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RF2054

LOW POWER PLL AND VCO WITH INTEGRATED MIXERS

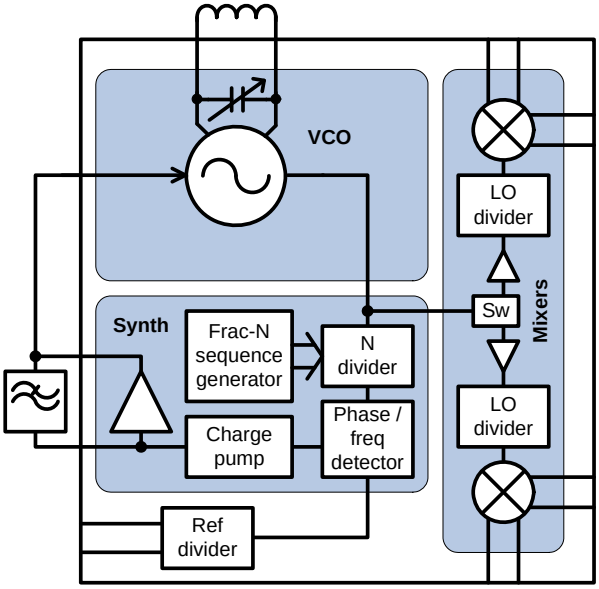
Package: QFN, 32-Pin, 5mm x 5mm

Features

- Fractional-N Synthesizer
- Very Fine Frequency Resolution 1.5Hz for 26MHz Reference
- LO Frequency Range 940MHz to 1000MHz
- Low Phase Noise VCO
- Integrated LO Buffers
- Two Wideband RF Mixers
- Mixer Frequency Range 30MHz to 2500MHz
- Mixer Input IP3 +12dBm
- Mixer Bias Adjustable for Low Power Operation
- 2.1V to 2.3V Power Supply
- Low Current Consumption 45mA typ. at 2.2V
- 3-Wire Serial Interface

Applications

- Band Shifters
- Super-Heterodyne Radios
- Diversity Receivers
- Wireless Telemetry



Functional Block Diagram

Product Description

The RF2054 is a low power, high performance, frequency conversion chip with integrated local oscillator (LO) and a pair of RF mixers. The synthesizer includes an integrated fractional-N phase locked loop that can control the VCO to produce a low phase noise and low spurious LO signal with very fine frequency resolution. The VCO output can then be divided by one, two, or four in the LO divider, the output of which drives the mixer, which converts the signal into the required frequency band. The LO generation block has been optimized to operate with the VCO covering the frequency range from 940MHz to 1000MHz, set by the value of the external inductor used. The mixers are broadband and can operate from 30MHz to 2500MHz at the input and output, enabling both up and down conversion. An external reference source of between 10MHz and 26MHz can be used with the RF2054.

All on-chip registers are controlled through a simple three-wire serial interface. The RF2054 has been characterized for 2.2V operation and low power consumption. It is available in a plastic 32-pin, 5mm x 5mm QFN package.

Optimum Technology Matching® Applied

☐ GaAs HBT	☐ SiGe BiCMOS	☐ GaAs pHEMT	☐ GaN HEMT
☐ GaAs MESFET	☐ Si BiCMOS	☑ Si CMOS	☐ BiFET HBT
☐ InGaP HBT	☐ SiGe HBT	☐ Si BJT	☐ LDMOS

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Absolute Maximum Ratings

Parameter	Rating	Unit
Supply Voltage (V_{DD})	-0.5 to +3.6	V
Input Voltage (V_{IN}), any Pin	-0.3 to V_{DD} +0.3	V
RF/IF Mixer Input Power	+15	dBm
Operating Temperature Range	-40 to +85	°C
Storage Temperature Range	-65 to +150	°C

Caution! ESD sensitive device.

Exceeding any one or a combination of the Absolute Maximum Rating conditions may cause permanent damage to the device. Extended application of Absolute Maximum Rating conditions to the device may reduce device reliability. Specified typical performance or functional operation of the device under Absolute Maximum Rating conditions is not implied.

RFMD Green: RoHS compliant per EU Directive 2002/95/EC, halogen free per IEC 61249-2-21, < 1000ppm each of antimony trioxide in polymeric materials and red phosphorus as a flame retardant, and <2% antimony in solder.

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
ESD Requirements					
Human Body Model					
General	2000			V	
RF Pins	1000			V	
Machine Model					
General	200			V	
RF Pins	100			V	
Operating Conditions					
Supply Voltage (V_{DD})	2.1	2.2	2.3	V	
Temperature (T_{OP})	-20		+75	°C	
Logic Inputs/Outputs					V_{DD} = Supply to DIG_VDD pin
Input Low Voltage	-0.3		+0.5	V	
Input High Voltage	1.5		V_{DD}	V	
Input Low Current	-10		+10	uA	Input = 0V
Input High Current	-10		+10	uA	Input = V_{DD}
Output Low Voltage	0		0.2 * V_{DD}	V	
Output High Voltage	0.8 * V_{DD}		V_{DD}	V	
Load Resistance	10			kΩ	
Load Capacitance			20	pF	
Static					V_{DD} = +2.2V, MIX_IDD = 001
Supply Current (I_{DD})					
One Mixer Enabled	42	45	48	mA	FULLD = 0
Both Mixers Enabled		57		mA	FULLD = 1
Standby		3		mA	Reference oscillator and bandgap only.
Power Down Current		140		μA	ENBL = 0 and REF_STBY = 0
Mixer					Mixer output driving 4:1 balun, MIX_IDD = 001
Gain (DUT Only)	-6	-3.5	-2	dB	Not including balun losses.
Gain		-6.5		dB	Including balun losses, 1GHz to 2GHz conversion.
Noise Figure		11		dB	
IIP_3		+12		dBm	
Pin1dB		+1		dBm	
RF and IF Port Frequency Range	30		2500	MHz	
Mixer Input Return Loss		10		dB	100Ω differential

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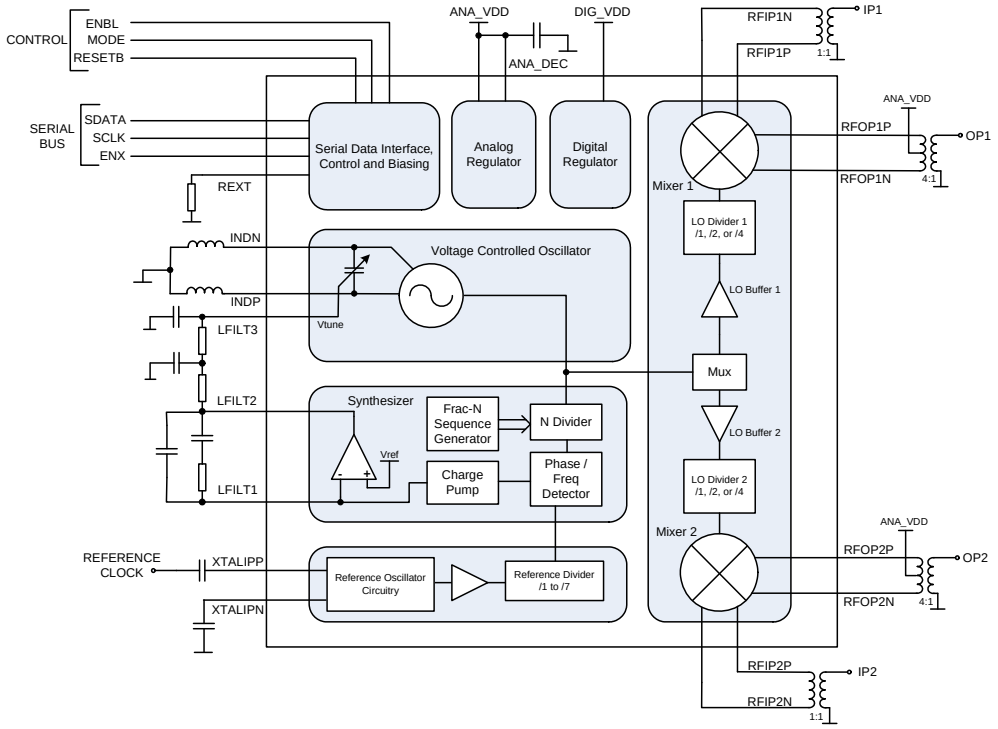
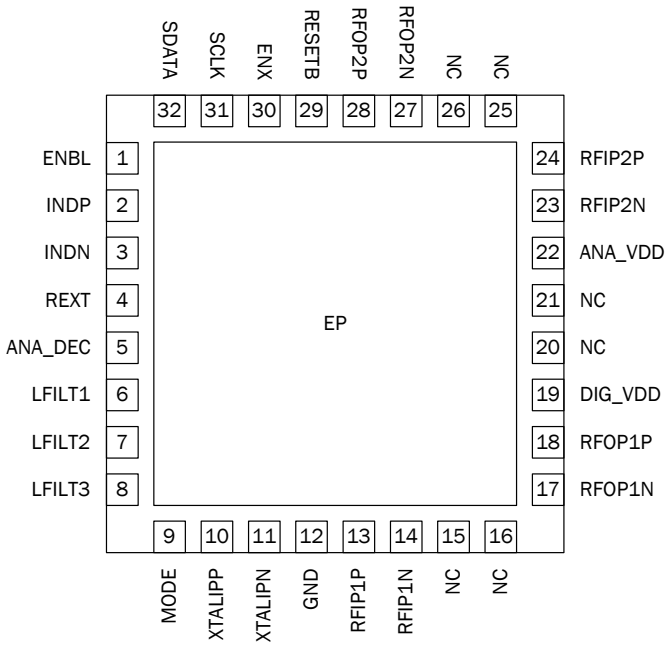
Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Voltage Controlled Oscillator					3.3nH (*2) VCO Inductor
VCO Frequency Range	900		1150	MHz	
Open Loop Phase-Noise at 1MHz Offset					
960MHz LO Frequency		-134		dBc/Hz	
VCO Tuning Gain					
960MHz LO Frequency		15		MHz/V	
Reference Oscillator					
External Reference Frequency	10	21	26	MHz	
Reference Divider Ratio	1		7		
External Reference Input Level	500	800	1200	mV_{P-P}	AC-coupled
Local Oscillator					3.3nH (*2) VCO Inductor
Synthesizer Output Frequency	940		1000	MHz	
Phase Detector Frequency			26	MHz	
Closed Loop Phase-Noise at 960MHz LO					21MHz phase detector frequency
10kHz Offset		-90		dBc/Hz	
100kHz Offset		-100		dBc/Hz	
1MHz Offset		-130		dBc/Hz	

Detailed Functional Block Diagram



Pin Out



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Pin Names and Descriptions

Pin	Name	Description
1	ENBL	Ensure that the ENBL high voltage level is not greater than V_{DD}. An RC low-pass filter could be used to reduce digital noise.
2	INDP	VCO 3 differential inductor. Connect to ground for DC bias.
3	INDN	VCO 3 differential inductor. Connect to ground for DC bias.
4	REXT	External bandgap bias resistor. Connect a 51kΩ resistor from this pin to ground to set the bandgap reference bias current. This could be a sensitive low frequency noise injection point.
5	ANA_DEC	Analog supply decoupling capacitor. Connect to analog supply and decouple as close to the pin as possible.
6	LFILT1	Phase detector output. Low-frequency noise-sensitive node.
7	LFILT2	Loop filter op-amp output. Low-frequency noise-sensitive node.
8	LFILT3	VCO control input. Low-frequency noise-sensitive node.
9	MODE	Mode select pin. An RC low-pass filter can be used to reduce digital noise.
10	XTALIPP	Reference oscillator input. Should be AC-coupled if an external reference is used. See note 3.
11	XTALIPN	Reference oscillator input. Should be AC-coupled to ground if an external reference is used. See note 3.
12	GND	Connect to ground.
13	RFIP1P	Differential input 1. See note 1.
14	RFIP1N	Differential input 1. See note 1.
15	NC	
16	NC	
17	RFOP1N	Differential output 1. See note 2.
18	RFOP1P	Differential output 1. See note 2.
19	DIG_VDD	Digital supply. Should be decoupled as close to the pin as possible.
20	NC	
21	NC	
22	ANA_VDD	Analog supply. Should be decoupled as close to the pin as possible.
23	RFIP2N	Differential input 2. See note 1.
24	RFIP2P	Differential input 2. See note 1.
25	NC	
26	NC	
27	RFOP2N	Differential output 2. See note 2.
28	RFOP2P	Differential output 2. See note 2.
29	RESETB	Chip reset (active low). Connect to DIG_VDD if external reset is not required.
30	ENX	Serial interface select (active low). An RC low-pass filter could be used to reduce digital noise.
31	SCLK	Serial interface clock. An RC low-pass filter could be used to reduce digital noise.
32	SDATA	Serial interface data. An RC low-pass filter could be used to reduce digital noise.
EP	Exposed pad	Connect to ground. This is the ground reference for the circuit. All decoupling should be connected here through low impedance paths.

