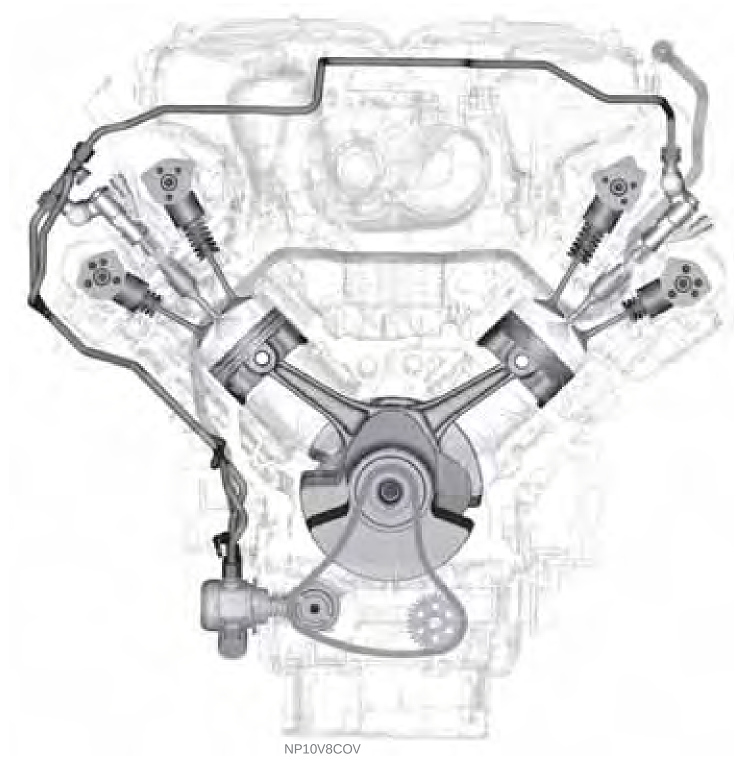
Technical Training

Technical Introduction

NP10-V8JLR: AJ133 5.0-Liter DFI V8 Engine



NP10V8COV

Engine Management System

NP10-V8JLR 04/2009
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OVERVIEW

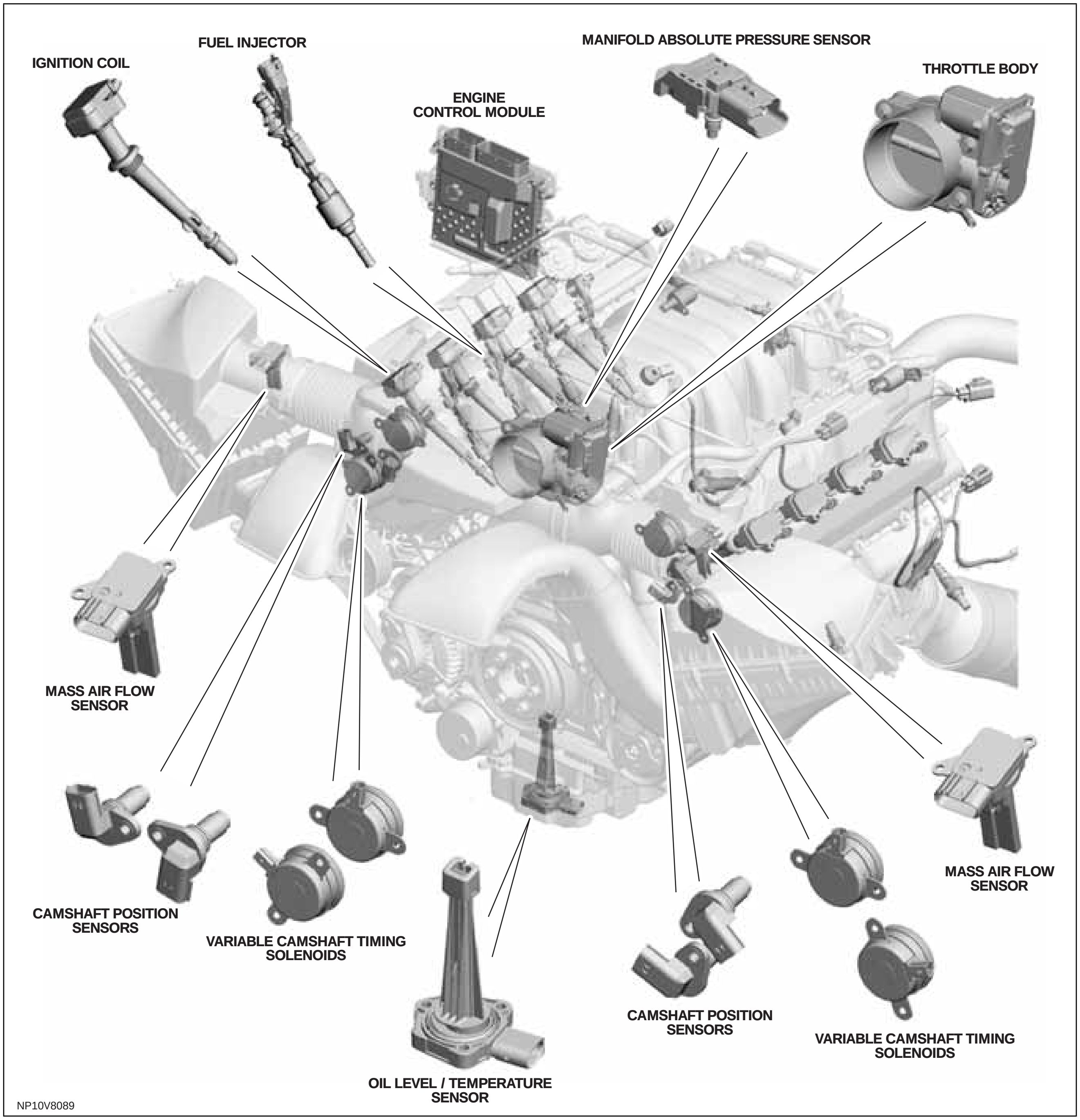
The 5.0-Liter V8 normally aspirated (NA) and supercharged (SC) engines are managed by the engine control module (ECM), which controls the following:

- Engine fuel metering
- Ignition timing
- Camshaft timing
- Camshaft Profile Switching (CPS)
- Closed loop fuel metering
- Knock control
- Idle speed control
- Emission control
- On-Board Diagnostics (OBD)
- Interface with the immobilization system
- Speed control

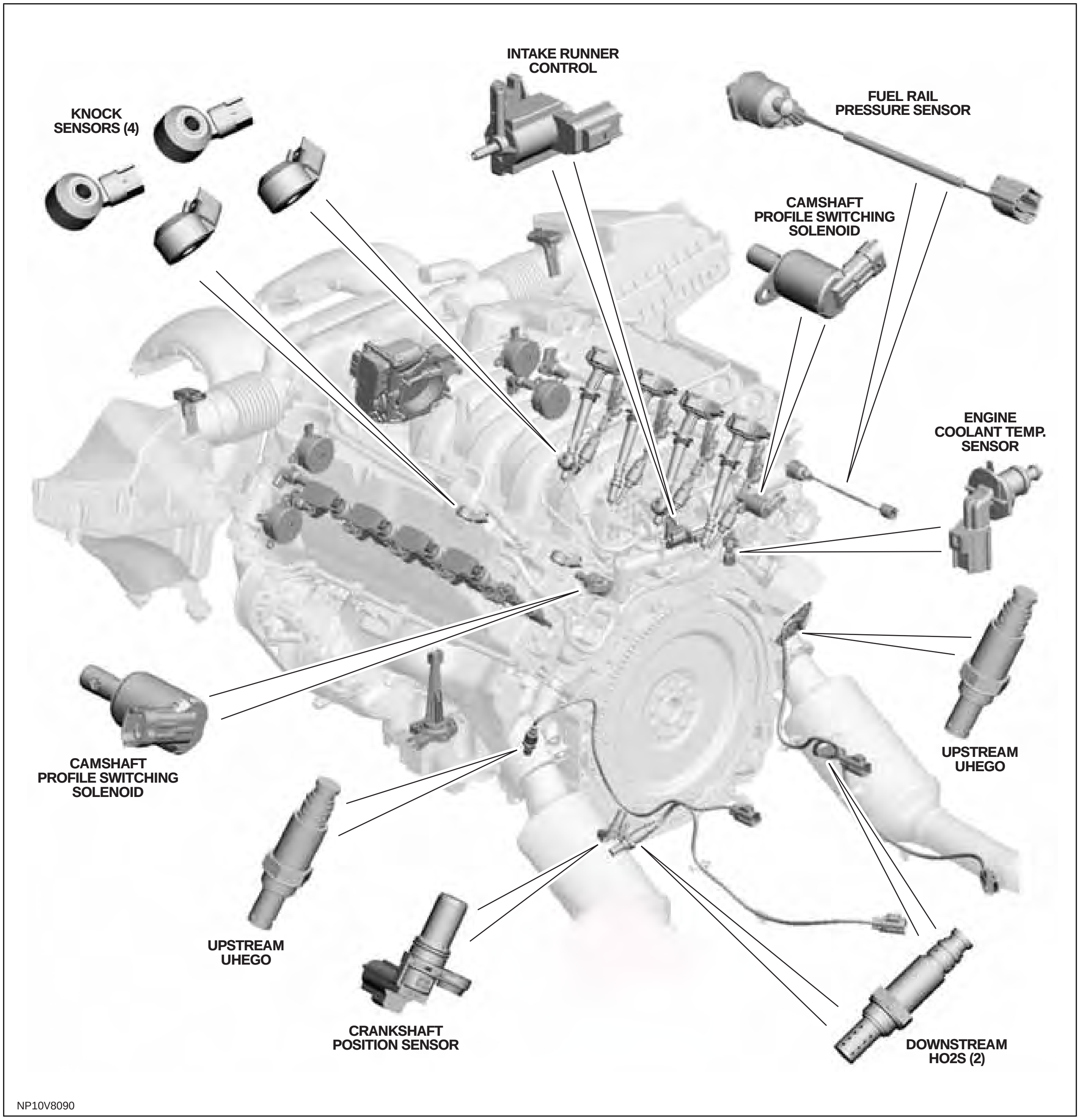
The ECM controls the engine fuel metering by providing sequential fuel injection to all cylinders. Ignition is controlled by a direct ignition system, provided by eight coil-on-plug (COP) units. The ECM is able to detect and correct for ignition knock on each cylinder and adjust the ignition timing for each cylinder to achieve optimum performance.

