INTEGRATING CUSTOM SHOCK ABSORBERS INTO MOTION CONTROL SYSTEMS

How shocks work, how they control motion, and how twin tube and monotube designs differ

www.QA1.net

INTEGRATING CUSTOM SHOCK ABSORBERS INTO MOTION CONTROL SYSTEMS

When most people think about shock absorbers, the first thing that comes to mind is the ones bolted on the four corners of their vehicle. The role of shocks in this application is to absorb bumps without transferring the jolt to the passengers, allowing the driver to confidently steer through curves without excessive body roll. This same force-damping technology can be incorporated into many designs beyond automotive applications to provide optimal performance for various motion control applications.

With origins stemming from the automotive aftermarket, QA1 has built a reputation as a go-to manufacturer and supplier of superior shock absorbers at an affordable price. Drawing on decades of shock and suspension innovation, QA1 produces a wide array of shocks and motion control components for several industries, including agriculture, medical, turf care, recreation, and more. If you have a need to control the motion of a mechanical system, QA1 can help. Their dedicated staff of engineers, machinists, and fabricators will work with you to design, develop, and manufacture a system custom-tailored to your needs.

The following Q&A is intended to help you determine if a custom shock for use in a motion control system from QA1 can benefit your project.

WHAT IS A SHOCK AND WHAT ARE ITS TYPICAL COMPONENTS?

Simply stated, a shock, or damper, is a device that transfers kinetic energy (motion) into thermal energy (heat). By transforming the motion into heat, the system into which the shock is integrated has smoother and more consistent movement. A shock is most typically constructed from a cylindrical aluminum or steel main body filled with oil, and a polished steel rod going through the oil in the center of the body serves as a piston rod. The piston rod has an aluminum or steel piston that rides internally in the oil chamber housed in the body.

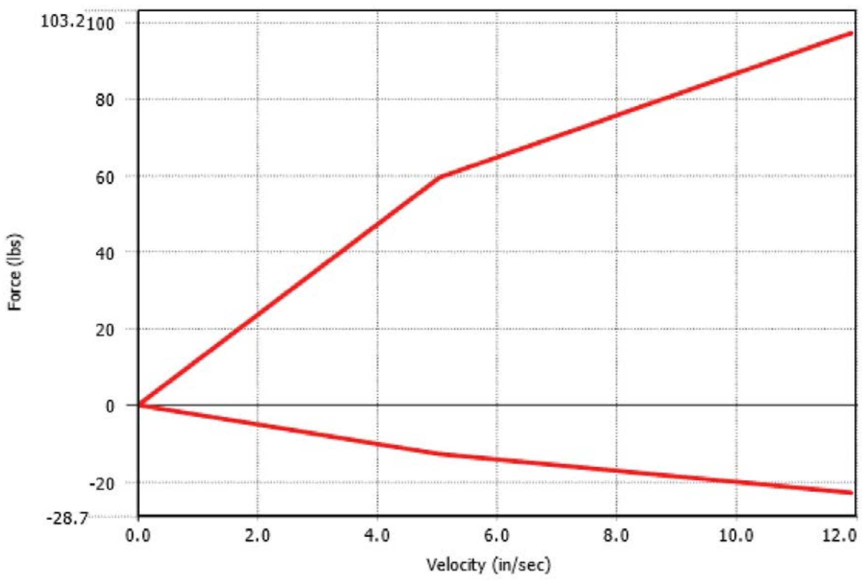
The body is generally sealed at one end (called the base), where a bearing or bushing is attached for mounting to the suspension system. At the other end of the body is a bushing and seal assembly. The piston rod exits the body through the bushing and seal assembly, which keeps the oil in and debris out. The external end of the shaft is also attached to a suspension system with a bushing or bearing. Force in a shock is controlled via valving in either (or both) the piston and base of the shock. These valves create a flow restriction for the oil to produce a frictional force.

HOW DOES A SHOCK WORK?

As the piston rod is compressed into the shock body or extended out of the body, fluid is forced through valving. The movement of fluid through the valves causes friction, and this friction resists the motion of the piston rod. Typically, as the velocity of the piston rod increases, so does the friction. This increase in friction creates a corresponding increase in force. Therefore, the higher the rod velocity, the higher the force necessary to move the rod. This means that one could think of a shock absorber as a device that effectively senses the velocity of the piston rod and produces a proportional force to damper and control it. The heat generated by the friction in the movement of the piston back and forth is dissipated through the oil and shock body to the atmosphere.

