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Aggiornamento attività UR Milano
Relazione Scientifica

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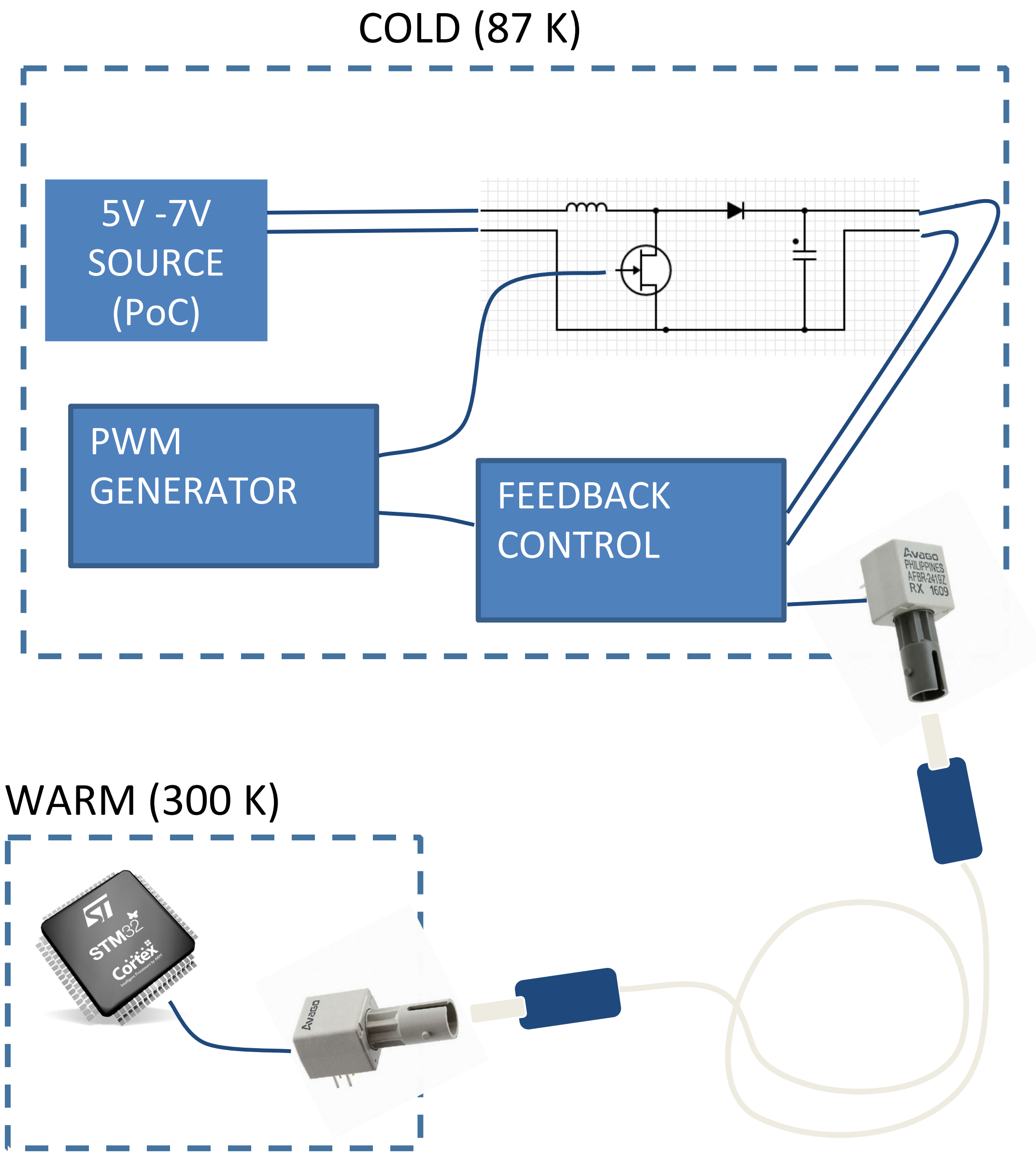
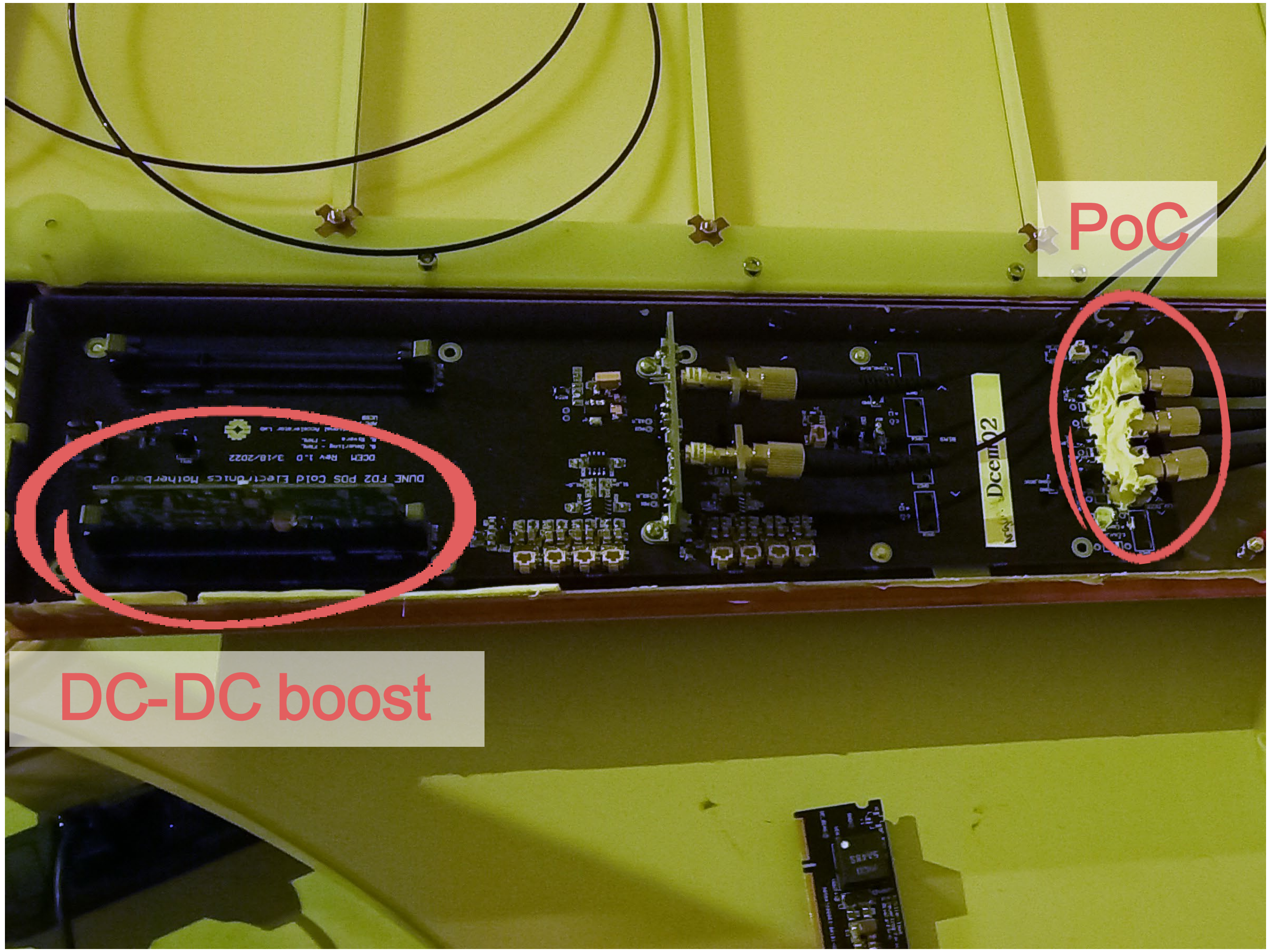
System overview

- DC-DC boost converter: HV for SiPM bias at cold
- Evolution in relation to DUNE collaboration needs
- **Power supply provided by PoC** (Power optical Converter): 5 V to 7 V range
- **Typical boost topology with MOS** transistor: output voltage up to 50 V
- **PWM generation** with two possible controls:
  - Inner feedback setting output voltage at nominal point (e.g. 48 V)
  - Optical input to change the setting voltage within few volts



Content

- GaAs Power optical Converter (PoC)
- DC-DC boost design
  - Component characterization
  - Performance
- Control design
- OpAmp characterization
- Conclusions