The ECM uses a torque-based strategy to generate the torque required by driver demand and the other vehicle control modules, using input from various sensors to calculate the required torque. The ECM also interfaces with other vehicle electronic control modules to obtain additional information (road speed from the ABS control module, for example). The ECM processes these signals and determines how much torque to generate, using various actuators to supply air, fuel, and spark to the engine (electronic throttle, injectors, coils, etc.).

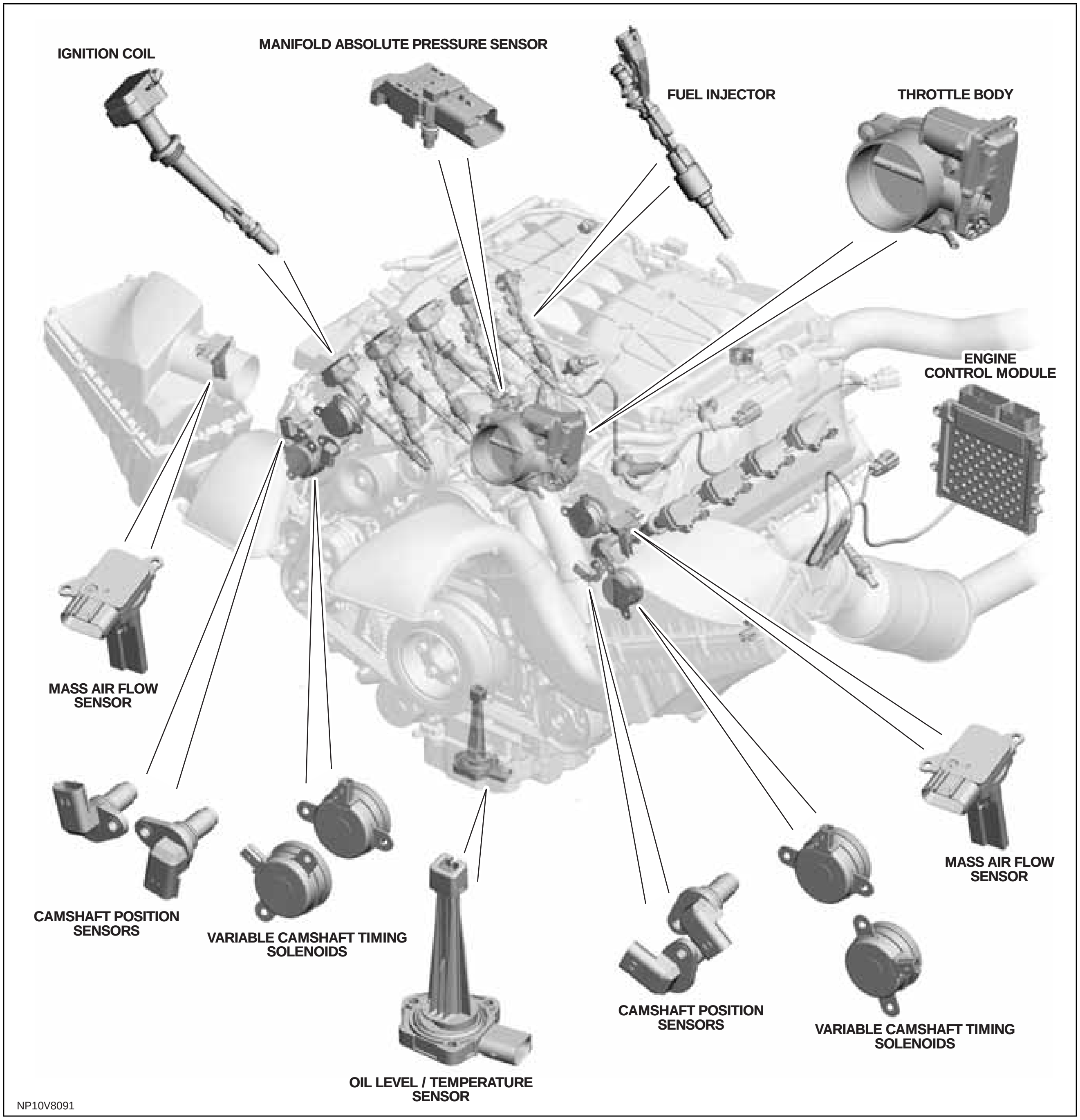
NA Component Location: Front of Engine



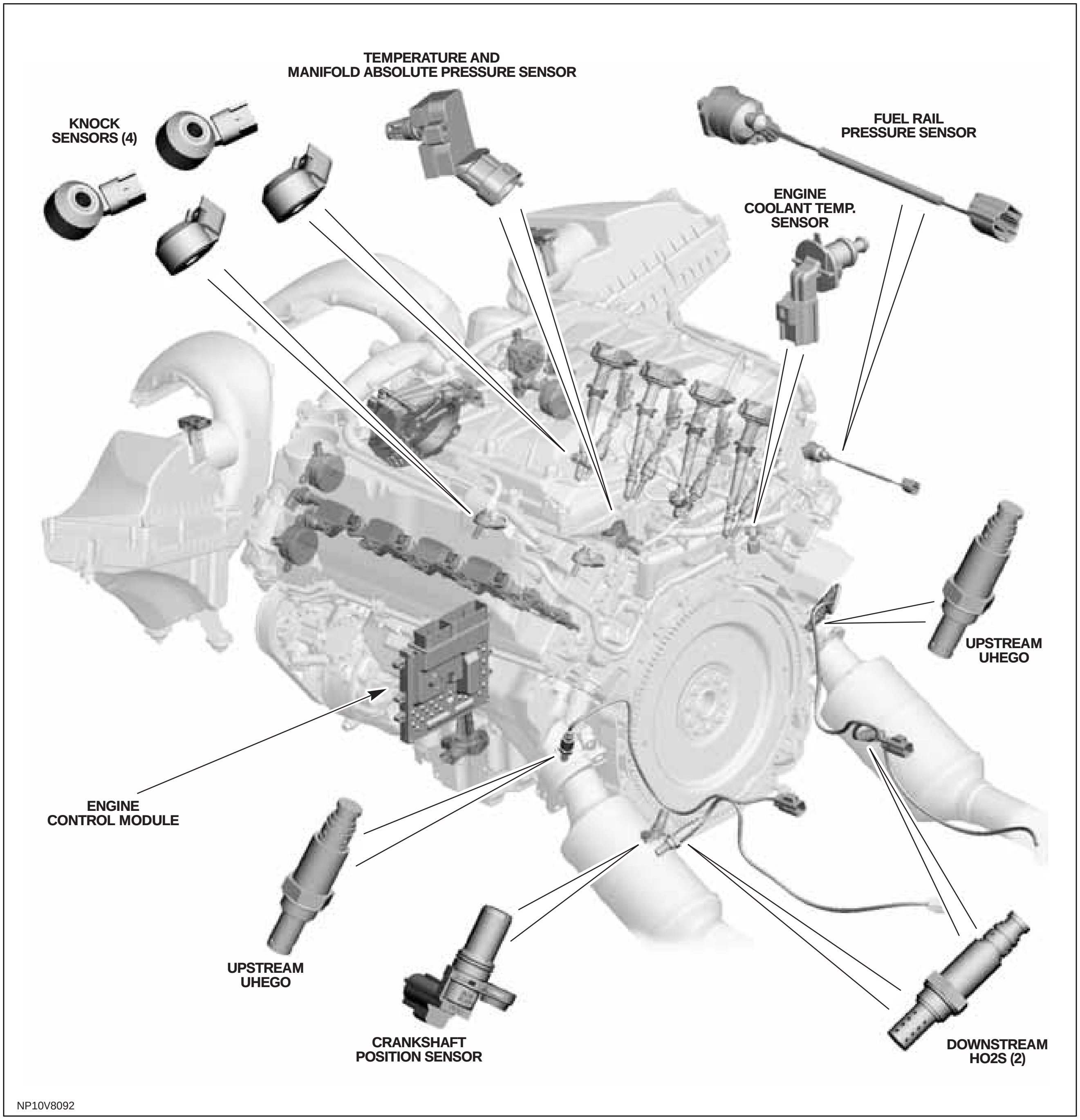
NA Component Location: Rear of Engine



SC Component Location: Front of Engine



SC Component Location: Rear of Engine



WARNINGS:

- **Direct injection injectors require high booster voltages (65V); special care must be taken to guarantee proper electrical isolation of the cable harness and all connectors. The ECM outputs for the injectors are protected in case of open and short circuit.**
- **Due to the high currents in the injectors, strong magnetic fields are created. An influence within a distance of up to 0.2m from the wiring harness or control unit is to be expected. Each vehicle type must therefore be checked to ensure that this distance is maintained. In particular, the interference-free function of pacemakers cannot be guaranteed.**

CAUTIONS:

- **DO NOT connect test probes connected to battery positive supply to any ground pins, as this will DESTROY the ECM.**
- **Use care when probing connectors for wiring checks. The gold plating used on low current signal connector terminals is easy to damage by inserting a probe.**
- **Do not use probes that pierce wiring insulation since they damage/sever wiring, leaving it vulnerable to corrosion.**

ENGINE CONTROL MODULE

The ECM is supplied with battery voltage from a 5A fuse and an ignition supply from the ECM relays through a 15A fuse, both located in the CJB. A regulator located within the ECM supplies a 5V current to internal components such as the microprocessor unit. Other components or functions requiring full battery voltage are controlled by external relays or internal switching modules.

