POSTAL Book Package 2021

Instrumentation Engineering

Objective Practice Sets

Sensors & Industrial Instrumentation

Contents

MADE EASY Publications

5 CHAPTER

Piezo-Electric Transducers

Q.1 Piezoelectric crystal is generally employed for the measurement of which one of the following
(a) flow (b) velocity
(c) acceleration (d) temperature

Q.2 Rochelle salt is a crystalline material used in producing
(a) velocity transducer
(b) photoelectric transducer
(c) piezoelectric transducer
(d) differential transformer transducer

Q.3 Piezoelectric type of load cells can be used for measurement of
(a) dynamic forces only
(b) dynamic forces and static forces provided that the load cells have large time constant
(c) dynamic forces and static forces provided that the load cells have small time constant
(d) none of the above

Q.4 A typical piezoelectric pressure transducer has a range of
(a) 0 to 10 kPa (b) 0 to 100 MPa
(c) 0 to 700 kPa (d) 0 to 20 MPa

Q.5 The piezoelectric crystal sensitivity is defined as
(a) voltage developed per unit stress
(b) charge developed per unit stress
(c) voltage developed per unit force
(d) field developed per unit force

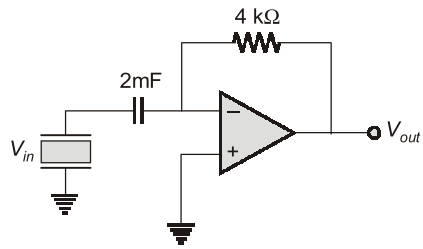
Q.6 A piezoelectric crystal has a sensitivity of 200 pC/N and a capacitance of 150 pF. The output voltage produced by the crystal when a force of 5 N is applied across the crystal, is _____ V.

Q.7 The voltage generated from 8 mm thick crystal having a sensitivity of 0.045 Vm/N if a pressure of 2 MPa is applied to it is _____ Volts.

Q.8 A piezoelectric crystal has a voltage sensitivity of 2 mV/N. When a static force of 10 N is applied to the crystal. The output generated by the crystal at steady state is
(a) 0 mV (b) 40 mV
(c) 20 mV (d) 19.6 mV

Q.9 A piezoelectric crystal is characterized by voltage sensitivity 14×10^{-3} V-m/N. It has a dielectric constant of 1.62×10^{-8} F/m and Young's modulus of 1.2×10^{11} N/m^2. Its diameter is 8 mm, thickness is 2 mm and a leakage resistances of $10^8\ \Omega$. The sensitivity of the crystal for the measurement of force is _____ V/N.

Q.10 A piezoelectric crystal transducer of 0.6 cm^2 area and 1 mm thickness is connected to a charge amplifier. The charge sensitivity of the crystal is 3 pC/N. The crystal is subjected to sinusoidal input force of $25 \times 10^{-3} \sin 160t$ N. This output is connected to the op-amp circuit on shown in the figure below.



The output voltage V_{out} is
(a) $-2.5\cos 160t$ (b) $-2.75\sin 160t$
(c) $-5.1\cos 160t$ (d) $-5.7\sin 160t$

Q.11 Output singla of a piezoelectric transducer is conditioned by a
(a) push pull amplifier
(b) charge amplifier
(c) emitter follower
(d) positive feedback op-amp circuit

Q.12 A piezoelectric transducer has an output voltage of 5 V at no load conditions. It has a capacitance of 500 pF. It is connected to a load capacitance of 150 pF. The voltage across the load at high frequencies is

(a) 3.33 V (b) 1.67 V
(c) 3.84 V (d) 5.67 V

Q.13 Piezoelectric type accelerometers

(a) should only be used for vibrations of low input frequency.
(b) have low natural frequency.
(c) can be used for measurement of very high input frequency.
(d) should not be used for vibrations of input frequency about 200 Hz.

Q.14 A piezo-electric transducer has a sensitivity of 40 pC/N. An output voltage of 2 V is produced when a force of 1 N is applied across the piezo electric crystal. The capacitance of the piezoelectric transducer is _____ pF.

Q.15 The output generated by the piezoelectric transducer is connected to an amplifier having an input resistance of 500 kΩ. The minimum output resistance of the crystal such that the loading error in the measurement should not exceed 1%, is _____ kΩ.

Q.16 A peizo-electric crystal having a Young's modulus of 2.1×10^9 N/m^2 is used as a load sensor. The crystal has a thickness of 1.2 μm and a diameter of 310 mm. The voltage sensitivity of the crystal is 6400 V/μm. The voltage produced by the crystal when a load of 300 N is applied an the crystal is _____ mV.

