LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

*LIGO Laboratory / LIGO Scientific Collaboration*

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# Characterization of P-Cal PD Circuit Boards

Sam Elzarian, Richard Savage

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This is an internal working note
of the LIGO Laboratory.

**California Institute of Technology**
**LIGO Project – MS 18-33**
**Pasadena, CA 91125**
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

**Massachusetts Institute of Technology**
**LIGO Project – MS 20B-145**
**Cambridge, MA 01239**
Phone (617) 253-4824
Fax (617) 253-7024
E-mail: info@ligo.mit.edu

**LIGO Hanford Observatory**

**LIGO Livingston Observatory**

http://www.ligo.caltech.edu/

# 1 Introduction

This document is intended to serve as an aid to anyone considering the performance of the PCal PD circuit boards (D1300210-v1)

The PCal PD boards are designed around the C30665GH Photodiode and serve as a transimpedance amplifier that converts the output current of the photodiode to voltage signal that is compatible for use with the Optical Follower Servo circuitry.

These PCal PD Boards can be assembled in one of three configurations, and the distinguishing component values for each configuration can be found in Figure 3 below.

It is essential to the function of the Photon Calibrator that the PD circuits have a flat transfer function response up to ~100kHz. Naturally, it is also essential to the operation of the photon calibrator that there is as little variation as possible between devices.

# 2 Flatness Tests with AC Current Injection

To test the flatness of the PD circuit chain, a sinusoidal current was injected into the downstream contact of the Test Jumper using a modified connector. The "Buffout" signal was then monitored on both a Keithley 2100 DMM and a Tektronix 3034C digital oscilloscope. The input current was set to 22uA and the frequency was swept from 1Hz to 100kHz.

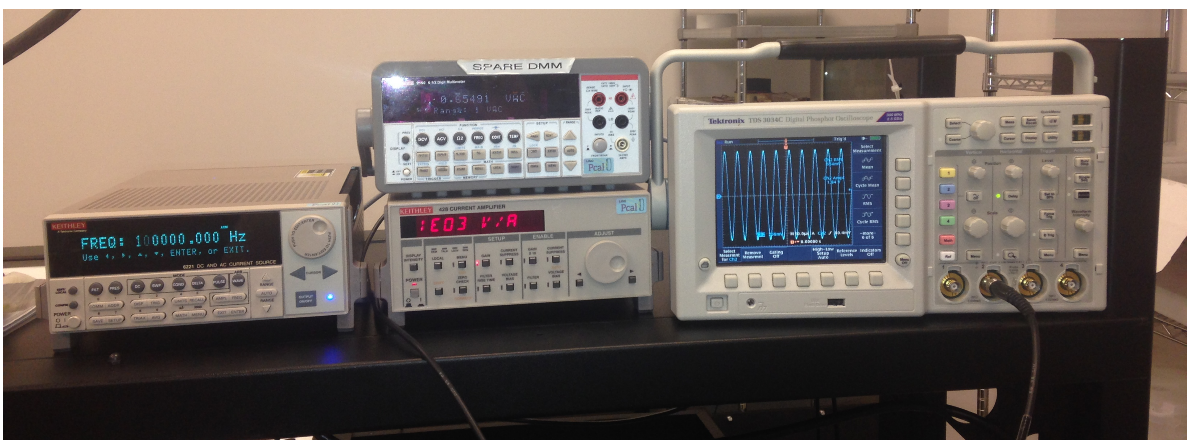


**Figure 1 Picture of Test Setup**

Keithley 6221 AC and DC Current Source(Left) Keithley 2100 DMM (Upper Middle)

Keithley 428 Current Amplifier (Lower Middle) Tektronix TDS 3034C (Right)

