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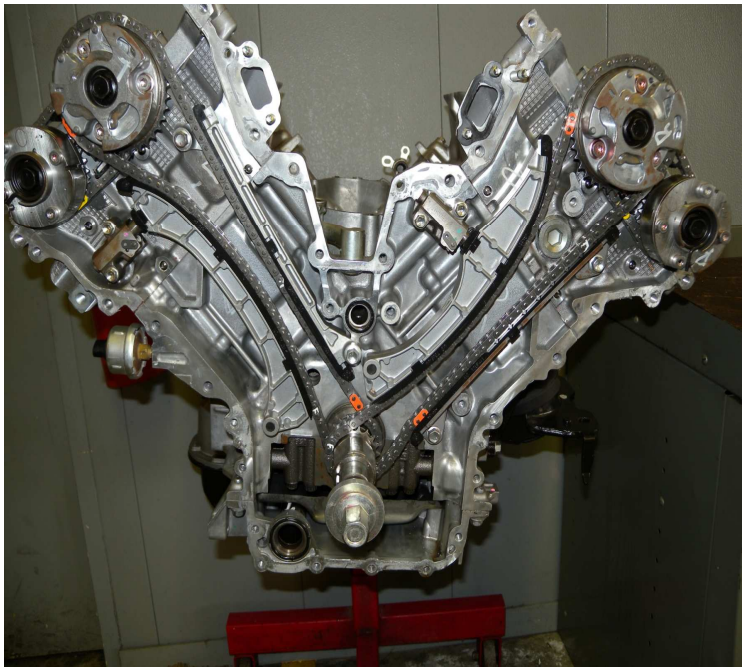
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ADVANCED TECHNOLOGY- VEHICLE EFFICIENCY IMPROVEMENTS

Variable valve Control, Cylinder deactivation, gasoline direct injection and Electronic Throttle

Developed by Doc Nall and Bill Peek, these two have been collaborating for over 25 years.

VARIABLE VALVE TIMING SYSTEMS



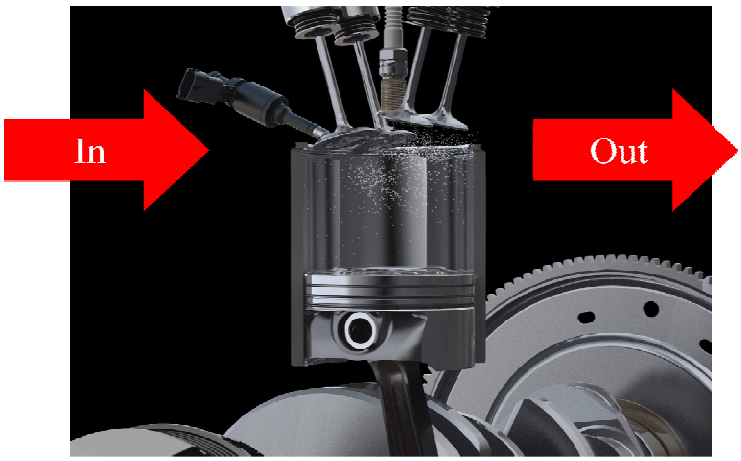
Objectives

Introduction to Variable Valve Control
Identify the different operations for VVT **s**ystems
Identify the advantages and disadvantages of the different systems
Discuss the operation of Variable Valve lift
Discuss how Variable Valve Control and high pressure direct injection makes using different 4-cycle operations possible

Background

California Air Resources Board did a study on which new vehicle technologies were best suited to reduce fuel consumption and reduce green house gases with improved vehicle performance
Improved vehicle performance makes smaller displacement engines more attractive to motorist
Other factors include Emissions, Power, Economy and implementation costs are factors

CARB sees more control as the solution



Today's vehicles offer technologies from the CARB list. The good news is this technology is rugged and doesn't break often. The bad news is when it does break we do not have a lot of experience with it and find it difficult to diagnose and repair. When you think about it the newer technology is designed around a lot of old technology and if we don't panic we can use what we already know.

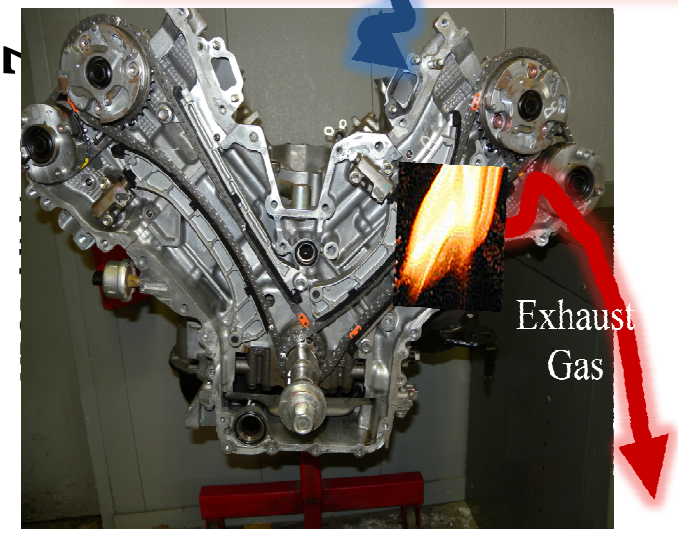
Technology	Manufacturers using or have announced plans to use technology
Gasoline Direct Injection (GDI)	GM, Ford, DC, Toyota, BMW, Nissan
GDI & Turbocharging	GM, Ford, VW, BMW, Mazda, Nissan
Valve Control	All
6-speed automatic & automated manual, CVT	GM, Ford, DC, VW, Toyota, Nissan, Mazda
Electric Power Steering, Electrohydraulic Power Steering	GM, Honda, Toyota
Cylinder Deactivation	GM, DC, Honda

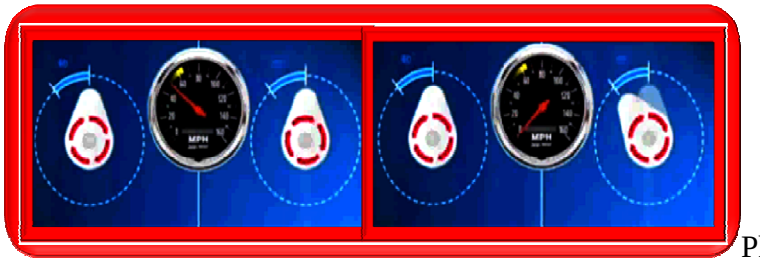
California Environmental Protection Agency AIR RESOURCES BOARD

CARB's List OF Important Techngologies 73

Optimizing the airflow

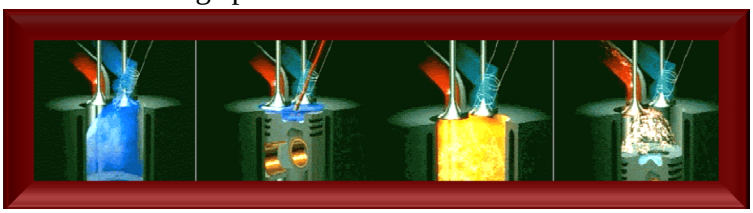
In an internal combustion engine, optimizing the airflow in and out of each combustion chamber is a key to just about every aspect of performance. Power, emissions, fuel economy and other critical parameters are all dependent upon how good the engine air flows in and out. It has been said that the engine is a large air pump. If you accept that description you must clearly see that moving air into and out of the engine is the most important function.




Phasing and Variable Timing Phase 1

Phasing or timing in discrete steps

Variable to change positions with conditions



Those that use; Suck – Squeeze – Bang – Blow to describe the 4 cycles of the Otto engine don't understand it.

The air/fuel mixture is pushed into the cylinder by atmospheric pressure (Or Supercharged). I guess a simple person might use squeeze to describe compression isn't too far off. But, BANG! Burning hot expanding gases should never create a bang. The exhaust system you use in your shop to vent the exhaust fumes blow. However a scavenger system that is used on an engine doesn't. Saying something in a cute way is one thing, but words have meanings and it is best to use the correct ones.

To complete the 4 cycles 720 degrees of crankshaft rotation is required. Each event is 180 degrees. 4 times 180 degrees is 720.

The Otto, Atkinson, and Miller cycles will be covered

The Atkinson cycle / The Miller cycle:

The Atkinson cycle design is based on crankshaft.

The Miller cycle design is based on valve timing.

The Miller cycle frequently has a super charger.

These two designs offer high efficiency while overall power is decreased. They allow the intake, compression, power, and exhaust to occur in one crankshaft rotation. The intake valve is held open longer than normal to allow a reverse flow into the intake manifold. This reduces the effective compression ratio by reducing combustion chamber volume. The Atkinson design doesn't have application in the automotive industry. Atkinson has a complicated crankshaft design. Honda has used it in lawn mowers. Mazda has used the Miller design in their vehicles. The design allows the expansion ratio to exceed the compression ratio while retaining a normal compression pressure. This is desirable for good fuel economy because the compression ratio in a spark ignition engine is limited by the octane rating of the fuel used, while a high expansion ratio delivers a longer power stroke and reduces the heat wasted in the exhaust.

The Atkinson/Miller cycle

High efficiency, but overall power is decreased

Allows intake, compression, power, and exhaust to occur in two crankshaft rotations

The intake valve is held open longer than normal to allow a reverse flow into the intake manifold, compression stroke has started
This reduces the effective compression ratio by reducing combustion chamber volume
Used in a two mode hybrid vehicles
A hybrid vehicle has two different propulsion options, an Internal Combustion Engine and an electric motor
The ICE needs to be efficient at Mid-range only
A hybrid's ICE relinquishes Low & High end power and torque to be efficient at Mid-range
The electric motor assist with acceleration and high power demands

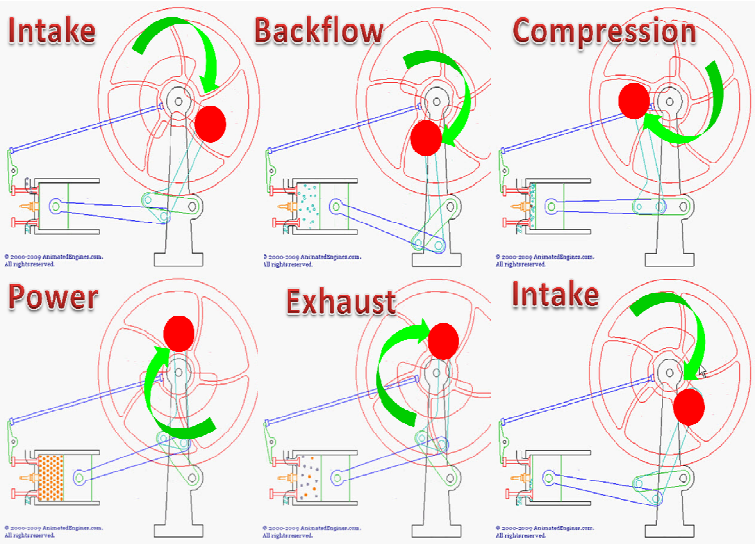
5 Events not 4 cycles

Otto cycle

1. Intake
2. Compression
3. Power
4. Exhaust

Atkinson/Miller

1. Intake

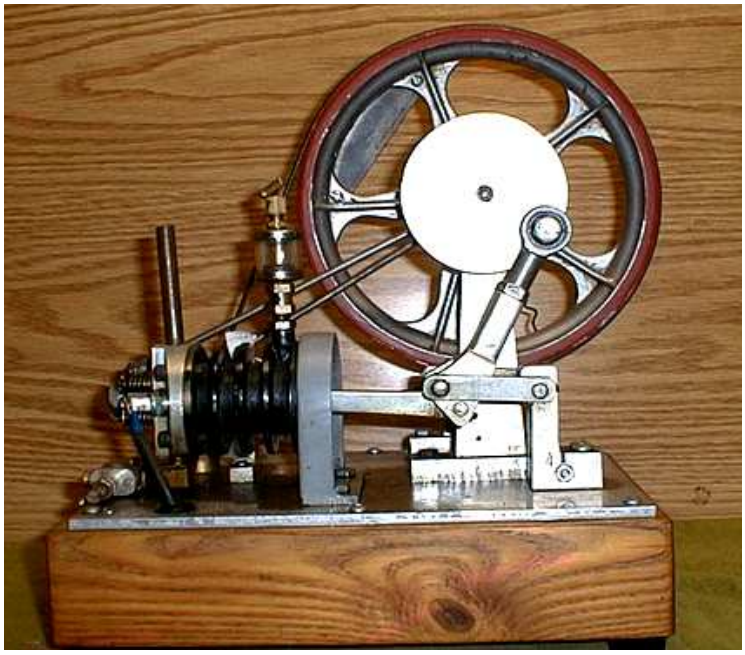


2. Backflow
3. Compression
4. Power
5. Exhaust

The (Short Version)
Atkinson/Miller has a longer power stroke than the compression stroke.
By keeping the intake valve open longer than is normal.
Although some of the fuel is pushed back through the intake, overall economy is increased.
The crankshaft bore is offset (12mm); it lowers the piston side forces on the power stroke, which reduces engine friction.

The Atkinson completes the four cycles with the use of a lever.
Today's hybrids accomplish the same thing through valve and variable valve timing.
That is why it is referred to as: The Atkinson/Miller cycle

This is a true Atkinson using a lever.

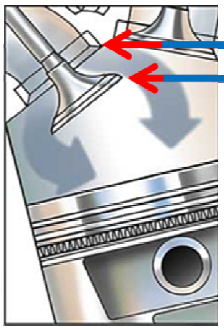


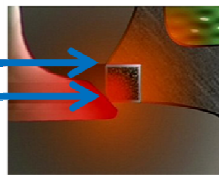
The Atkinson completes the four cycles with the use of a lever
Today's hybrids accomplish the same thing through valve and variable valve timing
That is why it is referred to as:
The Atkinson/Miller cycle
This is an example of variable valve timing
We will examine valve operation to understand the reasons for variable valve timing on other vehicles

Cam's are technically very cool

Even if total mastery of a cam's numerology is a little deeper than you want to go. The average tech can gain an understanding of Cam basics. A fundamental understanding of these concepts will help you understand VVT.
"Lift" refers to how far the valve is opened off the seat in fractions of an inch
The gross lift is the cam's actual "lobe lift," multiplied by the rocker ratio







Cams have a vocabulary of their own.
"Lift" refers to how far the valve is opened off the seat in fractions of an inch.
The gross lift is the cam's actual "lobe lift," multiplied by the rocker ratio.
The amount of this displacement is the actual lobe lift of the cam.
The lobe lift isn't the same as the amount of lift at the valve, since this lift is multiplied by the rocker ratio.
The rocker ratio is created because the pushrod side of the rocker is closer to the rocker's pivot point than the valve side.
The rockers in most OEM cams ranged from 1.5:1 to 1.75:1.
"Duration" is how long the open cycle lasts.
How long is given in degrees of crankshaft rotation.
Measured from when the lobe starts raising the lifter/valve, until the same lobe finishes by dropping the lifter back down to the start position.
There is a standard measuring procedure used by engineers when establishing duration. They start measuring when the lifter has moved 0.050' off of the seat. That is the reason there is a difference between published and actual specifications.
The amount of cam position displacement is the lobe lift of the cam

The lobe lift isn't the same as the amount of lift at the valve, since lobe lift is multiplied by the rocker ratio



"Duration" is how long the open cycle lasts
How long is given in degrees of crankshaft rotation
Measured from when the lobe starts raising the lifter/valve, until the same lobe finishes by dropping the lifter back down to the start position



Though lift and duration alone can fully describe an individual lobe, each cylinder of an engine has intake and exhaust lobes, and the timing of these events relative to each other has a significant influence on engine performance. Neither lift nor duration gives any clue as to this aspect of a cam's design.

Lobe separation angle (LSA)

Lobe separation angle (LSA) does that. Simply put, the (LSA) is a measurement of how the intake and exhaust lobes are phased with each other. LSA is in cam degrees (duration is quoted as crank degrees). Lobe separation will have a big impact on performance. After all, the valve timing events have to occur at the most advantageous moments to glean the desired results from an engine. An LSA of zero would have the intake and exhaust valves open and close at the same time and that won't work for an engine.
Simply put, the (LSA) is a measurement of how the intake and exhaust lobes are phased or timed with each other
LSA is in cam degrees (duration is quoted as crank degrees)
Lobe separation will have a big impact on performance
The valve timing events have to occur at the most advantageous moments to glean the desired results from an engine
An LSA of zero would have the intake and exhaust valves open and close at the same time

Narrow LSA characteristics

- **Increased valve overlap**
- **Increased low-rpm torque**
- **Narrower power band**
- **Reduced idle quality**
- **Increased cranking compression**



- **Decreased piston-to-valve clearance**

Wide LSA characteristics

- **Reduced valve overlap**
- **Improved top-end power**
- **Wider power band**
- **Improved idle quality**
- **Reduced cranking compression**
- **Increased piston-to-valve clearance**

Cam grinders have found the range for fixed LSA is in the range of 104-115° degrees for most applications

The profile, position and shape of the cam lobes are designed for optimum performance at certain engine RPM.

There is always a trade off: Normally limiting; Low-end torque or high-end power. You cannot have it all in a cam shaft. That is what makes VVT so appealing. VVT allows the cam profile to change: Which results in greater efficiency and power, over a wider rev-range

There is always a trade off:

Normally limiting;

Low-end torque

Or high-end power

Variable Camshafts

VVT allows the cam profile to change LSA

This results in greater efficiency and power,

Over a wider rev-range

With good idle quality

At high engine speeds, an engine requires large amounts of air

The intake valves may close before all the air has flowed in, reducing performance

If the cam keeps the valves open for longer periods of time, as with a racing cam, problems start to occur at the lower engine speeds

This will cause un-burnt fuel to exit the engine since the valves are still open (High HCs)

This leads to lower engine performance and increased emissions. That's why pure racing engines have difficulty idling at the low speeds which is expected of a family vehicle.





Cam timing on a fixed camshaft is a balance between the following conflicting engine requirements:

- Meeting emissions regulations

- Allowing for good fuel economy
- Producing acceptable power and torque
- Maintaining good idle quality

No single cam timing will give optimum results under all engine operating conditions. Compromise timing is chosen depending on the specific engine application.

Viper VS Neon



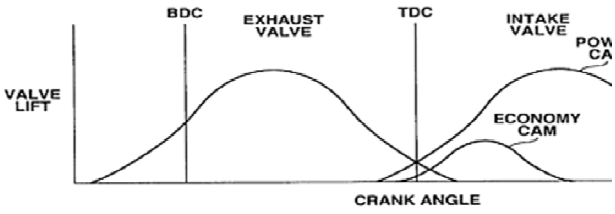


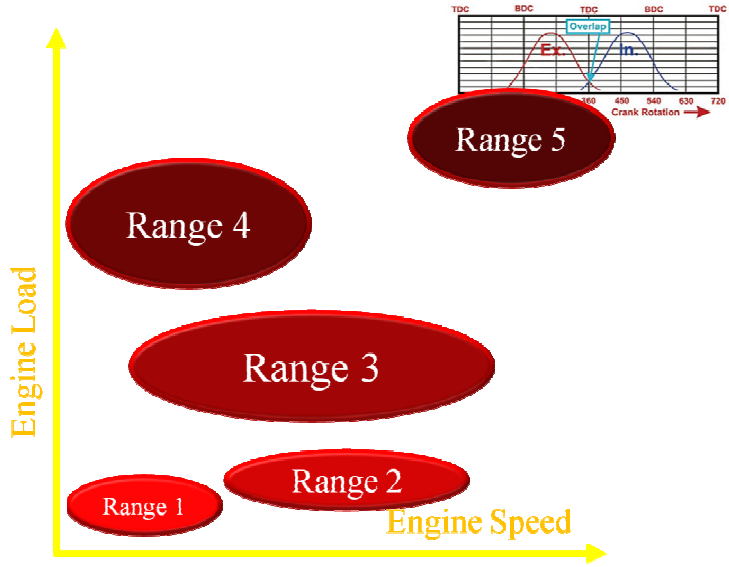
VVT for Power and Torque

At any specific speed and load, increasing the intake of air into the combustion chamber allows us to burn more fuel, thus resulting in more power being produced. This is measured in terms of an engine's volumetric efficiency (the actual volume induced / the static cylinder volume). During normal engine operation, pressure pulses are set up within both the intake and exhaust manifolds from the continuous opening and closing of the valves and the intermittent motion of the gasses into and out of the combustion chamber. To get the best volumetric efficiency at a particular operating point, one must tune the valve events to be in-sync with these pulses. Unfortunately, the frequency, magnitude and timing of these pulses varies with speed, so the volumetric efficiency of an engine with fixed valve timing will only be optimum at one speed.
With VVT, the engine can be optimized at all speeds
This will yield significant improvements in low speed torque and top end power

Variable Valve timing operation

Through manufacture specific hardware and software control the computer adjust cam timing for





Different operating conditions

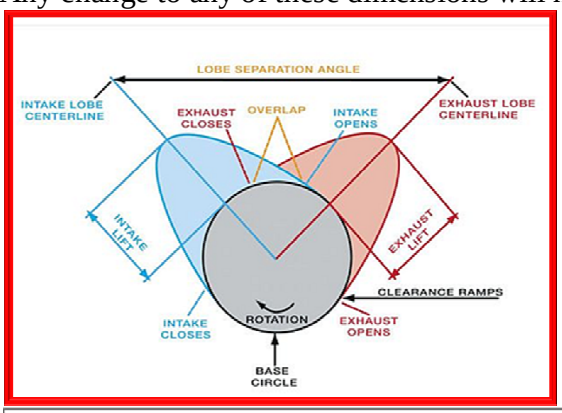
This chart shows the difference in SLA and valve lift
Different manufacturers will have a different number of ranges. But this gives us an idea of what is going on. On the newest systems the timing and lift changes on a continuous bases.

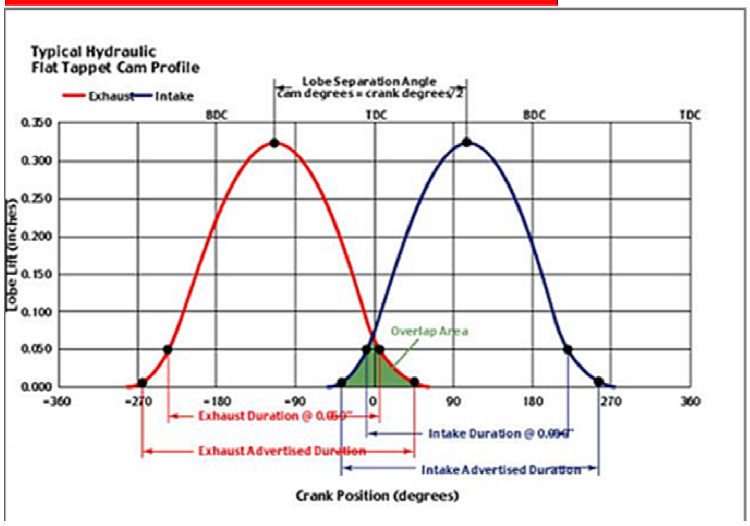
PCM calculates the optimal valve timing for each driving condition
In proportion to:

- Engine RPM
- Throttle position
- Coolant temperature
- Intake air volume

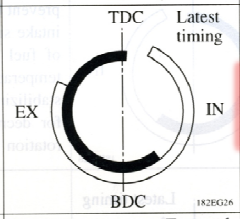
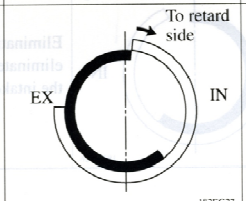
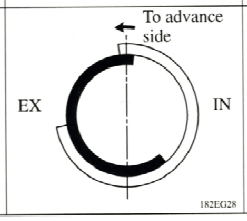
PCM commands a solenoid (Oil control valve)

Any change to any of these dimensions will have a major impact on valve overlap

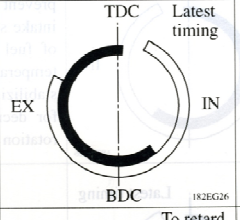
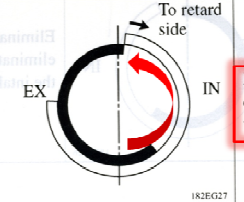
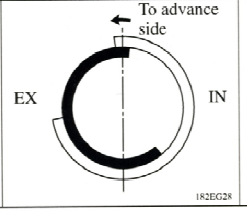




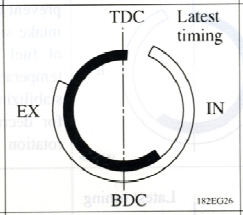
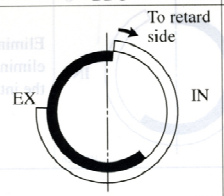
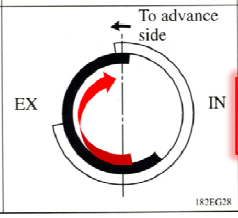
Intake Valve Timing

Operation State	Range	Valve Timing	Objective	Effect
During Idling	1		Eliminating overlap to reduce blow back to the intake side	Stabilized idling rpm Better fuel economy
At Light Load	2		Decreasing overlap to eliminate blow back to the intake side	Ensured engine stability
At Medium load	3		Increasing overlap to increase internal EGR for pumping loss elimination	Better fuel economy Improved emission control

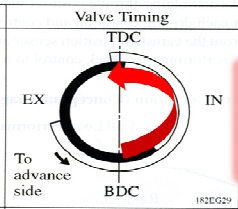
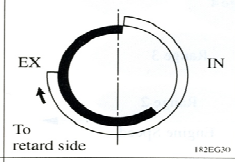
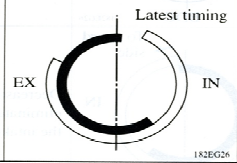
Valve timing for light load

Operation State	Range	Valve Timing	Objective	Effect
During Idling	1		Eliminating overlap to reduce blow back to the intake side	Stabilized idling rpm Better fuel economy
At Light Load	2		Decreasing overlap to eliminate blow back to the intake side	Ensured engine stability
At Medium load	3		Increasing overlap to increase internal EGR for pumping loss elimination	Better fuel economy Improved emission control

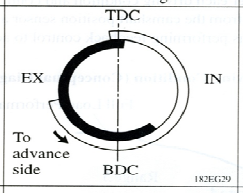
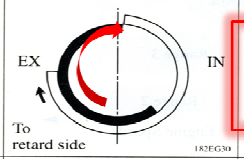
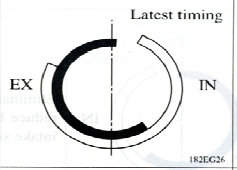
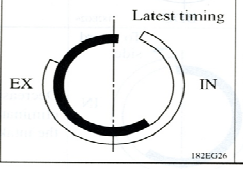
Valve timing for medium load

Operation State	Range	Valve Timing	Objective	Effect
During Idling	1		Eliminating overlap to reduce blow back to the intake side	Stabilized idling rpm Better fuel economy
At Light Load	2		Decreasing overlap to eliminate blow back to the intake side	Ensured engine stability
At Medium load	3		Increasing overlap to increase internal EGR for pumping loss elimination	Better fuel economy Improved emission control

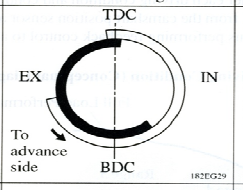
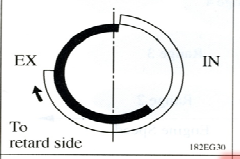
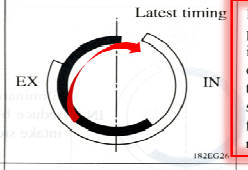
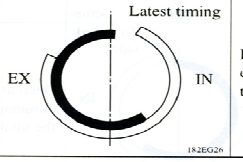
Valve timing for medium speed with a heavy load

Operation State	Range	Valve Timing	Objective	Effect
In Low to Medium Speed Range with Heavy Load	4		Advancing the intake valve close timing for volumetric efficiency improvement	Improved torque in low to medium speed range
In High Speed Range with Heavy Load	5		Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At Low Temperatures	—		Eliminating overlap to prevent blow back to the intake side for reduction of fuel increase at low temperatures, and stabilizing the idling rpm for decreasing fast idle rotation	Stabilized fast idle rpm Better fuel economy
Upon Starting/ Stopping the Engine	—		Eliminating overlap to eliminate blow back to the intake side	Improved startability

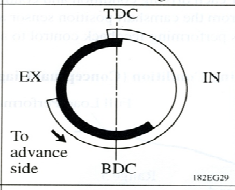
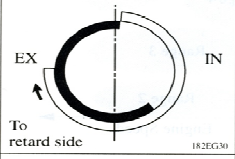
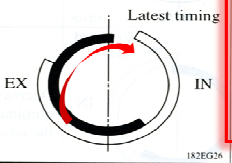
Valve timing for high speed with a heavy load

Operation State	Range	Valve Timing	Objective	Effect
In Low to Medium Speed Range with Heavy Load	4		Advancing the intake valve close timing for volumetric efficiency improvement	Improved torque in low to medium speed range
In High Speed Range with Heavy Load	5		Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At Low Temperatures	—		Eliminating overlap to prevent blow back to the intake side for reduction of fuel increase at low temperatures, and stabilizing the idling rpm for decreasing fast idle rotation	Stabilized fast idle rpm Better fuel economy
Upon Starting/ Stopping the Engine	—		Eliminating overlap to eliminate blow back to the intake side	Improved startability

Valve timing for cold temperatures

Operation State	Range	Valve Timing	Objective	Effect
In Low to Medium Speed Range with Heavy Load	4		Advancing the intake valve close timing for volumetric efficiency improvement	Improved torque in low to medium speed range
In High Speed Range with Heavy Load	5		Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At Low Temperatures	—		Eliminating overlap to prevent blow back to the intake side for reduction of fuel increase at low temperatures, and stabilizing the idling rpm for decreasing fast idle rotation	Stabilized fast idle rpm Better fuel economy
Upon Starting/ Stopping the Engine	—		Eliminating overlap to eliminate blow back to the intake side	Improved startability

Valve timing for starting or stopping the engine

Operation State	Range	Valve Timing	Objective	Effect
In Low to Medium Speed Range with Heavy Load	4		Advancing the intake valve close timing for volumetric efficiency improvement	Improved torque in low to medium speed range
In High Speed Range with Heavy Load	5		Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At Low Temperatures	—		Eliminating overlap to prevent blow back to the intake side for reduction of fuel increase at low temperatures, and stabilizing the idling rpm for decreasing fast idle rotation	Stabilized fast idle rpm Better fuel economy
Upon Starting/ Stopping the Engine	—		Eliminating overlap to eliminate blow back to the intake side	Improved startability

Valve timing needs to change to match the engine's operating condition from moment to moment because of the physics of air

Air may feel weightless to us, but air has mass

That means it takes time to put air into motion or to stop air motion

At idle, a typical cylinder has to fill with air and empty itself of exhaust gases about five times every second

The airflow in and out of the engine has to start and stop just as often

At redline, it gets far more intense

The same cylinder might have to fill and empty 50 times per second—maybe more

Obviously, when working more than 10-times faster than it does at idle, there's very little time for the air that's stopped in the intake manifold to accelerate into the combustion chamber when the intake valve opens

We need is a way to give the air a head start

Variable valve timing can do this

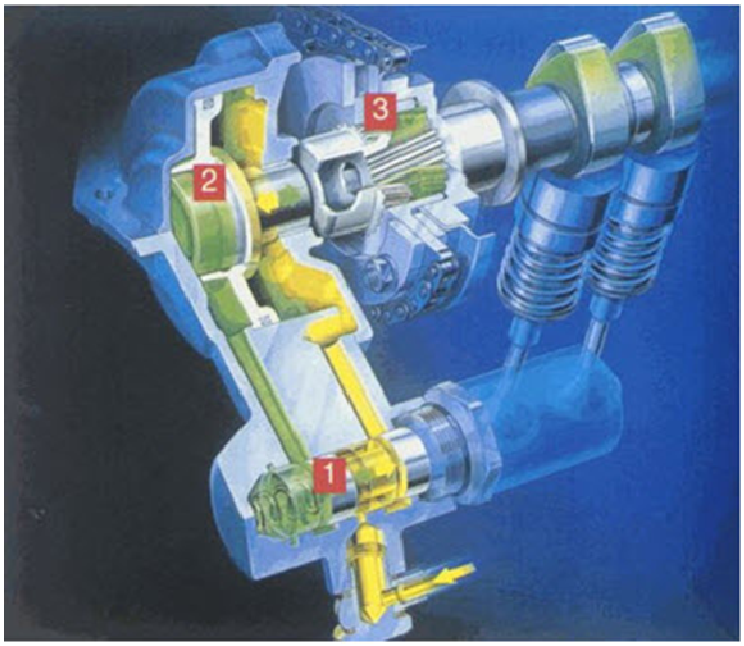
The increased volumetric efficiency produces more power

Advancing the intake cam timing as needed pays significant benefits,

Broadening an engine's power delivery range to make it pull harder at low rpm, without running out of steam at high revs is only possible with variable valve timing

A turbo for example, would only help high rev operation, because of turbo lag at low speeds

By providing just the right amount of valve-timing advance



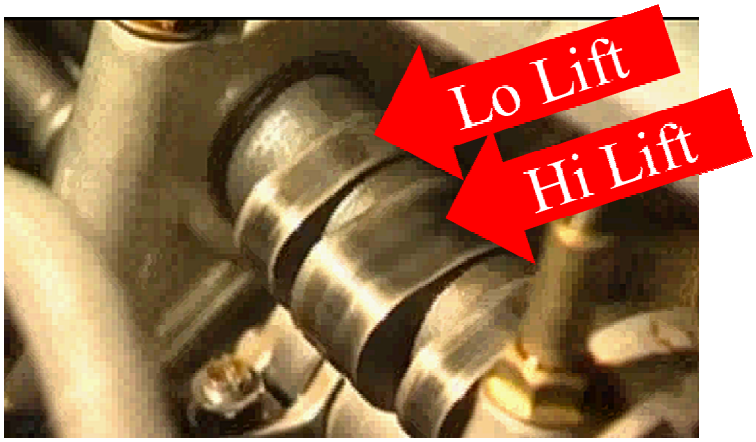
Variable valve timing can provide more complete cylinder filling at all engine speeds

1. **Hydraulic control valve**
2. **Cam phaser**
3. **Helical gear to change cam timing**

Basic variable cam timing systems advance the whole cam, which means that the valves affected, open sooner at high revs (good) but also close sooner (often not

necessarily desirable). There are ways to further fine-tune the opening and closing of the valves. Systems that allow valve lift can further improve airflow. Ferrari has a novel camshaft design on some engines; it features cam lobes that are tapered along the length of the camshaft. An electronically controlled system then moves the cam laterally in proportion to engine rpm, so that the effective cam timing, lift and duration can be varied.

