Bosch Motronic Basic, Motronic 1.1, Motronic 1.2, and Motronic 1.3 Fuel Injection Tech Article

The technical/repair portion of this article is essentially finished. I will still add to it and update it from time to time.

Introduction:

This article is intended to help owners of cars with Bosch Motronic Fuel injection perform their own service. The article is based on the Original Bosch Motronic system used on the 1987 E28 BMW 535i.

While this article is primarily intended as a fuel injection article, it will include testing information for some components of the ignition and other systems related to the Motronic system. This is because the Motronic system ties into a lot of things, ignition, emission, even the 535i's automatic cabin temperature control. Everything it ties into will be covered.

You will not need any Bosch or BMW testing equipment, this article should allow you to test and troubleshoot with just basic tools and an inexpensive multi meter.

Disclaimer: I have no factory training. Use this information at your own risk. I strongly suggest having a fire extinguisher nearby whenever working on an automotive fuel system. As a matter of fact, just stop reading this right now and go buy a factory BMW shop manual.

How to use this article:

You can use this article in a few ways, first you could follow it through step by step. This would very thoroughly check out your fuel injection and ignitions systems. I recommend this method if you have plenty of time,   if your car has more than one problem, or if you just purchased the car and want to get it running just right. If your car has one simple problem you can use this article as a sort of trouble shooting and testing guide for specific components. To make trouble shooting easier I have included the symptoms associated with a defect for each part of the injection system. The sections showing these symptoms can be found quickly by looking for the * Symbol. As a general rule the components that can cause the most problems and/or the biggest problems are towards the beginning of this article. For example, air leaks in the vacuum hoses, lack of power to the fuel injection system, fuel pressure and fuel injectors can all cause a variety of problems, and even prevent the car from running. A faulty idle air control valve will only cause problems at idle so it's covered later in the article.

What cars does this article cover?

The article specifically covers the **E28 535i**. It also covers most of the changes associated with the **S38** engine in the **E28 BMW M5,** the **E34 BMW M5** and the **BMW E24 M6**.

Can this article help me with other cars?

YES! The short verison is this. If you car has Bosch Motronic AND has a distributor, it's version that's

covered in this article.

With a few minor variations the same Motronic system is used on many other BMWs from the 1980's including the BMW 533i, 633i, 733i, 635i, 735i, 528e (Note: some early 533, 633, 733 BMWs use Bosch L-Jetronic. Please refer to my L-Jetronic tech articles for those cars.) Various BMW E30s, the the 325i and 325e use Motronic, however they are set up differently. Most of the component tests in this article are relevant for the Motronic E30s, however the locations of the components will usually be different. I will try to point out the variations in these cars within this article, but there is no way I can nail every variation.

There were many other cars built in the 80's and early 90's using this same basic fuel injection and ignition system including the Alfa Romeo 164, Rolls Royce Silver Spur, and others. The Japanese built clones of this system under license and many Japanese cars from the 90's use this system.

Some BMW 635 cars use the **Motronic 1.3** system. It's essentially the same as the 1.1 system. In some cases, it still uses the cold start valve/injector, unlike the 1.1 system in the 528e. The big change in the 1.3 system was its ability to store more fault codes, and keep them in memory when the car is shut off. To allow it to do this, the 1.3's ECU (electronic control unit, which is the "Motronic Control Unit", or fuel injection and ignition computer) is hard wired to the battery, so it always has voltage if the battery is charged and connected.

Motronic 1.2 is essentially just like 1.1 with the addition of a hot wire air flow sensor replacing the older flapper type. The BMW E34 M5 uses 1.2 with addition of a plenum divider and an air pump, both of which are covered in the article.

Most BMWs I know of using the Original Motronic system (often called Motronic Basic) have a diagnostic connector like the one shown in the picture below. If your 80's BMW connector has 15 pins, it's Motronic Basic. If it has 20 it's Motronic 1.1.

As far as I know all E28 BMW 535i cars use Motronic Basic. The only E28 I know of that used Motronic 1.1 was the later BMW 528e (build dates from 3-1987 and on). Except where noted, all text and pictures in this article are from Motronic Basic. I will try to cover the 1.1 system in this article, but I don't have a 1.1 car here to take pictures of.

Important Note, the car used in the photos has SILVER Vacuum lines in most locations. They show up in the pictures fairly well. The lines on your car will probably be black.

Pictured below is our 1987 535i. It has a silver silicone hose kit installed. This kit includes engine compartment vacuum lines, windshield washer lines, and two coolant lines. The pieces are pre cut and the kit includes excellent instructions with two good diagrams.

If your BMW has these fuel lines coming out of the passenger's side firewall, check them right away. If they fail fuel can spray onto the exhaust manifold catching the car on fire!

Let's Get Started!

Step 1, Eliminate air leaks. (also called "vacuum leaks". Yes, I am aware that technically vacuum doesn't leak, but leaks in the vacuum system can be called "vacuum leaks" for convenience)

Air leaks are one of the biggest problems on Motronic cars. It's not quite as sensitive to air leaks as the older L-Jetronic system, but it's still sensitive. If you want to see just how air leaks effect the motor, pull the oil dipstick out while the motor is idling. That introduces only a small leak, yet the effect is dramatic. *****Air leaks can cause a lot of problems including difficult cold and/or hot starting, loss of power, poor emissions, and general drive ability problems. In an extreme case they can even cause internal engine damage. Motronic will compensate for very minor leaks by adjusting idle speed with the idle stabilization valve. In other words if you have a slight leak you won't see any real change at idle because the system will adjust idle. However it's ability to compensate once the throttle is advanced is marginal at best.

Air leaks cause problems for two reasons. First, the Motronic system measures the volume and density of the air passing through the air flow meter and sends that information to the fuel injection computer also called the ECU. The ECU then calculates fuel requirements based largely on that information. If an air leak allows air to enter the system downstream of the airflow meter then the ECU has no accurate measurement of how much air is entering the engine. The second problem is that various devices including the fuel pressure regulator and evaporative purge valve (both discussed in detail later) as well as many other components require vacuum to function properly. An air leak will not only introduce un metered air into the system it will prevent important components from working properly.

It makes sense to start troubleshooting by looking for air leaks. This is because they are a possible and common cause of nearly every fault, and they are about the easiest and cheapest problems to solve. You don't want to throw hundreds of dollars in parts at a problem only to find out it was an air leak.

Lets start by looking at the main air intake tube or "rubber boot" that connects the throttle body to the air flow meter. This thing has a lot of potential for leaks. It should be inspected very carefully for cracks. They tend to form on the bottom of the tube so you really need to remove it to properly inspect it. If it has any cracks it should be replaced. If you can't replace it because you can't find the part, or due to economic realities I suggest using "Shoo Goo" from the sporting goods section of Wal Mart. I have also found it in the shoe section of Wal Mart (by the shoe laces and polish). This product is designed for repairing the soles of tennis shoes and will seal up any air leaks on this tube. (don't laugh, Shoo Goo lasts almost forever in this application)

Next start inspecting all the vacuum lines in the engine compartment. All of them are related to the fuel injection system in some way, and a leak in any of them can cause problems. This can be time consuming because a lot of these vacuum lines are hard to see and have to be removed to be inspected effectively. If your lines are 20 years old they will probably have to be replaced. They are almost certainly cracked and brittle with age and it will be very difficult to remove them without cracking them. (Sales pitch alert!!! Our silicone hose kit has all the vacuum lines pre cut for the 535i and includes easy to follow step-by-step instructions and diagrams. It also includes all the windshield washer hoses, and a couple coolant hoses. We use very high quality silicone and the lines should outlast everything else under the hood. It can be found here:
http://www.hiperformancestore.com/BMW.htm all BMW Silicone Vacuum Hose Kits Link)

BMW E34 M5 Additional vacuum system data:

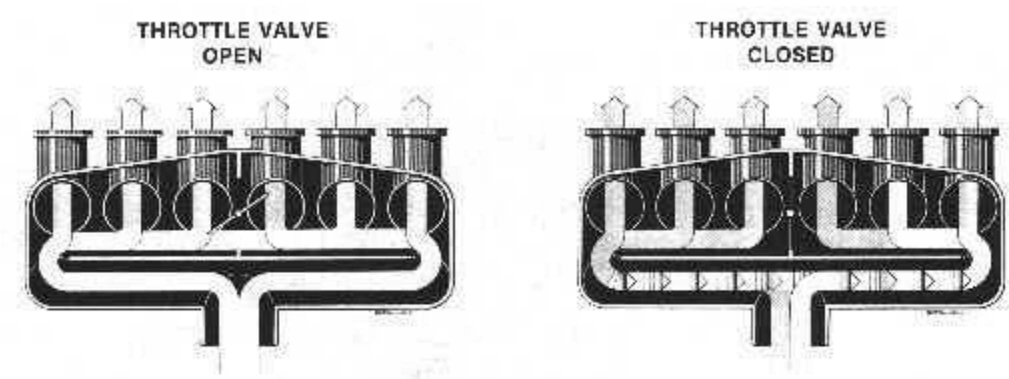
Resonance Flap Control and Air Injection Control:

The S38 engines found in these cars have a significantly different vacuum system. Most of the differences are related to the “resonance flap control system”. * This system is important for performance and if faulty will cause a loss of horsepower and torque in certain conditions. It can also cause other minor running issues, like poor response, irregular idle, or high emissions.

The resonance system is confusing as heck. Let’s talk about it. The system uses a flap inside the plenum to essentially divide the plenum into halves whenever maximum performance is needed, that means full throttle.

However, under certain conditions, the engine is happier without the plenum divided. So at part throttle, or at full throttle but between 4120 and 6720rpm the flap is open and the plenum is not divided.

OK, the picture below shows the two different paths the air takes. The picture on the RIGHT is the flap closed plenum divided picture. There is a lot of confusion about this because the “throttle valve mentioned in the diagram refers to the flap inside the plenum and NOT the six individual throttles.



From a performance standpoint, the entire point of this system is to increase torque between 4120rpm and 6720rpm. At full throttle outside of that RPM range, the flap is closed and the plenum is divided. For reasons having to do with resonance, at full throttle the engine makes more torque with the flap open within a certain rpm range so the system provides the engine with two different plenum configurations while at full throttle.

When not at full throttle, the flap is open and the plenum is not divided. This improves the engine’s operation at part throttle.

OK, so that’s what it does, but how does it work? Well, it’s electronically controlled, but VACUUM activated. There is an actuator that uses vacuum to operate the flap. There is a component called a change over valve. This valve either lets vacuum reach the actuator to close the flap, or it doesn’t, in which case the flap opens due to spring pressure. The changeover valve gets it’s signal from the resonance flap control unit, which knows throttle position and engine rpm.

The beautiful S38 engine pictured below has our M5 silicone vacuum hose kit. The red arrow I have added to the picture shows the vacuum operated actuator. From that actuator you can follow the vacuum lines to find most of the other related system components, and the air injection components.

Blatant commercial comment: We have vacuum hose kits for all 6 cylinder M5s. Our E34 kit shown here is available in 7 different colors. We have even had some customers order the kits with a combination of Blue, Purple, and Red hoses for the “M” color scheme. There are a lot of vacuum hoses on these cars, many of which are not visible in this photo. Our kit replaces them all as well as the oil drain hoses out of the plenum, and various coolant hoses, and it includes a vacuum diagram. We also have silicone radiator hoses for the E34 M5. End of commercial ☺

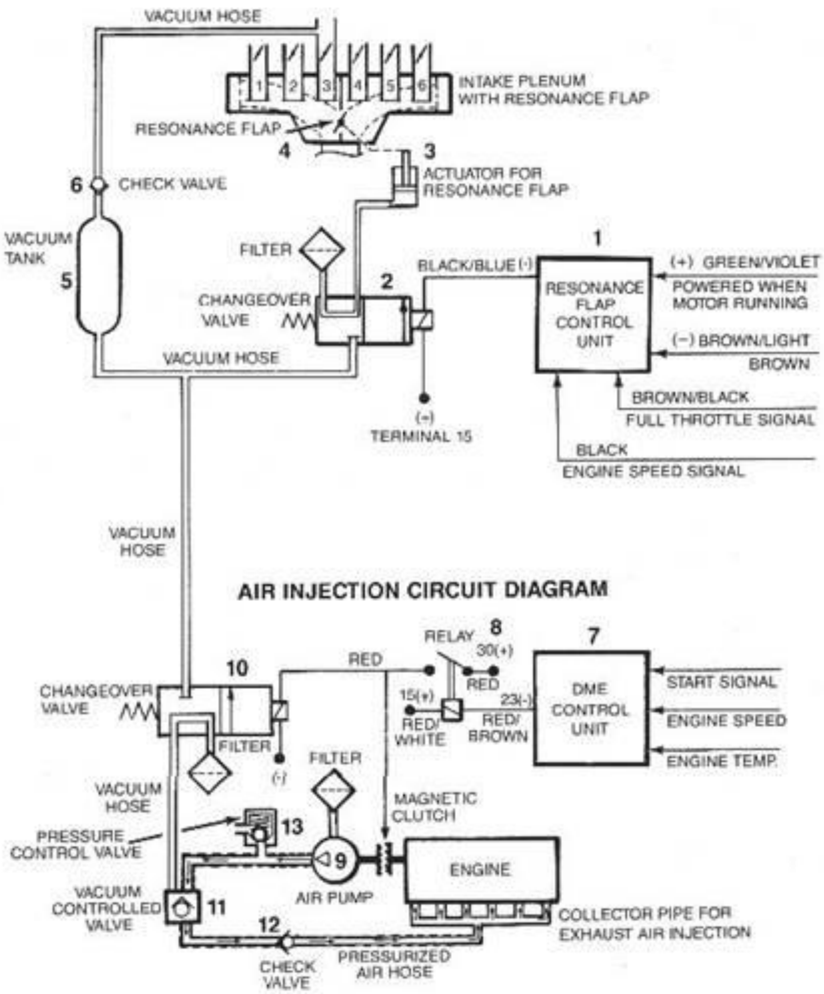
OK, so, the system uses vacuum from the intake plenum to physically move the flap into the close position. It will move it twice if you run it at full throttle through the entire rpm range. When you first go to full throttle at low rpm, it will close the flap, allow it to reopen at 4120rpm and close it again at 6720. Are you seeing a big problem here? I am, and so did the BMW engineers. At full throttle there isn’t enough vacuum in a well designed performance intake plenum to move anything, let alone to move this valve twice before the driver shifts. So, they installed a vacuum reservoir. The reservoir stores enough vacuum to move the actuator six times. When you let off on the throttle to shift, or when driving like a normal human being, the reservoir stores up some vacuum to move the valve when needed. It also stores vacuum for the system’s self test when it moves the valve right after engine start.

The reservoir itself has a check valve, and vacuum lines associated with it. These are all included in our silicone vacuum hose kit. A loss of vacuum is big problem for these cars.

Oh, and just for more fun, the BMW engineers decided to use the same reservoir to provide vacuum for the

Air Injection System, so let’s go over that.

Resonance Flap Control and Air Injection Control systems are connected by vacuum lines. They both use manifold vacuum from the same hose through the same reservoir.



The air injection system is designed to inject air into the exhaust for the sole purpose of reducing emissions. The system does NOT run all the time. It uses an air pump with a magnetic clutch. When the clutch is engaged, it pumps air, at all other times it just sits there. *Problems with the air injection system can cause high emissions, and if various valves fail, it can allow exhaust into the vacuum system. If enough check valves failed or if the system was connected incorrectly it could cause all sorts of running problems. It can also allow air into the exhaust when it's not called for thus giving the O2 sensor a false lean reading.

