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Selecting the Best Sensing Technology for Pressure Applications

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Factors to be considered when selecting the most appropriate pressure sensing technology for an application include up-front cost, static/total error band, interface requirements, installation costs, and the total lifecycle costs of the solution. We will examine four steady-state pressure measurement technologies for a general-purpose pressure measurement including metal-foil strain gage, thin film, silicon MEMS, and capacitive pressure transducers. Performance factors relevant to pressure measurement such as response time, sensitivity to temperature, and the effects of vibration will be reviewed in this application note.

All general-purpose pressure-sensing technologies utilize mechanical force collectors, typically pressure diaphragms, to aid in the conversion of gas and/or liquid energy into a corresponding electrical signal. The mechanical properties of the diaphragms and the quality of their linkage to the electrical transconduction elements are critical to understanding the performance limitations of any pressure transducer. The degree of isolation between the pressure sensing components and the physical case of the transducer also factor into the evaluation. Ultimately, the quality of the pressure measurement will depend on the selection of the sensing technology, the way the media is introduced to the pressure-sensing element, and the operating environmental conditions.

Metal Foil Strain Gage Sensing

Metal foil strain gages have been manufactured since the 1950s. They are small, flat grid-type structures that increase in resistance when stretched and decrease in resistance when compressed. Their availability followed the development of electrical circuit boards constructed using photolithography techniques.[1] A pressure-sensing element is formed by cementing insulated metal-foil strain gages to a solid metal force-collecting diaphragm in locations where tension and compression are localized and of similar strain levels. Common materials for the construction of the wetted parts include 316L stainless steel, 17-4 PH stainless steel, and high-nickel alloys like Hastelloy or Inconel. The choice of material mainly depends on the media and expected pressure cycling. The diaphragm material is minimally elastic resulting in a slight deformation when pressure/vacuum is applied. The bonded metal foil strain gages change shape and resistance as input pressure deforms the diaphragm. The diaphragm must be robust enough that the operating pressure does not induce a permanent change in shape after removal of the applied pressure, resulting in output hysteresis.

A skilled technician bonds the copper-nickel or nickel-chromium alloy metal foil gages with an adhesive to a metal diaphragm and then clamps them in place for curing. After curing, usually at an elevated temperature, the four individual metal-foil gages are soldered into a Wheatstone bridge network. This strain gage network is on the non-wetted side of the diaphragm, safely removed from any media contamination. Applying the proper voltage excitation will convert the small changes in resistance into low-level voltage outputs suitable for transmission to an electrical readout device. This change in output is proportional to the amount of pressure applied. These hand-assembled products are subject to long-term creep and repeatability degradation due to dissimilar materials in the construction of the force-collecting diaphragm, the quality of the bonding, moisture absorption of the organic bonding material, and repeated temperature/pressure cycling of the assembly.

Metal Thin-Film Sensing

The first commercially viable thin-film pressure transducers were manufactured in the 1960s. As with metal-foil strain gage transducers, the thin-film gage elements deposited in a Wheatstone bridge configuration and attached to a pressure-sensitive diaphragm generate a voltage output that is proportional to the applied pressure. The material selection depends on the temperature range, required sensitivity, power requirements, and long-term stability requirements. Although thin-film technology is often presented as an improvement over metal-foil designs, both sensing technologies share a number of common shortcomings including low sensitivities and hybrid force collecting assemblies containing several materials exhibiting varying thermal coefficients of expansion (TCE). Additionally, the force collecting diaphragm design is always a compromise between output sensitivity and overpressure capability.

Metal thin-film manufacturing includes multiple steps using a combination of chemical and physical vapor deposition processes. As with metal-foil gages, photolithography techniques are used in the formation of the desired 2-dimesional grid structures. A dielectric layer is deposited on the internal side of the diaphragm to insulate circuit elements from the conductive material. Then a thin film of resistive alloy is sputtered over the dielectric layer. This layer may be laser trimmed to produce the balanced resistors of the Wheatstone bridge. Passive compensation networks, bonding pads, and electrical pathways are added to complete the circuit and provide conductive pathways for input power and output signal via wire-bonds. An encapsulation layer often coats the final assembly to protect the thin film network from moisture. The resulting thin-film sensor is typically very pure, electrically stable, and molecularly bonded to the diaphragm.

