

# Feature Article

## Pressure Insensitive Mass Flow Module

— SEC-Z700 Series —

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Considering the gas-supply lines of semiconductor manufacturing equipment, demand has increased for the use of the system configuration from which line regulators, pressure sensors and filters are eliminated for the purposes of cost reduction and integration. We at HORIBA STEC have developed the SEC-Z700 series as a flow-rate control device that can support such system configurations. The following features are described in this article: higher precision in the actual flow rate; high-speed response (performance) for all specified flow rates; improved control of pressure fluctuation; a monitoring function that prevents any unexpected shutdown of the gas control system; and configuration software that allows the user to easily modify the specifications.

### Introduction

With the evolution of semiconductor manufacturing processes, gas supply parts now require advanced process control, repeatability, multi-functionality and high performance as well as a greater reduction in cost. The mass flow controller (MFC) is commonly used as a device to control the gas flow rate. In response to the trend toward higher functionality and greater multi-functionality, CPU-equipped digital MFCs are being introduced in increasing numbers. HORIBA STEC succeeded in developing the world's first digital MFC, the SEC-F1 Series, in 1990. Such digitization has made it easier to increase the accuracy of flow control and improve various functions such as the multi-gas function, which allows a single MFC to control the flow rates of multiple gases having different properties, and quick response over the entire control range. Line regulators, pressure sensors and filters are provided in the conventional gas lines for semiconductor manufacturing equipment because fluctuations in pressure could easily cause MFC cross-talk. We have developed the SEC-Z700 Series using the time-tested thermal mass flow controller as a platform. This model is barely affected by pressure variation, which has been considered a challenge, and constantly delivers steady flow control. The multi-display provided on top of the mass flow module is capable of displaying not just the flow rate output but also the

temperature and pressure. The module's communication is compatible with analog, RS-485 and DeviceNet interfaces. Various software applications are available, including one that can monitor and automatically save the state of flow control for the prediction of more complicated problems and cause analysis, another that can easily change the gas type and full scale flow rate, and others. Figure 1 shows the external view of an SEC-Z700 Series product.

#### Features of SEC-Z700 Series

- Pressure insensitive function<sup>\*1</sup>
- Multi-range and multi-gas functions
- Signal compatibility with previous models
- High accuracy:  $\pm 1.0\%$  of S.P.



Figure 1 External View of SEC-Z700

- Fast response: Within 1 second over the entire range
- Multi display

\*1: Pressure insensitive: To control so that the flow control isn't affected by fluctuations in supply pressure.

## High Accuracy and Multi-Functionality

MFC performance indices include the following: accuracy expressed as a percentage of setpoint; multi-gas, multi-range and other performance indices; as well as flow rate accuracy. While the accuracy of MFC flow rate was previously evaluated based on the percentage of full scale, the accuracy expressed as a percentage of setpoint has been employed in order to control the flow rate more precisely. Moreover, to allow a single MFC to accommodate multiple gas types and a broad selection of flow rate ranges (multi-gas and multi-range functionality), we have developed a new algorithm that is different from a single conversion factor<sup>\*2</sup>, as previously used, in an attempt to challenge the limits of the thermal MFC. In MFCs of earlier design, if there is a variation in the upstream pressure there will temporarily be an excessive flow into the flow rate sensor installed in the MFC. A valve will operate to prevent such variation, causing the rate of gas flow into the chamber to vary significantly. In the newly developed SEC-Z700, which is equipped with Variable Control Mode, the PID control constants will change, thereby improving stability in the steady state flow rate. Figure 2 illustrates the configuration of an SEC-Z700 Series product.

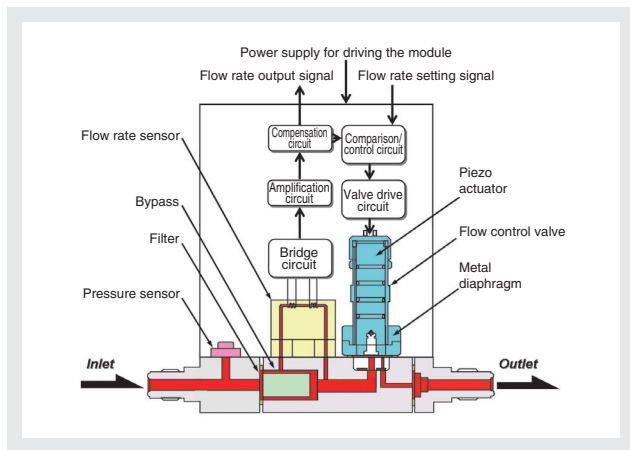


Figure 2 Configuration of SEC-Z700

\*2: Conversion factor: Ratio of actual gas flow to N<sub>2</sub> gas flow for a given sensor output

## High Accuracy: Accuracy Expressed as a Percentage of Setpoint (S.P.)

With the increasingly diverse film manufacturing processes, MFCs are required to provide precise control in an ever wider flow control range, from low to full scale flow rates. Accuracy of 1% of full scale (F.S.) was guaranteed for most of the conventional MFCs. Accordingly, to achieve highly accurate flow control, two MFCs with different full scale flow rates were placed in parallel and one of the MFCs was selected for use according to the flow rate being controlled. The SEC-Z700 Series, however, has achieved higher flow rate accuracy over the entire range of flow control through advanced compensation based on the approximating polynomial curve. Consequently, this mass flow module helps reduce the number of lines and contributes to a reduction in the cost of the gas system.