Honda's VTEC



Honda's VTEC system can switch between two different cam profiles each with different timing, lift and duration

Valve Lift

Control the flow of air and fuel, into the cylinders and out of the exhaust. When and how long the valves open (duration) and how much the valves move (lift) both affect engine efficiency. A typical valve lift may be 10 mm.

Economy is best with valve lift of 2 to 5 mm at light loads but limits high end power.
Best high end power is achieved with valve lift over 10 mm but has poor idle.
One design can't do it all.
Owners want performance
Government demands better MPG and emission standard
Performance takes a back seat

Variable Valve Lift

Variable valve lift results in a 6% to 10% fuel economy improvement with better performance
Variable valve lift is more difficult and expensive than cam phasing or timing
The time available for one intake cycle is approximately 34 ms at 700 RPM
At 2100 RPM, the available time is down to 11.4 ms
At 7000 RPM the available time is down to 3.4 ms
Ideal valve action for 3.4 msec will not be ideal for valve action at 34 msec (The air/fuel mass has inertia)
The amount of fuel mixture ignited is determined by Engine size and volumetric efficiency which is directly related valve train operation
Cam design is an area where the engine designer must make compromises

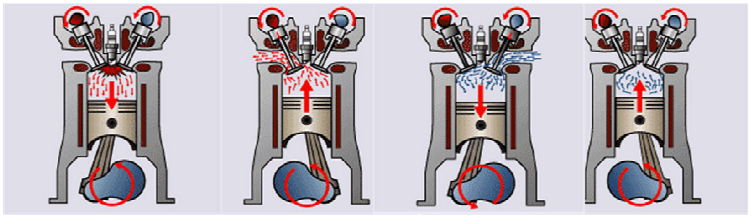


Cam designers will want to know the ideal engine speed for max torque because designs for high

speed will do poorly at low speeds and vice versa
Opening the exhaust valve earlier,
(Piston moving down)
(While gasses are still expanding)
(Cylinder pressure is still slightly elevated)
Will start exhaust flow sooner for better engine breathing
This can cause higher emissions at the low end of the RPM range
Closing the exhaust valve later will increase high end performance (Increased valve overlap)
Closing the valve at 22 degrees ATDC instead of 15 degrees ATDC will cool the engine, but reduce performance at low RPMs

This offers an EGR Effect
During intake stroke, exhaust valves are closed with the intake valves open
Intake valves opening at IE:
80 degrees BTDC, instead of 70 degrees BTDC will improve low end torque
There is no one number that works for every condition
There are advantages to having the valves overlap
Valve overlap occurs when the exhaust valve remains open while the intake valve is opening
Overlap will cause the incoming cooler mixture to cool a small amount of heated exhaust gas remaining in the cylinder
The cooling causes the mixture to be drawn into the cylinder cooling a small amount of exhaust gas in the cylinder, cooling the heated gas causes it to shrink, creating a low pressure
This effect is known as “draw through”

“Draw through” improves the volumetric efficiency of the engine
Draw through increases mid-range torque
Draw through at idle cause’s poor idle quality
During compression stroke**,** intake and exhaust valves are closed
The amount of mixture that is compressed is determined by volumetric efficiency, which is directly related valve train operation



The timing of valve events is a compromise between good idle and performance

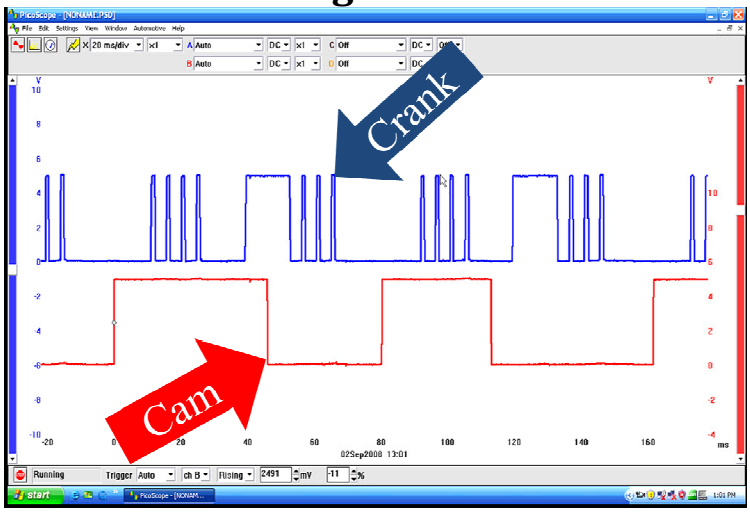
Variable valve timing is one approach to reducing the impact of the compromise between performance and smooth idle
Variable Valve Lift is another function that can be varied

VVC Systems currently in use

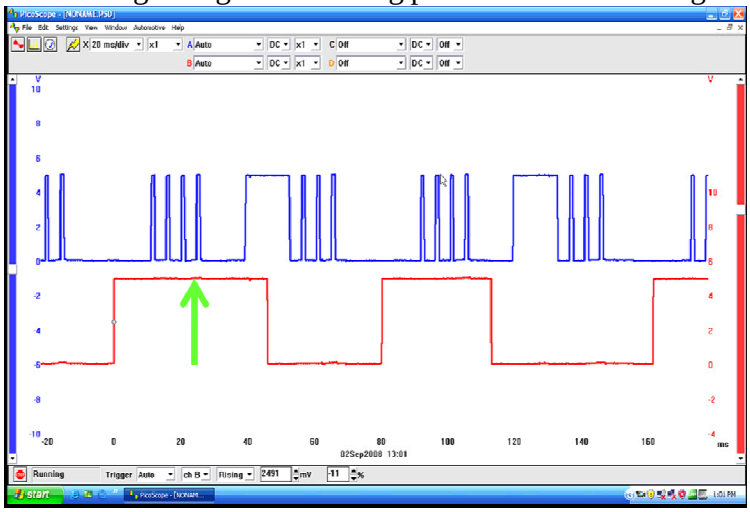
Intake Valve only: timing or phasing
Exhaust Valve only: timing or phasing
Intake and exhaust valve timing or phasing
Valve timing and lift control
Electro-hydraulic valve actuators

Variable valve timing or phasing is the starting point
Crank and cam signals are always important and have additional importance for VVC (control)
VVC relies on the cam and crank signals for position of the cam and engine speed data
Engine load data such as MAP, MAF, and TPS are used to set variable valve control
Correct any codes that relate to engine control as part of your diagnostic

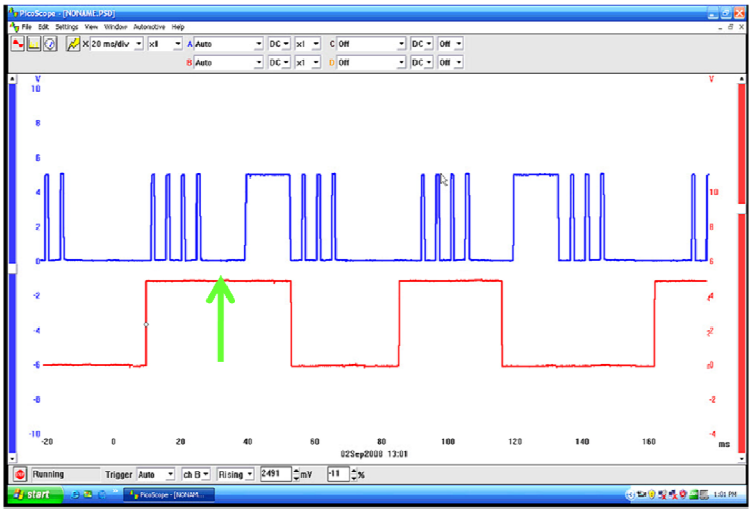
Cam and Crank Signals

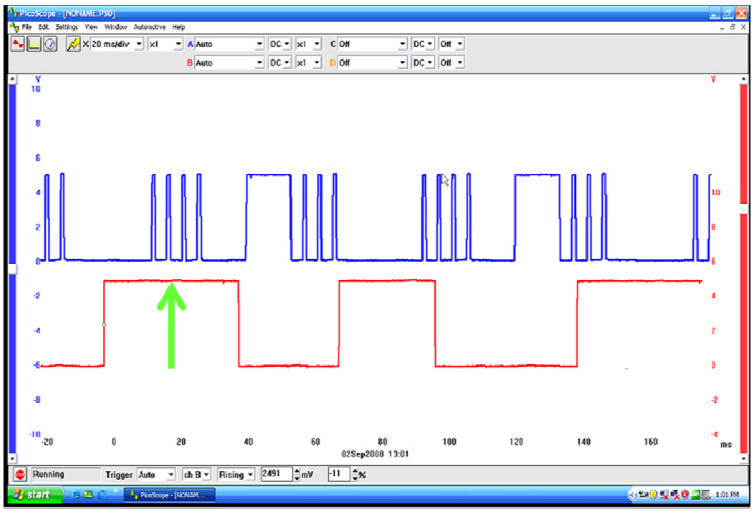


Cam timing changes the starting point of the red cam signal



The green arrow points to the center of the long cam signal. Changing cam timing will cause this point to move.





The red pattern above HAS MOVED TO THE RIGHT

The red pattern above has shifted to the left

Variable Valve Timing Operation

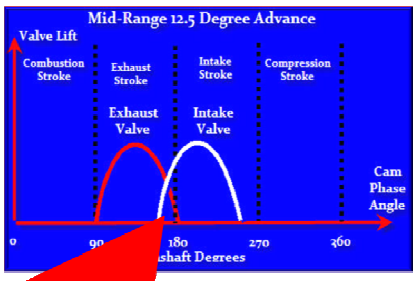
VVT changes the timing of the valve opening at different points throughout the engine operating range (Cam Phasing)
BMW calls their Cam Phasing, VANOS which was introduced in 1992

VANOS will be the starting point since it is also used by other manufacturers (Variable Nockenwellen Steuerung)
VANOS changes <u>intake</u> valve timing at set points in the engine speed range
VVT allows engine designers to use performance cams that are designed to give good idle



With the engine idling, intake timing is <u>retarded</u> for better idle quality

Many different manufacturers use the Variable Valve Timing system

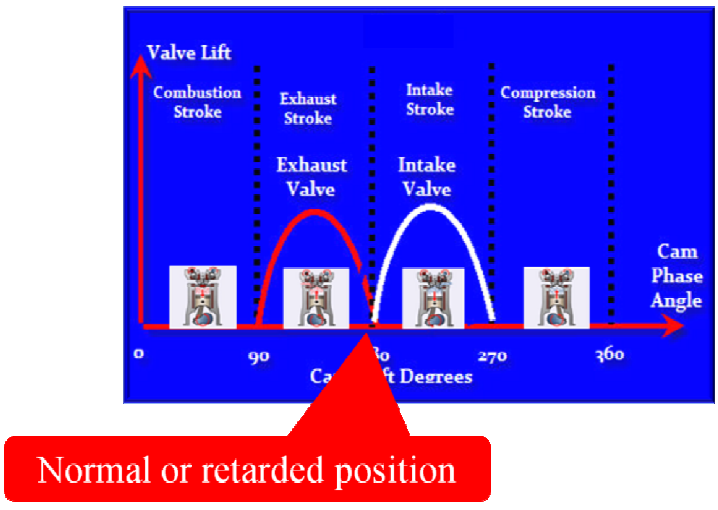


This is our starting point

VANOS operates on the intake camshaft in accordance with engine speed and accelerator pedal position. At the lower end of the engine-speed scale, the intake valves are opened later, which improves idling quality and smoothness. At moderate engine speeds, the intake valves open much earlier, which boosts torque and permits exhaust gas re-circulation inside the combustion chambers, reducing fuel consumption and exhaust emissions. Finally, at high engine speeds, intake valve opening is once again delayed, so that full power can be developed. VANOS was first introduced in 1992 on the BMW M50 engine.
VANOS changes intake valve timing at set points in the engine RPM range
Position one, normal position (No Advance)
Position two, advanced position (12.5°)
Early Ford Escorts used a similar system

Activation Parameters

The activation parameters are influenced by the following input signals:
• Engine speed
• Load (intake air mass)
• Engine temperature
• Camshaft position
• Oil temperature
Phase I changes intake valve timing at set points in the engine RPM range
Mid-range valve timing is advanced by 12.5° to improve mid-range power
With the engine idling, intake timing is retarded (back to zero advance) for better idle quality



With the engine idling, intake timing is retarded (A fixed normal position) for better idle quality

Takes advantage of Draw Through

Valve overlap causes the intake “draw through” effect to increase the mixture pulled into the cylinder (The “draw through” effect is caused by the

hot exhaust gas shrinking as it is cooled)
This action results in improved mid-range performance

Improved Mid-range Performance

The small amount of exhaust gas that mixes with the fuel mixture produces internal EGR action
The amount of EGR is determined by the amount of overlap

To eliminate an external EGR, the variable valve control system requires a range of authority of 20° to 25° degrees of crank rotation

Improved Fuel Charge

Advanced intake valve timing at idle will result in an erratic idle
Delaying the intake valve timing advance until mid-range engine speed, solves the poor idle problem and gives improved performance

Internal EGR Action

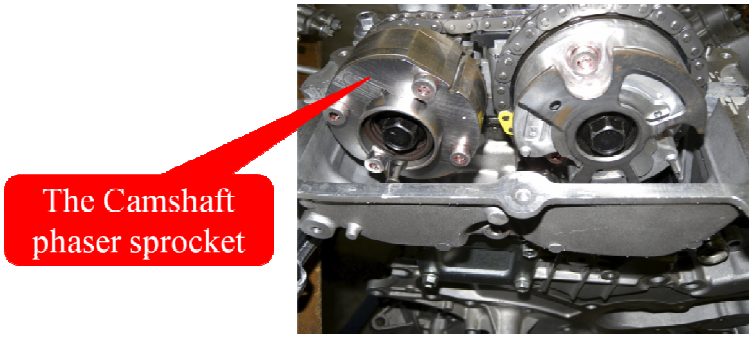
Internal EGR has several advantages
It eliminates the need for an external EGR
Exhaust gas is mixed inside each individual cylinder, which reduces the unbalanced mixing that can occur with an external EGR
Balanced EGR action allows the engine designer to increase compression ratios without pre-ignition or spark knock, this results in improved performance

Phase I Cam Phasing Summary

Sets valve timing in two discrete steps; this system has limited timing authority

1. Idle valve timing is retarded for smooth idle (Normal Position)
2. Mid-range engine speed intake valve timing is advanced 12.5 degrees for improved torque

This type of Cam Phasing (two discrete steps) is the now called phase one of valve timing
Cam Phasing does not vary valve lift, which is needed for large changes in high end performance

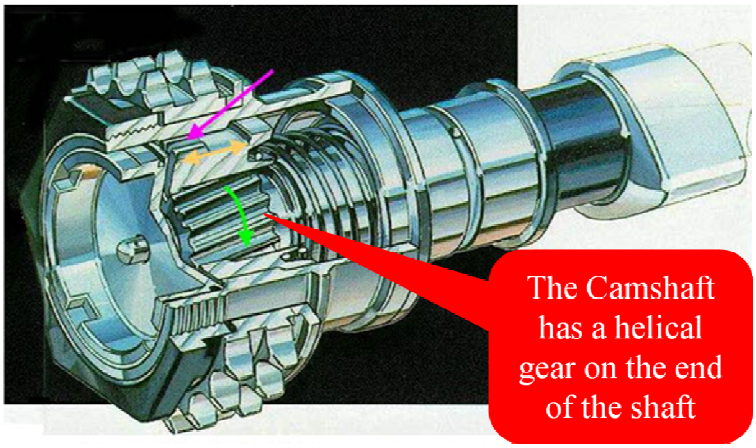


Phase 1 Hardware

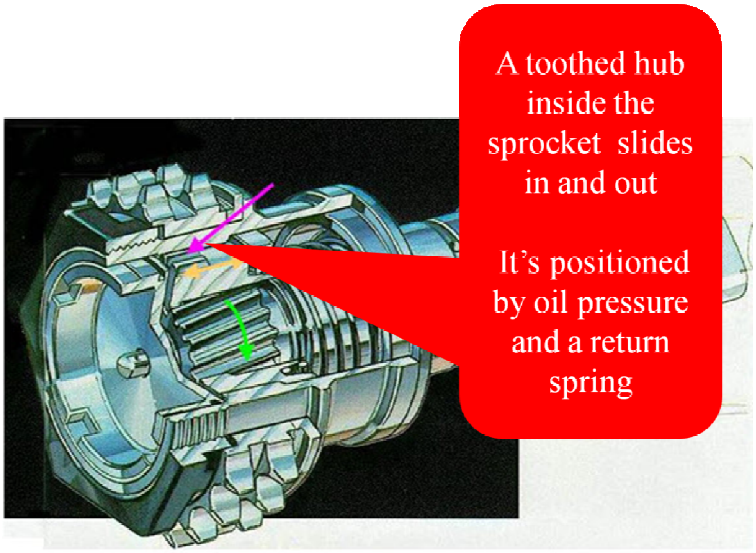
Uses a double chain to drive the camshafts
The intake Camshaft sprocket is not bolted directly to the camshaft

The Camshaft has a helical gear on the end of the shaft

A toothed hub inside the sprocket slides in and out

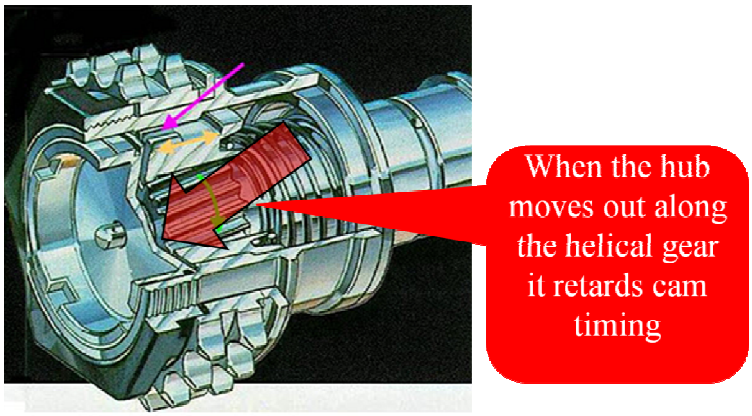


It's positioned by oil pressure and a return spring
The oil pressure control valve is used to position the hub on the helical gear
Uses 3 to 4 liters per minute of oil flow from the oil pump
The oil pressure is either on or off
When the hub moves in along the helical gear it Advances cam timing



The return spring forces the sprocket out when the oil pressure is removed

A phaser uses 3 to 4 liters per minute of oil flow from the oil pump to control valve timing.
Requires a larger oil pump and <u>clean oil</u>

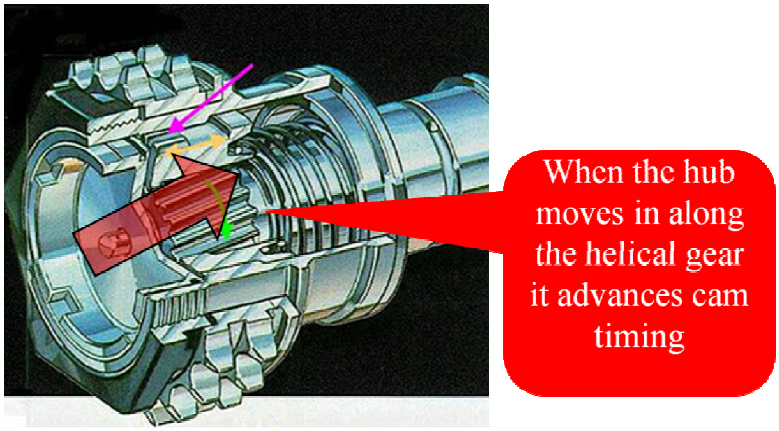


Advancing cam timing

Cam timing is advanced by oil pressure forcing the hub into the gear

Cam timing is retarded removing oil pressure so the return spring can force the hub out

Cam Phasing and Oil



The phaser may not operate correctly if the vehicle manufacturer's oil recommendations are not followed
Low oil level or dirty oil can impair phaser operation; this is a typical cause of failure
Neglected oil changes have been identified as the cause of early phaser failures by several manufacturers
This may be the reason BMW changes oil as part of the driving experience

VANOS Advantages

Cam Phasing increases mid-range engine output and torque
CAM Phasing has good idle quality with improved fuel economy
Inexpensive, simple and eliminates the external EGR
Ford Zetec engine has discrete intake cam phasing (Later versions use a continuous cam phasing)
These engines have two steps to their cam timing, which may not be ideal for all operating conditions or eliminating the external EGR
Newer designs use continuous valve phasing

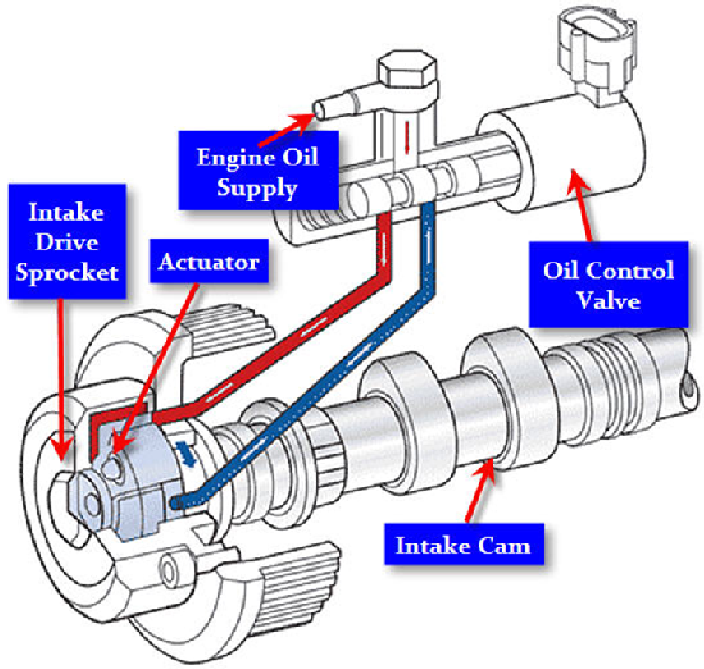
Continuous Valve Phasing

Continuous variable control uses controlled oil pressure to position cam phasing vane that continuously varies cam timing
An electrical solenoid controls a spool valve that opens or blocks two oil passages providing directional control

Hold current position
Advance timing
Retard timing

Intake Valve Phasing

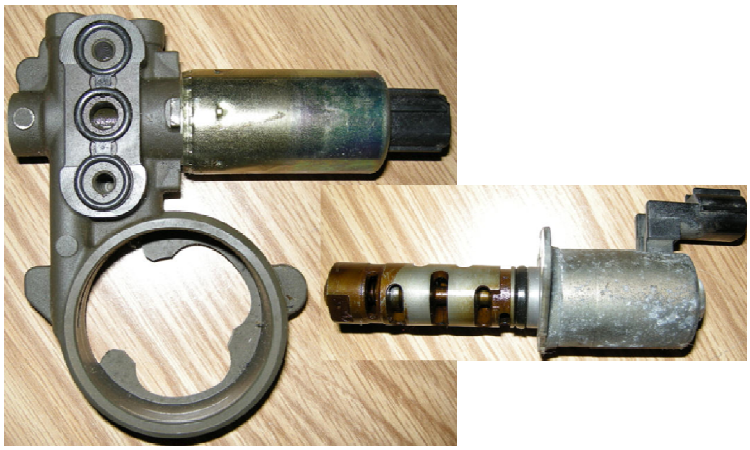
A control valve directs pressure to one side of the rotor's vanes or the other, rotating the rotor as required advancing or retarding the camshaft as directed by the engine computer
Position changes are verified by monitoring changes in cam position signal
A typical VVT oil control solenoid is driven by a 300 HZ signal that uses duty cycle control



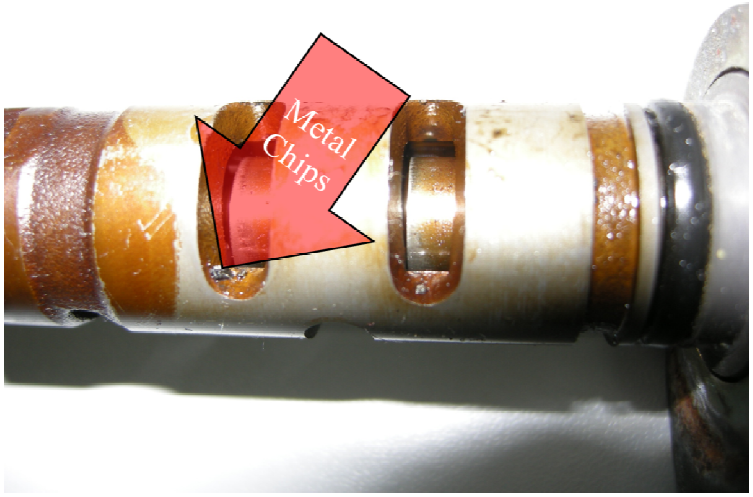
Valve Phasing

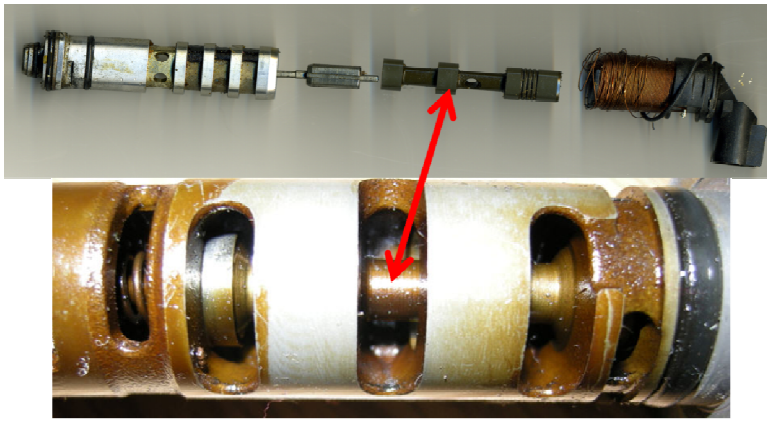
A typical VVT oil control solenoid is driven by a 300 HZ signal that uses duty cycle control to position the phaser

Oil control valves



These are magnets
They collect metal particles





The linear valves have a spoon inside to direct oil pressure

Dirty Control Valves

We are finding problems with poor maintenance that cause severe problems
Ford 5.4 L three valve engines are blowing spark plugs out of the head because of stuck VVT controls and minimum plug treading
GM is having problems because a screen filter ahead of the control becomes clogged; the timing cover has to be removed to clean the filter

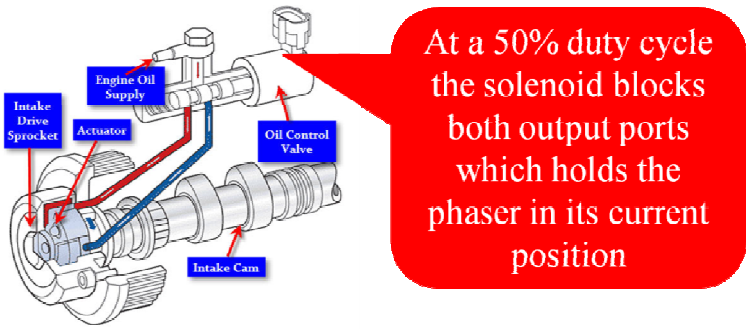
Cylinder Head Repair Kit

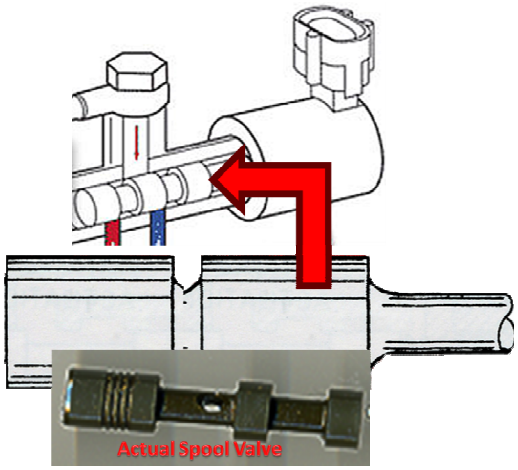
Special head repair kits are available; beware of difficulty getting access to the engine to repair damages cylinder heads



Continuously Variable Valve Control

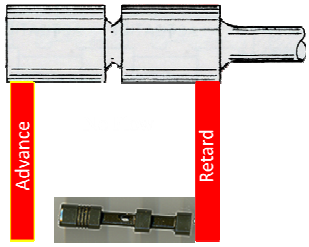
At a 50% duty cycle the solenoid blocks both output ports which holds the phaser in its current position

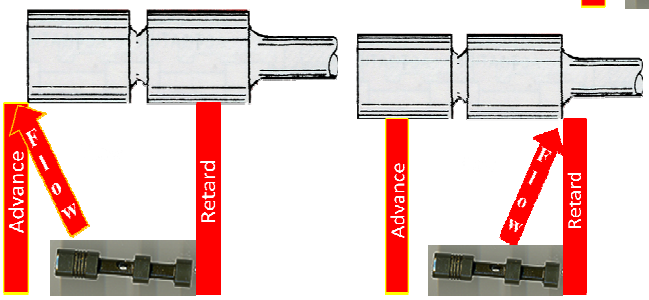




Typical Spool Valve

The spool valve is in the center of the control valve housing. The solenoid winding are used to move the spool into the desired position.



