Schrodingers Box

First edition

2022

Advanced DIY Auto Diagnostics & Repair

Matt Bernstein

Ayman Kamar

Preface and Introduction

I would like to start right off the bat by letting you know- this book is actually the work of a viewer on my YouTube Channel named Dr. Ayman Kamar. Ayman is from Egypt, and English is pretty distanced from his primary language but somehow he still managed to put together the bulk of what you have in front of you. I didn't even know he was working on this project- he literally just presented a draft to me out of the blue one day and I didn't even know what to say.

As you can see, this book was a tremendous amount of work and you really have Ayman to thank for it. I only put together the introductions and some descriptions on the diagrams. This is really Ayman`s creation and he wanted you to have it as a resource if you need quick refreshers while in the field as opposed to trying to search and view a relevant video from my YouTube channel or Paid Content channel www.schrodingersboxQM.com.

It is important to note that this book is intended as a supplement and review to my video content. You will definitely not be able to just pick up the book, read it cover to cover, and then be able to do advanced engine and electrical diagnostics. The diagrams will look like hieroglyphics at best until you understand the concepts quite well. But if you can understand the diagrams and text that is a great indication you have a good comprehension of the material and the book can be used as a quick review or reference. There are links to the relevant videos for every chapter and it will be necessary to understand the video material to get the most out of the book.

This will be an evolving work in progress so if you identify any corrections that need to be made or would like to request specific content, just let me know and we'll see about implementing those in future editions.

Ayman and I really do hope you enjoy the book and find it useful in cementing your understanding of these complex concepts and greatly elevating your capabilities as an advanced DIY.

Best wishes,
Matt Bernstein – Schrodinger`s Box

Advanced DIY Auto Diagnostics & Repair

Contents

Schrodingers Box

AUTOMOTIVE TERMS

Engine Fuel System		CTS	Coolant temp. sensor
FPS	Fuel pressure sensor	ECT	Engine coolant temperature
LTFT	Long term fuel trim	AC	Air Conditioning System
STFT	Short term fuel trim	EVAP	The Evaporative Emission System
AFR	Air fuel ratio	COP	Coil- on - Plug Ignition System
FPR	Fuel pressure regulator	**Basic electrical**	
Engine Air Intake System		DVOM	Digital Volt Ohm Meter
IAT	Intake air temp. sensor	V	Voltage
IAC	Idle air control actuator (valve)	I	Current
MAF	Mass air flow sensor	R	Resistance
MAP	Manifold absolute pressure sensor	GND	Ground
TPAP	Throttle plate angular position	GRD	Ground
TPS	Throttle position sensor	V.	VOLTS
WOT	Wide open throttle	Amp.	Amperage (current measuring unit)
VVT	variable valve timing	Omh. Ω	Resistance measuring unit
Engine Exhaust system		T°	Temperature
EGR	Exhaust gas regulator	**Diagnosis**	
O2S1	Oxygen upstream sensor	TDC	top dead centre
O2S2	Oxygen downstream sensor	B1	Bank 1
ETS	Exhaust temp. sensor	B2	Bank 2
OL	OPEN LOOP	IGN.	Ignition
CL	CLOSED LOOP	IGN-SW	Ignition Switch
Engine Sensors & systems		DTC	diagnostic trouble code
PCM	Power train control module	psi	Pounds per square inch
ECM	Engine control module	PWM	Pulse-width modulation
CPS	Camshaft position sensor	RPM	revolutions per minute
CKPS	Crankshaft position sensor		
CMP	Camshaft position sensor		
CKP	Crankshaft position sensor		
KS	Knock sensor		

SECTION 1

BASIC ELECTRICAL FOR BEGINNERS

This is by far the most important chapter in the book. If you can master basic electrical concepts, you will far exceed even the capabilities of many professional auto mechanics because most people in general have a very hard time understanding electrical. I strongly urge you to do the best you can to understand not only the concepts but also to be able to do some of the math equations as well. Most people just skip over Ohm's Law and all the "math stuff" but mastering this will help you to achieve the ultimate mastery of electrical- the ability to "visualize" it as opposed to following it by memorization or mechanically like a flow chart.

It really helps to visualize basic electrical by analogizing it with water. While there are a few exceptions, 95% of the time thinking about the behavior of water flowing through hoses or how rivers flow will be pretty similar to how electricity works. This will allow you to take a complex concept like Ohm's Law: V=IR (V)oltage equals (I)Amperage times (R)esistance and rather than just calculate it and follow whatever it says, you will be able to actually "see" it at work. In the case of a garden hose- the water faucet is the voltage- the starting pressure. You can imagine if you have good water pressure from the faucet and a really thin hose- we know water would shoot out of the end of the hose really far. This is because inside the thin hose we have high resistance which causes high pressure. But we also know that if you wanted to fill up a glass of water with this thin hose it would take an extra-long time because while the water shoots out impressively, there isn't actually all that much water coming out as opposed to if you just filled the glass right from the faucet without the hose. So we can "see" that increasing (R)esistance

reduces flow (I)amperage. We could also replace the thin hose with a much wider hose and fill a glass of water about the same as directly from the faucet but the water would hardly shoot out of the end of the hose because a wider hose has less resistance which increases the flow of water but pressure is reduced. You can imagine all kinds of combinations like this that would allow you to answer what would happen in various electrical situations. Why does a car with a bad battery not start? Well, it's because it's like having the faucet only turned on just a little bit and expecting it to operate a sprinkler. There isn't enough "pressure" and therefore both flow and resistance are reduced. What if the battery is good but there is a bad starter cable with lots of corrosion? The car still doesn't start but it's not for lack of pressure- remember pressure will be high to the starter motor because of the resistance, but there will be much less flow so just the same way the sprinkler would barely work if you used a really thin hose with it- we know the pressure is high because the hose is thin (increases resistance) but there isn't enough water flowing through the sprinkler to make it operate.

Please watch the basic electrical video links and then when looking at the diagrams in this book- see if it helps to think about water behavior to understand how variables impact electrical performance.

VIDEOS LINK

https://schrodingersboxqm.com/basic-electrical-for-beginners-part-1/

https://schrodingersboxqm.com/basic-electrical-for-beginners-part-2/

https://schrodingersboxqm.com/basic-electrical-for-beginners-part-3/

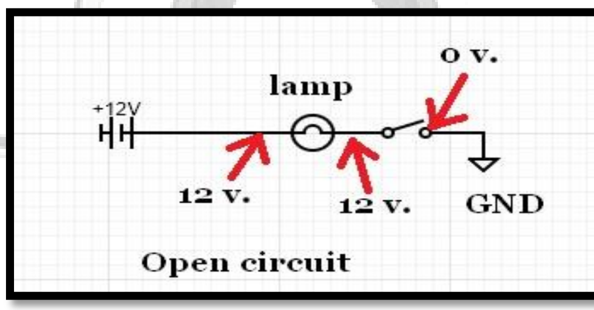
https://schrodingersboxqm.com/basic-electrical-for-beginners-pt-4-dvom-and-testlights/

https://schrodingersboxqm.com/basic-electrical-for-beginners-pt5-parallel-circuitscemf/

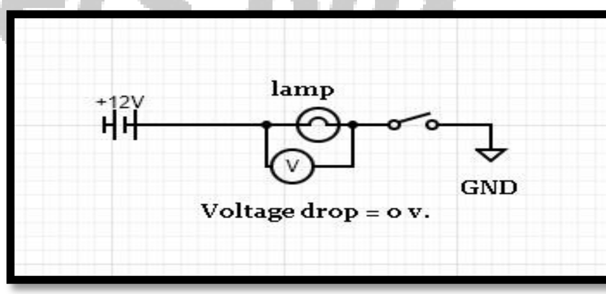
https://schrodingersboxqm.com/basic-electrical-for-beginners-pt6-applying-concepts/

https://schrodingersboxqm.com/basic-electrical-for-beginners-pt7-conclusion/

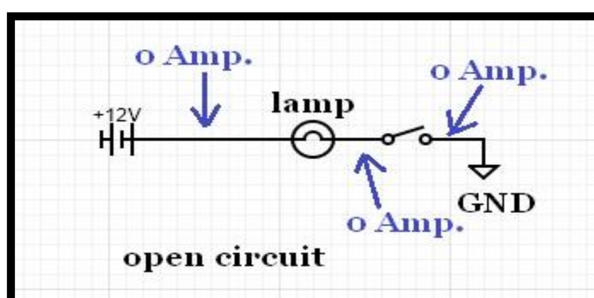
1.1 - Open circuit



- **Any position BEFORE the open switch will equal source voltage because there is no current (flow). Think of water analogy- the open switch is "capping" the hose so all pressure is equal before the cap.**



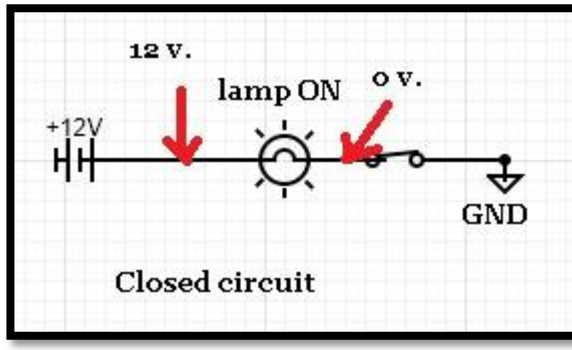
- **When we calculate voltage drop across the load (the lamp) it is zero because there is no current with switch open.**



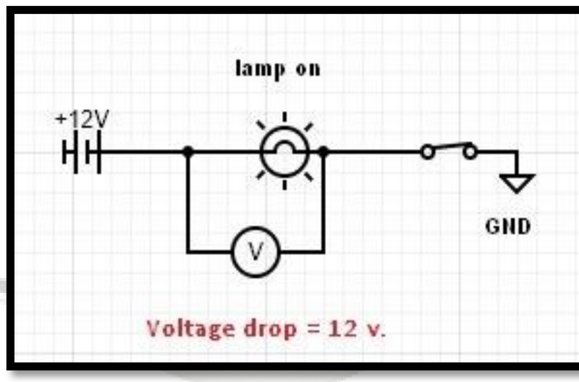
- **Current is zero Amps anywhere on circuit because there is no electrical flow with open switch. The lamp is not lit in any of these examples because switch it open—no flow.**

1.2- Closed circuit (switch closed)

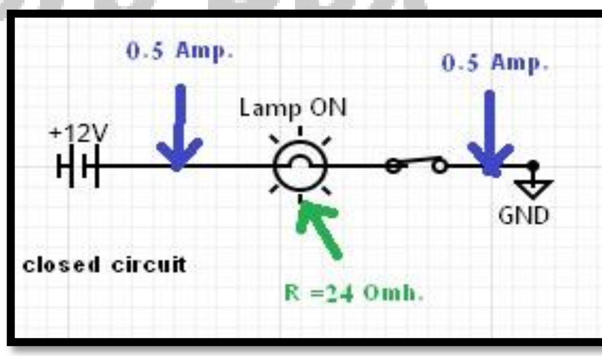
- **The voltage BEFORE the load (lamp) equals source voltage but AFTER the load it is zero. The load uses all the voltage no matter its resistance. Lamp is lit because of switch closed causing flow.**



- **When we calculate voltage drop across the lamp, it is 12V because it is source voltage before the load and 0V after the load.**



- **Unlike Voltage, CURRENT (amperage or I) will be the same across the ENTIRE circuit. Again, think of water analogy- water flow is same before or after a "pinch" in the hose. You can't have water flow slower or faster within different points of a closed system- it's all the same.**

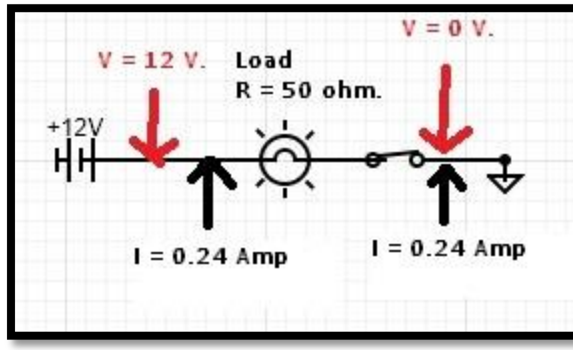


1.3- Ohm`s Law

V=Voltage I=Current (Amperage) R=Resistance

V = I*R

I = V / R



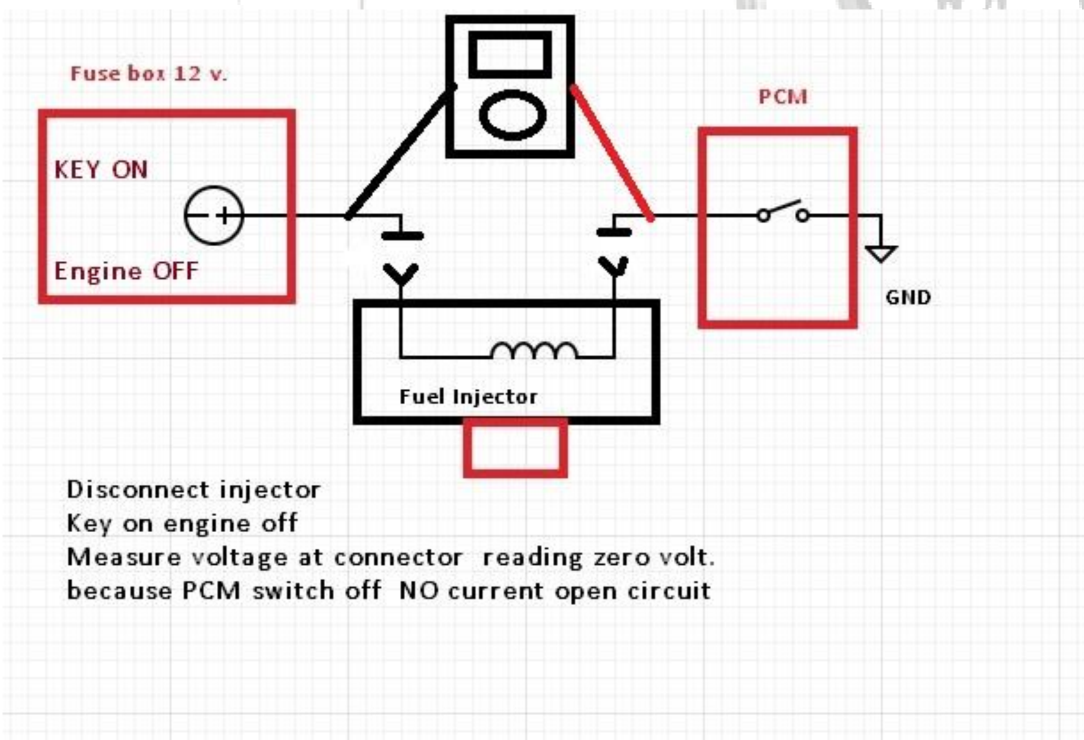
V = 12 V.

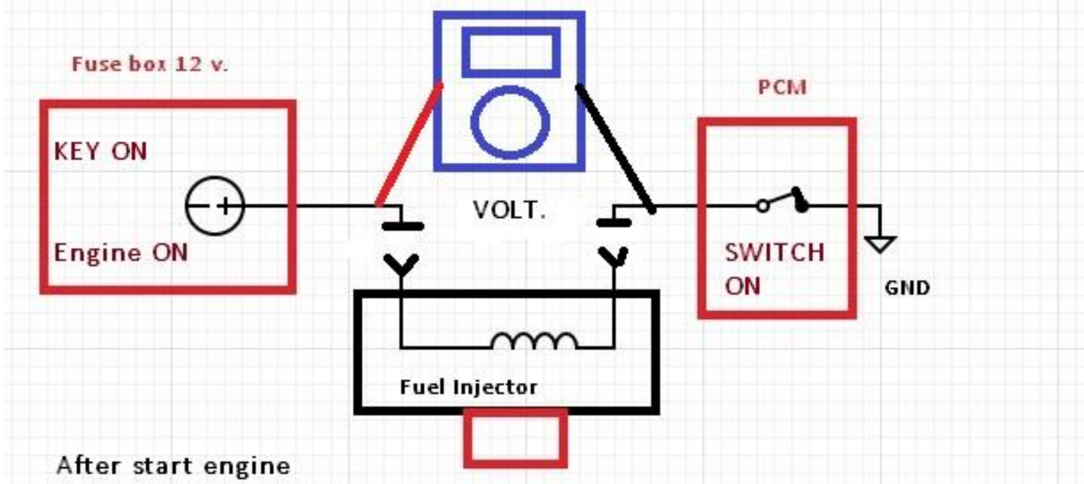
R = 50 Ω

I = 12 / 50 = 0.24 Amp.

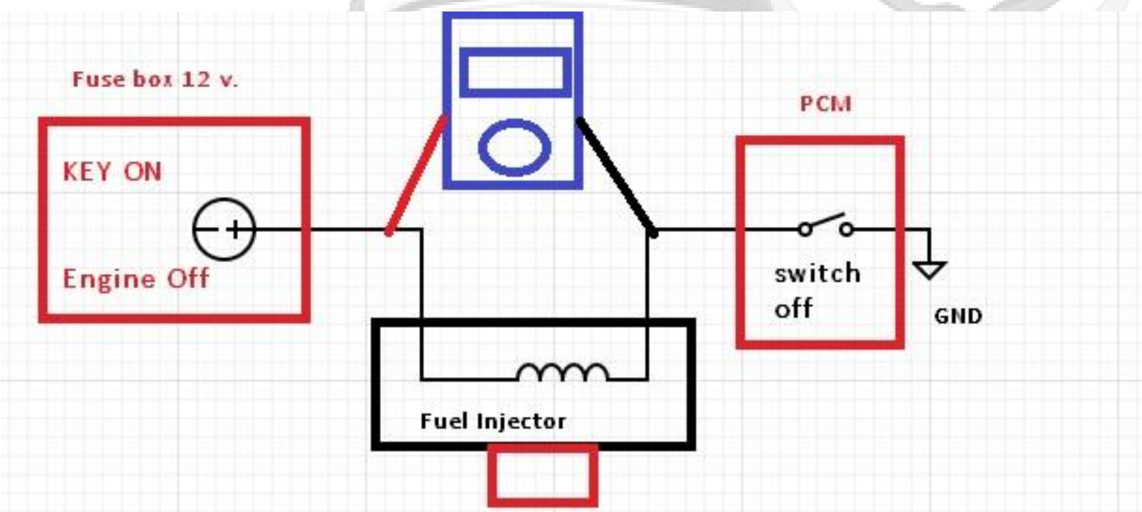
1.4- How to measure voltage

Example: fuel injector

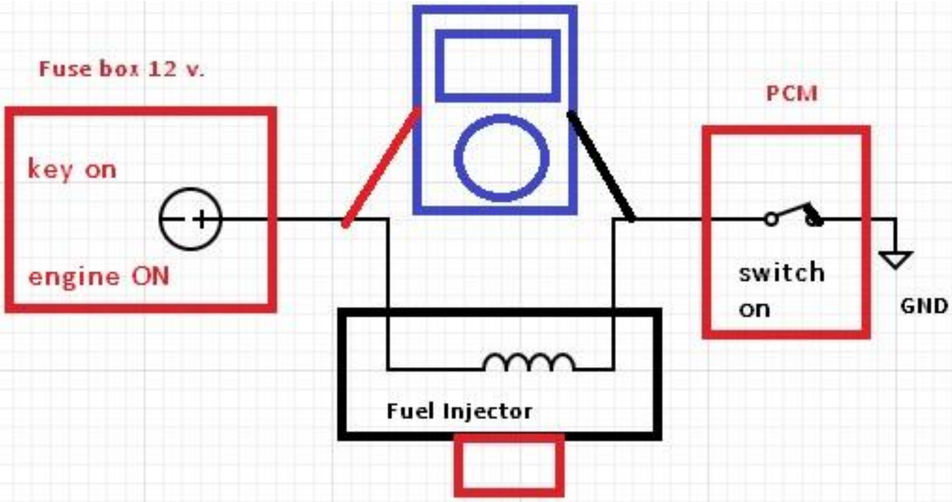




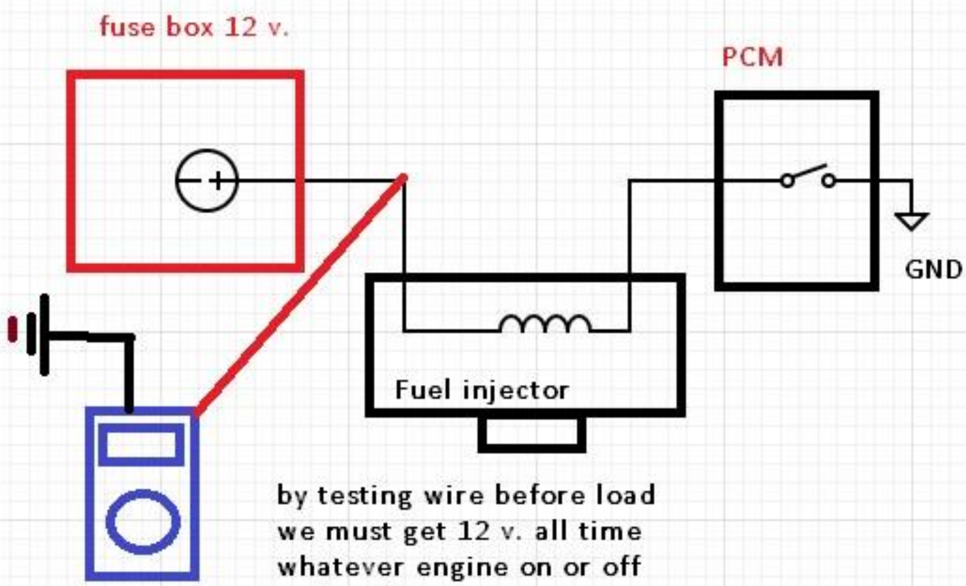
After start engine
PCM close the circuit
by measuring voltage
reading the average volt. about 6 volt
because PCM turns switch on & off periodically



