Electronic Fuel Injection for Hot Rods

Part 3 – The Engine Control Unit

In this section, we shall attempt to describe various EFI applications so that you can choose one that fits your car, your budget and your ability. We'll look at how the sensors are fitted, including custom adaptations for non-factory installations and we'll look closely at a couple of components we haven't examined yet, like fuel pressure regulators and fuel pumps. Firstly, however, let's get some safety aspects out in the open that are applicable to EFI systems as opposed to carbs and points.

EFI Safety

- Electronic equipment is sensitive to current surges and voltage spikes. The most common cause is connecting components while battery power is on and when using an arc/mig welder. **Disconnect the battery before removing and replacing EFI components. Disconnect the ECU and the battery when welding on a vehicle.**
- Reverse current *will* damage electronic equipment. Ensure the battery is connected the correct way, negative (-) to the body/chassis.
- Wrong voltages can damage equipment. The ECU and powered sensors operate internally on 4.5 volts. Only connect 12 Volt power to the power feed wires of the ECU.
- Disconnect the battery before charging and when removing/replacing any of the EFI components.
- Use *reverse-current protected* jumper leads when jump starting your EFI vehicle. Jump starts should only be a last resort, in an emergency. NEVER use normal, unprotected jumper leads!
- **Do not** test for the presence of 12 Volt power by touching wires together and looking for a spark.
- Prolonged exposure to heat can adversely affect electronic equipment. Remove the ECU before placing the car in a paint oven.
- Fuel from an EFI system is under high pressure, and stays under pressure even when the engine has stopped. Take care with fuel lines, as fuel could spray into your eyes if a fuel line or hose is being disconnected.
- To work on any part of the fuel system, be sure to follow this procedure to bleed fuel pressure off safely:
  1. Remove the Fuel Pump fuse.
  2. Start the engine and let it run until it stalls from lack of fuel.
  3. Crank the engine again for a few seconds.
  4. Turn the ignition OFF.
  5. Let the engine cool.
  6. It is now safe to work on the fuel system.

- Electronic Ignitions use MUCH HIGHER voltages than your old points system. Treat trigger boxes with respect and always use at least 8mm good quality carbon spiral core ignition cables. **NEVER, NEVER, NEVER** USE SOLID CORE WIRE CABLE ON ELECTRONIC IGNITION SYSTEMS!

Alpha-N Fuel Injection

A brief word on the *Alpha-N* system of EFI, which is a fancy name for *TPS Mode*. The *Alpha-N* method of fuel delivery uses the *Throttle Position Sensor* and engine speed (tacho) to determine engine load, not the *Manifold Absolute Pressure* sensor. The ECU simply responds to the angle of the GO-Pedal. Alpha-N systems are good for race engines that have so much cam that vacuum is unreliable.[1] For Hot Rods and race engines with wild cams, or for mechanical injection conversions (eg, Hilborn/Enderle style stack injection conversions) where there is low vacuum because of so much exposure to the air from all those butterflies, an *Alpha-N* system may be the answer.

Sensors, Actuators

The following topics suggest ways of mounting or connecting the various sensors and actuators. Not all the following sensors are used in all applications. Some systems use only a few sensors, whereas some use others not mentioned here. Check the specifications of the EMS you decide to use and make sure you have all the necessary sensors and actuators fitted.

Mounting of these sensors in non-factory applications is a matter of Hot Rodding ingenuity. When setting up your Hot Rodded EFI system, look at the factory mounting and try to replicate it. After-market components usually come with detailed instructions, adapters and/or bungs that can assist with the installation.

Manifold Air Temperature (MAT)[2]. The MAT sensor can be located in the air filter to provide inlet air temperature information to the ECM. It plays a part in determining air/fuel ratios. Some MAT sensors are easily located in the inlet cuff of a typical air filter by drilling a (3/8" or so) hole and pressing the sensor into the drilled hole, but it must be located somewhere between the air filter and throttle body.

Figure 1 - MAT and connector. Image courtesy of MSD.

Coolant Temperature Sensor (CTS). The CTS usually mounts in the water passage in the same manner as you would fit a temperature sender unit.

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[1] This method is also employed on 2-strokes engines and rotaries.

2 Also referred to as Idle Air Temperature (IAT) sensor or Air Charge sensor.

Figure 2 - CTS. Photo courtesy of MSD.

Figure 3 - Location of CTS. This high performance Holden manifold has a provision for the CTS right next to the Temp gauge sender. Photo courtesy of Performance Engineering, Queanbeyan.

Oxygen Sensor (O2 Sens, EGO). The O2 Sensor must be mounted as close to the exhaust ports as practicable. This is to ensure that it heats up as quickly as possible. For headers, a bung can be welded into the collector and the sensor screwed into place. For manifolds, the same technique can be used at the closest point to the exhaust manifold flange as possible.

O2 sensor bungs can be purchased from Castle Auto Electrics.

Figure 4 - O2 Sensor bung welded into an exhaust header flange ready for mounting. Mount the O2 sensor as close as possible to the heat source (head). Photo courtesy of Castle Auto Electrics.

Heated Exhaust Oxygen Sensor (HEGO). Heated O2 sensors are 2 or 3 wire units that have their own heat source via a 12Volt supply. Use one of these in preference to the single wire unit. The same mounting procedure applies.

Figure 5 - Oxygen Sensor and weld in bung. Heated O2 Sensor shown.

Warning: Leaded fuel, anti-freeze, vapours from silicone sealants and long exposure to a rich mixture can destroy an O2 Sensor.

