DEVELOPMENT OF RF PEAK DETECTOR AND PHASE MONITORING UNIT AT THE AUSTRALIAN SYNCHROTRON

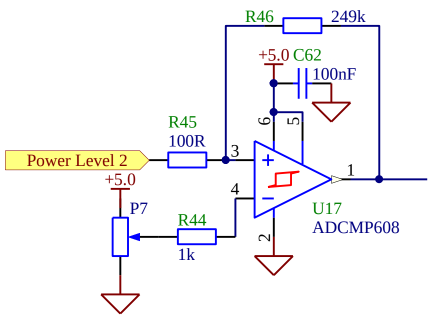
Supported by

Australian Government

State Government Victoria

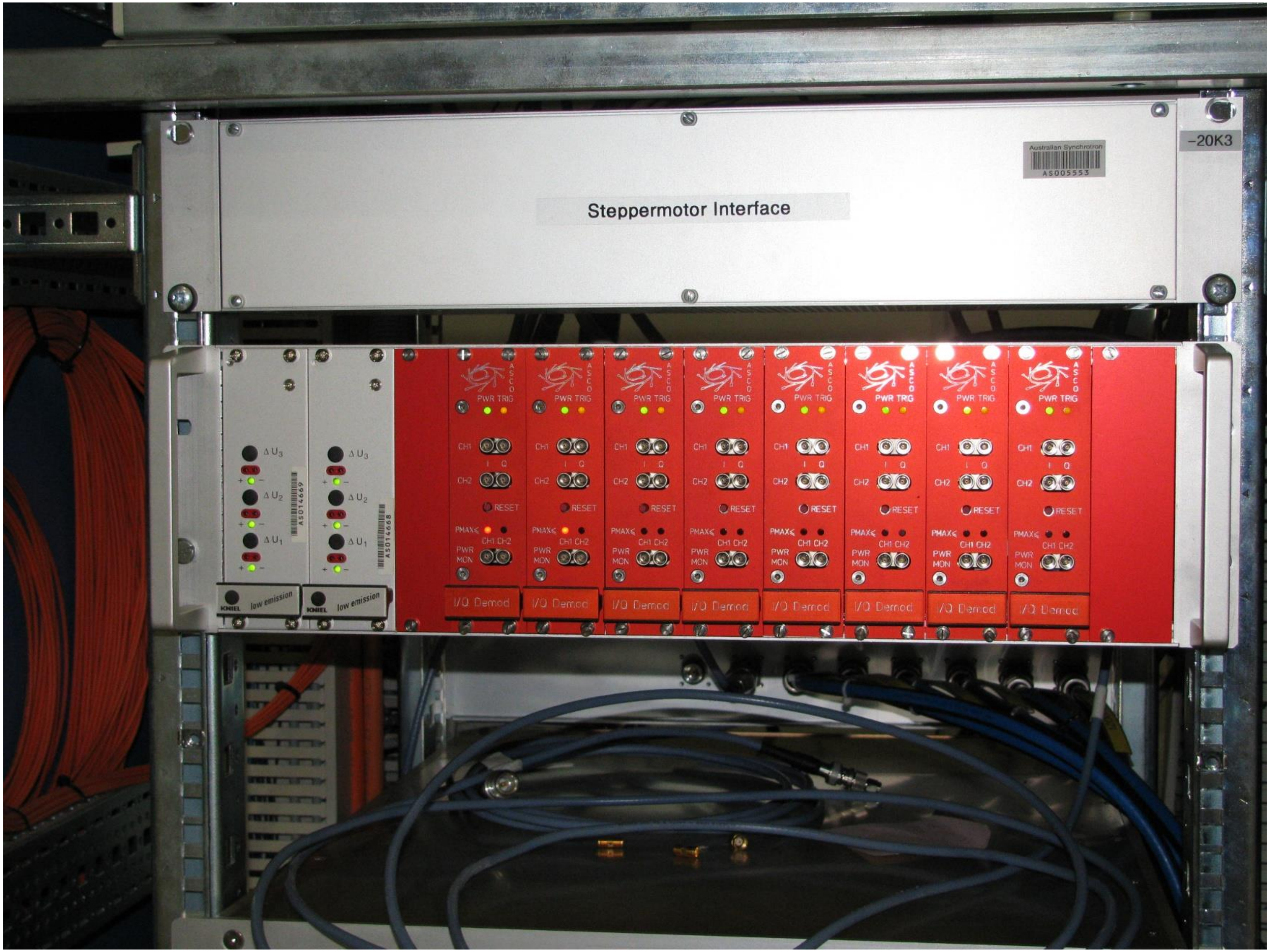
THE NEED

- Existing system had insufficient Peak Detector accuracy
- Existing Peak Detector was also manifesting stability and/or noise issues
- Availability of spares - customized solution
- We needed phase monitoring system to improve diagnostic
- Possibility of saving space



Power comparator – very, very bad example of reference voltage

WHAT WE BUILD?

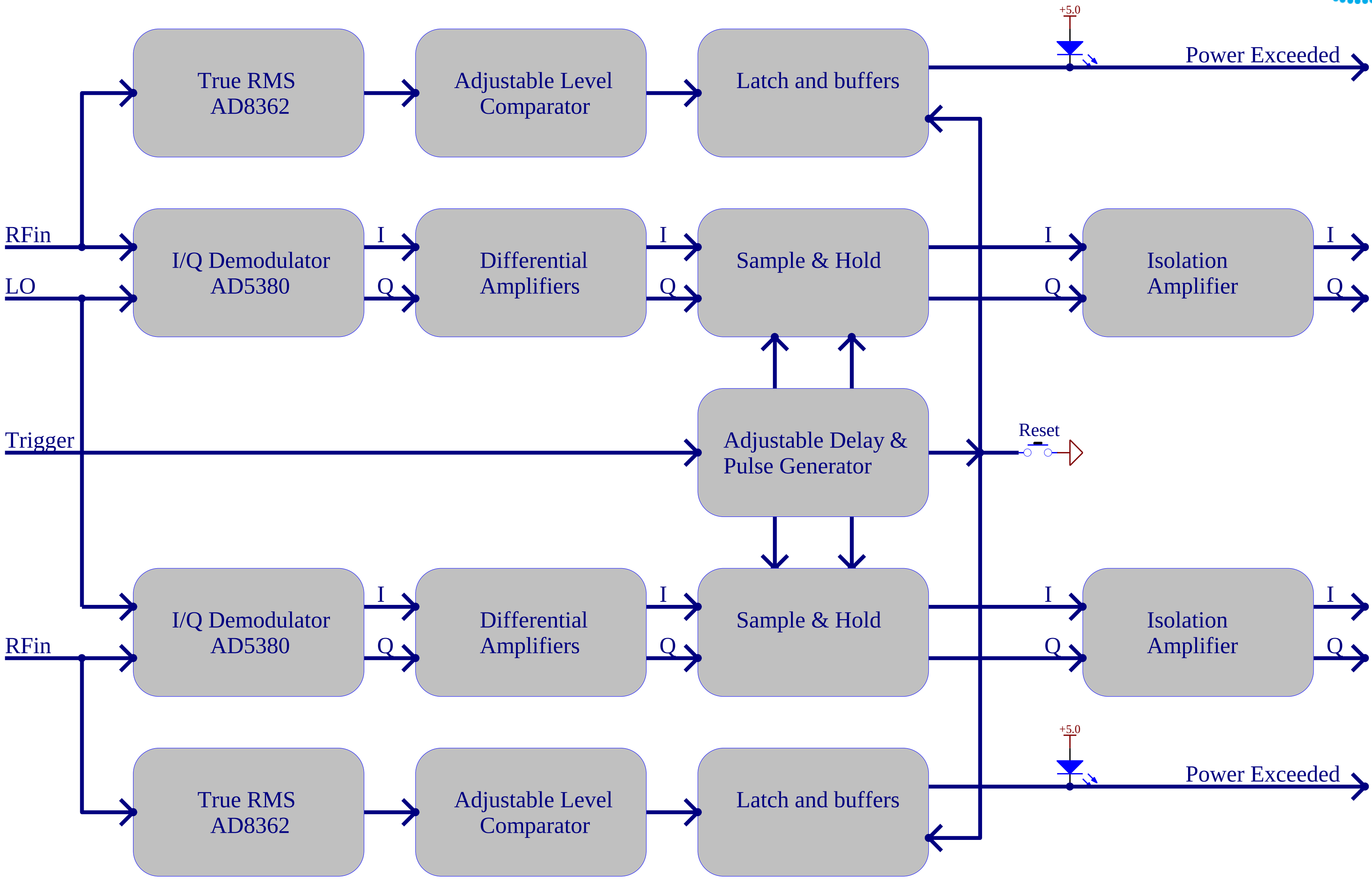


SPECIFICATION

- Isolation from mains and all auxiliary voltages derived from mains
- System should avoid earth loops
- Should be capable of continuous waveform (CW) or synchronised pulsed measurements
- Measurements between pulsed and CW mode should vary no more than 0.1dB
- The system shall be calibrated at nominal power and provide a linearity of better than ± 0.3 dB for a dynamic range of > 30dB
- Phase accuracy should be better than two degrees and phase resolution better than half a degree at nominal power.
- The minimum frequency range for the system is from the MO reference frequency up to six times the MO frequency.
- All phase measurements are relative to the reference signals.
- The maximum system input power level shall be:

