Electronic Fuel Injection for Hot Rods

Part 1 - The Basics

While doing some internet/email research into a new book, I kept coming across discussions, stories and anecdotes about the way computer technology has "invaded" the Hot Rodding fraternity. By reading between the lines, I could see that the problem was a lack of understanding of the way modern engines use computer technology to increase engine efficiency (which translates to reliable horsepower). Even more cutting was the way many "traditional" rodders viewed the fast four and rotary fraternity, who talk about gigabytes, chips and injectors as opposed to torque, cams and carbies. It may come as a surprise to many that today's engines are the same as yesterday's. What has changed is the way we feed them! As a result, I have compiled a series of articles that are intended to describe, in true Hot Rodding terms, what has happened to engines since carbies and points have died. In so doing, I intend to show, with clear and easy-to-understand text, how we can cash in on the now abundant range of new, clean and efficient power plants without compromising our Hot Rodding roots. Better still, I can show you how easy it is to convert from carbs and points to injectors and electronic ignition, what you need to do it and where to go to get it.
The news is all good!

First of all, let's just clear the air (no pun intended) of a couple of issues. I do not subscribe to the scams perpetrated by oil companies and (well meaning) environmentalists, that our modified cars are gross pollutants. A well tuned, well maintained V8 carbureted engine will emit as much pollution (in fact, probably less) as an average five year old car. That's because catalytic converters have a life span of about 4 – 5 years – after that, they allow some pretty gross stuff to leak from our exhausts, far nastier than the lead that governments had us believing would kill us all![1] We also know that the "ozone holes" of a few years ago is a scam, and that what was happening over the poles was a naturally occurring phenomenon[2]. Having said that, there is still a lot of junk in the atmosphere that is gradually being reduced through the application of sensible, realistic and scientifically endorsed methods.
Like electronic fuel injection. (EFI).

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1 "Hushed Up Dangers", Explore, Vol 5, No 5/6, 1994.
S. Grose, "Choose Your Poison", Canberra Times, March 26, 1994.
"Scientists Debate Carcinogenic Risk of Cars", Australian, August 13, 1994.
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C. Simons, "The Lies of Unleaded Petrol", Nexus, April/May, June/July 1995.
P. Sawyer, Green Hoax Effect, Groupacumen Publications, Victoria, 1990.
http://www.greenleft.org.au/back/1995/198/198p11.htm

2 http://www.despatch.cth.com.au/Books_D/environ1.htm
P. Sawyer, Green Hoax Effect, Groupacumen Publications, Victoria, 1990

What Is EFI?

Fuel Injection itself is not new. It has been used on street driven cars since the thirties. There are plenty of historical books around on the subject, so we won't dwell on that here. However, let's just remind ourselves of the basics of fuel injection:

