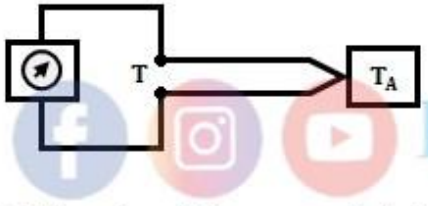
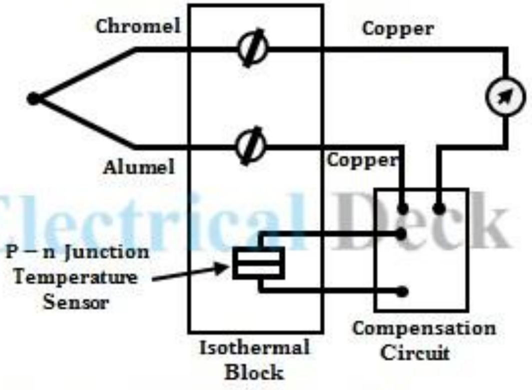
IoT 4211: Sensor Technology

SIGNAL CONDITIONING Part 2

Cold Junction Compensation Circuit for Thermocouple



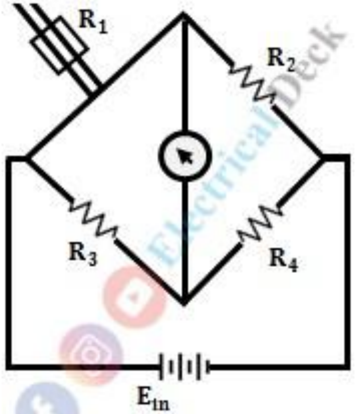
Cold Junction of Thermocouple Left at an Arbitrary Temperature



Compensation Circuit for Cold Junction Temperature

When the measurement circuit consists of a temperature-sensitive compensating resistor then the arrangement is used for cold junction compensation.

The change in ambient temperature affects both the reference junction of a thermocouple and compensating resistor since a temperature-sensitive compensating resistor is placed near the reference junction.



Wheatstone Bridge of Cold Junction Compensation

As the temperature of the reference junction increases, the resistance of a temperature-sensitive compensating resistor increases, hence we find some amount of drop in the output emf of the thermocouple. Therefore, the increase in the resistance value of compensating resistor results in a decrease in emf of the thermocouple.

The resistance of the compensating resistor increases with temperature because it is made of a temperature-sensitive material, typically one with a positive temperature coefficient of resistance (PTC). This means that the material's resistance increases as its temperature rises. Here's how it works:

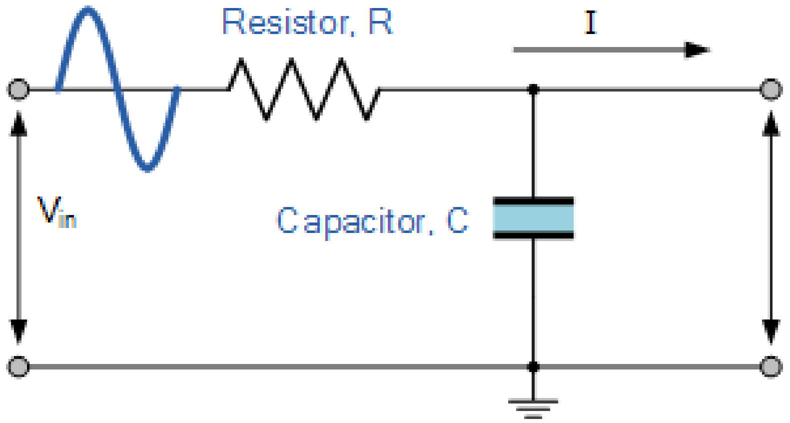
RC Low Pass Filter

cutoff frequency

$$f_L = \frac{1}{2\pi RC}$$

$$V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2}$$?

