

Exhaust System Bypass Valves and Exhaust Valve Bypass Controller

Basic Primer on Exhaust System Flow Velocity and Backpressure

The information about exhaust system theory was obtained from research on the Internet. Unfortunately, I do not know who the original author was to give him or her credit that is due.

Basic Theory

An automotive exhaust system is designed to evacuate gases from the combustion chamber quickly and efficiently. Exhaust gases are not produced in a smooth stream; exhaust gases originate in pulses. An 8 cylinder engine motor will have 8 distinct pulses per complete engine cycle and a 12 cylinder engine will have 12 pulses. As more pulses are produced, the exhaust flow becomes more continuous.

Within the exhaust system, there is an inherent resistance the flow of the exhaust gases – backpressure – loosely defined as the resistance to positive flow of the exhaust system. With any modern engine, the inherent backpressure within the exhaust system consists of the exhaust manifold, the catalytic converter, the system muffler (silencer) and the connecting pipes. While one would think that lower back pressure would be better, that is not always the case when designing an exhaust system for a modern engine.

Automotive exhaust designers produce systems that balance exhaust flow capacity with velocity. The objective is to evacuate the exhaust gases as fast as possible. At lower engine RPM and lower exhaust gas volume, the velocity of the exiting gases is lower. If one could artificially impose a restrictor in the exhaust system that would increase the back pressure, the velocity of the exiting gases will increase and this will improve the evacuation of the gases from the engine. A simple comparison is water flowing from a garden hose. If you let water trickle from an unrestricted hose, the water flow rate (velocity) will be low. If you cover the hose opening with your finger, you will increase backpressure and the flow rate will increase. But, at some point, if you cover the opening of the hose too much, you will have caused so much backpressure that the velocity then declines ... eventually to zero.

Why is Exhaust Velocity Important?

The faster an exhaust pulse moves, the better it can scavenge out all of the spent gasses during valve overlap. The general idea is a fast moving pulse creates a low pressure area behind it. This low pressure area acts as a vacuum and draws along the gas behind it. A similar example would be a vehicle traveling at a high rate of speed on a dusty road. There is a low pressure area immediately behind the moving vehicle - dust particles get sucked into this low pressure area causing it to collect on the back of the vehicle. This is why we mentioned exhaust pulses above. It is because of these pulses in the exhaust combined with velocity that tend to produce this scavenging effect.

You may have noticed that turbo charged engines tend to have larger exhaust pipes. The reason is simple. Since the turbo is in the exhaust stream, the gas flow spinning the impeller tends to come out of the turbo with pulses greatly diminished, which tend to negate the scavenging effect. So turbo charged cars typically have larger pipes to accommodate gas volume — leaving the turbo to perform the task of scavenging the spent exhaust gases.

Dealing with Variable Exhaust Flow Rates in Modern Engines

Automotive engineers design exhaust system taking into account many factors, including the number of cylinders (pulses), the power curve they are seeking and environmental considerations. The maximum scavenging effect is achieved when the exhaust

velocity is high and time between pulses is relatively long. So, when engine RPM is low and the total volume of gases is correspondingly low, the designers typically utilize smaller diameter pipes to create a bit of back pressure. But as engine RPM increases, the volume of gas increases and the time between pulses decreases, which in turn reduces the scavenging effect. Now, back pressure becomes a bad thing. In these conditions larger diameter pipes are appropriate to reduce the backpressure and accommodate the increased volume of gases.

These variables present a challenge when designing effective engine exhaust systems. At lower engine RPM, the flow rate is low and we want to induce some backpressure to improve engine efficiency and power. While at higher engine RPM, the engine is producing more exhaust gases (higher volume) and we want to reduce backpressure. The trick is to have an exhaust system that will evacuate the gases as quickly as possible (high velocity) at the RPM range that you want your power band located. As discussed above, smaller exhaust pipe diameters are best suited at lower engine RPM when the volume of gases is small. But at higher engine RPM, a smaller exhaust pipe will then create unacceptably high amounts of backpressure and reduce the exhaust velocity when the engine is producing greater volume of gas. This will have a negative effect on power output and engine efficiency. When backpressure is not optimized in the exhaust system, there is a tendency to reduce engine efficiency resulting in decrease in power output and higher fuel consumption.

