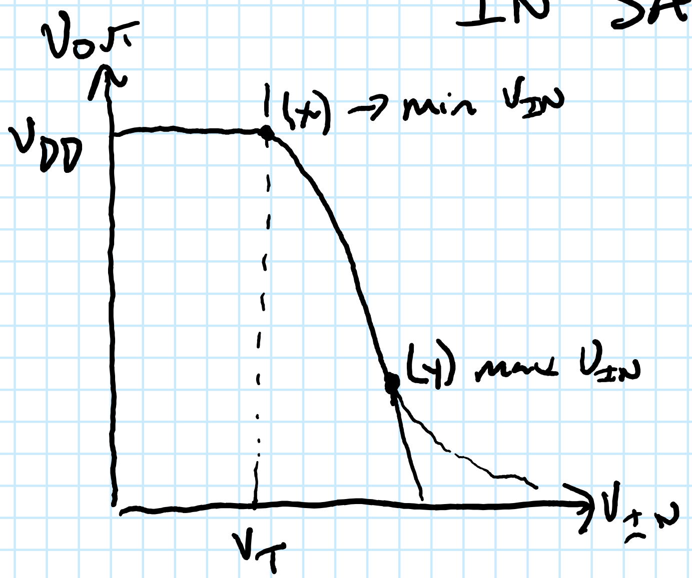
LARGE-SIGNAL ANALYSIS

LARGE SIGNAL ANALYSIS → behavior under large changes in input voltage

- same magnitude as operating parameters

- ① FIND TRANFER FUNCTION – V_{OUT} VS V_{IN}

② RANGE OF VALID INPUTS TO REMAIN IN SAT & CORRESPONDING OUTPUTS

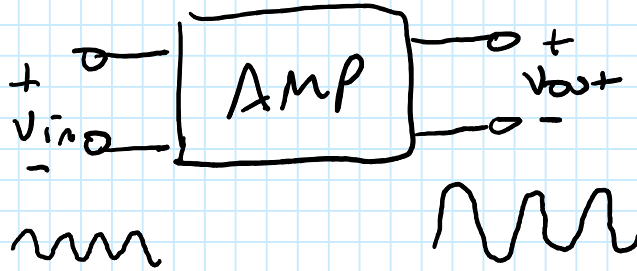


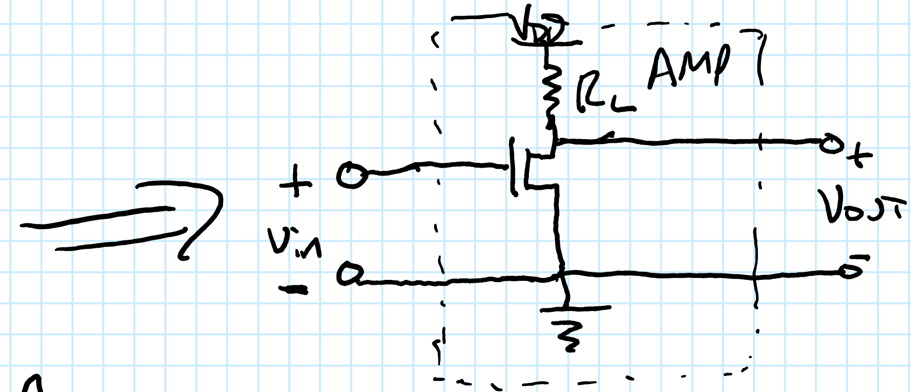
LOWEST VALID INPUT → MAX OUTPUT

(X) $V_{IN} > V_T$ $\quad V_{OUT} = V_{DD}$

