WHIP
GAS CONTROLLER

WHIP is a fast, accurate, and repeatable electronic pressure regulator designed specifically to maximize performance and reliability of pulsed power systems. Inside an EMP-hard enclosure, an electropneumatic servomechanism compares spark gap pressure measured by a vacuum-referenced pressure sensor with a user-supplied command voltage. The servomechanism adds or removes gas from the spark gap being controlled so that the pressure inside the spark gap matches the command signal. A digital PID algorithm tuned for spark gaps directs the servomechanism to optimally respond to abrupt changes while also maintaining steady-state stability.

SPECIFICATIONS

Output Pressure Range	0-100 psia (0-150 psia or 0-10 bar option)
Atmospheric Pressure Effect	0.001 psi
Command Repeatability and Hysteresis	±0.05 psi
Display Resolution	0.03 psi
Sense Location	Remote pneumatic sensing at spark gap
Sense Accuracy (non-linearity, repeatability, hysteresis, offset, span)	±0.3 psi
Steady-State Command/ Sense Offset	±0.2 psi
Long-Term Stability	±0.1 psi per year
Flow Coefficient Cv	0.97
Maximum Flow	48 SCFM / 1350 SLPM
Rise/Fall Time	80 ms
Control Signal Input	0-10 V, 300 kΩ BNC connector
Monitor Signal Output	0-10 V, 90 Ω BNC connector
Gas Compatibility	Dry air or inert gas
Gas Fittings	Toolless push-to-connect ¼ inch OD hose for Sense and ½ inch OD hose for other connections
Quiescent Gas Flow	0.6 SCFH / 0.3 SLPM at 100 psia setpoint
Supply Inlet Pressure Range	Atmosphere to +150 psig
Exhaust Outlet Pressure Range	Vacuum to +150 psig
Mass	8.9 lb / 4.0 kg
Input Power	20 VA; 85-264 V; 47-440 Hz IEC 60320 C13/C14
Electrical safety	Internal bonding and ground User accessible fuses

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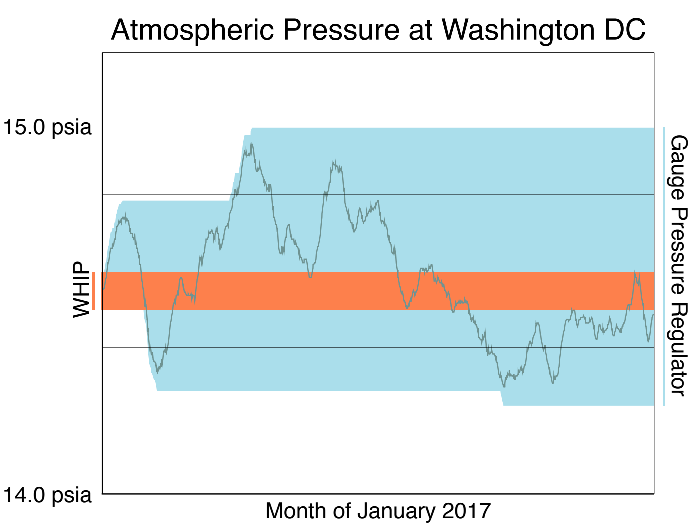
WHAT WHIP WILL DO FOR YOU

Maximize Peak Current

Maximizing the peak current delivered by terawatt pulsed power systems requires synchronization of large numbers of triggered spark gaps. Any spread in individual spark gap runtime acts as excess inductance and resistance that degrades rise time and peak current. Because spark gap runtime is a function of gas pressure, synchronization requires tight pressure control across all spark gaps. Synchronization would be easy to achieve passively if all spark gaps operate at the same pressure, share common plumbing, and there is no flow to generate a pressure gradient. This sort of global passive control relies on complete freedom from gas leaks and prevents tuning performance of individual modules. Distributed active control of pressure is necessary in real-world systems.

