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How to Build a GM EFI System

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INTRODUCTION

This document describes how to build a GM Fuel Injection system from commonly available GM EFI parts found in junkyards and on Ebay. If you are resourceful in acquiring your parts, you can build a GM EFI system for about the same cost as a new carburetor. From my experience, there are four critical issues to solve when retrofitting GM EFI to any other vehicle. Those issues are ignition, fuel delivery, electronics, and software. In the following pages, I will explain the tips and tricks you will need to get a GM EFI system working on just about any vehicle.

One of the common misconceptions is that just bolting the EFI hardware on to any similar size engine will allow the system to work just as it did on the donor vehicle. This is far from the truth. The fact is that most GM EFI engines of the late 80s and early 90s were much improved engine designs over the 50's, 60's, and 70's designs that this book was intended for. Modern engines have more efficient cylinder heads with higher volumetric efficiency. This means that for a given vacuum reading, a modern engine will take in more air than an older engine. Since the chip is programmed to deliver fuel to match the ingested air at that given vacuum reading, most factory GM calibration chips will run too rich on older engines. Also, since modern heads produce more turbulence for good mixing of the air and fuel, there is no need for large amounts of spark advance. This means that the spark advance tables from a typical GM calibration are way too late to run an early model engine. I typically have to lower the fuel tables and raise the spark timing on my EFI retrofit kits. The purpose of stating this in the introduction is to emphasize the importance of reprogramming the EPROM chip in the GM ECM. If you don't do that, you might as well keep your carburetor. It will run better.

My suggestion on the use of this manual is to read the software section first so that you can decide if re-tuning the chip is beyond your abilities. It's not hard, just a lot of tedious detail. If you don't think you want to tackle that section, you may want to consider having someone else build the EFI kit for you. If you are thinking that maybe you can build everything else and then let someone else do the chip for you, that is not a good idea either. Getting someone else to do the chip is a risky situation. Doing the chip right takes a lot of time for someone that doesn't know your system intimately, and most chip tuners can't put in the needed effort for what you will want to pay them. Besides, for less than the cost of paying someone else to do your chip, you can buy the tools to make it yourself, and you will have much more fun doing it.

This manual covers GM EFI systems between the years 1985 and 1995. These systems are the easiest to retrofit onto older vehicles. This manual does not cover the LT-1 or later GM engines that used sequential EFI systems without distributors. The reasons for my position on this are found on my web site.

This manual is a continuous work in progress. When you receive the manual, email my site at John@customefis.com and ask for a Username and Password to gain access to updates to the manual.

IGNITION

The first task to accomplish is to get a GM ECM to control the ignition timing. This task is critical not because you have to control timing with the ECM, but because the communications from the GM ignition module to the ECM are absolutely necessary for the ECM to begin controlling fuel. Fortunately, this is a relatively easy task as long as you already have an electronic distributor with a magnetic pickup. There are two different styles of ignition modules you can use. I'll call them the Corvette style and the Camaro style (also called a 7-pin and an 8-pin module respectively). The Corvette style is the best to use when converting a GM HEI non-computer distributor to computer control because the ignition module is mounted inside the distributor cap and gives a factory look. The Camaro style is the best to use on a non-GM distributor because the connectors are weatherproof and have a good seal from the elements. For those considering using a stock GM Camaro-style small-cap external coil distributor for your project, you may want to reconsider. I receive a lot of these distributors in the used systems I buy and they are usually corroded beyond repair. Occasionally I'll get a decent looking one, but for the most part, they wear out much faster than the large coil in cap HEI Corvette style. When I build a kit for a customer, I provide the appropriate connector to match the ignition module style chosen. The following sections provide instructions for converting your distributor to GM EFI computer control.

GM HEI DISTRIBUTOR CONVERSION TO COMPUTER CONTROL

This section describes how to modify a GM HEI non-computer distributor such that a GM EFI ECM can completely control the ignition timing. This conversion is the cleanest since the ignition module is mounted inside the distributor for a factory installed look. The first step is to buy an ignition module for a 1985 Corvette or any other GM computer controlled distributor with the large coil in cap HEI style distributor (You can also buy a 1985 Corvette magnetic pickup coil and get a better installation, but this is optional). Remove the cap and rotor on your distributor and then remove the non-computer ignition module and the power connector and noise suppressor condenser. Once these parts are removed, look for the magnetic pickup wires. They are green and white. If you elect to reuse the existing pickup coil, cut the plastic connector off the wires at the connector leaving as much wire as possible. Then solder a 1/8" female spade terminal on the end of both wires (See Figure 1).

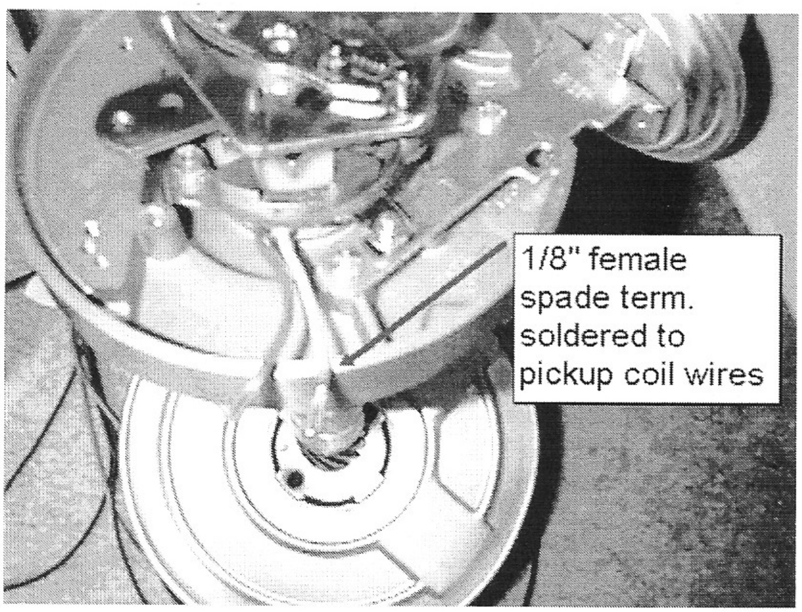

Figure 1

After the solder cools, cover the terminals with heat shrink tubing. If you bought the new Corvette pickup coil, install it instead of soldering terminals on the old pickup. This requires removing the distributor shaft though so its not nearly as easy. Next, take your new computer controlled Corvette ignition module and file or break off the locating pins on the bottom of the module. These will interfere with the proper seating of the module for heat dissipation. Be sure to spread the heat conducting paste on the bottom of the ignition module before installing it permanently. Next, connect the power connector/condenser to the Corvette module and test the fit. The connector will have to be partially pushed onto the module. If it is pushed all the way on, the module won't fit in the distributor housing such that the screws line up (See Figure 2).

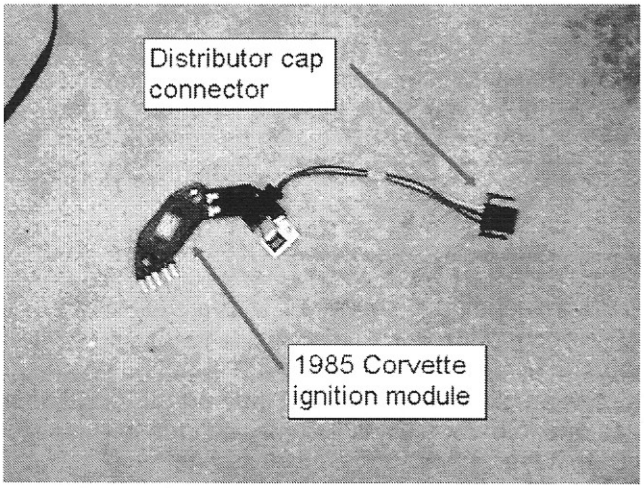

Figure 2

Now that you have the ignition module connected to the power connector, temporarily install it so that one screw hole lines up. The other hole in the module will not line up so you'll have to drill and tap the hole yourself. I don't recommend using just one hole since the module needs to have firm contact with the distributor housing for heat dissipation. (See Figure 3).

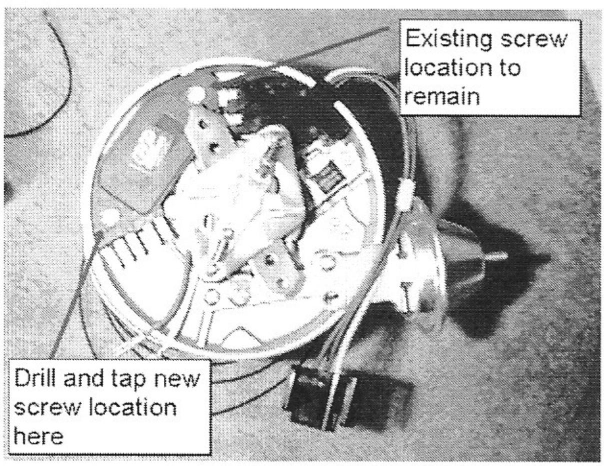

Figure 3

Once you have both screws installed, you can now connect the magnetic pickup coil wires to the module. The green wire goes to the "P" terminal and the white wire goes to the "N" terminal. (See Figure 4).

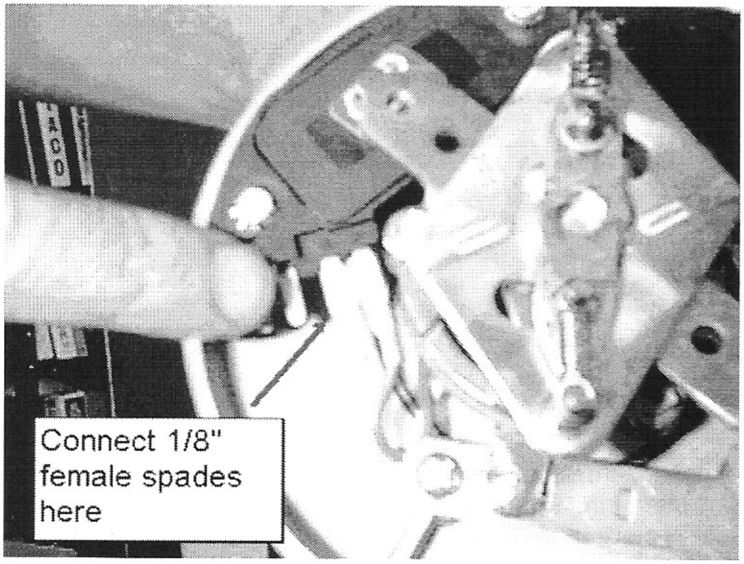

Figure 4

Next, make a harness that will connect the module to the computer. The wiring diagram is on the www.diy-efi.org web site in the incoming directory. The file name is 7pingmgif.zip. I use a 4 way shroud (as opposed to tower) Packard-Delphi Weatherpak connector with male pins, which is the factory configuration. I then solder 1/8" female spade terminals on the module end of the wires. The factory wire colors are white for the EST (E) terminal, purple/white for the timing reference HI signal (R), tan/black for the bypass signal (B), and black/red for the reference ground wire (no terminal on the Corvette module). These colors are standard on every GM distributor based EFI system made. The module terminals E, R, and B correspond to the WeatherPAK terminals A,B,C. The WeatherPAK D terminal connects to the distributor body. Beware that the ABCD terminal designations are reversed when using the 8-pin Camaro module, so pay careful attention to the correct diagram when wiring the module. The reversal has tricked me up before. (See Figures 5 and 6).

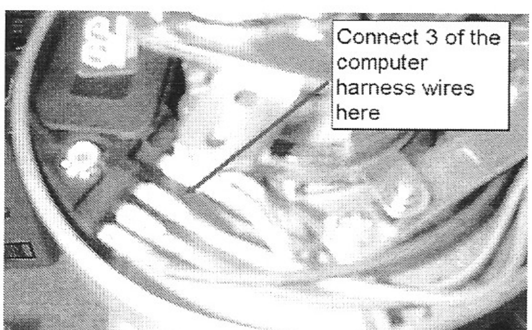

Figure 5

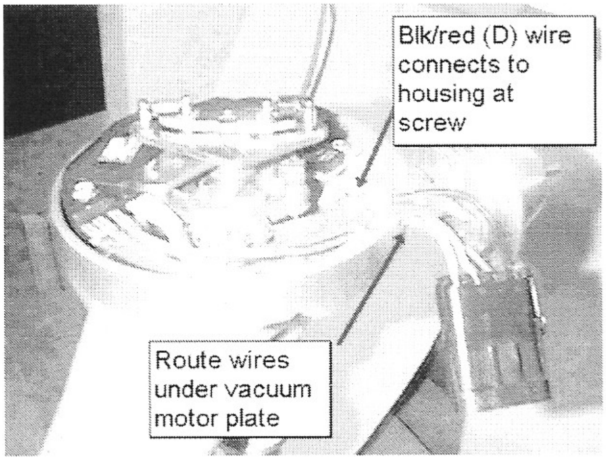

Figure 6

Now that the electrical items have been done, you need to make the mechanical modifications. Since you don't want the centrifugal advance or the vacuum advance mechanisms interfering with the computer controlled timing, you have to disable these two devices. Start by cutting a thin (1/8" thick?) piece of metal into a 1 inch long by 3/8" wide strip. Then drill two holes in the strip a little more than 5/8" apart. The diameter of the holes should match the pin diameters holding the distributor weight springs. Once you have the strip made, remove the centrifugal advance springs, the centrifugal weights, the E-clips holding the weight stop to the distributor shaft, and the weight stop. Install the metal strip you made above on one pair of pins. It doesn't matter which set of pins, either will do. Then, replace the E-clips, and the springs. The weight stop and the weights will be leftover parts. The centrifugal advance is now disabled without any damage to the distributor. As an alternate method, you can weld the reluctor shaft to the distributor shaft. Finally, to disable the vacuum advance, simply leave the vacuum line off the vacuum motor port. I recommend putting a rubber plug over the port, but you could also cut it off for a more permanent modification. If you leave the port open, an unknowing mechanic might reconnect a vacuum line to the vacuum motor and damage your engine. You have now completed the HEI computer controlled distributor conversion (See Figure 7).

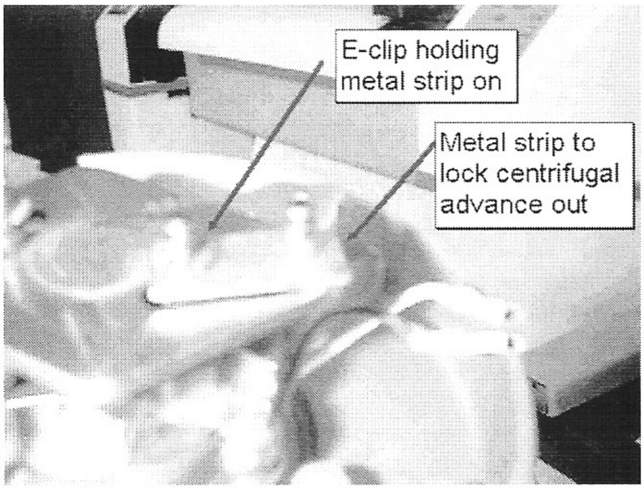

Figure 7

HOW TO CONVERT A NON-GM DISTRIBUTOR TO GM COMPUTER CONTROL

This section describes how to modify a non-GM distributor such that a GM EFI ECM can completely control the ignition timing. This conversion is only possible if your distributor currently has a magnetic pickup, so you'll need to check that first. In this conversion, the ignition module is mounted remote from the distributor so you might as well choose a mounting location that is easy to get to if you have to replace the module later. The first step is to buy an ignition module for a 1989 Chevy truck, or if doing a port injection setup, get a 1991 IROC Camaro ignition module. Next, remove the cap and rotor on your distributor and then remove the non-computer ignition module if it is mounted inside the distributor. Once these parts are removed, look for the two magnetic pickup wires. On a Ford Duraspark distributor, they are purple and orange. If you aren't sure what kind of pickup you have, look for a pointed, star shaped gizmo on the distributor shaft. The number of points on the star will match your engine's cylinders. If you have a V8, there will be 8 points. The star shaped gizmo is called a reluctor. Whenever the reluctor tips pass by the magnetic pickup, the ignition module is triggered to fire the coil, except when the module is computer controlled. In this case, the computer controls when the firing takes place. If your existing ignition module is mounted remote already, as it is on some Jeeps, it is best to mount the GM module there. Find where the magnetic pickup wires connect to your existing ignition module and cut them in a convenient place. Then solder a 1/8" female spade terminal on the end of each cut wire. After the solder cools, cover the terminals with heat shrink tubing. Next, take your new computer controlled ignition module (Figure 8) and file or break off the locating pins on the bottom of the module (or drill holes for the pins). Next, find a 6" or longer strip of metal in which to mount the ignition module and use self-drilling screws to mount the ignition module to the strip of metal. Once you have a good solid mounting spot on the metal strip for the ignition module, remove it and spread the heat conducting paste that came with the module on the back of the module. The metal strip is needed to help remove heat from the module. Now, find a place to attach the metal strip to the vehicle's body or frame and fasten it tightly. If this mounting location does not provide a good solid ground connection, then you'll need to make a ground wire and run it from the metal strip to the engine's ground terminal. This is an important step since I spent a week trying to find an intermittent misfire caused by not having a well-grounded ignition module. The module fires the coil by opening the coil's negative terminal path to ground. The ground connection is through the ignition module's metal back plate, so this plate has to be well grounded. Connect the magnetic pickup wires to the P and N terminals on the GM ignition module. For the Ford Duraspark magnetic pickup, the purple wire goes on the P terminal and the orange wire goes on the N terminal. The polarity is important and the only way I know to tell which way to hook one up is to try and check the timing with the GM module firing the coil. If you haven't disturbed the timing setting, then your timing with the GM ignition module without the computer hooked up should still be the same as it was with your original ignition module. You can check this with a timing light and by just turning the motor over with the starter. However, I'm getting ahead of myself so I'll discuss getting power to the module now. Connect a switched source of 12V power to the + terminal on the module. This 12V source has to be hot in both the start and the run ignition switch position. You'll need a special 2 pole GM Metripak connector that can be bought at most auto parts stores. On the other pin of this connector is the coil negative terminal. This terminal goes to the negative side of the ignition coil, or if you are using an MSD or Jacob's ignition, this goes to the tachometer trigger input. Finally, there is a 4 way GM Metripak terminal labeled GBRE. All pins of this connector go to the ECM. They are Ground, Bypass, Reference, and Electronic Spark Timing. The wire colors will be black/red, tan/black, purple/white, and white in all GM distributor based systems. You'll need to acquire the pin-out diagram for your particular ECM to find out where these four wires terminate at the ECM end. Once you have substituted a GM module for the stock module, you'll have to disable the centrifugal advance mechanism in your distributor. The basic task is to prevent relative movement between the reluctor shaft and the distributor shaft, either with a tack weld or some other means. On Jeep distributors, it's a simple matter of removing the centrifugal weights and reinstalling the strongest springs you can find. A better solution is to make a metal locking tab as in Figure 9 below. To disable the vacuum advance, just leave it disconnected and cut off the port on the vacuum motor just to be safe. If you don't have a magnetic pickup in your current distributor, or there isn't an electronic version of your distributor made, you might be able to install the Ford Duraspark magnetic pickup and reluctor in your distributor with some custom made brackets and some machining of the distributor shaft. These parts can be bought individually from any auto parts store. I did this on a British Lucas distributor and it turned out well (See Figure 9.) Another solution is to contact this site (www.davessmallbodyheis.com) or myself about converting your distributor if you don't want to do it yourself.

The last comment about converting distributors to electronic ignition is that you must get the rotor in phase with the distributor cap at the triggering condition. This is critical on retrofits especially or you will have misfires on the hiway due to high timing and cross firing inside the cap. To phase the rotor, line up the rotor firing tip centerline just past the distributor cap post centerline (any post will do). You must know the direction of rotation of the distributor and line up the rotor on the late side of the distributor post. You could line up the rotor and cap post exactly, but I like to set it up for just past since at WOT, the timing will be advanced 15-20 degrees and this allows the rotor to stay opposite the post under this condition. Once the rotor is positioned, you must rotate either the reluctor (if its attached to the shaft you can't rotate it and it is fixed) or the magnetic pickup so that they are in the trigger position. On my Lucas retrofit. I located the magnetic pickup first and then rotated the reluctor to match. Then I machined a groove for the reluctor to lock in place on the shaft in that position. I then used a spring to hold the timing locking tab in place.

