

50-MHz TO 6-GHz QUADRATURE MODULATOR

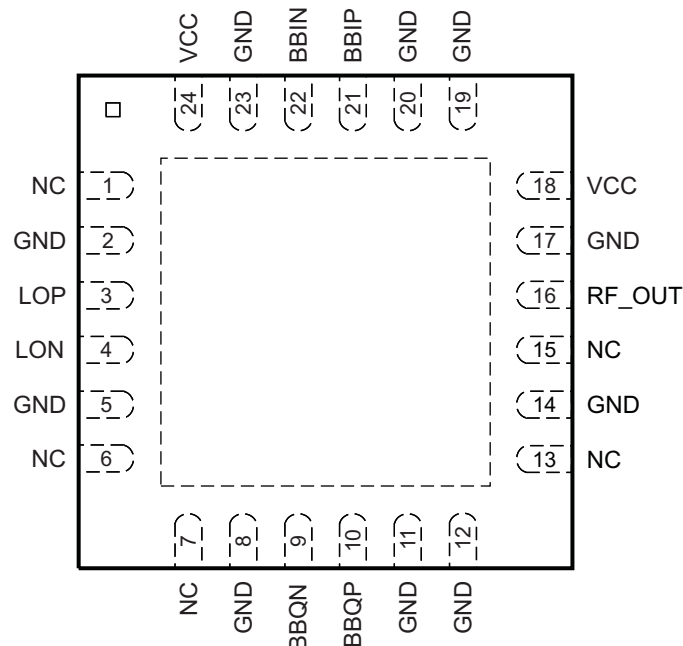
Check for Samples: [TRF370417](#)

FEATURES

- 76-dBc Single-Carrier WCDMA ACPR at –8 dBm Channel Power
- Low Noise Floor: –162.3 dBm/Hz at 2140 MHz
- OIP3 of 26.5 dBm at 2140 MHz
- P1dB of 12 dBm at 2140 MHz
- Carrier Feedthrough of –38 dBm at 2140 MHz
- Side-Band Suppression of –50 dBc at 2140 MHz
- 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
- Point-to-Point (P2P) Microwave
- Wideband Software-Defined Radio
- Public Safety: TETRA/APC025
- Communication-System Testers
- Cable Modem Termination System (CMTS)

**RGE PACKAGE
(TOP VIEW)**


P0024-04

DESCRIPTION

The TRF370417 is a low-noise direct quadrature modulator, capable of converting complex modulated signals from baseband or IF directly up to RF. The TRF370417 is a high-performance, superior-linearity device that operates at RF frequencies of 50 MHz through 6 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 TRF370417 requires a 1.7-V common-mode voltage for optimum linearity performance.



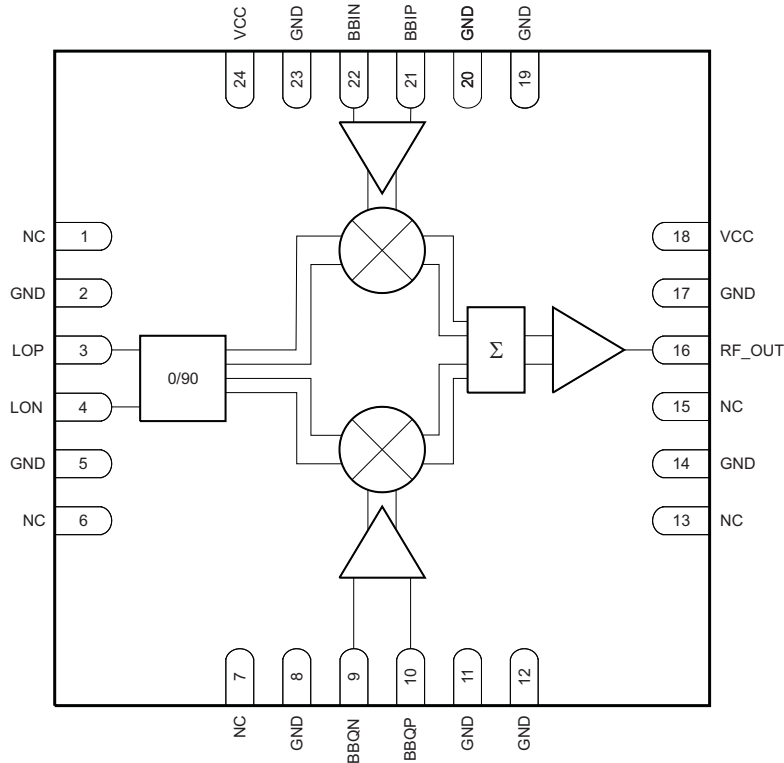
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



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

DEVICE INFORMATION

TERMINAL FUNCTIONS

| TERMINAL | | I/O | DESCRIPTION |
|----------|-------------------------------------|-----|---------------------------------|
| NAME | NO. | | |
| 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 Rating | HBM | 75 | V |
| ESD Rating | 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 _{θJA} | Thermal resistance, junction-to-ambient High-K board, still air | 29.4 | °C/W |
| R _{θJC} | Thermal resistance, junction-to-case | 18.6 | °C/W |
| R _{θJB} | Thermal resistance, junction-to-board | 14 | °C/W |

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 | 0.05 | | 6 | 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 | | 1 | | GHz |
| Z _{I(single ended)} | Input impedance, resistance | | 5 | | kΩ |
| | Input impedance, parallel capacitance | | 3 | | pF |

RF OUTPUT PARAMETERS

over recommended operating conditions, power supply = 5 V, $T_A = 25^\circ\text{C}$, $V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended in quadrature, $f_{BB} = 50\text{ kHz}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--------------------------|---|-----|--------|-----|--------|
| $f_{LO} = 70\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | -8 | | dB |
| P1dB | Output compression point | | | 7.3 | | dBm |
| IP3 | Output IP3 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 22 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 69 | | dBm |
| | Carrier feedthrough | Unadjusted | | -46 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -27.5 | | dBc |
| $f_{LO} = 400\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 24.5 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 68 | | dBm |
| | Carrier feedthrough | Unadjusted | | -38 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -40 | | dBc |
| $f_{LO} = 945.6\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 25 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 65 | | dBm |
| | Carrier feedthrough | Unadjusted | | -40 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -42 | | dBc |
| | Output return loss | | | 9 | | dB |
| | Output noise floor | $\geq 13\text{ MHz offset from } f_{LO}; P_{out} = -5\text{ dBm}$ | | -161.2 | | dBm/Hz |
| $f_{LO} = 1800\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 26 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}; P_{out} = -8\text{ dBm per tone}$ | | 60 | | dBm |
| | Carrier feedthrough | Unadjusted | | -40 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -50 | | dBc |
| | Output return loss | | | 8 | | dB |
| | Output noise floor | $\geq 13\text{ MHz offset from } f_{LO}; P_{out} = -5\text{ dBm}$ | | -161.5 | | dBm/Hz |

RF OUTPUT PARAMETERS (continued)

over recommended operating conditions, power supply = 5 V, $T_A = 25^\circ\text{C}$, $V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended in quadrature, $f_{BB} = 50\text{ kHz}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|-------------------------------|--|-----|--------|-----|--------|
| $f_{LO} = 1960\text{ MHz}$ at 8 dBm | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}$; $P_{out} = -8\text{ dBm}$ per tone | | 26.5 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}$; $P_{out} = -8\text{ dBm}$ per tone | | 60 | | dBm |
| | Carrier feedthrough | Unadjusted | | -38 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -50 | | dBc |
| | Output return loss | | | 8 | | dB |
| | Output noise floor | $\geq 13\text{ MHz}$ offset from f_{LO} ; $P_{out} = -5\text{ dBm}$ | | -162 | | dBm/Hz |
| EVM | Error vector magnitude (rms) | 1 EDGE signal, $P_{out} = -5\text{ dBm}$ ⁽¹⁾ | | 0.43% | | |
| ACPR | Adjacent-channel power ratio | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽²⁾ | | -76 | | dBc |
| | | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽³⁾ | | -74 | | |
| | | 2 WCDMA signals; $P_{out} = -11\text{ dBm}$ per carrier ⁽³⁾ | | -68 | | |
| | | 4 WCDMA signals; $P_{out} = -14\text{ dBm}$ per carrier ⁽³⁾ | | -67 | | |
| | Alternate-channel power ratio | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽²⁾ | | -80 | | dBc |
| | | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽³⁾ | | -78 | | |
| | | 2 WCDMA signals; $P_{out} = -11\text{ dBm}$ per carrier ⁽³⁾ | | -72 | | |
| | | 4 WCDMA signals; $P_{out} = -14\text{ dBm}$ per carrier ⁽³⁾ | | -69 | | |
| $f_{LO} = 2140\text{ MHz}$ at 8 dBm | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}$; $P_{out} = -8\text{ dBm}$ per tone | | 26.5 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}$; $P_{out} = -8\text{ dBm}$ per tone | | 66 | | dBm |
| | Carrier feedthrough | Unadjusted | | -38 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -50 | | dBc |
| | Output return loss | | | 8.5 | | dB |
| | Output noise floor | $\geq 13\text{ MHz}$ offset from f_{LO} ; $P_{out} = -5\text{ dBm}$ | | -162.3 | | dBm/Hz |
| ACPR | Adjacent-channel power ratio | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽²⁾ | | -76 | | dBc |
| | | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽³⁾ | | -72 | | |
| | | 2 WCDMA signals; $P_{out} = -11\text{ dBm}$ per carrier ⁽³⁾ | | -67 | | |
| | | 4 WCDMA signals; $P_{out} = -14\text{ dBm}$ per carrier ⁽³⁾ | | -66 | | |
| | Alternate-channel power ratio | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽²⁾ | | -80 | | dBc |
| | | 1 WCDMA signal; $P_{out} = -8\text{ dBm}$ ⁽³⁾ | | -78 | | |
| | | 2 WCDMA signals; $P_{out} = -11\text{ dBm}$ ⁽³⁾ | | -74 | | |
| | | 4 WCDMA signals; $P_{out} = -14\text{ dBm}$ per carrier ⁽³⁾ | | -68 | | |

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

(2) Measured with DAC5687 as source generator; with 2.5 MHz LPF.

(3) Measured with DAC5687 as source generator; no external BB filters are used.

RF OUTPUT PARAMETERS (continued)

over recommended operating conditions, power supply = 5 V, $T_A = 25^\circ\text{C}$, $V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended in quadrature, $f_{BB} = 50\text{ kHz}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|------------------------------|---|-----|------|-----|------|
| $f_{LO} = 2500\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}$; $P_{out} = -8\text{ dBm}$ per tone | | 29 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}$; $P_{out} = -8\text{ dBm}$ per tone | | 65 | | dBm |
| | Carrier feedthrough | Unadjusted | | -37 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -47 | | dBc |
| EVM | Error vector magnitude (rms) | WiMAX 5-MHz carrier, $P_{out} = -8\text{ dBm}^{(4)}$ | | -47 | | dB |
| | | WiMAX 5-MHz carrier, $P_{out} = 0\text{ dBm}^{(4)}$ | | -45 | | dB |
| $f_{LO} = 3500\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}$ | | 25 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}$ | | 65 | | dBm |
| | Carrier feedthrough | Unadjusted | | -35 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -36 | | dBc |
| EVM | Error vector magnitude (rms) | WiMAX 5-MHz carrier, $P_{out} = -8\text{ dBm}^{(4)}$ | | -47 | | dB |
| | | WiMAX 5-MHz carrier, $P_{out} = 0\text{ dBm}^{(4)}$ | | -43 | | dB |
| $f_{LO} = 4000\text{ MHz at } 8\text{ dBm}$ | | | | | | |
| 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 | $f_{BB} = 4.5, 5.5\text{ MHz}$ | | 22.5 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}$ | | 60 | | dBm |
| | Carrier feedthrough | Unadjusted | | -36 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -36 | | dBc |
| $f_{LO} = 5800\text{ MHz at } 4\text{ dBm}$ | | | | | | |
| G | Voltage gain | Output rms voltage over input I (or Q) rms voltage | | -5.5 | | dB |
| P1dB | Output compression point | | | 12.9 | | dBm |
| IP3 | Output IP3 | $f_{BB} = 4.5, 5.5\text{ MHz}$ | | 25 | | dBm |
| IP2 | Output IP2 | $f_{BB} = 4.5, 5.5\text{ MHz}$ | | 55 | | dBm |
| | Carrier feedthrough | Unadjusted | | -31 | | dBm |
| | Sideband suppression | Unadjusted; $f_{BB} = 4.5, 5.5\text{ MHz}$ | | -36 | | dBc |
| EVM | Error-vector magnitude | WiMAX 5-MHz carrier, $P_{out} = -12\text{ dBm}^{(4)}$ | | -40 | | dB |

(4) Sideband suppression optimized with LO drive level; EVM contribution from instrument is not accounted for.