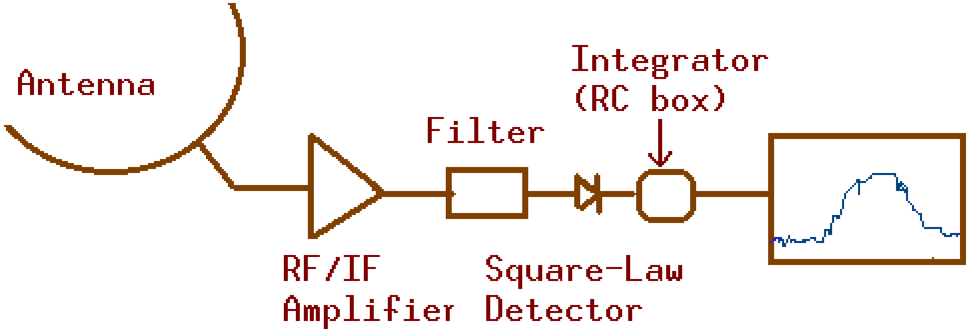
500 MHz	11 dBm and
3 GHz	15 dBm

PROPOSAL OF SYSTEM ARCHITECTURE



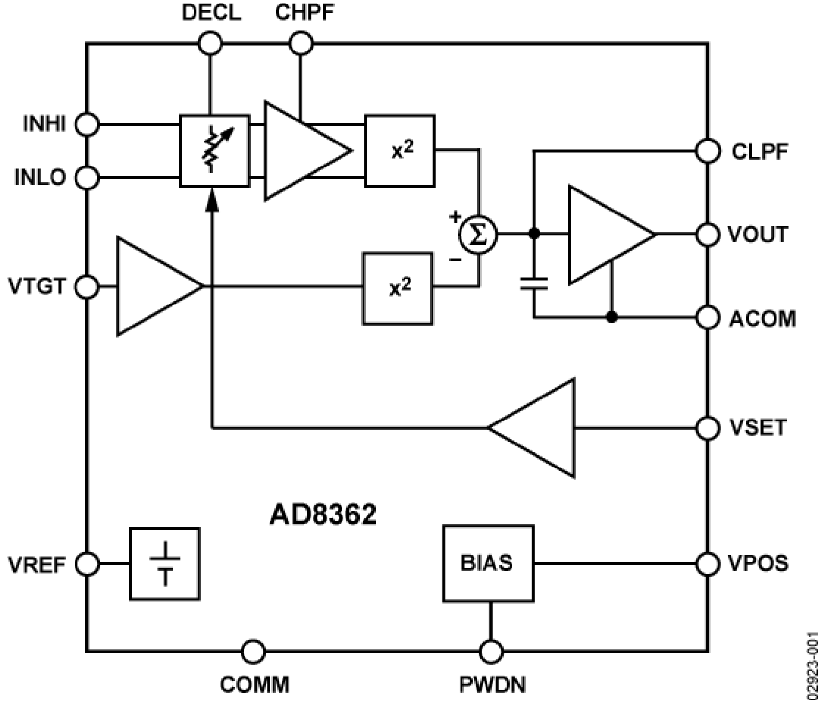
PEAK DETECTOR - POWER METER

Square Law Detector - output DC is voltage proportional to the input power

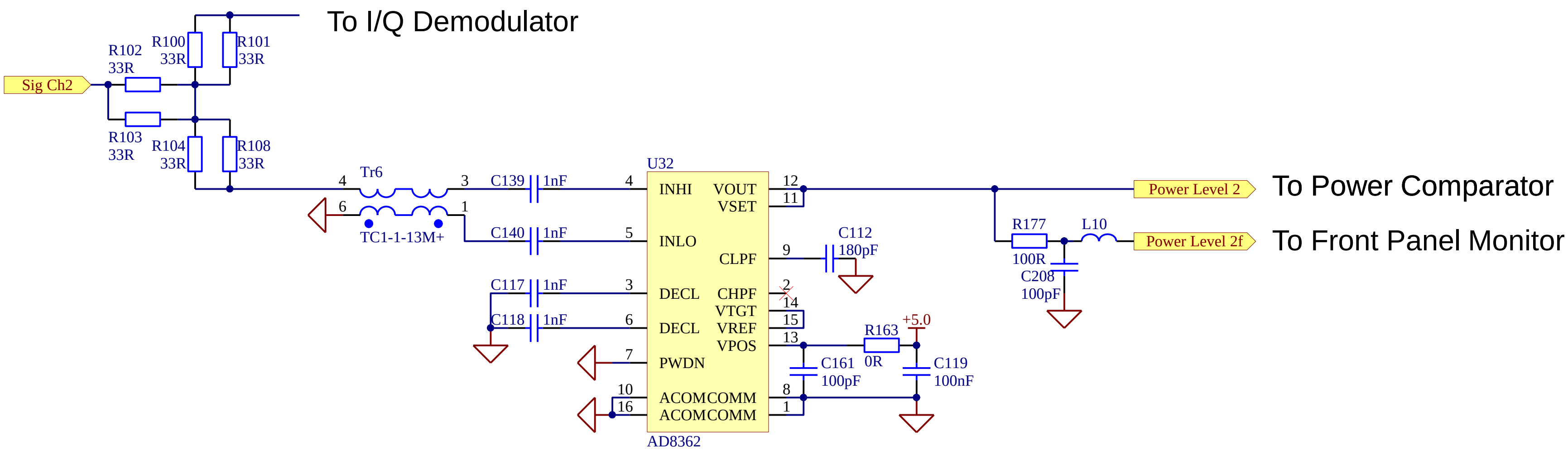


Key Futures of AD8362 (square-law detector):

- Complete fully calibrated measurement/control system
- Accurate rms-to-dc conversion from 50 Hz to 3.8 GHz
- Input dynamic range of >65 dB: −52 dBm to +8 dBm in 50 Ω
- Waveform and modulation independent, such as GSM/CDMA/TDMA
- Linear-in-decibels output, scaled 50 mV/dB, Law conformance error of 0.5 dB
- All functions temperature and supply stable
- Operates from 4.5 V to 5.5 V at 24 mA
- Power-down capability to 1.3 mW

