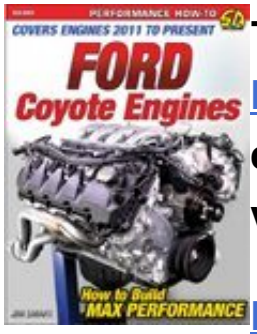
Ford Coyote Engine Ignition and Starting Performance Guide

Filed Under: Ford Coyote Engines, Ford Tech Tips

The Coyote's electronic engine control, ignition, starting, and charging systems are advanced, state-of-the-art designs that are easy to maintain and tune. Electronic engine control (EEC), known as the Copperhead system, evolved from generations of systems originally born at the cusp of the 1980s. What makes the Copperhead system the most advanced to date is what it does. It has more responsibility and function than any other Ford EEC system in history. Copperhead manages fuel and spark curve, throttle function, transmission shift programming, and variable cam timing, just to scratch the surface of what it does.



This Tech Tip is From the Full Book, FORD COYOTE ENGINES: HOW TO BUILD MAX PERFORMANCE. For a comprehensive guide on this entire subject you can visit this link:

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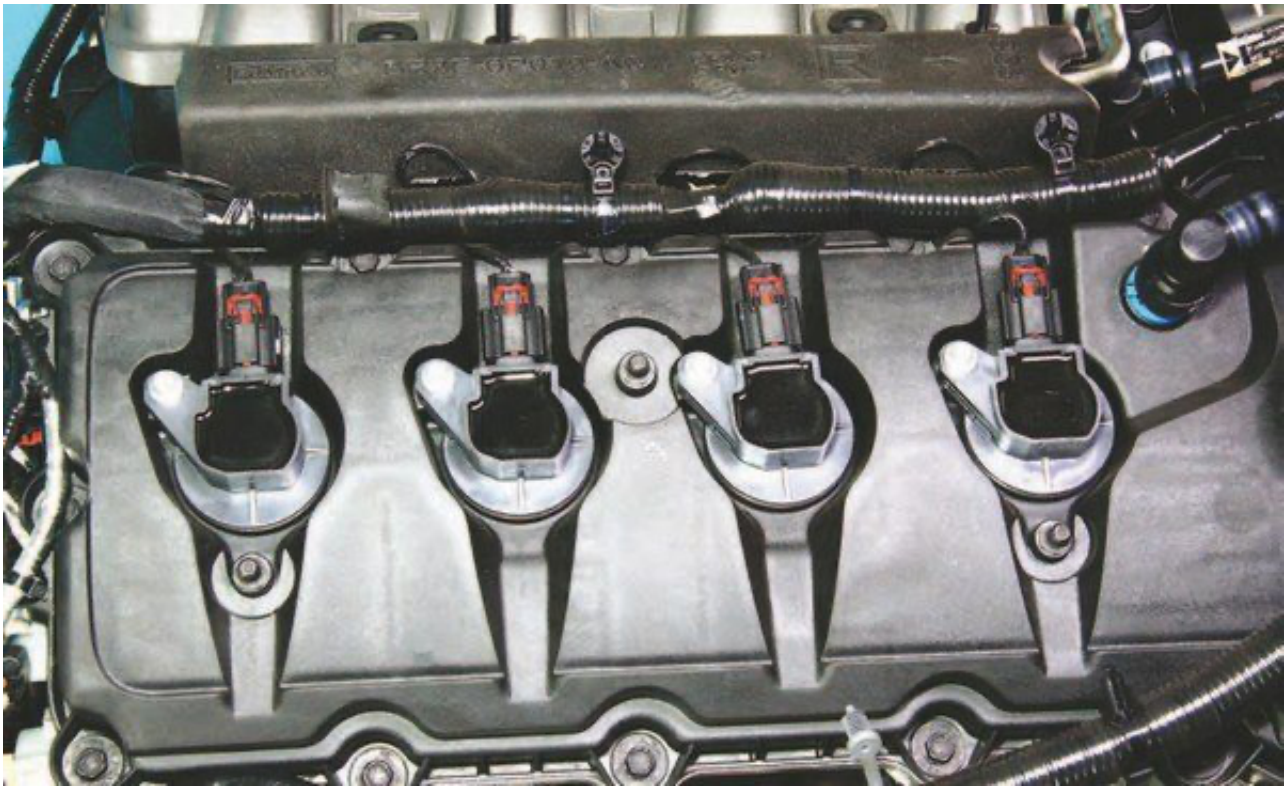
Copperhead is very complex in what it does; variable cam timing alone

involves tremendous amounts of memory/function. For 2011–2014, Ti-VCT was more a simple on/off function. It was either on or off. For 2015–up Ti-VCT is evolved so that variable cam timing rolls in and out in linear fashion instead of straight on/off. Ford powertrain engineers found a way to make variable cam timing even more driver friendly. Ford's Ti-VCT for 2015–2016 follows your foot on the gas and rolls valve timing in and out accordingly. Ford engineers weren't sure that 15 tables would have enough cam timing input, but they do. Ford's Copperhead system also manages to integrate the new ZF 6R80 6-speed transmission and engine into one highly efficient controller, which adds complexity to the mix.

The "One Touch Start" ignition key needs but a moment in the "start" position before handing function off to the PCM/ECU as aggressive deceleration fuel shutoff and torque-based deceleration when you come off the gas. These functions shut off the fuel during deceleration more often and sooner than previous systems while coasting, on long downhill deceleration, and during mid-shifts with the new Getrag MT-82 6-speed manual transmission.



The 5.0L Ti-VCT Coyote and 5.2L Voodoo engines have the same coil-on-plug ignition system fired by the Copperhead electronic engine control system. Ford's family of electronic engine control (EEC-III, EEC-IV, and EEC-V) systems have led to the Copperhead system you have today in the Coyote and Voodoo "drive-by-wire" systems. What makes Copperhead different from its EEC predecessors is drive-by-wire technology along with coil-on-plug ignition and variable cam timing. It really is a complete engine and driveline electronic control system.

