# RF2948B

## 2.4GHz SPREAD-SPECTRUM TRANSCEIVER

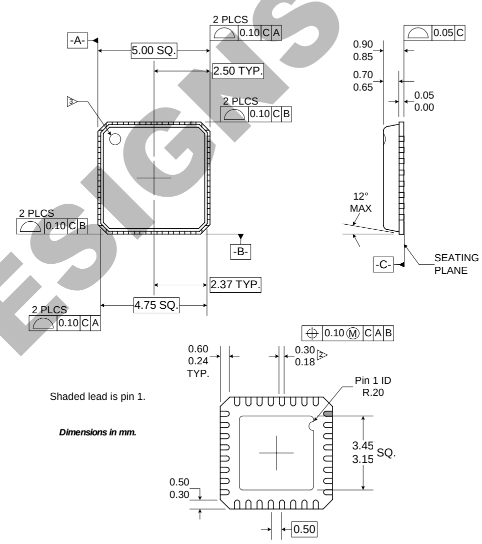
### Typical Applications

- IEEE 802.11b WLANs
- Wireless Residential Gateways
- Secure Communication Links
- High Speed Digital Links
- Wireless Security
- Digital Cordless Telephones

### Product Description

The RF2948B is a monolithic integrated circuit specifically designed for direct-sequence spread-spectrum systems operating in the 2.4GHz ISM band. The part includes: a direct conversion from IF receiver with variable gain control; quadrature demodulator; I/Q baseband amplifiers; and, on-chip programmable baseband filters. For the transmit side, a QPSK modulator and upconverter are provided. The design reuses the IF SAW filter for transmit and receive reducing the number of SAW filters required. Two-cell or regulated three-cell (3.6V maximum) battery applications are supported by the part. The part is also designed to be part of a 2.4GHz chipset consisting of the RF2494 LNA/Mixer, one of the many RFMD high-efficiency GaAs HBT PA's and the RF3000 Baseband Processor.

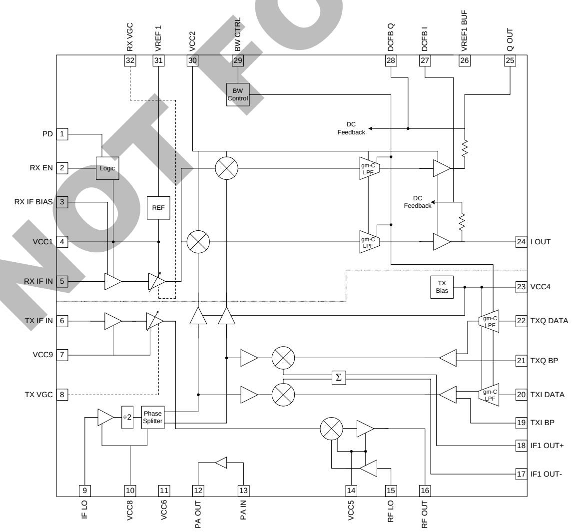





**Package Style: QFN, 32-Pin, 5x5**

### Optimum Technology Matching® Applied

- [ ] Si BJT
- [x] Si Bi-CMOS
- [ ] InGaP/HBT
- [ ] GaAs HBT
- [ ] SiGe HBT
- [ ] GaN HEMT
- [ ] GaAs MESFET
- [ ] Si CMOS
- [ ] SiGe Bi-CMOS




**Functional Block Diagram**

### Features

- 45MHz to 500MHz IF Quad Demod
- On-Chip Variable Baseband Filters
- Quadrature Modulator and Upconverter
- 2.7V to 3.6V Operation
- Part of IEEE802.11b Chipset
- 2.4GHz PA Driver

### Ordering Information

| | |
|---|---|
| RF2948B | 2.4GHz Spread-Spectrum Transceiver |
| RF2948BTR13 | 2.4GHz Spread-Spectrum Transceiver (Tape & Reel) |
| RF2948B PCBA | Fully Assembled Evaluation Board |

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## Absolute Maximum Ratings

| Parameter | Rating | Unit |
|---|---|---|
| Supply Voltage | -0.5 to +3.6 | $V_{DC}$ |
| Control Voltages | -0.5 to +3.6 | $V_{DC}$ |
| Input RF Level | +12 | dBm |
| LO Input Levels | +5 | dBm |
| Operating Ambient Temperature | -40 to +85 | °C |
| Storage Temperature | -40 to +150 | °C |

MSL JEDEC level 3 at 240°C

Refer to “Handling of PSOP and PSSOP Products” on page 16-15 for special handling information.

Refer to “Soldering Specifications” on page 16-13 for special soldering information.

**Caution!** ESD sensitive device.

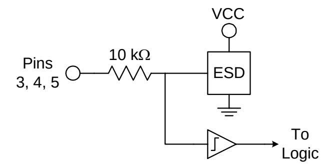
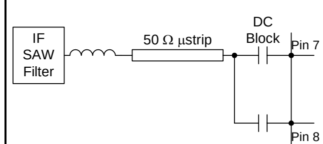
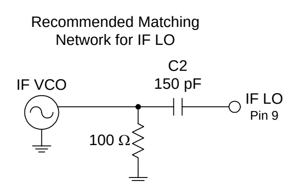
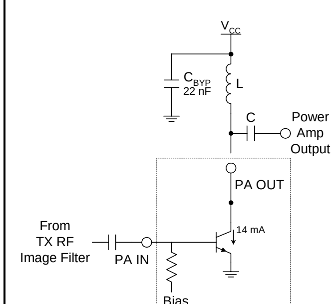


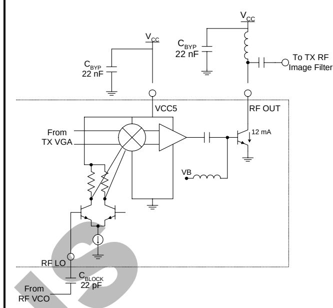
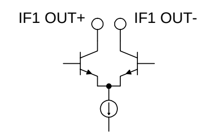


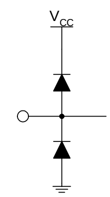
| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **Overall Receiver** | | | | | T=25°C, $V_{CC}$=3.0V, Freq=374MHz, $R_{BW}$=10kΩ |
| RX Frequency Range | 45 | 374 | 500 | MHz | |
| Cascaded Voltage Gain | 65 | | 76 | dB | RX $V_{GC}$=1.2V |
| | 0 | | 3 | dB | RX $V_{GC}$=2.0V |
| Cascaded Noise Figure | 5.5 | | 35.0 | dB | Varies with gain. |
| Cascaded Input IP3 | | 50 | | dBμV | $V_{GC}$ <1.2V |
| Cascaded Input IP3 | | 115 | | dBμV | $V_{GC}$>2.0V |
| IF LO Leakage | | -68 | | dBm | f=374MHz, LO Power=-10dBm |
| Quadrature Phase Variation | | 0 | ±3 | ° | With expected LO amplitude and harmonic content. |
| Quadrature Amplitude Variation | | 0 | ±1 | dB | |
| Output P1dB | 1.2 | | | $V_{PP}$ | 1.4<RX $V_{GC}$<1.8V |
| Distortion | | | 2 | % | At 0.70$V_{PP}$ output level. |
| **IF AMP and Quad Demod** | | | | | |
| Gain | | 4.5 | 7.5 | dB | $V_{GC}$=1.95V=min gain |
| | 65 | 70 | | | $V_{GC}$=1.25V max gain |
| Noise Figure | | 5.5 | | dB | Single Sideband, max gain. |
| IF Input Impedance | | 515-j994 | | Ω | Single-ended. 374MHz |
| **RX Baseband Amplifiers** | | | | | |
| THD | | 2 | | % | At 0.707$V_{P-P}$ output level |
| Output Voltage | | 700 | | $mV_{PP}$ | $R_L$≥5kΩ, $C_L$≤15pF |
| DC Output Voltage | VREF1-15 | VREF1 | VREF1+15 | mV | |
| **RX Baseband Filters** | | | | | |
| Baseband Filter 3dB Bandwidth | 1 | 10 | 35 | MHz | 5th order Bessel LPF. Set by BW CTRL (RBW) |
| Passband Ripple | | | 0.1 | dB | |
| Baseband Filter 3dB Frequency Accuracy | | ±10 | ±30 | % | |
| Group Delay | | 15 | | ns | At 35MHz, increasing as bandwidth decreases. |
| Group Delay | | 400 | | ns | At 2MHz. |
| Baseband Filter Ultimate Rejection | | >80 | | dB | |
| Output Impedance | | 20 | | Ω | Designed to drive≥5kΩ, ≤15pF load. |

| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **Transmit Modulator and LPF** | | | | | |
| Filter Gain | | 0 | | dB | Any setting |
| Baseband Filter 3dB Bandwidth | 1 | | 35 | MHz | 5th order Bessel LPF, Set by BW CTRL |
| Passband Ripple | | | 0.1 | dB | |
| Group Delay | | 15 | | ns | At 35MHz, increasing as bandwidth decreases. |
| Group Delay | | 400 | | ns | At 2MHz. |
| Ultimate Rejection | | >80 | | dB | |
| Input Impedance | 3 | | | kΩ | Single-ended |
| Input AC Voltage | | 100 | | $mV_{p-p}$ | Linear, Single-ended. |
| Input P1dB | 200 | | | $mV_{p-p}$ | Single-ended. |
| Input DC Offset Requirement | 1.6 | 1.7 | 1.8 | V | For correct operation. |
| IF Frequency Range | 45 | | 500 | MHz | |
| Differential Output Resistance | | 22 | | kΩ | Between output pins. Open collector when TX on, Hi Z when TX off |
| Differential Output Capacitance | | 0.436 | | pF | Between output pins. |
| Shunt Output Capacitance | | 0.4 | | pF | From each pin to ground. |
| I/Q Phase Balance | | 0 | ±3 | | |
| I/Q Gain Balance | | 0 | ±1 | dB | |
| Conversion Transconductance | | 0.0185 | | S | Single-ended voltage input to differential output current conversion gain. |
| Carrier Output | -18 | -26 | | dBc | Without external offset adjustments. 374MHz. Compared to modulated signal, 100$mV_{P-P}$ input. |
| Harmonic Outputs | | -30 | | dBc | |
| **Transmit VGA and Upconverter** | | | | | |
| VGA Gain Range | | 17 | | dB | |
| VGA Control Voltage Range | | 1.0 to 2.0 | | V | Positive Slope |
| VGA Gain Sensitivity | | 17 | | dB/V | |
| VGA Input Impedance | | 515-j994 | | Ω | 374MHz |
| RF Mixer Output Impedance | | 50 | | Ω | With matching elements. |
| VGA/Mixer Conversion Gain | | -3 to +14 | | dB | With 50Ω match on the output. |
| VGA/Mixer Output Power | | -9 | | dBm | 1dB compression - Single Sideband, TX GC=1.0V. (Desired signal power) |
| VGA/Mixer Output Power | | -4 | | dBm | 1dB compression - Single Sideband, TX GC=2.0V. (Desired signal power) |

| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **Transmit Power Amp** | | | | | |
| Linear Output Power | | 6 | | dBm | |
| Gain | | 9 | | dB | |
| Output P1dB | 10 | 12 | | dBm | |
| Output Impedance | | 50 | | Ω | Nominal |
| Input Impedance | | 50 | | Ω | Nominal |
| **Power Down Control** | | | | | |
| Logical Controls "ON" | $V_{CC}$-0.3V | | $V_{CC}$+0.3V | V | Voltage supplied to the input, not to exceed 3.6V. |
| Logical Controls "OFF" | -0.3 | 0 | 0.3 | V | Voltage supplied to the input. |
| Control Input Impedance | | >1 | | MΩ | |
| RX $V_{GC}$ Response TIme | | 200 | | ns | Full step in gain, to 90% of final output level. |
| RX EN Response TIme | | 2 | | μs | I/Q output VALID |
| TX EN Response TIme | | 330 | | ns | To IF output VALID |
| $V_{PD}$ to RX Response TIme | | 1.33 | | ms | To I/Q output VALID |
| $V_{PD}$ to TX Response TIme | | 50 | | μs | To IF output VALID |
| **IF LO Input** | | | | | The IF LO is divided by 2 and split into quadrature signals to drive the frequency mixers. |
| Input Impedance | | 1050-j1200 | | Ω | f=748MHz |
| Input Power Range | -15 | -10 | 0 | dBm | peak |
| Input Frequency | 90 | | 1000 | MHz | (2x IF Frequency) |
| **RF LO Input** | | | | | |
| Input Impedance | | 33-j110 | | Ω | f=2.04GHz unmatched. |
| Input Power Range | -10 | | 0 | dBm | |
| Input Frequency | 2000 | | 2400 | MHz | |
| **VREF1 Buffered** | | | | | |
| Source/Sink Current | | | 1 | mA | |
| Output Voltage | VREF1-10 | | VREF1+10 | mV | |
| VREF1 | 1.6 | 1.7 | 1.8 | V | |
| **Power Supply** | | | | | |
| Voltage | 2.7 | 3.3 | 3.6 | V | |
| Total Current Consumption | | | | | $V_{CC}$=3.3V, Baseband BW 1MHz to 40MHz |
| Sleep Mode Current | | 1 | | μA | PD=0, RX EN=1 |
| PA Driver Current | | 18 | | mA | TX EN=1 |
| RX Current BW (MHz) | | | | | |
| 9 | | 65 | 85 | mA | |
| 12-20 | | 70 | | mA | |
| 20-30 | | 110 | | mA | |
| TX Current BW (MHz) | | | | | |
| 9 | | 95 | 136 | mA | |
| 12-20 | | 105 | | mA | |
| 20-30 | | 115 | | mA | |