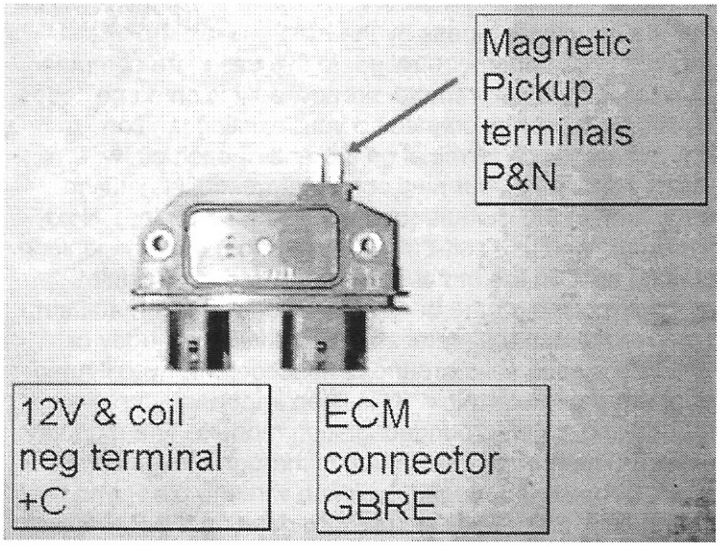

Figure 8

Figure 9

IGNITION TIPS AND TRICKS

A GM computer controlled ignition module has two modes of operation. The predominant mode is under control of the ECM such the ECM completely takes over the ignition timing. The other mode, limp home mode (failure of the ECM CPU) allows the ignition module to run the engine without being controlled by the ECM. As a matter of fact, you could reinstall a carburetor and remove the ECM and the engine would still run with a computer controlled ignition module. However, there is a catch. When the ignition module is running in limp home mode, there is a built in RPM only (no vacuum) based advance of about 11 degrees. This advance kicks in at about 2000 RPM. The ramifications of this are that you can't leave the stock centrifugal advance mechanism intact and have the ECM not control the timing (actually, there is a way and I'll explain that below). The ignition module's built in advance and the centrifugal advance will both kick in and you'll end up with way too much RPM advance. Having said this, I will now contradict myself and discuss four different methods to control ignition timing. The first 3 methods leave the stock ignition timing controls intact i.e., the centrifugal weights and the vacuum advance motor continue to function. The 4th method is just the factory method of letting the ECM completely control ignition timing, which is my preferred way.

The first method uses a special electronic circuit built from resistors and capacitors. This circuit is necessary to filter out voltage spikes that would be harmful to the ECM. The circuit connects between the coil negative terminal and the ECM's reference input pin (purple/white wire). This is the way Howell Engine Development does it on their systems in which they don't control timing via the ECM. I don't like this method because the expense of a GM ignition module is so low that you might as well do it like the factory does it and eliminate the circuit altogether. You'll then have the option of taking over the ignition timing with the ECM at a later time with a minimum of effort. The advantage of this method is that if you don't have a magnetic pickup distributor, this is a cheap way to get fuel only control to work.

UPDATE 11/17/02 - The Howell circuit that I have apparently is no good. Several DIY customers have tried it with no luck getting it to work. No worry though because I am very close to getting a circuit ready that not only will let you trigger the ECM with points, but also control the timing in a points distributor as well. Once I have this circuit finished, it will replace the method here.

The second method is to use two ignition modules and wire the magnetic pickup in parallel into both modules. The computer-controlled module then only connects to the ECM to provide a reference pulse and nothing else. The stock ignition module is left intact and continues to fire the coil normally. This method could be a viable way to keep the stock timing curves so that you can work on the fuel only control before attempting to work on the spark timing. In my opinion, this is a better method to use when you want to retain the stock distributor timing controls for emissions reasons.

The third method is to take control of the ignition timing with the ECM, but reprogram the spark timing tables in the ECM's EPROM to zero so that no action takes place. This allows the stock timing controls to continue working, but there is a drawback. If the ECM goes into limp home mode and the ignition module reverts to its built in RPM based advance, you'll get too much advance. However, since this should only be a temporary situation for tuning purposes only, this drawback isn't very significant. Another caution about this method is that the ECM has startup advance and other timing events that you may not be aware of. Even though the tables are zeroed out, this method is risky.

The last method is to disable the stock timing controls and use the ECM for all spark timing functions. What I do for a non-GM engine is reprogram the EPROM with the timing curves from a factory service manual for the vehicle in question. This gives me a good starting point. From there it's a trial and error tweaking process, if I even consider it necessary. There is probably 5-10% more power/economy hidden in the tweaking, if you have the time to spend doing it.

There is now a 5th way to control spark timing and it has some interesting uses. If you re-wire the distributor harness such that the Ref Hi signal is fed into both the ECM and the EST pin on the ignition module, the module will fire the coil immediately. This makes a computer controlled module act just like a non-computer type. The EST wire from the ECM is left unconnected and will set a code 42, so you have to disable code 42 in the EPROM. You also have to disconnect the bypass wire at the ECM end and splice the bypass wire into the 5-volt TPS reference wire. This is needed to keep the ignition module from going into limp home mode. This method allows the stock mechanical and vacuum timing controls to be left intact. The interesting use of this method is that if you have one of the newer PCM's that control the transmission, you can leave the transmission controls intact and yet install a carburetor and non-computer HEI distributor in the engine. Converting an EFI engine to carburetor while keeping the transmission control is an advanced topic. Email me for more info if this is something you want to consider.

There are four wires connecting the ECM to the ignition module. The colors are white, purple/white, tan/black, and black/red. The colors are standard for all GM EFI systems that control a distributor. The white wire is the timing signal (EST) from the ECM to the ignition module. This is what determines the ignition timing when in normal mode. The purple/white wire is the reference pulse signal (REF) from the ignition module to the ECM. This is the most important signal because this signal is how the ECM times the fuel pulses. You don't need the white wire or the tan/black wire for the ECM to control fuel, but you do need the purple/white wire. The tan/black wire is for the ECM to control when the ignition module is in limp home mode or normal mode. When the engine first starts, the ignition module runs in limp home mode for a few seconds. Once the ECM is satisfied that everything is normal, it puts 5 volts on the tan/black wire. The 5 volts signals the ignition module to begin using the ECM generated timing signal instead of the ignition module's internal timing signal. The upshot of this is that when setting the static ignition timing, you disconnect the tan/black wire so that the ECM no longer controls the ignition timing. But you must also make sure that the engine is not revving past 2000 RPM or the limp home mode advance will kick in and mess up your timing settings. An alternate way of setting the ignition timing is to disconnect the four ECM to ignition module wires altogether and use the starter to turn the engine while checking the timing with a timing light. The engine won't start since the ECM isn't getting reference pulses from the ignition module, but the ignition module will fire the coil and give you a spark.

FUEL DELIVERY

For fuel delivery, you have two choices, throttle body injection or port injection. I prefer throttle body injection for its simplicity and unless you are building a high performance (5000 RPM plus) motor, port EFI is an unnecessary expense. Throttle body injection works almost as well as port EFI on daily drivers and is much easier to install. You'll get the same gas mileage with both since they control to a 14.7 air fuel ratio. Port EFI has a tad better throttle response, but isn't worth the money in my opinion. Some EFI shops claim that port EFI makes more power than TBI or carbs because the air isn't laden down with fuel as it travels through the manifold and can therefore move faster into the engine thereby filling it better. However, I have read that carbs consistently beat port EFI in WOT drag racing. The reason stated was that fuel vaporizes in the carb bores as it enters the manifold. The vaporizing of the liquid fuel removes heat from the air stream due to the latent heat of vaporization of the gasoline. This has the effect of making the air more dense (colder air is more dense) so that the engine gets filled with cooler, denser air, with more oxygen. And oxygen with fuel is what makes power. This seems more plausible to me because, really, how much more can the gasoline vapor make the air weigh at an 11-12 air fuel ratio? I have no direct experience to weigh in with my 2 cents, but what this means is that TBI, which is basically an electronic carburetor, ought to be able to hang with port EFI in a drag race. I will admit though that port EFI would probably have better drivability on a drag racing engine than TBI because the large single plenum drag manifolds are terrible for delivering fuel and air to the engine at lower RPMs.

THROTTLE BODY INJECTION

If you decide to go with TBI, look for a GM TBI setup from any engine similar in size to the one you are working on. The 4.3L, 5.0L, and 5.7L TBIs all are the same size as far as throttle plates/bore size is concerned. They flow approximately 450 CFM, so this is the same as bolting on a large 2 bbl carb. The only difference is the injector sizes. As a basic rule, a 4.3L uses (2) 46 #/hr, a 5.0L truck uses (2) 49 #/hr, a 5.0 car uses 54 #/hr, and a 5.7L uses (2) 61 #/hr injectors. Some cop cars use 65#/hr and some heavy duty 5.7L trucks use 68 #/hr injectors. 454 TBIs use either 80 or 90 #/hr depending on the year. These flow rates were calculated from the data in the actual EPROMs associated with these injectors. These flow rates are also at the stock fuel pressure of 12 PSI. On any injector, to calculate the flow rate at a higher (or lower) PSI, use this equation: New flow = old flow x square root (new pressure/old pressure). For ex., my pumps frequently raise the pressure to 15 PSI. So a 61 #/hr injector at 15 PSI flows 61 #/hr x sqrt (15 PSI/12 PSI) = 68.2 #/hr. This is a 12% increase and makes a big difference in the power potential of this injector. You can use a larger injector for a smaller engine by reprogramming the EPROM (discussed later), but I wouldn't recommend using smaller injectors on larger engines. I sometimes install 4.3L injectors on my 5.7L engine, but only to test whether they work or not. I have to reprogram the EPROM to get it to run period. To calculate the HP of TBI injectors, take the injector flow rate X 2, X 85%, X 2 and you have the maximum recommended HP from that TBI's fuel injectors. Two 61#/hr injectors will make 207 HP based on this guide. If you cut the safety factor from 85% to 90%, then you could make 220 HP.

When buying a used TBI, the injectors are the most critical items. New ones will set you back $125 each for GM injectors or $65 each for after-market injectors. It is probably cheaper to just look for another used TBI if your injectors are bad. On the other hand, new injectors are probably good insurance. If you are cheap like me though, you can take the injector apart and clean it and usually a bad injector will come back to life. There are some spot welds on the injector nozzle. Grind these welds away just enough to remove the injector nozzle. Once the nozzle is out, all the internal parts will come out. Be careful and note the order that the parts are installed. At the very center of the injector is a solenoid core and a spring. This core corrodes after sitting unused for a while and makes the injector sluggish. All that is needed is some emery cloth to make the core smooth again and the injector will work again. I have yet to see a "dirty" TBI injector and cleaning by ultrasonic means won't get the corrosion out, so don't be duped by cleaning services. Reassemble the injector and use Loctite 271 (red) on the nozzle threads and you will have repaired your injectors. Be careful not to cross thread the nozzle and also return the nozzle to its exact position in the threads by lining up the grooves left from grinding the welds away. To test injectors, I use an Actron fuel injector and harness tester. This device pulses an injector with a one half-second pulse every time I press a button. By measuring the amount of gasoline sprayed into a graduated 10mL test tube, I can calculate the flow rate of an injector. For example I recently tested 8 TPI injectors. Each one flowed 9.1mL with four 1/2 second pulses. Doing the math showed that these injectors were flowing 26.0lb/hr at 48PSI rail-pressure. The other two items to note on a used TBI are the throttle position sensor (TPS) and the idle air control motor (IAC). TPS's rarely go bad, so they are not of too much concern. IAC motors are very prone to getting clogged with carbon deposits. I always have to remove and clean these with Gunk and a toothbrush. A sticking IAC is very annoying since it causes your idle speed to be unstable. A new after-market IAC costs $25, so it's not a problem if yours is beyond repair.

Other issues of concern on used TBIs are how your linkage will connect to the GM TBI and how to mount the TBI to your intake manifold. GM used a small pin with a groove for the throttle cable linkage. Older Jeeps use a carburetor ball stud. I buy the ball studs in bulk from a national carb repair shop, but most any auto parts store should have one. The problem is the ball size. If you can't get one that matches your carb linkage, buy one a size larger and file it down in a drill press. Once you have the right size ball stud, you'll have to remove the factory pin on the TBI linkage. I grind them out from the back with my bench grinder. The pin is made from some tough metal, so hack sawing it is too time consuming. Once the pin is out, I install the ball stud and use a Nyloc nut to hold it in. If you have an automatic transmission, you'll have to go further and make a linkage extension to mount a transmission downshift cable. I use aluminum bar and cut and drill it to match the location and radius of the carburetor trans linkage pin. Since transmission linkages differ so much from vehicle to vehicle, I'll leave it up to you figure this out. As long as the trans linkage travels the same distance and manner as it did with the carburetor linkage, you shouldn't have any problems. While you are working on the TBI, knock out the factory plug covering the idle speed screw. This screw is only used to set the absolute minimum idle speed, not the standard idle speed, which is controlled by the EPROM program. The procedure for setting this screw's minimum position is in the Appendix to this manual. However, if you have a bad IAC motor, you can set your idle speed with this screw temporarily if you fully extend the IAC motor.

As for mounting the TBI to a carb manifold, I buy 1/2" thick aluminum plate in 4' X 1' sizes. I then use a band saw and cut out the outer dimensions of the TBI adapter plate. Then I use my drill press and drill 4 corner-mounting screws with a Uni-Bit. A Uni-Bit comes in real handy for cleaning up the holes and giving a slight countersinking. I then use a 1-11/16" bi-metal hole saw and cut out the holes for the throttle body bores. This size hole saw works for all 4.3L, 5.0L, and 5.7L GM TBI sizes. After cutting the holes, I use fine emery cloth to smooth the edges of the holes. For the three bolts holding the TBI to the adapter, I drill three holes with a size G drill bit (size G came with my 5/16"-18 tap) and then tap the plate with a 5/16"-18 tap. I use an aluminum block as a guide to keep the tap perpendicular to the adapter. Once the threads are tapped, I use a hacksaw and cut three 5/16"-18 studs about 2-1/2 inches long out of threaded rod. I clean up the cut ends with a bench grinder and then use high strength Loctite 271 to hold the studs in the aluminum plate adapter. I found that using 5/16" bolts quickly strips out the soft aluminum threads. If you are wondering how I locate the holes on the adapter, I built templates from aluminum plate, one for each different manifold that I have adapted to. I created an Autocad drawing of each template. Email me if you want a copy of this drawing but you must have Autocad to read it.

To get fuel to the TBI, you'll need an electric fuel pump. I use an external fuel pump designed for mounting on the vehicle frame. The fuel pump that I buy is for a 1985 Mercury Marquis 302 V8 fuel injected engine. Be sure to ask for an external pump. Also, I prefer the Master (Airtex) E2182 model. This pump is typically $75 in my area. Another pump from Airtex, the E8094 is an external pump with a built in regulator specifically made for TBI systems but costs $150. I get a 3 PSI increase in fuel pressure using the E2182 though, and this allows me to get more power from the injectors, as explained previously. This is the exact same pump that MSD, Accel, AC-Delco and all the other EFI shops are selling for EFI systems, but at a $50 markup. I have used two of these on my trucks with no problems for two years. I have had problems with other brands, namely Borg Warner. To mount the fuel pump, I use a 2" electric conduit clamp and 3" long 5/16"-18 bolt and nyloc nut from my local builders supply store, and mount the clamp above my transmission cross-member. Then I place the pump in the clamp with the rubber strip (comes with the pump) around the pump. I then tighten a 1/4" nyloc nut on the clamp bolt. The clamp bolt doesn't come with a nyloc nut, and I highly recommend using a nyloc nut to keep it from vibrating lose. When connecting rubber fuel line to the pump inlet and outlet, make sure that you clamp them well, but not so much that the clamps cut into the rubber. If the connection is tight enough, you should not be able to turn the hose on the fitting with your hand at all. Also, the hose should be slipped over the barb all the way on the pump and clamped. Keep in mind that the return line system is the most dangerous side of the fuel system but is fortunately the least likely to leak. If you have a major gas leak on the supply side the engine will stop running and the ECM will turn off the fuel pump, stopping the loss of fuel. A minor leak on the supply side will however spray fuel everywhere under high pressure, so if you hear a hissing sound and smell gas, be careful when opening the hood. A major leak on the return side however will just continue to dump out fuel until you run out. The engine will keep running because the fuel pressure regulator will keep the fuel pressure high. For this reason, carefully inspect and double check all return side fuel connections, just as you would the high pressure supply side connections.

One more comment about frame mounted fuel pumps. Since you are retrofitting a high volume pump to a vehicle with a gas tank that was not designed for EFI, there is the tendency to run out of gas much sooner than you normally would. I consider 1/8 of a tank as "VERY" empty with this pump arrangement. I have run out of gas twice with 1/8 of a tank. Once when going around a curve and another when I was absentmindedly accelerating hard going to a gas station. Factory tanks built for EFI not only have the pumps installed inside the tanks, but also have baffles to keep the fuel from sloshing away from the fuel inlet to the pump. Once an EFI pump inlet is no longer covered by copious amounts of fuel, the fuel pressure dies almost instantly and the engine will stall. For this reason, consider 1/8 of a tank as the absolute lowest fuel level you can allow. There is one way to solve this problem and that is to use what is called a surge tank. For more discussion of this tank, I'll refer you to this link:

http://www.sdsefi.com/techsurge.htm

With this auxiliary tank, your stock mechanical pump can pump just about all the fuel in your main tank into the auxiliary tank so you can use nearly every drop of available fuel before running out. One variation of the surge tank I am planning on trying in the near future is to have a small fuel reservoir at the back of an in-tank TBI pump mounted on the frame (the specifics of this will be revealed in a future update). I will use the stock mechanical pump to fill this reservoir and then have the return line from the TBI come back to this reservoir. I know it will work with an inline low pressure electric fuel pump between the gas tank and the reservoir, but I am concerned about fuel pulses from a mechanical pump affecting the pressure at the injectors. For accurate tuning, you want this pressure to be constant. This is basically a return-less system. If you want one of these systems to save you the expense of cutting into your tank, contact me soon and I should be able to provide the parts. The cost will be very reasonable because you will have to buy a more expensive pump otherwise. Also, with a return-less system you will get the advantage of having all your gas available before running out if it is set up correctly.

I have some new information about the E2182 pump. To make sure it did indeed flow as much as the E2000 that I used to buy, I ran my TBI return line into a bucket and let my engine idle. I used a stopwatch to measure the time it took to pump 1/2 gallon of gas into the bucket. It took 45 seconds to pump 1/2 gallon against 15 PSI. This means the pump was flowing at least 40 gallons per hour at 15 PSI because some of the fuel was being used by the idling engine. This also means this pump (E2182) is capable of supporting 480 plus TBI horsepower (40 GPH x 6 lb/gallon = 240 lbs./hour; 240 lb/hr / 0.5 BSFC = 480 horsepower). For more information on this equation, see MSD's fuel management document online.

One of the biggest obstacles to retrofitting EFI is the fuel return line. This line allows excess fuel to return to the gas tank. Both TBI and port EFI systems pump more gasoline than needed in a continuous loop from the tank, to the TBI or port EFI rails, and back to the tank. The size of this line should ideally be no smaller than 5/16", but I have gotten 1/4" lines to work. 3/8" would be the best. One of the reasons I do kits primarily for Jeeps is that they all have return lines built in at the factory. This saves a customer a lot of work since installing a return line is a hassle. If you have to install a return line, I'll just say use as much steel or aluminum fuel line as possbile and run it along the frame. Rubber line is OK too if you can keep it secured against the frame so that undercar debris can't catch on the line. One possibility is to run EMT electrical conduit on the frame and then snake the rubber line inside that. If you don't have a fitting on your gas tank where the return line can connect, Moroso makes a fitting that goes in your fuel tank filler inlet hose. This is much faster and easier than removing your gas tank and adding a fitting. Before you do this, check with me since I am working on a return-less system.

If you are looking for more performance, you can try and find a TBI from a 454. These TBI's have 2" throttle plates/bores and larger 80 #/hr injectors. Also, the Holley aftermarket TBIs have 2" bores for the 4.3L thru 5.7L size TBIs. The problem with the Holley aftermarket TBIs is that the stock GM 5.7L TBI manifolds only have 1-11/16" bores, so the 2" bores don't match up. Holley doesn't mention this when you buy one as a retrofit. I guess because they want you to buy one of their aftermarket TBI manifolds too. But if you are building your own custom adapter, this won't matter. Dodge uses Holley injectors and throttle bodies and I frequently use them on my port systems without the injector pods. I have noticed on the late model Jeep TBIs that I have bought, that the Holley logo is all over them, so I guess Jeep uses Holley EFI parts also.

PORT FUEL INJECTION

GM Port EFI is similar to throttle body injection in that most sensors are interchangeable and the control logic and tuning methods are the same. The differences are that the fuel is delivered at a higher pressure to 8 separate injectors, one for each cylinder. Building a port EFI system is done by choosing a manifold, mounting injectors, fabricating a fuel delivery system of rails, hoses, and pressure regulator, and choosing a throttle body. This is an oversimplification since there is a lot more custom fabrication than with a throttle body EFI system.

In choosing a port EFI manifold, you want one with cylinder runners that enter the heads at about the same level. Examples of these type manifolds are the single plane Edelbrock Torker for AMC engines and the Edelbrock Torker II for Chevy engines. The reason is that you have to weld injector bosses on to the manifold runners and having runners that are uneven makes the welding difficult, if not impossible. Also, you want the injector fuel ends to all be at the same height and having runners at different levels makes this impossible as well. This is not to say that a port EFI system can't be installed on an Edelbrock Performer style manifold. I just prefer to use the single plane style manifolds.

MSD makes injector sockets that can be epoxied on to the manifold. Then you can make the fuel delivery system based on flexible hoses rather then aluminum fuel rail. However, I have recently discovered a method of building a fuel rail to fit dual plane manifolds with different injector heights. Photos of this method will be on my website as soon as I have the opportunity to build a manifold like this.