Note 1: The signal should be connected to this pin such that DC current cannot flow into or out of the chip, either by using AC coupling capacitors or by use of a transformer (see evaluation board schematic).

Note 2: DC current needs to flow from ANA_VDD into this pin, either through an RF inductor, or transformer (see evaluation board schematic).

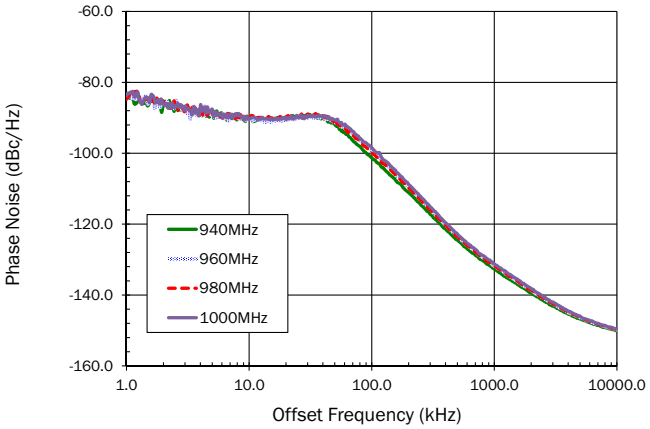
Note 3: Alternatively an external reference can be AC-coupled to pin 11 XTALIPN, and pin 10 XTALIPP decoupled to ground. This may make PCB routing simpler.

Typical Performance Characteristics: PLL and VCO

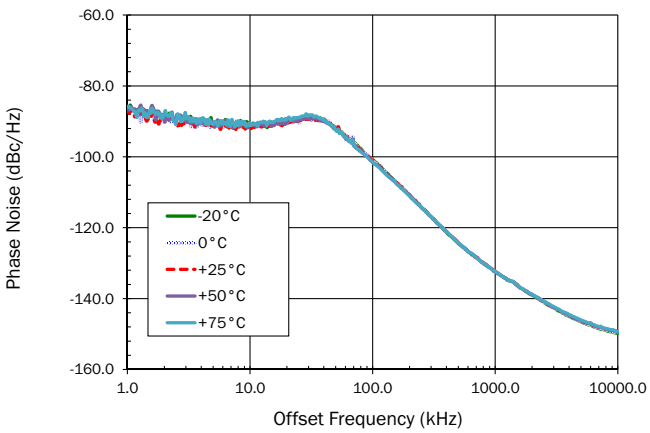
V_{DD} = +2.2V, T_A = +25°C unless stated, as measured on RF2054 evaluation board.

See schematic page 36.

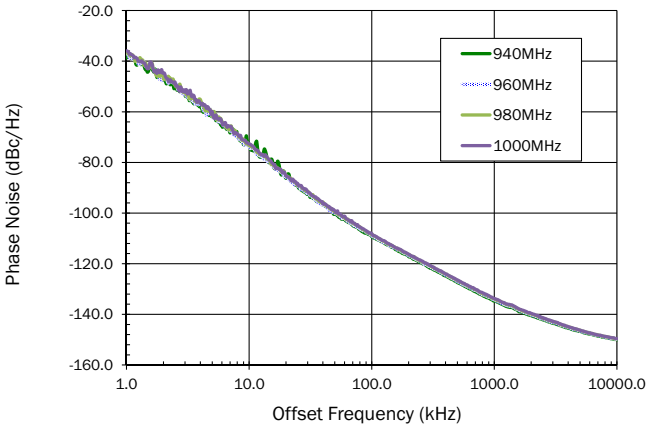
Synthesizer Phase Noise versus Frequency
21MHz Reference and +2.2V Supply



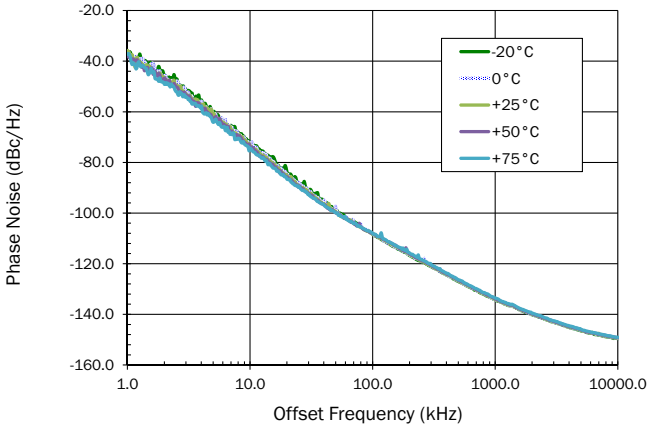
Synthesizer Phase Noise versus Temperature
LO = 960MHz, 21MHz Reference and +2.2V Supply



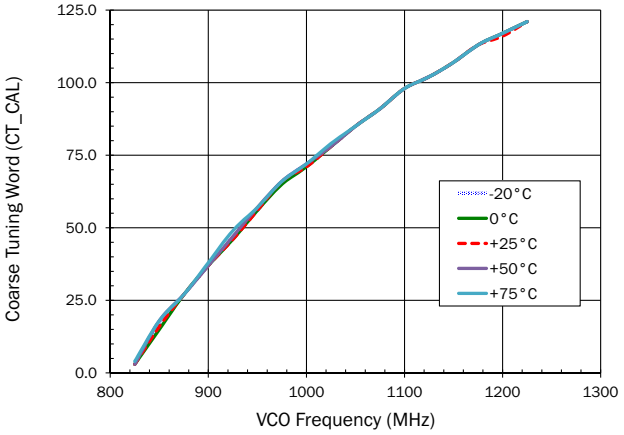
VCO Phase Noise versus Frequency
+2.2V Supply



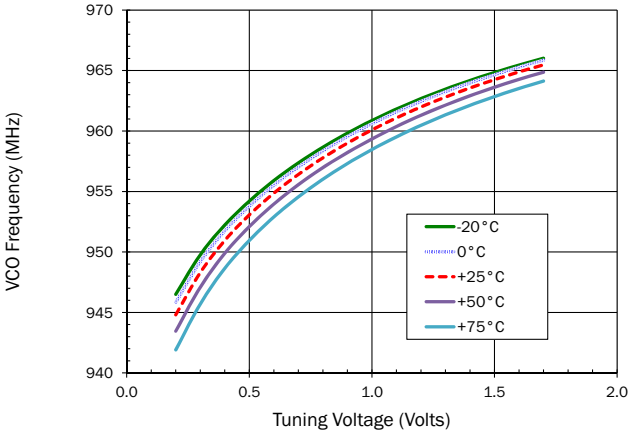
VCO Phase Noise versus Temperature
VCO Frequency 960MHz, +2.2V Supply



VCO Coarse Tuning versus Frequency
3.3nH VCO Inductors and +2.2V Supply



VCO Frequency versus Tuning Voltage and Temperature
For the Same Coarse Tune Setting, +2.2V Supply



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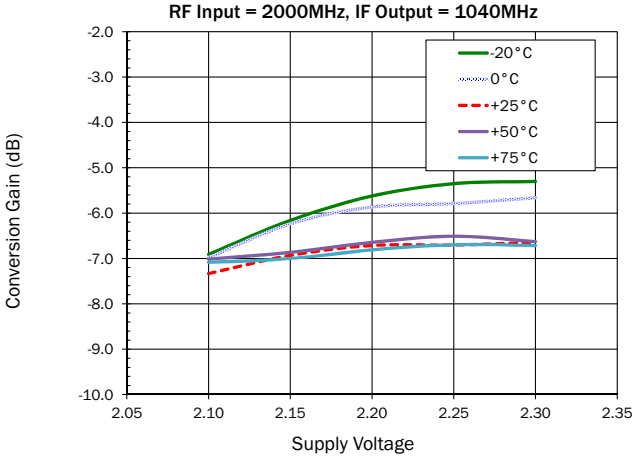
Typical Performance Characteristics: RF Mixer 1, Downconversion

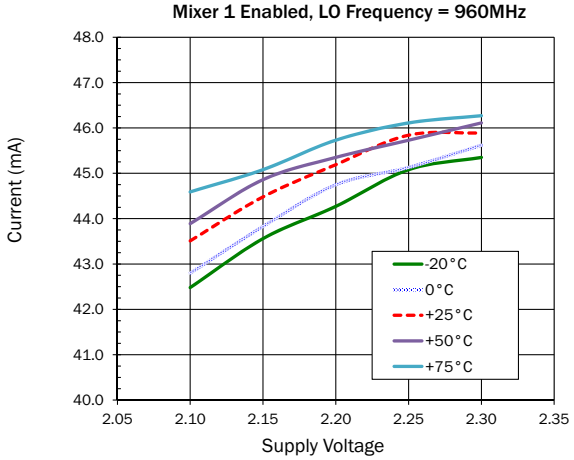
V_{DD} = +2.2V, T_A = +25°C, unless stated, as measured on RF2054 evaluation board.

See schematic page 36.

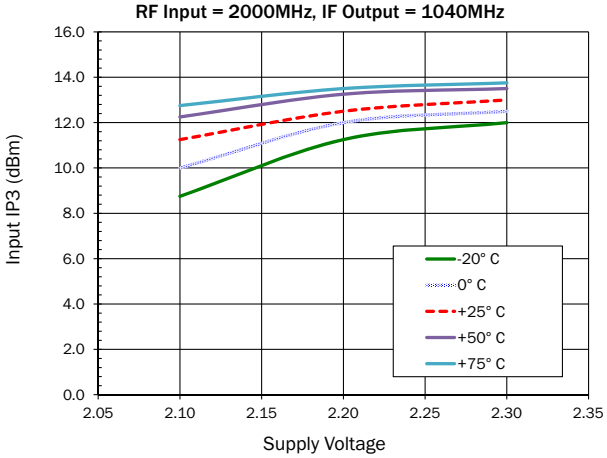
Mixer 1 Conversion Gain versus Temp and Voltage
RF Input = 2000MHz, IF Output = 1040MHz



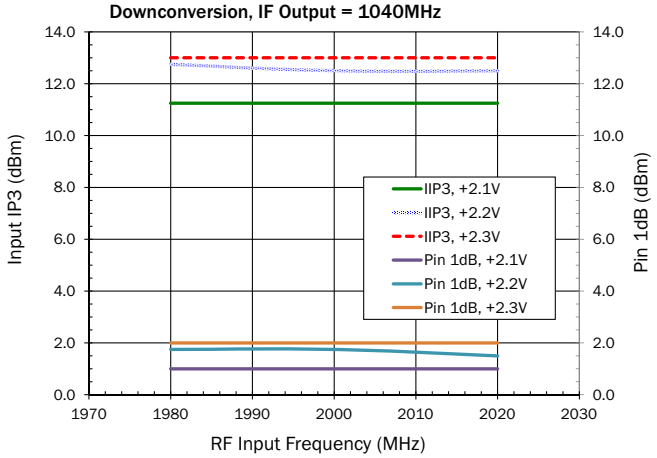
Total Supply Current versus Temp and Voltage
Mixer 1 Enabled, LO Frequency = 960MHz



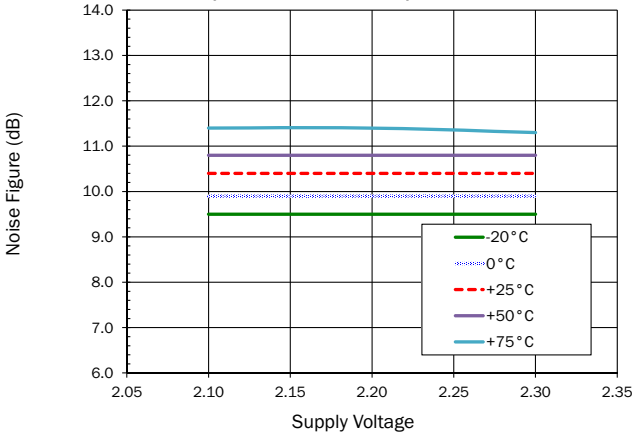
Mixer 1 Input IP3 versus Temp and Voltage
RF Input = 2000MHz, IF Output = 1040MHz



