Characterization of CMOS Transistors and Testing of LVDS Circuit at Cryogenic Temperatures

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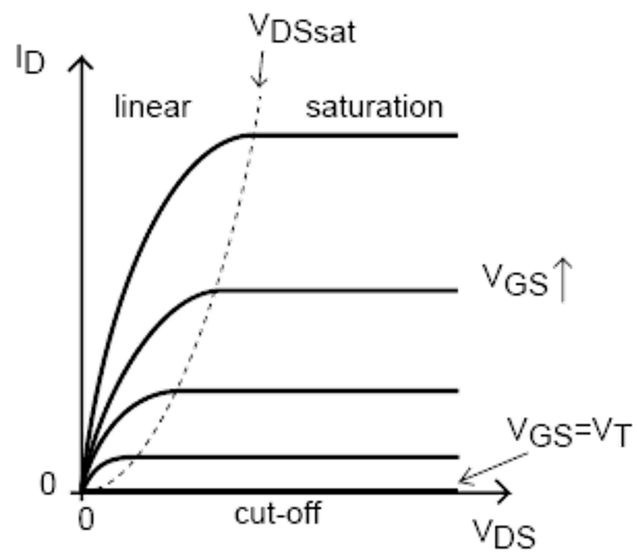
Final Report– 25th September 2018

1) Characterization of CMOS Transistors at Cryogenic Temperatures

Characterization of CMOS transistors at different temperatures, starting from room temperature down to 65K

Goals

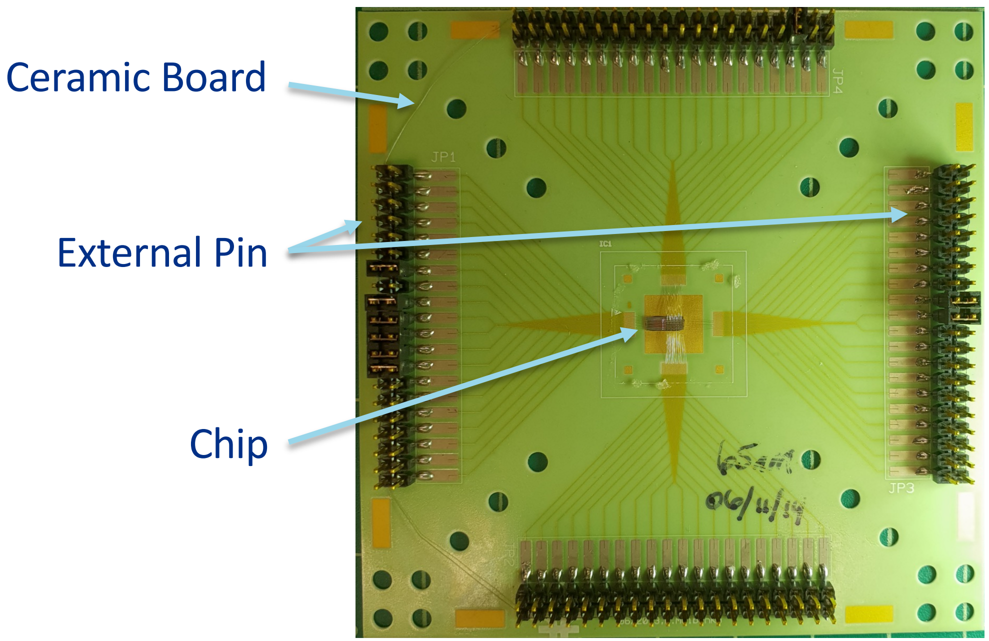
- Get familiar with standard device models
- Understand the effect of temperature on devices
- Learn how to use the test structure boards and instrumentations (SMU, cryocoolers, ..)
- Do measurement to model device

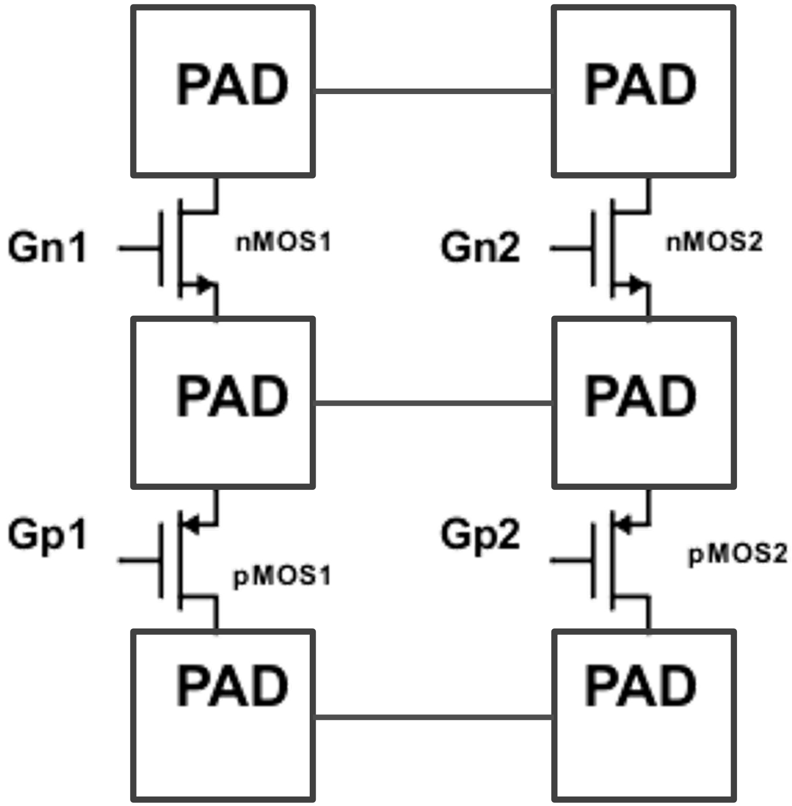


Test Structure Boards

Devices that are to be characterized at 300K down to 65K:

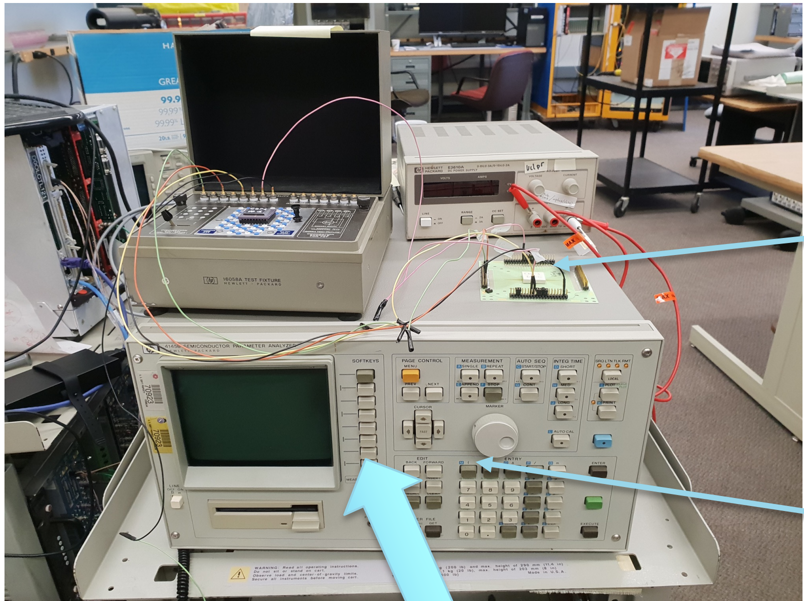
- Standard 65nm CMOS transistor thick-oxide: 2 nMOS and 2 pMOS (10/0.28 and 10/0.36)
- (Standard 65nm CMOS transistor thin-oxide: 15 nMOS and 15 pMOS)





Measurement Setup

Room (300K) and Low Temperature

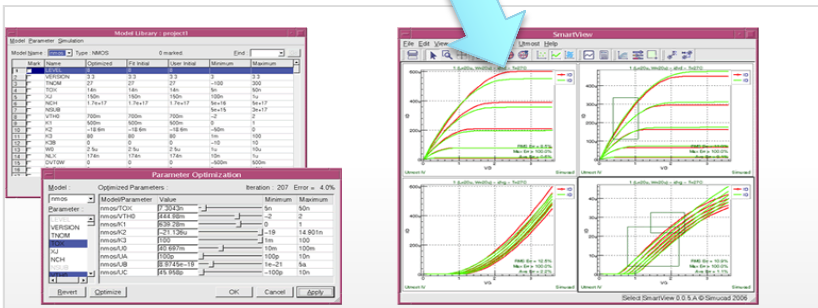


Cupper plate

Test Structure Board

Cryocooler

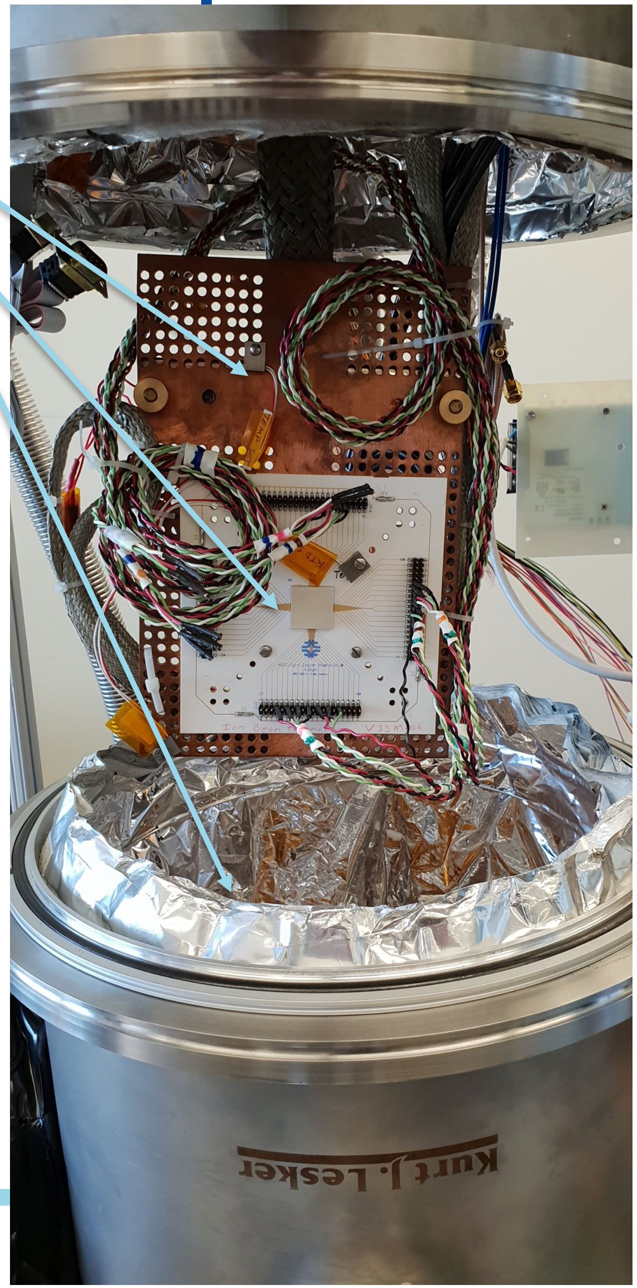
HP 4145B Semiconductor Parameter Analyzer (SMU)