Ford Performance Parts offers the complete coil-on-plug ignition kit for the Coyote and Voodoo V-8s. The beauty of high-output coil-on-plug ignition is precision spark timing and long-term durability. If you're running higher-cylinder pressures with boost or nitrous you're going to need a hotter, more powerful spark to keep the fires lit. Each coil is fired in time with valve and piston-timing events to a point at which misfires virtually never happen, reducing hydrocarbon emissions and improving power.

The Ti-VCT Coyote V-8 also features a new digital mass-air meter and universal exhaust-gas oxygen sensors, which report a finite numerical air/ fuel ratio to something like the fourth decimal point, finer than a human hair so to speak. Previous systems weren't much more than

rich/lean. But Ford had to tighten it up even finer to meet tougher Federal emission and fuel economy standards.

Ford engineers spent nearly a year developing the Coyote's electronic engine control function for the 2011 Mustang GT. It was a grueling, lengthy period of testing and programming that lasted the better part of 2008–2009 before they had a fully functioning Coyote in a Mustang test mule. Then they conducted more testing, in every environment imaginable from extreme Arizona desert heat to extreme cold and high altitude, to make sure it all shook out. The Coyote had to function properly under the very worst conditions. It is one thing to test an engine and its electronics in a laboratory and quite another to take it out there and shake it about the firmament on bumpy roads, open highway, stop-and-go traffic, mountain twisties, and more. By the end of 2009, Ford powertrain engineers had the Coyote in seamless smooth operation.

Ignition coil service and replacement is easy on the Coyote. No ignition wires to sweat out. Only an 8-mm socket, plug coil disconnection, and removal. When you service

the ignition remember to apply a dielectric compound to the boot for sealing and protection. These coils are life-of-the-engine durable.

This is the Coyote's ignition system one cylinder at a time. Each of these coils fires in perfect time with valve and piston events. Aside from precision and durability these coils are designed to keep moisture and dust out.

What made the Copperhead system challenging for Ford engineers was getting a drive-by-wire system to feel like a linear throttle cable. What does make drive-by-wire different is that ever-so-slight lag when you lean on the throttle. It isn't as quick as the humble throttle cable. There's a nanosecond lag and a certain amount of surging during throttle tip in. These dynamics vary from vehicle to vehicle. In time, drive-by-wire will be completely seamless.

Ignition System

The Coyote's ignition system does not have coil packs or ignition wires, just eight ignition coils and platinum-tip spark plugs to fire the mixture. The Copperhead PCM/ECU takes all of the known elements

(driver input, speed, environmental conditions, and engine timing events) and turns them into a firing order cadenced in perfect time with piston and valve timing events to fire spark plugs at just the right moment.

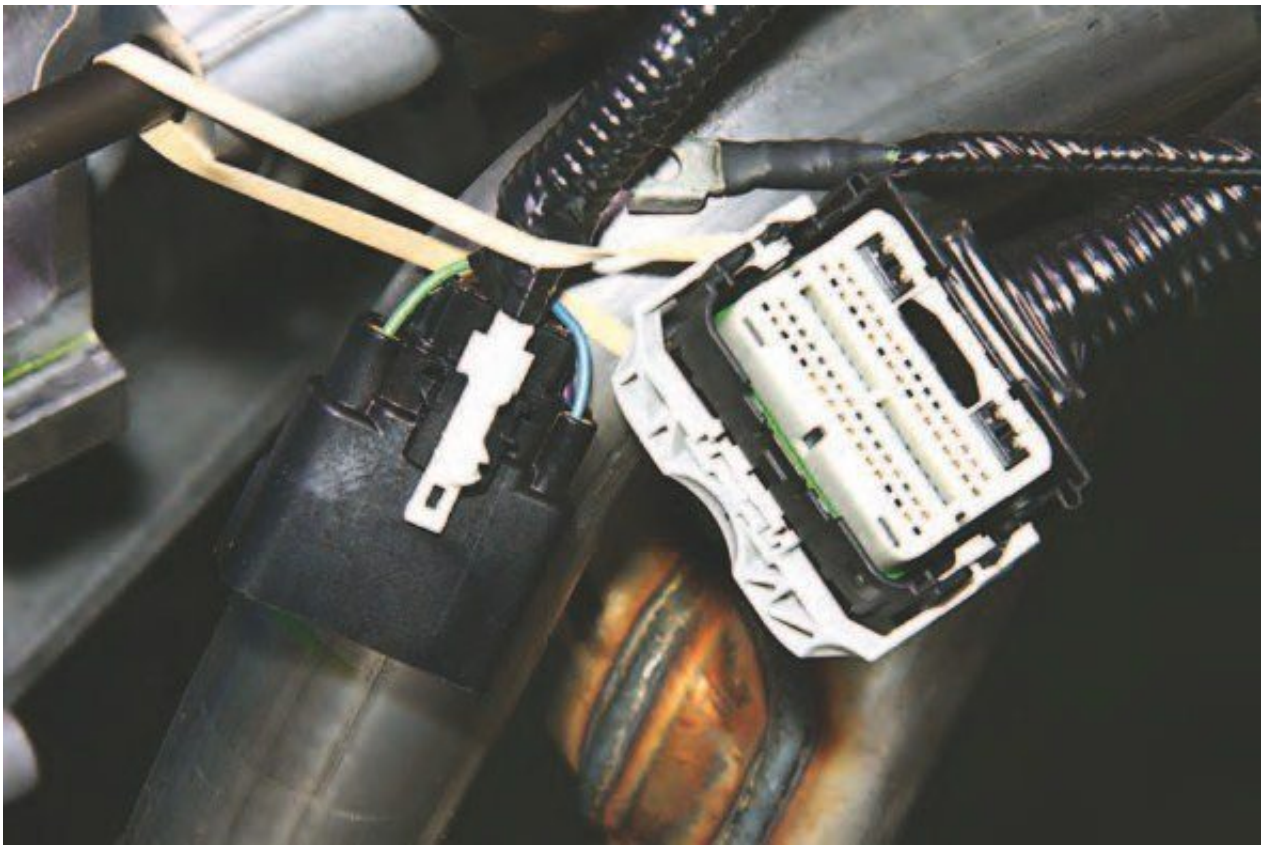
Coil-on-plug ignition is undoubtedly the best ignition system innovation in automotive history. Eight high-energy ignition coils and deep-reach Motorcraft platinum-tip spark plugs extend deep into the middle of Coyote's four-valve chambers for more complete combustion. Ignition coil spark plug boots protect both plug and terminal from corrosion issues that can cause misfire. An umbrella boot completely covers the spark plug well to keep dust and moisture out. A weathertight Copperhead harness runs along the fuel rail, providing power to both ignition coils and injectors. Coils are fired in perfect time, as are injectors. Injector and ignition coil plugs are all positioned such that it is impossible to get them mixed up. The engine harness involves all of the sensors, senders, and evaporative