Manifold Absolute Pressure (MAP). The MAP is used in *Speed Density* systems to help calculate engine load. They are often located inside the ECU, and you simply hook a manifold vacuum hose to the barbed end. They can be mounted just about anywhere.

Warning: Some vacuum lines are made of synthetic rubber that conducts electricity. DO NOT lay manifold vacuum lines across the printed circuit board of the ECU!

Figure 6 - Manifold Absolute Pressure sensor. One connector is the plug to the ECU. The other is the vacuum source. Photo courtesy of MSD.

MAP sensors are available in 1 Bar, 2 Bar or 3 Bar sizes. The ECU reads manifold pressure as an absolute value, that is, as the pressure inside the manifold, not as a vacuum with respect to outside atmosphere (Barometric pressure). For normally aspirate engines, the 1 bar MAP is fine. For turbo and supercharged engines, the 2 and 3 Bar MAPs are required, as they have to measure higher absolute pressure than the vacuum inside a normally aspirated manifold.

Barometric Pressure Sensor (BAR, BARO, BAP). The BARO sensor detects barometric pressure of the atmosphere. The ECU uses BARO to help determine engine load, and, therefore, air/fuel ratio. The BARO sensor responds to changes in altitude, and the ECU can make adjustments accordingly. MAP and BARO sensors are often combined. Like MAP sensors, too, they can be mounted inside the ECU. BARO sensors are not used much any more because the ECU can use the MAP to read BARO at engine start up.

Throttle Position Sensor (TPS). The TPS is a *variable resistor* (potentiometer) that tells the ECU what the throttle angle is at any given time. It is usually a three-wire sensor mounted to the shaft of the throttle body. Throttle position is used to determine A/F ratio, spark timing, idle speed, torque converter lockup (TCC), A/C clutch, and is the primary controller in an Alpha-N system.