MEMS Silicon on Insulator Piezoresistive Sensing

Piezoresistive-based transducers rely on the piezoresistive effect that occurs when the electrical resistance of a material changes in response to applied mechanical strain. The piezoresistive effect in silicon is due primarily to changes at the atomic level and exhibits a gage factor approximately two orders of magnitude larger than that of metal strain gages.[2] As stress is applied, the average effective mass of the carriers in the silicon either increases or decreases. Direction of the stress, the crystallographic orientation, and the direction of current flow alter the silicon’s carrier mobility and hence its resistivity.[3] As a result, silicon strain gages can produce 100 to 300 mV full scale signals. In metals, this effect is completely dependent on changes in geometry with applied mechanical strain. Consequently, thin-film and metal-foil gaged transducers are generally limited to 20 – 30 mV full-scale output.

The dielectrically isolated Silicon on Insulator (SOI) pressure sensors manufactured by Kulite are truly solid state devices as the force collector and sensing elements are all part of a 3-dimensional monolithic silicon crystal structure forming a pressure chip. The SOI pressure chip may be constructed with a vented header for gage/differential inputs or with a sealed cavity at vacuum for absolute pressure measurements. SOI-based pressure transducers are often favored over metal-foil or thin-film transducers due to the outstanding transconduction properties of doped single-crystal silicon.

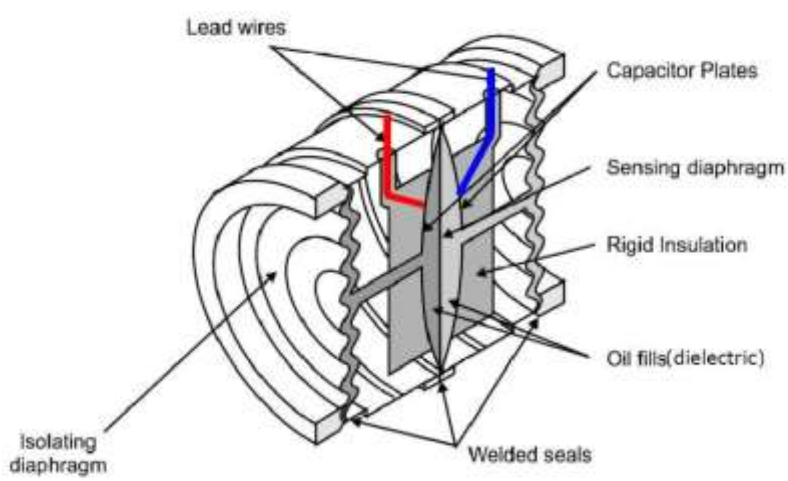
The SOI pressure sensor incorporates a very strong diaphragm while exhibiting the properties of crystalline structures. The Young’s modulus of silicon is approximately 90% that of stainless steel. Single-crystal silicon also exhibits extreme elasticity. Creep and thermal sets are virtually nonexistent as the silicon piezoresistors are atomically bonded to the underlying silicon diaphragm and possess matching TCEs. Additionally, stresses are much lower in SOI pressure sensors as the higher gage factor of silicon allows for elevated output voltages (5X to 10X) at significantly lower strain levels.

These properties lead to outstanding overpressure survivability with much improved linearity, negligible hysteresis, and minimal repeatability error. The force-collecting diaphragm of an SOI piezoresistive pressure sensor cannot be deformed to produce an unreliable pressure response as it will catastrophically fail at the material fracture point. This characteristic essentially eliminates the possibility of acquiring low-quality data due to an over-proofed sensor. The SOI pressure sensor also exhibits outstanding long-term stability and a predictable thermal response due to the complete electrical isolation of the atomically regulated piezoresistive gage elements from the underlying silicon dioxide diaphragm.

Capacitive Sensing

Capacitance pressure sensing uses the position and movement of a diaphragm to alter levels of electrical capacitance. The capacitor usually consists of two parallel conductive surfaces separated by a narrow gap containing a dielectric material. The area of the plates, the dielectric constant of the media between the plates, and the distance between the plates determine values of the capacitance. A variable capacitance pressure transducer often has the diaphragm function as one capacitive plate and another capacitive plate (electrode) fixed to an unpressurized surface. Lowering the pressure will typically widen the gap between the two electrically isolated plates and decrease the capacitance.

