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Test Procedure for New Low Noise VCO

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# Introduction

The following Test Procedure describes the test of proper operation of the new Low Noise VCO. The unused RF outputs should always be properly terminated with 50 Ohms. Further information can be found on the [wiki page](http://ilog.ligo-wa.caltech.edu:7285/advligo/LowNoiseVco).

S/N \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Tester \_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Test Equipment

* Voltmeter and Oscilloscope
* Stanford Research SR785 analyzer
* Tektronix AFG3101 function generator
* RF Power Meter Agilent E4418A
* RF Frequency counter Agilent 53131A
* VCO tester, LIGO [D1100545](https://dcc.ligo.org/LIGO-D1100545)
* Schematics, LIGO [D2100570](https://dcc.ligo.org/LIGO-D2100570) and [D0600609-v3](https://dcc.ligo.org/LIGO-D0900609) (version 3 or higher)
* Wenzel Bluephase

# Tests

*The new Low Noise VCO,* [*D2100570*](https://dcc.ligo.org/LIGO-D2100570)*, uses the Low Noise Power Module (*[*D0901846*](https://dcc.ligo.org/LIGO-E1200129)*, rev D) with the RF Distribution Amplifier Interface (*[*D1000064*](https://dcc.ligo.org/LIGO-D1000064)*, rev A).*

1. **Verify the proper current draw.**  Using a bench DC supply apply +- 24Volts to P7 and +- 17 Volts to P6 of the low noise power Module (D0901846). Measure the current draw of the board.

+24 Volt current \_\_\_\_\_\_\_\_\_\_\_\_\_\_ 0.1 A Nom.

-24 Volt current \_\_\_\_\_\_\_\_\_\_\_\_\_\_ 0.0 A Nom.

+17 Volt current \_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 0.6 A

-17 Volt current \_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 0.2 A

1. **On the low noise power module check the voltage on TP 1-13.**

TP1 ( +17V ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_ TP2 (-17V ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TP3 , 4 ( GND ) TP5 (+ 5V)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TP6 (-15V ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ TP7 (+24V ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TP8 ( GND ) TP9 ( -24V ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TP10 ( GND ) TP11 (+15V ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

TP12 (+VREF ) \_\_\_\_\_\_\_\_\_\_\_\_\_ TP13 (-VREF ) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. **If TP 1 , 2, 7 , 9 and 8 are correct then pin 5 on U1 and U7, ( OK, TP14 ) should be**

**Logic high ~3Volts. Confirm.\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. **The noise on TP 12, 13, 11 and 6 should be measured with a SR785 using an**

**rms power spectrum.**

TP12 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_less than 20 nVrms/sqrt Hz at 140 Hz

TP13 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_less than 20 nVrms/sqrt Hz at 140 Hz

TP11 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 20 nVrms/sqrt Hz at 140 Hz

TP6 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 30 nVrms/sqrt Hz at 140 Hz.

1. **Test the power monitors by applying a 30 MHz, 10 dBm rf signal through an 20dB attenuator to each of the RF detectors.**  Measure the output voltages mon1, mon2 and mon3, and with a RF power meter measure the RF power applied to the detector input.

Depending on variant, not all monitors are equipped with RF power detectors!

**Mon1**

|  |  |  |  |
| --- | --- | --- | --- |
| **Nom input pwr** | **Measured Pwr dBm** | **Monitor Voltage (M)** | **Measured Volt** |
| **+10 dBm** |  | 4.2 Volts ( 1.05 ) |  |
| **+5 dBm** |  | 4.7 Volts ( 1.175 ) |  |
| **0 dBm** |  | 5.2 Volts ( 1.30 ) |  |
| **-5 dBm** |  | 5.7 Volts ( 1.425 ) |  |
| **-10 dBm** |  | 6.2 Volts ( 1.55 ) |  |

**Mon 2**

|  |  |  |  |
| --- | --- | --- | --- |
| **Nom input pwr** | **Measured Pwr dBm** | **Monitor Voltage (M)** | **Measured Volt** |
| **+10 dBm** |  | 4.2 Volts ( 1.05 ) |  |
| **+5 dBm** |  | 4.7 Volts ( 1.175 ) |  |
| **0 dBm** |  | 5.2 Volts ( 1.30 ) |  |
| **-5 dBm** |  | 5.7 Volts ( 1.425 ) |  |
| **-10 dBm** |  | 6.2 Volts ( 1.55 ) |  |

**Mon 3**

|  |  |  |  |
| --- | --- | --- | --- |
| **Nom input pwr** | **Measured Pwr dBm** | **Monitor Voltage (M)** | **Measured Volt** |
| **+10 dBm** |  | 4.2 Volts ( 1.05 ) |  |
| **+5 dBm** |  | 4.7 Volts ( 1.175 ) |  |
| **0 dBm** |  | 5.2 Volts ( 1.30 ) |  |
| **-5 dBm** |  | 5.7 Volts ( 1.425 ) |  |
| **-10 dBm** |  | 6.2 Volts ( 1.55 ) |  |

*We now move on to the Low Noise VCO: Oscillator Source (D0900609).*

1. **On the Low Noise VCO: Oscillator Source (D0900609) check the voltage on the following test points.** Terminate the tune input with 50 ohms.

