OMEGADYNE, INC. REVOLUTIONIZES SILICON PRESSURE TRANSDUCERS

*A new line of Micro-Machined Silicon pressure transducers, the MM Series from Omegadyne, Inc., Sunbury, OH, promises to revolutionize a product category in which custom design requirements and long lead times, seem to be the norm. Unlike similar pressure transducers, **the MM Series is available in over a million different configurations, with lead times of 2 weeks or less**, assuring a precise match to nearly any application requirement, along with timely receipt of product. Figure 1 shows typical models from the huge number of choices. Before taking a closer look at this product, let's examine some of the key issues in pressure transducer design and application.*

About Pressure Transducers

The function of a pressure transducer is to convert pressure into an analog or digital electrical signal, from which a reading can ultimately be derived. There are a number of technologies that can be used for this, but for critical military, aerospace, and industrial applications, the strain gage is by far the more popular technology. The most widely used strain gages are constructed from either a metal foil or a semiconductor. Metal foil devices are typically made from nickel-chrome or copper-nickel alloy foils, arranged in a grid pattern and utilize the change in resistance resulting from deforming the foil elements. Semiconductor devices use a silicon or germanium strain gage and utilize the piezo-resistive properties of these materials.

Figure 1 MM Series Micromachined Modular Technology Pressure Sensors

In order to use strain gages to measure load or pressure, the gages need to be configured into a Wheatstone Bridge (Figure 2).

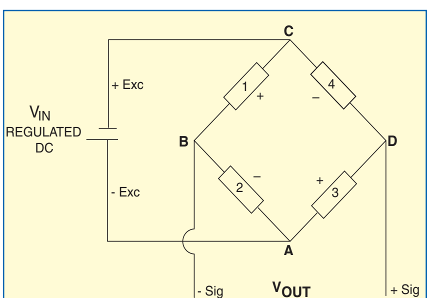

Figure 2 4 Gage Wheatstone Bridge

Generally, there are four strain gages, however, in some instances, only 2 are used, in which case, passive resistors are required to complete the Wheatstone Bridge. In this form, when voltage is applied to the "Bridge" across points C and A, any resistance change in the strain gages due to pressure or load, causes a change in the voltage at B and D. This differential voltage output across B and D is directly proportional to the pressure or load acting on the gages. Such a system can be calibrated to provide a sensitivity factor expressed in mV/V/psi or mV/V/pound force.

This is the fundamental principle that strain sensitive pressure sensors are based on. These foil or piezo-resistive strain gages are bonded to a pressure gathering diaphragm using a number of materials from high strength epoxies to glass frit. The pressure gathering diaphragm can be made from a number of materials such as steel or ceramic and is generally circular (Figure 3). This technique of "gaging" diaphragms has a number of drawbacks and does not lend itself to high volume manufacturing.

