A Guide to Accelerometer Specifications

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Long ago, “Shake, Rattle and Roll” found a home in rock ‘n’ roll music. But shakes, rattles, and rolls are always out of place in safe and stable motor vehicles. If you’ve added all three to your vehicle’s “hit parade,” you’ll need accelerometers to measure them.

To help you choose the best accelerometers for your applications, we’ve prepared “sheet music”—specifications for a representative accelerometer—shown at right. Let’s go through the spec sheet item by item.

• **Accelerometer type.** Four accelerometer technologies compete to cover most applications. Piezoelectric accelerometers produce an electrical charge in response to mechanical stress, while piezoresistives alter resistance in response to stress. These devices don’t offer static-load (or DC) response but are suitable for most general-purpose and high-shock measurements.

   Capacitive accelerometers offer true static-load response. They work well for vehicular-suspension testing, which requires mathematical integration to obtain component velocity and position data.

   Microelectromechanical system (MEMS) sensors feature micromachined silicon mechanical components and integrated support electronics. Early versions used resistive elements. Today’s technology favors capacitive sensors to create truly integrated and very small accelerometers, typically packaged in surface-mount ICs. Besides instrumentation applications, tens of millions of MEMS accelerometers see service in automotive air-bag actuators.

• **Amplitude range.** Select an accelerometer by matching its output for expected acceleration levels. Don’t “crowd” the full-scale specifications. Allow a margin for unexpectedly large accelerations. Using only the lower 20% of an accelerometer’s response range will ensure ample margins for unpredicted overloads.

• **Shock limits.** The shock limit generally explains how many g’s of shock an accelerometer can withstand. Shock duration and impulse shape play a role, with narrow impulses causing more damage than broad-duration, relatively slowly changing shock pulses.

   Suspension tests impose unexpectedly high shock loads. If you choose an accelerometer for high-resolution, low-g measurements, then an unplanned encounter with a pothole could produce a 2000-g shock. That shock can damage an accelerometer, so make sure your sensor is resistant to shocks of 2000 g and higher.

   Protect your accelerometer investment. Never drop an accelerometer—a 2-in. fall onto a benchtop can easily generate a 2000-g spike, while a longer plunge onto concrete can produce more than 20,000 g. Store an unused accelerometer in its padded shipping carton, and only remove it for immediate, carton-to-UUT travel and installation.
Commodity-grade accelerometers for air-bag actuators that simply make a go/no-go decision sell for approximately $5 each in large quantities. In contrast, instrumentation-grade accelerometers cost from $100 to $1000 each—a strong incentive to protect these pricey components from damage or destruction.

### Spec Sheet for Sample Accelerometer

**Accelerometer type:** Piezoelectric, piezoresistive, capacitive, or MEMS

**Amplitude range:** ±500 g peak

**Shock limits:** ±2000 g peak for half-sine excitation pulse of 200 ms or longer

**Temperature range:** -50°C to +100°C operating, -65°C to +125°C storage/nonoperating

**Packaging:** Hermetically sealed stainless-steel cylinder measures 1.4 in. from base to 10-32 threaded coaxial connector face, 0.55 in. in diameter. Mounting consists of a 10-32 UNF by 1/2-in. stud protruding from 11/16 hex flange on lower end of cylinder.

**Weight:** 1.5 oz

**Base strain sensitivity:** & 0.02 g per microstrain (µe)

**Transverse sensitivity:** &2.5% for 1° positioning error

**Frequency range:** 1 to 2000 Hz, flat within ±5%
0.5 to 3400 Hz, flat within ±10%

**Sensitivity:** 10 mV/g ±10%

**Resolution:** ±0.02 g peak

**Amplitude linearity:** ±0.9% of full scale

**Temperature coefficient of sensitivity:** &0.05% per °C over operating temperature range

**Discharge time constant:** 1 s nominal

**Risetime:** &100 µs

**Excitation voltage:** 15 VDC to 30 VDC
• **Temperature range.** The maximum ambient temperature the accelerometer will encounter must not exceed the sensor’s operating temperature range (212°F, 100°C). Inside a closed vehicle, solar heat-soak temperatures can exceed 140°F (60°C). Inside the engine compartment, a hot exhaust manifold or catalytic converter can drive temperatures over 100°C.

For hot spots, charge-mode accelerometers can operate at temperatures up to 254 °C if you place your signal-processing electronics in a cooler area. Packaging methods and a piezoelectric element’s Curie-point temperature define temperature limits.

• **Packaging.** Depending on its location, an accelerometer may get splashed with (or immersed in) hot or cold hostile fluids ranging from fresh-water or saltwater, oil, and hydraulic fluids to engine coolants and battery acids or bases. Many accelerometers feature waterproof hermetic seals and titanium, stainless steel, or plastic packaging. So, choose appropriately for the test’s chemical environment. Chemical exposure can also damage cables and connectors. Avoid using delicate laboratory-rated accelerometers in a field-measurement environment.

You also need to select an accelerometer based on its size relative to the component under test. For example, attaching a relatively massive accelerometer to a sheet-metal panel will alter the panel’s mass load and its vibration frequency. An accelerometer that approximates a weightless point with respect to the UUT’s mass and dimensions will maximize accuracy. As a rule of thumb, select an accelerometer whose mass and mounting dimensions don’t exceed 1% of those of the UUT.

• **Base strain sensitivity.** If you use a stud-mounted accelerometer and tighten it against a concave surface, you strain the accelerometer’s base and alter its sensitivity. Avoid overtightening, and consider welding flat mounting pads onto a UUT’s uneven surfaces. Ensure that an added mounting pad will not significantly alter mechanical properties (for example, stiffness) of the UUT.