Let's talk for a moment about what an air injection system does. The theory is that injecting air into the exhaust manifold will clean up the exhaust by allowing unburned fuel to burn up. Many, probably most cars build in the late 70's had these systems. However they didn't work very well at actually improving emissions. It's more likely they increased emissions which is one of the reasons they started to vanish in the 80's are and essentially disappeared by 1995. What they do VERY well is give the illusion of cleaner emissions. If you live in a state like California, you have probably been through a smog check. One of the things they look for on this check is unburned hydrocarbons. That's great, but they measure this pollutant in particles per million (ppm). Pumping air into the exhaust reduces the pollution in terms of ppm largely because it's adding non pollutants to the equation. In other words and in simple math, if you had 50ppm, out of 1million total particles, then added another million particles of non pollutants your ppm would drop to 25, although you didn't really reduce pollution one bit. In fact, in this example you probably increased it because you had to burn fuel to pump that extra air.

This is the big problem with the air pump, it add complexity, weight, expense, and requires burning a small about of extra fuel to operate, yet the real benefits are marginal at best. That said, you need the dang thing to work, or passing a smog check will be difficult.

OK, so why does the E34 M5 have this when neither the E28 M5 nor 535i have it? Simple, one word, camshafts. The E34 M5 has cams with both higher lift and longer duration. In order to get it to idle during the warm up period they needed to run a relatively rich mixture, and that leads to high hydrocarbons in the exhaust. An air pump is a guaranteed way to get the numbers down into the passable range without redesigning any actual engine components.

OK, back to the actual system. As I said, it doesn’t run all the time. It fact, it only runs for 125 seconds before it shuts off. It runs during the warm up period as determined by a coolant temp of 86F(30C). It also runs while the engine is being started. Additionally it never runs when the engine is above 4600rpm, probably to avoid adversely affecting published horsepower numbers, or possibly to avoid over-speeding the pump.

So, how does this thing work? When the above conditions are met, a relay (number 8 in the diagram) provides power to engage a magnetic clutch on the air pump and cause it to start pumping. At the same time it provides power to the change over valve (10) which will allow vacuum to open the vacuum controlled valve (11). From there air flows through a check valve and into the exhaust. The check valve prevents exhaust from flowing the other way when the pump isn’t running. If you have exhaust in your vacuum system, take a look at that check valve.

The vacuum controlled valve is the valve that opens to let air into the exhaust. When closed it prevents any venturi effect in the exhaust manifold from drawing air in when the air injection system is not operation thus causing a false lean reading from the O2 sensor. If the pump engages and the vacuum controlled valve doesn’t open, the air will blow out through the pressure control valve (13), thus preventing damage to the system.

That’s it for the air injection system. The parts of the system are very reliable, and most problems really do relate to the hoses, so replace them with high quality high temperature hoses right away!

Step 2, Test the evaporative emission system.

Pictured below is the main intake tube called the "rubber boot" in the BMW manual. The valve attached to it is the Evaporative Purge Valve called the "air valve" in the BMW manual.

Attached to the tube on the forward side is the "air valve". This valve is designed to open when the throttle is closed or nearly closed with the engine running (in other words at high vacuum/low manifold pressure conditions). When it opens it allows vapors from the charcoal canister to enter the motor. Give the valve a good visual inspection to make sure it's not cracked. Check its connection to the intake tube. If it looks like it leaks replace it or use the Shoe Goo technique.

Once you are sure the valve is OK on the outside, we need to make sure the thing actually works. You will need a helper for this. Get the wife or girlfriend to help with this one! First you need to blow on the larger port (the one with the green tube in the picture). Air should not go through unless you blow really hard and force it open. Now have your helper suck on the smaller port (the one with the red tube). While your helper is sucking, the valve should open and you should easily be able to blow air through the larger port. If it fails either one of these tests you have to replace it.

On the other side of the tube is the Idle Stabilization Valve. This is the cylinder that has an electrical plug on the end near the firewall. This item is explained and tested later in this article. For now just make sure its connection to the tube is leak free.

The part my finger is touching in the picture below is the "Thermo Valve" sometimes called the "evaporative purge valve vacuum switch". It's located near the thermostat at the front of the motor.

The Thermo Valve's entire purpose in life is to shut off the evaporative emission system until the engine is warmed up (meaning a coolant temperature of 110F (44C). It's immersed in coolant so once the coolant temp reaches the specified amount it opens up allowing engine vacuum to reach the evaporative purge valve we just tested, thus allowing fuel vapors to be sucked through the charcoal canister and into the motor. When the coolant temp drops below about 92F (34C) it closes again. *****A faulty Thermo Valve can cause irregular running during the warm up period if it's stuck open. If it's stuck closed it will have an adverse effect on emissions.

Testing this thing is really easy. With the engine cold, pull both its vacuum lines off at the other ends (that means not off the thermo valve). Now blow into one line. Air should not go anywhere, the valve should be closed stopping you from blowing any air through it. Put everything back together, start and run the motor until it warms up. Shut the motor off, pull the lines off again and blow through one. The valve should be open and you should be able to blow right through the valve.

Note: If the Thermo Valve and the Evaporative Purge Valve are functioning correctly and your car has a problem only when cold then it's not a problem related to the Evaporative emission system.

Pictured below is the Charcoal Canister. It's located just forward of the windshield washer reservoir.

The Charcoal canister is designed to improve emissions.   IT DOES NOT HARM PERFORMANCE! A lot of folks remove these thinking they are gaining something. Leave it in there it truly helps emissions and has no adverse effects. It has two vacuum lines going to it. One comes from the fuel tank, and one goes to the Evaporative Purge Valve.

This device is really simple. Think of it as a fuel vapor filter. Whenever the car is warmed up and the Purge and Thermo valves are working correctly, fuel vapors from the fuel tank get sucked through it and into the intake system by manifold vacuum. That's about it. No moving parts to test or wear out. The only possible fault it can have is a physical damage causing a vacuum leak. Testing it is really simple. Take the two lines off of it so you can blow through them and into the canister. Plug one line with your finger and blow into the other one. If you can't blow into it then it's fine. If you can, it's leaking. Remove it, find the leak and seal it with epoxy. That will make it good as new.

Step 3, the cabin air temperature sensor.

What the heck does this thing have to do with fuel injection? That's a good question. The Motronic system on the 535i has one built in air leak. It's a calibrated leak and the ECU knows about it so it's OK. The leak is at the cabin air temperature sensor. It's important to make sure the sensor is not clogged or this calibrated leak will not allow the correct amount of air in, plus your automatic cabin temperature control won't work!

The cabin air temperature system must have a way of constantly sampling the air so it can adjust cabin temperature up or down. It does this with a sensor located just inboard of the hood release handle inside the cabin. To provide air flow through the sensor without the complexity of moving parts, BMW simply ran a vacuum line from the underside of the intake plenum into the cabin and to this sensor. There is also a very small restrictor orafice in the vacuum line near the sensor. When the engine is running it sucks a small amount of air through the sensor and into the engine. Note: I recently learned about and played with the restricting orifice. It's so minor that it has zero effect on the operation of the engine, or cabin temp sensor. However without it the suction noise through the sensor is more noticeable.

You can check to make sure air is flowing through the sensor by starting the engine and putting you head down near the hood release lever. You should hear air flowing into the sensor. Put your finger over the little intake hole and you should feel a slight amount of suction. It you do, then the sensor is not clogged and the vacuum line is intact. However, the odds are, air won't be moving through it and you will have to remove the sensor and replace its vacuum line.

To remove the sensor you have to remove the lower part of the driver's side dash by removing some screws and pulling the panel free. Replace its vacuum line and make sure its rubber boot seals to its body. The rubber boot will be old so you will probably have to reseal it with silicone and put a small hose clamp on it to keep it in place. Make sure the little foam filter on the intake side is clean and free of debris. Blow through it to make sure it's clear, use your mouth, NOT compressed air, it's delicate.

While you are here it makes sense to test this sensor. It's really easy, get out your OHM meter! Under no circumstances should you touch the OHM meter to the wiring harness. That will send electricity to a place that may not be expecting it and could be damaged. **All testing with an OHM meter is done on the part itself, not the wiring in the car**.

To test the sensor note which terminals connect to the blue and brown wire. Those are the terminals we will be checking. Resistance between these terminals varies with temperature. Use the chart below and check that the resistance values are close to those specified.

104F (40C) = 4700-5400 ohms, 86F (30C) 7500=8400 ohms, 77F (25C) 8599-10500 ohms, 68F (20C) 12000-13300 ohms, 59F (15C) 15100-17200 ohms, 50F (10C) 19400-22100 ohms, 32F (0C) 32400-37700 ohms.

This picture shows me testing the cabin air temperature sensor. The air temperature was about 65F and it registered 12,480 ohms, just about right. I doubt you will ever see one that doesn't test correctly. The issues with these things are a clogged inlet and inadequate vacuum to the sensor.

Step 4, Motronic Powering UP! Electrical power supply and grounds.

Now we will start to go deeper into the Motronic system. * Problems with the system's power supply and or grounds will often cause the engine to quit running and or prevent the car from starting. If your car cranks over but won't start, this is probably the section for you.

Powering up check.

First we need to see if the Motronic system is powering up. * If it doesn't your car won't run. With Motronic Basic we will have to remove a connector from a fuel injector. It's easiest to remove it from the forward most injector.   These connectors are normally grey in color. Carefully remove the metal retaining clip with a tiny screwdriver. DO NOT try to force off the connector until you have removed that clip or damage to the connector will result.

Next turn on the ignition and connect your voltmeter to an electrical contact in the connector (either one) and a ground, you should see battery voltage or very close to it. If you don't have a voltmeter you could use a test light, but a voltmeter is better.

DANGER DANGER!!! Make sure your multi meter is NOT selected to Ohms.   If it is, it will send current into the Motronic control unit (the ECU). As a general rule, power going into the ECU where it's not supposed to is bad. Damage could result. Make sure it's selected to read voltage. As a general rule, when we are checking something at the wiring harness, it's voltage, when checking an actual component we are checking Ohms.

The picture below shows this test on a Motronic Basic car. The voltmeter's red wire is touching the connector, the black is grounded to the manifold support bracket. The voltmeter shows battery voltage so the check is good!

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If you have Motronic 1.1 this test is a little different. Instead of looking for battery voltage at a fuel injector's connector we are going to look for it at the idle air control valve's connector. With the ignition on check for battery voltage between the connector's red/white wire, and a ground.

Now, if the car passed that test, that's great news. We just verified a whole bunch of things work. Now we know that the car's Main Relay is good. The ignition switch works (well, at least the ignition position of that switch), and a whole lot of the wiring is intact. If the car didn't pass this test we need to check the Main Relay

The Main Relay: *

If this thing doesn't work, the car won't run, period. Checking it is easy. On most E28s this relay is located on the inboard side of the fuse box. It's the relay nearest the front of the car. It plugs into a relay socket that's attached to the side of the fuse box. IMPORTANT NOTE: For some reason on 1985-1986 528e cars, the relay is in a different location. On these cars it's on the inboard side of the fuse box, second from the front (where the fuel pump relay is located on the other E28s). ANOTHER IMPORTANT NOTE: The relay sockets can be switched around. There is just enough wiring length for some mechanic to swap the first and second relay socket positions. To make sure it's the Main relay you are looking at, check to see if it has two large (about 4mm diameter) wires going into it from below.

When the ignition switch is turned on this relay should click. You can feel it click if you have a friend work the ignition switch. If it clicks and you didn't have power in the powering up check, the relay is bad. If it doesn't click, the relay is probably bad, but to be sure we will need to verify it's getting power.

To check to make sure it's getting power, use your voltmeter to look for battery voltage between the relay socket's terminal #30 and ground. This terminal is wired directly to the battery so it's always hot. You should see battery voltage there with the ignition on or off. To figure out where the correct terminal is, look at the underside of the relay (they are also labeled on top, but that's usually worn off by now). Look to see where terminal #30 on the relay plugs into the relay's socket, and that's where to check for power.

In the picture below I am verifying we have battery voltage between the main relay's socket terminal #30 and ground. It checks out fine.

If we have voltage there, great! If not it's a certainty we have a wiring problem, probably at the positive terminal on the battery. Simply inspect the heavy wire that connects to the relay socket below terminal #30 and follow it to the battery. It's only about a foot long so this should be easy. Look for a break in the wire, but the problem is probably going to be the connection at the battery, or possibly at the relay socket.

Next, we need to make sure it's getting power. In all 1983 and later model year E28s, the main relay gets its electrical signal to close from the on-board computer when you turn your ignition switch to ON or START. The on-board computer is the thing in the dash that tells you your fuel economy, outside air temperature, etc. This is probably the only really stupid thing in the E28's otherwise really good electrical system. I can't believe they supply power to a critical relay through that piece of junk. Anyway you need check for battery voltage between terminal 86 and ground WITH THE IGNITION ON. Power goes to the on-board computer through the ignition switch. Inside the on-board computer is a little relay that closes when the ignition switch is in the ON, or START positions. The on-board computer also has internal fuses, but those are NOT involved in the operation of the Motronic system.

Here I am checking out voltage between terminal 86 and ground. It checks out fine. Notice voltage is slightly lower than the value seen at terminal 30. This is normal and is due to the route the voltage has to

take to get to this terminal.

If we don't have voltage at terminal 86 with the ignition on, we probably have a problem with the ignition switch. If it's not the switch, it's the ECU or a wiring issue.

If we have voltage at both terminals 30 and 86 and the car did not pass the "powering up check" it's a certainty that the Main Relay is bad and should be replaced.

I strongly suggest carrying a spare main relay in the car, as well as a selection of relays and fuses if you use your E28 a lot.

Grounds.

* Every single possible running problem you car might have can be caused by poor grounds. This includes difficult or impossible starting, poor running, high emissions, low power, high fuel consumption and more. Thankfully, unlike some other cars I work on, the E28's grounds are easy to get at, and are rarely bad. Simply locate them, clean them up and tighten them. In the pictures below I will show some of the typical ground locations on a 535i.

This is the main grounding point of the entire electrical system. It's located just outboard of the battery on the inner fender.

This grounding strap is located on the passenger's side firewall. It's easy to miss.

The grounds in the picture below are located on the head. These are often neglected.

There is one other big grounding strap connected the the passenger's side motor mount. Don't forget to check this one.

Step 5, Testing the Fuel Pumps and pressure regulator.

The 535i and all the other E28s sold in the U.S. actually have two fuel pumps. They have a low pressure "transfer" pump located in the fuel tank, and a relatively high pressure "main" fuel pump located under the car. The purpose of the transfer pump is to insure a positive supply of fuel to the main pump. The car will normally run with an inoperative transfer pump, however * an inoperative transfer pump may cause difficult starting when the car is hot, or when the fuel tank quantity is low. It may also cause hesitation under certain conditions. If your car runs well until you are low on fuel, the problem is probably a bad transfer pump.

The main fuel pump is a critical component. * When they fail, they normally fail completely and the car simply won't run. If the main fuel pump works, but is faulty, it can cause difficult or impossible starting and can cause a large loss of horsepower.

The pumps normally only run when the engine is cranking over, or running. Of course it's hard to hear them over the noise of the engine. They do run for a moment with the engine off when you first turn on the ignition switch, but it's so brief you can't really hear them.

