculation (EGR) valve |
| 5. Manifold Air Pressure (MAP) sensor | 13. Coolant Temperature Sensor (CTS) |
| 6. Mass Air Temperature (MAT) sensor | 14. Knock sensor |
| 7. Throttle Position Sensor (TPS) | 15. Fuel pump |
| 8. Direct Ignition (DI) module and coils | 16. Pulsator |
| | 17. Fuel filter |

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1.3 BLOCK DIAGRAM



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1.4 WIRING DIAGRAMS

1.4.1 TURBO O/L

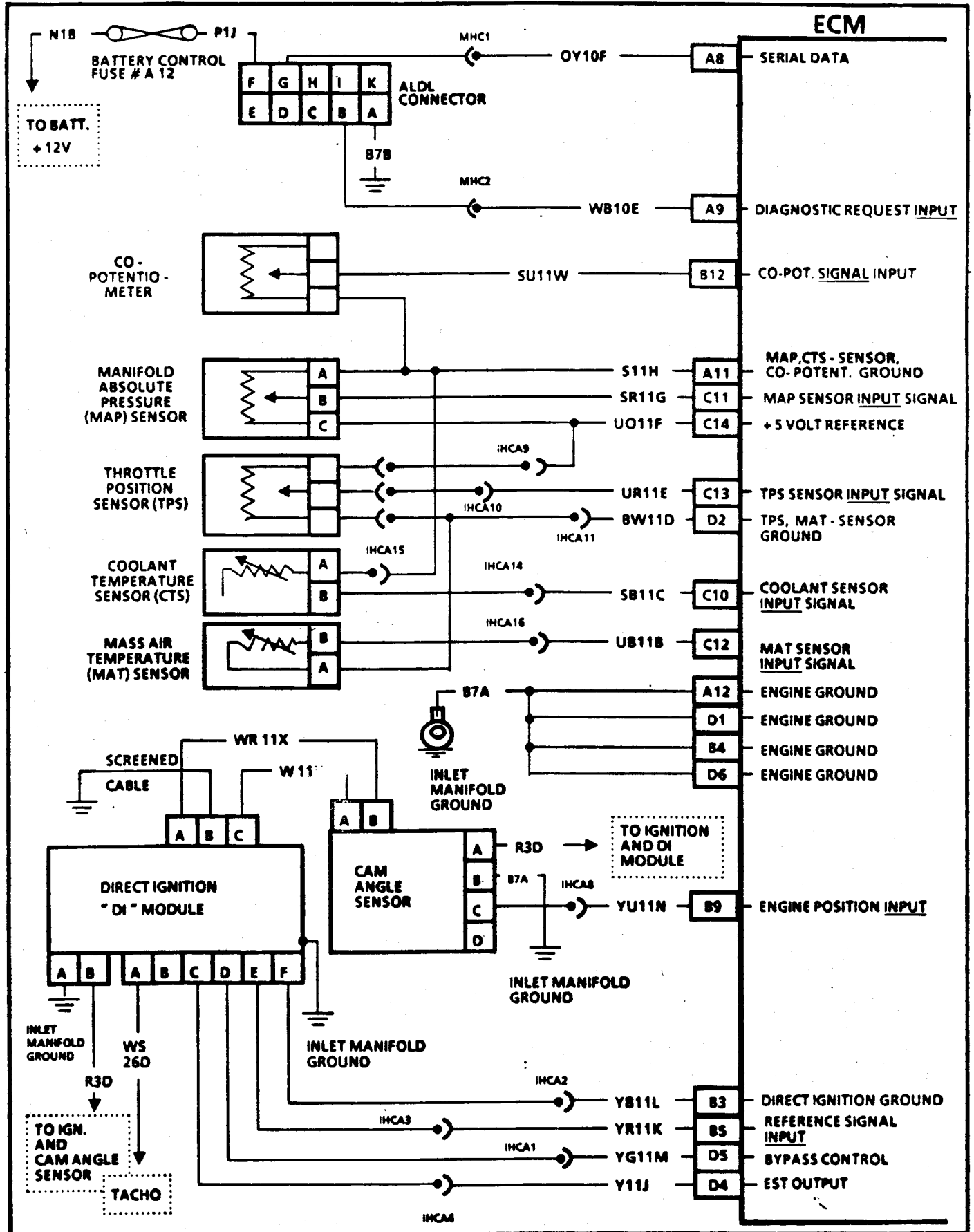


Figure EMK.4-5 - ECM Wiring Diagram - 1.6L TURBO LOTUS ELAN (1 of 3)

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1.4 WIRING DIAGRAMS

1.4.2 TURBO O/L

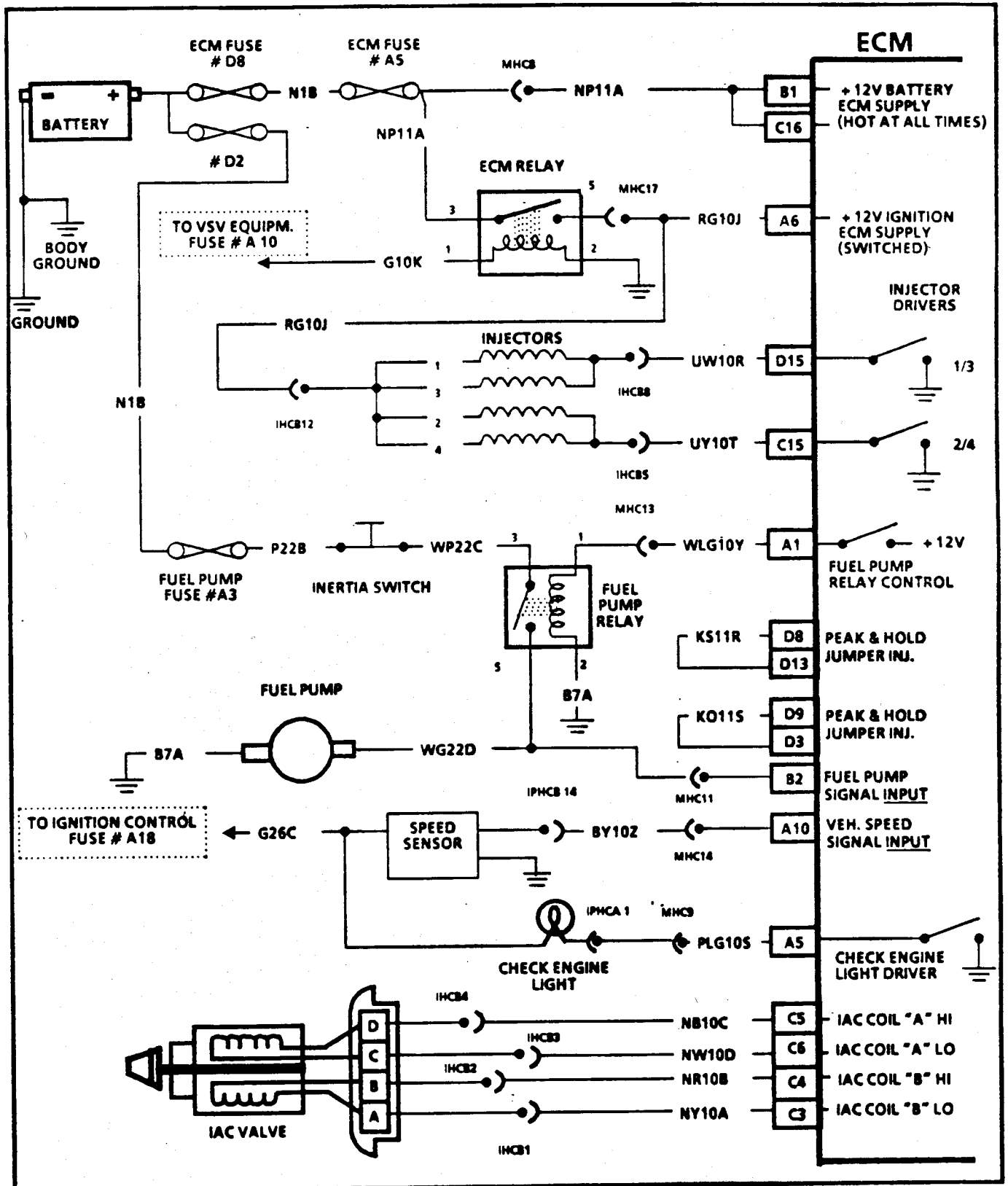


Figure EMK. 4-6 - ECM Wiring Diagram - 1.6L TURBO LOTUS ELAN (2 of 3)

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1.4 WIRING DIAGRAMS

1.4.3 TURBO O/L

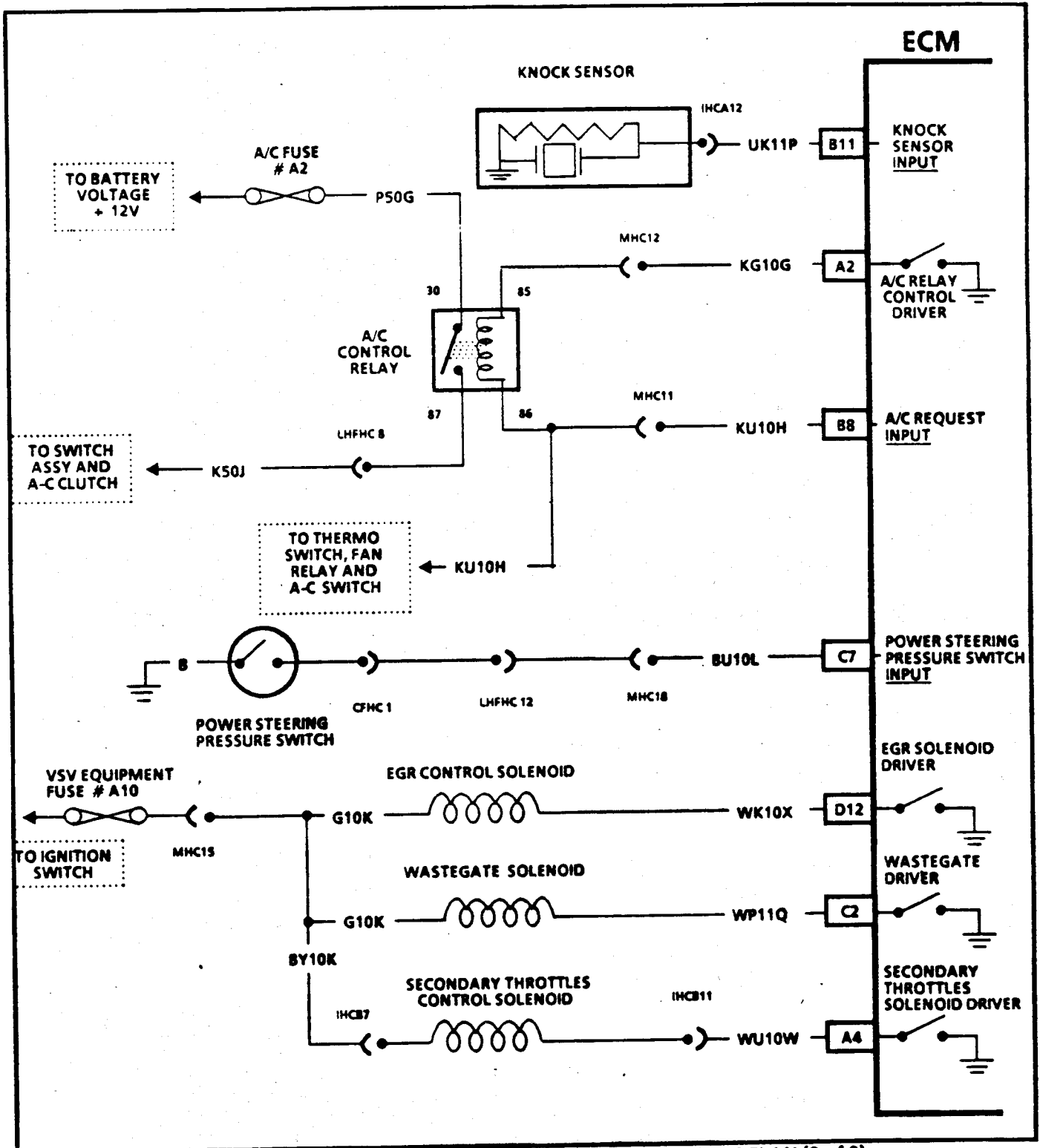


Figure EMK.4 - 7 - ECM Wiring Diagram - 1.6L TURBO LOTUS ELAN (3 of 3)

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1.5 WIRING DIAGRAMS

1.5.1 NATURALLY ASPIRATED

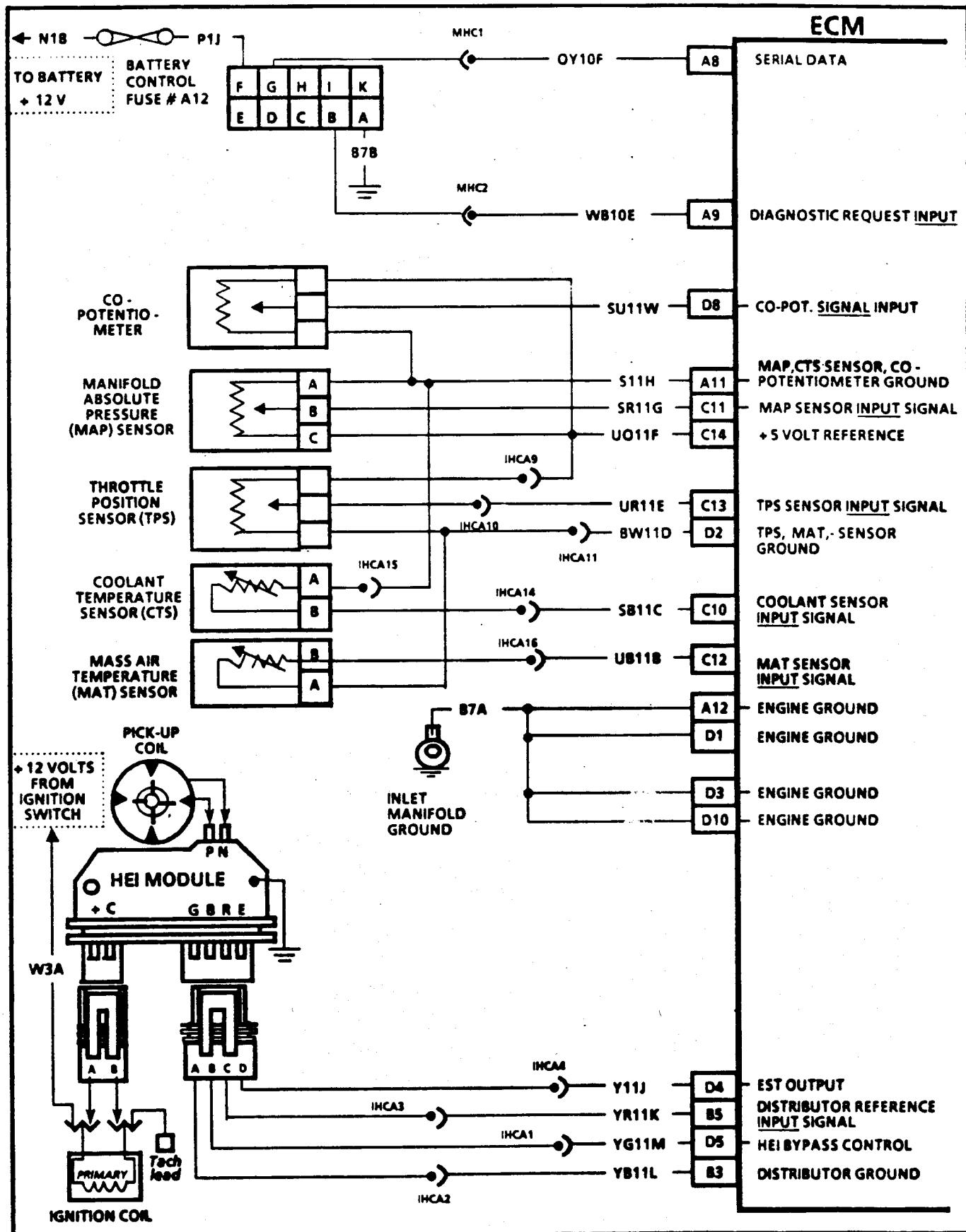


Figure EML.4-5 - ECM Wiring Diagram - 1.6L LOTUS ELAN (1 of 3)

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1.5 WIRING DIAGRAMS

1.5.2 NATURALLY ASPIRATED

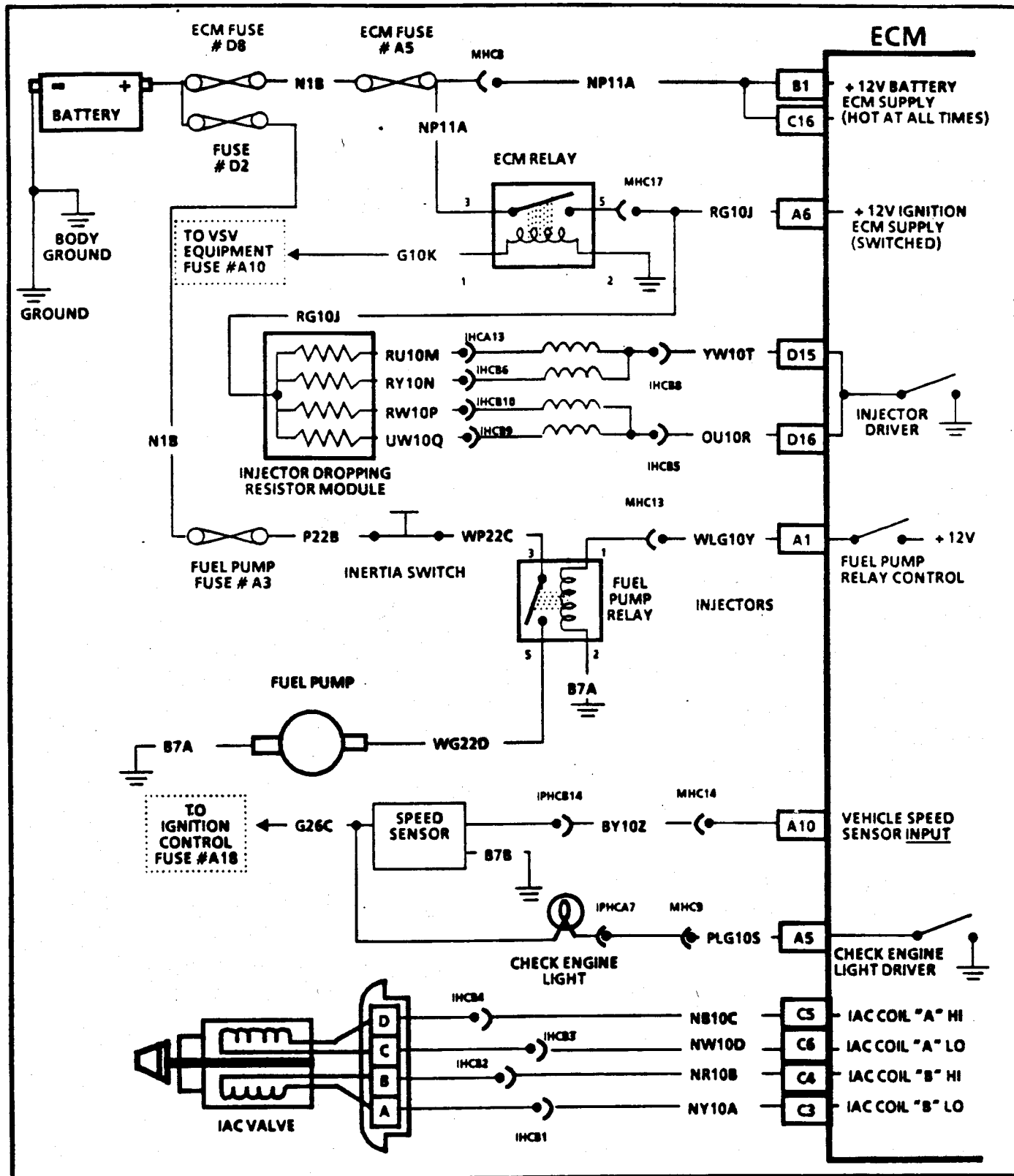


Figure EML4-6 - ECM Wiring Diagram - 1.6L LOTUS ELAN (2 of 3)

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1.5 WIRING DIAGRAMS

1.5.3 NATURALLY ASPIRATED

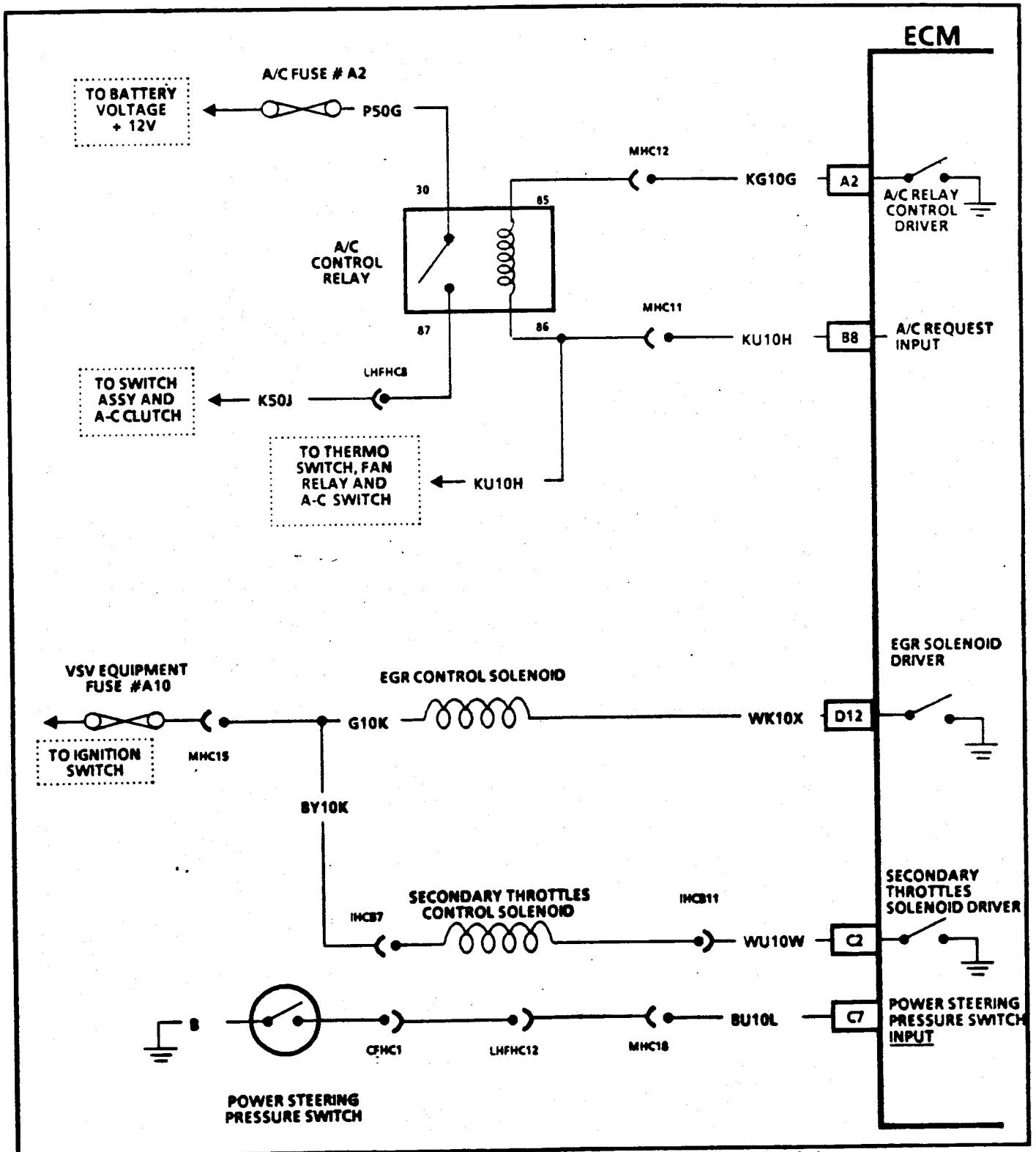


Figure EML.4 - 7 - ECM Wiring Diagram - 1.6L LOTUS ELAN (3 of 3)

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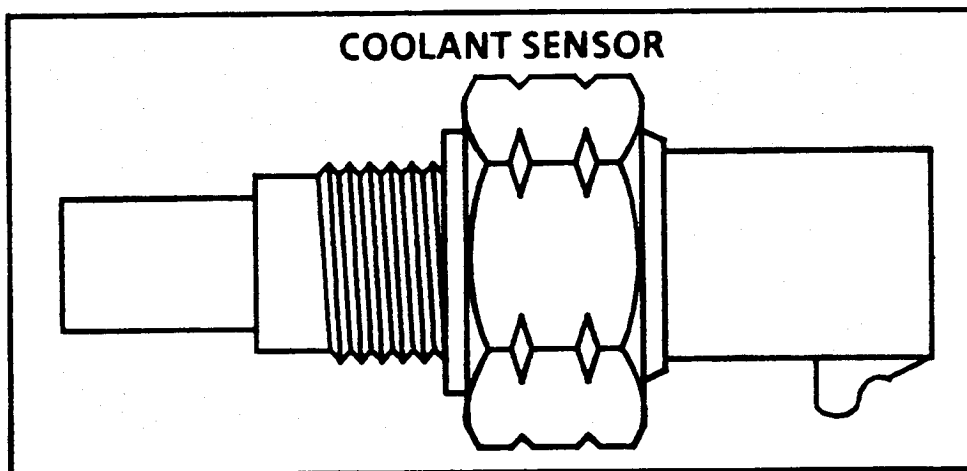
2.0 SYSTEM COMPONENTS

2.1 N/A AND TURBO O/L COMMON COMPONENTS

2.1.1 COOLANT SENSOR

The coolant sensor is a thermistor mounted in the coolant stream. The thermistor changes its resistance with changes of coolant temperature. Low temperature produces a high resistance, approximately 25,000 ohms at -20°C. As coolant temperature increases, sensor resistance decreases to about 185 ohms at 100°C.

