AUTOMOTIVE ELECTRONICS

with MAJOR AL YOUNGER (USAR, Ret.)

GMH's C-3 Engine Management System

If you have a JD/JE Camira, VL EFI Commodore 'Group A', 1.6/1.8 litre Astra or V6/V8 VN Commodore that is not a badge change, you have this system. It's used on both TBI (throttle body injection) and PFI (port fuel injection) engines. This article will give you a basic rundown on how the system works.

The C-3 system has been around for quite a while. It's actually a fourth generation system, but as a GM engineer told me, "We can't call it the C-4 system — after all, Ford has a transmission called a C-4". So much for how 'Detroit' thinks.

Incidentally, talking about 'Detroit', I received a letter from an Aussie reader who wanted to know exactly where Detroit is located. Well, I use the term 'Detroit', for any US automotive manufacturer, regardless of their geographic location. Even in the USA, the term 'Detroit' is only used as a general symbol for US auto manufacturers, since most of them have more than one manufacturing facility, generally not located in Detroit.

The city of Detroit in Michigan is the home of General Motors, and it's known as 'Motor City'. Ford's headshed is Dearborn, also in Michigan. But many of the trucks and vans for Ford and Chrysler are made in Canada; in fact Ford's factory in Windsor, Canada is famous for the Ford Windsor (302/351) engines. Windsor is actually only a very short drive from Detroit Michigan, and many Canadians work in Detroit and commute.

But back to Australia and the GMH C-3 system. The Holden people made a wise choice when they selected this system, because it allows one ECU to fit all of the Australian manufactured Holdens. It's only necessary to change the Mem-cal (memory-calibration) unit (Fig.1).

The Mem-cal unit contains firmware that identifies the vehicle parameters — such as engine type, vehicle weight, axle ratio, transmission type and diagnostic data. It also contains operating and diagnostic instructions for that particular version of the C-3 system.

The C-3 controls the following:

- Air/fuel ratio (AFR)
- Timing
- Idle speed
- A/C clutch control
- Fuel pump operations
- Emissions
- Transmission lock-up
- 'Check engine' lamp (CEL)
- Radiator fan control
- Diagnostics (code & data stream)
- Trip computer
- Cruise control
- Anti-theft device

As you can see, it has plenty to do.

Overview

The ECU is located on the passenger side, behind the left hand cowl panel. The diagnostic connector on VN's is located behind the ECU. On other vehicles, it's under the dash panel near the glove box.

The ECU's central processor unit or 'CPU' is an eight-bit device that runs at a clock speed of 8.388MHz. It contains input/output conditioning circuits, solenoid/injector drivers, a reference voltage source (5V), an ignition control driver and RAM memory. The RAM monitors indicator circuits, sets codes and reads codes and provides data stream output, when requested. The inserted mem-cal adds ROM and PROM memory for vehicle information, processing of infor-

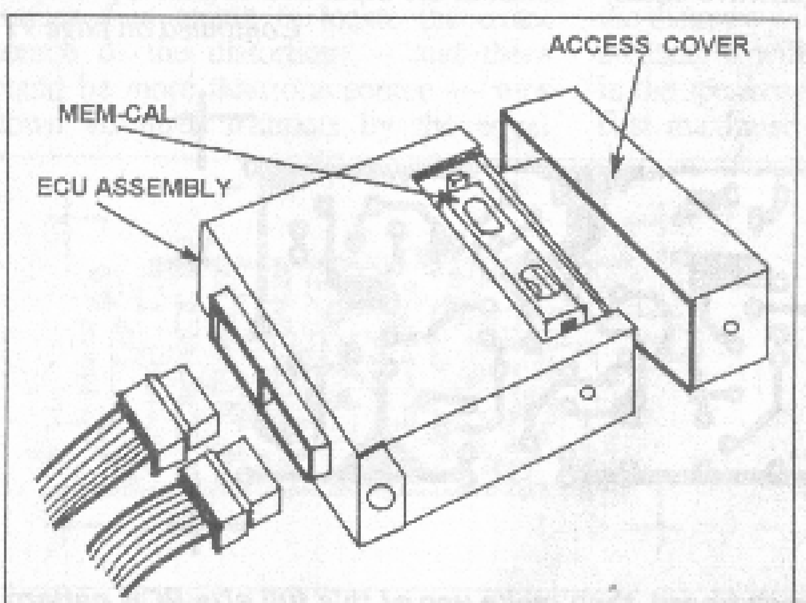

Fig.1: A 'memory calibration' unit is used to customise the C-3 system for each model of GMH vehicle.