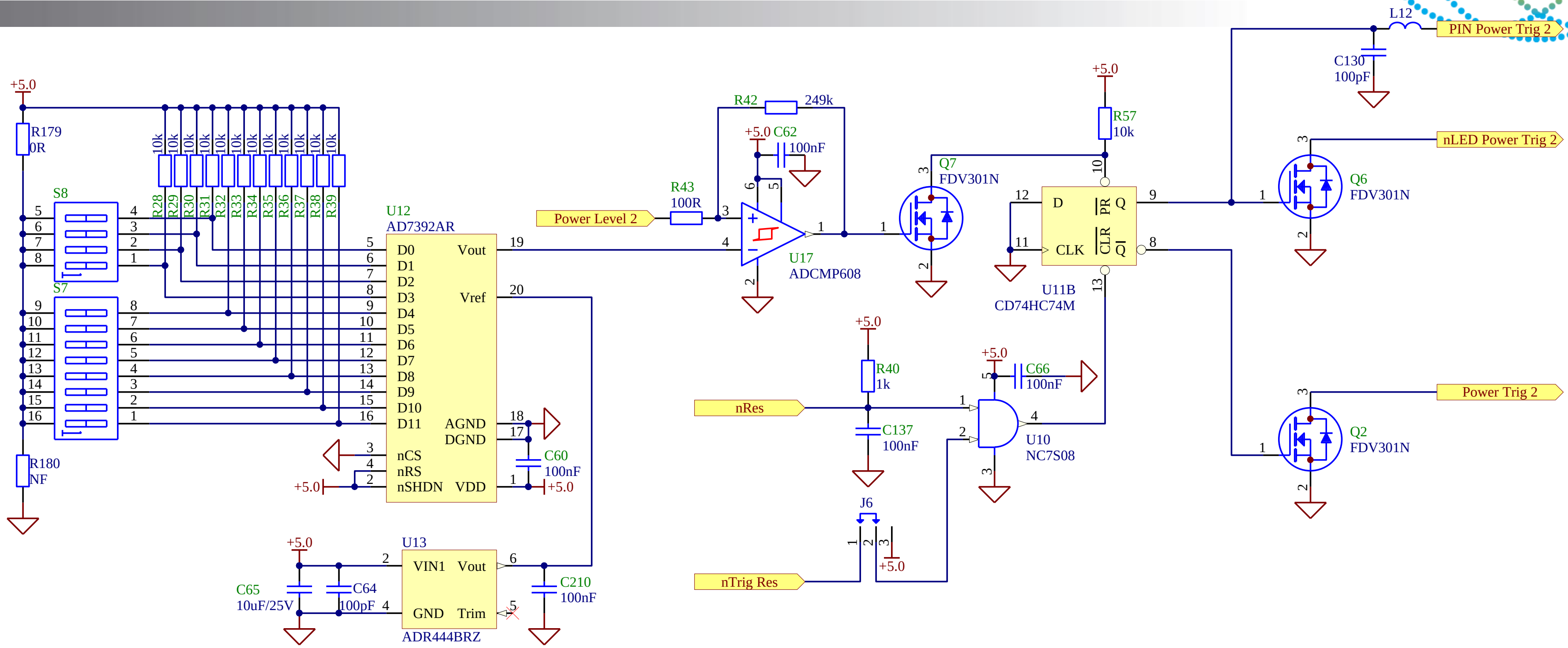


PEAK DETECTOR - POWER METER



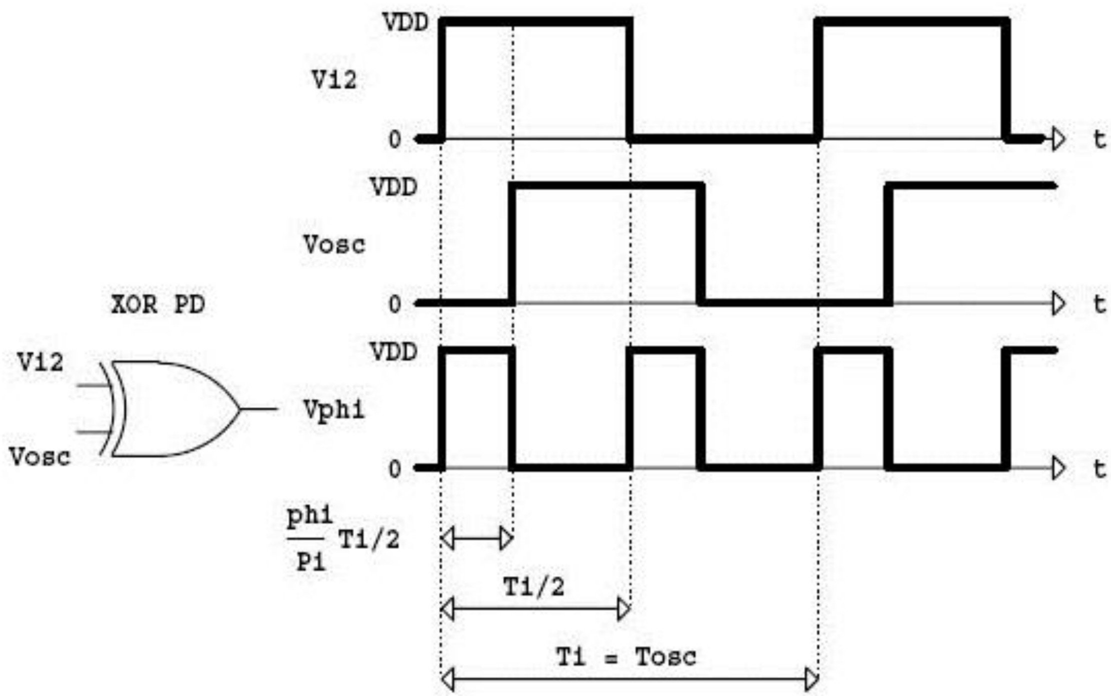
- CLPF capacitor sets corner frequency of the filter. We had to experimentally select the value to avoid overshoots creating false Power Exceeded trips.
- Additional Front Panel Output allow us to monitor power envelope of the signal.
- R177, L10 and C208 are output and EMC protection components.
- Resistive splitter provides signal to Power Meter and I/Q Demodulator

PEAK DETECTOR - COMPARATOR



- Fast comparator with additional hysteresis
- U12 Digital to Analog converter – 12 bits (2^{12}=4096)
- U13 – Reference Voltage – 4.096V
- U11 – Power exceeded latch.
- U10 – Few reset options.

Multiplier Phase Detector – Simple but which signal is first?



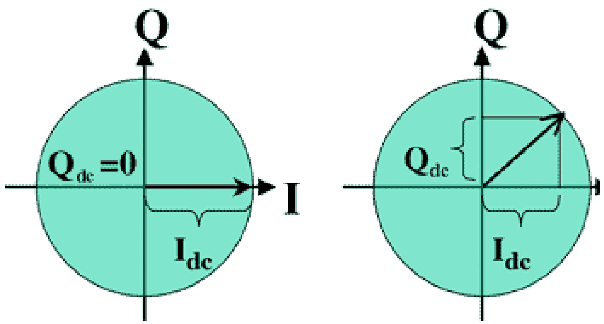
I/Q DEMODULATOR

- Amplitude modulation: s(t)= A(t)sin(ωt + φ)

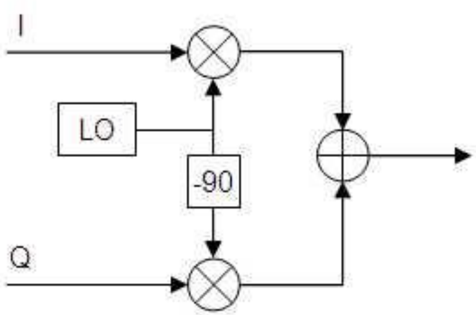
  sin(α + β) = cos(α) cos(β) - sin(α) sin(β);

- IQ Modulation: s(t)= I(t)cos(ωt + φ(t)) or s(t)=I(t)cos(ωt) - Q(t)sin(ωt)

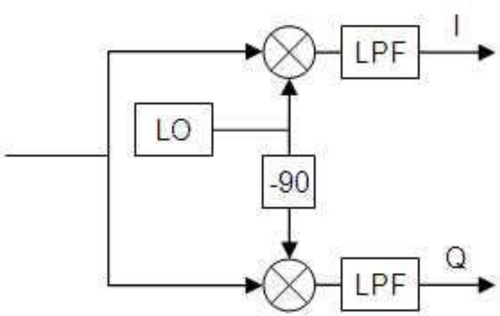
  where: I(t)=A(t)cos(φ(t)) and Q(t)= A(t)sin(φ(t))



I/Q Modulator



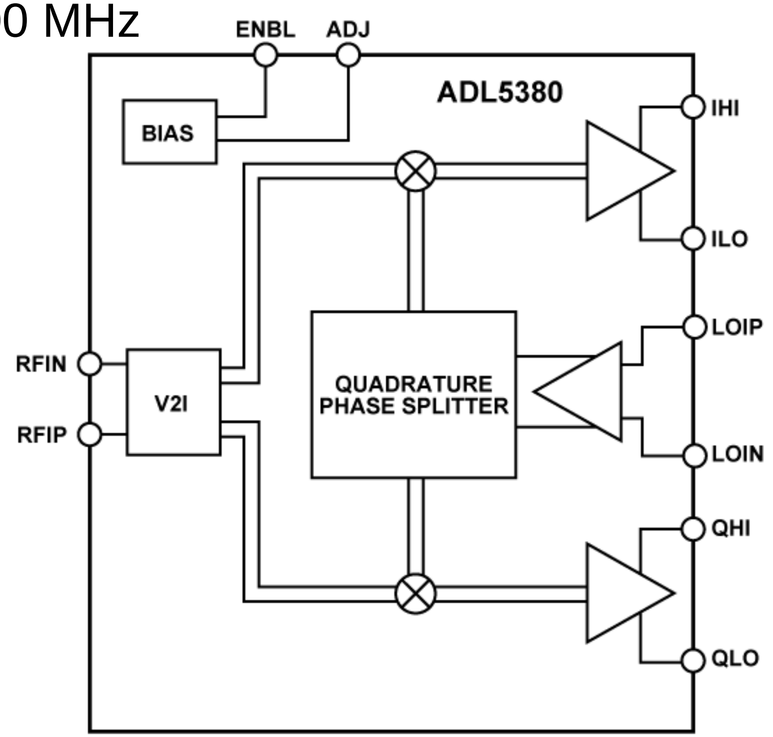
I/Q Demodulator



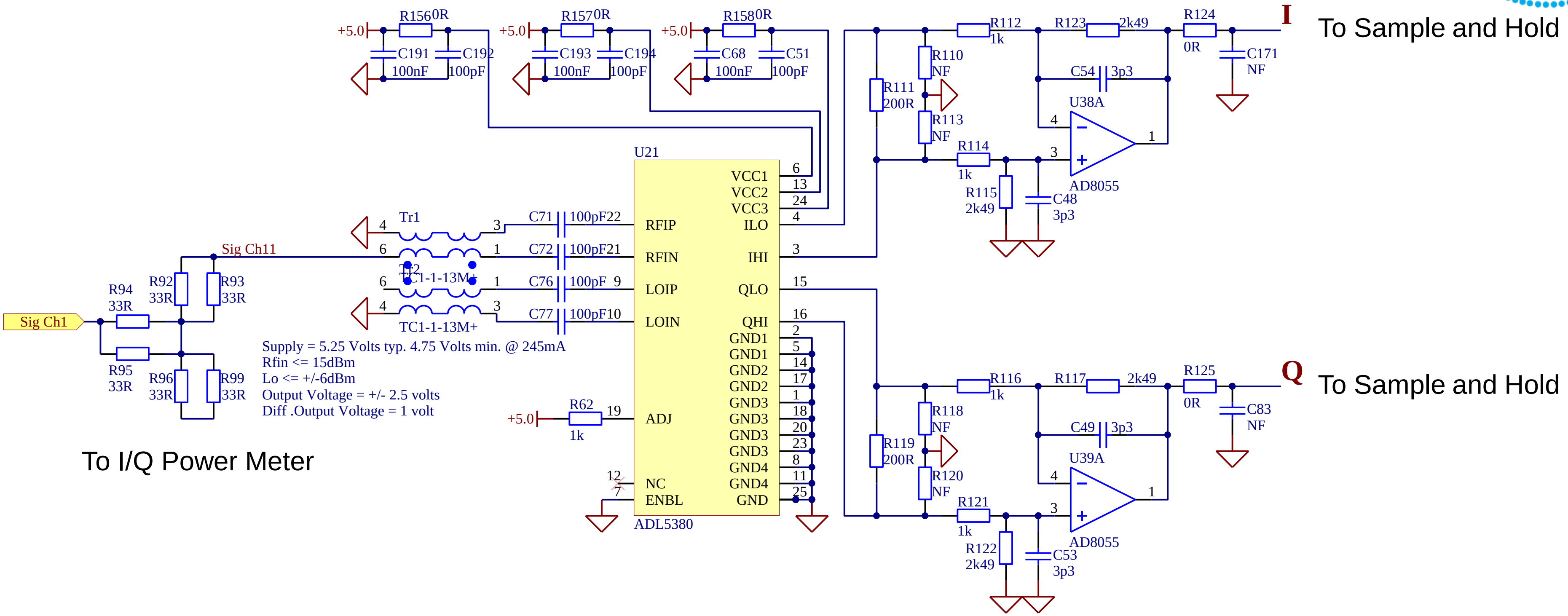
I/Q DEMODULATOR

Key Futures of ADL5380:

- Operating RF and LO frequency: 400 MHz to 6 GHz
- Input P1dB (IP1dB): 11.6 dBm @ 900 MHz
- Voltage conversion gain: ~7 dB
- Quadrature demodulation accuracy @ 900 MHz
- Phase accuracy: ~0.2°
- Amplitude balance: ~0.07 dB
- Demodulation bandwidth: ~390 MHz
- Baseband I/Q drive: 2 V p-p into 200 Ω
- Single 5 V supply

