ECEN-607: Advanced Analog IC Design

Assignment #1: Transistor Characterization

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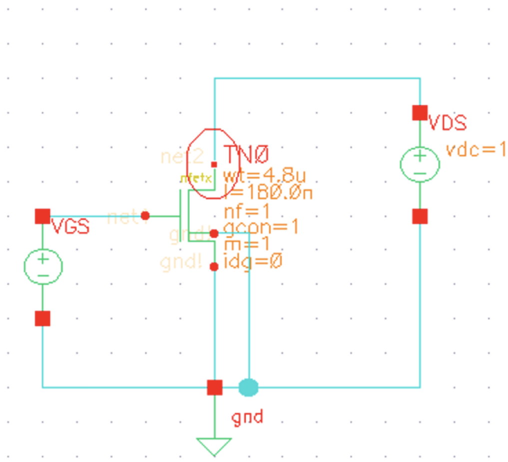
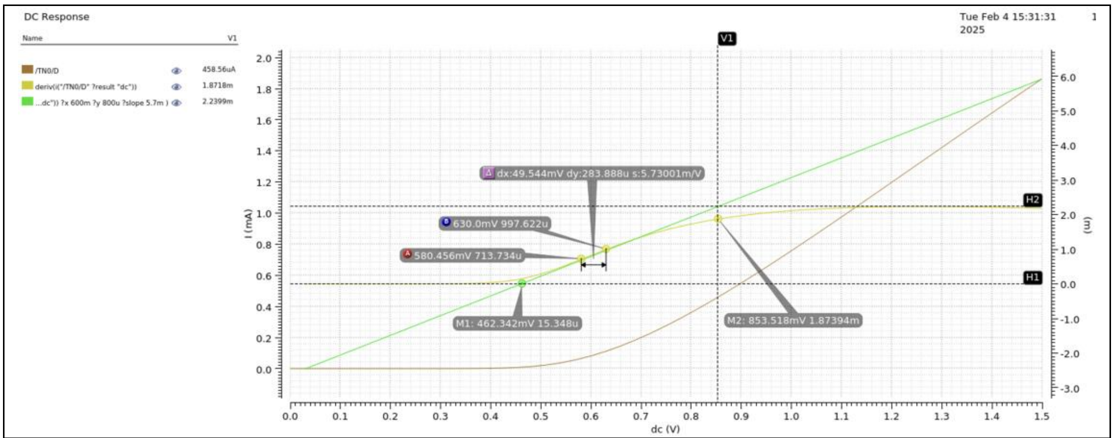
Due: 02/06/2025
Instructor: Jose Silva-Martinez

Use the technology you are using in the lab and characterize a single N-type transistor employing W=4.8µm and L=0.18µm. Use the IBM 0.18 technology you are using in the laboratory; please check it with your TA.