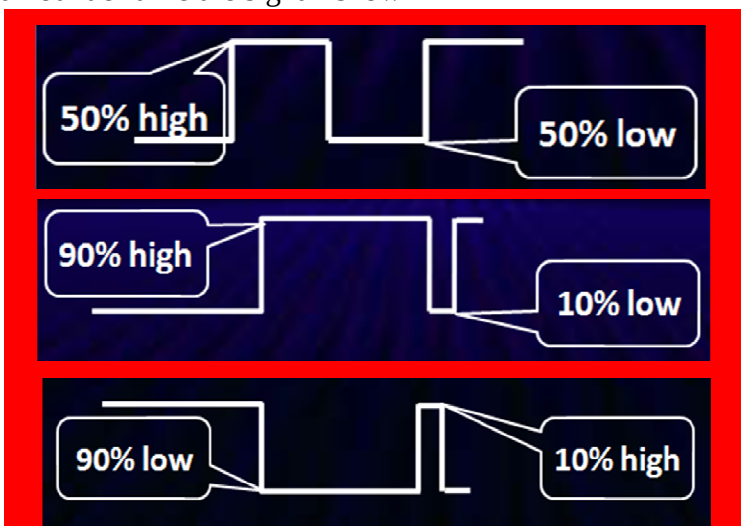


50% duty cycle holding phaser Position

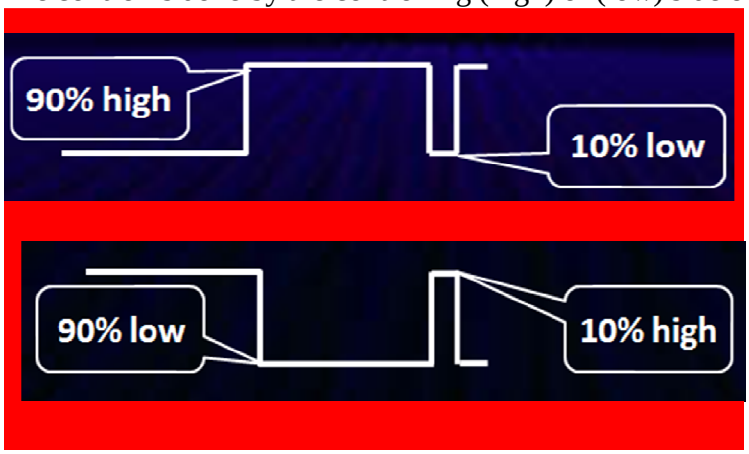
The spool blocks both the advance and retard ports which results in no oil flow. The cam phaser remains in its current position.

Duty Cycle Control Summary

Cam control duty cycle is varied around a midpoint known as the “holding mode” which is 50% duty cycle, current flow will be in the middle of its range; this holds the valve in the center
Cam timing is retarded with a lower duty cycle that results in lower current flow
Cam timing is advanced with a higher duty cycle, which results in higher current flow.
PWM is based on Duty Cycle where the amount of time the signal is high is compared to the amount of time the signal is low



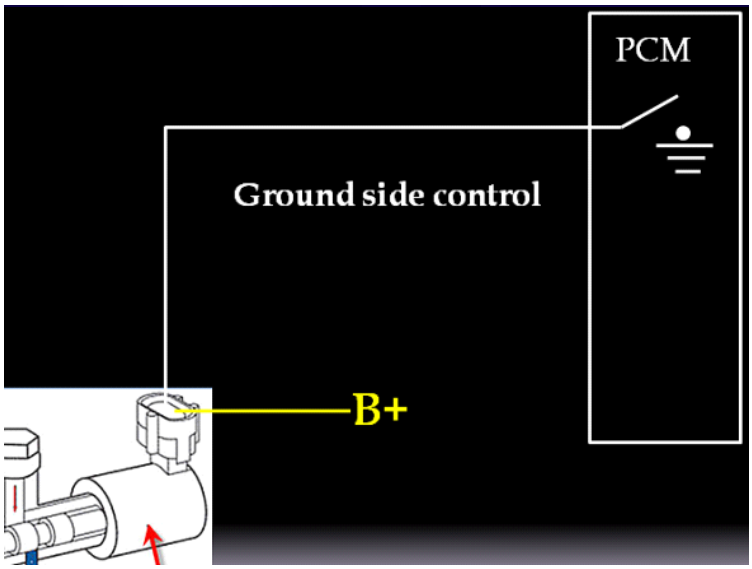
The control is done by the controlling (high) or (low) side of the solenoid coil



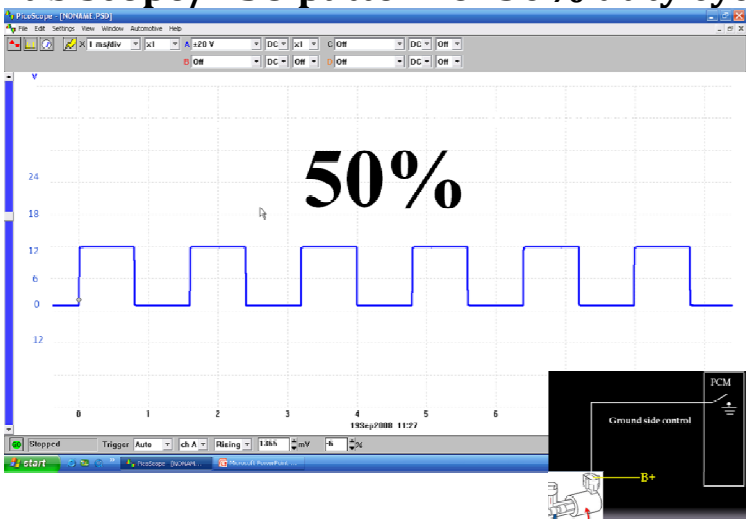
Ground side switching is low side control
B+ side switching is high side control
You need to know which control system is used to determine the control direction.
Fortunately, we use scan data where the calculation is already done.

High Side Control

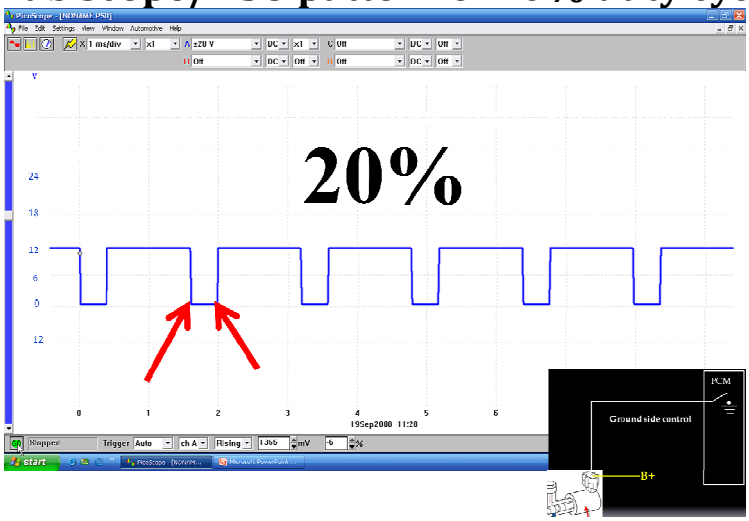
The PCM applies B+ to energize the solenoid in the control valve.



Lab scope/DSO pattern of 50% duty cycle

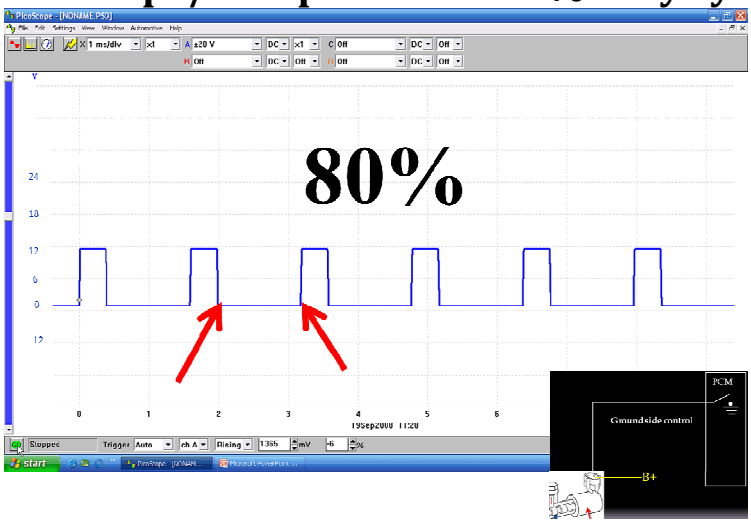


Lab scope/DSO pattern of 20% duty cycle



Because low side control is used the amount of time the signal is low is measured.

Lab scope/DSO pattern of 80% duty cycle

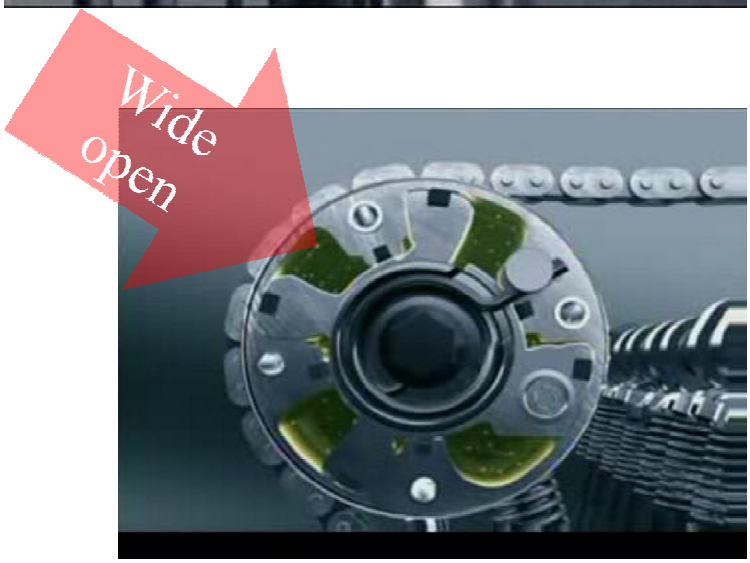


The low side is low 80% of the cycle.

Duty cycle versus valve opening

Low duty cycle is for retarding, which results in a lower current flow

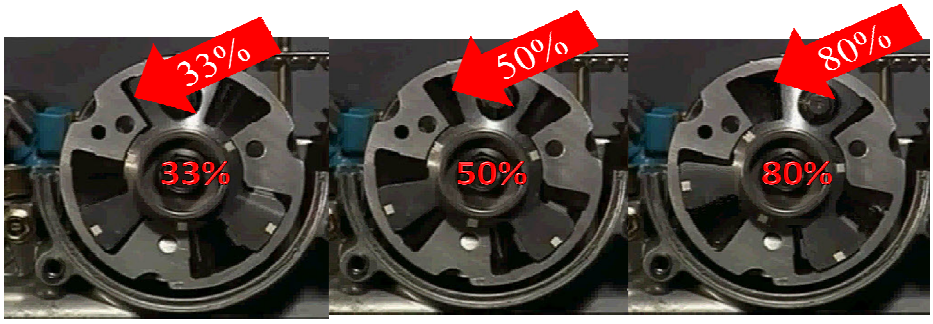




Higher duty cycle is for advancing, which results in a higher current flow
Higher current flow opens the valve more for higher oil flow.

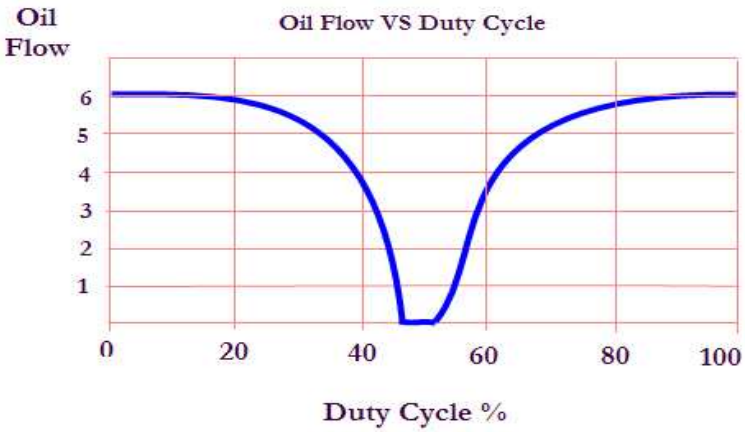
Duty cycle summary

Duty cycle control varies current flow which controls the opening of the oil control valve. This example is a rotary control valve.

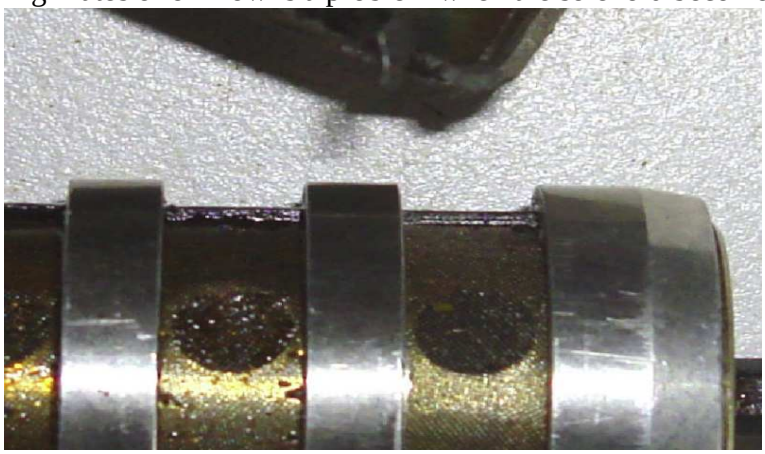


Oil flow versus duty cycle

Oil flow changes with duty cycle

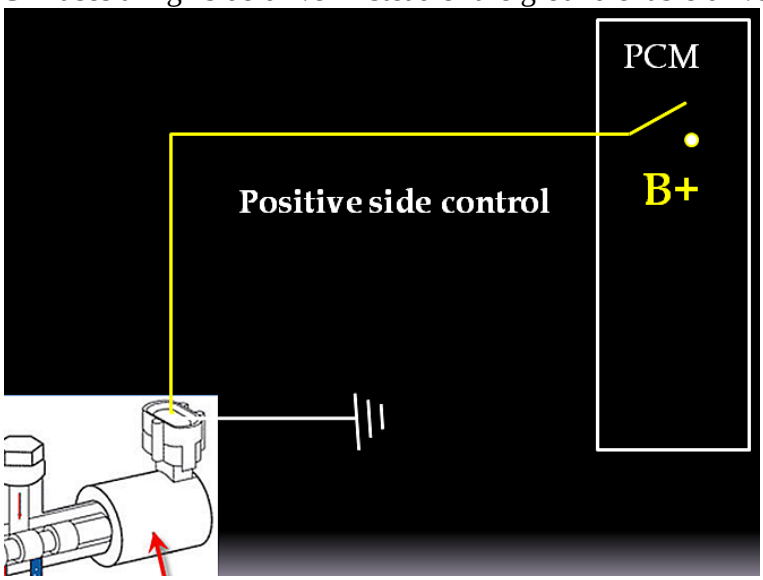


Oil flow will be low at 50% duty cycle
Oil flow increase away from 50%
Oil direction will change with duty cycle
High rates of oil flow is a problem when the solenoid becomes contaminated



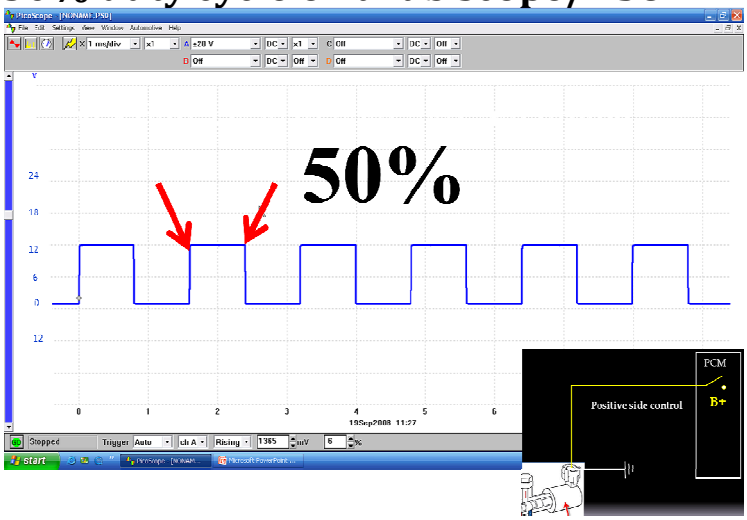
GM's Continuous Variable Control

GM uses a high side driver instead of the ground enable driver

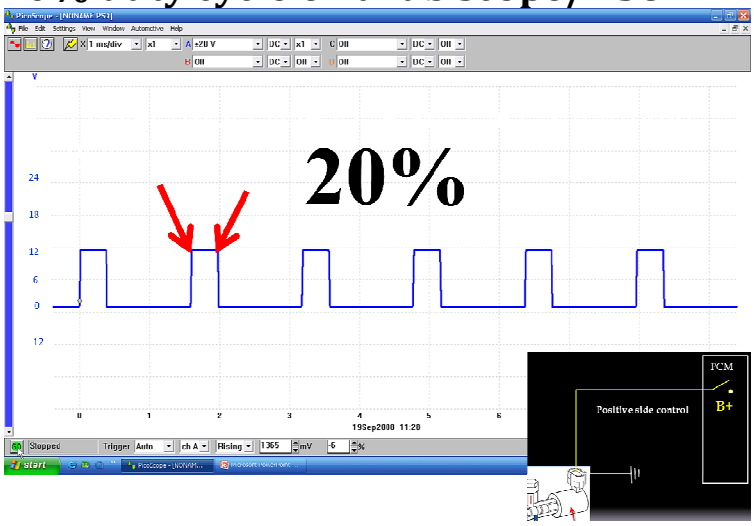


B+ is applied to energize the solenoid

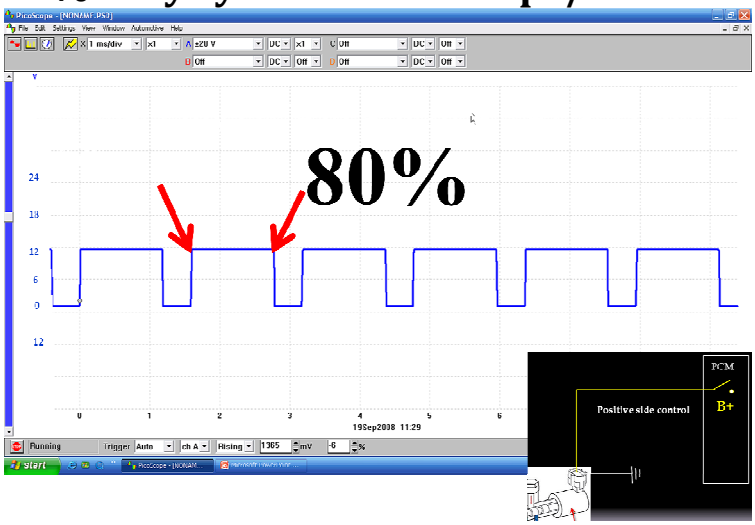
50% duty cycle on a lab scope/DSO



20% duty cycle on a lab scope/DSO



80% duty cycle on a lab scope/DSO



This section was covered to help you avoid the mistake we made early on when we assumed all duty cycles values were the same. The lab scope pattern will be different for high side and low side control circuits. Remember, scan data is going to be used to check duty cycle; this helps you understand the scope pattern.

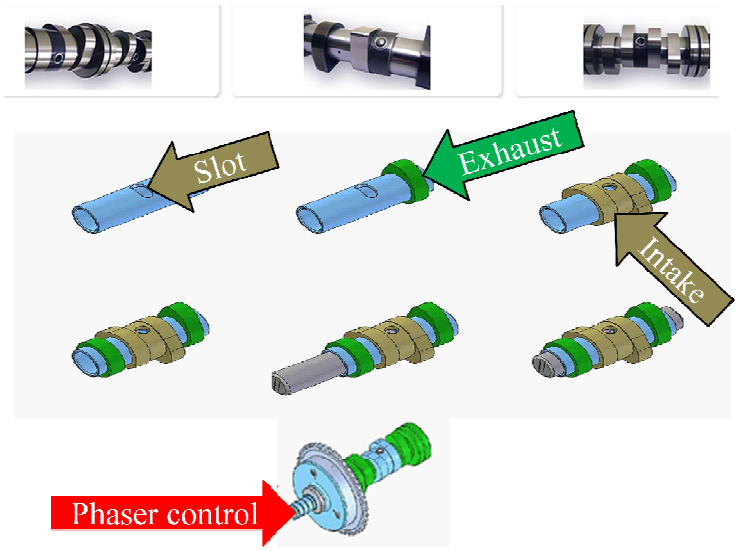
Ground and High side Drivers

Both drivers, low and high side control, have the "hold position" is in the center (50% duty cycle) with current in the center of its range.

Chrysler's Single Overhead Cam Timing

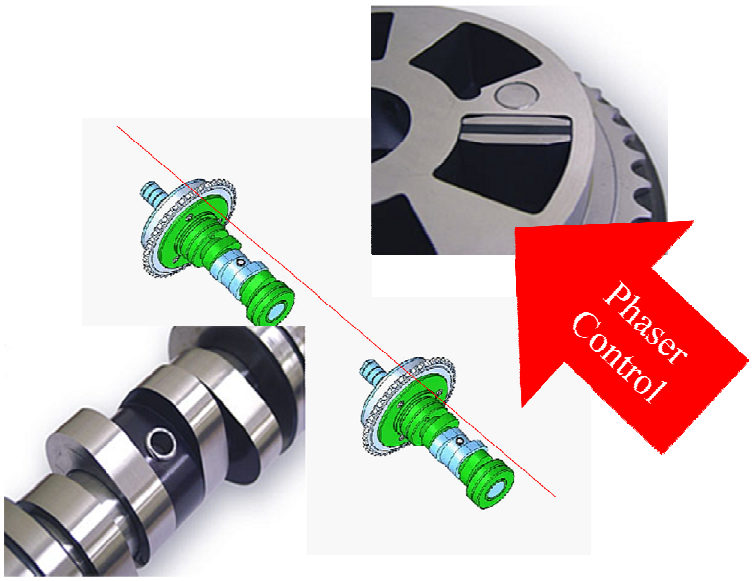
The camshaft is two concentric camshafts in a single assembly - **A cam within a cam**
Cams are made from a solid inner camshaft and an outer cam tube assembly
They contain two types of cam lobes
Fixed cams: These are fixed to the outer cam tube
Moving cams: These are pinned to the inner camshaft through slots in the outer tube

The phase of the moving cams is controlled by the inner camshaft and the phase of the fixed cams is controlled by the outer cam tube
The exhaust lobes are conventionally attached to the outer shaft
The intake lobes, are keyed to the inner shaft with pins



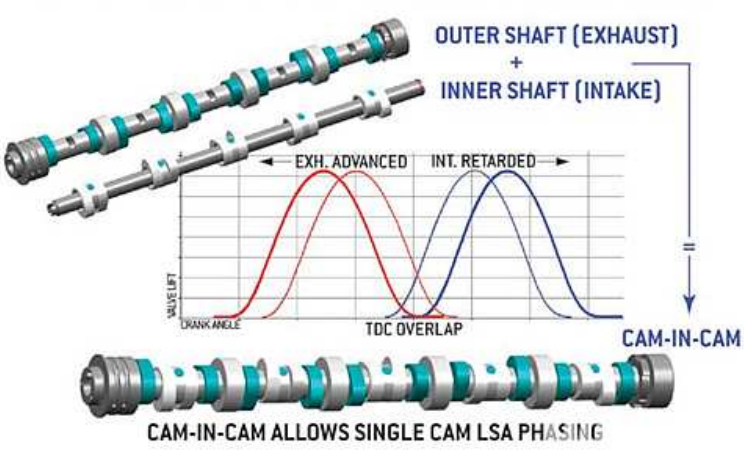
Utilizing 40 degrees of authority

Minimal valve phasing = Minimum overlap for smooth, quiet idle and clean emissions
Maximum valve phasing= Large overlap to boost power
Between idle and 3000 rpm, depending on throttle position, the overlap increases to the maximum amount



Chrysler's Single Overhead Cam



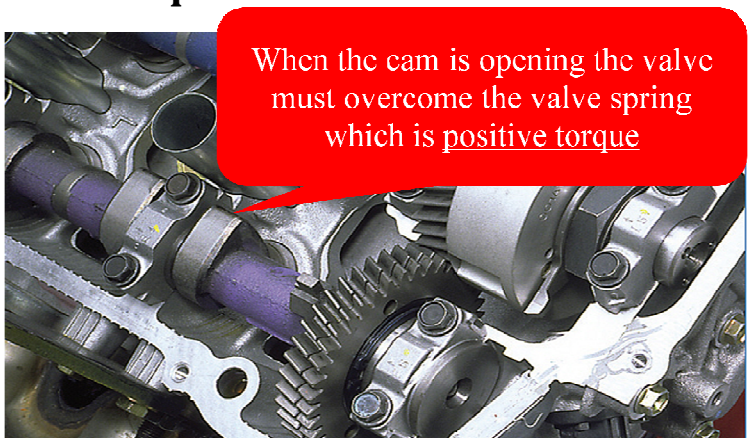


GM's Low Oil Flow Control

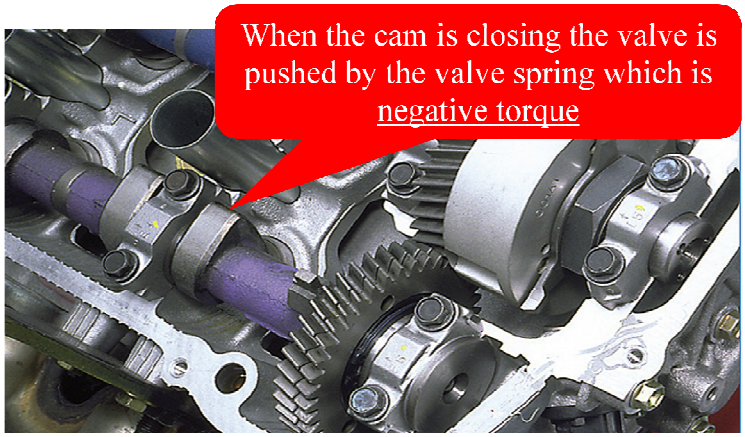
GM uses the new low oil flow phaser
GM's torque assists phaser
Torque is used to move the vane
The torque from the valves springs opening and closing are used to change the position of the vane.
Oil pressure is used to lock and unlock the vane



Cam Torque Patterns



When the cam is opening the valve must overcome the valve spring which is positive torque

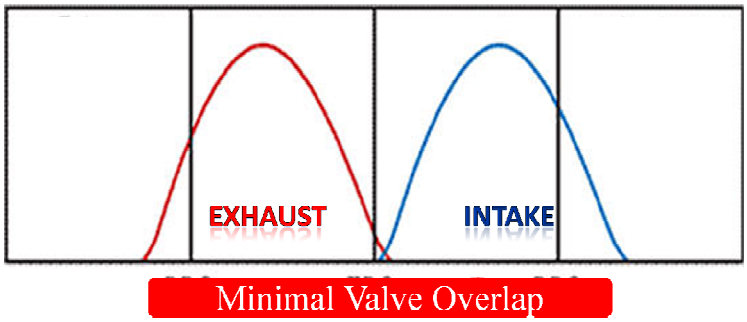


When the cam is closing the valve is pushed by the valve spring which is negative torque.

Continuous Valve Phasing logic

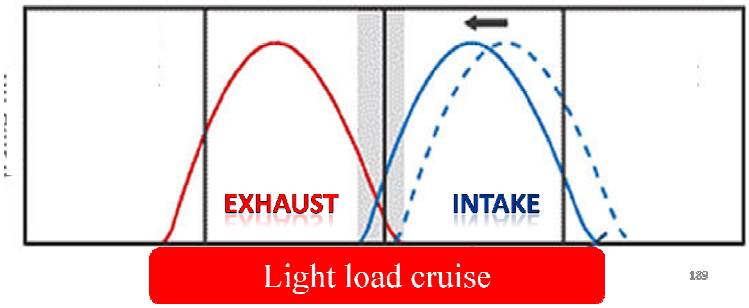
Continuous Intake Valve Phasing with Continuous Variable Control
Sometimes referred to as Phase 2 variable valve timing
CVC has more adjustment than the discrete two step change of phase 1
Continuous Variable Valve timing can be adjusted to match a wider range of operating conditions
The 20 to 25 cam timing degrees required to eliminate the external EGR is possible
The operating principles are the same as the discrete step version except for variable adjustments with more authority.
We have covered the control valves and now it's time to discuss the logic of valve control.

