

LMX2491 具有斜坡/线性调频生成功能的 6.4GHz 低噪声 RF PLL

1 特性

- -227dBc/Hz 标准化锁相环 (PLL) 噪声
- 500MHz 至 6.4GHz 宽带 PLL
- 3.15V 至 5.25V 电荷泵 PLL 电源
- 多用途斜坡/超宽带信号源生成功能
- 200MHz 最大相位检测器频率
- 频移键控/相移键控 (FSK/PSK) 调制引脚
- 数字锁检测
- 3.3V 单电源供电

2 应用

- 调频连续波 (FMCW) 雷达
- 军用雷达
- 微波回程
- 测试和测量
- 卫星通信
- 无线基础设施
- 适用于高速模数转换器/数模转换器 (ADC/DAC) 的采样时钟

3 说明

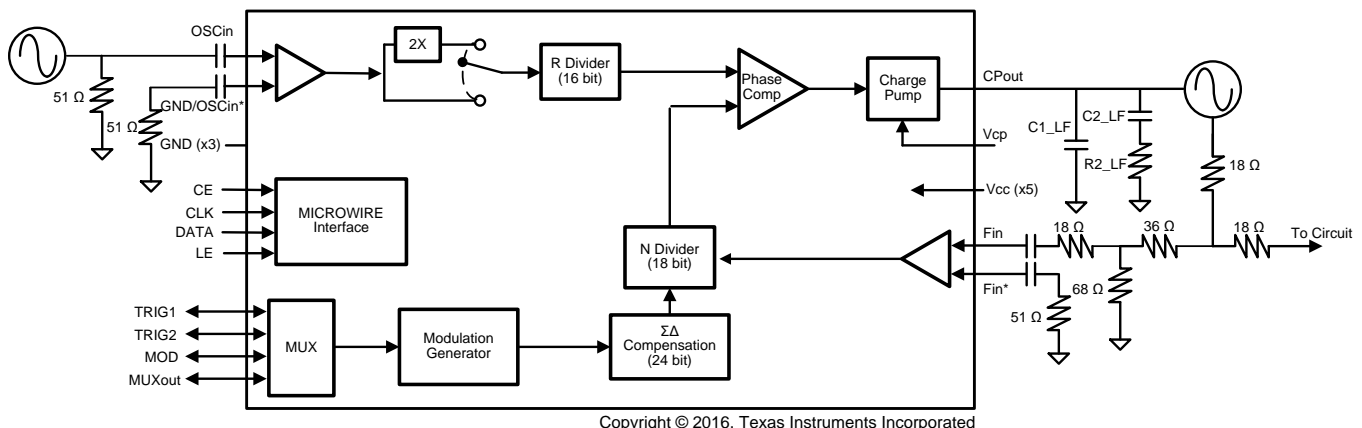
LMX2491 器件是一款具有斜坡/线性调频生成功能的低噪声 6.4GHz 宽带 $\Delta\Sigma$ 分数 N PLL。它由一个相位频率检测器、可编程电荷泵以及适用于外部 VCO 的高频输入组成。LMX2491 广泛支持各类灵活的斜坡功能，包括 FSK、PSK 和多达 8 段的可配置分段线性 FM 调制配置文件。该器件具有精密 PLL 分辨率和快速斜升功能，相位检测器速率高达 200MHz。LMX2491 允许读回其任一寄存器。LMX2491 可由 3.3V 单电源供电运行。此外，该器件支持电压高达 5.25V 的电荷泵，无需使用外部放大器即可提供相位噪声性能得到改善的简易解决方案。

器件信息

| 器件编号 | 封装 | 封装尺寸 (标称值) |
|---------|-----------|-----------------|
| LMX2491 | WQFN (24) | 4.00mm x 4.00mm |

(1) 要了解所有可用封装，请见数据表末尾的可订购产品附录。

简化原理图



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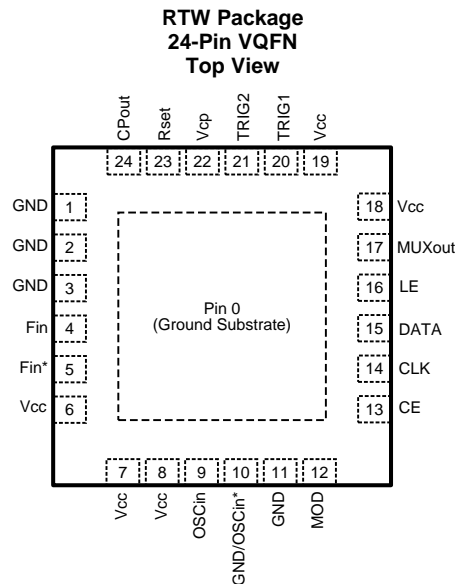
4 修订历史记录

Changes from Original (October 2016) to Revision A

Page

| | |
|---|----|
| Deleted Charge pump output pin from the table | 4 |
| Changed to Supply voltage | 4 |
| Changed to I/O input voltage | 4 |
| Changed to Power down current | 5 |
| Changed DATA field bit description | 6 |
| Added new plots in Typical Characteristics | 7 |
| Changed Table 1 title | 9 |
| Added CMP0 and CMP1 definition. Changed Equation 1 description. | 12 |
| Added Register Readback | 13 |
| Added MSB bit description | 14 |
| Changed the format in Window and f_{PD} Frequency column | 21 |
| Changed to correct register bits location | 23 |
| Changed to correct value | 25 |
| Added correct start time | 26 |
| Added design details and plots in Typical Application | 27 |

5 Pin Configuration and Functions



Pin Functions

| TERMINAL | | TYPE | DESCRIPTION |
|----------|----------------|--------------|---|
| NO. | NAME | | |
| 0 | DAP | GND | Die Attach Pad. Connect to PCB ground plane. |
| 1 | GND | GND | Ground for charge pump. |
| 2, 3 | GND | GND | Ground for Fin Buffer |
| 4, 5 | Fin Fin* | Input | Complimentary high frequency input pins. Should be AC-coupled. If driving single-ended, impedance as seen from Fin and Fin* pins looking outwards from the part should be roughly the same. |
| 6 | Vcc | Supply | Power Supply for Fin Buffer |
| 7 | Vcc | Supply | Supply for On-chip LDOs |
| 8 | Vcc | Supply | Supply for OSCin Buffer |
| 9 | OSCin | Input | Reference Frequency Input |
| 10 | GND/ OSCin* | GND/Input | Complimentary input for OSCin. If not used, it is recommended to match the termination as seen from the OSCin terminal looking outwards. However, this may also be grounded as well. |
| 11 | GND | GND | Ground for OSCin Buffer |
| 12 | MOD | Input/Output | Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics |
| 13 | CE | Input | Chip Enable |
| 14 | CLK | GND | Serial Programming Clock. |
| 15 | DATA | GND | Serial Programming Data |
| 16 | LE | Input | Serial Programming Latch Enable |
| 17 | MUXout | Input/Output | Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics |
| 18 | Vcc | Supply | Supply for delta sigma engine. |
| 19 | Vcc | Supply | Supply for general circuitry. |
| 20 | TRIG1 | Input/Output | Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics |
| 21 | TRIG2 | Input/Output | Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics |
| 22 | Vcp | Supply | Power Supply for the charge pump. |
| 23 | Rset | NC | No connect. |
| 24 | CPout | Output | Charge Pump Output |

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) ⁽¹⁾

| | | MIN | MAX | UNIT |
|-----------------------|-------------------------------------|-----------------|-----------------------|------|
| V _{CP} | Supply voltage for charge pump | V _{CC} | 5.5 | V |
| V _{CC} | Supply voltage | −0.3 | 3.6 | V |
| V _{IN} | I/O input voltage | −0.3 | V _{CC} + 0.3 | V |
| T _{Solder} | Lead temperature (solder 4 seconds) | | 260 | °C |
| T _{Junction} | Junction temperature | | 150 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 Storage Conditions

applicable before the DMD is installed in the final product

| | | MIN | MAX | UNIT |
|------------------|-------------------------|-----|-----|------|
| T _{stg} | DMD storage temperature | −65 | 150 | °C |
| T _{DP} | Storage dew point | | 3 | °C |

6.3 ESD Ratings

| | | VALUE | UNIT |
|--------------------|-------------------------|--|-------|
| V _(ESD) | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±2500 |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±1500 |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.4 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| PARAMETER | | MIN | NOM | MAX | UNIT |
|-----------------|----------------------------|-----------------|-----|------|------|
| V _{CC} | Supply voltage | 3.15 | 3.3 | 3.45 | V |
| V _{CP} | Charge pump supply voltage | V _{CC} | | 5.25 | V |
| T _A | Ambient temperature | −40 | | 85 | °C |
| T _J | Junction temperature | −40 | | 125 | °C |

6.5 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | LMX2491 | UNIT |
|-------------------------------|--|------------|------|
| | | RTW (VQFN) | |
| | | 24 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 39.4 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 7.1 | °C/W |
| ψ _{JB} | Junction-to-board characterization parameter | 20 | °C/W |

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

6.6 Electrical Characteristics

3.15 V ≤ V_{CC} ≤ 3.45 V, V_{CC} ≤ V_{CP} ≤ 5.25 V, −40 °C ≤ T_A ≤ 85 °C, except as specified. Typical values are at V_{CC} = V_{CP} = 3.3 V, 25 °C.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT | |
|--|---|--|---------------------------|-----------------------|-----------------------|-----------------------|-----------------|--------|
| I _{CC} | Current consumption | All V _{CC} pins | f _{PD} = 10 MHz | | | 45 | mA | |
| | | | f _{PD} = 100 MHz | | | 50 | | |
| | | | f _{PD} = 200 MHz | | | 55 | | |
| | | V _{CP} pin | K _{PD} = 0.1 mA | | | 2 | | |
| | | | K _{PD} = 1.6 mA | | | 10 | | |
| | | | K _{PD} = 3.1 mA | | | 19 | | |
| I _{CCPD} | Power down current | POWERDOWN | | | | 3 | | |
| f _{OSCin} | Frequency for OSCin terminal | OSC_DIFFR = 0, doubler disabled | | 10 | | | 600 | MHz |
| | | OSC_DIFFR = 0, doubler enabled | | 10 | | | 300 | |
| | | OSC_DIFFR = 1, doubler disabled | | 10 | | | 1200 | |
| | | OSC_DIFFR = 1, doubler enabled | | 10 | | | 600 | |
| V _{OSCin} | Voltage for OSCin pin ⁽¹⁾ | | | 0.5 | V _{CC} − 0.5 | | V _{PP} | |
| f _{Fin} | Frequency for Fin pin | | | 500 | | | 6400 | MHz |
| P _{Fin} | Power for Fin pin | Single-ended operation | | −5 | | | 5 | dBm |
| f _{PD} | Phase detector frequency | | | | | 200 | MHz | |
| PN1Hz | PLL figure of merit ⁽²⁾ | | | −227 | | | | dBc/Hz |
| PN10kHz | Normalized PLL 1/f noise ⁽²⁾ | Normalized to 10-kHz offset for a 1-GHz carrier. | | −120 | | | | dBc/Hz |
| I _{CPoutTRI} | Charge pump leakage tri-state leakage | | | | | 10 | nA | |
| I _{CPoutMM} | Charge pump mismatch ⁽³⁾ | V _{CPout} = V _{CP} / 2 | | 5% | | | | |
| I _{CPout} | Charge pump current | V _{CPout} = V _{CP} / 2 | CPG = 1X | 0.1 | | mA | | |
| | | | ... | | | | | |
| | | | CPG = 31X | 3.1 | | | | |
| LOGIC OUTPUT TERMINALS (MUXout, TRIG1, TRIG2, MOD) | | | | | | | | |
| V _{OH} | Output high voltage | | | 0.8 × V _{CC} | V _{CC} | | V | |
| V _{OL} | Output low voltage | | | 0 | | 0.2 × V _{CC} | V | |
| LOGIC INPUT TERMINALS (CE, CLK, DATA, LE, MUXout, TRIG1, TRIG2, MOD) | | | | | | | | |
| V _{IH} | Input high voltage | | | 1.4 | V _{CC} | | V | |
| V _{IL} | Input low voltage | | | 0 | 0.6 | | V | |
| I _{IH} | Input leakage current | | | −5 | 1 | 5 | μA | |
| t _{CELOW} | Chip enable low time | | | 5 | | | μs | |
| t _{CEHIGH} | Chip enable high time | | | 5 | | | μs | |

(1) For optimal phase noise performance, higher input voltage and a slew rate of at least 3 V/ns is recommended

(2) PLL Noise Metrics are measured with a clean OSCin signal with a high slew rate using a wide loop bandwidth. The noise metrics model the PLL noise for an infinite loop bandwidth as:

$$PLL_Total = 10 \times \log(10^{PLL_Flat / 10} + 10^{PLL_Flicker(Offset) / 10})$$

$$PLL_Flat = PN1Hz + 20 \times \log(N) + 10 \times \log(f_{PD} / 1 \text{ Hz})$$

$$PLL_Flicker = PN10kHz - 10 \times \log(Offset / 10 \text{ kHz}) + 20 \times \log(f_{VCO} / 1 \text{ GHz})$$

(3) Charge pump mismatch varies as a function of charge pump voltage. Consult typical performance characteristics to see this variation.

6.7 Timing Requirements, Programming Interface (CLK, DATA, LE)

| | | MIN | TYP | MAX | UNIT |
|-----------|----------------------------|-----|-----|-----|------|
| t_{CE} | Clock to LE low time | 10 | | | ns |
| t_{CS} | Data to clock setup time | 4 | | | ns |
| t_{CH} | Data to clock hold time | 4 | | | ns |
| t_{CWH} | Clock pulse width high | 10 | | | ns |
| t_{CWL} | Clock pulse width low | 10 | | | ns |
| t_{CES} | Enable to clock setup time | 10 | | | ns |
| t_{EWH} | Enable pulse width high | 10 | | | ns |

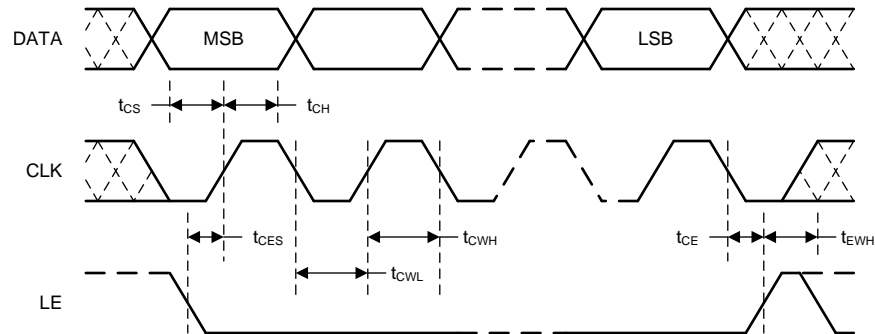
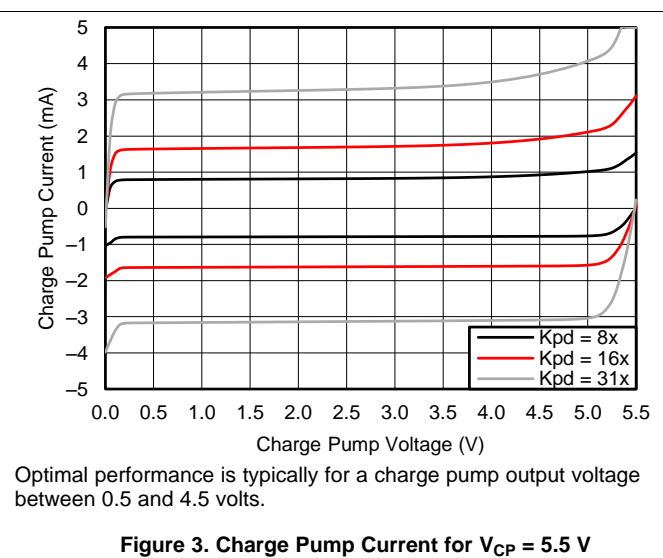
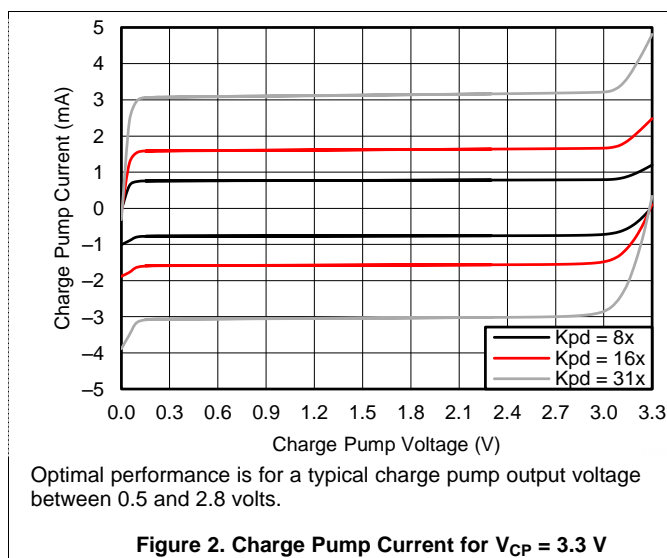


Figure 1. Serial Data Input Timing

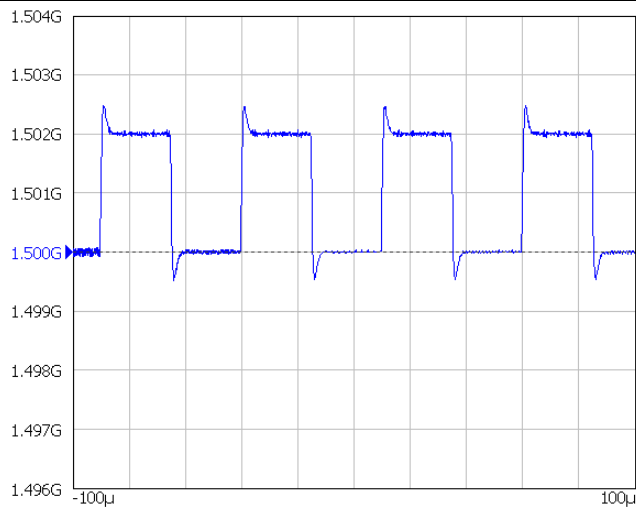
There are several other considerations for programming:

- The DATA is clocked into a shift register on each rising edge of the CLK signal. On the rising edge of the LE signal, the data is sent from the shift register to an actual counter.
- If no LE signal is given after the last data bit and the clock is kept toggling, then these bits are read into the next lower register. This eliminates the need to send the address each time.
- A slew rate of at least 30 V/ μ s is recommended for the CLK, DATA, and LE signals
- Timing specs also apply to readback. Readback can be done through the MUXout, TRIG1, TRIG2, or MOD terminals.