**Figure 2 Modified Jumper**

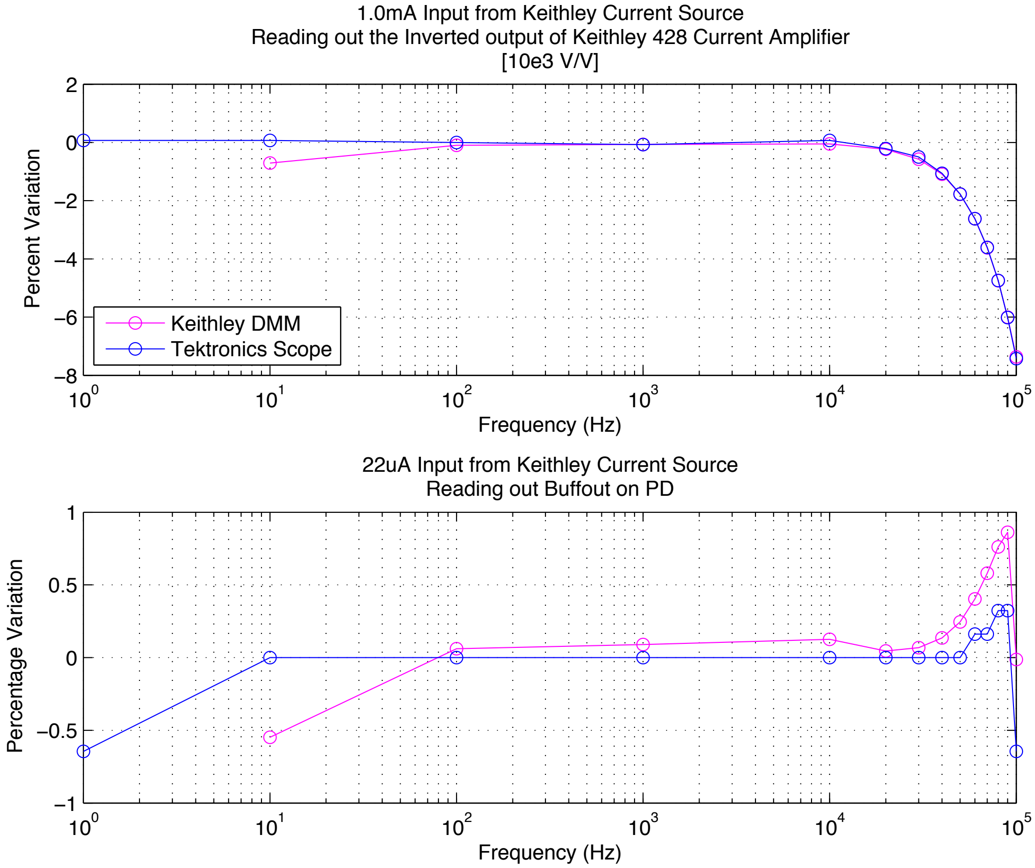


**Figure 3: Flatness test of test equipment (upper) and flatness test of Photodetector circuit (lower)**

### Conclusion

In the plot of the test equipment (without PD), the response seems to be rolling off at higher frequencies (>10kHz). It should be noted that the current source output was 1mA, which is approximately 45 times larger than the 22uA source level used when testing the PD circuit. Also, the Keithley DMM exhibited a decrease in accuracy at lower frequencies, and was unable to produce data at 1Hz.

Overall, the data collected shows that the PD circuit's response is flat within 1% over the frequency range 1Hz to 100kHz, and flat within .2% from 10Hz to 10Khz.

# 3 TF Uniformity Tests

To test the uniformity of PD circuit chain:

1.1 The presented data were collected using a SR785 Signal Analyzer. The plots produced are frequency responses collected by injecting the source signal into TP4 on the photodiode boards and reading out of the "BuffOut+" on the 9-pin connector.

