DESIGN AND ANALYSIS OF A LWIR DETECTOR ELECTRONIS FOR SPACE APPLICATIONS

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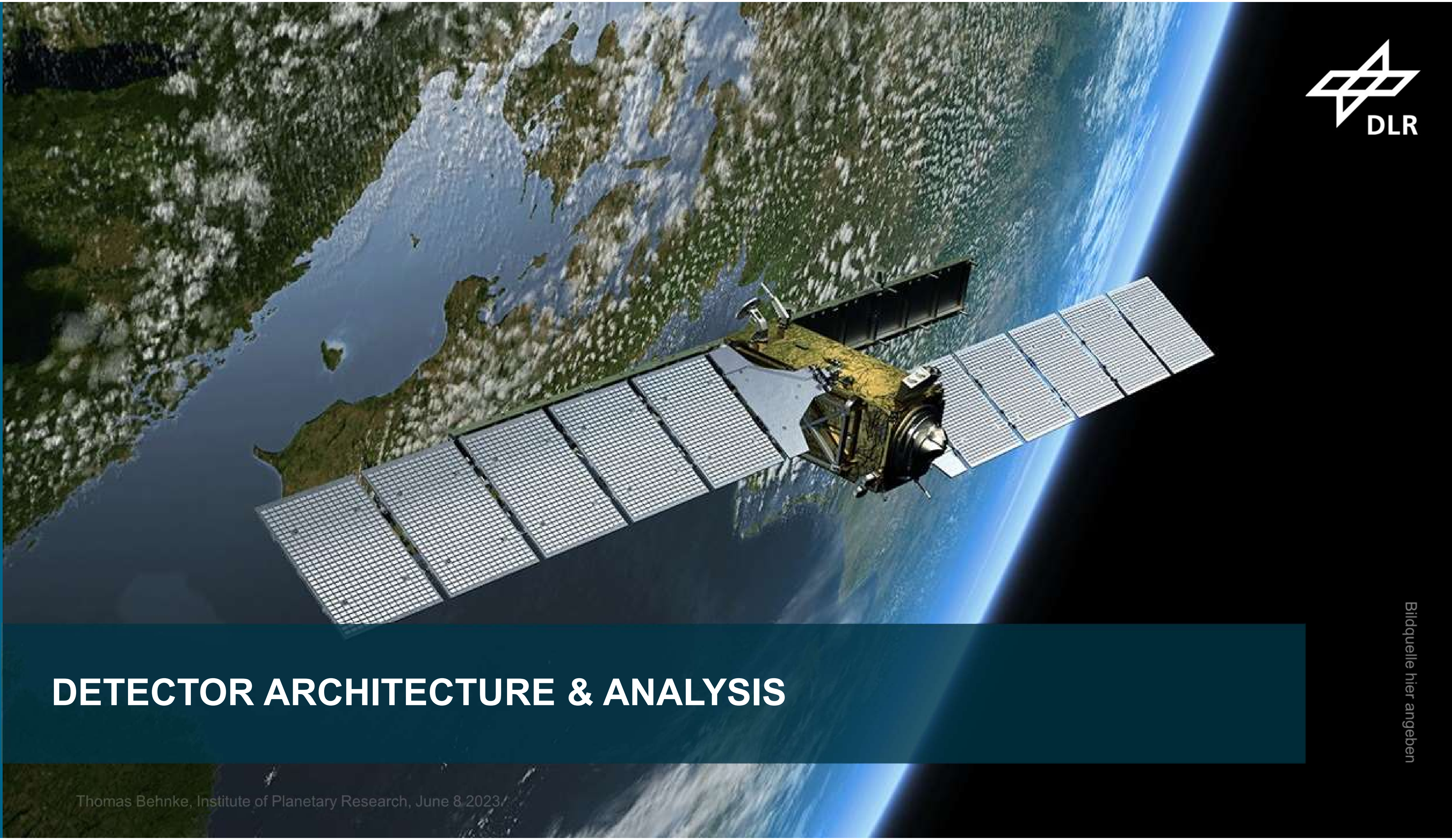
Outline

1. Detector Architecture and Analysis
2. Detailed Design Concept
3. Signal Chain Performance
4. Detector Characterization Lab
5. Summary



