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What's the Diff?

Limited-slip and other performance differentials are designed to allow each wheel to travel at its own pace while preventing excess wheelspin from the unloaded side when the hammer is dropped.

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There's one key factor when it comes to on-track success: efficiently getting the power to the ground. That's a pretty easy task when the road is straight, as a set of ring and pinion gears turning a solid drive axle will do the job just fine. Difficulties arise when the going gets curvy.

As a car rounds a bend, the outside wheels have to travel farther and faster than the inside wheels. This difference in both distance and speed must be managed. Why? If the car simply used a solid, locked axle, the inside wheels would have to drag the outer tires—kicking and screaming—along for the ride. The result? Lots of scrubbing and binding. Clearly this setup isn't a recipe for stable or predictable handling.

Enter the differential. This assembly avoids scrubbing by allowing two wheels on a single drive axle to travel at different speeds. It uses a series of gears to manage this differential in speed while still transmitting power, hence its name.

A standard automotive differential—commonly referred to as an open unit—is found in most production cars. This type of unit does have a shortcoming, as it can allow for excess wheelspin under power delivery if one of the wheels becomes unloaded. The power of the engine will essentially seek the path of least resistance, and if that means lots of smokey wheelspin from the inside tire, so be it.

From Slip to Grip

Alternatives do exist for those who crave an extra dose of performance. Limited-slip and other performance differentials are designed to allow each wheel to travel at its own pace while preventing excess wheelspin from the unloaded side when the hammer is dropped. There are four common performance differential designs: clutch, locker, viscous and gear. Viscous units are rare in racing, so we can cross that option off the list.

The clutch type uses friction discs and springs to preload the differential gears so they don't spin as freely as they would in an open unit. As the axles try to move at differing speeds, the discs or clutches slide against each other, resisting this action. The result is a partially locked-together axle that still allows differential wheelspin, especially as the clutches wear.

A locker differential is activated and deactivated by the gas pedal: Under power, it locks the wheels together; when the driver lifts off the accelerator, the wheels are unlocked. These actions are accomplished by a series of gears and plates within the unit, and the result is much like an on/off switch. The unit is either locked or unlocked, which can create some instability as power is added in mid-corner. On the plus side, there is nothing to wear out and the units can lead long lives.

Gear differentials, like those marketed by Quaife or Torsen, use a series of parallel worm gears to distribute power to the wheel that has the most traction. The gear differential is typically more expensive than the other types, but it also has nothing to wear out or adjust. There is a downside, however: If one wheel is completely unloaded, the differential can act in the same manner as an open differential, thus making these units less than ideal for bumpier tracks and off-road use.

Finally, as with any attempt at categorizing the world, there are many variations of the three types—all different ways to skin the same cat. Some of the more popular aftermarket units are hybrids of the clutch and locker types. These units provide the benefit of solid lockup on hard acceleration, but the transition from locked to unlocked is generally smoothed out by a series of internal friction plates.

Reality Check

Choosing a differential seems easy enough. Just pick the type that best fits your needs, right? While this approach works for cars like the Mazda Miata and Honda S2000, reality often plays a bigger role in the selection process: Not all differentials are available for every make and model. The Dodge and Plymouth Neons, for example, only leave owners with one option: Get the darn Quaife and go racing.

Longtime GRM friends Peter Lier and Ian Stewart were two drivers searching for that ideal setup, and they were fortunate to have a few available options. Following Ian's national Solo title in 2007, the pair turned their attention to road racing, specifically the SCCA's Touring 3 class. They felt that the Torsen unit originally fitted to their Honda S2000 was allowing too much wheelspin. Luckily, class rules allow cars to run any differential. So, which one would they choose?

Knowing a product test opportunity when we see one, we pooled our resources to make this a scientific exercise. We all wanted to accurately compare the stock gear-type unit against the clutch-type Kaaz and OS Giken differentials. Our test site would be the tight and twisty confines of Central Florida's Ocala Gran Prix. This track is really tough on differentials and would highlight any differences between the three units. Wheelspin, even with the grippiest of tires, will usually rear its head in four of the track's nine corners.

We ran the stock differential for five laps, followed by the Kaaz and OS Giken units. The conditions throughout the day were quite consistent, and we verified that fact with control runs in a second car. To facilitate rapid swaps, each differential was fitted in its own housing along with the stock ring and pinion gears.

Torsen LSD (stock gear-type)

list price: comes stock

fast lap: 36.79 sec.

mean time: 36.97 sec.