1.2 Each of the frequency responses were compared to and normalized to the mathematical model that was calculated to be characteristic of the photodiode board

1.3 The model equation for all configurations is given by:

$$\frac{V_o}{V_i} = \frac{j\omega C_7 R_t}{(1 + j\omega C_t R_t)(1 + j\omega C_{11} R_6)}$$

$$Where\colon\ C_7 = 390pF \qquad C_{11} = 470nF \qquad R_6 = 470nF$$

In the case of the Tx configuration the second gain stage op-amp is not modeled in the equation. To include the additional gain in the Tx model the numerator of the equation becomes $[j\omega C_7 R_t * 10]$

| Photodiode | Transimpedance Resistor, Rt | Transimpedance Cap., Ct | Gain Resistor, Rg |
|---|---|---|---|
| OFS (10) | 422 Ohms | 30pF | 2K |
| Rx, GS (15) | 8.45K | 6.8pF | 2K |
| Tx (10) | 11K | 5.6pF | 20K |

Figure 4: **Distinguishing component values between PD circuit configurations**

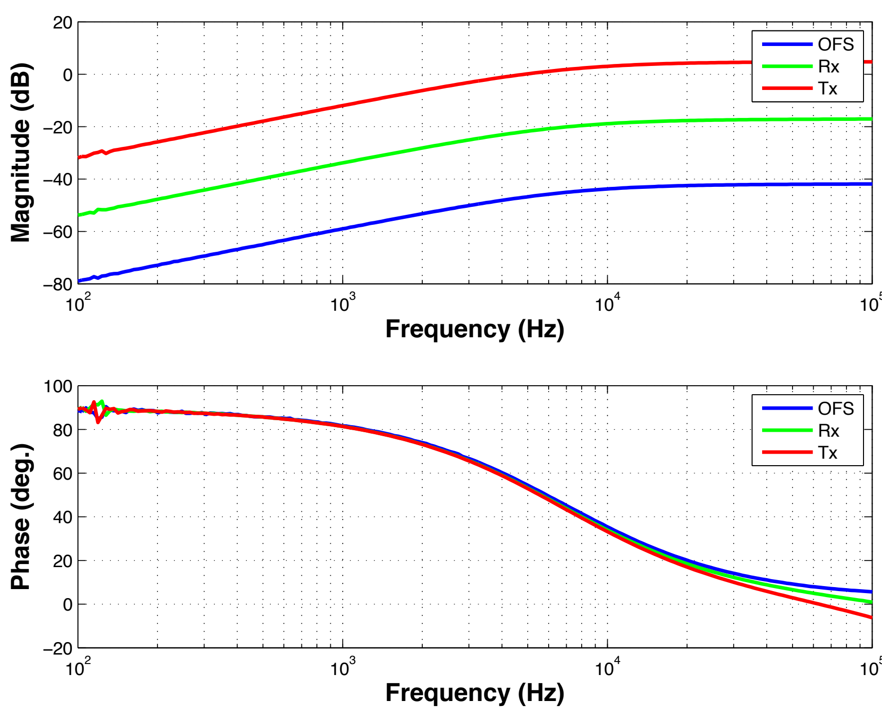


