PLLatinum™ Low Power Dual Frequency Synthesizer for RF Personal Communications

LMX2330L 2.5 GHz/510 MHz
LMX2331L 2.0 GHz/510 MHz
LMX2332L 1.2 GHz/510 MHz

Check for Samples: LMX2330L, LMX2331L, LMX2332L

FEATURES

- **Ultra Low Current Consumption**
- **2.7V to 5.5V Operation**
- **Selectable Synchronous or Asynchronous Powerdown Mode:**
  - **I_{CC} = 1 µA Typical at 3V**
- **Dual Modulus Prescaler:**
  - **LMX2330L (RF) 32/33 or 64/65**
  - **LMX2331L/32L (RF) 64/65 or 128/129**
  - **LMX2330L/31L/32L (IF) 8/9 or 16/17**
- **Selectable Charge Pump TRI-STATE mode**
- **Selectable Charge Pump Current Levels**
- **Selectable Fastlock Mode**
- **Upgrade and Compatible to LMX233XA Family**

APPLICATIONS

- **Portable Wireless Communications**
  - **(PCS/PCN, Cordless)**
- **Cordless and Cellular Telephone Systems**
- **Wireless Local Area Networks (WLANs)**
- **Cable TV Tuners (CATV)**
- **Other Wireless Communication Systems**

DESCRIPTION

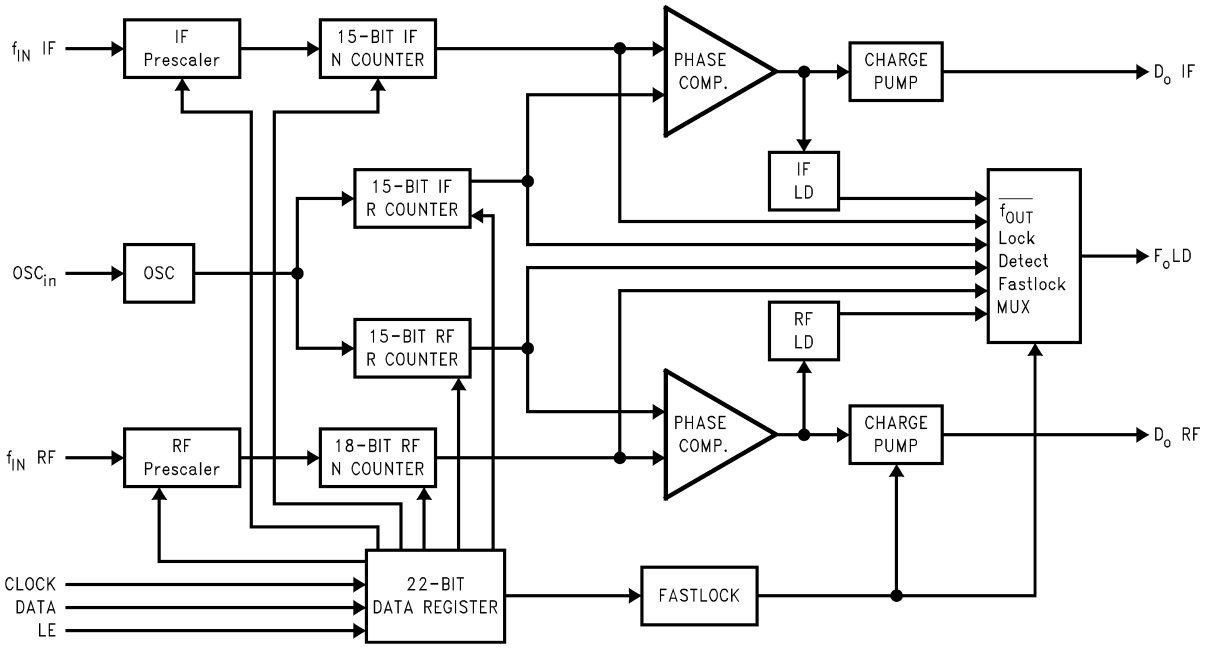
The LMX233XL family of monolithic, integrated dual frequency synthesizers, including prescalers, is to be used as a local oscillator for RF and first IF of a dual conversion transceiver. It is fabricated using TI's 0.5µ ABiC V silicon BiCMOS process.

The LMX233XL contains dual modulus prescalers. A 64/65 or a 128/129 prescaler (32/33 or 64/65 in the 2.5 GHz LMX2330L) can be selected for the RF synthesizer and a 8/9 or a 16/17 prescaler can be selected for the IF synthesizer. LMX233XL, which employs a digital phase locked loop technique, combined with a high quality reference oscillator, provides the tuning voltages for voltage controlled oscillators to generate very stable, low noise signals for RF and IF local oscillators. Serial data is transferred into the LMX233XL via a three wire interface (Data, Enable, Clock). Supply voltage can range from 2.7V to 5.5V. The LMX233XL family features very low current consumption;

LMX2330L—5.0 mA at 3V, LMX2331L—4.0 mA at 3V, LMX2332L—3.0 mA at 3V.

The LMX233XL are available in a TSSOP 20-pin, LGA 24-pin surface mount plastic package, and thin LGA 20-pin surface mount plastic package.

Functional Block Diagram



Connection Diagrams

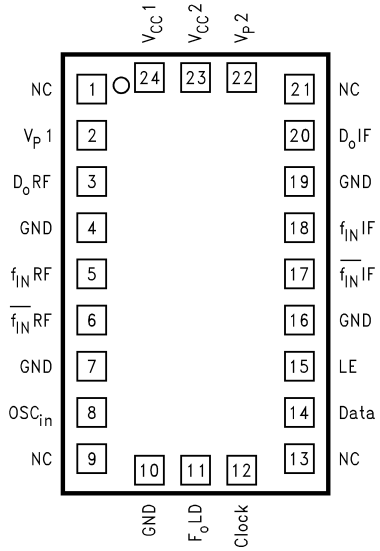


Figure 1. Chip Scale Package (NPH)
(Top View)
See Package Number NPH0024A

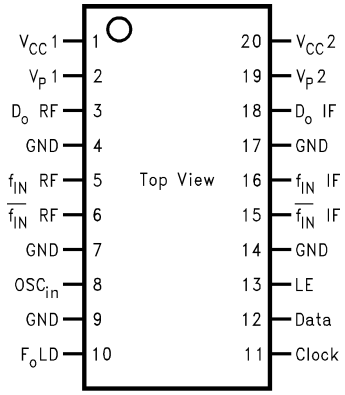


Figure 2. Thin Shrink Small Outline Package (PW)
(Top View)
See Package Number PW0020A

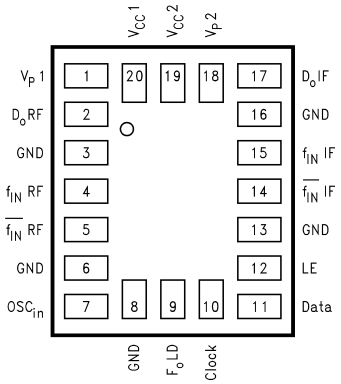


Figure 3. 20-Pin Thin Chipscale Package (NPJ)
(Top View)
See Package Number NPJ0020A

