# Analog Electronics

## Course No: AE-2

## Lec: Crystal Oscillators & waveform generation circuits

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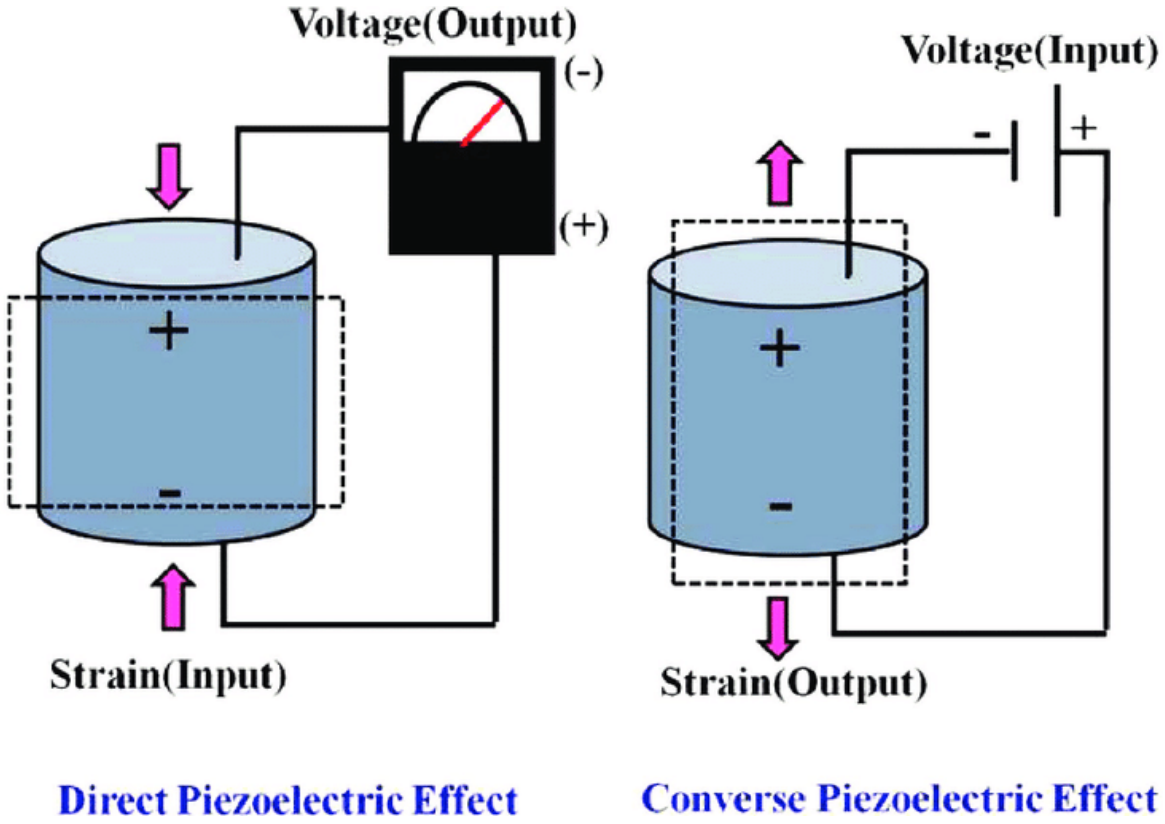
PDEU PANDIT DEENDAYAL ENERGY UNIVERSITY

*Formerly* **Pandit Deendayal Petroleum University**

# Crystal Oscillators

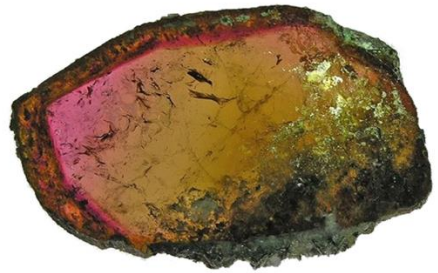
- **Piezoelectric crystals are those materials which start vibrating under the application of ac voltage and vibration frequency is equal to the applied voltage. This effect is known as piezoelectric effect. Some examples are quartz, tourmaline, Rochelle Salt...etc.**




