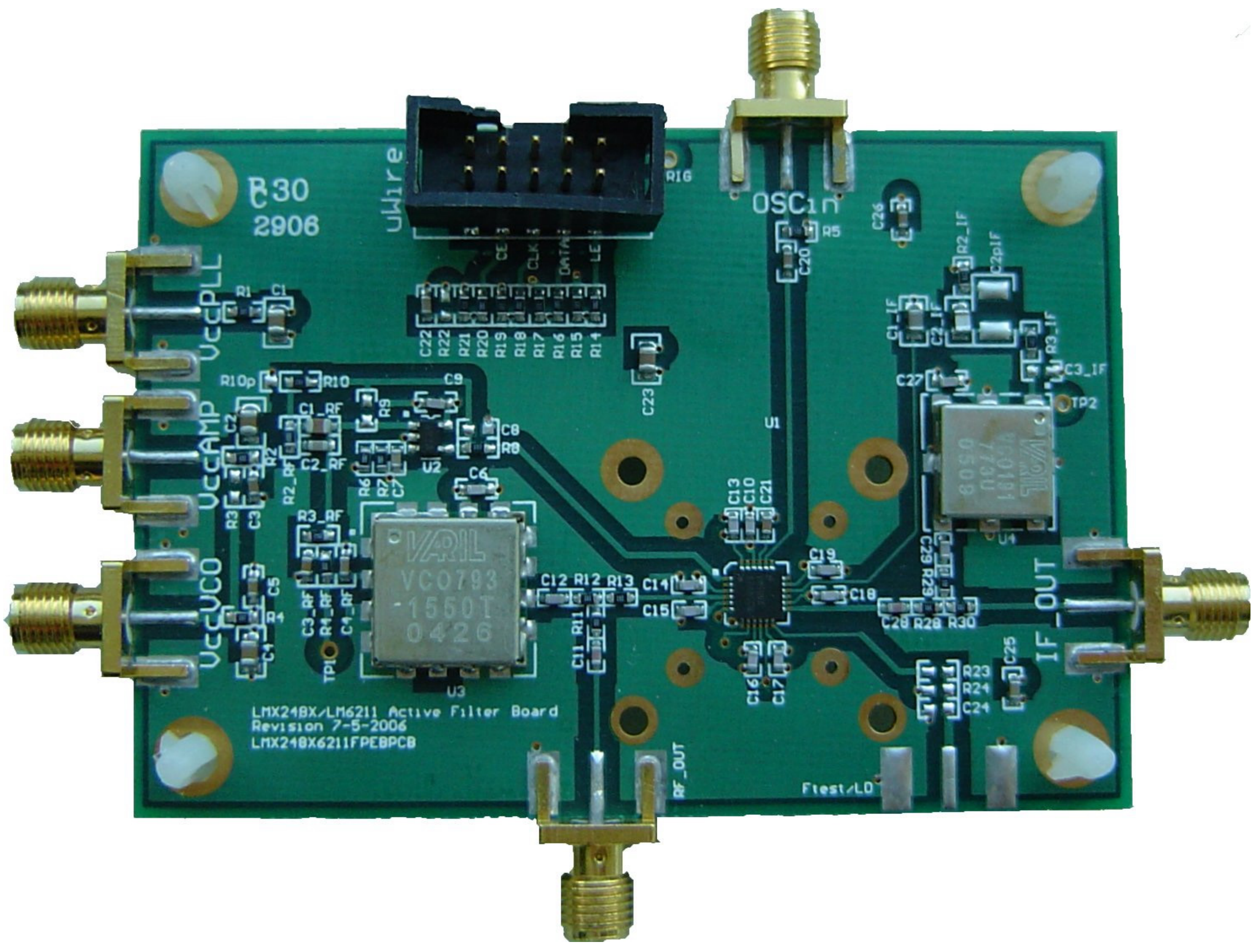
LMX2485 with Active Filter Using LM6211

Evaluation Board Operating Instructions



National Semiconductor Corporation
Wireless Communications, RF Products Group

2900 Semiconductor Dr.
M/S A2-600
Santa Clara, CA, 95052-8090

LMX2485LM6211SLEFPEBI Rev 11.02.2006

LMX2485 Evaluation Board with LM6211 Active Filter

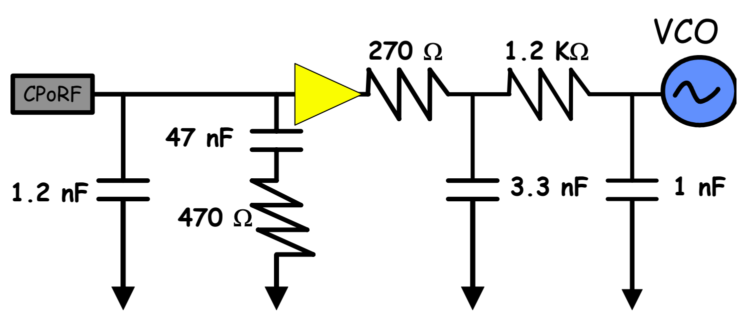
Operating Instructions

General Description

The LMX2485 Evaluation Board simplifies evaluation of the LMX2485 2.6 GHz/0.8 GHz ***PLLatinum***[TM] ***dual frequency synthesizer***. The board enables all performance measurements with no additional support circuitry. The evaluation board consists of a LMX2485 device, a RF VCO module and IF VCO & RF/IF loop filters built by discrete components. The SMA flange mount connectors are provided for external reference input, RF and IF VCO outputs, and the power and grounding connection. A cable assembly is bundled with the evaluation board for connecting to a PC through the parallel printer port. By means of ***MICROWIRE***[TM] serial port emulation, the *CodeLoader* software included can be run on a PC to facilitate the LMX2485 internal register programming for the evaluation and measurement.

RF LOOP FILTER

Phase Margin	46.6 deg	Pole Ratio T3 /T1	318.2 %
Loop Bandwidth	28.4 KHz	Pole Ratio T4/T3	34.9 %
Theoretical Lock Time	168 uS	Roll-Off @ 200 kHz	-27.9 dB



Settings for Operation

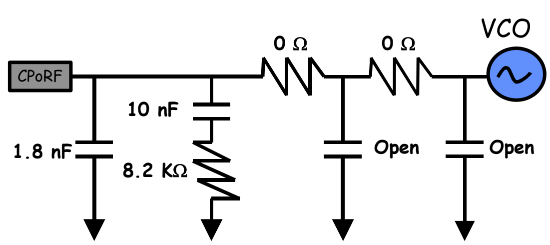
Kϕ	8X (760 uA)
Comparison Frequency	10 MHz
Output Frequency	950 - 2150 MHz
OP Amp Supply	24 Volts
PLL Supply	3.3 Volts
VCO Supply	12 Volts

Other Information

VCO Used	Sirenza VCO793-1550T
VCO Gain	67 MHz/Volt@1.0 GHz 75MHz/Volt@1.5 GHz 60 MHz/Volt@2.0 GHz
VCO Input Capacitance	22 pF

IF LOOP FILTER

Phase Margin	46.4 deg	Lock Time	760 - 780 MHz MHz to 1 KHz tolerance in 508 uS
Loop Bandwidth	4.7 KHz	Spur Gain @ 50 KHz	50.5 dB

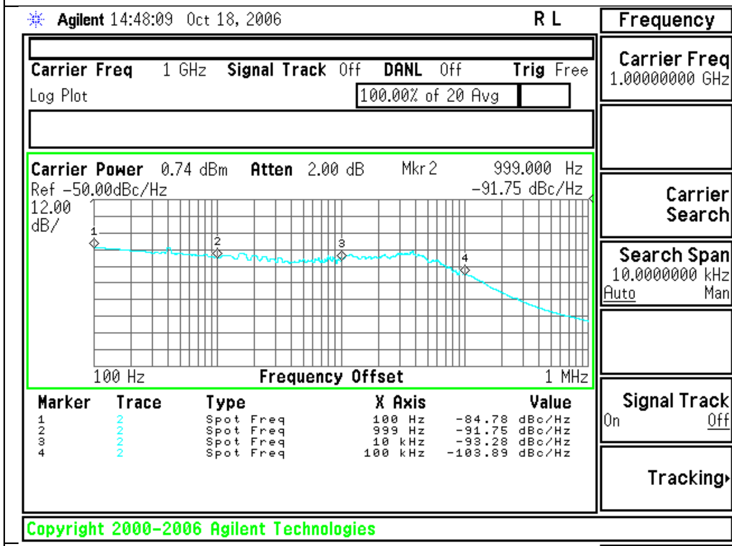
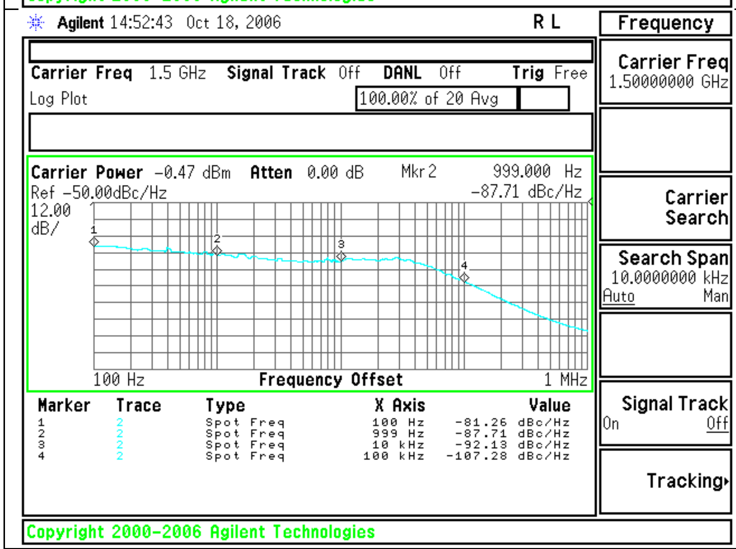
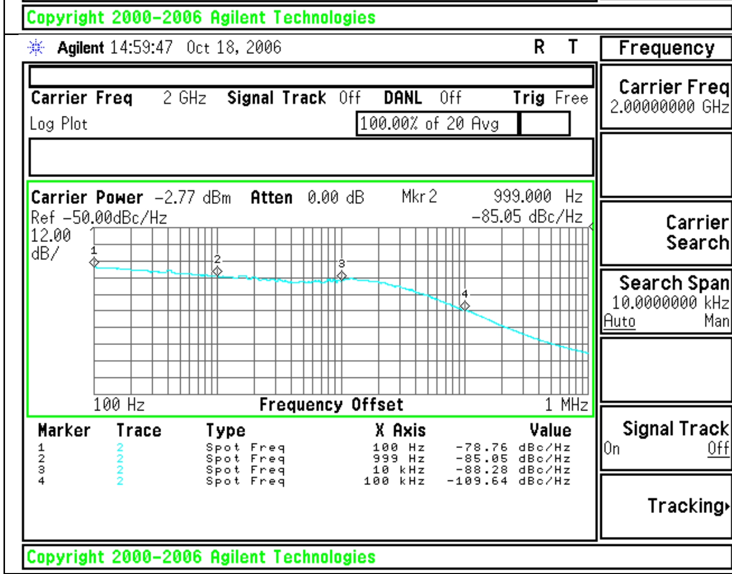


