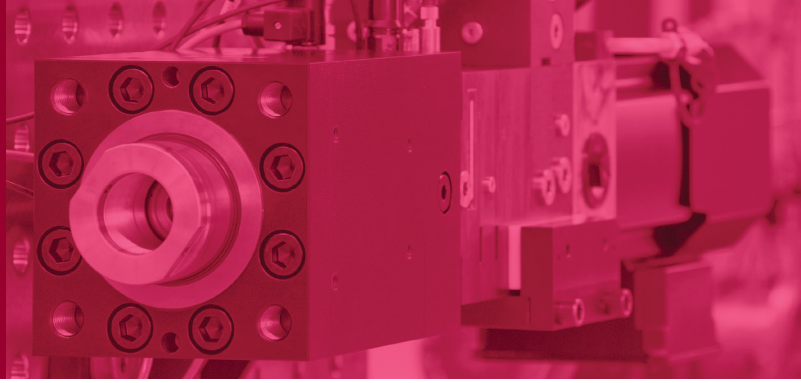
FROM THE SKIES TO INDUSTRIAL MACHINERY

The Success Story of Moog's Electrohydrostatic Actuation Systems (EAS)



Summary

Originally developed for aerospace applications, Moog's EAS have evolved into a proven solution for industrial machinery. By replacing conventional hydraulics with decentralized, pump-controlled actuation, significant performance gains can be achieved:

- Up to 60 % lower energy consumption through power-on-demand operation.
- Up to 90 % reduction in hydraulic oil volume.
- Reduced system footprint and complexity by eliminating central HPUs.
- Increased efficiency through energy recovery and intelligent energy management.

Background

An EAS converts electrical power into hydraulic flow under pressure to create mechanical motion. An electric servo motor drives a bidirectional, variable-speed pump that is connected to a single- or double-rod hydraulic cylinder. The cylinder speed is directly proportional to the pump's flow rate, meaning the actuator's movement can be controlled by changing the pump's rotation speed. The energy or power demand is load-dependent without any inherent losses. Such a hydrostatic drive can be integrated into a very compact unit with a completely self-contained hydraulic circuit.

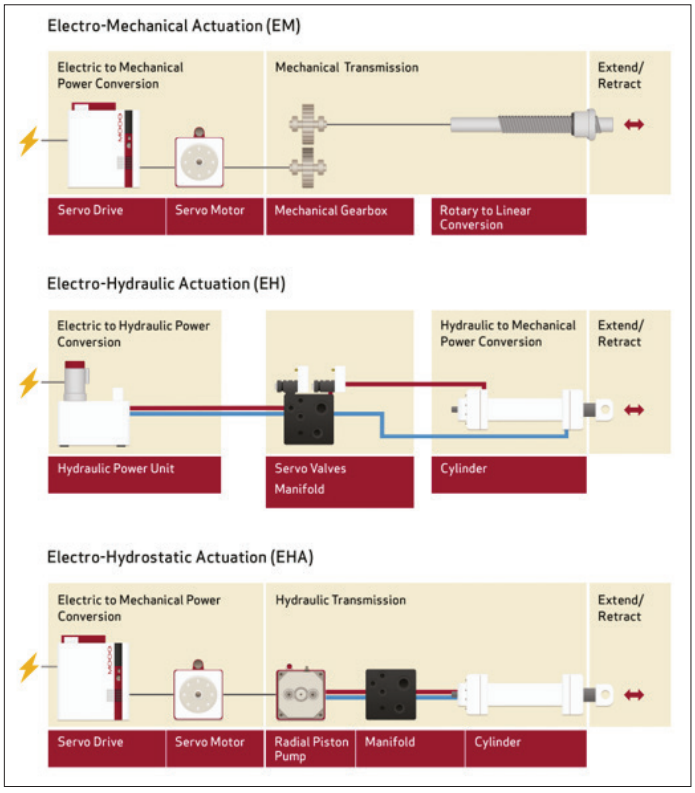
The elimination of the central hydraulic power unit (HPU), hoses, pipes, and couplings as well as the integration of traditionally separate components for hydraulic drives are the most obvious advantages over a conventional hydraulic solution. The heart of the system is the drive consisting of a pump and servo motor. This is available in various designs and sizes and can be combined with manifolds and actuators to create an optimally adapted EAS.