Q.17 A piezo-electric type accelerometer has a sensitivity of 150 mV/g. The transducer is subjected to a constant acceleration of 5 g. The steady state output of the transducer will be

(a) 0.6 V (b) 0 V
(c) 6 V (d) 10 V

Q.18 A piezoelectric crystal transducer of 0.6 cm^2 area and 1 mm thickness is connected to a charge amplifier. The charge sensitivity of the crystal is 3 pC/V. The crystal is subjected to a sinusoidal input force of 25×10^{-3} sin150t N. The peak to peak output voltage of the crystal, is

(a) 0.0375 Volt (b) 0.0416 Volt
(c) 0.0762 Volt (d) 0.0275 Volt

Q.19 A piezoelectric transducer has a capacitance of 2000 pF and a charge sensitivity of 20×10^{-3} c/m. The capacitance of connecting cable is 300 pF and that of the oscilloscope for the readout is 60 pF in parallel with a resistance of 2 MΩ. The sensitivity of the measuring systems is

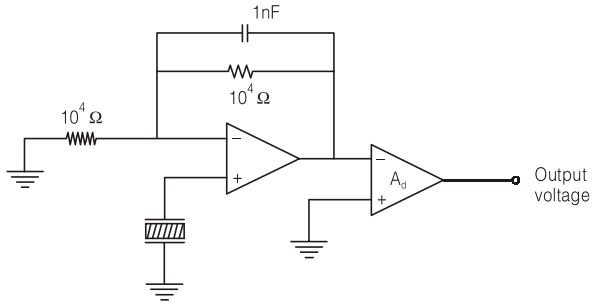
(a) 8.5×10^6 V/m (b) 10×10^6 V/m
(c) 15.5×10^6 V/m (d) 5.5×10^6 V/m

Q.20 A quartz crystal has a sensitivity of 80 pc/N. An output voltage of 2 V is produced when a force of 4 N is applied across the crystal. The capacitance of the crystal, is _____ pF.

Q.21 A piezoelectric pressure transducer gives an output of the 3 V per 270 kPa. The output of the transducer is connected to an amplifier having a gain of 20, with an infinite input impedance and zero output impedance. The output of the amplifier is connected to an oscillator having vertical sensitivities of 1, 10, 20 and 150 mV/mm. The viewing area of the oscilloscope section in 100 mm × 100 mm. The transducer is used to measure a pressure fluctuating at a frequency of 60 Hz between upper and lower levels of about 600 kPa and 50 kPa respectively.
Optimum setting of the vertical sensitivities is

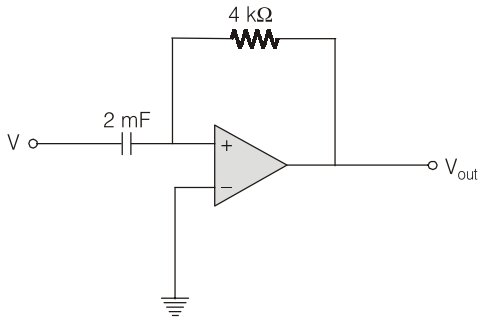
(a) 1 mV/mm (b) 10 mV/mm
(c) 20 mV/mm (d) 150 mV/mm

Q.22 A peizoelectric transducer is connected to the non-inverting input of an op-amp as shown in the figure below. The crystal has a charge sensitivity of 2.2pC/N and a capacitance of 1600 pF together with an internal resistance of 10^{12} Ω. It is connoted to charge amplifier as shown. When a force of 0.1 sin10 t N is applied to the transducer find the differential gain of the op-amp to get an output of 10 V.



(a) 16 (b) 18
(c) 14.5 (d) 15.5

Q.23 A piezoelectric crystal transducer of 0.6 cm^2 area and 1 mm thickness is connected to a charge amplifier. The charge sensitivity of the crystal is 3 pC/V. The crystal is subjected to a sinusoidal input force of $25 \times 10^{-3} \sin 150t$ N. This output is connected to the op-amp circuit as shown in the figure below:



The output voltage V_{out}, is
(a) $-0.25\cos 150t$ (b) $+0.62\sin 150t$
(c) $-0.51\cos 150t$ (d) $-0.57\sin 150t$

■■■■

Answers Piezo-Electric Transducers

1. (c)	2. (c)	3. (b)	4. (d)	5. (b)	8. (a)	10. (b)	11. (b)	12. (c)
13. (c)	17. (b)	18. (d)	19. (a)	21. (b)	22. (c)	23. (a)		

Explanations Piezo-Electric Transducers

6. (6.67)

$$\text{Sensitivity (S)} = \frac{Q}{F} = \frac{CV}{F}$$

$$200 \times 10^{-12} = \frac{150 \times 10^{-12} \times V}{5}$$

$$\therefore \quad V = 6.67 \text{ Volt}$$

7. (720)

$$V = S_v PD$$
$$S_v = 0.045 \text{ Vm/N}$$
$$= 0.045 \times 2 \times 10^6 \times 8 \times 10^{-3} \text{ V}$$
$$= 720 \text{ V}$$

8. (a)

At steady state the output genrated by piezo-electric crystal for static force is zero.

