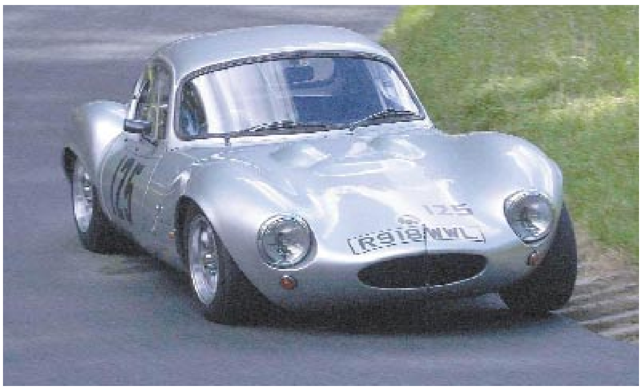
design news



LEADER OF THE PACK: Servovalves are increasingly being applied in clutches, gear shifts, differentials, and throttles on racing vehicles.

HYDRAULICS

Miniature Servovalves Go to the Races

New hydraulic technology helps pack speed and power into Formula One racing vehicles

NEWTON, MA—Racing cars will receive a hydraulic boost this summer, as a new family of tiny servovalves quietly takes its place in clutches, differentials, and throttles on the motorsports circuit.

The new valves, designed and built by Moog Controls Ltd., a division of Moog, Inc. (www.moog.com), perform two important functions: They provide a level of servo feedback and control that isn't available on commercial vehicles; and they demonstrate to the world's technical community that hydraulic power isn't just for bulldozers and automation products.

"These are very, very specialized devices," notes Martin Jones, Moog's market manager for motorsports in Europe. "They're much lighter and much faster-acting than anything you would see in a commercial application."

Indeed, the hydraulic technology incorporated in the new family of servovalves is so effective that Formula One racing rules limit its use to clutches, differentials, throttles, gear shifts, and engine intake valves. They do not allow the technology in brakes, suspensions, and steering gears, where it could potentially provide drivers with an unfair performance advantage.

FORMULA ONE RACING BODIES DON'T ALLOW USE OF THE SERVOVALVE ANYWHERE IT COULD POTENTIALLY CAUSE AN UNFAIR PERFORMANCE ADVANTAGE.

The main benefits of servovalves in racing applications are speed and power density. The new E024 series of subminiature valves offers a response time of just 2.8 msec, enabling them to react about 350 times per second. What's more, the new valves weigh only 92 gm and measure just 1.25 ˘ 1.25 ˘ 1.34 inches, while capable of flow rates of 1.9 gpm (7 ℓpm) at a 1,000 psi (70 bar) pressure drop. Moog engineers say that the tiny valves are capable of controlling about 10 hp, despite their miniscule 92-gm mass.

With those product specifications, the new valve family is expected to serve in a select group of applications. Moog is aiming the devices at aircraft, high-speed tilt trains, and racing vehicles, all of which call for high speed and small size.

"Engineers in those industries are prepared to pay more to bring the weight and size down," notes Peter Wright, technical advisor to the FIA Foundation, a Formula 1 racing organization.

Servo control

In fact, motorsports engineers don't seem to be intimidated by a price tag of several thousand dollars for sub-miniature servovalves. In some vehicles, they use as many as four or five of the devices.

Typically, the servovalves are connected to a central electronic controller, or "black box," usually located near the radiator cooling ducts, where cooling air is more plentiful.

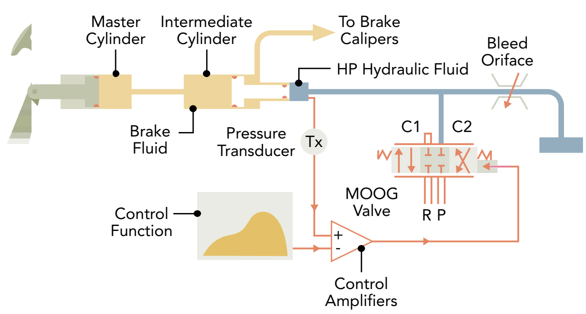
Applications for the servovalves include:

■ **Throttle control.** Typically, a closed loop throttle control system uses a potentiometer or some other type of sensor at the accelerator pedal, which sends position information to the central electronic controller. The controller reads the data, determines the desired throttle opening, and sends a command signal to the servovalve, which pressurizes the hydraulic actuator that opens and closes the throttle. Racing teams want servo control of the throttle, not only because the valve has a response time of 2.8 msec, but because the servohydraulic system affords more precise control, allows for the controller to "look" at other data inputs, and weighs considerably less than a mechanical linkage.