Settings for Operation

Kϕ	3.5 mA
Comparison Frequency	50 kHz
Output Frequency	760 - 780 MHz
PLL Supply	3.3 Volts

Other Information

VCO Used	VARIL191-773U
VCO Gain	18 MHz/Volt
VCO Input Capacitance	100 pF

<table>
<tr><th colspan="2">Phase Noise</th></tr>
<tr><td>
</td><td>Phase Noise for a 1 GHz output Frequency</td></tr>
<tr><td>
</td><td>Phase Noise for a 1.5 GHz output Frequency</td></tr>
<tr><td>
</td><td>Phase Noise for a 2 GHz output Frequency</td></tr>
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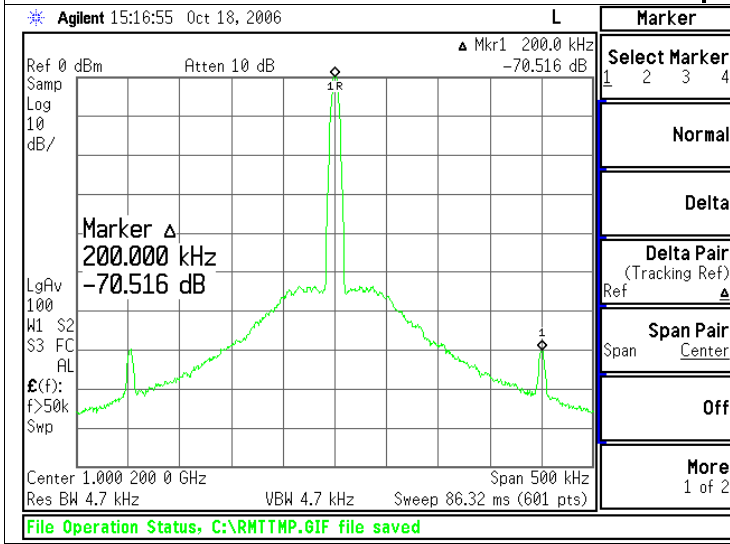
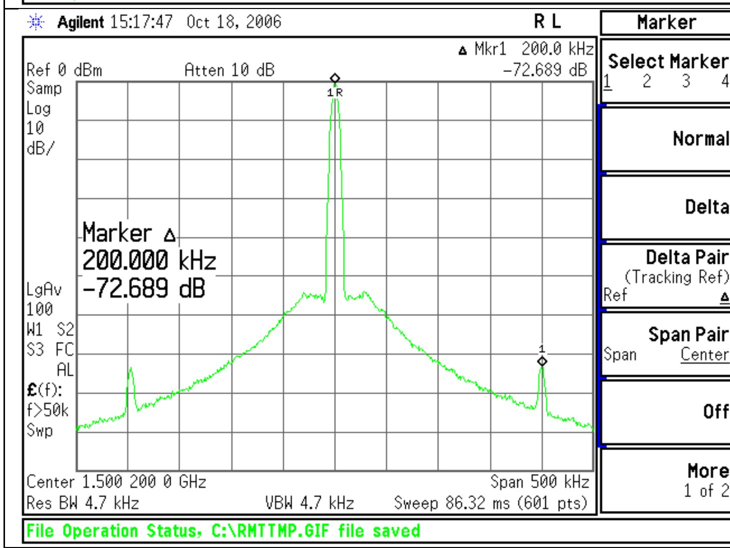
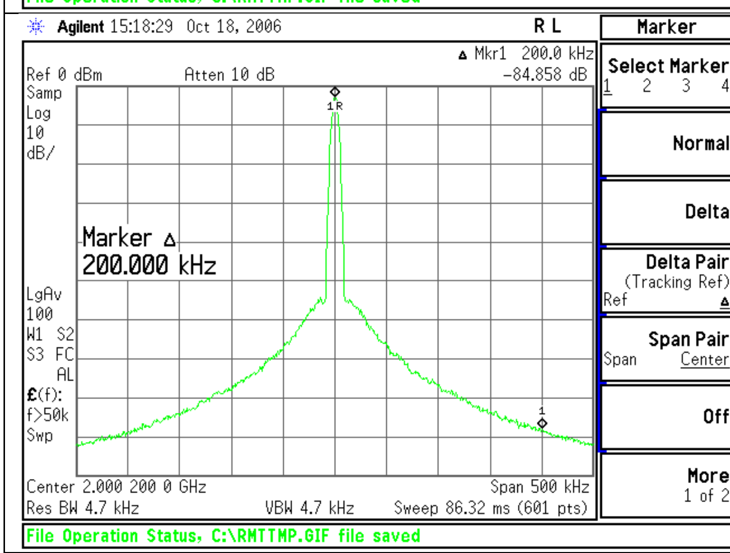
Fractional Spurs



Fractional spurs for a worst case fraction at 1000.2 MHz output frequency.

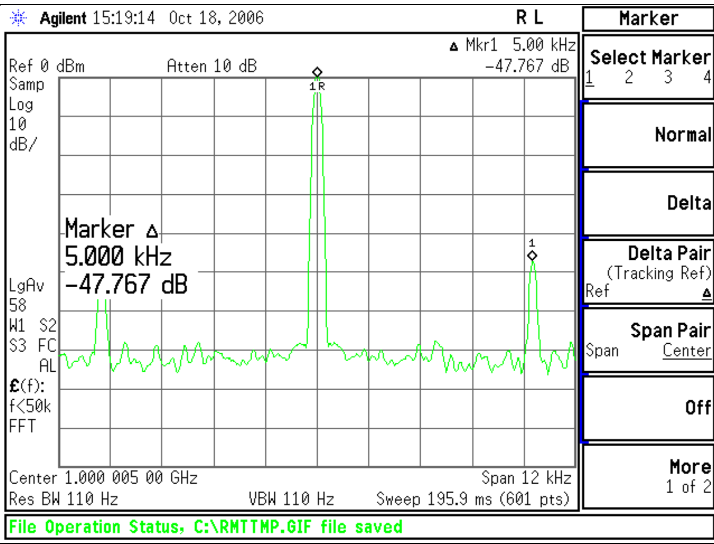


Fractional spurs for a worst case fraction at 1500.2 MHz output frequency.

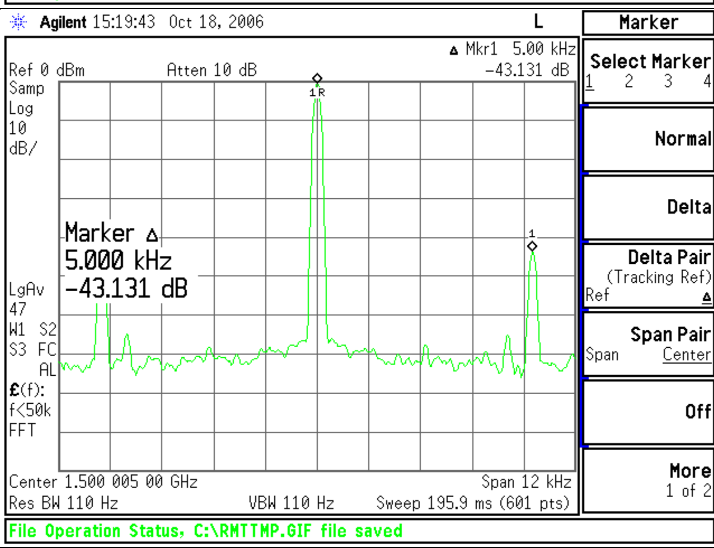


Fractional spurs for a worst case fraction at 2000.2 MHz output frequency.

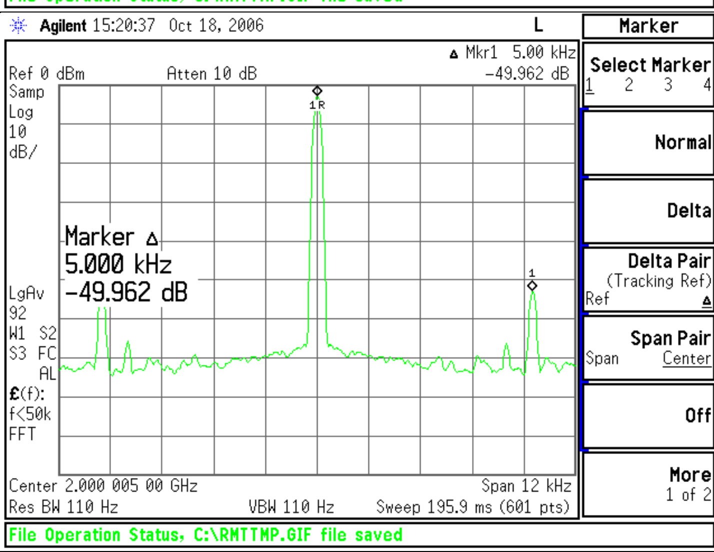
In-Band Fractional Spurs



In band fractional spur for a 1000.005 MHz output frequency.

