HOW SUPERCHARGERS WORK

Supercharger Basics

A basic engine with the addition of a supercharger.
An ordinary four-stroke engine dedicates one stroke to the process of air intake. There are three steps in this process:

1. The piston moves down.
2. This creates a vacuum.
3. Air at atmospheric pressure is sucked into the combustion chamber.

Once air is drawn into the engine, it must be combined with fuel to form the charge -- a packet of potential energy that can be turned into useful kinetic energy through a chemical reaction known as **combustion**. The spark plug initiates this chemical reaction by igniting the charge. As the fuel undergoes oxidation, a great deal of energy is released. The force of this explosion, concentrated above the cylinder head, drives the piston down and creates a reciprocating motion that is eventually transferred to the wheels.

Getting more fuel into the charge would make for a more powerful explosion. But you can't simply pump more fuel into the engine because an exact amount of oxygen is required to burn a given amount of fuel. This chemically correct mixture -- 14 parts air to one part fuel -- is essential for an engine to operate efficiently. The bottom line: To put in more fuel, you have to put in more air.

That's the job of the supercharger. Superchargers increase intake by compressing air above atmospheric pressure, without creating a vacuum. This forces more air into the engine, providing a "boost." With the additional air in the boost, more fuel can be added to the charge, and the power of the engine is increased. Supercharging adds an average of 46 percent more horsepower and 31 percent more torque. In high-altitude situations, where engine performance deteriorates because the air has low density and pressure, a supercharger delivers higher-pressure air to the engine so it can operate optimally.

Unlike turbochargers, which use the exhaust gases created by combustion to power the compressor, superchargers draw their power directly from the crankshaft. Most are driven by an accessory belt, which wraps around a pulley that is connected to a drive gear. The drive gear, in turn, rotates the compressor gear. The rotor of the compressor can come in various designs, but its job is to draw air in, squeeze the air into a smaller space and discharge it into the intake manifold.

Photo courtesy Muscle Mustang
ProCharger D1SC centrifugal supercharger

To pressurize the air, a supercharger must spin rapidly -- more rapidly than the engine itself. Making the drive gear larger than the compressor gear causes the compressor to spin faster. Superchargers can spin at speeds as high as 50,000 to 65,000 rotations per minute (RPM).

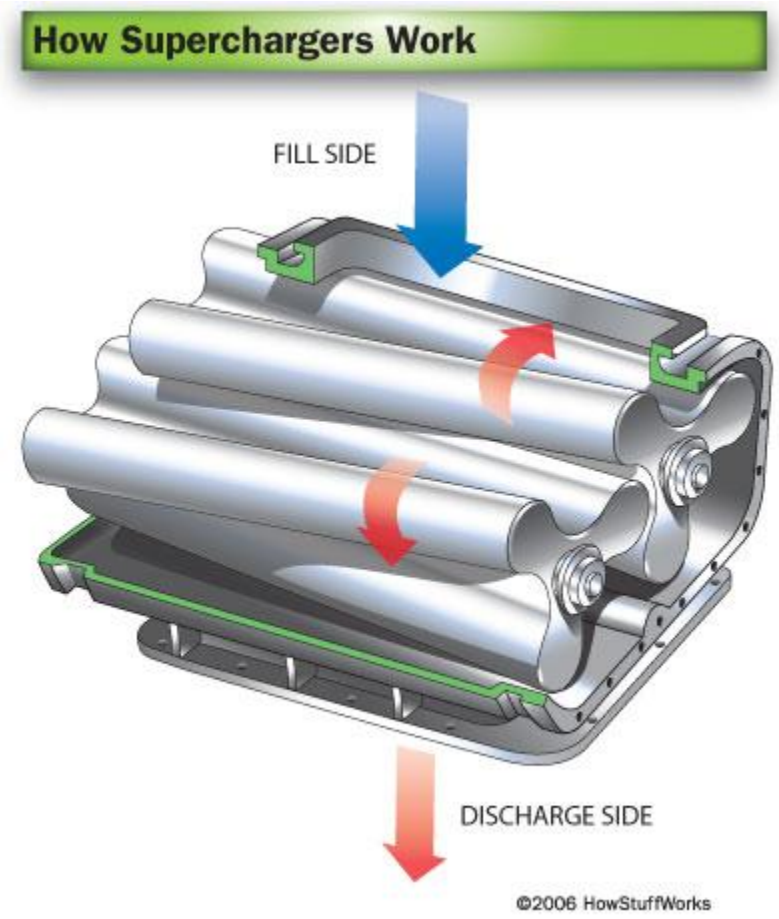
A compressor spinning at 50,000 RPM translates to a boost of about six to nine pounds per square inch (psi). That's six to nine additional psi over the atmospheric pressure at a particular elevation. Atmospheric pressure at sea level is 14.7 psi, so a typical boost from a supercharger places about 50 percent more air into the engine.