(Y) $V_{OUT} = V_{IN} - V_T$ → BORDER OF TRIODE

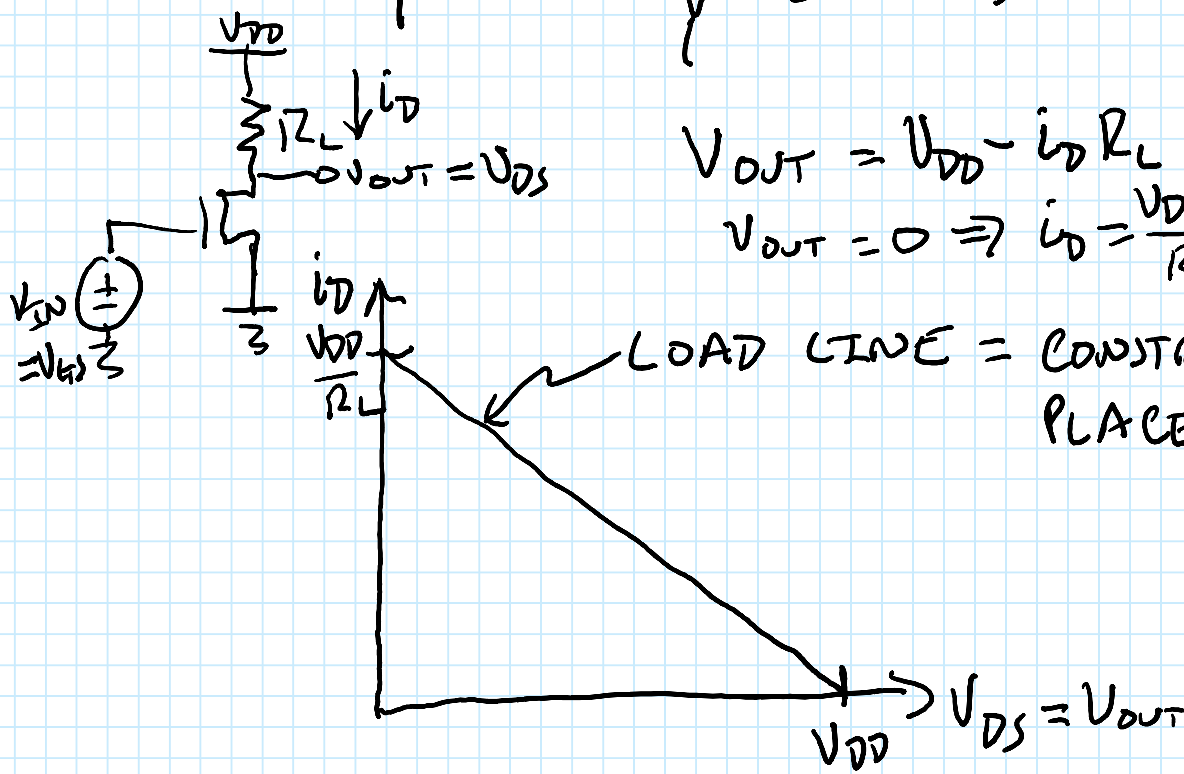
LARGE SIGNAL MODEL





SCS MODEL ⇒ LARGE SIGNAL MODEL

$\frac{K}{2}(V_{GS}-V_T)^2$

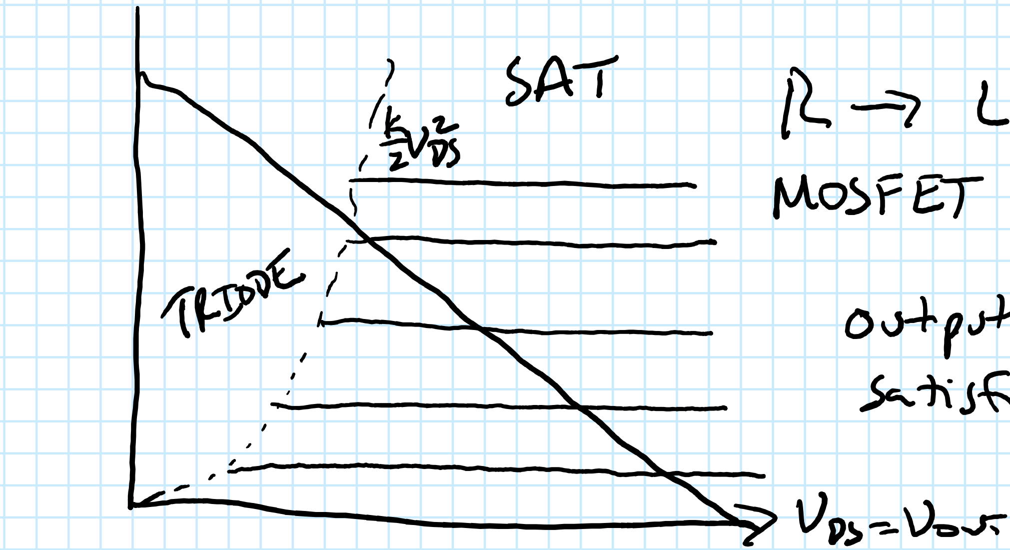


$V_{OUT} = V_{DD} - i_D R_L$

$V_{OUT} = 0 \Rightarrow i_D = \frac{V_{DD}}{R_L}$

LOAD LINE = CONSTRAINT LINEAR ELEMENT PLACE ON NON-LINEAR DEVICE

LOAD LINE

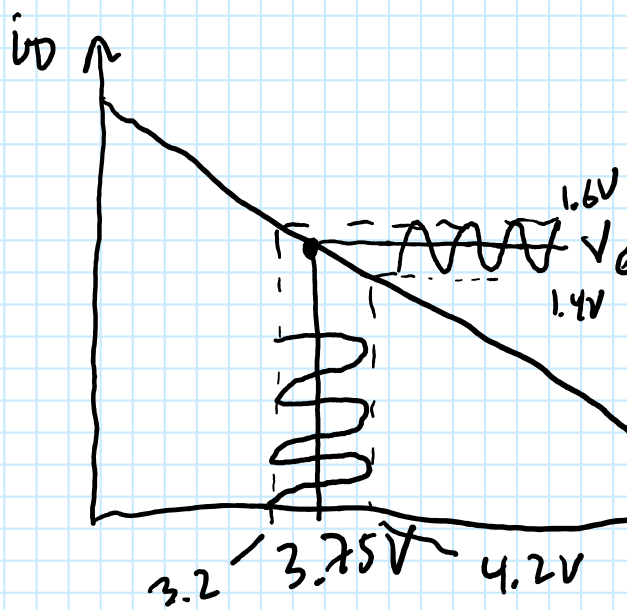


