The digital absolute radiometer DARA and its Relatives

Retrospection to Last Decade of Digitally Controlled Radiometers for Space Application from the Engineering Perspective

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History

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<tr><td>JTSIM</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">Phase C/D</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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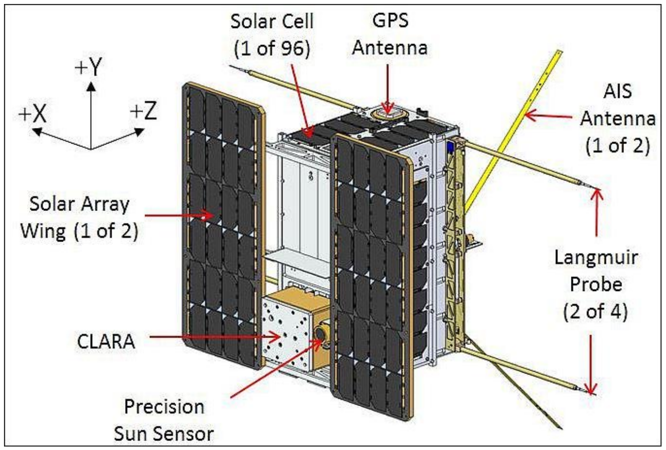
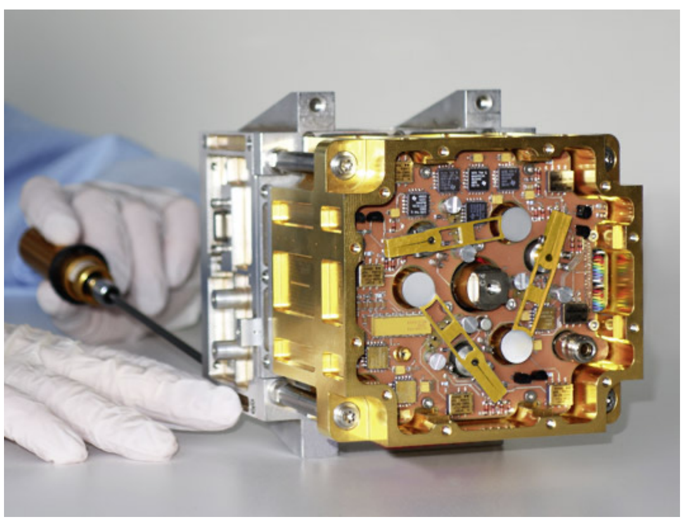
- In 2010 we developed the DARA prototype
- In 2014/2015 Clara was developed, a Norwegian mission
- Between 2015 and 2019 we finalized DARA for the PORBA-3 ESA mission as well as JTSIM-DARA for FY-3E Chinese mission