To work around the RPM specific nature of pipe diameters and their effect on backpressure, engineers may use setups that have the effect of changing the pipe diameter on the fly. Advanced exhaust systems (e.g., Ferrari, Maserati) have two exhaust paths after the header - at low RPM only one path is open to maintain exhaust velocity, but as RPM climbs and exhaust volume increases, the second path is opened to curb backpressure and improve flow velocity. Since there is greater exhaust volume, there is no loss in flow capacity.

Exhaust Bypass Valves

Ferrari's and Maserati's (and other vehicles as well) utilize exhaust bypass valves to achieve two distinct flows for the exhaust gases. Generally, the exhaust bypass valves are positioned behind the catalytic converters. They could be placed before the silencer or after. In either case, opening the valve(s) will have the net effect of reducing the back pressure, but in the former case, opening the valve(s) will also increase the sound level.

With the exhaust bypass valve closed, the gases have only one path ... through the silencer. This increases backpressure and improves the velocity of the escaping gases through the system resulting in improved power at lower RPMs

As RPM increases, the vehicle ECU will open the exhaust bypass valve. This can be a progressive opening that occurs over a range of RPM, but generally the opening of the bypass valves occurs immediately when key parameters are achieved (e.g., engine RPM and throttle position). When the bypass valve opens, it presents a second path for escaping exhaust gases and if the valve(s) are located before the silencer, the gases will then "bypass" the muffler (hence the term). The net effect is the reduction of backpressure in response to the increase in flow rate thereby maintaining (or improving) the velocity. In so doing, the engine is more able to achieve higher efficiencies and power at the elevated RPM.

How do Automobile Manufacturers Control the Bypass Valves

Exhaust bypass valves can be manually actuated, electrically actuated or vacuum actuated. It is more common in high end cars to utilize vacuum actuation.

For vacuum actuation, the exhaust bypass valve is a vacuum actuated simple butterfly-type valve that is placed in-line in the exhaust pipe. Normally, if vacuum is applied to the valve, it opens. Remove the vacuum and it closes. In some vehicles it may work in reverse. This will depend on the vehicle.