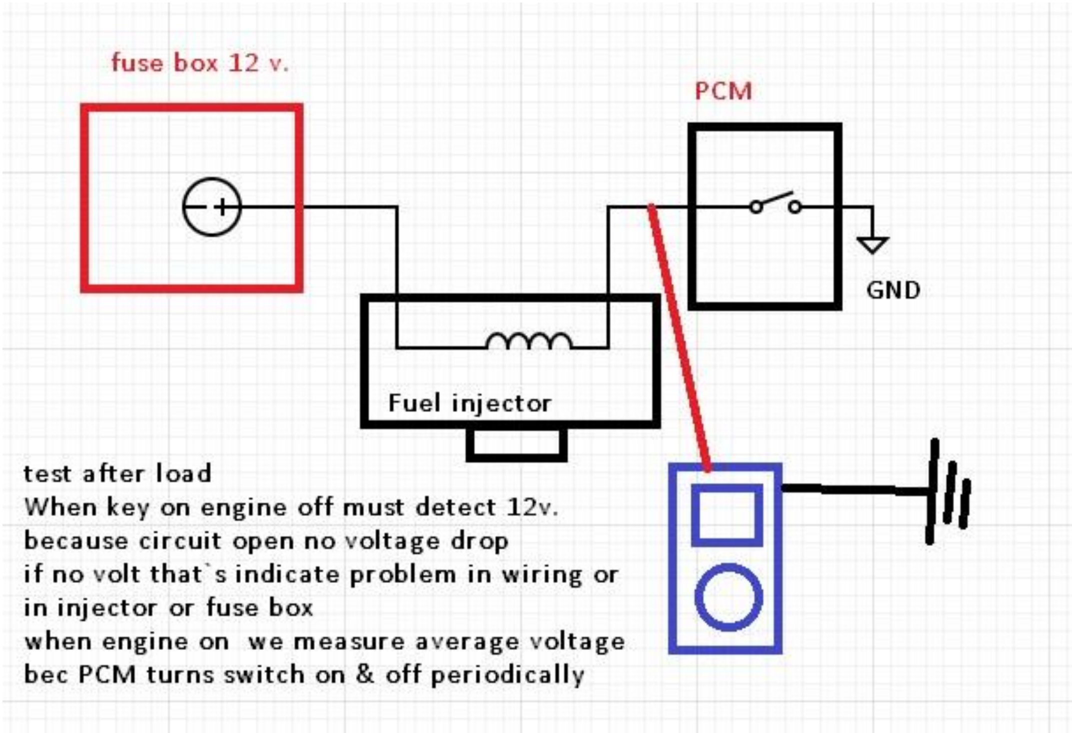
Connect injector
Key ON Engine off
Measuring voltage at connection
reading zero volt.
because PCM switch off No current open circuit

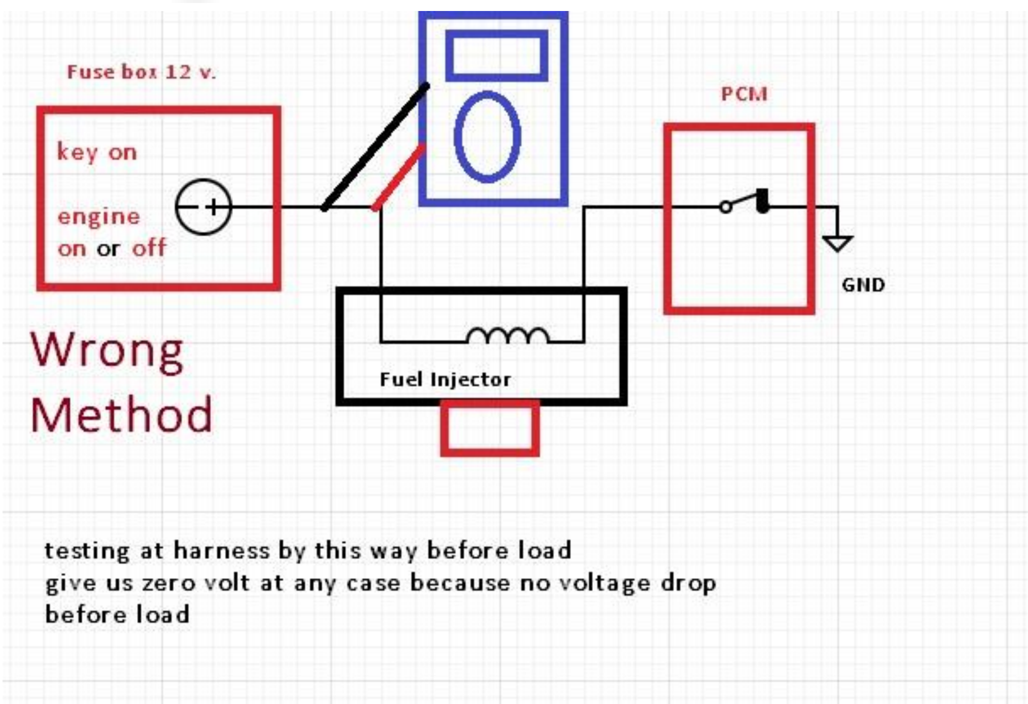


After starting engine
PCM close the circuit
by measuring voltage
Average volt. will be about 6 volt
because PCM turns switch on & off periodically



by testing wire before load
we must get 12 v. all time
whatever engine on or off
as long key on
if we get zero volt that is indicate problem in wiring
or fuse box

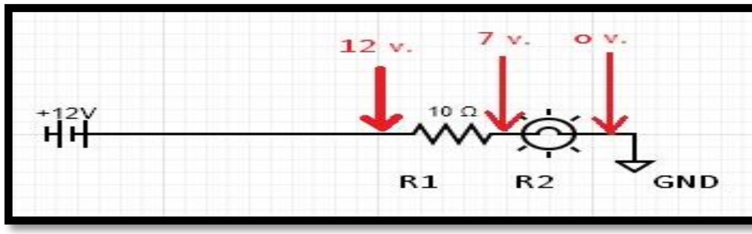

fuse box 12 v.
PCM
GND
Fuel injector
test after load
When key on engine off must detect 12v.
because circuit open no voltage drop
if no volt that`s indicate problem in wiring or
in injector or fuse box
when engine on we measure average voltage
bec PCM turns switch on & off periodically

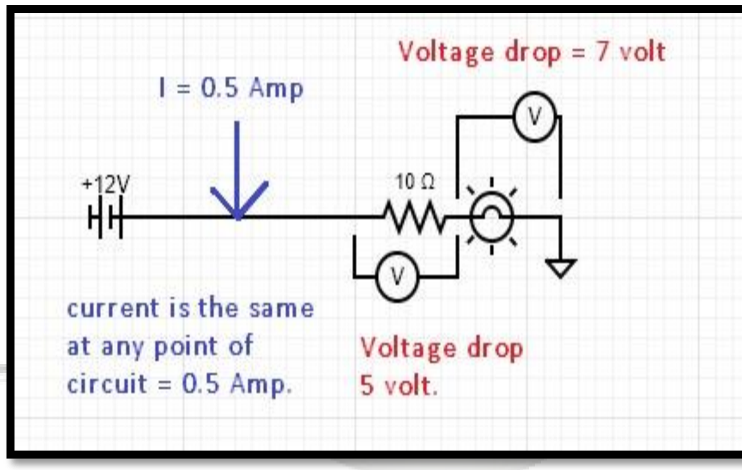

Fuse box 12 v.
key on
engine
on or off
PCM
GND
Fuel Injector
Wrong
Method
testing at harness by this way before load
give us zero volt at any case because no voltage drop
before load

1.5- CIRCUITS WITH LOAD AND RESISTANCE

Resistance before load

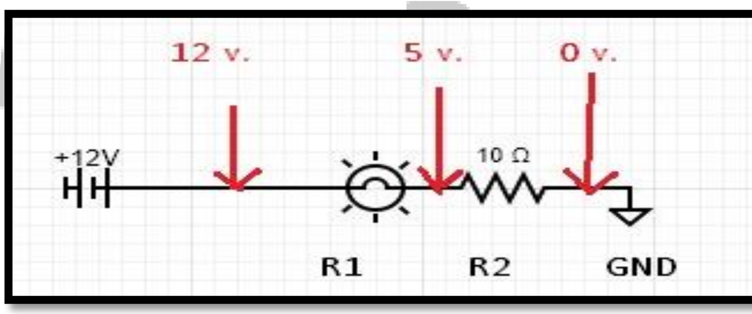
- I= 0.5 Amp
- R1 = 10 Ω = RESISTANCE
- R2 = 14Ω = LOAD BULB
- **At R1 RESISTANCE**
- V=I R
- V= 0.5 X 10 = 5 VOLT
- Voltage drop = 5 volt
- Voltage after R1 = 7 volt
- **At R2 LOAD BULB**
- V=I R
- V= 0.5 X 14 = 7 VOLT
- Voltage drop = 7 volt
- Voltage before R2 = 7 volt
- Voltage after R2 = 0 volt

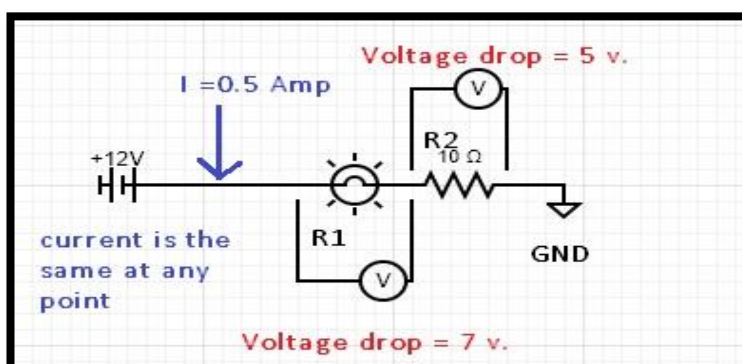




Resistance after load

- I= 0.5 Amp
- R1 = 14Ω = LOAD BULB
- R2 = 10 Ω = RESISTANCE
- **At R1 LOAD BULB**
- V=I R
- V= 0.5 X 14 = 7 VOLT
- Voltage drop = 7 volt
- Voltage after R1 = 5 volt
- **At R2 RESISTANCE**
- V=I R
- V= 0.5 X 10 = 5 VOLT
- Voltage drop = 5 volt
- Voltage before R2 = 5 volt
- Voltage after R2 = 0 volt

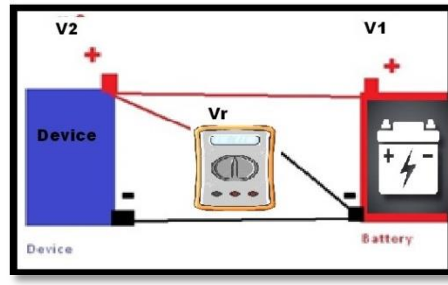




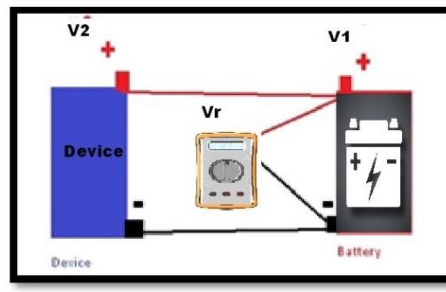
1.6- Voltage drop test

Video link
https://youtu.be/DfLyh43iihM

1 – FIRST WAY

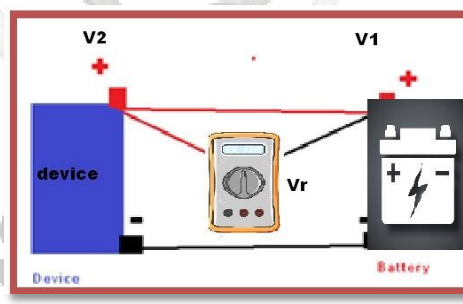


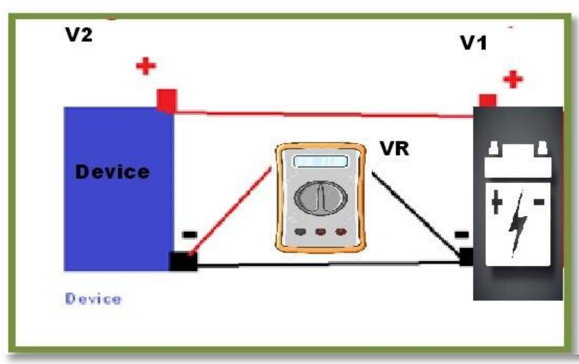
- Check voltage at device positive terminal vs battery negative terminal (Figure 1) and subtract from battery voltage (Figure 2). Difference is voltage drop across positive cable. Remember-DEVICE MUST BE OPERATING! No current flow=no voltage drop.



2- SECOND WAY

- Connect +on device to +on source. This shows voltage drop on positive.
- If shows approximately zero, it means no voltage drop. Look for >.6V on a starter motor.



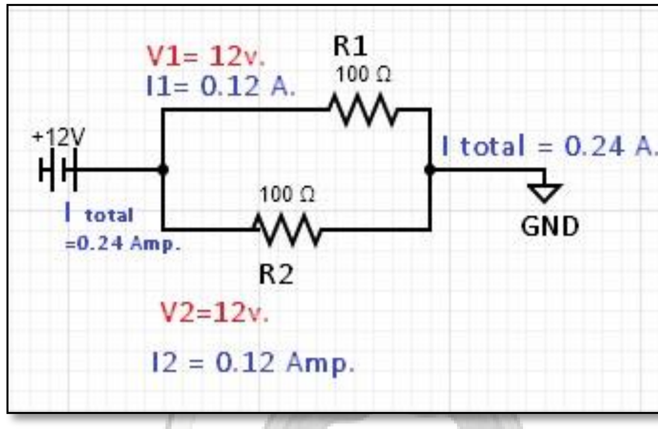


- Repeat second way on Negative side to get voltage drop on the negative. Again-the circuit MUST HAVE AMPERAGE FLOW!! Voltage drop will show zero if there is no current flow EVEN IF THERE IS HIGH RESISTANCE!!

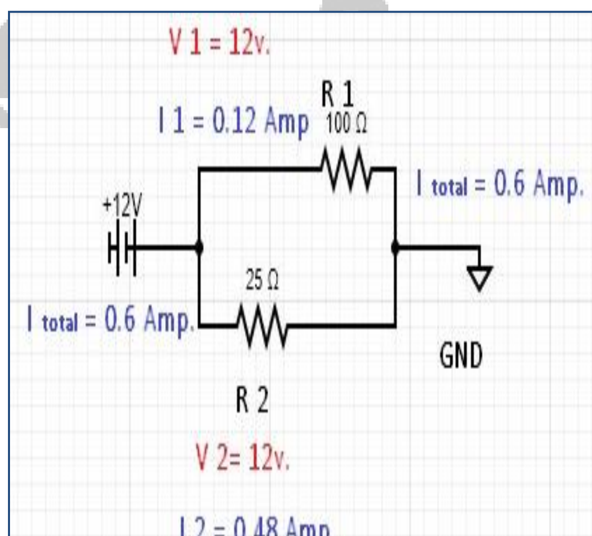
1.7- Parallel Circuits

(See basic electrical series on www.schrodingersboxQM.com for walkthrough)

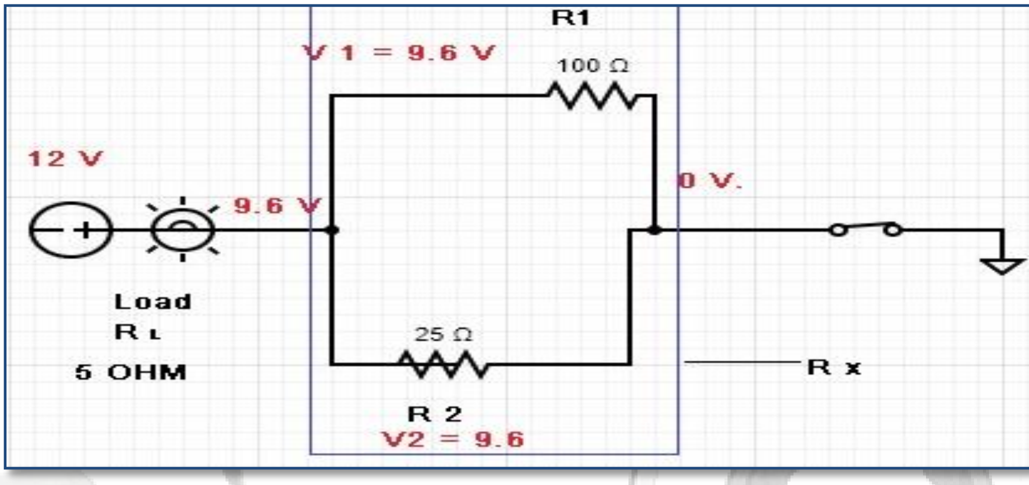
- TWO PARALLEL RESISTANCES CIRCUIT
- example 1
- R1=100Ω
- R2=100Ω
- Rt = Total resistance
- $Rt = \frac{R1 \times R2}{R1+R2}$
- $\text{Rt} = \frac{100 \times 100}{100+100} = 50\Omega$
- V = I × R
- $\text{It} = \frac{Vt}{Rt} = \frac{12}{50} = 0.24\ Amp.$
- $\text{I1} = \frac{V1}{R1} = \frac{12}{100} = 0.12\ Amp.$
- $\text{I2} = \frac{V2}{R2} = \frac{12}{100} = 0.12\ Amp.$



- example 2
- $Rt = \frac{R1 \times R2}{R1+R2}$
- $\text{Rt} = \frac{100 \times 25}{100+25} = 20\Omega$
- V = I × R
- $\text{It} = \frac{Vt}{Rt} = \frac{12}{20} = 0.6\ Amp.$
- $\text{I1} = \frac{V1}{R1} = \frac{12}{100} = 0.12\ Amp.$
- $\text{I2} = \frac{V2}{R2} = \frac{12}{25} = 0.48\ Amp.$



- **Example 3**



R_1= 100Ω

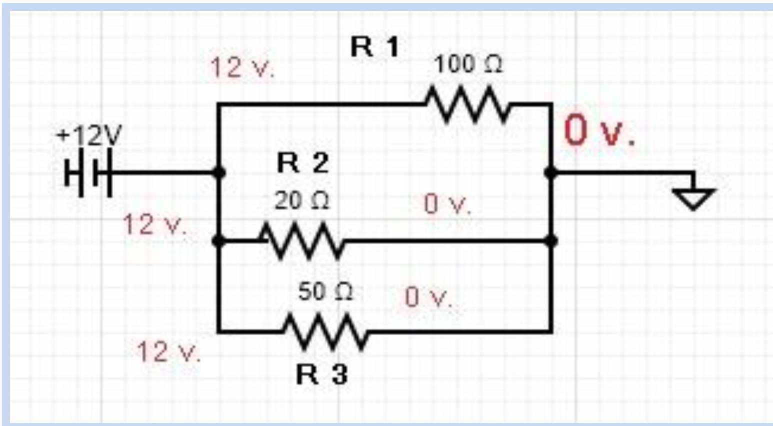
R_2= 25Ω

R_L=Resistance at load = 5Ω

Rx = Resistance at R1 & R2 circuit

- $Rx = \frac{R1 \times R2}{R1 + R2}$
- $\mathrm{Rx} = \frac{100 \times 25}{100+25} = 20\Omega$
- **Rt = R_L + R_X = 5+20=25Ω**
- $\mathrm{It} = \frac{Vt}{Rt} = \frac{12}{25} = 0.48\ Amp$
- **Voltage drop at load =I x R = 0.48 X 5 = 2.4 V.**
- $\mathrm{IL} = \frac{VL}{RL} = \frac{2.4}{5} = 0.48\ Amp$
- $\mathrm{I1} = \frac{V1}{R1} = \frac{9.6}{100} = 0.096\ Amp.$
- $\mathrm{I2} = \frac{V2}{R2} = \frac{9.6}{25} = 0.384\ Amp.$
- **Ix =I_1 + I_2 = 0.096 + 0.384 = 0.48 Amp**