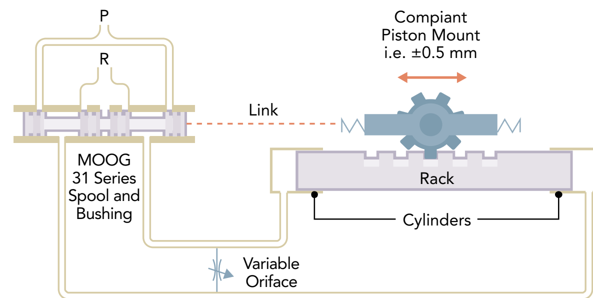
■ **Gear changes.** On Formula One cars, drivers typically have so-called "paddle switches" on the steering wheel that allow them to change gears with the mere flick of a finger. When they do that, the switch sends a discrete signal to the controller, which then sends command signals to valves that pressurize hydraulic actuators at the clutch and gear-shift linkage.

big punch: Moog's new E024 sub-miniature valve offers a response time of just 2.8 msec and weighs only 92 gm.

"The computer manages the up-change or down-change, cuts the ignition to the engine, or backs off the throttle when necessary," Wright says. The system also accepts input signals from position sensors at the clutch, which "knows" where the take-up point on the clutch is, based on how much wear it has been subjected to.



BRAKE DANCE: Predecessors of the E024 servovalves have also been used in Formula One servo-assisted braking applications. Typical schematic is shown here.



GOOD STEER: Moog's servovalves have served in power steering applications on some racing vehicles. Typical schematic is shown here.

DATA

50

Percent of total fluid power sales in the mobile hydraulic segment

Source: NFPA

Racing experts contend that such "semi-automatic" shifting is partially responsible for the fact that drivers overtake each other less often during today's races. "The fact that the driver doesn't have to worry about gear changes while braking heavily through corners can make a difference," Jones contends. "If you're changing gears 50, 60, or 70 times per minute, fractions of a second for each gear change add up."

■ **Differential control.** Control of the vehicle's differential operates under the watchful eye of a complex control algorithm that looks at such inputs as wheel speeds, steering wheel angle, engine rpm, and an inferred estimate of engine torque. Sensors feeding the input signals include rotary potentiometers and rotary variable differential transformers. Based on inputs from those sensors, the controller then sends command signals to servovalves that pressurize actuators, which operate a series of clutch plates that then introduce friction into the differential.

■ **Engine intake tracts.** Positioning of the variable length intake tracts, or "trumpets," is mostly dependent on a Hall Effect sensor that measures engine revolutions. The controller uses the engine information and servovalves to pressurize small hydraulic actuators that move the trumpets through a small stroke, typically between one and two inches. Engineers say that the 2.8-msec response time of the E024 is critical to engine operation. "The whole motion is over in about 10 msec, and the trumpet has to move very fast to keep up with the changing engine revs," Jones says. "You need speed of response and you have to close the loop. That's critical to the power output of the engine.

Reigning in the competition

Although control of engine, differential, throttle, and gear change are the only servo functions allowed by Formula One racing at the current time, design engineers have employed servovalves for other automotive functions in the past.

A decade ago, racing vehicles used servo technology for steering, brakes, and suspension systems, as well. Initial efforts started out as far back as 1981 at Lotus, where researchers began working on active suspensions that could quickly pressurize one corner of the suspension to improve stability and handling.

At the time, Lotus engineers quickly locked on to the idea of using servovalves and subsequently entered into a joint venture with Moog. As a result, they pioneered the use of active suspensions in racing cars and eventually stretched the use of active servo systems into other auto racing functions.

"Once we had the computer and the hydraulic power supply on a racing car, everything else came along for just a little extra cost," says Wright, who worked for Lotus at the time. "The only other thing we needed was the valves."

Their efforts hit a peak in 1993, when racing organizations still allowed servohydraulic control of braking, steering, and suspension, and engineers employed as many as eight or nine servovalves per vehicle. Ultimately, though, racing organizations disallowed the use of such systems, mainly as a means of keeping the competition focused on the drivers.

"Motorsports is a form of competition between engineers, but it's mainly a sport of competition between drivers," Wright says. "Servo systems change the stability and control of the vehicle so much that they have the potential to detract from that competition between drivers."

DATA

184.5

$ millions spent on hydraulic valves imported to U.S. in 2002

Source: NFPA

Pushing the envelope

Unlike other high-tech advances that tend to trickle down to low-end vehicles, design engineers say that servovalves aren't likely to move into production cars any time soon. The reasons, they say, are obvious: Outside of active suspension systems, automakers don't have a need for hydraulic systems with such precise control, nor can they necessarily afford to pay the several thousand dollar price tags that go hand-in-hand with the incorporation of sub-miniature hydraulic servovalves in vehicles.

Still, they expect use of the devices in racing vehicles to continue. "When it comes to racing, you never quite know how much performance you're going to need," Wright concludes. "So you always design in the maximum that the regulations allow."