The microprocessor within the ECM receives signals from different components and control modules and uses a program within the ECM software to interpret the signal information and issue signals which relate to how the engine components and functions should be controlled. The ECM communicates with other control modules via bidirectional Controller Area Network (CAN) communication interfaces.

The ECM uses the following inputs and outputs:

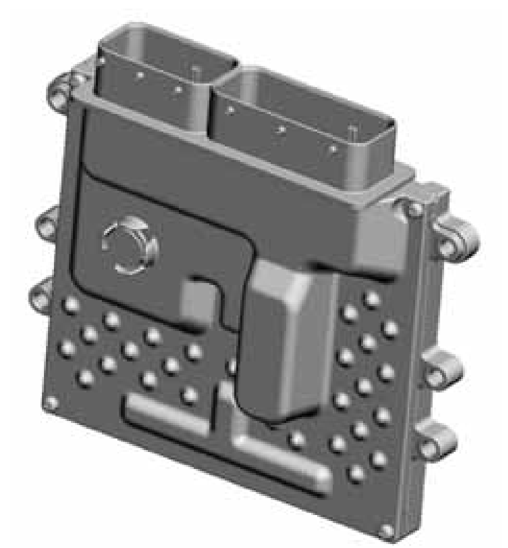
Inputs

- Camshaft position (CMP) sensor
- Crankshaft position (CKP) sensor
- Fuel rail high-pressure sensor
- Mass air flow (MAF) sensors (2)
- Knock sensors (4)
- Engine coolant temperature (ECT) sensor
- Manifold absolute pressure (MAP) sensor
- Electronic throttle position sensor
- Accelerator pedal position (APP) sensor
- Cooling fan speed
- Upstream Universal Heated Exhaust Gas Oxygen (UHEGO) sensors (2)
- Brake switch
- Speed control cancel/suspend switch
- Intake air temperature (IAT) sensor (integrated into the MAF) (2)
- Ambient air temperature (AAT) sensor
- Engine oil level and temperature sensor
- Temperature and manifold absolute pressure (TMAP) sensor (SC only)

Outputs

- Throttle Actuator
- Coil-on-plug (COP) ignition coils (8)
- Upstream Universal Heated Exhaust Gas Oxygen (UHEGO) sensors (2)
- Downstream Heated Oxygen Sensors (HO2S) (2)
- Direct injection fuel injectors (8)
- Variable camshaft timing (VCT) solenoids (4)
- Camshaft profile switching (CPS) solenoids (2)
- Intake manifold tuning solenoid
- Carbon canister purge valve
- Fuel pump relay
- Starter relay
- A/C condenser fan relay
- ECM main relay viscous fan control
- Generator control
- Air flap solenoid (SC only)
- Pump control diagnostics
- Diagnostic Monitoring of Tank Leakage (DMTL)

The aluminum ECM case has two large black electrical connectors with red lock-levers. The label indicates an engineering number with the format **** – 12B864 – **.


NP10V8093

The dimensions of the ECM are 155 x 170 x 40mm (6 x 6.7 x 1.6 in.).

Diagnostics

Diagnostic Trouble Codes (DTCs) are listed in the Diagnosis and Testing section of the GTR WSM. Codes are listed in numerical order and each entry has:

- A notes column to detail any care points relating to the failure
- An indication column. 2-trip MIL means that the failure must be detected on two subsequent drive cycles for the MIL to illuminate. Any other lamp indicator will be recorded in this column. There may also be a message displayed on the instrument cluster while the failure is being detected that is not detailed in this document.
- A description of any default action the module undertakes in response to the detection of the failure
- A list of possible causes of the failure
- Which pin (if any) on the control module is associated with the failure
- The DTC description
- Test conditions. Operating the vehicle as described in this column should result in the running of the monitor relating to the DTC.

NOTE: The operating conditions described have been specified to ensure successful monitor operation is possible in most cases; however, the monitor may operate outside of these conditions.

NOTE: Not all DTCs may be logged by all vehicle types.

RELAYS

Main Relay

The main Engine Management System (EMS) relay is not a main power input; it is used to initiate the power-up and power-down routines within the ECM.

This input comes from the engine junction box (EJB). When the ignition is turned on 12V is applied to the ignition sense input. The ECM then starts its power-up routines and turns on the ECM main relay, the main power to the ECM and its associated system components.

When the ignition is turned OFF, the ECM will maintain its powered-up state for several seconds (or up to 20 minutes in extreme cases when cooling fans are required) while it initiates its power-down routine and, on completion, will turn off the ECM main relay.

The main relay is located in the EJB. The operation of the main relay is controlled by the ECM, which provides a ground path for the main relay coil, energizing the relay and closing the relay contacts.

The main relay supplies battery voltage to the following engine sensors and actuators:

- Throttle position (TP) sensor (through ECM)
- Fuel injectors
- Ignition coils
- Coil capacitor
- CPS solenoids
- All heated oxygen sensors
- Evaporative emission (EVAP) canister purge valve
- Diagnostic Monitoring of Tank Leakage (DMTL)

Failure Modes

- Relay drive open circuit
- Short circuit to battery voltage or ground
- Component failure

Failure Symptoms

- Engine will not start

Starter Relay

The starter motor relay is located in the EJB. Operation of the starter motor relay is controlled by the ECM, which provides a ground path for the relay coil, energizing the relay and closing the relay contacts. When the relay contacts are closed, battery voltage is supplied, through the starter motor relay, to the starter module solenoid coil.

The starter solenoid is energized and connects the starter motor with a direct battery feed to operate the starter motor.

Once the engine has started, the ECM removes the starter motor relay ground, opening the relay contacts and terminating the battery feed to the starter solenoid, which in turn stops the operation of the starter motor.

NOTE: Diagnose using Jaguar Land Rover approved diagnostic equipment.

CRANKSHAFT POSITION SENSOR

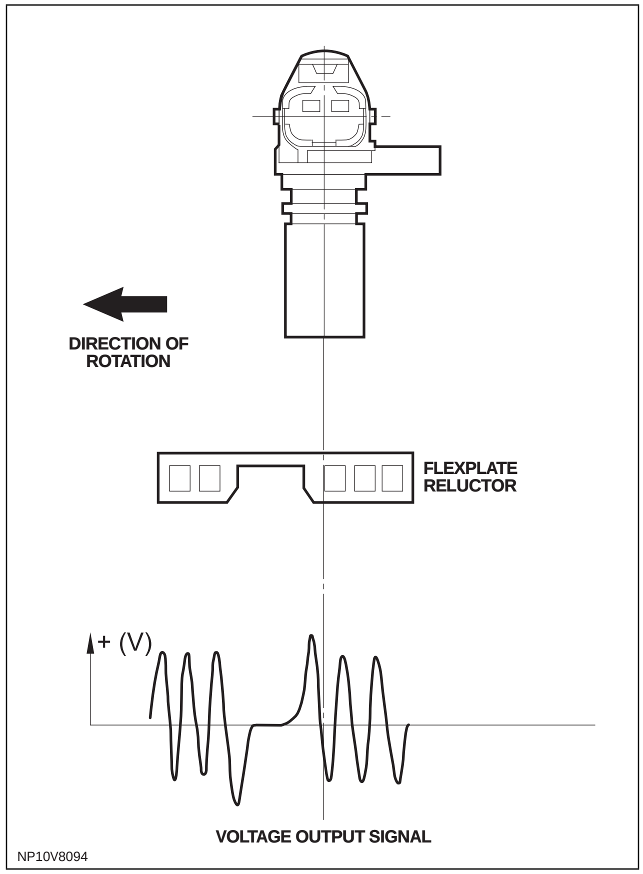
The crankshaft position (CKP) sensor is located on the forward side of the transmission torque converter housing, in line with the engine flexplate.

The sensor is secured with a single bolt into the flywheel housing. A reluctor ring is fitted to the outer diameter of the crankshaft flexplate; the sensor reacts to the gaps in the reluctor ring to determine engine speed and position information.

The CKP sensor is an inductive-type sensor which produces a sinusoidal output voltage signal. This voltage is induced by the proximity of the moving reluctor ring gaps, which excite the magnetic flux around the tip of the sensor when each gap passes.