Some industrial designs include two metal isolation diaphragms each transmitting pressure via non-conductive fluid to an internal cell.[4] Silicon oil is often the pressure transfer medium between the plates to ensure a stable dielectric constant. Each cell is constructed by machining a concave surface from a rigid non-conductive material such as glass and plating the surface. A rigid metal diaphragm is placed between the two cells to form a push-pull pair of balanced capacitive sensors for differential and gage pressure measurements. The temperature of each cell is monitored for thermal compensation. The balanced capacitance approach gives higher output and increased sensitivity over the single electrode pair design in a manner similar to the sensitivity ratios between ¼-bridge and ½-bridge strain gage networks.



Much like the metal-foil and thin-film transducers, many capacitive pressure transducers operate naturally as differential or gage pressure devices. Manufacturers of large, industrial capacitive pressure transmitters use a sealed-vacuum reference cell paired with the gage input pressure cell to determine absolute pressure. Each pressure cell can be larger than 3 inches in diameter to provide the capacitance dynamic range necessary to support the pressure sensitivity requirements. Other designs utilize an internal ceramic capsule that is sealed under vacuum. The input pressure surrounds the capsule and forces the two plates inside the capsule towards one another with increasing pressure.

The sensor usually interfaces to a circuit designed to oscillate at frequencies determined by the input capacitance of the single capacitive sensor or as determined by the difference in capacitance between dual electrode pairs. The dynamic range of these capacitance changes may be one or two orders of magnitude higher than resistive pressure sensors. The oscillating signal is then converted to a voltage so it can be interfaced to an electrical readout device. Alternatively, the capacitance can be measured more directly by measuring the time taken to charge the capacitor from a current source through a precision resistor. This measured time constant is then compared against a reference capacitor using the same resistor to compensate thermal drift.

Other Pressure Sensing Technologies

Other technologies used for pressure measurement include unbonded strain gage (resistive wire), piezoelectric, variable differential transformers, variable reluctance, resonant silicon and resonant quartz. These technologies are briefly described below. They are not considered as general-purpose pressure transducers and typically support limited use cases.

1. **Unbonded strain gage** sensing technology typically uses a ½ bridge circuit with two active wire elements and two inactive elements exposed to the same thermal conditions. Wires are wound around a pressurized tube so that increasing pressure stretches the wire and increases the resistance. The output is similar to levels generated by metal-foil and thin-film transducers due to the high gage factor of the wire. The output is linear with constant current excitation, but requires a polynomial curve fit (2^{nd}-order) with constant voltage excitation.[5] Unbonded wire pressure transducers are typically limited to high-pressure and/or high temperature installations.
2. **Piezoelectric** pressure transducers rely on the piezoelectric effect, which occurs when a crystal re-orients under stress forming an internal polarization. All piezoelectric sensors are self-generating and develop electrical potential (charge) in proportion to applied stress. They are a hybrid structure with stacked layers of bulk-material sensing elements (usually synthetic quartz) compressed using a preload screw and mechanically linked to the diaphragm. They have an inherent low-frequency roll-off that is dependent on the external signal conditioning's low-frequency time constant. Consequently, they are not usable at DC or steady state conditions.
3. **Linear/rotary variable differential transformers (LVDT and RVDT)** pressure transducers are manufactured using differential transformers to sense pressure. They require AC excitation, typically 400 Hz to 5 kHz, to drive the primary coil residing on the force collector that excites the pair of differential magnetic coils used for measuring displacement of the primary coil. They require special interfacing circuits, are fairly sensitive to vibration, exhibit substantial error at the null position, exhibit higher linearity/hysteresis errors, and are more subject to magnetic interference than other sensors. Prior to the all-media, SOI piezoresistive pressure sensing advancements pioneered by Kulite, the Aerospace pressure transducer market had been dominated by electro-mechanical pressure transducers relying on Bourdon tubes with complex mechanical linkages to AC-excited transducing elements including synchros, LVDTs, and RVDTs.