NorSat-1 CLARA

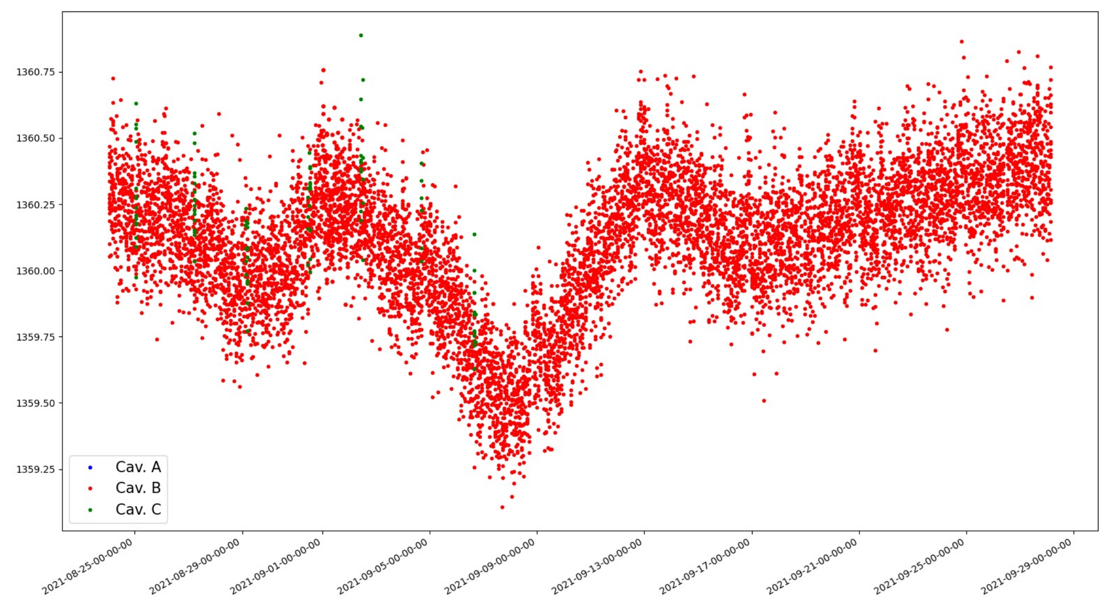




- **Launch date:** 14 July 2017 Baikonur, Kazakhstan
- **Orbit:** Sun-synchronous orbit, altitude 600 km
- **Status**: Instrument is operating, but pointing is not stable due to two defective giro-wheels

FY-3E (DARA-JTSIM)

- **Launch date:** 4. July 2021
- **Orbit:** Sun-synchronous orbit, altitude 836 km
- **Status:** Commissioning is running, first data have been received and are under evaluation



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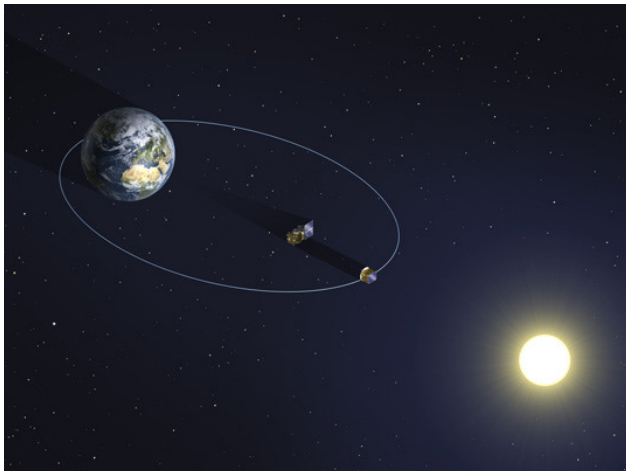
PROBA-3
DARA



- **Launch date:** mid 2022
- **Orbit:** High Elliptical Earth orbit, 19.7 hours orbital period, 60 530 km apogee, 600 km perigee
- **Status:** Deliver in November 2021, currently in the optical laboratory for none equivalence measurement

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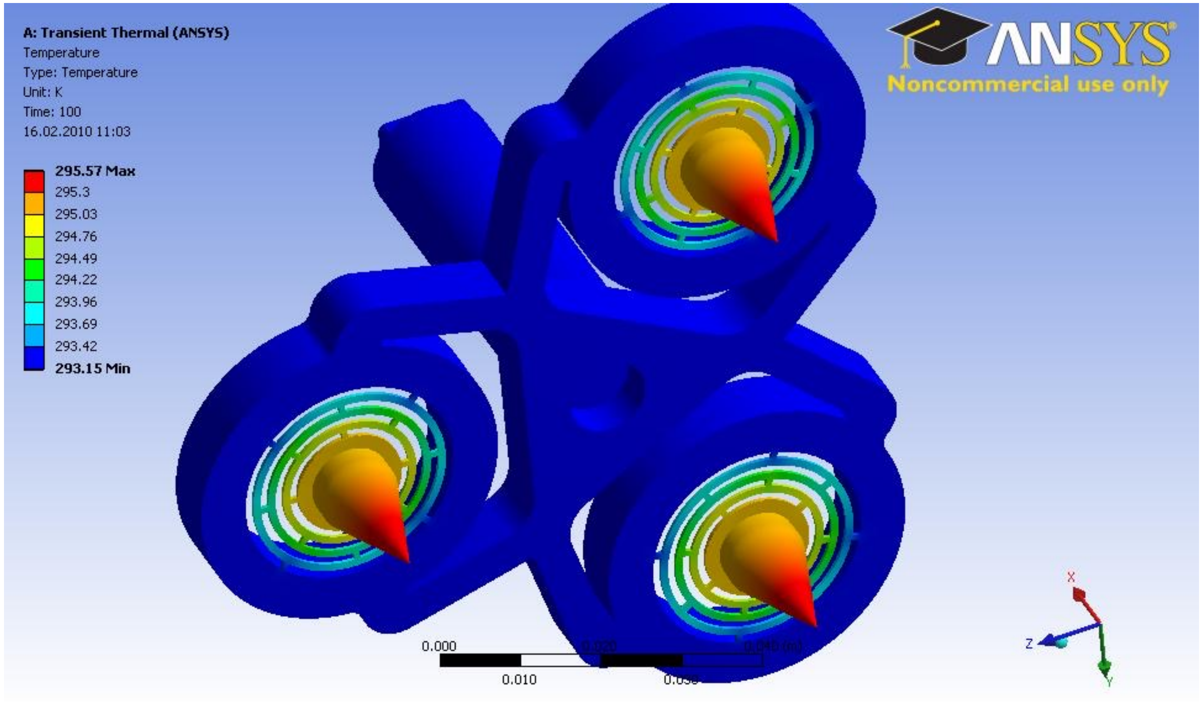
DARA Features