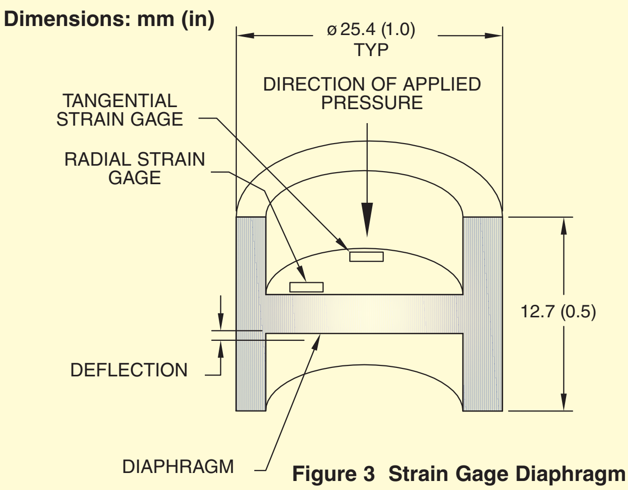

Figure 3 Strain Gage Diaphragm

WAFER LEVEL MEMS MANUFACTURING

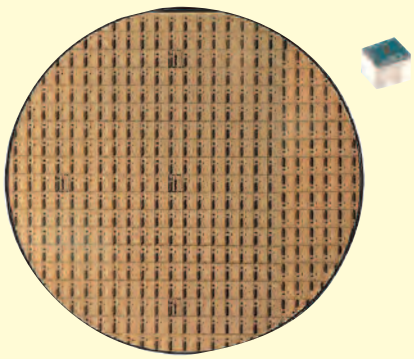

Figure 4 Micro Machine Silicon Wafer

MicroElectroMechanical systems (MEMS) are the twenty first century solution to these drawbacks. MEMS are mechanical silicon structures that can be fabricated at the wafer level (Figure 4). **Characteristics such as high sensitivity, small size, low signal to noise, excellent repeatability and low hysteresis, high overload, high yields, process repeatability have made Micro Machine Silicon the sensing element of choice for building reliable, flexible and stable pressure sensing devices**.

We will demonstrate how the latest high level silicon technology can be readily applied to designing and manufacturing an integrated family of pressure sensing devices. MicroElectroMechanical Systems (MEMS) are a combination of manufacturing processes that may be used to build thousands of small mechanical elements on a silicon wafer using very large scale integrated circuit processing. These mechanical elements are the building blocks of high performance pressure transducers.

A silicon wafer can hold thousands of these building blocks, each device performing almost identically to its neighbor as a result of using identical wafer fabrication processing and post wafer fabrication processing. These processes integrate the mechanical characteristics of silicon with the electronic characteristics of silicon, on a single silicon substrate (Figure 5).

The combination of the excellent elastic properties and the ability to diffuse strain gages into the internal lattice of silicon using ion implantation gives rise to the micro-machined silicon strain element where molecularly embedded piezo-resistive strain gages measure the strain induced by pressure in the diaphragm.

Omegadyne uses a number of micro-machined silicon designs for both gage, absolute, differential and compound pressure sensors that are fabricated in a state-of-the-art Wafer Lab. **The micro-machined silicon has been used in many applications ranging from Aerospace to Medical applications over the years.**

MEMS characteristics

These small electro-mechanical elements have outputs up to 50 times greater than that of metal foil strain gages. Their thermal characteristics are highly repeatable and are ideally suited to a number

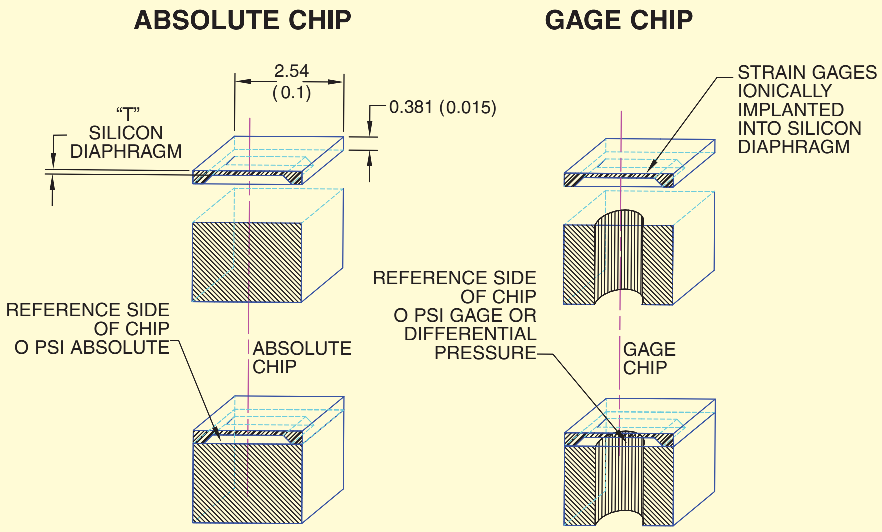

Figure 5 Absolute and Gage Chip

Dimensions: mm (in)

of different methods of temperature compensation ranging from digital techniques, to look up tables, to passive or analog methods.

The excellent elasticity of silicon, translates into lower hysteresis effects but more importantly provides a very strong platform for linearization and other signal correction techniques as a result of almost zero non-repeatability error.