| Pin | Function | Description | Interface Schematic |
|---|---|---|---|
| 1 | PD | This pin is used to power up or down the transmit and receive baseband sections. A logic high powers up the quad demod mixers, TX and RX GmC LPF's, baseband VGA amps, data amps, and IF LO buffer amp/ phase splitter. A logic low powers down the entire IC for sleep mode. Also, see State Decode Table. |  |
| 2 | RX EN | Enable pin for the receiver 15dB gain IF amp and the RX VGA amp. Powers up all receiver functions when PD is high, turns off the receiver IF circuits when low. Also, see State Decode Table.<br>When this pin is a logic "high", the device is in receive mode. When this pin is a logic "low", the device is in transmit mode. | See pin 1. |
| 3 | RX IF BIAS | Shunt resistor of 23.7±1% to ground. Biases IF AMPS. | |
| 4 | VCC1 | Power supply for RX VGA amplifier, IC logic and RX references. | |
| 5 | RX IF IN | IF input for receiver section. Must have DC-blocking cap. The capacitor value should be appropriate for the IF frequency. For half-duplex operation, connect RX IF IN and TX IF IN signals together after the DC blocking caps, then run a transmission line from the output of the IF SAW. AC coupling capacitor must be less than 150pF to prevent delay in switching RX to TX/TX to RX. | See pin 6. |
| 6 | TX IF IN | Input for the TX IF signal after SAW filter. External DC-blocking cap required. For half-duplex operation, connect RX IF IN and TX IF IN signals together after the DC-blocking caps, then run a transmission line from the output of the IF SAW. AC coupling capacitor must be less than 150pF to prevent delay in switching RX to TX/TX to RX. |  |
| 7 | VCC9 | Power supply for the TX 15dB gain amp and TX VGA. | |
| 8 | TX VGC | Gain control setting for the transmit VGA. Positive slope. | |
| 9 | IF LO | IF LO input. Must have DC-blocking cap. The capacitor value should be appropriate for the IF frequency. LO frequency=2xIF. Quad mod/demod phase accuracy requires low harmonic content from IF LO, so it is recommended to use an n=3 LPF between the IF VCO and IF LO. This is a high impedance input and the recommended matching approach is to simply add a 100Ω shunt resistor at this input to constrain the mismatch. |  |
| 10 | VCC8 | Power supply for IF LO buffer and quadrature phase network. | |
| 11 | VCC6 | Power supply for transmitter bias generator. | |
| 12 | PA OUT | This is the output transistor of the power amp stage. It is an open collector output. The output match is formed by an inductor to $V_{CC}$, which supplies DC and a series cap. |  |

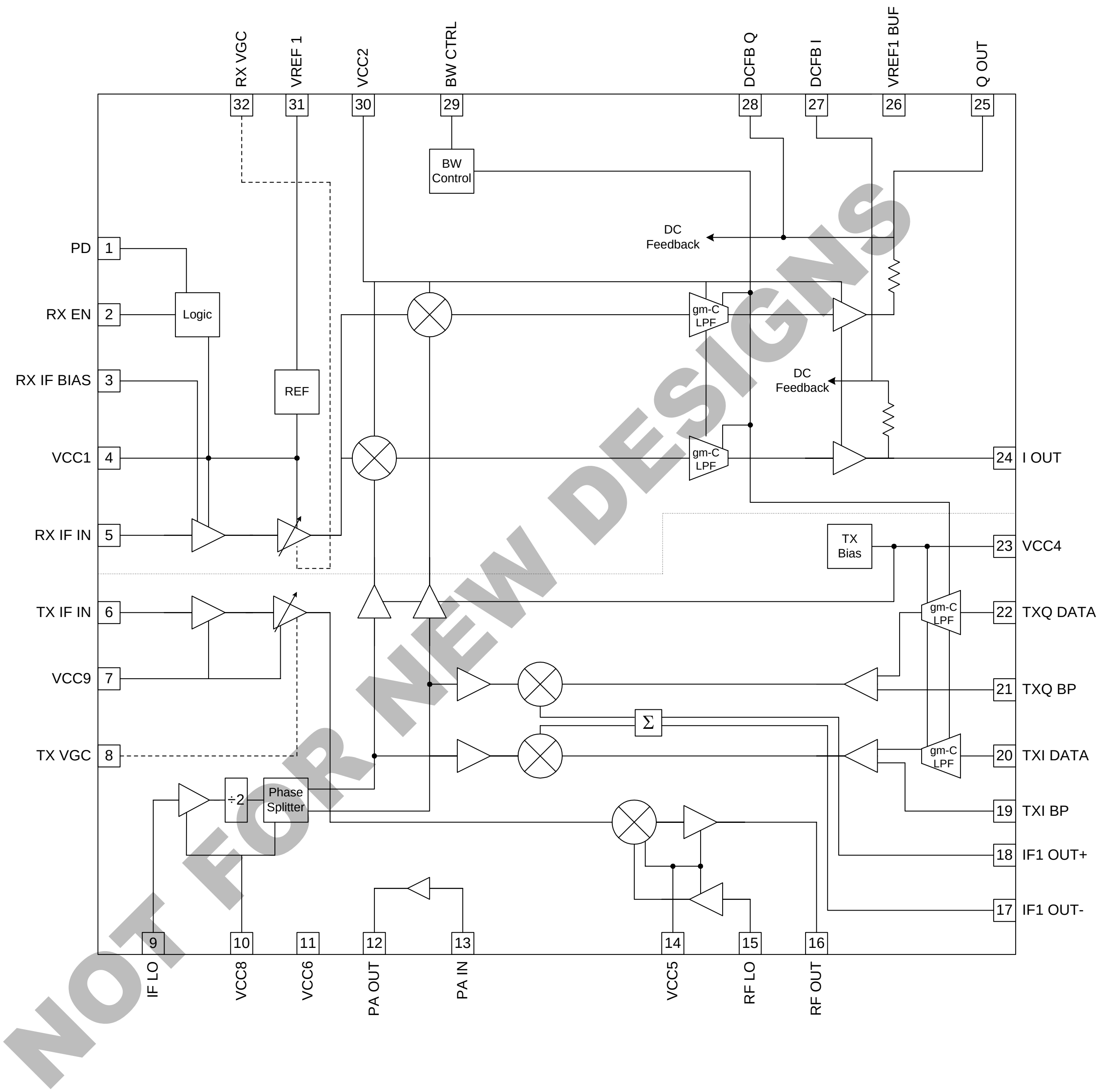
| Pin | Function | Description | Interface Schematic |
|---|---|---|---|
| 13 | PA IN | Input to the power amplifier stage. This is a 50Ω input. Requires DC-blocking/tuning cap. | See pin 12. |
| 14 | VCC5 | Supply for the RF LO buffer, RF upconverter and amplifier. |  |
| 15 | RF LO | Single-ended LO input for the transmit upconverter. External matching to 50Ω and a DC-block are required. | See pin 14. |
| 16 | RF OUT | Upconverted Transmit signal. This 50Ω output is intended to drive an RF filter to suppress the undesired sideband, harmonics, and other out-of-band mixer products. | See pin 14. |
| 17 | IF1 OUT- | The inverting open collector output of the quadrature modulator. This pin needs to be externally biased and DC isolated from other parts of the circuit. This output can drive a Balun with IF1 OUT+, to convert to unbalanced to drive a SAW filter. The Balun can be either broadband (transformer) or narrowband (discrete LC matching). Alternatively, just IF1 OUT+ can be used to drive a SAW single-ended with an RF choke (high Z at IF) from $V_{CC}$ to IF1 OUT-. |  |
| 18 | IF1 OUT+ | The non-inverting open collector output of the quadrature modulator. This pin needs to be externally biased and DC isolated from other parts of the circuit. This output can drive a Balun with IF1 OUT-, to convert to unbalanced to drive a SAW filter. The Balun can be either broadband (transformer) or narrowband (discrete LC matching). Alternatively, just IF1 OUT+ can be used to drive a SAW single-ended with an RF choke (high Z at IF) from $V_{CC}$ to IF1 OUT+. | See pin 17. |
| 19 | TXI BP | This is the in-phase modulator bypass pin. A 10nF capacitor to ground is recommended. | |
| 20 | TXI DATA | I input to the baseband 5 pole Bessel LPF for the transmit modulator. | |
| 21 | TXQ BP | This is the quadrature phase modulator bypass pin. A 10nF capacitor to ground is recommended. | |
| 22 | TXQ DATA | Q input to the baseband 5 pole Bessel LPF for the transmit modulator. | |
| 23 | VCC4 | Power supply for quadrature modulator. | |
| 24 | I OUT | Baseband analog signal output for in-phase channel. 700mV$_{P-P}$ linear output. | |
| 25 | Q OUT | Baseband analog signal output for quadrature channel. 700mV$_{P-P}$ linear output. | |
| 26 | VREF1 BUF | Buffered version of the VREF1 output. See pin 31. Sink/Source current <1mA. | |
| 27 | DCFB I | DC feedback capacitor for in-phase channel. Requires capacitor to ground. (22nF recommended) | |
| 28 | DCFB Q | DC feedback capacitor for quadrature channel. Requires decoupling capacitor to ground. (22nF recommended) | |
| 29 | BW CTRL | This pin requires a resistor to ground to set the baseband LPF bandwidth of the receiver and transmit GmC filter amps. | |
| 30 | VCC2 | Supply for the I and Q baseband and GmC filters. This pin should be bypassed with a 10nF capacitor. | |