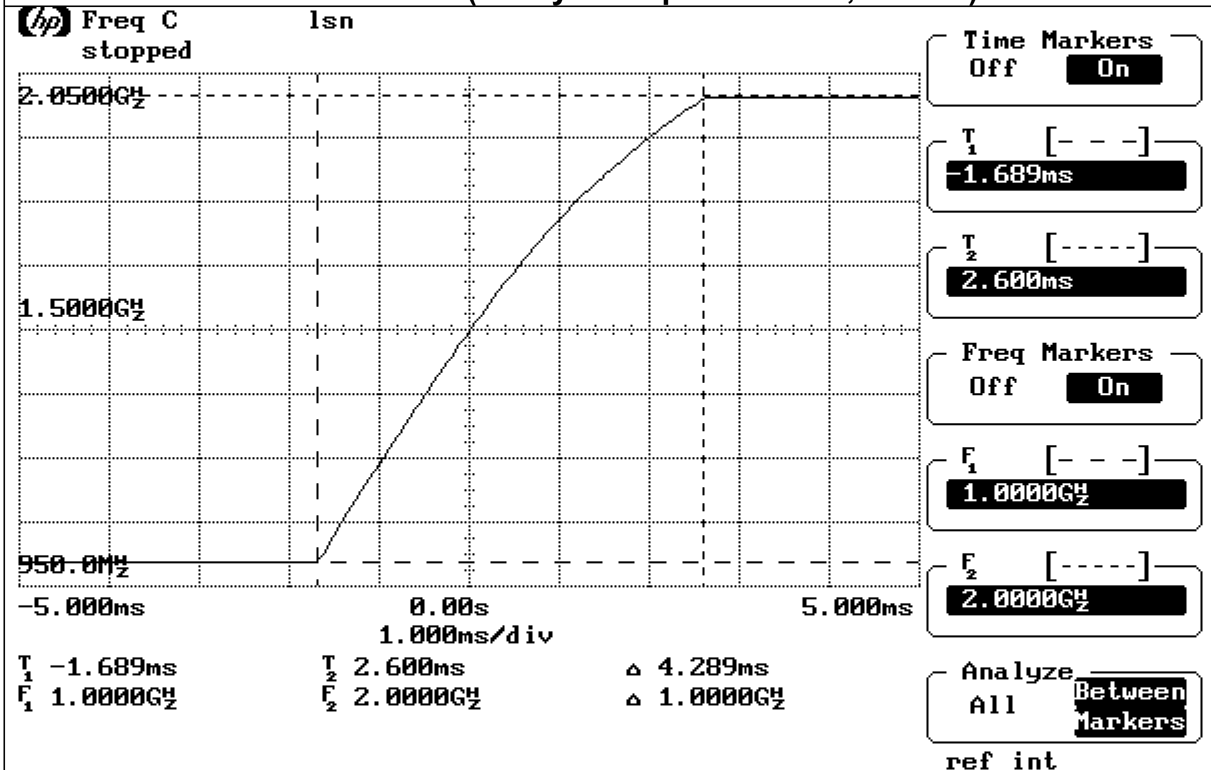


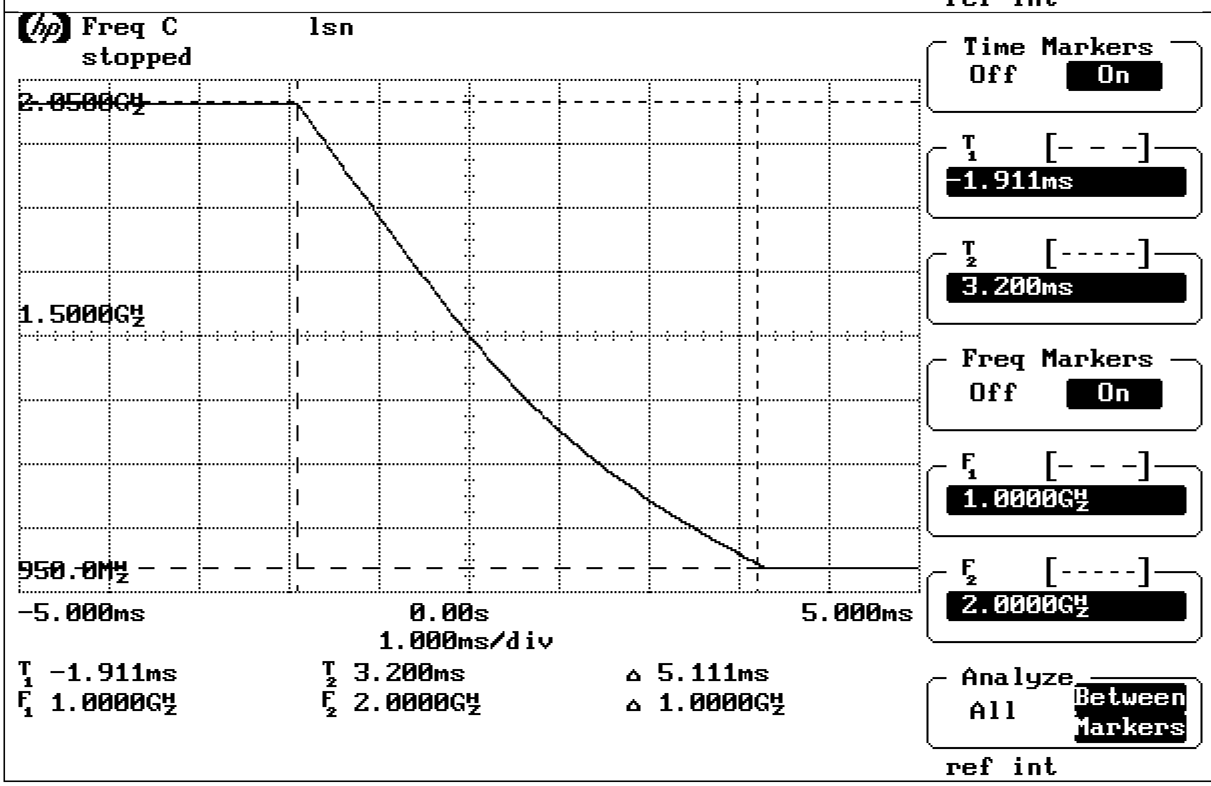
In-Band fractional spur for a 1500.005 MHz output frequency.



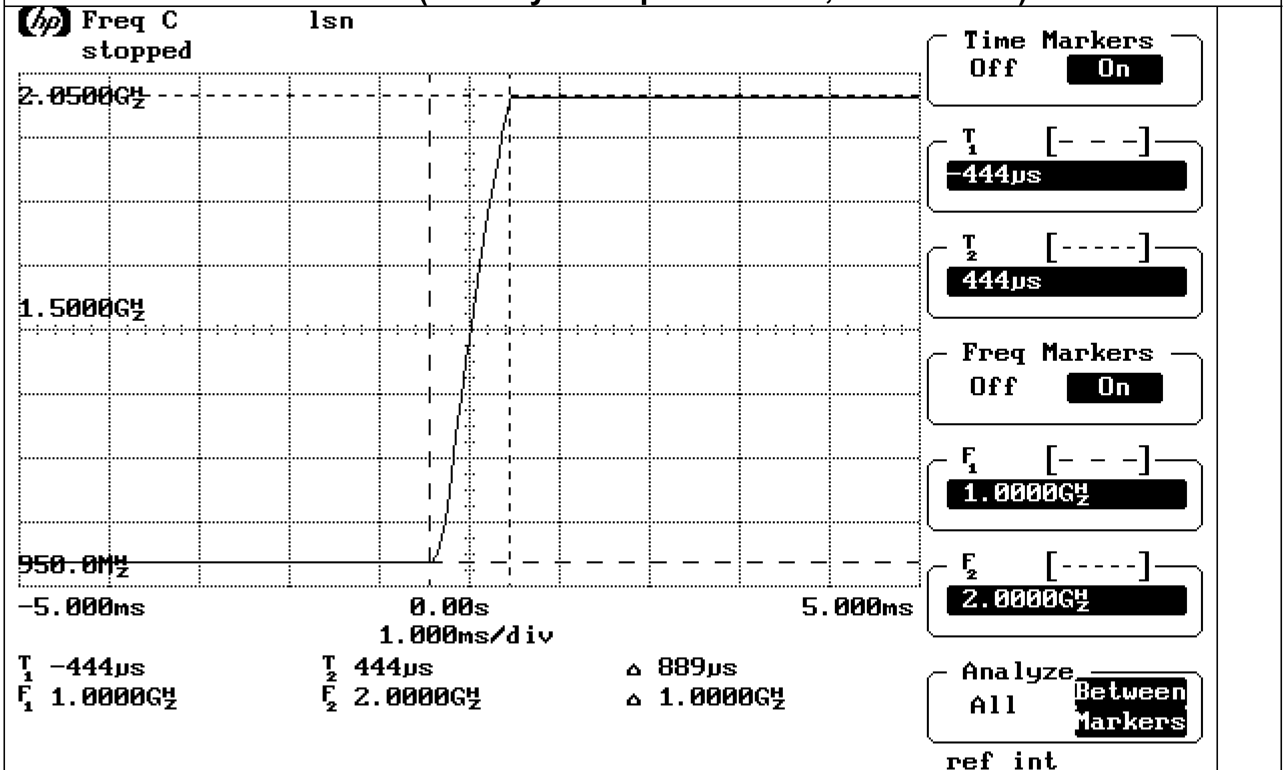
In-Band fractional spur for a 2000.005 MHz output frequency.

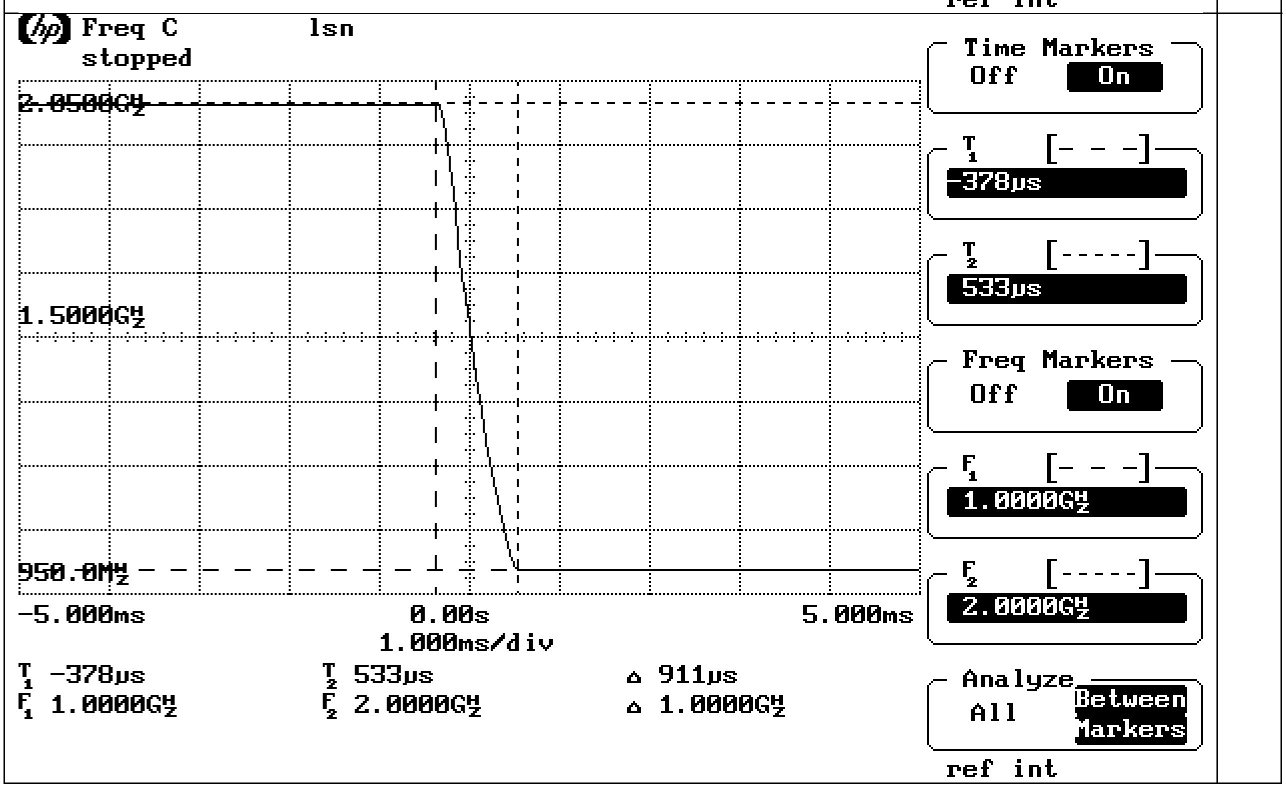
Rise Time (No Cycle Slip Reduction, TOC=0)



