MOVING YOUR WORLD
IDEAS IN MOTION CONTROL FROM MOOG INDUSTRIAL
JANUARY 2006 ISSUE 10 MOOG

## FEATURE

### A SHORT HISTORY OF MOOG'S INVOLVEMENT IN MOTORSPORT

by Martin S. Jones, Motorsport Market Manager, Moog Controls Ltd.

For over 20 years, Moog has been applying its most advanced motion control components and systems, to assist in the advance of motorsport technology.


Fully active Lotus 92 F1 car

The first involvement in the early 1980's was in the field of active suspension, working with Team Lotus on the fully active suspension of the Lotus 92 Formula 1 car. Revolutionary in the extreme, this vehicle suspension dispensed completely with conventional springs and dampers. These were replaced with computer controlled hydraulic actuators. Controlled by Moog Series 30 aerospace servo-valves. This system allowed infinitely variable control of vehicle pitch, roll, ride height as well as spring and damper characteristics. This allowed the car to maintain a level attitude, reducing aerodynamic drag under acceleration. Handling was also enhanced, as it was possible to reduce or eliminate roll and the suspension characteristics were able to adapt to the track conditions. In practice a significant amount of engine power was required to power the hydraulics and the car was only moderately successful during the 1983 season.

Soon after the F1 experiment this technology was successfully transferred to a high performance road cars. There was an actively suspended Lotus Esprit produced by Team Lotus' sister company Lotus Cars. In this application, higher flows were required and high response Moog E771 industrial valves were used. This technology was first demonstrated to the World's press in 1983 and won worldwide praise for the remarkable quality of its ride and handling. [See the photo below of the behaviour of a standard and active car cornering 'on the limit']

Standard Lotus & Active Lotus cornering on test track

Meanwhile, by the end of the 1980's Formula 1 was pushing forward with new technologies involving hydraulic controls. There were successful developments in the field of 'active ride height'. [Essentially a system retaining springs and dampers, but controlling vehicle attitude by means additional of short stroke actuators placed in line with the springs]. Now that a hydraulic power supply was integral to the F1 car and it became feasible to adopt hydraulic actuation of other systems, such as 'semi-automatic gear shifting'. This is now the universal system whereby the driver up and down-shifts gears by means of two steering wheel mounted switches or paddles.

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## FEATURE

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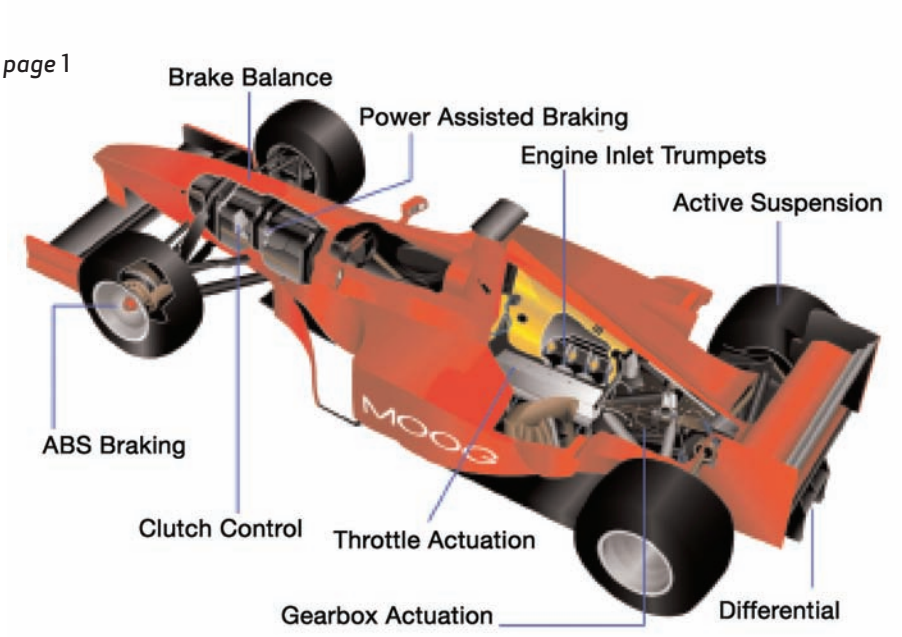
By the early Nineties this technology race had progressed to the extent that some F1 cars had as many as 10 axies of servo-hydraulic control, each utilising a Moog Series 30 valve. Typical applications are shown in the diagram to the right:

Formula 1 today has many technical restrictions that were originally intended to control the cost of the sport. [Many, including the author, believe that in reality the sponsors of the team determine the racing budget and not the technology!]




