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### FEATURES

- IQ modulator with integrated fractional-N PLL**
- Output frequency range: 2050 MHz to 3000 MHz**
- Internal LO frequency range: 2500 MHz to 2900 MHz**
- Output P1dB: 12.1 dBm @ 2700 MHz**
- Output IP3: 27.2 dBm @ 2700 MHz**
- Noise floor: -158.3 dBm/Hz @ 2700 MHz**
- Baseband bandwidth: 750 MHz (3 dB)**
- SPI serial interface for PLL programming**
- Integrated LDOs and LO buffer**
- Power supply: 5 V/226 mA**
- 40-lead 6 mm × 6 mm LFCSP**

### APPLICATIONS

- Cellular communications systems**
  - GSM/EDGE, CDMA2000, W-CDMA, TD-SCDMA, LTE
- Broadband wireless access systems**
- Satellite modems**

### GENERAL DESCRIPTION

The **ADRF6704** provides a quadrature modulator and synthesizer solution within a small 6 mm × 6 mm footprint while requiring minimal external components.

The **ADRF6704** is designed for RF outputs from 2050 MHz to 3000 MHz. The low phase noise VCO and high performance quadrature modulator make the **ADRF6704** suitable for next generation communication systems requiring high signal dynamic range and linearity. The integration of the IQ

modulator, PLL, and VCO provides for significant board savings and reduces the BOM and design complexity.

The integrated fractional-N PLL/synthesizer generates a  $2 \times f_{LO}$  input to the IQ modulator. The phase detector together with an external loop filter is used to control the VCO output. The VCO output is applied to a quadrature divider. To reduce spurious components, a sigma-delta ( $\Sigma$ - $\Delta$ ) modulator controls the programmable PLL divider.

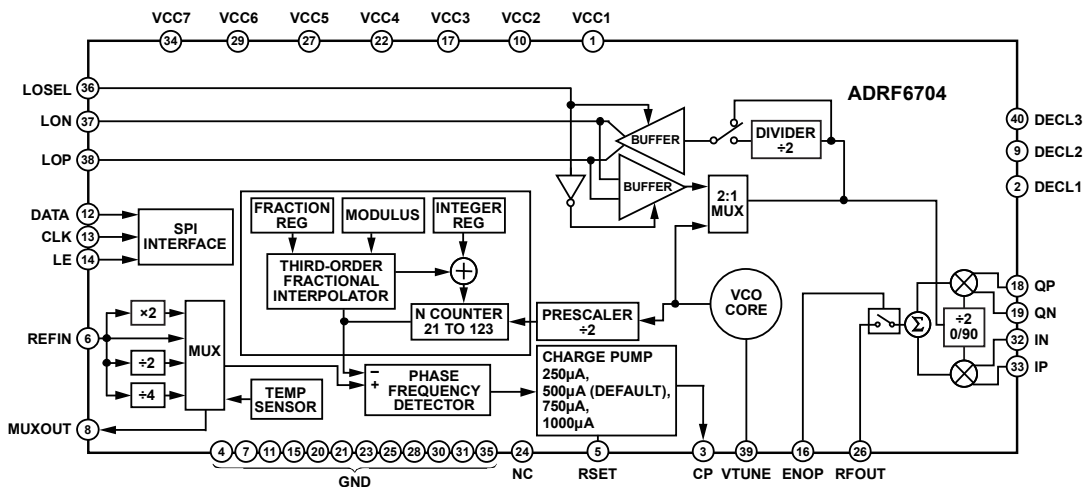
The IQ modulator has wideband differential I and Q inputs, which support baseband as well as complex IF architectures. The single-ended modulator output is designed to drive a 50  $\Omega$  load impedance and can be disabled.

The **ADRF6704** is fabricated using an advanced silicon-germanium BiCMOS process. It is available in a 40-lead, exposed-paddle, Pb-free, 6 mm × 6 mm LFCSP package. Performance is specified from -40°C to +85°C. A lead-free evaluation board is available.

Table 1.

Part No.	Internal LO Range	IQ Modulator $\pm 3$ dB RF Output Range
<b>ADRF6701</b>	750 MHz	400 MHz
	1150 MHz	1250 MHz
<b>ADRF6702</b>	1550 MHz	1200 MHz
	2150 MHz	2400 MHz
<b>ADRF6703</b>	2100 MHz	1550 MHz
	2600 MHz	2650 MHz
<b>ADRF6704</b>	2500 MHz	2050 MHz
	2900 MHz	3000 MHz

### FUNCTIONAL BLOCK DIAGRAM



NOTES  
1. NC = NO CONNECT. DO NOT CONNECT TO THIS PIN.

Figure 1.

08871-001

### Rev. 0

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# ADRF6704\* PRODUCT PAGE QUICK LINKS

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## COMPARABLE PARTS

View a parametric search of comparable parts.

## EVALUATION KITS

- ADRF6704 Evaluation Board

## DOCUMENTATION

### Application Notes

- AN-1100: Wireless Transmitter IQ Balance and Sideband Suppression

### Data Sheet

- ADRF6704: 2500 MHz to 2900 MHz Quadrature Modulator with Integrated Fractional-N PLL and VCO Data Sheet

## TOOLS AND SIMULATIONS

- ADIsimPLL™
- ADIsimRF

## REFERENCE MATERIALS

### Press

- Industry's First Half Watt RF Driver Amplifier with Dynamically Adjustable Bias and Extended Temperature Range

### Product Selection Guide

- RF Source Booklet

### Technical Articles

- Integrated Devices Arm Infrastructure Radios

## DESIGN RESOURCES

- ADRF6704 Material Declaration
- PCN-PDN Information
- Quality And Reliability
- Symbols and Footprints

## DISCUSSIONS

View all ADRF6704 EngineerZone Discussions.

## SAMPLE AND BUY

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## REVISION HISTORY

10/11—Revision 0: Initial Version

## SPECIFICATIONS

$V_S = 5\text{ V}$ ;  $T_A = 25^\circ\text{C}$ ; baseband I/Q amplitude = 1 V p-p differential sine waves in quadrature with a 500 mV dc bias; baseband I/Q frequency ( $f_{\text{BB}}$ ) = 1 MHz;  $f_{\text{PFD}} = 38.4\text{ MHz}$ ;  $f_{\text{REF}} = 153.6\text{ MHz}$  at +4 dBm Re:50  $\Omega$  (1 V p-p); 130 kHz loop filter, unless otherwise noted.

Table 2.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
OPERATING FREQUENCY RANGE	IQ modulator ( $\pm 3\text{ dB}$ RF output range)	2050		3000	MHz
	PLL LO range	2500		2900	MHz
RF OUTPUT = 2500 MHz	RFOUT pin				
Nominal Output Power	Baseband VIQ = 1 V p-p differential		6.2		dBm
IQ Modulator Voltage Gain	RF output divided by baseband input voltage		2.2		dB
OP1dB			12.9		dBm
Carrier Feedthrough			-41.2		dBm
Sideband Suppression			-42.4		dBc
Quadrature Error			$\pm 1$		Degrees
I/Q Amplitude Balance			0.06		dB
Second Harmonic	$P_{\text{OUT}} - P(f_{\text{LO}} \pm (2 \times f_{\text{BB}}))$		-67		dBc
Third Harmonic	$P_{\text{OUT}} - P(f_{\text{LO}} \pm (3 \times f_{\text{BB}}))$		-45.6		dBc
Output IP2	$f_{1\text{BB}} = 3.5\text{ MHz}$ , $f_{2\text{BB}} = 4.5\text{ MHz}$ , $P_{\text{OUT}} \approx -2\text{ dBm}$ per tone		65.4		dBm
Output IP3	$f_{1\text{BB}} = 3.5\text{ MHz}$ , $f_{2\text{BB}} = 4.5\text{ MHz}$ , $P_{\text{OUT}} \approx -2\text{ dBm}$ per tone		25.4		dBm
Noise Floor	I/Q inputs = 0 V differential with 500 mV dc bias, 20 MHz carrier offset		-157.8		dBm/Hz
RF OUTPUT = 2700 MHz	RFOUT pin				
Nominal Output Power	Baseband VIQ = 1 V p-p differential		5.5		dBm
IQ Modulator Voltage Gain	RF output divided by baseband input voltage		1.5		dB
OP1dB			12.1		dBm
Carrier Feedthrough			-40.6		dBm
Sideband Suppression			-37.7		dBc
Quadrature Error			0 to 2		Degrees
I/Q Amplitude Balance			0.06		dB
Second Harmonic	$P_{\text{OUT}} - P(f_{\text{LO}} \pm (2 \times f_{\text{BB}}))$		-66		dBc
Third Harmonic	$P_{\text{OUT}} - P(f_{\text{LO}} \pm (3 \times f_{\text{BB}}))$		-47.1		dBc
Output IP2	$f_{1\text{BB}} = 3.5\text{ MHz}$ , $f_{2\text{BB}} = 4.5\text{ MHz}$ , $P_{\text{OUT}} \approx -2\text{ dBm}$ per tone		63.8		dBm
Output IP3	$f_{1\text{BB}} = 3.5\text{ MHz}$ , $f_{2\text{BB}} = 4.5\text{ MHz}$ , $P_{\text{OUT}} \approx -2\text{ dBm}$ per tone		27.2		dBm
Noise Floor	I/Q inputs = 0 V differential with 500 mV dc bias, 20 MHz carrier offset		-158.3		dBm/Hz
RF OUTPUT = 2900 MHz	RFOUT pin				
Nominal Output Power	Baseband VIQ = 1 V p-p differential		4.1		dBm
IQ Modulator Voltage Gain	RF output divided by baseband input voltage		0.1		dB
OP1dB			11.8		dBm
Carrier Feedthrough			-41.5		dBm
Sideband Suppression			-32.7		dBc
Quadrature Error			1 to 2.8		Degrees
I/Q Amplitude Balance			0.1		dB
Second Harmonic	$P_{\text{OUT}} - P(f_{\text{LO}} \pm (2 \times f_{\text{BB}}))$		-67		dBc
Third Harmonic	$P_{\text{OUT}} - P(f_{\text{LO}} \pm (3 \times f_{\text{BB}}))$		-51.4		dBc
Output IP2	$f_{1\text{BB}} = 3.5\text{ MHz}$ , $f_{2\text{BB}} = 4.5\text{ MHz}$ , $P_{\text{OUT}} \approx -2\text{ dBm}$ per tone		62.7		dBm
Output IP3	$f_{1\text{BB}} = 3.5\text{ MHz}$ , $f_{2\text{BB}} = 4.5\text{ MHz}$ , $P_{\text{OUT}} \approx -2\text{ dBm}$ per tone		29.6		dBm
Noise Floor	I/Q inputs = 0 V differential with 500 mV dc bias, 20 MHz carrier offset		-157.5		dBm/Hz
SYNTHESIZER SPECIFICATIONS	Synthesizer specifications referenced to the modulator output				
Internal LO Range		2500		2900	MHz
Figure of Merit (FOM) <sup>1</sup>			-221.4		dBc/Hz/Hz