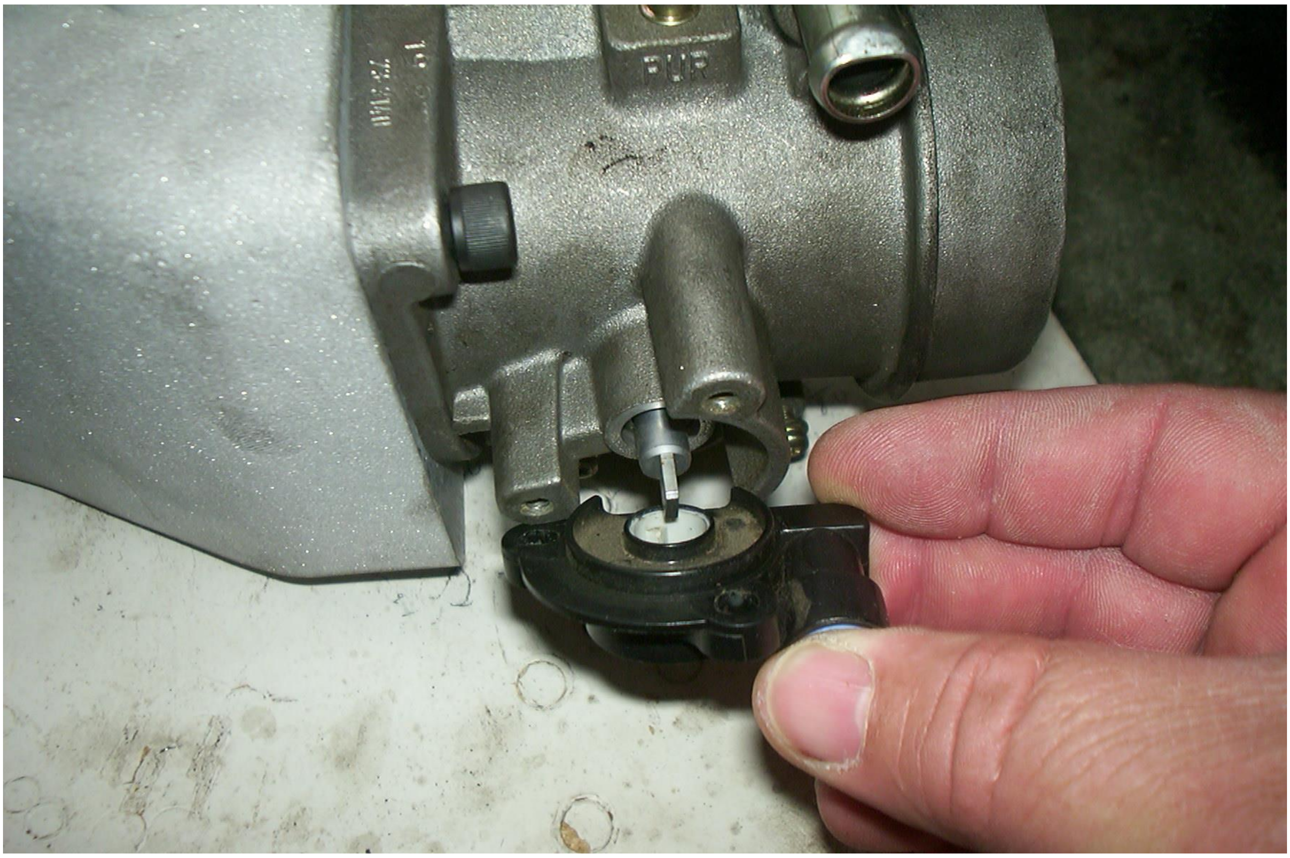

Figure 7 - TPS on a VN Commodore throttle body

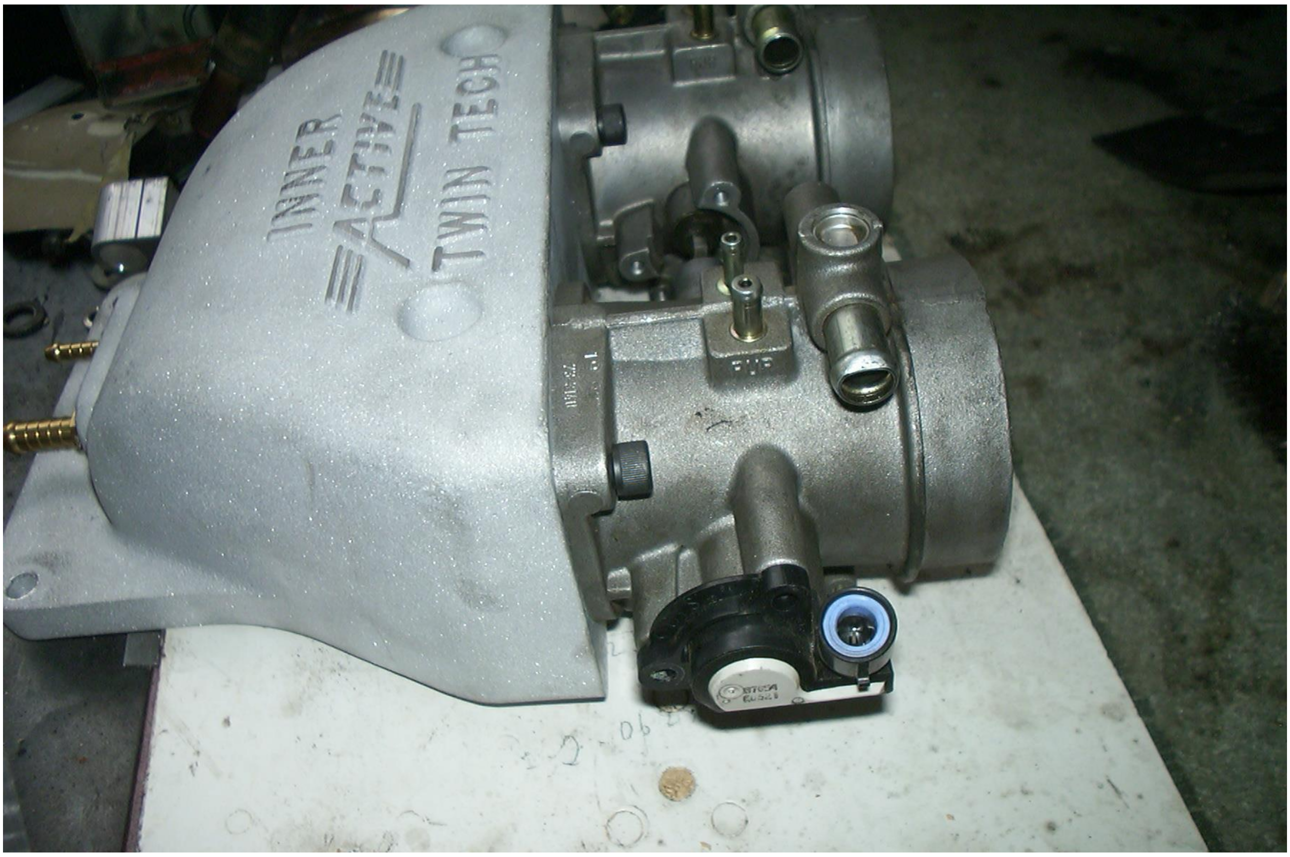

Figure 8 - TPS in place. Two throttle bodies are used on this Twin Tech adapter from Inner Active Manifolds in Blacktown, NSW. Only one TPS is required. The Twin Tech adapter bolts to a square bore inlet manifold.

Using factory throttle bodies like the Commodore types, means that you already have the TPS and Idle Air Control valve (see below) fitted. If you are using modified carbs, stack injection or a custom built throttle body, you need to consider ways of mounting the TPS.

Engine Speed Sensor (ESS). The ESS monitors engine speed and, in some applications, crank position. It is used to calculate injector pulse width. There are various factory and non-factory types, and can be mounted on the flywheel housing, harmonic balancer, etc. The ESS is rarely used in non-factory applications, as engine speed can be easily determined by the Tacho signal.

Vehicle Speed Sensor (VSS). The Vehicle Speed Sensor (VSS) sends a signal to the ECM which the ECM converts to a speed reference. This sensor mainly controls the operation of the automatic transmission's Torque Converter Clutch (TCC) system as found on GM T700 transmissions. It also provides an input for anti-lock brake systems, electronic cruise control and the electronic speedometer. On GM cars, the VSS is mounted directly in the transmission extension housing, where the speedometer drive gear sleeve would have been. If your car uses a speedometer cable, the VSS can be a small unit mounted to the back of the instrument panel behind the speedometer and driven by the speedometer cable. In most Street Rod or similar installations this function is not required, unless you would be interested in having the TCC function totally as originally designed, or adapting a late GM electronic cruise control to the installation.

Crankshaft Position Sensor (CKS). A CKS is mounted close to a toothed wheel (or a notched wheel), usually on the harmonic balancer, but also on the flywheel/flex plate. As each tooth moves past the sensor, a pulse is induced in it, which is sent to the ECU. Each tooth produces a pulse. The number of pulses per second is the *Frequency* of the signal. The frequency translates to engine speed, which is used to time the ignition.

