

## 1.5-GHz to 2.5-GHz QUADRATURE MODULATOR

### FEATURES

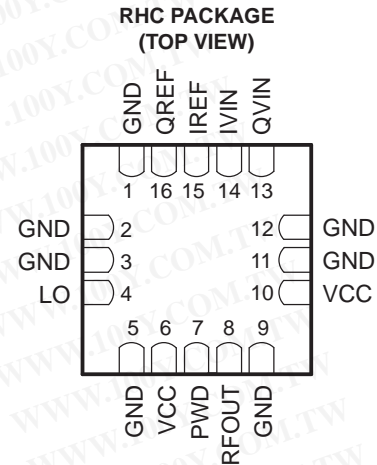
- 71-dBc Single-Carrier WCDMA ACPR at -14-dBm Channel Power
- P1dB of 7 dBm
- Typical Unadjusted Carrier Suppression 35 dBc at 2 GHz
- Typical Unadjusted Sideband Suppression 35 dBc at 2 GHz
- Very Low Noise Floor
- Differential or Single-Ended I, Q Inputs
- Convenient Single-Ended LO Input
- Silicon Germanium Technology

### APPLICATIONS

- Cellular Base Transceiver Station Transmit Channel
- IF Sampling Applications
- TDMA: GSM, IS-136, EDGE/UWC-136
- CDMA: IS-95, UMTS, CDMA2000
- Wireless Local Loop
- Wireless LAN IEEE 802.11
- LMDS, MMDS
- Wideband Transceivers

### DESCRIPTION

The TRF3702 is an ultralow-noise direct quadrature modulator that is capable of converting complex input signals from baseband or IF directly up to RF. An internal analog combiner sums the real and imaginary components of the RF outputs. This combined output can feed the RF preamp at frequencies of up to 2.5 GHz. The modulator is implemented as a double-balanced mixer. An internal local oscillator (LO) phase splitter accommodates a single-ended LO input, eliminating the need for a costly external balun.



P0003-01



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.

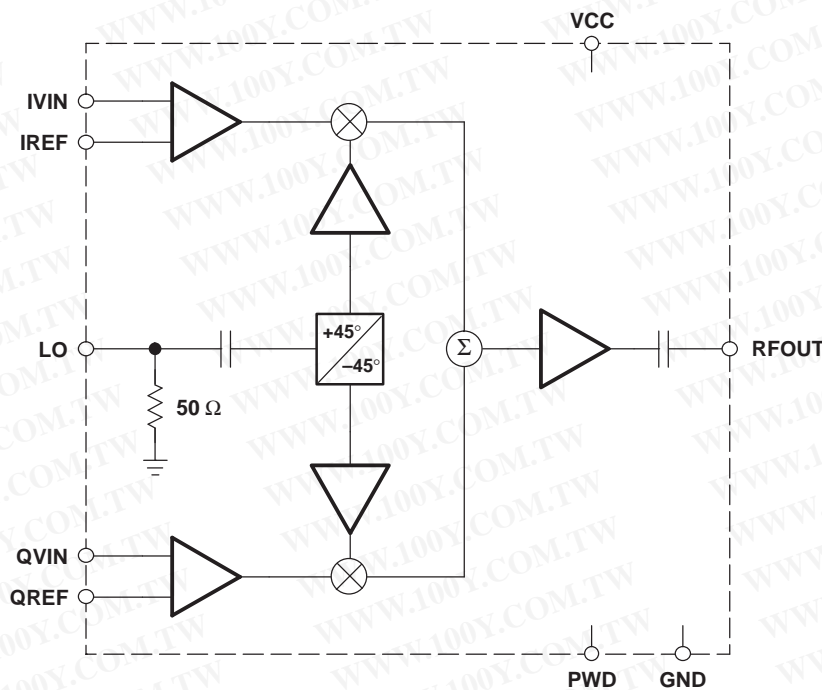
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

**AVAILABLE OPTIONS**

| T <sub>A</sub> | 4-mm × 4-mm 16-Pin RHC (QFN) Package <sup>(1)</sup> |
|----------------|---|
| -40°C to 85°C  | TRF3702IRHC   |
|                | TRF3702IRHCR (Tape and reel)                        |

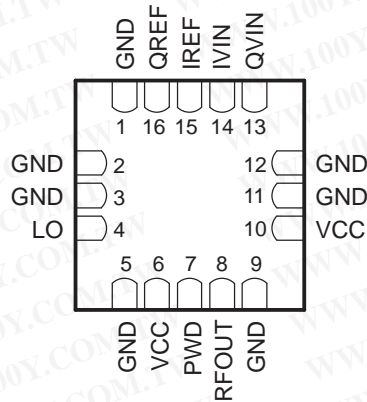
(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).