Once you choose a manifold and mount the injectors, you build a fuel delivery system. I use aluminum fuel rail from the EFI shops. Then I tap the rail with 3/8" NPT threads on both ends for JIC flared fittings. Then I drill appropriately spaced holes for the injectors. Dimensions of the fuel rail holes and the injector mount holes are standardized for most all port injectors and these dimensions can be found on MSD's website. For a fuel pressure regulator, I use a Buick V6 port EFI regulator from just about any V6 Buick port EFI engine, and custom fit that to my fuel rail. This is a high quality Bosch unit that easily mounts to a custom rail. Finally, I choose a throttle body with an idle control motor and throttle position sensor built in. I can usually find a decent GM throttle body on Ebay. You can use a TBI throttle body with the injector pod removed if you wanted to, or you can use a carburetor with the venturis removed and a TPS mounted.

Since there is a lot of custom fabrication when building a port EFI system, I'll refer you to the port EFI photos for more clarification on what is involved. You really have to be creative with used parts on port EFI since typical off the shelf parts aren't cheap.

One of the most creative things I've done lately is to figure out how to use my drill press as a milling machine for making injector mount holes. For years, I have had to pay to have my manifolds machined for injectors. The problem was my drill press could not drill on the side of a sloped manifold runner. The drill bit, no matter how small, always walked down the slope and the hole would no longer be accurately positioned. I discovered that by chucking a ½" shaft, ¾" end mill into my drill press, I can cut a flat on the manifold slope without the end mill walking. Then, I use a small 1/8" Uni-bit to accurately start a hole on the slope in the intended location. After the small Uni-bit gets the hole to ¼", I switch to a larger Uni-bit to finish out the hole to ¾". I use Uni-bits to keep all the holes concentric about the intended location. Keeping the holes concentric is important for lining up all the injectors under the fuel rail. This trick saved me $150 per manifold.

FUEL DELIVERY TIPS AND TRICKS

There aren't that many fuel delivery tips to discuss, but they are gems. The first one is that Ford port injectors will fit GM TPI manifolds or any other common port manifold (most injector dimensions are standardized), and they are very inexpensive compared to GM and Bosch injectors. You can get a set of 8 Ford 24 #/hr or 30 #/hr injectors for $220 brand new from www.Summitracing.com. At this price, why risk buying a used or cleaned set? If you use Ford injectors in a GM TPI system, take note that Ford rates their injectors at a lower pressure of 39 PSI instead of the 43.5 PSI that GM uses. You must re-calculate the Ford injector flow rate at whatever higher pressure you use in a GM TPI fuel rail. Another tip is that you can use other manufacturer's throttle bodies on a GM system. You may have to remote mount a custom made Idle Control Motor, but it can be done. Most throttle position sensors have the same electrical characteristics, so if you can wire them up to a GM ECM, they will work. Be sure to grab the TPS connector from the Dodge harness though since the TPS does not use a GM connector. Finally, I have had bad experience with the later GM Multec ball style (MSD sells these) injectors from Corvettes and Camaros after 1989. www.lindertech.com also doesn't recommend this style either. Stick with the Bosch style pintle tipped injectors (Fords).

ELECTRONICS AND SENSORS

In this section, I will discuss how to choose an ECM, how to reprogram the EPROM in the ECM, how to build your own wiring harness, and which sensors you will need and why.

CHOOSING AN ECM

Choosing an ECM is a relatively simple decision for me. You have to choose one that is reprogrammable, bottom line. To help with this decision, I'll provide some background information first. The reason I am able to build GM EFI systems is that some really sharp computer guys have reverse engineered the code in some GM ECMs. This is called "hacking" or having a "hac" for an ECM. When the code is hacked, the locations and the meaning of the digital data on the EPROM (the calibration chip in the ECM) is understood. Since the data on the EPROM is binary data, locating it, understanding it, and reprogramming it is next to impossible without first hacking the ECM it came from. Once an ECM is hacked, a program can be written (called a Tuning Editor or Editor) that will edit the binary data in the ECM's EPROM so that you can retune the calibration data. The tuning editor "knows" where the data is located on the EPROM and what the purpose of that data is. However, the tuning editor program doesn't know what to change or why. That's what you as the tuner must learn and understand by knowing how engines work and what you want to accomplish. Typically, the data has to be converted from binary numbers to real world units like temperature, RPM, AFR, MPH, etc. The Tuning Editor performs these conversions on specific binary file locations. Once the binary file editing is complete, the file is then re-burned onto an erased EPROM. Typically, it takes many burns to get the calibration just right.

There are two different designations for GM engine computers. The early ones were called ECMs (Engine Control Module) since they only controlled the fuel and spark timing of the engine and sometimes the lockup torque converter in the transmission. In the early 90s, PCMs (Powertrain Control Modules) were introduced when the fully electronic transmissions became available. Between 1992 and 1995, both were used in the GM vehicle line. After 1995, all engine computers were PCMs, and flash to boot. Flash means the chips were no longer removable from the PCM and had to be reprogrammed thru the ALDL connector in the car. I don't like flash PCMs for a variety of reasons, but the main one is that they are very fickle. If a single glitch occurs when programming a flash PCM, the entire PCM is damaged and requires a $200 flash replacement repair. I don't want to pay $200 every time a PCM is killed because someone opened the car door and the drop in voltage caused a glitch. Flashing a PCM is a DIY operation only if you ask me. The flash PCMs were introduced with the 1992 LT-1 Corvette and the Camaro LT-1 in 1993. Fortunately, the truck PCMs kept MEMCALs thru 1995. These MEMCAL (removable chip) based truck PCMs are the ones I use for top of the line TBI systems. The data quantity and speed from these TBI PCMs equals that of the V8 TPI ECMs, so they are a must for a critical application. The early TBI ECMs were about 50 times slower spitting out data and included no spark timing information in the data frame. The later ECMs and PCMs spit all kinds of data about 6-7 times per second for a complete data frame. A data frame is a complete list of all the engine sensor information used by the ECM. If you can afford it, you want the fastest ECM/PCM you can get.

So, how do you find a hacked ECM? For me, I just look for the supported ECM list on www.Tunercat.com. These guys are professional GM ECM hackers. Tunercat consists of two parts, the main program and the TDF file or Tuner Definition File. The main program runs all the TDF files and each TDF file is unique for a given ECM model number. Think of the main program as your brain and each TDF file as a road map of a particular city. When you travel to a foreign city, you use the same brain but a unique road map for that city to learn the addresses of where you want to go. The TDF files are the road maps to the information contained in each ECM, and each ECM model's tuning data locations are different from another.

The other source for hacked ECM information is www.diy-efi.org. There are four other tuning editor programs that I know of: Promedit, GMEPRO, WINBIN, and LT-1 Edit. Promedit is a freeware dos based tuning editor found on the diy-efi website. It is very primitive but works well. The capability of promedit is completely dependent on the ECU file that you use with the program. An ECU file is equivalent to the Tunercat TDF file. I'll refer you to www.diy-efi.org for more info on how to use Promedit, Winbin, GMEPRO, and LT-1 Edit. Since the first two of these are free, those on a budget may want to use these, but I like Tunercat for the technical support. WINBIN is nice because it is Windows based and free, but it is basically a Windows version of Promedit with no tech support.

For more info on choosing an ECM, go to the DIY-EFI website and look in the GMECM FAQ link. But for a quick run down on the most popular and least expensive ECMs, follow this guide:

TBI EFI - ECM model 1227747 is the most popular and best hacked; port EFI - ECM model 1227730 is the most popular, with 1227727 (Corvette version) being identical electronically but in a weather-resistant case. Turbo port EFI - ECM model 1227749 is from the Syclone/Typhoon turbo charged trucks (there is a whole separate Email list covering these trucks and ECMs; www.syty.org). This selection covers 99% of the GM custom EFI market.

Note that the above ECMs all have removable EPROMs or MEMCALs of some fashion or another. There is a reason I only mention these. I like to be able to remove the EPROM but leave the ECM in the car. This way, all you need is a backup EPROM or MEMCAL and you can keep driving the car while your primary one is being reprogrammed. On the later (1993 and up Vette LT-1) PCMs, there is no removable chip. The entire PCM has to be removed from the car and shipped to a reprogrammer for any changes. This means you would have to keep a spare $200 PCM around to continue driving the car, and you would have to pay for more expensive shipping of a huge (comparatively speaking) PCM back and forth to your reprogrammer.

One more comment. Many people ask if a port ECM can be used to run a throttle body system. The answer is no, although some DIY er's have tried it. The reason is the timing of the fuel injector pulses and the injector drivers inside the ECM. GM port EFI ECMs are batch fire ECMs that fire all 8 injectors once every revolution (usually), but TBI ECMs fire each injector every other ignition event. So this is what happens. If you are using a port batch ECM with TBI, you will be starving 2 out of 4 cylinders of fuel because only the cylinder on the intake stroke gets fuel. The other two in the firing order on that manifold plane miss out because their intake valve closes before the ECM fires the injector again. This is kind of hard to explain. Another reason that you don't use port ECMs on TBI is that TBI injectors are what's called peak and hold injectors. Because of their size and flow rate, it takes a good jolt of current to quickly open a TBI injector. The sudden jolt of current will fry a port ECM. Port ECMs use saturated injectors, or high impedance injectors. These injectors use the same current pretty much whenever they are open, and don't need the current jolt. On the other hand, you run into problems using a TBI ECM with port injectors too. Since a TBI ECM fires its injectors twice as much as port ECMs, you end up spraying too much fuel with port injectors. You might could compensate in the EPROM for this, but I think you'd also run out of time for an adequate duty cycle at higher RPM. For me, bottom line is stick with what works. GM EFI is hard enough without trying to do circus tricks with this stuff.

PROGRAMMING A GM ECM EPROM

A quick and dirty overview of what is needed to reprogram a GM EPROM is as follows. I will describe each tool in the order that you will use them. First, you will have to gather diagnostic data from your vehicle's ECM while driving. For this, you will need an ALDL cable (I sell them for $31 (TBI) and $41 (TPI) or you can make one yourself from Radio-Shack parts) and a diagnostic software program. The free programs are WINALDL for TBI ECMs and Craig Moate's GM ECM for TPI ECMs. There are links to free and not so free diagnostic programs in my EFI links section on my homepage. These programs do nothing but gather ECM sensor info and store it in a file on your laptop computer's hard drive. You then analyze the data with Microsoft Excel's data sort function to find where you need to make changes to the chip. Learning HOW to analyze the data is the big enchalada and is covered at the end of the software section. After you analyze the data, you will then need a Tuning Editor program. The free ones are Promedit and WINBIN. Others are Tunercat, GMEPRO, and LT-1 Edit for LT-1 engines only. Next, you will need an EPROM programmer to read the data from your chip. Then, change the data with the tuning editor program above, and burn the edited file back on the chip (EPROM). Finally, you'll need an EPROM eraser to erase the EPROM before you burn the new file onto it. However, if you are using a new flash chip in a TPI MEMCAL, you don't need the eraser. Links to purchase all the least expensive tools above are found in my EFI links section. If you are still confused about what to buy to reprogram a GM EPROM, check out the following link. It goes into great detail on the technique of how to reprogram your own EPROMs. Once you have read this site you can return here to learn how to build a wiring harness next. Keep in mind that this link only discusses the method of reprogramming EPROMs. It doesn't tell you what to change on the chip or why in any detail. The site is: http://www.thirdgen.org/newdesign/tech/promintro.shtml

As you probably read in the above link, there is no one book or document that explains how to recalibrate a chip. My ultimate goal is to provide that document herein.

BUILDING A WIRING HARNESS

Now for the fun stuff. Its time to discuss wiring harnesses. I find that it's fastest and easiest for me to build a harness from scratch with new wire, but I frequently take a factory harness, strip it down to bare wires for each sensor, clean the wires with Gunk, and then reassemble the harness with only the wires necessary to run the EFI system and nothing else. This way, if there is a problem with my harnesses, I know that there isn't some other device in the car interfering with the EFI system. This can happen with a factory harness because you have the cruise control devices, the alternator wiring, and some other circuits that I still haven't identified in there. If you don't need these to operate your EFI system, why have them in there? I suppose I could just send a customer an unmodified factory harness, but I am 100% certain that they would not be able to follow any kind of instructions to install it. It literally is a big rats nest of wires. Another reason I like to use factory harnesses is that the wire colors match the factory circuit diagrams and make tracing down shorts and wiring problems much easier. Fortunately, GM used the same wire colors for the same sensors just about every time. I have only found a few exceptions to this rule. For ex., the idle air control motor colors are grn/wht, grn/blk, blu/wht, and blu/blk on every single TPI and TBI harness that I have ever rebuilt, with no exceptions. The last reason I like factory harnesses is that if I buy them with the TPI or TBI system, I usually get them practically free. This of course depends on what you end up paying for the whole system. In general, you should be able to buy a whole TPI system with all the aluminum parts, the distributor, the ECM, the harness, the fuel rails and injectors, and maybe a few sensors thrown in for no more than $400. At this price, don't expect a MEMCAL in the ECM unless it is a MAF ECM, and don't expect a fuel pump, O2 sensor, MAP sensor, speed sensor, knock sensor, or air filter. I'll go into more detail about the sensors later. Also, at this price, odds are good that the runners will be dented (some severely), the distributor will be shot, a few bolt holes will be stripped, and the metal parts and harness will be very dirty. I have seen TPI systems without the harness go for $400 often, so I would hold out for a more complete system. It won't be ready to install, but it will save you $250-350 for a Painless Wiring harness. They seem to be everybody's darling when it comes to buying a harness. If you get a used harness, I will give you the tips here to rebuild that harness into a much better harness than you can buy from Painless Harness. Sorry for getting off topic here. I think the best way to discuss how to rebuild a harness is to take a factory wiring diagram, or pinout sheet as some call them, and go pin by pin and discuss what to do with each wire.

HOW TO BUILD A TBI HARNESS

The first step is to download the factory pinout diagrams for the 1227747 ECM, the most hacked TBI ECM, pages 1 thru 7 at the bottom of this link from the DIY-EFI website, http://www.diy-efi.org/gmecm/ecm_info/1227747/. As you download them, take note of the order of the sheets since I will discuss them in the order they appear on the DIY-EFI site.

General Notes

The first sheet is titled "TBI Fuel Injection ECM Connector Identification" It consists of the ECM connector pin list and troubleshooting steps and voltages expected on each pin during operation. The list shows the pin number, starting with A1, factory wire colors, the circuit name, and the voltages on the pins with the engine running and with the key on but engine not running. In the following discussion, I will use a convention on naming wires like this: tan/blk means a tan wire with a black stripe, dk grn/wht means a dark green wire with a white stripe, lt blu/wht means a light blue wire with a white stripe. One other convention is that all wires go continuously from the ECM terminal to the appropriate sensor terminal without splices, or taps, unless I specifically identify where a tap or splice should occur. In my own harnesses, I sometimes splice factory colored wires to general purpose black wires when the factory wires are not long enough for the custom length needed.

Pins A1, B1, B2, And C16

Lets start with pin A1 and go down the list. A1 is the fuel pump relay control. When the ECM energizes this pin with 12 volts, the fuel pump runs. When the ECM turns off pin A1, the fuel pump stops. Flipping through the rest of the sheets, you'll notice that pin A1 appears on sheet 2 near the bottom, sheet 3 near the top (actually it is missing and is a typo) and near the bottom, and sheet 4 near the top. The reason is that there are different ways to wire the fuel pump relay depending on what type and size truck you have. This is a common occurance in GM wiring diagrams and you just have to figure out which mutually exclusive option is the best one for you to use. The circuit at the bottom of sheet 2 is the simplest and that is the one that I use on all of my harnesses. It shows pin A1 going directly from the ECM to fuel pump relay terminal A with a dk grn/wht wire. Then the relay's terminal C goes to ground. Now, when rebuilding a harness, some of the older ones used a non-sealed relay and these usually are too corroded and melted to be reused, so don't. Just buy a 30 amp 12 volt style automotive relay at any auto parts store and use that. Pin A1 will go to the relay's coil positive and the relay's coil negative will go to ground. The fuel pump will be powered with the normally open contacts of your fuel pump relay. By the way, it's best to run all your grounds back to the engine block. Ground problems are hard to trace and solve, and attaching all ground wires to the engine block is the best way to eliminate bad grounds.

You'll also notice in the circuit at the bottom of sheet 2 that 12V power goes through a 10 amp fuse (labeled ECM B), then goes to ECM pins B1 and C16 with orange wires. There is a splice in this wire that also goes to fuel pump relay terminal D, and another spliced wire that goes to an oil pressure switch. There was a long debate on the GMECM list about the oil pressure switch which I will cover later. For now, I'll just say that I leave out the oil pressure switch on all my harnesses. They are easy to add in later by installing the oil pressure switch across the fuel pump relay "normally open" terminals D and B. "Normally open" or N.O., is engineering jargon meaning the state of the relay when it is not turned on, i.e the contacts are open when the relay is off and closed when the relay is turned on. Most relays also have contacts that are closed ("normally closed" or N.C.) when the relay is turned off as well, so you have to get them right. Terminal E is the N.C. terminal of the fuel pump relay at the bottom of sheet 2 and terminal D is the N.O. terminal. When the fuel pump relay closes, 12V is fed to fuel pump relay terminal B, which powers the fuel pump. The fuel pump test connection goes to different places on the truck depending on what truck you have. Some go to the ALDL connector, and some just stop somewhere in the engine bay. The test connection runs the fuel pump when 12 volts is applied to the test terminal. I don't install this wire (unless the relay has it already) in my harnesses because it's easy to jumper 12 volts to the fuel pump wire at the relay terminals if I want to test my fuel pump. In addition to the fuel pump test wire, there is a tan/wht wire that goes from relay terminal B to ECM pin B2. This is the fuel pump status signal back to the ECM that the fuel pump is running, and also allows the ECM to monitor the fuel pump voltage. I'm not sure what it does with this information, but you will get a code without the wire. Now looking at sheets 3 and 4, you will notice some more fuel pump wiring diagrams that I don't use. The difference is that there is an additional device in the circuit called a fuel module. On the GMECM list, it was mentioned that this device was a timer that kept the fuel pump running after the ECM shut off to keep the fuel from boiling in fuel lines of the heavy duty trucks, but I have a problem with that explanation. The fuel module is fed with a 20amp fuse from an IGN source and the module has no separate 12V trigger or any other source. If this were a time delay off relay, it would need a 12volt source from the battery to keep running the fuel pump. If the ignition is turned off, the module loses all power, so it could not keep feeding 12 volts to the pump. I think the module is some sort of voltage monitor and raises the fuel pump voltage if it drops too low. A 20 amp fused supply is a lot of current for a passive device, so it must deliver extra juice to the fuel pump, but I'm not sure when. It doesn't really matter to me, since I never use them and I see no reason for you to either. So far, we know that the fuel pump relay power is fed straight from the battery through a 10 amp fuse, that the same wire provides 12 volt non-switched power to ECM pins B1 and C16, the fuel pump power after the relay is fed back to the ECM at pin B2, and that pin A1 turns on the fuel pump. The continuous power at pins B1 and C16 is important. This is what maintains the ECM's memory when the ignition switch is turned off. It also provides power for the ECM's internal functions. Lets move on to the next pin on sheet 1, pin A4. A2 and A3 are not used.

A4

A4 is for controlling the EGR valve solenoid and its circuit is shown in the middle of sheet 5. Notice that there are two separate circuits depending on the size of the engine. The 4.3 and 5.0 EGR valves are constant on EGR valves, and the 5.7 and 7.4 EGR valves are modulated by pulsing the EGR valve. Note that the EGR valve is controlled by a solenoid on the 4.3 and that the EGR valve itself is controlled on the 5.7. For 99% of the retrofit applications, you will want to use the EGR solenoid and use that to control engine vacuum signals to the EGR valve already on your vehicle. Refer to my general wiring diagram notes for ECM operated solenoids in a later section. For now, note that the EGR solenoid is fed with 12V through a 10 amp fuse and that the ECM grounds the solenoid to turn it on.

A5

This is the Service Engine Soon (SES) light, or check engine light as some call it. The circuit is shown in the middle of sheet 4. The light is fed with a 10 amp fuse and then the ECM grounds pin A5 to turn on the light. Notice the "IP" connector next to the ECM. This is a white connector under the dash that is the interface between all dash devices and the ECM. Whenever you see "IP", it means the devices and circuits are inside the car rather than in the engine bay. What does this mean to you? It means that the SES light is located in the dash and will not be a part of most harnesses sold on Ebay or pulled from a junkyard. Most harnesses are disconnected at the "IP" connector, so everything inside the passenger compartment gets left behind. This is not too big a deal as you will see later.

A6

This pin is the ignition feed to the ECM. The circuit is shown near the bottom of sheet 5. 12 volts comes from the ignition switch through a 10 amp fuse and then goes to ECM pin A6 among others. This is what "wakes up" the ECM so that it will run the car. With 12 volts here, as soon as the distributor turns, the injectors will start firing. Note that this pin is only hot with key in the run or start position.

A7

A7 is for either the lock-up torque converter on a 700R4 automatic transmission, or for the shift light on a manual transmission. If you use an automatic calibration as your starting point, this pin will determine when the torque converter locks up. If you use a manual calibration, it can be used to turn a shift light on and off. I don't recommend connecting a shift light on a retrofit because the shift points were selected for a stock GM engine and your engine may run better with higher or lower shift points. On the other hand, the torque converter lock up values are adjustable in the chip, so this is a good feature to use if you have a 700R4. If you look at sheet 4, you'll see that pin A7 completes a circuit to ground and that the positive side of the circuit goes through a brake switch first. This releases the torque converter when you press the brake pedal.

