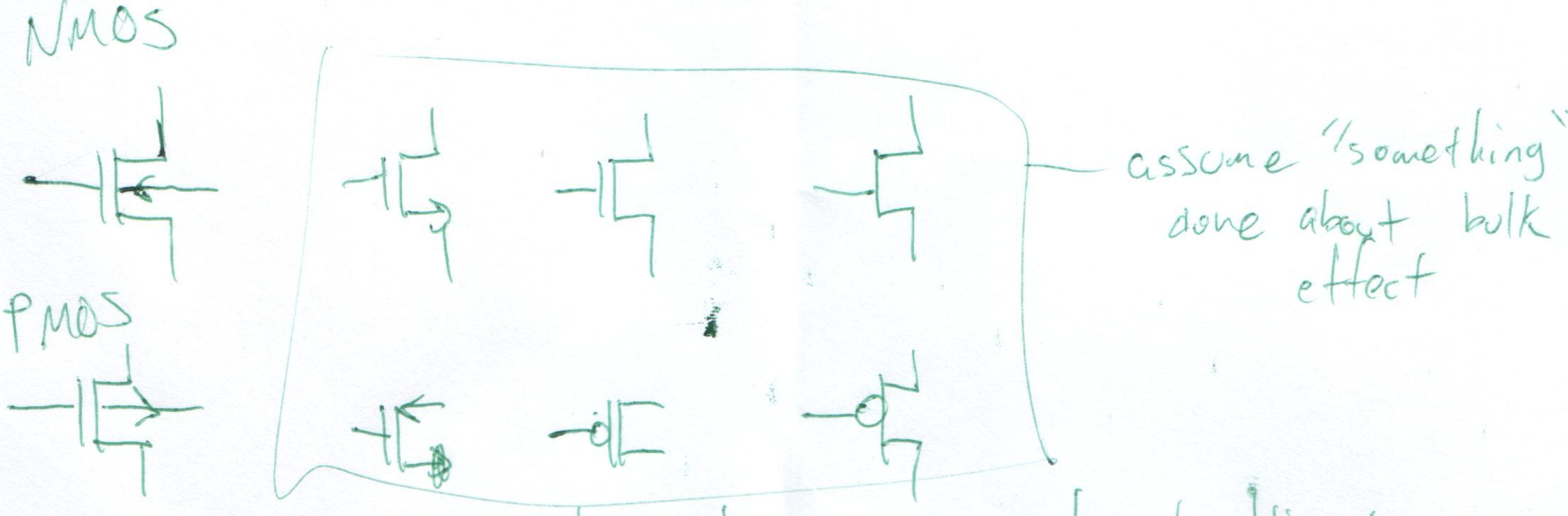


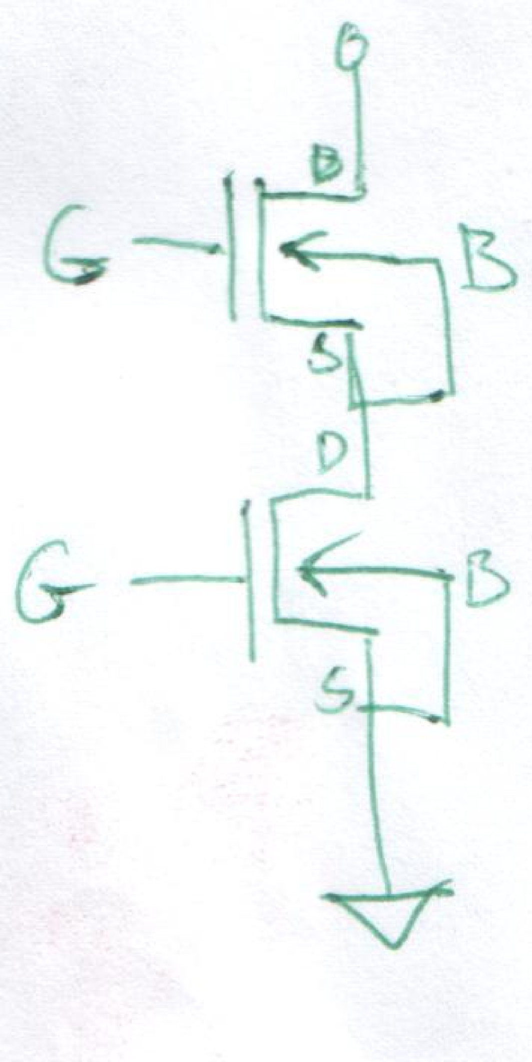
Depletion Mode: Consult the apparently brilliant wizards that have you doing depletion mode devices.

$$V_{TN} = V_{T0} + \gamma\left(\sqrt{V_{SB} + 2\phi_F} - \sqrt{2\phi_F}\right) \longleftarrow \text{?!?}$$

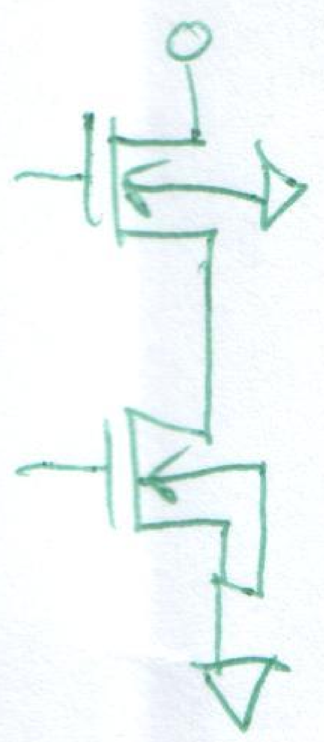
V_{T0}: V_{TN} @ 0v V_{SB}

γ: Some constant

ϕ_F: Some other constant

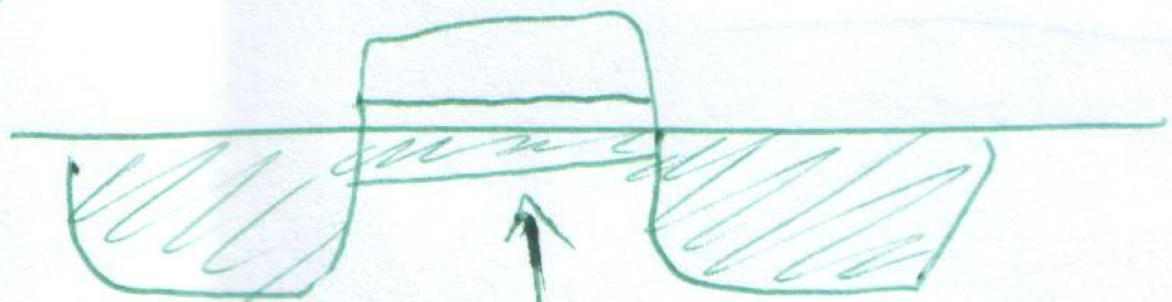


$V_{SB} = 0$, no bulk effect



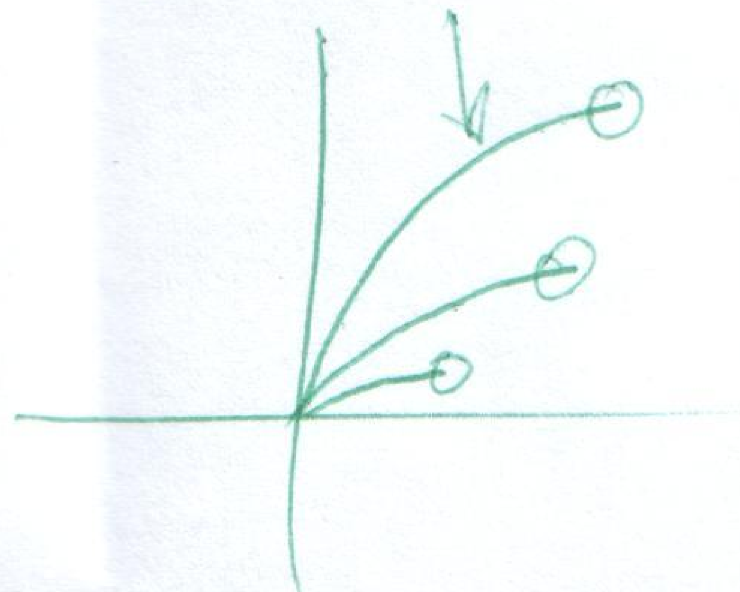
~~Cutoff~~ region	Current Equation	Condition
Cutoff	$i_D = 0$	$V_{GS} < V_{TN}$
Triode/Linear	$i_D = K_n' \frac{W}{L}\left(V_{GS} - V_{TN} - \frac{V_{DS}}{2}\right)V_{DS}$	$V_{GS} \geq V_{TN}$, $V_{GS} - V_{DS} \geq V_{TN}$
Saturation	$i_D = K_n' \frac{W}{L} \cdot \frac{1}{2}\left(V_{GS} - V_{TN}\right)^2 (1 + \lambda V_{DS})$ (upslope)	$V_{GS} > V_{TN}$, $V_{GS} - V_{DS} < V_{TN}$

what. → Linear:

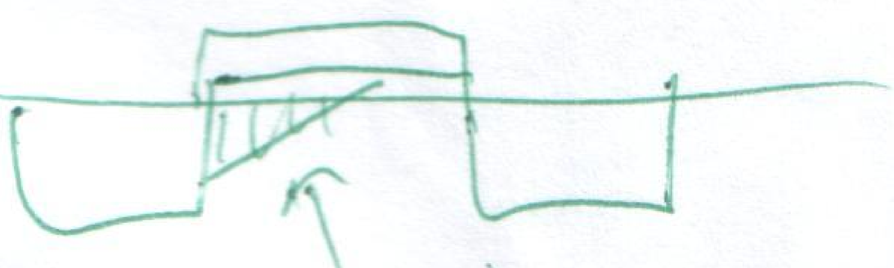


shape of region modeled as linear.