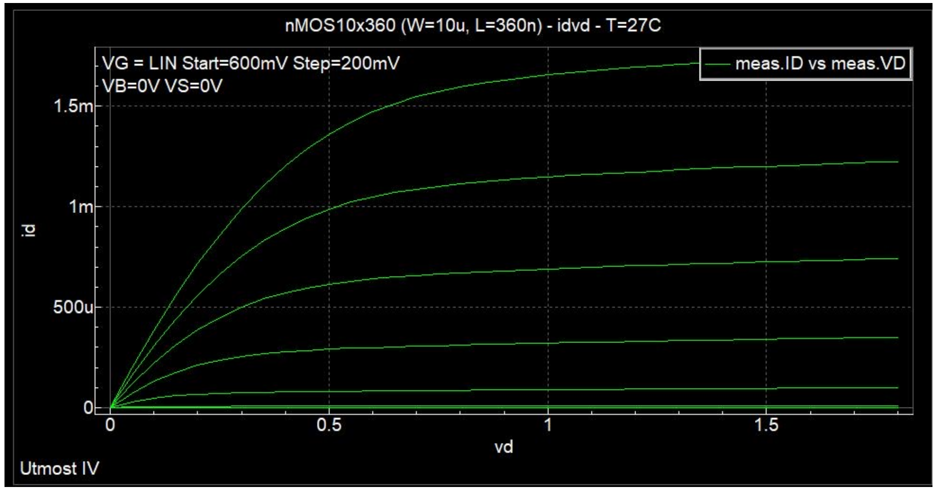
Rubberband optimization of any number of parameters

View and optimize any number of targets

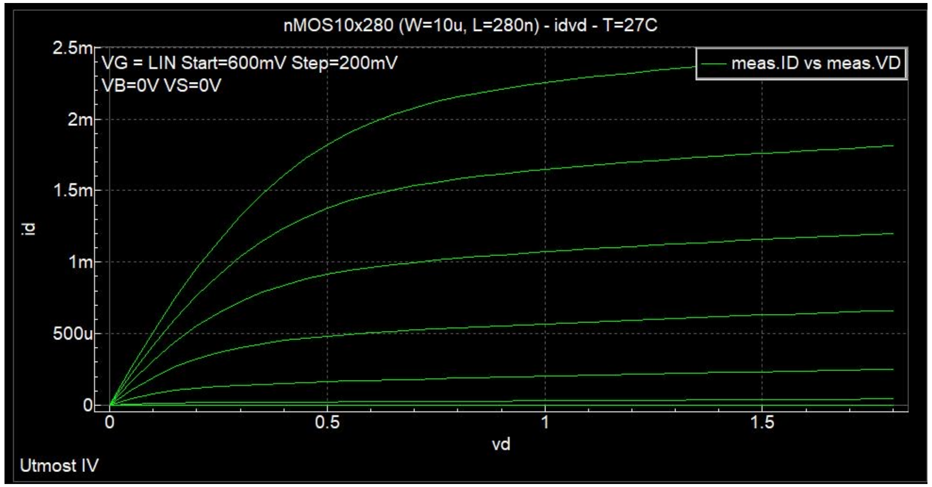
Silvaco UTMOST



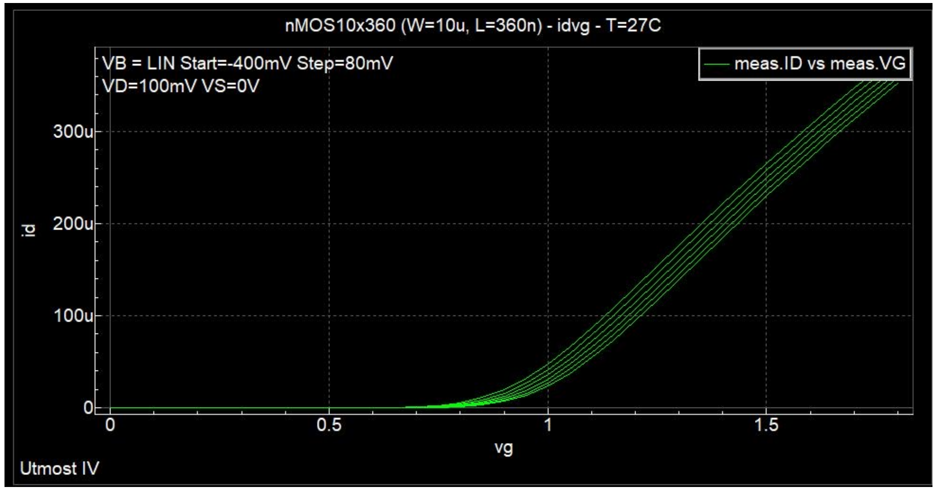
Examples of Measurement Performed at Room Temperature – Thick Oxide



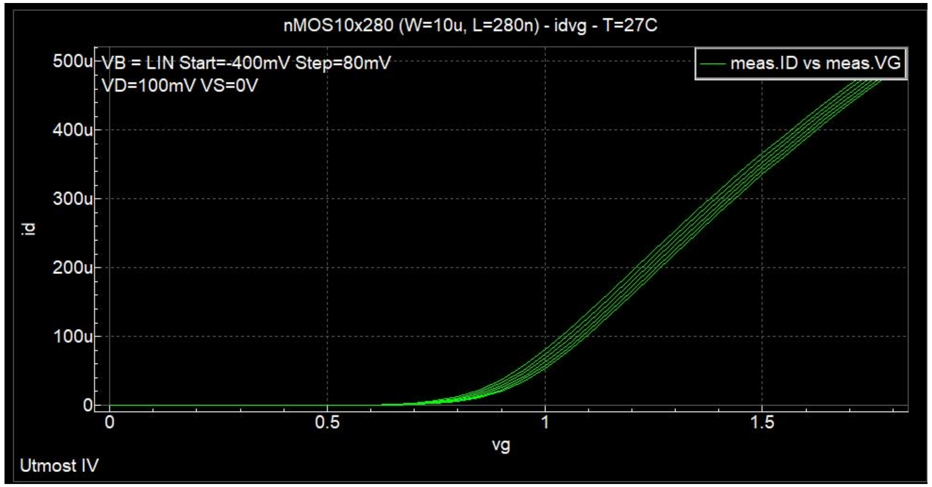
nMOS 10µ x 360n Output Characteristic



nMOS 10µ x 280n Output Characteristic



nMOS 10µ x 360n Input Characteristic



nMOS 10µ x 280n Input Characteristic

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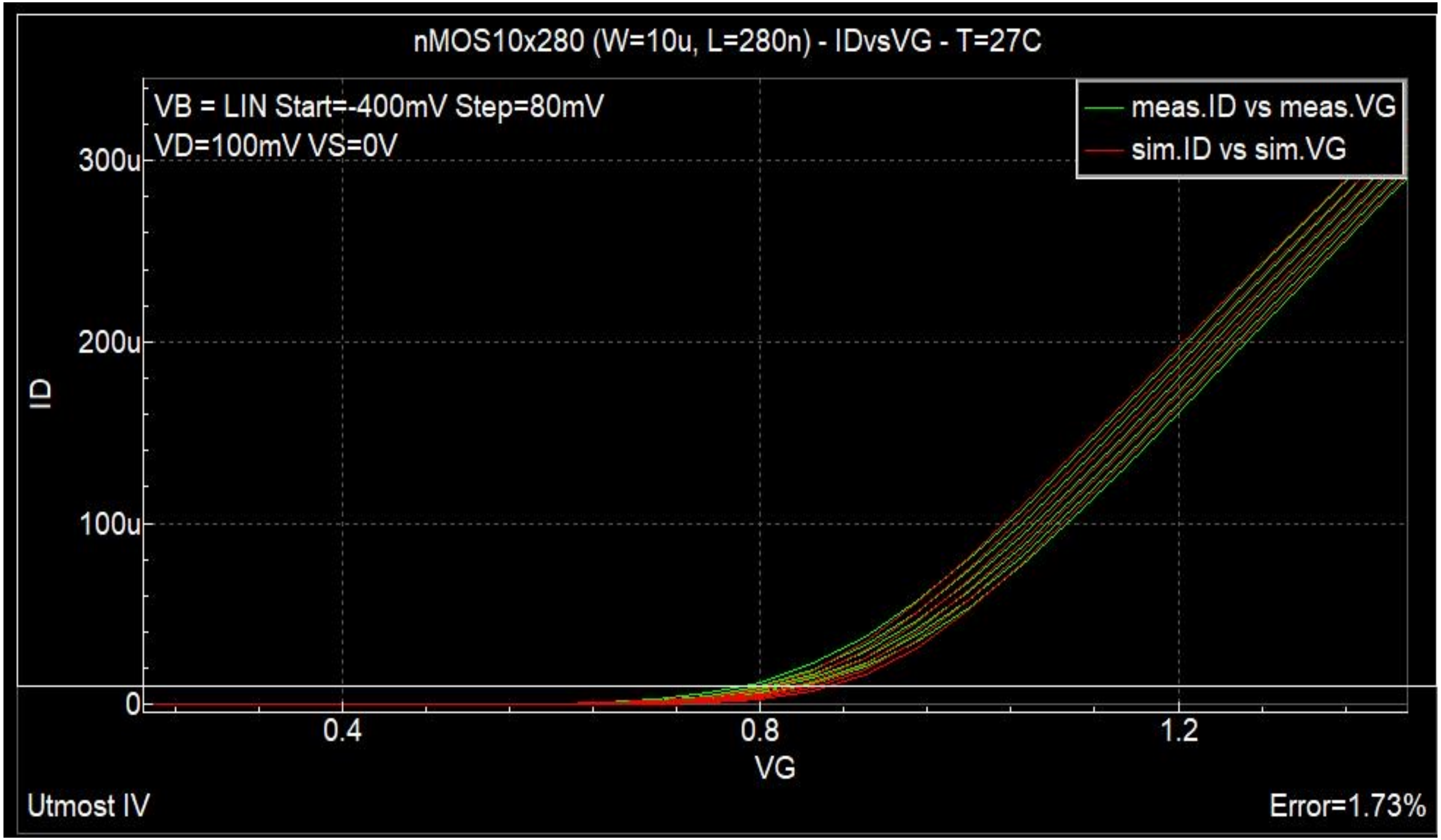
Example of Optimized Measurement at Room Temperature – Thick Oxide



