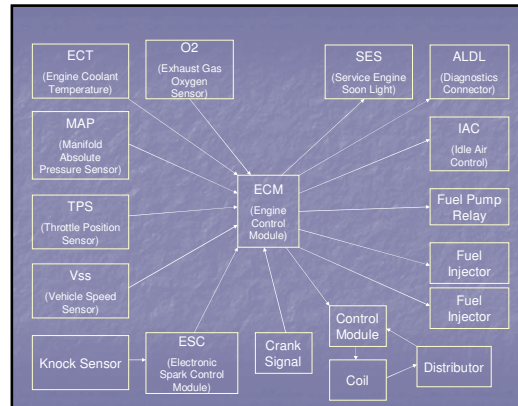**By: Ray Swartzendruber**

Generic TBI Fuel Injection

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

Block diagram:

- ECT (Engine Coolant Temperature)
- O2 (Exhaust Gas Oxygen Sensor)
- SES (Service Engine Soon Light)
- ALDL (Diagnostics Connector)
- MAP (Manifold Absolute Pressure Sensor)
- IAC (Idle Air Control)
- TPS (Throttle Position Sensor)
- ECM (Engine Control Module)
- Fuel Pump Relay
- Fuel Injector
- Vss (Vehicle Speed Sensor)
- Fuel Injector
- Knock Sensor
- ESC (Electronic Spark Control Module)
- Crank Signal
- Control Module
- Coil
- Distributor

Generic TBI Fuel Injection

- Block Diagram & Acronyms
- Individual Components and Their Function

O2 Sensor

- Screws into exhaust manifold or exhaust pipe
- Connects directly to ECM
- Senses oxygen level in exhaust gases and feeds info to computer which adjusts fuel delivery to match 14.7 air/fuel ratio
- GM P/N 25166816 (Delphi # ES10004) used widely on GM engines
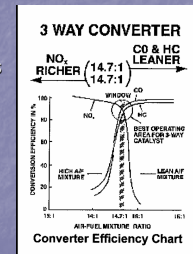

O2 Sensor Types

- 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

Why 14.7 air/fuel ratio ???

- 14.7 AFR is <u>NOT</u> necessarily most fuel efficient, but the CC (catalytic converter) is
- As AFR gets leaner, CC becomes more efficient burning HC & CO
- As AFR gets richer, CC becomes more efficient burning NOx
- 14.7 AFR is where they cross and both are 90%+ eliminated
- The ECM has an unincorporated highway mode that leans the mixture during cruising

Converter Efficiency Chart

By: Ray Swartzendruber

ECT Sensor



- Connects directly to ECM with two wire connector
- GM P/N 12146312 or 29036979 (Delphi TS10075) used widely in GM vehicles
- Sensor is a non linear thermistor which varies resistance with temperature. The ECM sends a precise 5V reference to the thermistor, and uses the return voltage to establish temperature by means of a look up table of voltage vs. 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???)

MAP Sensor
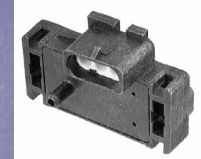
- Three wire connection to ECM plus manifold vacuum
- GM P/N 2131545, 16137039, 16017460 (Delphi # PS10076) widely used throughout GM prior to 1995
- Do NOT get one off a super or turbo charged engine, or from pre TBI cars such as the 307 Olds engine. They are MDP (manifold differential pressure) sensors
- Output is opposite manifold vacuum; 100 kPa (kilopascal) = 0" vacuum = 1 atmosphere pressure

What does MAP affect?

- Key in calculating air flow in the SD (speed density) system we use as opposed to MAF (mass air flow) used in most PFI engines
    - Air flow (along with other things) determines fuel delivery rate.
- Spark calculations
- Barometric pressure readings
- Switch pitch on/off if used

TPS

GM 17111787
Delphi SS10424

GM 17112679
GM 17112404
GM 17106681
Delphi SS10425

SS10424   SS10425

- Three wire connector to ECM
- 5V reference is sent to the TPS by the ECM, .5V is returned @ closed throttle, 4.5V @ open
- Earlier 454's used the style to the left; later ones used the style to the right. Changed around 1990.
- Both were widely used throughout GM

What does the TPS affect?