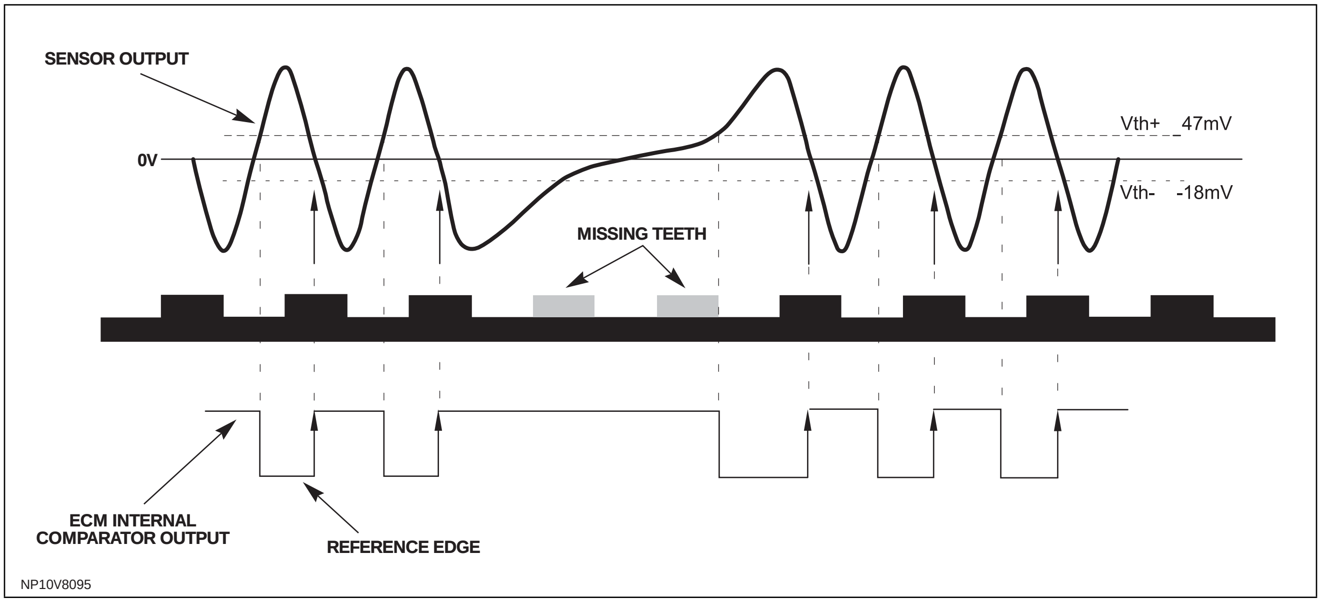
The output voltage increases in magnitude and frequency with the engine speed and, consequently, with the speed at which the reluctor ring gaps pass the sensor.

NOTE: The output is also dependent on the air gap between the sensor and the teeth (the larger the gap, the weaker the signal, the lower the output voltage).



The reluctor is manufactured to have a ‘tooth’ pattern based on 60 – 2 pattern, where there are 58 teeth in total at 6° intervals. The two teeth are removed to provide a hardware reference mark, with a centerline that is 21° BTDC on cylinder 1, RH bank.

The signal voltage can be as low as 0.1V at low engine speeds and up to 100V at high engine speeds. The ECM does not react to the output voltage (unless the voltage is extremely low or high); instead it measures the time intervals between each pulse (signal frequency).



Safety Precautions

⚠ **CAUTIONS:**

- **Before installing the CKP sensor, check that no ferrous material has been attracted to the device by its internal magnet.**
- **Ensure that the air gap is correct.**
- **Due to the location and orientation of the sensor, ensure that it is not damaged during engine installation or by any debris that may be picked up from the road.**

Failure Modes

- Sensor assembly loose
- Incorrect air gap – Nominal air gap 1.5mm (This is normally pre-set unless there is damage to the mounting)
- Short/open circuit
- Mounting and integrity of the sensor
- Water/coolant ingress within connector
- Inability of the ECM to detect the software reference point
- Ferrous contamination of CKP sensor pin/reluctor

Failure Symptoms

- Engine will start picking up a signal from the CMP sensors (long crank time)
- Default 3000rpm (limp home mode)

CAMSHAFT POSITION SENSOR

The camshaft position (CMP) sensors are magneto-resistive element (MRE) sensors, which have digital output with zero speed recognition. They show a high signal if the camshaft position target is directly in front of the sensor, and low if the camshaft position target is not in front of the sensor.

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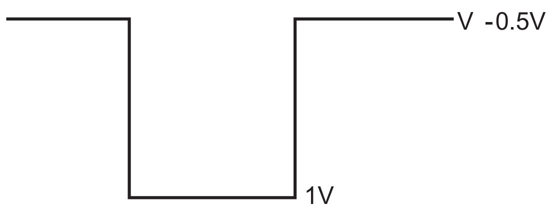
There are four common sensors, one per camshaft.



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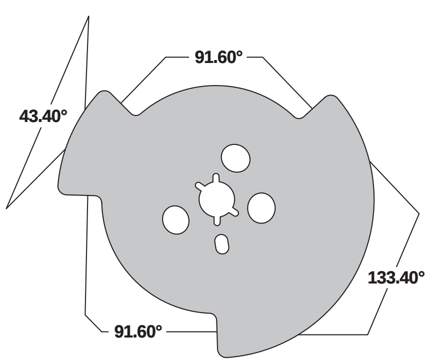

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Failure Modes

- Sensor open circuit
- Short circuit to vehicle battery supply or ground
- Mechanical fitting and integrity of the sensor
- Camshaft wheel tolerances/camshaft end float excessive
- Camshaft and crankshaft misalignment/valve timing error
- Camshaft wheel magnetized/residual magnetism
- Speed signal correlation with crankshaft sensor input
- Incorrect air gap between camshaft and sensor

NOTE: If both the CKP sensor and the CMP sensor fail, the engine will stall or not start.

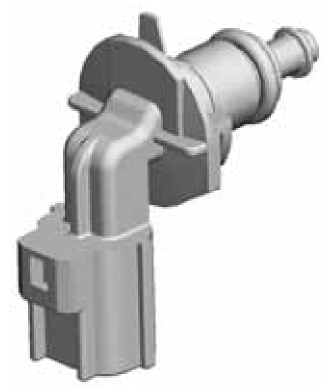
Failure Symptoms

- Ignition timing reverting to the base mapping, with no cylinder correction
- VCT is disabled

Specification	Function
Pin 1	Supply
Pin 2	Ground
Pin 3	Signal
Operating voltage	4.5 to 7 V
Maximum supply current	22 mA

ENGINE COOLANT TEMPERATURE SENSOR

The engine coolant temperature (ECT) sensor is a negative temperature coefficient (NTC) thermistor, used to monitor engine coolant temperature.



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The ECT sensor is vital to the correct running of the engine, as a richer mixture is required at lower block temperatures for good quality starts and smooth running, leaning off as the temperature rises to maintain emissions and performance.

The sensor has a twist-lock design with a latch mechanism, and is located at the rear of the engine in the water crossover pipe, between the two heads.

Failure Modes

- Uses engine-off time and MAF for calculation

Failure Symptoms

- Poor cold and hot start
- Poor driveability
- Cooling fans on permanently

Specification	Function
Supply voltage	5V ± 0.1V
Operating temperature range	-30°C to 125°C (-22°F – 257°F)
Pin 1	Sensor output signal
Pin 2	Sensor ground

Sensor Resistance vs. Coolant Temperature

Coolant Temperature	Approx. Resistance
-20°C (-4°F)	15.04 +0.90/-0.83 kOhms
20°C (68°F)	2.45 +0.10/-0.09 kOhms
80°C (176°F)	0.318 ±0.007 k Ohms
110°C (230°F)	0.1471 ±0.0018 k Ohms

NOTE: If the ECT sensor fails, the ECM uses a default value. The electric fan control module is sent a default coolant temperature value and switches the cooling fan(s) on permanently.

The voltages shown represent the signal processed by the ECM. When a defective coolant sensor is detected, the coolant value defaults to 40°C (104°F) and remains fixed until the ECM is powered down.

KNOCK SENSORS

The ECM uses active knock control, which serves to prevent engine damaging pre-ignition or detonation under all operating conditions, enabling the engine to operate without additional safety margins.

The ECM uses 4 piezo-ceramic knock sensors to determine the point at which a cylinder is pre-detonating. Two sensors are mounted on the intake side of each cylinder head.

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Each sensor monitors engine knock by converting the engine block noise into a suitable electrical signal, which is then transmitted back to the ECM via a twisted-pair cable. The signal is processed within the ECM to identify the data that characterizes knocking.

This information is compared to known signal profiles to determine whether pre-ignition is present. If so, the closed loop control system retards the ignition on that cylinder for a number of cycles, after which it gradually moves back towards its original setting.

Safety Precautions

⚠ **CAUTION: Terminals in sensor and connector are gold plated for corrosion/temperature resistance. Do not probe connections.**

NOTE: Accurate orientation of the knock sensors on the cylinder block is required to ensure correct connection to the vehicle wiring harness.