pmod wrc

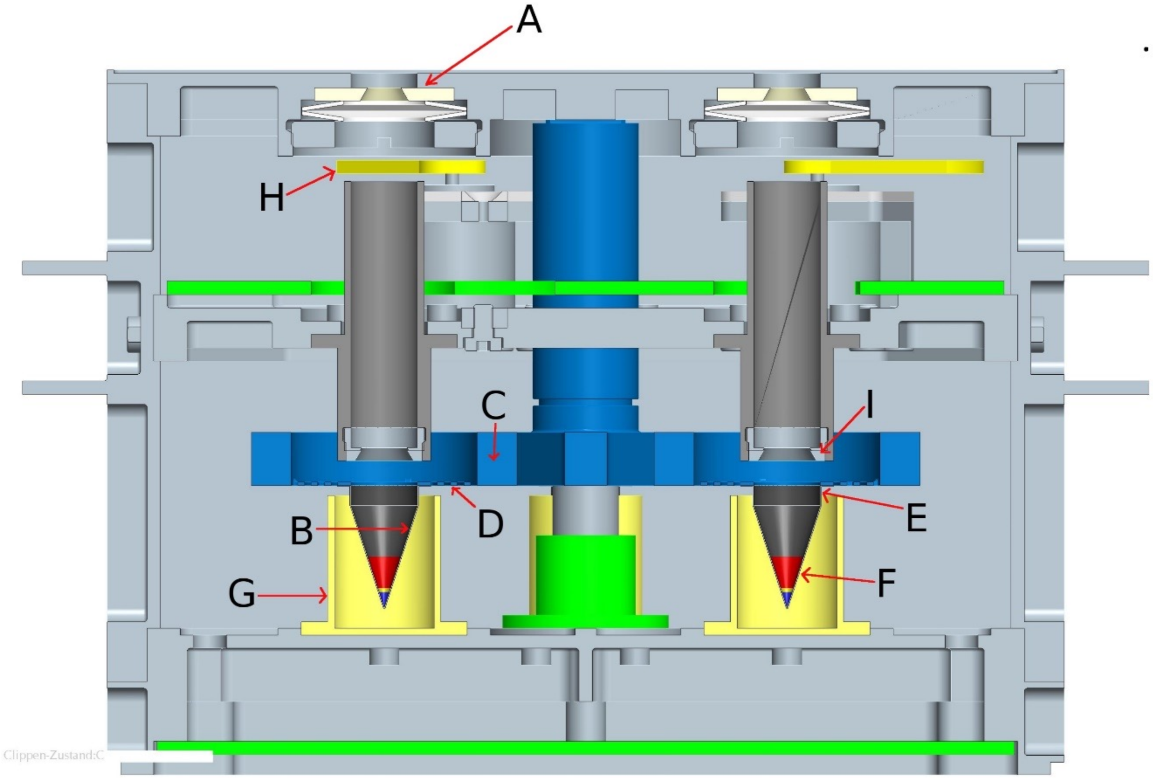
- 3 independently controllable cavities
- Offers several open/close measurement sequences
- Independent PID controllers for closed and open shutter state
- ~20 bit data acquisition for each I and U channel
- Measurement period down to a few seconds
- Uncorrelated sinus carrier for thermal error signal
- Cavities with minimal "Non-Equivalence"
- Very fast shutter speed (few steps and < 100 ms)
- New aperture geometry in comparison to PMO6
- Reduced stray light
- Remove uncertainties due to "Aperture Warming"
- Embedded SW using a RTOS and runs on a MC68332
- Sensor head is thermally isolated to the measurement electronic box

