MACH ONE™
MASS FLOW CONTROLLER

MACH ONE SERIES
flow control
MASS FLOW CONTROLLERS
at the speed of sound.

MACH ONE SERIES
MASS FLOW CONTROLLER

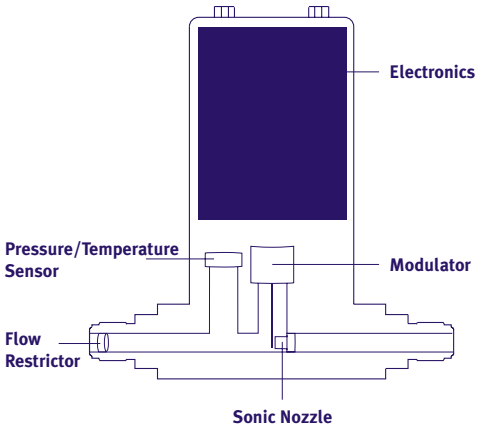
FLOW CONTROL AT THE SPEED OF SOUND

The Mach One revolutionary mass flow controller (MFC) combines sonic nozzle technology with an advanced digital control valve. This combination of technologies significantly improves mass flow control performance and substantially reduces product cost of ownership. The Mach One MFC's simple flow through design and construction eliminates flow bypass accuracy errors, slow response times, and clogging problems associated with traditional thermal based mass flow measurement.

BENEFITS

- ***High accuracy to ±0.5% of reading***
- ***Precise control***
- ***Increased long-term accuracy and stability***
- ***Extends time between calibrations***
- ***Significantly reduces inventory and setup time***
- ***Reduces delivery system size***
- ***Improves safety***

Present day MFC technology requires feedback control to produce the desired flow rate. Inherent to this control scheme is the problem of slow response and the tendency to over-shoot or under-shoot the desired setpoint. The Mach One MFC solves these problems and improves performance using feed forward control, a technique that sets the desired flow rate rather than finding the proper valve position through a process of trial and error (feedback control). The Mach One MFC uses feedback only to monitor, not to control, the MFC.



FEATURES AND BENEFITS

Accuracy to ±0.5% of Reading

Unlike most MFCs whose accuracy is measured as a percent of full scale, the Mach One MFC's flow through design enables it to deliver an accuracy of up to ±0.5% of reading—making your process highly repeatable.

Precise Control

Operating in only two states, fully opened and fully closed, the modulator changes states in milliseconds to affect precise flow control at both high and low flow rates. Conventional MFC designs utilize feedback control, a scheme that can add seconds of delay and cause flow instability. Through its feed forward design, the Mach One MFC achieves the desired flow rate in milliseconds, not seconds, without compromising accuracy.

Increased Long-Term Accuracy and Stability

The flow through design of the Mach One MFC ensures better long term stability and accuracy because it eliminates flow bypass errors and reduces susceptibility to clogging. Existing MFC designs split the flow between the flow sensor and control valve and assume the ratio between the two remains constant under all conditions and flow rates. This design type can enable minute particles to be trapped in the capillary-size metering tube thus changing the ratio—sometimes significantly—and causing inaccuracy. In addition, these MFC design types rely on heat to measure flow rates. Raising the temperature of the capillary tube can cause reactions in the gas resulting in clogging. The Mach One design requires no flow splitting or heating. In addition, it has a relatively large diameter flow passage thus 100% of the gas is metered at all times and accuracy is maintained.

Extends Time Between Calibrations

The pressure/temperature transducer of the Mach One MFC is an ultra-precision instrument that measures the slight variations in pressure (P_1) and temperature (T_1) variables. The P/T transducer's long term stability is rated at 0.25% per year, thus

enabling the Mach One MFC to deliver the longest mean time between calibration (MTBC), significantly reducing its cost of ownership.

Significantly Reduces Inventory and Setup Time

The Mach One MFC is a digital mass flow controller that can be programmed to run various gases without recalibration. The Mach One MFC can store an unlimited number of calibration curves for multiple gases, thus enabling the user to maintain a significantly reduced inventory of spare MFCs. Because of the unique Mach One design, there are only a handful of different unit sizes that are needed to cover the entire range of your process gases. In addition, the Mach One configuration software is easy-to-use, making setup and reconfiguration simple.

Reduces Delivery System Size

The Mach One MFC can simplify the gas delivery system by eliminating the need for some of the components found in a thermal MFC gas stick such as pressure transducers, filters, bypass valves, and in some cases, pressure regulators. This simplification saves money for the original equipment manufacturer (OEM) and improves end user cost of ownership.

Improved Safety

The Mach One MFC is also designed to operate with subatmospheric supply pressures, enabling hazardous gas usage, such as ion implant gases, without fear of external leakage.

The user-friendly configuration software significantly reduces time to use of the Mach One MFC.

Theory of Operation

The physics of flow through a nozzle is well understood and a long-established principle for metering the flow of gas. As the pressure drop across a nozzle is increased, the flow increases exponentially until the speed of sound is reached. At which point, the flow is said to be 'choked,' or flow limited. Further increases in pressure drop will have no effect on the mass flow rate. For a particular gas, the mass flow rate is directly proportional to the pressure and inversely proportional to the square root of the absolute temperature.