Camshaft Position Sensor (CPS). With assistance from the *Crankshaft Position Sensor*, the CPS tells the ECU where #1 TDC is. Because the engine's firing order is programmed into the ECU, it can use #1 TDC as a reference point to fire coil packs in a *Direct Ignition System* and/or to synchronise injector firing for SEFI systems. The CPS is similar to the CKS in construction, although some use a toothed wheel with a longer tooth or a double tooth to mark #1 TDC. In some applications (eg, on Toyota quad cam V8s) this sensor is called the Variable Valve Position sensor

Mass Airflow Sensor (MAF). The MAF sensor measures the amount of air passing through the engine. There are two basic types:

- Hot Wire MAF
- Vane MAF

The Hot Wire type MAF sensor determines air flow by measuring the current required to maintain a heated wire at a constant temperature as intake air passes over the wire. The Vane type utilises a plate that sits in the incoming air stream. The force of the air passing through deflects the plate, which is mounted on a shaft. The shaft is connected to the sliding part of a variable resistor, much like the TPS. This, in turn, sends a voltage to the ECM in proportion to the angle of the vane.

The MAF sensor must be mounted between the air cleaner assembly and the throttle body.

Knock Sensor (Knock Sens). The knock sensor, located on the engine block, detects vibrations that are the acoustic signature of detonation. The Knock Sensor informs the ECM that detonation is occurring, and to retard the timing in an attempt to eliminate the detonation. Up to 20 degrees of timing can be retarded to compensate for bad fuel, high engine temperature, or any other combination of factors that produce detonation.

Idle Air Control (IAC). The IAC valve is an electrically operated valve or stepper motor which regulates a volume of air bypassing the closed throttle body butterflies. The IAC establishes a stable idle when the engine is cold and maintains idle speed when it has warmed up.

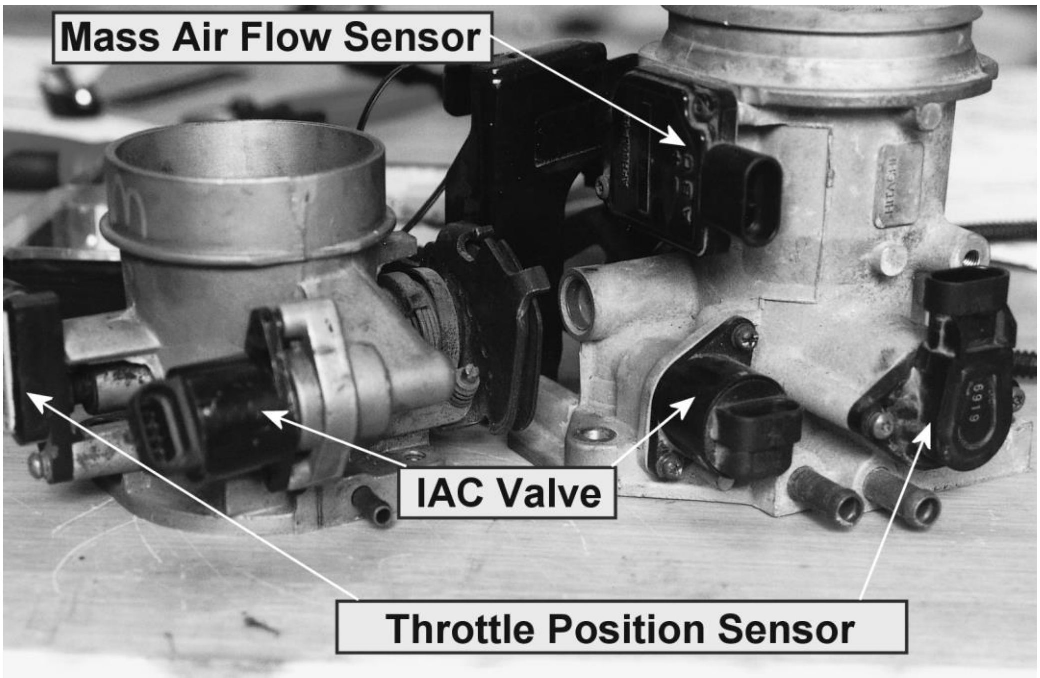

Figure 9 - This is how an IAC valve is mounted in GM Throttle Body. The throttle body on the right is a Mass Air Flow type. The one on the left is a speed/density type from VN Commodore. When custom building a manifold and throttle body set-up, you may want to consider a remote IAC.

The stepper motor type of IAC valve bypasses an amount of air determined by the number of "steps" the motor takes – the more steps, the larger the air flow opening and the more air is bypassed. The IAC can also be an On/Off type, which bypasses a set amount of air when it is activated.

Fuel Pump Relay.

The fuel pump relay is controlled by the ECM and acts as a remote switch to route power to the electric fuel pump. A relay is necessary because most EFI fuel pumps can draw up to approximately 10 amps of current.

Fuel Pressure Regulator

There are many different EFI fuel pressure regulators, but their purpose is the same - to maintain fuel pressure at a certain value above the intake manifold pressure. The inner mechanism usually consists of a sealed diaphragm, a spring, bypass valve and a manifold pressure reference port (a vacuum line). The bypass valve is connected to the diaphragm and the spring pushes against it from the manifold pressure side. The spring pressure determines the base fuel pressure. If there is vacuum at the port (eg, at idle), the spring pressure on the diaphragm is less, therefore the fuel pressure under vacuum conditions is lowered. If there is pressure on the port, such as under boost, spring pressure increases, as does fuel pressure. Most regulators have a static pressure of between 38 and 44 psi.

Figure 10 - Fuel Pressure Regulator. Image courtesy of Accel.

The fuel pump is always producing an excess of fuel volume. Once the base pressure is met, the regulator controls the pressure in the fuel rail by bypassing unused fuel back to the fuel tank. At idle, about 95% of the fuel delivered to the fuel rail is returned to the tank. At full power, somewhere between 5% and 50% of the fuel is returned to the tank.