GaAs PoC

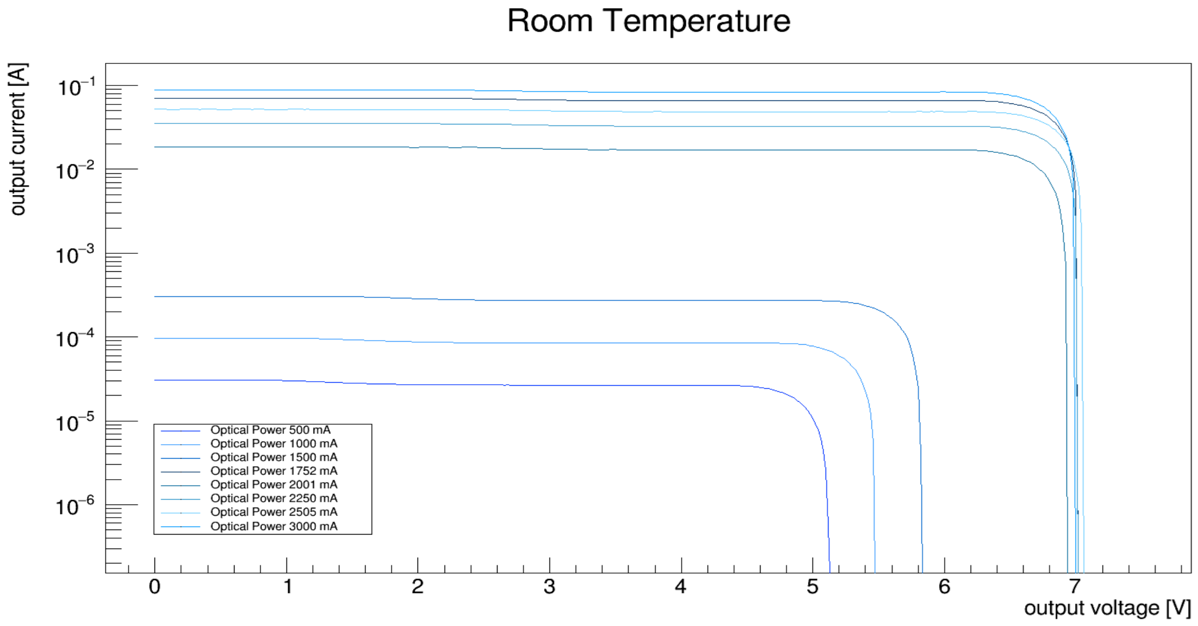
5 V to 7 V range power supply from PoC:

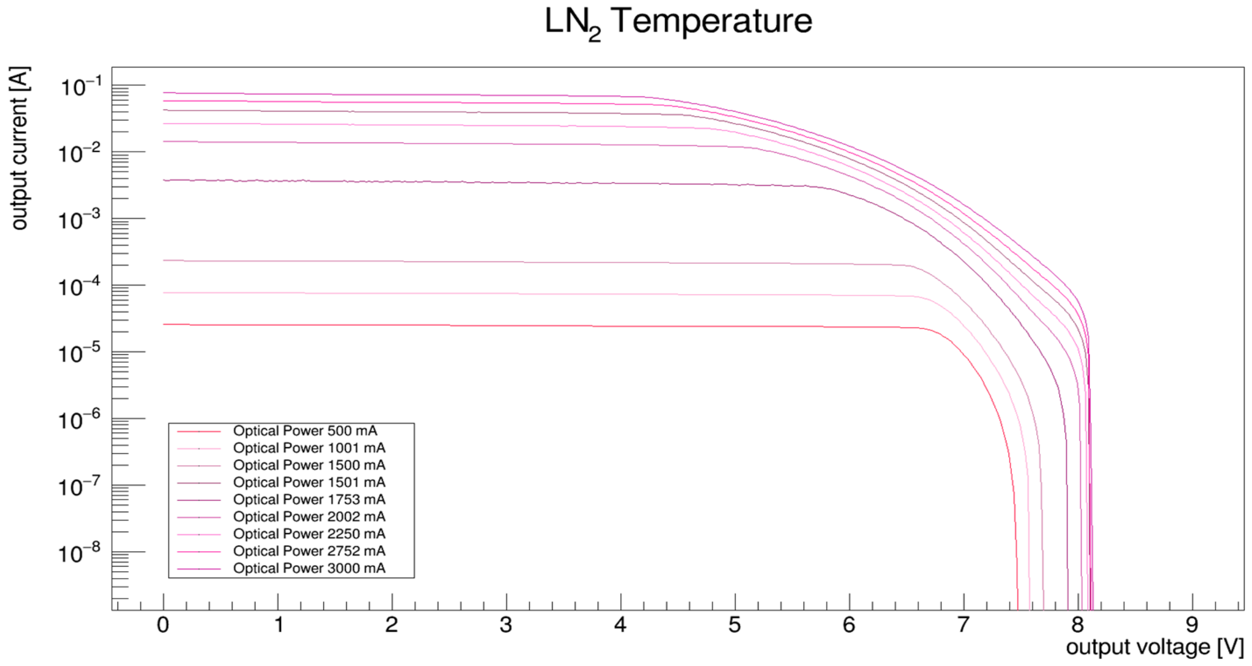
- Tests with **Broadcom AFBR-406L** based on GaAs technology
- Powered by **808 nm Lumics laser** (8 W max)
- **Multimode 200 μm** core fiber
- **B1505A Semiconductor Analyzer** to fix the output voltage and **measure the current**
- RTD sensor used for PoC temperature check

GaAs PoC

5 V to 7 V range power supply from PoC:

- **Curves labeled** according to **laser input current** ($P_{opt} \propto I$)
- Reference: 3 A →1.5 W_{opt}
- Measurements both at RoomT and at LN_2 temperature
- Voltage increases **from 7 V to 8 V** (at 3000 mA) between Room and LN_2 temperature



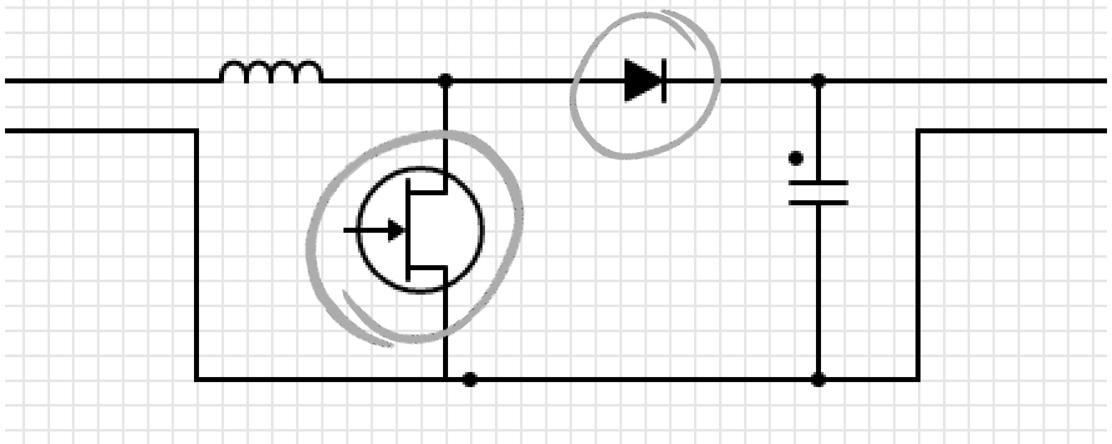


DC characterization of MOSFET and diode

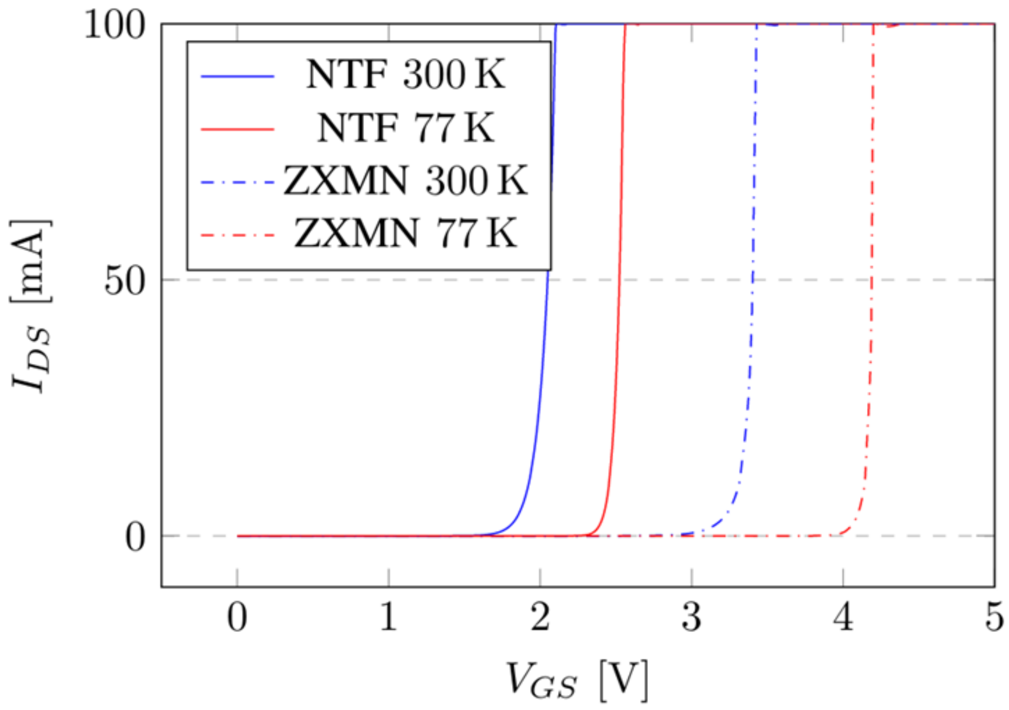
MOSFETs characterized at Room and at LN2 temperature with a B1505A Semiconductor Analyzer:

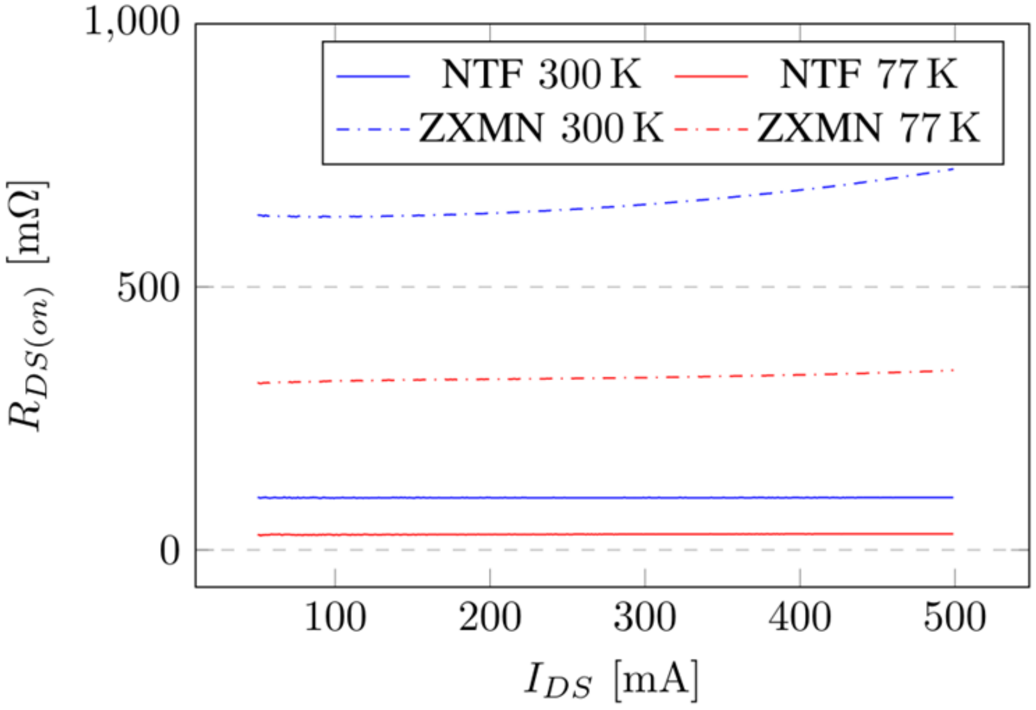
- I_D vs V_{GS} (at various V_{DS}) to measure the **threshold**
- V_{DS} vs I_D (at various V_{GS}) to measure the **on resistance $R_{DS(on)}$**

Diode forward I-V curve to measure the **junction voltage V_D**



MOSFET results

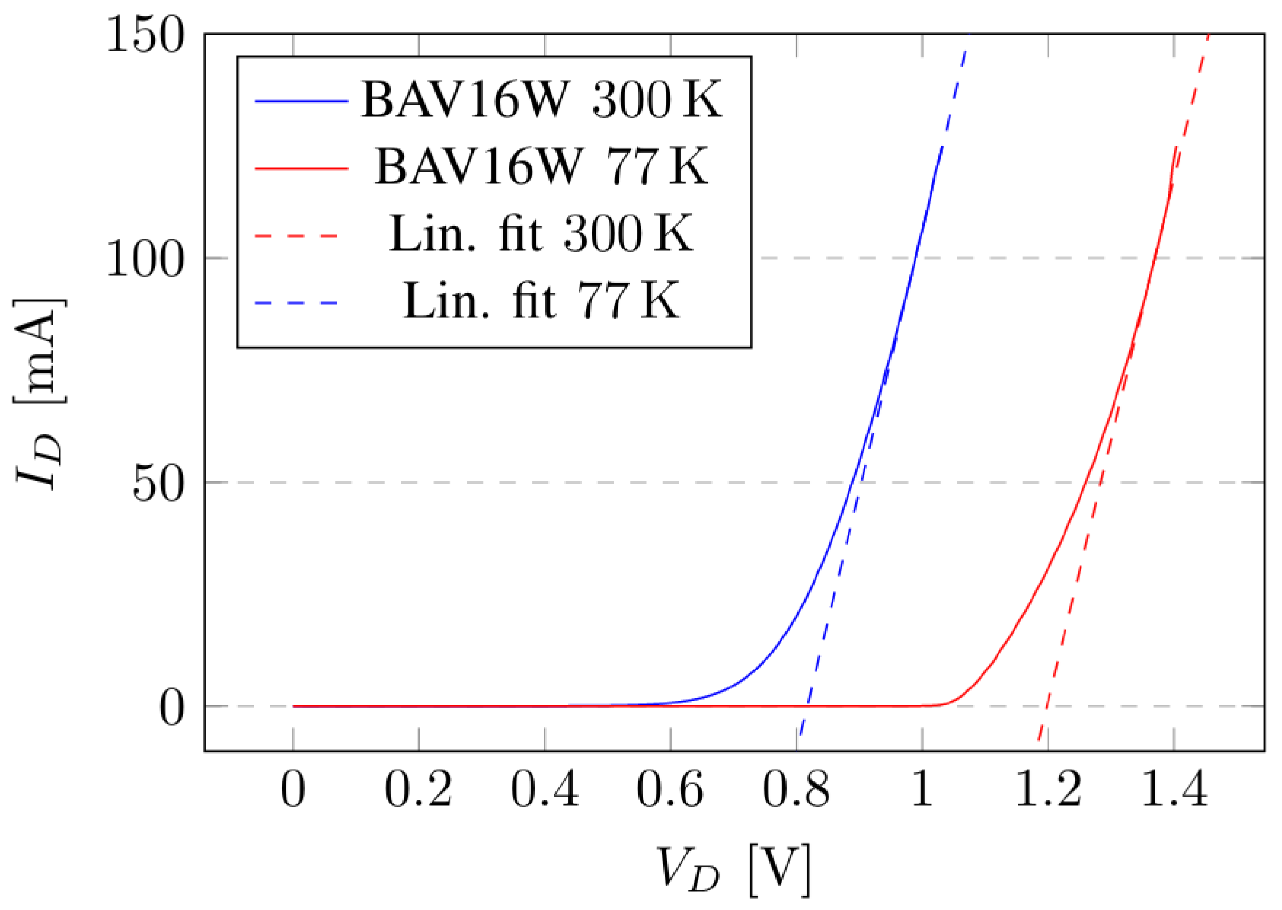




- Drain current vs Gate-to-Source voltage: **threshold increases** of about **0.6 V** (77 K)
- **On resistance reduces** considerably at 77 K, for NTF resulting in 30 mΩ.

Diode results

- Diode current vs applied voltage (forward bias mode): **junction voltage increase** of about **0.4 V**
- Same behavior between BAV16W and BAS16LD diodes

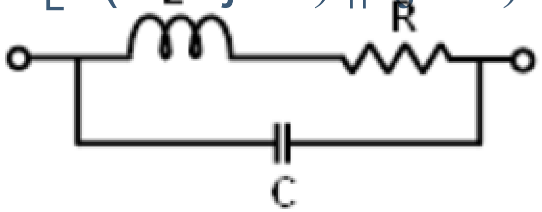


AC characterization of inductor

- *Tests on B8244T1106K050*10 mH inductor
- HP 4395A Impedance Analyzerused in Reflection mode to analyze the impedance as a function of frequency

Model:

$$Z_L=(R_L+ j\omega L) \,||\, (j\omega C)^{-1}$$



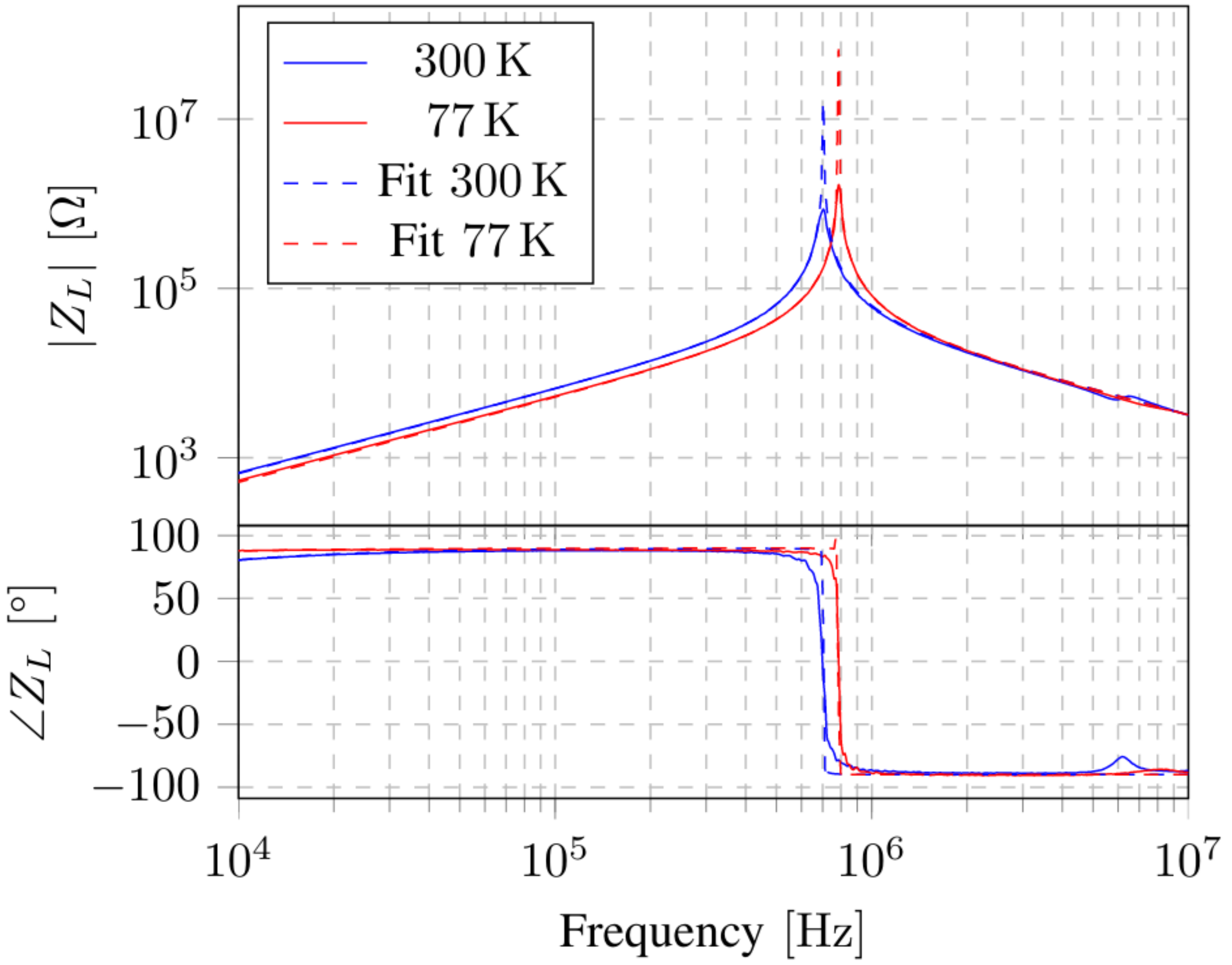
- Results fitted and parameters extracted

