Fig. Equivalent circuits of piezoelectric transducers.

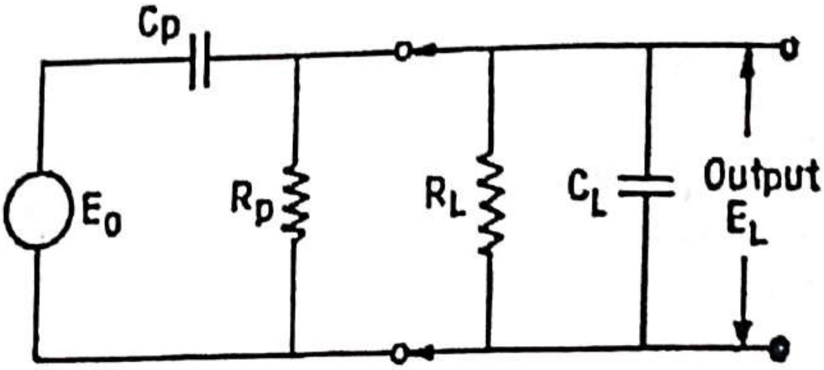
The charge generator can be replaced by an equivalent voltage source having a voltage of

$$E_0 = \frac{Q}{C_p} = \frac{dF}{C_p}$$

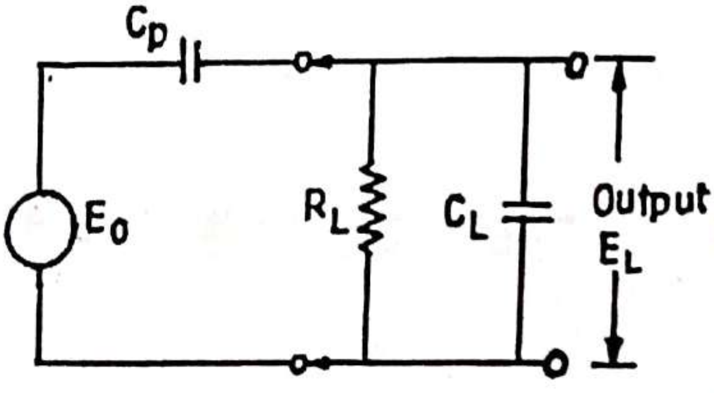
in series with a capacitance, C_p, and resistance, R_p, as shown in Fig (b).

Loading Effects and Frequency Response

Let the transducer loaded by a capacitance C_L an a resistance R_L. The capacitance C_L is the combina capacitance of the load, the capacitance of the cable and the stray capacitance. The diagram showin connected to a piezoelectric transducer is given in Fig. (a).



(a)



(b)

Fig. Circuit of a Piezoelectric crystal under conditions of load

The value of leakage resistance, R_p, of the crystal is very large. It is of the order of $0.1 \times 10^{12}\ \Omega$. The load resistance, R_L, is considerably smaller than R_p and hence the equivalent circuit of the Piezoelect load conditions is as shown in Fig. (b) In which the leakage resistance, R_p, of the crystal has been dropp

- The voltage output of the transducer under no load conditions, is therefore E_0. Under conditions

Impedance of load $\quad Z_L = \dfrac{R_L}{1 + j\omega C_L R_L}$

Total impedance of circuit $Z_t = \frac{1}{j\omega C_p} + \frac{R_L}{1 + j\omega C_L R_L} = \frac{1 + j\omega R_L (C_p + C_L)}{(j\omega C_p)(1 + j\omega C_p R_L)}$

Hence, the voltage across the load,

$$E_L = \frac{Z_L}{Z_t} \times E_L = \frac{R_L}{(1 + j\omega C_L R_L)} \times \frac{(j\omega C_p)(1 + j\omega C_p R_L)}{1 + j\omega R_L (C_p + R_L)} E_0$$

