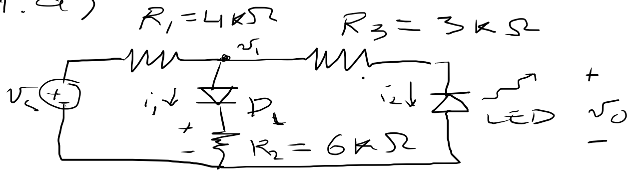
EXAME 8/7/21 — Part 2 resolution

1. a)



$\underline{V_s = 2V} \Rightarrow D_1$ ON, LED OFF

$i_2 = 0 \Rightarrow v_O = v_1 = V_{R_2} + V_{D_1 ON}$

$= \frac{R_2}{R_1+R_2}(V_S - V_{D_1 ON}) + \underset{(0.5V)}{V_{D1\,ON}} = 1.4V$

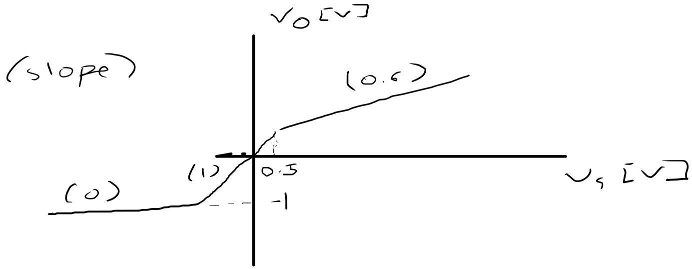
$\underline{V_s = -3V} \Rightarrow D_1$ OFF, LED ON $\Rightarrow v_O = -V_{LED\,ON} = -1V$

b) $v_s < -1V \Rightarrow D_1$ OFF, LED ON $\Rightarrow v_O = -1V$

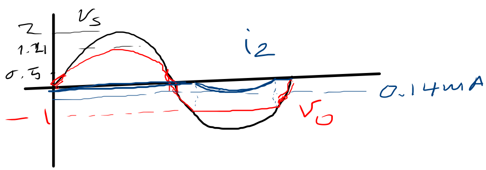
$-1V \leq v_s < 0.5V \Rightarrow D_1$, LED OFF $\Rightarrow i_1 = i_2 = 0 \Rightarrow V_O = v_S$

$v_S \geq 0.5V \Rightarrow D_1$ ON, LED OFF $\Rightarrow v_O = V_{R_2} + V_{D_1 ON} = \frac{R_2}{R_1+R_2} v_s + \frac{R_1}{R_1+R_2} v_{D1\,ON}$

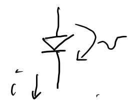
$v_o = 0.6 v_S + 0.2 \; V$



c) $v_s = 2\sin(\omega t)$



d) Instantaneous power is $p(t) = v(t)\,i(t)$

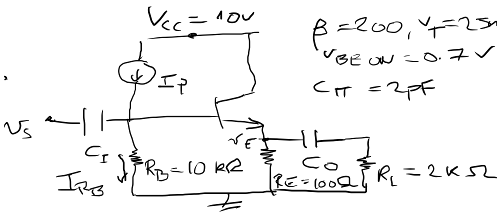


Max occurs when i is max since $v = V_{DON}$ is fixed

$$i_1\,max = \frac{2 - V_{D1ON}}{R_1 + R_2}, \quad -i_2\,max = \frac{2 - V_{LED\,ON}}{R_1 + R_3}$$

$$P_{1\,max} = V_{D1ON}\, i_{max} = 75\mu W \qquad P_{2\,max} = V_{LED\,ON}\, i_{2\,max} = 143\mu W$$

2.



$\beta = 200$, $V_T = 25mV$
$v_{BE\,ON} = 0.7V$
$C_\pi = 2pF$

a) $V_E = 6V$ at 0.P., All capacitors open-circuit

$$I_E = \frac{V_E}{R_E} = 60\,mA, \quad I_B = \frac{I}{\beta+1}, \quad I_{RB} = \frac{V_E + 0.7}{R_B}$$

$$I_P = I_B + I_{RB} = 0.97\,mA$$

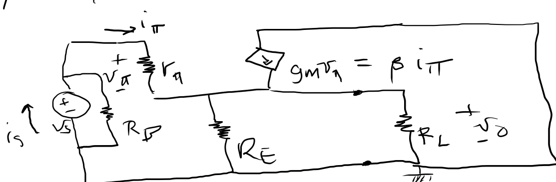
b) Incremental circuit for passband

$V_{CC} \equiv GND$

$I_P \equiv$ open-circuit

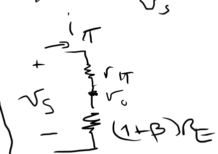
$C_I, C_O \equiv$ short-circuit

$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} \approx 83.(3)\,\Omega$



$$Z_i = \left(r_\pi + (1+\beta)R_E\right) // R_B = 6.67\,k\Omega$$

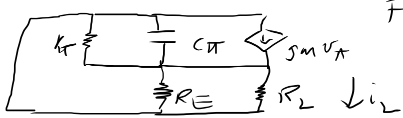
$$A_v = \frac{v_o}{v_s} = \frac{(1+\beta)R_E}{r_\pi + (1+\beta)R_E} \approx 1$$



