WHITE PAPER

Servoelectric versus servohydraulic technologies in automotive buzz, squeak and rattle (BSR) testing

A comparison of use in a four poster road simulator

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Abstract

For more than 40 years, servohydraulic four poster test systems have been vital to the evaluation and testing of automotive components and designs and have contributed to major improvements in automotive safety and quality. However, in recent years, the introduction of four posters based on servoelectric technology have provided manufacturers and testing organisations with greater testing flexibility and improved testing performance, while also offering significant improvements in energy efficiency and reduced environmental risks. This eMpulse white paper offers an in-depth discussion of the various components, limitations, and advantages of servohydraulic and servoelectric technologies in four poster systems used in automotive testing.

Content

01 - Introduction

In automotive testing, hydraulically- actuated (servohydraulic) and direct electrically-actuated (servoelectric) Transportable Environmental Four Poster (TEFP) systems, as well as the fixed, in-ground environmental and non-environmental four poster systems, are part of eMpulse Test Systems standard product range. Traditional four posters are hydraulically-actuated systems which have been the backbone of OEM squeak and rattle prevention activities for decades. The hydraulic option generally has a lower initial acquisition cost not considering the facilities infrastructure requirements, but overall system costs are similar when all facilities and subsystems are included in the complete system costs.

One area of consideration common to both systems are the civil requirements. As each system generates similar forces, reaction mass sizing and its corresponding isolation from surrounding structures and equipment must still be taken into account. While the servoelectric technology does create higher frequency content, motions for both systems should operate above the designed reaction mass natural resonance for either system, so any suitable vibration damping materials used for servohydraulics are adequate for servoelectric systems.
The use of hydraulic fluid power as a means of storing, transmitting, and controlling energy conversion from electrical to mechanical motion occurred primarily with the invention of the servo valve in the mid-1960s. While there are many limitations, 50 years of development have addressed many of the system limitations, and servohydraulics has become widely adopted and accepted in many testing applications throughout the world. While the technology has matured, installing, tuning, maintaining, and troubleshooting does require personnel with a technical aptitude and expertise for these types of systems.

The more recent advent of servoelectric four poster technology is exciting and offers certain advantages over comparable hydraulic systems.

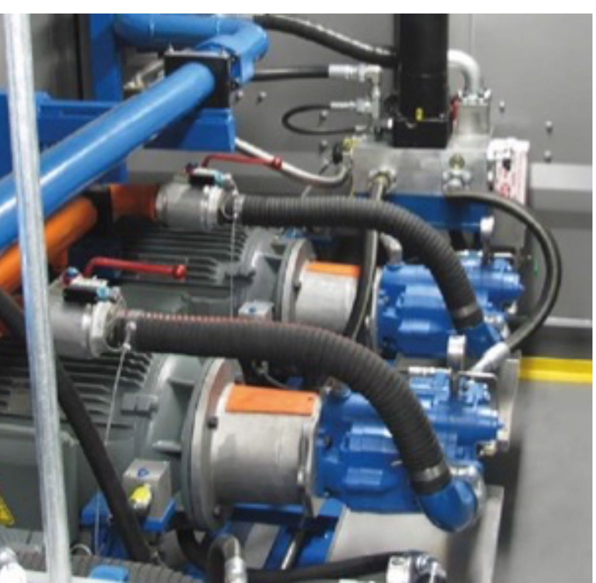
While relatively new to the automotive testing area, the replacement of hydraulics with servomotors has been steadily occurring since the mid-1990s, and one would be hard pressed today to find a CNC machine builder not currently using servomotors for precision axis motion control. Specifically, the servoelectric systems discussed here employ linear Direct Current (DC) brushless servomotors, available worldwide in a variety of force

and velocity configurations. This technology converts electrical energy directly to mechanical motion through the servo motors, thus avoiding entirely the use of hydraulic fluid power energy transmission. Servoelectric technology is a “greener” approach than the traditional servohydraulic systems. The servoelectric four poster system does not contain large quantities of hydraulic oil with the potential for high pressure line and/or hose rupture along with the associated risk of environmental concerns and costly Hazardous Materials (HazMat) clean-up. Servoelectric also uses far less energy which pays back every year. On average, servoelectric systems use 80-90 percent less energy than comparably-sized servohydraulic and supporting systems. For these reasons as well as superior performance, OEMs are choosing eMpulse’s integrated servoelectric technology for road simulation, quality control, and new model launch needs.

02 – Major components of a servohydraulic four poster system

A servohydraulic four poster system consists of several common elements, sized according to the vehicle specifications and testing requirements. These major subassemblies consist of a hydraulic power supply, hydraulic service manifolds, pedestal actuator assemblies, oil cooling circuit, hydraulic distribution, and servo controller.

The hydraulic power supply (HPS) provides the servohydraulic actuators with pressurised hydraulic oil, up to a designed maximum continuous flow rate. The major components of the hydraulic power supply are a reservoir, an Alternating Current (AC) induction motor, either a fixed displacement or variable volume hydraulic pump, high pressure filtration, solenoid valves to provide low or high pressure to the outlet, and additional warning and shutdown functionality to prevent additional warning and shutdown functionality to prevent fault conditions such as



Reservoir sizing is typically three to four times the system flow rate of the four poster, or approximately 90-120 gallons.