DETECTOR ARCHITECTURE & ANALYSIS

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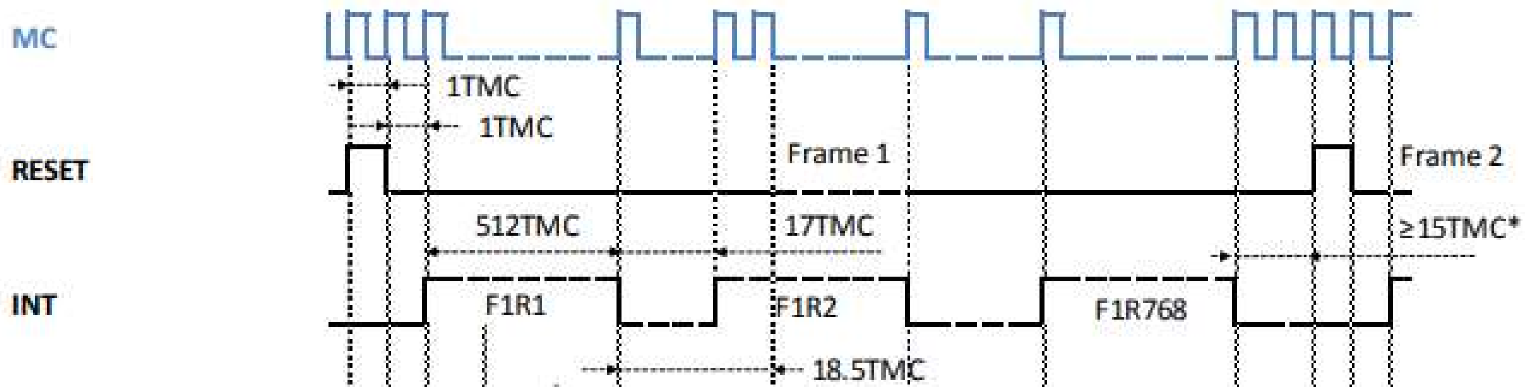
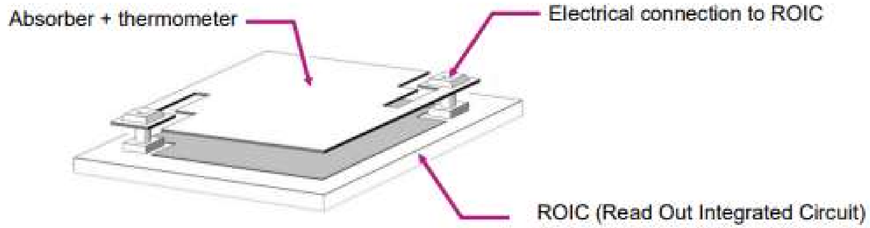
- PICO1024 is a high resolution 1024x768 image sensor with 17 µm pitch
- Sensitive to IR radiation in the LWIR (8 to 14µm) spectral range
- Based on amorphous Silicon (α-Si)
- Operation temperature between -40°C to +85°C
- Thermal sensitivity 30-50 mK
- Thermal time constant <12 ms
- Power consumption <220mW
- Providing a raw analog video signal (up to 4 outputs)
- Input clock signals: master clock, integration time, reset frame synchronization

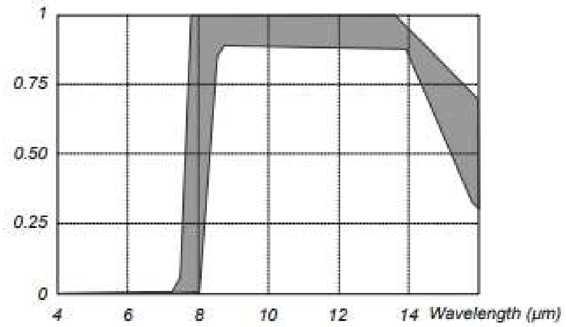


- 73 bit register to configure ROIC (gain, windowing, scanning direction) via SPI

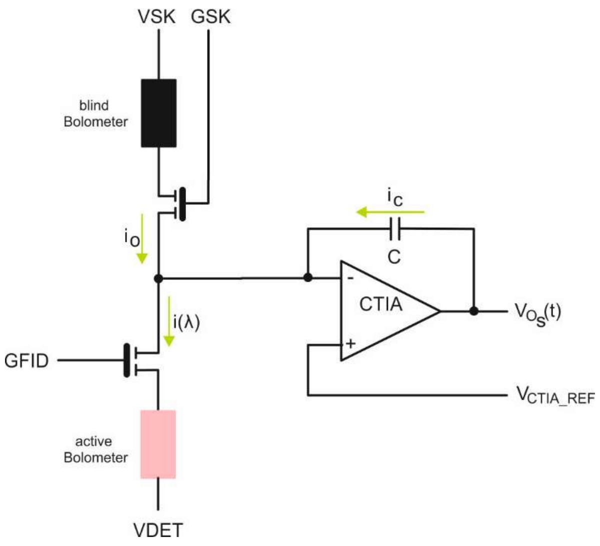
- Each pixel is electrically connected to an input of the readout integrated circuit (ROIC) designed to read each thermometer and multiplex the signals generated by all the pixels to a video output.



- The PICO1024™ sensor present a normalized spectral response within the spectral range 8-14 µm.



Capacitance Trans-Impedance Amplifier



$$i(\lambda) = i_0 + i_c$$

$$\frac{v_{CTIA\_REF}}{R(\lambda)} = i_0 + C * \frac{\Delta(v_{O_S} - v_{CTIA\_REF})}{\Delta t}$$

$$\Delta t = integration\ time$$

$$\int_0^t \frac{v_{CTIA\_REF}}{R(\lambda)} dt = \int_0^t i_0\, dt + C * \int_0^t \frac{d(v_{O_S} - v_{CTI\_REF})}{dt} dt$$

Signal:

$$v_{O_S}(t) = v_{CTIA\_REF} + \frac{1}{C} * t * \left[\frac{v_{CTIA\_REF}}{R(\lambda)} - i_0\right]$$

CTIA Capacitance [pF]	Gain
5.3	1.00
4.3	1.25
2.3	2.30
1.3	4.10

Noise:

$$v_{O_N}(t) = \sqrt{e^2_{v_{CTIA\_REF}}\,\Delta f + \frac{1}{C^2} * t^2 * \left[\frac{e^2_{v_{CTI\_REF}}\,\Delta f}{R(\lambda)} + \frac{4kT\Delta f}{R(\lambda)} + 2q i_0 \Delta f\right]}$$