Failure Modes

- Sensor open circuit
- Short circuit to vehicle ground or battery voltage
- Faulty component or incorrectly torqued / coming loose
- Noise on vehicle 12V supply could look like knock signal causing knock fault
- Min fault usually due to open circuit
- Max fault short circuit to battery voltage or extreme mechanical engine noise/piston slap
- ECM calculates the default value if one sensor fails on each bank of cylinders

Failure Symptoms

- Knock control is disabled and a default ‘safe ignition map’ is used
- Possible rough running and reduced engine performance

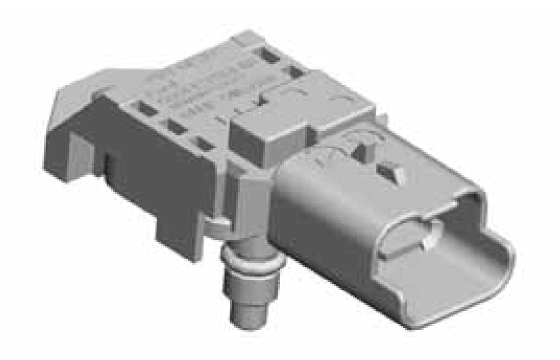
Failure Mode Behaviors

- The vehicle control system constantly checks open circuit of knock sensor. Therefore, the knock sensor is connected to the power source via pull-up line of the ECM.
- When short/open circuit occurs to the knock sensor signal circuit, the system detects it, sets failure flag, and commences maximum retard control on spark advance.
- As far as the behavior of knock sensor is concerned, however, the above-mentioned failure modes cannot cause serious outcomes such as heat generation, smoke emission and/or fire hazard.

Specification	Function
Power Source	N/A
Wiring Type	Twisted Pair
Shunt Resistance	4.8M Ohms
Operating Range	3kHz – 22kHz
Mounting Torque	20Nm +/- 3.8Nm

MANIFOLD ABSOLUTE PRESSURE SENSOR

The manifold absolute pressure (MAP) sensor provides a voltage proportional to the absolute pressure in the intake manifold. This signal allows the load on the engine to be calculated and used within the internal calculations of the ECM.



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The MAP sensor is mounted on the top of the engine, at the front behind the throttle body. The purpose of the sensor is to measure the absolute pressure in the intake manifold and provide information to the ECM, which will determine the injection time.

The sensor is a semi-conductor type, which responds to pressure acting on a membrane within the sensor, altering the output voltage.

The sensor receives a 5V reference voltage and a ground from the ECM and returns a signal of between 0.5 – 4.5V to the ECM. A low pressure returns a low voltage signal to the ECM and a high pressure returns a high voltage.

The MAP sensor detects quick pressure changes in the intake manifold after the electronic throttle. The signal is used in conjunction with the MAF sensor signal to calculate the injection period. The ECM monitors the engine MAP sensor for faults and can store fault related codes.

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- Intake air restricted
- Default value of 1 bar (14.5 psi)

Failure Symptoms

- Rough running
- Difficult starting
- Poor driveability

Specification	Function
Power Source	5V ±0.25V
Pin 1	Power
Pin 2	Ground
Pin 3	Output Signal
Operating Range	13.3 kPa – 250 kPa

MASS AIR FLOW SENSOR

Mass air flow is determined by the cooling effect of intake air passing over a 'hot film' element contained within the device. The higher the air flow the greater the cooling effect and the lower the electrical resistance of the 'hot film' element. The ECM then uses this analog signal from the mass air flow (MAF) sensor to calculate the air mass flowing into the engine.

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The measured air mass flow is used in determining the fuel quantity to be injected in order to maintain the stoichiometric air/fuel mixture required for correct operation of the engine and exhaust catalysts. Should the device fail, there is a software backup strategy that will be activated once a fault has been logged.

The intake air temperature (IAT) sensor is integrated into the MAF sensor. The IAT sensor is an NTC thermistor, meaning that the sensor resistance decreases as the sensor temperature increases.

The sensor forms part of a voltage divider chain with an additional resistor in the ECM. The voltage from this device changes as the sensor resistance changes, thus relating the air temperature to the voltage measured by the ECM.

Because the engine requires a twin air intake induction system, there are two MAF sensors per vehicle.

Safety Precautions

⚠ **CAUTIONS:**

- **Component should not be dropped or handled roughly.**
- **Ensure that no contamination enters the device.**
- **Some terminals in MAF and connector are gold-plated for corrosion resistance – DO NOT probe.**

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- Contaminated/damaged sensor element
- Air leak after MAF sensor
- Intake air restricted
- Resistance in the harness, causing signal offset
- Damaged sensor element

Failure Symptoms

- During driving the engine rpm might dip (before recovering)
- Difficulty in starting or start/stall
- Poor throttle response/engine performance
- Emissions incorrect
- Lambda control and idle speed control halted
- MAF signal offset

Specification	Function
Supply Voltage	8 – 14V (rated supply voltage: 14V)
Pin A	Output (Vg)
Pin B	Ground for Output (Vg)
Pin C	Power Source
Pin D	IAT Sensor Ground
Pin E	IAT Sensor Output

TEMPERATURE AND MANIFOLD ABSOLUTE PRESSURE SENSOR

The temperature and manifold absolute pressure (TMAP) sensor is used only on SC variants. The TMAP sensor provides a voltage proportional to the absolute pressure between the supercharger intercooler and the intake valve and the air charge temperature. These signals allow the ECM to calculate the air charge density.

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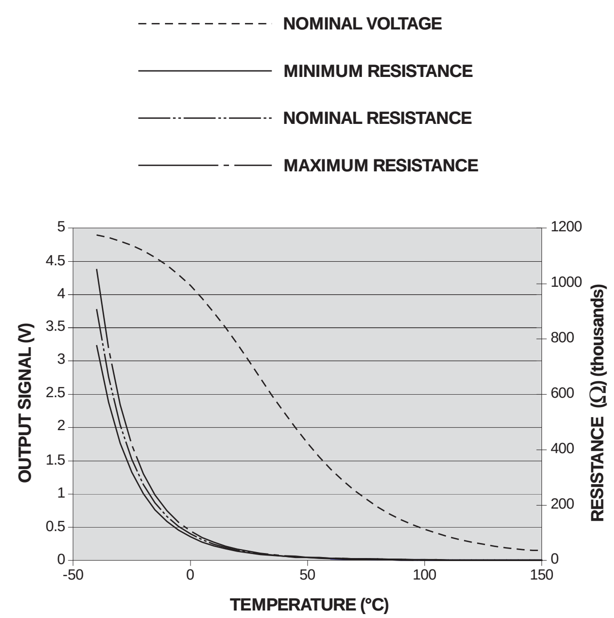
The TMAP sensor is mounted at the rear of the engine, below the charge air cooler of the LH bank.

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- Intake air restricted
- Boosted air leak

Specification	Function
Pin 1	Pressure Output Signal
Pin 2	Supply Voltage
Pin 3	Temperature Signal
Pin 4	Ground

Temperature Signal



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Pressure Signal

NP10V8114

THROTTLE POSITION SENSOR

The engine torque is regulated via an electronic throttle body (‘drive-by-wire’ system), where an electronic pedal assembly determines throttle opening.

The throttle position (TP) sensor is mounted in the integrated cover plate on the throttle body assembly. The throttle body assembly is mounted at the top front of the engine, in a similar position for both NA and SC variants.

NP10V8105

This value is input into the ECM and the throttle is opened to the correct angle by means of an electric direct current (DC) motor integrated into the throttle body. Movement of the motor is achieved by changing the PWM signal to the DC motor, allowing it to be operated in both directions.

The dual-output TP sensor in the throttle body is used to determine the position of the throttle blade and the rate of change in its angle.

A software strategy within the ECM enables the throttle position to be calibrated each ignition cycle. When the ignition is turned ON, the ECM commands the throttle to open and close fully, thus performing a self-test and calibration, learning the position of the full closed hard stop position.

Safety Precautions

⚠ **CAUTION: Terminals in sensor and connector are gold-plated for corrosion/temperature resistance – DO NOT probe.**

Failure Modes

- Sensor open circuit
- Short circuit to battery voltage or ground
- If signal failure occurs the ECM will enter a limp home mode where the maximum engine speed is 2000 rpm
- Signal offset
- Vacuum leak

Failure Symptoms

- Poor engine running and throttle response
- Limp home mode – maximum 2000 rpm
- Emission control failure
- No closed loop idle speed control

Specification	Function
Supply voltage	5V ± 0.2 V
Supply current	Max. 10 mA/1 output
Tolerance – closed position	±150 mV
Tolerance – WOT position	±150 mV
Operating temperature range	-40°C – 160°C (-40°F – 320°F)
Pin 1	Throttle motor valve open: direction +
Pin 2	Throttle motor valve open: direction –
Pin 3	Position sensor output 2 (Gold)
Pin 4	Ground (Gold)
Pin 5	Position sensor output 1 (Gold)
Pin 6	Position sensor 5V supply (Gold)

Throttle Body Motor

The air mass flow through the throttle body is a function of throttle angle, air temperature, air pressure before throttle plate, and differential air pressure over the throttle plate.

Specification	Function
Control signal	500Hz PWM
Resistance	1.2 Ohms
Normal operating voltage range	13.5 V to 14.2 V
Tolerance – WOT position	±150 mV
Operating temperature range	-40°C – 160°C (-40°F – 320°F)

ACCELERATOR PEDAL POSITION SENSOR

The accelerator pedal position (APP) sensor provides a pedal position signal to the ECM. The ECM uses this information to actuate the damper motor in the electronic throttle assembly to move the throttle disc to the correct angle in relation to the pedal position.

The APP sensor signals are checked for range and plausibility. Two separate reference voltages are supplied to the pedal. Should one sensor fail, the other is used as a limp home input.

The accelerator pedal position (APP) sensor provides two outputs. If the ECM detects a difference between the two signals, a fault code is stored. The ECM will use the signal with the lowest value for electronic throttle control.