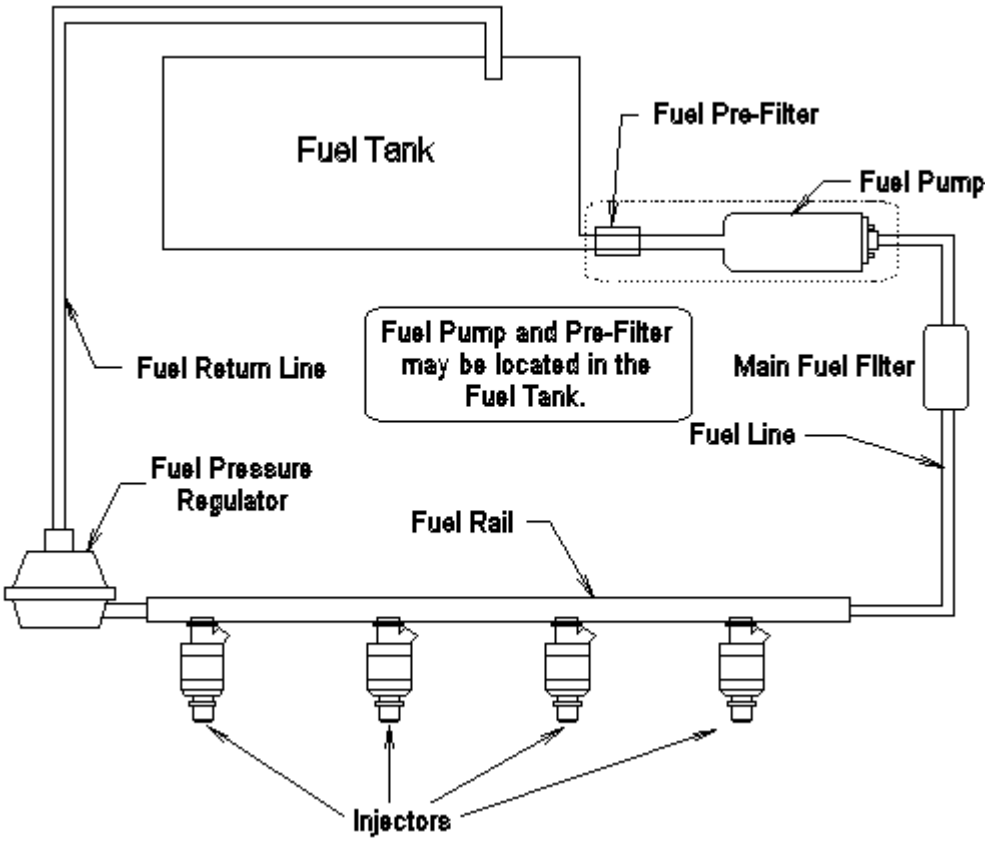

Figure 1 - Basic Fuel Injection Diagram

Fuel Tank. It's just a fuel tank. It should be baffled to prevent fuel sloshing around which can cause fuel starvation.
Fuel Filter. A Fuel Injection fuel pump is a positive displacement pump. Gunk from dirty fuel can stall, and eventually destroy the pump. A "pre-filter" prevents foreign matter from entering the fuel pump and a good quality, canister type fuel filter should be used after the fuel pump.
Fuel Pump. A high-pressure pump (usually 45 – 60 psi) supplies fuel to the injectors..
Fuel Line. Transports the fuel from the pump to the fuel rail. Due to the high pressure involved, steel and high pressure flexible line are required.
Fuel Rail. A small fuel manifold which distributes fuel to the injectors in a straight line. Because fuel injectors "pulse" (open and close) a fuel rail is required to contain the pulsing fuel.
Injectors. Electrically operated valves which, when open, allow fuel to be injected into the engine under high pressure. Fuel Injectors are connected to the fuel rail via a clip and 'O' ring which has to contain the high pressure within the fuel system.
Fuel Pressure Regulator. Maintains a constant pressure to the injectors, depending on injector size and engine demand. It also returns excess fuel to the Fuel Tank
Fuel Return Line. Bleeds excess fuel back to the fuel tank.

Now most rodders will cringe at the thought, but EFI is the best thing that's happened to the V8 engine since the flathead rolled out of Detroit!
Why?
Because computer technology has made real time combustion and timing control a reality. What's more, the technology has progressed so far now that, like VCRs, DVDs and home computers, the

prices have dropped to the point where we can all have one!
EFI is the combination of Fuel Injection, electronic ignition and a computer. The basic engine is the same, it's just that the fuel is squirted into the engine by an electrically operated *Injector*, as opposed to being *sucked* in through a carburetor, in one of two broadly described methods.

- Throttle Body Injection (TBI)
- Multi-Point Injection (MPI)

Throttle Body Injection.

The first mass produced EFI engines were of this design, and were virtually a replacement of the carb. Put simply, it is a *Wet Manifold* method of fuel injection. The *Throttle Body* (in much the same manner as a carburetor) lets air into the intake manifold and the Injectors squirt the fuel into the manifold at the base of the throttle body. The air and fuel combine and the mixture is distributed to the cylinders via the intake runners in the same manner as a carburetor. Also called *Central Fuel Injection* (CFI), this form of fuel injection is not as efficient as *Multi Point Injection*, but is still far better than a carb, as the amount of fuel and air is constantly maintained at an optimum ratio across the rev range.

Multi-Point Injection.