## Meeting Multi-Gas and Multi-Range Needs

With the SEC-Z700 Series, when choosing a full scale flow rate within the range of 3 slm to 50 slm for standard gases, one can choose from nine different full scale types. The calibration data and response constants for different gas types are installed in the SEC-Z700 Series module using a software application specifically designed for the SEC-Z700 Series. Previously, only one type of gas with one type of full scale flow rate range could be chosen for one MFC. Therefore, in order to change the type the MFC had to be returned to the manufacturer along with a request for a certain modification, or flow rate conversion had to be performed using the conversion factor. Because the multi-gas, multi-range compatible MFC allows the user to freely change the gas type and full scale flow rate, as shown in Figure 3, not only does it easily accommodate any change in process conditions but it can also help significantly reduce the number of spares kept by the user. Figure 3 shows how the multi-gas and multi-range functions work.

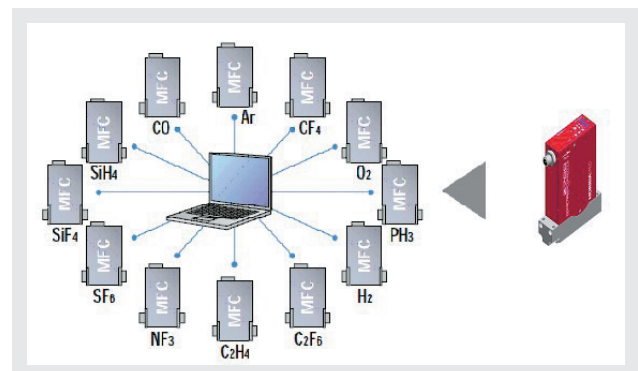


Figure 3 Multi-Gas, Multi-Range Functionality

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### Faster Response over the Entire Flow Rate Range: Continuously Optimized PID

While general MFCs achieve a high-speed response of one second or less near the full scale flow rate, their response speed is slower in the low flow rate range, taking several seconds to respond. Consequently, there may be variations in response among different lines according to the set flow rates. The SEC-Z700 Series ensures high-speed response performance over the entire range of flow rate settings, eliminating variations in response among different lines. In an MFC the flow control circuit uses PID closed loop control. In general MFCs, only one PID coefficient would be provided, or one PID coefficient would be provided for each of the set flow rate zones. This method enables faster response at certain flow rate settings, although it is difficult to provide high-speed response (one second or less) over the entire range of flow rate settings.

The continuously optimized PID control function employed in the SEC-Z700 Series significantly improves response performance by continuously changing the PID according to the desired flow rate and physical properties of the gas. High-speed response performance is maintained even when the gas type and/or full scale flow rate are changed. The above performance is essential for multi-range, multi-gas functionality.

### Greater Resistance to the Pressure Effect and Improved Control: Variable Control Mode

In semiconductor manufacturing, MFCs are installed for the respective feed flow paths when supplying gases to the equipment in order to control the gas flow rates. A pressure regulator is placed in series with each MFC to prevent extreme fluctuations in pressure in the flow path of each MFC, thereby improving the stability of flow control. In recent years, however, the increased number of system configurations has been such that a regulator is only installed for a gas cylinder or other source of fluid supply and MFCs are provided for the respective feed paths branching out from the source, as shown in Figure 3, although individual regulators are no longer provided for the respective MFCs. The previous MFCs are sensitive to a certain degree of variation in upstream pressure, resulting in flow rate variations that exceed specifications. Our newly developed Variable Control Mode function can prevent fluctuations in flow rate even in the case of a pressure variation and other disturbances,

as shown in Figure 4, by changing the PID control constants without sacrificing the speed of response to the change in the flow rate setting. Thanks to this function we are now able to offer MFCs that can be employed in systems without regulators. Figure 4 illustrates how a gas panel can be simplified, while Figure 5 shows MFC behaviors in response to variations in upstream pressure.

