

# LMX2370/LMX2371/LMX2372 PLLatinum™ Dual Frequency Synthesizer for RF Personal Communications

**LMX2370** 2.5 GHz/1.2 GHz

**LMX2371** 2.0 GHz/1.2 GHz

**LMX2372** 1.2 GHz/1.2 GHz

## General Description

The LMX237x family of monolithic, integrated dual frequency synthesizers, including prescalers, is designed to be used as a first and second local oscillator for dual mode or dual conversion transceivers. It is fabricated using National's 0.5u ABiCV silicon BiCMOS process. The LMX237x contains two dual modulus prescalers. A 32/33 or a 16/17 prescaler can be selected for the 2.5 GHz and 2.0 GHz RF synthesizers with the 16/17 prescaler rated for input frequencies below 1.2 GHz. A 16/17 or an 8/9 prescaler can be selected for the 1.2 GHz RF synthesizers with the 8/9 prescaler rated for input frequencies below 550 MHz. Using a digital phase locked loop technique, the LMX237x can generate very stable, low noise control signals for UHF and VHF voltage controlled oscillators (VCOs). Serial data is transferred into the LMX237x via a 1.8 V three wire interface (Data, Enable, Clock) compatible with low voltage baseband processors. Supply voltage can range from 2.7V to 5.5V. The LMX237x family features very low current consumption typically: LMX2370 - 6.0 mA at 3V, LMX2371 - 5.0 mA at 3V, LMX2372 - 4.0 mA at 3V.

The LMX237x are available in a 24-pad chip scale (CSP) or a 20-pin TSSOP surface mount plastic package.

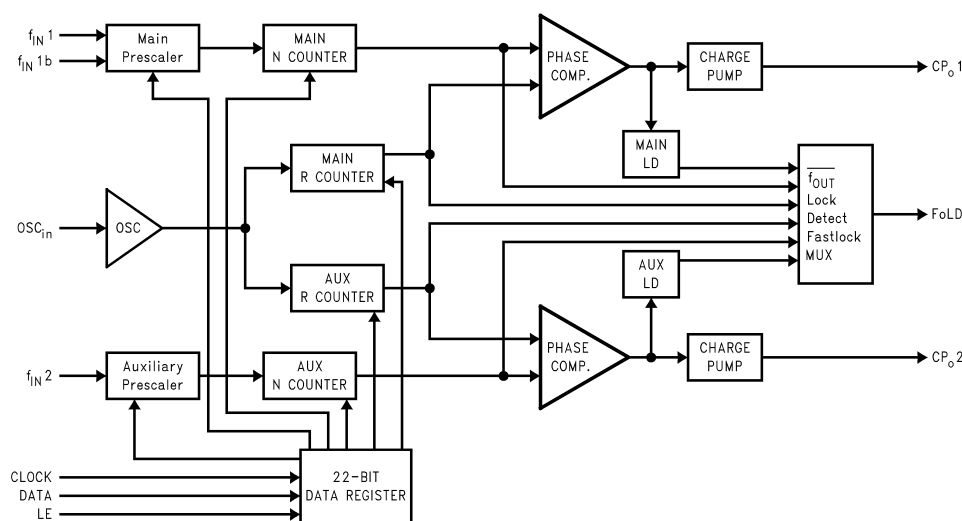
## Features

- 2.7V–5.5V operation
- Ultra low current consumption
- Low phase detector noise floor
- Low voltage MICROWIRE™ interface (1.8V up to  $V_{CC}$ )
- Low prescaler values
  - 32/33 at  $f_{IN} \leq 2.5$  GHz
  - 16/17 at  $f_{IN} \leq 1.2$  GHz
  - 8/9 at  $f_{IN} \leq 550$  MHz
- Selectable charge pump current levels
- Selectable FastLock™ mode
- Enhanced ESD protection
- Available in small 24-pad chip scale package (3.5 x 4.5 x 1.0 mm)

## Applications

- Portable wireless communications (PCS/PCN, cordless)
- Dual mode cellular telephone systems
- Spread spectrum communication systems (CDMA)
- Cable TV tuners (CATV)

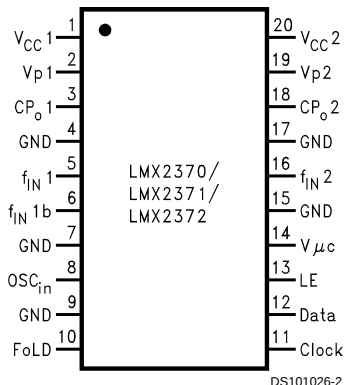
## Functional Block Diagram



DS101026-4

# Connection Diagrams

TSSOP 20-Pin Package

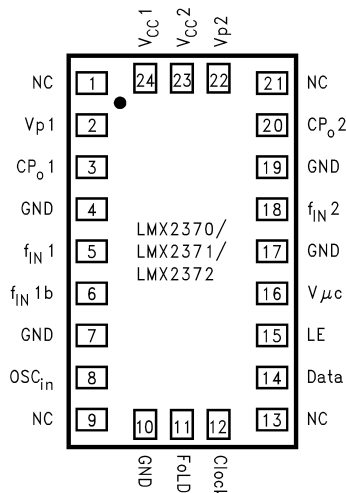


DS101026-2

Top View

Order Number LMX2370TM, LMX2370TMX,  
LMX2371TM, LMX2371TMX,  
LMX2372TM or LMX2372TMX  
See NS Package Number MTC20

CSP 24-Pin Package



DS101026-3

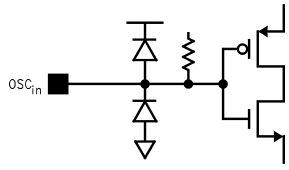
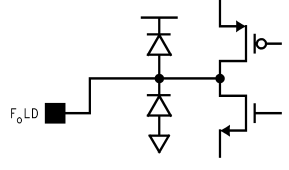
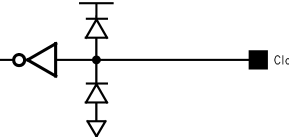
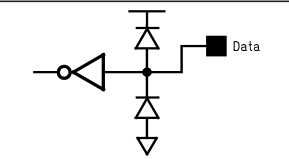
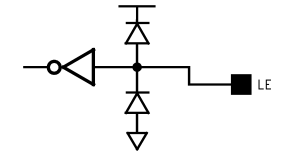
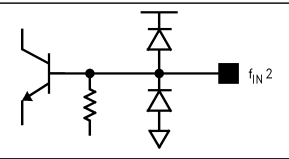
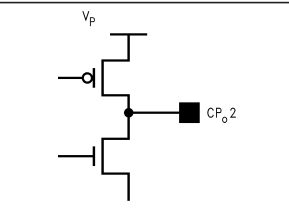
Top View

Order Number LMX2370SLBX,  
LMX2371SLBX or LMX2372SLBX  
See NS Package Number SLB24A

## Pin Descriptions

| Pin No.    |              | Pin Name          | I/O | Description                                                                                                                                                                                                                                                            |  |
|------------|--------------|-------------------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| 24-Pin CSP | 20-Pin TSSOP |                   |     |                                                                                                                                                                                                                                                                        |  |
| 24         | 1            | V <sub>CC1</sub>  | —   | Power supply voltage input for RF analog and RF digital circuits. Input may range from 2.7V to 5.5V. V <sub>CC1</sub> must equal V <sub>CC2</sub> . Bypass capacitors should be placed as close as possible to this pin and be connected directly to the ground plane. |  |
| 2          | 2            | V <sub>p1</sub>   | —   | Power supply for Main charge pump. Must be ≥ V <sub>CC</sub> .                                                                                                                                                                                                         |  |
| 3          | 3            | CP <sub>o1</sub>  | O   | Internal Main charge pump output. For connection to a loop filter for driving the input of an external VCO.                                                                                                                                                            |  |
| 4          | 4            | GND               | —   | Ground for Main digital circuitry.                                                                                                                                                                                                                                     |  |
| 5          | 5            | f <sub>IN1</sub>  | I   | Main prescaler input. Small signal input from the VCO.                                                                                                                                                                                                                 |  |
| 6          | 6            | f <sub>IN1b</sub> | I   | Main prescaler complementary input. For single ended operation, a bypass capacitor should be placed as close as possible to this pin and be connected directly to the ground plane.                                                                                    |  |
| 7          | 7            | GND               | —   | Ground for Main analog circuitry.                                                                                                                                                                                                                                      |  |

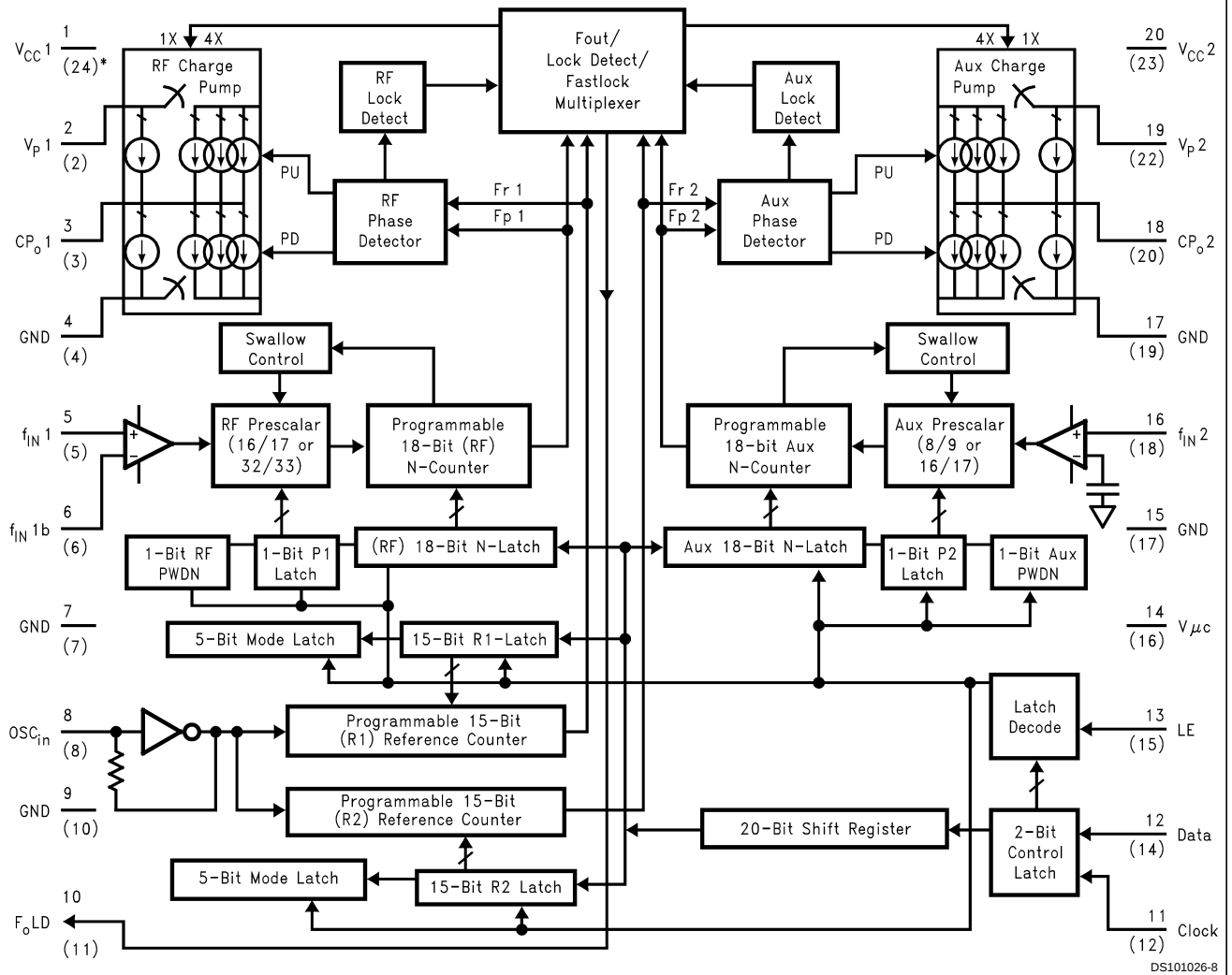
## Pin Descriptions (Continued)

| Pin No.    |              | Pin Name          | I/O | Description                                                                                                                                                                                 |                                                                                       |
|------------|--------------|-------------------|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 24-Pin CSP | 20-Pin TSSOP |                   |     |                                                                                                                                                                                             |                                                                                       |
| 8          | 8            | OSC <sub>in</sub> | I   | Oscillator input. The input has a $V_{CC}/2$ input threshold and can be driven from an external CMOS or TTL logic gate.                                                                     |    |
| 10         | 9            | GND               | —   | Ground for Aux digital, MICROWIRE, FoLD, and oscillator circuits.                                                                                                                           |                                                                                       |
| 11         | 10           | FoLD              | O   | Multiplexed output of the Main/Aux programmable or reference dividers, Main/Auxiliary lock detect signals and Fastlock mode. CMOS output (see <i>Programmable Modes in the Datasheet</i> ). |    |
| 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.                                                            |    |
| 14         | 12           | Data              | I   | Binary serial data input. Data entered MSB first. The last two bits are the control bits. High impedance CMOS input.                                                                        |   |
| 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).                      |  |
| 16         | 14           | V <sub>μc</sub>   | —   | Power supply for MICROWIRE circuitry. Must be $\leq V_{CC}$ . Typically connected to same supply level as $\mu$ processor or baseband controller to enable programming at low voltages.     |                                                                                       |
| 17         | 15           | GND               | —   | Ground for Aux analog circuitry.                                                                                                                                                            |                                                                                       |
| 18         | 16           | f <sub>IN2</sub>  | I   | Auxiliary prescaler input. Small signal input from the VCO.                                                                                                                                 |  |
| 19         | 17           | GND               | —   | Ground for Aux digital, MICROWIRE, FoLD, and oscillator.                                                                                                                                    |                                                                                       |
| 20         | 18           | CP <sub>o2</sub>  | O   | Aux internal charge pump output. For connection to a loop filter for driving the input of an external VCO.                                                                                  |  |
| 22         | 19           | Vp2               | —   | Power supply for Aux charge pump. Must be $\geq V_{CC}$ .                                                                                                                                   |                                                                                       |

