电子学基础——第十次作业

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2019.12.12

8.10 A truck weighing station inorporates a sensor whose resistance varies linearly with the weight: $R_S = R_0 + \alpha W$. Here R_0 is a constant value, α a proportionality factor, and W the weight of each truck. Suppose R_S plays the role of R_2 in the noninverting amplifier (Fig. 8-47). Also, $V_{in} = 1\text{V}$. Determine the gain of the system, defined as the change in V_{out} divided by the change in W.

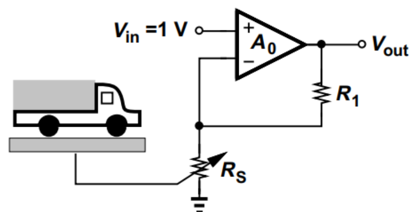


Figure 8-47

解

$$V_- = V_+ = 1\text{V}$$

$$\therefore V_{out} = V_+ + \frac{V_-}{R_S} \cdot R_1 = (1 + \frac{R_1}{R_S})V_{in}$$

$$\therefore V_{out} = (1 + \frac{R_1}{R_0 + \alpha W})V_{in}$$

$$\therefore \frac{\partial V_{out}}{\partial W} = \frac{-\alpha R_1 V_{in}}{(R_0 + \alpha W)^2} = \frac{-\alpha R_1}{(R_0 + \alpha W)^2}$$

8.17 An inverting amplifier is designed for a nominal gain of 8 and a gain error of 0.1% using an op amp that exhibits an output impedance of 2kΩ. If the input impedance of the circuit must be equal to approximately 1kΩ, calculate the required open-loop gain of the op amp.

解

$$\begin{cases} \dfrac{R_F}{R_{in}} = 8 \\ \dfrac{1}{A_0}(1 + \dfrac{R_F}{R_{in}}) = 0.1\% \end{cases}$$

$$\therefore A_0 = 9000$$

8.19 The integrator of Fig. 8-51 senses an input signal given by $V_{in} = V_0 \sin \omega t$. Determine the output signal amplitude if $A_0 = \infty$.

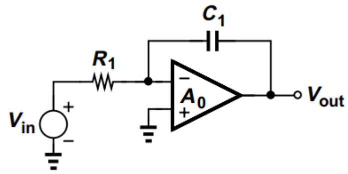


Figure 8-51

解

$$\dot{V}_{out} = -\frac{\mathrm{j}}{\omega C_1 R_1}\dot{V}_{in}$$

则V_{out}振幅为$\frac{V_0}{\omega C_1 R_1}$

8.24 The differentiator of Fig. 8-52 is used to amplify a sinusodial input at a frequency of 1MHz by a factor of 5. If $A_0 = \infty$, determine the value of $R_1 C_1$.

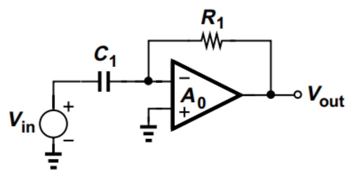


Figure 8-52

解

$$\dot{V}_{out} = \mathrm{j}R_1 C_1 \omega \dot{V}_{in}$$

$$\therefore R_1 C_1 \omega = 5, R_1 C_1 = 7.96 \times 10^{-7} \mathrm{s/rad}^{-}1$$

8.32 The voltage adder of Fig. 8-54 employs and op amp having a finite output impedance. R_{out}. Using the op amp model depicted in Fig. 8-44, compute V_{out} in terms of V_1 and V_2.

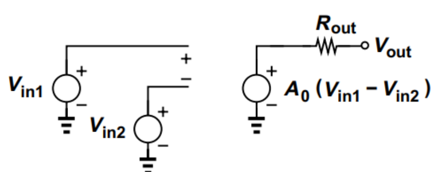


Figure 8-44

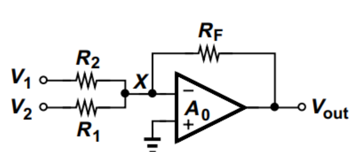


Figure 8-54

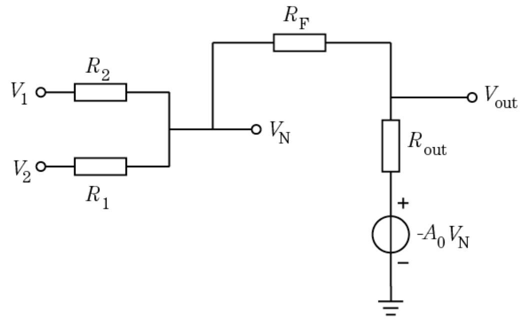


Figure p8-32

解 等效电路如图 p8-32 所示。

$$\begin{cases} V_{out} = V_N - R_F\left(\dfrac{V_1 - V_N}{R_2} + \dfrac{V_2 - V_N}{R_1}\right) \\ \dfrac{V_N + A_0 V_N}{R_F + R_{out}} = \dfrac{V_1 - V_N}{R_2} + \dfrac{V_2 - V_N}{R_1} \end{cases}$$