The voltage drop across the coolant sensor varies from 0 to 5 volts. This voltage, measured at the ECM, will decrease as coolant temperature increases; therefore, disconnecting the coolant sensor simulates a cold engine, and shorting across the sensor simulates a hot engine.



COOLANT TEMPERATURE SENSOR CIRCUIT

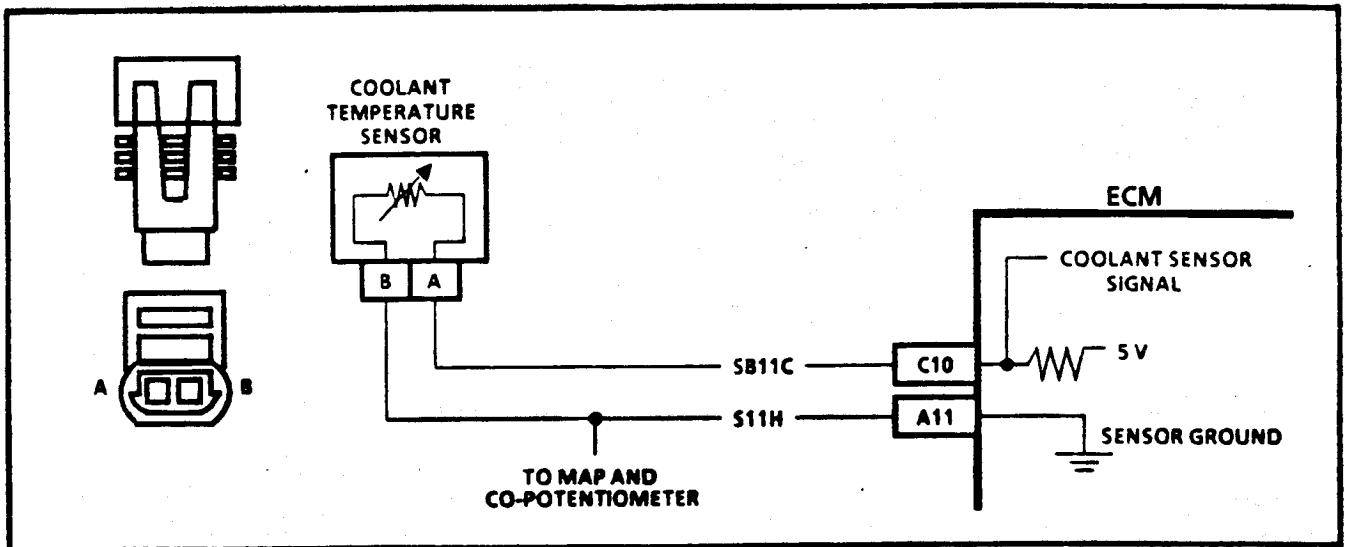
Circuit Description:

The coolant temperature sensor uses a thermistor to control the signal voltage at the ECM. The ECM applies a voltage on SB11C to the sensor. When the engine is cold the sensor (thermistor) resistance is high, therefore ECM terminal "C10" voltage will be high.

As the engine warms, the sensor resistance becomes less, and the voltage drops. At normal engine operating temperature, the voltage will measure about 1.0 to 2.4 volts at ECM terminal "C10".

Coolant temperature is one of the inputs used to control:

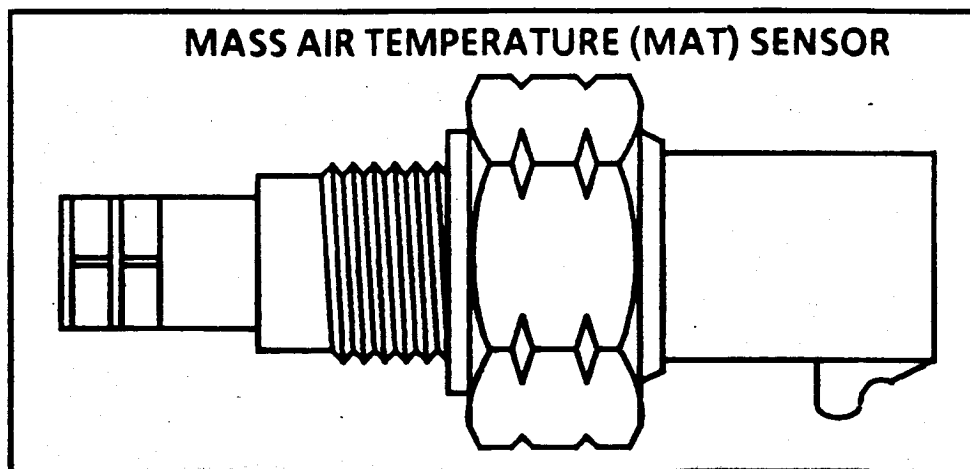
- Fuel delivery
- Engine Spark Timing (EST)
- Idle Air Control (IAC)
- Exhaust Gas Recirculation (EGR)
- Air Conditioning
- Boost Control (TURBO only)
- Secondary Throttles



2.1.2 MASS AIR TEMPERATURE (MAT) SENSOR

The Mass Air Temperature (MAT) sensor is fitted into the inlet of the intake plenum chamber. The ECM uses this signal in conjunction with others to calculate air density and the appropriate fuel delivery for both starting and running.

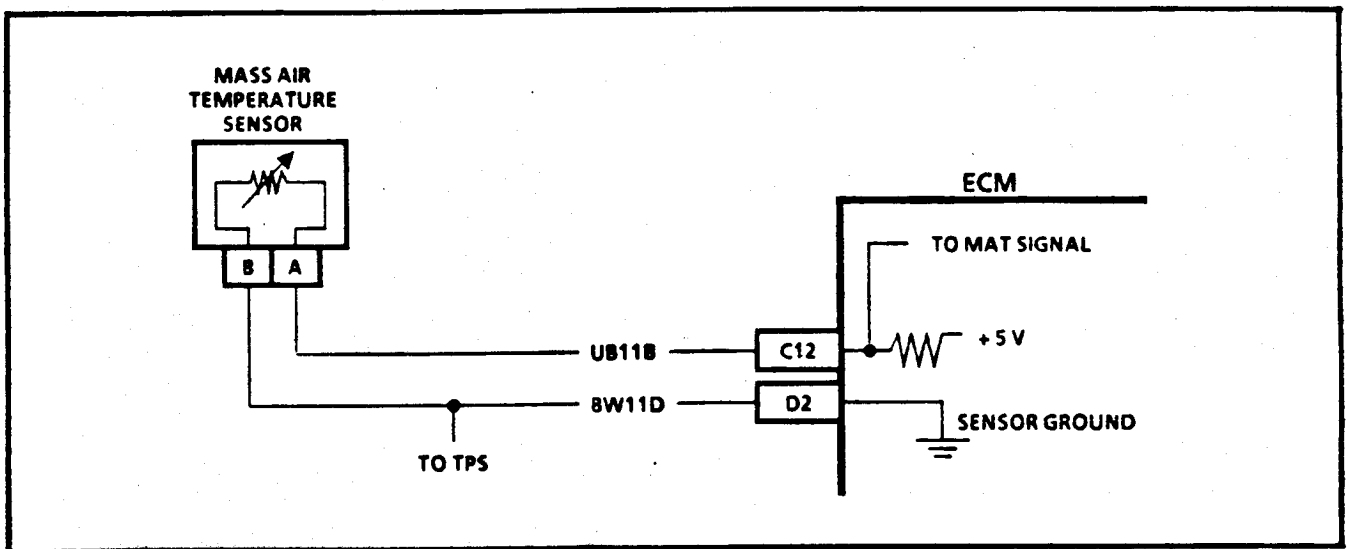
The MAT sensor is a thermistor (a resistor which changes value with temperature) similar to the coolant temperature sensor. Low temperature produces a high resistance (100,000 ohms at minus 40°C) while high temperature causes low resistance (185 ohms at 100°C). The ECM supplies a 5 volt reference signal to the MAT sensor, and by measuring the sensor output voltage is able to calculate the sensor resistance, and thereby the air temperature.



MASS AIR TEMPERATURE (MAT) SENSOR CIRCUIT

Circuit Description:

The MAT sensor uses a thermistor to control the signal voltage to the ECM. The ECM applies a voltage of about 5 volts on CKT UB11B to the sensor. When the air is cold, the sensor (thermistor) resistance is high, therefore, the ECM terminal "C12" voltage is high. As the air warms, the sensor resistance becomes less, and the voltage drops. As the incoming air gets warmer, the sensor resistance decreases, causing ECM terminal "C12" voltage to decrease.



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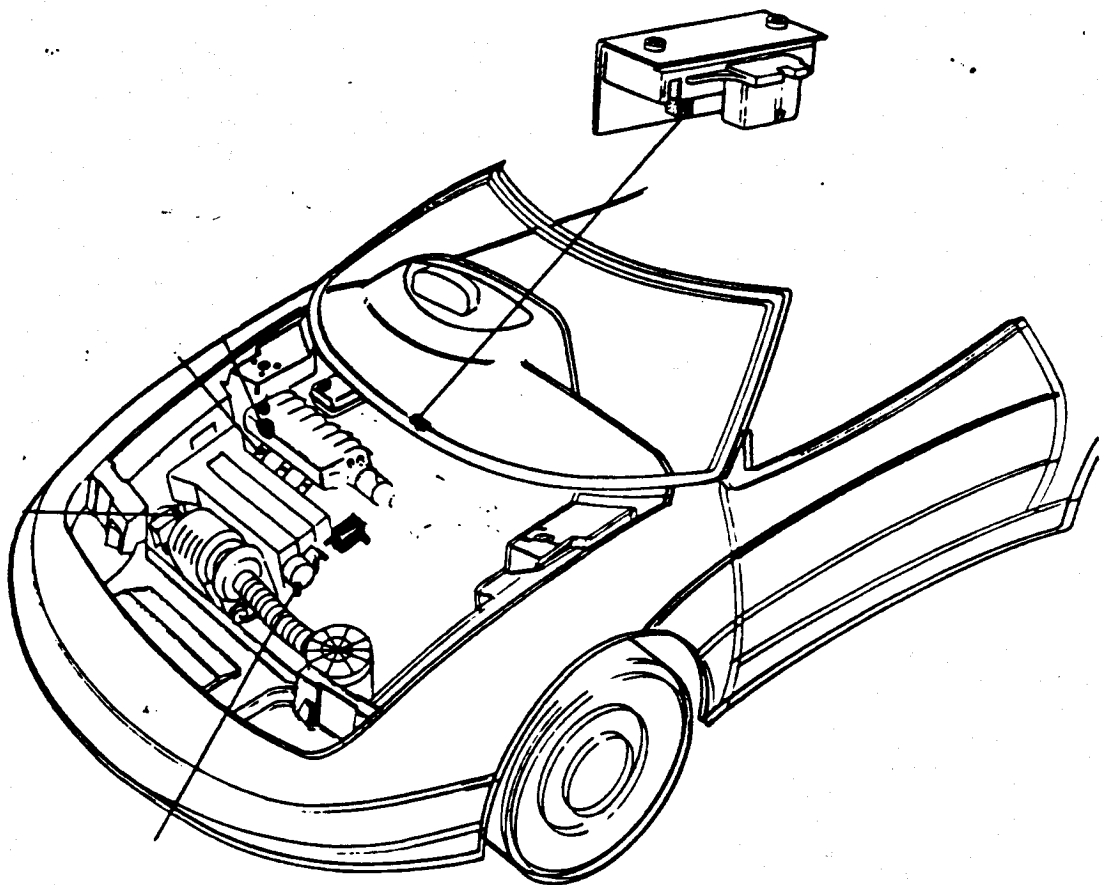
2.1.3 MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR

The MAP sensor is mounted in the engine bay at the centre top of the cabin front bulkhead and is connected by hose to the inlet manifold.

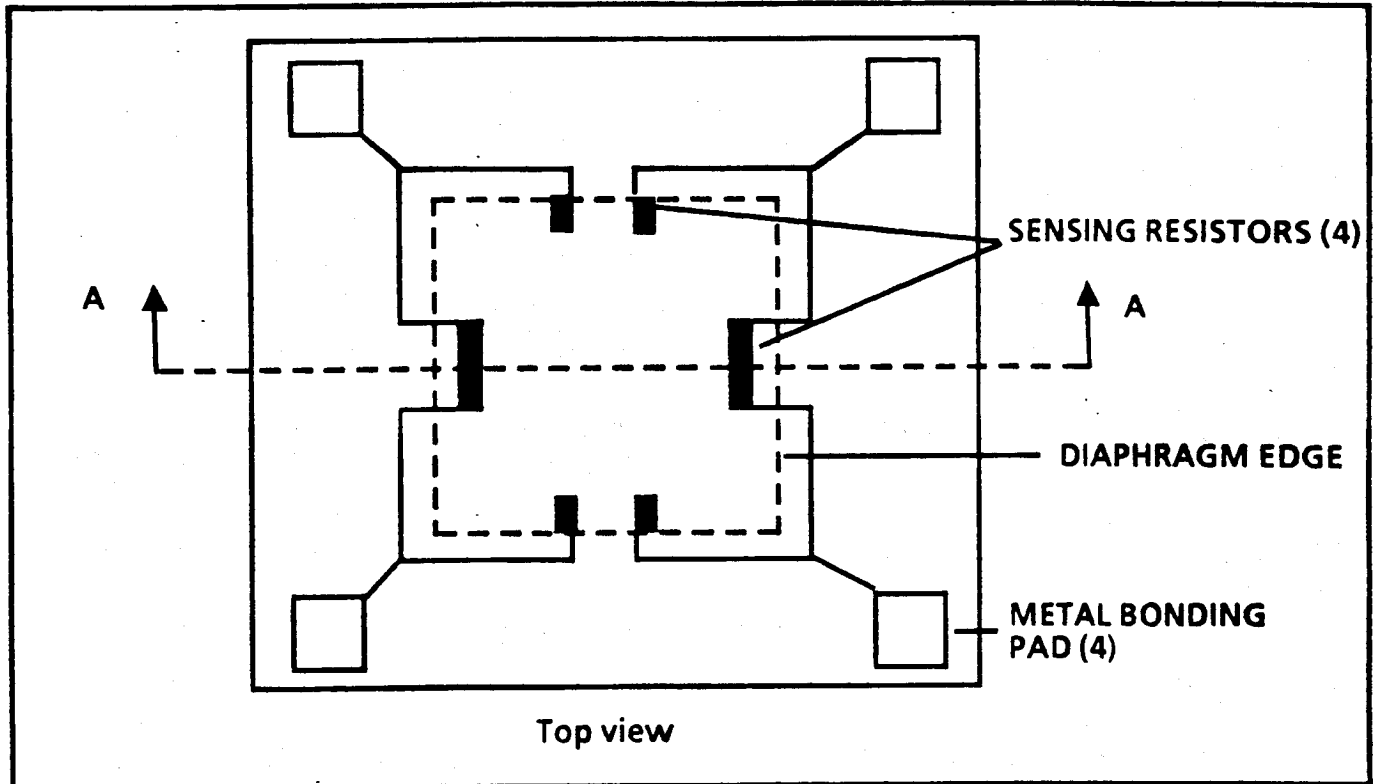
The manifold absolute pressure sensor measures the changes in the intake manifold pressure which result from engine load and speed changes.

The sensor uses a silicon chip approximately 3mm square. The chip is attached to a pyrex plate to form a diaphragm approximately 0.25mm thick. Resistors are diffused into the chip to form a bridge network. When the chip is sealed to a pyrex plate a vacuum cavity is formed called a reference cavity. As pressure is applied to the opposite side of the reference cavity, the diaphragm deflects causing the diffused resistor to change value proportional to the pressure.

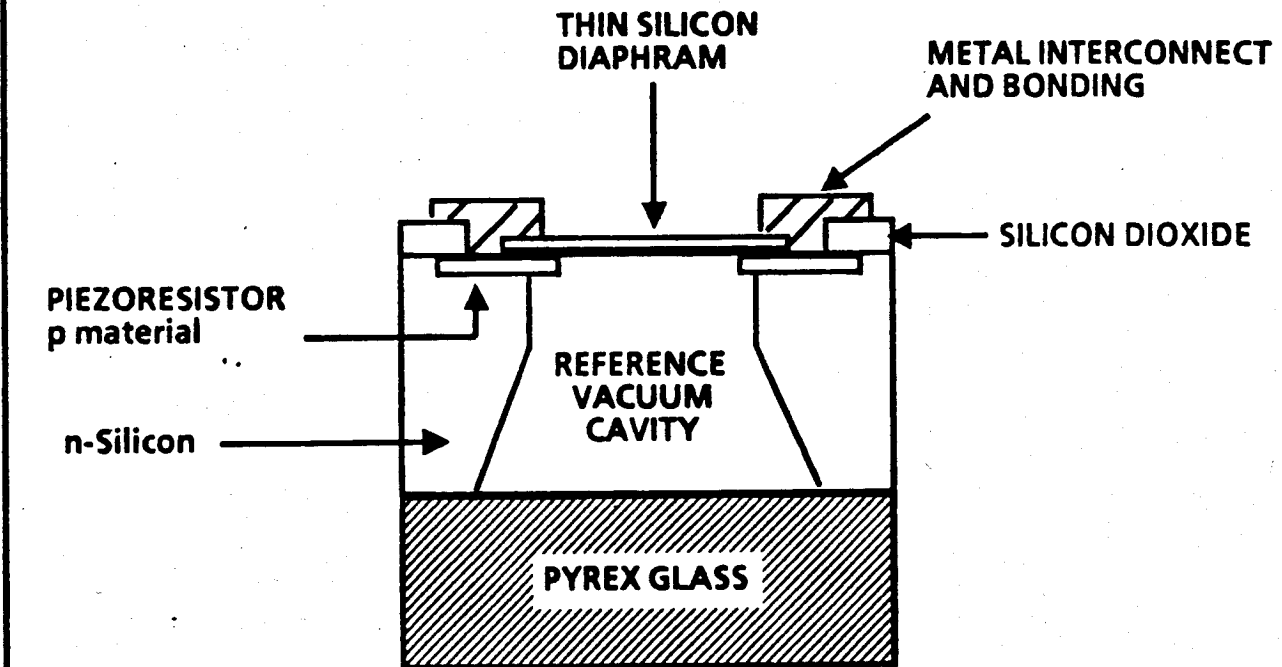
The change in resistance causes a change in voltage which is used by the ECM. The output voltage is approximately 0.7 to 1.0 volts at (idle) and 2.5 volts at 105kPa (atmospheric pressure). The ECM uses this voltage to compute intake manifold pressure.



Delco Electronics manufactures eight different pressure sensors with the same physical appearance. These sensors are not interchangeable and are color coded by the plastic insert in the plug. The sensor plug inserts are keyed so they cannot be used in the wrong system application. The Lotus MAP sensor insert is orange.



