MOTOR AGE®

Mastering Modern Brakes: Systems, Technologies, and Trends

Image credit: AdobeStock_377661057

MASTERING MODERN BRAKES: SYSTEMS, TECHNOLOGIES, AND TRENDS

BROUGHT TO YOU BY

AutoZone

BRAKING SYSTEMS REIMAGINED: EXPLORING THE EVOLVING SCIENCE OF STOPPING POWER

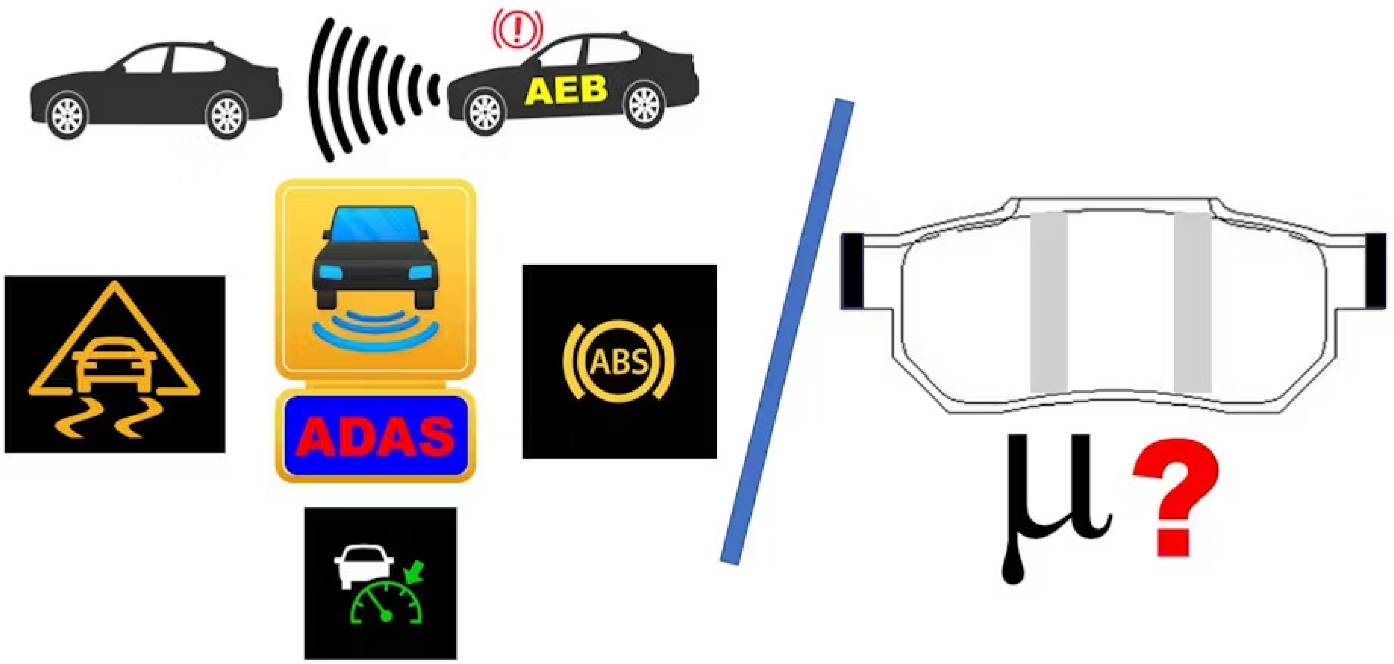
The modern braking system is no longer just a mechanical means of bringing a vehicle to a halt — it's a complex integration of software, hardware, and safety-critical technology. In today's rapidly evolving automotive landscape, technicians, shop owners, and engineers must keep pace with changes that extend far beyond the traditional understanding of pads and rotors.

We have compiled five timely and relevant articles that explore the evolving landscape of brake technology.

You'll learn how brake pad friction plays a surprising role in the performance of ADAS technologies that rely on consistent stopping power to function properly. We'll also explore how regenerative braking systems in hybrid and electric vehicles are changing the game, requiring a new understanding of energy recovery and brake wear.

The collection addresses the often-overlooked issue of brake rotor runout, a leading cause of vibration complaints and uneven wear, and explains how to properly diagnose and address it. You'll gain insight into why drum brakes are making a comeback in some modern vehicles, thanks to their packaging and performance benefits. Finally, we examine GM's innovative trailer brake technology, showcasing how advanced braking systems are now tailored to meet specific towing and load demands.

Together, these articles provide a well-rounded perspective on the evolving landscape of brake system design, maintenance, and innovation. They serve as a valuable resource for staying informed and prepared as vehicle technologies continue to advance.



HOW BRAKE PAD FRICTION AFFECTS ADAS

Using the wrong type of replacement pads on an ADAS-equipped vehicle could have far-reaching consequences.

BY TRACY MARTIN — ORIGINALLY PUBLISHED JULY 2, 2023

BRAKE PADS MAKE A DIFFERENCE

A 2021 model year vehicle is in your shop for brake work. The car has an advanced driver assistance system (ADAS) that includes automatic emergency braking (AEB) and traction control. All four rotors look serviceable, but the brake pads are worn. Will your choice of brake pads cause an unhappy customer leading to a comeback, an accident, or even legal problems for your shop?

The customer picks up his vehicle, drives off and becomes distracted as he approaches a red light at a busy intersection. He fails to apply the brakes in a timely manner, but the ADAS attempts to come to the rescue. The ADAS uses radar/lidar to determine that the vehicle is not slowing sufficiently to avoid hitting a vehicle stopped in the intersection, so it commands the brakes, through the automatic emergency braking system, to apply braking force. The car starts to slow -- but not enough -- and it hits the other vehicle. Why did the AEB system fail?

Sometimes replacement brake pads are made with a compound that had too low

Figure 2- A vehicle's automatic emergency braking (AEB) system is triggered when its radar indicates an imminent collision. Are the brake pads your shop installs up to this task?

of a coefficient of friction (more on this later). Because the brake pad compound did not develop the same friction as quality aftermarket pads or OEM pads, the result was a fender-bender. This scenario could have been much worse—not stopping effectively for pedestrians in a crosswalk. Other issues with ADAS traction control can occur with brake pads that don't perform as expected.

A vehicle's braking system uses software that controls ADAS, stability control and emergency braking systems. The software is programmed so that for a given amount of hydraulic brake pressure, the brakes will produce a specific amount of stopping power, or brake torque. The software assumes that the factory-installed brake pads, OEM service replacement, or quality aftermarket pads are installed with a specific coefficient of friction, or friction profile. When OE pads are replaced with pads that use a vastly different friction compound, the ADAS could have problems.

ADAS VS. BRAKE PAD PROBLEMS

Brake pads that don't develop sufficient friction could take more time to control the vehicle. If pad material is too aggressive, it could abruptly correct or overcorrect when used for adaptive cruise control, causing uneven brake performance.

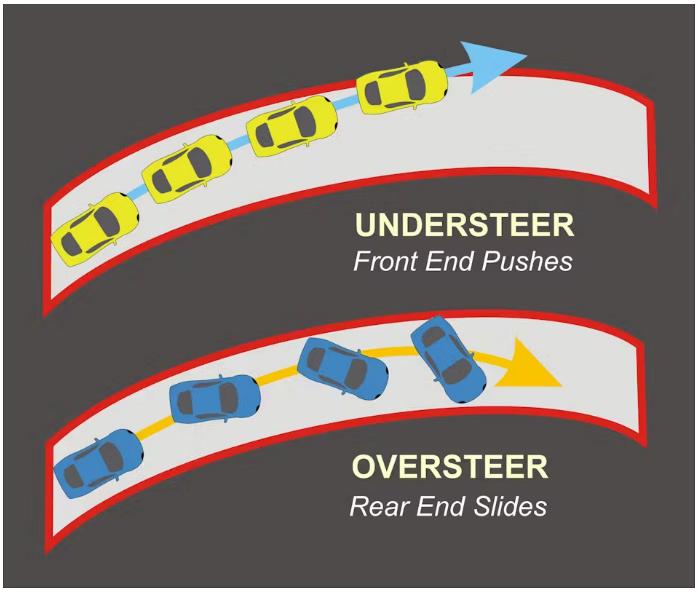


Figure 3- Aftermarket brake pads that have lower, or higher friction values from OE pads can affect ADAS traction control trying to correct for oversteer, or understeer.

Using aftermarket brake pads that have a significant difference in their coefficient of friction from OE pads can cause problems with stability control systems. Often, this can result in overcorrections when the stability control system tries to correct for understeer, which turns the situation into an oversteer condition, with the vehicle possibly ending up unintentionally going off-road.

Understeer, or "pushing," is when a car turns less than the steering input from the driver, resulting in the car traveling wide of the intended path and occurs when the front wheels lose traction before the rears.

Oversteer occurs when a vehicle turns more than the driver's input to the steering wheel. This takes place when the rear wheels lose traction before the fronts, resulting in the rear-end sliding out, or a complete spin.

Another issue is the ADAS software's ability to estimate brake pad temperature. The brake controller monitors how much the brakes are used (based on ADAS, ABS, and stability control system inputs) and calculates if the brakes pads are overheating, which causes brake fade. This condition may cause the controller to temporarily stop the use of stability or traction control until the pads cool down. This scenario is sometimes called brake fade compensation, and because it's programmed for the friction produced by OE brake pads, any replacement pads should have much the same, or similar, friction characteristics.

COEFFICIENT OF FRICTION?

Braking takes place when hydraulic pressure is applied by the driver pressing the brake pedal. The caliper pistons force the brake pads against the spinning rotor to create friction. Friction transforms the kinetic energy of the moving vehicle into heat as the vehicle slows. Braking is simply a matter of converting energy from one form to another. Think of this concept as "horsepower" absorbed by brake systems.

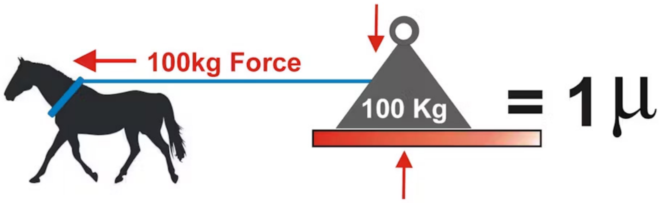


Figure 4- The coefficient of friction of 1 µ ("µ" is the frictional value) takes place when 100kg (kilograms) of force is required to move an object that weighs 100kg.

Engines make horsepower by creating heat; braking systems reverse this process by absorbing energy to create heat. Kinetic energy is the weight, or mass, of a vehicle traveling along a road at speed. When the brakes are applied, this energy is converted to heat caused by friction between the brake pads and rotors. And the more heat these components can generate, the more efficiently a vehicle will stop.

If a pickup truck has a weight of 6,400 lbs. and is moving at 60 mph, it has an amount of kinetic energy. When the truck comes to a stop from 60 mph, the kinetic energy is transferred into the braking system as heat. The time elapsed to come to a complete stop from 60 mph is also a factor in how much heat is transferred. If the truck stops in 140 feet, the kinetic energy must be absorbed in around three seconds. Energy transferred in a given time can be expressed as power. In this example, the brakes must absorb 465 hp.