6.8 Typical Characteristics

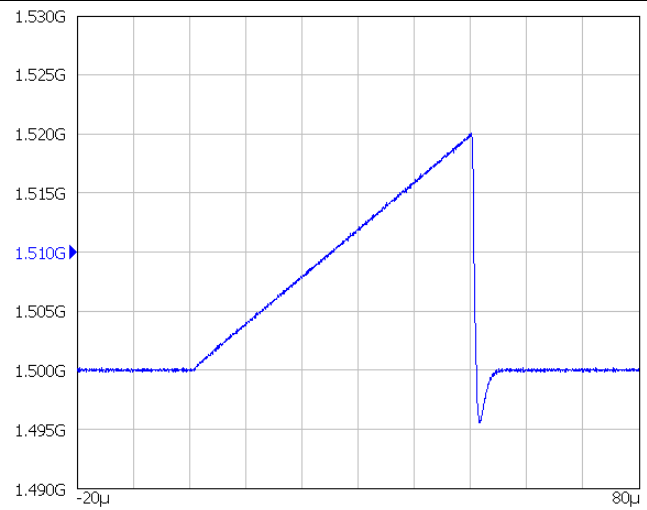


Typical Characteristics (continued)



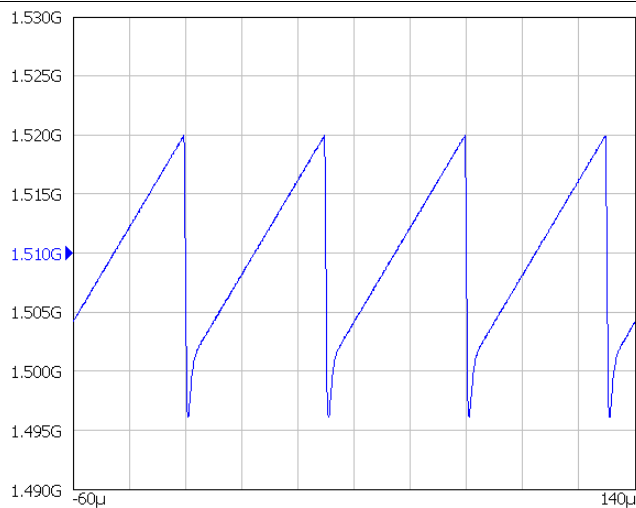
See [Frequency Shift Keying Example](#) for the detail of configuration.

Figure 4. Frequency Shift Keying



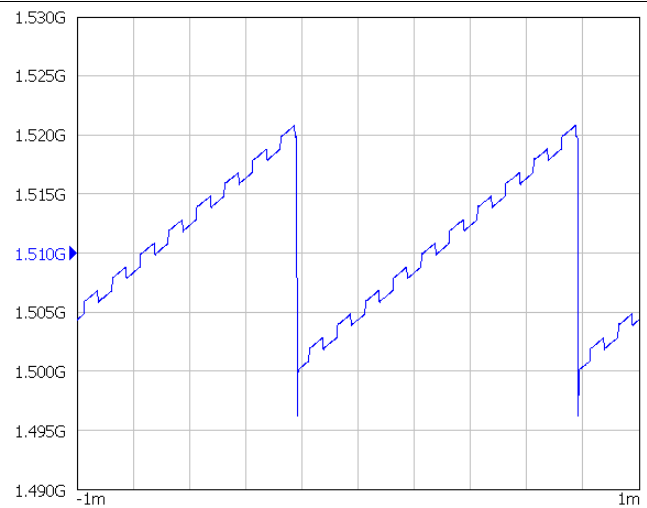
See [Single Sawtooth Ramp Example](#) for the detail of configuration.

Figure 5. Single Sawtooth Ramp



See [Continuous Sawtooth Ramp Example](#) for the detail of configuration.

Figure 6. Continuous Sawtooth Ramp



See [Continuous Sawtooth Ramp with FSK Example](#) for the detail of configuration.

Figure 7. Continuous Sawtooth Ramp with FSK

Typical Characteristics (continued)

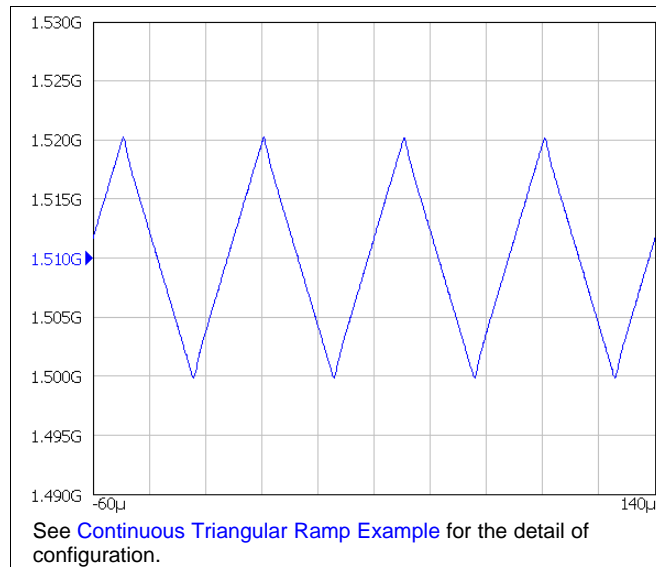


Figure 8. Continuous Triangular Ramp

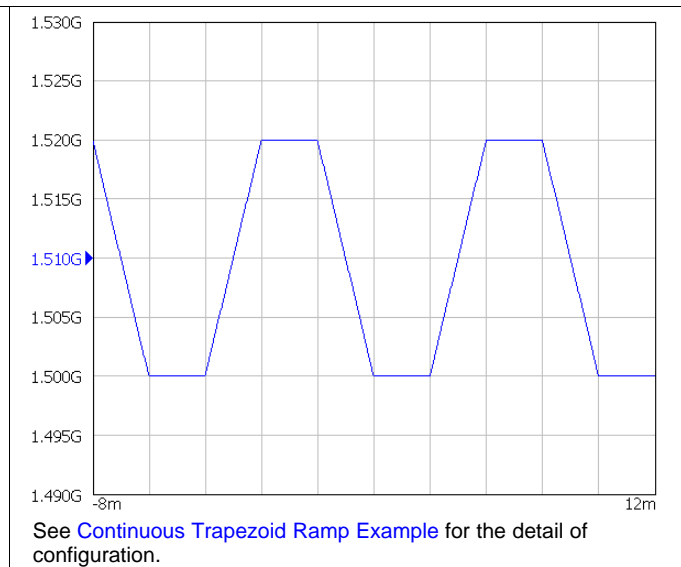


Figure 9. Continuous Trapezoid Ramp

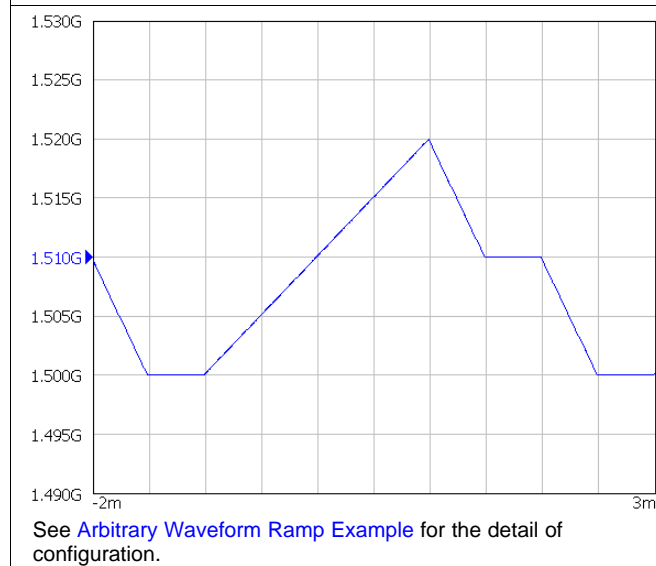


Figure 10. Arbitrary Waveform Ramp

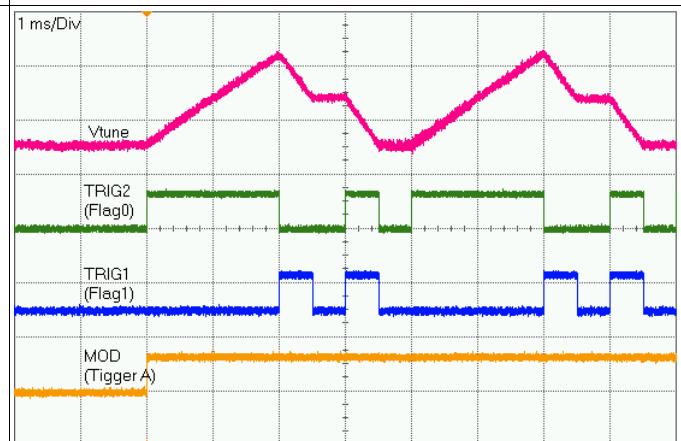


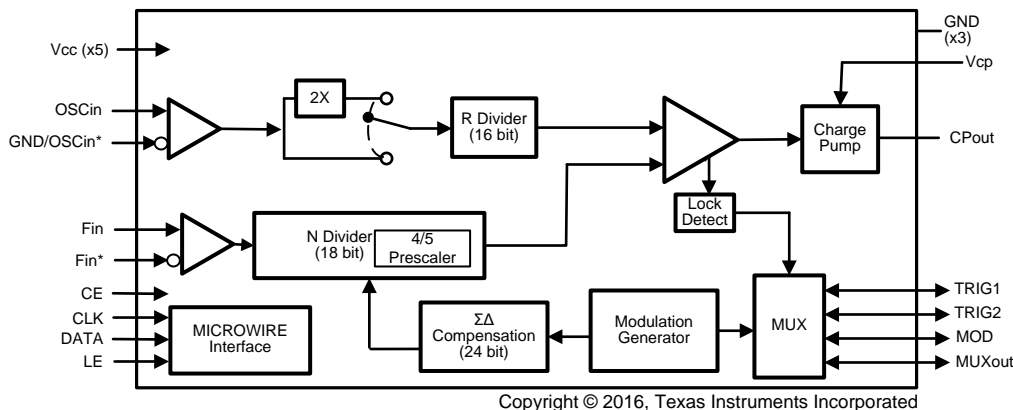
Figure 11. Output Flags

7 Detailed Description

7.1 Overview

The LMX2491 is a microwave PLL, consisting of a reference input and divider, high frequency input and divider, charge pump, ramp generator, and other digital logic. The V_{CC} power supply pins run at a nominal 3.3 volts, while the charge pump supply pin, V_{CP} , operates anywhere from V_{CC} to 5 volts. The device is designed to operate with an external loop filter and VCO. Modulation is achieved by manipulating the MASH engine.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 OSCin Input

The reference can be applied in several ways. If using a differential input, this must be terminated differentially with a 100- Ω resistance and AC-coupled to the OSCin and GND/OSCin* terminals. If driving this single-ended, then the GND/OSCin* terminal may be grounded, although better performance is attained by connecting the GND/OSCin* terminal through a series resistance and capacitance to ground to match the OSCin terminal impedance.

7.3.2 OSCin Doubler

The OSCin doubler allows the input signal to the OSCin to be doubled to have higher phase detector frequencies. This works by clocking on both the rising and falling edges of the input signal, so it therefore requires a 50% input duty cycle.

7.3.3 R Divider

The R counter is 16 bits divides the OSCin signal from 1 to 65535. If DIFF_R = 0, then any value can be chosen in this range. If DIFF_R = 1, then the divide is restricted to 2, 4, 8, and 16, but allows for higher OSCin frequencies.

7.3.4 PLL N Divider

The 16-bit N divider divides the signal at the Fin terminal down to the phase detector frequency. It contains a 4/5 prescaler that creates minimum divide restrictions, but allows the N value to increment in values of one.

Table 1. Allowable Minimum N Divider Values

| MODULATOR ORDER | MINIMUM N DIVIDE |
|-----------------------------------|------------------|
| Integer Mode, 1st-Order Modulator | 16 |
| 2nd-Order Modulator | 17 |
| 3rd-Order Modulator | 19 |
| 4th-Order Modulator | 25 |

7.3.5 Fractional Circuitry

The fractional circuitry controls the N divider with delta sigma modulation that supports a programmable first, second, third, and fourth-order modulator. The fractional denominator is a fully programmable 24-bit denominator that can support any value from 1, 2, ..., 2^{24} , with the exception when the device is running one of the ramps, and in this case it is a fixed size of 2^{24} .

7.3.6 PLL Phase Detector and Charge Pump

The phase detector compares the outputs of the R and N dividers and generates a correction voltage corresponding to the phase error. This voltage is converted to a correction current by the charge pump. The phase detector frequency, f_{PD} , can be calculated as follows: $f_{PD} = f_{OSCin} \times OSC_2X / R$.

The charge pump supply voltage on this device, V_{CP} , can be either run at the V_{CC} voltage, or up to 5.25 volts to get higher tuning voltages to present to the VCO.

7.3.7 External Loop Filter

The loop filter is external to the device and is application specific. Texas Instruments website has details on this at www.ti.com.

7.3.8 Fastlock and Cycle Slip Reduction

This PLL has a Fastlock and a cycle slipping reduction feature. The user can enable these two features by programming FL_TOC to a non-zero value. Every time PLL_N (the feedback divider, register R17 and R16) is written, the Fastlock feature engages for the prescribed time set in FL_TOC. There are 3 actions that can be enabled while the counter is running:

1. Change the charge pump current to the desired higher value FL_CPG. Typically this value would be set to the maximum at 31x. This increases the loop bandwidth and hence reduces lock time.
2. Change the phase detector frequency with FL_CSR to reduce cycle slipping. The phase detector frequency can be reduced by a factor 2 or 4 to reduce cycle slipping.
3. The loop filter can be configured to have a switchable R2 resistor to increase loop bandwidth and hence reduce lock time. A resistor R2pLF is added in parallel to R2_LF and connected to the a terminal on the PLL to use the internal switch. Any of the terminal MUXout, MOD, TRIG1, or TRIG2 can be configured for the function. The terminal configuration is set as *Output TOC Running*. Also set the terminal as *output inverted OD* (OD for open-drain) so the output will be high impedance in normal operation and act as ground in Fastlock. The suggested schematic for that feature is shown in Figure 12.

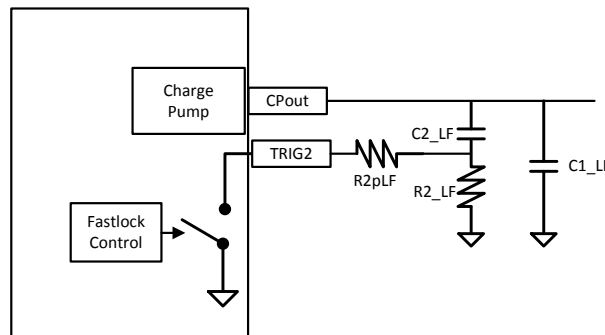


Figure 12. Suggested Schematic to Enable the Variable Loop Bandwidth Filter In Fastlock Mode

Table 2. Fastlock Settings: Charge Pump Gain and Fastlock Pin Status

| PARAMETER | NORMAL OPERATION | FASTLOCK OPERATION |
|--|------------------|--------------------|
| Charge Pump Gain | CPG | FL_CPG |
| Device Pin (TRIG1, TRIG2, MOD, or MUXout) | High Impedance | Grounded |

The resistor and the charge pump current are changed simultaneously so that the phase margin remains the same while the loop bandwidth is by a factor of K as shown in the following table:

Table 3. Suggested Equations to Calculate R2pLF

| PARAMETER | | CALCULATION |
|-----------|------------------------------|--|
| FL_CPG | Charge Pump Gain in Fastlock | Typically use the highest value. |
| K | Loop Bandwidth Multiplier | $K = \sqrt{\text{FL_CPG} / \text{CPG}}$ |
| R2pLF | External Resistor | $R2 / (K - 1)$ |

Cycle slip reduction is another method that can also be used to speed up lock time by reducing cycle slipping. Cycle slipping typically occurs when the phase detector frequency exceeds about 100x the loop bandwidth of the PLL. Cycle slip reduction works in a different way than fastlock. To use this, the phase detector frequency is decreased while the charge pump current is simultaneously increased by the same factor. Although the loop bandwidth is unchanged, the ratio of the phase detector frequency to the loop bandwidth is, and this is helpful for cases when the phase detector frequency is high. Because cycle slip reduction changes the phase detector rate, it also impacts other things that are based on the phase detector rate, such as the fastlock timeout-counter and ramping controls.

7.3.9 Lock Detect and Charge Pump Voltage Monitor

The LMX2491 offers two methods to determine if the PLL is in lock: charge pump voltage monitoring and digital lock detect. These features can be used individually or in conjunction to give a reliable indication of when the PLL is in lock. The output of this detection can be routed to the TRIG1, TRIG2, MOD, or MUXout terminals.