Additional design considerations include an internal reservoir baffle to minimise oil frothing, air breather elements to reduce external contamination, a spring-loaded check valve in the pressure line to both prevent reverse rotation of the pump during shutdown, and another in the return line, to maintain a nominal pressure in the return line for improved servo valve control. Various methods are employed for soft startup under load and rapid heat up to get the oil up to operating temperature, in addition to unloaded rapid cooling in the event of an overheat condition.
Some systems also employ a separate smaller pump and motor to continuously cycle the oil through the cooling circuit, known as a kidney loop filter. Studies have shown that filter elements release built up contamination when subject to oil that is varying in flow rates, referred to as sloughing, which commonly occurs with four posters and other dynamic motion systems.

Typical hydraulic pressure for a North American hydraulic power supply is 3,000 psi, or 208 bar, while 4,000 psi, or 280 bar systems are more common in Europe. Globally, either of these standards can be found. Flow rates for a typical Noise, Vibration and Harshness (NVH) four poster are in the 30-40 gpm (120-150 lpm) flow range, while dual use NVH and durability four posters will have flow rates above 120 gpm (450 lpm).

Sample of a hydraulic power supply showing major components

Accumulators

Accumulators

To meet instantaneous peak flow demands, the hydraulic power supply is typically equipped with addition accumulators, which are essentially pressure vessels with an internal nitrogen-filled bladder. Once energised at system operating pressure, these accumulators provide additional oil volume as the system pressure drops below the normal operating pressure. These accumulators have a limited time response and limited capacity, and are typically sized in volume based on the difference between the peak velocity requirements and the root mean square (rms) or average continuous velocity requirements. It is worth noting

Hydraulic Service Manifold

that, as the accumulator discharges, this increased flow is only available in the system as the pressure drops, so the available force from the actuator is reduced and will not be at its static rated force capacity.

Hydraulic service manifold

A typical four poster consists of a pair of hydraulic service manifolds (HSMs) to control pressure to the actuator assemblies. These items are placed between the hydraulic power supply and the actuators, typically one per side, and provide solenoid-controlled smooth ramp up pressure to avoid the application of instant pressure to the servo valves, which would cause the actuators to move in an uncontrolled manner. Additional functionality typically found on an HSM includes localised high pressure filtration and accumulators for both the high-pressure supply and low pressure return. Low pressure accumulators are helpful in reducing pressure fluctuations in the return flow, as the servo valves respond to the pressure difference between the pressure and return lines. It is also worth noting the high-pressure filtration is of a non-bypass design, which means any contamination will be trapped in the filter element regardless of the condition of the filter element. If it is in need of replacement, the flow to the actuators will be restricted due to the reduced flow capacity of the occluded filter elements.

Pedestal actuator assembly

For NVH four posters, the servohydraulic actuator assembly typically consists of a double-ended hydraulic actuator with dual 15-gallon per minute servo valves mounted directly on the actuator manifold. The servo valves operate in parallel, providing up to 30 gallons per minute (gpm), or 114 litres per minute (lpm) of flow to the hydraulic actuator. The active piston area is typically sized to provide enough force to both support the vehicle weight statically and deliver enough force to generate the required displacement, velocity, and accelerations contained in the road profiles.

For NVH applications, the static force capacity of the actuators is 5,500 to 6,300 pounds (25 kN), typical stroke capacity is 6” or 150 mm, typical accelerations to 15 g’s, and typical velocity peaks to approximately 1.5 m/sec. Some ‘dual mode’ applications will also run higher velocity and acceleration content to simulate harsher road conditions.

The actuator assembly is supported on a pedestal base that is typically integral to the actuator assembly. As the actuators are fixed, with wheel pans attached directly to the piston rod, significant side loading of the actuator occurs. For this reason, most four poster actuators incorporate additional side load support in the form of oversized piston rods and hydrostatic bearings.

In addition to higher side load support, another benefit of hydrostatic bearings is the reduced friction when compared to polymer bearings. Hydrostatic bearings are essentially four symmetric pockets of high pressure oil on both the top and bottom of the piston rod that help keep the piston rod centered. Without

Pedestal actuator assembly

hydrostatic bearings, this work must be done with polymer bearings, which increase friction. Therefore, whenever the piston rod changes direction, the difference in friction in one direction to the other must be overcome, leading to control errors. In addition, the effect of the difference between static friction and dynamic friction comes into play. This effect is called stiction and can greatly affect overall performance. Hydrostatic bearings are also very sensitive to oil contamination and require extensive efforts to maintain very stringent hydraulic cleanliness levels.

A disadvantage of the hydrostatic bearings is their requirement for clean hydraulic fluid. If a hydrostatic bearing pocket is partially occluded due to foreign objects, the piston rod will become side-loaded internally, and major damage in the form of metal to metal direct contact between the piston rod and hydrostatic bearing occurs, requiring replacement of the bearing assembly and/or the re- chroming the piston rod plating can be necessary, in addition to re-flushing the entire hydraulic circuit. If this happens, downtime for repairs can exceed three months.

Servo valve

The motion of the actuator is affected by controlling the current to the servo valve, which is essentially a velocity-controlled device. As the current increases, the flow into and out of the actuator increases. Unfortunately, the flow through the servo valve is not linear, and responds as a square root function of a sharp-edged orifice.