As the air is compressed, it gets hotter, which means that it loses its density and can not expand as much during the explosion. This means that it can't create as much power when it's ignited by the spark plug. For a supercharger to work at peak efficiency, the compressed air exiting the discharge unit must be cooled before it enters the intake manifold. The intercooler is responsible for this cooling process. Intercoolers come in two basic designs: air-to-air intercoolers and air-to-water intercoolers. Both work just like a radiator, with cooler air or water sent through a system of pipes or tubes. As the hot air exiting the supercharger encounters the cooler pipes, it also cools down. The reduction in air temperature increases the density of the air, which makes for a denser charge entering the combustion chamber.

Roots Superchargers

There are three types of superchargers: Roots, twin-screw and centrifugal. The main difference is how they move air to the intake manifold of the engine. Roots and twin-screw superchargers use different types of meshing lobes, and a centrifugal supercharger uses an impeller, which draws air in. Although all of these designs provide a boost, they differ considerably in their efficiency. Each type of supercharger is available in different sizes, depending on whether you just want to give your car a boost or compete in a race.

The Roots supercharger is the oldest design. Philander and Francis Roots patented the design in 1860 as a machine that would help ventilate mine shafts. In 1900, Gottleib Daimler included a Roots supercharger in a car engine.



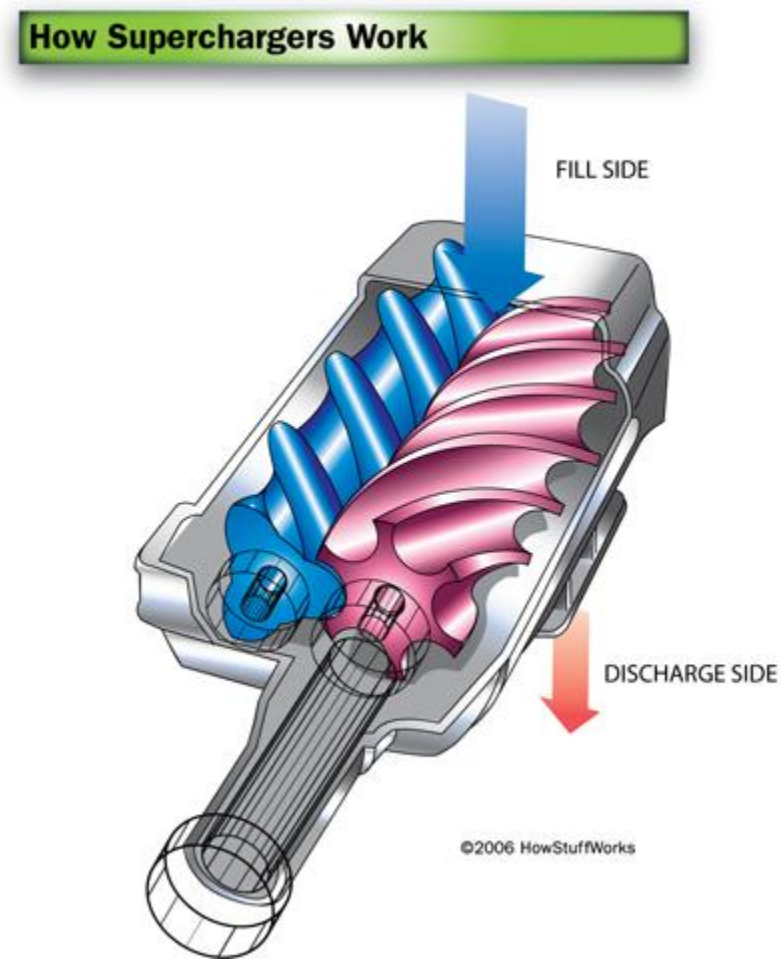
Roots supercharger

As the meshing lobes spin, air trapped in the pockets between the lobes is carried between the fill side and the discharge side. Large quantities of air move into the intake manifold and "stack up" to create positive pressure. For this reason, Roots superchargers are really nothing more than air blowers, and the term "blower" is still often used to describe all superchargers.

Roots superchargers are usually large and sit on top of the engine. They are popular in muscle cars and hot rods because they stick out of the hood of the car. However, they are the least efficient supercharger for two reasons: They add more weight to the vehicle and they move air in discrete bursts instead of in a smooth and continuous flow.

Twin-screw Superchargers

A twin-screw supercharger operates by pulling air through a pair of meshing lobes that resemble a set of worm gears. Like the Roots supercharger, the air inside a twin-screw supercharger is trapped in pockets created by the rotor lobes. But a twin-screw supercharger compresses the air inside the rotor housing. That's because the rotors have a conical taper, which means the air pockets decrease in size as air moves from the fill side to the discharge side. As the air pockets shrink, the air is squeezed into a smaller space.