One factor used to rate brake pads is the pad material's coefficient of friction. This is the ratio of the frictional force between two surfaces (brake pads and rotors) and the force pushing them together (hydraulic pressure on the brake caliper pistons). Friction is the force in which one surface or object (such as a brake pad) rubs against another (such as a rotor) to resist motion. The symbol for coefficient of friction is Mu, or "μ," the 12th letter of the Greek alphabet.

The coefficient of friction that equals 1 takes place when 100kg (kilograms) of force is required to move an object that weighs 100kg. If the same object can be moved with 50kg, the μ is 0.5. The braking torque that takes place during braking, and the hydraulic pressure causing the calipers to push the brake pad material against the rotor's surface are used to calculate coefficient of friction. The smaller the coefficient of friction, the less force that is required for the brake pads and rotor to slide past each other. The higher the coefficient of friction, the more force that is necessary for the pads and rotors to slide.

There are three factors that relate to the coefficient of friction. Most importantly is for the brake pads to reach their maximum friction level instantly after the brakes are applied. Poor braking power can be attributed to brake pads that do not have a good initial bite against the rotors. The second important factor is the stability of the coefficient of friction at various temperatures. It is common for the coefficient of friction to be lower at low and extremely high temperatures.

The third factor is the stability of the coefficient of friction at different vehicle speeds. Brake pads used for passenger vehicles would be dangerous if a stable coefficient of friction was achieved during braking at 100 mph but the coefficient of friction during braking at 40 mph was unstable. Pads with this μ would work well at a racetrack where vehicle speeds are constantly high but be a disaster on the street because of the lower speeds at which the brakes operate most of the time.

Figure 5- A technician tests brake pads with this Link Engineering brake dynamometer that simulates driving conditions and assess stopping ability, noise, durability and heat ranges of brake pads.

BRAKE PAD FRICTION CODES

Some aftermarket brake pads are marked with friction code letters that indicate friction performance. These codes are not U.S. Department of Transportation (DOT) regulated but are used by some, but not all, brake pad manufacturers. Using OE brake pads as a guideline, quality brake pad manufacturers use their own standards for testing to determine friction codes. Friction ratings for brake pads, expressed as μ, or Mu, range from 0.20 to 0.60. On average, OE brake pads have a coefficient of friction of 0.3 to 0.4, and performance brake pads have a coefficient of friction of 0.4 to 0.5. For comparison, full-racing pads can be 0.60 or higher.

A two-letter code is used (SAE Standard J866) to identify the temperatures for pads designed for street use. The first letter designates the normal, low-temperature (200 degrees F to 400 degrees F) friction performance and the second letter the high-temperature (300 degrees F to 650 degrees F) performance. The code letters stand for friction potential with letters in alphabetical order. For example, pads with a "D" rating would not indicate as much friction potential as "E" rated pads. Ideally, street brake pads should have good friction at both high and low temperatures, in which case both letters would be the same, or near the midpoint of the available letter-sequence, like "FF."

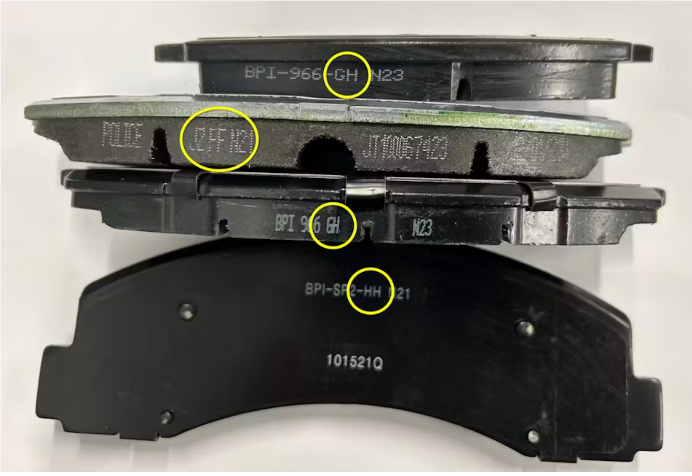


Figure 6- These brake pads have friction codes (GH, FF and HH -- yellow circles) that show various levels of the friction material used in their compounds. Not all aftermarket or OEM brands use brake pad friction codes, as they are not mandated by government regulations.

If the first letter is lower than the second letter, it means the pad works better at high temperatures and requires some heat to be fully effective; if the second letter is lower than the first, the pad may fade at high temperatures. Many of the better brake pads intended for street use have a GG friction rating (the highest rating available for street-legal pads). A typical auto parts store carries economy pads that have EE or EF ratings. These pads will work well for most vehicles and drivers. However, if better braking performance is the goal, then pads with minimum FF, GF or FG ratings are a good choice. High-end premium pads are available with ratings like FG or GG. Brake pads used for closed-circuit racing can have HH ratings or higher. The downside of pads with this high friction rating is that they wear out quickly, and many are designed for single-race use.

Identifying codes/letters can be found on the edge of the pads or on the backing plate. Many manufacturers use three groups of alphanumeric characters. The first identifies the manufacturer of the pad material; the second number is the formulation, or composition, of the pad material; and the third group of letters is the coefficient of friction rating and effective temperature range.

Other numbers could be present, including part numbers, manufacturing date codes, and an environmental code that represents the percentage of heavy metals and asbestos fibers used. The environmental code and manufacturing year are usually the very last three digits in the full sequence, but the exact position of the three standard groups of preceding numbers may vary. Some manufacturers use proprietary classifications, such as color-coding the pads or even their own numbering schemes.

TYPES OF BRAKE PADS

What matters most with any brake pad replacement is the coefficient of friction

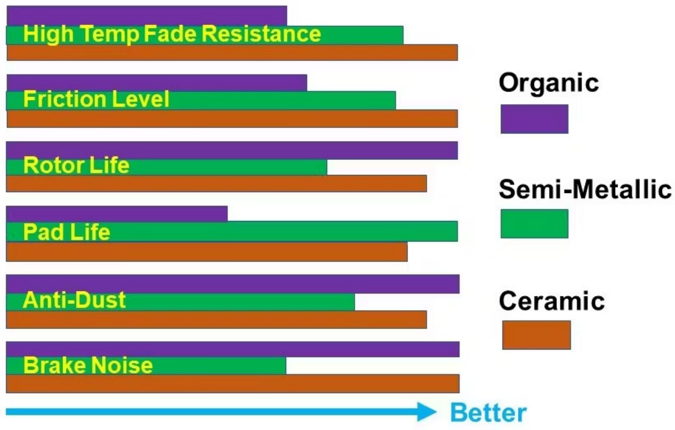


Figure 7- This chart shows relative performance comparisons between organic, semi-metallic and ceramic brake pads. Specific aftermarket and OE pad characteristics may be different than illustrated.

Figure 8- Duralast Gold semi-metallic brake pads are one option for replacement.

between the pad and the rotor. There are three types of brake pad material: organic (non-metallic), semi-metallic and ceramic. Knowing the characteristics of each type will help you select the right material for your customer's vehicle.

ORGANIC

Organic brake pads provide a low level of friction without producing a lot of heat, making them appropriate for drivers who use their cars for commuting and everyday driving. Organic pads are not a good choice for high-performance cars or heavy-duty applications like SUVs and pickup trucks, as they don't provide the required stopping power and are prone to brake fade during repeated, heavy braking.

With the high cost of brake rotor replacement, organic pads offer an advantage in that they minimize rotor wear compared to other pad compounds. In use, organic pads provide quiet operation. Another advantage of organic pads is their cost as they are the least expensive of brake pad types. Around 50 percent of new cars sold in the U.S. are factory-equipped with organic brake pads, which are made of a mixture of fibers and other materials, including rubber, carbon compounds, glass or fiberglass, and Kevlar and bound together with resin.

SEMI-METALLIC

These pads come standard for high-performance cars, SUVs and light trucks. Using metal as part of the pad compound makes them ideal for vehicles that continually require high or frequent braking forces to absorb the energy created by heavy vehicles and/or high speeds.

The metal used in these pads makes them more resistant to heat and wear than organic brake pads. However, the metal in the pad compound has a lower coefficient of friction at low temperatures, and more pedal power

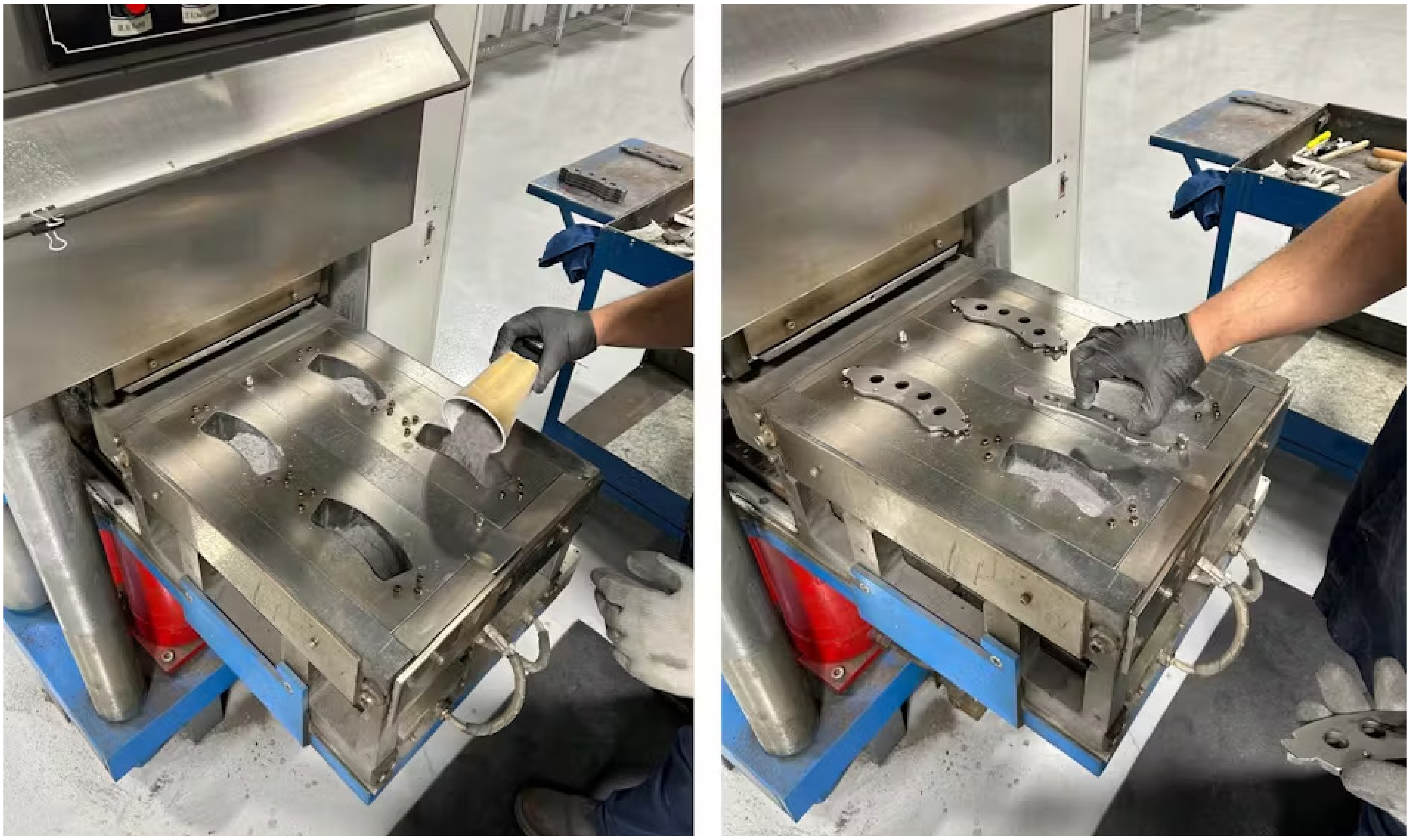


Figure 9- This machine is a positive mold tool and friction hot press. The pad material mix is poured into the mold cavity and cured using heat and pressure. A set of brake pads can be pressed and cured (heated) in about five minutes.

is required to create the same braking force as organic pads. Semi-metallic pads are made using a blend for synthetics and metals that form a metallic hybrid pad compound. They do have some disadvantages compared to organic pads as they cost more, wear rotors faster and create brake dust and noise.