HOW DO YOU KNOW THE FORCE PRODUCED BY A SHOCK?

The curve below is an example of a Peak Velocity Plot.



A peak velocity plot, or PVP, is a typical graph that is produced after a shock is tested on a dynamometer (dyno). The graph displays the peak force recorded by a dyno as it cycles a shock on a crankshaft at varying speeds. In this case, the shock was tested to a maximum velocity of 12 in/sec in compression and rebound travel. This shock displays a mostly linear force curve. The curve tells us the force the shock produces at any velocity; the positive numbers are the forces generated in compression, and the negative numbers show the forces generated in rebound. For instance, when the piston rod is forced into the body at 10 in/sec, the compression force is 87 lbs. When the piston rod is pulled out of the body at 10 in/sec, the rebound force resisting this motion is 20 lbs.

IF A SHOCK IS FILLED WITH OIL, HOW CAN YOU COMPRESS A SHAFT INTO THE SHOCK? WHERE DOES THE OIL GO?

When a piston rod is forced into a shock body during compression, it is displacing a volume of oil equal to the volume of the rod. This is called "liquid displacement." Another example of liquid displacement occurs when a person steps into a bathtub; if the tub was completely full, it would overflow when a person steps in. The same thing happens in a shock. It can't be completely full of oil, or the shaft would not be able to enter the shock body. To address this, shock designers typically underfill the shock by a volume approximately double that of the piston rod. Instead of oil, a gas (typically nitrogen) takes up the rest of the space in the shock. Gasses are compressible, so as the rod enters the shock, the gas compresses to accommodate the volume of the shaft.

WHY WOULD A PISTON ROD EXTEND OUT OF A SHOCK ON ITS OWN?

Often, the gas in a shock is pressurized. This internal pressure pushes against the area of the piston rod and forces it out of the shock body. Pressure is utilized differently depending on the construction of the shock (more on this later) but is used to improve the consistency of the force a shock generates and to ensure the oil and valving function correctly.

WHAT ARE COMMON TYPES OF SHOCK ABSORBERS AND HOW DO THEY DIFFER?

There are many different types of shock absorbers. Choosing the correct type of shock absorber is critical to ensuring optimum performance and value for your application. The list below describes several common designs.

Twin Tube Shocks
A twin tube shock is constructed with internal and external tubes. The internal tube is called the compression tube, and it has the piston riding inside. The outer tube is the shock body. The space between the two tubes creates a cavity for oil and gas to accommodate the liquid displacement during shock compression. A twin tube utilizes valving on the piston to generate rebound force. Compression force is created with two valves: a primary valve on the piston and a secondary valve at the end of the compression tube near the base, aptly named a base valve. During compression, oil displaced by the piston rod is forced through the base valve, while oil in the compression tube is forced through the piston valves, creating a combined frictional force.

Twin tube shocks are desirable in applications where it could be easy to dent a shock body, as the body serves as protection for the compression tube. In addition, due to the base valve construction, a twin tube shock can adequately function with little to no gas pressure. Twin tube shocks typically are mounted vertically with the base down so that gas cannot collect in the compression tube (if gas collects in the tube, the shock will not function correctly). A workaround is to utilize gas bags. The gas bag contains an inert gas and is completely sealed. This keeps the gas from migrating into the compression tube and allows the shock to be mounted in any orientation.

By the nature of their construction, twintube shocks have a smaller diameter piston than a monotube shock with the same body diameter. A small piston produces less force than a large piston given equal pressures, so it is common for twin tubes to be utilized in lowerforce applications. Twin tubes also do not transfer heat as easily as a monotube shock because the working fluid is partially trapped in the compression tube, which is not in direct contact with the atmosphere.