- THREE PARALLEL RESISTANCES CIRCUIT



- $\frac{1}{Rt} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{?} \ldots \ldots ..$
- $\frac{1}{Rt} = \frac{1}{100} + \frac{1}{20} + \frac{1}{50} = 12.5\Omega$
- $I1 = \frac{V1}{R1} = \frac{12}{100} = 0.12\ Amp.$
- $I2 = \frac{V2}{R2} = \frac{12}{20} = 0.6\ Amp.$
- $I3 = \frac{V3}{R3} = \frac{12}{50} = 0.24\ Amp.$
- $It = \frac{Vt}{Rt} = \frac{12}{12.5} = 0.96\ Amp$

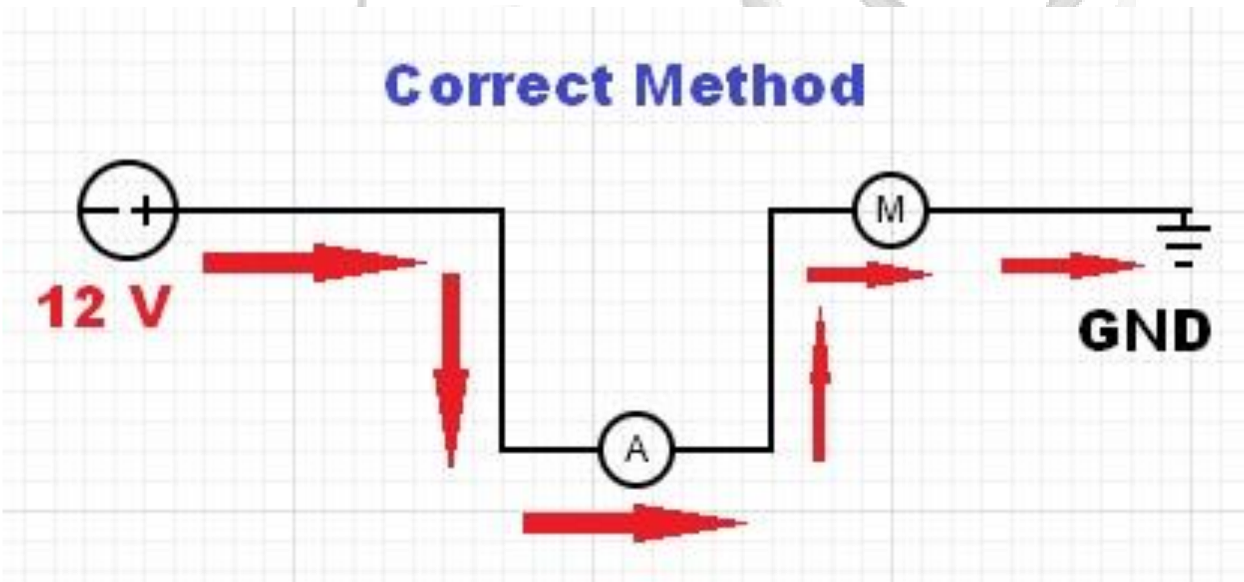
V = I R
$Rt = \frac{R1 \times R2}{R1 + R2}$
$\frac{1}{Rt} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{?} \ldots \ldots ..$

1.8 – How to measure current using a basic DVOM.

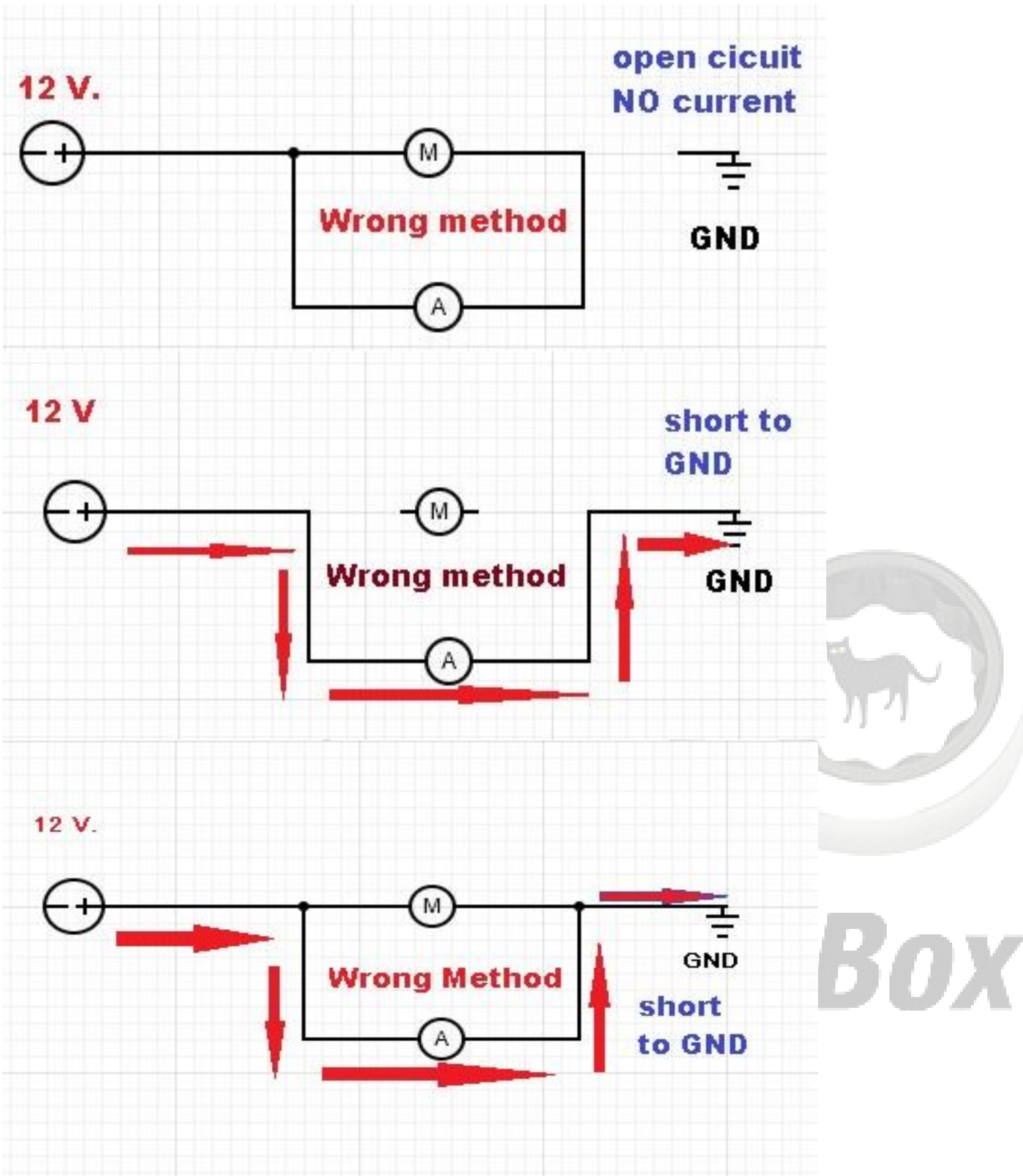
- **Attention :**

If you are not familiar with all basics for car electricity, don't try to measure current in this way because wrong methods can damage your PCM!! It works by creating a “jumper” wire between point without a load!!

- **Turn DVOM Meter to a suitable range of Amperage (green circle)**
- **Make sure to connect the probe in the specific position of measuring high amperage (red circle)**
- **After measuring don`t forgets you return the probe to the default position to be able to make other measurements correctly without any damage**



Here we have the Ammeter (A) correctly placed IN SERIES in the circuit. This can be done either before or after the load (M) because remember current flow is the same everywhere in the circuit, You could just as well connect between the (M) and the ground and get same result. “In Series” means you are “plugged into” EITHER the positive side OR the negative side ONLY! If you connect positive to negative you will have a short circuit!



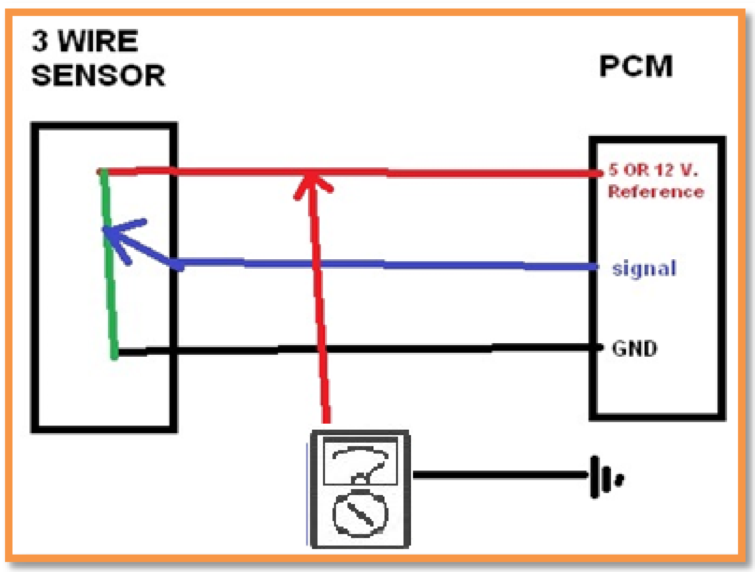
In the first wrong method we are trying to measure amperage on an open circuit. Reading will be zero because of no flow. The second and third diagrams are also wrong but also DANGEROUS!! We are basically "bypassing" the load with a jumper wire so we create a short circuit and can cause damage. Measuring VOLTAGE will not do this- but measuring AMPERAGE will!!!! This is also why its so important when measuring voltage to be certain your meter is not in amperage configuration!!!

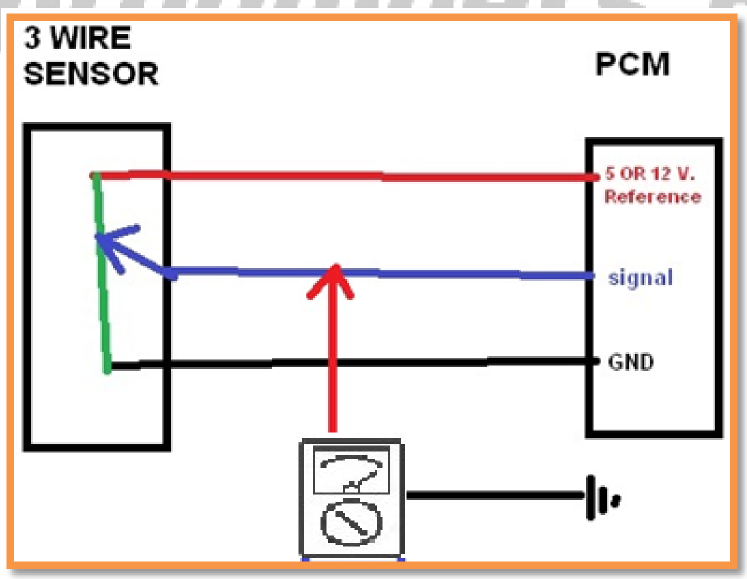
1.9- DIAGNOSIS PROBLEMS IN 3 WIRE SENSORS CIRCUIT

A -NORMAL CIRCUIT

Can be tested by checking the voltage

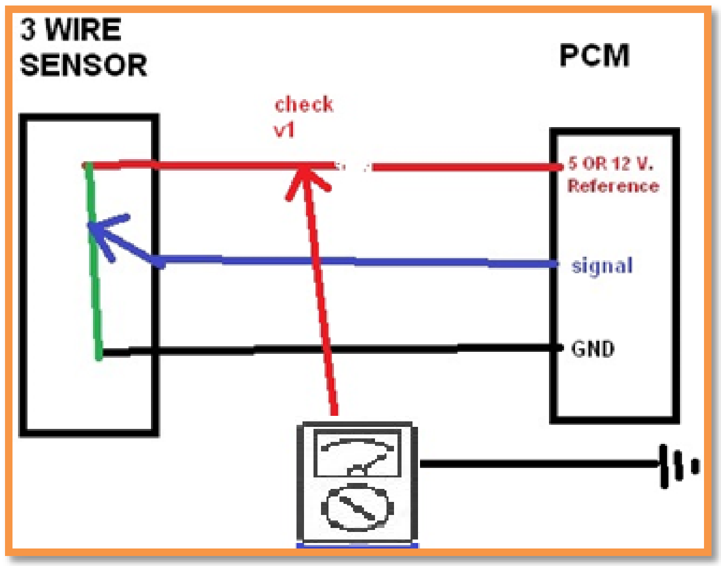
- At reference = 5 v.
- At signal = 0.5 to 5 v.

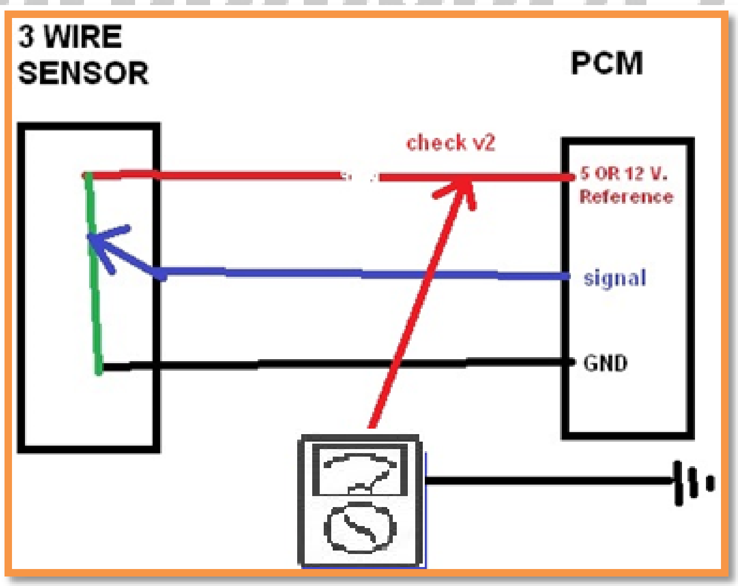




B – OPEN CIRCUIT

- Check connectivity at all sides
  Of connection wire from PCM
  to sensor
- Check voltage at 2 sides of reference = 5 v.
- Check voltage at 2 sides of signal v1 = v2

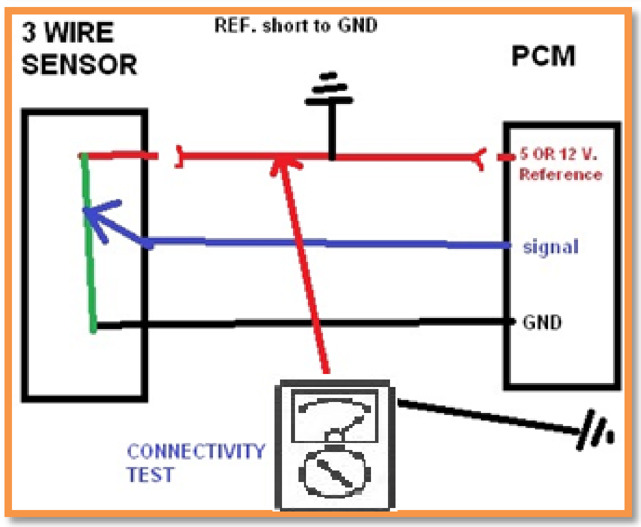


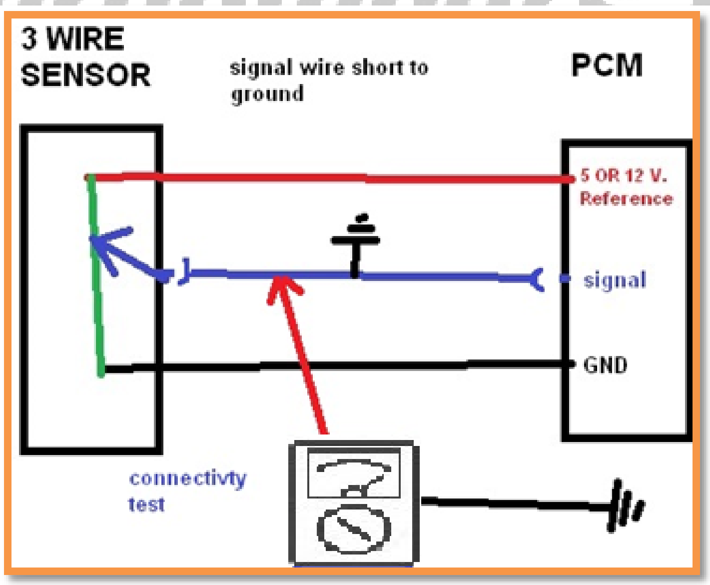


C – SHORT TO GROUND

- **METHOD 1 : disconnect sensor & PCM**
- **Check cable connectivity to the ground**
- **If = O.L is normal no short**
- **If = sound it`s short**

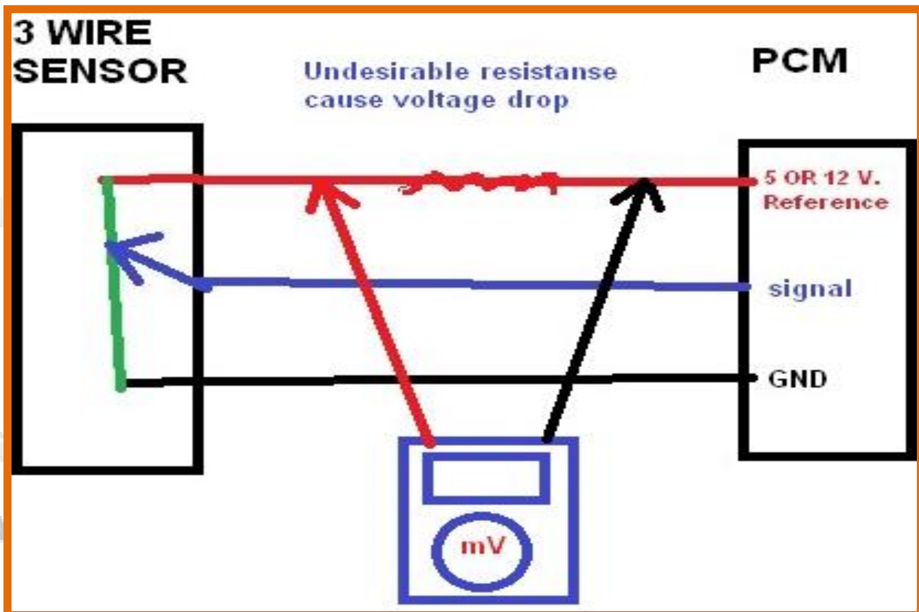
- **METHOD 2 : disconnect sensor & PCM**
- **Apply 12v. Test lamp to reference if the light on it`s a short**
- **Apply 12v. Test lamp to Signal if the light on it`s a short**

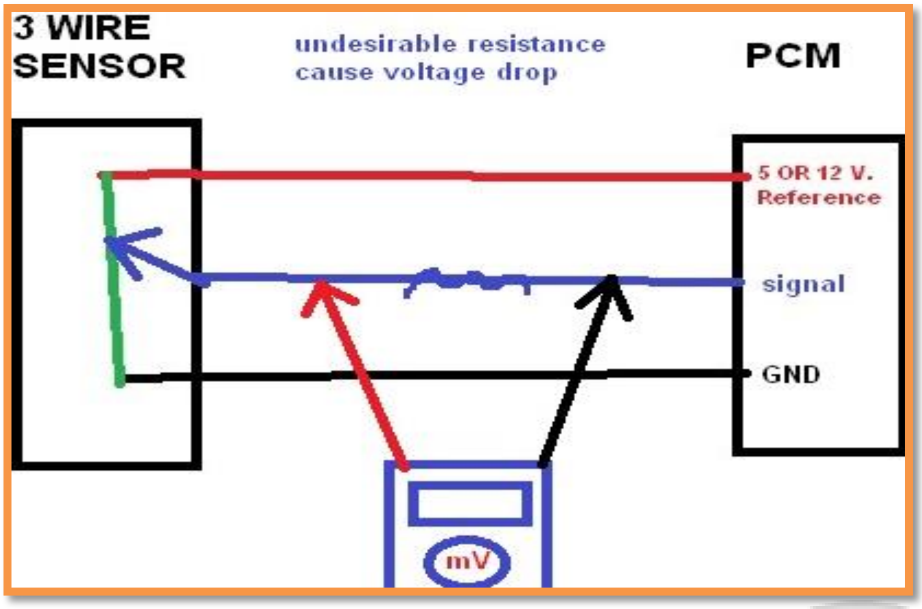


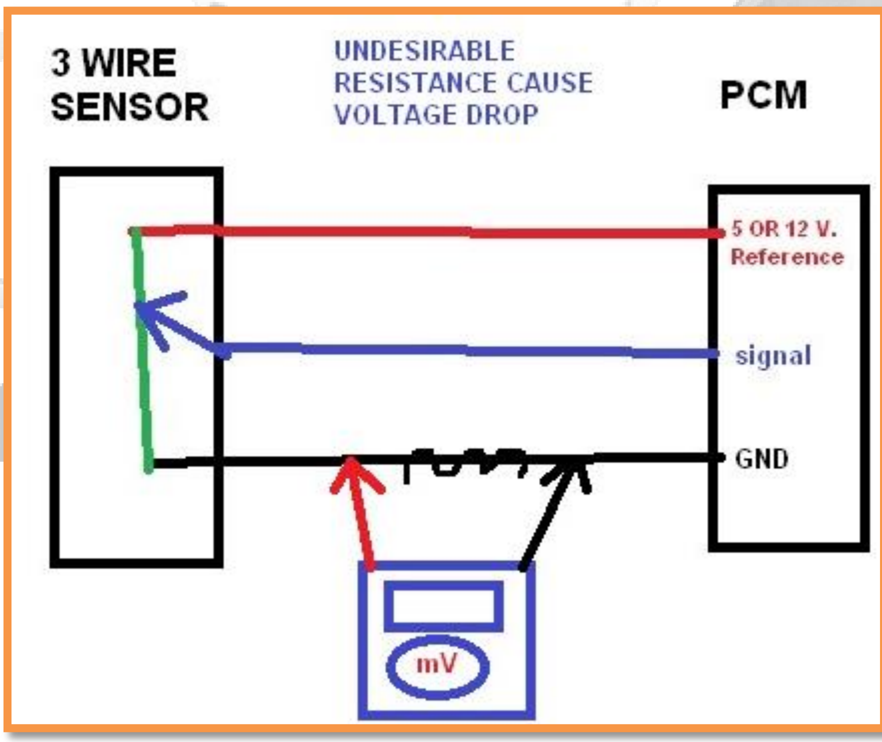


D - UNDESIRABLE RESISTANCE (VOLTAGE DROP)