Direct Piezoelectric Effect

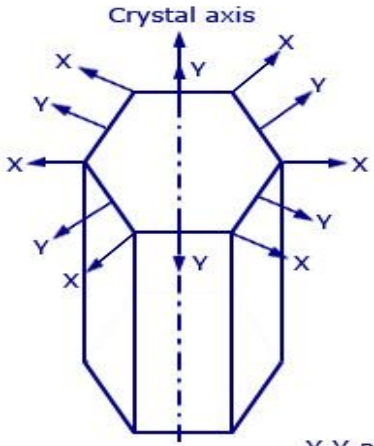
Converse Piezoelectric Effect

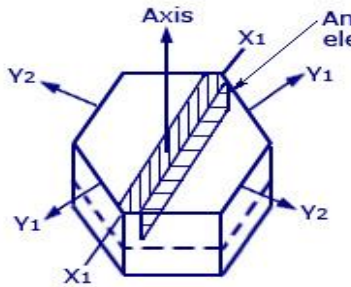
Quartz



Tourmaline

Rochelle Salts





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X-Y axes of a piezoelectric crystal

# Crystal Oscillators

- Piezoelectric crystals are those materials which start vibrating under the application of ac voltage and vibration frequency is equal to the applied voltage. This effect is known as piezoelectric effect. Some examples are quartz, tourmaline, Rochelle Salt...etc.

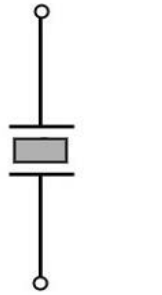
- In Crystal Oscillator, piezoelectric crystal is used in feedback network in place of RC or LC circuit.

- Each crystal has a natural frequency which is given by

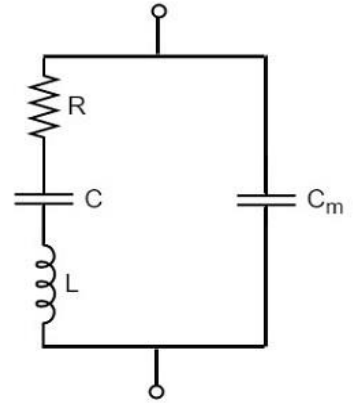
$$f = \frac{K}{t}$$

Where K is a constant depends on the cut;

t : thickness of the crystal



Symbol of a Crystal




Equivalent circuit of a crystal

- Extremely thin crystal may break due to vibrations which puts the limit to the frequency obtainable. Crystal oscillator can be used in the frequency range of 25kHz to few hundred MHz.

**The frequency of CO changes by less than 0.1% due to temperature or other changes.**

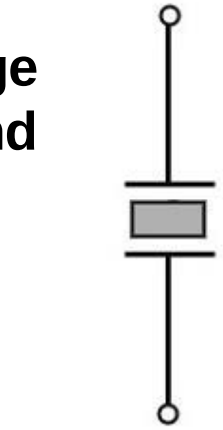
# Crystal Oscillator

- **In order to use the crystal in an electronic circuit, it is placed between two metal plates.**

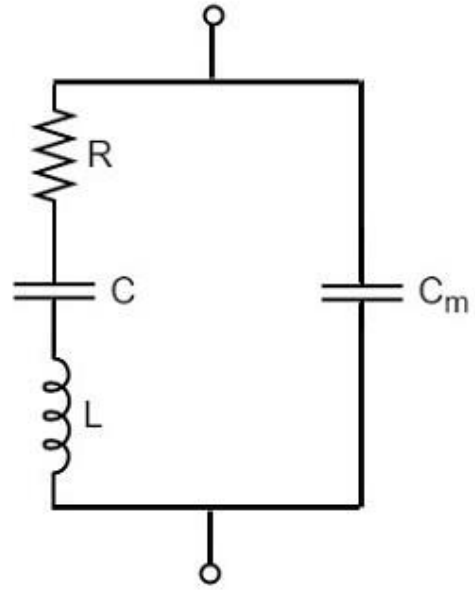
- **A piezoelectric crystal exhibit electromechanical resonance characteristics.**

- **The resonance properties are characterized by large inductance L, a very small series capacitance C, and small series resistance R to make Q factor very high.**

$$Q = \frac{\omega L}{R}$$



Symbol of a Crystal




Equivalent circuit of a crystal

# Crystal Oscillator (series resonating frequency)

**The crystal has two resonant frequencies:**

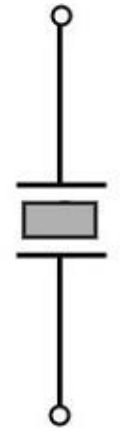
- **Series resonant frequencies at $\omega_s$**
- **Parallel resonant frequencies at $\omega_P$**

