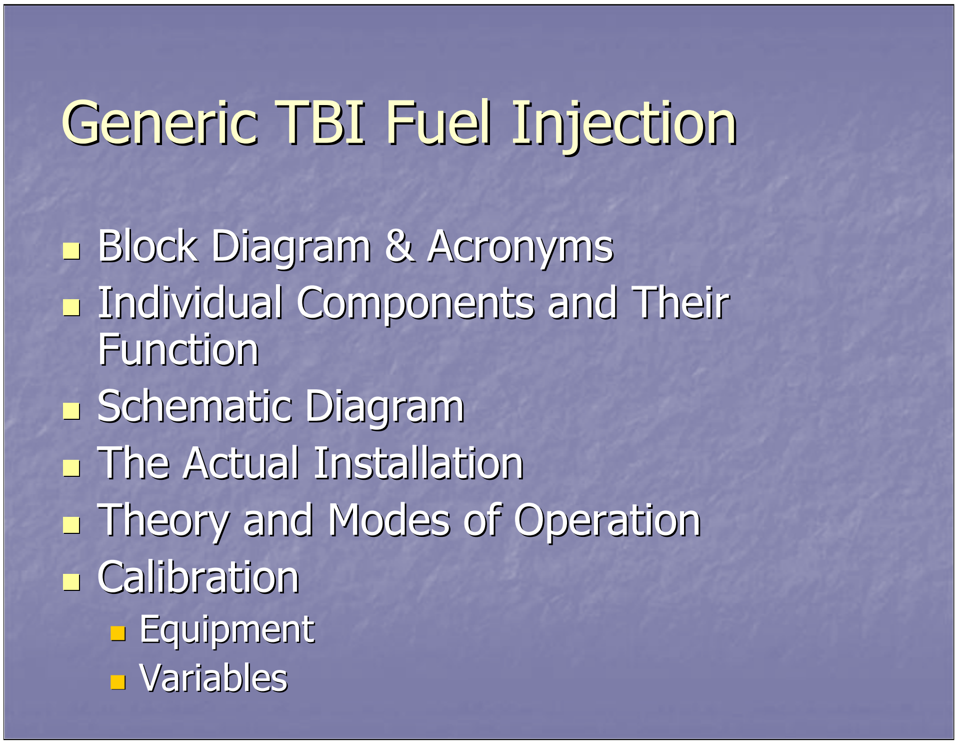
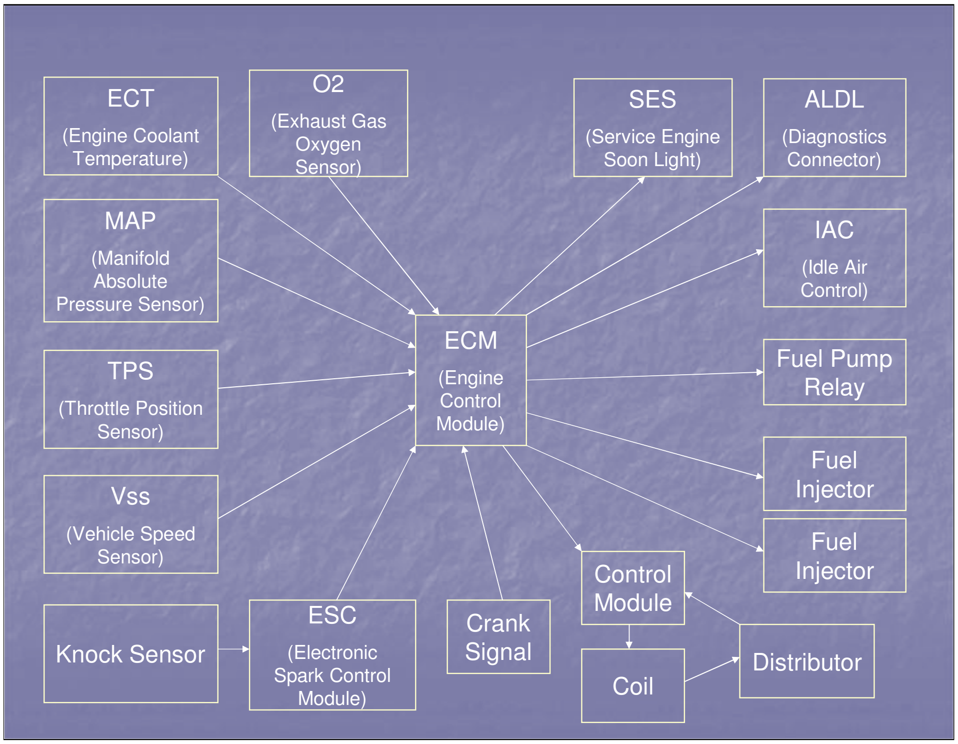
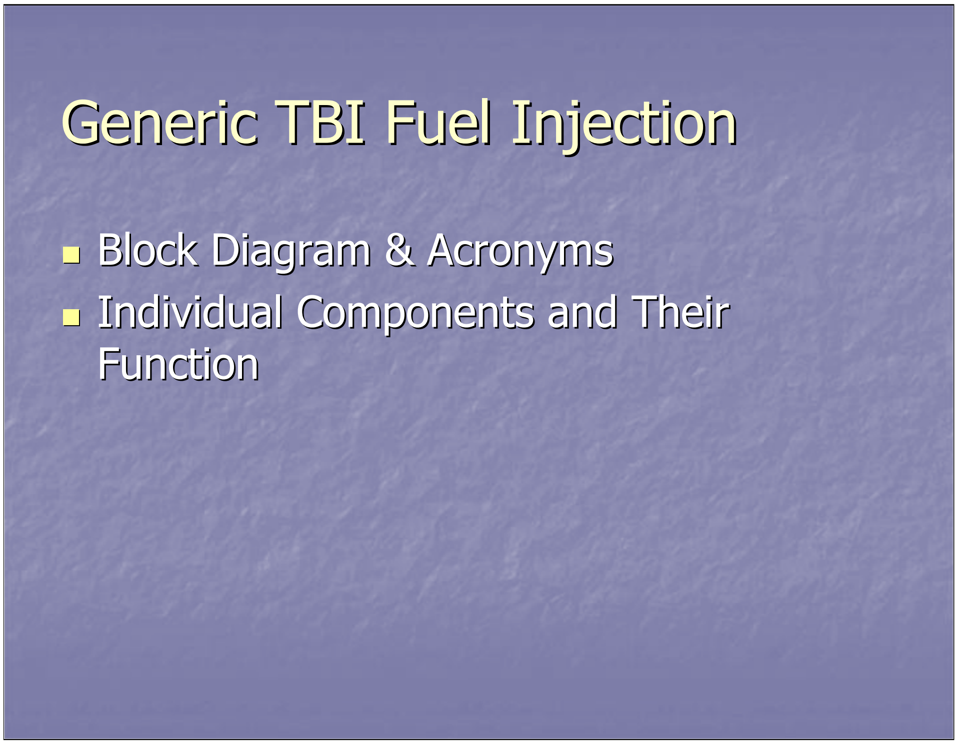


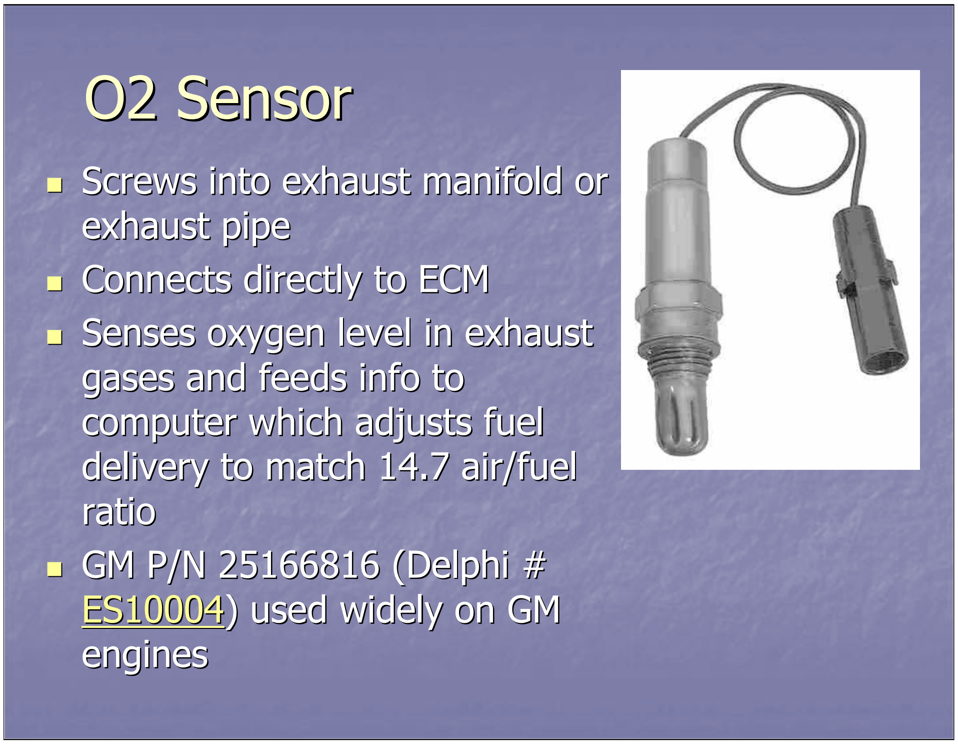
The subject of this session is throttle body fuel injection. What is covered here is generally applicable to most TBI systems, but we will be putting particular emphasis on how it applies to our GMC's. Before we get started, please be advised that this presentation, along with most of the words spoken, is available on a CD. There are several here, and if we need more, I can make them. Price is $3 to cover the cost of the CD and making it. Feel free to use the information on the CD in any way you want as long as it is not for commercial purposes. <c>We will start out by looking at a block diagram of the various components. These individual blocks call out the name of the component along with the acronym if we will be using one.<c> Next, we will take a look at the individual components and what function they play in the system, their wiring connections, and a possible source or two with part numbers. <c> Then we will look at a couple schematics that show you pin connections for each component, and normal GM wiring color codes. GM has been quite consistent in using the same color codes for wires through the years and throughout the various divisions.<c> By then we should be ready to consider the details of making an installation, including making up your own wiring harness and fabricating the necessary hardware. Before we get into the last subject of calibration, we will consider some <c> theory and modes of operation, and finally, take a look at how to go about calibrating your new installation. Most of you will probably want to consider purchasing a calibration EPROM from Howell or Turbo City, or any one of a number of independents you may be able to locate on the web or elsewhere.<c>



First, the “big picture” block diagram. The components you will see on the left are sensors, or inputs into the ECM. The components on the right are controlled by the ECM based on the inputs it receives from the sensors. The inputs are: <c> O2 Exhaust Gas Oxygen Content Sensor, <c> ECT Engine Coolant Temperature Sensor, <c> MAP Manifold Absolute Pressure Sensor, <c> TPS Throttle Position Sensor, <c> Vss Vehicle Speed Sensor (not always used), <c> and the Knock Sensor <c> whose signal is conditioned by the ESC Electronic Spark Control Module before reaching the ECM. The generation ECM after the one we normally use in our GMC’s is usually referred to as a PCM (Powertrain Control Module). It contains the knock sensor signal conditioning on board, so the ESC was pretty much eliminated in the mid 90’s with the PCM’s.<c> Finally, we have the Crank Signal whose job it is to tell the ECM we are trying to start the engine. On the other side of the equation, we have <c> SES Service Engine Soon Light, <c> ALDL Diagnostics Connector, both of which control nothing, but provide information and means of human interface to the ECM. The components actually controlled by the ECM are: <c> IAC Idle Air Control, <c> Fuel Pump Relay, <c> the two fuel injectors, <c> and the spark timing. The computer tells the Control Module in the Distributor how much to advance/retard spark, but the Control Module actually tells the Coil when to fire based on information from the ECM and the magnetic pickup in the Distributor (that’s where initial timing enters in). The Distributor rotor and cap send the spark to the correct cylinder.<c>



We have covered <c> the block diagram and acronyms and are now ready to take a look at the <c> function of the individual components, and some general information about them, and how to procure them. <c>

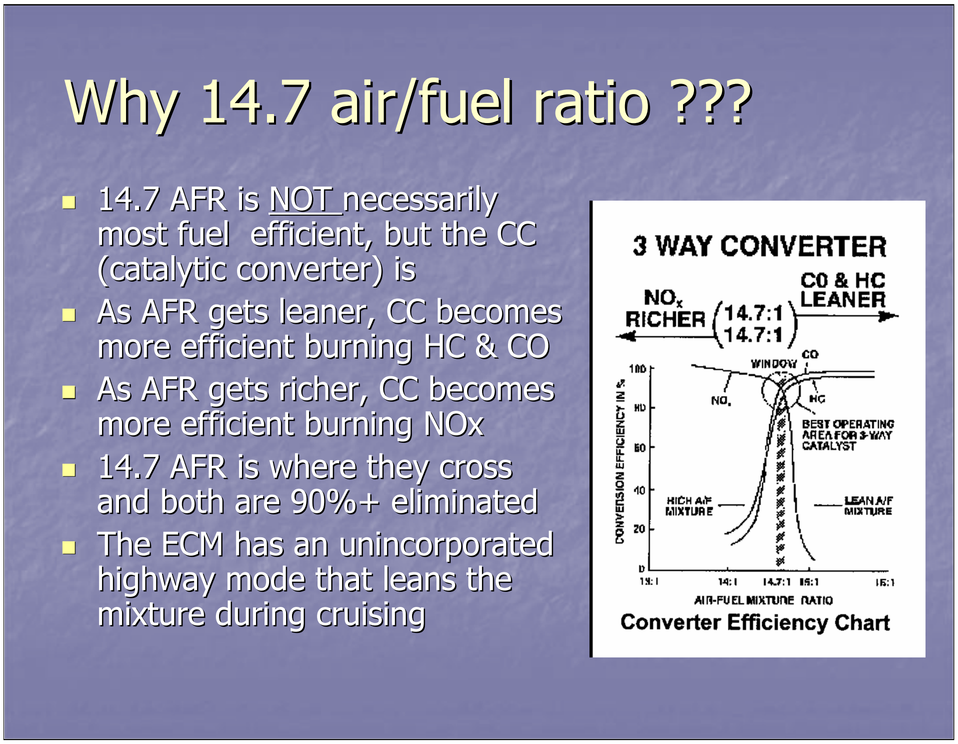


Let’s talk first about the <c> O2 Sensor. <c> It screws directly into the exhaust manifold or the exhaust pipe as close to the manifold as possible. If you screw it into the exhaust pipe, you will first have to weld a suitable bung onto the pipe. The bung can be procured from Summit or any number of other places.<c> The sensor’s job is to send a voltage to the ECM which tells it to adjust fuel delivery to match the target 14.7 air/fuel ratio. <c> These are widely available in wrecking yards off almost any GM vehicle newer than the late 80’s, but I suggest you buy a new one. The single wire sensor works great for our application if placed reasonably close to the manifold. It needs high exhaust gas temperature to function properly. By the way, the yellow underlined text used throughout this presentation can be clicked upon to direct you to further information on the internet if you get a PowerPoint copy of this session. <c>

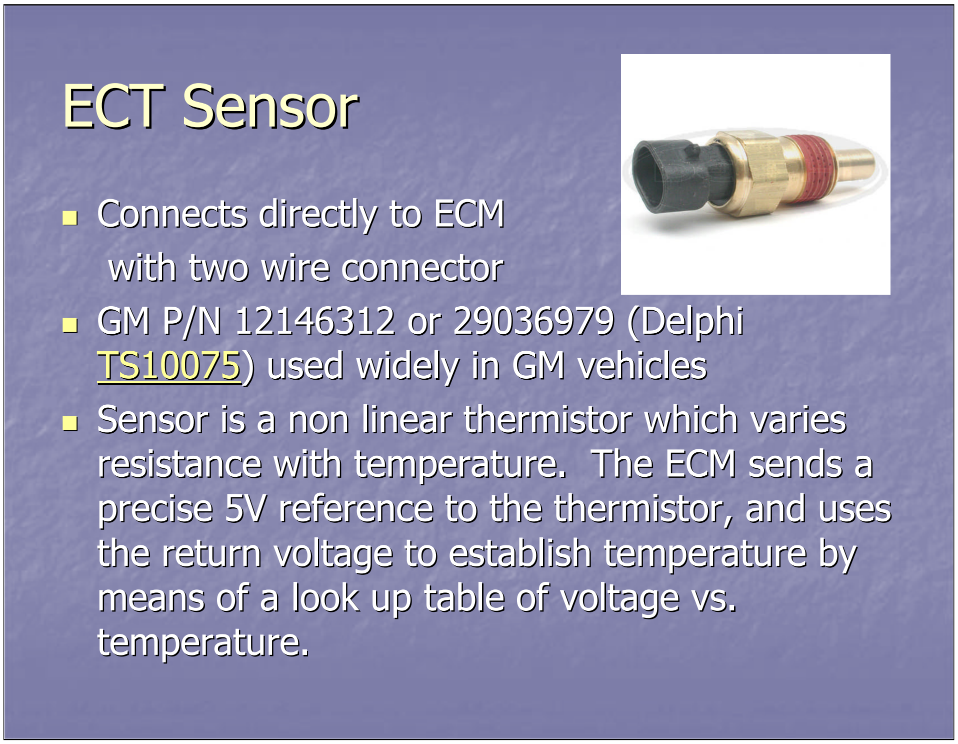
O2 Sensor Types

- We typically use a single wire sensor (grounds through block).
- Exhaust gases heat to operating temp.
- In or very near exhaust manifold for quickest heat
- Has a very narrow operating band (essentially over/under 14.7 AFR)
- Three wire sensors (12V, GND, and signal leads) work much like single wire except they self heat.
- Four wire sensors have two signal leads; one indicates high AFR, the other low AFR.
- A wide band O2 sensor has a much wider band.
  - Very helpful in calibration work
  - Good for a couple points AFR either side of 14.7

As I mentioned, we typically use <c> the single wire sensor which <c> takes advantage of exhaust gas heat to reach operating temperature. <c> That is why it needs to be within a foot or so of the exhaust manifold, preferably closer to reach temperature faster. <c> It has a very narrow operating band, and is essentially like an on/off switch. It either reads over or under 14.7 AFR. <c> The three wire sensor is much like the single wire sensor, except it has two additional wires to a heater element that provides quick heat to get it up to operating temperature quickly. <c> The four wire sensor has two signals; one for high AFR and one for low AFR. At least it provides for a narrow band that says AFR is OK rather than always being over or under the target 14.7 AFR. <c> Some vehicles use a wide band sensor which can give fairly accurate readings a couple points on either side of 14.7. These are most helpful if you plan to do your own calibration work, or if you would like to be assured of a rich enough mixture at or near WOT. <c>



Why is the target AFR 14.7:1? It is a common misconception that the most efficient fuel economy is obtained at 14.7. This is not necessarily true. However, it is the most efficient operating point for the catalytic converter. <c> If you take a look at the 3 Way Converter Function Graph which plots converter efficiency vs. AFR, you will note that <c> as the AFR gets leaner, the CC becomes more efficient in controlling hydrocarbons and carbon monoxide. <c> As AFR gets richer, the CC becomes more efficient in controlling oxides of nitrogen. <c> Where they cross, the AFR is 14.7:1, and at that point, all the nasties are 90% eliminated. Thus, the target of 14.7 AFR is defined by catalytic converter considerations, not maximum fuel economy. <c> The ECM does have an unincorporated feature called Highway Mode. When in highway mode, O2 feedback is not used to control fuel delivery, but is rather an open loop enleanment process to maximize fuel economy. I read somewhere that the reason it is not incorporated is because someone determined the feature to be a nifty way of defeating emissions controls to improve economy. DUH! <c> Russ Harms is experimenting with the Highway Mode in his PFI coach.