Inductor results

- Fitted parameters are:

T [K]	R [Ω]	L [mH]	C [pF]
300 K	106	10	5
77 K	20	8	5

- Resonance frequency is 700 kHz (**800 kHz**) at 300 K (**77 K**): good at f_{SW} = 100 kHz
- Series resistance drops drastically at 77 K: DC-DC converter better performances



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DC-DC boost converter

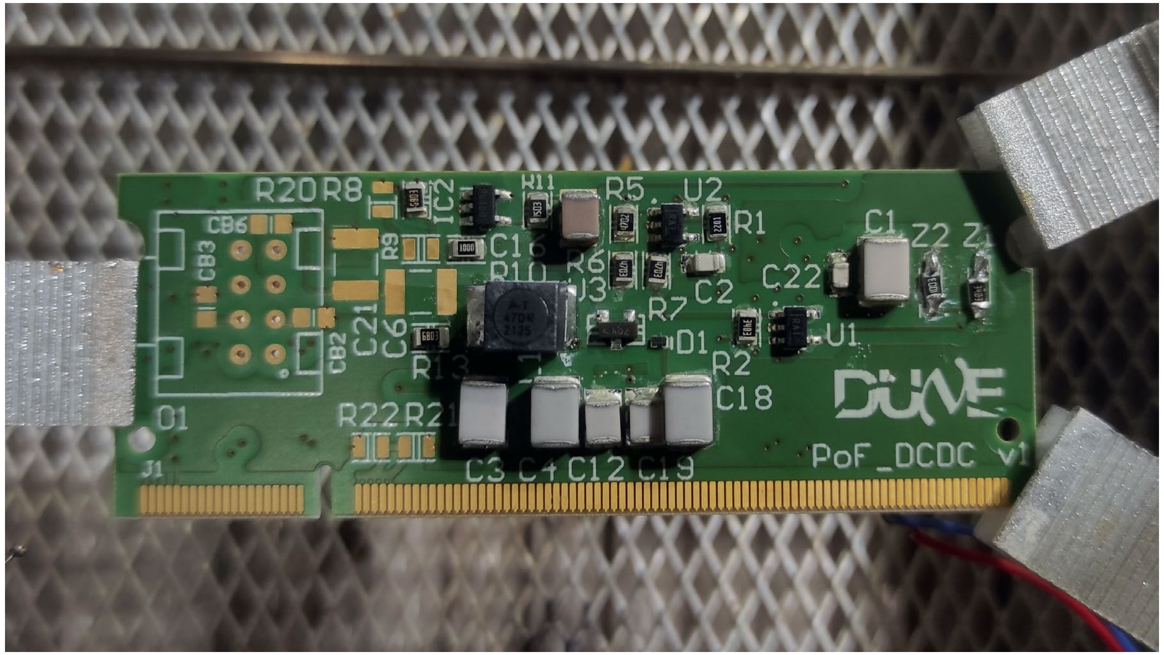
Components selection:

- MOSFET: ***NTF3055L108T1G***, *ZXMN10A07FTA, VN2460N8, 2N7002H6327XTSA2, 2N7002CK*
  - *Lowest on-resistance*
- Switching Diode: ***BAV16W***, *BAS16LD*
  - *Very similar device, slightly better max current*
- Inductor: *B82442T1125K000 (680uH, 1 MHz), B8244T1106K050 (10mH, 100 kHz)*
  - *Good to mitigate input current ripple*
- Capacitor: ***C1812C104J1GACTU (C0G 100 nF)***
  - *C0G for cryogenic use*

N. Gallice et al., "Development of a cryogenic DC-DC Boost Converter: devices characterization and first prototype measurements," 2022 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), Ottawa, ON, Canada, 2022, pp. 1-6, doi: 10.1109/I2MTC48687.2022.9806646.

DC-DC boost first prototype

- **DC input** provided by **linear supply**
- **Control signal** produced by **Pattern Generator**
- System tested at room and LN2 temperature with different inputs (4 V, 5 V) and different duty cycles [0.1, 0.93]