CERAMIC

When ceramic pads for passenger vehicles started showing up in the late '90s, they were only found on small Asian cars. As the formulations for ceramic pad materials improved, they were fitted to larger vehicles, including SUVs and light trucks.

Clay and other materials molded into the ceramic pad compound provide a high coefficient of friction, giving them lots of stopping power, the ability to absorb high braking heat, and a high tolerance to brake fade. Don't confuse ceramic brake pads for passenger cars and light trucks with those intended for use at the racetrack.

When designed for high-performance cars that may be driven on a racetrack, ceramic brake pads excel at absorbing heat once they are up to operating temperature. But that is the inherent problem with using them for normal street driving, as they don't provide good stopping power when cold.

For example, imagine driving along the Interstate for several hours with no slowing down or stopping. A deer crosses the highway in front of the vehicle and the driver slams on the brakes. Because the racetrack-oriented pads are cold, the vehicle fails to slow down, and the result is an expensive trip to the body shop.

Another disadvantage is that their manufacturing costs are high, as they are the most expensive of brake pad types. Also, because the ceramic pad material doesn't absorb as much heat as other types of pads, more of the heat from braking will have to be dissipated by the rotors and brake calipers.

WHAT TO LOOK FOR IN A PAD

Be aware of the friction codes on aftermarket brake pads that you use for replacements. Make sure you have the proper type of pad for the vehicle you are servicing and its intended use. As a rule-of-thumb, brake pads can either provide superior stopping power, last a long time, or have quiet operation — you can't get all three in one pad.

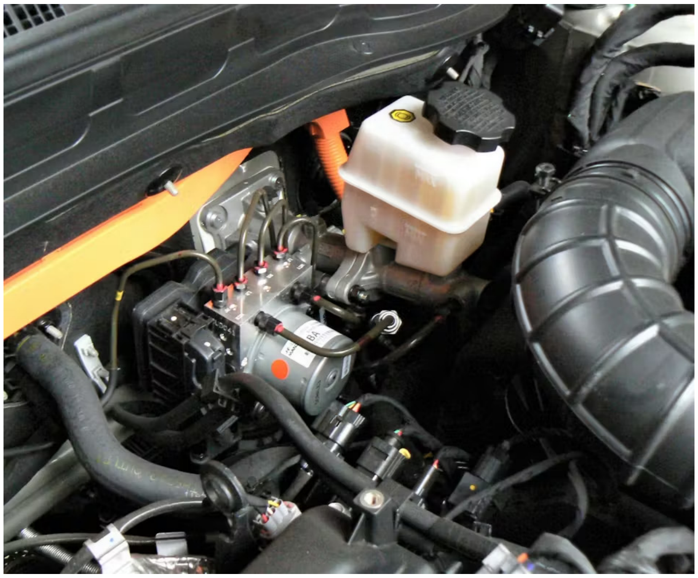
Use quality aftermarket or OEM pads that come in a box with the company's name on it. Name brands will have friction rating testing and other information available if there are legal problems related to a possible future accident. Avoid brake pads that come in a "white box" with no markings, as they may not have friction rating test data available, or even identify the manufacturer who made them. The proverb "You get what you pay for" applies, and saving a few dollars using economy, no-name brake pads of a questionable origin may put the "brakes" on your business.

HOW REGENERATIVE BRAKING WORKS

The basic concept of regenerative, or recuperative braking, is to hold off using the conventional hydraulic brakes and let the drive wheels slow down an EV using the high voltage drive motor(s) as a generator.

BY CRAIG VAN BATENBURG — ORIGINALLY PUBLISHED DECEMBER 2, 2024

Understanding the process of changing one form of energy to another is basic physics. In that conversion, there is always a loss of some energy, mainly as heat. That heat generation is usually unwanted and makes the process inefficient. When you put any vehicle into gear and start to drive it, you are building up kinetic energy. That is the energy stored in a moving object. The heavier the vehicle and the faster it is moving, the more kinetic energy you have. Once you stop accelerating, unless you are going downhill, the vehicle will slow by itself. What is happening? The friction with the tires, outside air, the driveline (engine, transmission, wheel bearings, axles, etc.) is turning the kinetic energy into — guess what? More heat. When you step on the brake pedal (or the vehicle may do that for you if you are not paying attention — No texting while driving!), the brakes are designed to heat up quickly to replace most of the kinetic energy and bring the vehicle to a complete and safe stop. Unless you are pointing downhill, all the kinetic energy is now gone and the cycle repeats itself when you step on the accelerator.



This modern EV has a single unit that controls all hydraulic braking functions.

WHAT IS REGENERATIVE BRAKING?

The basic concept of regenerative, or recuperative braking, is to hold off using the conventional hydraulic brakes and let the drive wheels slow down the xEV (a term for any high voltage vehicle) using the high voltage drive motor(s) as a generator. Without modern computer controls, that would not be possible. Imagine only having front brakes and trying to stop a car in all conditions. That would be dangerous as the rear wheel brakes add stability. To have a computer stop the vehicle with both a hydraulic system (think of a four-channel ABS system) and one or more generators in the drive line, the xEV's computer would need the following data:

1. Speed of each wheel
2. Speed of the vehicle
3. Stopping force requested
4. Actual "G" force in real time
5. Yaw rate
6. Hydraulic pressure at each wheel
7. Exact position of the brake pedal
8. Brake fluid pressure in the master cylinder
9. Pressure in the accumulator
10. Vacuum in the brake booster (if equipped)
11. How fast the driver pressed the brake pedal
12. State-of-charge of the high voltage battery pack
13. Other data may also be used

A smart dedicated computer would combine the generator and hydraulic brakes seamlessly and stop the xEV. At ACDC we call this computer a BECU or Braking Electronic Control Unit.

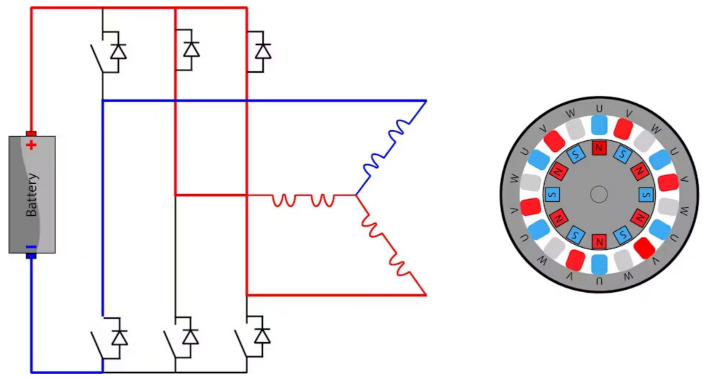
That is what the majority of OEMs are doing and that changes the way the kinetic energy is given up, so now a car, truck, or even a motorcycle can stop safely without losing all the energy it has built up while driving. The heat normally wasted in friction brakes, or using the internal combustion engine (ICE) to slow down, is ultimately converted into DC electricity and stored in the HV battery pack.

High voltage packs are normally kept below 60% on hybrids and below 80% on plug-in vehicles so that the regenerated electricity has some room left in the high voltage battery pack to be stored. Reusing momentum is smart so xEVs are smart. Brake-by-wire (at ACDC we use that phrase loosely) is a term we define in class as meaning the hydraulic action of the friction brakes is being controlled by the BECU all the time. The only time the friction brakes are non-computerized is in a "fail-safe" event. In other words, the BECU is in control of each friction brake, not the driver's foot.

Two technicians studying scan data on a road test.

WHEEL END

If you remove a wheel to check the brakes on an xEV, it will look no different than a conventional car or truck. The wheels and axels that connect to the drive motor are the same wheels that will slow down the xEV in regenerative braking mode. As a rule, recuperative braking transitions to hydraulic friction at low speeds, typically between 3 to 7 mph as the kinetic energy left in the xEV is very low, so there is little energy to



This diagram is the basis for a generator control during braking.

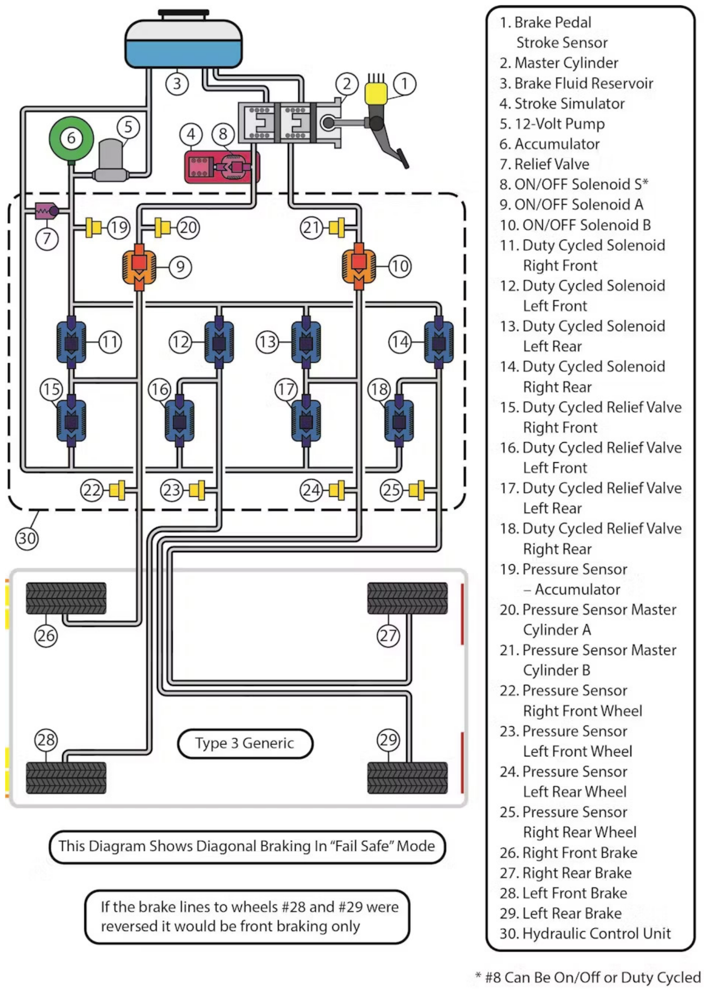
recycle. Plus, the electric motor would stop the vehicle in segments as the electromagnetic fields swapped poles.

