# Lab 3 – Notes

## Spring 2024

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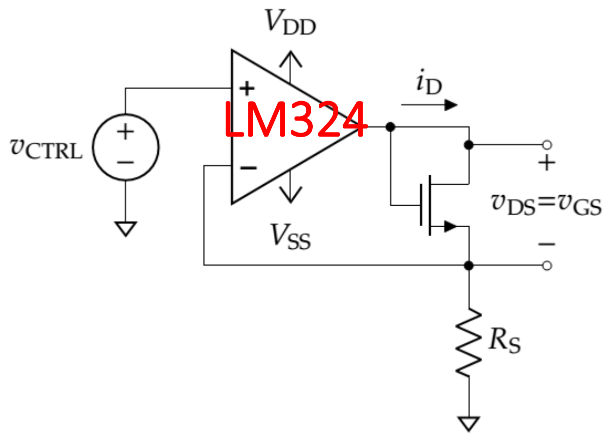
# General Notes

- Starting from lab 3, you will begin dealing with ALD chips (1105/1106/1107).
- The ALD chips are not in the kit, they will be handed to you with other extra components including the ESD wristband.
- ALD chips are very sensitive to electrostatic charge.
- Please make sure to wear a ESD wristband and connect it to ground before touching any of the ALD chips (check the ESD safety section in the video).
- Don’t touch directly the pins of the chips, always try to handle it from the package.

# Task 1

**Task 3.7.1: Determine $V_{tn}$**

1. *Connect* your ESD wristband to ground and put on the wristband.
2. *Place* the ALD1106 into your breadboard and connect $V-$ to ground and $V+$ to $V_{DD}$.
3. *Build* the circuit in figure 3.2 using $R_S = 100\,k\Omega$, $V_{DD} = 5\,V$, and $V_{SS} = -5\,V$. Use any of the four transistors on the ALD1106.
4. *Set* $v_{CTRL}$ to the value calculated in prelab step 4.
5. *Measure* the voltage across $R_S$ to ensure that $i_D$ is set to $1\,\mu A$.
6. *Measure* $v_{GS}$. This is the threshold voltage of the transistor.
7. *Repeat* the threshold voltage measurement for all four transistors on the ALD1106.
8. *Compare* the threshold voltages of the four measured transistors. Do the transistors have similar threshold voltages?
9. *Compare* the threshold voltages to the range listed on the ALD1106 datasheet. Does your measurement fall within the range listed on the datasheet?




* V- is connected to ground in this task.

* The opamp chip is LM324.

4. Check the value of Vctrl with a GTA.

5/6 Measure the voltages using the voltmeter tool.

7. Measure Vgs (Vth) for all the 4 transistors.

# Task 2

**Task 3.7.2: Estimate $k_n$**

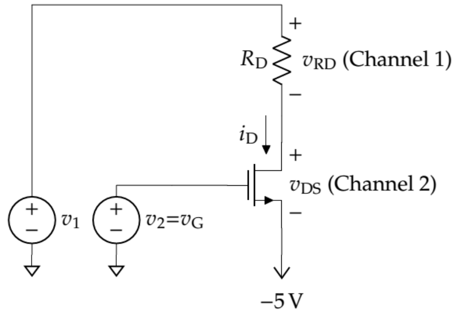



**Figure 3.4:** Test set for measuring the drain characteristics.

1. *Place* the ALD1106 in your breadboard and connect $V-$ to $\mathbf{V}_{SS}$ and $V+$ to $V_{DD}$.
2. *Set up* the to measure the drain I–V characteristics of the transistor by building the circuit in figure 3.4 with $R_D = 470\,\Omega$. Use W1 to generate $v_1$ and W2 to generate $v_2$. Use the oscilliscope channel ~~1~~ 2 to measure $v_{DS}$ and channel ~~2~~ 1 to measured $v_{RD}$. Make sure to connect the source of the NMOS in the ALD1106 to $V_{SS}$.
3. *Set* the power supplies to $V_{DD} = 5$ V and $V_{SS} = -5$ V then turn them on.
4. *Open* the "Tracer" tool in Waveforms[a].
5. *Set* the device to "N-FET" and change the adapter dropdown to "No Adapter."
6. *Open* the options dropdown and change "Emitter" to −5 V.
7. *Ensure* that "Measure" is set to "Id/Vds"
8. *Configure* the curve tracer to measure from $v_{GS} = 0$ V to $v_{GS} = 5$ V in even 500 mV steps over the range $0\,\text{V} \le v_{RD} < 10$.
9. *Set* $R_D = 470\,\Omega$ in the tracer tool.
10. *Run* the curve tracer and save a screenshot of the output.
11. *Calculate* the $k_n$ value for each curve that the transistor enters saturation. Use the $V_{tn}$ measured in task 3.7.1.