7.3.9.1 Charge Pump Voltage Monitor

The charge pump voltage monitor allows the user to set low (CMP_THR_LOW) and high (CMP_THR_HIGH) thresholds for a comparator that monitors the charge pump output voltage.

Table 4. Desired Comparator Threshold Register Settings for Two Charge Pump Supplies

| V _{CP} | THRESHOLD | SUGGESTED LEVEL |
|-----------------|--|--------------------|
| 3.3 V | CPM_THR_LOW $= (\text{Vthres} + 0.08) / 0.085$ | 6 for 0.5-V limit |
| | CPM_THR_HIGH $= (\text{Vthres} - 0.96) / 0.044$ | 42 for 2.8-V limit |
| 5.0 V | CPM_THR_LOW $= (\text{Vthres} + 0.056) / 0.137$ | 4 for 0.5-V limit |
| | CPM_THR_HIGH $= (\text{Vthres} - 1.23) / 0.071$ | 46 for 4.5-V limit |

7.3.9.2 Digital Lock Detect

Digital lock detect works by comparing the phase error as presented to the phase detector. If the phase error plus the delay as specified by the PFD_DLY bit is outside the tolerance as specified by DLD_TOL, then this comparison would be considered to be an error, otherwise passing. The DLD_ERR_CNT specifies how many errors are necessary to cause the circuit to consider the PLL to be unlocked. The DLD_PASS_CNT specifies how many passing comparisons are necessary to cause the PLL to be considered to be locked and also resets the count for the errors. The DLD_TOL value should be set to no more than half of a phase detector period plus the PFD_DLY value. The DLD_ERR_CNT and DLD_PASS_CNT values can be decreased to make the circuit more sensitive. If the circuit is too sensitive, then chattering can occur and the DLD_ERR_CNT, DLD_PASS_CNT, or DLD_TOL values should be increased.

NOTE

If the OSCin signal goes away and there is no noise or self-oscillation at the OSCin pin, then it is possible for the digital lock detect to indicate a locked state when the PLL really is not in lock. If this is a concern, then digital lock detect can be combined with charge pump voltage monitor to detect this situation.

7.3.10 FSK/PSK Modulation

Two-level FSK or PSK modulation can be created whenever a trigger event, as defined by the FSK_TRIG field is detected. This trigger can be defined as a transition on a terminal (TRIG1, TRIG2, MOD, or MUXout) or done purely in software. The RAMP_PM_EN bit defines the modulation to be either FSK or PSK and the FSK_DEV register determines the amount of the deviation. Remember that the FSK_DEV[32:0] field is programmed as the 2's complement of the actual desired FSK_DEV value. This modulation can be added to the modulation created from the ramping functions as well.

Table 5. How to Obtain Deviation for Two Types of Modulation

| RAMP_PM_EN | MODULATION TYPE | DEVIATION |
|------------|-----------------|---|
| 0 | 2 Level FSK | $f_{PD} \times \text{FSK_DEV} / 2^{24}$ |
| 1 | 2 Level PSK | $360^\circ \times \text{FSK_DEV} / 2^{24}$ |

7.3.11 Ramping Functions

The LMX2491 supports a broad and flexible class of FMCW modulation formed by up to 8 linear ramps. When the ramping function is running, the denominator is fixed to a forced value of $2^{24} = 16777216$. The waveform always starts at RAMP0 when the LSB of the PLL_N (R16) is written to. After it is set up, it starts at the initial frequency and have piecewise linear frequency modulation that deviates from this initial frequency as specified by the modulation. Each of the eight ramps can be individually programmed. Various settings are as follows:

Table 6. Register Descriptions of the Ramping Function

| RAMP CHARACTERISTIC | PROGRAMMING FIELD NAME | DESCRIPTION |
|-----------------------|-------------------------------------|--|
| Ramp Length | RAMPx_LEN RAMPx_DLY | The user programs the length of the ramp in phase detector cycles. If RAMPx_DLY = 1, then each count of RAMPx_LEN is actually two phase detector cycles. |
| Ramp Slope | RAMPx_LEN RAMPx_DLY RAMPx_INC | The user does not directly program slope of the line, but rather this is done by defining how long the ramp is and how much the fractional numerator is increased per phase detector cycle. The value for RAMPx_INC is calculated by taking the total expected increase in the frequency, expressed in terms of how much the fractional numerator increases, and dividing it by RAMPx_LEN. The value programmed into RAMPx_INC is actually the two's complement of the desired mathematical value. |
| Trigger for Next Ramp | RAMPx_NEXT_TRIG | The event that triggers the next ramp can be defined to be the ramp finishing or can wait for a trigger as defined by Trigger A, Trigger B, or Trigger C. |
| Next Ramp | RAMPx_NEXT | This sets the ramp that follows. Waveforms are constructed by defining a chain ramp segments. To make the waveform repeat, make RAMPx_NEXT point to the first ramp in the pattern. |
| Ramp Fastlock | RAMPx_FL | This allows the ramp to use a different charge pump current or use Fastlock |
| Ramp Flags | RAMPx_FLAG | This allows the ramp to set a flag that can be routed to external terminals to trigger other devices. |

7.3.11.1 Ramp Count

If it is desired that the ramping waveform keep repeating, then all that is needed is to make the RAMPx_NEXT of the final ramp equal to the first ramp. This runs until the RAMP_EN bit is set to zero. If this is not desired, then one can use the RAMP_COUNT to specify how many times the specified pattern is to repeat.

7.3.11.2 Ramp Comparators and Ramp Limits

The ramp comparators and ramp limits use programmable thresholds to allow the device to detect whenever the modulated waveform frequency crosses a limit as set by the user. The difference between these is that comparators set a flag to alert the user while a ramp limits prevent the frequency from going beyond the prescribed threshold. In either case, these thresholds are expressed by programming the Extended_Fractional_Numerator. CMP0 and CMP1 are two separated comparators but they work in the same fashion.

$$\text{Extended_Fractional_Numerator} = \text{Fractional_Numerator} + (N - N^*) \times 2^{24} \quad (1)$$

In Equation 1, N^* is the PLL feedback value without ramping. Fractional_Numerator and N are the new values as defined by the threshold frequency. The actual value programmed is the 2's complement of Extended_Fractional_Numerator.

Table 7. Register Descriptions of Ramp Comparators and Limits

| TYPE | PROGRAMMING BIT | THRESHOLD |
|------------------|------------------------|--|
| Ramp Limits | RAMP_LIMIT_LOW | Lower Limit |
| | RAMP_LIMIT_HIGH | Upper Limit |
| Ramp Comparators | RAMP_CMP0 RAMP_CMP1 | For the ramp comparators, if the ramp is increasing and exceeds the value as specified by RAMP_CMPx, then the flag goes high, otherwise it is low. If the ramp is decreasing and goes below the value as specified by RAMP_CMPx, then the flag goes high, otherwise it is low. |

7.3.12 Power-on-reset (POR)

The power-on-reset circuitry sets all the registers to a default state when the device is powered up. This same reset can be done by programming SWRST = 1. In the programming section, the power on reset state is given for all the programmable fields.

7.3.13 Register Readback

The LMX2491 allows any of its registers to be read back. MOD, MUXout, TRIG1 or TRIG2 pin can be programmed to support register-readback serial-data output. To read back a certain register value, follow the following steps:

1. Set the R/W bit to 1; the data field contents are ignored.
2. Send the register to the device; readback serial data will be output starting at the 17th clock cycle.

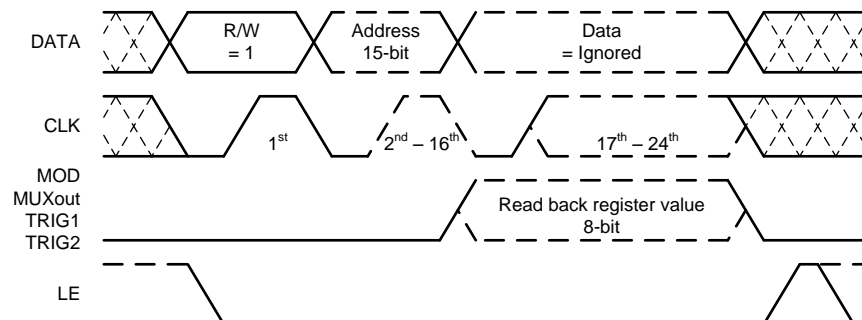


Figure 13. Register Readback Timing Diagram

7.4 Device Functional Modes

The two primary ways to use the LMX2491 are to run it to generate a set of frequencies

7.4.1 Continuous Frequency Generator

In this mode, the LMX2491 generates a single frequency that only changes when the N divider is programmed to a new value. In this mode, the RAMP_EN bit is set to 0 and the ramping controls are not used. The fractional denominator can be programmed to any value from 1 to 16777216. In this kind of application, the PLL is tuned to different channels, but at each channel, the goal is to generate a stable fixed frequency.

7.4.1.1 Integer Mode Operation

In integer mode operation, the VCO frequency needs to be an integer multiple of the phase detector frequency. This can be the case when the output frequency or frequencies are nicely related to the input frequency. As a rule of thumb, if this can be done with a phase detector of as high as the lesser of 10 MHz or the OSCin frequency, then this makes sense. To operate the device in integer mode, disable the fractional circuitry by programming the fractional order (FRAC_ORDER), dithering (FRAC_DITH), and numerator (FRAC_NUM) to zero.

Device Functional Modes (continued)

7.4.1.2 Fractional Mode Operation

In fractional mode, the output frequency does not need to be an integer multiple of the phase detector frequency. This makes sense when the channel spacing is more narrow or the input and output frequencies are not nicely related. There are several programmable controls for this such as the modulator order, fractional dithering, fractional numerator, and fractional denominator. There are many trade-offs with choosing these, but here are some guidelines

Table 8. Fractional Mode Register Descriptions and Recommendations

| PARAMETER | FIELD NAME | HOW TO CHOOSE |
|--------------------------------------|----------------------|--|
| Fractional Numerator and Denominator | FRAC_NUM FRAC_DEN | The first step is to find the fractional denominator. To do this, find the frequency that divides the phase detector frequency by the channel spacing. For instance, if the output ranges from 5000 to 5050 in 5-MHz steps and the phase detector is 100 MHz, then the fractional denominator is $100 \text{ MHz} / 5 = 20$. So for an output of 5015 MHz, the N divider would be $50 + 3/20$. In this case, the fractional numerator is 3 and the fractional denominator is 20. Sometimes when dithering is used, it makes sense to express this as a larger equivalent fraction. Note that if ramping is active, the fractional denominator is forced to 2^{24} . |
| Fractional Order | FRAC_ORDER | There are many trade-offs, but in general try either the 2nd or 3rd-order modulator as starting points. The 3rd-order modulator may give lower main spurs, but may generate others. Also if dithering is involved, it can generate phase noise. |
| Dithering | FRAC_DITH | Dithering can reduce some fractional spurs, but add noise. Consult application note AN-1879 Fractional N Frequency Synthesis for more details on this. |

7.4.2 Modulated Waveform Generator

In this mode, the device can generate a broad class of frequency sweeping waveforms. The user can specify up to 8 linear segments to generate these waveforms. When the ramping function is running, the denominator is fixed to a forced value of $2^{24} = 16777216$

In addition to the ramping functions, there is also the capability to use a terminal to add phase or frequency modulation that can be done by itself or added on top of the waveforms created by the ramp generation functions.

7.5 Programming

7.5.1 Loading Registers

The device is programmed using several 24-bit registers. Each register consists of a data field, an address field, and a R/W bit. The MSB is the R/W bit. 0 means register write while 1 means register read. The following 15 bits of the register are the address, followed by the next 8 bits of data. The user has the option to pull the LE terminal high after this data, or keep sending data and it applies this data to the next lower register. So instead of sending three registers of 24 bits each, one could send a single 40-bit register with the 16 bits of address and 24 bits of data. For that matter, the entire device could be programmed as a single register if desired.

7.6 Register Maps

Registers are programmed in REVERSE order from highest to lowest. Registers NOT shown in this table or marked as reserved can be written as all 0s unless otherwise stated. The POR value is the power on reset value that is assigned when the device is powered up or the SWRST bit is asserted.

Table 9. Register Map

| REGISTER | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | POR |
|----------|-----------|------------|----|----|----|----|-------|----------------|------|
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0x18 |
| 1 | 0x1 | Reserved | | | | | | | 0x00 |
| 2 | 0x2 | 0 | 0 | 0 | 0 | 0 | SWRST | POWERDOWN[1:0] | 0x00 |
| 3 - 15 | 0x3 - 0xF | Reserved | | | | | | | - |
| 16 | 0x10 | PLL_N[7:0] | | | | | | | 0x64 |

Register Maps (continued)

Table 9. Register Map (continued)

| REGISTER | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | POR |
|----------|-------------|-------------------|-----------------|-------------------|-------------------|------------------|-----------------|---------------|---------------|------|
| 17 | 0x11 | PLL_N[15:8] | | | | | | | | 0x00 |
| 18 | 0x12 | 0 | FRAC_ORDER[2:0] | | | FRAC_DITHER[1:0] | | PLL_N[17:16] | | 0x00 |
| 19 | 0x13 | FRAC_NUM[7:0] | | | | | | | | 0x00 |
| 20 | 0x14 | FRAC_NUM[15:8] | | | | | | | | 0x00 |
| 21 | 0x15 | FRAC_NUM[23:16] | | | | | | | | 0x00 |
| 22 | 0x16 | FRAC_DEN[7:0] | | | | | | | | 0x00 |
| 23 | 0x17 | FRAC_DEN[15:8] | | | | | | | | 0x00 |
| 24 | 0x18 | FRAC_DEN[23:16] | | | | | | | | 0x00 |
| 25 | 0x19 | PLL_R[7:0] | | | | | | | | 0x04 |
| 26 | 0x1A | PLL_R[15:8] | | | | | | | | 0x00 |
| 27 | 0x1B | 0 | FL_CSR[1:0] | | PFD_DLY[1:0] | | PLL_R_DIFF | 0 | OSC_2X | 0x08 |
| 28 | 0x1C | 0 | 0 | CPPOL | CPG[4:0] | | | | | 0x00 |
| 29 | 0x1D | FL_TOC[10:8] | | | FL_CPG[4:0] | | | | | 0x00 |
| 30 | 0x1E | 0 | CPM_FLAGL | CPM_THR_LOW[5:0] | | | | | | 0x0A |
| 31 | 0x1F | 0 | CPM_FLAGH | CPM_THR_HIGH[5:0] | | | | | | 0x32 |
| 32 | 0x20 | FL_TOC[7:0] | | | | | | | | 0x00 |
| 33 | 0x21 | DLD_PASS_CNT[7:0] | | | | | | | | 0x0F |
| 34 | 0x22 | DLD_TOL[2:0] | | | DLD_ERR_CNTR[4:0] | | | | | 0x00 |
| 35 | 0x23 | MOD_MUX[5] | 1 | MUXout_MUX[5] | TRIG2_MUX[5] | TRIG1_MUX[5] | 0 | 0 | 1 | 0x41 |
| 36 | 0x24 | TRIG1_MUX[4:0] | | | | | TRIG1_PIN[2:0] | | | 0x08 |
| 37 | 0x25 | TRIG2_MUX[4:0] | | | | | TRIG2_PIN[2:0] | | | 0x10 |
| 38 | 0x26 | MOD_MUX[4:0] | | | | | MOD_PIN[2:0] | | | 0x18 |
| 39 | 0x27 | MUXout_MUX[4:0] | | | | | MUXout_PIN[2:0] | | | 0x38 |
| 40 - 57 | 0x28 - 0x39 | Reserved | | | | | | | | - |
| 58 | 0x3A | RAMP_TRIG_A[3:0] | | | | 0 | RAMP_PM_EN | RAMP_CLK | RAMP_EN | 0x00 |
| 59 | 0x3B | RAMP_TRIG_C[3:0] | | | | RAMP_TRIG_B[3:0] | | | | 0x00 |
| 60 | 0x3C | RAMP_CMP0[7:0] | | | | | | | | 0x00 |
| 61 | 0x3D | RAMP_CMP0[15:8] | | | | | | | | 0x00 |
| 62 | 0x3E | RAMP_CMP0[23:16] | | | | | | | | 0x00 |
| 63 | 0x3F | RAMP_CMP0[31:24] | | | | | | | | 0x00 |
| 64 | 0x40 | RAMP_CMP0_EN[7:0] | | | | | | | | 0x00 |
| 65 | 0x41 | RAMP_CMP1[7:0] | | | | | | | | 0x00 |
| 66 | 0x42 | RAMP_CMP1[15:8] | | | | | | | | 0x00 |
| 67 | 0x43 | RAMP_CMP1[23:16] | | | | | | | | 0x00 |
| 68 | 0x44 | RAMP_CMP1[31:24] | | | | | | | | 0x00 |
| 69 | 0x45 | RAMP_CMP1_EN[7:0] | | | | | | | | 0x00 |
| 70 | 0x46 | 0 | FSK_TRIG[1:0] | | RAMP_LIMH[32] | RAMP_LIML[32] | FSK_DEV[32] | RAMP_CMP1[32] | RAMP_CMP0[32] | 0x08 |
| 71 | 0x47 | FSK_DEV[7:0] | | | | | | | | 0x00 |
| 72 | 0x48 | FSK_DEV[15:8] | | | | | | | | 0x00 |
| 73 | 0x49 | FSK_DEV[23:16] | | | | | | | | 0x00 |
| 74 | 0x4A | FSK_DEV[31:24] | | | | | | | | 0x00 |

