LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Test Procedure for Low Noise VCO

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1 Introduction

The following Test Procedure describes the test of proper operation of the Low Noise VCO. The unused RF outputs should always be properly terminated with 50 Ohms. Further information can be found on the wiki page.

2 Test Equipment

- Voltmeter
- Oscilloscope
- Stanford Research SR785 analyzer
- Tektronix AFG3101 function generator
- RF Power Meter Agilent E4418A
- RF Frequency counter Agilent 53131A
- VCO tester, LIGO D1100545-v1
- Board Schematics, LIGO D0900605-v2 and D0900609-v2

3 Tests

The Low Noise VCO uses the Low Noise Power Module (D0901846, rev D) with the RF Distribution Amplifier Interface (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 1.1 A

-17 Volt current _______________ less than 0.01 A

2) 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) ____________________

3) 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._____________________

4) 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.

5) **Test the power monitors by applying a 30 MHz, 10 dBm rf signal through an 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.

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).

6) **On the Low Noise VCO: Oscillator Source (D0900609) check the voltage on TP1-6, TP8, TP10P, TP20P, TPREF and TPREF5.** Terminate the tune input with 50 ohms.

TP1______________ nominal 0.0V

TP2 ______________ nominal 0.0V

TP3 ______________ nominal +11.0V, trim R25 to nominal voltage.

TP4 ______________ nominal +11.0V

TP5 ______________ adjusted

TP6 ______________ nominal +11.0V

TP8 ______________ nominal +11.0V

Monitor ______________ nominal 0V (front panel)

TP24P ______________ nominal +24V

TP24N ______________ nominal -24V

TP15P ______________ nominal +15V

TP15N ______________ nominal -15V

TPVCC ______________ nominal +5V

TP10P ______________ nominal +10V

TP20P ______________ nominal +20V

TPREF ______________ nominal +10V

TPREF5 ______________ nominal +5.46V

7) **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 30 nVrms/sqrt Hz at 140 Hz.

TP2 noise ______________________ less than 30 nVrms/sqrt Hz at 140 Hz.

TP3 noise ______________________ less than 30 nVrms/sqrt Hz at 140 Hz.

TP4 noise ______________________ less than 30 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 30 nVrms/sqrt Hz at 140 Hz (front panel).

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

TP10P noise ____________________ less than 30 nVrms/sqrt Hz at 140 Hz.

TP20P noise ____________________ less than 30 nVrms/sqrt Hz at 140 Hz.

TPREF noise ____________________ less than 20 nVrms/sqrt Hz at 140 Hz.

We now move on to the full assembly of the Low Noise VCO (D0900605).

8) **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°		0 dB/0°		3 dB/-4°
1 Hz		6 dB/0°		0 dB/0°		1.5 dB/-32°
10 Hz		6 dB/0°		0 dB/0°		-13 dB/-67°
100 Hz		6 dB/0°		0 dB/0°		-24 dB/-21°
1 kHz		6 dB/0°		0 dB/0°		-25 dB/-2°
10 kHz		6 dB/0°		0 dB/0°		-25 dB/0°
100 kHz		6 dB/-3°		0 dB/-3°		-25 dB/-3°

9) **Measure RF powers and RF frequencies.** Hook a 10dBm/71.000 MHz OCXO source to the Ref input. For all but the measurements on VCO connector, connect the VCO output to the DIV input. Terminate the Tune input. Always terminate the open outputs.

Port	**Tune**	**Power (dBm)**	**Freq. (MHz)**	**Nominal**
VCO	**0V**			~13 dBm/136 MHz
OUT1	**0V**			>13 dBm/79.5 MHz
OUT2	**0V**			>13 dBm/79.5 MHz

10) **Measure RF powers and RF frequencies as function of the tuning voltage.** Hook a 10dBm/71.000 MHz OCXO source to the Ref input. Connect the VCO output to the DIV input. 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/78.11 MHz
OUT1	**-6V**			>13 dBm/78.22 MHz
OUT1	**-5V**			>13 dBm/78.38 MHz
OUT1	**-4V**			>13 dBm/78.57 MHz
OUT1	**-3V**			>13 dBm/78.79 MHz
OUT1	**-2V**			>13 dBm/79.02 MHz
OUT1	**-1V**			>13 dBm/79.27 MHz
OUT1	**0V**			>13 dBm/79.53 MHz
OUT1	**+1V**			>13 dBm/79.79 MHz
OUT1	**+2V**			>13 dBm/80.05 MHz
OUT1	**+3V**			>13 dBm/80.29 MHz
OUT1	**+4V**			>13 dBm/80.51 MHz
OUT1	**+5V**			>13 dBm/80.71 MHz
OUT1	**+6V**			>13 dBm/80.88 MHz
OUT1	**+7V**			>13 dBm/80.92 MHz

11) **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____________________.

Check that the Excitation switch and the excitation readback 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)			5.6 V / >8 V
Temperature (M1)			6.2 V
RF power (M2)			4.9 V / >8 V
Temperature (M2)			6.2 V
RF power (M3)			<5.4 V / >8 V
Temperature (M3)			6.2 V

Set the manual tuning frequency and check the VCO tune monitor as well as the frequency on Out1. The tuning sensitivity should be around 12.5 kHz/V.

Manual Freq Tune	**VCO tune monitor**		**Out Frequency**	
	Value	**Nominal**	**Value**	**Nominal**
+10 V		100 mV		79.40 MHz
0 V		0 mV		79.53 MHz
-10 V		-100 mV		79.66 MHz

12) **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	-60 dBc/Hz	-90 dBc/Hz	
100 Hz	-97 dBc/Hz	-110 dBc/Hz	
1 kHz	-128 dBc/Hz	-140 dBc/Hz	