Unlike bonded foil strain gage devices, there are no adhesives used between the diaphragm and the gage. Strain gage bonding mechanism can cause a non-linear resistance-to-strain relationship and errors due to creep and hysteresis. The small mechanical diffused strain gages in the MEMS element eliminate the use of a bonding agent—thus, these sources of error. In addition, micro-machined silicon has a very useful overpressure capability. Bonded foil is typically capable of withstanding 2 or 3 times its working pressure before there are noticeable signs of plastic deformation in the diaphragm which is detectable as non repeatability. Because silicon is essentially perfectly elastic any deformation due to overpressure is fully recoverable until fracture occurs. Four times over pressure is typical for silicon but over pressures as high as 10 can be designed into custom specials.

The electro-mechanical elements lend themselves to modular interchangeable concepts. The silicon-based piezo-resistive sensing elements are packaged in such a way as to create modular interchangeable building blocks that can be incorporated into a fully ruggedized pressure sensing family of products.

At Omegadyne this configurable product is called the MM Series of pressure transducers.

See Figure 6. Additional electronics within the transducer compensate for temperature and linearity and provide exceptional performance characteristics. The heart of the device—the electro-mechanical-element—is mounted in a sealed chamber and protected by a stainless steel diaphragm.

A small volume of incompressible fluid transfers the media pressure through the diaphragm to the micro-machined silicon diaphragm. The silicon deflection is directly proportional to the applied pressure and results in an imbalance in the strain gage bridge that represents itself as an mV/V signal. **In the event that an overpressure condition ruptures the diaphragm, a unique feature provides secondary containment for pressures up to 10,000 psi.**