BRAKE WORK

A brake job on most xEVs must be done with high quality parts as there is typically no engine and exhaust noise to mask other noises. Pure EVs are always quiet. Everything you have been taught when replacing pads, shoes, drums, and discs applies to xEVs. You will have return visits from your xEV customers if the brakes are not repaired with the utmost care and the best parts. Even a slight squeal will annoy them.

BLEEDING THE BRAKES

Once you start working on these regenerative brakes (many of you have already), the equipment you will need includes a good scan tool to "air bleed" the system, and some OEMs may require pressure introduced at the master cylinder reservoir. Removing trapped air in a brake-by-wire system is much like bleeding a four-channel ABS. If you only work on the wheel end, and you do not let the brake fluid run completely out of the master cylinder, then

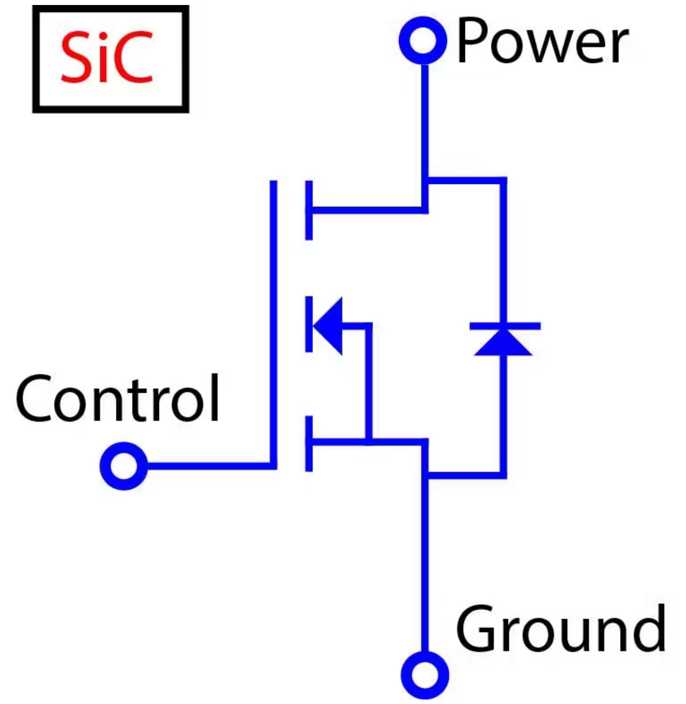


Studying this diagram will help you see how an ABS system can be enhanced.

manual bleeding will work in most cases. If the braking problems are caused by the electronics, get your electrical wizard hat on.

INVERTER FUNCTIONING AS AN AC TO DC PROCESSOR

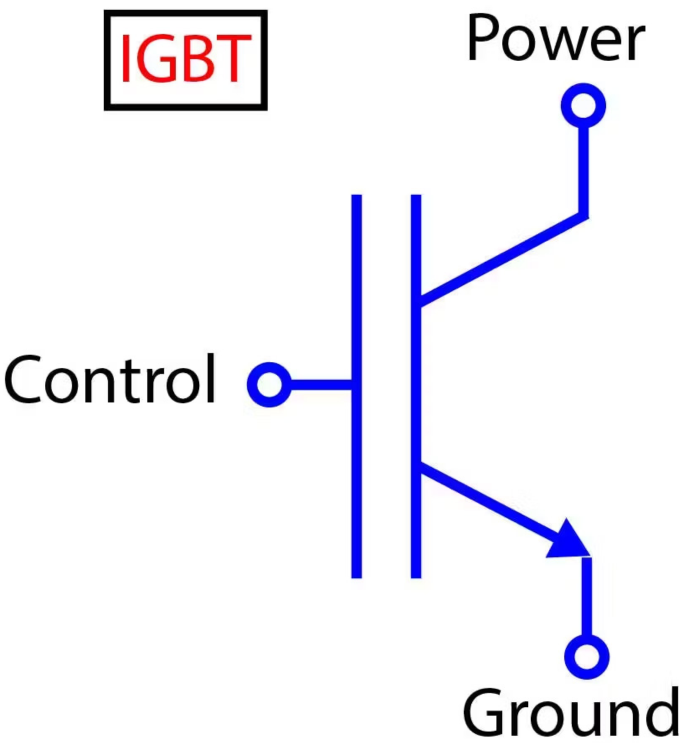
What is next is a brief overview of the high voltage generator part of regenerative braking. Anytime a permanent magnet (PM) motor/generator has the rotor spinning, it will generate voltage and current if it's connected to a circuit. As you have learned in automotive classes, the definition of watts



SIC MOSFET is the latest and greatest transistor.

is volts multiplied by amps. Watts is also a measurement of power. The basic principle of recuperative brakes is to switch the high voltage transistors (located on the inverter circuit board) on and off. These transistors were typically IGBT (Insulated Gate Bipolar Transistor) and lately some OEMs are using SiC MOSFET (Silicon Carbide Metal–Oxide–Semiconductor Field-Effect Transistor).

Using duty cycle, the current produced by the HV generator is controlled by these transistors so that the current heading to the HV battery pack is modulated indirectly with the brake pedal. The HV transistors also keep the voltage high enough to charge the HV battery. In its simplest form, the faster you charge the battery, the faster the xEV will slow down. The slower you put energy back into the battery pack, the slower the xEV will stop. How do we control the deceleration of the car or truck with just a brake pedal, while not using hydraulic pressure? It is the programming of the inverter circuit board that performs that function. With more on-time, more current flows and the xEV stops faster. With less on-time it will take longer to stop. This is assuming that there is no hydraulic function at that time in the braking event. This is pretty straightforward and logical, but there is more to it than that. By controlling the output of the generator, braking functions can be controlled. Your scan tool is also extremely valuable as it will get a lot of data into your head and hands quickly. A technician can never achieve great success without a great scan tool. In ACDC's latest book we go into more detail. We have dedicated an entire chapter to this subject if you want to know more.

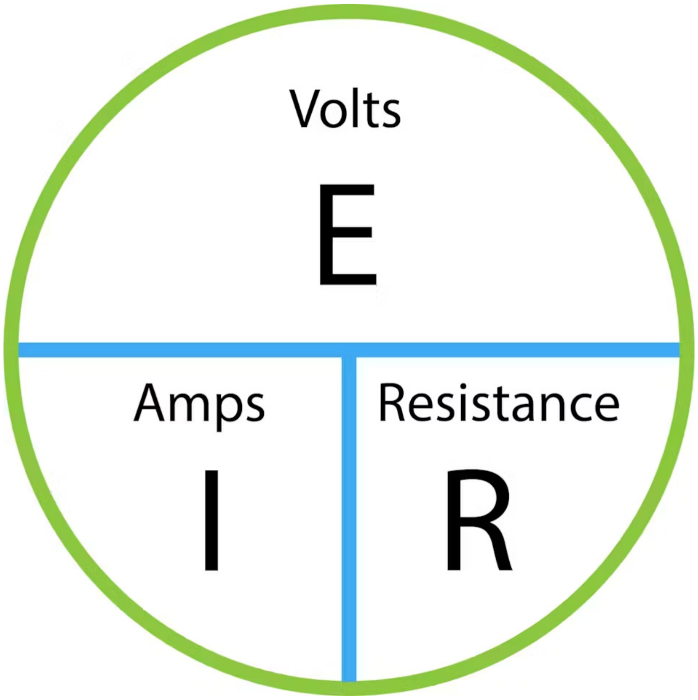


IGBT functions as a very fast relay.

HOW BRAKE FLUID IS CONTROLLED

Looking at the ACDC HCU (hydraulic control unit) diagram, most OEMs use a two speed 12-volt motor to pressurize the brake fluid into an accumulator, #5 and #6 in the diagram. It will create this pressure before driving or will set a warning lamp if it fails to do so and set codes. The pressure is normally about 2,700 psi, #19. With that much pressure all we need now is to use it, but when?

The HCU has many solenoid valves. Some are on/off valves and others can be duty cycled. The reason for all the valves is to allow the fluid pressure to be precisely metered into each brake line for each wheel brake. Unlike ABS that uses a similar principle to release a locked wheel and allow steering, this system will brake each wheel when needed. It also can be used for traction control (TC), vehicle stability control (VSC), and automatic braking system (ABS). On more modern vehicles, this brake-by-wire system can be used with lane departure or lane assist, adaptive cruise control and automatic braking. To accomplish that, there is a lot going on, so most OEMs use a dedicated CAN bus. When the xEV is in READY, two valves will close, #9 and #10. These on/off valves block the two lines leaving the master cylinder that normally go to calipers or wheel cylinders. Once they are closed the brake fluid in the master cylinder cannot reach anything except a device called a stroke simulator, #4. The stroke simulator is there to fool your foot into thinking it is doing something. It also mimics a vacuum booster. Some "brake feel" is simulated better than others. If valve #8 is opened slowly (duty cycled) while you are stepping on the brake pedal when starting the xEV, it can feel like the booster is being slowly connected to a vacuum source. Some OEMs just open and close it. The new owner of a high voltage vehicle expects it to operate like their old carbon-era vehicle did.



Time to study OHMs law again?