emissions purge valve connections. It is impossible to get any of these connections mixed up because each component has a different multiplex plug.

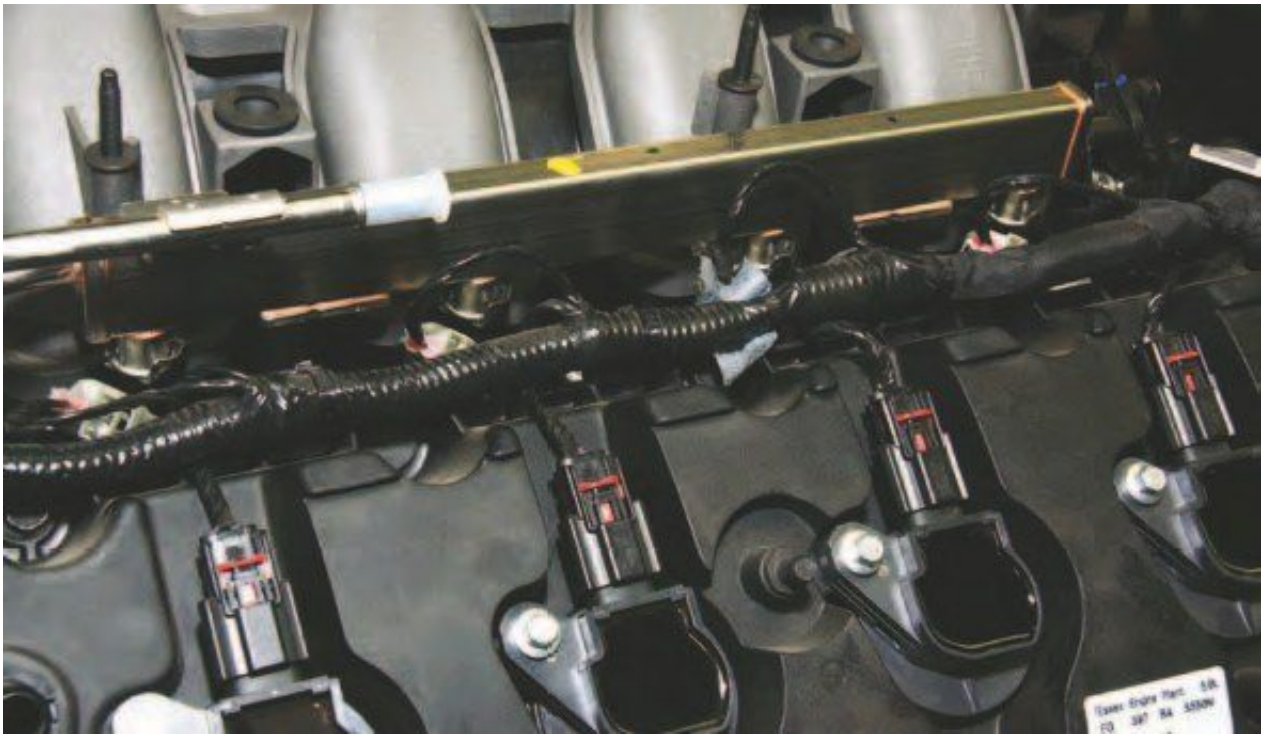
Ti-VCT Coyote Firing Order

1 5 4 8 6 3 7 2

Traditional Ford V-8 pattern with cylinders 1 to 4, right bank; and 5 to 8, left bank.



The 5.0L Ti-VCT Coyote and sibling Voodoo is a plug-and-play electronics package. These two weathertight multiplex connectors plug right into the electronic engine control harness and PCM/ECU. If you're performing a swap on a vintage Ford or perhaps a 1979–1993 Fox-body Mustang, Ford Performance Racing Parts makes short work of a Coyote swap with a complete package and detailed instructions. This means complete, easy-to-install engine and transmission packages shipped right to your door. It has never been easier to perform an engine swap.



The Coyote's electronic engine control system is simple. The engine harness shown here consists of fuel injection and ignition along the fuel rails. The rest, which is not visible, goes to sensors and senders.