**FUNCTIONAL BLOCK DIAGRAM**



B0002-01

**RHC PACKAGE  
(TOP VIEW)**



P0003-01

**TERMINAL FUNCTIONS**

| TERMINAL |                       | I/O | DESCRIPTION   |
|----------|-----------------------|-----|---|
| NAME     | NO.                   |     |   |
| GND      | 1, 2, 3, 5, 9, 11, 12 |     | Ground  |
| IREF     | 15                    | I   | In-phase (I) reference voltage/differential input   |
| IVIN     | 14                    | I   | In-phase (I) signal input                           |
| LO       | 4                     | I   | Local oscillator input                              |
| PWD      | 7                     | I   | Power down  |
| QREF     | 16                    | I   | Quadrature (Q) reference voltage/differential input |
| QVIN     | 13                    | I   | Quadrature (Q) signal input                         |
| RFOUT    | 8                     | O   | RF output   |
| VCC      | 6, 10                 |     | Supply voltage                                      |

**ABSOLUTE MAXIMUM RATINGS**

over operating free-air temperature range (unless otherwise noted)<sup>(1)(2)</sup>

|                 |   |                    |
|-----------------|---|--------------------|
| V <sub>CC</sub> | Supply voltage range                        | -0.5 V to 6 V      |
|                 | LO input power level                        | 10 dBm             |
|                 | Baseband input voltage level (single-ended) | 3 V <sub>p-p</sub> |
| T <sub>A</sub>  | Operating free-air temperature range        | -40°C to 85°C      |
|                 | Lead temperature for 10 seconds             | 260°C              |

- (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) Measured with respect to ground

**RECOMMENDED OPERATING CONDITIONS**

|  | MIN  | NOM | MAX  | UNIT |
|--|------|-----|------|------|
| <b>Supplies and References</b>                         |      |     |      |      |
| V <sub>CC</sub> Analog supply voltage                  | 4.5  | 5   | 5.5  | V    |
| VCM (IVIN, QVIN, IREF, QREF input common-mode voltage) |      | 3.7 |      | V    |
| <b>Local Oscillator (LO) Input</b>                     |      |     |      |      |
| Input frequency  | 1500 |     | 2500 | MHz  |
| Power level (measured into 50 Ω)                       | -6   | 0   | 6    | dBm  |
| <b>Signal Inputs (IVIN, QVIN)</b>                      |      |     |      |      |
| Input bandwidth  |      | 700 |      | MHz  |

**ELECTRICAL CHARACTERISTICS**

Over recommended operating conditions, V<sub>CC</sub> = 5 V, VCM = 3.7 V, f<sub>LO</sub> = 2140 MHz at 0 dBm, T<sub>A</sub> = 25°C (unless otherwise noted)

| PARAMETER                                     | TEST CONDITIONS                             | MIN | TYP     | MAX | UNIT |
|---|---|-----|---------|-----|------|
| <b>Power Supply</b>                           |   |     |         |     |      |
| I <sub>CC</sub> Total supply current          | V(PWD) = 5 V                                |     | 145     | 170 | mA   |
|   | V(PWD) = 0 V                                |     | 13      | 30  |      |
| Turnon time                                   |   |     | 120     |     | ns   |
| Turnoff time                                  |   |     | 20      |     | ns   |
| Power-down input impedance                    |   |     | 11      |     | kΩ   |
| <b>Local Oscillator (LO) Input</b>            |   |     |         |     |      |
| Input impedance <sup>(1)</sup>                |   |     | 27 + j8 |     | Ω    |
| <b>Signal Inputs (IVIN, QVIN, IREF, QREF)</b> |   |     |         |     |      |
| Input bias current                            | I, Q = VCM = 3.7 V (all inputs tied to VCM) |     | 16      |     | μA   |
| Input impedance                               | Single-ended input                          |     | 260     |     | kΩ   |
|   | Differential input                          |     | 130     |     |      |

(1) For a listing of impedances at various frequencies, see [Table 1](#).