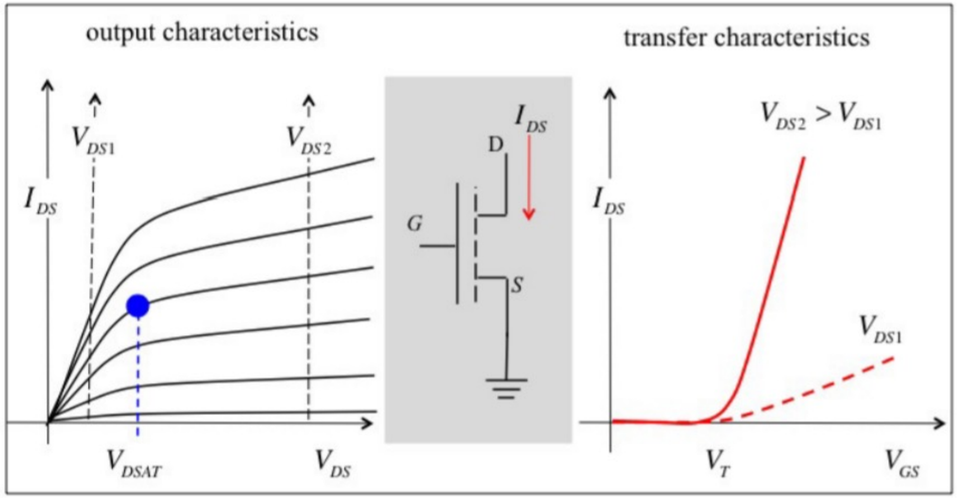
nMOS 10µ x 280n Input Characteristic

Measurement Performed at Low Temperature (Only Thick Oxide)

Type of Measurement:
- Input Characteristic
- Output Characteristic
- Weak Inversion Output Char.
- Strong Inversion Output Char.

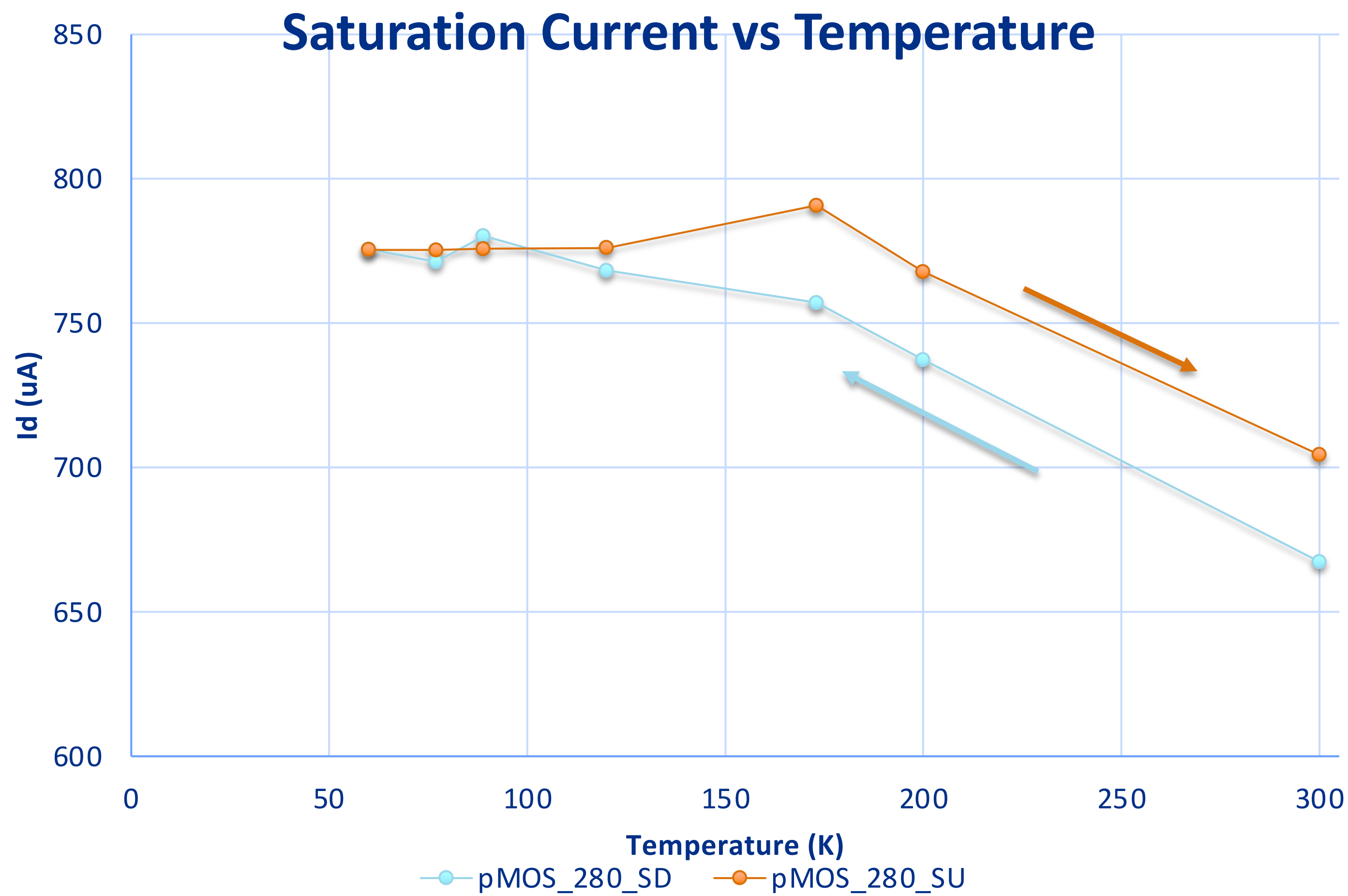
List of Device Tested:
- 65nm nMOS W/L (µm) = 10/0.28
- 65nm nMOS W/L (µm) = 10/0.36
- 65nm pMOS W/L (µm) = 10/0.28
- 65nm pMOS W/L (µm) = 10/0.36

Temperatures:
- 200K
- 173K
- 120K
- 87K – Liquid Argon
- 77K – Liquid Nitrogen
- 65K – Lowest Temp. Achievable

