# 0.4-GHz TO 4-GHz QUADRATURE MODULATOR

Check for Samples: TRF370317

## FEATURES

- **76-dBc Single-Carrier WCDMA ACPR at −8 dBm Channel Power**
- **Low Noise Floor: −163 dBm/Hz**
- **OIP3 of 26.5 dBm**
- **P1dB of 12 dBm**
- **Unadjusted Carrier Feedthrough of −40 dBm**
- **Unadjusted Side-Band Suppression of −45 dBc**
- **Single Supply: 4.5-V–5.5-V Operation**
- **Silicon Germanium Technology**
- **1.7-V CM at I, Q Baseband Inputs**

## APPLICATIONS

- **Cellular Base Station Transceiver**
- **CDMA: IS95, UMTS, CDMA2000, TD-SCDMA**
- **TDMA: GSM, IS-136, EDGE/UWC-136**
- **Multicarrier GSM**
- **WiMAX: 802.16d/e**
- **3GPP: LTE**
- **Wireless MAN Wideband Transceivers**

**RGE PACKAGE**
**(TOP VIEW)**
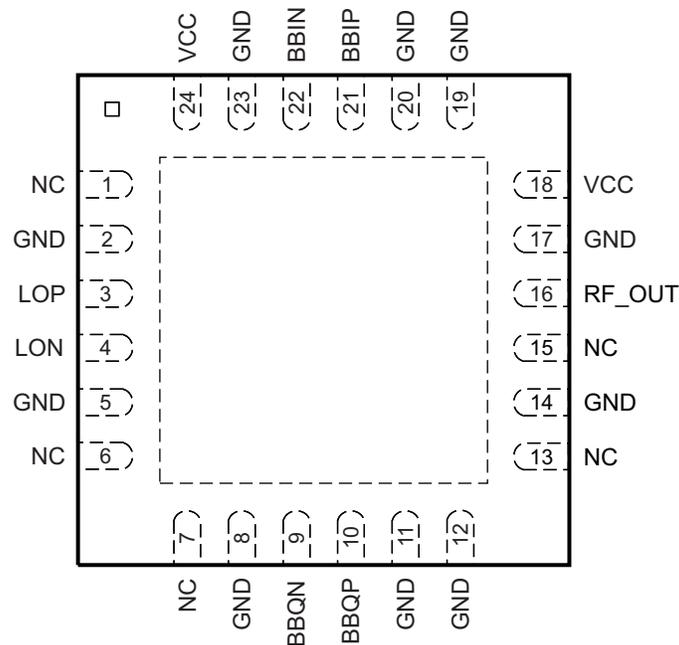


P0024-04

## DESCRIPTION

The TRF370317 is a low-noise direct quadrature modulator, capable of converting complex modulated signals from baseband or IF directly up to RF. The TRF370317 is a high-performance, superior-linearity device that is ideal to RF frequencies of 400 MHz through 4 GHz. The modulator is implemented as a double-balanced mixer. The RF output block consists of a differential to single-ended converter and an RF amplifier capable of driving a single-ended 50-Ω load without any need of external components. The TRF370317 requires a 1.7-V common-mode voltage for optimum linearity performance.

⚠ Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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# TRF370317

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## Functional Block Diagram
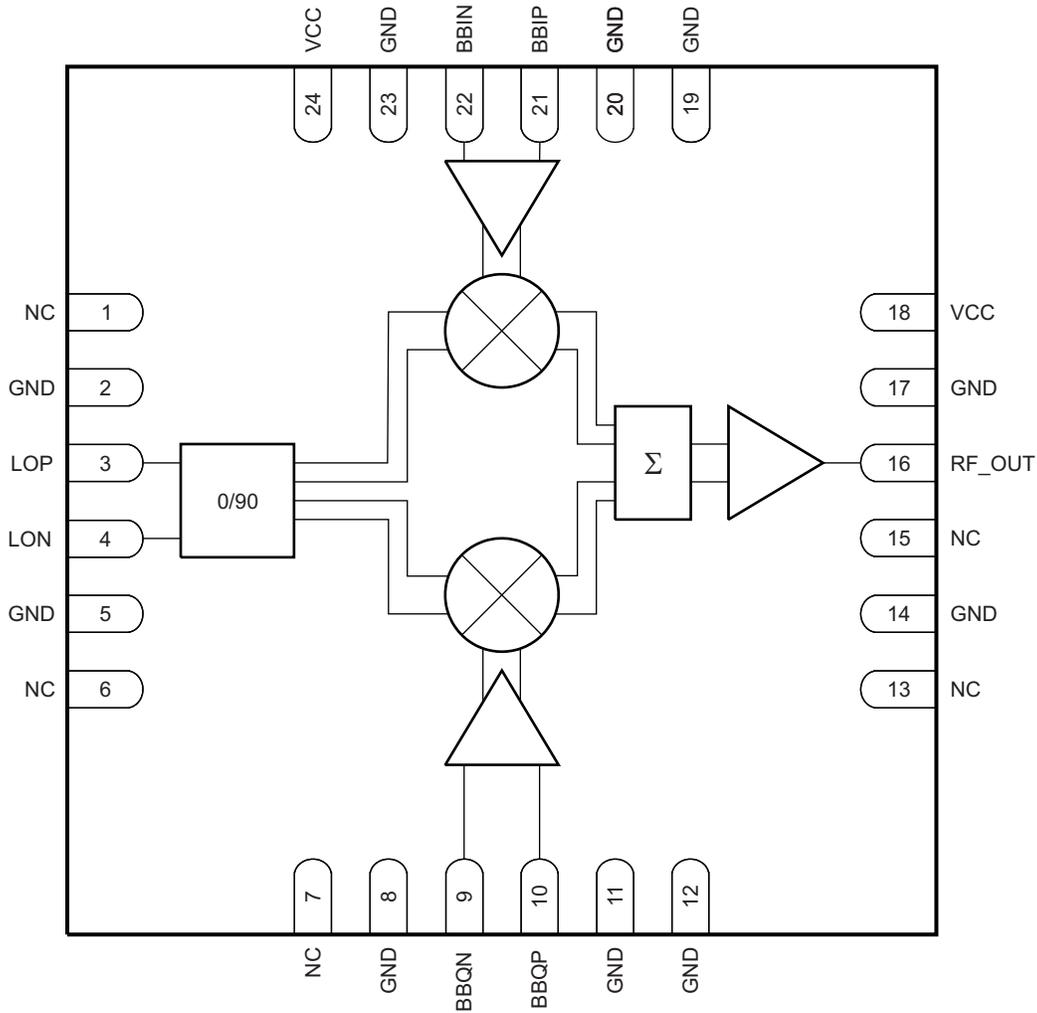


B0175-01

NOTE: NC = No connection

Product Folder Link(s): *TRF370317*

## DEVICE INFORMATION

### TERMINAL FUNCTIONS

| TERMINAL NAME | NO. | I/O | DESCRIPTION |
|---|---|---|---|
| BBIN | 22 | I | In-phase negative input |
| BBIP | 21 | I | In-phase positive input |
| BBQN | 9 | I | Quadrature-phase negative input |
| BBQP | 10 | I | Quadrature-phase positive input |
| GND | 2, 5, 8,11, 12, 14, 17, 19, 20, 23 | – | Ground |
| LON | 4 | I | Local oscillator negative input |
| LOP | 3 | I | Local oscillator positive input |
| NC | 1, 6, 7, 13, 15 | – | No connect |
| RF_OUT | 16 | O | RF output |
| VCC | 18, 24 | – | Power supply |

## ABSOLUTE MAXIMUM RATINGS[1]

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

| | | VALUE[2] | UNIT |
|---|---|---|---|
| | Supply voltage range | −0.3 V to 6 | V |
| $T_J$ | Operating virtual junction temperature range | −40 to 150 | °C |
| $T_A$ | Operating ambient temperature range | −40 to 85 | °C |
| $T_{stg}$ | Storage temperature range | −65 to 150 | °C |
| ESD | Electrostatic discharge ratings | Human body model (HBM) | 75 | V |
| | | Charged device model (CDM) | 75 | V |

(1)  Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2)  All voltage values are with respect to network ground terminal.

## RECOMMENDED OPERATING CONDITIONS

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

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{CC}$ | Power-supply voltage | 4.5 | 5 | 5.5 | V |

## THERMAL CHARACTERISTICS

| PARAMETER | | TEST CONDITIONS | VALUE | UNIT |
|---|---|---|---|---|
| $R_{\theta JA}$ | Thermal resistance, junction-to-ambient | High-K board, still air | 29.4 | °C/W |
| $R_{\theta JC}$ | Thermal resistance, junction-to-case | | 18.6 | °C/W |

# TRF370317

## ELECTRICAL CHARACTERISTICS

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

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **DC Parameters** | | | | | | |
| $I_{CC}$ | Total supply current (1.7 V CM) | $T_A$ = 25°C | | 205 | 245 | mA |
| **LO Input (50-Ω, Single-Ended)** | | | | | | |
| $f_{LO}$ | LO frequency range | | 0.4 | | 4 | GHz |
| | LO input power | | −5 | 0 | 12 | dBm |
| | LO port return loss | | | 15 | | dB |
| **Baseband Inputs** | | | | | | |
| $V_{CM}$ | I and Q input dc common voltage | | | 1.7 | | |
| BW | 1-dB input frequency bandwidth | | 350 | | | MHz |
| $Z_{I(single\ ended)}$ | Input impedance, resistance | | | 5 | | kΩ |
| | Input impedance, parallel capacitance | | | 3 | | pF |

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **400 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| **RF Output Parameters** | | | | | | |
|---|---|---|---|---|---|---|
| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | −1.9 | | dB |
| P1dB | Output compression point | | | 11 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 24.5 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 68 | | dBm |
| | Carrier feedthrough | Unadjusted | | −38 | | dBm |
| | Sideband suppression | Unadjusted | | −40 | | dBc |

Product Folder Link(s): *TRF370317*

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **945.6 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| RF Output Parameters | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | | **TEST CONDITIONS** | **MIN** | **TYP** | **MAX** | **UNIT** |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | −2.5 | | dB |
| P1dB | Output compression point | | | 11 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 25 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 65 | | dBm |
| | Carrier feedthrough | Unadjusted | | −40 | | dBm |
| | Sideband suppression | Unadjusted | | −42 | | dBc |
| | Output return loss | | | 9 | | dB |
| | Output noise floor | ≥13 MHz offset from $f_{LO}$; $P_{out}$ = −5 dBm | | −163 | | dBm/Hz |
| EVM | Error vector magnitude (rms) | 1 EDGE signal, $P_{out}$ = −5 dBm[1] | | 0.64% | | |

(1)   The contribution from the source of about 0.28% is not de-embedded from the measurement.

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **1800 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| RF Output Parameters | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | | **TEST CONDITIONS** | **MIN** | **TYP** | **MAX** | **UNIT** |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | −2.5 | | dB |
| P1dB | Output compression point | | | 12 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 26 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 60 | | dBm |
| | Carrier feedthrough | Unadjusted | | −40 | | dBm |
| | Sideband suppression | Unadjusted | | −50 | | dBc |
| | Output return loss | | | 8 | | dB |
| | Output noise floor | ≥13 MHz offset from $f_{LO}$; $P_{out}$ = −5 dBm | | −162 | | dBm/Hz |
| EVM | Error vector magnitude (rms) | 1 EDGE signal, $P_{out}$ = −5 dBm[1] | | 0.41% | | |

(1)   The contribution from the source of about 0.28% is not de-embedded from the measurement.