Register Maps (continued)
Table 9. Register Map (continued)

| REGISTER | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | POR |
|----------|------|------------------------|----------|------------------|----------------------|----|-----------|-----------------|----|------|
| 75 | 0x4B | RAMP_LIMIT_LOW[7:0] | | | | | | | | 0x00 |
| 76 | 0x4C | RAMP_LIMIT_LOW[15:8] | | | | | | | | 0x00 |
| 77 | 0x4D | RAMP_LIMIT_LOW[23:16] | | | | | | | | 0x00 |
| 78 | 0x4E | RAMP_LIMIT_LOW[31:24] | | | | | | | | 0x00 |
| 79 | 0x4F | RAMP_LIMIT_HIGH[7:0] | | | | | | | | 0xFF |
| 80 | 0x50 | RAMP_LIMIT_HIGH[15:8] | | | | | | | | 0xFF |
| 81 | 0x51 | RAMP_LIMIT_HIGH[23:16] | | | | | | | | 0xFF |
| 82 | 0x52 | RAMP_LIMIT_HIGH[31:24] | | | | | | | | 0xFF |
| 83 | 0x53 | RAMP_COUNT[7:0] | | | | | | | | 0x00 |
| 84 | 0x54 | RAMP_TRIG_INC[1:0] | | RAMP_AUTO | RAMP_COUNT[12:8] | | | | | 0x00 |
| 85 | 0x55 | Reserved | | | | | | | | 0x00 |
| 86 | 0x56 | RAMP0_INC[7:0] | | | | | | | | 0x00 |
| 87 | 0x57 | RAMP0_INC[15:8] | | | | | | | | 0x00 |
| 88 | 0x58 | RAMP0_INC[23:16] | | | | | | | | 0x00 |
| 89 | 0x59 | RAMP0_DLY | RAMP0_FL | RAMP0_INC[29:24] | | | | | | 0x00 |
| 90 | 0x5A | RAMP0_LEN[7:0] | | | | | | | | 0x00 |
| 91 | 0x5B | RAMP0_LEN[15:8] | | | | | | | | 0x00 |
| 92 | 0x5C | RAMP0_NEXT[2:0] | | | RAMP0_NEXT_TRIG[1:0] | | RAMP0_RST | RAMP0_FLAG[1:0] | | 0x00 |
| 93 | 0x5D | RAMP1_INC[7:0] | | | | | | | | 0x00 |
| 94 | 0x5E | RAMP1_INC[15:8] | | | | | | | | 0x00 |
| 95 | 0x5F | RAMP1_INC[23:16] | | | | | | | | 0x00 |
| 96 | 0x60 | RAMP1_DLY | RAMP1_FL | RAMP1_INC[29:24] | | | | | | 0x00 |
| 97 | 0x61 | RAMP1_LEN[7:0] | | | | | | | | 0x00 |
| 98 | 0x62 | RAMP1_LEN[15:8] | | | | | | | | 0x00 |
| 99 | 0x63 | RAMP1_NEXT[2:0] | | | RAMP1_NEXT_TRIG[1:0] | | RAMP1_RST | RAMP1_FLAG[1:0] | | 0x00 |
| 100 | 0x64 | RAMP2_INC[7:0] | | | | | | | | 0x00 |
| 101 | 0x65 | RAMP2_INC[15:8] | | | | | | | | 0x00 |
| 102 | 0x66 | RAMP2_INC[23:16] | | | | | | | | 0x00 |
| 103 | 0x67 | RAMP2_DLY | RAMP2_FL | RAMP2_INC[29:24] | | | | | | 0x00 |
| 104 | 0x68 | RAMP2_LEN[7:0] | | | | | | | | 0x00 |
| 105 | 0x69 | RAMP2_LEN[15:8] | | | | | | | | 0x00 |
| 106 | 0x6A | RAMP2_NEXT[2:0] | | | RAMP2_NEXT_TRIG[1:0] | | RAMP2_RST | RAMP2_FLAG[1:0] | | 0x00 |
| 107 | 0x6B | RAMP3_INC[7:0] | | | | | | | | 0x00 |
| 108 | 0x6C | RAMP3_INC[15:8] | | | | | | | | 0x00 |
| 109 | 0x6D | RAMP3_INC[23:16] | | | | | | | | 0x00 |
| 110 | 0x6E | RAMP3_DLY | RAMP3_FL | RAMP3_INC[29:24] | | | | | | 0x00 |
| 111 | 0x6F | RAMP3_LEN[7:0] | | | | | | | | 0x00 |
| 112 | 0x70 | RAMP3_LEN[15:8] | | | | | | | | 0x00 |
| 113 | 0x71 | RAMP3_NEXT[2:0] | | | RAMP3_NEXT_TRIG[1:0] | | RAMP3_RST | RAMP3_FLAG[1:0] | | 0x00 |

Register Maps (continued)

Table 9. Register Map (continued)

| REGISTER | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | POR |
|-------------|---------------|------------------|----------|------------------|----------------------|----|-----------|-----------------|----|------|
| 114 | 0x72 | RAMP4_INC[7:0] | | | | | | | | 0x00 |
| 115 | 0x73 | RAMP4_INC[15:8] | | | | | | | | 0x00 |
| 116 | 0x74 | RAMP4_INC[23:16] | | | | | | | | 0x00 |
| 117 | 0x75 | RAMP4_DLY | RAMP4_FL | RAMP4_INC[29:24] | | | | | | 0x00 |
| 118 | 0x76 | RAMP4_LEN[7:0] | | | | | | | | 0x00 |
| 119 | 0x77 | RAMP4_LEN[15:8] | | | | | | | | 0x00 |
| 120 | 0x78 | RAMP4_NEXT[2:0] | | | RAMP4_NEXT_TRIG[1:0] | | RAMP4_RST | RAMP4_FLAG[1:0] | | 0x00 |
| 121 | 0x79 | RAMP5_INC[7:0] | | | | | | | | 0x00 |
| 122 | 0x7A | RAMP5_INC[15:8] | | | | | | | | 0x00 |
| 123 | 0x7B | RAMP5_INC[23:16] | | | | | | | | 0x00 |
| 124 | 0x7C | RAMP5_DLY | RAMP5_FL | RAMP5_INC[29:24] | | | | | | 0x00 |
| 125 | 0x7D | RAMP5_LEN[7:0] | | | | | | | | 0x00 |
| 126 | 0x7E | RAMP5_LEN[15:8] | | | | | | | | 0x00 |
| 127 | 0x7F | RAMP5_NEXT[2:0] | | | RAMP5_NEXT_TRIG[1:0] | | RAMP5_RST | RAMP5_FLAG[1:0] | | 0x00 |
| 128 | 0x80 | RAMP6_INC[7:0] | | | | | | | | 0x00 |
| 129 | 0x81 | RAMP6_INC[15:8] | | | | | | | | 0x00 |
| 130 | 0x82 | RAMP6_INC[23:16] | | | | | | | | 0x00 |
| 131 | 0x83 | RAMP6_DLY | RAMP6_FL | RAMP6_INC[29:24] | | | | | | 0x00 |
| 132 | 0x84 | RAMP6_LEN[7:0] | | | | | | | | 0x00 |
| 133 | 0x85 | RAMP6_LEN[15:8] | | | | | | | | 0x00 |
| 134 | 0x86 | RAMP6_NEXT[2:0] | | | RAMP6_NEXT_TRIG[1:0] | | RAMP6_RST | RAMP6_FLAG[1:0] | | 0x00 |
| 135 | 0x87 | RAMP7_INC[7:0] | | | | | | | | 0x00 |
| 136 | 0x88 | RAMP7_INC[15:8] | | | | | | | | 0x00 |
| 137 | 0x89 | RAMP7_INC[23:16] | | | | | | | | 0x00 |
| 138 | 0x8A | RAMP7_DLY | RAMP7_FL | RAMP7_INC[29:24] | | | | | | 0x00 |
| 139 | 0x8B | RAMP7_LEN[7:0] | | | | | | | | 0x00 |
| 140 | 0x8C | RAMP7_LEN[15:8] | | | | | | | | 0x00 |
| 141 | 0x8D | RAMP7_NEXT[2:0] | | | RAMP7_NEXT_TRIG[1:0] | | RAMP7_RST | RAMP7_FLAG[1:0] | | 0x00 |
| 142 - 32767 | 0x8E - 0x7FFF | Reserved | | | | | | | | 0x00 |

7.6.1 Register Field Descriptions

The following sections go through all the programmable fields and their states. Additional information is also available in the applications and feature descriptions sections as well. The POR column is the power on reset state that this field assumes if not programmed.

7.6.1.1 POWERDOWN and Reset Fields

Table 10. POWERDOWN and Reset Fields

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | |
|--------------------|----------|-----|--|--|
| POWERDOWN [1:0] | R2[1:0] | 0 | POWERDOWN Control | Value |
| | | | | POWERDOWN State |
| | | | | 0 Power Down, ignore CE |
| | | | | 1 Power Up, ignore CE |
| | | | | 2 Power State Defined by CE terminal state |
| SWRST | R2[2] | 0 | Software Reset. Setting this bit sets all registers to their POR default values. | 3 Reserved |
| | | | | Value |
| | | | | Reset State |
| | | | | 0 Normal Operation |
| | | | | 1 Register Reset |

7.6.1.2 Dividers and Fractional Controls

Table 11. Dividers and Fractional Controls

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | | |
|----------------------|---------------------|-----|--|--------------|-----------------------------|
| PLL_N [17:0] | R18[1] to R16[0] | 16 | Feedback N counter Divide value. Minimum count is 16. Maximum is 262132. Writing of the register R16 begins any ramp execution when RAMP_EN = 1. | | |
| FRAC_DITHER [1:0] | R18[3:2] | 0 | Dither used by the fractional modulator | Value | Dither |
| | | | | 0 | Weak |
| | | | | 1 | Medium |
| | | | | 2 | Strong |
| | | | | 3 | Disabled |
| FRAC_ORDER [2:0] | R18[6:4] | 0 | Fractional Modulator order | Value | Modulator Order |
| | | | | 0 | Integer Mode |
| | | | | 1 | 1st Order Modulator |
| | | | | 2 | 2nd Order Modulator |
| | | | | 3 | 3rd Order Modulator |
| | | | | 4 | 4th Order Modulator |
| | | | | 5-7 | Reserved |
| FRAC_NUM [23:0] | R21[7] to R19[0] | 0 | Fractional Numerator. This value should be less than or equal to the fractional denominator. | | |
| FRAC_DEN [23:0] | R24[7] to R22[0] | 0 | Fractional Denominator. If RAMP_EN = 1, this field is ignored and the denominator is fixed to 2 ²⁴ . | | |
| PLL_R [15:0] | R26[7] to R25[0] | 1 | Reference Divider value. Selecting 1 bypasses counter. | | |
| OSC_2X | R27[0] | 0 | Enables the Doubler before the Reference divider | Value | Doubler |
| | | | | 0 | Disabled |
| | | | | 1 | Enabled |
| PLL_R_DIFF | R27[2] | 0 | Enables the Differential R counter. This allows for higher OSCin frequencies, but restricts PLL_R to divides of 2, 4, 8 or 16. | Value | R Divider |
| | | | | 0 | Single-Ended |
| | | | | 1 | Differential |
| PFD_DLY [1:0] | R27[4:3] | 1 | Sets the charge pump minimum pulse width. This could potentially be a trade-off between fractional spurs and phase noise. Setting 1 is recommended for general use. | Value | Pulse Width |
| | | | | 0 | Reserved |
| | | | | 1 | 860 ps |
| | | | | 2 | 1200 ps |
| | | | | 3 | 1500 ps |
| CPG [4:0] | R28[4:0] | 0 | Charge pump gain | Value | Charge Pump State |
| | | | | 0 | Tri-State |
| | | | | 1 | 100 µA |
| | | | | 2 | 200 µA |
| | | | | ... | ... |
| | | | | 31 | 3100 µA |
| CPPOL | R28[5] | 0 | Charge pump polarity is used to accommodate VCO with either polarity so that feedback of the PLL is always correct. IF reference (R) output is faster than feedback (N) output, R28[5]==0 THEN charge pump will source current R28[5]==1 THEN charge pump will sink current | Value | Charge Pump Polarity |
| | | | | 0 | Positive |
| | | | | 1 | Negative |

7.6.1.2.1 Speed Up Controls (Cycle Slip Reduction and Fastlock)
Table 12. FastLock and Cycle Slip Reduction

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | | |
|------------------|-----------------------------|-----|---|--------------|----------------------------------|
| FL_CSR [1:0] | R27[6:5] | 0 | Cycle Slip Reduction (CSR) reduces the phase detector frequency by multiplying both the R and N counters by the CSR value while either the FastLock Timer is counting or the RAMPx_FL = 1 and the part is ramping. Care must be taken that the R and N divides remain inside the range of the counters. Cycle slip reduction is generally not recommended during ramping. | Value | CSR Value |
| | | | | 0 | Disabled |
| | | | | 1 | x 2 |
| | | | | 2 | x 4 |
| | | | | 3 | Reserved |
| FL_CPG [4:0] | R29[4:0] | 0 | Charge pump gain only when Fast Lock Timer is counting down or a ramp is running with RAMPx_FL = 1 | Value | Fastlock Charge Pump Gain |
| | | | | 0 | Tri-State |
| | | | | 1 | 100 μ A |
| | | | | 2 | 200 μ A |
| | | | | ... | ... |
| FL_TOC [10:0] | R29[7:5] and R32[7:0] | 0 | Fast Lock Timer. This counter starts counting when the user writes the PLL_N(Register R16). During this time the FL_CPG gain is sent to the charge pump, and the FL_CSR shifts the R and N counters if enabled. When the counter terminates, the normal CPG is presented and the CSR undo's the shifts to give a normal PFD frequency. | Value | Fastlock Timer Value |
| | | | | 0 | Disabled |
| | | | | 1 | 1 x 32 = 32 |
| | | | | ... | |
| | | | | 2047 | 2047 x 32 = 65504 |

7.6.2 Lock Detect and Charge Pump Monitoring

Table 13. Lock Detect and Charge Pump Monitor

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | | |
|-----------------------|----------|------|--|--------------|---|
| CPM_THR_LOW [5:0] | R30[5:0] | 0x0A | Charge pump voltage low threshold value. When the charge pump voltage is below this threshold, the LD goes low. | Value | Threshold |
| | | | | 0 | Lowest |
| | | | | ... | ... |
| | | | | 63 | Highest |
| CPM_FLAGL | R30[6] | - | This is a read only bit. Low indicates the charge pump voltage is below the minimum threshold. | Value | Flag Indication |
| | | | | 0 | Charge pump is below CPM_THR_LOW threshold |
| | | | | 1 | Charge pump is above CPM_THR_LOW threshold |
| CPM_THR_HIGH [5:0] | R31[5:0] | 0x32 | Charge pump voltage high threshold value. When the charge pump voltage is above this threshold, the LD goes low. | Value | Threshold |
| | | | | 0 | Lowest |
| | | | | ... | ... |
| | | | | 63 | Highest |
| CPM_FLAGH | R31[6] | - | This is a read only bit. Charge pump voltage high comparator reading. High indicates the charge pump voltage is above the maximum threshold. | Value | Threshold |
| | | | | 0 | Charge pump is below CPM_THR_HIGH threshold |
| | | | | 1 | Charge pump is above CPM_THR_HIGH threshold |
| DLD_PASS_CNT [7:0] | R33[7:0] | 0xFF | Digital Lock Detect Filter amount. There must be at least DLD_PASS_CNT good edges and less than DLD_ERR edges before the DLD is considered in lock. Making this number smaller speeds the detection of lock, but also allows a higher chance of DLD chatter. | | |
| DLD_ERR_CNT [4:0] | R34[4:0] | 0 | Digital Lock Detect error count. This is the maximum number of errors greater than DLD_TOL that are allowed before DLD is de-asserted. Although the default is 0, the recommended value is 4. | | |
| DLD_TOL [2:0] | R34[7:5] | 0 | Digital Lock detect edge window. If both N and R edges are within this window, it is considered a "good" edge. Edges that are farther apart in time are considered "error" edges. Window choice depends on phase detector frequency, charge pump minimum pulse width, fractional modulator order and the users desired margin. | Value | Window and f_{PD} Frequency |
| | | | | 0 | 1 ns (f _{PD} > 130 MHz) |
| | | | | 1 | 1.7 ns (80 MHz < f _{PD} ≤ 130 MHz) |
| | | | | 2 | 3 ns (60 MHz < f _{PD} ≤ 80 MHz) |
| | | | | 3 | 6 ns (45 MHz < f _{PD} ≤ 60 MHz) |
| | | | | 4 | 10 ns (30 MHz < f _{PD} ≤ 45 MHz) |
| | | | | 5 | 18 ns (f _{PD} ≤ 30 MHz) |
| | | | | 6 and 7 | Reserved |

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7.6.3 TRIG1, TRIG2, MOD, and MUXout Pins
Table 14. TRIG1, TRIG2, MOD, and MUXout Terminal States

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | | |
|---------------------|----------|-----|--|-------|--------------------------------------|
| TRIG1_PIN [2:0] | R36[2:0] | 0 | This is the terminal drive state for the TRIG1, TRIG2, MOD, and MUXout Pins | Value | Pin Drive State |
| | | | | 0 | TRISTATE (default) |
| | | | | 1 | Open Drain Output |
| | | | | 2 | Pullup / Pulldown Output |
| TRIG2_PIN [2:0] | R37[2:0] | 0 | | 3 | Reserved |
| MOD_PIN [2:0] | R38[2:0] | 0 | | 4 | GND |
| MUXout_PIN [2:0] | R39[2:0] | 0 | | 5 | Inverted Open Drain Output |
| | | | | 6 | Inverted Pullup / Pulldown Output |
| | | | | 7 | Input |