PRESSURE SENSOR CHIP



Section A-A

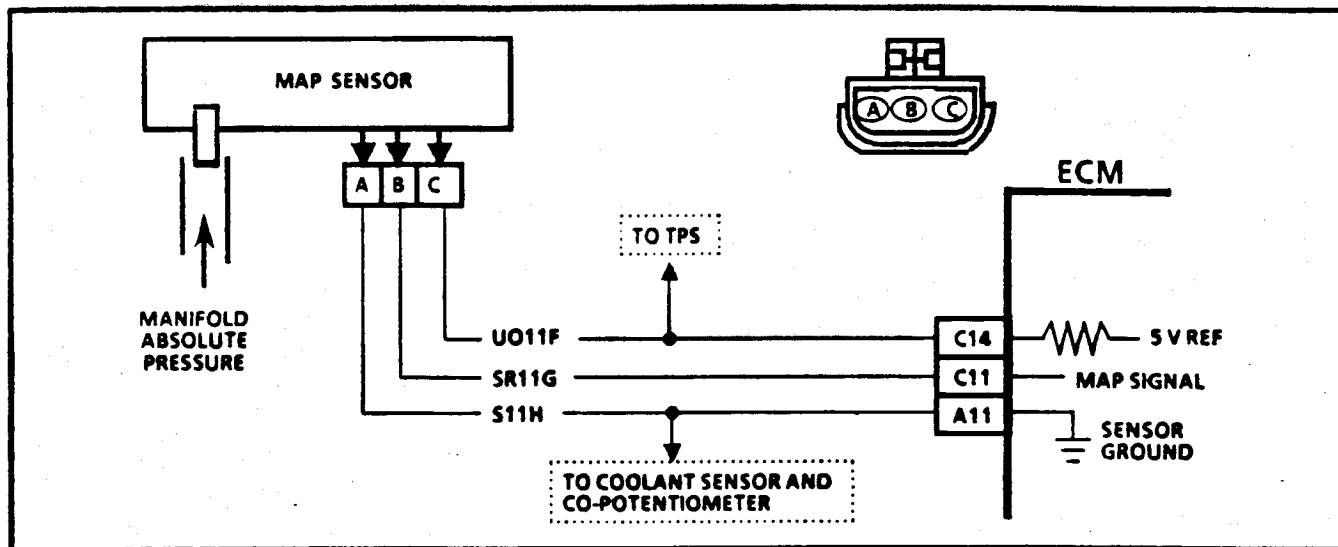
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MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR CIRCUIT

Circuit Description:

The manifold absolute pressure (MAP) sensor responds to changes in manifold pressure (vacuum). The ECM receives this information as a signal voltage that will vary from about 0.7 to 1.0 volts at idle, when manifold pressure is low (high vacuum), to 4.5 volts at wide open throttle and full boost on the TURBO application or 2.4 volts on the N/A.

If the MAP sensor fails, the ECM will substitute a fixed MAP value and use the throttle position sensor (TPS) and other sensors to control fuel delivery and spark timing.



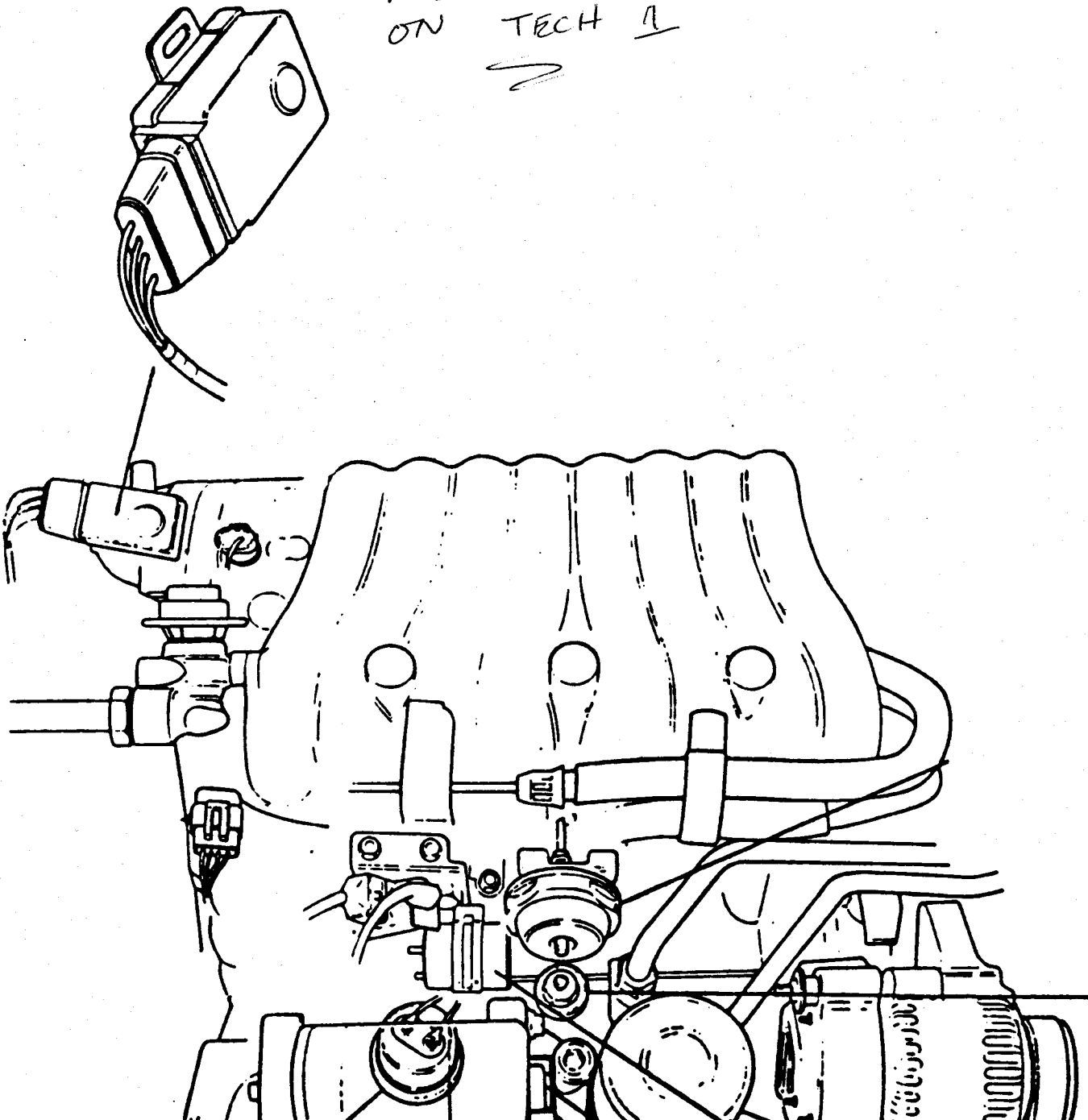
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2.1.4 THROTTLE POSITON SENSOR

The throttle positon sensor is a potentiometer fitted to the rear end of the throttle spindle on the primary throttle body. The ECM supplies 5 volts to the sensor, and by monitoring the voltage on a returning signal line, the ECM is able to determine throttle position and calculate the fuel requirement.

With the throttle closed, the TPS output is low (typical 0.5 volt), but increases as the throttle is opened until at wide open throttle output voltage is about 4.0 volts. This signal is one of the most important inputs used by the ECM for fuel control and for many of the ECM controlled outputs. If a fault is detected and a trouble code set, the ECM will substitute an artificial default value for the TPS signal to enable the vehicle to " limp home". This mode may result in a high idle speed.

MUST READ 95% ~~APR 2008~~ 97%
ON TECH 1
~



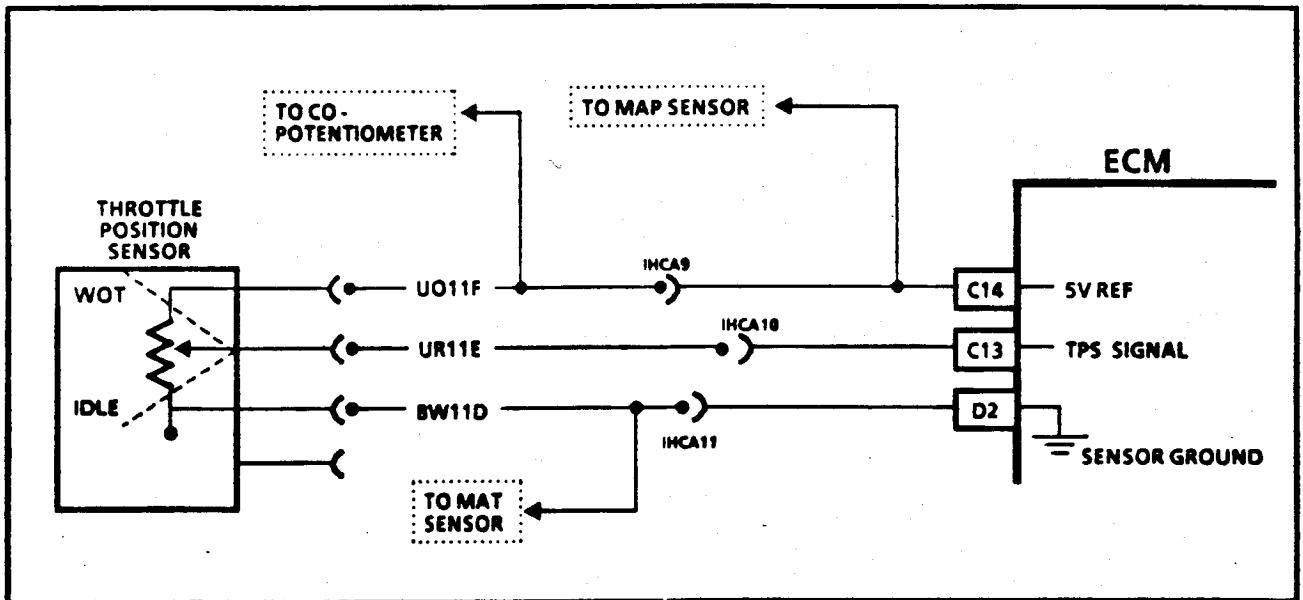
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THROTTLE POSITION SENSOR (TPS) CIRCUIT

Circuit Description:

The ECM applies a "reference voltage" of about 5 volts on CKT UO11F. The throttle position sensor (TPS) sends back a voltage signal that changes relative to the throttle opening. Signal voltage will vary from about 0.40 to 0.70 volt at idle to about 4.0 volt at wide open throttle (WOT).

The Tech 1 tools also have the ability to display the throttle angle and should display 0% when the throttle is closed, and increase smoothly to near 100% at WOT. A failure in the TPS or circuit should set a Code 21 or 22.



65%

2.1.5 VEHICLE SPEED SENSOR (V.S.S.)

Vehicle speed information is supplied to the ECM by the vehicle speed sensor which is an optical pulse generator incorporated into the back of the speedometer head. The generator produces a pulsing AC voltage whenever the vehicle speed is over about 2 km/h (1mph) and which increases in frequency with increasing vehicle speed.

This information is used by the ECM in its control of fuel, spark timing as well as the air conditioning, idle air control valve and exhaust gas recirculation.

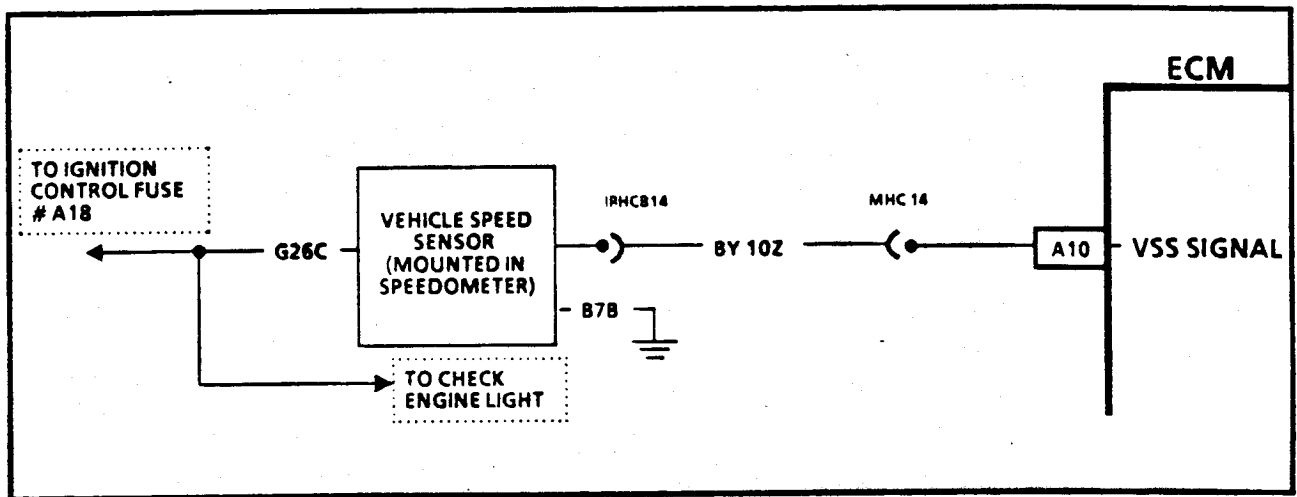
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VEHICLE SPEED SENSOR CIRCUIT

Circuit Description:

The ECM provides 12 volts on CKT BY10Z. The VSS driven by the tacho cable grounds the 12 volts periodically when turning the front wheel.



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2.1.6 IDLE AIR CONTROL (IAC) VALVE

The purpose of the idle air control (IAC) valve assembly is to control engine idle speed, while preventing stalls due to changes in engine load.

The IAC valve is mounted on the left hand of the intake manifold and controls an airway between the upstream side of the primary throttle body (to which it is connected by hose) and an air rail which connects with each of the four intake ports. By moving a conical valve (called a pintle) IN (to decrease air flow) or OUT (to increase air flow), a controlled amount of air is allowed to bypass the throttle plates. If rpm is too low, more air is bypassed around the throttle valves to increase rpm. If rpm is too high, less air is bypassed to decrease rpm.

The electronic control module (ECM) moves the IAC valve in small steps, called "Counts". These can be measured by the "Tech 1" tool.

During idle, the proper position of the IAC valve is calculated by the ECM, based on battery voltage, coolant temperature, engine load, and engine rpm. If the rpm drops below specification, and the throttle valve is closed, the ECM senses a near stall condition and calculates a new valve position to prevent stalls.

The ECM "learns" the proper positioning of the IAC valve and retains this information in memory. This means that disconnecting power to the ECM can result in incorrect idle control after start. Reset of the IAC is necessary.

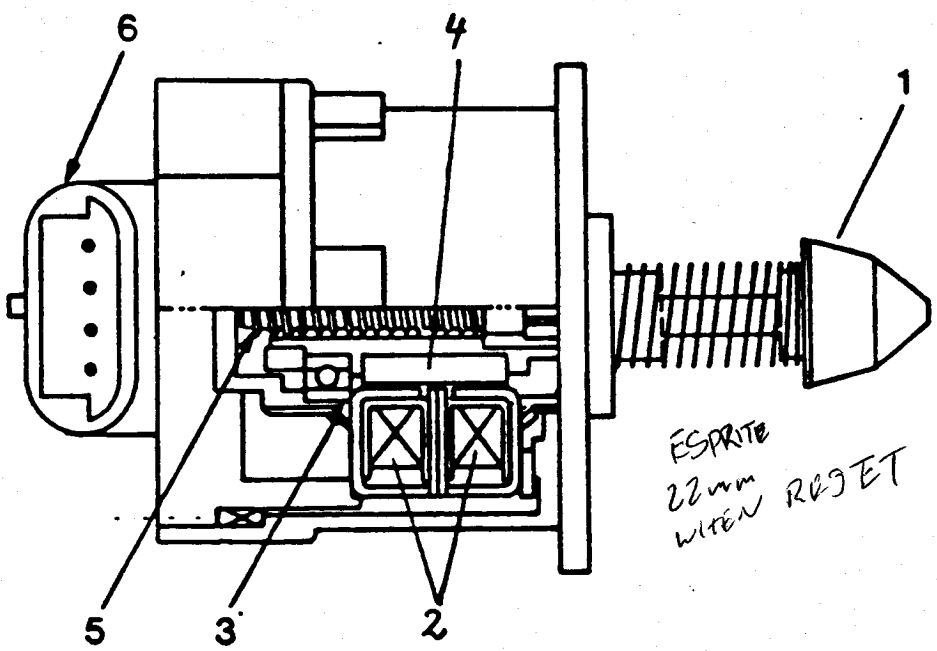
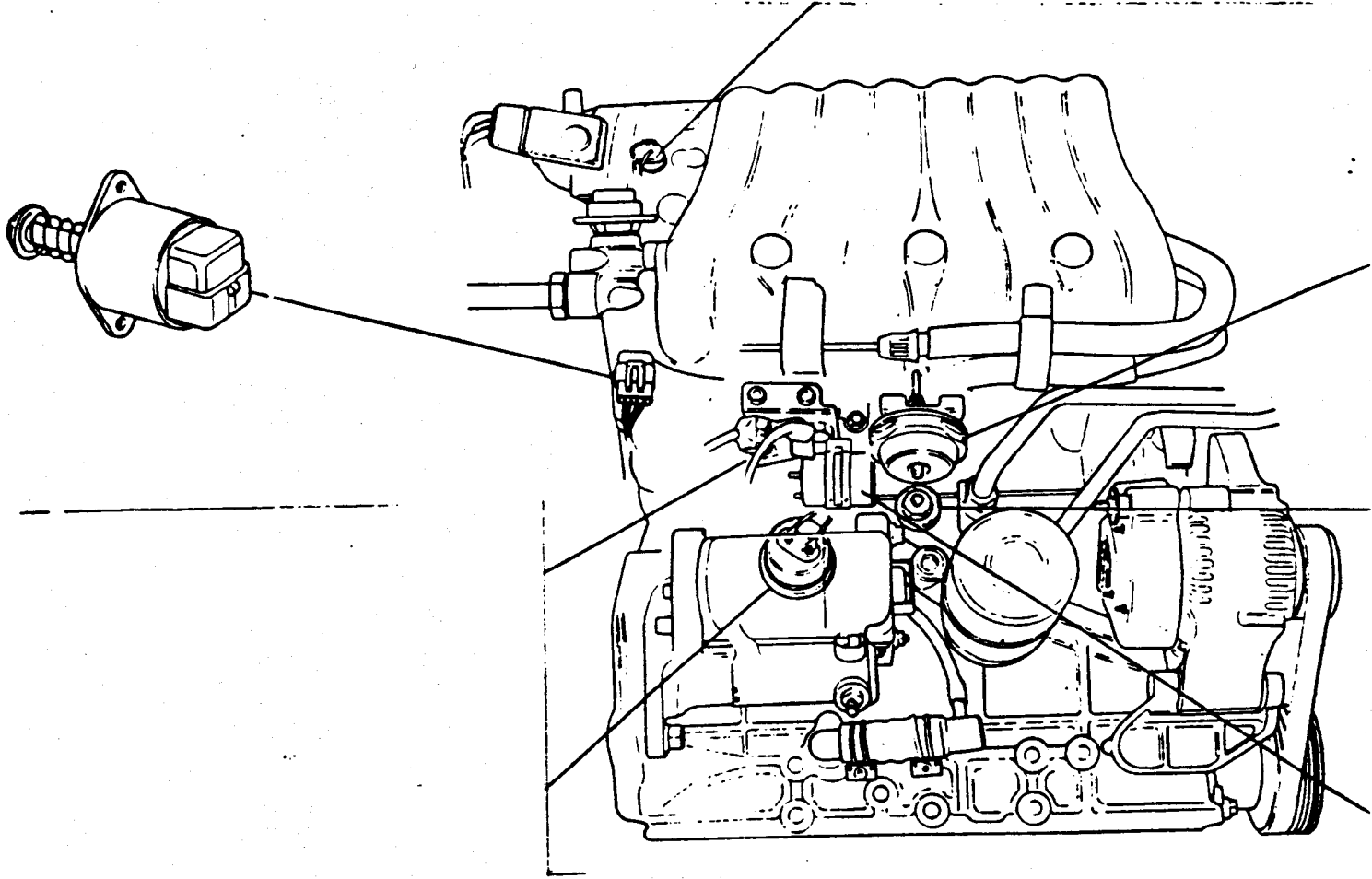
If the IAC valve is disconnected and reconnected while the engine is running, the resulting idle rpm may be wrong, and resetting of the IAC valve will be required.

The ECM resets the IAC valve by seating it (all the way out) to establish the zero count position and then backing it in to the desired position.

This occurs:

- After ignition had been turned off
- When the car is driven above 20mph and no "learned" value is stored in memory (once every ignition cycle).
- TECH 1 has been connected for the first time in "FO Data List" mode and engine speed exceeds 2000 rpm.

When servicing the IAC valve, it should only be disconnected or connected after the ignition has been "OFF" for at least 10 seconds. This allows time for the ECM to move the IAC valve to the 80 count position where it is "parked" while the ignition is "OFF". If this procedure is not followed, the ECM will lose track of IAC valve position resulting in starting or idle control problems.



- 1 PINTLE
- 2 COILS
- 3 BEARING
- 4 ROTOR
- 5 WORM GEAR
- 6 CONNECTOR

*ESPRITE
22mm
WIRE ROSET*

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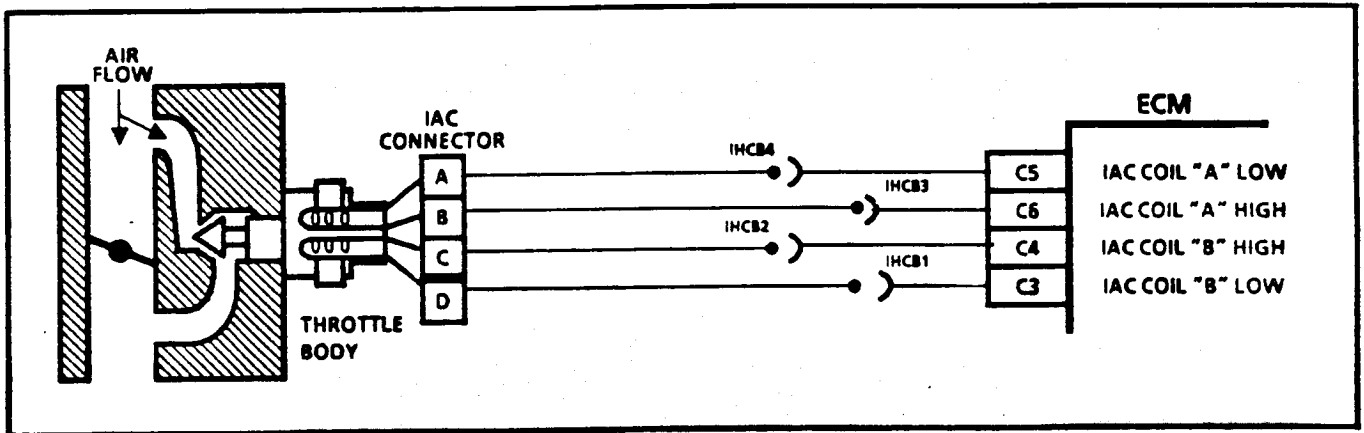
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IDLE AIR CONTROL (IAC) VALVE

IAC CIRCUIT

The idle air control stepper motor consists of a housing with two coils. The rotor on the inside consists of permanent magnets. The rotary motion of the 24 pole rotor with alternating north and south poles is converted to a linear motion with the aid of a worm gear.

The ECM closes the coil circuits alternately. This results in a torque acting on the rotor, which then turns in a specific direction.