A8

A8 is the ALDL serial data line. This is the wire that the ECM transmits diagnostic information to a scan tool or a laptop computer with a special cable. This wire goes to terminal "E" in the ALDL connector. This wire and the other ALDL wires usually don't get stuffed into your main wire loom. Since the ALDL connector remains inside the car, these wires are run separately into the dash of the car.

A9

A9 is another ALDL pin, but this one is the diagnostic terminal. This wire goes to terminal "B" in the ALDL connector. When this terminal is jumpered to ALDL terminal "A" (ground), the ECM enters diagnostic mode. In this mode, if the engine is not running but the ignition switch is turned on, the check engine light will flash trouble codes to you. If the engine is running, the ECM will enter field service mode, which flashes the O2 sensor status in the check engine light. See my "AMC TBI Kit Installation" link for more info on the diagnostic mode and field service mode operation.

A10

A10 is the speed sensor input. The speed sensors inputs to the TBI ECMs are 2000 pulse per mile optical (square wave) inputs, meaning that 2000 times per mile, this input is alternately connected to ground and opened again. The other side of the speed sensor connects to ground.

A11

A11 is a ground for the MAP sensor. The wire from MAP sensor terminal A lands here. See sheet 7 for the wiring diagram.

A12

A12 is one of the main ground wires for the ECM. It always has a thick black/wht wire coming from the connector. I usually join it with pin D1 a few inches from the ECM and then run at least a 16 Ga. black wire as the main ground wire to the engine block.

B1

B1 was discussed above, but it has 12 volts on it as long as the battery is connected.

B2

B2 was discussed above. Pin B2 is the fuel pump voltage input and is used by the ECM to detect a fuel pump relay fault.

B3

B3 is the distributor reference low signal. It is probably just a dedicated ground from the ignition module back to the ECM, although I haven't tested this. At any rate, the reference signal is a pulse generated by the ignition module that the ECM uses to calculate the engine RPM. The ECM "knows" (from the EPROM program) how many cylinders there are. And since there are 4 pulses per revolution for a V8, 3 for a V6, and 2 for a 4 cylinder, it can calculate the RPM by measuring the time between each pulse. This is why GM ECMs can't be used on odd fire engines with uneven times between ignition events. The RPM calculations would be scattered and the system would not be stable. There is a solution for odd fire engines which I will cover in later sections. Pins B3 and B5 are shown on sheet 6 of the factory wiring diagram.

B4

Pin B4 is not used.

B5

B5 is the distributor reference high signal. See pin B3 for discussion of this pin. This is the pin that can be connected to the coil negative terminal on a fuel only EFI retrofit, but you must use an electronic filter to filter out voltage spikes. The spikes will damage the ECM without the filter. A diagram of the filter is available from me. Just Email me if you need it. Otherwise, this pin connects to the ignition module. See the diagram for your particular ECM for which terminal of the ignition module to land this wire on.

B6

Pin B6 is not used.

B7

B7 is the ESC signal. ESC stands for Electronic Spark Control. ESC is the knock sensor and module system that allows the ECM to retard timing when engine knock is detected. The ESC system works like this. The knock sensor itself is just a microphone. It detects engine noises and converts them into electronic signals. The ESC module is a noise filter. Its function is to electronically "listen" to the noise and filter out noises that are not engine knock, such as bearing noises, lifters, etc. Anything that resembles the hard pinging of engine detonation will be interpreted as engine knock. When the ESC module determines that knock is present, it signals the ECM on pin B7. Then the ECM retards the ignition timing in quantities and durations programmed into the EPROM. Now, the signal on pin B7 is important for this reason. When there is no engine knock, the ESC module sends a high signal to the ECM on pin B7 and when there is knock, the ECM sends a low signal. This means that if you remove the ESC module, there is now a low signal on pin B7 and the ECM will interpret that as engine knock and will attempt the retard the timing. At this point, I'm not sure if the ECM retards the timing continuously, or if it decides after so much time that the knock signal is false and just ignores it. The solution is to re-program the EPROM and set the ignition retard tables to zero. Otherwise, you must leave the ESC module connected and powered. The bottom of sheet 5 shows that the ESC module is wired to switched 12 volts, ground, and ECM pin B7. The knock sensor connects to the ESC module on ESC terminal E. On the later TPI and TBI ECMs of the early 1990s, the ESC module is contained on the MEMCAL, a removable calibration module that plugs into the ECM. So on these type ECMs, the knock sensor connects directly to the ECM, but the same principle is still at work here. The ESC still determines the knock condition and alerts the ECM as a go/no-go condition.

B8

B8 is the Air conditioning compressor signal. The wiring of this signal is shown at the top of sheet 2. What I do on my harnesses is just provide a wire that you splice into the compressor clutch positive wire, so that when the A/C system engages the A/C compressor clutch, it signals the ECM that you have turned on the air conditioning. The ECM then adds a little extra fuel pulse and opens the IAC motor just a little to keep the idle speed from dropping. The amount of fuel and idle counts is reprogrammable in the EPROM, provided you know the EPROM addresses of the data.

B9

Pin B9 is not used.

B10

B10 is the park/neutral switch pin. When this pin is grounded through a switch on the transmission linkage, the ECM thinks the transmission is in park or neutral. When this pin is open, or not connected, the ECM thinks the transmission is in drive. This signal helps the ECM make smooth transitions when switching from park to drive and from drive to park. The ECM has to open the IAC motor a tad and add a pulse of fuel when the transmission is placed in drive from park, otherwise the idle RPM will drop and the ECM will have to play catch up. The reverse is true when changing from drive to park. The sudden loss of load on the engine would cause it to race before settling back down, so this switch allows the ECM to close the IAC instantly keeping the engine from racing. I don't use this pin on my Chevy truck and I have minor idle stability problems because of it, but I do use it on Jeep kits with automatic transmissions. Its actually fairly easy to connect this pin on a Jeep, but much more difficult on a GM vehicle to retrofit. I'll go into more detail why in another section. The wiring for pin B10 is shown in the middle of sheet 5. Pins B11 and B12 are not used.

C1

C1 is not used.

C2

C2 - EAC Solenoid – This pin controls a single stage air pump valve. On some trucks, an air pump provided air for the exhaust manifold. This pin controlled a valve that diverted the air to atmosphere under warmed up conditions.

C3-C6

C3 through C6 - These pins are for the Idle Control Motor (IAC). The idle control motor controls the idle speed by letting controlled amounts of air bypass the throttle plates. The idle control motor is a two way stepper motor that opens or closes when signals are present on the 4 control wires. The thing to know here is that if no signal is on the 4 control wires, the idle control motor stays where it is, i.e it won't move unless it is told to. This means you can disconnect the connector and it will stay put. The procedure for setting minimum idle air relys on this fact. You drive the IAC in all the way by jumpering ALDL terminals A and B with the key on/engine off, pull the IAC connector, remove the jumper, start the engine and then adjust the idle speed with the TBI screw to get the lowest stable idle speed you can. Reconnect the IAC and shut off the engine. The wiring for the IAC is shown at the bottom of sheet 7. The colors shown there are a typo. Refer to sheet 1 for the proper colors.

C7

C7 is the Hi Gear Switch and is a contact inside the transmission that signals the ECM when the transmission is in high gear. The ECM uses this info to control the lock-up torque convertor. Other than that, I don't think it has any effect on the system. I don't connect anything to this terminal on systems without a GM 700-R4 transmission. The wiring for pin C7 is shown on sheet 4.

C8

Pin C8 is not used.

C9

C9 is the Crank Signal. The crank signal is used to signal the ECM when the starter is cranking the engine. The ECM uses a crank fuel table to determine the amount of fuel during cranking. I have successfully built systems without using this input, like on my Chevy 350 truck engine, but I usually connect it when I sell a system. On Jeeps, there is already a wire at the AMC ignition module that has 12 volts on it when the engine is cranking, so making this connection is easy on those systems. On any other system, you will need to run a wire from pin C9 to the starter solenoid start terminal to get 12 volts when cranking. Wiring for this pin is shown on sheet 7.

C10

C10 is the Coolant Temperature Signal (CTS). This is the input for the coolant temperature sensor signal wire. The CTS has two wires. Terminal B of the CTS connects to the ECM on Pin C10 and the other wire (A) connects to either A11 or D2 sensor ground. As to which one, just follow the diagram on sheet 7. The coolant sensor itself is a thermistor, which is a variable resistor whose resistance changes with temperature. There is a table on www.diy-efi.org that shows the resistance vs. the temperature. One of my favorite tricks is to use a manual potentiometer to fool the ECM into seeing a different temperature than the true temperature. This way, I can make the ECM do interesting things by reprogramming the tables on the chip that are based on temperature values.

C11

C11 is the Map Signal. MAP stands for Manifold Absolute Pressure and is basically measuring the vacuum inside your engine, but in an inverse way. In other words, low MAP is high vacuum and high MAP is low vacuum. 100 Kpa (kiloPascals) is zero vacuum and 0 Kpa is -30 inches Hg. The MAP signal goes from terminal B of the green MAP connector to ECM pin C11. Unless you are building a system for a supercharged or turbocharged engine, you will always use a green MAP connector and a 1 bar MAP sensor. A bar is a metric unit of pressure measurement corresponding to one atmosphere of pressure, or the pressure that exists at sea level. If you have a normally aspirated engine, i.e. non turbocharged or supercharged, then you will never have a pressure greater than 1 bar inside your engine's intake manifold, hence the 1 bar map sensor. If you have a turbocharger that makes up to 15 PSI of boost, then you will need a 2 bar MAP sensor. And if you are making more than 15 PSI of boost, then you need a 3 bar MAP sensor, which is as high as they get. MAP sensor wiring is shown on sheet 7.

C12

Pin C12 is not used.

C13

C13 is the Throttle Position Sensor (TPS)signal. This sensor is mounted on the TBI or the throttle shaft and measures the position of the throttle blades. What is usually more important on a GM system is not the position but how fast did the position change. The rate of change is what triggers the ECM to add extra fuel for sudden acceleration, similar to an accelerator pump shot on a carburetor. Unlike a Holley Projection 2Di system, which depends on both position and rate of change for fuel control, GM systems don't rely that heavily on the TPS sensor for fuel control except for the accelerator pump shot. When an EFI system uses the TPS as a primary indicator of fuel demand, the system is called ALPHA-N. One of my on-going projects is to convert a GM EFI system over to Alpha-N, but its not easy. GM ECMs measure the barometric pressure with the MAP sensor just before you start the engine, so eliminating the MAP sensor so you can use the TPS as a load indicator is not trivial. The dark blue TPS signal wire goes to the B terminal on the TPS sensor connector as shown on sheet 7.

C14

C14 is the 5 volt supply for both the MAP and the TPS sensors. Both sensors have 5 volts on their C terminals. This wire is tapped in the harness, such that one wire leaving the ECM becomes two somewhere in the harness. I like to make the tap at the end of the main harness trunk near the engine. This way, I keep the wires in the main trunk to a minimum where the harness goes thru the firewall.

While I'm on the subject of the MAP and TPS sensor wiring, both sensors have a signal ground wire (terminal A on both sensors). The signal ground wires go to either A11 or D2 sensor ground ECM pins, and I'll leave it up to you to figure out which pin based on wiring diagram sheet 7. In reality it doesn't matter because both sensor grounds are tied together internally and to the ECM case.

C15

Although pin C15 is shown in the diagram as only used on the 7.4L (454) TBI systems, I will usually wire this pin so that I have two pins paralled for injector B. I built a harness once that would not fire a fairly large injector, although it wasn't a 454 injector. It took me a while to figure out that I did not have enough juice with one pin firing that large of an injector. Ever since, I use two pins for my injector wires (tapped a few inches from the ECM into a single 16 gauge wire) except for the 4.3L V6 TBIs. It can't hurt to have too much wire. See sheet 6 for more info on wiring the injectors.

C16

C16 was discussed above under pin A1.

D1

D1 is one of two main ground wires for the ECM. It always has a thick black/wht wire coming from the connector. I usually join it with pin A12 a few inches from the ECM and then run at least a 16 Ga. black wire as the main ground wire to the engine block.

D2

D2 is a ground for the TPS and CTS sensors. The wires from CTS terminal A and TPS terminal A must be spliced somewhere in the harness and then connect to pin D2 as one wire. I like to make the tap in my harnesses about 6 inches before the end of the main harness trunk. This way, when the two wires come out of the harness trunk, I can enclose the CTS A and B wires in smaller wire loom and the TPS wires in a separate loom as well. If the wires are tapped past the end of the harness trunk, you can't enclose each sensor group of wires in separate loom. See sheet 7 for the wiring diagram.

D3

Pin D3 is not used.

D4

D4 is the distributor Electronic Spark Timing (EST) signal. This wire is what controls the timing when the ignition module is not in bypass mode. The ECM can also detect a bad module with this wire and will set a code 42 when the timing is not being controlled. See sheet 6 for the wiring diagram.

D5

D5 is the distributor Bypass signal. This wire is what signals the ignition module to begin using the timing signal on pin D4 to control the timing. If the ECM has a malfunction and goes into limp home mode, this wire will have zero volts on it which signals the ignition module to use its own internal timing function. Otherwise, this wire will always have 5 volts on it. This wire should have a connector that is easily pulled apart somewhere in the harness so that the timing can be set. I usually put this timing connector within a few inches of the ignition module, but it can go anywhere in the wire. See sheet 6 for the wiring diagram.

D6

D6 is the O2 sensor ground wire. On some of my first harnesses, I tapped this wire into the A12/D1 main ground wire, but now I always run this wire from the ECM to the engine block for a low resistance ground connection. The O2 sensor signal is so weak, that a good clean ground is essential for a clean signal. The wiring for this pin is shown on sheet 7.

D7

D7 is the O2 sensor signal wire. This wire needs to go directly from the ECM to the O2 sensor. Due to the low signal on this wire, it is a good idea to try and keep it away from spark plug wires or any other wire that would cause electro-magnetic interference (EMI).

D14

D14 is the main pin for injector B. I usually tap this wire with pin C15 on V8 harnesses so that I have two pins paralled for injector B. See sheet 6 for more info on wiring the injectors.

D15 and D16

D15 and D16 are the main pins for injector A. I usually tap these wires on V8 harnesses so that I have two pins paralled for injector A. On 6 cylinder harnesses, I just use pin D16. See sheet 6 for more info on wiring the injectors.

HOW TO BUILD A TPI HARNESS

General Notes

To begin, download the TPI diagrams (7 sheets) at the bottom of this link for the 1227730 TPI ECM ('92 F body 5.0 and 5.7):

NOT 1227747

http://www.diy-efi.org/gmecm/ecm_info/1227730/

As you download them, take note of the order of the sheets since I will discuss them in the order they appear on the DIY-EFI site.

To simplify this section, I will only discuss those TPI harness pins that are different from the TBI harness pins. For this reason, I recommend you read the TBI harness section first for a good understanding of what the pins are for.

Lets start with sheet 5 from the downloaded sheets. This sheet and the next three list the pins in order that they are used on a MAP based TPI 1227730 ECM. Lets start with the BA/BB connector which is a 24 pin black connector. The first pin used is BA4.

BA4, BA5

These pins are the 5 volt reference voltages for the MAP sensor and TPS sensor respectively. They serve the same function as pin C14 on the TBI ECM, however, on this ECM the pin is not shared by these two sensors.

BA6

Pin BA6 is the ignition feed and is the same as TBI pin A6.

BA8

Pin BA8 is the serial data pin and is the same as TBI pin A8.

BA11

Pin BA11 is the fuel pump relay drive and is the same as TBI pin A1.

BA12, BD1

These two pins are the same as TBI pins A12 and D1 respectively.

BB1, BC16

These two pins are the same as TBI pins B1 and C16 respectively.

BB5

This pin serves as the TPS and MAT sensor ground and is the same as pin D2 on a TBI ECM. The wires from these two sensors are connected together somewhere in the harness and land on pin BB5 as one wire.

BB6

This pin serves as the MAP and CTS sensor ground and is the same as pin A11 on a TBI ECM. The wires from these two sensors are connected together somewhere in the harness and land on pin BB6 as one wire.

BB9 and BB10

These two pins are for a magnetic speed sensor. Unlike the TBI speed sensor which is a single wire sensor (other side goes to ground), this ECM requires two wires from the sensor with neither of them grounded. These two wires are unique to the TPI ECM. I will go into more detail about speed sensors later.

BB11, BC1

These two wires are outputs to other systems in the vehicle that need a speed signal to function. BB11 is a 4000 pulse per mile (PPM) output and BC1 is a 2000 PPM output. There are no TBI equivalent pins for this function. I will discuss the purpose of these pins in my speed sensors discussion later. These two pins are not normally used in a TPI retrofit into an older car. This concludes the BA/BB connector pins.

BC1
This pin was discussed immediately above.

BC7
This pin is the same as pin D5 on a TBI ECM.

BC8
This pin is the same as pin D4 on a TBI ECM.

For more information about TPI Harnesses visit: http://www.customefis.com

GM EFI SENSORS AND MISC. PARTS

In this section I will discuss the sensors used in GM EFI. The first sensor to discuss is the knock sensor because the knock sensor systems are the most complicated. In order to discuss knock sensors I must also touch on the different chips and MEMCALs used in GM EFI systems from 1985 to 1995.

In the pre-1990 years (except for TPI V8s and a few others), the chips were mounted in the ECM in separate plastic sockets (see Figure 10). The EPROM is the larger chip and the CALPAK (also called NETRES) is the smaller chip. Both are held in place by a plastic clip that goes over the chip and locks on the pins. See my website for the method to remove the chip from the clip. The EPROM is an eraseable and reprogrammable digital chip that contains the normal and primary calibration data used by the ECM's microprocessor during normal engine running. The CALPAK is an analog chip that is used in limp home mode, which is a crude fuel only backup mode that will run the engine well enough to get you home, but gas consumption will double since the engine runs very rich for safety. The CALPAK is dependent primarily on engine size and injector flow rate, which means if the injectors are drastically different from stock for your engine size the CALPAL may not work with your combo. But unless you insist on having a working limp home mode, that is not a significant problem. The EPROMs in most all TBI systems using C3 ECMs were 2732A 4K Byte (32Kilobit) EPROMs (there were exceptions). C3 stands for Computer Command Control and represents all the early GM ECMs. Later year ECMs were called P4 ECMs, since they used a faster more powerful microprocessor. Figure 10 shows a C3 ECM with the two separate chips and a remote ESC module (described below).

The P4 ECMs used in the 1987 and later TPI V8 engines (among others) used what is known as a MEMCAL (see Figure 11). The MEMCAL is an electronic enclosure that contains three separate circuits, the re-programmable EPROM, the ESC circuit, and the CALPAK chips. So instead of these circuits being 3 separately installed parts like in the C3 ECMs, the MEMCAL contains all 3 and the MEMCAL is plugged into a slot in the ECM as one part. The exception to this is that thru the 1989 model year, the ESC circuit was not mounted on the MEMCAL and was still the engine bay mounted ESC module like on the C3 ECMs.

In all 1989 and earlier GM EFI systems, the ECMs used what was called an ESC (Electronic Spark Control) module in the knock sensor system. The ESC module is an electronic noise filter that deciphers the electrical signal coming from the knock sensor. The ESC module was mounted somewhere in the engine bay and was a small square plastic box (See Figure 10). The knock sensor is a microphone that picks up engine noises and is mounted in the engine block in various places depending on the engine type. On Chevy 5.7L engines, the knock sensor is installed in the passenger side block drain hole next to the starter. The ESC module is tuned to respond to the noise made by engine knock (pinging) for a particular engine block size and knock sensor combination. The ESC module interprets the knock sensor signal as either knock or no knock. So the result is the ECM gets a yes or no signal on the ESC input. The problem is that the no knock signal is a high signal on the ECM input, so if the ESC module is not connected and powered, the ECM will receive the equivalent of a knock signal on the ESC input. For this reason, you must reprogram the chip to remove the ESC effect if you don't have an ESC module installed. Since ESC modules are tuned to specific engines, the part #s vary greatly from one engine size to another, and from year to year also. I have put together a table that shows the different ESC modules and which knock sensors go with them. This table is available by emailing me at Questions@customefis.com. The main question is, “Will a knock sensor/ESC module work on your engine? The answer is I don’t know but try it and see. I have been successful using 5.7L knock sensors/ESC modules (16052401) on AMC 360 engines, but I haven’t really tried it on others enough to say that it works on all engines.