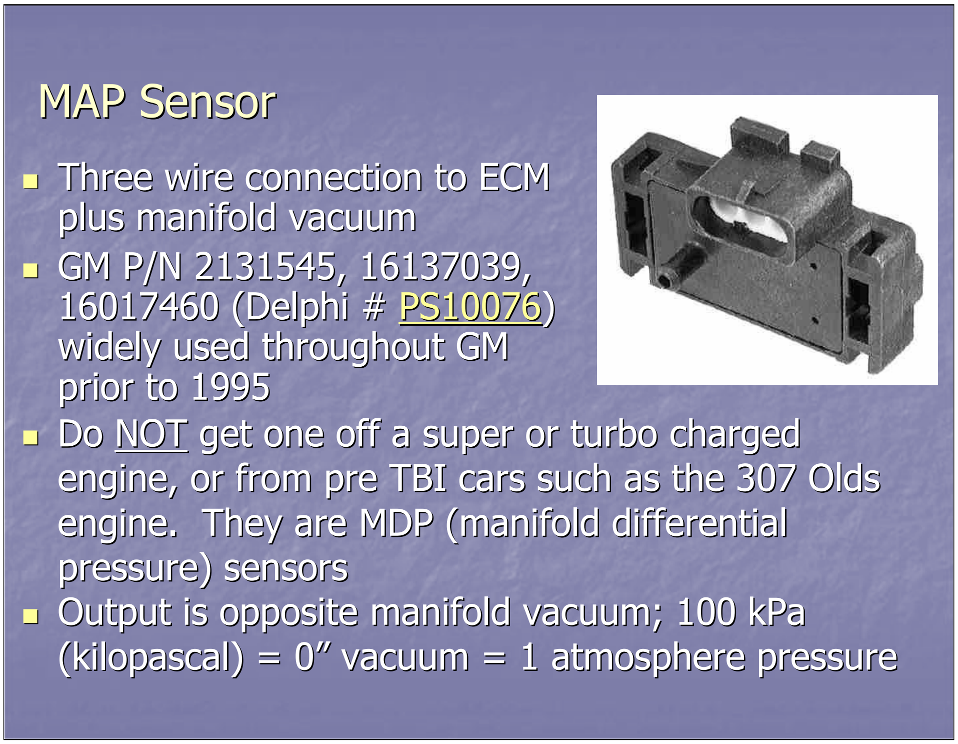


Moving on to something much more straight forward and less controversial, let’s consider the ECT sensor. <c> It connects directly to the ECM by means of two connection wires. <c> These things are a dime a dozen in wrecking yards and they almost never fail, so save yourself $20-$30 and pick one up at you favorite men’s mall. <c> The sensor element is a non linear thermistor which varies resistance with temperature. The ECM sends a precise 5V reference to the thermistor. It reads the return voltage and compares it to a lookup table embedded in the program ROM to establish actual temperature.

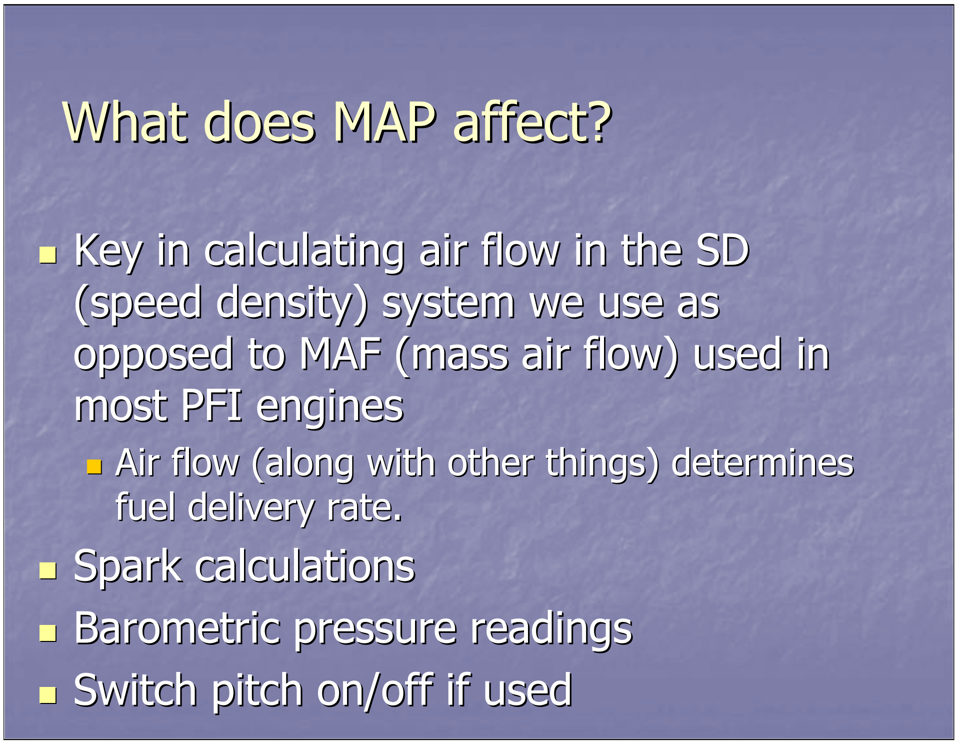
What does ECT affect?

- Fuel delivery
- Ignition timing relative to initial setting
- Knock detection system, thus spark retard
- Idle speed
- Torque converter clutch application (switch pitch converter???)

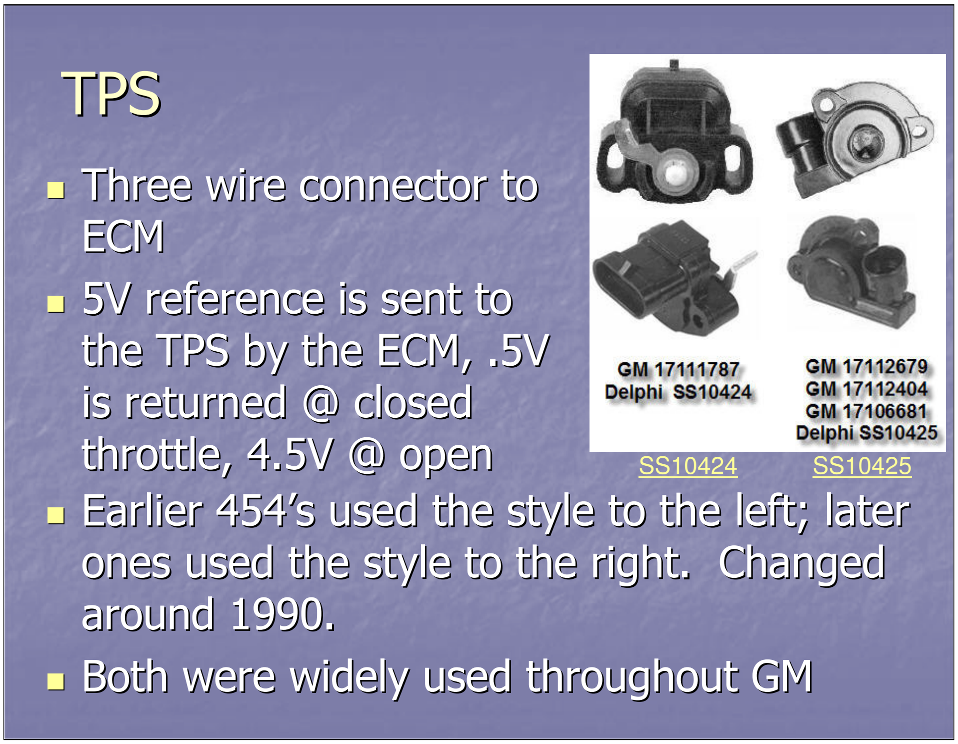
What does the ECT sensor affect? <c> Fuel delivery, <c> Ignition timing relative to initial setting, <c> knock detection system, thus spark retard, <c> idle speed, <c> and torque converter clutch application in later vehicles. We have a switch pitch torque converter in our GMC and I would like to experiment with using the ECM to control it. <c>



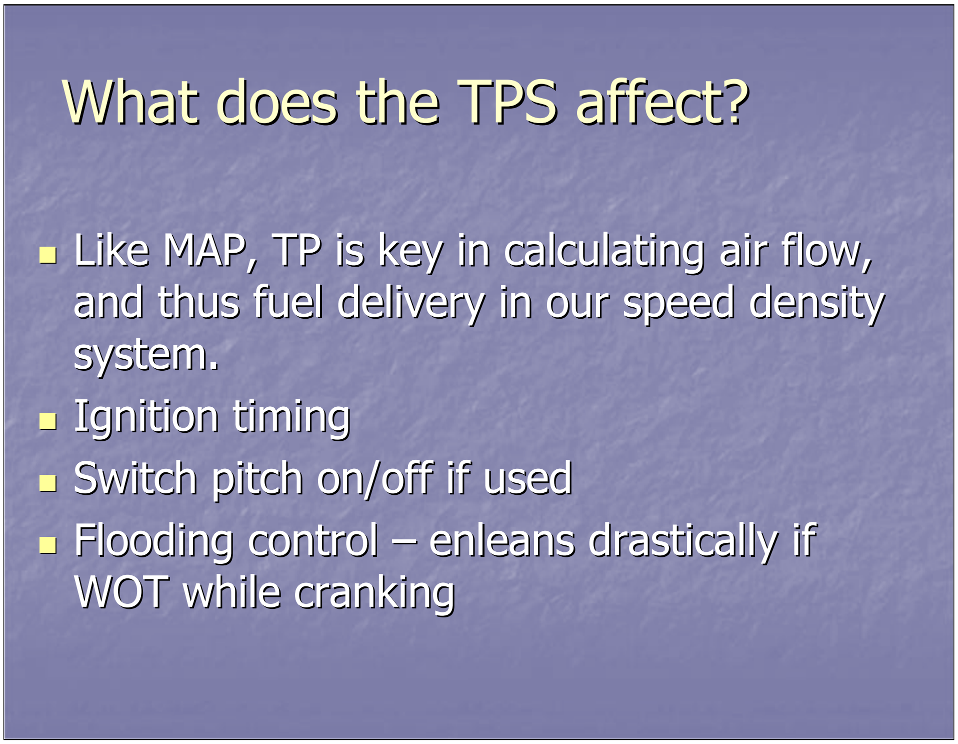
The MAP Sensor has a three wire connection to the ECM consisting of a 5V reference, ground, and a signal wire. It is a variable resistor that varies resistance in proportion to absolute pressure and sends nominally a 0 to 5V signal to the ECM. The other connection to the MAP Sensor is to manifold vacuum.<c>These are plentiful in salvage yards because they were widely used throughout GM up until about 1995. <c>Do not get one off a super or turbo charged engine, or from pre TBI cars such as the 307 Olds engine you will be looking for to find a suitable distributor. They are manifold differential pressure sensors as opposed to absolute pressure sensors. <c>Output is a bit confusing because it is opposite what we are used to dealing with, and is typically shown in kPa (kilopascals). 100 kPa is nominally equal to 0" of vacuum at sea level which also equals 1 atmosphere of pressure. Temperature and humidity and other atmospheric conditions affect atmospheric pressure a little bit, and altitude affects it a lot, so on top of Pike's Peak, 100 kPa is considerably more than atmospheric pressure. Thus in the signal sent to the ECM by the MAP sensor is automatically altitude compensated. <c>



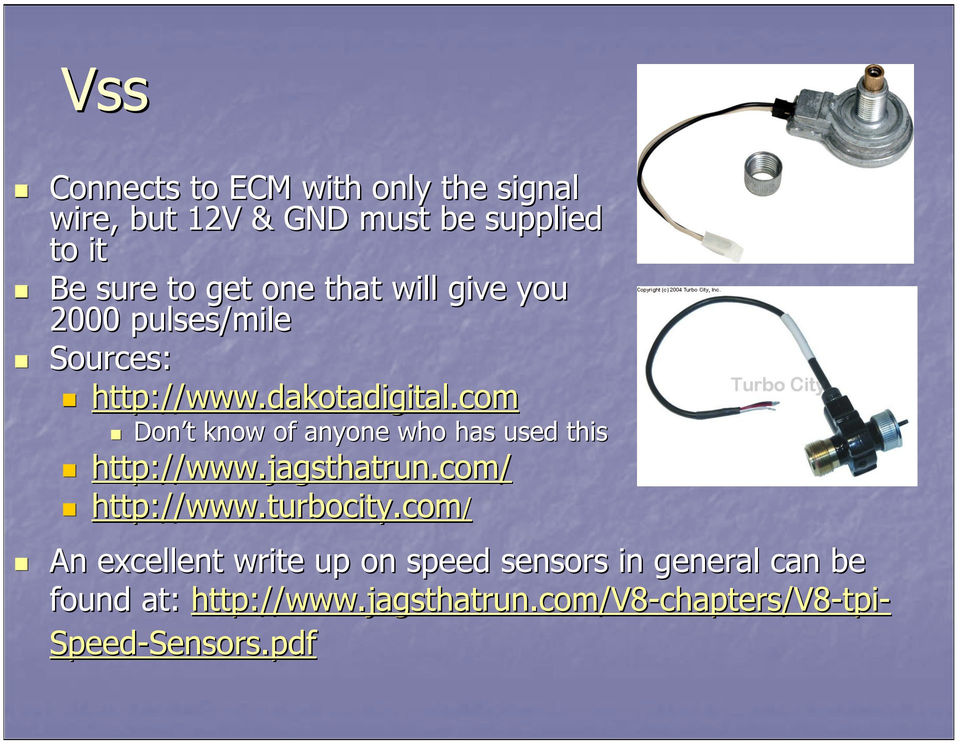
MAP is one of two key factors in calculating air flow in the SD (speed density) system we use as opposed to MAF (mass air flow) systems used on most PFI modern day engines. <c>Air flow is obviously the most important factor in determining fuel delivery rate, although there are a number of other factors the ECM takes into account when calculating injector pulse width. <c>MAP is also used in making spark advance/retard calculations, <c>Barometric pressure readings, <c>and in turning our imaginary switch pitch on and off. <c>



The TPS (throttle position sensor) also has a three wire connector to the ECM consisting of a 5V reference, ground, and the signal wire. It is a variable resistor connected to the throttle blade shaft. <c>At closed throttle, it sends nominally a .5V signal to the ECM, and at WOT it sends nominally a 4.5V signal. It is easy to troubleshoot because you can see the voltage or resistance vary uniformly as you open and close the throttle blade. When I first cranked up my system, it ran, but very erratically and I got TPS error readings. The readings coming from the TPS seemed perfect until I finally noticed the voltage readings were backwards. After swapping the ground and 5V wires it ran perfectly. Check the obvious first! It would have saved me a frustrating day had I done that!<c>Earlier 454's used the style to the left, and after about 1990, they used the one to the right. <c> Both are fairly plentiful in salvage yards as they were used widely throughout GM. <c>



TP is the other key factor, along with MAP mentioned earlier, that is key in calculating air flow and thus fuel delivery in our speed density system. <c>Other things affected by TP are: <c>Ignition timing, <c>turning our imaginary switch pitch on and off, <c>and in controlling flooding while the engine is cranking. If TP is over about 75% WOT, air fuel ratio is drastically enleaned. A surprising number of people are unaware of that. A friend called one day and said his Buick ran fine when he put it away, but it would not start and he smelled gas. I told him to hold the accelerator to the floor and crank, and it started right up. <c>



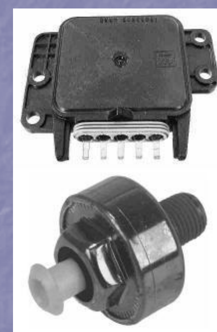
The Vss, if you use one, connects to the ECM with only one wire, the signal wire. 12V and ground must be supplied separately, at least to the sensor I used. I'm not sure if it is an optical sensor or how it works, but somehow it counts teeth on a gear turned by the speedometer shaft. If you look closely at the one on the top, it has only two wires, so it probably is a magnetic pickup of some sort that counts teeth. <c>In any case, be sure to get one that gives you 2000 pulses per mile. <c>The sources I am aware of are shown. However, I don't know of anyone who has used the one shown on the top from Dakota Digital. Frank Folkman has one and plans to use it on his system, but it is not up and running yet. If it works, it will save you considerable $. <c>An excellent write up on speed sensors and various ways to sense speed can be found at www.jagsthatrun.com or by clicking on the link above if you get a copy of this presentation. <c>

What does the Vss affect?

- Short answer is not much
- IAC reacts differently when Vss is very low.
- Switch pitch on/off if used
- Gives nice speed output through ALDL connector
- Some kits do not use Vss

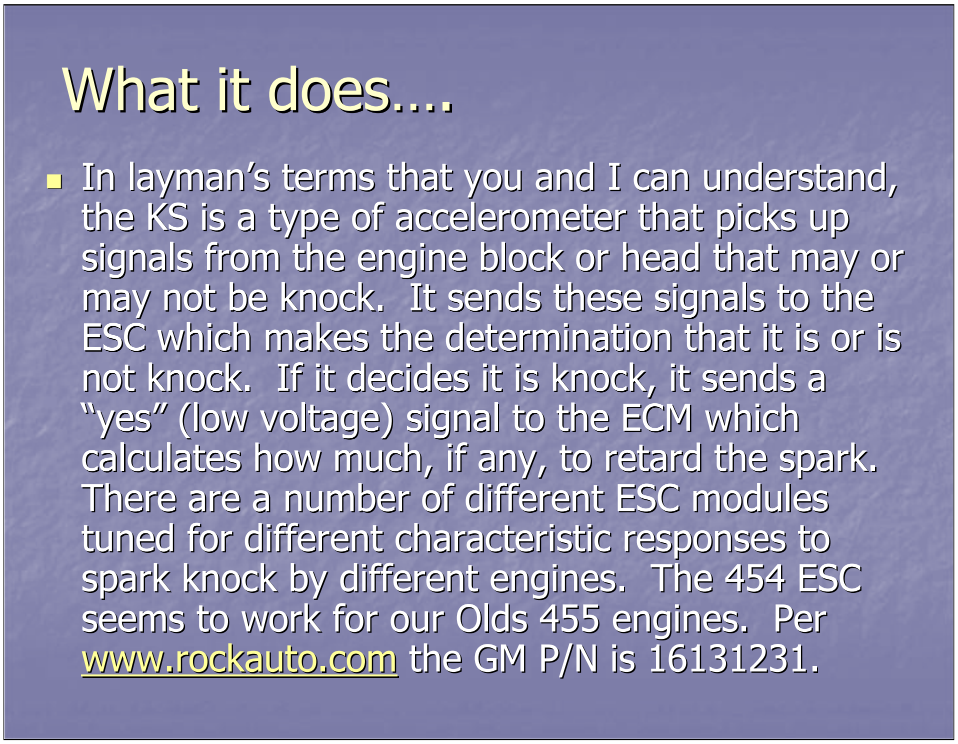
What does Vss affect? The short answer is not much. <c>I am told the IAC reacts differently when Vss is very low, <c>and it would affect when our imaginary switch pitch is turned on and off. <c>It gives a nice ground speed indication through the ALDL connector, although mine worked fine at first, it presently says I am going about 95 when I am actually doing 60. I don’t have a clue what is wrong with it, but have not noticed anything different in how the engine runs. <c>Some kits do not include Vss sensors. <c>

Spark Retard System – Knock Sensor and ESC Module



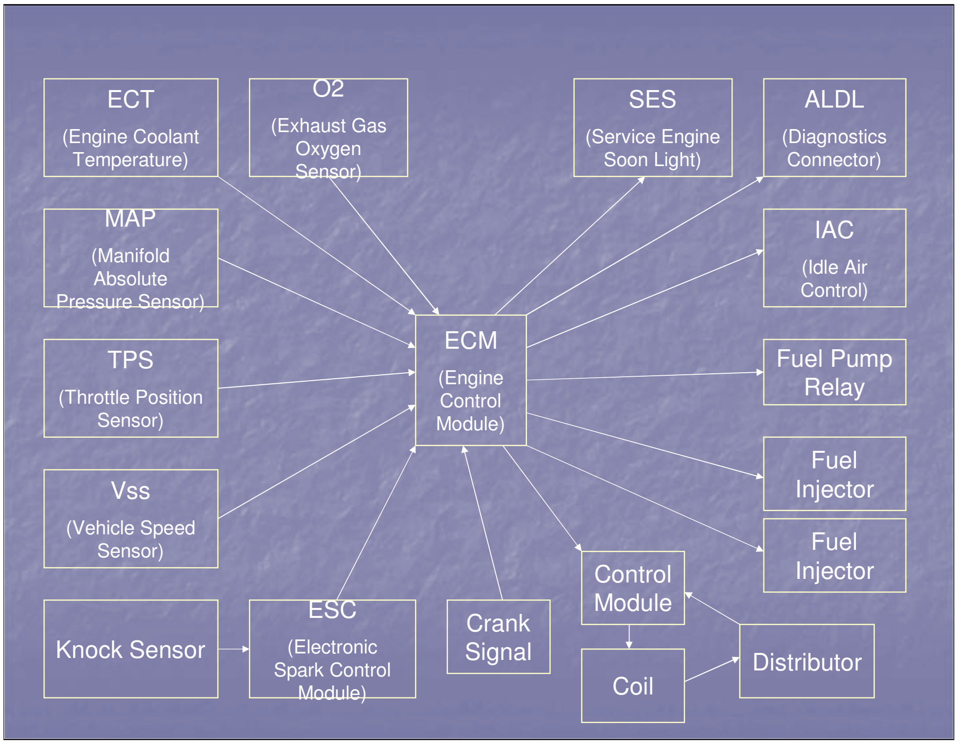
- Single wire Knock Sensor to ESC – grounds through block
- Single wire ESC to ECM but 12V and GND required to ESC
- Later ECM's and PCM's have ESC built into them.
- KS GM P/N is 10456288 (Delphi # AS10015) – suggest you buy new
- ESC GM P/N is 16131231