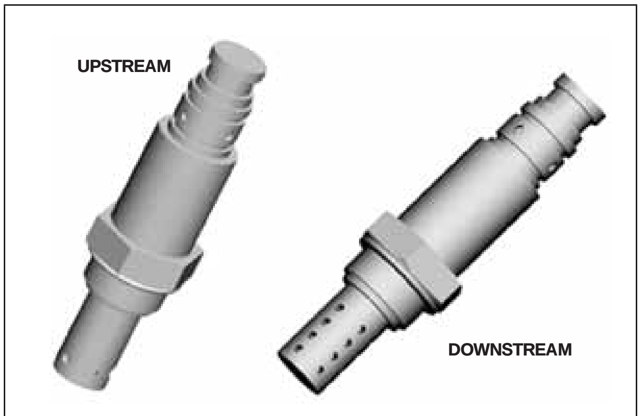
Pin	Function
Pin 1	5V 1
Pin 2	Demand 1
Pin 3	Ground 1
Pin 6	5V 2
Pin 5	Demand 2
Pin 4	Ground 2

HEATED OXYGEN SENSORS

The heated oxygen sensors monitor the level of oxygen in the exhaust gases and are used to control the fuel/air mixture. Positioning the sensors in the stream of exhaust gasses from each bank enables the ECM to control the fuel metering on each bank independently of the other, allowing much closer control of the air/fuel ratio and catalyst conversion efficiency.

There are four heated oxygen sensors per engine:

- One upstream Universal Heated Exhaust Gas Oxygen (UHEGO) sensor per bank
- One downstream Heated Oxygen Sensor (HO2S) per bank.



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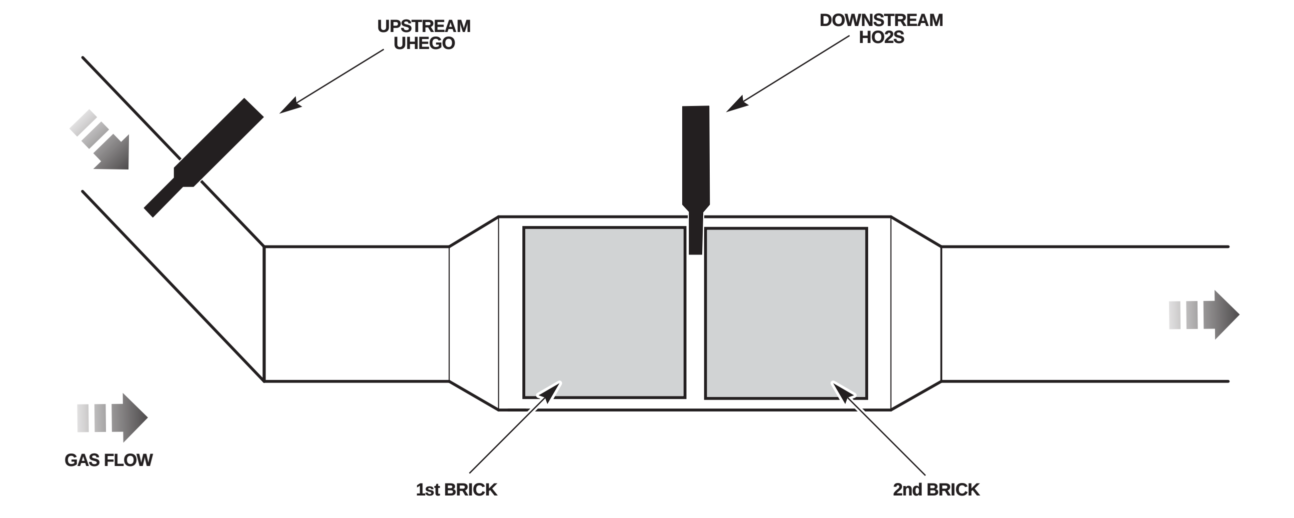

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Upstream Universal Heated Exhaust Gas Oxygen Sensors

In order to improve the control of the air : fuel ratio (AFR) under varying engine conditions, a linear or ‘universal’ heated exhaust gas oxygen (UHEGO) sensor is used in the upstream location. The UHEGO has a varying current response to changes in the exhaust gas oxygen content.

The AFR can be maintained more precisely within a range from approximately 12:1 to 18:1, not just stoichiometric. Voltage is maintained at approximately 450 mV by applying a current.

The current required to maintain the constant voltage is directly proportional to the AFR. A higher current indicates a leaner condition; a lower current indicates a richer condition. The current varies with the temperature of the sensor and is therefore difficult to measure for technician diagnostic purposes.

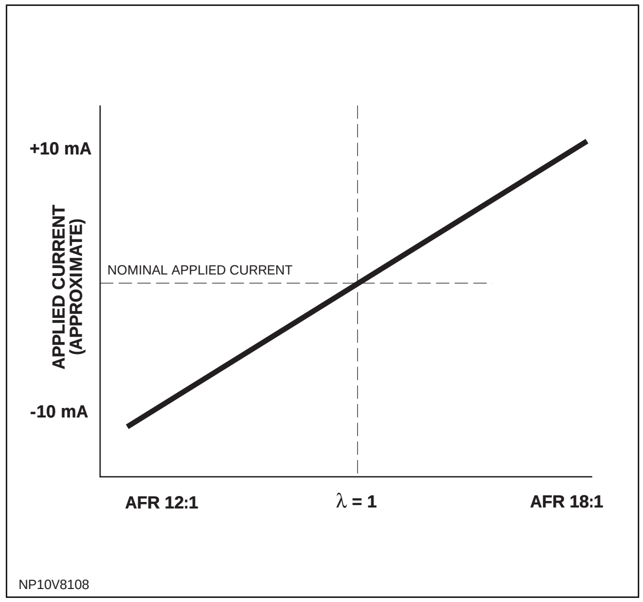
The upstream UHEGO sensors need to operate at high temperatures – 750°C (1,382°F) – in order to function correctly. To achieve this, the sensors are fitted with heater elements that are controlled by a PWM signal from the ECM.

The heater elements are operated immediately following engine start and also during low load conditions when the temperature of the exhaust gases is insufficient to maintain the required sensor temperatures.

A non-functioning heater delays the sensor’s readiness for closed loop control and influences emissions. The PWM duty cycle is carefully controlled to reduce thermal shock risk to cold sensors.

The upstream UHEGO sensors are mounted to the engine on the exhaust manifolds, in the mating flange to the exhaust pipes. There is one sensor per bank. The sensors are fitted during engine assembly.

Upstream UHEGO Output



Downstream Heated Oxygen Sensors

The latest switching downstream exhaust sensors are precise-control heated oxygen sensors (HO2S). These sensors have a tighter lean/rich tolerance compared to previous HO2S. The only visible distinction between the current and previous HO2S is the part number.

The downstream HO2S uses smaller elements in its construction to enable quicker heat-up times to control fuel metering at lower temperatures (emissions).

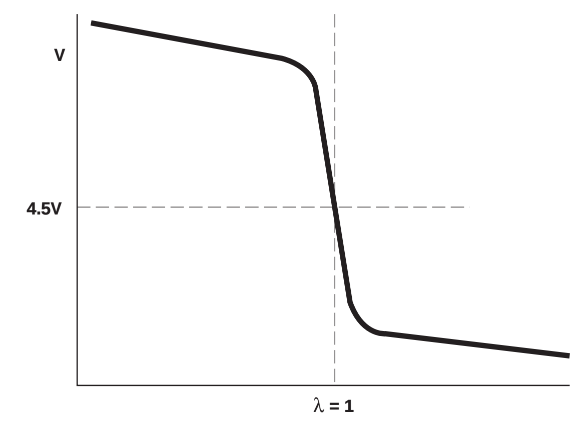
The primary function of the downstream HO2S is to ensure correct operation of the three way catalyst.

The downstream HO2S uses Zirconium technology that produces an output voltage dependant upon the ratio of exhaust gas oxygen to the ambient oxygen. The device contains a Galvanic cell surrounded by gas-permeable ceramic, the voltage of which depends upon the level of O2 diffusing through.

Nominal output voltage of the device for lambda = 1 is 300 – 500mV. As the fuel mixture becomes richer (<1) the voltage tends towards 900mV and as it becomes leaner (lambda > 1) the voltage tends towards 0 volts.

The downstream HO2S are mounted in the exhaust system part way in the rear of the catalyst.

Downstream HO2S Output



Safety Precautions

⚠ WARNINGS:

- **Anti-seize compound used on service sensor threads may be a health hazard. Avoid skin contact.**
- **Exhaust system components, catalysts in particular, operate at high temperatures and remain hot for a long time after operation.**

⚠ CAUTIONS:

- **Oxygen sensors must be treated with the utmost care before and during the fitting process. The sensors have ceramic material within them that can easily crack if dropped or over-torqued. They must be tightened to the specified torque figure with a calibrated torque wrench. Care should be taken not to contaminate the sensor tip when the anti-seize compound is used on the thread.**
- **To prevent damage to the sensors, a special tool (box spanner) should be used when removing.**
- **If the sensor sticks in the exhaust, apply de-seize product and use a repeating tighten and loosen strategy.**
- **Ensure that the sensor harness is robustly secured away from moving or hot parts.**

Failure Modes

- Mechanical fitting and integrity of the sensor (i.e. cracked)
- Sensor open circuit/disconnected
- Short circuit to battery voltage or ground.
- Lambda ratio outside operating band
- Crossed sensors (RH bank fitted to LH bank and vice-versa)
- Contamination from leaded fuel or other sources
- Harness damage
- Air leak into exhaust system (cracked pipe/weld or loose fixings)

Failure Symptoms

- Default to open loop fuel metering
- High CO reading
- Strong smell of sulfur (rotten eggs) until default condition
- Excess emissions
- Unstable operation
- Reduced performance

AMBIENT AIR TEMPERATURE SENSOR

The ambient air temperature (AAT) sensor is located in the underside of the LH exterior door mirror. The sensor is an NTC thermistor – the element resistance decreases as the sensor temperature increases, which produces a low signal voltage.