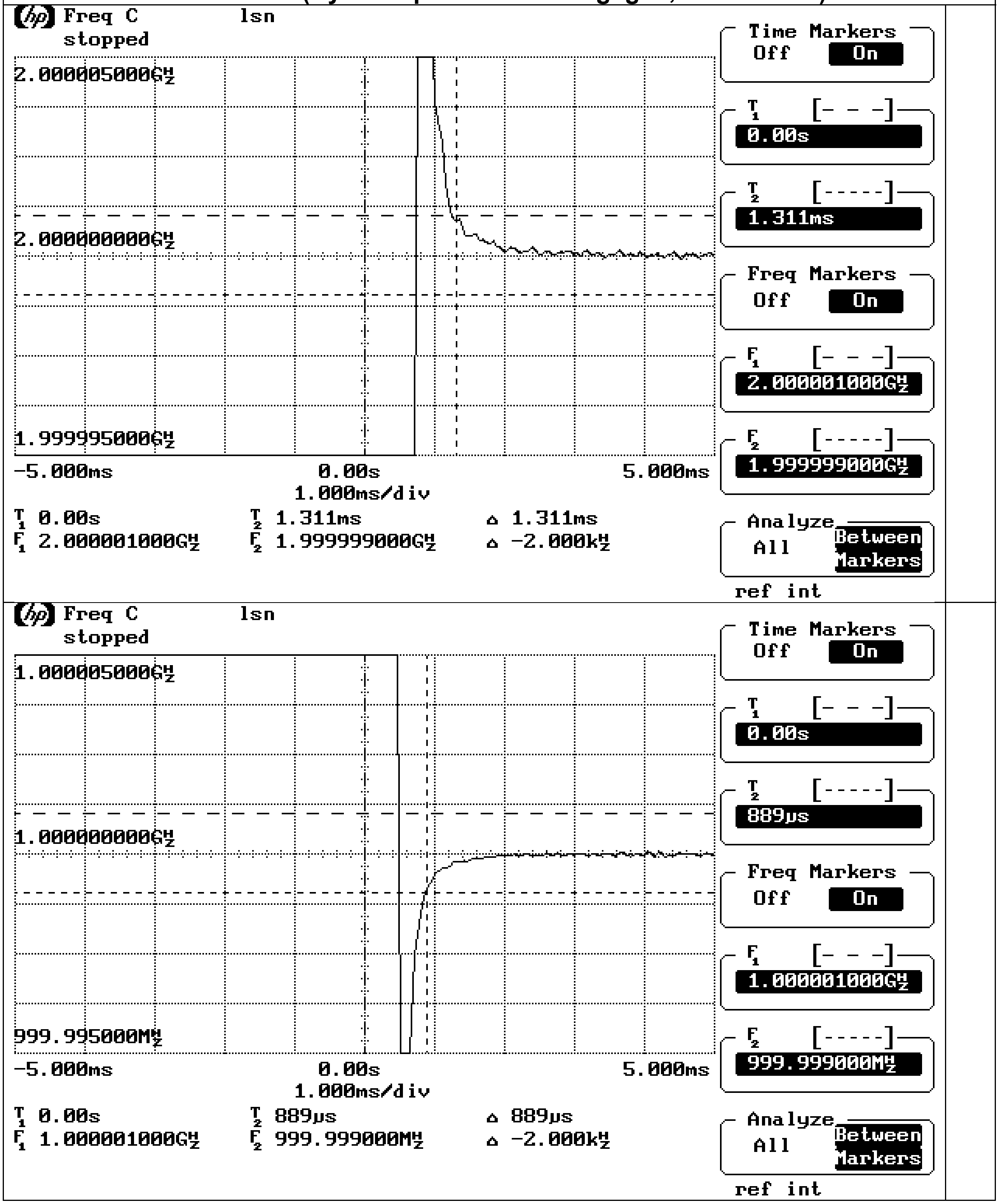


Rise Time (With Cycle Slip Reduction, TOC=16383)

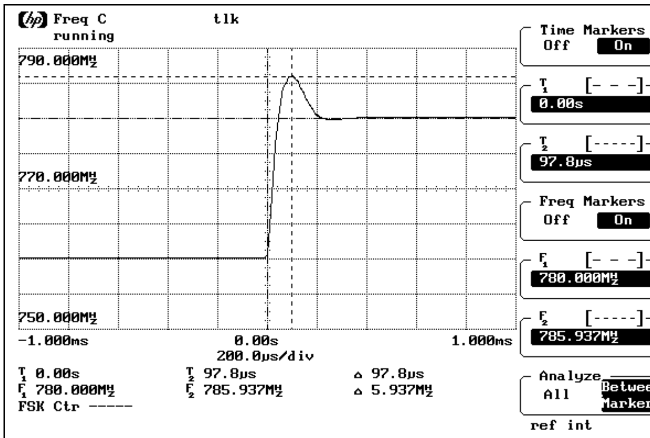




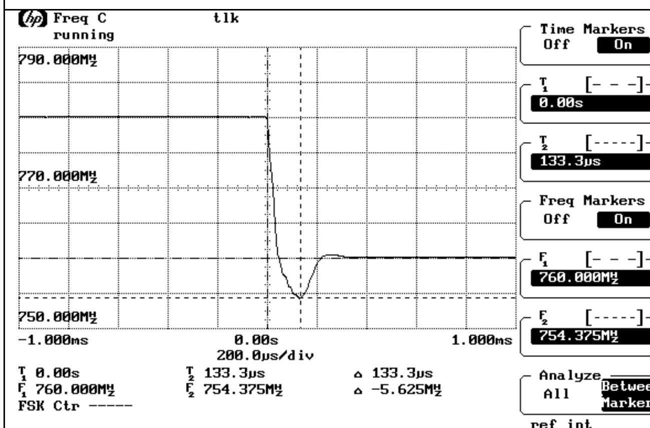
Lock Time (Cycle Slip Reduction Engaged, TOC=16383)