A quick way to check to see if the main fuel pump is working is to hold the return line exiting the fuel pressure regulator (it's the rubber hose) while a friend cranks the engine over. If the pumps and regulator are working, you will feel the fuel going through that hose. If you don't feel any fuel going through, it's time to check the power supply.

Checking the fuel pumps power supply.

As with most electrical components, the first thing to check is the fuse. The fuel pumps share one fuse. It's a 16 amp fuse located in the main fuse box in position #1. This is the location on the inboard side of the box all the way towards the front of the car. In other words, it's located in the front inboard corner position. If this fuse is blown, or has bad contacts, the pumps, and thus the engine will not run. Check the fuse and the contacts.

Next, we should check the fuel pump relay. On the 535i this relay is located just aft of the Main Relay we checked earlier. Make sure it's not the main relay, as the positions of the relay sockets can be swapped around as I explained in "The Main Relay" section of this article.

On the 535i with the ignition switch off, there should be approximately battery voltage between the fuel pump relay socket's terminal #30 and ground. In the unusual case of the 1982 528e, the ignition must be on for this test (ignition switch in run, or start positions).

This picture shows a good voltage test on the fuel pump relay socket's terminal #30.

If you don't get voltage at this terminal, look at the wire going into the terminal under the socket. That's the most likely source of the problem. It's a red wire, and it goes to the battery, sometime it disappears into a wiring bundle first, making it a pain to trace.

If you have good voltage at terminal #30 we need to move on and test the fuel pumps to make sure they run. There are a few ways to do this, but I suggest the following. I use a jumper wire (ideally one with a 16 amp inline fuse) and connect the fuel pump socket's terminals 30 and 87. This will turn on both pumps. If this works, and the pumps turn on, but didn't run earlier, you have a bad fuel pump relay.

If the pumps don't run with the jumper wire, you have either a bad pump(s) or bad connection(s). The bad connection will almost certainly be at the pump itself.

Fuel Pressure:

At this point, we know the fuel pumps run. However just because they run doesn't mean we have proper fuel pressure. A faulty main pump can work, but deliver low fuel pressure. A faulty fuel pressure regulator can cause pressure to be either too high or too low.

Incorrect fuel pressure can cause just about any possible problem including: *****difficult hot or cold starting, poor idle, lack of power, poor fuel economy, high emissions, stalling, starting and stalling or any combination of these.

Let's take a break from testing things for a moment to discuss fuel pressure. This may be a little confusing so you may have to read it twice. I know I would. Proper fuel pressure is very important on the E28s. The Motronic ECU maintains control of the fuel air mixture by measuring the engine's air intake and then injecting in the proper amount of fuel. It controls fuel delivery exclusively by controlling the amount of time the fuel injectors are open (except during starting, which will be covered later). If fuel pressure is too high or too low the ECU won't know it, and at idle or full throttle it will make no attempt to compensate. Under these conditions if fuel pressure is too high the injectors will allow too much fuel to spray in because the ECU won't know to reduce the amount of time they are open. If it's too low, we have the opposite problem. The Motronic system can compensate for small variations in fuel pressure during normal driving (i.e. **not** during starting, warm up, idle, or high power operations). It does this via inputs from the O2 sensor. We will cover that later.

Before we get into testing fuel pressure, let's go over how much fuel pressure these cars should have. **With the engine off, and the pumps running the 535i should have 43.5psi +/- .9psi.** For you Metric guys, that's 3 bar, +/- .6 bar. Under the same conditions **the 533i and 528e should have 36.3psi +/-.7 psi.** If you love the Metric system that's 2.5 bar +/-.06 bar.

Of course it has to get more complicated than that! Notice those numbers are with the engine off. The actual values with the engine running MUST vary. Follow along to understand why. The pressure regulator is not designed to hold the pressure at a fixed value. It IS designed to hold the pressure differential between the fuel pressure at the inlet side of the injectors, and the air pressure in the manifold constant. Think of it this way. If our system held fuel pressure at a constant 36 psi and we had 37 psi of air pressure in the intake manifold when the fuel injectors opened, fuel would not flow into the manifold. Instead air would flow into the fuel system. Of course on a stock E28 that can't happen because manifold pressure in these cars will rarely exceed 15psi. The point is that if fuel pressure was constant, then variations in manifold pressure would affect the amount of fuel injected for a given injector duration period.

Manifold pressure in these cars varies from about 7psi to about 15psi depending on throttle position, rpm, etc. In order to keep the fuel pressure differential constant the pressure regulator raises and lowers fuel pressure in response to changes in manifold pressure. **With the engine idling we should see 42 psi on a 535i, and about 34psi on a 533i or 528e** (Note, the actual number may vary. The official range is 40.6-46.4 on the 535i and 33.4-39.0 on the 533i/528e). What's important here is that the value is lower with the engine idling than it was with the engine off. If you remove the vacuum line from the fuel pressure regulator it will think the engine is at or near full throttle and fuel pressure should increase to about the value normally seen with the engine off. What's important here is that it does increase when you remove the vacuum line.

Important Note For Turbo and Supercharged applications: If you have one of the ultra rare turbo BMWs with this system (i.e. E23 745i) fuel pressure must increase directly with boost. For example at 5psi of boost, fuel pressure should go up 5psi. If you are doing a turbo or supercharged conversion on your E28, E24, or other Motronic BMW this is still true. On that subject Motronic with various inexpensive modifications is well suited to these projects up to about 10 pounds of boost. However that's another article for another time. If you are supercharging or turbo charging an E28 and need help, feel free to contact me. In regards to forced induction I can provide good tech help for Bosch L-Jetronic, Early Motronic, SDS brand fuel injection, water and water/methanol injection, and supercharger selection. I don't provide any tech help for any other fuel injection systems.

Testing the Fuel Pressure. Under Construction

Now that we understand how fuel pressure should react, and we know what values to look for, let's test the main pump and regulator for proper pressure.

In the picture below, my hand is holding the high pressure hose that delivers fuel under pressure to the fuel rail. From there it goes to the fuel injectors.

There are many fuel lines under the hood of an E28. However most of them are low pressure hoses. We need to take a fuel pressure measurement from a high pressure hose. On all 533i, and 535i cars we can splice into the high pressure line at the back of the fuel rail near the firewall. The same is true of the 528e with Motronic 1.1 injection. If you have a 528e with Motronic Basic splice into the fuel line going to the cold start injector (often called a cold start valve). Make sure you are splicing into the the hose that actually connects to the back of the fuel rail. Many of the other hoses under the hood are low pressure.

This next picture shows a fuel pressure tester and a "T" type fitting used to splice into a high pressure line.

High pressure fuel line is expensive so I didn't want to cut into mine for the sake of a photo. However, from the two pictures above, it should be pretty easy to see how and where to take the pressure reading.

Once you have your fuel pressure tester connected. Get your fire extinguisher ready. With the engine off energize the fuel pump via the fused jumper wire described in the "Checking the fuel pumps power supply" section of this article. Watch carefully for leaks. Once you are sure everything is OK, note the fuel pressure. Make sure it's within the parameters described earlier. Start the engine and make sure the fuel pressure is within parameters at idle. It should be lower than it was with the engine off, because the manifold has vacuum while idling. Blip the throttle a few times and make sure the fuel pressure goes up and down with throttle application. Note: fuel pressure does NOT vary with RPM, it varies with manifold pressure/vacuum. It's possible to have the engine at 2000rpm with very little throttle, in which case it would have quite a bit of vacuum and relatively low fuel pressure. Conversely at full throttle and 2000rpm it would have almost no vacuum, so fuel pressure will be relatively high.

Ok, you have tested fuel pressure and it's too high or too low, what next?

If fuel pressure is **too high** under all conditions, you need to replace your fuel pressure regulator. If it's too high ONLY under vacuum (engine at idle) it's very likely the vacuum line on the fuel pressure regulator isn't air tight. Replace the vacuum line. There is a very small chance that the problem could be caused by a blockage in the fuel return system. The rubber fuel line on the fuel pressure regulator is a return line. There are actually four rubber return lines under the hood of a typical 535i. If in doubt replace them all. (Shameless commercial alert! At Hi Performance Store, Inc. we sell a fuel line kit for the 535i, it includes the correct sizes of pre-cut high and low pressure hoses and easy to follow step-by-step instructions with a diagram) BMW Fuel Line Kit Link

If the fuel pressure is **too low** it could be either a bad fuel pressure regulator or a bad fuel pump. It's pretty easy to figure out which one. Simply perform an engine off fuel pressure check as described above. Slowly pinch off the fuel pressure regulator's return line, if the pressure doesn't rise you have a bad pump. If it does rise you have a bad regulator. CAUTION FIRE HAZARD. If your fuel lines are old, they may and often do split when you pinch them off. This causes fuel to suddenly spray everywhere at high pressure causing a serious fire hazard, and possible injury. If in doubt replace the fuel lines BEFORE you perform this test. Be aware that if you fully pinch off the line a properly working pump will raise the fuel pressure to about 70psi! If your fuel system is in good shape, this isn't a problem, but it can burst old hoses.

The Fuel Pressure Regulator is located near the front of the engine at the forward end of the fuel rail (535i)

If you don't have a 535i you will have to find your fuel pressure regulator. They all look pretty much the same so the picture above should help. On Motronic cars they are almost always located on the fuel rail and have one vacuum line, and one fuel line attached to them.

Step 6, Fuel Injector on and off car checks.

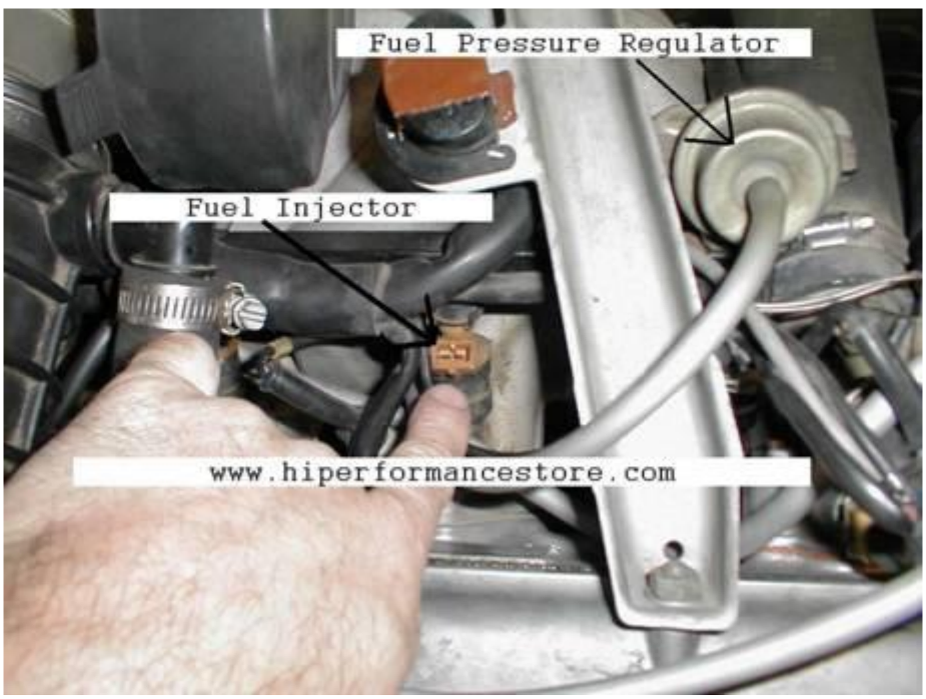
If you have been following this article from the start, your car is now free of vacuum leaks, the injection system powers up properly, the grounds are good and it has good fuel pressure. Next we need to look at the fuel injectors. *Fuel injectors are another major component of the injection system, and they can cause a wide range of problems including difficult hot or cold starting, irregular idle, low power, high emission, poor fuel economy, stalling, and the starts and stalls syndrome. The injectors work by opening and closing at a rate and duration specified by the Motronic ECU. When open, fuel under pressure sprays in. The injectors can develop external leaks, they can stick open, stick closed, they can stick a little bit so they don't open and close at the correct rate, they can leak internally, and most common they can be partially clogged so they don't flow the correct amount of fuel.

A word of caution. Each injector has its own fuel filter. The filter's inlet screen is so fine the holes are not visible to the naked eye!   DO NOT put fuel system cleaner or fuel injector cleaner in your E28's fuel tank.   All this will do is wash debris that's been building up for all these years downstream into these tiny filters. At least it will tend to clog all the filters equally, and this may actually improve running if it's masking another fault, however partially clogged injectors will not deliver enough fuel at full throttle and if knocking occurs as a result you could have serious engine damage. Trust me on this one, don't use these products on older cars. Well, I guess there is one exception to this. If you are going to pull and have your injectors cleaned anyway, it wouldn't hurt to use these products right before you did that. That would clean out the fuel system and since you are having the injector filters replaced there won't be any harm.

The bad news is it's not possible to fully test the fuel injectors with them on the car. The good news is there are a couple checks we can do with them on the car, and these checks are pretty good at finding some of the more serious possible problems.

First, we need to check the injectors' electrical impedance. Once again you will need to get out your OHM meter. We do this test first because if the injector fails this test, it's junk and can not be fixed. Start by locating the injectors. There will be one per cylinder, meaning on all E28s sold in the U.S. there are six main fuel injectors (there is also a 7th injector called a "cold start valve" which we will cover later). The injectors are easy to find, they are all attached to the fuel rail so look for the fuel pressure regulator which is attached to the front end of the fuel rail. Follow the rail back until you find all six injectors. Each injector has an electrical connector on it.

In this picture, my finger is touching cylinder #2's fuel injector. The injector's connector has been removed for clarity.



Remove the injector's electrical connector. Be careful, it's held on with a tiny metal retaining clip. This metal clip must be removed before you pull the connector off or damage to the connector will result. Use a really small screwdriver to pry the clip away. Don't drop it! Well, you probably will drop one at some point, so have a magnet nearby. (note: some cars have the squeeze to release type metal clips.) Once the clip is off you can see the injector has a two terminal electrical connection. We need to measure the resistance between these two terminals. It should fall within the following values. For the 528e with Motronic 1.1, and all 535i cars resistance should be between 14.5 and 17.5 ohms. If you have a 528e with Motronic Basic, or a 633i the values should be between 2 and 3 ohms. Test for these values with your OHM meter, be sure to test for resistance between the terminals on the injector. DO NOT touch the ohm meter to the wiring harness' connectors. If an injector fails this test, it's junk and must be replaced. Also, don't reinstall those metal clips yet.   You will need those to be off the the next test.

This BMW 535i injector passes its Ohms test!

Here is a Bosch BMW E30 injector. It's very similar to most E28 injectors. On the left is a removed injector inlet filter. The filter's screen holes are too small to be seen with the naked eye! If you think fuel system cleaner will flush debris through that, you are wrong! All it will do is clog the inlet screens with 20 years worth of debris from upstream in the fuel system.

The **second** check we can perform is something called a "balance check". This is the same check the dealers perform. It's pretty easy, but it does have some serious flaws. First of all, it only compares the injectors against each other. So if they are all partially clogged it won't help us. Second, if your engine and ignition system are not in like new condition the results will be unreliable. Of course since dealers tend to work on newer cars they love this test. The cars they usually deal with are newer and thus don't usually have clogged injector issues or worn out engines or ignition systems. Now, if your car has one or two really bad injectors this test will find the problem, so it is a helpful test.