• **Transverse sensitivity.** To achieve specified accuracy, make sure the accelerometer’s preferred axis aligns precisely with the direction of the acceleration you’re measuring. A small offset misalignment introduces a lateral-acceleration error vector into the straight-line measurement. Alignment methods vary with UUT configuration and accelerometer design and accessibility—consult the accelerometer’s manufacturer for suggested methods.

• **Frequency range.** Specification sheets often omit important data such as flat-frequency response range. For example, an accelerometer specification offering “... flat response to 5 kHz (–3 dB)” describes a 30% high-end response loss—that’s hardly “flat.”

To clarify any confusion, use a calibrated shaker table to search for an accelerometer’s resonances and to explore its frequency and phase responses.

As with amplitude response, avoid “crowding” the frequency-response limits. An undamped accelerometer’s amplitude vs. frequency response may peak sharply near its upper end due to internal components’ mechanical-resonance frequency. For accurate measurements, use only the lower 20% of the accelerometer’s response curve.

For a damped accelerometer, ensure accurate response by plotting the device’s phase shift vs. frequency. Consider the accelerometer’s response as flat below its 908 phase-shift frequency.

• **Sensitivity.** After you select an accelerometer that can survive predicted worst-case shock limits, compute the sensor’s output voltage. At a sensitivity of 10 mV/g, for example, an accelerometer that encounters a 100-g shock will produce a 1-V peak signal. Make sure that your data-acquisition system’s sensitivity and range of linear operation can accommodate the accelerometer’s
• **Resolution.** A minimum-resolution specification of 0.02 g, which corresponds to a voltage of 200 mV, establishes a lower sensitivity limit analogous to a “noise floor.”

• **Amplitude linearity.** Next, account for any nonlinearity error, which at 0.9% of full scale (500 g) corresponds to 4.5 g. If you’re using 20% of full scale range, you’d expect a 0.9-g linearity error.

• **Temperature coefficient of sensitivity.** A comprehensive accelerometer spec sheet includes a value for temperature coefficient of sensitivity. Yet, other parameters that aren’t characterized on the spec sheet may also change as a function of temperature.

If you configure a test vehicle in a warm building and drive it outdoors into a Minnesota winter, or expose a crash-test vehicle to hundreds of kilowatts of illumination, consider thermal transients and allow time for stabilization. When in doubt, thoroughly characterize your accelerometers at multiple temperatures between high and low extremes.

• **Discharge time constant.** For nonstatic (non-DC) accelerometers, discharge time constant defines the lower-frequency corner (or -3-dB departure from midband amplitude) of the accelerometer’s response. One time constant after application of a step-function change in acceleration, the sensor’s output will fall to 63.7% of its initial value.

• **Risetime.** Typically specified as a 10% to 90% value, risetime defines an accelerometer’s response to a step-function transient (that is, when the sensor’s output will reach 90% of its final value). Risetime relates to the accelerometer’s high-frequency response.

• **Excitation voltage.** This value specifies the allowable voltage range you can use with an accelerometer. While manufacturers specify a range of excitation voltage or current, use a well-regulated, well-filtered power supply to nail down one more potentially variable factor affecting measurements.

### Calculate Errors

After you select an accelerometer, you must evaluate the sources of measurement errors and quantify them. Compute the root-sum-square of all possible errors to arrive at a value for measurement accuracy. Note that two readings differing by 1% within a 5% error margin don’t differ significantly.

Don’t overlook installation-related error sources. Mechanical compliance (stiffness) of its interconnecting cables can alter an accelerometer’s response. Cable defects can render a sensor useless. For example, high-compliance silicone rubber-insulated cables mounted beneath a vehicle’s chassis may fail quickly due to chemicals and abrasions, while Teflon-insulated cables survive in style. If you use piezoelectric accelerometers, be sure to select cables built with special lubricants between insulation layers to reduce errors due to triboelectric effects.

Accelerometers equipped with connectors simplify installation and wire routing, but the junction between accelerometer and cable connectors typically requires sealing to prevent moisture contamination. Rigidly attaching an accelerometer to its UUT via a thin layer of adhesive minimizes attenuation of high frequencies of interest, while a thicker adhesive layer or double-sided adhesive
tape dampens high-frequency response. A thin layer of grease between an accelerometer’s case and the UUT can improve high-frequency coupling.

If you use an accelerometer as a control element in a closed-loop test system, permanently mount the accelerometer on the UUT. If such an accelerometer becomes disconnected from the UUT, it will drive the system to its full uncontrolled output.

Before you perform actual tests, use “dress rehearsals” and make exploratory measurements at excitation levels below those that may damage the UUT. Thoroughly debug the procedure and data-acquisition processes before you commit the UUT to what’s often an expensive one-shot measurement.

If you are an electronically oriented test engineer who is unfamiliar with mechanical terminology, this step-by-step tour of an accelerometer’s specification sheet should help to ease you through the selection process. You will also find it helpful to compare several vendors’ specification sheets for allegedly identical products. Note any outstanding or missing parameters, and don’t be reluctant to question vendors.

Do you still feel challenged? Fortunately, most accelerometer vendors publish extensive application notes that supplement spec sheets and are worth reading for their technical content. And never hesitate to request advice from an accelerometer manufacturer’s applications-engineering staff. Chances are, someone else has already experienced—and solved—your “unique” measurement problems. T&MW

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