TYPICAL CHARACTERISTICS

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

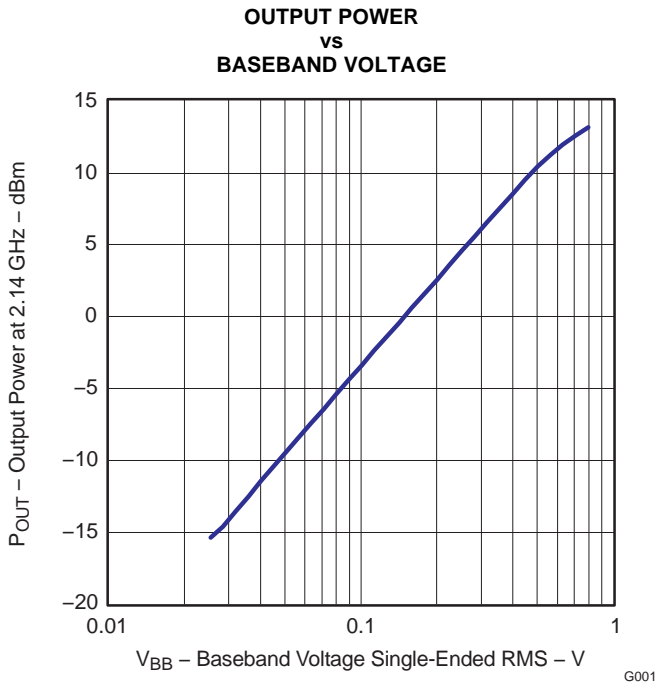


Figure 1.

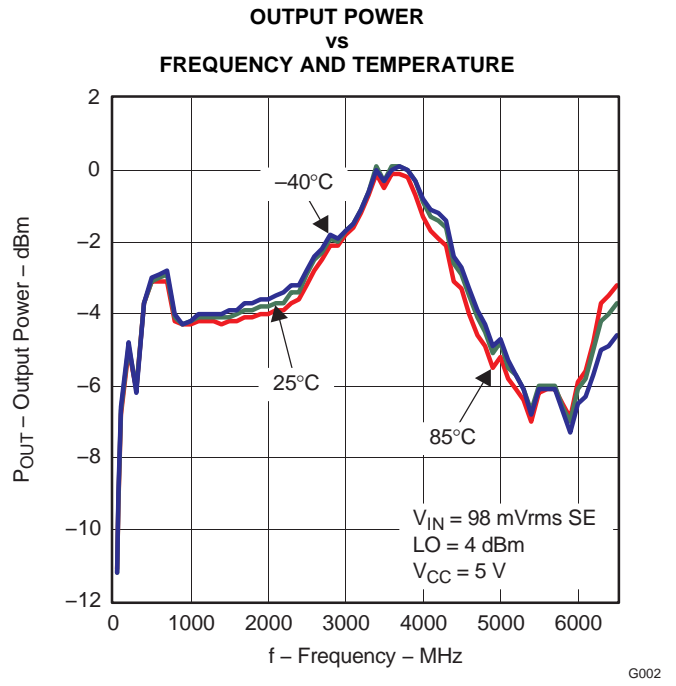


Figure 2.

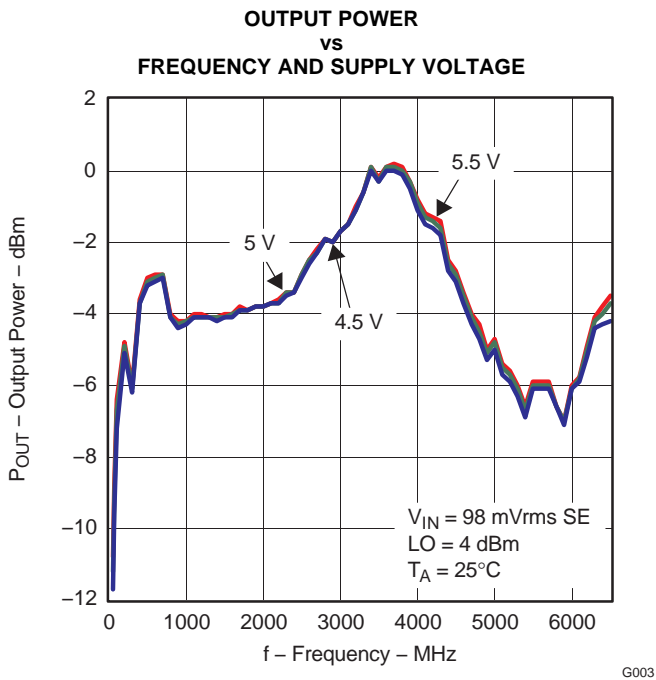


Figure 3.

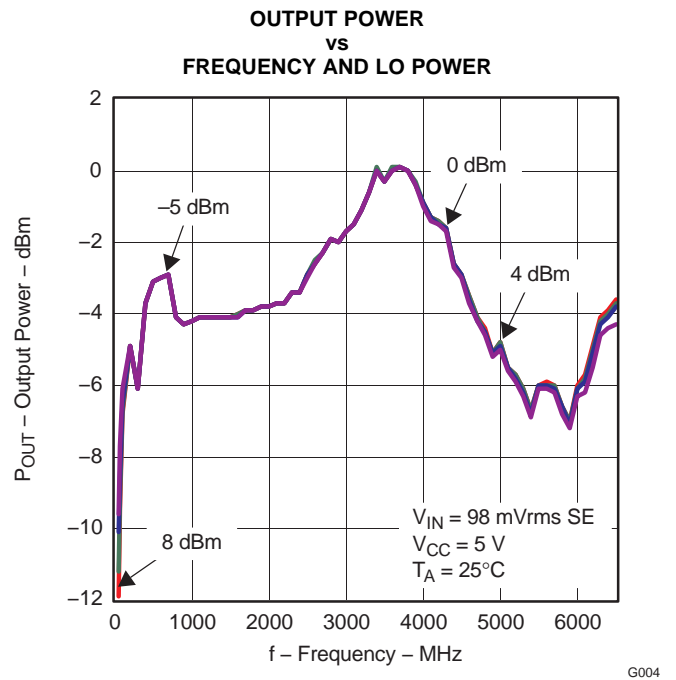


Figure 4.

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

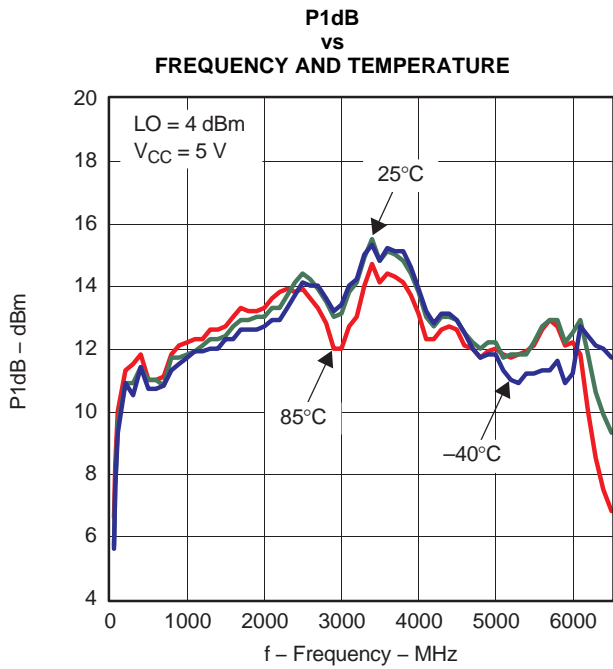


Figure 5.

G005

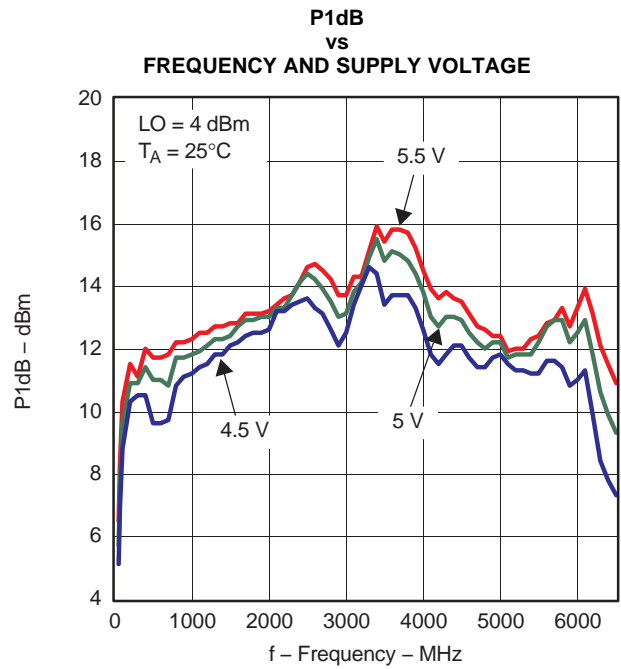


Figure 6.

G006

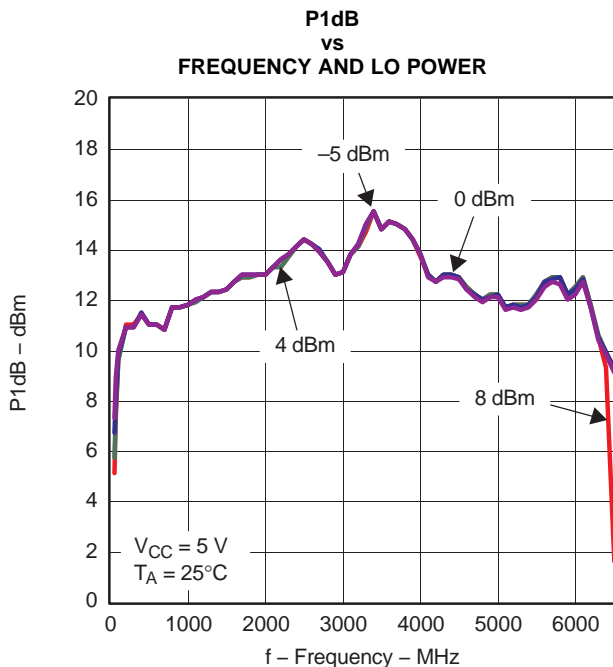


Figure 7.

G007

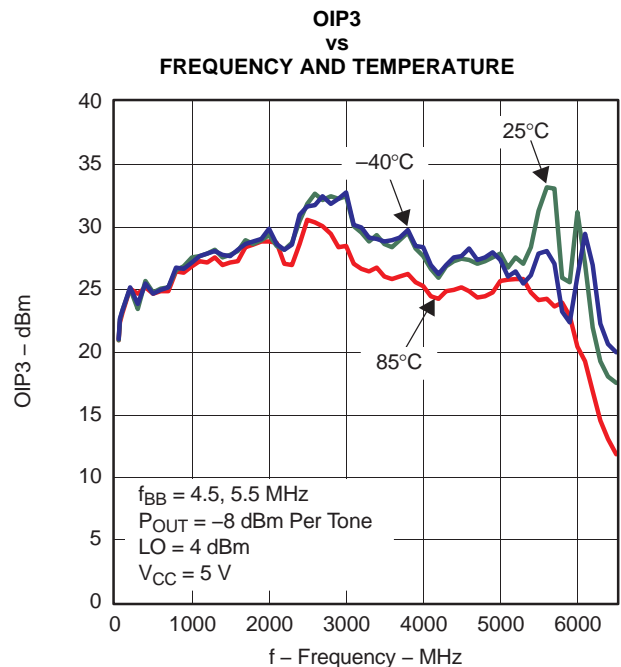


Figure 8.

G008

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

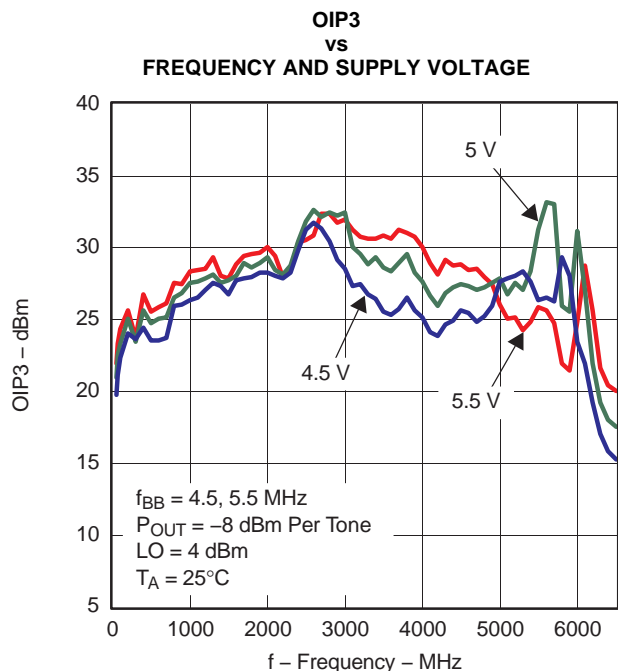


Figure 9.