3 Cavity Design

Thermal Simulation

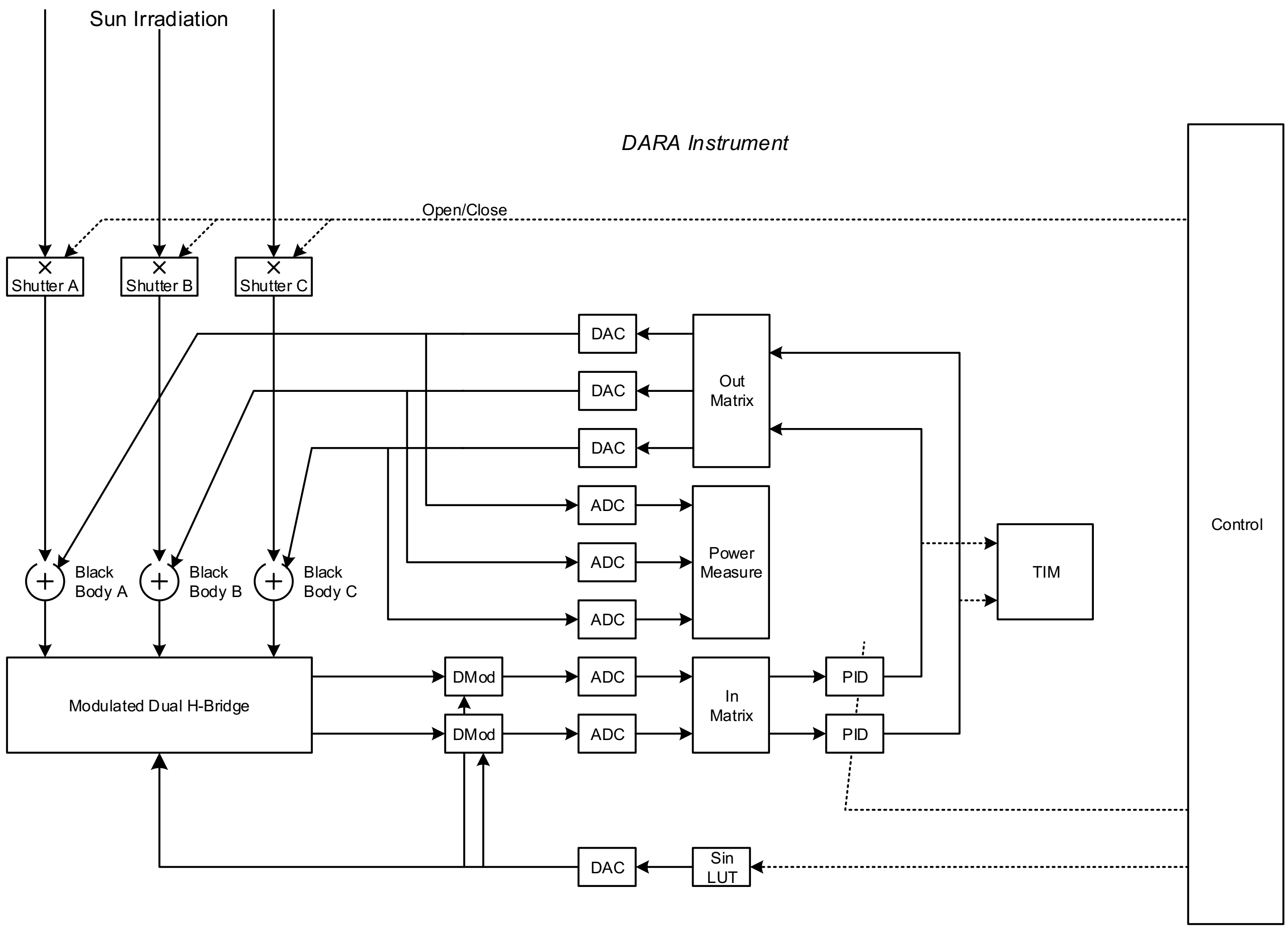


Instrument Geometry



A) Precision Aperture
B) Cavity, Aeroglaze Z302 Coating
C) Heat Sink
D) Thermal Resistor
E) Thermometer
F) Electrical Heater