- Like MAP, TP is key in calculating air flow, and thus fuel delivery in our speed density system.
- Ignition timing
- Switch pitch on/off if used
- Flooding control – enleans drastically if WOT while cranking

By: Ray Swartzendruber

Vss

- Connects to ECM with only the signal wire, but 12V & GND must be supplied to it
- Be sure to get one that will give you 2000 pulses/mile
- Sources:
  - http://www.dakotadigital.com
    - Don't know of anyone who has used this
  - http://www.jagsthatrun.com/
  - http://www.turbocity.com/
- An excellent write up on speed sensors in general can be found at: http://www.jagsthatrun.com/V8-chapters/V8-tpi-Speed-Sensors.pdf

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

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.
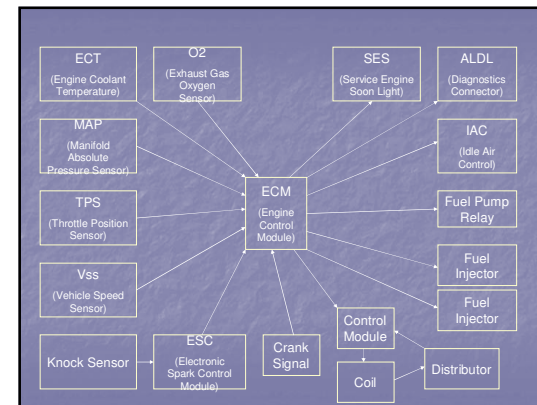- KS GM P/N is 10456288 (Delphi # AS10015) – suggest you buy new
- ESC GM P/N is 16131231

What it does….

- 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.

Crank Signal

- Is merely a fused tap into the heavy purple wire that goes to the starter solenoid along the right valve cover
- Tells ECM the engine is cranking so it can calculate fuel delivery and spark accordingly
- Keeps the fuel pump relay energized until engine starts and you have oil pressure.

ECT (Engine Coolant Temperature)
O2 (Exhaust Gas Oxygen Sensor)
SES (Service Engine Soon Light)
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Crank Signal
Control Module
Coil
Distributor

By: Ray Swartzendruber

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SES and ALDL

- The SES output is a single wire going to a warning light in view of the driver to signal a problem detected by the ECM.
- The ALDL output is a three wire connection
  - Ground
  - Serial Data
  - Diagnostic Test

IAC

- Four wire connector to ECM
- Controls low amounts of air flow when throttle blade is closed or nearly closed such as at idle
- Unique to the 454 TB with 2" throats and a very limited number of 4.3L applications in the S-10 around 1991-96, probably the "Cyclone"
- GM P/N 17111788 (Delphi CV10027)

Fuel Pump Relay Output

- Single wire 12V output from ECM to fuel pump relay, active only when cranking
- Relay COM term connects 12V to fuel pump
- NO term connects to fuel pump
- NC term can go to ALDL "G" for diagnostics
- Fuel pump gets 12V through NO oil pressure switch in parallel with relay
  - Stops fuel pump if engine quits...relay cranks, OP sw runs
- Also a single wire attaches 12V fuel pump terminal to ECM as "Fuel Pump Signal"
  - Sole purpose is to tell ECM that 12V is actually being applied to fuel pump...diagnostics?

A Word About Pumps

- A Commercial: for an EXCELLENT write up on fuel delivery, visit John Wilson's website at www.customefis.com and pop for $30 to buy his DIY manual. It has been the single most helpful document to me.
- John recommends the E2182 pump above.
- Available most auto supply stores under $75
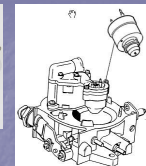- Use an inline filter between tanks and pump

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A Word About Relays
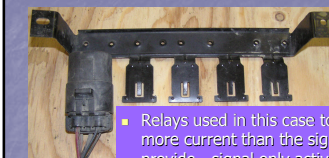
- Relays used in this case to carry more current than the signal can provide - signal only activates coil

- Relays such as these are "almost" free. I like these because a variety of brackets are available, they are weatherproof, snap in place and are very reliable. The bracket and relay on the left came from an early '80's GM "A Car" (Celebrity, 6000, Century, Ciera)...not sure where the parts on the right came from. There are different attachment types, so make sure your relay(s) fit your bracket(s). Parts similar to the left ones are available from the GM "dustbuster" vans. Get ones with heavy wires as long as possible.