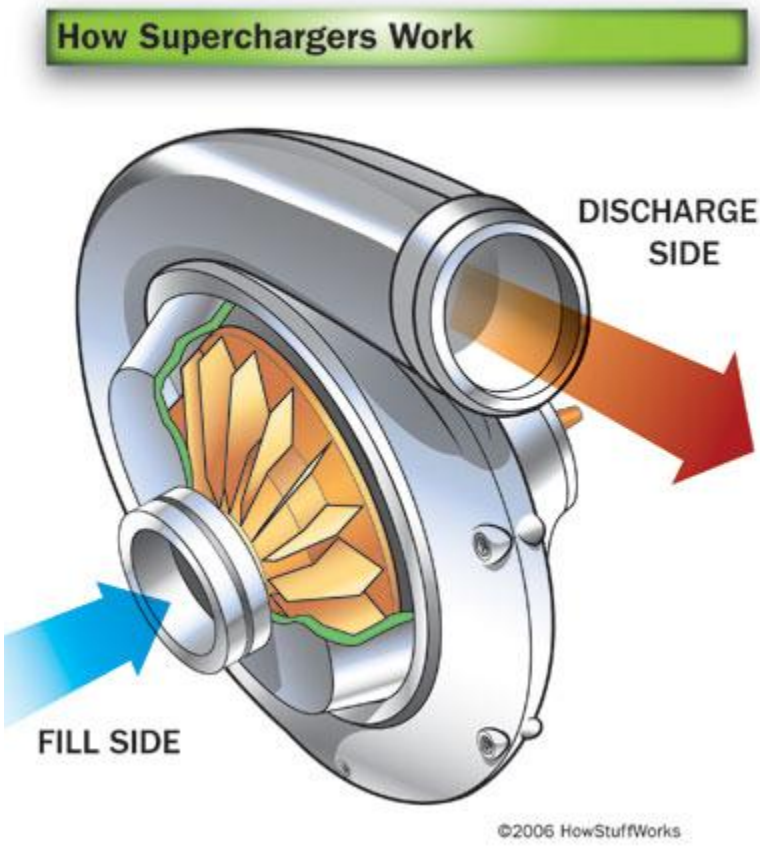


Twin-screw supercharger

This makes twin-screw superchargers more efficient, but they cost more because the screw-type rotors require more precision in the manufacturing process. Some types of twin-screw superchargers sit above the engine like the Roots supercharger. They also make a lot of noise. The compressed air exiting the discharge outlet creates a whine or whistle that must be subdued with noise suppression techniques.

Centrifugal Superchargers

A centrifugal supercharger powers an impeller -- a device similar to a rotor -- at very high speeds to quickly draw air into a small compressor housing. Impeller speeds can reach 50,000 to 60,000 RPM. As the air is drawn in at the hub of the impeller, centrifugal force causes it to radiate outward. The air leaves the impeller at high speed, but low pressure. A diffuser -- a set of stationary vanes that surround the impeller -- converts the high-speed, low-pressure air to low-speed, high-pressure air. Air molecules slow down when they hit the vanes, which reduces the velocity of the airflow and increases pressure.



Centrifugal supercharger

Centrifugal superchargers are the most efficient and the most common of all forced induction systems. They are small, lightweight and attach to the front of the engine instead of the top. They also make a distinctive whine as the engine revs up -- a quality that may turn heads out on the street.

Photos courtesy HowStuffWorks Shopper

Both the Monte Carlo and the Mini-Cooper S are available with superchargers.

Any of these superchargers can be added to a vehicle as an after-market enhancement. Several companies offer kits that come with all of the parts necessary to install a supercharger as a do-it-yourself project. In the world of funny cars and fuel racers, such customization is an integral part of the sport. Several auto manufacturers also include superchargers in their production models.

Next, we'll learn about the advantages of supercharging your car.