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
REFERENCE CHARACTERISTICS	REFIN, MUXOUT pins				
REFIN Input Frequency		11		160	MHz
REFIN Input Capacitance			4		pF
Phase Detector Frequency		22		40	MHz
MUXOUT Output Level	Low (lock detect output selected)			0.25	V
	High (lock detect output selected)	2.7			V
MUXOUT Duty Cycle			50		%
CHARGE PUMP					
Charge Pump Current	Programmable to 250 $\mu$ A, 500 $\mu$ A, 750 $\mu$ A, 1000 $\mu$ A		500		$\mu$ A
Output Compliance Range		1		2.8	V
PHASE NOISE (FREQUENCY = 2500 MHz, $f_{\text{PFD}} = 38.4$ MHz)	Closed loop operation (see Figure 35 for loop filter design)				
	10 kHz offset		-100.9		dBc/Hz
	100 kHz offset		-100		dBc/Hz
	1 MHz offset		-126		dBc/Hz
	10 MHz offset		-148.3		dBc/Hz
Integrated Phase Noise	1 kHz to 10 MHz integration bandwidth		0.37		$^{\circ}$ rms
Reference Spurs	$f_{\text{PFD}}/2$		-111		dBc
	$f_{\text{PFD}}$		-87.3		dBc
	$f_{\text{PFD}} \times 2$		-93.6		dBc
	$f_{\text{PFD}} \times 3$		-92.8		dBc
	$f_{\text{PFD}} \times 4$		-98.2		dBc
PHASE NOISE (FREQUENCY = 2700 MHz, $f_{\text{PFD}} = 38.4$ MHz)	Closed loop operation (see Figure 35 for loop filter design)				
	10 kHz offset		-97.7		dBc/Hz
	100 kHz offset		-97.6		dBc/Hz
	1 MHz offset		-126.1		dBc/Hz
	10 MHz offset		-148.4		dBc/Hz
Integrated Phase Noise	1 kHz to 10 MHz integration bandwidth		0.46		$^{\circ}$ rms
Reference Spurs	$f_{\text{PFD}}/2$		-110.4		dBc
	$f_{\text{PFD}}$		-89.9		dBc
	$f_{\text{PFD}} \times 2$		-92		dBc
	$f_{\text{PFD}} \times 3$		-89.9		dBc
	$f_{\text{PFD}} \times 4$		-94.5		dBc
PHASE NOISE (FREQUENCY = 2900 MHz, $f_{\text{PFD}} = 38.4$ MHz)	Closed loop operation (see Figure 35 for loop filter design)				
	10 kHz offset		-92.3		dBc/Hz
	100 kHz offset		-96.4		dBc/Hz
	1 MHz offset		-125.2		dBc/Hz
	10 MHz offset		-148.5		dBc/Hz
Integrated Phase Noise	1 kHz to 10 MHz integration bandwidth		0.62		$^{\circ}$ rms
Reference Spurs	$f_{\text{PFD}}/2$		-110.7		dBc
	$f_{\text{PFD}}$		-90.9		dBc
	$f_{\text{PFD}} \times 2$		-89.8		dBc
	$f_{\text{PFD}} \times 3$		-92.1		dBc
	$f_{\text{PFD}} \times 4$		-93.7		dBc
RF OUTPUT HARMONICS	Measured at RFOUT, frequency = 2700 MHz				
	Second harmonic		-44.4		dBc
	Third harmonic		-76.7		dBc
LO INPUT/OUTPUT	LOP, LON				
Output Frequency Range	Divide by 2 circuit in LO path enabled	2500		2900	MHz
	Divide by 2 circuit in LO path disabled	5000		5800	MHz
LO Output Level at 2700 MHz	1 $\times$ LO mode, into a 50 $\Omega$ load, LO buffer enabled		-2		dBm
LO Input Level	Externally applied 2 $\times$ LO, PLL disabled		0		dBm
LO Input Impedance	Externally applied 2 $\times$ LO, PLL disabled		50		$\Omega$

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
BASEBAND INPUTS	IP, IN, QP, QN pins				
I and Q Input DC Bias Level		400	500	600	mV
Bandwidth	$P_{OUT} \approx -7$ dBm, RF flatness of IQ modulator output calibrated out				
	0.5 dB		350		MHz
	3 dB		750		MHz
Differential Input Impedance			920		$\Omega$
Differential Input Capacitance			1		pF
LOGIC INPUTS	CLK, DATA, LE, ENOP, LOSEL				
Input High Voltage, $V_{INH}$		1.4		3.3	V
Input Low Voltage, $V_{INL}$		0		0.7	V
Input Current, $I_{INH}/I_{INL}$			0.1		$\mu$ A
Input Capacitance, $C_{IN}$			5		pF
TEMPERATURE SENSOR	VPTAT voltage measured at MUXOUT				
Output Voltage	$T_A = 25^\circ\text{C}$ , $R_L \geq 10$ k $\Omega$ (LO buffer disabled)		1.579		V
Temperature Coefficient	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ , $R_L \geq 10$ k $\Omega$		3.8		mV/ $^\circ\text{C}$
POWER SUPPLIES	VCC1, VCC2, VCC3, VCC4, VCC5, VCC6, VCC7				
Voltage Range		4.75	5	5.25	V
Supply Current	Normal Tx mode (PLL and IQMOD enabled, LO buffer disabled)		226		mA
	Tx mode using external LO input (internal VCO/PLL disabled)		135		mA
	Tx mode with LO buffer enabled		276		mA
	Power-down mode		22		mA

<sup>1</sup> The figure of merit (FOM) is computed as phase noise (dBc/Hz) – 10log<sub>10</sub>( $f_{PFDD}$ ) – 20log<sub>10</sub>( $f_{LO}/f_{PFDD}$ ). The FOM was measured across the full LO range, with  $f_{REF} = 80$  MHz,  $f_{REF}$  power = 10 dBm (500 V/ $\mu$ s slew rate) with a 40 MHz  $f_{PFDD}$ . The FOM was computed at 50 kHz offset.

TIMING CHARACTERISTICS

Table 3.

Parameter	Limit	Unit	Test Conditions/Comments
t <sub>1</sub>	20	ns min	LE to CLK setup time
t <sub>2</sub>	10	ns min	DATA to CLK setup time
t <sub>3</sub>	10	ns min	DATA to CLK hold time
t <sub>4</sub>	25	ns min	CLK high duration
t <sub>5</sub>	25	ns min	CLK low duration
t <sub>6</sub>	10	ns min	CLK to LE setup time
t <sub>7</sub>	20	ns min	LE pulse width

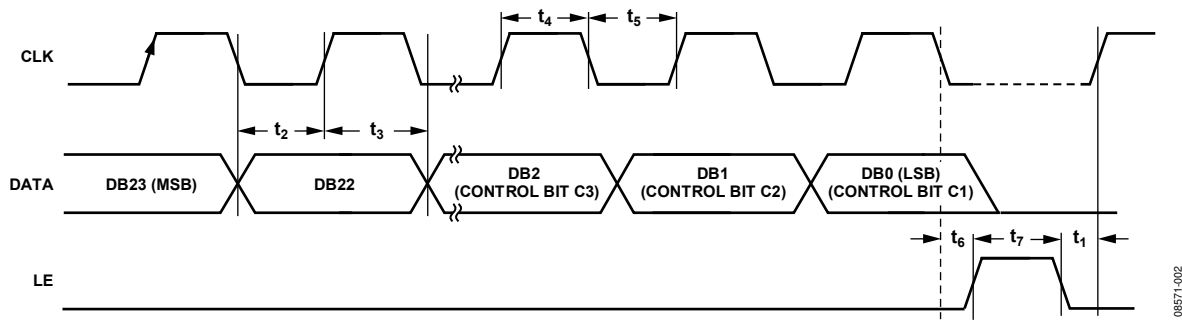


Figure 2. Timing Diagram

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## ABSOLUTE MAXIMUM RATINGS

Table 4.

Parameter	Rating
Supply Voltage (VCC1 to VCC7)	5.5 V
Digital I/O, CLK, DATA, LE	-0.3 V to +3.6 V
LOP, LON	18 dBm
IP, IN, QP, QN	-0.5 V to +1.5 V
REFIN	-0.3 V to +3.6 V
$\theta_{JA}$ (Exposed Paddle Soldered Down) <sup>1</sup>	35°C/W
Maximum Junction Temperature	150°C
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-65°C to +150°C

<sup>1</sup> Per JEDEC standard JESD 51-2.

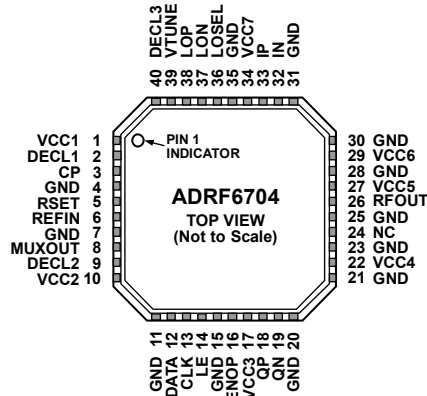
Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### ESD CAUTION



**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

## PIN CONFIGURATION AND FUNCTION DESCRIPTIONS



**NOTES**  
 1. NC = NO CONNECT. DO NOT CONNECT TO THIS PIN.  
 2. THE EXPOSED PADDLE SHOULD BE SOLDERED TO A LOW IMPEDANCE GROUND PLANE.

Figure 3. Pin Configuration

Table 5. Pin Function Descriptions

Pin No.	Mnemonic	Description
1, 10, 17, 22, 27, 29, 34	VCC1, VCC2, VCC3, VCC4, VCC5, VCC6, VCC7	Power Supply Pins. The power supply voltage range is 4.75 V to 5.25 V. Drive all of these pins from the same power supply voltage. Decouple each pin with 100 pF and 0.1 μF capacitors located close to the pin.
2	DECL1	Decoupling Node for Internal 3.3 V LDO. Decouple this pin with 100 pF and 0.1 μF capacitors located close to the pin.
3	CP	Charge Pump Output Pin. Connect VTUNE to this pin through the loop filter.
4, 7, 11, 15, 20, 21, 23, 25, 28, 30, 31, 35	GND	Ground. Connect these pins to a low impedance ground plane.
24	NC	Do not connect to this pin.
5	RSET	Charge Pump Current. The nominal charge pump current can be set to 250 μA, 500 μA, 750 μA, or 1000 μA using DB10 and DB11 of Register 4 and by setting DB18 to 0 (CP reference source).  In this mode, no external RSET is required. If DB18 is set to 1, the four nominal charge pump currents (I <sub>NOMINAL</sub> ) can be externally tweaked according to the following equation:  $R_{SET} = \left( \frac{217.4 \times I_{CP}}{I_{NOMINAL}} \right) - 37.8 \Omega$ where I <sub>CP</sub> is the base charge pump current in microamps. For further details on the charge pump current, see the Register 4—PLL Charge Pump, PFD, and Reference Path Control section.
6	REFIN	Reference Input. The nominal input level is 1 V p-p. Input range is 11 MHz to 160 MHz. This pin has high input impedance and should be ac-coupled. If REFIN is being driven by laboratory test equipment, the pin should be externally terminated with a 50 Ω resistor (place the ac-coupling capacitor between the pin and the resistor). When driven from an 50 Ω RF signal generator, the recommended input level is 4 dBm.
8	MUXOUT	Multiplexer Output. This output allows a digital lock detect signal, a voltage proportional to absolute temperature (VPTAT), or a buffered, frequency-scaled reference signal to be accessed externally. The output is selected by programming DB21 to DB23 in Register 4.
9	DECL2	Decoupling Node for 2.5 V LDO. Connect 100 pF, 0.1 μF, and 10 μF capacitors between this pin and ground.
12	DATA	Serial Data Input. The serial data input is loaded MSB first with the three LSBs being the control bits.
13	CLK	Serial Clock Input. This serial clock input is used to clock in the serial data to the registers. The data is latched into the 24-bit shift register on the CLK rising edge. Maximum clock frequency is 20 MHz.