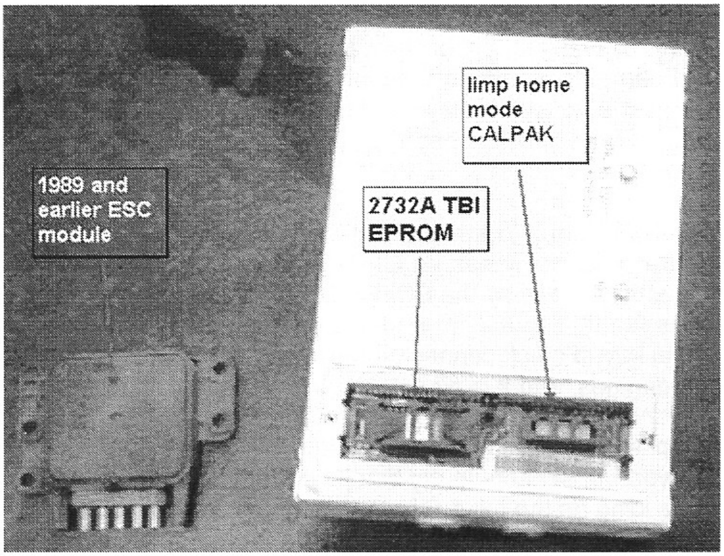

Figure 10

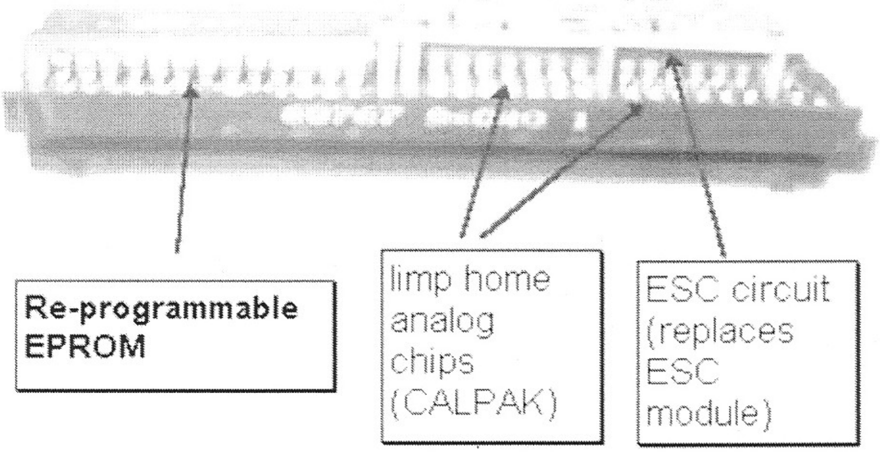

Figure 11

Starting in 1990, the ESC module was changed over to an ESC circuit and mounted on top of the MEMCAL. The circuit still does the same function, but the old knock sensor is not compatible with the new ESC circuit and you have to use a knock sensor for the 1990-95 model years. The advantage of this is that the knock sensor is wired directly to the ECM and you don't have the ESC module as a middleman in the way. Also, since you have to use a MEMCAL anyway, you get an ESC circuit for free (ESC modules cost $60 new), and adding knock control is no more difficult than buying a $30 knock sensor. In my website, I offer a high speed TBI P4 PCM as a $150 option. I can provide a free knock sensor system with this PCM because it uses a MEMCAL which I must order from a dealer (unless I find one in a junkyard) anyway. So trading the C3 ECM for the cost of the knock sensor gets the knock sensor system for free with this PCM. The $150 comes from the cost of the MEMCAL ($75) and the cost of the high speed ECM, which can be anywhere from $50 to $75, and the cost of the two transistor cable needed for this PCM. So on all my MEMCAL based systems, I include a knock sensor since the incremental cost is so low. It may work and it may not, but for $30 you might as well install it and see. This completes my discussion about knock sensors and how they interface with the ECM. Now for the rest of the sensors.

Coolant Temperature Sensors (CTS) - GM coolant sensors are thermistors. Thermistors are resistors that change resistance with temperature. The resistance change with temperature is not linear, so a lookup table is used in the EPROM to calculate the temperature from the resistance of the sensor seen by the ECM. GM CTS's are very durable and I grab all that I can from a junkyard on my trips. Every one is like finding a $10 bill sitting on the top of the engine. You'll need a ¾" deep socket to get them out. They use a special keyed black connector called a metri-PAK connector. This same connector is used for the air temp sensor on TPI V8 engines, and it is also used for the brake fluid level sensor on some 90s vehicles. When I am at a junkyard, I cut everything I can as fast as I can and then ask questions later. Usually, the JY owner has no idea what all this greasy crap is in my plastic tub and sells it to me for a nominal $20 charge. What he doesn't know is that I have $2000-$3000 worth of sensors in my box if I bought them brand new. He charges me full price for used ECMs and TBIs and the rest is icing on the cake. The free sensors are how I make a profit selling GM EFI systems. My experience is that coolant sensors don't go bad, and if they do, it's completely bad. The ECM will set a code when they crap out. If your idle fluctuates, and the engine hesitates and bucks, suspect the coolant sensor. If it is bad enough to set a code, the ECM will switch to a default CTS value to get you home. The CTS stayed the same from 1983 to at least 1995, the last year I need to know about.

Intake Air Temperature (IAT) Sensor - The IAT sensor is not used on the truck TBI ECM/PCMs. It is used on car TBI ECMs and the V8 TPI ECMs. It is also a thermistor and has the same electrical footprint as the CTS. The IAT casing has different configuratoins. Some were 3/8" threaded and screwed into the aluminum intake manifold. Others were plastic and were inserted into a rubber grommet in the air intake duct between the MAF sensor and the throttle body. Grab all of them since you can find a way to use them somehow. The IAT connector is gray and is also keyed to only fit the IAT sensor. One common trick with IAT sensors is to move them from the aluminum manifold to the air cleaner housing or anywhere else you can sense cool air. The IAT affects the ignition timing mostly, and cooler air will allow more timing for more power. I've seen the IAT rise 30 degrees on TPI systems as the engine bay got warmer. The IAT sensor will soak up heat from the intake manifold the longer you drive.

MAP (Manifold Absolute Pressure) Sensor - MAP sensors measure the pressure inside the intake manifold relative to absolute zero pressure. Atmospheric pressure is 14.7 PSI, so the highest a normally aspirated MAP sensor can measure is 14.7 PSI. The unit of MAP used most often in diagnostic software is the kilo-Pascal (Kpa). The range of absolute zero pressure to atmospheric pressure is 0 -100 KPA. This makes it easy to imagine the MAP as an indicator of engine load from zero to 100 percent. The MAP sensor is a primary load indicating sensor, and is critical in calculating both fuel and spark timing. The MAP sensor replaces the function of a MAF (Mass Air Flow) sensor when a MAF is not present. I prefer MAP sensor based EFI for reasons explained elsewhere. The MAP sensor is easy to spot since it uses a bright green connector. You might see other sensors that look like MAP sensors, but unless they have a green connector, don't waste time getting them. They are barometric pressure sensors used on some of the hybrid carb/EFI engines and won't work with a pure EFI system. The MAP sensor is connected to the intake manifold with a rubber hose and it usually has a dedicated port on the TBI or throttle body or plenum. Don't connect the hose to an intake runner since that cylinder's pulses will effect the sensor. MAP sensors are like finding nuggets of gold since they cost $30 new and rarely wear out. They can be mounted just about anywhere, but keep the hose port pointing down to keep moisture out of the sensor. To me, MAP sensor based EFI is easier to reprogram, but MAF based EFI doesn't need reprogramming under some limited circumstances so it's a toss up as to which is better.

MAF (Mass Air Flow) Sensor - MAF sensors actually measure the air mass entering the engine. This makes it easy for the ECM to calculate fuel because if the mass of air is known directly, and the air/fuel ratio desired is known, then it's a simple division problem to calculate fuel required. The downside is that the MAF sensor has to be mounted in the air intake tract and requires support and that is not always easy. The other downside is that the MAF is a restriction to airflow when you try and get more air into your large cubic inch engine. The upside is that if you keep the injector flow rate and MAF relationship the same, and not control the ignition timing with the ECM, then you can install a MAF based EFI system on a similar size engine and not have to reprogram the chip. But to me, not reprogramming the chip is like eating dry cereal. It tastes ok, but it just isn't the same. As you can tell, I don't like MAF sensors. GM used MAP sensors on the V8 TPI system from 1990 to 1992, but brought back MAF sensors with the LT-1. That's another good reason I don't like the LT-1.

Throttle Position Sensor (TPS) - The TPS measures the throttle angle with a rotating potentiometer connected to the throttle body shaft. The TPS is used primarily for determining when to go into PE mode (Power Enrichment) and when to add extra fuel for quick throttle openings. Some TPS are adjustable and some aren't. The adjustable ones need to be adjusted to measure 0.5 volts on terminal B with the throttle closed against the idle speed screw. For this reason, when you adjust the idle speed screw, you have to readjust the TPS. I have found that most TPS are 5K ohm pots, and therefore other manufacturers TPS are compatible with GM ECMs. This means that you can use Ford and Chrysler TPS with GM ECMs. But Fords are not the ticket for another reason. The TPS is a robust sensor. Since throttle bodies are basically butterfly air valves, you can use an old 4bbl carburetor as a throttle body if you can mount a TPS to the primary bore shaft and mechanically link the secondary shaft to the primary. Just strip out the venturies, seal up any unneeded ports, and you have a cheap humongous throttle body. Without the venturies, the carb probably flows 30% more air. The problem is the idle air control motor.

Idle Air Control (IAC) Motor - The IAC is a stepper motor that controls idle speed. The IAC motor moves a tapered piston in and out of an orifice. One side of the orifice is on the air cleaner side of the throttle plates and the other side of the orifice is below the throttle plates. So the IAC motor is basically an ECM controlled vacuum leak. The ECM can rapidly move the tapered piston to regulate idle speed, prevent stalling, and add more air for power. One thing the IAC does is allow the ECM to have an electronically controlled throttle follower. This can be annoying. Throttle following is when the throttle is held open under extremely light loads (like decelerating or coasting downhill). With manual transmission calibrations, the throttle follower action can get annoying, since the engine RPM stays above 1000 RPM for a long time after stopping in traffic. And if you don't have a speed sensor, it sometimes never comes down. For this reason, I like to use automatic calibrations even in manual tranny vehicles. Automatic calibrations don't have as much throttle follower action because the engine would be fighting the transmission while braking using up gasoline and wearing out the brakes. All IAC motors on 5.7L TBIs and smaller have the same electrical connector. However, I don't know if that means they are all the same part #. The 7.4L TBIs use a different IAC and connector. One trick I do with IAC's is to mount them remotely on an aluminum plate drilled appropriately. This allows me to use a carb as a throttle body and still maintain ECM controlled idle speed. The IAC needs to stay clean since a sluggish IAC will cause erratic idle.

For more information about this topic visit www.customefis.com.

GM ECM SOFTWARE AND CHIP RE-CALIBRATION

BACKGROUND

Before reading this section, you should read Appendix A - "Why GM EFI Needs Reprogramming". I discuss the basics of GM EFI and the terminology there. Keep in mind that all GM EFI reprogramming is only possible due to the reverse engineering efforts of some sharp computer types. GM doesn't condone or assist with this effort. I will assume that you have purchased Tunercat (www.tunercat.com) in order to retune your GM ECM and that you have an EPROM programmer and eraser. The free program WINBIN will also work provided you have the correct ECU file for your particular ECM (mask ID $42 for the 1227747 ECM). I will discuss the programming in the order of Tunercat's $42 TDF file for the 1227747 TBI ECM. There are three data formats in a GM ECM EPROM file. They are switches, constants, and tables.

SWITCHES

Switches are single bit data that represent a two position parameter that can only be on or off, hi or lo, enabled or disabled, etc. They have no value other than one of two positions. A single 8 bit byte in the EPROM can store 8 separate switches. Most of the time the switches are for error code enabling or disabling. For ex. if you don't have a speed sensor and don't want a speed sensor nuisance error code, you can turn off the speed sensor error code so that you will not get a check engine light when the speed sensor diagnostic test is run. This does not mean the test itself is disabled, just that the ECM won't turn on the Check Engine light. An example of another switch is whether the VATS (Vehicle Anti-Theft System) is enabled or disabled. I won't individually discuss the switches in the $42 TDF since they should be self-explanatory now.

CONSTANTS

Constants are non-varying values that don't change based on some other parameter. Examples are the size of one cylinder of your engine in liters, the flow rate of one injector in #/hr at 100% duty cycle, the static setting of the distributor in your engine, the maximum speed before fuel shutoff on a speed limiter, etc. The constants in Tunercat are as follows:

Main Spark Bias

This is hard for most beginners to understand but it allows negative spark advance amounts to be programmed. The spark table itself can't hold negative numbers, but if you subtract 10 degrees from every single value in the main spark table, you can get a net negative advance. For ex. if the main spark table has a value of 6 degrees, subtracting 10 degrees makes the net advance -4 degrees, or 4 degrees retarded. Most of the time, the main spark bias will be 10 degrees. I have seen values of 20 degrees though. Best advice here is to leave this value unchanged. Tunercat automatically subtracts the main spark bias from the main table value so that net spark advance is displayed. Likewise, when you change a value in the main table with Tunercat, Tunercat adds the bias to it before saving the change in the main table. I don't think WINBIN does this. WINBIN and promedit are more primitive than Tunercat so you have to be careful when applying this discussion to programs other than Tunercat.

Initial Spark Advance

This is the amount of degrees BTDC that your distributor is physically set to. On most GM trucks, this value is zero. The purpose of this value is so that the spark table can be programmed to represent the real spark advance from zero degrees BTDC. For ex., say that the value in the chip is 0 degrees. If you have the distributor set at 10 BTDC, and the spark table says 10 degrees in some places in the table, your true timing will be 20 degrees because the distributor is adding an extra 10 degrees on top of the 10 that the table contains. If you set the distributor to 10 BTDC, and then change the initial spark advance setting to 10 degrees in the chip, where ever the table says 10 degrees means the true timing will be 10 degrees BTDC. The table says 10, then the inital setting value is subtracted, which would leave a net value of zero degrees coming from the ECM, but since the distributor is set at 10 BTDC, the true timing will be 10 BTDC.

Extended Spark RPM Slope

The purpose of this table is to determine how much spark advance occurs above the main spark table range. As you will see later, the main spark table stops at 3600 RPM in the 1227747 ECM. Any spark above this RPM is determined by multiplying the Extended Spark RPM Slope by the current RPM minus 3600 RPM. For ex., say your slope is 5 degrees/1000 RPM. If the current RPM is 4000 RPM, you are 400 RPM over 3600. 400 X 5/1000 = 2 degrees. So you will have 2 more degrees than the value in the main table at 3600 RPM. The maximum advance is limited by another

EPROM parameter called max RPM for spark slope. The $42 TDF file doesn't show this value, but it does exist and is usually around 4800 RPM. This means once you reach 4800 RPM, the spark advance is maxed out and will not increase.

Min. Speed to Enable Hiway Mode Spark

This parameter is the minimum speed to maintain before hiway spark mode will be enabled. Hiway mode is a special open loop mode in which the ECM runs leaner than 14.7 AFR. There are two functions that occur in hiway mode. They are hiway spark mode and hiway fuel mode. In order to enter hiway mode, certain conditions have to be met; ECM has to be in closed loop for a certain amount of time, the speed has to be higher than a programmed speed and the engine load (MAP) has to be less than a programmed amount. A certain amount of time also has to lapse since the hiway mode conditions have been met, but the other criteria have to be met before hiway spark will occur. I don't recommend hiway mode for beginners. Wait until you have a lot of experience with GM EFI before trying to engage hiway mode. If you have the experience, then you won't need me to explain how to set this up. There is documentation (hiway747.zip) and a code patch that allows hiway mode on the 1227747 ECM. It is located in the incoming directory of www.diy-efi.org.

Time Delay to Enable Hiway Mode Spark

See above description.

Bypass Power Enrichment Delay

Power Enrichment (PE) mode is the full throttle mode when maximum power is needed. The ECM uses only coolant temperature and the throttle position sensor (TPS) for determining when to enter PE mode. However, in some calibrations, the ECM will delay PE mode when the engine RPM is less than this value. This is an economy feature that prevents PE mode from quick stabs at the throttle. Below this RPM, the throttle has to maintained above the PE mode threshold for a programmed time before PE mode will be in effect. But above this RPM, the delay is ignored and PE mode takes effect immediately.

Power Enrichment Mode Delay

This is the programmed amount of time that PE mode is delayed when the RPM is below the Bypass Power Enrichment Delay RPM. See above description.

BPW Constant

THIS IS THE MOST IMPORTANT PARAMETER that you can adjust in a GM TBI EFI system. If you read nothing else in this entire manual, read this paragraph. This number is a universal fuel rate number. Raising this number increases the fuel delivery across the board and lowering it does the opposite. It has the same effect as changing the fuel pressure. Ideally you want to calculate this number based on the measured flow rate of your injectors and your actual engine displacement and not use this parameter to fine tune a calibration. Without going into the details, this constant is determined by the size of one engine cylinder in liters and the flow rate of one injector in grams/sec. The equation is:

BPW = 1461.5 X engine size in liters/# of cylinders / injector flow rate in gms/sec

Lets do an example of this. Say you have a 5.7L V8 and you have a twin injector TBI with 66 lb/hr injectors. First convert 66 lbs/hr to gms/sec. 66lbs/hr X 453.6 gms/lb. X 1hr/3600 sec = 8.316 gms/sec. Then 1461.5 X (5.7/8) / 8.316 = 125. So 125 would be the BPW for this calibration. Some people will raise or lower this number to get the fuel delivery in line using the BLM fuel trim number. This is acceptable as long as you don't vary this number too far. When you measure an injector, you can have errors due to evaporation, spills, gasoline film left in the measuring flask, etc. Since the BPW is based on this measurement, there is more than likely some error in the exact number, so changing it a little doesn't hurt. As you will see later, any changes to the BPW constant can be offset in the VE tables. If you don't have a way to measure the flow rate of your injectors, take the stock flow rate listed in my site, correct the flow rate for your fuel pressure, and use that flow rate in this equation and you will be close enough. The only reason you might be off is if your injectors are dirty or defective and don't flow at their rating.

EGR On / Off (%TPS)

These are EGR qualifiers that turn EGR on above a programmed TPS % and off below another TPS %.

EGR On / Off (Speed)

These are EGR qualifiers that turn EGR on above a programmed MPH and off below another MPH. I use these parameters to disable EGR on my calibrations. If you set the EGR on speed at 255 MPH and the EGR off speed at 254 MPH, EGR will never be enabled because you can't reach these speeds. Setting the parameters at an unrealistically high (or low) value is a common way of disabling a feature.

Low MAP EGR On / Off

Again, these are EGR qualifiers that turn EGR on above a programmed MAP and off below another MAP. All the qualifiers have to be met for EGR to be enabled and there are others that are not even shown in Tunercat's $42 TDF file. I have added the EGR enable temp to my $42 TDF file myself with Tunercat's TDF Editor software.

Minimum/Maximum MAP for BLM

These qualifiers determine the range that the BLM function is allowed to operate between. I have not seen a calibration that reduced the MAP range from 10 to 100 MAP.

Maximum RPM for BLM

This parameter prevents BLM operation above the programmed value. Typically, this value is 3000-3500 RPM.

Speed To Enable Open Loop Idle

Describing the purpose of this parameter is going to be difficult. I will have to go into detail about all the different open loop situations. The way I see it, there are 3 different ways you can be in open loop. There is normal open loop, abnormal open loop, and forced open loop. Normal open loop is when the ECM is in open loop because one of the normal qualifiers to enter closed loop has not been satisifed. It could be that the O2 sensor is not hot enough or that the coolant is still too cold to enter closed loop. This is considered normal operation. Abnormal open loop is when all the closed loop qualifiers should have been met, but something is keeping the ECM in open loop. This could be a broken O2 sensor wire, or a defective coolant sensor, or any number of faults that will prevent the ECM from entering closed loop mode. Technically, normal and abnormal open loop are the same thing, but usually an error code will set if you remain in abnormal open loop. Forced open loop is when a special programming feature of the ECM is used to force the ECM out of closed loop and into open loop as a normal part of system operation. Open loop idle is one of those features. Power Enrichment (PE) mode and Hi-way modes are two others.

Open loop idle is a feature that allows the ECM to leave closed loop mode when the engine is idling. Typically, the AFR is programmed richer than 14.7 in open loop idle mode to help the engine have a more stable idle. I have found that engines with significantly non-stock cams will idle better with an AFR around 13.5. The ECM will go into open loop idle mode when certain criteria are met, one of those being the speed is less than this programmed value. 2-4 MPH is a good value for this parameter.

%TPS to Enable Open Loop Idle Mode

This is another open loop idle mode qualifying parameter. The TPS has to be less than this amount (i.e. foot off the gas) before the ECM will engage open loop idle mode.

Maximum AFR At Open Loop Idle

This is the AFR that the ECM uses when in open loop idle mode. It is an upper limit to the AFR that the ECM will use in open loop idle mode. I suppose the AFR could be less than this, but I don't know of any conditions that would allow this to happen, as you will see later. I typically use values of 13.5 to 12.5 here. You have to experiment with your engine to determine the best value. However, don't forget that the VE tables (or the BLM has had time to adjust) must be accurate or this AFR value will have no meaning.