Mustang GT Ford Performance Racing Parts Calibration System with High-Flow K&N Air Filter

- M-9603-MGTB
- Fits 2011–2014 Mustang GT
- Approximate peak increase of 16 hp and 7 ft-lbs on 93-octane fuel
- Up to 60 ft-lbs torque increase at 1,500 rpm
- Eliminates "skip-shift" on 2011–2012 Mustang MT-82 6-speed manual transmission

The kit includes:

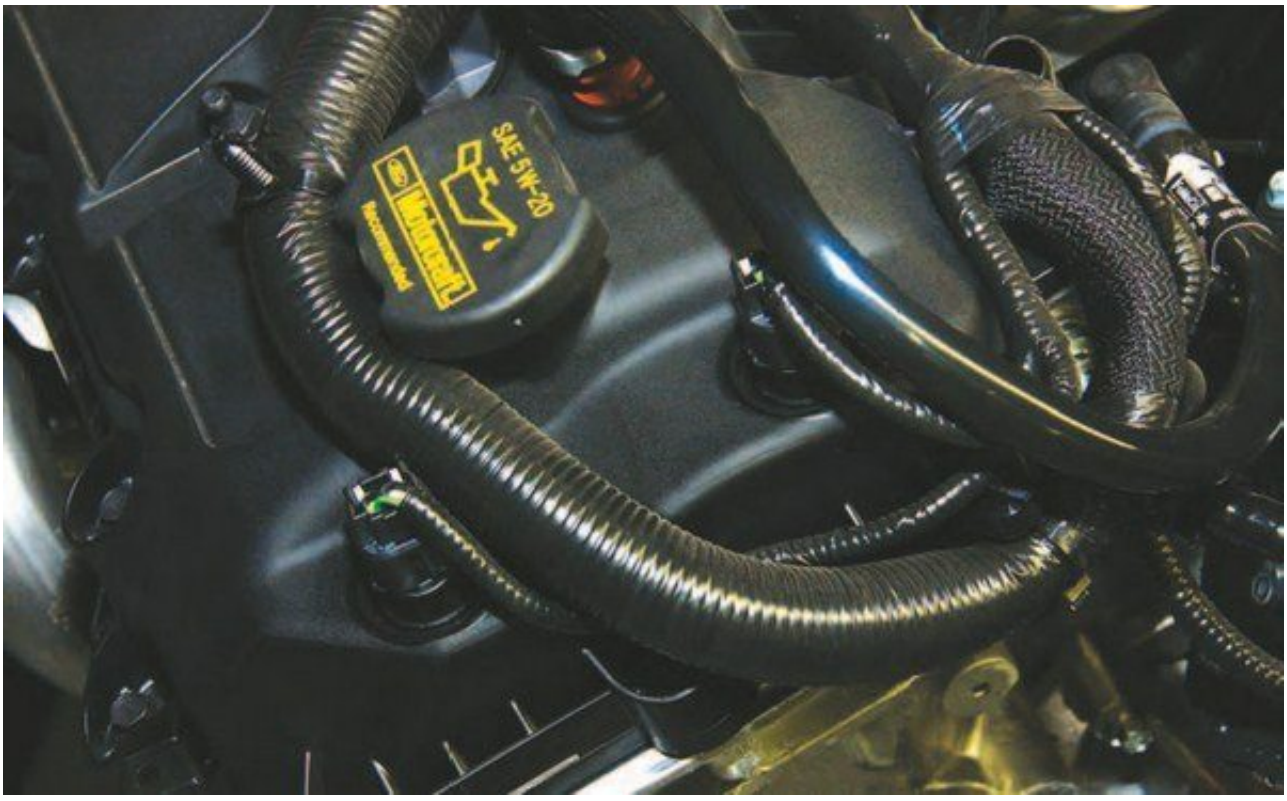
- Ford Racing ProCal tool with performance calibration
- 2011–2014 Mustang GT high-flow K&N/Ford Racing air filter M-9601-MGT
- Premium (91 octane or higher) fuel only

- Due to multiple powertrain calibrations, online registration is required to receive ProCal calibration delivery tool after purchase
- Ford Performance Racing Parts does not ship ProCal tools directly overseas. Customers must make special arrangements with their Ford Performance Racing Parts Distributor
- Powertrain calibrations are developed and supported for U.S. and Canadian vehicles only
- This Ford Racing Power upgrade package is 50-state emissions legal and eligible for limited warranty when installed by a Ford or Lincoln Dealer
- Federal and state laws prohibit any person from installing aftermarket add-on or modified parts prior to the sale of a new motor vehicle

It can be asked, how would you improve the Ti-VCT Coyote's ignition system? By upgrading to a more powerful aftermarket ignition coil from Ford Performance, MSD, Accel, or Granatelli Motorsports. A naturally aspirated Coyote lives happily with a stock Ford ignition coil. The more potent the spark the better, which is especially true in

boosted applications.

This is the crank sensor, which is triggered by the reluctor (shutter wheel) at the crankshaft. Replacement is easy with an 8-mm socket should replacement ever be necessary. You will likely not ever have to replace this sensor.