Since the 1980s, Moog EAS have been used in the aerospace industry for positioning wing flaps, landing gear, aileron and rudder controls. Moog was one of the first developers and manufacturers of EAS for the aerospace industry and has built up extensive expertise over the years.

In 2011, Moog launched the first commercial EAS for the pitch control of wind turbines and a few years later the second generation for industrial machines (powder presses).

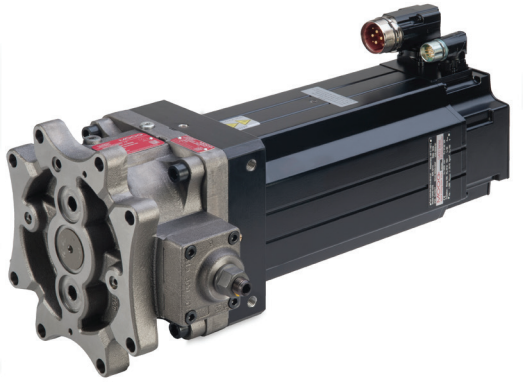
Since then, the product portfolio has grown continuously and today Moog offers various products and solutions for different requirements. These include among others the Electrohydrostatic Pump Unit (EPU) as a core component, the Electrohydrostatic Pump System (EPS) as a standardized module and various linear or customized Electrohydrostatic Actuation Systems.

To date, Moog has designed and commissioned more than 1,000 electrohydrostatic solutions for over 100 machine manufacturers and operators worldwide. Well-known customers include the manufacturer of offshore access systems Ampelmann, the automotive supplier Meritor and the injection molding machine manufacturer Plastic Metal, as well as numerous OEMs from the metal forming and press industries.



Overview and building blocks of different actuation technologies (EM, EH, EHA)

The Centerpiece: Electrohydrostatic Pump Unit (EPU)

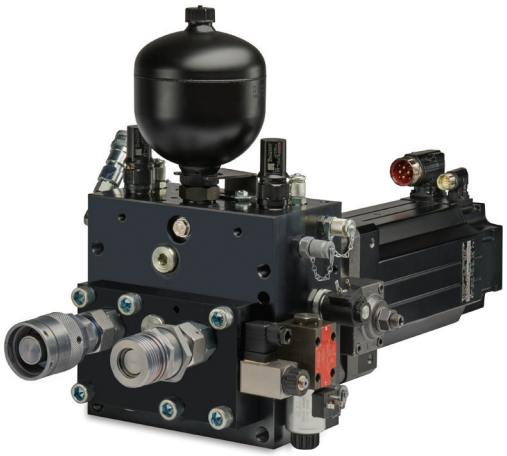


The Moog EPU is a 4-quadrant pump, characterized by a compact design and a standardized interface that enables direct mounting on a manifold, thus minimizing the space required on each axis.

Notable benefits include a very high energy efficiency thanks to the 4-quadrant and power-on-demand operation, which reduces operating costs. The total oil demand can be reduced by 90 %, providing an eco-friendly and safe power unit. Thanks to the brushless servo motor, very high dynamics can be achieved without the need for an additional control or servo valve.

The EPU is available as a fixed, dual and variable displacement unit with digital control to optimally cover different cylinder sizes, loads and process cycles of different applications.

The Entry-level: Electrohydrostatic Pump System (EPS)



The EPS is based on the EPU, which is supplemented with a standard manifold and an accumulator. It is offered as a sub-system without an actuator and can be integrated directly into existing or new machine designs as well as retrofits. The EPS can be operated in both closed and half-open circuits. It is equipped with a fixed or optionally variable displacement pump whose displacement volume can be reduced via a control valve to achieve the optimum performance of the motor. It is available in sizes 19 to 140 cm^3 with 3 different motor classes and cooling options (convection, water). To enable the highest flexibility in system integration, axial and radial mounting is possible.