A single wire connects the knock sensor to the ESC (Electronic Spark Control) Module, and it grounds through the block. <c>There is also a single signal wire connecting the ESC to the ECM, but 12V and ground must be supplied to it separately, so that the ESC has four leads: 12V, ground, signal, and knock sensor. <c>Later ECM's and PCM's have the ESC circuitry built into what GM calls the Calpack (presumably the calibration package?) along with the engine calibration and "limp home" information. The Calpack plugs into the computer, and is specific to each different calibration, thus eliminating the ECS Module. You will see an example of this generation computer later in the presentation. <c>You will probably have to buy a new knock sensor and ESC unless you are lucky enough to find the 454 parts in a salvage yard, or you are willing to experiment with other components. <c>

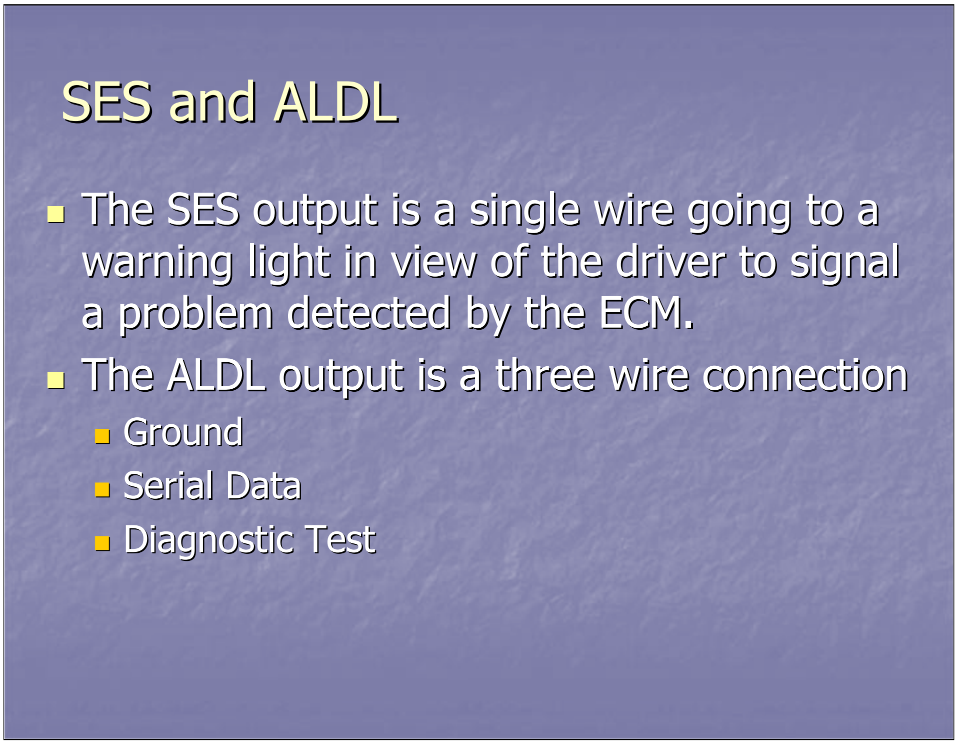


In layman’s terms that you and I can understand, the KS is a type of accelerometer that picks up signals from the engine block or head that may or may not be knock. It sends these signals to the ESC which makes the determination that it is or is not knock. If it decides it is knock, it sends a “yes” (low voltage) signal to the ECM which calculates how much, if any, to retard the spark. There are a number of different ESC modules tuned for different characteristic responses to spark knock by different engines. The 454 ESC seems to work for our Olds 455 engines. Per www.rockauto.com the GM P/N is 16131231. I am using an ESC of unknown origin, probably out of a late 80’s or early 90’s GM pickup that had a 305 or 350 engine. It works fine picking up knock whenever Carol or I hear it, and sometimes when we don’t hear it. So there are others out there that work, but there are no guarantees. <c>

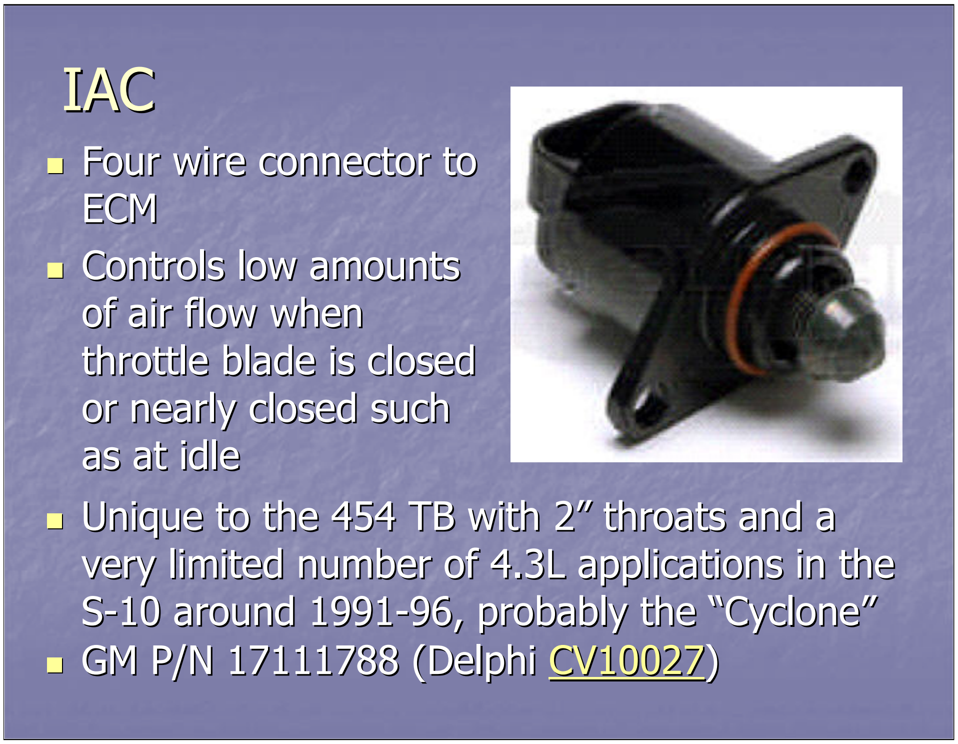
The crank signal is simply a fused tap into the heavy purple starter solenoid wire that runs along the RH valve cover. <c>It tells the ECM the engine is cranking so it can calculate fuel delivery and spark timing accordingly. <c>The crank signal also tells the ECM to keep the fuel pump relay energized until you have oil pressure at which time the oil pressure switch takes over fuel pump power supply responsibilities. <c>



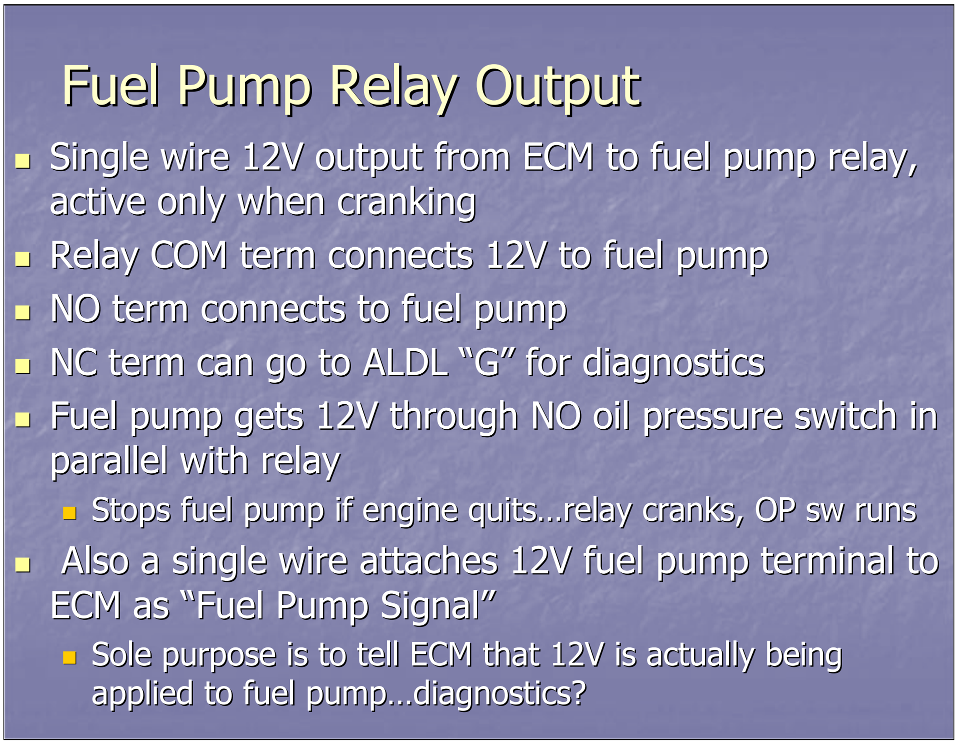
We have now covered all the inputs shown on the left (pause)<c> and are ready to tackle the outputs on the right of the chart.(pause) <c>



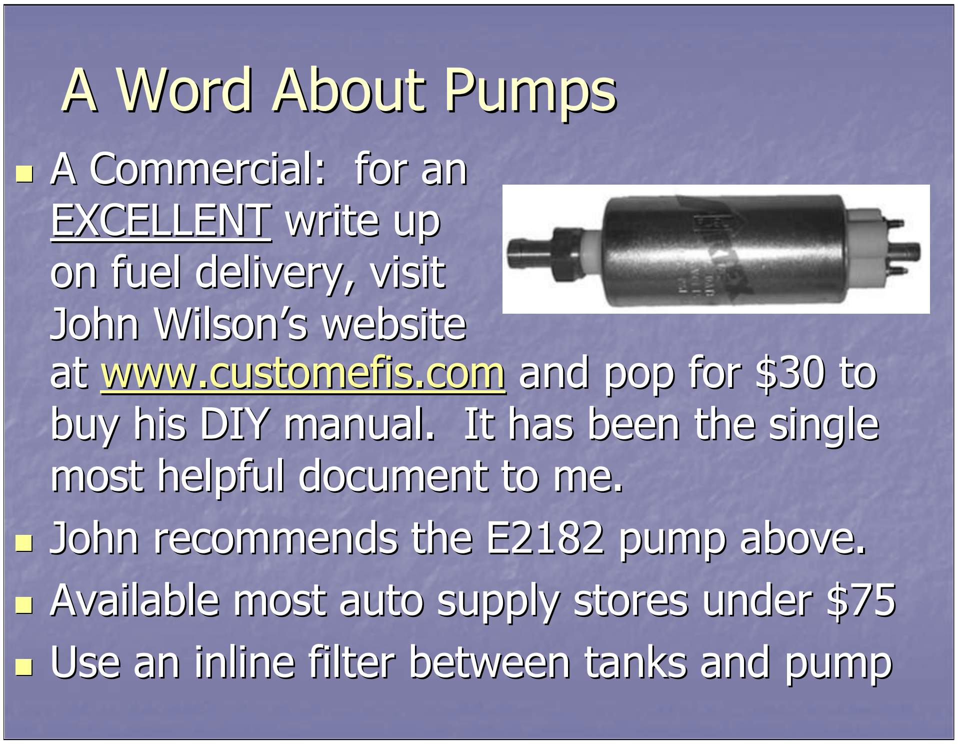
The first two outputs, Service Engine Soon and ALDL are to provide driver and service information. The SES output is a single wire going to a warning light in view of the driver to signal that a problem has been detected by the ECM. <c>The ALDL has three leads: ground, serial data, and one for diagnostic test purposes. <c>



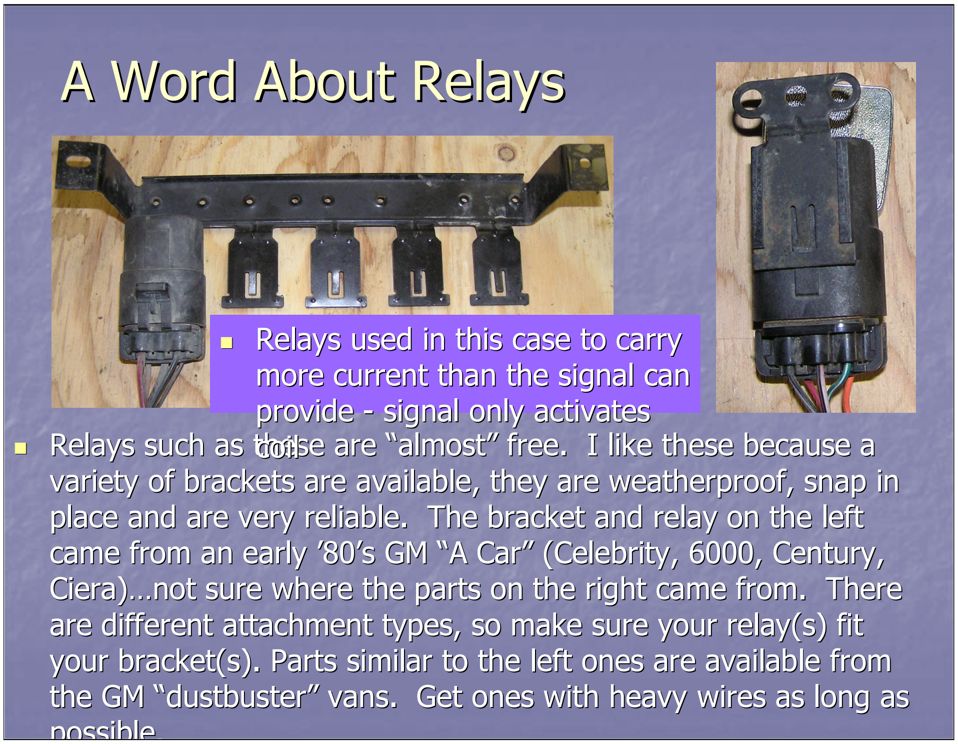
The idle air control is connected to the ECM with four leads. The ECM needs to be able to move the plunger in and out precisely and needs to know exactly where the plunger is at all times. <c> As the plunger retracts, it opens a passage that bypasses the throttle blade, and provides small amounts of filtered air to the intake manifold. Thus, it can provide accurately metered amounts or air at low air flows such as at idle.<c> This IAC looks similar to many others, but is unique to the throttle body with the 2” bores. The 2” bore throttle bodies were used only on the 454’s, and a limited number of 4.3L applications in the S10, presumable the supercharged “Cyclone” rockets of the early and mid 90’s. Make sure the throttle body you get has one of these already on it, or you will pay some $60 to buy a new one. <c>



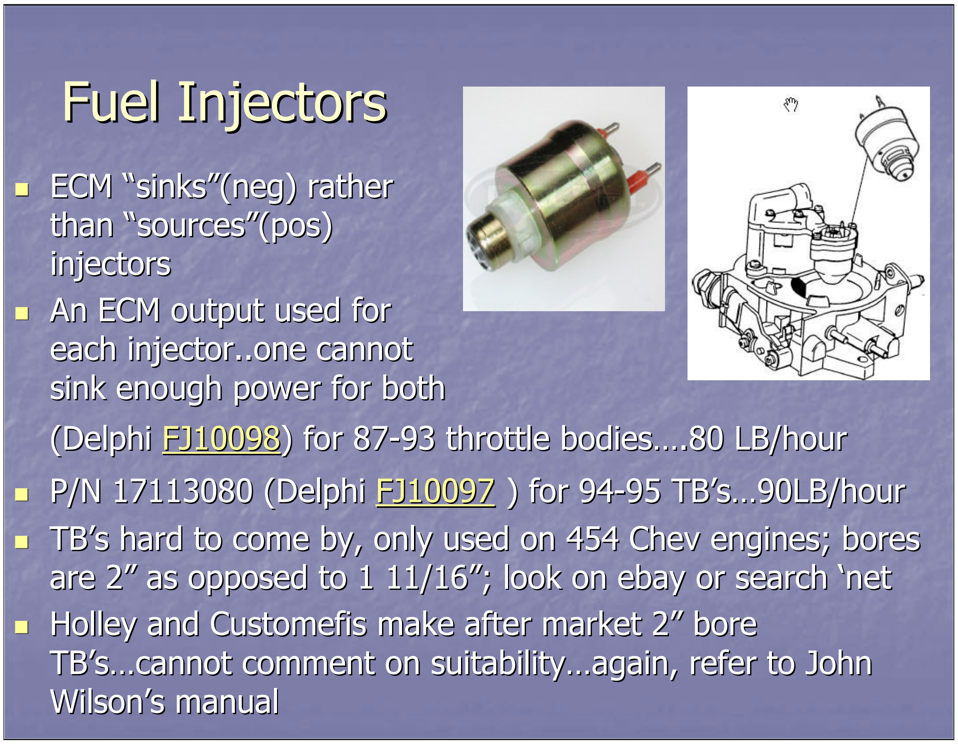
The fuel pump relay is a single wire 12V output from the ECM to the fuel pump relay and is active only when cranking. <c>The common terminal of the relay contacts connects a 12V volt source to the fuel pump <c> through the normally open terminal. <c>The normally closed terminal can go to the ALDL "G" terminal for diagnostics. <c>Once the engine is running, the fuel pump gets 12V through a normally open oil pressure switch wired in parallel with the relay. That way, if the engine loses oil pressure for whatever reason, the fuel pump stops. So all the relay does is provide 12V to the pump while the engine is cranking; an "ignition on" 12V supply provides 12V to the pump through the oil pressure switch as long as there is oil pressure and the switch is on. <c>There is also a wire connecting the fuel pump 12V terminal to the ECM whose sole purpose is to tell the ECM the fuel pump is seeing 12V. I'm not sure what the ECM does with that information. It is possibly used for diagnostic purposes. <c>



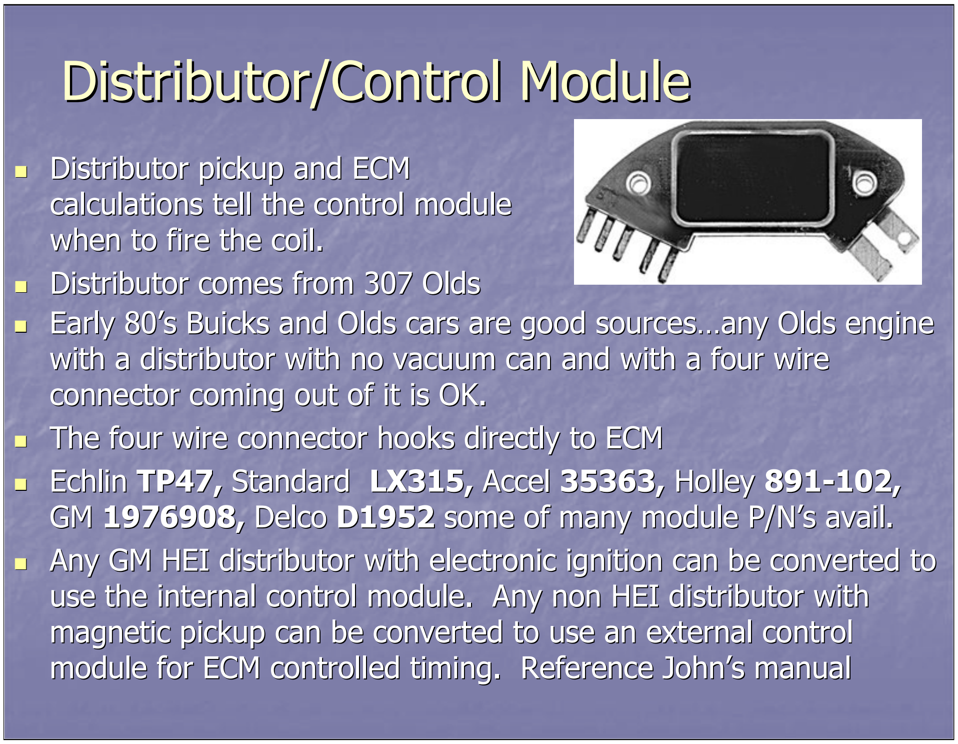
This is probably an appropriate place to interject a word or two about fuel pumps, and a commercial. <c>John Wilson wrote a short manual on DIY fuel injection that covers both TBI and PFI. He has an excellent write up on fuel delivery, and a whole lot more. If you are interested in procuring one, you can do so at his website www.customefis.com or you can buy one from me today. Either way it is $30 well spent. It has been the single most helpful source of information to me along with the websites mentioned at the end of this presentation.<c> John recommends the E2182 pump which was used on some mid 80's Ford products, and is <c>readily available at AutoZone, Parts America, and many other auto supply stores for around $75. <c>Now would be a good time to install an inline filter between the tanks and the new pump. Some people are using the filter that screws off a base for easy changing, and some are putting it outside the frame rail for easy access. I did neither, but while changing a plugged filter at a rally last year, I had somebody kick me for not doing so. <c>



