FS-5/AIP

Advanced Ionospheric Probe Onboard FORMOSAT-5 Satellite

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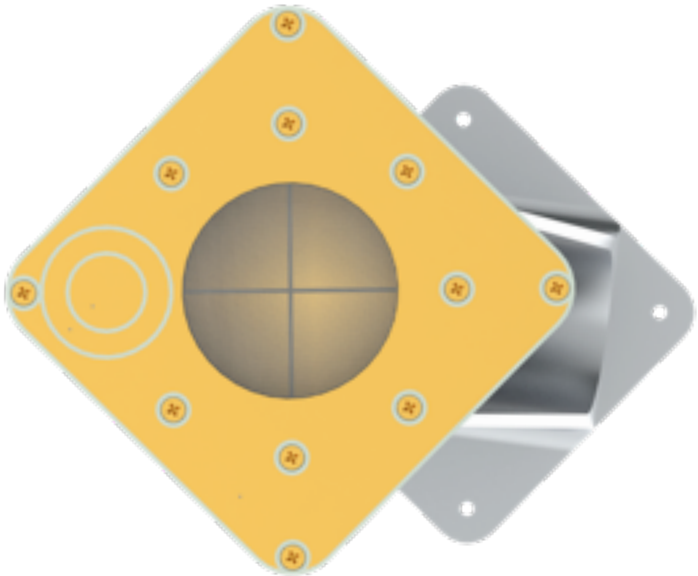
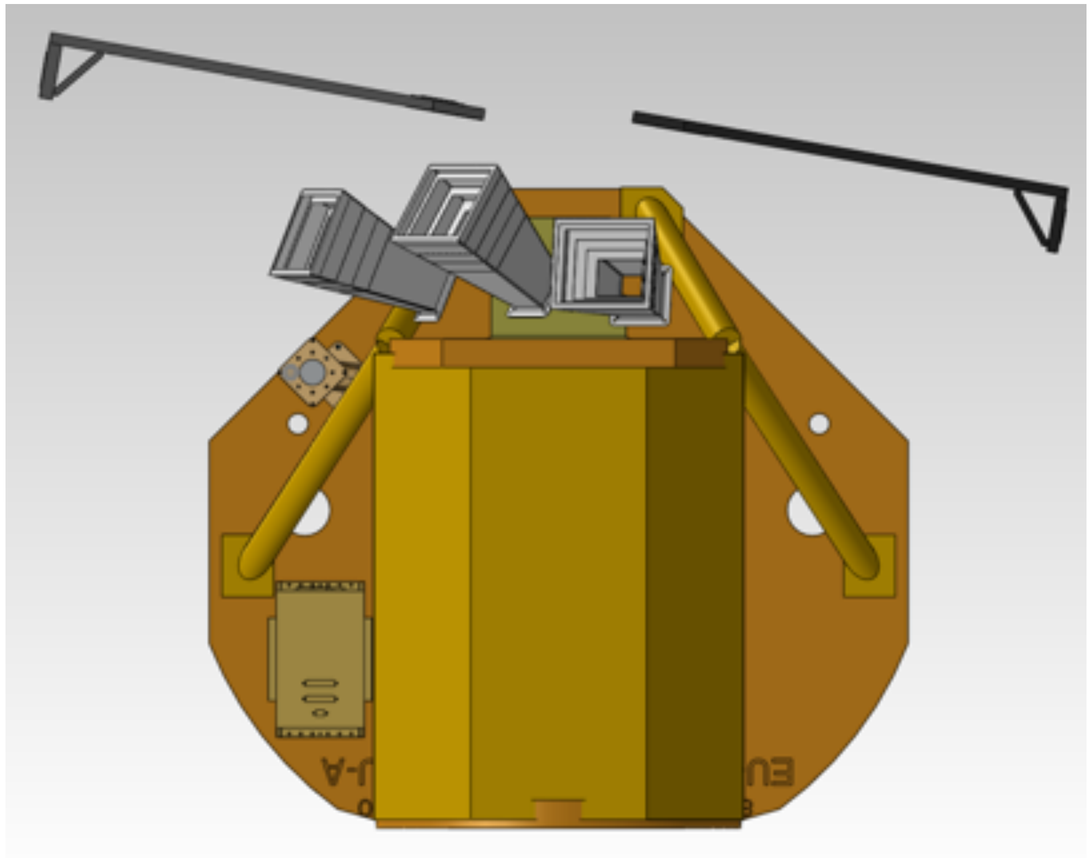
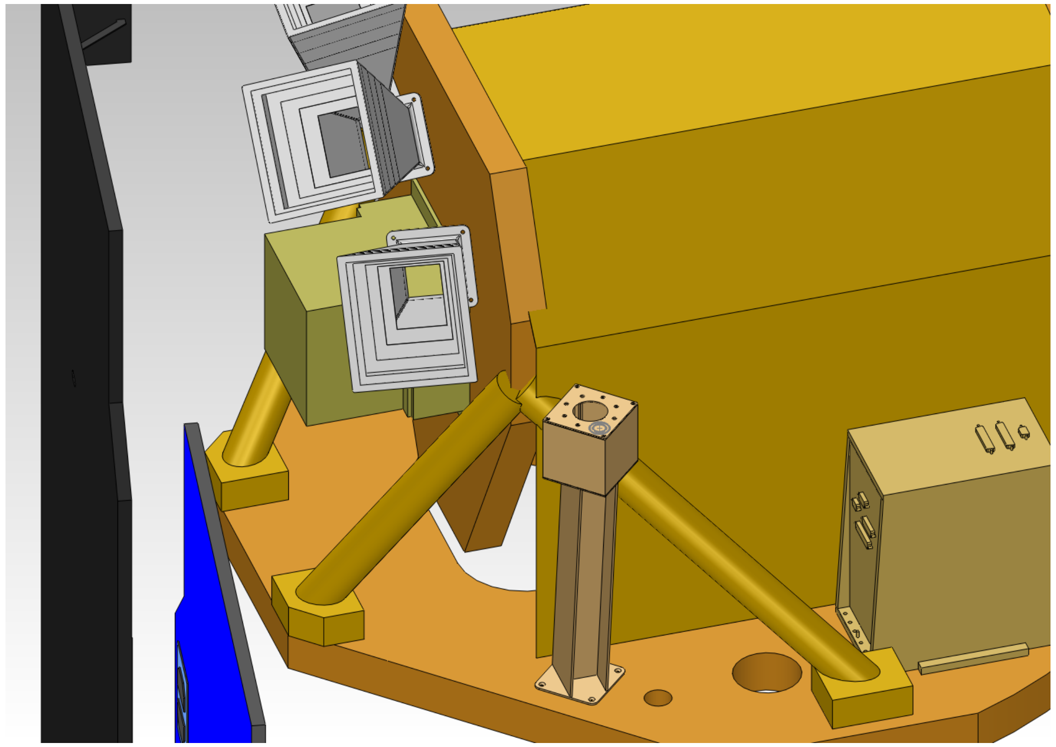
Outline

- Advanced Ionospheric Probe (AIP)
- Specifications
- Functional verifications
- Summary







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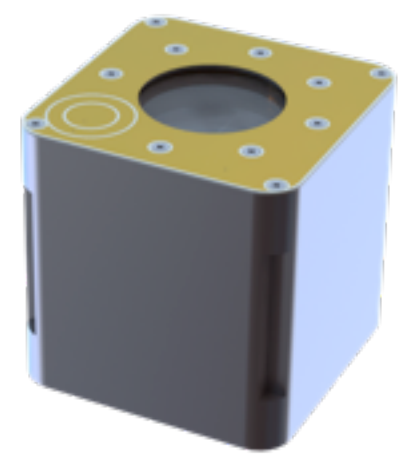
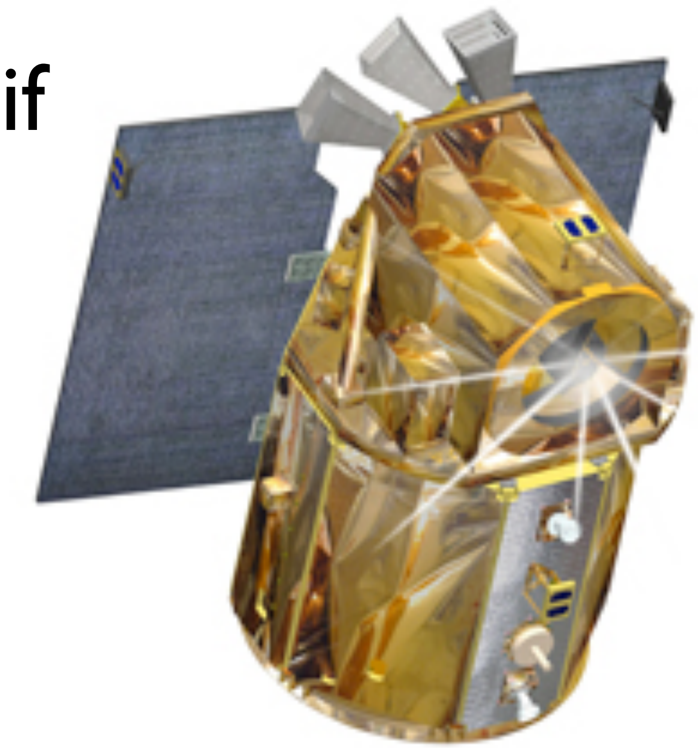
Advanced Ionospheric Probe

- FORMOSAT-5 mission orbit is anticipated at **720** km altitude with inclination **98.28°** as a sun-synchronous orbit in equatorial descending time between 9:45 am and 10:15 am LT.
- A piggyback science payload can be accepted if
  - Mass: < 5 kg.
  - Power in average: < 5 W.
  - Mission life time: > 2 years.





- Advance Ionospheric Probe is an **all-in-one plasma sensor** to install on the FORMOSAT-5 satellite with sampling rate up to 8,192 Hz to measure ionospheric plasma concentrations (N_i), velocities ($\boldsymbol{V}_i$), and temperatures (T_i and T_e) over a wide range of spatial scales in a time-sharing way.