9. (0.557)

$$g = 14 \times 10^{-3} \frac{\text{V/m}}{\text{N/m}^2}$$
$$= 14 \times 10^{-3} \text{ Vm/N}$$

$\because \quad g = \frac{d}{\varepsilon}$

$$d = g\varepsilon = 14 \times 10^{-3} \times 1.62 \times 10^{-8}$$
$$= 22.68 \times 10^{-11} \text{ C/N}$$

Capacitance of the piezoelectric sensor, is

$$C = \frac{A\varepsilon}{t}$$

$$= \frac{\pi\left(\frac{8}{2} \times 10^{-3}\right)^2 \times 1.62 \times 10^{-8}}{2 \times 10^{-3}}$$

$$= 40.69 \times 10^{-11} \text{ F}$$

20. (160)

$$\text{Sensitivity} = \frac{Q}{F} = \frac{CV}{F}$$

$$80 \times 10^{-12} = \frac{C \times 2}{4} = 160 \times 10^{-12}$$

$$C = 160\ \text{pF}$$

21. (b)

The extreme pressure of 600 kPa and 50 kPa given the output voltage, as

$\frac{3}{270} \times 600 \times 20$ and $\frac{3}{270} \times 50 \times 20$ respectively

i.e.133.33 mV and 11.11 mV respectively

The corresponding peak to peak voltage are 2×133.33 mV and 11.11×2

$\Rightarrow$ 266.67 mV and 22.22 mV respectively

Suppose we use the oscilloscope sensitivity of 1 mV/m

$\therefore$Deflection on the screen corresponding to maximum pressure = 266.67/1 = 266.67 mm

Since, the length of the screen of the oscilloscope is 100 mm, the waveform is out of range and hence the sensitivity setting of 1 mV/mm should not be used.

For sensitivity 10 mV/mm

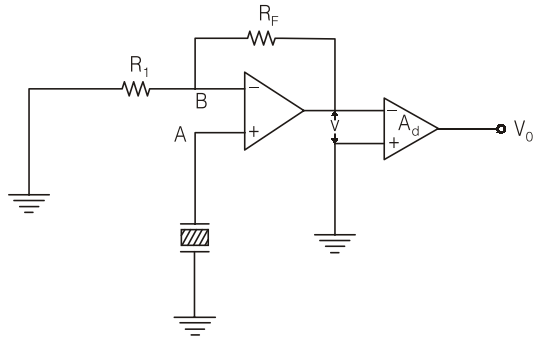
the peak to peak deflection

$$= \frac{266.67}{10} = 26.67\ \text{mm}$$

this is within the range of oscilloscope

also, 20 mV/mm and 150 mV/mm are within, the range but have 10 mV/mm is the optimum.

22. (c)



$$F = 0.1 \sin 10\,t$$

$\therefore$ $\omega = 10$

$$R_F = 10^8 \| X_c = 10^8 \| \frac{1}{\omega C}$$

$$= 10^8 \| \frac{1}{10 \times 10^{-9}}$$

$$= 0.5 \times 10^8\ \Omega$$

$$R_1 = 10^4\ \Omega$$

$$V_A = \frac{Q}{C_P} = \frac{2.2 \times 10^{-12} \times 0.1 \sin 10t}{1600 \times 10^{-12}}$$

$$= 0.1375 \sin 10\,t\ \text{mV}$$

$$V = \left(1 + \frac{R_F}{R_1}\right) V_A$$

$$= \left(1 + \frac{0.5 \times 10^8}{10^4}\right) \times 0.1375 \times 10^{-3}$$

$$= 0.6875\ \text{volts}$$

$$A_d = \frac{V_0}{V} = \frac{10}{0.6875} = 14.5$$

23. (a)

$$V_{out} = \frac{1}{RC} \frac{d}{dt}(V)$$

$$V = \frac{Q}{C} = \frac{KF}{C}$$

$$= \frac{3 \times 25 \times 10^{-3} \sin 150t}{8.85 \times 10^{-12} \times 0.6 \times 10^{-4}}$$

$$= 0.1375 \sin 150t$$

$$V_{out} = -\frac{1}{2 \times 10^{-1} \times 4 + 10^3} \frac{d}{dt}(0.01375 \sin 150t)$$

$$= -\frac{1}{8} \times 0.01375 \times 150 \cos 150t$$

$$= -0.25 \cos 150t$$

■■■■