## Pin Descriptions (Continued)

| Pin No.      |              | Pin Name  | I/O | Description                                                                                                                                                                                                                                                                   |
|--------------|--------------|-----------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 24-Pin CSP   | 20-Pin TSSOP |           |     |                                                                                                                                                                                                                                                                               |
| 23           | 20           | $V_{CC2}$ | —   | Power supply voltage input for Aux analog, Aux digital, FoLD, and oscillator circuits. Input may range from 2.7V to 5.5V. $V_{CC2}$ must equal $V_{CC1}$ . Bypass capacitors should be placed as close as possible to this pin and be connected directly to the ground plane. |
| 1, 9, 13, 21 | —            | NC        | —   | No Connect                                                                                                                                                                                                                                                                    |

## Block Diagram (Note 1)



**Note 1:** \* The numbers in () represent the equivalent chipscale package (CSP) pinout

DS101026-8

**Absolute Maximum Ratings** (Notes 2, 3)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

## Power Supply Voltage

|             |               |
|-------------|---------------|
| $V_{CC1}$   | -0.3V to 6.5V |
| $V_{CC2}$   | -0.3V to 6.5V |
| $V_{p1}$    | -0.3V to 6.5V |
| $V_{p2}$    | -0.3V to 6.5V |
| $V_{\mu c}$ | -0.3V to 6.5V |

## Voltage on any pin with

$$GND = 0V (V_I) \quad -0.3V \text{ to } V_{CC} + 0.3V$$

$$\text{Storage Temperature Range } (T_S) \quad -65^\circ\text{C to } +150^\circ\text{C}$$

$$\text{Lead Temperature (solder, 4 sec.) } (T_L) \quad +260^\circ\text{C}$$

$$\text{ESD - Human Body Model (Note 3)} \quad < 2 \text{ keV}$$

**Recommended Operating Conditions** (Note 4)

## Power Supply Voltage

|                     |                   |
|---------------------|-------------------|
| $V_{CC1}$           | 2.7V to 5.5V      |
| $V_{CC2}$           | 2.7V to 5.5V      |
| $V_{CC1} - V_{CC2}$ | -0.2V to 0.2V     |
| $V_{p1}$            | $V_{CC}$ to 5.5V  |
| $V_{p2}$            | $V_{CC}$ to 5.5V  |
| $V_{\mu c}$         | 1.72V to $V_{CC}$ |

Operating Temperature ( $T_A$ )

$$-40^\circ\text{C to } +85^\circ\text{C}$$

**Note 2:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

**Note 3:** This device is a high performance RF integrated circuit and is ESD sensitive. Handling and assembly of this device should only be done at ESD free workstations.

**Note 4:**  $V_{CC}$  is defined as  $V_{CC} = V_{CC1} = V_{CC2}$ .

**Electrical Characteristics** ( $V_{CC} = V_p = V_{\mu c} = 3.0V$ ;  $-40^\circ\text{C} < T_A < 85^\circ\text{C}$  except as specified).

| GENERAL                               |                                                        |                |                                                  | Value |       |                 | Unit            |
|---------------------------------------|--------------------------------------------------------|----------------|--------------------------------------------------|-------|-------|-----------------|-----------------|
| Symbol                                | Parameter                                              |                | Conditions                                       | Min   | Typ   | Max             |                 |
| I <sub>CC</sub>                       | Power Supply Current                                   | LMX2370        | Main = On, Aux = On                              |       | 6     | 8.5             | mA              |
|                                       |                                                        | LMX2371        | Main = On, Aux = On                              |       | 5     | 7.5             | mA              |
|                                       |                                                        | LMX2372        | Main = On, Aux = On                              |       | 4     | 6.0             | mA              |
|                                       |                                                        | LMX2370 /71/72 | Aux Only                                         |       | 2     | 3.25            | mA              |
| I <sub>CC-PWDN</sub>                  | Power Down Current                                     |                | EN_Main, EN_Aux = 0                              |       | 15    | 50              | μA              |
| f <sub>IN1</sub>                      | Main PLL Operating Frequency                           | LMX2370        | P = 32/33                                        | 1.2   |       | 2.5             | GHz             |
|                                       |                                                        |                | P = 16/17                                        | 45    |       | 1200            | MHz             |
|                                       |                                                        | LMX2371        | P = 32/33                                        | 1.2   |       | 2.0             | GHz             |
|                                       |                                                        |                | P = 16/17                                        | 45    |       | 1200            | MHz             |
|                                       |                                                        | LMX2372        | P = 16/17                                        | 45    |       | 1200            | MHz             |
|                                       |                                                        |                | P = 8/9                                          | 45    |       | 550             | MHz             |
| f <sub>IN2</sub>                      | Auxiliary PLL Operating Frequency                      | P = 16/17      | 45                                               |       | 1200  | MHz             |                 |
|                                       |                                                        | P = 8/9        | 45                                               |       | 550   | MHz             |                 |
| f <sub>φ</sub>                        | Phase Detector Frequency                               |                |                                                  |       |       | 10              | MHz             |
| Pf <sub>IN1</sub> , Pf <sub>IN2</sub> | RF Input Sensitivity                                   |                | 2.7 ≤ V <sub>CC</sub> ≤ 3.6V                     | −15   |       | 0               | dBm             |
|                                       |                                                        |                | 3.6 ≤ V <sub>CC</sub> ≤ 5.5V                     | −10   |       | 0               | dBm             |
| OSCILLATOR INPUT                      |                                                        |                |                                                  | Value |       |                 | Unit            |
| Symbol                                | Parameter                                              |                | Conditions                                       | Min   | Typ   | Max             |                 |
| OSC <sub>in</sub>                     | Reference Oscillator Input Operating Frequency         |                |                                                  | 2     |       | 50              | MHz             |
| V <sub>OSC</sub>                      | Oscillator Input Sensitivity                           |                | OSC <sub>in</sub>                                | 0.5   |       | V <sub>CC</sub> | V <sub>PP</sub> |
| I <sub>IH</sub>                       | OSC <sub>in</sub> Input Current                        |                | V <sub>IH</sub> = V <sub>CC</sub> = 5.5V         |       |       | 100             | μA              |
| I <sub>IL</sub>                       | OSC <sub>in</sub> Input Current                        |                | V <sub>IL</sub> = 0, V <sub>CC</sub> = 5.5V      | −100  |       |                 | μA              |
| CHARGE PUMP                           |                                                        |                |                                                  | Value |       |                 | Unit            |
| Symbol                                | Parameter                                              |                | Conditions                                       | Min   | Typ   | Max             |                 |
| ICP <sub>o-source</sub>               | Main and Auxiliary Charge Pump Output Current (Note 5) |                | VCP <sub>o</sub> = Vp/2, ICP <sub>o_4X</sub> = 0 |       | - 1.0 |                 | mA              |
| ICP <sub>o-sink</sub>                 |                                                        |                | VCP <sub>o</sub> = Vp/2, ICP <sub>o_4X</sub> = 0 |       | 1.0   |                 | mA              |
| ICP <sub>o-source</sub>               |                                                        |                | VCP <sub>o</sub> = Vp/2, ICP <sub>o_4X</sub> = 1 |       | - 4.0 |                 | mA              |
| ICP <sub>o-sink</sub>                 |                                                        |                | VCP <sub>o</sub> = Vp/2, ICP <sub>o_4X</sub> = 1 |       | 4.0   |                 | mA              |

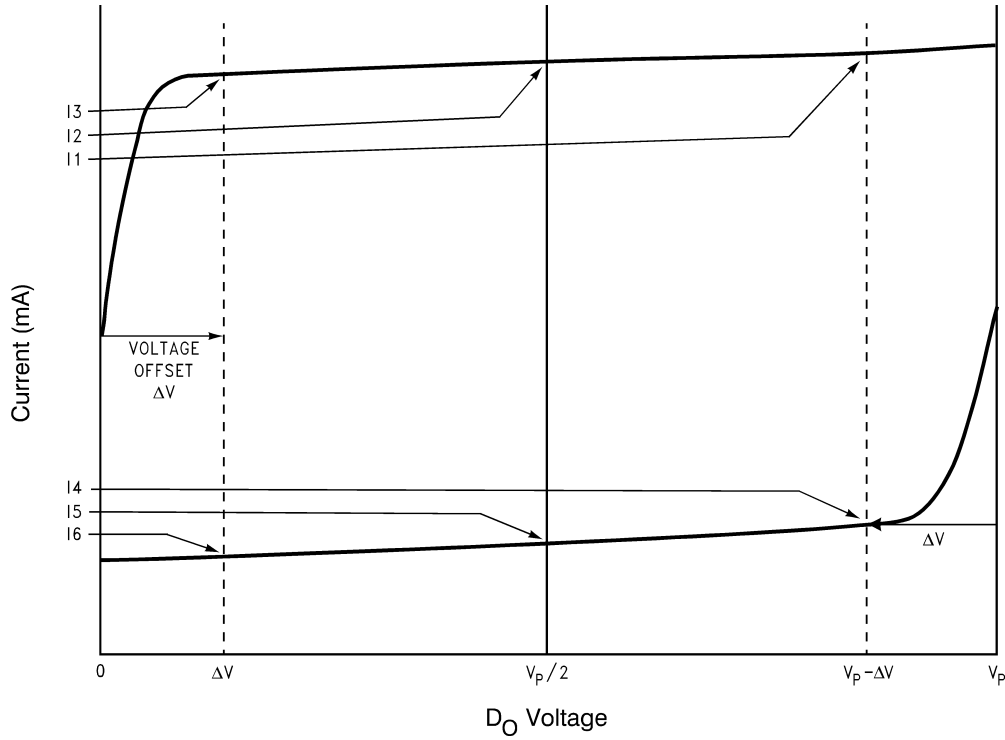
# Electrical Characteristics ( $V_{CC} = V_p = V_{\mu c} = 3.0V$ ; $-40^{\circ}C < T_A < 85^{\circ}C$ except as specified). (Continued)