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **1960 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| RF Output Parameters | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | | **TEST CONDITIONS** | **MIN** | **TYP** | **MAX** | **UNIT** |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | −2.5 | | dB |
| P1dB | Output compression point | | | 12 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | 23.5 | 26.5 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 60 | | dBm |
| | Carrier feedthrough | Unadjusted | | −38 | | dBm |
| | Sideband suppression | Unadjusted | | −50 | | dBc |
| | Output return loss | | | 8 | | dB |
| | Output noise floor | ≥13 MHz offset from $f_{LO}$; $P_{out}$ = −5 dBm | | −162.5 | | dBm/Hz |
| EVM | Error vector magnitude (rms) | 1 EDGE signal, $P_{out}$ = −5 dBm[1] | | 0.43% | | |
| ACPR[2] | Adjacent-channel power ratio | 1 WCDMA signal; $P_{out}$ = −8 dBm | | −74 | | dBc |
| | | 2 WCDMA signals; $P_{out}$ = −11 dBm per carrier | | −68 | | |
| | | 4 WCDMA signals; $P_{out}$ = −14 dBm per carrier | | −67 | | |
| | Alternate-channel power ratio | 1 WCDMA signal; $P_{out}$ = −8 dBm | | −78 | | dBc |
| | | 2 WCDMA signals; $P_{out}$ = −11 dBm per carrier | | −72 | | |
| | | 4 WCDMA signals; $P_{out}$ = −14 dBm per carrier | | −69 | | |

(1)  The contribution from the source of about 0.28% is not de-embedded from the measurement.
(2)  Measured with DAC5687 as source generator

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **2140 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| RF Output Parameters | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | | **TEST CONDITIONS** | **MIN** | **TYP** | **MAX** | **UNIT** |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | −2.4 | | dB |
| P1dB | Output compression point | | | 12 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 26.5 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 66 | | dBm |
| | Carrier feedthrough | Unadjusted | | −38 | | dBm |
| | Sideband suppression | Unadjusted | | −50 | | dBc |
| | Output return loss | | | 8.5 | | dB |
| | Output noise floor | ≥13 MHz offset from $f_{LO}$ ; $P_{out}$ = −5 dBm | | −162.5 | | dBm/Hz |
| ACPR[1] | Adjacent-channel power ratio | 1 WCDMA signal; $P_{out}$ = −8 dBm | | −72 | | dBc |
| | | 2 WCDMA signal; $P_{out}$ = −11 dBm per carrier | | −67 | | |
| | | 4 WCDMA signals; $P_{out}$ = −14 dBm per carrier | | −66 | | |
| | Alternate-channel power ratio | 1 WCDMA signal; $P_{out}$ = −8 dBm | | −78 | | dBc |
| | | 2 WCDMA signal; $P_{out}$ = −11 dBm | | −74 | | |
| | | 4 WCDMA signals; $P_{out}$ = −14 dBm per carrier | | −68 | | |

(1)  Measured with DAC5687 as source generator

Product Folder Link(s): *TRF370317*

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **2500 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| **RF Output Parameters** | | | | | | |
|---|---|---|---|---|---|---|
| | PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | −1.6 | | dB |
| P1dB | Output compression point | | | 13 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 29 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 65 | | dBm |
| | Carrier feedthrough | Unadjusted | | −37 | | dBm |
| | Sideband suppression | Unadjusted | | −47 | | dBc |
| EVM | Error vector magnitude (rms) | WiMAX 5-MHz carrier, $P_{out}$ = −8 dBm, LO = 8 dBm | | −47 | | dB |
| | | WiMAX 5-MHz carrier, $P_{out}$ = 0 dBm, LO = 8 dBm | | −45 | | dB |

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **3500 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| **RF Output Parameters** | | | | | | |
|---|---|---|---|---|---|---|
| | PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | 0.6 | | dB |
| P1dB | Output compression point | | | 13.5 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 25 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 65 | | dBm |
| | Carrier feedthrough | Unadjusted | | −35 | | dBm |
| | Sideband suppression | Unadjusted | | −36 | | dBc |
| EVM | Error vector magnitude (rms) | WiMAX 5-MHz carrier, $P_{out}$ = −8 dBm, LO = 6 dBm | | −47 | | dB |
| | | WiMAX 5-MHz carrier, $P_{out}$ = 0 dBm, LO = 6 dBm | | −43 | | dB |

## ELECTRICAL CHARACTERISTICS

over recommended operating conditions, power supply = 5 V, $T_A$ = 25°C, $V_{CM}$ = 1.7 V, $f_{LO}$ = **4000 MHz** at 8 dBm, $V_{inBB}$ = 98 mVrms single-ended in quadrature, $f_{BB}$ = 50 kHz (unless otherwise noted)

| **RF Output Parameters** | | | | | | |
|---|---|---|---|---|---|---|
| | PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | 0.2 | | dB |
| P1dB | Output compression point | | | 12 | | dBm |
| IP3 | Output IP3 | $f_{BB}$ = 4.5, 5.5 MHz | | 22.5 | | dBm |
| IP2 | Output IP2 | $f_{BB}$ = 4.5, 5.5 MHz | | 60 | | dBm |
| | Carrier feedthrough | Unadjusted | | −36 | | dBm |
| | Sideband suppression | Unadjusted | | −36 | | dBc |

## TYPICAL CHARACTERISTICS

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**OUTPUT POWER**
**vs**
**BASEBAND VOLTAGE**
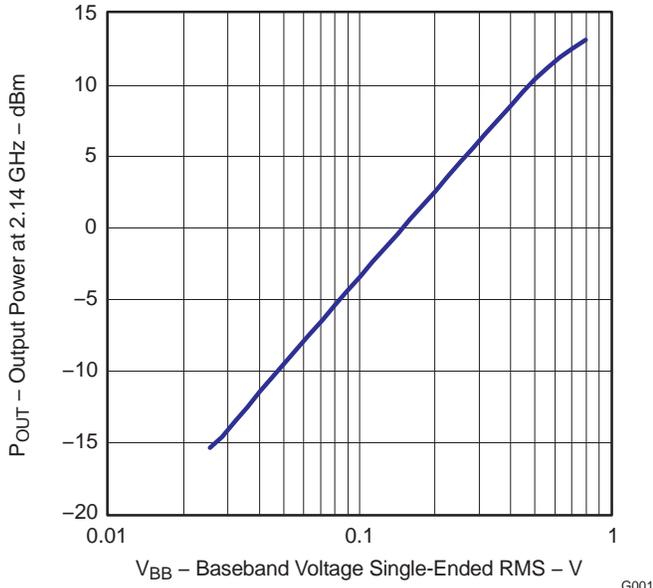


**Figure 1.**

**OUTPUT POWER**
**vs**
**FREQUENCY AND TEMPERATURE**
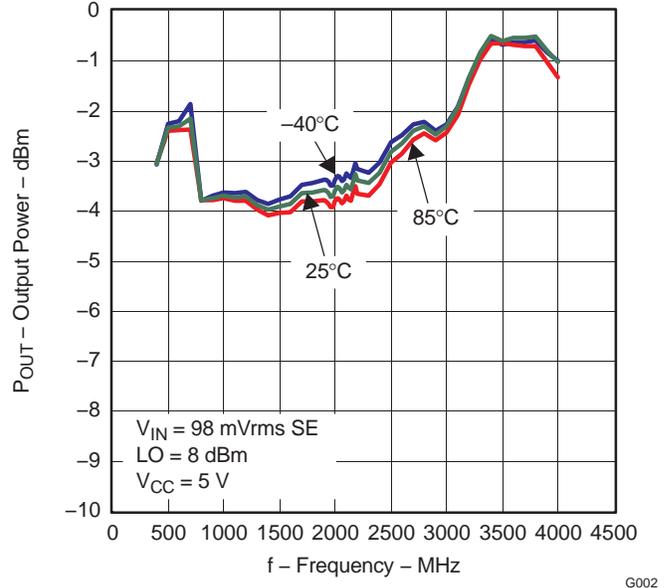


**Figure 2.**

**OUTPUT POWER**
**vs**
**FREQUENCY AND SUPPLY VOLTAGE**
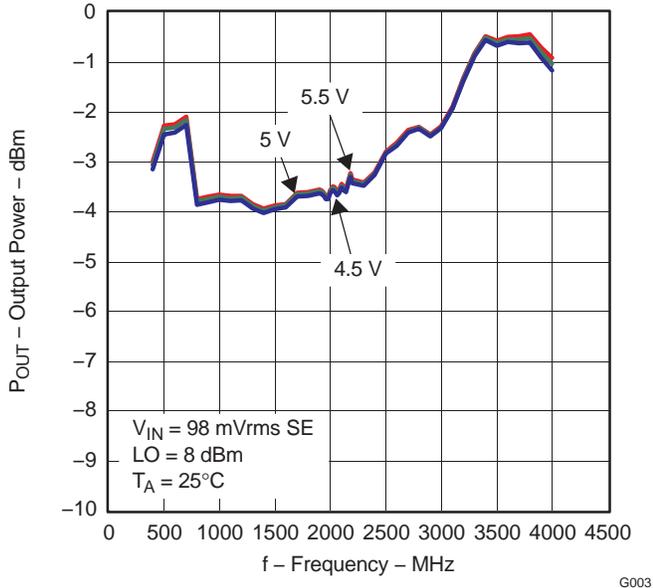


**Figure 3.**

**OUTPUT POWER**
**vs**
**FREQUENCY AND LO POWER**



**Figure 4.**

Product Folder Link(s): *TRF370317*

## TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**P1dB
vs
FREQUENCY AND TEMPERATURE**



Figure 5.

**P1dB
vs
FREQUENCY AND SUPPLY VOLTAGE**



Figure 6.

**P1dB
vs
FREQUENCY AND LO POWER**



Figure 7.

**OIP3
vs
FREQUENCY AND TEMPERATURE**



Figure 8.

## TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).



OIP3
vs
FREQUENCY AND SUPPLY VOLTAGE

Figure 9.



OIP3
vs
FREQUENCY AND LO POWER

Figure 10.



OIP2
vs
FREQUENCY AND TEMPERATURE

Figure 11.



OIP2
vs
FREQUENCY AND SUPPLY VOLTAGE

Figure 12.