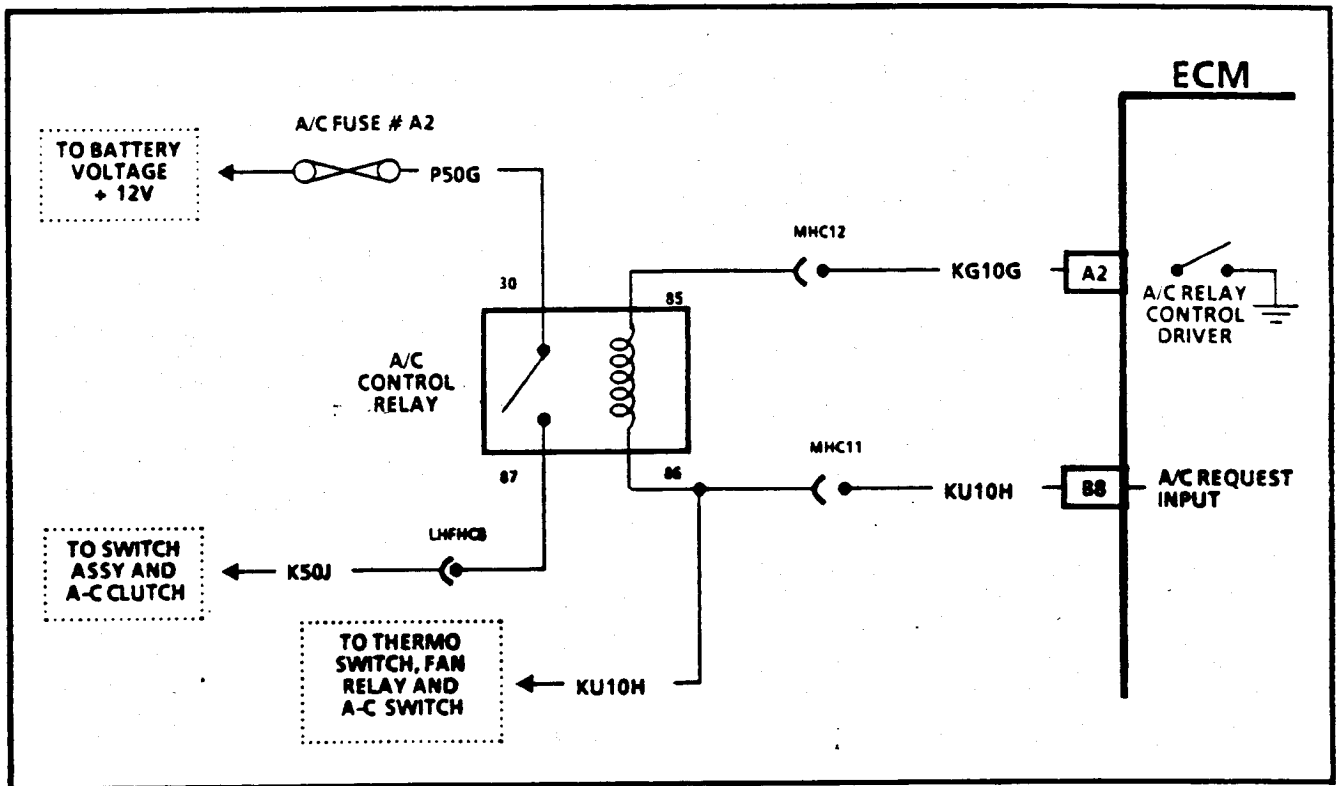


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2.1.7 AIR CONDITIONING CONTROL.

When the air conditioning is switched on, the ECM receives the signal from the thermistor control unit requesting operation of the compressor. Before energizing the A/C compressor, the ECM first amends the idle speed setting via the idle air control valve to compensate for the extra loading on the engine.

Some engine operating conditions will override the A/C request signal and switch off the air conditioning. These includes: engine not running; wide open throttle to make available full engine power; near maximum vehicle speed to increase engine cooling system margins; very hot engine (to prevent overheating).



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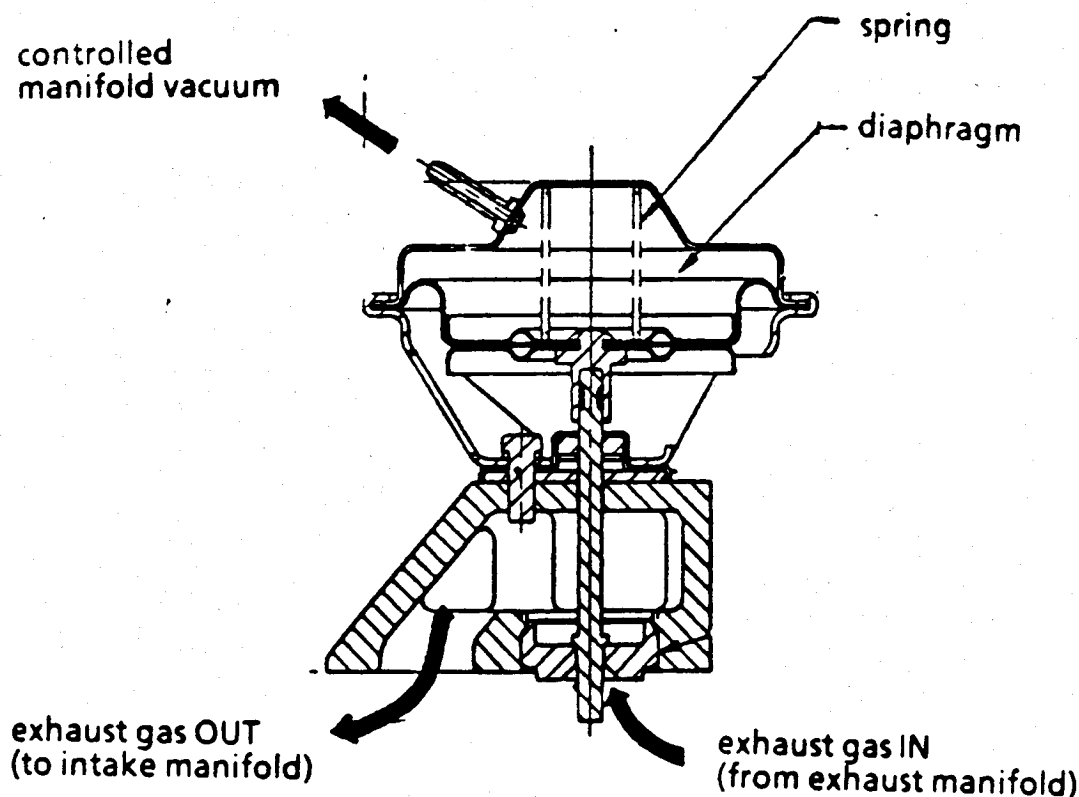
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2.1.8 EXHAUST GAS RECIRCULATION (EGR) CONTROL

During normal combustion, cylinder temperatures may reach 3500°F (2000°C). At approximately 2500°F (1400°C), the nitrogen in the combustible mixture starts to form oxides of nitrogen. As combustion temperatures increase, so does the quantity of oxides of nitrogen. The combustion temperature must be lowered in order to lower the emission of oxides of nitrogen.

The exhaust gas recirculation (EGR) system is used to lower the NO_x (nitrous oxide) levels. A vacuum operated diaphragm valve is used to feed small amounts of exhaust gas back into the intake plenum chamber in order to reduce combustion temperature. Too much recirculation would result in poor combustion.

The EGR valve is mounted on the left hand end of the intake plenum chamber, and controls the flow of exhaust gas in a pipe connecting the exhaust manifold with the plenum. The diaphragm valve is normally held closed by spring pressure, and is opened by the application of vacuum to the top of the diaphragm.

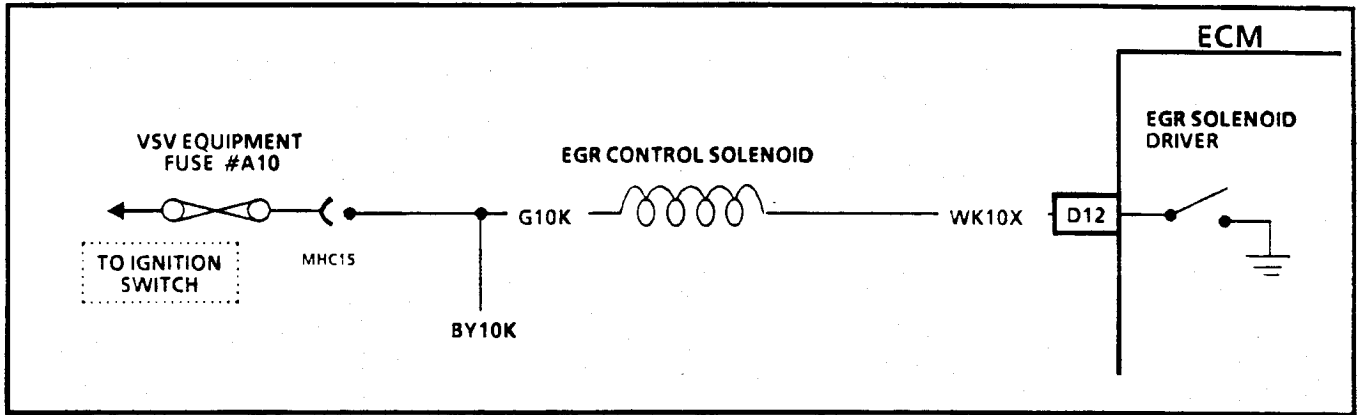


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EGR CONTROL CIRCUIT

The vacuum line is controlled by a solenoid valve (mounted on the left hand wheelarch), itself switched by the ECM. The ECM energises (opens) the solenoid valve, to permit the throttle edge ported vacuum signal to be applied to the EGR valve and allow exhaust gas to recirculate, under the following conditions:

- above a specified coolant and air (MAT) temperature
- throttle opening above idle
- engine speed above idle
- MAP indicating engine under load
- vehicle speed above certain limit

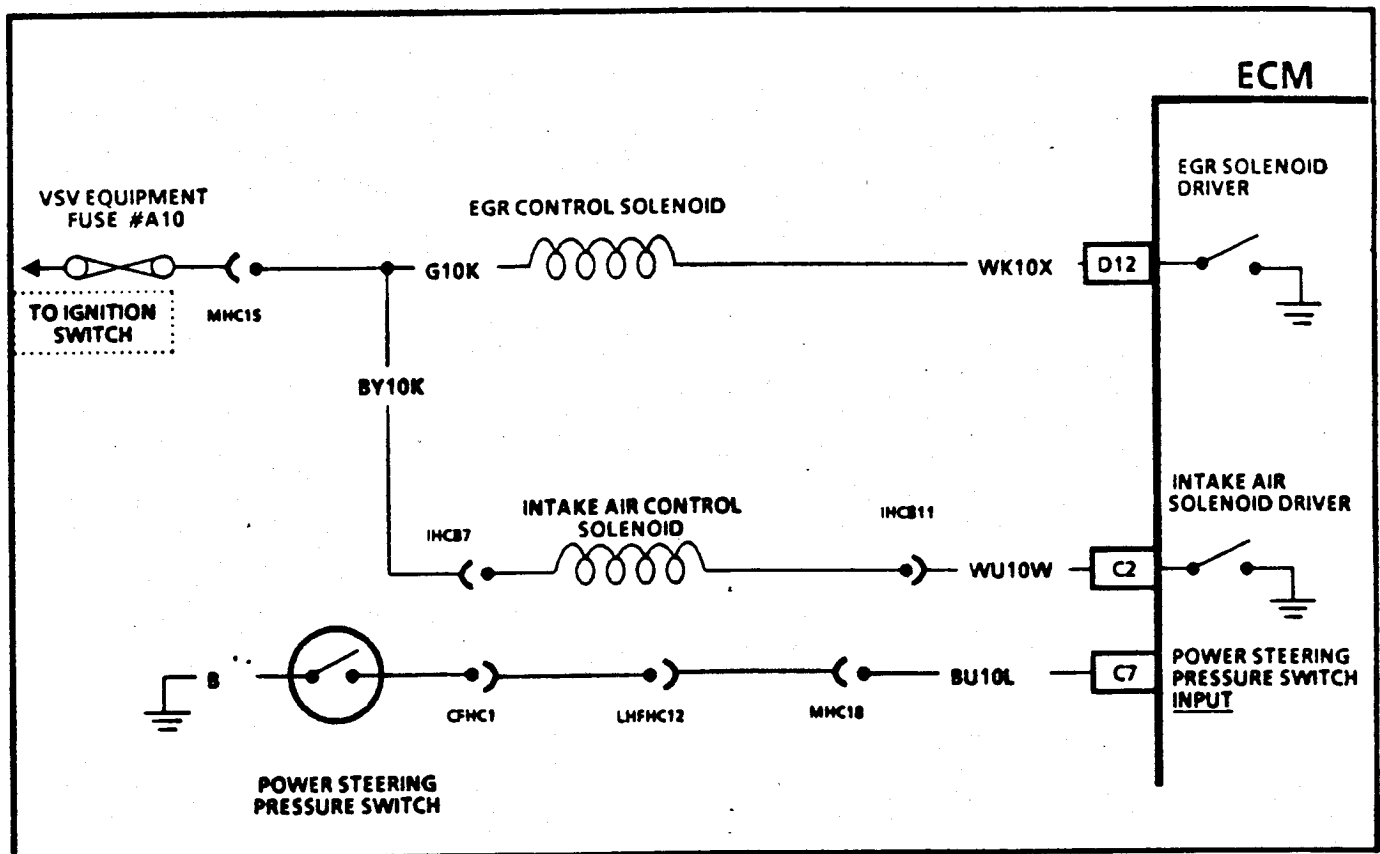


2.1.9 POWER STEERING INPUT

This switch is fitted into the power steering pump and detects when the pump is under heavy load (e.g. parking manoeuvre). The ECM uses this signal to amend the IAC valve position to compensate for the increased engine loading and prevent stalls.

POWER STEERING CIRCUIT

The ECM supplies 12 volts on CKT BU10L. When the steering wheel is turned to the far left or right end heavy load is applied on the power steering pump, the switch closes and grounds CKT BU10L.

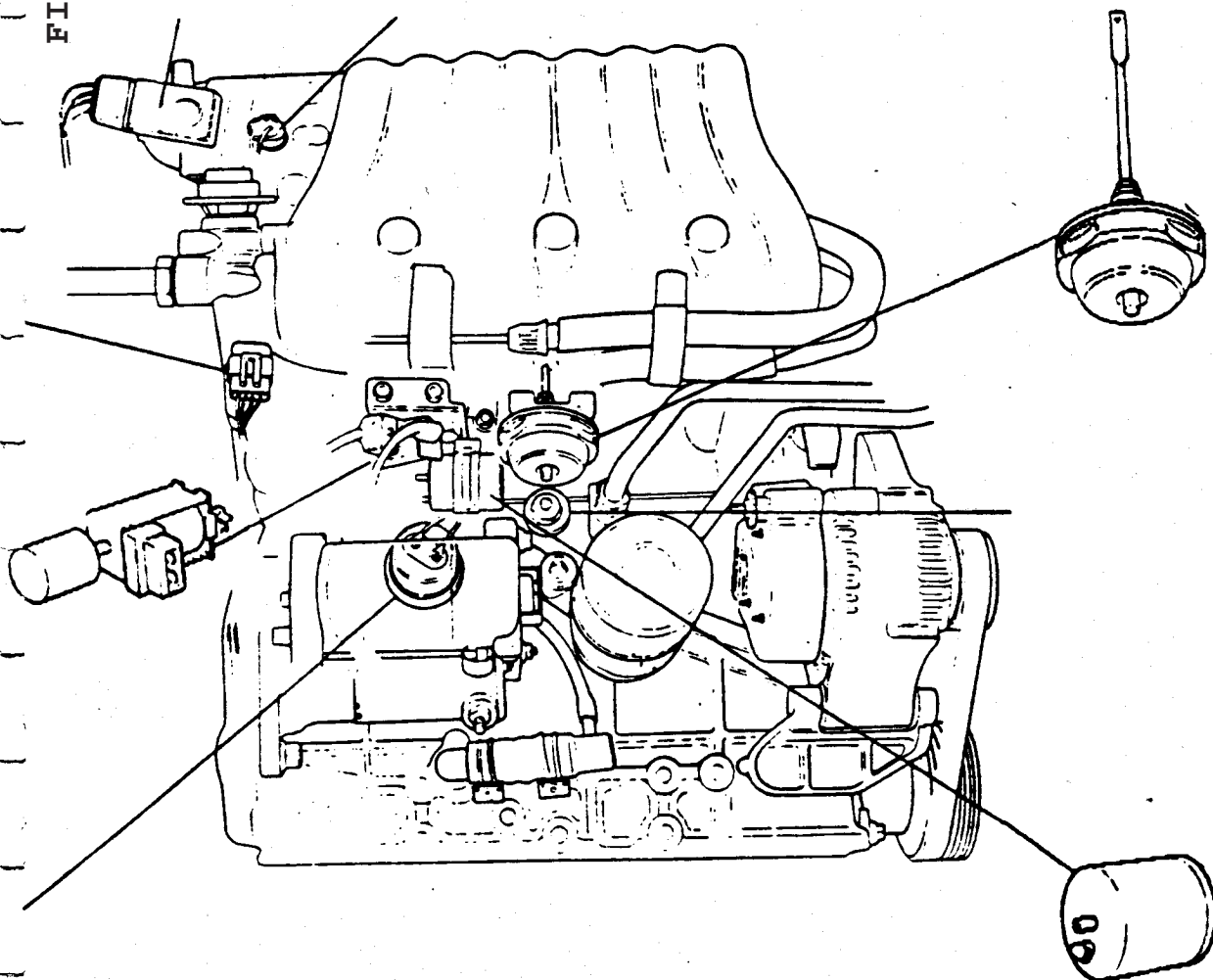


2.1.10 SECONDARY THROTTLE CONTROL

The intake system incorporates a water heated throttle body containing a primary throttle valve; an plenum chamber integral with eight individual intake tracts; and a lower intake manifold feeding the four bifurcated cylinder head ports. The lower intake manifold contains a fuel injector for each of the four ports and a secondary throttle valve controlling one of the two tracts for each cylinder. These secondary throttle valves are operated by a single vacuum actuator whose vacuum supply is controlled by a vacuum switching solenoid.

At engine speeds below 4,700 RPM on the TURBO and below 5,200 RPM on the N/A the ECM energises the solenoid valve.

Vacuum is supplied to the actuator and the secondary throttles are closed. Above these engine speeds the ECM deenergises the solenoid, the vacuum feed to the actuator is vented and the throttles are opened by spring load.



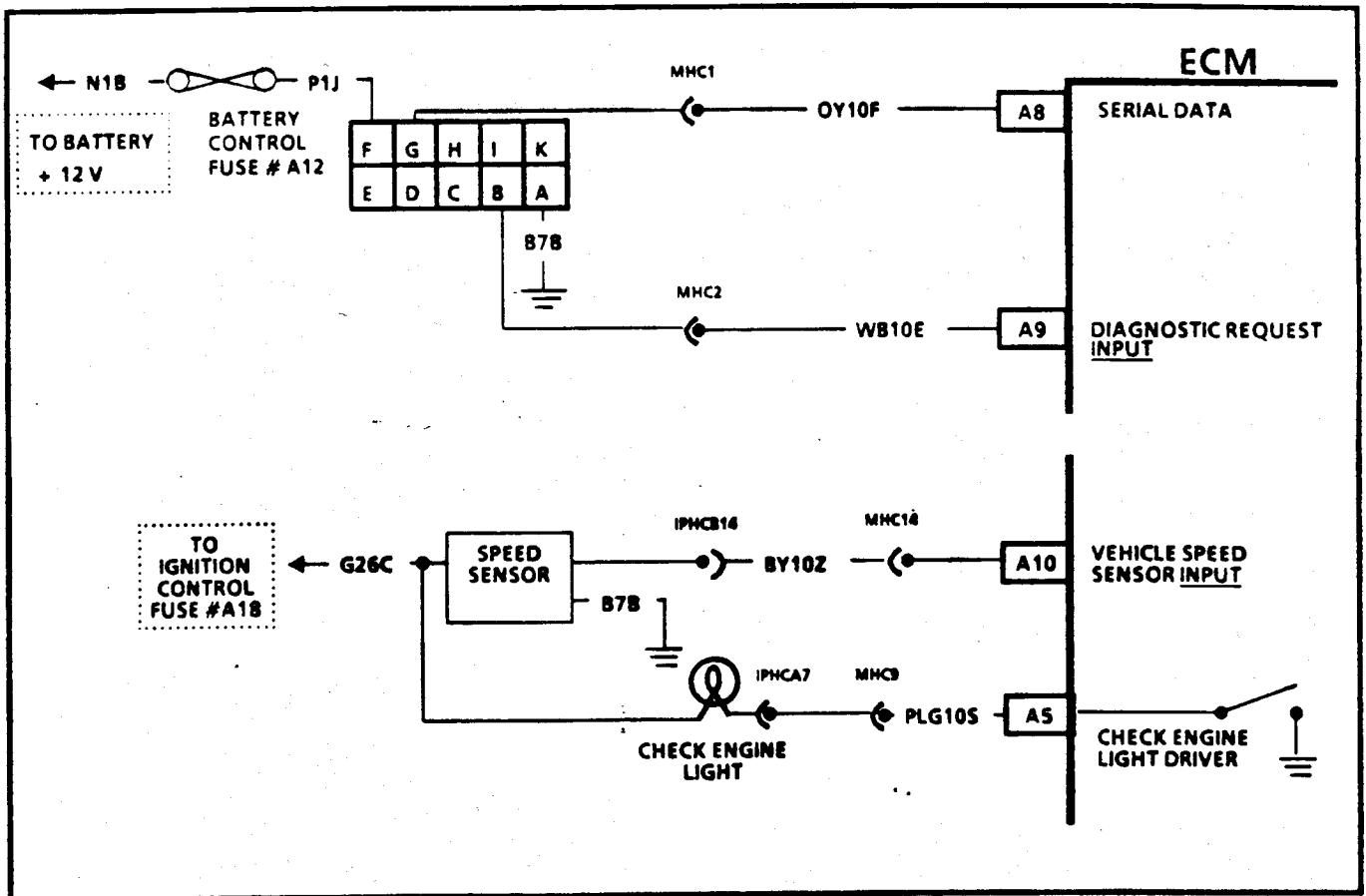
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2.1.11 ALDL CONNECTOR & CHECK ENGINE LIGHT

An "Assembly Line Diagnostic Link" (ALDL) connector plug in the passenger footwell close to the ECM, is provided for use both at the end of the assembly line to check for correct system operation, and in service, for diagnostic purpose. A special hand held electronic scanner tool (Tech 1) plugs into this connector and enables all the sensor readings, other engine parameters and trouble codes to be stored and displayed.

The ECM can also recognize operational problems and alert the driver via a "Check Engine" tell tale lamp on the fascia, whilst storing a "trouble code" to help the technician make rapid fault diagnosis.