The magnitude of voltage across the load is :

$$\therefore \quad E_L = \left[\frac{\omega C_p R_L}{\sqrt{1 + \omega^2 (C_p + C_L)^2 R_L^2}} \right] \text{as } E_0 = \frac{dF}{C_p}$$

$$= dF \left[\frac{\omega R_L}{\sqrt{1 + \omega^2 (C_p + C_L)^2 R_L^2}} \right]$$

At medium and high frequencies:

$$\omega^2 (C_p + C_L)^2 R_L^2 >> 1$$

$$\therefore \quad E_L = \frac{E_0 C_p}{(C_p + C_L)}$$

Thus at medium and high frequencies, the response is independent of frequency, but is dependent upon C_L, i.e. the capacitance of load circuit. In practice this transducer is nearly always coupled to virtual Earth point of an amplifier which has a feedback capacitor, this arrangement being known as charge amplifier.

From Eqn. it is clear that under steady state conditions i.e., when $\omega = 0$, the transducer does not provide any output. As far as the maximum frequency limit is concerned, it is imposed by the mechanical resonance of the piezoelectric crystal and its associated mountings.

The piezoelectric transducers are mainly used for measurement of displacement. They can be used for measurement of force, pressure or acceleration. These quantities when measured with piezoelectric transducers are first converted into displacement and the displacement is subsequently applied to these transducers to produce an output voltage. Hence the conversion of displacement into voltage by piezoelectric crystals is considered here.

For the purpose of analysis it is necessary to consider the transducer, the connecting cable and the amplifier as a unit. The impedance of the transducer is very high and hence an amplifier with a high input impedance has to be used in order to avoid loading errors.

Fig. (a) Shows the complete set-up for measurement of displacement.

Charge produced $\quad q = K_q x_i$ coulomb

where $\quad K_q$ = sensitivity ; C/m, and x_i = displacement ; m.

Fig (b) shows the equivalent circuit of the measurement set up.

R_p = leakage resistance of transducer; Ω, C_p = capacitance of transducer, F

C_c = capacitance of cable; F, C_A = capacitance of amplifier; F,

R_A = resistance of amplifier; Ω

The charge generator is converted into a constant current generator as shown in Fig (c). The connected across the current generator is C where:

$$C = C_p + C_c + C_A$$

Resistance $$R = \frac{R_A R_p}{R_A + R_p}$$

Since the leakage resistance of transducer is very large (of the order of 0.1×10^{12} Ω) and therefore,