| CHARGE PUMP                                         |                                 |                                                                         | Value           |     |                 | Unit |
|-----------------------------------------------------|---------------------------------|-------------------------------------------------------------------------|-----------------|-----|-----------------|------|
| Symbol                                              | Parameter                       | Conditions                                                              | Min             | Typ | Max             |      |
| ICP <sub>o-TRI</sub>                                | Charge Pump TRI-STATE® Current  | $0.5 \leq VCP_o \leq V_p - 0.5$ ,<br>$-40^{\circ}C < T_A < 85^{\circ}C$ | -2.5            | 0.1 | 2.5             | nA   |
| ICP <sub>o-sink</sub> vs<br>ICP <sub>o-source</sub> | CP Sink vs Source Mismatch      | $VCP_o = V_p/2$ , $T_A = 25^{\circ}C$                                   |                 | 3   | 10              | %    |
| ICP <sub>o</sub> vs<br>VCP <sub>o</sub>             | CP Current vs Voltage           | $0.5 \leq VCP_o \leq V_p - 0.5$ , $T_A = 25^{\circ}C$                   |                 | 8   | 15              | %    |
| ICP <sub>o</sub> vs T <sub>A</sub>                  | CP Current vs Temperature       | $VCP_o = V_p/2$ , $-40^{\circ}C < T_A < 85^{\circ}C$                    |                 | 8   |                 | %    |
| DIGITAL INTERFACE (DATA, CLOCK, LE)                 |                                 |                                                                         | Value           |     |                 | Unit |
| Symbol                                              | Parameter                       | Conditions                                                              | Min             | Typ | Max             |      |
| V <sub>IH</sub>                                     | High-Level Input Voltage        | $V_{\mu c} = 1.72V$ to $5.5V$                                           | $0.8 V_{\mu c}$ |     |                 | V    |
| V <sub>IL</sub>                                     | Low-Level Input Voltage         | $V_{\mu c} = 1.72V$ to $5.5V$                                           |                 |     | $0.2 V_{\mu c}$ | V    |
| I <sub>IH</sub>                                     | High-Level Input Current        | $V_{IH} = V_{\mu c} = 5.5V$                                             | -1.0            |     | 1.0             | μA   |
| I <sub>IL</sub>                                     | Low-Level Input Current         | $V_{IL} = 0$ , $V_{\mu c} = 5.5V$                                       | -1.0            |     | 1.0             | μA   |
| V <sub>OL</sub>                                     | Low-Level Output Current        | $I_{OL} = 1.0$ mA, $V_{EXT} = 1.8V$ (Note 6)                            |                 | 0.1 | 0.4             | V    |
| MICROWIRE TIMING                                    |                                 |                                                                         | Value           |     |                 | Unit |
| Symbol                                              | Parameter                       | Conditions                                                              | Min             | Typ | Max             |      |
| t <sub>CS</sub>                                     | Data to Clock Setup Time        | See Data Input Timing                                                   | 50              |     |                 | ns   |
| t <sub>CH</sub>                                     | Data to Clock Hold Time         | See Data Input Timing                                                   | 20              |     |                 | ns   |
| t <sub>CWH</sub>                                    | Clock Pulse Width High          | See Data Input Timing                                                   | 50              |     |                 | ns   |
| t <sub>CWL</sub>                                    | Clock Pulse Width Low           | See Data Input Timing                                                   | 50              |     |                 | ns   |
| t <sub>ES</sub>                                     | Clock to Load Enable Setup Time | See Data Input Timing                                                   | 50              |     |                 | ns   |
| t <sub>EW</sub>                                     | Load Enable Pulse Width         | See Data Input Timing                                                   | 50              |     |                 | ns   |

**Note 5:** Main and Auxiliary Charge Pump magnitude are controlled by Main\_ICP<sub>o-4X</sub> and Aux\_ICP<sub>o-4X</sub> bits respectively.

**Note 6:** Lock Detect open drain output only pulled up to V<sub>EXT</sub>. Typically V<sub>EXT</sub> = V<sub>CC</sub>.

## Charge Pump Current Specification Definitions



DS101026-19

I1 = CP sink current at  $V_{DO} = V_P - \Delta V$

I2 = CP sink current at  $V_{DO} = V_P/2$

I3 = CP sink current at  $V_{DO} = \Delta V$

I4 = CP source current at  $V_{DO} = V_P - \Delta V$

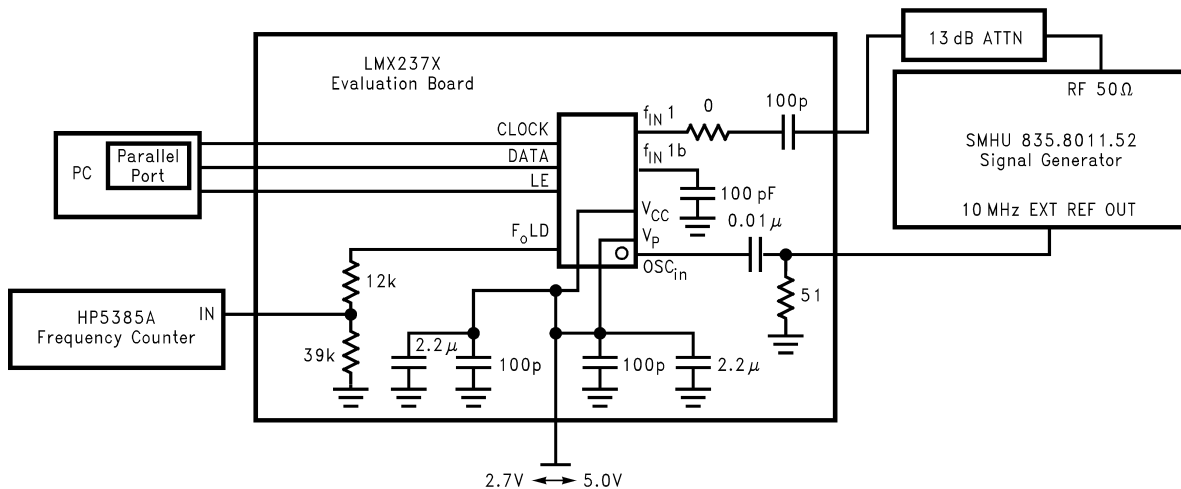
I5 = CP source current at  $V_{DO} = V_P/2$

I6 = CP source current at  $V_{DO} = \Delta V$

$\Delta V$  = 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.

1.  $I_{DO}$  vs  $V_{DO}$  = Charge Pump Output Current magnitude variation vs Voltage =  $\frac{1}{2} \cdot \frac{|I1| - |I3|}{|I1| + |I3|} \cdot 100\%$  and  $\frac{1}{2} \cdot \frac{|I4| - |I6|}{|I4| + |I6|} \cdot 100\%$
2.  $I_{DO-sink}$  vs  $I_{DO-source}$  = Charge Pump Output Current Sink vs Source Mismatch =  $\frac{|I2| - |I5|}{|I2| + |I5|} \cdot 100\%$
3.  $I_{DO}$  vs  $T_A$  = Charge Pump Output Current magnitude variation vs Temperature =  $\frac{|I2 @ temp| - |I2 @ 25^\circ C|}{|I2 @ 25^\circ C|} \cdot 100\%$  and  $\frac{|I5 @ temp| - |I5 @ 25^\circ C|}{|I5 @ 25^\circ C|} \cdot 100\%$

## RF Sensitivity Test Block Diagram



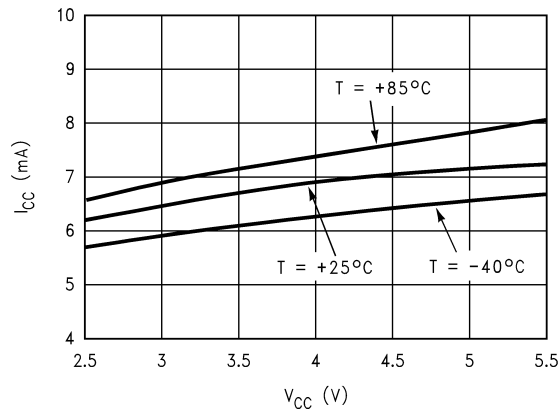
DS101026-20

Note: N = 10,000 R = 50 P = 64

Note: Sensitivity limit is reached when the error of the divided RF output, F<sub>o</sub>LD, is  $\geq 1$  Hz.

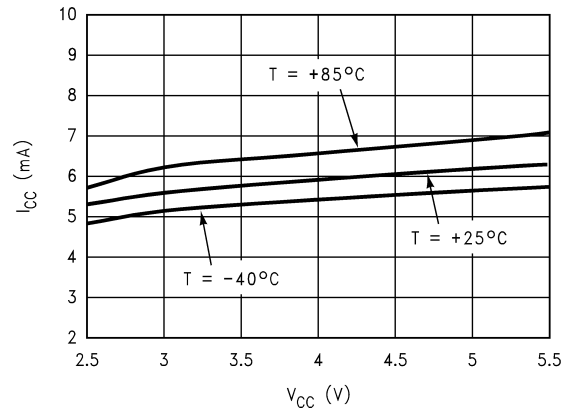
## Typical Performance Characteristics

**$I_{CC}$  vs  $V_{CC}$**   
**LMX2370**



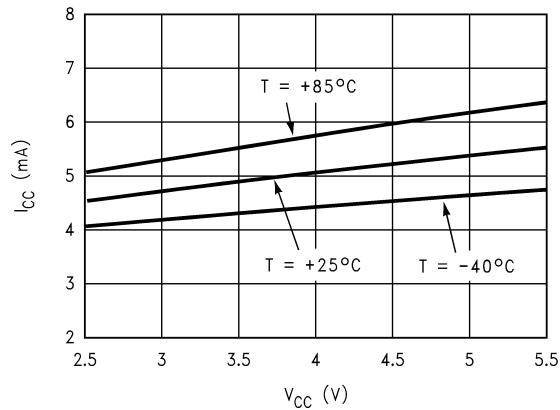
DS101026-21

**$I_{CC}$  vs  $V_{CC}$**   
**LMX2371**



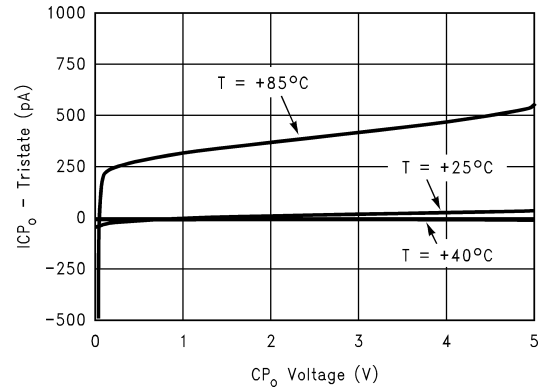
DS101026-22

**$I_{CC}$  vs  $V_{CC}$**   
**LMX2372**



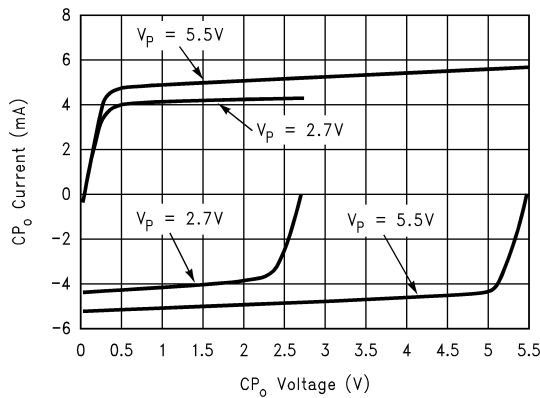
DS101026-23

**$ICP_O$  TRI-STATE**  
**vs  $CP_O$  Voltage**



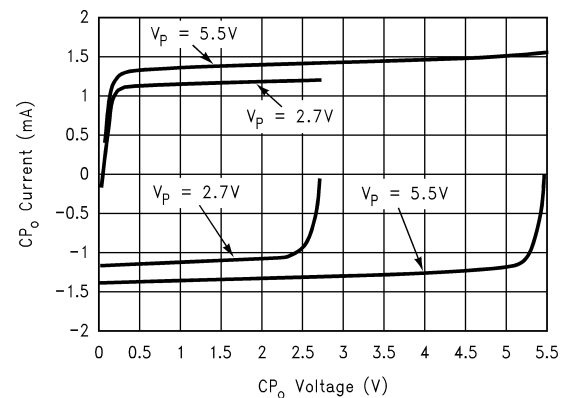
DS101026-24

**Charge Pump Current vs  $CP_O$  Voltage**  
 **$ICP_O = \text{HIGH}$**



DS101026-25

**Charge Pump Current vs  $CP_O$  Voltage**  
 **$ICP_O = \text{LOW}$**

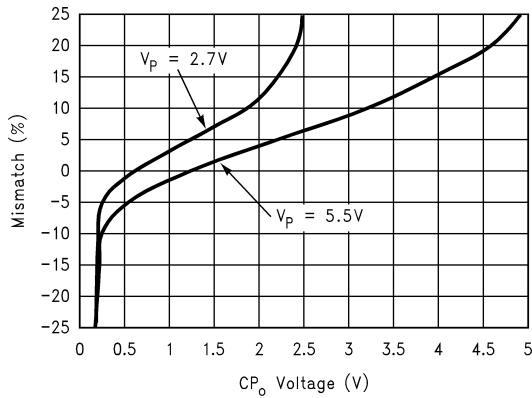


DS101026-26

## Typical Performance Characteristics (Continued)

### Sink vs Source 1x-Mode Mismatch

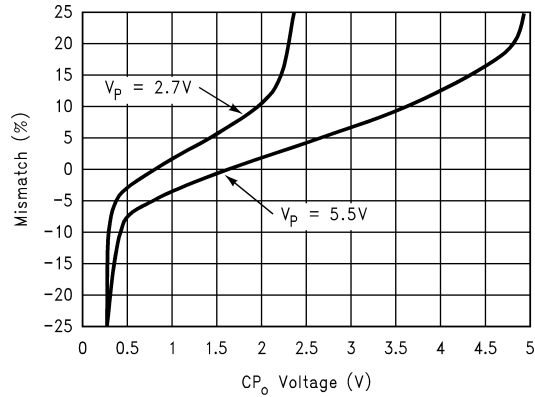
(See Note 2 under Charge Pump Current Specification Definitions)