Kulite has replaced many legacy LVDT/RVDT, variable reluctance, and potentiometric transducers with designs utilizing SOI sensing technology coupled with custom internal signal conditioning. Replicating the legacy output with modern, solid state sensors and electronics results in dramatic reliability improvements without the need for a system level redesign.[6]

4. **Variable reluctance** pressure transducers are manufactured using differential coils to sense pressure. Pressure changes cause a magnetic, high-permeability spring member to move between the two coils changing their inductance. They require AC excitation, typically 1 kHz to 10 kHz in an inductive bridge configuration. They require special interfacing circuits, are sensitive to vibration, and are more subject to magnetic interference than other sensors. Variable reluctance pressure transducers are typically found in all-media low differential pressure and/or high line pressure installations that do not require a fast pressure response.
5. **Resonant silicon and resonant quartz** designs are among the most accurate pressure sensing technologies available. A voltage driven through a highly engineered piezoelectric material typically resonates in the 10 kHz to 80 kHz frequency range depending on the input pressure, temperature, and the external passive circuit components. Sophisticated timer/counter circuits determine change in resonant frequency of the stressed member. This inherently averages the pressure signal resulting in high-resolution measurements at a low frequency response – typically 2 Hz or slower over a digital interface. Resonant pressure transducers may be used at elevated temperatures in downhole applications, for example, but most transducers are designed for laboratory use and are compensated over a limited temperature range.

Pressure Response Time

The natural frequency of the pressure diaphragm will determine the highest measurable frequency for a flush installation. The frequency response of metal foil and thin-film transducers varies proportionally with operational pressure range due to the stiffness (and natural frequency) of the diaphragm. However, metal foil and thin-film transducers typically have relatively large dead volumes that limit their dynamic response. Low-pressure units using a bellows/pushrod approach or a thin diaphragm will begin to amplify the input pressure at frequencies of 100 Hz or lower (~20% of the transducer's natural frequency). The flexural strength of the steel plate limits the force-collecting diaphragm to a relatively low overpressure range with a high burst pressure. Excessive pressure levels may occur if the process contains pressure dynamics that align with the resonant frequency of the transducer dead volume and/or diaphragm. A failure is to be expected after the fatigue limit of the diaphragm is exceeded by repeated pressure cycling.

The output voltages of film and foil-based pressure transducers would normally increase to saturation due to the mechanical amplification of the diaphragm at resonance. However, the analog bandwidth of metal foil and thin-film transducers is often set to the usable bandwidth of the low-pressure ranges within an entire product family. The electronic filter can mask pressure spikes that would otherwise saturate the output amplifier and downstream electronics. The combination of overpressure and pressure cycling causes the hysteresis and repeatability performance of the transducer to worsen while it appears to be generating a reasonable output signal. Several manufacturers offer complementary mechanical pressure snubbers to restrict the media and slow the transducers response.

SOI piezoresistive transducers, in contrast to metal-foil and thin-film devices, utilize a micro-machined silicon force-collecting diaphragm with atomically bonded piezoresistive strain gages. Kulite piezoresistive sensors are inherently small (on the order of 0.035" x 0.035") giving Kulite the unique ability to accurately measure dynamic pressures to 50 kHz and above. Oil-filled SOI pressure transducers also exhibit extreme frequency response capability and flush-mount designs are used in blast testing. The thin stainless steel isolation diaphragm transmits the pressure to the SOI pressure chip mounted to a custom header through incompressible silicone oil. The resulting sensor is effectively an all-media, solid-state sensor capable of capturing rise times faster than 1 microsecond. Transducer mounting in test environment tends to be the dominant factor in determining the useable bandwidth/frequency range of the pressure transducer.

General-purpose capacitive pressure transducers require relatively large plates to achieve sufficient signal to noise ratio (SNR). Industrial designs with capacitive plates of 3” in diameter are inherently slow to respond and are electrically limited to frequencies of a few hertz. MEMS capacitive microphones are available that operate to frequencies of 20 kHz, but the majority of these designs are not rated for industrial operations. Most general-purpose capacitive pressure transducers report response times ranging from 1 – 10 mS operation which limit the usable bandwidth to frequencies lower than 350 Hz.

Operating Pressure

The diaphragms for mid to high-pressure thin-film and metal-foil designs are thick enough that they may be reliably machined. As the pressure decreases to 100 PSI the diaphragms become too thin for consistent production. Some designs increase the surface area in order to allow for greater thickness tolerance. Other designs compensate for the low-pressure challenge by using a bellows and pushrod design to deflect a gaged cantilever beam. Metal-foil and thin-film pressure transducers can support the measurement of pressure to 100,000 PSI and higher. The limitation on the upper pressure range is the acceptable shear stress transfer through a thick diaphragm, typically constructed using 17-4 PH stainless steel, as the output linearity suffers with increasing pressure. Metal-foil and thin-film designs typically withstand two to three times the working pressure before plastic deformation of the diaphragm begins. A single overpressure event will result in a non-repeatable measurement going forward.