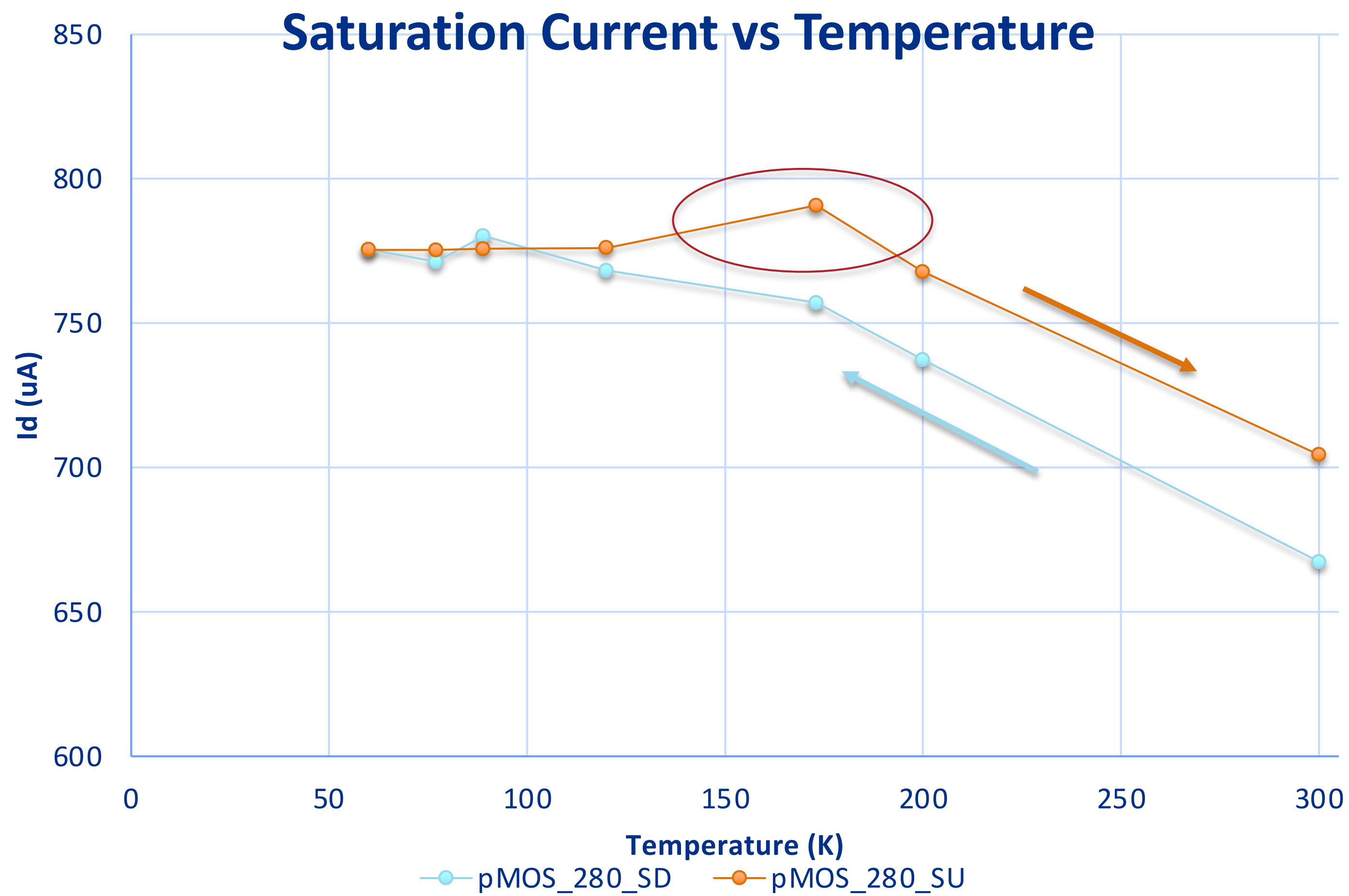


Procedure:
- Measurement taken while decreasing Temperature (Step-Down cycle)
- Measurement taken while increasing Temperature (Step-Up cycle)

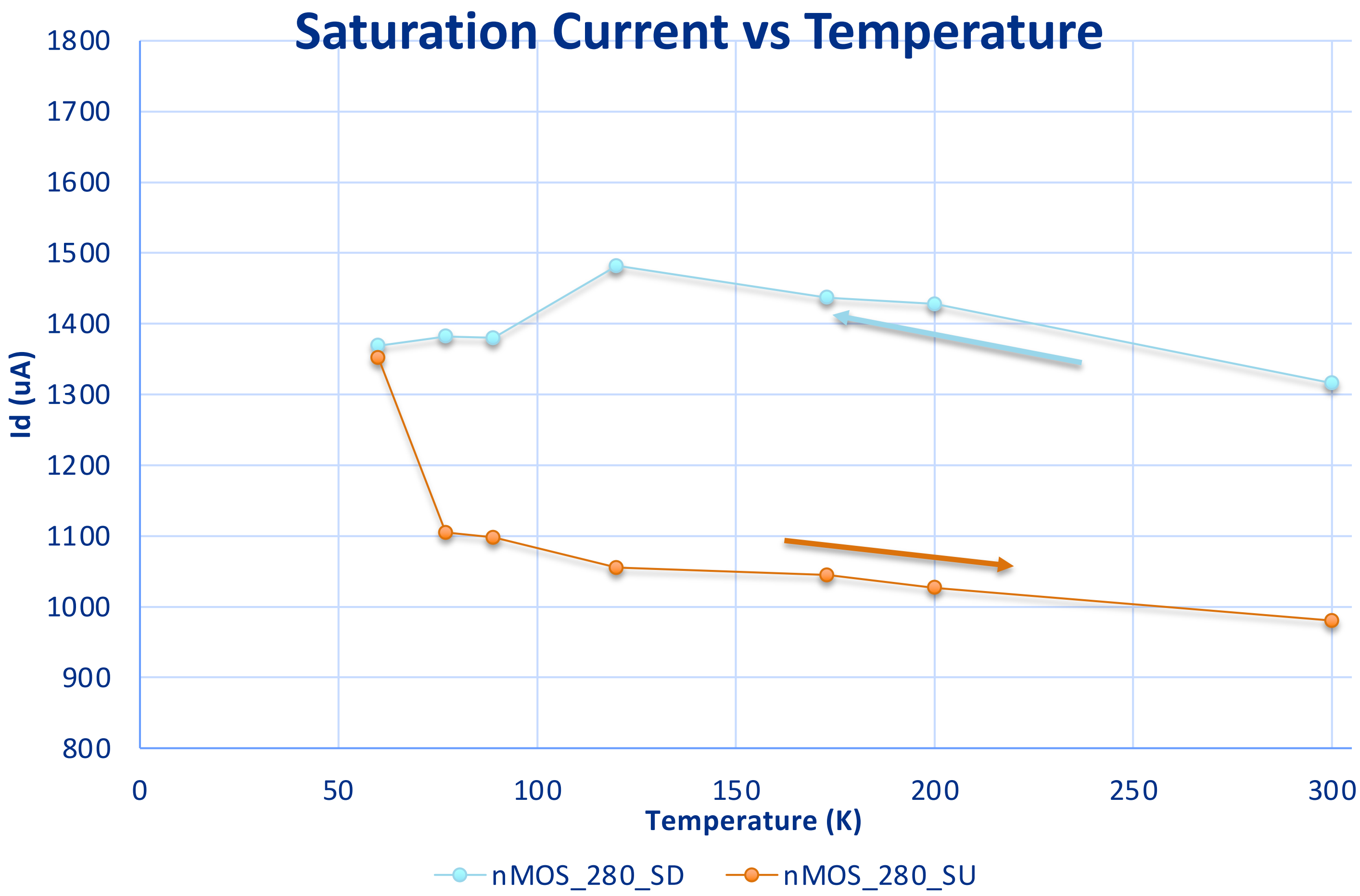
Results – Saturation Current Plot



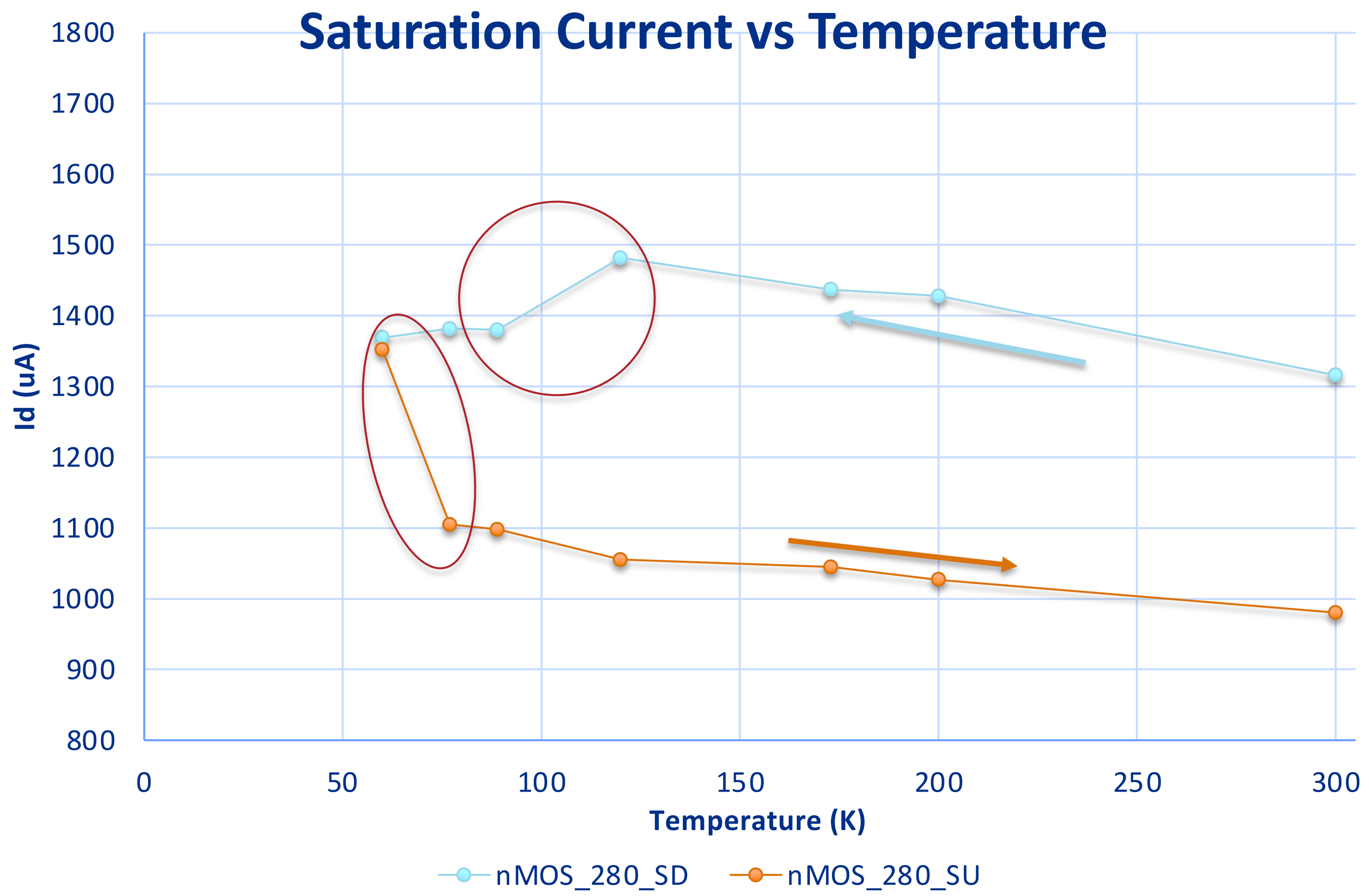
Results – Saturation Current Plot



Results – Saturation Current Graph:



Results – Saturation Current Plot



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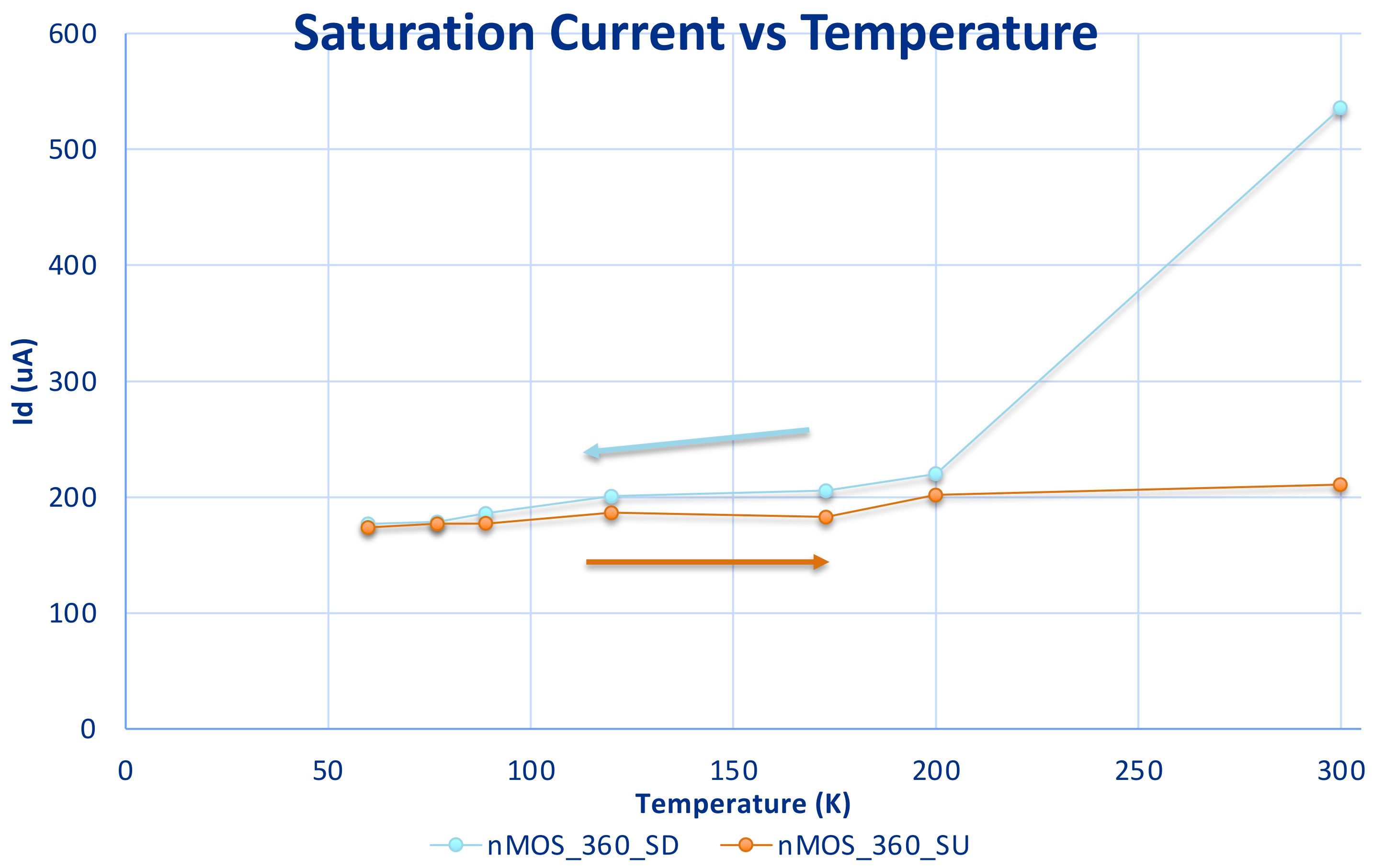
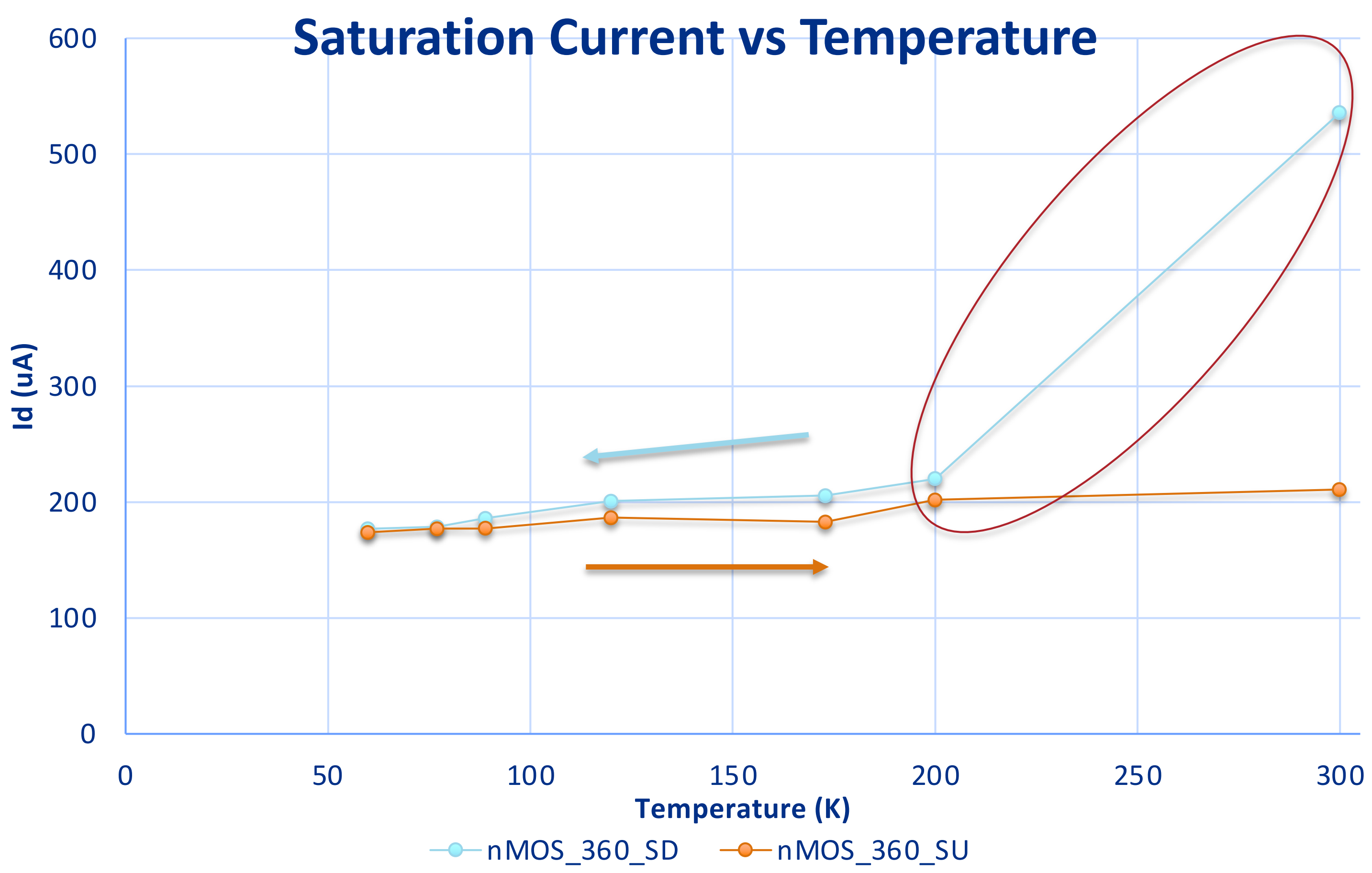
Results – Saturation Current Plot