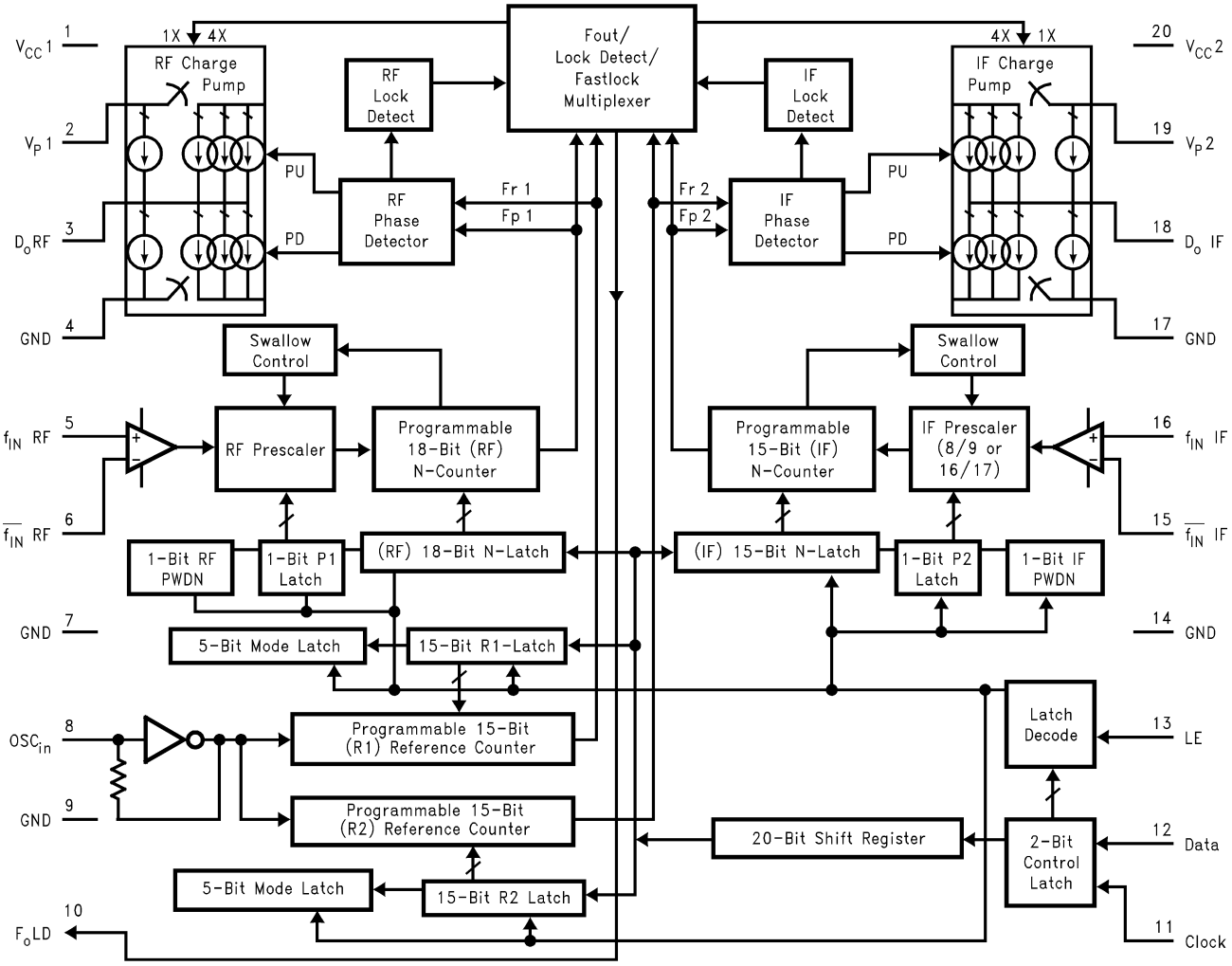
PIN DESCRIPTIONS

Pin No. LMX233XLNPJ 20-pin Thin LGA Package	Pin No. LMX233XLNPH 24-pin LGA Package	Pin No. LMX233XLPW 20-pin TSSOP Package	Pin Name	I/O	Description
20	24	1	$V_{CC}1$	—	Power supply voltage input for RF analog and RF digital circuits. Input may range from 2.7V to 5.5V. $V_{CC}1$ must equal $V_{CC}2$. Bypass capacitors should be placed as close as possible to this pin and be connected directly to the ground plane.
1	2	2	V_P1	—	Power Supply for RF charge pump. Must be ≥ V_{CC}.
2	3	3	D_o RF	O	Internal charge pump output. For connection to a loop filter for driving the input of an external VCO.
3	4	4	GND	—	Ground for RF digital circuitry.
4	5	5	f_{IN} RF	I	RF prescaler input. Small signal input from the VCO.
5	6	6	$\overline{f_{IN}}$ RF	I	RF prescaler complementary input. A bypass capacitor should be placed as close as possible to this pin and be connected directly to the ground plane. Capacitor is optional with some loss of sensitivity.
6	7	7	GND	—	Ground for RF analog circuitry.
7	8	8	OSC_{in}	I	Oscillator input. The input has a $V_{CC}/2$ input threshold and can be driven from an external CMOS or TTL logic gate.
8	10	9	GND	—	Ground for IF digital, MICROWIRE, F_oLD, and oscillator circuits.
9	11	10	F_oLD	O	Multiplexed output of the RF/IF programmable or reference dividers, RF/IF lock detect signals and Fastlock mode. CMOS output *(see PROGRAMMABLE MODES)*.
10	12	11	Clock	I	High impedance CMOS Clock input. Data for the various counters is clocked in on the rising edge, into the 22-bit shift register.
11	14	12	Data	I	Binary serial data input. Data entered MSB first. The last two bits are the control bits. High impedance CMOS input.
12	15	13	LE	I	Load enable high impedance CMOS input. When LE goes HIGH, data stored in the shift registers is loaded into one of the 4 appropriate latches (control bit dependent).
13	16	14	GND	—	Ground for IF analog circuitry.
14	17	15	$\overline{f_{IN}}$ IF	I	IF prescaler complementary input. A bypass capacitor should be placed as close as possible to this pin and be connected directly to the ground plane. Capacitor is optional with some loss of sensitivity.
15	18	16	f_{IN} RF	I	IF prescaler input. Small signal input from the VCO.
16	19	17	GND	—	Ground for IF digital, MICROWIRE, F_oLD, and oscillator circuits.
17	20	18	D_o IF	O	IF charge pump output. For connection to a loop filter for driving the input of an external VCO.
18	22	19	V_P2	—	Power Supply for IF charge pump. Must be ≥ V_{CC}.

PIN DESCRIPTIONS (continued)

Pin No. LMX233XLNPJ 20-pin Thin LGA Package	Pin No. LMX233XLNPH 24-pin LGA Package	Pin No. LMX233XLPW 20-pin TSSOP Package	Pin Name	I/O	Description
19	23	20	$V_{CC}2$	—	Power supply voltage input for IF analog, IF digital, MICROWIRE, F_oLD, and oscillator circuits. Input may range from 2.7V to 5.5V. $V_{CC}2$ must equal $V_{CC}1$. Bypass capacitors should be placed as close as possible to this pin and be connected directly to the ground plane.
X	1, 9, 13, 21	X	NC	—	No connect.

Block Diagram



Note: The RF prescaler for the LMX2331L/32L is either 64/65 or 128/129, while the prescaler for the LMX2330L is 32/33 or 64/65.

Note: $V_{CC}1$ supplies power to the RF prescaler, N-counter, R-counter and phase detector. $V_{CC}2$ supplies power to the IF prescaler, N-counter, phase detector, R-counter along with the OSC_{in} buffer, MICROWIRE, and F_oLD. $V_{CC}1$ and $V_{CC}2$ are clamped to each other by diodes and must be run at the same voltage level.

Note: V_P1 and V_P2 can be run separately as long as $V_P \geq V_{CC}$.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings (1)(2)(3)

Power Supply Voltage	
V_{CC}	−0.3V to +6.5V
V_P	−0.3V to +6.5V
Voltage on Any Pin with GND = 0V (V_I)	−0.3V to V_{CC}+0.3V
Storage Temperature Range (T_S)	−65°C to +150°C
Lead Temperature (solder 4 sec.) (T_L)	+260°C

(1) This device is a high performance RF integrated circuit with an ESD rating <2 keV and is ESD sensitive. Handling and assembly of this device should only be done at ESD protected work stations.
(2) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Recommended Operating Conditions indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed.
(3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.

Recommended Operating Conditions (1)(2)

Power Supply Voltage	
V_{CC}	2.7V to 5.5V
V_P	V_{CC} to +5.5V
Operating Temperature (T_A)	−40°C to +85°C

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Recommended Operating Conditions indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed.
(2) This device is a high performance RF integrated circuit with an ESD rating <2 keV and is ESD sensitive. Handling and assembly of this device should only be done at ESD protected work stations.

Electrical Characteristics

V_{CC} = 3.0V, V_P = 3.0V; −40°C < T_A < 85°C, except as specified

Symbol	Parameter		Conditions	Value			Units
				Min	Typ	Max	
I_{CC}	Power Supply Current	LMX2330L RF + IF	V_{CC} = 2.7V to 5.5V		5.0	6.6	mA
		LMX2330L RF Only			4.0	5.2	
		LMX2331L RF + IF			4.0	5.4	
		LMX2331L RF Only			3.0	4.0	
		LMX2332L IF + RF			3.0	4.1	
		LMX2332L RF Only			2.0	2.7	
		LMX233xL IF Only			1.0	1.4	
$I_{CC\text{-}PWDN}$	Powerdown Current		(1)		1	10	µA
f_{IN} RF	Operating Frequency	LMX2330L		0.5		2.5	GHz
		LMX2331L		0.2		2.0	
		LMX2332L		0.1		1.2	
f_{IN} IF	Operating Frequency	LMX233xL		45		510	MHz
f_{OSC}	Oscillator Frequency			5		40	MHz
f_φ	Maximum Phase Detector Frequency			10			MHz
Pf_{IN} RF	RF Input Sensitivity		V_{CC} = 3.0V	−15		0	dBm
			V_{CC} = 5.0V	−10		0	dBm
Pf_{IN} IF	IF Input Sensitivity		V_{CC} = 2.7V to 5.5V	−10		0	dBm
V_{OSC}	Oscillator Sensitivity		OSC_{in}	0.5			V_{PP}
V_{IH}	High-Level Input Voltage		(2)	0.8 V_{CC}			V

(1) Clock, Data and LE = GND or V_{cc}.
(2) Clock, Data and LE does not include f_{IN} RF, f_{IN} IF and OSC_{IN}.

Electrical Characteristics (continued)

V_{CC} = 3.0V, V_P = 3.0V; −40°C < T_A < 85°C, except as specified

Symbol	Parameter	Conditions	Value			Units
			Min	Typ	Max	
V_{IL}	Low-Level Input Voltage	(2)			0.2 V_{CC}	V
I_{IH}	High-Level Input Current	V_{IH} = V_{CC} = 5.5V (2)	−1.0		1.0	µA
I_{IL}	Low-Level Input Current	V_{IL} = 0V, V_{CC} = 5.5V (2)	−1.0		1.0	µA
I_{IH}	Oscillator Input Current	V_{IH} = V_{CC} = 5.5V			100	µA
I_{IL}	Oscillator Input Current	V_{IL} = 0V, V_{CC} = 5.5V	−100			µA
V_{OH}	High-Level Output Voltage (for F_oLD, pin number 10)	I_{OH} = −500 µA	V_{CC} − 0.4			V
V_{OL}	Low-Level Output Voltage (for F_oLD, pin number 10)	I_{OL} = 500 µA			0.4	V
t_{CS}	Data to Clock Set Up Time	See SERIAL DATA INPUT TIMING	50			ns
t_{CH}	Data to Clock Hold Time	See SERIAL DATA INPUT TIMING	10			ns
t_{CWH}	Clock Pulse Width High	See SERIAL DATA INPUT TIMING	50			ns
t_{CWL}	Clock Pulse Width Low	See SERIAL DATA INPUT TIMING	50			ns
t_{ES}	Clock to Load Enable Set Up Time	See SERIAL DATA INPUT TIMING	50			ns
t_{EW}	Load Enable Pulse Width	See SERIAL DATA INPUT TIMING	50			ns