G) Radiation Shield
H) Shutter
I) View Limiting Aperture

Signal Processing



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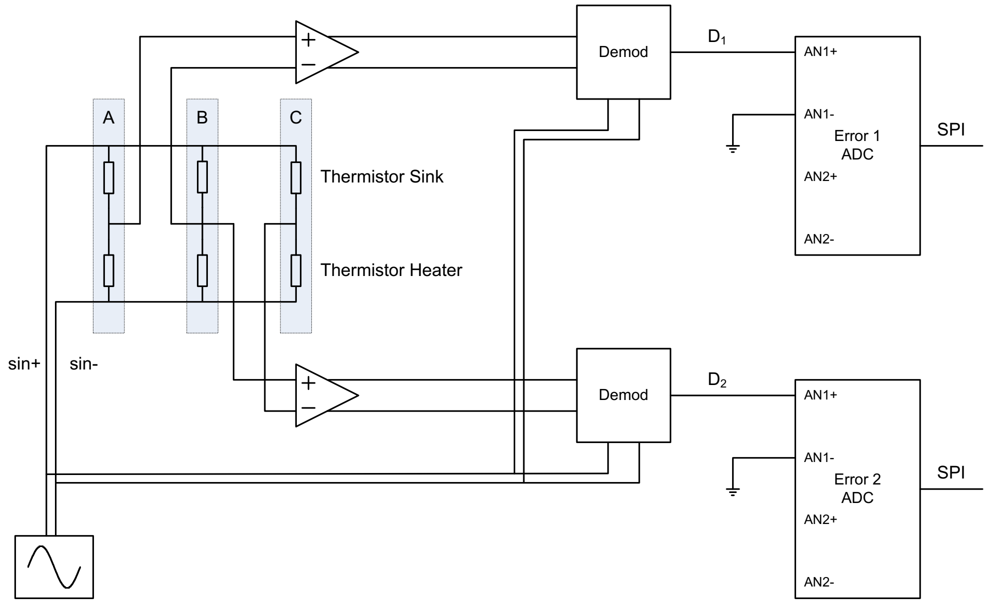
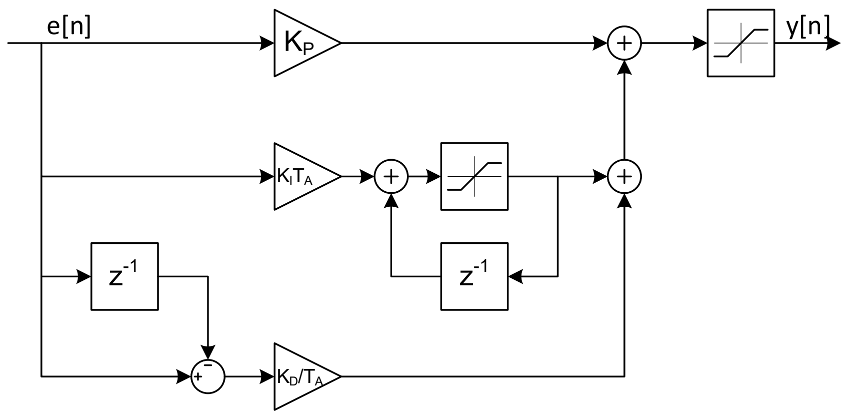
Thermal Balancing