Lean Idle AFR at Open Loop

This parameter's name is misleading and Tunercat's explanation in their help file is also questionable about this parameter. By my own experimenting, I have found that this parameter is the lean AFR limit when the ECM is in normal open loop mode, but idling. This is not the same as the forced open loop idle mode above and has nothing to do with it. As you will read later, the AFR can be much leaner than 14.7 (as lean as 17 AFR) in normal open loop mode. But the engine will have a hard time idling at 17 AFR, so when the engine is idling in normal open loop, this value caps the AFR, so it is a lean AFR limit. This is completely different than the AFR in open loop idle mode. Open loop idle mode is forced, whereas open loop idling is just idling, but in open loop. The criteria that determine idling in open loop are not the same as the ones that force open loop idle mode. They are adjustable, but are not a part of the standard $42 TDF file.

Maximum AFR In Open Loop (Non-idle)

As the name states, this parameter is an upper limit on the AFR when the ECM is in normal open loop mode, but not idling. This value can be as high as 20 AFR without any problems, which is where I program mine. I am not really sure why this parameter is even needed, but GM put it in there.

Warm Closed Loop Delay Timer

This value is the amount of time that the ECM waits before entering closed loop mode after cranking, but with a warm engine. How warm? Thats another value in the calibration that's not in the $42 TDF.

Cold Closed Loop Timer

Same as above, but for a cold engine.

Minimum Coolant Temp for Closed Loop Fuel

This value is the lowest temperature that the ECM will attempt to enter closed loop mode. This and other qualifiers must be met before the ECM will enter closed loop. I set this value to 150 Deg C. often to keep the ECM in normal open loop mode. If my VE tables are adjusted correctly, I can get better mileage this way, as you will read later.

Open Loop Idle AFR Enable RPM Threshold

This is the engine RPM below which the ECM will enter open loop idle mode, provided the other qualifiers have also been met, such as the speed and %TPS parameters. I typically set this value at 900 RPM when I want to use open loop idle mode.

Open Loop Idle AFR Disable RPM Threshold

This is the engine RPM above which the ECM will leave open loop idle mode and re-enter closed loop mode. By having a separate disable value, the ECM is prevented from rapidly going in and out of open loop idle mode. I typically set this value at 1100 RPM when I set up open loop idle mode.

Open Loop Idle AFR Enable Delay

This is the amount of time in seconds that all Open Loop Idle qualifiers must be satisfied before the ECM will attempt to enter open loop idle mode. Once this time has been reached, another timer is started before the ECM will go into open loop idle mode. The factory setting for this value is about 8 seconds.

Open Loop Idle AFR Time Delay

This is a timer that starts once the Open Loop Idle mode Enable delay has completed. The factory setting for this value is about 5 seconds. The ECM will enter open loop idle mode when this timer times out.

TCC Lock Speeds

These parameters determine when the lock up torque convertor in a GM 700R4 transmission locks up, with different values used depending on whether the transmission is in high gear or the lower gears. The earlier GM ECMs did not control any other function of the transmission. I will not address these values since most of my projects do not involve a GM transmission.

IAC (Idle Air Control motor) Park Position

This is the number of IAC counts (steps) that the IAC motor moves when the engine is shut off. The IAC counts are an indication of the IAC motor's position. Zero IAC counts means the IAC is completely closed, whereas 256 counts means the IAC is wide open.

IAC Park or Neutral Offset

This is the relative number of IAC counts that the IAC motor will move when the transmission is shifted from Park to Drive or vice versa. For ex., say this parameter is 25 counts. If the engine is idling at 600 RPM in park, and the IAC counts are 30, the IAC counts will imediately jump to 55 counts when the transmission is shifted to drive. The purpose of this parameter is to prevent the engine idle speed from suddenly dropping or rising when shifting in and out of gear. I have found a good value to use on my AMC 360 chips is 25 counts.

Idle RPM Adder A/C On

This value is the amount of engine RPM added to the idle speed when the air conditioner is switched on. This allows the A/C to cool better.

Maximum/Minimum BLM/INT Values

These are the maximum and minimum BLM values and INTEGRATOR values that the ECM uses when in closed loop to maintain a 14.7 AFR. Narrowing the range covered by these values will hinder the ability of the ECM to control the AFR when in closed loop. I rarely change these values.

PROM ID

This is a code used by GM to identify the exact calibration in this particular file. Some tuners use it to keep track of the changes they have made to their calibrations. This value has no effect on the system tune.

This concludes the discussion of the constants in the Tunercat $42 TDF. Keep in mind that there are many more constants in the $42 calibration that Tunercat elected not to include. I have Tunercat's TDF editor program so I added some more constants to my $42 TDF that I considered important. For those using WINBIN instead of Tunercat, a registered member sent me one of the most complete $42 ECU files that I have ever seen. Email me if you want a copy.

TABLES

Tables can be either 2 dimensional or 3 dimensional. 2D tables have a parameter that varies as one other item varies. For ex., the target idle RPM vs. Coolant Temperature is a 2D table, whereas the Main Spark Advance vs. RPM vs. MAP is a 3D table since the spark advance varies as two other items change. The tables in Tunercat's $42 TDF are as follows:

Main Spark Table

This 3D table displays the spark timing from TDC in degrees at the crankshaft. Next to the main fuel table, this table is the most important for optimizing your GM EFI system. Looking at the Tunercat display screen, you have MAP (in Kpa) increasing across the top and RPM increasing along the left side. This means that spark timing is dependent on both RPM and engine vacuum (MAP is the opposite of vacuum, but both indicate engine load; 100 MAP is zero vacuum). Now, from the carburetor days, we know that the spark advance increased as engine RPM increased. So to isolate the RPM only effect, look at the right most column and you will see the 100 MAP column. This column is the spark advance when the throttle is to the floor, or WOT. It changes only as the RPM climbs. So you can derive the RPM only contribution from this column. But remember that the entire table shows spark advance relative to zero BTDC. So the lowest value here is probably the distributor timing setting. For ex. in my spark table of my AMC 360 chip, the lowest value is 10 degrees, which corresponds to the distributor setting on a stock AMC 360. So to get the RPM only curve, subtract the lowest value from all the other values in the 100 MAP column, and this is your RPM only contribution to spark timing. Now, look on the 400-600 RPM row of the table. The RPM stays constant as you move along this row from 30 all the way to 100 MAP. This row is the vacuum only contribution to the spark table, but again, the static distributor timing setting must be subtracted from all values to get the vacuum only contribution. What does this mean when retrofitting GM EFI to any other engine? Well, if you have the RPM advance curve and vacuum advance curve from the distributor in your carburetored engine, you can transfer those curves to the chip. I wrote an Excel spreadsheet that does this. If you know the RPM advance curve and the vacuum advance curve, and the distributor setting, you put that info in the spreadsheet and it will calculate the spark timing at each location in the table. Then all you do is cut and paste from Excel into Tunercat and you have your spark table. (WARNING - Most centrifugal and vacuum advance factory spark curves are setup for EGR operation at all part throttle conditions; you must subtract out 3-6 degrees from the factory curves at part throttle before plugging the numbers into my Excel spreadsheet; The sheet is only for the non-EGR main timing table; EGR timing is applied in another table in the EPROM) Keep in mind that this is to be considered as a starting point for your spark table and that more than likely, tweaking it here and there can gain you some power or efficiency. If you want a copy of my spark table spreadsheet, just Email me. I will discuss some spark table tweaking tips later in this section.

Coolant Compensation Spark Table

This table is an adjustment to the main spark table based on coolant temperature. Typically, the timing is advanced considerably when the engine is cold for more power and retarded when the engine is very hot to reduce detonation under load. I experimented with the CTOs of my Jeep AMC 360 engine and figured out the temperatures at which the CTOs and the non-linear valve effected the spark timing. I then used this table to perform the same functions as those emissions devices on an AMC 360 engine. For an understanding of what the CTOs do, read my "Understanding

Emissions Controls And How To Reconnect Them" link on my home page. For better understanding of what this table does, use Tunercat and study some factory EPROM files from the www.diy-efi.org site. The most important comment about this table is that the MAP values are vacuum, and they stop at 40 MAP vacuum (60 MAP absolute). But the timing corrections in the 40 MAP vacuum column apply to all vacuum values less than 40, which means that all absolute MAP less than 60 has the 40 MAP vacuum column corrections applied.

Power Enrichment Spark Table

This table contains spark advance that is added to the main table values when the ECM is in Power Enrichment (PE) mode. This allows the main table to be conservative while the PE table adds agressive timing. However, from what I have heard, the PE table will not be activated unless the knock sensor system passes its diagnostic test, and since most of my EFI kits do not have a knock sensor, I don't use the PE table. I just zero it out. You can compensate in the main table by just raising the 100 MAP timing.

Hiway Mode Spark Advance vs. Vacuum

This table contains spark advance that is added to the main table values when the ECM is in Hiway mode. The purpose of this added timing is to make the engine more efficient when running at lean AFR values. Lean mixtures burn slower and this allows the timing to be advanced slightly to get a little more efficiency. I do not know of any factory calibrations that enabled hiway mode. The values I have seen in hiway mode tables in other ECMs are at most 2-3 degrees advance. As I have explained before, hiway mode is an advanced topic that I would rather not elaborate on in this manual. Once you have enough experience to be able to retune your ECM adequately in all other modes, then you will have enough knowledge to figure out hiway mode for yourself.

Max. Knock Retard vs. RPM (in PE)

This table contains spark timing that is subtracted from the main table values when the ECM is in PE mode and knock is detected. The table is the maximum amount of timing that will be pulled out when the ECM gets a signal that knock is present. This does not mean that the maximum will always be pulled out. Knock retard is accumulated over time. The longer the ECM gets a signal that knock is present, the timing will be reduced by a certain rate. This rate is programmable in degrees per millisecond, but is not part of the Tunercat TDF. However, this table limits the amount of timing that will be pulled out. Once the knock signal goes away, the ECM will put timing back in at another prescribed rate until the engine either begins to knock again, or you let off the gas and reduce the load. As a tuning issue, it is much better not to ever have knock, because once knock starts, it takes a disproportionate amount of knock retard to get rid of it, and pulling timing kills power. So most tuners start conservative on the low side, and gradually increase timing until knock is detected, then they pull 1-2 degrees at a time until the knock no longer occurs. This is far better than leaving the timing over advanced in the chip and letting the knock sensor get rid of the knock. Keep in mind that lean mixtures can promote knock even when the timing is OK, so if you have knock, increase the fueling a little at that load condition first to see if the knock goes away. I once had WOT knock with my PE fuel table set for 13 AFR everywhere. I lowered the PE fuel table to 12.5 and the knock went away and the engine had more power. 13 AFR was pushing it too close, esp. with a chip that wasn't fine tuned on a dyno.

Max. Knock Retard vs. MAP

This table contains the maximum spark timing that is subtracted from the main table values when the ECM is not in PE mode and knock is detected. The table is based on MAP (engine load) instead of RPM. All comments from the PE Mode Knock Retard table above apply here as well.

Main Fuel Table #1 (% Volumetric Efficiency)

(The first thing I should mention is that the Main Fuel Table #2 below is added to table #1 to arrive at the total VE value, so you must include table #2 when making changes to table #1). The VE table contains values ranging from 0 to

100% that correct the fuel equation for the engine's air pumping efficiency. This is the second most important fuel adjustment function in any speed density calibration, with the base pulse width constant being the first. The most important thing to understand about this table is that when adjusted properly, this table adjusts the fuel quantity required to achieve a target AFR when there is no closed loop fueling correction. For ex., if the ECM is programmed to maintain a 12.0 AFR at all load conditions, you will get a 12.0 AFR going into the engine if this table is correct at all load conditions. Due to emissions control reasons, the majority of the time the ECM is trying to maintain a 14.7 AFR, and if this table is adjusted correctly, there will be no need for closed loop corrections. However, since engines wear causing compression changes and valves to gradually lose lift, the VE table programmed at the factory gradually gets out of tune. This is where the closed loop logic kicks in and the BLM function corrects the operating VE to achieve the target AFR when the calibrated VE table is no longer accurate. Don't think of this table as fuel efficiency because it is not. This table is the efficiency of the engine to suck in air, and to maintain a given AFR, a higher VE value means the engine needs more fuel to mix with the greater amount of air at that load condition. So for tuning purposes, what this table really represents is the amount of fuel needed to maintain a 14.7 AFR at a given load when the ECM is in closed loop, but the BLM function is not making any corrections. To tune this table, you try to reduce or eliminate any closed loop correction. From another link in my site you should understand by now how the BLM corrects the VE table to maintain a 14.7 AFR in closed loop. What you do is drive the vehicle in closed loop and record the BLM values at different load conditions. If you have Tunercat, open a $42 file and look at VE table #1. Note that the axes of RPM and MAP intersect at convenient values, say for ex. 1200 RPM and 50 MAP. This intersection represents a load condition that might for ex. have a BLM value of 135 associated with it. This means the closed loop logic is adding (135/128= 1.05) 5% to the fuel quantity to maintain a 14.7 AFR. This means VE table #1(summed with table #2) is deficient by 5% at 1200 RPM and 50 MAP. WINALDL will record an average BLM at this load point if you happen to drive at this load condition for very long. The longer you drive at this condition, the better the average will be since it will have more samples to include in the average. There are two averages that WINALDL will save, narrow average and wide average. Narrow is better for tuning because only BLM values associated with a narrow band around the load intersection point is considered in the average. Wide average uses any BLM value associated with a range halfway between the adjacent load intersections. Its Ok to use wide average when tuning, but the accuracy of the BLM will not be as good as the narrow average BLM. Once you have decided which BLM average value to use at a given load condition, divide the avg. BLM by 128 and multiply the VE value at that load condition by the result. The equation is (new VE table entry = old VE table entry x BLM avg./128). Repeat this equation for each load condition that you have an avg. BLM for. Lets run thru an example. Lets say at 2000 RPM and 60 MAP, you have a narrow BLM of 135, but there is only one sample. You also have a wide BLM avg. of 134 with 15 samples. I would use the wide average since there are not enough samples in the narrow average for it to have much accuracy. Now lets say the VE value (sum of table #1 and #2) at 2000 RPM and 60 MAP is 85%. So the correction at this load condition is 134/128 X 85% = 89%. So you would replace the 85% VE entry with 89% in that load condition only. You would then move on to another intersection of RPM and MAP and run through the same procedure of choosing an average BLM and correcting the VE table at that load condition. Now, obviously, to make as many VE table corrections as possible at each chip tuning session, you need to drive in a way that populates the entire BLM tab in WINALDL so that you will have an average BLM value for every intersection of the RPM and MAP axes. This is impossible to do since it is very hard to populate the extreme edges of the BLM tab table. As long as you populate as much of the BLM tab as you can, it will suffice. If you set WINALDL up to display the BLM tab on narrow average, you can see where the engine is running based on the green cursor on the computer screen. If there are any blank spaces, slow down until the engine RPM is about 100 RPM less than the RPM of the blank space you want to fill. Then, feather the gas to make the green cursor jump into the blank space. Its easier to manipulate the MAP than it is the RPM. By slowing down and then speeding up to come into the blank space from the low RPM side, you can make the MAP vary widely with small changes in throttle application. Since the engine has a lot of intertia to overcome, you can't make the RPM change drastically without a lot of throttle input, which would send the MAP to 100 MAP instantly. One final thing to mention is that the VE table values should change smoothly from one load condition to the next. Drastic jumps in the VE table usually mean something is wrong. I have found the usual problem is that a customer has not disabled the EGR valve operation, and this really messes up the closed loop tuning process. The BLM function tries to correct for a rich mixture caused by the EGR valve reducing the oxygen pulled into the engine. You will end up with a VE table way off at part throttle. To properly tune the VE table, you should disconnect the EGR valve in the engine bay, and you should disable the EGR logic in the ECM EPROM.

Main Fuel Table #2 (% Volumetric Efficiency Adder)

The Main Fuel Table #2 VE values are added to the Table #1 values to arrive at the total engine VE. It's not clear to me why GM split the VE table into two tables, but my theory is that it improves the resolution of the table allowing finer adjustments. The gist of this table is that it must be added to the main fuel table #1 before you make any percent corrections. In other words, the equation really should be (new VE table #1 entry + table #2 entry) = (old VE #1 table entry + table #2 entry) x BLM avg./128.

%TPS Threshold Vs. RPM for PE Mode

This table determines when the ECM enters PE mode based on throttle position. When the throttle is opened above the values in this table, the ECM will leave closed loop mode and use a different target AFR to increase power output. Exactly how to adjust this table is not clear, but I believe it has a lot to do with the size of the throttle body. If you install a much larger throttle body than the engine really needs, the engine will get all the air it can pull in at much smaller throttle openings. So you should lower the %TPS to bring on PE mode when you change to a larger throttle body. On the other hand, if you install a much larger engine keeping the throttle body size the same, you should raise the %TPS so that the engine doesn't enter PE mode all the time.

Power Enrichment Air Fuel Ratio vs. RPM

Remember when I said the ECM is in closed loop most of the time and tries to maintain a 14.7 AFR? When the %TPS for PE mode table value is exceeded, the ECM uses the values in this table as the target AFR, however, the actual AFR may or may not match the target AFR. Since a standard O2 sensor can only detect a 14.7 AFR, the ECM can't use the O2 sensor to check the AFR in PE mode, so it just assumes the BLM has done its job and the target AFR is being maintained in open loop. For most stock engines, this table should have values between 12.5 to 13 AFR. Performance engines can range from 10 to 13. This table and the 100 MAP columns (non-turbo) of the Main VE table and the Main Spark table are where hotrodders spend all of their tuning time on a dyno. I will explain how to tune on a dyno in a later advanced tuning section.

Accel. Enrichment vs. Differential TPS

This table is similar to the pump shot of a carburetor. When the throttle is pressed quickly, the % change in the TPS causes extra fuel delivery above what would normally be called for to cover the sudden power demand. I normally leave this table alone if my factory binary file closely matches the engine size that I am tuning. If you do adjust this table, get everything else done first. You don't want to cover problems with the tune elsewhere with this table since it would just be a band aid fix. A study of the pump cams from a Holley carburetor would probably give you some insight on how to make changes to this table.

Accel. Enrichment vs. Differential MAP

This table has no similar function in a carburetor that I know of. It adds extra fuel when there is a sudden change in MAP signal. But to me, it would seem improbable that the MAP could suddenly change without the TPS changing drastically also. So I don't know exactly when this table would be applicable all by itself. Again, as long as my starting factory binary closely matches my application, I never change it.

Open Loop AFR vs. Coolant Temp

This table determines the AFR when not in closed loop, whether as a normal condition or abnormal condition. But in order for this discussion to make sense, I have to include the Open Loop vs. MAP table in this paragraph. The Open Loop AFR vs. Coolant Temp table changes only with coolant temp and generally max's out at 13.0 AFR when the engine is fully warm. But at cruising loads and idling, you don't need as much fuel as you would at full power. So the Open Loop AFR vs. MAP table modifies the Open Loop AFR vs. Coolant Temp table to lean out the AFR when the

MAP decreases. For ex. look at just about any factory $42 calibration and notice that the AFR at 92 degrees C is about 13.0. This is the AFR at 100 MAP. But as the MAP decreases, the Open Loop AFR vs. MAP table adds up to 4 AFR points to this 13.0 AFR. So your total AFR at 20 MAP on some calibrations is 17.0 AFR. This is very lean and will barely run on most engines. If you look at the ASDU factory binary for a 5.7L engine, the Open Loop AFR vs. MAP table shows a 3.2 AFR at 40 MAP and 3.0 AFR at 50 MAP. Since 40 to 50 MAP is the MAP at hiway cruise speeds, the total AFR is 16.2 to 16.0 AFR on the hiway. Well, guess what. This means your gas mileage will actually be better by (16.2/14.7=1.102) 10% in open loop than it would be in closed loop where you would be running with a 14.7 AFR. This probably goes against what you've been told about running in open loop. As long as the VE table and/or the BLM function is doing its thing, you will get better mileage in open loop. So get on the hiway, drive for a while in closed loop, and then throw a switch disconnecting your O2 sensor. This will get you 10% better mileage. This is exactly what hiway mode does, but instead of disconnecting the O2 sensor, hiway mode re-enters closed loop mode every 60 seconds to recheck the AFR and adjust the BLM to make sure the AFR is still under control. Of course your emissions will go up and it is against the law, but it won't hurt the engine. Running leaner than 16.0 doesn't do much good though. There is a chart in the WINALDL site that shows the fuel economy vs. AFR. Above 15.4 there are diminishing returns.

Having said all this, running in open loop on an untested and untuned system could be dangerous to your engine. Remember that outside of closed loop, any programmed AFR is a target AFR, and it may or may not be achieved. If the VE table is not accurately tuned and the BLM function hasn't had time to correct for these inaccuracies, the open loop AFR could be way off, and instead of running at a cruise AFR of 16.2, you could be up in the 17 and higher AFR range if the tune is initially lean. This could possibly damage your engine. I hope by now you can understand the importance of tuning the Base Pulse Width Constant and VE tables first in closed loop before making any other adjustments to fuel tuning. Only in closed loop when the O2 sensor can verify the target AFR will you really know the actual AFR entering the engine. And since all other target AFR values are dependent on closed loop tuning, it only makes sense to do that first.

Air Fuel Ratio at Startup vs. Coolant Temp (choke)

One of the main benefits of EFI is improved cold weather drivability. This table is responsible for that. This table is subtracted from the sum of the open loop AFR vs. coolant and MAP tables. At any given temperature, the value in this table is subtracted from the other open loop tables to make the target AFR richer when cold. However, as time progresses after an engine start, the values in this table are gradually lowered until they completely disappear by the time the engine is warm. I will explain how in the next paragraph. For now, I find that most retrofitted engines need this table increased by 1 to 2 AFR points across the board. By increasing this table, the cold engine AFR is made lower (richer). This table is similar to how tight you have a choke adjusted on a carb.