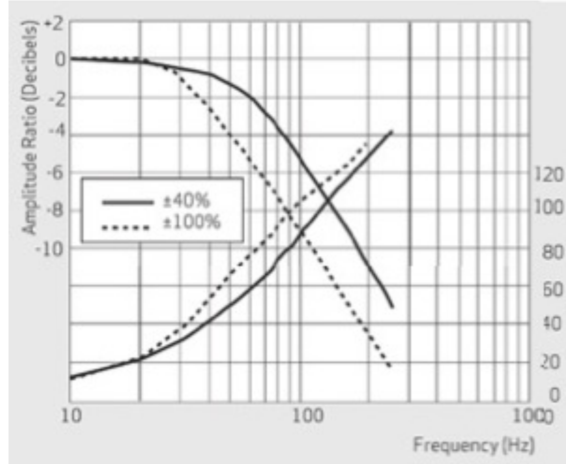
This nonlinearity also affects system performance according to system tuning, and is the reason why some systems, when attempting to perform small motions, do not respond the same as when attempting to perform larger, higher velocity motions.

Servo valves are also very sensitive to contamination, and a recommended oil cleanliness level of ISO 4406
13/10 (Beta >75 5 micron absolute) is required.

While there are many more factors which go into the overall frequency response and power transfer within a servohydraulic actuator, the system can do no better than the response of the servo valve.

A general rule of thumb to represent the frequency response is to determine the -3 dB point, in either power or amplitude. This is the ratio where the power transfer is 50 %, or the amplitude ratio is 70.7 %. At 100 % demand, this line at about 40 Hz.

An important point worth noting is the pressure drop through the servo valve, which is standardised as a 1,000 psi (67 bar) drop at the nominal valve flow rating. For example, a 15 gpm (57 lpm) servo valve will reduce the effective pressure

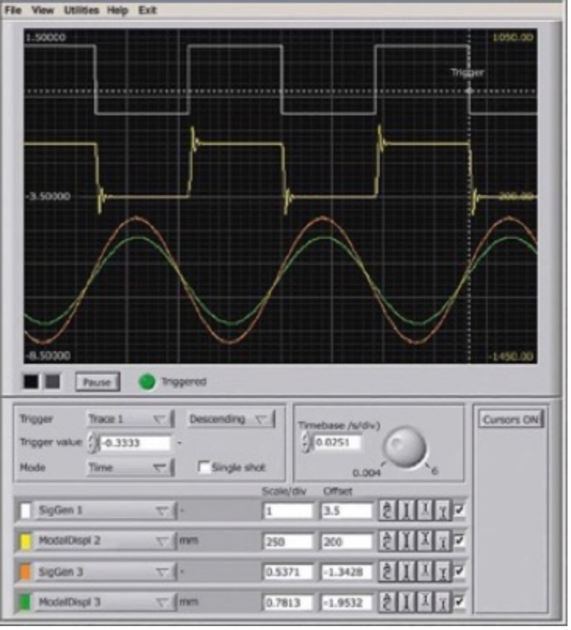


Frequency response of 15 gpm servo valves[1]

delivered to the actuator from 3000 psi to 2000 psi (200 to 134 bar) when operating at rated capacity. This effectively reduces the dynamic force capacity of the actuator during higher velocity events.

Another factor affecting overall frequency response is the compressibility of hydraulic fluid, which is typically 0.5 % / 1000 psi (67 bar), or about 1.5 % at 3,000 psi (200 bar). Because of this compressibility, the fluid moving in and out of the actuator, which is generating the required velocities and forces, has a spring component, and will generate a system resonance. This hydraulic resonance is governed by the oil viscosity, which is dependent on temperature, as well as the actuator piston area and tightly coupled masses. To compensate for this system resonance, many hydraulic systems employ a compensation method called

Delta-P. Delta-P measures the pressure difference from one side of the actuator relative to the other, and a portion of this inverted signal is applied to the servo valve command.



Servo controller

Feedback from the actuator assembly is typically a position feedback in the form of a Linear Variable Differential Transformer, or LVDT. The LVDT is coaxially mounted inside the piston rod for reduced footprint and to provide a degree of protection from outside influence.

Servo controller

The servo valve command is driven by the servo controller, which continuously reads the feedback, generates an error signal, and outputs this as the current command. This real time closed loop control happens 6000 times per second on controls provided by eMpulse. This update rate of 6 kHz is often referred to as the “closed loop iteration rate,” and is critical when higher frequency response is required, although this iteration rate typically is not an issue with servohydraulic test systems.

The servo controller provides signal conditioning for various transducers such as the LVDTs, pressure feedbacks, and includes digital inputs and outputs. The servo controller also continuously monitors limits and fault conditions, provides remote control of the Hydraulic Power Supply and Hydraulic Service Manifolds, and includes a graphical user interface for operation of the actuators as a four poster system. This allows the user to quickly perform functions such as fixed and swept sine waves for various modes including heave, pitch, roll and twist, and quickly select road profiles for replay.