Valve timing for idle operation for smooth idle



The red exhaust curve has minimal overlap with the blue intake curve.

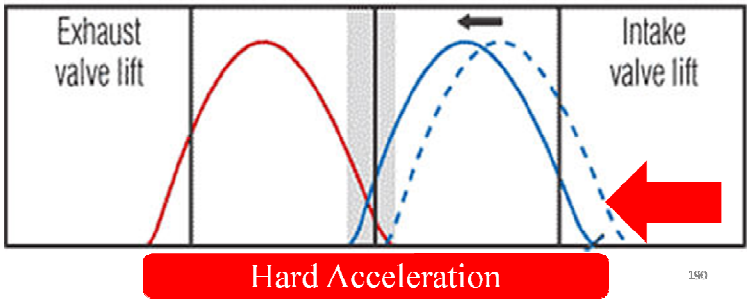
Valve Overlap



Solid line is for light load cruise where internal EGR and higher torque is needed.
The amount of overlap is adjustable.

Valve timing for hard acceleration

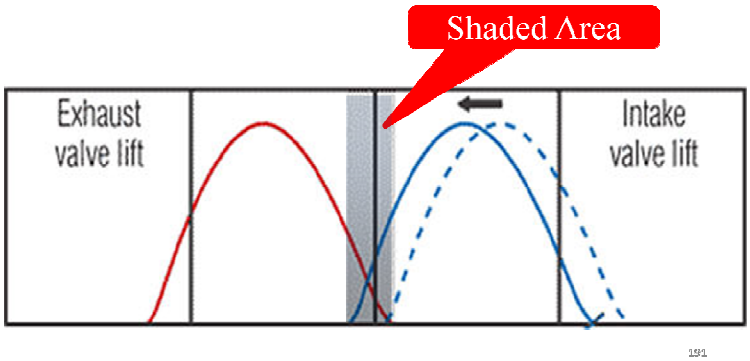
Valve timing position for hard acceleration with no EGR (dotted Line)



Minimal valve overlap on hard acceleration

Valve timing position for hard acceleration where no EGR is needed, shown with the dotted Line.

Minimal valve overlap is needed for hard acceleration.



Range of timing authority

Valve timing can vary in the shaded area on the chart.
The PCM determines the ideal timing based on conditions.

Valve timing by manufacturer

Toyota VVT-I uses CVVT
GM uses CVVT on their cars and trucks
Volvo modular engines use CVVT
Ford's uses CVVT on their newer cars and trucks
Mazda's S-VT uses phaser cam timing
Subaru's AVCS, active valve control system, uses CVVT
Many manufacturers have vehicles using CVVT
CVVT can be used with valve lift
Honda's I-VTEC (don't confuse with VTEC)

Exhaust and intake phasing

Exhaust and intake valve phasing is the latest trend in valve phasing
Exhaust valve phasing improves fuel economy and reduces emissions
Hydrocarbon is reduced by late exhaust valve closure recalculating some of the left over HC in the exhaust
NO_X is reduced with internal EGR and the wide timing authority that varies with conditions

Manufacturers with Dual cam timing

BMW Double VANOS
Ford Variable valve timing, later models
GM Continuous variable valve timing
Honda I-VTEC
Hyundai/Kia Continuous variable valve timing
Mitsubishi MIVEC
Nissan Continuous variable valve timing
Toyota Variable valve timing with intelligence
Volvo Continuous variable valve timing

Cam Phaser Summary

Variable cam timing can vary timing between 0 and 50 degrees of crank rotation, maximum authority varies with engine design
Some of the early systems are fixed at one value
Valve lift is the next part of variable valve control

Diagnose with Scan Data and codes

Use available Variable Valve Timing Scan Data when it is available

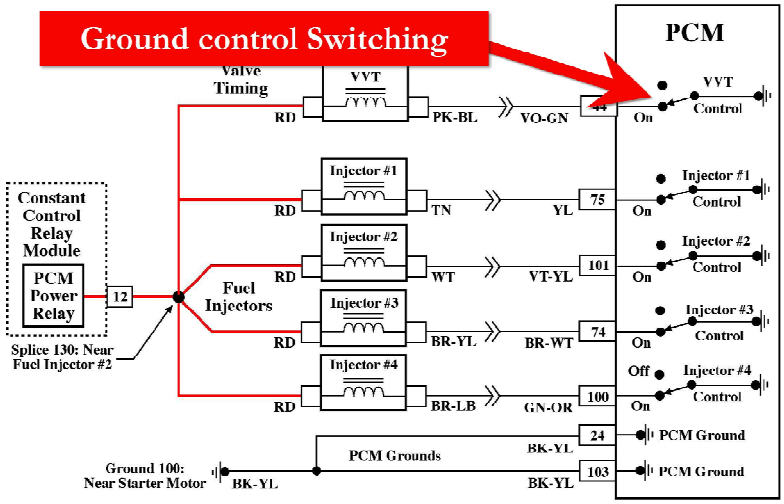
Diagnostic trouble codes

We are going to divide the codes into groups that relate to specific areas that need tests.

P0010 Intake cam position actuator circuit problem for Bank 1
P0013 Exhaust cam position actuator circuit problem for Bank 1
P0020 Intake cam position actuator circuit problem for Bank 2
P0023 Exhaust cam position actuator circuit problem for Bank 2

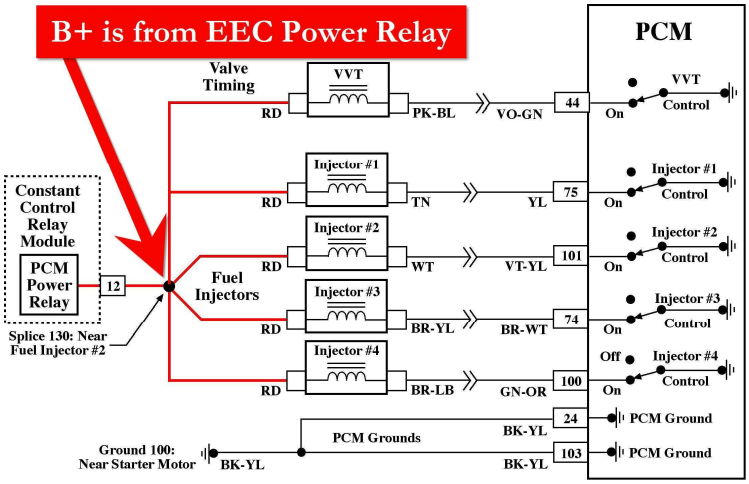
Actuator Circuit Problems

The PCM has determined the voltage signals do not match the expected values
Control voltage is determined by the type of control used
High side switching like GM supplies B+ to the control
Low side switching like Ford supplies ground to the control
Determine the type of control used
The duty cycle should dither around 50%; a sticking phaser will result in duty cycle that “hangs” outside 50% too long
Use Description of Operation in Service Publications…
Use vehicle specific information and schematics

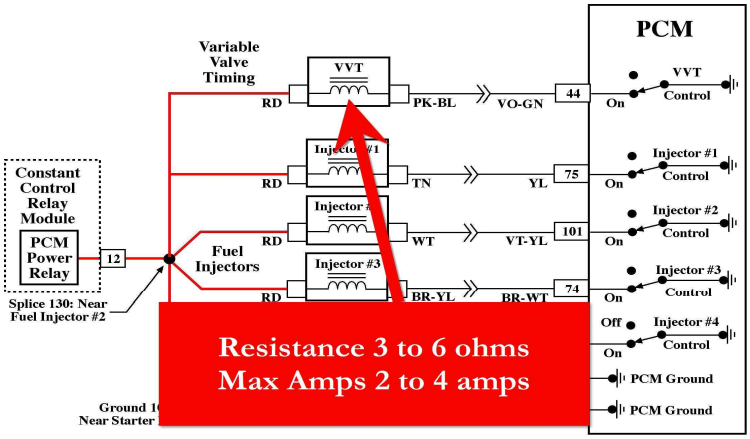


Diagnostics with Ground Side Switching

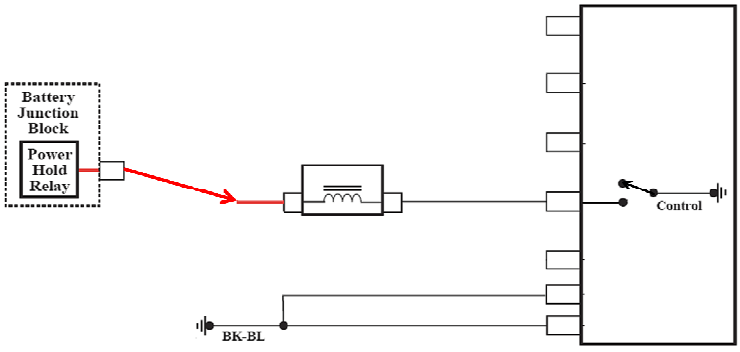
The first step is to identify the control system. This diagram shows ground side control.



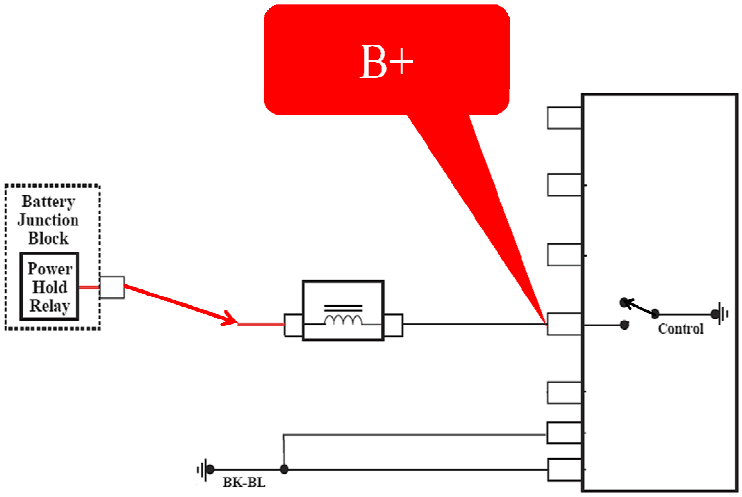
Next locate the B+ supply and verify that B+ is applied to the VVT control.



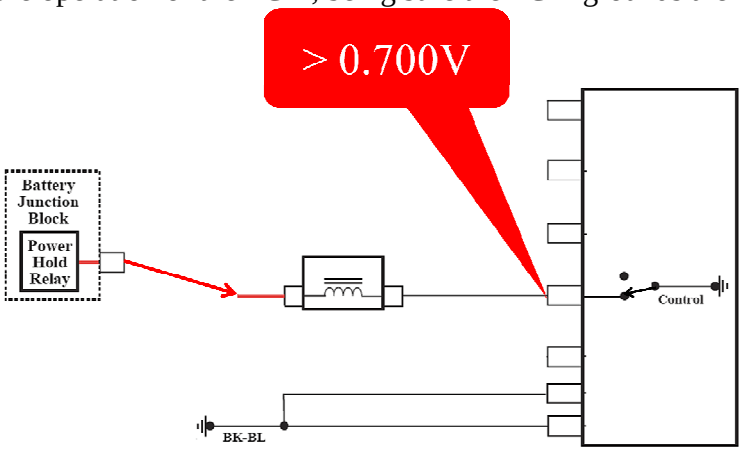
Locate resistance specifications if they are available. We can use ohms and amps testing to verify the operation of the valve control.



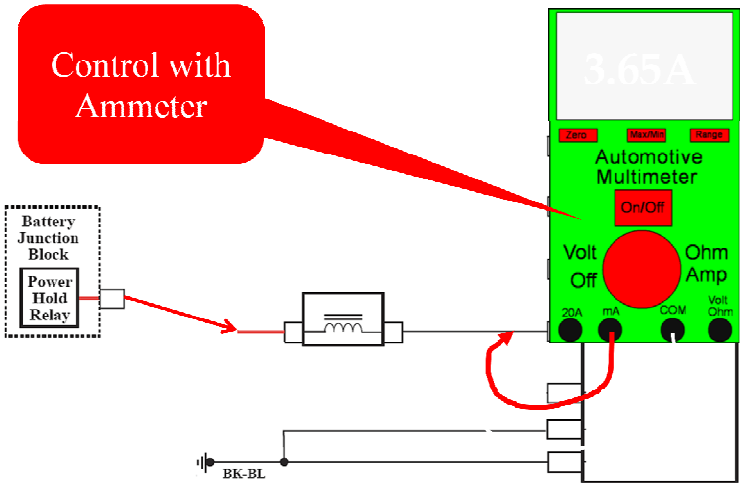
When there is a diagnostic trouble code for the actuator circuit. Test the B+ supply to the control. Make sure the fuse and relays are working properly if B+ is missing.



After verifying B+ is applied to the power side of the control, check the voltage at the control side of the valve. If B+ is present, the PCM is not supplying ground to energize the valve. Check the operation of the PCM, being sure the PCM grounds are not open.



Normal ground control voltage will be under 0.700 V when the solenoid is energized. The control signal should not be off or on all the time. Normal activity is for the PCM to control the valve with varying duty cycle.



Complete circuit testing can be done by using an amp meter to supply the ground to the control circuit. This test set up will show the maximum current, while fully advancing valve timing. Advancing valve timing at idle should cause rough idle, if the actuator is moving.

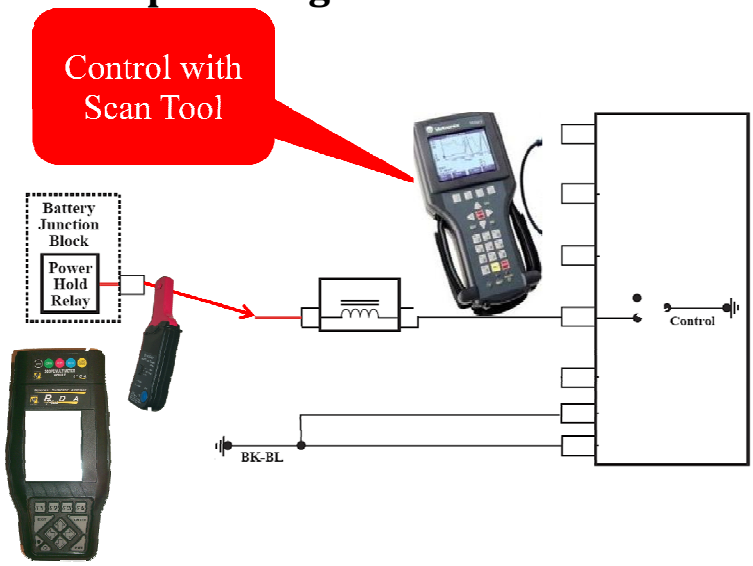
Current Measurement

The battery voltage will vary between 12.8 V and 13.8 V
Voltage divided by resistance equals Current.
Because of the varying voltage and resistance you need to do your own specifications
Example:

$$13.4\ V \div 4\ \Omega = 3.35\ A$$

This is the maximum current we expect to see with the amp meter supplying ground to the ground control circuit.

Low amps testing with a scan tool

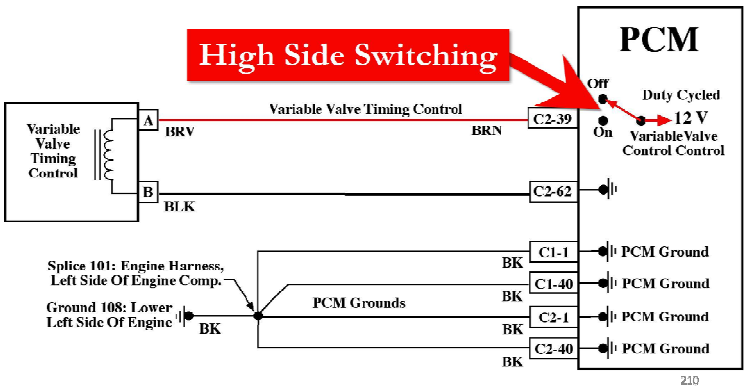


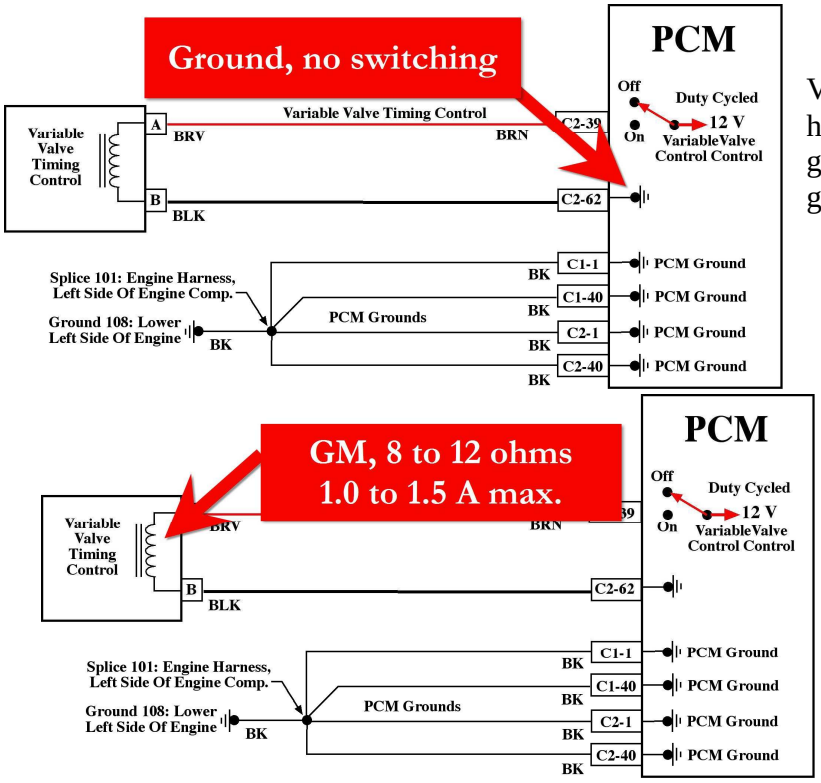
Use a scan tool to energize the solenoid and connect a low amps probe to measure the current flow.

Diagnostics High Side Switching

We added this because the rest procedures will be different. You must use the correct procedure for the control system to get valid test results.

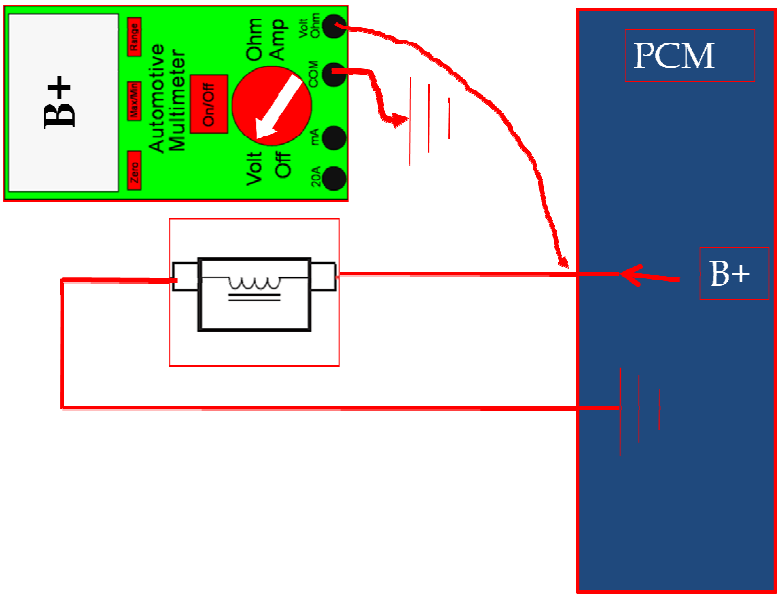
Identify the control system by using a vehicle specific diagram. This is high side switching where the PCM supplies B+ to energize the valve.



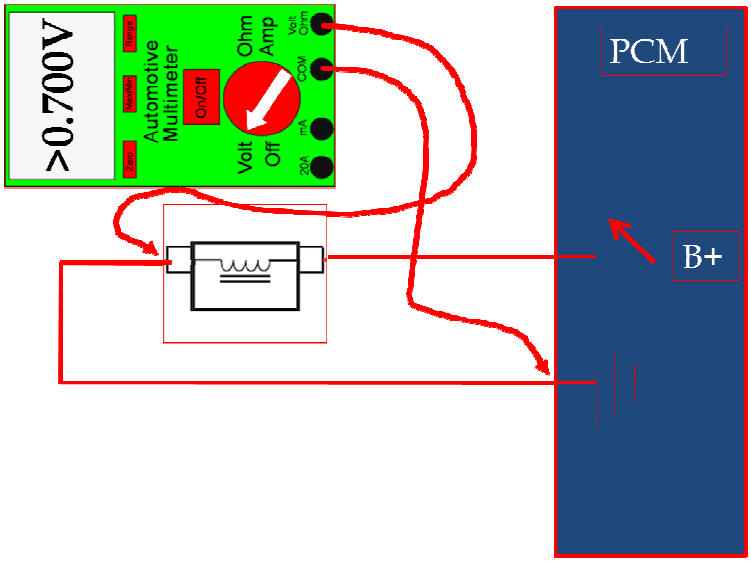


Verify the other side of the valve has a good ground. The PCM grounds are used to supply the ground from inside the PCM.

Locate resistance specifications if possible. Current can be used to test the valve operation and verify the condition of the circuit.



Check the control signal for B+. Normal circuit operation will have a varying voltage with duty cycle control.



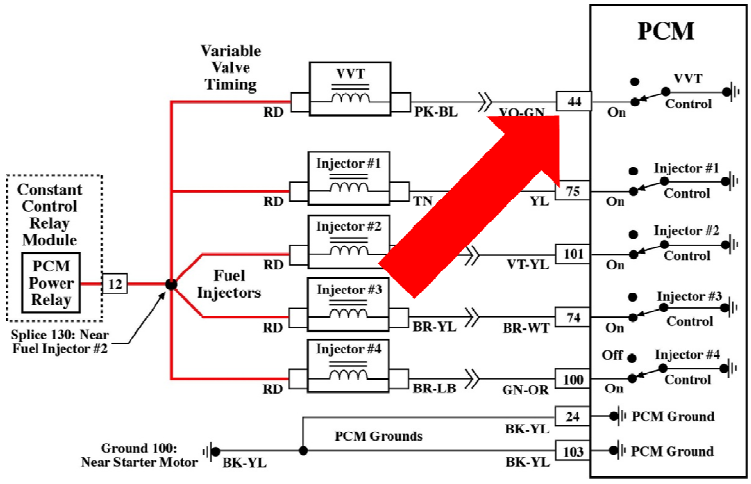
The PCM must supply ground to the solenoid for normal operation. Be sure the PCM grounds are normal.

Current flow testing

The resistance of the control can vary by manufacturer
Determine the maximum current flow by doing a current draw test
If max current can be reached, the actuator resistance is normal, check voltage during normal operation

Voltage Levels on Control Circuit

Testing with a voltmeter can give an indication of the duty cycle activity. We present this for shops that don't have a graphing voltmeter or lab scope. It is better to use a lab scope to study the patterns.
Duty cycle changes the average voltage on the control circuit



Connect your test equipment to the control signal; notice that this example uses ground side switching.
B+ = 13.8 volts
@ A 50% duty cycle (Ground Side)
Is 6.9 volts

B+ = 13.8 volts
@ A 40% duty cycle (Ground Side)
Is 8.28 volts

B+ = 13.8 volts
@ A 60% duty cycle (Ground Side)
Is 5.52 volts

If the circuit has high side switching the signal voltages will be different.
B+ = 13.8 volts
@ A 50% duty cycle (High Side)
Is 6.9 volts

B+ = 13.8 volts
@ A 40% duty cycle (High Side)
Is 5.52 volts

B+ = 13.8 volts
@ A 60% duty cycle (High Side)
Is 8.28 volts

Voltage Levels on Control Circuit

The duty cycle caused the average voltage to vary
The main thing to remember is the signals are specific to the type of switching used. We started our circuit testing because we are covering the diagnostic trouble codes that deal with circuit problems. Next we will look at scan data.
Use an enhanced scan tool that shows duty cycle for the valve timing actuator

VALVE TIMING SCAN DATA (GM)

CAM HI to LO [0 to 65534 (65535)]
CAM LO to HI [0 to 65534 (65535)]
Displays a count of the number of camshaft position sensor signal changes as voltage goes from Low to High and High to Low

CAM PHASE ACT (°) [0 to 25°] Actual value
The PCM's commanded camshaft retard in degrees

CAM PHASE DES (°) [0 to 25°] Desired value
Indicates the PCM desired camshaft angle

WATCH FOR DIFFERENCES IN ACTUAL AND DESIRED. Sticking and dirty control valves will have frequent differences that stay different for a period of time.

CAM PHASE DUTY (%)
[0 to 100%]
Displays the duty cycle the PCM is applying to the solenoid (Advance/Retard)

CAM PHASE VARI [0 to 25°]
Indicates the difference between desired and actual camshaft angle
This is another indication to watch to detect sticking control valves and dirty phasers

CAM REF MISSED [0 to 8]
Displays the number of cam/sensor pulses missed
0 is normal 1-8 not normal
For intermittent conditions only
If the signal is missing for a longer period it will read 0
This is a code for the cam pick up that is critical for cam timing operation.

CAM RETARD (°) [0 to 360°]
Displays the camshaft position sensor retard value in degrees

CAM SIG PRESENT [0 to 255]
Displays the number of the camshaft position sensor signal inputs into the PCM
Resets to ZERO after reaching 255
This number should count up to 255 smoothly then reset and start over.

VALVE TIMING SCAN DATA (FORD)

CAMDC 1 [0-100%]
CAMDC 2 [0-100%]
Indicates the duty cycle command to the solenoid
CAMDC 1 is Bank 1
CAMDC 2 is Bank 2
Both banks should have the same value.

CAMDCR [0 to 99%]
Indicates the retard time of the solenoid
Warm engine at idle = near 0%
Warm engine at a steady cruise speed = near 50%

CAMERR 1 [Range not published]
CAMERR 2 [Range not published]

Indicates the variable cam timing error in crankshaft degrees
CAMERR 1 is Bank 1
CAMERR 2 is Bank 2
A sticking control will show an error. The two banks should be equal.

VALVE TIMING SCAN DATA (CHRYSLER)

CAM SYNC START [Yes / No]
YES indicates the camshaft is locked, this is the normal value
NO all other times

CAM TIMING POS (°) [0 to 127°]
D**isplays variations from the *learned* camshaft position**

CAM /CRANK DIFF (°)
[0 to 17°]
Indicates the amount of change in phase between cam and crank signals from initial set
Indicates the amount of belt stretch
DTC sets at 17° or less (1 Tooth of Belt)

Service Codes for Intake Timing

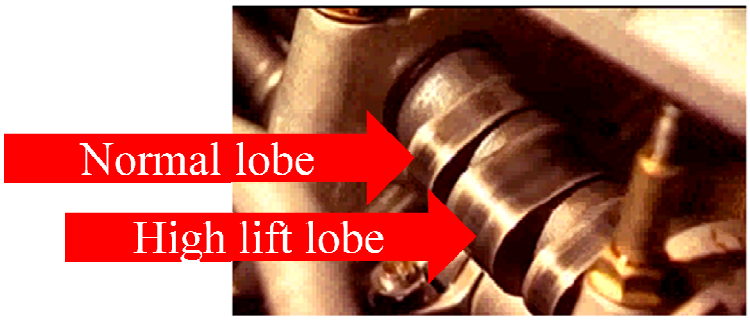
These are SAE codes that relate to the wrong cam timing. They may not be available on all vehicles.
DTCs that indicate the phaser is in the wrong position for the duty cycle commanded
P0011 Intake cam position is over advanced bank 1
P0021 Intake cam position is over advanced bank 2
P0012 Intake cam position is over retarded bank 1
P0022 Intake cam position is over retarded bank 2

Root Causes of Failures

We are repeating somewhat but this is important information. This relates to the position codes listed above.
Oil pressure should be normal at 1500 RPM for proper phaser operation
Low oil pressure can cause erratic phaser operation
Dirty oil or oil that is the wrong specification can cause erratic operation
Check for sludge in the valve cover because this is one cause of problems

VARIABLE VALVE LIFT

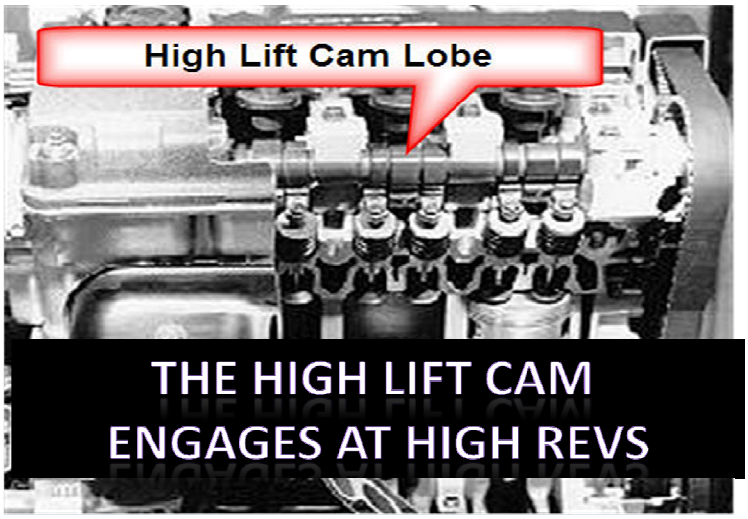
Valve lift is the next step and it offers more increased horsepower that valve timing alone.