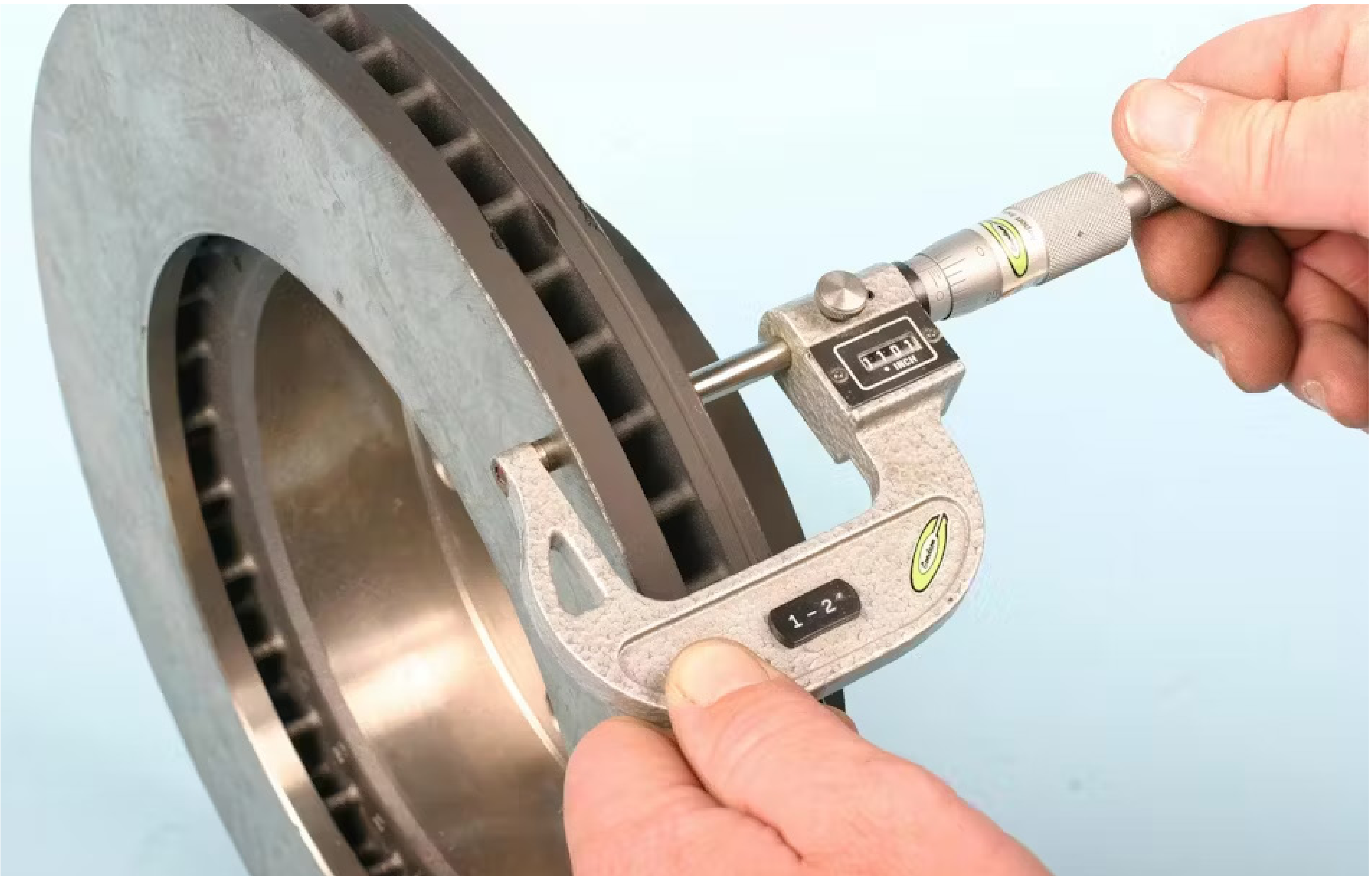
Once the brake master computer has determined it has to use some hydraulic brakes for any reason, a message is sent on the CAN bus to activate one or more linear valves (#11 to #14) that are holding back the brake fluid that is under high pressure. These four linear valves allow the brake fluid to get to the wheels, if it is a four-wheel brake system, or fewer valves for a motorcycle. The exact pressure needed is achieved by "duty cycling" the proper linear valve. There are four more linear valves (#15 to #18) that act as pressure release valves, if the hydraulic pressure exceeds the requested pressure. There are four pressure sensors (#22 to #25), one for each wheel, that are incorporated into the HCU and are used for instant feedback in the event that the pressure to any wheel is not correct. The release valves will release the extra pressure back into the fluid reservoir (#3) when the sensor reads too high a pressure. If the hydraulic line pressure to a certain wheel is too low, the ECU will increase the duty cycle to #11, 12, 13, or 14, depending on the wheel pressure. There is one more pressure sensor that reports the accumulator pressure (#9) and will request a higher speed of the pump motor if the pressure is not reached in the timeframe it is programmed to look for.

So, we have mentioned nine linear valves (#8, #11 to #18) and two on/off valves (#9 and #10), and seven pressure sensors (#19 to #25). The brake pedal position sensor (#1) and the master cylinder (#2) provide three sensor readings that are critical to a brake-by-wire system. The master cylinder will produce hydraulic pressure that is measured by pressure sensors #20 and #21. The brake pedal has a sensor that is really two sensors in a single unit (#1) that check each other so the reading is perfect all the time.

As you can see the BMC has complete control of each wheel. It is just a matter of the Master Brake Computer knowing what the xEV is doing every microsecond and then making extremely fast decisions so the HV battery stays charged up and the wheels do the right thing.

If you work in a part of America where you see rust, service the calipers frequently. Our four year old Tesla had caliper issues already.

Thanks for studying more about your future.



BRAKE ROTOR RUNOUT

Whenever servicing brake rotors, it's important to take a few measurements. Measure lateral runout, disc thickness and measure for thickness variation.

BY MIKE MAVRIGIAN — ORIGINALLY PUBLISHED FEBRUARY 28, 2024

Whenever servicing brake rotors, always take the time to take a few measurements, even if the customer hasn't complained about a bouncing brake pedal. Measure lateral runout, disc thickness and measure for thickness variation.

Poorly machined or abused rotors, or rotors that have been warped as a result of uneven or over-tightening of the wheel fasteners can easily create a pulsating brake pedal. Aside from the annoying feel of this, if the pedal is pulsating/bouncing, this means that the pads are not in a consistent, full contact with the disc surface — which results in a varying contact patch between the disc and pad, which reduces braking efficiency and potentially generates hot spots on the rotors which will increase the chance of warping.

Measuring lateral runout is a simple process, and there's no reason to avoid the task, whether you're dealing with used or even new rotors. Why check new rotors? While the new rotor may be fine, mounting it to its hub and checking it may allow you to discover a runout issue with the hub.

With the wheel removed, install all of the wheel fasteners to secure the rotor to the hub. Installing only two or three fasteners can result in an erroneous runout reading, which can easily fool you into thinking that the rotor has more runout than it actually has. This is especially critical when dealing with thin-hat rotors. Uneven and incomplete deflection at the hub can easily result in warped discs that display excessive runout.

Always install and fully torque to specification all of the wheel's fasteners. In order to avoid damaging the nut (or bolt) seat surfaces, it's also a good idea to install conical washers between the fasteners and rotor hat surfaces. As an example, by installing only two nuts on a five-bolt hub, you might obtain a runout reading of, say, 0.005-inch. By installing three nuts the reading might be 0.003-inch. But by installing all five, the reading may be 0.002-inch, which may be within manufacturer's spec. (Always refer to the vehicle maker's runout specifications.) Torque all fasteners to equal value.

Mount a dial (or digital) indicator to a stationary area that doesn't move in relation to wheel rotation (frame, strut, etc.) Indicator mounts are available with magnetic bases or clamp-on designs (usually featuring a vise-grip). Position the indicator's plunger at 90-degrees to the disc surface, and push the plunger in to provide about 0.050-inch preload. Then zero the gauge face. Ideally, the indicator's plunger should feature a small roller bearing at the tip to provide a consistent reading. The plunger tip should be placed about a half-inch inboard from the outer edge of pad contact. Slowly rotate the rotor and locate the low spot, then zero the gauge again. Using a Sharpie, make a reference mark on the disc at the lowest reading location. Slowly rotate the rotor, observing the gauge, noting the highest reading. The difference represents the amount of runout. Vehicle manufacturer specifications may vary, but as a rule of thumb, the maximum allowable runout is about 0.001-inch to 0.002-inch for most applications. Depending on the rotor design, you may be able to correct for runout using an on-car lathe, or you may need to simply replace the rotor. However, before replacing a rotor that you suspect of having excess runout, make a matchmark on the rotor hat and a corresponding wheel stud, then remove the rotor and reinstall at the next clockwise position and re-check runout. You may have a stack-up situation where combined tolerances between the rotor and the hub are creating the excess runout. Continue to relocate the rotor on the hub, checking runout with each change. You may be able to install the rotor with the high point of the rotor aligned with the low point of hub runout, thereby potentially correcting the runout issue.

In a situation where you find a lateral runout condition (where a stack-up of tolerance between the rotor and hub exists), you may be able to easily correct this without replacing parts by using a tapered correction shim between the rotor and hub. These shims are available to correct problems from initial runout of 0.003-inch to 0.006-inch.

DISC THICKNESS

Rotor disc thickness variation is also known as parallelism. Both sides of the rotor must be parallel to prevent pedal pulsations.

Measure rotor disc thickness using a micrometer. (Avoid using a caliper. A micrometer will provide a much more accurate measurement). Avoid making any decision based on only one measurement location. Even if one measurement location is within the allowable thickness, measuring for thickness variation at several spots may locate a thickness that is too close to minimum. This is sort of a double-check of findings that result from checking runout. Generally speaking, allowable thickness variation should be no more than 0.0005-inch. (Some OEs may spec a tolerance range of 0.001-inch to as little as 0.0004 inch.) Again, refer to the manufacturer's specification. Thickness limits usually can be found on the inside of the rotor hub hat.

The thickness measurements should be taken approximately 0.40-inch (10 mm) from the rotor's outer edge.

Measure rotor disc thickness at a minimum of six locations, but preferably at eight equidistant points along the rotor — at 12 o'clock, 45 degrees, 90 degrees, 135 degrees, 180 degrees, 225 degrees, 270 degrees and 315 degrees. Record all measurements. The total thickness variation equals the maximum thickness minus the minimum thickness. If total variation is beyond the manufacturer's specification for that vehicle, the rotor may be resurfaced (only using an on-the-car caliper mounted lathe) — or replaced.

It's best to monitor both runout and thickness variation at the same time.

Checking lateral runout and thickness variation applies to all vehicle applications, and should not be limited only to vehicles that exhibit a brake pulsation issue. Ideally, these checks should be an integral part of any complete brake job.

HOT SPOTS

In the days of old (not that long ago), brake pads were made of relatively soft materials that contained asbestos and other material mixes. They tended to wear the rotor evenly. Today, many pad materials contain ceramic, designed to transfer a small amount of pad material to the rotor. If the rotor has no excess runout, the transfer is evenly deposited on the disc face. If the rotor has excessive runout, the transfer takes place unevenly, resulting in higher build-up at the point(s) of higher runout. This results in hot spots, resulting in varying degrees of friction between the pad and rotor (causing a "slip-stick"). The excess, or uneven buildup can also be caused by improper caliper piston return, rusted or sticking caliper slides or even worn/loose hub bearings. If you see uneven bluing wear on the discs, suspect this uneven pad transfer, resulting from too much runout or the aforementioned caliper issues.

Remember: excessive rotor runout can be caused by worn or loose hub bearings and may not be caused by the rotor itself.

PRE-INSTALLATION WASH

Whether you're dealing with new or used rotors, always clean the disc surfaces thoroughly. While spraying brake cleaning solvent is viable for certain applications, it's not the ideal final-cleaning product for brake rotors. Prior to installing any rotor (new, used or reconditioned), each rotor should be washed with hot soapy water (as opposed to brake clean solvents, which tend to dry too fast) to remove any metal fragments left over from the machining process. These small particles can impede the pads/shoes bedding process and cause noise or affect the brake pedal feel and stopping distance. Many brake experts and even some leading brake manufacturers specifically recommend the use of hot water and Dawn dishwashing liquid and a nylon bristle brush. While other cleaning agents may work, the Dawn brand is very popular and seems to work reliably for removing oils and particles from the machined surfaces. You can certainly follow up with brake cleaning solvent, but don't rely on the solvent alone. Seriously, wash with Dawn and then dry.

In most cases a new rotor is going to be installed, but if we just machined it, either on the vehicle or a lathe, again, it's critical to wash the rotor clean with mild soap and hot water to remove all the metal debris and graphite from the previous brake pads and/or the machining process. When not properly removed from the surface of the freshly machined rotor, materials left over from machining — including those too small to be visible by the naked eye — can be transferred to the new pads, and this can result in noise, uneven braking and a host of other issues. Many times the problem is fixed by changing the pads that are contaminated with the small machining particles with a new set of non-contaminated pads. But the actual issue was improper cleaning of the machined rotor.

Even when you're dealing with new rotors, cleaning the rotor disc surfaces is imperative to remove deposits and/or anti-rust materials that were applied at the factory prior to shipping. Removing all foreign material exposes the microscopic surface finish peaks and valleys to provide proper friction material transfer onto the disc surface.