To perform a balance check you will need to be able to easily pull off each injector's electrical connector. That means before you start this test you need to remove each little metal clip securing the injector's connector. Leave the connector on the injector, without the clip, start the engine and let it fully warm up. Once it's fully warmed up and idling very steadily, remove each injector's connection one at a time and note the RPM drop. Now in a perfect world the cylinder with the LOWEST RPM drop is the one with the worst injector. In other words, if the RPM does not drop at all, then it stands to reason that fuel injector is not delivering any fuel. I can't stress enough the flaw in this test is the lack of a perfect world situation on a 20 year old car. It could be the lowest RPM drop is on a cylinder with a really good injector but poor compression, or a weak spark. Heck it could just be time for a new cap, rotor, and spark plugs. This test has one other BIG flaw. It only tests the injector when it's under low demand. It's not unusual for an injector to work perfectly at idle but poorly under high demand conditions (i.e., full power, high rpm), which is the way I drive my BMW.

In order to really thoroughly test fuel injectors I am afraid they must be off the car and tested on a machine that can measure their output within the operating ranges of fuel pressure, duration, and RPM.

I offer fuel injector flow checking and overhaul service on the latest

type of machine for BMW owners. I have a fuel injector servicing shop. I have the latest flow checking and injector cleaning equipment. Details are at www.okinjectors.com . We overhaul BMW injectors with the correct parts!

If you would like your injectors overhauled I can ultrasonically clean them, replace the filters, pintle caps, and all seals for a very good price. I very thoroughly check them all all the RPM levels and pulse widths your injectors will experience on the car. Most shops only check them at idle. I also warranty the injectors I service for 12 months. I have found that when injectors are serviced by other shops they often start to leak about 6 months after the service. This is because the internal seals are delicate and can be easily damaged by the fluids many shops use to clean and flow check. The correct fluids to test and clean these early injectors are $20 a quart so many shops don't bother to use them. I do, that's why I can warranty the injectors I service against external leakage, or any other problems.

After a full overhaul, old BMW injectors usually work like new and our warranted for 12 months.

Here is a set of BMW E30 325i injectors from a running car. You can see that relative to injector 3, they are all a low. Cylinders 1 and 4 were so low it's a miracle the engine didn't blow a hole in a piston.

What the picture above doesn't show is that all the injectors were actually low. I just ran the check until the first injector hit 100ccs so the percentage of variation would be easy to see in the picture. After my injector overhaul service this set of injectors was usable again.

The same set of injectors after level 3 service. The picture speaks for itself.

The only way to have a known good set of injectors is to have them flow checked at a variety of rpm and duration levels, and at the correct fuel pressure values. Obviously it's important that the person testing them knows what these values should be. It's also important that the injectors be cleaned and flow checked with the correct types of fluids. (Obviously we can't use gasoline or we would blow ourselves up.) The correct fluid for BMW injectors is about $20 a quart. That's so expensive a lot of injector shops just don't use it. Using the wrong fluid tends to damage the injector's internal seals resulting in external leakage about 6 months later. They tend to develop these leaks between the injector's metal body and plastic cap. At my shop we use the correct fluids, that's one of the reasons we can warranty the injectors we service. Also, the correct fluid has to have the same specific weight of gravity as gasoline or the flow checking results will be meaningless compared to original specs.

New injectors: New Bosch injectors are expensive, but they are high quality. There are various other brands that can substitute for the 535's Bosch injectors. These other injectors that will physically fit and are so close in flow rate that they will work. The only drawback is that the Bosch injectors seem to be more precise. The Bosch injectors are usually within 3% of each other, the other brands tend to be within 5% of each other. For serious performance applications I like to flow check a couple dozen injectors and pick the six that are closest to each other. This normally allows me to get injectors within 1%.

Step 7, Coolant Temperature Sensor!

The coolant temp sensor is one of my favorite components to test. Probably because it's so easy, and yet, it's such an important device. This device reports the coolant temperature to the Motronic ECU. The ECU uses that information to adjust mixture for engine temperature. It richens the mixture when cold.

If you are a veteran of working on earlier L-Jetronic systems you probably remember how a bad connection at this sensor would instantly shut off the engine. Well it seems somebody at Bosch decided that wasn't such a good thing because they improved it for the Motronic system. On the E28s if this sensor is disconnected or if the the connection is poor, the engine will still run. It may not start, and it will run poorly, but at least it will run so it's no longer a device that can leave you stranded on I-10, 20 miles outside of Lordsburg, New Mexico.

The coolant temperature sensor is located at the front of the engine near the thermostat housing.

If your coolant temp sensor is bad, it can cause a lot of problems, although most likely, your car will still run. These problems include * poor fuel economy, lack of power, difficult or impossible cold, or hot starting, irregular idle, and rough running. Depending on how bad the sensor is, these problems can range from minor to severe.

Testing the coolant temperature sensor is easy. Once again, get out your ohm meter. If you want to be really thorough you will need to test the sensor when the engine is cold, partially warmed up, and fully warmed up. Simply remove the sensor's electrical connector. Once again we have that dang metal clip that must be removed first. Here are the resistance values we should see on a good sensor:

On a 528e with Motronic Basic, or a 533i if the coolant temperature is 12F-16F (-9C to -11C) resistance between the two terminals should be 7000-11600 ohms. At a coolant temperature of 66F-70F (19C-21C) it should be 2100-2900 ohms. When the engine is fully warmed up the coolant temperature should be 174F-178F (79C-81C) and you should have 270-400 ohms of resistance.

If you have a 528e with Motronic 1.1 or a 535i you are looking for a slightly different set of values. With a coolant temperature of 12-16F (-9C to -11C) resistance between the two terminals should be 8200-10500 ohms. At a coolant temperature of 66F-70F (19C-21C) it should be 2200-2700 ohms. When the engine is fully warmed up the coolant temperature should be 174F-178F (79C-81C) and you should have 300-360 ohms of resistance.

This test is simple. Measure resistance between the two terminals on the coolant temp sensor. If the sensor is faulty, it should be replaced.

Step 8, Speed Sensor and Reference Sensor!

So, you are cruising along on interstate 10 in your Motronic Basic 528e, 533i, or 535i secure in the knowledge that Robert Bosch improved the Motronic system so that a coolant temp sensor won't leave you stranded like it did with the old L-Jetronic system in your E12 528i. Now is when you find out he added two new sensors that will leave your stranded. *Failure of either of these will stop your car dead, right NOW! Well, that's a little bit of an exaggeration, but not much. Please read on.

The Motronic Basic 528e, 533i, or 535i all have two sensors mounted on the bell housing. The first is called the speed sensor. As you may have guessed it reports engine RPM to the Motronic ECU. Failure of this sensor may or may not totally disable your car. It's supposed to limp along poorly constantly missing if this sensor fails. Reality may be different.

The reference sensor is more critical. Without it the car will not run.

These are both mounted on the driver's side of the bellhousing. The speed sensor is mounted above the reference sensor. Caution: the two sensors are actually identical, so it's possible to connect them incorrectly. If the speed sensor is plugged into the connector for the reference sensor, and vice versa, the car won't run. The speed sensor mounts above the reference sensor and connects to the BLACK plug. The reference sensor connects to the GREY plug.

Both of these plugs have the Bosch style connectors on them with the dreaded metal clip. It's probable that the connectors will have been damaged at some point in the cars life. Mechanics love to test these sensors, but they really don't like messing with the metal clips so they tend to force and break things. If the connector is damaged DO NOT try to cut off the connector and solder on a new one. You won't be able to do it. You will have to find another way to secure the connector (tape, zip ties, etc.), or replace the entire sensor.

The Speed and Reference sensors connect to the Motronic wiring harness at the crossover bracket. Watch out, these two connectors can be reversed so make sure the upper sensor connects to the black connector.

Thankfully it's very easy to test these sensors. Once again, get out your Ohm meter. Remove one of the connectors. Note that this time there are three electrical terminals present. That means three tests per sensor. The terminals are numbered 1, 2, and 3 from left to right as viewed from the front of the car. If your car's crossover bracket is missing orient the sensor so that the single tab is up, and the two tabs are down. Now the terminal on the left is number 1.

Measure resistance between terminals 1 and 2. You should have 864-1056 ohms. Between terminals 1 and 3 you should have 100,000 ohms minimum. Between 2 and 3, again, 100,000 ohms minimum. Now Bosch wants you to take this reading with the outside air temperature of 77F (25C). I find it doesn't make much difference, but if it's really hot or cold out and the sensor is a little out of spec, I probably wouldn't worry about it.

Now test the other sensor. The values we are looking for are the same because these two sensors are EXACTLY the same part number.

In the picture below I am testing the reference sensor between terminals 1 and 2. The sensor passes!

It's a really good idea to carry a spare sensor with you if you are taking a long trip. Since they are both the same you really only need to keep one with your spare fuses and relays.

Sharp observers will notice a position sensor mounted on the front of the engine of a Motronic Basic 528e, 533i, or 535i. This sensor has NOTHING to do with the running of the engine. It's not linked to the Motronic system in any way. It's used to hook up some device the dealers have.

If you have a 528e with Motronic 1.1, your car does not have the two reference sensors on the bellhousing. Instead it has a "pulse sensor" mounted at the front of the engine. Test the resistance of this sensor and look for an ohm reading from 486-594. You also need to verify that the tip of the sensor is within .7mm-1.3mm from the toothed wheel.

Step 9, Air Flow Sensor (AFS)

The Air Flow Sensor is a very important part of the Motronic system. * It's another component that can cause a large variety of problems, including the starts and stalls syndrome, irregular idle, lack of power, and high emissions. In some rare situations it can cause high fuel consumption.

This device does two things. First it measures the volume of air flowing into the engine. Second it measures the temperature of the air. It measures the volume with a spring loaded door. Air entering the engine has to pass through this door, the more air that goes through, the farther it pushes the door open. As the door opens it actuates a potentiometer which varies a voltage signal to the ECU. The Motronic ECU uses this airflow and temperature data from the AFS to calculate the weight of the air entering the engine. The ECU then combines this information with data from other sensors and determines how much fuel to inject for various operating conditions.

The Air Flow Sensor is a very reliable device. They seem to last a really long time, like 30 years and

300,000 miles. They were replaced in later fuel injection systems with Hot Wire Mass Air Flow Sensors. The hot wire sensors are a newer design, and have no moving parts, yet they have never achieved the reliability and longevity of the older flapper type sensors. It's quite common to hear people claim that the AFS is a HUGE restriction in the intake system. I am quite certain these people never actually measured just how much of a restriction it is. It's not the horrible blockage that some people think. I will discuss the AFS's effects on airflow and power in the performance section of this article.

In the picture below I am holding the AFS's electrical connector. This connector plugs in to the AFS low on the firewall side of the device. It has a push to release metal clip, that pushes up from the bottom. (why didn't they use this style clip on everything?)

Ok, it's time to break out the voltmeter. **DANGER DANGER!!!** Make sure your multi meter is NOT selected to Ohms. If it is, it will send current into the Motronic control unit (the ECU). As a general rule, power going into the ECU where it's not supposed to is bad. Damage could result. Make sure it's selected to read voltage. As a general rule, when we are checking something at the wiring harness, it's voltage, when checking an actual component we are checking ohms.

It's time to test for voltage supply to the AFS. Look at the connector, it has five sockets. For the sake of simplicity, I am going to number them 1-5 from left to right. With the metal retaining clip down, like in the picture below the one on the far left is blank. The next four have electrical terminals that connect to the AFS.

With the ignition on you should see the following voltage readings on your BMW E28 535i. Terminal 1, blank, nothing to test, Terminal 2, Zero volts, Terminal 3, 4.0-5.0 volts, Terminal 4, 2.0-4.0 MILLIVOLTS! I am not kidding, they supplied this terminal in Millivolts. Hopefully your voltmeter can read that low. Terminal 5, 4.0-5.0 volts.

In the picture below I am testing for voltage at terminal 3 with the ignition on. (this picture looks like I am touching terminal 2, but I am not.)

Hopefully your car passed that voltage supply test. If so, do not put the connector back on yet, we have more to test. If it did not pass the voltage supply test your problem is most likely in the ECU or the wiring harness. Double check steps 4 and 5 to make sure the Motronic system is powering up and is grounded. If you still have a problem getting power to the AFS go to step 15.

If your car passed that test, it's time to test the AFS's internal door, and potentiometer. Testing the door is simple. Remove the hard plastic elbow that connects the AFS to the air filter box. Reach inside with your fingers and simply push the door. It should move freely without any strange noises, or binding. Assuming it does, do not put the elbow back on yet, move on to the electrical test.

Locate the electrical plug on the AFS, the one where the connector plugs in. We are going to test for ohms on the AFS itself. There are four terminals on the AFS. For the sake of this article I am numbering them 1,2,3 and 4. Terminal 1 is the outboard terminal, nearest the fender, 4 is inboard nearest the engine. Test for ohms at terminals 1 and 2. You should see about 550 ohms. Now test between 1 and 3. Here you should see about 80 ohms with the door closed. Start to open the door and ohms should increase. They should increase to about 1200, and then as the door opens farther, start dropping. (note: It's so sensitive it's actually very difficult to get it to read 1200.)The OHM reading with the door fully open should be about 600. The last test here will be between terminals 2 and three. Look for about 600 ohms with the door closed. The reading should increase to about 1000 as the door opens and drop to about 100 with the door fully open.

Here,

I am testing the Air Flow Sensor for ohms between terminals 1 and 3. With the AFS's door partially open I am getting 886 ohms. With the door open a little more it went to about 1200. This sensor is acceptable.

That's all for the airflow sensor, at least until the performance section of this article.

Step 10, Idle Air Stabilizer Valve / Idle Air Control Valve

*If your car has a problem with its idle speed, there is a good chance your idle air stabilizer valve needs some love. This is a somewhat troublesome device is sometimes called an idle air control valve. Thankfully, it can only cause serious problems at idle. It can't harm performance, fuel economy or emissions (except at idle) or much of anything else. It is not a critical item. It's possible for it to cause minor irregularities during light throttle operations but under no conditions can it cause any problems at full throttle.

Back in the days of carburetors and early fuel injections systems, if we wanted to change the idle speed of an engine we simply adjusted the throttle stop. If we needed to raise rpm at idle we turned a screw to hold the throttle open more at idle and vice versa. Most early systems has some sort of mechanism to hold the throttle open farther when the engine was cold for a fast idle. Other than that, they had no automatic control. If you turned on the A.C. idle speed would drop. If you heavily loaded the electrical system or drove up to a higher altitude, idle speed would drop. Of course this wasn't a big deal, if the drop was unacceptable, a quick turn of the screwdriver, and all was well again.

Fast forward into the 1980's and everything changes. First of all, consumers don't like to see their idle speed change, so an automatic idle control system was needed so the engine, once warmed up would always idle at about the same speed. More importantly were the ever increasing emission issues and they didn't want people messing with the injection system's settings.

Bosch addressed these issues by installing a fixed throttle plate, which is not easily adjusted. When the throttle of a Motronic car is closed, very little air can pass through it, far too little to allow the car to idle. In fact, the throttle essentially closes all the way, with only the slightest gap present to prevent it from jamming closed. Of course with the throttle closed, they needed to come up with a device that would allow enough air past the throttle so the engine would idle.

This device they came up with is the Idle Air Stabilizer Valve. It's an electronically operated valve. It opens to allow air to flow from the intake downstream of the air filter directly into the intake plenum, bypassing the throttle. When the engine needs to idle faster, like when it's cold, it lets more air in and vice versa.