| Pin | Function | Description | Interface Schematic |
|---|---|---|---|
| 31 | VREF 1 | This is a bypass pin for the bias circuits of the GmC filter amps and for I/Q inputs. No current should be drawn from this pin (<10μA). 1.7V nominal. | |
| 32 | RX VGC | Receiver IF and baseband amp gain control voltage. Negative slope. | |
| Pkg Base | | Ground for all circuitry in the device. A very low inductance from the base to the PCB groundplane is essential for good performance. Use an array of vias immediately underneath the device. | |
| | ESD | This diode structure is used to provide electrostatic discharge protection to 3kV using the Human body model. The following pins are protected: 1-4, 7, 8, 10, 19-32. |   |

| State Decode Table | Input Pins | | Internally Decoded Signals | | |
|---|---|---|---|---|---|
| | PD | RX EN | BB EN | RXIF EN | TXRF EN |
| Sleep Mode | 0 | x | 0 | 0 | 0 |
| Receive Mode | 1 | 1 | 1 | 1 | 0 |
| Transmit Mode | 1 | 0 | 1 | 0 | 1 |

| | |
|---|---|
| **NOTES** | |
| **BB_EN Enables:** | |
| | TX_LPF's and buffers |
| | Quad Demodulator mixers |
| | Baseband Amps and gm-C LPF's |
| | IF LO buffer/phase splitters |
| | |
| **RXIF_EN Enables:** | |
| | Front-end IF amplifier (RX) |
| | RX IF VGA amplifiers |
| | |
| **TXRF_EN Enables:** | |
| | Front-end IF amplifier (TX) |
| | TX VGA |
| | RF upconverter and buffer |
| | PA driver |
| | RF LO buffer |
| | Quad Modulator mixers |

# Detailed Functional Block Diagram



# Theory of Operation

## RECEIVER

### RX IF AGC/Mixer

Being essentially high impedance, RX IF IN responds to the input voltage (rather than power), and amplifies that voltage by the gain specified in the datasheet, then presents the output voltage at a high impedance (after downconversion). For characterization purposes, a 50Ω shunt resistor is placed on the IF signal path, before AC-coupling to the input. A 50Ω signal source is applied directly across the shunt resistor, through a coaxial test lead. The signal source sees the shunt resistor and therefore a low SWR. Voltage gain is then simply the ratio of the output voltage to the input voltage.

The front end of the IF AGC starts with a single-ended input and a constant gain amp of 15dB. This first amp stage sets the noise figure and input impedance of the IF section, and its output is taken differentially. The rest of the signal path is differential until the final baseband output, which is converted back to single-ended. Following the front end amp are multiple stages of variable gain differential amplifiers, giving the IF signal path a gain range of 4.0dB to 70.0dB. The noise figure (in max gain mode) of the IF amplifiers is 5dB, which should not degrade the system noise figure.

The IF to BB mixers are double-balanced, differential in, differential out, mixers with negligible conversion gain. The LO for each of these mixers is shifted 90° so that the I and Q signals are separated in the mixers.

### RX Baseband Amps, Filters, and DC Feedback

At baseband frequency, there are fully integrated gm-C low pass filters to further filter out-of-band signals and spurs that get through the SAW filter, anti-alias the signal prior to the A/D converter, and to band-limit the signal and noise to achieve optimal signal-to-noise ratio. The 3dB cut-off frequency of these low pass filters is programmable with a single external resistor, and continuously variable from 1MHz to 35MHz. A five-pole Bessel type filter response was chosen because it is optimal for data systems due to its flat delay response and clean step response. Butterworth and Chebychev type filters ring when given a step input making them less ideal for data systems. The filter outputs drive the linear 700mV$_{PP}$ signal off-chip.

DC feedback is built into the baseband amplifier section to correct for input offsets. Large DC offsets can arise when a mixer LO leaks to the mixer input and then mixes with itself. DC offsets can also result from random transistor mismatches. A large external capacitor is needed for the DC feedback to set the high pass cutoff.

## LO INPUT BUFFERS

### RF LO Buffer

The RF LO input has a limiting amplifier before the mixer on both the RF2494 (RX) and RF2948B (TX). This limiting amplifier design and layout is identical on both ICs, which will make the input impedance the same as well. Having this amplifier between the VCO and mixer minimizes any reverse effect the mixer has on the VCO, expands the range of acceptable LO input levels, and holds the LO input impedance constant when switching between RX and TX. The LO input power range is -18dBm to +5dBm, which should make it easy to interface to any VCO and frequency synthesizer.

### IF LO Buffer

The IF LO input has a limiting amplifier before the phase splitting network to amplify the signal and help isolate the VCO from the IC. Also, the LO input signal must be twice the desired intermediate frequency. This simplifies the quadrature network and helps reduce the LO leakage onto the RX_IF input pin (since the LO input is now at a different frequency than the IF). The amplitude of this input needs to be between -15dBm and 0dBm. Excessive IF LO harmonic content affects phase balance of the modulator and demodulator so it is recommended that IF LO harmonics be kept below -30dBc.

### TRANSMITTER

#### TX LPF and Mixers

The transmit section starts with a pair of 5-pole Bessel filters identical to the filters in the receive section and with the same 3dB frequency. These filters pre-shape and band-limit the digital or analog input signals prior to the first upconversion to IF. These filters have a high input impedance and expect an input signal of 100mV$_{PP}$ typical. Following these low pass filters are the I/Q quadrature upconverter mixers. Each of these mixers is half the size and half the current of the RF to IF downconverter on the RF2494. Recall that this upconverted signal may drive the same SAW filter (in half-duplex mode) as the RF2494 and therefore share the same load. Having the sum of the two BB to IF mixers equal in size and DC current to the RF to IF mixer, will minimize the time required to switch between RX and TX, and will facilitate the best impedance match to the filter.

#### TX VGA

Being essentially high impedance, TX IF IN responds to the input voltage (rather than power), and amplifies that voltage by the gain specified in the datasheet, then presents the output voltage at a 50Ω impedance (after upconversion). For characterization purposes, a 50Ω shunt resistor is placed on the IF signal path, before AC-coupling to the input. A 50Ω signal source is applied directly across the shunt resistor, through a coaxial test lead. The signal source sees the shunt resistor and therefore a low SWR. Voltage gain is then the same as power gain, simply the difference in dB between the output power and the input power.