Product Folder Link(s): TRF370317

## TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).



**Figure 13.**



**Figure 14.**
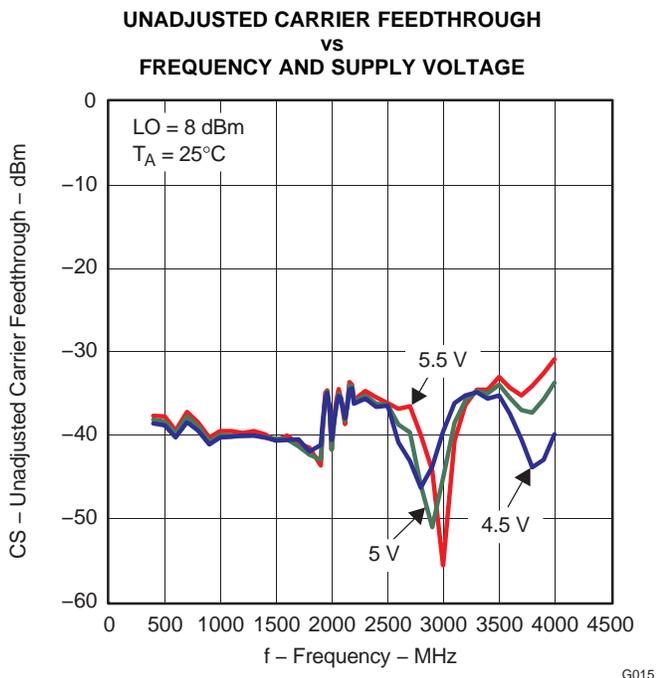


**Figure 15.**
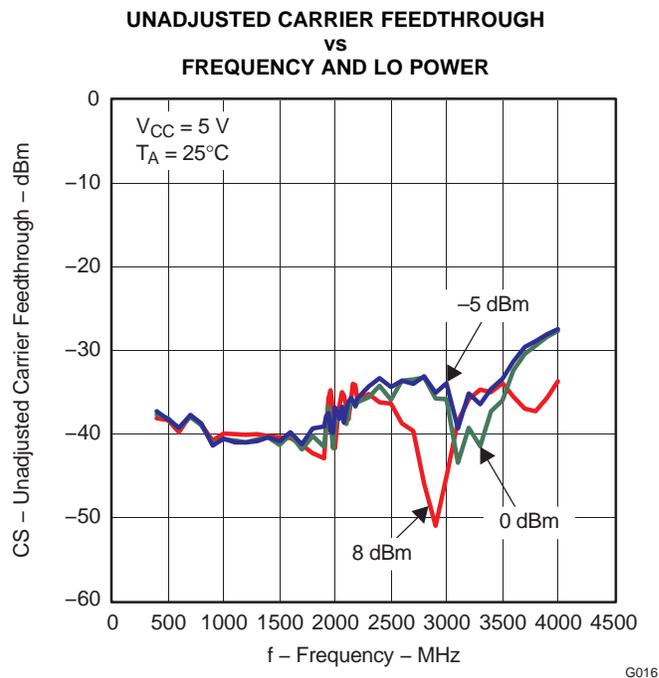


**Figure 16.**

# TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**UNADJUSTED SIDEBAND SUPPRESSION
vs
FREQUENCY AND TEMPERATURE**
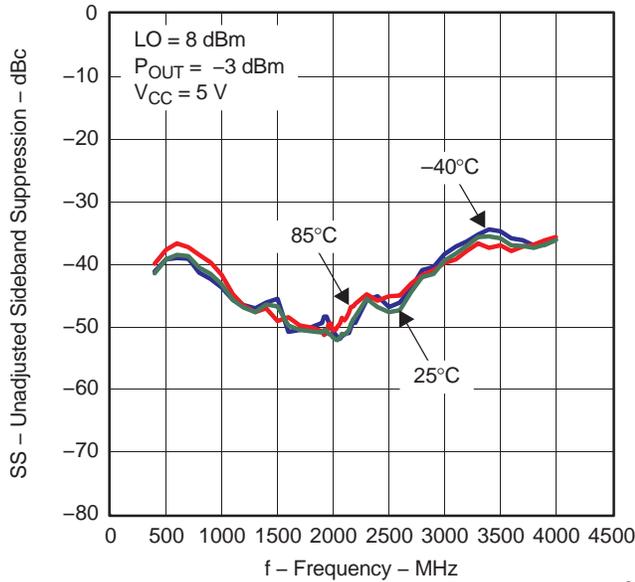


Figure 17.

**UNADJUSTED SIDEBAND SUPPRESSION
vs
FREQUENCY AND SUPPLY VOLTAGE**
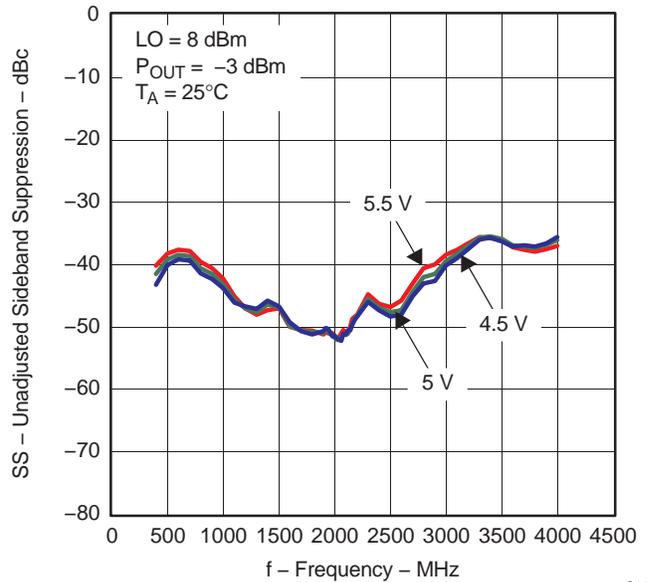


Figure 18.

**UNADJUSTED SIDEBAND SUPPRESSION
vs
FREQUENCY AND LO POWER**
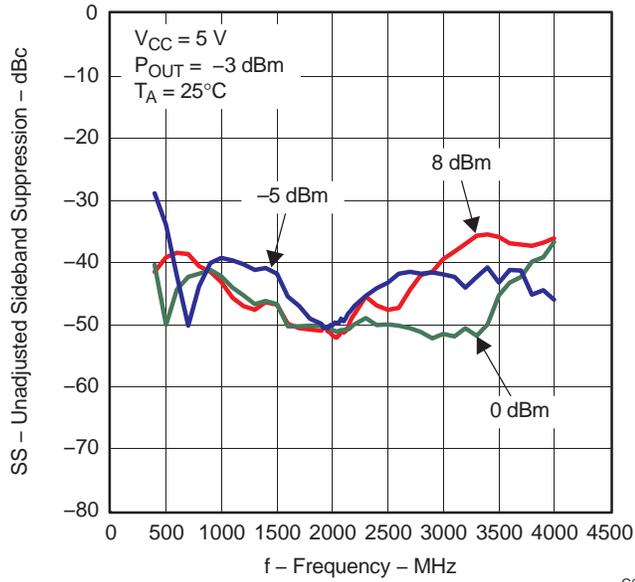


Figure 19.

**NOISE AT 13-MHz OFFSET (dBm/Hz)
vs
FREQUENCY AND TEMPERATURE**
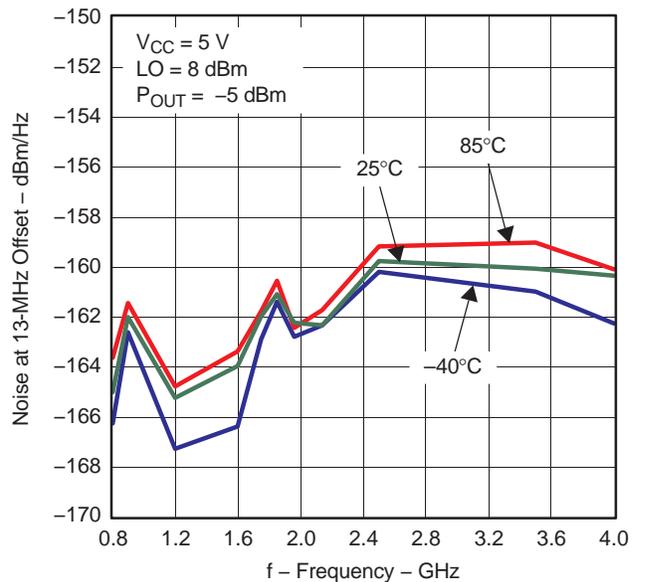


Figure 20.

Product Folder Link(s): *TRF370317*

## TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**NOISE AT 13-MHz OFFSET (dBm/Hz)**
**vs**
**FREQUENCY AND SUPPLY VOLTAGE**
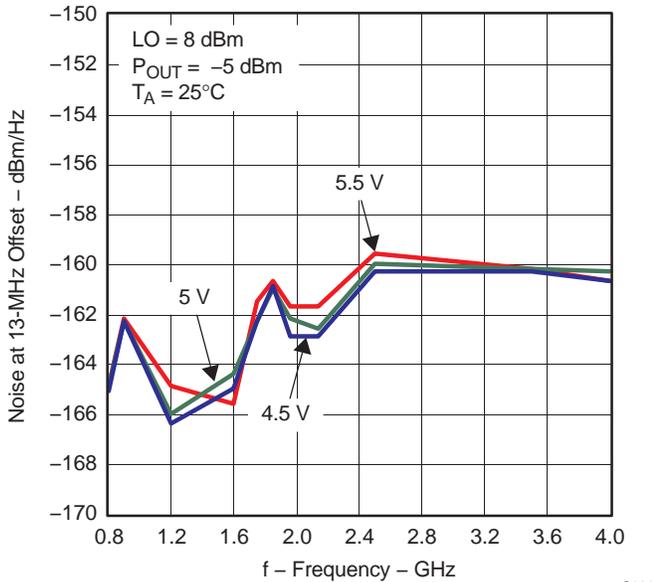


**Figure 21.**

**NOISE AT 13-MHz OFFSET (dBm/Hz)**
**vs**
**OUTPUT POWER**
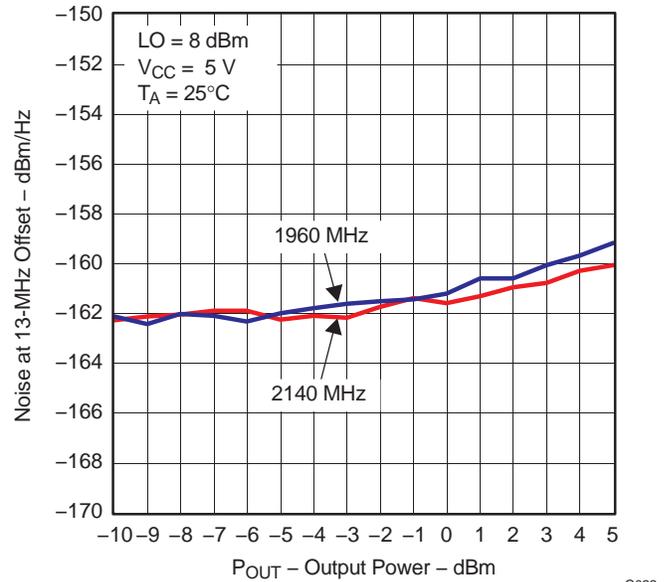


**Figure 22.**

**ADJUSTED CARRIER FEEDTHROUGH**
**vs**
**FREQUENCY AND TEMPERATURE**
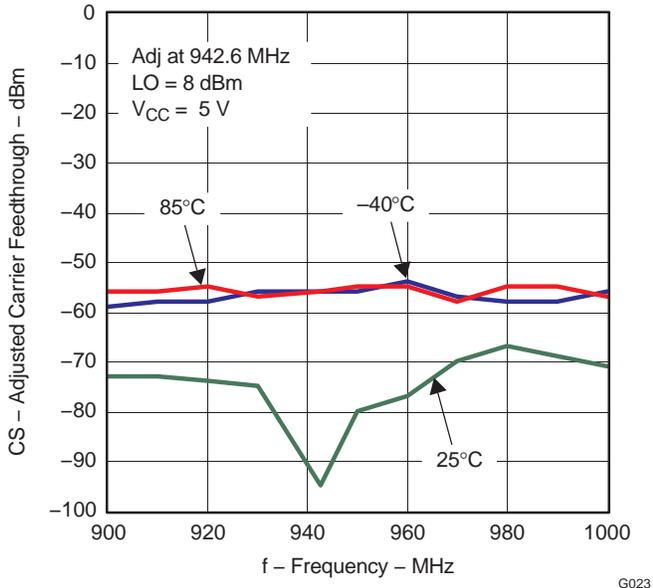


**Figure 23.**

**ADJUSTED CARRIER FEEDTHROUGH**
**vs**
**FREQUENCY AND TEMPERATURE**
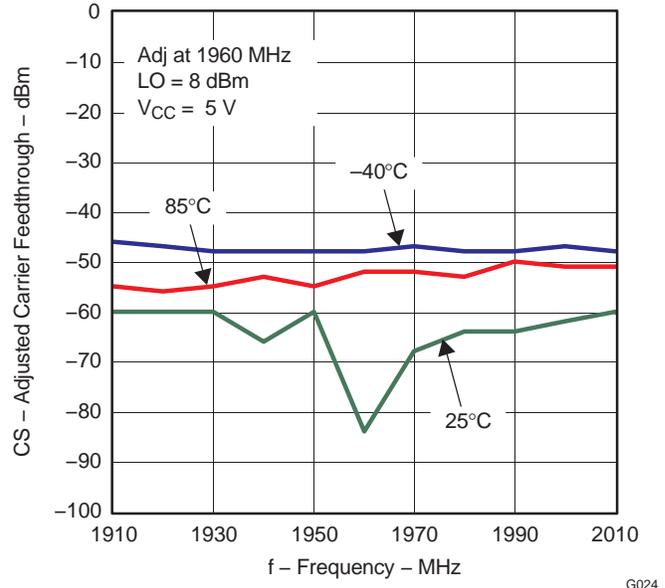


**Figure 24.**

Product Folder Link(s): TRF370317

# TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**ADJUSTED CARRIER FEEDTHROUGH**
**vs**
**FREQUENCY AND TEMPERATURE**
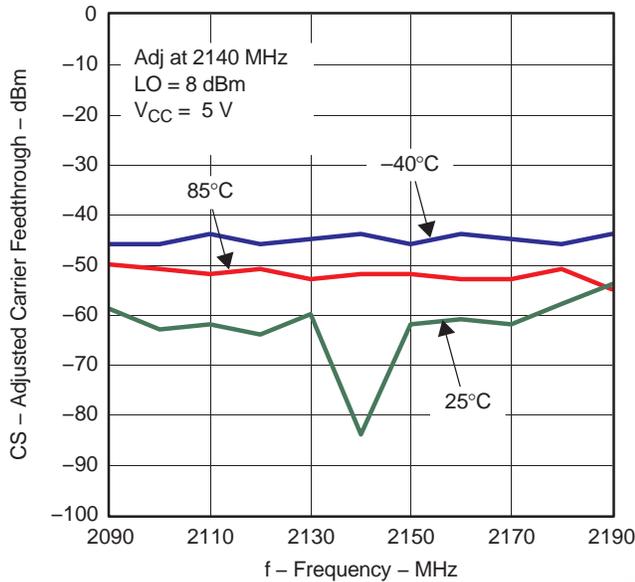