[a] If you can't find this tool, you need to update to the newest version of waveforms.

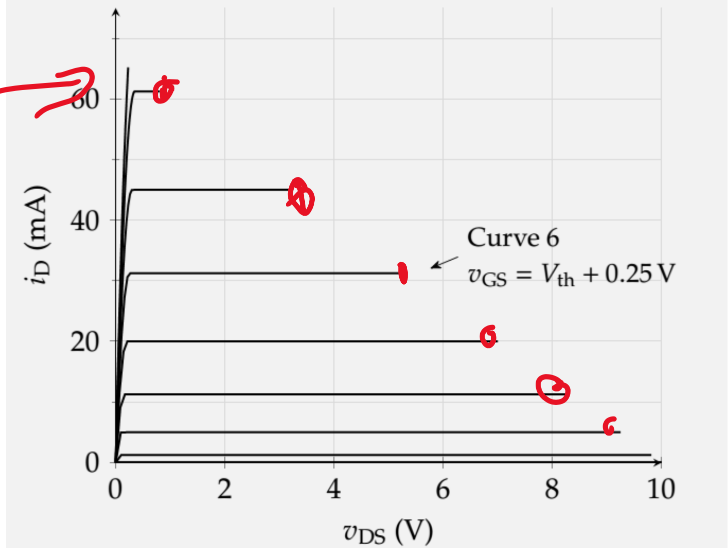
* V- is connected to -5v in this task.

* Check the demo on the curve tracer tool in the video for this task.

2->10 Follow the instruction to plot the I-V characteristics for 11 curves.

11. Compute Kn for all curves. Use Vth from task 1. get Id and Vgs values from the curves.

$$k_n = \frac{2 i_D}{(v_{GS} - V_{th})^2}$$



# Task 3

**Task 3.7.3: Estimate $g_m$**

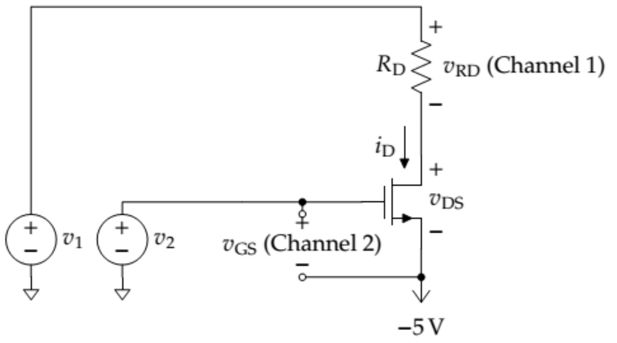



**Figure 3.5:** Test set for measuring the $i_D$ vs. $v_{GS}$ characteristics.

1. *Construct* the circuit in figure 3.5. This is almost the same circuit as task 3.7.2, except channel 2 is now measuring $v_{GS}$.
2. *Configure* the tracer tool in Waveforms to measure "iD/vGS."
3. *Set* the drain voltage to a constant 5 V
4. *Configure* the gate voltage to sweep from 0 V to 5 V in 100 mV steps.
5. *Run* the curve tracer.
6. *Capture* a screenshot of the curve tracer output.
7. *Export* the data from the curve tracer and load it into MATLAB, Excel, or a similar tool.
8. *Calculate* $g_m$ for each point using equation (3.5).
9. *Plot* $g_m$ vs. $i_D$. What is the correlation between $i_D$ and $g_m$?
10. *Plot* $g_m$ vs. $v_{GS}$ and your answer to prelab question 2. Use the $V_{tn}$ you measured in task 3.7.1 and the $k_n$ you calculated for the curve corresponding to $v_{GS}$ = 2.5 V in task 3.7.2. Over what range of voltages does the model agree with the measurement?

* V- is connected to -5v in this task.

* Check the video on how to export data and compute gm using excel or Matlab.

* Make sure to put the steps of Vrd: 1 in the settings, to get only 1 curve for Id vs Vgs

6. Take screenshot for Id-Vgs

9. Plot gm vs Id from the measured data (using excel for example) + comment on correlation.

10. Draw 2 curves for gm vs Vgs on the same plot:

a) Curve 1: From measured data (using excel for example).

b) Curve 2: From the theoretical relation $g_m = K_n(V_{gs} - V_{th})$. Use Vth from task 1, and Kn from task 2 for the curve corresponding to vgs = 2.5v.

Comment on the range of agreement between the 2 curves