

STATIC-DYNAMIC TRANSDUCER

STATIC-DYNAMIC TRANSDUCER XTEL-SD-625



1) **Background:** The push to improve the efficiency of gas turbine engines has lead to an increase in flow instabilities within the combustion chamber of the engine. Detecting the earliest onset of these flow instabilities can help engineers manipulate the flow to re-stabilize it. If these flow instabilities are not addressed, they can grow in magnitude and severely damage the engine. The pressure within the engine is composed of a high static pressure (of the order of several hundred psi) together with a much lower dynamic pressure (on the order of several psi). High pressure transducers are typically unable to capture the acoustic level pressures that are characteristic of these flow instabilities because the signal generated from these low pressures is similar in magnitude to the noise within the system. To help gas turbine manufacturers detect and then solve such flow instabilities, Kulite Semiconductor Products Inc. has developed a piezoresistive sensor which combines on a single chip a differential low-pressure high frequency dynamic sensor together with a high-pressure static sensor. The composite sensor is shown in Figure 1. One may note that the sensing diaphragm of the dynamic sensor is much larger than that of the static sensor and is vented gage instead of absolute. To fashion such a sensor from a single slice of silicon one requires the same thickness but different dimensions obtaining, therefore, different sensitivities. The Kulite static-dynamic transducer, shown in Figure 2 and Figure 3, also uses innovative patented [1,2] low-pass mechanical filtering structures to insure that the dynamic gage pressure sensor will capture all high frequency pressure oscillations on the order of 10 psi or less that may exist within the high pressure environment of 200 psi and greater within the turbine engine. While this dynamic transducer measures the low-pressure oscillatory signals that may exist, a second, high-pressure static sensor within the static-dynamic transducer measures the large pressures in the engine of 200psi and greater. In this way, a single transducer is capable of measuring high static or quasi-static pressures, while simultaneously measuring low-pressure dynamic signals with a high signal to noise ratio.

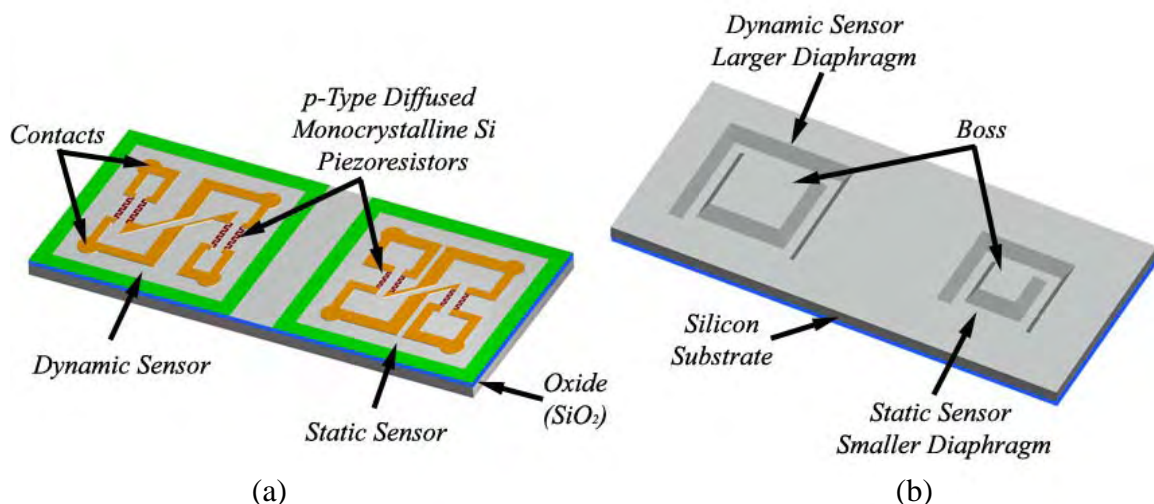


Figure 1: Front (a) and back (b) of static-dynamic silicon-on-insulator sensing elements.

