Testing of DAE LLRF and RFPI systems for the PIP-II Linac

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Introduction

The PIP-II project is the first US/DOE accelerator project with significant contributions from international partners. As part of these collaborations, LLRF and RFPI systems developed at BARC were recently delivered to Fermilab for eventual testing with cold superconducting cavities at the FNAL STC facility. The results of preliminary bench testing of the LLRF system components are presented.

RFPI System

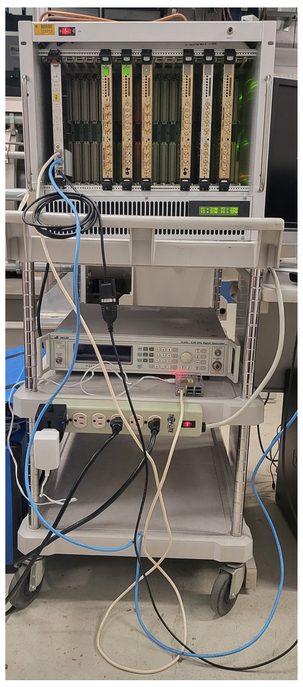
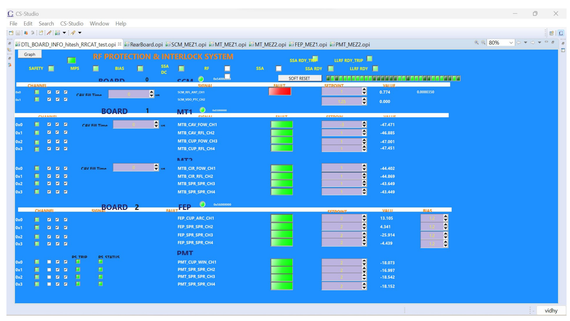


Fig.1 RFPI Test Setup with Connection to Raspberry Pi.

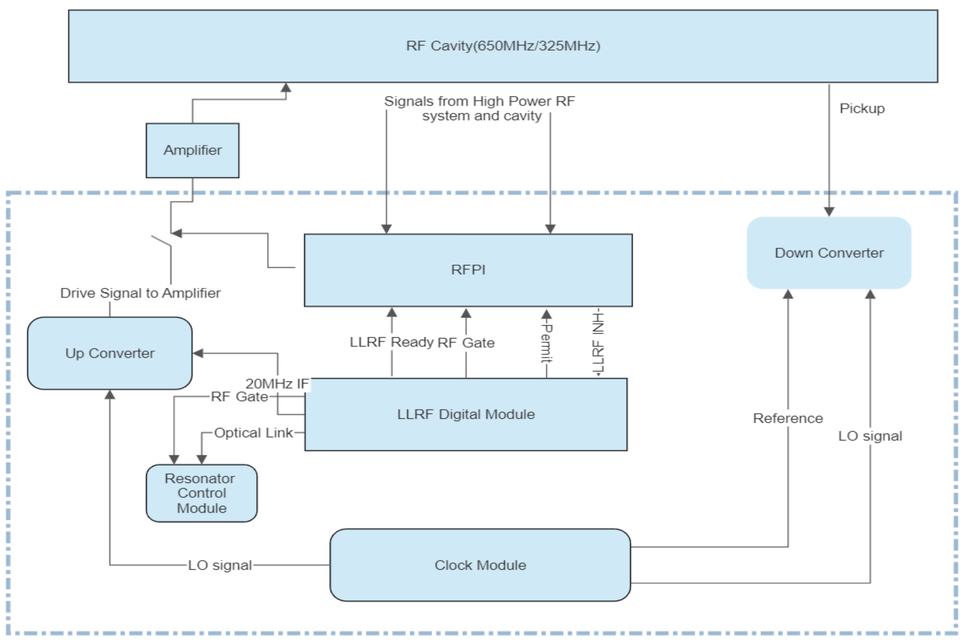
RFPI Crate Installed and Powered up.

A remote EPICS GUI is required to set thresholds for the various parameters of RFPIs. All the Indicators on the remote GUI display green if the system is healthy.



System status indicating trip in the Antenna channel of SCM module.

RFPI system status indicating the post-mortem data for Antenna channel



The block diagram of the system indicating the interfaces between cavity-coupler system, LLRF and RFPI.

LLRF Control System

Digital Controller Module

The output DAC signal of the LLRF control system, when provided with an input feedforward signal of amplitude of 0.5 was observed to be 20MHz I and Q signals. The different ADC output signals (amplitude and phase signals of the Cavity, Forward and Reflected ports) were observed by setting the PLL Gain to 4 and the Preset to 1 using the EPICS command.

Upconverter / Downconverter

DAE 4-Channel Upconverter

DAE 8-Channel Downconverter

The acceptance tests for the 4-channel upconverters included-power supply current measurement, IF Input vs RF Output plot, RF output linearity plot, crosstalk measurements and the RF Output Spectrum. The acceptance tests for the 8-channel downconverters included power supply current measurement data, IF/RF/LO monitor measurement data, IF Input vs RF output plot, RF output linearity plot, crosstalk measurements, return loss: IF inputs, RF inputs, LO output, IF output spectrum, sideband and carrier suppression and uncorrelated additive phase noise measurements.

	RF Input 10dBm	RF channel to channel isolation dB							
	IF output in dBm	IF 1	2	3	4	5	6	7	8
1	5.778	0	99.008	99.338	100.513	101.128	101.278	104.128	109.513
2	5.667	94.937	0	97.117	97.897	101.392	102.442	105.217	107.402
3	5.197	101.347	100.912	0	102.447	103.347	104.547	105.932	108.347
4	5.55	103.6	104.7	104.7	0	105.6	106.585	111.315	112.4
5	5.67	101.72	102.82	104.345	106.9	0	105.79	106.82	108.72
6	5.61	105.76	109.86	105.92	99.26	94.39	0	93.66	94.76
7	5.6	104.95	100.85	102.15	100.35	97.75	92.1	0	92.725
8	5.59	109.325	109.325	101.325	98.325	94.84	93.94	92.74	0

Downconverter Isolation

IF In - 1dBm, RF Output (dBm)	IF Channels				
RF Channels	1	2	3	4
12.55	1	0	93.4	89.13	91.2
12.5	2	89.19	0	78.26	83.15
12.42	3	88.34	79.19	0	88.94
12.65	4	90.19	83.27	84.15	0

Upconverter Isolation

	Measurement	$dBV_{RMS}/\sqrt{HZ}$
1	Measurement @ 20 Hz	-101
2	Offset add = Measurement - (Volts/rad) - 60 – 3	-150.3988822
3	1 Hz Assuming 10 dB/decade of 1/f noise slope	-137.3988822 dBc
4	Integrate Noise from 0.02 to 20 Hz 10^(meas/10) * ln(20/0.02)	-129.0055128
5	Convert to radians: sqrt(2 * 10^([dBc meas]/10)) in rad	5.01464E-07
6	Frequency of calculation Hz	3.25E+08
7	Covert to fs:	2.46E-01

Phase Noise Measurements

Summary

Initial Testing is promising. Detailed testing with cavities will commence when the visiting team from DAE arrives at Fermilab early in 2024.

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