\ there is two methods of doing Variable valve lift systems

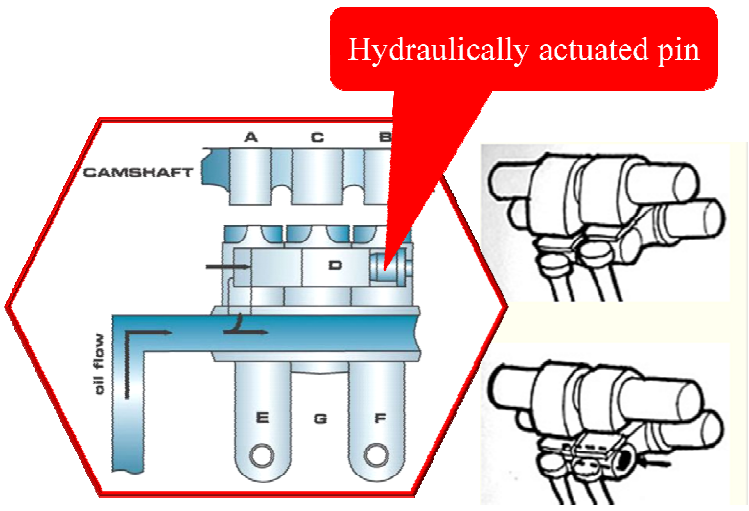
- Step changes at an operating point
- Continuously variable

This example is the Honda VTEC. Variable valve lift is used to improve performance while improving fuel economy for normal driving patterns
Early systems like Honda's VTEC change valve timing and lift above a specified speed
The PCM switches cam profiles between 5600 and 6000 RPM where engine power jumps by 20 horse power



Honda's Variable Valve Lift VTEC

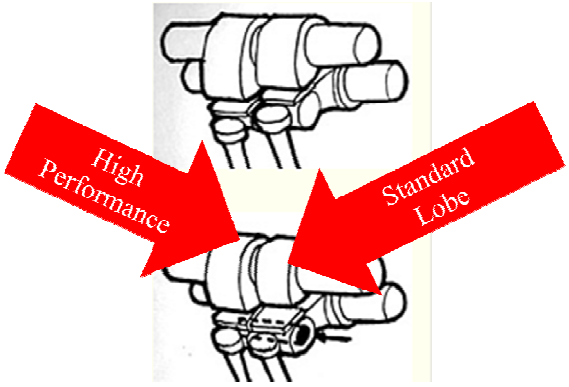
Two sets of cam lobes are used for valve timing and lift
During low speed operation the valves run on a standard cam lobe
Above *5500 to 6000* RPM the PCM switches to a high performance cam lobe



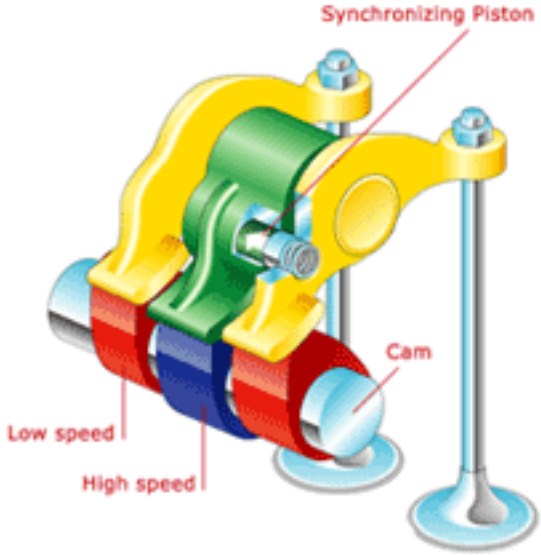
VTEC Operation

The basic mechanism used by the VTEC technology is a simple hydraulically actuated pin
This pin is hydraulically pushed horizontally to link adjacent cam lobes. A spring mechanism is used to return the pin back to its original position when pressure is released

The cam lobe on the left has a high performance profile, it will open its valve earlier, open it more, and close it later, compared to the one on the right



The pin actuation mechanism links the mild-cam lobe to the performance lobe
This effectively makes the two lobes work as operate as one with the performance lobe opening earlier and closing later



This "composite" cam lobe now clearly follows the performance cam profile of the left
The color codes graphic shows the actual arrangement of the lobes.
The performance lobe is in the blue lobe, the two normal lobes are red

Honda VTEC Notes

The VTEC system is extremely reliable
Low oil pressure can cause a failure to switch to the high cams

Cam grinding has been a problem; both sets of lobes must be matched carefully to insure the locking pin goes into position easily

VALVE LIFT WITH THROTTLE CONTROL

Continuously variable valve lift can be used to control engine speed
Intake valve control on engine speed has unexpected advantages



Eliminate the Throttle Plate
Eliminate Pumping Loss

Intake throttle plate control

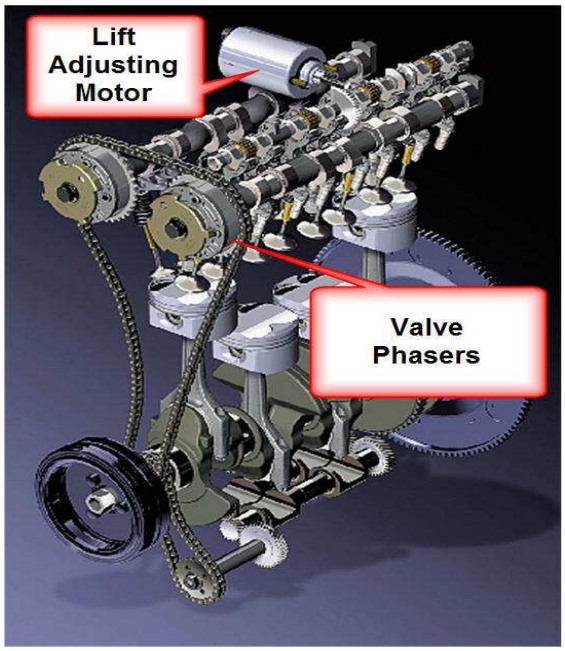
The throttle plate restricts intake air entering the manifold creating a partial vacuum to limit engine speed
The engine must overcome this vacuum to pull air into the cylinder
The work done to overcome the partial vacuum is called throttling losses

Throttle Losses

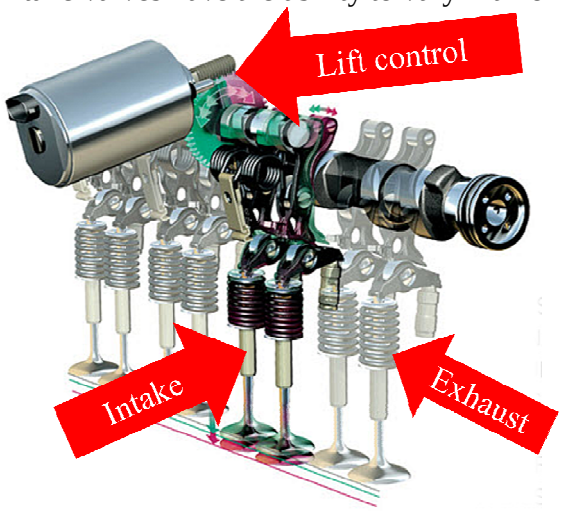
Controlling engine speed can be done with intake air control or fuel control
Fuel control has limited control without causing performance problems
Variable Intake valve lift can eliminate the throttle plate in the intake by controlling the air entering the cylinder
Valve controlled throttling has very little manifold vacuum because the intake is not restricted
BMW was the first to use valve lift control of engine speed

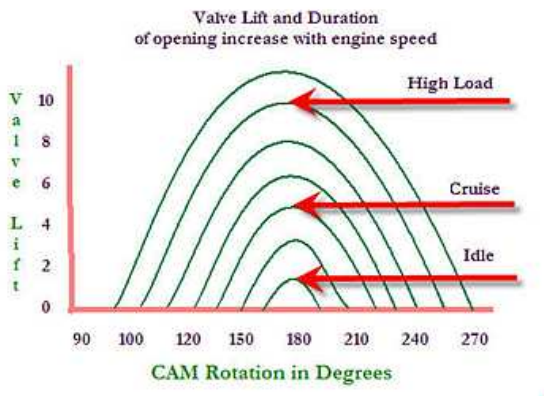
BMW Valvetronic

BWM's Valvetronic uses continuously variable valve lift and cam phaser timing control
Valvetronic is the first to use valve control to control engine speed instead of a throttle plate to restrict intake air
Valvetronic has a throttle plate that is closed for starting the engine then completely opens for valve controlled engine speed, it is a backup safety device in case of a failure
The throttle plate is used for emergency idle control (limp in mode)



Valve timing uses a valve phaser to control timing.
A lift adjusting motor is used for controlling intake valve lift.
Intake valves have the ability to vary lift from 0 mm to 12 mm or anything in between





Intake valves have the ability to vary lift from 0 mm to 12 mm or anything in between.
Short duration and low valve lift is limiting air intake to control idle.
Valve lift between 2 and 5 mm gives the best fuel economy during cruise.
Maximum power is developed with valve lift over 10 mm.

Variable Valve Lift and Timing advantages

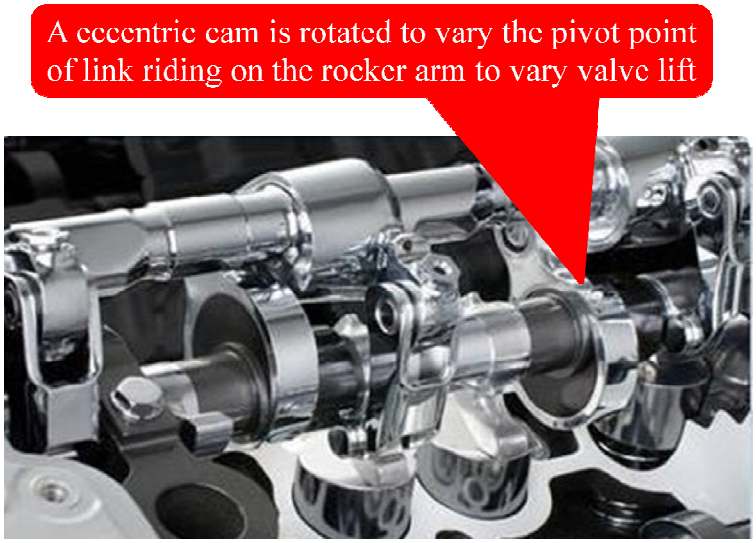
Catalyst warm up is improved by optimized valve timing for cold start up.
Low valve lift is used in the low to mid-range to reduce hydrocarbon emissions.

BMW Valvetronic Disadvantages

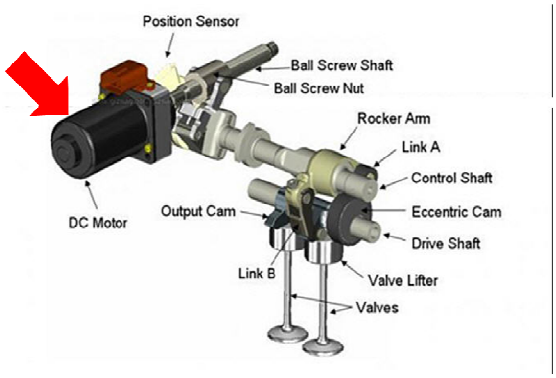
The valve train has a large mass which limits the maximum Revs
The system is expensive

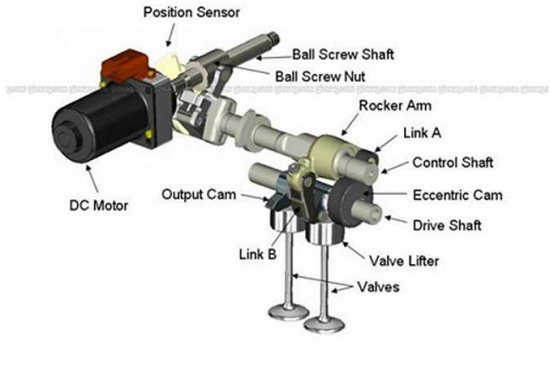
Nissan Variable Valve Event and Lift- VVEL

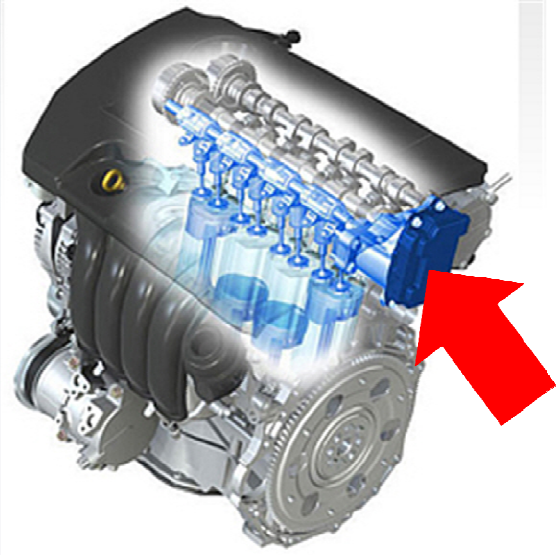
Nissan has a similar valve lift system that also controls cam timing with a phaser control
The lift control uses an eccentric cam to vary the amount of lift, eccentric means the hole in the disk is not in the center of the disk, it is offset to one side.
This is a good system to study because it is easier to visualize. All the system operate in a similar fashion



An electric motor drives a screw shaft with a ball nut to vary the position of a control shaft







Toyota's Valvematic

Toyota's Valvematic uses an electric motor, like BWM and Nissan, to continuously vary intake valve timing and eliminate the throttle plate in the intake bore



Variable Lift Summary

Lift can be a step function like the Honda of continuously variable like most other manufacturers
Most of the diagnostics rely on trouble codes, but engine performance changes are likely if a problem develops

Valve Lift Codes

P0026 Intake valve lift control actuator has a circuit problem for bank 1
P0027 Exhaust valve lift control actuator has a circuit problem for bank 1
P0028 Intake valve lift control actuator has a circuit problem for bank 2
P0029 Exhaust valve lift control actuator has a circuit problem for bank 2
P0075 Intake valve control actuator has a circuit problem for bank 1
P0076 Intake valve control actuator has low voltage for bank 1
P0077 Intake valve control actuator has high voltage for bank 1
P0076 Intake valve control actuator has low voltage for bank 1
P0077 Intake valve control actuator has high voltage for bank 1
P0078 Exhaust valve control actuator has a circuit problem for bank 1
P0079 Exhaust valve control actuator has low voltage for bank 1
P0080 Exhaust valve control actuator has high voltage for bank 1
P0081 Intake valve control actuator has a circuit problem for bank 2
P0082 Intake valve control actuator has low voltage for bank 2
P0083 Intake valve control actuator has high voltage for bank 2
P0084 Exhaust valve control actuator has a circuit problem for bank 2

Valve Lift Diagnostics

Diagnose these codes in the normal fashion
Codes for voltage deal with circuit problems
The valve lift uses a position sensor and reports desired and actual valve lift actuator

VALVE CONTROL FOR CYLINDER DEACTIVATION



Bad memories of the 1981 8-6-4 engine can be put to rest
The biggest advancement in cylinder deactivation is the use of sophisticated electronic control
Computers are now 50 times faster than the one used in 1981

Cylinder Deactivation Operation

Chrysler's cylinder deactivation is called Displacement on Demand (uses a special set of lifters which are referred to as "lost motion devices")
GM uses a similar system that is called Active Fuel Management
Both systems use special lifters
Deactivation Roller Hydraulic Valve Lifters (DRHVL)
Both systems work with the Eaton lifters and Delphi controls to selectively deactivate cylinders



The power comes back in about 3 msec when the throttle is moved
Highway gas mileage shows a marked improvement if the vehicle is driven properly.
These are 8 cylinder engines that can cruise on 4 cylinders, if the operator does not demand too much power
Honda's variable cylinder management is used on 4 and 6 cylinder engines.
In typical light load driving the driver uses only around 30 percent of an engine's maximum power
Deactivating cylinders can decrease fuel consumption by 8% to 25%, the driving cycle limits when cylinder deactivation can be used. It is only available for low power demand conditions.
Cylinder deactivation captures an air charge when the systems is activated to prevent the dead cylinder from acting as a pump
This reduces pumping losses and increases pressure in each operating cylinder



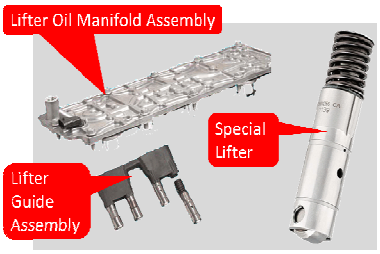
Cylinder deactivation is achieved by keeping the intake and exhaust valves closed during deactivation
Keeping both valves closed creates an 'air spring' in the combustion chamber.
Exhaust gases are compressed during the upstroke.
The "air spring" pushes down on the piston during its down stroke.
The compression and decompression of the trapped exhaust gases have an equalizing effect – overall, there is virtually no extra load on the engine. The PCM cuts fuel/spark to the disabled cylinders.
The transition between normal engine operation and cylinder deactivation is smoothed using changes in ignition timing, throttle position and valve control.
In order to deactivate a cylinder, the exhaust valve is prevented from opening after the power stroke and the exhaust gas charge is trapped in the cylinder and compressed during the exhaust stroke. This requires precise timing with a fast PCM which was not possible back in 1981.
When more power is called for, the exhaust valve is reactivated and the old exhaust gas is expelled during the exhaust stroke. Then the intake valve is reactivated and normal engine operation is resumed. The reactivation takes about 3 msec.

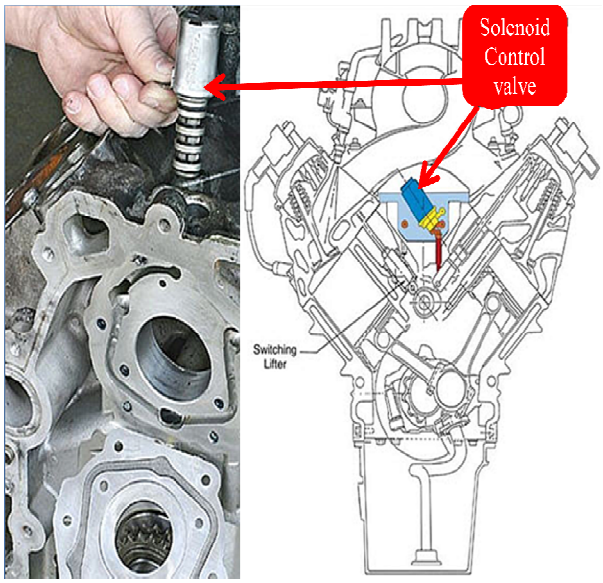
Deactivation Lifter operation

Lifters are fed oil at high pressure

This oil pressure (controlled by ECU operated solenoids) pushes on an internal locking pin that causes the lifter to collapse

Cylinder Deactivation includes a Lifter Oil Manifold Assembly and a Lifter Guide Assembly.

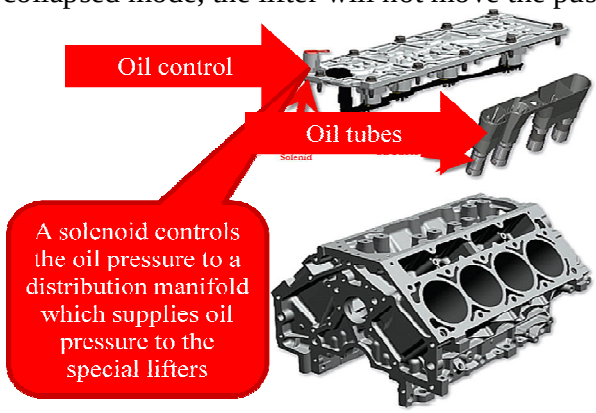




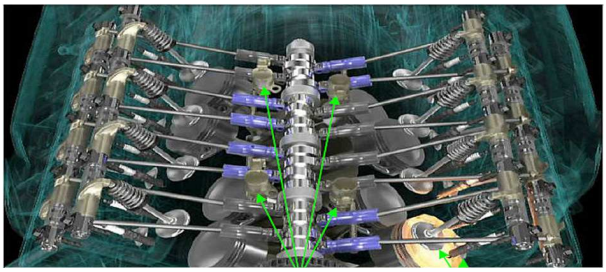
This shows the removal of the solenoid control valve.



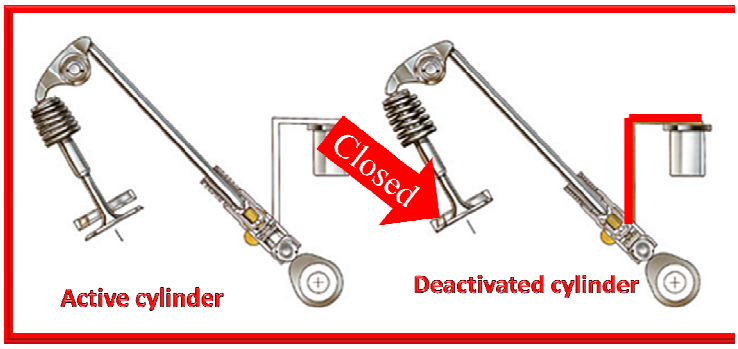
This shows the locking spring the locks the lifter when oil pressure is removed.
The lifter deactivates when oil pressure is applied to overcome the locking spring tension. In the collapsed mode, the lifter will not move the push rod when the cam raises the lifter.



The distribution manifold controls the oil pressure to individual cylinders.



The oil pressure tubes are attached to the lifters that are blue.



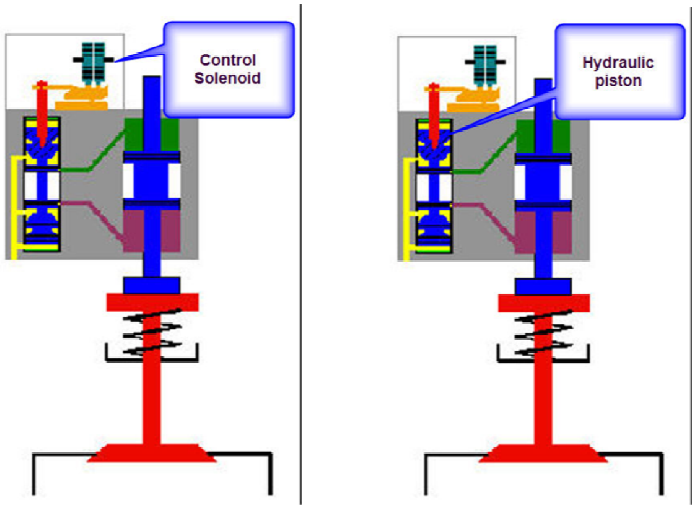
Cylinder deactivation is most effective when the engine produces enough power to operate on reduced cylinder at highway cruise. Deactivation does not offer much improvement in city driving because of constantly changing load conditions.

NEW!

ELECTRO-HYDRAULIC VALVE LIFTERS

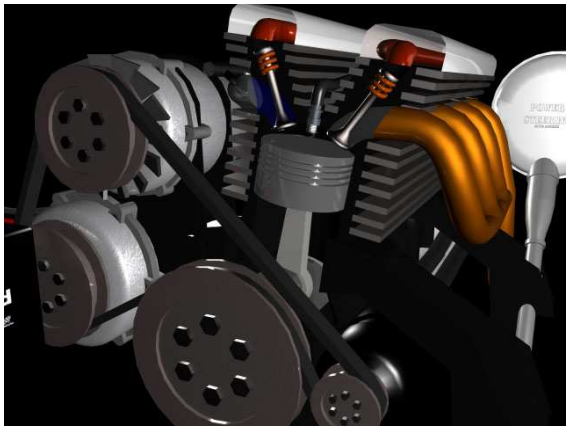


The camshaft can be replaced with fast acting electronic lifters
This overcomes the disadvantage of the limited RPM because .of the heavy cam shaft.
An electrical solenoid controls oil pressure to a hydraulic piston that is used to open the valve.



Electro-hydraulic control allows complete control of lift and timing.
The speed of valve action can be increased with heaver return springs without the wear problems associated with mechanical valve lifters.
The EH system is lighter and can be used at higher speeds.
This is currently in the final stages of development; expect to see it soon to meet the café fuel economy standards that are going to require more advanced technology.

GASOLINE DIRECT INJECTION GDI

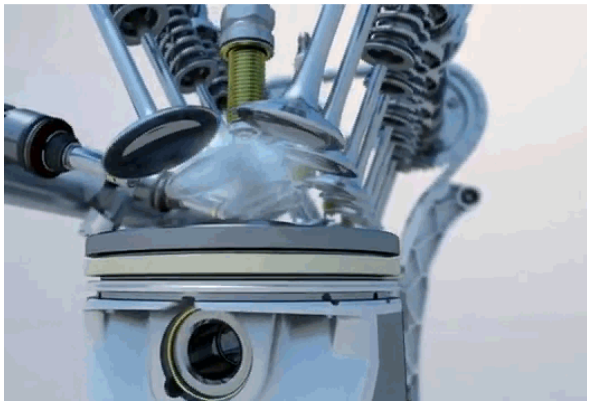


Gasoline Direct Injection injects fuel at 2900 PSI. Currently is used on high performance engines. The technology will be applied to many new engine designs like the new series of engines for Ford pickup trucks, where it is currently being used.
Vehicles with variable valve control and direct injection are producing engines that match the horsepower per cubic inch produced by NASCAR engines build to last one race.

GDI offers improved horsepower, torque, and emission control while improving fuel economy for similar engines without GDI.

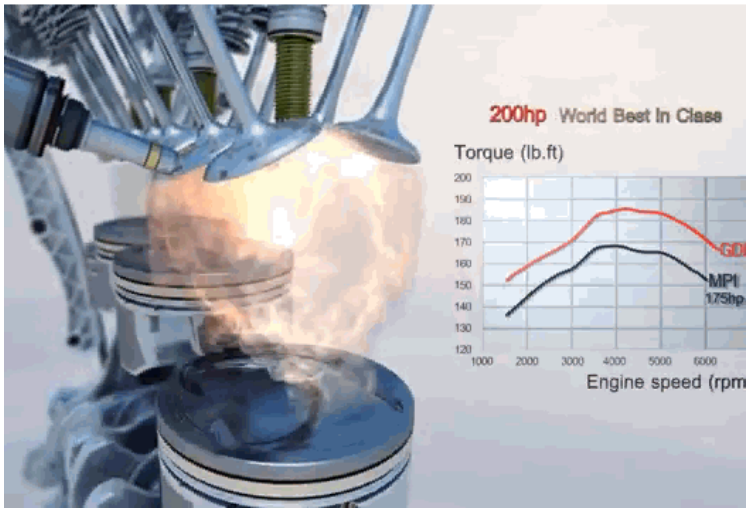






Stratified charge for improved combustion

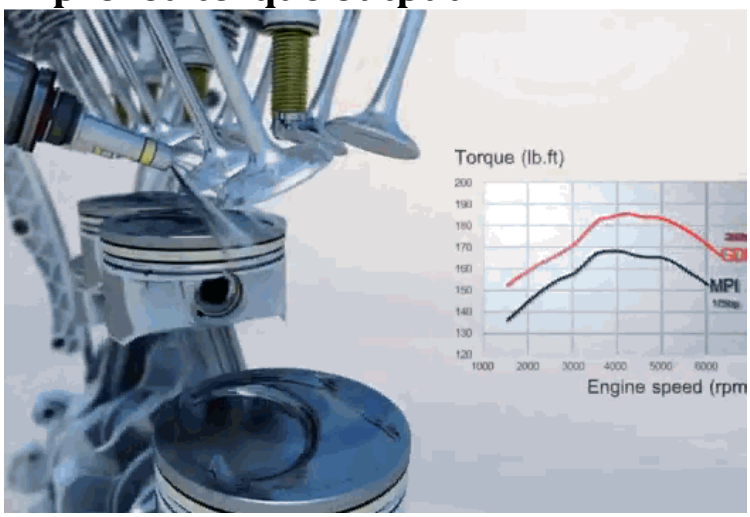
The fuel is injected as a stratified charge near the spark plug. The fuel is in the area where it can burn more completely. This achieves a much better stratified charge than any attempt to achieve a stratified charge in the past. Adding a turbo charger to get more air into the cylinder improves performance to high performance applications.



Horsepower improvement

The graph shows the horsepower improvement for two similar engines. The GDI engine puts out 25 more horsepower with improved fuel economy and better emissions. Notice the improvement covers the entire speed range of the engine. Turbo charging would only improve high engine speed operation.

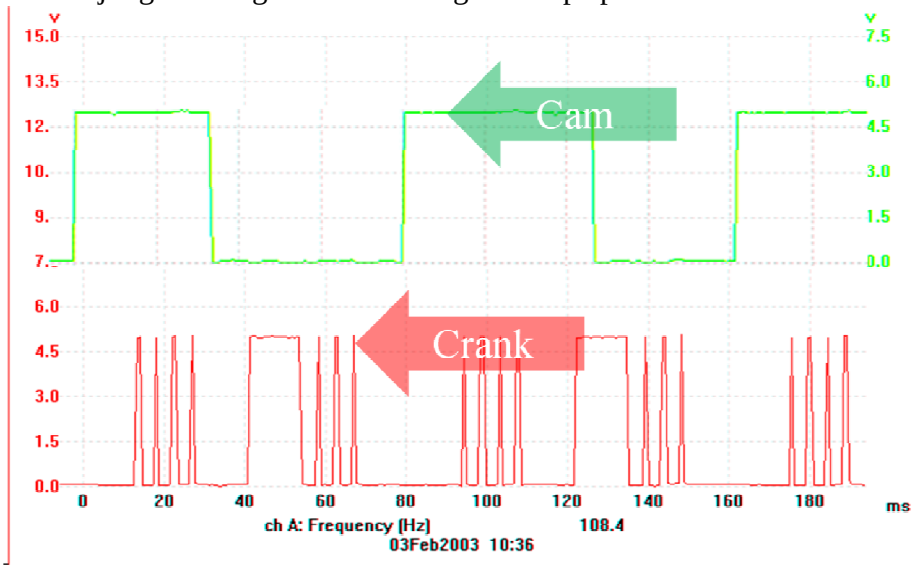
Improved torque output



Notice the torque curves, the mid-range and high end torque is much better the MPI engine. ALL OF THESE IMPROVEMENTS WERE ACHIEVED WITHOUT A TURBO CHARGER. Adding a turbo charger like the Ford Eco-boost engines, improves mid-range and top end performance even more that this example shows. We have complete control of fuel; we only need more air to produce more power.

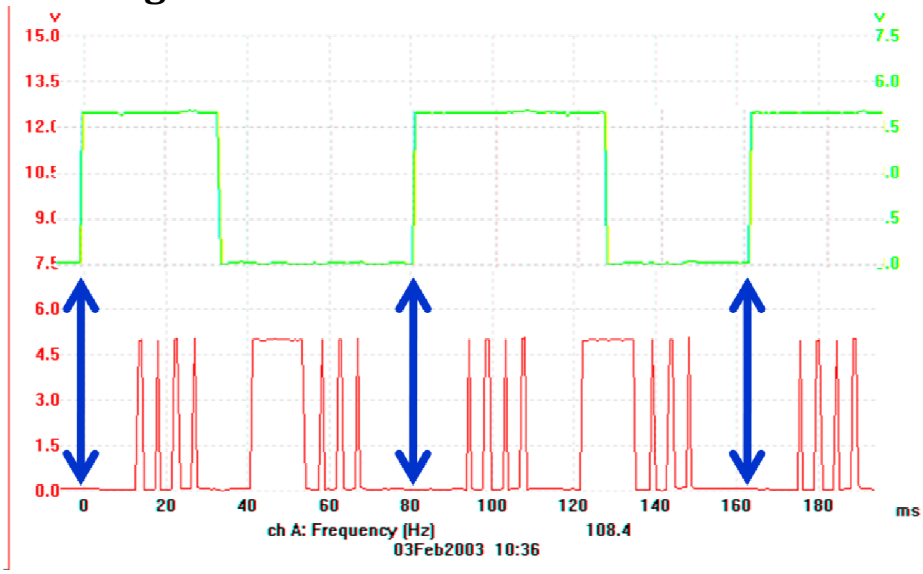
CAM AND CRANK ALIGNMENT

Cam timing adds importance to the cam pick up signal. The timing between crank and cam are also more important since the cam timing will be changing, it is important to know the mechanical alignment is in its normal position.
We can judge the alignment but using lab scope patterns.