DS101026-27

### Sink vs Source 4x-Mode Mismatch

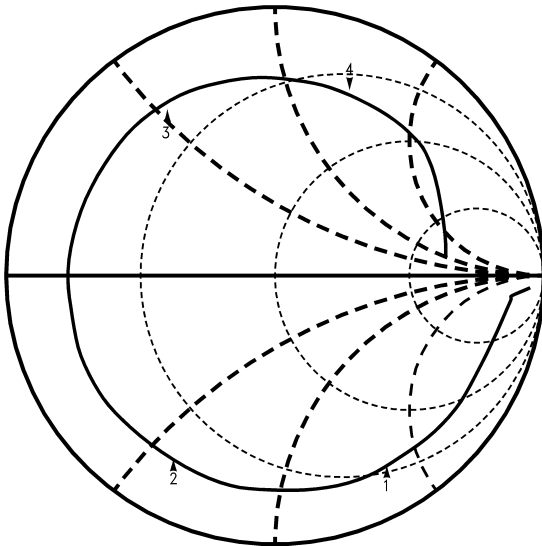
(See Note 2 under Charge Pump Current Specification Definitions)



DS101026-28

### RF Input Impedance, $T = 25^{\circ}\text{C}$

$V_{CC} = 2.7\text{V to } 5.5\text{V}$ ,  $f_{IN1} = 30\text{ kHz to } 3\text{ GHz}$

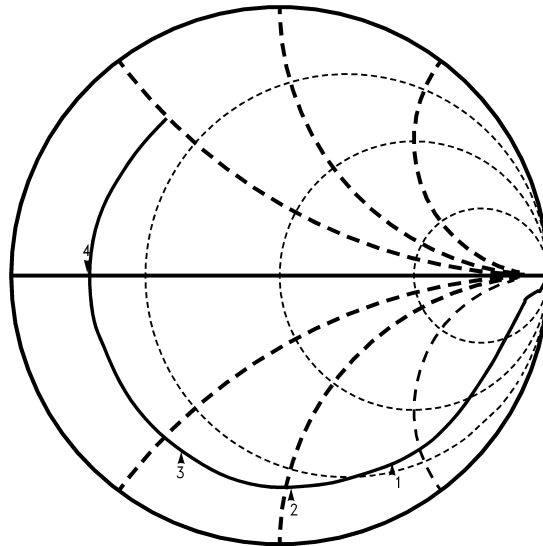


DS101026-29

Marker 1 = 500 MHz, Real = 21.602, Imag. = -84.160  
 Marker 2 = 1 GHz, Real = 9.2314, Imag. = -28.793  
 Marker 3 = 2 GHz, Real = 9.9365, Imag. = 27.582  
 Marker 4 = 2.5 GHz, Real = 25.867, Imag. = 71.137

### AUX Input Impedance, $T = 25^{\circ}\text{C}$

$V_{CC} = 2.7\text{V to } 5.5\text{V}$ ,  $f_{IN2} = 10\text{ MHz to } 1000\text{ MHz}$

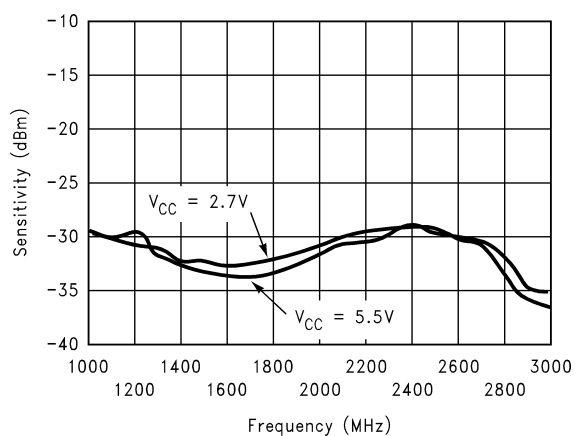


DS101026-30

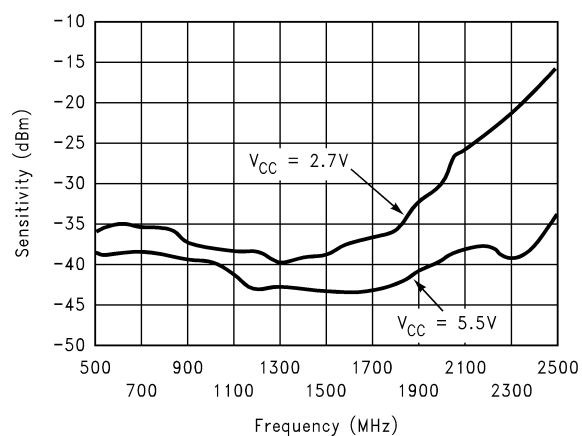
Marker 1 = 500 MHz, Real = 21.836, Imag. = -85.836  
 Marker 2 = 750 MHz, Real = 12.824, Imag. = -50.973  
 Marker 3 = 1 GHz, Real = 9.6270, Imag. = -29.989

## Typical Performance Characteristics (Continued)

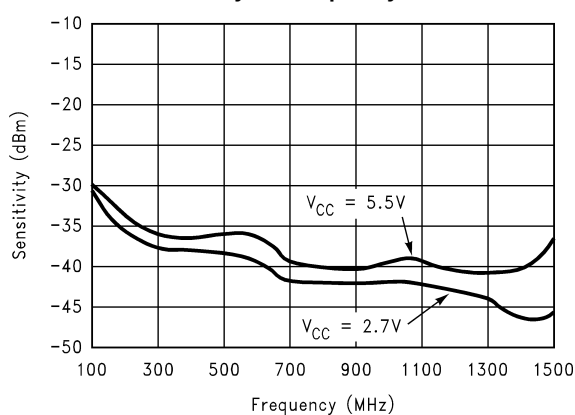
LMX2370 RF Sensitivity vs Frequency



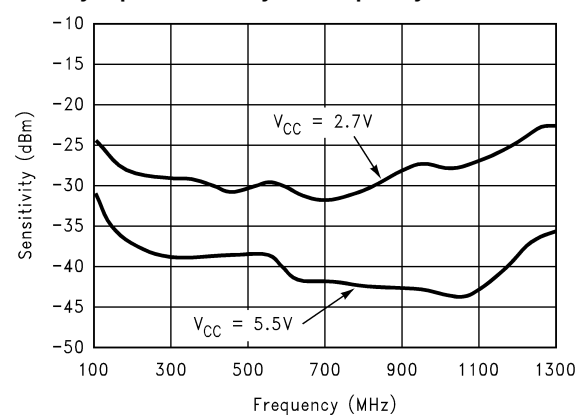
LMX2371 RF Input Sensitivity vs Frequency



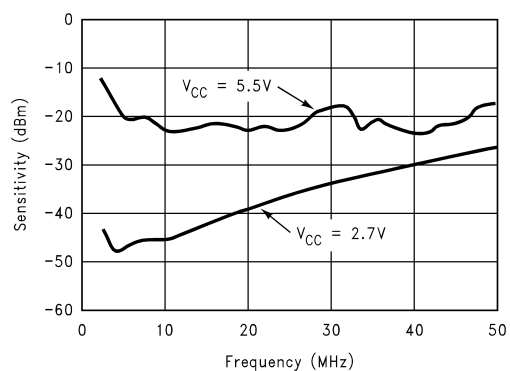
LMX2372 RF Sensitivity vs Frequency



Auxiliary Input Sensitivity vs Frequency



Oscillator Input Sensitivity vs Frequency



## 1.0 Functional Description

The basic phase-lock-loop (PLL) configuration consists of a high-stability crystal reference oscillator, a frequency synthesizer such as the National Semiconductor LMX2370/2371/2372, a voltage controlled oscillator (VCO), and a passive loop filter. The frequency synthesizer includes a phase detector, a current mode charge pump, as well as programmable reference [R] and feedback [N] frequency dividers. The VCO frequency is established by dividing the crystal reference signal down via the R-counter to obtain a comparison reference frequency. This reference signal ( $f_R$ ) is then presented to the input of a phase/frequency detector and compared with the feedback signal ( $f_N$ ), which is obtained by dividing the VCO frequency down by way of the N-counter. The phase/frequency detector's current source output pumps charge into the loop filter, which then integrates into the VCO's control voltage. The function of the phase/frequency comparator is to adjust the control voltage presented to the VCO until the feedback signal frequency and phase match that of the reference signal. When this "Phase-Locked" condition exists, the VCO frequency will be N times that of the comparison frequency, where N is the integer divide ratio.

### 1.1 REFERENCE OSCILLATOR INPUT

The reference oscillator frequency for the Main and Auxiliary PLLs is provided from the external reference through the  $OSC_{in}$  pin.  $OSC_{in}$  can operate up to 50 MHz with input sensitivity of 0.5  $V_{PP}$ . The  $OSC_{in}$  pin drives both the Main R-counter and the Auxiliary R-counter. The input has a  $V_{CC}/2$  input threshold that can be driven from an external CMOS or TTL logic gate. Typically, the  $OSC_{in}$  is connected to the output of a crystal oscillator.

### 1.2 REFERENCE DIVIDERS (R-COUNTERS)

The Main and Auxiliary R-counters are both clocked through the oscillator block in common. The maximum frequency is 50 MHz. Both R-counters are CMOS design and 15-bit in length with programmable divider ratio from 2 to 32,767.

### 1.3 PRESCALERS

The complimentary  $f_{IN}$  and  $f_{INB}$  inputs drive a differential-pair amplifier which feeds to the respective prescaler. The Main PLL complementary  $f_{IN1}$  and  $f_{IN1b}$  inputs can be driven differentially, or the negative input can be AC coupled to ground through an external capacitor for single ended configuration. The Auxiliary PLL has the complimentary input AC coupled to ground through an internal 10 pF capacitor. The Auxiliary PLL complimentary input is not brought out to a pin, and is intended for single ended configuration only. The LMX237x has a dual modulus prescaler with 2 selectable modulo. For PLL's rated at 2.5 GHz or 2.0 GHz a 32/33 or 16/17 prescaler is available. For PLL's rated at 1.2 GHz a 16/17 or 8/9 can be chosen. Both Main and Auxiliary prescalers' outputs drive the subsequent CMOS flip-flop chain comprising the programmable N feedback counters. The proper prescaler value must be chosen to in order not to exceed the maximum CMOS frequency. For  $f_{IN} > 1.2$  GHz, the 32/33 prescaler must be selected, similarly for  $f_{IN} > 550$  MHz, the prescaler value must be at least 16/17, and for  $f_{IN} < 550$  MHz, an 8/9 prescaler value is allowable.

### 1.4 FEEDBACK DIVIDERS (N-COUNTERS)

The Main and Auxiliary N-counters are clocked by the output of Main and Aux prescalers respectively. The N-counter is composed of a 13-bit integer divider and a 5-bit swallow counter. Selecting a 32/33 prescaler provides a minimum continuous divider range from 992 to 262,143 while selecting a 16/17 or 8/9 prescaler value allows for continuous divider values between and 240 to 131,087 and 56 to 65,559 respectively.

### 1.5 PHASE/FREQUENCY DETECTORS

The phase/frequency detectors are driven from their respective N- and R-counter outputs. The maximum frequency at the phase detector inputs is 10 MHz unless limited by the minimum continuous divide ratio of the dual-modulus prescaler. The phase detector output controls the charge pump. The polarity of the pump-up or pump-down control is programmed using **Main\_PD\_POL** or **Aux\_PD\_POL**, depending on whether Main or Auxiliary VCO characteristics is positive or negative. The phase detector also receives a feedback signal from the charge pump in order to eliminate dead zone.

### 1.6 CHARGE PUMPS

The phase detector's current source output pumps charge into an external loop filter, which then integrates into the VCO's control voltage. The charge pump steers the charge pump output  $CP_O$  to  $V_P$  (pump-up) or Ground (pump-down). When locked,  $CP_O$  is primarily in a TRI-STATE mode with small corrections. The charge pump output current magnitude can be selected as 1.0 mA or 4.0 mA by programming the **Main\_ICP\_O\_4X** or **Aux\_ICP\_O\_4X** bits.