TP1\_\_\_\_\_\_\_\_\_\_\_\_\_ nominal 0.0V

TP2 \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal 0.0V

TP3 \_\_\_\_\_\_\_\_\_\_\_\_\_ adjust to +10.0V by trimming R25.

TP4 \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +10.0V with adjusted R25.

TP5 \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal −11.7V with adjusted R25.

TP6 \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +5.0V

TP8 \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +10.0V

Monitor \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal 0V (front panel)

TP24P \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +24V

TP24N \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal −24V

TP15P \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +15V

TP15N \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal −15V

TP VDD \_\_\_\_\_\_\_\_\_\_\_\_ nominal +3.33V

TP VCC \_\_\_\_\_\_\_\_\_\_\_\_ nominal +3.33V Check for oscillations

TP PVCO \_\_\_\_\_\_\_\_\_\_\_ nominal +12V (1600 variant) Check for oscillations

TP P20 \_\_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +20V Check for oscillations

TP REF \_\_\_\_\_\_\_\_\_\_\_\_\_ nominal +10V

TP TREF \_\_\_\_\_\_\_\_\_\_\_\_ nominal +4.22V (1600 variant)

1. **The noise on TP1-6, TP8, TP10P, TP20P and TPREF should be measured with a SR785 using an rms power spectrum.**

TP1 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 40 nVrms/sqrt Hz at 140 Hz.

TP2 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 40 nVrms/sqrt Hz at 140 Hz.

TP3 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 40 nVrms/sqrt Hz at 140 Hz.

TP4 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 40 nVrms/sqrt Hz at 140 Hz.

TP5 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 30 nVrms/sqrt Hz at 140 Hz.

TP8 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 30 nVrms/sqrt Hz at 140 Hz.

Monitor noise\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 500 nVrms/sqrt Hz at 140 Hz (front panel).

TP6 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 10 nVrms/sqrt Hz at 140 Hz.

TP VCC noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 30 nVrms/sqrt Hz at 140 Hz.

TP PVCO noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 30 nVrms/sqrt Hz at 140 Hz.

TP P20 noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 30 nVrms/sqrt Hz at 140 Hz.

TP TREF noise \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ less than 20 nVrms/sqrt Hz at 140 Hz.

*We now move on to the full assembly of the Low Noise VCO (D2100570).*

1. **Measure the transfer function of the tune input**. Use a SR785 in network mode. Take the following transfer functions:

* Tune input to monitor output
* Excitation input to the monitor output
* Tune input to TP6

The first two transfer function should be flat at 6 dB and -20 dB, respectively. The third transfer function should show a pole at 1.5 Hz and a zero at 40 Hz. The DC gain is 3 dB, whereas the high frequency gain is around -25 dB. Save the transfer functions on floppy.

Magnitude/Phase response

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Monitor/Tune** | | **Monitor/Exc** | | **TP6/Tune** | |
| **Frequency** | **Meas.** | **Nom.** | **Meas.** | **Nom.** | **Meas.** | **Nom.** |
| **0.1 Hz** |  | 6 dB/0° |  | −20 dB/0° |  | −3 dB/-4° |
| **1 Hz** |  | 6 dB/0° |  | −20 dB/0° |  | −4.5 dB/-32° |
| **10 Hz** |  | 6 dB/0° |  | −20 dB/0° |  | −19 dB/-67° |
| **100 Hz** |  | 6 dB/0° |  | −20 dB/0° |  | −30 dB/-21° |
| **1 kHz** |  | 6 dB/0° |  | −20 dB/0° |  | −31 dB/-2° |
| **10 kHz** |  | 6 dB/0° |  | −20 dB/0° |  | −31 dB/0° |
| **100 kHz** |  | 6 dB/-5° |  | −20dB/-7° |  | −31 dB/-5° |

Monitor/Tune has an additional minus sign.