- Integration time controls detector output swing
- The noise floor is dominated by integration time, only V_{CTIA_REF} fraction can be suppressed at large T_{INT}

DESIGN CONCEPT

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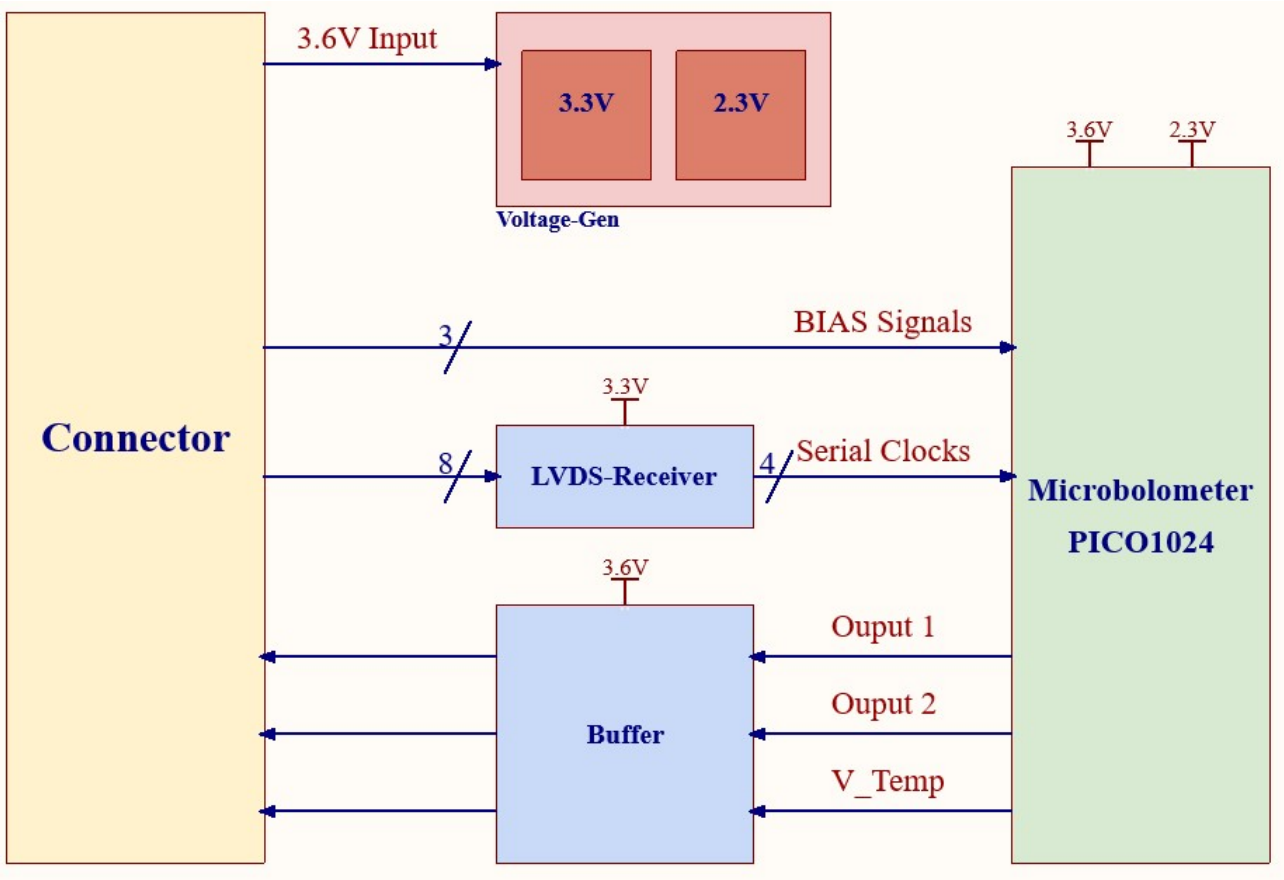
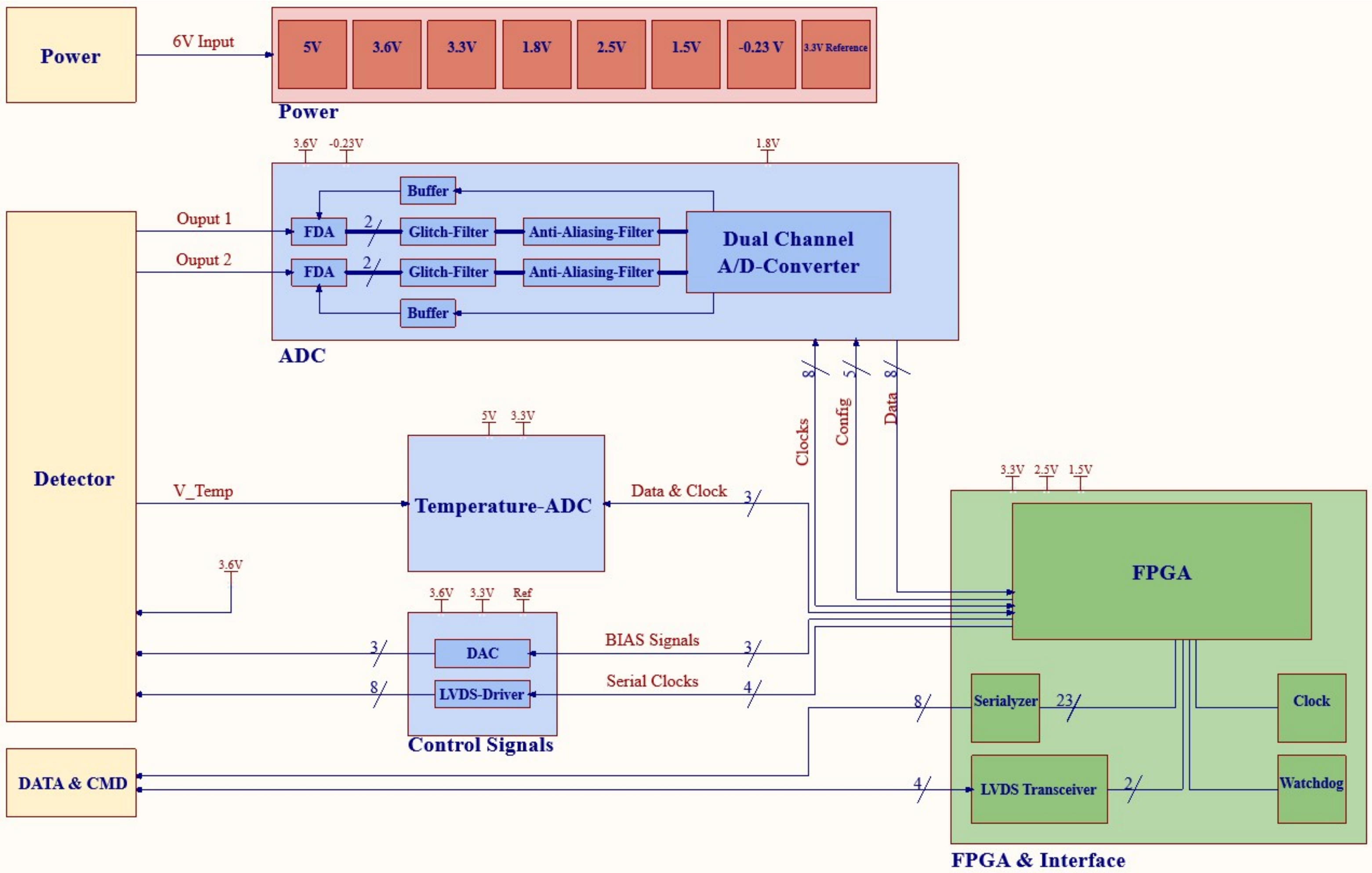
Blockdiagram of the Focal Plane Assembly