**Typical Moog applications in Formula 1.**

At the time of writing, the hydraulic system of an F1 car typically incorporates 4 or 5 Moog E024 series servovalves. The Moog E024 is a sub-miniature valve designed and developed specifically for Formula 1. It has less than half the mass [92 gm] of the smallest aerospace valve yet can control hydraulic systems controlling power levels of up to 3.5KW. It has the remarkably quick response time of less than 3 ms, essential for a sport where every millisecond is vital to success.

**Moog E024 valve with 1 Euro coin for reference.**

In addition Moog makes a range of miniature 'on-off' valves, precision hydraulic actuators, fuel control valves, and power steering systems widely used in F1. [See the "Product Spotlight" article in this newsletter] Latterly, Moog have been involved in developments of custom motion-control systems with individual teams on a strictly confidential basis.

Over the years other types of Motorsport have embraced the servo-hydraulic Technology developed for F1, in particular Rallying [World Rally Championship cars] and motorcycling [Moto GP].

WRC Rally cars use Moog servovalves for control of transmission and suspension systems designed to improve traction and handling on a variety of road surfaces. Again Moog have been pro-active in producing a miniature, high response servo-valve designed to survive the extreme environmental demands of Rallying. This is the Moog E050 Cartridge DDV, which uses linear motor technology to actuate the servovalve spool, enabling the valve to operate on hydraulic systems designed to be serviced in the field. [Or forest…]

The availability of the tiny Moog E024 valve has made it possible to implement hydraulic control systems on experimental motorcycles, and it is probable that this technology will appear on Moto GP motorcycles in the near future.

As to the future, it is probable that Moog will be involved in the uniquely innovative field of Motorsport for many years to come. At present, planned developments include more energy efficient hydraulics, even lighter actuators and electromechanical actuation. However, with our motorsport customers employing hundreds of the most creative engineers in the world, it's difficult to predict what Moog's motorsport engineers will be developing next week…

***About the Author:***

*Martin S. Jones is responsible for the Motorsport business around the world. He has worked for Moog for 25 years in sales and applications engineering for a range of industries including mobile equipment, marine and offshore, blow molding, and rolling mills. He studied Physics and Economics at the University of East Anglia.*

## DID YOU KNOW

### MOOG COMPONENTS GROUP OFFERS FRACTIONAL HORSEPOWER BRUSHLESS DC MOTORS

By Vladimir Benada, Applications Engineer, Moog Germany

Moog Components Group specializes in the design and manufacturing of optical components, fiber optics and electronic systems for a wide variety of applications. Formerly called Poly-Scientific, this division is known for motion technology such as high performance motors, slip rings, fiber optic rotary joints, and actuators as well as electronic systems. Since being acquired by Moog in 2003, this division has continued to grow and integrate with the industrial organization to provide a variety of unique solutions for customers. As part of our newsletter theme on customized high performance solutions, this article focuses on offerings of fractional horsepower brushless motors.


The Silencer™ line of fractional horsepower motors from the Moog Components Group provides solutions for a wide variety of applications ranging from medical equipment to textiles (see below). This line consists of six frame sizes (BN12, 17, 23, 28, 34 and 42) with compact aluminum housings in outside diameters from 30.5 mm (1.2 in.) to 106 mm. (4.2 mm) Each frame size is available in four different lengths with a variety of windings. Continuous torques range from 13 mNm (2.4 oz-in) to 3,670 mNm (519 oz-in), speeds up to 16,000 rpm, rated power ranges from 17 to 874 watts. These motors have been designed for low terminal voltages (mostly in range 12 - 50V) allowing for a power supply from a low voltage source or a battery.

