# Electrical Science: 2021-22

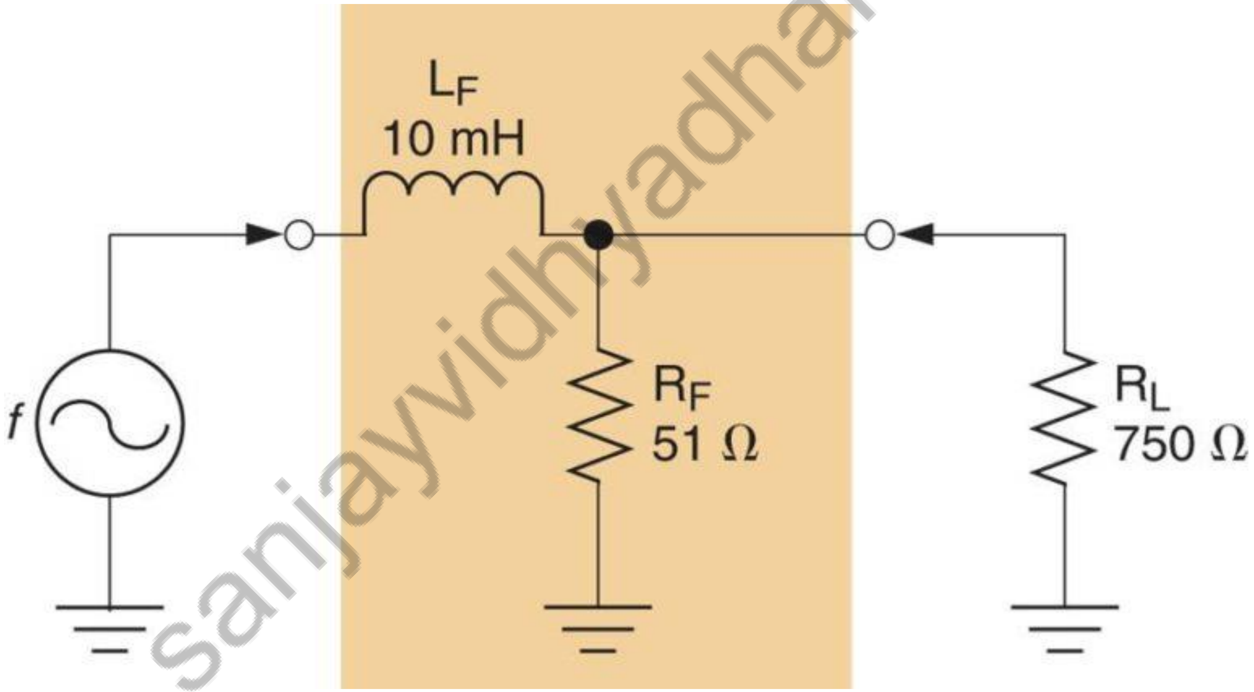
## Tutorial 9

## Passive Filters & Transformers

**By Dr. Sanjay Vidhyadharan**

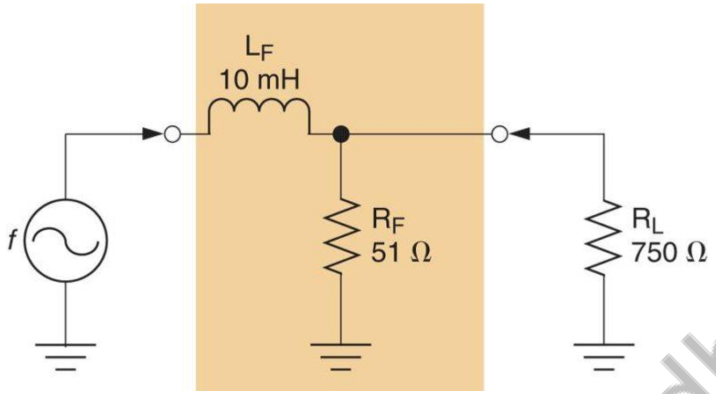
# Example 1

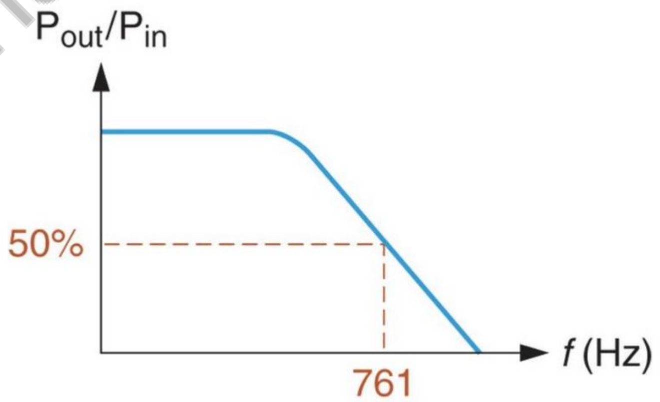
Calculate the cutoff frequency for the circuit shown in the figure



# Example 1

Calculate the cutoff frequency for the circuit shown in the figure




First, the value of $R_{EQ}$ is found as:

$$R_{EQ} = R_F || R_L = \frac{51 \times 750}{51 + 750} = 47.8\Omega$$

Now, the cutoff frequency of the circuit can be found as:

$$f_C = \frac{R_{EQ}}{2\pi L} = \frac{47.8\Omega}{2\pi \times 10mH} = 761Hz$$

# Example 2

The following circuit diagram shows a band-pass filter connected to a signal generator, with $V_{IN}$ set to 10 V. The inductor has a resistance $r_L$ of 3 Ω. $V_{IN}$ is kept at 10 V as the frequency is increased to find the maximum value of $V_{OUT}$ .

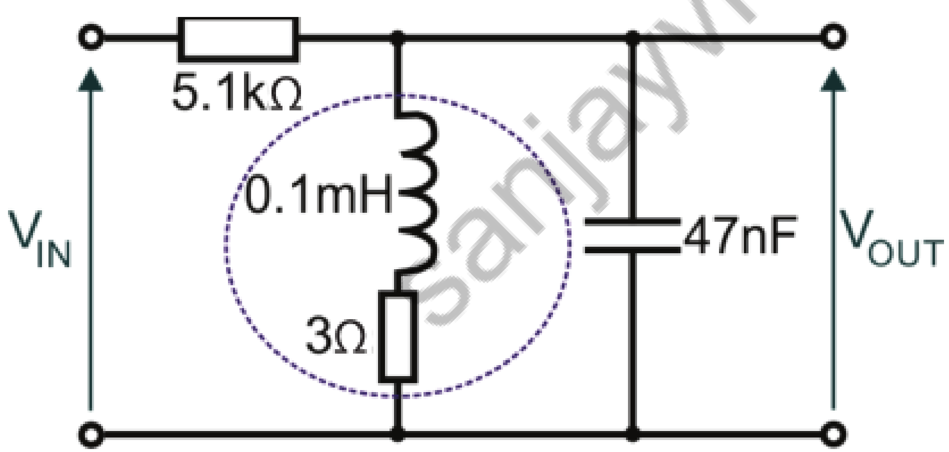
(a) Calculate the frequency at which $V_{OUT}$ is a maximum.

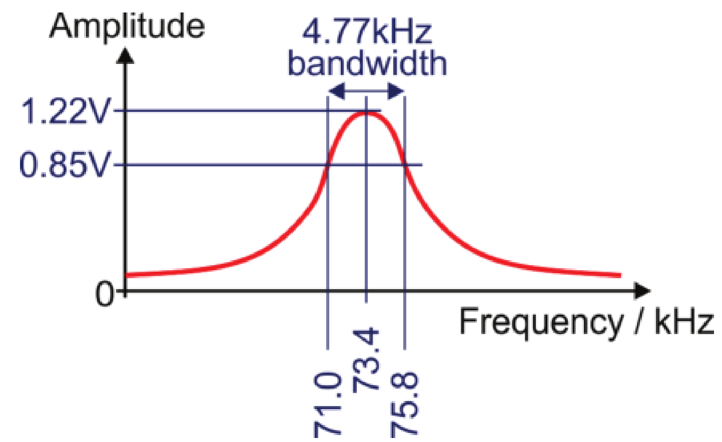
(b) Calculate the dynamic resistance, $R_D$ , of the filter and hence determine the maximum value of the voltage $V_{OUT}$ when $V_{IN}$ is set to 10 V.

