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ELECTRONIC HARDWARE AG

MEASUREMENT SPECIALTIES

# Piezo Film Sensors

# Technical Manual

## Internet Version

## Part 2 of 18

Lead Attachment Techniques

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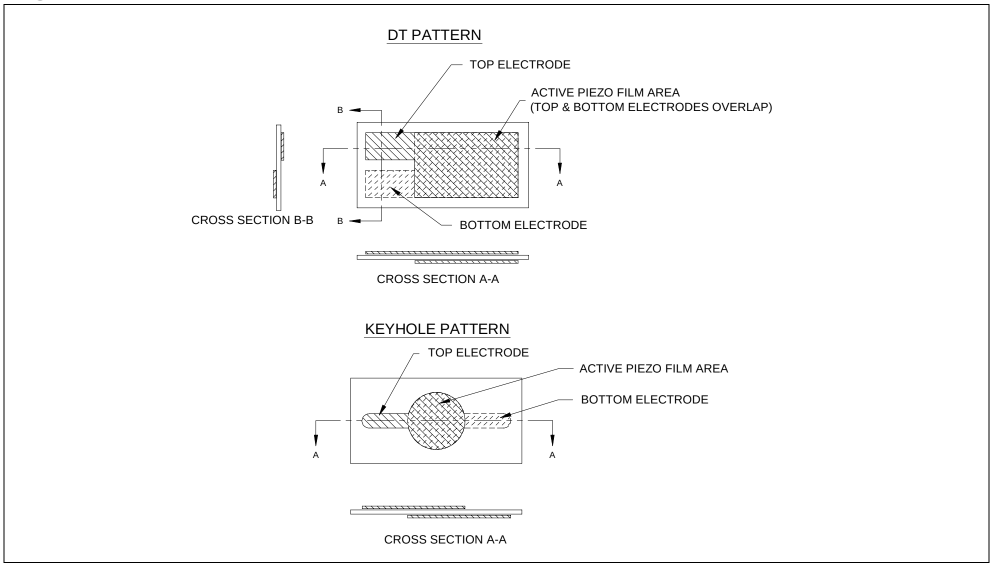
# LEAD ATTACHMENT TECHNIQUES FOR PIEZO FILM SENSORS

## Introduction

How to make reliable interconnection to piezo film is one of the most frequently asked customer questions. With this in mind, MSI has paid great attention to the development of techniques to simplify interconnection to piezo film elements. Today, most of the sensor elements supplied to customers from our Division have leads already attached. The aim of this article is to examine and discuss available interconnection options.

**Figure 3. Patterns**




Some of the most convenient interconnection techniques require that MSI apply patterned electrodes on one or both surfaces of the piezo film—this can always be done to customers' requirements during manufacture— alternatively, a simple method achieving the same goal is presented at the end of the text. In general, patterned electrodes are achieved during piezo film manufacturing by screen printing conductive inks, metal masking during sputtered electrode deposition, or chemically etching patterns by photolithographic techniques.

## The Targets

Considered here are the design objectives desired for the lead-attach method. Not all objectives can be achieved with any one technique. Designers should identify the most important objectives and select among the interconnection options accordingly.

- High conductivity/low resistance — surprisingly, high conductivity interconnection is not a particularly important parameter for most piezoelectric applications. Piezo transducers are frequently used in high-impedance circuits where inclusion of a few ohms does not usually affect performance. More important, however, is consistence—the resistance should not fluctuate during use since this will introduce a source of electrical noise.
- Low mass — this is especially important when the piezo film is not to be clamped to a mechanical support structure. The acoustic effect created by the mechanical vibration of the mass of the interconnection on an otherwise flexible structure can be dramatic.
- Low profile — many piezo film applications arise by virtue of the low thicknesses of piezo film. Interrupting this with bulk terminations is often prohibited. Contact vibration sensors can show distinct resonances if film is not bonded flush to the contact surface to include the interconnection. Flexibility — here again is a property that must often match that of the film itself. Some degree of flexibility is a distinct advantage in many applications.
- Low area — useful piezo devices can be quite literally be employed as "point" receivers. Small piezo-active areas (where the top and bottom conductors fully overlap) can be configured with

displaced or off-set lead-attach tabs. The top and bottom tabs are off-set with respect to each other (when viewed through the film thickness). This allows a precisely defined active area (overlapped electrodes) with non-piezo conductors (off-set tabs) leading to remote bonding sites, a technique most frequently employed for "small" devices.

