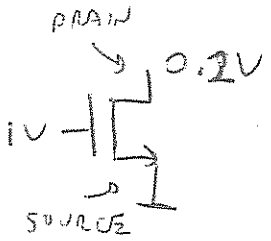
LECTURE 3

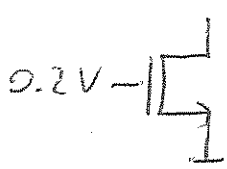
SLIDE 19)



$\Rightarrow$ $\Delta V = 1 - V_{THn} = 0.5V$

SINCE $V_{DS} < \Delta V$

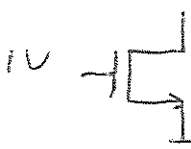
$\Rightarrow$ DEVICE IS IN TRIODE REGION



$\Rightarrow$ $\Delta V = 0.2 - V_{THn} < 0$ $\Rightarrow$

$\Rightarrow$ ΔV IS NOT VALID

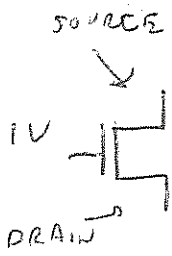
$\Rightarrow$ DEVICE IS IN SUBTHRESHOLD REGION



$\Rightarrow$ $\Delta V = 1 - V_{THn} = 0.5V$

SINCE $V_{DS} = 0.7V > \Delta V$

$\Rightarrow$ DEVICE IS IN SATURATION REGION

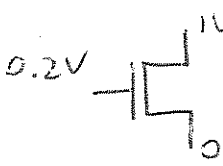


$\Rightarrow$ SOURCE CORRESPONDS TO NON-GATE TERMINAL AT THE LOWEST POTENTIAL

$\Rightarrow$ $\Delta V = 1V - 0.2 - V_{THn} = 0.3V$

SINCE $V_{DS} = 0.4 - 0.2 = 0.2V$

$V_{DS} < \Delta V \Rightarrow$ DEVICE IS IN TRIODE REGION



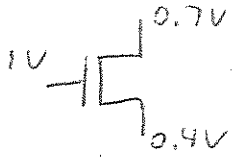
$\Rightarrow$ $\Delta V = 0.2V - 0.4V - V_{THn} < 0$

$\Rightarrow$ ΔV IS NOT VALID

$\Rightarrow$ DEVICE IS IN SUBTHRESHOLD REGION

FOR THIS LOW OF A GATE BIAS (I.E. $V_{GS} \leq 0$) WE WOULD OFTEN SAY THE DEVICE IS IN ITS CUTOFF REGION

SLIDE 19 (CONT.)

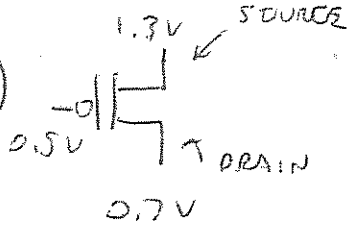


$\Delta V = 1V - 0.4V - V_{THn} = 0.1V$

SINCE $V_{DS} = 0.3V > \Delta V$

$\Rightarrow$ DEVICE IS IN SATURATION

SLIDE 20)