Shown are the right-hand-bank (passenger) VCT solenoid connectors. VCT gives the

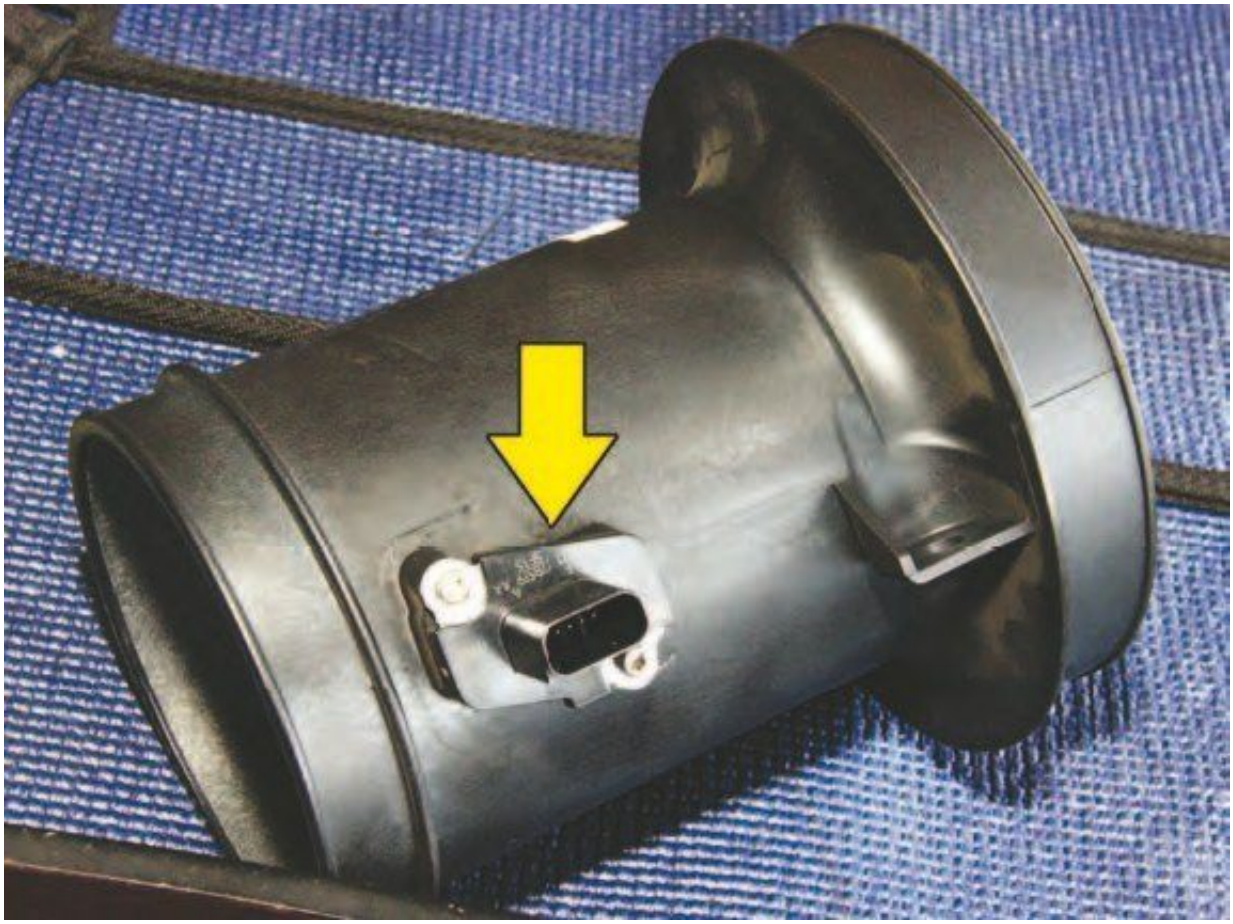
Coyote precision valve timing based on demand. The 2011–2014 VCT is different from the 2015–up VCT. For 2011–2014, valve timing is simple on/off. The 2015 and onward is more finitely modulated to driving demands.

Here's the left-hand (driver) side with cam covers removed. Visible are the cam reluctors inside and cam sensors outside. This is a Hall Effect trigger system that signals the PCM/ECU where cams are positioned/ indexed. Note the sensor colors: Exhaust sensors are gray and intake sensors are black.

These are the Ti-VCT solenoid connections for variable cam timing. These solenoids modulate the VCT valves to advance valve timing. Each cylinder bank has two of these solenoid valves: one for intake and one for exhaust cam indexing. This is the left-hand (driver) bank.

Cam sensors are found at the rear of each cylinder head. This is the right-hand (passenger) side. These sensors are tied to the PCM/ECU to keep track of cam indexing. Note the foil insulation to protect wiring from heat.

The Coyote's knock sensors are located in the valley, up close and personal to each cylinder bank. Ford has this dialed in so precisely that ignition timing and fuel curve are quickly corrected should spark knock occur.



Here's the Coyote's MAF sensor, located in the intake duct. The MAF works hand in hand with the PCM/ECU's gang of sensors to keep ignition and fuel curves on track. The MAF enables you to perform constructive modifications on the Coyote and Voodoo without consequence. All you need is a qualified professional tuner. Never trust your Coyote to anyone less than a seasoned professional tuner. And remember, anyone can hang up a sign and call himself (or herself) a tuner. Investigate any tune shop thoroughly before entrusting them with your investment.

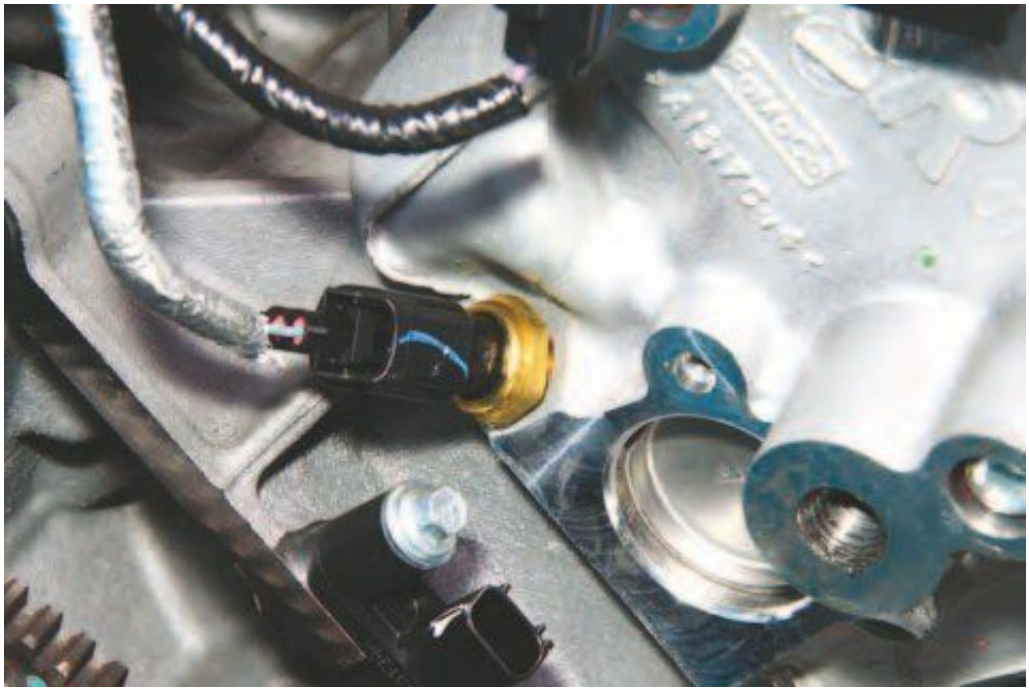
Modular applications in the past have normally included four oxygen sensors, with one ahead of each catalytic converter and one aft to gauge emissions before and after. The Coyote works the same way. There are two oxygen sensors for each bank, one ahead of the cat and one in the cat. This makes the Coyote both fuel efficient and clean burning.

