Microelectronics Circuit Analysis and Design Homework(15th)

Yuejin Xie U202210333

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15.15 Consider the bandpass filter in Figure P15.15.(a) Show that the voltage transfer function is

$$A_v(s) = \frac{v_O}{v_I} = \frac{-1/R_4}{(1/R_1) + sC + 1/(sCR_2R_3)}$$

(b) For $C = 0.1\mu\mathrm{F}$, $R_1 = 85\ \mathrm{k}\Omega$, $R_2 = R_3 = 300\Omega$, $R_4 = 3\ \mathrm{k}\Omega$, and $R_5 = 30\ \mathrm{k}\Omega$, determine: (i) $|A_v(\max)|$;(ii) the frequency f_o at which $|A_v(\max)|$ occurs; and (iii) the two 3 dB frequencies.

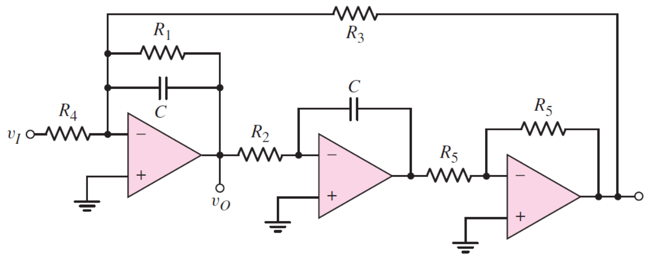

Figure 1: Problem 15.15

Solution:

(a)Because of "KCL", and virtual open and short, we have equation as follow:

$$\begin{cases} \dfrac{v_I}{R_4} = -\dfrac{v_2}{R_3} - \dfrac{v_o}{R_1 \,\|\, (\frac{1}{sC})} \\ \dfrac{v_o}{R_2} = -\dfrac{v_1}{(\frac{1}{sC})} \\ \dfrac{v_1}{R_5} = -\dfrac{v_2}{R_5} \end{cases} \Rightarrow A_v(s) = \frac{v_O}{v_I} = \frac{-1/R_4}{(1/R_1) + sC + 1/(sCR_2R_3)}$$

(b)$C=0.1\mu$F, $R_1=85$ kΩ, $R_2=R_3=300\Omega$, $R_4=3$ kΩ, and $R_5=30$ kΩ, Now

$$A_v(s)=\frac{v_O}{v_I}=\frac{-1/R_4}{(1/R_1)+sC+1/(sCR_2R_3)}=-\frac{R_1}{R_4}\cdot\frac{1}{1+sR_1C+\dfrac{R_1}{sCR_2R_3}}$$
$$=-\frac{R_1}{R_4}\cdot\frac{1}{1+j(\omega R_1C-\dfrac{R_1}{\omega CR_2R_3})}$$

$$\Rightarrow |A_V(j\omega)|=\frac{R_1}{R_4}\cdot\frac{1}{\sqrt{1+(\omega R_1C-\dfrac{R_1}{\omega CR_2R_3})^2}}$$

(i)When $\omega R_1C-\dfrac{R_1}{\omega CR_2R_3}=0, |A_v(jw)|_{\max}=28.33$

(ii)$\omega=\dfrac{1}{C\sqrt{R_1R_2}}, f_o=\dfrac{\omega}{2\pi}=5.31\text{kHz}$

(iii)For 3dB frequencies, we have equation:

$$(\omega R_1C-\frac{R_1}{\omega CR_2R_3})^2=1, f=\frac{\omega}{2\pi}\Rightarrow f=5.32\text{kHz}, 5.30\text{kHz}$$

15.17 For each of the circuits in Figures P15.17, derive the expressions for the voltage transfer function $T(s)=V_o(s)/V_i(s)$ and the cutoff frequency $f_{3\text{dB}}$.

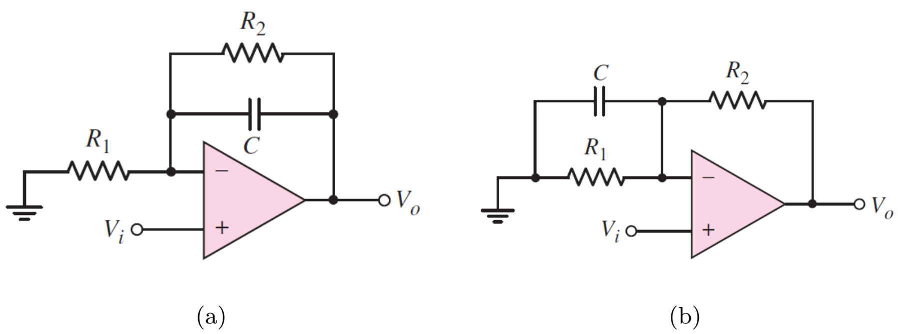

Figure 2: Problem 15.17

Solution:

(a)Because of "KVL", and virtual open and short, we have equation:

$$T(s)=V_o(s)/V_i(s)=\frac{R_1+R_2||\frac{1}{sC}}{R_1}=\left(1+\frac{R_2}{R_1}\right)\cdot\frac{1+s(R_1\parallel R_2)C}{1+sR_2C}$$

$$\Rightarrow f_H=\frac{1}{2\pi R_2C}, f_L=\frac{1}{2\pi(R_1||R_2)C}$$

(b)Because of "KVL", and virtual open and short, we have equation:

$$\Rightarrow T(s) = V_o(s)/V_i(s) = \frac{R_2 + R_1 || \frac{1}{sC}}{R_1 || \frac{1}{sC}} = \frac{R_2 + R_1}{R_1} \cdot (1 + s(R_1 \parallel R_2)C)$$

$$\Rightarrow f = \frac{1}{2\pi(R_1||R_2)C}$$

15.46 Consider the Schmitt trigger in Figure P15.46. Assume the saturated output voltages are $\pm V_P$. (a) Derive the expression for the crossover voltages V_{TH} and V_{TL}. (b) Let $R_A = 10$ kΩ, $R_B = 20$ kΩ, $R_1 = 5$ kΩ, $R_2 = 20$ kΩ, $V_P = 10$ V, and $V_{\text{REF}} = 2$ V. (i) Find V_{TH} and V_{TL}. (ii) Sketch the voltage transfer characteristics.

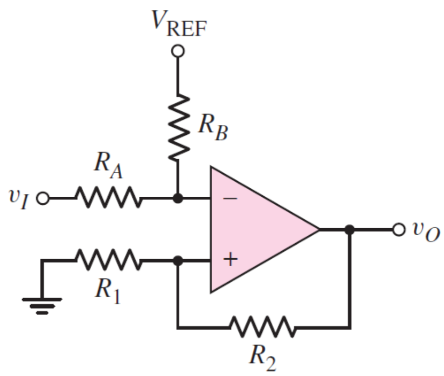

Figure 3: Problem 15.46

Solution:

(a)For $V_O = +V_P$:

$$\frac{R_A}{R_A + R_B} V_{REF} + \frac{R_B}{R_A + R_B} V_{TH} = \frac{R_1}{R_1 + R_2} V_P \Rightarrow V_{TH} = \left(\frac{R_A + R_B}{R_1 + R_2}\right)\left(\frac{R_1}{R_B}\right) V_P - \left(\frac{R_A}{R_B}\right) V_{REF}$$

For $V_O = -V_P$:

$$V_{TL} = -\left(\frac{R_A + R_B}{R_1 + R_2}\right)\left(\frac{R_1}{R_B}\right) V_P - \left(\frac{R_A}{R_B}\right) V_{REF}$$

(b)$R_A = 10$ kΩ, $R_B = 20$ kΩ, $R_1 = 5$ kΩ, $R_2 = 20$ kΩ, $V_P = 10$ V, and $V_{\text{REF}} = 2$ V, so

(i)

$$V_{TL} = -4\text{V}, V_{TH} = 2\text{V}$$

(ii)

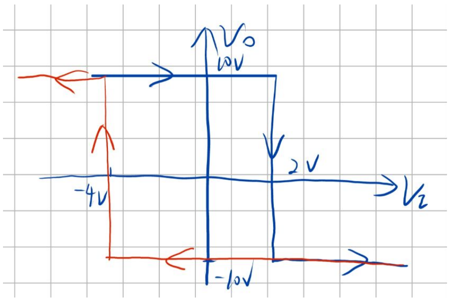

Figure 4: Problem 15.46 voltage transfer characteristics

15.47 The saturated output voltages are $\pm V_P$ for the Schmitt trigger in Figure P15.47. (a) Derive the expressions for the crossover voltages V_{TH} and V_{TL} (b) If $V_P = 12$V, $V_{REF} = -10$V, and $R_3 = 10$kΩ, find R_1 and R_2 such that the switching point is $V_S = -5$ V and the hysteresis width is 0.2 V. (c) Sketch the voltage transfer characteristics.