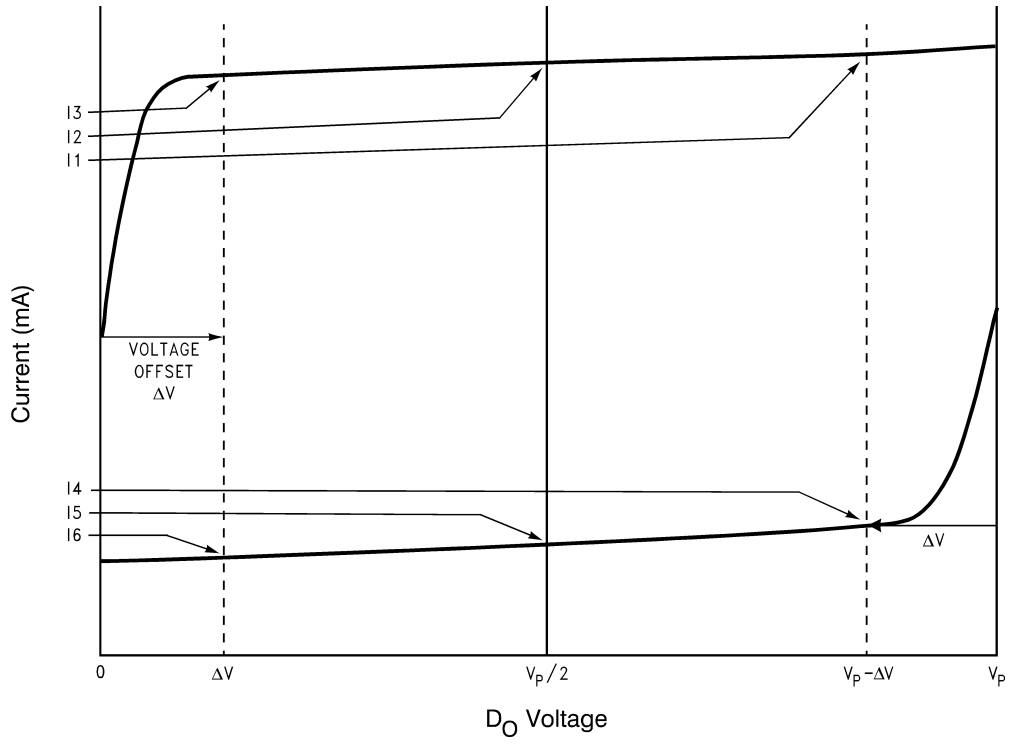
Charge Pump Characteristics

V_{CC} = 3.0V, V_P = 3.0V; −40°C < T_A ≤ 85°C, except as specified

Symbol	Parameter	Conditions	Value			Units
			Min	Typ	Max	
I_{Do}-SOURCE	Charge Pump Output Current	V_{Do} = V_P/2, I_{CPo} = HIGH (1)		−4.0		mA
I_{Do}-SINK		V_{Do} = V_P/2, I_{CPo} = HIGH (1)		4.0		mA
I_{Do}-SOURCE		V_{Do} = V_P/2, I_{CPo} = LOW (1)		−1		mA
I_{Do}-SINK		V_{Do} = V_P/2, I_{CPo} = LOW (1)		1		mA
I_{Do}-TRI	Charge Pump TRI-STATE Current	0.5V ≤ V_{Do} ≤ V_P − 0.5V −40°C < T_A < 85°C	−2.5		2.5	nA
I_{Do}-SINK vs I_{Do}-SOURCE	CP Sink vs Source Mismatch (2)	V_{Do} = V_P/2 T_A = 25°C		3	10	%
I_{Do} vs V_{Do}	CP Current vs Voltage (3)	0.5 ≤ V_{Do} ≤ V_P − 0.5V T_A = 25°C		10	15	%
I_{Do} vs T_A	CP Current vs Temperature (4)	V_{Do} = V_P/2 −40°C ≤ T_A ≤ 85°C		10		%

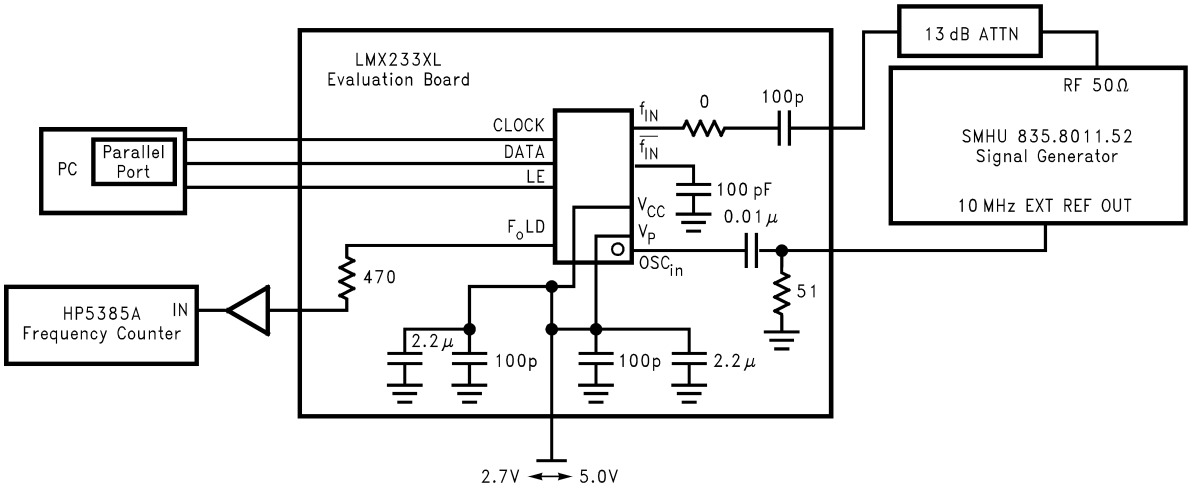
(1) See PROGRAMMABLE MODES for I_{CPo} description.
(2) $I_{Do\text{-}sink}$ vs $I_{Do\text{-}source}$ = Charge Pump Output Current Sink vs Source Mismatch = [|I2| - |I5|]/[½ * {|I2| + |I5|}] * 100%
(3) I_{Do} vs V_{Do} = Charge Pump Output Current magnitude variation vs Voltage = [½ * {|I1| - |I3|}]/[½ * {|I1| + |I3|}] * 100% and [½ * {|I4| - |I6|}]/[½ * {|I4| + |I6|}] * 100%
(4) I_{Do} vs T_A = Charge Pump Output Current magnitude variation vs Temperature = [|I2 @ temp| - |I2 @ 25°C|]/|I2 @ 25°C| * 100% and [|I5 @ temp| - |I5 @ 25°c|]/|I5 @ 25°C| * 100%

Charge Pump Current Specification Definitions



I1 = CP sink current at V_{Do} = V_P − ΔV
I2 = CP sink current at V_{Do} = V_P/2
I3 = CP sink current at V_{Do} = ΔV
I4 = CP source current at V_{Do} = V_P − ΔV
I5 = CP source current at V_{Do} = V_P/2
I6 = CP source current at V_{Do} = ΔV
ΔV = Voltage offset from positive and negative rails. Dependent on VCO tuning range relative to V_{CC} and ground. Typical values are between 0.5V and 1.0V.

RF Sensitivity Test Block Diagram



Note 1: N = 10,000 R = 50 P = 64
Note 2: Sensitivity limit is reached when the error of the divided RF output, F_oLD, is ≥ 1 Hz.

Typical Performance Characteristics

I_{CC} vs V_{CC} LMX2330L

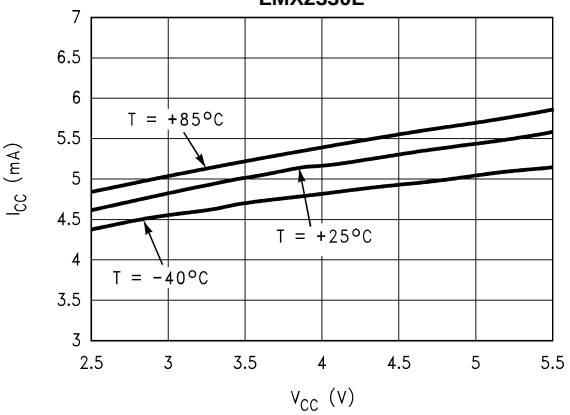


Figure 4.

I_{CC} vs V_{CC} LMX2331L

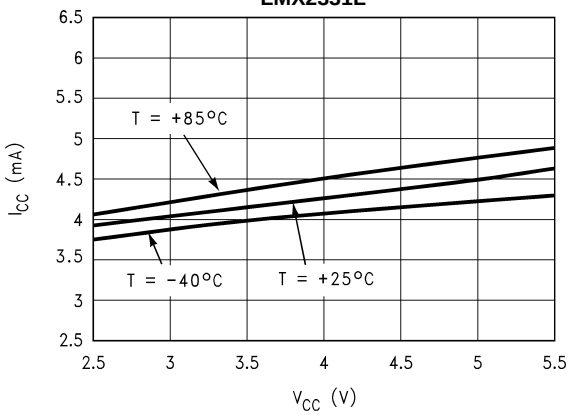


Figure 5.

I_{CC} vs V_{CC} LMX2332L

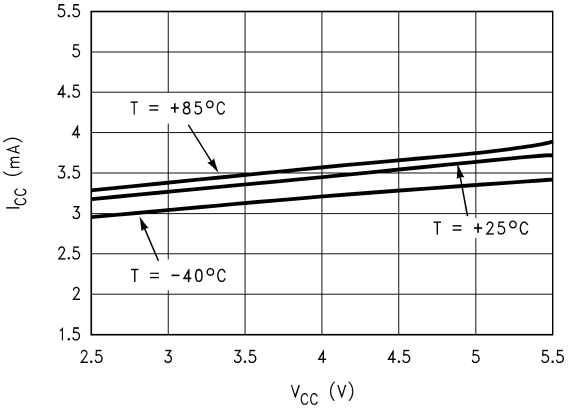


Figure 6.