Pin No.	Mnemonic	Description
14	LE	Latch Enable. When the LE input pin goes high, the data stored in the shift registers is loaded into one of the six registers, the relevant latch being selected by the first three control bits of the 24-bit word.
16	ENOP	Modulator Output Enable/Disable. See Table 6.
18, 19, 32, 33	QP, QN, IN, IP	Modulator Baseband Inputs. Differential in-phase and quadrature baseband inputs. These inputs should be dc-biased to 0.5 V.
26	RFOUT	RF Output. Single-ended, 50 $\Omega$ internally biased RF output. RFOUT must be ac-coupled to its load.
36	LOSEL	LO Select. This digital input pin determines whether the LOP and LON pins operate as inputs or outputs. This pin should not be left floating. LOP and LON become inputs if the LOSEL pin is set low and the LDRV bit of Register 5 is set low. External LO drive must be a 2 $\times$ LO. In addition to setting LOSEL and LDRV low and providing an external 2 $\times$ LO, the LXL bit of Register 5 (DB4) must be set to 1 to direct the external LO to the IQ modulator. LON and LOP become outputs when LOSEL is high or if the LDRV bit of Register 5 (DB3) is set to 1. A 1 $\times$ LO or 2 $\times$ LO output can be selected by setting the LDIV bit of Register 5 (DB5) to 1 or 0 respectively (see Table 7).
37, 38	LON, LOP	Local Oscillator Input/Output. The internally generated 1 $\times$ LO or 2 $\times$ LO is available on these pins. When internal LO generation is disabled, an external 1 $\times$ LO or 2 $\times$ LO can be applied to these pins.
39	VTUNE	VCO Control Voltage Input. This pin is driven by the output of the loop filter. Nominal input voltage range on this pin is 1.3 V to 2.5 V.
40	DECL3	Decoupling Node for VCO LDO. Connect a 100 pF capacitor and a 10 $\mu$ F capacitor between this pin and ground.
	EP	Exposed Paddle. The exposed paddle should be soldered to a low impedance ground plane.

Table 6. Enabling RFOUT

ENOP	Register 5 Bit DB6	RFOUT
X <sup>1</sup>	0	Disabled
0	X <sup>1</sup>	Disabled
1	1	Enabled

<sup>1</sup> X = don't care.Table 7. LO Port Configuration<sup>1, 2</sup>

LON/LOP Function	LOSEL	Register 5 Bit DB5(LDIV)	Register 5 Bit DB4(LXL)	Register 5 Bit DB3 (LDRV)
Input (2 $\times$ LO)	0	X	1	0
Output (Disabled)	0	X	0	0
Output (1 $\times$ LO)	0	0	0	1
Output (1 $\times$ LO)	1	0	0	0
Output (1 $\times$ LO)	1	0	0	1
Output (2 $\times$ LO)	0	1	0	1
Output (2 $\times$ LO)	1	1	0	0
Output (2 $\times$ LO)	1	1	0	1

<sup>1</sup> X = don't care.<sup>2</sup> LOSEL should not be left floating.

### TYPICAL PERFORMANCE CHARACTERISTICS

$V_S = 5\text{ V}$ ;  $T_A = 25^\circ\text{C}$ ; baseband I/Q amplitude = 1 V p-p differential sine waves in quadrature with a 500 mV dc bias; baseband I/Q frequency ( $f_{BB}$ ) = 1 MHz;  $f_{PFD} = 38.4\text{ MHz}$ ;  $f_{REF} = 153.6\text{ MHz}$  at +4 dBm Re:50  $\Omega$  (1 V p-p); 130 kHz loop filter, unless otherwise noted.

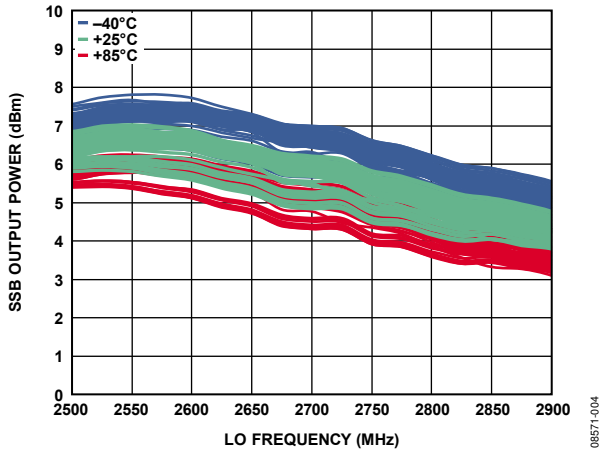


Figure 4. Single Sideband (SSB) Output Power ( $P_{out}$ ) vs. LO Frequency ( $f_{LO}$ ) and Temperature; Multiple Devices Shown

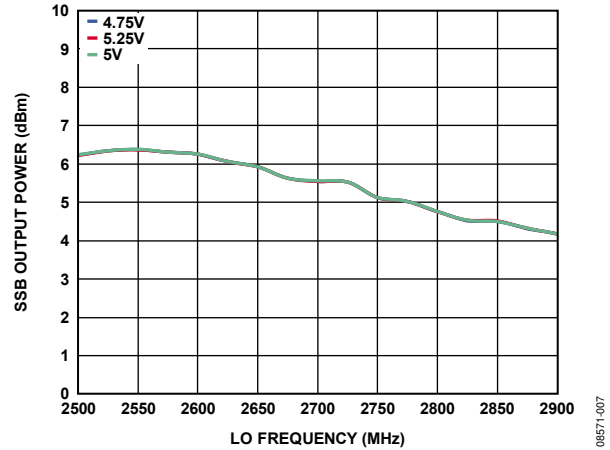


Figure 7. Single Sideband (SSB) Output Power ( $P_{out}$ ) vs. LO Frequency ( $f_{LO}$ ) and Power Supply; Multiple Devices Shown

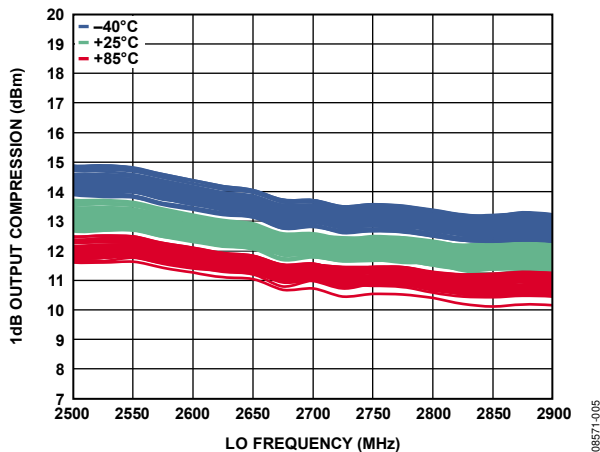


Figure 5. SSB Output 1dB Compression Point ( $OP_{1dB}$ ) vs. LO Frequency ( $f_{LO}$ ) and Temperature; Multiple Devices Shown

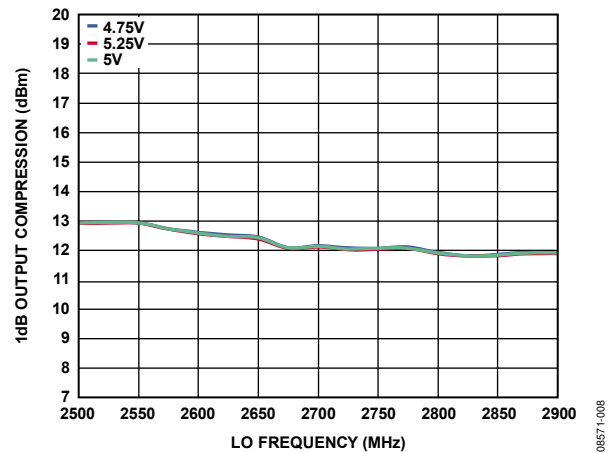


Figure 8. SSB Output 1dB Compression Point ( $OP_{1dB}$ ) vs. LO Frequency ( $f_{LO}$ ) and Power Supply

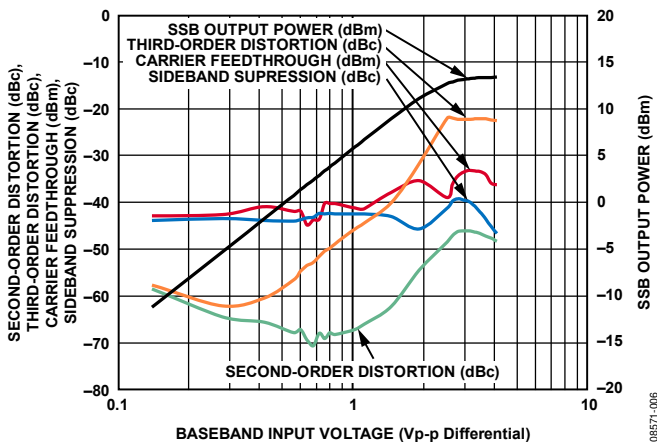


Figure 6. SSB Output Power, Second- and Third-Order Distortion, Carrier Feedthrough, and Sideband Suppression vs. Baseband Differential Input Voltage ( $f_{OUT} = 2500\text{ MHz}$ )

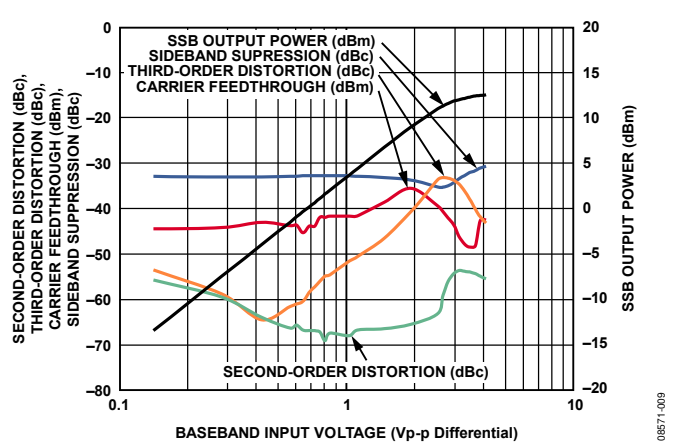


Figure 9. SSB Output Power, Second- and Third-Order Distortion, Carrier Feedthrough, and Sideband Suppression vs. Baseband Differential Input Voltage ( $f_{OUT} = 2900\text{ MHz}$ )