**Figure 5 Examples of expected transfer function for each configuration**

## 3.1 Optical Follower Configuration (OFS)

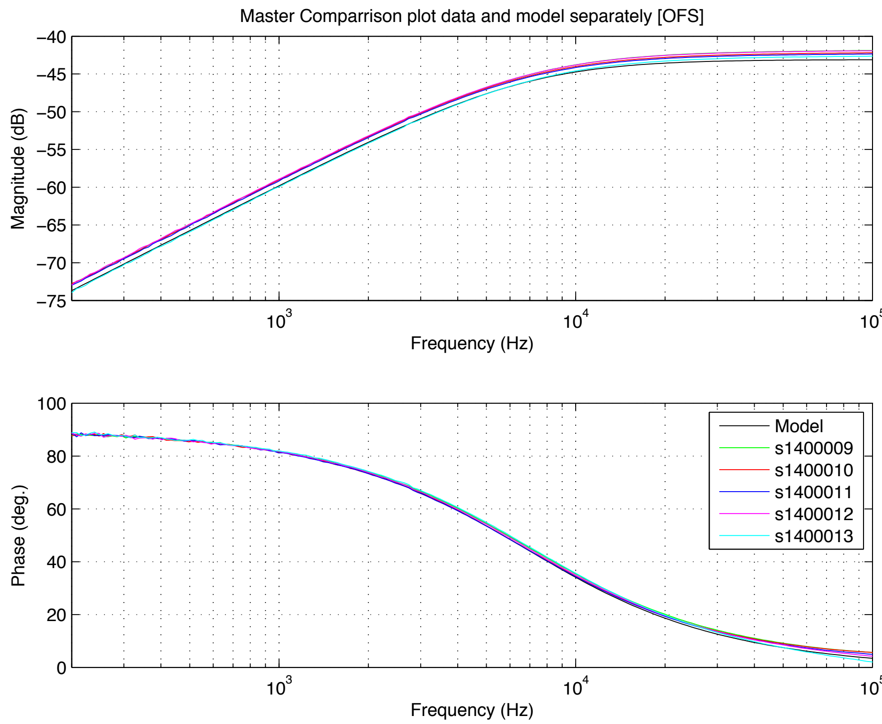


**Figure 6**

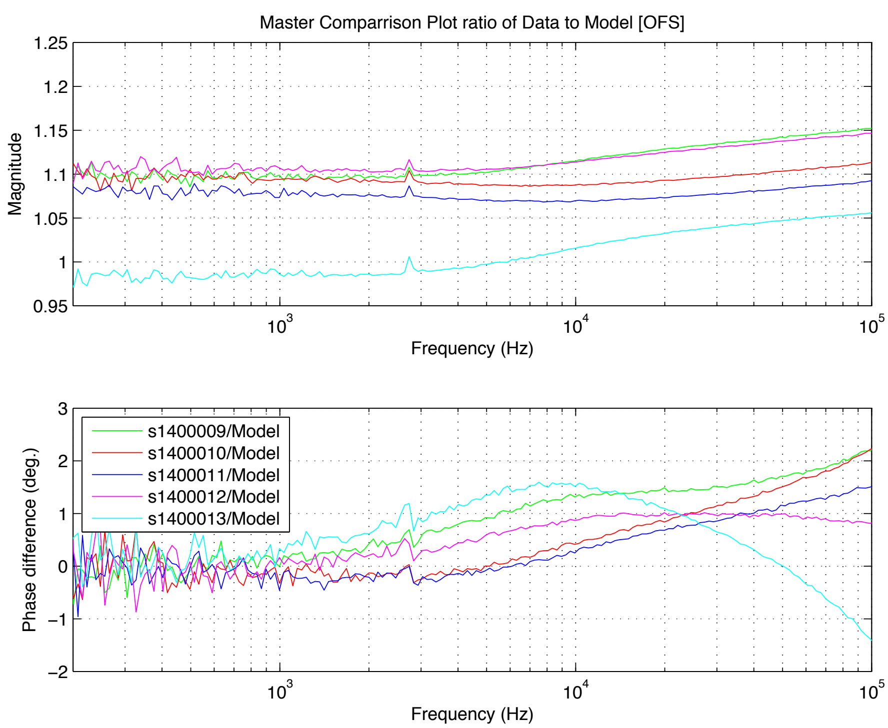


**Figure 7**

## 3.2 Receiver Configuration (Rx)

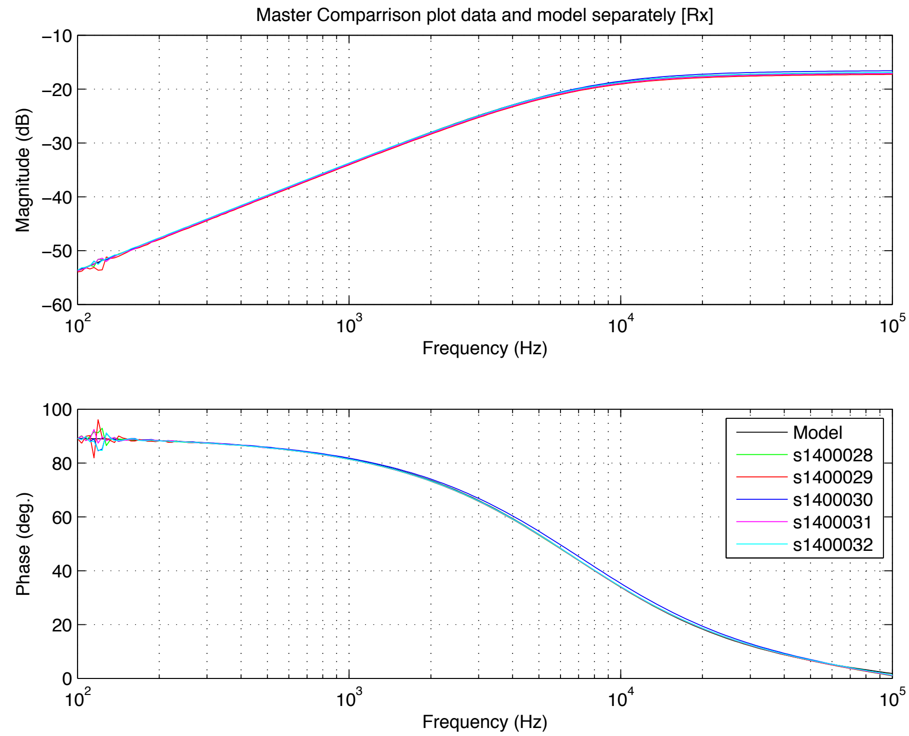


**Figure 8**

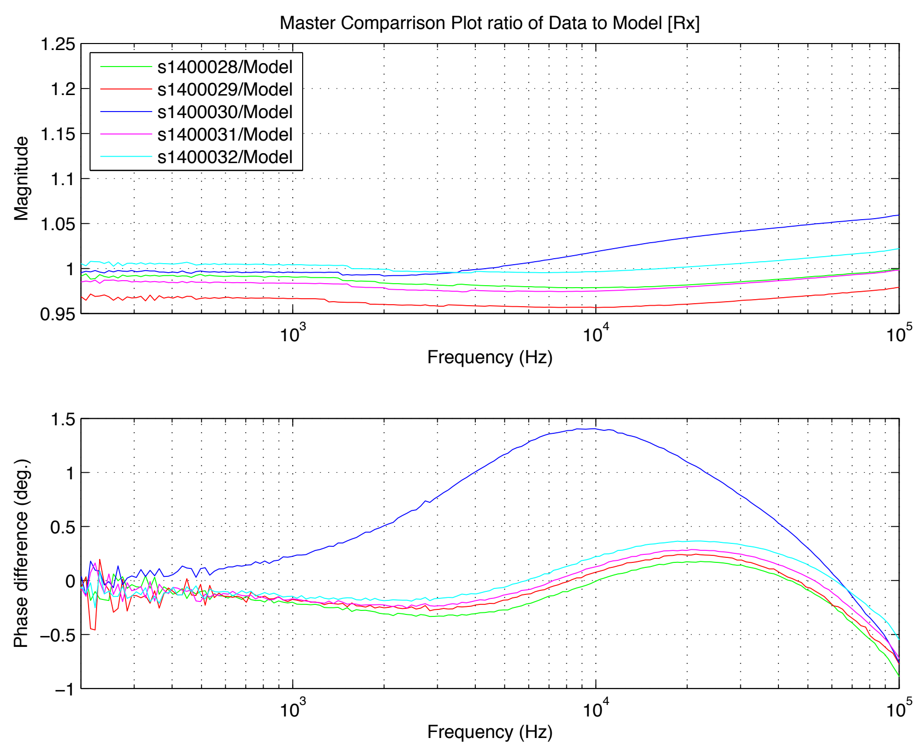


**Figure 9**

## 3.3 Transmitter Configuration (Tx)

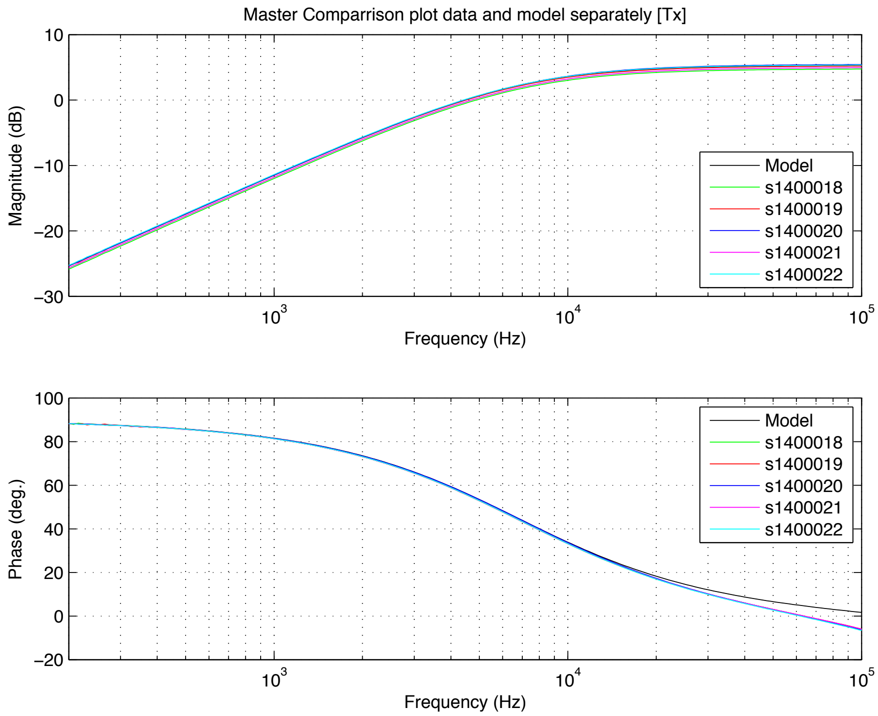