**Figure 25.**

**ADJUSTED CARRIER FEEDTHROUGH**
**vs**
**FREQUENCY AND TEMPERATURE**
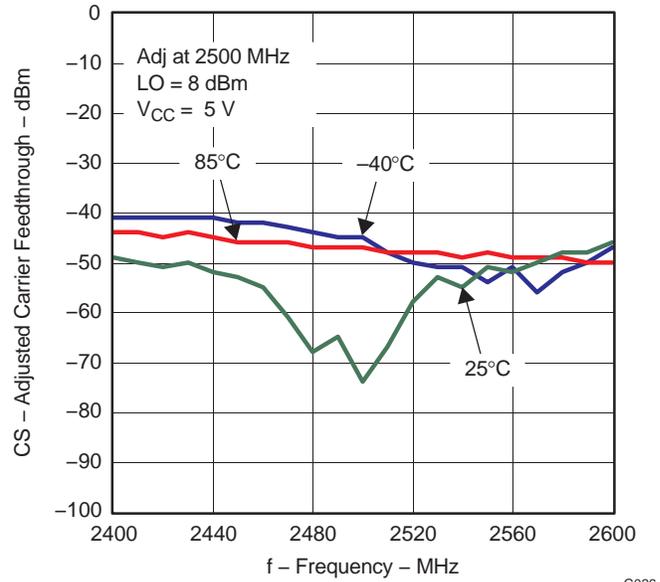


**Figure 26.**

**ADJUSTED CARRIER FEEDTHROUGH**
**vs**
**FREQUENCY AND TEMPERATURE**
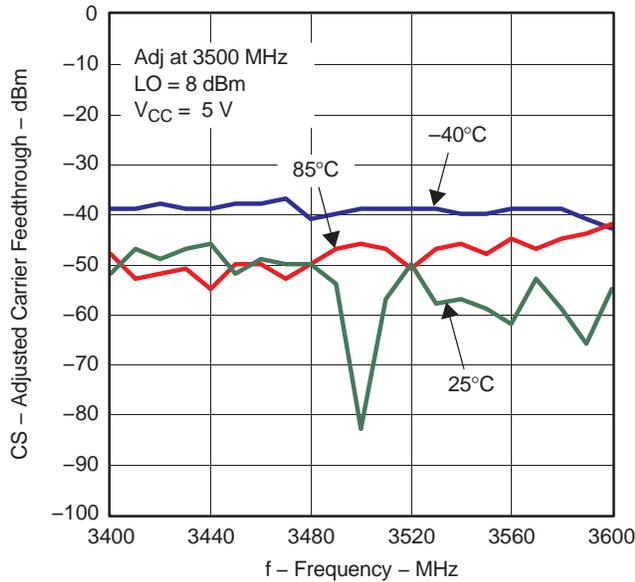


**Figure 27.**

**ADJUSTED SIDEBAND SUPPRESSION**
**vs**
**FREQUENCY AND TEMPERATURE**
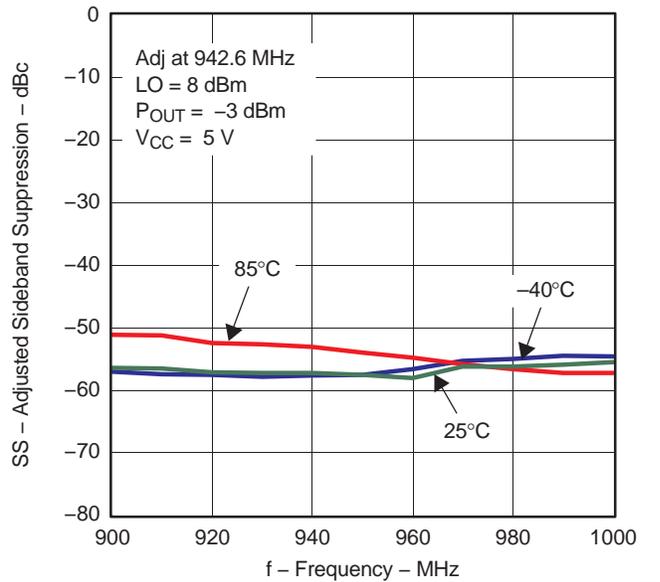


**Figure 28.**

Product Folder Link(s): *TRF370317*

## TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).
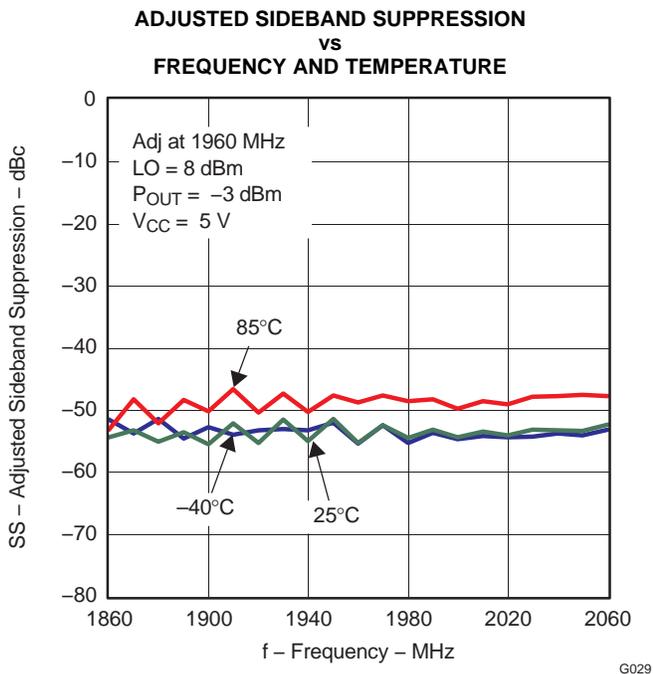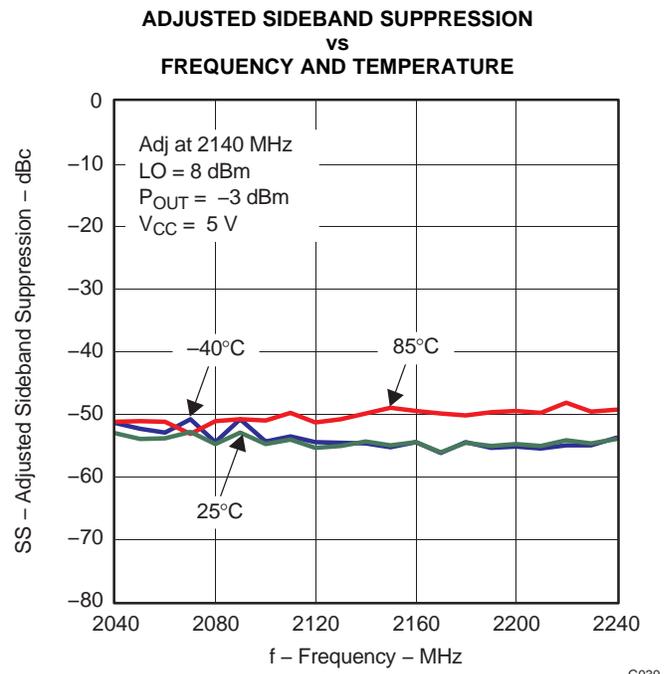


**Figure 29.**



**Figure 30.**
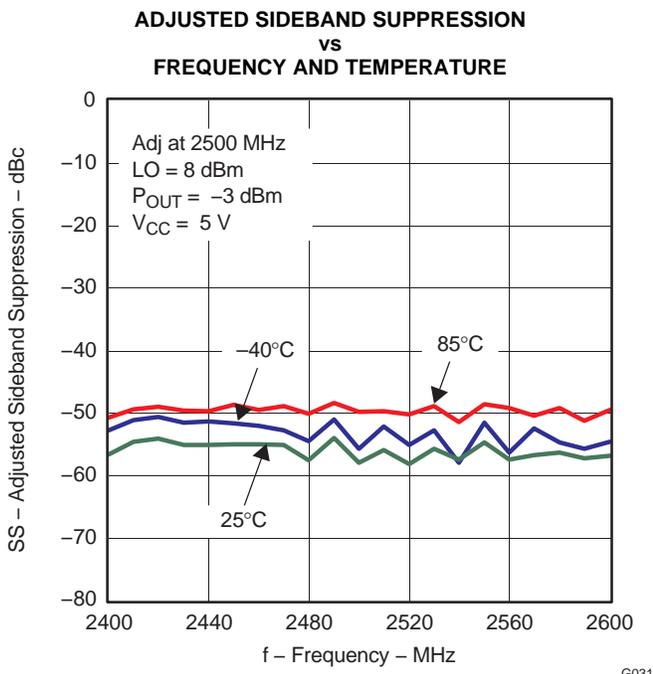


**Figure 31.**
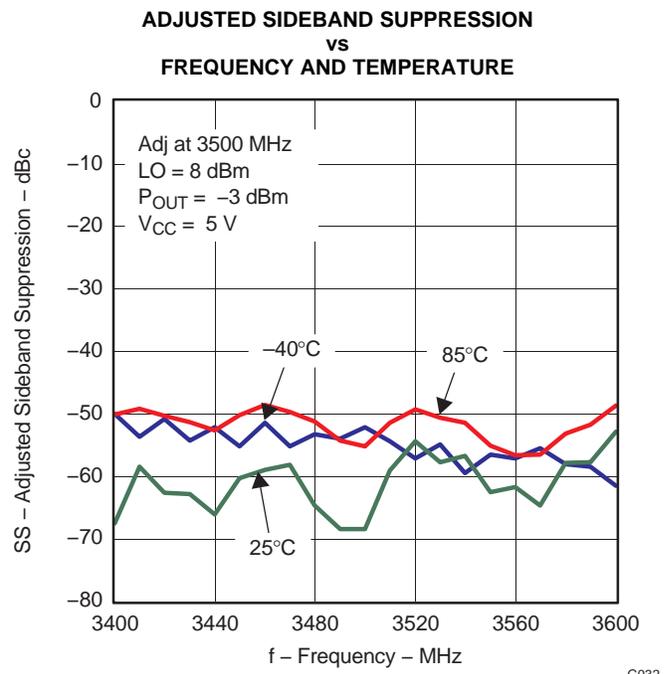


**Figure 32.**

# TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**OIP3**
**vs**
**COMMON-MODE VOLTAGE**



Figure 33.

**OIP2**
**vs**
**COMMON-MODE VOLTAGE**



Figure 34.

**ADJACENT CHANNEL POWER RATIO**
**vs**
**OUTPUT POWER**



Figure 35.

**ADJACENT CHANNEL POWER RATIO**
**vs**
**OUTPUT POWER**



Figure 36.