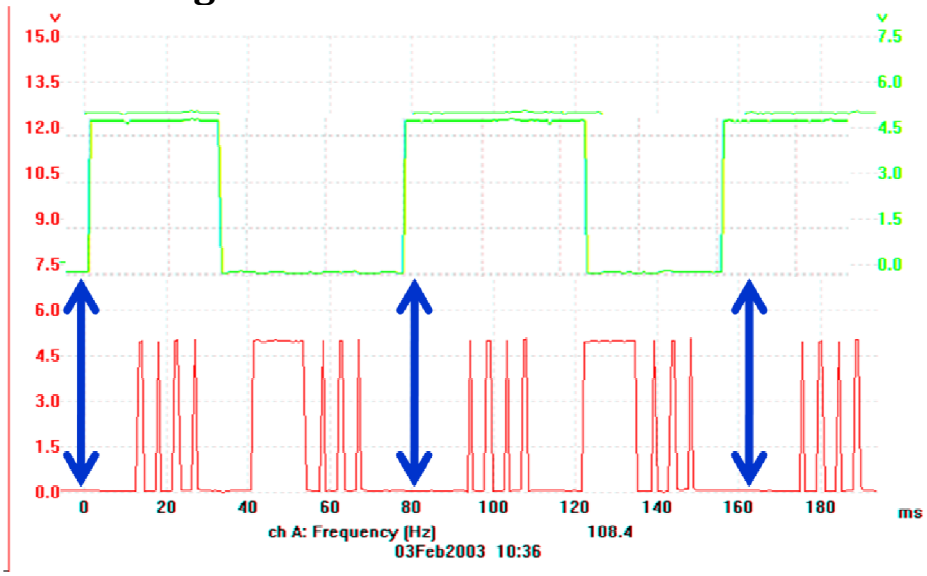
Identify points of reference to identify cam timing.

Cam Alignment without VVT



We selected the rising and falling edge of the cam signal to locate a position on the crank signal.
You need known good waveforms to judge cam timing.

Cam timing as VVT is activated



We capture the scope pattern as the valve timing was activated. This confirms the operation of the phaser and control valve. If no movement happens when VVT is activated, it confirms there are malfunctioning components. Inspect the control valve for varnish and sludge. The timing cover will have to be removed to check the phaser. You do this test to confirm and diagnose the cause of a valve timing diagnostic trouble code.

Known good waveforms

A technician always needs vehicle specific information
Known good waveforms are no different

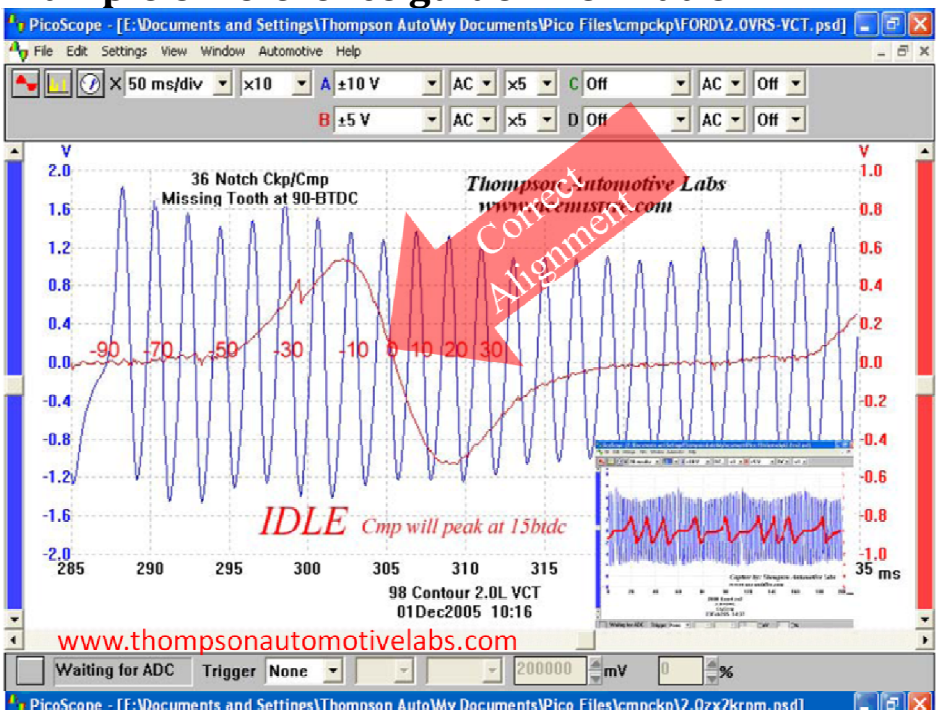


The A.C.E. Crank and Cam Signal Reference

www.thompsonautomotivelabs.com

Provides known good examples of 60 different proper relationships with 104 known good patterns for domestically produced engines
This handy guide available on CD can save you hours of teardown time verifying that a timing belt /timing chain is aligned correctly

Example of reference guide information



This page shows you how to identify the proper cam timing on a 1998 Contour 2.0L with VVT. You have the degrees represented from the signature pattern and the advance indicated for crank position before the 0 degree point. This type of information can be developed if you want to take the time to research the vehicle you get into your short, but you may find it better to have known good references.

ELECTRONIC THROTTLE CONTROL

This is also known as fly-by-wire throttle control. There is no mechanical linkage between the accelerator pedal and the throttle plate.

Objectives

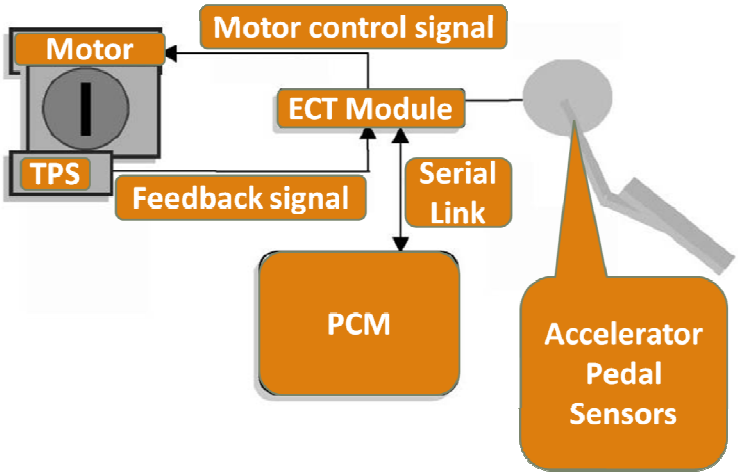
- Introduce Electronic Throttle systems
- Discuss the different systems
- Identify Electronic throttle components
- Gain an understanding of operation
- Select the correct diagnostic procedure

Electronic Throttle Control

- Early as 1980
- Today's versions are more reliable
- Redundant path software
- ***Combined with:***
  - Variable valve timing
  - Direct injection
  - Electronic stability control

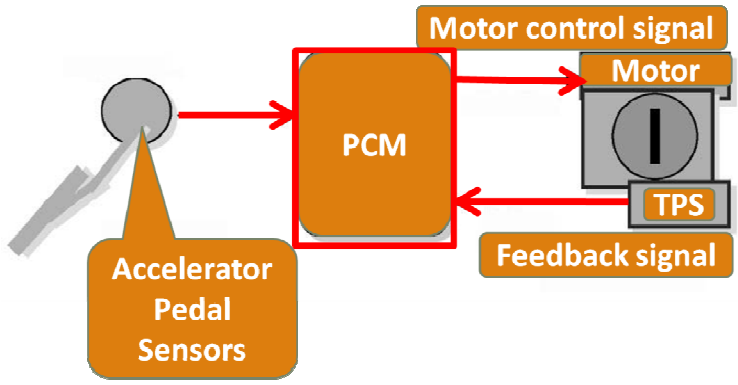
There are two configurations on vehicles. The first is a system that has a separate ETC module.

With ETC Module



The PCM is connected to the ETC module by serial communications. The PCM does the engine speed calculation and sends the commands to the ETC module. The ETC module positions the throttle actuator motor to the commanded position. The TPS sensor sends the position information back to the ECT module.

<u>Without</u> ETC Module



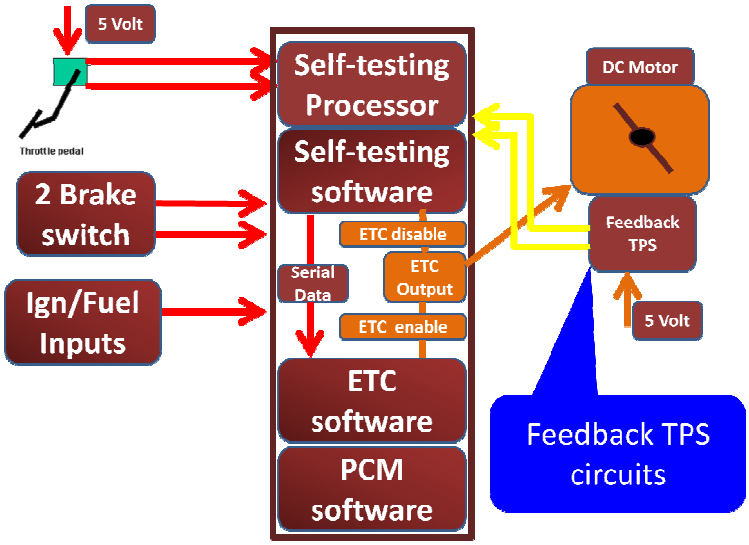
Newer vehicle doesn't have a separate ETC module. The throttle actuator motor is controlled by the PCM. The red lines are electrical signal. The actual signal is redundant, meaning there is more than one signal, to insure safe vehicle operation.

Redundant path software



The PCM has redundant software to be sure the ECT calculations are correct. There is self testing software and processor to check for abnormal operation. There is a separate ETC program running inside the PCM that compares its calculation to the calculations from the PCM software.

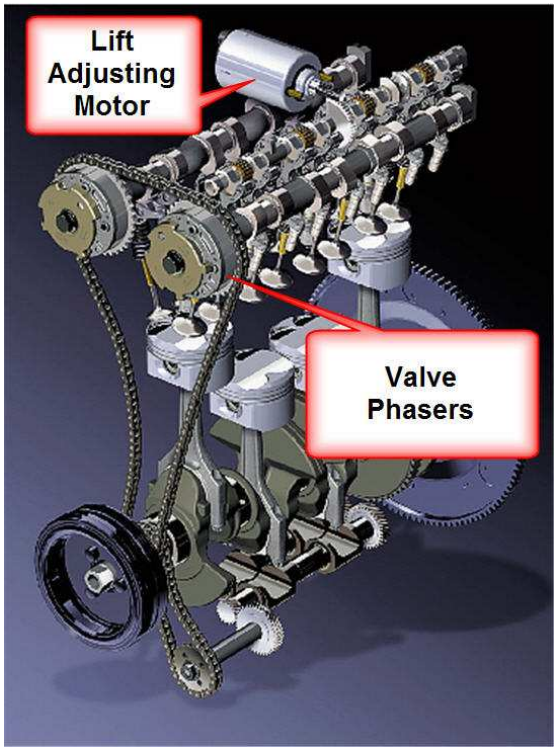
ECT Data structure



The result of the redundant functions inside the PCM is a safety protocol that can disable ETC, return the engine to idle. The safety protocol can even shut down the engine if engine run away is indicated. Most vehicle have brake over ride the disables the ETC if the accelerator pedal position is lost or at idle with the engine off idle. The brake over ride is required for all ETC systems in the future, because of the Toyota throttle problems.

ETC doesn't provide benefits by itself

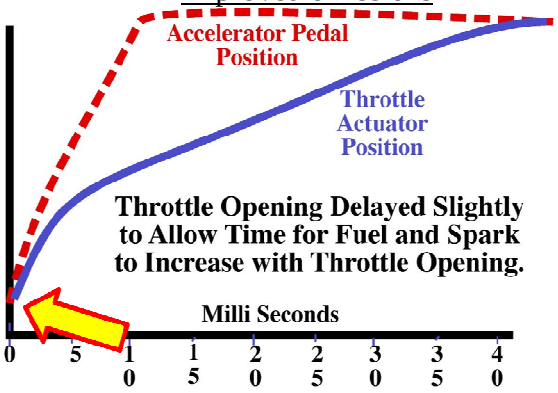
The benefits are realized when there is total control over the engine



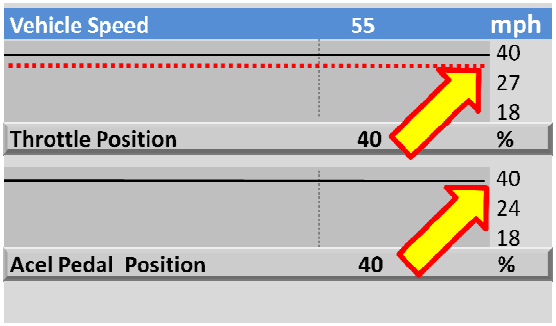
.

Electronic throttle works with other advanced electronic systems to improve vehicle performance.

- ETCS provides different benefits
  - Improved emissions

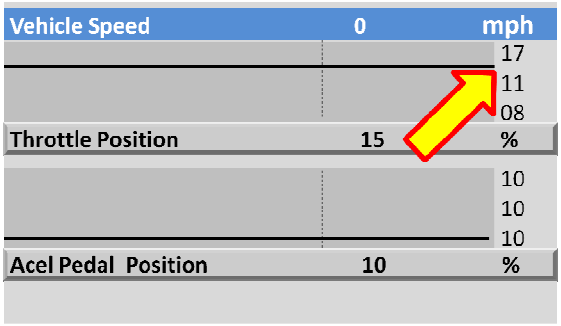


  - Altitude compensation



The throttle position is slightly lower that accelerator pedal position to adjust for altitude compensation. This could also be an example of speed governing. Vehicle stability programs back off the throttle slightly to slow the vehicle when the vehicle is near a skid condition.

Idle Air Control Cold Start



During cold engine starts, the throttle is opened to increase cold idle speed.

  - Cruise Control



Cruise control expense is reduced by eliminating the vacuum operated throtte servo for cruise control.

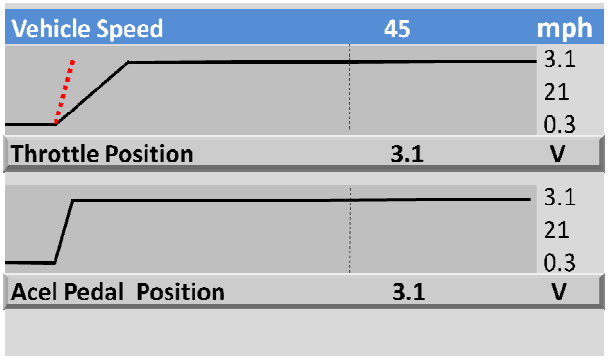
Driver Selectable Performance

This is an option that is starting to be used more frequently.

- Newer vehicles are giving the driver additional control of the engine's performance.
- *Modify* (Through software) the vehicle's response to accelerator inputs.
- Operating modes
  - Normal,
  - Power
  - Winter

Normal Mode

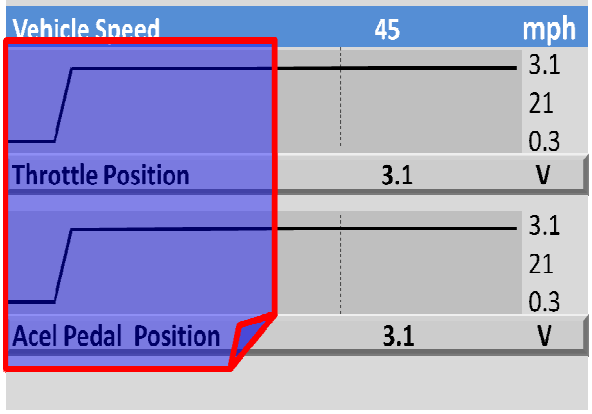
- Normal: Is the default setting that provides the acceleration response that most drivers prefer for most driving conditions



Throttle position values agree with the accelerator pedal position signals.

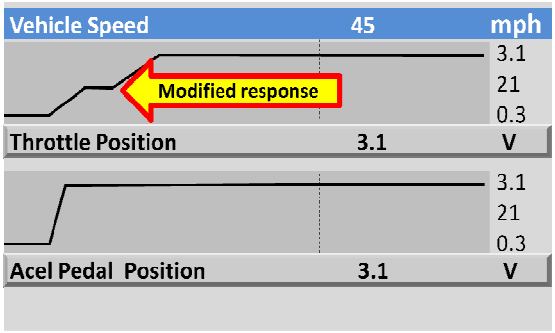
Normal Mode

When the Power mode is selected, ETC system responses become more aggressive. The result is a sporty feel, especially during launch from a stop.



Throttle position responses faster to APP changes.

- The winter mode is selected during low traction conditions where fine control of power is needed. Works in conjunction with traction control.
- Winter mode results in very conservative throttle gains that are adjusted to accelerate without wheel slip



Self-Testing Features

- **Safety is critical for any ETCS**
- **A fail safe operation is required**
- **The fail safe system must focus on detecting operational problems and respond in a specific way to compensate for them**

Common ETC Complaints

- Stall at stops
- (Bad) Hesitation
- Sudden lunge (Especially following a cold start-up)
- Engine will only run at idle
- Engine runs at low RPM only
- No response from the accelerator pedal
- Unintended acceleration
- Hesitation then Engine accelerates too fast
- Jerkiness
- Unintended deceleration

Some of these complaints are the result of safety reactions to conditions that cause the PCM to be unsure of the motorist intentions. If the PCM's redundancy systems have different interpretations of conditions, it may go back to idle until the conditions is corrected. We need to look at the complaints, because the diagnostic response to the problems can be different.

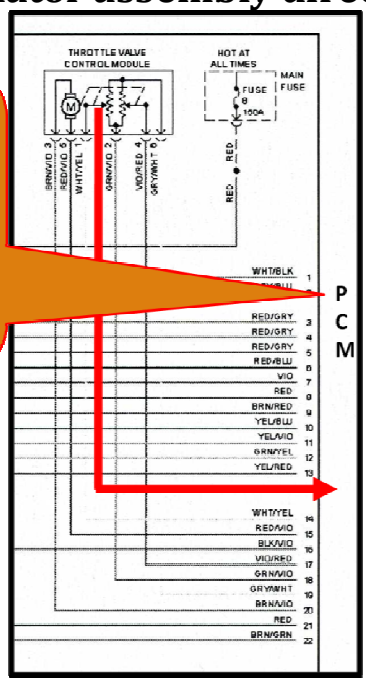
- More than one million 2002 and 2003 Toyota Camry's, Solaris, and Lexus ES 300s were involved in an investigation.
- 2010 the problems caused major recalls for Toyota.
- Audi A6 had 16 drivers complained about the engine picking up speed while already moving is still under investigation

ETCS Components

- Power train Control Module
  - The PCM handles all calculations for the ETCS
- ETCS Module
  - A separate control module handles some of the calculations for the ETCS. This was used on early ETC applications.
  - The PCM handles other calculations for the ETCS

PCM Controls the throttle actuator assembly directly

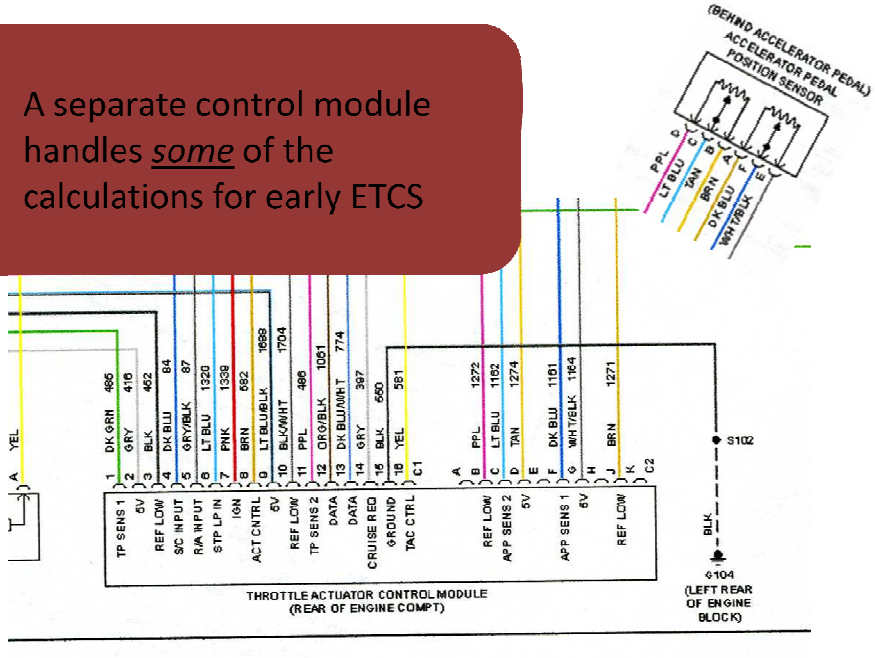
The PCM handles almost all calculations for the ETCS



The diagrams show the throttle control motor, TPS sensor and APP sensor all going to the PCM.

ETC control module for throttle actuator

A separate control module handles *some* of the calculations for early ETCS



The diagrams show a separate module for the throttle actuator.

Redundant processors

- The PCM performs almost all ETC management tasks.

- If you are dealing with a system that seems to be illogical, remember, the PCM handles most of the calculations
- The checking processor performs the redundant checking of sensors, ETC diagnostics, redundant security modeling, fuel and spark output enable control and self check
- The ETC can affect drivability and set DTCs if it thinks the data is wrong

Redundant processors

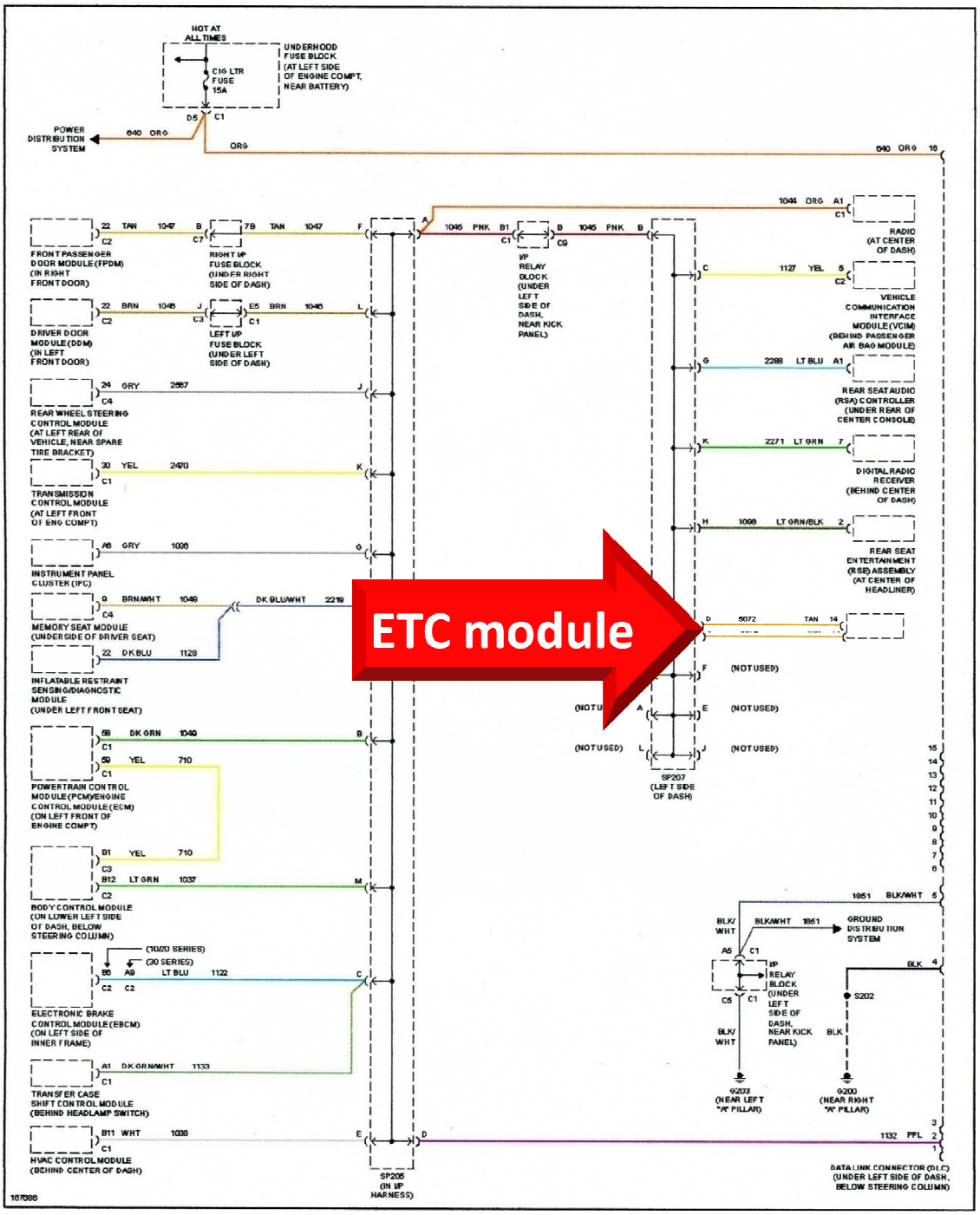
- ETC controller integrity is ensured through different self-diagnostics
- Redundant computations are done for all critical operating condition
- Rationality diagnostics, and power modeling is used to detect problems that would affect engine power (drivability)

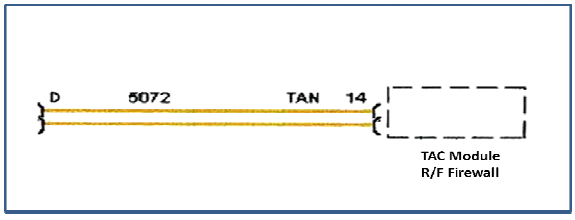
A separate throttle control module

- **When equipped with a throttle control module it interfaces with ETC components and does a small portion of processing**
- **The majority of the processing is performed by the PCM**
- **This was a standalone system developed for vehicles without ETC**
- **When there is a separate processor the PCM and that processor will communicate over the communication network's data line**
- **If you have a DTC relating to a communication problem, as an example, "U0107", you are dealing with a communication (Network) problem**
- **You need to need to correct the communication problem before the throttle control will work**

Communication network

This is an example of a communication network for a vehicle we worked on that would not respond to the APP.

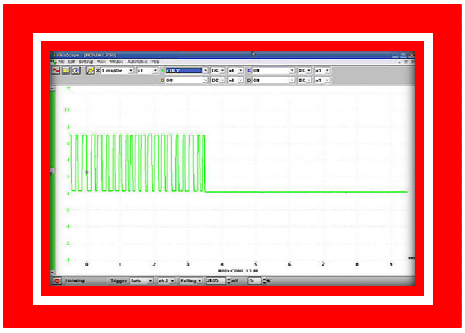

HOT AT ALL TIMES
UNDERHOOD FUSE BLOCK (AT LEFT SIDE OF ENGINE COMPT, NEAR BATTERY)
C16 LTR FUSE 15A
POWER DISTRIBUTION SYSTEM
640 ORG
ORG
640 ORG 16
1044 ORG A1
RADIO (AT CENTER OF DASH)
FRONT PASSENGER DOOR MODULE (FPDM) (IN RIGHT FRONT DOOR)
RIGHT I/P FUSE BLOCK (UNDER RIGHT SIDE OF DASH)
I/P RELAY BLOCK (UNDER LEFT SIDE OF DASH, NEAR KICK PANEL)
1127 YEL 5
VEHICLE COMMUNICATION INTERFACE MODULE (VCIM) (BEHIND PASSENGER AIR BAG MODULE)
DRIVER DOOR MODULE (DDM) (IN LEFT FRONT DOOR)
LEFT I/P FUSE BLOCK (UNDER LEFT SIDE OF DASH)
2288 LT BLU A1
REAR SEAT AUDIO (RSA) CONTROLLER (UNDER REAR OF CENTER CONSOLE)
REAR WHEEL STEERING CONTROL MODULE (AT LEFT REAR OF VEHICLE, NEAR SPARE TIRE BRACKET)
2271 LT GRN 7
DIGITAL RADIO RECEIVER (BEHIND CENTER OF DASH)
TRANSMISSION CONTROL MODULE (AT LEFT FRONT OF ENG COMPT)
1098 LT GRN/BLK 2
REAR SEAT ENTERTAINMENT (RSE) ASSEMBLY (AT CENTER OF HEADLINER)
INSTRUMENT PANEL CLUSTER (IPC)
MEMORY SEAT MODULE (UNDERSIDE OF DRIVER SEAT)
5072 TAN 14
ETC module
INFLATABLE RESTRAINT SENSING/DIAGNOSTIC MODULE (UNDER LEFT FRONT SEAT)
(NOT USED)
POWERTRAIN CONTROL MODULE (PCM/ENGINE CONTROL MODULE (ECM)) (ON LEFT FRONT OF ENGINE COMPT)
S207 (LEFT SIDE OF DASH)
BODY CONTROL MODULE (ON LOWER LEFT SIDE OF DASH, BELOW STEERING COLUMN)
1851 BLK/WHT 5
GROUND DISTRIBUTION SYSTEM
(10/20 SERIES)
(30 SERIES)
ELECTRONIC BRAKE CONTROL MODULE (EBCM) (ON LEFT SIDE OF INNER FRAME)
S202
TRANSFER CASE SHIFT CONTROL MODULE (BEHIND HEADLAMP SWITCH)
G203 (NEAR LEFT "A" PILLAR)
G200 (NEAR RIGHT "A" PILLAR)
HVAC CONTROL MODULE (BEHIND CENTER OF DASH)
1132 PPL 2
DATA LINK CONNECTOR (DLC) (UNDER LEFT SIDE OF DASH, BELOW STEERING COLUMN)
S205 (IN I/P HARNESS)
107886


D 5072 TAN 14
TAC Module
R/F Firewall

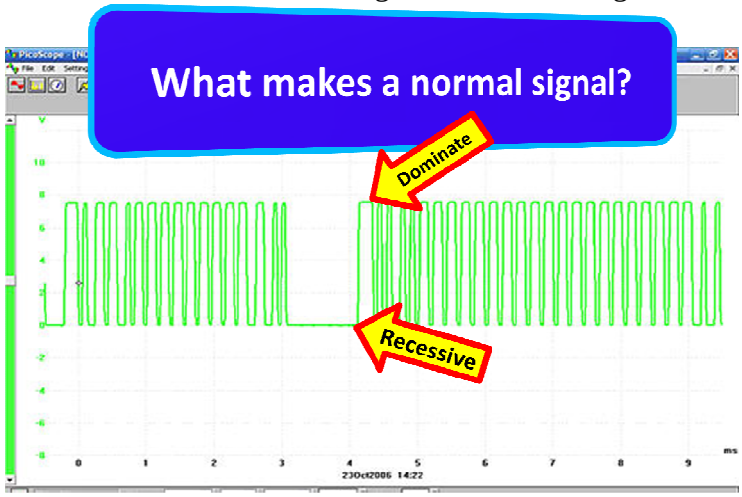
This page is here as an example to show how many modules are on the same communications data bus. The ETC module did not respond to the PCM because there was an open in the wiring after a collision.