Exhaust Bypass Valve



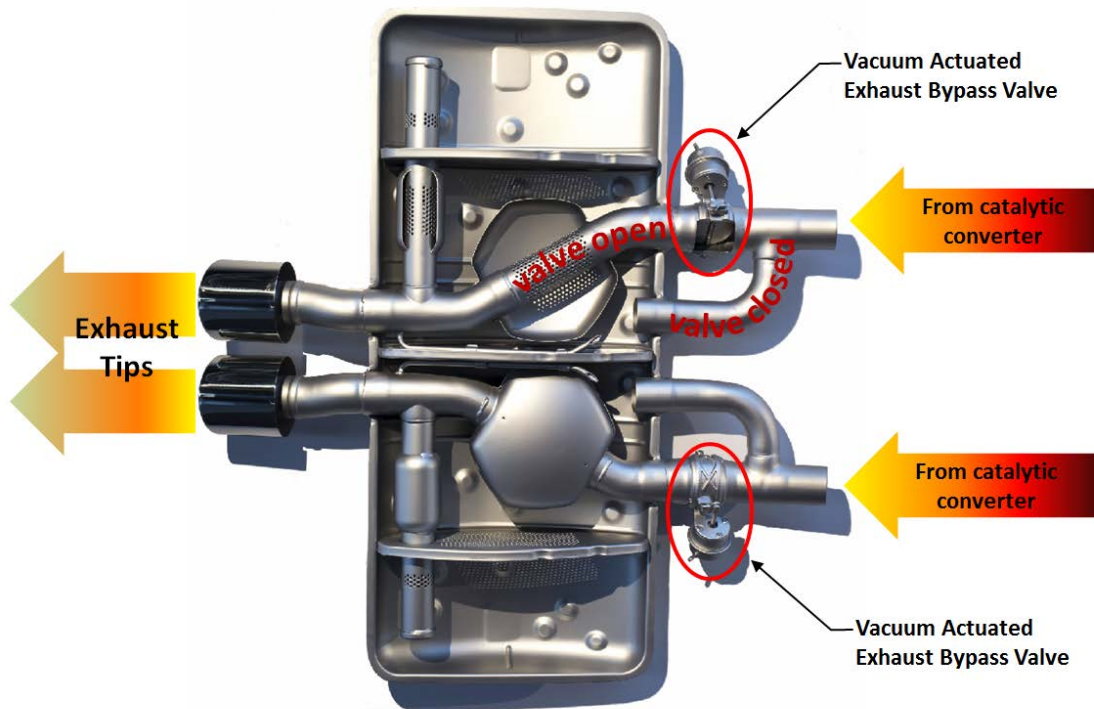
Vacuum Solenoid Valve

The vacuum solenoid valve controls the vacuum delivered to the bypass valves. There is a vacuum line from the engine to the solenoid valve and a vacuum line from the solenoid valve to the bypass valve. The solenoid itself is an electrically actuated magnetic coil that opens and closes the vacuum valve. With the application of an electric signal, the solenoid valve will either open or close to apply vacuum to the bypass valve or vent the bypass valve to atmosphere.

Examples of Exhaust Bypass Valve Implementation

Using the Jaguar F-Type as an example, when the vehicle's ignition is off and no vacuum is available, the exhaust bypass valve springs will, by default, open. When the vehicle is first started, the ECU on the vehicle will want to close the exhaust bypass valves. This is performed by signaling the solenoid valve to apply a vacuum on the exhaust bypass valve, thereby forcing the valves to close. In the closed position, exhaust gases will follow a route through the silencer which will provide a bit of back pressure and, of course, reduce the noise level.

When certain thresholds are reached (engine RPM, throttle position, etc.), the ECU will signal the solenoid valve to release the vacuum to the bypass valve, the bypass valves' springs will then open the butterfly valves to allow exhaust gases to follow the bypass route which is less restrictive, reducing the back pressure and raising the noise level.



Ferrari uses a similar setup with vacuum actuated exhaust bypass valves. Here is how Ferrari has incorporated the exhaust bypass valve in the exhaust tips of the Ferrari 599, showing the bypass valve in the outboard tip in the closed and in the open position.



Manually Controlling the Exhaust Bypass Valves

If your vehicle comes equipped with exhaust bypass valves and you want to optimize power and engine efficiency for normal driving, you should not employ manual methods for controlling the bypass valves. Let the vehicle's ECU manage that for you.

So, why would you want to manually control the valves? I can only think of two reasons:

1. You are racing or tracking the vehicle. In these situations you are likely going to be keeping the engine RPM in the higher ranges and your throttle will likely be positioned more open than closed. You want the least restrictive exhaust so you can maximize exhaust gas velocity.
2. You want to hear the glorious sound from your engine. The immediate effect of an open exhaust bypass valve is to "bypass" the muffler (at least for a portion of the exhaust gases) with the net result of a louder exhaust note.

So, let's assume your reason is the latter. You want to make some noise. By manually controlling the bypass valves, you can make that noise any time. And, you can return control of the bypass valves to the vehicle's ECU when you want to quiet things down ... e.g., coming into your neighborhood you don't want to disturb the neighbors ... or maybe to deny the local constable from having another excuse to have a conversation with you.

How to Incorporate the Forza Componenti Controller to Control the Bypass

The Forza Componenti Exhaust Bypass Valve Controller merely intercepts the signal to the Vacuum Solenoid Valve. In simple terms, it is the insertion of an in-line relay on the ground side of the electrical connection to the Vacuum Solenoid Valve. In practice, this in-line relay is activated using either a remote control transmitter, in the form of a key fob, or a manual on/off switch. The critical element is that all the switching circuits only control the negative side of the circuit. There is no insertion of switching circuitry on the positive side which mitigates the risk of posing a hazard to the vehicle's sensitive electronics.