- Mechanical Strength — very often the greatest strain experienced by a polymer transducer is around the connection, whether by accident (tripping over the cable) or by design. In general, those methods which involve the interconnection penetrating through the film at the off-set tab locations with crimps, eyelets or rivets yield the best ultimate strain resistance. Often the lead attach area is reinforced with polyester to improve the strength of the penetrative interconnection.
- Long-term Stability — including all the usual environmental parameters. Most interconnections have unlimited life (crimps, eyelets, conductive rubber connectors). Others have a more limited shelf life (conductive tapes)
- Speed and Ease of application — of particular importance when high volume production is planned. Many interconnection techniques are supported by semi-automatic equipment for volume production (crimps, eyelets) while others are labor intensive (conductive adhesives).
- Electrical strength — an issue associated mainly with electrically driven (high voltage) elements such as loudspeakers and actuators.

## The Design Considerations

Two major issues control the selection of lead-attach methods:

- Is anchorage of the film allowed at the site of lead-attach? This can be a major advantage, for example, direct connection to the conductive traces of a printed-circuit board.
- Is special patterning of the film available, which would allow penetrative techniques? (with MSI Sensors custom patterning service, the answer is almost always "yes.") Simple experimental methods allow the same result.

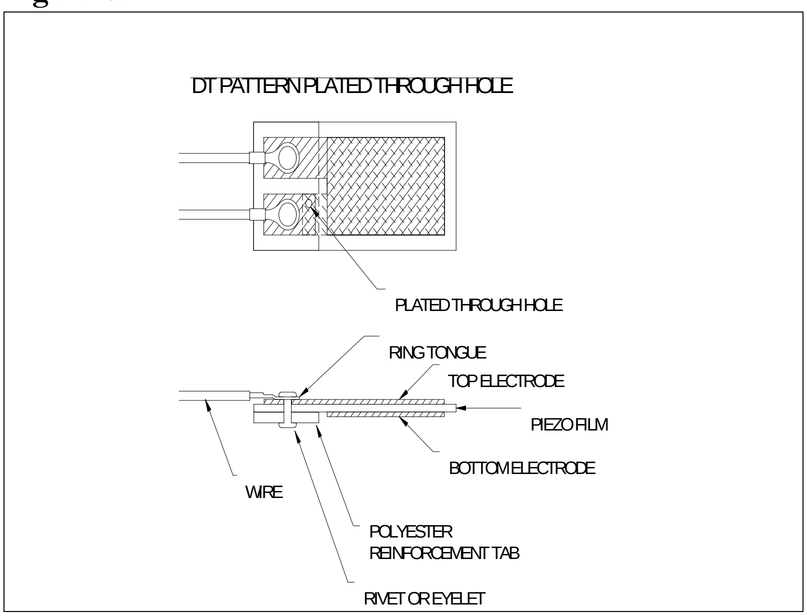
This concludes the "questions" section—now, hopefully, are the "answers."

## The Methods

Penetrative - Here the techniques involve piercing the film (and possibly additional reinforcing laminates to give sufficient thickness and strength), and thus the film should be patterned with a displaced or off-set lead-out arrangement to prevent shorting of upper and lower electrodes by the inserted connector. This can be done during manufacture or by the user.

- Rivets or eyelets can be affixed to the off-set conductive traces on the piezo film. Included between the eyelet or rivet can be a ring tongue lug terminal with wire attached.

**Figure 4.**



The eyelet or rivet mechanically presses the conductive ring against the off-set patterned electrode to make reliable interconnection.

- To affix the piezo film directly to a PCB, small "POP" or "blind" rivets or eyelets can be used in conjunction with patterned film electrodes and the conductive tracks on the PCB to allow a single operation to form the interconnection. During screen printing of conductive ink electrodes, a small “plated through hole” can be formed in one of the off-set tabs, thereby bringing both conductors to the same side of the piezo film. This greatly facilitates riveting the film electrode tabs to the corresponding PCB traces. If the “plated through hole” technique is not used, then the top film electrode can be electrically connected by the rivet to a conductive trace on the underside of the PCB. The bottom film electrode is electrically connected to a corresponding trace on the top of the PCB and held in intimate contact by the pressure exerted by the rivet.