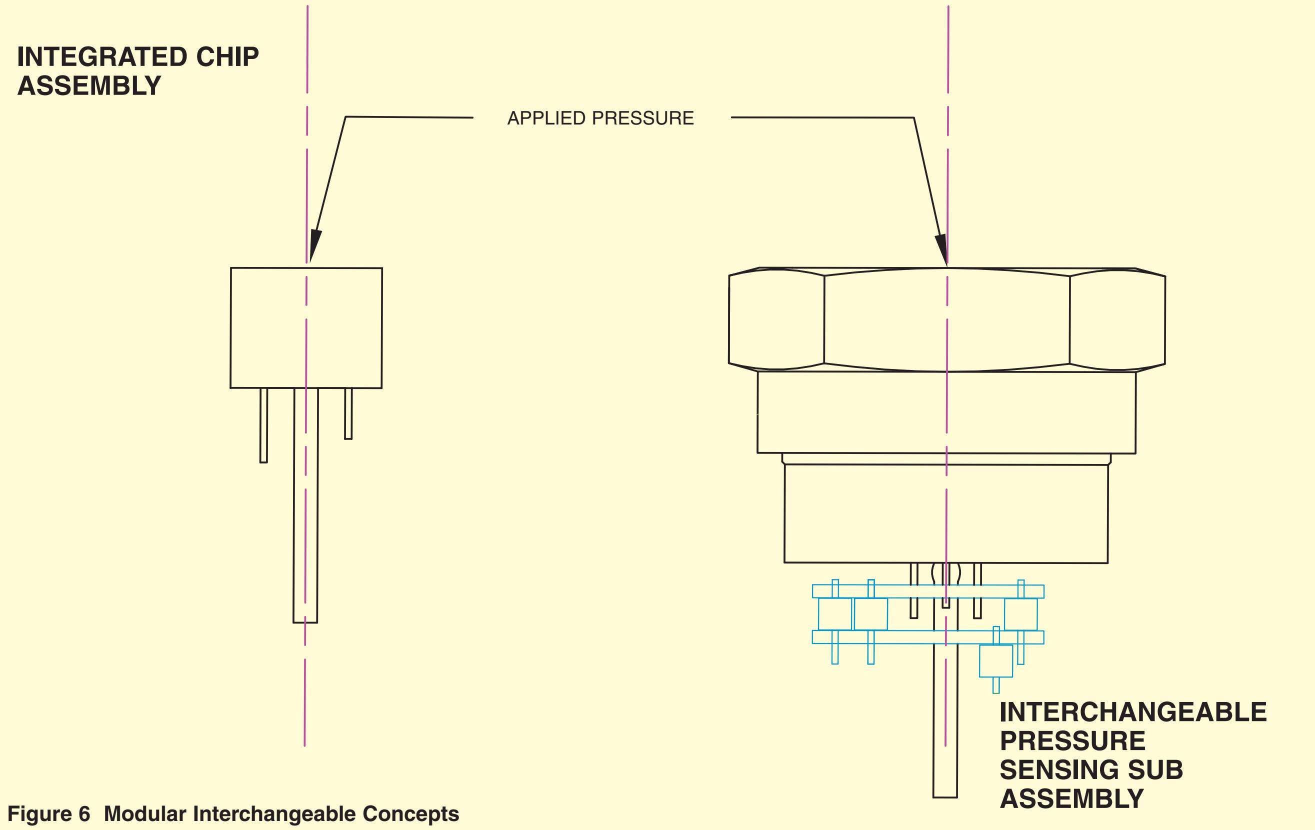

Figure 6 Modular Interchangeable Concepts

Real World Requirements for Pressure Transducers

High performance pressure transducers are used for critical applications in a wide variety of applications. These range from R&D lab equipment to submarine instrumentation, from medical equipment to advanced military and commercial aircraft, from industrial processes to aerospace hardware. The physical conditions of these applications vary dramatically as do the requirements for the physical packaging, signal conditioning, mechanical interface and media compatibility. To make matters even more complicated, there are many different types of pressure measurement to choose from. To get a feel for the challenges facing both users and manufacturers, let's go through the main questions to be asked for a typical application.

First, what kind of pressure measurement? (The sidebar lists the most common options.) What pressure range? What operating temperature range? What pressure port or fitting style? (See the side bar for typical options.) What electrical termination? What output signal? (See sidebar for examples.)

An important consequence of using modular interchangeable sub assemblies is that should the standard models not meet all the customer requirements then there is the very valuable option of being able to easily configure a customer specific product using the configurator tool, with the added bonus of a two week delivery.

Yet an additional benefit of this program is that should the customer require an even more unusual sensor product that would be considered fully custom, the design process for such a product is to use as many standard modular interchangeable parts and reconfigure only those necessary. This specials custom capability minimizes lead times for products to approximately 4 to 6 weeks.

Omegadyne's build to order methodology requires that the product and the manufacturing system be fully integrated for maximum efficiency. The integrated system is designed to offer the customer a service second to none in terms of being responsive. Omegadyne has addressed the issues described above with the MM Series of Pressure Transducers. Through the use of state-of-the-art sensing devices, flexible product design, and innovative manufacturing techniques, these products offer very high performance, multiple product choice, standard products, customer specific products and special custom products all with lead times that beat the competition.

Types of Pressure Measurement	
Gage	Vacuum
Absolute	Low
Compound	Barometric
Differential wet/wet uni-directional	
Differential wet/wet bi-directional	
Differential wet/dry uni-directional	
Differential wet/dry bi-directional	

Typical Pressure Port Options	
1/8-27 NPT	Male or Female
1/4-18 NPT	Male or Female
7/16-20 UNF	Male or Female
9/16 UNF	Male of Female
G 1/8B	Male or Female
G 1/4B	Male of Female
M12X1.5	Male or Female

Typical Output Signals	
3 mv/V	±3 mv/V
10 mv/V	±10 mv/V
0 to 5 Vdc	±0 to 5 Vdc
0 to 10 Vdc	±0 to 10 Vdc
4 to 20 mA	4 to 20 mA, 12 mA zero

Most common options for pressure measurement

Configurations are available that can measure pressures that range from10 in-H20 to 5000 psi with a 1 msec response time and a life expectancy of at least 1 million pressure cycles. All this, while achieving accuracies up to 0.03% BSL (Best Straight Line), based on a 5-point NIST traceable calibration. Table 1 shows the number of standard options available in each category. All told, there are over 1-million possible combinations. Typically, any of these combinations can be delivered within 10 working days and the most popular configurations are stocked for same day shipment. Because the underlying technology is so flexible, even when the standard options don't meet all requirements just around the corner are millions of additional alternatives all with two week delivery.

Parameter	Options	Range or Choices
Accuracy	5	from ±0.40% to ±0.03%
Pressure Ranges	92	from 10 in-H20 to 5000 psi
Electrical Outputs	10	shown in sidebar
Thermal Ranges	4	from -51 to 127°C (-60 to 260°F)
Pressure Ports	14	shown in sidebar
Electrical Terminations	4	including cable, twist lock, conduit and DIN

Table 1 - Options for MM Series Pressure Transducers