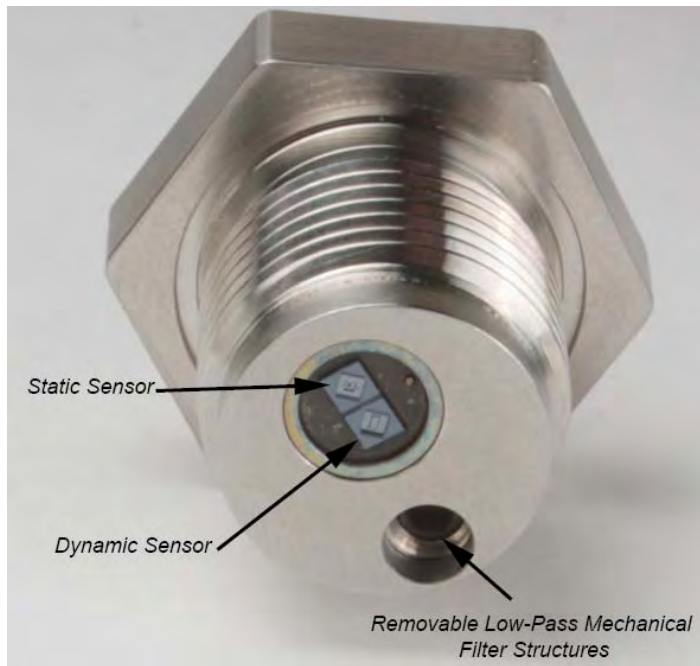


Figure 2: Photograph of static-dynamic sensors fabricated on a single structure.

- 2.) Installation and Operation: The static-dynamic transducer screws into a machined port on a gas turbine engine. The front of the transducer is capable of operation at temperatures up to 500°C (930°F). The backend of the unit and cable should be kept below temperatures of 350°C (662°F).

The static-dynamic transducer has a 5/8-24 UNEF-2A thread along with a high temperature nickel crush ring to form a seal with the engine surface at the 7/8in hex at the back of the unit. The sensors require a power input of 10VDC. There are two individual millivolt outputs, one that is for the large static pressure within the engine of 200psi and greater, and the second is for the acoustic-level oscillatory of a fraction of a psi to several psi. The innovative low-pass mechanical filter structures within the static-dynamic transducer were designed into a removable module (shown in Figure 4) since it is possible that the filter may become clogged with soot or dirt over time from engine operation. In the event the mechanical filtering structures do become clogged, the user can simply remove the filter module using a 1/16 inch hex key and either clean it or replace it with a new one.