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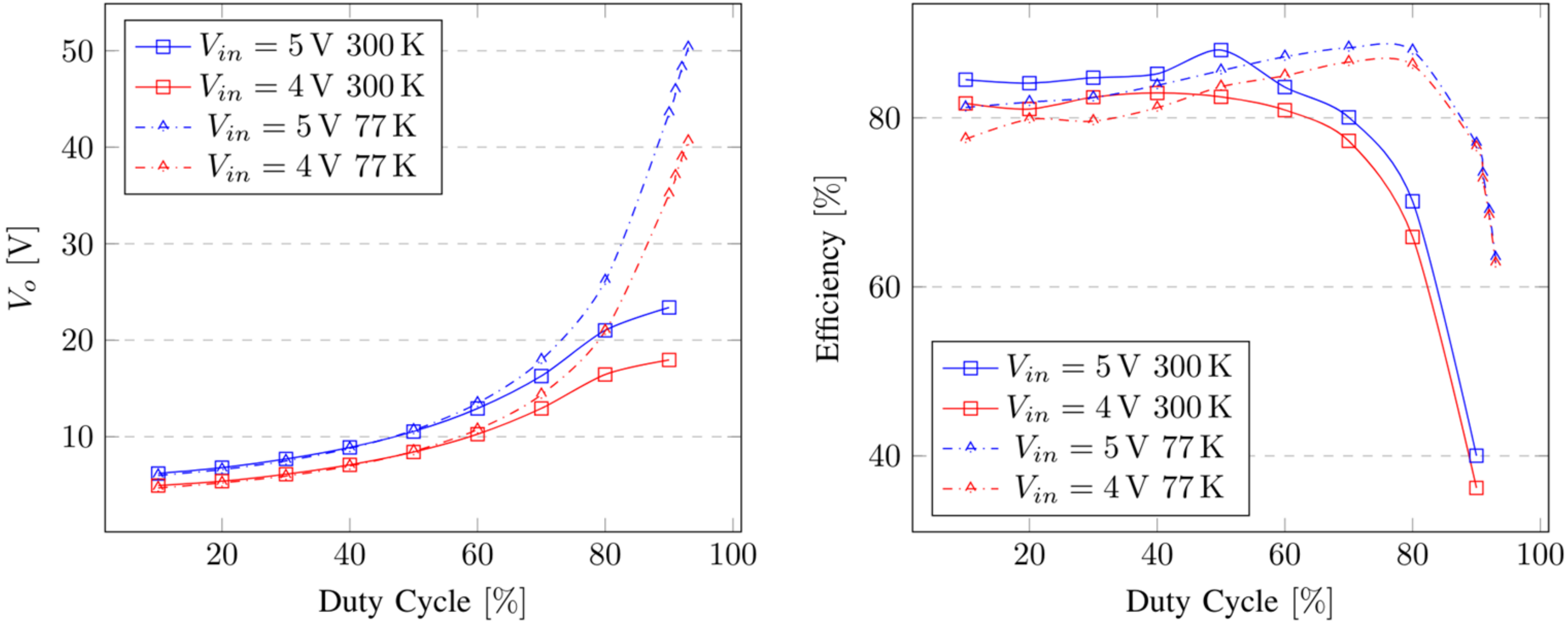
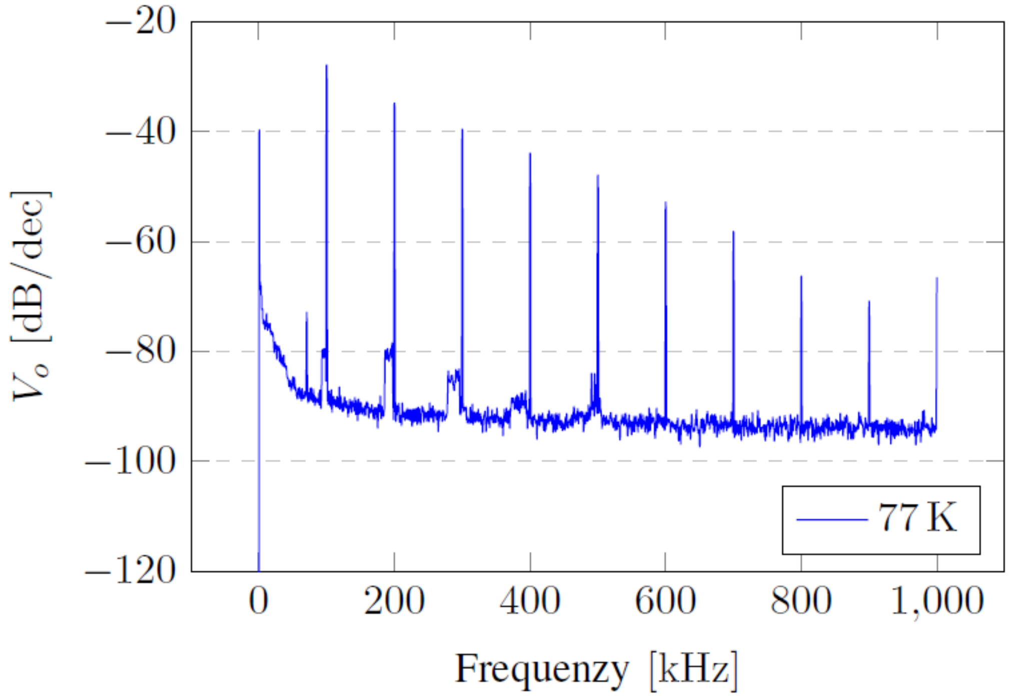
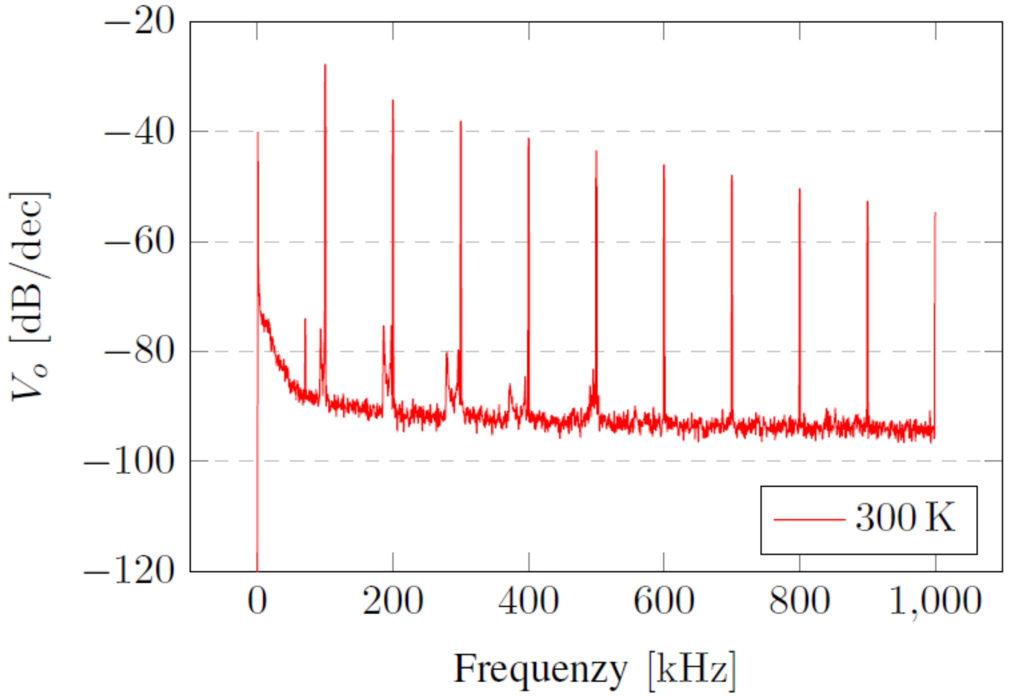
DC-DC prototype results



- **Output voltage** at RoomT limited by the inductor series resistor. At LN2 T, it is possible to reach 50 V at 93% of Duty Cycle
- The **efficiency at LN2** is always **greater than 60%**

DC-DC prototype results





- Output voltage FFT measurements at 77K (blue) and 300K (red)

Content

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  - Performance ✓
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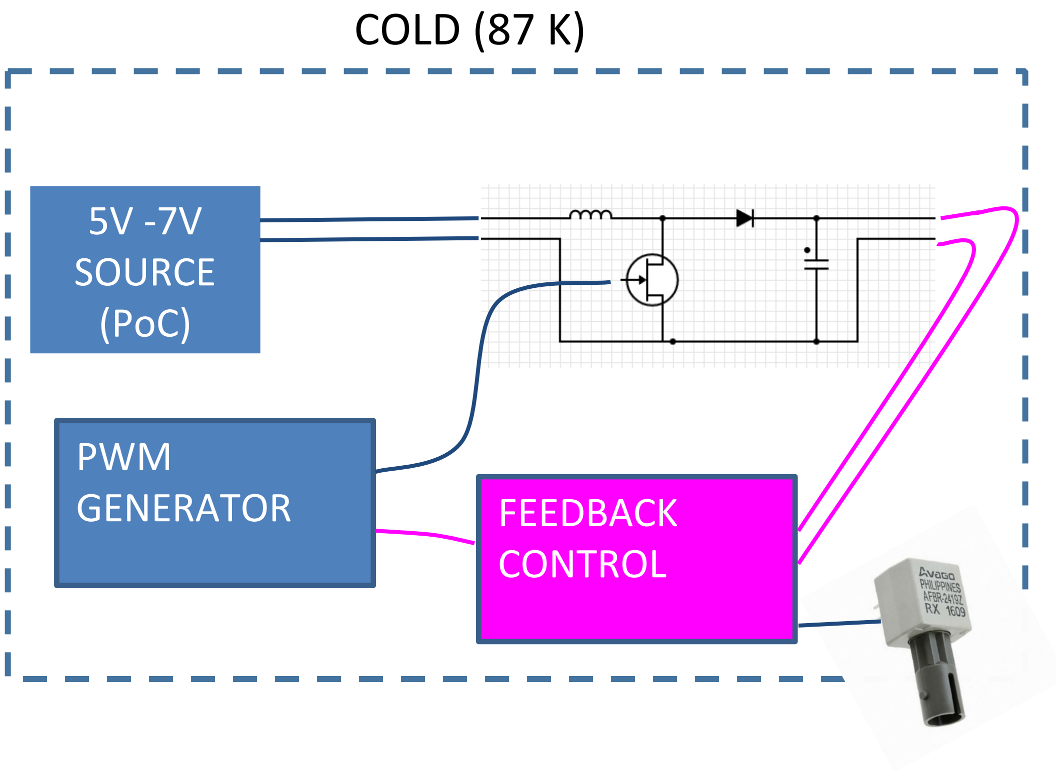
Control design

Internal feedback: output voltage control at desired set point

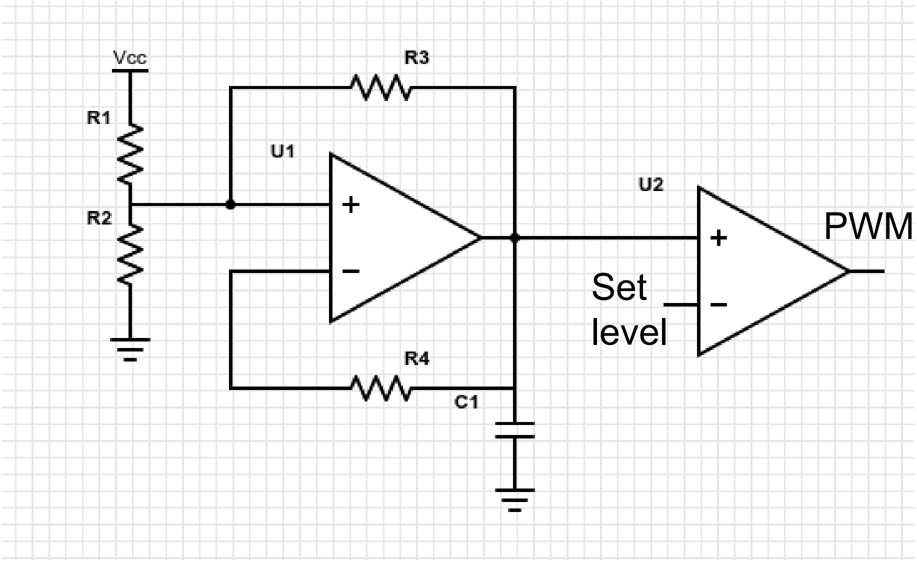
The **set point** can be:

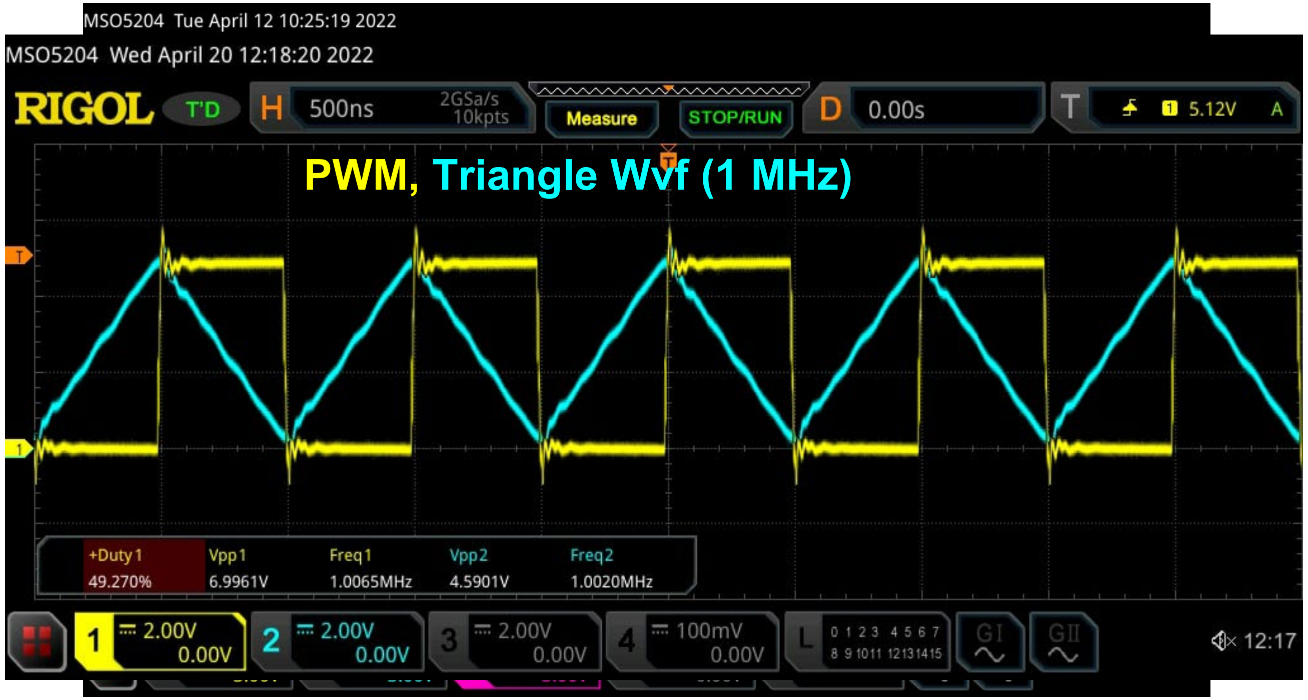
- **Nominal**: set at design stage and fixed throughout the entire run (standalone mode)
- **External**: set point adjusted through external communication (in case of failure, nominal set-point)



PWM generation

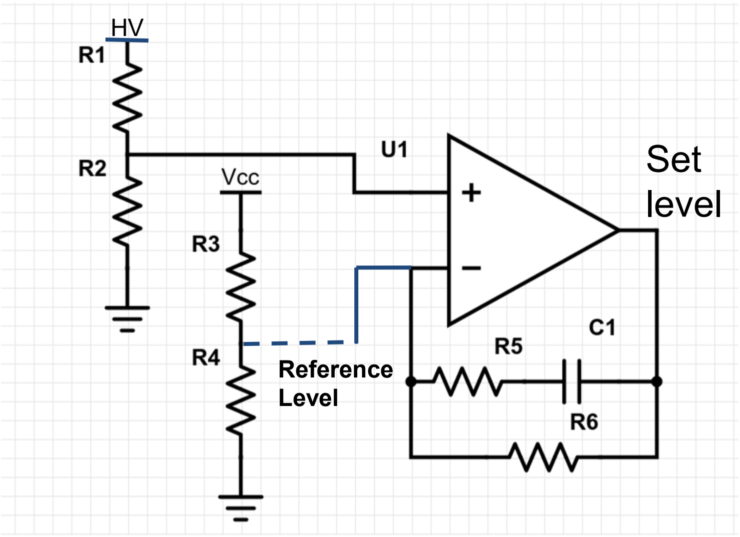
- **PWM (Pulse Width Modulator) generation** based on **two comparators**
- Comparators tested to work in LN_2
- **First comparator** set in a positive feedback circuit: oscillator
- **Second comparator** produces the PWM through **triangle waveform (carrier) and voltage set level (modulation)** inputs
- Tests at f_{SW} from ~100 kHz to ~1 MHz

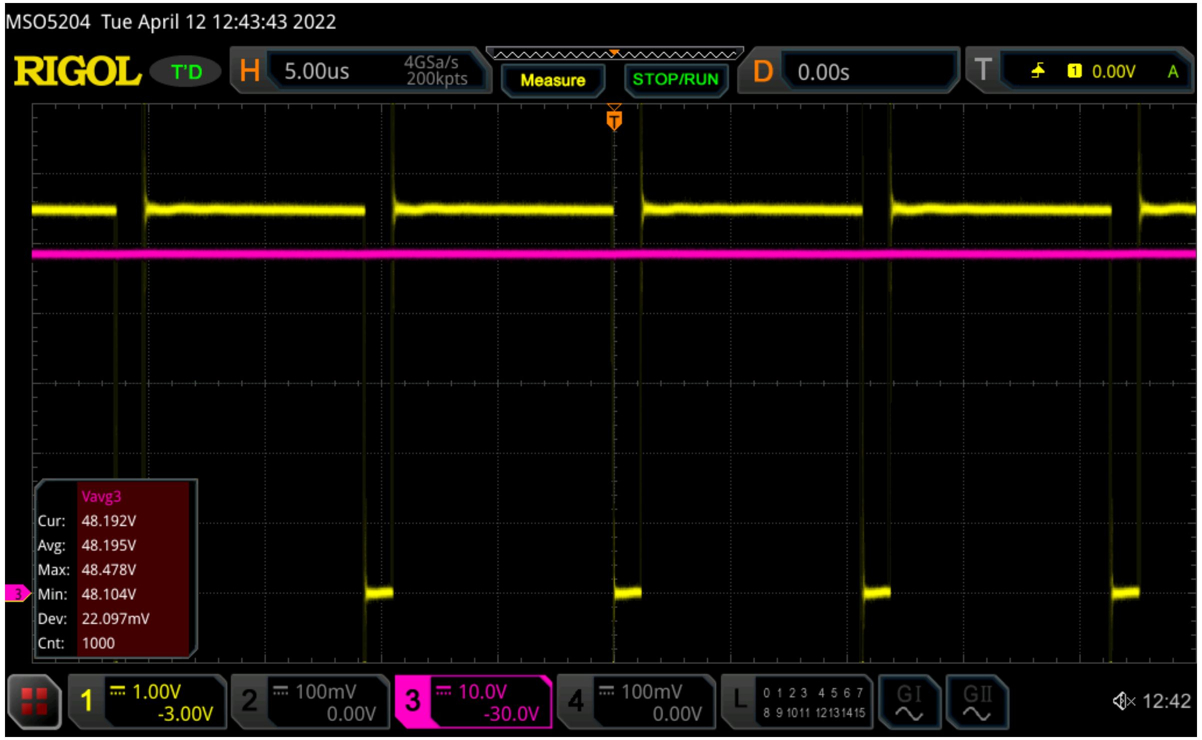




Control feedback

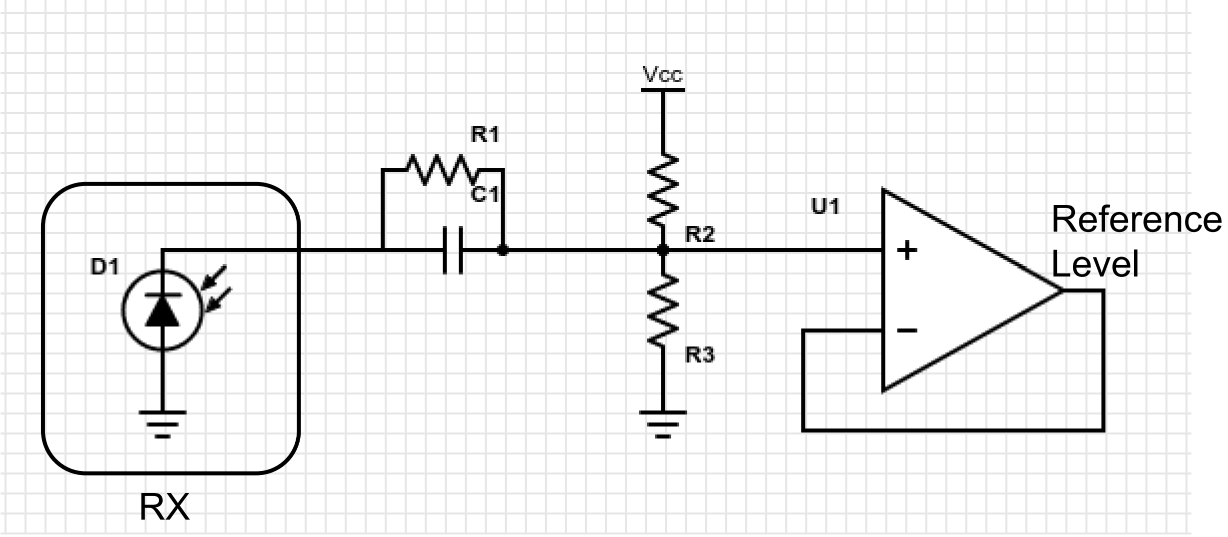
- **Output of DC-DC** boost converter **compared with nominal** working point (error amplifier)
- Operational amplifier tested to work in LN_2
- **48.2 V** generated and kept constant by the internal feedback at LN_2 temperature (5.5 V input)
- 100 kΩ load → 485 μA
- Overall current consumption: 10.3 mA ~ 50% efficiency