(c) Determine the bandwidth of this filter.

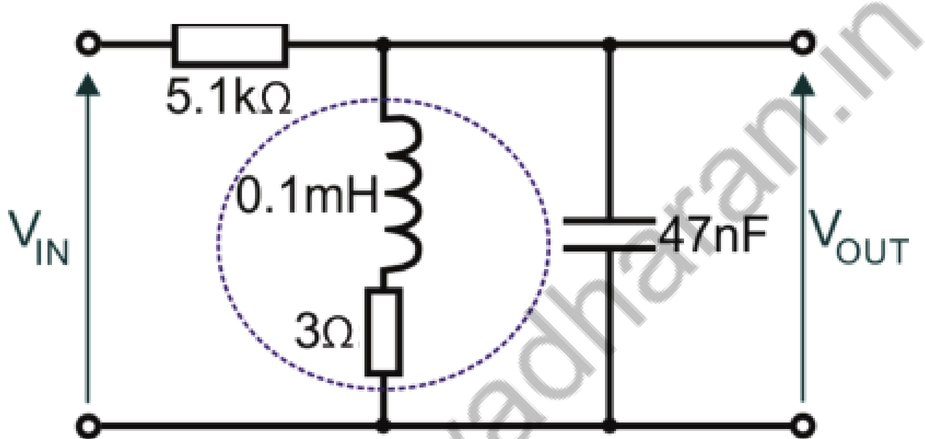
(d) Sketch the frequency response of the filter





# Example 2




(a) Calculate the frequency at which $V_{OUT}$ is a maximum.

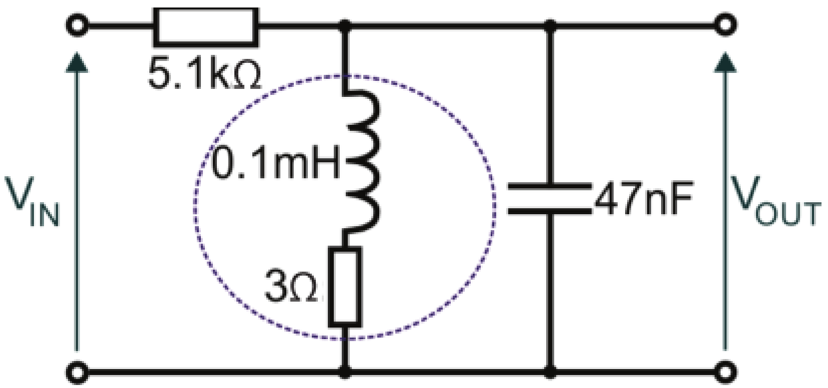
$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.1\times10^{-3}\times47\times10^{-9}}} = 73413\text{Hz} = 73.4\text{kHz}$$

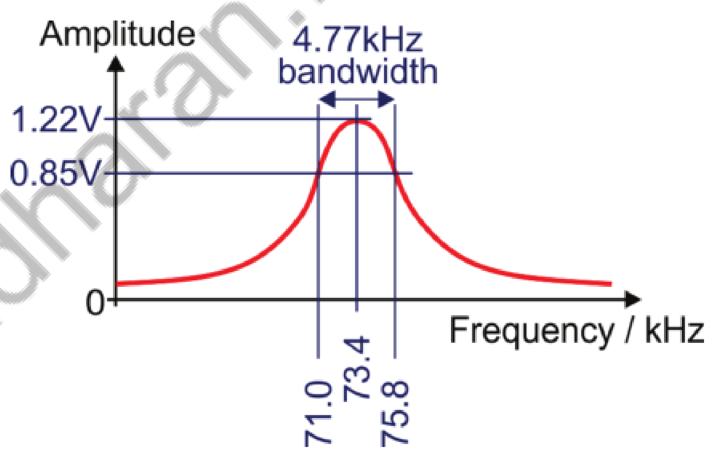
(b) Calculate the dynamic resistance, $R_D$, of the filter and hence determine the maximum value of the voltage $V_{OUT}$ when $V_{IN}$ is set to 10 V.