$R \rightarrow$ LOAD LINE

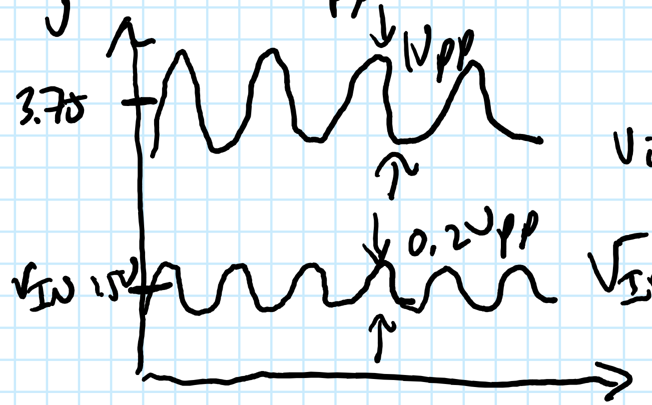
MOSFET FORCES $i_D = \frac{K}{2}(V_{GS} - V_T)^2$ SAT

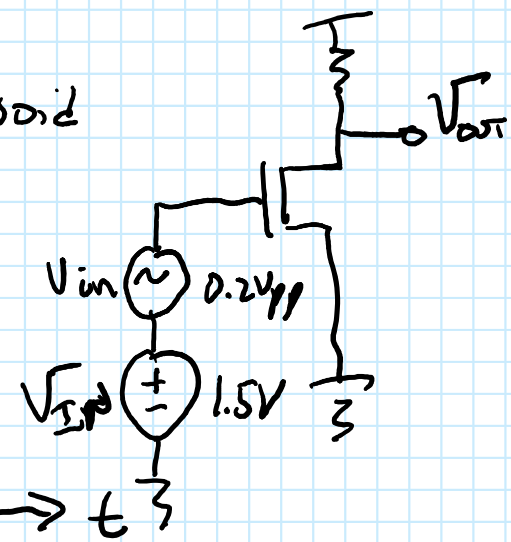
output voltage & current must satisfy both load line & MOSFET (V_{DS} vs i_D)

$R_L = 10k\Omega$, $K = 1mA/V^2$, $V_{DD} = 5V$, $V_T = 1V$

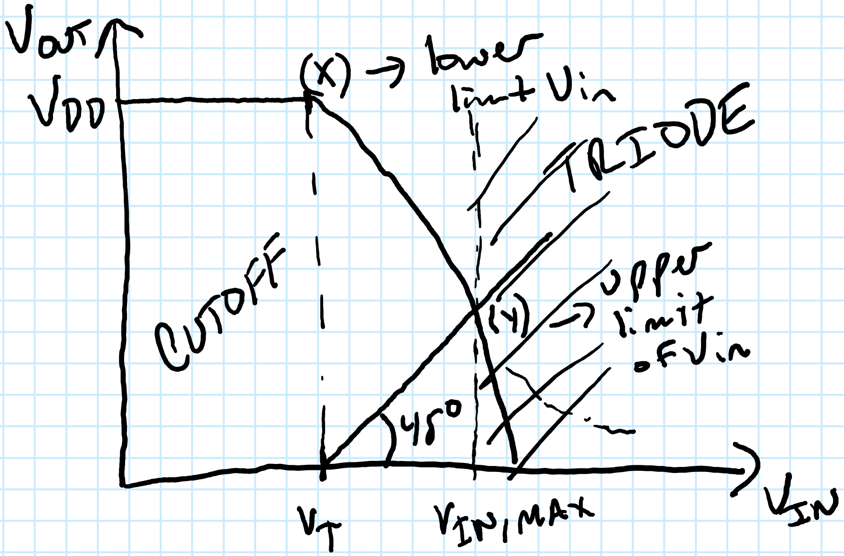


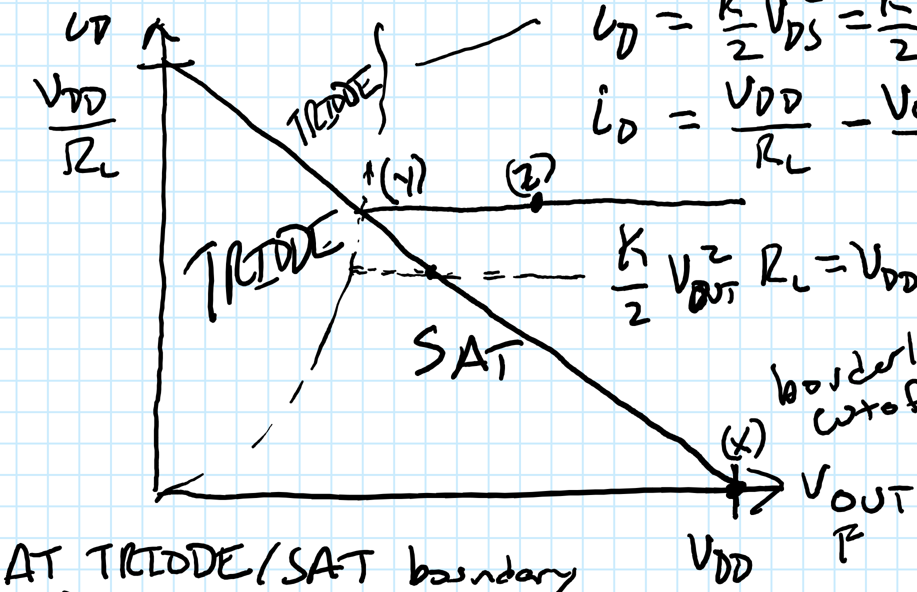
$V_{GS} = V_{IN} = 1.5V \rightarrow 0.2V_{pp}$ Sinusoid