The Mach One MFC generates the desired flow rate by modulating the flow through the nozzle between two flow states: *No Flow* and *Choked Flow*. By varying the on/off time ratio between states—pulse width modulation (PWM)—a means of mass flow control is achieved. In other words, the average mass flow rate, $\overline{m}$, is proportional to the time the gas flows through the nozzle.

$$\overline{m} = \dot{m} \bullet \frac{t_{on}}{t_{on} + t_{off}}$$

COMPARISON OF THERMAL-TYPE MFCs AND MACH ONE MFC

	TMFC	Mach One MFC	Benefit
Control Strategy	Feedback	Feed Forward	Increased speed and precision
Valve	Analog	Digital	Nonthrottling; the valve is either fully opened or fully closed
Flow Control	Temperature	Time	Greater stability and increased response speed
Flow Splitting	Yes	No	Improved accuracy and insensitivity to mounting attitude; flow through design eliminates potential clogging

APPLICATIONS

The benefits obtained from the Mach One MFC apply to most gas delivery systems. At right are a few examples of applications where the Mach One is particularly well-suited.

- Atomic layer CVD
  Where delivery speed and time to setpoint are critical
- HDP-CVD, tungsten CVD (WF_6)
  Where precise control of the flow rate is critical
- Ion implant
  Where hazardous gases must be used without fear of external leakage; the Mach One MFC enables the use of Safe Delivery Systems
- Reactive gases
  Sonic nozzle technology is perfect for reactive and unstable gases like B_2H_6.

SPECIFICATIONS

PERFORMANCE	
Standard Flow Ranges	2 sccm to 3 slm (N2 Equivalent @ 30 psia) (See flow range table)
Accuracy	±0.5% of reading (5–100% of flow range) ±2% of reading (5% of flow range)
Repeatability	±0.25% of reading
Turndown Ratio	50:1
Response Time to Setpoint	≤250 ms
Zero Drift	±0.25% of reading/year
Gases Supported	Most SEMI E52-0298 gases, except corrosives and CO

MECHANICAL	
Maximum Inlet Pressure	15 psig/30 psia/100 KPa
Maximum Outlet Pressure	50% of absolute inlet
Control Valve	Normally open
Materials Exposed to Process Gas	316LSS, nickel, sapphire, paralene
Surface Finish	<32 Ra
Internal Seals	Nickel
Valve Leak Rate	<0.1% of maximum flow (Qmax)
External Leak Rate	$1x10^{-9}$ scc/s He
Operating Temperature Range	0–120°F (0–50°C)
Fittings	¼" VCR
Weight	2.0 lbs (0.91 Kg)

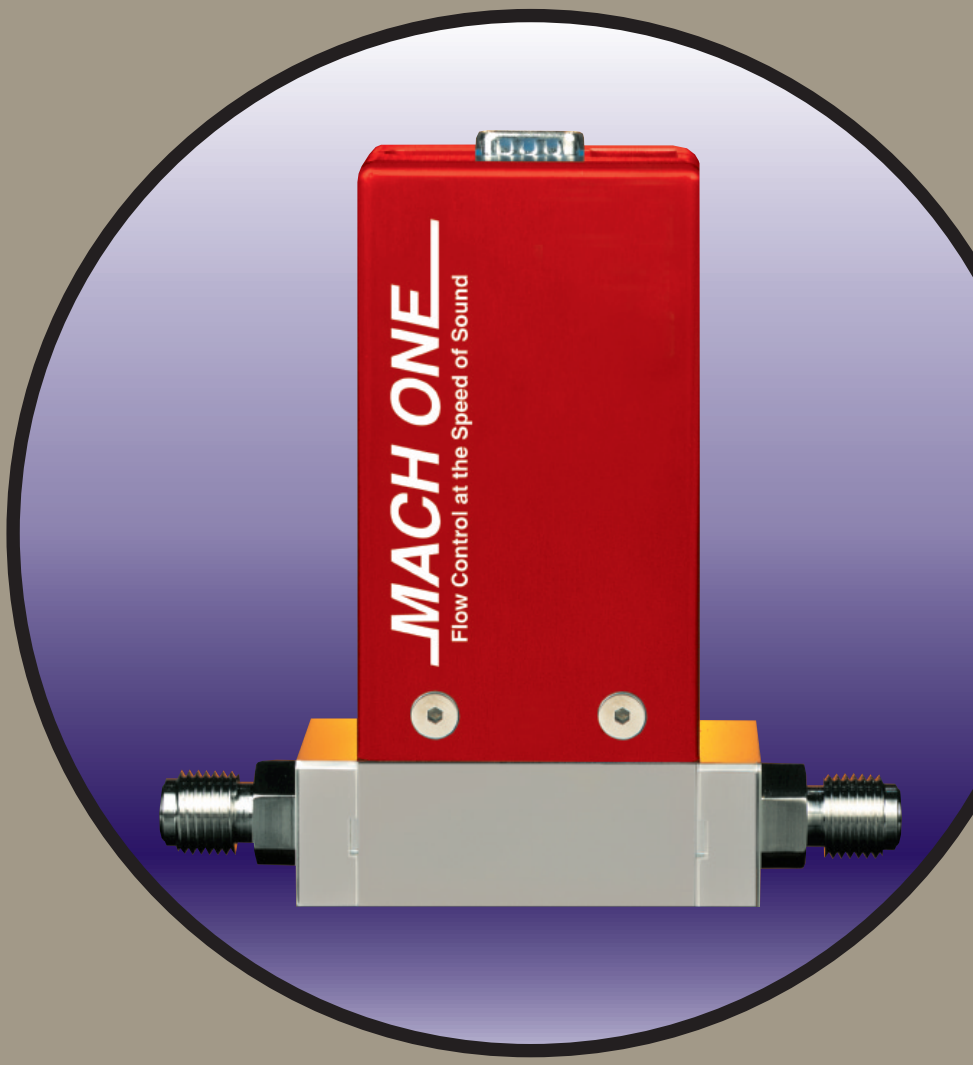
FLOW RANGE (N2 @ 30 psia)						
Model	**10**	**25**	**50**	**100**	**150**	**300**
Qmax (sccm)	100	250	500	1000	1500	3000
Qmin (sccm)	2	4	8	14	20	40