G009

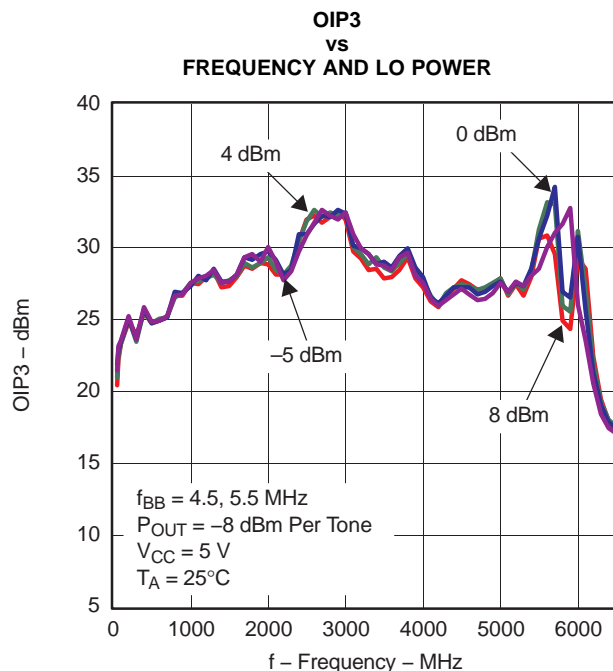


Figure 10.

G010

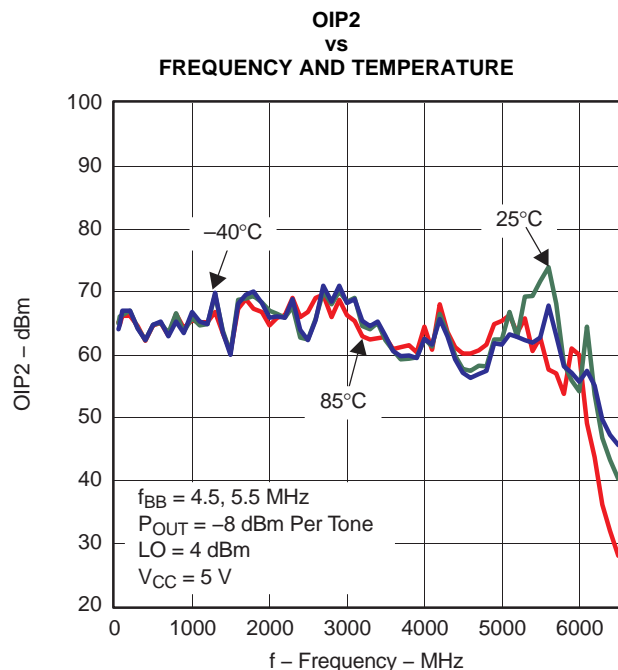


Figure 11.

G011

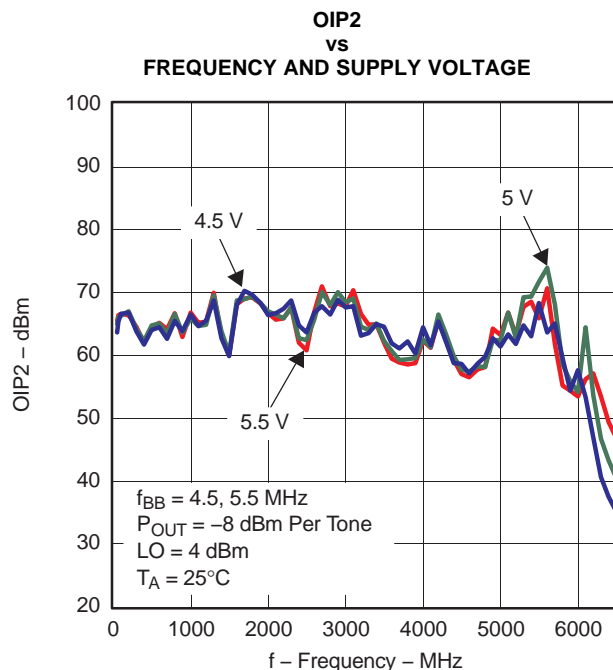


Figure 12.

G012

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

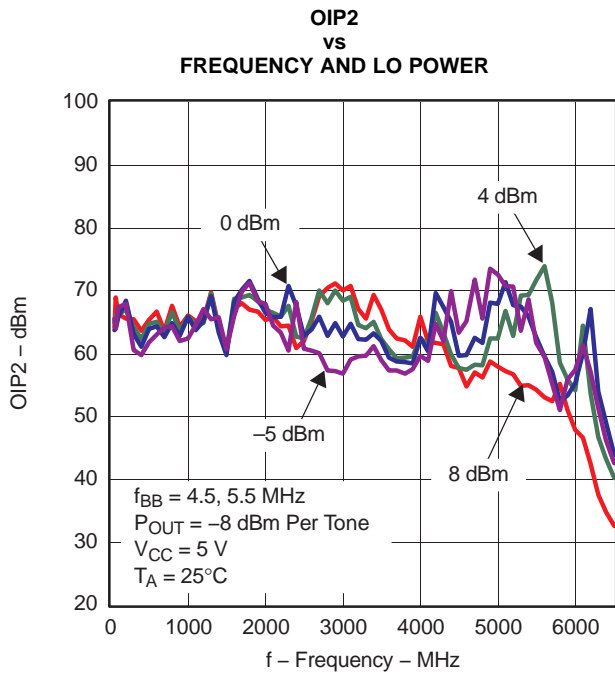


Figure 13.

G013

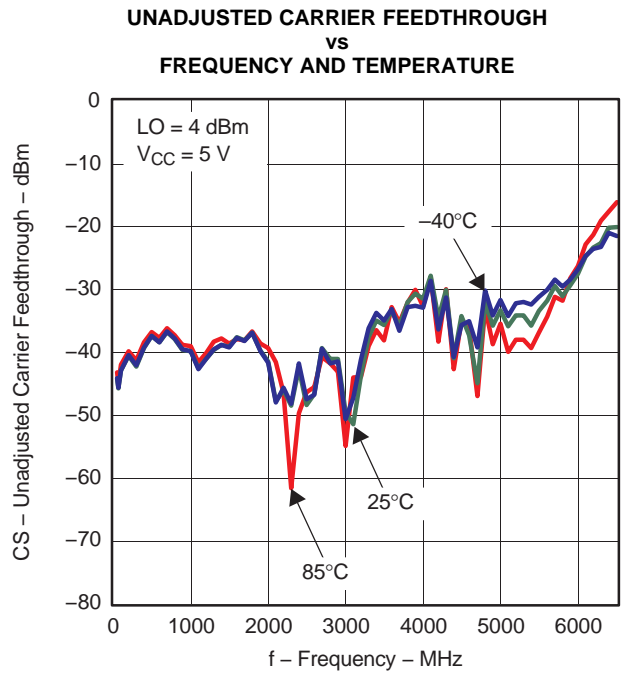


Figure 14.

G014

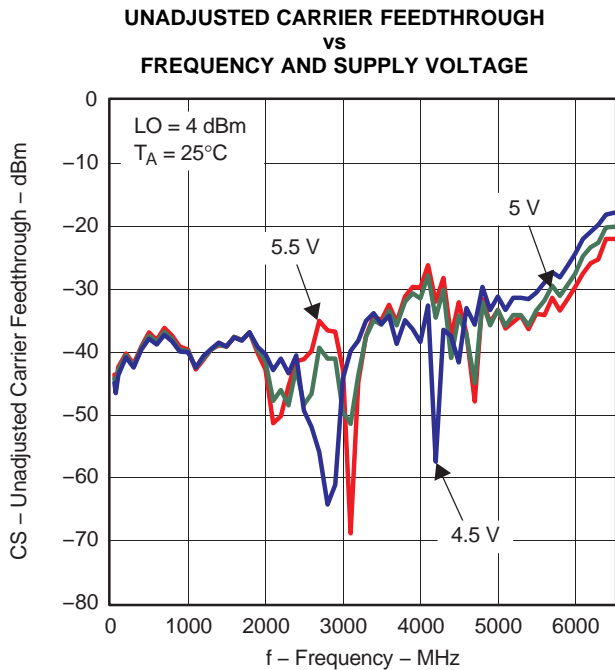


Figure 15.

G015

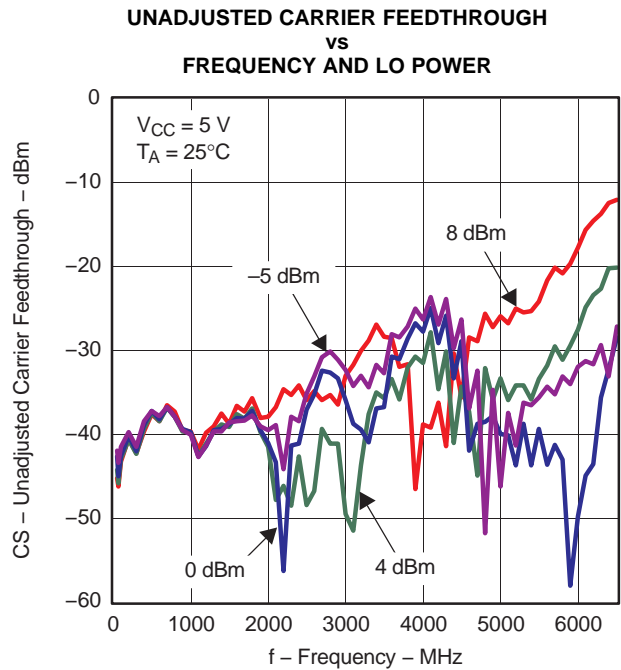


Figure 16.

G016

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

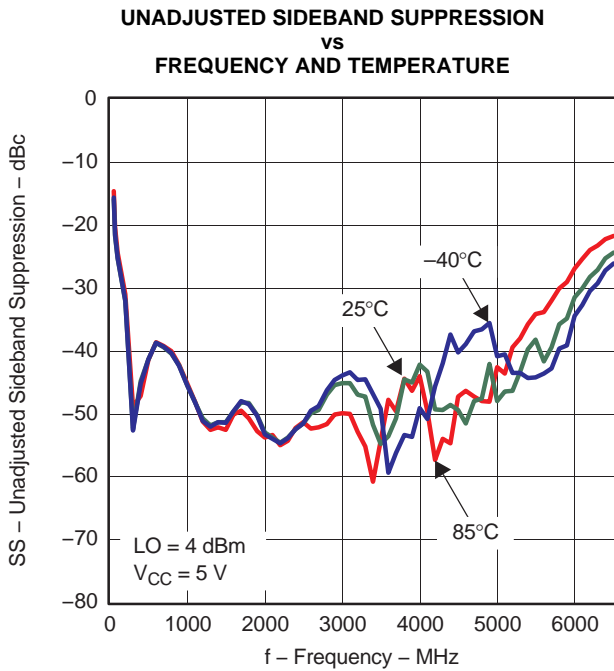


Figure 17.

G017

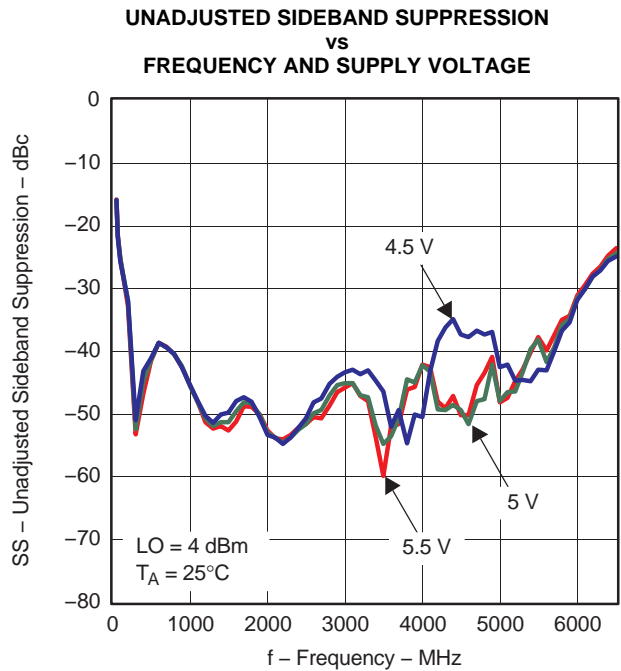


Figure 18.