This method (also known as *Multi-Port Injection*) squirts the fuel directly at the base of each intake valve. The *Throttle Body* carries out the same function as TBI (regulates the air that enters the engine) but only air travels through the intake runners, and is, therefore, called a *Dry Manifold* system. This is arguably the better of the two EFI systems, and is the focus of these articles. It is more complex and more expensive than TBI, but the advantages will be evident as you gain an insight to the way it works. For now, remember this:

- *Dry Inlet Manifold*. Higher inlet flow rates are achievable with a dry inlet manifold. The fuel and air don't mix together on their way through the manifold - this occurs right at the very end.
- *Equal Distribution of Fuel*. The Air/Fuel mixture to each cylinder is consistent. This also means higher compression ratios are available (just remember that petrol from the pump may be unsuitable for anything over 10:1 compression).
- *Accurate Distribution of Fuel*. At any given RPM and engine load, every cylinder gets the optimum amount of air and fuel which will squeeze out the highest horsepower.

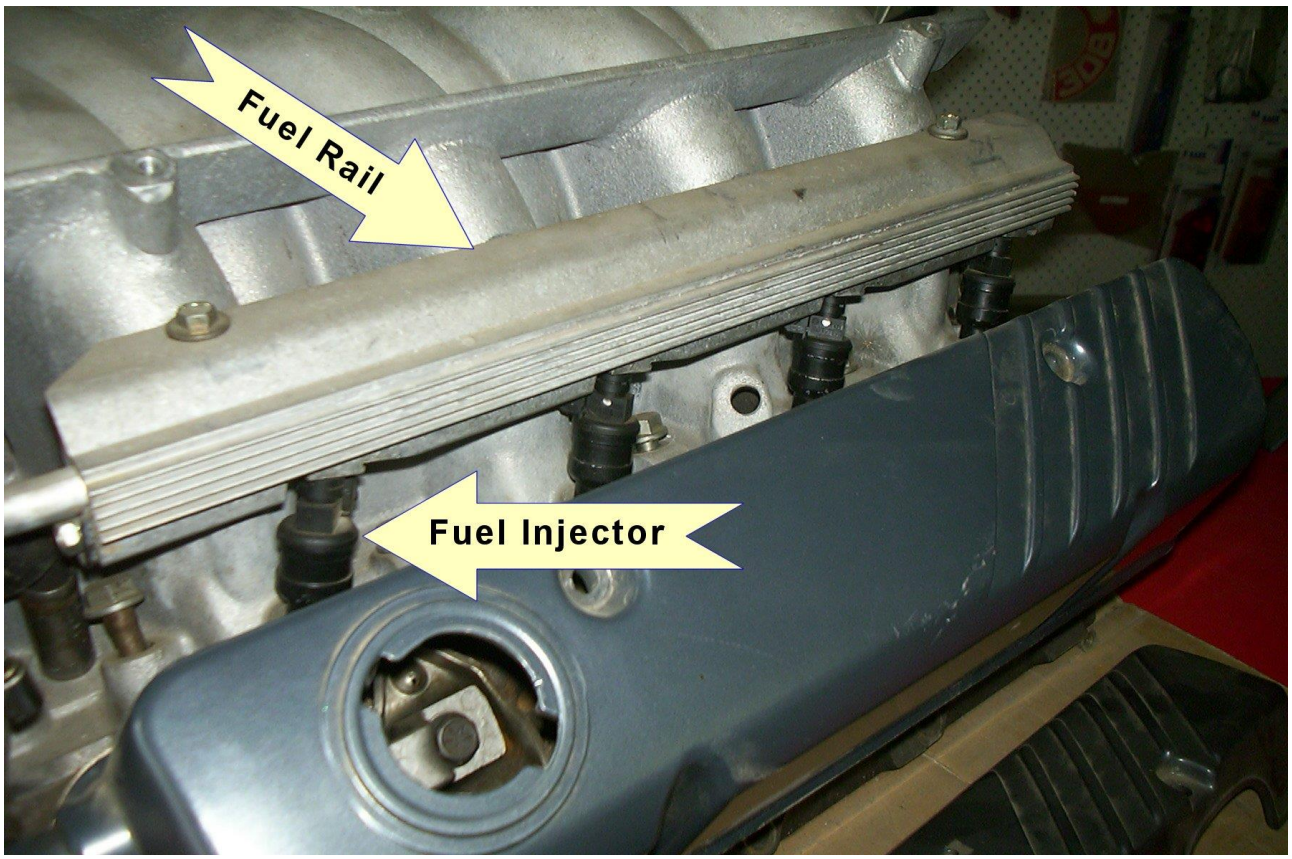

Figure 2 - Holden SFI V8. Photo courtesy of CJs Holden Spares, Queanbeyan NSW.

