ENDEVCO
AN AMPHENOL COMPANY

Endevco Model 12 Picochip™ Accelerometer
Surface Mount Technology Accelerometer

Technical Paper 298

ENDEVCO MODEL 12
PICOCHIP™ ACCELEROMETER
Surface Mount Technology Accelerometer

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INTRODUCTION

The ENDEVCO Model 12 Picochip is a high-performance piezoelectric accelerometer packaged as a surface mounted chip component. The Model 12 is engineered for integration in standard hybrid or SMT electronics packaging. The accelerometer may be mounted in a wide range of customer electronic packages for use with associated signal conditioning in miniature systems. Mounting hardware and cabling are eliminated. The accelerometer is physically and electrically integrated into the host electronics.

Potential applications include:

- **Avionics boards stress screening**
- **PC board vibration monitoring**
- **Crash sensing**
- **Transportation/ride monitoring**
- **Hybrid circuit OEM components**
- **Security Systems**
- **Medical and Health Monitoring**

The Model 12 Picochip is a piezoelectric accelerometer utilizing batch-processing technology to effectively compete in the same price-performance marketplace as micro-machined, silicon, piezoresistive accelerometers. However, the Model 12 is a self-generating transducer that requires no external electric power for operation.

Features and advantages of the Endevco Model 12 Picochip include:

- **Self-generating – no power required**
- **Rugged – no moving parts**
- **Easy to mount – no mounting hardware or cabling**
- **Small size/high output –wide dynamic range**

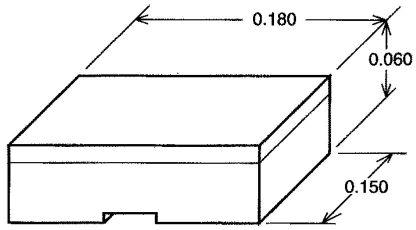
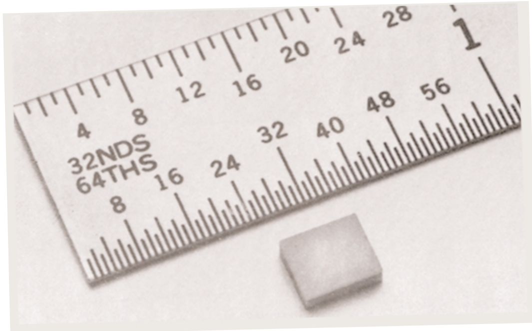


Figure 1: Endevco Model 12 Picochip™ Dimensions



SUMMARY OF TYPICAL PERFORMANCE

Dynamic	
CHARGE SENSITIVITY	2.0 pC/g
FREQUENCY RESPONSE (±5%)	1 to 2000 Hz
MOUNTED RESONANCE	10 kHz
TRANSVERSE SENSITIVITY (max.)	5 %
LONG-TERM SENSITIVITY STABILITY	< ±2%
Electrical	
TRANSDUCER CAPACITANCE	550 pF
TRANSDUCER RESISTANCE (minimum)	
At room temperature	10 GΩ
At maximum operating temperature	100 MΩ
Physical	
SENSING ELEMENT	PIEZITE® P-8
WEIGHT	0.003 oz (0.085 gm)
CASE MATERIAL	Alumina
MOUNTING	Conductive Epoxy
Environmental	
ACCELERATION LIMITS (in any direction)	
Vibration (sinusoidal)	500 g
Shock	1000 g
TEMPERATURE RANGE	–85°F to +302°F (–65°C to +150°C)
Calibration Data Supplied	
SENSITIVITY (at 100 Hz and 10 g pk)	pC/g
CAPACITANCE (at 1000 Hz)	pF

ENDEVCO

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OPERATING THEORY

The ENDEVCO Model 12 Picochip is a miniature piezoelectric accelerometer based on bimorph bender technology. It is a high-impedance output device which operates into a voltage-measuring circuit as an AC voltage source in series with the specified internal capacitance (as shown in Figure 2A), or into a charge-measuring circuit as an AC charge source in parallel with the specified internal capacitance (as shown in Figure 2B). The charge output Q_0 is the product of the accelerometer charge sensitivity (in pC/g) and the acceleration (in g). The voltage output V_0 (in mV/g) is the product of the accelerometer voltage sensitivity (charge sensitivity Q_0 divided by capacitance C_a) and the acceleration (in g).