There are two types, a two wire, and a three wire. The car used in this article is a 535i Automatic, and it has the three wire type. Regardless of which type you have, it should come to life as soon as you turn on the ignition. Turn your key and this thing should start humming and vibrating. If it doesn't, either it's not getting power, or it's totally shot.

Check to make sure you IAC is getting battery voltage with the ignition on.

If it's not getting voltage, go to step 4 of this article and make sure your Motronic system is powering up. Then check the grounds in step 5. If steps 4 and 5 check out OK, and you still don't have power here it's either in the Motronic ECU, or the wiring harness, go to step 15.

If your IAS valve (sometime called IAC valve) is getting power but your idle speed is too high, too low, or irregular you will need to check the valve itself. Once again, get out your OHM meter.

In the photo below I am testing a three wire Bosch IAS valve. The resistance between the two outer terminals is acceptable.

If you have the three wire valve, measure the ohms between the two outer terminals. You should have about 40 ohms. Next measure between the center terminal and each outer terminal. You should see about 20 ohms.

The two wire IAS valve should have about 10 ohms between its terminals.

If your IAS / IAC valve fails this check, it's junk and must be replaced.

If your IAS / IAC valve passed this check, it may still be junk. The problem is that while it's electronics may be fine, it could have mechanical issues. I suggest removing it from the vehicle and thoroughly clean it out with carburetor cleaner. This will almost always fix it, especially if it's off a running vehicle. If it's off a vehicle that's been sitting for years, it may be stuck beyond hope.

EXTREME Danger! After cleaning this, or any other part with carburetor cleaner be sure to wash the part and remove ALL traces of the stuff. If exposed to extreme heat (like welding heat) carburetor cleaner turns to what is essentially Mustard Gas. Breathing in even a super small amount can cause serious injury or death.

If your IAS valve is clean and it passed the electrical check it's almost certainly OK. If the car still has an idle problem and the engine is mechanically in good condition, it's time to check other sections of this article. Look for air leaks, bad grounds, fuel injector issues, etc.

Important note: The communication between the ECU and the IAC is a one way street, meaning the ECU sends a signal to the IAC and the IAC does not report back to the ECU. It doesn't need to, because the ECU will see the idle speed changes caused by the IAC. Why does this matter? Because it means you can remove the IAC and replace it with a simple cable operated manual valve. This is a great way to eliminate this expensive and somewhat unreliable part. It means you will have to pull a cable to open the valve for cold starts, then push it back in when the car is warmed up (a lot like the operation of a manual choke on an older carburated car). The advantage is lower operating cost, and greater reliability. It also improves starting at really low temperatures.

Step 11, Throttle position switch

The throttle position switch is an often misunderstood device. I am going to slightly oversimplify here, but think of it this way. It's purpose in the fuel injection system is simply to tell the ECU when to ignore the signal from the Oxygen (O2) sensor. It does this under two conditions. First, it does it at idle. This is because at idle the mixture requirements are different than those during normal driving, and because low exhaust flow hampers accurate measurements from the O2 sensor. Second at full throttle, at full throttle the engine requires a richer mixture than it does at part throttle. In the rare case of the 1986-1988 535i automatic, the throttle position switch has other functions described later in this section.

So, the switch sends one of three signals to the ECU. It tells the ECU, the engine is at idle (throttle closed) and it ignores the O2 sensor. Or, it says, I am at full throttle, please ignore the O2 sensor. Or, if the throttle is somewhere in between it says, my owner is driving like a normal human being, please use information from the O2 sensor to adjust my air fuel ratio to about 14.7:1 for optimal fuel economy and emissions. At full throttle, it ignores the signal and the ECU goes to a pre-programmed fuel schedule that will give an air fuel ratio of about 12.5:1, ideal for power!

Pictured below is the relatively complex double throttle position switch system used on the 1986-1988 BMW 535i with an automatic transmission. It's actually quite rare in the Motronic world. Almost every other car from this era, including all other E28s have the more common single switch with three terminals. At the time of this writing this switch assembly is over $300, if you can find one. Thankfully, they almost never fail.

* A casual driver could have a bad throttle position switch and never notice a change in the engine's behavior. The symptoms of a bad throttle position switch vary depending on just how it failed. If it failed at the full throttle, or idle position, the car will run almost perfectly, but will suffer from an increase in fuel consumption, and high emissions. It's quite possible you could drive for years with it failed like this and never know it. Of course you should fix it, the fuel savings will add up, especially in highway driving.

If the switch failed in the part throttle, or cruise position, it's a bigger problem, although again, the issues are subtle. The engine will idle poorly, but it will still idle, and the car will lose a little bit of horsepower at full throttle. The loss of horsepower will be minor, about 5hp in the case of a 535i. If you have a modified car (high compression or forced induction, modified ignition curve etc.) this failure can cause detonation (pinging or knock) causing greater power loss and possibly engine damage. In extreme cases with modified engines it can cause piston failure.

Now that we know what this thing does, and the problems it can cause if it fails, lets look at the device itself. There are two types. The first is a three position switch, it's black in color and has a three terminal Bosch plug on it. This is BY FAR the more common type, and it's on virtually every Bosch fuel injected car made in the 80's, including all the E28 cars covered in this article with one exception. That one exception is the 535i when equipped with the 4HP 22 EH Automatic transmission. These transmissions were only installed in the 1986-1988 model years. If you have this transmission, you have the other throttle position switch.

Although it's outside the scope of this article, I should mention that the 4HP 22 EH automatic has one serious glitch in an otherwise very good transmission. It's possible to destroy the transmission during a smog check. This actually happened a lot when they first starting doing smog checks in these things, and there is a service bulletin about it. Here is how it happens. The tech drives the car into the service bay, puts it in park, and shuts off the engine. Next, the tech starts it and without moving the shift lever revs it up and sustains about 2500rpm for a few minuets. Now the transmission is heavily damaged! The fix is to drive it in a gear before putting it in park and revving it up. Before you go in for a smog check research this so you don't screw it up. I am not sure I am remembering this correctly, and we don't have smog checks anymore where I live.

OK, back to the throttle position switch. If you have the more common type, and you probably do take a look at it and notice you have three terminals on the switch labeled numbered 2, 18, and 3. Terminal 18 is the middle one. Look carefully to figure out which terminals are 2 and 3.

Note: A bad Bosch throttle position switch is very rare. An incorrectly adjusted switch is common.

Pictured below is the common type of Bosch Throttle position switch used on the 528e, 535i with manual transmission, and most other 80's BMWs.

Let's test the more common type of switch first. Locate the switch, it's attached to the throttle body. Remove the electrical connector, which is a standard Bosch type connector. Before we begin, it's a good idea to make sure the switch gets power. Using a volt meter on the wiring harness (NOT IN THE OHMS POSITION OR DAMAGE COULD RESULT) test for voltage at the center terminal, #18 with the ignition on. Again, in this case we are testing for voltage on the wiring harness, not the throttle switch itself. With the ignition on you should have about 5 volts here between the center terminal and either of the outboard terminals. If it doesn't your throttle switch isn't getting power due to a wiring or ECU problem. Go to sections 4 and 15 of this article to find the problem. If it passes the power test, continue below.

Next we are going to use our OHM meter to test the switch itself. We will be checking for continuity between the various terminals at various throttle positions. Now, we are testing the switch, NOT the wiring harness. Never touch an ohm meter to the wiring harness.

First lets test it with the **throttle closed.** With the throttle closed you should see continuity (meaning essentially zero ohms of resistance) between terminals **2 and 18**. If it doesn't pass this test, it could mean that the switch is bad. More likely it's simply out of adjustment. Normally a working, and well adjusted switch will make an audible (barely) click when the throttle is closed. To verify this, advance the throttle slightly and listen for the switch to make a click sound as you close the throttle. If it fails to make an audible click, or even if it does, but it failed the ohms test with the throttle closed, you should try to adjust it.

Adjusting this thing is easy. Loosen the two mounting screws and rotate it with the throttle closed until you hear the switch click. You want it to click just as the throttle closes, not before. Once adjusted, tighten the screws in that position and repeat the ohms check. Odd are it will now be fine. If not, you need a new switch.

Important note: On the **528e** the throttle position switch is located on the bottom of the throttle body. That means you have to remove the throttle body to adjust it. I just love that.

Next, we will test it in the **part throttle** position. If it fails this, you need a new switch, period. Open the throttle about 1/3 of the way, enough so the switch doesn't trigger the idle position, but not so much it's even close to full throttle. OK, get out the ohms meter again. You should have NO continuity (meaning infinite ohms) between **2 and 18, AND between 3 and 18.**

Last, we need to check **full throttle**. I know this is the most important position for the enthusiast. It's also the easiest to check. With the throttle fully open, make sure you have continuity (essentially zero ohms) between terminals **3 and 18**. If you don't, and the switch is even close to correctly adjusted, the switch is junk.

1986-1988 535i Automatic

Ok, lets suppose, that like me, you have a daughter that insisted on having an E28 535i with an automatic transmission, and you caved in. Don't fear, it's still a much cooler car than those her friends drive, and the throttle position switch isn't too bad. The switch looks totally different from the type in the other E28s. It's under a big round rubber covering located on the throttle body towards the front of the car. This switch is actually two separate switches, one for the idle position, and one for full throttle. If neither is engaged, the ECU assumes you are in cruise. This switch does essentially the same thing as the other type, but it communicates in a different way. It sends a full throttle signal to the automatic transmission control unit (located in the dash near the headlight switch). That unit then sends a signal to the ECU saying "full throttle". I don't want to turn this into a transmission article, but know that if your BMW automatic is shifting hard, won't upshift when it should or has various other issues, it could be this switch!

With the cover off look at the switch assembly and you will see that it's actually two switches. As you face the switches from the front of the car, the switch on your right (driver's side of the car) is the full throttle switch, and the other is the idle switch. Caution, this is correct, various automotive manuals have this backwards!

To test the idle switch unplug the connectors (each terminal has its own connector) and measure the resistance between the two terminals on the SWITCH side of the connector. With the throttle at idle, you should have continuity (essentially zero ohms) between the two terminals. Advance the throttle and once it's off idle by any significant amount you should have NO continuity, or infinite ohms. This is actually a tough test to do. I had to use a very long probe to reach that back connector. It's also tough to get those connectors on and off. I did it, and took a picture of it for this article and accidentally erased it. So the picture I have isn't the actual test.

The position of the sensor can be adjusted, so if it doesn't test correctly play with the adjustment before you buy a new switch. To adjust it, loosen the mounting screws and rotate the switch. With the throttle at idle rotate the switch until it clicks. It should click as the throttle reaches idle or just barely before. This switch almost never fails or gets out of adjustment so it's not likely to be a problem.

The picture below gives a good idea of what a good test of the idle switch should look like with the throttle at idle. Be sure to disconnect the switch before you do this test to avoid the risk of damage to the ECU.

Testing the full throttle switch is very different from testing the other throttle positions switches on Motronic cars. First of all you don't disconnect the switch, and you will be testing for voltage, not ohms. With the ignition ON, use a volt meter with pointy terminals and back probe the wires going into the switch. That means shove the pointy terminal into the back of the connector so it makes contact with the wire.

When back probing you should get the following results. With the throttle at idle, you should see about 5 volts between the black wire (terminal 3) and ground. You should also have about 5 volts between the black wire and the brown wire (terminal 1).

Now measure voltage between the yellow wire (terminal 2) and the brown wire. Voltage should be about .7 volts with the throttle closed and increase as the throttle opens to about 4.78 when it's fully open.

That's all for this section, let's move on!

Step 12, Ignition system checks, coil, distributor cap, rotor, etc.

OK, this is a fuel injection article. However Bosch tied the fuel and ignition systems together in such a way, that it's all related. That, plus the fact that I wanted this article to be fairly complete means I will have to touch on some ignition issues.

If your engine doesn't have a spark, this is probably the section for you. There are a number of ways to check for a spark. I like to put a timing light on each spark plug wire, one at a time and crank the engine. That way I can watch the light flash and not only tell if current is flowing, I can watch the rhythm of the light and make sure it's flashing in equal and consistent intervals. If it is, the ignition is probably fine. Of course that doesn't insure that the plug is firing, only that power is reaching the plug. The plugs themselves can be bad, and often are the source of ignition trouble. Of course you can test spark plugs by removing them, connecting them to a spark plug wire, grounding the insulator to the engine and cranking. You can then see it spark. Somehow when I do this no matter how careful I am, I end up shocking the heck out myself, and the E28s ignition system has about 40,000+ volts, so it HURTS.

My preferred method for testing for a spark is to put in new plugs and use the timing light method explained above. It works well with minimal risk of shock.

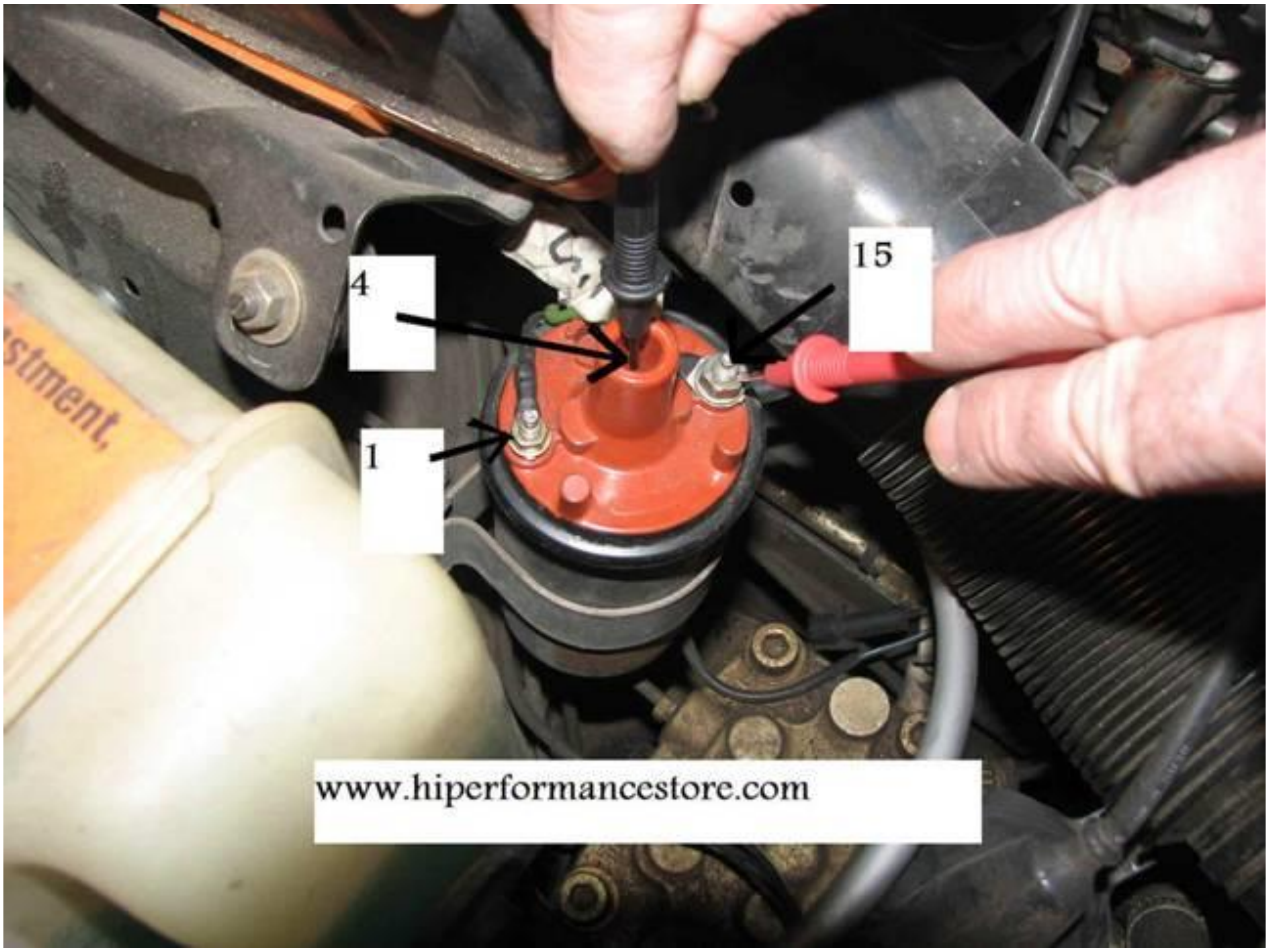
Step 1. Make sure the coil has power. If it doesn't, you don't get a spark. To check this, remove the coil's protective cover and main wire (the big one that goes to the distributor). Next turn on the ignition and with either a test light, or a volt meter, verify you have power at the positive side of the coil. The positive side is terminal 15, and is labeled as such, but the wiring sometimes makes it difficult to see the label. If you don't have power at the coil, go back up to Step 4. If everything is ok in Step 4, and you still don't have power, your life is about to get complex. Go to step 15.

