Piezo Film FAQs

Frequently Asked Questions

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Revised 2012-02-08

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Electrical:

E1 Does the film generate voltage or current?

A: Piezo film develops a voltage (potential difference) between its upper and lower surfaces when the film is stressed. This voltage arises from the generation of charge within the material. If this charge is removed by the external circuit, no further charge is generated until the stress is changed. Therefore the film does not produce any significant current, even though the voltage (with no load) may be very high.

E2 What is the electrical model for piezo film?

A: The overlapping electrodes on the upper and lower surfaces of the film form the plates of a capacitor (with capacitance given by $C = \varepsilon A/t$, where ε = permittivity, 106E-12 F/m, A = surface area of overlapping electrodes in square m, and t = thickness of film in m). A good electrical model for most applications is the place an "ideal" voltage source, with voltage directly proportional to mechanical stress or strain, in series with this capacitance. Normally the other side of the voltage source will be assumed to be connected to ground. Then the effect of placing a resistive load across the film can easily be seen – the load resistor forms part of a potential divider, with the film capacitance forming the other part. This network becomes a high-pass filter, with lower limiting frequency at $f_c = 1/(2\pi RC)$, where R is the value of the load resistor, and C is the film capacitance as calculated above.

E3 How can I look at the signals from a piezo sensor?

A: Signals from piezo film sensors are often observed using an oscilloscope, although it should be noted that even a 1 MΩ input resistance (as normally found using a simple "x1" probe) may not be high enough to capture all signals of interest. It is often better to use a "x10" or even "x100" probe (with 10 MΩ or 100 MΩ resistance respectively), even though the observed signal will be reduced accordingly. If the signals are very small, a preamplifier may be required. MEAS offers a suitable preamplifer (Piezo Film Lab Amp, p/n 1007214). There are many options regarding the selection of a digital oscilloscope – a good range of "virtual" instruments (modules that simply plug in to ports on PC or laptop) is available from Pico Technology (www.picotech.com)

E4 Why do I not see any low frequency signals?

A: Referring back to E2 above, it is very important that the lower limiting frequency $f_c = 1/(2\pi RC)$ is low enough to capture all the signals of interest. Another way to express this is that the "time constant" formed by the film's capacitance and the input resistance of the external circuit must be sufficiently long. If a step function of mechanical stress is applied, the voltage across the sensor will instantaneously change, but then the voltage will leak away into the external circuit. After one time constant, the voltage will have decayed to around 37% of initial value. One way to extend the time constant is, of course, to use a higher input resistance R. An alternative, if the signal levels are reasonably high, is to increase the source capacitance by adding capacitance in parallel with the sensor. This increases the effective C, but reduces the overall voltage.

E5 How do I get rid of 50Hz/60Hz noise?

A: Piezo film sensors are basically capacitors that develop charge within their dielectric, and are therefore very high impedance devices. It is very common to connect a sensor with one electrode connected to electrical ground, and the other as "signal". But this signal electrode may be very susceptible to electrical interference, unless another grounded surface is brought very close. It is sometimes possible to fold over a film element so that the ground electrode completely shields the signal electrode (our SDT1-028K element uses this principle). It is also possible to add a further ground electrode over the signal electrode by lamination, or simply to place the sensor within a shielded enclosure, or in close proximity to a large grounded plane. The wires connecting the sensor to an electronic circuit are also susceptible to electrical pick-up, and should be trimmed as short as possible, or if necessary replaced with shielded or coaxial cable.

E6 What sort of amplifier should I use?

A: Signals from piezo film may be considered to be either voltage or charge, so either a voltage-mode amplifier (with high input impedance, ideally 10 MΩ or greater) or a charge-mode amplifier may be used. Note that a "charge amplifier" does not actually amplify charge, but rather produces an output voltage proportional to charge input. The advantages of a charge-mode amplifier are that (a) the low frequency response of the amplifier is not affected by the capacitance of the film element, and (b) the presence of additional capacitance such as unstressed piezo film regions or cable capacitance does not influence the sensitivity or low frequency response. A charge-mode amplifier effectively "shorts out" the film, maintaining zero volts potential difference across the film and amplifier input, and all the generated charge flows directly onto the feedback capacitor within the circuit. In contrast, the aim of an ideal voltage amplifier is to present an open-circuit to the film so that no charge is withdrawn. In practice, either circuit can function well. In cases where no or little gain is required and only impedance-matching is important, a simple FET buffer may be used. Note that, in all cases, some finite low frequency limit for the circuit must be defined, or the electrical output may drift to rail due to slow thermal effects which create an electrical response from the film that cannot easily be distinguished from slowly changing stress.