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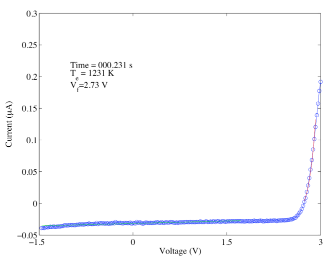
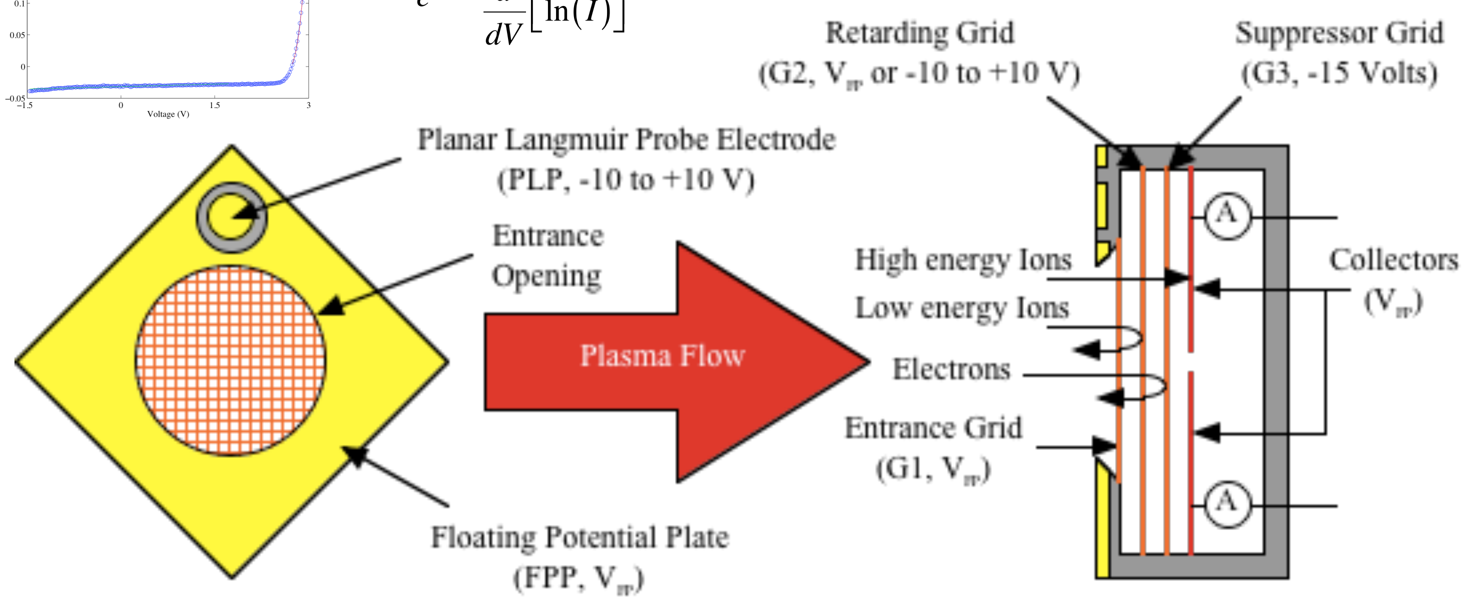
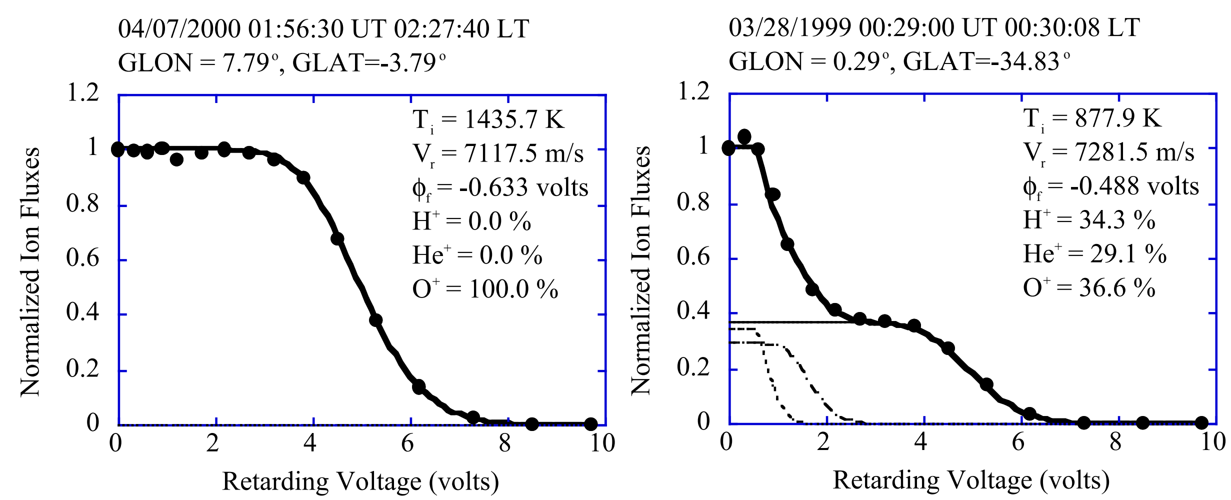
Principle of measurement

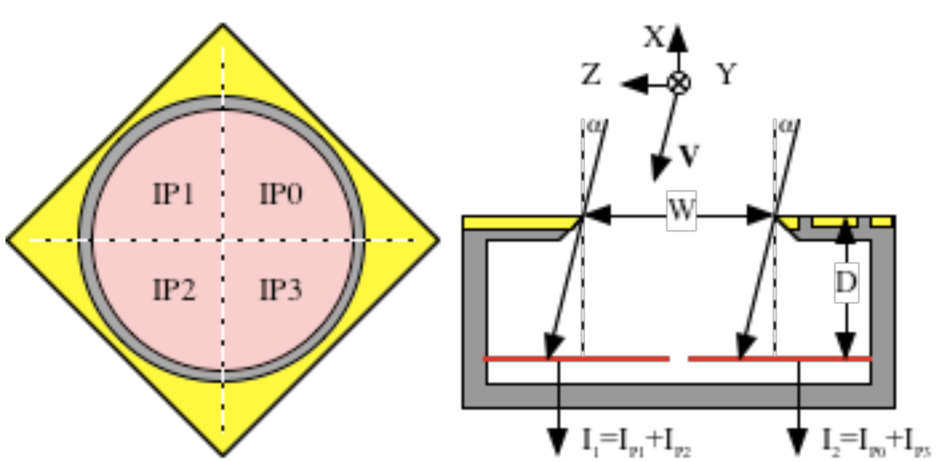


$$\frac{\kappa T_e}{e} = \frac{1}{\frac{d}{dV}\left[\ln(I)\right]}$$

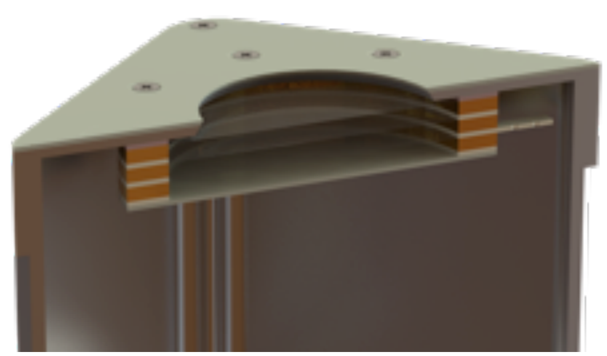


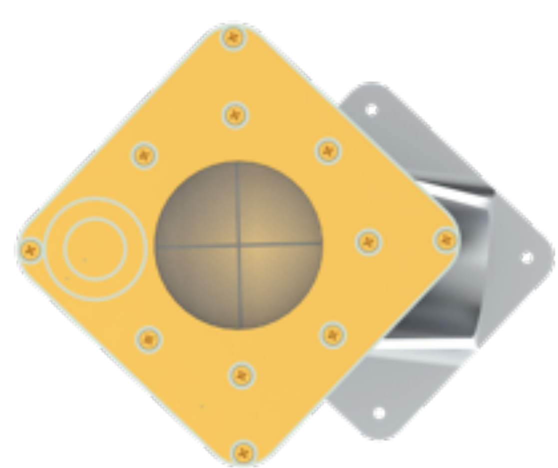


$$I(V_M) = \sum_i I_i(V_M) = A\sum_i q_i n_{oi} U_i \left\{ \frac{1}{2}\left[1 + erf(\beta_i F_i) + \frac{\exp\left[-(\beta_i F_i)^2\right]}{\sqrt{\pi}\beta_i U_i} \right] \right\}$$



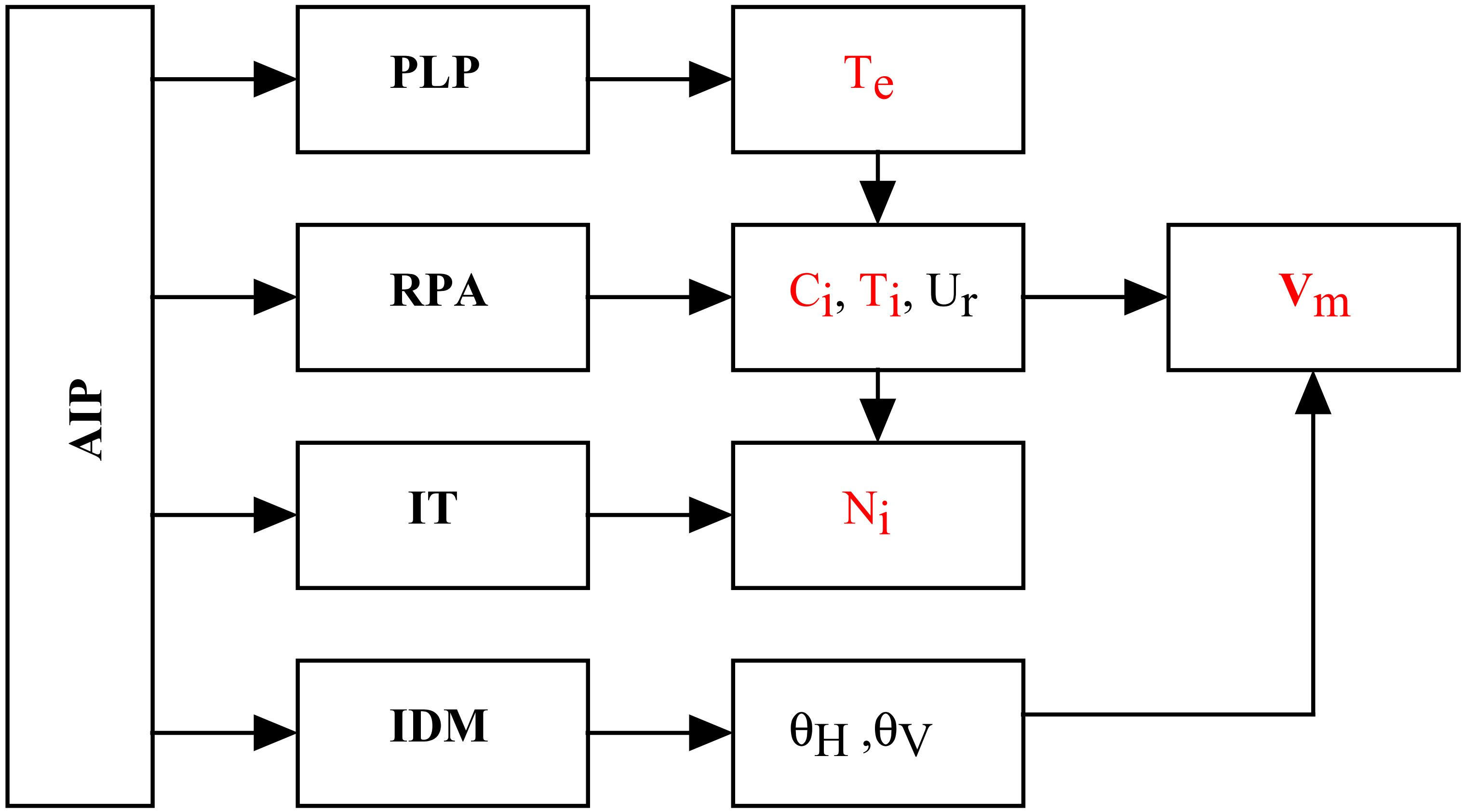
$$\tan\alpha = \left(\frac{W}{2D}\right)\left(\frac{I_1 - I_2}{I_1 + I_2}\right)$$





Mode	N_i	Transverse components of the ion velocity	Others
NORMAL	128 Hz	32 Hz	1 Hz
FAST	1,024 Hz	256 Hz	1 Hz
BURST	8,192 Hz	2,048 Hz	1 Hz