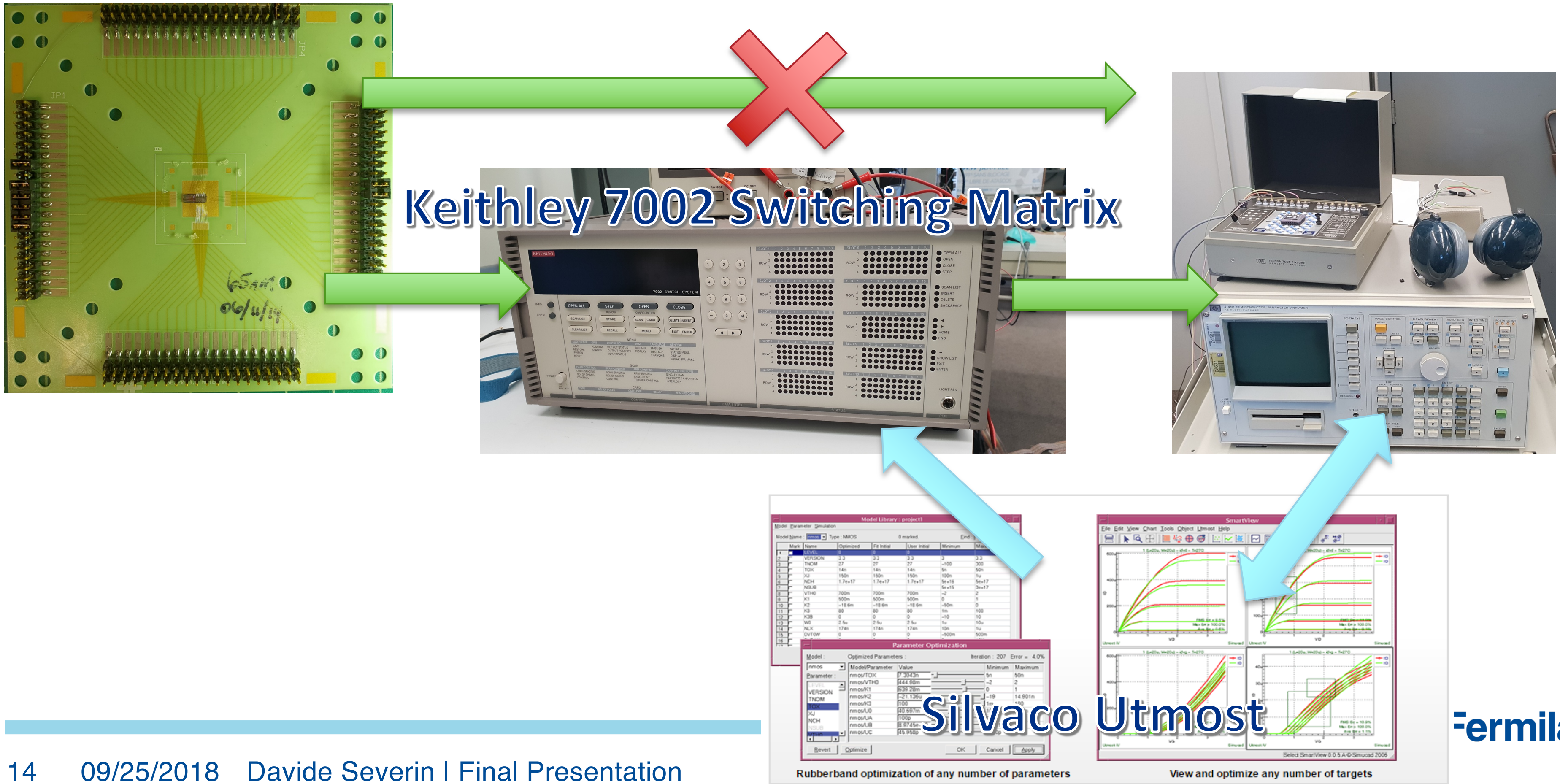
Results – Saturation Current Plot



Troubleshooting

Small technologies are very sensitive to ESD and mechanical damages

Manipulating cables is the main cause of damages



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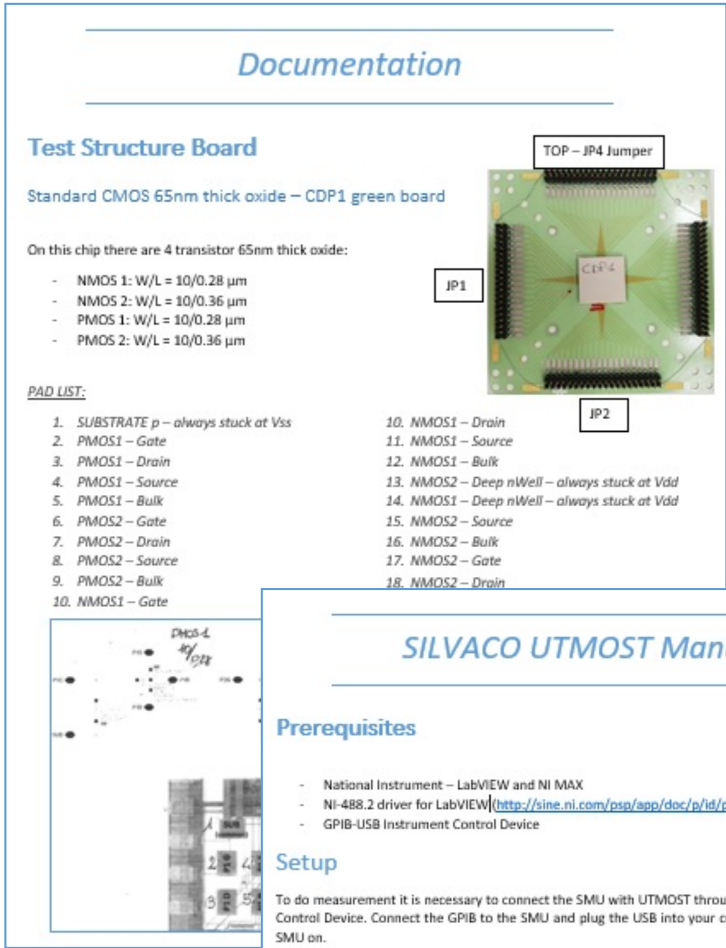
Documentation

- The measurement setup: performing measurement and instrumentation instruction

- Test structure boards report: boards layout

- UTMOST software manual: synthesis of UTMOST software configuration



Documentation

Test Structure Board

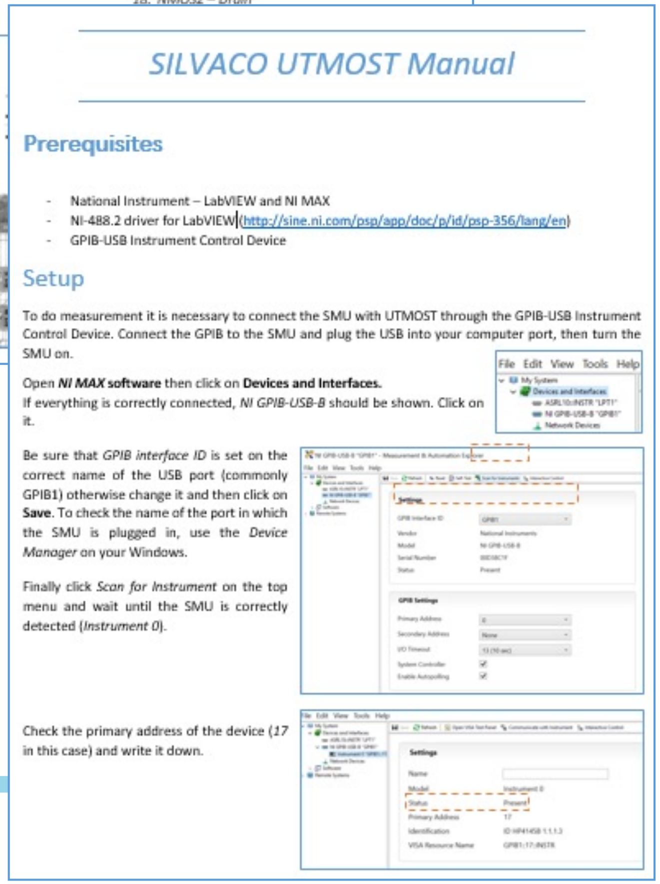
Standard CMOS 65nm thick oxide – CDP1 green board

On this chip there are 4 transistor 65nm thick oxide:

- NMOS 1: W/L = 10/0.28 µm
- NMOS 2: W/L = 10/0.36 µm
- PMOS 1: W/L = 10/0.28 µm
- PMOS 2: W/L = 10/0.36 µm

PAD LIST:

1. *SUBSTRATE p – always stuck at Vss*
2. *PMOS1 – Gate*
3. *PMOS1 – Drain*
4. *PMOS1 – Source*
5. *PMOS1 – Bulk*
6. *PMOS2 – Gate*
7. *PMOS2 – Drain*
8. *PMOS2 – Source*
9. *PMOS2 – Bulk*
10. *NMOS1 – Gate*
10. *NMOS1 – Drain*
11. *NMOS1 – Source*
12. *NMOS1 – Bulk*
13. *NMOS2 – Deep nWell – always stuck at Vdd*
14. *NMOS1 – Deep nWell – always stuck at Vdd*
15. *NMOS2 – Source*
16. *NMOS2 – Bulk*
17. *NMOS2 – Gate*
18. *NMOS2 – Drain*



SILVACO UTMOST Manual

Prerequisites

- National Instrument – LabVIEW and NI MAX
- NI-488.2 driver for LabVIEW (http://sine.ni.com/psp/app/doc/p/id/psp-356/lang/en)
- GPIB-USB Instrument Control Device

Setup

To do measurement it is necessary to connect the SMU with UTMOST through the GPIB-USB Instrument Control Device. Connect the GPIB to the SMU and plug the USB into your computer port, then turn the SMU on.

Open ***NI MAX* software** then click on **Devices and Interfaces.** If everything is correctly connected, *NI GPIB-USB-B* should be shown. Click on it.

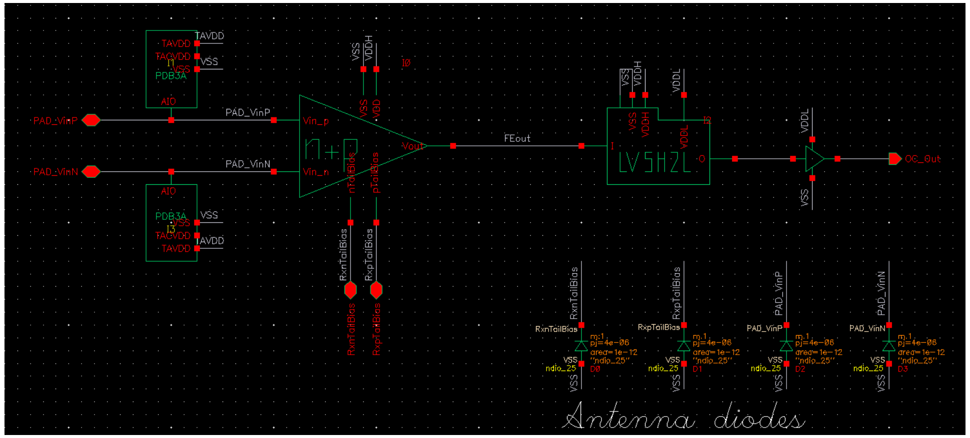
Be sure that *GPIB interface ID* is set on the correct name of the USB port (commonly GPIB1) otherwise change it and then click on **Save**. To check the name of the port in which the SMU is plugged in, use the *Device Manager* on your Windows.

Finally click *Scan for Instrument* on the top menu and wait until the SMU is correctly detected (*Instrument 0*).

Check the primary address of the device (*17* in this case) and write it down.