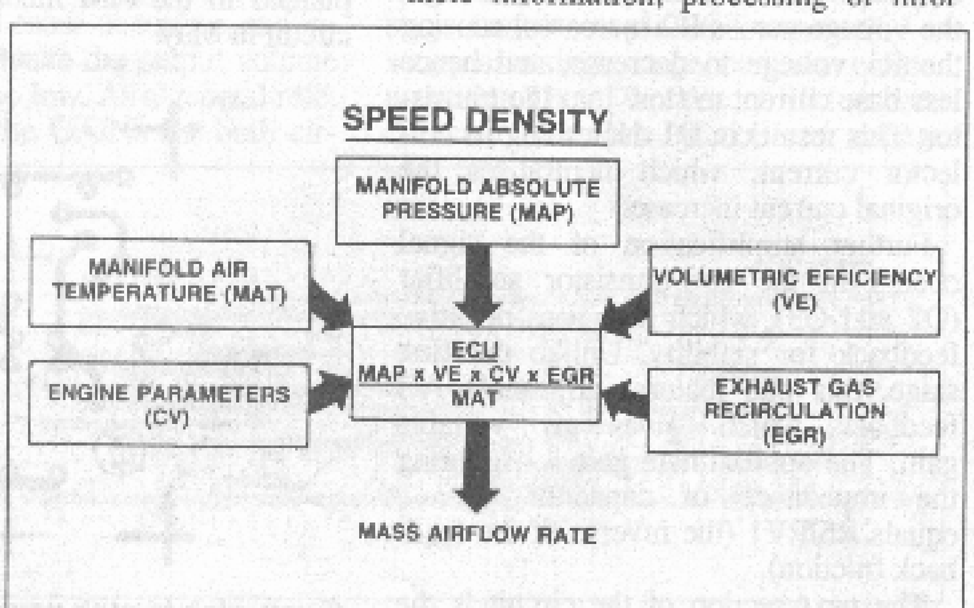

Fig.2: In Australia, the C-3 system uses the MAP speed density system for fuel control.

mation (inputs) and issuing of commands (outputs).

MAP Density System

The C-3 system in GM's Australian vehicles uses the speed or MAP Density system for fuel control (Fig.2). It has many advantages over AFC (Air Flow Control). It does not require a barometric pressure sensor for atmospheric compensation, as AFC does. In addition, MAP sensors cost much less than AFM (air flow meter) or MAF (mass air flow) sensors.

The MAP (manifold absolute pressure) sensor monitors both atmospheric pressure and engine vacuum (Fig.3). The absolute type fitted is unique in operation. When the engine is not running, the atmospheric pressure pushes against the diaphragm. When the ignition key is turned on, the ECU reads the MAP output, which represents atmospheric pressure. This data is stored in memory for fuel calculations.

After the ECU receives a signal (RPM) that the engine is running, it then reads the MAP output as vacuum. So if you're driving up a mountain and your engine starts running like the proverbial 'hairy goat', just shut the engine off and start it up again. The ECU will then get an updated and better reading for atmospheric pressure, and it will run properly again.

AFR control: The system will attempt to manage the AFR at the optimum ratio of 14.7:1, in all modes of operation. This happens even if there's no control signal from the O_2 sensor.

Ignition

The C-3 system allows the use of many different types of ignition system. Most of the GMH vehicles concerned are fitted with a HEI (high energy ignition) system, except the VN 3800 V6 which has a DFI (direct fire ignition) or distributor-less system.

In all cases, if the ECU fails to provide EST (electronic spark timing) or for any reason the system defaults, the ignition system runs the engine in the diagnostic or 'limp' mode. More about this subject soon, under diagnostics.

The ECU monitors all the sensors to determine the proper mode of engine operation. The modes then control the basic AFR requirements, as follows. Not that not all modes are available in all vehicles.

STARTING: The injector pulse width is determined by engine temperature. The system exits this mode at 300rpm.

BACKFIRE INHIBIT — WHILE CRANKING: Uses the 'crank' signal to shut off the injectors until 450rpm, to prevent backfires.