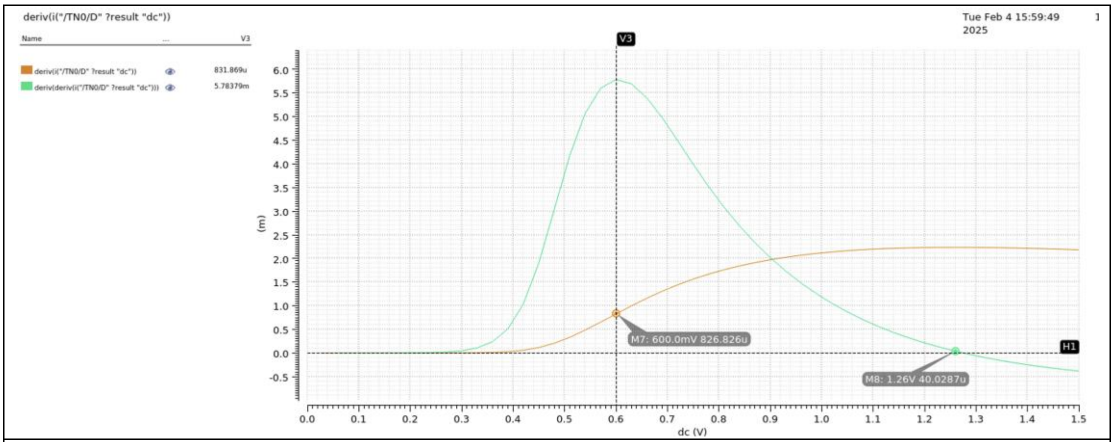


schematic

1. *Set the drain-source voltage at 1V and sweep the gate-source voltage from 0 up to 1.5V. Plot ids, Gm, $dGm/dVgs$, and $d^2Gm/dVgs^2$ versus gate-source voltage.*



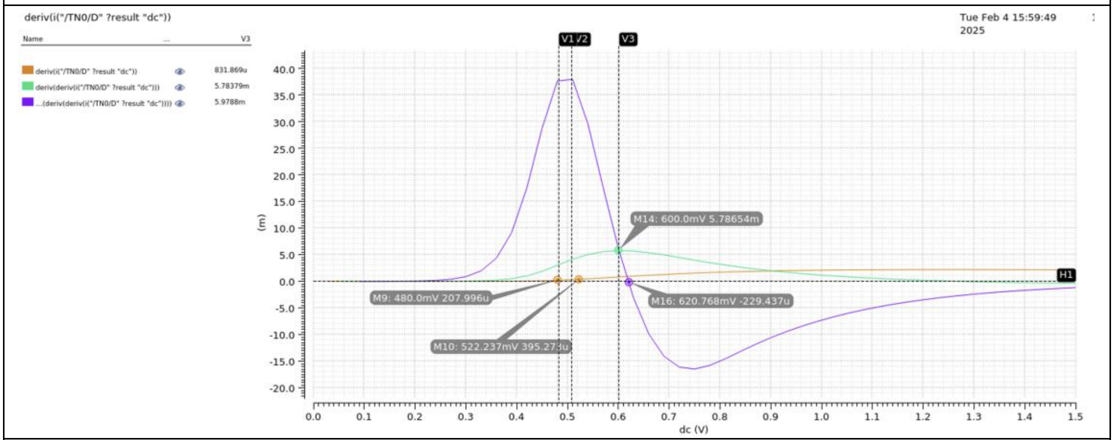
Brown line: Id/Vgs
Yellow line: Gm= $dId/dVgs$
(Vth: 0.462v)



Brown line: Gm= $d\mathrm{Id}/dVgs$

Green line: $dGm/dVgs$

When VGS=0.6v, MOSFET gain is maximized rate of change



Brown line: Gm= $d\mathrm{Id}/dVgs$

Green line: $dGm/dVgs$

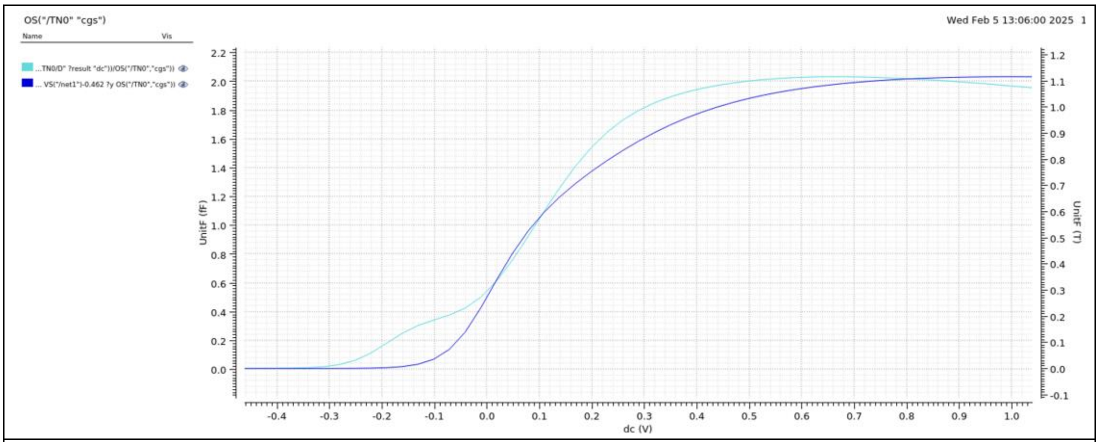
Purple line: $d^2Gm/dVgs^2$

When VGS is around 0.522v, MOSFET gain is the most stable, meaning the best linearity.