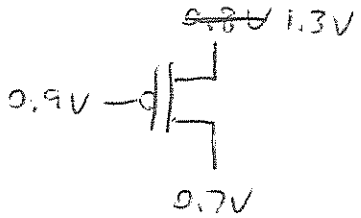


$\Delta V = 1.3 - 0.5 - |V_{THp}| = 0.3V$

$V_{SD} = 1.3 - 0.7 = 0.5V$

SINCE $V_{SD} > \Delta V$

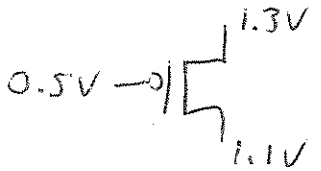
$\Rightarrow$ DEVICE IS IN SATURATION



$\Delta V = 1.3 - 0.9 - |V_{THp}| < 0$

$\Rightarrow$ ΔV IS NOT VALID

$\Rightarrow$ DEVICE IS IN SUBTHRESHOLD REGION

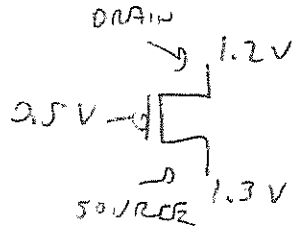


$\Delta V = 1.3V - 0.5V - |V_{THp}| = 0.3V$

$V_{SD} = 1.3 - 1.1 = 0.2V$

SINCE $V_{SD} < \Delta V$

$\Rightarrow$ DEVICE IS IN TRIODE REGION

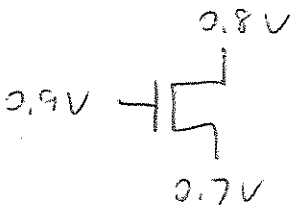


SOURCE CORRESPONDS TO NON-GATE TERMINAL AT THE HIGHEST POTENTIAL

$\Delta V = 1.3 - 0.5 - |V_{THp}| = 0.3V$

$V_{SD} = 1.3 - 1.2 = 0.1V$

SINCE $V_{SD} < \Delta V \Rightarrow$ DEVICE IS IN TRIODE REGION



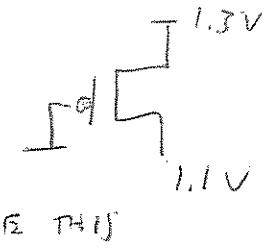
$\Delta V = 0.8 - 0.9 - |V_{THp}| < 0$

$\Rightarrow$ ΔV IS NOT VALID

$\Rightarrow$ DEVICE IS IN SUBTHRESHOLD REGION

FOR THIS LOW OF A GATE BIAS (I.E., $V_{SG} \leq 0$) WE WOULD OFTEN SAY THE DEVICE IS IN ITS CUTOFF REGION

SLIDE 20 (CONT.)

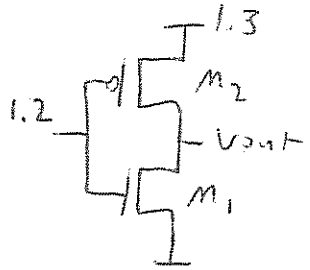


$\Delta V = 1.3V - 0V - |V_{THp}| = 0.8V$

$V_{SD} = 1.3 - 1.1 = 0.2V$

SINCE $V_{SD} < \Delta V \Rightarrow$ DEVICE IS IN TRIODE REGION

SLIDE 21



M_2: $\Delta V = 1.3 - 1.2 - |V_{THp}| < 0$

$\Rightarrow$ M_2 IS IN SUBTHRESHOLD REGION

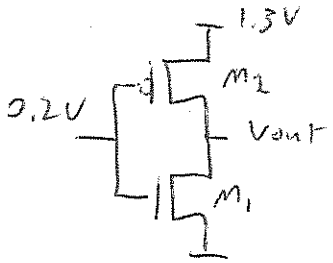
M_1: $\Delta V = 1.2 - V_{THN} = 0.7V$

$\Rightarrow$ M_1 IS IN SATURATION OR TRIODE

SINCE M_1 AND M_2 HAVE THE SAME SIZE, M_1 WILL SUPPORT MUCH MORE CURRENT FLOW THAN M_2 UNDER THE GIVEN BIAS CONDITIONS IF $V_{out} \approx \frac{1.3}{2}$

$\Rightarrow$ V_{out} WILL TEND TOWARD 0V

$\Rightarrow$ M_1 WILL BE IN THE TRIODE REGION



M_2: $\Delta V = 1.3 - 0.2 - |V_{THp}| = 0.6V$

$\Rightarrow$ M_2 IS IN SATURATION OR TRIODE

M_1: $\Delta V = 0.2 - V_{THN} < 0$

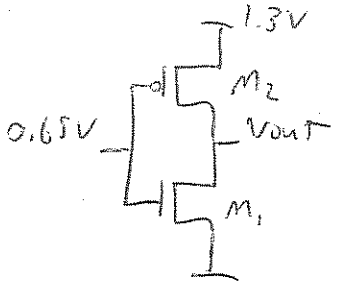
$\Rightarrow$ M_1 IS IN SUBTHRESHOLD REGION

SINCE M_1 AND M_2 HAVE THE SAME SIZE, M_2 WILL SUPPORT MUCH MORE CURRENT FLOW THAN M_1 UNDER THE GIVEN BIAS CONDITIONS IF $V_{out} \approx \frac{1.3}{2}$

$\Rightarrow$ V_{out} WILL TEND TOWARD 1.3V

$\Rightarrow$ M_2 WILL BE IN TRIODE REGION

SLIDE 20 (CONT.)