G018

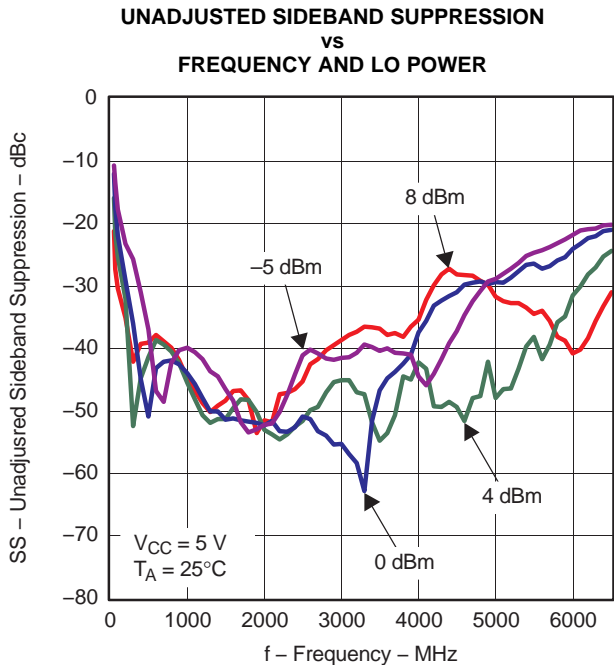


Figure 19.

G019

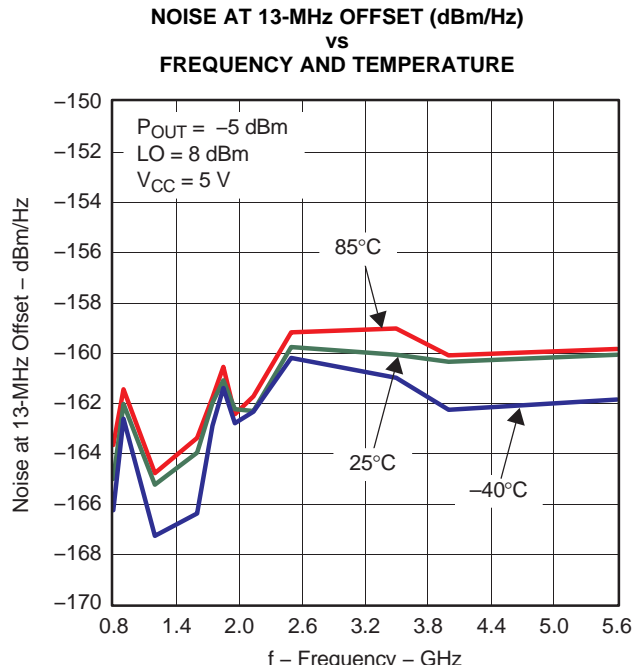


Figure 20.

G020

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

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

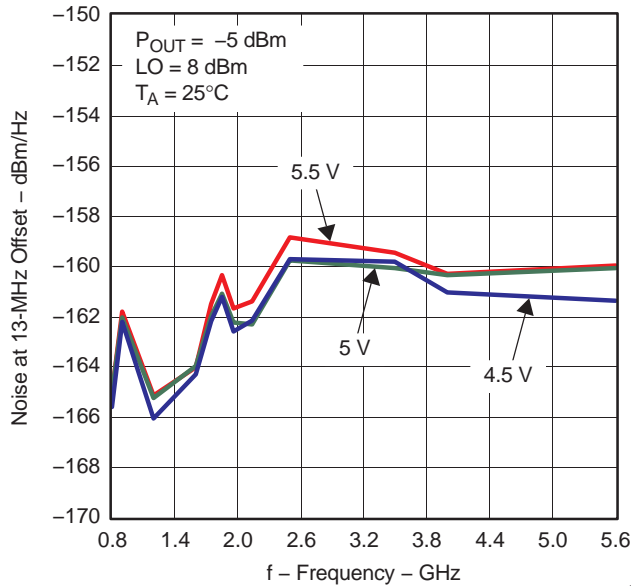


Figure 21.

G021

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

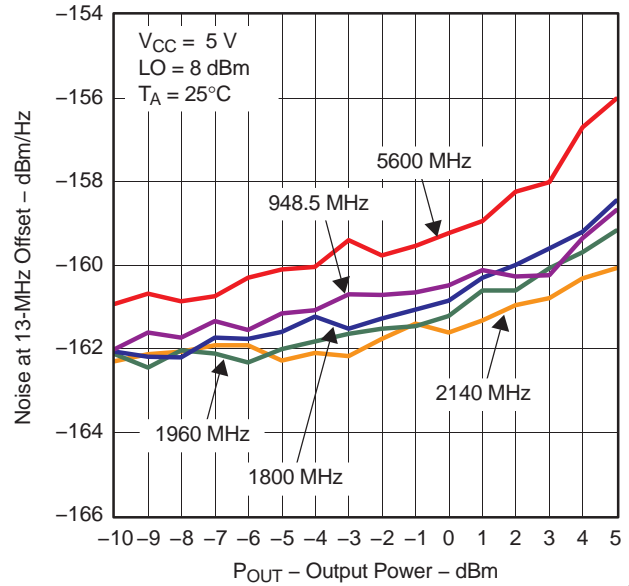


Figure 22.

G022

ADJUSTED CARRIER FEEDTHROUGH
vs
FREQUENCY AND TEMPERATURE

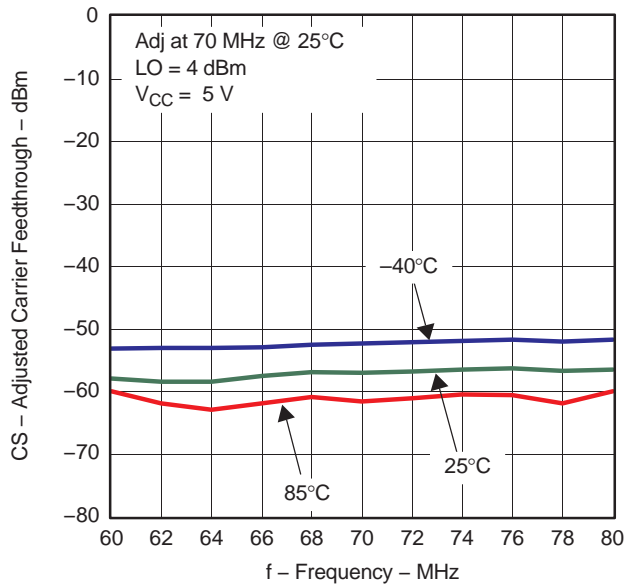


Figure 23.

G023

ADJUSTED CARRIER FEEDTHROUGH
vs
FREQUENCY AND TEMPERATURE

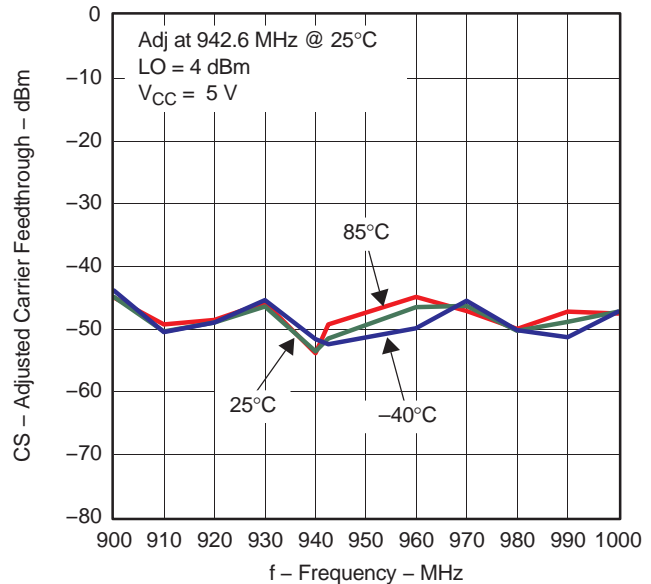


Figure 24.

G024

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

**ADJUSTED CARRIER FEEDTHROUGH
vs
FREQUENCY AND TEMPERATURE**

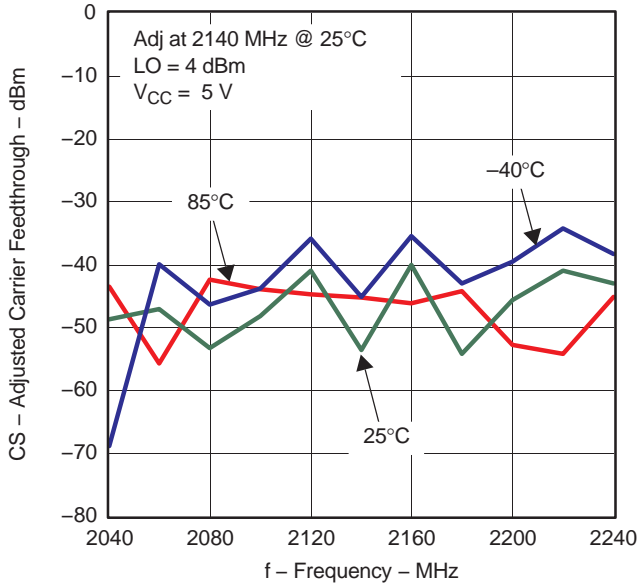


Figure 25.

**ADJUSTED CARRIER FEEDTHROUGH
vs
FREQUENCY AND TEMPERATURE**

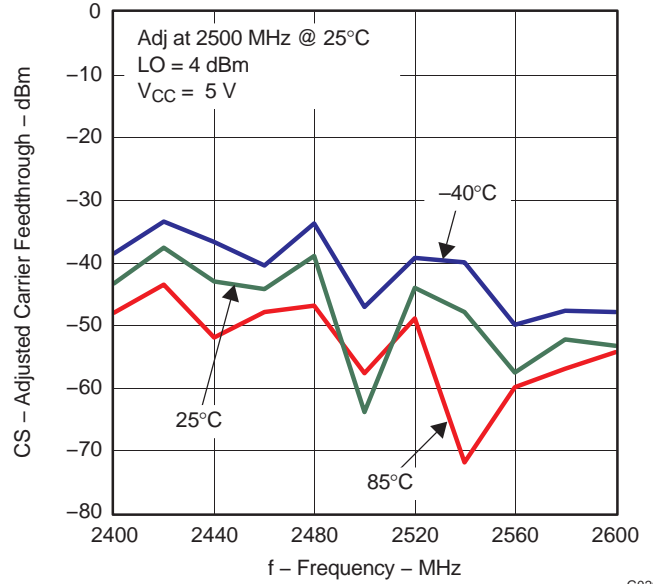


Figure 26.

**ADJUSTED CARRIER FEEDTHROUGH
vs
FREQUENCY AND TEMPERATURE**

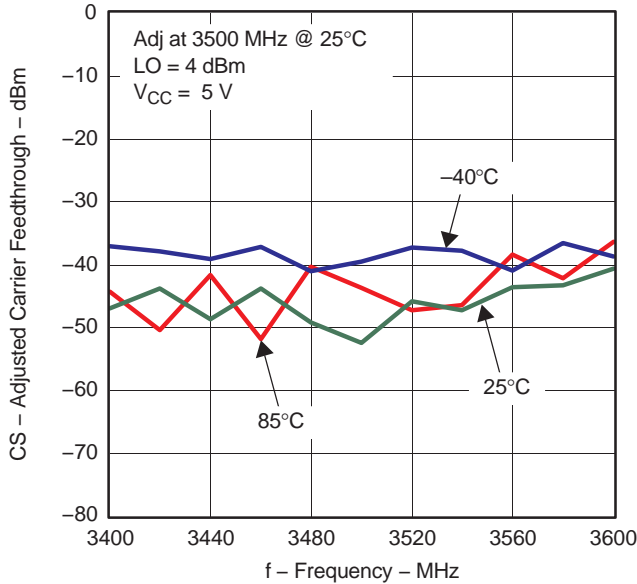


Figure 27.

**ADJUSTED CARRIER FEEDTHROUGH
vs
FREQUENCY AND TEMPERATURE**

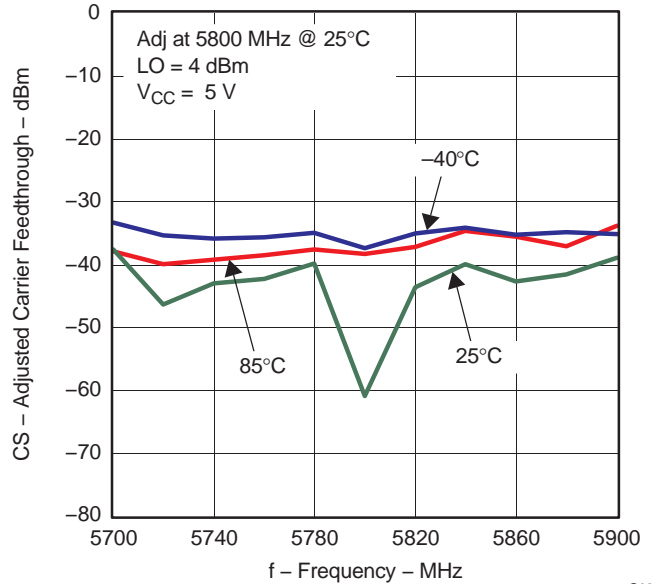


Figure 28.