Product Folder Link(s): *TRF370317*
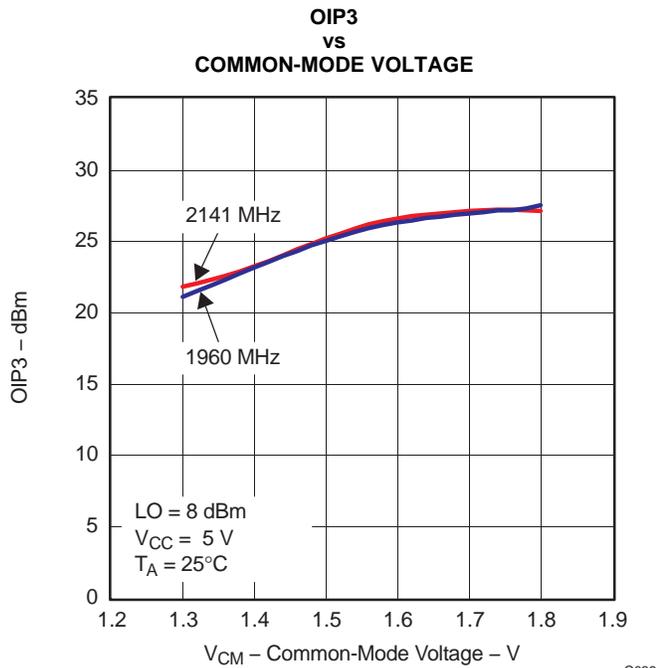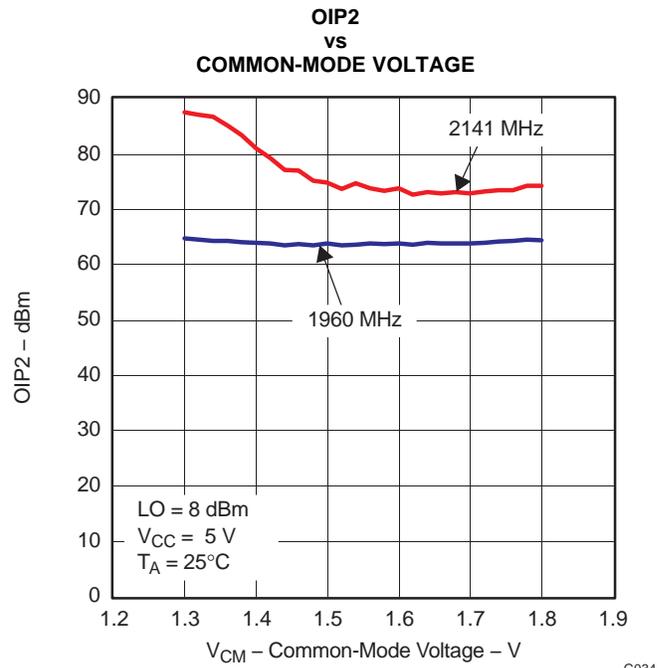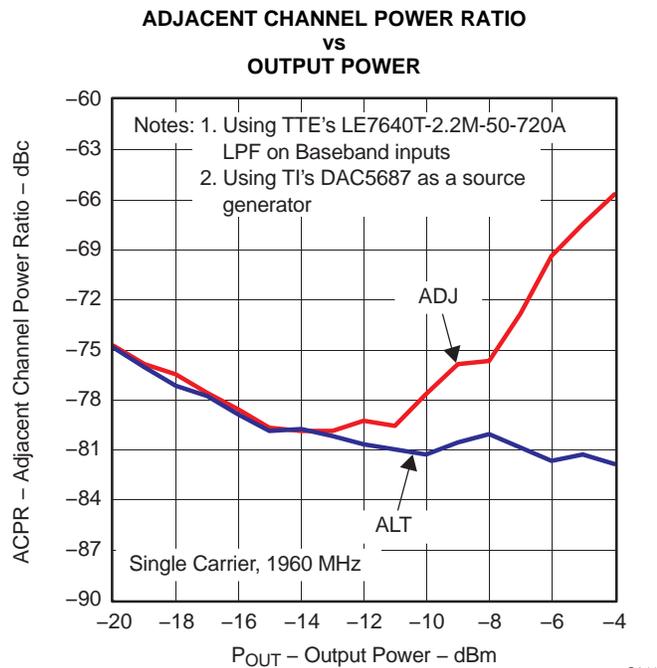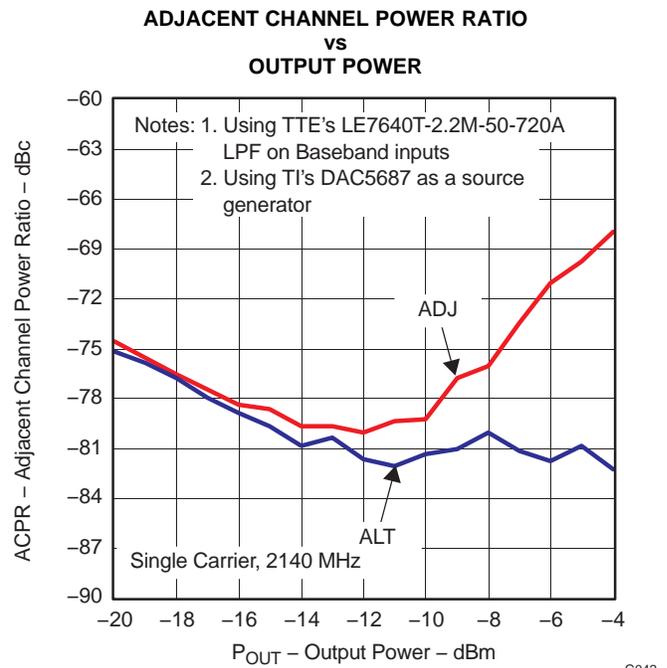
# TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**OIP3 at 1960 MHz DISTRIBUTION**
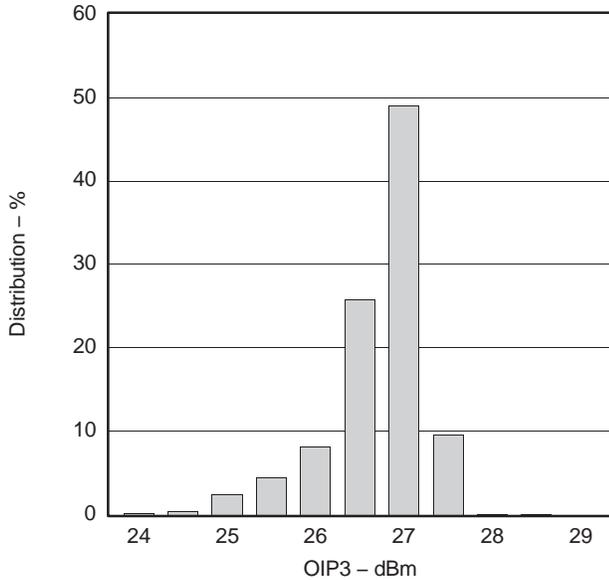


G036

Figure 37.

**OIP2 at 1960 MHz DISTRIBUTION**
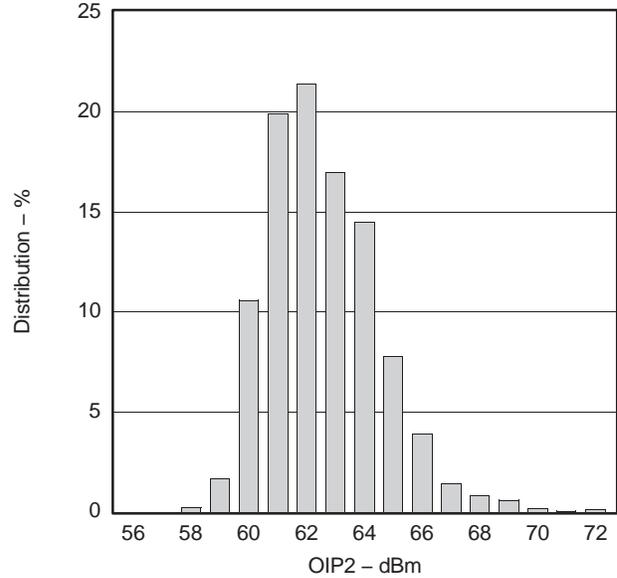


G037

Figure 38.

**UNADJUSTED CARRIER FEEDTHROUGH
at 1960 MHz DISTRIBUTION**
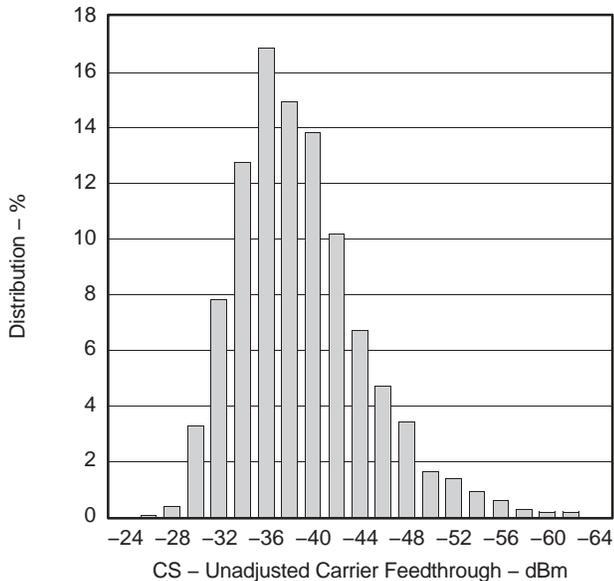


G038

Figure 39.

**UNADJUSTED SIDEBAND SUPPRESSION
at 1960 MHz DISTRIBUTION**
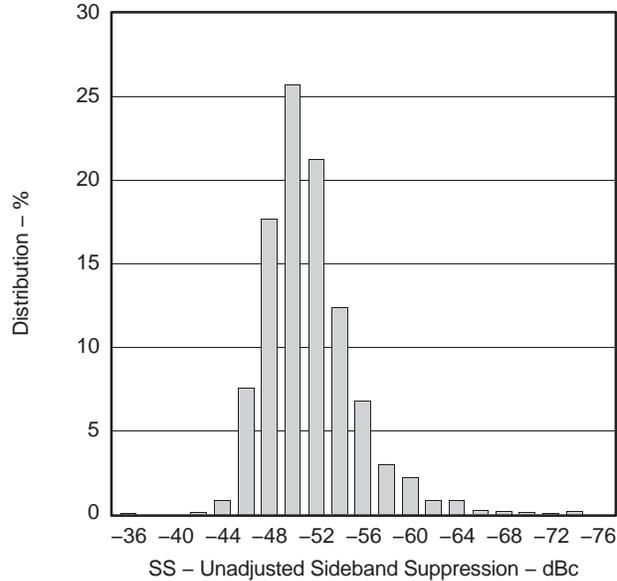


G039

Figure 40.

## TYPICAL CHARACTERISTICS (continued)

$V_{CM}$ = 1.7 V, $V_{inBB}$ = 98 mVrms single-ended sine wave in quadrature, $V_{CC}$ = 5 V, LO power = 8 dBm (single-ended), $f_{BB}$ = 50 kHz (unless otherwise noted).

**P1dB at 1800 MHz DISTRIBUTION**
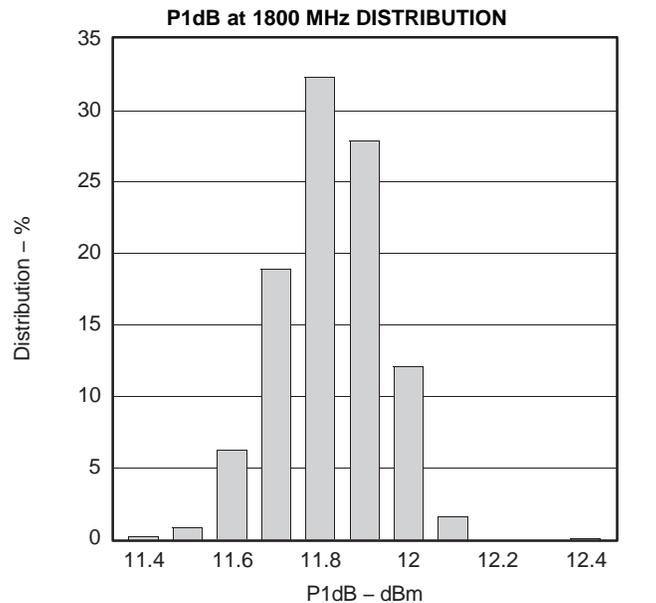
Figure 41.

## APPLICATION INFORMATION AND EVALUATION BOARD

### Basic Connections

- See Figure 42 for proper connection of the TRF3703 modulator.
- Connect a single power supply (4.5 V–5.5 V) to pins 18 and 24. These pins should be decoupled as shown on pins 4, 5, 6, and 7.
- Connect pins 2, 5, 8, 11, 12, 14, 17, 19, 20, and 23 to GND.
- Connect a single-ended LO source of desired frequency to LOP (amplitude between –5 dBm and 12 dBm). This should be ac-coupled through a 100-pF capacitor.
- Terminate the ac-coupled LON with 50 Ω to GND.
- Connect a baseband signal to pins 21 = I, 22 = $\bar{\text{I}}$, 10 = Q, and 9 = $\overline{\text{Q}}$.
- The differential baseband inputs should be set to the proper common-mode voltage of 1.7V.
- RF_OUT, pin 16, can be fed to a spectrum analyzer set to the desired frequency, LO ± baseband signal. This pin should also be ac-coupled through a 100-pF capacitor.
- All NC pins can be left floating.

