UC《电工电子学》2020-夏

Quiz 4

1. Consider the instrumentation quality differential amplifier shown in Figure T1, with $R_1 = 1$ kΩ, $R_2 = 9$ kΩ, and $R = 10$ kΩ. The input signals are given by

$v_1(t) = 0.5 \cos(2000\pi t) + 2 \cos(120\pi t)$, $v_2(t) = -0.5 \cos(2000\pi t) + 2 \cos(120\pi t)$

a. Assuming ideal op amps, find expressions for the voltages at the output terminals of X_1 and X*2*.

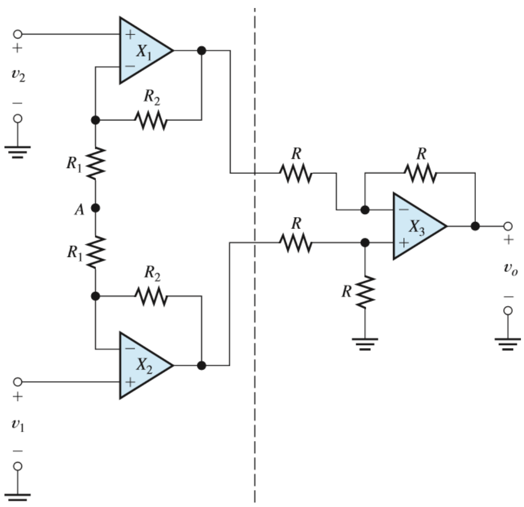

Fig. T1

b. Again assuming ideal op amps, find an expression for the output voltage $v_o(t)$.

Solution:

The differential and common-mode components of the input signal are:

$$v_{id} = v_1 - v_2 = \cos(2000\pi t)$$
$$v_{icm} = \tfrac{1}{2}(v_1 + v_2) = 2\cos(120\pi t)$$

The first-stage gain for the differential signal is $1+R_2/R_1$, which for the values given is 10. On the other hand, the first-stage gain for the common-mode component is unity.

Thus the output voltages are:

$$v_{X1out} = 5\cos(2000\pi t) + 2\cos(120\pi t)$$
$$v_{X1out} = -5\cos(2000\pi t) + 2\cos(120\pi t)$$

Assuming ideal op amps and perfectly matched components, the output of the circuit is

$v_o(t) = (1+ R_2/R_1)(v_1 - v_2) = 10 \cos(2000\pi t)$

2. Derive an expression for the voltage gain of the circuit shown in Figure T2 as a function of *T*, assuming an ideal op amp. (*T* varies from 0 to unity, depending on the position of the wiper of the potentiometer.)

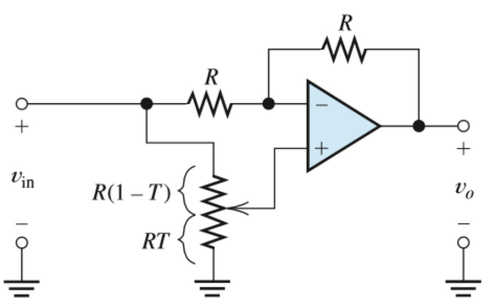

Fig. T2

Solution: By the voltage-division principle, we have

$$v_x = \frac{RT}{RT + (1-T)R} v_{in} = T v_{in}$$

Then, we can write

$$i_x = \frac{v_{in} - v_x}{R} = \frac{v_{in}(1-T)}{R}$$
$$v_o = -R i_x + v_x$$
$$= -v_{in}(1-T) + T v_{in}$$
$$= v_{in}(2T - 1)$$

3. Consider the circuit shown in Figure T3 which has $R_s = 0.5\ \Omega$, $R_L = 1000\ \Omega$, and $N_1/N_2 = 0.1$.

a. Determine the rms values of the currents and voltages with the switch open. b. Repeat with the switch closed.

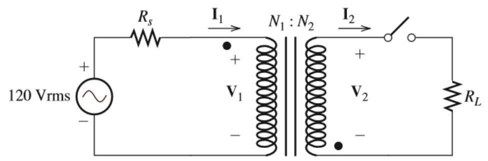

Fig. T3

(a) With the switch open, we have $I_{2\text{rms}} = 0$, $I_{1\text{rms}} = 0$ and the voltage across R s is zero. Therefore, we have $V_{1\text{rms}} = 120$ V and $V_{2\text{rms}} = (N_2/\ N_1)\ V_{1\text{rms}} = 1200$ V. (The dots affect the phases of the voltages but not their rms values.)

(b) With the switch closed, the impedance seen looking into the primary is $R_L' = (N_1/N_2)^2 R_L = 0.1^2 \times 1000 = 10\Omega$. Then, using the voltage division principle, we have $V_{1rsm} = 120 \times \frac{R_L'}{R_S + R_L'} = 114.3\text{V}$, $V_{2rsm} = \left(\frac{N_2}{N_1}\right) V_{1rsm} = 1143\text{V}$, $I_{1rsm} = \frac{V_{1rsm}}{R_S + R_L'} = \frac{120}{10.5} = 11.43\text{A}$, $I_{2rsm} = (N_1/N_2) I_{1rsm} = 1.143\text{A}$