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|-----------|------------------|
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| Refer to: | LIGO-E1300845-v1 |
| Date:     | Nov 3, 2013      |

## Phase locked loop Board Test Procedure

### Test Preparation

Enter Name, Date, Revision, Board Serial Number VCO chassis serial number:

| Test Engineer | Date                    | Pass                      |
|---------------|-------------------------|---------------------------|
| JAX SANDERS   | 02/05/14                | ✓                         |
| Board         | PLL Board Serial Number | VCO chassis serial number |
| D1300812      | —                       | 51200572                  |

### Required Test and Ancillary Equipment

- 1 – One PLL Tester D1300797
- 1 - Tektronix AFG 3101 Signal Generator or equivalent
- 1 - Tektronix TDS 210 Oscilloscope or equivalent
- 1 – Fluke Multimeter or equivalent
- Calibrator (or DC voltage source)
- 1 - HP 4395A Network analyzer (1Hz to 10MHz) or equivalent
- 1 - Stanford Research Systems Signal Analyzer Model SR785
- 1 - GPIB to Cat5 adapter
- 1 - Cat5 cable
- 1 – Laptop CPU using Windows operating system
- 1 – Folder containing Test File Scripts
- 2 - DC Power Supplies (Five Channels Required. Continuous Supply Voltages: +/- 24VDC, +/- 17VDC, and +5VDC)
- 1 - 17VDC Power Cable
- 1 - 24VDC Power Cable
- 1 – 5VDC Power Cable (Banana Plug to Banana Plug Cable and Jumper)
- 1 - custom cable adapting the DB9 Monitor port on the D0901781 front panel into three BNCs. ( Refer to Common Mode Board: DAQ, Number D040180 Rev E, Sheet 17 of 17 for DB9 pinout detail)
- 1 - 25 pin D sub cable male to female
- 3 – TNC male to BNC female adapters
- 1 – 2 pin lemo to BNC adapter
- 3 – BNC Female to Female Adapters (Barrels)
- 1 - BNC Tee Connector
- 1 – BNC to grabber adapter

- 3 - BNC Female to Double Stacking Banana Plugs
- 1 - SMA to BNC adapter
- 2 - 50 ohm BNC terminations
- 4 - BNC Male to BNC Male Cables

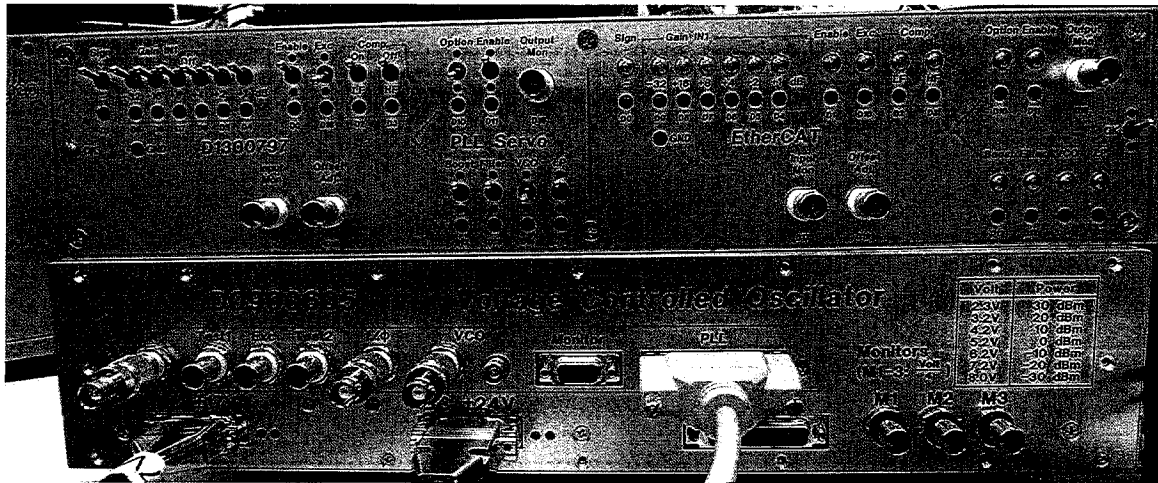
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**IMPORTANT NOTES:**

1. On the PLL Tester (D1300797) front panel, all switches must be returned to default positions (up) after each test and/or step, unless otherwise instructed.
2. Always turn on 24 V power supply before 17 V, and turn off 17 V before 24V.