This is the ETC module for this vehicle with the communications problem.



This is the communications signal after the wiring was corrected.



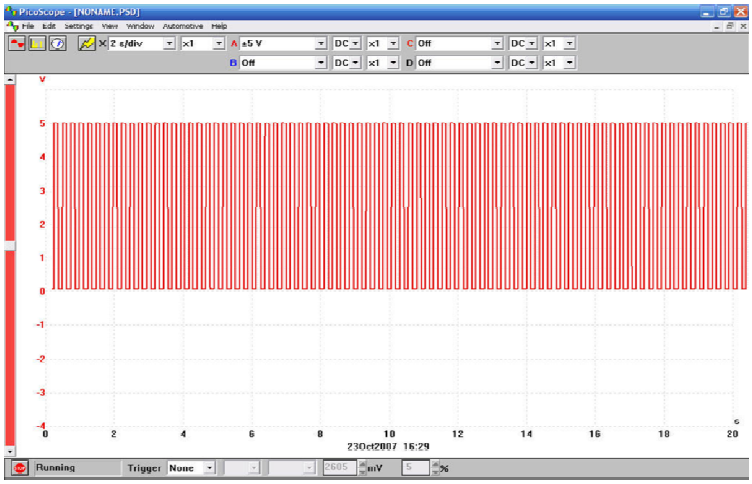
These signals must match the signal on pin 2 of the data link connector, indicating the wiring is connected between the two points.

The dominate signal must reach its normal voltage level and the recessive portion must come close to zero. Modules must wait for recessive time before they can communicate on the data bus. This signal did not match the signal at pin 2 on the data link connector until the open circuit was repaired.

GM uses Class II, a single wire protocol that operates at 10.4 Kbs. The signal is 7.0 to 7.5 volts.

Chatter-Box

Sometimes a module never stops sending data; frequently it is the occupant classification module under the seat that gets flooded with water because of open windows or during a heavy rain storm.



This is an example of a chatter box. Modules must wait for recessive time when no other modules are communicating before they can get on the data bus.
We have a completer communications training program that goes into much more detail.

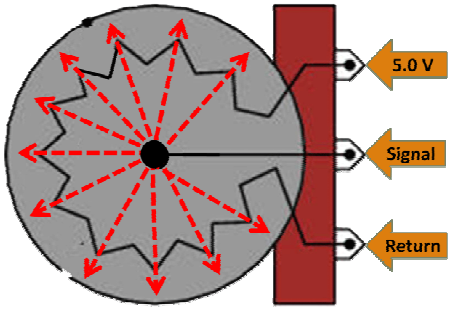
Multiple Sensor input

- **Accelerator pedal sensors**
- **Throttle position sensors**
- **Brake switches**

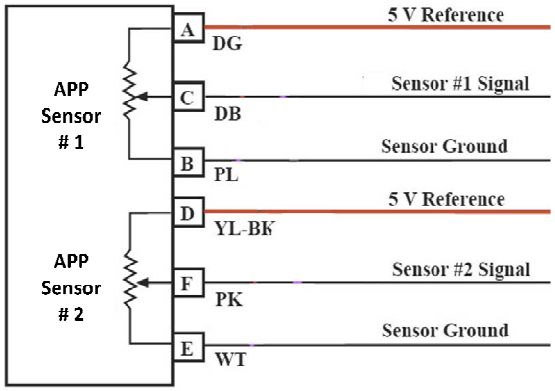
ETC systems use 2 or 3 accelerator pedal position sensors

- The accelerator pedal position sensors are inputs for the ETC
- They signal the driver's request for torque to the controller
- They are potentiometers which measure accelerator pedal movement
- Potentiometer: A device for measuring EMF or potential by comparison with a known voltage (Reference Voltage)



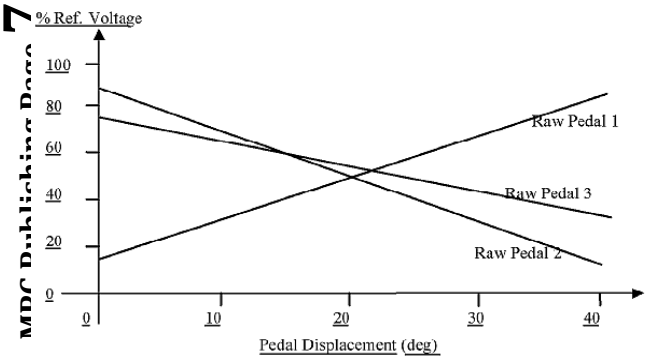


They are three wire sensors like TPS sensors with redundant sensors connected to the APP pedal



This is a diagram of a two sensor application.

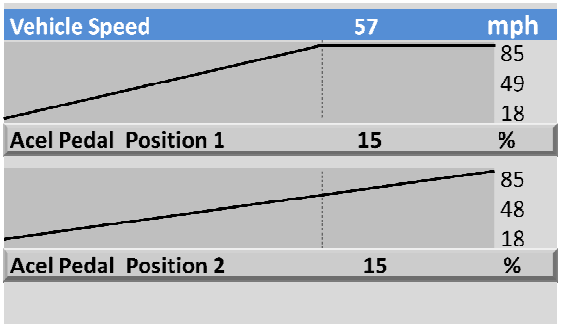
APP sensor output voltages



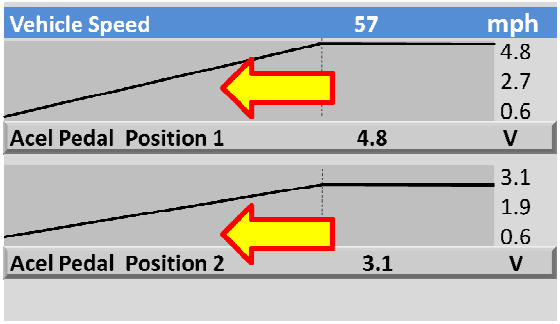
This chart shows the output voltage of a 3-sensor APP as it is swept through its operating range.

Voltage signal vary by manufacturer.

Both APP signals increase but with different ranges



This example has a linear change on the bottom pattern with a change in slope on the top pattern.



This pattern has the same rate of change but the voltage range is different.



This is the lab scope pattern of this type APP sensors outputs.
The PCM compares the signal to a look up table to determine the driver's request for torque.
Here is a sample of the lookup table with just the top and bottom end of the table shown'

Voltage	Pedal position
• 4.79 V	100 %
• 4.78 V	99%
• 4.77 V	98%
• 4.76 V	97&

- 4.75 V 96%
- 1.5 V 12%
- 1.4 V 11%
- 1.3 V 10%
- 1.2 V 9%
- 0.5 V 0%

Your scan tool will show the percentage; this is an example of how the percentage is calculated.

Plausibility check (IPC software)

The internal software is always doing a plausibility comparison with operating conditions to verify they match with the APP signal indications. The check tries to answer a series of questions;

- Is it a valid request?
- Is this value acceptable?
- Is this value credible?

Redundant processors check to see if they have the same answers
Rationality diagnostics, and power modeling is used to detect problems that would affect safety. This may change engine power (drivability).

Calculated throttle position

The PCM is going to calculate the expected throttle position

- Based off other inputs:
  - Vehicle speed:
  - Transmission Gear:
  - Camshaft position:
  - Crankshaft position:
  - Oxygen Sensor input:
  - Knock Sensor input:
  - Coolant Temperature:
  - Inlet Air Temperature:
  - Battery Voltage:
  - Mass Air Input:
  - Brake Switch input

These values are also used for fuel control and spark timing

Critical inputs with unusual indications

- **Battery Voltage**
  - **When battery voltage gets too low the processors will place the ETC into a fault mode**
  - **This will change engine performance**
  - **Wheel/Vehicle speed and brake input**
- **Wheel/Vehicle speed and brake input**
  - **The computer must always be informed of the driver's intentions to brake or to stop the vehicle**

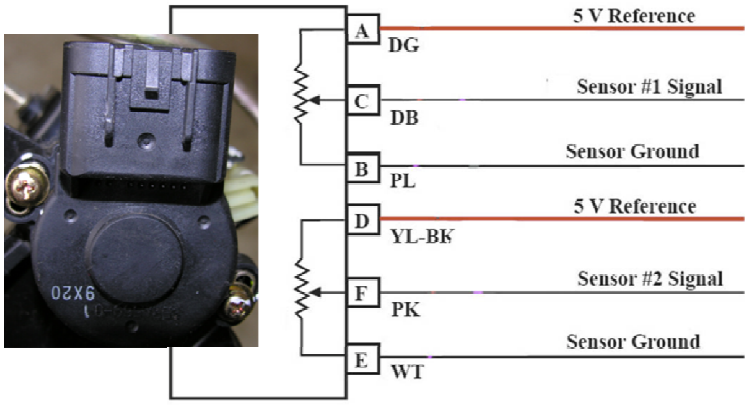
- **The PCM is looking for conflicts between vehicle operation and torque request as indicated by the APP sensors, the PCM will change engine performance if it detects a problem**
- **The computer must always be informed of the driver's intentions to brake or to stop the vehicle**

- **The PCM monitors other systems to perform these checks;**
  - **Vehicle speed:**
  - **Transmission Gear:**
  - **Camshaft position:**
  - **Crankshaft position:**
  - **Oxygen Sensor input:**
  - **Knock Sensor input:**
  - **Coolant Temperature:**
  - **Inlet Air Temperature:**
  - **Battery Voltage:**
  - **Mass Air Input:**
  - **Brake Switch input**

Be careful not to overlook problems in scan data that you think is unimportant because that data may cause the PCM to make adjustments to vehicle performance for safety reasons.

APP Diagnostics

You are testing position sensors like we have in the past, except now we have more than one sensor measuring the same thing.



Check for diagnostic trouble codes

Code P1125- Accelerator pedal position sensor signals from two of the three sensors don't agree

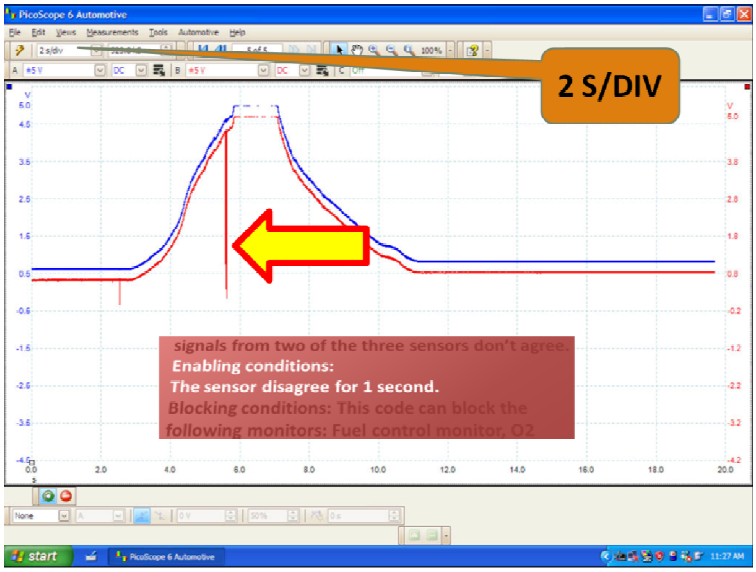
Understand what you should look for during the diagnostic tests. Use the enabling condition

Enabling conditions:

The sensor signals disagree for 1 second.

Beware that some intermittent problems may not set a code but could cause problems under some conditions.

An example of a fast signal glitch;

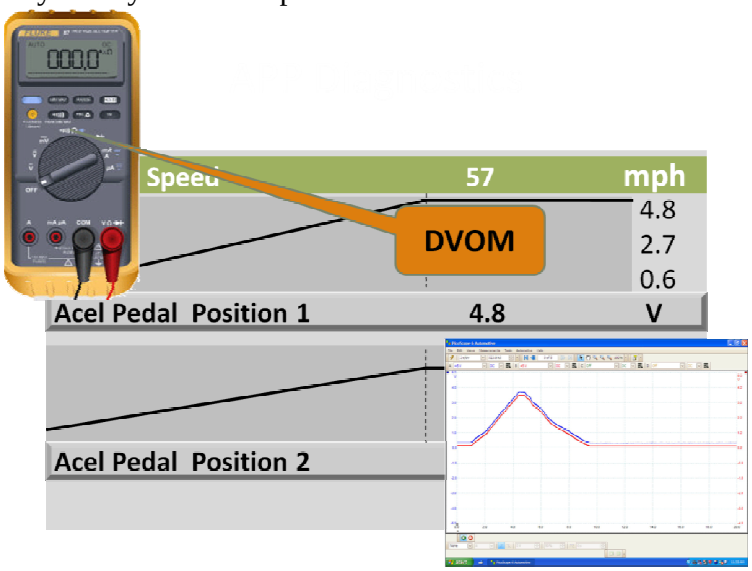


The enabling conditions tell you that the fast glitch we captured with our lab scope will not set a code. Some problems are going to need more diagnostics than usual, we have seen vehicle where a glitch like this does not affect the vehicle and other vehicles go into reduced power mode for a few seconds. This is why it is important for you to understand how the ETC operates.

Use information with clear diagnostic testing to locate problems like the example;

> **Testing: Check the operation of the sensors. Pedal position #1 should be 0.65 to.075 volts at idle and go to over 3.03 volts at wide open throttle. Pedal position # 2 should be 4.30 to 4.40 volts at idle and go under 1.0 volt at wide open throttle. Sweep test the sensors to make sure they change smoothly as the pedal is moved.**

Use the test equipment you have to test the vehicle, but understand there will be times when you may need your lab scope.



ETC DTC examples

- **P2121**
  Throttle/Pedal Position Sensor/Switch D Circuit Range/Performance

- **P2122**
  Throttle/Pedal Position Sensor/Switch D Circuit Low
- **P2123**
  Throttle/Pedal Position Sensor/Switch D Circuit High
- **P2139**
  Throttle/Pedal Position Sensor/Switch D / F Voltage Correlation
- **P0229**
  Throttle/Pedal Position Sensor/Switch C Circuit Intermittent

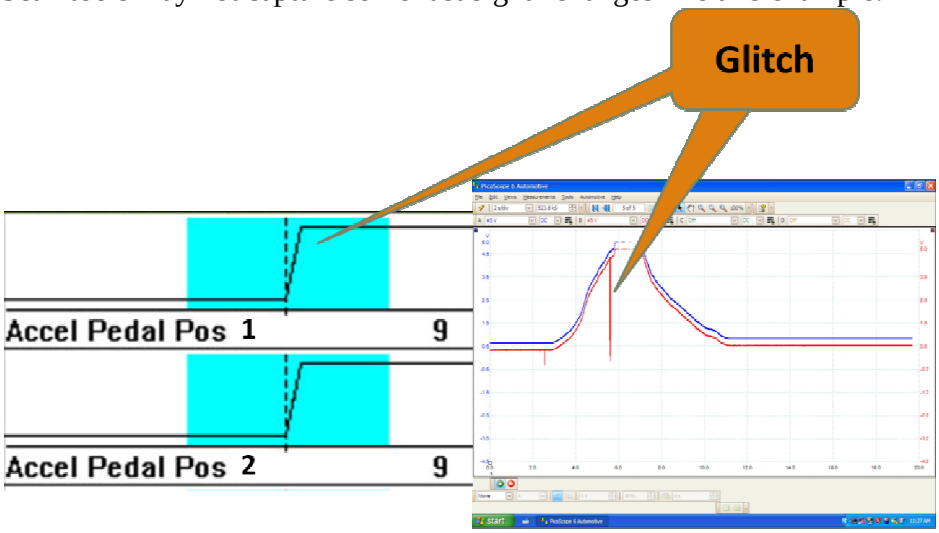
APP Configurations

There are basically three different configurations.

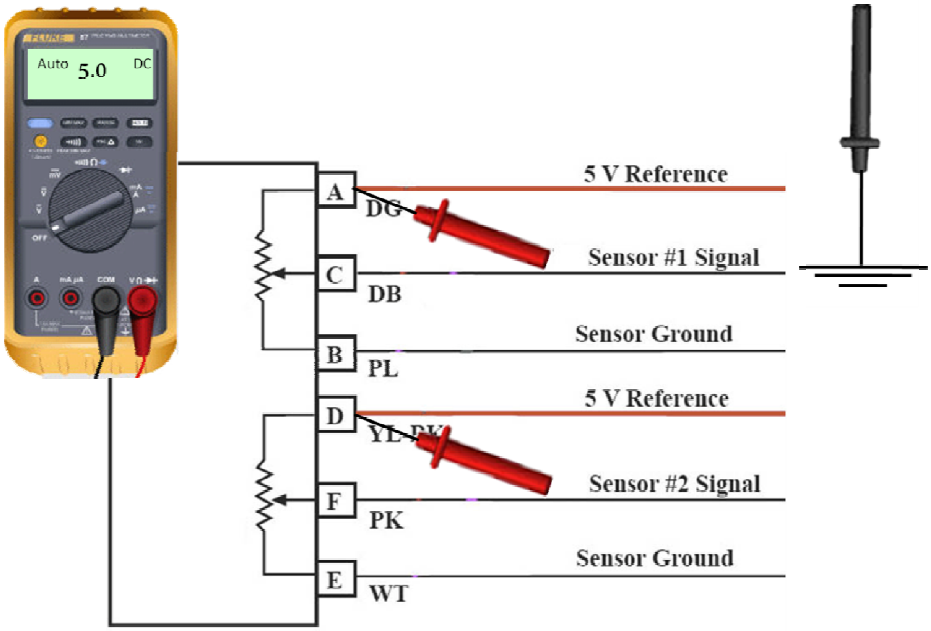
1. Both signals are the same
2. The two signals are opposite
3. Each signal has a different peak voltage

Equipment for Diagnostics

Scan tool VS DSO
Scan tools may not capture some fast signal changes like this example.

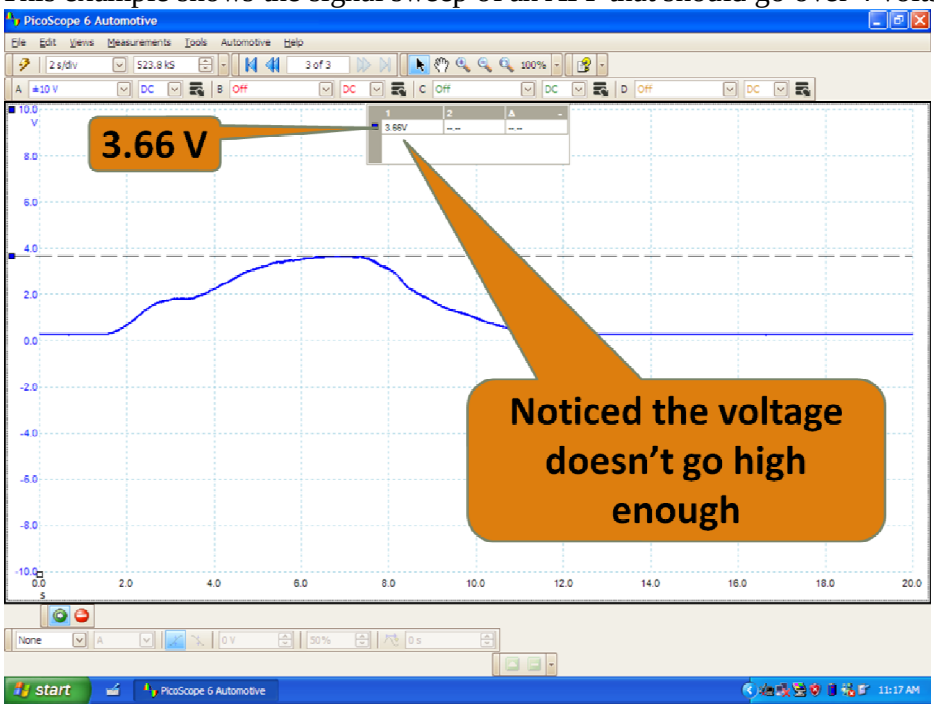


There maybe times where a lab scope is required to locate a difficult problem.
Do your routine checks before replacing parts.
Check for 5 volt reference;

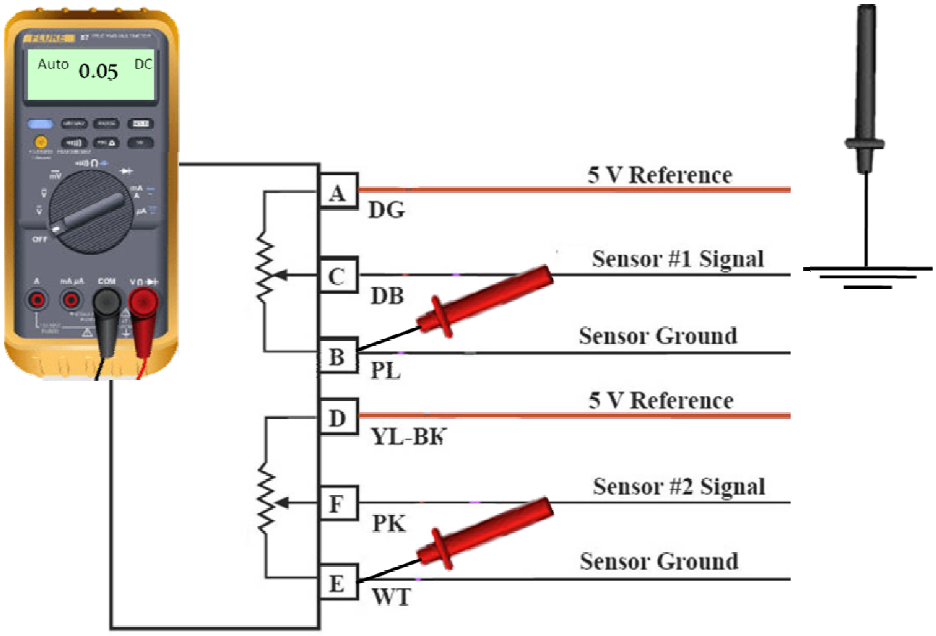


Low 5 volt reference can reduce the output voltage of the sensor. This is a diagnostic aid to remember, low output voltage maybe caused by low reference voltage; it is very rare that reference is high.

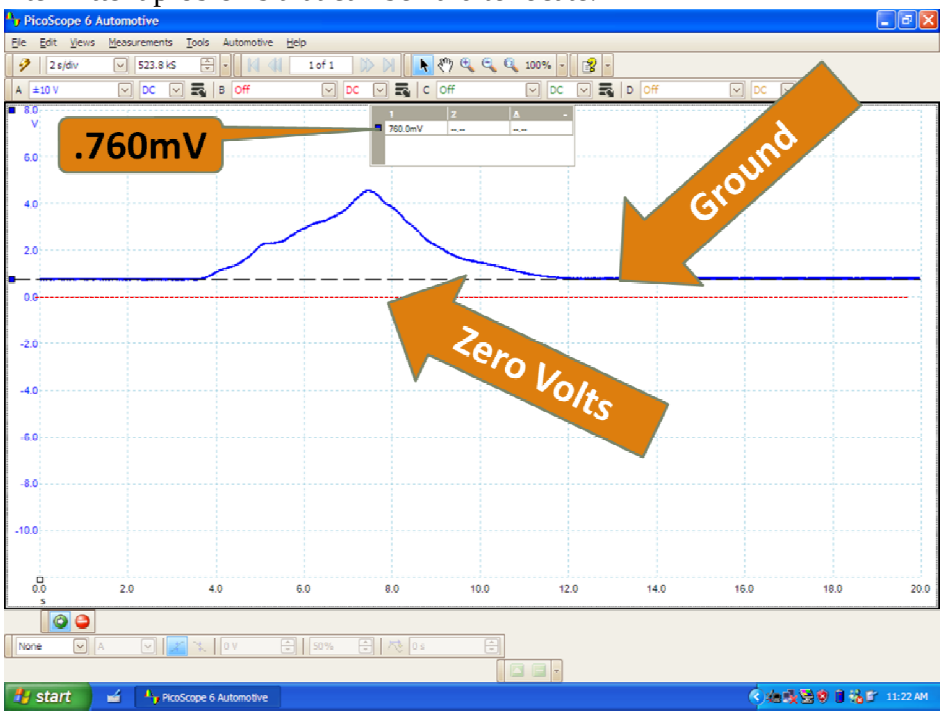
This example shows the signal sweep of an APP that should go over 4 volts;



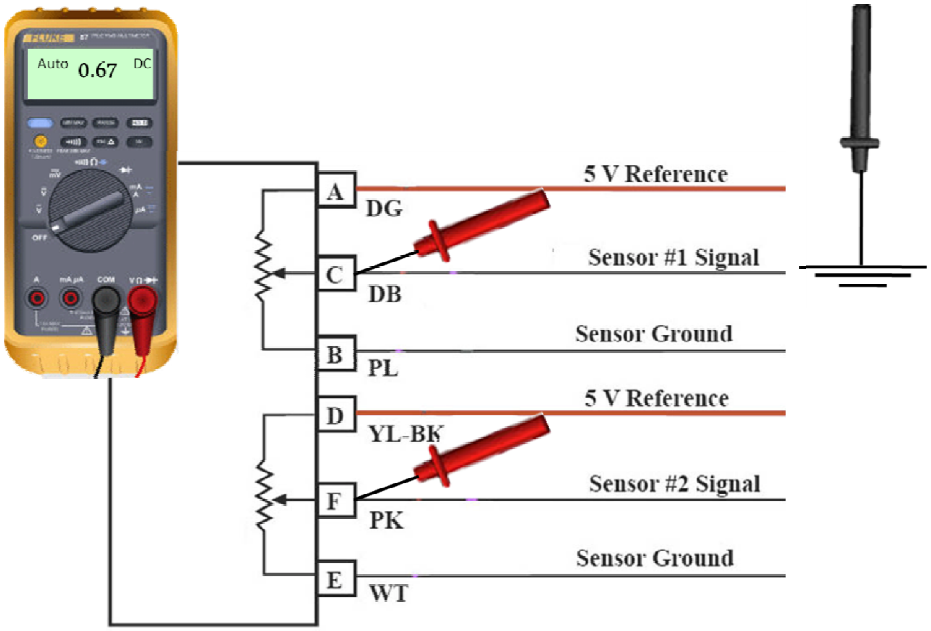
Check ground to the sensor;



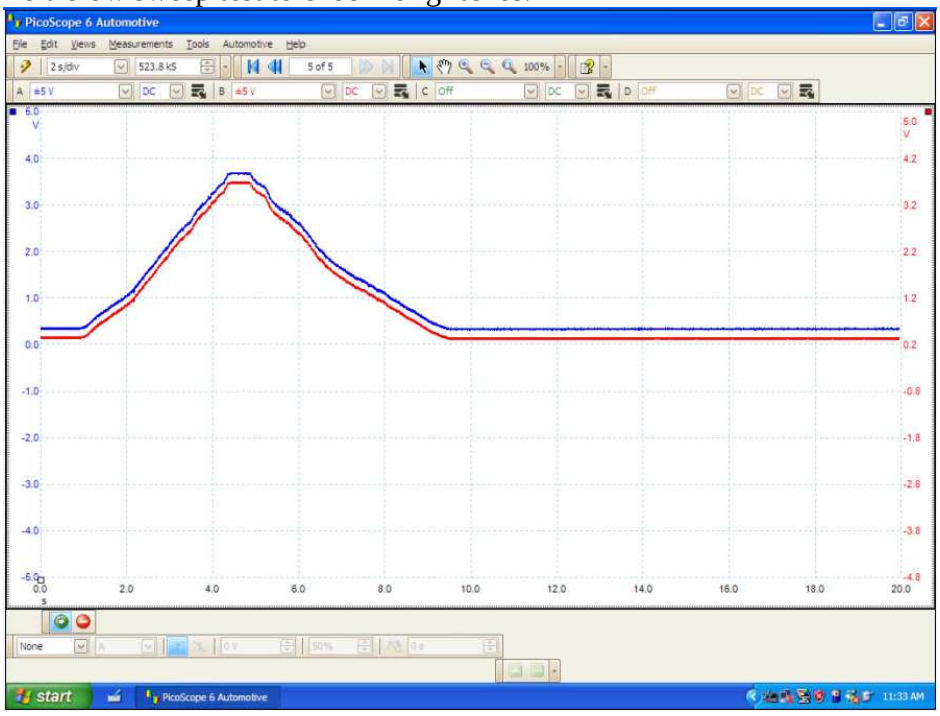
Is the voltage normal, we like to see signal grounds under 0.050 V. This is a realistic value developed from testing, do expect problems until the voltage is higher, but this helps identify intermittent problems that can be hard to locate.



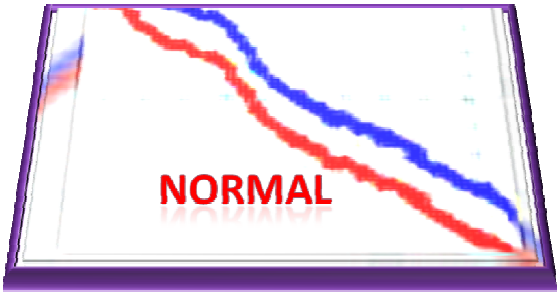
High ground voltage causes signals voltages to read higher than normal. Check the signal voltage and compare it to a good specification.