The standard construction of these motors involves a permanent magnet rotor on the inside that is surrounded by the wound stator with a three-phase winding. Due to the utilization of bonded neodynium magnets, these motors provide high power density in a very compact package. A high number of poles (8) and skewing of magnet poles reduces torque ripple (cogging). Built-in "Hall effect switches" provide feedback information to the drive to electronically commutate the motor for velocity control

The Silencer™ series of brushless motors from Moog Components Group provide smooth, efficient and reliable operation. They are ideal for a wide range of industrial applications where a precise speed control, quiet operation and long life are a requirement.

**Motor Versions**

- High Speed Motors: The four pole motors offer relatively high speed (up to 36,000 rpm) in the same package size. They are ideal for applications demanding high speed levels, such as centrifuges, blowers and medical drills.
- High Performance Motors: When maximum performance and minimum size are important, this option that utilizes high energy sintered Neo magnets, offers an increased (almost 2 times) torque in the same frame size.
- Motors with Integral Drive Electronics: Complex wiring is eliminated by integrating the drive electronics directly onto the motor, coupled with the internal connections of the "Hall effect switches." This ensures system integration is substantially simplified and offers compact packaging to minimize the space required.

Motor with integral drive electronics

**Typical Applications**

- Medical equipment
- Automatic door and window openers
- Textile industry
- Packaging and printing products
- Labeling equipment
- Food processing machinery
- Pumps and ventilators
- Semiconductor handling

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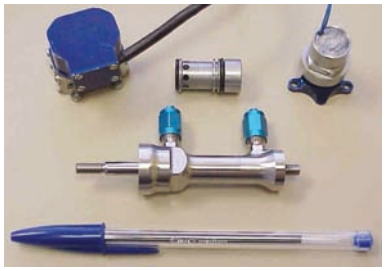
## PRODUCT SPOTLIGHT

### MOOG'S MOTORSPORT FAMILY OF MINIATURE HYDRAULIC VALVES

By Martin S. Jones, Motorsport Market Manager, Moog Controls Ltd.

The story of Moog's product development for Motorsport involves a long-term intimate knowledge of the application, close collaboration with the customer, and advanced expertise in product development. One of the key features of motorsport engineering is designing for the absolute minimum of weight, which creates demands for Moog's design engineers when creating high performance valve product for this application.

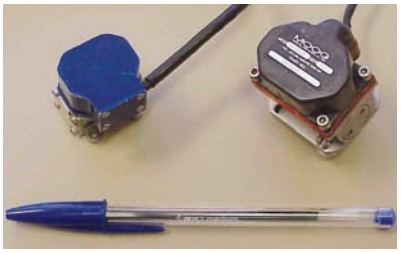
The issue of weight is a complicated one in motorsport. A leading designer once postulated that if a racing car was correctly designed and not over-engineered, then it should disintegrate immediately after passing the finishing line! This 'weight watching" culture is particularly prevalent in the arena of Formula 1, where much effort is expended to shave a few grams of mass from even the smallest component. Bizarrely all of the current F1 cars have to carry ballast to achieve the minimum allowed weight of 600 kg. (1,326 lb). However, there is considerable competitive advantage to be gained, by maximising the quantity of ballast and placing it low and central in the vehicle. This gives advantages in the car's handling and facilitates the on-track set-up procedure, as moving the mass fore and aft can alter the centre of gravity.



Microvalve, Microsolenoid, Actuator, and Fuel Regulator

The first products supplied to the F1 industry by Moog were custom versions of its specialist miniature aerospace product range. Typically these components were in use on commercial and military aircraft as well as missiles and spacecraft. However, it soon became clear to Moog's engineers that even these tiny components were not truly optimised for the demands of F1.

Therefore at the beginning of 2001, Moog began the development of the smallest 2–stage Servovalve in the 50-year history of the company called the 024 Series 'Microvalve'. Within 6 months, prototype valves were being tested on F1 cars around the circuits of Europe. The 'Microvalve was soon adopted for all of the proportional hydraulic control functions on F1 cars.