### ESD Sensitivity

RF devices may be extremely sensitive to electrostatic discharge (ESD). To prevent damage from ESD, devices should be stored and handled in a way that prevents the build-up of electrostatic voltages that exceed the rated level. Rated ESD levels should also not be exceeded while the device is installed on a printed circuit board (PCB). Follow these guidelines for optimal ESD protection:

- Low ESD performance is not uncommon in RF ICs; see the *Absolute Maximum Ratings* table. Therefore, customers' ESD precautions should be consistent with these ratings.
- The device should be robust once assembled onto the PCB ***unless*** external inputs (connectors, etc.) directly connect the device pins to off-board circuits.

Product Folder Link(s): *TRF370317*
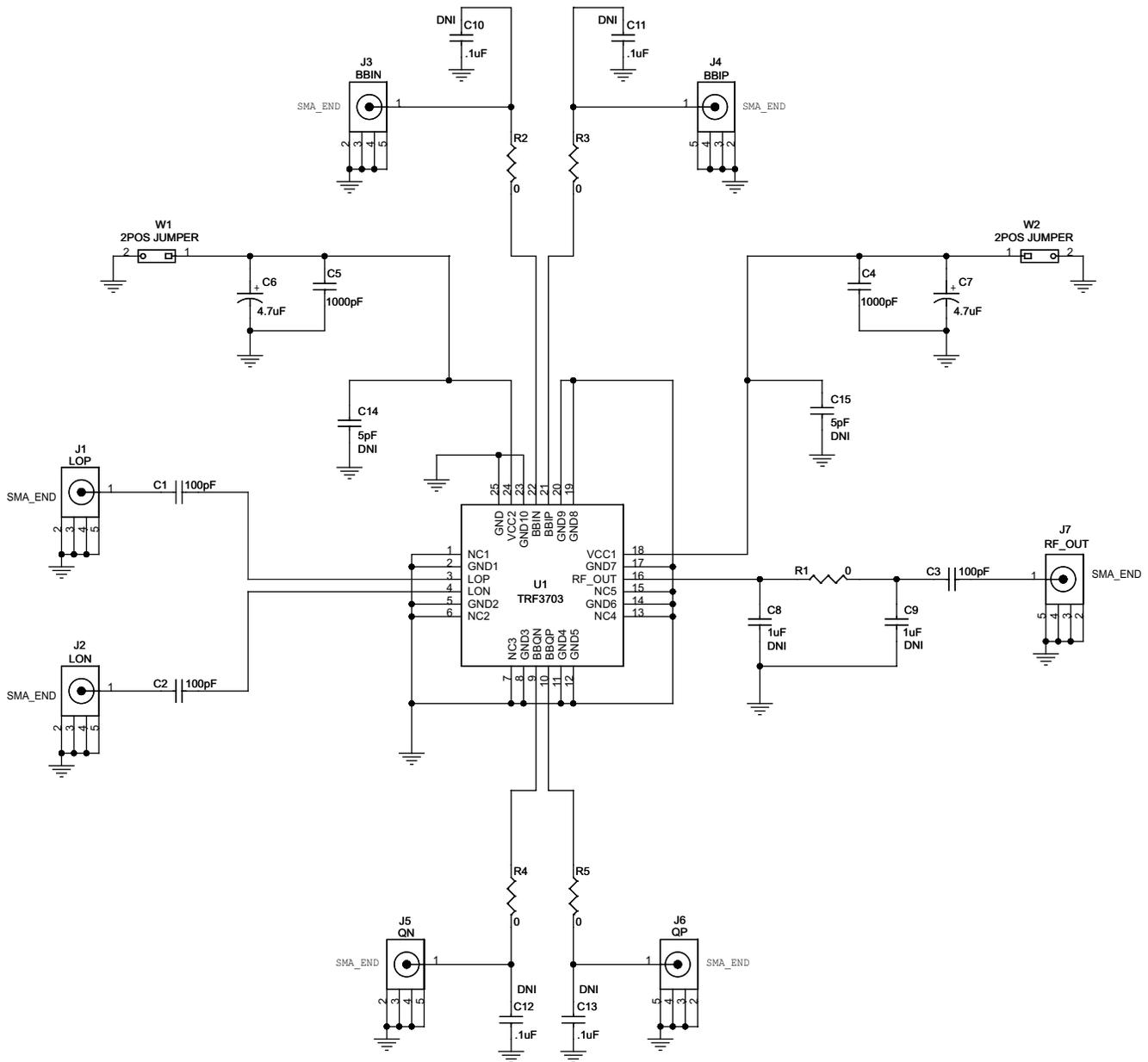
NOTE:  DNI = Do not install.

**Figure 42.  TRF3703 EVM Schematic**

Figure 43 shows the top view of the TRF3703 EVM board.
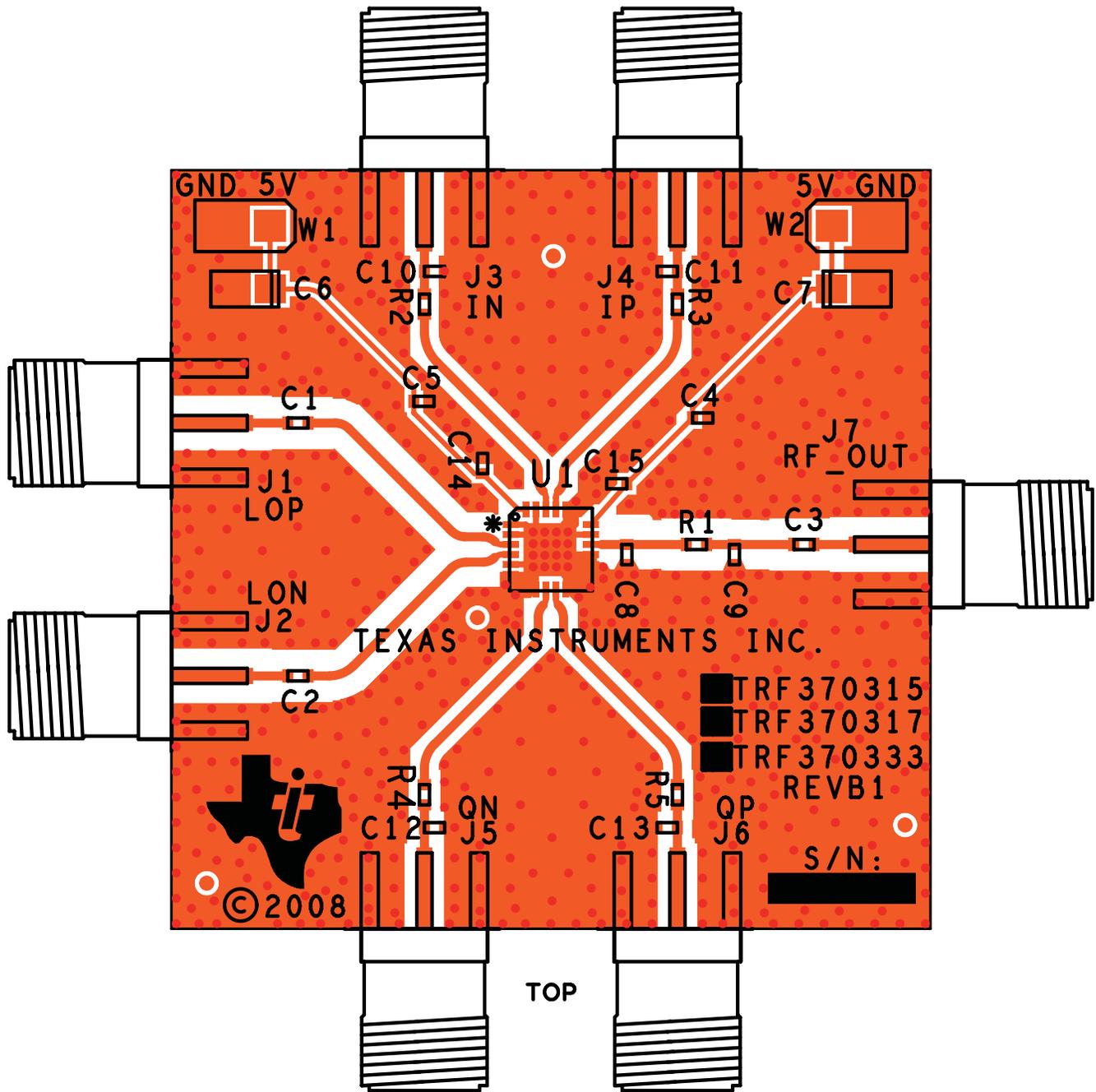


Figure 43. TRF3703 EVM Board Layout

Product Folder Link(s): TRF370317

**Table 1. Bill of Materials for TRF3703 EVM**

| Item Number | Quantity | Part Reference | Value | PCB Footprint | Mfr Name | Mfr Part Number | Note |
|---|---|---|---|---|---|---|---|
| 1 | 3 | C1, C2, C3 | 100 pF | 0402 | Panasonic | ECJ-0EC1H101J | |
| 2 | 2 | C4, C5 | 1000 pF | 0402 | Panasonic | ECJ-0VC1H102J | |
| 3 | 2 | C6, C7 | 4.7 μF | TANT_A | KEMET | T491A475K016AS | |
| 4 | 0 | C8, C9 | 1 μF | 0402 | Panasonic | ECJ-0EC1H010C_DNI | DNI[1] |
| 5 | 0 | C10, C11, C12, C13 | 0.1 μF | 0402 | Panasonic | ECJ-0EB1A104K_DNI | DNI[1] |
| 6 | 0 | C14, C15 | 5 pF | 0402 | Panasonic | ECJ-0EC1H050C_DNI | DNI[1] |
| 7 | 7 | J1, J2, J3, J4, J5, J6, J7 | LOP | SMA_SMEL_250x215 | Johnson Components | 142-0711-821 | |
| 8 | 1 | R1 | 0 | 0402 | Panasonic | ERJ-2GE0R00X | |
| 9 | 4 | R2, R3, R4, R5 | 0 | 0402 | Panasonic | ERJ-2GE0R00 | |
| 10 | 1 | U1 | TRF3703 | QFN_24_163x163_0p50mm | TI | TRF370317 | |
| 11 | 2 | W1, W2 | Jumper_1x2_thvt | HDR_THVT_1x2_100 | Samtec | HTSW-150-07-L-S | |

(1) DNI = Do not install.

## GSM Applications

The TRF370317 is suited for GSM and multicarrier GSM applications because of its high linearity and low noise level over the entire recommended operating range. It also has excellent EVM performance, which makes it ideal for the stringent GSM/EDGE applications.