When two wires at the ALDL connector are shorted the ECM transmits any stored trouble codes by flashing the "Check Engine Light" (CEL).



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2.2 N/A SPECIFIC COMPONENTS

2.2.1 HIGH ENERGY IGNITION (HEI)

The High Energy Ignition system fitted on naturally aspirated engines, uses a distributor unit driven off the left hand end of the exhaust camshaft, an ignition coil mounted at the left hand side of the engine bay, and control circuitry within the ECM.

A four position reluctor, pick up coil and module in the distributor, provide the ECM with rpm and crankshaft position information which it uses to control ignition and fuel injector pulse timing.

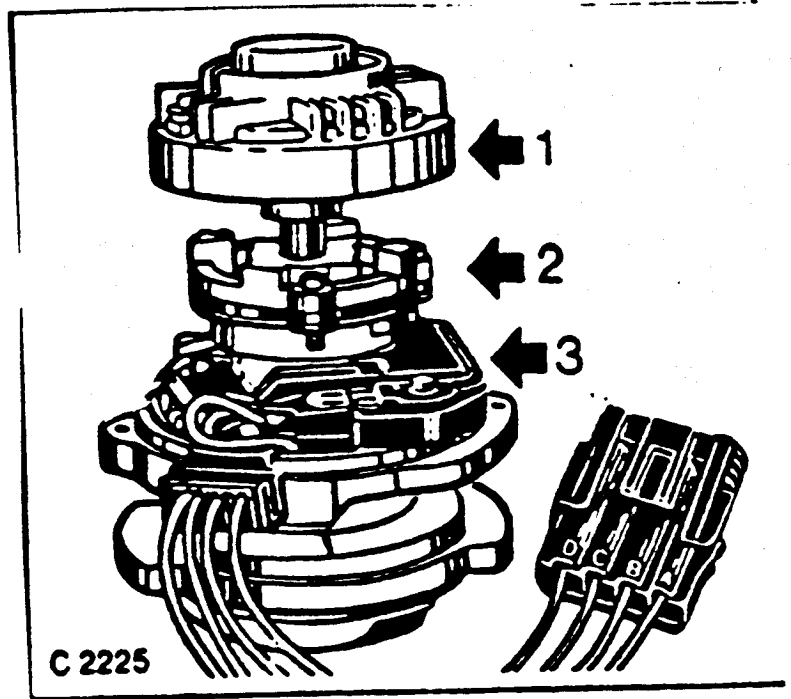
The distributor body may be rotated to adjust the basic timing position. If this is set incorrectly, the whole ignition advance curve will be incorrect, in both module and EST modes.

Secondary current is received from the ignition coil by the distributor, which uses a rotor and distributor cap to supply the appropriate spark plug.

*TECH 1 FELTED SERVICE MODE
16° TO SET TIMING AT IDLE*



1. Distributor rotor
2. Inductive pick up coil and reluctor
3. Ignition module



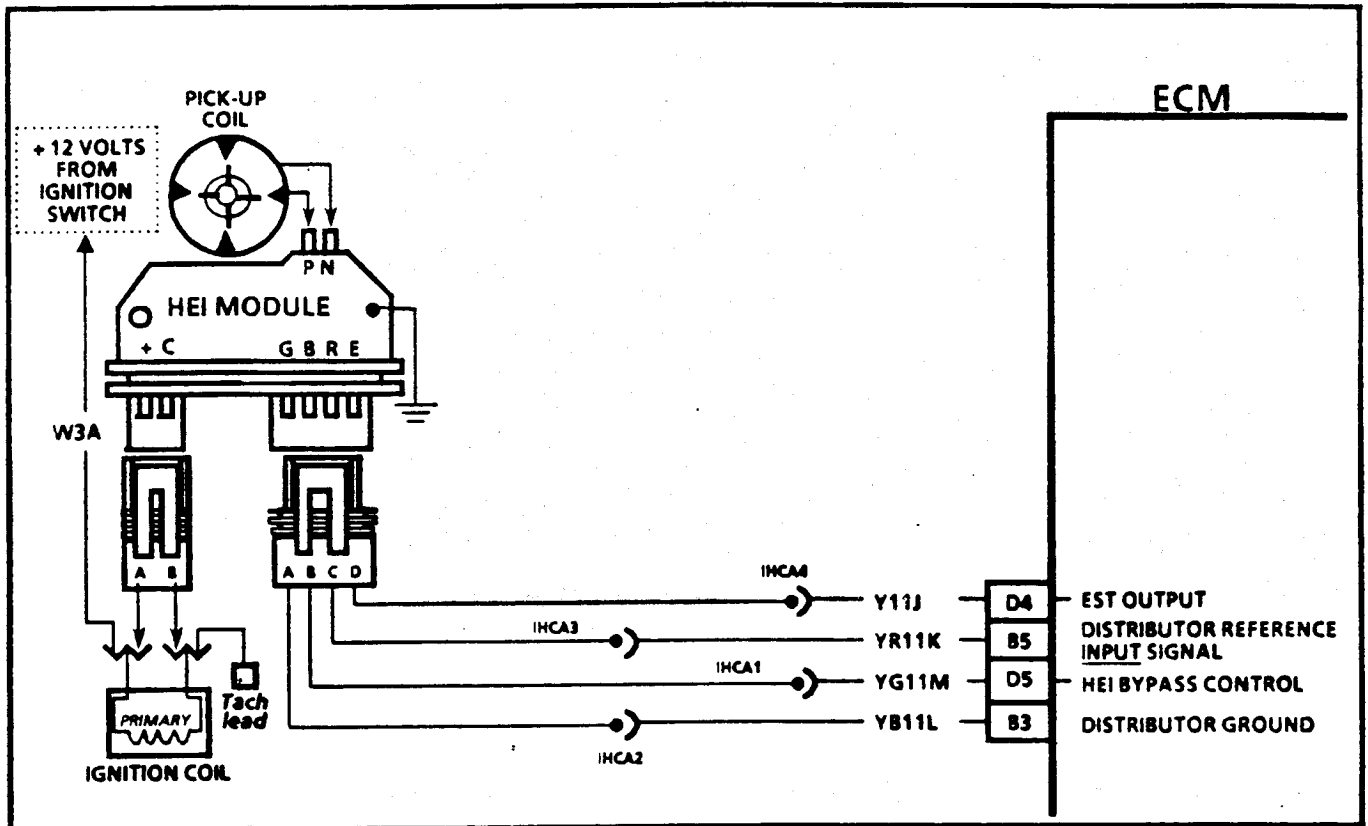
LOTUS TRAINING

HEI CIRCUITRY

The reluctor and pick up coil assembly provides a sine wave signal twice every engine revolution. This sine wave is converted into a square wave signal in the ignition module and sent to the ECM on CKT YR11K in order to determine crankshaft position and engine speed.

Below 800 rpm the ignition module triggers the ignition coil directly, the "bypass" line voltage will be low.

Above 800 rpm the bypass line voltage on CKT YG11M will be raised to approx. 5 volts, the ECM takes over spark timing and sends a square wave signal back to the ignition module on CKT Y11J which then triggers the ignition coil.



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2.2.2 FUEL CONTROL SYSTEM

FUEL PUMP

The fuel pump is a roller vane type, high pressure electric pump mounted submerged within fuel tank. The pump supplies fuel at a pressure of 211 - 379 kPa (30.5 - 55 psi) dependent on operating conditions, through an in line filter by the fuel tank, to the fuel rail assembly. A fuel strainer is attached to the fuel pump inlet line and prevents dirt particles from entering the fuel line and tends to separate water from the fuel. A pulsator is fitted above the fuel pump and is connected to its outlet line to reduce pressure pulsations in the supply line. The whole assembly of pump, strainer and pulsator is fixed by the supply and return pipes, to a mounting plate secured by cam ring to the top face of the tank.

The pump is able to deliver 4 - 5 times the engines maximum requirement, so that fuel is constantly circulated through the fuel rail, and via the fuel pressure regulator, back to the tank. This fuel circulation helps avoid excessive fuel temperature with consequent risk of vapour locks.

FUEL RAIL + PRESSURE REGULATOR

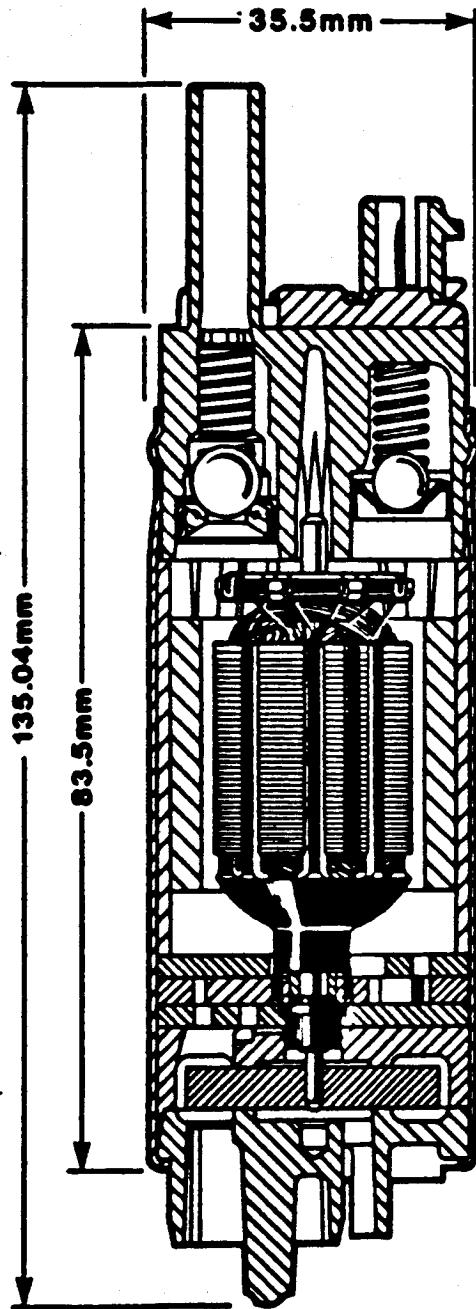
The extruded aluminium fuel rail receives fuel at its forward end (from the in-line filter) and supplies all four injectors with fuel, the pressure of which is controlled by the fuel pressure regulator fitted to the rear end of the rail. The pressure regulator assembly is a diaphragm operated relief valve with fuel pump pressure acting on one side of the diaphragm, and regulator spring pressure and intake manifold pressure on the other. The function of the regulator is to maintain a constant pressure differential across the injectors at all times i.e. a constant difference between fuel pressure supplied to the injector, and inlet manifold pressure at the injector nozzle. By using an inlet manifold pressure signal to supplement regulator spring pressure in the valve, the valve is able to regulate fuel supply pressure in accordance with engine load. The pressure regulator is not adjustable and is serviced as a complete assembly.

FUEL INJECTORS

The port fuel injector assembly is a solenoid-operated device, controlled by the electronic control module (ECM), that meters pressurized fuel to a single engine cylinder. The ECM energizes the low impedance (2.0 ohms) solenoid to open a normally closed ball valve and through a recessed flow director plate at the injector outlet. The director plate has six machined holes that control the fuel flow, generating a conical spray pattern of finely atomized fuel at the injector tip. Fuel from the tip is directed at the intake valve, causing it to become further atomized and vaporized before entering the combustion chamber.

LOTUS TRAINING

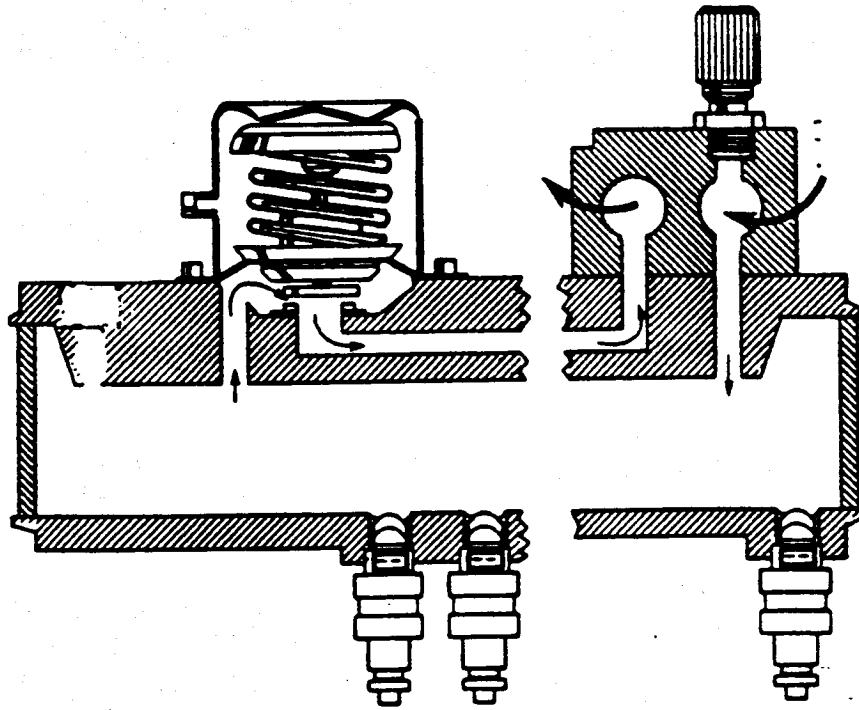
ROLLERVANE FUEL PUMP



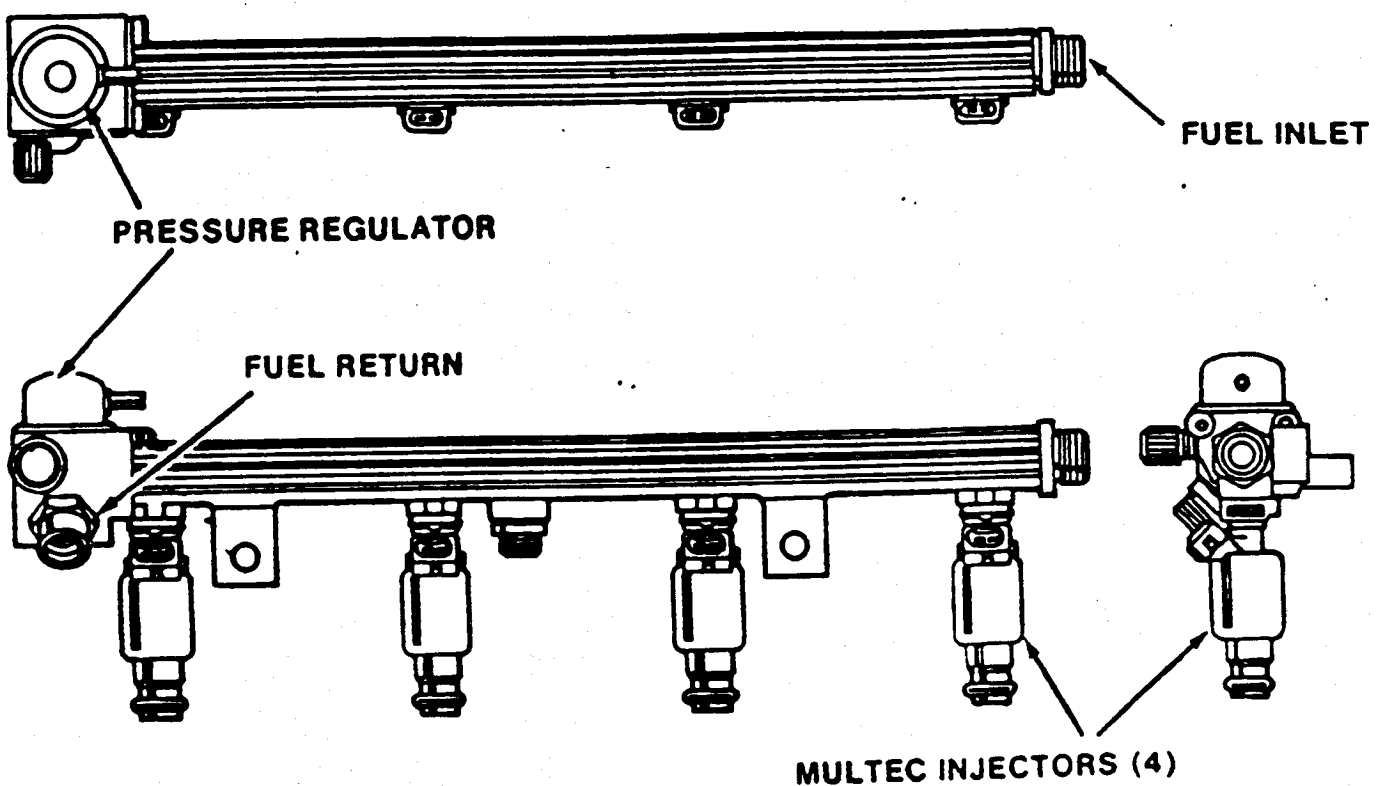
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LOTUS TRAINING

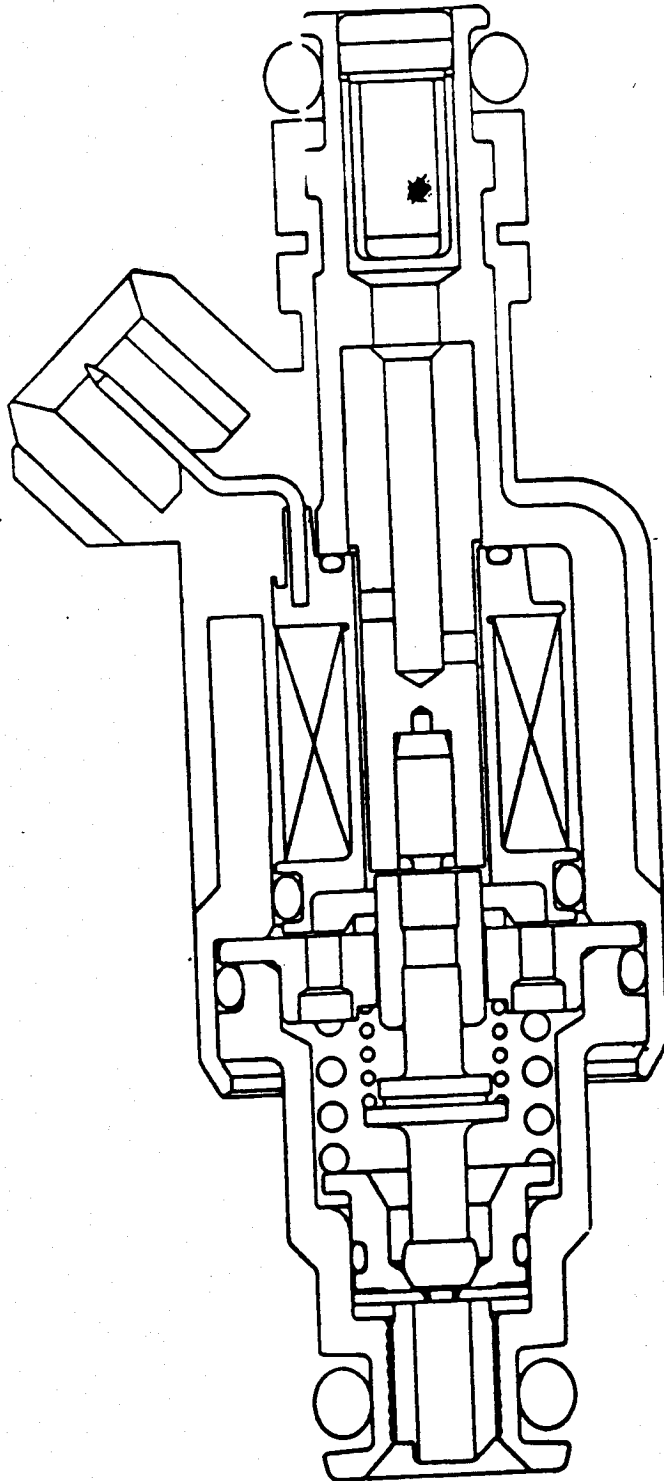
FUEL RAIL AND PRESSURE REGULATOR



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FUEL INJECTOR



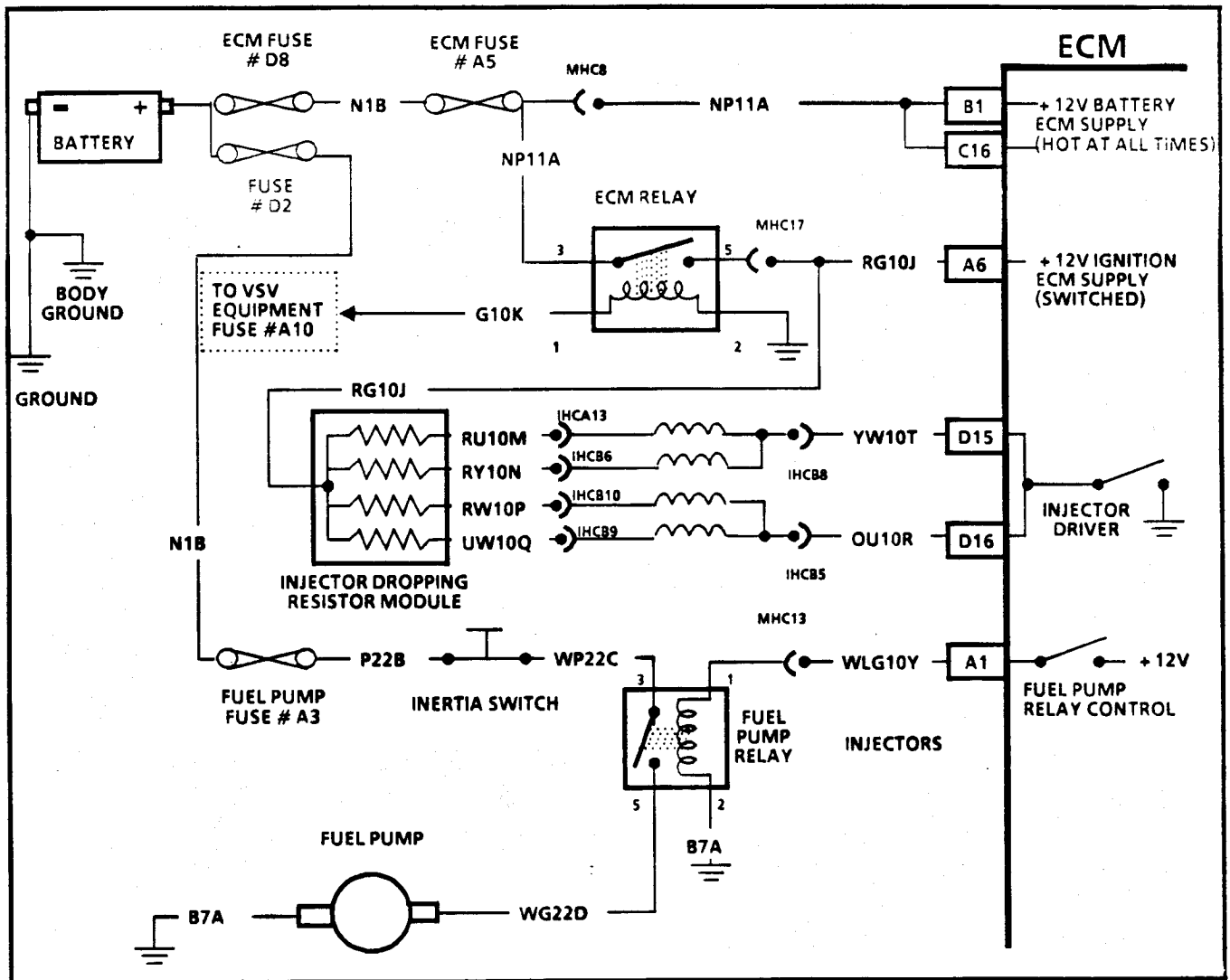
LOTUS TRAINING

FUEL INJECTION CIRCUITRY

When the ignition is switched on, the ECM energises the fuel pump which will continue to run for as long as the ECM receives ignition pulses from the ignition module (engine cranking or running). If no ignition pulses are received, the ECM switches off the pump either 2 seconds (approx.) after the ignition was switched on, or about 10 seconds after a stall.