Data flow and capabilities



Parameters	Range	Sensitivity	Accuracy
C_i	3% to 100%	1%	10%
N_i	4×10^2 to 1.2×10^7 cm^{-3}	1%	10%
$\mathbf{V}_i$	±3.2 km s^{-1} ± 5 km s^{-1} (ram)	± 10 m s^{-1} ± 100 m s^{-1}	± 50 m s^{-1} ± 200 m s^{-1}
T_i	500 to 10,000 K	±50 K	±200 K
T_e	500 to 10,000 K	±50 K	±200 K

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Fine structures inside the equatorial spread F

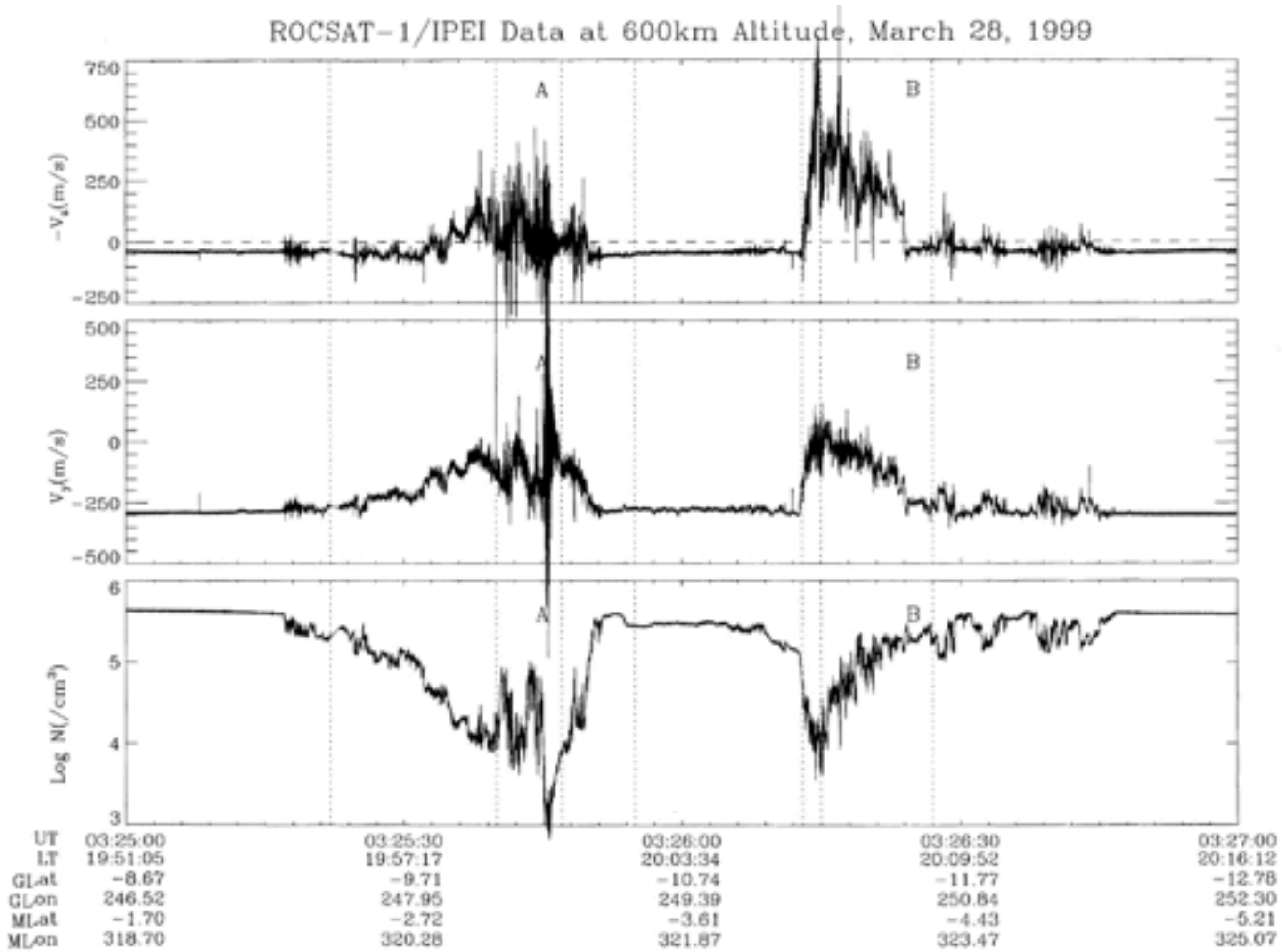


Figure 2. The expanded plot of Figure 1 for the time period 0325-0327 UT for bubble A and bubble B near the magnetic equator. The corotation component in V_y has been removed. Vertical dotted lines indicate the locations of sampled 1-s power spectra plotted in Figure 3.

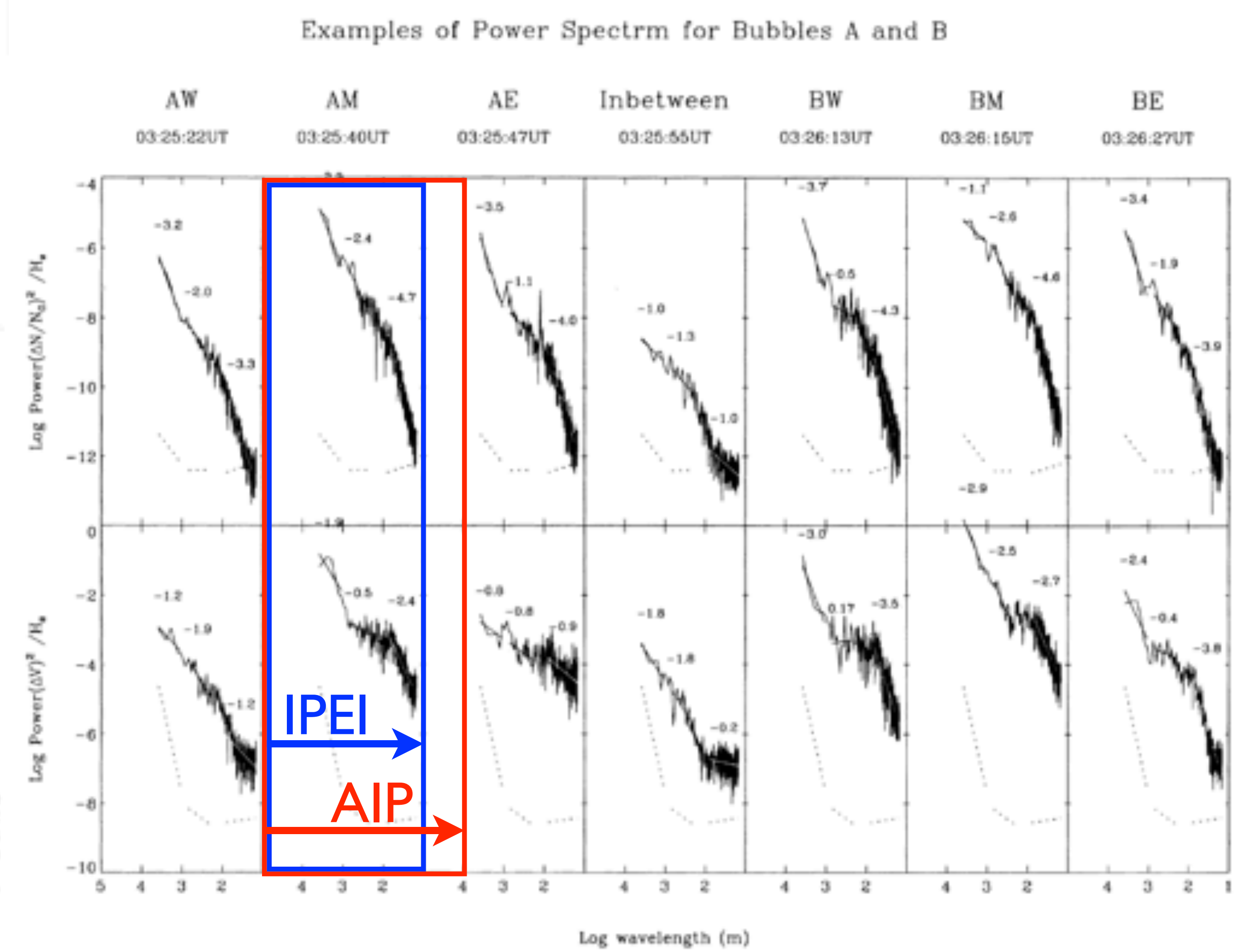
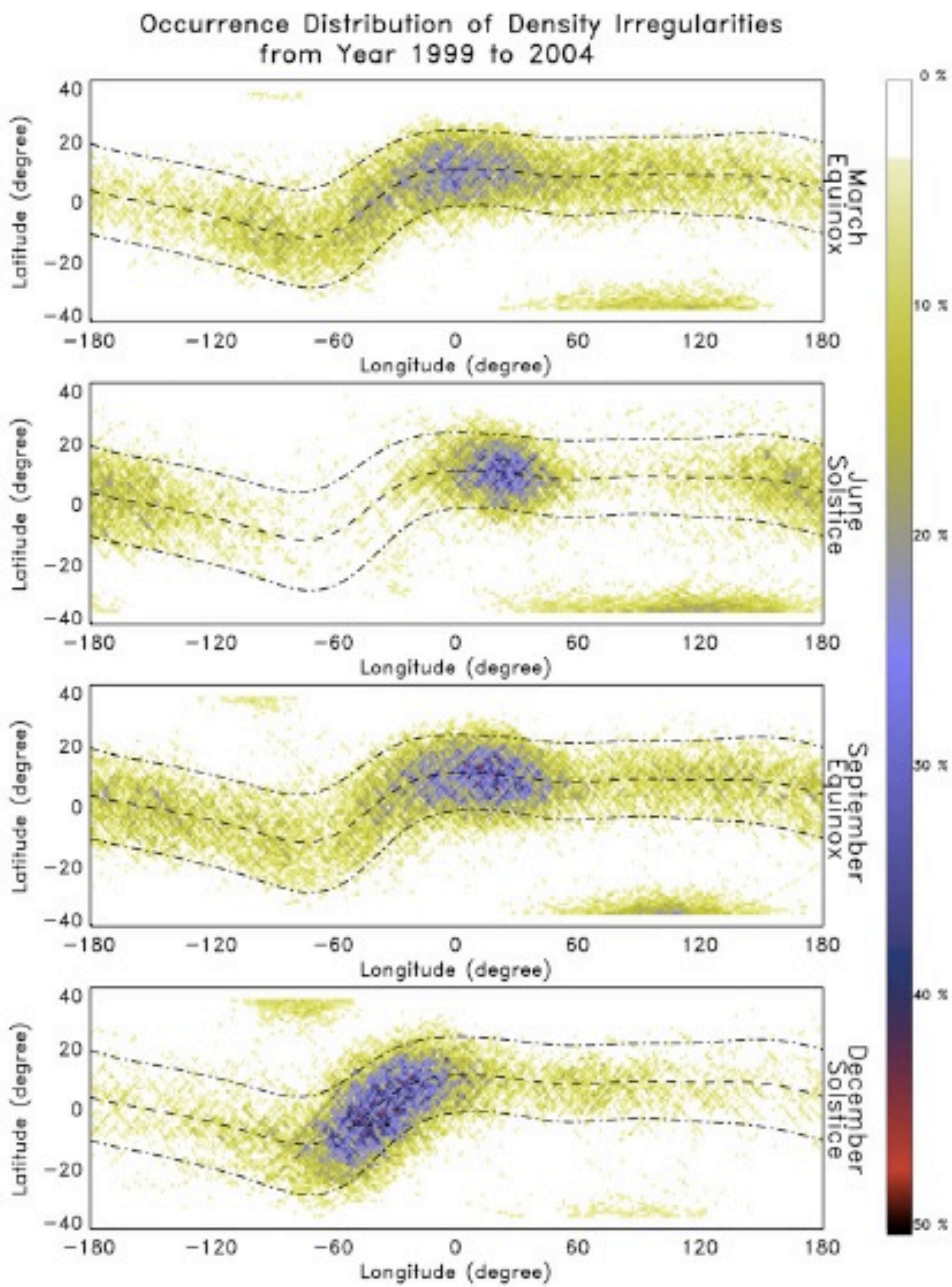


