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ISC Dual Frequency WFS RFPD Test Procedure:

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1 Introduction

This document describes the testing of the ASC RFPD photodetectors used in the aLIGO ISC subsystem. A summary of the characteristics of this detector are available in [T1100402](#). The schematics for the ASC detector can be found in [D1101614](#). A list of ISC detectors (RF & DC) can be found in [T1000264](#).

This procedure relies upon a familiarity with the complex nature of this circuit and the techniques of network analysis, modulated laser light sources, and shot noise limited sensitivity measurements. Minimal instructions are included in this procedure to avoid lengthy and complex tutorials.

All final data results are recorded in [T1200346](#)

This procedure is broken into the following sections:

- ***Serial number*** – Unique identification of the unit is recorded in the form of the serial number if the internal circuit board and associated schematic details
- ***DC checks*** – Current draw into the detector and verification of all internally regulated voltages
- ***DC path transimpedance*** – A measurement of the DC transimpedance of the DC path of the RFPD.
- ***Notch tuning*** – Adjustment of RF notch frequencies
- ***Notch rejection ratios*** – Measurement of RF notch depths
- ***RF transimpedance*** – A white-light based measurement of the RF transimpedance
- ***Shot noise limited input sensitivity*** – Verification that the RF noise performance is within design limits
- ***Test input transconductance*** – A measurement of the RF transimpedance of the test input path

2 Product Perspective

As shown in Figure 1, the ASC RFPD is mounted in a metal housing with all connections on the top surface. There are 4 SMA connectors for the RF outputs. Power and the DC outputs are on the 15-pin D-sub connector.

Figure 1



3 D-Connector Pinout

15 pin D Pin	Function
1	Q1 Readout Positive
9	Q1 Readout Negative
2	Q2 Readout Positive
10	Q2 Readout Negative
3	Q3 Readout Positive
11	Q3 Readout Negative
4	Q4 Readout Positive
12	Q4 Readout Negative
5	No Connect
13	No Connect
6	DC Power Positive
14	Ground
7	DC Power Negative
15	Ground
8	No Connect

4 Serial Number Data

Record the serial number and relevant schematic D-number/revision in [T1200346](#)

5 DC Checks

Record the total circuit board quiescent current draw and regulated voltages in [T1200346](#). Use caution in believing the digital readouts of laboratory triple output power supplies. Their meters are not highly accurate. When in doubt, use a multimeter on the appropriate scale in series with the supply to be measured.

6 DC Readout Path

Using a handheld current calibrator, inject 1mA DC into the anode circuit of the RFPD through a 100 Ω resistor. By observation of the DC voltages present at each differential DC readout

terminal-pair on the 15 pin D-connector, calculate the transimpedance of the DC readout chain for each quadrant, Z_{dc} by:

$$Z_{dc} = \frac{V_{out}}{0.001A}$$

Record each result in [T1200346](#).

7 Notch Tuning

The ASC photodetector circuit has series resonant RF notches that are tuned to allow amplification of some frequencies, while providing rejection at other frequencies. The notches are tuned by means of surface mounted RF trimmer capacitors on the photodetector PCB. Table 1 shows which capacitor to tune for each notch frequency. Due to the fact that there is no electrical monitor of the anode of each quadrant, the fundamental frequency notch must be adjusted by using a FET probe right on the anode of the quadrant under test. The 2ω notch is visible at the SMA output connector for each quadrant under test.

Using a laser capable of RF AM modulation, and an RF network analyzer, perform a frequency sweep from the photodiode to the FET probe for the fundamental frequency, and each RF output connector on the top surface of the photodetector housing for the 2ω notch.

Table 1, Notch Adjustment Frequencies

Notch Frequency	Adjustment Capacitor
Fundamental Frequency	C10 & C16
2ω Notch	C21
4ω Notch	C22
6ω Notch	C23
10ω Notch	C24

After adjusting each notch, record into [T1200346](#) the achieved tuning frequency as indicated.

8 Notch Rejection Ratios

With the series resonant portions of the circuit tuned to the appropriate frequencies, a measurement can be performed to establish the ratio of the gain at the desired readout frequencies to the gain at the undesired frequencies corresponding to the rejection notches.

Using a laser capable of RF, AM modulation and an RF network analyzer, perform a frequency sweep from the photodiode to each coaxial output connector on the top surface of the photodetector housing. Use the delta marker function to record the difference between each notch and the relevant RF operating frequency. Be sure to note the DC photocurrent for each quadrant when it is

illuminated by the laser light source. This data allows for normalization if so desired later on. Record the results in [T1200346](#).

9 RF Transimpedance Measurement

Illuminate the photodiode with white light (as generated by a shot noise limited source such as an incandescent bulb) to generate between 5 mA and 10 mA of photocurrent. At each coaxial connector, use an RF spectrum analyzer to measure the RF power spectral density at the readout frequency associated with each output. A low noise RF pre-amplifier (gain ~20dB) is useful to boost the signal to a comfortable level. Be sure the measurement is not electronically noise limited by careful attention to signal levels.

Establish a photocurrent between 6mA and 10mA. Observe the RF power spectral density present at the operating frequency of the detector. Convert the RF PSD to an rms amplitude (voltage) spectral density, V_{rms} assuming 50Ω and note it as well as the associated DC photocurrent I_{DC} . Using the Microsoft Excel worksheet available in the DCC as a related document to this document, enter the data as needed to calculate the transimpedance, Z_{RF} with the following:

$$Z_{RF} = \sqrt{\frac{V_{rms}^2 I_{DC}}{3.2 \times 10^{-19}}}$$

Enter the transimpedances in the appropriate spots on [T1200346](#).

10 Shot Noise Limited Sensitivity

The shot noise limited sensitivity will characterize the minimum useful optical signal level below which the photodetector will be limited by electronics noise. Using the Microsoft Excel worksheet available in the DCC as an attached document to T1200335, enter the data as needed to calculate shot noise limited sensitivity. In general, the formula used is:

$$I_{lim_{rf}} = I_{DC} \times \frac{V_{dark}^2}{V_{light}^2}$$

Where I_{DC} is the DC photocurrent associated with the illuminated diode, and V_{light} is the RF voltage as derived from a spectrum analyzer reading at the detector fundamental operating frequency

Record the resulting shot noise limited sensitivities in [T1200346](#).

11 Test Input Transconductance and Isolation

An RF test input is provided for modulation, diagnostics, and RF notch tuning. The RF test input circuitry is implemented by use of a common-base RF transistor current source. This section measures the gain of the test input at each of the two operating frequencies, RF HI, and RF LOW.

Using an RF network analyzer, with the internal RFPD test switch enabled, take a transfer function measurement in through the test input and out of each of the two main RF outputs. Record the dB magnitude of each transfer function, Mag_{on} at the operating frequency of the respective output with the test input switch enabled. While observing the magnitude of the transfer function with the test switch on, disable the test switch and note the dB magnitude of the transfer function, Mag_{off} with the test switch disabled. Calculate the test input transconductance C_t by use of the linear magnitude of the transfer function, Mag_{on} divided by the calculated average transimpedance, Z for that RF path as recorded in section 9. The Microsoft Excel worksheet available in the DCC as an attached document to T1200335 can also be used to perform this calculation.

$$C_t = \frac{10^{\left(\frac{Mag_{on}}{20}\right)}}{Z}$$

$$Isolation = Mag_{on} - Mag_{off}$$

Record the resulting transconductance and test switch isolation in [T1200346](#) for each of the two RF frequencies of operation