- **1- Check voltage at both sides of the reference**
  IF V1 = V2 it`s normal NO VOLT. DROP
- **2- Check voltage at both sides of the signal**
  IF V1 = V2 it`s normal NO VOLT.DROP
- **3-Check Mille voltage at both sides of the ground cable**
  If voltage < 100 millivolt it`s normal NO Volt. DROP
  If voltage > 100 millivolt it`s volt. drop




3 WIRE
SENSOR
undesirable resistance
cause voltage drop
PCM
5 OR 12 V.
Reference
signal
GND
mV

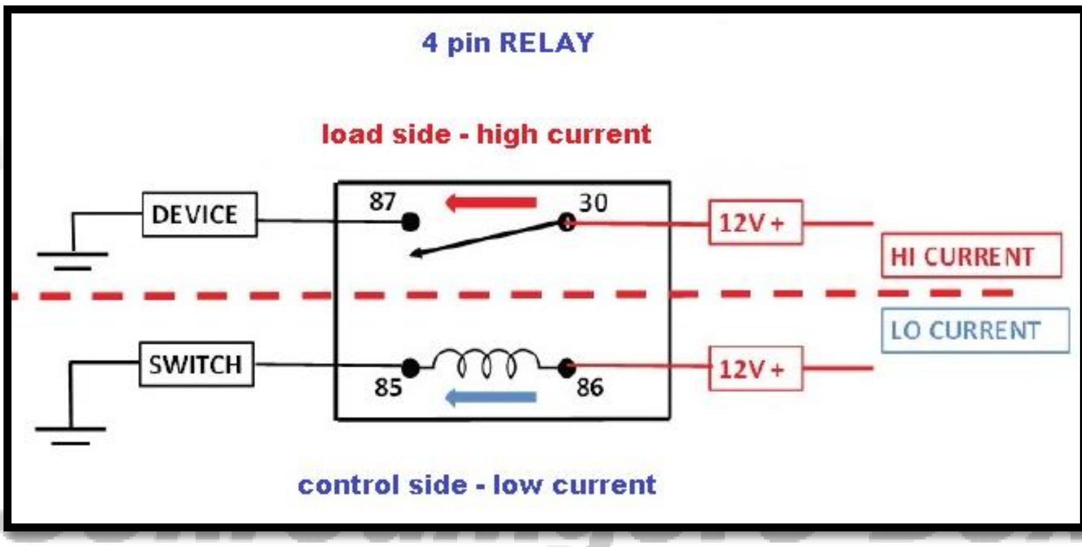

3 WIRE
SENSOR
UNDESIRABLE
RESISTANCE CAUSE
VOLTAGE DROP
PCM
5 OR 12 V.
Reference
signal
GND
mV

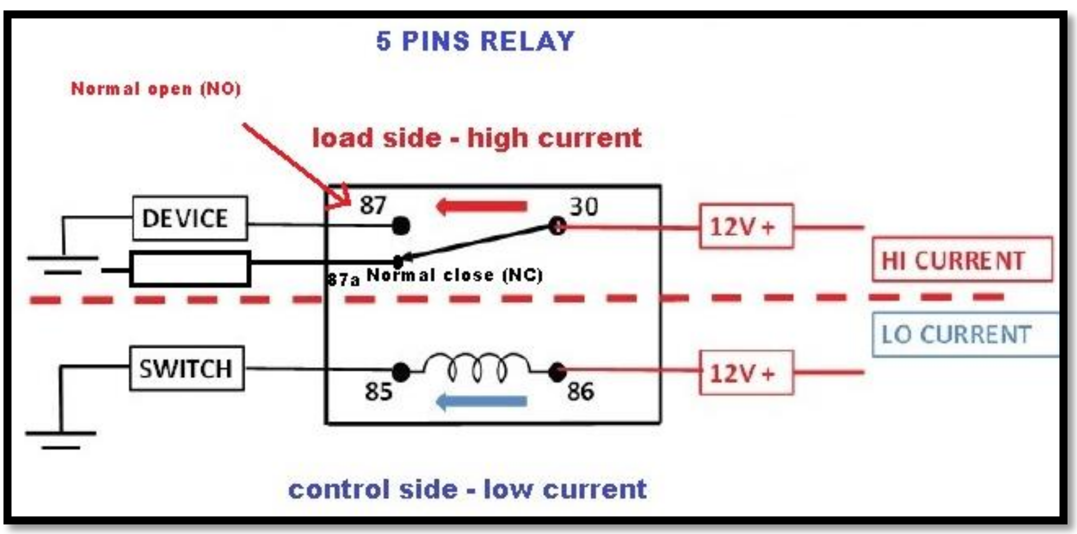
1.10- Relays

https://www.youtube.com/watch?v=Gg20X-FwGzg&t=28s&ab_channel=SchrodingersBox

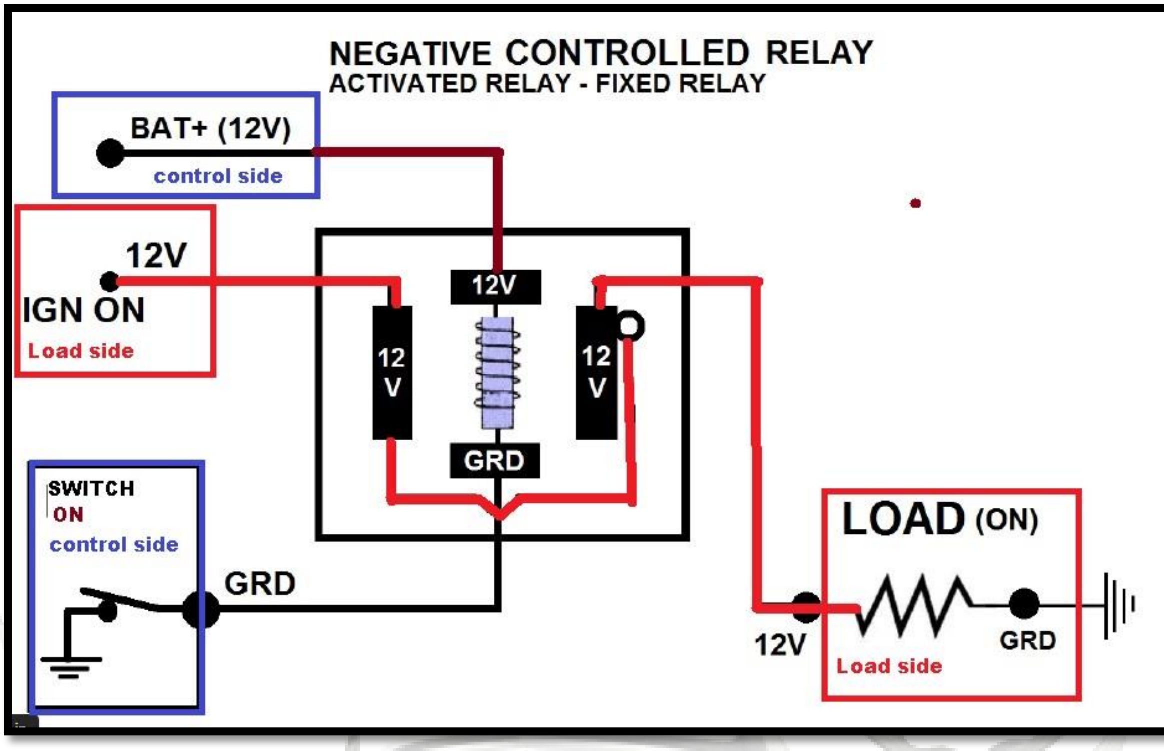
https://www.youtube.com/watch?v=fxGZIBNTFPE&t=3s&ab_channel=SchrodingersBox

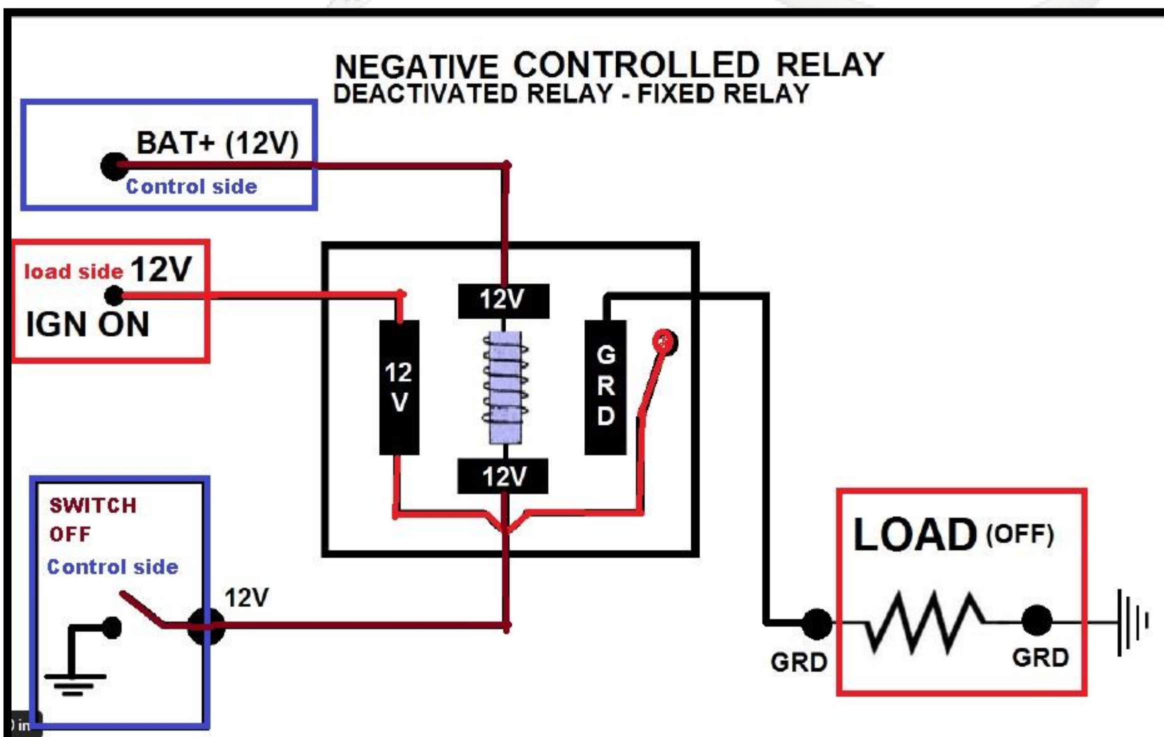
In a relay regardless of how many pins, there are essentially 2 sides- control and load. The idea is to allow a low current to be able to control a high current which is easier on a switch and also safer. The control side is the low voltage side that the operator controls with a switch- maybe a headlamp switch. This closes the control side circuit and operates a magnet inside the relay that magnetically pulls the high current switch to close and complete circuit to operate the load (headlamp device in this example). Additional pins basically put load to different parts of circuit.

