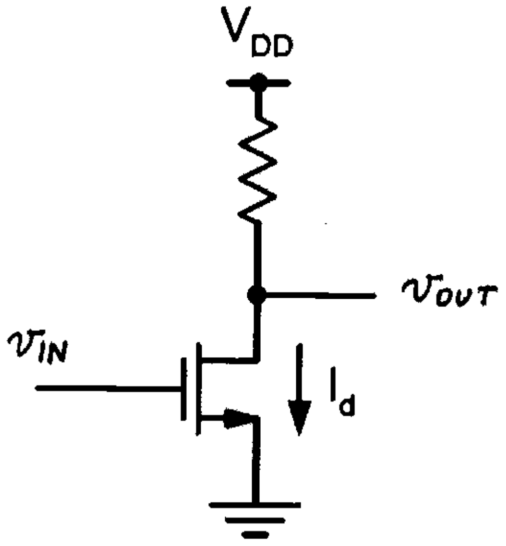
Common Source Amplifier



$v_{OUT} = V_{OUT} + v_{out}$

$v_{out} = \Delta V_{out}$

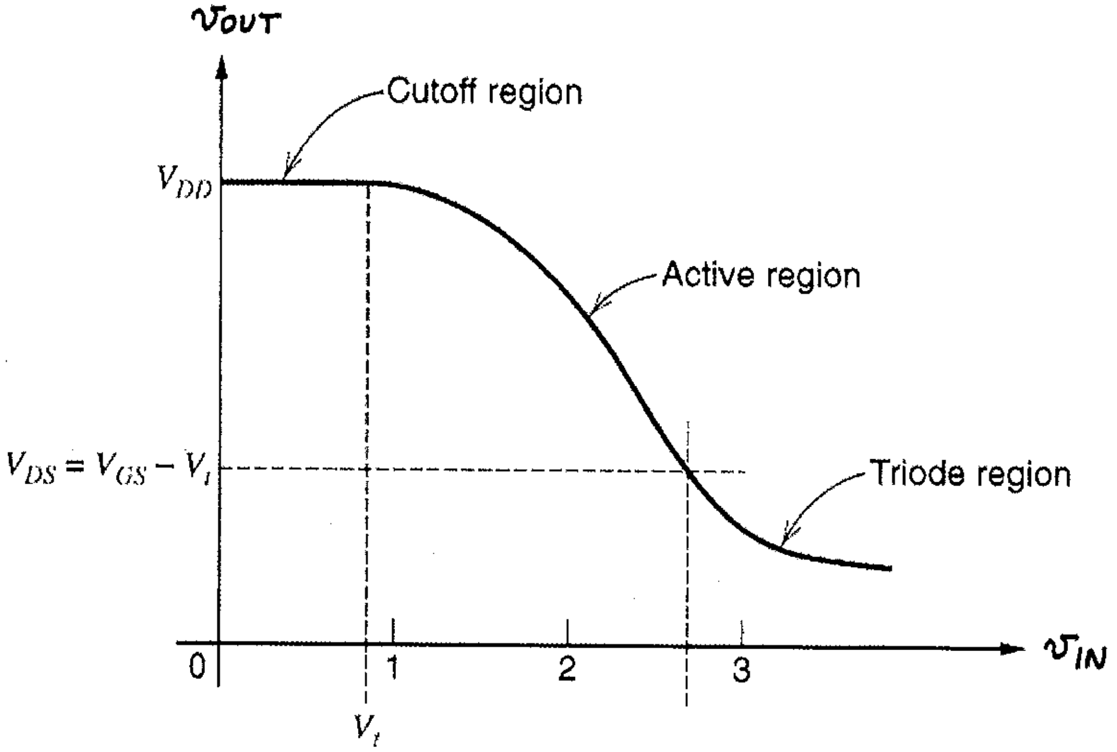
$v_{IN} = V_{IN} + v_{in}$

$v_{in} = \Delta V_{in}$

$i_D \approx I_D + i_d$

$i_d = \Delta I_d$

V_t = threshold voltage



Tranfer characteristic of CS amplifier

Common Source maximum signal swing

Source:
B. Murmann, *Analysis and Design of Elementary MOS Amplifier Stages*, NTS press

Example 2-4: Signal clipping

Consider the circuit of Figure 2-9, using the parameters from Example 2-2(b): $V_{DD} = 5$ V, $R_D = 10$ kΩ, $W/L = 10$, and V_{IN} is adjusted to 1.5 V, so that $V_{OUT} = 2.5$ V at the circuit's operating point. Calculate the most negative excursion that the incremental input voltage v_{in} can assume before the output is "clipped" to V_{DD} [as in Figure 2-11(a)].