E050 Aerospace Valve and E024 F1 Valve

Since then, a range of complimentary hydraulic control products, designed specifically for F1, has joined the Microvalve. These include:

- E050 'Microsolenoid valves, used for reverse gear selection and fuel flap actuation.
- E085 Miniature actuators, used for throttle control.
- E050 Rotary Power steering valves.

Currently Moog is developing valves customised for use in other areas of Motorsport such as Moto GP and WRC Rally Cars. Additionally a tiny 27gram (0.96 oz) fuel pressure regulation valve is now available for the high-pressure F1 fuel systems currently under development for the 'V8' F1 engines of the future..

F1 Power Steering Valve and Direct Drive Valve (DDV)

## HOT WEBSITES:

### FORMULA 1, WORLD RALLYING, EUROSPORT

**The Official Formula 1 Website** www.formula1.com

This site will give you a complete official overview of the just past Formula 1 season with countless news articles, statistics, circuit locations, driver info and much more.

**ITV, Formula 1 Site** www.itv-f1.com

This site offers a somewhat more irreverent view of Formula 1 with extensive photographs and editorials that should entertain and inform.

**The Independent Webzine of World Rallying**
www.worldrallynews.com

Moving now towards a related sport, FIA World Rally Championship, this site claims "Independent, unbiased reporting - all the spins without the spin." It has full coverage of World Rallying with exhaustive statistics and articles about each race throughout this sport's history.

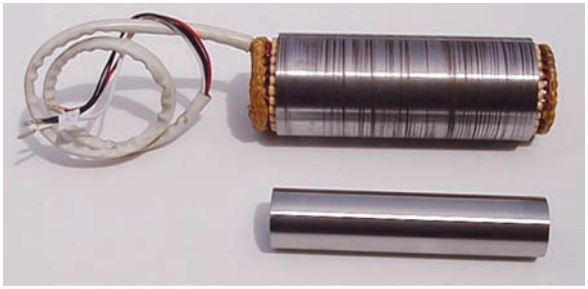
**Eurosport/MotoGP** www.eurosport.co.uk/motogp

Covering nearly every sport imaginable from a European point of view this site has an exhaustive list of motorsports to choose from to investigate including the MotoGP area, cited here. Filled with everything from results, standings to rule changes and testing you should find this site entertaining and complete.

## ASK THE EXPERT

### WHAT ARE SOME WAYS THAT SERVOMOTORS CAN BE CUSTOMIZED FOR SPECIAL APPPLICATIONS?

By R. Scott Scheffler, Project Engineer and Tom Cimato, Senior Design Engineer



Frameless motor: rotor and stator components

As experts in customizing servomotors Moog can design and build multiple special features into housed or frameless servomotors that meet the exact needs of special machine applications. One industry where Moog has vast experience designing complex customized servomotors is down hole oil/gas drilling - one of the world's most demanding applications. In this application, the servomotor designer needs to accommodate high temperature and high-pressure environmental concerns, while creating a custom high performance solution in an extremely small package size.

For over 20 years, Moog has provided a variety of products to the oil drilling industry with a reputation for products that are reliable, high performance and designed to exact application requirement. Some of the primary requirements for down hole oil drilling are solutions that offer high performance, small package size and the ability to withstand tough down hole conditions. We have provided thousands of motors with sizes ranging from 34.9 mm (1.375 in) in diameter to 177.8 mm 7 in. in diameter operating with supply voltages from 24 VDC to over 1000 VDC in ambient temperatures over 200 degrees C (392 degrees F). Demanding environmental conditions we must meet include: 1,406 kg/cm2 (20,000 psi), 220 degrees C (428 degrees F), and 250 G shock. Applications include telemetry, sampling, tractor and directional drilling tools in a variety of applications. Moog provides expert engineering support to ensure easy integration of the customized solution to meet the needs of each of these applications.

**New Challenges**

Now our down hole drilling customers are challenging us even further with a new technology called HTHP that is increasingly important as new market directives are pushing oil producers further offshore. The acronym HTHP (high temp/high pressure) is synonymous with ultra deep water drilling (water depth over 1,828 Meter (6,000 feet) with actual drilling depths over 6,096 Meter (20,000 feet). This will require even stricter guidelines and new designs to be tested and stretched to their limits. Unbelievable environmental requirements of 2,460 kg/cm2 (35,000 psi,) 300 degree C (572 degree F), 250 G shock are being placed on our components.