The AGC after the SAW filter starts with a switch and a constant gain amplifier of 15dB, which is identical to the circuitry on the receive IF AGC. This was done so that the input impedance will remain constant for different gain control voltages. Following this 15dB gain amplifier is a single stage of gain control offering 15dB gain range. The main purpose of adding this variable gain is to give the system the flexibility to use different SAW filters and image filters with different insertion loss values. This gain could also be adjusted real time, if desired.

#### TX Upconverter

The IF to RF upconverter is a double-balanced differential mixer with a differential to single-ended converter on the output to supply 0dBm peak linear power to the image filter. The upconverted SSB signal should have -6dBm power at this point, and the image will have the same power, but due to the correlated nature of the signal and image, the output must support 0dBm of linear power to maintain linearly.

#### +6dBm PA Driver

The SSB output of the upconverter is -6dBm of linear power. The image filter should have at most 4dB of insertion loss while removing the image, LO, 2LO and any other spurs. The filter output should supply the PA driver input -10dBm of power.

The PA driver is a one-stage class A amplifier with 10dB gain and capable of delivering 6dBm of linear power to a 50Ω load, and has a 1dB compression point of 12dBm. For lower power applications, this PA driver can be used to drive a 50Ω antenna directly.

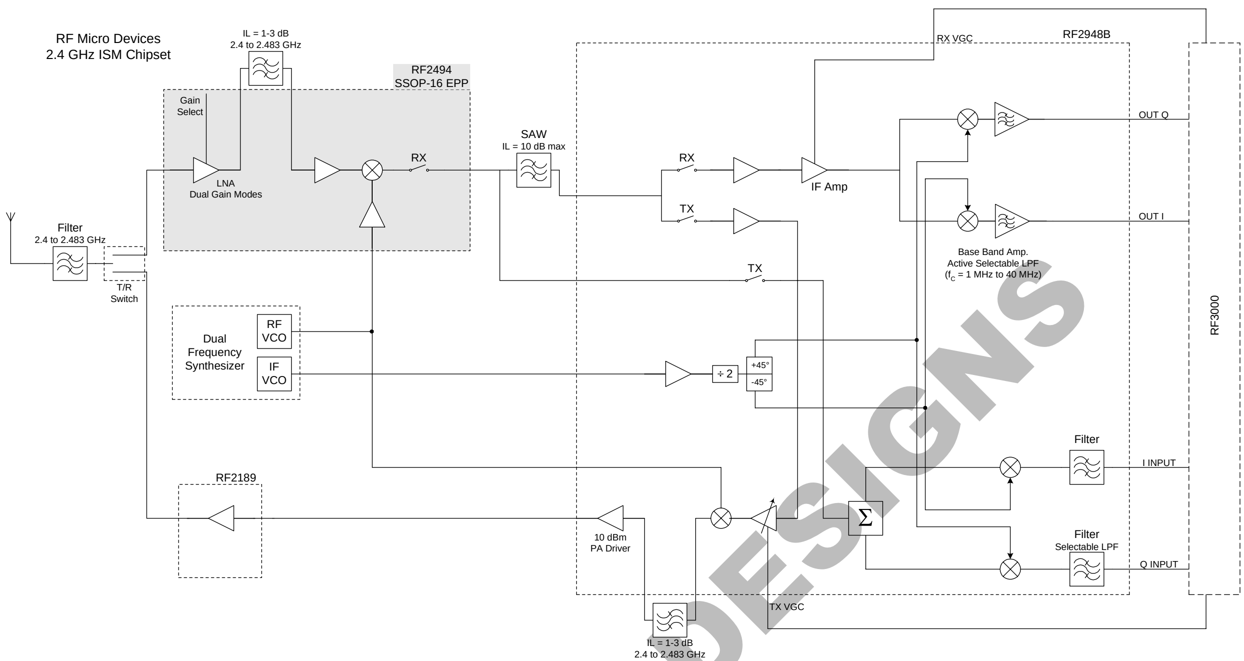
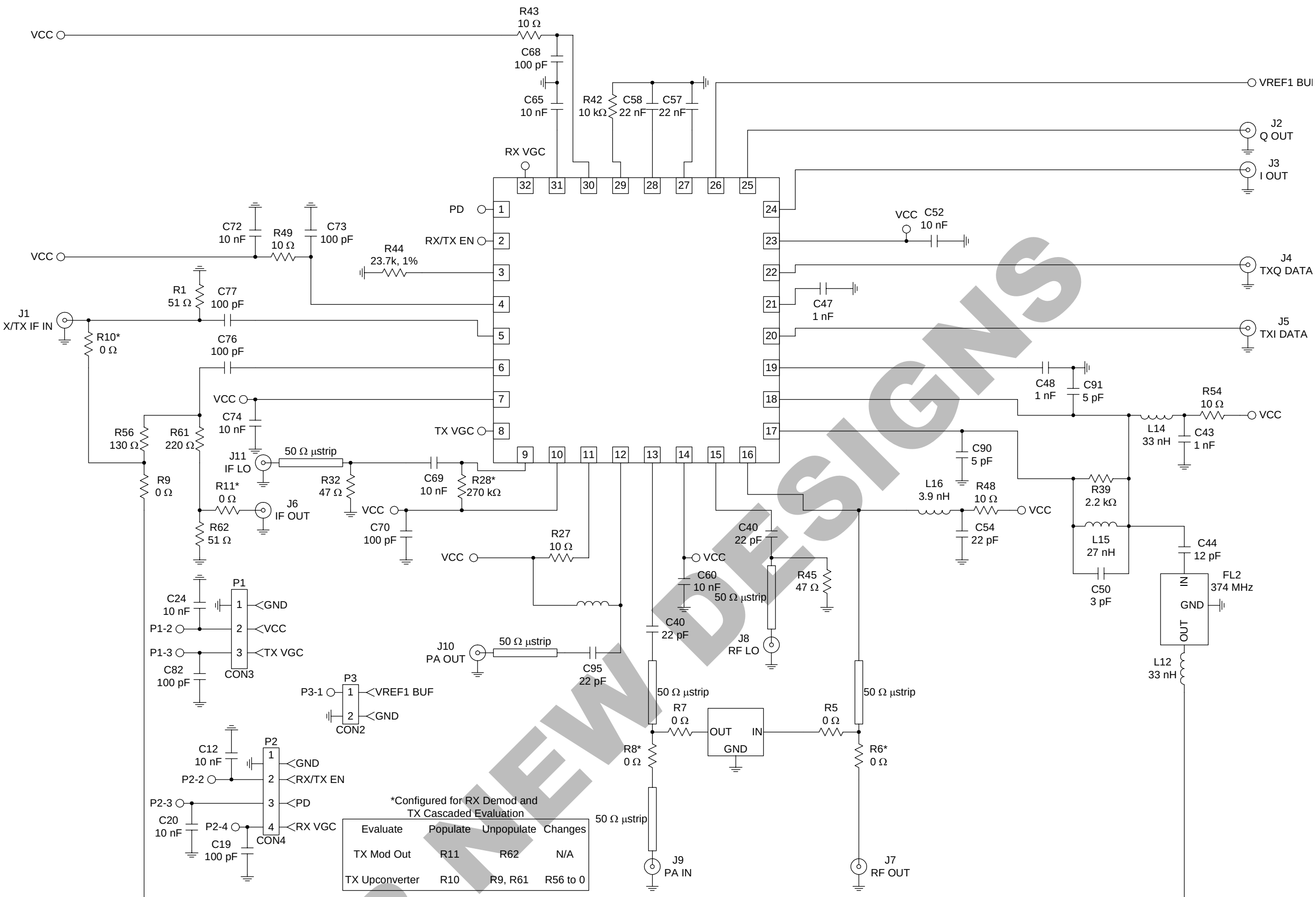