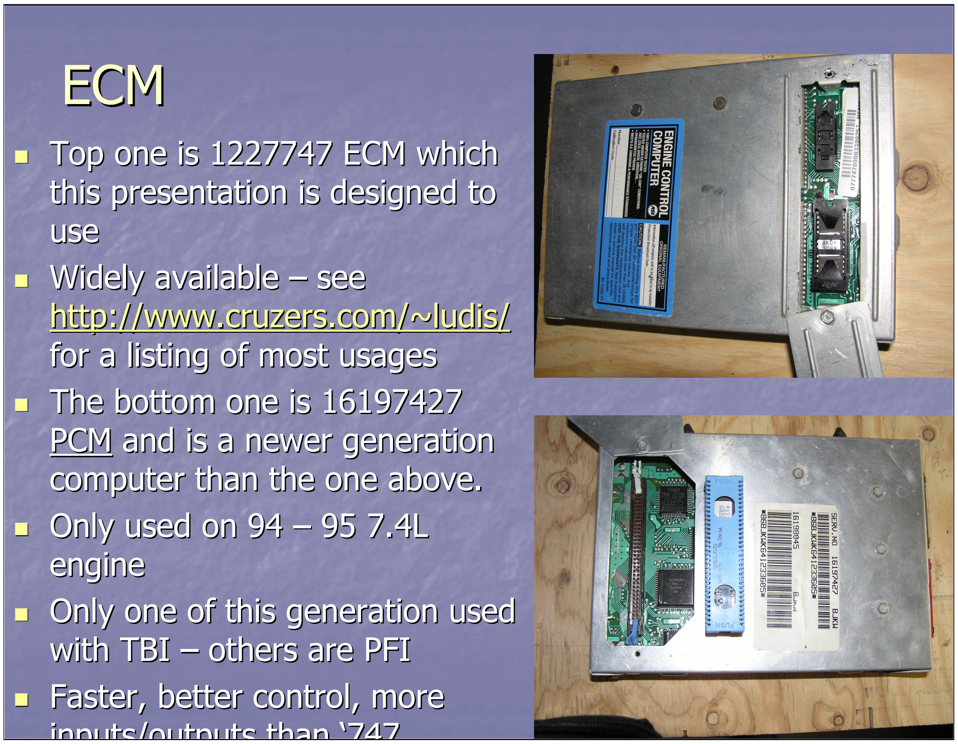
This would also be a good time to interject a few comments about relays. For those of you who are not well acquainted with them, relays are used for a number of reasons. In the case of the fuel pump relay, we use a relay because the 12V source from the ECM is not capable of powering the fuel pump. So it is one way of using a few milliamp signal to power a multiple amp device. Another reason for using a relay is to power something at a voltage level different than the signal, such as using a 5V signal to power a 12V or even 120V device. A third reason for using a relay is to isolate various branches of voltage from power spikes that may be present in another branch. A fourth reason a relay might be necessary is for control circuitry. <c>Relays such as the ones pictured are "almost" free at the mall, and are very versatile. A variety of brackets are available, they are weatherproof, snap in place, and are very reliable. I particularly like the bracket and relay shown on the left. They came from an early 80's GM "A" Car which is the Celebrity size car, and are located conveniently on the radiator support bracket. A similar configuration is available off the "Dustbuster" GM vans with a slight variation on the attaching scheme. Make sure your relays and brackets match because there are several different variations. Get ones with heavy wires with as much wire attached to them as possible. <c>



An “ignition on” 12V supply is connected directly to the injectors, and then the ECM sinks the current from the injectors. That is necessary because fuel delivery is controlled by actually turning on and off the injectors at a much higher rate of speed than could be done with relays, so the ECM itself (or a solid state relay) has to be capable of handling current from the injectors. <c>An ECM output is used for each injector because the ability for one output to sink two injectors is marginal. <c>An 80 lb/hr injector was used on the 454 engine from 1987 through 1993, and a 90 lb/hour injector was used on the ’94 and ’95 454’s. Either will work for us, but it takes a slight calibration change to switch from one to the other. <c>454 throttle bodies are getting very hard to come by and are quite expensive. It will be your single most expensive item. The ones we want were used almost exclusively on the 454 engine from 1987 through 1995. They have 2” bores as opposed to 1 11/16” bores as used on the 350 engines and most other V-8’s and large V-6’s. Look on ebay and the internet and wrecking yard search engines to find one. Several people on ebay take the smaller one and enlarge the bores, but I have no idea how successful that operation is. Customefis and Holley and probably others make after market 2” bore throttle bodies. I cannot comment on the suitability of them either. I do believe, however, that the 1 11/16” bore throttle body would work just fine in our application where we seldom see more than 3500 RPM, and have very mild cams, and restrictive exhausts, but that is just speculation at this point. Ken Henderson is considering installing the smaller throttle body on his coach. It will be interesting to see how it works out because that could knock a couple hundred $ off the price. <c>



As mentioned before, the distributor pick up and the ECM calculations tell the control module when to fire the coil. <c>The distributor you need is still readily available, but they are disappearing quickly. I had four of them picked out at a local mall and when I went back to get them they were all stacked on top of each other. They did kindly unstack them for me, however. Look for early to mid 80's, maybe even '78 and '79 full size Buicks and Oldsmobile RWD sedans, and the same vintage FWD Toros and Rivieras. The ones you are looking for have the Olds engine which you can identify by the rear distributor and distinctive rocker arm covers, and the little right angle hose on top of the water pump. If the distributor has no vacuum can on it, you hit pay dirt. Be sure to take both halves of the 4 wire connector along with loooonnnnggg leads. Some of these come out hard so take a pry bar, but <u>do not</u> pry hard on the underside of the distributor body… they break easily. I speaketh from experience. Expect to pay $25 to $50.<c>The leads from the four wire connector go directly to the ECM, and again, GM has been remarkably consistent in the color codes of these wires <c>I suggest you install a new module and keep the old one as a spare. They are available from any number of places under many different part numbers. Note it has seven pins instead of the usual 5 pins.<c>As a side note, any GM HEI distributor, including ours, can be converted to a suitable distributor by disabling vacuum and mechanical advance and installing the correct control module. Even non HEI and non GM distributors can be modified as long as they have a magnetic pickup. However, a readily available external control module must be used with these distributors. See John Wilson's DIY manual for further information. <c>

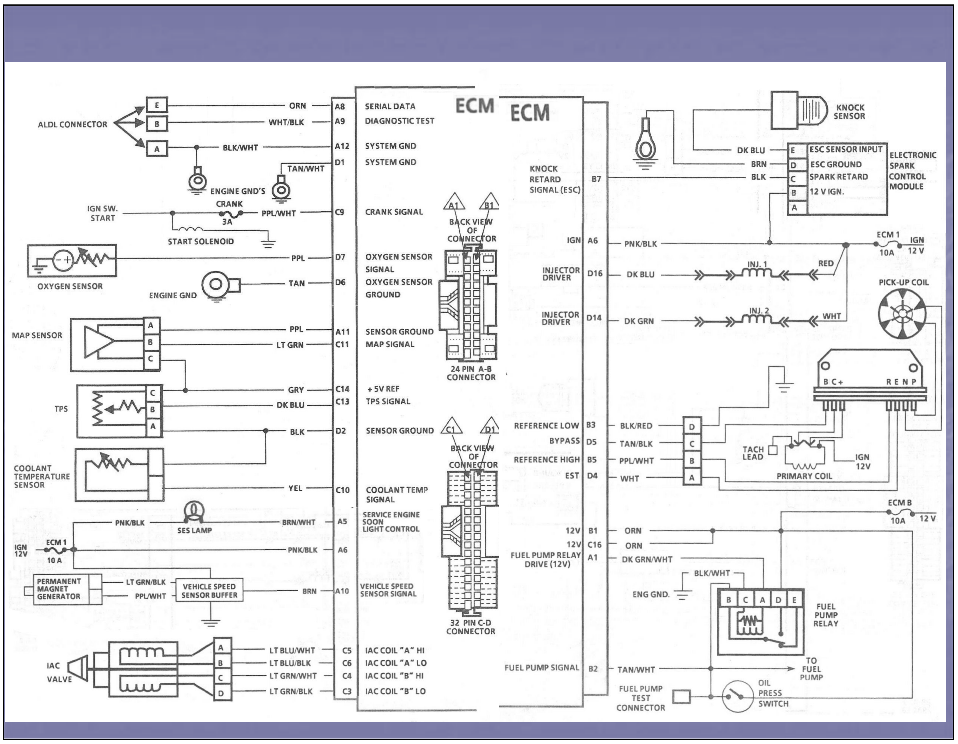


Now we are down to the ECM itself. The top one shown is the 1227747 ECM which is the one that all GMC TBI installations that I am aware of have used. <c> These are widely available and were used in many applications. Go to the www.cruzers.com/~ludis/ link shown where you can find a listing of all the places this part number ECM was used. I like the 80's "M" vans (Astro) because they are easy to get to and are well protected behind the kickpad by the passengers feet. They come out looking like new. <c> The bottom one is a 16197427 PCM which is a generation newer than the '747 computer, <c> and was used with the '94 and '95 454 TBI engine. Shown sitting on top of the ECM is the Calpack referred to earilier. I believe this is the only PCM of the newer generation that was used with TBI….the rest were used with PFI. <c>It is much faster and can handle larger matrices of variables and thus give more precise control. It also has many more inputs and outputs which really don't do much for us. It also has the ESC internal as mentioned before, so it would have one less component and less wiring. I have one at home, but have not mustered up the ambition to build a new wiring harness to install it. I do not know of anyone who is using this PCM, but it should work fine. It just has no history to support it like the '747.

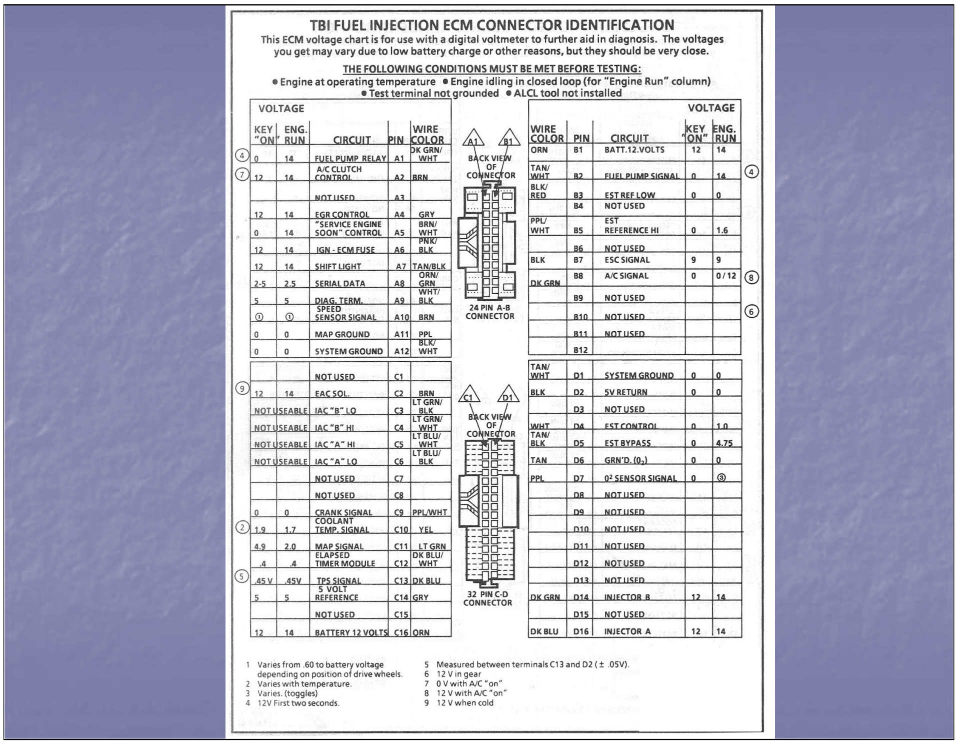
Generic TBI Fuel Injection

- Block Diagram & Acronyms
- Individual Components and Their Function
- Schematic Diagram

So, that completes coverage the individual components and we can move on to the fun stuff….hooking it all together. <c> First a look at a couple schematics. <c>



This is a very busy schematic, but it shows all the components of the system. I borrowed heavily from about 6 pages of the 1990 Chevy truck manual to come up with this schematic. Note it has the names of all the components, terminal connections, and wire color codes. You will refer to this often if you decide to tackle this project and make your own wiring harness. Notice the locations and sizes of fuses.<c>



TBI FUEL INJECTION ECM CONNECTOR IDENTIFICATION

This ECM voltage chart is for use with a digital voltmeter to further aid in diagnosis. The voltages you get may vary due to low battery charge or other reasons, but they should be very close.

THE FOLLOWING CONDITIONS MUST BE MET BEFORE TESTING:

- Engine at operating temperature
- Engine idling in closed loop (for "Engine Run" column)
- Test terminal not grounded
- ALCL tool not installed

	VOLTAGE KEY "ON"	VOLTAGE ENG. RUN	CIRCUIT	PIN	WIRE COLOR
4	0	14	FUEL PUMP RELAY	A1	DK GRN/ WHT
7	12	14	A/C CLUTCH CONTROL	A2	BRN
			NOT USED	A3	
	12	14	EGR CONTROL	A4	GRY
	0	14	"SERVICE ENGINE SOON" CONTROL	A5	BRN/ WHT
	12	14	IGN - ECM FUSE	A6	PNK/ BLK
	12	14	SHIFT LIGHT	A7	TAN/BLK
	2-5	2.5	SERIAL DATA	A8	ORN/ GRN
	5	5	DIAG. TERM.	A9	WHT/ BLK
	1	1	SPEED SENSOR SIGNAL	A10	BRN
	0	0	MAP GROUND	A11	PPL
	0	0	SYSTEM GROUND	A12	BLK/ WHT
			NOT USED	C1	
9	12	14	EAC SOL.	C2	BRN
	NOT USEABLE		IAC "B" LO	C3	LT GRN/ BLK
	NOT USEABLE		IAC "B" HI	C4	LT GRN/ WHT
	NOT USEABLE		IAC "A" HI	C5	LT BLU/ WHT
	NOT USEABLE		IAC "A" LO	C6	LT BLU/ BLK
			NOT USED	C7	
			NOT USED	C8	
	0	0	CRANK SIGNAL	C9	PPL/WHT
2	1.9	1.7	COOLANT TEMP. SIGNAL	C10	YEL
	4.9	2.0	MAP SIGNAL	C11	LT GRN
	.4	.4	ELAPSED TIMER MODULE	C12	DK BLU/ WHT
5	.45 V	.45V	TPS SIGNAL	C13	DK BLU
	5	5	5 VOLT REFERENCE	C14	GRY
			NOT USED	C15	
	12	14	BATTERY 12 VOLTS	C16	ORN

WIRE COLOR	PIN	CIRCUIT	VOLTAGE KEY "ON"	VOLTAGE ENG. RUN	
ORN	B1	BATT.12.VOLTS	12	14	
TAN/ WHT	B2	FUEL PUMP SIGNAL	0	14	4
BLK/ RED	B3	EST REF LOW	0	0	
	B4	NOT USED			
PPL/ WHT	B5	EST REFERENCE HI	0	1.6	
	B6	NOT USED			
BLK	B7	ESC SIGNAL	9	9	
DK GRN	B8	A/C SIGNAL	0	0/12	8
	B9	NOT USED			
	B10	NOT USED			6
	B11	NOT USED			
	B12				
TAN/ WHT	D1	SYSTEM GROUND	0	0	
BLK	D2	5V RETURN	0	0	
	D3	NOT USED			
WHT	D4	EST CONTROL	0	1.0	
TAN/ BLK	D5	EST BYPASS	0	4.75	
TAN	D6	GRN'D. (O_2)	0	0	
PPL	D7	O^2 SENSOR SIGNAL	0	3	
	D8	NOT USED			
	D9	NOT USED			
	D10	NOT USED			
	D11	NOT USED			
	D12	NOT USED			
	D13	NOT USED			
DK GRN	D14	INJECTOR B	12	14	
	D15	NOT USED			
DK BLU	D16	INJECTOR A	12	14	

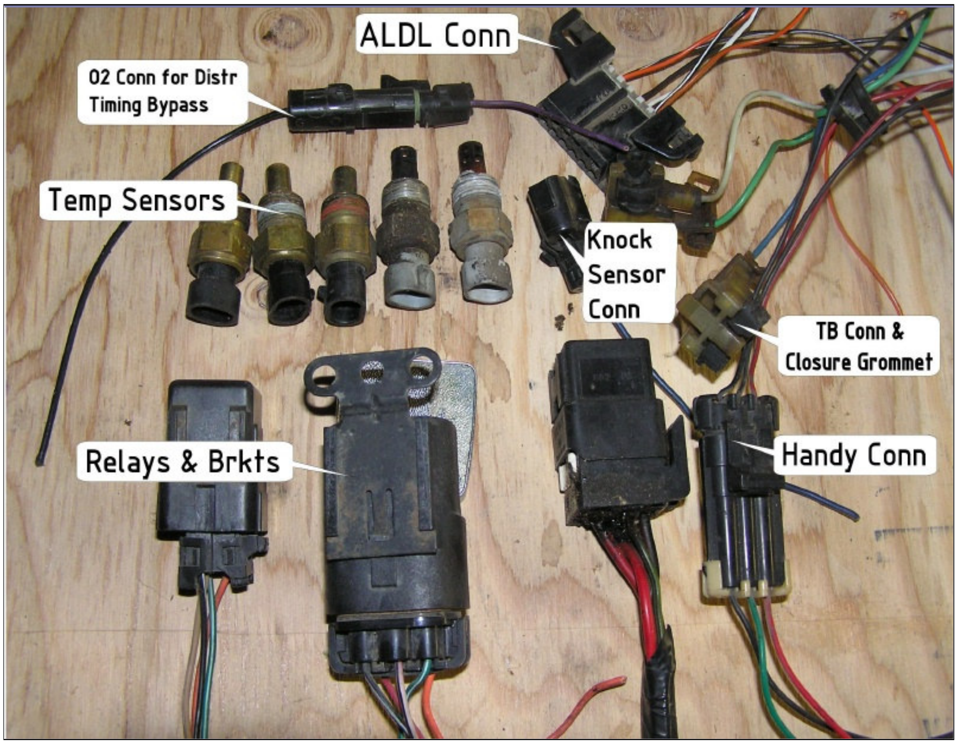
1 Varies from .60 to battery voltage depending on position of drive wheels.
2 Varies with temperature.
3 Varies. (toggles)
4 12V First two seconds.
5 Measured between terminals C13 and D2 (± .05V).
6 12 V in gear
7 0 V with A/C "on"
8 12 V with A/C "on"
9 12 V when cold

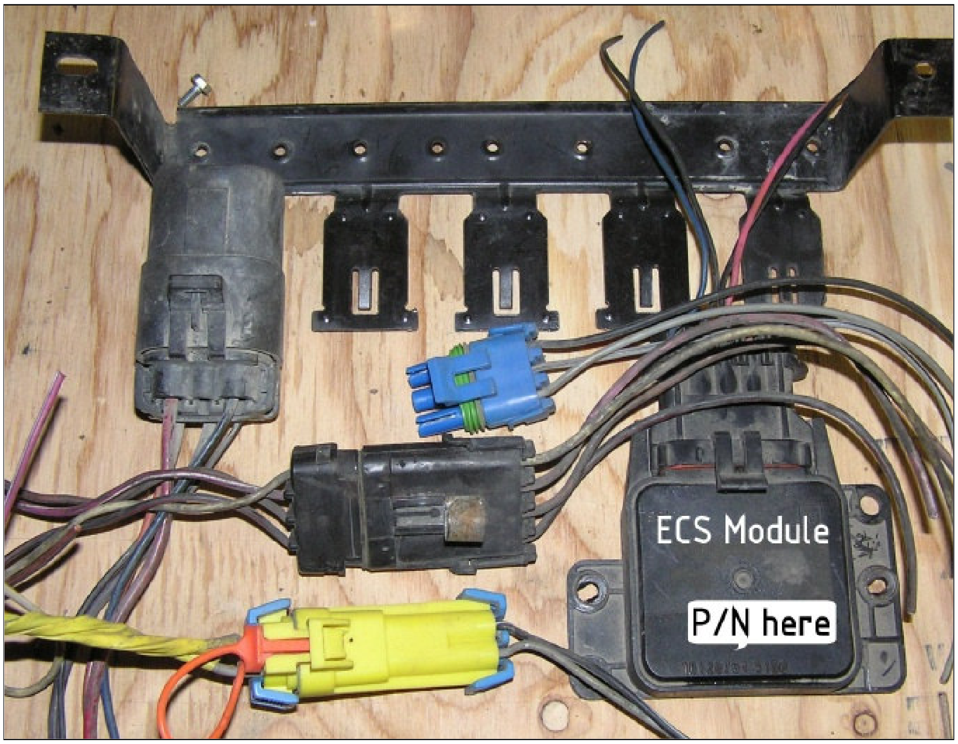
This is the second part of the schematic showing the ECM connector details, how to identify the ECM terminals, and wiring color codes. <c>