I_{Do} TRI-STATE vs D_o Voltage

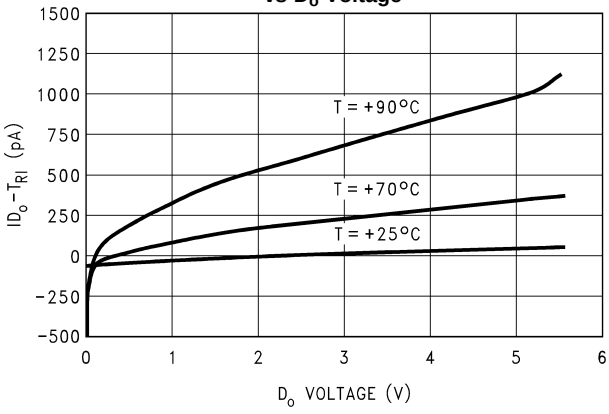


Figure 7.

Charge Pump Current vs D_o Voltage I_{CP} = HIGH

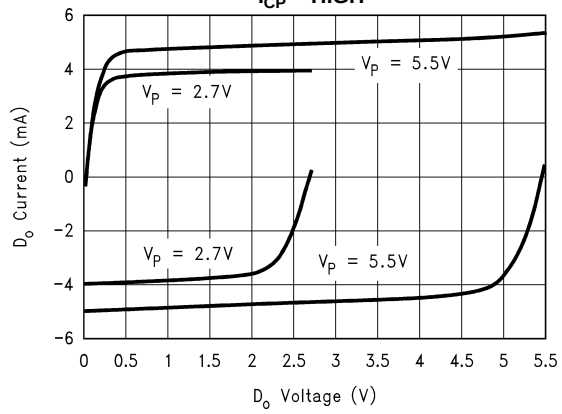


Figure 8.

Charge Pump Current vs D_o Voltage I_{CP} = LOW

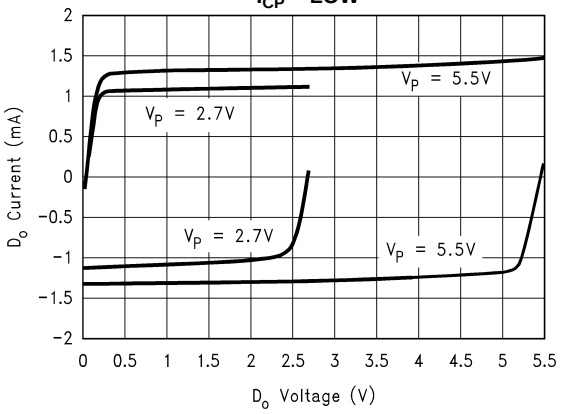


Figure 9.

Typical Performance Characteristics (continued)

Charge Pump Current Variation vs Sink vs Source Mismatch
(See (1) under Charge Pump Current Specification Definitions)

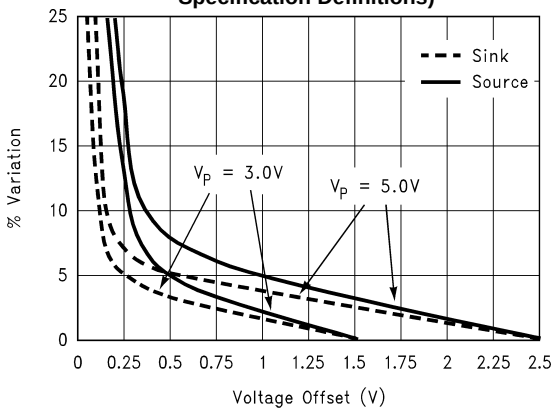


Figure 10.

(See (2) under Charge Pump Current Specification Definitions)

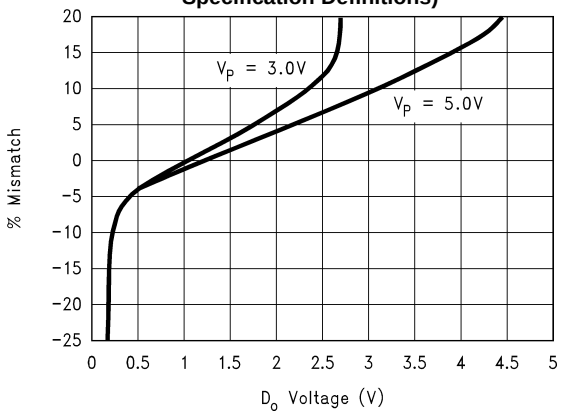
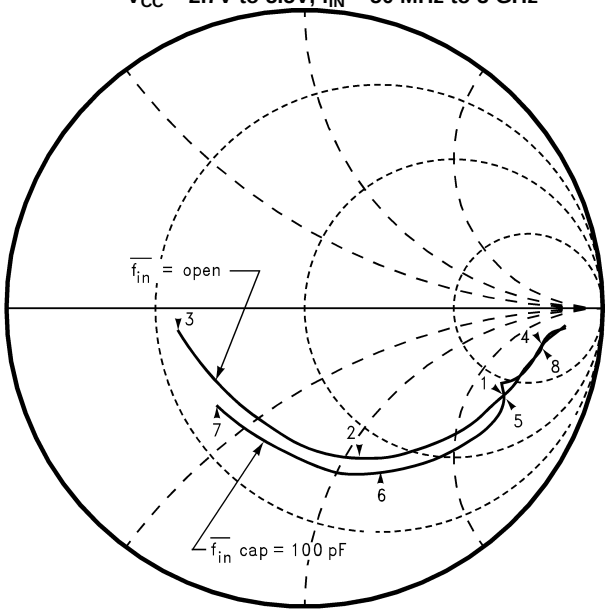


Figure 11.

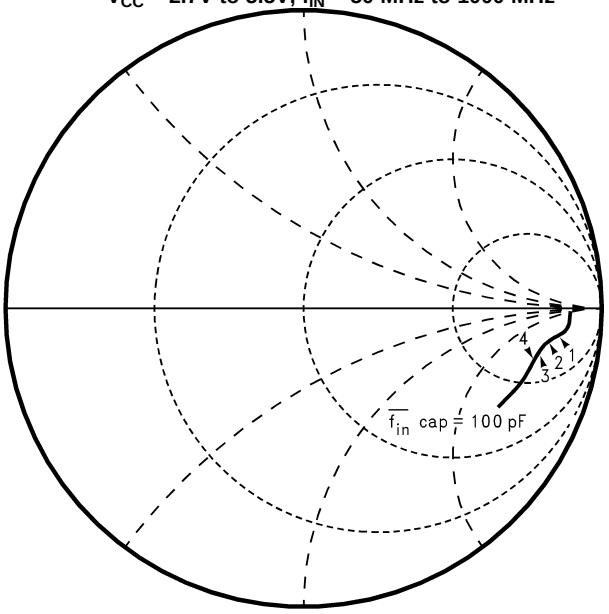
RF Input Impedance
V_{CC} = 2.7V to 5.5V, f_{IN} = 50 MHz to 3 GHz



Marker 1 = 1 GHz, Real = 123, Imaginary = −141
Marker 2 = 2 GHz, Real = 39, Imaginary = −52
Marker 3 = 3 GHz, Real = 21, Imaginary = −3
Marker 4 = 500 MHz, Real = 237, Imaginary = −185
Marker 5 = 1 GHz, Real = 128, Imaginary = −144
Marker 6 = 2 GHz, Real = 38, Imaginary = −64
Marker 7 = 3 GHz, Real = 24, Imaginary = −18
Marker 8 = 500 MHz, Real = 207, Imaginary = −184

Figure 12.

IF Input Impedance
V_{CC} = 2.7V to 5.5V, f_{IN} = 50 MHz to 1000 MHz



Marker 1 = 100 MHz, Real = 443, Imaginary = −249
Marker 2 = 200 MHz, Real = 348, Imaginary = −214
Marker 3 = 300 MHz, Real = 297, Imaginary = −208
Marker 4 = 500 MHz, Real = 222, Imaginary = −198

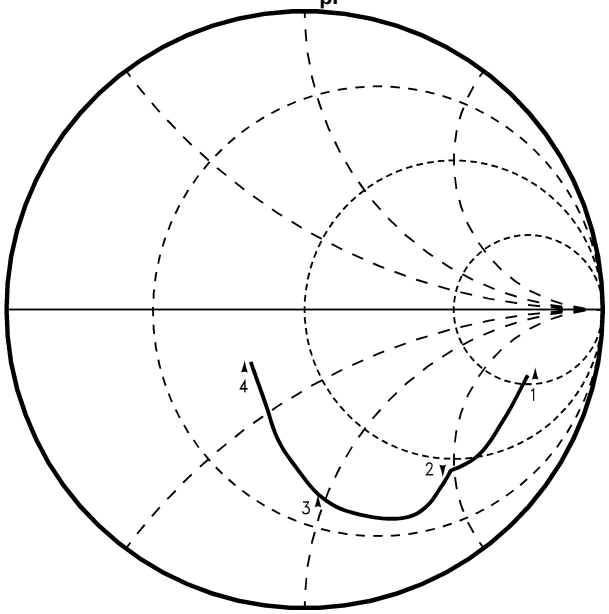
Figure 13.