To compensate for the frequency roll-off, system resonances, and force reduction with increased velocity, various software methods have been developed to drive the system. Online methods include adaptive inverse control, which constantly measure the system transfer function and acts as a real-time equaliser to boost or reduce frequencies that are either underachieving or overachieving. Offline methods include remote parameter control (RPC), which is a common format. RPC also calculates a system transfer function, but then further iterates this file with a portion of the following error on each pass. Once an acceptable level has been achieved, this new drive file is saved for future runs. A similar package is offered by Tiab called MIMIC (multiple input, multiple output iterative control). While the results are similar, neither package is inexpensive, and requires extensive math modelling and experienced personnel to operate properly.

Oil cooling circuit

A hydraulic system is relatively inefficient at energy conversion. Each time energy is converted from one form to another, energy is lost in the form of heat. This heat must be removed, and the capacity of the cooling circuit is often rated at 100 percent of the total power capacity of the hydraulic systems.

Depending upon the available facilities infrastructure at the local installation, various methods of cooling are employed. These include direct oil-to-air and oil-to-water. While oil-to-water is more efficient, this then requires a method of removing this waste heat from the water. A typical oil-to-water heat exchanger then requires a chiller circuit, often mounted on a rooftop or other outside location. It consists of a large air-to-water radiator with a fan to cool the water used to cool the oil. An additional pump is required to circulate the water through the air- to-water heat exchanger.

Each of these cooling systems further increases the power consumption, and therefore reduces the overall system efficiency.

Oil cooling circuit

03 – Major components of a servoelectric four poster system

A servoelectric four poster system consists of several common elements, sized according to the vehicle specifications and testing requirements. These major subassemblies consist of the Direct Current (DC) brushless linear motors actuator assembly including pneumatic static load support, servo drive/amplifier, cooling circuit, and servo controller.

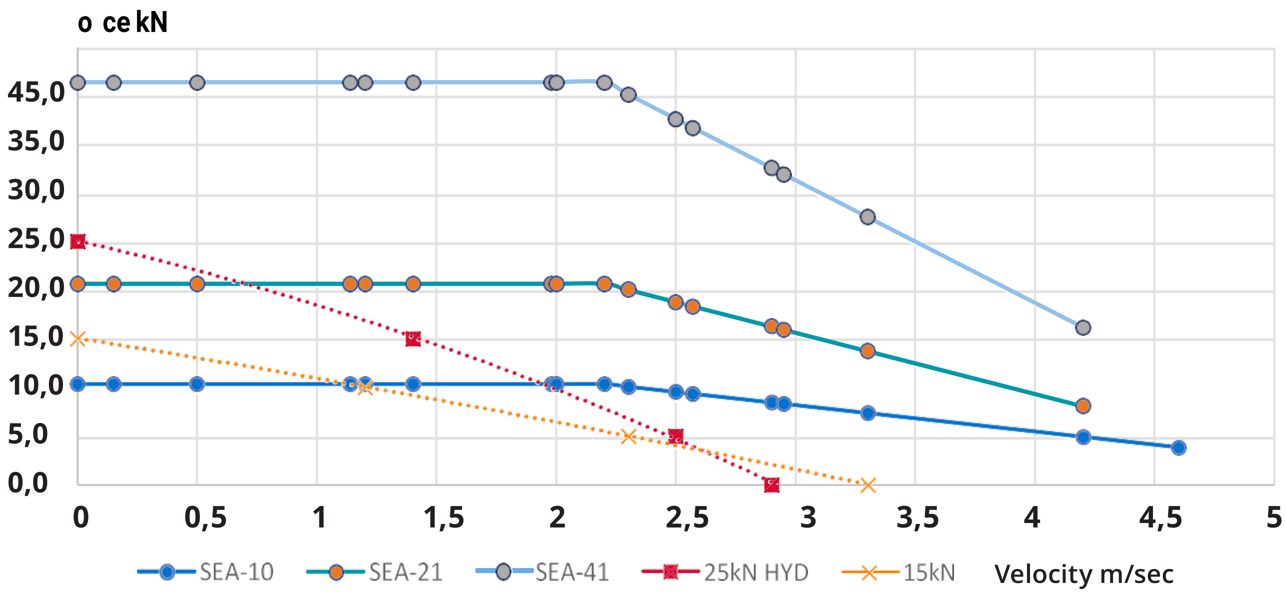
Actuator assembly

The systems currently supplied by eMpulse employ a combination of flat plate Direct Current (DC) brushless linear motors arranged about a central support structure. These consist of a non-contacting forcer which contains multiple coils which moves parallel to rare earth neodymium magnet tracks. The forcer coils are arranged in a three-phase winding configuration, and commutation is Pulse Width Modulation (PWM) sinusoidal. Because of the non-contact design, standard external bearings can be employed to handle any off-axis loading and are easily replaceable.
While servomotors are very efficient at higher velocities, they are very inefficient at low velocity, and will overheat when trying to support a static load for any significant length of time. To compensate for this limitation, as well as extend the available peak force for higher load capacity, the linear motors utilise a pneumatic static load support system. Similar to what has been used for decades on electrodynamic (ED) shakers, the static air support essentially removes any static load from the system, such as vehicle weight, and allows the motors to provide the dynamic components of the motion required.

The existing design employs one or two servomotors per actuator. The magnet tracks are attached to a central support structure, which also carries the static load of the vehicle through the use of dual pneumatic air springs. These air bags support the static weight of the vehicle, and appear to the servomotors as a soft spring in the system.