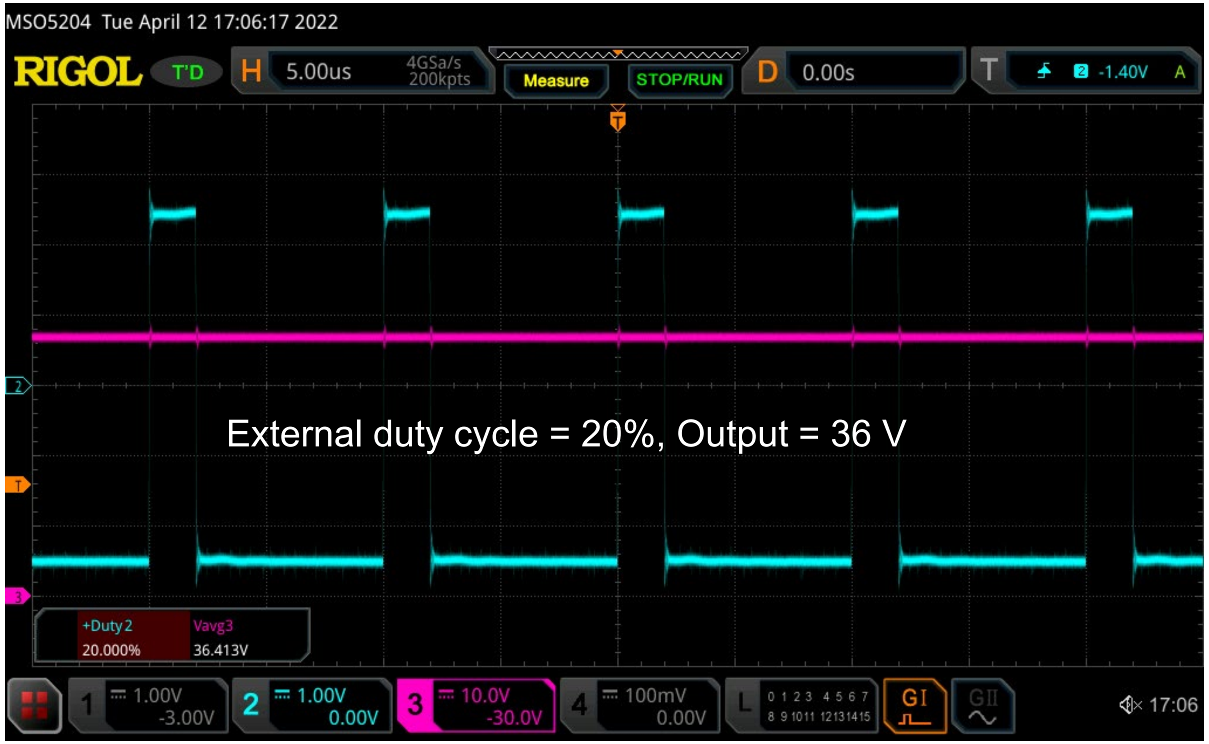




External set point

- External PWM signal drove through optical fiber: **external set point**
- Reference level changes
- AC-coupling in case of external PWM, otherwise reference set by R2-R3 divider
- E.g. with f_{SW} ~100 kHz, 5.5 V input, 20 % external duty-cycle: boost voltage output ~ 36 V (max = 51 V)





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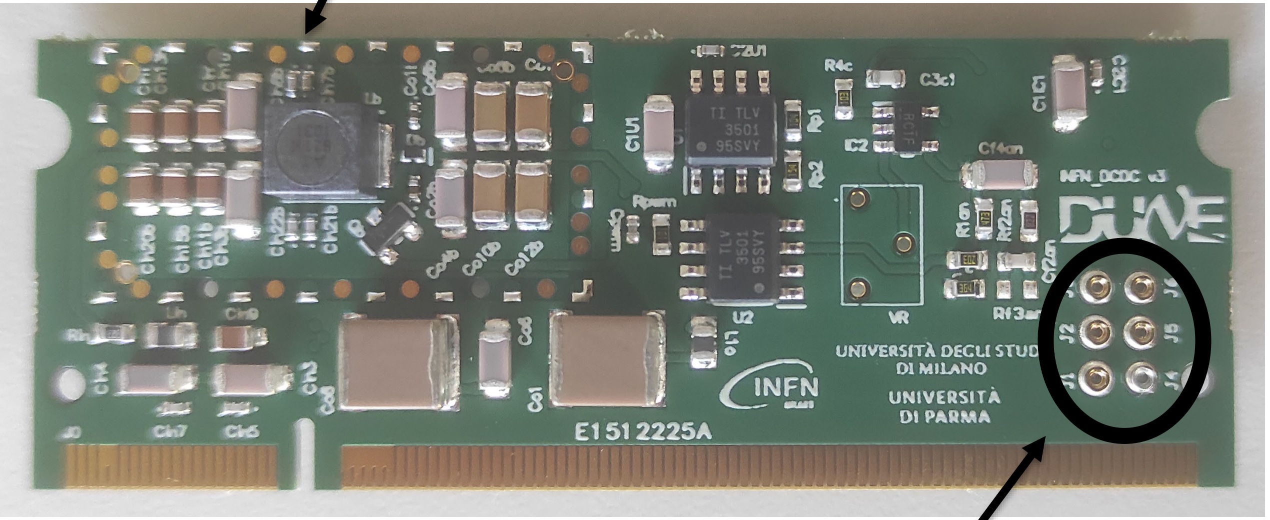
Future developments

- Adding card for **external** DC-DC boost converter **control**
- Connection pins available on the DC-DC boost converter PCB
- **Shield integration** for EMI reduction

Connection pads for shield integration

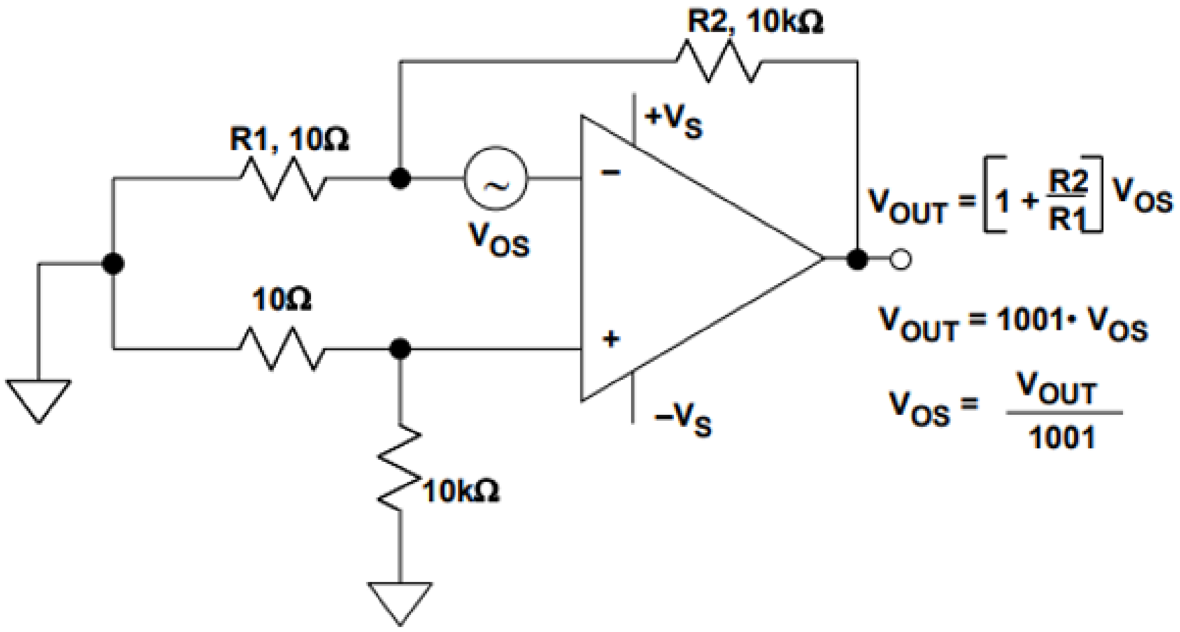


External card slot

Component characterization: OpAmps

First characterization circuit for OpAmps

- DUT: OpAmp LMV321
- Input offset voltage test
- DUT in climate chamber with LN2 injection
- Offset recovery at each temperature step
- Automatic test bench control