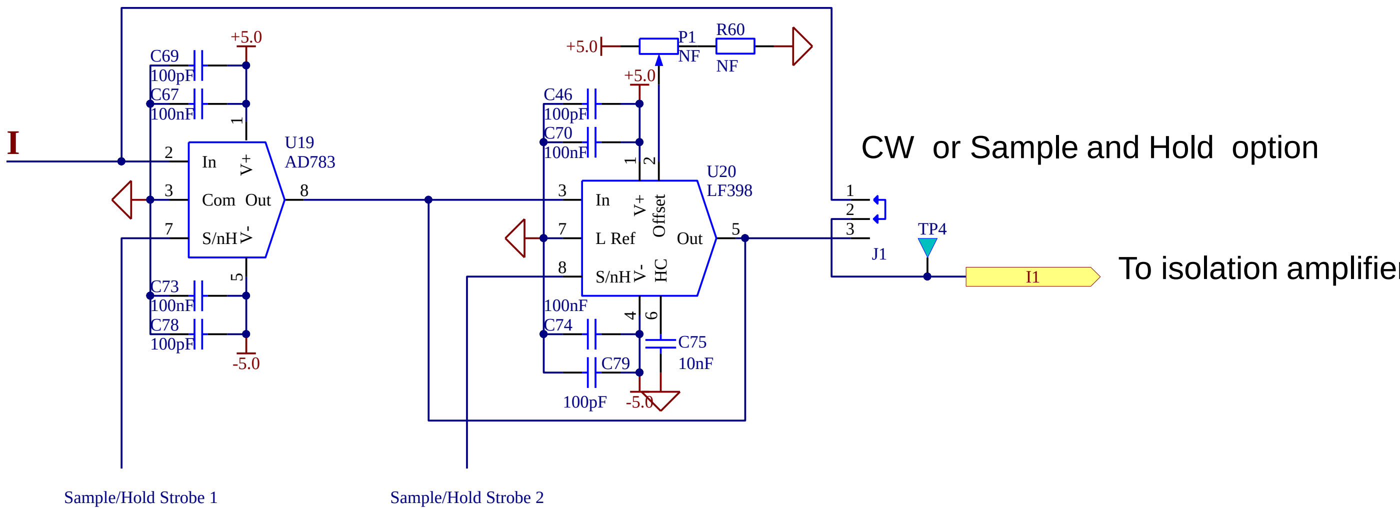


I/Q DEMODULATOR



- Differential amplifiers to extract I/Q signals and provide also filtering
- R124 and C171 additional low pass filter – if needed
- R110, R111 and R113 different options of loading outputs.

CW and Pulsed RF measurements - Sample and Hold



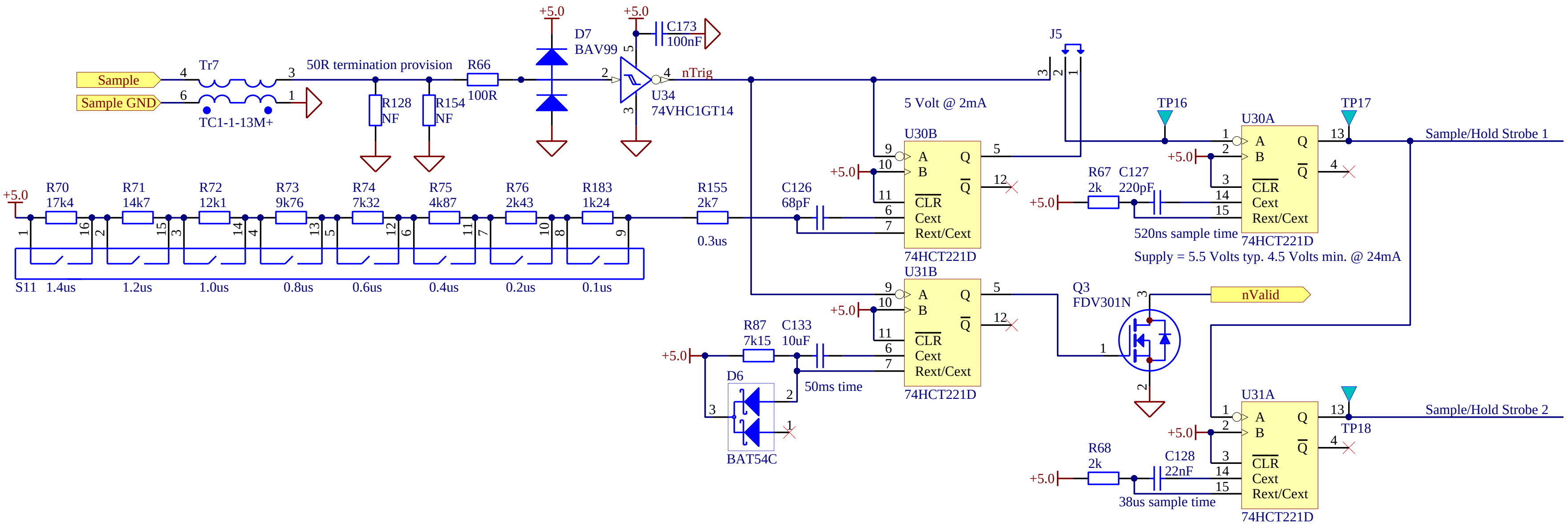
KFEATURES of AD783

- High speed Sample and Hold Amplifier
- Acquisition Time to 0.01%: 250 ns Typical
- Low Droop Rate: 0.02 mV/ms
- Fully Specified and Tested Hold Mode Distortion
- Internal Hold Capacitor

KFEATURES of LF398

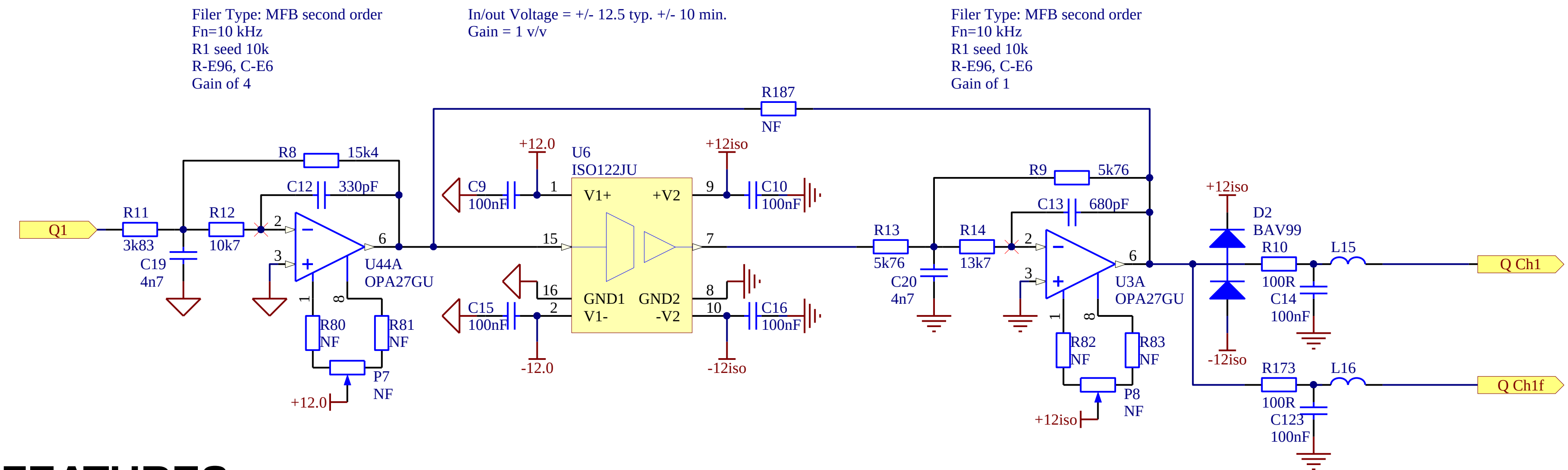
- Less than 10 μs acquisition time
- 0.5 mV typical hold step at Ch = 0.01 μF
- Low input offset
- 0.002% gain accuracy
- High supply rejection ratio in sample or hold

CW and Pulsed RF measurements - Sample and Hold



- U30B - option to delay trigger signal
- Switch programmable delay
- Extended trigger pulse for visualisation purposes (Front Panel)
- Sub-sequential sample and hold triggers - U30A and U31A