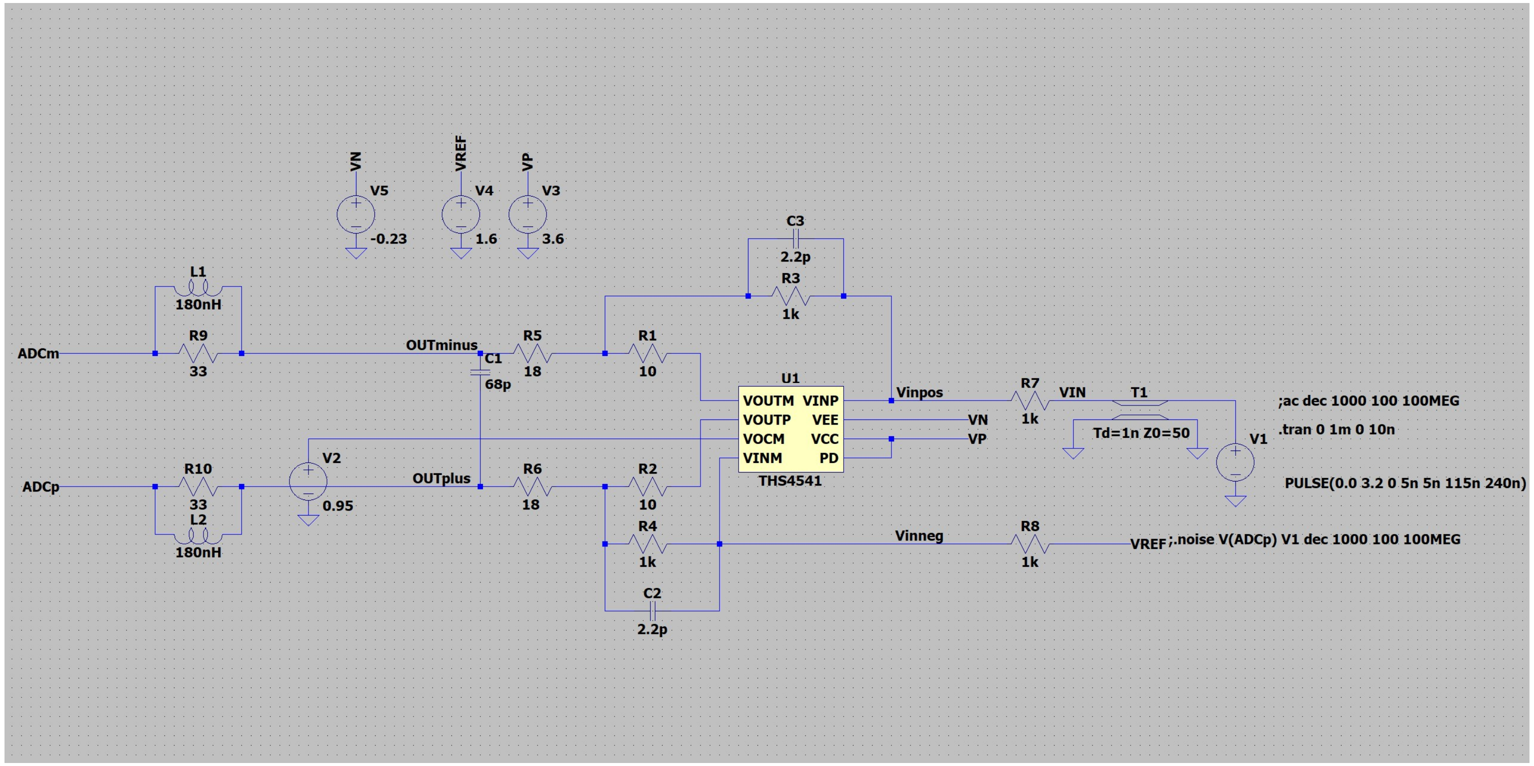


Blockdiagram of the Proximity Electronics



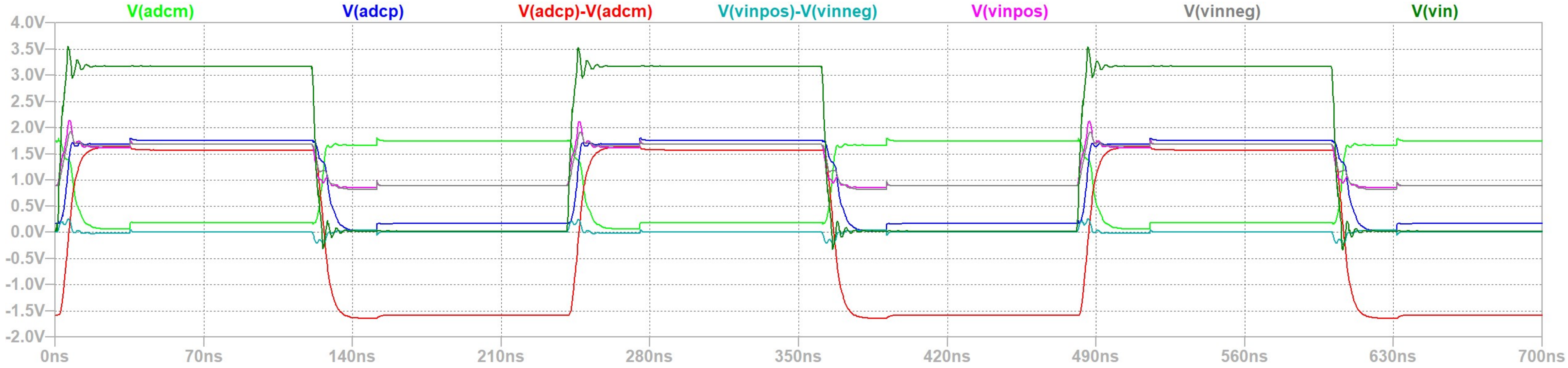
SIGNAL CHAIN PERFORMANCE

Spice signal analysis



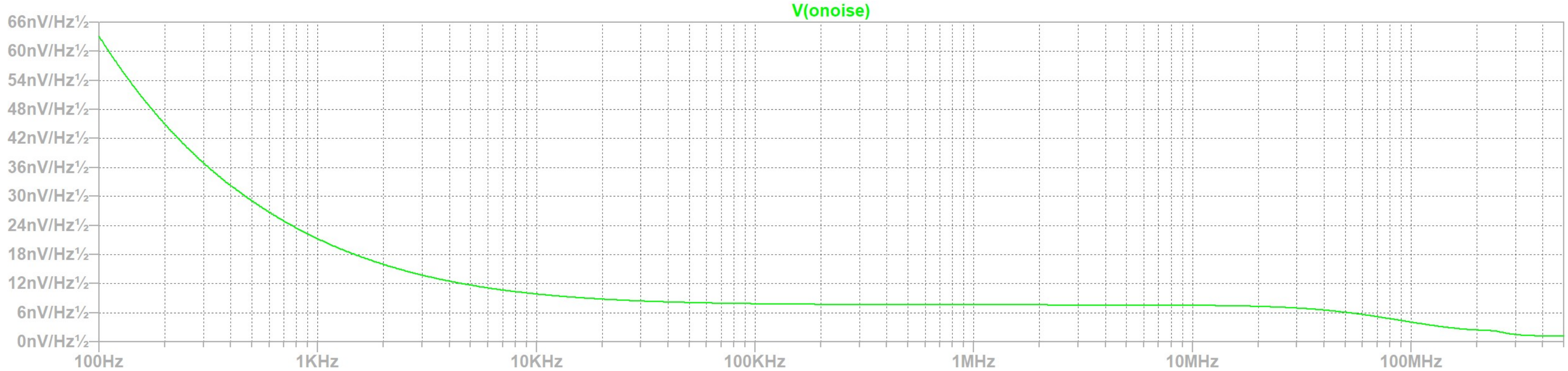
AC Analysis

- µBolometer output voltage swing ~3.2V unipolar single ended
- Signal chain provides transformation to 1.6V pp full differential balanced signal
- Pixel clock amounts to 8 MHz