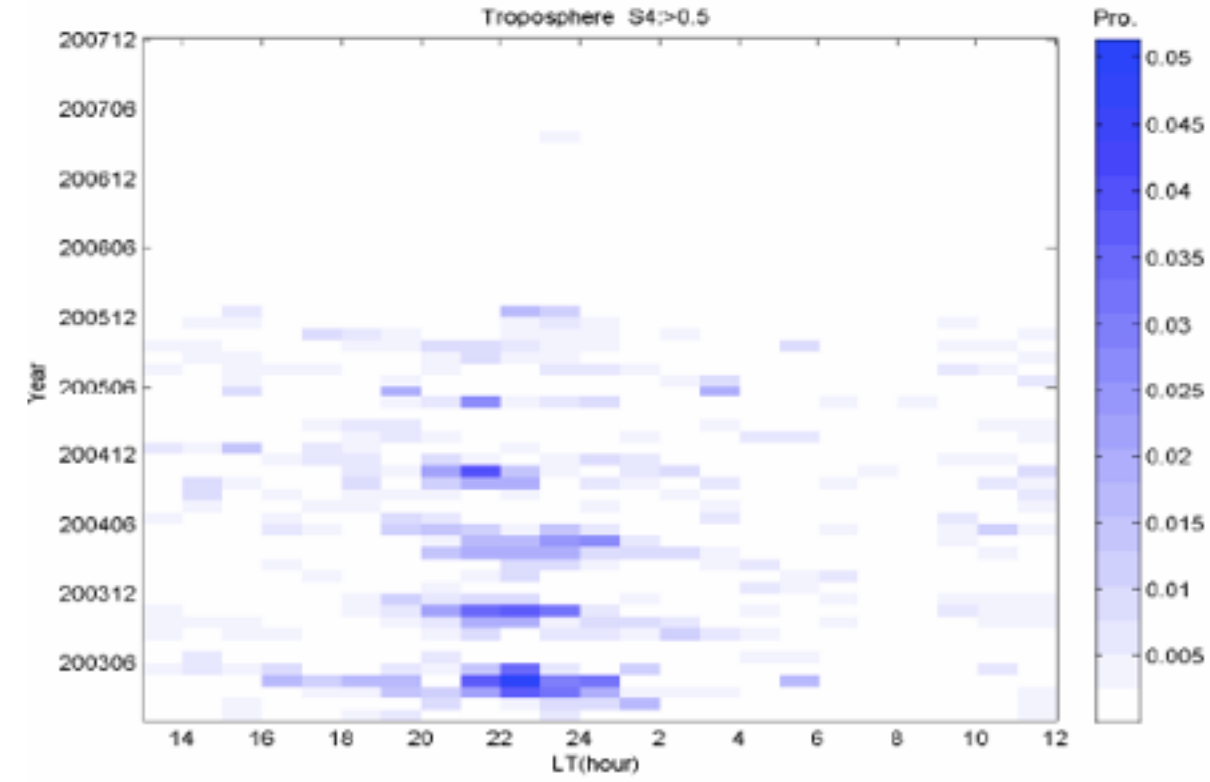
Figure 3. Examples of power spectra for ($\Delta N/N_0$) and ΔV_y fluctuations at various parts of the bubbles as indicated by vertical lines in bubbles A and B in Figure 2.

Su et al., 2001, JGR

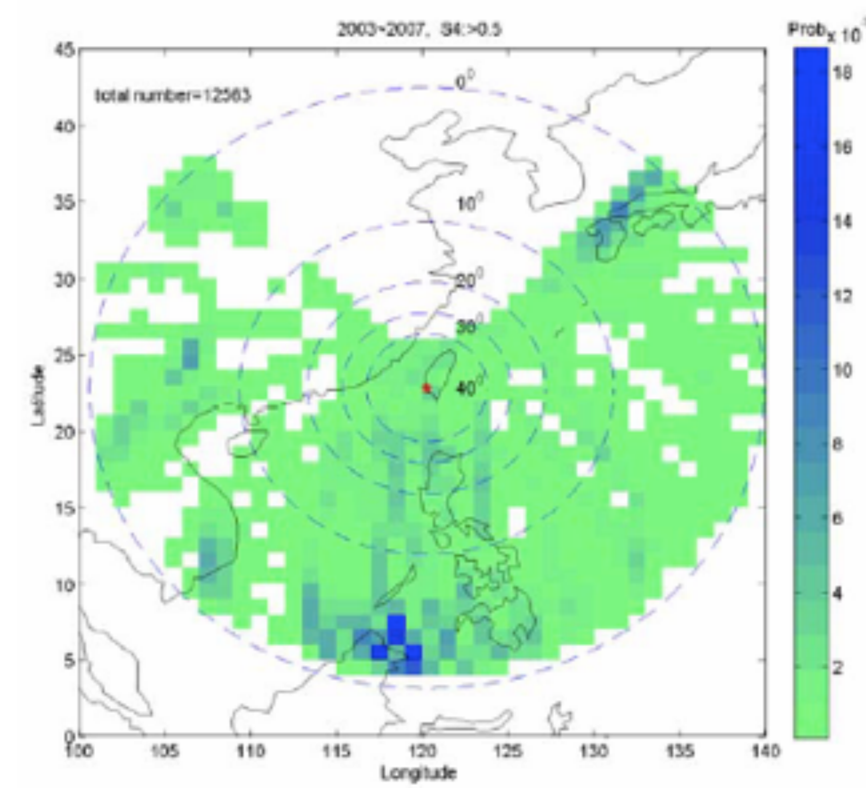
The AIP can explore 8 x finer scale fluctuations than those by ROCSAT-1/IPEI.

Global observations on plasma irregularities





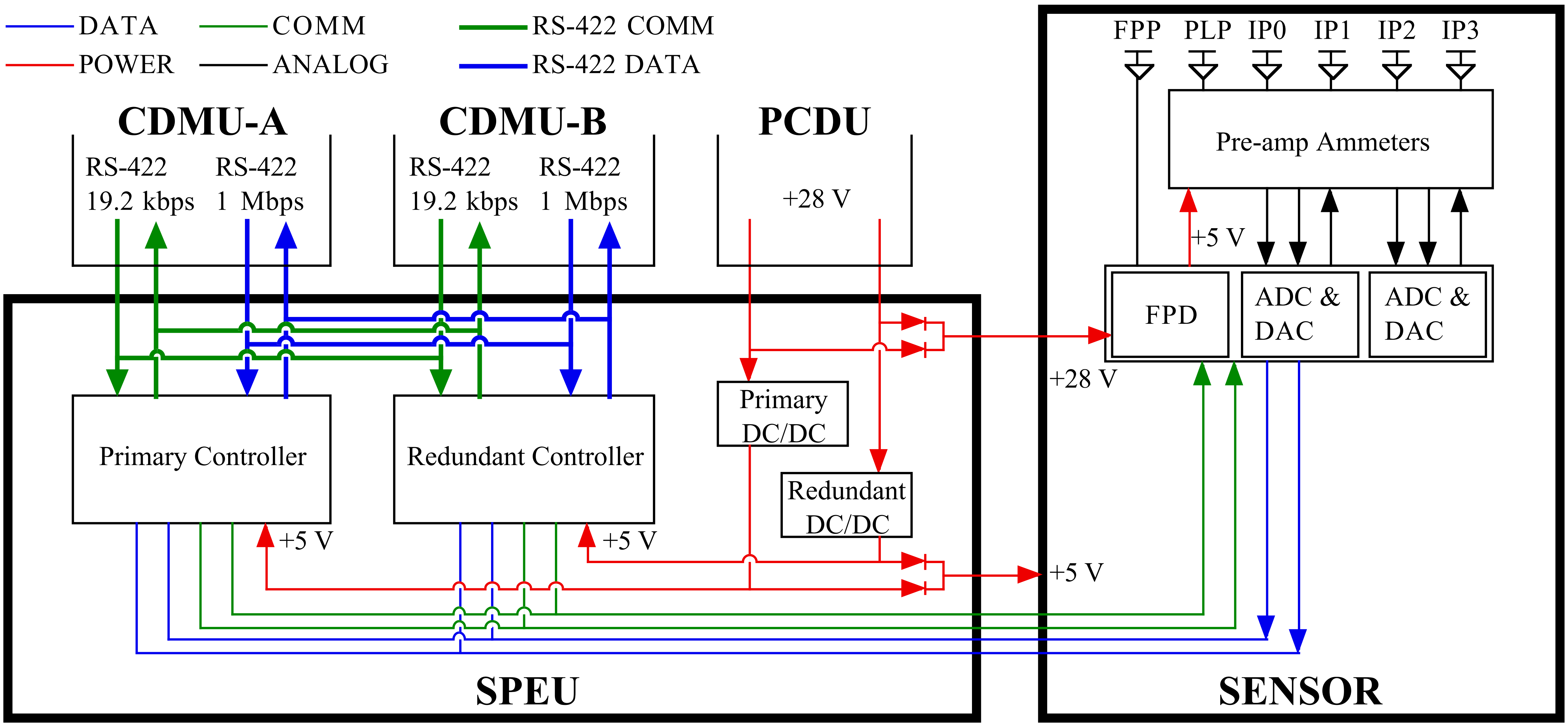
Taiwan GPS scintillations (S_4 >0.5) caused by ESF