OPTICAL ISOLATION AND FILTERING

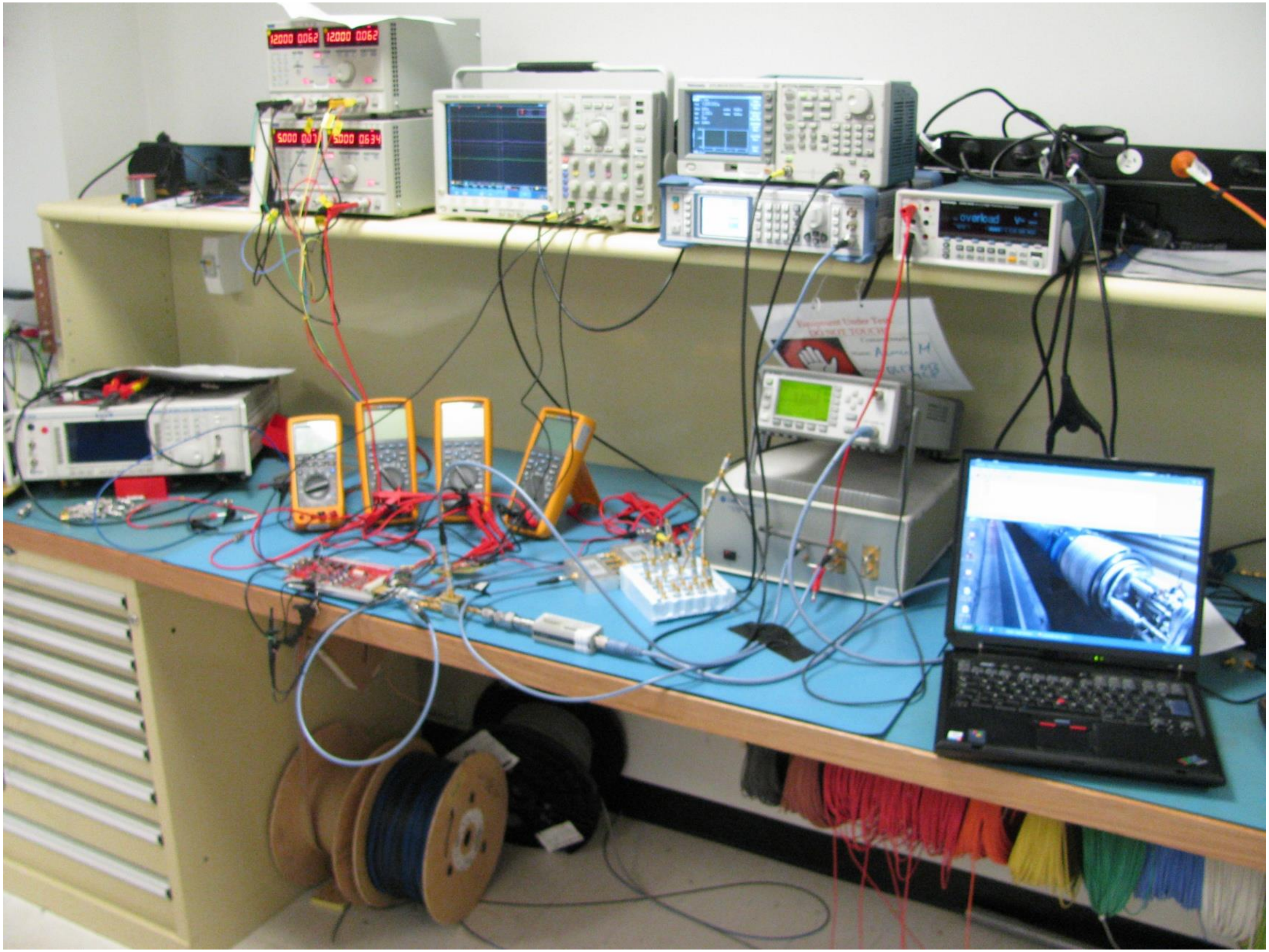


FEATURES

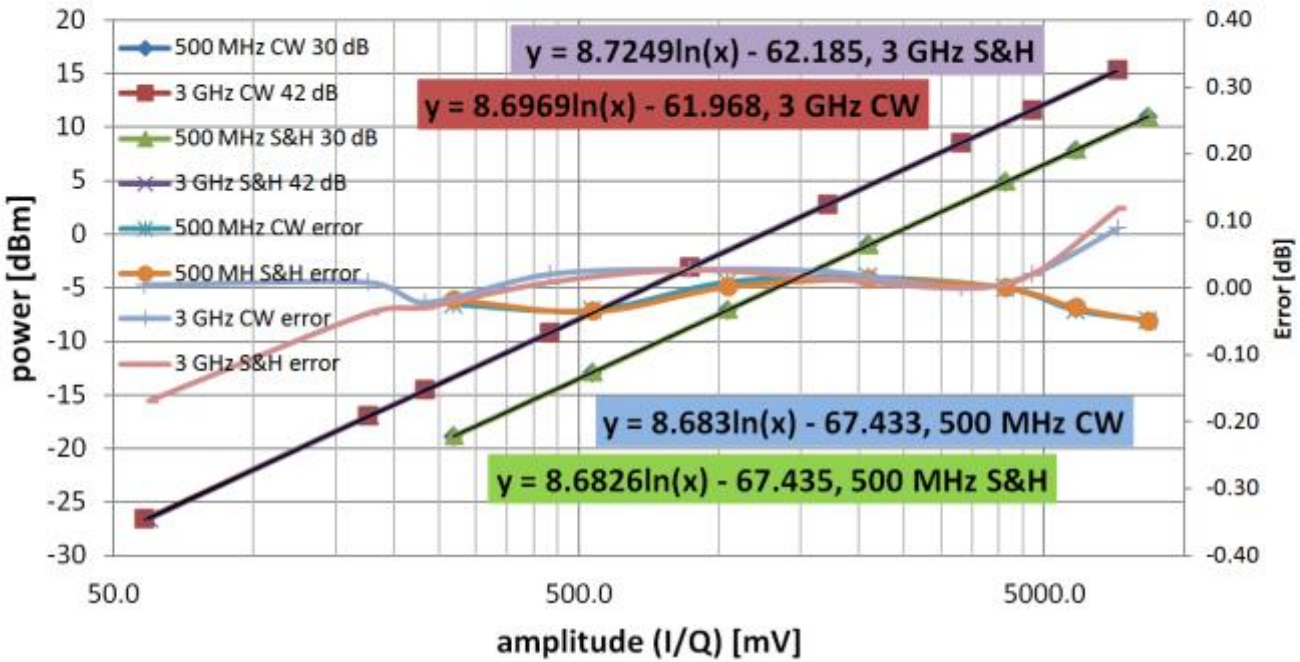
- 100% tested for high-voltage breakdown, rated 1500Vrms
- 0.010% max Nonlinearity
- Bipolar operation: VO = ± 10V
- The signal is transmitted digitally across capacitive barrier – requires filtering!!!
- Again outputs and EMC protection components – never enough!

TESTING

2ns responds to 0.6m
0.1ps responds to 30um!



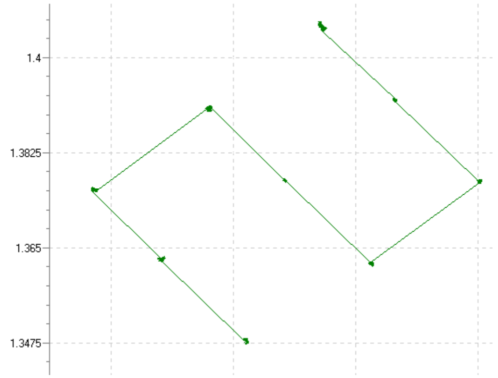
TESTING – Dynamic Range



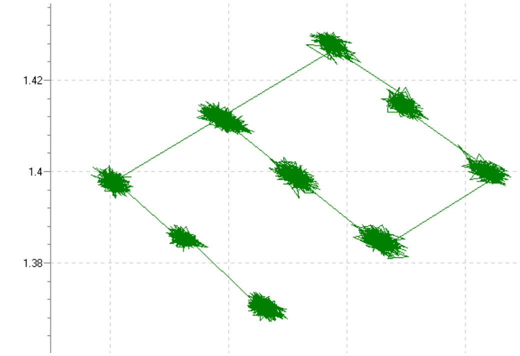
- The measured noise figures were excellent and achieved a resolution of 0.1 degrees and 0.02 dB respectively; and still remarkably 1 deg and 0.2 dB at -32 dB in pulsed mode.
- Both gains for CW and pulsed mode are equal without the need for adjustment.

TESTING – Resolution

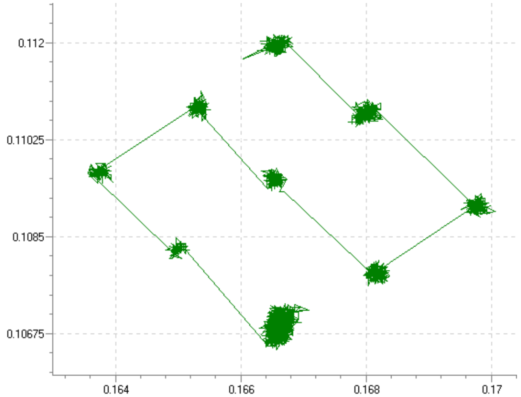
Input: 3 GHz, CW, 2.4 dBm
steps:0.1 dB/0.5 ps (0.54 deg)
scale: 17.5 mV/div



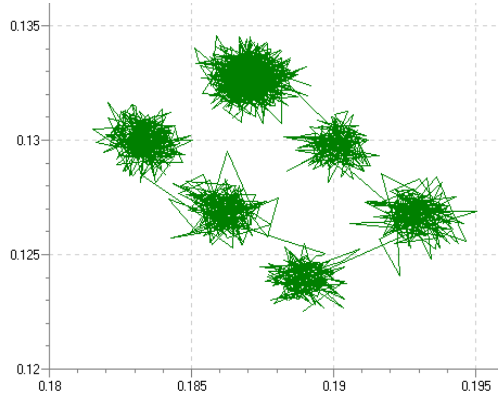
Input: 3 GHz, SH, 2.4 dBm
steps:0.1dB 0.5ps (0.54 deg)
scale:20 mV/div