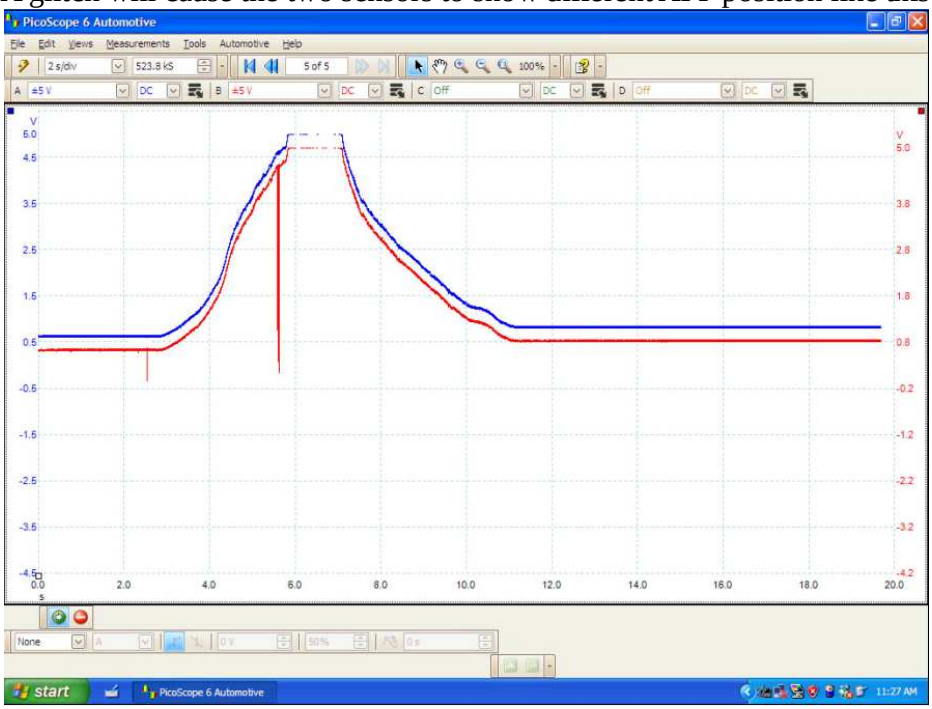
Do a slow sweep test to check for glitches.



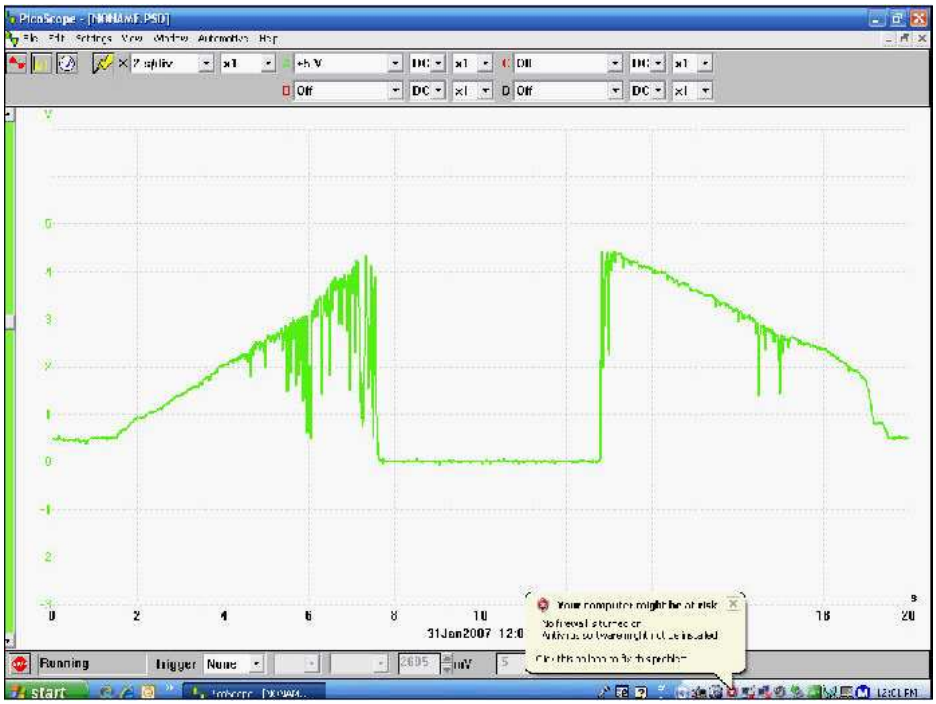
This is a good pattern. Notice that there are minor differences between the two signals, but there are not big differences. The PCM can handle minor differences, as long as the two sensors don't show different APP positions.



This is normal variations in the signal.
A glitch will cause the two sensors to show different APP position like this example;



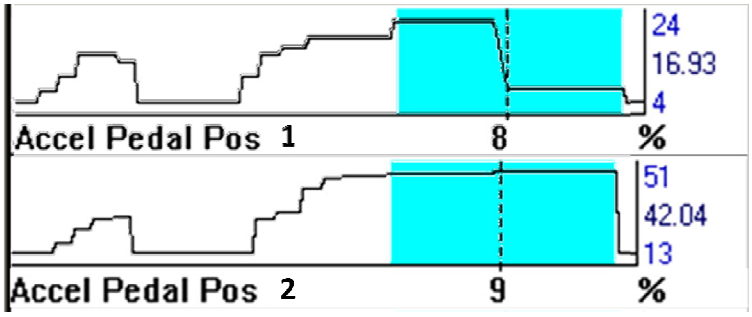
If you have symptoms of surging, hesitation, low power or returning to idle when the brake is pressed, this could be the cause and it may not set a code.
This is the worst pattern we have ever seen and it did set a code;



This condition caused the ECT to go into limited power mode when it could not be sure of the correct torque request.

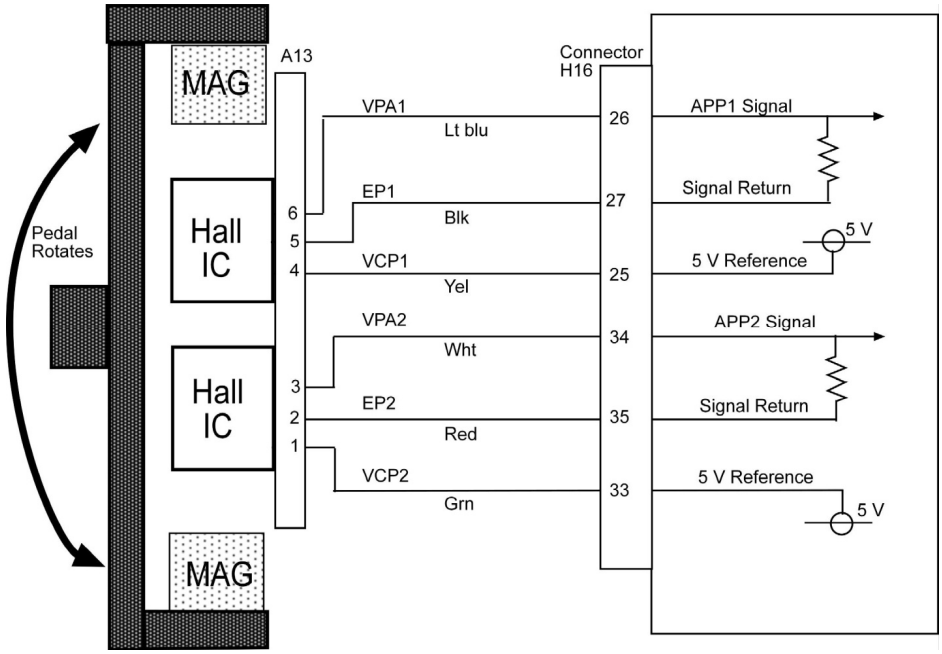
This is scan data of the problem;

Code P1125- Accelerator pedal position sensor signals don't agree



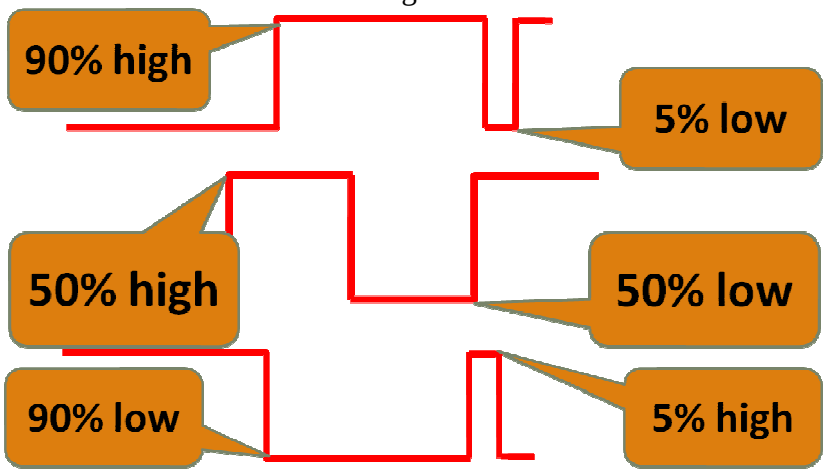
Three-wire linear Hall-effect APP sensors

- Designed to be used in dirty environments
- Output accurately tracks the changes in magnetic flux density
- Depending on the magnetic pole being affected the voltage increases or decreases
- North = Decrease
- South = Increase



Throttle actuator motor

- There is no mechanical link between the APP and the throttle plate.
- A motor is used to move the throttle plate
- There is no mechanical link between the APP and the throttle plate.
- A motor is used to move the throttle plate
- A DC operated motor is used to control the throttle
- The motor circuit is controlled on the ground side
- Battery positive is constant and the ground is duty cycled to control the amount of opening
- PWM is based on Duty Cycle where the amount of time the signal is high is compared to the amount of time the signal is low

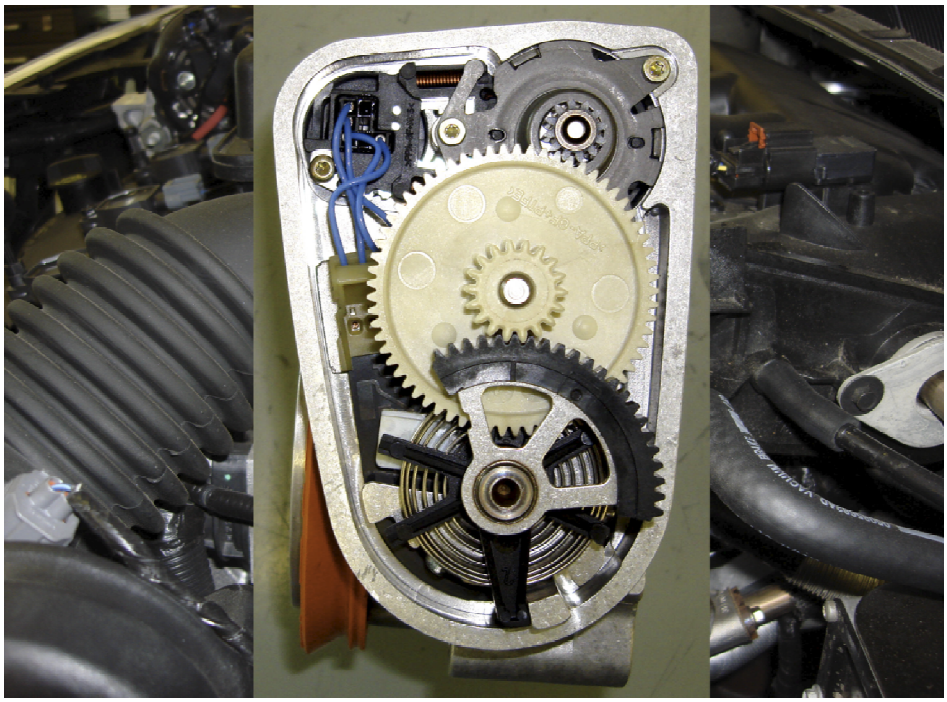


50% Duty Cycle

- **In most instances (Theoretically) a duty cycle of greater than 50% is used to open the throttle**
- **A duty cycle of less than 50% is used to close the throttle**
- **NOTE!**
- **It requires a duty cycle greater than 50% to open the throttle against the spring**
- **A direct DC voltage cannot be used because the throttle rotates only about 90% and the direct DC voltage would try to continue to rotate with the shaft locked and eventually burn out**



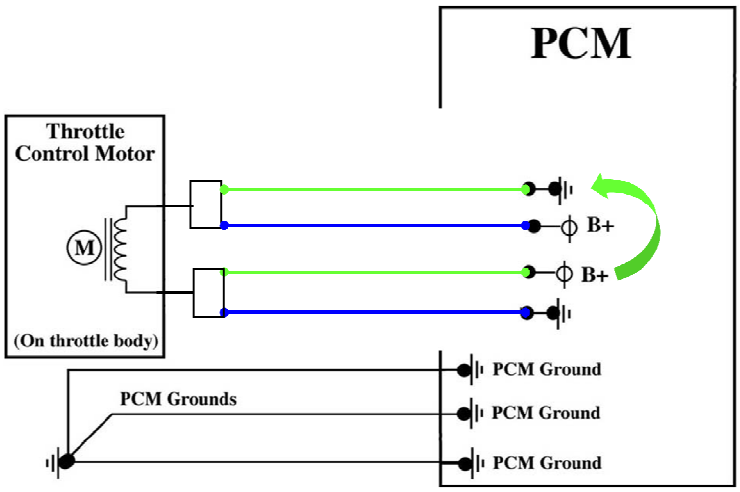




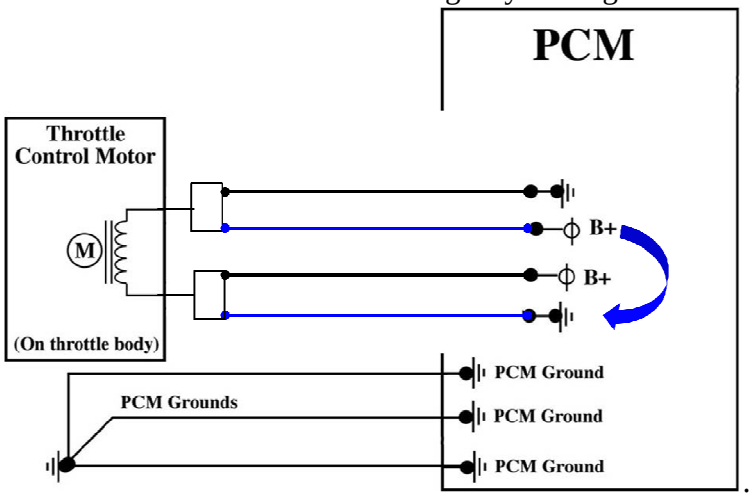
Don't force the throttle plate to move, you may damage the gears that drives the throttle plate. The motor is mostly closed by spring action**.**

If the processor recognizes that the throttle plate isn't closing quickly enough or that is isn't closing it can reverse the motor to help the throttle close electrically**.**

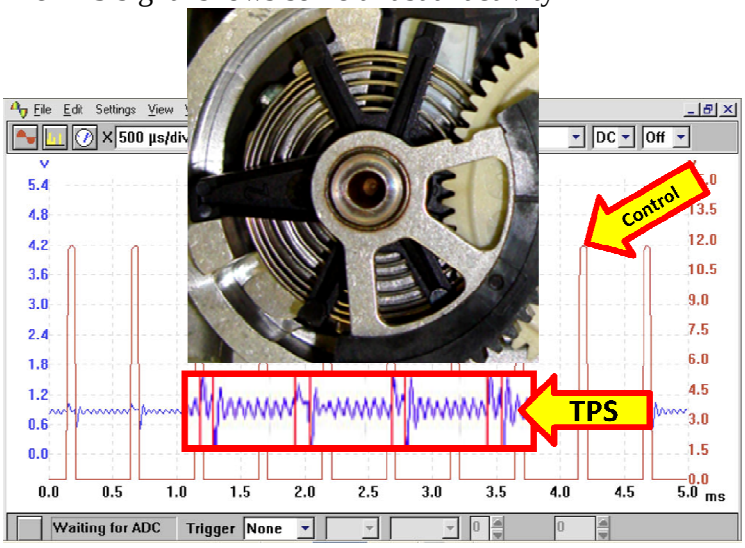
Motor control



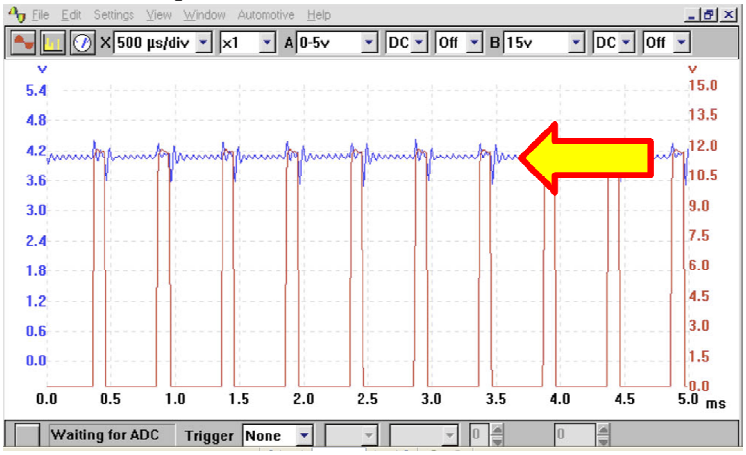
This is the normal mode of control
The motor can be reversed for emergency closing.



The TPS signal shows some unusual activity

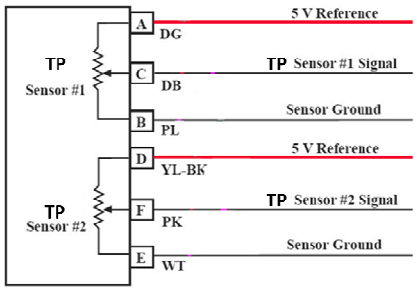


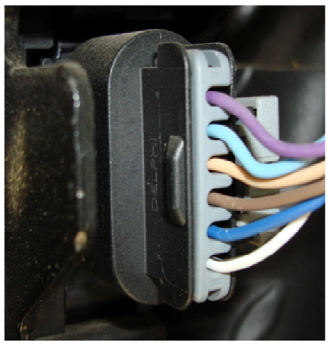
The motor control is working against a spring, which causes minor oscillations in the TPS voltage, this is normal.
The TPS voltage increases as the throttle is opened.
This is wide open throttle;



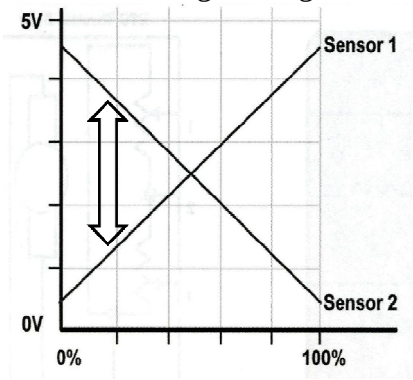
Throttle position Sensor

- The electrical connector for the TPS may be the same connector that the throttle actuator motor is on, or a separate one
- They are potentiometers which measure throttle motor movement
- Review potentiometers in the Pedal Position Sensor section



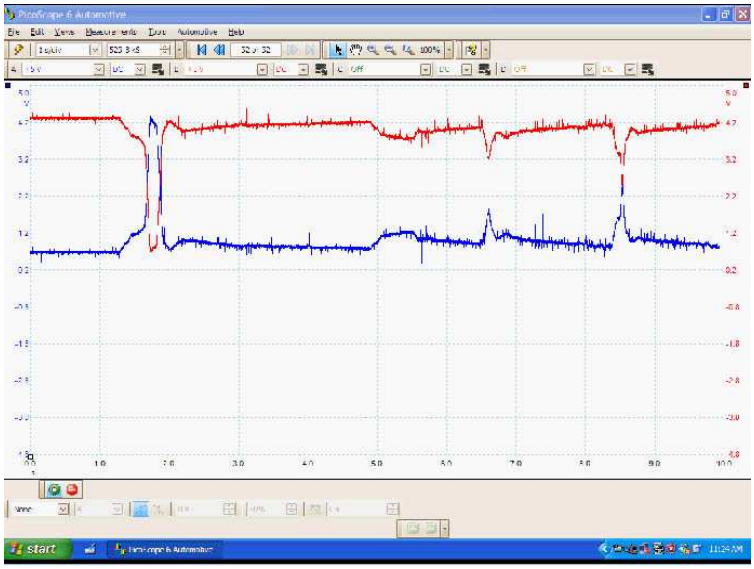


In this example, TPS 1 starts out at a low voltage and increases with throttle opening. TPS 2 starts out at a high voltage and decreases as the throttle is opened

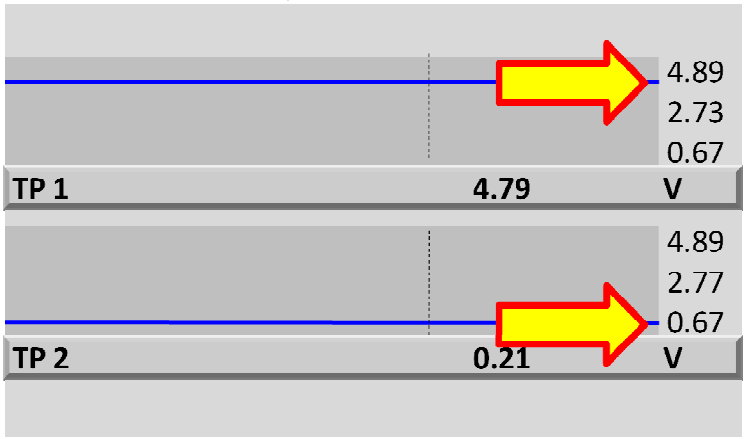


Adding the Signals equals 5.00 Volts

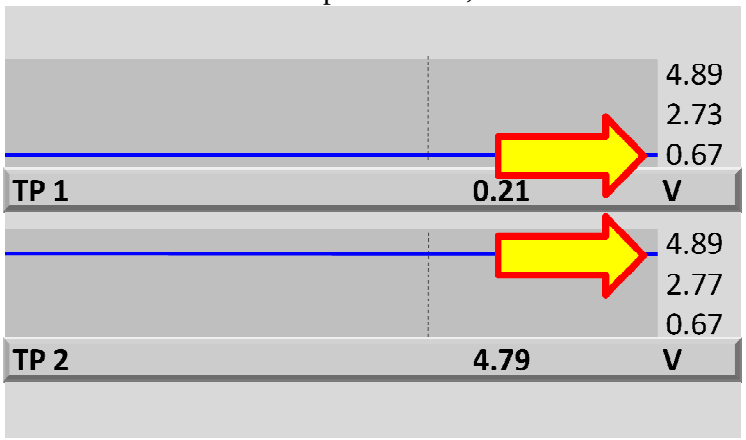
This is the scope pattern for a TPS sweep test



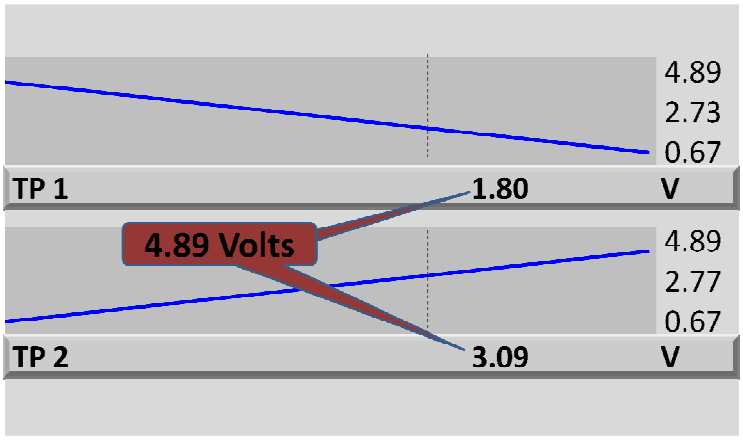
There is noise in the two signals but it affects both signals and the PCM can eliminate it.
Scan data screen at idle;



Scan data screen at wide open throttle;



We can use a scan tool to check to see if the two signals total 5 volts



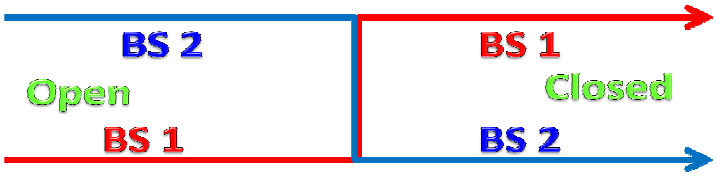
Adding the voltages at this point is 4.89 volts, that's 0.11 volts from 5 volts which is acceptable.

- Use the same diagnostic procedures as was used on Accelerator Pedal Position sensors
- Don't forget to look up DTC's

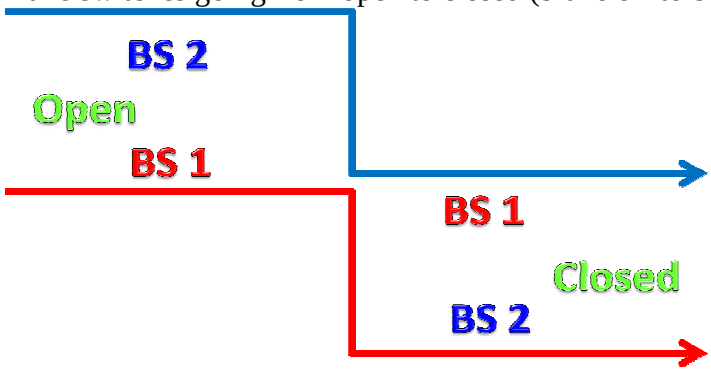
Brake Switch Inputs

- There are two brake switch inputs
- They are redundant for safety reasons

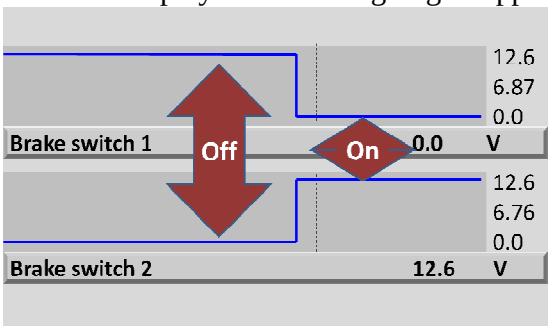
Brake switches going from open to closed (brake off to brake applied)



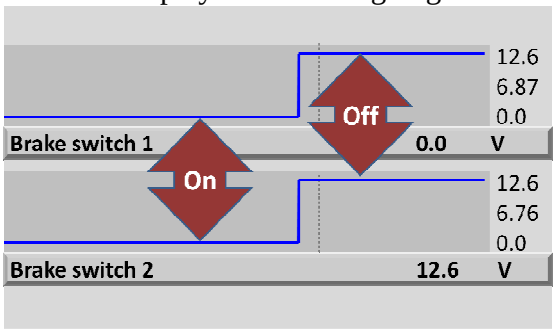
Brake switches going from open to closed (brake off to brake applied)



Scan data display of switches going in opposite directions



Scan data display of switches going in the same directions



Brake Switches closed

Brake switch 1	Yes
Brake switch 2	Yes

Brake Switches open

Brake switch 1	No
Brake switch 2	No

- The sensors are compared to each other and logic (range and rationality) to find faults
- The voltage must be acceptable, the voltage must correlate with redundant sensors
- Unreliable sensors are excluded from system control
- They are also checked for a “stuck” state in which one switch changes state and one doesn’t
- Look for DTC’S
- P0504
    - **Brake Switch A / B Correlation**

Throttle Motor Diagnostics

- The throttle actuator motor is diagnosed by using known good throttle position sensors and engine load sensors. (Air Mass / Absolute Pressure)

ETC Fault Modes

- Based upon the overall failure the PCM may allow full engine power, reduced engine power, or shut the engine down. (Throttle Authority Limiting)

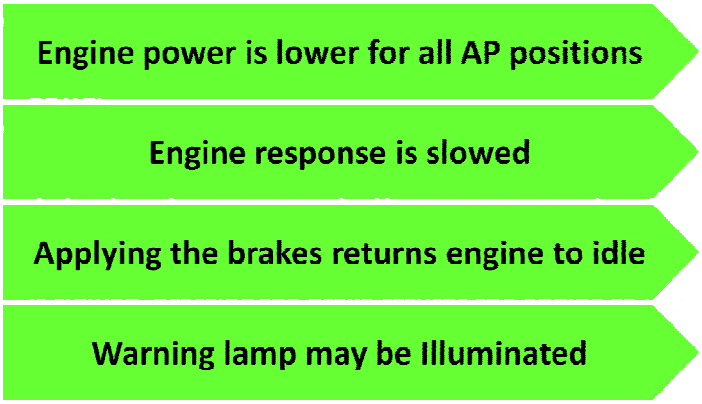
ETC normal Mode

- This mode is selected at power up and remains as long as no faults are present
- **The accelerator pedal provides full control over engine power and performance**

ETC Limit Performance Mode

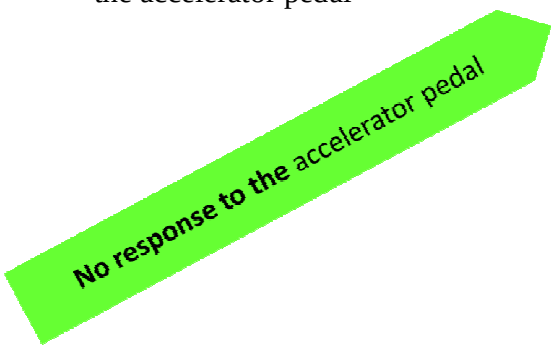
- This mode becomes active when a fault is set indicating a problem between driver intent and actual engine power.
- This mode is set when sensors redundancy indications are not valid.
- In limit performance mode, the engine power for all pedal positions is lower, maximum engine power is limited, engine response to increases in pedal position is slowed, pressing the brake returns the engine to idle power and a warning lamp for the driver may be Illuminated.

Summary of actions



ETC forced idle mode

- This mode becomes active when there is a total failure with the accelerator pedal sensors
- When no driver intent is available the engine will start and run but will not respond to the accelerator pedal



ETC Engine Shut Down Mode

- This mode will set when the ETC system is unable to correctly process the control algorithms or cannot control engine power
- **This mode becomes active when the processors lose their redundancy (Both fuel and spark are disabled)**
- **Check for diagnostic trouble codes**

An ETC code or one of these can place the system into a fail mode

- **Vehicle speed:**
- **Transmission Gear:**
- **Camshaft position:**
- **Crankshaft position:**
- **Oxygen Sensor input:**
- **Knock Sensor input:**
- **Coolant Temperature:**
- **Inlet Air Temperature:**
- **Battery Voltage:**
- **Mass Air Input:**
- **Brake Switch input:**

Use a vehicle specific wiring schematic
Use vehicle specific information
Remember
It’s not the space shuttle
It’s a Chevy
Use this information about failure modes to understand some symptoms that may cause confusion if you don’t consider why the vehicle is not performing properly.