Servoelectric actuator assembly

ORCE CAPACITY VS. VELOCITY COMPARISON



Comparison of actuator force capacity versus velocity (dotted lines are hydraulic actuators;blue solid lines are servomotor standard force capacity options currently available)

The above graph shows a comparison of the available force at different velocities of linear servomotors compared to servohydraulic actuators. The vertical axis is force in kN, the x axis is velocity in m/sec. As can be seen, the servohydraulic capacity is reduced as the velocity requirements increase to the extent that, at 2 m/sec, the available force from a servohydraulic system is approximate half of its static rated capacity. The solid blue lines represent four poster typical configurations. Servoelectric systems maintain their full peak dynamic force capacity past 2 m/ sec, beyond the required velocity range for typical NVH four posters.

Also, due to the inherent ‘electrical stiffness’ of the servomotor, higher frequency response is achieved. Compared to the oil compressibility, the electrical force field developed within the servomotor is hundreds of times stiffer. This allows servomotor systems to be more easily tuned, without compensating for hydraulic oil resonance, temperature variations, servo valve nonlinearities and wear, and varying specimen dynamics.

Because of the use of low friction bearings, the effects of stiction are virtually eliminated, and additional tuning is not required for low velocity/low force and high velocity/high force, as well as low amplitude/high frequency versus high amplitude/low frequency.

Another advantage of the servomotor technology is that the peak power demands are provided by built in capacitors, which essentially act as electrical power accumulators, providing short term, high power to the motors for high acceleration events.

Servo drive/Amplifier

The motors within each actuator are driven by a servo drive. By utilising a common absolute optical linear encoder for position feedback, the same commutated command applies to each motor acting in parallel. The power for the amplifier is provided by a rectified DC bus, and the three-phase DC command is controlled by the amplifier in current, velocity, and position control. The command to the motors is commutated at high frequencies, typically 4 kHz to 16 kHz, resulting in high frequency response and very accurate position control.

Amplifier

Cooling circuit

During normal operation, cooling is not typically required. However, when harsh drive files are used, or the system is run at higher amplitudes or frequencies, higher loads can result in heat buildup in the motors. With thermal monitoring of all forcer assemblies, the system can apply a cooling medium to the forcer surfaces for extended operation. This can be either air cooling or water cooling, depending on the requirements. In the event of operation beyond the design intent, redundant over temperature monitoring in the form of embedded motor thermal sensors prevent damage before it can occur. Liquid cooling is preferred as heat removal is twice as effective than the use of compressed air.

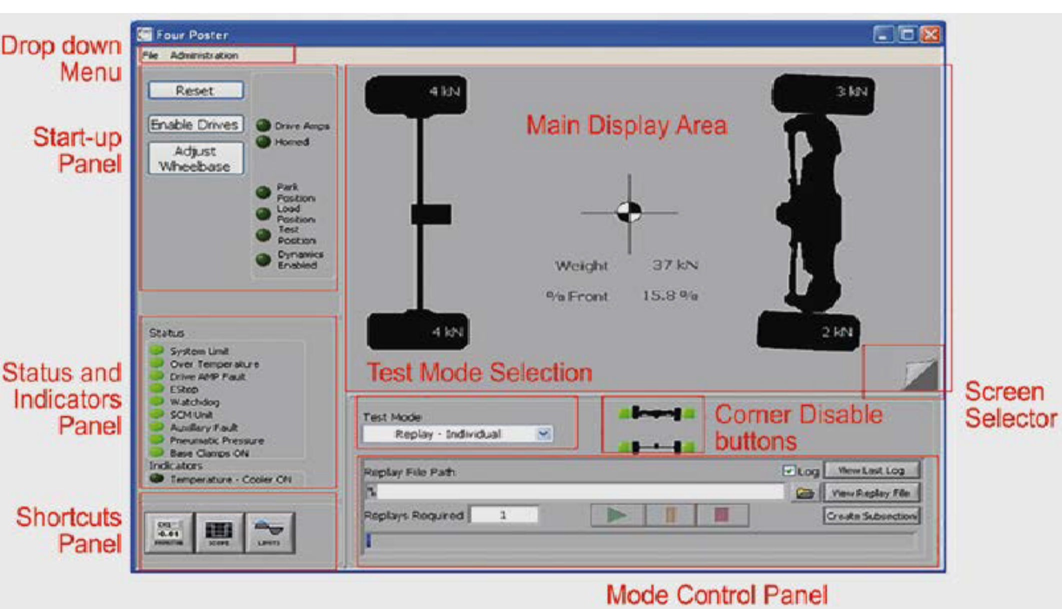
Servo controller

With the additional of Profinet isochronous real time digital communications, the same servo controller, with the same user interface and functionality, is employed on the servoelectric four poster as is with the servohydraulic four poster. This greatly simplifies training, communises system operation across multiple locations, and minimises the requirements for different suppliers based on the motion technology selected. In addition, Tiab servo controllers can be upgraded to run servoelectric systems at a later time, maximising the investment in controls technology.

An important item to consider is that, due to the inherent higher frequency response of a servoelectric system, advanced control schemes such as RPC and MIMIC may not be required for direct file playback, saving initial investment money

Servo controller

as well as eliminating the requirements for operator expertise with these software packages. With a servoelectric system, files are simply selected and played out directly, resulting in very accurate motion replication. If laser-mapped displacement files are used for four poster operation, no additional software packages, such as MIMIC or RPC, are required. If, however, the original road or track data is in the form of acceleration data, software packages such as MIMC or RPC can convert these acceleration drive files into the appropriate displacement drive files.