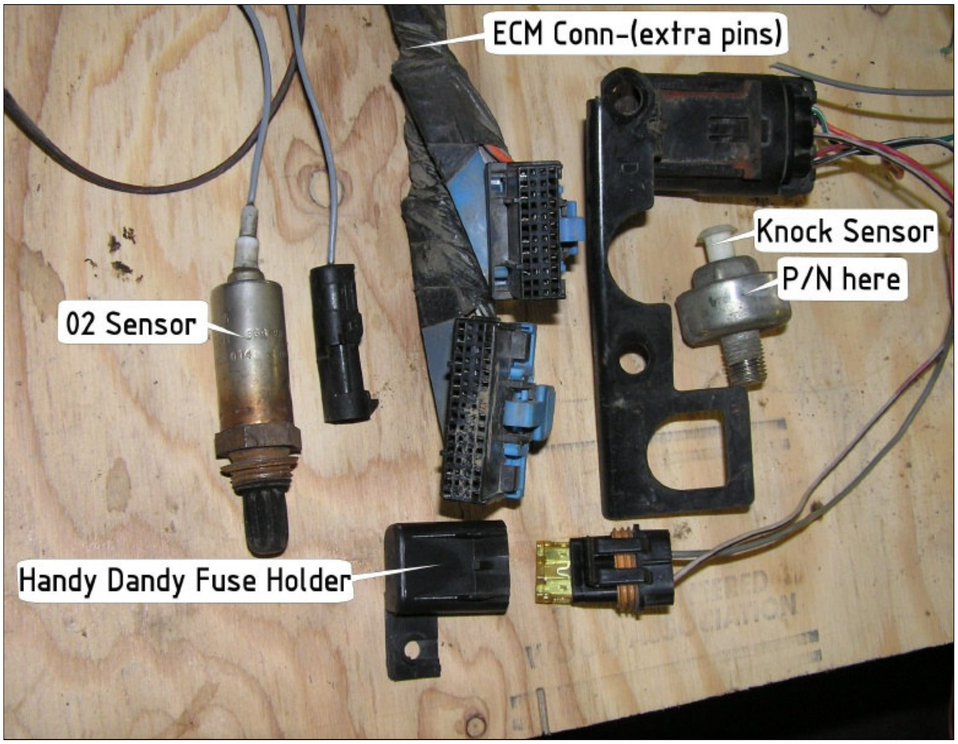
Generic TBI Fuel Injection

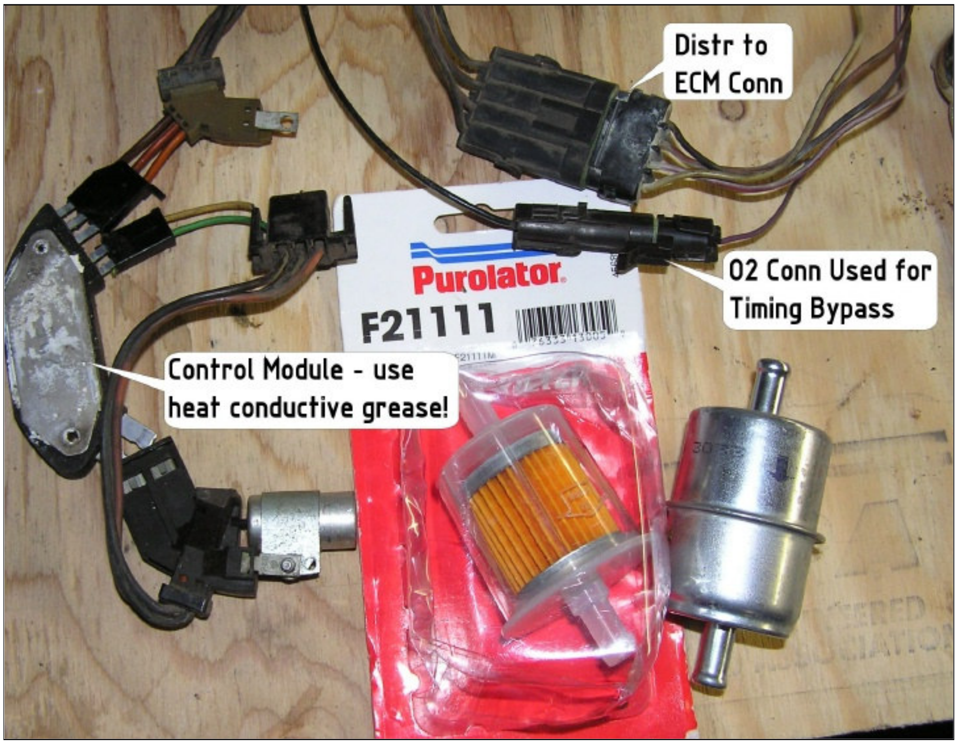
- Block Diagram & Acronyms
- Individual Components and Their Function
- Schematic Diagram
- The actual installation
  - Gather components

We have covered everything down to the actual installation of a system. The first thing we want to do before we start the installation is to gather up all the components. That includes the major items we just discussed, plus at least four fuses and fuseholders to protect anything connected to 12V, and at least one relay to drive the fuel pump. If you refer to the wiring schematic from two slides back, you can identify where the fuses go, and the size of the fuses. It also shows how to wire the fuel pump relay. I also added a relay to handle the current required by the injectors and the “ignition on” connection to the ECM itself. The reason for that was to minimize the amount of current flowing through the ignition switch. Lots of “stuff” is connected to the ignition switch, and by adding a relay to handle “ignition on” current, only the current for the relay coil flows through the ignition switch. Let’s look at some pictures of example components.<c>

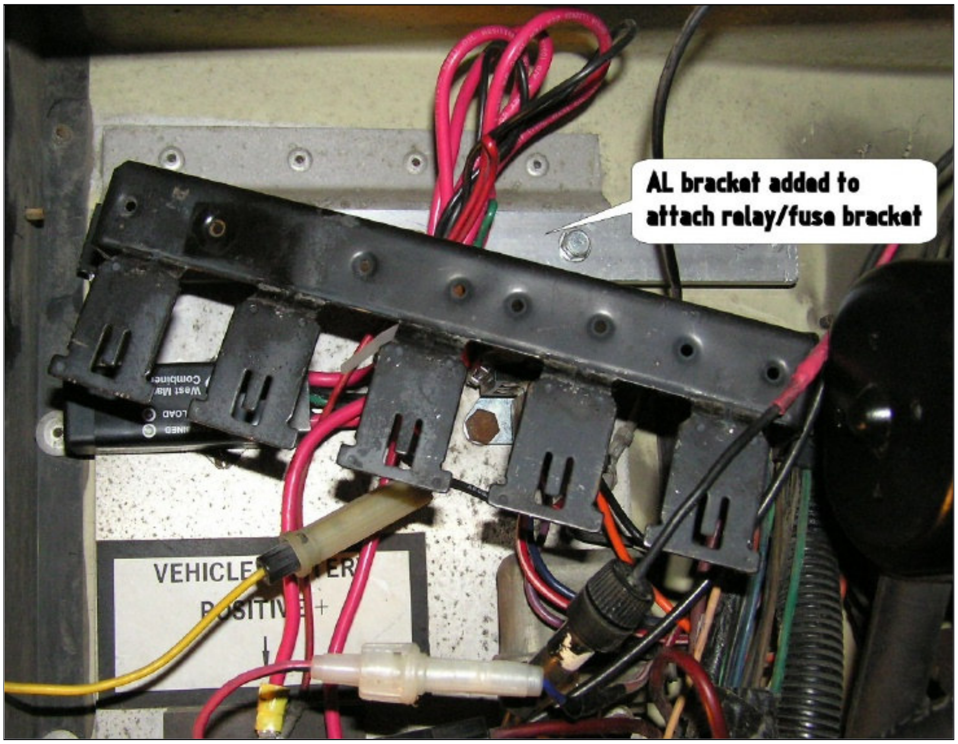

ALDL Conn
O2 Conn for Distr Timing Bypass
Temp Sensors
Knock Sensor Conn
TB Conn & Closure Grommet
Relays & Brkts
Handy Conn

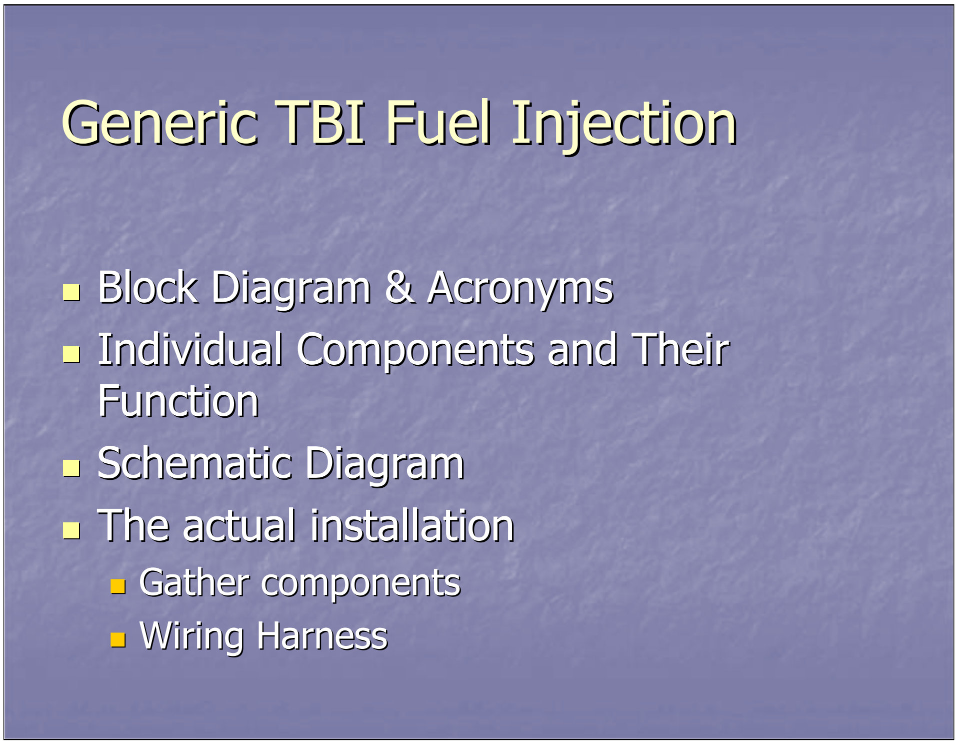

ECS Module
P/N here


ECM Conn-(extra pins)
Knock Sensor
P/N here
02 Sensor
Handy Dandy Fuse Holder

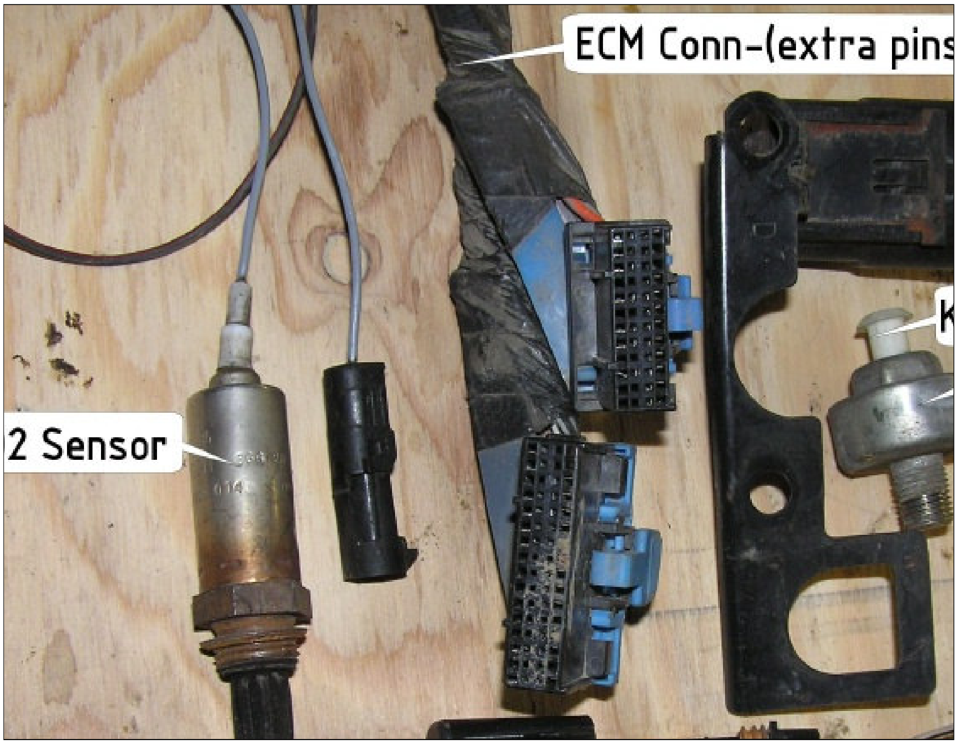

Distr to
ECM Conn
O2 Conn Used for
Timing Bypass
Control Module - use
heat conductive grease!
Purolator
F21111


466
GM
C B A
039 2010
Last 3 digits (039)
of MAP P/N here

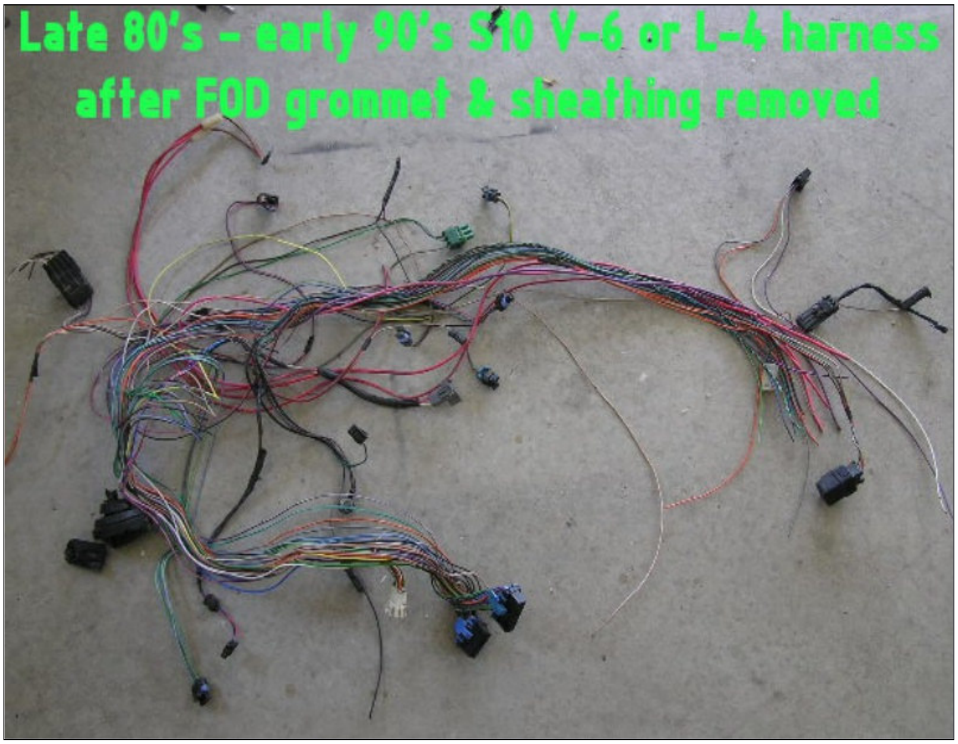

AL bracket added to
attach relay/fuse bracket
VEHICLE
POSITIVE +



Next, let’s look at making the wiring diagram. This step will take the most planning on your part unless you decide to purchase one from someone like Turbo City. They will sell the wiring harness by itself, but be forewarned it is fairly expensive.<c>

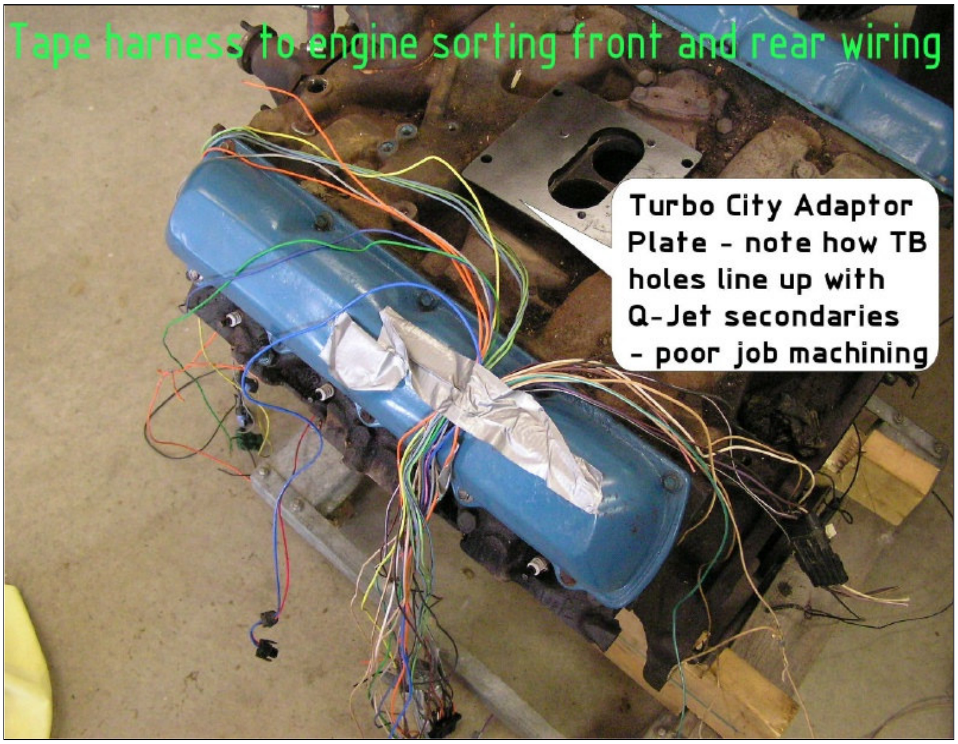


The bare minimum you will need to make your harness are, of course, connectors to all the components you gathered in the last step, plus the ECM connectors shown above. Get as much wire with the connectors you can so you can minimize the number of splices you will need to make. It is better to get a complete harness from a vehicle that uses the above connectors. I chose to use the harness from an S10 that uses the 1227747 computer. The reason I chose that harness is because all the wires go through a grommet in the front of dash rather than through a large bulky connector. I used one from an L-4 equipped S10, but a harness from a V-6 would be slightly better because they used two injectors rather than a single injector like the L-4, thus making your modifications somewhat simpler. Internet sites are identified at the end of this presentation that can be used to identify which vehicles use the ‘747 ECM. Many other ECM’s use these same connectors, but I am not sure which ones.<c>