**Figure 5.**

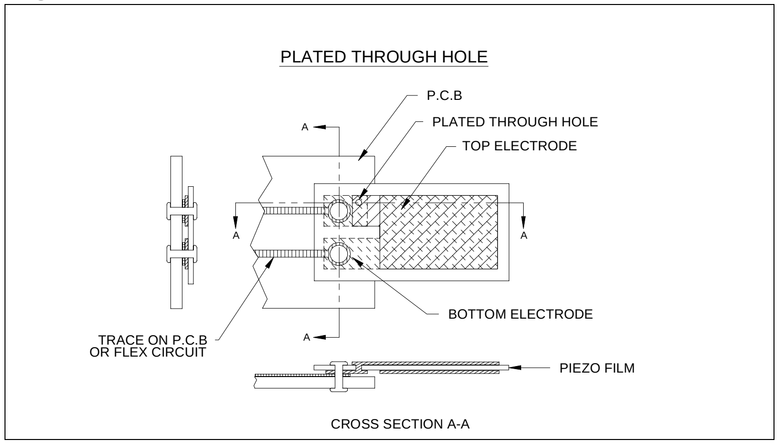
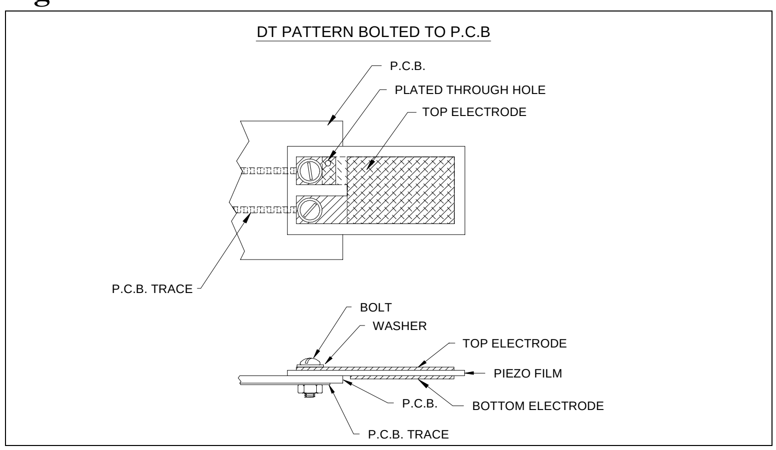


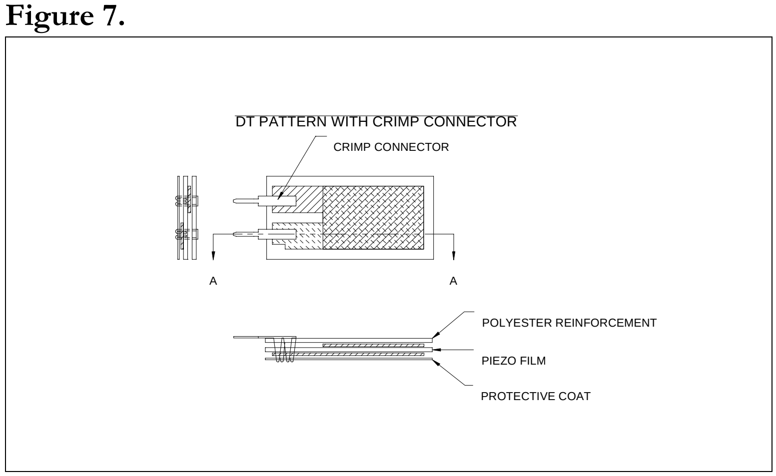

**Figure 6.**




- Nuts and bolts - Wires terminated with washers, ring-tongue lugs, solder-tags, etc. can easily be incorporated with small nuts and bolts.
- Crimp Connectors — generally, crimps designed for flexible circuit technology work well with piezo film elements. Crimps can have solder tabs for affixing wires, or the crimp ends can be inserted into corresponding holes in a PCB and soldered to the underside of the PCB (maximum of a few second soldering time so as not to overheat the film).

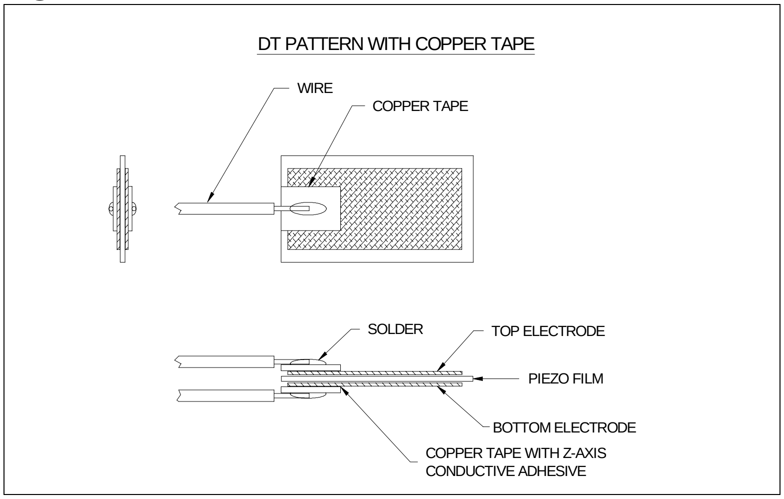
Like the eyelets mentioned above, crimps are normally designed to work with a specified thickness of "substrate," so film may require "padding" on one side (i.e., polyester reinforcement) to accommodate the crimp connectors. Additionally, a complete multi-way connector may be crimped to a more complex device, giving straight plug-in compatibility with other connectors.