Four poster user interface

04 – Major components of a servoelectric four poster system

MAJOR CONTRIBUTORS TO ENERGY CONSUMPTIONOF SERVOHYDRAULIC FOUR POSTER
Input electrical power is converted to rotary motion in the AC induction motor. The overall efficiency of this three phase TEFC induction motor in the 75 HP range is typically 93 percent.
The motor is directly connected to the hydraulic pump. A fixed displacement vane pump in the 75 HP range operates at about 73 percent efficiency.
Some energy loss occurs through friction with the hydraulic distribution system, flow through solenoid valves, etc., but is dependent on flow rate. These losses are estimated at five percent.
The servo valve also induces significant losses, and at nominal flow rate, the power transfer efficiency is 66 percent. Because these losses are not constant, and occur during peak flow events, the losses for a servo valve are estimated at 85 percent. To sum up these losses: Input Power x (.93) x (.73) x (.95) x (.85) = Output Power Output Power = .54 x Input Power For 75 HP Input Power, approximately 40.5 HP is available as Output Power

Because four posters are not run continuously, and the fact that actuator sizing, hydraulic pump sizing, cooling circuit capacity, and even vehicle-specific loading factors contribute to the overall power consumption, it is difficult to determine a single energy consumption number for either system. However, an analysis of the typical usage on a typical servohydraulic four poster with 5.5 kip actuators and a 40 gpm hydraulic power supply, can provide some representative energy efficiency and consumption numbers for comparative purposes.

For a servohydraulic four poster, the overall energy consumption of the power used to generate hydraulic power is fairly straight forward.

The mentioned inefficiencies in the table show up as heat buildup in the hydraulic fluid, and the cooling circuit introduces its own power losses.

Heat exchanger sizing depends primarily on the ambient environmental temperature. For the hydraulic system operating at 115 degF (46 degC), the amount of air or water flow required to remove this heat is directly related to the temperature difference between 115 degF and the ambient temperature. A general rule of thumb based on the fact that water has a specific heat capacity double that of hydraulic fluid, in order to cool 40 gpm hydraulic flow, approximately 20 gpm of cooling water is required. Typically, the water cooling circuit is operated at 40 psi, or approximately 0.5 HP. A 10 HP fan is typically employed to draw air across the heat exchanger.

Therefore, the cooling circuit consumes approximately 10.5 HP, So the overall input power for this configuration is estimated at 85.5 HP, or 64 kW. This is a continuous power draw once the hydraulic power supply is operating and up to temperature.

Based on power usage measurements of an existing servoelectric system operating a five-minute evaluation file, energy consumption was measured at 3.04 kVA per actuator.

If the file is run continuously, the average power requirement for the actuators is 3.04 kW x 4 actuators = 12.15 kW. Depending on the vehicle dynamics, cooling may be required, and a good rule of thumb is about 10.5 HP (7.8 kW) total for a four poster, if the cooling is required continuously.

Note that cooling power consumption is a significant contributing factor in overall power consumption of the servoelectric actuators if continuous cooling is required.

For intermittent operation, which is normally the case in NVH testing applications, actual motion is required, on average, about 15 minutes per hour.

- In the case of servohydraulics, the power consumption is fairly constant, so the energy usage stays the same whether the actuators are moving or not.
- For servoelectric systems, the actuators do not consume energy when not moving, so the energy usage can be estimated as a percent of the time moving over the total time, or 15/60 minutes, or 25 percent. In addition, cooling is typically not used, and therefore affects the overall energy consumption significantly.

A general energy usage table listed below summarises these main points

Type of System	Continuous Duty	Intermittent Duty
Servohydraulic	64 kW	64 kW
Servoelectric	20 kW	3.1 kW (cooling not required)

Typical energy consumption comparison

Type of System	Continuous Duty	Intermittent Duty
Servohydraulic	256,000 kWh = $25,600/year	256,000 kWh = $25,600/year
Servoelectric	80,000 kWh = $8,000/year	12,400 kWh = $1,240/year

Typical annual energy costs comparison at $0.10/kWh

Type of System	Continuous Duty	Intermittent Duty
Servohydraulic	384,000 kWh = $38,400/year	384,000 kWh = $38,400/year
Servoelectric	120,000 kWh = $12,000/year	18,600 kWh = $1,860/year

60 gpm hydraulic power supply comparison – typical annual energy costs comparison at $10/kwh

For a typical two shift operation, the total hours per year = 16/day x 250 days/year = 4000 hours/year.

Comparing the above estimates, annual energy savings of a servoelectric system over a servohydraulic system would vary in the range from $17,600 to $24,360 per year.

When comparing energy usage to a 60 gpm hydraulic power supply, the energy costs can be estimated 50 percent higher than those calculated above.