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

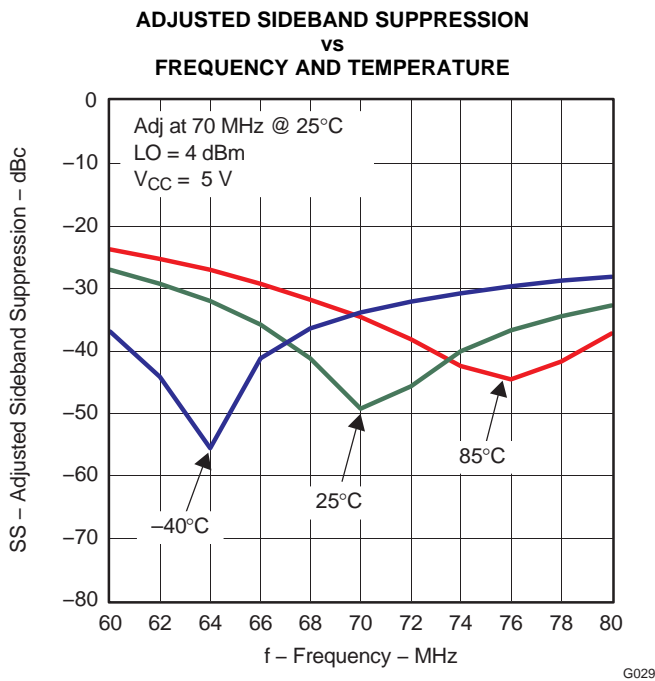


Figure 29.

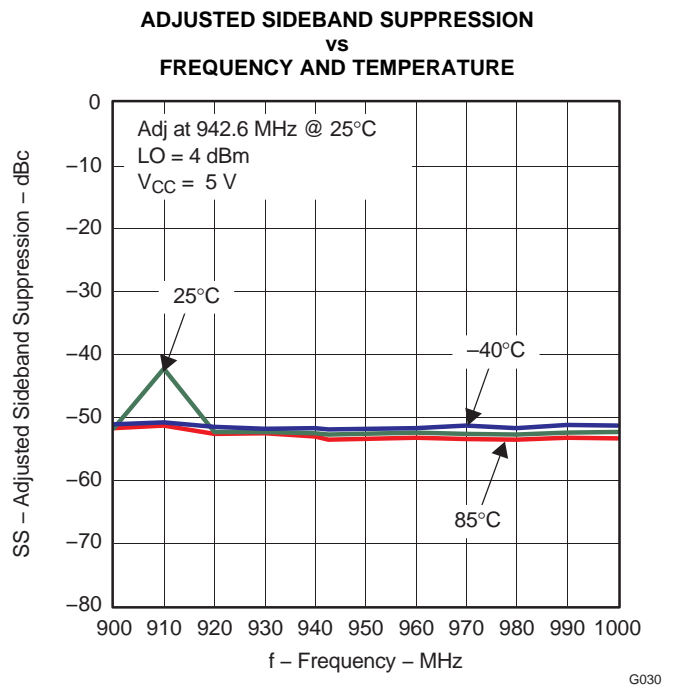


Figure 30.

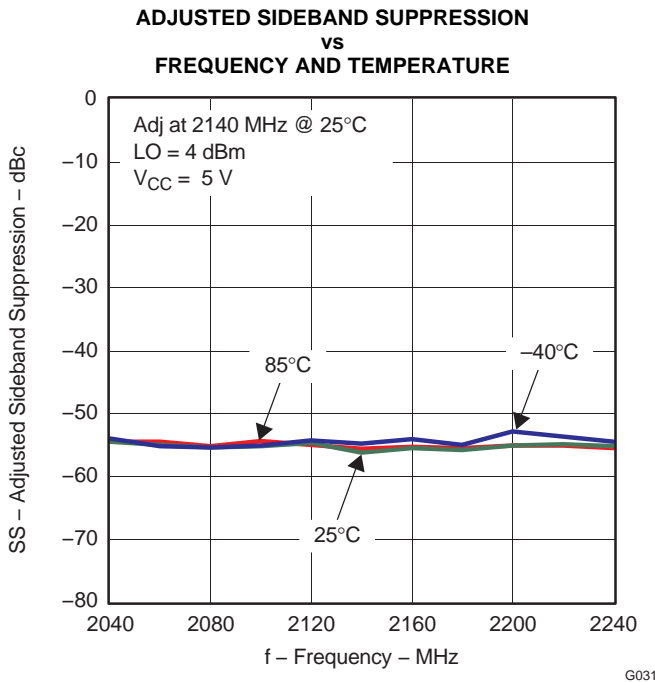


Figure 31.

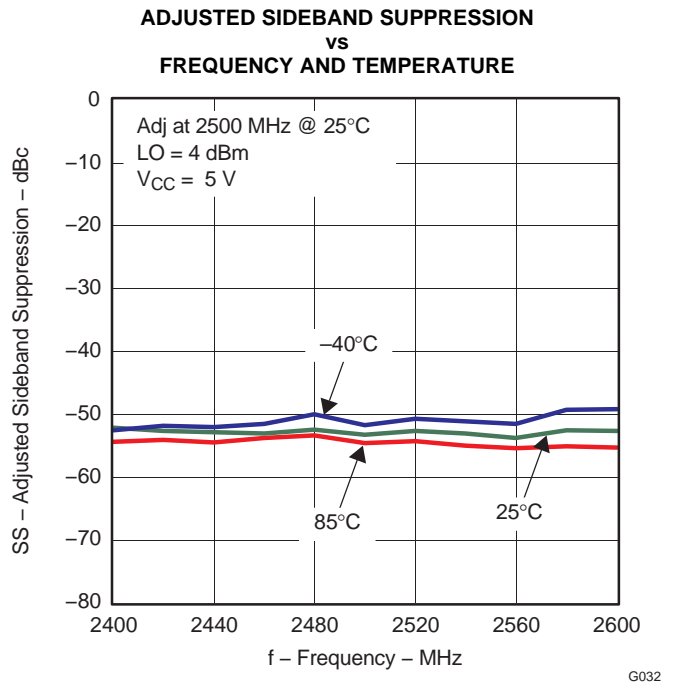


Figure 32.

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

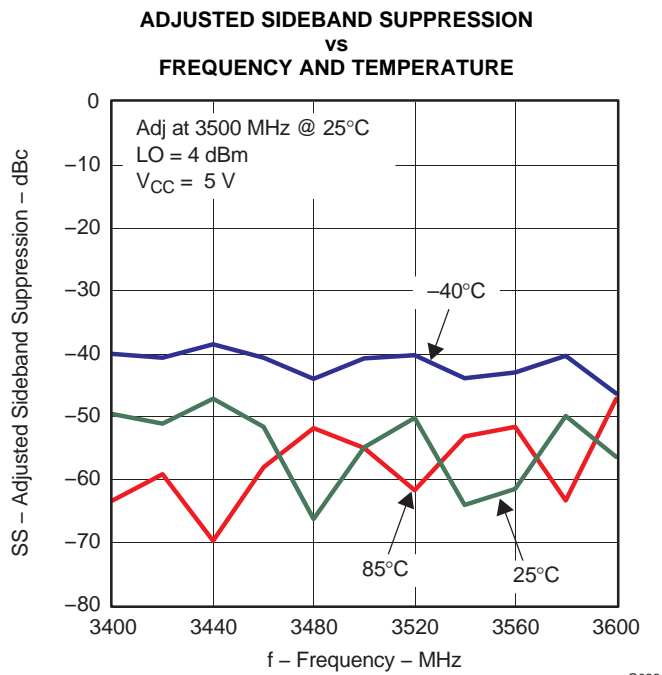


Figure 33.

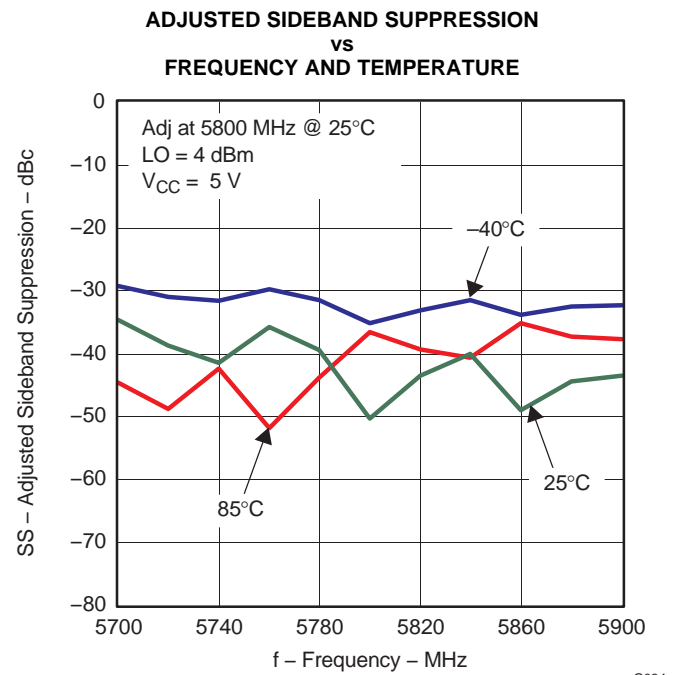


Figure 34.

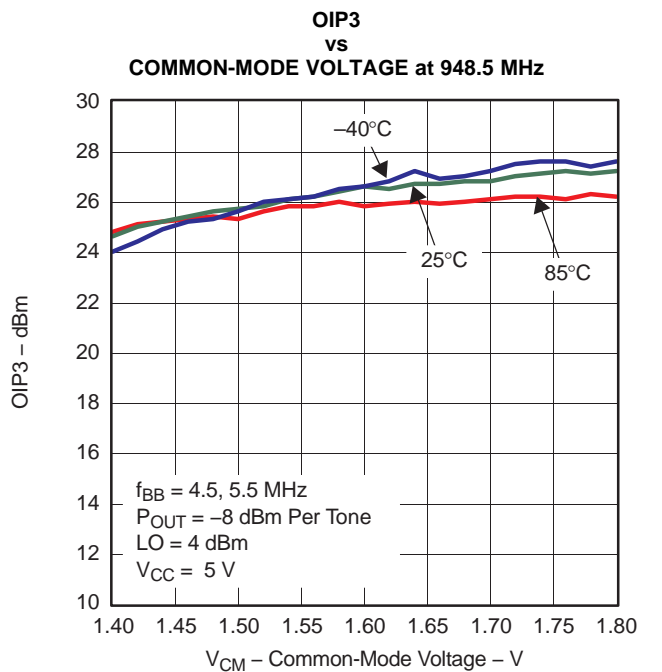


Figure 35.

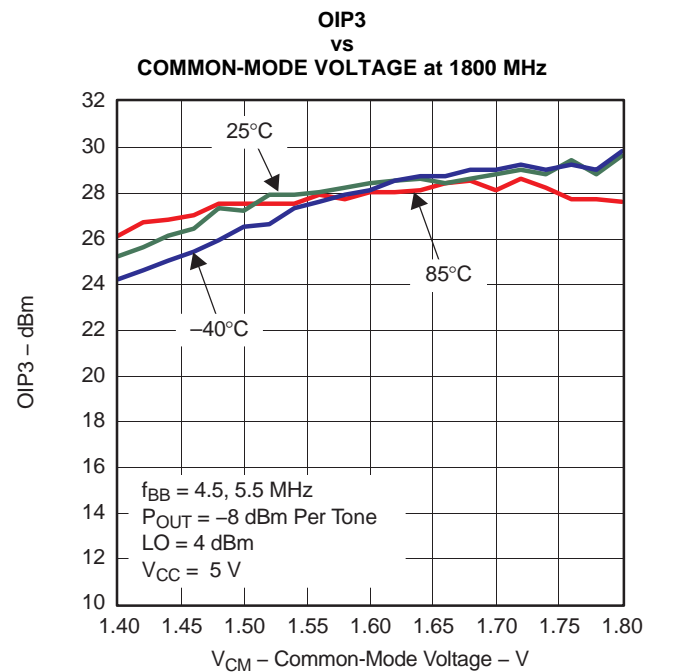


Figure 36.