**Figure 10**

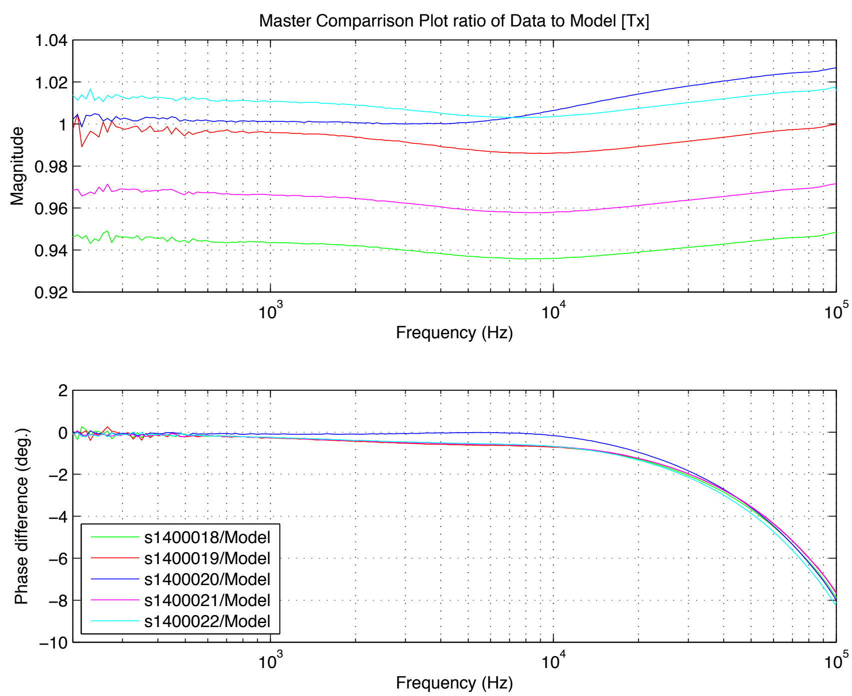


**Figure 11**

### 3.4 Conclusion

The transfer function uniformity between PD circuit boards for most cases appear to have variation of less than 2%. There are come outliers that should be considered and may require further testing. It should be noted that the data presented in this report only represents fifteen PD circuit boards total, five for each configuration.