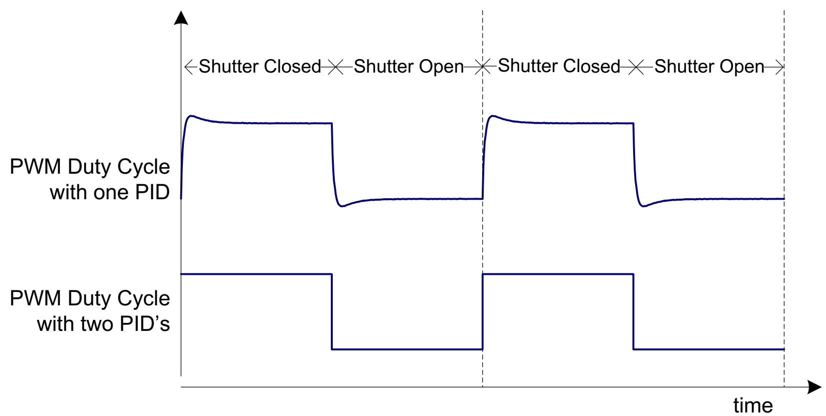


- Reducing noise in the error H-bridge by using a sine carrier
- Using a uncorrelated sine carrier frequency
- Means f_{Sin} is not an overtone of f_{ADC}
- f_{ADC} = 20 Hz, f_{Sin} = 750 Hz