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

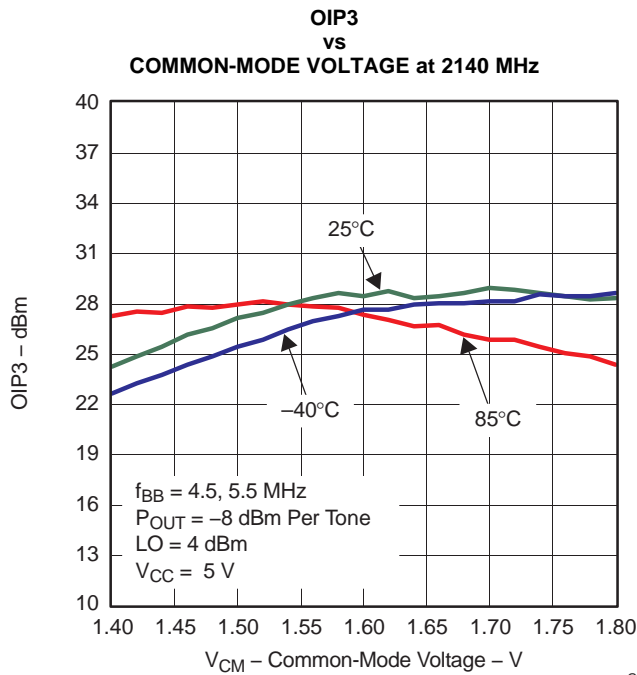


Figure 37.

G037

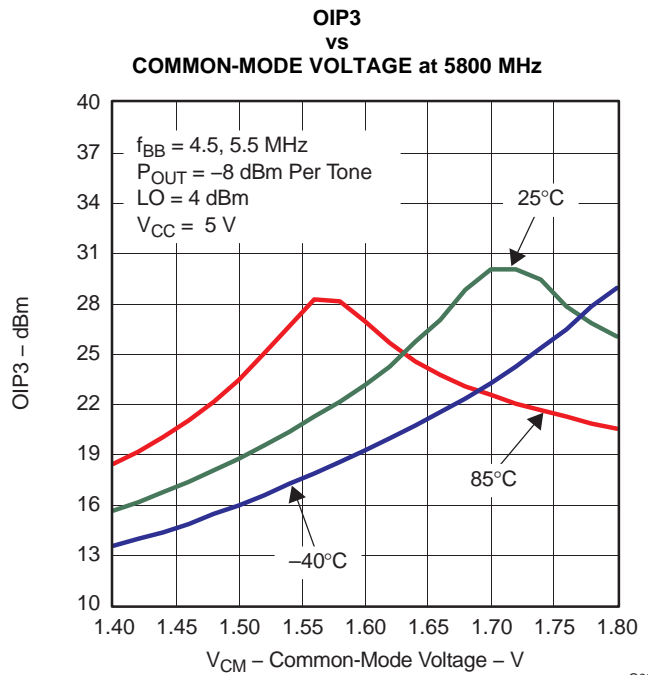


Figure 38.

G038

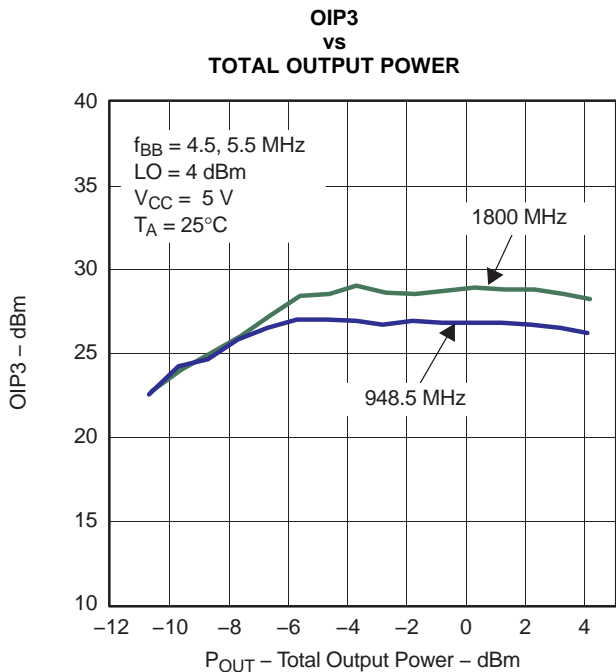


Figure 39.

G039

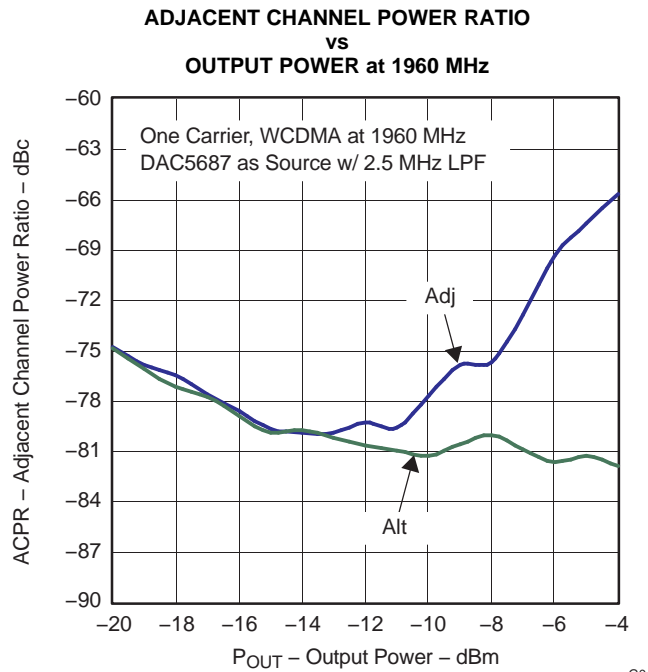


Figure 40.

G040

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

**ADJACENT CHANNEL POWER RATIO
vs
OUTPUT POWER at 2140 MHz**

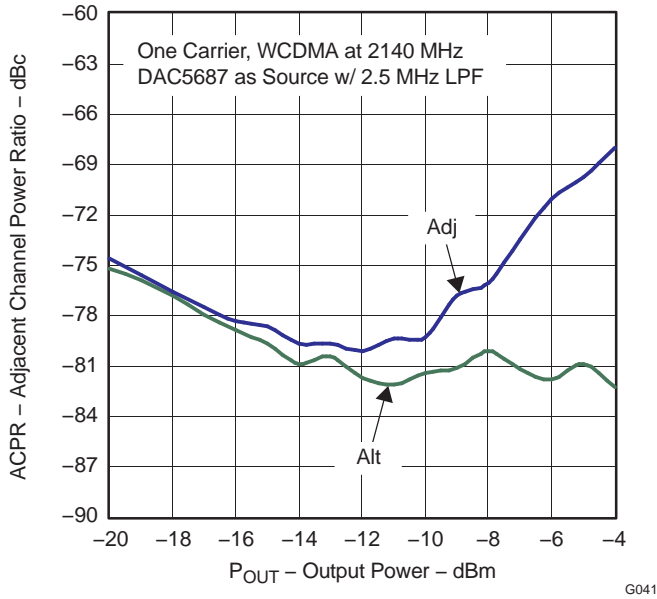


Figure 41.

G041

OIP3 at 1960 MHz DISTRIBUTION

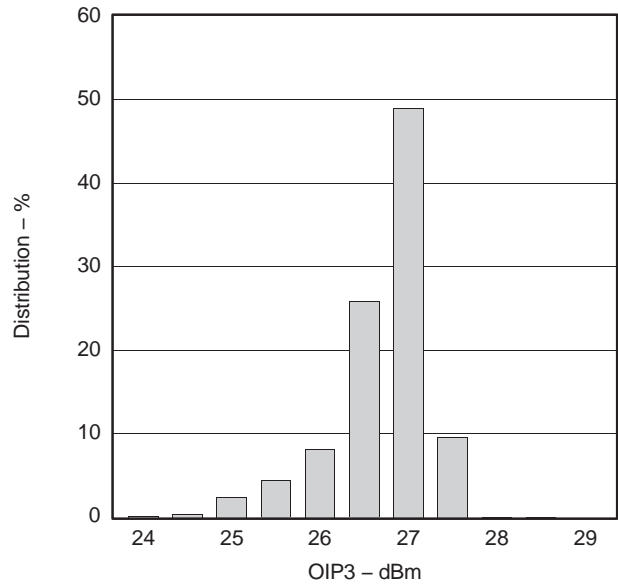


Figure 42.

G042

OIP2 at 1960 MHz DISTRIBUTION

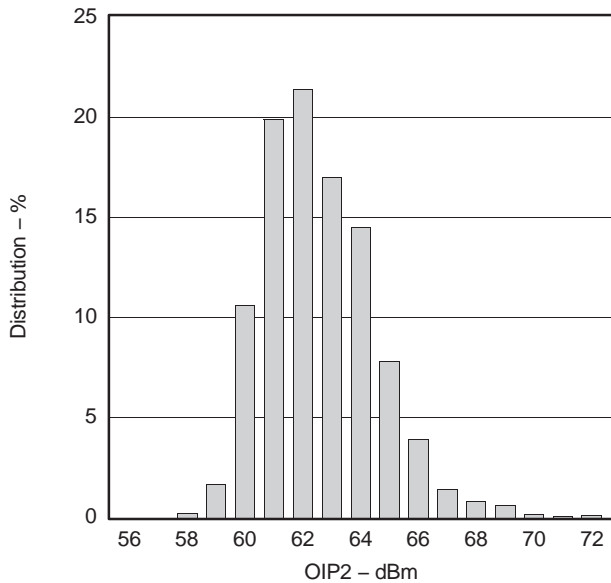


Figure 43.

G043

**UNADJUSTED CARRIER FEEDTHROUGH
at 1960 MHz DISTRIBUTION**

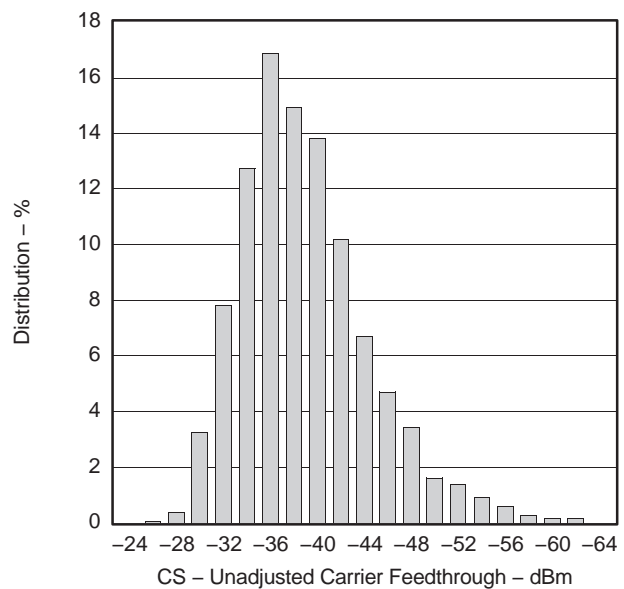


Figure 44.

G044

TYPICAL CHARACTERISTICS (continued)

$V_{CM} = 1.7\text{ V}$, $V_{inBB} = 98\text{ mVrms}$ single-ended sine wave in quadrature, $V_{CC} = 5\text{ V}$, LO power = 4 dBm (single-ended), $f_{BB} = 50\text{ kHz}$ (unless otherwise noted).

**UNADJUSTED SIDEBAND SUPPRESSION
at 1960 MHz DISTRIBUTION**

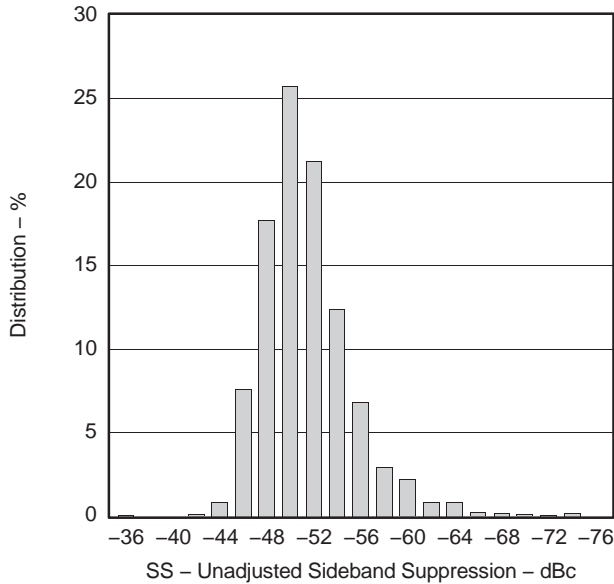


Figure 45.