SOI piezoresistive pressure transducers support operational ranges from low-pressure acoustics to 5000 PSI in miniature packages. This range of SOI pressure sensing has a high overpressure range. The yield point and the failure point of silicon are essentially equal resulting in a pressure transducer that typically reports valid (or overload) pressure measurements until extreme pressure – well above the rated operational pressure – permanently damages the pressure chip. The burst pressure is conservatively estimated at 3X to 5X the operating pressure range. Larger case sizes consistent with all-media, oil-filled pressure capsules support ranges from 2.5 PSID and 5 PSIA to 60,000 PSI. Ranges to 100,000 PSI are in development to support the testing of high-energy explosives and/or outfit hydraulic presses. Microsystem processing techniques result in predictable and controllable mechanical deformation and electrical response to input pressure.

Capacitive-based pressure transducers can be operated to very low full-scale differential pressures, 1” of water full-scale and lower. Mechanical stops can be designed into both SOI piezoresistive pressure sensors and into capacitive cells. Capacitive-based pressure transducers are typically limited to 10,000 PSI in the larger industrial formats due to the large diameter of the sensing plates and the mechanical housing required to maintain a sufficient pressure safety rating. Smaller gas panel and OEM models are capable of operating pressures to 25,000 PSI.

Thermal Response Time

Valid pressure measurements using SOI piezoresistive sensors are available within a few milliseconds of turn-on due to three factors: the minimal mass of the pressure chip, the low power requirements, and the predictable zero and span response to temperature. Any self-heating is minimal and localized to the SOI pressure chip. Metal-foil and some thin-film designs typically consume four to ten times the power of SOI pressure sensors with the strain gages spread out over a much larger surface area. Warm up times of one minute are typical for these designs. Due to their rather large sensing elements and inclusions of internal oscillators, capacitance-based transducers for general-purpose or industrial measurements typically take fifteen minutes or longer after turn-on to thermally stabilize and meet specifications. Some capacitive transducer designs contain internal heating elements that take thirty minutes to stabilize.

Compensation components used in SOI piezoresistive transducers are insensitive to temperature and are not in contact with the silicon diaphragm. These components control the excitation delivered to the pressure chip to continuously and automatically compensate the transducer sensitivity while electrically cancelling the sensor offset. The thermally stable passive compensation resistors may be placed some distance from the pressure sensor.

Metal-foil and thin-film designs use similar zero and span compensation approaches, but the added elements are temperature-responsive and therefore must be in the same thermal environment as the strain gages. This leads to long thermal settling times and poor performance during thermal transients. Capacitive pressure transducers typically have very poor response to thermal transients. Single cell transducers having large diaphragms tend to distort with temperature gradients. The two separate capacitive cells of industrial capacitive transmitter designs each have their own temperature sensor used in a digital compensation algorithm. Any gradient across the transmitter body will generate a response that is indistinguishable from pressure and well outside their quoted measurement accuracy.

Operating Temperature

The operating temperature of metal-foil pressure transducers is limited by the properties of the strain gage elements and the different TCEs of the components used in their construction. Constantan used in most metal-foil designs typically exhibits a continuous drift at temperatures above 150° F.[7] This characteristic drift coupled with the TCE mismatches between the strain gages, insulators, bonding agents, and diaphragm limit the compensated temperature range of the transducer. Thermal sets are common following excursions into the upper regions of the compensated temperature range. The zero stability of the metal-foil pressure transducer is the worst among general-purpose transducers.

Thin-film pressure transducers tend to be more thermally stable than metal foil designs due to the high purity and molecular bonding of the strain gages. Operating temperature ranges from -40° F to 250° F (-40° C to 121° C) and somewhat wider are common, but the compensation range is usually much more restricted. Much of the engineering in thin-film pressure transducers involves stress isolation of the sensing area from the other structures including the case, diaphragm, bellows, pushrods, etc.

