PCB PIEZOTRONICS
MTS SYSTEMS CORPORATION

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PLACEBO TRANSDUCERS: A TOOL FOR DATA VALIDATION

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For any testing in which the environmental operating conditions of a transducer vary with time and/or location, several requirements must be fulfilled before measurement uncertainty analysis is justified. Included among the requirements are good measurement system design practices, such as adequate low- and high-frequency response and data-sampling rates, appropriate anti-aliasing filter selection, proper grounding and shielding, and much more.

In addition to these requirements, data validation must be performed to establish that each transducer responds only to the environmental stimulus for which it is intended. For piezoelectric transducers, "placebo" (IEST-RP-DTE011.1) transducers enable data validation to be accomplished. The referenced IEST standard defines a placebo transducer as 'identical to a "live" unit in every parameter except for mechanical sensitivities.' The placebo transducer should respond only to extraneous "environmental factors." Ideally, its output would be zero. Any signal output from it would indicate that signals from the "live" transducers could be corrupted.

Some examples of test environments where validation should be performed include all flight tests, highly hazardous testing (blast, munitions, etc.), and electrodynamic shaker testing. In the latter example, in addition to acceleration, the shaker produces, as a minimum, temporally and spatially varying magnetic fields.

Every transducer responds to its environment in every way it can. For example, accelerometer specifications include their response to thermal, acoustic, strain, and radiation stimuli, to name a few. While accelerometers must have their response to acoustic pressure specified, pressure transducers must have their response to acceleration specified. Thus, one transducer's desired response becomes another's undesired response.

Transducer manufacturers try to minimize the effect of these undesired responses in the design process, but they can never be completely eliminated. These undesired responses can cause a change in transducer sensitivity or can result in additive, spurious signals at the transducer's output attributable to thermoelectric, electromagnetic, triboelectric and other self-generating noise phenomena. Since the test or instrumentation engineer has the best understanding of the test environment, he/she becomes responsible for data validation. The transducer manufacturer can assist by supplying "placebo" transducers to support this validation process. Let's now investigate how placebo transducers are manufactured.

Figure 1 shows a boule of quartz from which piezoelectric elements are cut to be integrated into the manufacture of force, pressure, and acceleration transducers. This boule possesses different piezoelectric properties for cuts in different directions, as illustrated by Equation set (1) below. While details of the system of equations aren't important for this discussion, note the third equation in the set shows there is one direction (z-axis) that produces no piezoelectric output. Cuts along this axis provide the quartz for placebo transducers.

$$
\begin{aligned}
P_{xx} &= d_{11}\sigma xx - d_{11}\sigma yy + 0\,\sigma_{zz} + d_{14}\tau_{yz} + 0\,\tau_{zx} + 0\,\tau_{xy} \\
P_{yy} &= 0\,\sigma_{xx} + 0\,\sigma_{yy} + 0\,\sigma_{zz} + 0\,\tau_{yz} - d_{14}\tau_{zx} - 2d_{11}\tau_{xy} \\
P_{zz} &= 0\,\sigma_{xx} + 0\,\sigma_{yy} + 0\,\sigma_{zz} + 0\,\tau_{yz} + 0\,\tau_{zx} + 0\,\tau_{xy}
\end{aligned}
\qquad (1)
$$

As opposed to piezoelectric transducers for pressure and force, which almost exclusively use quartz, many accelerometers use ceramic-based materials for their sensing elements. These ceramics result from complex manufacturing processes. The commonality of the processes is this: In order to behave in a piezoelectric manner, the ceramics have to have a high poling voltage placed across their electrodes at a high temperature during the final stages of their manufacture (as illustrated in Figure 2). If this poling is intentionally skipped, an inert sensing element is produced, and it can be used in a placebo transducer. Neither the z-cut quartz, nor unpoled ceramic placebo transducers, can produce a piezoelectric output. However, they do respond the same as a "live" transducer to the undesired environmental factors described previously.

