

EE3122 Analogue Circuit Fundamentals Tutorial 5

1(a). When ignoring Early Effect, M_R = ratio of currents = ratio of sizes

(i) Hence, $I_{D4}/I_{D3} = 8/4 = 2$

(ii) Hence, $I_{D4} = 2 \times 446 \text{ uA} = 892 \text{ uA}$

(iii) For V_X , consider V_{SG3} (of M3) = $V_{DD} - V_X$

$$I_{D3} = K_p' / 2 (W/L)_3 (V_{SG3} - |V_{TP}|)^2 = 446 \text{ uA}$$

From this, we can solve $V_{SG3} = 3.49 \text{ V}$ and hence, $V_X = 6.51 \text{ V}$

For V_Y , consider V_{GS5} (of M5) = V_Y

$$I_{D5} = I_{D4} = K_n' / 2 (W/L)_5 (V_{GS5} - |V_{TN}|)^2 = 892 \text{ uA}$$

From this, we can solve $V_{GS5} = 2.61 \text{ V}$ and hence, $V_Y = 2.61 \text{ V}$

(b)

$$\begin{aligned} \frac{I_{D4}}{I_{D3}} &= \frac{(W/L)_4}{(W/L)_3} \frac{(1 + \lambda V_{SD4})}{(1 + \lambda V_{SD3})} = \frac{8}{4} \cdot \frac{(1 + \lambda (V_{DD} - V_Y))}{(1 + \lambda (V_{DD} - V_X))} \\ &= 2 \times \frac{(1 + 0.02 (10 - 2.61))}{(1 + 0.02 (3.49))} = \frac{2.295}{1.069} = 2.15 \end{aligned}$$

Hence, $I_{D4} = 2.15 \times 446 \text{ uA} = 958.9 \text{ uA}$

2. For each case, we need to find the maximum voltage swing, i.e. peak amplitude of the largest sinusoid at the output V_{op} . This will correspond to the maximum power $P_{max} = V_{op}^2 / 2R_L$ (1)

(a) The sine wave is centered around $V_{CC}/2$ and the signal swings from $V_{CC} - V_{CE(sat)}$ to $V_{CE(sat)}$.

$$\text{Hence, } V_{op} = V_{CC}/2 - V_{CE(sat)}$$

Solving equation (1) gives $V_{CC} = 36 \text{ V}$

(b) The sine wave is centered around 0V and the signal swings from $V_{CC} - V_{CE(sat)}$ to $-V_{CC} + V_{CE(sat)}$.

$$\text{Hence, } V_{op} = V_{CC} - V_{CE(sat)}$$

Solving equation (1) gives $V_{CC} = 18 \text{ V}$

(c) This is a differential circuit.

On each side, the sine wave is centered around $V_{CC}/2$ and the signal swings from $V_{CC} - V_{CE(sat)}$ to $V_{CE(sat)}$ on left side and $V_{CE(sat)}$ to $V_{CC} - V_{CE(sat)}$ on right side.

Considered differentially, the sine wave is centered around 0V and the signal swings from $V_{CC} - 2V_{CE(sat)}$ to $-V_{CC} + 2V_{CE(sat)}$.

$$\text{Hence, } V_{op} = V_{CC} - 2V_{CE(sat)}$$

Solving equation (1) gives $V_{CC} = 20 \text{ V}$