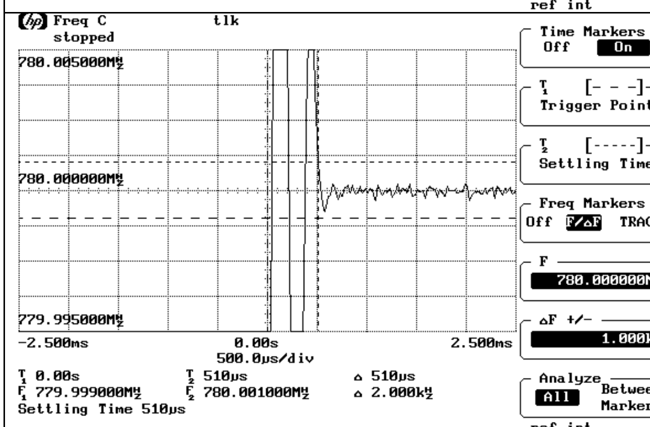
IF PLL Lock Time



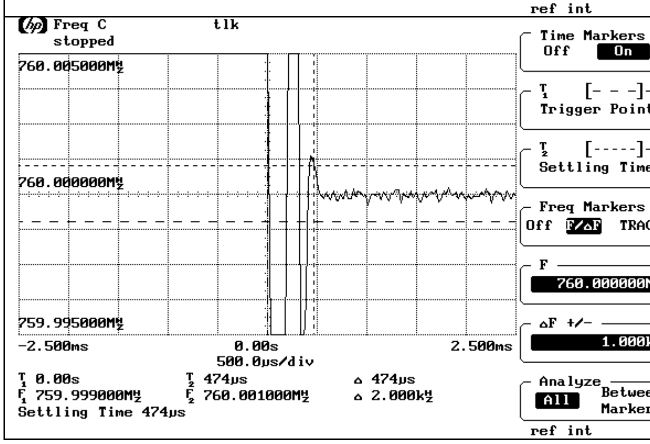
Peak time is 97.8 uS



Peak Time is 133.3 uS

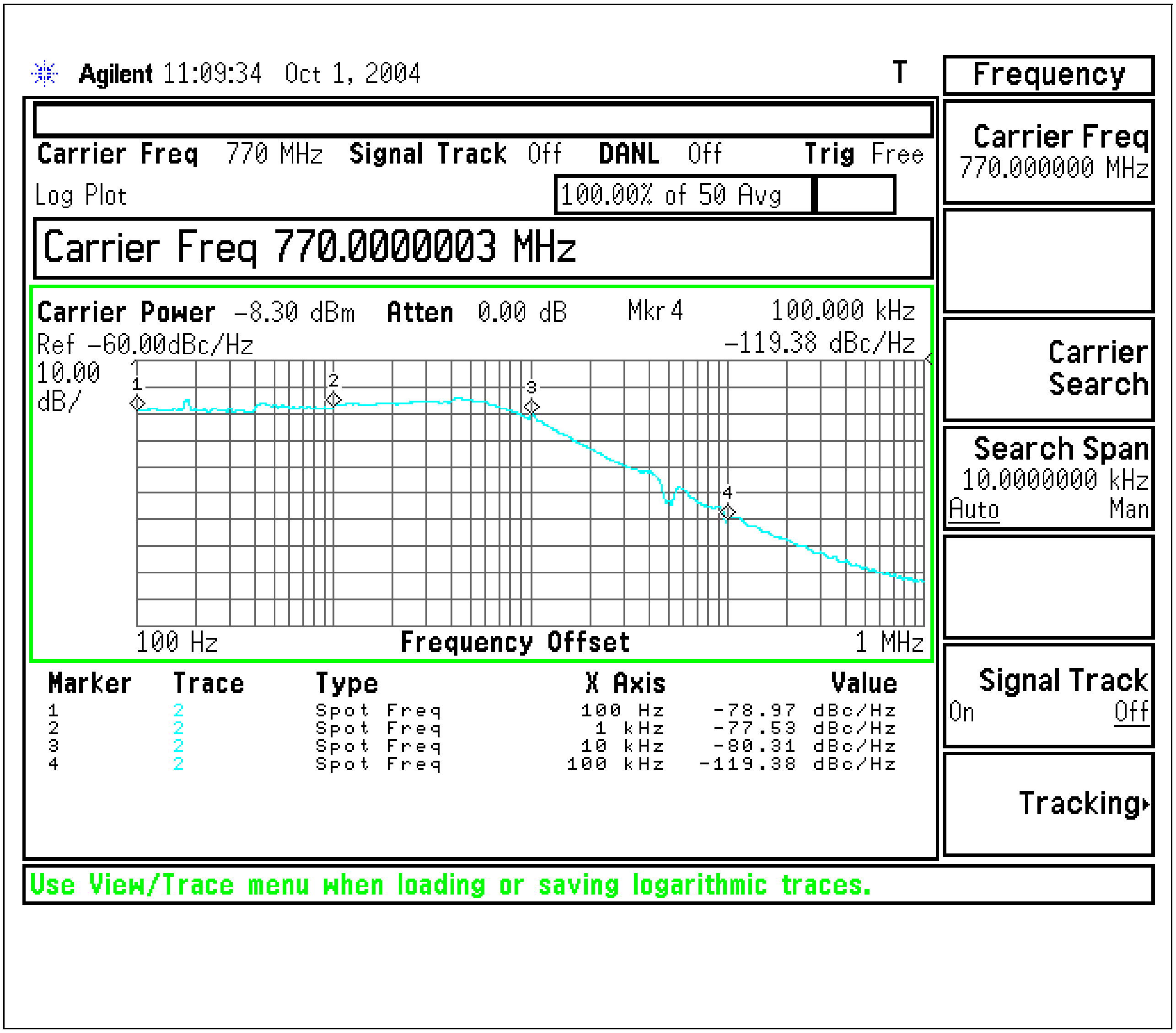


Positive Lock time is 510 uS

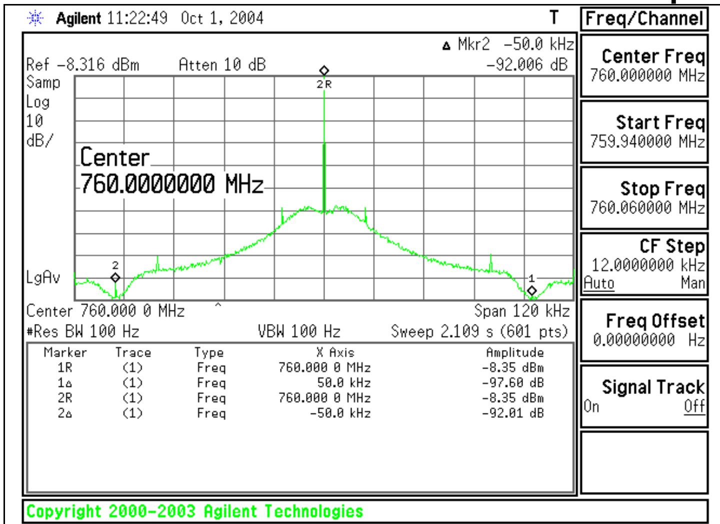


Negative Lock Time is 474 uS

IF PLL Phase Noise

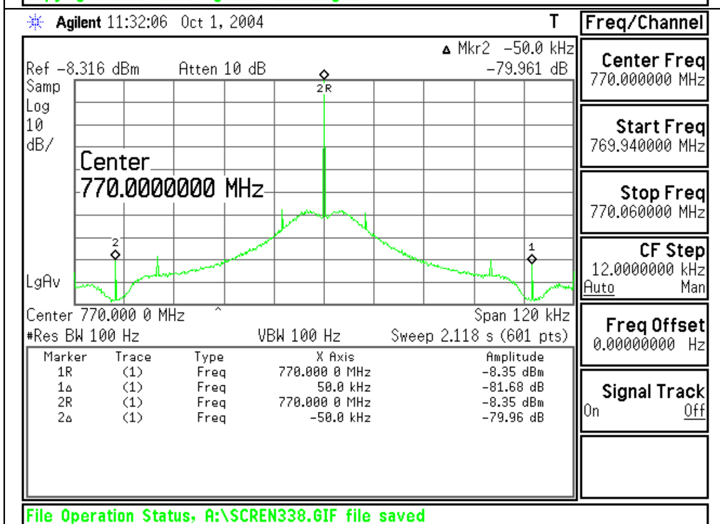


IF PLL Spurs

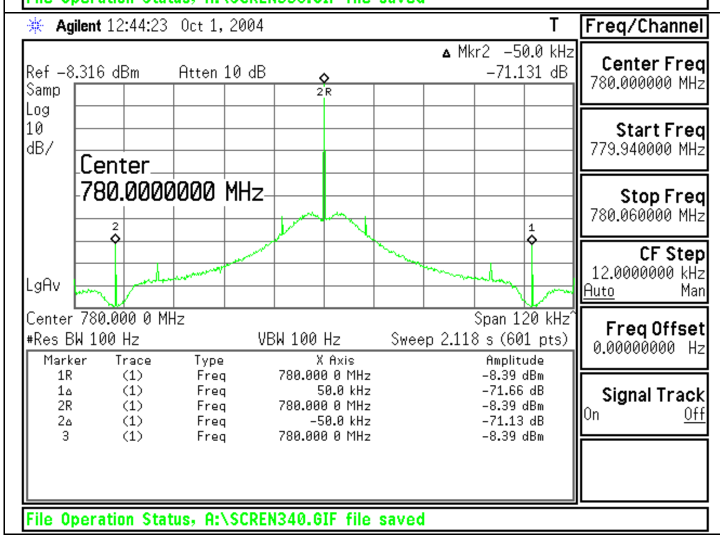


Spurs at 50 kHz offset for an output frequency of 760 MHz are -97.5 dBc.

Note the cusping effect at 50 kHz. This is because the loop bandwidth is wide relative to the comparison frequency. This is due to the discrete sampling action of the phase detector.

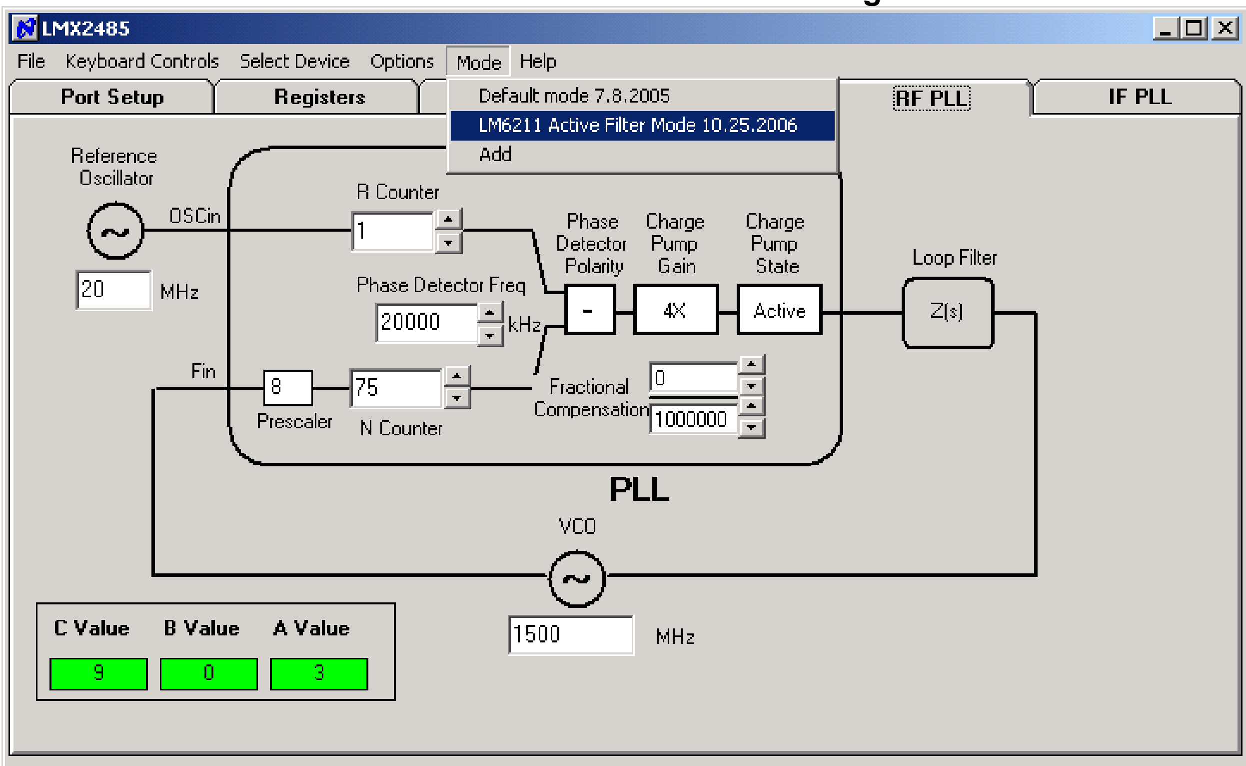


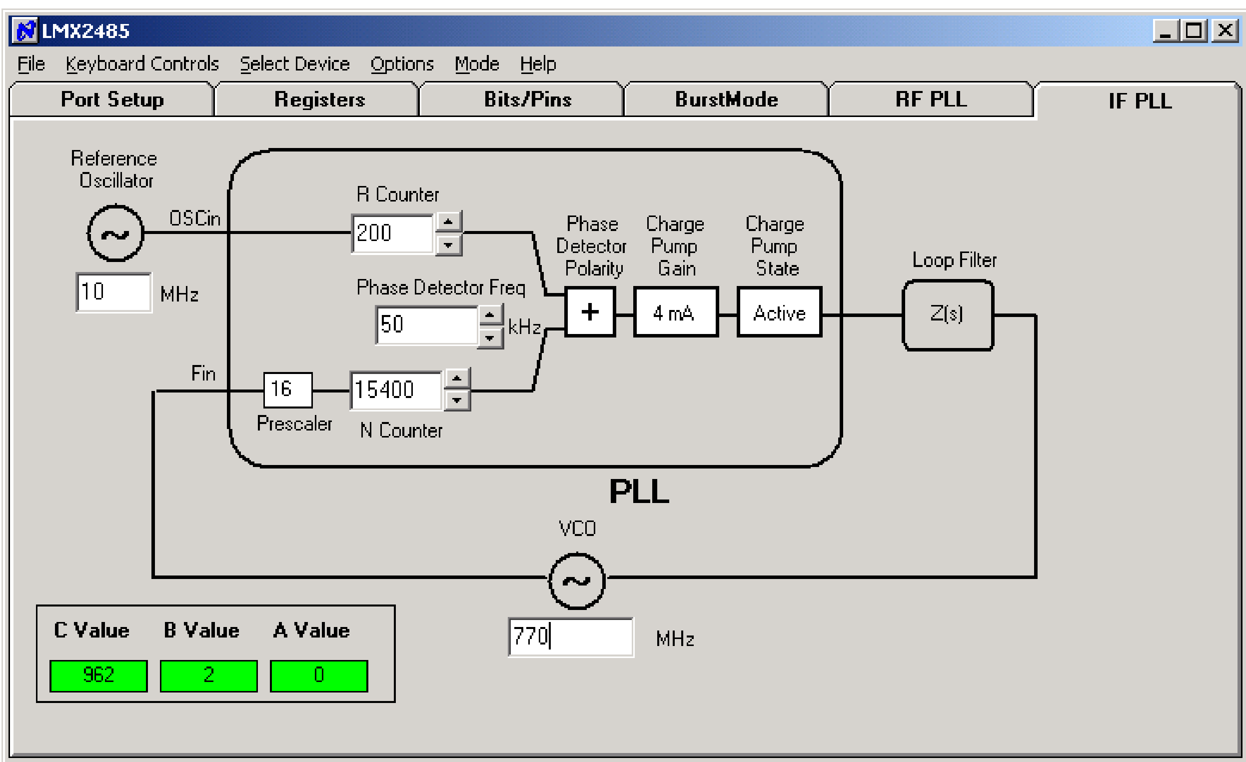
Spurs at 50 kHz offset for an output frequency of 770 MHz are -81.7 dBc.