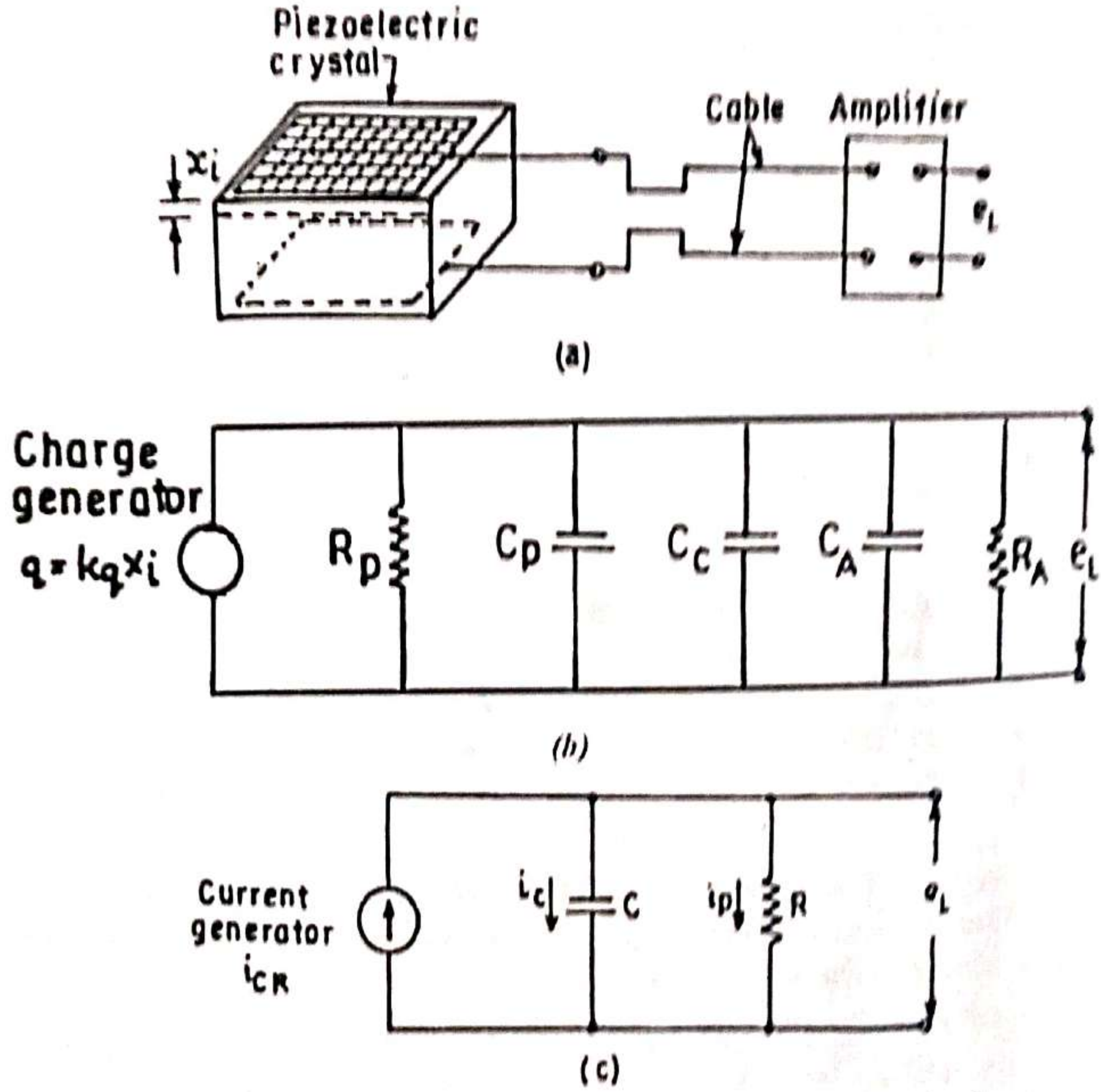


Fig. Setup of a piezo – electric transducer and its equivalent circuit

4 TEMPERATURE MEASUREMENT

Introduction

- A number of definitions of temperature have been proposed. In a layman's language one could define this as the degree of hotness or coldness of a body or an environment measured on a definite scale.
- Another simplified definition of temperature is base its equivalence to a driving force or potential that caused the flow of energy as heat. Thus, we can define temperature as a condition of a body by virtue of which heat is transferred to or from other bodies.
- Temperature is a fundamental quantity, much the same way as mass, length and time. The law that is used in temperature measurement is known as the Zeroth law thermodynamics. This states that if two bodies are in thermal equilibrium with a third body, then they are all in thermal equilibrium with each other. In other words, all the three bodies would have the same temperature.

Temperature Scales

Two temperature scales in common use are the Fahrenheit and Celsius scales. These scales are based on a specification of the number of increments between freezing point and boiling point of water at the standard atmospheric temperature. The Celsius scale has 100 units between these points, while the Fahrenheit scale has 180 units

K (Absolute temperature, Kelvin scale) = °C + 273.15

Where °C is temperature on Celsius scale.

R (Absolute temperature, Rankin scale) = °F + 459.69

Where °F is the temperature on the Fahrenheit scale.

The boiling and freezing points of water at a pressure of one atmosphere (101.3 kN/m^2) are taken as 100° and 0° on the Celsius scale and 212° and 32° on the Fahrenheit scale.

$$°F = 32 + \frac{9}{5}°C$$

$$R = \frac{9}{5}K$$