EE210: HW-3 Solution

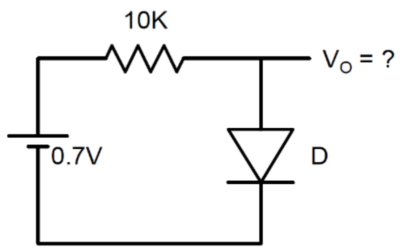
Date: 23.01.2019

The diode in the problems given below has the following characteristics:

$I_S = 2 * 10^{-15}$A; n = 1; $V_T = 26mV$; $C_{j0} = 2.63pF$; $V_{bi} = 0.85V$; m = 0.5; $\tau = 26$ns

Q.1 Using iterative analysis, determine the current flowing in a circuit shown in Fig. 1.

Sol.:



Let, $V_0 = 0.6$V (initial guess)

First iteration

$$I_D = \frac{0.7 - 0.6}{R} = 10\mu\text{A}$$

$$V_0 = V_T * ln\left(\frac{I_D}{I_S}\right) = 0.581\text{V}$$

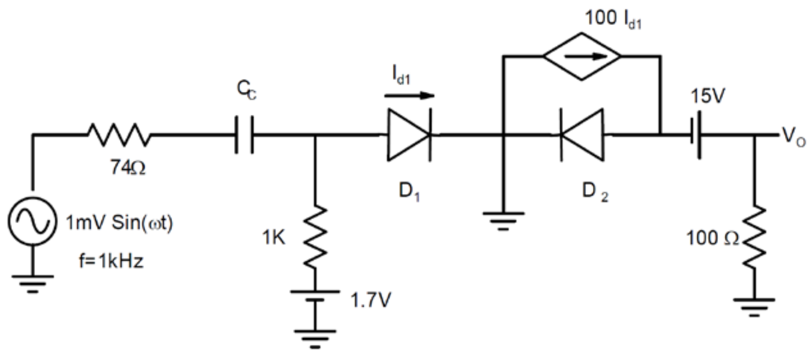
Second iteration

$$V_0 = 0.581\text{V}$$

$$I_D = \frac{0.7 - 0.581}{R} = 11.9\mu\text{A}$$

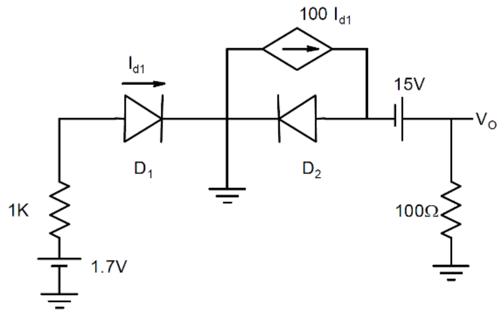
$$V_0 = V_T * ln\left(\frac{I_D}{I_S}\right) = 0.585\text{V}$$

Q.2 For the circuit shown in Fig. 2, first, carry out a dc analysis of the circuit assuming a simple diode model to determine the dc value of output voltage. Using small signal analysis and small signal diode model, next, determine the sinusoidal output voltage. Assume that capacitor C_C is large enough, so that it can be approximated as a short for small signal ac analysis. Since the frequency is low, the internal capacitance of the diodes can be ignored. Sketch the complete output voltage (dc + ac).



Sol:

Draw the dc equivalent circuit for dc analysis –



Clearly diode D_1 is forward biased. We assume that D_2 is reverse biased. Need to verify this

