EE101: Electrical Sciences

Tutorial-8, Oct. 27, 2017

Pre-Tutorial Problem

A resistor R_{AB} has the following characteristics.

$$R_{AB} = \begin{cases} \infty & \text{for } V_{AB} < 0.7 \\ 0 & \text{for } V_{AB} \geq 0.7 \end{cases}$$

(i) Plot the I-V characteristics (X-axis is V_{AB} and Y-axis is I_{AB}) of this resistor.

(ii) Draw the transfer characteristics of the following circuits.

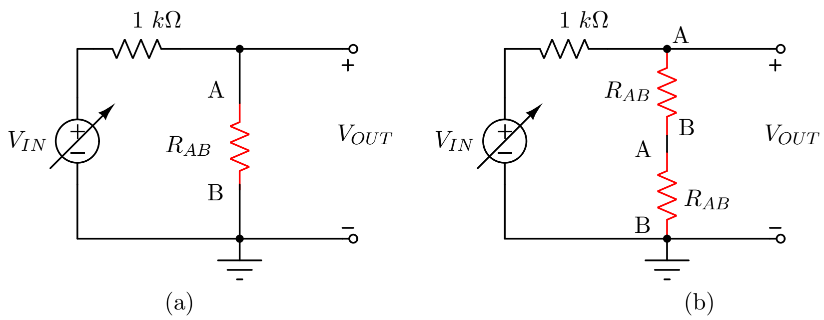


Figure 1: Circuits for pre-tutorial problem

(iii) Can you think of an application of this circuit (assuming the resistor R_{AB} really exists)?

Solution

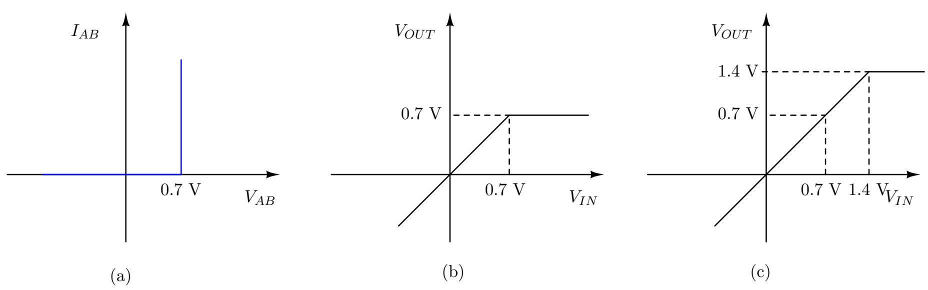


Figure 2:

(i) See (a) in the above the figure.

(ii) see (b) and (c) in the above figure respectively.

(iii) Voltage regulators. Wait for some more time.

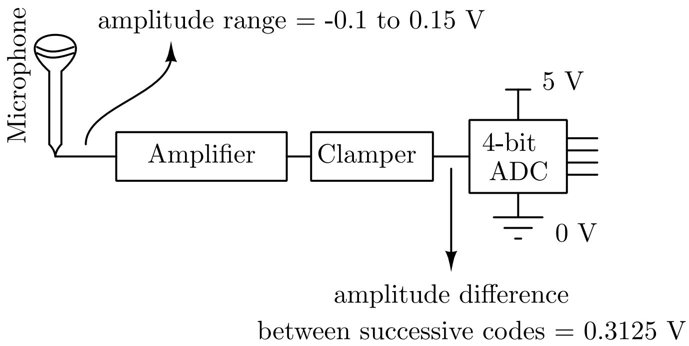


Figure 3: Block diagram of an audio system

Tutorial Problems

1. Block diagram of an audio system is shown below.

   Under no load condition (or infinite load impedance), the amplitude of the voltage signal generated by the microphone is in the range of -0.1 V to 0.15 V. This signal needs to be processed by an ADC such that the full-range of ADC codes (0000 for 0 V and 1111 for 5 V) are used.

   (i) What is gain of the amplifier required?
   (ii) What is the DC-offset that need to be provided by the clamper circuit?
   (iii) The microphone can't drive any (low) impedance (i.e., it can't output any current). Realize the above amplifier using an ideal opamp and resistors. What is your choice of configuration and why?