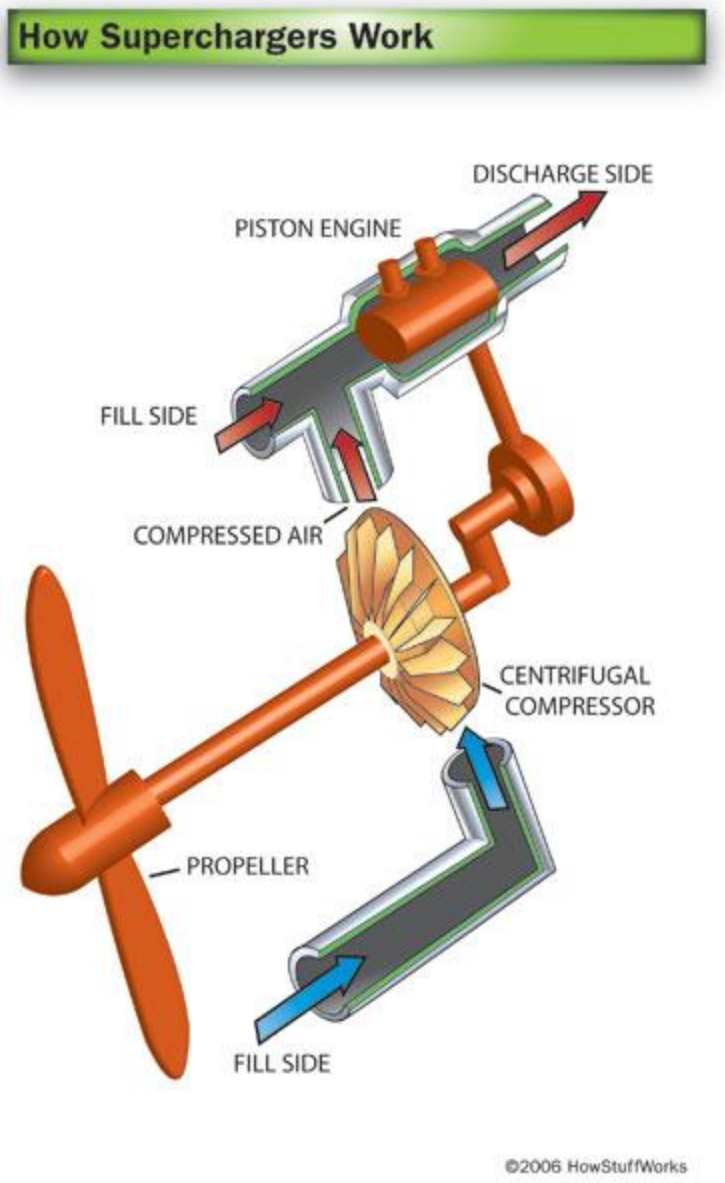
Supercharger Advantages

The biggest advantage of having a supercharger is the increased horsepower. Attach a supercharger to an otherwise normal car or truck, and it will behave like a vehicle with a larger, more powerful engine.

But what if someone is trying to decide between a supercharger and a turbocharger? This question is hotly debated by auto engineers and car enthusiasts, but in general, superchargers offer a few advantages over turbochargers.

Superchargers do not suffer lag -- a term used to describe how much time passes between the driver depressing the gas pedal and the engine's response. Turbochargers suffer from lag because it takes a few moments before the exhaust gases reach a velocity that is sufficient to drive the impeller/turbine. Superchargers have no lag time because they are driven directly by the crankshaft. Certain superchargers are more efficient at lower RPM, while others are more efficient at higher RPM. Roots and twin-screw superchargers, for example, provide more power at lower RPM. Centrifugal superchargers, which become more efficient as the impeller spins faster, provide more power at higher RPM.

Installing a turbocharger requires extensive modification of the exhaust system, but superchargers can be bolted to the top or side of the engine. That makes them cheaper to install and easier to service and maintain.



The basic setup for an airplane with a centrifugal supercharger, or compressor.

Finally, no special shutdown procedure is required with superchargers. Because they are not lubricated by engine oil, they can be shut down normally. Turbochargers must idle for about 30 seconds or so prior to shutdown so the lubricating oil has a chance to cool down. With that said, a good warm-up is important for superchargers, as they work most efficiently at normal operating temperatures.

Superchargers are common additions to the internal combustion engines of airplanes. This makes sense when you consider that airplanes spend most of their time at high altitudes, where significantly less oxygen is available for combustion. With the introduction of superchargers, airplanes were able to fly higher without losing engine performance.

Superchargers used with aircraft engines work just like those found in cars. They draw their power directly from the engine and use a compressor to blow pressurized air into the combustion chamber. The illustration above shows the basic setup for a supercharged airplane.

Supercharger Disadvantages

The biggest disadvantage of superchargers is also their defining characteristic: Because the crankshaft drives them, they must steal some of the engine's horsepower. A supercharger can consume as much as 20 percent of an engine's total power output. But because a supercharger can generate as much as 46 percent additional horsepower, most think the trade-off is worth it.

Supercharging puts an added strain on the engine, which needs to be strong to handle the extra boost and bigger explosions. Most manufacturers account for this by specifying heavy-duty components when they design an engine intended for supercharged use. This makes the vehicle more expensive. Superchargers also cost more to maintain, and most manufacturers suggest high-octane premium-grade gas.

Despite their disadvantages, superchargers are still the most cost-effective way to increase horsepower. Superchargers can result in power increases of 50 to 100 percent, making them great for racing, towing heavy loads or just adding excitement to the typical driving experience.

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