In addition, Moog has created designs with increased air gaps and unique construction with specialized materials. Since most of these assemblies are oil filled and efficiency is a critical element, Moog engineers even considers viscous losses in their equations when designing motors.

**Speed/torque and Physical Size Requirements**

- 34.9 mm (1.375 in.) to 177.8 mm (7 in. diameter) stators
- Specialized rotors to customer interface
- Speeds up to and beyond 10,000 rpm
- Torques over 225 Nm (2,000 lbf in.)
- Voltage ranges from 24V to 1000 volts

To meet all of these strict requirements, our design group uses specific processes and quality controls to insure compliance and integrity in these applications. In addition, distinct construction techniques and design guidelines have been developed over time to guarantee manufacturing quality. Even special assembly and test tools were developed for this market.

Moog takes the same approach when designing servomotors for other challenging applications. What we learn in applications such as down-hole drilling can help us when making customized solutions that need smaller package sizes, tight integration and other special features in a variety of machines.

***About the Authors:***

*R. Scott Scheffler has over 15 years experience in engineering, systems integration and sales in the motion control industry including the past 4 years as Project Engineer for down hole oil drilling products. He has a B.S. degree in*

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## ASK THE EXPERT *continued from page 5*

*electrical engineering from State University of New York at Buffalo and a Masters of Business Administration degree from St. Bonaventure University.*

*Tom Cimato has over 40 years of experience designing electromagnetic devices. Since 1983 Tom has been designing Brushless Motors here at Moog along with Design and Project Engineering on various aerospace actuation programs. Tom has continued his education with advanced courses in AC Machines, Brushless DC Motor Design, Permanent Magnets and Control Systems.*

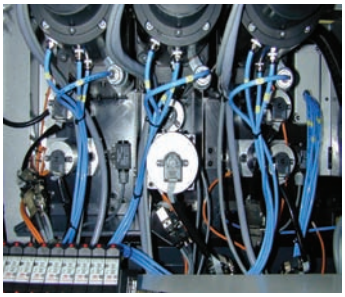
## DID YOU KNOW *continued from page 4*

**Additional Offerings**

• **Electronic Drives:** The Silencer™ Series electronic drives are matched for optimum performance with BN motors. The drives are low profile packages designed for ease of mounting in a small envelope, requiring minimal space in a cabinet. Features include:
- Efficient PWM speed control
- Feedback using "Hall effect sensors" or an encoder
- Terminal blocks to facilitate easy of wiring
- Internal thermal cutoff prevents heat overload

• **Planetary Gearheads:** Used by applications demanding low speeds. Features include:
- Mechanical interface matched with BN motors
- Availability in a wide range of ratios and output torques
- Compact design, maintenance-free operation
- Low moments of inertia

• **Encoders:** The motor rear side is matched for fixing standard optical encoders from HP (resolutions up to 1024 CPR). Improved feedback allows more precise velocity control at lower motor speeds.



Original Solution

Customized solution

**Customized Solutions Example**

Moog Components Group also offers customized products designed to meet OEM's special system requirements. An example of a unique small-package solution we developed is a special motor for Gallus Ferd. Rüesch AG, the label printer manufacturer based in Switzerland. The customer needed motor assemblies (motor types BN23 and BN34), gearheads, and encoders for auxiliary driving axes. The important requirement was a "ready to mount" solution without the need for additional harnessing. Our engineering team quickly created a new design and the solution was delivered to the customer on time and to the unique specification.

***About the Author:***

*Vladimir Benada is an Applications Engineer for Moog in Germany, providing technical support for Moog Components Group (MCG) products. He designed servomotors for over 10 years and worked previously for LPPI (a former distributor of MCG in Europe) focusing on supporting motors and slip ring products. He has a Masters degree in Power Electrical and Electronic Engineering from the Technical University of Brno.*

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