The ECM supplies the sensor with a 5V reference voltage and ground, and measures the returned signal voltage as an outside temperature.

The AAT signal is used by the ECM for a number of functions including engine cooling fan control and A/C compressor displacement control.

The ECM also transmits an ambient temperature message on the high speed CAN bus for use by other control modules.

Pin	Function
Pin 1	5V supply
Pin 2	Ground

NOTE: If there is a fault with the AAT sensor, the ECM calculates the AAT from the temperature inputs of the IAT sensors. If the AAT sensor and the temperature inputs of the IAT sensors are all faulty, the ECM adopts a default ambient temperature value of 20°C (68°F).

Failure Mode

- Default value of 20°C (68°F)

IGNITION COILS

The ignition coil operates according to the laws of induction. The unit consists of two magnetically-coupled copper coils (primary and secondary windings).The coil has a 3-pin connector and incorporates an internal switching module.

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Energy is stored in the primary winding's magnetic field by allowing a current to flow through the primary circuit switched by the switching module.

At the firing point the current flow is interrupted by the ECM, which induces secondary voltage in the coil's secondary winding.

The secondary circuit has a diode on the ground side in order to reduce any undesired switch-on voltage, which could lead to misfiring into the intake manifold to an uncritical value.

The switching module will limit the primary current to a maximum value. It also limits the maximum primary voltage by voltage clamping. This protects the switching module and (along with other parameters) determines the maximum possible secondary voltage.

Safety Precautions

⚠ **WARNING:**

- **Ignition coils generate high voltages that can cause personal injury. Appropriate safety instructions on handling high voltages must be observed.**

⚠ **CAUTIONS:**

- **The spark plugs fitted are critical to the performance of the ignition and misfire detection systems. No attempt should be made to 'clean' or 'gap' these spark plugs. They are very reliable and unlikely to cause problems. If a faulty spark plug is suspected, try substituting it before condemning it. It is essential that only factory-approved spark plugs be used in service. DO NOT attempt to use 'equivalent' spark plugs, even if they are of a similar design. Use of unapproved spark plugs will cause the misfire detection system to malfunction and erroneously store misfire faults.**
- **To avoid damage to the insulator, always use the correct specified spark plugs and correct plug removal/refit plug socket.**

NOTE: A single capacitor is used in the engine harness to suppress interference from the ignition coil power supply.

Radio Frequency Interference Suppressor

The radio frequency interference (RFI) suppressor is mounted on the harness carrier bracket on at the upper rear of the engine.

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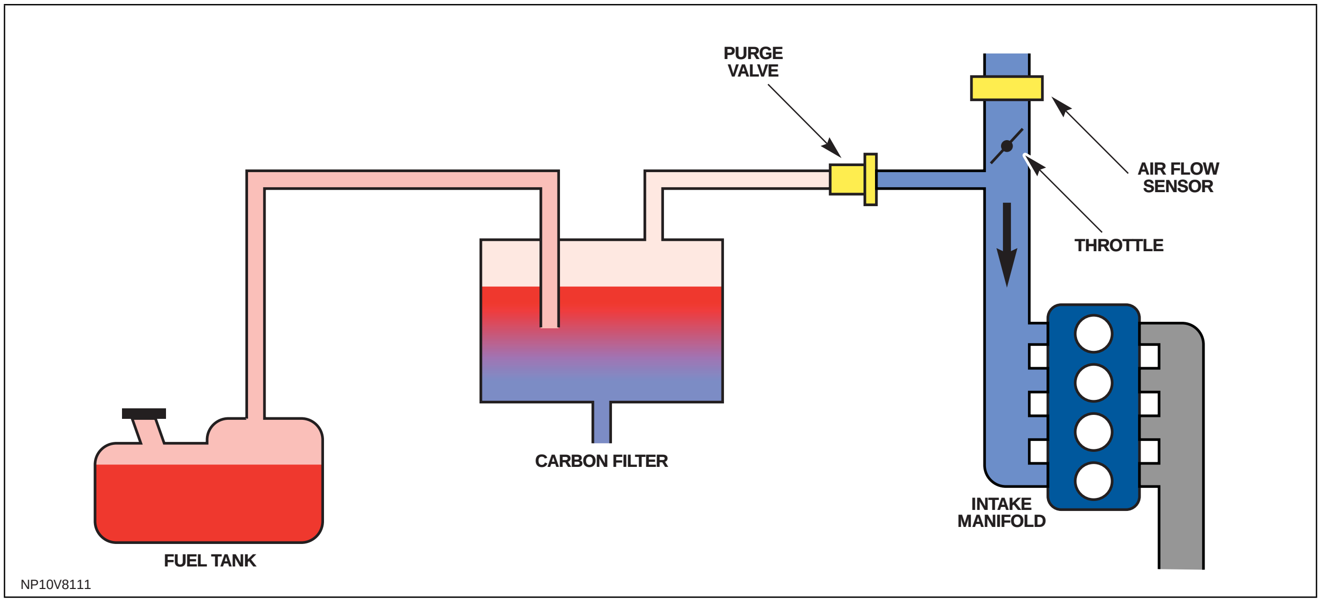
FUEL TANK CANISTER PURGE VALVE

To comply with legislation in fuel evaporative loss, the evaporative emissions loss control system is used on all vehicles. Its purpose is to minimize the evaporative loss of fuel vapor from the fuel system to the atmosphere. This is achieved by venting the fuel system through a vapor trap – a canister filled with vapor-absorbing charcoal. The charcoal acts like a sponge and stores the vapor until the canister is purged under the control of the ECM into the engine for combustion. The carry-over system uses the DMTL system to check for fuel tank integrity.

The canister is connected with the intake manifold, after the throttle body, via a purge valve. This valve is opened and closed according to a PWM signal from the ECM. The system does not work properly in the case of leakage or clogging within the system or if the purge valve cannot be controlled.



The canister is purged by drawing clean air through the charcoal, which carries the hydrocarbons into the engine where they are combusted. To maintain driveability and emission control, purging must be closely controlled as a 1% concentration of fuel vapor from the canister in the air intake may shift the air/fuel ratio by as much as 20%. Purging must be carried out at regular intervals to regenerate the charcoal, since the storage capacity is limited. The purge function is alternated with the fuel metering adaptation, as both cannot be active at the same time.

The ECM alters the PWM signal to the purge valve to control the rate of purging of the canister. The purging of the canister is done in a controlled manner in order to maintain the correct stoichiometric air/fuel mixture for the engine.

The ECM also ensures that the canister itself is purged frequently enough to prevent fuel saturation of the charcoal, which could lead to an excessive buildup of fuel vapor (and vapor pressure) in the system, increasing the likelihood of vapor leaks.

Failure Modes

- Valve drive open circuit
- Short circuit to battery voltage or ground
- Valve/pipe work blocked
- Valve stuck open
- Pipe work leaking/disconnected
- Noisy valve

Failure Symptoms

- Engine may possibly stall on return to idle (if valve stuck open)
- Poor idling quality (if valve stuck open)
- Fuel metering adaptations forced excessively rich if canister is clear with valve stuck open
- Fuel metering adaptations forced excessively lean if canister is saturated with valve stuck open
- Saturation of canister (if valve stuck closed)

VISCOUS FAN CONTROL (LAND ROVER ONLY)

On Land Rover vehicles, the ECM uses an electronically-controlled viscous-coupled fan to provide engine cooling. The ECM supplies the fan with a PWM signal that controls the amount of slippage of the fan, thus providing the correct amount of cooling fan speed and airflow. The EMS uses a Hall-effect sensor to determine the fan speed.

Failure Modes

- Solenoid drive open circuit
- Short circuit to battery voltage or ground
- Fan speed monitor open circuit
- Physically damaged fan or viscous coupling

CONTROLLER AREA NETWORK

The Controller Area Network (CAN) is a high-speed serial interface for sharing dynamic signals between electronic control modules. CAN communications are 'self-checked' for errors, and if an error is detected the message is ignored by the receiving electronic control module.

Due to the high rate of information exchange, the system has a high degree of latency. This allows for a high number of errors to be present without reducing the data transfer rate. In practice, this is a very reliable system.

Each CAN message is transmitted by one electronic control module and received by all other electronic control modules on the CAN bus. Each message contains a fixed structure of signals. The data exchanged is used so that each electronic control module does not need to have a hardwired sensor for each input. The CAN message identifiers are arranged by a network tool, which can guarantee that all messages meet their specified timing needs.

Signal Overview

The CAN communication system is a differential bus using a twisted pair that is normally very reliable. If either or both of the wires of the twisted pair CAN bus is open- or short-circuited, a CAN time-out fault will occur.

Below is a list of additional electronic control modules that the ECM will communicate with on the CAN network:

- Instrument cluster
- Steering angle sensor
- TCM
- Active rear locking differential, if equipped
- Adaptive cruise control
- Electronic parking brake

Failure Modes

- CAN bus wiring short circuit or open circuit
- Incompatible software and message versions

ON-BOARD DIAGNOSTIC MONITORING

Some OBD monitors are continuous, that is they operate all the time the ignition is on.