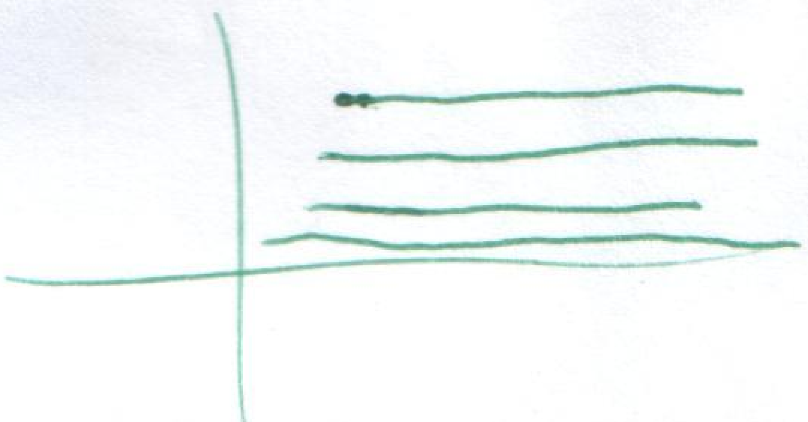
Idea: resistance increases as V_{DS} increases

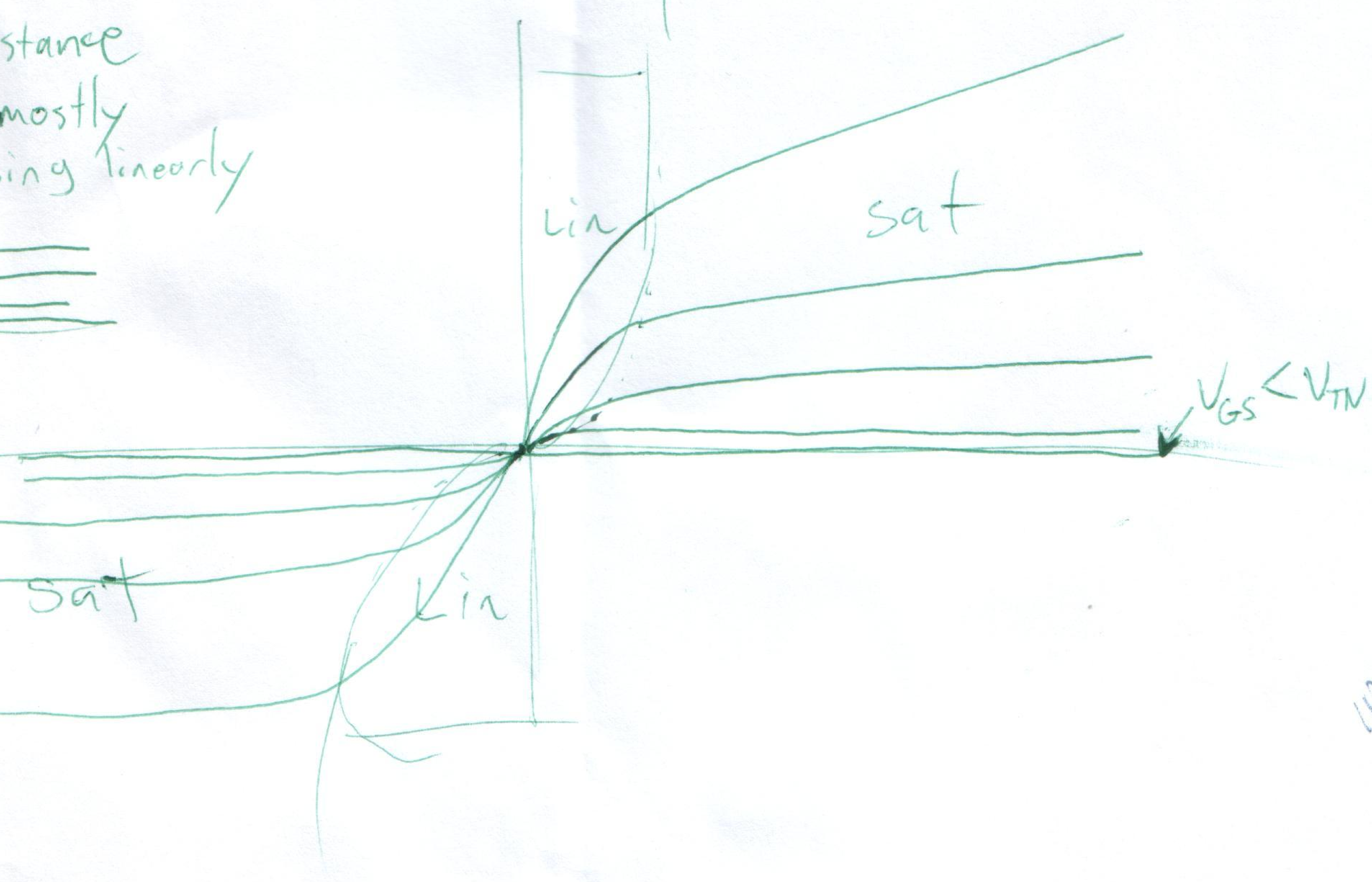


Saturation



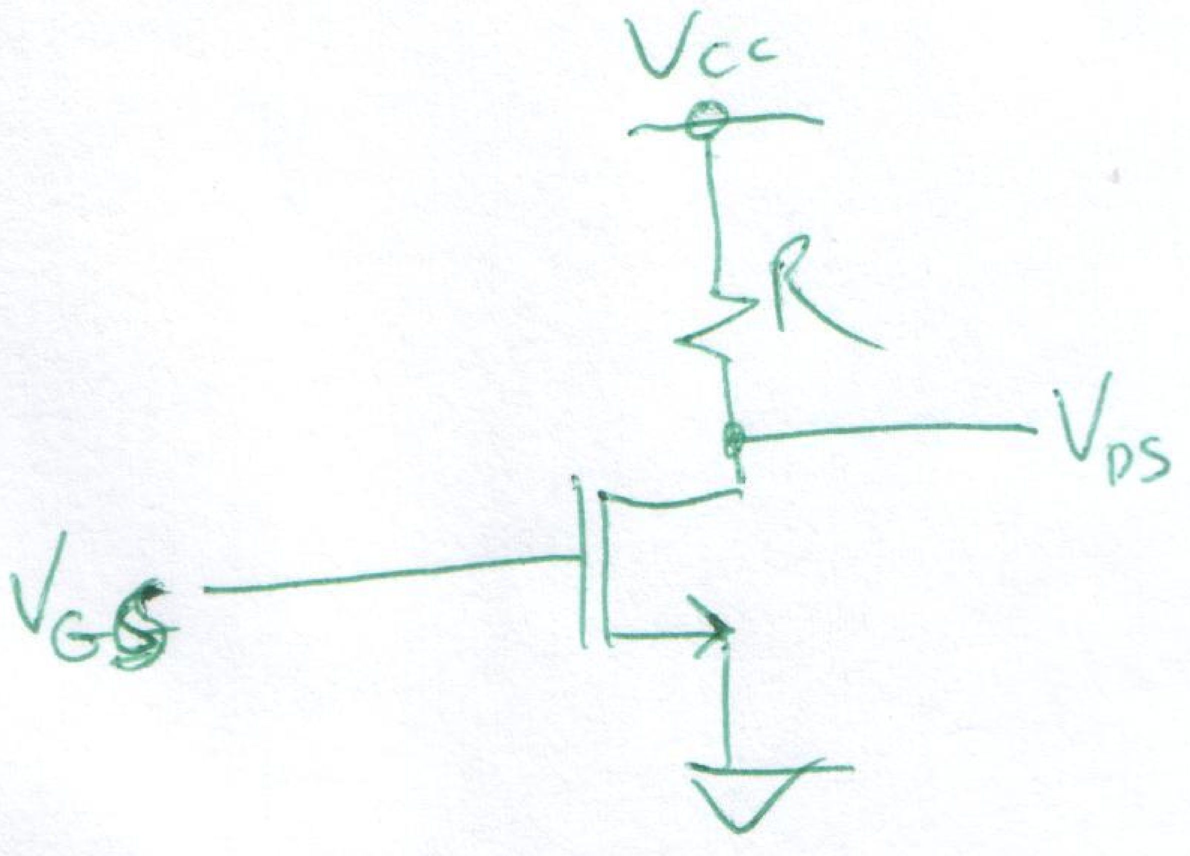
resistance now mostly increasing linearly