If you're going to run boost or nitrous you're going to need an ignition coil and spark plug that can stand up to extreme cylinder pressures. You may also want a cooler spark plug that dissipates heat better than the factory range. Ford Performance Racing Parts, as one example, markets a one-range-colder spark plug for boosted/nitrous applications. The same can be said for MSD and Accel. Both have heat ranges you can work with.

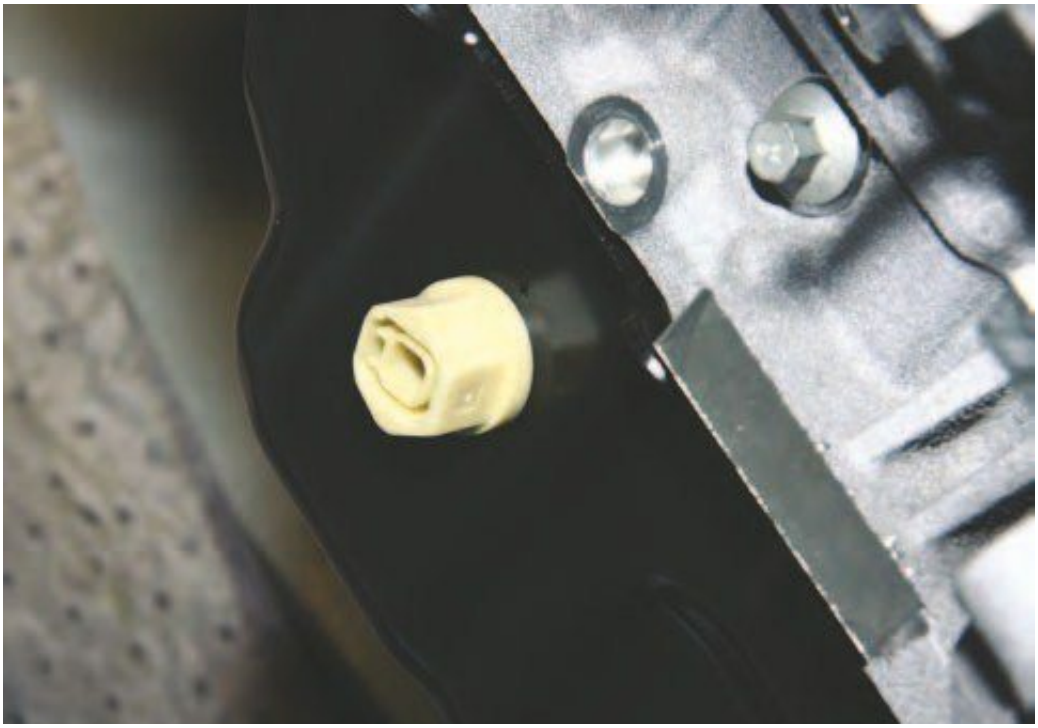
Sending Unit

Although the Coyote's electrics are the most advanced in Ford history, some elements have never changed. Sending units and sensors still

tend to operate on the principle of resistance to ground. This statement isn't true for all senders and sensors, but most of them. When you have high resistance to ground this means you have low current flow to ground. With high resistance, the instrument needle reads low. With low resistance to ground, the needle reads high. Using a cylinder head temperature or oil pressure gauge as an example, high temperature or high pressure creates low resistance to ground and a high reading.



This is the cylinder-head temperature sensor, which contributes to the electronic engine control picture and temperature gauge.



The oil level sensor is in the oil pan. Continuity via oil level determines whether or not you get a low oil level warning. These oil level sensors tend to leak regardless of what you do with them. They are vulnerable to temperature and vibration extremes.

This is the oil pressure sender, which controls resistance to ground for the oil pressure gauge. The greater your Coyote's oil pressure the lower the resistance to ground, which affects gauge needle position. The lower the resistance, the higher the needle.

MSD Ignition markets these individual coil packs for coil-on-plug ignition. This is a true aftermarket ignition system with coils and wires for racing applications. However, you can run this system on your street Coyote. Boots are protected the same way as the stock coil-on-plug system.

The Coyote's starter is virtually the same as the 4.6L and 5.4L Modular. It remains a three-bolt reduction gear Motorcraft starter with an integral solenoid/ drive. This starter package is easily adapted to vintage Ford Coyote conversions. Keep the original remote solenoid as a relay and route power to the starter and integral solenoid. You then have two solenoids doing the work. Ford Performance Parts makes it easy with this complete M-11000-C50 starter installation kit, which includes starter, hardware, and wiring harness.

Motorcraft 9G Alternator Specifications

- Minimum output: 96 amps at 650 rpm
- Maximum output: 156 amps at 6,000 rpm
- Pulley ratio (automatic transmission): 2.69:1
- Pulley ratio (manual transmission): 2.98:1
- Internally regulated

Like its Modular predecessors, the 5.0L Ti-VCT Coyote has long-reach Motorcraft platinum-tip spark plugs. The main thing you want to be concerned with is heat range. Stock naturally aspirated Coyote engines don't need an alternative heat range. If you're going to supercharge, raise compression, or go nitrous. There's the Ford Performance Racing Parts M-12405-M50 spark plug, which is one heat range lower than stock. The M-12405-M50 is a colder plug engineered for higher-cylinder pressures. Suggested gap is in the .035-inch range for boosted applications.