VALID OPERATING RANGES





$i_D = \frac{K}{2}V_{DS}^2 = \frac{K}{2}V_{OUT}^2$

$i_D = \frac{V_{DD}}{R_L} - \frac{V_{OUT}}{R_L}$

$\frac{K}{2}V_{OUT}^2 R_L = V_{DD} - V_{OUT}$

AT TRIODE/SAT boundary

$V_{DS} = V_{GS} - V_T$

$\boxed{V_{OUT} = V_{IN} - V_T}$

HIGHEST VALID V_{IN} IN SAT

$V_{OUT} = V_{DD} - \frac{K}{2}(V_{IN} - V_T)^2 R_L$

$(V_{IN} - V_T) = V_{DD} - \frac{K}{2}(V_{IN} - V_T)^2 R_L$

$R_L \frac{K}{2}(V_{IN} - V_T)^2 + (V_{IN} - V_T) - V_{DD} = 0$

$V_{IN} - \cancel{V_T} = \frac{-1 \cancel{\pm} \sqrt{1 + 2V_{DD}R_L K}}{R_L K} + V_T$

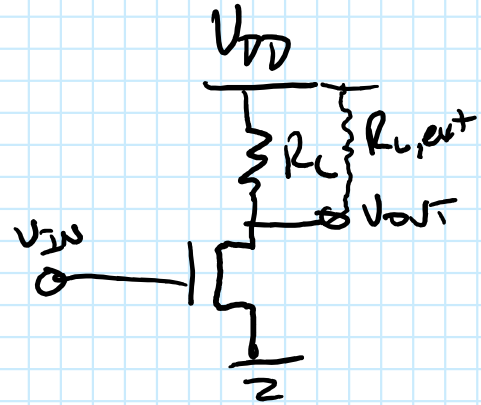
$$\boxed{\frac{-1+\sqrt{1+2V_{DD}R_L K}}{R_L K} + V_T > V_{IN} \geq V_T}$$

$$\boxed{\frac{-1+\sqrt{1+2V_{DD}R_L K}}{R_L K} < V_{OUT} \leq V_{DD}}$$

$$\boxed{\frac{K}{2}(V_{IN} - V_T)^2 > i_D > 0}$$

plug in $V_{IN,MAX}$

OPERATING RANGE EXAMPLE



$R_L = 10k\Omega$

$K = 1\frac{mA}{V^2}$

$V_{DD} = 5V$

$V_T = 1V$

LOW END OF INPUT RANGE? V_T

$V_{GS} = V_{IN} \geq V_T$ CUTOFF

WHAT'S V_{OUT}?

$V_{DD} = 5V$

HIGH END V_{IN}

$$V_{IN} \leq V_T + \frac{-1 + \sqrt{1 + 2V_{DD}R_LK}}{R_LK}$$

$$\leq 1.9V$$

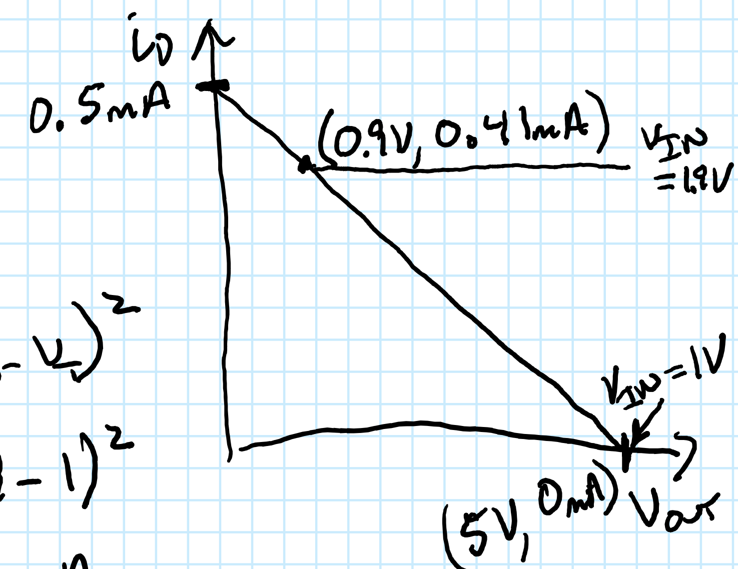
What's $V_{OUT,min}$?