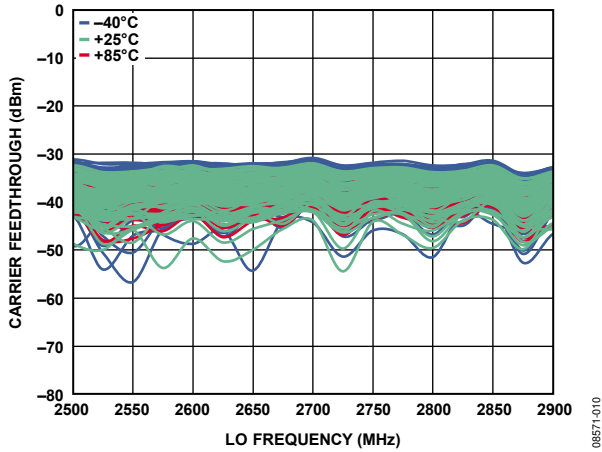


Figure 10. Carrier Feedthrough vs. LO Frequency ( $f_{LO}$ ) and Temperature; Multiple Devices Shown

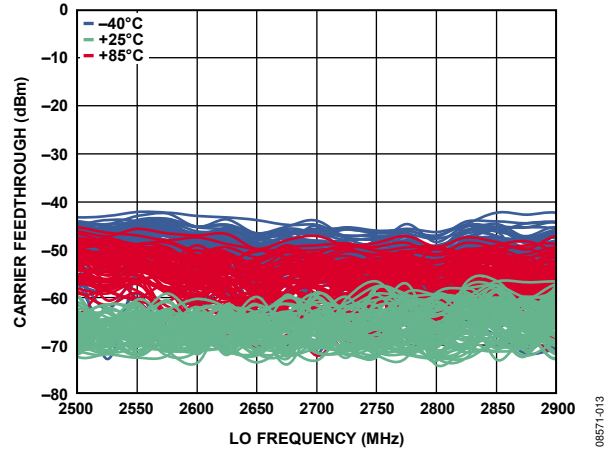


Figure 13. Carrier Feedthrough vs. LO Frequency ( $f_{LO}$ ) and Temperature After Nulling at 25°C; Multiple Devices Shown

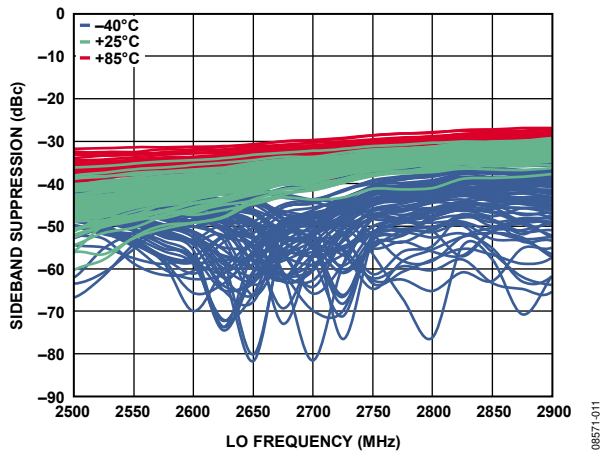


Figure 11. Sideband Suppression vs. LO Frequency ( $f_{LO}$ ) and Temperature; Multiple Devices Shown

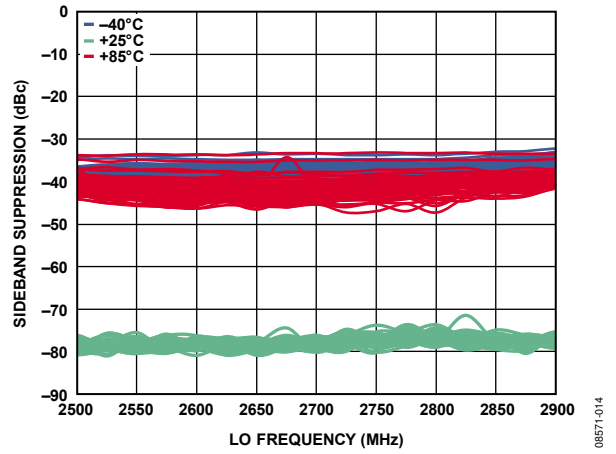


Figure 14. Sideband Suppression vs. LO Frequency ( $f_{LO}$ ) and Temperature After Nulling at 25°C; Multiple Devices Shown

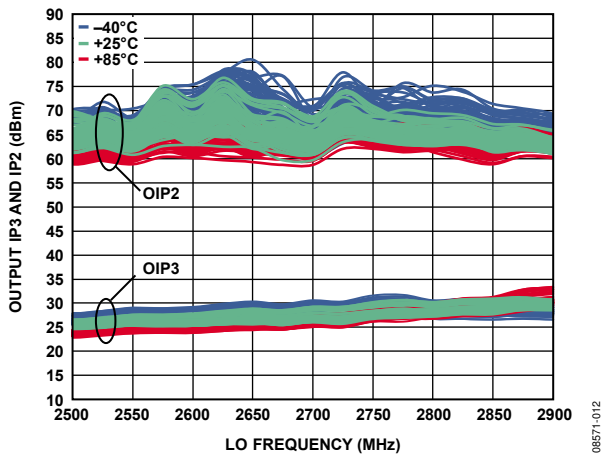


Figure 12. OIP3 and OIP2 vs. LO Frequency ( $f_{LO}$ ) and Temperature ( $P_{OUT} \approx -2$  dBm per Tone); Multiple Devices Shown

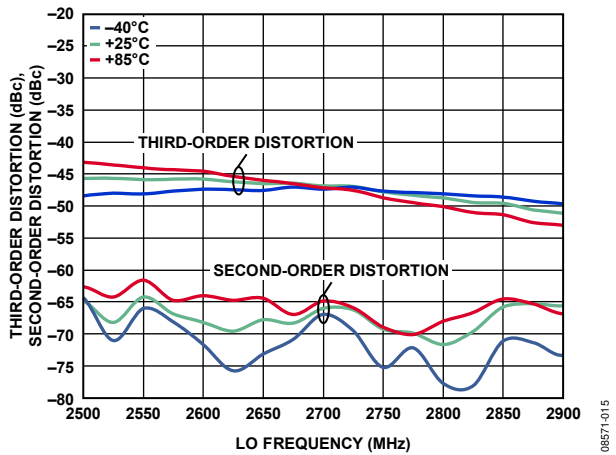


Figure 15. Second- and Third-Order Distortion vs. LO Frequency ( $f_{LO}$ ) and Temperature

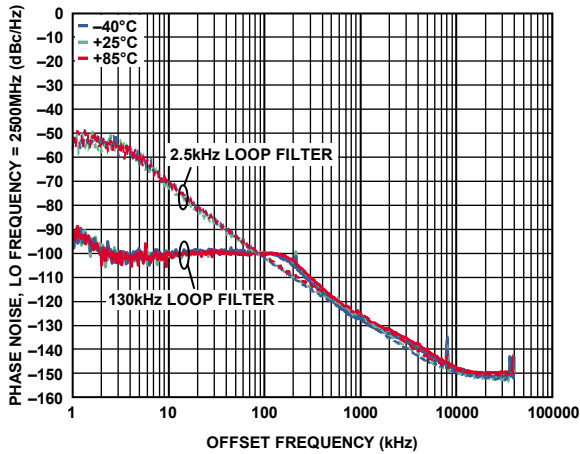


Figure 16. Phase Noise vs. Offset Frequency and Temperature,  $f_{LO} = 2500$  MHz

08571-016

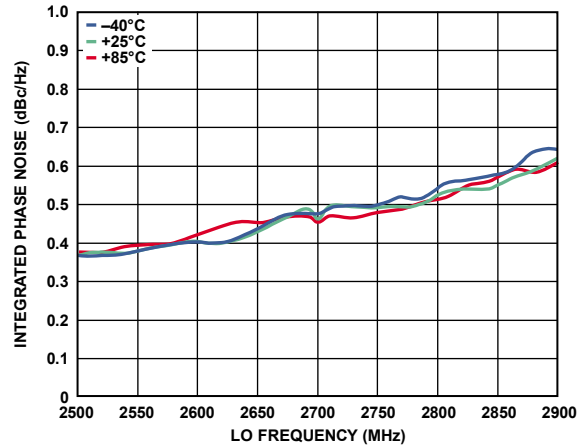


Figure 19. Integrated Phase Noise vs. LO Frequency

08571-019

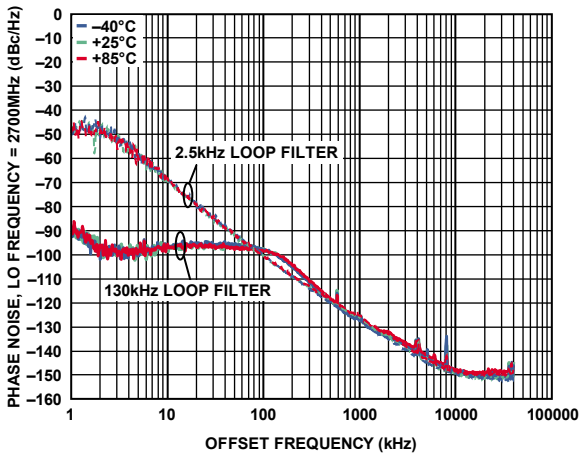


Figure 17. Phase Noise vs. Offset Frequency and Temperature,  $f_{LO} = 2700$  MHz

08571-017

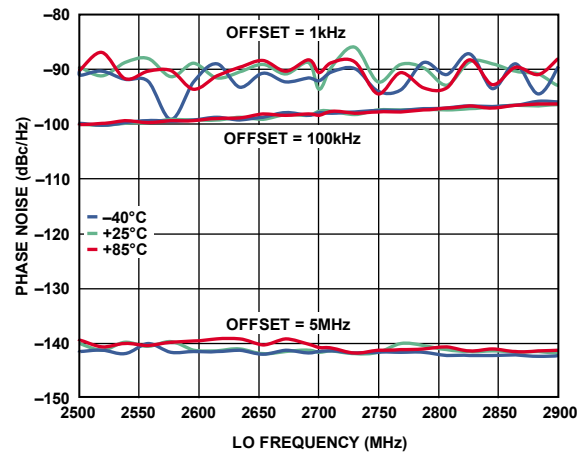


Figure 20. Phase Noise vs. LO Frequency at 1 kHz, 100 kHz, and 5 MHz Offsets

08571-020

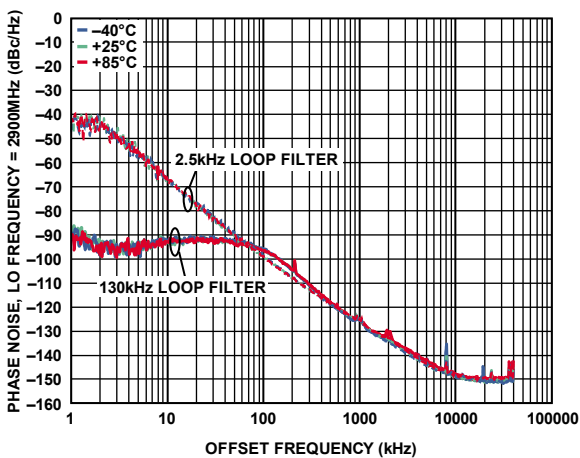


Figure 18. Phase Noise vs. Offset Frequency and Temperature,  $f_{LO} = 2900$  MHz