Picture 1



Rear Panel of D0900605 Voltage Controlled Oscillator and D1300797 PLL Servo Tester.

### Tests Part 1.

On the PLL board, **Connect** the positive multimeter test lead to the following test points and **Connect** the negative multimeter test lead to GND.

**Record** the observed voltages in the data boxes below, place a check if the front panel OK LED is lit.

| TP17 | TP18 | TP19 | TP20 | TP21 | TP22 | TP23 | TP24 | TP25 | TP26 | OK  |
|------|------|------|------|------|------|------|------|------|------|-----|
| 15   | -15  | 5    | GND  | GND  | GND  | GND  | GND  | GND  | GND  | ✓   |
| +15V | -15V | +5V  | GND  | GND  | GND  | GND  | GND  | GND  | GND  | lit |

### Power Supplies

**Turn OFF Power Supplies, first turning off 17V then 24V each time.**

**Connect** 25 pin PLL control cable to corresponding jacks on tester (on rear, labeled controls) and VCO chassis rear panel (labeled PLL).

**Turn ON Power Supplies**

**Check** current draw from the  $\pm 17V$  power supply is about 1 Amp.

On the front panel of Power Supplies, **Observe** and **Record** the amperage displayed.

| Power supply | Current | Nominal |
|--------------|---------|---------|
| +24V         | 0.07    | 0.1     |
| -24V         | 0.02    | 0.02    |
| +17V         | 1.03    | 1       |
| -17V         | 0.26    | 0.26    |

## Oscillations

Connect oscilloscope and Set oscilloscope coupling to **AC Coupling**.

Connect oscilloscope probe to the following outputs. Ensure no oscillating wave forms are observed.

Place checkmark in corresponding box below each output.

| Outputs  | Test1 | Test2 | f/φ | VCO (TNC) | VCO(Lemo) | Tester Input Mon (D17) | Tester Output Mon (D18) |
|----------|-------|-------|-----|-----------|-----------|------------------------|-------------------------|
| CheckBox | ✓     | ✓     | ✓   | ✓         | ✓         | ✓                      | ✓                       |

## Adjust DC Bias

Set Oscilloscope coupling to DC Coupling.

**Connect** On tester connect Input Mon (D17) to the oscilloscope.

**Ground** IN using a BNC 50 ohm termination.

**Adjust** DC bias (R46) for zero volts observed at Input Mon.

**Connect** Multimeter to VCO output, disable LF compensation filter by flipping D2 down. Readjust R46 for 0V observed at VCO output.

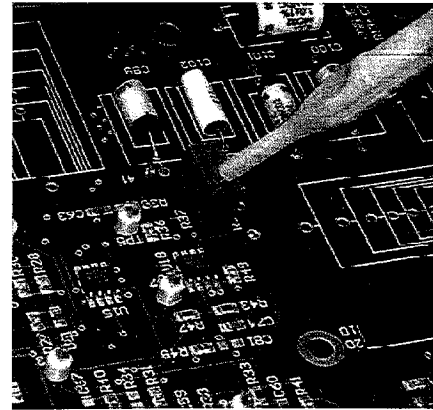


Figure 1: Potentiometer similar to R46

**Enable** the first compensation filter, flipping D2 up. Adjust R46 for zero volts observed at VCO out.

**Enable** the second compensation filter, flipping D3 down. Adjust R46 for zero volts observed at VCO out.

**Return** switches to defaults.

Use a voltage calibrator to send a voltage into Offset Adjust (D19) on the tester.

|                              |       |       |        |
|------------------------------|-------|-------|--------|
| Input to Offset Adjust (D19) | 0V    | 10V   | -10V   |
| Input Mon (D17)              | 11 mV | 66 mV | -44 mV |
| Nominal Input Mon            | 0     | 55mV  | -55mV  |

**Connect** Function Generator Output (sine wave, 100Hz, 1 Vpp, 1 V offset) to PLL IN jack.

**Connect** Test1 to the oscilloscope.

**Toggle** Sign (Input polarity, D1) on tester, and check that polarity of the signal on oscilloscope flips. Circle here if correct.

**Toggle** Enable (D0), check that signal goes to zero when disabled. Circle here if correct.

### Gain slider:

Set offset on function generator to 0V.