AT TRIODE/SAT BORDER

$V_{OUT} = V_{IN} - V_T$

$V_{OUT} \geq 0.9V$

$V_{DS} \geq V_{GS} - V_T$

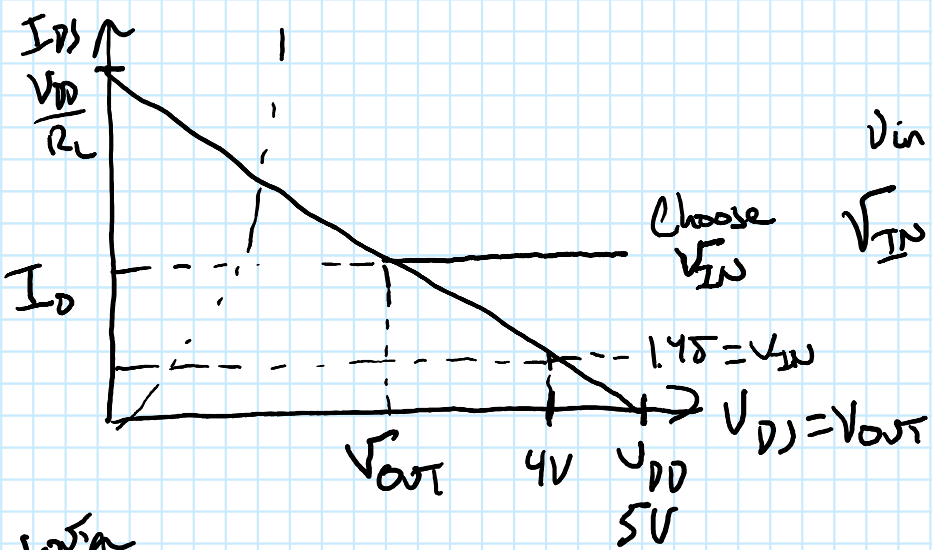


$$i_D = \frac{K}{2}(V_{IN} - V_T)^2$$

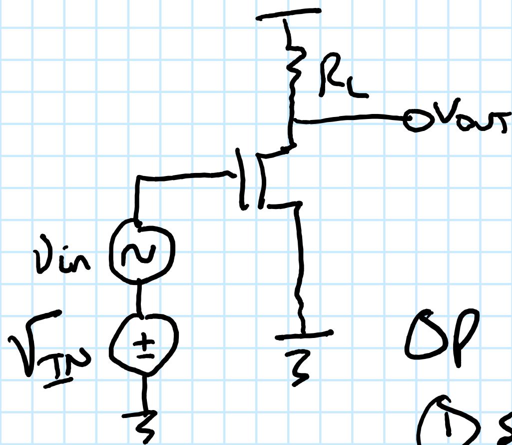
$$= \frac{1m}{2}(1.9 - 1)^2$$

$$= 0.41mA$$

OPERATING POINT SELECTION



ADD DC OFFSET (OR BIAS) AT V_{IN}

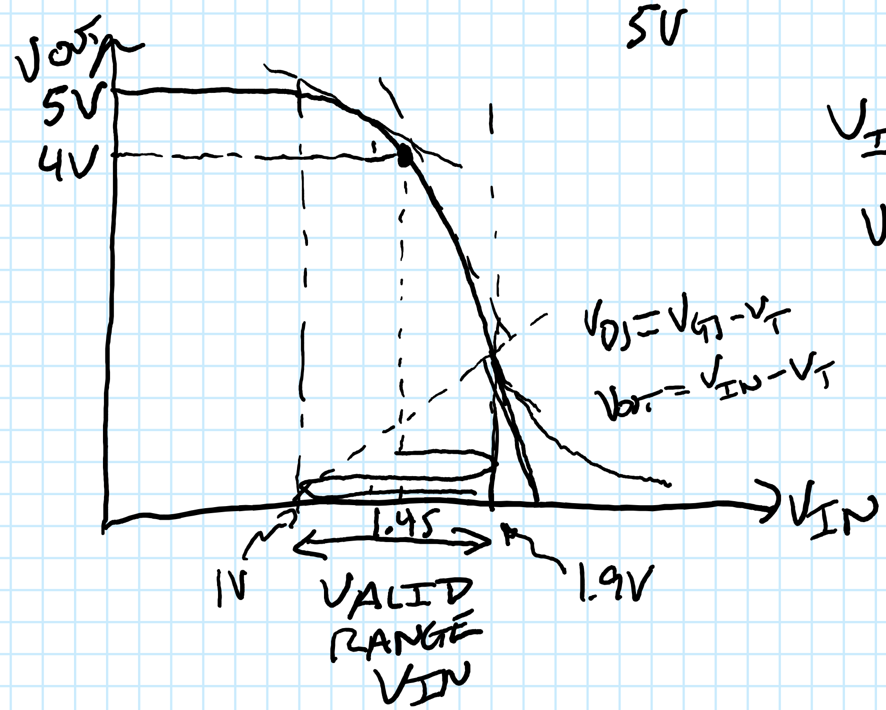


→ OUTPUT OFFSET

V_{OUT} → only when V_{IN} applied

OP POINT SELECTION