Solution

   (i) Peak to peak amplitude of the input signal is 0.25 V (=0.15-(-0.1)). This needs to be amplified to the 5 V peak to peak (ADC range = (5 - 0) V). Gain required is $\frac{5}{0.25} = 20$.
   (ii) The amplitude range at the output of the amplifier will be -0.1×20 to 0.15×20 V, i.e. -2 to 3 V. ADC can handle the amplitude within the range of 0 to 5 V. So, we need to introduce a DC-offset of +2 V into the ouput of the amplifier.
   (iii) A non-inverting amplifier with $R_f = 19R_1$ (any R_1 will work at low frequencies) is a preferred amplifier topology, as the R_{in} of an ideal non-inverting amplifier is ∞.

2. Derive the voltage gain expressions of the following circuits.

Solution

   (i) As shown in (a), the current flowing through the inductor is $\frac{v_{in}}{R}$ and the voltage across the inductor is $-v_{out}$. As per the inductor characteristics, $-v_{out} = L\frac{di}{dt} = \frac{L}{R}\frac{dv_{in}}{dt}$.
   (ii) If we assume a virtual short at the opamp input terminals and write the KCL at the intermediate node,
   $$\frac{v_{in} - v_x}{R_1} = \frac{v_x}{R_2} + \frac{v_x - v_{out}}{R_f}.$$
   There is no other equation! What is wrong?
   There is no real ground at the negative input terminal of the opamp and no current flows into the opamp. Hence $v_x = 0$ V and the opamp gain is still $\frac{-R_f}{R_1}$.

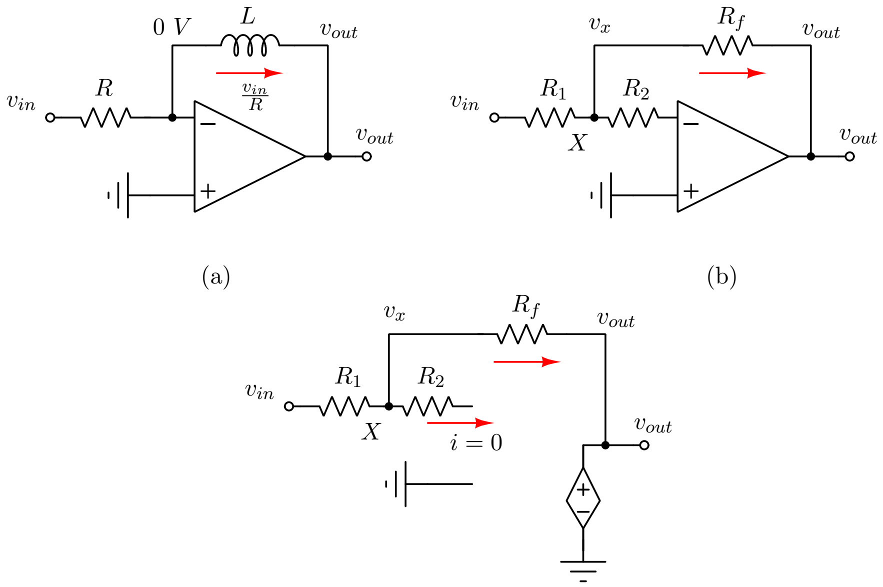
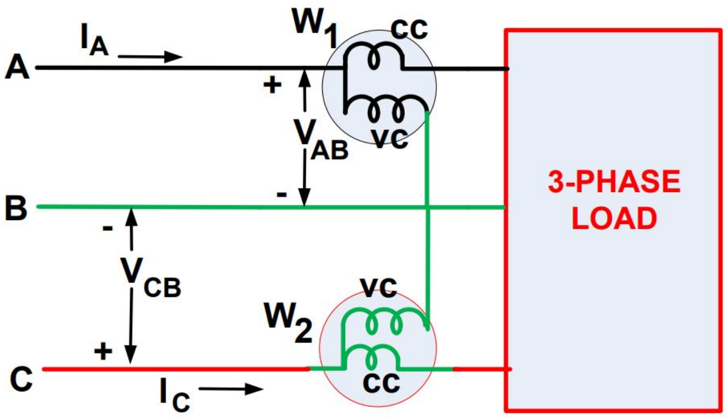


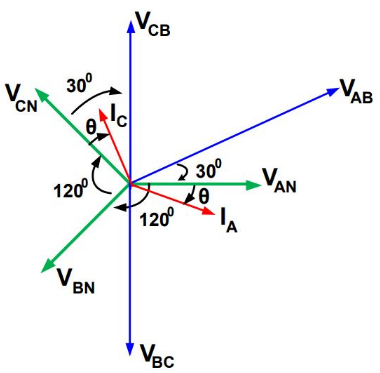
Figure 4:

3. Three identical coils, each having a reactance of 20 Ω and a resistance of 20 Ω are connected (a) in star, (b) in delta across 440 V, 3-phase line. Calculate for each method of connection, the line current and the readings on each of the two wattmeters connected to measure the power.