where: $R_1 + R_2 = R_T$, the total resistance of the circuit



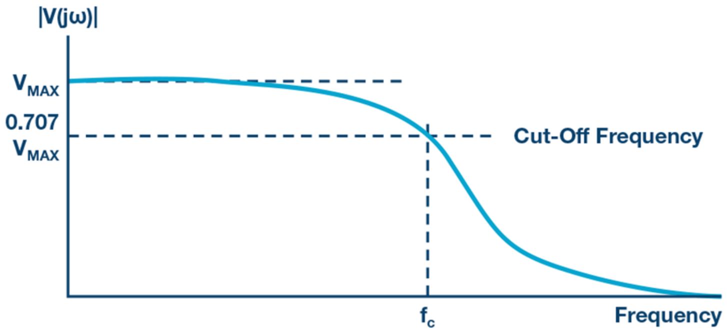
We also know that the capacitive reactance of a capacitor in an AC circuit is given as:

$$Z_C = \frac{1}{j\omega C}$$

$$X_C = \frac{1}{\omega C}$$

$$X_C = \frac{1}{2\pi f C} \text{ in Ohm's}$$

$$\omega = 2\pi f$$



Opposition to current flow in an AC circuit is called **impedance**, symbol Z and for a series circuit consisting of a single resistor in series with a single capacitor, the circuit impedance is calculated as:

$$Z = \sqrt{R^2 + X_C^2}$$

RC Potential Divider Equation

$$V_{out} = V_{in} \times \frac{X_C}{\sqrt{R^2 + X_C^2}} = V_{in} \frac{X_C}{Z}$$

Below the cutoff frequency, the filter passes signals with little attenuation. Above the cutoff frequency, the filter attenuates signals, with the attenuation increasing as the frequency increases.

RC Low Pass Filter

R

A Low Pass Filter circuit consisting of a resistor of 4k7Ω in series with a capacitor of 47nF is connected across a 10v sinusoidal supply. Calculate the output voltage at a frequency of 100Hz.

Vin Vout

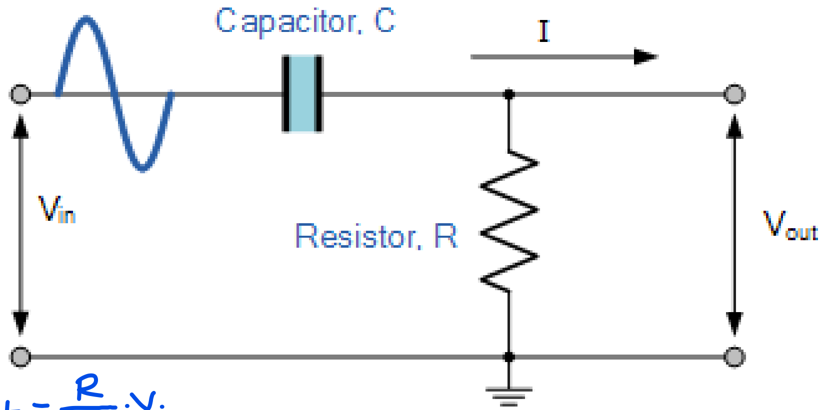
C f

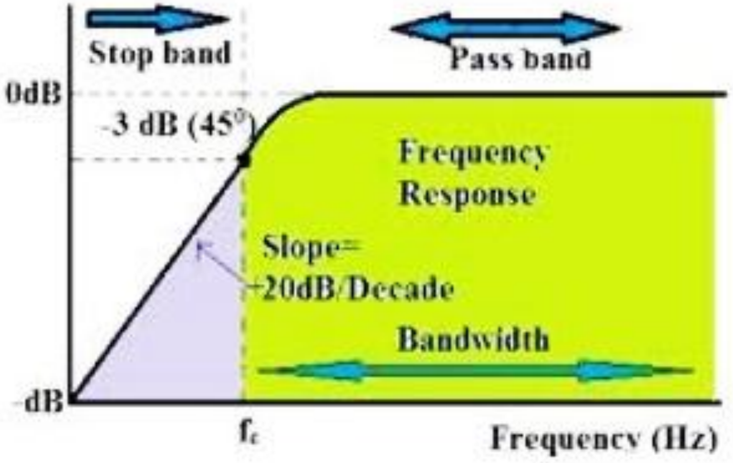
Voltage Output at a Frequency of 100Hz.