1. Signal Gain $= \frac{\Delta V_{OUT}}{\Delta V_{IN}}$
2. MAX DYNAMIC RANGE
   max +ve & −ve excursions



$V_{IN} = 1.45V$

$I_D = \frac{k}{2}(V_{IN} - V_T)^2$

$= 0.1mA$

$$V_{OUT} = V_{DD} - \frac{k}{2}(V_{IN} - V_T)^2 R_L$$

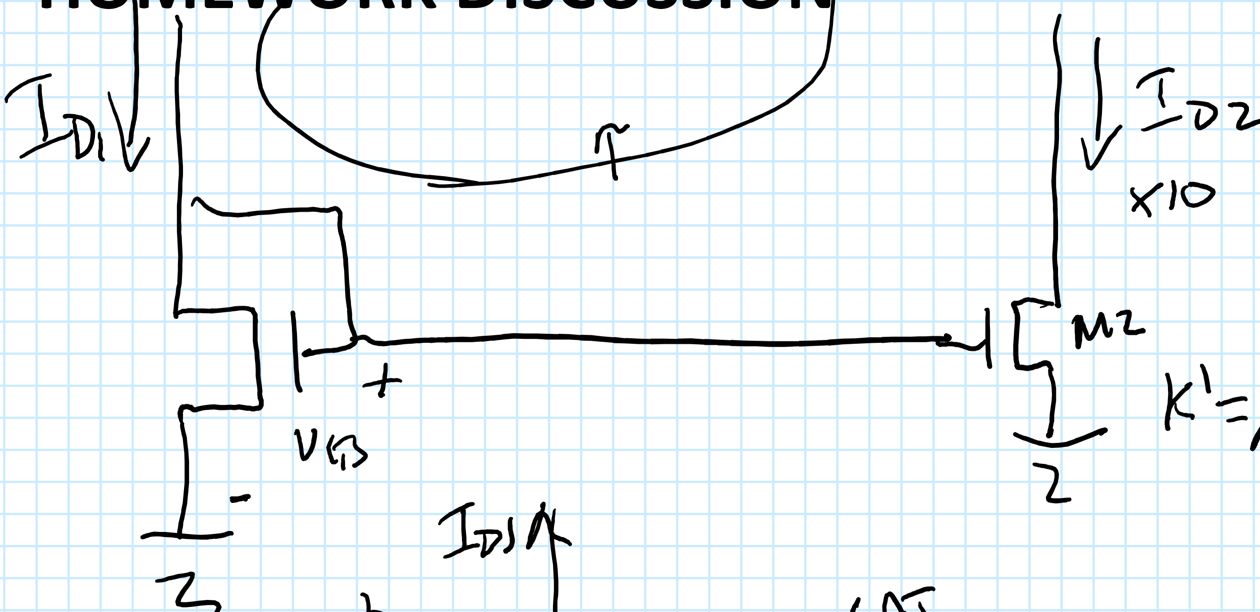
$$= 5 - \frac{10^{-3}}{2}(1.45V - 1V)^2 10^4$$

$$= 4V$$

→ MAX RANGE

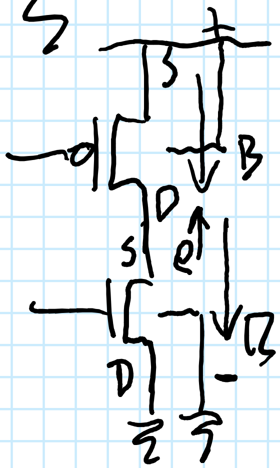
VERY NON UNIFORM GAIN
= DISTORTION AT OUTPUT