08571-018

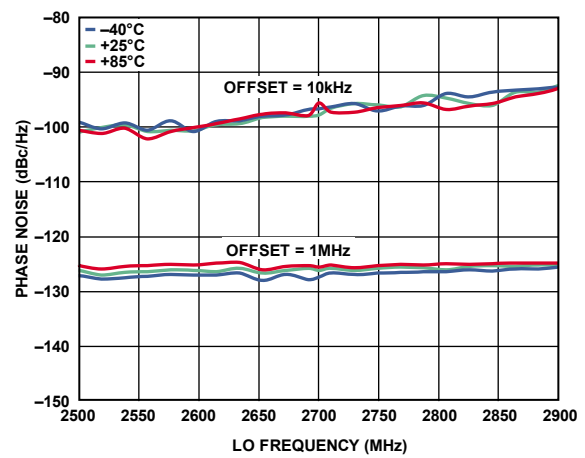


Figure 21. Phase Noise vs. LO Frequency at 10 kHz and 1 MHz Offsets

08571-021

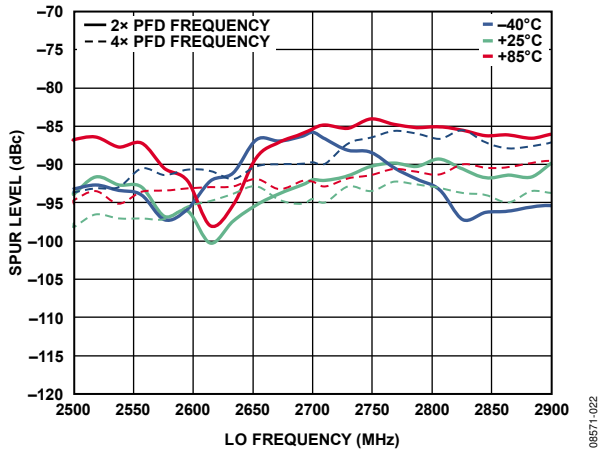


Figure 22. PLL Reference Spurs vs. LO Frequency (2x PFD and 4x PFD) at Modulator Output

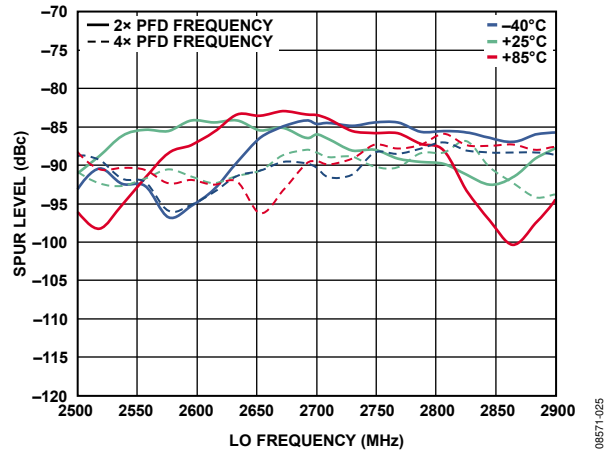


Figure 25. PLL Reference Spurs vs. LO Frequency (2x PFD and 4x PFD) at LO Output

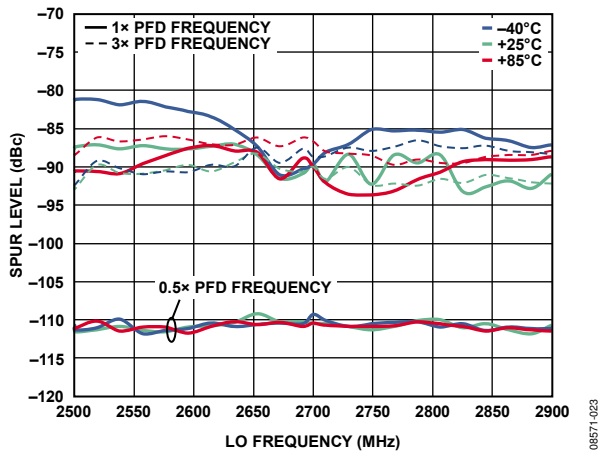


Figure 23. PLL Reference Spurs vs. LO Frequency (0.5x PFD, 1x PFD, and 3x PFD) at Modulator Output

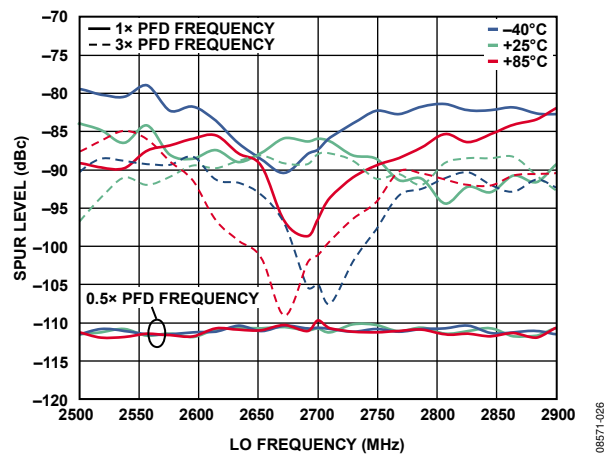


Figure 26. PLL Reference Spurs vs. LO Frequency (0.5x PFD, 1x PFD, and 3x PFD) at LO Output

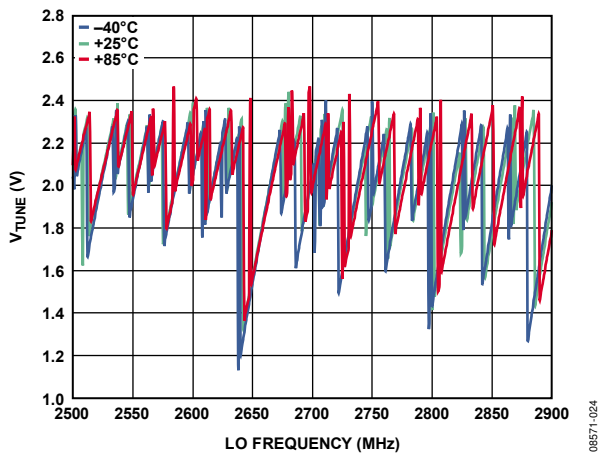


Figure 24. VTUNE vs. LO Frequency and Temperature

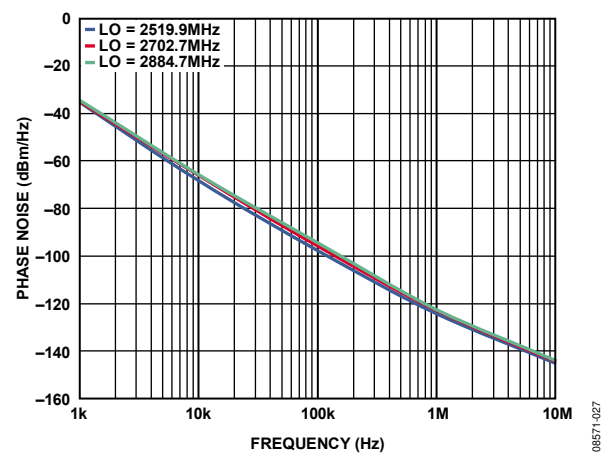


Figure 27. Open-Loop VCO Phase Noise at 2519.9 MHz, 2702.7 MHz, and 2884.7 MHz

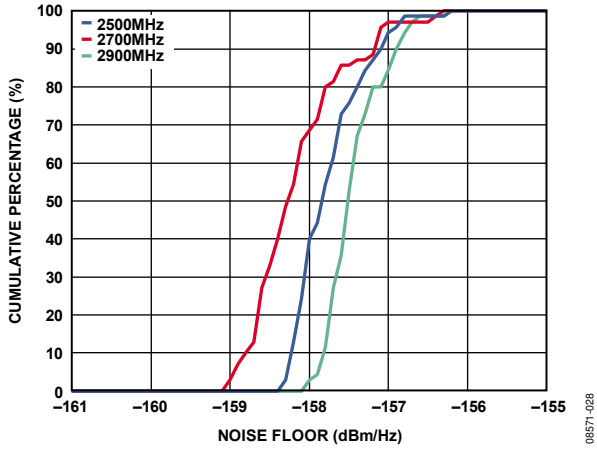


Figure 28. IQ Modulator Noise Floor Cumulative Distributions at 2500 MHz, 2700 MHz, and 2900 MHz

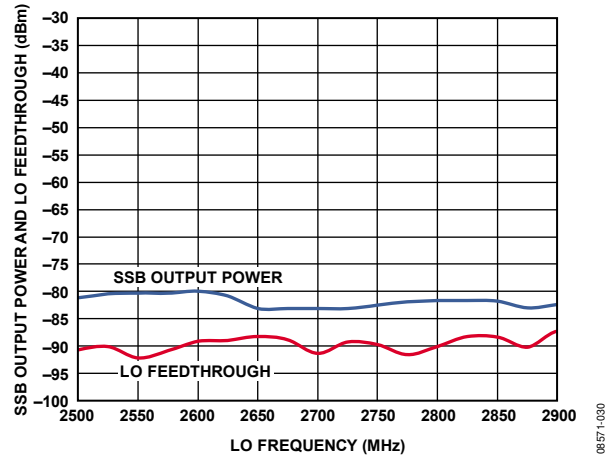


Figure 30. SSB Output Power and LO Feedthrough with RF Output Disabled

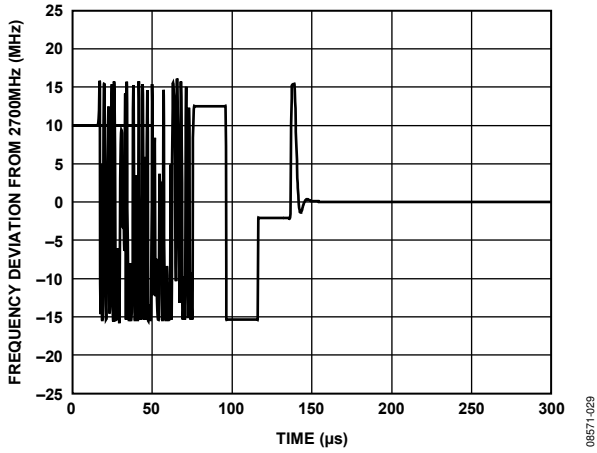


Figure 29. Frequency Deviation from LO Frequency at LO = 2.71 GHz to 2.7 GHz vs. Lock Time