SOLUTION

The circuit's output voltage is given by

$$v_{OUT} = V_{DD} - R_D \cdot \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(V_{IN} + v_{in} - V_{Tn})^2$$

Clipping v_{OUT} to the supply voltage implies $v_{OUT} = V_{DD}$. This requires

$$\begin{aligned} 0 &= V_{IN} + v_{in} - V_{Tn} \\ v_{in} &= -(V_{IN} - V_{Tn}) = -V_{OV} \\ v_{in} &= -(1.5V - 0.5V) = -1V \end{aligned}$$

In words, applying a negative signal (v_{in}) at the input of magnitude larger than 1 V will cause the output to reach the supply voltage. Making v_{in} more negative will create a "plateau" in the output waveform as shown in Figure 2-11(a).

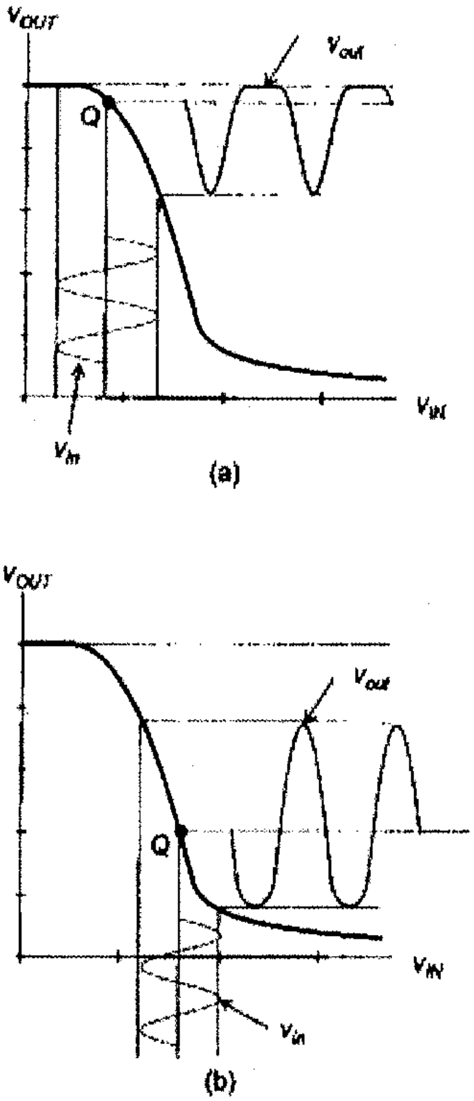


Figure 2-11: Examples of signal clipping and distortion. (a) Output waveform is clipped due to supply voltage limit. (b) Output waveform drives the MOSFET into the triode region.

calculate the most positive escursion that the incremental input voltage $v_{in} \equiv \Delta v_{IN}$ can assume before the output is distorted (that is the transistor enters triode region)

$$v_{OUT} = V_{DD} - R_D \cdot \frac{\mu C_{ox}}{2} \frac{W}{L} \left(V_{IN} + v_{in} - V_{TH} \right)^2$$

the transistor enters triode when

$$v_{OUT} \leq V_{IN} - V_{TH}$$

$$\downarrow$$

$$V_{DD} - R_D \cdot \frac{\mu C_{ox}}{2} \frac{W}{L} \left(V_{IN} + v_{in} - V_{TH} \right)^2 \leq V_{IN} - V_{TH}$$

$$\begin{aligned} V_{DD} - V_{IN} + V_{TH} \leq\ & R_D \frac{\mu C_{ox}}{2} \frac{W}{L} \left(V_{IN} - V_{TH} \right)^2 + \\ & + R_D \frac{\mu C_{ox}}{2} \frac{W}{L} \cdot v_{in}^2 + \\ & + R_D \mu C_{ox} \frac{W}{L} v_{in} \cdot \left(V_{IN} - V_{TH} \right) \end{aligned}$$

to simplify the algebra let's assume the escursion is small:

$$v_{in} << 2 \left(V_{IN} - V_{TH} \right) = 2V$$

$$\frac{2V}{80mV} = 25$$

$\uparrow$ assumption is correct!

$$\downarrow$$

$$\frac{V_{DD} - V_{IN} + V_{TH}}{R_D \mu C_{ox} \frac{W}{L} \left(V_{IN} - V_{TH} \right)} \leq v_{in}$$

$$\Updownarrow$$

$$\frac{5 - 1.5 + 0.5}{10 K \cdot 10 \cdot 50\mu \left(1.5 - 0.5 \right)} = \frac{4}{10^5 \cdot 50 \cdot 10^{-6}} = \frac{4}{50} = 80mV$$

$$\Delta v_{IN} = v_{in} \geq 80mV$$