Fuel Injectors

- ECM "sinks"(neg) rather than "sources"(pos) injectors
- An ECM output used for each injector..one cannot sink enough power for both
  (Delphi FJ10098) for 87-93 throttle bodies....80 LB/hour
- P/N 17113080 (Delphi FJ10097) for 94-95 TB's...90LB/hour
- TB's hard to come by, only used on 454 Chev engines; bores are 2" as opposed to 1 11/16"; look on ebay or search 'net
- Holley and Customefis make after market 2" bore TB's...cannot comment on suitability...again, refer to John Wilson's manual

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By: Ray Swartzendruber

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Distributor/Control Module

- Distributor pickup and ECM calculations tell the control module when to fire the coil.
- Distributor comes from 307 Olds
- Early 80's Buicks and Olds cars are good sources...any Olds engine with a distributor with no vacuum can and with a four wire connector coming out of it is OK.
- The four wire connector hooks directly to ECM
- Echlin **TP47**, Standard **LX315**, Accel **35363**, Holley **891-102**, GM **1976908**, Delco **D1952** some of many module P/N's avail.
- Any GM HEI distributor with electronic ignition can be converted to use the internal control module. Any non HEI distributor with magnetic pickup can be converted to use an external control module for ECM controlled timing. Reference John's manual

ECM

- Top one is 1227747 ECM which this presentation is designed to use
- Widely available – see http://www.cruzers.com/~ludis/ for a listing of most usages
- The bottom one is 16197427 PCM and is a newer generation computer than the one above.
- Only used on 94 – 95 7.4L engine
- Only one of this generation used with TBI – others are PFI
- Faster, better control, more inputs/outputs than '747

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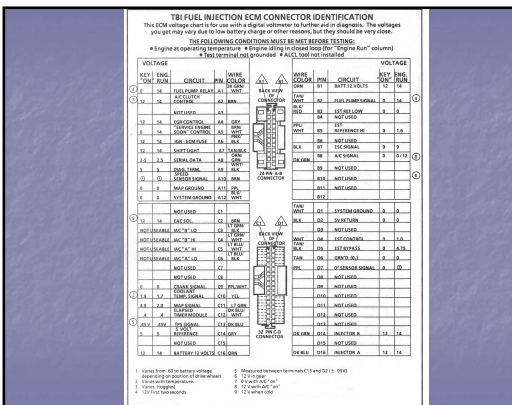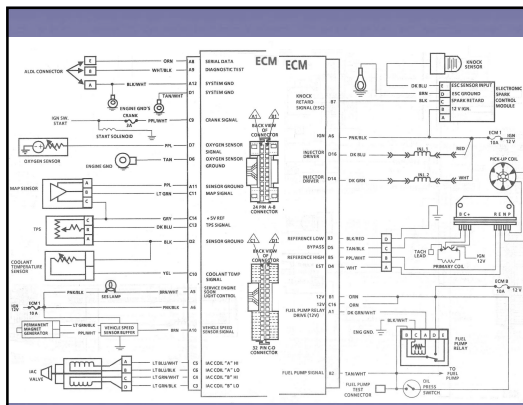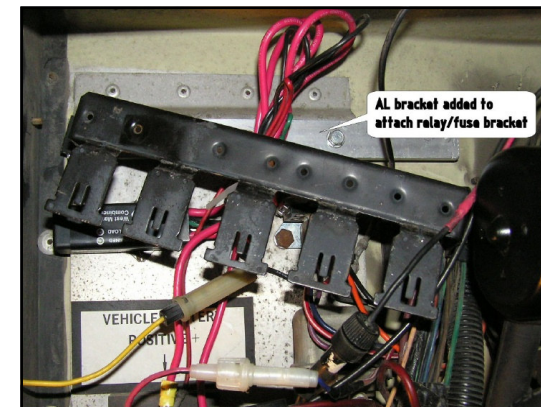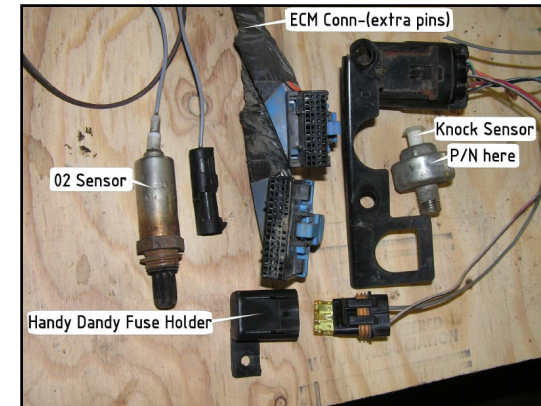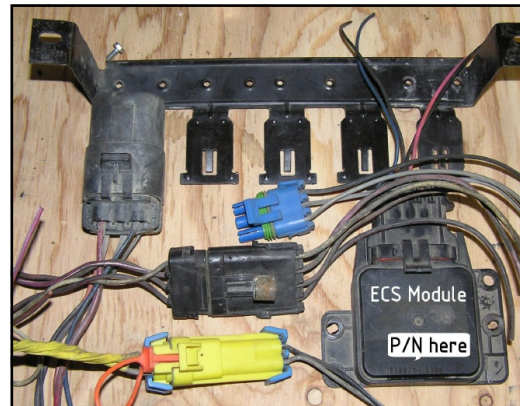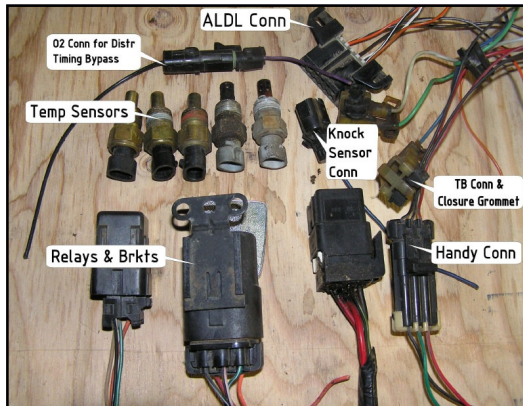