**In series path impedance**

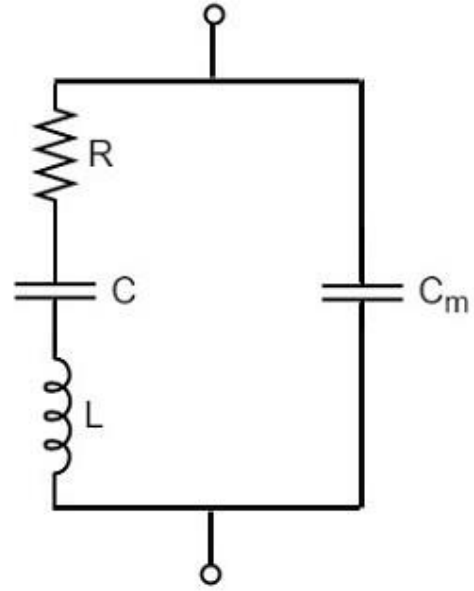
$$Z = R + j(\omega L - \frac{1}{\omega C})$$

**Imaginary part has to be zero:** $\omega_s L - \frac{1}{\omega_s C} = 0$

$$f_s = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$



Symbol of a Crystal




Equivalent circuit of a crystal

# Crystal Oscillator (parallel resonating frequency)

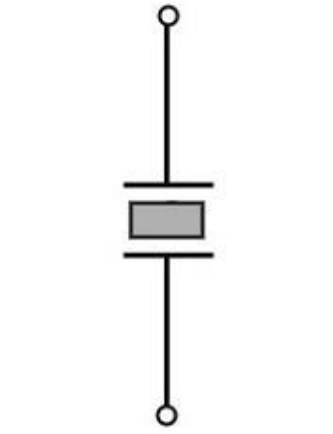
$$\frac{1}{Z_T} = \frac{1}{Z_{sp}} + \frac{1}{Z_{pl}}$$

$$= \frac{1}{j(\omega L - \frac{1}{\omega C})} + j\omega C_m$$

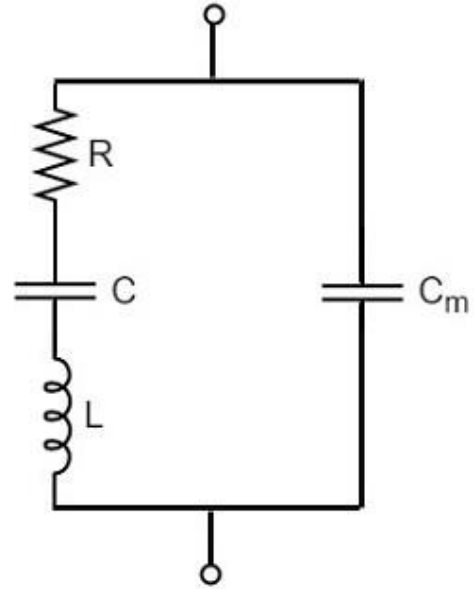
**Imaginary part has to be zero:**

$$-\frac{j}{\left(\omega L - \frac{1}{\omega C}\right)} + j\omega C_m = 0$$

$$\boldsymbol{f_p = \frac{1}{2\pi} \times \frac{1}{\sqrt{\frac{LCC_m}{(C + C_m)}}}}$$