Solution



(a) For star connection,



Phase current = Line Current = Phase voltage / Per Phase Impedance

Phase voltage = Line voltage / $\sqrt{3}$ = 440 / $\sqrt{3}$= 254 V = $\mathbf{V}_P$
Per Phase Impedance = 20 + j 20 = $\mathbf{Z}_P$
Line current $\mathbf{I}_L = \frac{\mathbf{V}_P}{\mathbf{Z}_P} = 8.98\angle-45°$
In a two wattmeter power measurement method, the sum of the two wattmeter readings is equal to the total real power. The difference of the wattmeter readings is the reactive power divided by $\sqrt{3}$.

$$W_1 + W_2 = \sqrt{3}V_L I_L \cos\phi = 4839.2$$

$$W_1 - W_2 = V_L I_L \sin\phi = 2794$$

Solving the two equations gives, $W_1 = 3.816$ kW and $W_2 = 1.022$ kW.

(b) For delta connection,
Line Current = $\sqrt{3}$ × Phase Current
Phase voltage = Line voltage = 440 V (given)
Per Phase Impedance = 20 + j 20 = $\mathbf{Z}_P$
Line current $\mathbf{I}_L = \frac{\mathbf{V}_P}{\mathbf{Z}_P} = 26.94\angle-45°$
In a two wattmeter power measurement method, the sum of the two wattmeter readings is equal to the total real power. The difference of the wattmeter readings is the reactive power divided by $\sqrt{3}$.

$$W_1 + W_2 = \sqrt{3}V_L I_L \cos\phi = 14517.6$$

$$W_1 - W_2 = V_L I_L \sin\phi = 8381.76$$

Solving the two equations gives, $W_1 = 11.430$ kW and $W_2 = 3.060$ kW.

4. For the magnetic circuit of Fig. 5, N = 400 turns. Mean core length $l_c = 50\ cm$. Air gap length $l_g = 1.0\ mm$. Cross-sectional area $A_c = A_g = 15cm^2$. Relative permeability of core $\mu_r = 3000$. $i = 10.0A$.

   Find: (a) Flux and Flux density in the air gap. (b) Inductance of the coil.

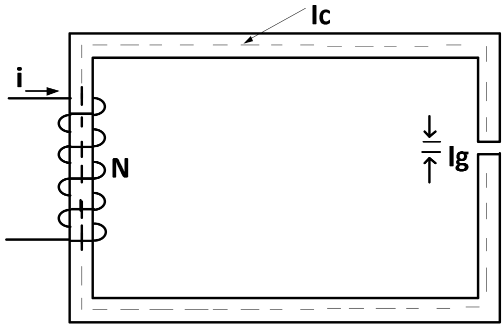


Figure-5

Solution:

(a) Reluctances of the core and the air-gap are:

$$\mathfrak{R}_c = \frac{l_c}{\mu_r\mu_0 A_c} = \frac{50\times10^{-2}}{3000\times4\pi\times10^{-7}\times15\times10^{-4}} = 88.42\times10^3\ AT/Wb$$

$$\mathfrak{R}_g = \frac{l_g}{\mu_0 A_g} = \frac{1\times10^{-3}}{4\pi\times10^{-7}\times15\times10^{-4}} = 530.515\times10^3 At/Wb$$

The equivalent electrical circuit is shown in Fig. 5

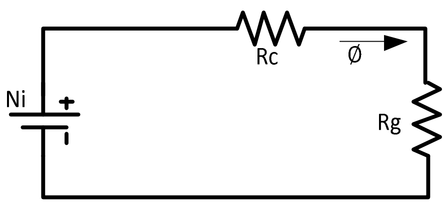


Figure-6

$$\Phi = \frac{Ni}{\mathfrak{R}_c + \mathfrak{R}_g} = \frac{400\times10}{(88.42+530.515)10^3}$$

$$B = \frac{\Phi}{A_g} = \frac{0.6463\times10^{-3}}{15\times10^{-4}} = 0.4309T$$

(b) $$L = \frac{N^2}{\mathfrak{R}_c+\mathfrak{R}_g} = \frac{400^2}{(88.42+530.515)10^3} = 258.52\times10^{-3}H$$

OR $$L = \frac{\lambda}{i} = \frac{N\Phi}{i} = \frac{400\times0.6463\times10^{-3}}{1.0} = 258.52\times10^{-3}H$$