1. **Measure RF powers and RF frequencies.** Terminate the Tune input. Always terminate the open outputs. Make sure the on/off switches are on (front panel).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Port** | **Tune** | **Power (dBm)** | **Freq. (MHz)** | **Nominal** |
| **OUT1** | **0V** |  |  | >13 dBm/79.02 MHz |
| **OUT2** | **0V** |  |  | >13 dBm/79.02 MHz |

1. **Measure RF powers and RF frequencies as function of the tuning voltage.** Always terminate the open RF outputs. Around zero the tuning sensitivity should be around 250 MHz/V.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Port** | **Tune** | **Power (dBm)** | **Freq. (MHz)** | **Nominal** |
| **OUT1** | **-7V** |  |  | >13 dBm/77.24 MHz |
| **OUT1** | **-6V** |  |  | >13 dBm/77.33 MHz |
| **OUT1** | **-5V** |  |  | >13 dBm/77.69 MHz |
| **OUT1** | **-4V** |  |  | >13 dBm/77.99 MHz |
| **OUT1** | **-3V** |  |  | >13 dBm/78.27 MHz |
| **OUT1** | **-2V** |  |  | >13 dBm/78.53 MHz |
| **OUT1** | **-1V** |  |  | >13 dBm/78.78 MHz |
| **OUT1** | **0V** |  |  | >13 dBm/79.02 MHz |
| **OUT1** | **+1V** |  |  | >13 dBm/79.26 MHz |
| **OUT1** | **+2V** |  |  | >13 dBm/79.50 MHz |
| **OUT1** | **+3V** |  |  | >13 dBm/79.73 MHz |
| **OUT1** | **+4V** |  |  | >13 dBm/79.97 MHz |
| **OUT1** | **+5V** |  |  | >13 dBm/80.19 MHz |
| **OUT1** | **+6V** |  |  | >13 dBm/80.40 MHz |
| **OUT1** | **+7V** |  |  | >13 dBm/80.48 MHz |

1. **Use the VCO tester and check the signals through the rear connector.** Terminate the tune input at the front panel and use the frequency counter on Out1.

Check that the OK LED is on\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (front panel / tester).

Check that the front panel excitation and the excitation readback

front panel LED \_\_\_\_\_\_\_\_\_ and tester LED \_\_\_\_\_\_\_\_\_ toggle together.

Write down the power and temperature monitors. For the off-value disable the two power switches at the front panel.

|  |  |  |  |
| --- | --- | --- | --- |
| **Signal** | **Value** | **Off value** | **Nominal** |
| **RF power (M1)** |  |  | 3.6 V / >8 V |
| **Temperature (M1)** |  |  | 5.6 V |
| **RF power (M2)** |  |  | 3.6 V / >8 V |
| **Temperature (M2)** |  |  | 5.6 V |
| **RF power (M3)** |  |  | 3.6 V / >8 V |
| **Temperature (M3)** |  |  | 5.6 V |

Test the relay by toggling the “excitation enable” switch on the tester (with the two power switches at the front panel in the on states) \_\_\_\_\_\_\_\_\_\_\_\_\_\_.

Write down the voltage at the RF power/Spare readback (with the two power switches at the front panel in different states). Clip to pins 12/25 by a DB25 breakout board.

|  |  |  |
| --- | --- | --- |
| **Signal** | **Value** | **Nominal** |
| **Both power switches off** |  | < -1.5V |
| **VCO power switch on / FDD (right) off** |  | > -1.5V & < -4.5V |
| **VCO power switches off / FDD (right) on** |  | > -4.5V & < -7.5V |
| **Both power switches on** |  | > -7.5V |

Set the manual tuning frequency and check the VCO tune monitor as well as the frequency on Out1. The tuning sensitivity should be around 125 kHz/V.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Manual Freq Tune** | **VCO tune monitor** | | **Out Frequency** | |
|  | **Value** | **Nominal** | **Value** | **Nominal** |
| **+10 V** |  | 8.6 V |  | 80.18 MHz |
| **0 V** |  | 5.0 V |  | 79.02 MHz |
| **-10 V** |  | 1.4 V |  | 77.70 MHz |

1. **Measure the Phase noise of the Low Noise VCO Output (Out1 or Out2)** using the Wenzel single channel phase noise measurement technique (3.5.3), Figure 3.5.2-1, which can be found at

<http://www.wenzel.com/pdffiles1/BP1000Manual/BP_1000_v101_2_.pdf>.

A reasonable FFT analyzer is the SR785, which can be set to measure power units if you start in Display Setup. A Reference Source must be provided which can be just a Wenzel crystal oscillator of frequency 78.89 MHz, properly powered and connected to the Wenzel phase noise measurement system. The output of the Low Noise VCO will need to be attenuated by about 3 dB to provide the amplitude needed by the Wenzel phase noise measurement system (about 10 dBm).

Out1 or Out2

|  |  |  |  |
| --- | --- | --- | --- |
| **Offset freq. Hz** | **Phase noise spec.** | **Ref osc. phase noise** | **LN VCO noise** |
| **10 Hz** | -45 dBc/Hz | -90 dBc/Hz |  |
| **100 Hz** | -80 dBc/Hz | -110 dBc/Hz |  |
| **1 kHz** | -110 dBc/Hz | -140 dBc/Hz |  |
| **10 kHz** | -140 dBc/Hz | -160 dBc/Hz |  |