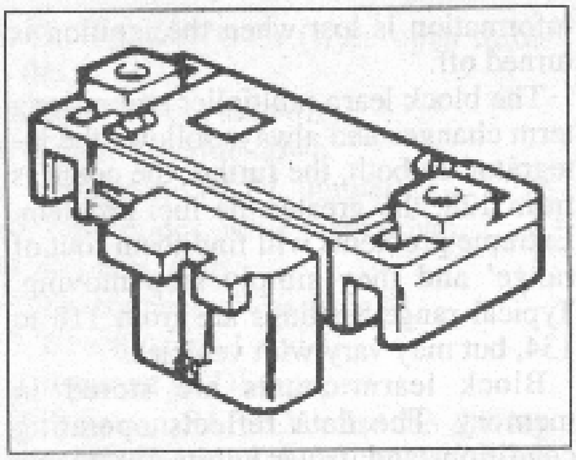

Fig.3: The C-3's MAP (manifold absolute pressure) sensor, which monitors both atmospheric pressure and engine vacuum.

CLEAR FLOOD: Holds the injector pulse width to 8ms, until the engine starts. Conditions are with the accelerator 'floored' and engine revs below 300rpm.

RUN OPEN LOOP: This mode remains effective until the engine is at operating temperature, with the oxygen sensor working and the engine not at idle.

RUN CLOSED LOOP: Based on the signal from the oxygen sensor. Provides an injector signal for precise control of AFR at 14.7:1.

IDLE MODE: Applies when the throttle is closed with the vehicle speed less than 5kph. The oxygen sensor signal is ignored.

ACCELERATION: In this mode the ECU provides the engine with extra fuel. If the demand is great enough, it will add extra injector pulses.

DECELERATION: The ECU decreases injector pulse width to maintain idle.

DECEL FUEL CUTOFF: The injector pulses are cut off if the rpm is above 1500 or the vehicle speed is over 35kph.

BATTERY VOLTAGE CORRECTION: The injector dwell time or idle speed are increased if battery voltage is down.

FUEL CUTOFF: The injectors are shut off if the engine revs exceed 5400rpm or the vehicle speed is over 220kph.

Most of these modes should be self-explanatory, except perhaps for the Run Closed Loop. The conditions for this mode are (a) the engine at operating temperature; (b) the O_2 sensor heated by the exhaust, to 300°C; and (c) the sensor providing a signal output to the ECU.

To aid in the precise control of AFR, a 'block learn multiplier cell' method is used, as a fuel management program. This consists of 16 blocks of data (00 to 15), which represent RPM and IPW (injector pulse width in milliseconds) at the ideal combustion (AFR) ratio of 14.7:1, as the base. The cells each have a count of between 0 and 255, with 128 representing an AFR of 14.7:1.

To explain how 'block learn' works can be very complicated, so I will proceed in very layman-level terms. First, we must have a brief understanding of how the O_2 sensor operates.

Oxygen (O_2) sensor

The O_2 sensor monitors the exhaust gases for oxygen ions. It outputs a varying DC voltage of between 0 and 1V. If the exhaust O_2 content is high (lean condition), the voltage is low; conversely if the exhaust O_2 content is low (rich condition), the voltage is high.

This signal is sent to the ECU. The ECU then gives an opposite command to the injectors, to correct the situation. So if it receives a signal indicating a rich condition (high O_2 sensor voltage), it 'leans out' the injectors by changing (reducing) the IPW. If the signal should indicate lean (low voltage), and the ECU then enriches the system by increasing the IPW.

Now many people in the trade think the O_2 sensor voltages should be the other way around, with higher voltage meaning more oxygen. But you electronic blokes will understand, when you learn the O_2 sensor is referenced to outside oxygen, which far exceeds the oxygen content in the exhaust.

'Hunting' action

If you monitor the O_2 sensor output with a DMM or other high input impedance (10M or 20M) voltmeter, you should see it moving between about 0.2 and 0.8 of a volt. This action is referred to as 'hunting'. Just remember that this is due to the action of the ECU in changing the AFR, in its effort to maintain it at the optimum 14.7:1. The O_2 sensor does not switch its output by itself — it's only reacting to the changing oxygen content in the exhaust.

Some people get confused over the sensor's temperature-related switching characteristics. If the sensor is at 350°C it takes 100ms, while at 800°C it takes 50ms (including hysteresis). But just remember that the ECU controls the 'hunting'.

Of course if the O_2 sensor is faulty or it's not hot enough, there will *be* no 'hunting'.

(NOTE that Holdens do *not* have heated O_2 sensors. So to monitor O_2 sensor operation, it's necessary to run the engine at a fast idle of about 1800rpm. The exhaust gases will then heat the sensor to its operating temperature — 300°C or higher.)

So what we are trying to achieve is *stoichiometry* or optimum fuel burning, which is synonymous with an AFR of 14.7:1. This also corresponds to a count of 128 in one of our block learn multiplier cells, and also to an average O_2 sensor voltage of 0.45V. OK so far?