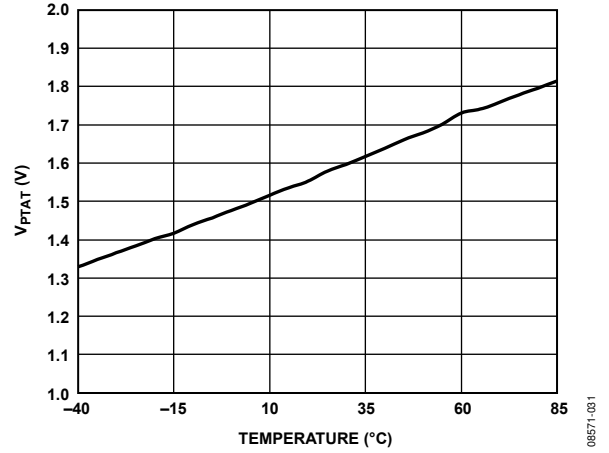


Figure 31. VPTAT Voltage vs. Temperature



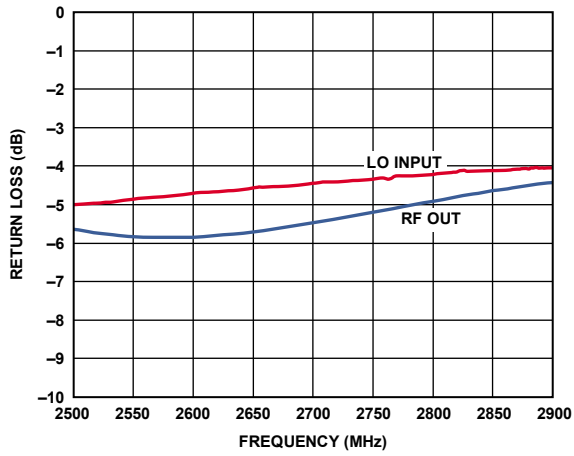


Figure 32. Input Return Loss of LO Input (LON, LOP Driven Through MABA-07159 1:1 Balun) and Output Return Loss of RFOUT vs. Frequency

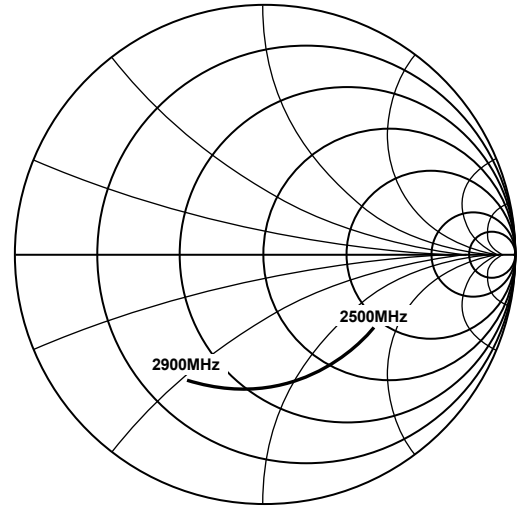


Figure 34. Smith Chart Representation of RF Output

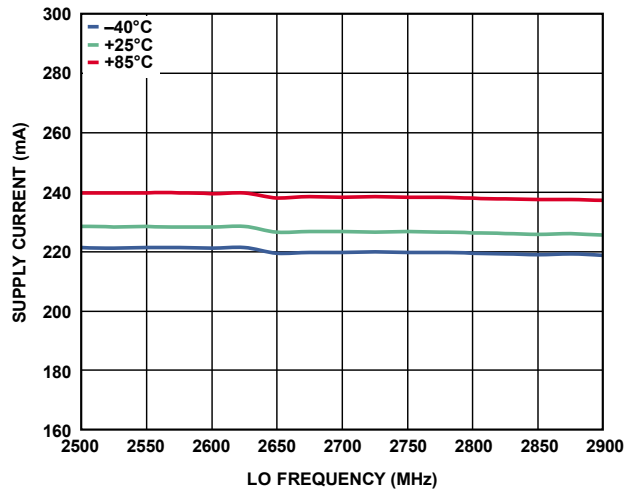


Figure 33. Power Supply Current vs. Frequency and Temperature (PLL and IQMOD Enabled, LO Buffer Disabled)

## THEORY OF OPERATION

The [ADRF6704](#) integrates a high performance IQ modulator with a state of the art fractional-N PLL. The [ADRF6704](#) also integrates a low noise VCO. The programmable SPI port allows the user to control the fractional-N PLL functions and the modulator optimization functions. This includes the capability to operate with an externally applied LO.

The quadrature modulator core within the [ADRF6704](#) is a part of the next generation of industry-leading modulators from Analog Devices, Inc. The baseband inputs are converted to currents and then mixed to RF using high performance NPN transistors. The mixer output currents are transformed to a single-ended RF output using an integrated RF transformer balun. The high performance active mixer core, coupled with the low-loss RF transformer balun results in an exceptional OIP3 and OP1dB, with a very low output noise floor for excellent dynamic range. The use of a passive transformer balun rather than an active output stage leads to an improvement in OIP3 with no sacrifice in noise floor. At 2700 MHz the [ADRF6704](#) typically provides an output P1dB of 12.1 dBm, OIP3 of 27.2 dBm, and an output noise floor of  $-158.3$  dBm/Hz. Typical image rejection under these conditions is  $-37.7$  dBc with no additional I and Q gain compensation.

### PLL + VCO

The fractional divide function of the PLL allows the frequency multiplication value from REFIN to the LOP/LON outputs to be a fractional value rather than restricted to an integer as in traditional PLLs. In operation, this multiplication value is  $INT + (FRAC/MOD)$  where INT is the integer value, FRAC is the fractional value, and MOD is the modulus value, all of which are programmable via the SPI port. In previous fractional-N PLL designs, the fractional multiplication was achieved by periodically changing the fractional value in a deterministic way. The downside of this was often spurious components close to the fundamental signal. In the [ADRF6704](#), a sigma delta modulator is used to distribute the fractional value randomly, thus significantly reducing the spurious content due to the fractional function.

## BASIC CONNECTIONS FOR OPERATION

Figure 35 shows the basic connections for operating the [ADRF6704](#) as they are implemented on the device's evaluation board. The seven power supply pins should be individually decoupled using 100 pF and 0.1  $\mu$ F capacitors located as close as possible to the pins. A single 10  $\mu$ F capacitor is also recommended. The three internal decoupling nodes (labeled DECL3, DECL2, and DECL1) should be individually decoupled with capacitors as shown in Figure 35.

The four I and Q inputs should be driven with a bias level of 500 mV. These inputs are generally dc-coupled to the outputs of a dual DAC (see the DAC-to-IQ Modulator Interfacing and IQ Filtering sections for more information).

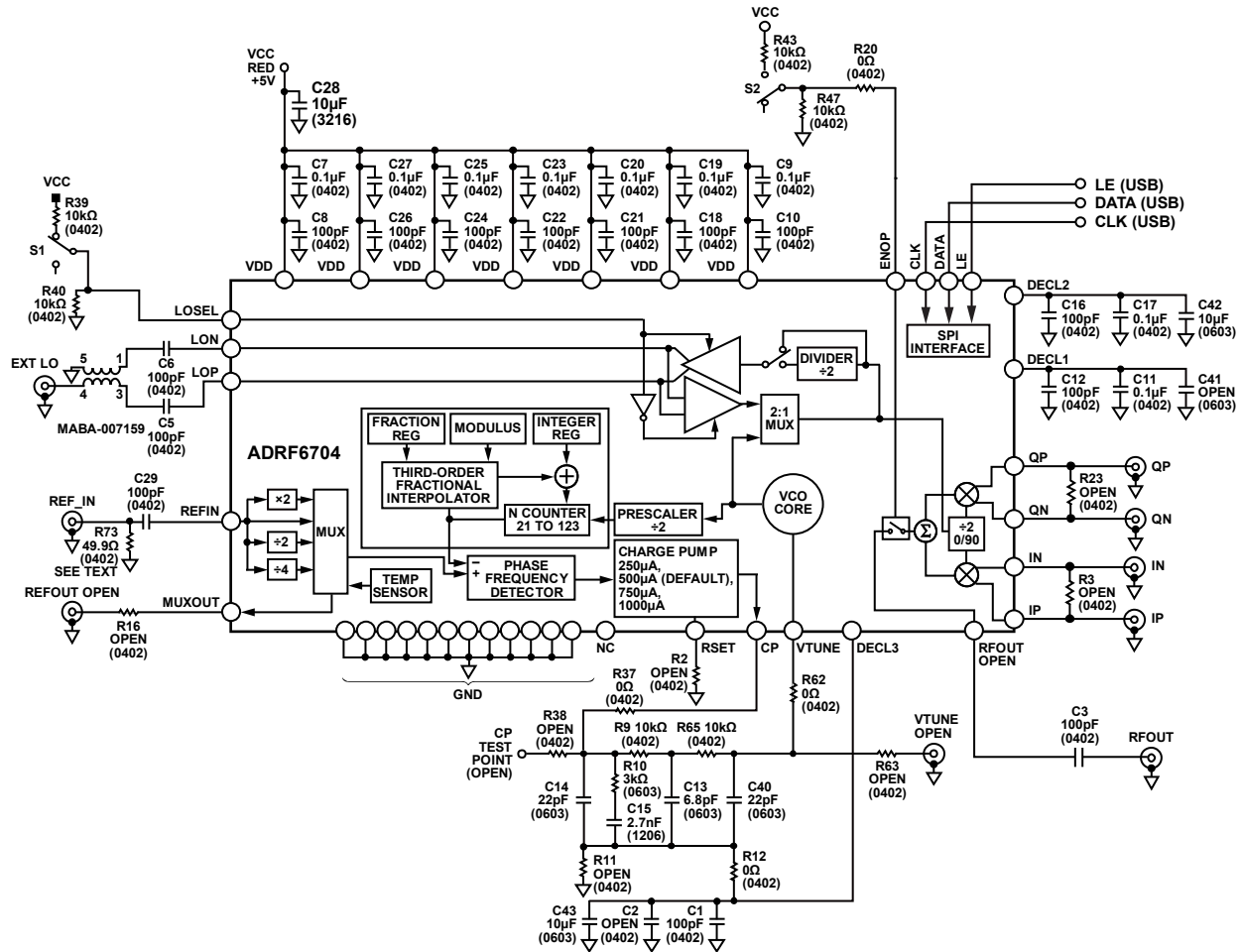
A 1 V p-p (0.353 V rms) differential sine wave on the I and Q inputs results in a single sideband output power of +5.5 dBm (at 2700 MHz) at the RFOUT pin (this pin should be ac-coupled as shown in Figure 35). This corresponds to an IQ modulator voltage gain of +1.5 dB.

The reference frequency for the PLL (typically 1 V p-p between 11 MHz and 160 MHz) should be applied to the REFIN pin, which should be ac-coupled. If the REFIN pin is being driven from a 50  $\Omega$  source (for example, a lab signal generator), the pin should be terminated with 50  $\Omega$  as shown in Figure 35 (an RF drive level of +4 dBm should be applied). Multiples or fractions of the REFIN signal can be brought back off-chip at the multiplexer output pin (MUXOUT). A lock-detect signal and an analog voltage proportional to the ambient temperature can also be brought out on this pin by setting the appropriate bits on (DB21-DB23) in Register 4 (see the Register Description section).

### EXTERNAL LO

The internally generated local oscillator (LO) signal can be brought off-chip as either a  $1\times$  LO or a  $2\times$  LO (via pins LOP and LON) by asserting the LOSEL pin and making the appropriate internal register settings. The LO output must be disabled whenever the RF output of the IQ modulator is disabled.

The LOP and LON pins can also be used to apply an external LO. This can be used to bypass the internal PLL/VCO. To turn off the PLL Register 6, Bits[20:17] must be zero.



NOTES  
1. NC = NO CONNECT. DO NOT CONNECT TO THIS PIN.