You should route the fuel from the pump to one end of the fuel rail to feed the injectors. The regulator is mounted on the opposite (low pressure) end of the rail. Remote mounted regulators can be mounted on the firewall and plumbed with high pressure fuel line. Mounting the regulator on the low-pressure side allows any hot fuel in the rail to be purged back to the tank after a hot start to reduce vapour lock and fuel boiling.

Figure 11 - Adjustable Fuel Pressure Regulator. This is a Holley regulator, a new product. It can be mounted just about anywhere. Image courtesy of Holley.

For supercharger or turbocharger applications, you'll need a Rising Rate regulator (sometimes called a Fuel Management Unit (FMU)). Rising Rate regulators increase fuel pressure at a multiplication factor of boost. Instead of computer tuning and thrashing injection duty cycles, these systems increase fuel pressure to add fuel. They are installed downstream from the normal regulator and only start to add pressure under boost. When the engine is off boost, normal tuning and drivability is maintained.

Warning: Setting the fuel pressure regulator to extreme pressures (over 60psi) can cause your engine to run extremely rich without you knowing it. It can cause serious fires in catalytic converters or fuel up your exhaust system, destroying your O2 sensor and creating a fire hazard. Be careful!

Injectors

Choosing an injector means selecting the correct flow rate and the type supported by your ECM. See Part 2 of this series for details on the different types and how to determine the correct flow rate. The following are things to consider for your EFI project.

Fuel Transfer and Sealing

Transferring fuel from the fuel rail to the injectors is via O-rings seals. Sealing injectors to the intake manifold is similar, typically a 14mm round section O-ring sitting in an isolated groove in the manifold or the injector bung. Securing the injectors can be achieved by simply holding the fuel rail against a bracket welded to the manifold.

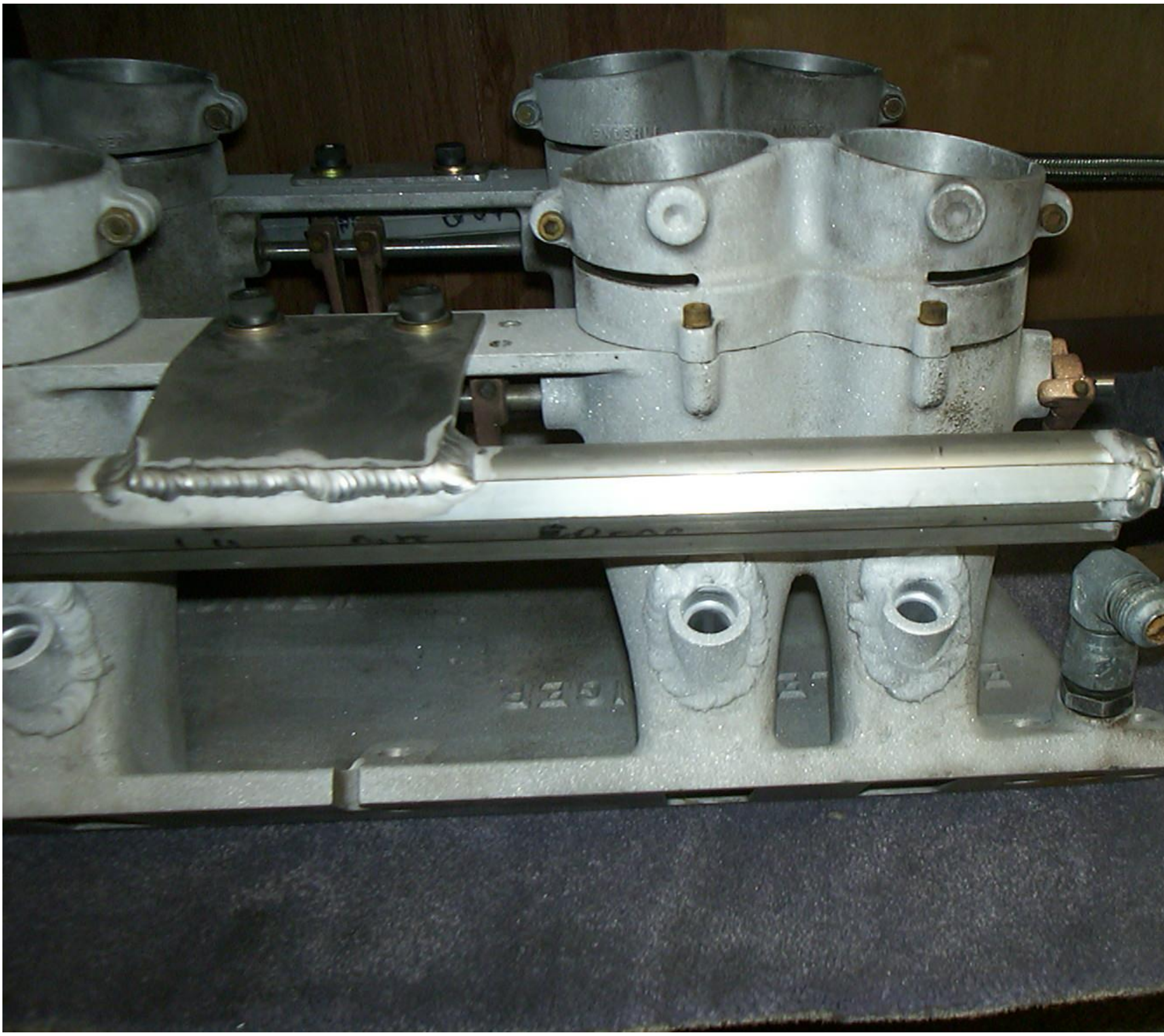

Figure 12 - On this Stack Injection conversion, a bracket has been welded to the fuel rail and bolted to the throttle bodies. Simple but practical, it should clean up nicely. The injectors haven't been fitted yet. Photo courstesy of Inner Active Manifolds, Blacktown.