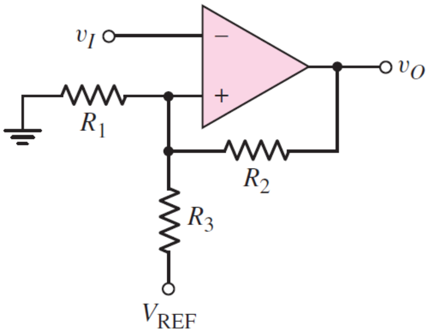

Figure 5: Problem 15.47

Solution:

(a)For $V_O = V_P$:

$$\frac{V_O - V_{TH}}{R_2} + \frac{V_{REF} - V_{TH}}{R_3} = \frac{V_{TH}}{R_1} \Rightarrow V_{TH} = \frac{\dfrac{V_{REF}}{R_3} + \dfrac{V_P}{R_2}}{\left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}\right)}$$

For $V_O = -V_P$:

$$\frac{V_O - V_{TH}}{R_2} + \frac{V_{REF} - V_{TH}}{R_3} = \frac{V_{TH}}{R_1} \Rightarrow V_{TH} = \frac{\dfrac{V_{REF}}{R_3} - \dfrac{V_P}{R_2}}{\left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}\right)}$$

(b) Equations as follow:

$$
\left\{
\begin{aligned}
&\frac{\dfrac{V_{REF}}{R_3}}{\left(\dfrac{1}{R_1}+\dfrac{1}{R_2}+\dfrac{1}{R_3}\right)} = -5 \\
&\Delta V_T = V_{TH} - V_{TL} = \frac{\dfrac{2V_P}{R_2}}{\left(\dfrac{1}{R_1}+\dfrac{1}{R_2}+\dfrac{1}{R_3}\right)} = 0.2
\end{aligned}
\right.
\Rightarrow R_1 = 10.17\text{k}\Omega, R_2 = 600\text{k}\Omega
$$

(c)$V_{TL} = -5.1\text{V}, V_{TH} = -4.9\text{V}$

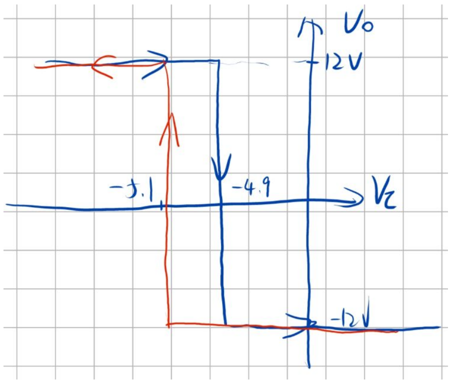

Figure 6: Problem 15.47 voltage transfer characteristics

15.48 (a) Plot the voltage transfer characteristics of the comparator circuit in Figure P15.48 assuming the open-loop gain is infinite. Let the reverse Zener voltage be $V_Z = 5.6$ V and the forward diode voltage be $V_\gamma = 0.6$ V. (b) Repeat part (a) for an open-loop gain of 10^3.(c) Repeat part (a) for 2.5 V applied to the inverting terminal of the comparator.

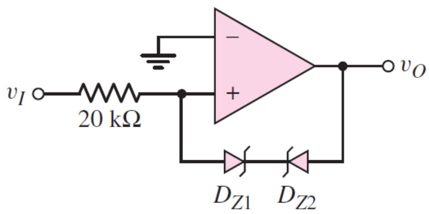

Figure 7: Problem 15.48

Solution:

(a)case 1: $|V_P| < 6.2\text{V}$, the Diodes are open:

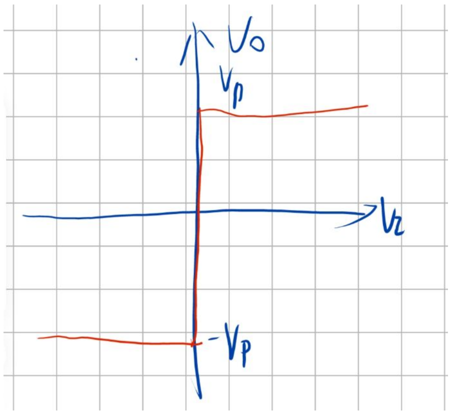

Figure 8: Problem 15.48

case 2: $|V_P| > 6.2$V, the one of the Zener Diodes work, $|V_O| = 6.2$V and input can be ignored

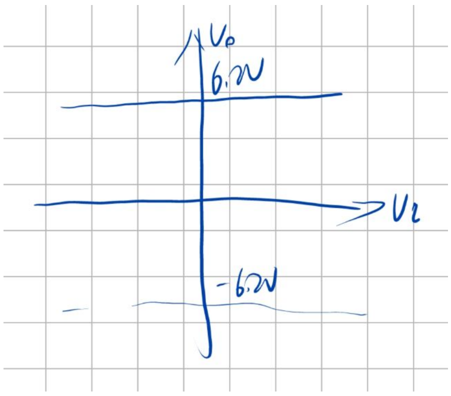

Figure 9: Problem 15.48

(b) Same as (a)