(1) I_{D0} vs V_{D0} = Charge Pump Output Current magnitude variation vs Voltage = [½ * {|I1| - |I3|}]/[½ * {|I1| + |I3|}] * 100% and [½ * {|I4| - |I6|}]/[½ * {|I4| + |I6|}] * 100%

(2) $I_{Do\text{-}sink}$ vs $I_{Do\text{-}source}$ = Charge Pump Output Current Sink vs Source Mismatch = [|I2| - |I5|]/[½ * {|I2| + |I5|}] * 100%

Typical Performance Characteristics (continued)

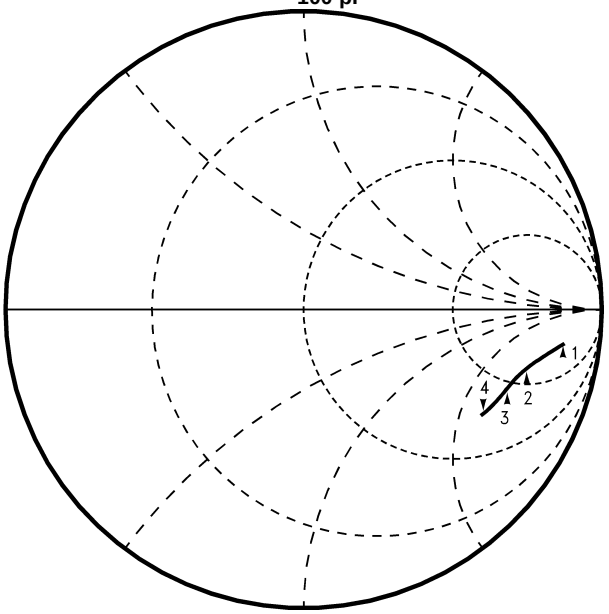
LMX233xNPJ RF Input Impedance
V_{CC} = 2.7V to 5.5V, f_{IN} = 500 MHz to 3 GHz, $\overline{f_{IN}}$RF CAP = 100 pF



Marker 1 = 500 MHz, Real = 202.98, Imaginary = −200.09
Marker 2 = 1.8 GHz, Real = 32.36, Imaginary = −91.42
Marker 3 = 2.5 GHz, Real = 25.51, Imaginary = −46.41
Marker 4 = 3.0 GHz, Real = 30.46, Imaginary = −9.50

Figure 14.

LMX233xNPJ IF Input Impedance
V_{CC} = 2.7V to 5.5V, f_{IN}IF = 100 MHz to 400 MHz, $\overline{f_{IN}}$IF CAP = 100 pF



Marker 1 = 100 MHz, Real = 374.33, Imaginary = −301.45
Marker 2 = 200 MHz, Real = 257.14, Imaginary = −245.79
Marker 3 = 300 MHz, Real = 194.08, Imaginary = −224.24224.24
Marker 4 = 400 MHz, Real = 89.03, Imaginary = −131.21

Figure 15.

LMX2330L RF Sensitivity vs Frequency

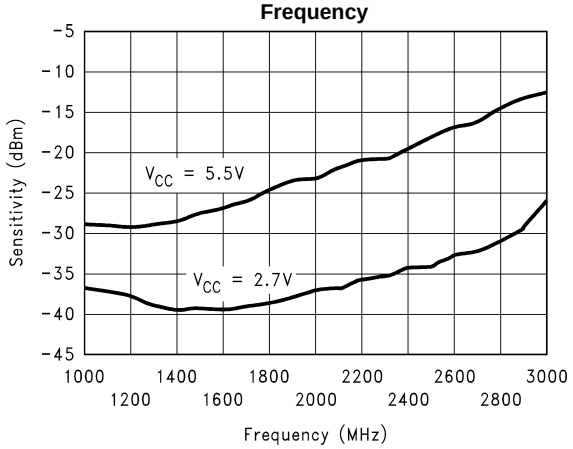


Figure 16.

LMX2331L RF Sensitivity vs Frequency

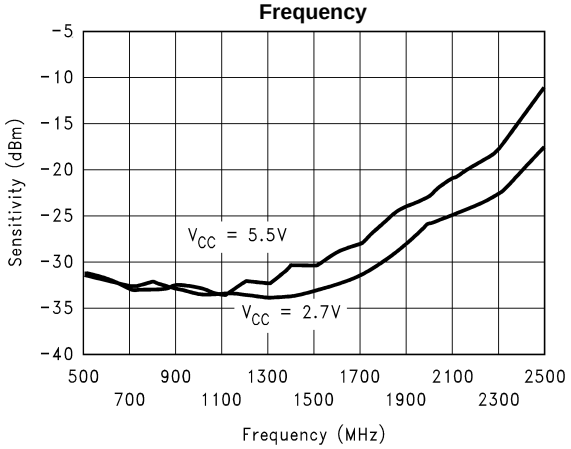


Figure 17.

Typical Performance Characteristics (continued)

LMX2332L RF Sensitivity vs Frequency

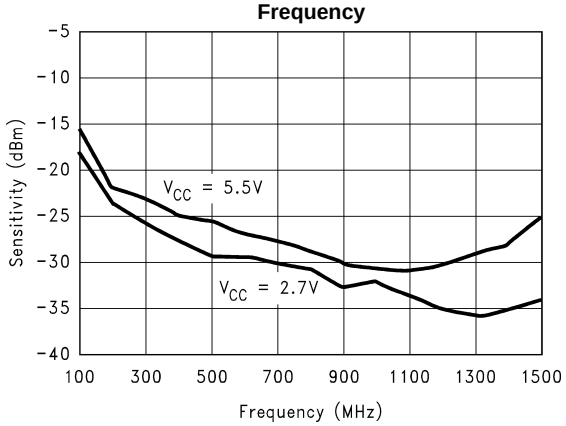


Figure 18.

IF Input Sensitivity vs Frequency

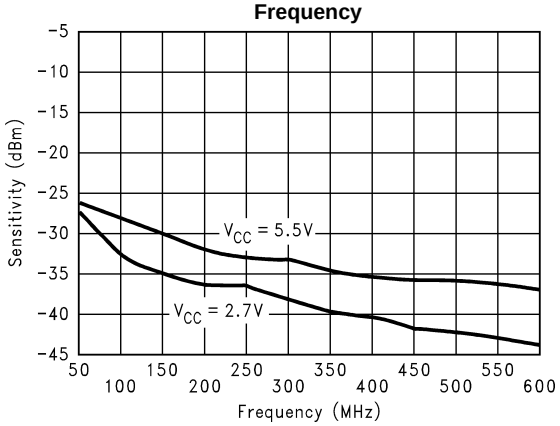


Figure 19.

Oscillator Input Sensitivity vs Frequency

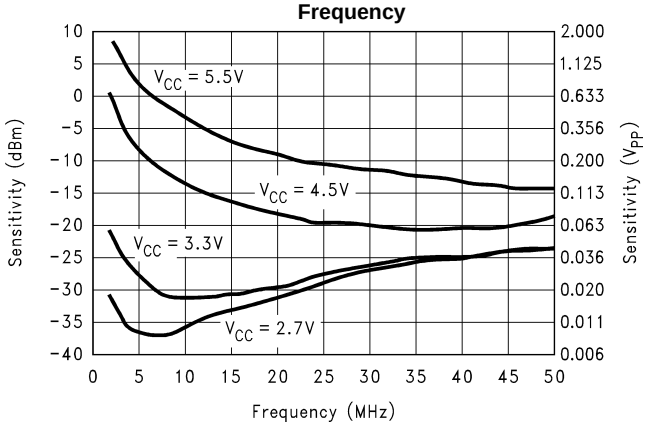
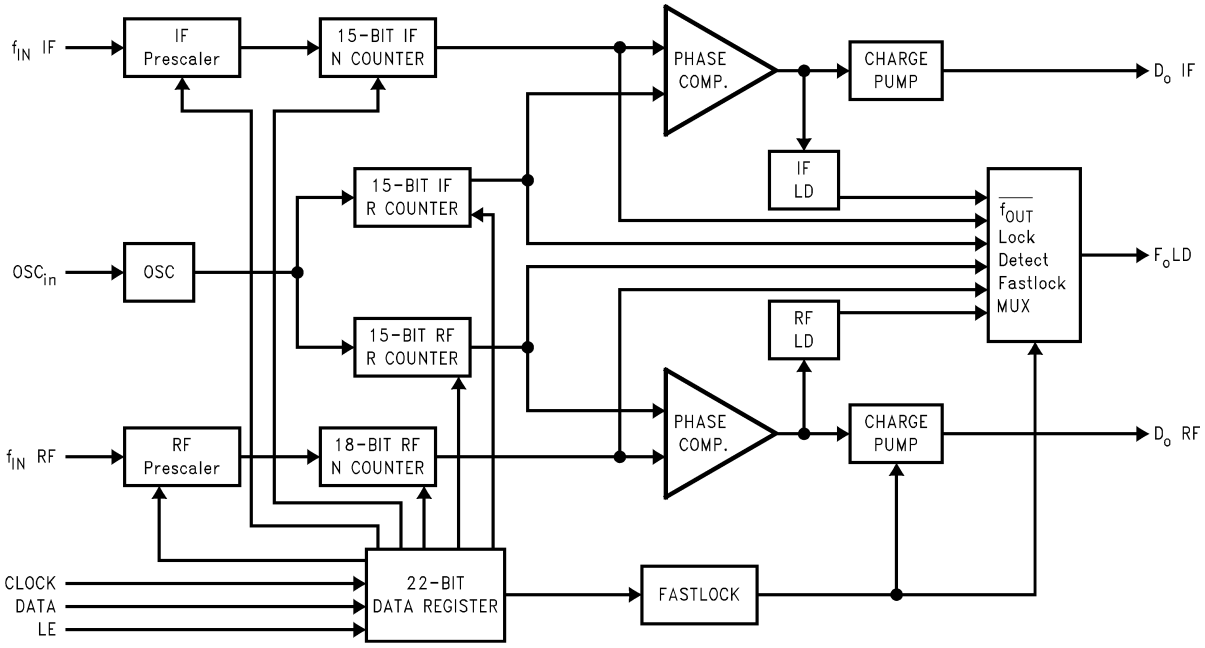


Figure 20.