Factory installations usually utilise a clip at the base of each injector, but no matter which method you choose, they must be held securely in place in case of a back-fire. Under normal conditions, the O rings will hold them in the manifold just fine, but sudden surges in fuel pressure, too much overlap from your lumpy cam or backfire may dislodge the injectors unless they are held in place. Blower or turbo systems will also cause a fair amount of back pressure, too, so be aware of this when setting up a method of securing your fuel rails.

Figure 13 - The fuel rails on this 351 Clevo are secured by a couple of posts that are actually two of the manifold bolts. Very clever, very easy and very neat. Photo courstesy of Inner Active Manifolds, Blacktown.

Flow Rates/ Pressure

Most factory injectors are quite small because of the lower power production engines. Fuel metering is also more precise with small injectors and are also better for smooth idle and emissions. Very few production engines use an injector flowing more than 500cc/minute or 50lbs./hr. For performance applications, engines often require much larger injectors to satisfy the increase in fuel flow. Often larger factory injectors can be fitted from a different engine. Sometimes aftermarket ones must be used. Here are a few things to consider when deciding on injectors:

- Choose an injector large enough to feed your engine at maximum power.
- Use factory injectors where possible – they are much cheaper and more readily available. Most factory EFI systems maintain a fuel pressure of between 36 and 43.5 psi over the intake manifold pressure, so use this as a guide.

- Fuel pressure can be raised to increase the rate of fuel flow. To double fuel flow, you must increase fuel pressure by a factor of 4. Do not exceed 60 psi in most cases. Raising the pressure too high will hurt the fuel pump and can lead to leaks or failures in the plumbing and injectors themselves. Use the proper flow rate for the intended application.
- Injectors for performance engines should be flow and leak tested first. If they are not in peak condition, the engine will never run well.

Which System?

Batch or Sequential? Mass Air or Speed Density? Factory or after-market ECU? Because every Hot Rod project is different, it will be difficult to decide which EFI system will work best for a particular engine - it depends on the application of the car. The focus might be on performance rather than economy, or daily use vs weekend use. As with any system, when performance is a priority, engine speeds are going to be higher and fuel flow rates are going to be higher. This is a most important aspect to consider when putting all the EFI components together.

Let's take a quick look at what we learned in Parts 1 and 2 of this series. We looked at the advantages and disadvantages of *Batch Injection* and *Sequential Injection*. We examined the differences between *Mass Air* and *Speed Density* systems. We looked at the most common *Sensors* that EFI systems use to monitor engine performance and the most common *Actuators* that control the engine's fuel delivery and ignition timing.

The following should, by now, be obvious:

As engine speed increases, the amount of time available to inject the fuel decreases.

The batch-fired system is injecting fuel for the entire period of crankshaft rotation. The only time allowed for the SEFI system to squirt fuel is when the intake valve is opening. To compensate, SEFI systems must have larger injectors to achieve the engine's rated horsepower. Also, air velocity is low in the port and runner until well after the valve is open. If the injection pulse starts early and finishes late to compensate, then we have lost the fine-tuning advantage that SEFI provides in a less performance-oriented engine. On a high revving engine, a scant few milliseconds are all that's available to inject fuel before the next cycle begins.

With batch injection, fuel is squirted at the back of a closed intake valve at least once per cycle. Most *Batch Injection* systems are actually *Bank Injection* (sometimes called *Group Injection*), where the cylinders are divided into two or four *Banks*, depending on the firing order (that is, during the first cycle, one bank is fired. During the next cycle, the next bank is fired). As engine speed increases, the time that the fuel sits in the port shortens, so this action has little bearing on wide open throttle performance. In reality, there is little difference in fuel economy between the two systems, although emissions at part throttle are better with SEFI, but this is what it was developed for in the first place. To be perfectly candid, performance applications of EFI disregard emissions in the same manner that we disregarded them with carbs. When you bolt a tunnel ram to that V8 and run a half inch cam, you aren't doing it to get fuel economy! However, converting to EFI, even for the wildest engine, means lower emissions across the rev range of the engine, so we can still get a warm, fuzzy feeling between bursts of 12 second passes. Remember also that if your car is not equipped with a catalytic converter, it will be difficult (but not impossible) to reach today's emissions standards anyway.

In Part 1, we said that batch systems are far less complicated from a software and hardware standpoint. It stands to reason, then, that the engine management systems will be less expensive to purchase and easier to program. SEFI systems require timing input to the ECU either derived from a *Camshaft Position Sensor* and/or from multiple input signals from the *Crankshaft Position Sensor*. Because each injector is timed, SEFI computers require a separate driver for each injector, a separate wire for each injector, stored information such as cam timing, injector response times, firing order, etc, not to mention the software to process the data. Programming the ECU will require higher levels of computing skills so that all these aspects, which inter-relate to each other, can be brought together.

Programmable Engine Management Systems

Manufacturers of after-market engine management systems have vastly simplified the programming of the ECUs so that even a trained monkey can install, wire, and program the most sophisticated SEFI systems. They are usually constructed for multiple configurations, and can be set up as batch, bank, sequential or Alpha-N (or *TPS Mode*). They can also be speed density or mass air. You can set it up for mild, economical grocery-getter or as an all out race car. This means you are paying for a sophisticated SEFI engine management system even though you only want to run it in batch mode. The software that drives the system is designed to be as intuitive and user-friendly as possible, and it accomplishes this by only providing tuning for a set number of engine parameters. Compared to factory EMS like the GM TPI or Ford EEC systems which control something like 300 maps, the programmable EMS may only control 20 maps.