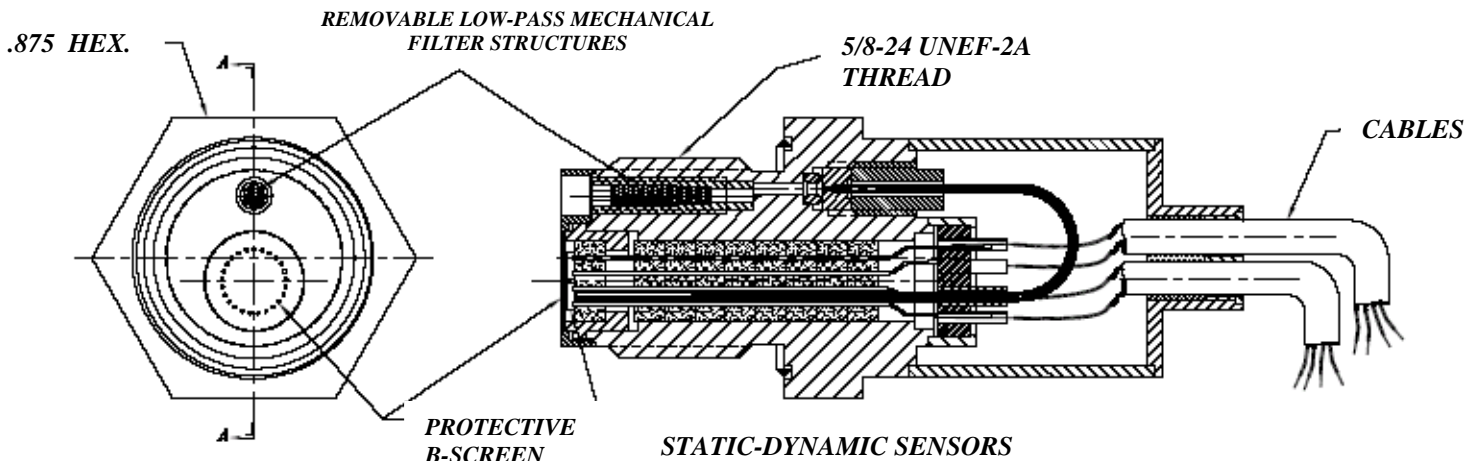


Figure 3: Static-dynamic transducer assembly

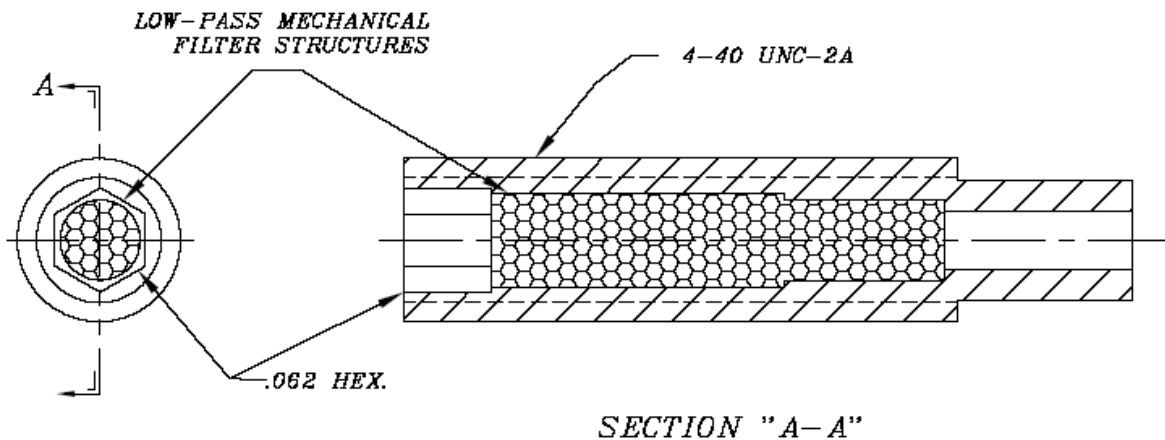


Figure 4: Filter module.

- 3.) Low-Pass Mechanical Filter Structures & Static-Dynamic Transducer Bandwidth: The key advancement of the static-dynamic transducer is its unique ability to detect low-level dynamic pressure signals within a high pressure environment through the use of a mechanical filter rather than an electrical filter. The static-dynamic transducer uses various mechanical structures to filter out high frequency dynamic pressure perturbations that may be superimposed on large static pressures. These large static pressures are then routed to the backside of the highly sensitive differential pressure sensor via a reference tube. In this way, the front of the differential sensor is exposed to the static plus the dynamic pressure, while the back is exposed only the static pressure. The sensor responds therefore to the difference of these two pressures which is the dynamic signal alone. Because the dynamic sensor responds only to the small dynamic signal, it is made much more sensitive than the static sensor without the danger of over-pressure.

To measure the larger static pressure a second sensor with a lower sensitivity is also included in the transducer. By combining the signals of the dynamic and static sensors, continuous ultra accurate pressure measuring is achieved in high pressure

environments. Thus, the static-dynamic transducer uses a pressure transducer designed to measure low pressures of less than 10psi to capture these low-level pressure oscillations rather than attempting to determine these pressure perturbations from a measurement made by a high pressure transducer, designed to measure large pressures of 200psi and greater.