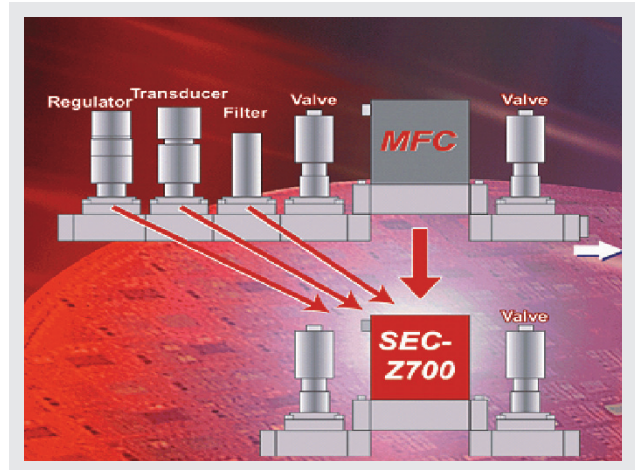


Figure 4 Simplification of Gas Panel

### Monitoring Function

It is difficult to troubleshoot the gas system effectively and efficiently by using data from conventional analog MFCs. The SEC-Z700 Series, however, is equipped with the digital communication function, which facilitates the monitoring of data on the MFC's conditions. Through proper management of the MFC conditions the user can find change (s) in the MFC before the MFC loses its control and schedule the necessary maintenance work instead of replacing and/or servicing the MFC after it loses control. This will prevent a sudden shutdown of the gas control system and improve the system's utilization.

### Configuration Software

We offer software specifically designed to allow the user to change the SEC-Z700 Series specifications easily. With this software, the gas type, full scale flow rate and other MFC specifications can be loaded on site via digital communication through the use of a PC without removing the MFC, even when it's connected to a pipe. Previously an MFC had to be returned to the manufacturer so that its specifications could be changed for a fee, but the use of this software will help reduce the time and cost that would otherwise be expended by the user. The user also had to have spare MFCs of many different specs ready in

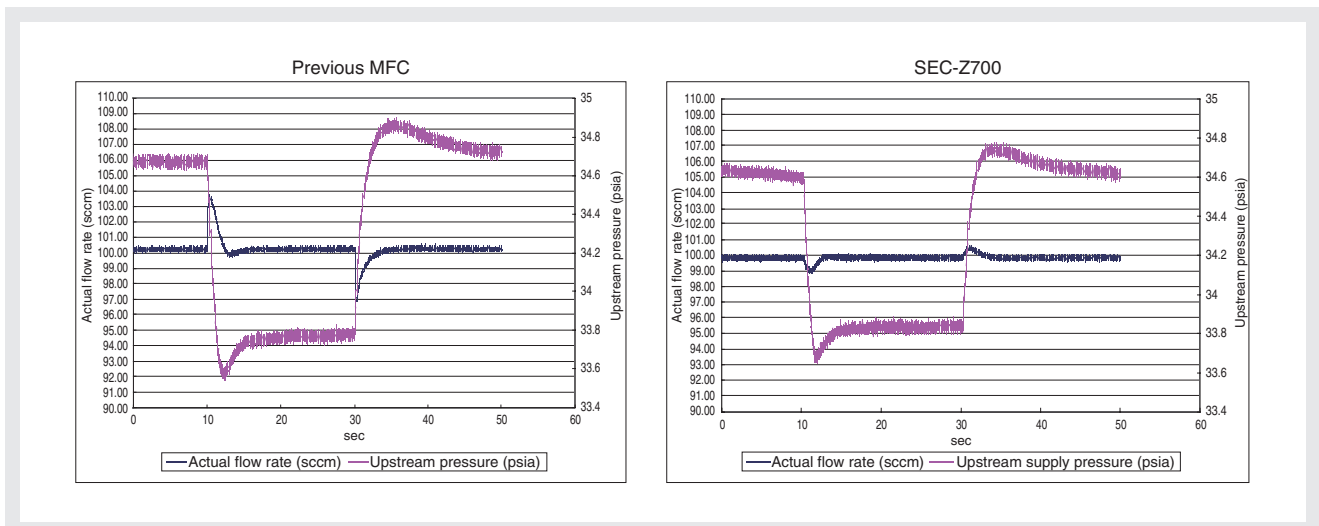


Figure 5 MFC Behaviors in Response to Variations in Upstream Pressure

the event any of the MFCs experienced a problem. Some users had as many as several dozen spares ready, so not only did they have to bear the cost but also had to implement a system for inventory control. However, this new spec loading technique allows the user to significantly reduce the number of spares, thus lightening the burden.

## Conclusions

I believe the SEC-Z700 Series achieves advanced process control, repeatability, multi-functionality and high performance as well as a further reduction in cost, all of which are demanded in semiconductor manufacturing processes. Hopefully we will continue our contribution to the growth of the semiconductor industry in the area of fluid control technology by further enhancing the sensing technology for a variety of fluids, control technology, software and other digital technologies, among others, thereby offering better products and services in a prompt manner.



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