With that said, note that OE and aftermarket rotors are available today with a special "E" coating that prevents (or at least dramatically delays) surface rusting. An E-coated rotor has the appearance of being painted with a gray or silver paint. This coating is applied to the entire rotor, reducing the chance of visible rotor edges and hats from turning brown. The coating also prevents rusting in the cooling vanes and the rotor's rear hub face. A coated rotor package will likely include a caution to avoid cleaning this coating off. It's best to avoid any solvents on the rotor, even on the disc surfaces. If you're dealing with brand new coated rotors, just make sure that no oils, dirty fingerprints, etc. are on the disc's surfaces. At the risk of repeating, only clean by simply washing in hot water and Dawn. While the E-coating will likely not be harmed with the application of a quality-brand brake cleaning solvent, you're safer by only washing and rinsing. By all means, never use a strong solvent such as lacquer thinner to clean a coated rotor, as this can ruin the coating.

ABS GLITCH AFTER HUB REPLACEMENT

Here's a useful tip from Raybestos. This applies to all ABS-equipped vehicles. The ABS light may be on and/or false ABS activation may occur following wheel bearing hub replacement on only one side of an axle.

If you diagnose a bad hub bearing on one side of a vehicle and the ABS wheel speed sensor or tone ring is integral to the bearing, you may need additional repairs to restore proper ABS functioning. In many cases, replacing one hub bearing will cause the driver to feel ABS false activation when coming to a slow stop on dry pavement.

False activation is usually described as a pulse in the brake pedal when not expected. The pulsation comes from the ABS valves cycling the supposedly locked up wheel. This is due to the difference in signal strength from the wheel speed sensors (WSS) side to side. The problem is usually associated with air gap difference or wiring and/or connector integrity. In many cases, removing the WSS from the other side, if possible, and cleaning the mounting surface may repair the problem. The rust buildup actually lifts the WSS from the bearing, increasing the air gap and weakening the signal. Another possible issue is play in the bearing causing sine wave frequency change and or AC voltage variation. The new bearing will have little to no play, while the remaining hub has acceptable play but can still affect signal strength. Again, the difference in signal from side to side may be enough to trigger false activation. If WSS is integral and not serviceable, replacing the hub bearings in pairs may be the only answer. The ABS is activating as designed, so no warning light will be illuminated in most cases. At least discuss this with the customer to prevent unnecessary surprise repairs in the future and prevent the dreaded "it never did this before you worked on it" conversation.

In some cases, the issue may not be caused by an air gap concern. Citing certain 1996-2005 Audi models as an example, the ABS light may be on under light braking when the wheels are not locking up. Check for damaged wheel speed sensors or mismatched tires. Out of specification wheel speed sensor air gaps are not the likely issue. The most likely problem will be tiny cracks in the ABS tone rings found at the outer CV joint, or inside the rotor or wheel hub. The best way to identify a crack or damaged tone ring is to use a lab scope. With the scope attached to the sensor, turn the ABS ring. A normal wheel speed sensor will show a smooth, round uninterrupted sine wave that increases in amplitude and frequency as the wheel speed increases. If a crack in the tone ring is present, a notch or a flat spot on the wave form will be present. If a scope isn't available, clean the tone ring and inspect carefully with a bright light. Cracks normally form at the base of the teeth.

Note: While shop time is obviously valuable, the use of an impact wrench is not recommended for wheel installation. Especially in the case of alloy wheels and thin-hat brake rotors, use only a calibrated torque wrench, and always follow the proper tightening sequence in order to evenly spread the clamping load across the hub face.

ROTOR RESURFACING

The rotor's purpose is to provide a rubbing surface for the friction material and to dissipate heat during braking. And, in order to have trouble-free performance, the rotor surface must be smooth regardless of whether it has a directional or a non-directional finish.

If the rotor surface is too rough, the brake pads won't perform from the start. As the vehicle is driven, the driver will likely apply excessive pedal pressure in order to stop. This will lead to overheating the brakes, which can lead to rotor warping and annoying brake vibration and noise. The result: the customer will likely demand that the brake job be re-done.

1. Using a rotor micrometer, measure the rotor's thickness to make sure that machining will not reduce it beyond the specified minimum thickness.
2. Clean the inner and outer hat area so that it is free of rust and corrosion to remove deposits that would hinder proper mounting to the lathe.
3. One or two fast cuts may be needed to clean the surface and correct any runout. The last cut should be made with the slowest possible lathe speed to provide a finish that's as smooth as possible.
4. A directional finish requires a bit more time. If the machining cut is taken too quickly or if the brake lathe bits are in poor condition, the rotor's surface will likely have shallow cutting grooves. Microscopic peaks and valleys reduce the surface contact of the pad and result in poor initial stopping power. The customer may also complain of a "thumping" noise due to the pad moving up and down in the caliper on the peaks and valleys as it tries to properly seat itself.
5. Ideally, once the rotor has been finished, you should use a profilometer to inspect for a smooth finish. (It's a hand held tool that is designed specifically to measure a rotor's roughness average.) Granted, your shop may not have access to a profilometer, as they can be on the pricier side. But if you really want to be picky with regard to your resurfacing efforts, a profilometer is extremely useful. Most new OEM and quality aftermarket rotors typically have a finish somewhere between 30 and 60 microinches RA (roughness average).

In their quest to reduce weight and increase fuel economy, carmakers have been installing the lightest rotors possible. It has gotten to the point that most of them are akin to Bic lighters: You just toss them out after use. The rotor is used up by the time the car is due for its first brake job. Rotors that are at or below the minimum thickness often lead to high pedal effort or long pedal travel.

If you wish to salvage a rotor, you may be able to machine it, preferably on the vehicle using an on-car lathe. This insures that the rotor is true, considering that any stack-up tolerances between the rotor and hub are corrected at the same time. If so, there are three measurements you need to keep in mind: nominal thickness, machine-to thickness and discard thickness. Nominal is the thickness of a new rotor. The machine-to thickness is the limit that will provide safe braking with new pads. Once it reaches the discard thickness, recycle it as scrap.

A major cause of brake noise is a poor rotor finish. A surface finish of less that 40 RMS (root mean squared) is usually alright — before creating the non-directional finish. Although there are comparison gauges to check the finish, you can get relatively close with a pen and paper. If you can draw a smooth line across the face of the rotor, it is probably okay. A dotted line is not.

Concerning pad and rotor burnishing (bed-in), new or newly machined rotors benefit from burnishing by 15-20 aggressive stops from about 40-50 mph. Allow time for the brakes to cool a bit between stops. Burnishing can remove surface rust from rotors that have been sitting in a humid environment. It also helps break in new pads. Particles from the brakes' friction material are transferred to the rotor surfaces during burnishing and improve stopping performance. Leaving this step out often results in the customer returning and complaining that the brakes don't work well enough. Bear in mind that some brake pad makers may suggest that no burnishing is required, but it's always a good idea to bed the pads in yourself to make sure that proper pad-to-rotor transfer occurs.

A hand-held digital infrared pyrometer is a useful diagnostic tool that allows quick and easy measurement of rotor heat, following a test drive. For instance, if the vehicle tends to pull right or left during braking, or if you suspect a brake drag during non-braking, taking a heat measurement of the right and left rotors provides a comparison. For instance, if the left rotor temperature measures 200 degrees Fahrenheit and the right rotor measures 400 degrees Fahrenheit after a series of braking stops, this may indicate a weak braking action on the left rotor (caliper piston or sliding caliper sticking, etc.)

As noted, proper torquing of not just the wheels but all the parts and pieces of the brake system on reassembly is important. Many parts need to be tight but not just impact gun tight. The proper torquing of caliper brackets is essential yet not something many of us do. Take the time to look up the specs. You will be surprised how tight many need to be to prevent unwanted noises.

If you are machining a rotor, a poor finish can easily create a noise. The rotor's machined surface finish should be non-directional and of the proper smoothness to allow the pad material transfer which creates the correct coefficient of friction. Improper machining can result in a record player effect on rotors that result in a slapstick banging noise as the pads are pulled away and released, so attention must be paid to bit condition, machining speeds and the final machined finish.

Both wheels and wheel bearings need to be properly torqued to prevent excessive runout. Unevenly torqued or over torqued wheels can easily cause rotor distortion.

THE RETURN OF DRUM BRAKES: COULD THE AUTO INDUSTRY SEE THE RESURGENCE OF THE HISTORIC BRAKING SYSTEM?

Yesterday's technology could play a role in the fight to reduce emissions.

BY DR. MARK PHIPPS — ORIGINALLY PUBLISHED SEPTEMBER 27, 2023

The automotive industry is undergoing a monumental shift toward electric vehicles, placing a renewed emphasis on sustainability. Sustainability goals outlined by world governments and supported by industry leaders means investments and resources are being funneled toward reducing emissions. In fact, brake dust, a major source of vehicle emissions, is under the microscope in the fight to reduce emissions – and an unlikely braking system could play a role in addressing it.

Most sustainable solutions require new or innovative technologies – but could there be a case for drum brakes, a long-surpassed braking solution, to be implemented on passenger vehicles going forward?

Drum brakes were first developed in France in 1902 and quickly became a standard brake solution for passenger automobiles due to decent performance and inexpensive cost. However, as new safety measures were implemented in the '50s and '60s, most drum brakes began to be phased out of passenger vehicles in favor of the disc brake. Although more expensive to produce, disc brakes offer better stopping power, especially important for the heavier cars of that era. Disc brakes were also a more reliable option as they were better equipped for drivers who were taking longer and more frequent trips.

BRAKE DUST IS CONTAINED WITHIN A DRUM BRAKE, REDUCING POLLUTION

However, the open-air design of the disc brake leaves much to be desired from an emissions-reduction standpoint – thus making room for the potential return of drum brakes.

When it comes to environmental impact, brake dust – or small particulate matter that is produced during the braking application – contributes up to 20 percent of overall fine particulate matter traffic pollution. It's a considerable amount, knowing that exhaust fumes contribute 7 percent. It's not just harmful to the environment; brake dust can actually lead to inflammation and impair the body's ability to fight off bacteria.

Brake dust is created from the friction used to stop the wheels. Disc brakes, for example, use clamping or pushing motions to create that friction, whereas drum brakes use brake shoes fitted with brake linings (the friction material) to press against the brake drums from the inside in order to stop the car.

The inherent design of drum brakes ensures that most of the brake dust that's produced is caught in the drum — allowing the vehicle owner or technician the ability to clean the brake with a soft bristled brush or wheel washcloth — though the drums aren't a perfect system, as some of the particulate matter can get into the air. However, it's more effective at limiting brake dust emissions than is the disc brake.

Outside of the sustainability elements, drum brakes do offer certain advantages over disc brakes as they are generally cheaper to manufacture, require low input force to be activated and are slightly easier to maintain since there's better corrosion resistance. These advantages, along with an increased focus on sustainability, make a solid case for implementing drum brakes on modern ICE and electric vehicles.

Drum brakes are a great option for electric vehicles and hybrids, as they can work in tandem with regenerative braking, which slows the car down and captures kinetic energy. Additionally, the drum brake's lack of drag makes it a great braking solution for EVs and hybrids.