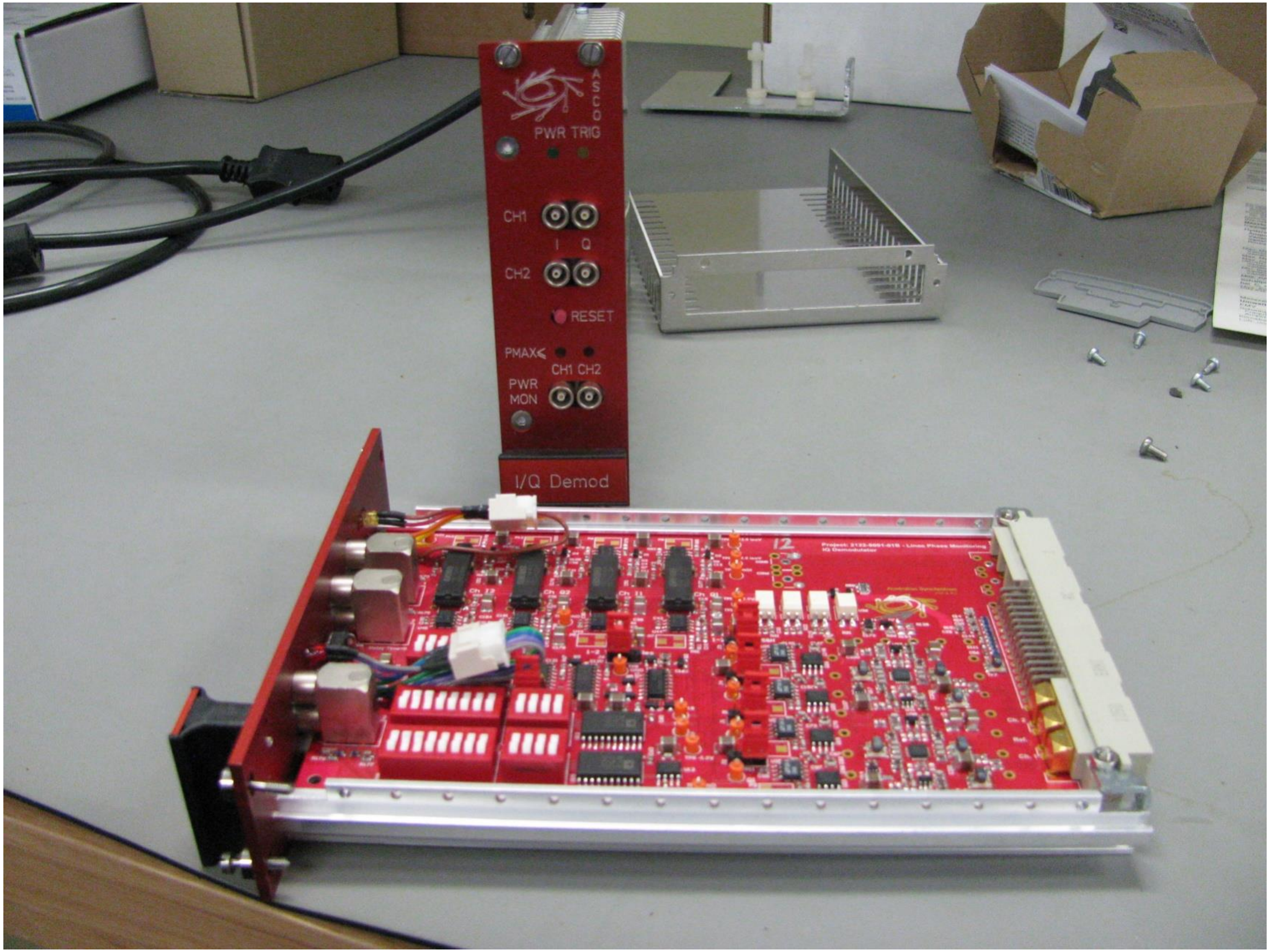
Input: 3 GHz, CW, -17dBm
steps: 0.1 dB/0.5 ps (0.54 deg)
scale:1.75/2.00 mV/div



Input: 3 GHz SH -17dBm
steps: 0.2dB 1ps (1.08deg)
scale: 5 mV/div

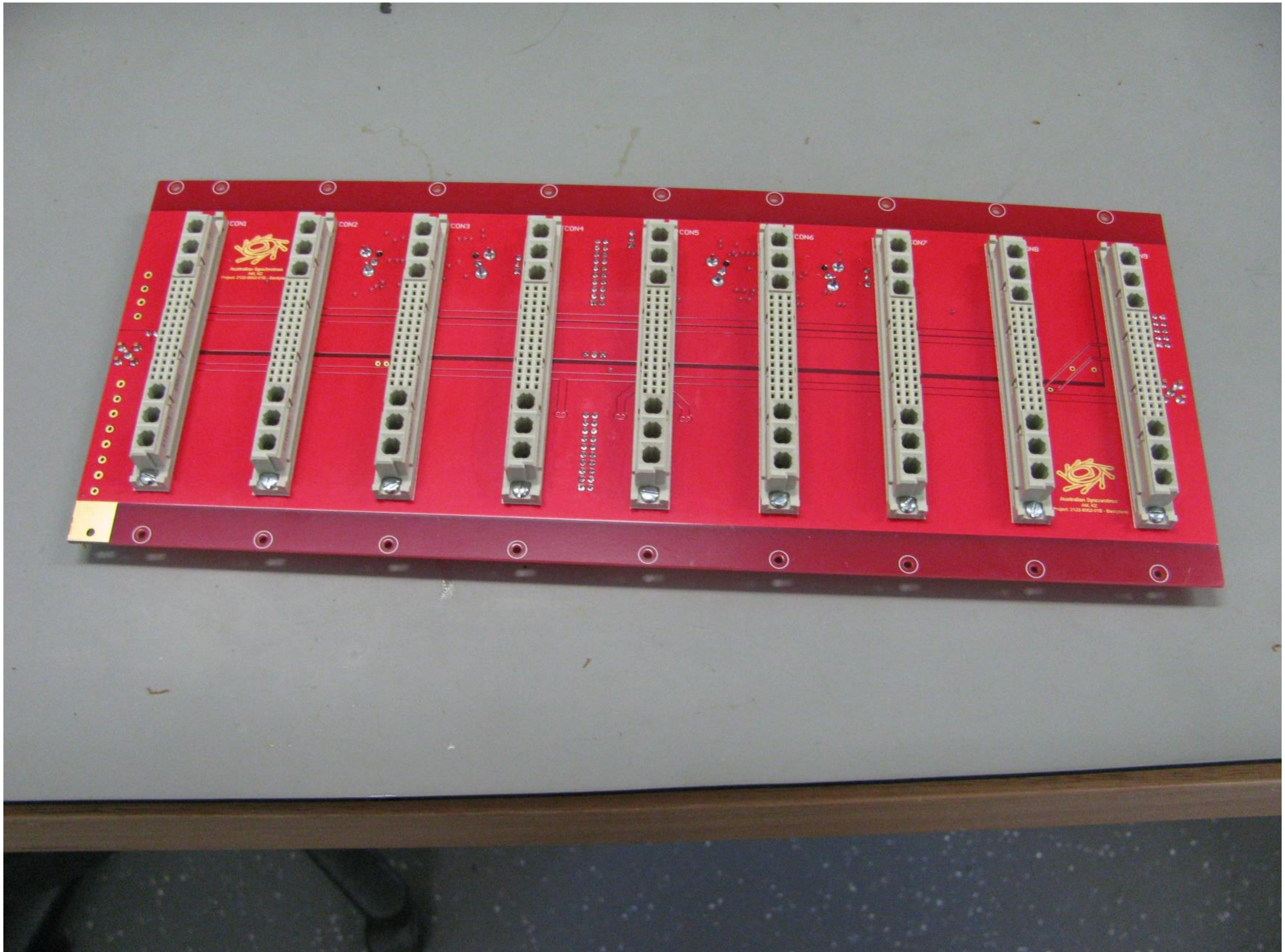


PACKAGING - 3U CRATE (boards100x160)

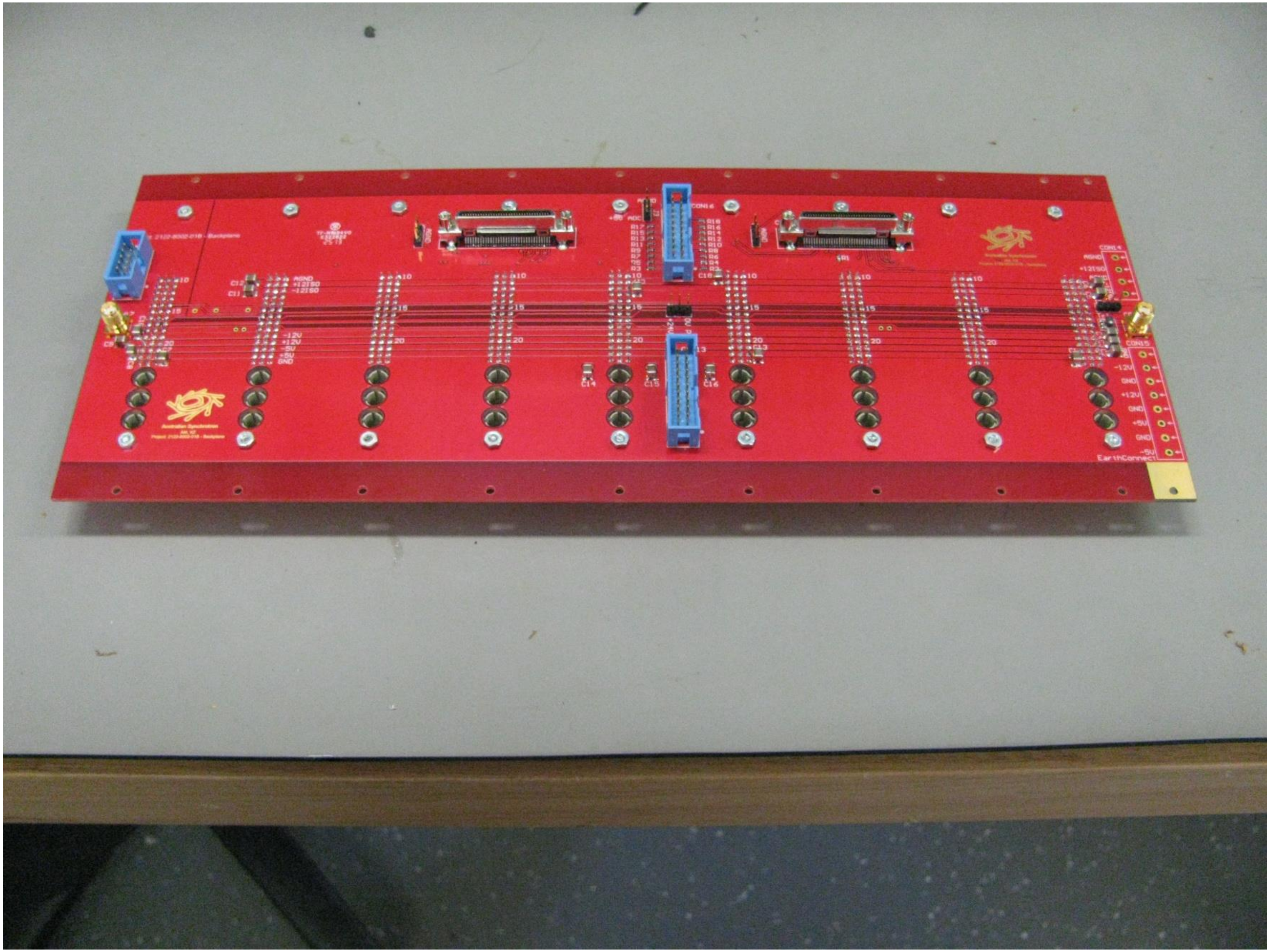


PACKAGING - 3U CRATE (boards100x160)