Su et al., 2008, JGR

Chang, 2008, master thesis

Functional diagram

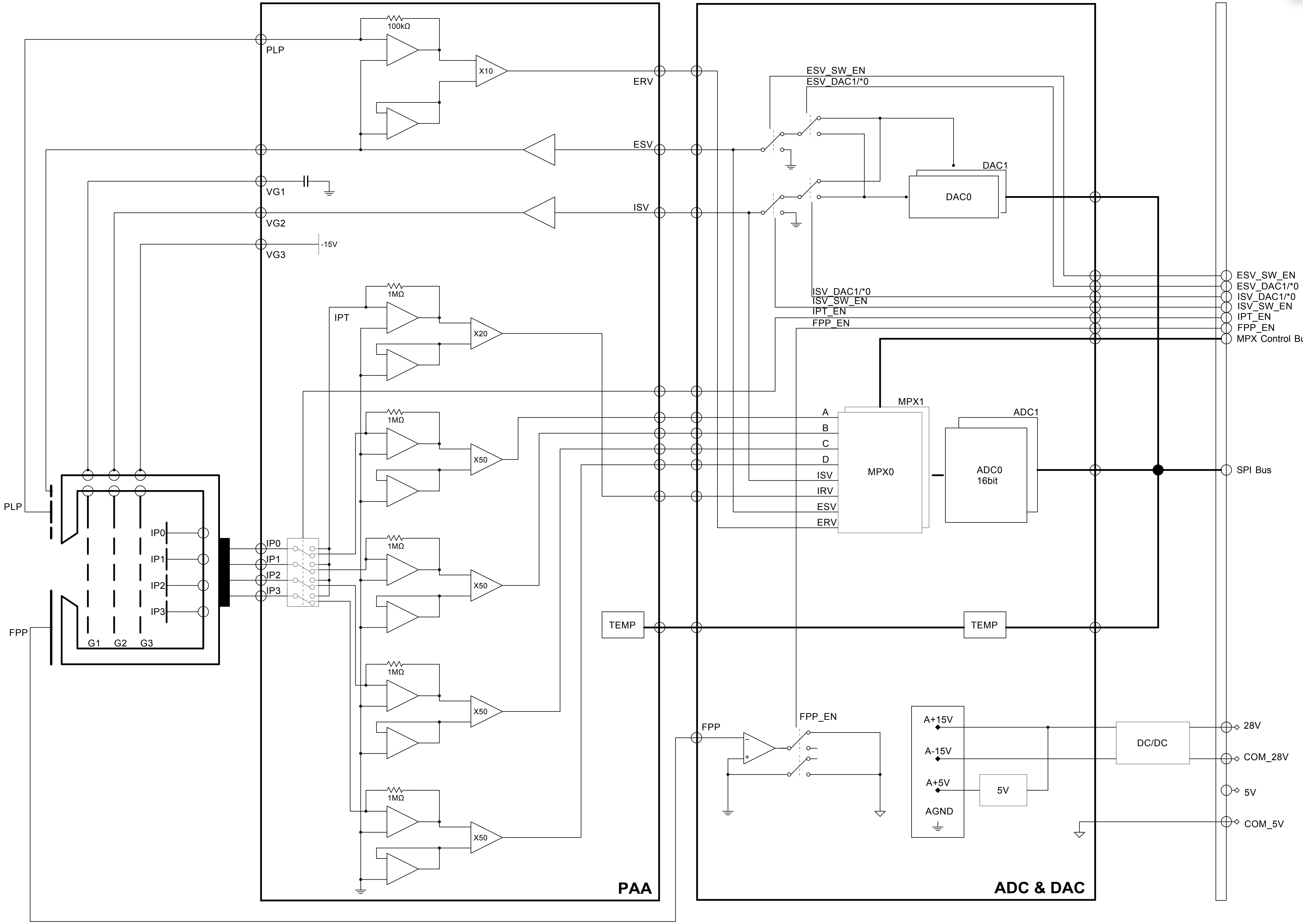


Redundant design for controllers, DC/DC, ADC and DAC, ammeters, etc.

Electrical specification

- Input voltage: 28±6 VDC (> the range between 26 V and 34 V).
- Power: ~**4.74** W in average
  - Sensor: 2.24 W (average).
  - SPEU: ~2.5 W (average).
  - **Single event latch-up protection**.
- Dual command and telemetry interfaces (asynchronous RS-422, 19.2 kbps)
- Dual science data interfaces (synchronous RS-422, 1Mbps)

Block diagram of the sensor



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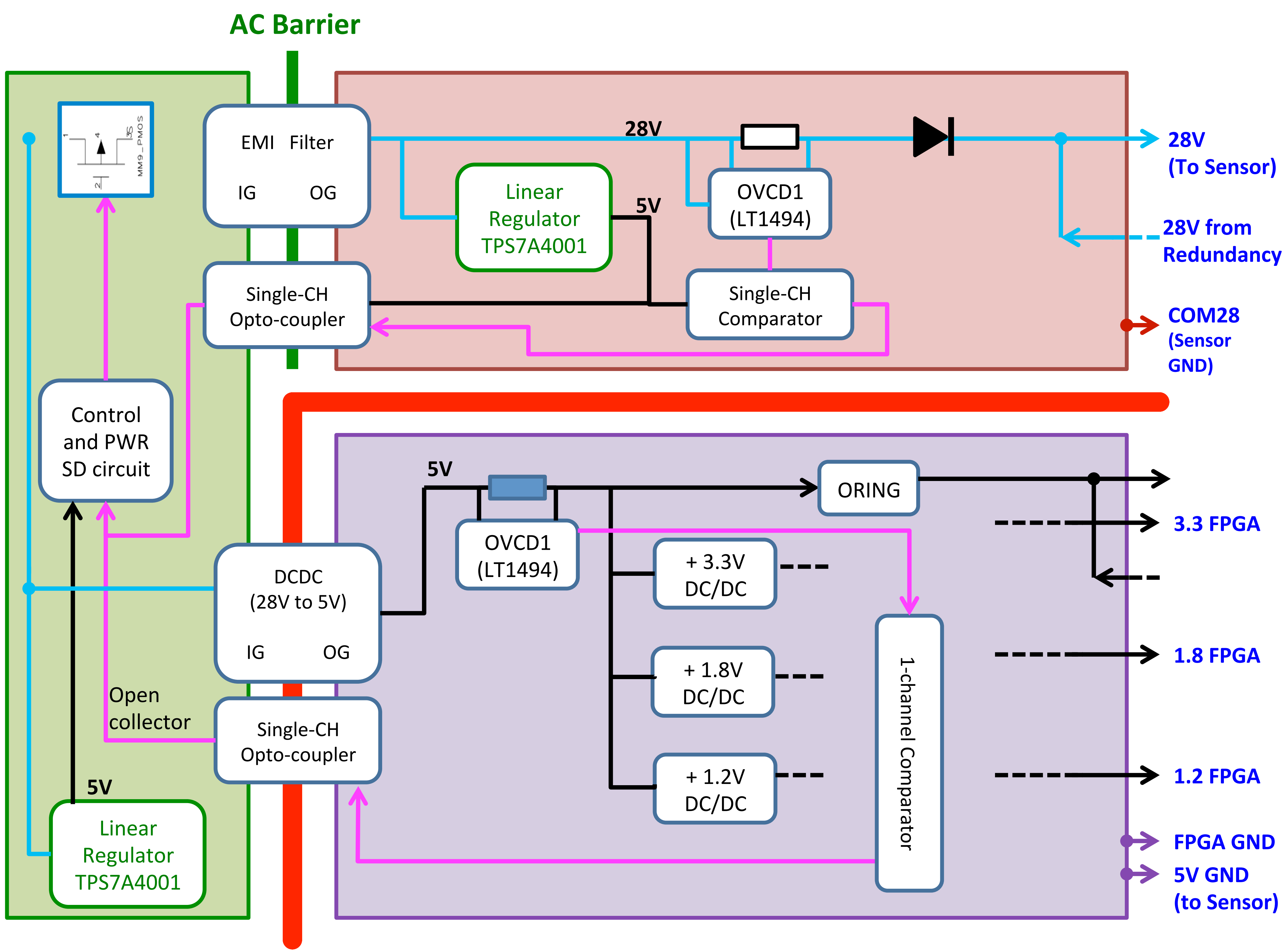
Single event latch-up protection



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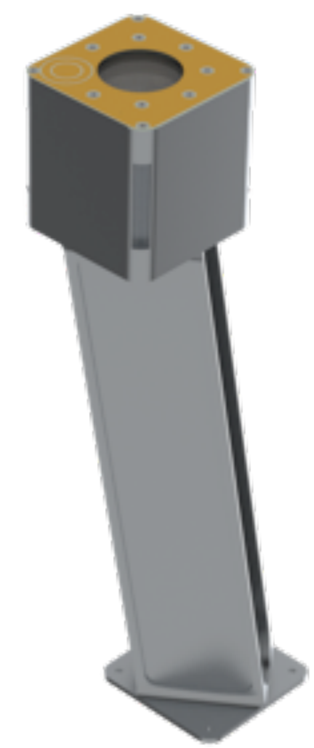
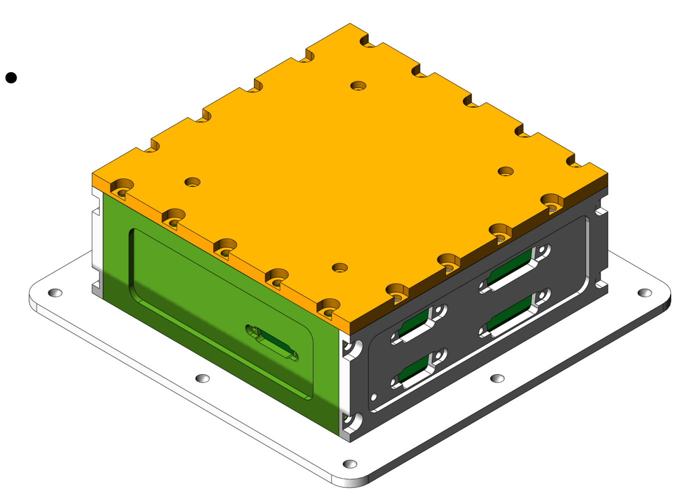
Mechanical specification

- Sensor: **1.46** kg (<1.5 kg) and located on the top panel.
  - Head: 52° field of view (>50°).
    - Dimension: 100 (L) x 100 (W) x 100 mm (H).
    - Weight: 0.582 kg (6061-T6).
  - Stand:
    - Dimension: 140 (L) x 130 (W) x 350 mm (H).
    - Weight: 0.878 kg (7075-T6).



- SPEU: located inside S/C.
  - Dimension: 180 (L) x 180 (W) x 60 mm (H).
  - Weight: ~ 1.950 kg (6061-T6).
- Harness from SPEU to sensor: < 1 kg.
- Total mass: ~ **4.448** kg (< 5 kg).



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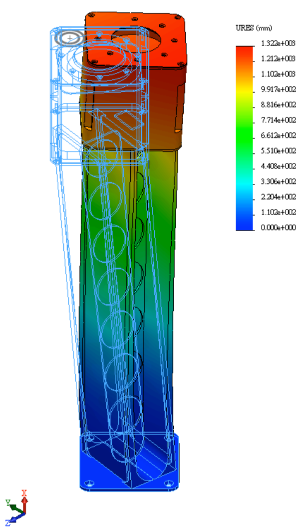
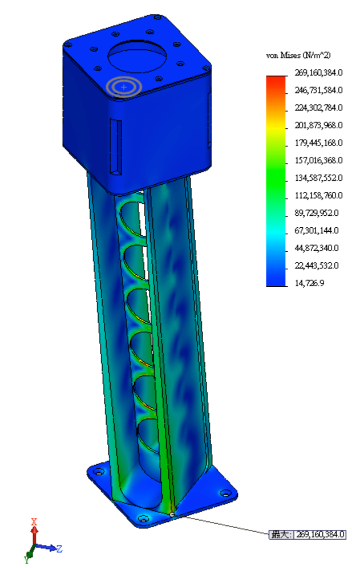
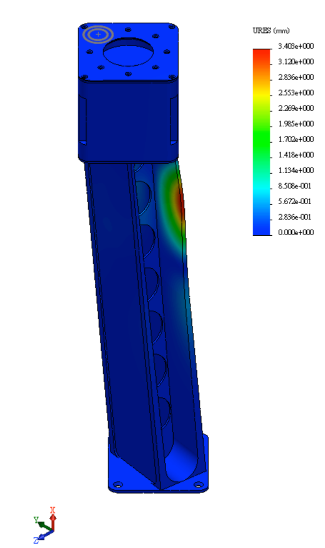
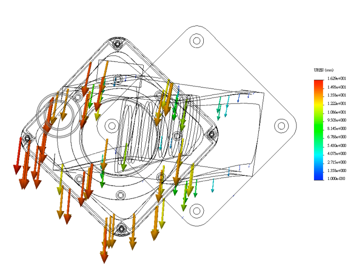
Structure analysis for sensor

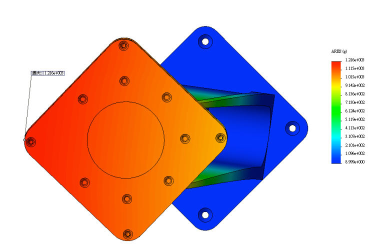
- Natural frequency: **145.6** Hz (>120 Hz).
- Load factors
  - Out of plane: **70** G (>20 G).
  - In-plane: **52** G (>20 G).
- Margin of safety (MS)
  - Ultimate: **2.10** (> 0).
  - Yield: **2.72** (> 0).
- Buckling safety margin (MS_B): **3.45** (> 0).
- Sinusoidal vibration (no collision during vibration)
  - 9G in-plane.
  - 10-300 Hz.