$$R_D = \frac{L}{r_L C} = \frac{0.1\times10^{-3}}{3\times47\times10^{-9}} = 709.2\Omega$$

$$V_{OUT} = V_{IN} \times \frac{R_D}{R_D+R} = \frac{10\times709}{709+5100} = 1.22\text{V}$$

# Example 2






(c) Determine the bandwidth of this filter.

$$Q = \frac{2\pi f_0 L}{r_L} = \frac{2 \times \pi \times 73413 \times 0.1 \times 10^{-3}}{3} = 15.38$$

$$\text{Bandwidth} = \frac{f_0}{Q} = \frac{73413}{15.38} = 4773\text{Hz}$$

# Example 3

If the bandstop filter in Figure.(8) is to reject a 200-Hz sinusoid while passing other frequencies, calculate the values of L and C. Take R = 150Ω and the bandwidth as 100 Hz.

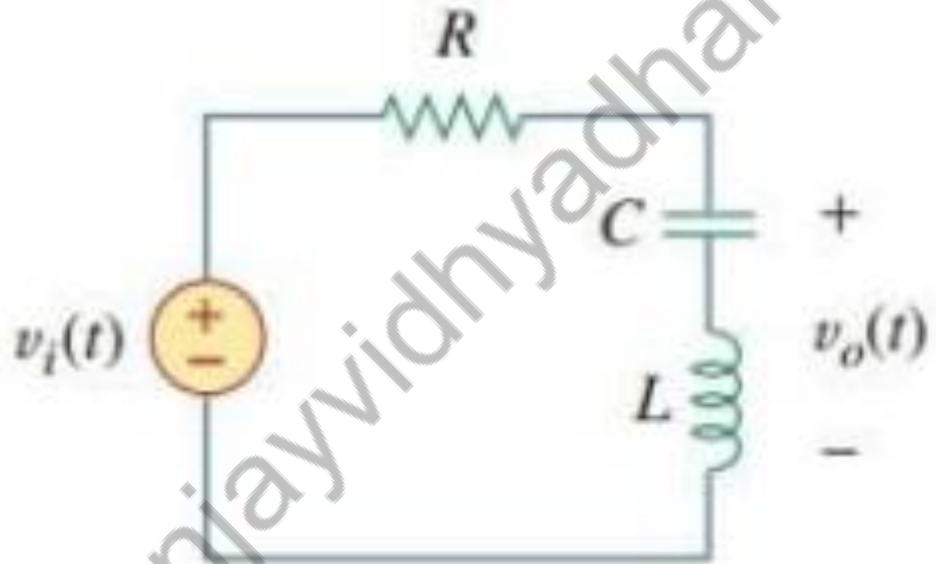



Figure 8. A bandstop filter.

# Example 3

If the bandstop filter in Figure.(8) is to reject a 200-Hz sinusoid while passing other frequencies, calculate the values of L and C. Take R = 150Ω and the bandwidth as 100 Hz.

$$B = 2\pi(100) = 200\pi \text{ rad/s}$$

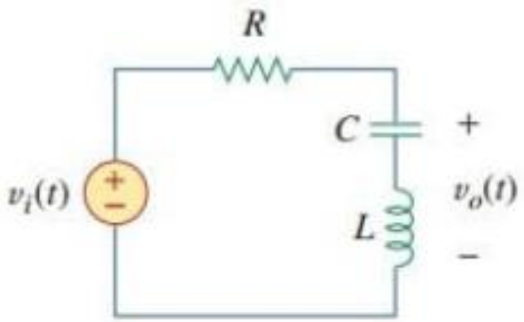



Figure 8. A bandstop filter.