The EPS is a perfect fit for various applications, where the cylinders are difficult to access or permanently installed in the machine, such as deep-drawing and die cushion systems. It is also used in test benches and simulation platforms; metal forming and presses as well as blow molding and injection molding machines. In addition to industrial applications, the EPS can also be used as a modular entry-level to electrohydrostatic actuation in hydraulic pressure intensifiers, marine, offshore, and deep-sea applications or mobile machines with hybrid or electric drive concepts.

As the EPS can be operated with both single-rod and double-rod cylinders, it is popular with customers that offer their own standard cylinder in their portfolio or have one installed in the machine. When used in a half-open system, the EPS with control cabinet can be used as a mobile test unit to connect various separate test benches. This reduces energy consumption and increases flexibility.

The Turnkey Solution: Electrohydrostatic Actuation System (EAS)

Moog offers a variety of EAS for various applications. The EAS consists of different modular building blocks such as the motor-pump unit (4Q EPU or 2x2Q IGP), a standard manifold and an actuator, which is connected directly to the manifold in a closed or half-open circuit via pipes or hoses.

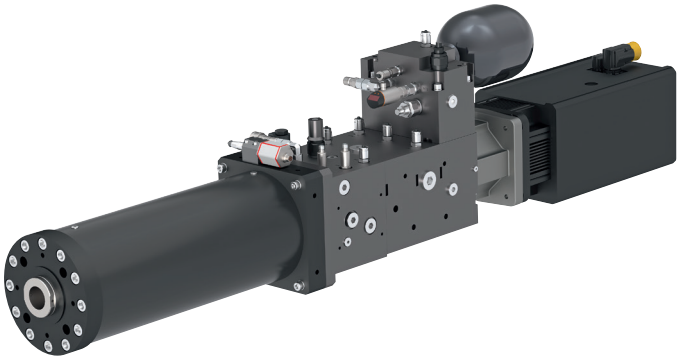
In addition to the plug-and-play actuation system, other motion control components such as power supply, servo drives, or energy storage units can be added to make the overall system even more efficient and cost-effective.

Due to its modular design and customization ability, the Moog EAS offers a high degree of flexibility and scalability making it an attractive option for demanding electrohydraulic or electromechanical applications. The advantages and added value for machine builders and operators are evident:

- High force capability and power density due to compact, hydrostatic gearbox/power pack.
- Power-on-demand: The variable-speed pump enables load-free idle speed at 0 rpm and only requires energy during operation with active load.
- Overload capacity: While EMAs with mechanical spindles can suffer considerable damage in the event of sudden load impacts, EAS are much less sensitive and robust.
- Low noise emission ensures quiet machine operation, even during fast, sinusoidal cycles.
- Eco-friendly: Up to 90 % less installed oil compared to comparable hydraulic systems.
- Fewer components reduce the risk of failure while enabling fast and easy maintenance.

- High dynamic response thanks to the low inertia of the EPU.
- 4-quadrant operation reduces energy consumption through energy recovery.
- High efficiency and performance thanks to the 4-quadrant operation and power-on-demand.
- Decentralized system eliminates the need for large hydraulic power units (HPU) and reduces piping and installation costs.

Compact EAS



The Compact EAS (CEAS) has been designed to generate linear movements for all industrial applications requiring a particularly compact solution with high power density and high dynamics. As a highly integrated and self-contained system, it consists of a servo motor, two 2-quadrant internal gear pumps, manifold, and standard cylinder. The integrated internal gear pumps are matched to the area ratio of the cylinder. Speed and direction of movement are controlled by the motion control architecture and the dynamic servo motor without directional or proportional valves.

Customized EAS

The Customized EAS is tailored precisely to specific applications and requirements. In close cooperation with customers, Moog has already developed and successfully commissioned more than 50 customized EAS for leading OEMs and end-users. Moog's global network and service team has all the expertise and experience to realize even the most demanding projects within budget and time.

Energy Management System (EMS) for EAS

In addition to its Electrohydrostatic Actuation Systems (EAS), Moog offers an Energy Management System (EMS) based on a smart Energy Module and Electronic Storage Units based on Capacitors (ESU-C), which are tailored to the respective power supply of the application. An EAS with EMS can significantly reduce the infeed power of the machine. As a result, various components of the power electronics can be downsized, further reducing the total conversion costs/investment.