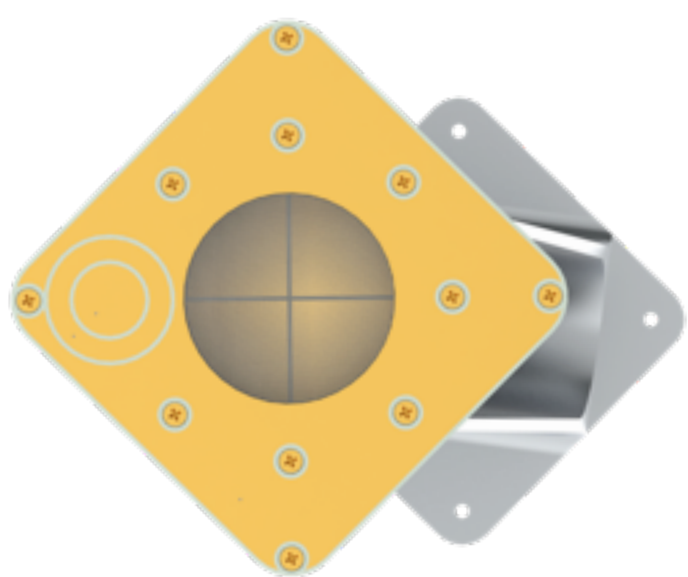


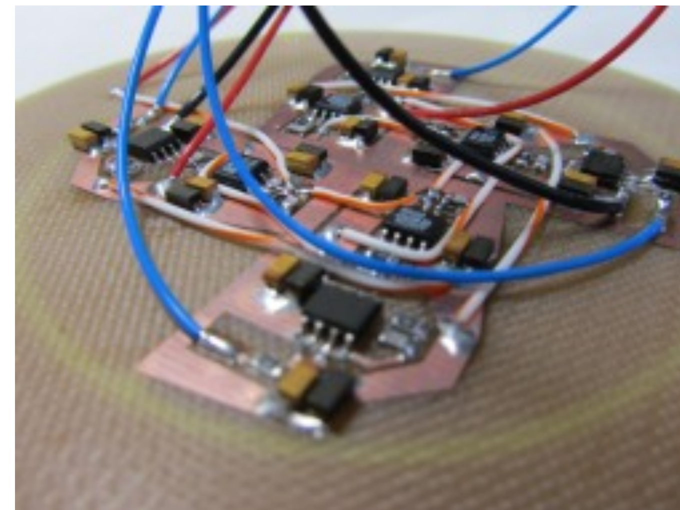


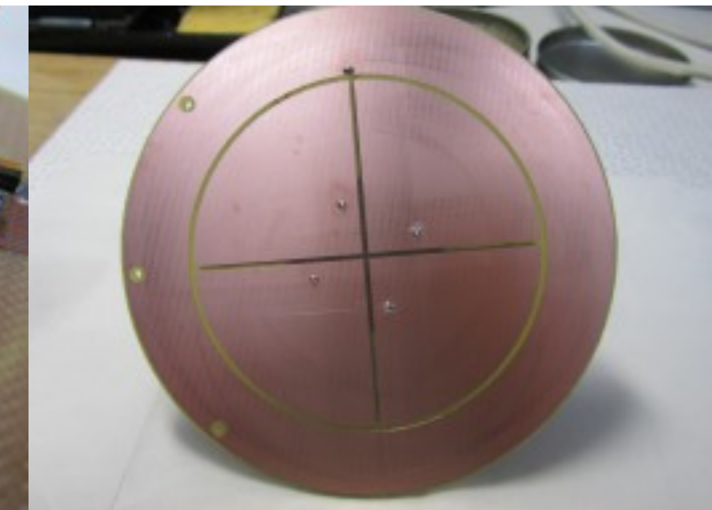


Functional verifications

- IT submode
- RPA submode
- IDM submode
- ISD test







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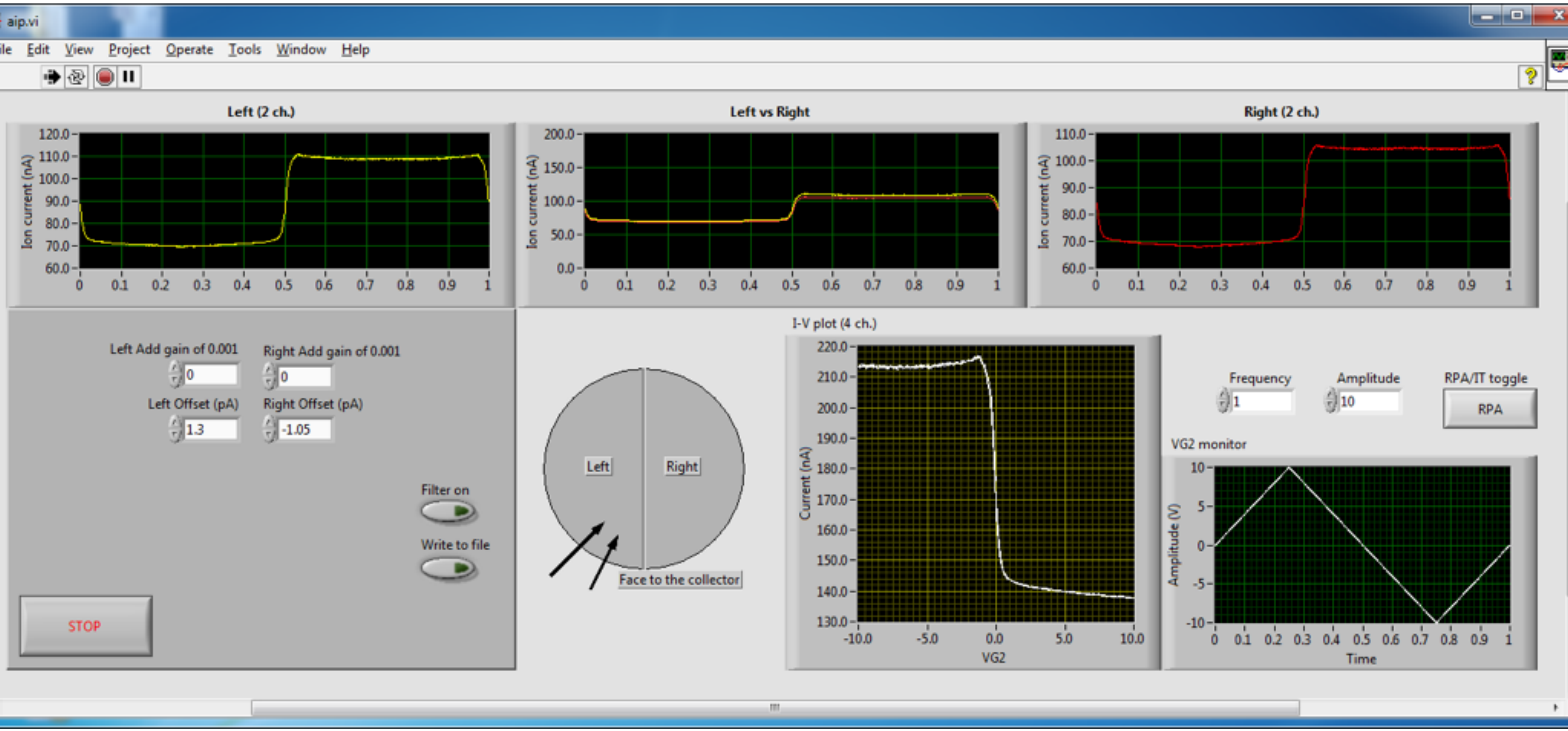
RPA mode (1 Hz)



AIP test on RPA mode with IRV = A+B+C+D (post-sum)

$T_{i\_total} \sim T_{i\_A} \sim T_{i\_B} \sim T_{i\_C} \sim T_{i\_D} \sim 2{,}000$ K

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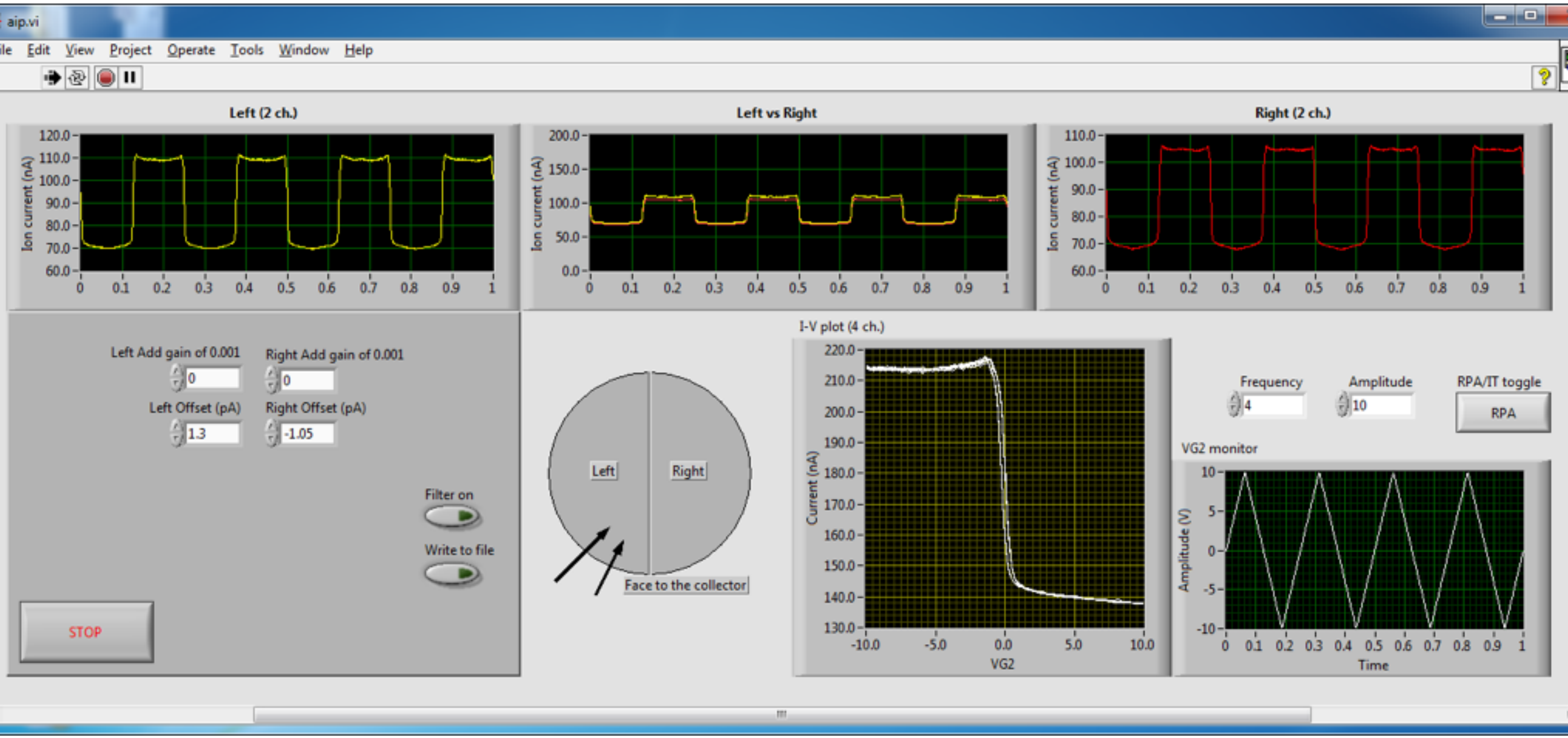
RPA mode (4 Hz)