The Honda S2000 uses a fantastic Torsen gear-type differential that has served many autocross and track drivers well. This piece of equipment has many things going for it, including the fact that it comes with the car at no charge. It also has no real bad habits, as it works well and will never wear out. It does, however, leave something on the table. It promotes understeer in tighter corners that eventually leads to wheelspin as the inside tire becomes unloaded. The Torsen also doesn't lock up the rear axle to the point where a driver can use power oversteer to bring around the tail. Unfortunately, the Torsen's behavior cannot be changed—it is what it is. Ian liked the Torsen's high-speed manners. He also found that he could maintain a good arc through the track's decreasing-radius, high-speed sweeper.

The Torsen-equipped S2000 turned consistent laps in the low-37-second range, with one flyer at 36.79. The average was 36.97 seconds. Now we could move on to the aftermarket units.

OS Giken Super Lock LSD

list price: $1390

fast lap: 36.45 sec.

mean time: 36.61 sec.

The OS Giken Super Lock LSD is a newcomer to the U.S. market, but that hasn't stopped this unit from establishing a rabid following. Like the Kaaz, the OS Giken is a 1.5-way differential that locks fully under acceleration and only partially while braking. However, the OS Giken uses more clutch plates than the Kaaz; OS Giken says that reduced wear and even more progressive locking action are the benefits.

On track, Ian loved how the OS Giken allowed for part-throttle understeer, then progressively led to oversteer as more throttle was added. The car was easy to modulate and remained consistent from lap to lap.

Essentially, the OS Giken provided the best of the two other differentials: Like the Torsen, the OS Giken was quiet and composed during the high-speed sections; like the Kaaz, the OS Giken allowed Ian to hang out the tail in the slower stuff.

Ian's times backed up his impressions, as he posted the fastest lap of the day when running the OS Giken: 36.45 seconds. He also clocked very consistent laps that yielded our fastest average of 36.61 seconds. Like the Kaaz, the OS Giken is also tunable for a variety of speeds and degrees of locking. However, we were very happy with the unit as delivered. Its very progressive lockup was just what our duo desired.

Kaaz 1.5-way LSD

list price: $895.50

fast lap: 36.73 sec.

mean time: 36.93 sec.

The Kaaz limited-slip differential is a variation on the clutch-type theme. When the vehicle is coasting, the internal clutch plates rotate freely without any preload, allowing the differential to act like an open unit. However, applying torque to the differential through either acceleration or braking causes a cone-shaped pressure ring to gradually lock the plates together.

The Kaaz is considered a 1.5-way limited-slip differential because it exhibits more lockup under acceleration than braking. A 1-way differential, by comparison, only locks under acceleration, while a 2-way unit exhibits the same amount of lock under both braking and acceleration. Generally speaking, a 1.5-way differential is easier to drive than a 2-way, as braking and turn-in are both smoother.

As expected, Ian found that the Kaaz offered very good exit speeds through the slower corners. "It's very effective for rotation," he noted. He also added that it responded almost immediately to throttle application.

The abrupt transition between understeer and oversteer did make for some exciting laps, as he found the Kaaz to be a little dicey during higher-speed maneuvers. For example, a turn that was stable and controlled with the Torsen became an exercise in knife-edge cornering with this unit; the car wanted to quickly transition to oversteer whenever Ian lifted off the throttle.

Despite the sketchiness at higher speeds, the predictable and welcome oversteer in the slower spots helped Ian really lay down some fast sessions. He initially scared himself a bit in that first, fast corner, landing a slow lap time of 37.44 seconds. After that, however, a string of high-36s flashed on the timer. His 36.93-second average was probably a tenth higher than it should have been thanks to that first-lap bobble.

A final word on this unit: While it's possible to tune the Kaaz, doing so requires tearing down the differential and reconfiguring the clutch discs.This job can be accomplished in a home shop, but it's probably not feasible trackside.

Two-Wheel Peel

The variety of available performance differentials is immense, each with its own positives and negatives. In this case, our on-track winner was the OS Giken, as it was both the fastest and easiest to drive. The OS Giken did come away with one strike against it, however, as it costs nearly $500 more than the runner-up, Kaaz.

Despite the higher price tag, Ian and Peter ran the OS Giken differential during the season-ending SCCA Runoffs. While Ian finished where he started—ninth out of 18 cars—the results don't show one important fact: During the race's opening moments, an overzealous overtaker spun Ian off course and to the back of the pack.

That spin put Ian into catch-up mode for the bulk of the race, and he discovered something else while making up those lost positions: His tire wear was significantly better than expected. "I caught several Kaaz-equipped S2000s that had simply run out of tire on the rear," Ian noted. "We are very pleased with this differential."

OS Giken distributed by:
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