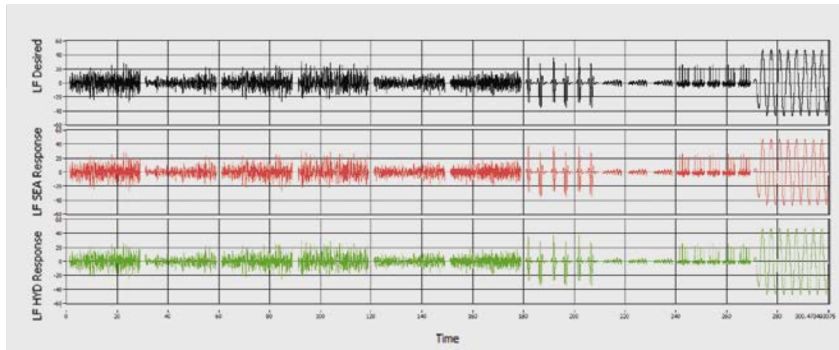
Comparing the above estimates, for a 60 gpm hydraulic power supply, annual energy savings of a servoelectric system over a servohydraulic system would vary in the range from $26,400 to $36,540 per year.

05 – Servohydraulic and servoelectric four posters: Comparing performance

While servohydraulic four posters have been in use since the early 1980s, the first servoelectric four poster was installed in 2010. Since then, the rapid acceptance of the servoelectric solution has created considerable discussions regarding the deployment of the newer technologies. Some manufacturers have adopted it as the only choice for new installations, while other have adopted a wait and see approach.

It is worth noting that, while servohydraulics do not have the extended frequency range and level of control precision that servoelectric systems do, it often comes down to how this four poster testing tool is implemented, and to what level of correlation from location to location, or test to test, is warranted. Servohydraulic four posters have been used successfully for many years and can provide a cost-effective return on investment in identifying root causes and repeatable results in the NVH world.

eMpulse is in a unique position in the industry and has provided systems using both technologies with expertise in designing, installing, commissioning, training, and maintaining both systems. Due to this we offer this technical comparison so the customer can make an informed decision on how best to utilise their resources.

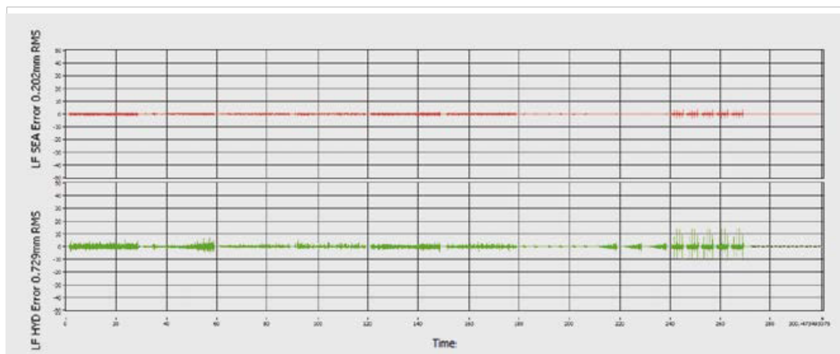


Displacement plots of desired, servoelectric, and hydraulic displacement feedbacks

Following are the results of a direct performance comparison between an older, fixed inground servohydraulic four poster with a servoelectric four poster. No changes were made to the existing servohydraulic four poster system, and it is entirely possible that additional tuning and optimisation may have resulted in better results.

File playback results

Customer provided laser-mapped road profiles, consisting of sequential segments of Harsh, Belgium Block, Cobblestone, gravel, Twist, and Impact. This file, known as Truck Twist Eval, was five minutes long.



Comparison of error (command-feedback) between servoelectric and hydraulic responses

06 – Technology comparison summary

Brief Review of the Advantages and Disadvantages of Servohydraulic and Servoelectric Technologies in TEFP Testing Systems

Advantages

Servohydraulic Four Poster Systems	Servoelectric Four Poster Systems
• Proven, mature technology • Many component and systems suppliers to choose from • Economies of scale have contributed to reduced pricing • Systems are reliable, provide that proper maintenance is employed	• Reduced number of components simplifies installation, maintenance and troubleshooting • Modular motors and amps mean reduced spare parts and lower replacement costs • Replaceable items, like pneumatic components, linear bearing, are relatively low cost • Increased frequency response without a force reduction with velocity • More accurate playback results • System design reduces performance variations and the need for system tuning • Enclosed actuator assemblies reduce external contamination, and increase operating life • A nearly 80 percent reduction in energy consumption over servohydraulic systems • Quieter operation provides lower background noise for NVH work

Disadvantages

Servohydraulic Four Poster Systems	Servoelectric Four Poster Systems
• System performance can be negatively impacted without proper setup and tuning • More spare parts, replacement items, and maintenance are required • Major spare parts, such as servo valves, actuator assemblies, etc., can be costly • Maintenance and service personnel must be proficient in servohydraulic technology • Downtime and repair costs can escalate without proper preventative maintenance • Expensive software (e.g. RPC, MIMIC) must be used to replicate accurately	• Servoelectro technology is still new in integrated automotive test applications • Limited number of component and systems suppliers • Continued operation at higher loads can lead to motor heating and require cool down time

07 – Working with eMpulse

eMpulse Test Systems is an automotive industry leader with fully developed and proven four poster system technology in both fixed and transportable formats, utilising proven technologies in servohydraulic and servoelectric systems. eMpulse has successfully designed, built, and deployed both BSR/NVH-rated and full environmental durability-rated four posters globally, including North America, the European Union (EU), South America, South Africa, and Asia. And additional installations are planned for deployment in the EU and in the Asia-Pacific and Australia regions.