The Piezo Film Lab Amp (MEAS p/n 1007214) offers either charge or voltage mode operation, allows down to 0.1 Hz measurement in charge mode, selectable low-pass filtering, and a wide range of gain options.

Mechanical:

M1 Can I measure force or pressure using piezo film?

A: Only dynamic (changing with time) quantities may be measured, and the limiting rate of change is related to the electrical time constant of the external electrical circuit (see E2 and E4 above). Static ("DC") quantities cannot be detected using the direct piezoelectric effect. Trying to measure very slowly-varying quantities is very difficult, as the electronic circuit requires very long time constant, and thermal response from the film (which is not normally observed when monitoring faster vibration signals) may become evident or dominant.

In addition, it is natural to think of detecting force or pressure as being applied normal to the film (i.e. in the direction of the film thickness). Although the film does indeed have sensitivity in this axis, it is often the case that the response to strain (change in length) will predominate. This is due to the 3D geometry of the film: generally, the cross-sectional area of a typical sensor is very much lower than the surface area, and so a tiny force in the stretch direction can create very high stress. Even when the film is bonded to a substantial and rigid block, it is quite possible for longitudinal strain to result from force applied in the thickness direction, and so the observed result can be a mixture of thickness-mode and stretch-mode response. It is extremely difficult, therefore, to observe a uniform sensitivity to normal force over a large area of film, and it is better to assume that the film will ONLY respond in stretch mode unless the boundary conditions are really unique. For this reason, we often describe a piezo film sensor as a "dynamic strain gauge".

The ratio of sensitivity (for a given unit of force applied) between stretch mode and thickness compression mode is usually several thousand to one.

M2 How can I bond the film to a substrate?

A: Because the film is flexible, compliant, lightweight, and usually has quite large surface area, it is very convenient to use pressure-sensitive adhesive in the form of tape (either double-coated, with an intervening carrier film, or as pure "transfer" adhesive in roll form with a release liner). Acrylic types have lower initial tack and a bond strength that increases after application. These can often allow repositioning of the sensor, and possibly re-use. It is of course possible to use liquid adhesives such as two-part epoxy resin, although these generally require mechanical clamping during the curing time, which may be inconvenient. It is rather difficult to ensure or maintain an even and predictable bondline thickness using liquid adhesives.

M3 Where can I find piezo film material data for my finite-element model?

A: The MEAS Technical Manual contains basic material properties, such as the piezoelectric "d" and "g" coefficients, Youngs Modulus, etc. However, most of the material properties are actually complex functions of time/frequency and temperature, and have natural batch-to-batch variation. MEAS has not published detailed studies. At time of writing, we would recommend a web search of the academic literature for specific parameters.

Film form/choice:

F1 What thickness of film should I use?

A: The voltage output of piezo film is directly proportional to its thickness, so thicker film means higher voltage – into an open circuit. But the capacitance of the sensor reduces with thickness. If the input resistance of the external circuit is fixed, then the low frequency limit of the system will be affected by the choice of film thickness. This can all be modeled relatively easily (see FAQ E2) but the net effect can often be that the selection of thickness is actually not too critical from the electrical point of view, and may be made from mechanical or film handling considerations.

F2 I want a smaller element of film – can I cut a larger sensor down to size?

A: If the film is a sheet with sputtered (vacuum-deposited) metallization, then yes, this may be cut to any shape using a fresh blade such as a surgical scalpel and a cutting mat. But if the sensor has screen-printed silver ink electrodes, then cutting through the overlapping electrode area will very probably create a short-circuit over the cut edge. Although we don't recommend this procedure, it may be possible to remove a region of ink from at least one of the surfaces first. Removal of the ink is not easy and generally requires using some solvent (e.g. acetone) in combination with rubbing action.

F3 How can I tell what metallization is on my film sheet?

A: Most of our elements are printed using silver-loaded ink. The ink surface is pale gray in color, and matt (although in some cases we print a very thin coating on top, which can give a shiny appearance). The great benefit of using silver ink is that patterns may be applied which create both overlapping (i.e. active sensor) regions and non-overlapping (i.e. conductor track, non-piezo) regions, as well as allowing "plated-through" holes which connect between electrode areas on opposite surfaces of the film. Vacuum-metallized or sputtered film has an appearance which is much more like a mirror. Our only standard product using this electrode form is simple sheet film.

F4 How can I etch the metallization to create a custom electrode pattern?

A: Only our metallized film can be etched (not the silver ink form). NiCu alloy and Cu-Ni dual layer metallization will etch using standard PCB etchant solution, although this will occur so rapidly that some dilution may be preferred). Etch-resist can be applied in a variety of ways: using standard photolithographic techniques in conjunction with laminated or dipped coatings, or by using etch-resist pen, or by physical masking using pressure-sensitive tape. MEAS cannot give detailed process information for etching.

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