Open Loop AFR vs. MAP

I discussed this table's function above so I will skip to the next one.

Choke AFR Multiplier vs. Coolant Temp

This table determines how fast the AFR startup vs. coolant temp table times out and is similar to a choke heat pull-off on a carb. There is a time interval at which the AFR startup value above is calculated. It is programmable, but I leave it at the 2 second stock value. Every 2 seconds, the startup AFR is reduced by the value in this table. For ex., if the value here is 95%, the next 2 second interval, the startup AFR correction will be 95% of what it was before, and the next interval it will be 95% of 95%. So each calculation interval, it is reduced by 95% of its previous value. In time, it is reduced to zero. Obviously, the higher the value in this table, the longer the startup AFR will be applied. Unless you have problems keeping the engine running after it is lukewarm, I wouldn't adjust this table. But if you lower this table, you might save gas by having the choke "pulloff" operate sooner.

Crank AFR vs. Coolant Temp

This table is not a modifier of other tables but a standalone table. The AFR values in this table are what the ECM uses during cranking. Cranking is when there is 12 volts on pin C9. Immediately after cranking, the ECM switches to the other open loop tables. I don't use this table on my systems unless hooking it up is easy, like on Jeeps. But even on those, I end up having customers disconnect them. The engine tends to flood out using this table i.e. having a wire hooked up on pin C9. More in depth hacking is needed to refine the purpose of this table. In my experience, leaving it disconnected has caused no problems, but I am in a mild climate.

IAC Steps vs. Coolant Temp

This table determines the IAC counts when the engine is cold and warming up. The IAC motor is driven to these values when the engine is just started and the IAC drops as the engine warms. But at a certain coolant temp and time lapse, the IAC counts are no longer used and the ECM goes into closed loop idle control (don't confuse this with closed loop fuel control) where it tries to maintain the idle speed at a certain RPM. The RPM in closed loop idle speed control is found in the next table. As for this table, raise it if the engine tends to die at idle when cold, or if you want a higher cold fast idle speed.

Target Idle RPM vs. Coolant Temp

This table is used to set the idle RPM after the ECM has timed out from a start condition and the coolant temp is above a certain threshold. It's the same as your curb idle speed adjustment on a carb, with the exception that the ECM can maintain the idle RPM even if devices load the engine. On most stock automatic engines, 600 RPM is good for most of this table. On engines with mild to wild cams, you will want to raise the values in this table to get a smoother idle.

The rest of the tables deal with either EGR or transmission torque converter lockup speeds. I will cover these tables in future updates since they are minor issues in retrofits. This completes the software section of the $42 ECM calibration template. I will discuss the $8D calibration template (MAP V8 TPI) in a future update to this manual. The discussion will focus only on the differences between the two ECMs. In the meantime, it's not that difficult to apply the principles discussed herein to other more complicated ECMs.

APPENDIX A – WHY GM EFI NEEDS REPROGRAMMING

This document describes how GM Fuel Injection manages fuel and spark in gasoline engines from a novice's point of view. There are three basic functions of GM fuel injection; fuel management, spark control, and transmission control. I will discuss fuel management first since that is the most important.

FUEL MANAGEMENT

EFI systems have different operating modes depending on the power output needed from the engine and operating conditions. The modes are open loop, closed loop, power enrichment and lean cruise modes. I will describe closed loop first since it is the predominant operating mode.

Closed loop mode means the engine control module (ECM) measures the A/F (air/fuel) ratio and uses this information to maintain the A/F ratio at a certain constant value. This mode uses feedback from an (oxygen) O2 sensor to close the loop. The A/F that the system tries to maintain is 14.7 to 1. The reason is that a 14.7 A/F ratio allows a catalytic converter to reduce exhaust emissions most efficiently. Engines don't necessarily run the best at 14.7 at all times, but they produce the least emissions with a catalytic converter at this ratio. Also, it just so happens that the standard O2 sensor is most accurate at 14.7 A/F ratio, which gives a good feedback signal.

The bottom line is that the ECM control logic tries to maintain a 14.7 A/F ratio during normal conditions. Normal conditions are a fully warmed engine and other than full throttle. Because of closed loop, engines can run for thousands of miles and the EFI system will compensate as the engine wears to keep fuel delivery consistent.

Open loop mode differs from closed loop in that the O2 sensor is ignored and the engine can be managed to run at A/F ratios other than 14.7, usually richer or lower than 14.7. The ECM controls the fuel injectors without getting any feedback that the calculated fuel delivery rate actually matches what the engine received. Without feedback, the loop is open, hence the term "open loop". A good example of open loop is when the engine is first started on a cold day. It requires a rich mixture to start a cold engine since a lot of the fuel doesn't reach the combustion chamber. This is because a portion of the gasoline doesn't vaporize and pools inside the manifold until engine heat vaporizes the fuel. Another reason that engines run in open loop when cold is that O2 sensors don't work until they reach about 600° F, so it takes a few minutes in cold weather for them to begin functioning. Open loop is sometimes used at idle conditions since some engines idle better with a rich mixture. In open loop, the ECM commands an A/F ratio that is determined from a table of A/F vs. engine coolant temperature. The open loop A/F is also adjusted to run richer as engine load increases.

Another mode is **power enrichment mode**. This mode only occurs under wide open throttle conditions and is solely determined by the throttle position sensor (i.e. above say 60% throttle opening.) In this mode, the ECM ignores the O2 sensor and commands a richer than 14.7 A/F ratio. This is because engines develop more power with a slightly richer mixture but not too rich. This is the area of tuning that interests hot rodders the most since PE mode is where the fuel delivery for all out power is determined.

Finally there is **lean cruise mode**. In this mode the ECM commands a leaner than 14.7 A/F ratio or less fuel. This mode can only used be used at light loads when the vehicle speed is above a certain value, in other words, hiway cruise. In this mode, the ECM commands the leaner A/F ratio, increases spark advance, and occasionally returns to closed loop mode to double check itself. There is one problem with this mode. GM ultimately did not enable this mode since it allowed them to circumvent the emissions laws to achieve better gas mileage. This mode is only used by GM EFI tuning experts with enough knowledge to make it work without damaging their engine. If the engine is run too lean, spark plugs, valves, and pistons can be damaged. However, when done correctly, up to 10% in mileage gains are possible above the already excellent mileage from closed loop mode.

In summary, GM EFI controls fuel to maintain a 14.7 A/F ratio at all times under normal conditions. During other than normal conditions, open loop mode is used so that A/F ratios other than 14.7 can be commanded.

From this point on, this document will go into greater detail about how the ECM implements the different modes and how the system can be retuned to control modified engines.

The best way to organize the rest of this document is to explain each term in the fuel delivery calculation individually. The pulse width of an injector determines the amount of fuel delivered to the engine. A pulse width is the amount of time an injector is turned on over a fixed time interval. If the injector is turned on longer, more fuel is injected. If the injector is turned off sooner, less fuel is injected. The equation that determines the injector pulse width is this:

BPW = BPC * MAP * T * A/F * VE * BVC * BLM * DFCO * DE * CLT * TBM

Where

BPW - Base Pulse Width

BPC - Base Pulse Constant

MAP - Manifold Absolute Pressure

T - Temperature

A/F - Air Fuel Ratio

VE - Volumetric Efficiency

BVC - Battery Voltage Correction

BLM - Block Learn

DFCO - Decel Fuel Cutoff

DE - Decel Enleanment

CLT - Closed Loop

TBM - Turbo Boost Multiplier

In the above equation, any term that has a value of 1 is essentially not contributing to fuel delivery or neutral. It is not taking away or adding to the fuel quantity.

BPW - Base Pulse Width means the pulse width under steady state engine conditions. Extra fuel is added when the throttle is juiced for acceleration. This is called asynchronous mode and will be discussed later. The above equation only consists of the synchronous mode contribution.

BPC - Base Pulse Constant is a term that is calculated from the volume of one cylinder, the flow rate of one injector, and a constant that converts the units to match other terms in the equation. For more on this term, see www.tunercat.com and the 1227747 ECM calibration help file.

MAP – Manifold Absolute Pressure is a measure of the load on the engine. It is the pressure inside the intake manifo in KiloPascals above absolute zero pressure. It is the opposite of engine vacuum meaning that a high vacuum readin is a low MAP value. Zero vacuum (full throttle) is 100 Kpa MAP. Although I don't fully understand the inclusion of this term in the equation, it is used extensively in all areas of engine control.

T – Temperature is actually the inverse of the absolute temperature. Once again, I don't fully understand the inclusion of this term in the equation, but as you will see later, I don't need to for the purpose of this document. It probably adjusts for the density of the air in calculating the fuel delivery.

A/F – Air Fuel Ratio is a term that I do understand. In closed loop mode, this term remains 1 and does not contribute to the equation. In open loop mode, this term takes on different values depending on coolant temperature, MAP, cranking status, clear flood condition, throttle position sensor, etc. When this term is other than 1, the closed loop term is held to 1 so that the two terms will not be fighting one another. This term is also where PE mode is implemented. In other words, this term is the controlling term when other than a 14.7 A/F is desired.

VE – Volumetric Efficiency is a term that corrects for different engine efficiencies. An engine is basically an air pump and the better the pump, the more power it can generate. Some engines are better pumps than others at a given RPM and MAP condition, so this term allows the equation to be calibrated for different engines. This is the single most important term that a speed density EFI system is famous for. There is a table in the ECM EPROM (chip) that gives VE for a given RPM and MAP condition. The important concept to grasp here is that the VE table is used in both open and closed loop modes, and essentially all modes. What is not so obvious to a novice is that this table, when programmed correctly, will result in a 14.7 A/F ratio with no closed loop or open loop correction taking place. In other words, this table provides a baseline that tells the ECM where 14.7 A/F ratio is so that other A/F ratios can be commanded and the ECM will be at the desired AFR. When this table is adjusted correctly, the engine runs the smoothest, not because the engine is running at 14.7 necessarily, but because all other ratios depend on this table being accurate. If this table is off, the closed loop term will correct the A/F ratio back to 14.7 to a degree. If this table is way off, the closed loop term can't compensate and the engine may not run period. A good example of when this table needs adjusting is when a hot cam is installed. A stock cam typically idles at 17 inches vacuum. But a hot cam might idle at 15 inches or less of vacuum. The VE table will be calling for more fuel at a lower vacuum reading (higher MAP), but the engine doesn't need the extra fuel because its still idling. In this case, the calibration doesn't match the engine's airflow characteristics. Unless the VE table is changed to lower the efficiency at this MAP and RPM, the engine will run very rich and probably stumble and blow black smoke. The majority of retuning a GM EFI system for non-GM and non-stock engines is done in the VE table since this is the baseline of the entire system. See Figure 12 for a sample of this table.

Main Fuel Table #1, % Volumetric Efficiency

RPM	MAP (Kpa)								
	20	30	40	50	60	70	80	90	100
400	12.9	22.7	24.6	23.0	26.6	31.3	38.3	42.6	44.5
800	17.2	27.0	31.3	39.5	40.6	43.8	46.9	48.8	46.5
1200	21.1	32.4	44.1	43.8	49.2	47.7	54.7	51.6	49.6
1600	22.7	38.7	48.4	49.2	49.6	52.3	55.9	56.3	56.3
2000	30.1	41.4	43.0	48.8	53.1	53.5	57.8	58.2	58.2
2400	34.4	46.5	52.7	54.3	57.8	58.6	60.5	60.5	60.5
2800	38.7	51.6	53.5	55.1	59.8	60.5	60.5	60.5	60.5
3200	36.7	49.2	57.8	51.6	57.8	57.4	59.4	60.5	60.5

Figure 12

BVC – Battery Voltage Correction is a term that corrects the fuel delivery rate for different battery voltages. The injector response is enhanced at higher voltages and is a bit sluggish by comparison at lower voltages. This term is a correction to offset the change in injector response due to battery voltage fluctuations. I suppose in time the closed loop term would correct the A/F ratio anyway, but this term catches it first. I see no reason to change this table since GM set it up based on their injectors' characteristics.

Block Learn – Block Learn is a term that is related to closed loop mode, but continues its influence during all modes. To make the block learn term easier to understand I will ask you to jump to the closed loop term discussion and then come back to this section. Now that you understand the closed loop term, I'll continue. The BLOCK LEARN term can be viewed as a semi-permanent automatic adjustment of the VE tables. I say semi-permanent because if you disconnect the battery, the BLM adjustments revert back to 128 or neutral (the neutral value for a BLM value is 128). Another name for the BLOCK LEARN term is long term fuel trim. Over time, the BLM numbers will settle at a value that gives a 14.7 A/F ratio with no closed loop term correction. I say values because there are more than one BLM value, unlike the single Integrator. The BLM can be up to 32 different numbers depending on the ECM model. The Block Learn term derives its name from the way the VE table is divided into blocks for the corrections to take place. To illustrate this better, see figure 1. I have drawn a grid over the VE table. The grid in the figure is for illustration purposes only. The actual BLM boundaries are decided by the ECM and the EPROM settings. Each division of the grid is called a Block Learn cell and each cell has its own BLOCK LEARN value. Each cell is associated with certain ranges of RPM and MAP in the VE table, so the BLM value in a given cell affects all the VE values in that cell. For ex., say cell 4 has a BLM value of 140. Every VE value in cell 4 will be increased by 140/128, or about 9 percent. In an adjacent cell, the BLM might be 110, which will decrease all VE values in that cell by 110/128, or 14 percent.

Now that you know how the BLM value affects the VE table, we can explain how the BLM itself is changed. In closed loop, it is discussed how the Integrator increases or decreases as the ECM gets feedback from the O2 sensor. The BLM value tracks the Integrator but has a delay. If the Integrator increases, so does the BLM, but the BLM lags behind the Integrator. The higher the Integrator climbs above 128, the faster the BLM rises. As the BLM rises, it begins to effect the AFR because remember, the VE table is being increased. As the AFR drops (gets richer) in response to the increased VE table, the Integrator will stop rising and begin to fall. Once the Integrator returns to a value of 128, the BLM will stop moving. Not only will the BLM stop moving, it will remain at that value permanently, essentially retuning the VE table at this engine operating condition. The only thing that will send the BLM back to 128 is removing power from the ECMs memory (or retuning the VE table manually with an EPROM burner). In reality, the BLM values never stay in one spot. They constantly jump around a bit near the 14.7 AFR. The tuning implications of this are as follows. Remember that the Integrator value can't be used to determine how far away from 14.7 you are. However, the BLM value can. Since the BLM settles at a value indicating how much more fuel is needed beyond what the VE table is delivering, you can use the BLM value to adjust the VE tables manually, i.e. with an EPROM burner. If your scantool shows a BLM of 150 at 2000 RPM and 50 KPa MAP, then you know that the VE table value at 2000 RPM and 50 KPa MAP needs to be raised by (150/128) 17 percent. The problem is that the ECM doesn't tell you where the cell boundaries are through a scantool, so you need a great deal of data to discover where the VE tables are off. This is where a datalogging program such as Datamaster or WINALDL come in handy. They allow you to drive for up to 25 minutes (longer with WINALDL) and record on your laptop hard drive every sensor and internal value in the ECM up to 7 times per second. Obviously, with this much data, you need a good analysis tool like Datamaster and a statistical analysis program. I take the Datamaster file and export it into Excel so that I can use the data sort functions to group the data into useful information. Once you get the VE table close, one trick is to reprogram the BLM upper and lower limits to 128 so that the BLM feature is disabled. Then, you can use just the Integrator to do the fine tuning. You can immediately see where the AFR is rich or lean at any location in the VE table. But you have to guess at how much to add or remove from the VE table since the Integrator value is not scalable like the BLM values. You can't use just the O2 sensor voltage though. If you are not in closed loop, the ECM will be trying to control to all kinds of A/F ratios, so the O2 sensor voltage will be meaningless. Unless you know all the factors affecting the AFR that the ECM is trying to control to, you have to do your VE table tuning in closed loop. The reason is that the ECM is definitely trying to maintain a 14.7 AFR by definition in closed loop. In general, if your BLM values are all significantly low, then you probably have your BPC set too high. If your BLMs are all too high, set the BPC a little higher. If the BLMs are both above and below 128, but not too far above (135) and below (120), your VE table is probably reasonably close. If your BLMs are way above and below 128 all over the VE tables, the calibration is probably significantly off and needs to be manually corrected in the chip with an EPROM burner.

Decel Fuel Cutoff – Decel fuel cutoff means exactly that. When you take your foot off the gas pedal going downhill or decelerating quickly, the ECM will cut off the fuel entirely. The difference between this term and the next one, DECEL FUEL ENLEANMENT, is that some fuel is allowed to reach the engine during DECEL Enleanment. As to when one or the other occurs, I don't know. I do know that on my TPI system, I noticed a lunge from the engine right around 1500 RPM, so I think this is where the DECEL fuel enleanment takes over from the DECEL FUEL CUTOFF. The lunge was significant and could easily cause you to run into the something if you weren't expecting it. I also believe a speed sensor is required for these two modes to operate period. So this is another reason to have a speed sensor.

Decel Fuel Enleanment – See Decel Fuel Cutoff above.

Closed Loop – Closed Loop is a term in which the ECM uses feedback from the O2 sensor to make corrections to the air fuel ratio. Another name for this term is short term fuel trim. The ECM makes immediate but temporary corrections to the fuel delivery to maintain the AFR at 14.7. The only ratio that can be maintained in closed loop is 14.7. This is due to the nature of the type oxygen sensor used on most passenger cars. There are other types of O2 sensors called wide band sensors, but they are expensive. They can be used to monitor the AFR at other than 14.7 AFR. The short term fuel trim value is called the Integrator in most early scan tools. The value of the integrator varies above and below 128 with 128 being no correction. For ex., if the Integrator is 140, the ECM is adding fuel because the O2 sensor is reading a lean mixture. If the Integrator is 115, the ECM is removing fuel because the O2 sensor is reading a rich mixture. Anytime the system is not in closed loop, the Integrator will immediately return to a value of 128 and stay there. There is only one Integrator and its value is solely dependent on the O2 sensor. When the engine is started, the ECM will keep the Integrator at 128 until the ECM determines that the O2 sensor is working correctly and that the engine temperature and time delay constraints before entering closed loop have been satisfied. Once the ECM goes into closed loop, the Integrator begins to adjust the fuel delivery to maintain a 14.7 A/F ratio, however, the Integrator term is only weighted half as much as the Block Learn term. The Integrator and BLOCK LEARN work together to re-tune the system to match any engine's charactersitics, up to a practical limit.

Turbo Boost Multiplier – This term adds extra fuel during boost conditions on turbo charged engines. Discussion of this term is beyond the scope of this document. It is recommended that you purchase Tunercat's SYTY TDF file if you want more information on this term.

Asynchronous Fuel Mode – This is not a term in the equation above but rather a temporary mode in which the injectors are commanded on longer for transient conditions. The accelerator pump shot is an asynchronous mode function in which extra milliseconds are added to the injector pulse width when the throttle postion sensor rapidly changes state. This will be illustrated later in other sections of this site.

SPARK MANAGEMENT

Unlike fuel management, spark management is an open loop only system. What you program in the chip is what the ECM uses with no automatic adjustment to improve performance or drivability. The exception to this statement is the knock sensor function of retarding timing to eliminate engine detonation, but this function does not advance the timing if the engine is running at less than optimum. The fact that spark timing is not automatically improved means that its up to you, the programmer, to optimize the spark timing tables, and herein lies the secret to tweaking more power from your vehicle. An engine operates at its best power level when the spark is timed to start combustion to give the maximum torque at that RPM and engine load. And getting spark timing this perfect requires extensive dyno testing or road testing. One fellow claims to have reprogrammed his chip 400 times to get it right on. The criteria for a good part throttle spark table is to be able to maintain a given speed and engine load (MAP) with a minimum amount of throttle input. I have found that a reasonably good spark table can be generated by duplicating the spark curves from a factory service manual for a particular non-GM engine or using the spark table from a stock GM binary file for a GM engine of similar size and specs. Beyond these methods, tuning a spark table is mostly trial and error by seeing what works the best and what doesn't. Figure 13 is the spark table I am running in my GMC 350 truck.