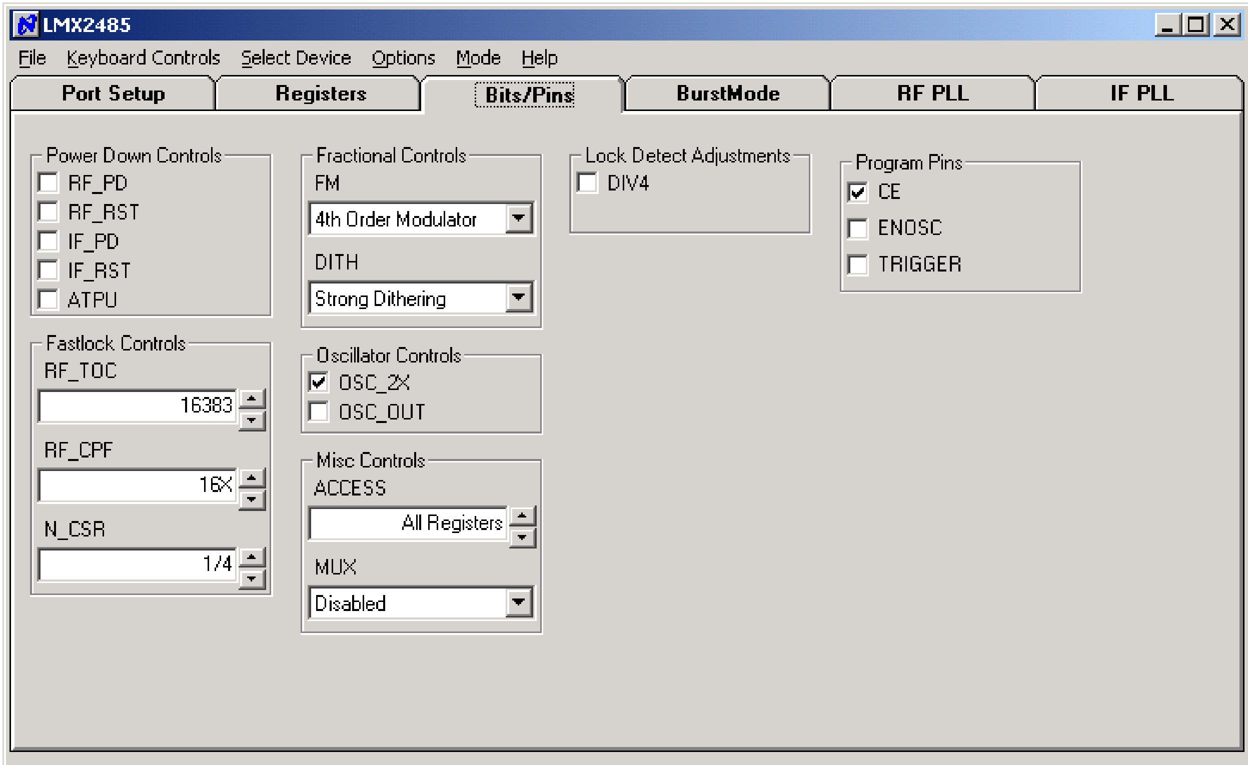


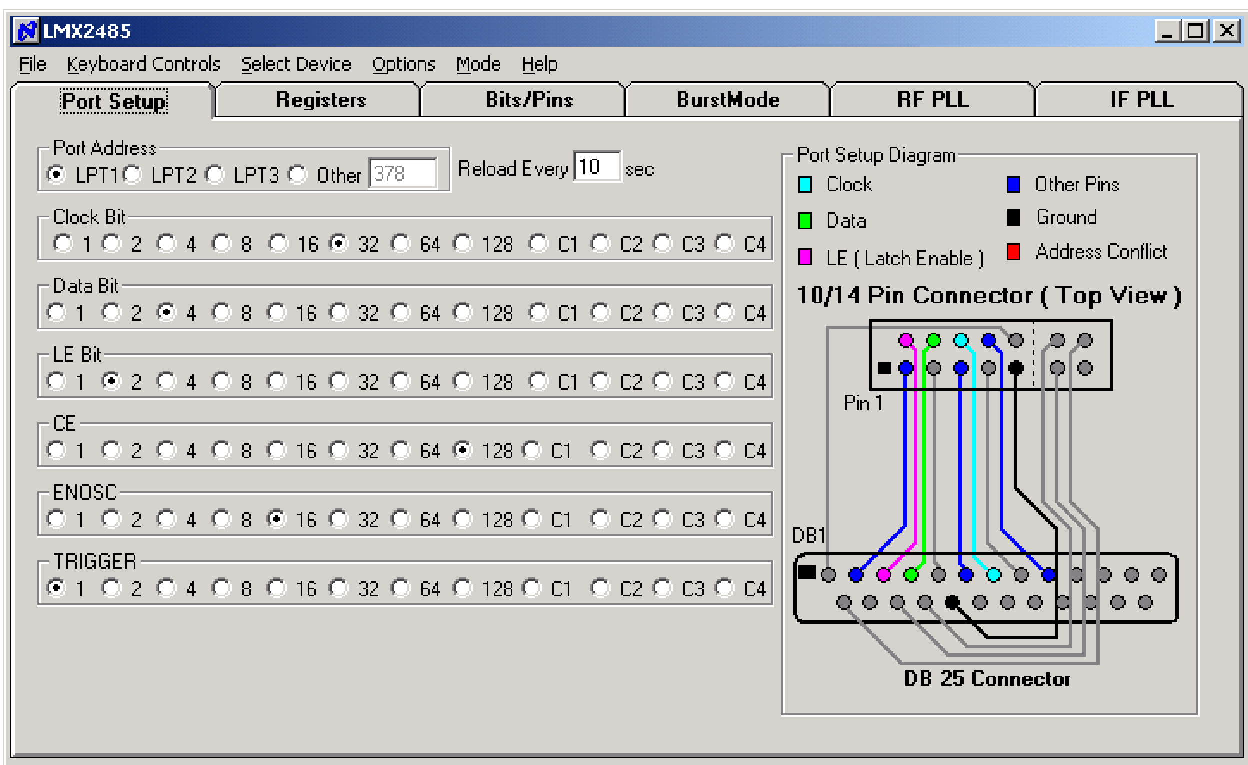
Spurs at 50 kHz offset for an output frequency of 780 MHz are -71.7 dBc.

LMX2485LM6211 CodeLoader Settings






LMX2485
File Keyboard Controls Select Device Options Mode Help
Port Setup
Registers
Bits/Pins
BurstMode
RF PLL
IF PLL
Power Down Controls
RF_PD
RF_RST
IF_PD
IF_RST
ATPU
Fractional Controls
FM
4th Order Modulator
DITH
Strong Dithering
Lock Detect Adjustments
DIV4
Program Pins
CE
ENOSC
TRIGGER
Fastlock Controls
RF_TOC
16383
RF_CPF
16X
N_CSR
1/4
Oscillator Controls
OSC_2X
OSC_OUT
Misc Controls
ACCESS
All Registers
MUX
Disabled

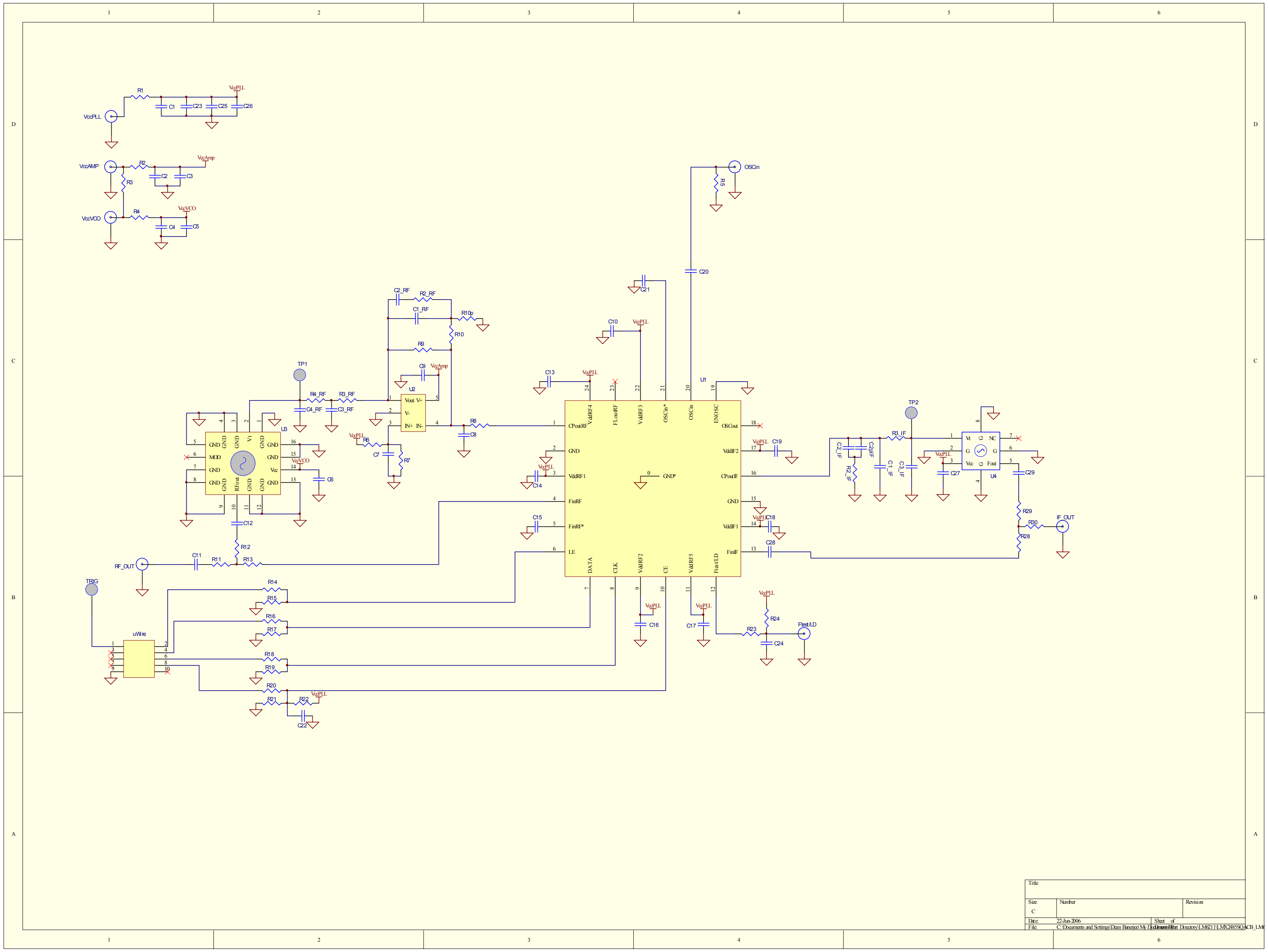

LMX2485
File Keyboard Controls Select Device Options Mode Help
Port Setup
Registers
Bits/Pins
BurstMode
RF PLL
IF PLL
Port Address
LPT1 LPT2 LPT3 Other 378
Reload Every 10 sec
Clock Bit
1 2 4 8 16 32 64 128 C1 C2 C3 C4
Data Bit
1 2 4 8 16 32 64 128 C1 C2 C3 C4
LE Bit
1 2 4 8 16 32 64 128 C1 C2 C3 C4
CE
1 2 4 8 16 32 64 128 C1 C2 C3 C4
ENOSC
1 2 4 8 16 32 64 128 C1 C2 C3 C4
TRIGGER
1 2 4 8 16 32 64 128 C1 C2 C3 C4
Port Setup Diagram
Clock
Other Pins
Data
Ground
LE (Latch Enable)
Address Conflict
10/14 Pin Connector (Top View)
Pin 1
DB1
DB 25 Connector