Kulite SOI piezoresistive pressure sensing technology supports a wide range of operating temperatures. Kulite specifies a maximum operating temperature limit of 932° F (500° C) for the XTEH-10L-190 and ETL-GTS-312 products. SOI piezoresistive sensors mounted in all-media, hermetic oil-filled pressure capsules are compensated to temperatures as high as 400° F (204°C) in products such as the HEM-375. The HKS-11LP-375 and HKS-11HP-375 transducers are protected from extreme heating events for short-duration by ablative RTV coatings. Kulite compensates the cryogenic line of pressure transducers to -302° F (-185°C), but customers often use these products to within a few degrees of absolute zero -460°F (-273° C).

Capacitive sensors feature a high signal-to-noise (SNR) ratio due to the wide-ranging capacitance over input pressure, but also exhibit relatively high levels of intrinsic noise due to their high impedance. This characteristic dictates that the frequency to voltage conversion electronics must be located with the sensor to avoid the introduction of additional noise due to parasitic capacitance. The capacitive sensing elements are more challenging to thermally compensate as the diameter of the plates increase. These two factors limit capacitive-based pressure transducer to a typical compensated temperature range of 185° F (85° C) and lower. Capacitive pressure sensors have very low power consumption because current only flows for dynamic signals. The inherent ability to block DC current and electrical isolation of the plates makes the MEMS capacitive pressure sensor ideal for portable applications such as microphones in consumer-grade electronics.

Vibration

The reaction of any force-collecting diaphragm to acceleration is a function of its stiffness, mass, thickness and diameter. High-pressure metal-foil and thin-film designs are minimally susceptible to orientation, vibration, and mechanical shock. Their high natural frequency ranging from 10 kHz to 100 kHz is usually well outside the acoustic and vibratory signatures found in a test cell or industrial installations. Lower pressure ranges are often installed on vibration-isolating fixtures including cushioned pipe clamps to minimize the constructive interference of external vibration with the diaphragm or pushrod assembly. The installer should verify that excessive tightening of the clamp does not induce an offset.

The large size of capacitance-based transducers makes them especially prone to produce an unwanted output responding to input vibration, particularly when the acceleration vector aligns with the plate deflection. The diaphragms of each of these three older technologies are mechanically coupled to the input fitting. Special machining of a mechanical coupler or the use of a mechanical bellows is required to minimize the transfer of case stress to the sensing element. These structures will locate the force-collecting diaphragm away from the fitting by standing the diaphragm off the main body of the pressure transducer in a cantilever manner. Ceramic capacitive elements are particularly prone to failure when exposed to moderate levels of vibration.

The active area of the Kulite SOI piezoresistive sensor diaphragm is extremely small, has a low mass, and is very stiff. These characteristics result in a pressure transducer that is not only physically very strong, but also has a very low sensitivity to both acceleration and vibration. The resulting sensor provides valid measurements in highly vibratory environments and under extreme gravitational loading. Acceleration compensated pressure chips are also available that remove nearly any trace of acceleration-induced errors well above 10 kg. Packaging becomes the larger concern when high g loads are present. Kulite never includes electro-mechanical potentiometers on any modern transducer designs, but those components are routinely incorporated in metal-foil, thin-film, and capacitance pressure transducers.

Lifecycle Costs

Understanding the complete system lifecycle up front enables organizations to plan yearly budget forecasts with better accuracy. The lifecycle costs include outlays for capital equipment, system design, installation, operations, maintenance, repair/downtime, and replacement costs. The frequency of performance validation including in-situ or lab calibrations is often the single largest component of these lifecycle costs. Reducing the labor required to keep a transducer operating within its advertised performance can vary significantly depending on the sensing technology. Kulite transducer installations can offer significant savings over the life of a system. Several years ago, the Air Force established the calibration interval on many amplified Kulite, general-purpose transducers and transmitters to be 36 months… the maximum permissible within the service branch for this class of instrument.

The calibration stability of general-purpose SOI piezoresistive pressure transducers is excellent. Their high output sensitivity is nominally five times the signal of a corresponding metal-foil or thin-film transducer. Amplifier drift in a metal-foil or thin-film transducer is interpreted as a larger error than in a similar Kulite design. Low power (high gage resistance) is a selling point of some thin-film transducers. Gage resistance levels of 5 kΩ to 10 kΩ are common, but this increases the intrinsic noise level of the sensing element by a factor of five to ten over the Kulite design.[8] Coupling the lower output, higher drift, and added noise with the non-ideal transconduction of stress through the metal diaphragm or pushrod assembly place the metal-foil or thin-film transducer in an accuracy class below the Kulite SOI piezoresistive technology.