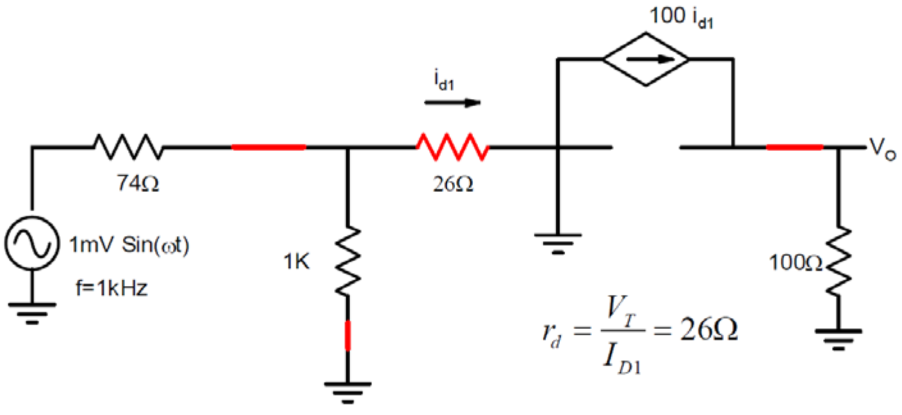
$$I_{D1} = \frac{1.7 - 0.7}{1K} = 1mA$$

$$V_0 = 10^{-3} * 10^2 * 10^2 = 10V$$

We can note that D_2 is reverse biased by -5V.

We next carry out the small signal analysis and assume that capacitances (internal diode and external) can be ignored.

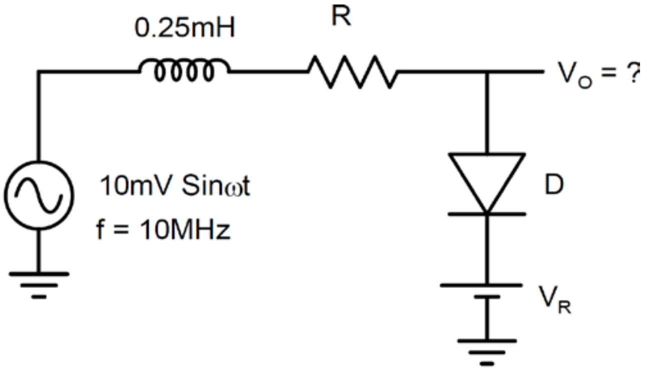
Small signal AC equivalent circuit:



$$r_d = \frac{V_T}{I_{D1}} = 26\Omega$$

$$v_0 = 100 * (100 i_{d1}) = 100 * 100 * \frac{v_s}{74 + 26} = 100mV * \sin(\omega t)$$

Q.3 The diode in the circuit shown in Fig. 3 is used as a variable capacitor. Determine a suitable value of resistor R and reverse bias voltage V_R so that output sinusoidal voltage has a magnitude of 100mV. (Use the concept of resonance.) Can we call this circuit an amplifier?



Sol.: Resonance frequency:

$$f_0 = \frac{1}{2\pi\sqrt{L * C}}$$

Given, C = 1pF

$$C = 1pF = \frac{C_{jo}}{\left(1 + \frac{V_R}{V_{bi}}\right)^{0.5}}$$

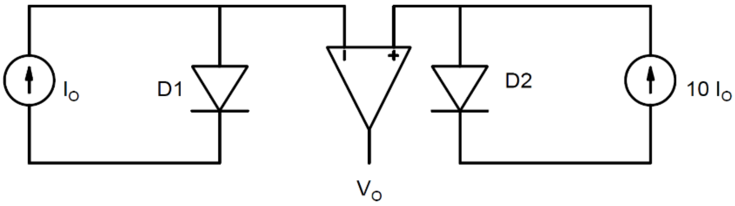
$$V_R = 5V$$

At resonance:

$$v_0 = \frac{v_s}{R} * \left(\frac{1}{j\omega C}\right)$$

$$\text{R} = 1.59\text{K}\Omega$$

Q.4 Determine an expression for the output voltage in the circuit shown below. Assume that diodes are identical and that differential amplifier does not draw any input current and has a differential voltage gain $A_V = \dfrac{V_0}{V_+ - V_-}$.