Some OBD monitors have conditions that must be met before the monitor is allowed to operate, such as engine speed 1000 – 4000 rpm and engine airflow 10 – 100 g/sec and intake air temperature -10 – +50°C, in order to ensure the vehicle is operating in such a manner that the failure may be correctly diagnosed. For this reason it may be possible for a failure to be present on the vehicle but remain undetected by the module.

Most OBD monitors use 2-trip detection: if on the first occasion the failure is detected, a pending DTC is recorded. If the failure is again detected on the next drive cycle, then a confirmed DTC is logged and the MIL may be illuminated.

A few OBD monitors operate on a single-trip basis where the MIL is illuminated as soon as the failure is diagnosed.

Detection of a failure may prevent the operation of other OBD monitors. This is to prevent the logging of multiple DTCs for a single. However, the system is not infallible, and a single fault may result in two or more failures being detected, with two or more DTCs being recorded.

CRANKCASE VENTILATION SYSTEM

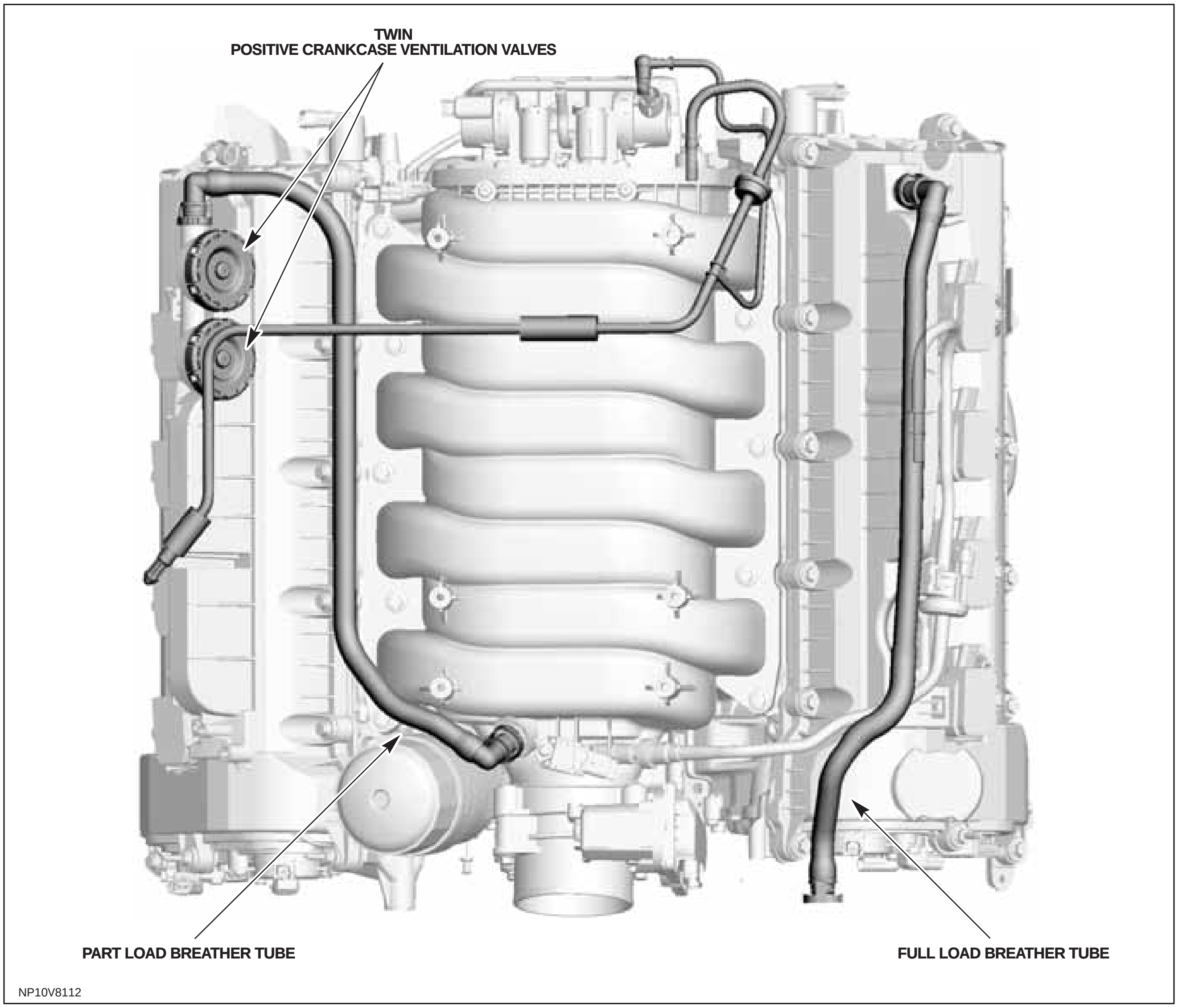
During a normal compression stroke, small amounts of gases in the combustion chamber escape past the piston. Approximately 70% of these gases are unburned fuel (Hydrocarbons).

The purpose of a Positive Crankcase Ventilation (PCV) system is to prevent crankcase pressure build-up, protect engine seals, and remove harmful gases from the crankcase and combine them with the engine's normal incoming air/fuel charge.

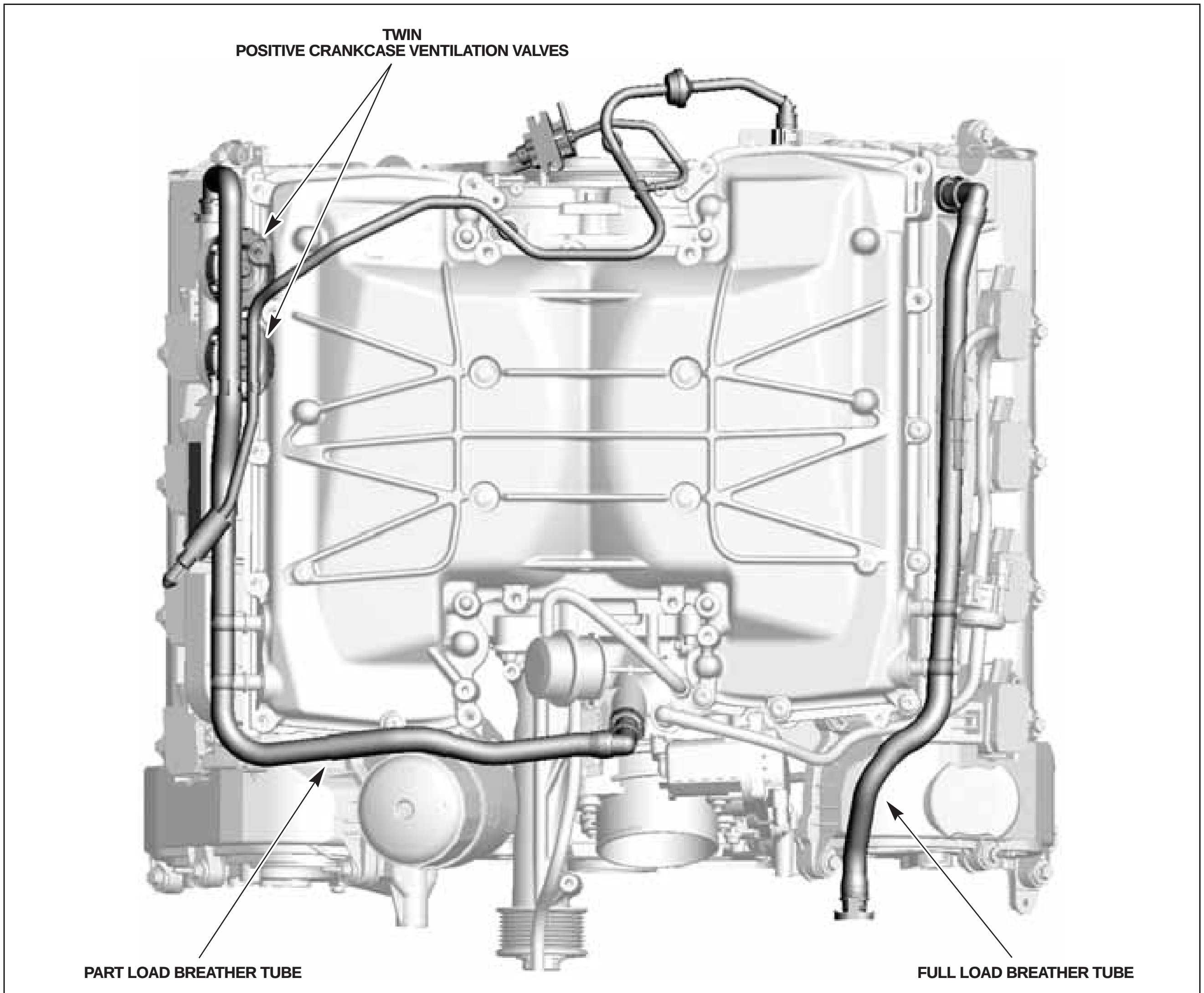
The crankcase is ventilated through part-load and full-load breathers and oil separators, which consist of a variable geometry oil separator, pressure control valves, and oil drain valve. This sophisticated system reduces oil pullover by over half.

The integrated twin PCV valves prevent the hose from icing and improve driveability in cold climates. The full load breather hose purges the crankcase and reduces condensation when the engine is cold.

NA Crankcase Ventilation System



SC Crankcase Ventilation System



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