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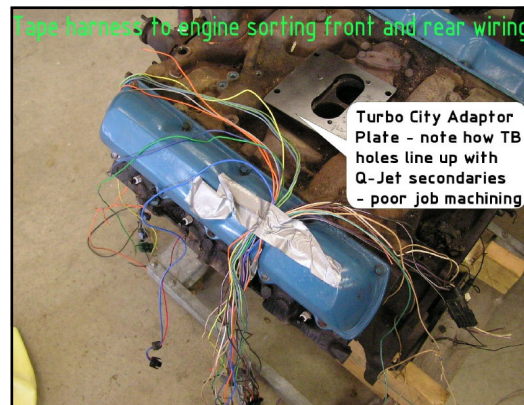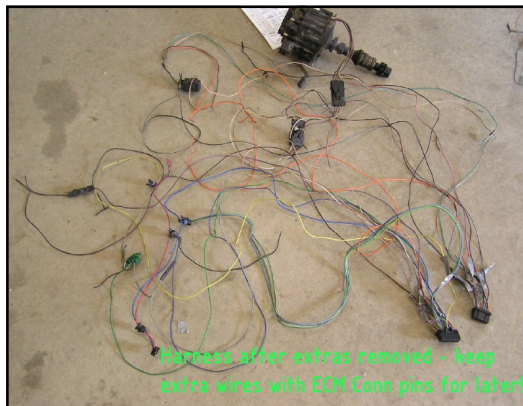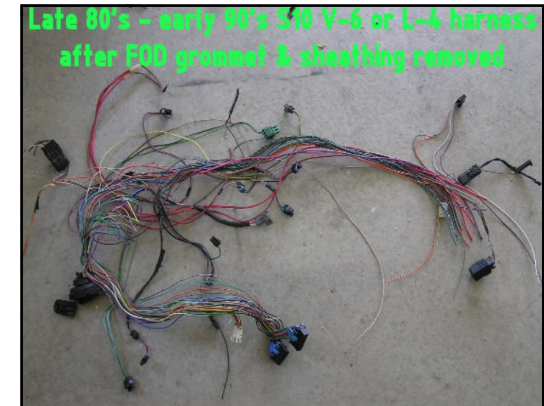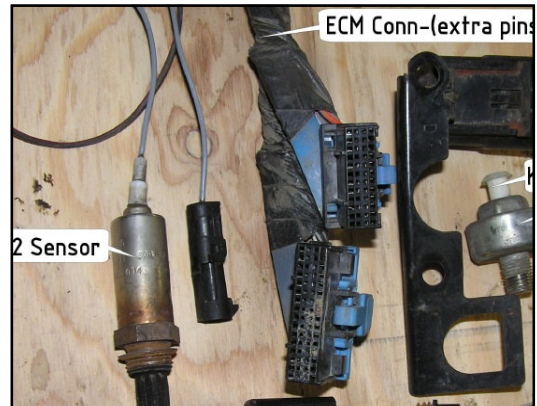 - Gather components

DISCLAIMER:
Information presented by GMCES is intended only to communicate thoughts, ideas, opinions and procedures to and from GMC owners; there is no attempt to replace or supersede recommendations from General Motors Corporation or any other component manufacturer. All opinions expressed are those of the authors and not GMCES. Mention of any product does not constitute endorsement by GMCES. Neither the authors nor GMC Eastern States assume any responsibility for what you choose to do to your coach.