* A bad **coil** can cause the car to stop running. I have only seen them either work perfectly, or not at all. With that said, it's possible for it to have intermittent problems which could cause almost any possible symptom including difficult hot or cold starting, low power, and generally poor running. In my personal experience where ever I have had these problems related to the coil it has always turned out to be an issue with power getting too the coil, and not the coil itself. So we will be checking that as well.

Here I am checking to make sure the coil has power. I am using a test light. A voltmeter would be a little better, we should see voltage about equal to battery voltage. The test light works well enough. You must have the ignition on for this test.

As long as the cover is off the coil, it's a good time to check the rest of it out. To do this remove both wires, make sure you have a way to remember which one is positive. If you forget, you can always check to see which one has voltage with the ignition on. We will test between the various terminals. They are labeled "15" which is positive, "1" which is negative, and terminal #4 which is the main outlet that connects the coil to the distributor.

The 535i coil is pictured below. It can sometimes rotate in its mount so make sure you know which terminal is positive. It's number 15, but sometimes you can't see the number. The number is molded into the orange plastic near the terminal itself as is the number 1 on the other terminal. Here I am checking resistance between 4 and 15. Note: You must disconnect the wires from the coil to do this accurately. I just did it this way to be quick for the photo.



Ok, with your ohm meter, it's time to check out the coil itself. This is easy. Disconnect all wires on the coil. The resistance between 1 and 15 should be about **.**5 ohms. Between 15 and 4 you should see about 6000 ohms.

That's it. If those things check out, the coil is good. Coils rarely fail, but they do fail, especially on 20+ year old cars. The stock Bosch coils are excellent, but it's a good idea to have a spare for long trips. Note for you turbo guys, coils don't like too much heat so if your turbo(s) are going to be in this area, it's a good idea to relocate the coil.

If your coil is good, and your car still isn't getting a spark, go up to Step 8 and make sure your Speed and Reference sensors are working before you continue in this section.

Distributor Cap and Rotor: I am not going to waste a lot of your time talking about these basic parts. They work just like every other cap and rotor on the planet. The cap has an unusual shape, and these parts are super expensive, but they are otherwise just like all the other caps and rotors out there.

To check these parts, remove the cap and inspect it for cracks or serious corrosion or pitting. If either of those things are present, replace the cap. These caps seem to last forever, if it looks pretty normal, clean up the contacts with very fine Emory cloth, or a soft brush and a Dremel. Verify the center button is spring loaded and moves nicely. Once you do these things it will usually work as well as new.

Remove the rotor and plastic dust shield behind it. If you find a lot of oil, it's leaking through a bad camshaft seal, which can cause irregular sparking. Assuming it's fairly clean in there, inspect the rotor for damage and clean or replace it.

If you have done all of these things, and your reference and speed sensors are good, and you are still not getting a spark, make sure the rotor is actually turning when you crank the engine. If it is, go to Step 15 and enter a world of pain.

Step 13, Oxygen Sensor

Ok, lets get one thing straight right away. The O2 sensor does not hurt performance. If you remove it, or disable it you car will burn more fuel and pollute more. It will not gain even one horsepower. The purpose of this device is to measure gasses in the exhaust and provide that information to the ECU. The ECU will then lean or richen the mixture in order to provide an optimal air:fuel ratio for fuel economy and emissions. For what it's worth, this ratio is about 14.7:1. That's 14.7 pounds of air, to every pound of fuel entering the engine. At full throttle the O2 sensor has no effect and the ECU defaults to an air:fuel ratio of 12.5:1, optimal for horsepower.

* Signs of a bad O2 sensor are poor fuel economy, and or high emissions. Normally these things last a really long time, like a hundred thousand miles and 10 years. However, these cars are old, and certain things can cause them to fail prematurely.

Let's talk about how it works. Well, not exactly how it works, for practical purposes it may as well operate on magic dust from unicorn fur, because we can't take it apart and fix it. However we can test it, at least too an extent, and we can avoid some of the things that cause it to fail.

Pictured below is a generic Bosch O2 sensor.

If your O2 sensor is more than 10 years old, or has 100,000 plus miles on it, it's probably time for a new one. That said there are a few things that will quickly damage an O2 sensor. First is leaded fuel. This isn't really a problem because it's normally hard to find leaded fuel anyway. However, you can buy it at race tracks, various fuel additives have it, and they sell leaded fuel at airports. (by the way airports sell 100LL (100 octane Low Lead) this stuff has 10 times the lead of leaded auto gasoline, it's death for these sensors. It will also foul spark plugs). Stay away from leaded fuels or lead additives. That shouldn't be a problem.

The second thing that kills O2 sensor is a problem. It's silicone. If exposed to oil, silicone gasket cement or engine sealers will break down and get into the engine's oil. Some of that oil will be burned and make its way to the O2 sensor where the silicone will, over time shorten it's life. How fast depends on how much oil your engine burns, and how much silicone is in it. Use silicone sealant for the cooling system, intake system, but not anywhere oil will come in contact with it on an engine that uses an O2 sensor.

Occasionally I see someone using silicone hose as fuel line. This is really bad, as it will quickly destroy the O2 sensor, and the hose itself will eventually fail. I am a silicone hose dealer and manufacture, so take this seriously. Don't use silicone hose for fuel. It's the best for vacuum and coolant, not for fuel.

BMW used a number of different O2 sensors on E28s. The 535i cars all have a 3 wire sensor. 528e cars built from March 1987 on have a 4 wire sensor, and all other Motronic E28s (as far as I know) have a 1 wire sensor. You may need to go under your car and find the sensor to figure out what you have. To an extent, they can interchange.

The O2 sensor uses heat from the exhaust and turns it into energy. It's essentially powered by exhaust heat. It measures the oxygen in the exhaust and converts this into a voltage signal and sends that to the ECU. The higher the voltage the richer the mixture. The basic units have only one wire, that's the wire that takes the signal to the ECU. The 3 and 4 wire units have extra circuitry to help them warm up faster. Without these extra wires the sensor takes a long time to warm up, and when the engine is at idle they can cool off so much they quit working reliably. In stop and go traffic, they don't work that well. To alleviate this, Bosch went to the electrically heated 3 and 4 wire sensors.

In the picture below my finger is touching the O2 sensor's heater relay in 535i. This is where the factory put the relay. It may have been moved in your car. It's the only relay here that has a green/blue wire going to it.

BMW decided to heat the O2 sensor through a relay. When the engine is running, it should be heated. To test the heating system go under the car and disconnect the O2 sensor and look for voltage on the harness side of the connector (not the sensor side). With the engine running it should be about 12 volts. If not, you almost certainly have a bad relay. Oh, which wire should you check? It depends on what car you have. On a 535i you are checking for voltage between the Green/Blue wire and the Brown wire. If you have 528e built from March 1987 on, check the voltage from the Grey/Blue wire and the Brown wire. If you have any other E28, you don't have a heated sensor.

Ok, so, your sensor is heated, or perhaps not, but that doesn't mean it's working. I am going to explain how to test the sensor, but be warned, this is a very unreliable test, if in doubt I suggest replacing it.

To test the O2 sensor we are going to measure its output voltage to the ECU. All E28 O2 sensors have a BLACK wire for the output, so that's the one you are looking for. Finding this wire can be a little tricky. It's not always located in a standard location. I need to add a picture of the test, but even with the picture it may not help due to the variation in locations.

The best way to find the black wire is to start under the car at the O2 sensor and follow the wire to the connector. It's normally located in the engine bay near the firewall. Warm the car up, if you have a non heated sensor, rev the car up a bit (caution if you have an automatic you can damage it read about the "serious glitch" in section 11. Look for the red highlighted text.) Even if you have a heated sensor you may need to rev it up to get a good reading. The sensor must be HOT. Now measure the voltage. The voltage output is 0-1, that's zero to ONE volt. As you are taking the reading introduce an air leak by removing the oil cap. This will cause the mixture to go lean the the voltage to drop. Now, as you do this you will probably be complaining about how hokey this test is. The voltage will by varying all over the place so it's hard to detect the drop. Do your best to average out the voltage swings in your head with and without the oil cap on, it should be lower without the cap. If so your sensor at least responds properly.

Of course the above test doesn't verify that's it's sending out the correct voltage, only that it responds in the correct direction. Plus, if your engine has other problems, the sensor could give you a weird but correct reading. I really think it's best to replace the sensor if you are in doubt.

I will discuss O2 sensor voltage a lot more in the performance section below. If you are curious, the voltage at a 14.7:1 air:fuel ratio should be about .45 (that's POINT 45). At 12.5:1 about .9. At full throttle it doesn't vary too badly so we can use this to verify the fuel injection system is spraying in the right amount of fuel. This can be very useful.

Step 14, The Cold starting system, the Cold Start Valve and Thermo Time Switch. Motronic Basic Only

If you have the Motronic 1.1 system you can skip this step. The 1.1 system's cold start enrichment is handled entirely through the system logic and main fuel injectors. If it does have a cold start issue, go back up to Step 7.

This cold start system in the E28 is relatively simple. There are two key components. The first is a "cold start valve" This is essentially a seventh fuel injector that only sprays fuel during cold starts. A bad cold start valve can cause a number of problems depending on how it fails. It can fail in a few ways. It can stick open or closed and it can clog up. This little injector has NO internal filter so it's very sensitive to debris in the fuel system. It's also very expensive. A new one for a later 528e is nearly $300. My injector shop can overhaul these and make them like new for $32 when sent with a complete injector set. I made a jig to test and service these, almost nobody else fixes them.

* If the **cold start valve** fails to open when it should, cold starting can be difficult or impossible. If it sticks open, it can make warm or hot starting difficult or impossible, as well as cause high fuel consumption, high emissions, and poor idling. If it sticks open it can also cause the dreaded starts and stalls syndrome. Note: if you car has the starts and stalls syndrome, it's also possible that the main injectors are not firing and the engine is starting ONLY on the fuel from the cold start injector.

Finding the cold start valve is simple. Locate the fuel rail and follow the hose to the cold start injector. On the 535i and other big six E28s it's located on the intake plenum below the throttle body. Remove the main air intake tube to get access to it. On all Motronic BMWs from the 80's the cold start valve will have a BLUE Bosch connector on it. They all look the same, and most will physically interchange, but the flow rates are different, so don't use a 535i cold start valve on your 528e.

In the picture below my finger is touching the fuel line that connects the fuel rail to the cold start valve on a 535i. If your car has the big six, follow this hose to find the cold start valve.

If you have a 528e, or another BMW with the same engine (i.e. 325e as pictured below) your cold start valve is very easy to get at. The arrow in the picture points to the valve.

Before we get into testing this valve we need to discuss the other key component in the cold start system. It's the **Thermo Time Switch** (TTS), and it's the device that controls the cold start valve. * If your **Thermo Time Switch** is bad, it can cause the cold start valve to stay open or closed when it shouldn't. This causes the exact same symptoms as a failed cost start valve, meaning you always have to diagnose the two together. The TTS is simply a an on/off switch that's immersed in the engine's coolant. When the coolant temperature is below 86F (30C) the switch closes allowing current to reach the cold start injector IF the starter motor is cranking the engine. In order to prevent flooding, the switch will open to shut off the cold start valve after a few seconds of cranking. Just how long the switch stays closed depends on coolant temperature. Under no conditions should it allow the cold start valve to spray longer than about 8 seconds.

There is a procedure for diagnosing the Thermo Time Switch, and I will cover it in this section. First I will say, that I have never seen a Thermo Time Switch that didn't work. They don't always seem to test correctly, but they do always seem to work. I think the official testing parameters have some issues. Anyway, here is how I test the cold start system.

To test this system, remove the cold start valve from the manifold, but don't take off the hose or the electrical connection. Disable the ignition via whatever your preferred method is, I disconnect power to the coil, aim the valve into a container, take all fire safety precautions, because we will be spraying fuel (have fire extinguisher ready, protective clothing on, the car outside, etc.) and have someone crank the car while you hold the valve so that fuel coming out sprays into a container. Fuel should spray in while the car is cranking and stop as soon as the cranking stops. Next, have your helper crank the car for about 20 seconds. The valve should stop spraying within about 8 seconds maximum, and the valve should not continue to drip when the engine is still cranking. The spray pattern should be a nice even cone.

If the valve sprayed and stopped spraying when it should have, the cold start system is good. If not, you have to figure out where the problem is.

If the problem is the valve doesn't stop spraying, disconnect the cold start valve's electrical connector. Do the test again. If it sprays, or drips, the cold start valve needs to be overhauled or replaced. If it doesn't, it's a certainly you need a new TTS.

If the valve sprayed, but the spray pattern was bad, overhaul or replace the cold start valve.

If the valve didn't spray when it should have it's probably stuck closed. However it could be that it's not getting a signal to open due to a faulty TTS. To check the signal from the TTS use a voltmeter or test light and verify you have current across the two terminals in the blue plug that attaches to the cold start valve. (we are testing on the wiring harness here, not the valve. Make sure you are set to read voltage.). If it's getting voltage and it doesn't open. Have it overhauled, or replace it.

If there is no voltage at these terminals the TTS is bad, or it could be a wiring issue. Before I assume the TTS is bad, I will check to make sure it's getting power.

In the picture below, the engine is cranking and I am making sure power is reaching the Thermo Time Switch. The test light is on, so power to the switch is good.

The picture above shows how to check for power to the TTS. The engine must be cranking! No power goes here unless the starter motor is turning the engine. We are looking for current between terminal "W" and ground. The terminals are labeled on the side of the switch itself.

If the TTS is getting power and yet there is no signal from the switch at the cold start valve, and the coolant temp is below 86F (30C), the switch is probably bad. I wouldn't bother to test it beyond this point. However you can check the switch itself, but I warn you, due to the number of different switches, and the variables due to coolant temperatures, this test isn't super accurate.

Basically, you measure resistance between terminal "W" and ground. Ohms here should be either zero or infinite. The reading should be zero at low coolant temperatures, and infinite when the coolant is fully warmed up. The coolant temperature at which it changes from zero to infinite is either 50F(10C)or 86F(30C) depending on what switch you have. As a general rule only the 1982 and 1983 cars have the 50F switch, but these things interchange so it's tough to know what switch you have. They do have numbers stamped on them, sometimes you can figure it out that way.