Voltage divider

$$Z_o = r_\pi // \frac{1}{g_m} // R_E \approx 0.41\,\Omega$$

c)



Find equivalent resistor seen from C_π

$$R_{eq} = r_\pi \,//\, R_E \,//\, \frac{1}{g_m} \,//\, R_L \approx \frac{1}{g_m} \approx Z_o$$

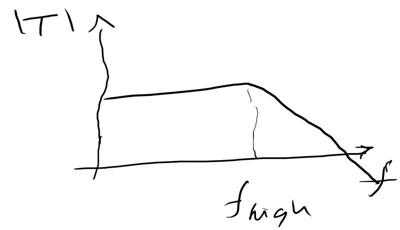
$$f_{high} = \frac{1}{2\pi C_\pi R_{eq}} \approx 192 \text{ GHz}$$

This is a low-pass filter from the perspective of $T(s) = \dfrac{i_L(s)}{i_S(s)}$

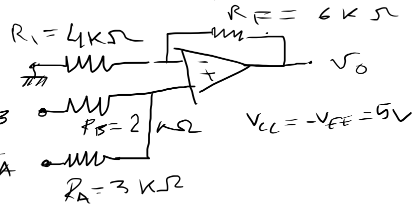
Note that this voltage follower circuit has $A_v \approx 1$ and its purpose is to amplify current to give to the load

When C_π becomes a short-circuit $g_m v_\pi = 0$

$\Rightarrow$ no more current gain!



3. a)



Superposition

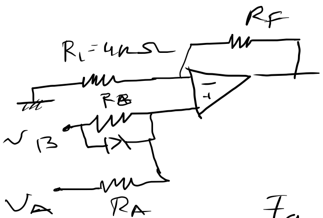
$$v_o = \left(\underbrace{\frac{R_B}{R_A+R_B}}_{} v_A + \underbrace{\frac{R_A}{R_A+R_B}}_{} v_B\right)\underbrace{\left(1+\frac{R_F}{R_1}\right)}_{} \qquad (1)$$

voltage dividers   non-inverting amp.

$v_A = -0.5V$, $v_B = 5V \Rightarrow v_o = 7V$ but the OP-AMP saturates and

$$\boxed{v_o = 5V}$$

b)



$V_A = 1V$, $v_B = -4V$, $V_D = -\frac{R_B}{R_A+R_B}(v_A - v_B) < 0$

Diode is OFF

Eq. (1) applies and $v_o = -5V$

saturation limit!

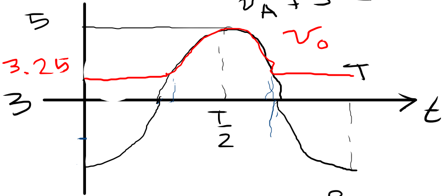
c) $v_A = -2\cos(\omega t)$, $v_B = 2V$

If $(v_B - v_A)\frac{R_B}{R_A+R_B} = 0.7 \Leftrightarrow V_A = 0.25$ the diode is at conduction threshold

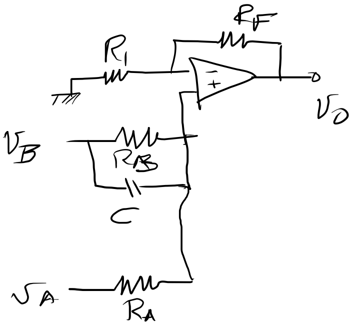
$v_A \le 0.25 \rightarrow$ D ON $\longrightarrow v_o = (v_B - 0.7)\left(1+\frac{R_F}{R_1}\right) = 3.25V$

$v_A > 0.25 \rightarrow$ D OFF, eq. (1) applies $\longrightarrow v_o = 3 + v_A$

$v_A + 3 = 3 - 2\cos(\omega t)$



d)



$$v_o = \left(\underbrace{\frac{Z_B}{R_A + Z_B} V_A}_{\substack{V_A \text{ contribution} \\ \text{varies with } f}} + \underbrace{\frac{R_A}{R_A + R_B} V_B}_{\substack{V_B \text{ contribution} \\ \text{is static}}} \right) \overbrace{\left(1 + \frac{R_F}{R_1} \right)}^{\substack{\text{non-inverting amp} \\ \text{form}}}$$

$$V_o = V_{oA} + V_{oB}$$

$$V_{oB} = \frac{R_A}{R_A + R_B}\left(1 + \frac{R_F}{R_1}\right)(-1) = -1.5\text{ V}$$

$$Z_B = R_B \parallel \frac{1}{sC} = \frac{R_B}{1 + sCR_B}$$

$$f = 1\text{KHz} \Rightarrow Z_B = \frac{R_B}{1 + j2\pi f C R_B}$$

$$\tilde{V}_{oA} = \frac{Z_B}{Z_B + R_A}\left(1 + \frac{R_F}{R_1}\right) = 0.40728 - j0.49133 \text{ V}$$

$$V_{oA}(t) = |\tilde{V}_{oA}| \cos(\omega t + \angle \tilde{V}_{oA})$$

$$V_A = \cos(\omega t)\text{ V}$$

$$V_B = -1\text{ V}$$

$$V_o(t) = 0.64 \cos(\omega t - 0.88) - 1.5\text{ V}$$