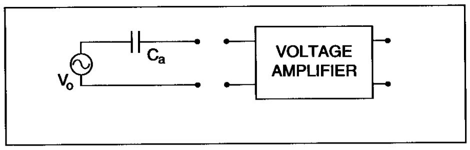


Figure 2A: Picochip Equivalent Circuit for Voltage.

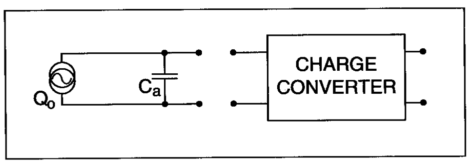


Figure 2B: Picochip Equivalent Circuit for Charge.

DYNAMIC RANGE: The effective dynamic range of the acceleration measurement is determined by the input signal/noise ratio of the signal conditioning circuitry at the low end, and by the accelerometer operating limits of 500 g sinusoidal and 1000 g shock at the high end. The unit is linear within 1% over this range.

TRANSVERSE SENSITIVITY: The sensitive axis of the Model 12 Picochip is normal to the mounting surface. Sensitivity to accelerations in the plane of the mounting surface is less than 5% of that in the sensitive axis (if the mounting bond thickness is not a constant, this transverse sensitivity will increase as the sine of the angle off normal).

POLARITY: The sensing polarity of the Model 12 Picochip is shown in Figure 3. Acceleration in the direction of the arrow (into the base of the accelerometer) produces a positive output on the electrode indicated.

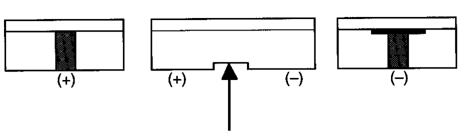


Figure 3: Polarity Indication

FREQUENCY RESPONSE: The effective frequency response of the acceleration measurement is determined by the signal conditioning circuitry at the low end, and by the accelerometer resonance at the high end.

For a voltage amplification circuit, the low frequency 3dB-down point is determined by the input resistance of the amplifier and the internal capacitance of the accelerometer ($f_{-3dB} = 1/(2\pi RC)$). For example, the 550 pF typical capacitance of the Model 12 requires a 30 megohm input impedance to set the –3dB corner at 10 Hz, providing 5% response down to 30 Hz).

For a charge converter circuit, the low frequency corner is set by the response of the charge amplifier.

The high frequency +5% point occcurs at about 20% of the resonant frequency, as shown in Figure 4. For the 10 kHz typical resonance of the Model 12, the 5% point is at 2000 Hz with no compensation. Simple frequency compensation may be used to extend the upper +5% point. (For the Picochip, inserting a 39kΩ series resistor between the accelerometer and the charge amplifier extends the 5% point to about 4 kHz.)

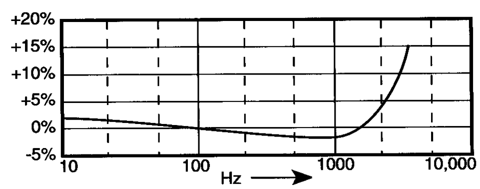


Figure 4: Typical Charge Sensitivity Deviation vs. Frequency

TEMPERATURE STABILITY: The charge sensitivity of the Picochip accelerometer is stable within ±2% from 0° to 80°C, and the typical deviation versus temperature is shown in Figure 5A. When used in a voltage amplification mode, the effect of the change in the source capacitance over temperature, as shown in Figure 5B, must be taken into consideration ($V_{sens} = Q_{sens}/C_a$).

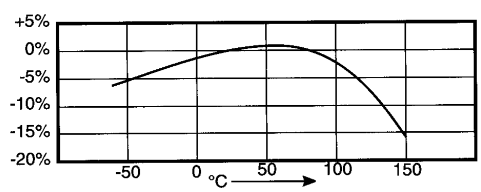


Figure 5A: Charge Sensitivity Deviation vs. Temperature

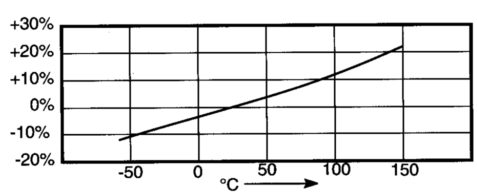


Figure 5B: Source Capacitance Deviation vs. Temperature

MOUNTING INSTRUCTIONS

The Model 12 Picochip is a fully operational accelerometer packaged as a surface mounted chip component. The enclosure is alumina and the two mounting pads have thick film gold metallization.