FUNCTIONAL DESCRIPTION

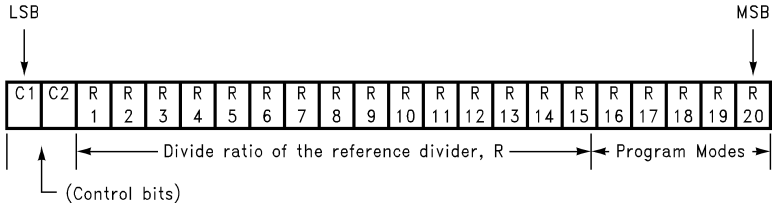
The simplified block diagram below shows the 22-bit data register, two 15-bit R Counters and the 15- and 18-bit N Counters (intermediate latches are not shown). The data stream is clocked (on the rising edge of Clock) into the DATA register, MSB first. The data stored in the shift register is loaded into one of 4 appropriate latches on the rising edge of LE. The last two bits are the Control Bits. The DATA is transferred into the counters as follows:

Control Bits		DATA Location
C1	C2	
0	0	IF R Counter
0	1	RF R Counter
1	0	IF N Counter
1	1	RF N Counter



PROGRAMMABLE REFERENCE DIVIDERS (IF AND RF R COUNTERS)

If the Control Bits are 00 or 01 (00 for IF and 01 for RF) data is transferred from the 22-bit shift register into a latch which sets the 15-bit R Counter. Serial data format is shown below.

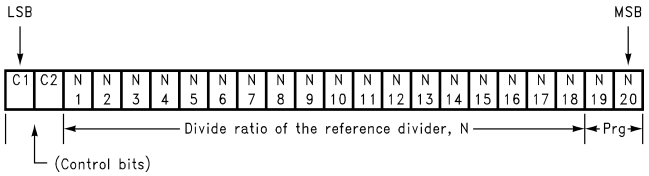


15-BIT PROGRAMMABLE REFERENCE DIVIDER RATIO (R COUNTER)

Divide Ratio	R 15	R 14	R 13	R 12	R 11	R 10	R 9	R 8	R 7	R 6	R 5	R 4	R 3	R 2	R 1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
32767	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

PROGRAMMABLE DIVIDER (N COUNTER)

The N counter consists of the 7-bit swallow counter (A counter) and the 11-bit programmable counter (B counter). If the Control Bits are 10 or 11 (10 for IF counter and 11 for RF counter) data is transferred from the 22-bit shift register into a 4-bit or 7-bit latch (which sets the Swallow (A) Counter) and an 11-bit latch (which sets the 11-bit programmable (B) Counter), MSB first. Serial data format is shown below. **For the IF N counter bits 5, 6, and 7 are don't care bits.** The RF N counter does not have don't care bits.



7-BIT SWALLOW COUNTER DIVIDE RATIO (A COUNTER)

Table 1. RF

Divide Ratio A	N 7	N 6	N 5	N 4	N 3	N 2	N 1
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1
•	•	•	•	•	•	•	•
127	1	1	1	1	1	1	1

Table 2. IF

Divide Ratio A	N 7	N 6	N 5	N 4	N 3	N 2	N 1
0	X	X	X	0	0	0	0
1	X	X	X	0	0	0	1
•	•	•	•	•	•	•	•
15	X	X	X	1	1	1	1

Table 3. 11-BIT PROGRAMMABLE COUNTER DIVIDE RATIO (B COUNTER)

Divide Ratio B	N 18	N 17	N 16	N 15	N 14	N 13	N 12	N 11	N 10	N 9	N 8
3	0	0	0	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	0	0	1	0	0
•	•	•	•	•	•	•	•	•	•	•	•
2047	1	1	1	1	1	1	1	1	1	1	1

PULSE SWALLOW FUNCTION

$f_{VCO} = [(P \times B) + A] \times f_{OSC}/R$

f_{VCO}: Output frequency of external voltage controlled oscillator (VCO)

B: Preset divide ratio of binary 11-bit programmable counter (3 to 2047)

A: Preset divide ratio of binary 7-bit swallow counter

(0 ≤ A ≤ 127 {RF}, 0 ≤ A ≤ 15 {IF}, A ≤ B)

f_{OSC}: Output frequency of the external reference frequency oscillator

R: Preset divide ratio of binary 15-bit programmable reference counter (3 to 32767)

P: Preset modulus of dual modulus prescaler (for **IF**; P = 8 or 16;
for **RF**; LMX2330L: P = 32 or 64 LMX2331L/32L: P = 64 or 128)

PROGRAMMABLE MODES

Several modes of operation can be programmed with bits R16–R20 including the phase detector polarity, charge pump TRI-STATE and the output of the F_oLD pin. The prescaler and powerdown modes are selected with bits N19 and N20. The programmable modes are shown in Table 4. Truth table for the programmable modes and F_oLD output are shown in Table 5 and Table 6.

Table 4. Programmable Modes

C1	C2	R16	R17	R18	R19	R20
0	0	IF Phase Detector Polarity	IF I_{CPo}	IF D_o TRI-STATE	IF LD	IF F_o
0	1	RF Phase Detector Polarity	RF I_{CPo}	RF D_o TRI-STATE	RF LD	RF F_o

C1	C2	N19	N20
1	0	IF Prescaler	Pwdn IF
1	1	RF Prescaler	Pwdn RF

Table 5. Mode Select Truth Table

	Phase Detector Polarity (1)	D_o TRI-STATE (2)	I_{CPo} (3)	IF Prescaler	2330L RF Prescaler	2331L/32L RF Prescaler	Pwdn (2)
0	Negative	Normal Operation	LOW	8/9	32/33	64/65	Pwrd Up
1	Positive	TRI-STATE	HIGH	16/17	64/65	128/129	Pwrd Dn

(1) PHASE DETECTOR POLARITY, Depending upon VCO characteristics, R16 bit should be set accordingly: (see Figure 21) When VCO characteristics are positive like (1), R16 should be set HIGH; When VCO characteristics are negative like (2), R16 should be se LOW.
(2) Refer to POWERDOWN OPERATION.
(3) The I_{CPo} LOW current state = 1/4 × I_{CPo} HIGH current.

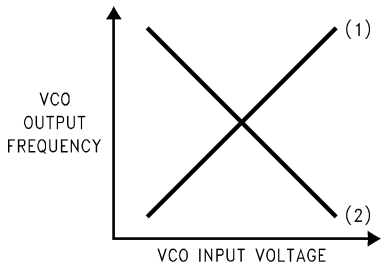


Figure 21. VCO Characteristics

Table 6. The F_oLD (Pin 10) Output Truth Table(1)

RF R[19] (RF LD)	IF R[19] (IF LD)	RF R[20] (RF F_o)	IF R[20] (IF F_o)	F_o Output State
0	0	0	0	Disabled (2)
0	1	0	0	IF Lock Detect (3)
1	0	0	0	RF Lock Detect (3)

(1) X = don't care condition
(2) When the F_oLD output is disabled, it is actively pulled to a low logic state.
(3) Lock detect output provided to indicate when the VCO frequency is in “lock.” When the loop is locked and a lock detect mode is selected, the pins output is HIGH, with narrow pulses LOW. In the RF/IF lock detect mode a locked condition is indicated when RF and IF are both locked.

Table 6. The F_oLD (Pin 10) Output Truth Table(1) (continued)

RF R[19] (RF LD)	IF R[19] (IF LD)	RF R[20] (RF F_o)	IF R[20] (IF F_o)	F_o Output State
1	1	0	0	RF/IF Lock Detect (3)
X	0	0	1	IF Reference Divider Output
X	0	1	0	RF Reference Divider Output
X	1	0	1	IF Programmable Divider Output
X	1	1	0	RF Programmable Divider Output
0	0	1	1	Fastlock (4)
0	1	1	1	IF Counter Reset (5)
1	0	1	1	RF Counter Reset (5)
1	1	1	1	IF and RF Counter Reset (5)

(4) The Fastlock mode utilizes the F_oLD output pin to switch a second loop filter damping resistor to ground during fastlock operation. Activation of Fastlock occurs whenever the RF loop's Icpo magnitude bit #17 is selected HIGH (while the #19 and #20 mode bits are set for Fastlock).

(5) The IF Counter Reset mode resets IF PLL's R and N counters and brings IF charge pump output to a TRI-STATE condition. The RF Counter Reset mode resets RF PLL's R and N counters and brings RF charge pump output to a TRI-STATE condition. The IF and RF Counter Reset mode resets all counters and brings both charge pump outputs to a TRI-STATE condition. Upon removal of the Reset bits then N counter resumes counting in “close” alignment with the R counter. (The maximum error is one prescaler cycle.)

POWERDOWN OPERATION

Synchronous and asynchronous powerdown modes are both available by MICROWIRE selection. Synchronously powerdown occurs if the respective loop's R18 bit (Do TRI-STATE) is LOW when its N20 bit (Pwdn) becomes HI. Asynchronous powerdown occurs if the loop's R18 bit is HI when its N20 bit becomes HI.

In the synchronous powerdown mode, the powerdown function is gated by the charge pump to prevent unwanted frequency jumps. Once the powerdown program bit N20 is loaded, the part will go into powerdown mode when the charge pump reaches a TRI-STATE condition.

In the asynchronous powerdown mode, the device powers down immediately after the LE pin latches in a HI condition on the powerdown bit N20.