The Ohms between terminal "G" and ground should be between 25 and 130 depending on temperature, and what switch you have. Just check it twice and verify that at higher temperatures you see a higher ohms reading.

In this next picture I am testing for ohms on the Thermo Time Switch. It's reading 68.4 between terminal "G" and ground. That's about right!

If this ohms test doesn't seem to work out, don't worry about it. Just determine if it's sending a signal to the cold start valve or not, using the methods I describe earlier. That's a lot more reliable.

More fun with the cold start valve. Ok, the ECU to Thermo Time Switch to Cold start valve communication is a one way street. That means, that the ECU talks to the TTS and the TTS sends a signal to the start valve. The ECU does not process any communication from the TTS or the valve.

So what? Well, it's important because it means you can eliminate the TTS from the system and connect the cold start valve to a manual switch or button. If your thermo time switch is bad, or you just want the cold start valve to be manual, you can disconnect the TTS's electrical plug and set up a manual control for the cold start valve. You can run 12 volts to the cold start valve, so you can tap into the electrical system almost anywhere you want.

Why would you want do to this? Well, most people won't. However if you can't afford or find a new TTS, it's a good option. Perhaps you are stranded and need the car to start. Sometimes on highly modified Motronic systems the TTS temperature settings are inappropriate (i.e. it fires when you don't need it, or vice versa). I have seen people connect them to pressure switches to come on at a certain level of boost in turbo and supercharged Motronic setups. (this is not very effective, I will discuss it further in step 16.)

Step 15, the Motronic ECU and wiring harness (under construction, pictures coming soon)

Welcome to step 15. If you are starting here, please don't. You probably need to start somewhere else, like Step 1.

The ECU, is the brain of the Motronic system. It's an electronic control unit, often called, the Motronic control unit. In this article, it's called an ECU. On all e28s the ECU is located just above the glove box. It has one large electrical connector on it. This connector is held in place by a locking mechanism, and in some cases a screw. Do not ever disconnect, or connect this connector to the ECU with the battery connected. This can cause damage to the ECU. There are some who believe that even an electric shock from static discharge can damage the ECU. I don't know if that's true but let’s be on the safe side and assume it is.

If you were lead to this step from somewhere else in this article, you are in a world of pain. It means you either have a bad ECU, or a problem in the wiring harness between the ECU and some under hood component. It's most likely going to be in the wiring.

There are some who say that ECUs don't fail. I can assure you that's incorrect. This logic comes from a time when electronic fuel injection was new, and perfectly working ECUs were often blamed for other faults, usually air leaks and weak grounds. Combine this with the fact that when new or newish, these ECUs were pretty much bullet proof and this lead people to over react and say that the ECUs never fail. Fast forward to present day. Now these ECUs are 20-30 years old. They have had a lot of heat and vibration over time. Some have been removed, re-installed, modified, and sometimes abused. It's still VERY VERY rare, but the ECUs can fail. *A bad ECU, or wiring harness can cause any possible running issue. Every symptom an engine can have related to fuel or spark can be caused by a failure in these components.

With that said, I have never seen a failed Bosch Motronic Basic or 1.1 ECU fail. I have seen problems with the Bosch L-Jetronic ECUs, however they are one generation older. So I can't stress enough, that the odds of you having a bad ECU are very low, but it's possible.

Unfortunately, a thorough, easy and efficient test of the Bosch ECU involves some very rare, and nearly unobtainable Bosch testing equipment. Without it, you will have to find ECU faults via the process of elimination. This isn't nearly as bad as it sounds. It involves checking the component, and the wiring harness. If those two things are OK, and the component in question still doesn't work, the problem is in the ECU. This method of testing is a lot easier than it sounds.

To understand how we are going to do this just follow along. First, DISCONNECT THE BATTERY. I used all capitals there for a reason. If you don't, you could damage the ECU. Next, remove the ECU. The connector is usually hinged at one end, and it will have some sort of retaining lock, and sometimes a screw. Remove the connector carefully. The electrical terminals are tiny and delicate.

Once the connector is off, take a look at all of the terminals. If there is any corrosion here it must be cleaned up. Now, put the ECU somewhere safe, like in the backseat. If you take it out of the car, you increase the risk of static electricity (although I think the risk is zero anyway). Now, go and connect the battery because for many of these tests you will need voltage at the connector.

If you have Motronic basic, you have a 35 pin connector. On this connector the terminals are numbered in a logical way. There are 18 connectors in one row and 17 in the other row. With the 18 connectors on top, they are numbered from left to right 1-18, the second row are 19-35.

If you have Motronic 1.1 the terminals are numbered backwards. There are 55 connectors , the first row has 19, the other two have 18. With the longer row on top they are numbered 1-19 STARTING FROM THE RIGHT. In other words you read the numbers right to left. The second row has 20-37 and the third 38-55. On a Motronic 1.1 system these are all numbered from right to left.

I like to start by making sure the ECU is getting power. Look at the charts below, make sure you are looking at the chart for your ECU, and follow the procedures. For example, If you have a 533i or 535i you will be working with terminals 18, and 35. Turn on your ignition and make sure you see approximately battery voltage between terminal 18 and ground, and between terminal 35 and ground. If you don't have power here, there is no way your car will run. Go back to Step 4 and check the main relay. The ECU gets its power from the main relay. If that checks out, then there is a connection loose somewhere, or a problem in the wiring.

Wiring Harness:

Like a bad ECU, a wiring harness can cause any possible running issue. * Every symptom an engine can have related to fuel or spark can be caused by a failure here.

LONG AND BORING SECTION AHEAD. ☹

First we need to do a good visual inspection. Look at all the connectors under the hood to make sure they are secure. Next looks for problems with the wiring itself. Most of these problems are usually found within just a few inches of a connector. This is because repeated flexing of the wire sometimes causes the insulation or the wiring itself to break. This is easy enough to test for. If the engine will idle, gently wiggle the suspected wire. If the idle characteristics change you probably have a problem with the connector or the wiring near it. For some reason, the wiring/connector problems I usually find are at or near the injector connectors. I am not really sure why. They are subjected to the same amount of heat and vibration as any other connector that mounted to the engine. It’s probably due to abuse at some point in the car’s life. These connectors can be frustrating to remove, especially if they are not the later “squeeze to release” type. I think this causes people to tug on them a little too hard.

OK, so all the wiring and connectors look OK but the car still has an issue, and we suspect it’s in the wiring somewhere between the connector and the ECU. This is actually pretty easy to test for. Obviously you can’t do this visually because the wires normally join into a bundle, which joins into a bigger bundle working its way towards the ECU. To check every wire visually would be a monumental task. There is another way!

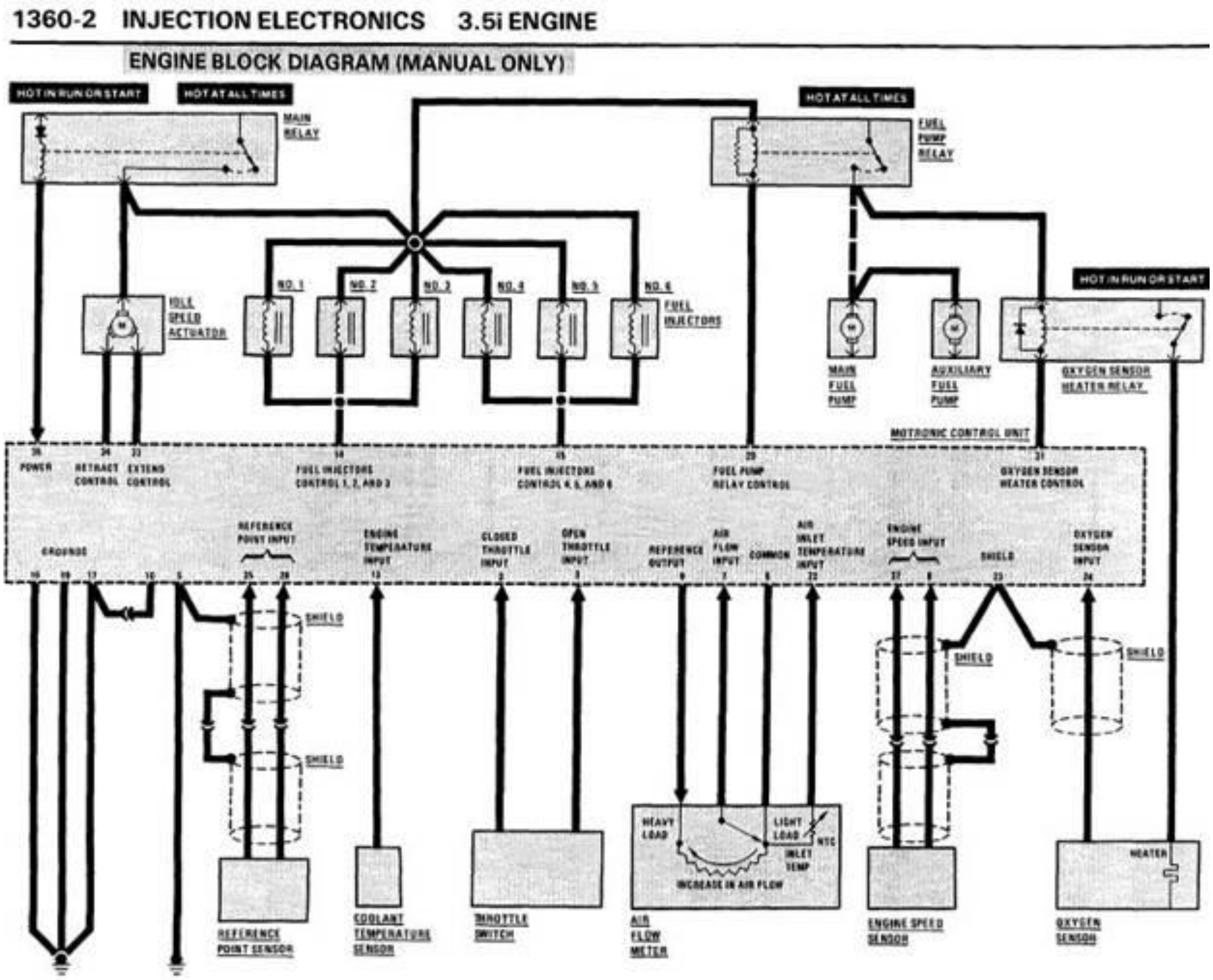
Once again, we are going to need our OHM meter. You could also do this with a continuity tester, but I am going to assume you have an OHM meter. Start by disconnecting the ECU, you will need easy access to the terminals on the ECU's connector. That means the connector that's a part of the wiring harness (NEVER TOUCH AN OHM METER TO ANY PART OF THE ECU). We are working with the big connector on the ECU's wiring harness.

All we need to do is to test for resistance between the terminal on the ECU's Connector and the connector that's at the other end of the associated wire. Simple right? To figure out which connector goes where we need to have a look at the factory wiring diagram. CAUTION! Just about every possible version of this car has a different ECU, and thus different wiring configuration. I am going to post the key diagrams for the MANUAL transmission E28 535i, the Automatic transmission version, and the M5 with the S38 engine. They are all different. MAKE SURE YOU ARE LOOKING at the correct diagram.

So, how are we going to do this? Well, in this example, let's say we have a 1988 535i with a manual transmission. It's been having a problem that seems related to the throttle position switch; however the switch itself tests fine so we need to check the associated wiring. We take a look at the correct wring diagram shown below and see that both terminals 2 and 3 connect the ECU to the switch. Using our OHM meter and probably some extra wiring so that it will reach, we check for resistance between terminal 2 on the wiring harness at the ECU end, and terminal 2 on the wiring harness at the switch end. The resistance should be zero, or at least very close to it. If the resistance is infinite, double check to make sure you are touching the correct terminals.

Every wire you check this way should have zero, or nearly zero resistance. If it doesn't, the wiring is probably damaged. The damage is probably near the connector itself, or at a high stress point, normally a place where the wiring harness attaches to a bracket or passes through the firewall.

NOTICE the diagram below is for the E28 535i with a MANUAL transmission.

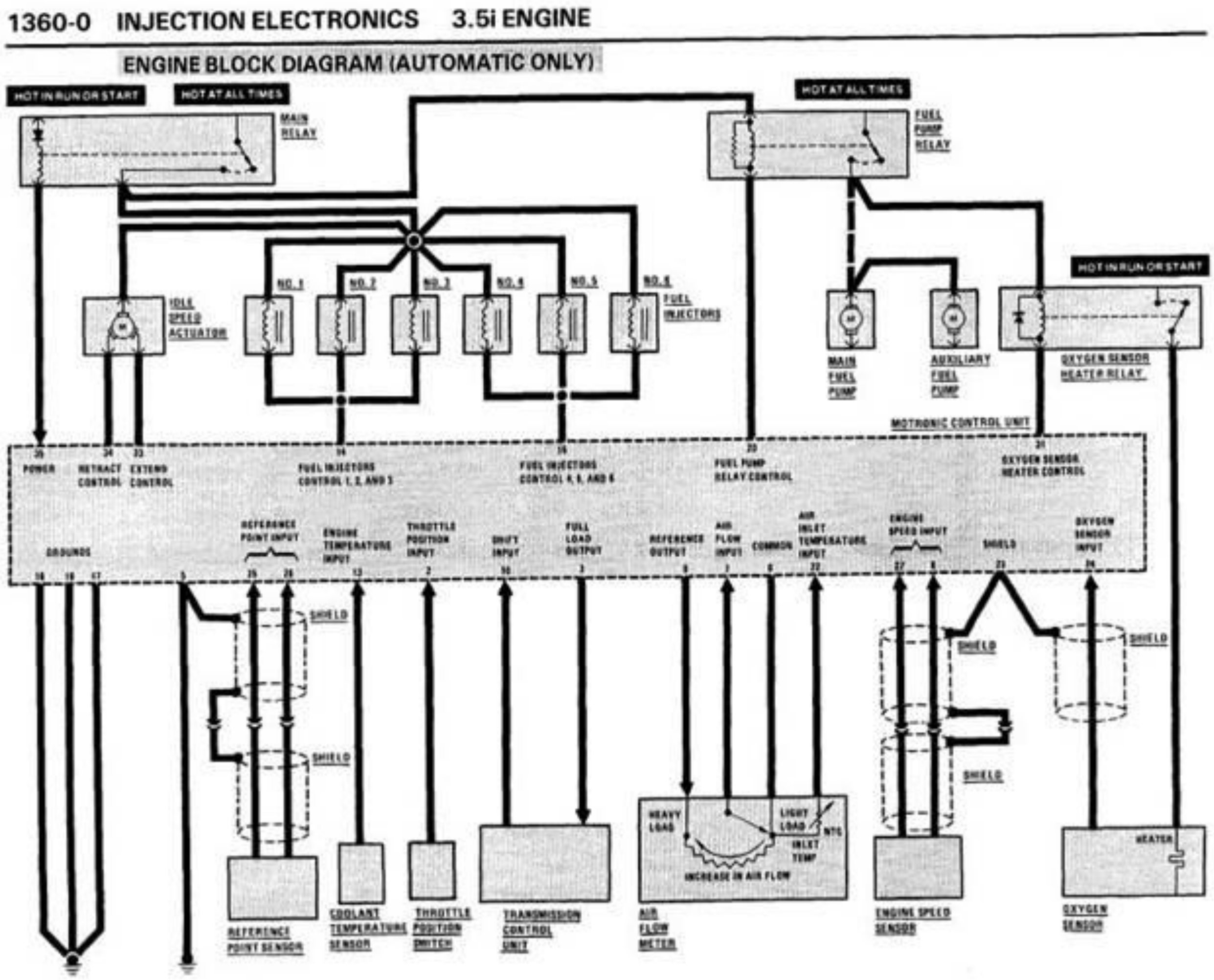


Testing the wires one at a time is the only way to do this. I know it sounds bad, but it actually goes pretty fast once you get started. Now, I am not going to go through every wire on the harness. You get the idea of what needs to be done.