But

$$B = \frac{R}{L} \quad \Rightarrow \quad L = \frac{R}{B} = \frac{150}{200\pi} = 0.2387 \text{ H}$$

Rejection of the 200-Hz sinusoid means that $f_0$ is 200 Hz, so that $\omega_0$ in Figure.(9)

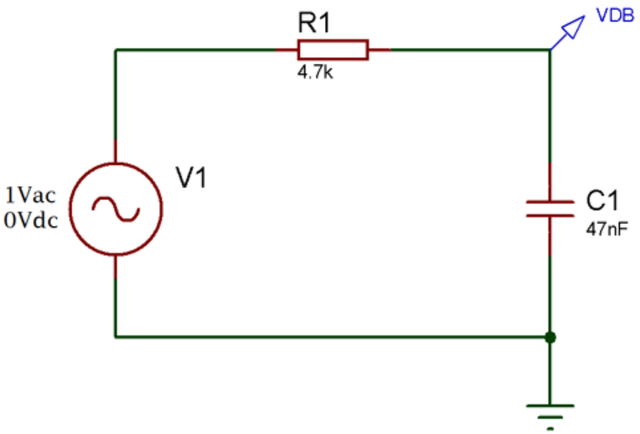
$$\omega_0 = 2\pi f_0 = 2\pi(200) = 400\pi$$

Since $\omega_0 = 1/\sqrt{(LC)}$,

$$C = \frac{1}{\omega_0^2 L} = \frac{1}{(400\pi)^2(0.2387)} = 2.653\ \mu\text{F}$$

# Example 4

Find the cut-off frequency and Output voltage at 500Hz.




$$fc = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 4700 \times 47 \times 10^{-9}}$$

720 Hz

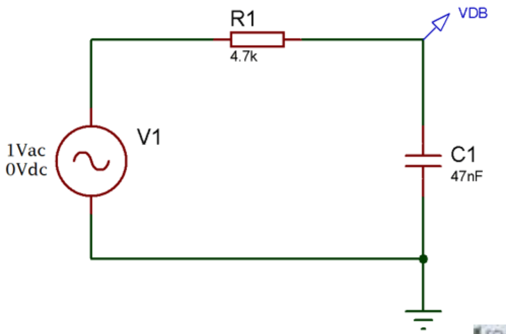
$$Xc = \frac{1}{2\pi f C} = \frac{1}{2\pi \ \times 500 \ \times 47 \ \times \ 10^{-9}} = 6773 \ Ohms$$