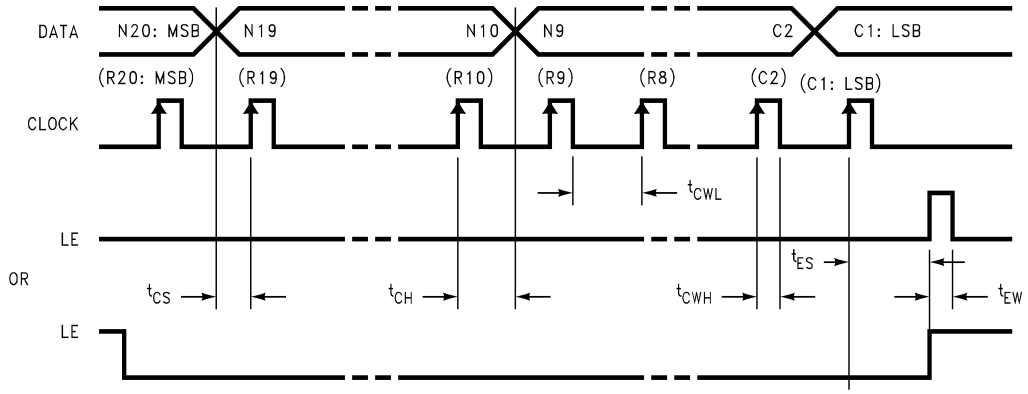
Activation of either the IF or RF PLL powerdown conditions in either synchronous or asynchronous modes forces the respective loop's R and N dividers to their load state condition and debiasing of its respective f_{IN} input to a high impedance state. The oscillator circuitry function does not become disabled until both IF and RF powerdown bits are activated. The MICROWIRE control register remains active and capable of loading and latching data during all of the powerdown modes.

The device returns to an actively powered up condition in either synchronous or asynchronous modes immediately upon LE latching LOW data into bit N20.

Table 7. Powerdown Mode Select Table

R18	N20	Powerdown Status
0	0	PLL Active
1	0	PLL Active (Charge Pump Output TRI-STATE)
0	1	Synchronous Powerdown Initiated
1	1	Asynchronous Powerdown Initiated

SERIAL DATA INPUT TIMING

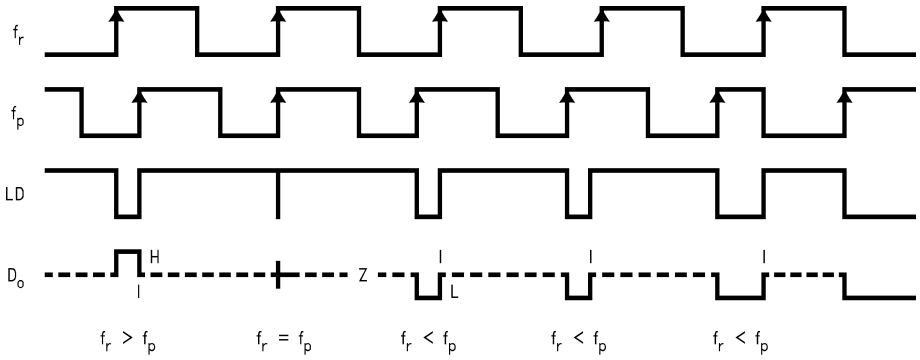


Note 1: Parenthesis data indicates programmable reference divider data.
Data shifted into register on clock rising edge.
Data is shifted in MSB first.

Note 2: t_{cs} = Data to Clock Set-Up Time
t_{CH} = Data to Clock Hold Time
t_{CWH} = Clock Pulse Width High
t_{CWL} = Clock Pulse Width Low
t_{ES} = Clock to Load Enable Set-Up Time
t_{EW} = Load Enable Pulse Width

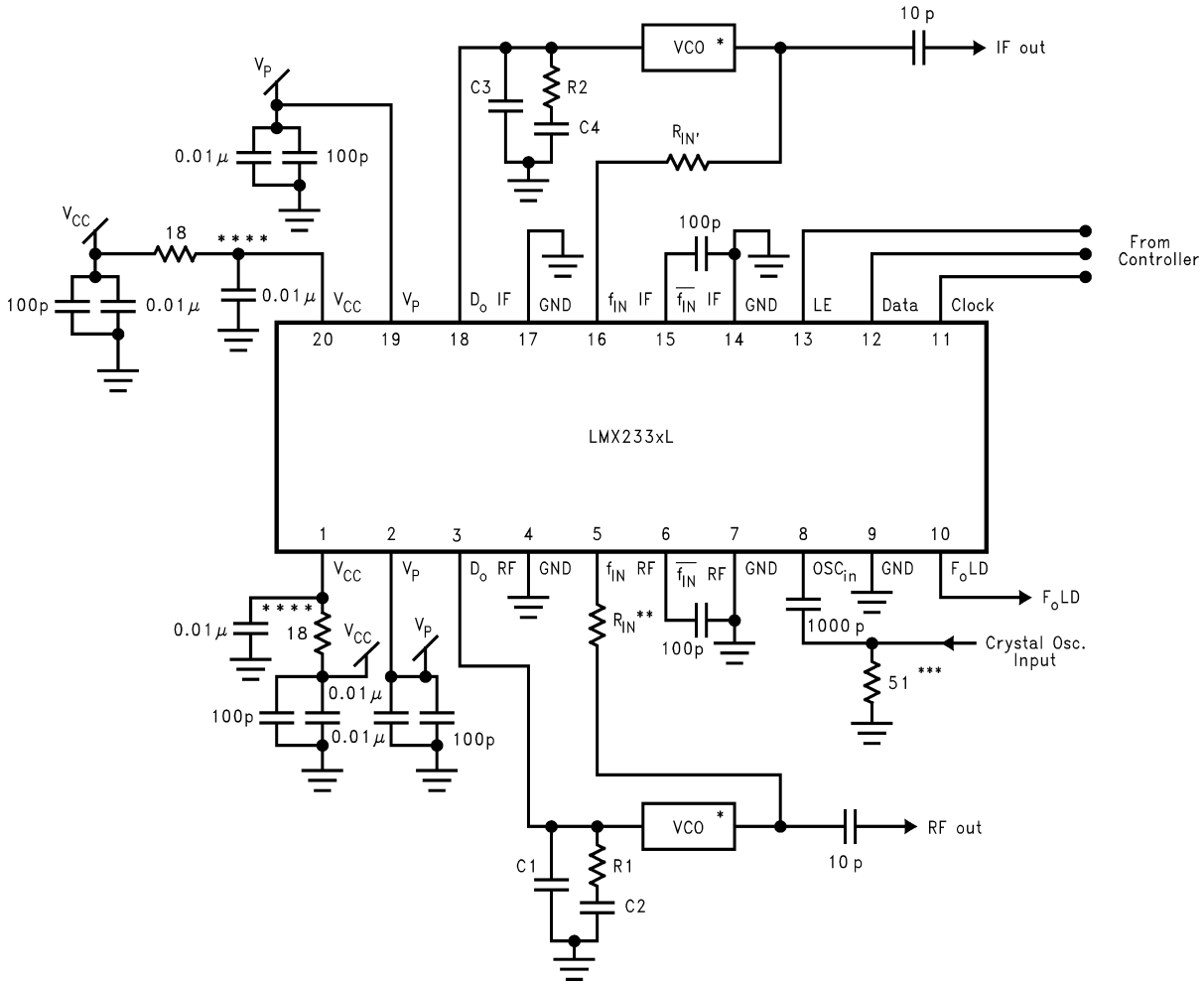
Test Conditions: The Serial Data Input Timing is tested using a symmetrical waveform around $V_{CC}/2$. The test waveform has an edge rate of 0.6 V/ns with amplitudes of 2.2V @ V_{CC} = 2.7V and 2.6V @ V_{CC} = 5.5V.

PHASE COMPARATOR AND INTERNAL CHARGE PUMP CHARACTERISTICS



Notes: Phase difference detection range: −2π to +2π
The minimum width pump up and pump down current pulses occur at the D_o pin when the loop is locked.
R16 = HIGH

Typical Application Example

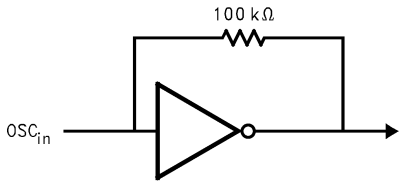


Operational Notes:

* VCO is assumed AC coupled.

** R_{IN} increases impedance so that VCO output power is provided to the load rather than the PLL. Typical values are 10Ω to 200Ω depending on the VCO power level. f_{IN} RF impedance ranges from 40Ω to 100Ω. f_{IN} IF impedances are higher.

*** Adding RC filters to the V_{CC} lines is recommended to reduce loop-to-loop noise coupling.



Application Hints:

Proper use of grounds and bypass capacitors is essential to achieve a high level of performance. Crosstalk between pins can be reduced by careful board layout.

This is an electrostatic sensitive device. It should be handled only at static free work stations.

Application Information

A block diagram of the basic phase locked loop is shown in Figure 22.