Fuel Delivery

Multi Point Injection (MPI) systems deliver the fuel in one of two ways:

- Batch Injection
- Sequential Injection

Batch Injection.

Sometimes called *Bank Injection*, the injectors squirt in Batches. An injection event takes place simultaneously during each crankshaft revolution. During the first of two revolutions that complete a firing sequence, fuel is injected at the base of the intake valve while it is still closed. The second injection is sprayed into the airstream entering the chamber while the valve is open.

Sequential Injection.

A more sophisticated version, the injector squirts fuel ONLY when the intake valve is opening. If the Engine Management System knows the relative position of each cylinder during the engine's cycle (by a signal from the Camshaft Position Sensor) then it can fire the injectors at the optimum time for that cylinder.

Batch vs Sequential Injection

There are advantages and disadvantages with both these systems. Batch Injection, obviously, uses more fuel, but makes use of it because fuel is already present and in vapour form at the intake stroke. It also requires far less sophisticated electronics, as the ECU only needs to provide two injection events per cycle, while *Sequential Fuel Injection* (SFI) requires eight (for a V8). On the other hand, SFI has the advantage of very fine tuning and fast throttle response. If the driver makes a sudden change (like tromps on the GO pedal) the engine reacts as soon as the next intake valve opens. With Batch Injection, the engine must go through a full cycle, as most of the intake valves

will be closed when the computer responds to the change. Regardless, Batch Injection systems have proven very satisfactory and have the advantage of simplicity. A SFI system needs a *Crankshaft Position Sensor* to trigger injection sequences. Batch Injection only needs a pulse from the ignition system such as a tachometer output pulse from an MSD box, to time fuel injection sequences.

Engine Management Systems

A computer controls the opening and closing of the injectors. It also maintains the optimum fuel:air ratio and ignition timing by measuring the amount of air the engine is sucking, the amount of oxygen in the exhaust, the position of the throttle, the position of the crankshaft and, depending on the sophistication of the system, a number of other engine parameters. The process and the components are known as the *Engine Management System* (EMS) and will be described in detail in upcoming articles.

Putting EFI and EMS to Work

My own project is a 36 Plymouth coupe powered by a 360 Chrysler with a tunnel ram. Big deal. HOWEVER….It's also got a home built engine management system and the most expensive part was drilling the holes in the tunnel ram for the injectors. The throttle bodies are a couple of worn out 450 Holley carbs which I simply gutted of boosters, fuel bowls and floats, then joined the primaries and secondaries together (I couldn't find mechanical secondary Holleys of that size). I could have used a couple of adapters and bolted 4 commodore V6 throttle bodies, but the twin Holleys just look too "traditional" to pass up.
I assembled my own computer (a Megasquirt batch injection computer, available from the internet for $AU150[3]) and use a MSD 6AL controller, Blaster coil and Flying Magnet Crank Trigger ignition for the fire (the second most expensive item).

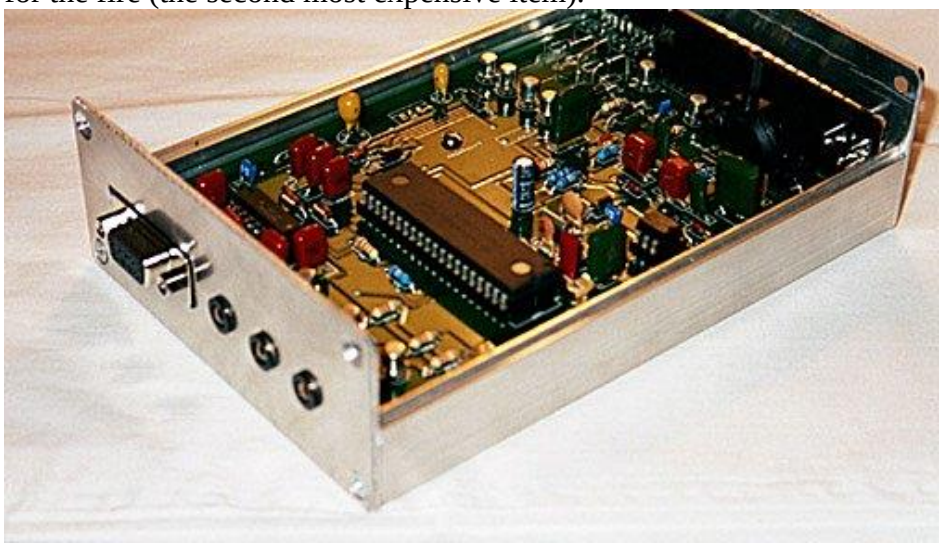

Figure 3 - Megasquiret Computer. You build it yourself for the cost of the components, but there are plenty of off-the-shelf EFI computers manufactured in Australia and the US that will suit a variety of applications.