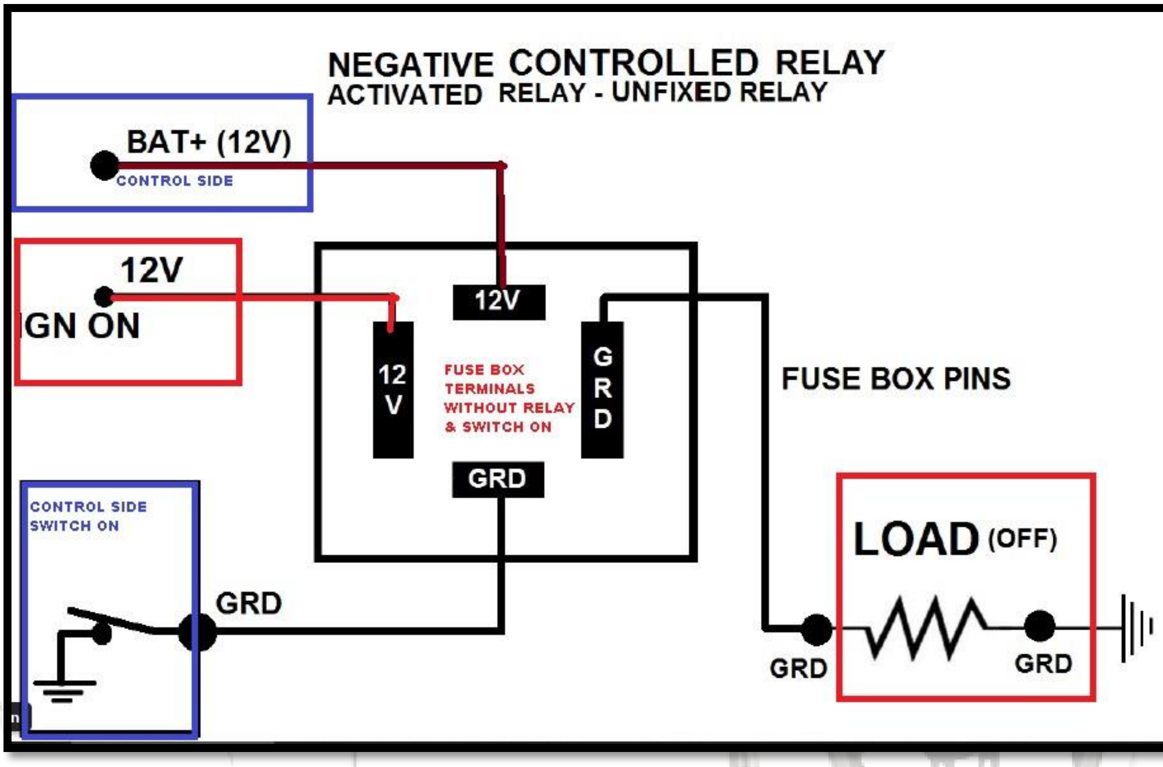


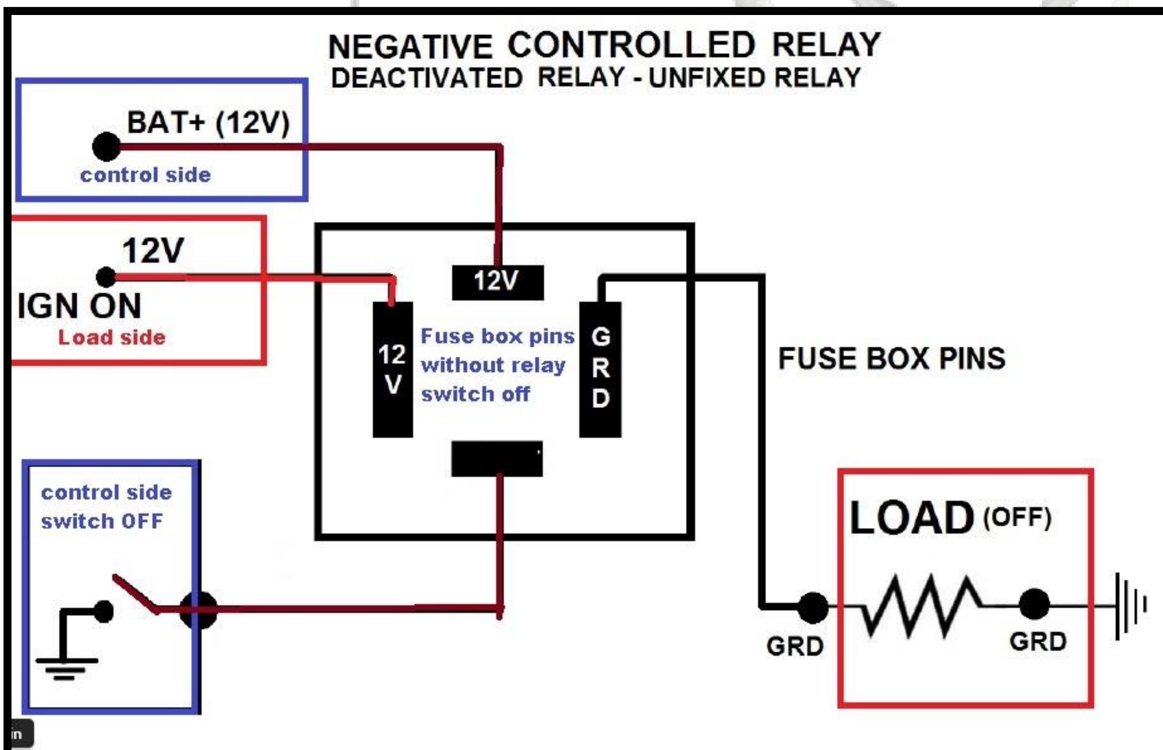


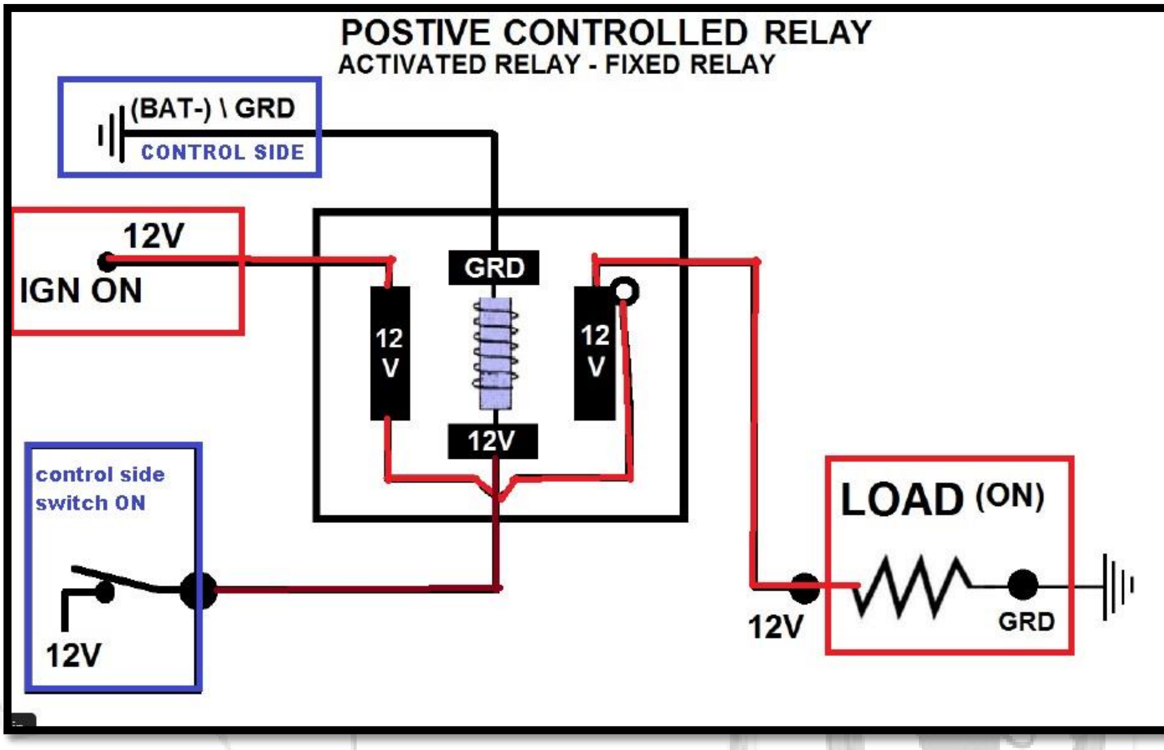
TESTING RELAYS

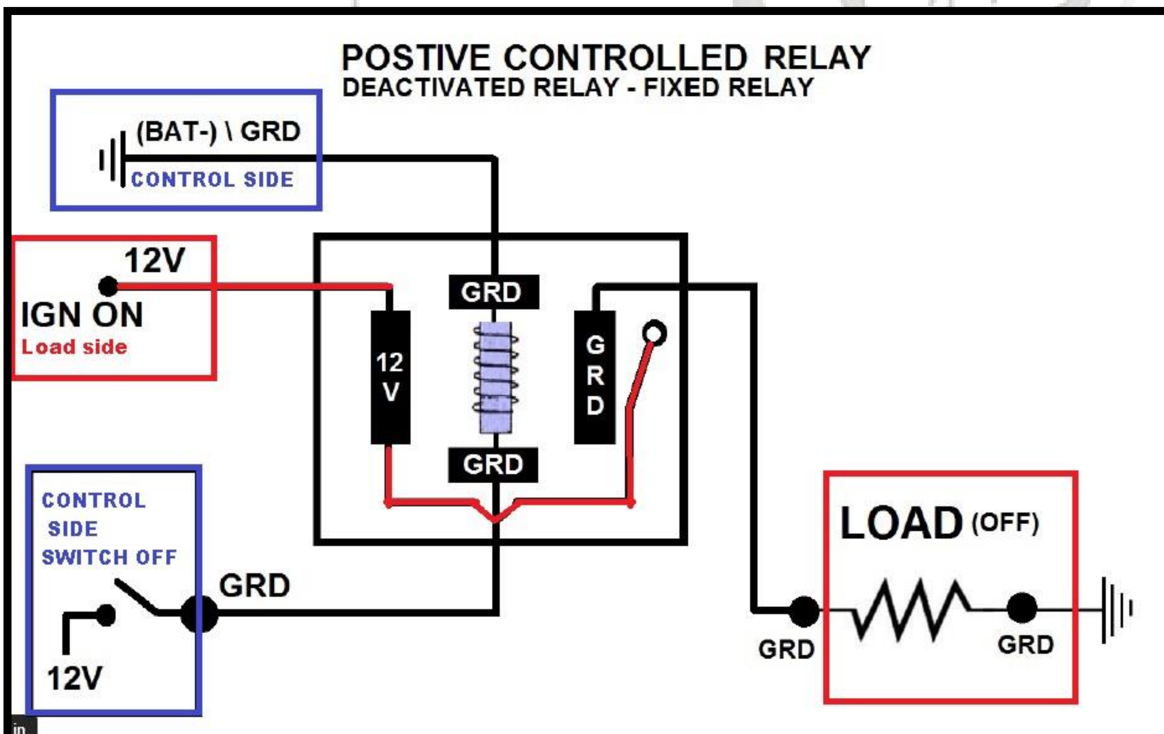


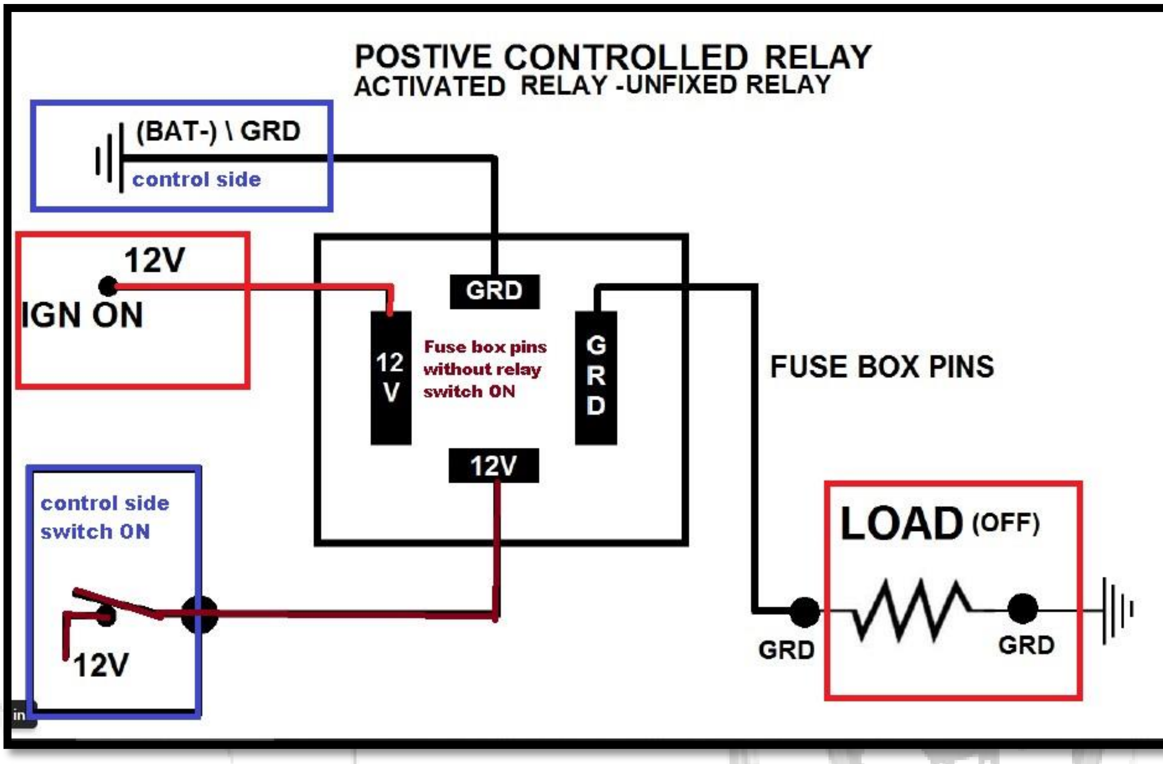


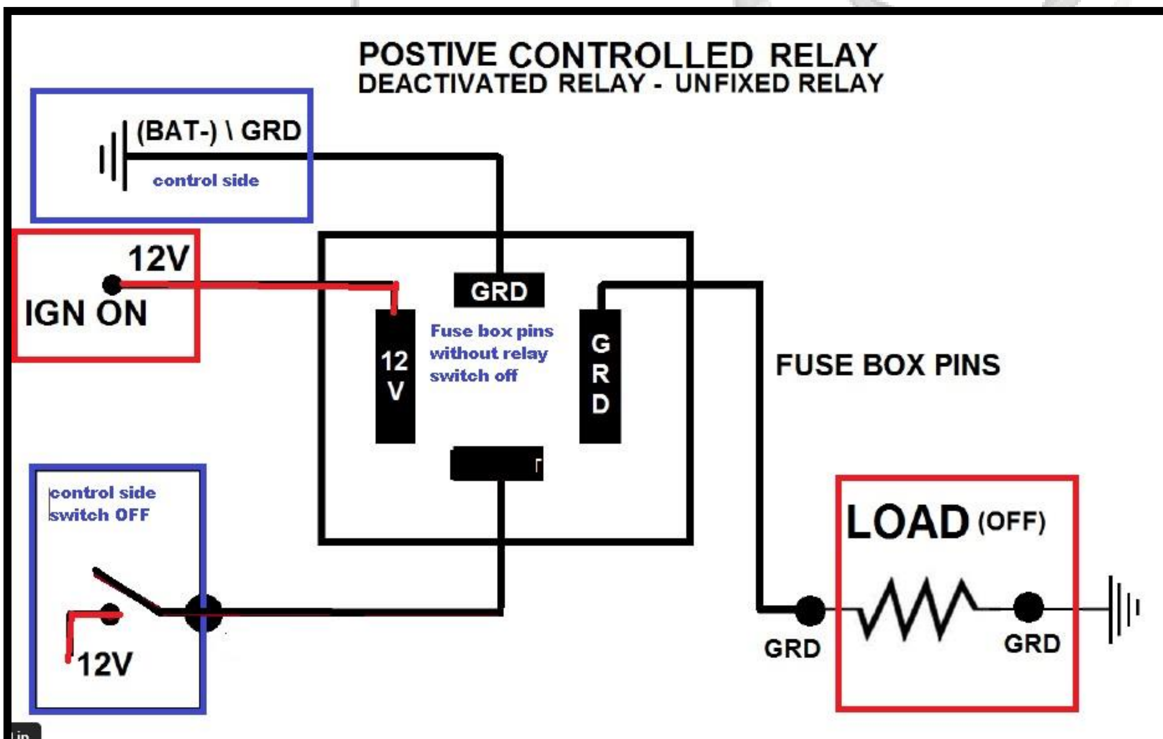

NEGATIVE CONTROLLED RELAY
ACTIVATED RELAY - UNFIXED RELAY
BAT+ (12V)
CONTROL SIDE
12V
IGN ON
12V
12 V
FUSE BOX TERMINALS WITHOUT RELAY & SWITCH ON
G R D
GRD
FUSE BOX PINS
CONTROL SIDE SWITCH ON
GRD
LOAD (OFF)
GRD
GRD


NEGATIVE CONTROLLED RELAY
DEACTIVATED RELAY - UNFIXED RELAY
BAT+ (12V)
control side
12V
IGN ON
Load side
12V
12 V
Fuse box pins without relay switch off
G R D
FUSE BOX PINS
control side switch OFF
LOAD (OFF)
GRD
GRD


POSTIVE CONTROLLED RELAY
ACTIVATED RELAY - FIXED RELAY
(BAT-) \ GRD
CONTROL SIDE
12V
IGN ON
GRD
12
V
12
V
12V
control side
switch ON
12V
LOAD (ON)
12V
GRD


POSTIVE CONTROLLED RELAY
DEACTIVATED RELAY - FIXED RELAY
(BAT-) \ GRD
CONTROL SIDE
12V
IGN ON
Load side
GRD
12
V
G
R
D
GRD
CONTROL
SIDE
SWITCH OFF
GRD
12V
LOAD (OFF)
GRD
GRD


POSTIVE CONTROLLED RELAY
ACTIVATED RELAY -UNFIXED RELAY
(BAT-) \ GRD
control side
12V
IGN ON
GRD
12 V
Fuse box pins without relay switch ON
G R D
12V
FUSE BOX PINS
control side switch ON
12V
LOAD (OFF)
GRD
GRD


POSTIVE CONTROLLED RELAY
DEACTIVATED RELAY - UNFIXED RELAY
(BAT-) \ GRD
control side
12V
IGN ON
GRD
12 V
Fuse box pins without relay switch off
G R D
FUSE BOX PINS
control side switch OFF
12V
LOAD (OFF)
GRD
GRD

1.11- Don`t blow your PCM

VIDEOS LINK

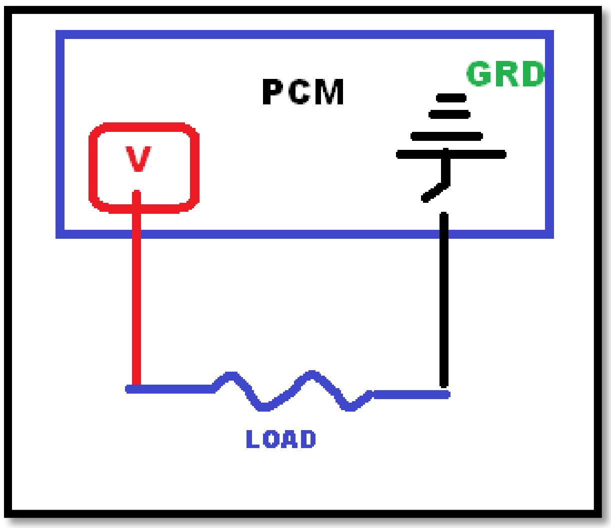
https://schrodingersboxqm.com/how-to-test-wires-at-the-pcm/

https://schrodingersboxqm.com/dont-blow-your-pcm-part-1/

https://schrodingersboxqm.com/dont-blow-your-pcm-part-2-2/

https://schrodingersboxqm.com/dont-blow-your-pcm-part-2/

https://schrodingersboxqm.com/dont-fry-your-pcm-final-exam/



LOAD

- SOLENOIDS
- LIGHTS
- RESISTORS
- COILS
- MOTORS

NOT LOADS

- SWITCHES
- FUSES
- JUMPER WIRES
- TRANSISTORS
- PCM

IMPORTANT RULES

RULE 1:

- Always needs to be a load in a circuit! If there is no load (no resistance) then you have a short circuit.

Rule 2 :

- DVOM in volts mode is almost always safe.
- Amp clamps are available for DVOM and are always safe

Rule 3 :

- DVOM continuity tests are almost always safe.
- It isn't safe if we exceed the amount of amperage that the circuit can tolerate.

Rule 4 :

- Led test lights are virtually fail-safe but incandescent ones should be used with caution. An incandescent test light draws 250mA. A LED test light draws only 50mA. If in doubt, use an LED. But Incandescent lights can be useful if you want to operate a circuit with low amperage.

Rule 5 :

- 5v. circuits are generally safe.
- 5v. circuits wires are thin wires
- Sensor signal wires can tolerate up to 5v.

Rule 6 :

- 12v. circuits are always orange flags.
-

Rule 7 :

- DVOM in amps mode should be used with extreme caution

It's potentially very dangerous to PCM since causing a short circuit on a PCM controlled switch (transistor) will likely blow it!!!

Rule 8

- Jumper wires are only used on the same side of a circuit (In Series) to bypass a switch or an open. Never jumper positive to negative without a load (such as test light)- ever!!!

Rule 9 :

- Never replace a bad PCM until you find out what caused it.

Rule 10

- If you are unsure of a design, research it first but even then you probably still won't be sure so if in doubt, best to not measure it.

SECTION 2

WIRING DIAGRAM TUTORIAL

VIDEOS LINK

https://schrodingersboxqm.com/wiring-diagram-tutorial-part-1/

https://schrodingersboxqm.com/wiring-diagram-tutorial-part-2/

https://schrodingersboxqm.com/wiring-diagram-tutorial-part-3/

https://schrodingersboxqm.com/wiring-diagram-tutorial-pt-4-case-study/

- Begin with the load you suspected then go back step by step
- Mostly power sources in the top and ground in the bottom
- You may find lines that go to the end of the page, on the next page you same lines with the numbering.
- Diagram always at rest state, all switches off except some devices are power all time like alarm system and clock
- The dotted box indicates that there are other components in this box that haven't appeared on this page.
- **Load devices must be controlled by a power source or by the ground.**
- **The most common PCM** controls **the ground of the relay, and then the relay controls load devices.**
- **Colors codes**

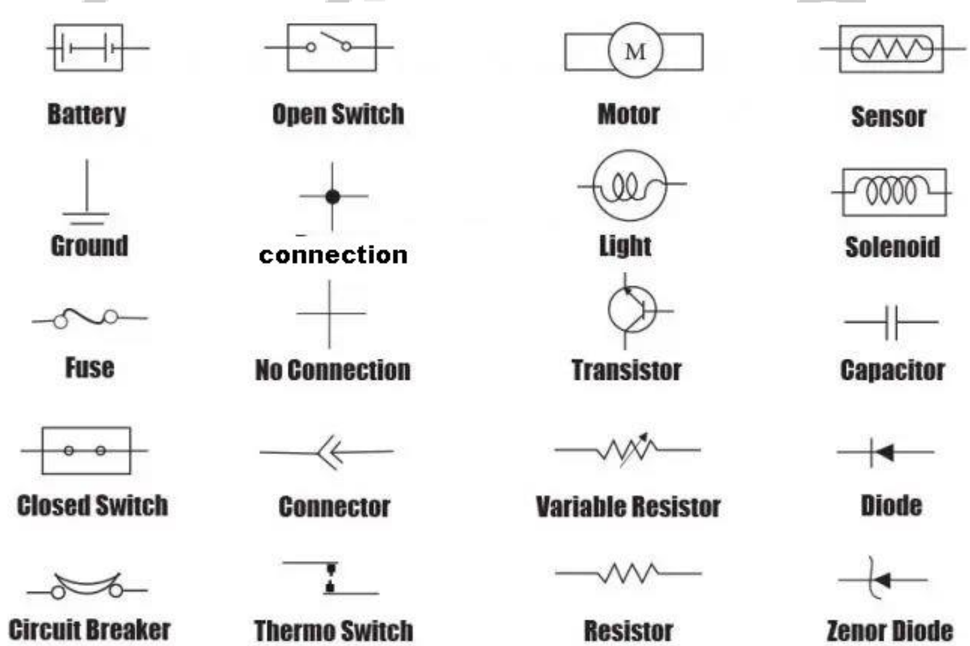
BLACK	BLK	BK	B	PINK	PNK	PK	K
BLUE	BLU	BU	U	PURPLE	PPL	PL	P
BROWN	BRN	BN	N	RED	RED	RD	R
CLEAR	CLR	CR	L	TAN	TAN	TN	-
DARK BLUE	DK BLU	DK BU	DB	VIOLET	VIO	VI	-
DARK GREEN	DK GRN	DK GN	DG	WHITE	WHT	WT	W
GREEN	GRN	GN	G	YELLOW	YEL	YL	Y
GRAY	GRY	GY	S	GROUND	GND	GN	G
LIGHT BLUE	LT BLUE	LT BU	-	CONNECTOR			C
LIGHT GREEN	LT GRN	LT GN	-	REFERENCE	REF		
ORANGE	ORG	OG	O	SKY BLUE		SB	

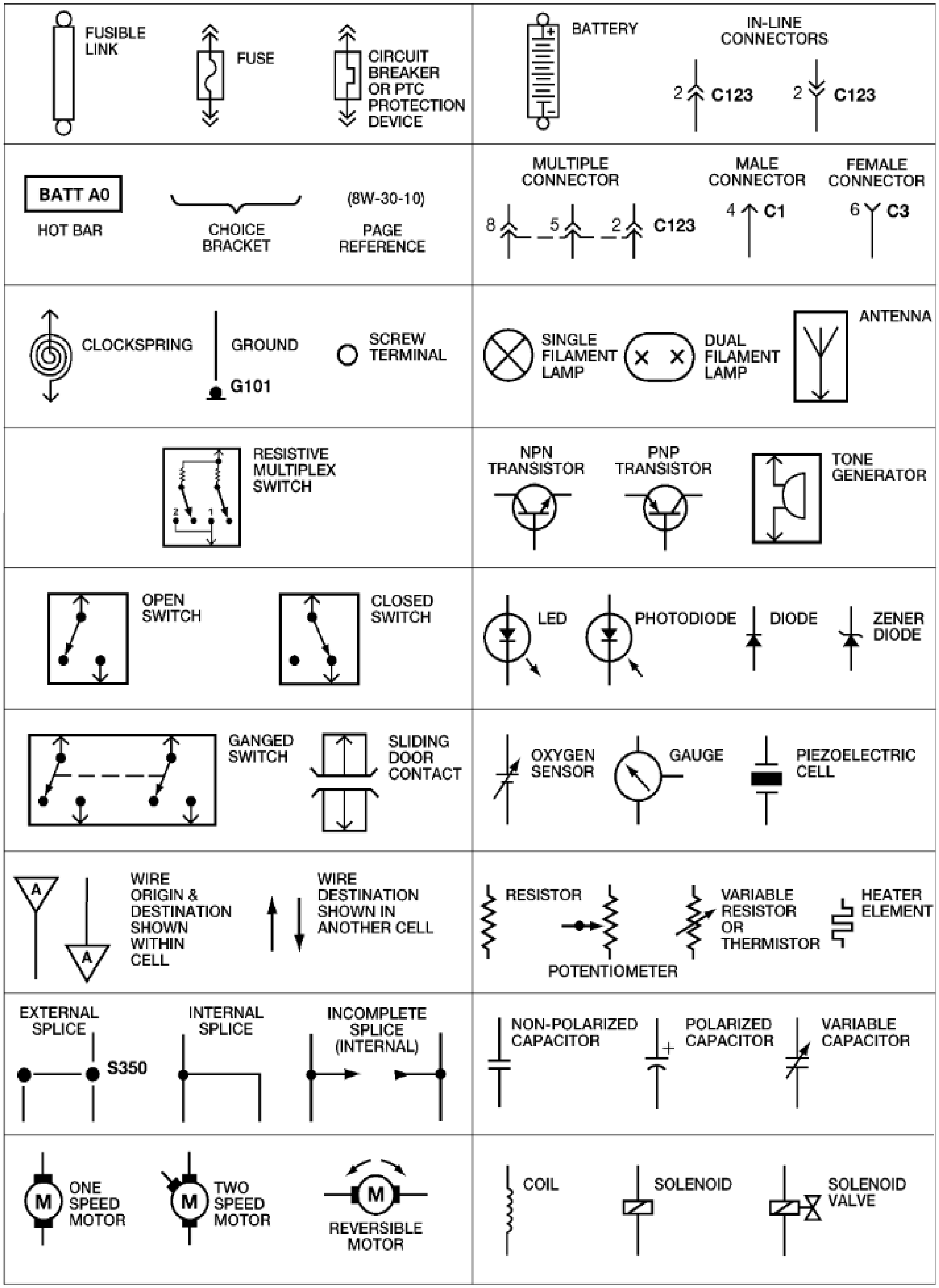
BLUE / BLACK	L/B	YELLOW / GREEN	Y/G
RED / WHITE	R/W	BLACK / WHITE	B/W
RED / YELLOW	R/Y	WHITE / GREEN	W/G
BLUE / YELLOW	L/Y	WHITE / RED	W/R
BLUE / GREEN	L/G	GREEN / YELLOW	G/Y
BLUE / WHITE	L/W	YELLOW / RED	Y/R
BROWN / WHITE	BR/W	YELLOW / BLACK	Y/B