$$f_{Sin} = f_{PWM}\left(n + \tfrac{1}{2}\right)$$

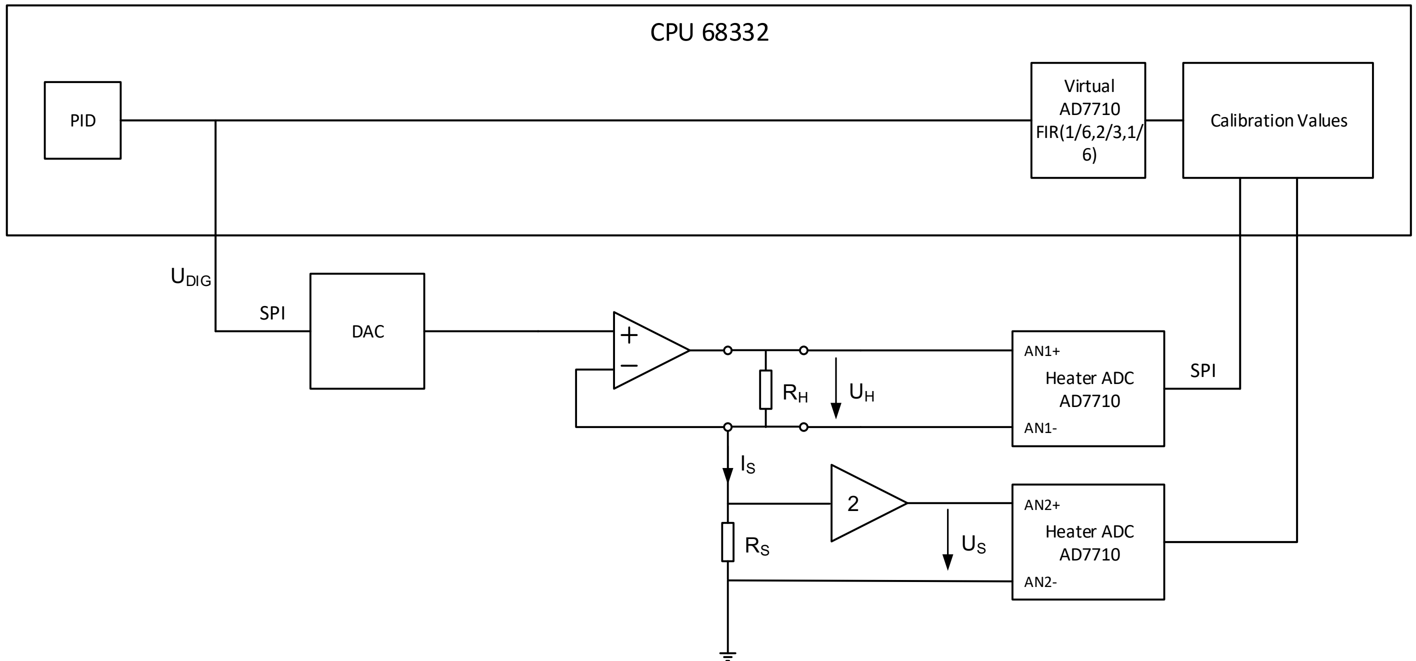
PID Controller Switching





- How can the settling time be reduced when changing the shutter state?
- Two PID controllers per channel
- Significantly less settling time is needed
- Measurement period can be reduced

Power Measurement and Calibration

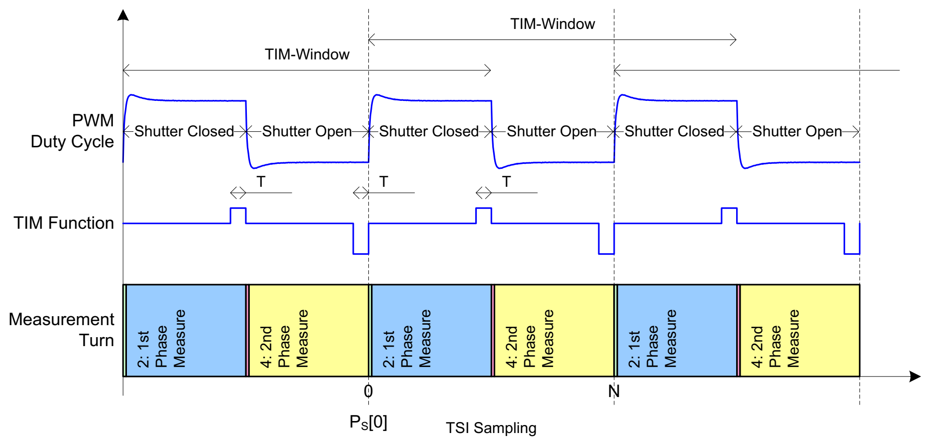


- The digital control value is used to calculate the TSI
- The gain of the heater driver and the heater resistor are periodically calibrated

$$R_H = \frac{2 \cdot U_H}{U_S} \cdot R_S$$

$$G = \frac{U_S}{2 \cdot F_{SINC3}(U_{DIG})}$$

TIM Measure



$$P_S = \sum_{n=-N/2-T}^{-N/2-1} P[n] - 2\sum_{n=-T}^{-1} P[n] + \sum_{n=N/2-T}^{N/2-1} P[n]$$

$$I_s = C_{WRR} W_{Ap} P_S$$

- Tail Integration Method or Traditional Irradiation Measure
- The tail data are integrated
- The sun power is calculated as the difference of 2 measurements made with closed shutter and 1 with open shutter
- One measure per open/close turn

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Data Management

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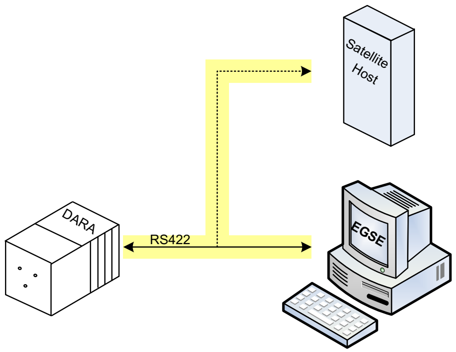

- RS422 communication
- Robust communication protocol
- EGSE software for data visualization and data storage

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Outlook

- Next generation of radiometers are already planed
- Intended features:
  - Increasing accuracy / lower the noise
  - Faster measurement cycles
  - Long term stable on-board voltage reference
  - New cavities design (flat receiver?) under evaluation
  - Leon 3 IP core CPU on a radiation tolerant FPGA