Characterization testbed

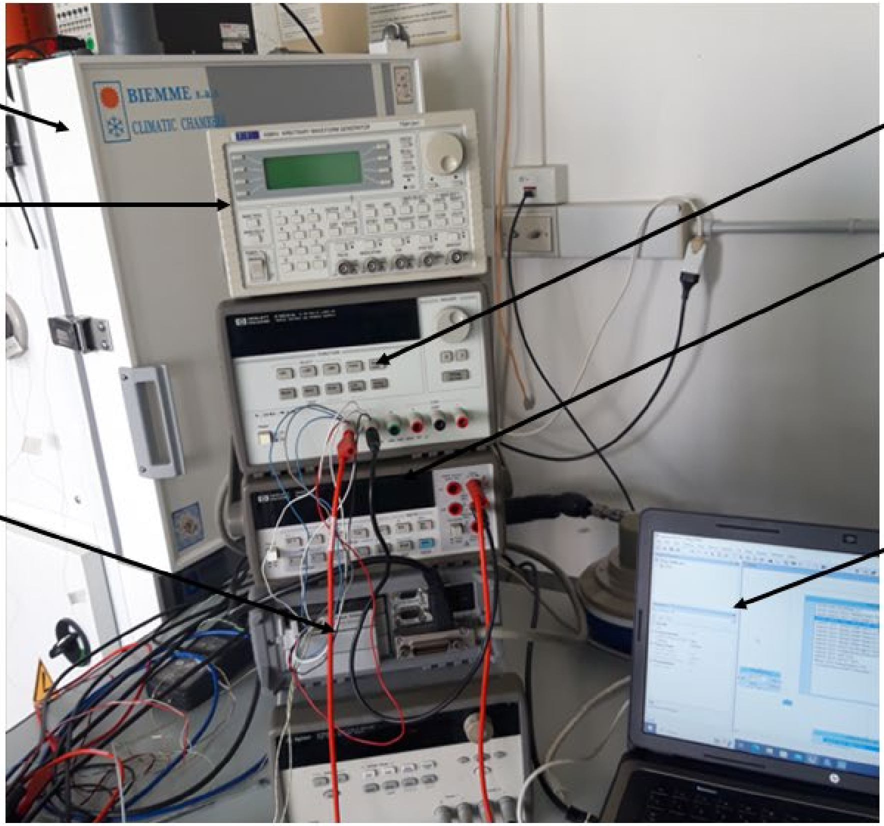
- DUT in climate chamber with LN2 injection

Climatic chamber

Waveform generator
TGA1241

Data acquisition/switch unit
Keysight 34970A

=>offset tension,
current biais, thermocouple



Power supply

Multimeter
Hp 34401A

Computer with Agilent
VEE pro
=>drive instruments and
extract data

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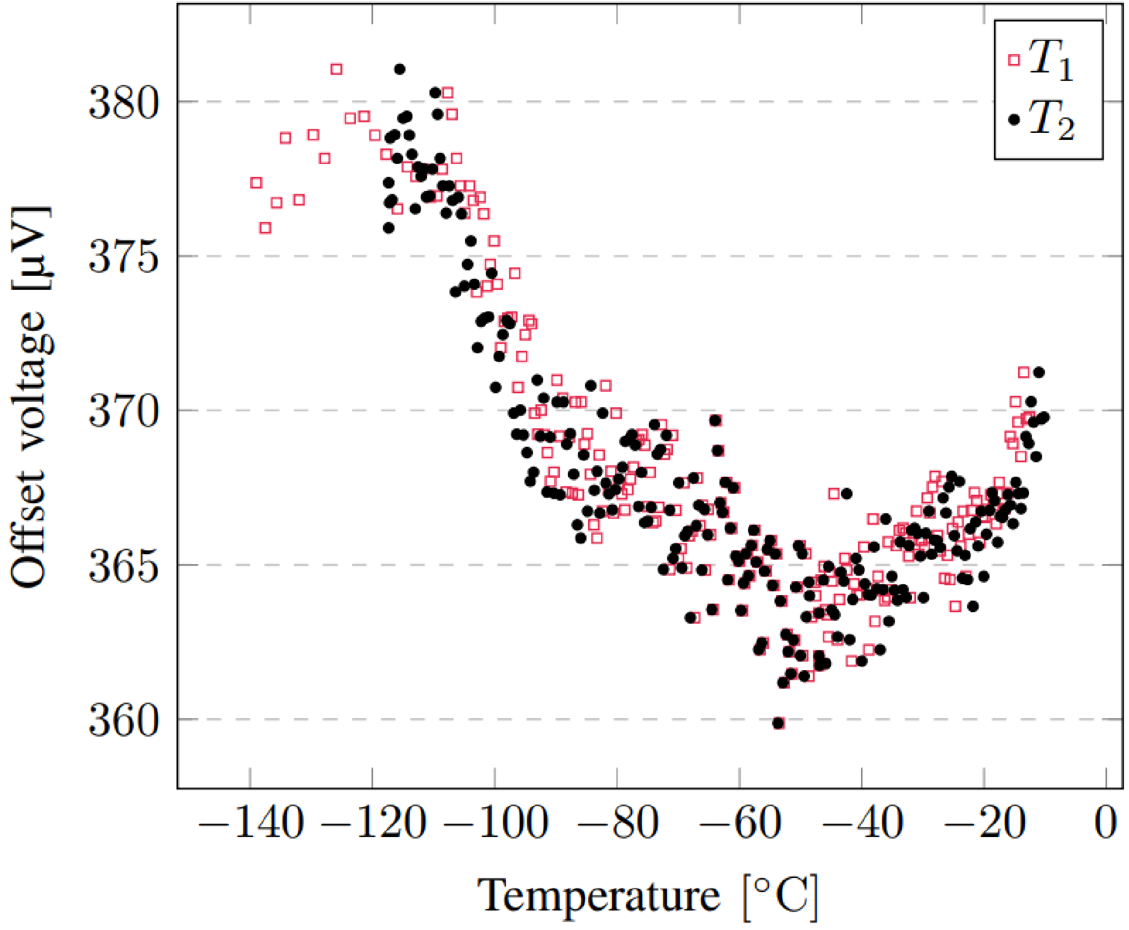
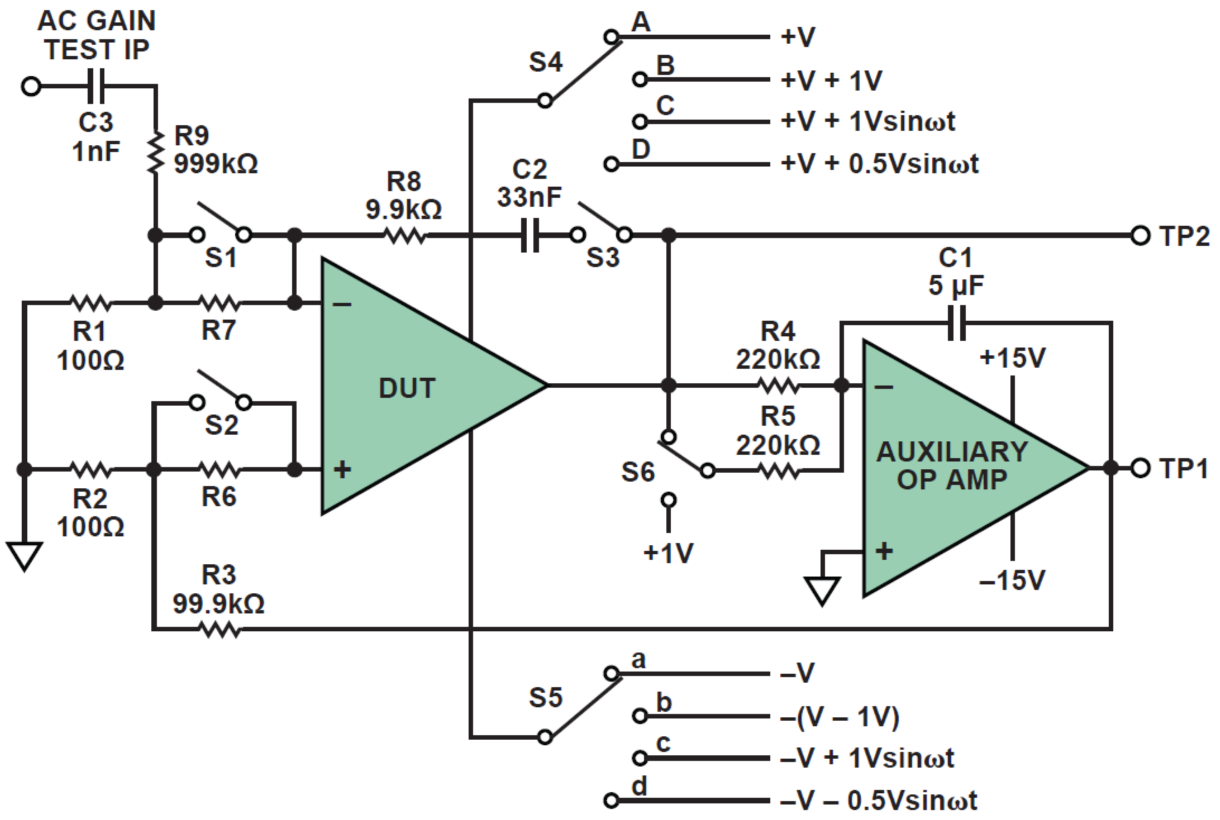
Early experimental results

- DUT: LMV321
- Temperature and input offset voltage data recovery
- Low measurement system sensibility



Revised characterization circuit

- OpAmp characterization for cyogenics:
  - **Input offest voltage**;
  - **Bias current**
  - **PSRR**
  - **Quiescent current**
- General circuit editable for all Op Amp parameters extraction
- OpAmps as DUT:
  - MCP6291
  - MCP6N11
  - LMV321
  - TLC271
  - AD8293



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Future developments

- Warm test card with Auxiliary OpAmp at 300 K
- Cold test card in climate chamber with LMV321

Issues:

- Revised PCB in arrival
- Dewar with more capacity necessary
- High-rate multiplexer for data acquisition unit necessary