Individually, **Toggle** each switch down (GND) and **Record** observed voltage. After each voltage observation, **Return** the switch to default position. Tolerance is +/-0.5dB (6%).

| Binary input (Switch Setting) | Measured Vpp | Nominal Vpp |
|-------------------------------|--------------|-------------|
| —(0dB)                        | 1.04         | 1           |
| D4 (1dB)                      | 1.16         | 1.12        |
| D5 (2dB)                      | 1.28         | 1.26        |
| D6 (4dB)                      | 1.64         | 1.59        |
| D7 (8dB)                      | 2.52         | 2.51        |
| D8 (16dB)                     | 6.32         | 6.31        |
| D7 & D8 (24dB)                | 15.8         | 15.9        |
| D9 (-32dB)                    | 0.026        | 0.025       |
| D9 & D7 (-24dB)               | 0.064        | 0.063       |
| D9 & D8 (-16dB)               | 0.160        | 0.159       |
| D9 & D7 & D8 (-8dB)           | 0.400        | 0.398       |

### Excitation

**Leaving** the excitation from the function generator on the input, measure the signal at Test2. If signal is the same as at Test 1 and input (1Vpp, 100Hz) circle here.

**Set D2 down** (turn off LF comp) , all other switches should be up.

**Inject** a 100Hz/1Vpp **Sine wave** to A:EXC (remove input from IN). **Measure** and **Record** the voltage at Test2 and VCO while toggling the switches **Down**. \*\* Tolerance is +/-0.5dB.

| Binary input                  | A:TEST2 | Nominal Vpp | VCO   | Nominal Vpp |
|-------------------------------|---------|-------------|-------|-------------|
| D2 down                       | off     | Off         | off   | Off         |
| D2+D16 (exc enable )<br>down  | 0.104   | 0.10        | 0.108 | 0.10        |
| D2+D16 & D10<br>(option) down | 0.104   | 0.10        | off   | Off         |

**Set** all switches up. **Inject** a 100Hz/1Vpp **Sine wave** to IN. **Measure** and **Record** the voltage at f/phi and VCO while toggling the switches **Down**. \*\* Tolerance is +/-0.5dB.

| Binary input | f/φ  | Nominal Vpp | VCO  | Nominal Vpp |
|--------------|------|-------------|------|-------------|
| —            | 3.68 | 3.9         | 18.4 | 17.4V       |



|                     |       |                          |       |      |
|---------------------|-------|--------------------------|-------|------|
| D2 (LF comp)        | 0.212 | 0.2                      | 0.992 | 1.00 |
| D2+D3 (LF +HF comp) | 2.12  | 2                        | 10.8  | 10.0 |
| D12 (boost)         | 4.08  | 3.9 (may have DC offset) | 18.4  | 17.8 |
| D13 (filter)        | 3.76  | 3.9                      | 18.4  | 17.8 |
| D14 (VCO)           | 3.68  | 3.6                      | 18.4  | 17.8 |
| D15 (low pass)      | 1.68  | 1.6                      | 18.4  | 17.8 |

Connect SMA to BNC adapter to J7 (towards rear of board). With 100Hz/1Vpp Sine wave still injected into IN, observe signal at J7.

| Binary input | J7   | Nominal Vpp |
|--------------|------|-------------|
| D2           | 1.04 | 1.0         |
| D2 and D11   | off  | off         |

### EPICS Readbacks

Inject a 1Hz/0.1V pp or 100Hz/1Vpp Sine wave to IN and Record the observed voltage.

\*\*The voltage tolerance is 1 dB of the nominal value.

| EPICS readback   | 1Hz/0.1Vpp | Nominal Vpp | 100Hz/1Vpp | Nominal Vpp |
|------------------|------------|-------------|------------|-------------|
| D17 (input mon)  | 0.1        | 0.09        | 0.086      | 0.080       |
| D18 (output mon) | 4.88       | 4.8         | 1.5        | 1.6         |

### Tests Part 2: SR785 Signal Analyzer Tests

**Important Notes: 1. Switch LF comp and VCO comp to off on the tester (D2 and D14 down) for all the measurements in this section, unless otherwise directed. 2. Closely Read and follow all On-Screen prompts.**

On a Windows operating system laptop, Create and Save a file called PLL\_TEST\_DATA to C: drive. The path is C:\PLL\_TEST\_DATA\.