Block learn multiplier

The data in the block learn multiplier cells is generated after engine mapping at the factory. This is an extensive process of engine testing at different RPM's and load factors ('load' is the MAP sensor output data). This information is placed in each cell as pre-programmed fuel requirements, referenced to an AFR of 14.7:1 — i.e., a count of 128. So, in each cell, the count factor (128) and the IPW are known.

Which cell data is selected by the ECU is a function of RPM and load. For instance, cell 00 is idle at NOT (normal operating temperature) with say, an IPW of 2-3ms (milliseconds). Then say cell 11 is reached by a heavy load demand and a sharp rise in RPM. The IPW in cell 11 is say 9-11ms, to meet this demand at the ideal AFR, again a count of 128. The cell information is different for each vehicle configuration.

I hope this is not too confusing. Other systems use lookup tables to determine fuel requirements. Think of the information in the cells as the ideal fuel requirements, relative to an AFR of 14.7:1, and the starting point or fuel factor, for corrective calculations.

Fuel integrator

The fuel integrator counter monitors short term fuel correction and has no memory. It makes no changes in open loop and has a fixed count of 128. In contrast the 'block learn' counter makes long term fuel correction and has memory. Both counts may be monitored in the data stream output. Of course, this takes special equipment, like a hand scanner. Autotechs who understand integrator-block learn operation use this count information to diagnose difficult fuel problems.

In closed loop, the integrator reads the O_2 sensor output and makes any short term corrections. If the count goes below 128, it's making a correction for a rich condition, by lowering the IPW.

For diagnosis, just remember **higher counts are compensating for lean mixtures and low counts for rich mixtures.** Note that the integrator information is lost when the ignition is turned off.

The block learn multiplier makes long term changes and always follows the integrator. In both, the further the count is from 128, the greater the fuel problem. Extreme problems will find them 'out of range' and they simply stop moving. Typical range readings are from 118 to 134, but may vary with vehicles.

Block learn counts are stored in memory. The data reflects operating conditions and *driver habits*. It remains in memory for 25 engine cycles or until the continuous power source to the ECU is disrupted (like the battery being disconnected).

So what happens if there's a small fuel problem? Yes, it's stored in memory and the vehicle acts accordingly. Many a GMH vehicle has been fixed, simply by disconnecting the battery and starting 'relearn' over again (more about this shortly in diagnostics).

Remember, anything that effects AFR — such as a small vacuum leak, dirty air or fuel filter, timing not spot-on, etc., — effects the block learn multiplier method. (NOTE: The JD Camira systems do not use this method.)

Diagnostics

The C-3 system has built-in self diagnostics. If a key sensor fails, it attempts to FIX itself, by substituting a fixed value for the sensor's output. If this occurs the CEL will come on.

If the system cannot correct the problem in this way, it will default to the diagnostic mode, which is the 'limp mode'. In this mode the system runs on the ignition system with fixed timing.

An ALDL (assembly line diagnostic link) connector allows code and data stream retrieval from the ECU. On the VN Commodores there's a field service mode that allows testing O_2 sensor operations. (NOTE: The term 'ALCL', standing for 'assembly line communications link', is synonymous with ALDL.)

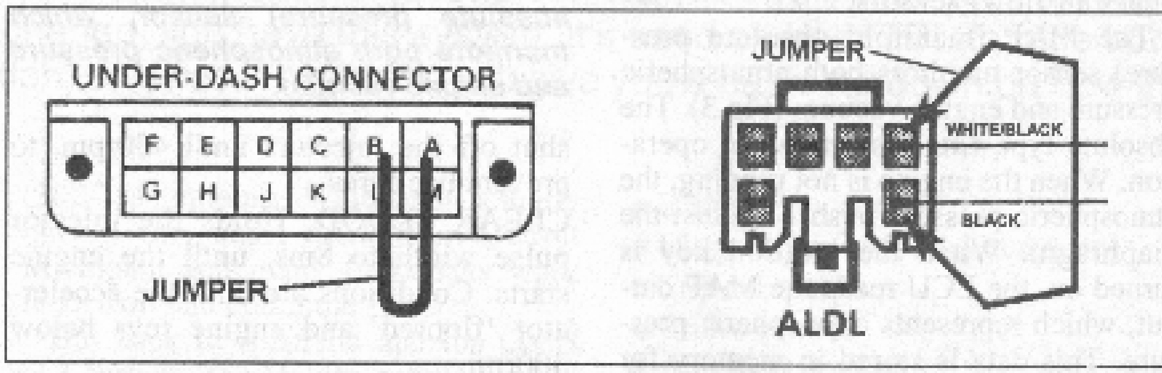

Fig.4: To retrieve diagnostic codes from the C-3 system, the technician earths the CEL path by bridging either the under-dash connector (left) or the ALDL connector (right) adjacent to the ECU.