Located in Zeeland, Michigan, eMpulse has provided new, used, and refurbished test equipment for over 20 years. Our equipment solutions team works with many original equipment manufacturers, and provides customised systems integration, allowing them to achieve their test equipment performance requirements. Due to our engineering and installation experience with multiple four posters customer equipment installations are routinely on-time and within budget. eMpulse is able to accomplish this as a result of our deep involvement with tier suppliers throughout the product development process.

Finally, as total systems integrators, eMpulse strives to achieve a level of component interchangeability, local sourcing, and redundancy of function so that we can assure our customers of continuous service support. This is especially important when it comes to the introduction of new technologies. Our service expertise and support knowledge support our customers in complementing leading-edge technology with minimum financial risk. This combined with competitively-priced integrated solutions provides high value for our customers.

08 – Benefits to your business

Save time and money – with an energy-efficient automotive testing solution that consumes more than 80 percent less energy, providing a shorter payback period and an excellent return on your investment.

Increase profitability – through the development of a high-quality product that has been tested and verified and delivers reduced downtime due to reduced failure modes and simplicity of troubleshooting and repairs.

Receive customised solutions – by using state-of-the-art servoelectric actuator technology that is faster, quieter and more environmentally friendly.

Benefit from a unified approach – with an end-to-end expert partner with global reach.

09 – Conclusion

eMpulse Test Systems is a world leader in providing Servo Electric 4-Posters having worked with the major OEM's, local specialist manufactures and New Energy Vehicle suppliers around the globe.

We provide the widest range of systems available and are the only supplier of SEA 4-posters to also offer Body Coupled excitation.

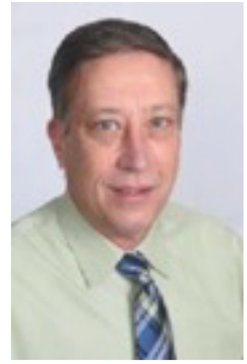
eMpulse have supplied turnkey solutions and worked with climatic chamber suppliers to meet the demands of our customers. We understand here at eMpulse that one solution does not fit all so are flexible enough to ensure the correct solution is available for all our customers.

Appendix

Servoelectric vs. hydraulic technology: A sample comparison of four poster performance factors

Parameter	Servoelectric	Servo-hydraulic	Notes
Max Peak Force Capacity Fmax, tot	7,221 lb, 32 kN	5.5 – 6.3 klb, 24.5 – 28 kN	Other Peak Force configurations available for bothelectric and hydraulic versions.
Continuous or Static Force Fstat or Fcont	4,320 lb 19.2 kN	5.5 – 6.3 klb, 24.5 – 28 kN	Static or Continuous Force required to support vehicle weight plus the average forces requiredduring operation.
Max Speed at Max Force Vmax, Fmax	75.5 in/sec 1.92 m/sec	N/A	Pressure drop in servohydraulics based on oilflow proportional to velocity.
Max Speed at Reduced Force Vmax, Fn	166 in/sec 4.2 m/sec	63 in/sec 1.6 m/sec	Vmax for servohydraulics based on dual 15 gpmservo valves with accumulation.
Typical Frequency Response at -3dB, Fn	149 Hz	40 Hz	Servohydraulic response based on Moog G761response, ignoring hydraulic resonance.
Energy Consumption, Continuous Usage, /hr	7 kW	84 kW	Servohydraulic 40 gpm @ 3000 psi + cooling.Servoelectric uses <20% of energy.
Energy Consumption, 50% Duty Cycle, /hr	4 kW	77 kW	Servoelectric uses very little power when idle.
System Performance affected by:- Temperature Accumulator pressure Servo valve wear Flow restrictions Hydraulic resonances Fluid dynamics Oil contamination Pressure losses	 No No No No No No No No	 Yes Yes Yes Yes Yes Yes Yes Yes	Servoelectric system performance unaffectedby many physical parameters that limit servohydraulic systems. Servoelectric systems do not require retuningbased on specimen variations or waveform content (same PID values for ALL conditions).
System Accuracy % RMS Error – typical file playback	1-2 %	10-30 %	Accuracy for servohydraulics depends greatly ontuning and waveform content.
Consumables Filters Seals Accumulators Servo valves Hydraulic oil Hydraulic hoses Cooling water & conditioning	Does Not Apply	Repair/Replace Annually	Annual maintenance costs for servoelectricsystems are virtually eliminated.
Built-In Performance Monitoring and Diagnostics	Disp Limits Supply Power Voltage and Phase Current (Force) Limits Peak Velocity and Accel control Dynamic Following Error Inertial Compensation Motor Temps Motor Cabling Displacement Feedback Energy Usage	Disp Limits Following error not effective due to poor dynamic response	Servoelectric solution provides easier setup andusage, as well as extended built-in diagnostic functions for identifying and correcting problemswhen they do occur.
Regenerative Energy	Yes	No	Regen returns captured energy back to the electric power system for greater efficiencies.

About the eMpulse expert



With more than 25 years of experience in the design and use of servohydraulic and servoelectric test systems, Douglas Boals has been in the forefront of technology innovation in the automotive testing equipment industry. Douglas holds a Bachelor of Engineering in Electrical Engineering from Youngstown State University.

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