Save Test Scripts in PLL\_TEST\_DATA. Test scripts are available as a zip file attached to this procedure in the DCC.

Connect an SR785 Signal Analyzer to the laptop with a GPIB to Cat5 adapter.

From the DOS CMD window, Type cd.. , Enter, Type cd.. ,Enter and Type cd TEST\_DATA.

**Type** and **Run** 'setgpib.bat' and **Enter** the adapter's IP address (which should be labeled on the adapter).

**Reset** the SR785's settings with 'resetSR785.bat'. If the SR785 resets when the script is run, the SR785 is properly connected to the PC.

### Monitor Channel Filtering (SR785MonitorTFs.bat)

In the DOS CMD window, **Type** SR785MonitorTFs

**Read** and **Follow** the On-Screen prompts for proper test equipment configuration and procedure.

**Measure** test transfer functions at 100Hz to 1Hz on IN to the indicated monitor channels on the tester and **Record** the data in the table below. When the command line

\*\* Tolerances for Lowpass filtering are +/-1dB and +/-5deg from nominal.

| Boost #          | @1Hz          | Nominal          | @10Hz          | Nominal          | @100Hz       | Nominal        |
|------------------|---------------|------------------|----------------|------------------|--------------|----------------|
| Input Mon (D17)  | -0.37<br>173  | -0.4dB<br>173deg | -4.41<br>128   | -4.5dB<br>129deg | -22.16<br>95 | -22dB<br>91deg |
| Output Mon (D18) | -6.41<br>-6.9 | -0.4dB<br>-7deg  | -4.48<br>-51.6 | -4.5dB<br>52deg  | -22<br>-84.2 | -22dB<br>85deg |

### Offset Adjustment Channel Filtering (SR785AdjustmentTFs.bat)

**Type** SR785AdjustmentTFs

**Test** the transfer functions at 10kHz to 1Hz on the offset adjust channel on the tester to VCO output. Verify filtering of at least -60dB at 100Hz and **Record** levels below in the boxes below.

|                  |      |
|------------------|------|
| Offset Adj.(D19) | - 89 |
|------------------|------|

### Distortion (SR785DistortionMeasurement.bat)

**Type** SR785DistortionMeasurement **Inject** a 1kHz/1Vrms sine wave to IN1. Use a spectrum analyzer (SR785) to measure the harmonic components at VCO; see Appendix 4. On the SR785, **Press** Marker to display THD level on right side of SR785 screen, and set cursor to 992Hz. **Repeat** the measurement using the f/phi output. **Record** the measurements in the boxes below.

|  | VCO out | SERVO  | f/phi | SERVO  |
|--|---------|--------|-------|--------|
| <b>Total Harmonic Distortion (THD)</b> | - 83    | <-70dB | - 85  | <-70dB |

### Noise Spectra (SR785NoiseMeasurements.bat)

Type resetSR785 and Allow the SR785 to reset. Type SR785NoiseMeasurements

Terminate IN using a 50 ohm terminator. Measure the noise density at VCO out and f/phi. Record the values at 100Hz, 1kHz, 10kHz and 100kHz in the table below. See Appendix A1 for typical examples.

| Frequency | VCO | < [nV/√Hz] | f/φ | < [nV/√Hz] |
|-----------|-----|------------|-----|------------|
| 100Hz     | 38  | 40         | 24  | 30         |
| 1kHz      | 38  | 40         | 15  | 30         |
| 10kHz     | 29  | 40         | 14  | 30         |
| 100kHz    | 29  | 40         | 13  | 30         |

### Basic Transfer Functions (SR785BasicTFs.bat)

Type SR785BasicTFs

Sweep the frequency from 100kHz down to 10Hz with 10mV source amplitude and Measure the transfer function from IN1 to VCO, with D3 down (HF comp) and all other switches on tester up (including D2, LF comp). Then repeat measurement from IN to f/phi with D2 down, D3 up, D12, D13 and D14 down (all other switches up), using a 500mV source amplitude. Then repeat measurement from IN to f/phi with D2 down, D3 up, D12, D13 and D14 up and D15 down (all other switches up), using a 500mV source amplitude. Record the values at 1Hz, 100Hz, 1kHz, 10kHz and 100kHz in the table below. See Appendix 5 for typical examples.

