電工學期末考參考解答

01/17/2007

1. (a) Shockley equation: $i_D = I_s\left[\exp\left(\frac{v_D}{nV_T}\right)-1\right]$, where $V_T = \frac{kT}{q}$,

$k = 1.38\times10^{-23}\,J/K$ is Boltzmann's constant, $q = 1.6\times10^{-19}\,C$ is the magnitude of the electrical charge of an electron, n is the emission coefficient, and I_s is the saturation current.

(b)

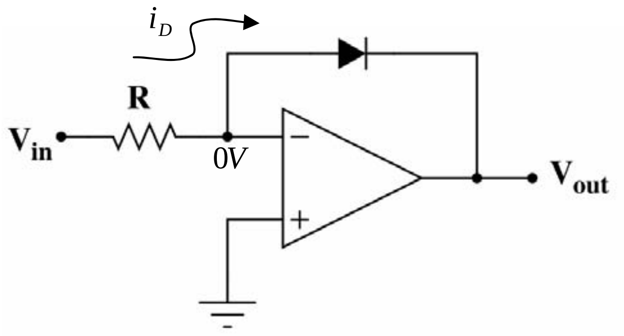


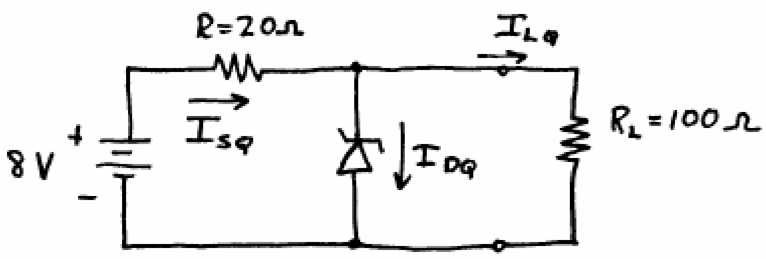
Fig. 1

For an ideal op-amp, the current flow is shown as Fig. 1.

$$i_D = I_s\left[\exp\left(\frac{v_D}{nV_T}\right)-1\right] = \frac{V_{in}-0}{R}, \quad v_D = nV_T\ln\left(\frac{V_{in}}{I_sR}+1\right),$$

$$V_{out} = 0 - v_D = -nV_T\ln\left(\frac{V_{in}}{I_sR}+1\right).$$

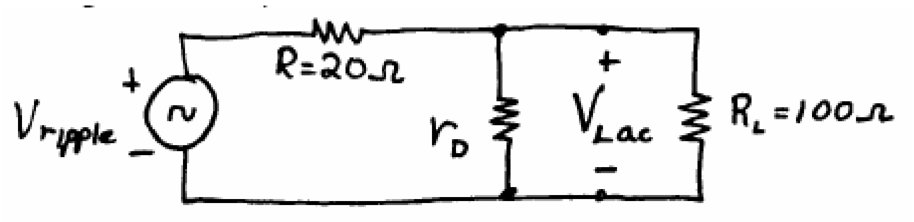
2. (a) To find the Q-point current, we ignore the ac ripple voltage and the circuit becomes:



Thus, we have:

$$I_{sQ} = \frac{8-5}{20} = 150mA, \quad I_{LQ} = \frac{5}{100} = 50mA, \quad I_{DQ} = I_{sQ} - I_{LQ} = 100mA.$$

(b) The small signal equivalent circuit is:



(c) Using the voltage-division principle, the ripple voltage across the load is

$$V_{Lax} = V_{ripple} \times \frac{R_p}{R+R_p}, \text{ where } R_p = \frac{1}{1/r_d + 1/R_L} = \frac{100 r_d}{100 + r_d}$$ is the parallel

combination of the load resistance and the dynamic resistance of the diode. So the overall voltage across the load resistance is

$$V_L + V_{Lax} = 5 + V_{ripple} \frac{\frac{100 r_d}{100 + r_d}}{20 + \frac{100 r_d}{100 + r_d}} = 5 + V_{ripple} \frac{100 r_d}{120 r_d + 2000}.$$

3. $$v_o = A_d v_{id} + A_{cm} v_{icm} = A_d (v_{i1} - v_{i2}) + A_{cm} \frac{1}{2}(v_{i1} + v_{i2}),$$

$$20mV = 200 \cdot 0 + A_{cm} \cdot \frac{1}{2}(10mV + 10mV), \quad A_{cm} = 2.$$

The CMRR of this amplifier is $20 \log \frac{|A_d|}{|A_{cm}|} = 20 \log \frac{200}{2} = 40.$

4. (a) The amplifier is linear because it obeys superposition principle.
(b) For $v_{in}(t) = A\cos(\omega t)$,

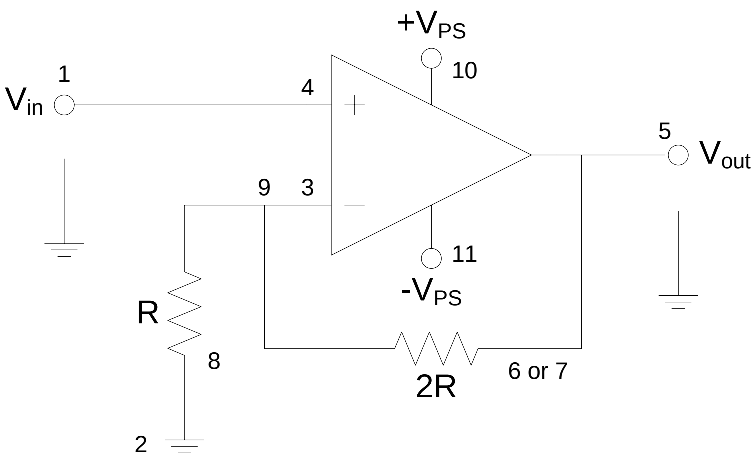
$$v_{out}(t) = v_{in}(t) + \frac{d}{dt} v_{in}(t) = A\cos(\omega t) + A(-\omega \sin(\omega t)) = A\cos(\omega t) + A\omega \cos(\omega t + \frac{\pi}{2})$$

$$\therefore A_v = v_{out}(t)/v_{in}(t) = 1\angle 0° + \omega \angle 90° = 1 + j\omega = \sqrt{1+\omega^2} \angle \tan^{-1} \omega$$

the amplitude is not a constant for different frequencies, so it produces amplitude distortion.

(c) By (b), the phase is not proportional to the frequency, so it produces phase distortion, too.

5. In order to get (output voltage) / (input voltage) = 3, we can design a non-inverting amplifier as follows:



The pin connections are also shown in the figure.

6. For an ideal op-amp, node A and B is virtually short. By using the voltage-division principle, $v_{in} = v_A = v_B = v_{out}\dfrac{R}{R+R} = \dfrac{v_{out}}{2}$.

Also, $v_A - v_{out} = R_L i_{in} \Rightarrow -\dfrac{v_{out}}{2} = R_L i_{in} \Rightarrow -v_{in} = R_L i_{in} \Rightarrow \dfrac{v_{in}}{i_{in}} = -R_L$.

So the input resistance is negative while R_L is positive.