Another signal of the potential return for drum brakes is the proposed Euro 7 standards — set to begin in 2035 — which call for the need to reduce brake emissions by 27 percent.

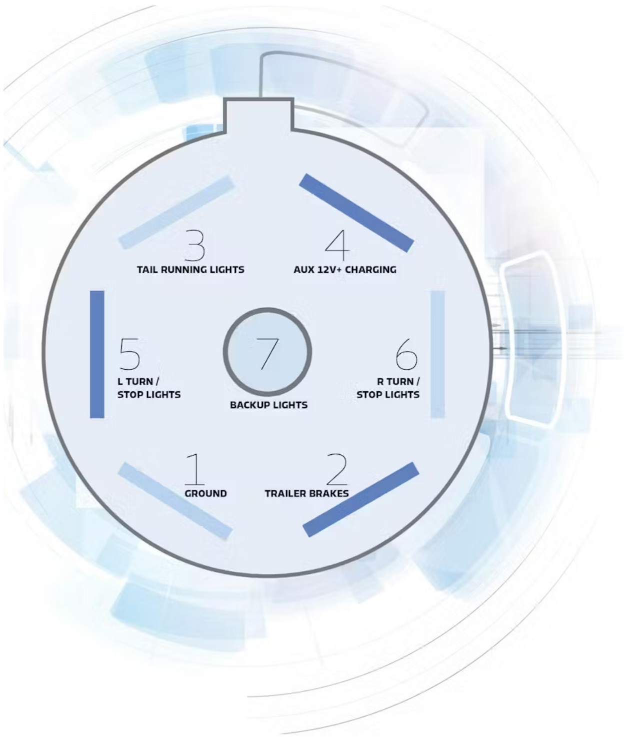
CAUTIOUS OUTLOOK FOR DRUM BRAKE RESURGENCE

That said, there's a long way to go before drum brakes return to modern vehicles. Disc brakes offer better performance, are more reliable during high-braking conditions (e.g. going downhill) and are easier to service. For instance, many modern disc brake solutions are designed for maximum durability and consistent wear, which prolongs the lifespan of the brake systems. These advantages position disc brakes as the optimal brake systems for front wheels. In fact, the Volkswagen ID.4 Electric crossover has rear drum brakes, but disc brakes on the front wheels.

The case for drum brakes is set to get stronger as we see OEMs and policymakers take steps to address emissions on passenger vehicles. The argument is bolstered even more when considering the emissions reduction capabilities, the cost advantage and ease of use in vehicles. While drum brakes may not be a perfect solution, their potential return could provide significant benefits to automakers striving to achieve vehicle emissions goals as the brake system's drum design can capture brake dust and can be easily cleaned and discarded. The stopping power and overall performance of disc brakes cannot be understated, and any implementation of drum brakes will be limited.

Automakers' adaptability and innovation in refining drum brake technology will be a key aspect to watch in the future. They may focus on enhancing drum brakes' design, exploring new materials, or integrating advanced electronic systems to further improve their performance. Alternatively, the industry might witness the exploration of cutting-edge braking technologies, potentially revolutionizing braking efficiency and emissions reduction. The race to find the optimal braking system will not only drive competition among manufacturers but will also shape the industry's journey toward a more sustainable automotive landscape.

A DEEP DIVE INTO GM'S TRAILER BRAKE TECHNOLOGY



In this article, we will explore the diagnostics, technical service bulletins (TSBs), known issues and the functioning of the GM trailer brake system.

BY JEFF TAYLOR — ORIGINALLY PUBLISHED APRIL 5, 2024

Chevrolet and GMC light-duty pickup trucks are at the forefront of towing innovation, featuring an advanced Trailer Towing System that elevates the towing experience. Commencing with the 2014 models, GM took a significant leap forward by integrating a sophisticated trailer brake control system into their light-duty pickup trucks, including the Colorado and Canyon. This innovative system not only enhances control during towing but also introduces the capability to automatically detect the specific type of trailer brakes in use, setting a new standard for precision and convenience in the world of towing technology.

GM's trailer towing systems can incorporate various sensors, multiple cameras and control modules to check and manage the trailer's behavior, to ensure a smooth and secure towing experience for drivers. However, like any complex system, it is not immune to occasional issues.

In this article, we will explore the diagnostics, technical service bulletins (TSBs), known issues and the functioning of the GM trailer brake system.

The correct power output applied to the trailer brakes is decided by the combination of the braking force exerted by the driver into the vehicle's brake system (via the brake pedal) and the type of trailer brakes that are used on the trailer being towed. The GM trailer brake control system manages the voltage supplied to the trailer brakes through the seven-way connector.

The factory equipped trailer towing system of the 2014 and newer GM pickup trucks includes features such as integrated trailer brake control, trailer sway control and a comprehensive set of vehicle sensors to check trailer conditions. The system uses information from these sensors to adjust braking force, stability control and other parameters, providing a more controlled towing experience.

Two distinct kinds of trailer brake systems are compatible with the GM trailer brake control system offered on 2014 and later GM light duty pickup truck models. Several modules on the vehicle (depending on model year and equipped options) are used to decide the type of trailer brakes being used. To apply the proper trailer brake output, the Chassis Control Module (CCM), Chassis Control Module Auxiliary (CCMA), or Brake System Control Module (BSCM) will figure out the type of trailer brakes.

This dash warning message will show up when a trailer is attached to the pickup truck's seven-way connector.

GM TRAILER BRAKE COMPONENTS

GM's trailer brake control system consists of the following components: Trailer Brake Control Switch (TBCS), Brake System Control Module (BSCM) and the Trailer Brake Power Control Module (TBPM).

The trailer brake system uses two separate communication networks to activate the trailer brakes. A dedicated LIN bus is used for communications between the TBPM and the CCM/CCMA (it will depend on year/make/model/ equipment level). This LIN bus also shares information with the instrument cluster, for displaying warnings and operational messages from the BSCM, TBCS and the TBPM. The High Speed GMLAN network attached to the BSCM provides access to other vital vehicle information shared on that network enabling the BSCM to make decisions for proper trailer brake operation based on vehicle driving conditions.

The **TBCS** mounted on the dash, allows the driver to adjust the amount of trailer brake output (trailer gain) sent to the trailer brakes. It also allows for the manual application of the trailer brakes by the driver.

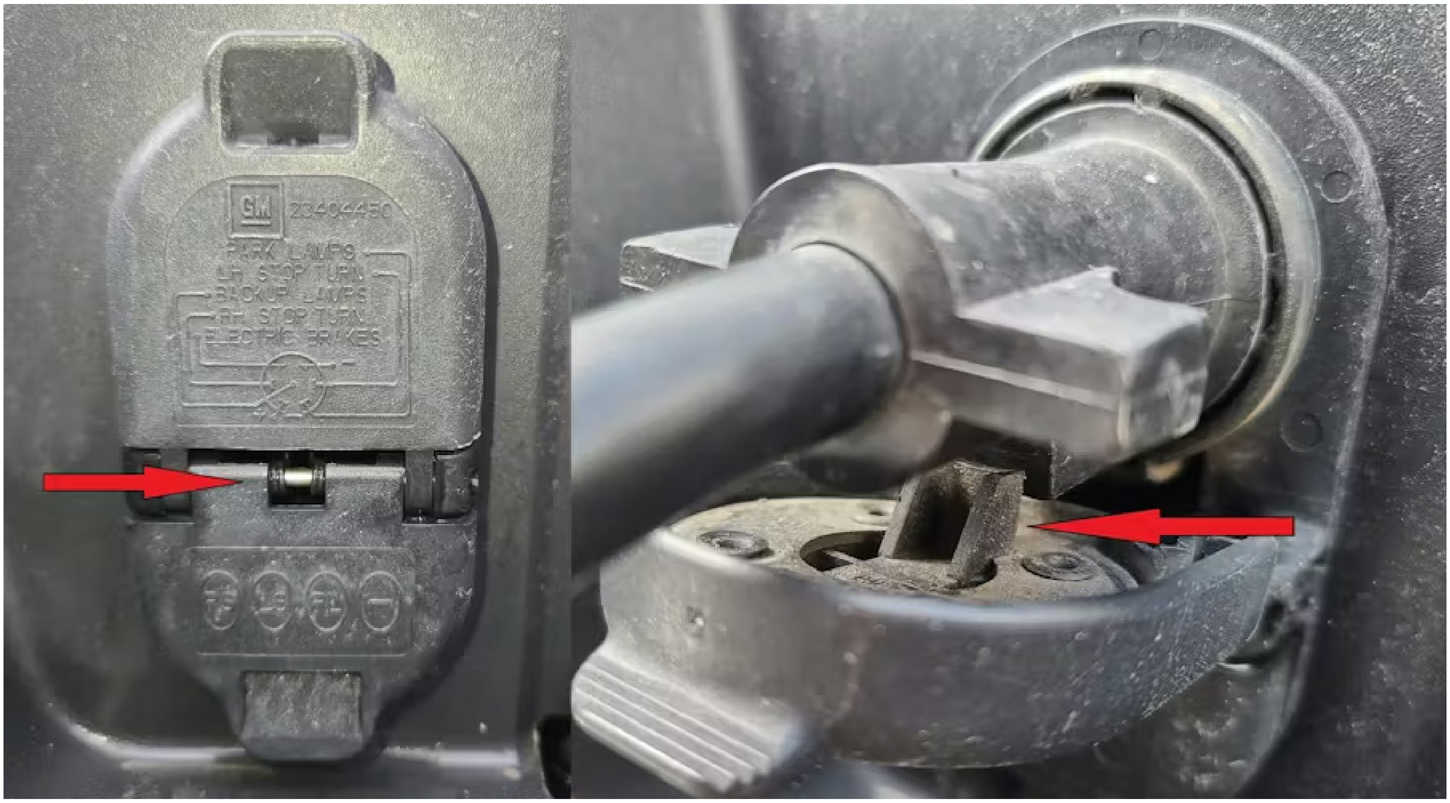
The **BSCM** is the truck's brake system controller. It's attached to the master cylinder and it controls the trailer brake operation, ABS braking, tractional control, Electronic Stability Control (ESC), trailer sway control, hill hold (if equipped) and many other brake/stability related system functions on the truck. The BSCM sends out duty cycled signal commands via the dedicated LIN bus to the TBPM for trailer brake application. The GM Trailer Sway Control uses the ESC system to identify instances of trailer instability and use differential braking to mitigate trailer oscillation and instability. To reduce or cut the back-and-forth motions of the trailer, GM's Trailer Sway Control can detect the unique vehicle dynamics associated with sway and, if needed, apply the brakes, and reduce engine torque.

The BSCM can activate the trailer brakes to slow down and stabilize the vehicle when a sway condition is encountered. The Trailer Sway Control system can detect and identify instances of recurring instability in the trailer, and then send a warning signal to the instrument display to alert the driver about the unsafe configuration of the trailer.

The **TBPM** is mounted above the spare tire of the truck. It receives the BSCM's commands and then provides the trailer brake output voltage, triggering the trailer brake operation. But that is not the TBPM's only task. It also helps to identify the type of trailer brakes being used and provides diagnostic information on the trailer brake circuit. The TBPM continuously sends test voltage pulses out through the trailer brake output circuit looking for a trailer. When a trailer is attached and plugged in, it will continue to send out these test pulses to identify the type of trailer brakes, and as a diagnostic feature of the trailer brake circuit and its connections.