Monotube Shocks

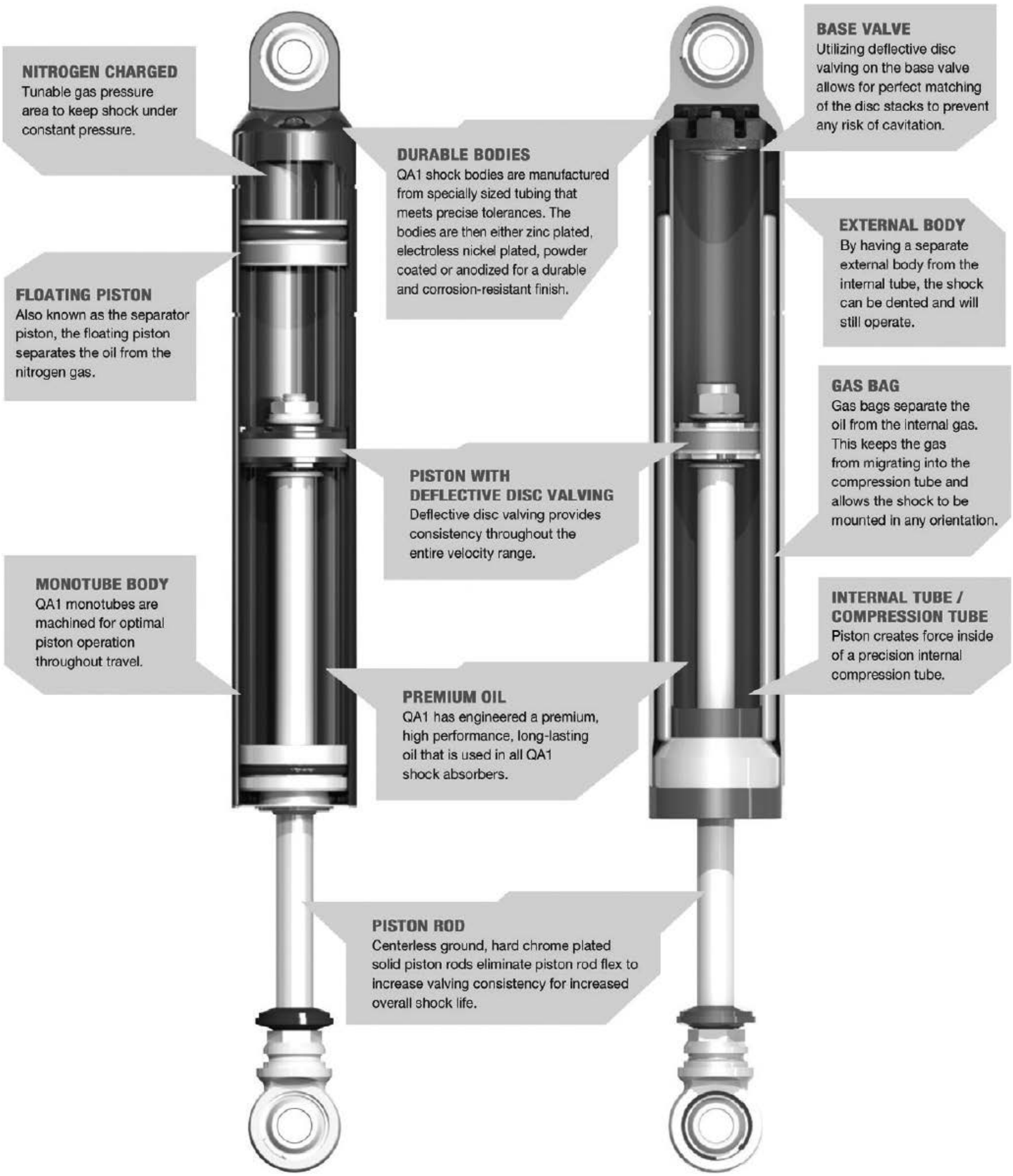
In some respects, monotube shocks utilize a simpler construction method when compared to twin tube shocks. The piston travels in the main body of the shock, enabling the use of the largest possible piston in relation to outer shock diameter. Both compression and rebound valving are typically located on the piston, but it is possible to utilize a twin tube–style base valve to aid compression. Rod volume displacement is most commonly accommodated using a floating piston near the base of the shock. The floating piston divides the oil from a pressurized nitrogen chamber. As the shaft enters the shock, the floating piston compresses the nitrogen gas.

