Australian Government ansto

3GHz Linac RF measurement system using micro-TCA technology

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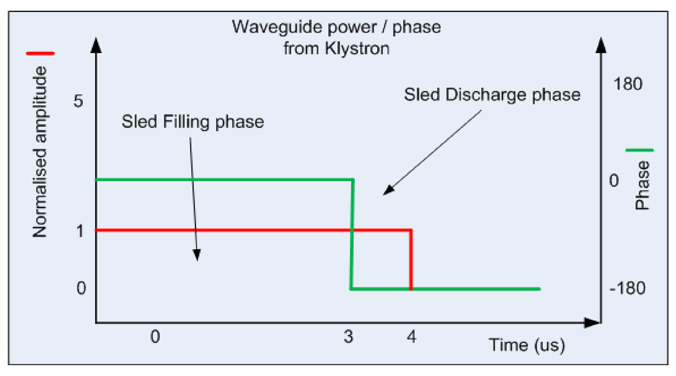
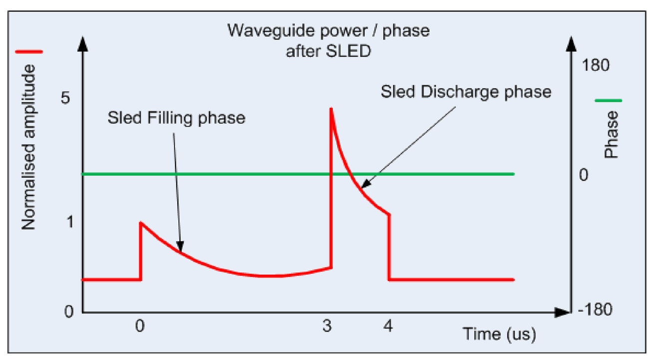
A system for measuring waveforms of RF Power and Phase has been produced using microTCA LLRF technology for use on the Australian Synchrotron pulsed 3GHz linac.

Background / Objective

In May 2017, a SLED cavity (Stanford Linac Energy Doubler) was installed in the Australian Synchrotron linac waveguide system in order to allow full energy injection into the booster ring using only 1 klystron instead of 2.

After installing the SLED cavity, the shape of the RF pulses downstream of the SLED became highly complex with fast changes in both amplitude and phase.





The previous phase and power monitoring system used sample and hold techniques to generate a single measurement per pulse, the system was too slow to allow waveform capture.

A new system was proposed to use digital LLRF techniques for fast waveform capture of RF pulses, revealing the fine structure of the pulses generated by the SLED cavity. 18 RF channels were required to monitor all of the waveguide directional couplers.

Hardware

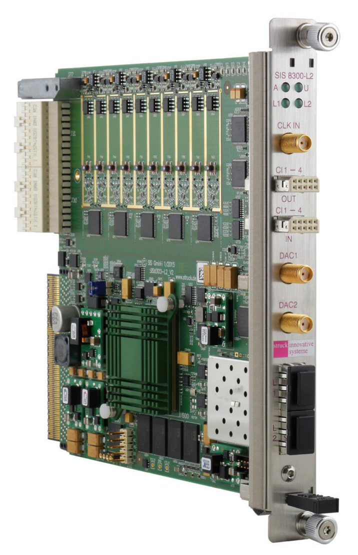
Commercial Off the Shelf (COTS) hardware was used to reduce the risk and effort inherent in building custom hardware. The exception to this was the Local Oscillator generator which was designed and manufactured in house.

Chassis

An NAT Native R5 starter kit was purchased. This consists of a ½ width 5 RU Schroff enclosure and backplane in the microTCA 4 format. An intel i7 processor and solid state hard drive host an EPICS server and perform high-level control and calculation tasks.

Digitisers / RTM

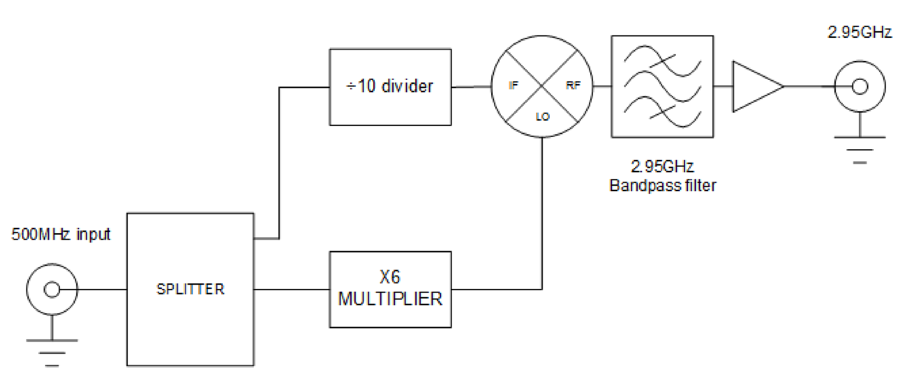
Struck SIS8300-L2 digitizer AMCs in combination with DWC8300 RTM down-converters were used to receive each RF signal, perform heterodyne downconversion to an IF and synchronously sample each channel at a rate of 125MHz. 2 AMC and RTM cards were required giving 20 channels.