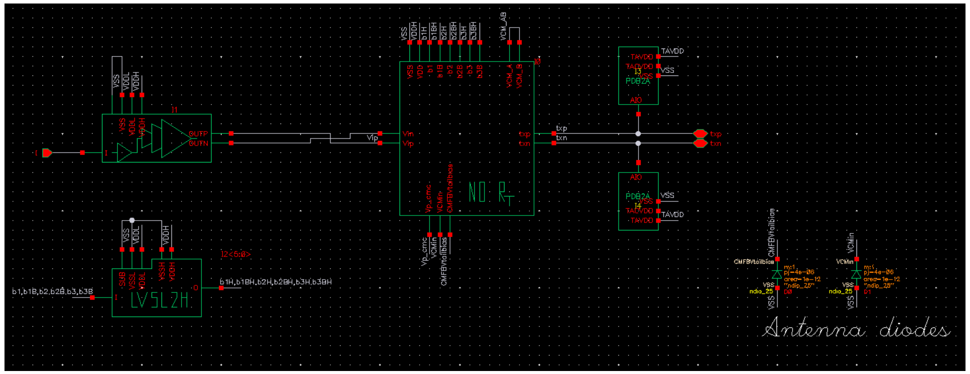
2) Preparing a LVDS prototype circuit to be tested at room and liquid argon temperature

LVDS (Low-Voltage Differential Signaling) is a technical standard protocol of serial communication with differential signals both in input and in output



Receiver:

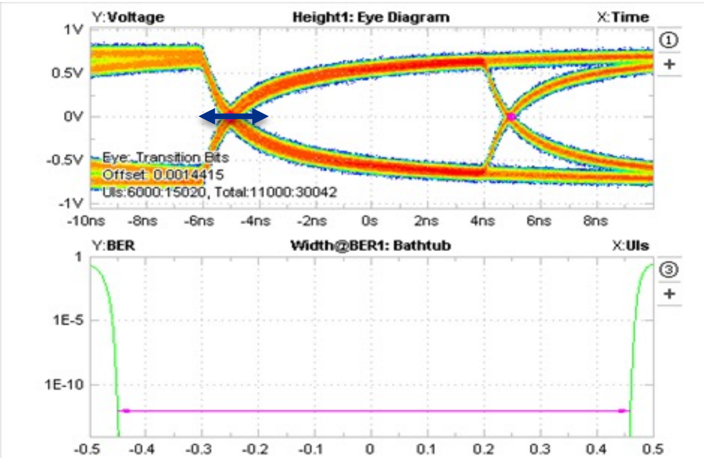
- Input voltage : 2.5V to 1.8V
- Input diff. voltage: from ±100mV
- Output voltage: 1.2V (to the TX)

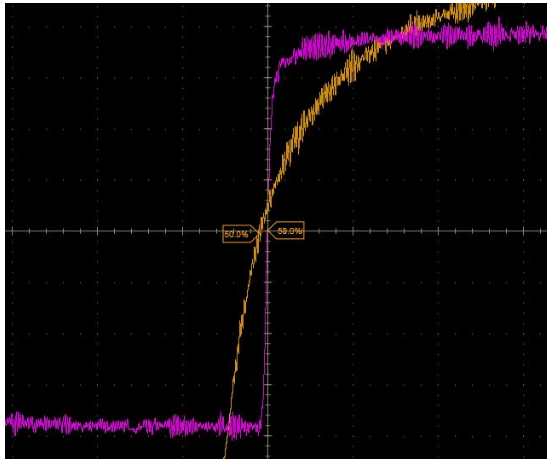


Transmitter:

- Input voltage: 1.2V (from the RX)
- Output voltage: 2.5V to 1.8V
- Programmable output current for driving long cables: ±2mA, ± 4mA, ± 6mA, ± 8mA

Type of Measurement and Instrumentation





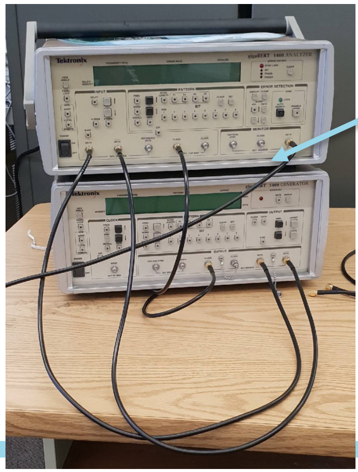
Type of Measurement

- Eye-Diagram
- Jitter
- BER
- Delay

Temperature:
- 300K
- 87 K

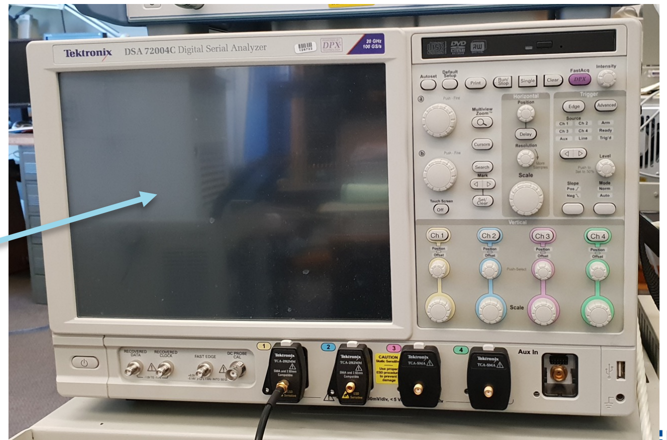
Speed:
- 128 MHz
- 1 GHz

Supply Voltage:
- 2.5 V (nominal)
- Minimum one



TekTronic 1400 Mb/s Bit Error Rate Tester Generator and Analyzer

TekTronic DSA 72004C Digital Serial Analyzer



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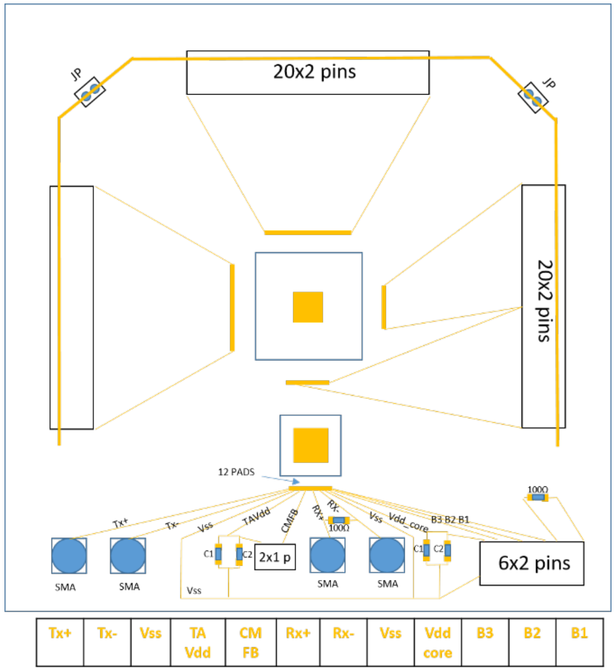
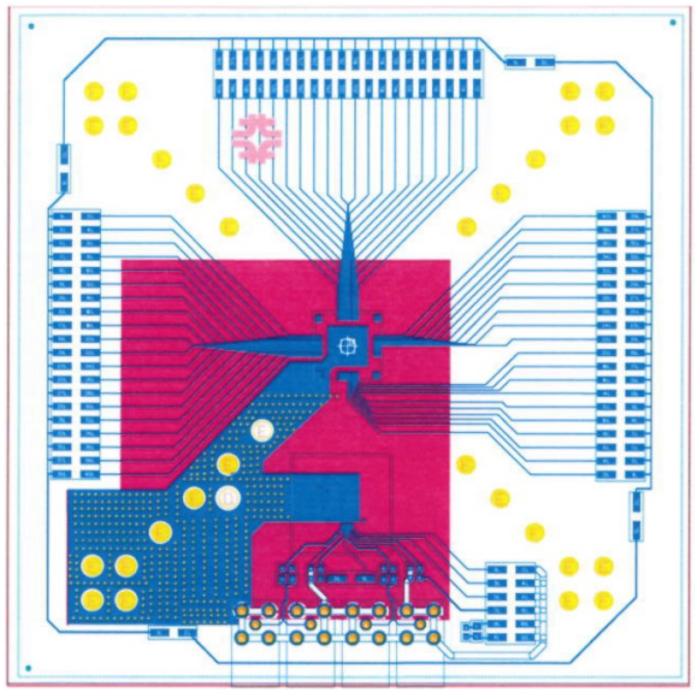
Designing and realizing the test structure board