**Figure 1. Entire Chipset Functional Block Diagram**

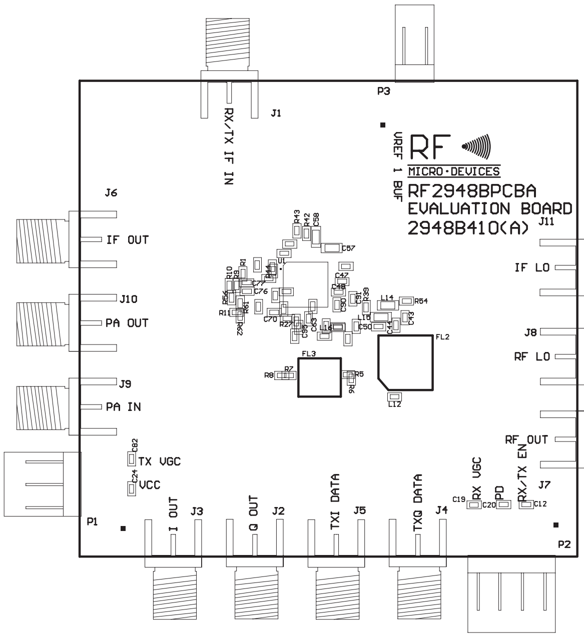
# Evaluation Board Schematic

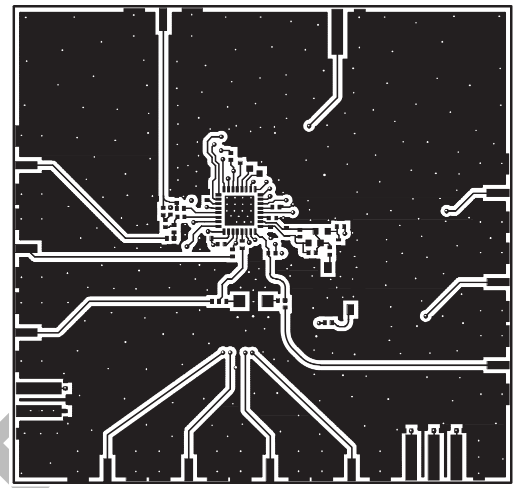
(Download Bill of Materials from www.rfmd.com.)

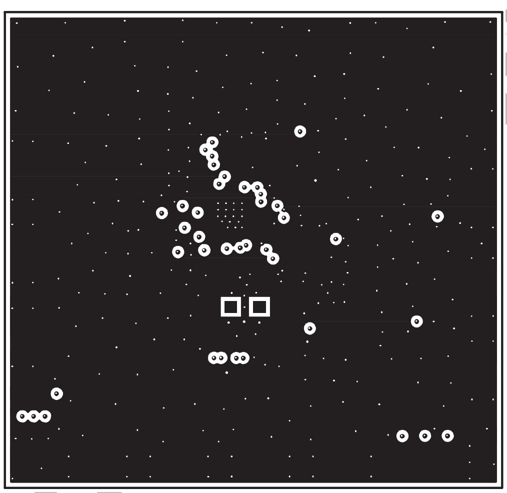


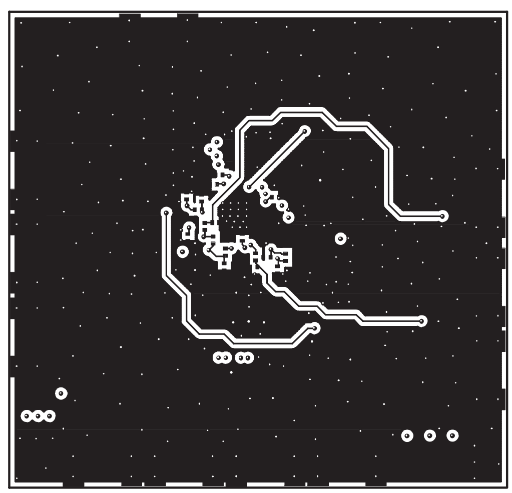
## Evaluation Board Layout
## Board Size 2.2” x 2.1”

Board Thickness 0.031”, Board Material FR-4, Multi-Layer

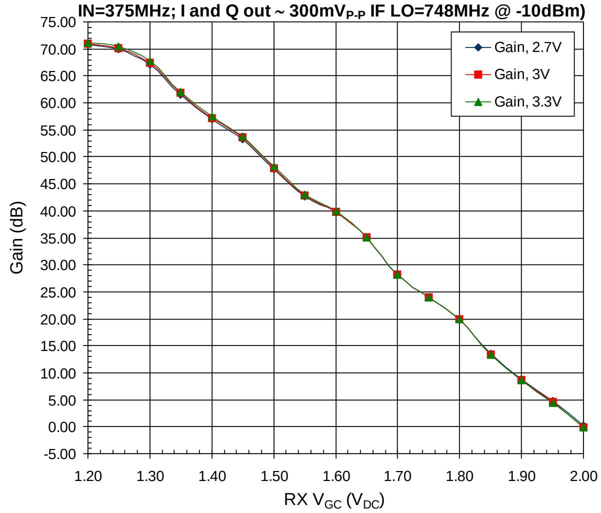


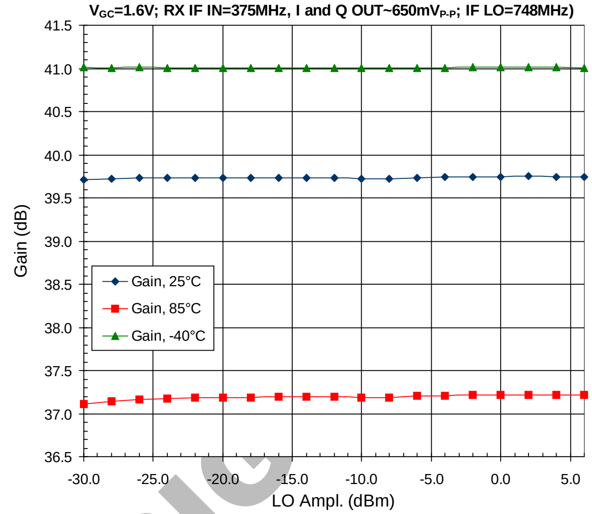




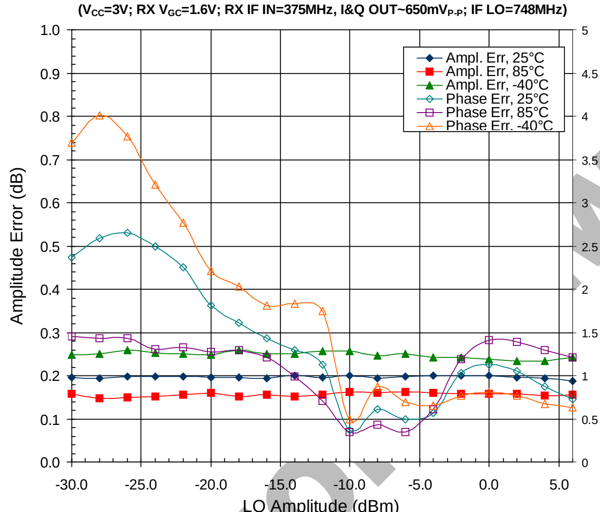
**RX Voltage Gain versus $V_{GC}$ and $V_{CC}$ (Temp=25°C; RX IF IN=375MHz; I and Q out ~ 300mV$_{P-P}$ IF LO=748MHz @ -10dBm)**