The unit may be installed on a circuit board or hybrid substrate using manual or automatic SMT mounting techniques. Due to the high-impedance level, the gap between circuit traces must be kept clean. The recommended conductive adhesive is Ablebond 85-1 gold epoxy, which conforms to MIL-STD-883C Method 5011. Silver epoxy is not recommended for high-reliability applications, because of its migration tendencies.

The following instructions should be followed for mounting protoypes using manual methods.

1. Apply approximately 1 milligram of epoxy to each contact on the accelerometer base, as shown in Figure 6A.

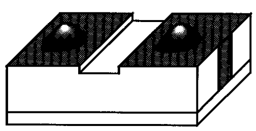


Figure 6A

2. Position the Model 12 accelerometer over the circuit traces (typical metallization on the hybrid substrate is shown in Figure 6B) and press into place with a force not exceeding 1 pound. The resulting bond thickness between the accelerometer and substrate should be approximately 0.001 inch.

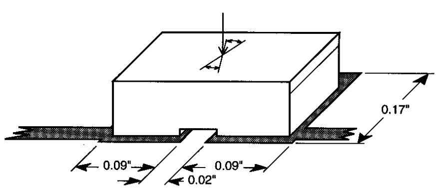


Figure 6B

3. Scrub the accelerometer over a <u>small</u> arc to distribute the epoxy evenly and to ensure that the accelerometer base is parallel to the substrate surface. Keep the angle of the arc small so that the epoxy cannot bridge the two contacts and short them together (the indentation between the contact is intended to reduce this possibility).

4. A bead of epoxy should be formed around the perimeter of the mounting feet, as shown in Figure 6C.

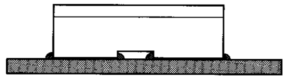


Figure 6C

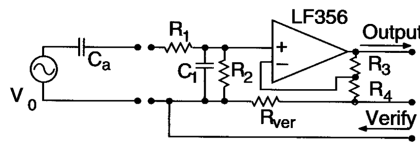
5. Cure the epoxy per the applicable specification. For Ablebond 85-1, cure at +150°C for 1 hour.

Other mounting techniques and adhesives may be suitable for your application.

RECOMMENDED CIRCUITRY

The Model 12 Picochip is intended to operate into user-supplied signal conditioning circuitry. The recommended circuit configurations are reviewed below.

VOLTAGE AMPLIFIER: A voltage amplifier can be built from a conventional operational amplifier, used in the non-inverting mode as shown in Figure 7A. The corner frequency of the –6 dB/octave low-pass filter is determined by $f_{-3dB} = 1/(2\pi R_1 C_1)$. This optional filter reduces the possibility of signal saturation due to high frequency vibration components. C_a and the input impedance of the amplifier set the corner frequency of the 6dB/octave high-pass filter.

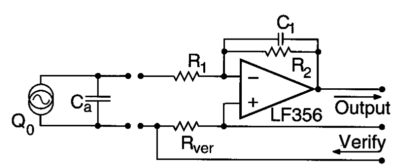


$$\frac{V_{output}}{V_0} = \frac{R_2}{R_1 + R_2} \times \frac{C_a}{C_a + C_1} \times \frac{\omega C_a R_2}{(\omega C_a R_2 + 1)(\omega C_1 R_1 + 1)} \times \frac{R_3 + R_4}{R_4}$$

For High Pass	-3dB @ 10 Hz	C_a = 550 pF	R_2 = 30 MΩ
For Low Pass	-3db @ 7 kHz	C_1 = 56 pF	R_1 = 390KΩ

Figure 7A: Voltage Amplifier Circuit

CHARGE CONVERTER: A charge converter can also be built from a conventional operational amplifier, used in the inverting mode as shown in Figure 7B. For an amplifier with high open loop gain and high input impedance, the gain of the charge amplifier is determined by the value of C_1 ($V_o/Q_0 = 1/C_1$). The corner frequency of the –6 dB/octave low-pass filter is determined by $f_{-3dB} = 1/(2\pi R_1 C_1)$. The corner frequency of the 6 dB/octave high-pass filter is set by $f_{-3dB} = 1/(2\pi R_2 C_1)$.