Table 15. TRIG1, TRIG2, MOD, and MUXout Selections

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | Value | MUX State |
|---|--|------------------------------|--|----------|-----------------------------------|
| | | | | 0 | GND |
| TRIG1_MUX [5:0] TRIG2_MUX [5:0] MOD_MUX [5:0] MUXout_MUX [5:0] | R36[7:3], R35[3] R37[7:3], R35[4] R38[7:3], R35[7] R39[7:3], R35[5] | 1 2 3 7 | These fields control what signal is muxed to or from the TRIG1, TRIG2, MOD, and MUXout pins. Some of the abbreviations used are: COMP0, COMP1: Comparators 0 and 1 LD, DLD: Lock Detect, Digital Lock Detect CPM: Charge Pump Monitor CPG: Charge Pump Gain CPUP: Charge Pump Up Pulse CPDN: Charge Pump Down Pulse | 1 | Input TRIG1 |
| | | | | 2 | Input TRIG2 |
| | | | | 3 | Input MOD |
| | | | | 4 | Output TRIG1 after synchronizer |
| | | | | 5 | Output TRIG2 after synchronizer |
| | | | | 6 | Output MOD after synchronizer |
| | | | | 7 | Output Read back |
| | | | | 8 | Output CMP0 |
| | | | | 9 | Output CMP1 |
| | | | | 10 | Output LD (DLD good AND CPM good) |
| | | | | 11 | Output DLD |
| | | | | 12 | Output CPMON good |
| | | | | 13 | Output CPMON too High |
| | | | | 14 | Output CPMON too low |
| | | | | 15 | Output RAMP LIMIT EXCEEDED |
| | | | | 16 | Output R Divide/2 |
| | | | | 17 | Output R Divide/4 |
| | | | | 18 | Output N Divide/2 |
| | | | | 19 | Output N Divide/4 |
| | | | | 20 | Reserved |
| | | | | 21 | Reserved |
| | | | | 22 | Output CMP0RAMP |
| | | | | 23 | Output CMP1RAMP |
| | | | | 24 | Reserved |
| | | | | 25 | Reserved |
| | | | | 26 | Reserved |
| | | | | 27 | Reserved |
| | | | | 28 | Output Faslock |
| | | | | 29 | Output CPG from RAMP |
| | | | | 30 | Output Flag0 from RAMP |
| | | | | 31 | Output Flag1 from RAMP |
| | | | | 32 | Output TRIGA |
| | | | | 33 | Output TRIGB |
| | | | | 34 | Output TRIGC |
| | | | | 35 | Output R Divide |
| | | | | 36 | Output CPUP |
| | | | | 37 | Output CPDN |
| | | | | 38 | Output RAMP_CNT Finished |
| | | | | 39 to 63 | Reserved |

7.6.4 Ramping Functions

Table 16. Ramping Functions

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | | |
|--|----------------------------------|-----|---|--------------|-----------------------------|
| RAMP_EN | R58[0] | 0 | Enables the RAMP functions. When this bit is set, the Fractional Denominator is fixed to 2 ²⁴ . RAMP execution begins at RAMP0 upon the PLL_N[7:0] write. The Ramp should be set up before RAMP_EN is set. | Value | Ramp |
| | | | | 0 | Disabled |
| | | | | 1 | Enabled |
| RAMP_CLK | R58[1] | 0 | RAMP clock input source. The ramp can be clocked by either the phase detector clock or the MOD terminal based on this selection. | Value | Source |
| | | | | 0 | Phase Detector |
| | | | | 1 | MOD Terminal |
| RAMP_PM_EN | R58[2] | 0 | Phase modulation enable. | Value | Modulation Type |
| | | | | 0 | Frequency Modulation |
| | | | | 1 | Phase Modulation |
| RAMP_TRIGA [3:0] RAMP_TRIGB [3:0] RAMP_TRIGC [3:0] | R58[7:4] R59[3:0] R59[7:4] | 0 | Trigger A, B, and C Sources | Value | Source |
| | | | | 0 | Never Triggers (default) |
| | | | | 1 | TRIG1 terminal rising edge |
| | | | | 2 | TRIG2 terminal rising edge |
| | | | | 3 | MOD terminal rising edge |
| | | | | 4 | DLD Rising Edge |
| | | | | 5 | CMP0 detected (level) |
| | | | | 6 | RAMPx_CPG Rising edge |
| | | | | 7 | RAMPx_FLAG0 Rising edge |
| | | | | 8 | Always Triggered (level) |
| | | | | 9 | TRIG1 terminal falling edge |
| | | | | 10 | TRIG2 terminal falling edge |
| | | | | 11 | MOD terminal falling edge |
| | | | | 12 | DLD Falling Edge |
| | | | | 13 | CMP1 detected (level) |
| | | | | 14 | RAMPx_CPG Falling edge |
| | | | | 15 | RAMPx_FLAG0 Falling edge |
| RAMP_CMP0 [32:0] | R70[0], R63[7] to R60[0] | 0 | Twos compliment of Ramp Comparator 0 value. Be aware of that the MSB is in Register R70. | | |
| RAMP_CMP0_EN [7:0] | R64[7:0] | 0 | Comparator 0 is active during each RAMP corresponding to the bit. Place a 1 for ramps it is active in and 0 for ramps it should be ignored. RAMP0 corresponds to R64[0], RAMP7 corresponds to R64[7] | | |
| RAMP_CMP1 [32:0] | R70[1], R68[7] to R65[0] | 0 | Twos compliment of Ramp Comparator 1 value. Be aware of that the MSB is in Register R70. | | |
| RAMP_CMP1_EN [7:0] | R69[7:0] | 0 | Comparator 1 is active during each RAMP corresponding to the bit. Place a 1 for ramps it is active in and 0 for ramps it should be ignored. RAMP0 corresponds to R64[0], RAMP7 corresponds to R64[7]. | | |
| FSK_TRIG [1:0] | R76[4] to R75[3] | 0 | Deviation trigger source. When this trigger source specified is active, the FSK_DEV value is applied. | Value | Trigger |
| | | | | 0 | Always Triggered |
| | | | | 1 | Trigger A |
| | | | | 2 | Trigger B |
| | | | | 3 | Trigger C |
| | | | | | |
| FSK_DEV [32:0] | R70[2], R74[7] to R71[0] | 0 | Twos compliment of the deviation value for frequency modulation and phase modulation. This value should be written with 0 when not used. Be aware that the MSB is in Register R70. | | |

Table 16. Ramping Functions (continued)

| FIELD | LOCATION | POR | DESCRIPTION AND STATES | | |
|---------------------------|--------------------------------|---------------------|---|--------------|---|
| RAMP_LIMIT_LOW [32:0] | R70[3], R78[7] to R75[0] | 0 | Two's complement of the ramp lower limit that the ramp can not go below. The ramp limit occurs before any deviation values are included. Care must be taken if the deviation is used and the ramp limit must be set appropriately. Be aware that the MSB is in Register R70. | | |
| RAMP_LIMIT_HIGH [32:0] | R70[4], R82[7] to R79[0] | 0x1FF FFFF FF | Two's complement of the ramp higher limit that the ramp can not go above. The ramp limit occurs before any deviation values are included. Care must be taken if the deviation is used and the ramp limit must be set appropriately. Be aware that the MSB is in Register R70. | | |
| RAMP_COUNT [12:0] | R84[4] to R83[0] | 0 | Number of RAMPs that is executed before a trigger or ramp enable is brought down. Load zero if this feature is not used. Counter is automatically reset when RAMP_EN goes from 0 to 1. | | |
| RAMP_AUTO | R84[5] | 0 | Automatically clear RAMP_EN when RAMP Count hits terminal count. | Value | Ramp |
| | | | | 0 | RAMP_EN unaffected by ramp counter (default) |
| | | | | 1 | RAMP_EN automatically brought low when ramp counter terminal counts |
| RAMP_TRIG_INC [1:0] | R84[7:6] | 0 | Increment Trigger source for RAMP Counter. To disable ramp counter, load a count value of 0. | Value | Source |
| | | | | 0 | Increments occur on each ramp transition |
| | | | | 1 | Increment occurs on Trigger A |
| | | | | 2 | Increment occurs on Trigger B |
| | | | | 3 | Increment occurs on Trigger C |

7.6.5 Individual Ramp Controls

These bits apply for all eight ramp segments. For the field names, x can be 0, 1, 2, 3, 4, 5, 6, or 7.

Table 17. Individual Ramp Controls

| FIELD | LOCATI ON | POR | DESCRIPTION AND STATES | | |
|----------------------------------|--------------|-----|--|-------|--|
| RAMPx _INC[29:0] | Varies | 0 | Signed ramp increment. | | |
| RAMPx_FL | Varies | 0 | This enables fastlock and cycle slip reduction for ramp x. | Value | CPG |
| | | | | 0 | Disabled |
| | | | | 1 | Enabled |
| RAMPx _DLY | Varies | 0 | During this ramp, each increment takes 2 f_{PD} cycles per LEN clock instead of the normal 1 f_{PD} cycle. Slows the ramp by a factor of 2. | Value | Clocks |
| | | | | 0 | 1 f_{PD} clock per RAMP tick.(default) |
| | | | | 1 | 2 f_{PD} clocks per RAMP tick. |
| RAMPx _LEN | Varies | 0 | Number of f_{PD} clocks (if DLY is 0) to continue to increment RAMP. 1 = 1 cycle, 2 = 2 cycles, etc. Maximum of 65536 cycles. | | |
| RAMPx _FLAG[1:0] | Varies | 0 | General purpose FLAGS sent out of RAMP at the start of a ramp pattern. | Value | Flag |
| | | | | 0 | Both FLAG1 and FLAG0 are zero. (default) |
| | | | | 1 | FLAG0 is set, FLAG1 is clear |
| | | | | 2 | FLAG0 is clear, FLAG1 is set |
| | | | | 3 | Both FLAG0 and FLAG1 are set. |
| RAMPx _RST | Varies | 0 | Forces a clear of the ramp accumulator at the start of a ramp pattern. This is used to erase any accumulator creep that can occur depending on how the ramps are defined. | Value | Reset |
| | | | | 0 | Disabled |
| | | | | 1 | Enabled |
| RAMPx_ NEXT _TRIG [1:0] | Varies | 0 | Determines what event is necessary to cause the state machine to go to the next ramp. It can be set to when the RAMPx_LEN counter reaches zero or one of the events for Triggers A, B, or C. | Value | Operation |
| | | | | 0 | RAMPx_LEN |
| | | | | 1 | Trigger A |
| | | | | 2 | Trigger B |
| | | | | 3 | Trigger C |
| RAMPx _NEXT[2:0] | Varies | 0 | The next RAMP to execute when the length counter times out | | |

8 Applications and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LMX2491 can be used in a broad class of applications such as generating a single frequency for a high frequency clock, generating a tunable range of frequencies, or generating swept waveforms that can be used in applications such as radar.

8.2 Typical Application

Figure 14 is an example that could be used in a typical application.

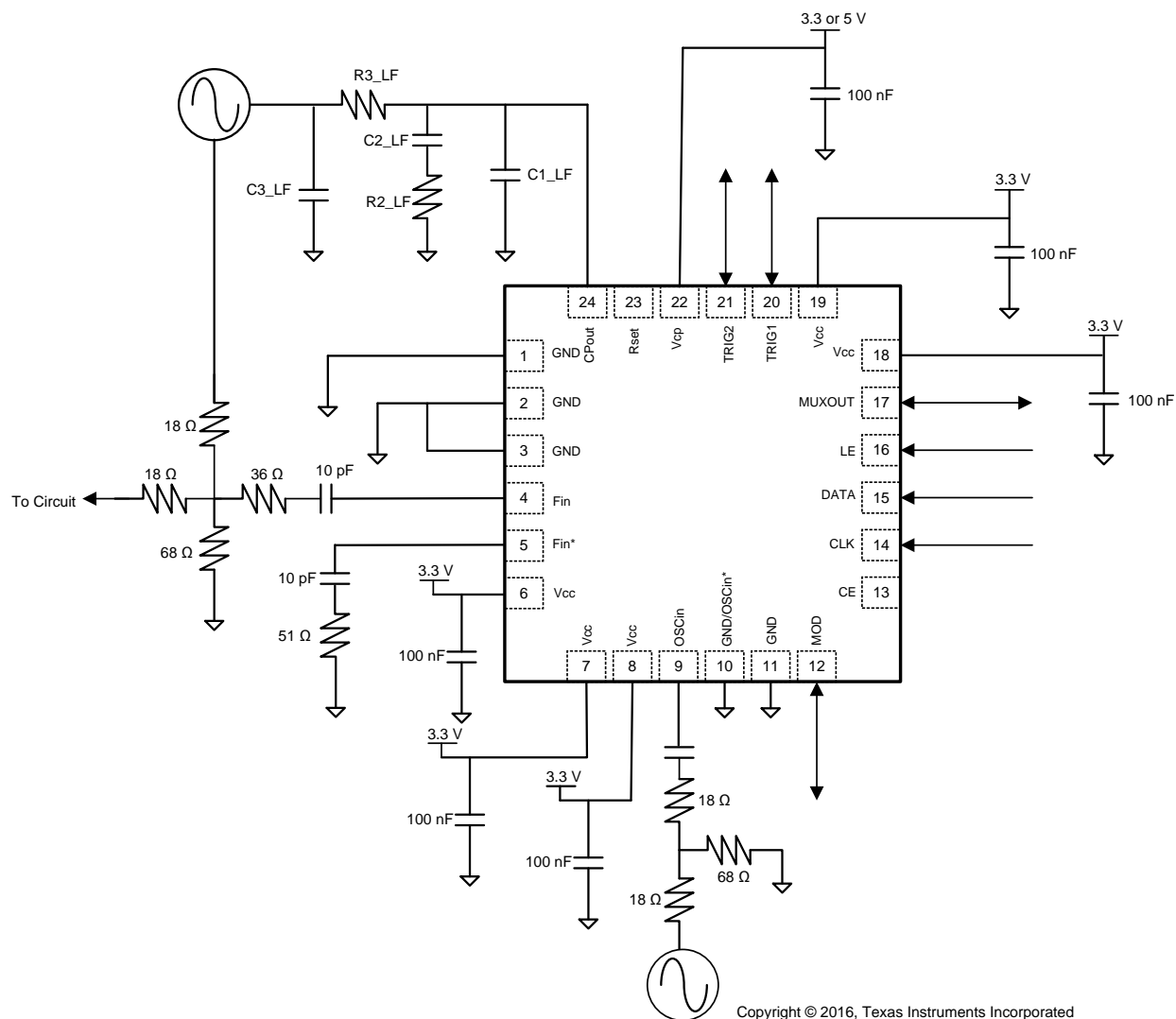


Figure 14. Typical Schematic

Typical Application (continued)

8.2.1 Design Requirements

For these examples, it will be assumed that there is a 100 MHz input signal and the output frequency is between 1500 and 1520 MHz with various modulated waveforms.

Table 18. Design Requirements

| PARAMETER | SYMBOL | VALUE | COMMENTS |
|--------------------------|--------------------|-----------------|---|
| Input frequency | f_{OSCin} | 100 MHz | |
| Phase detector frequency | f_{PD} | 50 MHz | There are many possibilities, but this choice gives good performance. |
| VCO frequency | f_{VCO} | 1500 - 1520 MHz | In the different examples, the VCO frequency is actually changing. However, the same loop filter design can be used for all examples. Unmodulated VCO frequency or steady state VCO frequency without ramp is 1500 MHz. |
| VCO gain | K_{VCO} | 65 MHz/V | This parameter has nothing to do with the LMX2491, but is rather set by the external VCO choice. |

8.2.2 Detailed Design Procedure

The first step is to calculate the reference divider (PLL_R) and feedback divider (PLL_N) values as shown in the table that follows.

Table 19. Detailed Design Procedure

| PARAMETER | SYMBOL AND CALCULATIONS | VALUE | COMMENTS |
|------------------------|---|--------------|--|
| Average VCO frequency | $f_{\text{VCOavg}} = (f_{\text{VCOmax}} + f_{\text{VCOmin}}) / 2$ | 1510 MHz | To design a loop filter, one designs for a fixed VCO value, although it is understood that the VCO will tune around. This typical value is usually chosen as the average VCO frequency |
| VCO gain | K_{VCO} | 65 MHz/V | This parameter has nothing to do with LMX2491, but is rather set by the external VCO choice. In this case, it was the CVCO55BE-1400-1624 VCO. |
| VCO input capacitance | C_{VCO} | 120 pF | This parameter has nothing to do with LMX2491, but is rather set by the external VCO choice. |
| PLL loop bandwidth | LBW | 380 kHz | This bandwidth is very wide to allow the VCO frequency to be modulated. |
| Charge pump gain | CPG | 3.1 mA | Using the larger gain allows a wider loop bandwidth and gives good phase performance. |
| R-divider | $\text{PLL_R} = f_{\text{OSCin}} / f_{\text{PD}}$ | 2 | |
| N-divider | $\text{PLL_N} = f_{\text{VCO}} / f_{\text{PD}}$ | 96 | |
| Loop filter components | C1_LF | 68 pF | These were calculated by TI PLLatinum Simulator Tool. |
| | C2_LF | 3.9 nF | |
| | C3_LF | 150 pF | |
| | R2_LF | 390 Ω | |
| | R3_LF | 150 Ω | |

Once a loop filter bandwidth is chosen, the external loop filter component values can be calculated with a tool such as [PLLatinum Simulator Tool](#). It is also highly recommended to look at the EVM User's Guide. [TICS Pro](#) software is an excellent starting point and example to see how to program this device.

8.2.3 TICS Pro Basic Setup

In the following application examples, TICS Pro is used to program the device to implement different ramp profiles. The following procedure shows how to setup TICS Pro to put the device to lock to 1500 MHz without modulation or ramp.