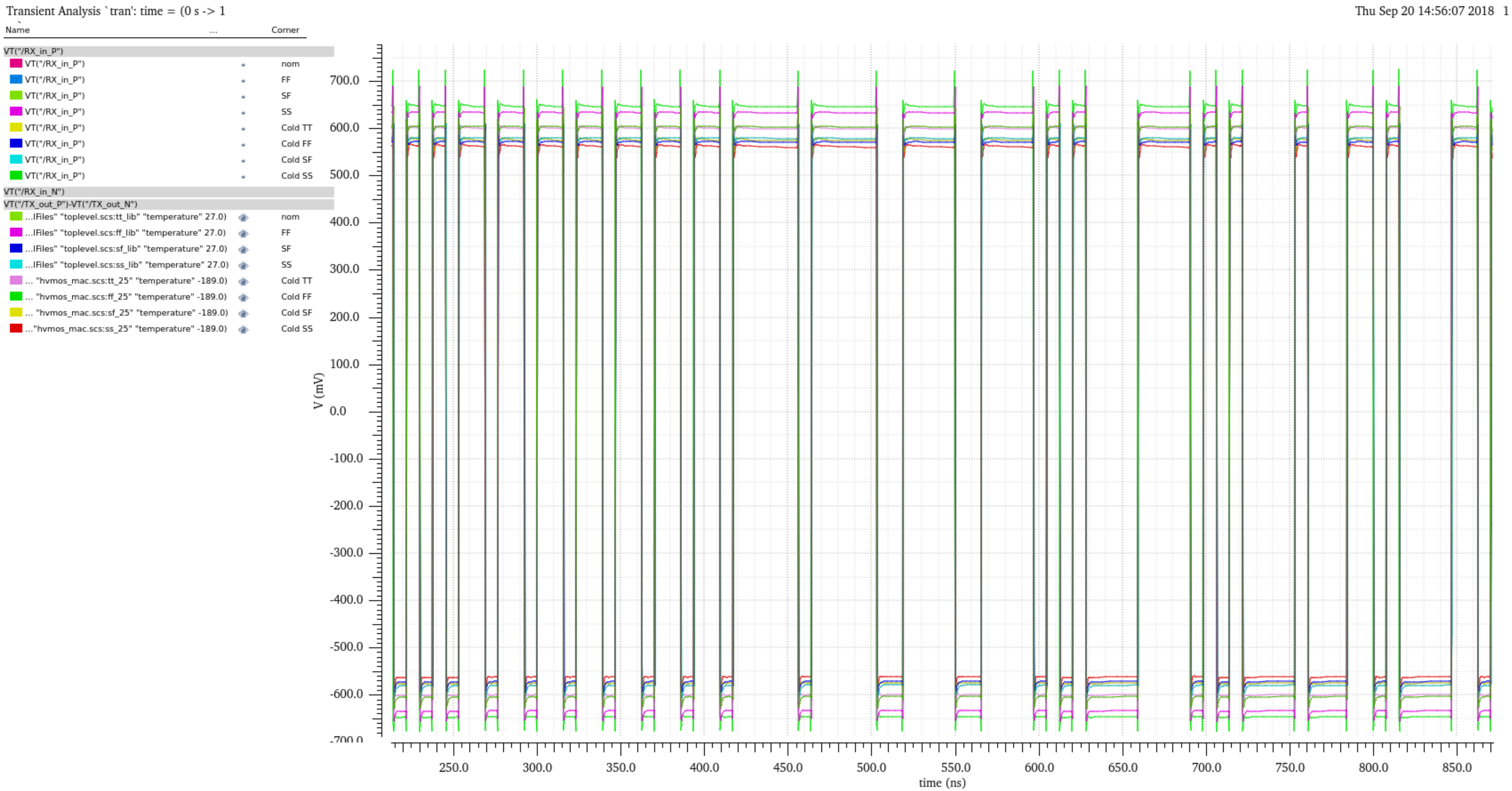
- Wire-bonding pads and connector pins
- 100Ohm resistor between the input of the receiver
- Test resistor to measure thermal variation
- SMA connectors
- Power supply by-pass capacitances



- Holes consistent with the cryostat grid
- General purpose
- Copper plates to make the temperature distribution more uniform

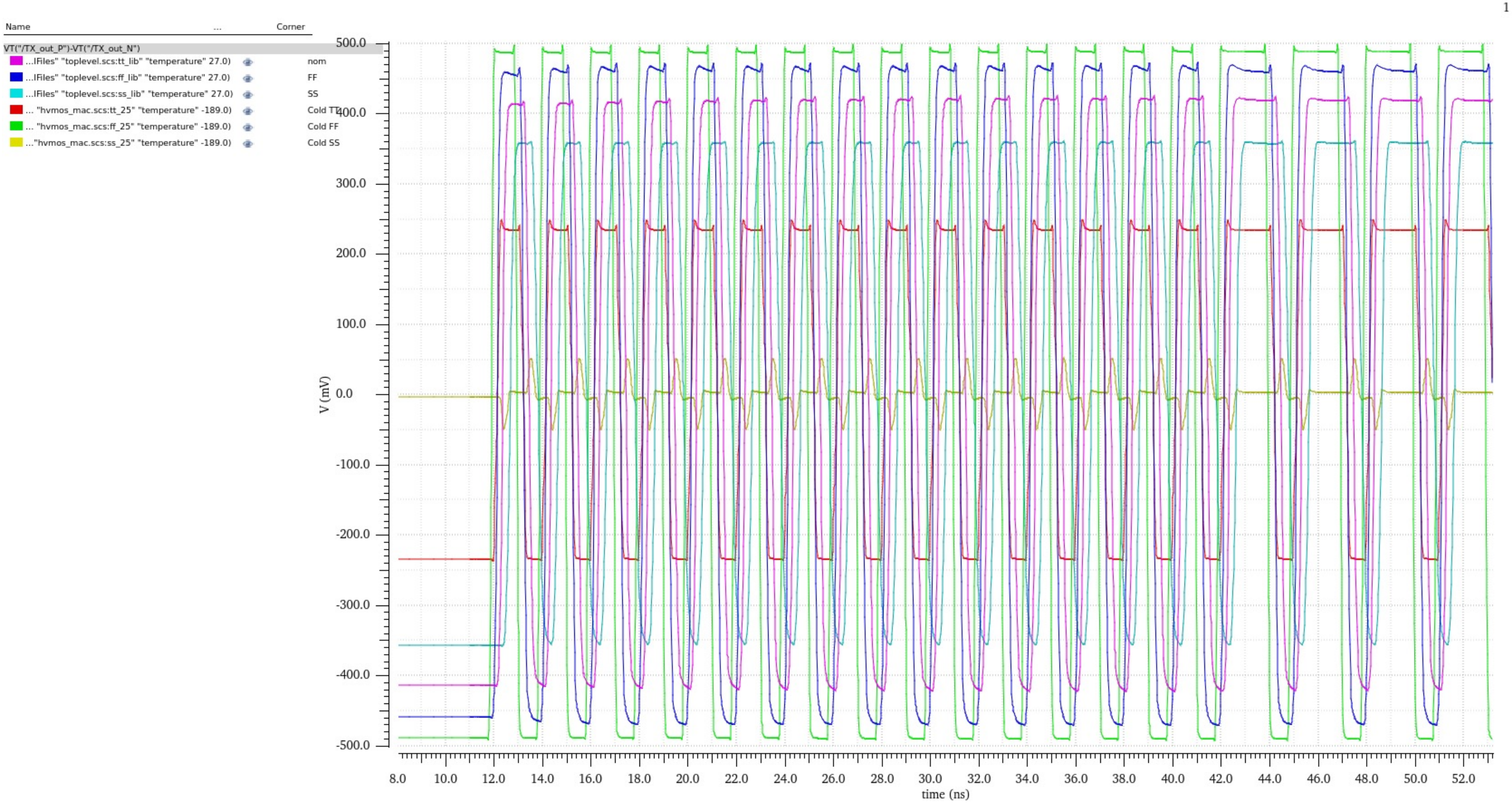
Simulations – Differential Output

128MHz, 300K and 84K, Different Corner, 2.5V HVDD, 1.2V VDD



Simulations – Differential Output

1GHz, 300K and 84K, Different Corner, 1.5V HVDD, 1.1V VDD



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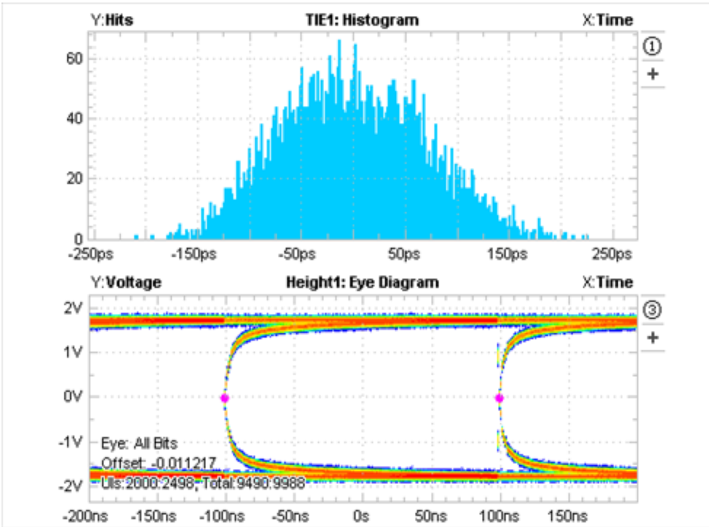
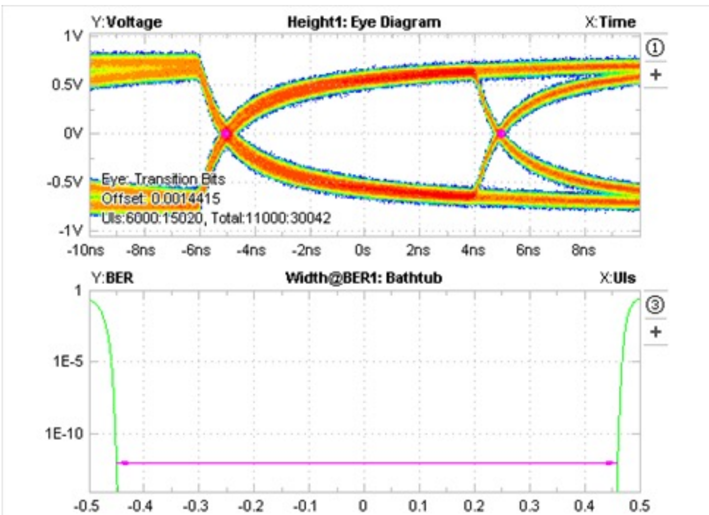
Cable Measurements at Room Temperature



25m Samtec Cable – 50 MHz (200ns)

- BER < $1x10^{-12}$
- Total Jitter p-p = 630 ps
- Delay ≈ 200 ps



25m Samtec Cable – 100 MHz (100ns)

- BER < $1x10^{-11}$
- Total Jitter p-p = 830 ps
- Delay ≈ 200 ps

Future Plans

- Prepare and test the board
- Perform BER, Jitter and Delay measurement

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Thanks for the attention