$$\therefore V_{out} = \frac{(R_1V_1 + R_2V_2)\left[1 - \frac{R_F(1+A_0)}{R_F + R_{out}}\right]}{R_1 + R_2 + \frac{R_1R_2(1+A_0)}{R_F + R_{out}}}$$

8.33 Due to a manufacturing error, a parasitic resistance R_P has appeared in the adder of Fig. 8-55. Calculate V_{out} in terms of V_1 and V_2 for $A_0 = \infty$ and $A_0 < \infty$. (Note that R_P can also represent the input impedance of the op amp.)

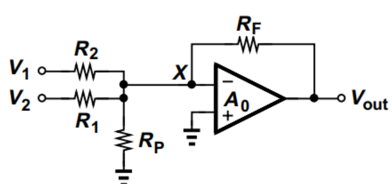


Figure 8-55

解 等效电路如图 p8-33 所示。

$$\begin{cases} I = \dfrac{V_N + A_0 V_N}{R_F + R_{out}} \\ I = \dfrac{V_1 - V_N}{R_2} + \dfrac{V_2 - V_N}{R_1} - \dfrac{V_N}{R_P} \\ V_{out} = V_N - R_F I \end{cases}$$

$$\therefore V_{out} = \left[1 - \frac{R_F(1 + A_0)}{R_F + R_{out}}\right] \frac{\frac{V_1}{R_2} + \frac{V_2}{R_1}}{\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_P} + \frac{1+A_0}{R_F + R_{out}}}$$

$$R_{out} \to +\infty, V_{out} \to \frac{\frac{V_1}{R_2} + \frac{V_2}{R_1}}{\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_P}}$$

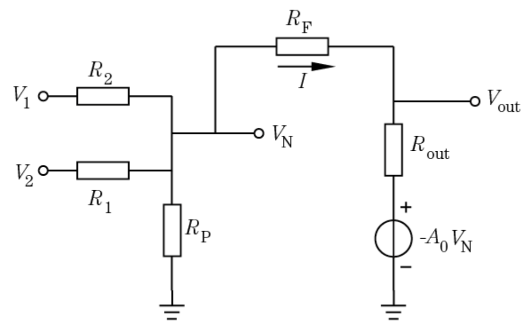


Figure p8-33

8.34 Consider the voltage adder illustrated in Fig. 8-56, where R_P is a parasitic resistance and the op amp exhibits a finite input inpedance. With the aid of the op amp model shown in Fig. 8-44, determine V_{out} in terms of V_1 and V_2.

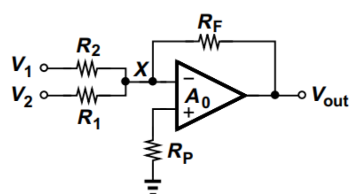


Figure 8-56

解 等效电路如图 p8-34 所示。由于V_P处无电流，则$V_P = 0$，从而可以忽略R_P的影响，则答案同题 8.32：

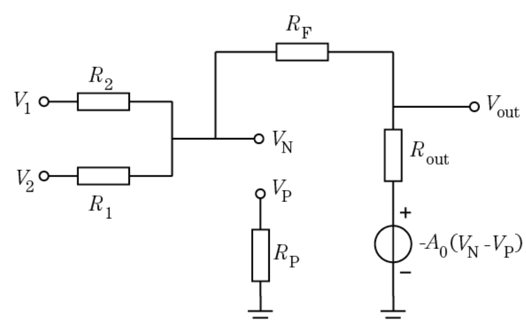


Figure p8-34

$$V_{out} = \frac{(R_1V_1 + R_2V_2)\left[1 - \frac{R_F(1+A_0)}{R_F+R_{out}}\right]}{R_1 + R_2 + \frac{R_1R_2(1+A_0)}{R_F+R_{out}}}$$

$$R_{out} \to +\infty, V_{out} \to \frac{R_1V_1 + R_2V_2}{R_1 + R_2}$$

8.46 Calculate V_out in terms of V_in for the circuit shown in Fig. 8-61.

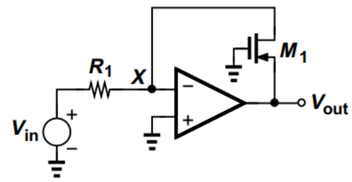


Figure 8-61

解 对M_1，$V_D = 0$, $I_D = \frac{V_{in}}{R_1}$，又

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(-V_{out} - V_{th})^2$$

$$\therefore V_{out} = \sqrt{\frac{2V_{in}}{R_1\mu_n C_{ox}(\frac{W}{L})}} - V_{th}$$