The ECM receives an engine speed and crankshaft position signal twice per engine revolution from the ignition module, and uses these to trigger the injectors.

The ECM uses a single injector driver circuit, controlling all four injectors. The injectors are pulsed simultaneously once every crankshaft revolution, with half of the fuel necessary for each cylinder's combustion delivered by each injector pulse.



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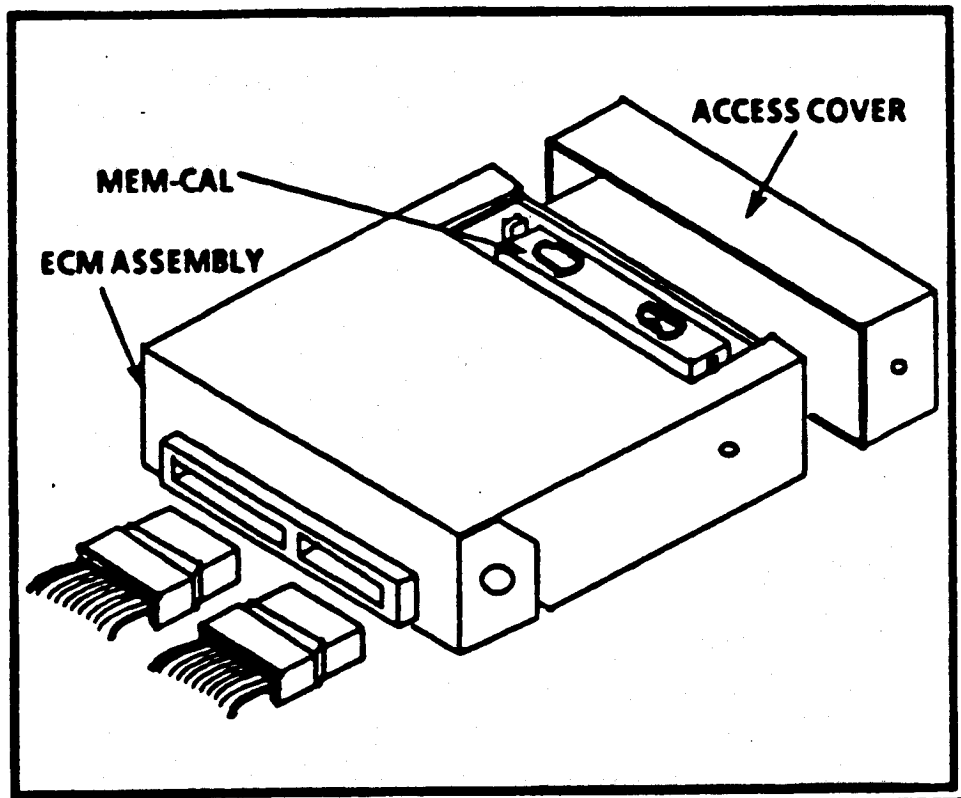
2.2.3 ELECTRONIC CONTROL MODULE (ECM)

The Electronic Control Module (ECM), located on the inboard side of the right hand footwell, is the controlling computer for the fuel injection and engine management system. It constantly monitors data received from various sensors and controls engine operation to provide optimum performance and driveability.

The ECM consists of two principal parts:

- Controller. This is the main body of the ECM and includes the basic control circuits.
- Mem-Cal. This is a "Memory and Calibration" cartridge which plugs into the controller. It contains data specific to particular vehicles, together with the functions of the EPROM (erasable programmable read only memory) and Cal-Pak (calibration package designed to allow fuel delivery in the event of malfunction in the controller or PROM, as a 'get you home' facility).

On the Elan, the ECM is a non-servicable sealed unit, which must not be opened.



1.6L NATURALLY ASPIRATED (N/A) PARAMETERS SENSED VS. PARAMETERS CONTROLLED

PARAMETERS SENSED	PARAMETERS CONTROLLED					
	FUEL	IDLE SPEED	SPARK TIMING	EGR CONTROL	SECONDARY THROTTLES	CHECK ENGINE LIGHT
ENGINE SPEED	X	X	X	X	X	X
VEHICLE SPEED	X	X	X	X		X
COOLANT TEMP.	X	X	X	X	X	X
MASS AIR TEMP.			X			X
MANIFOLD PRESSURE	X	X	X	X	X	X
BAROMETRIC PRESS.	X	X				
THROTTLE POSITION	X	X	X	X	X	X
BATTERY VOLTAGE	X	X				
POWER STEERING SWITCH INPUT		X				
CO-POTENTIOMETER	X					X
CAMSHAFT POSITION			X			
TIME	X	X	X	X		

LOTUS TRAINING

2.3 TURBO SPECIFIC COMPONENTS

2.3.1 DIRECT IGNITION SYSTEM (DIS)

The direct ignition (DI) system does not use the conventional distributor and coil. This ignition system consists of two separate ignition coils and an ignition module mounted on a base plate.

A cam angle sensor, related connecting wires and the electronic spark timing (EST) portion of the ECM make up the remainder of the system.

A distributorless ignition system, such as this one, uses a "waste spark" method of spark distribution. Each cylinder is paired with its opposite number (i. e. 1 with 4, and 2 with 3 with each pair of plugs being connected to a single, double-ended coil such that a spark occurs simultaneously in the cylinder coming up on the compression stroke and in the cylinder coming up on the exhaust stroke.

The cylinder on the exhaust stroke requires very little of the available energy to fire the spark plug. The remaining energy will be used as required by the cylinder on the compression stroke. The same process is repeated when the cylinders reverse roles.

CAM ANGLE SENSOR

The cam angle sensor consists of a baseplate and insulated cover mounted on the left hand end of the cylinder head, containing two electronic sensors, and a reluctor disc and a vane driven by the exhaust camshaft.

A magnetic (reluctance) pick-up at the rear of the cam angle sensor, detects the grooves in the periphery of the reluctor wheel, and enables the igniton module, by measuring the time interval between these pulses, to interpret engine speed. Twelve grooves are provided for this purpose, with 2 positional reference pulses provided by the doubling up of grooves at diametrically opposite points on the disc, which results in one reference pulse every crankshaft revolution. These signals are used to provide electronic spark timing (EST) data.

IGNITION MODULE & HT COILS

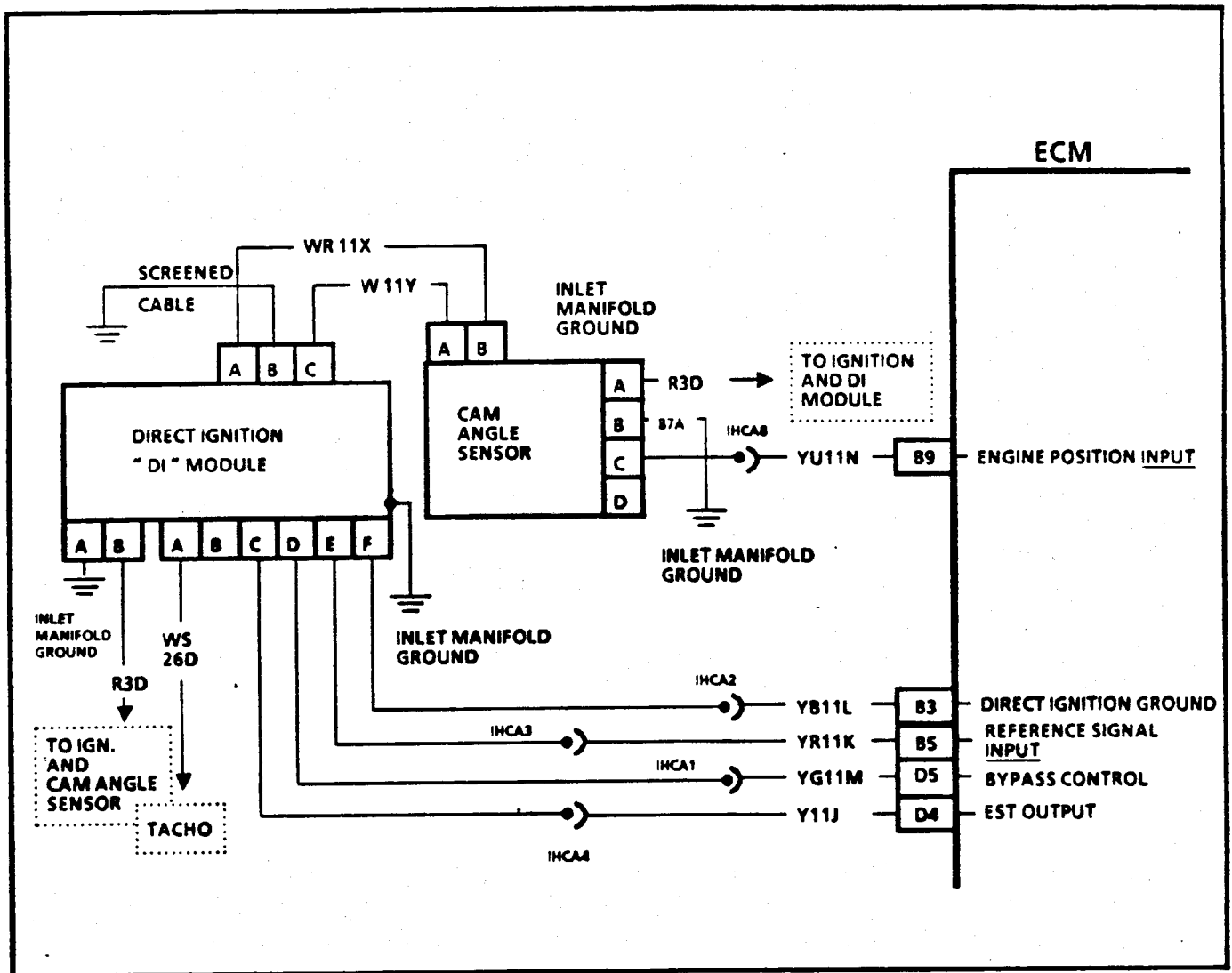
The ignition module and HT coils are mounted as a unit at the left hand side of the engine bay. Each coil provides the spark for two plugs simultaneously.

LOTUS TRAINING

DIRECT IGNITION SYSTEM CIRCUITRY

The ignition module monitors the cam angle sensor signals and sends reference signals to the ECM on CKT YR11K. Below 800 rpm the module controls spark engine speed only. During that time the bypass line voltage on CKT YG11M will be kept low.

Above 800 rpm the ECM controls spark timing (EST) by sending a square wave signal to the ignition module on CKT Y11J which triggers the coils. The bypass line voltage on CKT YG11M about 5 volts then.

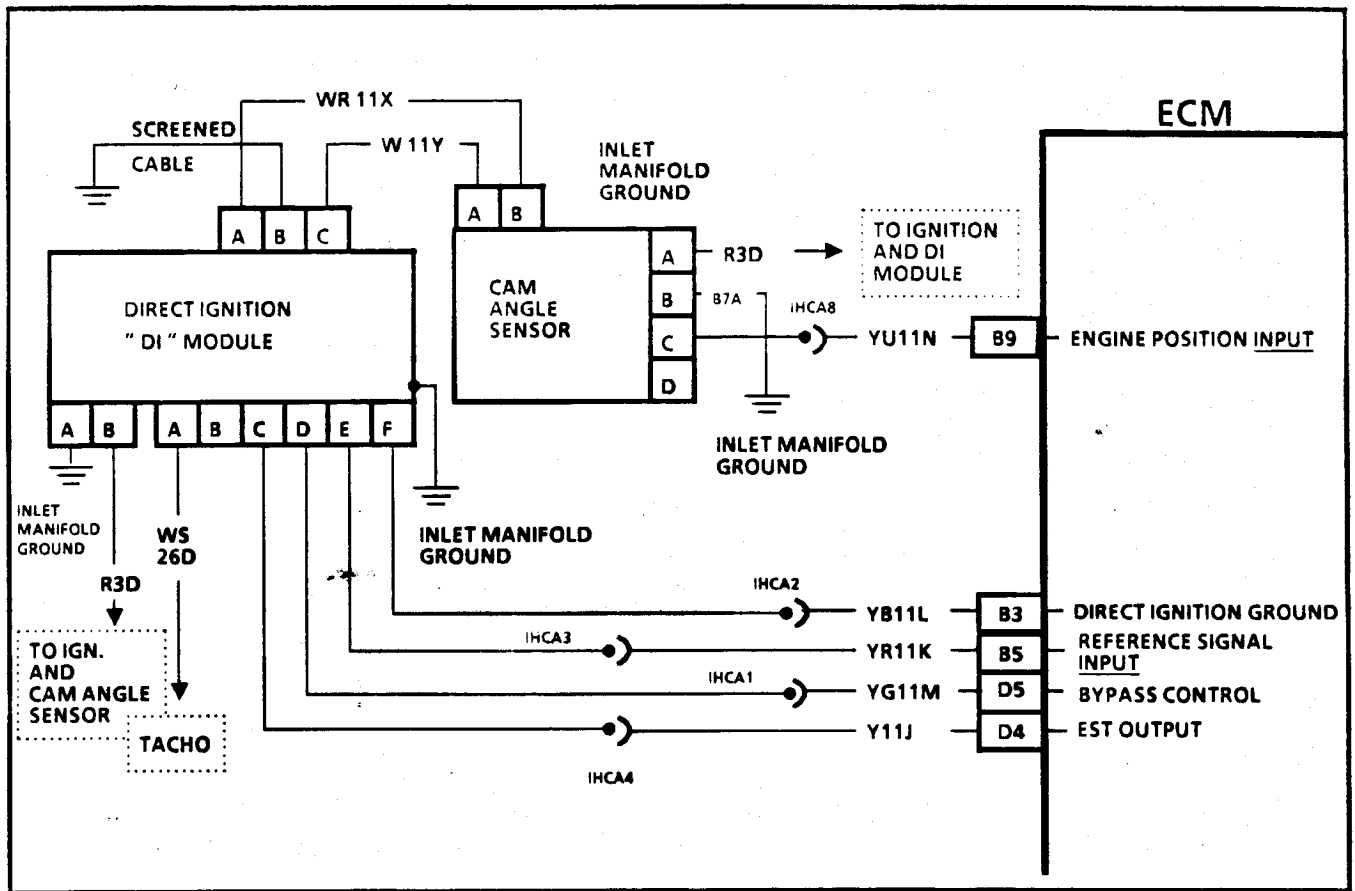


LOTUS TRAINING

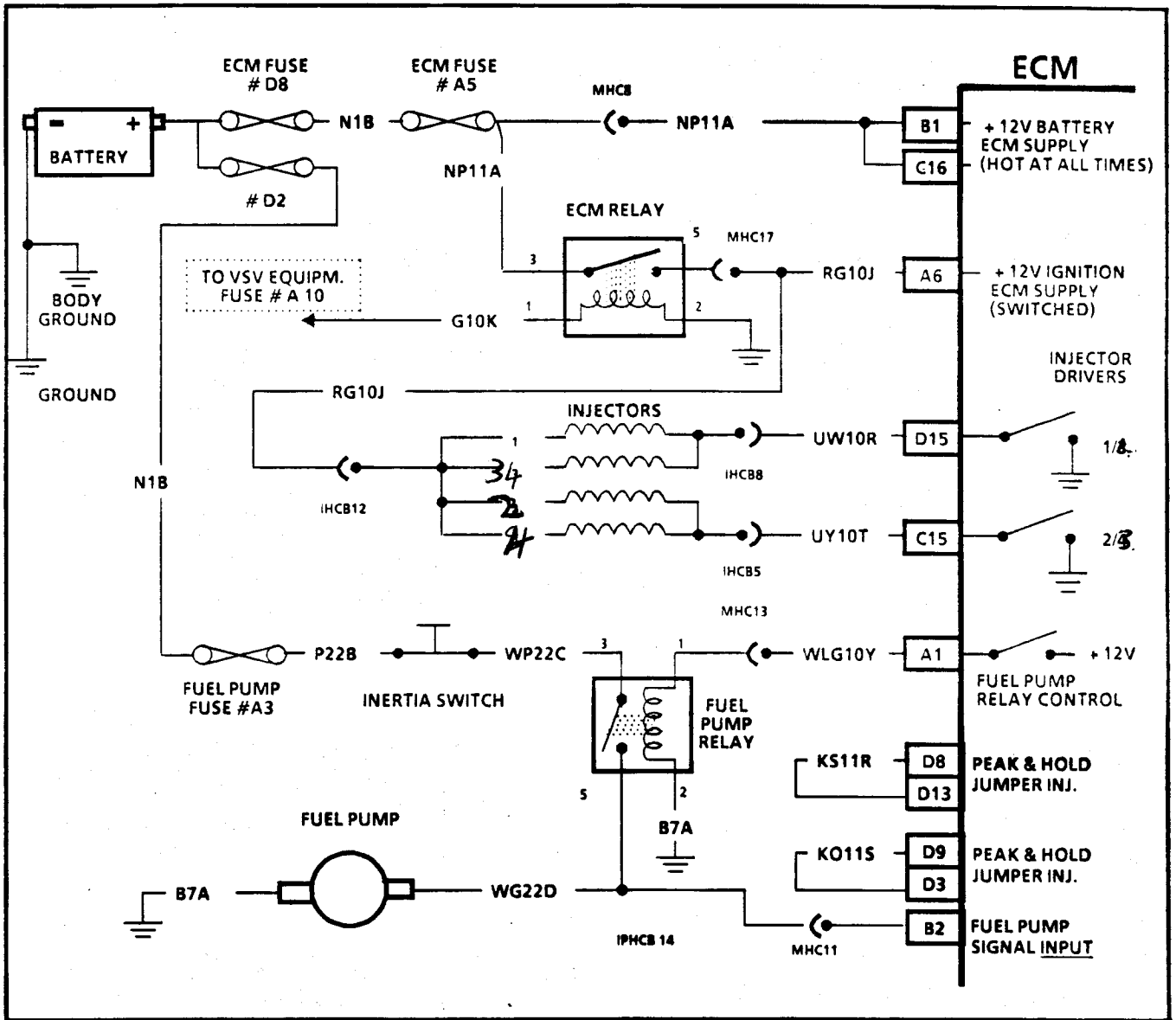
2.3.2 TURBO FUEL CONTROL SYSTEM

Different from the N/A system the TURBO ECM uses two injector driver circuits, with one circuit controlling injectors 1 and 3, and one controlling 2 and 4. Each circuit pulses both injectors simultaneously once every crankshaft revolution, with half of the fuel necessary for each cylinders combustion delivered by each injector pulse.

The ECM receives an engine speed signal (reference or REF) twice per engine revolution from the ignition module via CKT YR11K and a square wave signal once every 720 degrees crankshaft angle from the cam angle sensor an CKT YU11N. The ECM uses these to trigger the "alternate pairs" injector timing sequence.



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2.3.3 ELECTRONIC SPARK CONTROL (ESC) & BOOST CONTROL

This system comprises an engine "knock" sensor mounted in the right hand side of the cylinderblock, a turbo boost control solenoid valve, and an ESC module which is incorporated into the ECM "Mem-Cal" cartridge.

The ignition timing required for optimum performance can lead, under certain operating conditions, to detonation of the fuel mixture in the combustion chamber, causing excessive heat and pressures and a characteristic "knocking" noise. If allowed to continue unchecked, major engine damage can occur. The ESC system allows the engine to adhere as closely as possible to the optimum ignition timing and turbo boost settings without a damaging level of detonation.

When the knock sensor detects the onset of detonation, the ECM retards ignition, and then progressively advances ignition until detonation is again detected and the cycle repeats.