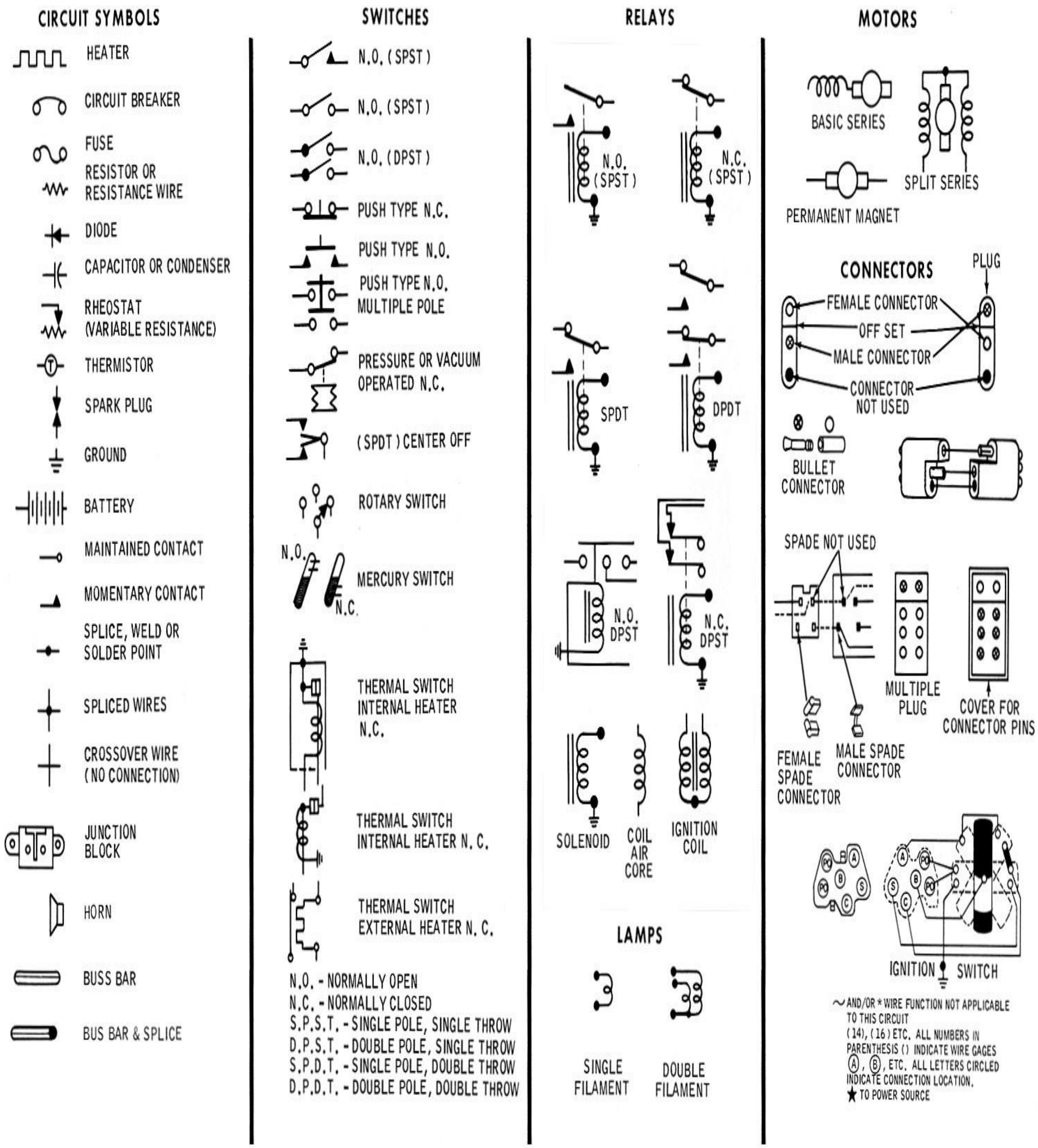
- Ground locations codes

G 1 - -	FRONT CAR	G 7 - -	LEFT REAR DOOR
G 2 - -	INSTRUMENTAL PANEL	G 8 - -	RIGHT REAR DOOR
G 3 - -	PASSENGER SIDE	G 9 - -	ROOF
G 3 - -	B CENTER PILLAR	G 9 - -	A FRONT PILLAR
G 4 - -	REAR CAR	G 9 - -	C REAR PILLAR
G 5 - -	LEFT FRONT DOOR		
G 6 - -	RIGHT FRONT DOOR		

- **Symbols**




FUSIBLE LINK
FUSE
CIRCUIT BREAKER OR PTC PROTECTION DEVICE
BATTERY
IN-LINE CONNECTORS
2 C123
2 C123
BATT A0
HOT BAR
CHOICE BRACKET
(8W-30-10)
PAGE REFERENCE
MULTIPLE CONNECTOR
8 5 2 C123
MALE CONNECTOR
4 C1
FEMALE CONNECTOR
6 C3
CLOCKSPRING
GROUND
G101
SCREW TERMINAL
SINGLE FILAMENT LAMP
DUAL FILAMENT LAMP
ANTENNA
RESISTIVE MULTIPLEX SWITCH
NPN TRANSISTOR
PNP TRANSISTOR
TONE GENERATOR
OPEN SWITCH
CLOSED SWITCH
LED
PHOTODIODE
DIODE
ZENER DIODE
GANGED SWITCH
SLIDING DOOR CONTACT
OXYGEN SENSOR
GAUGE
PIEZOELECTRIC CELL
A
A
WIRE ORIGIN & DESTINATION SHOWN WITHIN CELL
WIRE DESTINATION SHOWN IN ANOTHER CELL
RESISTOR
POTENTIOMETER
VARIABLE RESISTOR OR THERMISTOR
HEATER ELEMENT
EXTERNAL SPLICE
S350
INTERNAL SPLICE
INCOMPLETE SPLICE (INTERNAL)
NON-POLARIZED CAPACITOR
POLARIZED CAPACITOR
VARIABLE CAPACITOR
M
ONE SPEED MOTOR
M
TWO SPEED MOTOR
M
REVERSIBLE MOTOR
COIL
SOLENOID
SOLENOID VALVE


CIRCUIT SYMBOLS
HEATER
CIRCUIT BREAKER
FUSE
RESISTOR OR RESISTANCE WIRE
DIODE
CAPACITOR OR CONDENSER
RHEOSTAT (VARIABLE RESISTANCE)
THERMISTOR
SPARK PLUG
GROUND
BATTERY
MAINTAINED CONTACT
MOMENTARY CONTACT
SPLICE, WELD OR SOLDER POINT
SPLICED WIRES
CROSSOVER WIRE (NO CONNECTION)
JUNCTION BLOCK
HORN
BUSS BAR
BUS BAR & SPLICE
SWITCHES
N.O. (SPST)
N.O. (SPST)
N.O. (DPST)
PUSH TYPE N.C.
PUSH TYPE N.O.
PUSH TYPE N.O. MULTIPLE POLE
PRESSURE OR VACUUM OPERATED N.C.
(SPDT) CENTER OFF
ROTARY SWITCH
N.O.
N.C.
MERCURY SWITCH
THERMAL SWITCH INTERNAL HEATER N.C.
THERMAL SWITCH INTERNAL HEATER N. C.
THERMAL SWITCH EXTERNAL HEATER N. C.
N.O. - NORMALLY OPEN
N.C. - NORMALLY CLOSED
S.P.S.T. - SINGLE POLE, SINGLE THROW
D.P.S.T. - DOUBLE POLE, SINGLE THROW
S.P.D.T. - SINGLE POLE, DOUBLE THROW
D.P.D.T. - DOUBLE POLE, DOUBLE THROW
RELAYS
N.O. (SPST)
N.C. (SPST)
SPDT
DPDT
N.O. DPST
N.C. DPST
SOLENOID
COIL AIR CORE
IGNITION COIL
LAMPS
SINGLE FILAMENT
DOUBLE FILAMENT
MOTORS
BASIC SERIES
SPLIT SERIES
PERMANENT MAGNET
CONNECTORS
PLUG
FEMALE CONNECTOR
OFF SET
MALE CONNECTOR
CONNECTOR NOT USED
BULLET CONNECTOR
SPADE NOT USED
MULTIPLE PLUG
COVER FOR CONNECTOR PINS
FEMALE SPADE CONNECTOR
MALE SPADE CONNECTOR
IGNITION
SWITCH
~ AND/OR * WIRE FUNCTION NOT APPLICABLE TO THIS CIRCUIT
(14), (16) ETC. ALL NUMBERS IN PARENTHESIS () INDICATE WIRE GAGES
Ⓐ, Ⓑ, ETC. ALL LETTERS CIRCLED INDICATE CONNECTION LOCATION.
★ TO POWER SOURCE

SECTION 3

ENGINE SENSORS

3.1- Mass air flow sensor (MAF)

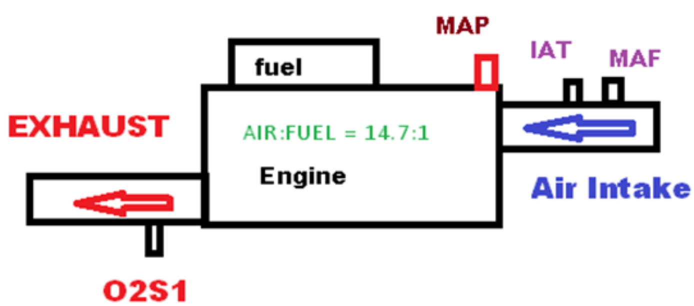
VIDEOS LINK

https://www.youtube.com/watch?v=MHsfAXog-FI&t=14s

https://www.youtube.com/watch?v=zxMxPH5jQmw&t=13s

Detect the amount of air entering the engine by Measuring air Flow (gram/second)

- Idle = 2 to 7 g/s
- RPM 2500 = 15 to 25 g/s
- Most models have IAT (Intake air temp sensor) integrated within.



- **PCM controls the temperature of the wire by holding the wire at a constant temperature above ambient temperature.**
- **More air enters leads to a decreased temperature of the wire**
- **PCM detects changes in current to measure airflow**

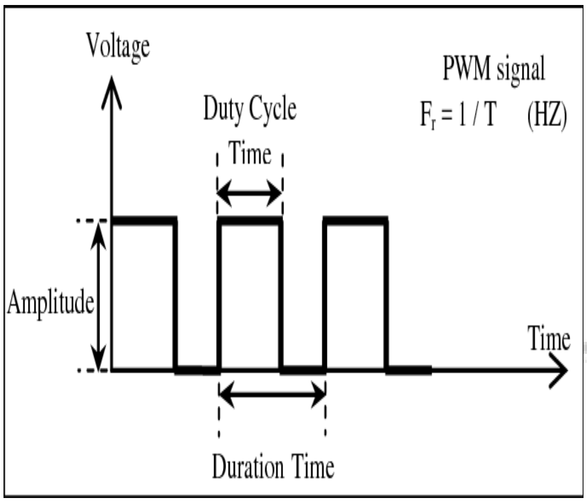
- **Hotwire MAF sensors have two types :**

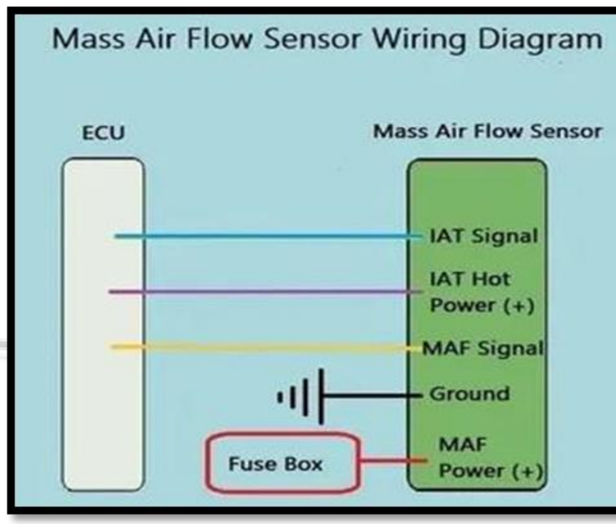
1- **Analogue** = 0 v. To 5 v.

Air ↑ → voltage ↑ WOT = 5 V.

2- **Digital** = 2000 Hz to 6000 Hz

- **Measure frequency of change in Volt. from 0 to 5 V (Duty cycle time)**





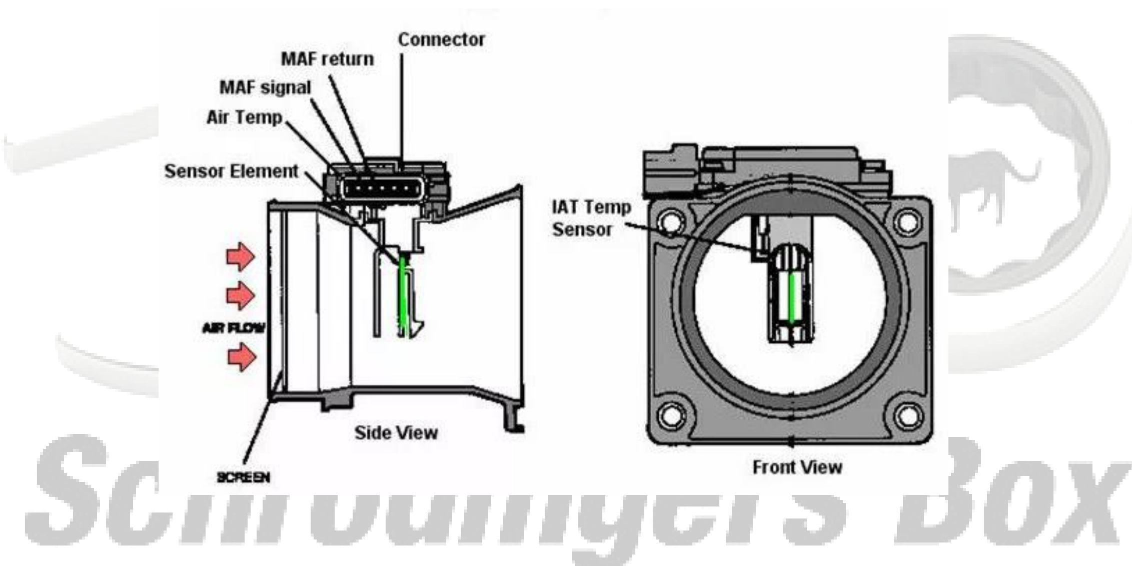
COMMON MAF SENSOR FAULT CODES

- **MAF circuit malfunction: P0100**
- **MAF circuit range/performance: P0101**
- **MAF circuit low input: P0102**
- **MAF circuit high input: P0103**
- **MAF circuit intermittent P0104**
- **MAF sensor a faulty or contaminated: P0171**

3.2- Intake Air Temp Sensor (IAT)

- Video link https://www.youtube.com/watch?v=1pOGSCsU-T8

- Can be tested on the bench by applying heat and measuring the change in resistance As temp increased Resistance decreased
- Can test signal wire for Voltage from 0v. To 5v.
- Temperature ↑→ R↓ → V ↑
- Some models have MAF integrated within
- 3 WIRE SENSOR



COMMON IAT SENSOR FAULT CODES

- **P0110 Intake Air Temperature Circuit Malfunction Bank 1**
- **P0111 Intake Air Temperature Circuit Range/Performance Problem Bank 1**
- **P0112 Intake Air Temperature Circuit Low Input Bank 1**
- **P0113 Intake Air Temperature Circuit High Input Bank 1**
- **P0114 Intake Air Temperature Circuit Intermittent Bank 1**

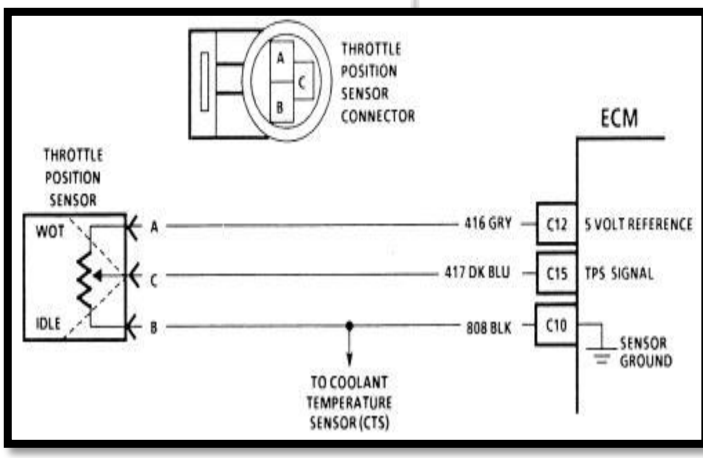
3.3- Throttle Position Sensor (TPS)

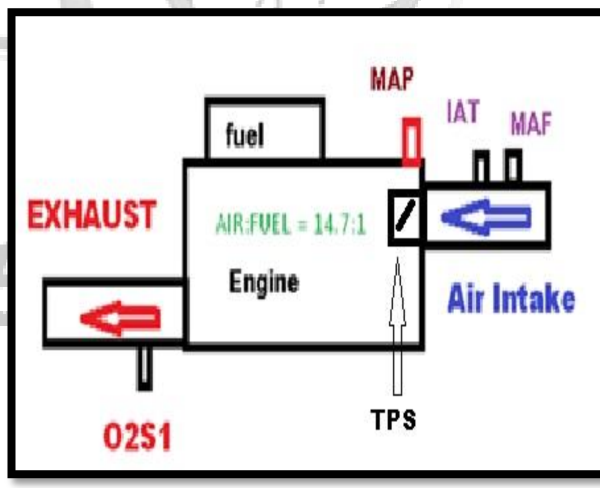
VIDEOS LINK

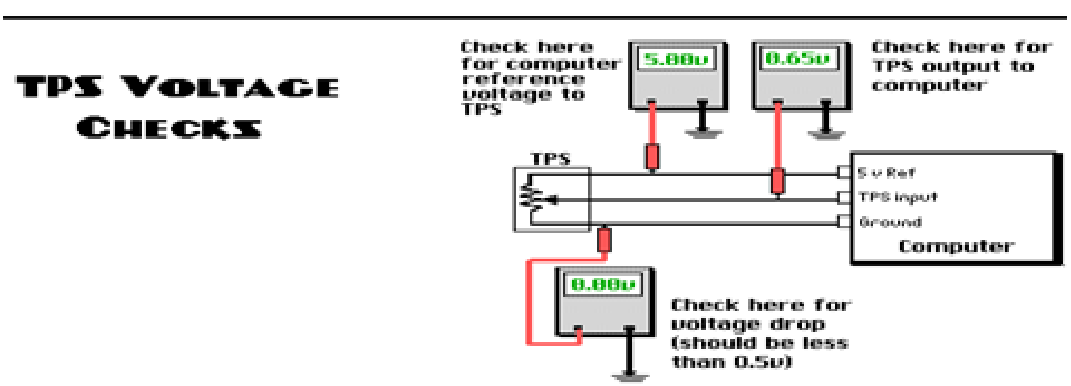
https://www.youtube.com/watch?v=FJobCD6y8fk&t=14s

https://www.youtube.com/watch?v=wP1CF4p8FGs

- **Used to monitor the air intake of an engine. The sensor is usually located on the butterfly spindle/shaft so that it can directly monitor the position of the throttle.**
- **Measures angle of the throttle shaft**
- **More openness leads to more Air leads to more volt.**
- **Can be tested on the bench by rotating it and measuring the change in resistance between signal & 5v. Reference wire**
- **Can test signal wire Voltage from 0.5v to 4.5v**