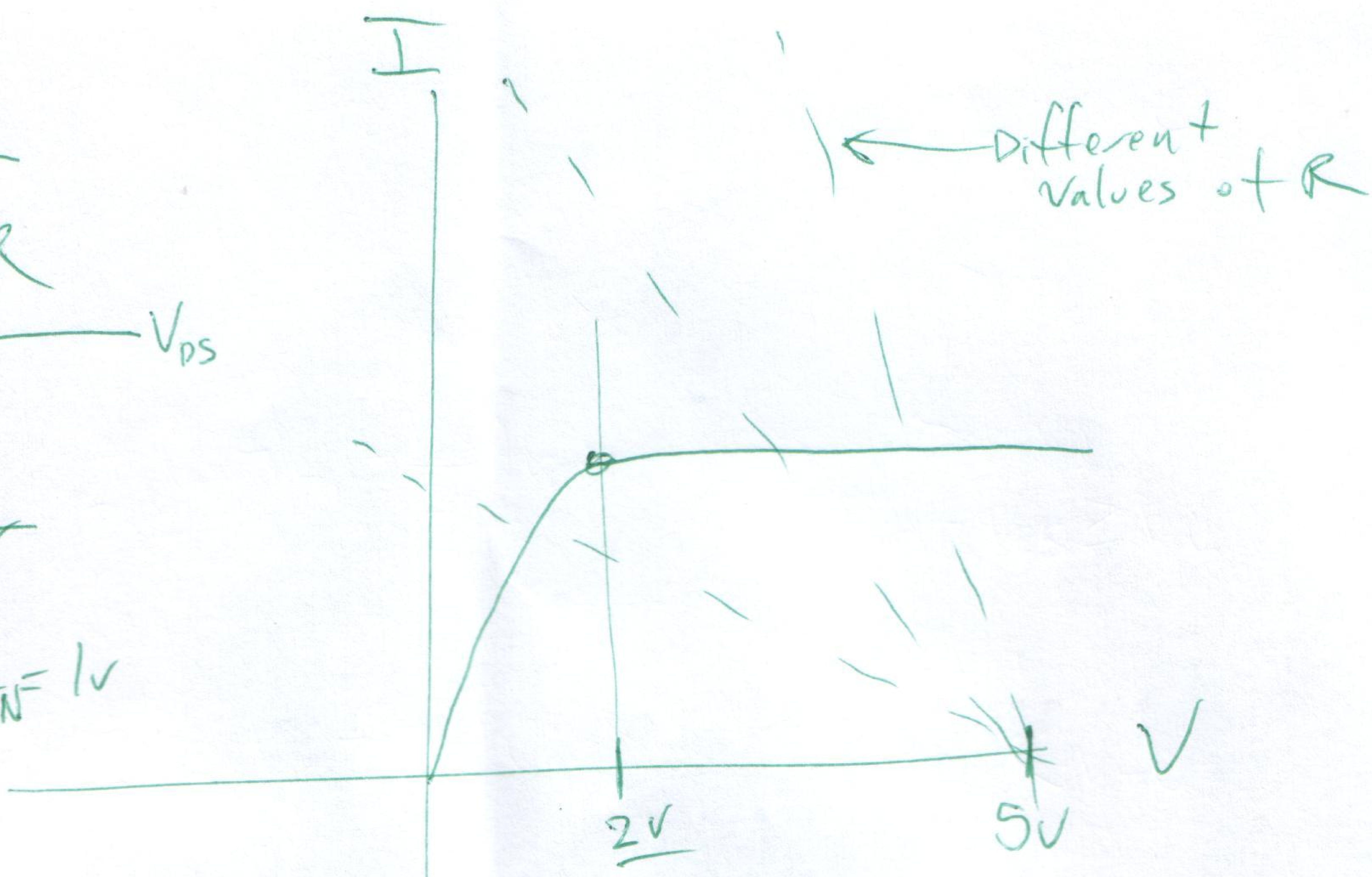




1st

$10\,\mu A/V^2$





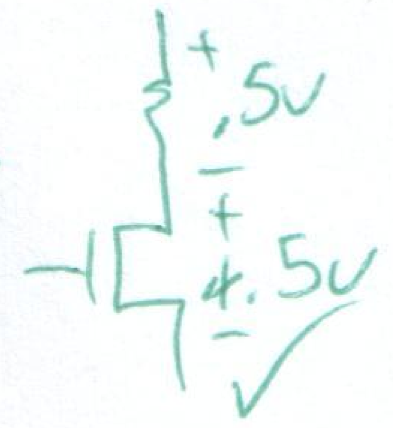
$K_n' = 25\mu A/V^2$ $V_{TN} = 1V$

$\frac{W}{L} = 10$

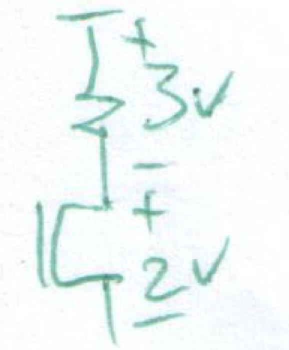
$K_n = 250\mu A/V^2$

Problem: whether we're in sat. or lin. is dependent on i_D!

.5mA thru 1K ⟹



.5mA thru 3K ⟹



RIGHT ON THE EDGE

Sat. current @ $V_{GS} = 3V$:

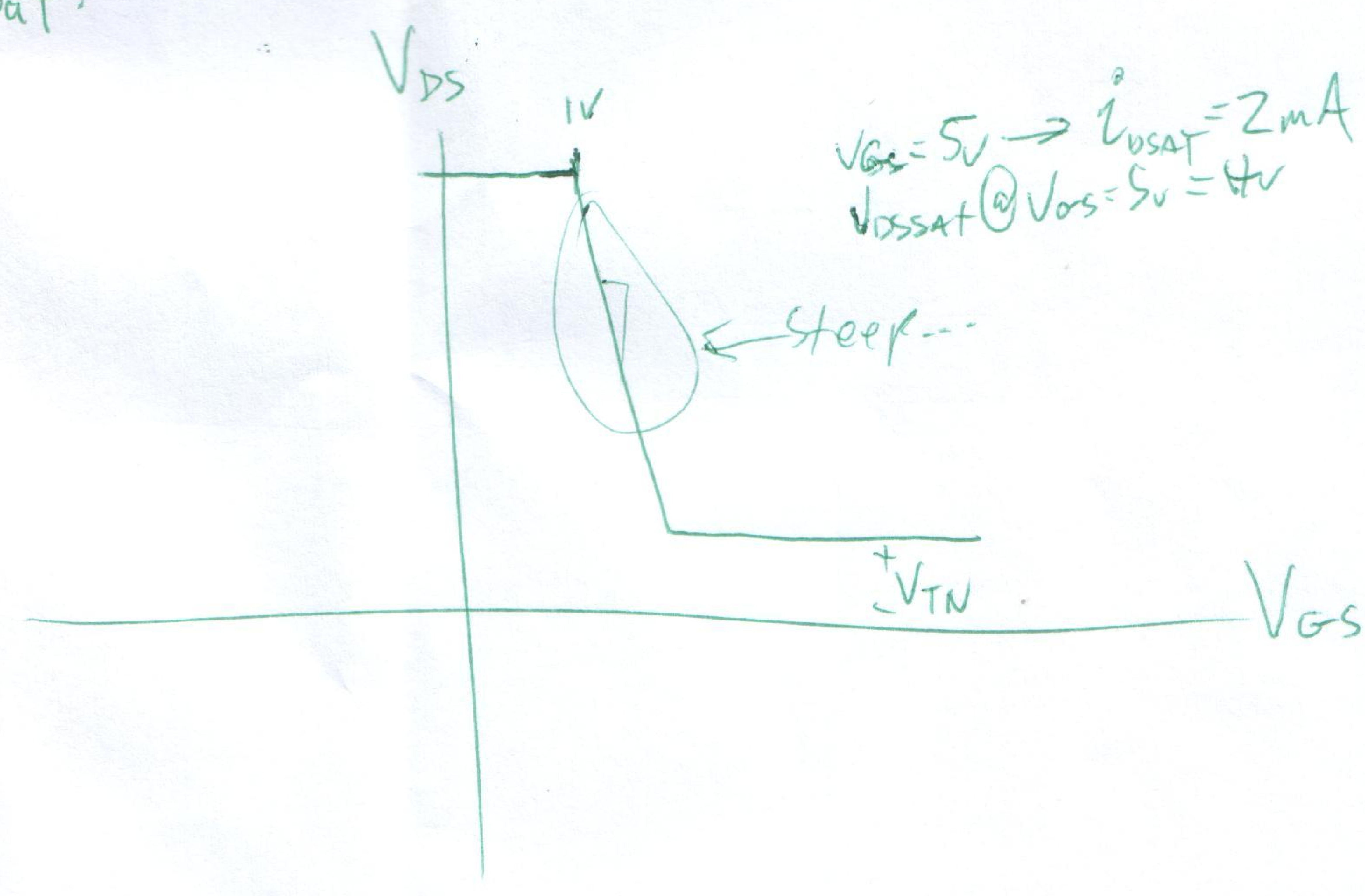
$$i_D = 250\mu A \cdot \frac{1}{2} \cdot (3-1)^2 = .5mA$$

transition to Lin-Sat:

$V_{GS} - V_{DS} > V_{TN}$

$3 - V_{DS} > 1$

$V_{DS} < 2$

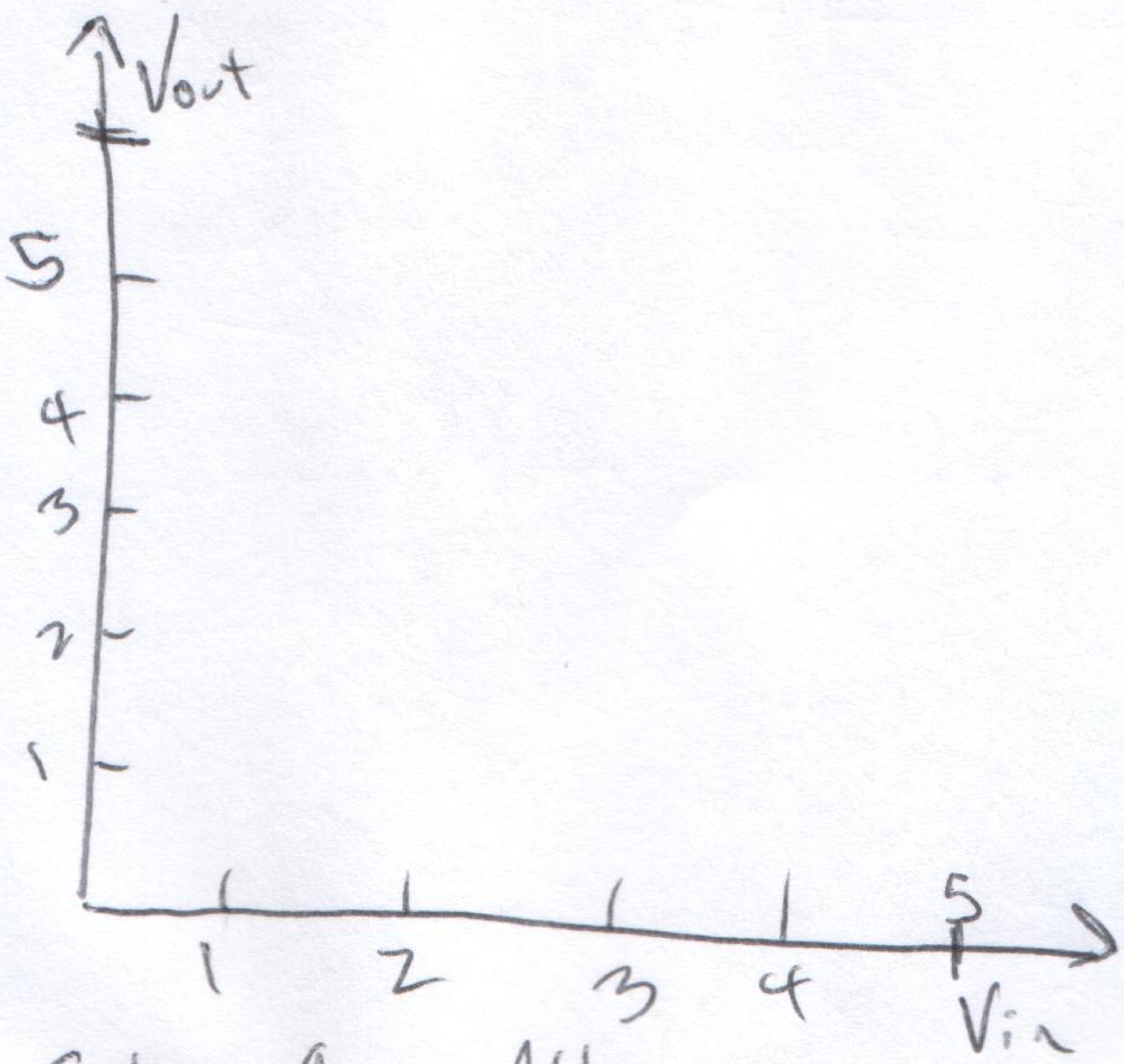


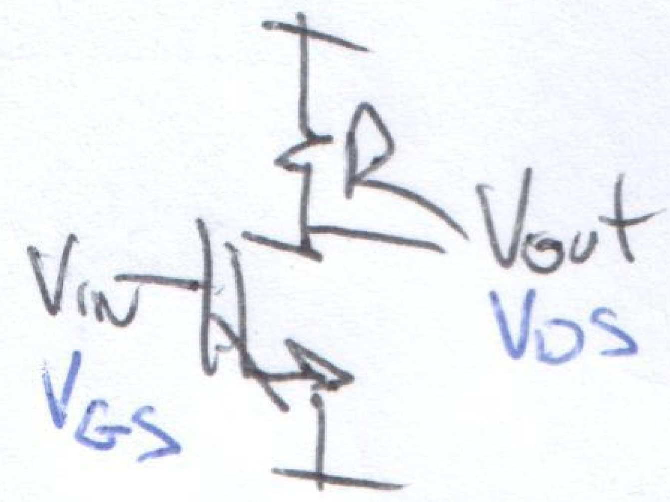
$V_{GS} = 5V \rightarrow i_{DSAT} = 2mA$

$V_{DSSAT} @ V_{GS} = 5V = 4V$

$K_n' = 10\mu A/V^2$ $\quad V_{TN} = 1v \quad R = $ ~~10K~~ 5K

$W/L = 10$

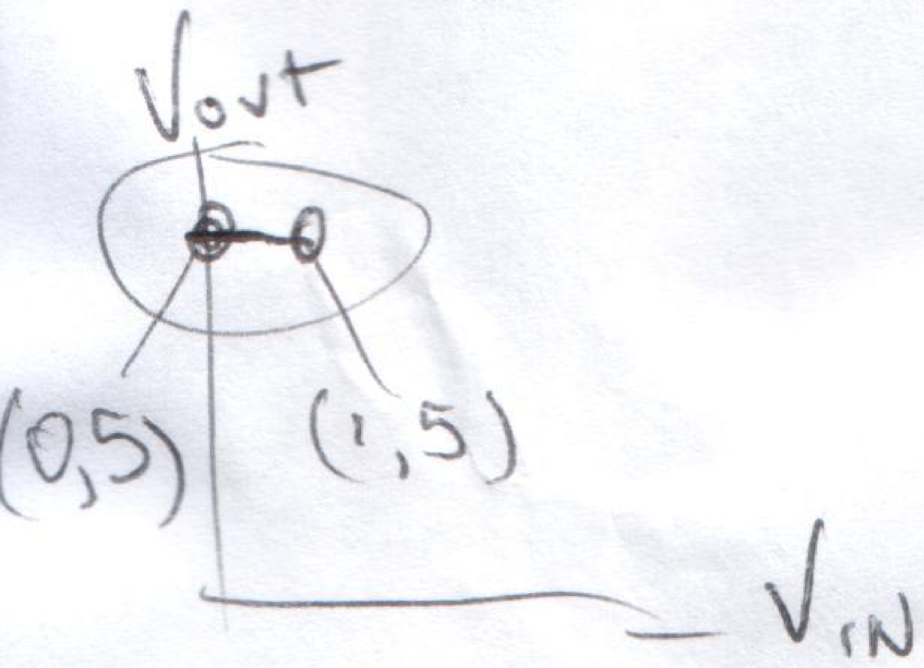


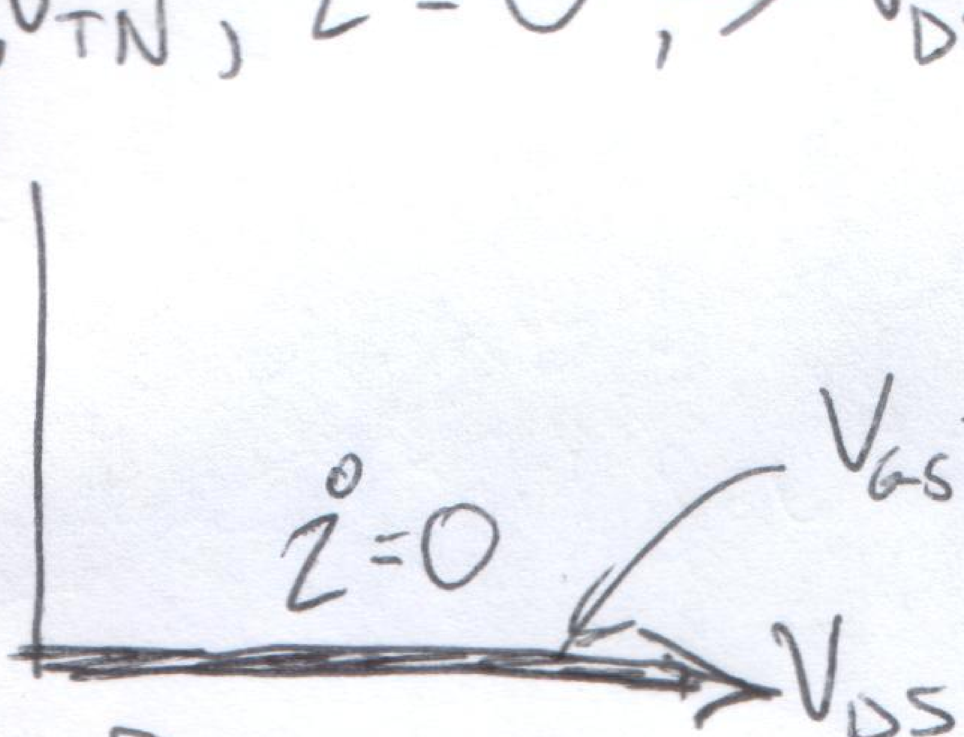


$V_{GS} = V_{IN}$,

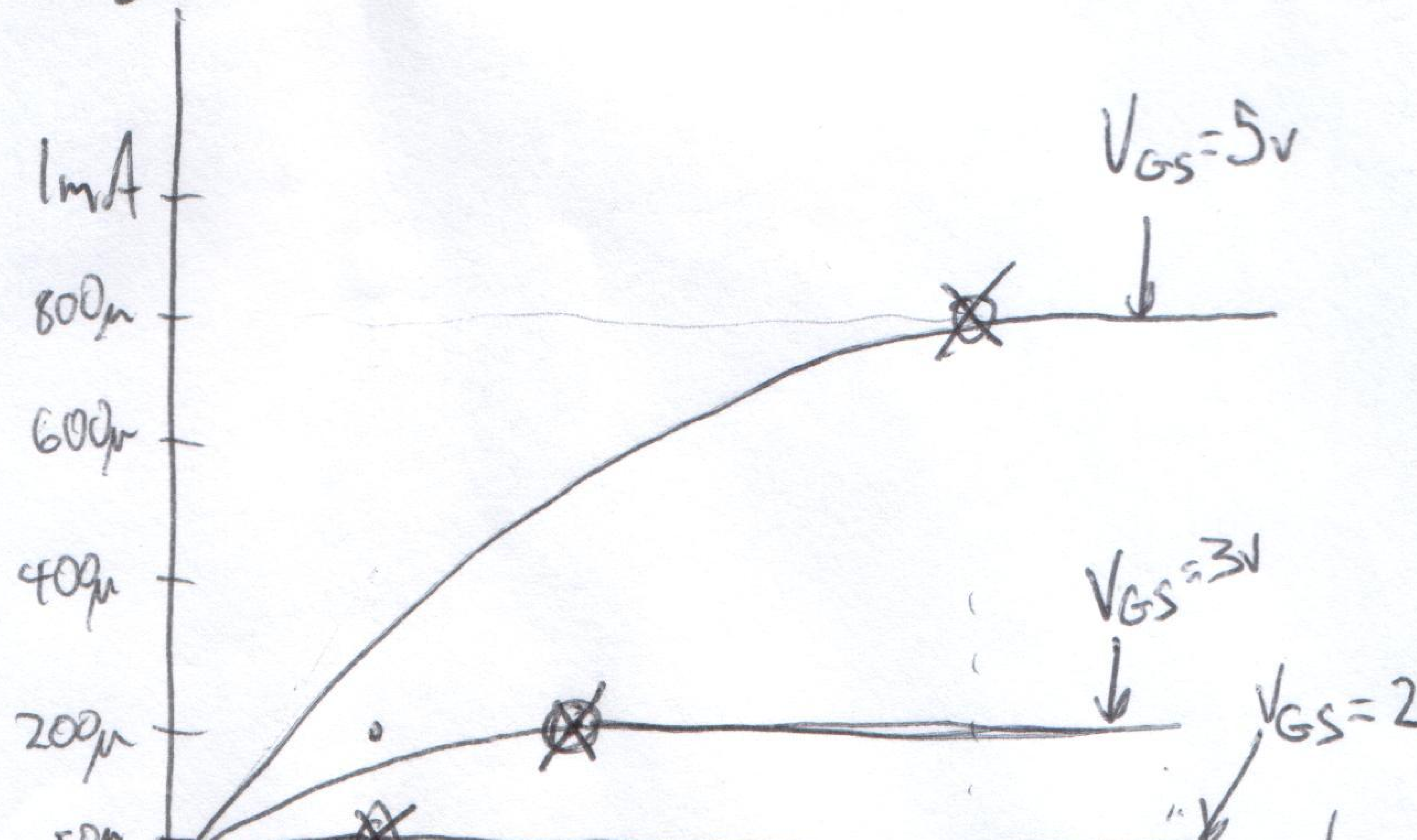
$V_{DS} = V_{OUT}$

Step 1: All $V_{GS} < V_{TN}$, $i = 0$, $\Rightarrow V_{DS} = 5v$





Step 2: $V_{GS} = 2v, 3v, 5v$:



$V_{GS} = 2v$: $i = $
- $\to 100\mu\left(V_{GS} - V_{TN} - \frac{V_{DS}}{2}\right)V_{DS}$ $\quad V_{GS} - V_{DS} > V_{TN}$ $\boxed{V_{DS} < 1v}$
- $\to 50\mu(V_{GS} - V_{TN})^2$ $\quad V_{GS} - V_{DS} < V_{TN}$ $\boxed{V_{DS} > 1v}$

for $V_{GS} = 2v$, $V_{DS} = 1v$ @ sat. thresh. & $i = 50\mu A$

$V_{GS} = 3v$: $i = $
- $\to 100\mu\left(V_{GS} - V_{TN} - \frac{V_{DS}}{2}\right)V_{DS}$
- $\to 50\mu(V_{GS} - V_{TN})^2$ $\quad \boxed{V_{DS} > 2v}$

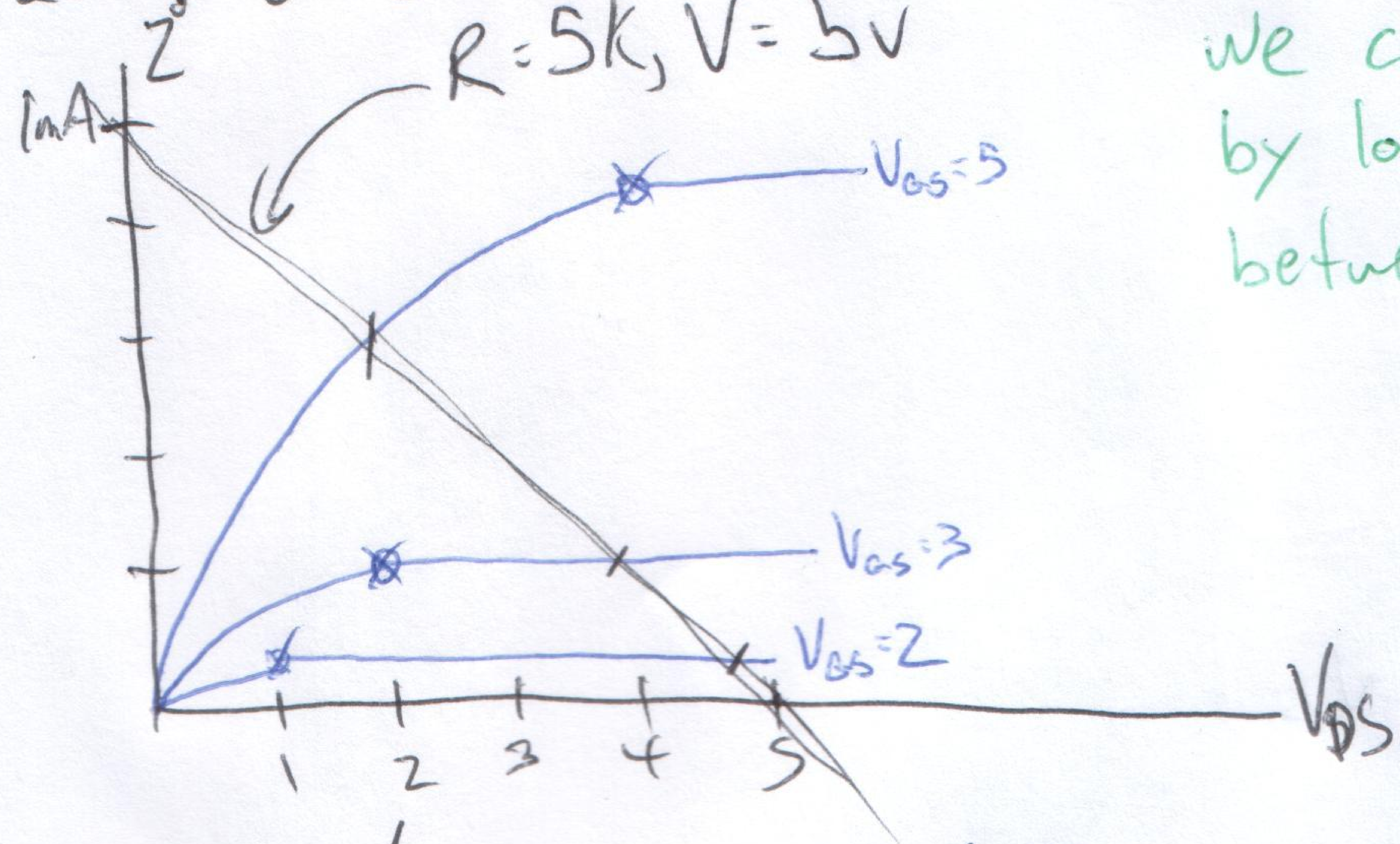
$V_{DS} = 2$, sat. thresh.

$i = 200\mu A$

$V_{GS} = 5v$: $i = $
- $\to 100\mu\left(5 - 1 - \frac{V_{DS}}{2}\right)V_{DS}$
- $\to 50\mu(5-1)^2$ $\quad V_{DS} > 4v$

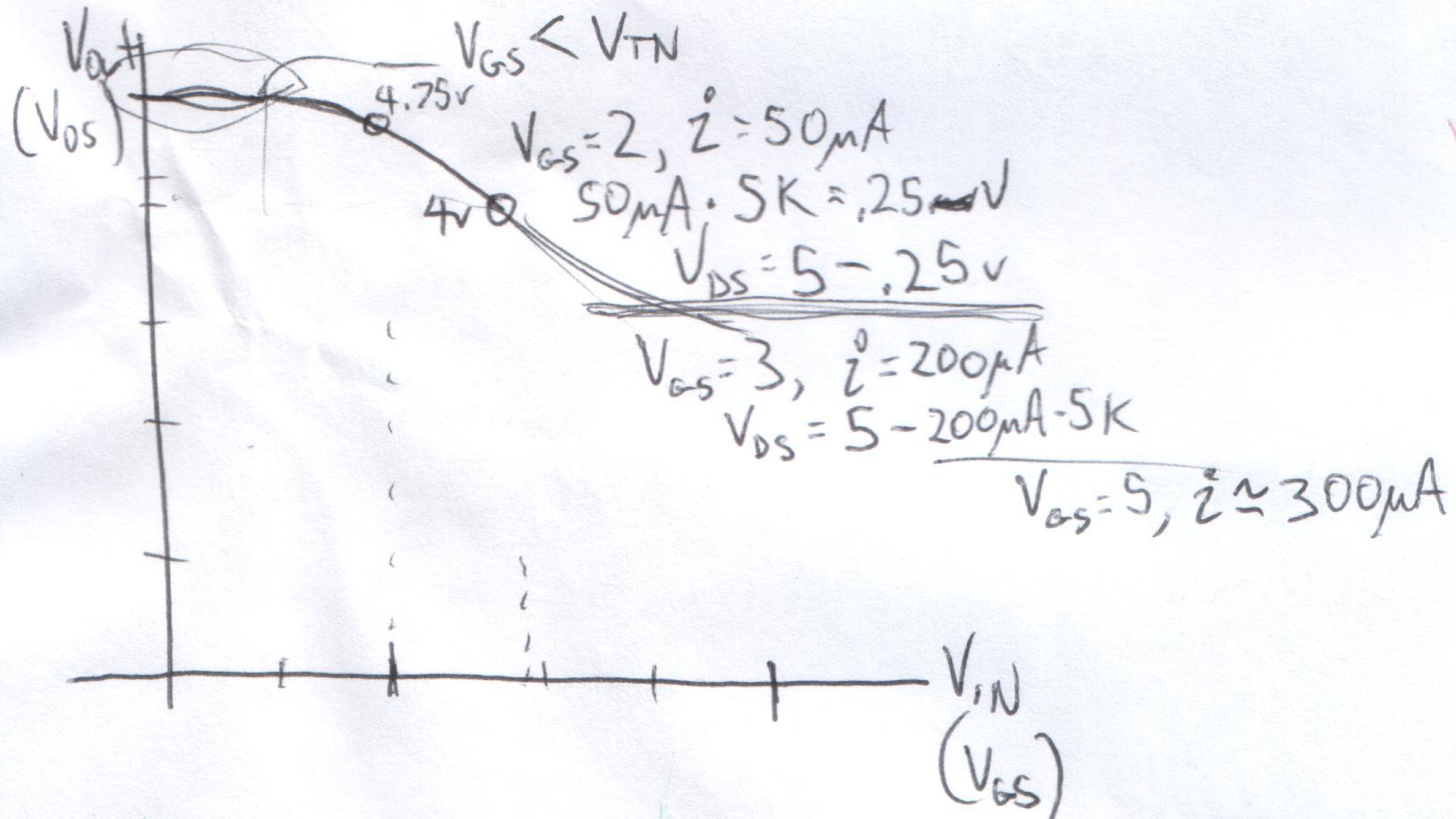
Step 3:

Load-line



We can solve graphically by looking for crossing points between R and the Transistor.