CALIBRATION REFERENCES	
Calibration Method	Rate of rise (ROR) of N2
Reference Conditions	0°C/760 Torr per SEMI E12-96
Traceability	All calibrations are traceable to NIST

MACH ONE FEATURES

Time Related Flow Control
Greater accuracy and stability.

No Flow Splitting
Eliminates flow bypass errors and reduces susceptibility to clogging.



Feed Forward Control Strategy
Decreases time to setpoint with no over-shoot or under-shoot.

Programmable for all SEMI-E52-0298 Gases
Greatly reduces inventory.

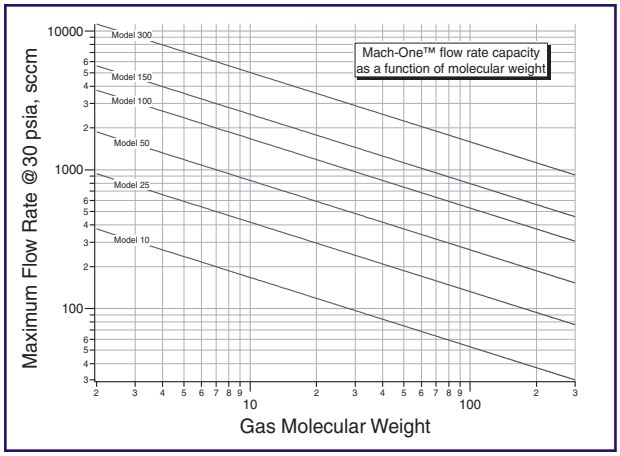
SPECIFICATIONS

ELECTRICAL	
Power Supply	+15 Vdc, ±5%, 150 mA maximum -15 Vdc, ±5%, 20 mA maximum
Analog Input	0–5 Vdc proportional to flow rate setpoint
Analog Output	0–5 Vdc proportional to flow rate
Digital Input	Two active 5 V, CMOS inputs for valve close and valve test/purge
Digital Output	One open-drain output for fault detection
Digital Communications	RS-485, 2-wire, half-duplex, 57600 bits/second, multi-drop compatible
Electrical Interface	15 pin subminiature-D

MODEL SELECTION GUIDE

CATEGORY	DESCRIPTION	SUFFIX CODES
Product	Mach One MFC	M1 … … … … …
Connection	¼" VCR	… –10 … … … …
Flow Range (N2 Equivalent @ 30 psia)	2 to 100 sccm 4 to 250 sccm 8 to 500 sccm 14 to 1000 sccm 20 to 1500 sccm 40 to 3000 sccm	… … –10 … … … … … –25 … … … … … –50 … … … … … –100 … … … … … –150 … … … … … –300 … … …
Inlet Pressure	30 psia (1500 Torr) standard <5 psia	… … … –01 … … … … … –02 … …
Electrical Interface	15 pin subminiature-D (standard)	… … … … –01 …
Special Options	None	… … … … … –00

Example: **M1–10–50–01–01–00**



ADVANCED ENERGY®
Advanced Energy Industries, Inc. ∘ 1625 Sharp Point Drive ∘ Fort Collins, Colorado 80525
T: 800.446.9167 or 970.221.4670 ∘ F: 970.221.5583 ∘ support@aei.com ∘ www.advanced-energy.com

SL-MACH1G5-230-01 0M 03/02

California T: 408.263.8784 F: 408.263.8992
New Jersey T: 856.627.6100 F: 856.627.6159
Texas T: 512.339.7100 F: 512.339.8889
United Kingdom T: 44.1869.320022 F: 44.1869.325004
Germany T: 49.711.779270 F: 49.711.7778700
Korea T: 82.3 1.705.2100 F: 82.31.705. 2766
Japan T: 81.3.32351511 F: 81.3.32353580
Taiwan T: 886.2.82215599 F: 886.2.82215050
China T: 86.755.3867986 F: 86.755.3867984