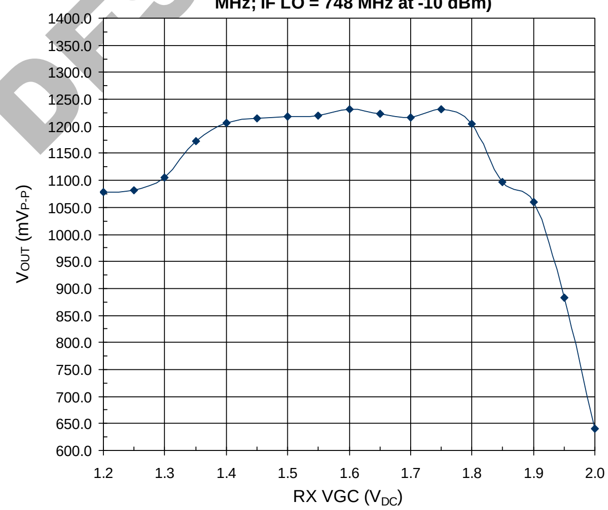

**RX Gain versus IF LO Amplitude and Temp ($V_{CC}$=3V; RX $V_{GC}$=1.6V; RX IF IN=375MHz, I and Q OUT~650mV$_{P-P}$; IF LO=748MHz)**



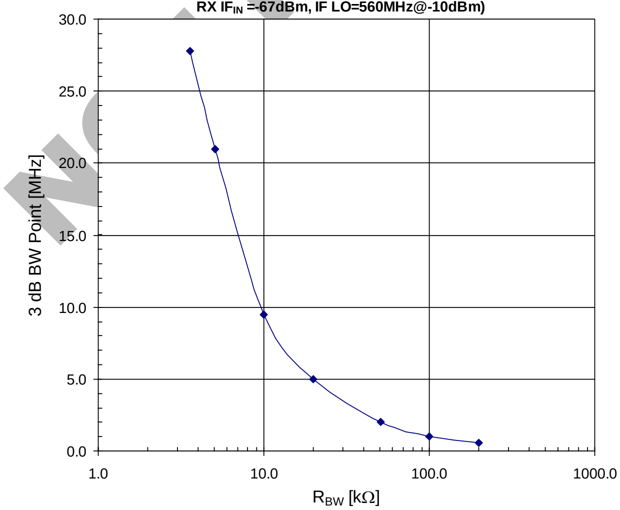

**RX IQ Amplitude and Phase Error versus IF LO Amplitude and Temp ($V_{CC}$=3V; RX $V_{GC}$=1.6V; RX IF IN=375MHz, I&Q OUT~650mV$_{P-P}$; IF LO=748MHz)**



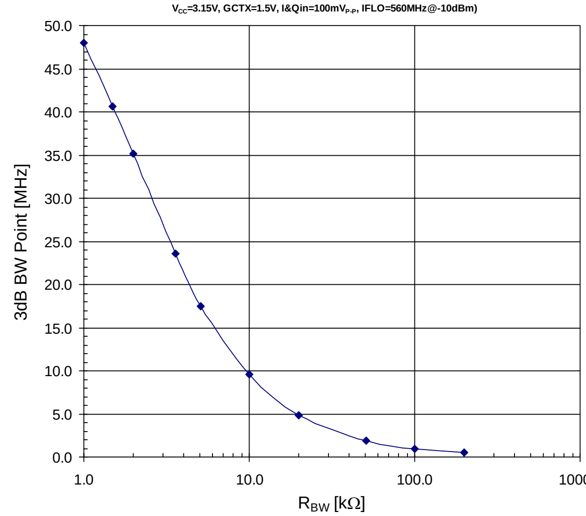

**RX OP1dB versus VGC and Temp ($V_{CC}$ = 3 V; RX $IF_{IN}$ = 375 MHz; IF LO = 748 MHz at -10 dBm)**



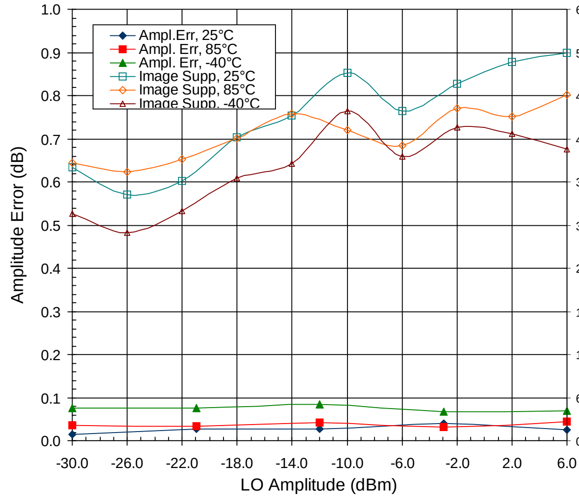

**RX 3dB BW versus $R_{BW}$ (Temp=Ambient, $V_{CC}$=3.15V, $V_{GC}$=1.6V, RX $IF_{IN}$ =-67dBm, IF LO=560MHz@-10dBm)**



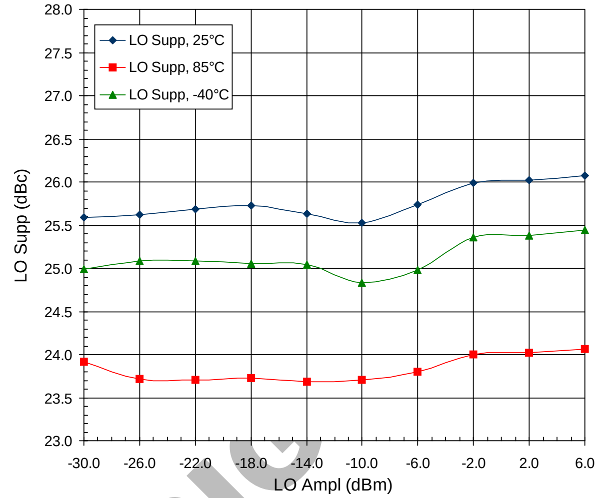

**TX 3dB BW Point versus $R_{BW}$ (Broadband 50Ω match on IFOUT, Temp=Ambient, $V_{CC}$=3.15V, GCTX=1.5V, I&Qin=100mV$_{P-P}$, IFLO=560MHz@-10dBm)**