\*\* Tolerances must be within 1dB and 5deg of nominal.

| VCO out/IN | dB   | Nom   | deg   | Nom    |
|------------|------|-------|-------|--------|
| 100Hz      | 53.4 | 54dB  | 165.4 | 172deg |
| 100Hz      | 44.8 | 45dB  | 111.2 | 111deg |
| 1kHz       | 25.4 | 25dB  | 94.9  | 95deg  |
| 10kHz      | 6.4  | 6.3dB | 117   | 117deg |
| 100kHz     | -0.1 | 0.0dB | 162   | 163deg |

| f/φ/IN(D2, D12, D13, D14 down) | dB   | Nom  | deg   | Nom    |
|--------------------------------|------|------|-------|--------|
| 1Hz                            | 12.4 | 12dB | -30.7 | -31deg |

|        |       |       |       |        |
|--------|-------|-------|-------|--------|
| 10Hz   | -2    | -2dB  | -69.2 | -67deg |
| 100Hz  | -13.7 | -14dB | -21.5 | -22deg |
| 1kHz   | -14.5 | -15dB | -3.34 | -3deg  |
| 10kHz  | -14.6 | -15dB | -0.97 | 0deg   |
| 100kHz | -14.6 | -15dB | -5.4  | -6deg  |

| f/φ/IN(D2 and D15 down) | dB    | Nom     | deg   | Nom      |
|-------------------------|-------|---------|-------|----------|
| 1Hz                     | 12    | 12dB    | -32.5 | -33deg   |
| 10Hz                    | -2.7  | -3dB    | -78.9 | -80deg   |
| 100Hz                   | -21.4 | -22.6dB | -85.2 | -85.7deg |
| 1kHz                    | -41.1 | -41dB   | -89.4 | -90deg   |
| 10kHz                   | -61   | -61dB   | -90   | -90deg   |
| 100kHz                  | -80   | -81dB   | -90   | -90deg   |

### Transfer Functions of DAQ Channels (SR785DAQTFs.bat)

Type SR785DAQTFs

Measure the transfer function from SR785 CH1 A to D0901781 Monitor jack (DAQ channels). Sweep the frequency from 10kHz down to 1Hz at 1mV source amplitude. Record the values at 1Hz and 10kHz in the table below. See Appendix A5 for typical examples.

\*\* Tolerances must be within 1dB and 5deg of nominal.

| Frequency | 1Hz          | Nominal    | 10kHz        | Nominal     |
|-----------|--------------|------------|--------------|-------------|
| IMON      | 25.7, 0.26   | 26dB, 0deg | 25.7, -2     | 26dB, 0deg  |
| CNTRLMON  | 5.69, -179.7 | -dB, -deg  | 5.68, -180.8 | 6dB, 180deg |

### Tests Part 3: 4395A Network/Spectrum Analyzer

Connect the 4395A in a similar fashion to the SR785, with a GPIB to Cat5 adapter.

## High Frequency Transfer Function (AG4395AHighFreqTF.bat)

These measurements should be done with D2 and D14 down, all other switches up.

Type AG4395AHighFreqTF

Use a network analyzer to measure the transfer function from IN1 to SERVO. Sweep the frequency from 10MHz down to 10kHz with -20dBm source. To remove cable delays first measure the transfer function against a BNC barrel and use as a reference. **Record** the displayed values at 100kHz, 300kHz and 1MHz in the table below. See Appendix A3 for typical examples.

\*\* Tolerances are within 1dB and 5deg of nominal.

| Frequency | VCO/IN [dB] | Nominal | VCO/IN [deg] | Nominal |
|-----------|-------------|---------|--------------|---------|
| 100kHz    | -0.51       | 0dB     | 165.6        | 170deg  |
| 300kHz    | -1.1        | 0dB     | 138.5        | 150deg  |
| 1MHz      | -5.5        | -5dB    | 60.5         | 52deg   |

Check for gain peaking around 4-5 MHz. If there is none, circle here.

| Frequency | VCO/IN [dB] | Nominal | VCO/IN [deg] | Nominal |
|-----------|-------------|---------|--------------|---------|
| 100kHz    | -14.8       | -15dB   | -9.3         | -9deg   |
| 300kHz    | -14.9       | -15dB   | -27.9        | -28deg  |
| 1MHz      | -16.5       | -16.3dB | -90.2        | -90deg  |

Check for gain peaking around 4-5 MHz. If there is none, circle here.