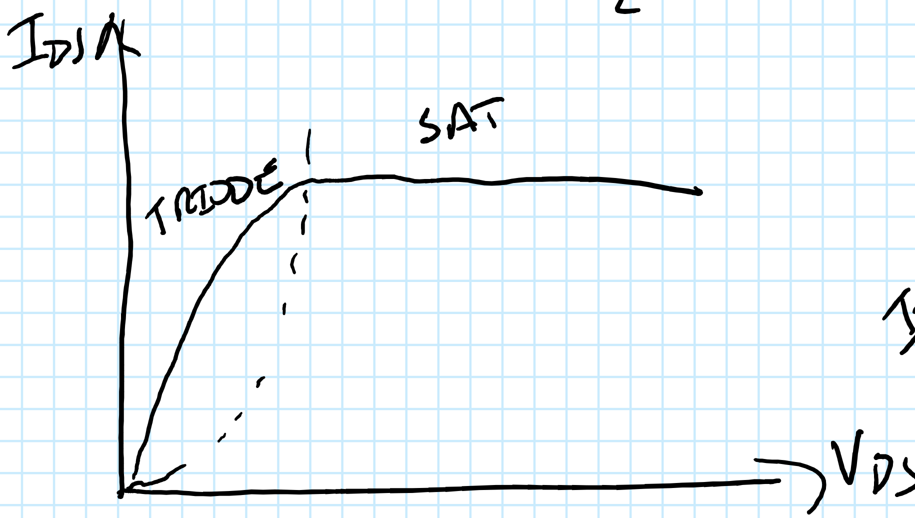
HOMEWORK DISCUSSION

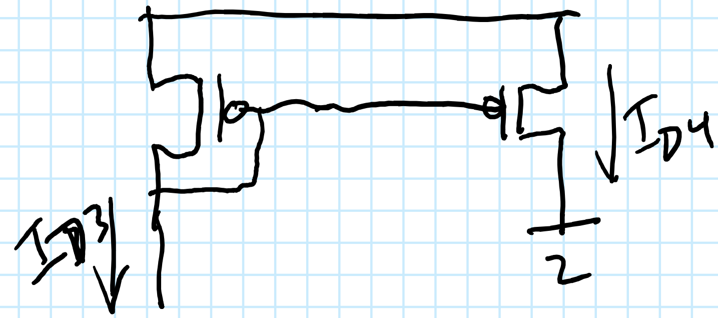


$K' = \mu C_{ox}$

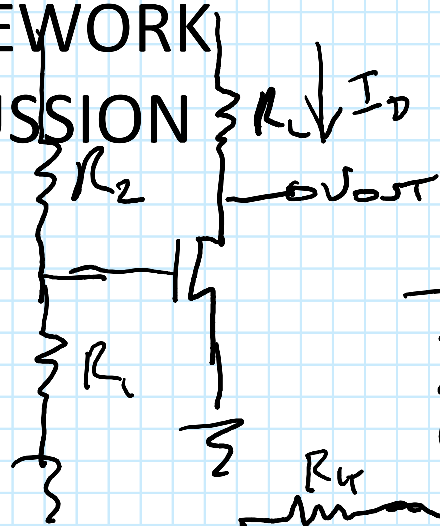
$$\frac{I_{D2}}{I_{D1}} = \frac{\frac{k_2}{\cancel{2}}\cancel{(V_{GS}-V_T)^2}}{\frac{k_1}{\cancel{2}}\cancel{(V_{GS}-V_T)^2}} = \frac{k'\left(\frac{W_2}{L_2}\right)}{k'\left(\frac{W_1}{L_1}\right)} = \frac{W_2}{W_1}$$