### 1.7 MICROWIRE SERIAL INTERFACE

The programmable register set is accessed through the Microwire serial interface. The interface is comprised of three signal pins: clock, data and load enable (LE). The supply for the MICROWIRE circuitry is separate from the rest of the IC to allow for controller voltages down to 1.8V. Serial data is clocked into the 22-bit shift register upon the rising edge of clock. The MSB bit of data shifts first. The last two bits decode the internal register address. On the rising edge of LE, data stored in the shift register is loaded into one of the four latches according to the address bits. The synthesizer can be programmed even in power down state. A complete programming description is followed in Section 2.0.

### 1.8 MULTIFUNCTION OUTPUTS

The LMX2370/LMX2371/LMX2372 FoLD output pin can be configured as the FastLock output or CMOS programmed output, analog lock detects as well as showing the internal block status such as the counter outputs.

## 1.0 Functional Description (Continued)

### 1.8.1 Lock Detect Output

An analog lock detect status generated from the phase detector is available on the Fo/LD output pin, if selected. The lock detect output goes high when the charge pump is inactive. It goes low when the charge pump is active during a comparison cycle. The lock detect signal output is an open drain configuration. When a PLL is in power down mode, the respective lock detect output is always high.

### 1.8.2 FastLock Outputs

When configured as FastLock mode, the current can be increased 4x while maintaining loop stability by synchronously switching a parallel loop filter resistor to ground, resulting in a ~2x change in loop bandwidth. The zero gain crossover point of the open loop gain, or the loop bandwidth is effectively shifted up in frequency by a factor of  $\sqrt{4} = 2$  during FastLock mode. For  $\omega' = 2\omega$ , the phase margin during FastLock will also remain constant. The charge pump current is programmed via MICROWIRE interface. When the charge pump circuit receives an input to deliver 4 times the normal current per unit phase error, an open drain NMOS on chip device (FoLD) switches in a second 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 resistor equal to the primary resistor value is wired in appropriately, the loop will lock faster without any additional stability considerations to account for.

## 1.9 POWER CONTROL

Each PLL is individually power controlled by device power-down (**PWDN**) bits. The **Main\_PWDN** and **Aux\_PWDN** bits determine the state of power control. Activation of any PLL power-down condition results in the disabling of the respective N-counter and de-biasing of its respective  $f_{IN}$  input (to a high impedance state). The R-counter functionality also becomes disabled under this condition.

The reference oscillator input block is powered down when both Main\_PWDN and Aux\_PWDN bits are asserted. The OSC<sub>in</sub> pin reverts to a high impedance state when this condition exists. Power down forces the respective charge pump and phase comparator logic to a TRI-STATE condition. During the power down condition, both N- and R-counters are held at reset. Upon powering up, the N-counter resumes counting in "close" alignment with the R-counter. The maximum error is at most one prescaler cycle. The MICROWIRE interface remains active and it is capable of loading and latching in data during all of the power down modes.

## 2.0 Programming Description

### 2.1 MICROWIRE INTERFACE

The LMX237x register set can be accessed through the MICROWIRE interface. A 22-bit shift register is used as a temporary register to indirectly program the on-chip registers. The shift register consists of a 20-bit DATA[19:0] field and a 2-bit ADDRESS[1:0] field as shown below. The address field is used to decode the internal register address. Data is clocked into the shift register in the direction from MSB to LSB, when the CLOCK signal goes high. On the rising edge of Load Enable (LE) signal, data stored in the shift register is loaded into the addressed latch.

|            |  |  |  |  |  |  |  |   |   |              |   |
|------------|--|--|--|--|--|--|--|---|---|--------------|---|
| MSB        |  |  |  |  |  |  |  |   |   | LSB          |   |
| DATA[19:0] |  |  |  |  |  |  |  |   |   | ADDRESS[1:0] |   |
| 21         |  |  |  |  |  |  |  | 2 | 1 |              | 0 |

#### 2.1.1 Registers' Address Map

When Load Enable (LE) is transitioned high, data is transferred from the 22-bit shift register into the appropriate latch depending on the state of the ADDRESS[1:0] bits. A multiplexing circuit decodes these address bits and writes the data field to the corresponding internal register.

| ADDRESS[1:0]<br>FIELD |   | REGISTER<br>ADDRESSED |
|-----------------------|---|-----------------------|
| 0                     | 0 | Aux_R Register        |
| 0                     | 1 | Aux_N Register        |
| 1                     | 0 | Main_R Register       |
| 1                     | 1 | Main_N Register       |

## 2.0 Programming Description (Continued)

2.1.2 Registers' Truth Table

| Most Significant Bit |                   |          |                  |             |             |                   |          |          |          | SHIFT REGISTER BIT LOCATION |         |         |         |         |         |         |         |                 |         | Least Significant Bit |                  |  |   |  |  |   |
|----------------------|-------------------|----------|------------------|-------------|-------------|-------------------|----------|----------|----------|-----------------------------|---------|---------|---------|---------|---------|---------|---------|-----------------|---------|-----------------------|------------------|--|---|--|--|---|
| 21                   | 20                | 19       | 18               | 17          | 16          | 15                | 14       | 13       | 12       | 11                          | 10      | 9       | 8       | 7       | 6       | 5       | 4       | 3               | 2       | 1                     | 0                |  |   |  |  |   |
| Data Field           |                   |          |                  |             |             |                   |          |          |          |                             |         |         |         |         |         |         |         |                 |         |                       |                  |  |   |  |  |   |
| Aux_R                | FoLD 1            | FoLD 0   | Aux_CP0_TRI      | Aux_CP0_4X  | Aux_PD_POL  | Aux_R_CNTR[14:0]  |          |          |          |                             |         |         |         |         |         |         |         |                 |         |                       | Address Field    |  |   |  |  |   |
|                      | Aux_R19           | Aux_R18  | Aux_R17          | Aux_R16     | Aux_R15     | Aux_R14           | Aux_R13  | Aux_R12  | Aux_R11  | Aux_R10                     | Aux_R9  | Aux_R8  | Aux_R7  | Aux_R6  | Aux_R5  | Aux_R4  | Aux_R3  | Aux_R2          | Aux_R1  | Aux_R0                | 0                |  |   |  |  |   |
|                      | Aux_PWDN          | P_Aux    | Aux_B_CNTR[12:0] |             |             |                   |          |          |          |                             |         |         |         |         |         |         |         | Aux_A_CNTR[4:0] |         |                       |                  |  | 0 |  |  |   |
| Aux_N                | Aux_N19           | Aux_N18  | Aux_N17          | Aux_N16     | Aux_N15     | Aux_N14           | Aux_N13  | Aux_N12  | Aux_N11  | Aux_N10                     | Aux_N9  | Aux_N8  | Aux_N7  | Aux_N6  | Aux_N5  | Aux_N4  | Aux_N3  | Aux_N2          | Aux_N1  | Aux_N0                | 0                |  |   |  |  |   |
|                      | FoLD 3            | FoLD 2   | Main_CP0_TRI     | Main_CP0_4X | Main_PD_POL | Main_R_CNTR[14:0] |          |          |          |                             |         |         |         |         |         |         |         |                 |         |                       | Address Field    |  |   |  |  |   |
|                      | Main_R19          | Main_R18 | Main_R17         | Main_R16    | Main_R15    | Main_R14          | Main_R13 | Main_R12 | Main_R11 | Main_R10                    | Main_R9 | Main_R8 | Main_R7 | Main_R6 | Main_R5 | Main_R4 | Main_R3 | Main_R2         | Main_R1 | Main_R0               | 1                |  |   |  |  |   |
| Main_N               | Main_PWDN         | P_Main   | Main_N17         | Main_N16    | Main_N15    | Main_N14          | Main_N13 | Main_N12 | Main_N11 | Main_N10                    | Main_N9 | Main_N8 | Main_N7 | Main_N6 | Main_N5 | Main_N4 | Main_N3 | Main_N2         | Main_N1 | Main_N0               | 1                |  |   |  |  |   |
|                      | Main_B_CNTR[12:0] |          |                  |             |             |                   |          |          |          |                             |         |         |         |         |         |         |         |                 |         |                       | Main_A_CNTR[4:0] |  |   |  |  | 1 |
|                      |                   |          |                  |             |             |                   |          |          |          |                             |         |         |         |         |         |         |         |                 |         |                       | 1                |  |   |  |  |   |

## 2.0 Programming Description (Continued)

### 2.2 PROGRAMMABLE REFERENCE DIVIDERS (Main and Aux R Counters)

#### 2.2.1 Aux\_R Register

If the ADDRESS[1:0] field is set to 0 0, data is transferred from the 22-bit shift register into the Aux\_R register when Load Enable (LE) signal goes high. The Aux\_R register sets the Aux PLL's 15-bit R-counter divide ratio and various programmable modes. The divide ratio is put into the Aux\_R\_CNTR[14:0] field. The divider ratio must be  $\geq 2$ . For the description of bits Aux\_R15–Aux\_R19 see Section 2.4.

|       | SHIFT REGISTER BIT LOCATION |         |              |             |            |                  |         |         |         |         |        |        |        |        |        |        |        |        |        |        |               | Least Significant Bit |   |
|-------|-----------------------------|---------|--------------|-------------|------------|------------------|---------|---------|---------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------------|-----------------------|---|
|       | 21                          | 20      | 19           | 18          | 17         | 16               | 15      | 14      | 13      | 12      | 11     | 10     | 9      | 8      | 7      | 6      | 5      | 4      | 3      | 2      | 1             | 0                     |   |
|       | Data Field                  |         |              |             |            |                  |         |         |         |         |        |        |        |        |        |        |        |        |        |        | Address Field |                       |   |
| Aux_R | FoLD 1                      | FoLD 0  | Aux_CP_o_TRI | Aux_CP_o_4X | Aux_PD_POL | Aux_R_CNTR[14:0] |         |         |         |         |        |        |        |        |        |        |        |        |        |        | 0             |                       | 0 |
|       | Aux_R19                     | Aux_R18 | Aux_R17      | Aux_R16     | Aux_R15    | Aux_R14          | Aux_R13 | Aux_R12 | Aux_R11 | Aux_R10 | Aux_R9 | Aux_R8 | Aux_R7 | Aux_R6 | Aux_R5 | Aux_R4 | Aux_R3 | Aux_R2 | Aux_R1 | Aux_R0 |               |                       |   |

#### 2.2.2 Main\_R Register

If the ADDRESS[1:0] field is set to 1 0, data is transferred from the 22-bit shift register into the Main\_R register which sets the Main PLL's 15-bit R-counter divide ratio when Load Enable (LE) signal goes high. The divide ratio is put into the Main\_R\_CNTR[14:0] field. The divider ratio must be  $\geq 2$ . For the description of bits Main\_R15–Main\_R19 see Section 2.4.

|        | SHIFT REGISTER BIT LOCATION |          |               |              |             |                   |          |          |          |          |         |         |         |         |         |         |         |         |         |         |               | Least Significant Bit |  |
|--------|-----------------------------|----------|---------------|--------------|-------------|-------------------|----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------------|-----------------------|--|
|        | 21                          | 20       | 19            | 18           | 17          | 16                | 15       | 14       | 13       | 12       | 11      | 10      | 9       | 8       | 7       | 6       | 5       | 4       | 3       | 2       | 1             | 0                     |  |
|        | Data Field                  |          |               |              |             |                   |          |          |          |          |         |         |         |         |         |         |         |         |         |         | Address Field |                       |  |
| Main_R | FoLD 3                      | FoLD 2   | Main_CP_o_TRI | Main_CP_o_4X | Main_PD_POL | Main_R_CNTR[14:0] |          |          |          |          |         |         |         |         |         |         |         |         |         |         | 1             | 0                     |  |
|        | Main_R19                    | Main_R18 | Main_R17      | Main_R16     | Main_R15    | Main_R14          | Main_R13 | Main_R12 | Main_R11 | Main_R10 | Main_R9 | Main_R8 | Main_R7 | Main_R6 | Main_R5 | Main_R4 | Main_R3 | Main_R2 | Main_R1 | Main_R0 |               |                       |  |

#### 2.2.3 Reference Divide Ratio (Main and Auxiliary R-Counters)

If the ADDRESS[1:0] field is set to 0 0 or 1 0 (00 for Aux and 10 for Main) data is transferred MSB first from the 22-bit shift register into a latch which sets the respective 15-bit R-counter. Serial data format is shown below.

|              | Main_R_CNTR[14:0] or Aux_R_CNTR[14:0] |     |     |     |     |    |    |    |    |    |    |    |    |    |    |
|--------------|---------------------------------------|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| Divide Ratio | R14                                   | R13 | R12 | R11 | R10 | R9 | R8 | R7 | R6 | R5 | R4 | R3 | R2 | R1 | R0 |
| 2            | 0                                     | 0   | 0   | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |
| 3            | 0                                     | 0   | 0   | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  |
| •            | •                                     | •   | •   | •   | •   | •  | •  | •  | •  | •  | •  | •  | •  | •  | •  |
| 32,767       | 1                                     | 1   | 1   | 1   | 1   | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |

**Note:** R-counter divide ratio must be from 2 to 32,767.

### 2.3 PROGRAMMABLE FEEDBACK [N] DIVIDERS

#### 2.3.1 Aux\_N Register

If the ADDRESS[1:0] field is set to 0 1, data is transferred from the 22-bit shift register into the Aux\_N register which sets the Auxiliary PLL's 18-bit N-counter, prescaler value and power-down bit. The 18-bit N-counter consists of a 5-bit swallow counter, Aux\_A\_CNTR[4:0], and a 13-bit programmable counter, Aux\_B\_CNTR[12:0]. Serial data format is shown below.