**Figure 7.**



Non-penetrative - Conductive-adhesive coated Copper Foil Tape (e.g., 3M #1181)—available in widths from 3mm up to 25mm. Best results are obtained by...

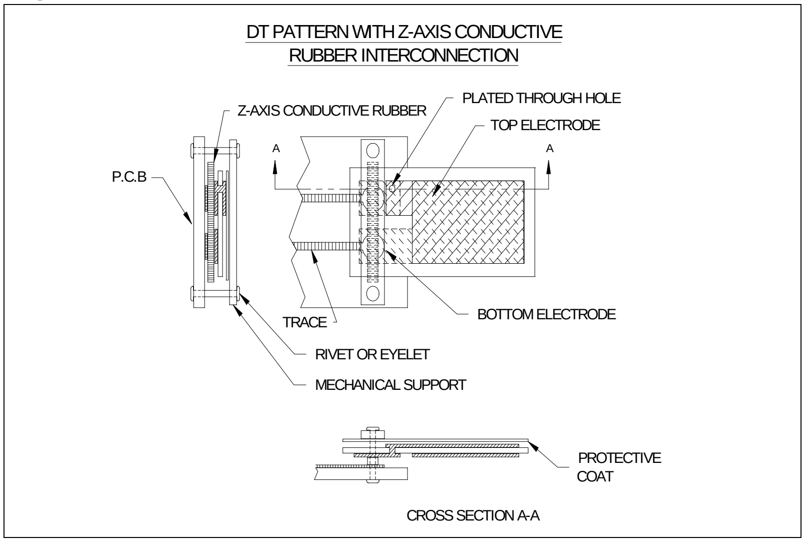
**Figure 8.**




- Using a "reasonable" area of tape (perhaps about 1cm or more). Small pieces do tend to lift off easily.
- Soldering wires to the tape FIRST, then removing the liner and adhering with gentle pressure to film. If small areas are to be used, solder before cutting the contact pad down to size, thus leaving the excess area to act as a heat sink. Soldering does appear to degrade the adhesive properties in the vicinity of the joint. NOTE: 3M does not recommend relying on the conductive adhesive in this way and suggest an embossed version of the same tape. The tape is really designed for large area contacts to metal, but results have shown this method to be an effective, if not guaranteed, technique. An aluminum version of this product is available (Part No. 1170). Beware of similar tapes that do not have conductive adhesives (although these can be used for shielding, etc.)
- Conductive Transfer Tape—e.g., 3M #9702 (Preliminary product). An acrylic adhesive layer loaded with conductive particles giving excellent "Z-axis" conductivity (i.e., through the thickness of the tape) with very high resistivity in the X and Y axes. Thus single or multiple-way connections may be made with a single strip. This material is relatively new. Initial results seem very promising. Obviously this can be used to make direct connection with PC board or strip, or to sections of foil with soldered leads.
- Negative aspects are a) high cost, and b) like all transfer adhesives, there is a tendency for the material to adhere to its own liners around the edge so that "stringing" occurs on liner removal. NOTE: Since time of writing, this product has been superseded by an improved version (#9703) with an easy-release liner. This may not yet be generally available.
- Conductive Epoxy. This is usually available in two-part form (adhesive and hardener). Precise metering and mixing of the small quantities usually required is rather difficult and messy. One-part, pre-mixed material is available as a product which is stored at very low temperature and should be used and cured at room temperature. Curing of any epoxy mix can usually be accelerated by use of higher temperature, but since the piezo film has a modest high-temp capability, curing is often a long term process (many hours, a day). Some mechanical clamping is usually required on the parts to be bonded. Again, sections of foil with pre-soldered leads can be used to spread the contact over a reasonable area. Final reinforcement with "ordinary" epoxy can be reassuring. Negative aspects: difficulty of use, cure time, higher cost, short "shelf life."
- Low melting-point Alloys—some alloys (e.g., Indium/Tin/Bismuth) which are known as "fusible alloys" rather than "solders," melt at temperatures which allow them to be used on Piezo Film with suitable metallization (e.g., gold, cooper, silver or silver ink). Rather aggressive fluxes are often required, and the joint may be brittle. Mechanical strength is limited by the adhesion of the metallization onto the film surface, so once again, reinforcement with epoxy may help. For joints that must be very small and do not need undue mechanical strength this may prove a valuable technique. Negative aspects: only certain metallizations are appropriate, sample quantities hard to come by. Mechanical strength limited [Indium Corp.]
- Zebra® Connectors — Conductive rubber spliced with insulating rubber as used to form contacts to LCD displays. High density multiple-way contacts may be made. External clamping of contacts is required.