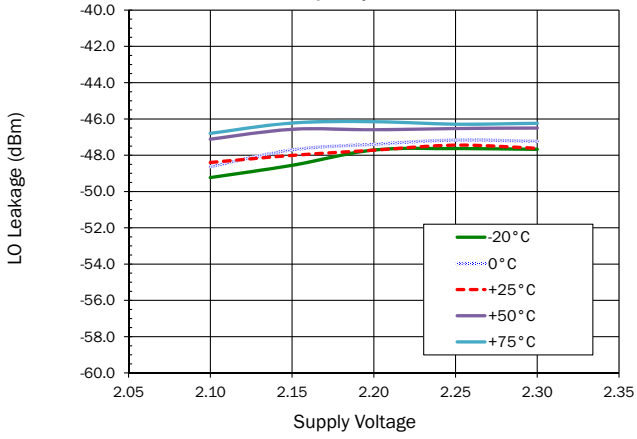
Mixer 1 Linearity versus Voltage
Downconversion, IF Output = 1040MHz



Mixer 1 Noise Figure versus Temp and Voltage
RF Input = 2000MHz, IF Output = 1040MHz



Mixer 1 LO Leakage versus Temp and Voltage
LO Frequency 960MHz

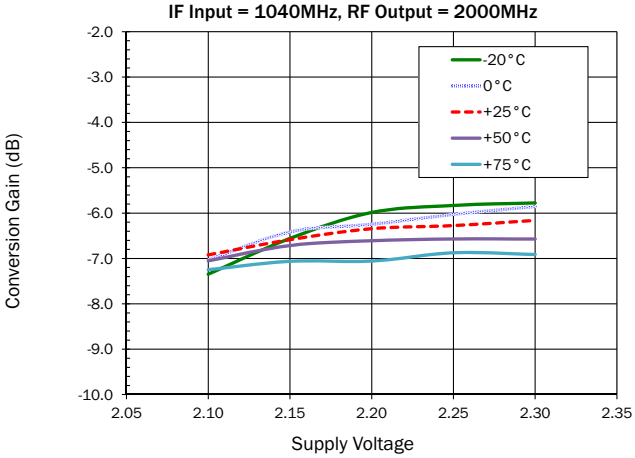


Typical Performance Characteristics: RF Mixer 2, Upconversion

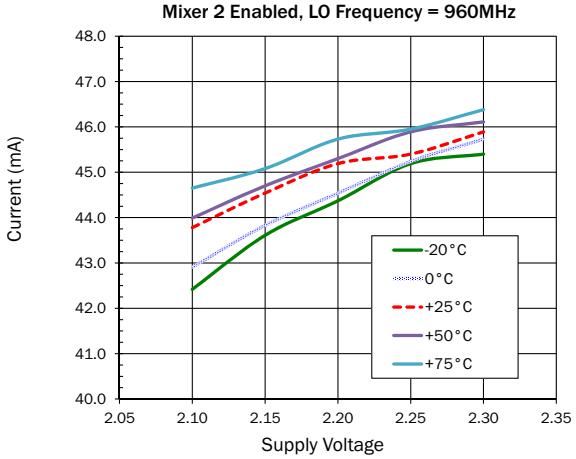
V_{DD} = +2.2V, T_A = +25°C unless stated, as measured on RF2054 evaluation board.

See schematic page 36.

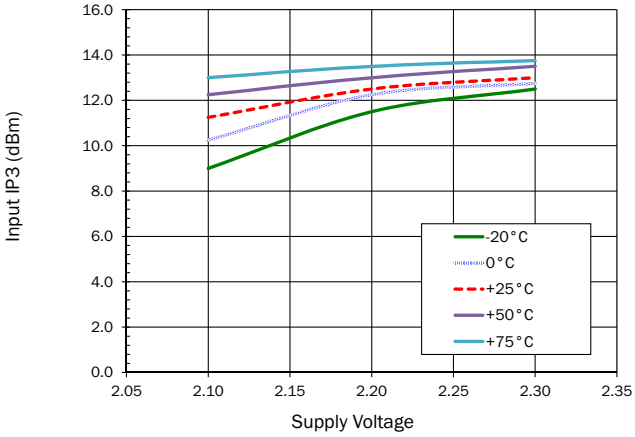
Mixer 2 Conversion Gain versus Temp and Voltage
IF Input = 1040MHz, RF Output = 2000MHz



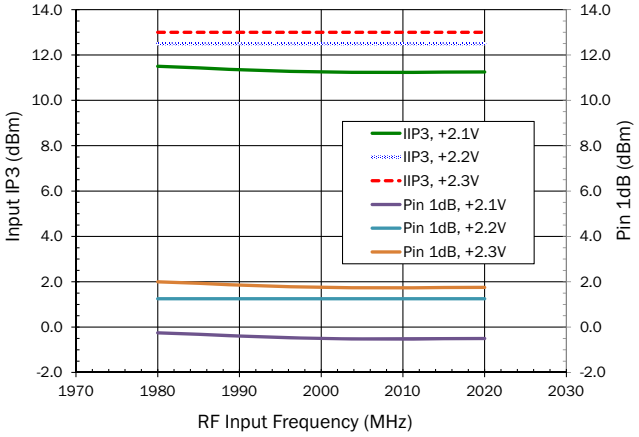
Total Supply Current versus Temp and Voltage
Mixer 2 Enabled, LO Frequency = 960MHz



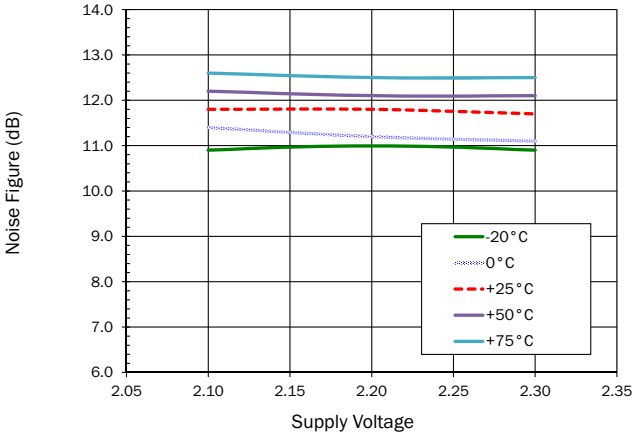
Mixer 2 Input IP3 versus Temp and Voltage
IF input = 1040MHz, RF Output = 2000MHz



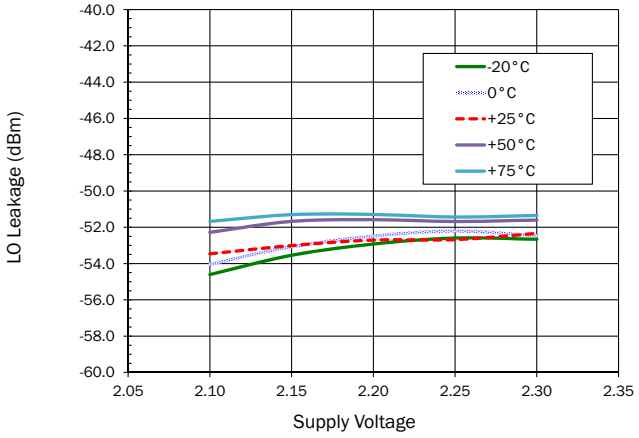
Mixer 2 Linearity versus Voltage
Upconversion, IF Input = 1040MHz



Mixer 2 Noise Figure versus Temp and Voltage
IF Input = 1040MHz, RF Output = 2000MHz



Mixer 2 LO Leakage versus Temp and Voltage
LO Frequency 960MHz



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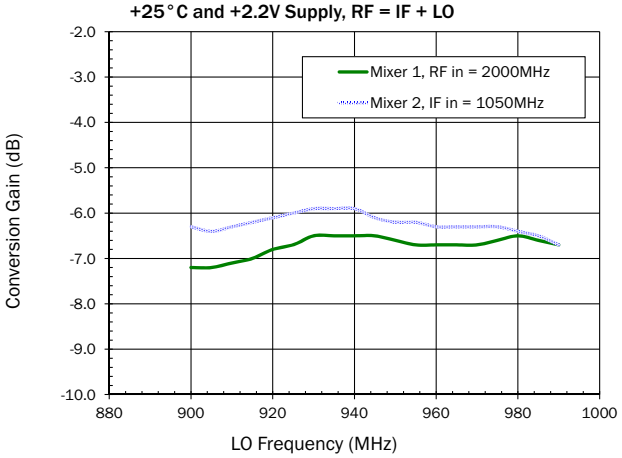
Typical Performance Characteristics: RF Mixers

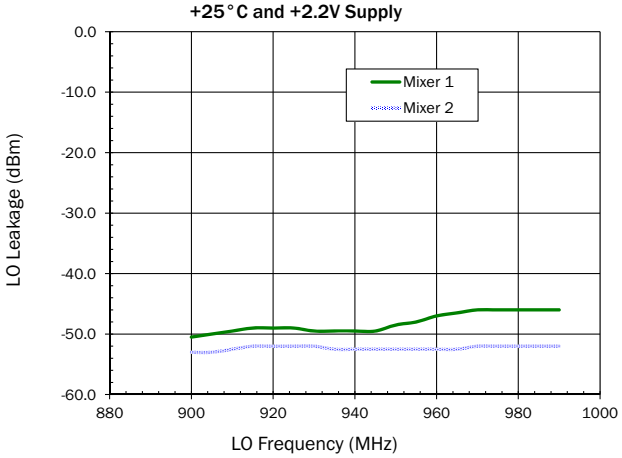
V_{DD} = +2.2V, T_A = +25°C unless stated, as measured on RF2054 evaluation board.

See schematic page 36.

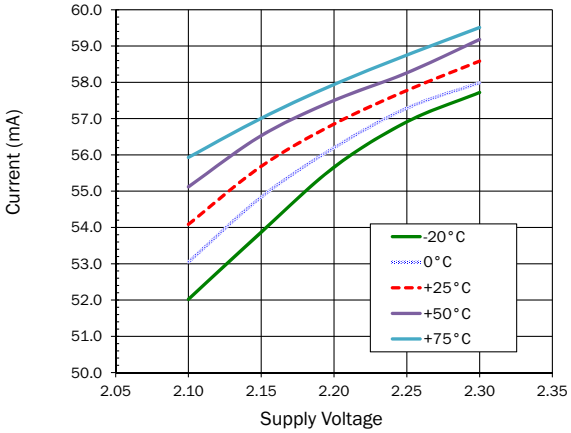
Typical Mixer Conversion Gain
+25°C and +2.2V Supply, RF = IF + LO



Typical LO Leakage at Mixer Output
+25°C and +2.2V Supply



Total Supply Current versus Temp and Voltage
Full Duplex Mode, LO Frequency = 960MHz



Detailed Description

The RF2054 is a frequency converter chip that includes a fractional-N phase locked loop, a low noise VCO core, an LO signal multiplexer, two LO buffer circuits, and two RF mixers. Synthesizer programming, device configuration, and control are achieved through a mixture of hardware and software controls. All on-chip registers are programmed through a simple three-wire serial interface.

VCO

The VCO core in the RF2054 consists of one VCO which covers a frequency range dependant on the value of the external inductor used. The RF2054 has been characterized with 3.3nH inductors, so the VCO covers from 940MHz to 1000MHz. Note that the VCO inductor is differential so the value given is the inductance on each device pin, and the total differential inductance will be twice this value.