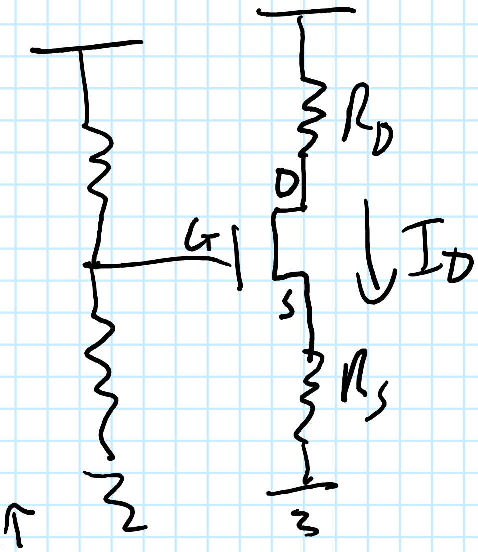
HOMEWORK DISCUSSION

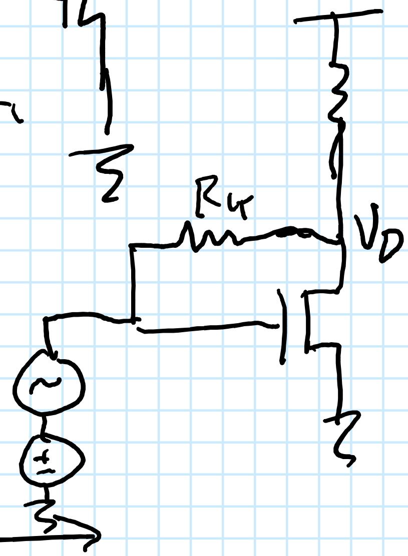


$$V_{OUT} = V_{DD} - I_D R_L$$

$$I_D = \frac{K}{2}(V_{GS} - V_T)^2$$

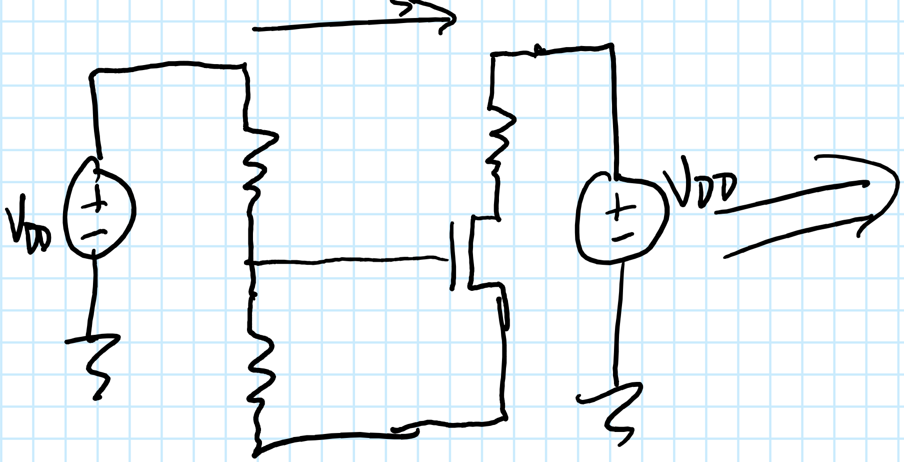
$K \uparrow \; V_{OUT} \downarrow$

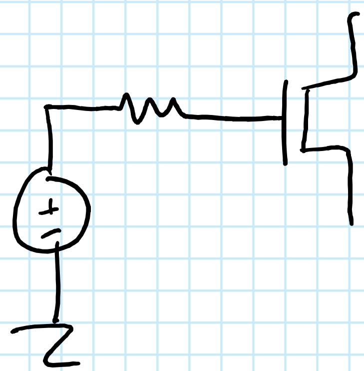




$K \downarrow \; I_D \downarrow \; V_{GS} \uparrow$
$I_D \uparrow$

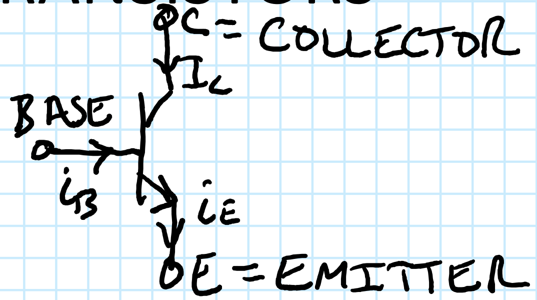
$K \uparrow \; I_D \uparrow \; V_{GS} \downarrow \; I_D \downarrow$

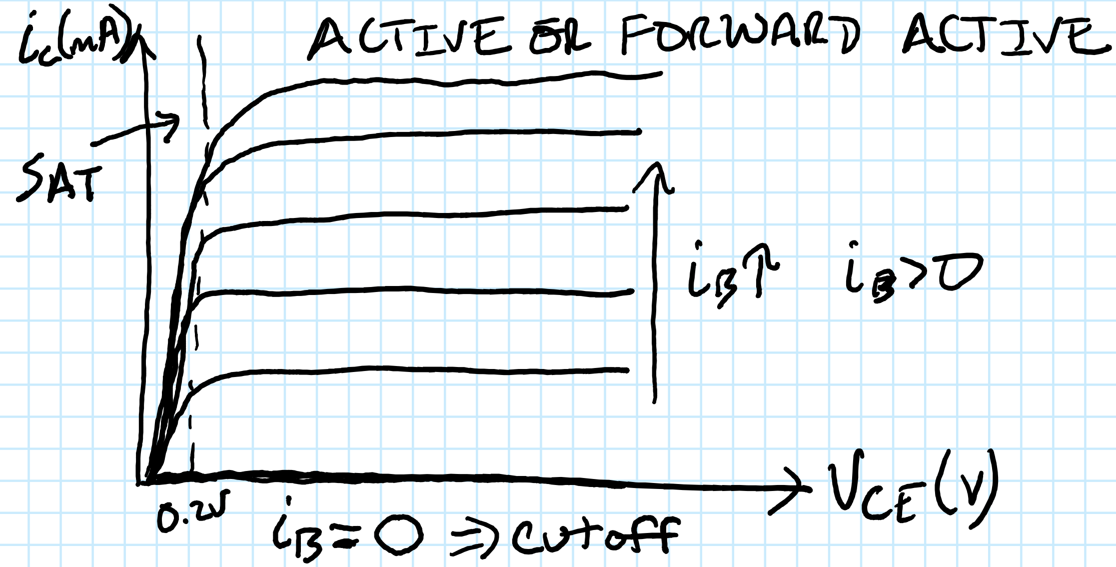




BIPOLAR JUNCTION TRANSISTORS

BJT = BIPOLAR JUNCTION TRANSISTOR

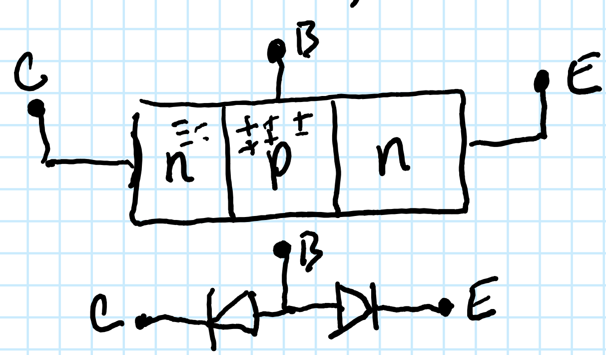




IN ACTIVE MODE LOOKS LIKE CURRENT SOURCE

$i_C \sim 100 \times i_B$

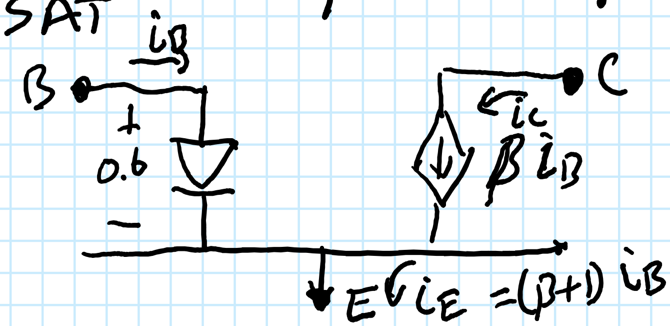
$i_B > 0$; $V_{CE} > 0.2V$



EMITTER-BASE JUNCTION
COLLECTOR- - - -

MODE	EBJ	CBJ
CUTOFF	Reverse	Reverse
ACTIVE	FORWARD	REVERSED
SAT	F	F

F.A $\Rightarrow$



$\beta \sim 100 \times$