- Mechanical clamping—simply sandwiching the film between two conductive surfaces (possibly using a thin layer of conductive-loaded rubber) can provide excellent results. Two rings can provide useful support for diaphragms, speakers, etc.
- Capacitive Coupling - In certain applications, no metal electrode is required on the piezo film itself. Thin, non-conductive adhesives can affix the unmetallized film to a conductive surface. The conductive surface in effect provides the film's electrodes in ac applications. A PCB, having conductive pads on one surface corresponding to the desired active sensor area, is an embodiment of this concept. The opposite piezo film surface can be metallized with a ground electrode. The film can be sandwiched between two conductive surfaces with or without adhesive to form electrodes.

**Figure 9.**




## User Etching of Piezo Film Electrodes

Patterned electrodes are available from MSI in either silver screen printed ink or as sputtered electrodes. In some instances, customers purchase fully metallized sheets for experimentation, and want to produce their own patterns. This is very difficult with screen printed inks as they cannot be easily etched or mechanically braided. For sputtered electrodes, standard photolithographic techniques work quite well.

In order to pattern Piezo Film in such a way as to allow penetration of film without shorting top and bottom electrodes, a very simple technique may be employed which works on any vacuum deposited electrodes (NOTE: not recommended for Ag Ink.)

One terminal of a power source (bench p.s.u. or 9 volt battery) is connected via a conductor pad or block by mechanical pressure to the piece of film in question. The other terminal is brought to a conductive point (needle, wire-end, blunt scalpel, etc.) and the area required to be isolated simply drawn around. Sufficient current normally passes to cause arcing at the point contact and the metallization is vaporized. Concentric "guard rings" may be drawn for extra confidence.

For more complex patterning of thin sputtered metallization, it is possible to coat the piezo film with photoresist aerosol (both sides if necessary). The cured spray can then be exposed through a mask using UV light, as with conventional PCB techniques, and then dipped in an etchant. Complete etching of the very thin metal layer occurs in seconds.

Copper/Nickel metallizations etch very well with standard PCB etchant (ferric chloride). Other metals require special etchants for good results (Aquaregia for gold). Remember that the metallization layer may only be a few hundred atoms thick (300-700 Å), and therefore fine traces are very vulnerable to scratching or cracking.

## High Voltage Techniques

The use of Piezo Film as a vibration exciter requires separate consideration. Since the impedance of a capacitive transducer decreases with frequency and approaches infinity for low frequencies, very high voltages (a few hundred volts typically) may be required to drive, for example, full audio-range loudspeakers. Frequently, transformers are used to step up moderate voltages to supply the required drive signal. Under these circumstances, extreme stresses may be placed upon the connections. Consider first applying a voltage step of 30V to a capacitor of 100nF with an overall circuit resistance of 2 ohms. The initial current pulse peaks at 15 amps (assuming the supply is capable of supplying this). Such a current "spike" may well show up defects in connectors.

Consider next a transformer which steps 12V signals up to 240V. A DC current in the primary of 200 μA (corresponding to an applied voltage of 0.5 volts), when broken, may cause a voltage surge of 830 volts across the secondary circuit, well in the excess of the expected X 20 magnification factor. Even with heavy capacitive loading, high voltages may be seen. Worse still, if the secondary circuit is broken, current pulses exceeding 60A with durations of only tens of nanoseconds may arise. Such phenomena should not trouble well-formed connections. But if a lead-attach method has been used which has any trapped air, the effect of the reduced dielectric constant may be to promote breakdown. Such events may be catastrophic, as the familiar crackling sound and lively blue sparks will testify.

Solutions are:
1. Silver ink electrodes are a must - the thin sputtered electrodes cannot withstand the high voltages
2. Large area contacts to reduce stress. We paint silver ink around eyelets/rivets to provide extra conduction paths to the film electrode.
3. (Possibly) a semi-resistive contact pad to reduce current surges—equivalent to including a series resistance in the circuit. Practical values up to about 1 k will produce only a fractional loss in output and will reduce the magnitude of current spikes.