VCO3 must be selected using the PLL1x0:P1_VCOSEL and PLL2x0:P2_VCOSEL control word and setting 10 for VCO3. The VCO has 128 overlapping bands to achieve an acceptable VCO gain (MHz/V) and hence a good phase noise performance across the whole tuning range. The chip automatically selects the correct VCO band (VCO coarse tuning) to generate the desired frequency based on the values programmed into the PLL1 and PLL2 register banks. For information on how to program the desired LO frequency into the PLL1 and PLL2 banks, refer to the next section. The automatic VCO band selection is triggered every time the ENBL pin is taken high. Once the band has been selected, the PLL will lock onto the correct frequency. During the band selection process, fixed capacitance elements are progressively connected to the VCO resonant circuit until the VCO is oscillating at approximately the correct frequency. The output of this band selection is made available in the RB1:CT_CAL read-back register. A value of 127 or 0 in this register indicates that the selection was unsuccessful; this is usually due to the wrong VCO being selected so the user is trying to program a frequency that is outside of the VCO operating range. A value between one and 126 indicates a successful calibration, the actual value being dependent on the desired frequency, as well as process variation. The band selection takes approximately 25μs with a 21MHz clock. The band select process will center the VCO tuning voltage at about 1.0V, compensating for manufacturing tolerances and process variation, as well as environmental factors, including temperature. For applications where the synthesizer is always on and the LO frequency is fixed, the synthesizer will maintain lock over the whole temperature range of -20°C to +75°C. However, it is recommended to re-initiate an automatic band selection for every 30 degrees of temperature change in order to maintain optimal synthesizer performance. This assumes an active loop filter. If start-up time is a critical parameter and the user is always programming the same frequency for the PLL, the calibration result may be read back from the RB1:CT_CAL register and written to PLL1x2:P1_CT_DEF or PLL2x2:P2_CT_DEF registers (depending on the desired PLL register bank). The calibration function must then be disabled by setting the PLL1x0:P1_CT_EN and/or PLL2x0:P2_CT_EN control words to 0. For further information, please refer to the RF205x Calibration User Guide.

The LO divide ratio is set by the PLL1x0:P1_LODIV and PLL2x0:P2_LODIV control words. The LO is routed to mixer1, mixer2, or both, depending on the state of the MODE pin and the value of CFG1:FULLD.

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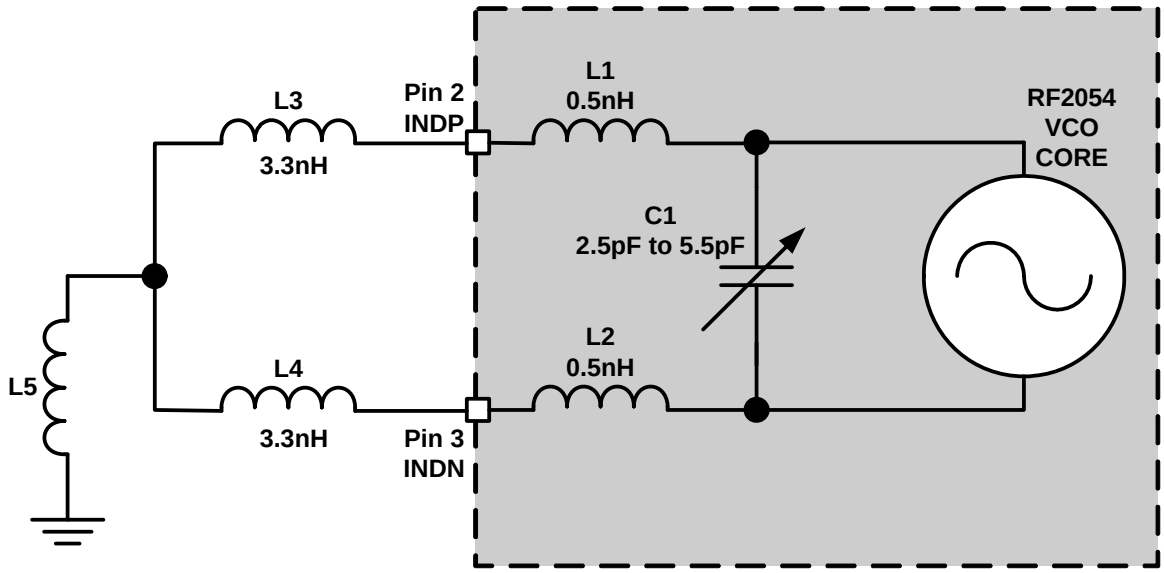
VCO External Inductor Selection

The RF2054 VCO resonator circuit can be simplified to the schematic shown below:



C1	Variable (coarse tune) capacitance plus varactor and stray capacitance.
L1 and L2	Bondwire inductance of 0.5nH on each pin.
L3 and L4	External inductors that form a differential inductor and provide a DC ground path to bias VCO.
L5	Inductance of ground via (not part of differential inductor).

The following equation can be used to calculate the VCO frequency range:

$$Fo = \frac{1}{2\pi\sqrt{LC}}$$

where C is the total differential capacitance C1, 2.5pF to 5.5pF, and L is the total differential inductance:

$$L = L3 + L4 + 1nH = 7.6nH$$

For L3 and L4 of 3.3nH, this equation gives total VCO frequency range of about 800MHz to 1150MHz.

Some margin must be left at the top and bottom of the VCO frequency range to allow for process, assembly and environmental variations. A CT_CAL margin of 25 bits is recommended at both the top and bottom, about 0.6pF of capacitance.

The VCO resonator will have the highest Q and lowest phase noise at the lower end of the coarse tuning curve. For applications where the LO frequency is fixed, or only tunes over a few MHz, it is recommended to design for CT_CAL of about 40 using C1 = 4.7pF.

Fractional-N PLL

The RF2054 contains a charge-pump based fractional-N phase locked loop (PLL) for controlling the VCO. The PLL includes automatic calibration systems to counteract the effects of process and environmental variations, ensuring repeatable lock time and noise performance. The PLL is intended to use a reference frequency signal of 10MHz to 26MHz. The reference path features a divider, but typically for best phase noise this is bypassed. The reference divider bypass is controlled by bit CLK DIV_BYP, set low to enable the reference divider and set high for divider bypass (divide by 1). The remaining three bits CLK DIV <15:13> set the reference divider value, divide by 2 (010) to 7 (111) when the reference divider is enabled.

Two PLL programming banks are provided, the first bank is preceded by the label PLL1, and the second bank is preceded by the label PLL2. For the RF2054, these banks are used to program mixer 1 and mixer 2 respectively, and are selected automatically as the mixer is selected (using the MODE pin).

The PLL will lock the VCO to the frequency F_{VCO} according to:

$$F_{VCO} = N_{EFF} * F_{OSC} / R$$

where N_{EFF} is the programmed fractional-N divider value, F_{OSC} is the reference input frequency, and R is the programmed R divider value (1 to 7).

The N divider is a fractional divider, containing a dual-modulus prescaler and a digitally spur-compensated fractional sequence generator to allow fine frequency steps. The N divider is programmed using the N and NUM bits as follows:

First determine the desired, effective N divider value, N_{EFF}:

$$N_{EFF} = F_{VCO} * R / F_{OSC}$$

N(9:0) should be set to the integer part of N_{EFF}. NUM should be set to the fractional part of N_{EFF} multiplied by 2^{24} = 16777216.

Example: VCO3 operating at 960MHz, 21MHz reference frequency, the desired effective divider value is:

$$N_{EFF} = F_{VCO} * R / F_{OSC} = 960 * 1 / 21 = 45.714285714285.$$

The N value is set to 45, equal to the integer part of N_{EFF}, and the NUM value is set to the fractional portion of N_{EFF} multiplied by 2^{24}:

$$NUM = 0.714285714285 * 2^{24} = 11983726.$$

Converting N and NUM into binary results in the following:

N = 0001 0110 1
NUM = 1011 0110 1101 1011 0110 1110

So the registers would be programmed:

P1_N (or P2_N) = 0001 0110 1
P1_NUM_MSB (or P2_NUM_MSB) = 1011 0110 1101 1011
P1_NUM_LSB (or P2_NUM_LSB) = 0110 1110

The maximum N_{EFF} is 511, and the minimum N_{EFF} is 15, when in fractional mode.

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PLL Lock Detect

The lock detect function is a window detector, indicating an out of lock condition when the VCO tuning voltage is outside of a certain voltage range. When out of lock then the LOCK bit will be high, bit 1 in the read back register RB1. It is possible that when an out of lock is indicated the PLL is still locked, but the tuning voltage has drifted outside of the window.

There are two windows for the lock detector set by LD_LEV, bit 14 in register CFG1. The following are the typical tuning voltage ranges for the lock detect circuit measured with +2.2V supply voltage to the RF2054:

LD_LEV = 0: 0.55V to 1.55V (narrow window)

LD_LEV = 1: 0.35V to 1.75V (wide window)

Phase Detector and Charge Pump

The chip provides a current output to drive an external loop filter. An on-chip operational amplifier can be used to design an active loop filter or a passive design can be implemented. The maximum charge pump output current is set by the value contained in the P1_CP_DEF/P2_CP_DEF field and CP_LO_I.

In the default state (P1_CP_DEF/P2_CP_DEF = 31 and CP_LO_I = 0) the charge pump current (ICPset) is 120μA. If CP_LO_I is set to 1 this current is reduced to 30μA.

The charge pump current can be altered by changing the value of P1_CP_DEF/P2_CP_DEF. The charge pump current is defined as:

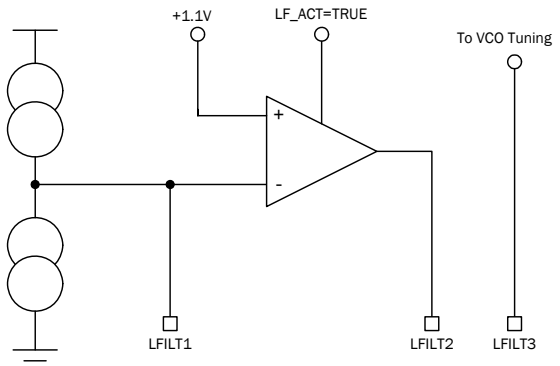
$$ICP = ICPset * CP\_DEF / 31$$

If automatic loop bandwidth correction is enabled the charge pump current is set by the calibration algorithm based upon the VCO gain. For more information on the VCO gain calibration, which is disabled by default, please refer to the RF205x Calibration User Guide.

The phase detector will operate with a maximum input frequency of 26MHz.

Loop Filter

The PLL may be designed to use an active or a passive loop filter as required. The internal configuration of the chip is shown below. If the CFG1:LF_ACT bit is asserted high, the op-amp will be enabled. If the CFG1:LF_ACT bit is asserted low, the internal op-amp is disabled and a high impedance is presented to the LFILT1 pin. The RF205x Programming Tool software can assist with loop filter designs. Because the op-amp is used in an inverting configuration in active mode, when the passive loop filter mode is selected the phase-detector polarity should be inverted. For active mode, CFG1:PDP = 1, for passive mode, CFG1:PDP = 0.



The charge pump output voltage compliance range is typically +0.7V to +1.5V. For applications using a passive loop filter VCO coarse tuning must be performed regularly enough to ensure that the VCO tuning voltage falls within this compliance range at all temperatures. The active loop filter maintains the charge pump output voltage in the center of the compliance range, and the op-amp provides a wider VCO tuning voltage range, typical 0V to +2.1V.

Reference Input

The RF2054 requires an external reference source. The external source (such as a TCXO) should be AC-coupled into one of the XO inputs, and the other input should be AC-coupled to ground.

The bias circuits in the reference path (XO) take approximately 200μsec to settle, and so for applications requiring rapid pulsed operation of the PLL (such as a TDMA system, or Rx/Tx half-duplex system) it is necessary to keep the XO running between bursts. However, when the PLL is used less frequently, it is desirable to turn off the XO to minimize current draw. The REFSTBY register is provided to allow for either mode of operation. If REFSTBY is programmed high, the XO will continue to run even when ENBL is asserted low. Thus the XO will be stable and a clock is immediately available when ENBL is asserted high, allowing the chip to assume normal operation. On cold start, or if REFSTBY is programmed low, the XO will need a warm-up period before it can provide a stable clock. It is recommended to program REFSTBY high at least 200 users before asserting ENBL high.

Wideband Mixer

The RF2054 includes two wideband, double-balanced Gilbert cell mixers. Each mixer has an input port and an output port that can be used for either IF or RF, i.e. for up conversion or down conversion. The mixer current can be programmed to between 5mA and 25mA in 5mA steps depending on linearity requirements, using the MIX1_IDD<3:0> word for mixer 1 and the MIX2_IDD<3:0> word for mixer 2, both of which are in the CFG2 register. The majority of the mixer current is sourced through the output pins via either a centre-tapped balun or an RF choke in the external matching circuitry to the supply. The RF2054 has been characterized for lowest current operation, so MIX1 _IDD and MIX2_IDD set to 001.

Mixer 1 of the RF2054 has been characterized for down conversion from approximately 2 GHz input to 1040MHz IF output. Mixer 2 of the RF2054 has been characterized for upconversion from IF input of 1040MHz to approximately 2GHz output.