The typical calibration interval for metal-foil or thin-film transducers range from six to twelve months. Larger inventory levels must be maintained depending on the time required to complete the calibration process. The yearly costs for one or two calibrations includes notification, identification, process shut down, removal, transportation, inspection, calibration, documentation, and many of the same steps in reverse order to bring the system back on-line or return the transducer to inventory. Often, the costs of a single Kulite transducer are less than the two-year calibration costs of a competing pressure technology.

Some capacitance-based pressure transducers have very good long-term stability and accuracies approaching that of Kulite SOI piezoresistive designs. Typically, these transducers must be located in a thermally controlled, vibration-dampened environment for best results. These additional treatments increase both installation and design costs while reducing the pressure response time. Capacitance-based transmitters have been widely used in plant and process control application since the 1960s. However, their combination of very slow pressure response, high sensitivity to thermal gradients, large size, and higher cost makes their installation considerably less attractive than the installation of a Kulite SOI piezoresistive transmitter. Kulite general-purpose transducers perform to all specifications in very challenging thermal, acoustic, and vibratory environments with little or no additional design treatments

Accidental overpressure is the most common failure mechanism. Common sources include water hammer, pressure cycling at elevated line pressure, resonant frequency vibration, expansion due to freezing, point loading due to poor installation, or cleaning practices. Metal-foil, thin-film, and capacitance-based designs exhibit many types of behavior in response to a damaged diaphragm or over pressurized input. Often, these issues can go unnoticed for months without any clear indication of a problem. Pressure offsets slowly accumulate as the ductile force-collecting diaphragm continues to yield.

Kulite pressure transducers behave much differently to overpressure conditions. Normally, no accuracy loss is seen following relief from a pressure overload and a subsequent calibration verification. Failure of an SOI piezoresistive sensing element generally results in a complete loss of signal with the fracture of the silicon crystal or wirebond. This failure mode is immediately recognizable and the ensuing alarm condition would be available immediately to aid in the identification of the pressure overload source and in the later repair.

Conclusion

There are numerous advantages of the Kulite piezoresistive oil-filled, Silicon-on-Insulator construction approach over the metal-foil, thin-film, and capacitive sensing technologies. The basic manufacturing processes involved in fabricating these competing styles of transducers are essentially unchanged since the 1960s. The advances in the construction of Kulite SOI pressure transducers have been quite substantial since that time. The development of the oil-filled, hermetically sealed metal isolation diaphragm in 1978 and the incorporation of SOI sensor technology into the all-media, oil-filled sub-assembly in 1985 provided a low-mass, rugged, and reliable pressure transducer that decidedly and permanently changed the Aerospace, Test, and Measurement pressure transducer market.

SOI piezoresistive transducers have always been very stable and repeatable when used in accordance with the guidelines prescribed by the manufacturer. In many ways, SOI pressure sensors were ahead of their time. Advancements in SOI pressure sensing technology continue as the supporting electronics have improved and miniaturized. The arguments that SOI piezoresistive transducers are noisy and temperature sensitive are misplaced. It would be more correct to state that SOI piezoresistive transducers have excellent signal-to-noise performance, exhibit a wide bandwidth, and their small size makes them the ideal sensor for advanced thermal compensation.

The invention of the modern SOI piezoresistive pressure sensor preceded advancements in circuit miniaturization and electrical performance that now permit transducer manufacturers to take full advantage of the benefits provided by the SOI sensing technology. Increasingly, test and product development engineers are finding the Kulite SOI pressure transducer technology to offer superior performance over the older technologies when paired with complementary measurement electronics.

Piezoresistive pressure transducer accuracies can now approach those of working standard pressure transducers while simultaneously providing an excellent dynamic pressure response. Additionally, SOI piezoresistive pressure sensing supports the widest ranging environmental capabilities of any general-purpose pressure sensing technology. The overpressure capability and long-term stability of the SOI piezoresistive pressure sensor make this technology the ideal pressure sensing technology for most Aerospace and Industrial applications. It naturally follows that the most accurate electronic pressure calibrators and industrial pressure transmitters available on the market today are now designed using MEMS piezoresistive pressure sensors.

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