## WCDMA Applications

The TRF370317 is also optimized for WCDMA applications where both adjacent-channel power ratio (ACPR) and noise density are critically important. Using Texas instruments' DAC568X series of high-performance digital-to-analog converters as depicted in Figure 44, excellent ACPR levels were measured with one-, two-, and four-WCDMA carriers. See *Electrical Characteristics*, $f_{LO}$ = 1960 MHz and $f_{LO}$ = 2140 MHz for exact ACPR values.
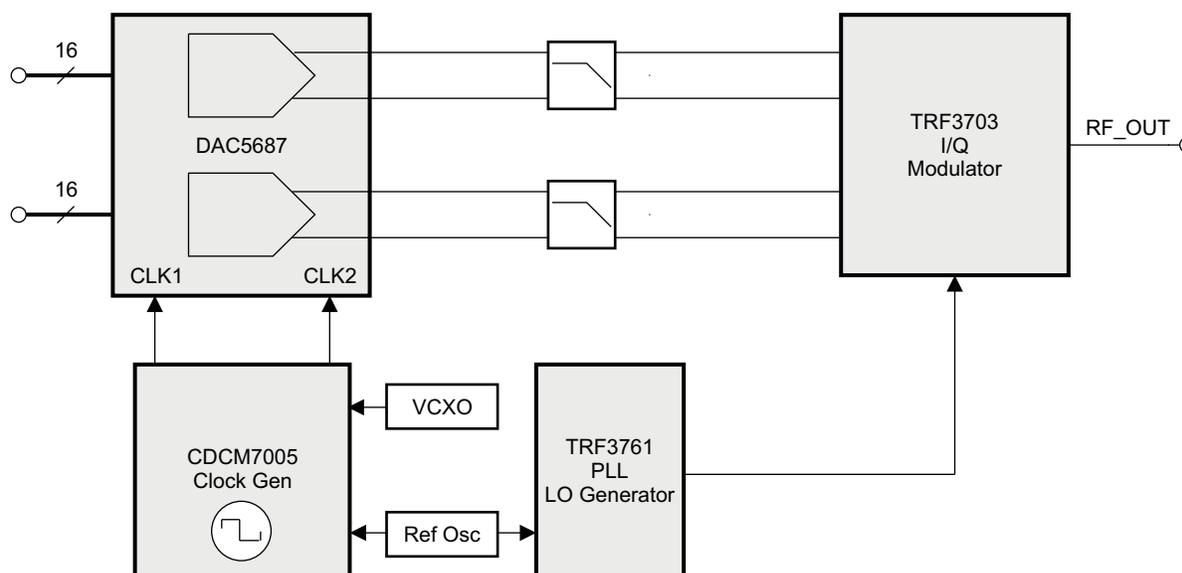


B0176-01

**Figure 44. Typical Transmit Setup Block Diagram**

## DAC-to-Modulator Interface Network

For optimum linearity and dynamic range, the digital-to-analog converter (DAC) can interface directly with the modulator; however, the common-mode voltage of each device must be maintained. A passive interface circuit is used to transform the common-mode voltage of the DAC to the desired set-point of the modulator. The passive circuit invariably introduces some insertion loss between the two devices. In general, it is desirable to keep the insertion loss as low as possible to achieve the best dynamic range. Figure 45 shows the passive interconnect circuit for two different topologies. One topology is used when the DAC (e.g., DAC568x) common mode is larger than the modulator. The voltage $V_{ee}$ is nominally set to ground, but can be set to a negative voltage to reduce the insertion loss of the network. The second topology is used when the DAC (e.g., DAC56x2) common mode is smaller than the modulator. Note that this passive interconnect circuit is duplicated for each of the differential I/Q branches.
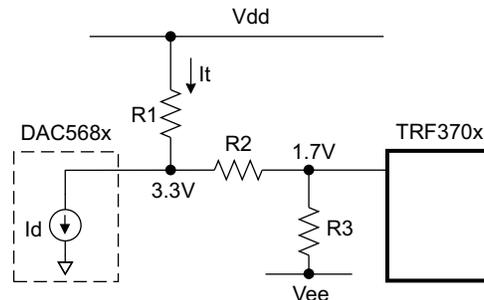


Topology 1: DAC Vcm > TRF370x Vcm
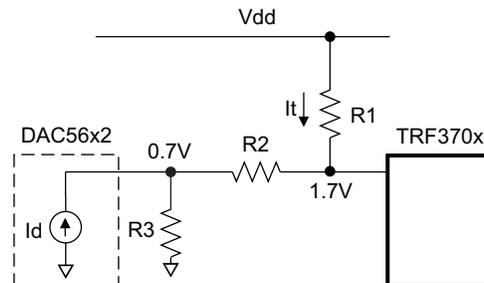
Topology 2: DAC Vcm < TRF370x Vcm

S0338-01

**Figure 45. Passive DAC-to-Modulator Interface Network**

**Table 2. DAC-to-Modulator Interface Network Values**

| | Topology 1 | | Topology 2 |
|---|---|---|---|
| | With Vee = 0 V | With Vee = –5 V | |
| **DAC Vcm [V]** | 3.3 | 3.3 | 0.7 |
| **TRF370x Vcm [V]** | 1.7 | 1.7 | 1.7 |
| **Vdd [V]** | 5 | 5 | 5 |
| **Vee [V]** | Gnd | –5 | N/A |
| **R1 [Ω]** | 66 | 56 | 960 |
| **R2 [Ω]** | 100 | 80 | 290 |
| **R3 [Ω]** | 108 | 336 | 52 |
| **Insertion loss [dB]** | 5.8 | 1.9 | 2.3 |

Product Folder Link(s): *TRF370317*

## DEFINITION OF SPECIFICATIONS

### Unadjusted Carrier Feedthrough

This specification measures the amount by which the local oscillator component is suppressed in the output spectrum of the modulator. If the common mode voltage at each of the baseband inputs is exactly the same and there was no dc imbalance introduced by the modulator, the LO component would be naturally suppressed. DC offset imbalances in the device allow some of the LO component to feed through to the output. Because this phenomenon is independent of the RF output power and the injected LO input power, the parameter is expressed in absolute power, dBm.

Some improvement to the unadjusted carrier suppression in a localized band is possible by introducing a simple RF filter in the baseband I/Q paths. The filter topology is a series resistor followed by a shunt capacitor. For example, using a series 50-Ω resistor ($R_2$, $R_3$, $R_4$, $R_5$ = 50 Ω) followed by a shunt 4.7-pF capacitor ($C10$, $C11$, $C12$, $C13$ = 4.7 pF) yields unadjusted carrier suppression improvement around the 2-GHz band. Figure 46 shows the performance improvement for that filter configuration.
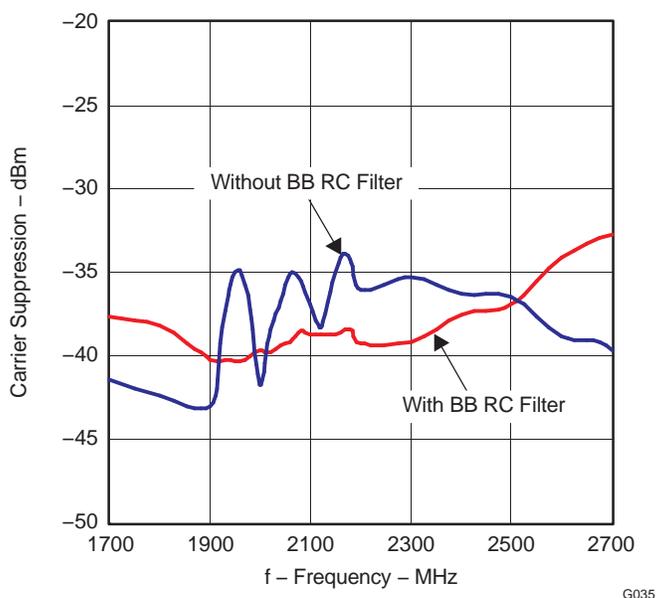


**Figure 46. Carrier Suppression Improvement With RC Filter**

### Adjusted (Optimized) Carrier Feedthrough

This differs from the unadjusted suppression number in that the baseband input dc offsets are iteratively adjusted around their theoretical value of VCM to yield the maximum suppression of the LO component in the output spectrum. This is measured in dBm.

### Unadjusted Sideband Suppression

This specification measures the amount by which the unwanted sideband of the input signal is suppressed in the output of the modulator, relative to the wanted sideband. If the amplitude and phase within the I and Q branch of the modulator were perfectly matched, the unwanted sideband (or image) would be naturally suppressed. Amplitude and phase imbalance in the I and Q branches results in the increase of the unwanted sideband. This parameter is measured in dBc relative to the desired sideband.

### Adjusted (Optimized) Sideband Suppression

This differs from the unadjusted sideband suppression in that the gain and phase of the baseband inputs are iteratively adjusted around their theoretical values to maximize the amount of sideband suppression. This is measured in dBc.

## Suppressions Over Temperature

This specification assumes that the user has gone though the optimization process for the suppression in question, and set the optimal settings for the I, Q inputs. This specification then measures the suppression when temperature conditions change after the initial calibration is done.

Figure 47 shows a simulated output and illustrates the respective definitions of various terms used in this data sheet.



$f_{BBn}$ = Baseband Frequency

fn = RF Frequency

$f_{3rdH/L}$ = 3$^{rd}$ Order Intermodulation Product Frequency (High Side/Low Side)

$f_{2ndH/L}$ = 2$^{nd}$ Order Intermodulation Product (High Side/Low Side)

LO = Local Oscillator Frequency

LSBn = Lower Sideband Frequency
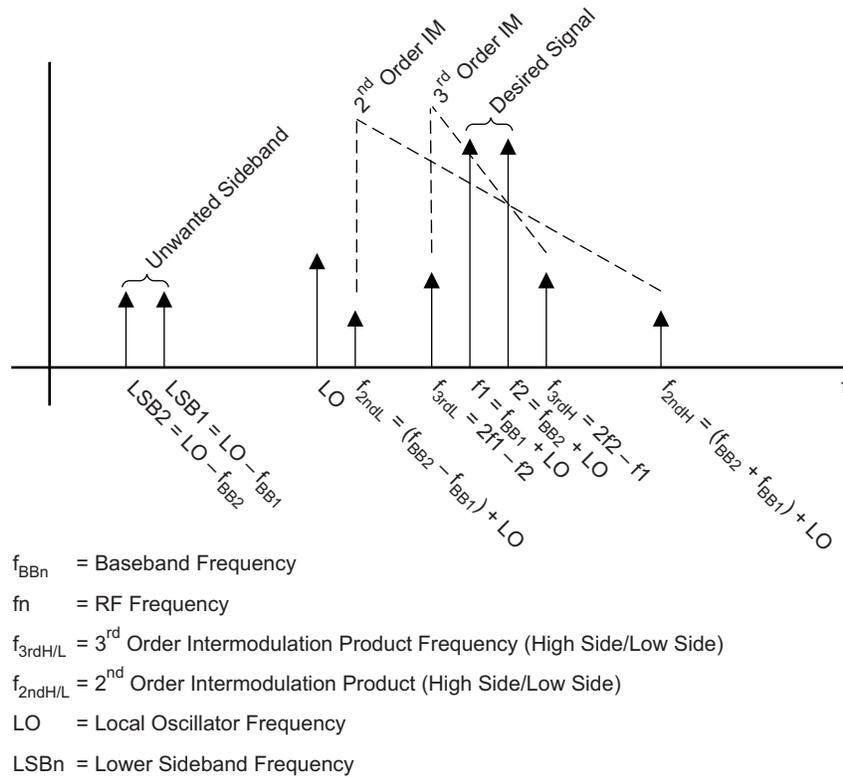
M0104-01

**Figure 47. Graphical Illustration of Common Terms**

Product Folder Link(s): *TRF370317*

# REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from Revision A (June, 2008) to Revision B**                                                          **Page**

- Added electrostatic discharge parameters to Absolute Maximum Ratings table ................................................................ 3
- Added *ESD Sensitivity* section ................................................................................................................. 18

**Changes from Original (March 2008) to Revision A**                                                             **Page**

- Added ACPR graph to Typical Characteristics based on customers' requests ...................................................... 16
- Added ACPR graph to Typical Characteristics based on customers' requests ................................................... 16

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TRF370317IRGER | ACTIVE | VQFN | RGE | 24 | 3000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TRF37 0317 | Samples |
| TRF370317IRGET | ACTIVE | VQFN | RGE | 24 | 250 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TRF37 0317 | Samples |

**(1)** The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

**(2)** **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

**(3)** MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

**(4)** There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

**(5)** Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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# PACKAGE MATERIALS INFORMATION