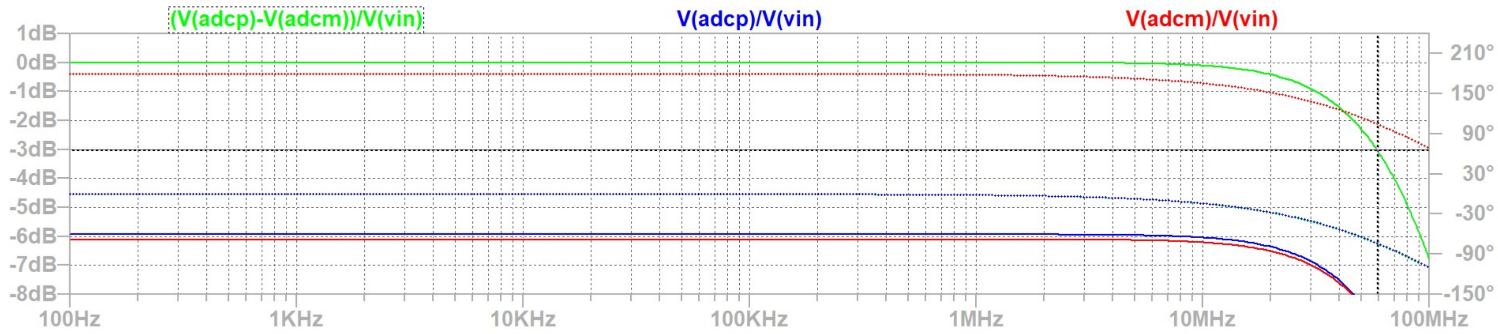


Noise Analysis

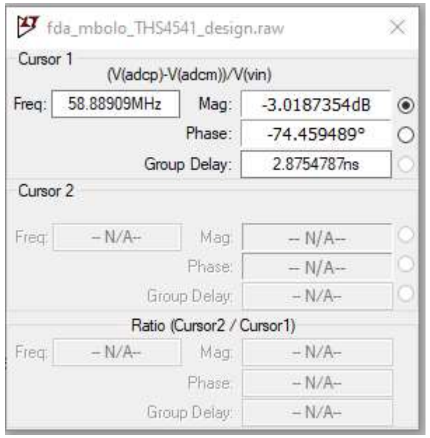
- Noise floor less than 8 nV/$\sqrt{Hz}$
- Equal to 50µV rms @ ~ 60MHz 3dB Bandwidth



Transient Analysis



- ~ 60 MHz 3dB flat bandwidth
- Unity gain signal



DETECTOR CHARACTERIZATION LAB

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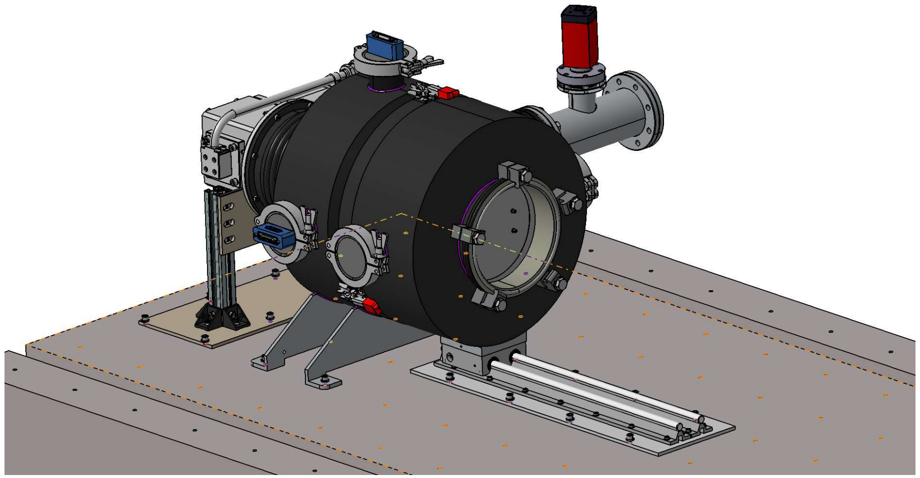
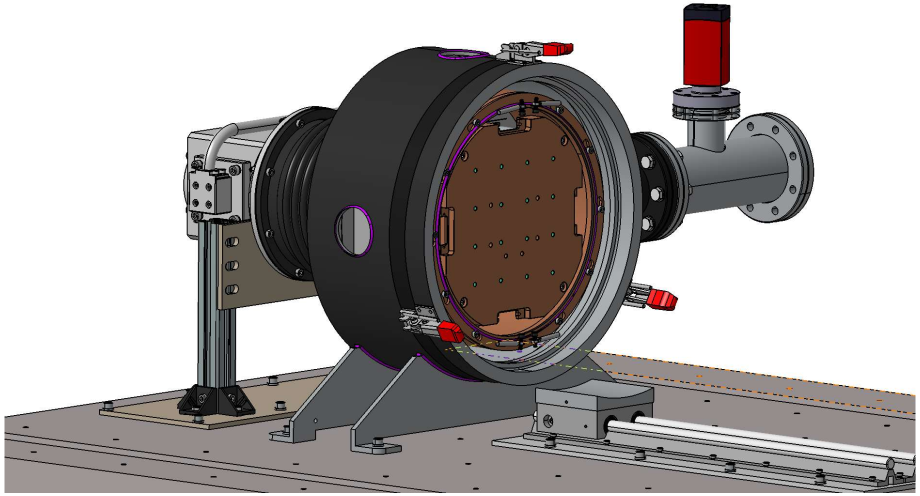
Cryostat Setup