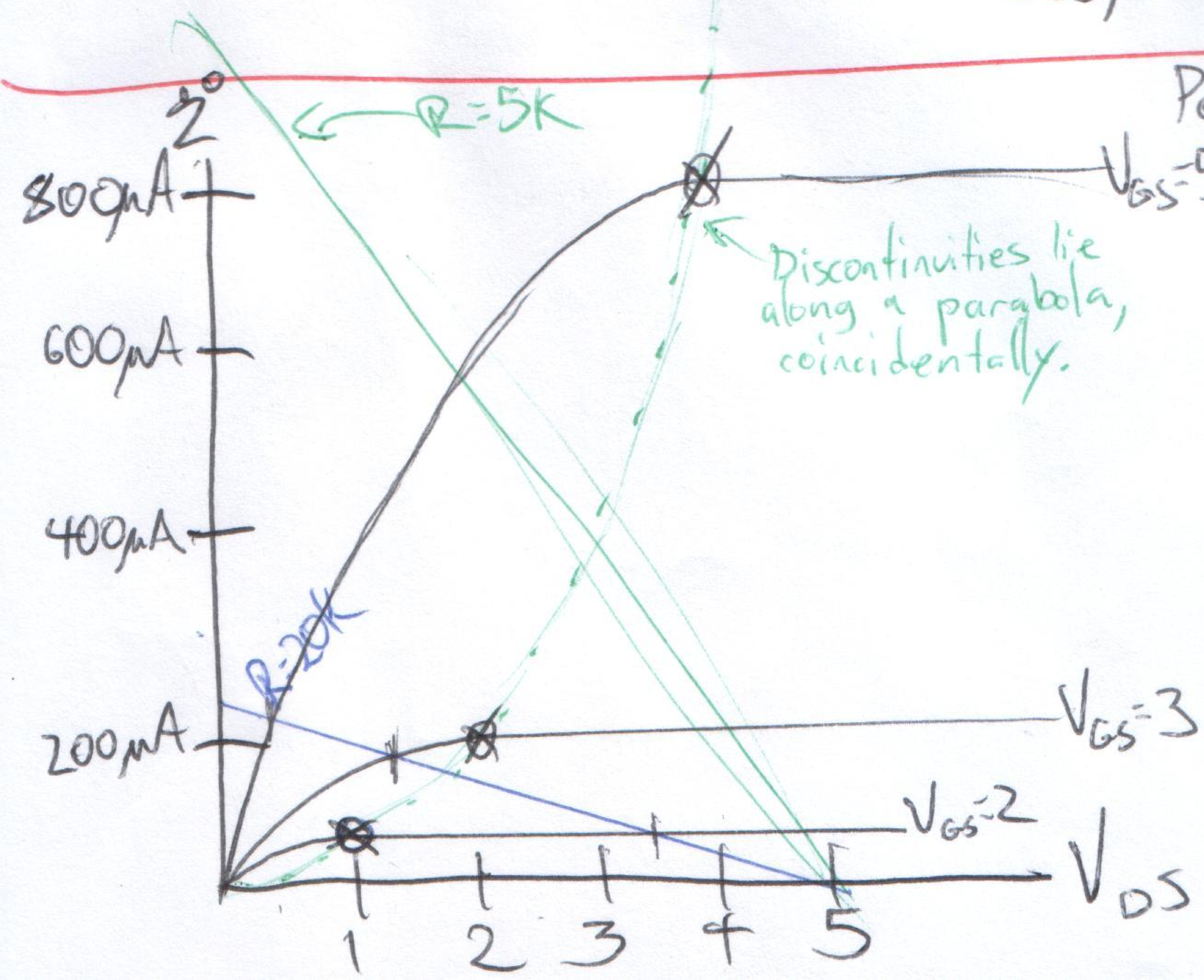
$V_{DS} \rightarrow V_{out}$ $V_{GS} \rightarrow V_{IN}$



Wow, this is terrible!

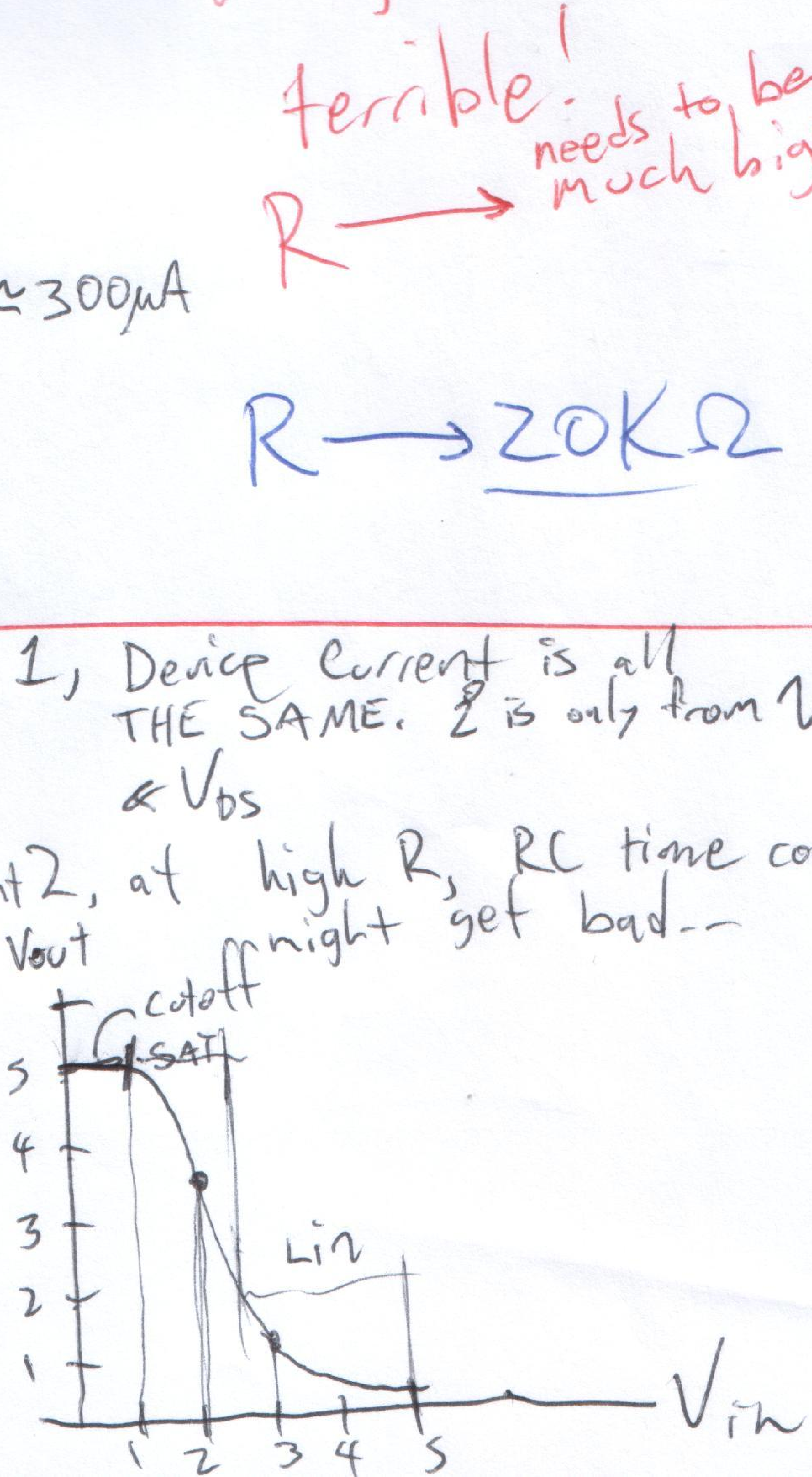
R ⟶ needs to be much bigger!

R ⟶ 20KΩ



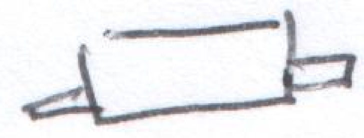
Point 1, Device Current is all THE SAME. i is only from V_{gs} & V_{DS}

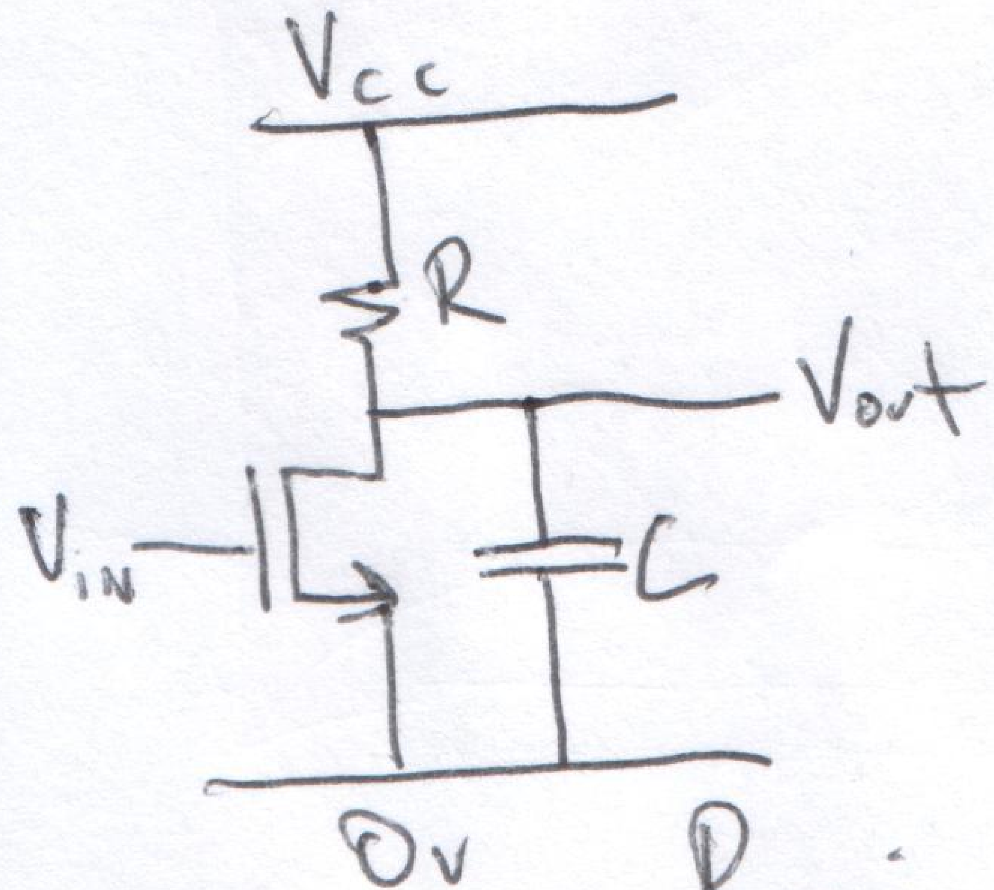
Point 2, at high R, RC time const. might get bad--