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

**TAPE DIMENSIONS**



| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |
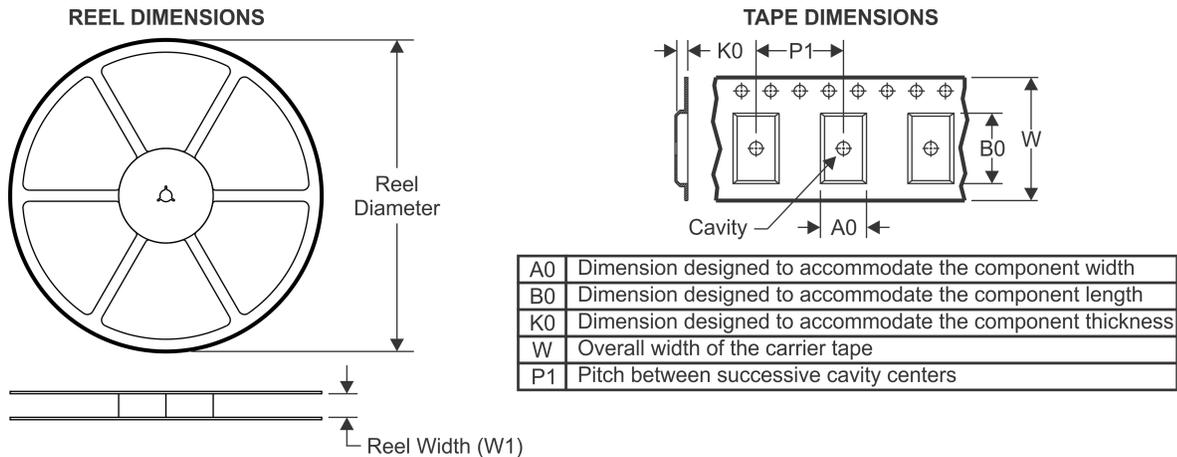
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**
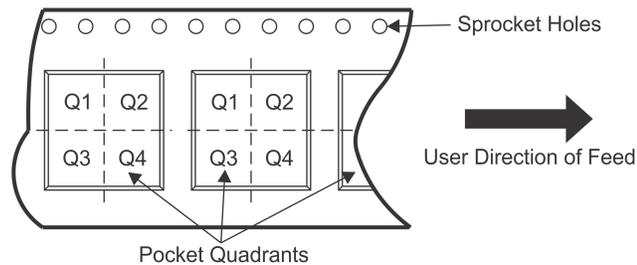


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRF370317IRGER | VQFN | RGE | 24 | 3000 | 330.0 | 12.4 | 4.3 | 4.3 | 1.5 | 8.0 | 12.0 | Q1 |
| TRF370317IRGET | VQFN | RGE | 24 | 250 | 330.0 | 12.4 | 4.3 | 4.3 | 1.5 | 8.0 | 12.0 | Q1 |

**TAPE AND REEL BOX DIMENSIONS**
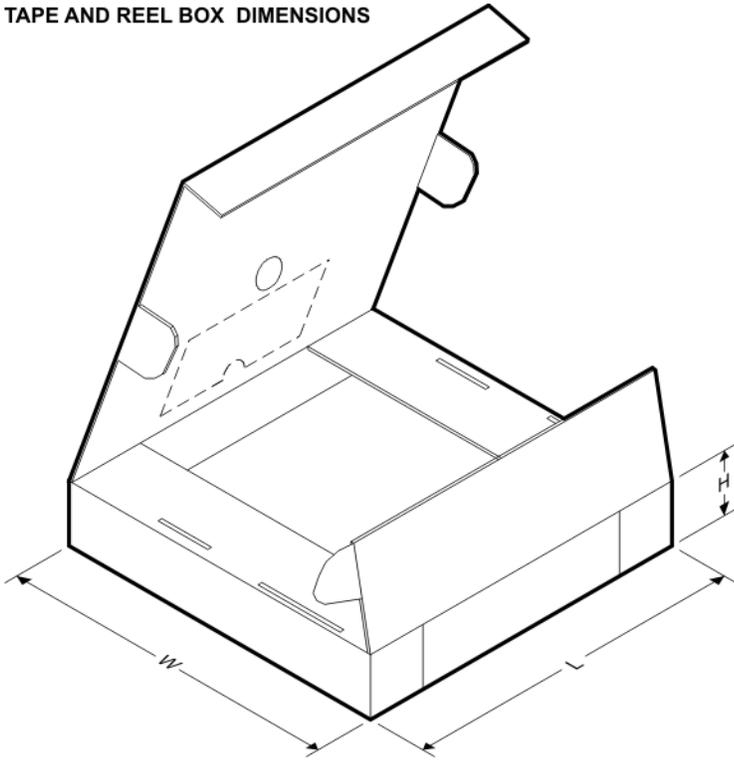


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------|--------------|-----------------|------|------|-------------|------------|-------------|
| TRF370317IRGER | VQFN | RGE | 24 | 3000 | 367.0 | 367.0 | 38.0 |
| TRF370317IRGET | VQFN | RGE | 24 | 250 | 367.0 | 367.0 | 38.0 |

# RGE 24

## VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD
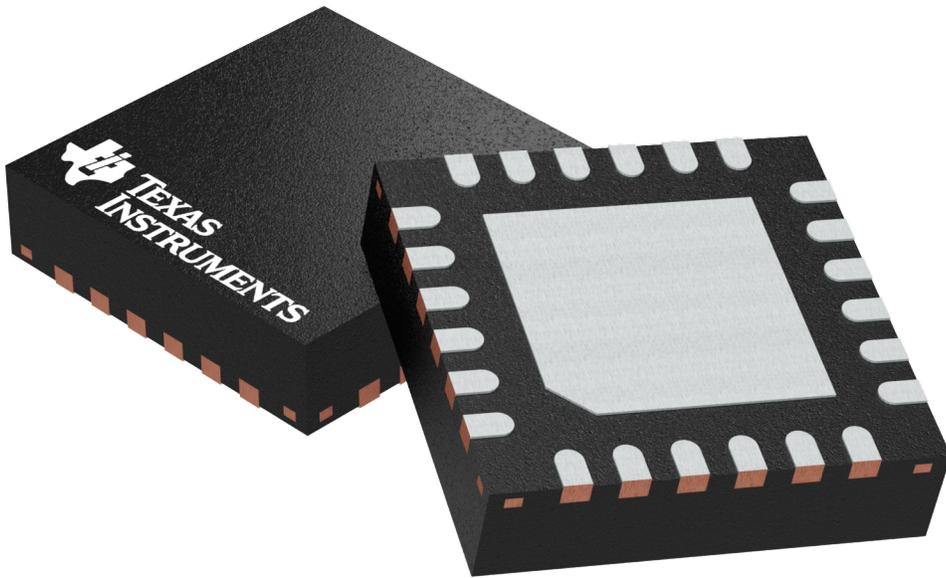


Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4204104/H

TEXAS
INSTRUMENTS

PIN 1 INDEX AREA

4.1
3.9

4.1
3.9

0.5
0.3

0.3
0.2

DETAIL
OPTIONAL TERMINAL
TYPICAL

1 MAX

0.05
0.00

C

SEATING PLANE

$\triangle$ 0.08 C

2X 2.5

$\square$ 2.45 ± 0.1

SEE TERMINAL
DETAIL

EXPOSED
THERMAL PAD

2X
2.5

SYMM
$\updownarrow$

20X 0.5

PIN 1 ID
(OPTIONAL)

SYMM
$\updownarrow$

24X 0.3
0.2

$\oplus$ | 0.1 Ⓜ | C A B
      | 0.05 Ⓜ |

24X 0.5
0.3

(0.2) TYP
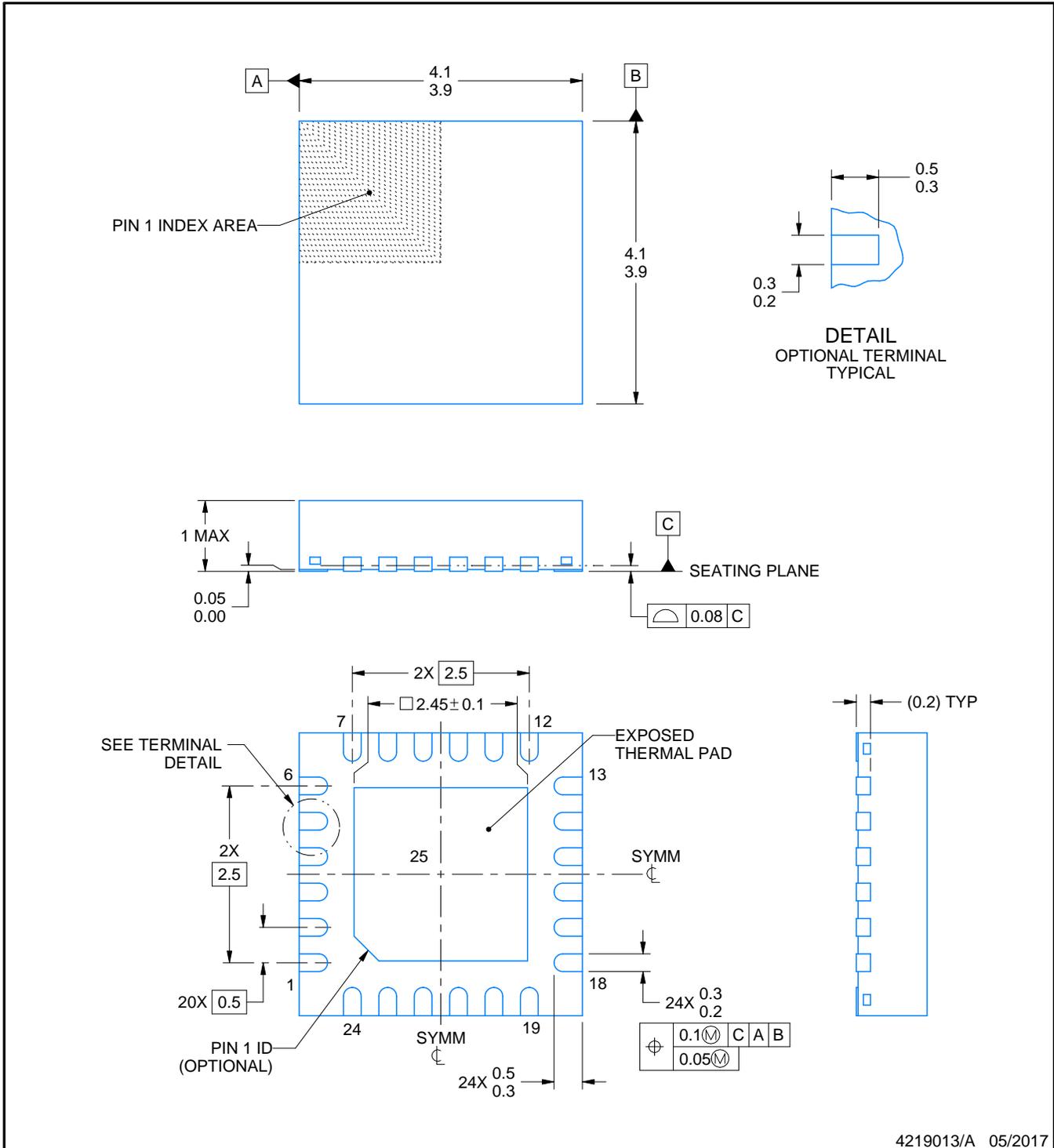
4219013/A   05/2017

NOTES:

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

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



NON SOLDER MASK
DEFINED
(PREFERRED)

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4219013/A   05/2017

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

## RGE0024B

4X (□ 1.08)

(0.64) TYP

24

19

24X (0.6)

1

25

18

24X (0.25)

(R0.05) TYP

SYMM
₵

(0.64)
TYP

(3.8)

20X (0.5)

6

13

METAL
TYP

7

12

SYMM
₵

(3.8)

**SOLDER PASTE EXAMPLE**
BASED ON 0.125 mm THICK STENCIL

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

4219013/A   05/2017

NOTES: (continued)

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

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