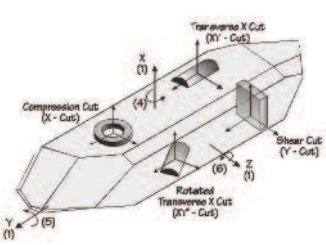

Figure 1:
Quartz Boule

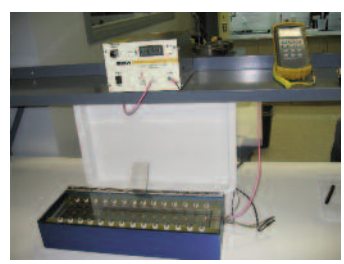

Figure 2:
Poling Ceramics

Finally, let's look at a couple of examples of the successful implementation of placebo transducers. Figure 3a and 3b, respectively, show the response of a placebo and an adjacent live transducer on an explosively loaded building. Both accelerometers are of the integral electronics (IEPE or ICP®) type. There is nothing about the highly complex signal of 3b (from the live transducer) that imparts confidence in the data. However, the zero-output from the placebo transducer in Figure 3a, even with its vertical scale expanded by a factor of 8 with respect to that of Figure 3b, builds confidence that the active or live transducer is properly responding to acceleration.

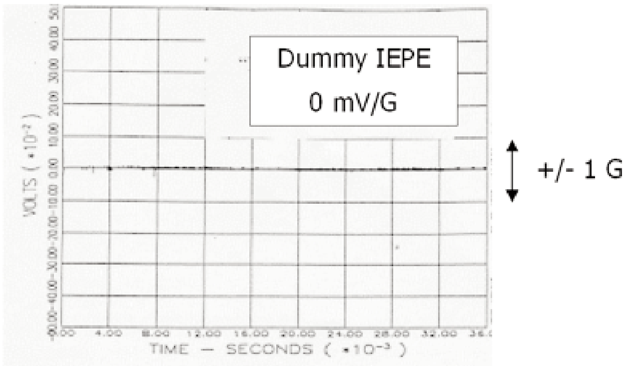

Figure 3a:
Placebo Transducer

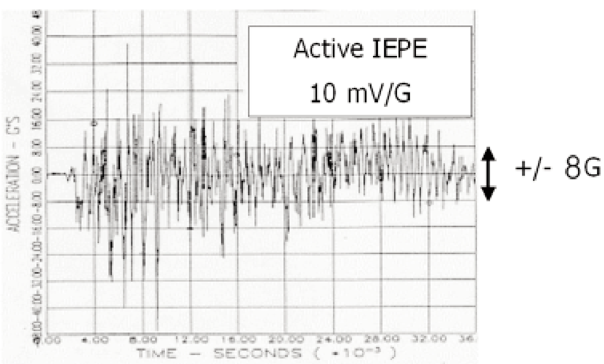

Figure 3b:
Live Transducer

Figures 4a and 4b further illustrate the value of integrating placebo transducers into a test. The uppermost three of the four records in each figure are from live accelerometers, and the bottom record from a placebo accelerometer. Each set of four accelerometers was assigned to a specific telemetry transmitter, the frequencies of which are shown, and the data recorded during a weapons test were subsequently noted to be anomalous. After the test, the set of accelerometers on the 239.4 MHz transmitter was removed from the system, mounted to a metal plate, and impacted with results shown below. The live accelerometers recorded data, as did the placebo! Not only that, but signals were emitted from all the accelerometers (live as well as placebo) on the 248.6 MHz channel, even though those accelerometers were not impacted. A ground loop was found to be the culprit, and bad data were not accepted as good. Design corrections to the measurement system were subsequently performed.

239.4 MHz

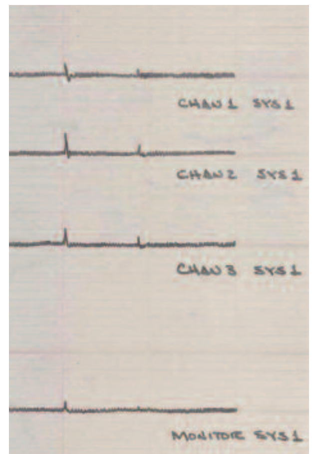

Figure 4a:
Transmitter 1

248.6 MHz

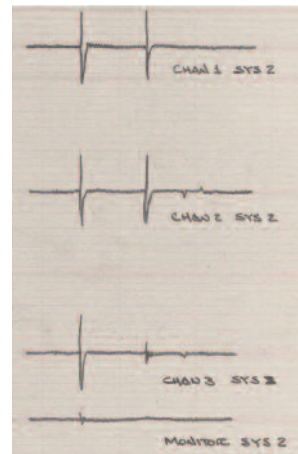

Figure 4b:
Transmitter 2

While the above examples have focused on acceleration data, as noted previously, placebo transducers are equally useful in dynamic testing, irrespective of whether force, pressure[1], or acceleration measurements are required. Their routine use should be encouraged.

Reference:

1. Walter, Patrick L., "Air-Blast and the Science of Dynamic Pressure Measurements", Sound and Vibration, pp 10-16, December 2004.

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