The RF mixer input and output ports are differential and require simple matching circuits optimized to the specific application frequencies. A conversion gain of approximately -3dB is achieved with 100Ω differential input impedance, and the outputs driving 200Ω differential load impedance. Increasing the mixer output load increases the conversion gain.

The mixer has a broadband common gate input. The input impedance is dominated by the resistance set by the mixer 1/gm term, which is inversely proportional to the mixer current setting. The resistance will be approximately 135Ω at the mixer low current setting (001). There is also some shunt capacitance at the mixer input.

The mixer output is high impedance, consisting of a resistance of approximately 2kΩ in parallel with some capacitance. The mixer output does not need to be matched as such, just to see a resistive load. A higher resistance load will give higher output voltage and gain. A shunt inductor can be used to resonate with the mixer output capacitance at the frequency of interest. This inductor may not be required at lower frequencies where the impedance of the output capacitance is less significant. For the RF2054 mixer 1 IF output a 33nH inductor is used (1040MHz) and for the mixer 2 RF output a 8.2nH inductor is used (2GHz).

For more information about the mixer port impedances and matching, please refer to the RF205x Family Application Note on Matching Circuits and Baluns.

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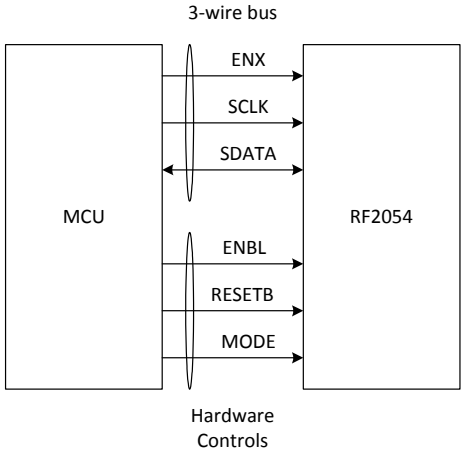
The mixer layout and pin placement has been optimized for high mixer-to-mixer isolation of over 60dB. The mixers can be set up to operate in half-duplex mode (1 mixer active) or full duplex mode (both mixers active). The mode selection is done via hardware control of the MODE pin and by setting the FULLD bit in the CFG1 register as shown in the table below. When in full-duplex mode, one can either use PLL register bank 1 or 2, the LO signal is routed to both mixers.

Mode Pin	FULLD Bit	Active PLL Register Bank	Active Mixer
Low	0	1	1
High	0	2	2
Low	1	1	Both
High	1	2	Both

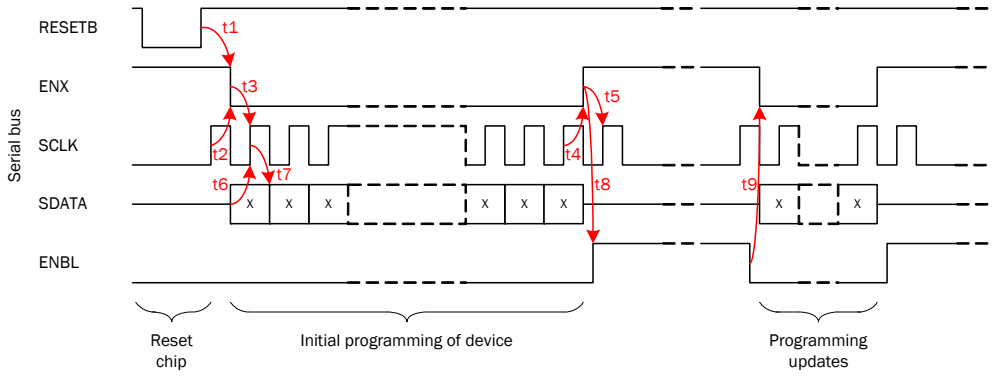
General Programming Information

Serial Interface

All on-chip registers in the RF2054 are programmed using a 3-wire serial bus which supports both write and read operations. Synthesizer programming, device configuration and control are achieved through a mixture of hardware and software controls. Certain functions and operations require the use of hardware controls via the ENBL, MODE, and RESETB pins in addition to programming via the serial bus.



Serial Data Timing Characteristics



Parameter	Description	Time
t1	Reset delay	>5ns
t2	Programming setup time	>5ns
t3	Programming hold time	>5ns
t4	ENX setup time	>5ns
t5	ENX hold time	>5ns
t6	Data setup time	>5ns
t7	Data hold time	>5ns
t8	ENBL setup time	>0ns
t9	ENBL hold time	>0ns

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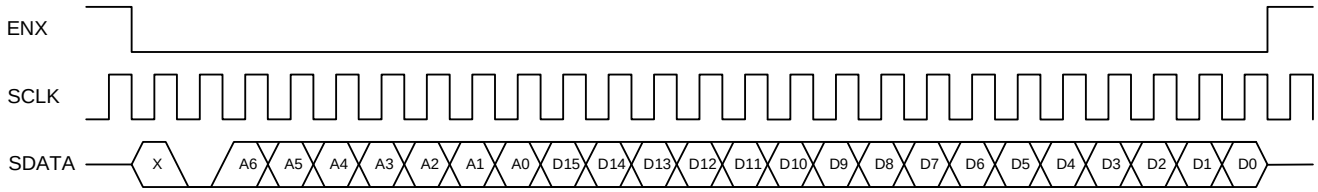
Write



Initially ENX is high and SDATA is high impedance. The write operation begins with the controller starting SCLK. On the first falling edge of SCLK the baseband asserts ENX low. The second rising edge of SCLK is reserved to allow the SDI to initialize, and the third rising edge is used to define whether the operation will be a write or a read operation. In write mode the baseband will drive SDATA for the entire telegram. RF2054 will read the data bit on the rising edge of SCLK.

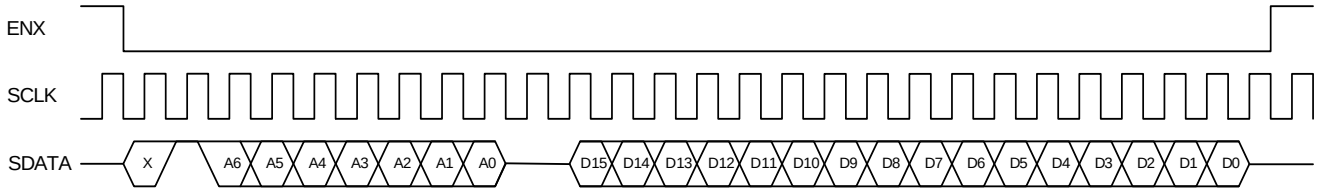
The next 7 data bits are the register address, MSB first. This is followed by the payload of 16 data bits for a total write mode transfer of 24 bits. Data is latched into RF2054 on the last rising edge of SCLK (after ENX is asserted high).

For more information, please refer to the timing diagram on page 16.

The maximum clock speed for a register write is 19.2MHz. A register write therefore takes approximately 1.3μs. The data is latched on the rising edge of the clock. The datagram consists of a single start bit followed by a '0' (to indicate a write operation). This is then followed by a seven bit address and a sixteen bit data word.

Note that since the serial bus does not require the presence of the reference clock, it is necessary to insert an additional rising clock edge before the ENX line is set low to ensure the address/data are read correctly.

Read



Initially ENX is high and SDATA is high impedance. The read operation begins with the controller starting SCLK. The controller is in control of the SDATA line during the address write operation. On the first falling edge of SCLK the baseband asserts ENX low. The second rising edge of SCLK is reserved to allow the SDI to initialize, and the third rising edge is used to define whether the operation will be a write or a read operation. In read mode the baseband will drive SDATA for the address portion of the telegram, and then control will be handed over to RF2054 for the data portion. RF2054 will read the data bits of the address on the rising edge of SCLK. After the address has been written, control of the SDATA line is handed over to RF2054. One and a half clocks are reserved for turn-around, and then the data bits are presented by RF2054. The data is set up on the rising edge of SCLK, and the controller latches the data on the falling edge of SCLK. At the end of the data transmission, RF2054 will release control of the SDATA line, and the controller asserts ENX high. The SDATA port on RF2054 transitions from high impedance to low impedance on the first rising edge of the data portion of the transaction (for example, 3 rising edges after the last address bit has been read), so the controller chip should be presenting a high impedance by that time.

For more information, please refer to the timing diagram on page 16.

The maximum clock speed for a register read is 19.2MHz. A register read therefore takes approximately 1.4μs. The address is latched on the rising edge of the clock and the data output on the falling edge. The datagram consists of a single start bit fol-

lowed by a '1' (to indicate a read operation), followed by a seven bit address. A 1.5 bit delay is introduced before the sixteen bit data word representing the register content is presented to the receiver.

Note that since the serial bus does not require the presence of the reference clock, it is necessary to insert an additional rising clock edge before the ENX line is set low to ensure the address is read correctly.

Hardware Control

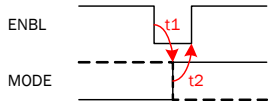
Three hardware control pins are provided: ENBL, MODE, and RESETB.

ENBL Pin

The ENBL pin has two functions: to enable the analog circuits in the chip and to trigger the VCO band selection as described in the VCO section on page 10.

ENBL Pin	REFSTBY Bit	XO and Bias Block	Analogue Block	Digital Block
Low	0	Off	Off	On
Low	1	On	Off	On
High	0	On	On	On
High	1	On	On	On

As outlined in the VCO section the chip has a built-in automatic VCO band selection to tune the selected VCO to the desired frequency. The band selection is initiated when the ENBL pin is taken high. Every time the frequency of the synthesizer is re-programmed, the ENBL has to be inserted high to initiate the automatic VCO band selection (VCO coarse tune).



Parameter	Description	Time
t1	MODE setup time	>5ns
t2	MODE hold time	>5ns

RESETB Pin

The RESETB pin is a hardware reset control that will reset all digital circuits to their start-up state when asserted low. The device includes a power-on-reset function, so this pin should not normally be required, in which case it should be connected to the positive supply.

MODE Pin

The MODE pin controls which mixer(s) and PLL programming register bank is active. See the PLL and Mixer description sections for details.

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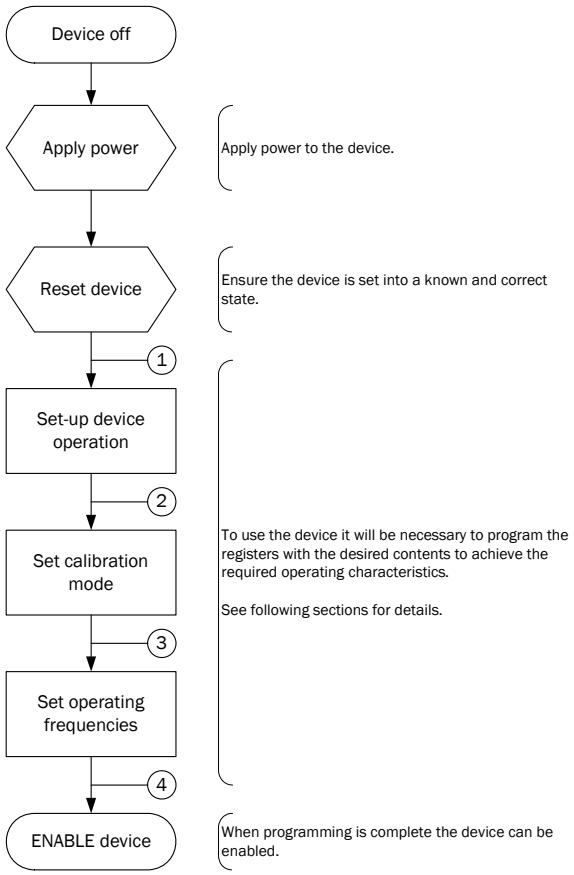
Programming the RF2054

The figure below shows an overview of the device programming.



Note: The set-up processes 1 to 2, 2 to 3, and 3 to 4 are explained further below.