## 2.0 Programming Description (Continued)

|       | SHIFT REGISTER BIT LOCATION |         |                  |         |         |         |         |         |         |         |        |        |        |        |                 |        |        |        |        |        |               | Least Significant Bit |  |
|-------|-----------------------------|---------|------------------|---------|---------|---------|---------|---------|---------|---------|--------|--------|--------|--------|-----------------|--------|--------|--------|--------|--------|---------------|-----------------------|--|
|       | 21                          | 20      | 19               | 18      | 17      | 16      | 15      | 14      | 13      | 12      | 11     | 10     | 9      | 8      | 7               | 6      | 5      | 4      | 3      | 2      | 1             | 0                     |  |
|       | Data Field                  |         |                  |         |         |         |         |         |         |         |        |        |        |        |                 |        |        |        |        |        | Address Field |                       |  |
| Aux_N | Aux_PWDN                    | P_Aux   | Aux_B_CNTR[12:0] |         |         |         |         |         |         |         |        |        |        |        | Aux_A_CNTR[4:0] |        |        |        |        |        | 0             | 1                     |  |
|       | Aux_N19                     | Aux_N18 | Aux_N17          | Aux_N16 | Aux_N15 | Aux_N14 | Aux_N13 | Aux_N12 | Aux_N11 | Aux_N10 | Aux_N9 | Aux_N8 | Aux_N7 | Aux_N6 | Aux_N5          | Aux_N4 | Aux_N3 | Aux_N2 | Aux_N1 | Aux_N0 |               |                       |  |

### 2.3.2 Main\_N Register

If the ADDRESS[1:0] field is set to 1 1, data is transferred from the 22-bit shift register into the Main\_N register which sets the Main PLL's 18-bit N-counter, prescaler value and power-down bit. The 18-bit N-counter consists of a 5-bit swallow counter, Main\_A\_CNTR[4:0], and a 13-bit programmable counter, Main\_B\_CNTR[12:0]. Serial data format is shown below.

|        | SHIFT REGISTER BIT LOCATION |          |                   |          |          |          |          |          |          |          |                       |         |         |         |                  |         |         |         |         |         |               |   |
|--------|-----------------------------|----------|-------------------|----------|----------|----------|----------|----------|----------|----------|-----------------------|---------|---------|---------|------------------|---------|---------|---------|---------|---------|---------------|---|
|        | Most Significant Bit        |          |                   |          |          |          |          |          |          |          | Least Significant Bit |         |         |         |                  |         |         |         |         |         |               |   |
|        | 21                          | 20       | 19                | 18       | 17       | 16       | 15       | 14       | 13       | 12       | 11                    | 10      | 9       | 8       | 7                | 6       | 5       | 4       | 3       | 2       | 1             | 0 |
|        | Data Field                  |          |                   |          |          |          |          |          |          |          |                       |         |         |         |                  |         |         |         |         |         | Address Field |   |
| Main_N | Main_PWDN                   | P_Main   | Main_B_CNTR[12:0] |          |          |          |          |          |          |          |                       |         |         |         | Main_A_CNTR[4:0] |         |         |         |         |         | 1             | 1 |
|        | Main_N19                    | Main_N18 | Main_N17          | Main_N16 | Main_N15 | Main_N14 | Main_N13 | Main_N12 | Main_N11 | Main_N10 | Main_N9               | Main_N8 | Main_N7 | Main_N6 | Main_N5          | Main_N4 | Main_N3 | Main_N2 | Main_N1 | Main_N0 |               |   |

### 2.3.3 Feedback Divide Ratio (Main B Counter, Auxiliary B Counter)

| Main_B_CNTR[12:0] or Aux_B_CNTR[12:0] |     |     |     |     |     |     |     |     |    |    |    |    |    |
|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|
| Divide Ratio                          | N17 | N16 | N15 | N14 | N13 | N12 | N11 | N10 | N9 | N8 | N7 | N6 | N5 |
| 3                                     | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0  | 0  | 0  | 1  | 1  |
| 4                                     | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0  | 0  | 1  | 0  | 1  |
| •                                     | •   | •   | •   | •   | •   | •   | •   | •   | •  | •  | •  | •  | •  |
| 8,191                                 | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1  | 1  | 1  | 1  | 1  |

**Note:** B-counter divide ratio must be  $\geq 3$ .

### 2.3.4 Swallow Counter Divide Ratio (Main A Counter, Auxiliary A Counter)

| Main_A_CNTR[4:0] or Aux_A_CNTR[4:0] |         |         |         |         |         |
|-------------------------------------|---------|---------|---------|---------|---------|
| Divide Ratio                        | Main_N4 | Main_N3 | Main_N2 | Main_N1 | Main_N0 |
| 0                                   | 0       | 0       | 0       | 0       | 0       |
| 1                                   | 0       | 0       | 0       | 0       | 1       |
| •                                   | •       | •       | •       | •       | •       |
| 31                                  | 1       | 1       | 1       | 1       | 1       |

**Notes:** A < P, B > A.

## 2.0 Programming Description (Continued)

### 2.3.5 PLL Prescaler Select (P\_Aux, P\_Main)

The LMX2370, LMX2371 and LMX2372 contain two dual modulus prescalers. A 32/33 or a 16/17 prescaler can be selected for the 2.5 GHz and 2.0 GHz RF synthesizers in the LMX2370 and LMX2371 respectively. The 16/17 prescaler is only rated for input frequencies below 1.2 GHz. A 16/17 or an 8/9 prescaler can be selected for the both 1.2 GHz synthesizers on the LMX2372 as well as the 1.2 GHz synthesizers on the LMX2370 and LMX2371. The 8/9 prescaler is only rated for input frequencies below 550 MHz.

| P_Main, (Main_N18) or<br>P_Aux (Aux_N18) | Prescaler Value |             |             |
|------------------------------------------|-----------------|-------------|-------------|
|                                          | 2.5 GHz PLL     | 2.0 GHz PLL | 1.2 GHz PLL |
| 0                                        | 16/17           | 16/17       | 8/9         |
| 1                                        | 32/33           | 32/33       | 16/17       |

| PLL Input Frequency               | Allowable Prescaler Values |                |              |
|-----------------------------------|----------------------------|----------------|--------------|
|                                   | 2.5 GHz PLL                | 2.0 GHz PLL    | 1.2 GHz PLL  |
| $f_{IN} > 1.2 \text{ GHz}$        | 32/33                      | 32/33          | NA           |
| $550 < f_{IN} < 1200 \text{ MHz}$ | 16/17 or 32/33             | 16/17 or 32/33 | 16/17        |
| $f_{IN} < 550 \text{ MHz}$        | 16/17 or 32/33             | 16/17 or 32/33 | 8/9 or 16/17 |

#### 2.3.5.1 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 13-bit programmable counter (3 to 8191)

A: Preset divide ratio of binary 5-bit swallow counter

$$0 \leq A \leq 31 \{P=32\}$$

$$0 \leq A \leq 15 \{P=16\}$$

$$0 \leq A \leq 7 \{P=8\}$$

$$A \leq B$$

$f_{OSC}$ : 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 (P = 8, 16, or 32)

### 2.3.6 PLL Power Down Control (Aux\_PWDN, Main\_PWDN)

The **Aux\_PWDN (Aux\_N19)** and **Main\_PWDN (Main\_N19)** bits are used to power down either the Main or Auxiliary PLL's charge pump portion, or the entire PLL block depending on the setting of the respective charge pump TRI-STATE bit (Aux\_CP\_o\_TRI or Main\_CP\_o\_TRI) in the R\_CNTR register. The power-down mechanism is described below. The R and N counters for each respective PLL are disabled and held at reset during the synchronous and asynchronous power down modes. This will allow a smooth acquisition of the Main RF signal when the oscillator input buffer is still active (Auxiliary loop powered up) and vice versa. Upon powering up, both R and N counters will start at the "zero" state, and the relationship between R and N will not be random.

#### Synchronous Power Down Mode

One of the PLL loops can be synchronously powered down by first setting the respective loop's TRI-STATE mode bit LOW (R17 = 0) and then asserting its power down mode bit (N19 = 1). The power down function is gated by the charge pump. Once the power down program bits Aux\_PWDN (Aux\_N19) and Main\_PWDN (Main\_N19) and TRI-STATE bits Aux\_CP\_o\_TRI (Aux\_R17) or Main\_CP\_o\_TRI (Main\_R17) are loaded, the part will go into power down mode upon the completion of a charge pump pulse event.

#### Asynchronous Power Down Mode

One of the PLL loops can be asynchronously powered down by first setting the respective loop's TRI-STATE mode bit HI (R17 = 1) and then asserting its power down mode bit (N19 = 1). The power down function is NOT gated by the charge pump. Once the power down program bits Aux\_PWDN (Aux\_N19) and Main\_PWDN (Main\_N19) and its respective TRI-STATE bit Aux\_CP\_o\_TRI (Aux\_R17) or Main\_CP\_o\_TRI (Main\_R17) are loaded, the part will go into power down mode immediately.

## 2.0 Programming Description (Continued)

### 2.3.7 Power Down Mode Table

| Main PLL     | Auxiliary PLL | Main Counters | Auxiliary Counters | OSC <sub>in</sub> Buffer |
|--------------|---------------|---------------|--------------------|--------------------------|
| Active       | Active        | ON            | ON                 | ON                       |
| Active       | Powered Down  | ON            | OFF                | ON                       |
| Powered Down | Active        | OFF           | ON                 | ON                       |
| Powered Down | Powered Down  | OFF           | OFF                | OFF                      |

### 2.4 PROGRAMMABLE MODES

Several modes of operation can be programmed with bits R15–R19 including the phase detector polarity, charge pump magnitude, charge pump TRI-STATE and the output of the Fo/LD pin. The programmable modes are shown in Table 1. Truth table for the programmable modes and Fo/LD output are shown in Table 2 and Table 3.

#### 2.4.1 Programmable Modes Table

| R19                           | R18    | R17                       | R16                      | R15                     | Address[1:0] |
|-------------------------------|--------|---------------------------|--------------------------|-------------------------|--------------|
| f <sub>OUT</sub> /Lock Detect |        | Charge Pump TRI-STATE     | Charge Pump Magnitude    | Phase Detector Polarity |              |
| FoLD 1                        | FoLD 0 | Aux_CP <sub>o</sub> _TRI  | Aux_CP <sub>o</sub> _4X  | Aux_PD_POL              | 0 0          |
| FoLD 3                        | FoLD 2 | Main_CP <sub>o</sub> _TRI | Main_CP <sub>o</sub> _4X | Main_PD_POL             | 1 0          |

#### 2.4.2 Mode Select Truth Table

|   | CP <sub>o</sub> _TRI (Note 7) | CP <sub>o</sub> _4X (Note 8) | PD_POL (Note 9) |
|---|-------------------------------|------------------------------|-----------------|
| 0 | Normal Operation              | 1X Current                   | LOW             |
| 1 | TRI-STATE                     | 4X Current                   | HIGH            |

**Note 7:** Both synchronous and asynchronous power down modes are available with the LMX237x family to be able to adapt to different types of applications. The MICROWIRE control register remains active and capable of loading and latching in data during all of the powerdown modes.

**Note 8:** ICP<sub>o</sub> (charge pump current magnitude) is dependent on V<sub>p</sub>. The ICP<sub>o</sub> LOW current state = 1/4 x ICP<sub>o</sub> HIGH current.