Figure 35. Basic Connections for Operation (Loop Filter Set to 130 kHz)

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**LOOP FILTER**

The loop filter is connected between the CP and VTUNE pins. The return for the loop filter components should be to Pin 40 (DECL3). The loop filter design in Figure 35 results in a 3 dB loop bandwidth of 130 kHz. The ADRF6704 closed loop phase noise was also characterized using a 2.5 kHz loop filter design. The recommended components for both filter designs are shown in Table 8. For assistance in designing loop filters with other characteristics, download the most recent revision of ADIsimPLL™ from [www.analog.com/adisimpll](http://www.analog.com/adisimpll).

**Table 8. Recommended Loop Filter Components**

Component	130 kHz Loop Filter	2.5 kHz Loop Filter
C14	22 pF	0.1 μF
R10	3 kΩ	68 Ω
C15	2.7 nF	4.7 μF
R9	10 kΩ	270 Ω
C13	6.8 pF	47 nF
R65	10 kΩ	0 Ω
C40	22 pF	Open
R37	0 Ω	0 Ω
R11	Open	Open
R12	0 Ω	0 Ω

**DAC-TO-IQ MODULATOR INTERFACING**

The **ADRF6704** is designed to interface with minimal components to members of the Analog Devices, Inc., family of TxDACs®. These dual-channel differential current output DACs provide an output current swing from 0 mA to 20 mA. The interface described in this section can be used with any DAC that has a similar output.

An example of an interface using the **AD9122** TxDAC is shown in Figure 36. The baseband inputs of the **ADRF6704** require a dc bias of 500 mV. The average output current on each of the outputs of the **AD9122** is 10 mA. Therefore, a single 50 Ω resistor to ground from each of the DAC outputs results in an average current of 10 mA flowing through each of the resistors, thus producing the desired 500 mV dc bias for the inputs to the **ADRF6704**.

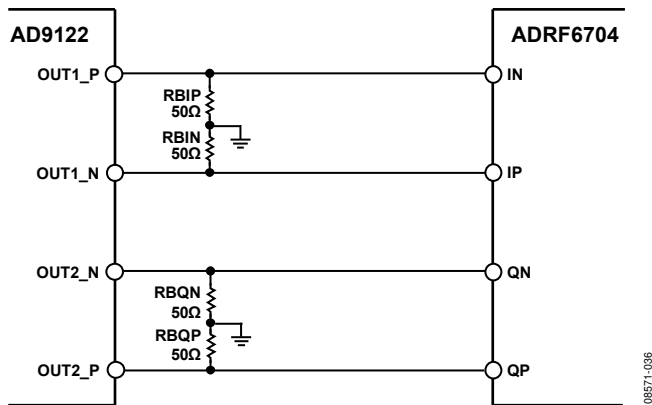


Figure 36. Interface Between the **AD9122** and **ADRF6704** with 50 Ω Resistors to Ground to Establish the 500 mV DC Bias for the **ADRF6704** Baseband Inputs

The **AD9122** output currents have a swing that ranges from 0 mA to 20 mA. With the 50 Ω resistors in place, the ac voltage swing going into the **ADRF6704** baseband inputs ranges from 0 V to 1 V (with the DAC running at 0 dBFS). So the resulting drive signal from each differential pair is 2 V p-p differential with a 500 mV dc bias.

**ADDING A SWING-LIMITING RESISTOR**

The voltage swing for a given DAC output current can be reduced by adding a third resistor to the interface. This resistor is placed in the shunt across each differential pair, as shown in Figure 37. It has the effect of reducing the ac swing without changing the dc bias already established by the 50 Ω resistors.

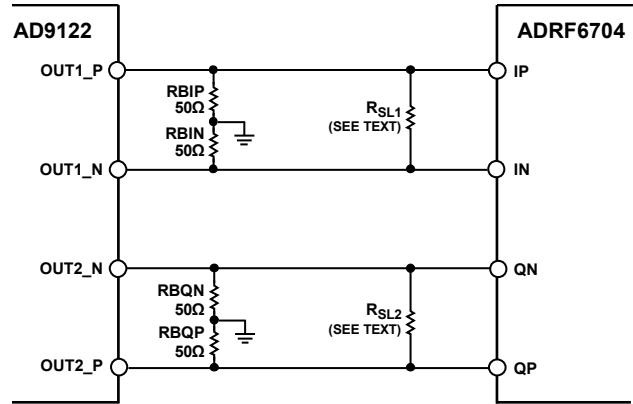


Figure 37. AC Voltage Swing Reduction Through the Introduction of a Shunt Resistor Between the Differential Pair

The value of this ac voltage swing limiting resistor ( $R_{SL}$  as shown in Figure 37) is chosen based on the desired ac voltage swing and IQ modulator output power. Figure 38 shows the relationship between the swing-limiting resistor and the peak-to-peak ac swing that it produces when 50 Ω bias-setting resistors are used. A higher value of swing-limiting resistor will increase the output power of the **ADRF6704** and signal-to-noise ratio (SNR) at the cost of higher intermodulation distortion. For most applications, the optimum value for this resistor will be between 100 Ω and 300 Ω.

When setting the size of the swing-limiting resistor, the input impedance of the I and Q inputs should be taken into account. The I and Q inputs have a differential input resistance of 920 Ω. As a result, the effective value of the swing-limiting resistance is 920 Ω in parallel with the chosen swing-limiting resistor. For example, if a swing-limiting resistance of 200 Ω is desired (based on Figure 37), the value of  $R_{SL}$  should be set such that

$$200 \Omega = (920 \times R_{SL}) / (920 + R_{SL})$$

resulting in a value for  $R_{SL}$  of 255 Ω.

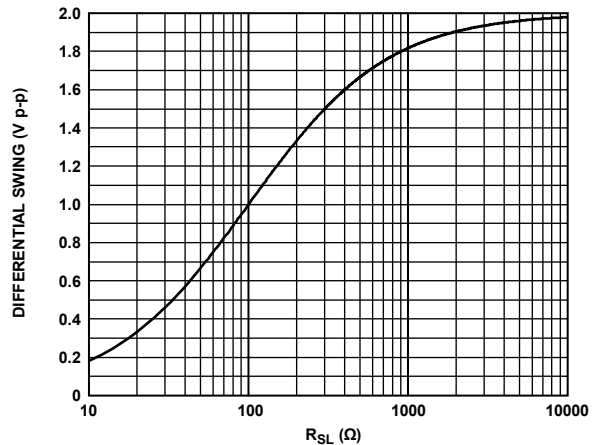


Figure 38. Relationship Between the AC Swing-Limiting Resistor and the Peak-to-Peak Voltage Swing with 50 Ω Bias-Setting Resistors

**IQ FILTERING**

An antialiasing filter must be placed between the DAC and modulator to filter out Nyquist images and broadband DAC noise. The interface for setting up the biasing and ac swing discussed in the Adding a Swing-Limiting Resistor section, lends itself well to the introduction of such a filter. The filter can be inserted between the dc bias setting resistors and the ac swing-limiting resistor. Doing so establishes the input and output impedances for the filter.

Unless a swing-limiting resistor of 100 Ω is chosen, the filter must be designed to support different source and load impedances. In addition, the differential input capacitance of the I and Q inputs (1 pF) should be factored into the filter design. Modern filter design tools allow for the simulation and design of filters with differing source and load impedances as well as inclusion of reactive load components.

**BASEBAND BANDWIDTH**

Figure 39 shows the frequency response of the ADRF6704's baseband inputs. This plot shows 0.5 dB and 3 dB bandwidths of 350 MHz and 750 MHz respectively. Any flatness variations across frequency at the ADRF6704 RF output have been calibrated out of this measurement.

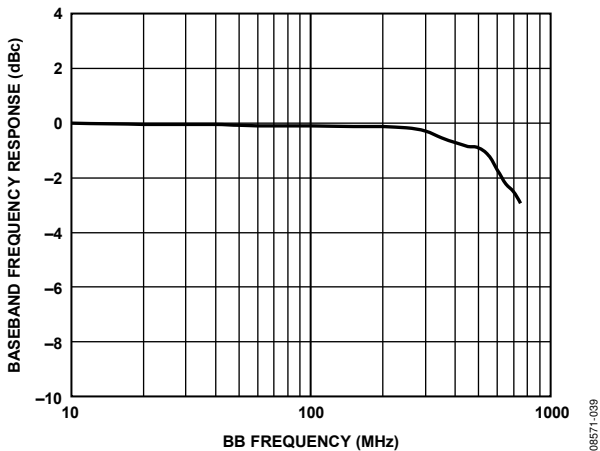


Figure 39. Baseband Bandwidth

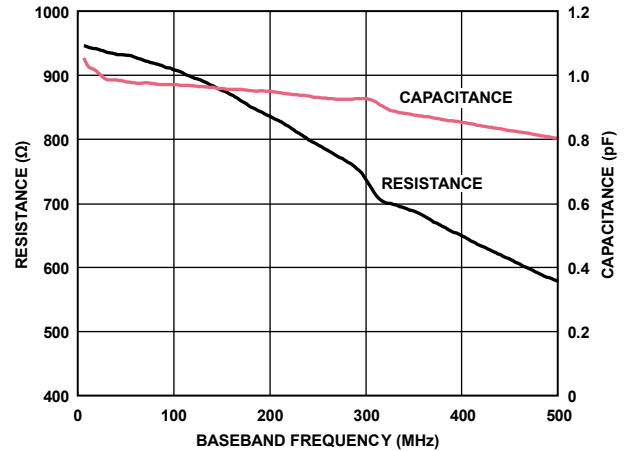


Figure 40. Differential Baseband Input R and Input C Equivalents (Shunt R and Shunt C)

**DEVICE PROGRAMMING AND REGISTER SEQUENCING**

The device is programmed via a 3-pin SPI port. The timing requirements for the SPI port are shown in Table 3 and Figure 2.

Seven programmable registers, each with 24 bits, control the operation of the device. The register functions are listed in Table 9. The seven registers should initially be programmed in reverse order, starting with Register 6 and finishing with Register 0. Once all seven registers have been initially programmed, any of the registers can be updated without any attention to sequencing.

Software is available on the ADRF6704 product page at [www.analog.com](http://www.analog.com) that allows programming of the evaluation board from a PC running Windows® XP or Windows Vista.

To operate correctly under Windows XP, Version 3.5 of Microsoft .NET must be installed. To run the software on a Windows 7 PC, XP emulation mode must be used (using Virtual PC).

## REGISTER SUMMARY

Table 9. Register Functions

Register	Function
Register 0	Integer divide control (for the PLL)
Register 1	Modulus divide control (for the PLL)
Register 2	Fractional divide control (for the PLL)
Register 3	$\Sigma$ - $\Delta$ modulator dither control
Register 4	PLL charge pump, PFD, and reference path control
Register 5	LO path and modulator control
Register 6	VCO control and VCO enable

# REGISTER DESCRIPTION

## REGISTER 0—INTEGER DIVIDE CONTROL (DEFAULT: 0x0001C0)

With Register 0, Bits[2:0] set to 000, the on-chip integer divide control register is programmed as shown in Figure 41.

### Divide Mode

Divide mode determines whether fractional mode or integer mode is used. In integer mode, the RF VCO output frequency ( $f_{VCO}$ ) is calculated by

$$f_{VCO} = 2 \times f_{PFD} \times (INT) \tag{1}$$

where:

$f_{VCO}$  is the output frequency of the internal VCO.

$f_{PFD}$  is the frequency of operation of the phase-frequency detector.