When VGS is over 0.62v, the MOSFET enters the non-linear region.

- (d3Gm/dVGS3 max) represents the MOSFET gain, which is the most stable and indicates the best linearity.(high linearity amplifiers, such as ADC preamplifiers.)
- (d2Gm/dVGS max) indicates that the gain of the MOSFET is maximized; however, linearity begins to (high-gain amplifiers.)

2. For same conditions as i), plot Cgs and Gm/Cgs versus Vgs-VT (overdrive voltage); this parameter represent the transistor’s ft, which is quite relevant when designing fast circuits; Gm/Cgs is also known as the transistor’s ft.

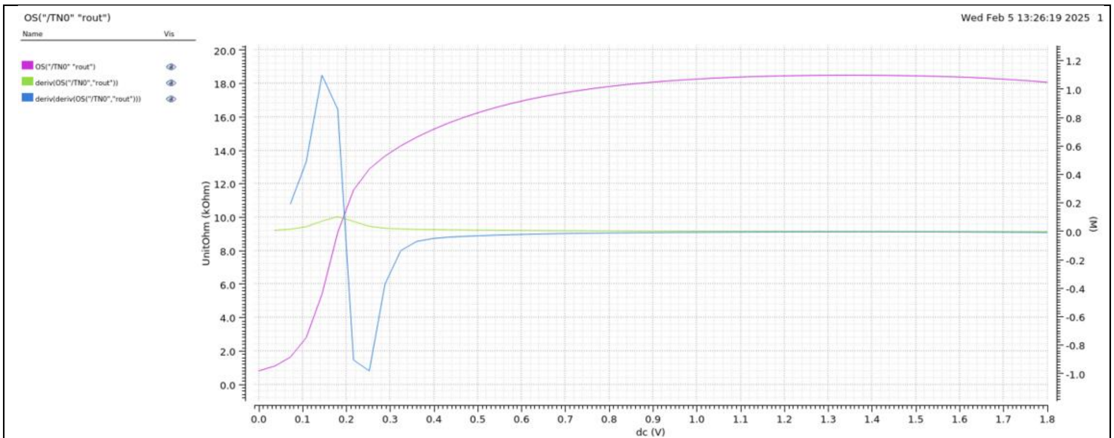


The bright blue line: Cgs versus Vgs-VT

The dark blue line: Gm/Cgs versus Vgs-VT

- The **transition frequency** (ft) of a MOSFET is defined as: ft=Gm/2πCgs

3. Set the gate voltage such that the overdrive voltage Vgs-VT=200mV, and sweep the drain voltage in the range 0-1.8V. Extract the transistor's output resistance and plot Rds, dRds/dVds, and d2Rds/dVds 2 versus drain-source voltage. Notice that the derivatives of Rds represent output resistor non-linearities. Certainly, Rds is a second order effect and very non-linear, though!