When a trailer is initially plugged into the truck's trailer plug, the test pulses sent from the TBPM on the trailer brake output circuit will be altered by the type of trailer brake system and its components and circuitry. The TBPM will report to the CCM and BSCM the way that the test pulse reacted/changed when the trailer plug was attached to the truck and the trailer brake output circuit. The CCM/BSCM will use that information to decide the type of trailer brakes being used.

Note on some wiring diagrams the TBPM may be shown as the CCM or the CCMA — it depends on the year/model and equipment level of the truck.



GM has had some issues with the truck's seven-way connector door spring and cable security tab, which can lead to a loose trailer seven-way plug and possibly cause the "Check Trailer Wiring" warning message. New revised parts are available to fix the issue.

ELECTRIC TRAILER BRAKES

This system uses the familiar electromagnet/lever arm assembly that is activated by a controlled electrical output signal from the truck, which in turn directly activates the brake mechanism. The light duty GM system can accommodate up to eight trailer brake electromagnets on a four-axle trailer. This trailer brake system will be displayed as "Electromagnetic Brakes" when using the scan tool.

This dash warning message will show up if the truck detects an issue in the trailer brake electrical circuit of the truck or the trailer. It is a normal condition when the trailer is unplugged, with the ignition on when disconnecting the trailer, but not when towing down the road. This warning only shows an issue with the trailer brake electrical circuit.

ELECTRIC OVER HYDRAULIC (EOH) TRAILER BRAKES

This trailer brake system utilizes the trailer's dedicated electric hydraulic brake system and controls the EOH system by an electrical output signal from the towing vehicle. The EOH braking system uses hydraulic pressure to activate the trailer brakes, but instead of the familiar surge brake hydraulic actuator on the trailer tongue, there is now an electrohydraulic actuator supplying the needed brake pressure to activate the trailer brakes. This system cuts the braking lag time that surge brakes encounter and provides much higher hydraulic braking pressure: 1000-1500 psi vs. 400-800 psi that the surge brake actuator could provide. This system allows for the use of trailers with disc brakes. The brake system will be displayed as "Electrohydraulic Brakes" when using the scan tool.

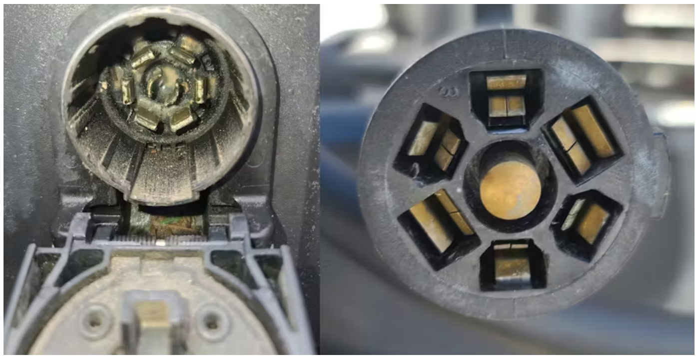
EOH brakes have some unique operating conditions. Most EOH systems require a 20-30% duty cycle to activate the pump motor, and if the trailer gain is set too low, and the brake pedal pressure is light, the pump motor may not function. This is normal. The operator should follow the owner's manual to ensure that the proper gain setting is set. If the truck has detected EOH and the vehicle is fully stopped, there will be no trailer brake output. This is also normal. Certain EOH systems require a special adapter module to be installed on the trailer for the truck to recognize the trailer and provide the proper trailer brake function. Certain EOH manufacturers have made these adapters available.

Note: If a trailer brake system that is not compatible is connected, the ability to brake the trailer may be partially or entirely disabled. An increased stopping distance or trailer instability may result in personal injury or damage to the vehicle, trailer or other property. An aftermarket controller is necessary for trailers equipped with air or surge trailer brake systems.

Once theCCM/CCMA or BSCM has determined the type of trailer that is plugged in, the TCBM continues to send test pulses, checking the trailer brake circuitry. If an issue is detected on the trailer brake circuit, the driver will be notified with the proper warning message on the instrument cluster and a DTC may be recorded to aid in diagnostics. There can be three distinct warning messages displayed on the instrument cluster:

1. "Check Trailer Wiring" comes up as a warning on the dash, even when there isn't a DTC. If the trailer brake output circuit detects an open or high resistance during the current ignition cycle, this message will be shown.
   A. This is normal when unhooking the trailer or removing the plug from the trailer's wiring while the ignition is turned on.
   B. This is also a common concern that will intermittently appear on the instrument cluster while towing, then the message goes away. This typically indicates a poor/loose connection on the seven-way trailer plug, (more on this later).
2. "Check Trailer Wiring" comes up as a warning on the dash supplemented with the C1114 DTC, but not the "Service Trailer Brake Message." The problem is likely to be due to a short to ground in the trailer brake output circuit.

A "Service Trailer Brake System" message will be accompanied with the C1114 DTC. A poor trailer ground circuit or a short to power on the trailer's brake output circuit could be to blame for this problem.



Corrosion inside the truck's seven-way connection or the trailer plug itself can cause dash warning messages and trailer brake issues.

EVALUATING THE TRAILER BRAKE SYSTEM

Trailer brake issues usually stem from wiring or brake issues on the trailer and often have nothing to do with the truck's electrical system. Wiring, connectors, splices and routing in most trailers aren't comparable with the quality and protection that you will find on the factory installed wiring harnesses and connections of today's vehicles.

Many times, push/block/snap connectors, pouch connectors and wire taps are used during the trailer manufacturing process. As a result, the CCM/BSCM may detect issues and defects that are difficult to identify as being specific to either the truck or the trailer.

GM does build a seven-way trailer brake module tester and trailer simulator (EL-52641) that will attach to the truck's trailer connector. It will simulate the electromagnetic trailer brakes, display that on the scan tool and allow for the checking of the other circuits at the seven-way trailer plug. But this tool does not simulate the load that the electromagnet of the trailer would produce.

GM recommends that techs build a tester with known good functional trailer brake magnets as the quickest and most straightforward method of testing issues in the brake output circuit on trailers with electromagnetic trailer brakes. This tester will apply the correct loads to the truck's electrical system, similar to what a trailer does without requiring the entire trailer. This test rig also makes use of real trailer braking magnets.

When building the brake circuit tester, construct a tester in which the number of trailer brakes can be adjusted by adding or removing pairs of magnets to match the quantity on the customer's trailer.

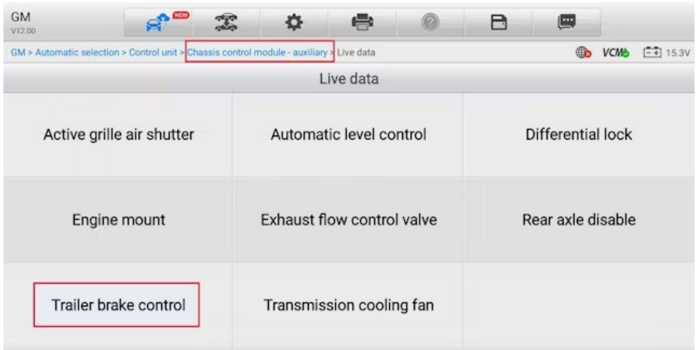
The test harness can be built using up to eight trailer brake magnets (four axles and the maximum number of trailer brake magnets the system is designed to accept).

Connecting the test harness to the truck's seven-way connector should cause the instrument cluster to indicate "Trailer Connected" and the scan tool to show "Electro-magnetic brakes" in the CCM/BSCM data parameter "Trailer Brake Type." Also, it is recommended to install the trailer brake magnet harness in the truck bed and ensure that the harness is sufficiently long to fit into the vehicle's seven-way connector. This will enable the driver to use the truck as though the trailer was hitched.

If when driving the truck with this test harness installed and you don't see any dash warning messages or DTCs, the truck is not likely the issue, and you will need to look closely at the trailer wiring, the trailer brakes themselves and the seven-way connector and cable.

COMMON ISSUES

Weak or poor connections at the seven-way trailer plug connector are the most



This screen shot from the scan tool shows that the trailer brake control data and testing is in the Chassis Control Module Auxiliary on this 2017 GMC Sierra. The location of the trailer brake control will depend on the level, types of options and year and model of a light duty GM pickup.

typical problems with this system. This issue commonly causes the "Check Trailer Wiring" message to flash on the dash while driving. Certain 2014-2018 trucks have suffered from an issue involving a weak spring-loaded door of the seven-way connector. This door spring not only holds out moisture and debris when the seven-way connector isn't being used, but it helps hold the trailer plug firmly in the connection. GM has an updated truck-side trailer connector available (PN. 23404450). There have been other updates to the truck side seven-way connector, socket and receptacle on various years or GM trucks, so be sure to check for part updates.

Issues can arise from excessive length trailer harnesses, looping or wrapping the harness under sway bars or sway bar connections causing the connections to be pulled or stressed. Corrosion, improper seven-way plug trailer repairs and poorly made replacement seven-way connector parts (both truck and trailer side) can result in the trailer brakes not functioning and warning messages on the dash. The location of the TBPM above the spare tire exposes

Automatic braking active signal	OK	
Automatic braking torque signal	OK	
Vehicle stability enhancement system signal	OK	
Trailer brake type	Electromagnetic brakes	
Induced voltage by trailer brake coil	4.7	V
Trailer brake control output circuit	Okay	
Trailer brake control duty cycle	0	%
Trailer brake power control module battery voltage	15.0	V

This screen shot shows that the Chassis Control Module Auxiliary has identified the type of trailer brakes being used on the trailer that is attached to the truck. The trailer brake control module is constantly testing the trailer brake control output circuit and is showing its test results as OK.

the module and its connectors to corrosion and moisture intrusion. There have also been concerns about the TBCS failing, which results in inoperative trailer brakes and sets a C1117 DTC. Evaluating the switch starts by looking at 5-volt reference and ground and then watching the switch control parameters on the scan tool.

Some trailers are factory equipped with electronic sway control, while others may have had this system added later. These systems will apply the trailer's brakes independently of the towing vehicle to control trailer sway. Be aware that these devices can affect the truck's ability to decide what type of trailer brake system is on the trailer and can cause dash warning messages and DTCs. There have also been concerns about aftermarket modules installed on trailers with EOH brake systems. These modules will allow a truck that only has electric trailer brake ability to tow an EOH trailer, but they can affect the way the GM system detects the type of trailer that is being attached to the truck.

The innovative trailer brake system used on the Chevrolet and GMC line of light-duty pickup trucks ensures a safe and controlled towing experience for drivers. The integrated features of the system not only adjust trailer braking force and stability control but also utilize advanced technologies such as ESC and Trailer Sway Control to mitigate trailer oscillation and instability.

However, like any complex technology, the GM trailer brake system is not immune to occasional issues. Loose connections, corrosion and other factors can impact its performance. Regular maintenance and adherence to proper procedures are essential to ensure the system operates at its best.


750,000+
WAYS TO TURN BAYS.
With more than 750,000 parts from over a thousand brands, AutoZone is here
to help you get exactly what you need, exactly how you need it.
That way, you can get more bays turned, faster. And more customers on their way, happier.