Main Spark Table, Degrees Spark

RPM	MAP (Kpa)														
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
400	26.0	26.0	26.0	26.0	26.0	23.9	22.1	19.0	16.2	14.1	12.0	9.8	8.1	7.0	6.0
600	26.0	26.0	26.0	26.0	26.0	26.0	26.0	19.0	16.2	14.1	12.0	9.8	9.8	9.8	9.8
800	26.0	26.0	26.0	26.0	26.0	23.9	22.1	19.0	16.9	14.1	12.0	10.9	9.8	9.8	9.8
1000	28.8	28.1	28.1	28.1	26.0	23.9	22.1	19.0	16.9	14.1	12.0	10.9	9.8	9.1	9.1
1200	30.9	29.9	28.8	28.1	26.0	23.9	22.1	20.0	19.0	16.9	15.1	15.1	14.1	12.0	12.0
1400	33.0	30.9	29.9	28.8	26.0	23.9	22.1	22.1	21.1	17.9	16.9	16.9	15.1	13.0	13.0
1600	34.1	32.0	29.9	28.8	27.1	25.0	25.0	23.9	23.9	21.1	20.0	19.0	16.9	15.1	14.1
1800	35.2	33.0	30.9	28.8	27.1	26.0	23.9	23.9	22.1	22.1	20.0	20.0	19.0	16.9	16.2
2000	35.9	34.1	32.0	29.9	28.1	27.1	26.0	23.9	23.9	22.9	20.0	20.0	19.0	16.2	15.1
2200	35.9	34.1	32.0	29.9	28.1	27.1	26.0	23.9	23.9	23.9	21.1	21.1	19.0	17.9	16.9
2400	36.9	35.2	33.0	30.9	28.8	28.1	27.1	26.0	26.0	26.0	26.0	22.1	19.0	17.9	17.9
2800	38.0	35.9	34.1	32.0	29.9	28.8	28.1	27.1	26.0	25.0	23.9	23.9	22.1	19.0	19.0
3200	38.0	35.9	35.2	33.0	30.9	29.9	29.9	29.9	29.9	29.9	28.8	22.9	22.1	20.0	20.0
3600	39.0	36.9	35.9	34.1	33.0	32.0	32.0	32.0	32.0	32.0	26.0	25.0	22.9	22.9	22.9

Figure 13

UPDATED 1/26/02

Many have asked me why the chip needs reprogramming if the fuel tuning is self adjusting. Well, its kind of like the difference between a cheap $200 paint job and a nice shiny $2000 paint job. If the ECM has to do a lot of self-tuning, there are some situations where although the car will be driveable, it will not be smooth and steady, but hesitant and sluggish. The best way to explain why this happens is to look at Figure 1 above once more. Look at the 2000 RPM row and the 40 - 70 range of MAP. Say you have been steadily cruising along at 2000 RPM and 70 MAP (up a significant hill). Also say the BLM at this load point settled at around 118, so the VE table at 2000 RPM and 70 MAP is too rich, requiring the subtraction of 8% (118/128) less fuel. Also say earlier in the day you were cruising at 2000 RPM and 60 MAP on a flatter road. Say that at this load point the BLM settled at 138. This would mean that the VE table value at 2000 RPM and 60 MAP is too lean by 8% (138/128). If we assume that the lines I drew on the chart are the BLM cell boundaries, then we have established that within the same cell, you can have drastically different BLMs. When this happens, your engine will surge, hesitate, and in general feel like it may run out of gas at any moment. It won't, it just feels that way. The reason is this. Say you were cruising at the 2000 RPM and 70 MAP load point for quite some time resulting in the same 118 BLM. Then you quickly peaked a hill and were going down the other side at 2000 RPM at 40 MAP. Now you have jumped from one cell to a lower one. Once you get to the bottom of the hill, you start back up a flatter hill at 2000 RPM and 60 MAP. You would feel a sluggishness and reluctance to go for a few seconds until the integrator and BLM could correct the mixture. What happened is that at 2000 RPM and 60 MAP, the VE table is too lean (138 BLM), but the last time you were in this cell, your BLM was 118 and it stayed there when you left the cell. So now, you are 17% too lean because you are running a 118 BLM where it needs to be 138. This is 16% (118/138) too little fuel. The engine would feel sluggish here for a few seconds until closed loop could correct it. In a very short time of probably less than 10 seconds, the 118 BLM will rise up to 138 BLM, so once you reach a steady unchanging load, the engine will smooth out. In the situation I have just described, the calibration is marginally matched to the engine, although it will run the engine and you can live with the car. But when you adjust the VE tables such that all VE table values in the same cell yield the same BLM, the engine will run much smoother. It doesn't mean the calibration is right, but better suited for the engine. What this means is that a well tuned chip smooths out the transitions from one load point to another so that you can't tell when you've crossed into another cell. Ideally, each load point in the VE table should have had its own floating BLM value, but I imagine that the processor memory and speed were insufficient to handle this complex of a task in the early to mid 1980s when this stuff was created. So, the goal of tuning using the WINALDL program on my site is to get all the BLM values to remain at 128 throughout all the different load points on the BLM chart above.

APPENDIX B – HOW TO CONVERT A MAF TPI SYSTEM TO SPEED DENSITY

In this section, I will discuss how to convert any year MAF TPI system to use the 1990-92 speed density ECM and sensors. This section will only discuss the aluminum hardware since the electronics and software are a part of my other DIY sections. Since a TPI manifold system consists of several parts, it makes sense to discuss each of the parts separately as they changed from year to year. The separate parts are the lower manifold, the fuel rails, the runners, the upper manifold or plenum, the throttle body, and the distributor. I'll start with the lower manifold.

LOWER MANIFOLD

The lower manifold is the part that is bolted onto the engine block first. There are significant differences between a Corvette manifold and a Camaro manifold. For most retrofits, the Camaro version is much easier. The main reason is that the 1987 and up Corvettes used aluminum heads that did not have internal EGR passages in the heads. Because of this, the Corvette TPI lower manifolds have an external EGR tube that runs from the exhaust manifold over the passenger valve cover and attaches to the lower TPI manifold just in front of the distributor hole. If you don't have the special EGR exhaust manifold and tube (see Figure 1), you'll have to make a custom blank off plate to seal the EGR opening in the Corvette manifold.

Another difference between Corvette lower manifolds and Camaro manifolds is the manifold center bolts. In 1987 and up Camaro iron head engines, the 4 bolts in the center of the engine (two on each side next to the EGR passages) were angled up so that they are more vertical. Both the TPI and TBI iron heads were modified this way. However, the Corvettes, continuing with the aluminum heads, did not get this modification, so the Corvette aluminum heads have all the intake manifold bolt holes at the same angle. This means that all Corvette TPI manifolds will fit all Chevy small block iron heads up through 1986. The Camaro TPI lower manifolds after 1986 have the angled center holes, but you can make them fit the older iron heads by enlarging (slotting) the 4 center bolt holes. I know it works because I've done it. However, I don't know that it works in reverse in which the pre-1987 lower manifolds will fit the newer iron heads. In other words, I know the newer manifolds (Corvette or Camaro) will fit the older heads, but I don't know that the older manifolds will fit the newer heads. Bottom line is look for the newest lower manifold you can find. As you will read later, this generally holds true for all the TPI parts (find the newest you can get).

Another item to note is the small coolant hose coming off the back of a Corvette lower manifold. This was used to vent air from the manifold to the coolant tank that was mounted on the passenger firewall. The Corvette radiator is lower than the manifold so the air had to be vented at the back. This is not a big deal and as long as your radiator is higher than the manifold, you can just plug the hole with a 1/8" NPT threaded plug.

I almost forgot about the EGR valve. It is bolted right in the center of the lower manifold with two small 3/8" (10mm maybe) head bolts. On the early MAF based systems, there was a temperature sensor that was used to tell the ECM if the EGR valve had malfunctioned, but on the speed density systems that I sell, the ECM can tell if the EGR valve is working via the software, so the temperature sensor isn't needed. I just unscrew the temperature sensors and throw them away. As you will read later, I wait until after I have the runners in place before I install the EGR valve. If you don't plan on using an EGR valve because your vehicle is old enough to be exempt from emissions laws in your state, you can just make a blank-off plate and bolt that down now before installing the runners. Don't forget to use the high temp gasket that came with your gasket set here.

If you are in the market to buy a used TPI manifold, watch out for these problems. Since aluminum is a fairly soft metal, bolt threads strip easily. Look out for stripped threads on the lower manifold, especially the ones that attach the runners. The threads are metric 8mm x 1.25. I always clean my threads with a tap before installing my TPI systems. Also, when starting the bolts in these threaded holes, always do it by hand and tighten them at least 3/4" of the way by hand. Using a powered air rachet is asking for disaster. You need to be able to feel that the bolt is starting in the hole properly and that it is turning smoothly all the way in. Any resistance needs to be investigated. Another problem area is the thermostat housing bolts. These frequently get stuck due to corrosion and they either break off in the hole or ruin the threads when removed. A helicoil insert is about the only thing that can save this manifold.

Finally, pay attention to the lower manifold bolts holding the manifold to the heads. For clearance to remove the runners, you need to use the lowest profile button head 3/8" bolts you can find. Standard 6 point bolt heads will NOT leave enough clearance to get the runners installed later. The factory Torx bolts are ok, but some of the aftermarket stainless steel allen head bolts are even better. Finally, bolting on the lower TPI manifold is no different from bolting on any other small block intake manifold. Just follow the directions in your gasket set and use black Permatex silicone sealant instead of the rubber end seals. The next part that is bolted on to a TPI system after the lower manifold is the fuel rails.

FUEL RAILS

The fuel rails have basically 4 different versions, two Corvette versions and two Camaro versions. The Corvette versions of all years have the fuel lines coming up the passenger side of the engine and then just stopping pretty much at the front of the engine. This is a problem when retrofitting these fuel rails onto an older engine with V-belt style accessories. The reason is that a special TPI V-belt top alternator bracket needs to attach to the manifold in this area and the fuel line connections block this access. The alternatives are to use Camaro fuel rails or hacksaw the alternator bracket (not the best thing to do) so that it does not attach to the manifold in this area. In contrast, the Camaro fuel lines run up the passenger side of the engine, but turn and go across the front of the engine so that they point down and towards the steering gear box. This is the easier set to retrofit because it gets the fuel connections out of the way. Fortunately, the Camaro fuel rails are interchangable with the Vette lower manifold.

The other major difference in the fuel rails for both Vettes and Camaros occurred in 1989. In the pre-89 TPI systems, there was what's called a cold start injector. This is a single 9th injector that plugs into the drivers side runner at the lower manifold. Its purpose was to provide extra fuel during cranking, much like a choke. It was controlled by a thermo-time switch threaded into the front of the lower manifold. When the key was turned to crank, the thermo-time switch engaged the cold start injector provided the engine was cold enough. As soon as the injector was turned on, a heater inside the switch began heating, and this would turn off the cold start injector in about 8 seconds. The cold start injector switch was completely independent of the ECM, which must have bothered GM engineers, because in 1989 MAF systems and all TPI MAP systems therafter, all TPI systems' cold start enrichment was handled by code in the ECM using the 8 main fuel injectors. So for all fuel rails in 1989 and later, the cold start injector disappeared. The way this affects changing to speed density is as follows. The cold start injector was provided with fuel from a small tube coming from the back of the drivers side fuel rail. On the newer fuel rails after 1988, this tube is not used. On the earlier fuel rails, this tube wrapped around the drivers side runner tubes and ran next to the valve cover to the cold start injector. Well, if you remove and replace your runners as much as I do, it gets to be a major pain to remove this tube first every time. So what I do is buy a 3/8" diameter aluminum rod, and turn the rod down to a 9 mm diameter. Then I cut a short dowel from the rod about 1/4" long and I install the alumnium dowel in place of the cold start injector fuel line reusing the rubber O-ring from the small fuel line. Then, I cut the small fuel tube right at the cold start injector and use the cold start injector only as a plug in the hole in the drivers side runner. This saves me the $20 cost of a kit from some TPI shops to get rid of the cold start injector. To summarize, you want to use Camaro fuel rails if you can, and you want to use the 1989 and later ones if possible.

On a side note, if you aren't convinced to go with a speed density TPI system, and you insist on a MAF based system, watch out for TPI units with the cold start injector still in place. Even on a MAF system, the 1989 $6E code (the best from what I have heard) doesn't need the cold start injector. So if you are in the market for a MAF system, don't let anyone tell you that a unit with a cold start injector is the best.

Another important part of the fuel rails is the fuel pressure regulator (FPR). There is a spring loaded rubber diaphragm under the regulator cover. This bleeds off excess fuel to keep the pressure constant (somewhat) in the fuel rails. One hot rodder trick is to buy an adjustable FPR so that fuel pressure can be increased (or decreased) at the drag strip for tuning. I don't think this is necessary on a daily driver, but there is another reason to raise fuel pressure. In another section of my website, I mention that Ford fuel injectors are an excellent alternative (READ: cheap) to GM fuel injectors as replacements.

New Ford injectors are cheaper than having your stock GM injectors cleaned. However, Ford injectors are rated at a lower pressure than GM injectors. So, to get the Ford injectors to match the injector size programmed into your MEMCAL, you may need to raise the fuel pressure. In other words, you can take 19 lb/hr Ford orange injectors, and raise the fuel pressure to 50 PSI and get them to 21.4 lb/hr. I believe 50 PSI is the maximum recommended increase in fuel pressure. This is almost to 22 lb/hr, which is the stock GM injector flow rate on a 350 TPI engine. However, to do this, you don't need to buy an adjustable FPR. All you need to do is put a quarter or nickel, or any other thin piece of metal under the FPR cover to raise the fuel pressure. As to exactly how thick this piece of metal needs to be, you'll just have to experiment with your regulator to get the fuel pressure where you want it.

Installation of the fuel rails is not that difficult as long as you go slow and be careful. The fuel rails are bolted onto the lower manifold with 4 bolts. You have to sort of wiggle and work the injectors into the injector holes while being careful not to damage the o-rings on the injectors. A good tip is to put Dexron ATF on the o-rings to lube them before pushing them into the holes. This holds true when installing the injectors in the fuel rails also (you did comletely disassemble the fuel rails and regulator and clean them out, didn't you?). Only after you have all 8 injectors inserted fairly well into the injector holes on both sides should you push harder to seat the rails on the lower manifold. Then install the 4 bolts and tighten them down. Don't forget to install the bolt in the front of the lower manifold that holds down the fuel line connections.

To connect the fuel rails to 6-AN fuel line fittings, you'll need to buy GM saginaw to 6-AN fittings. The cheapest place I know to get them is www.summitracing.com for about $6 a piece; part #s are EAR - 991954 and EAR - 991955. I buy the rest of my 6-AN flare to barb fittings and high pressure hose (250 PSI Parker PUSH-LOK) from my local Parker hose and fitting store. It's the same as Aeroquip's socketless fittings, but at 1/2 the price.

TPI RUNNERS

There isn't much to say about the runners other than there were changes in 1989 when the cold start injector was deleted by GM. When the cold start injector disappeared on the 1989 MAF TPI units, the hole in the driver's side runner was deleted and the metal was left as a metal tab covering the hole where the cold start injector used to be inserted in the lower manifold. So, if you can find a set of post 1988 runners, you don't need the old cold start injector as a plug for the hole. There was one other consequence of deleting the cold start injector that many people do not realize. This will take a fairly long explanation.

The overall purpose of the runners is to carry air from the upper plenum to the lower manifold and ultimately into the engine. The runners on the drivers side are actually carrying air for the passenger side and the runners on the passenger side are carrying air for the drivers side. This doesn't have any bearing on this discussion but just thought I'd mention it. On early runner sets, in addition to the 8 main tubes which are about 1-1/2" in diameter, there are also two other small tubes about 1/2" diameter, one on each set of runners. By the way, the drivers side and passenger side runners are not interchangable. Anyway, these small tubes serve separate functions. The one on the passenger side runner is to allow EGR gases to flow from the lower manifold, where the EGR valve sits, up into a passage cast in the bottom of the upper plenum. This passage delivers the EGR gases to two small holes just inside the mouth of the upper plenum where the throttle body bolts on. I'm not sure why GM went to the trouble to route the gases all the way up here, other than to make sure the EGR gases were delivered equally to all cylinders. But the problem is that this long passage gets filled up with carbon and is a bear to clean out. You have to have the lower manifold, runners, and upper plenum hot-tank cleaned (in tanks safe for aluminum) to get the carbon out of the EGR passages. Since EGR was used on all TPI systems, all years have the small tube on the passenger side runner.

This is not true however for the driver's side runner. Referring back to an earlier paragraph, remember that the cold start injector plugged into a hole on the bottom of the driver's side runner. This hole led down into a cavity inside the bottom of the lower manifold. This cavity then went from the front of the engine to the back. Also, there are small holes (1/4" diameter)drilled from this cavity up into the cylinder ports in the lower manifold leading to each cylinder. The purpose of these holes is to deliver the cold start injector fuel into the cylinder ports of the lower manifold. However, you can't just have liquid fuel only, it needs to mix with air to be carried equally to all cylinders. So, where does the air come from? Well, it comes from the small 1/2" diameter tube on the drivers side runner. There is a passage in the throttle body that allows air to enter the throttle body, flow through the idle air control motor orifice, and then enter another passage cast in the bottom of the upper plenum. This passage then leads over to the drivers side small tube to be delivered down to the cold start injector. But we don't have a cold start injector anymore, so why do we need the small tube on the drivers side runner? The answer is we don't, and that's why GM got rid of it. But this poses a problem. If the idle air goes through the throttle body and then flows into the passage in the bottom of the upper plenum, and then flows over to the small tube, but it isn't there, then what happens? Well, this is the problem. What this means is you can't use a newer (post 1988) set of runners with an older throttle body. This got me once on a system I sold. I sold a TPI system to a customer, but I did not have a good set of runners to send him. The set I had bought on Ebay looked good when I bid on them, but the seller packaged them poorly and dented them pretty bad. TPI nuts and bolts make good tumbling stones in a loosely packed box. Anyway, I sent the TPI system I sold with the bad runners, but promised to find a better set and send them later. Well, a month later, I bought a perfect set from a 1991 Firebird and sent them. When the customer got them installed, his car would not idle well. It would idle as long as the idle speed screw was turned in, but the ECM had no control of it. We finally determined that because the runners I bought did not have the drivers side small tube, the early throttle body on the customer's engine could not deliver any air flowing through the idle air control motor passages. To fix this, we had to modify the throttle body to use the late style runners. I will discuss the fix in the throttle body section later.

There are differences in the appearance of the runners between some of the Corvettes and the Camaros. The Corvette runners have a rough exterior texture sort of like aluminum oxide sandpaper. But I'm not sure if all the Corvette TPI systems had the rough texture runners or just the early years. The Camaro runners all had smooth exterior runner surfaces. Some people like to polish the outside of the smooth runners for a shiny finish, but to me when you see a lower manifold that is not polished and runners and an upper plenum that are polished, it looks worse than no polish at all. I like the uniform finish and tone of the dull aluminum, as long as it is clean.

Finally while we are on the subject of appearance, the number one problem with TPI systems that I buy is the runners. Nine times out of ten, the runners will be dented, some not too bad but some real bad. I try to stay away from the badly dented systems, but finding a system with a set of runners with no dents is very rare. If you find a system like this, and you want a perfect set of undented runners, you better go ahead and get it because they aren't that plentiful. You may have to pay the $400 price for a nice TPI system without a harness if you want a perfect set of runners. By the way, you can't buy TPI runners at the dealer, they are a discontinued item. You can buy aftermarket siamesed runners, but throughout this website, I will only be discussing stock parts. If you had the money to spend on after market parts, you probably wouldn't be reading this site anyway. And if you think you can remove the dents, think again. Once the runners are dented, it's real tough to get them back to an unblemished round look. Repaired runners stick out like a sore thumb, at least on the smooth Camaro ones. The rough Corvette runners don't show dents quite as bad. By the way, if you buy a system from me, unless you find your own runners, or pay the premium for an undented set, you'll get blemished runners. I'll send you digital photos of the runners so you will know what you are getting before I ship them and you won't be disappointed when they arrive. It's not as bad as this sounds, but absolutely perfect runners are hard to find, trust me. If the runners are really dented or are very blemished, I won't sell them. I have a few sets like this stashed away somewhere. I will take them to the recycling yard one of these days. There is a website that refurbishes TPI systems and claims to be able to get the dents out, but I have not bought from them. The site is: www.cruzinperformance.com.

To install your runners, you have to be careful and work slow. Careless hasty movements will result in dented runners, happens every time. The slightest bump into any other part of the car will create a dent. The reason is they are so light and unwieldy that you practically sling the things around in the engine compartment. To begin installing the runners, start with the driver's side. They sit further back and the bolts are harder to get to, so I like to get them installed first. Place the gaskets in their correct location and then position the runners in the general location they will be installed. Next, angle the top of the runners towards the center of the manifold and carefully work the bottom of the runners between the fuel injectors and under the fuel rail. Its tricky so work slow. Once you get the runners past the fuel rail, hold them against the lower manifold and start a couple of bolts. The one next to the cold start injector hole (don't forget to use the cold start injector as a plug for the hole) is a good one to start first. Then start the bolt closest to the front of the engine. After you get these two bolts started, insert all the rest of the bolts and hand tighten them with a rachet extension and a Torx bit. After all the bolts are run down by hand, then you can tighten them to their final torque with a rachet. Don't overtighten, just snug them down. Once the drivers side runner is installed, position the passenger side runner (gaskets first) in its general location and once again tilt the top of the runner towards the center of the manifold and work the bottom between the fuel injectors and beneath the fuel rail. Then hand start all the passenger runner bolts into the lower manifold, however, don't turn them anymore than that. The reason is that the upper plenum has to be inserted between the top of the runners and you need the slop in the passenger side runner to get the upper plenum in there. The system is now ready to install the upper plenum.

UPPER PLENUM COMING SOON TO CUSTOMEFIS.COM

APPENDIX C – HOW TO ADJUST AND TROUBLESHOOT GM EFI

Soon to be available at www.customefis.com!!