By: Ray Swartzendruber

Top-left photo labels:
- O2 Conn for Distr Timing Bypass
- ALDL Conn
- Temp Sensors
- Knock Sensor Conn
- TB Conn & Closure Grommet
- Relays & Brkts
- Handy Conn

Top-middle photo labels:
- ECS Module
- P/N here

Top-right photo labels:
- ECM Conn—(extra pins)
- Knock Sensor P/N here
- O2 Sensor
- Handy Dandy Fuse Holder

Bottom-left photo labels:
- Distr to ECM Conn
- Purolator F21111
- O2 Conn Used for Timing Bypass
- Control Module - use heat conductive grease!

Bottom-middle photo labels:
- GM
- 039 2010
- Last 3 digits (039) of MAP P/N here

Bottom-right photo labels:
- AL bracket added to attach relay/fuse bracket
- VEHICLE POSITIVE +

By: Ray Swartzendruber

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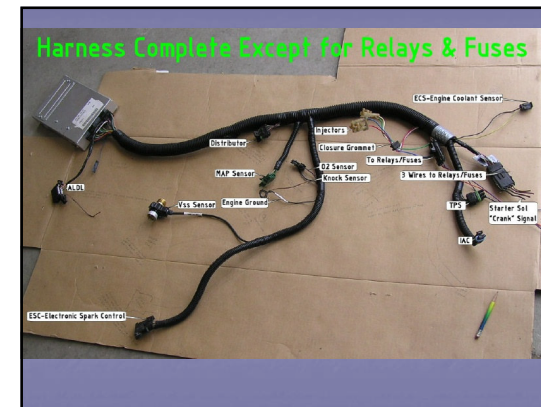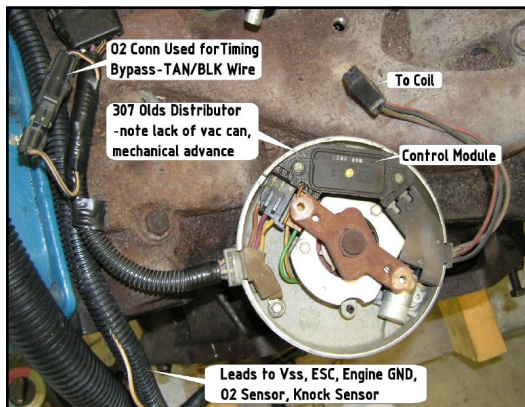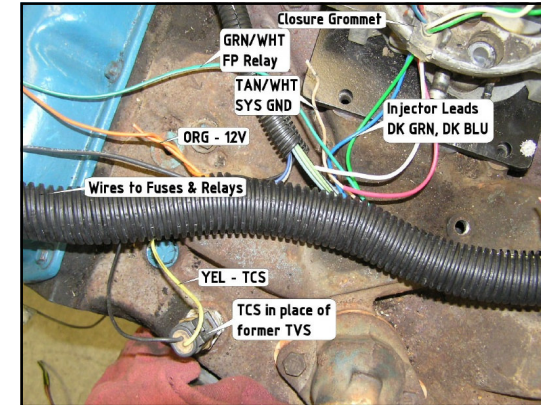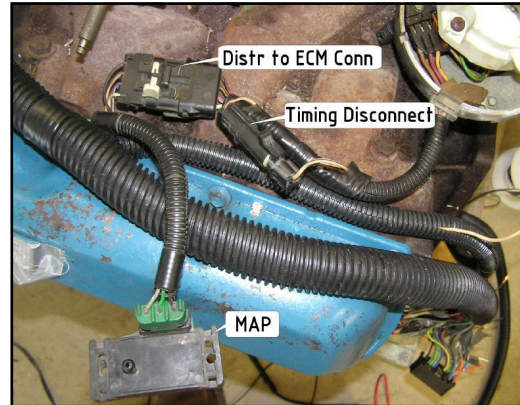 - Gather components
  - Wiring Harness

ECM Conn-(extra pins

2 Sensor

Late 80's – early 90's 5.0 V-6 or L-4 harness after EOD grommet & sheathing removed

Harness after extras removed - keep extra wires with ECM Conn pins for later!