KNOCK SENSOR

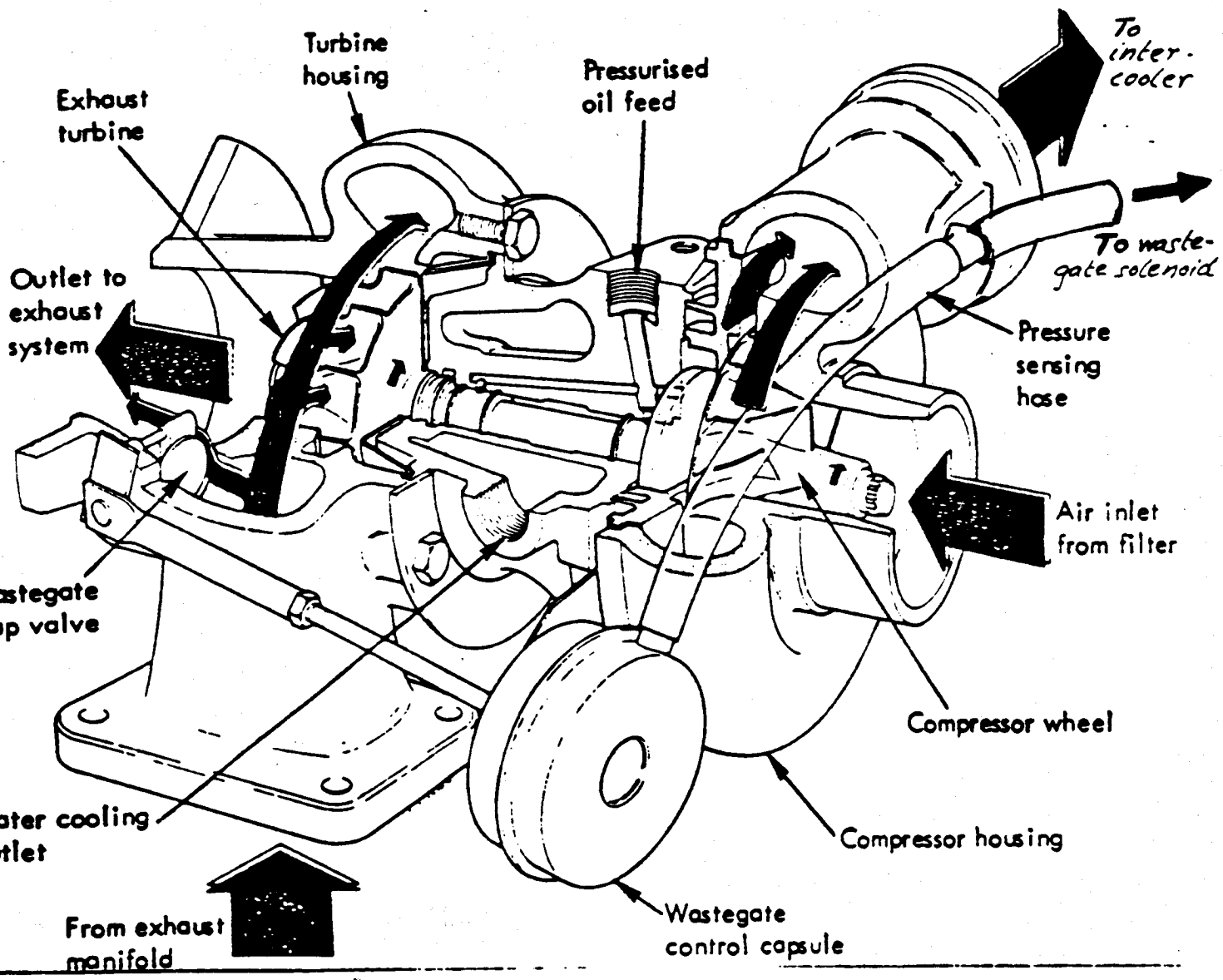
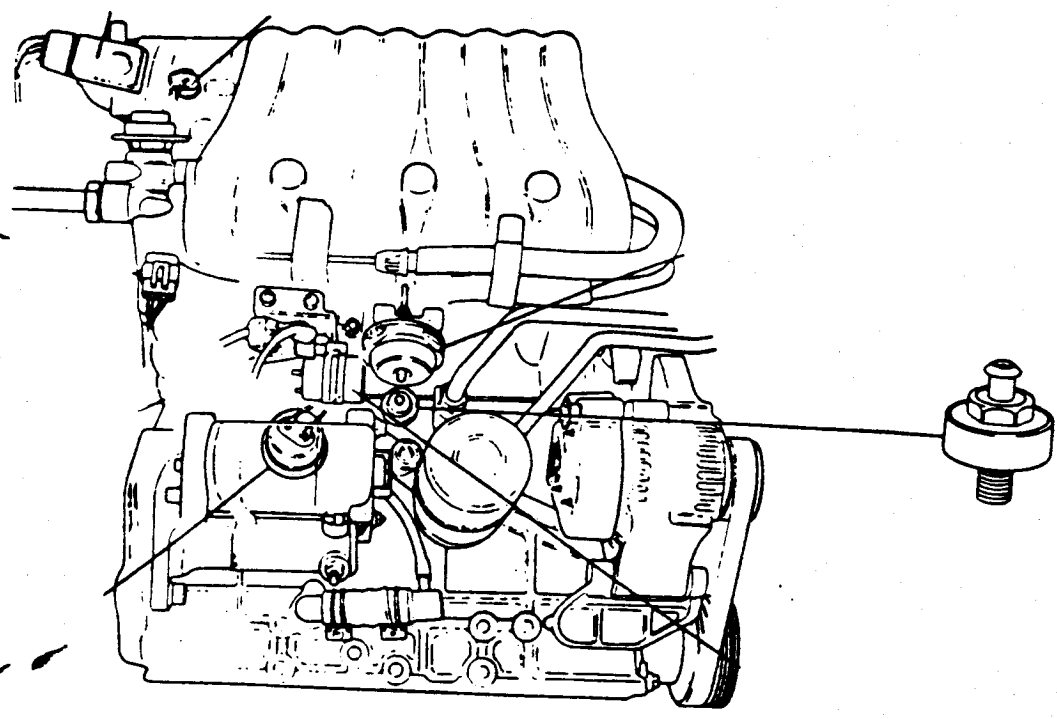
The knock sensor is mounted in the cylinder block, and is able to identify the detonation "knocking" noise and produce an AC output voltage which increases with the severity of the knock. The ECM monitors this signal and adjusts the electronic spark timing (EST) and boost pressure as necessary to reduce detonation.

BOOST CONTROL SOLENOID VALVE

The turbo boost control solenoid valve is located at the left hand side of the engine bay and is connected to the turbo wastegate capsule control pressure line. When the solenoid valve is de-energized, the wastegate capsule controls maximum boost pressure to 0.41 bar (6.0 lb/sq. in). If the solenoid valve is energised, boost pressure is vented to atmosphere which will then keep the wastegate shut, with boost pressure limited by the engine control system.

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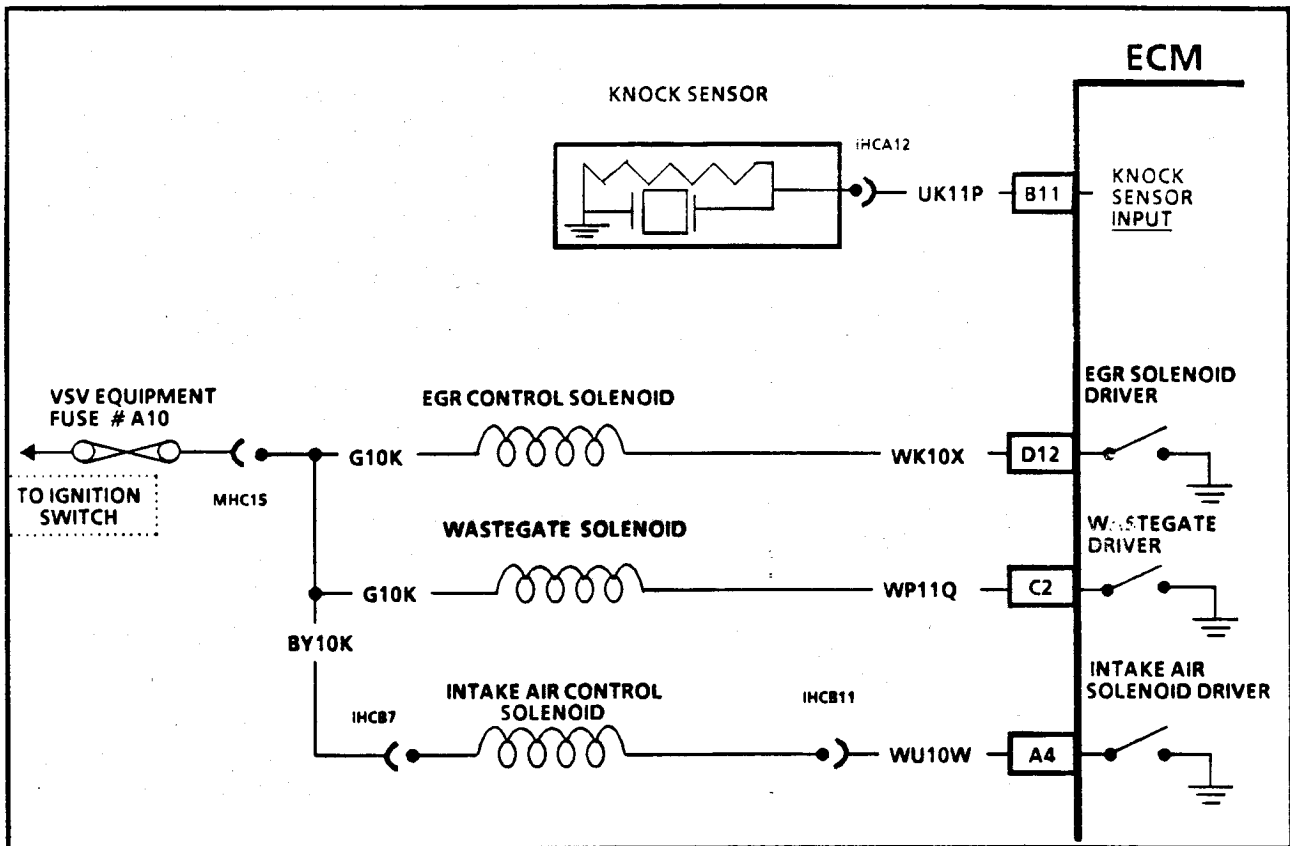


ELECTRONIC SPARK CONTROL (ESC) & BOOST CONTROL

The solenoid valve functions as a frequency valve, which is pulsed many times a second by a square wave signal of constant frequency but varying pulse width (Pulse Width Modulation). The proportion of time for which the valve is energised controls the amount of 'extra' boost that may be developed before the wastegate opens. At engine speeds below 2,900 rpm, the control pressure line is intact, with boost limited by the capsule to 0.41 bar (6.0 lb/in²).

At engine speeds above 2,900 rpm with throttle openings greater than 25%, the solenoid valve pulse width is modulated to allow boost pressure to rise in proportion to throttle opening, up to a maximum of 0.65 bar at full throttle.

In all cases the ECM will reduce pulse width to lower boost pressure if the knock sensor detects detonation. Under wide open throttle transient conditions, a short duration of overboost may occur. As an engine safeguard, in case of a boost control system failure, the ECM will switch off the fuel pump if boost pressure in excess of 0.92 bar is detected for more than 0.5 second. All quoted pressures are approximate and at sea level.



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2.3.4 ELECTRONIC CONTROL MODULE (ECM)

The ECM is located at the same place as the one on the N/A.

It allows more parameters to be sensed and operated, so the units are not interchangeable.

The controller contains all basic control circuits.

The Mem-Cal comprises:

- EPROM (erasable programmable read only memory) contains the programme and data
- Cal-Pak (Calibration Package) contains the back up fuel calibration
- ESC module performs knock control

1.6L TURBO O/L PARAMETERS SENSED VS. PARAMETERS CONTROLLED

PARAMETERS SENSED	PARAMETERS CONTROLLED							
	FUEL	IDLE SPEED	SPARK TIMING	EGR CONTROL	BOOST CONTROL	SECONDARY THROTTLES	AIR CONDITION	CHECK ENGINE LIGHT
ENGINE SPEED	X	X	X	X	X	X		X
VEHICLE SPEED	X	X	X	X			X	X
COOLANT TEMP.	X	X	X	X	X	X	X	X
MASS AIR TEMP.			X	X				X
MANIFOLD PRESSURE	X	X	X	X	X	X		X
BAROMETRIC PRESS.	X	X			X			
THROTTLE POSITION	X	X	X	X	X		X	X
BATTERY VOLTAGE	X	X			X			
POWER STEERING SWITCH INPUT		X					X	
CO-POTENTIOMETER	X							X
ENGINE DETONATION			X					X
A/C REQUEST		X					X	
CAMSHAFT POSITION	X		X					X
TIME	X	X	X	X	X		X	

3.0 MODES OF OPERATION

3.1 FUEL CONTROL MODES

STARTING MODE

CLEAR FLOOD MODE

RUN MODE

- TRANSIENT FUEL MODES

- ACCELERATION MODE

- DECEL FUEL CUTOFF MODE

- DECELERATION MODE

FUEL CUT-OFF MODE

LOTUS TRAINING

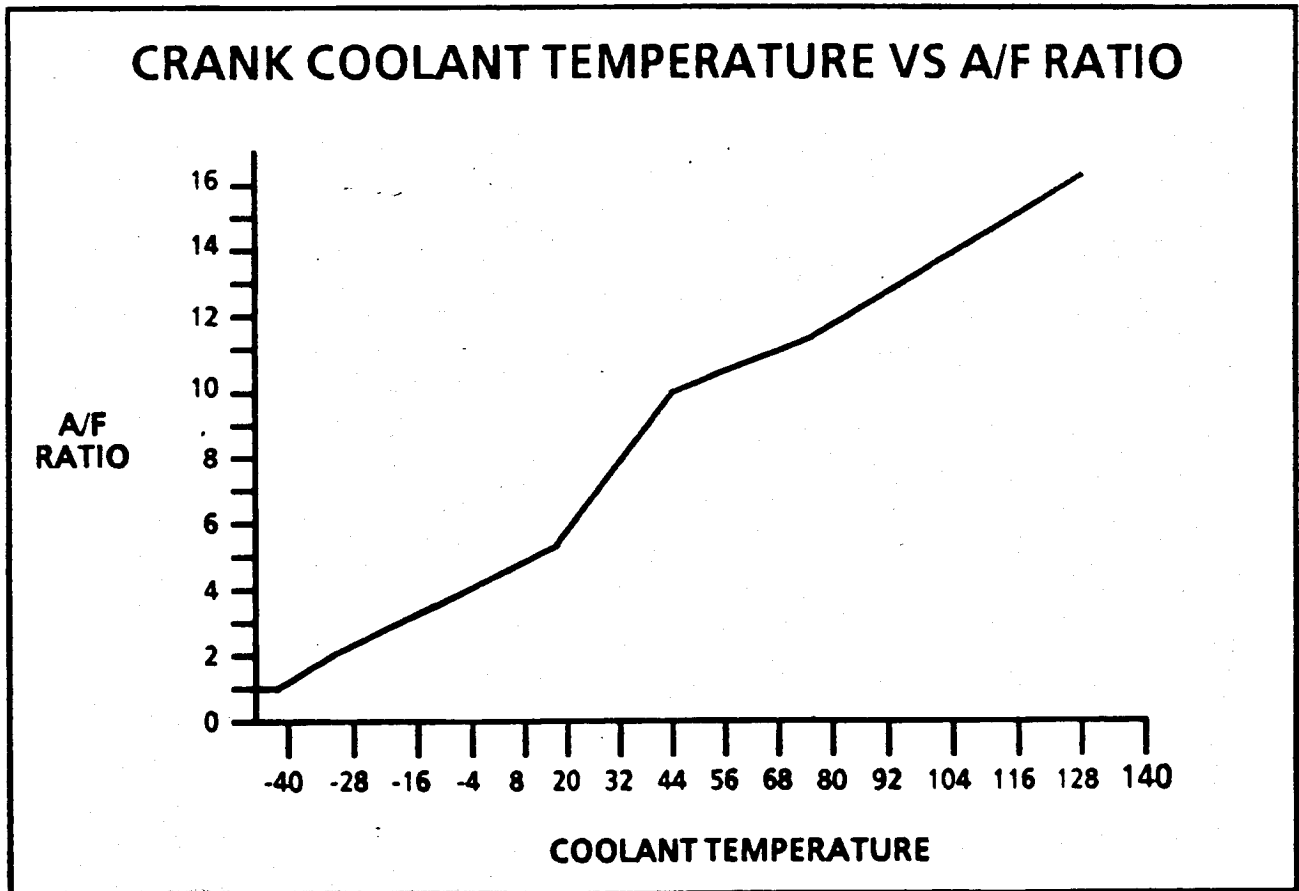
3.1 FUEL CONTROL MODES

The ECM uses voltage inputs from the sensor to determine how much fuel to deliver to the engine. The fuel may be delivered in any one of several different "modes" with the ECM controlling which mode is appropriate according to the readings it receives from the sensors at that particular time.

3.1.1 STARTING MODE

When the ignition is first turned on, the ECM turns on the fuel pump relay for two seconds to pressurize the system ready for starting. The ECM also checks the coolant temperature sensor and throttle position sensor readings and determines the appropriate air/fuel ratio for starting. This ranges from approximately 0.8 : 1 at minus 40°C to 16.8 : 1 at 104°C engine coolant temperature.

The ECM controls the quantity of fuel delivered by changing the injector pulse width i.e. length of time the injector is energised and opened.



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3.1.2 CLEAR FLOOD MODE

Provision is made for clearing a flooded engine as follows:

If the throttle is held fully open and the engine cranked, the ECM will decrease injector on time for as long as engine speed is below approx. 600 rpm. If throttle opening becomes less than approx. 70% the ECM returns to the starting mode.

3.1.3 RUN MODE

Above rpm the ECM switches to RUN MODE.

The amount of fuel supplied depends:

- engine speed
- manifold air pressure
- atmospheric pressure (baro)
- throttle position
- coolant temperature

LOTUS TRAINING

3.1.4 TRANSIT FUEL MODES

3.1.4.1 DECELERATION FUEL CUTOFF

The purpose of the decel fuel cutoff function is to remove fuel from the engine during deep deceleration conditions.

3.1.4.2 DECELERATION ENLEANMENT

During light deceleration injector pulse width is decreased depending on change of throttle position, change of MAP and engine speed.

3.1.4.3 ACCELERATION ENRICHMENT

During acceleration the mixture becomes richer based on engine speed, coolant temperature, TPS and MAP and difference in TPS and MAP readings in a given time.

3.1.5 FUEL CUTOFF MODES

There will be no fuel supplied when

- ignition is turned off
- RPM is greater than ...

LOTUS TRAINING

3.2 ELECTRONIC SPARK TIMING

3.2.1 ELECTRONIC SPARK TIMING MODES

BYPASS MODE

The bypass mode allows the ignition module in the N/A distributor or of the TURBO DIS to operate independently of the ECM. When the ECM is incapable of providing the spark timing information such as at low speeds like cranking, low system voltage, and with certain ECM or system malfunctions, the ignition module has control.

Figure 1 shows a simplified circuit diagram of the ignition module in the "engine crank" state on the N/A.

The sine wave signal generated by the inductive sensor (1) is converted into rectangular pulses (REF signals) in the signal converter (2). These rectangular pulses control the final controlling transistor (3) which switches the primary circuit to the ignition coil.

When the ignition is "ON", the ECM switches the bypass lead Ter.D5 to approx. ground potential ($<0.3V$). The "EST" lead from Ter.D4 is switched to ground in the ignition module. The transistors, which are shown here simply as relays (4), are thus activated (switches 5 and 6).

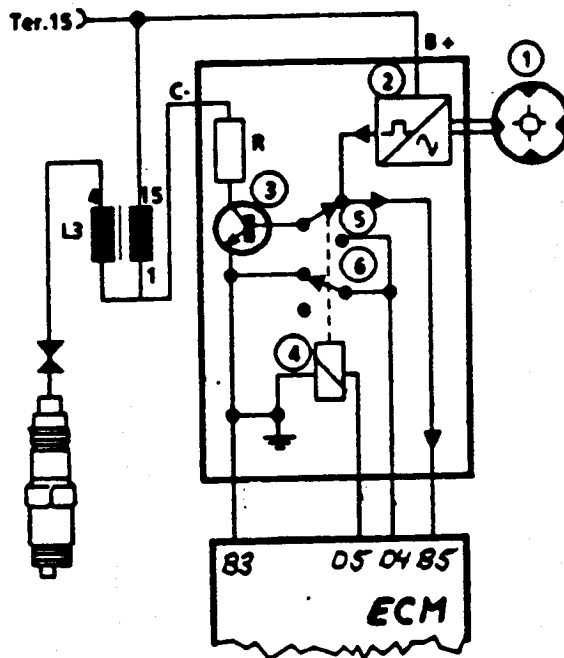


Fig. 1

ELECTRONIC SPARK TIMING MODES

EST MODE

The EST mode of operation occurs after system voltage is up, engine speed is above 800 rpm and the ECM is computing. At this time the bypass voltage is raised to approximately five volts, and an EST signal is fed into the module.

Figure 2 shows a simplified circuit diagram of the N/A ignition module in the "engine running" mode.

The REF signals on Ter.B5 enable the ECM to recognize an engine speed of >800 rpm. The ECM thus switches the bypass lead Ter.D5 to between 4V and 5V. Relay (4) is actuated (switches 5 and 6 are switched over). The ECM sends back a square wave signal on the EST line Ter.D4 which triggers the coil on the falling edge of the pulse.

Figure 3 on the following page explains the timing signal on the TURBO Direct Ignition System (DIS).