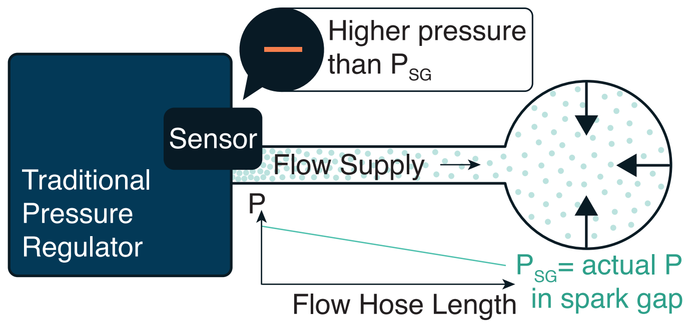
Suppress Drift

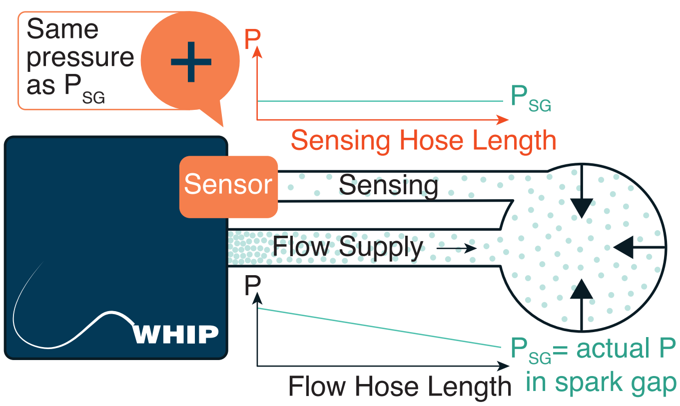
Distributed active pressure control at each module of a pulsed power system is only possible with controllers possessing high stability, repeatability, and absolute pressure sensing. Long term drift due to poor stability will cause performance of an optimized system to degrade as the pressures in each module slowly diverge. Repeatability errors lead to runtime variations that are observable as shot-to-shot variations in pulse shape and peak current. If gauge pressure is controlled rather than absolute pressure, variations in atmospheric pressure cause low-frequency jitter that tracks atmospheric conditions.



Test Your Hypothesis

Quantitative characterization of new plasma devices is made possible by pressure control that is accurate and absolute so that experimental runs at different times and in different facilities may be compared without ambiguity. Measuring pressure at the device, rather than in the plumbing, results in accurate data that is independent of gas flow.





Program Pulse Shape

Programmable waveform shaping demands high resolution pressure control with stability, repeatability, and absolute sensing. The output voltage and runtime of each module must be variable across a large dynamic range to generate repeatable arbitrary waveforms. Timing can be controlled electronically through the trigger chain as long as module runtime is stable and known across the full range of module voltages. But, as module voltages tare changed, pressure must track the voltage change so that each module is operating at the optimal pressure and runtime is as-expected. With modules running across a range of voltages, pulse shape is a function of atmospheric pressure if gauge pressure is controlled because a change in the atmospheric reference pressure affects low voltage / low pressure modules disproportionately.

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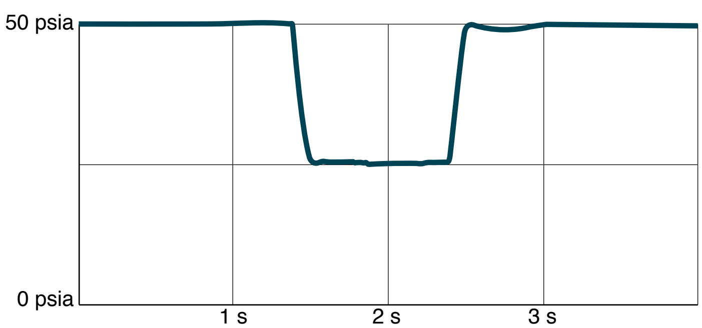
Control Amplitude and Timing

Controlling amplitude variations and temporal jitter when switching a pulse-charged energy storage device into a low-impedance load requires an output switch with repeatable breakdown voltage and runtime. For a fixed charging waveform, switch pressure is the single variable that controls breakdown voltage. Laser triggering or isolated electrical triggering can be used control the time at which a switch closes at the expense of complexity and reliability. Another option is to rely on a self-breaking switch with accurate pressure control so that the switch closes at the same time and voltage on each shot. When output voltage needs to be increased, switch pressure is increased to increase the breakdown voltage to a predictable value.

Extend Spark Gap Lifetime

Spark gap switches are most reliable when maintained through a combination of gas purging and manual disassembly and cleaning. Manually removing electrode erosion debris prevents prefires and destructive surface tracking at the expense of system downtime. Aggressive post-shot purging effectively increases the time between manual interventions by blowing out erosion products before they settle on critical dielectric surfaces. The high gas flow rates that are best for purging are made possible by locating a pressure controller close to each spark gap so that flow is not restricted by long hoses with high friction loss. Total gas usage is optimized by selecting a pressure waveform that uses only as much gas as is necessary to accomplish post-shot purging of debris.

25 psi, 1 second Pressure Pulse at FLASH Spark Gap



Set and Forget

Many pressure cycles are needed to characterize experimental components whether for pressure-triggering or post-shot purging. When measuring reliability is the main concern, a pressure controller with good repeatability and stability regardless of environmental factors and variations in supply pressure suffices. An electronic pressure controller makes repetitive pressure cycling a simple matter of pulsing an electronic pressure control signal. Pressure can be adjusted programmatically as a device under test deviates from its original performance.

Reject Interference

Data are often corrupted by the electromagnetic environment created by a pulsed power facility. Mechanical pressure regulators are immune to electromagnetic interference, but have poor performance when compared with electronic pressure control. Making the performance advantages of electronic pressure control available in a pulsed power environment requires that extensive shielding and electronic filtering be incorporated into the pressure controller.