9.50 Determine the value of R_P in the circuit of Fig. 9-70 such that $I_1 = 2I_{REF}$. With this choice of R_P, does I_1 change if the threshold voltage of both transistors increases by ΔV?

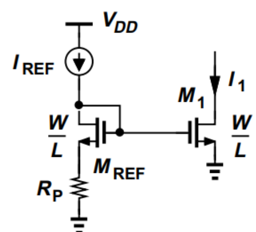


Figure 9-70

解 M_{REF}可视为$\frac{1}{g_{mREF}}$电阻，源端电压$V_S = I_{REF}R_P$，漏端电压同栅端电压$V_D = V_G = I_{REF}(\frac{1}{g_{mREF}} + R_P)$

$$\begin{cases} I_{REF} = \dfrac{1}{2}\mu_n C_{ox}\dfrac{W}{L}(I_{REF}\dfrac{1}{g_{mREF}} - V_{th})^2 \\ I_1 = 2I_{REF} = \dfrac{1}{2}\mu_n C_{ox}\dfrac{W}{L}(I_{REF}(\dfrac{1}{g_{mREF}} + R_P) - V_{th})^2 \end{cases}$$

$$\therefore R_P = (\sqrt{2} - 1)(\frac{1}{g_{mREF}} - \frac{V_{th}}{I_{REF}})$$

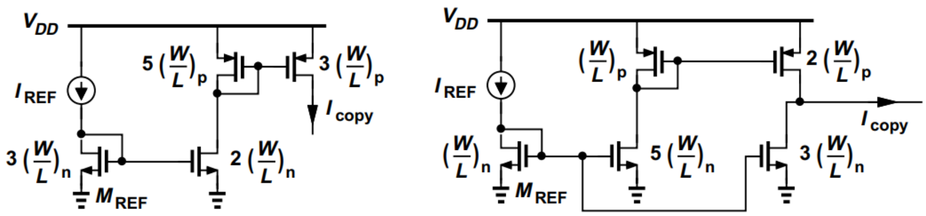
当确定R_P，V_{th}增长到$V'_{th} = V_{th} + \Delta V$时，

$$\frac{I_1}{I_{REF}} = \left(\frac{I_{REF}(\frac{1}{g_{mREF}} + R_P)}{I_{REF}\frac{1}{g_{mREF}}}\right)^2$$

$$\begin{aligned} \frac{\mathrm{d}I_1}{\mathrm{d}V_{th}}(R_P) &= 2I_{REF}\frac{I_{REF}(\frac{1}{g_{mREF}} + R_P)}{I_{REF}\frac{1}{g_{mREF}}} \cdot \frac{I_{REF}R_P}{(I_{REF}\frac{1}{g_{mREF}} - V_{th})^2} \\ &= 2\sqrt{2}I_{REF}\frac{I_{REF}R_P}{(I_{REF}\frac{1}{g_{mREF}} - V_{th})^2} \\ &= \frac{(4 - 2\sqrt{2})I_{REF}}{I_{REF}\frac{1}{g_{mREF}} - V_{th}} \end{aligned}$$

$$\therefore \Delta I_1 = \frac{(4-2\sqrt{2})I_{REF}}{I_{REF}\frac{1}{g_{mREF}} - V_{th}} \Delta V$$

9.52 Calculate I_{copy} in each of the circuits shown in Fig. 9-71. Assume all of the transisitors operate in saturation.



(a) (b)

Figure 9-71

解 以下各电流符号中下标表示长宽比所对应的MOS管的电流。

(a) $I_{2n} = \frac{2}{3} I_{REF}, I_{copy} = \frac{2}{3} \cdot \frac{3}{5} \cdot I_{REF} = \frac{2}{5} I_{REF}$

(b) $I_{5n} = 5I_{REF}, I_{2p} = 10I_{REF}, I_{3p} = 3I_{REF}$

$$\therefore I_{copy} = 7I_{REF}$$