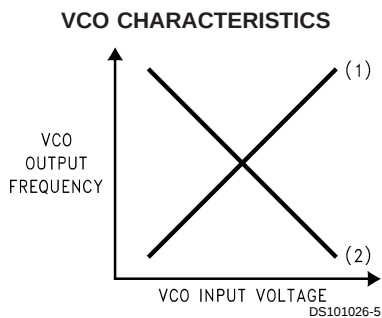
**Note 9:** See Section 2.4.3

#### 2.4.3 Phase Detector Polarity (Aux\_PD\_POL, Main\_PD\_POL)

Depending upon VCO characteristics, the Aux\_PD\_POL (Aux\_R15) and Main\_PD\_POL (Main\_R15) bits should be set accordingly:

When VCO characteristics are positive like (1), R15 should be set HIGH;

When VCO characteristics are negative like (2), R15 should be set LOW.



## 2.0 Programming Description (Continued)

### 2.4.4 The FoLD Output Truth Table

| Main R[18] | Aux R[18] | Main R[19] | Aux R[19] | Fo/LD Output State                                                   |
|------------|-----------|------------|-----------|----------------------------------------------------------------------|
| 0          | 0         | 0          | 0         | Disabled                                                             |
| 0          | 1         | 0          | 0         | Aux Lock Detect (Note 10)                                            |
| 1          | 0         | 0          | 0         | Main Lock Detect (Note 10)                                           |
| 1          | 1         | 0          | 0         | Main/Aux Lock Detect (Note 10)                                       |
| X          | 0         | 0          | 1         | Aux Reference Divider Output                                         |
| X          | 0         | 1          | 0         | Main Reference Divider Output                                        |
| X          | 1         | 0          | 1         | Aux Programmable Divider Output                                      |
| X          | 1         | 1          | 0         | Main Programmable Divider Output                                     |
| 0          | 0         | 1          | 1         | FastLock Output. Open Drain Output (Note 11)                         |
| 0          | 1         | 1          | 1         | Reset Aux R and N Counters and TRI-STATE Aux Charge Pump (Note 12)   |
| 1          | 0         | 1          | 1         | Reset Main R and N Counters and TRI-STATE Main Charge Pump (Note 12) |
| 1          | 1         | 1          | 1         | Reset All Four Counters and TRI-STATE both Charge Pumps (Note 12)    |

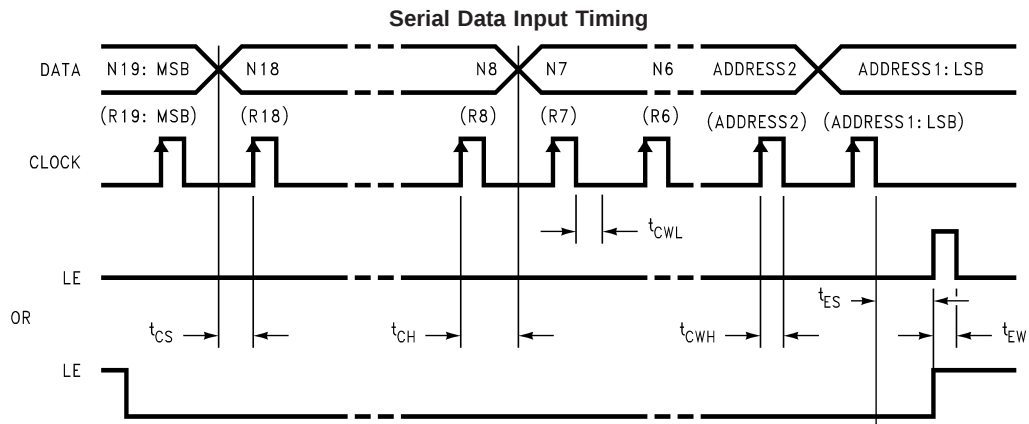
X - don't care condition

**Note 10:** Open drain lock detect output is provided to indicate when the VCO frequency is in "lock". When the loop is locked and a lock detect mode is selected, the pin is HIGH, with narrow pulses LOW. In the Main/Aux lock detect mode a locked condition is indicated when Main and Aux are both locked.

**Note 11:** The FastLock mode utilizes the FoLD output pin to switch a second loop filter damping resistor to ground during FastLock operation. Activation of FastLock occurs whenever the Main loop's ICP<sub>0</sub> magnitude bit R[16] is selected HI while the R[18] and R[19] mode bits are set.

**Note 12:** Aux and Main PLLs can be reset independently from each other by using the R[18] and R[19] bits. The Aux Counter Reset mode resets Aux PLL's R and N counters and brings Aux charge pump output to TRI-STATE condition. The Main Counter Reset mode resets Main PLL's R and N counters and brings Main charge pump output to a TRI-STATE condition. The Aux and Main Counter Reset modes reset all counters and bring both charge pump outputs to a TRI-STATE condition. Upon removal of the Reset bits, the N counter resumes counting in "close" alignment with the R counter. (The maximum error is one prescaler cycle.)

### 2.5 Serial Data Input Timing



DS101026-6

**NOTES:** Parenthesis data indicates programmable reference divider data.

Data shifted into register on clock rising edge.

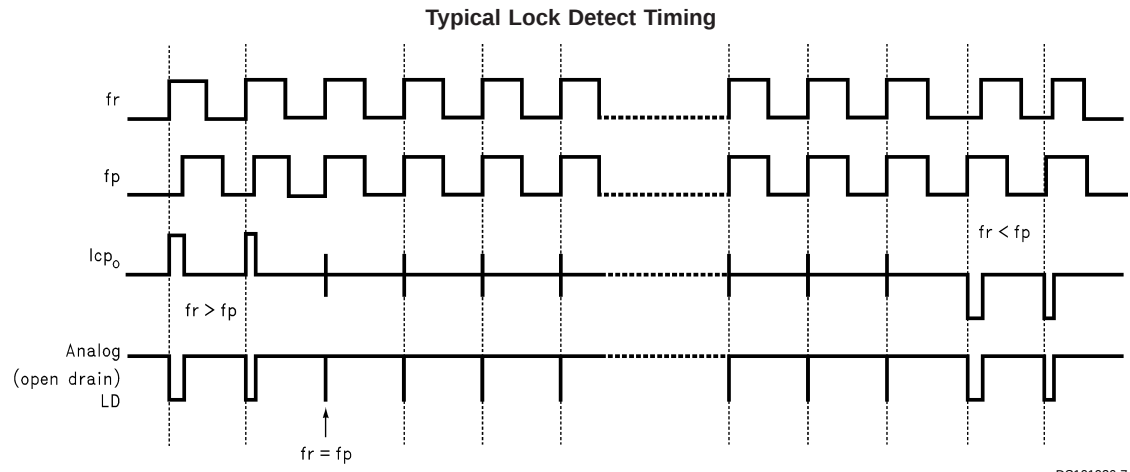
Data is shifted in MSB first.

**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 @  $V_{CC} = 5.5V$ .

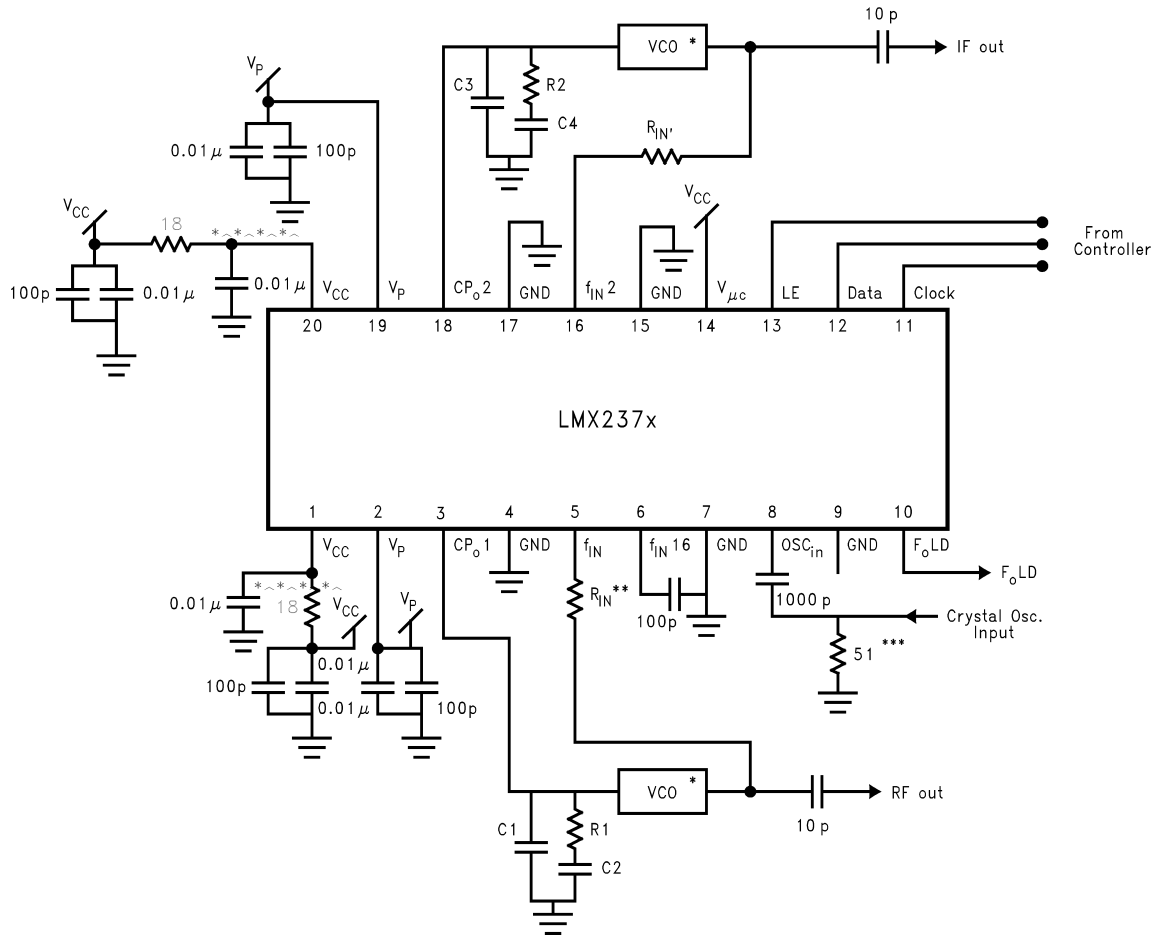
## 2.0 Programming Description

(Continued)

### 2.6 Typical Lock Detect Timing



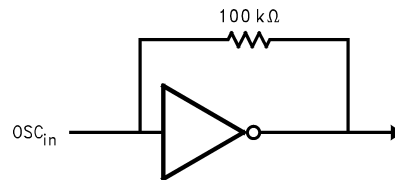
## Typical Application Example



DS101026-36

### 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 10 $\Omega$  to 200 $\Omega$  depending on the VCO power level.  $f_{IN}$  RF impedance ranges from 40 $\Omega$  to 100 $\Omega$ .  $f_{IN}$  IF impedances are higher.
- \*\*\* 50 $\Omega$  termination is often used on test boards to allow use of external reference oscillator. For most typical products a CMOS clock is used and no terminating resistor is required.  $OSC_{in}$  may be AC or DC coupled. AC coupling is recommended because the input circuit provides its own bias. (See *Figure* below)
- \*\*\*\* Adding RC filters to the  $V_{CC}$  line is recommended to reduce loop-to-loop noise coupling.



DS101026-37

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 1*.

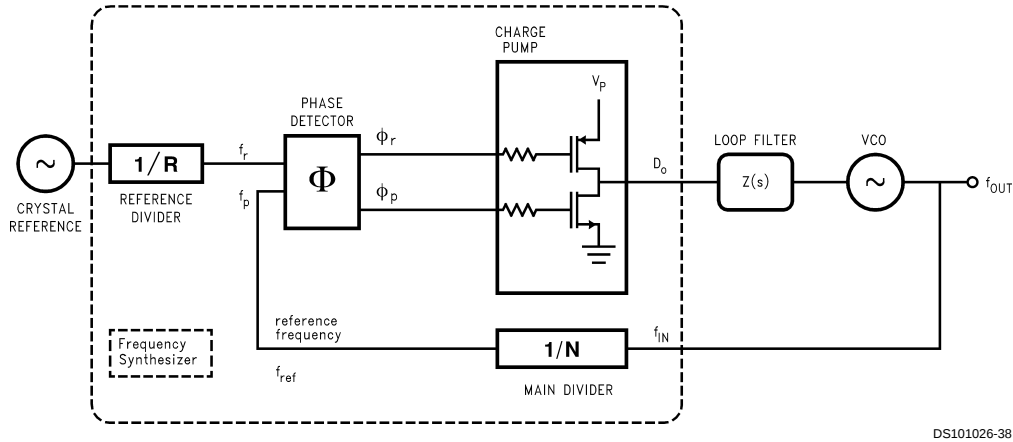


FIGURE 1. Basic Charge Pump Phase Locked Loop

### LOOP GAIN EQUATIONS

A linear control system model of the phase feedback for a PLL in the locked state is shown in *Figure 2*. The open loop gain is the product of the phase comparator gain ( $K_\phi$ ), 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 3*, while the complex impedance of the filter is given in *Equation (2)*.