Figure 5 below illustrates a typical situation where the static-dynamic transducer would be used. The actual pressure signal (shown in blue) is 2 psi peak-to-peak AC pressure which is superimposed on top of a 200 psi DC pressure. The static sensor (shown in red) can measure the DC portion of the signal, but its sensitivity is too low to effectively resolve the much smaller AC pressure. The dynamic sensor (shown in green), on the other hand, captures the AC pressure well because of its higher sensitivity. It filters out the DC pressure as is intended.

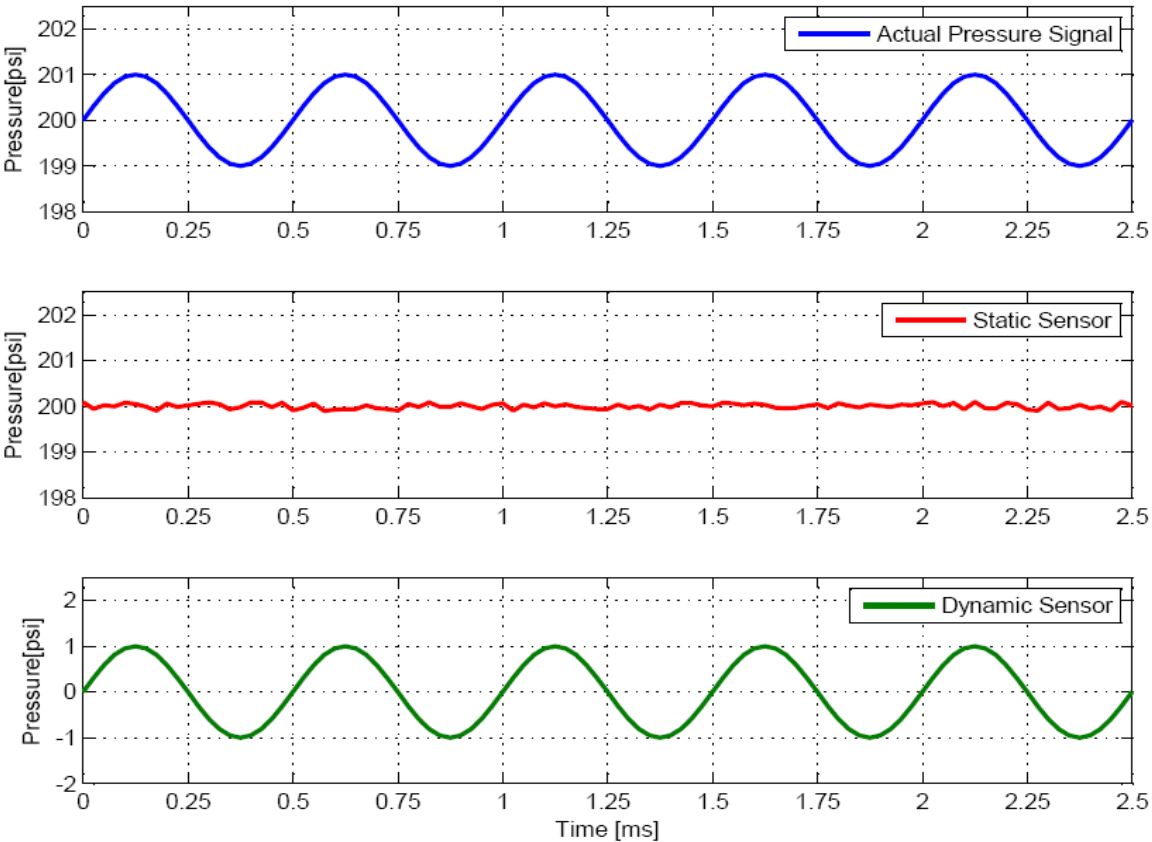


Figure 5: Outputs of the static-dynamic transducer for a typical pressure signal.

To characterize the frequency response of the static-dynamic transducer, a dynamic pressure source was swept from 10Hz to 2 kHz and a transfer function was computed. Figure 6 is a Bode plot of the dynamic transducer's performance.