The Forza Componenti control unit can be configured to use either the remote transmitter to control the switching or use a simple on/off switch on the ground wire to perform the same task. This gives the user the flexibility to choose the mode of operation to use. There are advantages and disadvantages to both methods.

<u>Device</u>	<u>Advantages</u>	<u>Disadvantages</u>
Remote Control Transmitter	<ul style="list-style-type: none">• Installation of entire kit is simple• Provide a fail-safe mode ... when power is disrupted to controller (e.g., switching engine off) full control returns to ECU	<ul style="list-style-type: none">• Potential loss of remote transmitter
Manual On/Off Switch	<ul style="list-style-type: none">• Long term reliability• Ability to operate is always at hand ... separate transmitter not required	<ul style="list-style-type: none">• Requires additional step to route control wire into passenger compartment

Exhaust Bypass Controller Design Considerations

The Controller Kit consists of two key components:

1. Control unit and remote transmitter
2. Connector cables

Key considerations went into the design:

- The kit must be plug-and-play. Design requires no wiring modifications, no splicing of wires and no drilling of holes.
- Everything has to resist high temperatures. Nothing is going withstand direct contact with the hot exhaust pipes or catalytic converters, but temperatures may easily exceed 100° C in the engine bay. The control box is aluminum and exposed wiring is manufactured using with heat tolerant wiring that is both oil and water resistant.
- Everything must be totally reversible. The owner of an expensive exotic vehicle may want to remove the kit and show no evidence that it ever existed.
- The electrical circuits must minimize any risk of causing electrical failures. By performing any switching on the ground side of the vehicle's electrical connections, this satisfies that requirement. All relays on the PCB use diode protection which reduces risks of reverse EMF back through the vehicle wiring.
- No diagnostic codes should be generated by the vehicle when manually controlling the exhaust bypass valves. When manually operating the exhaust bypass valves, circuitry is provided so the vehicle's ECU will not sense that the vacuum solenoid valve is not in the control loop, thereby mitigating the risk that that ECU would sense a failure and log a diagnostic code.

Control Unit



- Controller enclosure is extruded aluminum. This provides high strength and temperature tolerance in a compact and light weight package.
- All electronics are contained on a printed circuit board. Control relays on the PCB are rated at 10 amps which is overkill for the current they will carry.
- Controller uses a 433 MHz high frequency RF transmitter and receiver. A multi-position, high-gain antenna is included.
- The remote control receiver incorporates a learning function included on the circuit board of the receiver to program extra or replacement transmitters.
- Indicator LEDs in the end panel used to verify correct electrical polarity is established.
- The controller can be configured for either remote transmitter operation or a manual on/off switch installed in the passenger compartment. If the user elects to use a manual switch, the user must route a wire from the controller to the manual switch that they would provide.
- Most exhaust bypass valves default to open when vehicle ignition is off and no vacuum is available. Some exhaust bypass valves are the opposite. The controller module can be configured for either situation.
- The electrical cables use weatherproof connectors.

Connector Cables



- The connector cables are used to obtain power for the control unit as well as controlling the vacuum solenoid valve.
- Cables are manufactured using very flexible, high temperature resistant wiring that is both oil and water resistant as well.
- All connectors are high-quality weatherproof connectors.

Summary

The Exhaust Bypass Valve Control kit is an ideal accessory for the exotic car owner who wants to satisfy the desire to be able to manually control the position of the exhaust bypass valves without removing the vacuum line or disconnecting the solenoid vacuum valves. The valves can be opened any time and left open. The typical immediate effect is to raise the noise level of the engine exhaust. At any time, control of the valves can be returned to the vehicle's ECU, typically reducing the noise level.

Everything is *plug-and-play*. The DIYer can install the system themselves, requiring only simple tools. There are no wiring modifications required and the entire installation is 100% reversible.