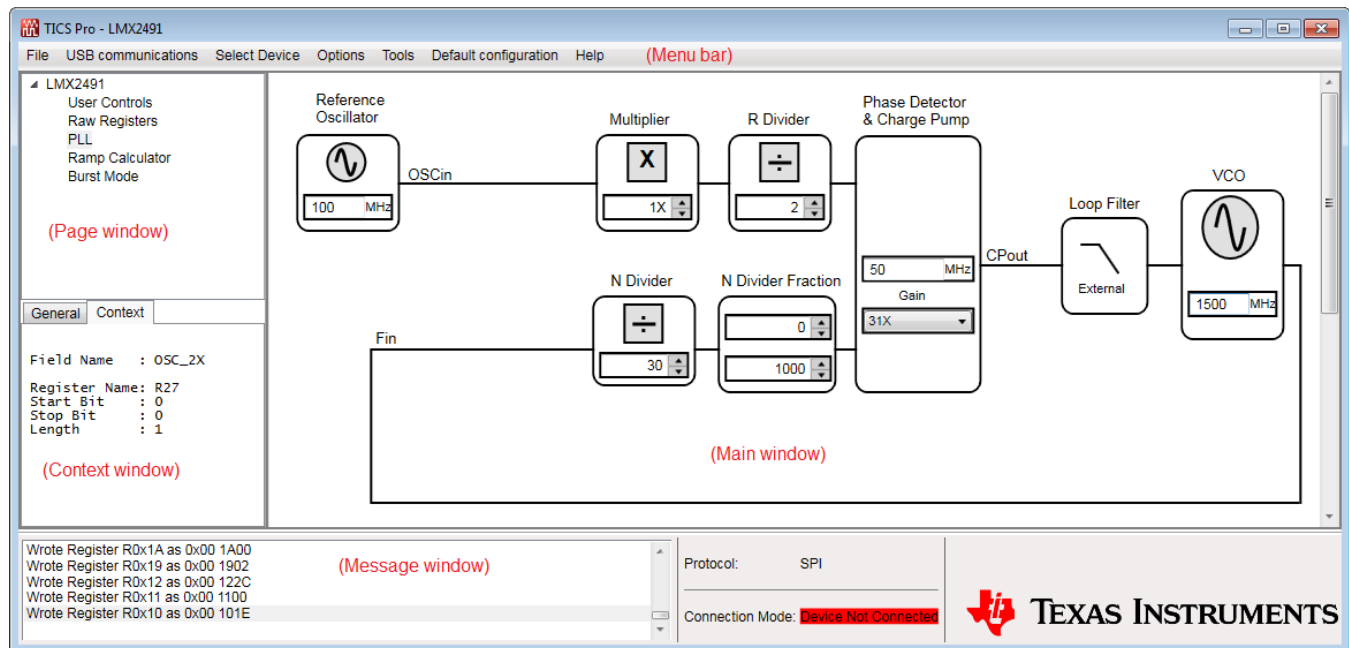


Figure 15. TICS Pro

1. In the Menu bar, click Select Device and then select LMX2491.
2. In the Menu bar, click Default Configuration and then select Default Mode.
3. In the Page window, click PLL.
4. In the Main window, change R Divider value to 2 and VCO value to 1500.
5. In the Menu bar, click USB Communications and then click Write All Registers. The device is now locked to 1500 MHz.

Other TICS Pro fundamentals:

- When a particular content in the Main window is moused-over, the Context window will show a brief description of that content.
- An alternative method to write all registers is press the Ctrl key and L key from the keyboard.
- Whenever a value is updated in the Main window, the Message window will show which register is being updated

8.2.4 Frequency Shift Keying Example

FSK operation requires an external input trigger signal at either MOD, TRIG1 or TRIG2 pin. In this example, MOD pin is selected as the Trigger A source. A 20 kHz square-wave clock will be applied to MOD pin to toggle the RF output to switch between 1500 MHz and 1502 MHz. That is, FSK frequency deviation is 2 MHz. The following register bits are required to set in order to initiate FSK operation.

Table 20. FSK Register Settings

| PARAMETER | REGISTER BIT | SETTING | COMMENTS |
|---------------------------|--------------|---------------------|--|
| Frequency deviation | FSK_DEV | 671089 = 2 MHz | Frequency deviation = $(f_{PD} \times \text{FSK_DEV}) / 2^{24}$ |
| MOD pin characteristic | MOD_PIN | 7 = Input | Set MOD pin as an input pin |
| FSK trigger source | FSK_DEV_TRIG | 1 = Trigger A | Use Trigger A to trigger FSK |
| Trigger source definition | RAMP_TRIGA | 3 = MOD Rising Edge | When there is a L-to-H transition at MOD pin, the set amount of frequency deviation will be added to the unmodulated carrier |
| Enable ramp | RAMP_EN | 1 = Enabled | Activate FSK operation |

The image shows two screenshots of the LMX2491 configuration tool. The top screenshot is the 'General' tab, and the bottom screenshot is the 'General Ramp Controls' tab. In the 'General' tab, the 'MOD_PIN' dropdown is highlighted with a red box and set to 'Input'. In the 'General Ramp Controls' tab, the 'RAMP_EN' checkbox is checked, 'RAMP_TRIGA' is set to 'MOD Rising Edge', 'FSK_DEV_TRIG' is set to 'Trigger A', and 'FSK_DEV' is set to '671089'. These four items are highlighted with red boxes.

Figure 16. TICS Pro FSK Configuration

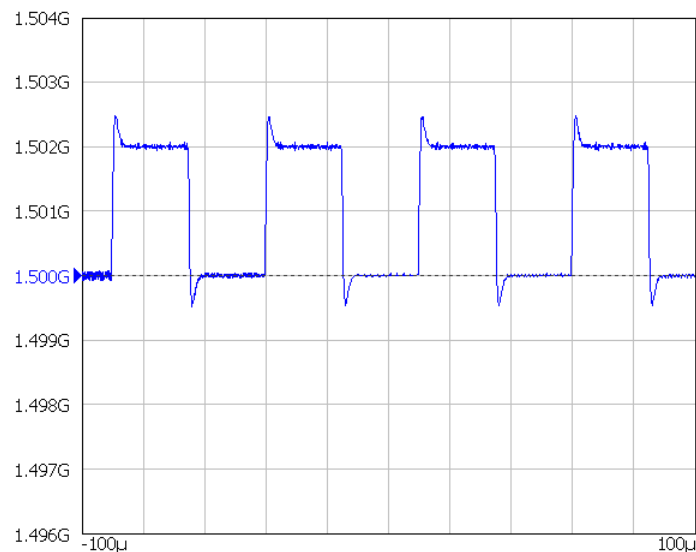


Figure 17. Frequency Shift Keying Example

8.2.5 Single Sawtooth Ramp Example

In this example, Trigger B is used to trigger the ramp generator of LMX2491 to generate a single frequency ramp between 1500 MHz and 1520 MHz. Ramp duration is 50 μ s. The ramp will finish and return back to 1500 MHz immediately when the output frequency reaches 1520 MHz. Trigger 1 pin is assigned as Trigger B source.

Two ramp segments are setup to create this one-time single ramp. RAMP0 is used to establish a trigger for the second ramp segment - RAMP1. When a trigger signal is received, RAMP1 will execute and bring the output frequency to 1520 MHz in 50 μ s.

Table 21. Single Sawtooth Ramp Register Settings

| PARAMETER | REGISTER BIT | SETTING | COMMENTS |
|--------------------------------------|----------------------|--|--|
| Set maximum ramp frequency threshold | RAMP_LIMIT_HIGH | 16777216 = 1550 MHz | This threshold frequency can be anything above 1520 MHz. The fractional numerator is equal to 0 at 1550 MHz. The N-Divider difference between 1500 MHz and 1550 MHz is 1. From Equation 1, this threshold is equal to $0 + (1 \times 2^{24}) = 16777216$. |
| Set minimum ramp frequency threshold | RAMP_LIMIT_LOW | 8573157376 = 1450 MHz | This threshold frequency can be anything below 1500 MHz. This threshold is equal to -16777216 . This is a 33-bit long register, 2's complement is therefore equal to 8573157376. |
| Number of ramp in each ramp segment | RAMP0_LEN, RAMP1_LEN | 2500 = for ramp duration equals 50 μ s | The duration of RAMP0 is not matter, for demonstration convenience, it has the same ramp duration as RAMP1. During ramp, LMX2491 ramp generator will increment its output frequency once per phase detector cycle. For ramp duration of 50 μ s and $f_{PD} = 50$ MHz, there are 2500 ramps [= 50 μ s / (1 / 50 MHz)]. |
| Frequency change per ramp in RAMP0 | RAMP0_INC | 0 | Since the output frequency would not change in RAMP0, there is no frequency increment. |
| Set next ramp segment | RAMP0_NEXT | 1 = RAMP1 | Set RAMP1 as the next ramp segment following RAMP0. |
| Set next ramp segment trigger source | RAMP0_NEXT_TRIG | 2 = Trigger B | Use Trigger B to trigger the execution of RAMP1. |
| Rest fractional numerator | RAMP0_RST | 1 = Reset | RAMP0 will execute again after RAMP1 is finished but RAMP1 does not end at 1500 MHz, a reset to the fractional numerator is required before RAMP0 is executed. |
| Frequency change per ramp in RAMP1 | RAMP1_INC | 2684 = 8 kHz | Between 1500 MHz and 1520 MHz, there are 2500 ramps. For each ramp, the output frequency will increment by $20 \text{ MHz} / 2500 = 8 \text{ kHz}$. For $f_{PD} = 50$ MHz and fractional denominator = 2^{24} , fractional numerator is incremented by a value of $(8 \text{ kHz} \times 2^{24}) / 50 \text{ MHz} \approx 2684$. |
| Set next ramp segment | RAMP1_NEXT | 0 = RAMP0 | Set RAMP0 as the next ramp segment following RAMP1. |
| Set next ramp segment trigger source | RAMP1_NEXT_TRIG | 0 = TOC Timeout | After RAMP1 is finished, the next ramp segment will execute immediately. |
| Trigger source definition | RAMP_TRIGB | 1 = TRIG1 Rising Edge | When there is a L-to-H transition at TRIG1 pin, RAMP1 will execute. |
| TRIG1 pin characteristic | TRIG1_PIN | 7 = Input | Set TRIG1 pin as an input pin. |

It is recommended to use the Ramp Calculator in TICS Pro to create the ramp profile. TICS Pro will calculate the ramp-related register values automatically.

Limits and Comparators

VCO Output Limit
High 1550 MHz
Low 1450 MHz

Valid In Ramp
0 1 2 3 4 5 6 7

CMP0 1500 MHz
CMP1 1500 MHz

Don't care because they are not enabled

| Register Programming | | |
|----------------------|---------------|----------------|
| Sign | Decimal Value | 2's Complement |
| High 0 | 16777216 | 16777216 |
| Low 1 | 16777216 | 8573157376 |

| Register Programming | | |
|----------------------|---------------|----------------|
| Sign | Decimal Value | 2's Complement |
| CMP0 0 | 0 | 0 |
| CMP1 0 | 0 | 0 |

Ramps

Ramp Enable ☒

| Ramp Number | Actual Start Frequency (MHz) | Desired End Frequency (MHz) | Duration (us) | Dly | Next Ramp | Start next ramp after | RST | FL | Flags | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|------------------------------|-----------------------------|---------------|-----|-----------|-----------------------|-------------------------------------|----|----------|----------------------------|--------|-----------------|
| 0 | 1500 | 1500 | 50 | | 1 | Trigger B | <input checked="" type="checkbox"/> | | Disabled | 1500 | 2500 | 0 |
| 1 | 1500 | 1520 | 50 | | 0 | TOC Timeout | | | Disabled | 1519.99735832 | 2500 | 2684 |
| 2 | -1 | 10500 | 100 | | 0 | TOC Timeout | | | Disabled | -1 | 5000 | 10000 |
| 3 | -1 | 10500 | 100 | | 0 | TOC Timeout | | | Disabled | -1 | 5000 | 10000 |
| 4 | -1 | 10500 | 100 | | 0 | TOC Timeout | | | Disabled | -1 | 5000 | 10000 |
| 5 | -1 | 10500 | 100 | | 0 | TOC Timeout | | | Disabled | -1 | 5000 | 10000 |
| 6 | -1 | 10500 | 100 | | 0 | TOC Timeout | | | Disabled | -1 | 5000 | 10000 |
| 7 | -1 | 10500 | 100 | | 0 | TOC Timeout | | | Disabled | -1 | 5000 | 10000 |

Ramp Count 0 Ramp Auto ☐ RAMP_AUTO Ramp In Source Ramp Transition

Trigger Source A Disabled
Trigger Source B TRIG1 Rising Edge
Trigger Source C Disabled

FSK Trigger Disabled
FSK Deviation 0
Phase Mod. En ☐ RAMP_PM_EN

| Increment (2s complement) | | |
|---------------------------|------|-----|
| 0 | 0 | 4 0 |
| 1 | 2684 | 5 0 |
| 2 | 0 | 6 0 |
| 3 | 0 | 7 0 |

Figure 18. TICS Pro Ramp Calculator

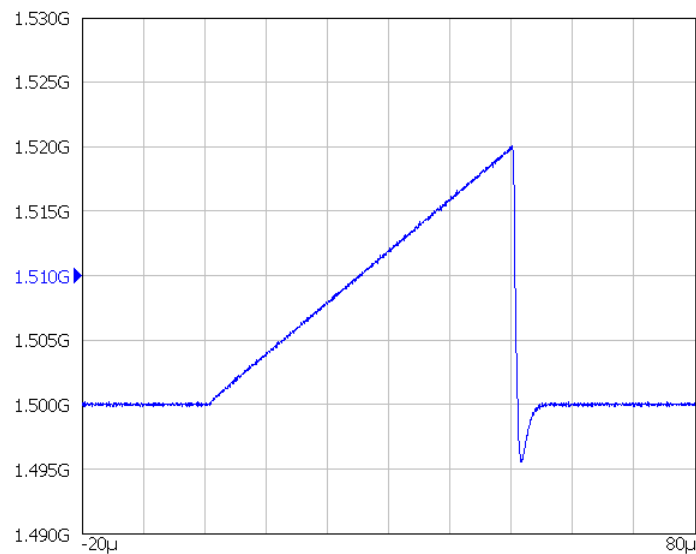


Figure 19. Single Sawtooth Ramp Example

8.2.6 Continuous Sawtooth Ramp Example

This example shows how to generate a continuous sawtooth ramp. Only one ramp segment is necessary as it will loop back to itself.

Ramps Ramp Enable ☒

| Ramp Number | Actual Start Frequency (MHz) | Desired End Frequency (MHz) | Duration (us) | Dly | Next Ramp | Start next ramp after | RST | FL | Flags | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|------------------------------|-----------------------------|---------------|--------------------------|-----------|-----------------------|-------------------------------------|--------------------------|----------|----------------------------|--------|-----------------|
| 0 | 1500 | 1520 | 50 | <input type="checkbox"/> | 0 | TOC Timeout | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Disabled | 1519.997358322500 | 2500 | 2684 |
| 1 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 2 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 3 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 4 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 5 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 6 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 7 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |

Ramp Count: 0 Ramp Auto: ☐ RAMP_AUTO Ramp In Source: Ramp Transition

Trigger Source A: Disabled Trigger Source B: Disabled Trigger Source C: Disabled

FSK Trigger: Disabled FSK Deviation: 0 Phase Mod. En: ☐ RAMP_PM_EN

Increment (2s complement)

| | | | |
|---|------|---|---|
| 0 | 2684 | 4 | 0 |
| 1 | 0 | 5 | 0 |
| 2 | 0 | 6 | 0 |
| 3 | 0 | 7 | 0 |

Figure 20. Continuous Sawtooth Ramp Configuration

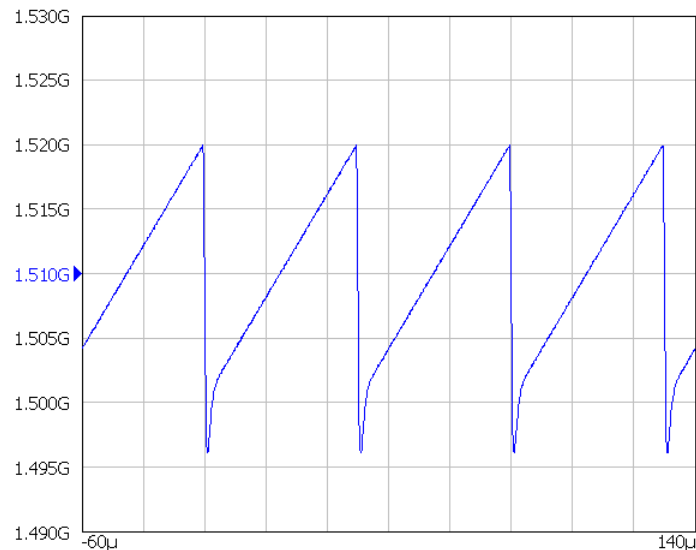


Figure 21. Continuous Sawtooth Ramp Example

8.2.7 Continuous Sawtooth Ramp with FSK Example

A ramp and FSK can coexist at the same time. Since the amount of FSK is added to the instantaneous carrier, the FSK will appear at the envelope of the ramp. Furthermore, a ramp and FSK are two independent operations, their register settings can be combined in a single configuration setting. That is, when RAMP_EN is enabled, both frequency ramp and FSK will be activated together.