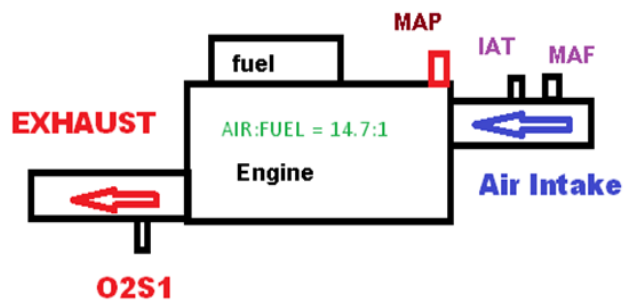




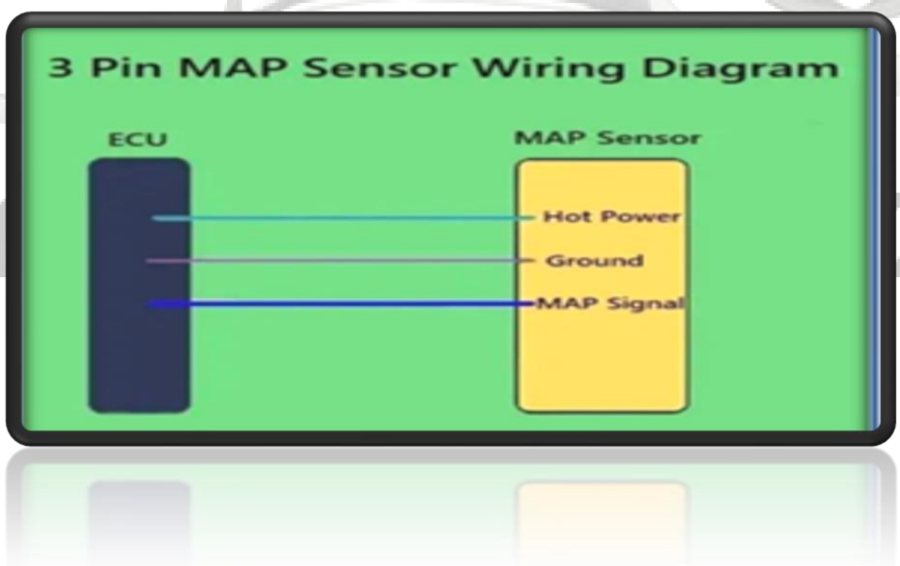
3.4- Manifold Absolute Pressure Sensor (MAP)

VIDEOS LINK

https://www.youtube.com/watch?v=xutynSVO0xI
https://www.youtube.com/watch?v=mL0B-I6WP6s

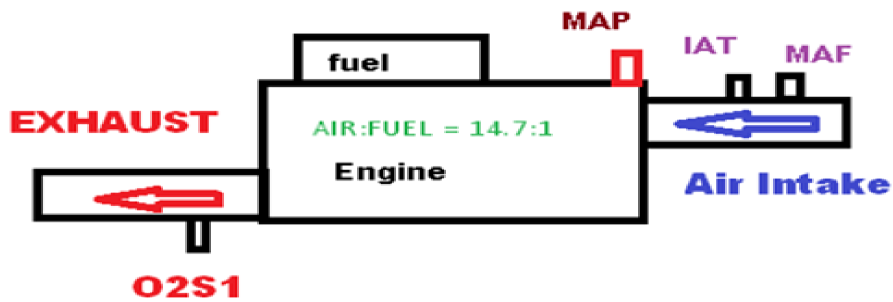


- Measures manifold intake air pressure
- Range from 1 v to 5 v
- Idle = 1.5 v
- Increasing **RPM** leads to increasing **Air intake** so increases **volt** reading

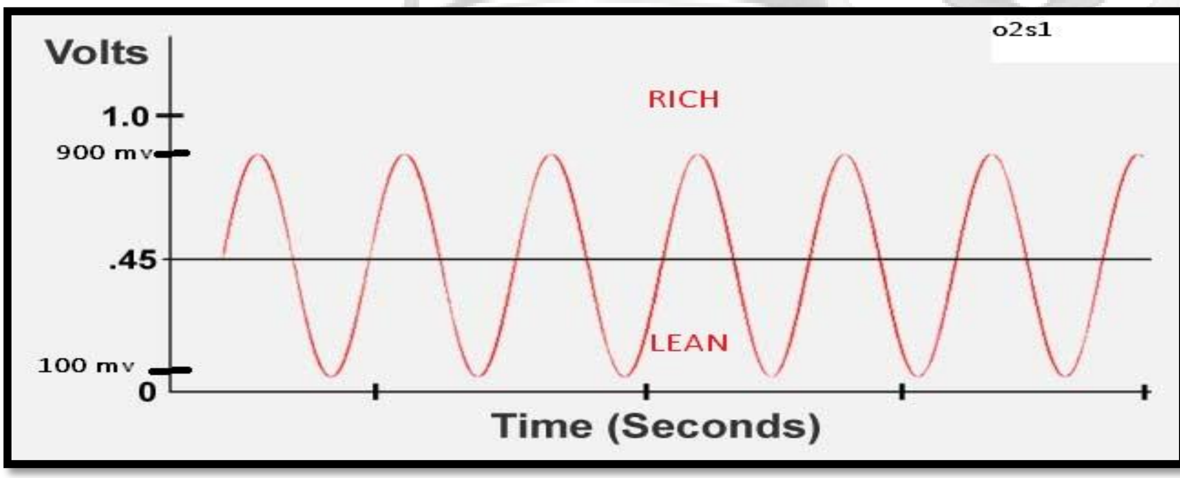


3.5- Oxygen up Stream Sensor (O2S1)

Videos link
https://www.youtube.com/watch?v=XQYDwIWS6Ho
https://www.youtube.com/watch?v=K8GLH6ubXoc



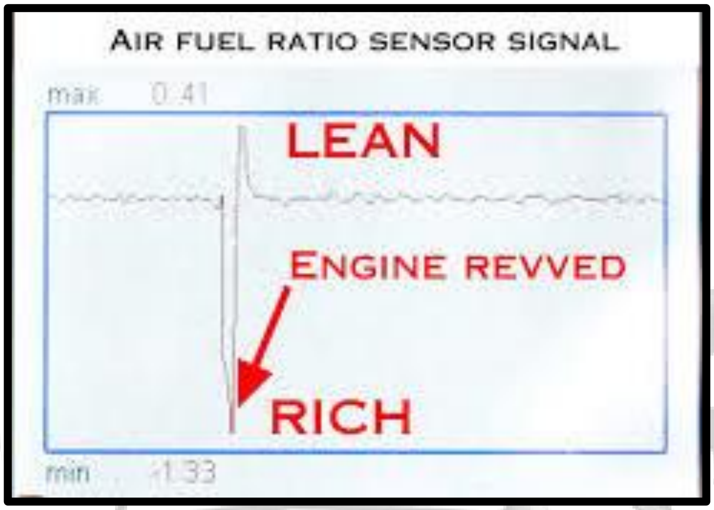
- **Detect oxygen & hydrocarbons in exhaust then send a voltage signal to PCM for control STFT & LTFT % to control AIR FUEL RATIO**
- **SIGNAL from 0.1 volt to 0.9 volt**

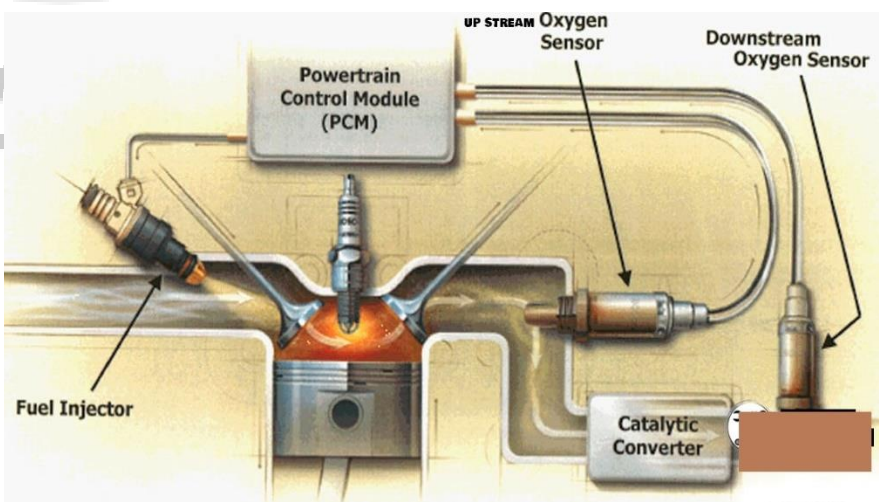


- **PCM oscillates reading from o2s1 between 100mv. and 900mv. give waveform reading**
- **If the engine is at a stoichiometric ratio it must be oscillating between100mv. & 900mv**
- **Above 450 mv. It is a rich condition**
- **Below 450mv. It is a lean condition**

3.6- Air fuel ratio sensor (A/F SENSOR)

- **Detect Air: Fuel ratio in exhaust then send current (Amperage) signal to PCM for control LTFT &STFT**
- **Signal from -1.33 (mA) To + 0.41 (mA)**





3.7- Knock Sensor (KS)

Videos link

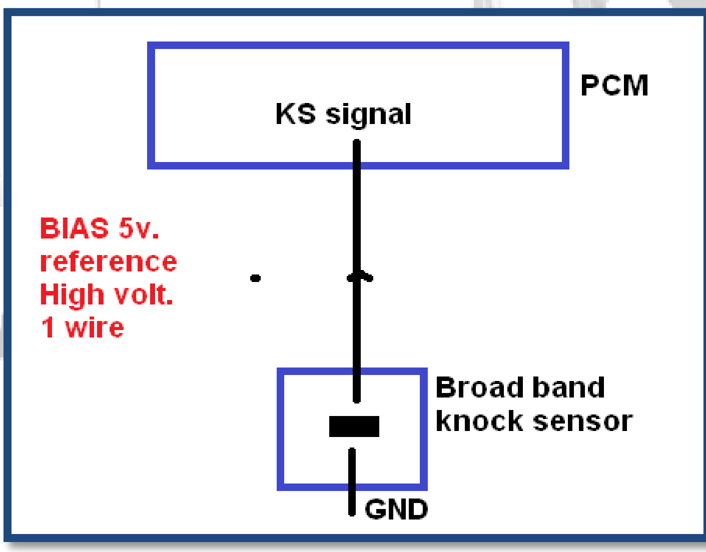
https://schrodingersboxqm.com/knock-sensors-diagnosis-and-understanding-part-1/

https://schrodingersboxqm.com/knock-sensors-diagnosis-and-understanding-part-2/

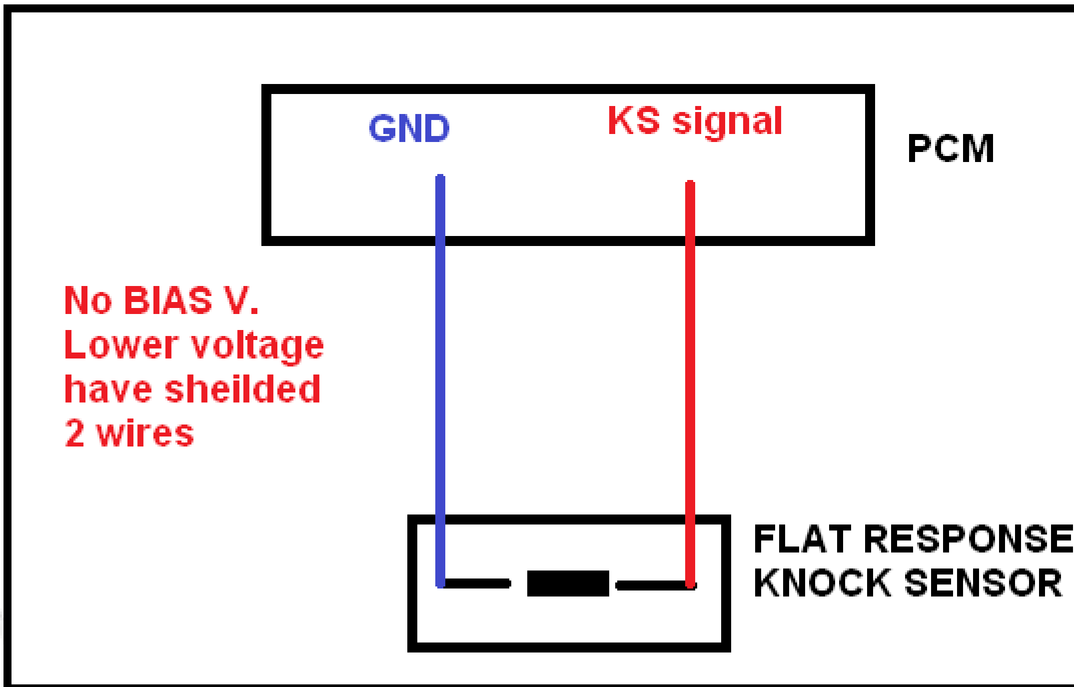
- **"Knocking" occurs when the air-fuel mixture self-ignites prematurely. Sustained knocking causes damage primarily to the cylinder head gasket and cylinder head.**
- **The knock sensor identifies the high-frequency engine vibrations characteristic of knocking and transmits a signal to the PCM**
- **PCM controls ignition timing till knock disappeared**

• Types of Knock Sensor

1. Broadband



2 – Flat response



3.8 – Engine coolant temperature sensor (CTS) (ECT)

Videos link

https://schrodingersboxgm.com/diagnosis-and-understanding-coolant-temp-sensor-part-1/

https://schrodingersboxgm.com/diagnosis-and-understanding-coolant-temp-sensor-part-2/

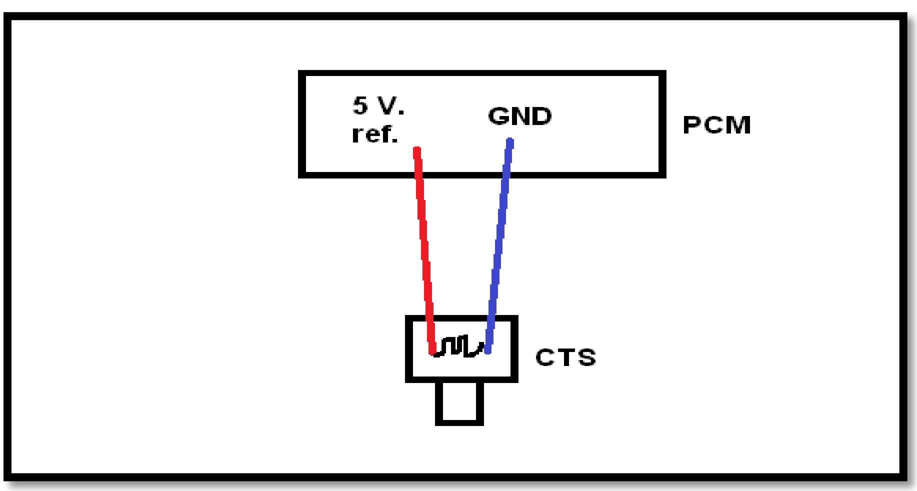
- **FUNCTION :**

1. **Reports engine temperature to PCM**
2. **Fan control**
3. **Temperature gauge**
4. **Important for Sparke to advance control**
5. **Important for Secondary Air Injection System (open\closed loop status)**

- **FAILURE SYMPTOMS :**

1. **Irrational fan control (over cooling \ heating)**
2. **Failure to enter closed loop.**
3. **Poor fuel economy (rich)**
4. **DTC**
5. **Inaccurate temperature gauge reading**

- **PCM detects voltage drop in a circuit to calculate the temperature**
- **Thermistors work by negative temperature coefficient**
- **When Temp. increased, the resistance decreased led to voltage drop decreased**

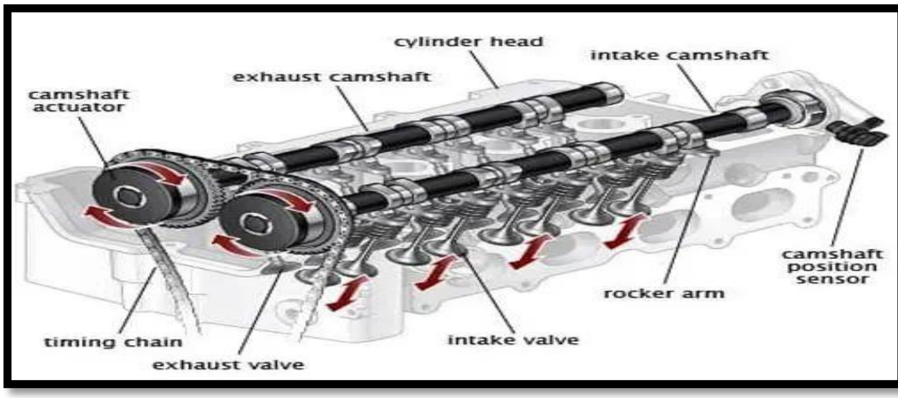


3.9 - Camshaft position sensor (CPS)
Crankshaft position sensor (CKPS)

Videos link

https://schrodingersboxqm.com/cam-and-crank-sensor-basics-part-1/
https://schrodingersboxqm.com/cam-and-crank-sensor-basics-part-2/

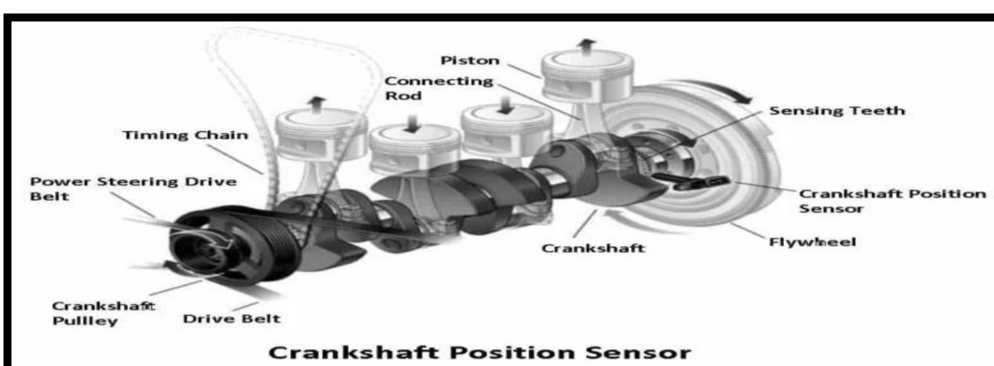
A- The camshaft position sensor



- **It determines the location of the camshaft and its angle to determine the position of the engine cylinder's piston to be operated.**
- **To produce the spark when the piston is at the top dead center**
- **To determine the duration of the injection pulse**
- **To know the firing order of the engine cylinder**

B -Crankshaft position sensor (CKPS)

- **Measures the position of the crankshaft.**
- **It detects the crankshaft position and sends the signal PCM to calculate the injection timing, ignition timing, and engine RPM according to the crankshaft position sensor's signals.**



TYPES OF CAMSHAFT & CRANKSHAFT POSITION SENSORS

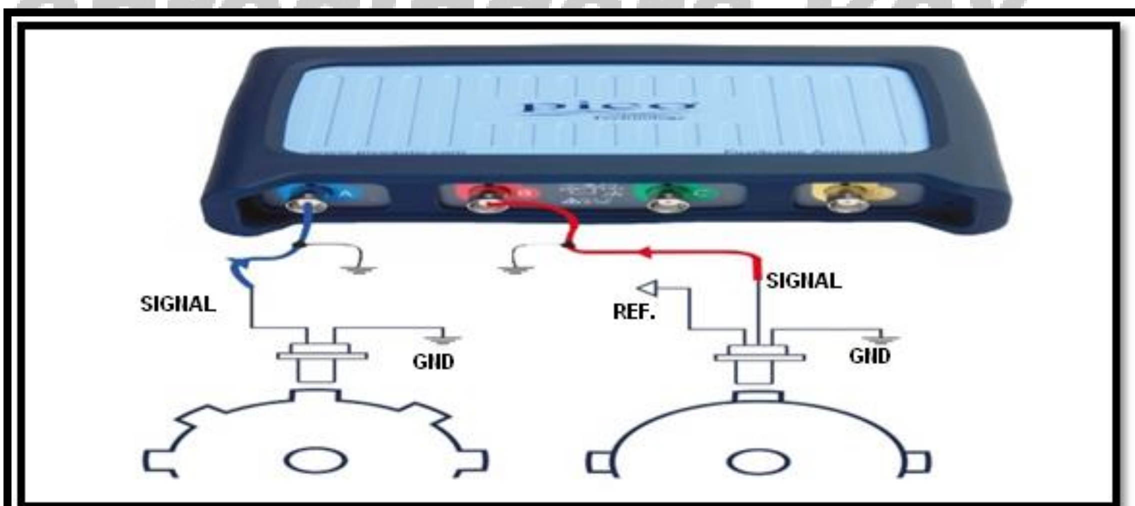
1 - INDUCTIVE SENSOR

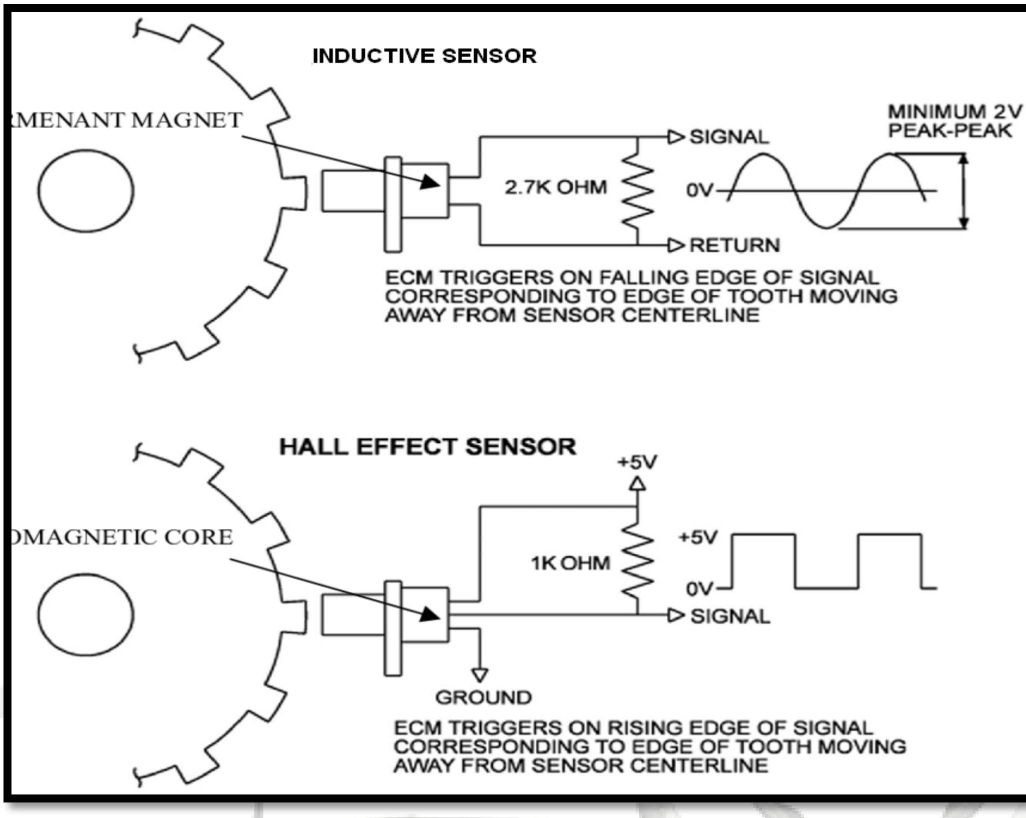
- This type of sensor is composed of a magnetic core and copper conductor winding mounted on an isolated coil that generates an AC voltage sending an alternating current signal to PCM
- 2 Wires sensor   Same concept in wheel speed sensor (WSS)
- Continuity through sensor
- 5v or 12v to diagnose any open circuit