Then the Vout is when applied 5V Vin at 500Hz:-

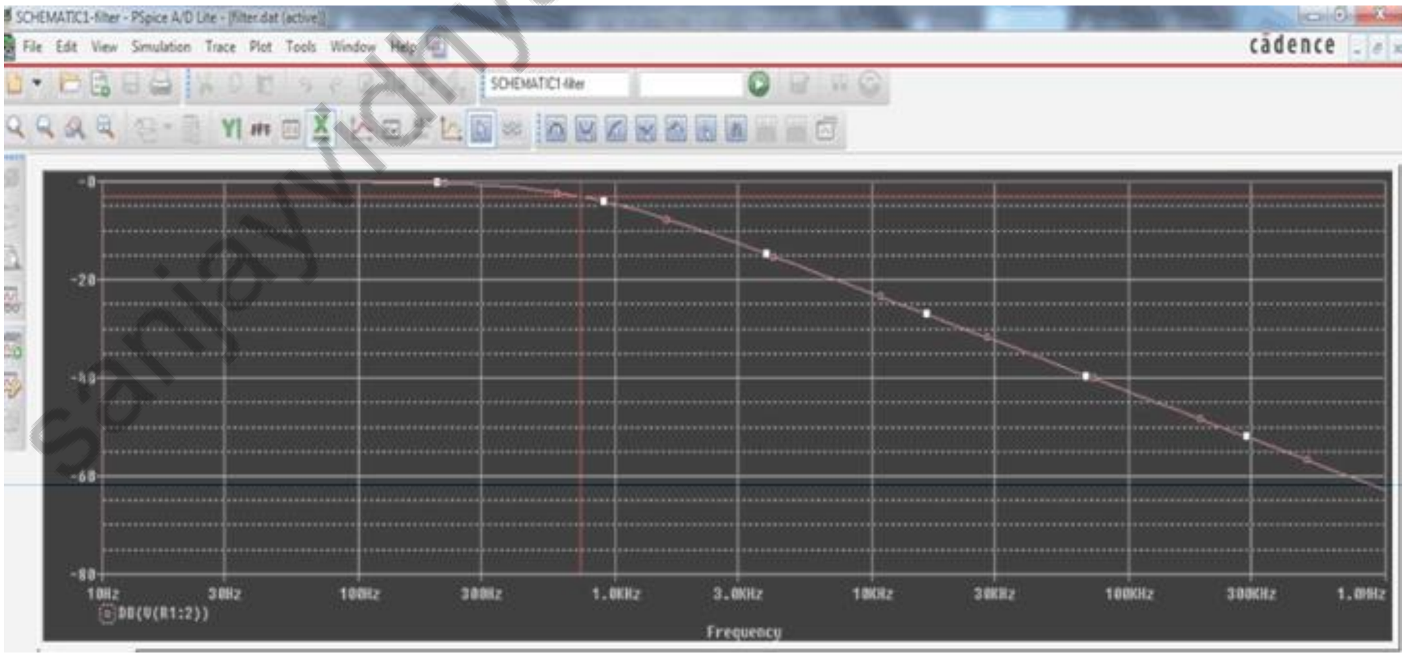
$$Vout = Vin \ \times \frac{Xc}{\sqrt{R^2 + \ X_C^2}} = 5 \ \times \frac{6773}{\sqrt{4700^2 + \ 6773^2}} = 4.11V \ (Approx)$$