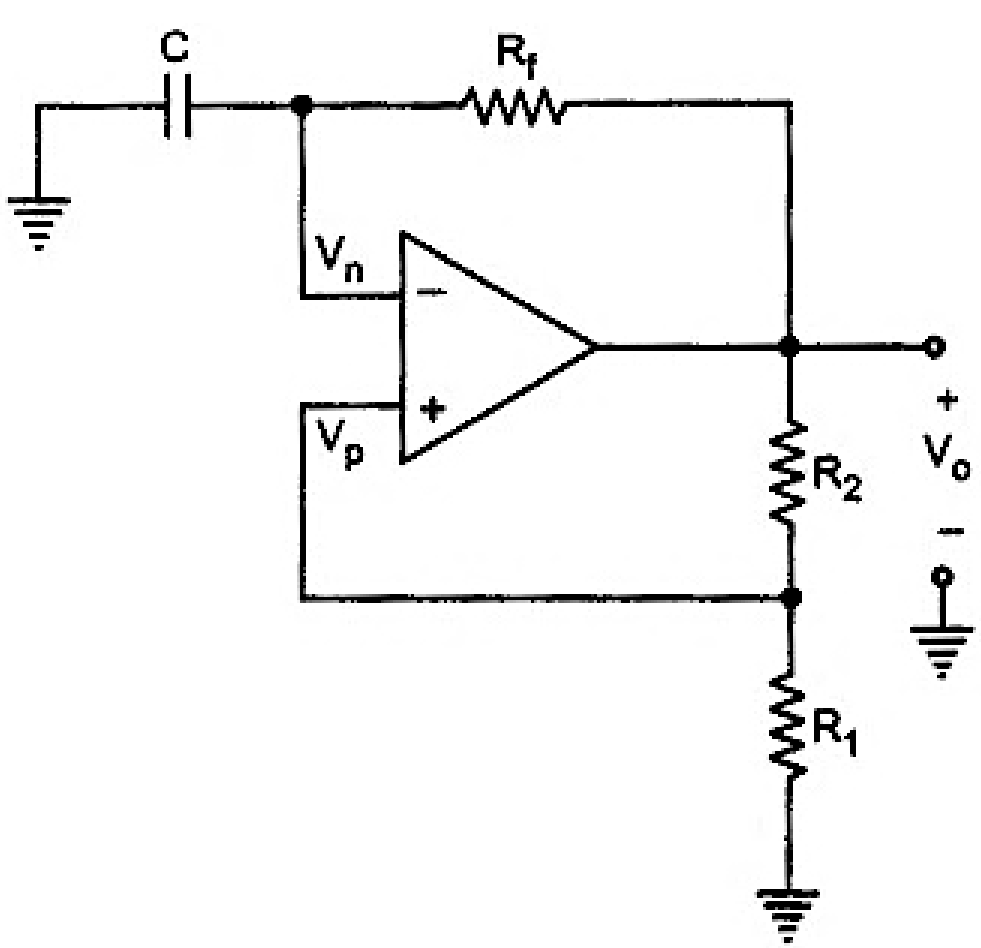


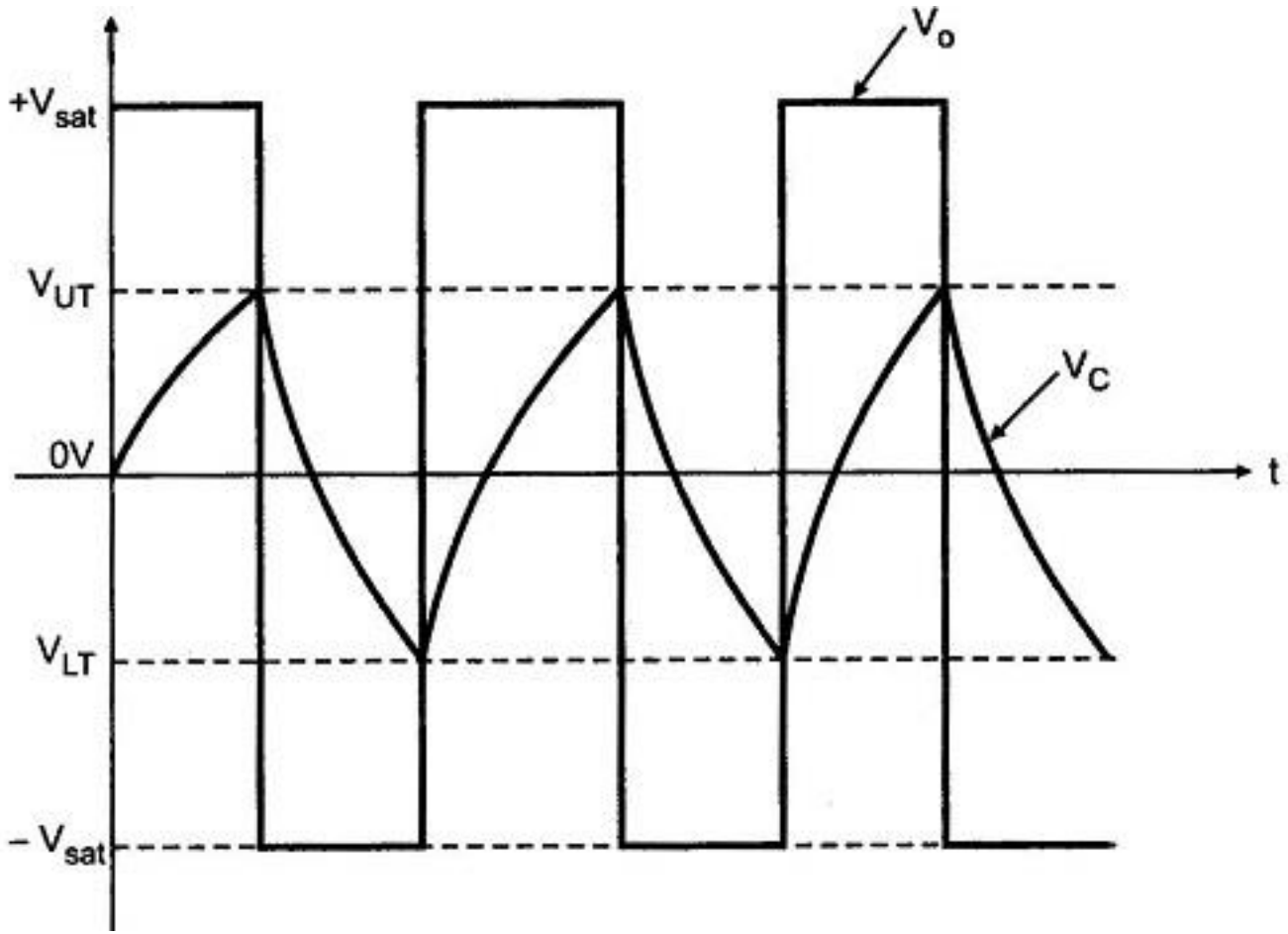
Symbol of a Crystal




Equivalent circuit of a crystal