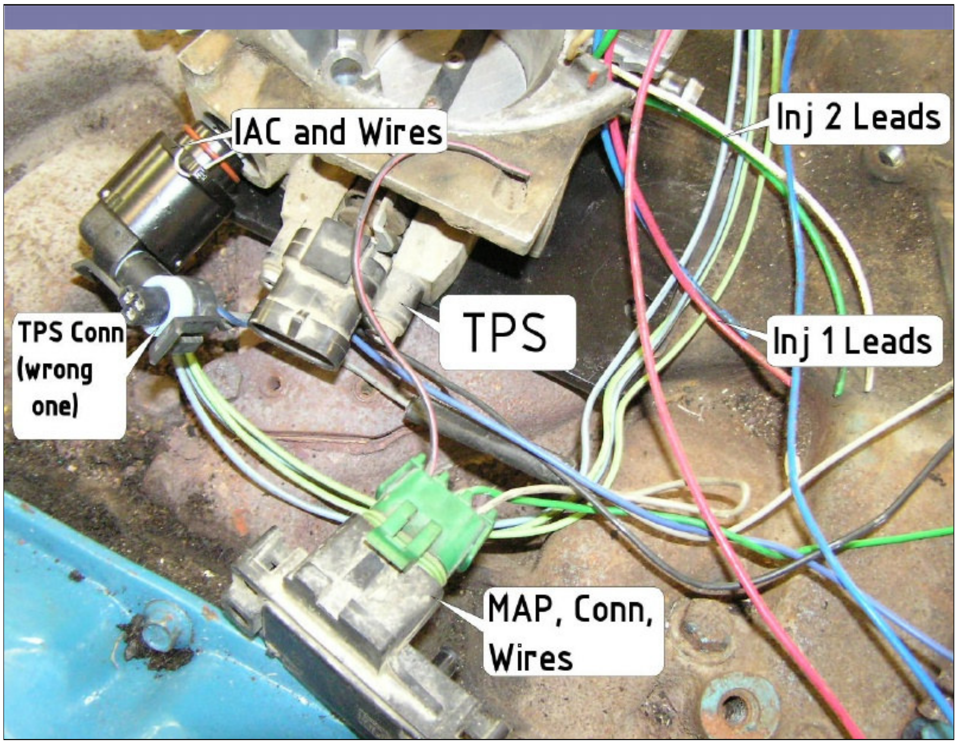
This is the S10 harness after the FOD grommet and all the corrugated sheathing is removed. Notice many of the connectors you are going to need are already part of the harness. The ESC module, distributor, ECM, MAP, TPS, and probably some other connectors can be identified on this picture.<c>

This is the harness after the extra wires have been removed from the ECM connectors. Keep those extra wires and particularly the ECM connector pins because you will be needing some of them later. Note the computer controlled ignition distributor without the familiar vacuum can, and the four wire connector with the correct color coded wires on both sides of the connector. This is a good example of how GM uses the same color coding on vehicles as diverse as those with the Olds 307 engine, and the S10 L-4 engine. Note the O2 sensor connector center/left, the coolant temp sensor to its immediate right, the ESC connector directly below the distributor body, the green MAP sensor, and the IAC and TPS connectors close to each other near the center of the picture. The red and blue wires lower/left are for one of the injectors, but wires for the second injector need to be added. Note also that the wires are identified with tape near the ECM connectors. I suggest you use something other than duct tape like I did.<c>

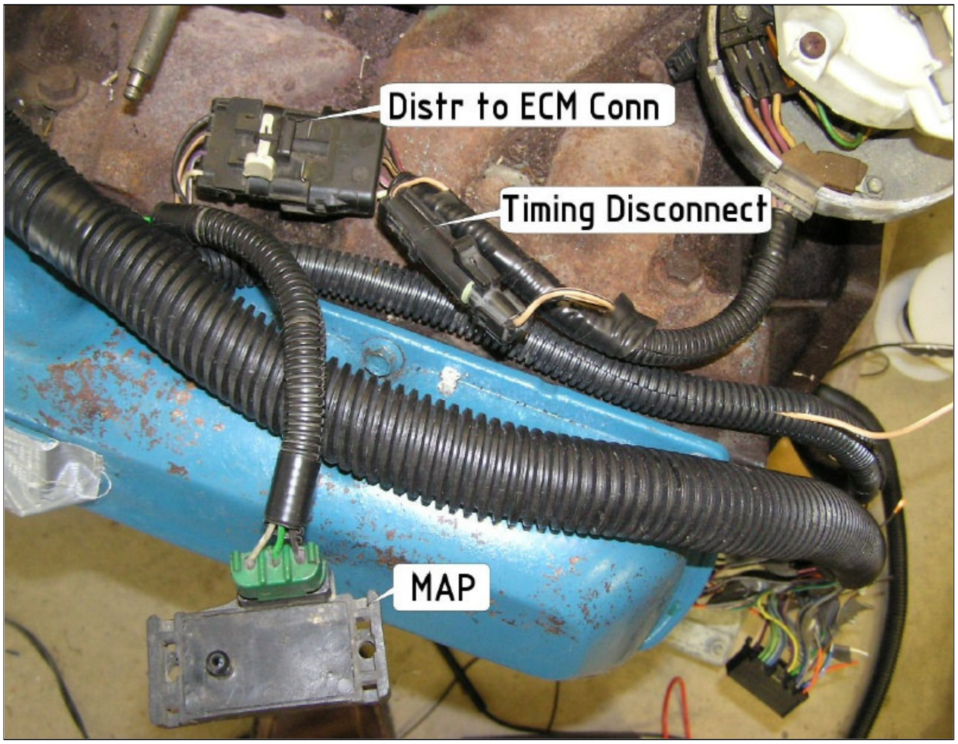


I happened to have the luxury of having my old engine on a cart that could be used to build the harness. That is much preferable to working upside down over the top of the engine in the coach. The first thing was to point the wires in the general direction of where they will end up, and to take inventory of what wires, if any, you need to add. I chose to locate the ECM under the driver's seat, but after seeing several other installations, I believe it is preferable to locate under the passenger seat. As a side "oh by the way", note the adaptor plate I purchased from Turbo City. The holes did not line up well at all to the secondary holes of the Q-Jet manifold. I filed and fit as best I could, but was not very pleased with the end result. It is very bad for air flow to have a sharp edge sticking out into its path. I would hope Turbo City has remedied their machining practice for this adapter by now.<c>

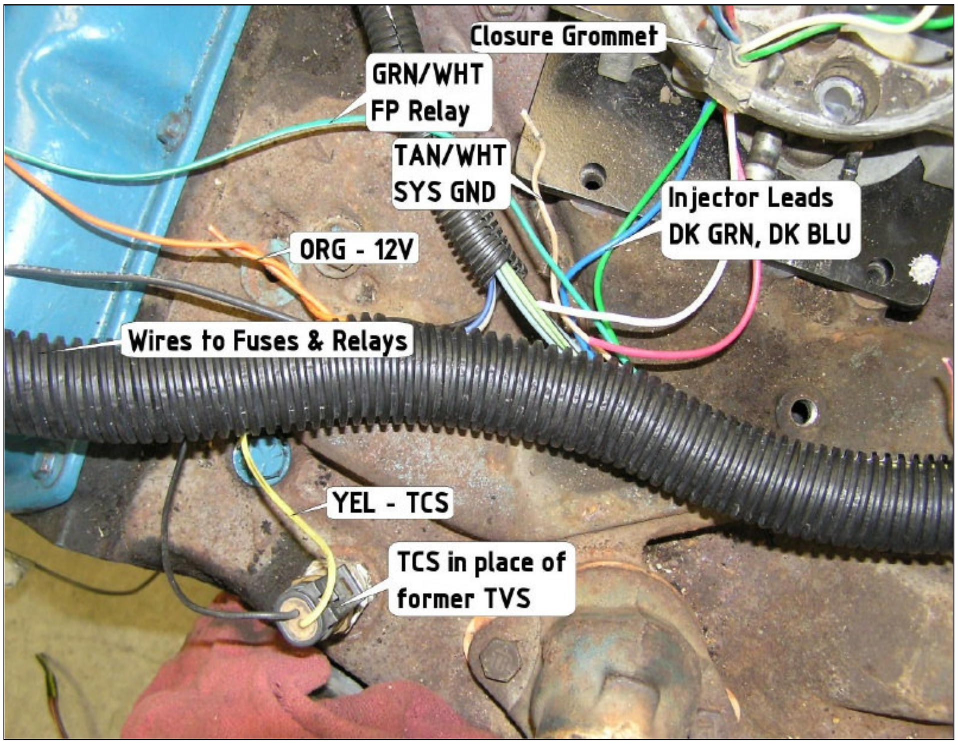
This is a closer view of the last slide to show the color coding of the wires better. If you compare to the schematics shown earlier in this presentation, you will see good correlation.<c>



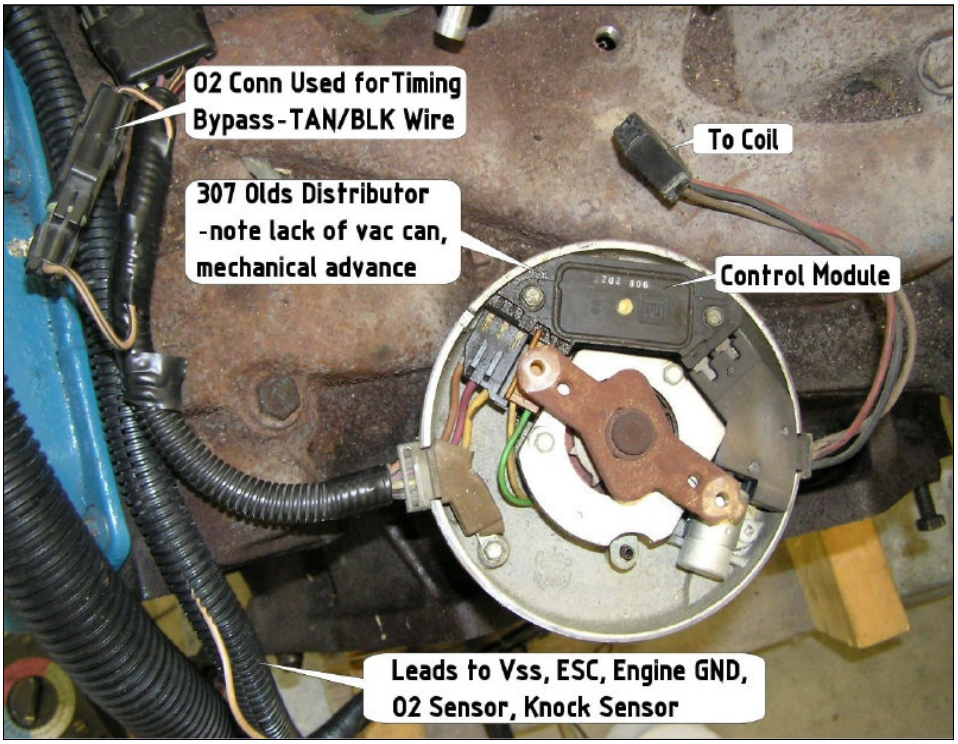
Here we are getting down to the nitty gritty. These are wires as they came from the S10 donor harness. Note the second set of injector leads (green and white) that need to be wired to the ECM and power source. These are readily available from other two barrel throttle bodies and do not have to be from a 454 throttle body. Note also that the TPS connector is not the right one for this throttle body. I believe the newer 454 TB has the type connection shown on the wiring harness. I chose to fold wire leads that were too long back on themselves and taping rather than cutting and spicing. These wires were difficult to solder because they were apparently oxidized somewhat and the solder would not stick. I had to use an electrical wire flux to make a nice solder joint. I then put electrical connection grease over the solder joint, and then sealed with heat shrink tubing.<c>



This shows the connection to the distributor. Note the timing disconnect spliced into the brown wire going to the distributor. This wire must be disconnected when setting the timing. A handy disconnect is a spare O2 sensor connector, readily available at your local men's mall.<c>

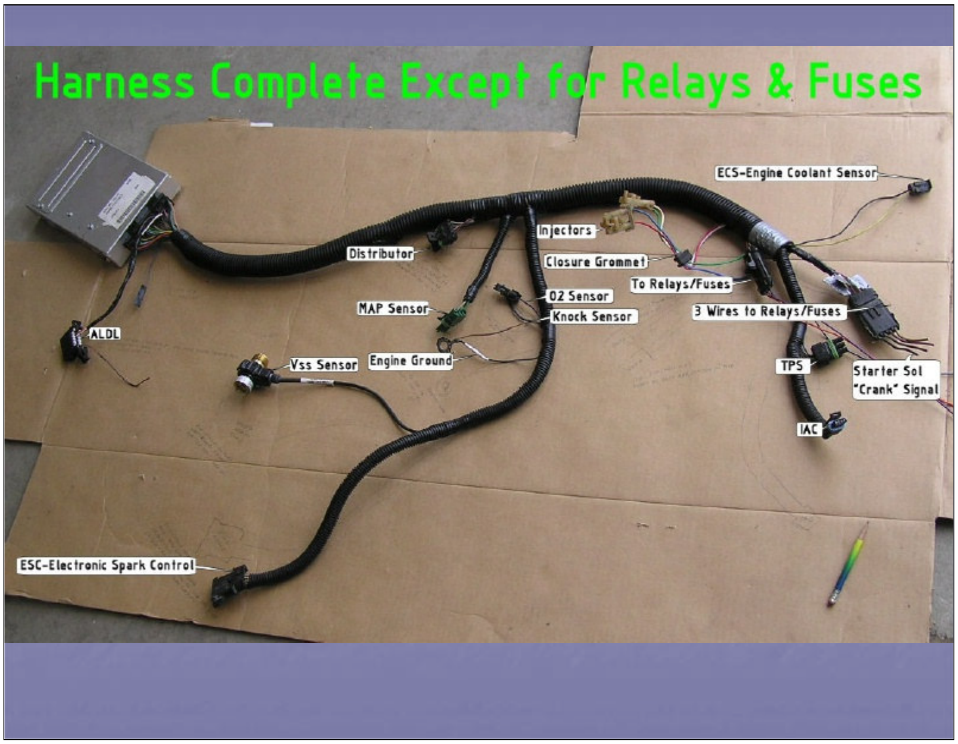


This shows another busy area for connections. The bundle of wires going off to the left goes to the fuses and relays located under the passenger side hood, a picture of which you saw earlier. Note the closure grommet for the injector wires. Be sure to pick one of these up at the mall when you get your proper injector connectors and wires. Since the TVS was no longer of any use, the TCS can be inserted in its place by using a reducer bushing.<c>

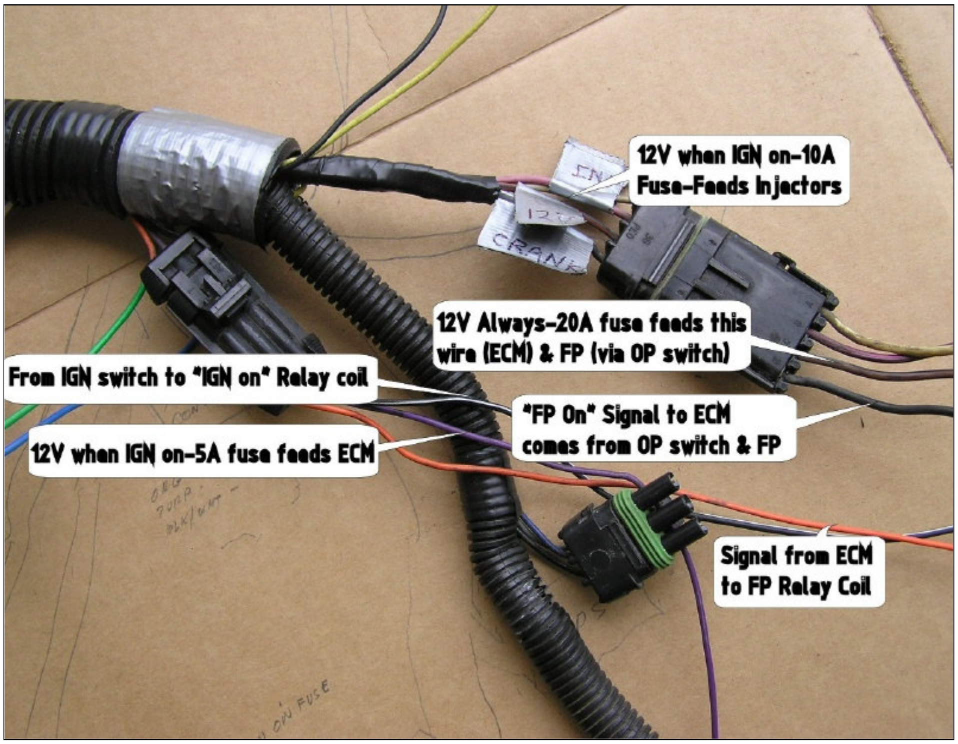


Here is a top view showing routing of wires for some of the other components. The Vss leads go to the Vss which is mounted on the cruise control module. The ESC connector goes to the ESC which is mounted on the step behind and to the left of the engine. I used one of the threaded bosses on the back of the left cylinder head for a good solid ground.<c>

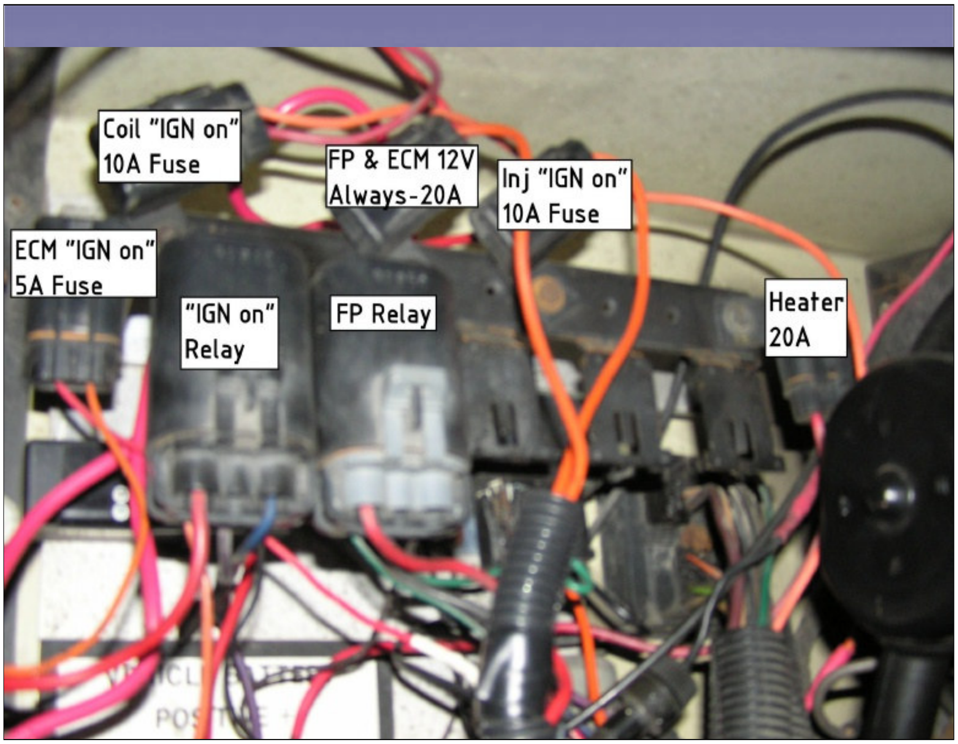
This is an overall view of the harness before transferring to the coach. They are not shown here, but I put some spare connectors on the wires going to the fuses and relays for easy disconnect.<c>



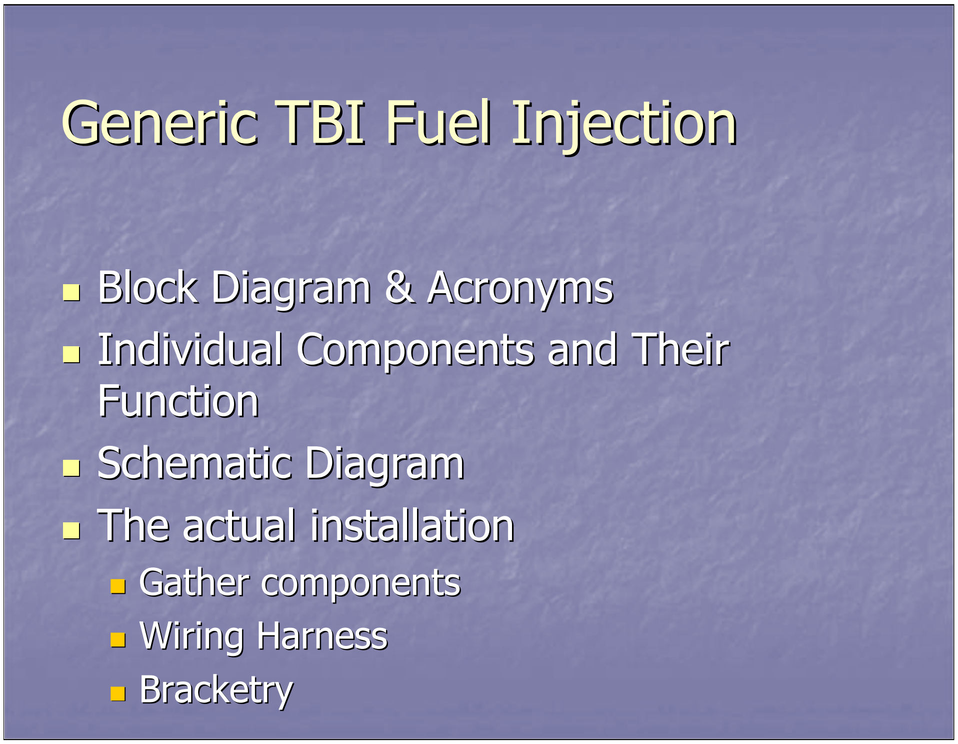
Here is the finished harness complete except for the relays and fuses located under the RH hood. This picture shows the connectors used to connect to the harness going to the under hood components. I took a pencil and drew an outline around all the components and connectors which could be used as a pattern for the next time.<c>