G045

P1dB at 1800 MHz DISTRIBUTION

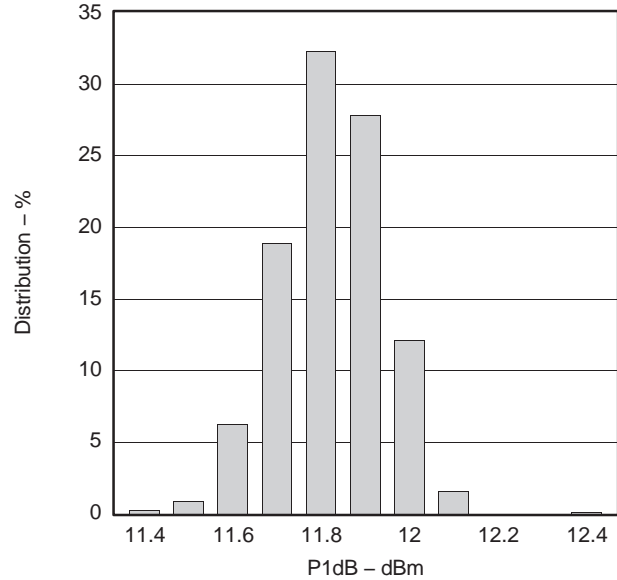


Figure 46.

G046

APPLICATION INFORMATION AND EVALUATION BOARD

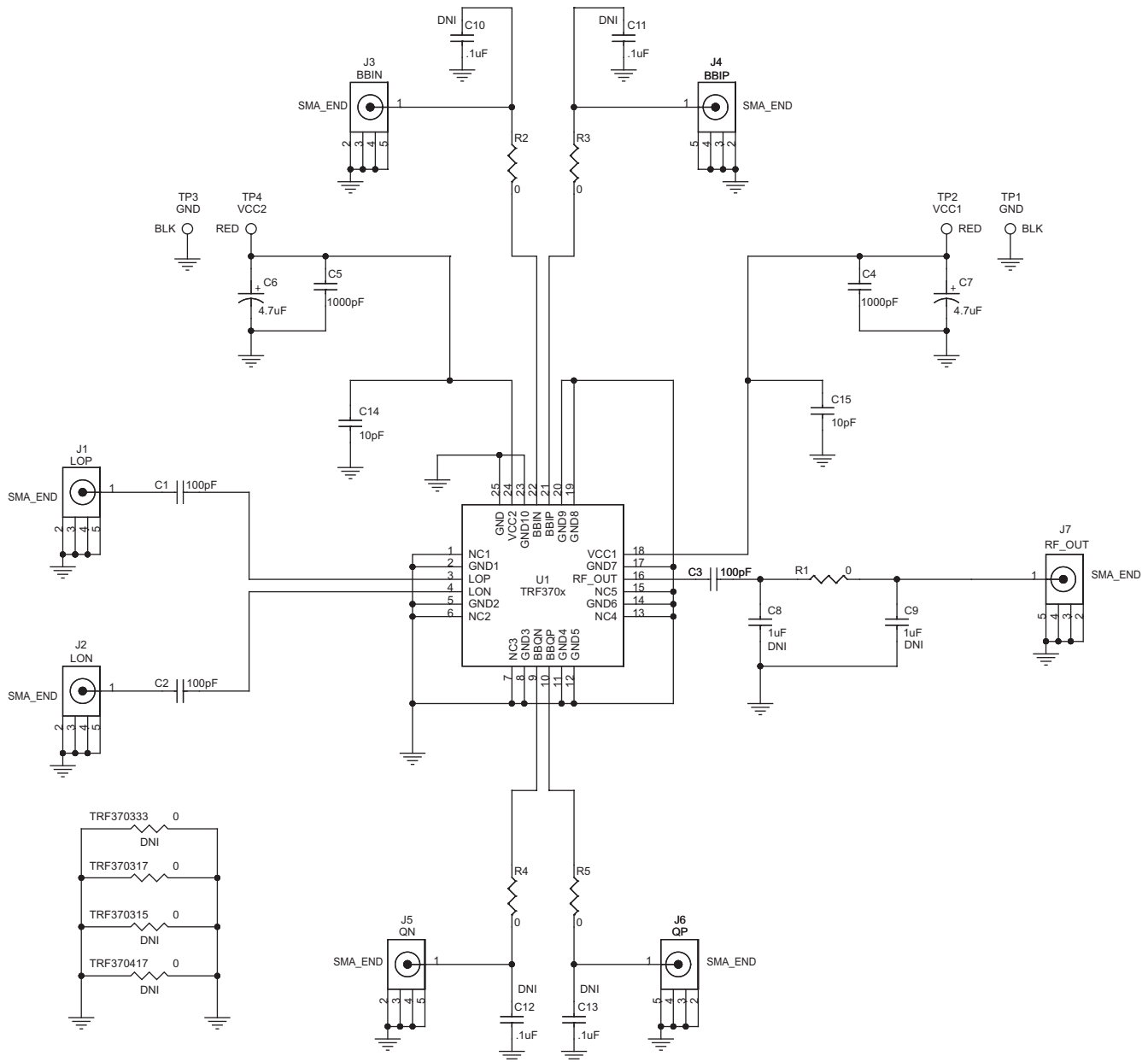
Basic Connections

- See [Figure 47](#) for proper connection of the TRF3704 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{I} , 10 = Q, and 9 = \bar{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 \pm 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.



S0214-03

NOTE: DNI = Do not install.

Figure 47. TRF3704 EVM Schematic

Figure 48 shows the top view of the TRF3704 EVM board.

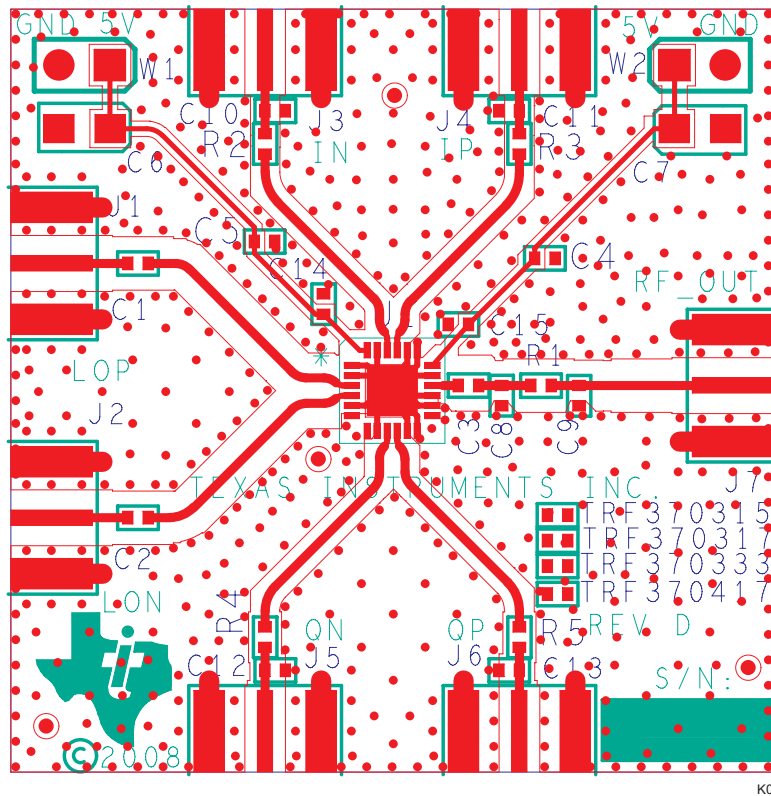


Figure 48. TRF3704 EVM Board Layout

Table 1. Bill of Materials for TRF370x EVM

| Item Number | Quantity | Reference Designator | 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 μ F | TANT_A | KERMET | T491A475K016AS | |
| 4 | 0 | C8, C9 | 1 μ F | 0402 | PANASONIC | ECJ-0EC1H010C_DNI | DNI |
| 5 | 0 | C10, C11, C12, C13 | 0.1 μ F | 0402 | PANASONIC | ECJ-0EB1A104K_DNI | DNI |
| 6 | 2 | C14, C15 | 10 pF | 0402 | MURATA | GRM1555C1H100JZ01D | |
| 7 | 7 | J1, J2, J3, J4, J5, J6, J7 | LOP | SMA_SMEL_250x215 | JOHNSON COMPONENTS | 142-0711-821 | |
| 8 | 2 | R1 | 0 | 0402 | PANASONIC | ERJ-2GE0R00 | OR EQUIVALENT |
| 9 | 4 | R2, R3, R4, R5 | 0 | 0402 | PANASONIC | ERJ-2GE0R00 | OR EQUIVALENT |

Table 1. Bill of Materials for TRF370x EVM (continued)

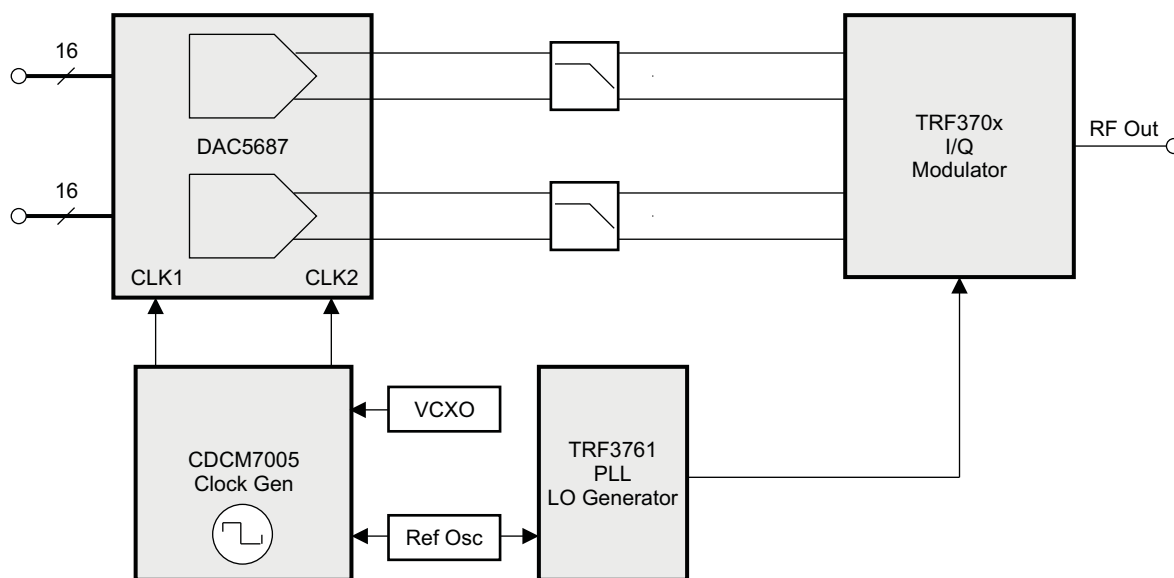
| Item Number | Quantity | Reference Designator | Value | PCB Footprint | Mfr. Name | Mfr. Part Number | Note |
|-------------|----------|----------------------|-----------|-----------------------|-----------|------------------|--------------------------------|
| 10 | 1 | U1 | TRF370333 | QFN_24_163x163_0p50mm | TI | TRF370333 | For TRF370333 EVM, TI supplied |
| | | | TRF370317 | QFN_24_163x163_0p50mm | TI | TRF370317 | For TRF370317 EVM, TI supplied |
| | | | TRF370315 | QFN_24_163x163_0p50mm | TI | TRF370315 | For TRF370315 EVM, TI supplied |
| | | | TRF370417 | QFN_24_163x163_0p50mm | TI | TRF370417 | For TRF370417 EVM, TI supplied |
| 11 | 2 | TP1, TP3 | BLK | TP_THVT_100_RND | KEYSTONE | 5001K | |
| 12 | 2 | TP2, TP4 | RED | TP_THVT_100_RND | KEYSTONE | 5000K | |

GSM Applications

The TRF370417 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 TRF370417 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 49, 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.



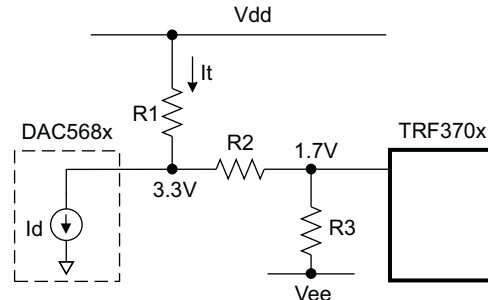
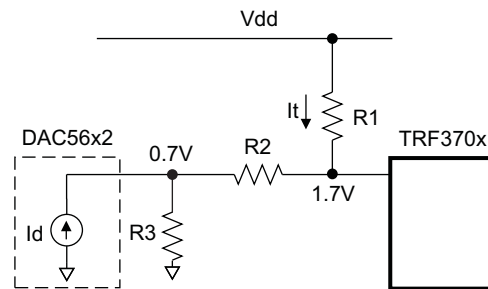
B0176-02

Figure 49. 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 50 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 $V_{cm} >$ TRF370x V_{cm} Topology 2: DAC $V_{cm} <$ TRF370x V_{cm}

S0338-01

Figure 50. Passive DAC-to-Modulator Interface Network**Table 2. DAC-to-Modulator Interface Network Values**

| | Topology 1 | | Topology 2 |
|----------------------|---------------------|----------------------|------------|
| | With $V_{ee} = 0$ V | With $V_{ee} = -5$ V | |
| DAC V_{cm} [V] | 3.3 | 3.3 | 0.7 |
| TRF370x V_{cm} [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 |

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.