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 100 \times 47 \times 10^{-9}} = 33{,}863\Omega$$

$$V_{OUT} = V_{IN} \times \frac{X_C}{\sqrt{R^2 + X_C^2}} = 10 \times \frac{33863}{\sqrt{4700^2 + 33863^2}} = 9.9v$$

RC High Pass Filter





$$V_{out} = \frac{R}{R+X_c} \cdot V_{in}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{R}{R + \frac{1}{jωC}}$$

$$\Rightarrow H(ω) = \left|\frac{V_{out}}{V_{in}}\right| = \frac{R}{\sqrt{R^2+X_c^2}}$$

$$\Rightarrow \frac{1}{\sqrt{2}} = \frac{R}{\sqrt{R^2+X_c^2}} = \frac{R}{\sqrt{R^2+\left(\frac{1}{ωC}\right)^2}}$$

$$\Rightarrow \frac{1}{2} = \frac{R^2ω^2C^2}{R^2ω^2C^2+1}$$

$$1+R^2ω^2C^2 = 2R^2ω^2C^2$$

$$\Rightarrow 1 - R^2ω^2C^2$$

$$\Rightarrow ω^2 = \frac{1}{R^2C^2}$$

$$\Rightarrow ω = \frac{1}{RC}$$

$$ω_c = \frac{1}{RC}$$

$$2\pi f_c = \frac{1}{RC}$$

$$f_c = \frac{1}{2\pi RC}$$

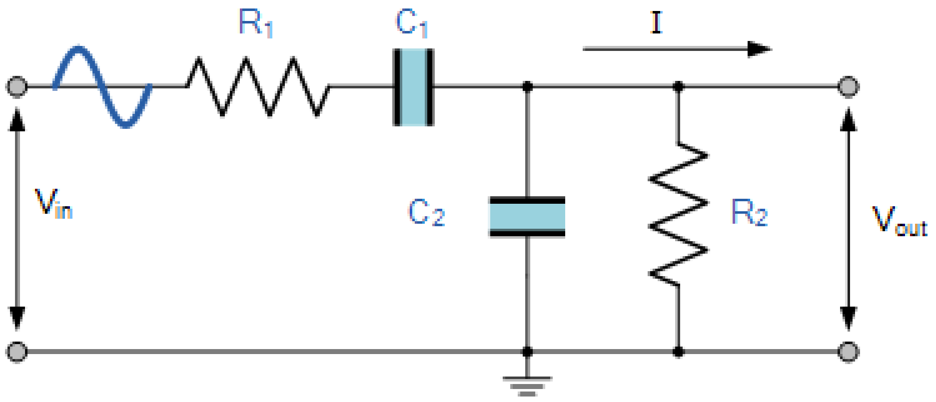
$$φ = \tan^{-1}\left(\frac{1}{ωRC}\right)$$

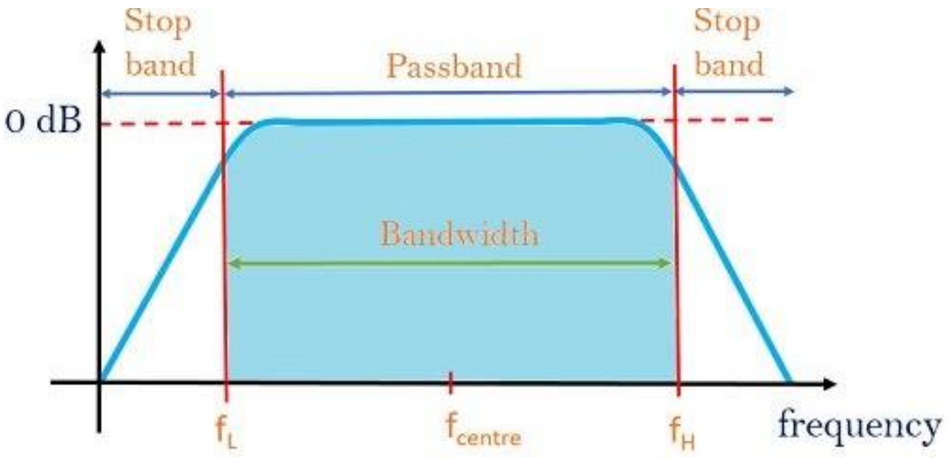
$ω = 0, \; φ = 90°$

$ω = ω_c, \; φ = 45°$

$ω = \infty, \; φ = 0°$

RC Band Pass Filter





Frequency response curve of a bandpass filter