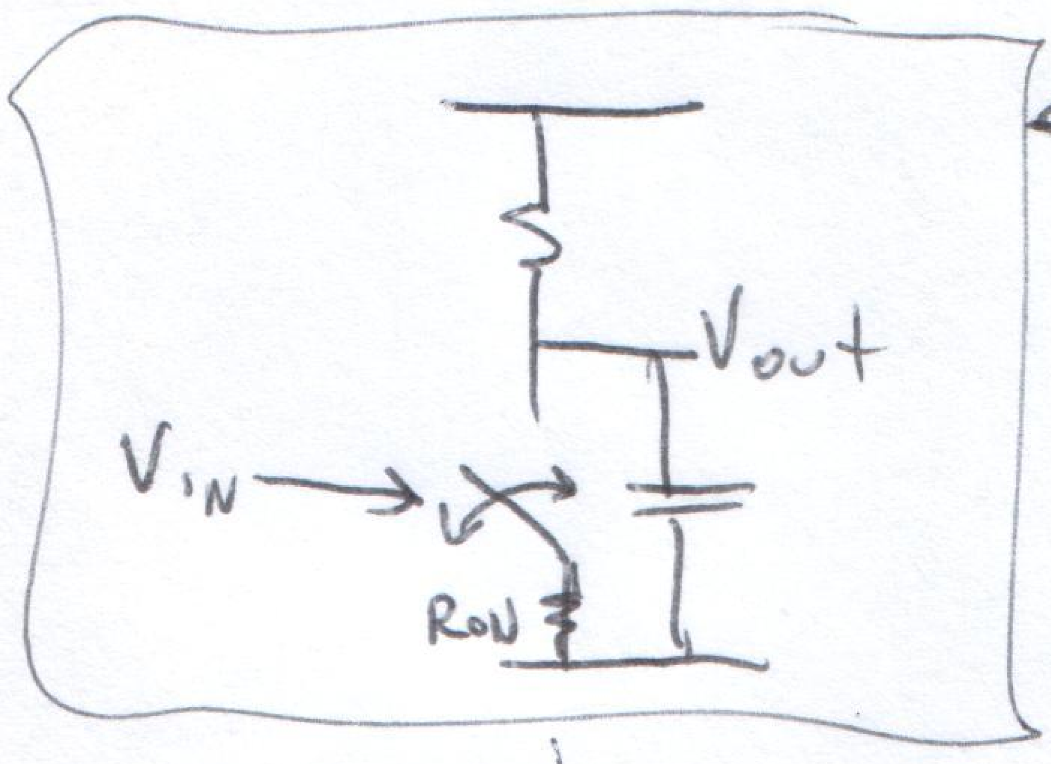


Transient Behavior:

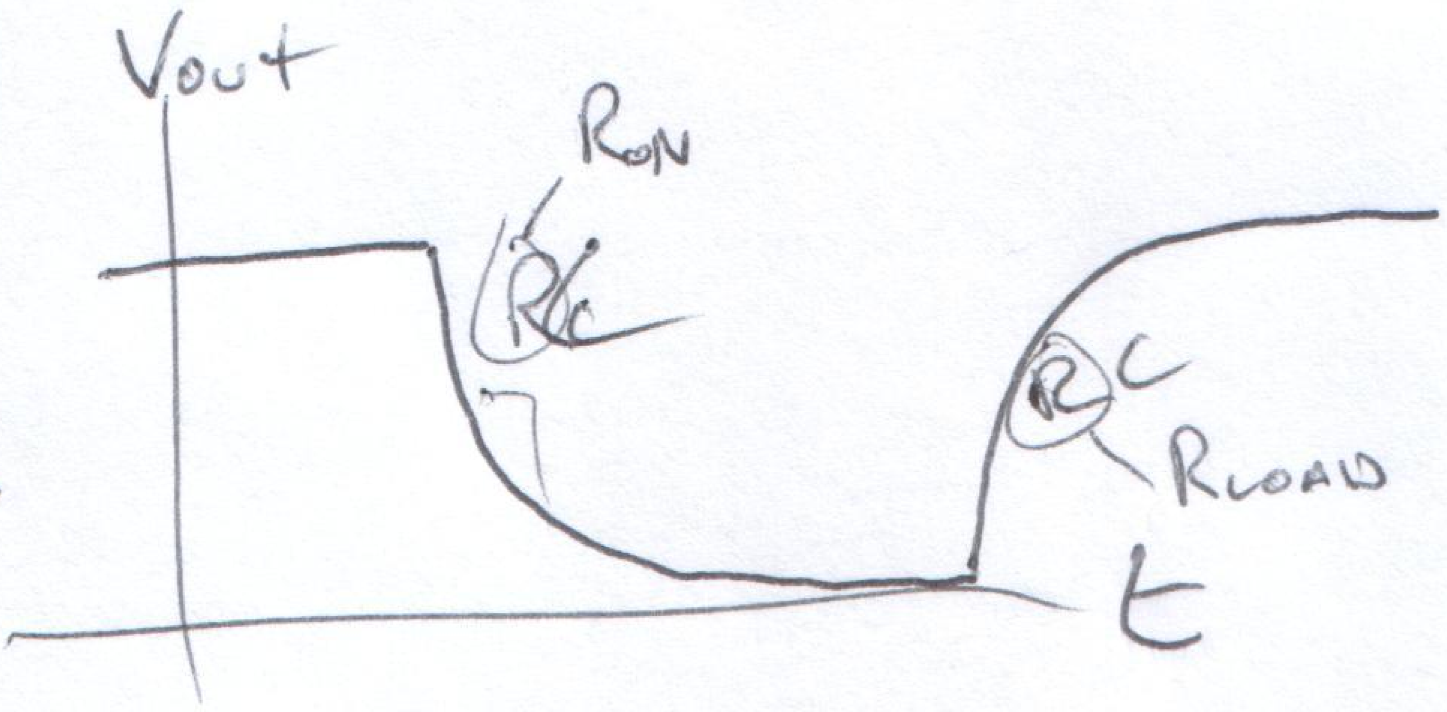
RC vs Harsh Reality



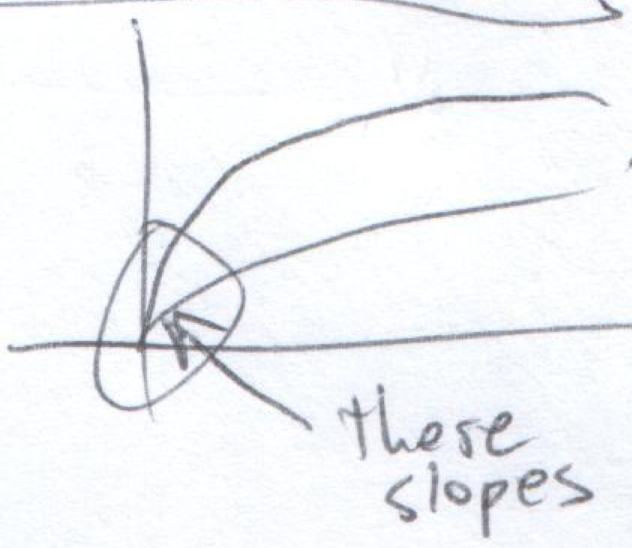




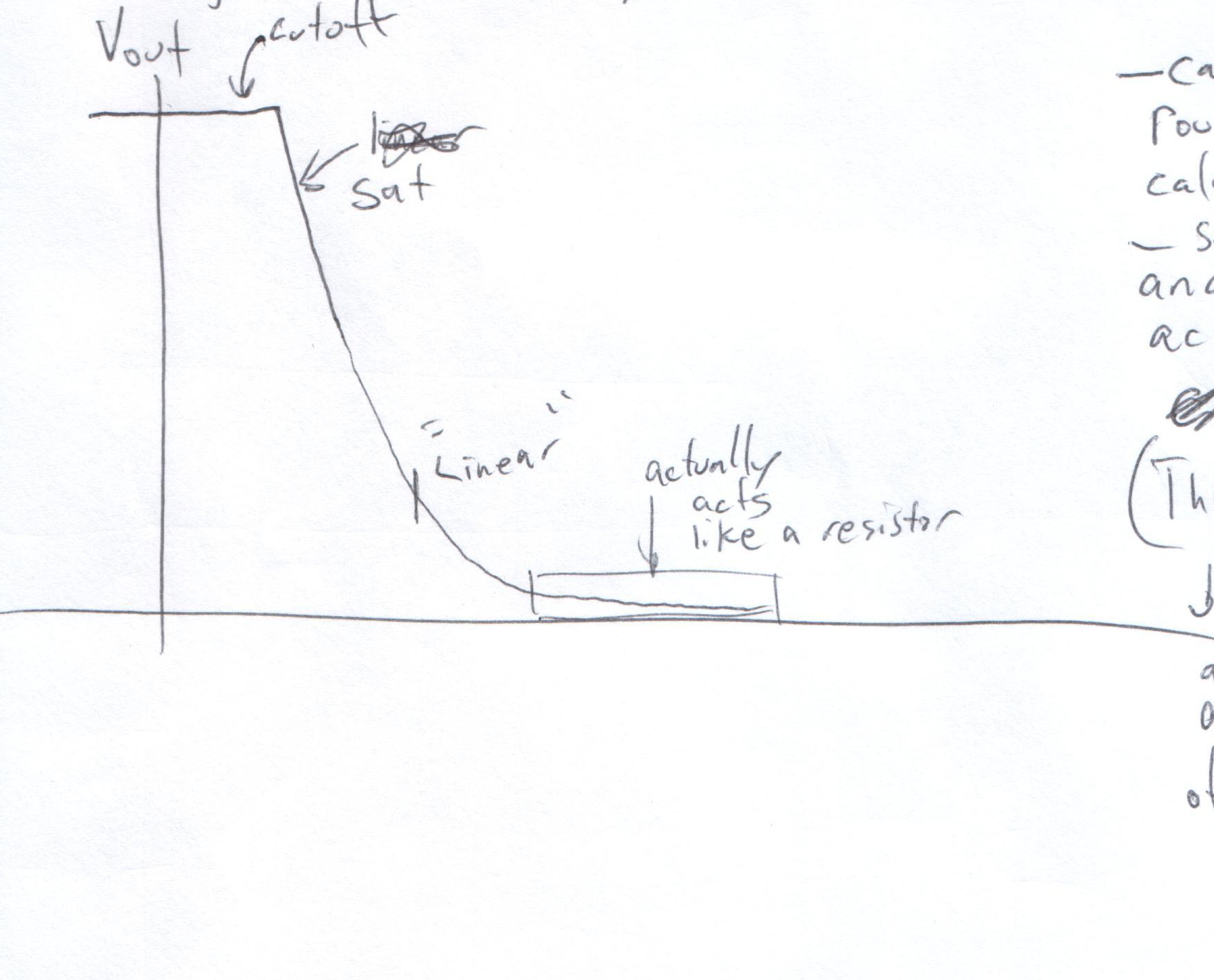
← Designers usually use this model



Ron: $\frac{1}{K_n' \frac{W}{L}(V_{CC}-V_{TN})}$



Cold, harsh reality:



Your Homework: simulate this!

- calculate: rough RC time constant calculation
- set $\Delta t << RC$ and compute the actual curve for ~~of~~ this system.

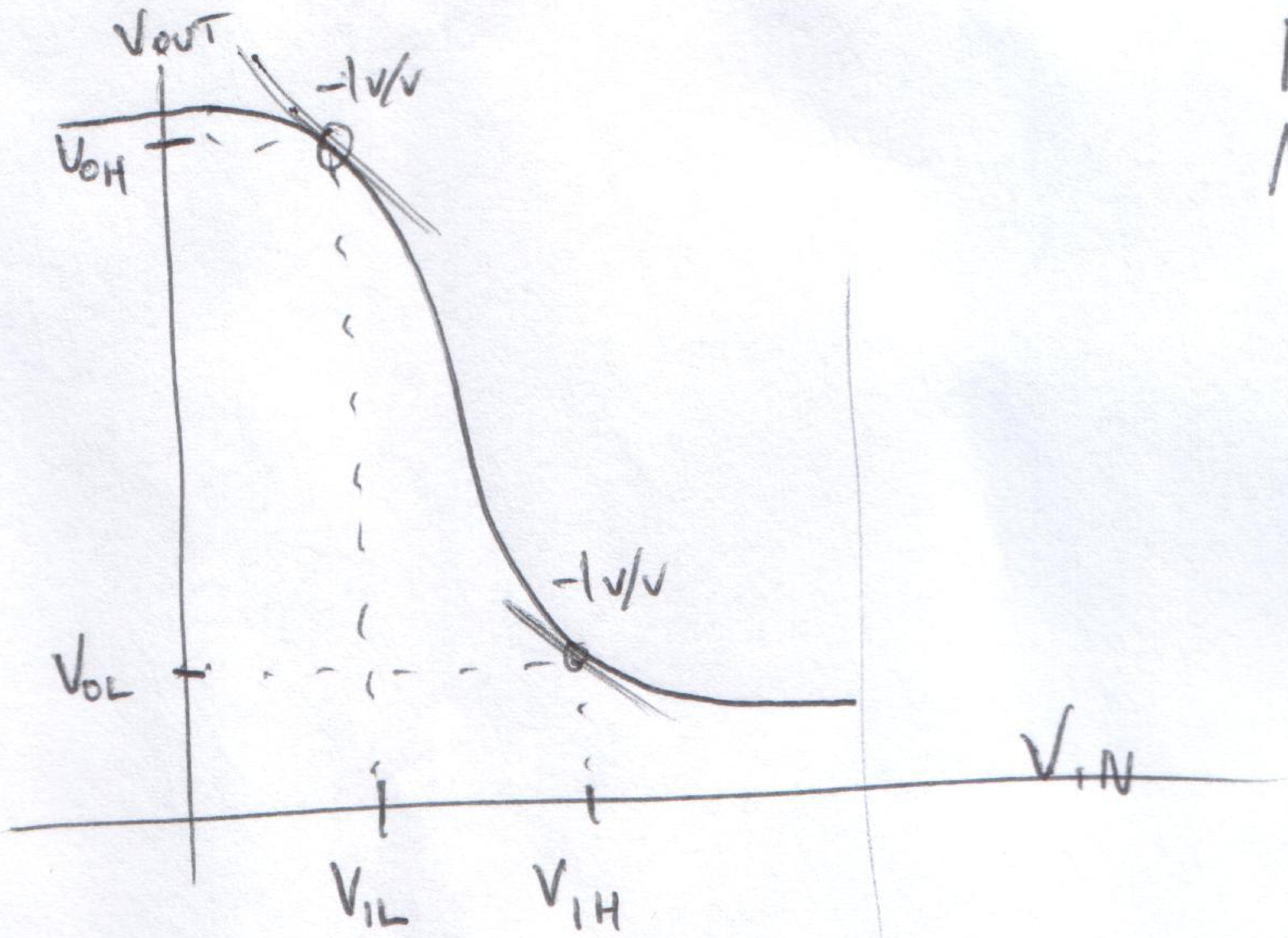
(This isn't as terrible as it sounds, just find V_{DS} over and over for new amounts of i pulled off C)

So Chapter 6 is kinda busted.

V_L; V_H: The "ideal" high/low

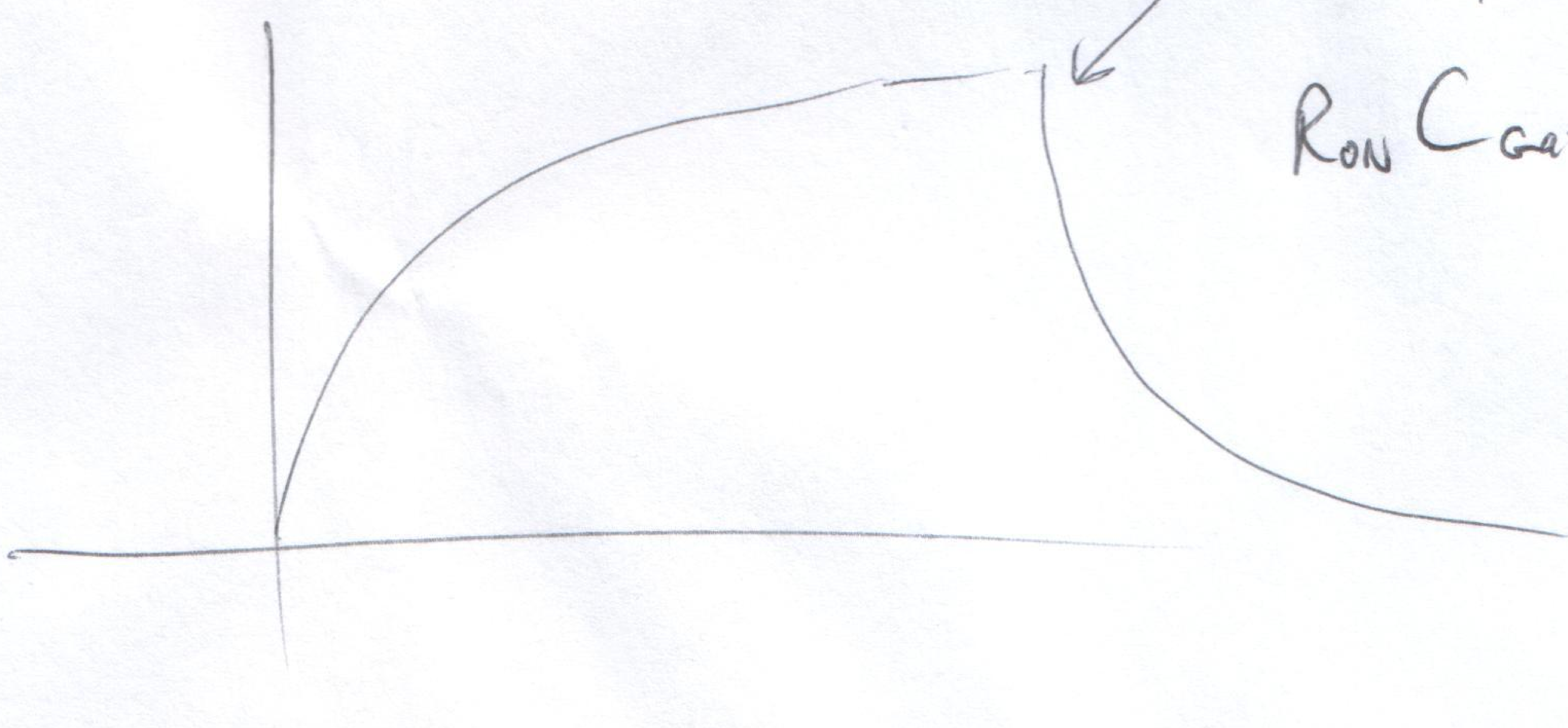
V_{OH}, V_{OL}: Output levels } defined by slope = 1 points

V_{IH}, V_{IL}: Input levels }



$NM_H = V_{OH} - V_{IH}$
$NM_L = V_{IL} - V_{OL}$
} somewhat blurry idea of "safety"

Rise, Fall times:



$R_{ON} C_{Gate}$