CFV Labs

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Custom Instrumentation

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String Monitoring Device

CFV Labs developed next-generation data acquisition equipment

- Works with higher voltages
  (600, 1000, and 1500 V versions available)
- PV optimized sampling and filtering functionality
- More accurate and higher resolution than string inverters
  - 150 mV / 5 mA resolution over 600 V / 18.5 A range for the 600 V model
  - Maximum error ± 0.13 %;
    (String inverters typically ± 3 % accurate)
- Power and communication lines galvanically isolated

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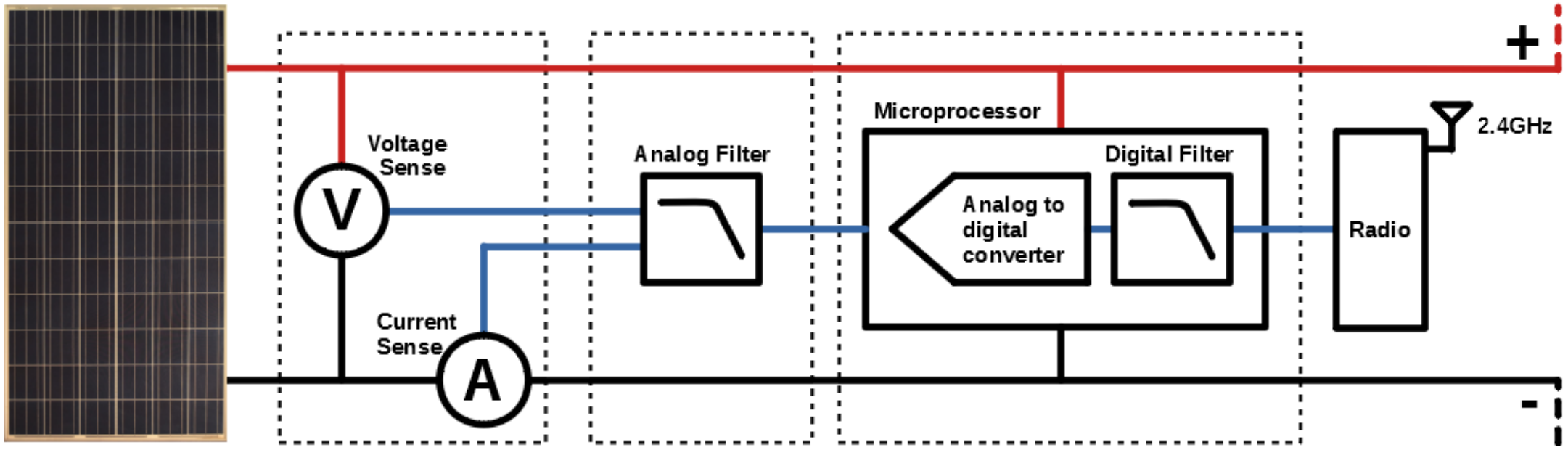
Device-Level Signal Processing



Scale voltage and current

Remove line noise (MPPT, anti-islanding, etc.)

Digitize (200 Hz) and process signal to match time response of irradiance sensor

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First Stage: Analog Filtering

- The DC lines contain high-frequency content due to line-frequency harmonics, perturbations from anti-islanding detection, MPPT searching action, etc.
- Based on the recommendations from a Sandia paper (figures shown below) we implemented an analog filter to remove high-frequency content.