LO Generator

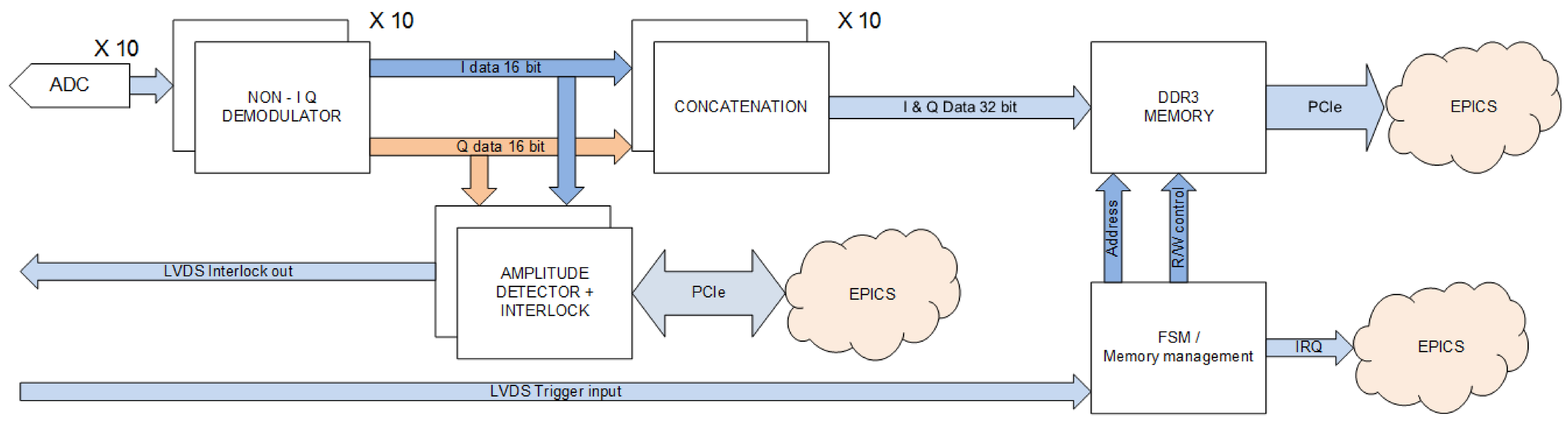
DSP processing is performed at an IF of 50MHz. An LO generator was produced to provide a synchronized 2.95GHz signal for mixing with 3GHz RF channels.

A divide by 10 module converts 500MHz from the machine to 50MHZ which is mixed with a 3GHz giving spurs at 2.95 and 3.05GHz. The 2.95 GHz signal is then selected using a band pass filter. The LO generator is temperature stabilized to $\pm$ 0.1 degrees C to reduce drift.