(c)when $V_O < 8.7$ V and $V_O >$3.7 V, work as comparator. Otherwise the input has no control

15.79 The voltage regulator shown in Figure P15.79 is a variable voltage, 0 to 5 A power supply. The transistor parameters are $\beta = 80$ and $V_{BE}(\text{on}) = 0.7$ V. The op-amp has a finite open-loop gain of $A_{OL} = 5 \times 10^3$ .The zero-current Zener voltage is $V_{ZO} = 5.6$ V and the Zener resistance is $r_z = 12\Omega.(a)$ For $I_Z = 12$mA,find R_1.(b) Determine the range of output voltage as the potentiometer R_3 is varied.(c) If the potentiometer is set such $x = 1$, determine : R_o of the op-amp is zero.

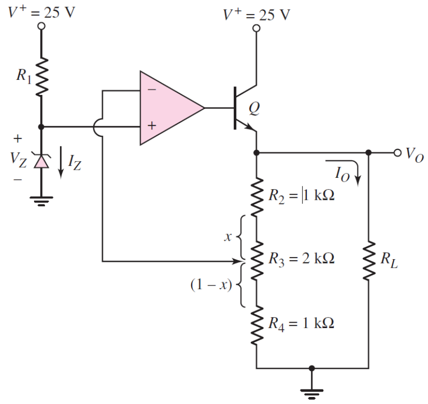

Figure 10: Problem 15.79

Solution:

(a)

$$R_1 + r_z = \frac{V^+}{I_Z} = \frac{25}{12} = 2.0833\text{k}\Omega \Rightarrow R_1 = 2.0713\text{k}\Omega$$

(b)$V^+ = V_Z + I_Z = 5.744$V

If $x = 0$,

$$V^+ = \left(\frac{R_3 + R_4}{R_2 + R_3 + R_4}\right) V_O \Rightarrow V_O == 7.659\text{V}$$

If $x = 1$,

$$V^+ = \left(\frac{R_4}{R_2 + R_3 + R_4}\right) \cdot V_O \Rightarrow V_0 = 22.976\text{V}$$

So $7.659 \leq V_O \leq 22.976$V

(c)???

15.80 The parameters of the transistor in Figure P15.80 are $\beta = 80$ and $V_{EB}(on) = 0.6$ V.The Zener diode is ideal with $V_{\mathbb{Z}} = 6.8$ V and the op-amp is ideal. (a) Determine the range of load resistance R_L such that the load current is a constant. What is the value of the constant load current? (b) If the Zener diode has a resistance $r_z = 20\Omega$ and the power supply is in the range $16 \leq V_S \leq 20$ V, determine the range in output current for $R_L = 5\text{k}\Omega$.

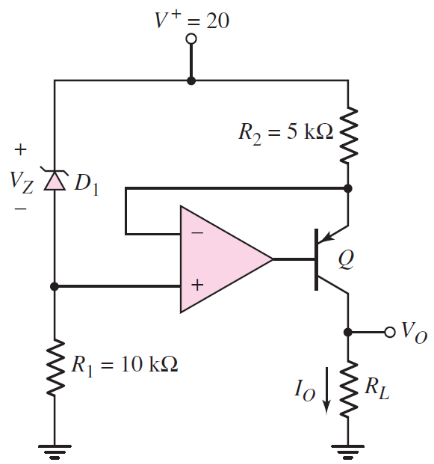

Figure 11: Problem 15.80

Solution:

(a)

$$I_O = \left(\frac{\beta}{1+\beta}\right) \cdot \frac{V_Z}{R_2} = 1.343\text{mA}$$

$$R_L(\max) = \frac{V^+ - V_Z - V_{BE}(on)}{I_O} = 9.38\text{k}\Omega$$

(b)For $V_S = 16\text{V}$

$$I_O = \left(\frac{\beta}{1+\beta}\right) \frac{V_S - \frac{R_1}{R_1 + r_Z}(V_S - V_Z)}{R_2} = 1.3484\text{mA}$$

For $V_S = 16\text{V}$

$$I_O = \left(\frac{\beta}{1+\beta}\right) \frac{V_S - \frac{R_1}{R_1 + r_Z}(V_S - V_Z)}{R_2} = 1.3468\text{mA}$$