Additional information on device use and programming can be found on the RF205X family page of the RFMD web site (http://www.rfmd.com/rf205x). The following documents may be particularly helpful:

- RF205x Frequency Synthesizer User Guide
- RF205x Calibration User Guide

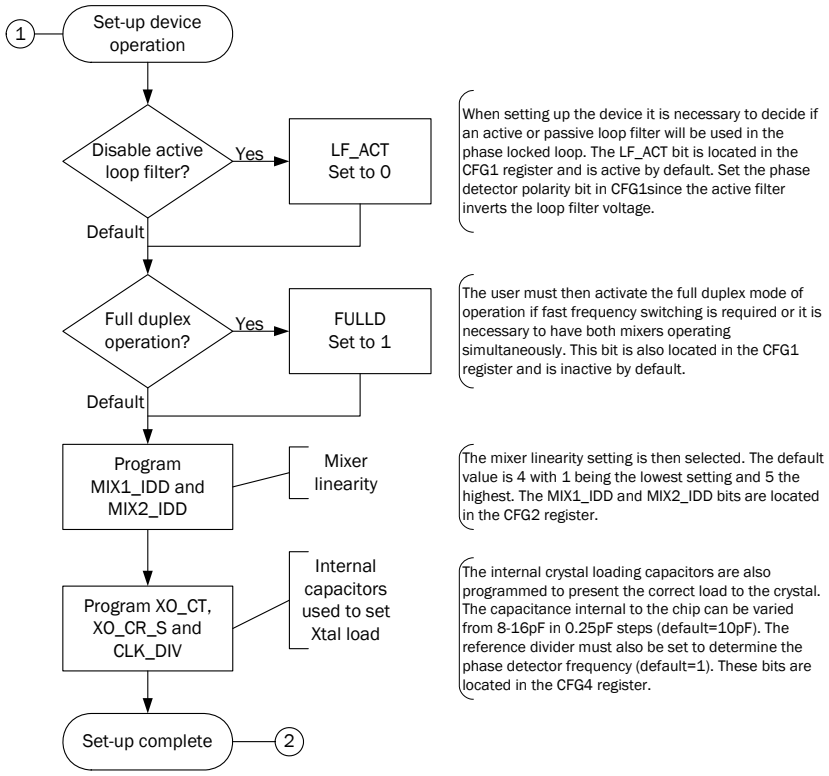
Start-up

When starting up and following device reset then REFSTBY=0, REFSTBY should be asserted high at least 200µs before ENBL is taken high. This is to allow the XO bias circuits to settle. The various calibration routines will also take some time depending on whether they are enabled or not. Coarse tuning calibration takes about 50µs and VCO tuning gain compensation takes about 100µs. Additionally, time for the PLL to settle will be required. All of these timings will be dependant upon application specific factors such as loop filter bandwidth, reference clock frequency, and so on. The fastest turn-on and lock time will be obtained by leaving REFSTBY asserted high, disabling all calibration routines, minimizing all calibration times, and setting the PLL loop bandwidth as wide as possible.

The device can be reset into its initial state (default settings) at any time by performing a hard reset. This is achieved by setting the RESETB pin low for at least 100ns.

Setting Up Device Operation

The device offers a number of operating modes which need to be set up in the device before it will work as intended. This is achieved as follows.



Three registers need to be written, taking 3.9µs at the maximum clock speed. If the device is used with an active filter in simplex operation it will not be necessary to program CFG1 reducing the programming time to 2.6µs.

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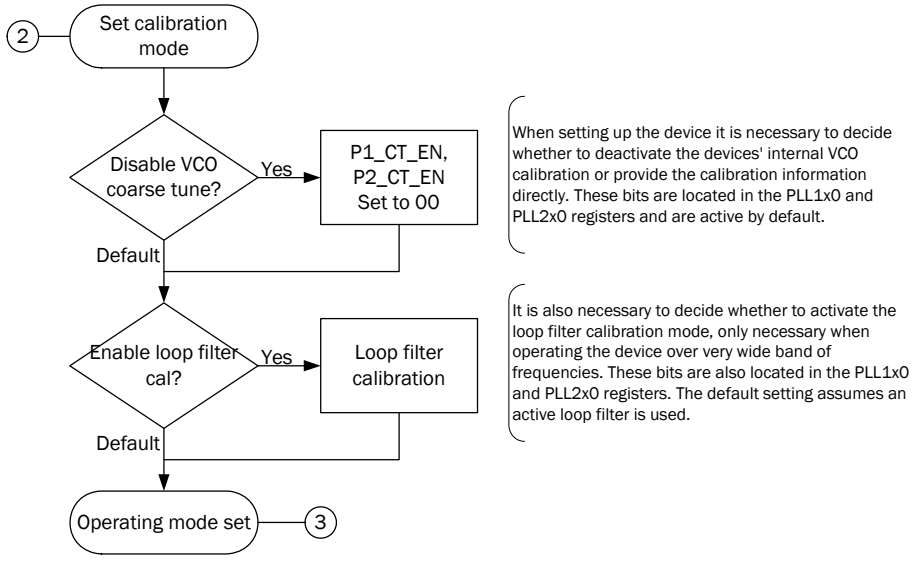
Setting Up VCO Coarse Tuning and Loop Filter Calibration

If the user wishes to disable the VCO coarse tune calibration or enable the loop filter calibration then the following programming operation will need to take place.

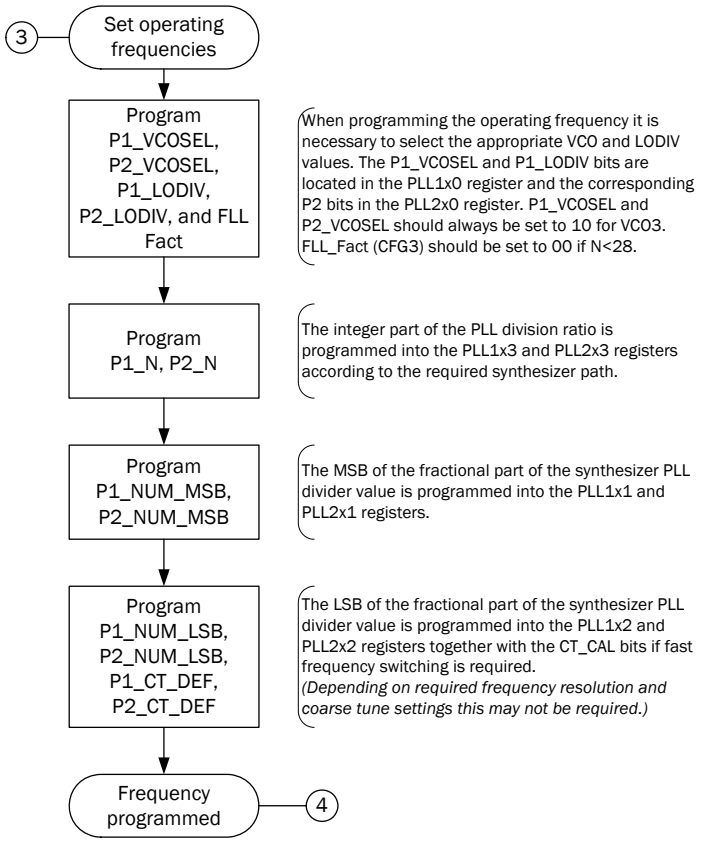


Two registers need to be written taking 2.6μs at maximum clock speed if the course tuning is deactivated or the loop filter calibration activated. Since it is necessary to program these registers when setting the operating frequency (see next section) this operation usually carries no overhead.

The coarse tune calibration takes approximately 26μs when using a 21MHz reference clock (it will take proportionally longer if a slower clock is used, and vice versa). This follows a VCO warm-up period also dependent on the reference clock, typically 10μs to 15μs.

Setting The Operating Frequency

Setting the operating frequency of the device requires a number of registers to be programmed.



A total of five registers must be programmed to set the device operating frequency for each path within the device. This will take 6.5μs for each path at maximum clock speed.

To change the frequency of the VCO it will be necessary to repeat these operations. However, it may not be necessary to reprogram the LODIV bits reducing the register writes to three per path.

For an example on how to determine the integer and fractional parts of the synthesizer PLL division ratio please refer to the detailed description of the PLL.

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Programming Registers

Register Map Diagram

Reg. Name	R/W	Add	Data															
			15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CFG1	R/W	00	LD_EN	LD_LEV	TVCO					PDP	LF_ACT	CPL		CT_POL	Res	EXT_VCO	FULLD	CP_LO_I
CFG2	R/W	01	MIX1_IDD			MIX1_VB	MIX2_IDD				MIX2_VB		Res	KV_RNG	NBR_CT_AVG		NBR_KV_AVG	
CFG3	R/W	02	TKV1				TKV2				Res				FLL_FACT		CT_CPOL	REFSTBY
CFG4	R/W	03	CLK_DIV_BYPASS				XO_CT				XO_I2	XO_I1	XO_CR_S	TCT				
CFG5	R/W	04	LO1_I				LO2_I				T_PH_ALGN							
CFG6	R/W	05	SU_WAIT										Res					
PLL1x0	R/W	08	P1_VCOSEL		P1_CT_EN		P1_KV_EN		P1_LODIV		Res		P1_CP_DEF					
PLL1x1	R/W	09	P1_NUM_MSB															
PLL1x2	R/W	0A	P1_NUM_LSB								P1_CT_DEF							Res
PLL1x3	R/W	0B	P1_N								Res				P1_VCOI			
PLL1x4	R/W	0C	P1_DN								P1_CT_GAIN			P1_KV_GAIN				Res
PLL1x5	R/W	0D	P1_N_PHS_ADJ								Res			P1_CT_V				
PLL2x0	R/W	10	P2_VCOSEL		P2_CT_EN		P2_KV__EN		P2_LODIV		Res		P2_CP_DEF					
PLL2x1	R/W	11	P2_NUM_MSB															
PLL2x2	R/W	12	P2_NUM_LSB								P2_CT_DEF							Res
PLL2x3	R/W	13	P2_N								Res				P2_VCOI			
PLL2x4	R/W	14	P2_DN								P2_CT_GAIN			P2_KV_GAIN				Res
PLL2x5	R/W	15	P2_N_PHS_ADJ								Res			P2_CT_V				
GPO	R/W	18	Res	P1_GPO1	Res	P1_GPO3	P1_GPO4		Res		P2_GP01	Res		P2_GPO3	P2_GPO4	Res		
CHIPREV	R	19	PARTNO								REVNO							
RB1	R	1C	LOCK	CT_CAL							CP_CAL						Res	
RB2	R	1D	V0_CAL								V1_CAL							
RB3	R	1E	RSM_STATE						Res									
TEST	R	1F	TEN	TMUX			CPU	CPD	FNZ	LDO_BYP	TSEL	Res	DACTEST	Res				

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CFG1 (00h) - Operational Configuration Parameters

#	Bit Name	Default		Function
15	LD_EN	1	9	Enable lock detector circuitry
14	LD_LEV	0		Modify lock range for lock detector
13	TVCO(4:0)	0		VCO warm-up time = (TVCO*32)/F_{REF}
12		0		
11		0	1	
10		0		
9		0		
8	PDP	1		Phase detector polarity: 0 = positive, 1 = negative
7	LF_ACT	1	C	Active loop filter enable, 1 = Active 0 = Passive
6	CPL(1:0)	1		Charge pump leakage current: 00 = no leakage, 01 = low leakage, 10 = mid leakage, 11 = high leakage
5		0		
4	CT_POL	0		Polarity of VCO coarse-tune word: 0 = positive, 1 = negative
3		0	0	
2	EXT_VCO	0		0 = Normal operation 1 = external VCO
1	FULLD	0		0 = Half duplex, mixer is enabled according to MODE pin, 1 = Full duplex, both mixers enabled
0	CP_LO_I	0		0 = High charge pump current, 1 = low charge pump current

CFG2 (01h) - Mixer Bias and PLL Calibration

#	Bit Name	Default		Function
15	MIX1_IDD	1	8	Mixer 1 current setting: 000 = 0mA to 101 = 25mA in 5mA steps. 110 and 111 unused. RF2054 characterized with setting 001 for lowest current.
14		0		
13		0		
12	MIX1_VB	0		Mixer 1 voltage bias.
11		1	C	
10	MIX2_IDD	1		Mixer 2 current setting: 000 = 0mA to 101 = 25mA in 5mA steps. 110 and 111 unused. RF2054 characterized with setting 001 for lowest current.
9		0		
8		0		
7	MIX2_VB	0	5	Mixer 2 voltage bias
6		1		
5		0		
4	KV_RNG	1		Sets accuracy of voltage measurement during KV calibration: 0 = 8bits, 1 = 9bits
3	NBR_CT_AVG	1	8	Number of averages during CT cal
2		0		
1	NBR_KV_AVG	0		Number of averages during KV cal
0		0		

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CFG3 (02h) - PLL Calibration