# Example 4

**Find the cut-off frequency and Output voltage at 500Hz.**

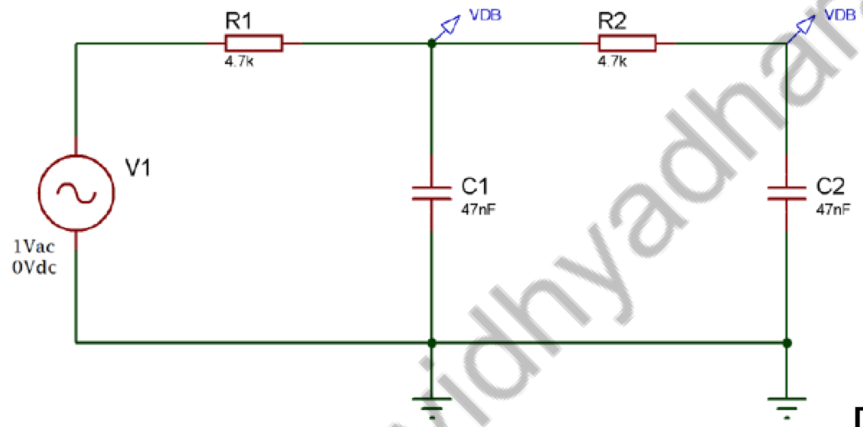



Demonstration in LT SPICE

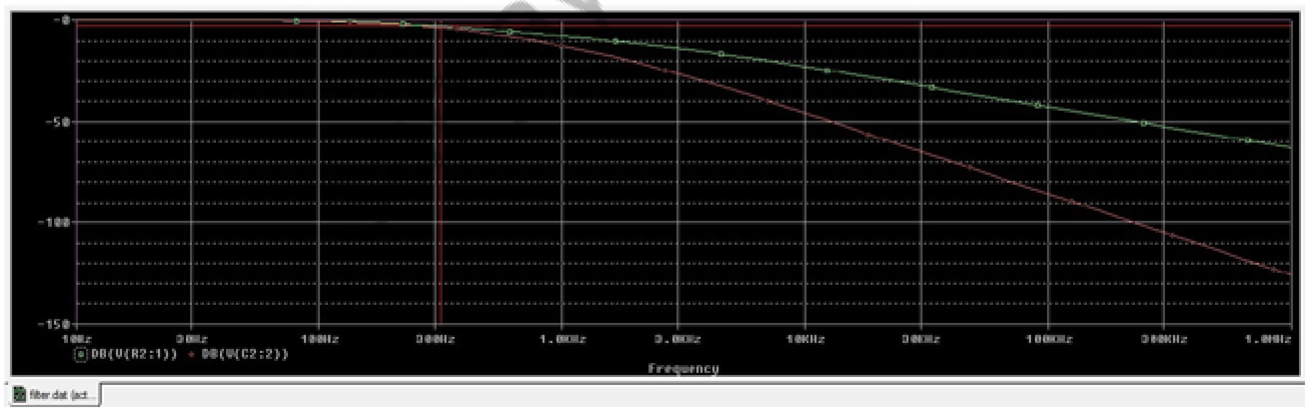


# Example 5

**Second Order Low Pass Filter:**

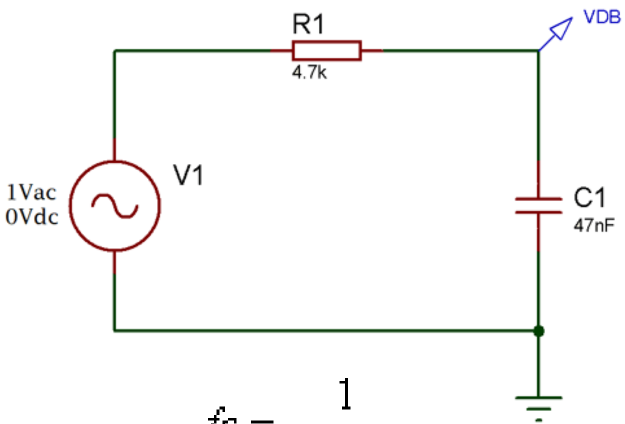



Demonstration in LT SPICE

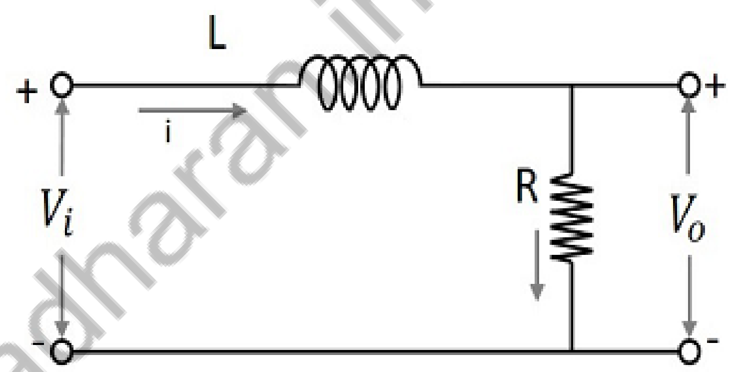


# Example 6

Find equivalent RL Filter at



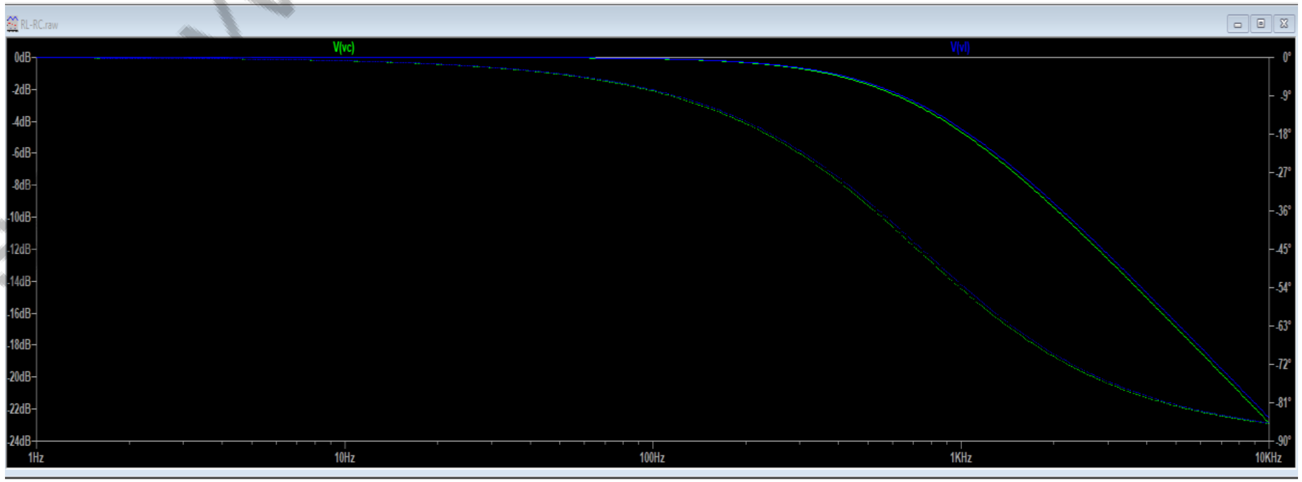

$$fc = \frac{1}{2\pi RC}$$




L= 1 H

$$fc = \frac{R}{2\pi L}$$

Demonstration in
LT SPICE



# Example 7

**Example:** For a magnetic circuit, on no-load condition, core loss is, $P_C = 16$ W; apparent power, $(VA)_{rms} = 20\,VA$, $E_{1_{max}} = 275$ V, N=200 turns. Assuming a sinusoidal flux waveform, find:

a) Power factor,

b) Iron current, $I_c$

c) Magnetizing current, $I_m$

(a) Core loss: $P_c = E_1 . I_\phi . cos\theta_c$

$$pf = \cos\theta_c = \frac{P_c}{VA} = \frac{16}{20} = 0.8$$

(b) $P_c = E_1 I_\phi \cos\delta_c$ , $E_{1rms} = \frac{275}{\sqrt{2}} = 194.5$ Volt

$$I_\phi = \frac{16}{(194.5)(0.8)} = 0.103 \text{ A}$$

$$I_c = I_\phi \cos\theta c = (0.103)(0.8) = 0.082 \text{ A}$$

(c) $I_m = I_\phi \sin\theta c = (0.103)\sin(cos^{-1} 0.8) = 0.062$ A