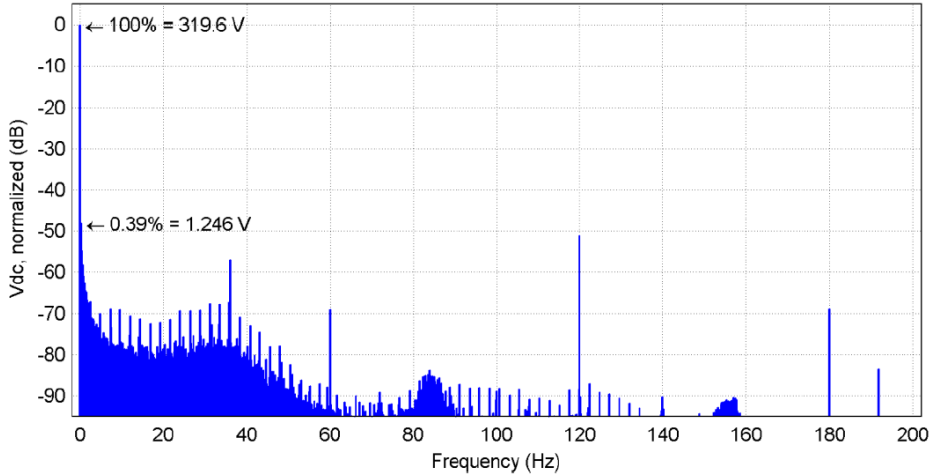

Figure 26 Average spectrum of the DC voltage signal under stable conditions

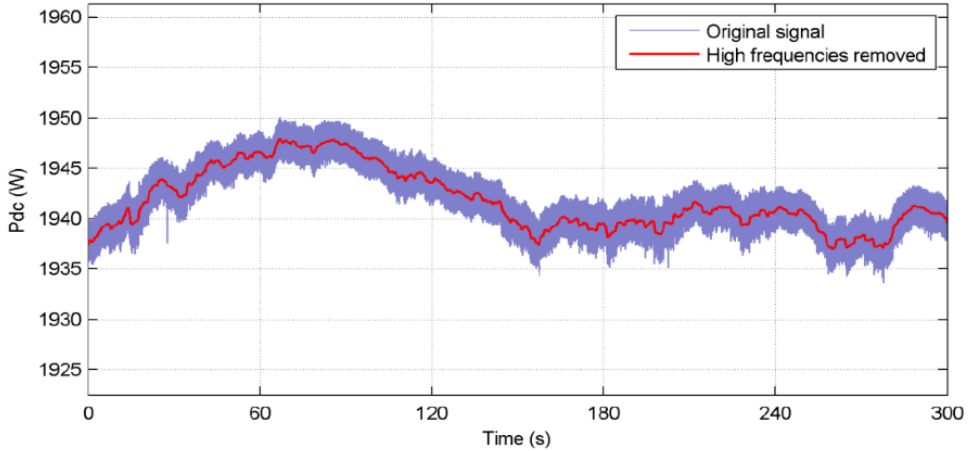

Figure 32 DC power signal with and without high-frequency content

A. Driesse, J. S. Stein, D. Riley and C. Carmignani, "Sampling and Filtering in Photovoltaic System Performance Monitoring," SANDIA REPORT SAND2014-19137.

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Second Stage: High-Speed Sampling and Digital Filtering

- Our device digitizes the signal at 200 Hz and processes it with a microprocessor.
- Current implementation: exponential filter. $y_k = \alpha y_{k-1} + (1-\alpha)x_k$
  - The microprocessor-computed output is polled by the datalogger at a lower frequency.
- Sampling and filtering at the device level simplifies the data collection and storage further down the pipeline.
  - You can scale up the number of devices without overcrowding the wireless network.
  - You are not overwhelmed with excessive data.
- The exponential filter was found effective at matching the time response of the device to an irradiance sensor.