There are a myriad of non-factory programmable *Engine Management Systems* to choose from. All of the ones listed at the end of this section provide some means of programming from a hand held device or a laptop. A degree of computer literacy is required. While the programming has been considerably simplified, it means that the overall control of the engine is going to be fairly basic compared to factory systems. If simplicity and ease of programming are major issues for you, an aftermarket programmable EMS may be the answer.

The most common programmable EMSs are Halltech, Motec, Hawk and 3D. There are many others, like SDS, Electromotive, FAST, but to detail all of them would take too much time, however, one Australian company deserves a special mention. The EM1/EM2 Programmable Engine Management System from Injec Racing Developments in Victoria will handle any engine you care to build, blown or unblown, while at the same time offering a simple programming solution in the form of a hand held controller. Contact details are available at the end of this article.

Hot Rodding a Factory EMS

OEM computers are built for specific engines and programmed for specific applications. You can't just grab the first computer you find in a wrecking yard and wire it in to your 351 Ford powered 36 Coupe or your 390 Cadillac powered Hi Boy roadster. It would be cheaper, though, wouldn't it? After all, factory EMS units control many more engine parameters than after market programmable ECUs. Unfortunately, most factory ECUs are designed for a specific mass produced engine, and the only sure way to ensure your engine will work using a factory EMS is to keep the engine and transmission exactly as it came from the donor vehicle. A factory EMS will not, as a general rule, tolerate engine modifications. It may still work, but not as efficiently. For us Hot Rodders, factory EMS salvation comes in the form of an Australian software company whose founder is a performance car enthusiast. Ken Young wrote and designed Kalmaker, the software used by many operators, including Castle Auto Electrics, to re-program the common or garden VP Commodore ECU. Alan Gibbs is the main distributor of Kalmaker, and his website is full of practical information:

http://www.kalmaker.com.au/

Kalmaker have designed and written software that "talks" to the GM AC Delco computer, referred to as type 808, used on VN and VP Commodores, Camiras and Astras. Other computers include the GM Delco 1986 – 1989 USA version for Chev TPI.[3] In Australia, the 1987 to 1996 Delco

[3] See my book, the Small Block Chev TPI System.

computers are all candidates for Kalmaker. For part numbers, identification details and applications, see the list at the end of this article. The good news is that these cheap, plentiful computers can be customised for any engine and any application – from street use to drag racing – simply by hooking a laptop computer to it and changing a few values. You save the values just like you'd save any computer file and then drive away.

So what does a rodder have to do to get a Commodore ECU re-programmed? You don't need to go and buy Kalmaker, you only need to buy the Commodore computer. Just visit one of their certified dealers with your car, tell them the specs and leave them to it. The tuner hooks up his own Kalmaker ECU to your engine (after unplugging your unit). This is called the "*Real Time ECU*", and is basically the standard Commodore ECU with a re-programmable chip in place of the factory chip. The *Real Time ECU* is also connected to a laptop computer, which runs the Kalmaker software. Kalmaker comes with many different configurations. The tuner loads one that looks close to your specifications to get the engine started, then, using the laptop computer, he takes the engine through its paces, from idle through cruise and then at WOT, making corrections all the way. If a Dyno is involved, it's possible to squeeze every ounce of horsepower available from your engine, but this kind of fine-tuning is usually unnecessary. By making a few runs up and down the road, the Kalmaker software can be tuned specifically to your engine. All modifications such as cam, compression, air-flow (ie, exhaust/intake porting), ignition, gears (transmission, diff and tyre size) etc are applied to the *Real Time ECU* and the engine data (known as *Maps*) updated to take the modifications into account. You can tune your engine for grunt, cruising or economy, but the best feature of this system is the *Lean Cruise* mode, where you tune for a smooth idle, economy at cruise and **grunt** at WOT. Wild cams that couldn't possibly idle under 1,000 rpm will now calmly rumble away at 600 rpm. Try THAT with carbs!

When the engine is humming nicely, the Kalmaker tuner switches everything off except the laptop and "burns" your engine's new configuration on to an *Electrically Erasable Programmable Read Only Memory* (EEPROM) chip and plugs it into your stock ECM in place of the factory chip. He then removes the Kalmaker *Real Time ECU* and puts yours back in its place, complete with its new configuration.

It's that easy.

If you are a bit of a boffin, then you might want to invest in the Kalmaker ECU so you can tune your own engine and leave the *Real Time ECU* in place.

Next: In **Part 4, Converting to EFI**, we examine a couple of case studies. We look at some examples of Hot Rod style EFI conversions such as multi-carb adaptations, tunnel ram adaptations, blower configurations and an appropriate computer. We look at programming the computer, general wiring and combating *Electro Magnetic Interference* (EMI) and *Radio Frequency Interference* (RFI).