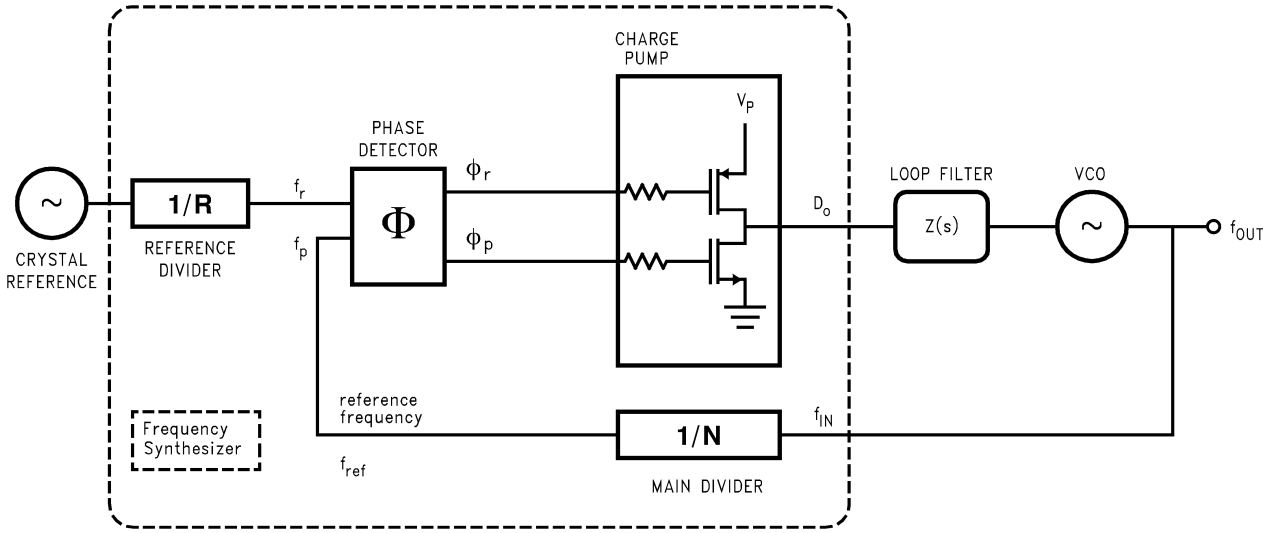


Figure 22. Basic Charge Pump Phase Locked Loop

LOOP GAIN EQUATIONS

A linear control system model of the phase feedback for a PLL in the locked state is shown in Figure 23. The open loop gain is the product of the phase comparator gain (Kφ), the VCO gain (K_{VCO}/s), and the loop filter gain Z(s) divided by the gain of the feedback counter modulus (N). The passive loop filter configuration used is displayed in Figure 24, while the complex impedance of the filter is given in Equation 1.

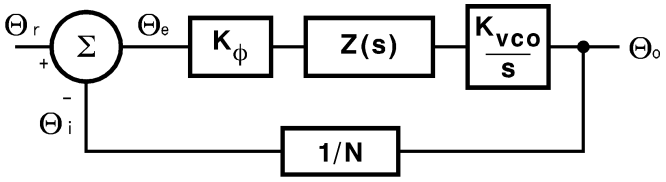


Figure 23. PLL Linear Model

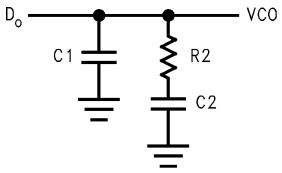


Figure 24. Passive Loop Filter

$$\text{Open loop gain} = H(s)\,G(s) = \Theta i/\Theta e = K_\phi Z(s)\,K_{VCO}/Ns$$

$$Z(s) = \frac{s(C2 \bullet R2) + 1}{s^2(C1 \bullet C2 \bullet R2) + sC1 + sC2} \quad (1)$$

The time constants which determine the pole and zero frequencies of the filter transfer function can be defined as

$$T1 = R2 \bullet \frac{C1 \bullet C2}{C1 + C2} \quad (2)$$

and

$$T2 = R2 \bullet C2 \quad (3)$$

The 3rd order PLL Open Loop Gain can be calculated in terms of frequency, ω, the filter time constants T1 and T2, and the design constants K_ϕ, K_{VCO}, and N.

$$G(s) \bullet H(s)|_{s = j \bullet \omega} = \frac{-K_\phi \bullet K_{VCO} (1 + j\omega \bullet T2)}{\omega^2 C1 \bullet N(1 + j\omega \bullet T1)} \bullet \frac{T1}{T2} \quad (4)$$

From Equation 2 and Equation 3 we can see that the phase term will be dependent on the single pole and zero such that the phase margin is determined in Equation 5.

$$\varphi(\omega) = \tan^{-1} (\omega \bullet T2) - \tan^{-1} (\omega \bullet T1) + 180° \quad (5)$$

A plot of the magnitude and phase of G(s)H(s) for a stable loop, is shown in Figure 25 with a solid trace. The parameter φ_p shows the amount of phase margin that exists at the point the gain drops below zero (the cutoff frequency wp of the loop). In a critically damped system, the amount of phase margin would be approximately 45 degrees.

If we were now to redefine the cut off frequency, wp', as double the frequency which gave us our original loop bandwidth, wp, the loop response time would be approximately halved. Because the filter attenuation at the comparison frequency also diminishes, the spurs would have increased by approximately 6 dB. In the proposed Fastlock scheme, the higher spur levels and wider loop filter conditions would exist only during the initial lock-on phase—just long enough to reap the benefits of locking faster. The objective would be to open up the loop bandwidth but not introduce any additional complications or compromises related to our original design criteria. We would ideally like to momentarily shift the curve of Figure 25 over to a different cutoff frequency, illustrated by the dotted line, without affecting the relative open loop gain and phase relationships. To maintain the same gain/phase relationship at twice the original cutoff frequency, other terms in the gain and phase Equation 4 and Equation 5 will have to compensate by the corresponding "1/w" or "1/w^2" factor. Examination of equations Equation 2, Equation 3, and Equation 5 indicates the damping resistor variable R2 could be chosen to compensate the "w"' terms for the phase margin. This implies that another resistor of equal value to R2 will need to be switched in parallel with R2 during the initial lock period. We must also insure that the magnitude of the open loop gain, H(s)G(s) is equal to zero at wp' = 2wp. K_{VCO}, Kφ, N, or the net product of these terms can be changed by a factor of 4, to counteract the w^2 term present in the denominator of Equation 2 and Equation 3. The Kφ term was chosen to complete the transformation because it can readily be switched between 1X and 4X values. This is accomplished by increasing the charge pump output current from 1 mA in the standard mode to 4 mA in Fastlock.

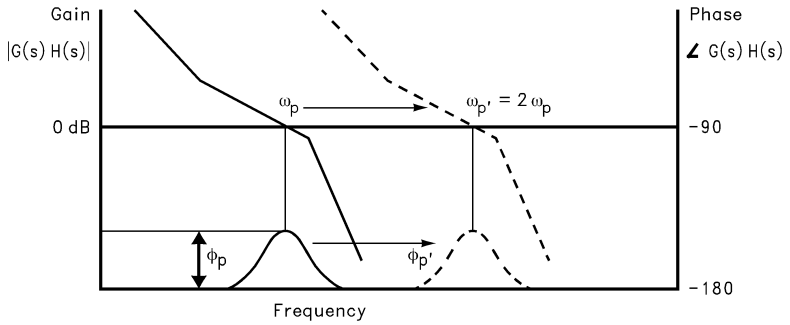


Figure 25. Open Loop Response Bode Plot

FASTLOCK CIRCUIT IMPLEMENTATION

A diagram of the Fastlock scheme as implemented in Texas Instruments LMX233XL PLL is shown in Figure 26. When a new frequency is loaded, and the RF Icp_o bit is set high the charge pump circuit receives an input to deliver 4 times the normal current per unit phase error while an open drain NMOS on chip device switches in a second R2 resistor element to ground. The user calculates the loop filter component values for the normal steady state considerations. The device configuration ensures that as long as a second identical damping resistor is wired in appropriately, the loop will lock faster without any additional stability considerations to account for. Once locked on the correct frequency, the user can return the PLL to standard low noise operation by sending a MICROWIRE instruction with the RF Icp_o bit set low. This transition does not affect the charge on the loop filter capacitors and is enacted synchronous with the charge pump output. This creates a nearly seamless change between Fastlock and standard mode.

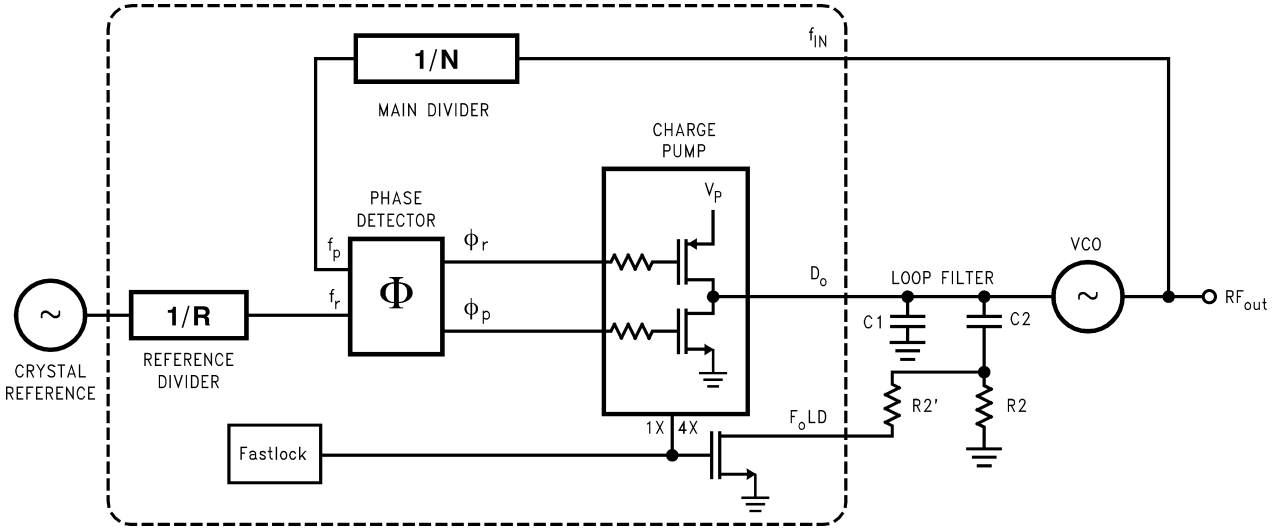


Figure 26. Fastlock PLL Architecture

REVISION HISTORY

Changes from Revision B (March 2013) to Revision C	Page
• Changed layout of National Data Sheet to TI format	20

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