Starting System

The Ti-VCT Coyote has the same basic starting system as the Modular engine family from which it was born: a lightweight Motorcraft reduction gear starter with an integral solenoid. Power energizes the solenoid, which plays double duty; it energizes the starter and operates the starter drive engagement. This is a three-bolt starter just like you find on the 4.6L and 5.4L engines. If you're doing a Coyote swap into a vintage Ford you can run the factory starter solenoid as a means to getting power to the Motorcraft starter solenoid. You are, in effect, activating two solenoids this way. You may also eliminate the classic remote starter solenoid and get power directly from your vintage Ford's ignition switch via the "S" lead, which energizes the

start solenoid down under at the starter.

Charging System

The Coyote utilizes a high-amp, internally regulated Motorcraft “9G” 150-amp alternator, which is more than adequate for most applications. Ford Performance Racing Parts offers you the 2012–2013 BOSS 302 alternator, M-8600-M50B-ALT, which is an off-the-shelf piece designed specifically for high-RPM operation. Because the 9G is internally regulated, there’s nothing to sweat out service-wise except regulator replacement, which is easy.

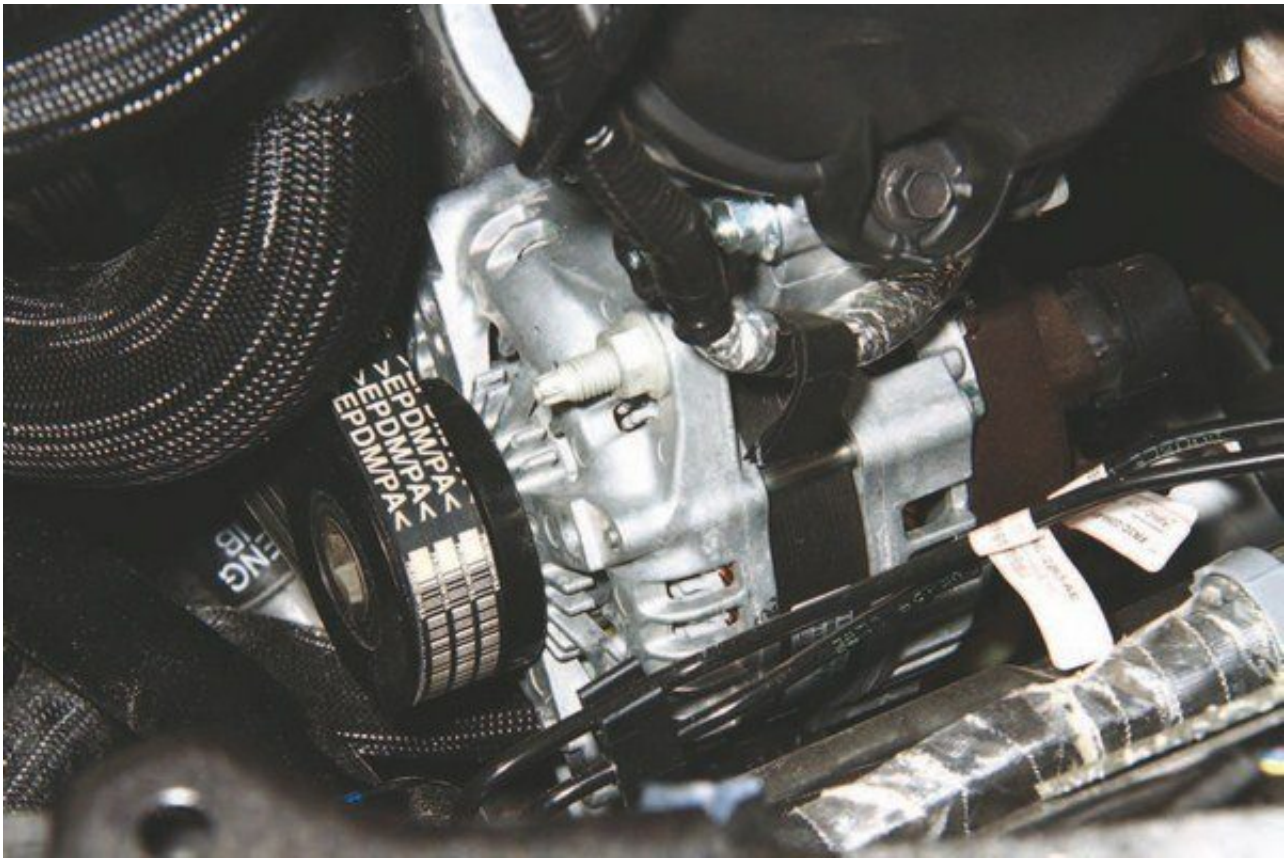
Ford no longer manufactures its own alternators. The 9G is manufactured by an outside supplier. It is available from the Ford Parts website for stock replacement. It is also available new and remanufactured from the aftermarket. Ford Performance offers you the BOSS 302 alternator, M-8600-M50B-ALT, which is the better

choice even if you're just doing a routine replacement.

BOSS 302 Alternator Conversion Kit

This fits the Mustang 5.0L Coyote engine and features the following:

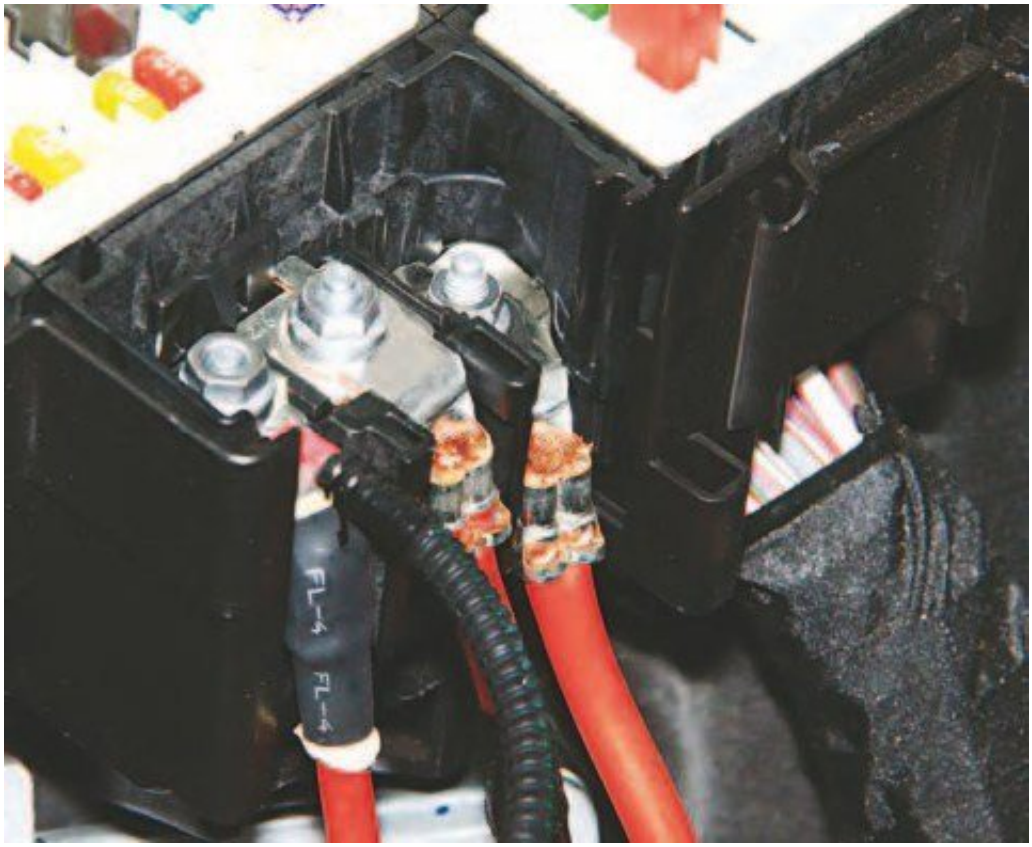
- High-performance BOSS alternator with one-way clutch to prevent belt hop during high-revving upshifts
- Higher-tension belt tensioner for belt security
- Larger pulley to slow the armature speed, reduce drag, and reduce power loss
- Also fits M-6007-M50, M-6007-A50NA, M-6007-A50XS, and M-6007-A50SC Ford Performance Racing Parts and Roush Performance crate engines
- Kit includes OEM Mustang BOSS 302 alternator, tensioner, idler pulley, belt, and mounting hardware



Coyote is fitted with a high-output state-of-the-art "9G" 150-amp alternator. Although this is a compact alternator it produces an outrageous amount of charging power. Its compact size makes it a good fit for the Coyote. If you intend to spin your Coyote high, consider the Ford Performance Racing Parts M-8600-M50B-ALT BOSS 302 alternator conversion upgrade. Because high-output sound systems are so popular these days, you need to consult with an audio shop on charging system options should you opt for a high-wattage audio system. The stock alternator may not stand up to the demand.

The Ford Performance Racing Parts 5.0L Coyote Boss 302 alternator kit, M-8600-M50B-ALT, includes special high-performance components as used in the production 2012–2013 Boss 302 Mustang. They're engineered to operate at much higher RPM using a one-way clutch to prevent belt failure during manic upshifts. The belt tensioner has greater tension for better belt control at high RPM, and the larger-diameter pulley slows armature speed, which reduces drag and parasitic power loss. This is not a higher-amp alternator. It is designed specifically for high-RPM use.

The Coyote's electronic engine control, known as Copperhead, is located closer to the engine these days instead of being inside the cabin. Access and service are easy. For 2011–2014 Mustang GT the PCM/ECU is located in the cowl behind the battery. For 2015-up it is located in front of the engine compartment on the right-hand side. Electrical systems have become more modular in nature, which means plug and play for ease of maintenance and durability.



Here's one example of the modular nature of Ford electrical systems today. This is the 2015 Mustang's main fuse and relay box, located underhood for easy access.

It may not seem like a big deal, but proper grounding is everything to proper PCM/ECU function. If you examine new Fords closely you see grounding everywhere to ensure solid negative ground continuity. The black and black with yellow stripe has been Ford's ground identity for more than a half-century.

Any time you make performance modifications to your 5.0L Ti-VCT Coyote or 5.2L Voodoo engine, it is strongly suggested you put it in the hands of a trusted electronic engine tuner. Some aftermarket software programs work quite well, but not all of them. Anyone can hang up a sign and call himself (or herself) a tuning shop. Check out the chat rooms and forums to see what people's experiences are. Most tune shops use existing off-the-shelf software to tune, which doesn't mean they know what they're doing. You want a tuner who can interface with your Coyote's Copperhead system and dial in spark and fuel curve based on dyno numbers. This is a 2014 Mustang GT being retuned at GAS after an exhaust system change.

BOSS 302 Alternator Conversion

The BOSS 302 Alternator Kit (M-8600-M50B-ALT) includes special high-performance components as used on the production 2012–2013 BOSS 302 Mustang and is designed to operate at a higher-RPM range, according to Ford Performance Racing Parts.

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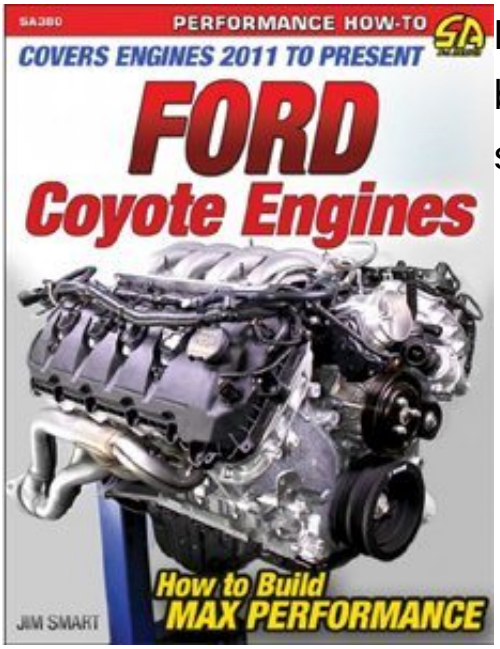

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