Appendix to Part 3

List of Abbreviations	
Abbreviation	**Definition**
A/F	Air fuel Ratio. Expressed in mass. 14.7 parts air to 1 part fuel is "stoich", the point at which, ideally, all of the fuel and all of the oxygen are consumed, with none left over. Less than 14.7 is rich, greater than 14.7 is lean
A/C	Air conditioning

ABDC	After Bottom Dead Center
ABS	Anti-Lock Braking System
AC	Alternating Current
AE	Acceleration Enrichment. Similar to the accelerator pump on a carb. Additional fuel is injected for rapid throttle openings, or rapid decreases in MAP. Compensates for sensor lag, and also for fuel condensing out of the air when MAP decreases. Less AE is used on dry manifold (port injected) applications.
AFR	Air Fuel Ratio
AIR	Air Injection Reaction
AIT	Air Intake Temp
ALCL	Assembly line communications link. This is the serial line over which scan tools communicate with the GM ECM/PCM. Trouble codes are available, as well as various engine parameters.
ALDL	Assembly Line Diagnostic Link. See ALCL.
Async	Fuel delivery Asynchronous to engine timing
AT	Automatic Transmission
ATDC	After Top Dead Center
AWG	American Wire Gauge
Baro	Barometric Pressure
BBDC	Before Bottom Dead Center
BCM	Body Control Module
BLM	Block Learn Multiplier. Part of the self tuning capability of the ECM. An ECM typically has a table of BLM values, indexed by MAP and RPM. When the engine is in closed loop mode, the O2 sensor is monitored and fuel is either added or subtracted to maintain 14.7:1. Over time these changes accumulate in the BLM table.
BPW	Base Pulse Width
BTU	British Thermal Units
C	Celsius
C/L	Closed Loop
C3	GM ECM using Motorola 68xx-like processor (1+ MHz CPU)
CCP	Controlled Canister Purge
CEL	Check engine light (see MIL, SES)
CID	Cubic Inch Displacement
CKP	Crankshaft position sensor
CMP	Camshaft position sensor
CP	Canister Purge
CPU	Central Processor Unit(the brains in the ecm)
CTS	Coolant Temp Sensor
DB	Decibels
DC	Duty Cycle On time, compared to total event time expressed as a percent
DC	Direct Current
DE	Decel Enleanment
DFCO	Deceleration Fuel Cut Off
DIS	Distributorless Ignition System
DVM	Digital Multi Meter
ECM	Engine Control Module
ECT	Engine Coolant Temp
ECU	Engine Control Unit
EFI	Electronic Fuel Injection
EGR	Exhaust Gas Recirculation

EGT	Exhaust Gas Temp
EPROM	Erasable Programmable Read Only Memory
ESC	Electronic Spark Control (Knock Control)
EST	Electronic Spark Timing
F	Fahrenheit
FED	Federal (emissions package)
GPS	Grams per sec
hego	Heated exhaust gas oxygen
HEI	High Energy Ignition
HO2S	Heated o2 sensor
I/O	Input/Output
IAC	Idle Air Control
IAT	Intake Air Temp
IC	Integrated Circuit
ICE	Internal Combustion engine
IGN	Ignition
IOT	Injector On Time. Time in milliseconds that an injector is on.
INT	Integrator
IPW	Injector Pulse Width
IS	Idle Speed
ISC	Idle Speed Control
kapwr	Keep alive power
kg	Kilogram
Kilohertz	(1,000 cycles / sec)
kPa	Kilopascals (Pressure)
KS	Knock Sensor
L	Litre (about 60 cubic inches)
LCD	Liquid Crystal Display
MAF	Mass Air Flow
MAP	Manifold Absolute Pressure
MAT	Manifold Air Temp
MDP	Manifold differential Pressure
MEMCAL	Memory Calibration Unit
MFI	Multi-port Injection
MIL	Malfunction Indicator Lamp (see CEL, SES)
MT	Manual Transmission
NC	Normally Closed
NEU	Neutral
NO	Normally Open
NPTC	National Pipe thread Course
NTPF	National Pipe Thread Fine
O2	Sensor for detecting rich lean exhaust mixtures.
OBD2	On Board Diagnostics, newer vehicle electronics, US standard.
OL	Open Loop
OTS	Oil Temp Sensor
P/N	Park neutral switch
P+H	Peak and Hold. High initial voltage to open then lower to keep it open
P4	GM ECM using early Motorola 68HCxx-like processor (2+ MHz CPU)
PCM	Powertrain Control Module (engine and trans control)
PE	Power Enrichment
MPFI,	Multi Port, or Multi Point Fuel Injection, each cyl has its own injector close to the intake valve
PS	Power steering
PSI	Pounds per square inch
PSIA	PSI absolute
PSIG	PSI Gauge
PW	Pulse Width

PWM	Pulse Width Modulation
QT	Quart
R-12	Refrigerant
RAM	Random Access Memory
RAP	Retained Accessory Power
RFI	Radio Frequency Interference
ROM	Read Only Memory
RR	Right Rear
RTV	Room Temperature Vulcanizing
RWD	Rear wheel drive
SEFI	Sequential Electronic Fuel Injection
SES	Service Engine Soon (see MIL, CEL)
SI	Saturated Injector *constant* voltage / current
SynchPulse	Fuel PW with delivery tied to timing of ref pulses
TAC	Thermostatic Air Cleaner
TB	Throttle Body
TBI	Injection system where the injectors are mounted above the butterflies
TCC	Torque Converter Clutch
TCM	Transmission Control Module
TDC	Top Dead Centre
TFT	Trans fluid temp
TH	Turbo-Hydramatic
TPI	Tuned Port Injection
TPS	Throttle Position Sensor
TRC	Throttle Return Control
TTS	Trans Temp Sensor
TV	Throttle Valve
TVS	Thermal Vacuum Switch
VATS	Vehicle Anti Theft System
VE	Volumetric Efficiency
VSS	Vehicle Speed Sensor
WBO2	Wide Band O2 sensor. This sensor differs from the O2 in so far that it is designed for a *linear* output
WG	Waste Gate
WOT	Wide Open Throttle