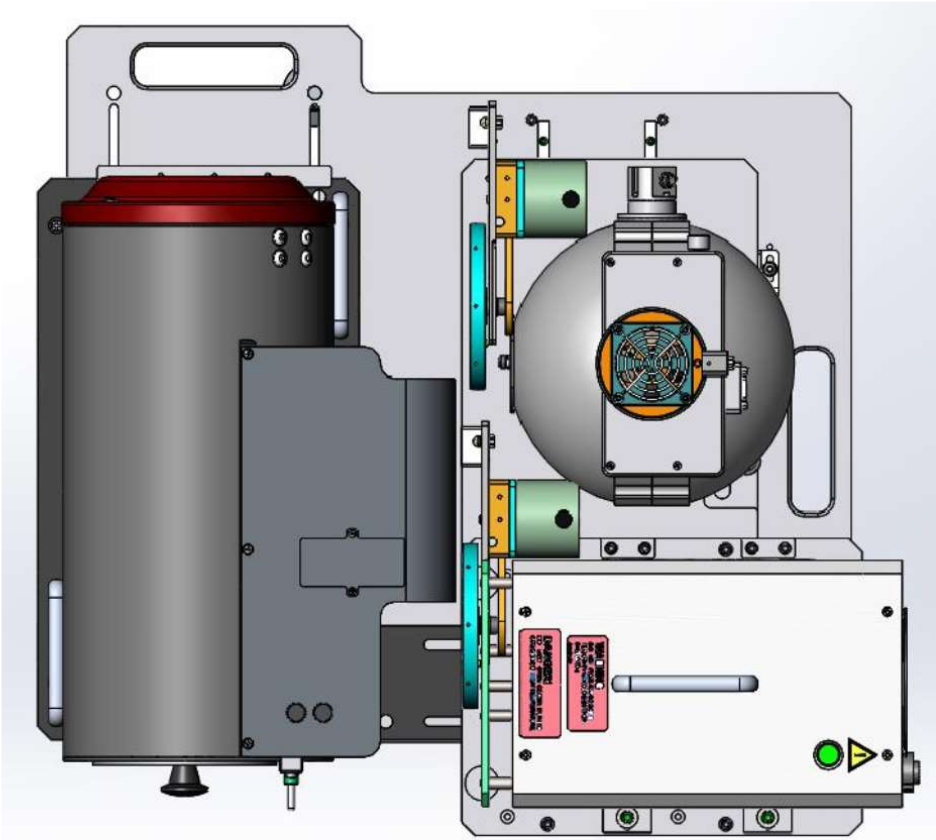




- Vacuum of 10^{-5} mbar, two independently controlled environments
- Temperature at the coldplate 50 K - 350 K, cold shroud 50 K - 350 K independently controlled
- Cooling power of 2 W at the DUT at 50 K
- Changeable, flange-mounted optical window for illumination, closed system for dark measurements
- Standard and thermally decoupled micro-D feedthroughs

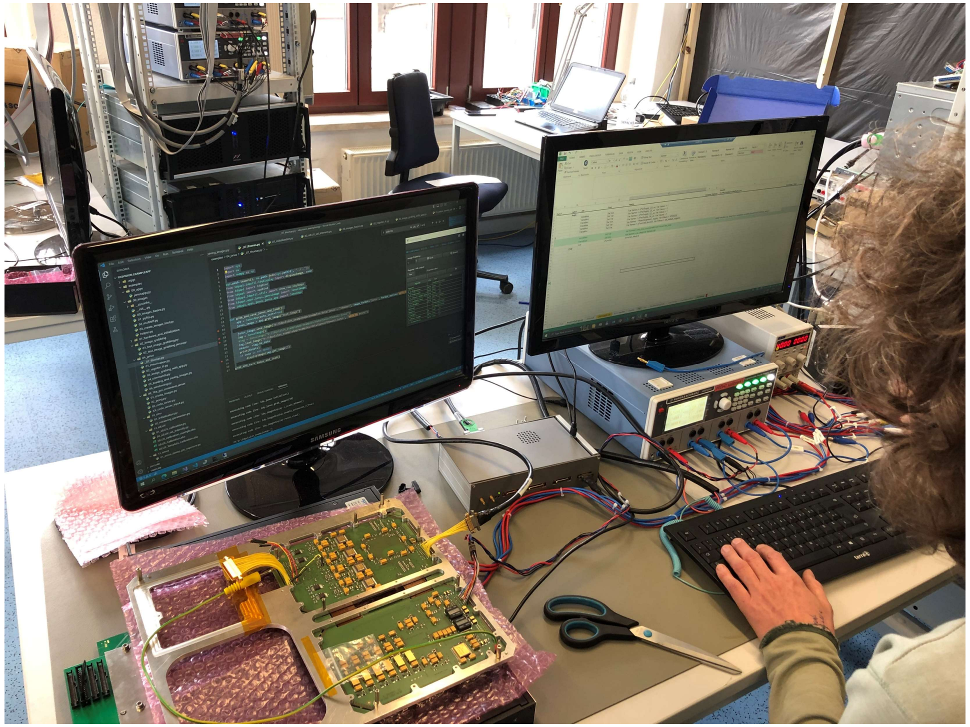
Thomas Behnke, Institute of Planetary Research, June 8 2023