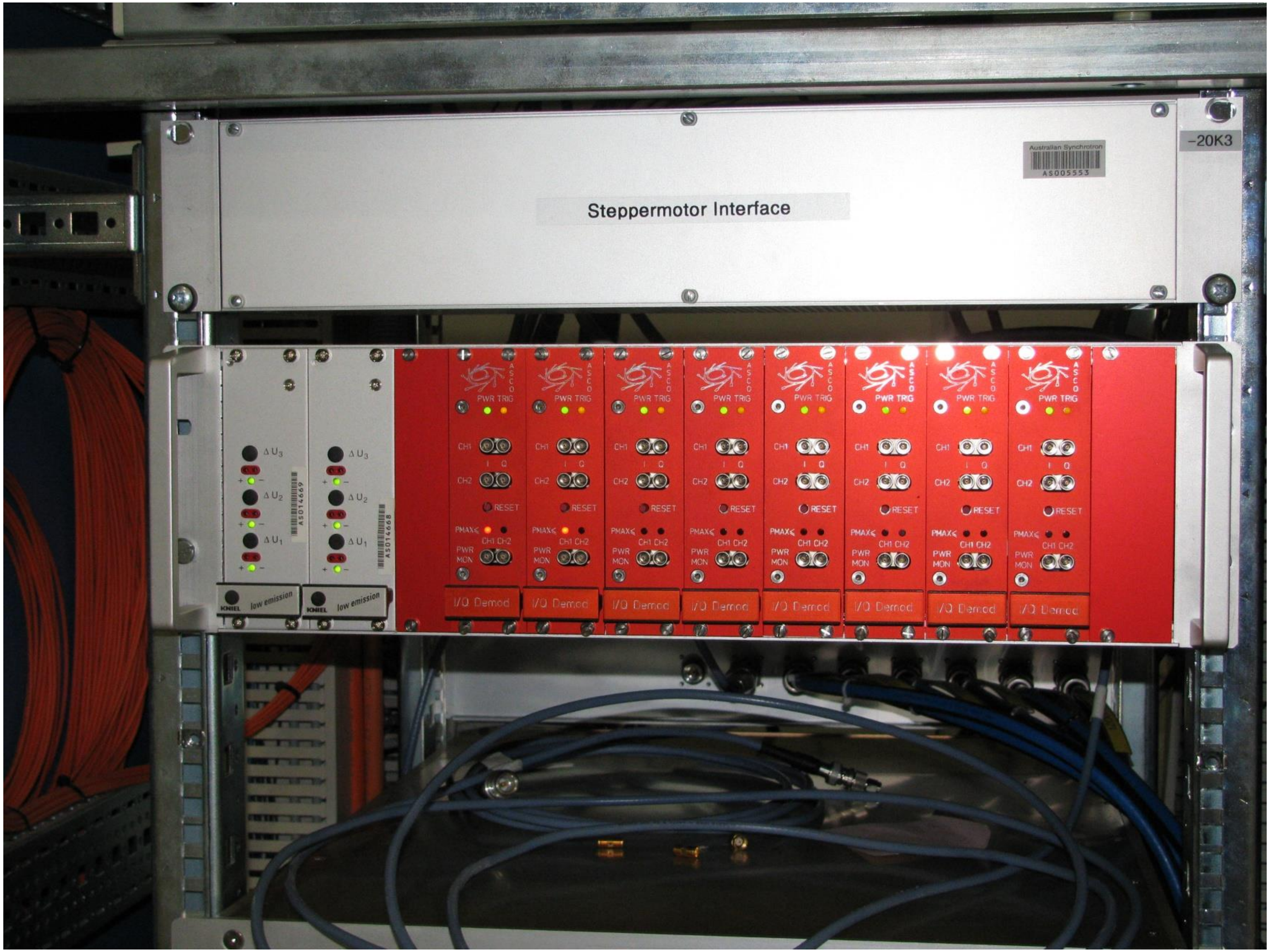
PACKAGING - 3U CRATE (Backplain)



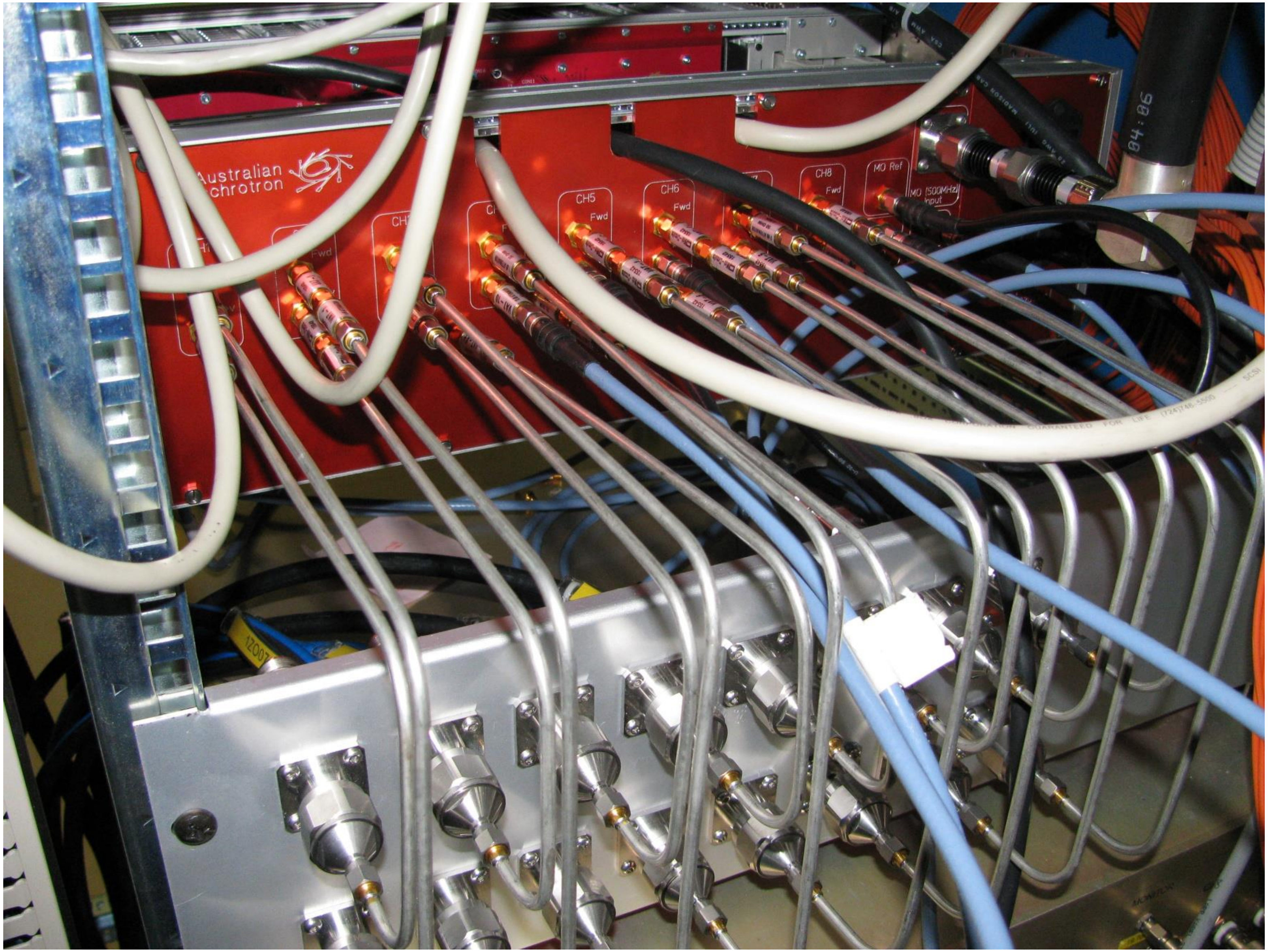
PACKAGING - 3U CRATE (boards100x160)