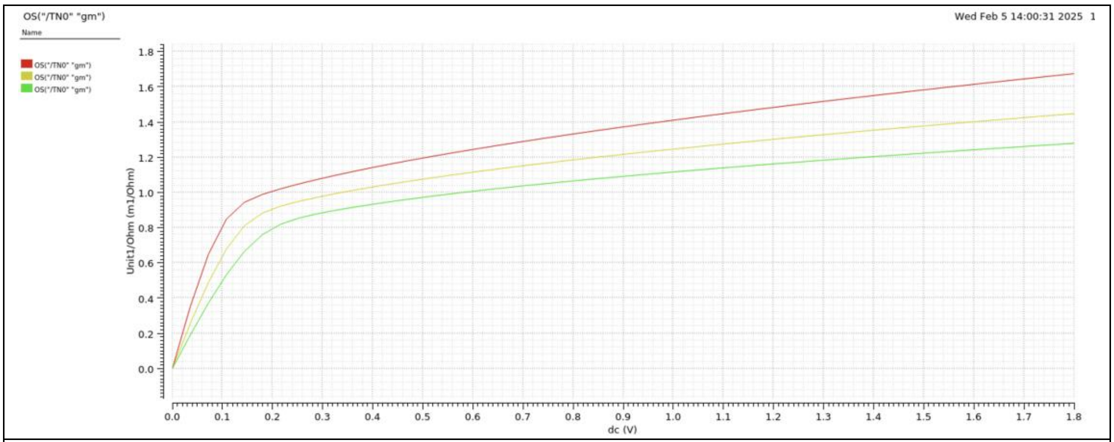


The pink line: Rds

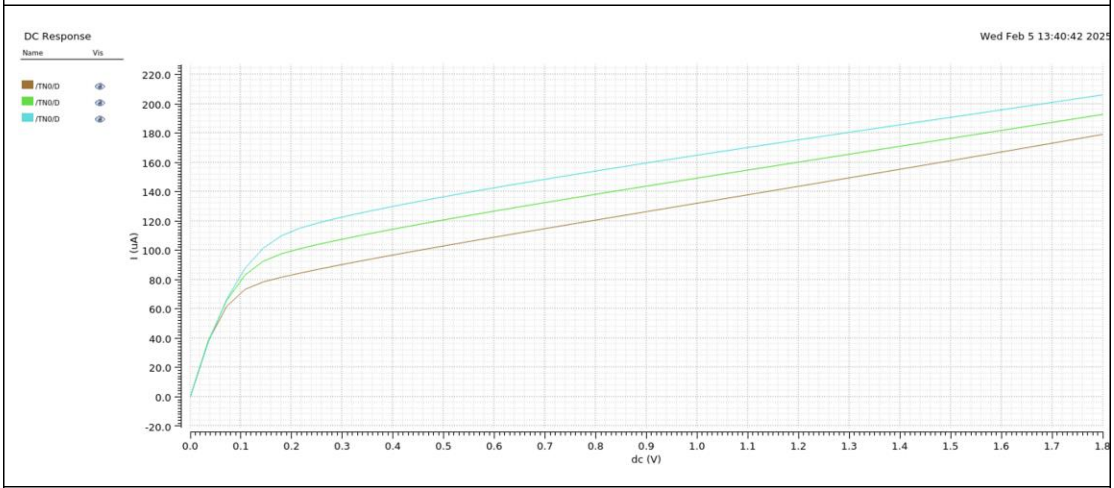
The green line: dRds/dVds,

The blue line: d2Rds/dVds 2

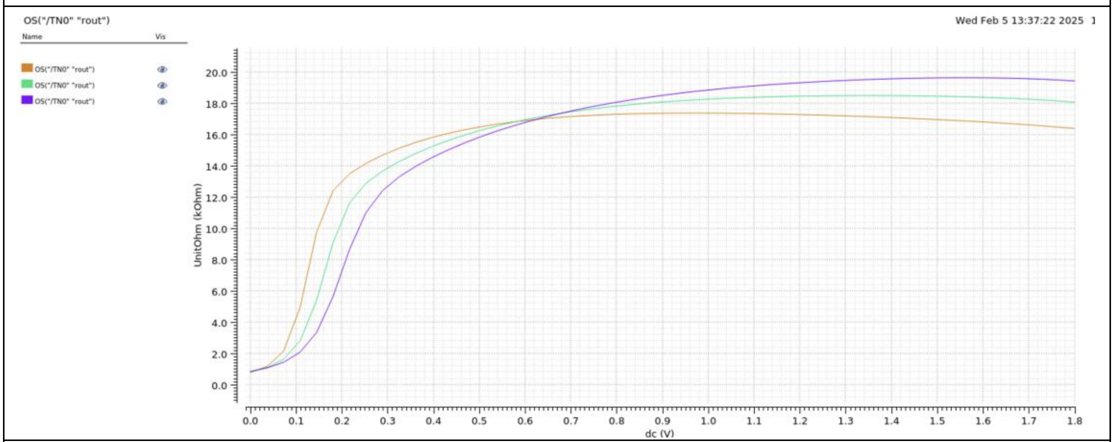
4. Repeat iii) for temperatures of -50, 27 and 100 degrees (Celsius). Make a table and compare Id, Gm and Rds for the 3 cases. For all these simulations keep constant the gate-source voltage; evidently Vdsat will not be constant due to VT variations.