Tape harness to engine sorting front and rear wiring

Turbo City Adaptor Plate - note how TB holes line up with Q-Jet secondaries - poor job machining

Note wire colors correspond with schematics

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Image 1 (top left):
- IAC and Wires
- Inj 2 Leads
- TPS Conn (wrong one)
- TPS
- Inj 1 Leads
- MAP, Conn, Wires

Image 2 (top center):
- Distr to ECM Conn
- Timing Disconnect
- MAP

Image 3 (top right):
- Closure Grommet
- GRN/WHT FP Relay
- TAN/WHT SYS GND
- ORG - 12V
- Injector Leads DK GRN, DK BLU
- Wires to Fuses & Relays
- YEL - TCS
- TCS in place of former TVS

Image 4 (bottom left):
- O2 Conn Used for Timing Bypass-TAN/BLK Wire
- To Coil
- 307 Olds Distributor -note lack of vac can, mechanical advance
- Control Module
- Leads to Vss, ESC, Engine GND, O2 Sensor, Knock Sensor

Image 5 (bottom center):
- Final Harness Before Transferring to Coach

Image 6 (bottom right):
- Harness Complete Except for Relays & Fuses
- ECS-Engine Coolant Sensor
- Injectors
- Distributor
- Closure Grommet
- To Relays/Fuses
- ALDL
- MAP Sensor
- O2 Sensor
- Knock Sensor
- 3 Wires to Relays/Fuses
- Vss Sensor
- Engine Ground
- TPS
- Starter Sol "Crank" Signal
- IAC
- ESC-Electronic Spark Control

By: Ray Swartzendruber

Labels on first image:
- 12V when IGN on–10A Fuse–Feeds Injectors
- From IGN switch to "IGN on" Relay coil
- 12V Always–20A fuse feeds this wire (ECM) & FP (via OP switch)
- 12V when IGN on–5A fuse feeds ECM
- "FP On" Signal to ECM comes from OP switch & FP
- Signal from ECM to FP Relay Coil

Labels on second image:
- Coil "IGN on" 10A Fuse
- FP & ECM 12V Always–20A
- Inj "IGN on" 10A Fuse
- ECM "IGN on" 5A Fuse
- "IGN on" Relay
- FP Relay
- Heater 20A
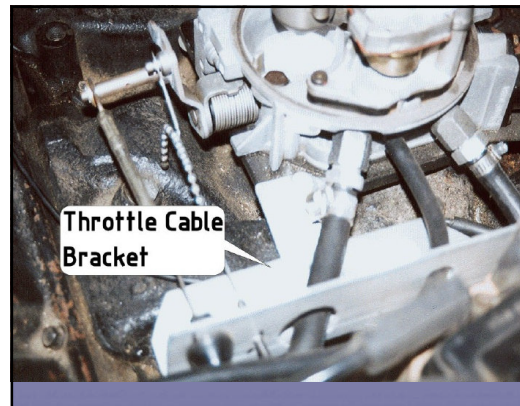
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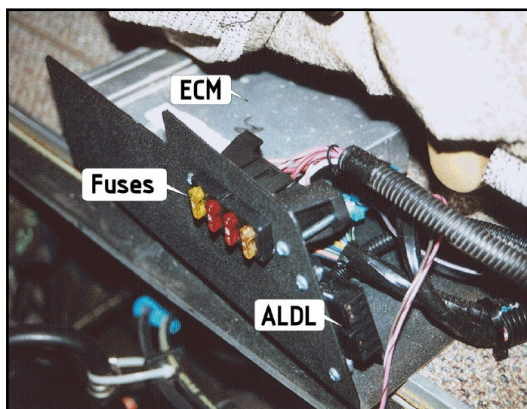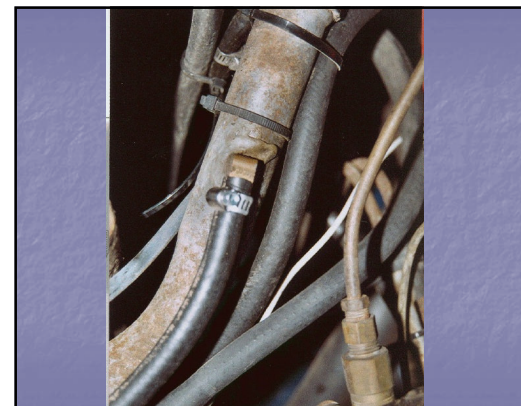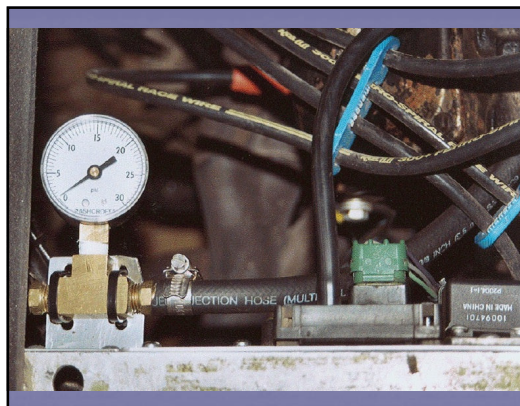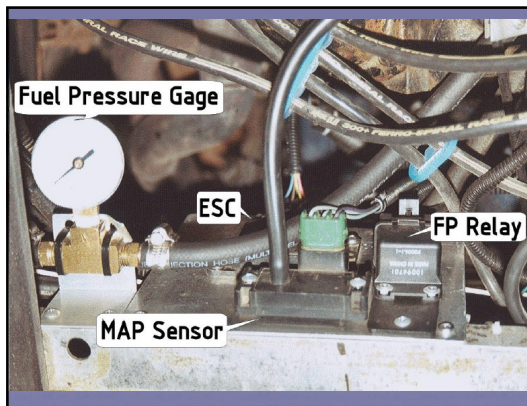 - Wiring Harness
  - Bracketry