M_2: $\Delta V = 1.3 - .65 - |V_{THp}| = 0.15V$

$\Rightarrow$ M_2 IS IN SATURATION OR TRIODE

M_1: $\Delta V = 0.65 - V_{THn} = 0.15V$

$\Rightarrow$ M_1 IS IN SATURATION OR TRIODE

CONSIDER $V_{OUT} = \frac{1.3}{2} = 0.65V$

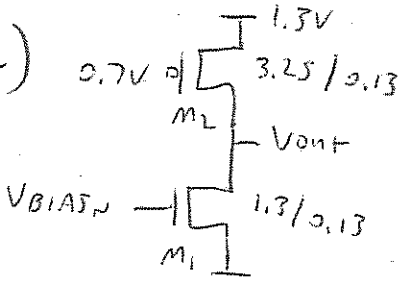
~~WITH M_1 & M_2~~ SINCE M_1 AND M_2 ARE THE SAME SIZE AND BOTH HAVE SAME $\Delta V > 0$, THEIR CURRENT CARRYING CAPABILITY WILL BE DETERMINED BY $\mu_n C_{ox}$ ~~VERSUS~~ VERSUS $\mu_p C_{ox}$.

$\Rightarrow$ SINCE $\mu_n C_{ox} > \mu_p C_{ox}$, M_1 WILL ~~NOT~~ HAVE GREATER CURRENT CARRYING CAPABILITY

$\Rightarrow$ V_{out} WILL TEND TOWARD ZERO

$\Rightarrow$ M_1 WILL BE IN TRIODE, M_2 WILL BE IN SATURATION

SLIDE 22)



DETERMINE CURRENT FROM M_2 ~~ASSUMED~~ ASSUMING $V_{out} = 0.5V$

M_2: $\Delta V = 1.3 - 0.7 - |V_{THp}| = 0.1V$

$V_{SD} = 1.3 - V_{out} = 0.8V$

$\Rightarrow$ M_2 WILL BE IN SATURATION

$$M_2: I_D = \frac{1}{2}\mu_p C_{ox}\frac{W}{L}\left(V_{SG} - (-\cancel{V_{THp}}^{0.5})\right)^2\left(1 + \cancel{\lambda}^{0} V_{SD}\right)$$

$$= \frac{1}{2}(20\times10^{-6})\frac{3.25}{0.13}(0.1)^2 = 2.5\mu A$$

M_1: WE ARE NOT SURE IF M_1 WILL BE IN TRIODE OR SATURATION (SUBTHRESHOLD IS VERY UNLIKELY SINCE DEVICE SIZE OF M_1 WOULD NEED TO BE MUCH LARGER THAN M_2 IN ORDER TO SUPPORT SIMILAR CURRENT WHILE IN SUBTHRESHOLD REGION)

SLIDE 22 (CONT.)

WE FIRST GUESS THAT M_1 IS IN SATURATION

$$\Rightarrow I_D = \frac{1}{2}\mu_N C_{ox}\frac{W}{L}(V_{GS}-V_{THN})^2\cancel{(1+\lambda V_{DS})}^{0}$$

$$2.5\times10^{-6} = \frac{1}{2}(50\times10^{-6})\left(\frac{1.3}{0.13}\right)(\Delta V)^2$$

$$\Rightarrow (\Delta V)^2 = 0.01 \Rightarrow \Delta V = 0.1V$$

SINCE THE ABOVE WORKED OUT, (I.E. $\Delta V > 0$ AND $V_{DS} = 0.5 > \Delta V$) OUR GUESS WAS CORRECT

$$\Rightarrow \boxed{V_{BIAS_N} = V_{THN} + \Delta V = 0.5 + 0.1 = 0.6\,V}$$

$\boxed{M_1 \text{ AND } M_2 \text{ ARE BOTH IN SATURATION}}$

NOTE: ONE COULD HAVE ALSO STARTED WITH THE GUESS THAT M_1 WAS IN TRIODE REGION

$$\Rightarrow I_D = \mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{THN}-V_{DS}/2)V_{DS}$$

SINCE V_{OUT} IS ASSUMED TO BE 0.5 V:

$$2.5\,mA = (50\times10^{-6})\left(\frac{1.3}{.13}\right)(V_{GS}-0.5-0.25)0.5$$

$$\Rightarrow 5\times10^{-3} = (V_{GS}-0.75)0.5$$

$$\Rightarrow 10\times10^{-3} = V_{GS}-0.75 \Rightarrow V_{GS} = 0.76$$

$$\Rightarrow \Delta V = V_{GS}-V_{THN} = 0.76-0.5 = 0.26$$

BUT $V_{DS} = 0.5$ ASSUMING $V_{OUT} = 0.5V$

$\Rightarrow$ SINCE $V_{DS} > \Delta V$ IN THIS CALCULATION, THE TRIODE REGION ASSUMPTION IS INCORRECT!