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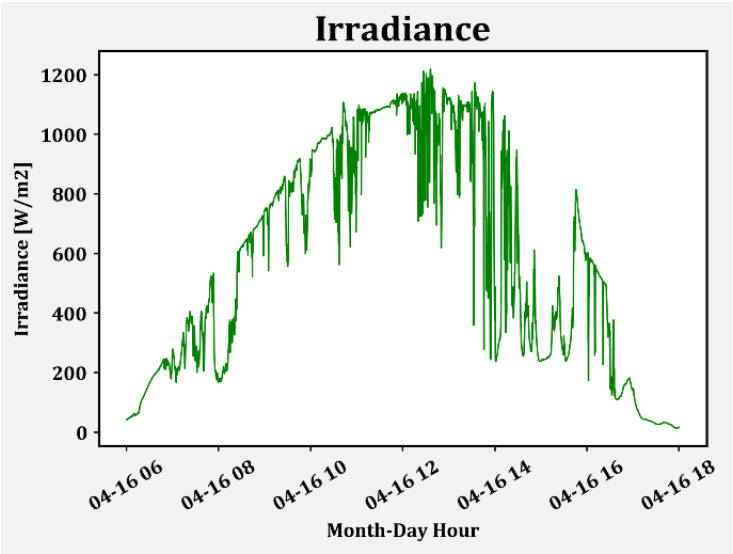
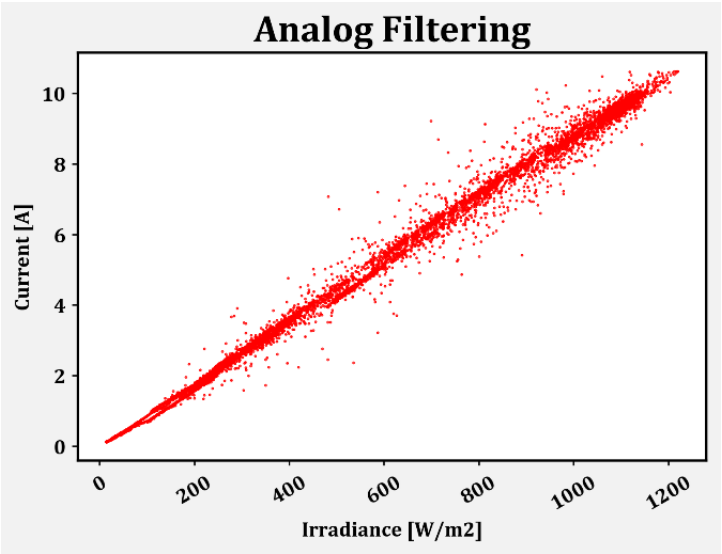
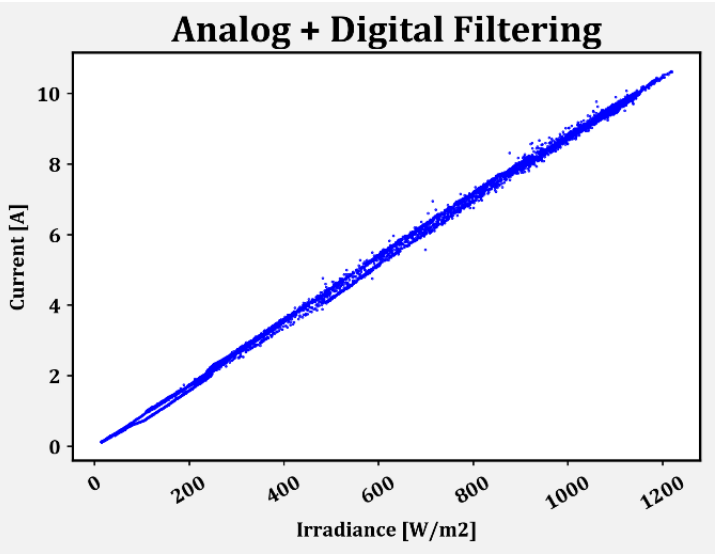
Matching the Time Response to a Pyranometer

- The root cause of the difficulties in analyzing cloudy days is the difference in time response between the pyranometer (slow) and the PV modules (fast).
- Data analysis becomes more straightforward when you match the time response of the module's output reading to the pyranometer (with the digital filter).







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Summary

- CFV's monitoring devices provide high resolution measurements which are beneficial to understanding the details of module performance specifically geared towards bifacial arrays.
- CFV developed its own module monitoring devices, with features optimized for PV monitoring:
  - Analog filtering to remove high-frequency noise specific to PV inverters
  - Digital filtering to match the time response to an irradiance sensor

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Thank you.

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