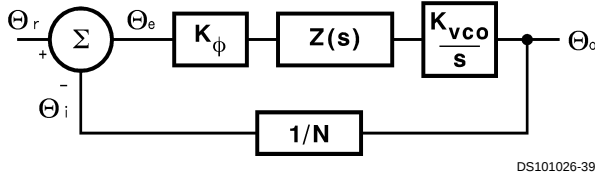


FIGURE 2. PLL Linear Model

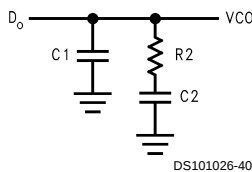


FIGURE 3. Passive Loop Filter

$$\text{Open loop gain} = H(s)G(s) = \frac{\Theta_i}{\Theta_e} = \frac{K_\phi Z(s)K_{VCO}}{Ns} \quad (1)$$

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

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

$$T1 = R2 \cdot \frac{C1 \cdot C2}{C1 + C2} \quad (3)$$

and

$$T2 = R2 \cdot C2 \quad (4)$$

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

$$G(s) \cdot H(s) \big|_{s=j\omega} = \frac{-K_\phi \cdot K_{VCO} (1 + j\omega \cdot T2)}{\omega^2 C1 \cdot N (1 + j\omega \cdot T1)} \cdot \frac{T1}{T2} \quad (5)$$

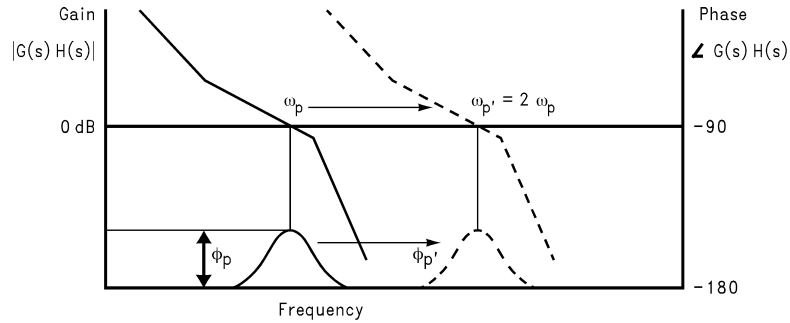
From *Equation (3)* we can see that the phase term will be dependent on the single pole and zero such that the phase margin is determined in *Equation (6)*.

$$\phi(\omega) = \tan^{-1}(\omega \cdot T2) - \tan^{-1}(\omega \cdot T1) + 180^\circ \quad (6)$$

A plot of the magnitude and phase of  $G(s)H(s)$  for a stable loop, is shown in *Figure 4* with a solid trace. The parameter  $\phi_p$  shows the amount of phase margin that exists at the point the gain drops below zero (the cutoff frequency  $\omega_p$  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,  $\omega_p'$ , as double the frequency which gave us our original loop bandwidth,  $\omega_p$ , 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 4* 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 *Equations (5), (6)* will have to compensate by the corresponding “ $1/\omega$ ” or “ $1/\omega^2$ ” factor. Examination of *Equations (3), (4), (6)* indicates the damping resistor variable  $R2$  could be chosen to compensate the “ $\omega$ ” 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 ensure that the magnitude of the open loop gain,  $H(s)G(s)$  is equal to zero at  $\omega_p' = 2\omega_p$ .  $K_{VCO}$ ,  $K_\phi$ ,  $N$ , or the net product of these terms can be changed by a factor of 4, to counteract the  $\omega^2$  term present in the denominator of *Equations (3), (4)*. The  $K_\phi$  term was chosen to complete the transformation because it can readily be switch 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.

## Application Information (Continued)



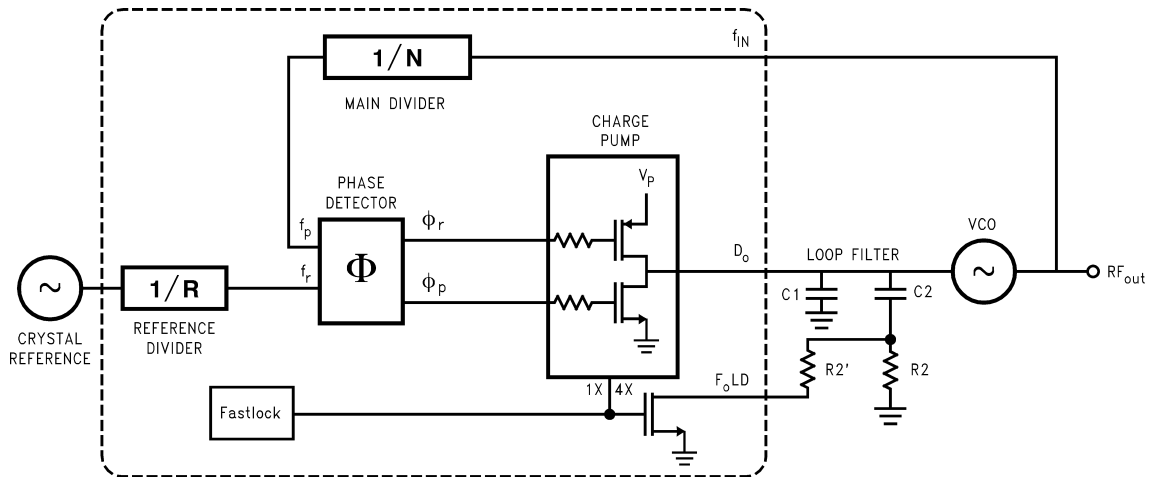
DS101026-43

FIGURE 4. Open Loop Response Bode Plot

### FASTLOCK CIRCUIT IMPLEMENTATION

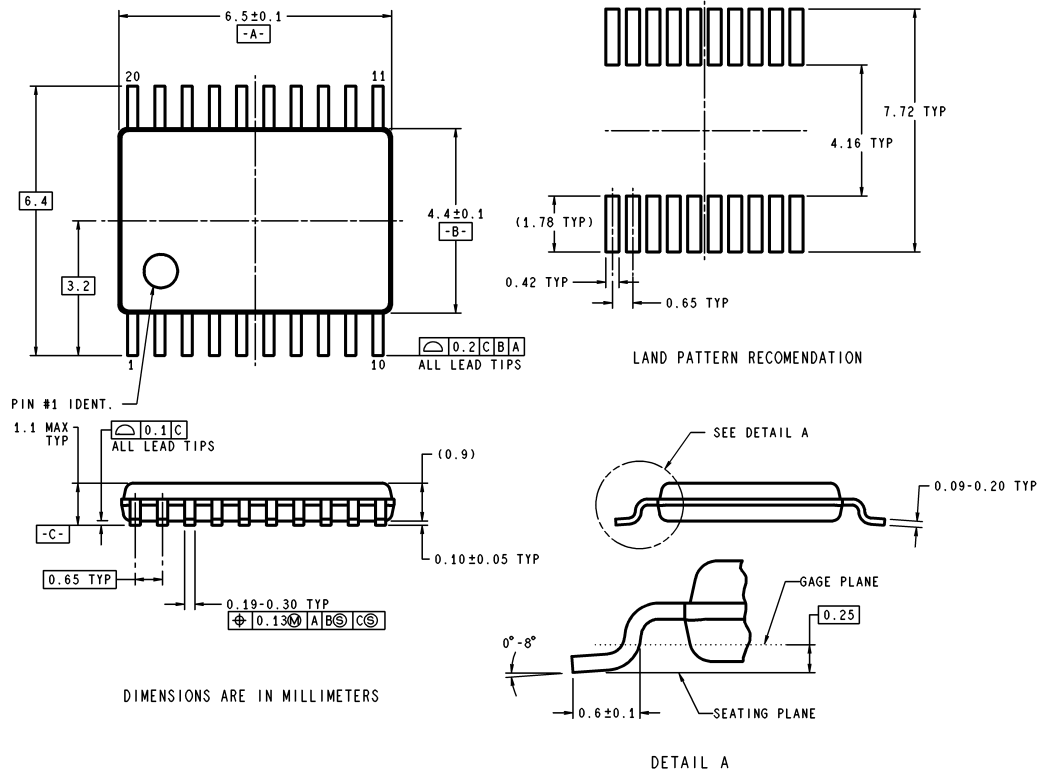
A diagram of the Fastlock scheme as implemented in National Semiconductors LMX233xA PLL is shown in Figure 5. When a new frequency is loaded, and the RF Icp<sub>o</sub> bit is set high the charge pump circuit receives an input to deliver 4 times the normal current per unit phase error while an open drain 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 iden-

tical 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<sub>o</sub> 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.



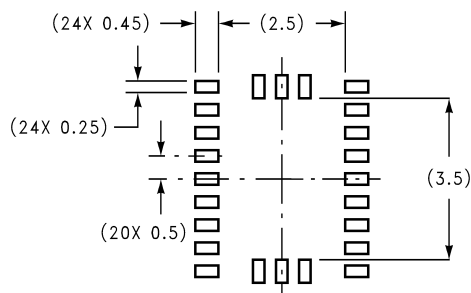
DS101026-44

FIGURE 5. Fastlock PLL Architecture



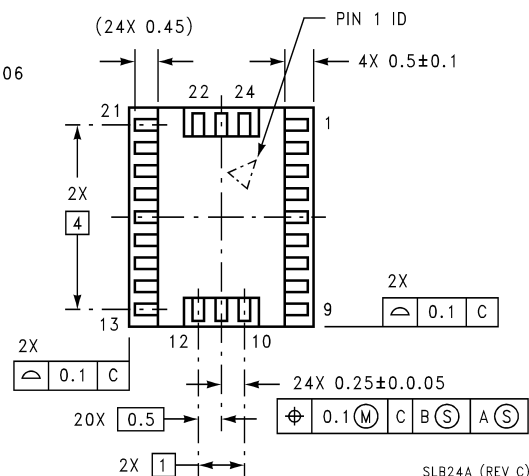
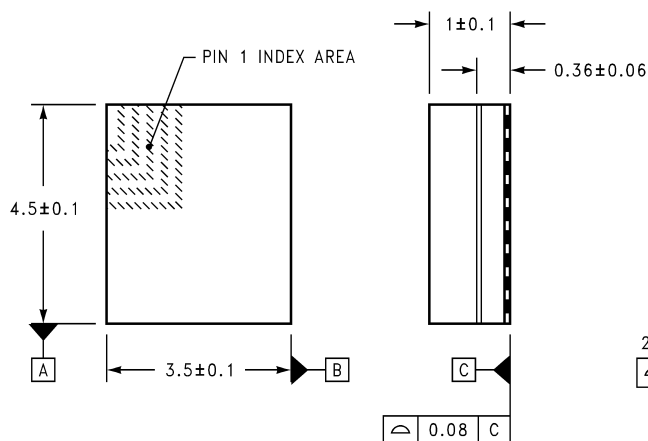
**Thin Shrink Small Outline (TSSOP) Package**  
**Order Number LMX2370TM, LMX2371TM or LMX2372TM**  
**\*For Tape and Reel (2500 units per reel)**  
**Order Number LMX2370TMX, LMX2371TMX or LMX2372TMX**  
**NS Package Number MTC20**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



DIMENSIONS ARE IN MILLIMETERS

**RECOMMENDED LAND PATTERN**  
1:1 RATIO WITH PACKAGE SOLDER PADS



SLB24A (REV C)

**Chip Scale Package**  
**For Tape and Reel (2500 Units Per Reel)**  
**Order Numbers: LMX2370SLBX, LMX2371SLBX, LMX2372SLBX**  
**NS Package Number SLB24A**

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



**National Semiconductor Corporation**  
Americas  
Tel: 1-800-272-9959  
Fax: 1-800-737-7018  
Email: support@nsc.com  
www.national.com

**National Semiconductor Europe**  
Fax: +49 (0) 180-530 85 86  
Email: europe.support@nsc.com  
Deutsch Tel: +49 (0) 69 9508 6208  
English Tel: +44 (0) 870 24 0 2171  
Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor Asia Pacific Customer Response Group**  
Tel: 65-2544466  
Fax: 65-2504466  
Email: ap.support@nsc.com

**National Semiconductor Japan Ltd.**  
Tel: 81-3-5639-7560  
Fax: 81-3-5639-7507