ECE 255, IC Biasing etc

14 November 2017

In this lecture, we will follow Section 8.2 of Sedra and Smith. It will be on IC biasing–current sources, current mirrors, and current-steering circuits. In this method, a **reference current** is generated by a circuit, and then replicated at other circuits by **current steering**.

1 The Basic Mosfet Current Source

When a MOSFET is operating in the saturation regime, which is achieved by shorting the drain to its gate, as shown in Figure **??**, then the drain current is given by

$$I_{D1} = \frac{1}{2}k_n' \left(\frac{W}{L}\right)_1 (V_{GS} - V_{tn})^2 \tag{1.1}$$

ignoring the Early effect. The drain current is supplied by V_{DD} through R. The gate currents are zero, and hence,

$$I_{D1} = I_{\text{REF}} = \frac{V_{DD} - V_{GS}}{R} \tag{1.2}$$

This is also a reference current, and hence named as I_{REF}. Changing R changes this reference current.

Now if Q_2 is also made to operate in saturation, then the current is

$$I_O = I_{D2} = \frac{1}{2}k_n' \left(\frac{W}{L}\right)_2 (V_{GS} - V_{tn})^2 \tag{1.3}$$

Hence, one gets

$$\frac{I_O}{I_{\text{REF}}} = \frac{(W/L)_2}{(W/L)_1} \tag{1.4}$$

Thus by controlling the geometry of the two MOSFETs, one can control the ratio of the two drain currents.

When $I_O = I_{\text{REF}}$, the second MOSFET mirrors the current of the first MOSFET. Even when the two drain currents are not equal, such designs are known as **current mirrors**.

Figure **??** shows a simplified picture of the current mirror. The ratio dictated by (1.4) is also called the **current transfer ratio**.

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1.1 Effect of V_O on I_O

In order for Q_2 to be saturated, it is needed that

$$V_O \geq V_{OV} = V_{GS} - V_{tn} \tag{1.5}$$

Ideally, I_O does not increase with increasing V_O but with the Early effect, I_O increases with V_O as shown in Figure **??**. This Early effect can be represented by the formula

$$I_O = \frac{(W/L)_2}{(W/L)_1} I_{\text{REF}} \left(1 + \frac{V_O - V_{GS}}{V_{A2}}\right) \tag{1.6}$$

The above implies that I_O matches I_{REF} perfectly at $V_O = V_{GS}$. The slope of the curve is such that

$$\Delta V_O \Delta I_O = \frac{V_{A2}}{I_{\text{REF}}} \approx \frac{V_{A2}}{I_O} \tag{1.7}$$

assuming that $\frac{(W/L)_2}{(W/L)_1} \approx 1$.

2 MOS Current-Steering Circuits

The current mirror can be used to implement current steering circuit as shown in Figure **??**. In this circuit, it is clear that

$$I_2 = I_{\text{REF}} \frac{(W/L)_2}{(W/L)_1}, \qquad I_3 = I_{\text{REF}} \frac{(W/L)_3}{(W/L)_1} \tag{2.1}$$

In the above figure,

$$V_{D2}, V_{D3} \geq -V_{SS} + V_{GS1} - V_{tn}, \text{ or } V_{D2}, V_{D3} \geq -V_{SS} + V_{OV1} \tag{2.2}$$

Notice that $V_D + V_{SS} = V_{DS}$. The above just imply that that V_{DS} of each transistor is larger than their overdrive voltage to be in the saturation regime.