Now, I really wanted to convert a stack injector – you know, the Hilborn/Enderle mechanical injection used on dragsters from the late 50s and still used today. But I couldn't find one for my Mopar. The sight of eight ram tubes and that fancy plumbing just looks the part, but mechanical, "constant flow" injection just isn't going to cut it on a street driven car (well, it will if you control it with a computer). This kind of fuel injection is known as *Constant Flow*. The fuel pump is mechanically driven by the crankshaft and maintains pressure to the *Barrel Valve,* which distributes fuel at high pressure to each injector. The *Barrel Valve* also contains the *Pill*, which senses the engine's demand and adjusts the flow in concert with the opening of the butterflies in the ram tubes.

3 http://www.bgsoflex.com/megasquirt.html

A return line re-directs the unrequired fuel to the fuel tank. This method is fine for flat out drag racing or marine applications only, but swap the constant flow injectors for some modern, pintle type Bosch units, install a few sensors and an off the shelf Engine Control Unit (ECU, or computer) and the entire setup will work as a modern EFI installation.
How about doing the same thing to a flathead? Mike Davidson[4] has been doing it for years, but if you want the "nostalgia" look, use a tri-carb setup, only use the carbs to control the amount of air that enters the engine - that's what *Throttle Bodies* do.

Figure 4 - Mike Davidson's (Flat Attack Racing) Hilborn style flathead EFI conversion

Young kids of today hop up their fast fours and rotaries by replacing chips, throttle bodies and ECUs. Body kits, fluro paint and rubber band tyres are their custom applications that may or may not sit well with us "old timers" but take a look at the ease with which they apply modern technology, and it's not hard to see where we can learn a few tricks of our own.
Engine Management is simply the total control of our fuel/air ratio and timing while the engine is idling or at wide open throttle. Imagine being able to instantly adjust the jets, float level and accelerator fuel pump on your 4 barrel carb as you jump on the accelerator. Or imagine re-dialing an advance curve on your distributor every meter of the way up the dragstrip. The simplest systems enable us to do this with ease, and I'm here to tell you your old, carby-equipped small and big block Chev, Ford or Mopar V8 can be converted easily and the result is amazing!
But it doesn't stop there!
How about a blown, injected big block that gets reasonable mileage and idles like it belongs on the street? How about adding nitrous to that, and not worry about high speed leanout or pinging?