Ramps Ramp Enable ☒

| Ramp Number | Actual Start Frequency (MHz) | Desired End Frequency (MHz) | Duration (us) | Dly | Next Ramp | Start next ramp after | RST | FL | Flags | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|------------------------------|-----------------------------|---------------|--------------------------|-----------|-----------------------|-------------------------------------|--------------------------|----------|----------------------------|--------|-----------------|
| 0 | 1500 | 1520 | 1000 | <input type="checkbox"/> | 0 | TOC Timeout | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Disabled | 1519.9675559650000 | 134 | |
| 1 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 2 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 3 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 4 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 5 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 6 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 7 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |

Ramp Count 0 Ramp Auto ☐ RAMP_AUTO Ramp In Source Ramp Transition

Trigger Source A MOD Rising Edge FSK Trigger Trigger A
 Trigger Source B Disabled FSK Deviation 335544
 Trigger Source C Disabled Phase Mod. En ☐ RAMP_PM_EN

Increment (2s complement)
 0 134 4 0
 1 0 5 0
 2 0 6 0
 3 0 7 0

Frequency ramp

Figure 22. Continuous Sawtooth Ramp with FSK Configuration

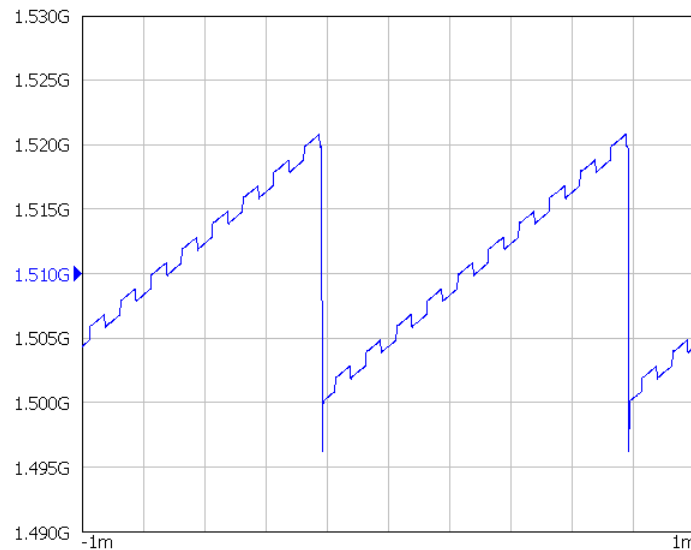


Figure 23. Continuous Sawtooth Ramp with FSK Example

8.2.8 Continuous Triangular Ramp Example

Two ramp segments are used to create this ramp pattern. RAMP0 ramps from 1500 MHz to 1520 MHz. RAMP1 brings the frequency back to 1500 MHz and then RAMP0 starts over again. Since RAMP1 already brought the frequency back to 1500 MHz, which is also the start frequency of RAMP0, a reset to fractional numerator is not required.

Limits and Comparators

VCO Output Limit
High 1550 MHz
Low 1450 MHz

Valid In Ramp
0 1 2 3 4 5 6 7

CMP0 1505 MHz ☒ ☒ ☐ ☐ ☐ ☐ ☐ ☐

CMP1 1515 MHz ☒ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Ramp Comparators are enabled

| Sign | Decimal Value | 2's Complement |
|--------|---------------|----------------|
| High 0 | 16777216 | 16777216 |
| Low 1 | 16777216 | 8573157376 |

| Sign | Decimal Value | 2's Complement |
|--------|---------------|----------------|
| CMP0 0 | 1677721 | 1677721 |
| CMP1 0 | 5033164 | 5033164 |

Ramps

Ramp Enable ☒

No reset here

| Ramp Number | Actual Start Frequency (MHz) | Desired End Frequency (MHz) | Duration (us) | Dly | Next Ramp | Start next ramp after | RST | FL | Flags | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|------------------------------|-----------------------------|---------------|--------------------------|-----------|-----------------------|--------------------------|--------------------------|----------|----------------------------|--------|-----------------|
| 0 | 1500 | 1520 | 25 | <input type="checkbox"/> | 1 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1520.00108361 | 1250 | 5369 |
| 1 | 1520.00108361 | 1500 | 25 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1500 | 1250 | -5369 |
| 2 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 3 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 4 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 5 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 6 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 7 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |

Ramp Count 0 Ramp Auto ☐ RAMP_AUTO Ramp In Source Ramp Transition

Trigger Source A Disabled Trigger Source B Disabled Trigger Source C Disabled

FSK Trigger Disabled FSK Deviation 0 Phase Mod. En ☐ RAMP_PM_EN

| Increment (2s complement) | 0 | 1 | 2 | 3 |
|---------------------------|---|---|---|---|
| 5369 | 4 | 0 | | |
| 1073736455 | 5 | 0 | | |
| 0 | 6 | 0 | | |
| 0 | 7 | 0 | | |

Figure 24. Continuous Triangular Ramp Configuration

Ramp comparators are enabled so as to output flag signals when the threshold frequencies are hit. MOD pin is assigned for CMP0 while TRIG1 pin is assigned for CMP1. RAMP_CMP0_EN is equal to 3 because ramp segment 0 and 1 are monitored.

General

PLL Controls
CPPOL Positive
FRAC_DITHER Disabled
FRAC_ORDER 2nd Order Modulator
PFD_DLY 860 ps
OSC_DIFFR ☐

POWERDOWN
Powered Up
SWRST ☐
CPM_THR_HIGH 50
CPM_THR_LOW 10

Readback
☐ CPM_FLAGL
☐ CPM_FLAGH

Lock Detect
DLD_PASS_CNT 32
DLD_TOL 1 ns
DLD_ERR_CNT 4

Output Pins
MUXout_MUX Output DLD&CPMON
TRIG2_PIN Tristate
TRIG1_MUX Output CMP1
MOD_PIN Output - PP
TRIG2_MUX Input TRIG2
MUXout_PIN Output - PP
MOD_MUX Output CMP0
TRIG1_PIN Output - PP

Speed Up Controls
FL_TOC 0
FL_CSR Disabled
FL_CPG Disabled

General Ramp Controls
☐ RAMP_CLK
☒ RAMP_EN
RAMP_TRIGA Disabled
RAMP_TRIGB Disabled
RAMP_TRIGC Disabled
RAMP_CNT 0
RAMP_TRIG_INC Ramp Transition

Frequency and Phase Module
☐ RAMP_AUTO
☐ RAMP_PM_EN
FSK_DEV_TRIG Disabled
FSK_DEV 0

Ramp Comparators
RAMP_CMP0 1677721
RAMP_CMP0_EN 3
RAMP_CMP1_EN 1

Ramp Limits
RAMP_LIMIT_LOW 8573157376
RAMP_LIMIT_HIGH 16777216

Figure 25. Ramp Comparators Configuration

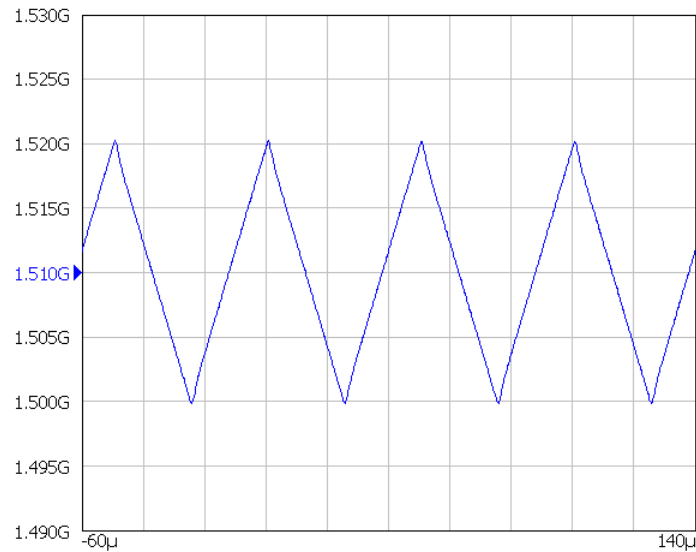


Figure 26. Continuous Triangular Ramp Example

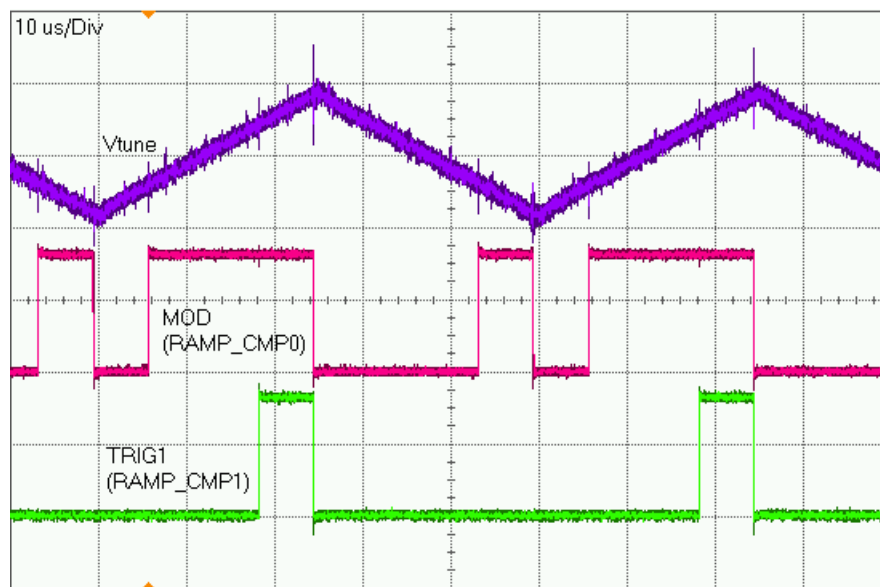


Figure 27. Ramp Comparators Output Flags

8.2.9 Continuous Trapezoid Ramp Example

This is a long-ramp example, the ramp duration is 2 ms. Since $f_{PD} = 50$ MHz, 100000 ramps are required for each ramp segment. However, LMX2491 supports up to a maximum ramp length (RAMPx_LEN) of 65536 only. There are two solutions to resolve this problem:

1. Reduce phase detector frequency. For example, reduce f_{PD} to 25 MHz, then the required RAMPx_LEN becomes 50000.
2. Enable RAMPx_DLY. When this register bit is set, the ramp generator will ramp every 2 phase detector cycles instead of the normal 1 f_{PD} cycle. In this example, this bit is set and as a result, RAMPx_LEN is 50000.

Four ramp segments are used to construct the ramp pattern. Again there is no need to reset the fractional numerator because the last ramp end frequency is equal to the first ramp start frequency.

Ramps Ramp Enable ☒ **RAMPx_DLY**

| Ramp Number | Actual Start Frequency (MHz) | Desired End Frequency (MHz) | Duration (us) | Dly | Next Ramp | Start next ramp after | RST | FL | Flags | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|------------------------------|-----------------------------|---------------|-------------------------------------|-----------|-----------------------|--------------------------|--------------------------|----------|----------------------------|--------|-----------------|
| 0 | 1500 | 1500 | 2000 | <input checked="" type="checkbox"/> | 1 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1500 | 50000 | 0 |
| 1 | 1500 | 1520 | 2000 | <input checked="" type="checkbox"/> | 2 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1519.9675559 | 50000 | 134 |
| 2 | 1519.9675559 | 1520 | 2000 | <input checked="" type="checkbox"/> | 3 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1519.9675559 | 50000 | 0 |
| 3 | 1519.9675559 | 1500 | 2000 | <input checked="" type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1500 | 50000 | -134 |
| 4 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 5 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 6 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 7 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |

Ramp Count: 0 Ramp Auto: ☐ RAMP_AUTO Ramp In Source: Ramp Transition

Trigger Source A: Disabled Trigger Source B: Disabled Trigger Source C: Disabled

FSK Trigger: Disabled FSK Deviation: 0 Phase Mod. En: ☐ RAMP_PM_EN

Increment (2s complement)

| | | | |
|---|------------|---|---|
| 0 | 0 | 4 | 0 |
| 1 | 134 | 5 | 0 |
| 2 | 0 | 6 | 0 |
| 3 | 1073741690 | 7 | 0 |

Figure 28. Continuous Trapezoid Ramp Configuration

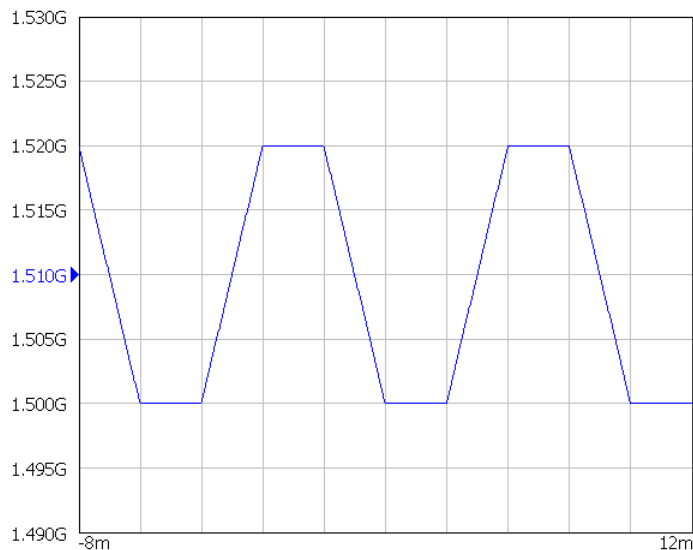


Figure 29. Continuous Trapezoid Ramp Example

8.2.10 Arbitrary Waveform Ramp Example

An arbitrary ramp waveform can be easily constructed with the 8 ramp segments provided in LMX2491. LMX2491 also provides flag signals output to indicate the start of a ramp. This example used the MOD pin to initiate the ramp and used TRIG1 and TRIG2 as the output flags to indicate the status of the ramp.

Ramps Ramp Enable ☒

| Ramp Number | Actual Start Frequency (MHz) | Desired End Frequency (MHz) | Duration (us) | Dly | Next Ramp | Start next ramp after | RST | FL | Flags | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|------------------------------|-----------------------------|---------------|-------------------------------------|-----------|-----------------------|--------------------------|--------------------------|---------------|----------------------------|--------|-----------------|
| 0 | 1500 | 1500 | 50 | <input type="checkbox"/> | 1 | Trigger A | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1500 | 2500 | 0 |
| 1 | 1500 | 1520 | 2000 | <input checked="" type="checkbox"/> | 2 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Flag0 | 1519.9675559 | 50000 | 134 |
| 2 | 1519.9675559 | 1510 | 500 | <input type="checkbox"/> | 3 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Flag1 | 1509.9837779 | 25000 | -134 |
| 3 | 1509.9837779 | 1510 | 500 | <input type="checkbox"/> | 4 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1509.9837779 | 25000 | 0 |
| 4 | 1509.9837779 | 1500 | 500 | <input type="checkbox"/> | 5 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Flag0 & Flag1 | 1500 | 25000 | -134 |
| 5 | 1500 | 1500 | 500 | <input type="checkbox"/> | 1 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | 1500 | 25000 | 0 |
| 6 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |
| 7 | -1 | 10500 | 100 | <input type="checkbox"/> | 0 | TOC Timeout | <input type="checkbox"/> | <input type="checkbox"/> | Disabled | -1 | 5000 | 10000 |

Ramp Count: 0 Ramp Auto: ☐ RAMP_AUTO Ramp In Source: Ramp Transition

Trigger Source A: MOD Rising Edge Trigger Source B: Disabled Trigger Source C: Disabled

FSK Trigger: Disabled FSK Deviation: 0 Phase Mod. En: ☐ RAMP_PM_EN

Increment (2s complement)

| Ramp Number | Actual End Frequency (MHz) | Length | Increment (dec) |
|-------------|----------------------------|--------|-----------------|
| 0 | 0 | 4 | 1073741690 |
| 1 | 134 | 5 | 0 |
| 2 | 1073741690 | 6 | 0 |
| 3 | 0 | 7 | 0 |

Figure 30. Arbitrary Waveform Ramp Configuration

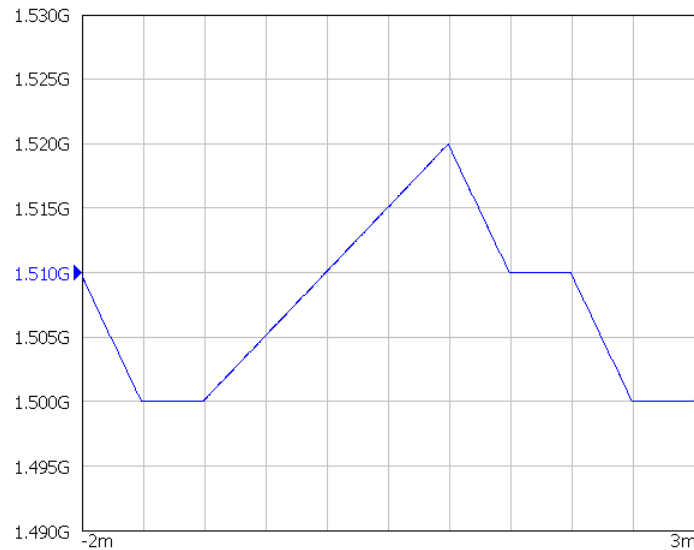


Figure 31. Arbitrary Waveform Ramp Example

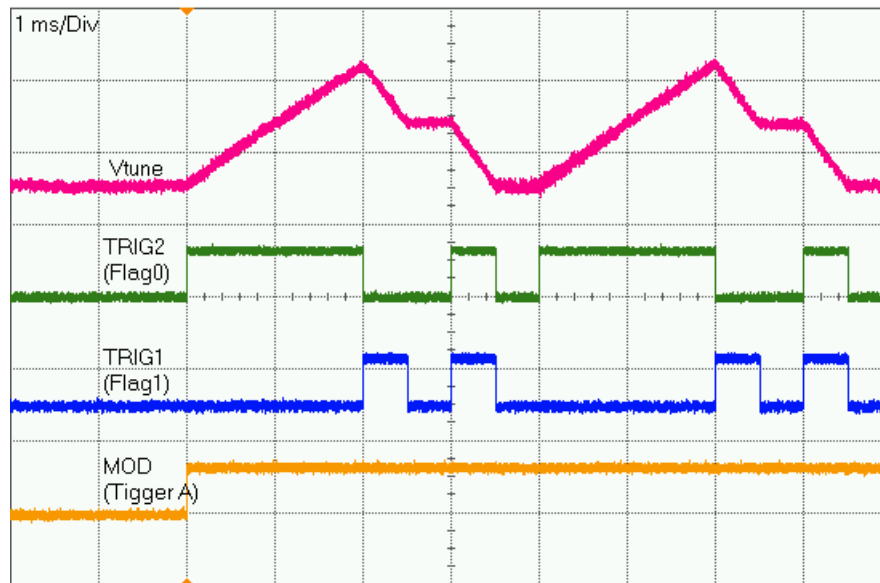


Figure 32. Arbitrary Waveform Ramp Timing

9 Power Supply Recommendations

For power supplies, TI recommends placing 100 nF close to each of the power supply pins. If fractional spurs are a large concern, using a ferrite bead to each of these power supply pins can reduce spurs to a small degree.