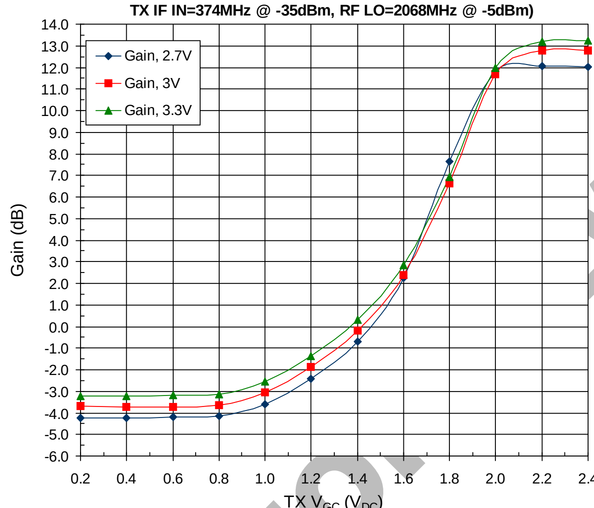
Modulator Amplitude Error and Image Suppression versus IF LO Amplitude and Temp ($V_{CC}$=3V; IF LO=748MHz; IQ IN=1MHz @ 100m$V_{P-P}$)



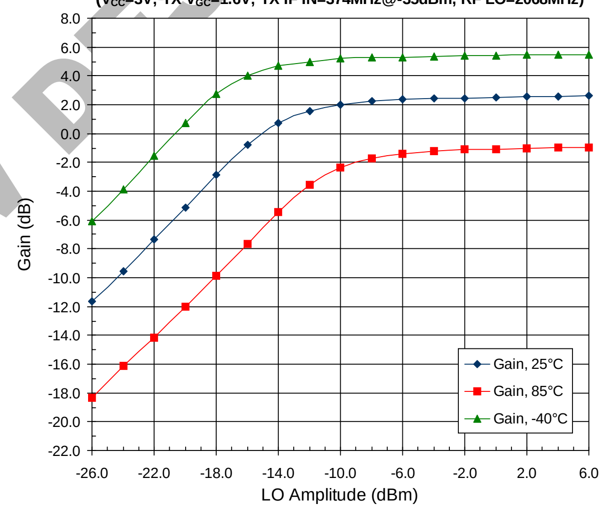

Modulator LO Suppression versus IF LO Amplitude and Temp ($V_{CC}$=3V; IF LO=748MHz; IQ IN=1 MHz @ 100m$V_{P-P}$)



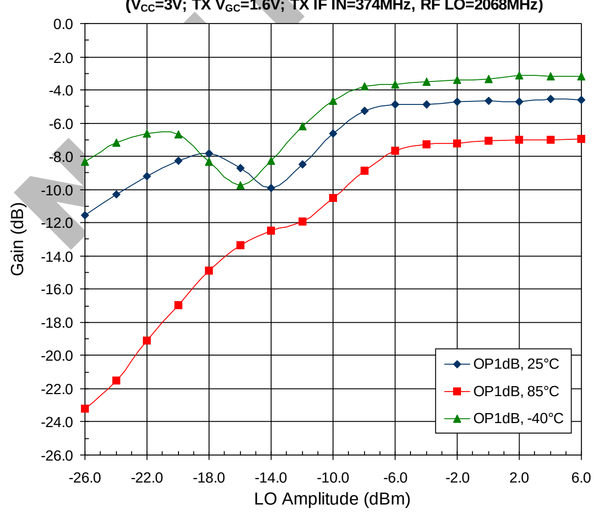

Upconverter Voltage Gain versus $V_{GC}$ and $V_{CC}$ (Temp=25°C; TX IF IN=374MHz @ -35dBm, RF LO=2068MHz @ -5dBm)



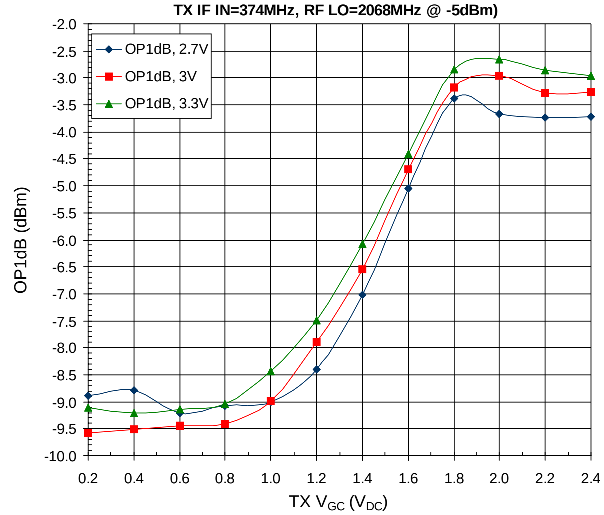

Upconverter Voltage Gain versus RF LO Amplitude and Temp ($V_{CC}$=3V; TX $V_{GC}$=1.6V; TX IF IN=374MHz@-35dBm, RF LO=2068MHz)

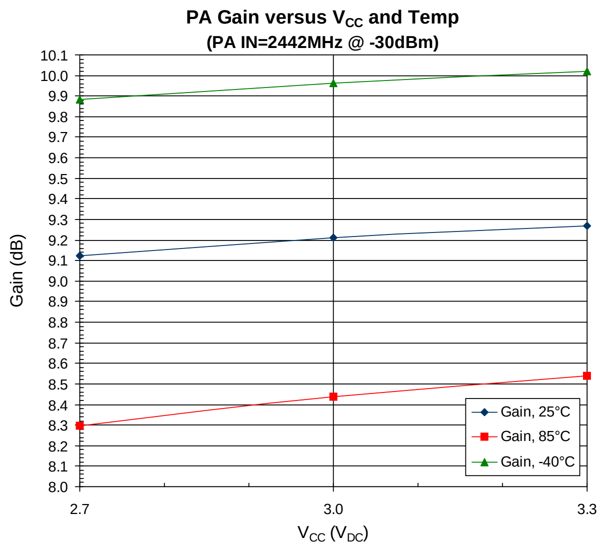


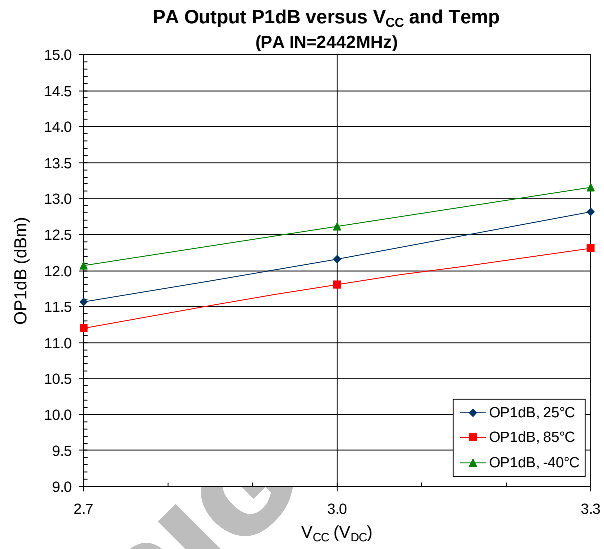

Upconverter Output P1dB versus RF LO Amplitude and Temp ($V_{CC}$=3V; TX $V_{GC}$=1.6V; TX IF IN=374MHz, RF LO=2068MHz)




Upconverter Output P1dB versus $V_{GC}$ and $V_{CC}$ (Temp=25°C; TX IF IN=374MHz, RF LO=2068MHz @ -5dBm)




PA Gain versus VCC and Temp
(PA IN=2442MHz @ -30dBm)
Gain (dB)
VCC (VDC)
Gain, 25°C
Gain, 85°C
Gain, -40°C


PA Output P1dB versus VCC and Temp
(PA IN=2442MHz)
OP1dB (dBm)
VCC (VDC)
OP1dB, 25°C
OP1dB, 85°C
OP1dB, -40°C