4 http://www.flatattackracing.com/

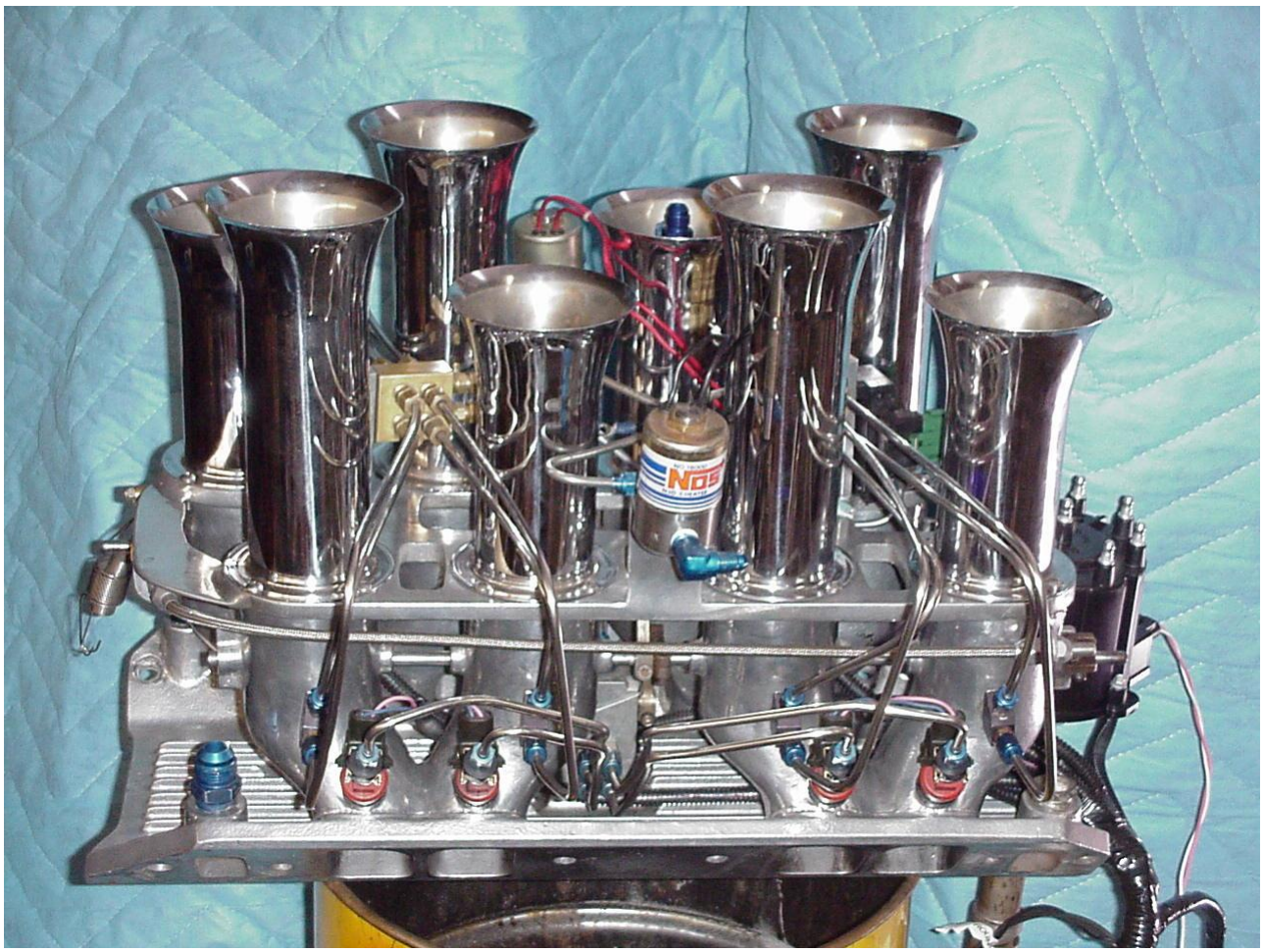

Figure 5 - Big Block Chev stack injector, with nitrous injection, that will work beautifully on the street. Idle, cruise and WOT is controlled by the ECU, as is the nitrous. Photo courtesy of Jim's Performance.[5]

There are off the shelf ECUs that cost under $1,000 that can handle 16 injectors AND nitrous AND boost AND cold starts, AND idle speed.
Excited?
Today's hot rod engines are aluminium, small displacement V8s that make more horsepower than a pre-TPI SBC ever will, and you can blow dry your hair with the exhaust. You'll see more quad-cam Toyota V8s in 32 Fords and Hi boys these days, not to mention the flood of aluminium small block Chev and Ford V8s and V10s. Viper engines and crate hemis are still a little expensive, but in the meantime, start hunting for oxygen sensors, knock sensors, manifold absolute pressure sensors, ECUs and injectors – you're gonna need them!

Next issue: **Part 2, Controlling Fuel and Ignition**. We find out what *Sensors* and *Actuators* are, what *Mass Air Flow* and *Speed Density* means. We learn how to control an injected engine at idle, cruise and WOT, as well as how to handle cold starts (no, you don't pull out the choke!). We also find out about ignition control.

Part 3, The Engine Control Unit, explores the vast mysteries of the EFI computer. We find out how to choose the best one for your project, what you need, how much it costs, where you can go to get it, how to wire it up and connect it to the sensors and actuators.

Finally, 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 adaptions, tunnel ram adaptions,

[5] www.jimsperformance.com

blower configurations and how to choose an appropriate computer. We look at programming the computer, general wiring and combatting *Electro Magnetic Interference* (EMI) and *Radio Frequency Interference* (RFI).