Bill of Materials

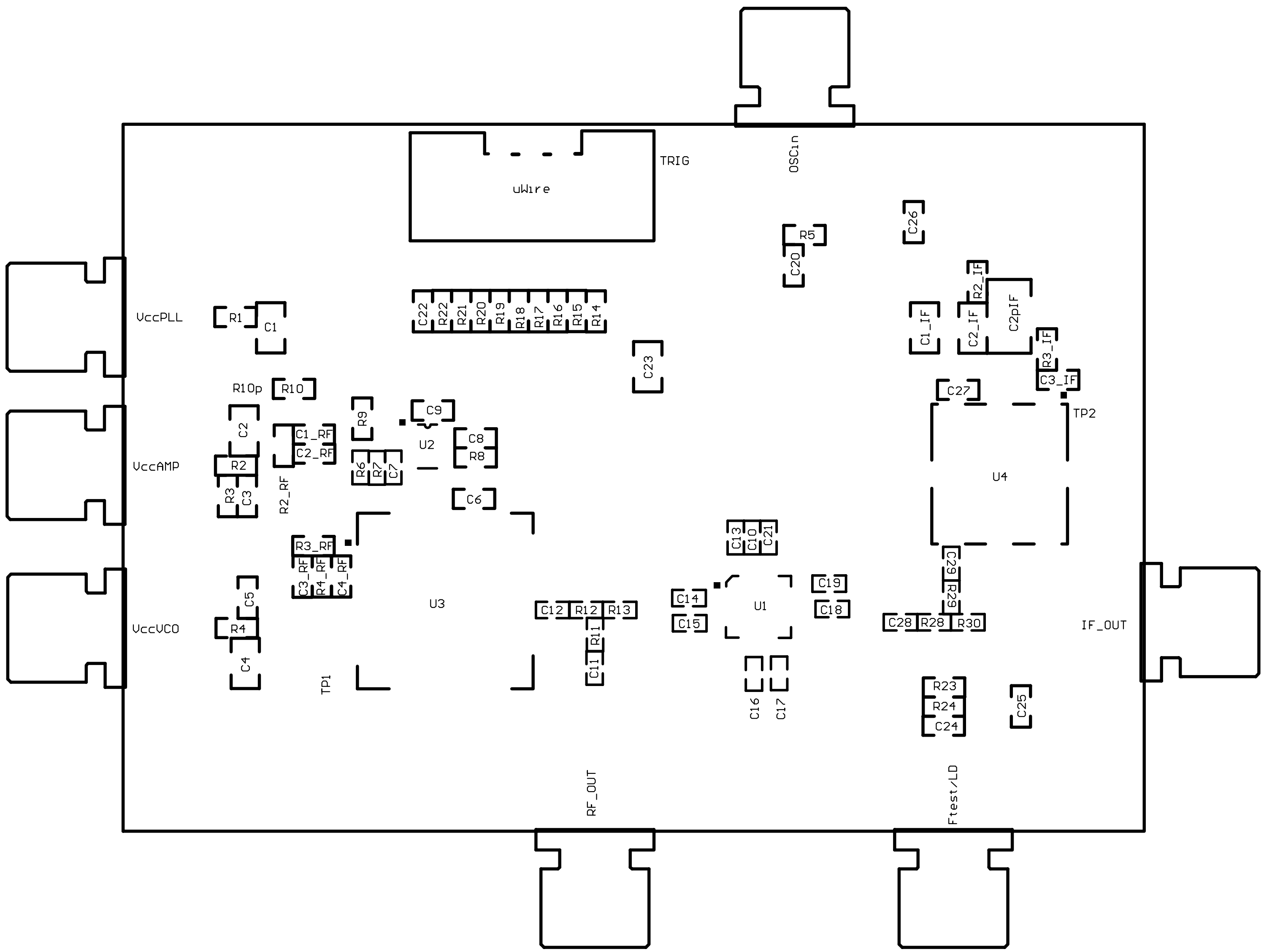
Revision	10/23/2006

Item	Qty	Manufacturer	Part #	Value	Unit	Size	Voltage	Tolerance	Material	Designator
0	11	Open								-- Ftest/LD - C2pIF, C3_IF, C8, C24 -- R3, R9, R10p, R22, R23, R24
1	1	National Semiconductor	LMX248X6211FPEBPCB Rev 6-29-2006	εr=4		Second Layer is 10 mils down			FR4	n/a
2	4	SPC Technology	SPCS-6	Stand-Offs		156mil	n/a	n/a	Nylon	Place in 4 holds in edge of board
3	1	FCI Electronics	52601-S10-8	10-Pin	Header		n/a	n/a	Plastic	uWire
4	6	Johnson Components	142-0701-851	Edge SMA					Metal	RF_OUT, IF_OUT, OSCin,VccPLL, VccAMP, VccVCO
5	15	Kemet	C0603C101J5GAC	100	pF	603	50 V	5%	C0G	C6, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C27, C28, C29
6	1	Kemet	C0603C102J5GAC	1	nF	603	50 V	5%	C0G	C4_RF
7	1	Kemet	C0805C182J3GAC	1.8	nF	805	25 V	5%	C0G	C1_IF
8	1	Kemet	C0603C332K5RAC	3.3	nF	603	50 V	5%	X7R	C3_RF
9	1	Panasonic	ECHU1C103JX5	10	nF	805	16 V	5%	Film	C2_IF
10	1	Kemet	C0603C122K5RAC	1.2	nF	805			X7R	C1_RF
11	5	Kemet	C0603C104K3RAC	100	nF	603	25 V	10%	X7R	C3, C5, C20, C21, C26
12	1	Kemet	C0603C473K4RACTU	47	nF	603	16 V	10%	X7R	C2_RF
13	3	Kemet	C0603C105K3PAC	1	uF	603	25 V	10%	X5R	C7, C22, C25
14	4	Kemet	C0805C106K8PAC	10	uF	805	10V	10%	X5R	C1, C2, C4, C23
15	3	Vishay	CRCW0603000ZRT1	0	ohm	0603	10 V	5%	Cermaic	R3_IF, R8, R10
16	9	Vishay	CRCW0603180JRT1	18	ohm	0603	10 V	5%	Cermaic	R1, R2, R4, R11, R12, R13, R28, R29, R30
17	1	Vishay	CRCW0603510FRT1	51	ohm	0603	10 V	1%	Cermaic	R5
18	1	Vishay	CRCW0603471JRT1	470	ohm	0603	10 V	5%	Cermaic	R2_RF
19	1	Vishay	CRCW0603271JRT1	270	ohm	0603	10 V	5%	Cermaic	R3_RF
20	1	Vishay	CRCW0603122JRT1	1.2	Kohm	0603	10 V	5%	Cermaic	R4_RF
21	1	Vishay	CRCW0603822JRT1	8.2	Kohm	0603	10 V	5%	Cermaic	R2_IF
22	6	Vishay	CRCW0603103JRT1	10	Kohm	0603	10 V	5%	Cermaic	R6, R7, R14, R16, R18, R20
23	4	Vishay	CRCW0603123JRT1	12	Kohm	0603	10 V	5%	Cermaic	R15, R17, R19, R21
24	1	National Semiconductor	LMX2485SQA	PLL	n/a	24P	3.6	n/a	Silicon	U1
25	1	National Semiconductor	LM6211	AMP	n/a	SOT23-5	24	n/a	Silicon	U2
26	1	SIRENZA	VCO793-1550T	950-2150	MHz	T	12 V	n/a	Can	U3
27	1	SIRENZA	VCO191-773U	760-780	MHz	U	3 V		Can	U4

Schematic



Build Diagram



Appendix A

LM6211 Phase Noise Evaluation for Active Loop Filters

Dean Banerjee

Introduction

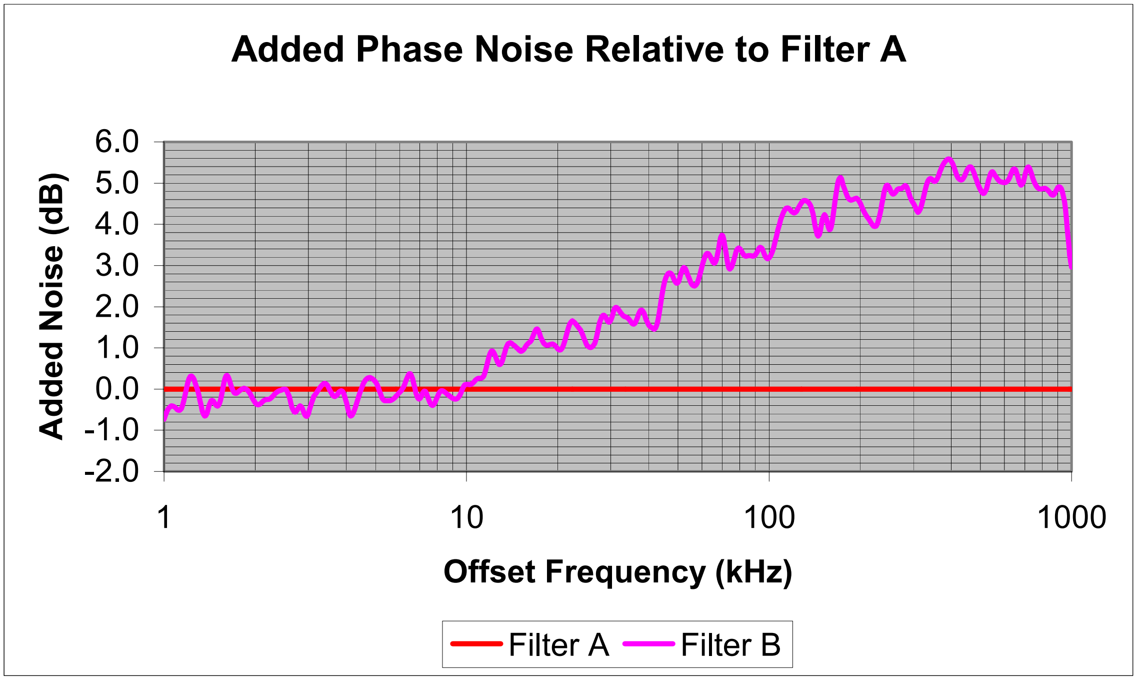
This report investigates the performance of the LM6211. For this evaluation five loop filters were designed and the performance was compared. The findings were that the LM6211 does not add very significant phase noise, except near the loop bandwidth, as simulations predict. For the active filters, a type A filter was used. In this type of filter, a bias voltage is established at the non-inverting input of the op-amp, and C1, C2, and R2 go in the feedback path of the op-amp. Series 39 kΩ and 12 kΩ resistors were used to divide down the op-ap supply of 5 volts down to a bias voltage of around 1.2 volts. Also, a 1 μF capacitor was placed in parallel with the 12 kΩ resistor in order to reduce the resistor noise. The utility board was used in order to obtain these results.