Data stream diagnosis of the C-3 system will not be discussed here, since it requires special equipment. Diagnosing using data stream is really the only way to go, but the equipment costs.

There's actually two types of code retrieval, one sent by the system automatically in response to a malfunction, and the other codes which must be requested by the autotech.

When the ignition is turned on, the ECU initially turns on the CEL. Then the little 'leprechaun' inside the ECU jumps on his electronic bike and does a quick tour of the system, gathering data along the way. If there's no malfunctions and the engine starts, he 'blows out' the CEL, by lifting its earth path. But if a malfunction is present, the CEL remains on and the leprechaun does an 'Irish jig' around it.

If a malfunction occurs when driving, the CEL will also come on. So if an autotech wishes to retrieve codes or do diagnostic testing, he simply earths the CEL path.

ALDL bridging

For ALDL bridging, place a jumper in the connector (Fig.4a and b), then turn the ignition on. A code 12 (Pass) should flash on the CEL, and continue until the jumper is removed. A 12 is indicated by one flash, a pause, then two more flashes. Any fault code present will flash continuously if there is only one and three times each if there's more than one code.

When the ignition is turned on, some circuits energise:

Radiator fan relay
A/C control relay
Torque converter solenoid
IAC/ISC (fully extends)

If the engine is now started, the timing will be fixed at 10° BTDC (before top dead centre), idle will be controlled as a function of temperature, the relays/solenoid will remain energised and the CEL stays On. You are now in the *diagnostic or limp mode*. No new codes may be logged into memory. If it's a VN Commodore, you are in the Field Service Mode.

If a problem is intermittent, the code will appear on the CEL, but will go out after 10 seconds. The code will stay in memory for 20 power-up cycles, or until cleared by power removal.

All faults indicated must be *fixed* and *cleared*. To clear, remove the 'eng comp' fusible link or disconnect the battery for 10 seconds. Then, retest and make sure you get a pass code 12.

If the ECU does not 'throw' you any code, you have deep troubles — possibly a bad ECU. But check all connectors, power and earth points on the ECU, before you condemn it.

Practical approach

Here's a down to earth, practical checklist for diagnosis and servicing of the GMH C-3 system 'by the numbers':

1. Place the jumper in the ALDL connector.
2. Read the codes and write them down.
3. Remove the jumper.
4. Disconnect power (fusible link/battery).
5. Start engine, run until HOT.
6. Do a few WOT's (wide open throttles).
7. Turn A/C on, then off.
8. Shut the engine down.
9. Replace the ALDL jumper.
10. Read codes, write them down.
11. Fix any faults.
12. Disconnect power (step 4).
13. Retest (steps 1 and 2).
14. Remove ALDL jumper.

If you can SAFELY raise the driving tires off the ground, it can be tested 'driving', albeit with a small load factor. If you have speedo, tripmeter or cruise control problems, this test will check the VSS (vehicle speed sensor) or road speed unit.

VN Field Service Mode: This test must follow the Key-on test with no fault codes present — i.e., you must have received a code 12 (Pass). This mode checks the ECU operation of fuel control, in open and closed loop operations. It can be used during a road test or stationary. Only the latter will be discussed.

The procedure is:

1. Place ALDL jumper.
2. Start the engine.
3. Set idle at 1800rpm (timing fixed at 10° before TDC).

And here's how to interpret the results:

A. Flashing open loop: the CEL will flash on and off 2.5 times per second (five times in two seconds).

B. Flashing closed loop, with fuel system operating normally: the CEL will flash on/off once per second.

C. Flashing closed loop, O_2 sensor indicates lean condition: the CEL will be *off*, all or most of the time.

D. Flashing closed loop, O_2 indicates rich condition: the CEL will be *on*, all or most of the time.

No diagnostic codes should be set during this field service mode test.

Summary

That's about all we have room for in this article. There's a lot more to know about the C-3 system than we have been able to cover here, of course. If you wish to get more detailed information, I can only suggest that you send for my GMH booklet for $60.00.

The following books are also still available: *The Ford EEC-IV* booklet ($60.00); *The Code Book* ($35.00); and *Maintaining the Electronic Motor Car* ($25.00). Send your orders to Major Al Younger, PO Box 477, Double Bay, NSW 2028. ❖