Throttle Cable Bracket

By: Ray Swartzendruber

Fuel Pressure Gage
ESC
FP Relay
MAP Sensor

ECM
Fuses
ALDL

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Main Modes

- Starting
  - Clear Flood – TPS beyond a certain point
- Run
  - Open Loop – totally program control
  - Closed Loop – O2 feedback and adjustment
  - Deceleration Enleanment
  - Power Enrichment – richer for more power, cooling
  - Block Learn – constantly adjusting fuel tables
  - Asynchronous mode – such as rapidly changing TPS signal ("accelerator pump" to prevent stumble)
  - HiWay Mode – not used runs in open loop

By: Ray Swartzendruber

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

Closed Loop

- Varies AFR based on voltage variations from O2
- Increases injector pulse width when voltage is less than 450 mv to enrichen AFR, decreases pulse when more than 450 mv to enlean
- Constantly over/under 450mv as AFR is adjusted
- Based on magnitude and frequency of adjustments, in Block Learn Mode, internal fuel tables are adjusted higher or lower

VE/BLM/INT/O2

Shown is a volumetric efficiency (VE) table which in essence is the "fuel table". This is an indication of the engine's

	VE as % (FL1)				
	4	8	12	16	20
100	58.59	60.94	63.67	70.70	72.27
90	57.03	62.89	66.02	70.70	72.27
80	52.73	61.33	68.75	70.31	71.88
70	45.70	58.20	62.11	66.80	67.58
60	39.84	53.52	62.11	62.50	65.63
50	36.33	51.95	56.64	62.11	61.72
40	33.20	39.06	50.78	54.69	50.00

efficiency in pumping air by charting RPM along the X axis and MAP along the Y axis. Changes such as cam timing & duration, intake & exhaust port configuration, valves, manifolds, headers, 3" exhaust, etc. affect this table. The more efficient, the higher the 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

VE/BLM/INT/O2 con't…

ECM calculates the injector pulse time from the chart, from the corresponding BLM (Block Learn Mode) value, and the Integrator (INT) value. The BLM is sometimes referred to as the "long term" correction to the table and the INT is referred to as the short term correction. The ECM keeps a table in memory of BLM values (which are reset if battery cable is removed). If a VE table value is perfect, the corresponding BLM value is 128. If a VE table value is lean, 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, the BLM 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, at that point

VE/BLM/INT/O2 con't…

you need no O2 feedback. 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 specified range. BLM values only change when in closed loop, but influence AFR in all modes.

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By: Ray Swartzendruber

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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"

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

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.

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.div-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