This is a close up of the wires that go to the under hood fuses and relays. The wiring harness from Turbo City is simpler in this regard. All their fuses are nicely located near the ECM. I'm not sure where their FP relay is located.<c>

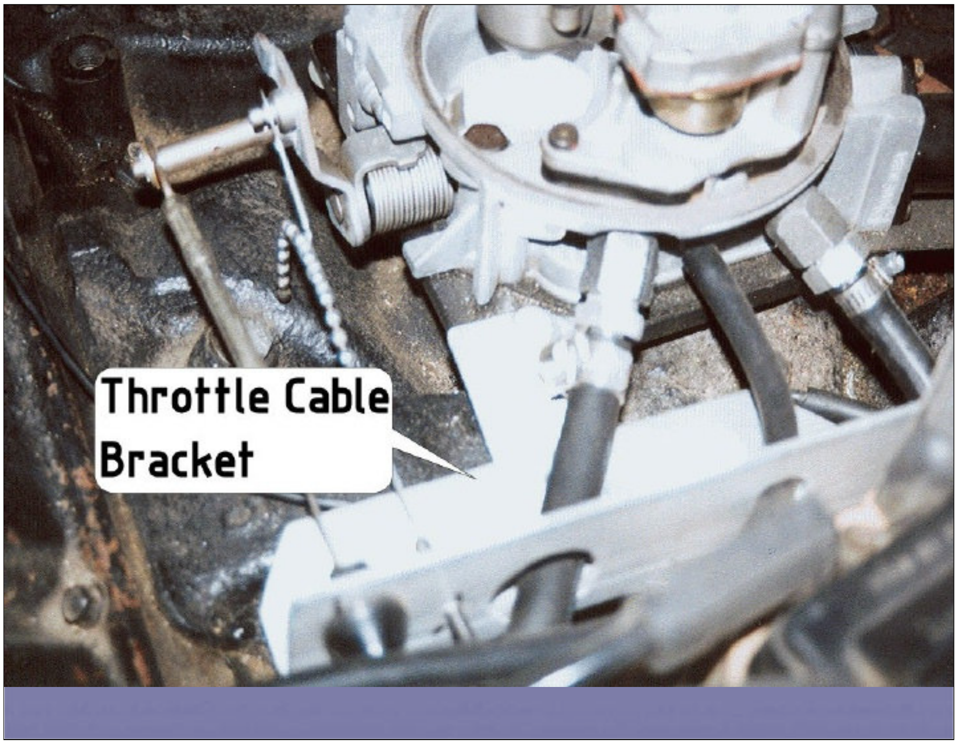


This is a poor picture, but serves to show placement of the fuses and relays. To orient yourself, note the heater blower motor on the right. The “ign on” relay is the one that is activated by the ignition switch, and handles the current for anything powered when the ignition switch is turned on. The fuel pump relay powers the fuel pump until there is oil pressure.<c>gf

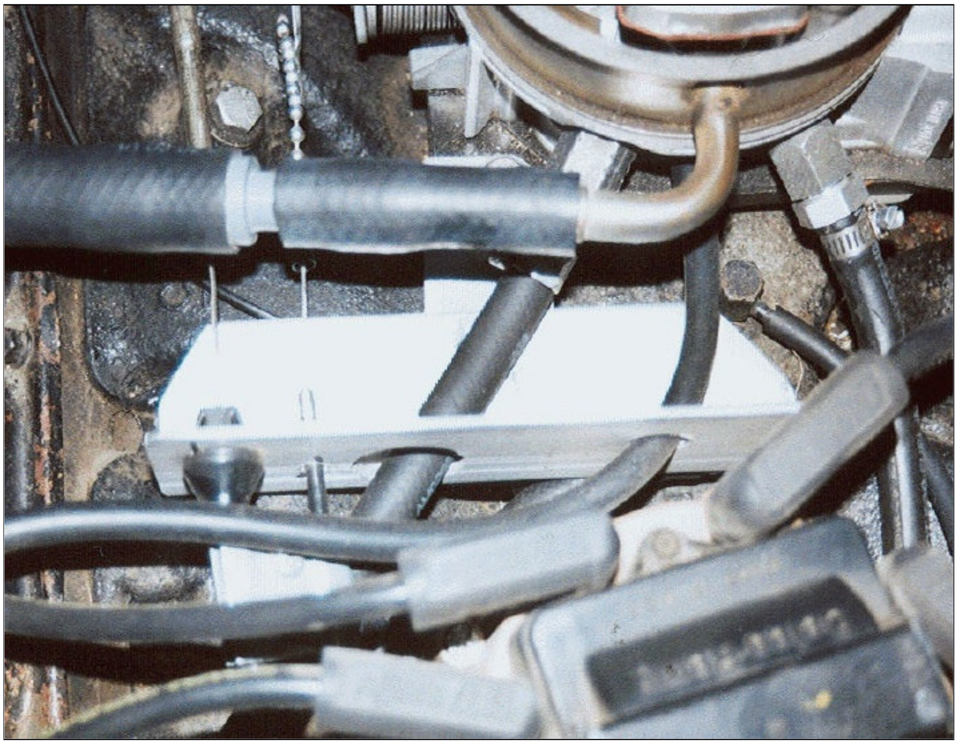


Finally, you will need to fabricate some bracketry to locate some components and hook up the speedometer and cruise control cables.

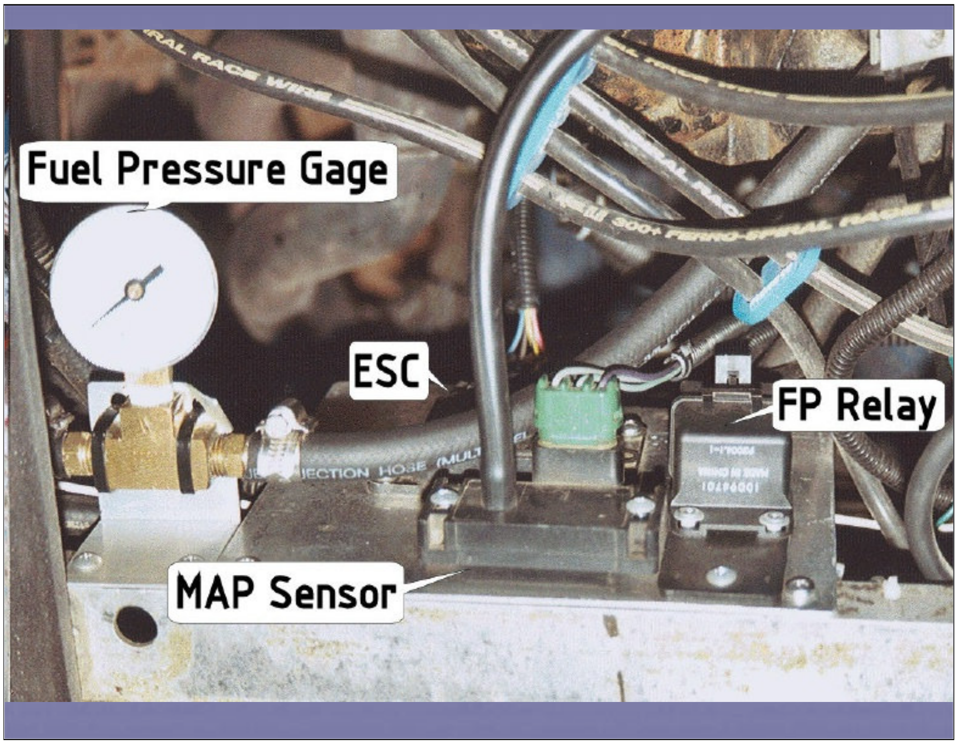
The stock air cleaner can be used and will clear the distributor if the Turbo City adaptor is used. This is Ron Bolser’s installation in which he mounts his air cleaner remotely. Note the spacer on top of the throttle body which can be used to hook up the crankcase vent on the LH rocker arm cover.<c>



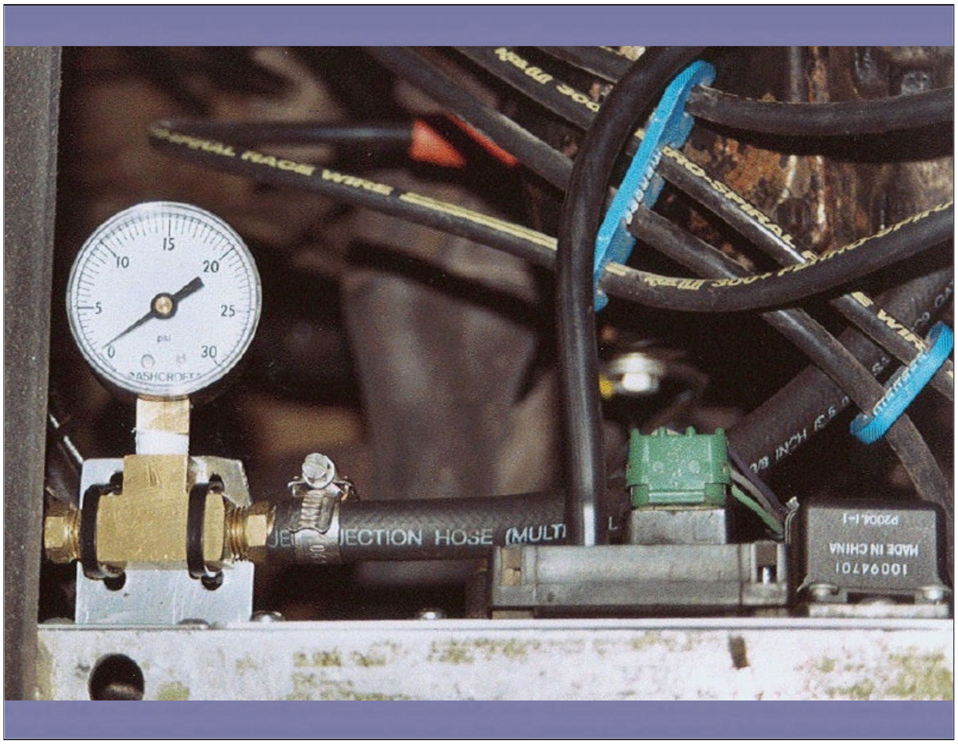
Again, this is Ron’s installation. We fabricated a throttle and cruise control cable bracket from a piece of 1.5” aluminum angle. Note the holes drilled for routing the fuel supply line. We attached the cable to the existing attachment arm on the throttle body. Off idle feel in the accelerator pedal is not good with this method because leverage is not right and it is difficult to control at low throttle openings. The attachment point needs to be located higher above the center line of the throttle blade shaft. If you are using your standard air cleaner, be aware of clearance to the underside of the air cleaner.<c>



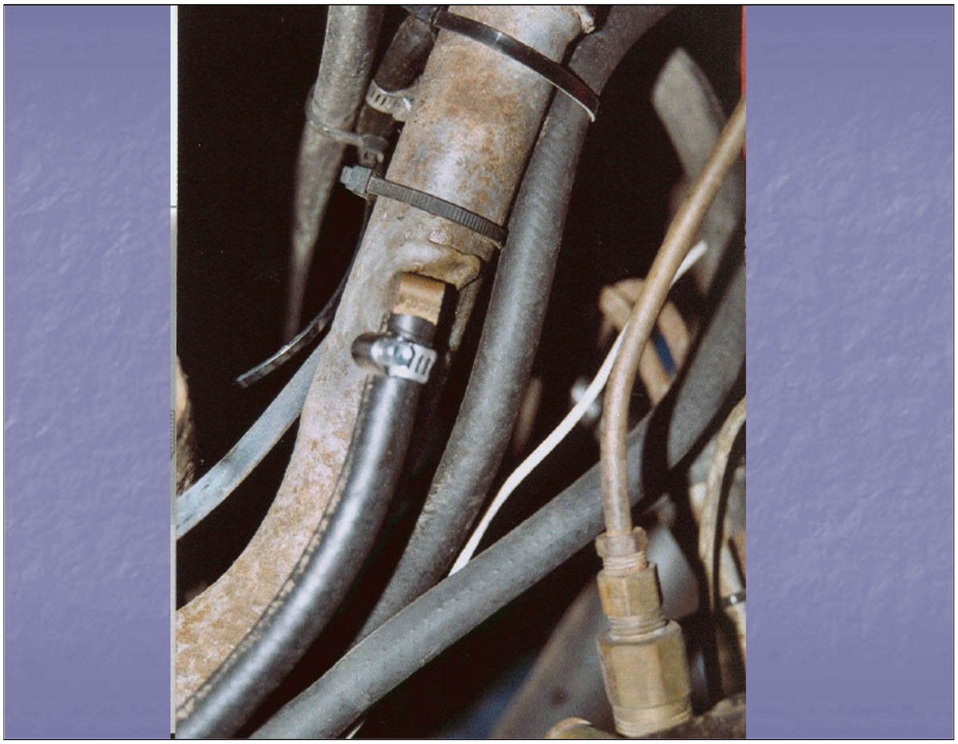
Here is another view of the fabricated cable bracket.<c>



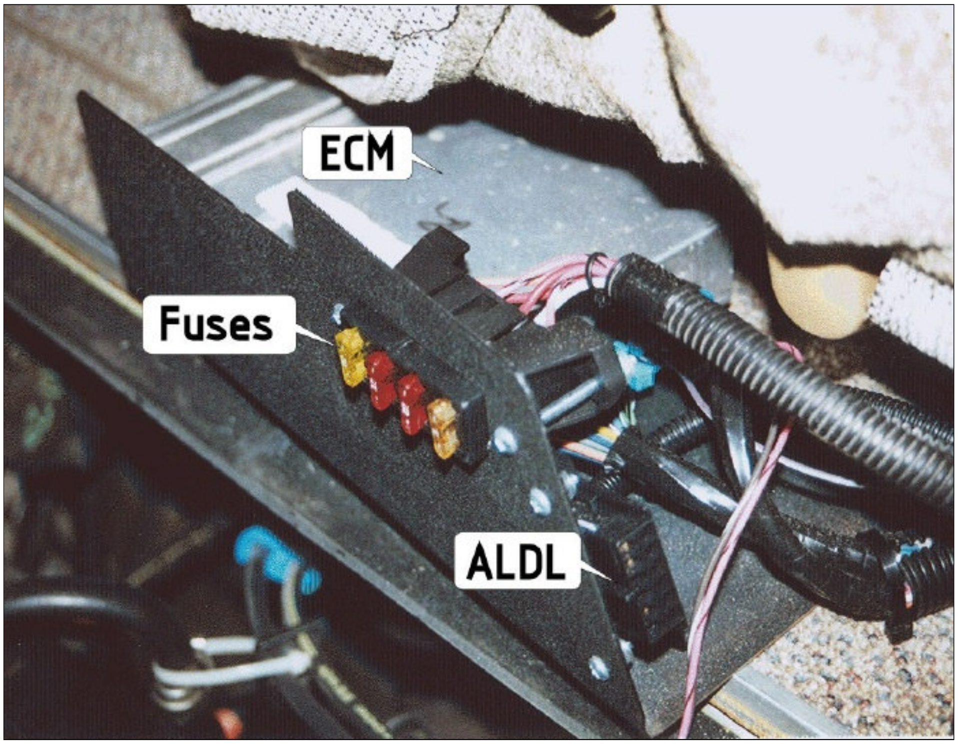
Ron made a very nice plate to which he attached the fuel pump relay, the electronic spark control module, the MAP sensor, and the fuel pressure gage. This makes for a very neat professional looking installation.<c>



This is another view of the same bracket.<c>



This is a picture of the fuel return line that taps into the side of the fuel filler pipe. To do this, remove the hose from the bottom of the filler pipe so metal filings fall on the ground while drilling the hole. Drill a half inch hole, and enlarge very slightly to accept the threaded portion of the 90 degree barbed fitting so that the threads fit snugly in the drilled hole. Clean the filler pipe thoroughly and bond the fitting to the pipe with the kind of epoxy that has the consistency of putty, or clay, such that it stays put while it sets. This makes a very good sturdy fuel proof return line connection.<c>

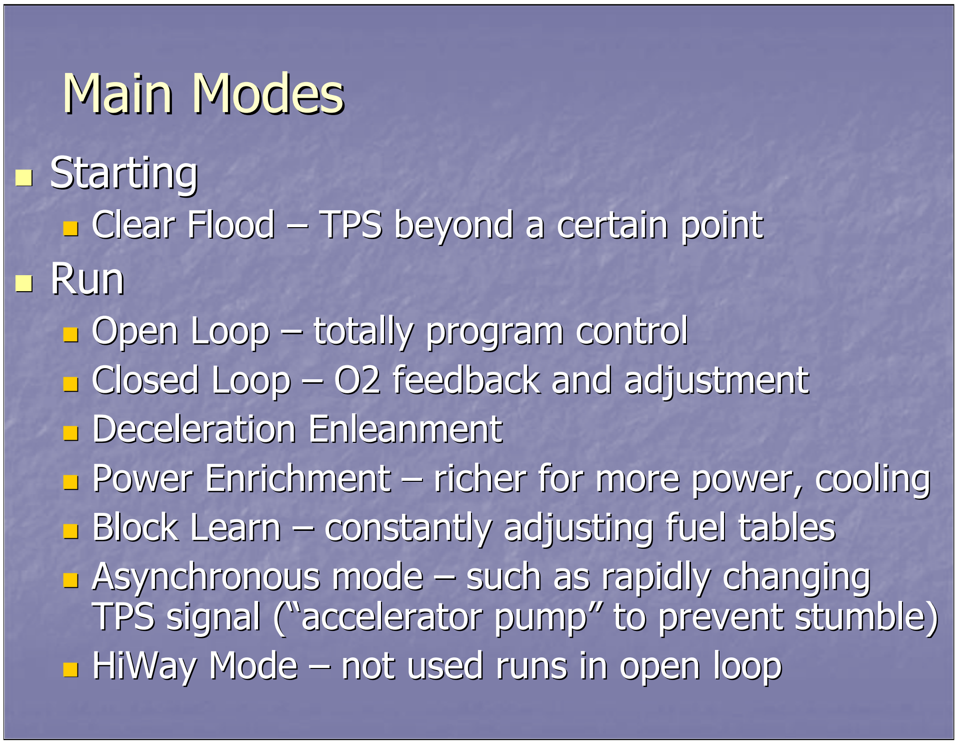


This is the bracket that Ron used to mount the ECM, ALDL connector, and the fuses that came as part of the Turbo City harness. Again, this makes for a very neat, compact, professional looking installation. I believe this is Bobby Moore's design, and works very well. Drawings of this bracket are available from Bobby or Ron, I believe.<c>

Generic TBI Fuel Injection

- Block Diagram & Acronyms
- Individual Components and Their Function
- Schematic Diagram
- The Actual Installation
- Theory and Modes of Operation

With that, let’s move on to some theory and various modes of operation. Knowledge of this section of the presentation is not necessary to convert to TBI unless you plan to do your own programming.f Or perhaps you are just interested or you can contribute to the discussion. This gets a little hairy at times, so please ask questions, or feel free to leave if you lose interest. In any case, let’s get started.<c>