Gm: -50, 27, 100 degrees (Celsius)



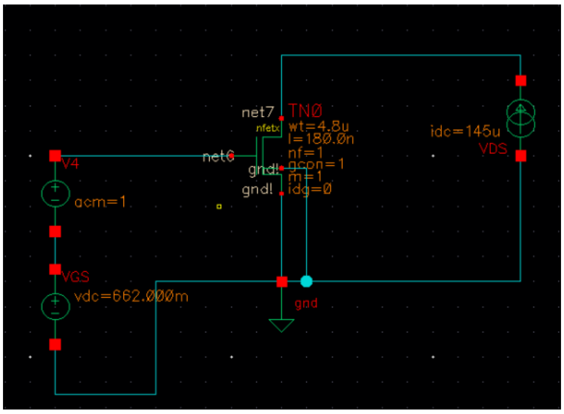
Id: -50, 27, 100 degrees (Celsius)

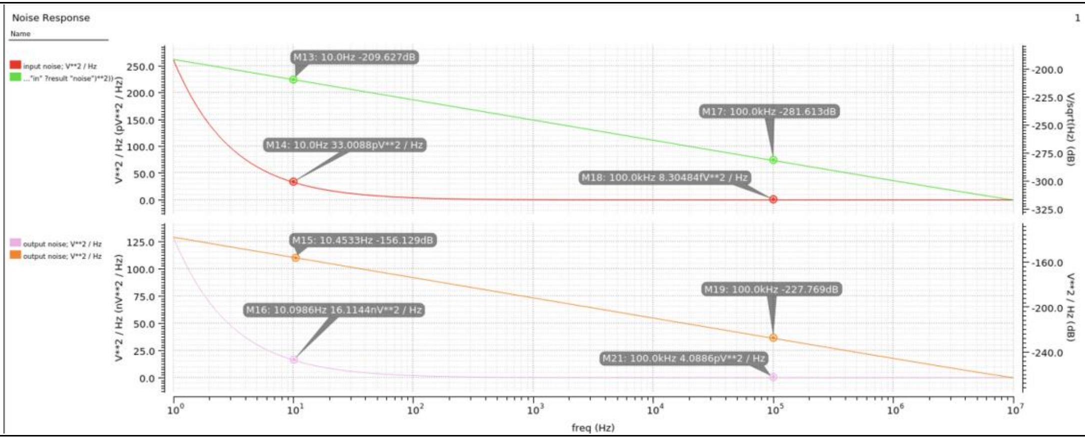


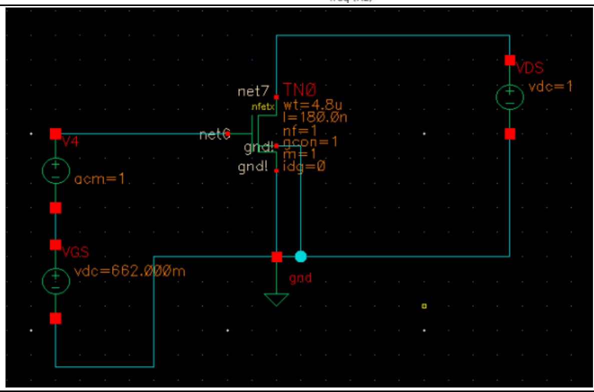
rds: -50, 27, 100 degrees (Celsius)

