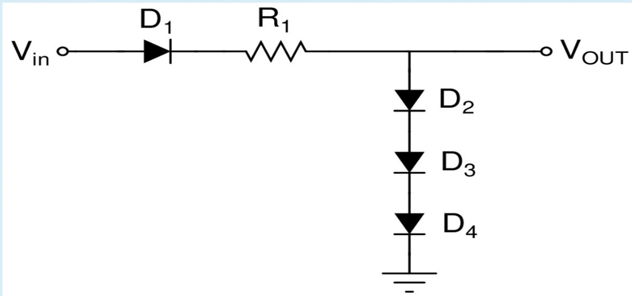
Tutorial_1 solution

In the figure below, assume each diode has a cut-in voltage of 0.8V and R1 = 4700 Ω. If the input voltage Vin is changed from 5V to 5.1V determine the corresponding change in the Vout (in mV). (Take V_T = 26mV , Give answer up to at least 3 decimal places).



Ans -

Applying KVL

$$I = \frac{5-(4\times 0.8)}{4700}$$

$$I = 0.3829\,mA$$

Diode small signal resistance $(r_d) = \frac{V_T}{I}\,\Omega$

Change in o/p voltage

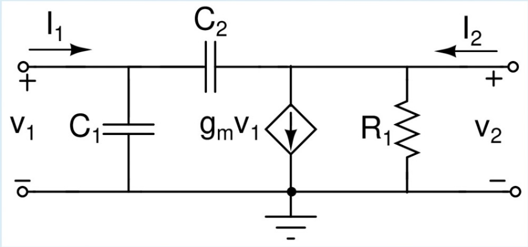
$$\Delta V_{out} = \frac{3r_d}{3r_d + R + r_d}\,\Delta V_{in}$$

$$= 4.09\,V$$

$\boxed{Ans = 4.09V}$

Note as the $R_1 \gg r_d$, so small signal approximation valid here.

For the given 2-port network, shown in the figure, calculate the magnitude of y_{21} . The operating frequency is kept at 220 MHz. Use C_1 = 1 μF, C_2 = 2 μF, g_m = 100 mS, R1 = 260 Ω.



(Give answer up to at least 3 decimal places)

Ans :-

$$y_{21} = \frac{I_2}{V_1}\Big|_{V_2=0}$$

Short the V_2 and applying KCL at the o/p node

$$I_2 = g_m V_1 - sC_2 V_1$$

$$\frac{I_2}{V_1} = g_m - sC_2$$

$$y_{21} = \sqrt{g_m^2 + (2\pi f C_2)^2}$$

$$y_{21} = \sqrt{(0.01)^2 + (2 \times 3.14 \times 220 \times 10^6 \times 2 \times 10^{-6}}$$

$$\boxed{y_{21} = 2763.200}$$

A small signal peak to peak current at a level of 2.7% of I_{DQ}, the quiescent bias current, is applied to a forward biased PN junction diode. If the DC bias current is kept at 2.5 mA, then the small signal peak to peak output voltage swing obtained (in mV) is: (Take V_T = 26mV)

Ans :-

Signal current level $(i_d) = \frac{2.7 \times I_{DQ}}{100}$

Small signal diode resistance

$$r_d = \frac{V_T}{I_D}$$

V_T = thermal voltage
I_D = DC bais current

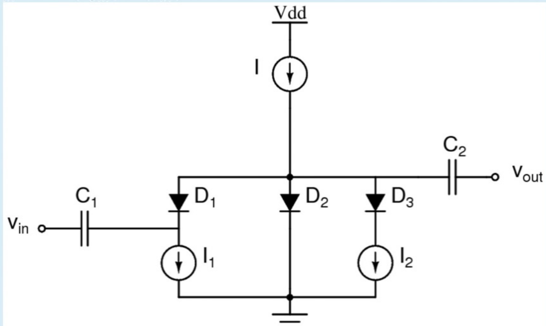
Voltage swing $= V_d = i_d r_d$

$$= \frac{2.7 \times 26mv}{100}$$

$$= 0.702 \, mv$$

$$\boxed{Ans = 0.702 \, mv}$$

In the circuit shown below, I=500 μA and $I_1 = 167$ μA , I_2 =333 μA, C_1 and C_2 are large coupling capacitors. For small signal input v_{in}, Find (v_{out}) / (v_{in})

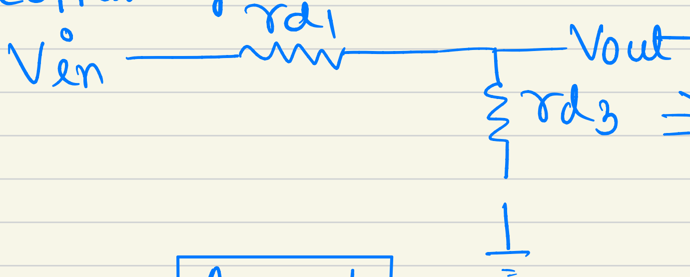


Ans :-

As, $I = I_1 + I_2$,

D_1 & D_2 are turned on, D_2 is turned off

For small signal analysis current sources will be off as they are DC.