Selectable Spectral Lightsource



- Radiometrically calibrated light sources
- Motorized stage allows selecting the light source:
  - Cavity blackbody, 50°C - 1200°C
  - VIS-SWIR integrating sphere
  - Each light source is equipped with a filter wheel
  - 12 filters each with λ/Δλ > 50
- Collimator:
  - Aperture 5″
  - Focal length 15″
  - FoV 2.0°
  - Target wheel with 6 standard targets

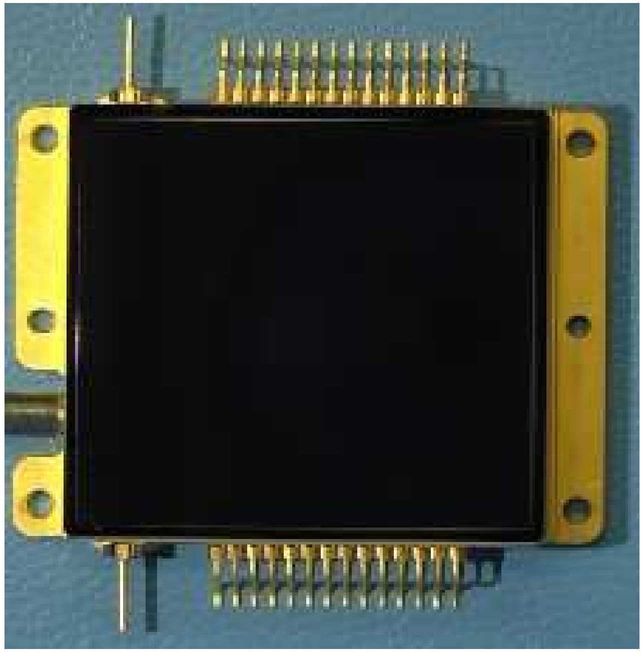
Data Acquisition System idqVision



- System supports 3 protocols: channel ling 21:3, 28:4 and up to 16 bit parallel (LVDS
- 200 Msps data rate (up to 40 fps)
- GUI for quick look investigation with basic image processing tools
- Open source PYTHON API i/f to control all hardware components and custom analysis
- Source measurement unit for bias voltage and current control is available

Thermal Infrared Testing

- Types of thermal detectors to be tested in the DCL:
  - Thermopile sensors, microbolometer
  - Photon detectors (InGaAs, InSb, MCT)
  - Microbolometers
- First test is commissioning of the Lynred PICO1024
- Determination of the PICO1024 operation parameters
- Planned test for the Lynred PICO1024 microbolometer:
  - Responsivity at room temperature
  - Noise equivalent power at room temperature
  - Pixel Response Non-Uniformity at room temperature
- Further tests:
  - Responsivity and Noise Equivalent Power as a function of sensor temperature
  - Performance under non-stabilized conditions and defined temperature drift
  - Spectral responsivity at room temperature



Space Components Approach

Components in use	Function	Space Grade Equivalent
OPA837IDCKT	OPAMP buffer	OPA4277-SP
ADA4897-1ARZ	OPAMP buffer	OPA2H112-SP
ADN4668ARUZ	4-channel LVDS receiver	RHFLVDS32A
PICO1024-048	microbolometer sensor array	Qualification program
ADM7151ARDZ-04	adjustable output LDO	RHFL4913A
ADM7151ACPZ-02-R7	adjustable output LDO	
ADM7150ACPZ-3.3-R7	3.3V fixed output LDO	
TPS62912RPUR	adjustable low noise buck converter	ISL70003
REF3433MDBVTEP	3.3V voltage reference	IS-1009RH
LM7705MMX/NOPB	negative bias generator	
AD5684BRUZ	4-channel DAC	DAC39RF10-SP
ADN4667ARZ	4-channel LVDS driver	RHFLVDS31A
LTC2313ITS8-14TRMPBF	ADC	ADC128S102QML-SP
ADC3661IRSBT	ADC	ADC3683QML-SP
THS4541IRGTT	FDA	LMH5485-SP, LMH6702QML-SP
TPS3899DL08DSER	Watchdog	ISL705AEH
XLH735128.000000I	128MHz Clock	Q-TECH
530NC128M000DG	128MHz differential output clock	
A3PE3000-2FGG484I	FPGA	RTAX2000
DS90CR217MTD/NOPB	Serialyzer	UT54LVDS217
DS90LV049TMT/NOPB	LVDS Transceiver	RHFLVDSR2D2

SUMMARY

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Summary

- Estimation of the detector output signal
- Design of a 16 bit 8 Msps readout electronics to operate LWIR PICO1024 detector
- Investigation and evaluation of the analog signal chain
- IEEE space option with power consumption < 4 W is feasible
- VIS-LWIR prospect of detector characterization
- Test campaign is scheduled for July/August 2023

THANK YOU FOR YOUR ATTENTION!

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