10 Layout

10.1 Layout Guidelines

For layout examples, the EVM instructions are the most comprehensive document. In general, the layout guidelines are similar to most other PLL devices. For the high frequency Fin pin, it is recommended to use 0402 components and match the trace width to these pad sizes. Also the same needs to be done on the Fin* pin. If layout is easier to route the signal to Fin* instead of Fin, then this is acceptable as well.

10.2 Layout Example

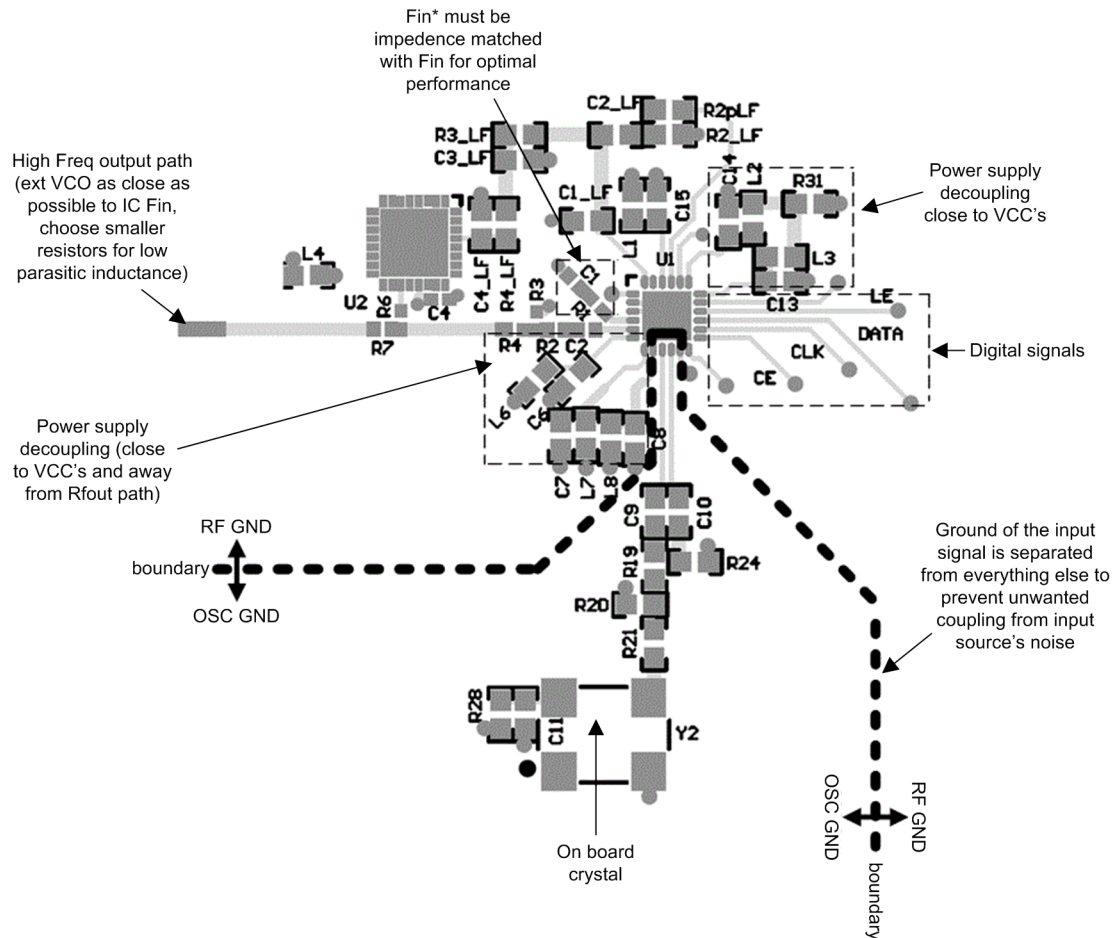


Figure 33. Layout Recommendation

11 器件和文档支持

11.1 器件支持

11.1.1 开发支持

德州仪器 (TI) 提供多款开发辅助软件工具，包括 TICS Pro 编程辅助工具、PLLatinum Simulator Tool 回路滤波器设计辅助工具以及相位噪声/毛刺仿真辅助工具。所有这些工具均可从以下网址获得：www.ti.com。

11.2 文档支持

11.2.1 相关文档

相关文档如下：

- [《AN-1879 分数 N 频率合成》](#)（文献编号：SNAA062）
- [《PLL 性能仿真和设计》](#)

11.3 接收文档更新通知

要接收文档更新通知，请导航至德州仪器 TI.com.cn 上的器件产品文件夹。请单击右上角的通知我 进行注册，即可收到任意产品信息更改每周摘要。有关更改的详细信息，请查看任意已修订文档中包含的修订历史记录。

11.4 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 [《使用条款》](#)。

TI E2E™ 在线社区 TI 的工程师对工程师 (E2E) 社区。此社区的创建目的在于促进工程师之间的协作。在 e2e.ti.com 中，您可以咨询问题、分享知识、拓展思路并与同行工程师一道帮助解决问题。

设计支持 TI 参考设计支持 可帮助您快速查找有帮助的 E2E 论坛、设计支持工具以及技术支持的联系信息。

11.5 商标

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

11.6 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

11.7 Glossary

[SLYZ022](#) — TI Glossary.

This glossary lists and explains terms, acronyms, and definitions.

12 机械、封装和可订购信息

以下页中包括机械封装、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据发生变化时，我们可能不会另行通知或修订此文档。如欲获取此产品说明书的浏览器版本，请参阅左侧的导航栏。

PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|-----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| LMX2491RTWR | Active | Production | WQFN (RTW) 24 | 1000 LARGE T&R | Yes | SN | Level-3-260C-168 HR | -40 to 85 | X2491 |
| LMX2491RTWR.A | Active | Production | WQFN (RTW) 24 | 1000 LARGE T&R | Yes | SN | Level-3-260C-168 HR | -40 to 85 | X2491 |
| LMX2491RTWT | Active | Production | WQFN (RTW) 24 | 250 SMALL T&R | Yes | SN | Level-3-260C-168 HR | -40 to 85 | X2491 |
| LMX2491RTWT.A | Active | Production | WQFN (RTW) 24 | 250 SMALL T&R | Yes | SN | Level-3-260C-168 HR | -40 to 85 | X2491 |

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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TAPE AND REEL INFORMATION



*All dimensions are nominal

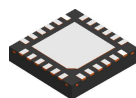
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LMX2491RTWR | WQFN | RTW | 24 | 1000 | 177.8 | 12.4 | 4.3 | 4.3 | 1.3 | 8.0 | 12.0 | Q1 |
| LMX2491RTWT | WQFN | RTW | 24 | 250 | 177.8 | 12.4 | 4.3 | 4.3 | 1.3 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

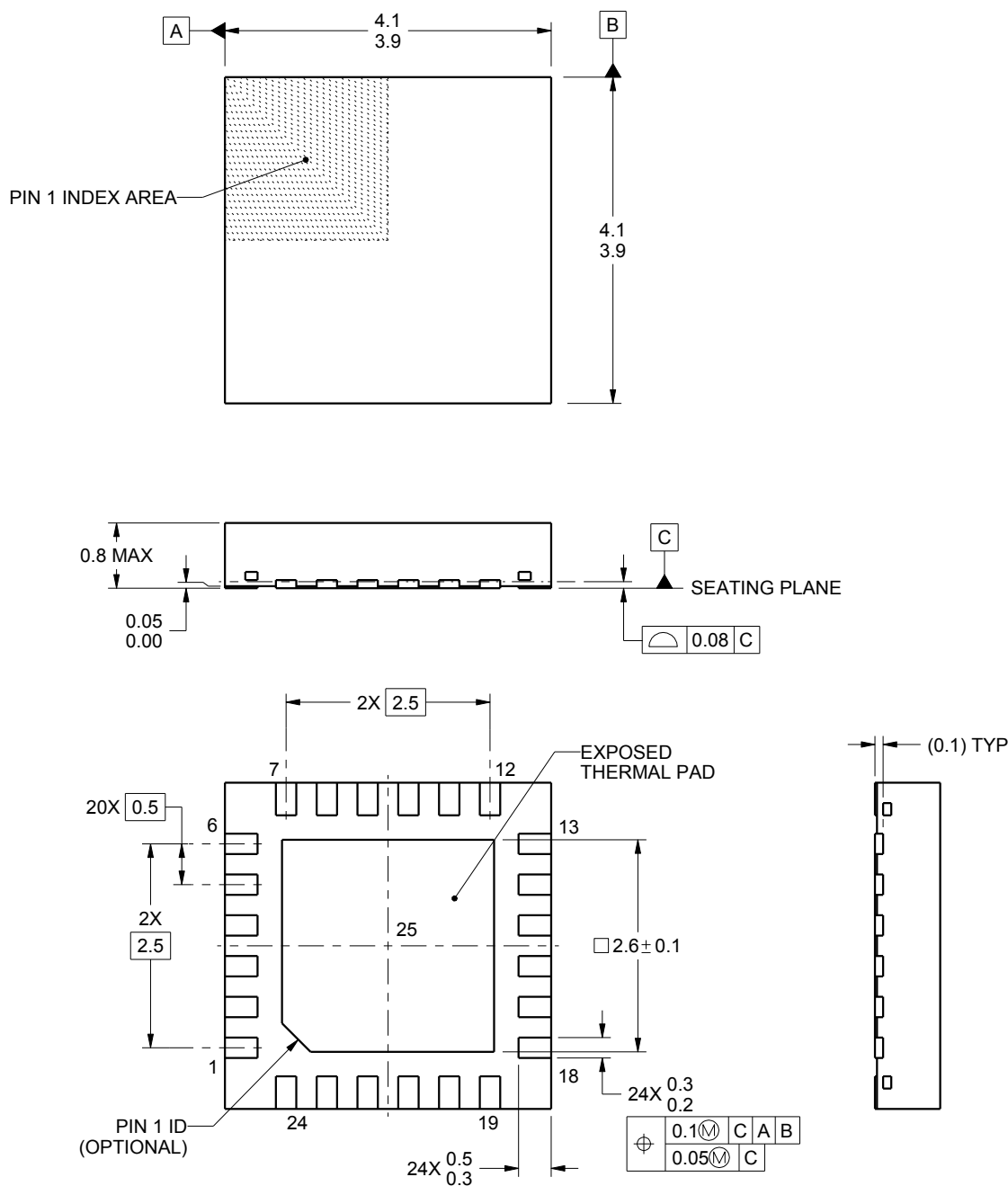
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LMX2491RTWR | WQFN | RTW | 24 | 1000 | 208.0 | 191.0 | 35.0 |
| LMX2491RTWT | WQFN | RTW | 24 | 250 | 208.0 | 191.0 | 35.0 |



PACKAGE OUTLINE

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



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NOTES:

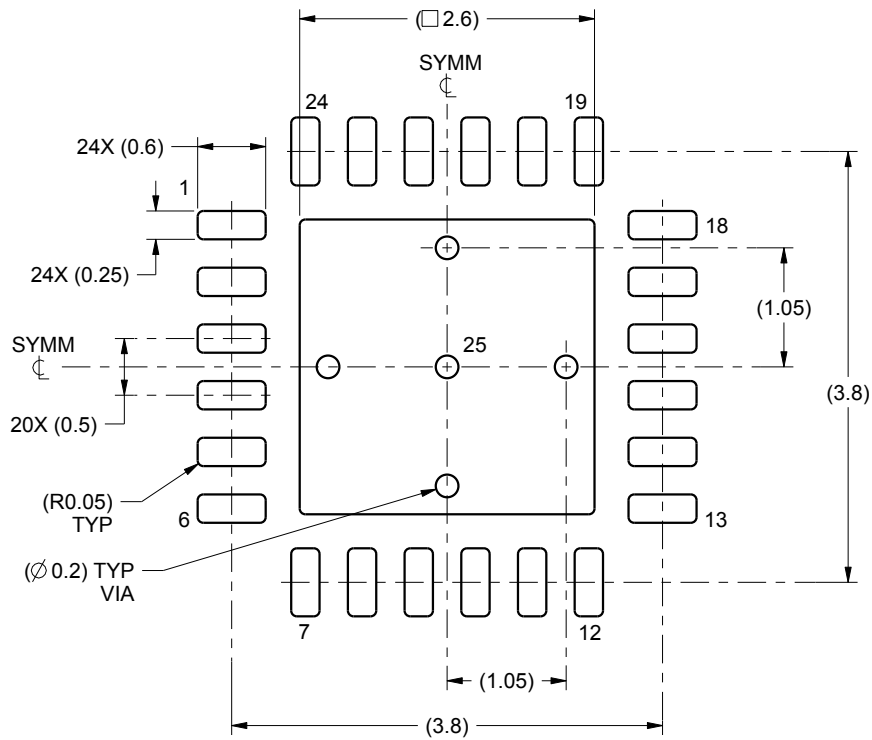
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

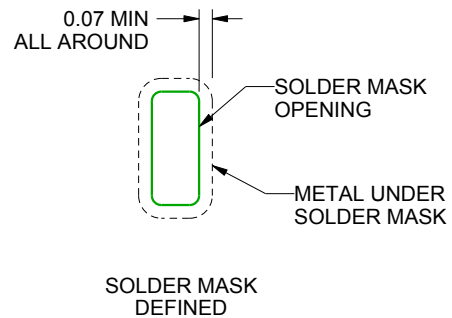
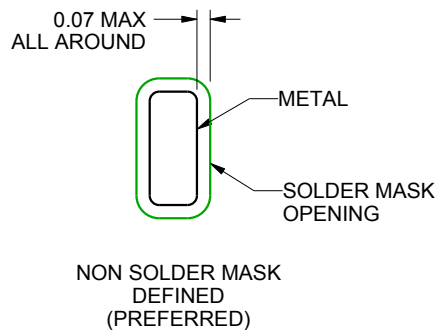
RTW0024A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
SCALE:15X



SOLDER MASK DETAILS

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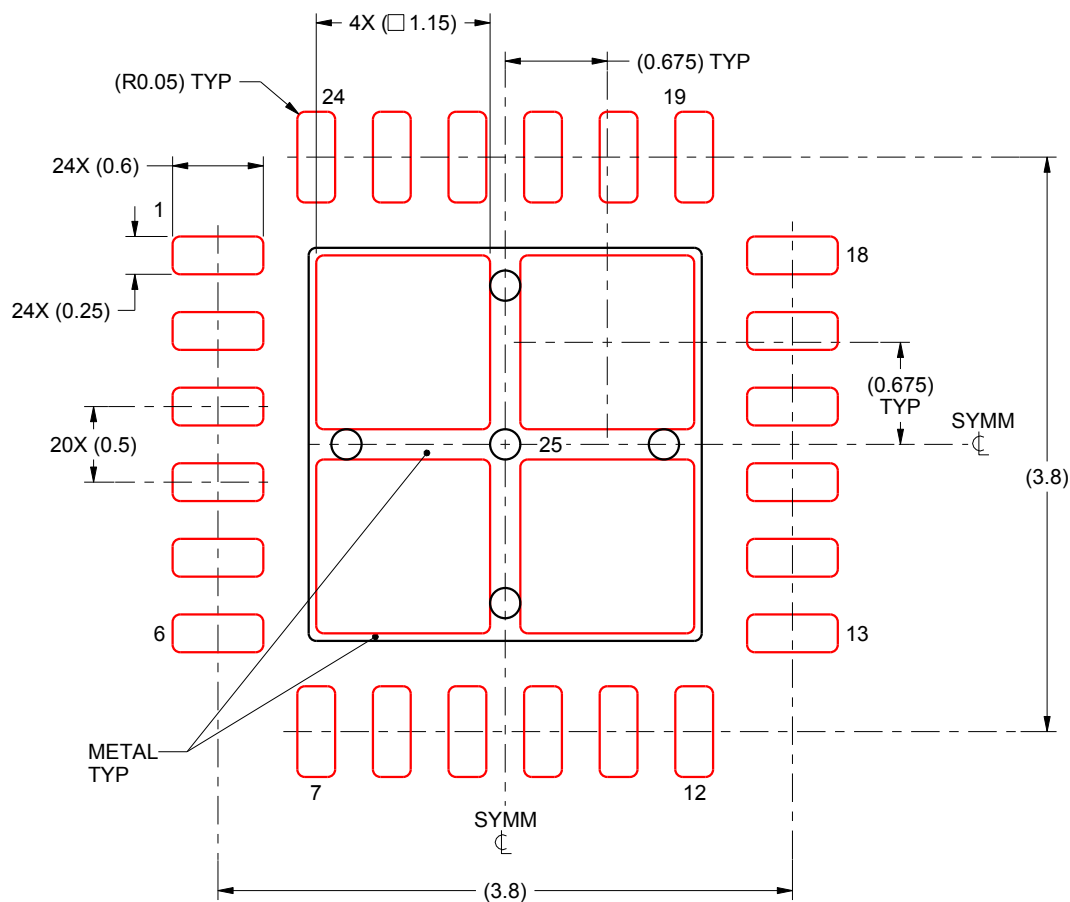
NOTES: (continued)

- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sluea271).

RTW0024A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 25:
78% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:20X

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NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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