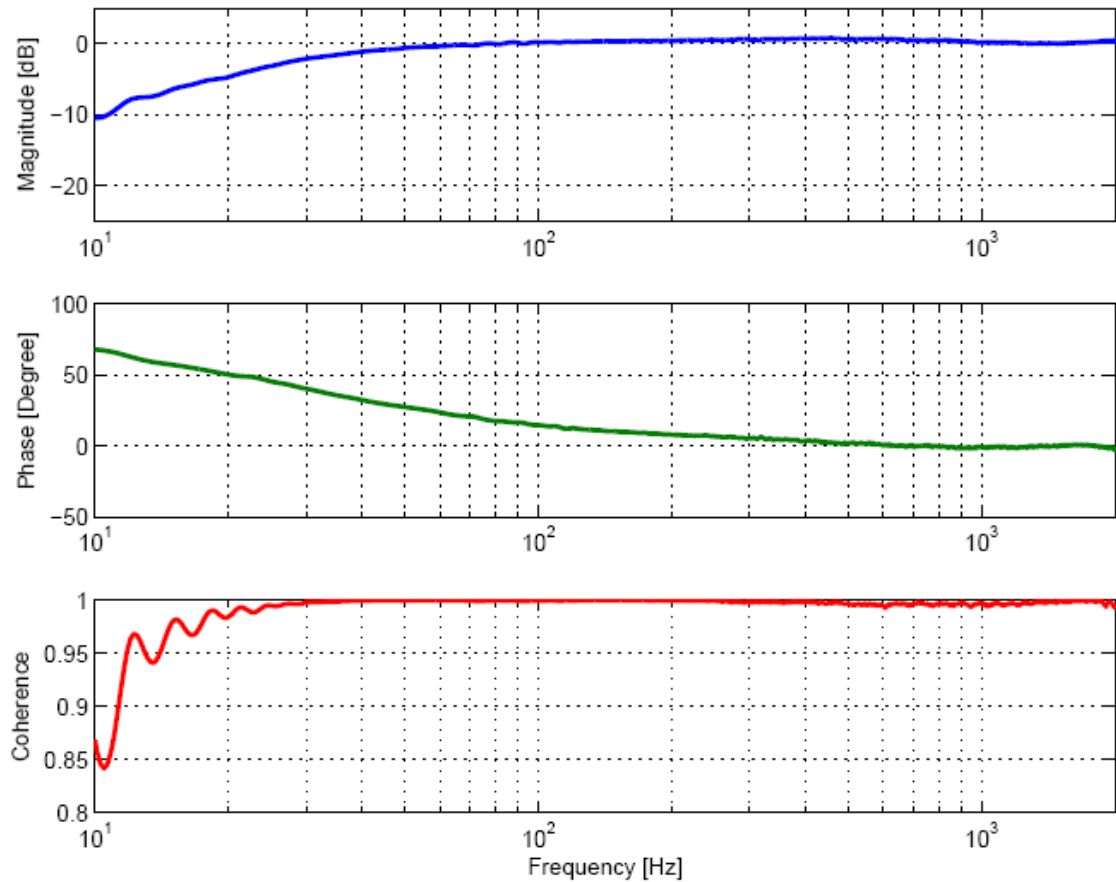


Figure 6: Dynamic sensor's spectral response.

The low-frequency cutoff frequency (-6dB) of the dynamic transducer is 15 ± 5 Hz. (This cutoff frequency can be adjusted if desired). The bandwidth of the dynamic sensor extends to greater than 10 kHz. The static sensor of the static-dynamic transducer likewise has a bandwidth of DC to greater than 10 kHz. It is important to note that the static sensor accurately measures the overall static and quasi-static pressures within the environment.

4.) Performance: Please see the attached data sheet for further specifications.

5.) References:

[1] Kurtz, Anthony D. "Pressure transducer for measuring low dynamic pressures in the presence of high static pressures." U.S. Patent 7,107,853, 18 September 2006.

[2] Kurtz, Anthony D., Shang, Tonghuo, and Kochman, Boaz. "Low pass filter semiconductor structures for use in transducers for measuring low dynamic pressures in the presence of high static pressures." U.S. Patent 7,188,528, 13 March 2007.