$$\frac{V_{output}}{V_0} = \frac{1}{C_1} \times \frac{\omega C_1 R_2}{(\omega C_1 R_2 + 1)(\omega C_a R_1 + 1)}$$

For High Pass	-3dB @ 10 Hz	C_1 = 550 pF	R_2 = 30 MΩ
For Low Pass	-3db @ 7 kHz	C_a = 550 pF	R_1 = 39KΩ

Figure 7B: Charge Converter Circuit

The circuits of Figure 7A and 7B also provide an optional verification feature. The resistor R_{ver} can be driven by an AC signal on the Verify line to provide a simulated accelerometer signal for checking out the system. In these circuits, the verify signal amplitude is determined by Vin = Accel Sens (mV/g or pC/g / C_a) x Desired g level.

NOTE: These high-impedance circuits should be located as close as possible to the Picochip, and the circuit traces should be carefully placed so as to minimize unwanted stray capacitance. Likewise, the circuitry should be located as far as possible from any noise and other interference. The accelerometer and input circuitry must be adequately shielded by a conductive enclosure to minimize EMI effects.

TYPICAL APPLICATION

The ENDEVCO Model 12 Picochip has been used in a number of innovative applications. One example is described below:

A Time Stress Measurement Device hybrid was designed by one of Endevco's customers to provide self-contained measurement of electrical and mechanical stress versus time for embedded circuit board application, or as the core for custom measurement modules. The device provides monitoring and digital storage of vibration, shock, temperature, dc voltages, and voltage transients. The functional block diagram of the hybrid device is shown in Figure 8.

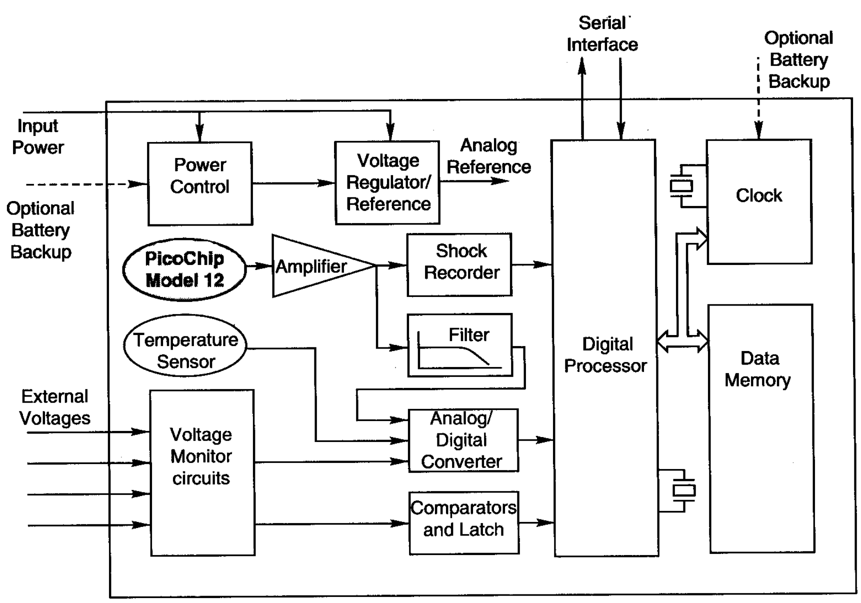


Figure 8: Functional Block Diagram – Time Stress Measurement Device

FEATURES

- 256K data memory
- DC voltage measurement
- Voltage transients counter
- Internal transient protection
- Real-time clock (with external battery)
- No external crystals required
- Internal temperature sensor
- Internal uniaxial vibration/shock sensor
- Transportation shock recording (with external battery)
- RS-232 interface
- Field-programmable recording parameters
- 5V (±10%) operation
- 1" by 2" hybrid flat pack (74 leads)

APPLICATIONS

- Environmental stress recorder for circuit boards
- Maintenance history record keeper
- Warranty verification
- Core for custom time stress measurement modules

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