2 - HALL EFFECT SENSOR

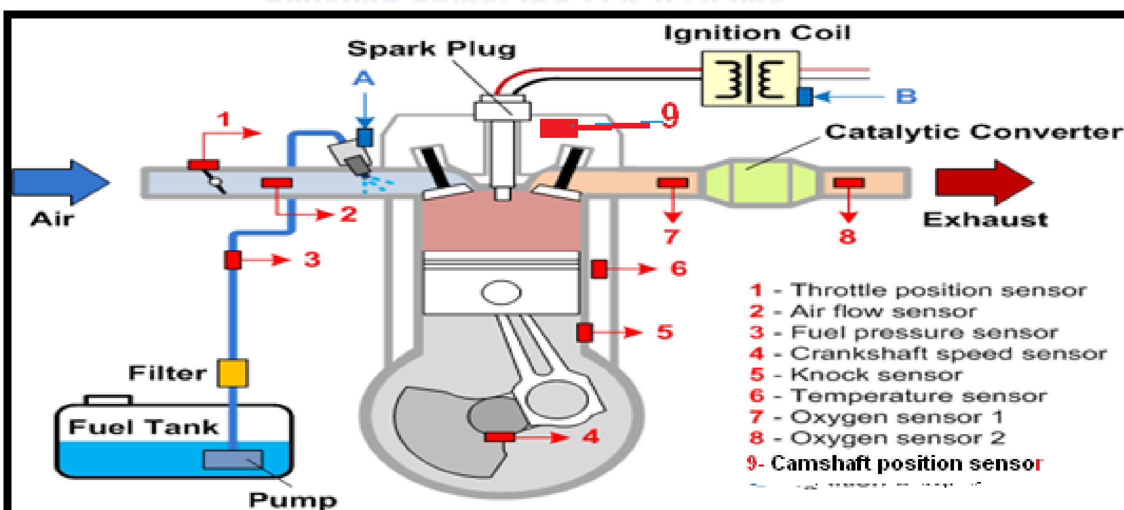
- Hall-effect sensors generate a digital square wave signal instead of an analog AC signal.
- It consists of a three-pin connector (reference voltage, ground, and signal).
- Hall Effect sensors offer the advantage that they can detect static (non-variable) magnetic fields

TESTING BY OSCILLOSCOPE



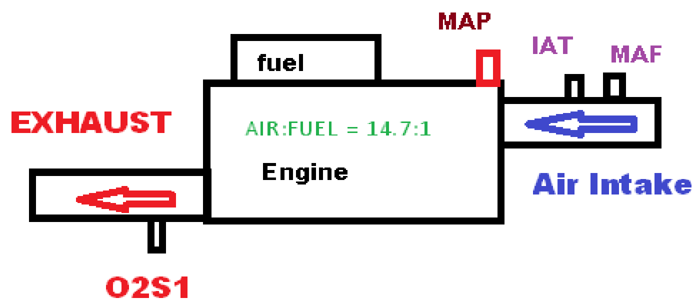


ENGINE SENSORS LOCATIONS



SECTION 4
FUEL TRIMS

Link to video
https://www.youtube.com/watch?v=5WnM_NsOtd8
https://www.youtube.com/watch?v=cARQ0jZZ4Qc



4.1 – fuel injection system

- **PCM** receives data from
  MAF(Mass airflow sensor
  IAT (Intake air temperature sensor)
  MAP (Manifold absolute pressure sensor)
  To detect how much air entered the engine
- **PCM** receives data from **O2S1** (Oxygen upstream sensor 1) or **A/F sensor** (Air fuel ratio sensor) to detect oxygen & hydrocarbons in the exhaust to adjust fuel trims
- The concept of fuel trims is identical in both **O2S1** & **A/F SENSOR**
- **O2S2** (Oxygen downstream sensor 2) to maintain the optimal activity of the catalytic converter
- stoichiometric ratio is Air : Fuel = 14.7 : 1 important for high performance & fuel economy
- **PCM** uses data from sensors to calculate the amount of fuel needed to be added to Stay in Stoichiometric Air Fuel
- Ratio by regulating pulse width of fuel injectors

4.2 -FUEL TRIMS definitions

Short-term fuel trim (STFT %)

Percentage of deviation from a normal amount of fuel added controlled by PCM to maintain stoichiometric ratio AFR

Long-term fuel trim (LTFT %)

Steady-state after the change in STFT % and become new state till a new change in STFT and change again to newer state and so on to keep stoichiometric ratio AFR

Normal range of LTFT & STFT is from -10% to +10%

DTC appeared if LTFT over +25% or less than -25%

4.3 - RELATION BETWEEN O2S1 & LTFT & STFT

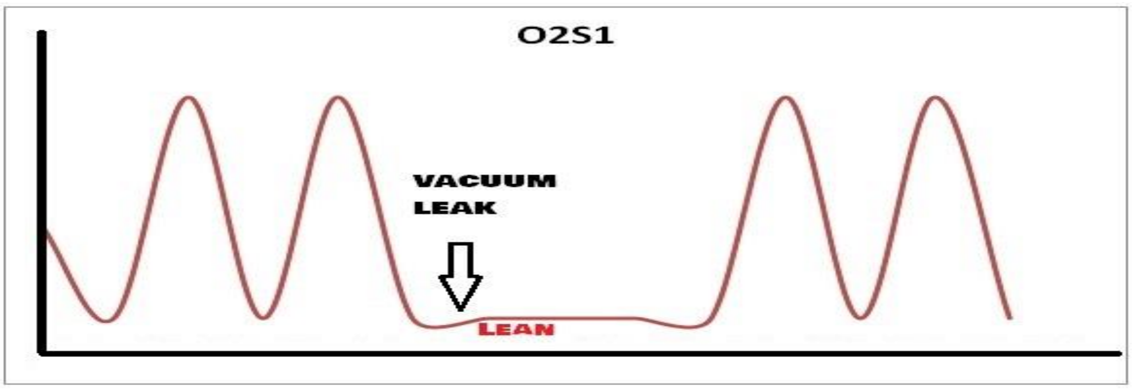
In Case a Vacuum leak

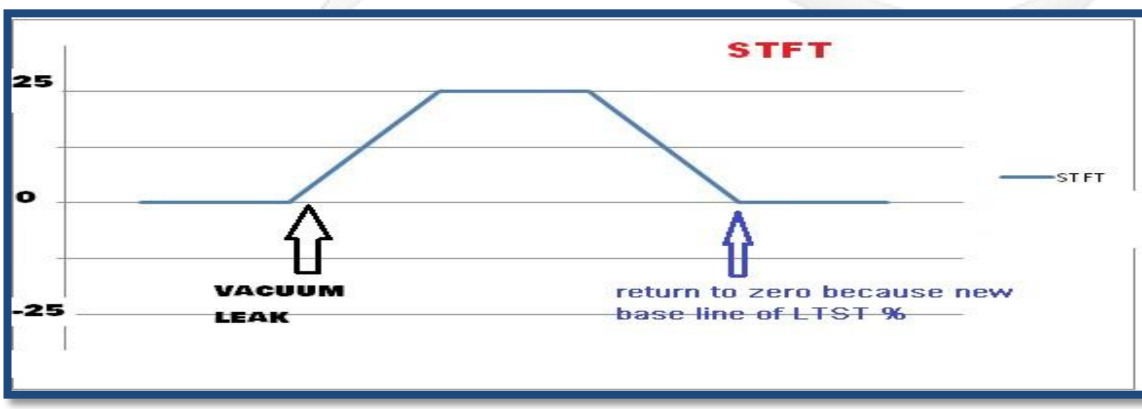
⇨Increase unmetered Air ⇨ Lean O2S1

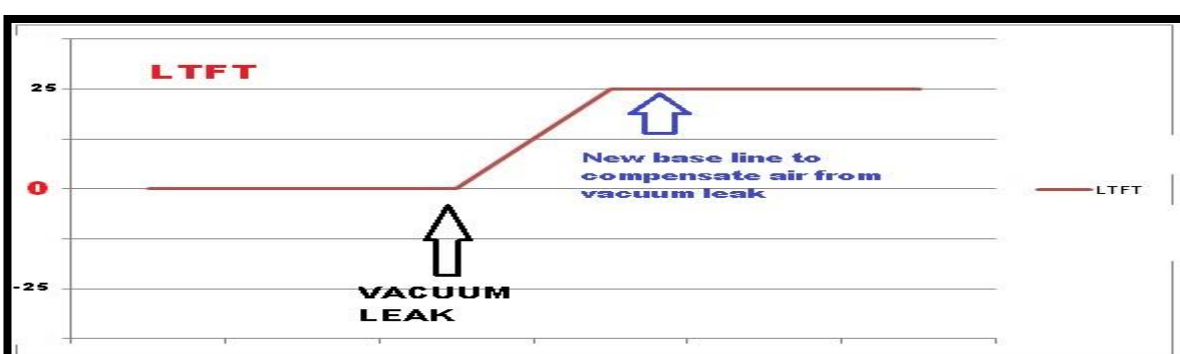
⇨ +25% increase STFT to compensate for air from the leak

⇨ ⇈ Fuel ⇨ ⇈ LTFT ⇨ New steady state of LTFT at +25%

⇨ Normal Air fuel ratio⇨ normal O2S1⇨ normal STFT







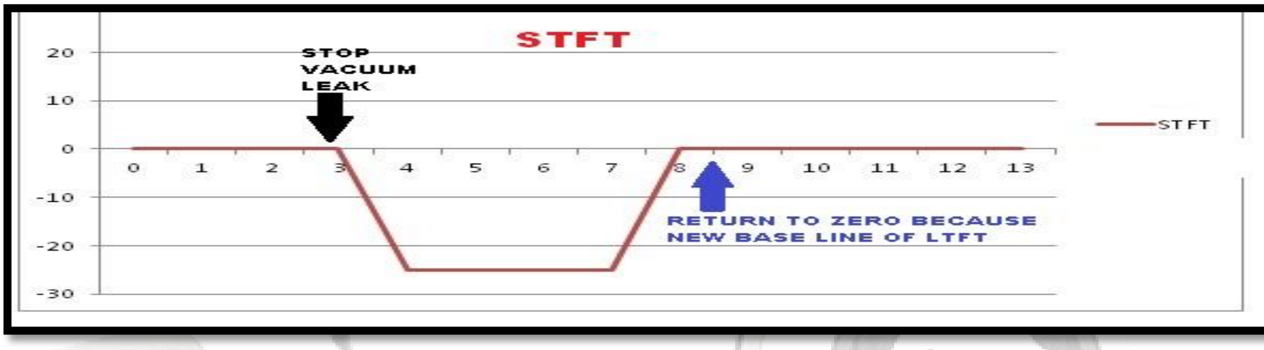
Stop Vacuum leak

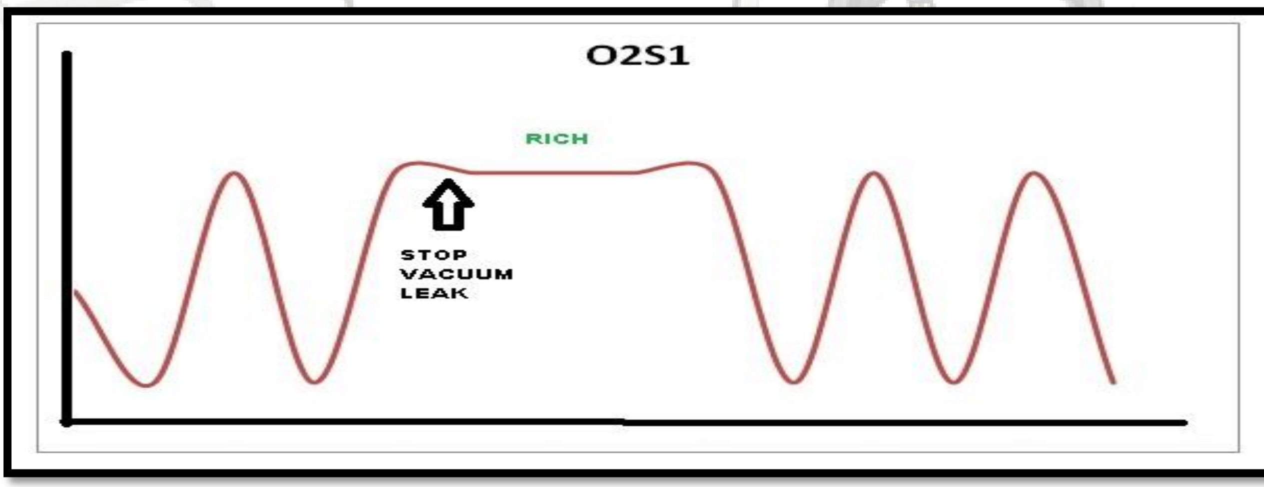
⇨stop unmetered Air ⇨ rich o2s1

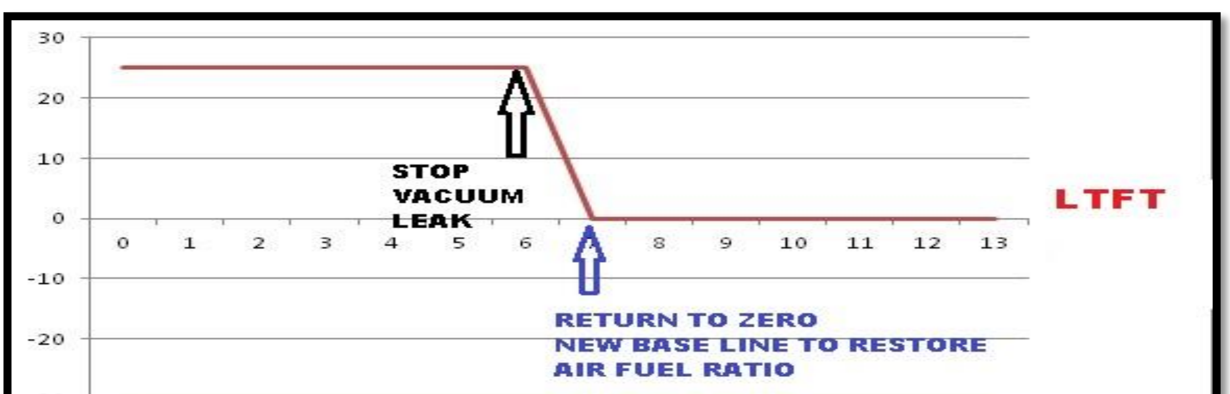
⇨ -25% STFT decrease due to rich condition

⇨ ⇊ Fuel ⇨ -25% LTFT ⇨ New steady state of LTFT at 0%

⇨ Normal Air fuel ratio⇨ normal O2S1⇨ normal STFT







4.5 - DIAGNOSIS BY O2S1 & LTFT & STFT

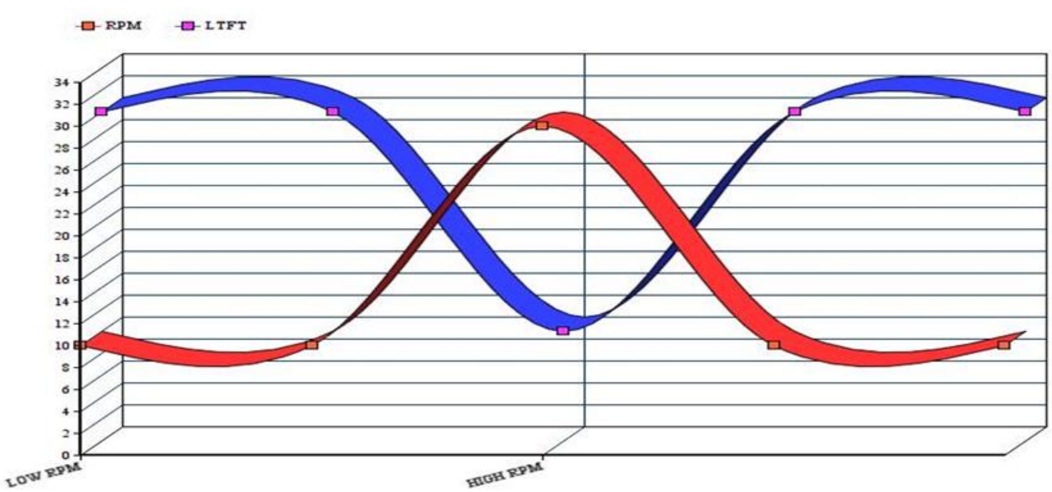
CODE P0171 **Engine run lean bank1**

- **STFT = 0%**
- **LTFT = +25%**
- **O2S1 = 0.1 V.**

CAUSES

A- AIR VACUUM LEAK

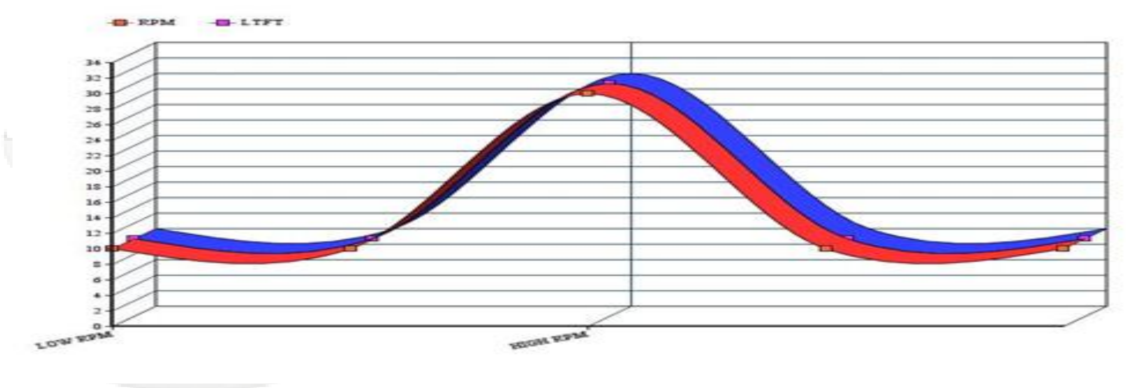
❁ BY ⇈ **RPM** ⇨ ⇈ Air intake ⇨ ⇊ % of unmetered air from leak to All air intake ⇨ ⇊**LTFT** TO Normal value
If ⇊ **RPM** to IDLE ⇨⇈ **LTFT** again❁



B- WEAK FUEL PUMP

❆Increase RPM ⇨ More Need to fuel ⇨ increase LTFT to overcome the weakness of the fuel pump

❆Test fuel pump pressure (normal range from 60 psi to 100 psi)



C- MAF DIRTY OR MALFUNCTION

Increase **RPM** = Increase unmetered Air intake = increase **LTFT**

CASE OF V ENGINE

- **LTFT1 =+25% & LTFT2 = 0% ⇨ CAUSE IS VACUUM LEAK**
- **LTFT1 = +25% & LTFT2 = +25% ⇨ CAUSE MY BE ONE OF A or B or C**