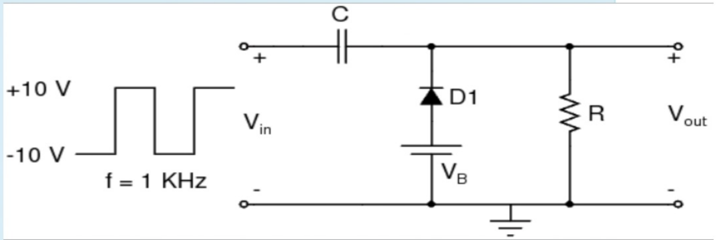


$$\Rightarrow \frac{V_{out}}{V_{in}} = 1$$

$$\boxed{Ans = 1}$$

Note for dc capacitors acts as a open circuit & for small signal acts as a short circuit.

Find the maximum value of V_{out} (in Volts) in the circuit given below for V_B = 5 V, R = 24.3 KΩ and C = 1 μF . Assume voltage drop across D1 to be 0.7 V when it is ON.



Ans :

When $V_{in} = -10V$, D_1 is on.

The voltage stored in cap C_1,

$$V_C = [5 - 0.7 - (-10)]V$$

$$V_C = 14.3 V$$

when $V_{in} = 10V$, D_1 is off

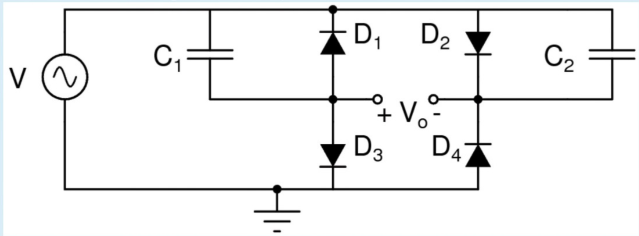
So, $V_{out} = (10 + V_C) V$

$= (10 + 14.3) V$

$= 24.3 V$

$$\boxed{Ans = 24.3 V}$$

In the circuit shown below V= V_m sin(6283t) where V_m =5 V, C_1 = 6 μF, C_2 = 3 μF. Find V_o at steady state in Volts. (Assume diode cut in voltage as 0.7 V)



Ans.

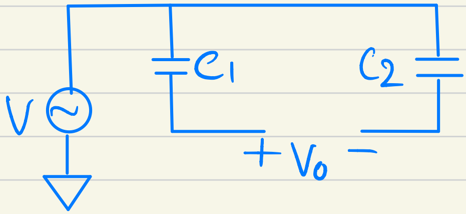
In the positive half cycle, D3 will be FB, D1, D2, & D4 are RB.

The voltage stored in the $C_1 = (5 - 0.7)$ V
$= 4.3$ V.

In the negtive half cycle, D4 will be FB, D1, D2, & D3 are RB.

The voltage stored in the $C_2 = -(5 - 0.7)$ V
$= -4.3$ V

At steady state, D1, D2, D3, D4 will be R.B.



If we apply KVL,

$$V_o = (-4.3 - 4.3)\ V$$
$$= -8.6\ V$$

$$\boxed{Ans = -8.6\ V}$$

Consider a nonlinear amplifier with input output characteristics $V_{out} = V_A \exp(V_{in} / V_A)$, Where $V_A = 144$ mV. To achieve small signal gain of 30, find out the upper limit of input (in mV) for which small signal approximation is valid? (Assume first order term is greater than second order term)

Ans :-

Small signal approximation,

$$\Delta V_{out} + V_{out} = f(V_{in} + \Delta V_{in})$$

$$= f(V_{in}) + \Delta V_{in} f'(V_{in}) + \frac{\Delta V_{in}^2}{2!} f''(V_{in}) + \text{---- higher order terms}$$

For small signal approximation to be valid

$$\Delta V_{in} f'(V_{in}) > \frac{\Delta V_{in}^2}{2} f''(V_{in})$$

$$\Rightarrow \Delta V_{in} < \frac{2 f'(V_{in})}{f''(V_{in})} \quad \text{---- (1)}$$

$$f'(V_{in}) = \exp\left(\frac{V_{in}}{V_A}\right), \quad f''(V_{in}) = \frac{1}{V_A} \exp\left(\frac{V_{in}}{V_A}\right)$$

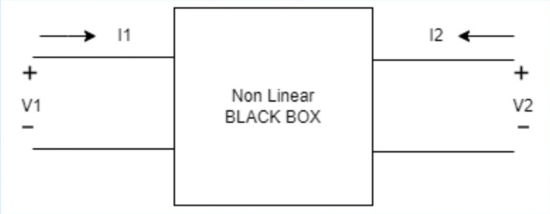
Form (1)

$$\Delta V_{in} < \frac{2 \exp\left(\frac{V_{in}}{V_A}\right)}{\frac{1}{V_A} \exp\left(\frac{V_{in}}{V_A}\right)}$$

$$\Delta V_{in} < 2 V_A$$

$$\boxed{\text{Ans} = 244 \text{ mv}}$$

A certain non-linear device has the following output current expression:



$I_2 = I_0 e^{V_1/V_T}(1 - e^{-V_2/V_T})$

Find the linear small signal approximated y-parameter corresponding to the device transconductance (in S). Take V1 = 520mV, V2 = 260mV, I_0 = 4x 10^{-10} A. (Take $V_T = 0.026V$)
(Give answer up to at least 3 decimal places)

Ans :-

Transconductance is given by change in o/p current due to a differential change in the i/p voltage.

$$\text{As, } y_{21} = \frac{dI_2}{dV_1}$$

So, y_{21} is the transconductance

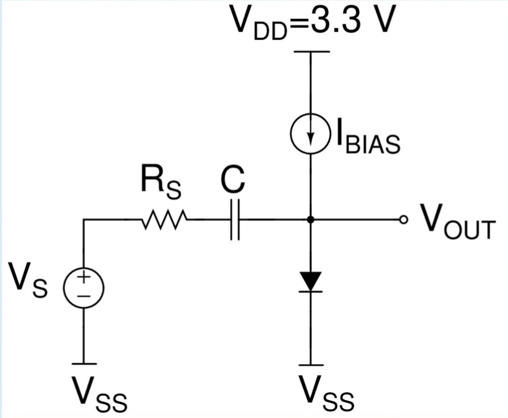
$$I_2 = I_0 e^{V_1/V_T}(1 - e^{-V_2/V_T})$$

$$\frac{dI_2}{dV_1} = \frac{d}{dV_1}\left[I_0 e^{V_1/V_T}(1 - e^{-V_2/V_T})\right]$$

$$= I_0\left[\frac{e^{20}(1 - e^{-10})}{0.026}\right]$$

$$\boxed{\text{Ans} = 7.456}$$

Consider a diode biased by I_{BIAS} = 3 μA. A small signal with source impedance Rs = 900 Ω is coupled to the Q-point using a large capacitor C. Find the small signal voltage gain V_{OUT}/V_s. (Give upto at least 3 decimal places.)



Ans

In dc, C will be acts as open circuit

So, small signal resistance

$$r_d = \frac{V_T}{I_{BIAS}}$$

In the small signal equivalent, C can be replaced with short ckt

$$V_o = \left[\frac{r_d}{r_d + R_s}\right] V_s$$

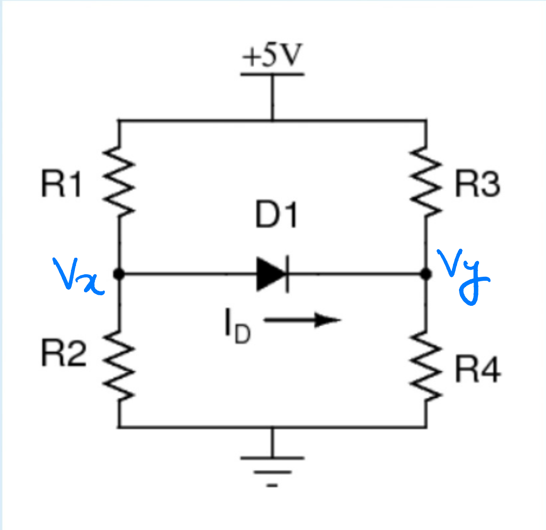
So, small signal gain,

$$\frac{V_o}{V_s} = \frac{V_T}{V_T + I_{BIAS} R_s}$$

$$= \frac{0.026}{0.026 + (3 \times 10^{-6}) \times (900)}$$

$$\boxed{A_v = 0.9059}$$

The circuit below contains resistors and a diode. If $R1$, $R2$, $R3$ and $R4$ are 2.2 KΩ, 8.8 KΩ, 6.6 KΩ and 4.4 KΩ respectively, find the operating current I_D through diode $D1$ (in milli-amperes). Assume voltage drop across $D1$ to be 0.7 V when it is ON. (Give answer upto 3 decimal places).



Ans :-

Assuming D_1 is off

$$V_x = \frac{5 \times 8.8}{2.2 + 8.8} = 4V$$

$$V_y = \frac{5 \times 4.4}{8.8 + 4.4} = 2V$$

$V_x > V_y \rightarrow D_1$ is on

[∵ Intial assumption was wrong]

Now if D_1 is on,

$$\frac{V_x}{8.8} + \frac{V_x - 5}{2.2} + I_D = 0 \quad \text{---- (1)}$$

$$\frac{V_y}{4.4} + \frac{V_y - 5}{6.6} + I_D = 0 \quad \text{---- (2)}$$

$$V_x - V_y = 0.7 \quad \text{---} \; (3)$$

If we solve the eq (1), eq (2) & eq (3)

we get, $V_x = 3.48\,V$

$V_y = 2.78\,V.$

Now again,

$$I_D = \frac{5 - 3.48}{2.2} - \frac{3.48}{8.8}$$

$$\boxed{I_D = 0.295}$$