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.

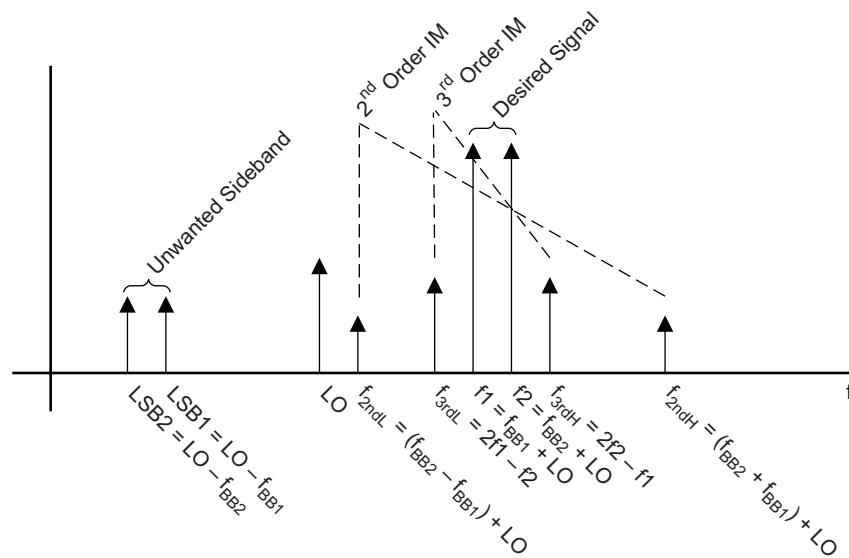
Adjusted (Optimized) Sideband Suppression

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 through 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 51](#) shows a simulated output and illustrates the respective definitions of various terms used in this data sheet.



f_{BBn} = Baseband Frequency

f_n = RF Frequency

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

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

LO = Local Oscillator Frequency

LSBn = Lower Sideband Frequency

M0104-01

Figure 51. Graphical Illustration of Common Terms

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| TRF370417IRGER | ACTIVE | VQFN | RGE | 24 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TRF37 0417 | Samples |
| TRF370417IRGET | ACTIVE | VQFN | RGE | 24 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TRF37 0417 | 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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

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TAPE AND REEL INFORMATION

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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TRF370417IRGER | VQFN | RGE | 24 | 3000 | 330.0 | 12.4 | 4.3 | 4.3 | 1.5 | 8.0 | 12.0 | Q1 |
| TRF370417IRGET | VQFN | RGE | 24 | 250 | 180.0 | 12.4 | 4.3 | 4.3 | 1.5 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS

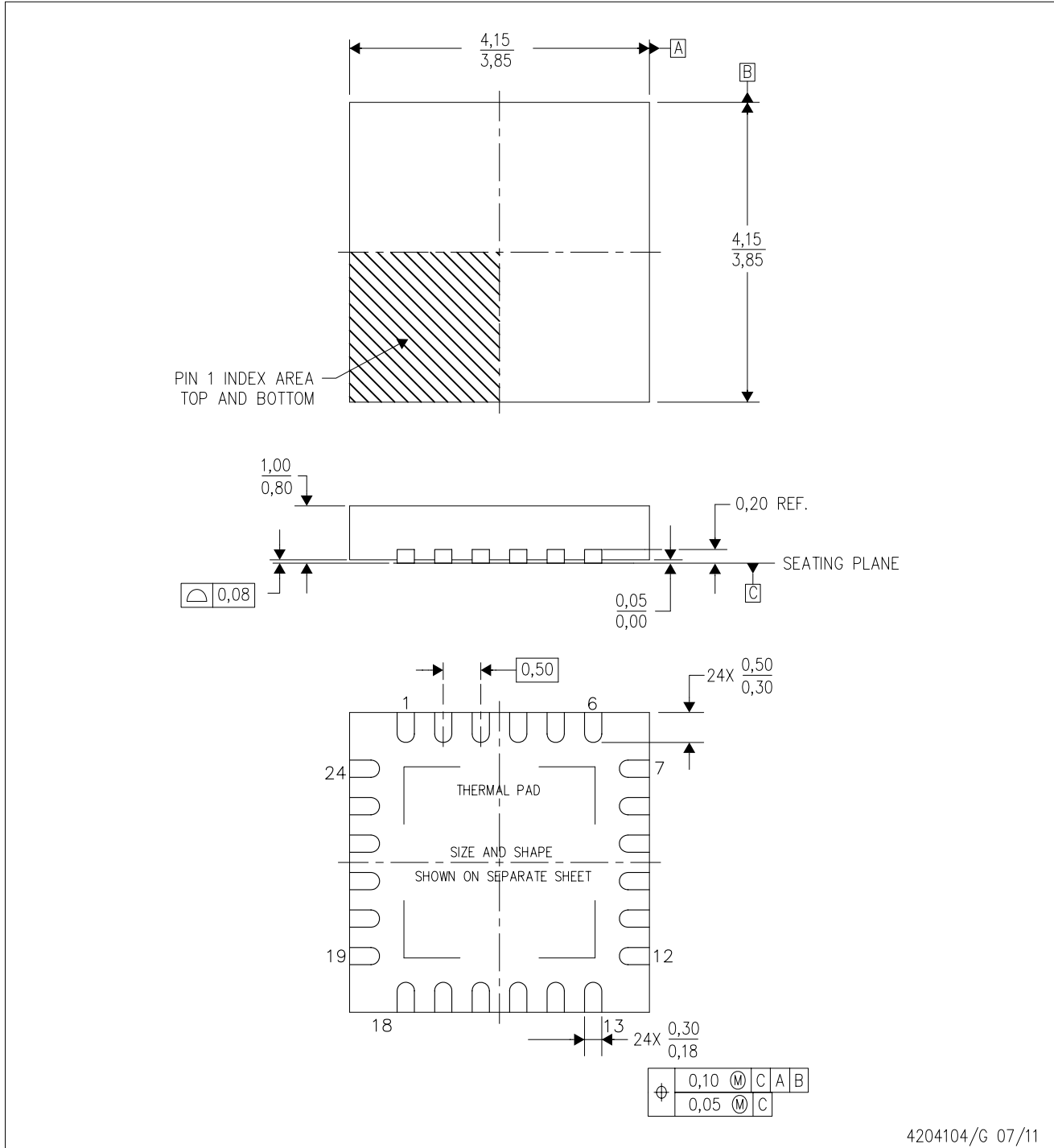


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TRF370417IRGER | VQFN | RGE | 24 | 3000 | 338.1 | 338.1 | 20.6 |
| TRF370417IRGET | VQFN | RGE | 24 | 250 | 210.0 | 185.0 | 35.0 |

RGE (S-PVQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



4204104/G 07/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Quad Flatpack, No-Leads (QFN) package configuration.
 - D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
 - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
 - F. Falls within JEDEC MO-220.

THERMAL PAD MECHANICAL DATA

RGE (S-PVQFN-N24)

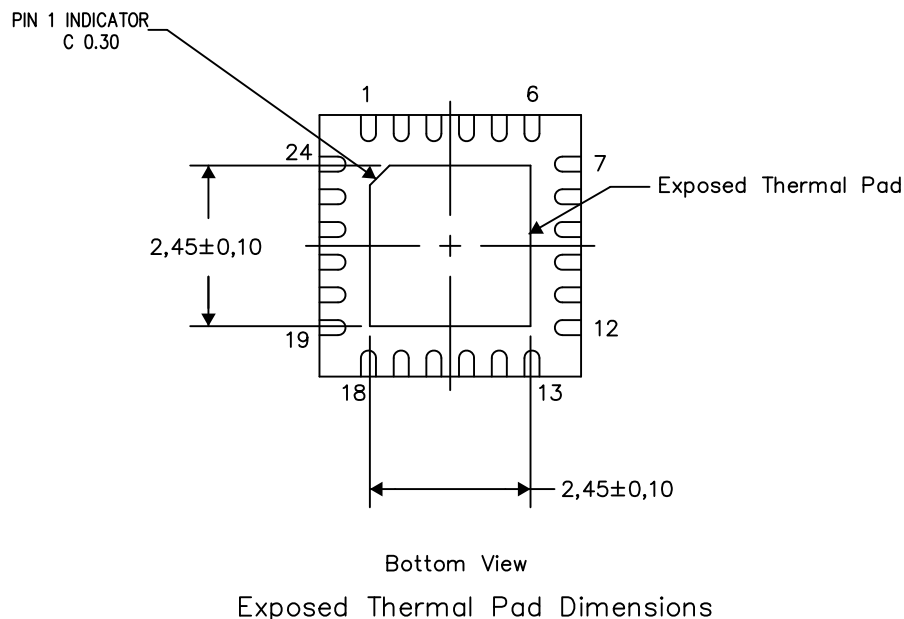
PLASTIC QUAD FLATPACK NO-LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.

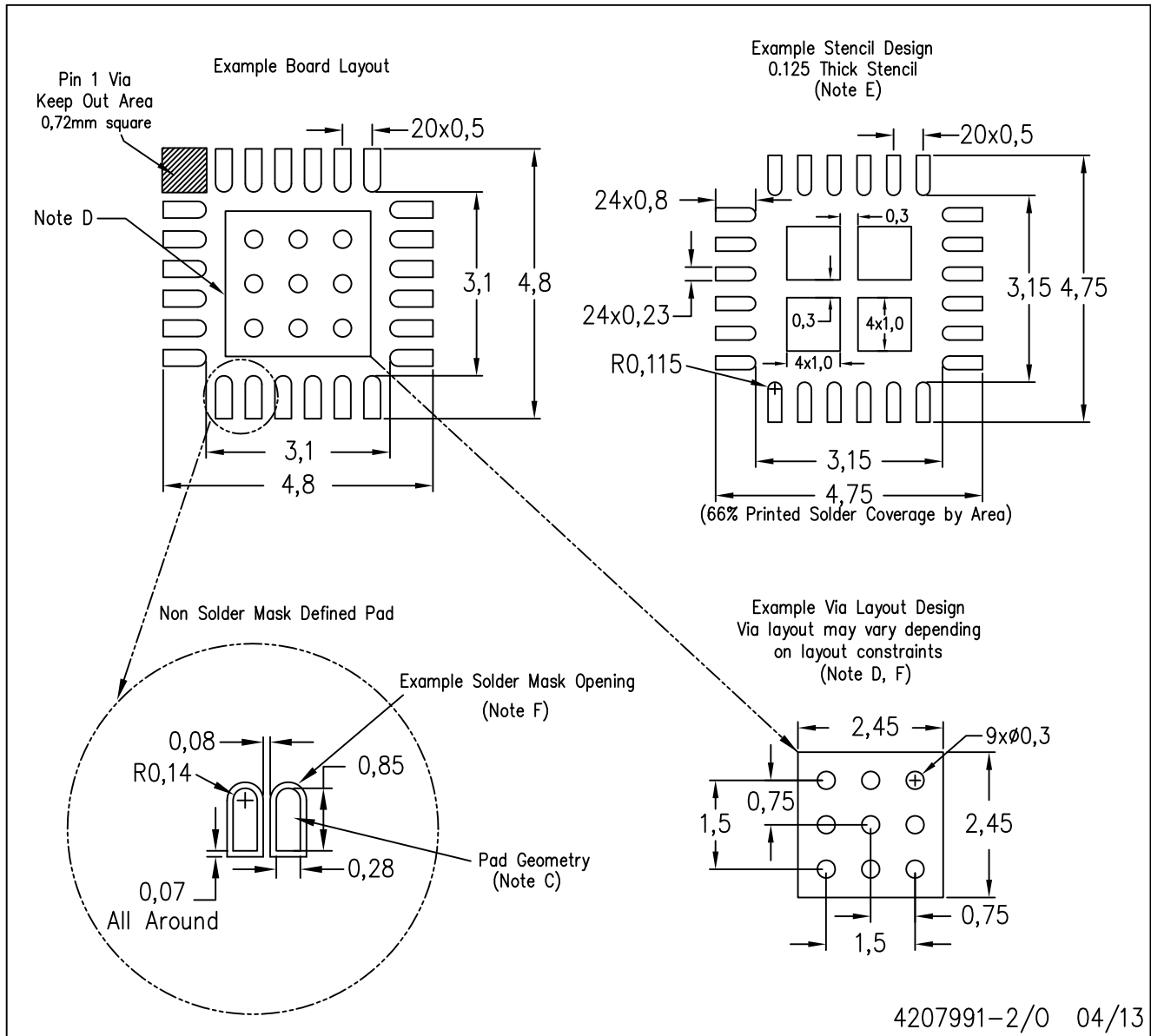


4206344-3/AC 03/13

NOTES: A. All linear dimensions are in millimeters

RGE (S-PVQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

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