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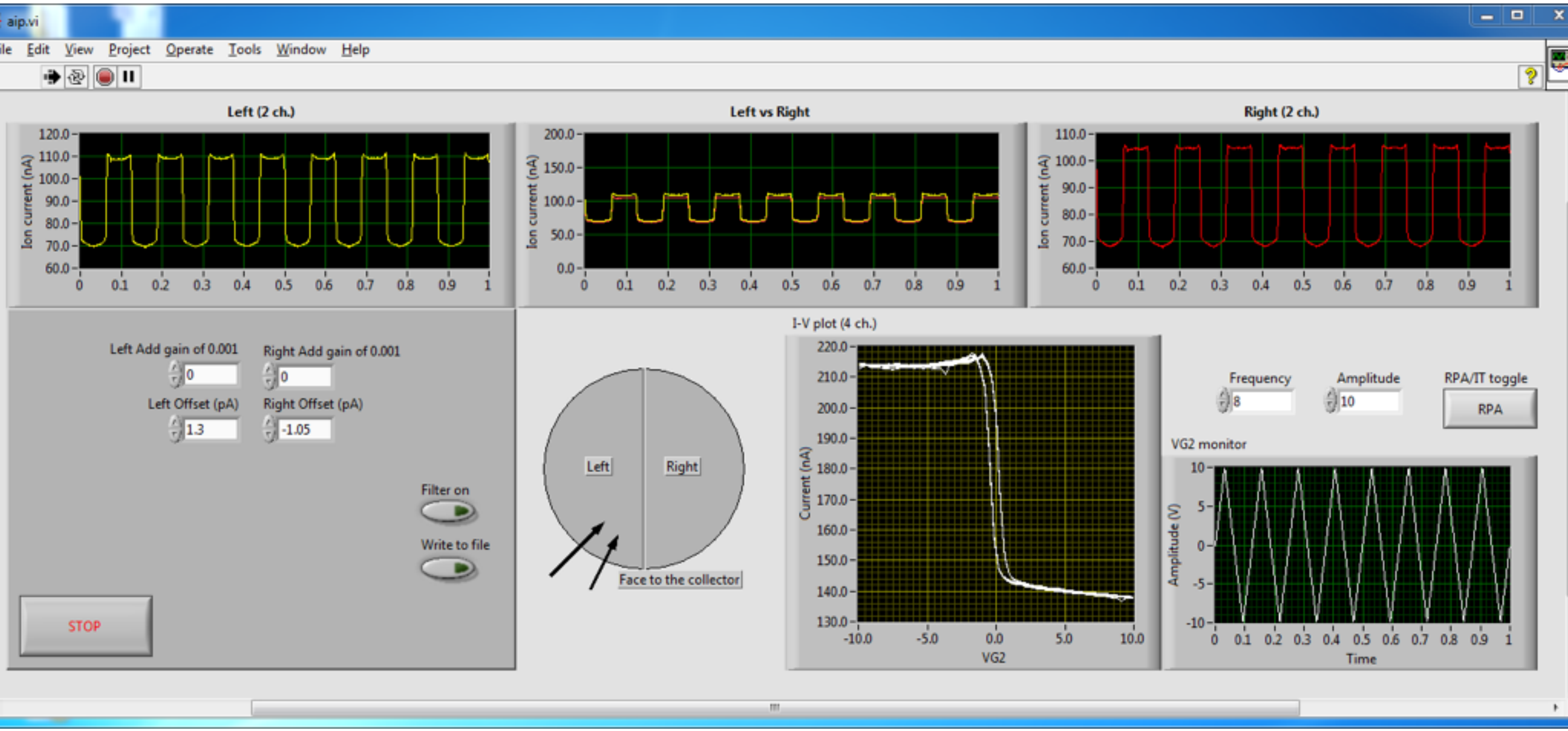
RPA mode (8 Hz)



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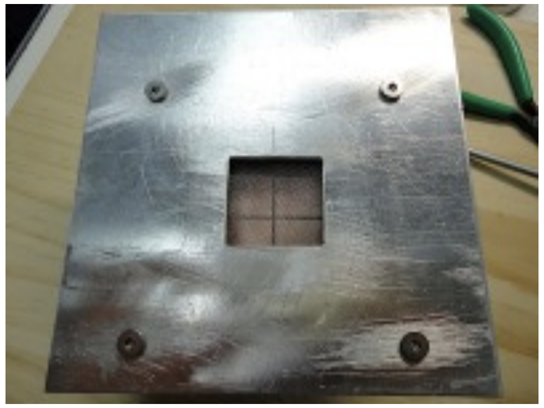
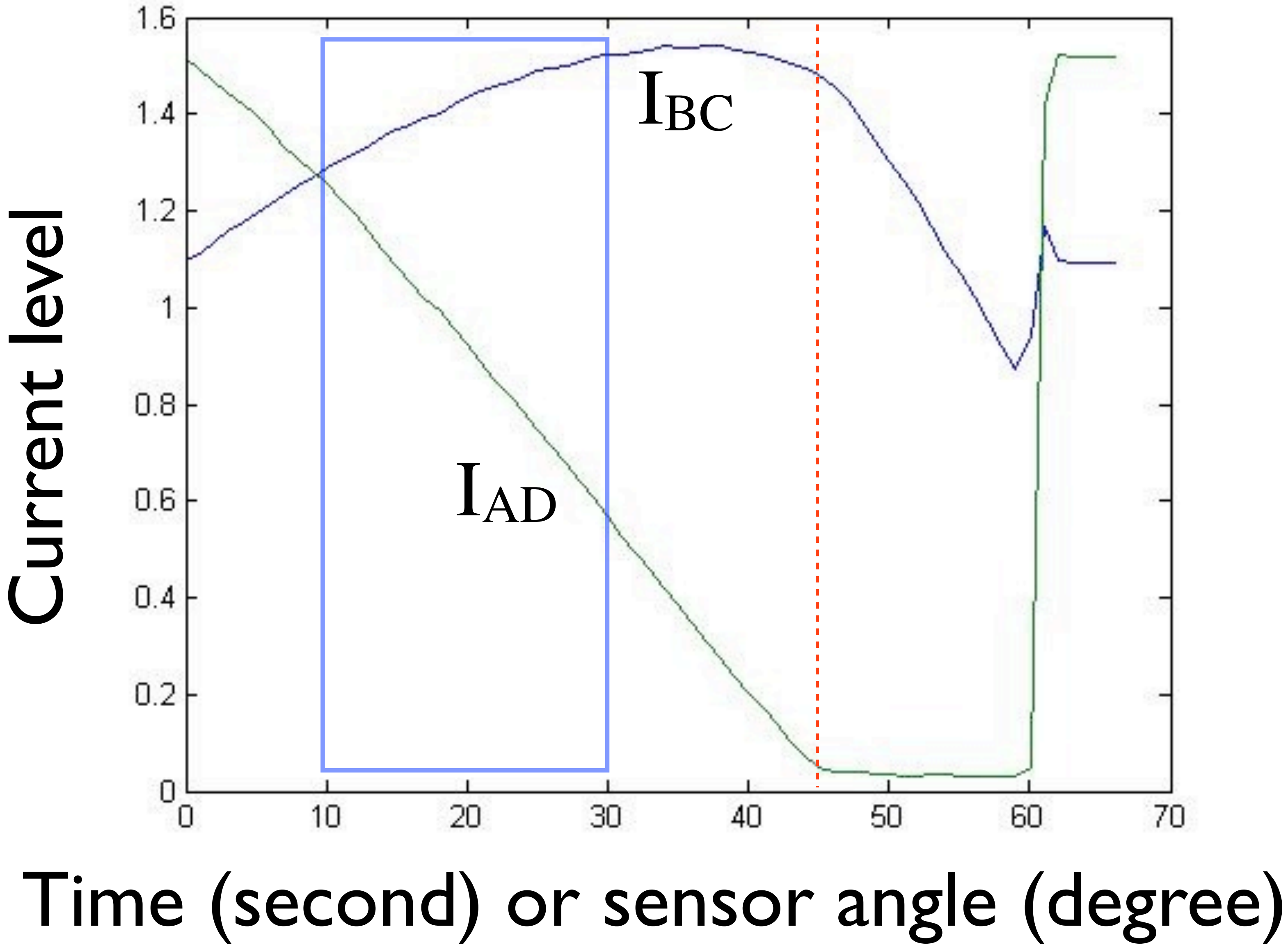
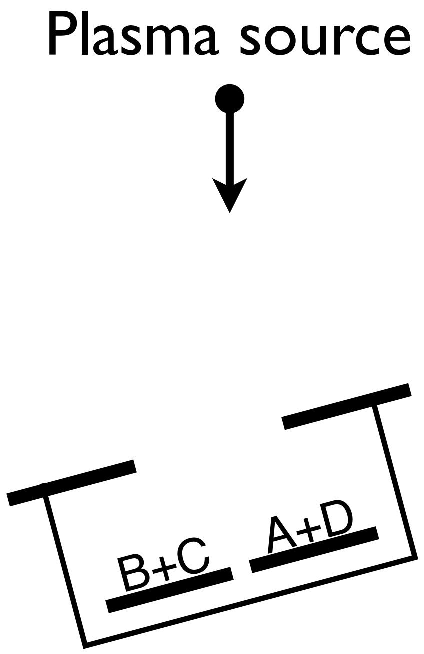
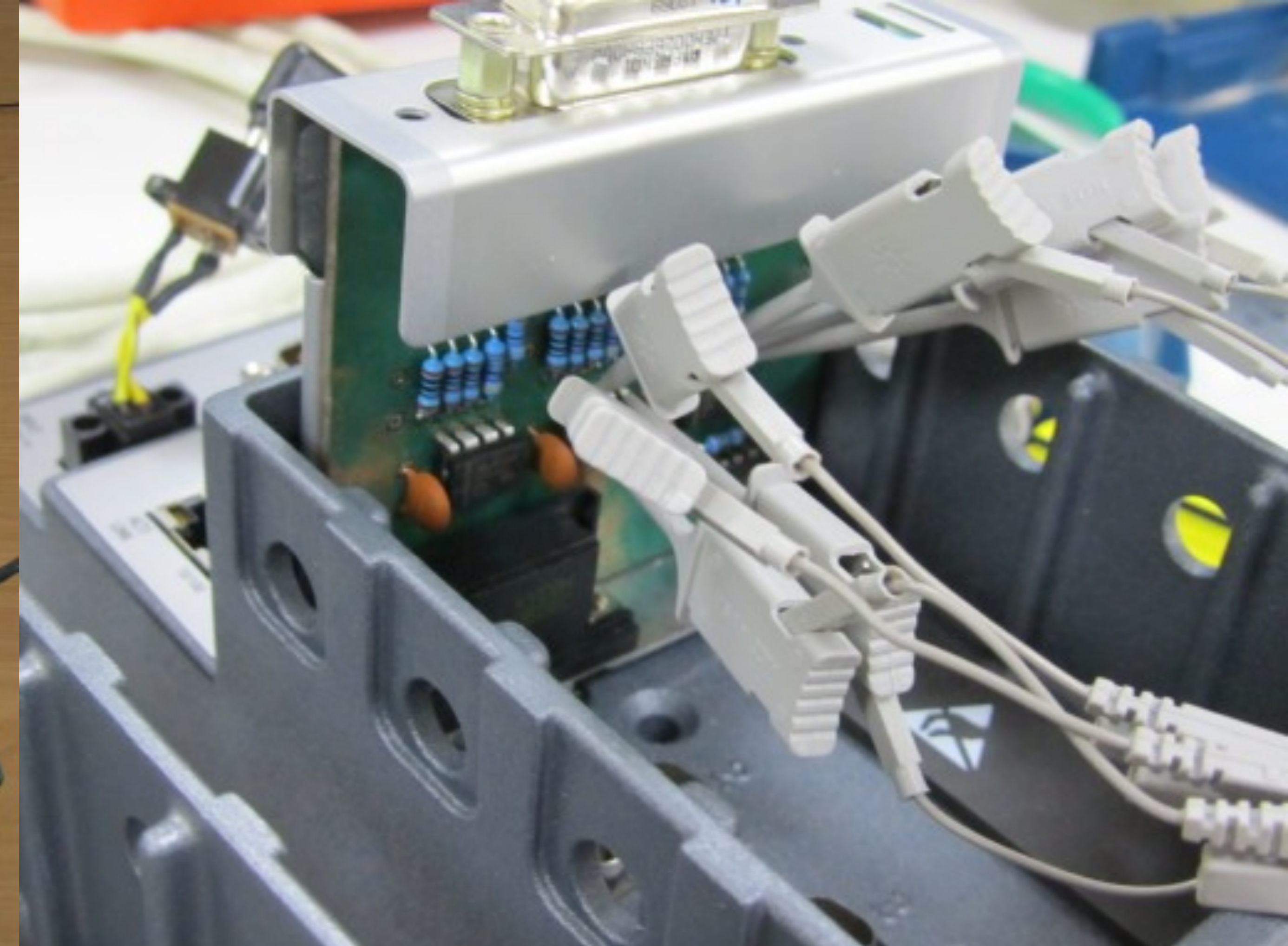
Ion drift meter mode