# Example 8

**Example:** A 50 Hz, two winding transformer is rated as 3 KVA, 220/110 Volt. This transformer is connected as a **step-up auto** transformer to deliver 330 V to a resistive load when the input is from a 220 V source. Assuming that the transformer is ideal find:

a-) the value of the load resistance for which rated current will flow in each winding.

b-) the power delivered by transformer .

$$I_1 = \frac{3000}{220} = 13.65\ Amp$$

$$I_2 = \frac{3000}{110} = 27.3\ Amp$$

(a) $R_L = \frac{330}{27.3} = 12.1\ \Omega$

(b) $P_T = 13.65 \times 220 = 3000\ Watt$

# Example 9

A 460-V:2400-V transformer has a series leakage reactance of 37.2 Ω as referred to the high-voltage side. A load connected to the low-voltage side is observed to be absorbing 25 kW, unity power factor, and the voltage is measured to be 450 V. Calculate the corresponding voltage and power factor as measured at the high-voltage terminals.

**Secondary**

$$I_2 = \frac{P_{load}}{V_{load}} = \frac{25000}{450} = 55.55 \text{ A} \quad \Rightarrow \quad \text{Primary current } I_1 = \frac{460}{2400} \times 55.55 = 10.65 \text{ A}$$

**Primary voltage:**

$$V_1 = j37.2 \ I_1 + V_2' \qquad V_2' = \frac{2400}{460} \times 450 = 2347.8 \text{ V}$$

$$\Rightarrow \ V_1 = j37.2 \ I_1 + V_2' = j37.2 \times 10.65 + 2347.8 = 2347.8 + j396.18 = 2381.0\angle 9.58^\circ \text{ V}$$

**Power factor at primary terminals: cos(9.58 ) = 0.9861 lagging**

# Thank you