#	Bit Name	Default		Function
15	TKV1	0	0	Settling time for first measurement in LO KV compensation
14		0		
13		0		
12		0		
11	TKV2	0	4	Settling time for second measurement in LO KV compensation
10		1		
9		0		
8		0		
7		0	0	
6		0		
5		0		
4		0		
3	FLL_FACT	0	4	Default setting 01. Needs to be set to 00 for N<28.
2		1		
1	CT_CPOL	0		
0	REFSTBY	0		Reference oscillator standby mode 0=XO is off in standby mode, 1=XO is on in standby mode

CFG4 (03h) - Crystal Oscillator and Reference Divider

#	Bit Name	Default		Function
15	CLK_DIV	0	1	Reference divider, divide by 2 (010) to 7 (111) when reference divider is enabled
14		0		
13		0		
12	CLK_DIV_BYPASS	1		Reference divider enabled = 0, divider bypass (divide by 1) = 1
11	XO_CT	1	8	Crystal oscillator coarse tune (approximately 0.5pF steps from 8pF to 16pF)
10		0		
9		0		
8		0		
7	XO_I2	0	0	Crystal oscillator current setting
6	XO_I1	0		
5	XO_CR_S	0		Crystal oscillator additional fixed capacitance (approximately 0.25pF)
4	TCT	0		Duration of coarse tune acquisition
3		1	F	
2		1		
1		1		
0		1		

CFG5 (04h) - LO Bias

#	Bit Name	Default		Function
15	LO1_I	0	0	Local oscillator Path1 current setting
14		0		
13		0		
12		0		
11	LO2_I	0	0	Local oscillator Path2 current setting
10		0		
9		0		
8		0		
7	T_PH_ALGN	0	0	Phase alignment timer
6		0		
5		0		
4		0		
3		0	4	
2		1		
1		0		
0		0		

CFG6 (05h) - Start-up Timer

#	Bit Name	Default		Function
15	SU_WAIT	0	0	Crystal oscillator settling timer.
14		0		
13		0		
12		0		
11		0	1	
10		0		
9		0		
8		1		
7		0	0	
6		0		
5		0		
4		0		
3		0	0	
2		0		
1		0		
0		0		

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PLL1x0 (08h) - VCO, LO Divider and Calibration Select

#	Bit Name	Default		Function
15	P1_VCOSEL	0	7	Always set to 10 = VCO3.
14		1		
13	P1_CT_EN	1		Path 1 VCO coarse tune: 00 = disabled, 11 = enabled
12		1		
11	P1_KV_EN	0	1	Path 1 VCO tuning gain calibration: 00 = disabled, 11 = enabled
10		0		
9	P1_LODIV	0		Path 1 local oscillator divider: 00 = divide by 1, 01 = divide by 2, 10 = divide by 4, 11 = reserved
8		1		
7		0	1	
6		0		
5	P1_CP_DEF	0		Charge pump current setting If P1_KV_EN = 11 this value sets charge pump current during KV compensation only
4		1		
3		1	F	
2		1		
1		1		
0		1		

PLL1x1 (09h) - MSB of Fractional Divider Ratio

#	Bit Name	Default		Function
15	P1_NUM_MSB	0	6	Path 1 VCO divider numerator value, most significant 16 bits
14		1		
13		1		
12		0		
11		0	2	
10		0		
9		1		
8		0		
7		0	7	
6		1		
5		1		
4		1		
3		0	6	
2		1		
1		1		
0		0		

PLL1x2 (0Ah) - LSB of Fractional Divider Ratio and CT Default

#	Bit Name	Default		Function
15	P1_NUM_LSB	0	2	Path 1 VCO divider numerator value, least significant 8 bits
14		0		
13		1		
12		0		
11		0	7	
10		1		
9		1		
8		1		
7	P1_CT_DEF	0	7	Path 1 VCO coarse tuning value, used when P1_CT_EN = 00
6		1		
5		1		
4		1		
3		1	E	
2		1		
1		1		
0		0		

PLL1x3 (0Bh) - Integer Divider Ratio and VCO Current

#	Bit Name	Default		Function
15	P1_N	0	2	Path 1 VCO divider integer value
14		0		
13		1		
12		0		
11		0	3	
10		0		
9		1		
8		1		
7		0	0	
6		0		
5		0		
4		0		
3		0	2	
2	P1_VCOI	0		Path 1 VCO bias setting: 000 = minimum value, 111 = maximum value. RF2054 characterized with 000.
1		1		
0		0		

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PLL1x4 (0Ch) - Calibration Settings

#	Bit Name	Default		Function
15	P1_DN	0	1	Path 1 frequency step size used in VCO tuning gain calibration
14		0		
13		0		
12		1		
11		0	7	
10		1		
9		1		
8		1		
7		1	E	
6	P1_CT_GAIN	1		Path 1 coarse tuning calibration gain
5		1		
4		0		
3	P1_KV_GAIN	0	4	Path 1 VCO tuning gain calibration gain
2		1		
1		0		
0		0		

PLL1x5 (0Dh) - More Calibration Settings

#	Bit Name	Default		Function
15	P1_N_PHS_ADJ	0	0	Path 1 frequency step size used in VCO tuning gain calibration
14		0		
13		0		
12		0		
11		0	0	
10		0		
9		0		
8		0		
7		0	1	
6		0		
5		0		
4	P1_CT_V	1		Path 1 course tuning voltage setting when performing course tuning calibration. Default value is 16.
3		0	0	
2		0		
1		0		
0		0		

PLL2x0 (10h) - VCO, LO Divider and Calibration Select

#	Bit Name	Default		Function
15	P2_VCOSEL	0	7	Always set to 10 = VCO3.
14		1		
13	P2_CT_EN	1		Path 2 VCO coarse tune: 00 = disabled, 11 = enabled
12		1		
11	P2_KV_EN	0	1	Path 2 VCO tuning gain calibration: 00 = disabled, 11 = enabled
10		0		
9	P2_LODIV	0		Path 2 local oscillator divider: 00 = divide by 1, 01 = divide by 2, 10 = divide by 4, 11 = reserved
8		1		
7			1	
6				
5	P2_CP_DEF	0		Charge pump current setting. If P2_KV_EN = 11 this value sets charge pump current during KV compensation only
4		1		
3		1	F	
2		1		
1		1		
0		1		

PLL2x1 (11h) - MSB of Fractional Divider Ratio

#	Bit Name	Default		Function
15	P2_NUM_MSB	0	6	Path 2 VCO divider numerator value, most significant 16 bits
14		1		
13		1		
12		0		
11		0	2	
10		0		
9		1		
8		0		
7		0	7	
6		1		
5		1		
4		1		
3		0	6	
2		1		
1		1		
0		0		

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PLL2x2 (12h) - LSB of Fractional Divider Ratio and CT Default

#	Bit Name	Default		Function
15	P2_NUM_LSB	0	2	Path 2 VCO divider numerator value, least significant 8 bits.
14		0		
13		1		
12		0		
11		0	7	
10		1		
9		1		
8		1		
7	P2_CT_DEF	0	7	Path 2 VCO coarse tuning value, used when P2_CT_EN = 00
6		1		
5		1		
4		1		
3		1	E	
2		1		
1		1		
0		0		

PLL2x3 (13h) - Integer Divider Ratio and VCO Current

#	Bit Name	Default		Function
15	P2_N	0	2	Path 2 VCO divider integer value
14		0		
13		1		
12		0		
11		0	3	
10		0		
9		1		
8		1		
7		0	0	
6		0		
5		0		
4		0		
3		0	2	
2	P2_VCOI	0		Path 2 VCO bias setting: 000 = minimum value, 111 = maximum value. RF2054 characterized with 000.
1		1		
0		0		

PLL2x4 (14h) - Calibration Settings

#	Bit Name	Default		Function
15	P2_DN	0	1	Path 2 frequency step size used in VCO tuning gain calibration
14		0		
13		0		
12		1		
11		0	7	
10		1		
9		1		
8		1		
7		1	E	
6	P2_CT_GAIN	1		Path 2 coarse tuning calibration gain
5		1		
4		0		
3	P2_KV_GAIN	0	4	Path 2 VCO tuning gain calibration gain
2		1		
1		0		
0		0		

PLL2x5 (15h) - More Calibration Settings

#	Bit Name	Default		Function
15	P2_N_PHS_ADJ	0	0	Path 2 synthesizer phase adjustment
14		0		
13		0		
12		0		
11		0	0	
10		0		
9		0		
8		0		
7		0	1	
6		0		
5		0		
4	P2_CT_V	1		Path 2 course tuning voltage setting when performing course tuning calibration. Default value is 16.
3		0	0	
2		0		
1		0		
0		0		

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GPO (18h) - Internal Control Output Settings

#	Bit Name	Default		Function
15		0	0	
14	P1_GPO1	0		Setting of GPO1 when path 1 is active, used internally only
13		0		
12	P1_GPO3	0		Setting of GPO3 when path 1 is active, used internally only
11	P1_GPO4	0	0	Setting of GPO4 when path 1 is active, used internally only
10		0		
9		0		
8		0		
7		0	0	
6	P2_GPO1	0		Setting of GPO1 when path 2 is active, used internally only
5		0		
4	P2_GPO3	0		Setting of GPO3 when path 2 is active, used internally only
3	P2_GPO4	0	0	Setting of GPO4 when path 2 is active, used internally only
2		0		
1		0		
0		0		

CHIPREV (19h) - Chip Revision Information

#	Bit Name	Default		Function
15	PARTNO	0	0	RFMD Part number for device
14		0		
13		0		
12		0		
11		0	0	
10		0		
9		0		
8		0		
7	REVNO	X	X	Part revision number
6		X		
5		X		
4		X		
3		X	X	
2		X		
1		X		
0		X		

RB1 (1Ch) - PLL Lock and Calibration Results Read-back

#	Bit Name	Default		Function
15	LOCK	X	X	PLL lock detector, 0 = PLL locked, 1 = PLL unlocked
14	CT_CAL	X		CT setting (either result of course tune calibration, or CT_DEF, depending on state of CT_EN). Also depends on the MODE of the device
13		X		
12		X		
11		X	X	
10		X		
9		X		
8		X		
7	CP_CAL	X	X	CP setting (either result of KV cal, or CP_DEF, depending on state of KV_EN). Also depends on the MODE of the device
6		X		
5		X		
4		X		
3		X	X	
2		X		
1		0		
0		0		

RB2 (1Dh) - Calibration Results Read-Back

#	Bit Name	Default		Function
15	VO_CAL	X	X	The VCO voltage measured at the start of a VCO gain calibration
14		X		
13		X		
12		X		
11		X	X	
10		X		
9		X		
8		X		
7	V1_CAL	X	X	The VCO voltage measured at the end of a VCO gain calibration
6		X		
5		X		
4		X		
3		X	X	
2		X		
1		X		
0		X		

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RB3 (1Eh) - PLL state Read-Back

#	Bit Name	Default		Function
15	RSM_STATE	X	X	State of the radio state machine
14		X		
13		X		
12		X		
11		X	X	
10		X		
9		0		
8		0		
7		0	0	
6		0		
5		0		
4		0		
3		0	0	
2		0		
1		0		
0		0		

TEST (1Fh) - Test Modes

#	Bit Name	Default		Function
15	TEN	0	0	Enables test mode
14	TMUX	0		Sets test multiplexer state
13		0		
12		0		
11	CPU	0	0	Set charge pump to pump up, 0 = normal operation 1 = pump down
10	CPD	0		Set charge pump to pump down, 0 = normal operation 1 = pump down
9	FNZ	0		0 = normal operation, 1 = fractional divider modulator disabled
8	LDO_BYP	0		On chip low drop out regulator bypassed
7	TSEL	0	0	
6		0		
5		0		
4	DACTEST	0		DAC test
3		0	0	
2		0		
1		0		
0		0		