Benefits:

- Significant reduction of infeed power.
- Downsizing of in-line components right up to the transformer (peak load reduction).
- Active peak shaving and stable grid load eliminates penalties.
- Load reduction on electronic components increases their service life.
- Maximizes machine efficiency up to 90 % by storing and recuperating energy.
- Modular approach: Best-fit energy supply and storage type for every application.
- Reduction of energy / operating costs and thus Total Cost of Ownership (TCO).
- The EMS can also be used for Electromechanical Actuation systems (EMAs).

EAS Control Software

CTRL

The EAS Control Software Module can be used to cover all control functions required for the operation of the EAS. It can be integrated into any PLC applications such as CODESYS V3.5, TwinCAT-3 or Siemens TIA environments without additional converters or interfaces.

The software module is installed on the PLC and compares the set values of the servo motor's speed control with the actual values. With the help of a position sensor and pressure sensors, the software controls the actuator motion precisely.

Electrohydrostatic Pump Unit EPU-G

Equipped with a 4-quadrant internal gear pump and a highly dynamic servo motor, the EPU-G is designed for applications with flow rates of 20 to 85 l/min and pressure levels of up to 345 bar.

The power-on-demand operation of the EPU-G reduces noise emissions at partial load and lowers energy consumption, leading to a reduction of operating costs. With high dynamics, low inertia and minimal pulsation at variable speed, the EPU-G improves the overall performance of the machine.

The EPU-G meets the requirements for comfort, modularity, electrification, energy efficiency, robustness, ease of maintenance and sustainability. With its compact design and reduced complexity, it is easy to handle and integrate without the need for extensive hydraulic expertise.

The EPU-G is available in sizes 5, 8, 13 and 20 cm^3 and complements the EPU product range, which extends up to 140cm^3.

With the introduction of the 4-quadrant internal gear pump, Moog now offers a comprehensive portfolio of different electrohydrostatic products and systems in the performance range from 5 to 120 kW, which are suitable for both high pressure build-up and holding as well as fast operating speeds.

Conclusion

The arguments in favor of upgrading to a future-proof and energy-efficient electrohydrostatic actuation system are obvious: A decentralized actuation and motion control technology without servo or proportional valves makes heavy and space-consuming hydraulic power units (HPUs) obsolete, which can reduce the amount of oil required by up to 90 %. In a self-contained system, such as the Compact EAS, hydraulic hoses and pipes are also eliminated, which means that installation and maintenance time can be reduced significantly.

By eliminating the central hydraulic system, the footprint and weight of the system can be reduced by 30 to 50 %, opening new possibilities for machine builders and system integrators in terms of design and integration into small installation spaces. Streamlining the hydraulic circuit simplifies system and assembly planning and reduces potential sources of faults and leaks, which in turn increases the reliability and ease of maintenance of the overall system.

The direct connection between servo motor and hydraulic pump without coupling and bell housing forms a robust unit with high rigidity, which is insensitive to pressure surges or peaks and practically wear-free even in continuous operation.

By switching from servo-hydraulic to electrohydrostatic actuation, power and efficiency losses are reduced many times over, as the throttle losses in the valve are replaced by a 4-quadrant variable-speed pump. Depending on the load, the pump can be operated in both directions (clockwise and counterclockwise) in pressure and suction mode. As the pump only operates when power is required, the energy demand is reduced by up to 60 %.

In combination with a smart Energy Management System (EMS) based on capacitors, the 4-quadrant pump can be used as a generator in the last 2 quadrants, allowing up to 30 % of energy to be recuperated and fed back into the process. Depending on process cycle and energy consumption, the overall efficiency of the machine can be improved by 90 %. Another benefit of the EMS is the automatic peak shaving function, which leads to a reduction of the infeed power and enables downsizing of various power electronics components.

Generally, the retrofit and transition to EAS pay off for machine operators within a few years. A drastic reduction in maintenance and energy costs over the course of more than 10 years of operation reduces the Total Cost of Ownership (TCO), meaning that the technology upgrade pays for itself after 2 to 3 years on average. What remains in the long term is a future-proof and highly efficient machine combining the power density of electrohydraulic and high efficiency of electromechanical actuation.

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