# Square and triangular wave generator from OPAMP



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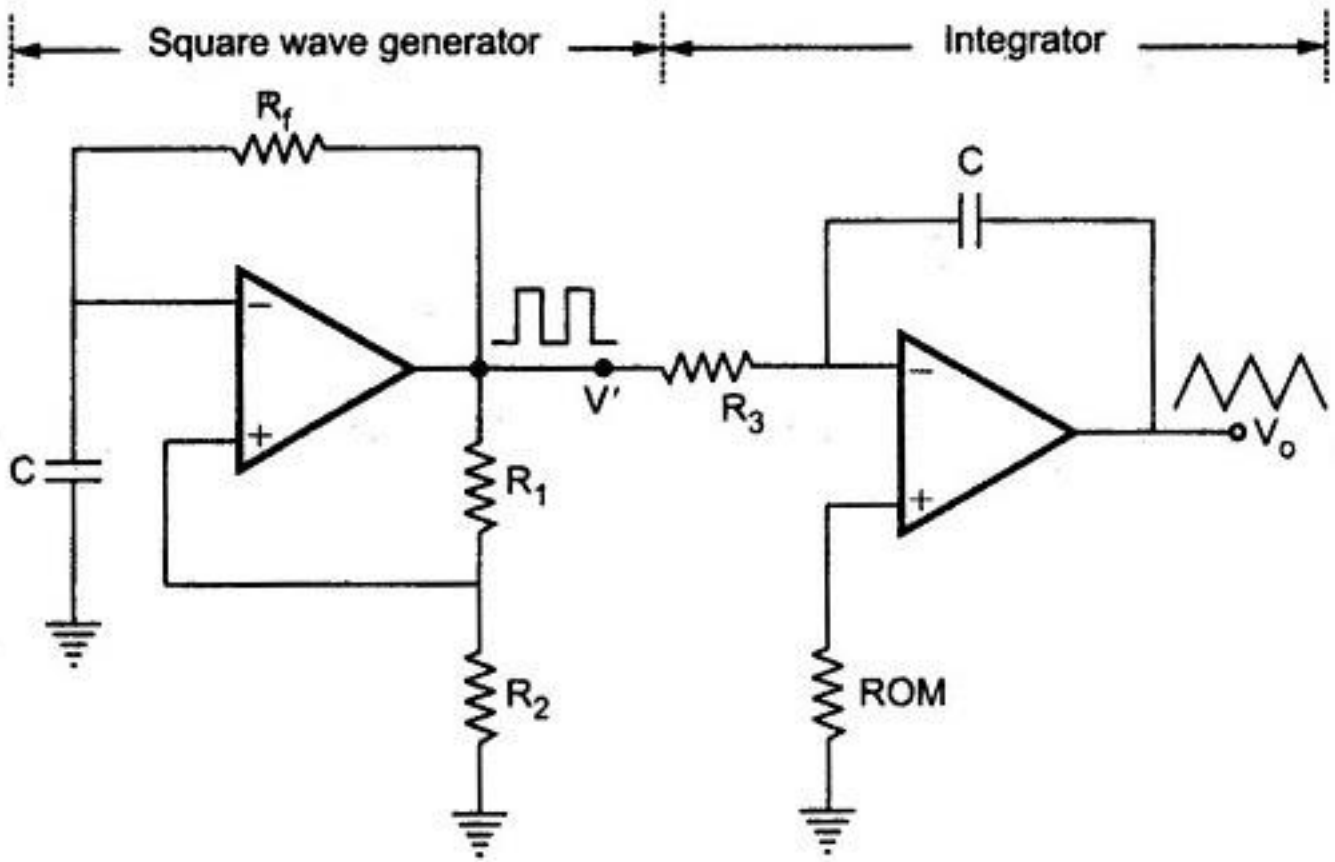

# THE END.