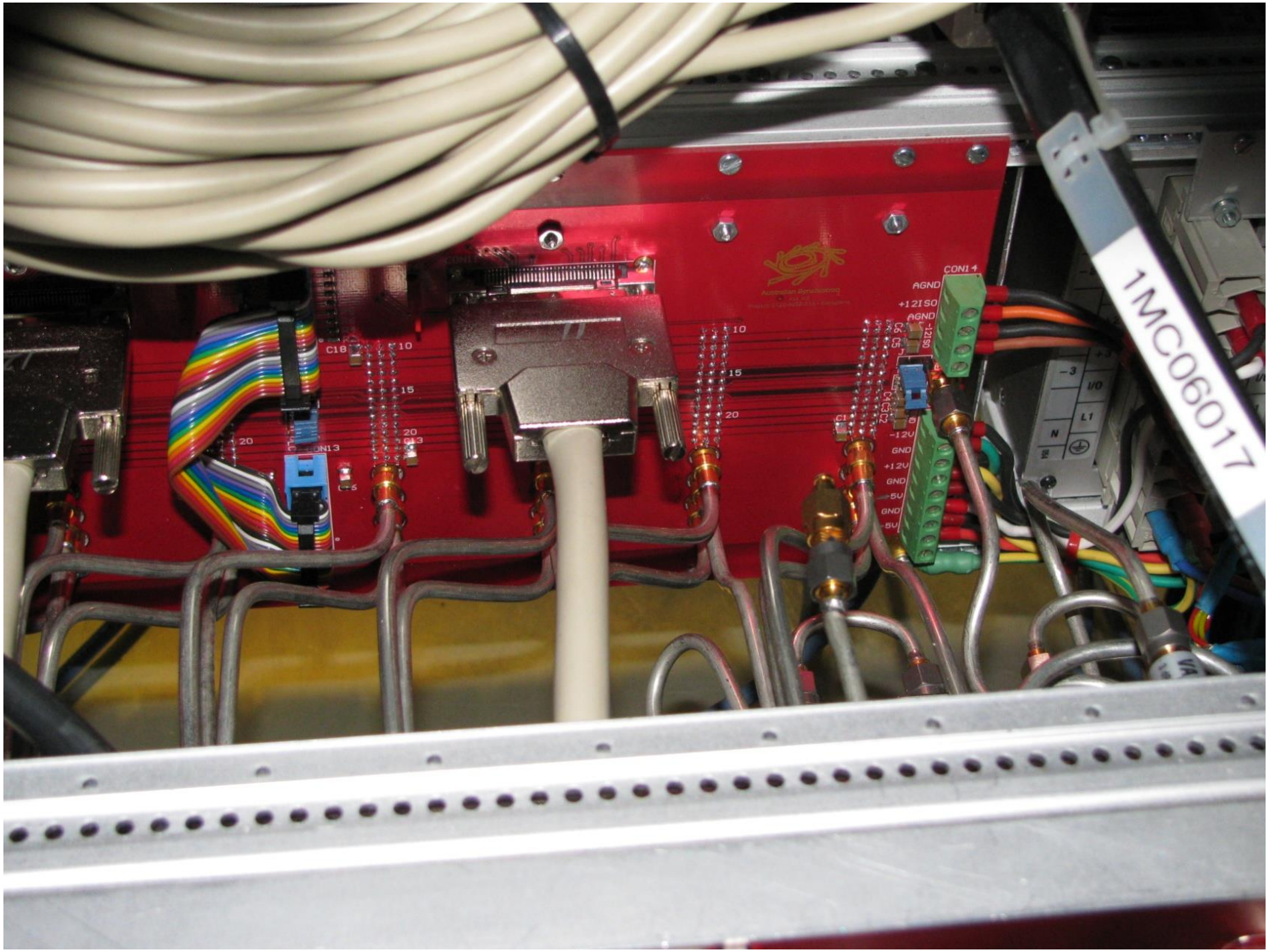
PACKAGING - 3U CRATE



PACKAGING - 3U CRATE (Patch panel)



PACKAGING - 3U CRATE (Patch panel)



PRACTICAL APPLICATION AND OUTCOMES

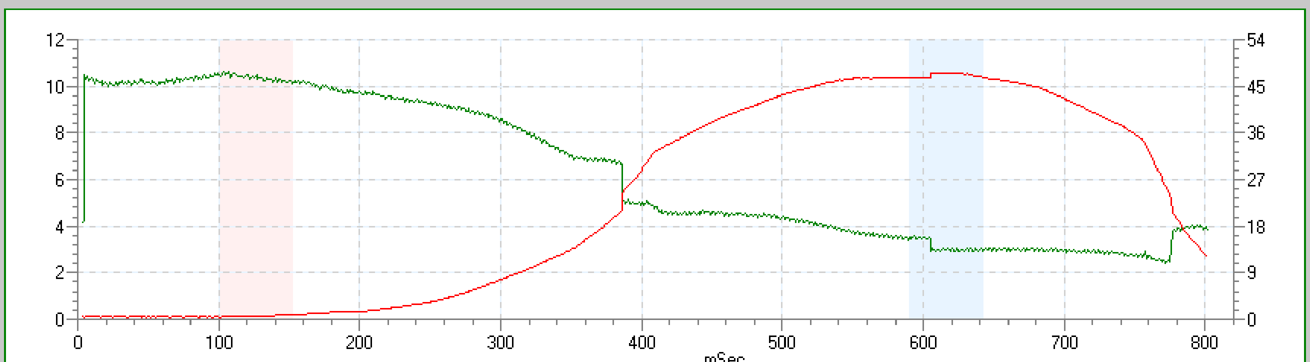
Booster Ring Phase/Amplitude Monitor

Framework General Vacuum Magnets Diagnostics Timing Ins Dev RF Injection Misc.

Booster Ring Phase/Amplitude Monitor

Measurement	Chan	Idle Phase	Idle Power	Peak Phase	Peak Power	Power Status
BR01RF01CAV01:PORT_02	1R	-163.1 °	0.64 kW	-170.4 °	48.85 kW	Okay
BR01RF01AMP02:OUT_FWD	1F	-107.6 °	6.32 W	-92.9 °	370.29 W	Okay
BR01RF01CAV01:PORT_04	2R	-120.5 °	0.52 kW	-127.7 °	39.01 kW	Okay
BR01RF01CAV01:PORT_03	2F	10.4 °	0.63 kW	3.1 °	47.21 kW	Okay
BR01RF01CAV01:REV	3R	-21.9 °	0.02 kW	121.5 °	0.03 kW	Okay
BR01RF01CAV01:FWD	3F	-155.7 °	0.53 kW	-150.3 °	38.17 kW	Okay
BR01RF01RLD01:REV	4R	-174.4 °	0.00 kW	-133.5 °	0.01 kW	Okay
BR01RF01RLD01:FWD	4F	73.7 °	0.06 kW	114.7 °	1.45 kW	Okay
BR01RF01IOT01:OUT_REV	5R	172.1 °	0.01 kW	158.2 °	0.48 kW	Okay
BR01RF01IOT01:OUT_FWD	5F	-37.1 °	0.61 kW	-36.4 °	29.88 kW	Okay
BR01RF01IOT01:IN_REV	6R	-1.8 °	1.05 W	13.9 °	124.08 W	Okay
BR01RF01IOT01:IN_FWD	6F	-3.8 °	5.97 W	11.1 °	349.92 W	Okay
BR01RF01AMP02:IN_REV	7R	-0.1 °	0.00 mW	33.6 °	0.01 mW	Okay
BR01RF01AMP02:IN_FWD	7F	-45.9 °	0.96 mW	-39.0 °	0.96 mW	Okay
BR01RF01AMP01:OUT_FWD	8R	109.3 °	1.83 mW	106.0 °	1.94 mW	Okay
BR01RF01LLE01:OUT_FWD	8F	-176.8 °	0.06 mW	-172.4 °	0.05 mW	Okay

Raw I/Q



Auto Scale | Revert Scale | Legend/Select: ☑ Phase ☑ Power | BR Phase Control | Power Exceeded Reset

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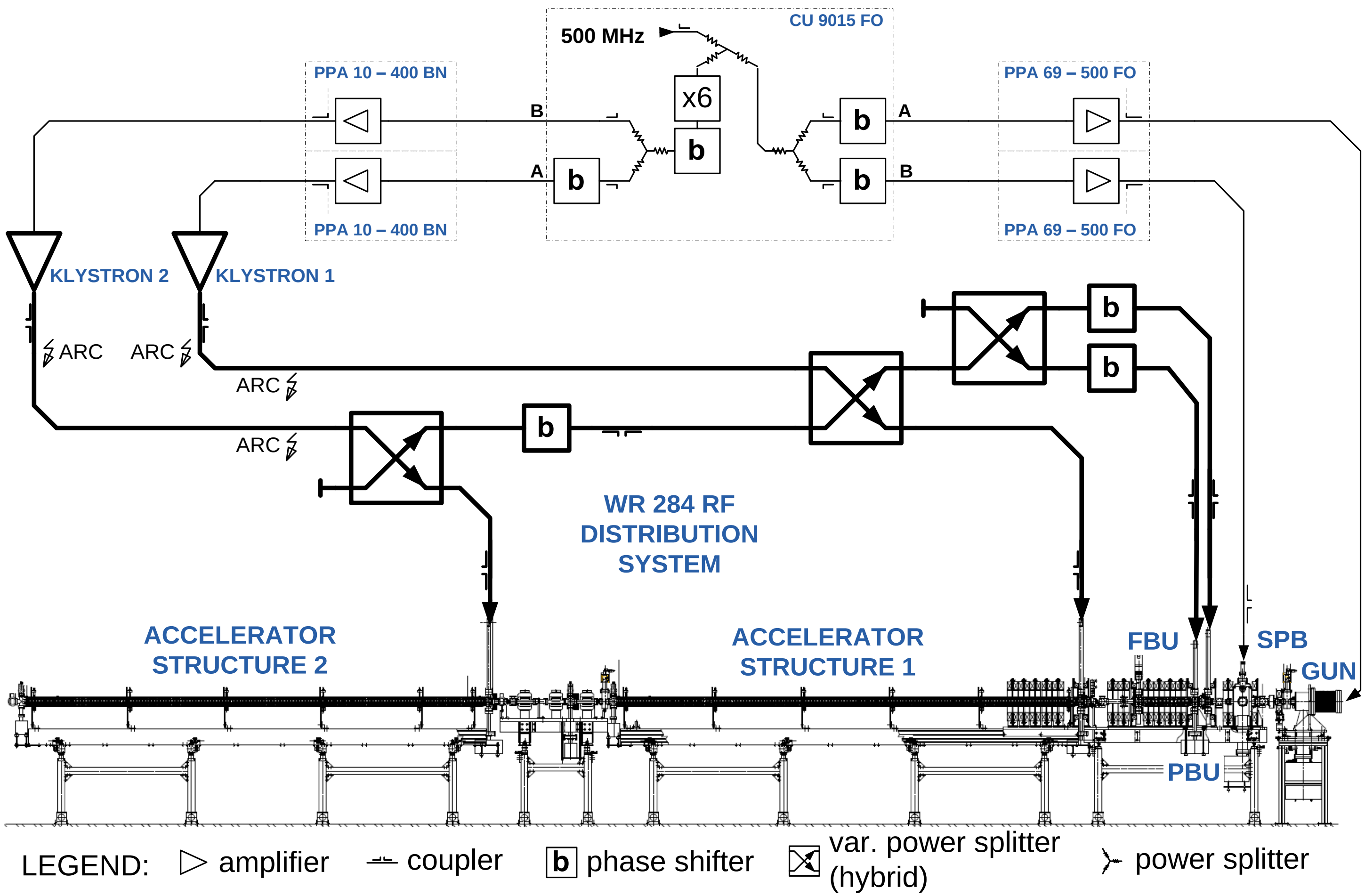
PRACTICAL APPLICATION AND OUTCOMES



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