Keep in mind the diagrams I am posting are only a few of the many diagrams for these cars. I chose the diagrams that show the key wires most often associated with injection problems. There are literally hundreds of factory wiring diagrams for E28 535i. They can be found in the “1987-1988 BMW 535i - M5 Electrical Troubleshooting Manual”. Add to that the fact that there are SEVEN different E28 electrical troubleshooting manuals for the various years and engines, and there are just too many diagrams to cover all the variations here.

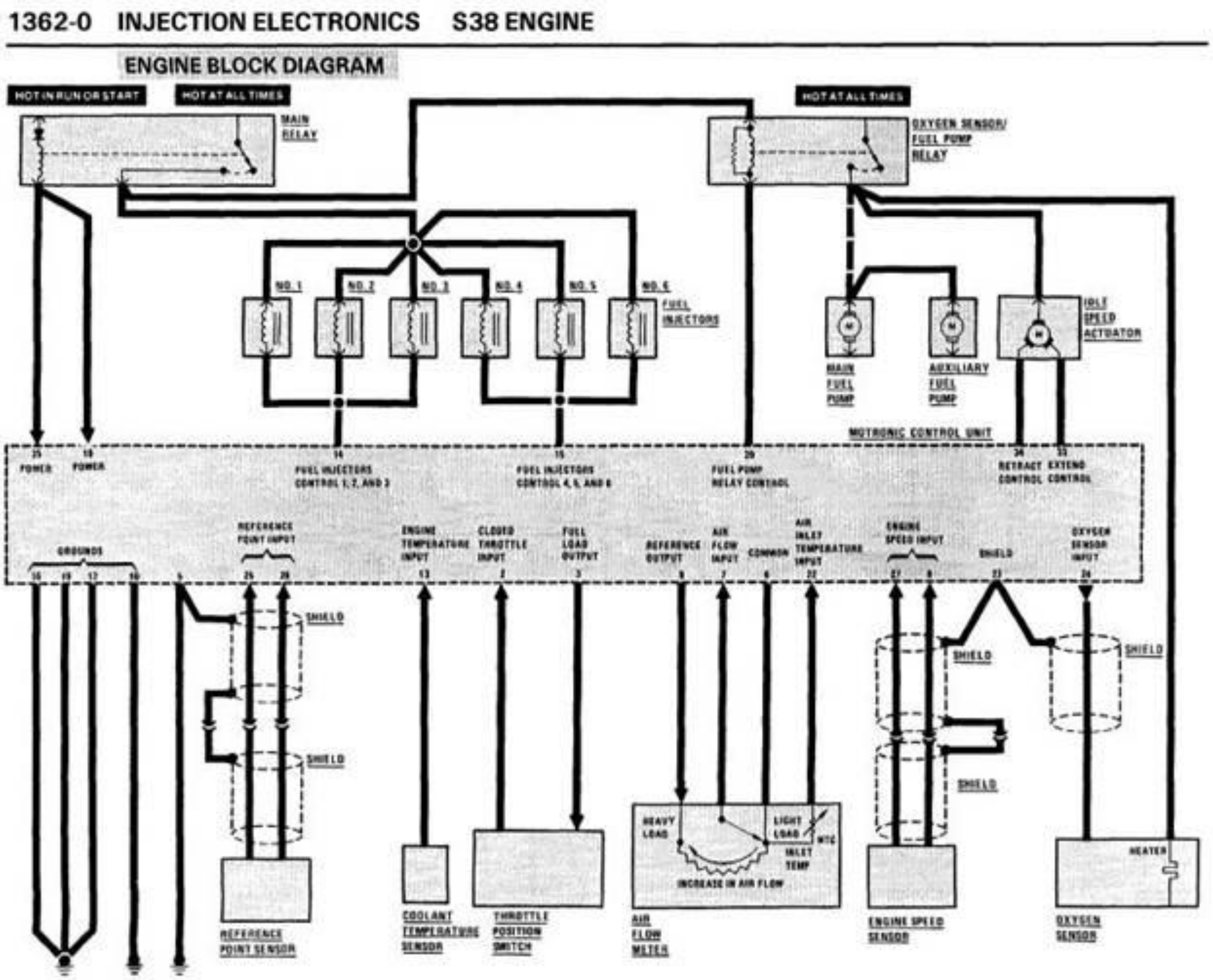
If you car had an engine bay fire, or other serious damage to the wiring harness, it’s probably best to get another one from a used car. Changing the whole thing isn’t nearly as bad as it sound. The Motronic wiring harness is mostly separate from the car’s wiring harness and only connects to main wiring at a few points. This is not the case with BMWs in the post E34 era.

Below is the E28 535i AUTOMATIC transmission diagram



Most of the difference in the E28 with the automatic relate to either the transmission itself, or the throttle position switch.

Below is the diagram for the E28 M5 with the S38 engine.



The E28 M5’s Motronic ECU and associated wiring harness are totally different from the E28 535i. Be careful to use the correct diagrams when working on an M5.

Step 16, Performance modifications

This section will cover increasing horsepower on a STOCK E28, and adapting the stock Motronic system for modifications including turbo or supercharging.

Section A: history and backround: Ok, this section deals with theory, and explains why souping up your E28 is a little different from a typical American V8 of the same period.

If this is you, just skip this entire section. All simple answers will be at the end of this article.

First a little backround on the E28. In its day, even the wimpy 528e was a pretty quick car. The 535i was one of the fastest cars you could buy. It could accelerate fast to a top speed over 130mph, when most new sedans couldn't top 100mph. The E28 M5 can reach 150mph!

For comparison, the California Highway Patrol's Dodge St. Regis police car, which were all over the place throughout the 80's, had a top speed (with the light bar installed) of about 90mph, and it took two MILES of flat road to reach it! The St. Regis was fast enough to catch most speeders. That should explain just how fast a 535i was relative to other cars of the period.

In the 80's this is what the cops in California were chasing people with. As shown here it has a top speed of about 90mph. Even worse, it couldn't exceed 60mph up the Conejo Grade, or the Grapevine Hill.

Times sure have changed. Today most 3.4 liter sixes have about 100hp more than the E28 535i, and quite a few engines in that size range have twice as much. Why does this matter? It matters because Automotive performance is relative, and relative to everything else from its time, the E28 is already pretty darn fast.

I am going to focus on the 535i's engine, but everything I write here will apply to the other BMWs of the period.

The BMW 535i's engine was pretty hot in its day. It has a somewhat aggressive camshaft, but low compression (8:1, which was normal for the time). Its exhaust, and intake are decent, and its ECU programming is pretty close to optimal. The factory did a good job with their engineering and didn't leave a lot of easy horsepower on the table.

We can easily modify the fuel injection system to spray in more fuel, but that by its self won't help. If it would, we could simply crimp the fuel pressure regulator's return line closed and see a big increase in power. Of course that won't work!

NOW THIS IS IMPORTANT, the engine puts the demand on the fuel injection system. It is not the other way around. In stock form, the Motronic system provides an air fuel ratio at full throttle of about 12.5:1. That ratio is ideal for power (excluding knock-limited power). This is backed up by a ton of data, both old and new. The ratio of 12.5:1 is ideal. Screwing with the fuel injection system on a stock engine will take the ratio away from that ideal value and decrease power. So, before you get started, it's worth it to go through the technical portion of this article and make sure your fuel injection system is working correctly in the first place. **It's counterproductive to add $1000 in performance parts that add 10 horsepower only to be losing 15 to clogged fuel injectors, vacuum loss or some other anomaly.**

The traditional methods of increasing horsepower, such as increasing compression, changing cams, free flowing intakes, free flowing exhaust, special chips, and so on, all work on the E28s. However they are less effective, and thus cost more in terms of horsepower per dollar, than on a typical American car from the era.

Let's back up for a moment, say to the 1970s and early 80s, and talk about automotive engine design. At that point, traditionally, when an American manufacturer wanted more power they simply increased the engine's displacement. If the customer buying a new Dodge needed more power than the base 225ci engine provided, they could opt for a 318, 360, 400, or 440. This offers the manufacturer a number of advantages. First is cost. On a mass production scale, the 318 and 360 cost essentially the same amount to make. They are essentially the same engine, just with different displacements. Second is ease of explaining things to the customer. More engine= More Power, and it costs more money! Any customer, salesman or advertizing executive can handle this concept. The third, and this relates to cost is the lack of engineering required. That's not to say that we didn't have good American engineers at the time, we did, it's just that the bean counters rarely allowed them to shine. It's very easy to increase power while retaining a smooth idle, and good driveability by increasing displacement.

The Germans simply didn't have that option. The price at the pump of gasoline in Europe made increases in power via displacement much less attractive due to the hit in fuel economy. Sure, they could have shoved in a 5.2 liter V8 with 165 horsepower (as in the police car mentioned above), but fuel economy would have suffered. So they went in another direction.

The 535i has a 3.4 liter 6 cylinder. In order to get the power of V8 into an engine with less displacement they used a decent cylinder head, a relatively hot cam, pretty good free-flowing intake, and exhaust. Furthermore, they used what at the time was the best fuel delivery system available, Bosch Motronic.

For comparison we can look at the Dodge 318 with 165hp. It has incredibly restrictive exhaust manifolds, a very wimpy cam, and its ability to inhale air is heavily restricted by a tiny two barrel carb. The carb is topped by an air filter that's not designed to flow well, it's designed to prevent carburetor ice, something that's just not a factor on an injected engine.

Traditional hot rodding technique became traditional because they worked so well on the old American V8s. It's no problem to get the old 318 up to 275, or 300 horsepower with heads, compression, cam, intake (in this case meaning converting to a a 4barrel carb or fuel injection), and headers. This was true of most American V8 of the era.

In effect, the 535i already has those mods. There just isn't that much left to improve on without sacrifices in some other area. **In fact before you make any changes; it's a good idea to ask yourself, why didn't the factory make that change?** Often it's because that change would hurt fuel economy or idle quality, as is usually the case with hotter camshafts. Perhaps it would require high octane fuel as is often the case with higher compression. Often it's related to noise, or emissions, you could install a nice tubular header, no cats and minimal mufflers, but the factory didn't do it because of emissions and noise.

Now, sometimes, it's simply related to costs. To go back to the American V8 example, you can literally improve every possible aspect of a Dodge 383, INCLUDING fuel economy, by converting it from a 2 barrel carb to a 4 barrel. They only reasons the factory didn't make every single 383 leave the factory with a 4 barrel were economic. That's just not the case with the 535i's engine. There is very little you will be able to do without adversely affecting something. With that in mind, let's talk about what you can do.

Section B: Bolt on power.

535i Exhaust

Although it's not exactly related to the Motronic system, let's start with exhaust. There is VERY LITTLE to be gained by modifying the exhaust system AFT of the exhaust manifolds if the engine is stock. For example I installed a very well designed exhaust system on my car. I know this stuff, and I think it's as good as or better than any other system for these cars. It uses two very free flowing cats, dual straight through glass packs and a lot fewer bends than the stock system. The result on my automatic 535i was an increase of 3 horsepower at the rear wheels with the cats and about 5 without. (YES, I dyoned it.). Obviously we need the cats for emissions, so 3 rear wheel horsepower is what I gained. That said, the system sounds great, and it's quite a bit lighter than stock and made from mostly 409 stainless, so it should last forever. It's been on there 5 years, and no issues whatsoever, but it's not a lot of power for the money.

Headers! I shamelessly took this picture from ebay. I hope the seller "vintagebmwsource" doesn't mind. All headers are not created equal. These look good to me. They have proper flange, collectors, equal length pipes, and good welding. If I was to buy headers for my E28 535i I would buy these.

I have not installed headers. I like the stock exhaust manifolds. They are legal, last forever, and are easy to take on and off if needed. For performance they are a decent design. Not great, but not that bad either. That said, a good set of tubular headers would increase power. I don't have any dyno results, but I am very confident you could gain 10 horsepower with a good set of headers. Most of that will be in the high RPM range where you don't drive that much. At low and mid range the gains on a stock engine will be minimal. Combine that with the cost, and it's easy to see why BMW didn't give us tubular headers on the 535i. At times like this, I like to look at what the factory did. On the M5 they did include tubular headers. That makes sense, the car was much more expensive, so as a percentage of the cost of the car, it wasn't too bad, and the engine was designed for higher rpm and higher power so the advantages would be greater.

Intake

Ok, hold on! Nothing in the performance world seems to create as much argument as aftermarket intake systems.

There is good news here. Changes to the intake can increase power, and for a reasonable cost, but not for the commonly held reasons. Almost everyone knows that with the other factors fixed, cold air is denser than warm air. A lot of self proclaimed experts will tell you "the factory already put in a cold air intake!" Thus any cone filter, or other aftermarket setup is a waste of money. Not true! First of all, nearly every fuel injected car ever made has a factory cold air intake. This certainly isn't unique to BMWs. Carbureted engines didn't normally have cold air intakes because the manufacturers were concerned with carburetor icing.

Now, there is another big factor with intake systems. It's normally a bigger factor than intake air temperature. This big factor is manifold pressure. Let's talk about manifold pressure for a few moments to make sure we are all on the same page.

Normal atmospheric pressure at sea level is 14.7 pounds per square inch. For some reason, in automobiles we measure pressure in normally aspirated cars (meaning NOT under boost from a turbo or supercharger) below atmospheric pressure as vacuum in inches of mercury (i.e. 15 inches of vacuum at idle or whatever) and pressure above as pounds of boost (i.e. 5 pounds of boost.) Thus a turbo car with 5 pounds of boost has 19.7psi of air pressure in it's manifold when it's under boost (5+14.7=19.7). At full throttle in a normally aspirated engine we will see about Zero vacuum. More on this later.

To keep with the automotive norms, I will discuss this in terms of vacuum in inches of Mercury. MORE vacuum equals less air in the intake manifold. Less vacuum means more. That means that when your car is sitting with the engine off, vacuum will be ZERO. That makes sense right? The engine isn't drawing in any air, and the intake isn't air tight, so atmospheric pressure is able to fully work its way into the plenum . Now, let's start the engine and let it idle. If you hook up a vacuum gauge you will see that it has about 15 inches of vacuum. Why is that? It's because the throttle blocks incoming air, and the engine is pumping air into the cylinders faster than the atmosphere can shove it through the intake system due to the closed throttle. As we increase the throttle air pressure in the plenum increases, meaning vacuum decreases. We are literally giving the engine more air. If Vacuum reaches zero, that means there is essentially no restriction in the intake system. The atmosphere is able to shove itself in as fast and the engine can suck it out of the intake manifold.

This is pretty easy to measure. Simply connect a vacuum gage to the intake manifold downstream of the throttle and drive the car. When you do this, you will notice something strange. In an E28 535i, at full throttle as the RPM increases pressure in the manifold will start to drop! Meaning it starts to develop vacuum even at full throttle. Why is this? It's because of restrictions in the intake system. We can figure out where they are, and how much power they are costing us. I'll cover this in the next update.