Relatively high gas pressure is required in a monotube shock to stop oil cavitation during the compression stroke of the shock. Cavitation is the formation of gas bubbles in the oil caused by a rapid change in pressure. Gas bubbles in the shock oil degrade the consistency and force capability of the shock and can damage components. Sufficient pressure in the shock stops the formation of these gas bubbles. Cavitation is a serious concern in shocks with high compression forces, but by using proper gas pressure with the possible addition of a base valve, the issue can be easily controlled.

Because the piston and oil in a monotube shock are in direct contact with the outer tube, heat transfer to the atmosphere is not usually a concern. Large piston size relative to the body outer diameter also enables high forces in compact shocks. Length is a consideration as monotube shocks incorporate additional length in their design to accommodate for the floating piston and gas pressure area. This means that typically, a twin tube shock absorber can be slightly shorter in overall length than a monotube unless an external canister is utilized on the monotube. Another consideration is that monotube shocks are more susceptible to damage from a rock or debris since the outer body also serves as the piston bore.

MONOTUBE vs TWIN TUBE

These cutaway images show the difference between a monotube and a twin tube shock construction and highlight the performance features of a QA1 shock absorber.



Adjustable Shocks
Both monotube and twin tube shocks can be designed with external force adjustability. There are a few commonly used adjustment mechanisms to achieve adjustable shock force:

Bleed adjust: The term "bleed" in a shock is used to describe an open path for oil to flow past a piston in compression and rebound. The size of the opening dictates the amount of force that is required to move the piston through the oil. A bleed adjuster works by enlarging or shrinking the area of the flow path. Bleed adjustments are most effective at lower shock velocities and typically have a significant effect on body roll in an automotive application.

Preload adjust: Most shocks utilize spring steel discs or valves controlled by a secondary spring to control high velocity forces. As the piston speeds through a shock, pressure builds to a point where it overcomes the spring force on a valve and opens the flow path. Increasing the preload of the spring increases the force necessary to open the valve. Likewise, decreasing preload allows the valve to open at a lower pressure, thus inducing a lower force in the shock. Preload adjustable shocks simply allow the user to turn a dial to control the initial spring force.

HOW DO SHOCKS AND SPRINGS WORK TOGETHER?

It is important to note that a shock absorber typically produces little to no static force. Shock absorbers require piston rod velocity to create a resultant force. Do not confuse a gas spring with a shock absorber. Gas springs are pressurized specifically to produce a static force just like a coil spring. Shock absorbers may have a gas charge, but it is typically only present to eliminate cavitation and not to provide a static load. Springs are utilized to provide a static load and a shock is used in conjunction with the spring to control the naturally occurring oscillations in the system.

WHAT IS THE BEST WAY TO MOUNT A SHOCK?

Care must be taken to ensure that twin tube shocks without a gas bag are not mounted horizontally or upside down. Twin tubes without gas bags can be mounted at a slight angle, but not so much that gas could enter the compression tube. Twin tube shocks with gas bags and all monotube shocks can be mounted in any direction.

It is important to minimize side loading on shock absorbers. Side loads create unnecessary wear on piston seals and bushings and will lead to premature failure or the chance of bending the piston rod.

Utilizing spherical bearings on both ends of the shock is the best way to minimize side load. If bushings are utilized, the designer must be very careful to align the bushing mounts so they are parallel to each other throughout full shock travel.

CAN QA1 DESIGN A CUSTOM SHOCK FOR MY APPLICATION?

QA1 specializes in working with customers to develop custom motion control systems. We have an extensive array of standard components that we can utilize to speed the development process and rapidly create a cost-effective solution to meet your exact specifications.

IS THERE INFORMATION I SHOULD KNOW PRIOR TO DISCUSSING A MOTION CONTROL SOLUTION?

We are happy to discuss your motion control needs at any stage in your product development process. The following list of items will give you some helpful topics to think about as you prepare to move forward with a custom solution:

- What are the physical space constraints for a shock in your system?
- What is the necessary range of motion? What is the maximum extended length?
- How do you wish to mount a shock?
- Does the shock need to be mounted horizontally or at an angle?
- Do you want a coil spring or is there an alternate means to generate a force?
- Do you want to generate a static load through the shock?
- What forces do you need to generate in the shock and at what speeds?
- Do you require force adjustments in the shock?
- What are your cost constraints?

Having preliminary answers to these questions will help us determine the best way to move forward. Please contact us for more information.

CONTACT US

sales@QA1.net
952-985-5675