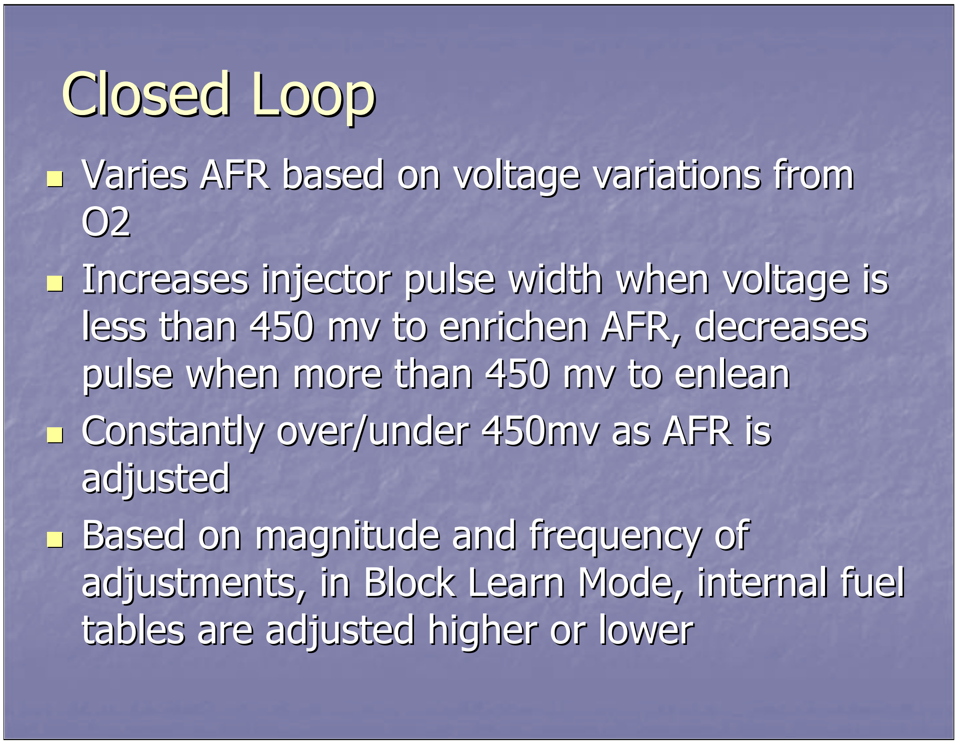


The Starting Mode is straight forward and obviously occurs while starting the engine. Depressing the accelerator beyond a certain point introduces the Clear Flood Mode.<c> In Open Loop mode, fuel delivery is calculated by the ECM with no feed back from the O2 Sensor<c>Closed Loop means the ECM is getting feedback from the O2 Sensor and is constantly adjusting fuel delivery to attain 14.7 AFR.<c>The name Deceleration Enleanment Mode tells it all. It enleans or totally cuts off fuel delivery under certain deceleration conditions. <c>Power Enrichment occurs during heavy or WOT throttle for additional power and to prevent meltdowns such as holes in pistons. <c>The ECM is in Block Learn Mode most of the time, but not all the time, when it is in Closed Loop. In Block Learn Mode, it is constantly updating the fuel tables based on O2 feedback. <c>Asynchronous Mode occurs when the system is in a state of change and usually occurs for only a short period of time. An example would be with rapid accelerator movement fuel delivery is briefly enriched to prevent stumble. <c>We mentioned highway mode before. It is not an incorporated feature, but would run in open loop if it were. <c>

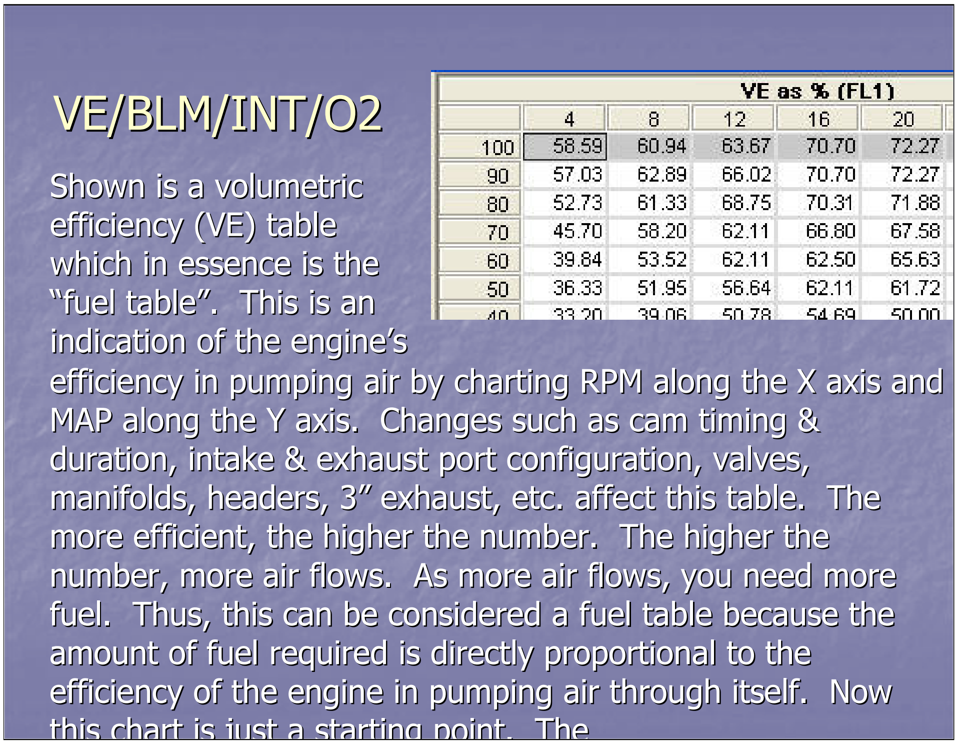
Open Loop

- No O2 feedback – ECM calculates fuel, spark, and RPM from programmed parameters and from these inputs:
  - TPS, ECS, MAP sensors and IGN pulses
- Goes into closed loop when:
  - ECM receives stable and valid O2 signal, and
  - ECT is above a specified value, and
  - A minimum specific amount of time has passed since starting

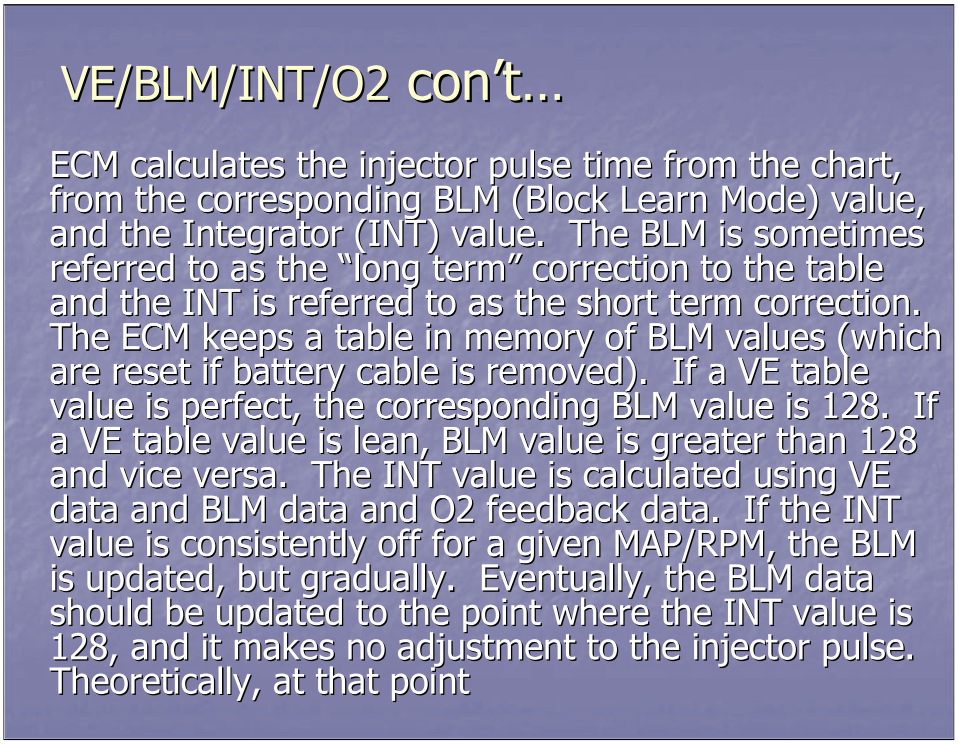
Several of these modes deserve a little closer look. In Open Loop, the ECM calculates fuel delivery, spark advance, and idle speed based on programmed parameters as <c> they relate to TPS, ECS, MAP, and IGN pulses. You could also throw in Vss and spark knock, but they play a minor role in Open Loop Mode. <c>When the engine is first started, it stays in Open Loop until the following all occur: <c> 1) The ECM must receive a stable and valid O2 signal, and <c> 2) The ECT must be above a specified value set in the programmed parameters, and <c> 3) A minimum amount of time has passed since starting as specified in the programmed parameters. <c>



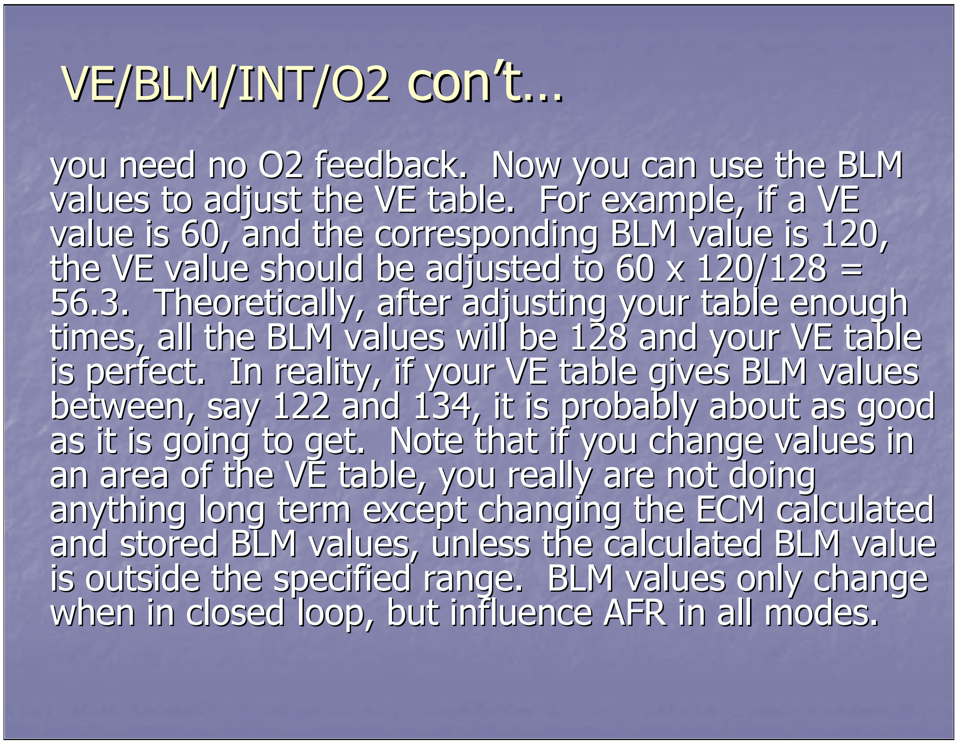
Once in Closed Loop, it remains in Closed Loop most of the time. The ECM receives feedback from the O2 Sensor and constantly varies fuel delivery based on this feedback. <c> Injector pulse width is increased when voltage is less than 450 mv to enrichen AFR, and pulse width is decreased when voltage is more than 450 mv to enlean AFR. <c>If you look at a plot of O2 Sensor voltage while in Closed Loop, you will see it hovering around 450mv, constantly switching from over to under to over 450 mv, which corresponds to 14.7 AFR <c>Based on the magnitude and frequency of these corrections, the internal fuel tables stored in RAM by the ECM are adjusted higher or lower when in Block Learn Mode. <c>



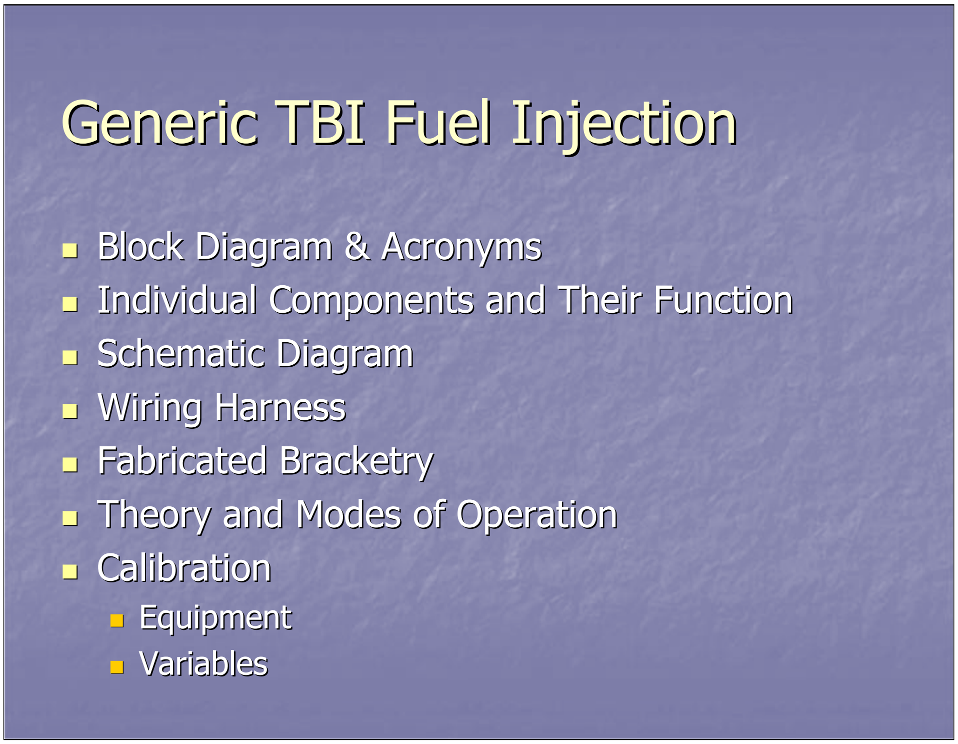
I am simply going to read the next several slides because things get pretty complicated. Don't expect to understand all this the first time through. You will have to read it several times, and it probably still will not make any sense. Again, I refer you to John Wilson's manual for further information, or I will try to answer your questions if I can. Shown is a Volumetric Efficiency (VE) Table which in essence is the "fuel table". This is an indication of the engine's efficiency in pumping air by plotting RPM vs. MAP. Changes such as cam timing & duration, intake & exhaust port configuration, valves, manifolds, headers, 3" exhaust, etc. affect this table. The more efficient the engine pumps air, the higher the efficiency number. The higher the number, more air flows. As more air flows, you need more fuel. Thus, this can be considered a fuel table because the amount of fuel required is directly proportional to the efficiency of the engine in pumping air through itself. Now this chart is just a starting point. The <c>



ECM calculates the injector pulse width from the fuel tables, from the corresponding BLM (Block Learn Mode) Value, and the Integrator (INT) Value. The BLM Value is sometimes referred to as the "long term" correction to the fuel tables. It is stored in memory and the more accurate this value is, the closer the ECM can hit the correct pulse width the first time at a given RPM/MAP condition. The INT Value is referred to as the short term correction and is not stored in RAM. It is constantly being recalculated based on O2 feedback. The ECM keeps the table of BLM values stored in RAM, so they are reset if the ECM loses 12V such as when a battery is replaced or discharged. If a VE table value is perfect, the corresponding BLM value is 128. If a VE table value is lean, the corresponding BLM value is greater than 128 and vice versa. The INT value is calculated using VE data and BLM data and O2 feedback data. If the INT value is consistently off for a given MAP/RPM value, the BLM for that point is updated, but gradually. Eventually, the BLM data should be updated to the point where the INT value is 128, and it makes no adjustment to the injector pulse. Theoretically, when that happens,<c>



you no longer need O2 feedback to maintain 14.7 AFR, but things change that are not accounted for in the algorithm used to calculate fuel delivery, so continued feed back is necessary. Now you can use the BLM values to adjust the VE table. For example, if a VE value is 60, and the corresponding BLM value is 120, the VE value should be adjusted to 60 x 120/128 = 56.3. Theoretically, after adjusting your table enough times, all the BLM values will be 128 and your VE table is perfect. In reality, if your VE table gives BLM values between, say 122 and 134, it is probably about as good as it is going to get. Note that if you change values in an area of the VE table, you really are not doing anything long term except changing the ECM calculated and stored BLM values, unless the calculated BLM value is outside the range specified in the programmed parameters. BLM values only change when in Closed Loop Block Learn Mode, but influence AFR in all modes.<c>



OK, after that little diversion, I am sure you are all ready to go out and pop for a bunch of equipment and dive into calibrating your newly installed TBI system, right? <c> Well if you are, you need to know a little bit about what equipment to get, where to get it, and how to go about changing the “programmed parameters” we’ve been talking about, along with a whole lot of others. <c>

What you need…

- First you need ability to gather data from the ALDL connector.
  - Cable to connect to laptop – www.customefis.com http://www.moates.net/
  - Software to view and save data http://winaldl.joby.se/ http://tunerpro.markmansur.com/
- Software to edit data
  - Free or very low cost http://tunerpro.markmansur.com/
  - Very good and fairly low cost www.tunercat.com
  - Need a “mask” for a particular ECM, in this case the 1227747. The mask identifies the variables and where they are in the ECM
  - Need a bin file to put specific data at the locations specified by the “mask”

The first thing you need is a cable to connect your laptop to the ALDL connector, and the software to accept, view, and store that data to your hard drive. Several sources for each are shown. <c>Next, you need the software that you will use to edit and change your program parameters (variables). <c> The oprogram I use is called TunerPro and I have been pleased with it. However, it has limited support, but enough if you stick with the ‘747 ECM. <c>TunerCat has better support, but costs a little more, and will probably be required if you stray from the ‘747 ECM. <c>This is a little confusing, but it need not be. You will need a mask for the particular ECM you are using. Most of the EPROM memory consists of thousands of individual instructions the microprocessor in the ECM executes as it goes about its business. Interspersed throughout the EPROM memory are the programmable parameters we have been talking about, and they are at different locations for different ECM or PCM part numbers. All the mask does is identify the locations of the variables we are interested in and may want to change. <c>Finally, you will need a bin file which is nothing more than a file that puts the variables you have decided upon in the appropriate locations in EPROM as defined by the mask. Simple, huh? <c>

What you need cont…

- The mask can likely be obtained where ever you get your editing software (probably TunerCat or TunerPro)
- The "starting point" bin file should be one meant for the GM 7.4L engine, or I can provide you with mine.
  - Both Turbo City's and Holley's bins are very close to the 7.4L bin.

- Once you get the bin file the way you want it, you need a programmer to burn a 2732 EPROM for your ECM.
  - The one from Craig Moates requires you to use a "flash" chip and an adapter he sells. It can also be used to change variables in real time http://www.moates.net/
  - The Pocket Programmer is a very good inexpensive one http://www.xtronics.com/memory/EPROM.htm

The mask can likely be obtained where ever you get your editing software…probably TunerPro or TunerCat, or I can send you the mask I have been using if you stick with the '747 ECM. <c>The starting point bin file should be one meant for the 454 engine, or I can provide you with mine. <c>Once you get the variables the way you want them, you need a programmer to burn the EPROM for your ECM. These run from about $150 to about $350. <c>The one from Craig Moates requires you to use a "flash" chip rather than the familiar 2732 EPROM normally used in the '747 ECM. This is great during the development process where you are continually changing the program to get it the way you want it. The flash chip can simply be reprogrammed whereas the 2732 has to be erased with UV light before it can be reprogrammed. The Moates programmer also serves as the connector to the ALDL, so you do not need to buy one of those if you use his programmer. Another big plus with his is that you can change variables in real time with his programmer as your wife drives down the highway. <c>The Pocket Programmer is a very good inexpensive programmer that will program almost any EPROM or flash chip or microprocessor with flash memory. <c>

To change variables…

- The program that will soon be opened is Mark Mansur's program called TunerPro. TunerCat is very similar but more expensive and better supported. Mark is a one man show…..open
- Open your saved bin from the editing program and burn your 2732 or the flash EEPROM if you have Craig's adapter. Put it in your ECM and hopefully you are off to evaluate your changes.

We will take a brief look at one of the editing programs referred to earlier called TunerPro. TunerCat is very similar, but is better supported and more expensive, approximately $100 which is still a bargain. <c> (open TunerPro)

Once you have your variables the way you want them, save them to a bin file, open the file with your programmer software, and burn it into the EPROM. If all goes well, you are ready to put it in your ECM and evaluate what you have screwed up{:>) Good Luck….. <c>

Links….

http://www.tunercat.com/ bin editing program and masks, very good links page

http://www.moates.net/ real time emulation, programmers, adapters, connector cables, other stuff

http://winaldl.joby.se/ program to read and store ALDL data, how to ALDL to laptop cable

http://tunerpro.markmansur.com/ bin, mask editing software, masks(ECU'S), sample bins, emulating software for Craig Moate's emulating hardware

http://www.cruzers.com/~ludis/ excellent ECM info site – where used, pinouts, schematics, etc.

http://www.thirdgen.org/ a wealth of info in Chat Rooms

http://www.thirdgen.org/newdesign/tech/ good tech articles

Links cont….

http://www.jagsthatrun.com/ good speed sensor write up, parts

http://www.diy-efi.org/gmecm/ excellent source of info, masks, bins, downloads

http://www.howell-efi.com/ parts to systems

http://www.zeitronix.com/ wide band O2 sensor – I have one and it works great – a must have if you are going to calibrate

http://www.turbocity.com/ one part to complete system

http://www.xtronics.com programmer, real time emulator

www.customefis.com how to book, EFI systems, many links