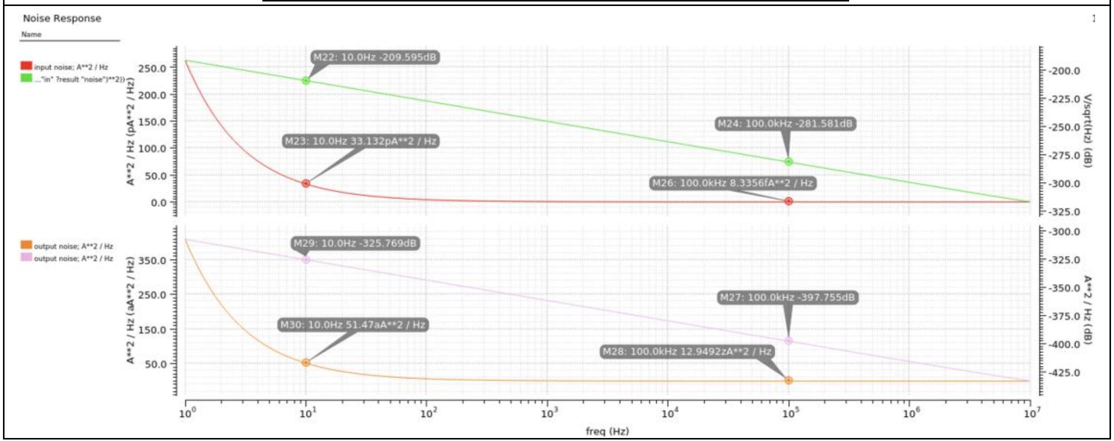
5. Simulate the transistor and report the input and output referred noise density. Include a screen shot showing the noise density in the frequency range of 1Hz up to 10MHz; use log10 scale in the x-axis and y-axis to visualize the flicker noise level (voltage) and the thermal noise level (current). Check these values with the theoretical values. The easiest way to do this is by biasing the gate voltage with a DC voltage source such that Vgs-VT=200mV in series with an AC voltage source. Connect at amplifier's drain terminal a power supply such that VDS is set at 1V. The

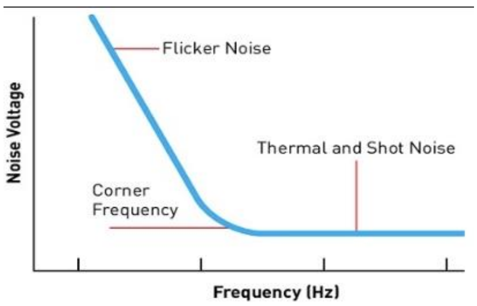
DC voltage source operates as short circuit for AC analyss and current can be measured.











The relationship between Io (noise) ^{2} = Vi (noise) ^{2} * GM ^{2}, which is at 10Hz, 51.47aA^2 / 33pV^2 Gm=1.24m at 10Hz

Flicker Noise (Low-Frequency Noise), the gate-referred noise voltage is given by $Vg^2(f)= k/fWLcox$

Thermal Noise (White Noise, Frequency-Independent)

The drain current noise is given by: 4KT*2/3*Gm

By those condition on the top we can rewrite the input noise as $Vi^2(f)= 8kT/3gm + k/fWLCox$, by this formula and the picture on the top we can calculate the flicker noise (in low freq) and thermal noise (at high freq), not matter Input out Output ($Vi^2*Gm^2=Io^2$).

Conclusion:

- (d3Gm/dVGS3 max) represents the MOSFET gain, which is the most stable and indicates the best linearity.(high linearity amplifiers, such as ADC preamplifiers.)
- (d2Gm/dVGS max) indicates that the gain of the MOSFET is maximized; however, linearity begins to (high-gain amplifiers.)
- The relationship between Io (noise) ^{2} = Vi (noise) ^{2} * GM ^{2}
- The input noise can be written as 8kT/3gm + k/fWLCox, which means low frequency is dominate by flicker noise and high frequency is dominate by thermal noise.