Setup

Parameter	Units	Value
PLL	*n/a*	LMX2471
VCO	*n/a*	Varil 1960U
op-amp	*n/a*	LM6211
VccPLL	*V*	2.75
VccVCO	*V*	3.3
VccAMP	*V*	5.0
Kϕ	*mA*	0.8
Kvco	*MHz/V*	45
N	*n/a*	1960
Fout	*MHz*	1960
Fcomp	*kHz*	1000

Parameter	Unit	Filter A	Filter B	Filter C	Filter D	Filter E
Filter Type	*n/a*	Passive	Active	Passive	Active	Active
Filter Order	*n/a*	2nd		3rd	3rd	3rd
Phase Margin	*deg*	50.57		46.3	49.13	46.56
Bandwidth	*kHz*	10.2		9.88	9.55	9.73
T3/T1 Ratio	*%*	0.0		8.96	91.79	1170.96
C1	*nF*	0.82		0.33	0.82	0.15
C2	*nF*	8.2		8.2	12	12
C3	*nF*	0.0		0.56	1.0	1.0
R2	*kΩ*	3.3		3.3	3.3	3.3
R3	*kΩ*	0.0		1.8	2.7	5.6

Results for Second Order Filters

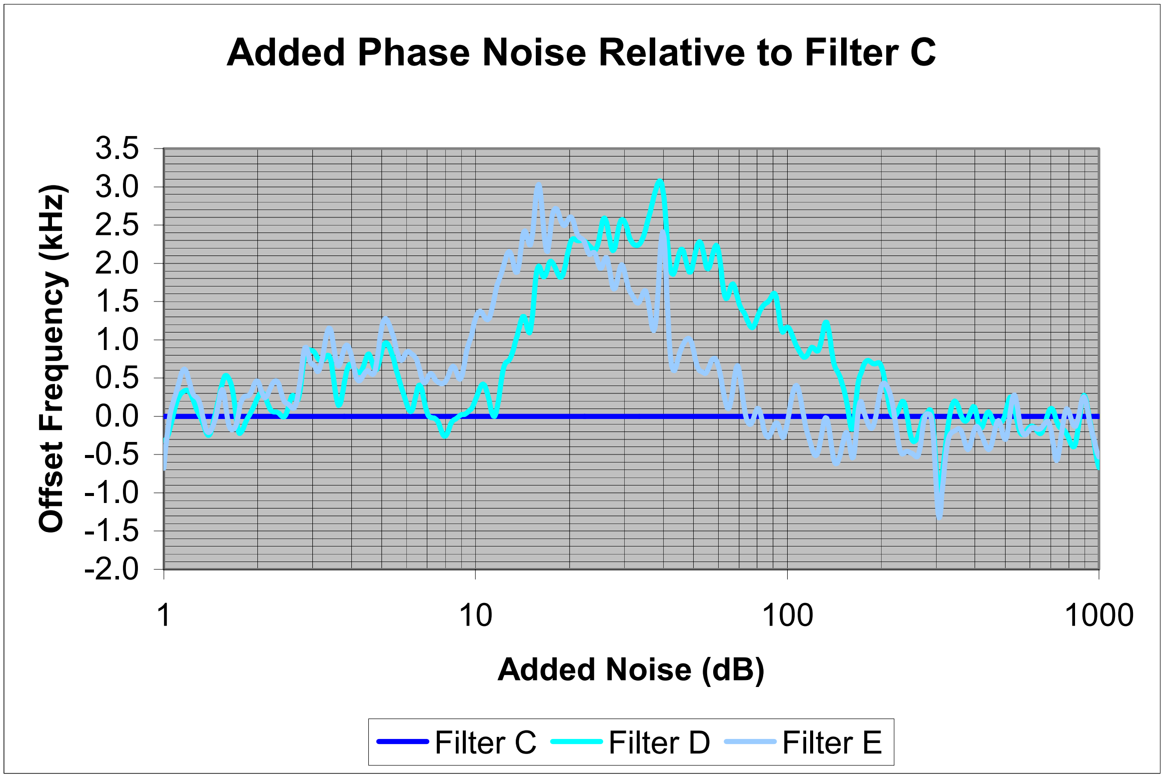


	Filter A	Filter B
Lock time from 1930 to 1990 MHz to 1 kHz	467 uS	380 uS
Lock time from 1990 to 1930 MHz to 1 kHz	300 uS	280 uS
Peak time from 1930 to 1990 MHz	109 uS	51 uS
Peak time from 1990 to 1930 MHz	38 uS	44 uS

Filter A: This is a basic second order passive loop filter which is used as a baseline for comparison.

Filter B: This is the same thing as filter A, except for there is an op-amp attached. This was never intended to be a good design, but rather something to make easy comparisons to filter A. As the measurements show, there is about 5 dB added phase noise out around 300 kHz. The ironic thing is the lock time is improved. The reason for this is that the loop filter is biased at 1 volt tuning voltage. This keeps the charge pump away from the rails and helps lock times. Note that filter A is struggling to get to 1990 MHz and the charge pump gain is giving out here. Although this was not measured, because the spur levels were too low, the spurs for the active loop filter should be better as well, since the charge pump is based closer to the center of the charge pump supply.

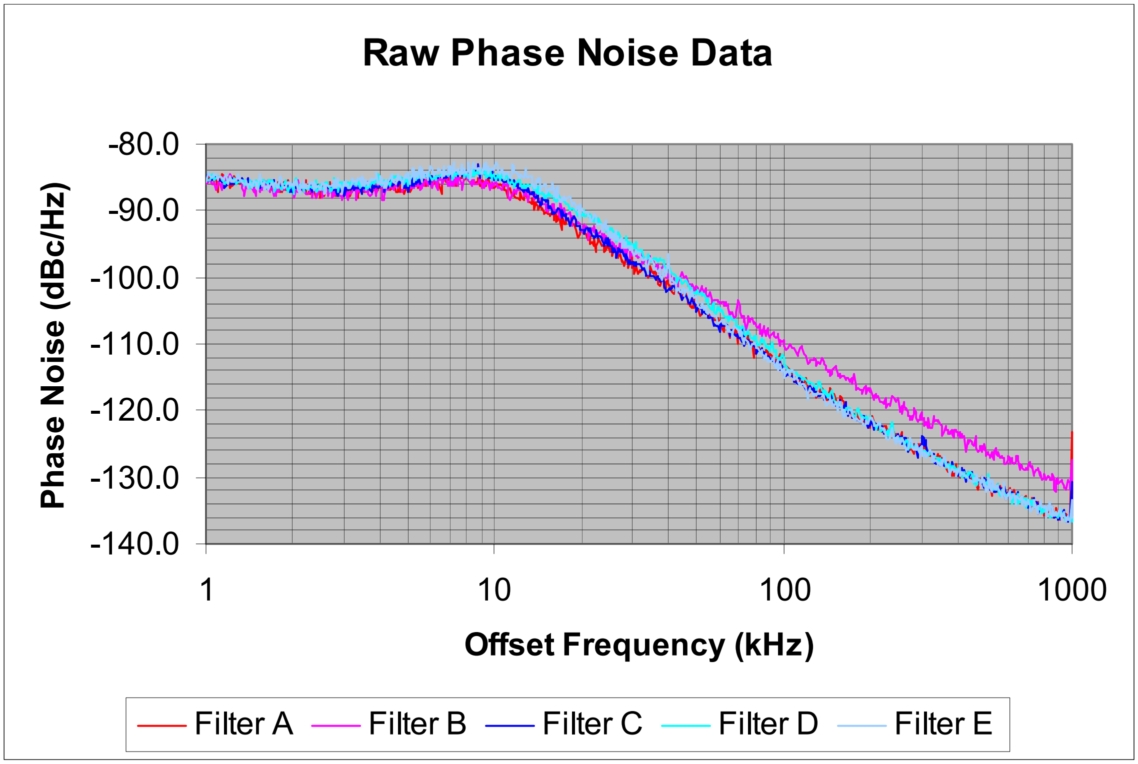
Results for Third Order Filters



Filter C: This is a passive third order loop filter used for comparisons. Now because the insertion of the op-amp does move the poles of the filter around, it is necessary to change the component values to compensate for this.

Filter D: This is an active third order loop filter. For this filter the T3/T1 ratio was about 92%, so the poles T3 and T1 are about equal. One advantage of the op-amp is that T3/T1 can be made close to or even equal to 100%, because of the added isolation of the op-amp. The most significant phase noise contribution is about 2.5 dB around 20 kHz offset. This noise contribution here may be slightly understated because this loop filter had a slightly higher phase margin and a lower loop bandwidth than filter C. Note that several rolling averages were applied to the raw data to smooth out the curves.

Filter E: The strategy behind this filter is the "pole switch" trick. For this type of filter, the poles T3 and T1 are swapped such that T3 is the larger pole. This can only be effectively done for active filters. By putting the bigger pole after the op-amp instead of before it, the op-amp noise contribution is reduced. The T3/T1 ratio for this filter is 1171%, which gives the same transfer function as having a pole ratio of, 8.5%, except for the op-amp noise is attenuated more. The most significant phase noise contribution is about 2.5 dB around 30 kHz offset. As in the case of filter E, several moving averages were applied to smooth the data.


Raw Phase Noise Data
Phase Noise (dBc/Hz)
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
1
10
100
1000
Offset Frequency (kHz)
Filter A
Filter B
Filter C
Filter D
Filter E