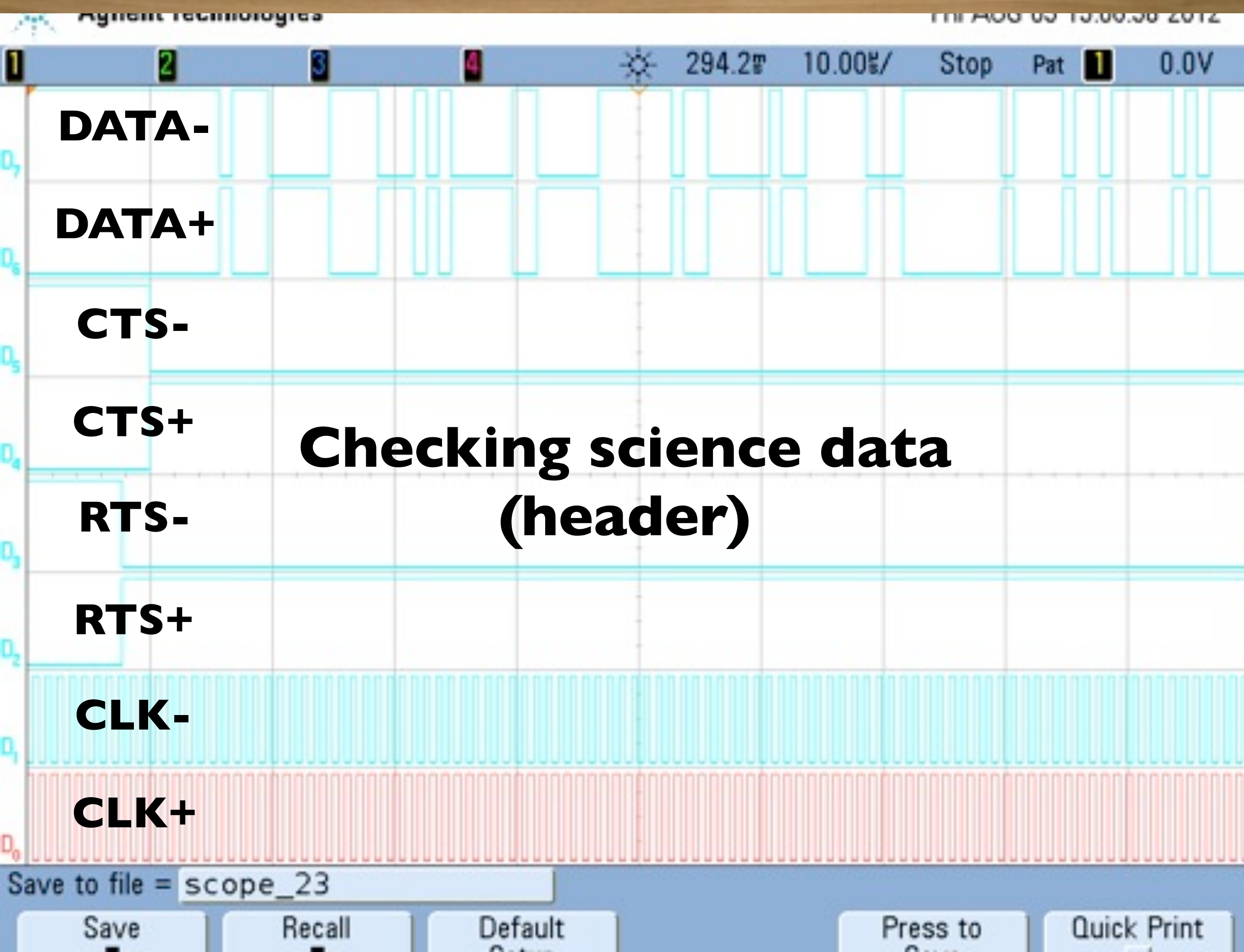


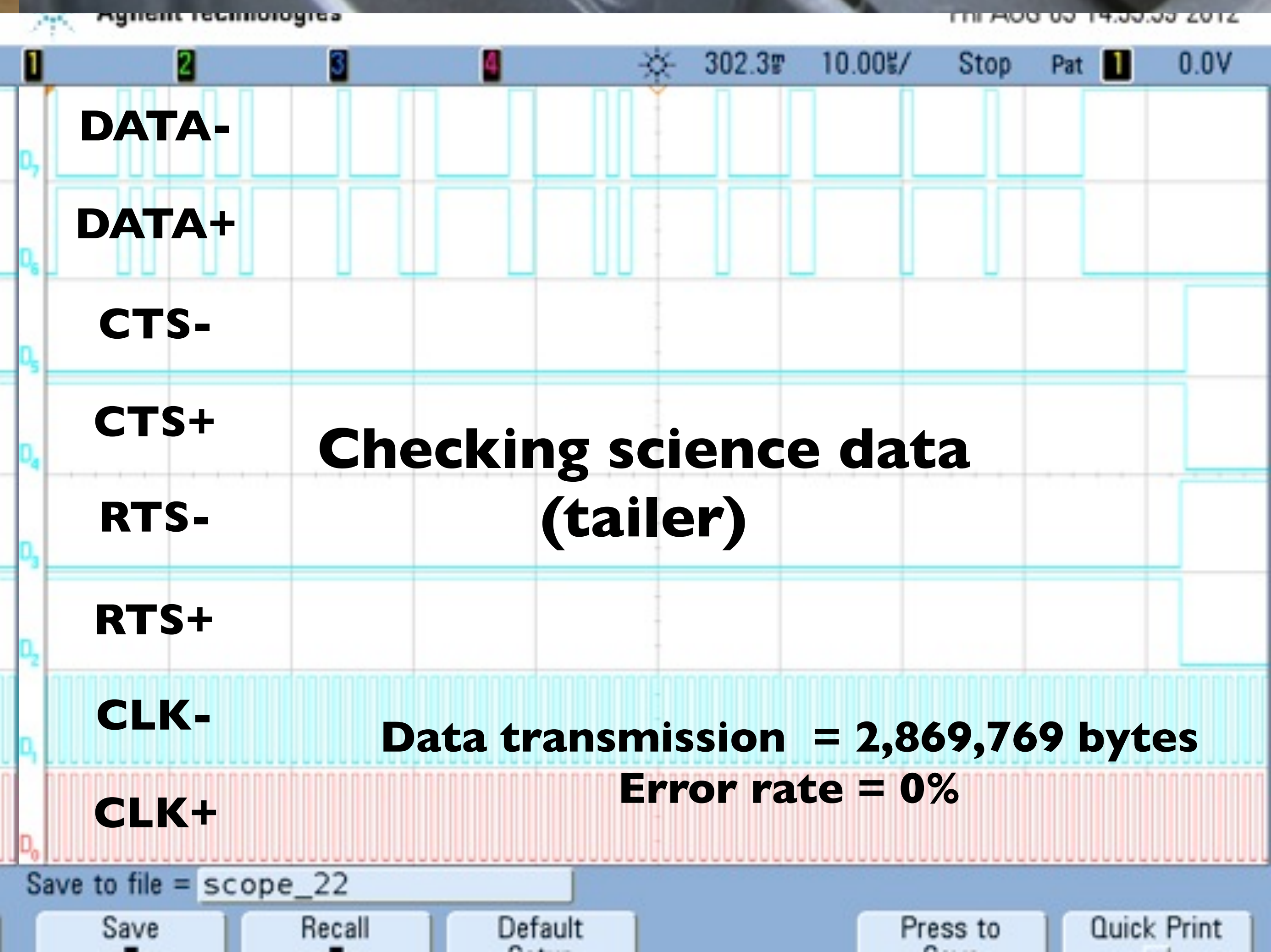





FS-5/AIP ISD Monitor (via RS-232)




Stop
Pat
0.0V
DATA-
DATA+
CTS-
CTS+
RTS-
RTS+
CLK-
CLK+
Checking science data (header)
Save to file = scope_23
Save
Recall
Default
Press to
Quick Print


Stop
Pat
0.0V
DATA-
DATA+
CTS-
CTS+
RTS-
RTS+
CLK-
CLK+
Checking science data (tailer)
Data transmission = 2,869,769 bytes
Error rate = 0%
Save to file = scope_22
Save
Recall
Default
Press to
Quick Print

Summary

- AIP progress: **WSD** (1/13/2012) → **MDR & SDR** (3/6/2012) → **PDR** (5/9/2012) → **ISD** (7/10/2012) → **CDR** (9/7/2012) → DRR (1/12/2013) → PAR (8/12/2013) …
- Electrical interfaces and mechanical structure analysis are done.
- A sweeping frequency (1 Hz) is selected for all modes to reduce quasi-hysteresis effect in the I-V curves.
- In the future, the AIP can also be applied to complement GPS radio occultation experiment with in-situ measurements in a constellation (from 7th to 12th) of the FORMOSAT-7 micro-satellites. It is also possible to fit in a nano-satellite configuration to provide complete parameters of ionospheric plasma.