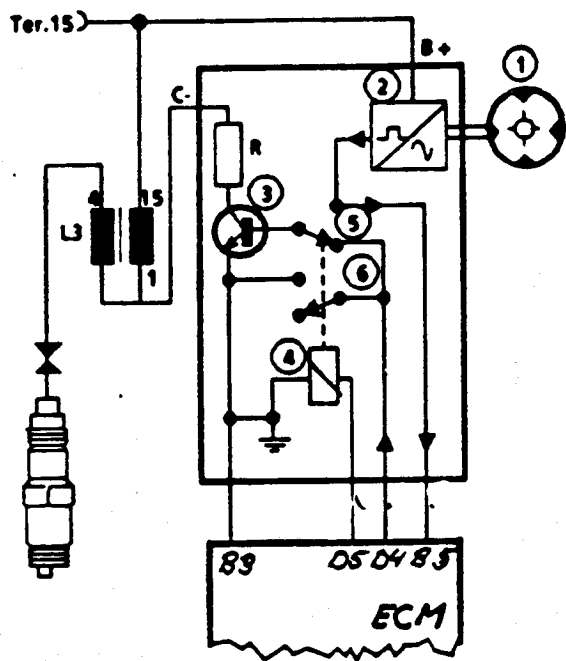


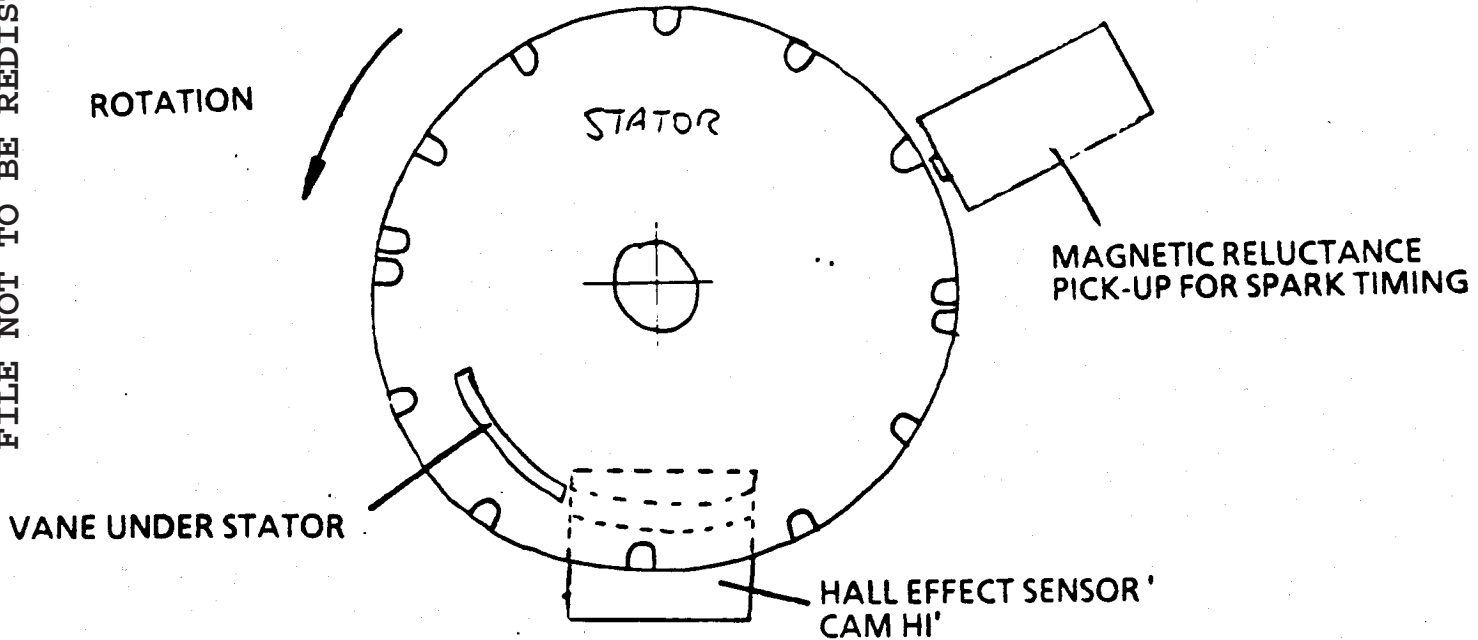
Fig. 2

LOTUS TRAINING

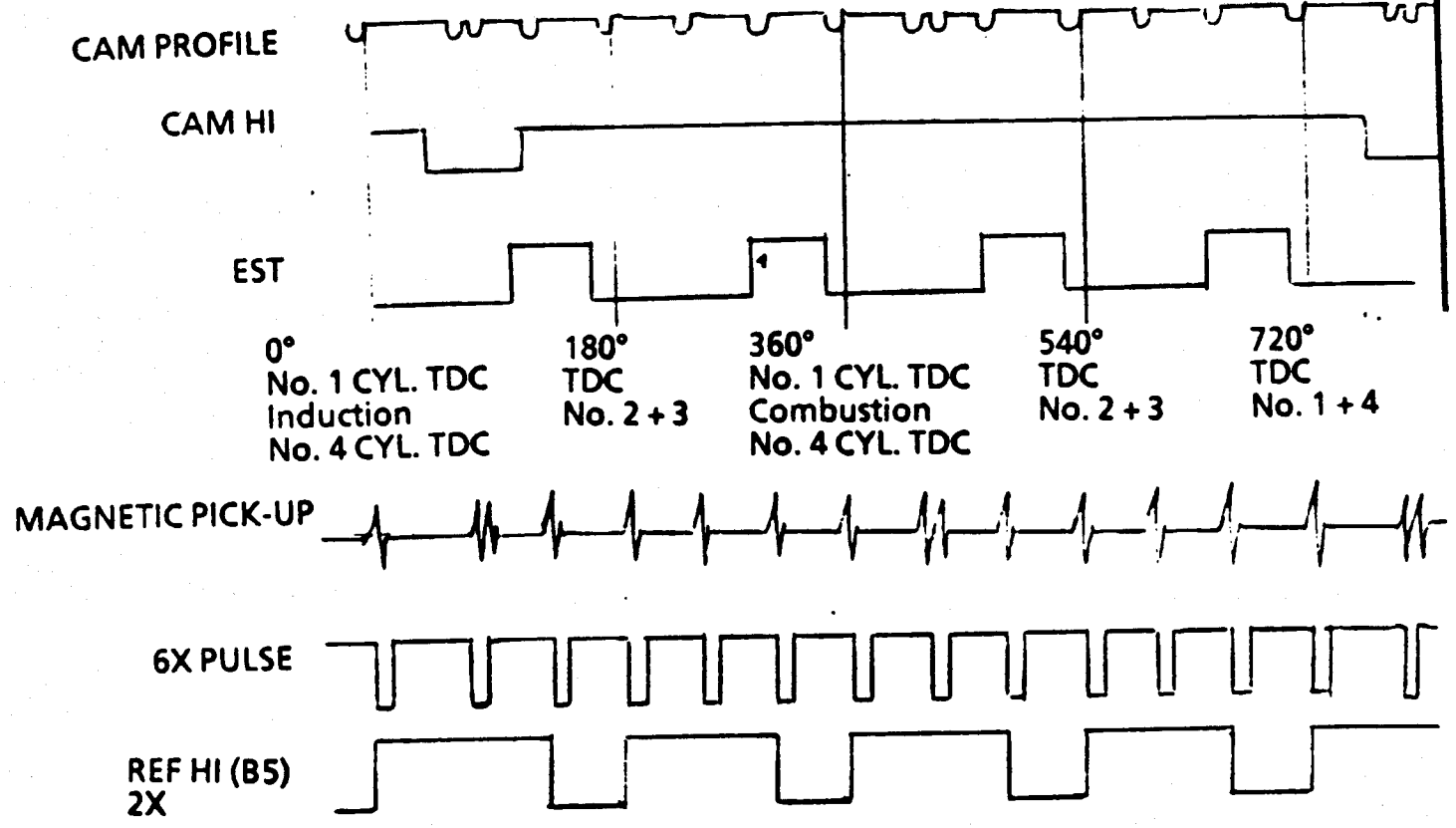
DIS IGNITION TIMING SIGNAL

FIGURE 3

CAM ANGLE SENSOR
VIEW WITH COVER REMOVED



TIMING SIGNALS



3.2.2 SPARK ADVANCE

ECM calculates spark timing by adding or subtracting values from various lookup tables. These tables are based on the following variables (sensor readings):

- RPM
- Manifold Absolute Pressure (MAP)
- Barometric Pressure
- Coolant Temperature
- Mass Air Temperature
- Throttle Position
- Knock Detection (TURBO only)

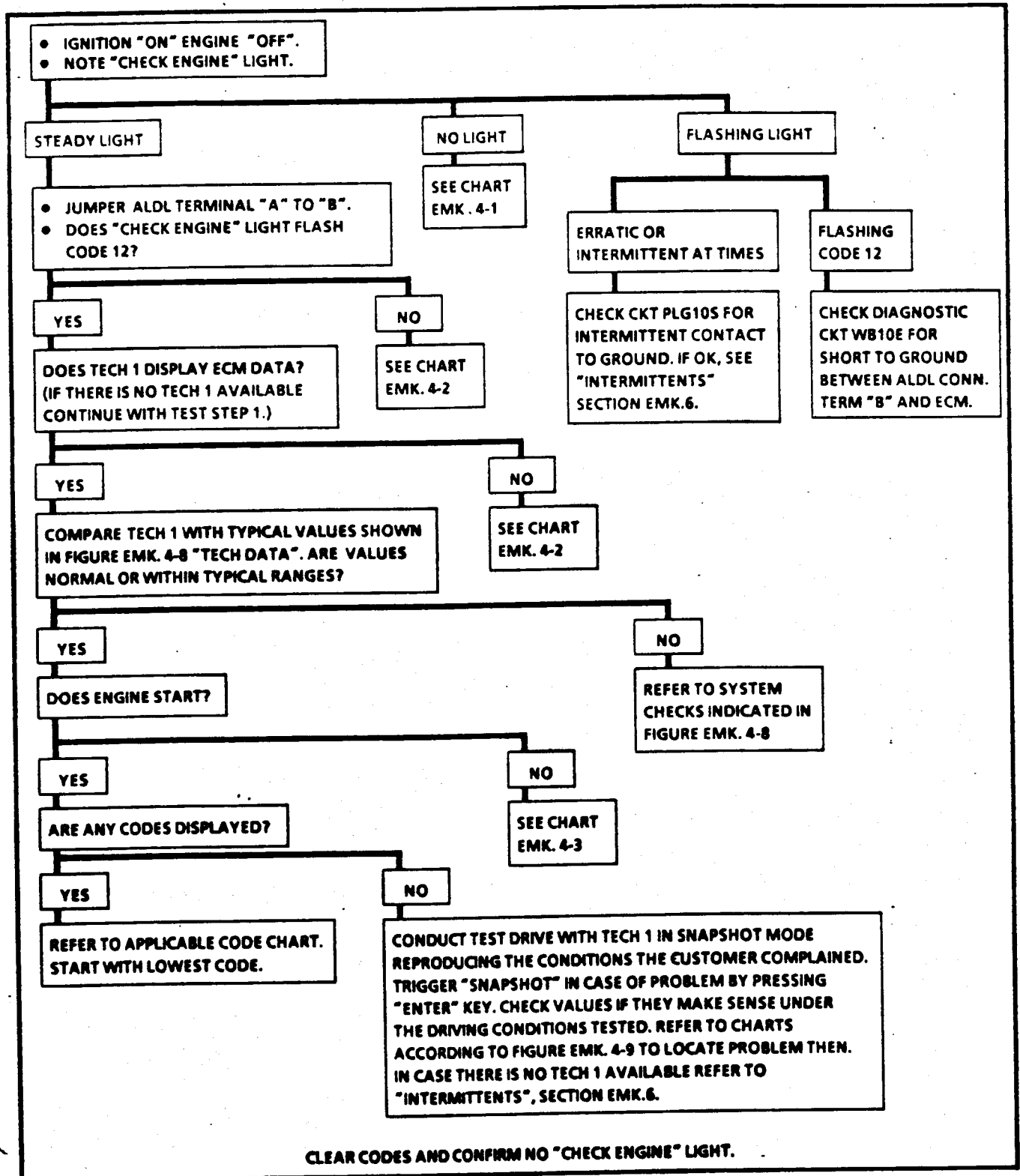
3.3 DEFAULT & DIAGNOSTIC MODES

- The system has SELFDIAGNOSTIC capability. In case of a problem it alerts the driver via the "Check Engine Light".
- In case of a problem the ECM automatically refers to pre-programmed "DEFAULT" values.
- The problem will be stored in ECM memory as a "TROUBLE CODE".
- A technician can read the code when the ECM "DIAGNOSTIC MODE" is requested or when a hand held "Tech 1" scanner tool is connected.
- The ECM also transmits sensor readings and other system parameters to the Tech 1 when "DATA MODE" is requested; this will aid rapid fault diagnosis.
- With the Tech 1 the ECM can be commanded to turn "ON/OFF" relays or solenoids in various "OUTPUT" checking modes.

4.0 DIAGNOSTICS

4.1 DIAGNOSTIC CIRCUIT CHECK

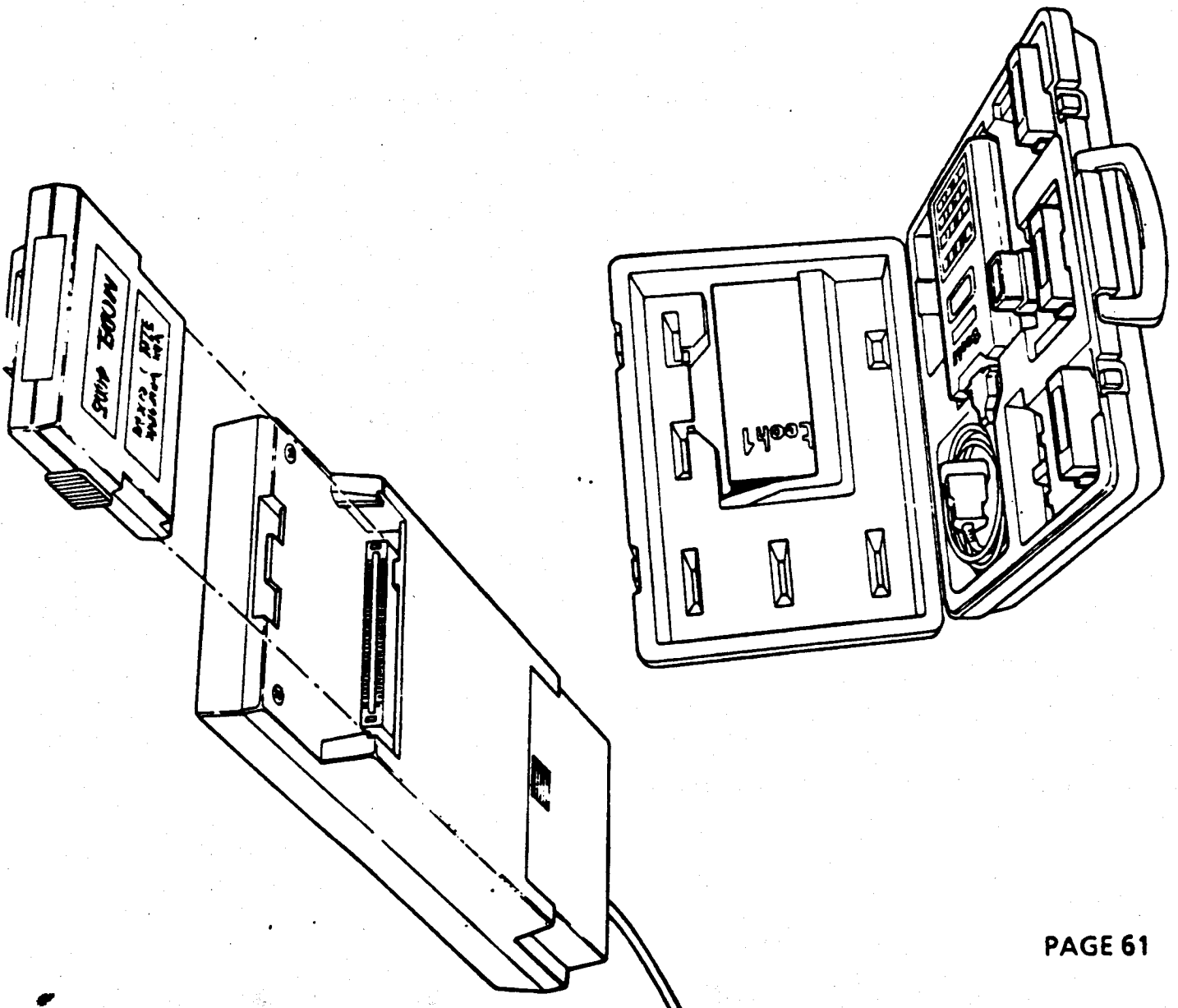
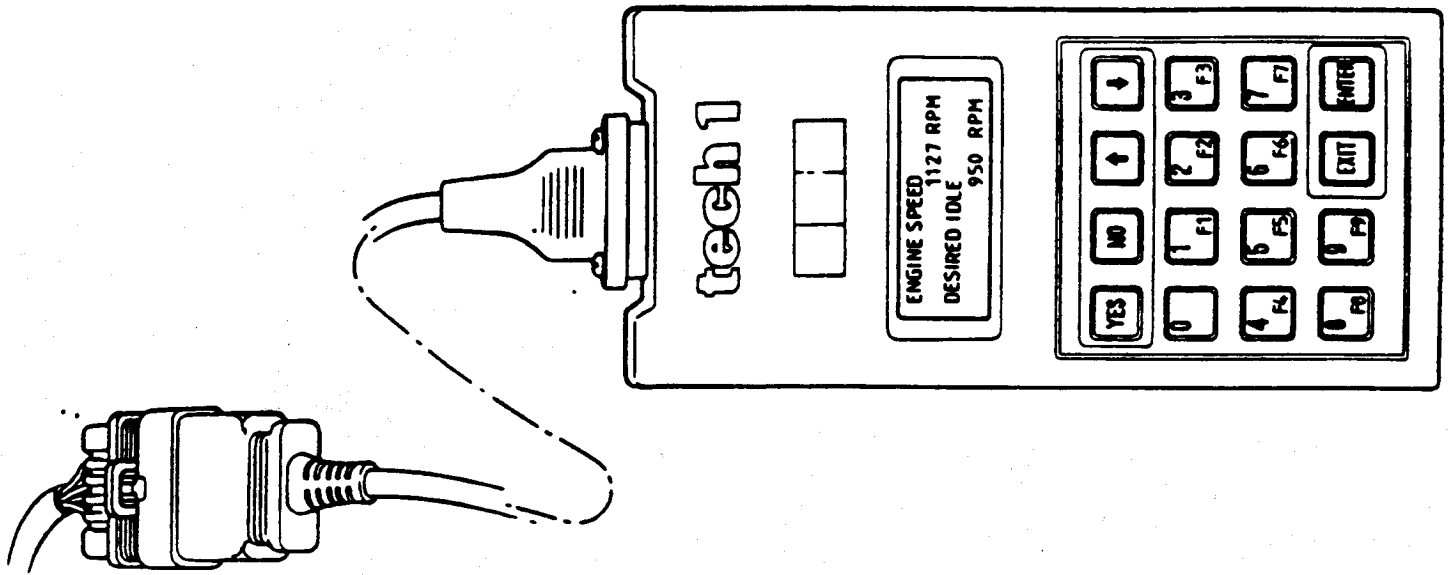
ALWAYS START HERE



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LOTUS TRAINING

4.2 TECH 1 TOOL



LOTUS TRAINING

4.3 TECH 1 DATA

"ENGINE OFF / IGNITION ON, ENGINE COLD"

<u>TECH 1 Position</u>	<u>Units Displayed</u>	<u>Typical Data Value (Range)</u>	<u>If Data Out Of Range, Refer To ...</u>
Engine Speed	RPM	0	-
Desired Idle	RPM	depends on coolant	-
Coolant Temp.	C/F	close to ambient	Code 14 / 15 Charts
Mass Air Temp.	C/F	ambient	Code 23 / 25 Charts
MAP	kPa/V	close to baro	Code 33 / 34 Charts
BARO	kPa/V	dep. on altitude and baro	Code 33 / 34 Charts
Idle Air Control	0-255	80	-
Engine Speed	RPM	0	-
Throt. Position	V	0.40-0.70 (closed)	Code 21 / 22 Chart
Throttle Angle	0 to 100%	0 closed, >95 at WOT	Code 21 / 22 Chart
Oxygen Sensor	mV	Not used	-
Inj. Pulse Width	ms	depends on coolant	-
Spark Advance	Degrees	0	-
MPH KPH	Units per hour	0 0	-
Fuel Integrator	Counts	Not used	-
Block Learn	Counts	Not used	-
Open/Closed Loop	Open/Closed Loop	Open Loop	-
Block Learn Cell	No.	Not used	-
Knock Retard	Degrees	0 Deg.	-
Knock Signal	Degrees	No	-
Battery Voltage	Volts	11.0 - 12.5	Check Battery Voltage
Purge Duty Cycle	Active / Inactive	Not used	-
A/C Request	Yes/No	No	Check A/C Select Switch
A/C Control	On/Off	Off	-
Sync Pulses	0-255	0	-
Park / Neutral	P- N / - R DL	- R - DL	-
Power Steering	High Press./Normal	Normal	Check Power Steering Switch
2nd Throttle Sol	Active / Inactive	Inactive	Check 2nd Throttle Sol
Air Control Sol	Active/Inactive	Not used	-
Exhaust Recirc.	Active/Inactive	Inactive	Check Exhaust Recirc.
CO Adj. Volts	Volts	0.6 - 4.2	Code 54 Chart
Wastegate D.C.	% Duty Cycle	0%	Check Wastegate Solenoid
PROM ID	#		PROM Specification
Time from Start	min:sec	0:00	-

Figure EMK.4-8 - 1.6L TURBO LOTUS ELAN TECH 1 DATA

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4.4 TROUBLE CODES

THIS TABLE IS A SUMMARY OF POSSIBLE TROUBLE CODES ON THE 1.6L N/A AND TURBO THE "CHECK ENGINE LIGHT" IS SWITCHED "ON" AND A CODE STORED WHEN THE ECM DETECTS ANY OF THE PROBLEMS LISTED BELOW. FOR MORE INFORMATION AND DIAGNOSTIC PROCEDURES REFER TO THE DIAGNOSTIC CHARTS SECTION EMK.4, EMK.5 (TURBO), EML.4, EML.5 (N/A).

CODE	COMPONENT / CIRCUIT	INDICATION	COMMENT
14	Coolant Temp Sensor	High temperature indicated	
15	Coolant Temp Sensor	Low temperature indicated	
21	Throttle Position Sensor	Signal voltage to ECM high	
22	Throttle Position Sensor	Signal voltage to ECM low	
23	Mass Air Temp. Sensor	Low temperature indicated	
24	Vehicle Speed Sensor	Incorrect signal to ECM	
25	Mass Air Temp. Sensor	High temperature indicated	
33	Manifold Absolute Pressure	Signal voltage high	
34	Manifold Absolute Pressure	Signal voltage low	
41	Engine Speed Signal Circuit	Engine speed signal missing	TURBO only
42	Electronic Spark Timing	Ignition module / circuit fault	TURBO only
43	Electronic Spark Control	Detonation circuit failure	TURBO only
51	MEM - CAL Error	ECM / MEM-CAL fault	
54	CO-Potentiometer Circuit	Signal Voltage high or low	

LOTUS TRAINING

4.5 TECH 1 DATA

"IDLE / ENGINE HOT / THROTTLE CLOSED"

Idle / Upper Radiator Hose Hot / Closed Throttle / A/C "OFF"

<u>TECH 1 Position</u>	<u>Units Displayed</u>	<u>Typical Data Value (Range)</u>	<u>If Data Out Of Range, Refer To ...</u>
Engine Speed	RPM	950	EMK.4-9 Chart
Desired Idle	RPM	950	-
Coolant Temp.	C/F	70 to 90	Code 14 / 15 Charts
Mass Air Temp.	C/F	20 to 60	Code 23 / 25 Charts
MAP	kPa/V	35 to 45	Code 33 / 34 Charts
BARO	kPa/V	dep. on altitude and baro	Code 33 / 34 Charts
Idle Air Control	0-255	10 to 30	EMK.4-9 CHART
Engine Speed	RPM	950	-
Throt. Position	V	0.40 - 0.70	Code 21 / 22 Charts
Throttle Angle	0 to 100%	0	-
Oxygen Sensor	mV	Not used	-
Inj. Pulse Width	ms	1.5 - 1.9	-
Spark Advance	Degrees	15 - 25	-
MPH KPH	Units per hour	0 0	Code 24 Chart
Fuel Integrator	Counts	Not used	-
Block Learn	Counts	Not used	-
Open/Closed Loop	Open/Closed Loop	Open Loop	-
Block Learn Cell	No.	Not used	-
Knock Retard	Degrees	0	Code 43 Chart
Knock Signal	Degrees	No	Code 43 Chart
Battery Voltage	Volts	13.0 - 15.0	Check Battery
Purge Duty Cycle	Active / Inactive	Not used	-
A/C Request	Yes/No	No	Check
A/C Control	On/Off	Off	-
Sync Pulses	0-255	0	Code 41 Chart
Park/Neutral	P- N / - R DL	- R - DL	-
Power Steering	High Press./Normal	Normal	EMK.3-H
2nd Throttle Sol	Active / Inactive	Active	EMK.3-L
Air Control Sol	Active/Inactive	Not used	-
Exhaust Recirc.	Active/Inactive	Inactive	EMK.3-T
CO Adj. Volts	Volts	0.6 - 4.2	Code 54 Chart
Wastegate D.C.	% Duty Cycle	0	EMK.3-R
PROM ID	#		
Time from Start	min:sec	depends on time	-

Figure EMK.4 - 9 - 1.6L TURBO LOTUS ELAN TECH 1 DATA