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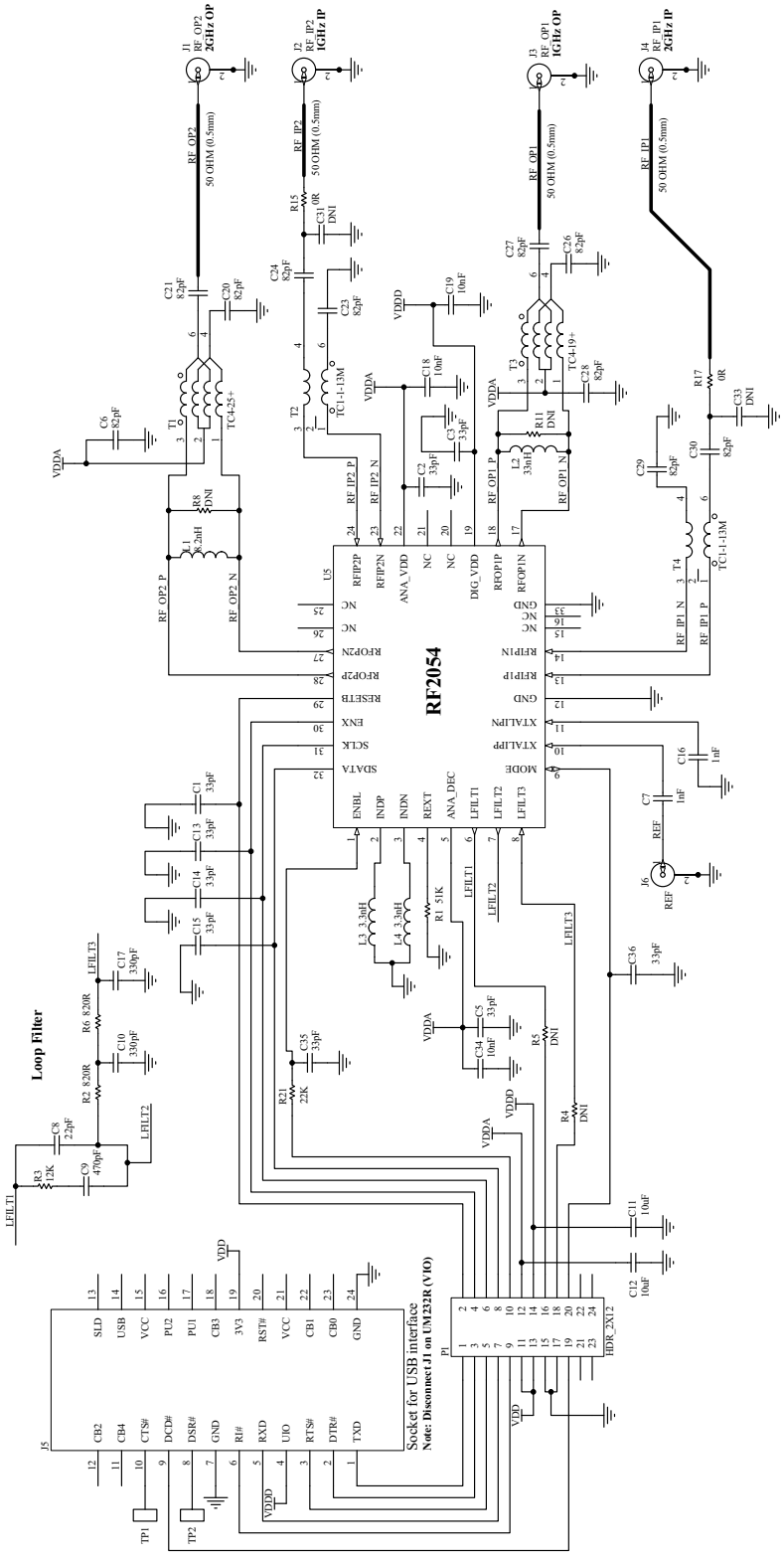
Evaluation Board Schematic



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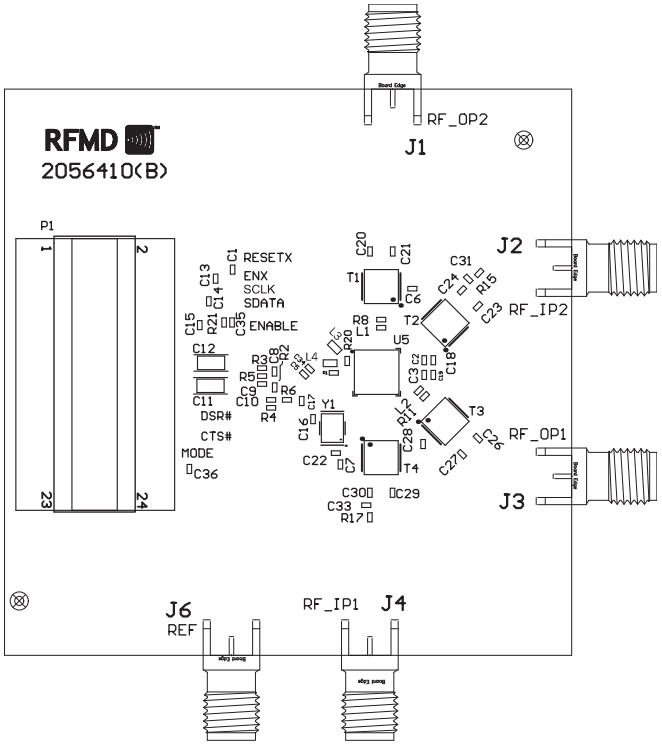
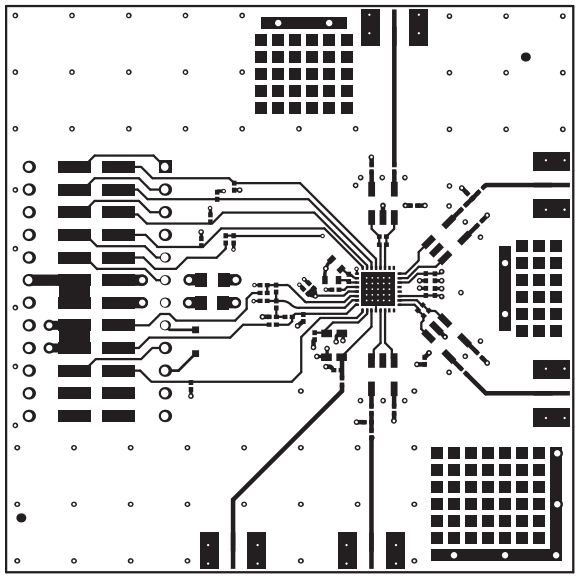
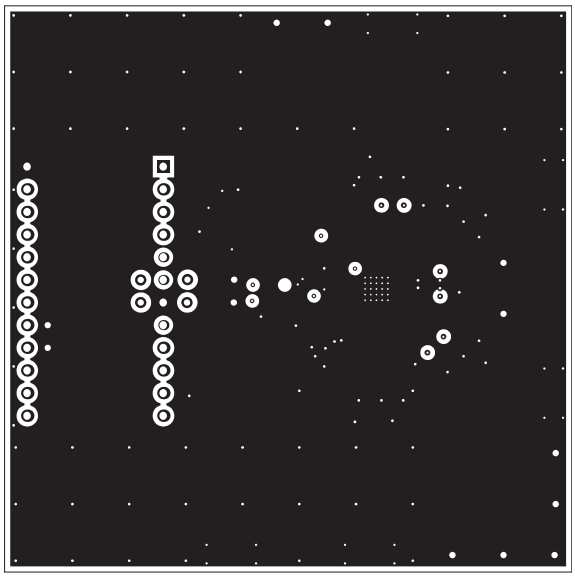
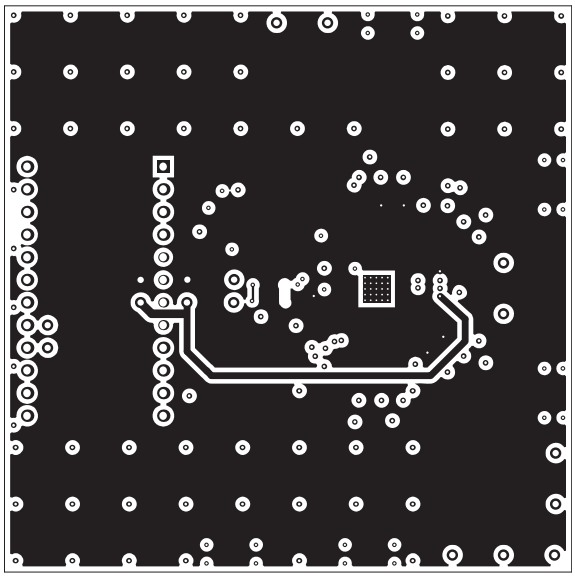
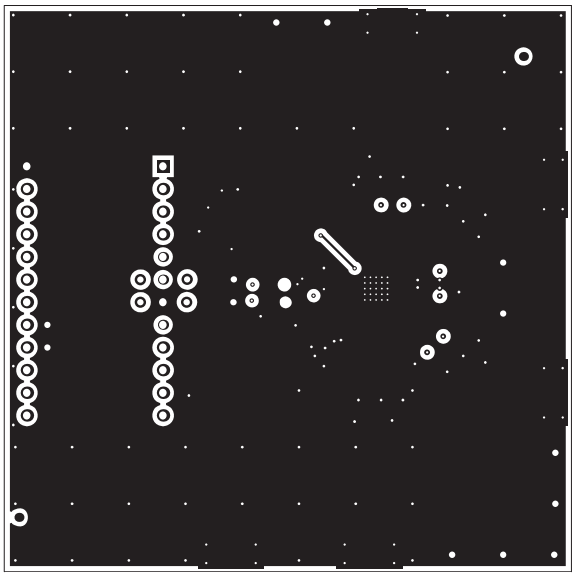
Evaluation Board Layout (RF2056)
Board Size 2.5” x 2.5”
Board Thickness 0.040”, Board Material FR-4











Note: The RF2054 was evaluated and characterized on a standard RF2056 evaluation board, but with component changes as defined in the schematic on page 36.

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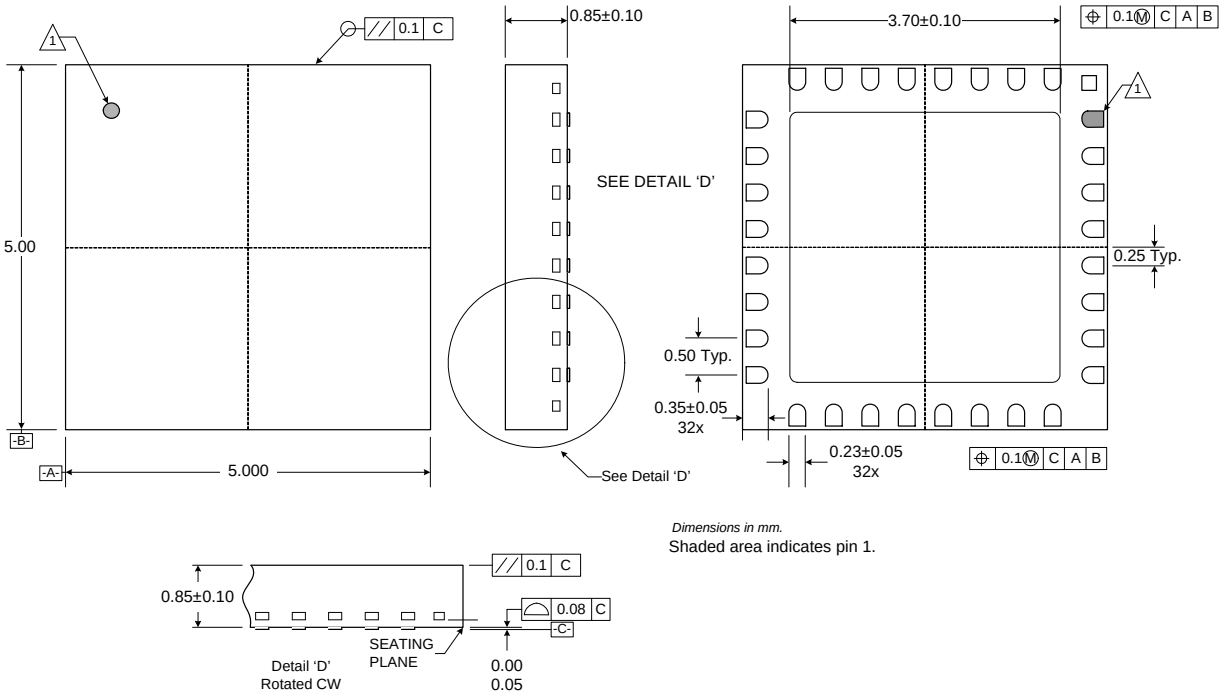
Package Drawing
QFN, 32-Pin, 5mm x 5mm



Support and Applications Information

Application notes and support material can be downloaded from the product web page: www.rfmd.com/rf205x.

Ordering Information

Part Number	Package	Quantity
RF2054	32-Pin QFN	25-Piece sample bag
RF2054SB	32-Pin QFN	5-Piece sample bag
RF2054SR	32-Pin QFN	100-Piece reel
RF2054TR7	32-Pin QFN	750-Piece reel
RF2054TR13	32-Pin QFN	2500-Piece reel