Firmware / Software

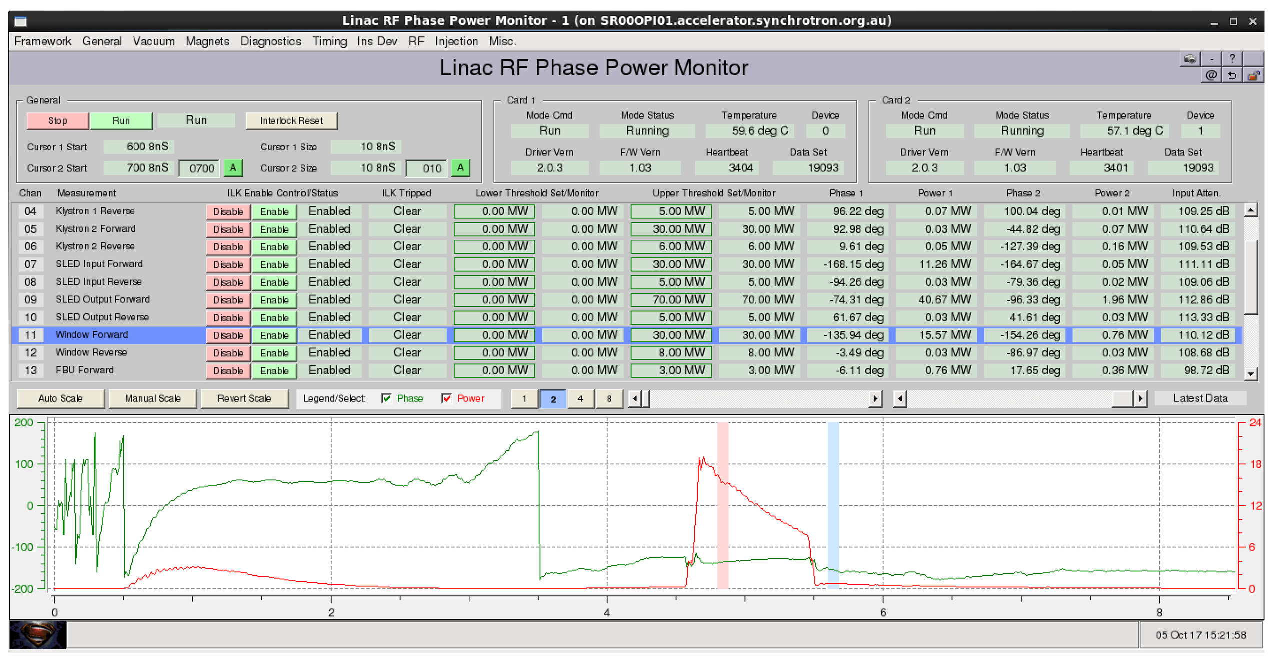
FPGA



EPICS / GUI

An EPICS IOC communicates with the FPGA over the PCI express bus. 1 channel of each AMC / RTM samples the machine 3GHz reference. The phase of the reference is subtracted from the phase of all other channels in the epics layer. A conversion from raw ADC voltage to calibrated power via a look up table is also performed by the IOC.

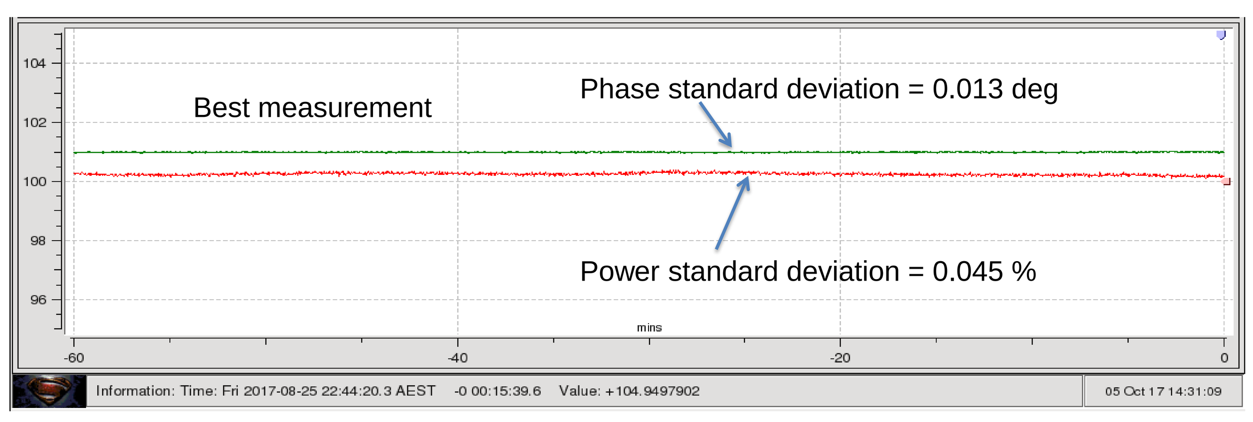
An operator control panel has been provided which allows remote programming / resetting of interlocks, and display of measured waveform data for each RF channel.



Measurement Performance

In order to establish the performance of the system under ideal conditions, ADC channels were driven by a high performance RF signal generator. Statistics were recorded for each channel.

Parameter	Specification	Measurement (mean across all ch)
10 minute phase Std. Deviation	0.1 degrees	0.03 degrees
24 Hour phase std. deviation	0.1 degrees	0.0337 degrees
10 minute power std. deviation	0.1% (W)	0.0627%
24 Hour power std. deviation	0.1% (W)	0.0898%
Rise / Fall time (10-90%)	60ns	40ns
Dynamic range (20dB above noise floor – max)	40dB	49dB
Interlock triggering time	100ms	1.5ms



Conclusion / Future plans

A very useful, accurate system has been produced to monitor RF Power and phase waveforms within a short pulse linac system. Future upgrades will include RF pulse generation, potentially employing phase modulation and pulse to pulse feedback.

Investigations into the use of microTCA technology for a future 500MHz LLRF system are continuing. We are open to suggestions from our community of experts and potential collaborations.