$INT$  is the integer divide ratio value (21 to 123 in integer mode).

### Integer Divide Ratio

The integer divide ratio bits are used to set the integer value in Equation 2. The INT, FRAC, and MOD values make it possible to generate output frequencies that are spaced by fractions of the PFD frequency. The VCO frequency ( $f_{VCO}$ ) equation is

$$f_{VCO} = 2 \times f_{PFD} \times (INT + (FRAC/MOD)) \tag{2}$$

where:

$INT$  is the preset integer divide ratio value (24 to 119 in fractional mode).

$MOD$  is the preset fractional modulus (1 to 2047).

$FRAC$  is the preset fractional divider ratio value (0 to  $MOD - 1$ ).

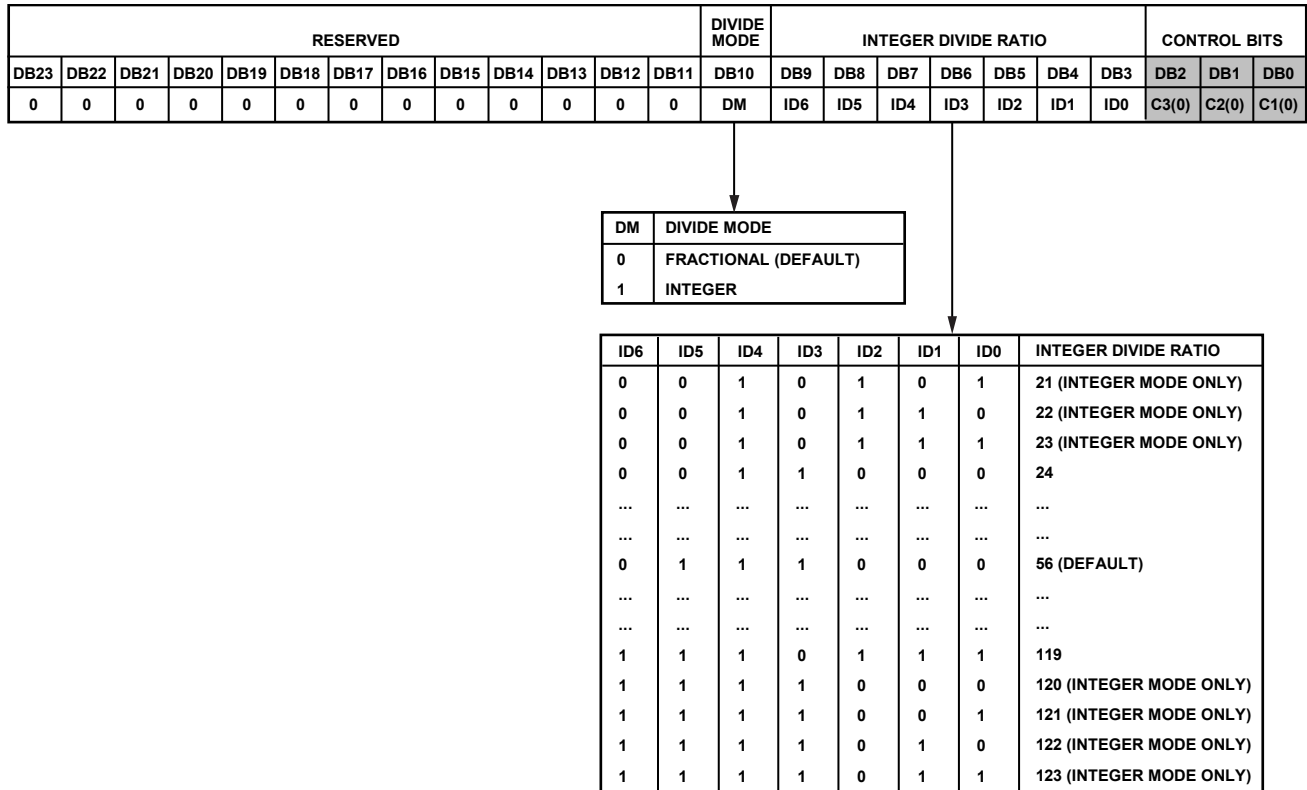


Figure 41. Register 0—Integer Divide Control Register Map

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**REGISTER 1—MODULUS DIVIDE CONTROL (DEFAULT: 0x003001)**

With Register 1, Bits[2:0] set to 001, the on-chip modulus divide control register is programmed as shown in Figure 42.

**Modulus Value**

The modulus value is the preset fractional modulus ranging from 1 to 2047.

**REGISTER 2—FRACTIONAL DIVIDE CONTROL (DEFAULT: 0x001802)**

With Register 2, Bits[2:0] set to 010, the on-chip fractional divide control register is programmed as shown in Figure 43.

**Fractional Value**

The FRAC value is the preset fractional modulus ranging from 0 to <MDR.

RESERVED										MODULUS VALUE										CONTROL BITS			
DB23	DB22	DB21	DB20	DB19	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	0	0	0	MD10	MD9	MD8	MD7	MD6	MD5	MD4	MD3	MD2	MD1	MD0	C3(0)	C2(0)	C1(1)

MD10	MD9	MD8	MD7	MD6	MD5	MD4	MD3	MD2	MD1	MD0	MODULUS VALUE
0	0	0	0	0	0	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0	1	0	2
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
1	1	0	0	0	0	0	0	0	0	0	1536 (DEFAULT)
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
1	1	1	1	1	1	1	1	1	1	1	2047

Figure 42. Register 1—Modulus Divide Control Register Map

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RESERVED										FRACTIONAL VALUE										CONTROL BITS			
DB23	DB22	DB21	DB20	DB19	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	0	0	0	FD10	FD9	FD8	FD7	FD6	FD5	FD4	FD3	FD2	FD1	FD0	C3(0)	C2(1)	C1(0)

FD10	FD9	FD8	FD7	FD6	FD5	FD4	FD3	FD2	FD1	FD0	FRACTIONAL VALUE
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
0	1	1	0	0	0	0	0	0	0	0	768 (DEFAULT)
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	<MDR

FRACTIONAL VALUE MUST BE LESS THAN MODULUS.

Figure 43. Register 2—Fractional Divide Control Register Map

08571-043



**REGISTER 3—Σ-Δ MODULATOR DITHER CONTROL (DEFAULT: 0x10000B)**

With Register 3, Bits[2:0] set to 011, the on-chip Σ-Δ modulator dither control register is programmed as shown in Figure 44. The recommended and default setting for dither enable is

enabled (1). The default value of the dither magnitude (15) should be set to a recommended value of 1.

The dither restart value can be programmed from 0 to  $2^{17} - 1$ , though a value of 1 is typically recommended.

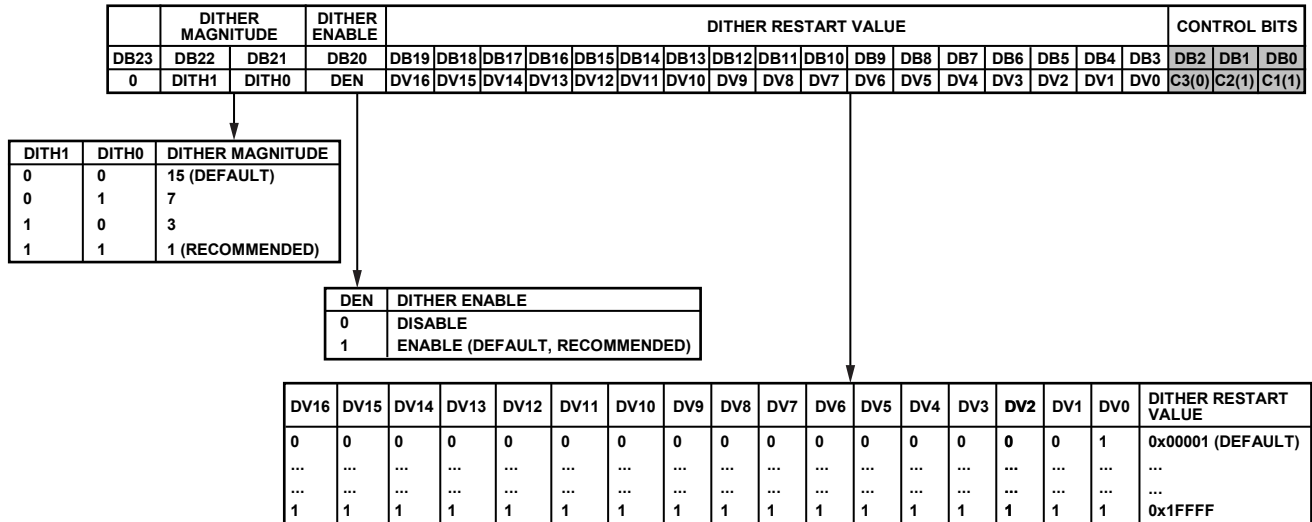


Figure 44. Register 3—Σ-Δ Modulator Dither Control Register Map

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#### REGISTER 4—PLL CHARGE PUMP, PFD, AND REFERENCE PATH CONTROL (DEFAULT: 0x12A7E4)

With Register 4, Bits[2:0] set to 100, the on-chip charge pump, PFD, and reference path control register is programmed as shown in Figure 45.

##### CP Current

The nominal charge pump current can be set to 250  $\mu\text{A}$ , 500  $\mu\text{A}$ , 750  $\mu\text{A}$ , or 1000  $\mu\text{A}$  using DB10 and DB11 of Register 4 and by setting DB18 to 0 (CP reference source).

In this mode, no external RSET is required. If DB18 is set to 1, the four nominal charge pump currents ( $I_{\text{NOMINAL}}$ ) can be externally tweaked according to the following equation:

$$R_{\text{SET}} = \left( \frac{217.4 \times I_{\text{CP}}}{I_{\text{NOMINAL}}} \right) - 37.8 \Omega \quad (3)$$

where  $I_{\text{CP}}$  is the base charge pump current in microamps.

The PFD phase offset multiplier ( $\theta_{\text{PFD,OFFS}}$ ), which is set by Bits[16:12] of Register 4, causes the PLL to lock with a nominally fixed phase offset between the PFD reference signal and the divided-down VCO signal. This phase offset is used to linearize the PFD-to-CP transfer function and can improve

fractional spurs. The magnitude of the phase offset is determined by the following equation:

$$|\Delta\Phi|(\text{deg}) = 22.5 \frac{\theta_{\text{PFD,OFFS}}}{I_{\text{CP,MULT}}} \quad (4)$$

The default value of the phase offset multiplier ( $10 \times 22.5^\circ$ ) should be set to a recommended value of  $6 \times 22.5^\circ$ .

This phase offset can be either positive or negative depending on the value of DB17 in Register 4.

The reference frequency applied to the PFD can be manipulated using the internal reference path source. The external reference frequency applied can be internally scaled in frequency by 2 $\times$ , 1 $\times$ , 0.5 $\times$ , or 0.25 $\times$ . This allows a broader range of reference frequency selections while keeping the reference frequency applied to the PFD within an acceptable range.

The device also has a MUXOUT pin that can be programmed to output a selection of several internal signals. The default mode is to provide a lock-detect output to allow the user to verify when the PLL has locked to the target frequency. In addition, several other internal signals can be passed to the MUXOUT pin as described in Figure 35.