Sol.:
At the inverting terminal of op-amp,

$$V_- = \frac{KT}{q} * ln\left(\frac{I_0}{I_S}\right)$$

At the non-inverting terminal of op-amp,

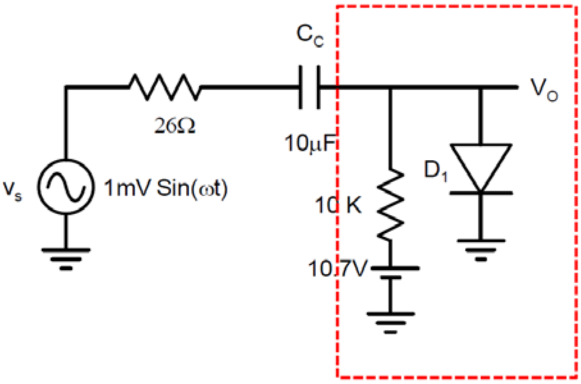
$$V_+ = \frac{KT}{q} * ln\left(\frac{10I_0}{I_S}\right)$$

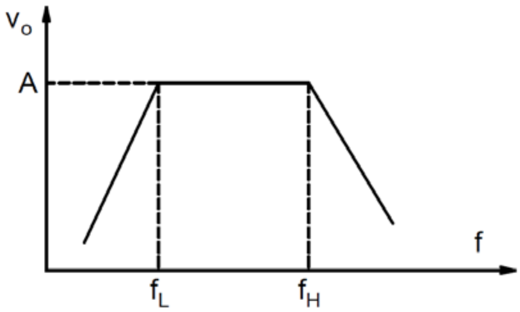
Output voltage will be,

$$V_0 = A_V * (V_+ - V_-) = \frac{KT}{q} * ln(10) * A_V$$

Note that output voltage is directly proportional to temperature.

Q.5 Figure 5a below shows a diode circuit, whose small signal sinusoidal response is shown in Fig. 5b. Determine the variables A, f_L and f_H. (Hint: For lower cutoff frequency f_L, only C_C matters, while for f_H, only diode capacitances matter).

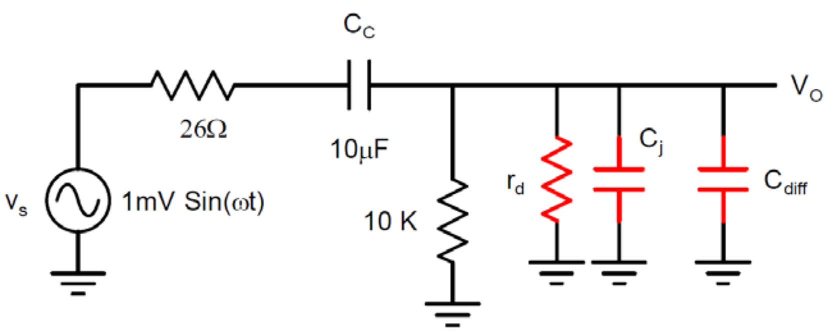




Sol.: DC analysis:

$$I_{D1} = \frac{1.7 - 0.7}{10K} = 1mA$$

Small signal AC equivalent circuit:

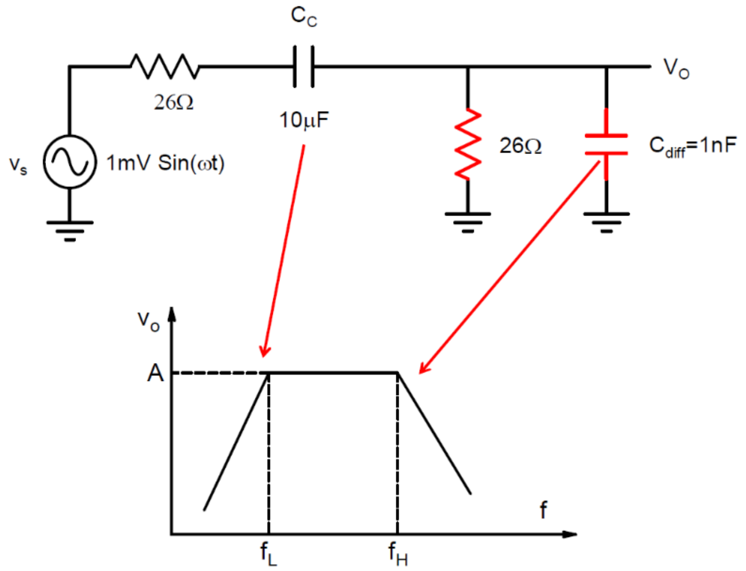


$$r_d = V_t/I_{D1} = 26\Omega, \qquad C_j \cong \frac{C_{jo}}{\left(1 - \frac{0.7}{V_{bi}}\right)^{0.5}} = 6.2\text{pF}, \qquad C_{diff} = \frac{I_{D1}}{V_T} * \tau = 1nF$$

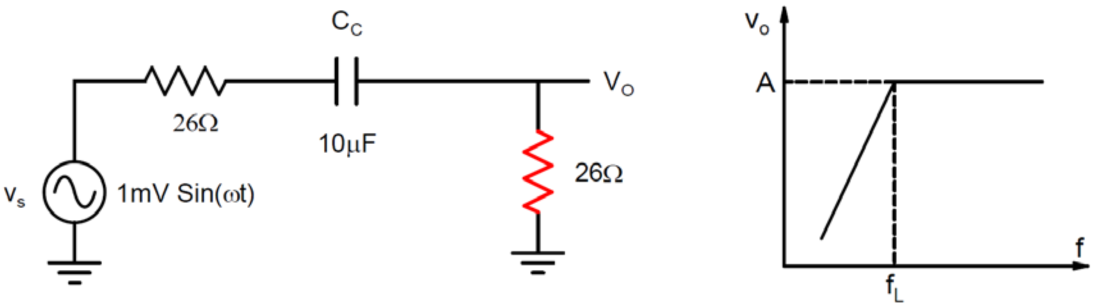
Note that diffusion capacitance is much larger than junction or depletion capacitance in forward bias and thus depletion capacitance can be neglected.

Simplified small signal AC equivalent circuit:

Remember that at 3dB frequency impedance of capacitor is comparable to resistance associated with it.



Lower cutoff frequency:

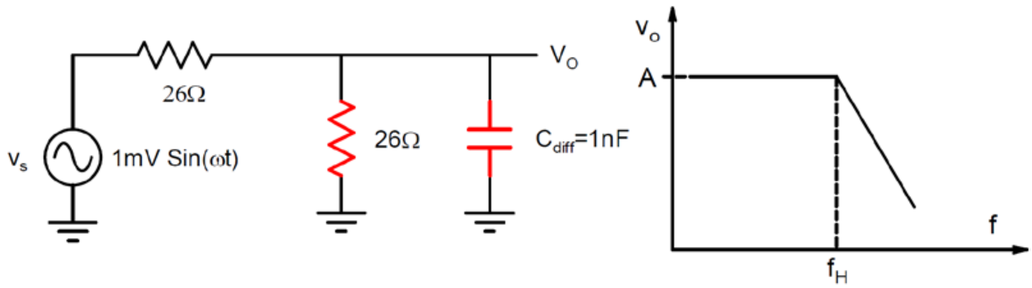


$$f_L = \frac{1}{2\pi(26+26)*10*10^{-6}} = 306\text{Hz}$$

$$\frac{1}{2\pi * f_L * C_{diff}} = 0.52\text{M}\Omega$$

So, the internal diode capacitance can be considered as an open circuit.

Upper cutoff frequency:



$$f_H = \frac{1}{2\pi(26\|26)*10^{-9}} = 12.24MHz$$

$$\frac{1}{2\pi * f_H * C_c} = 1.3*10^{-3}\Omega$$

So, the external coupling capacitor can be considered as a short.