**Table 1. RFOUT and LO Pin Impedance**

| Frequency (MHz) | Z (RFOUT Pin) | Z (LO Pin)    |
|-----------------|---------------|---------------|
| 1500            | 31 - j 4.7    | 31.7 - j 8.8  |
| 1600            | 30.9 - j 0.3  | 29.3 - j 6.2  |
| 1700            | 29.3 + j 3.1  | 27.3 - j 3.1  |
| 1800            | 27.9 + j 7.2  | 26.5 - j 0.17 |
| 1900            | 27.6 + j 13   | 26.1+ - j 2.7 |
| 2000            | 29.4 + j 19.8 | 26.5 + j 5.4  |
| 2100            | 34.6 + j 27.2 | 27 + j 7.6    |
| 2200            | 44.2 + j 33   | 28 + j 9.5    |
| 2300            | 60 + j 33.6   | 29 + j 10.6   |
| 2400            | 78 + j 21     | 29.5 + j 11   |
| 2500            | 82 - j 5.8    | 29.8 + j 12.2 |



## RF OUTPUT PERFORMANCE

Over recommended operating conditions,  $V_{CC} = 5\text{ V}$ ,  $V_{CM} = 3.7\text{ V}$ ,  $f_{LO} = 1842\text{ MHz}$  at 0 dBm (unless otherwise specified)

| PARAMETER  | TEST CONDITIONS  | MIN | TYP     | MAX                   | UNIT     |
|--|--|-----|---------|-----------------------|----------|
| <b>Single and Two-Tone Specifications</b>            |  |     |         |                       |          |
| Output power   |  | -5  | -2.5    |                       | dBm      |
| Second baseband harmonic (USB or LSB) <sup>(2)</sup> | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$  |     | -50     | -42                   | dBc      |
| Third baseband harmonic (USB or LSB) <sup>(2)</sup>  |  |     | -57     | -50                   | dBc      |
| IMD <sub>3</sub>                                     | I, Q <sup>(1)</sup> = 1 Vp-p (two-tone signal, $f_{BB1} = 928\text{ kHz}$ , $f_{BB2} = 992\text{ kHz}$ ) |     | -59     | -53                   | dBc      |
| P1dB (output compression point)                      |  |     | 7       |                       | dBm      |
| NSD Noise spectral density                           | I, Q = VCM = 3.7 VDC (all inputs tied to VCM), 6-MHz offset from carrier                                 |     | -155    |                       | dBm/Hz   |
|  | 6-MHz offset from carrier, $P_{out} = 0\text{ dBm}$ , over temperature                                   |     | -148.5  | -146.5 <sup>(3)</sup> |          |
| RFOUT pin impedance <sup>(4)</sup>                   |  |     | 28 + j8 |                       | $\Omega$ |
| Carrier suppression                                  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , unadjusted                                     |     | 30      |                       | dBc      |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , optimized                                      |     | 55      |                       |          |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , over temperature <sup>(5)</sup>                |     | 44      |                       |          |
| Sideband suppression                                 | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , unadjusted                                     |     | 35      |                       | dBc      |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , optimized                                      |     | 55      |                       |          |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , over temperature <sup>(5)</sup>                |     | 47      |                       |          |

(1) I, Q = 1 Vp-p implies that the magnitude of the signal at each input pin IVIN, IREF, QVIN, QREF is equal to 500 mVp-p.

(2) USB = upper sideband. LSB = lower sideband.

(3) Maximum noise values are assured by statistical characterization only, not production testing. The values specified are over the entire temperature range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ .

(4) For a listing of impedances at various frequencies, see [Table 1](#).

(5) After optimization at room temperature. See the *Definitions of Selected Specifications* section.

## RF OUTPUT PERFORMANCE

Over recommended operating conditions,  $V_{CC} = 5\text{ V}$ ,  $V_{CM} = 3.7\text{ V}$ ,  $f_{LO} = 1960\text{ MHz}$  at 0 dBm (unless otherwise specified)

| PARAMETER  | TEST CONDITIONS  | MIN | TYP      | MAX                   | UNIT     |
|--|--|-----|----------|-----------------------|----------|
| <b>Single and Two-Tone Specifications</b>            |  |     |          |                       |          |
| Output power   |  |     | -3       |                       | dBm      |
| Second baseband harmonic (USB or LSB) <sup>(2)</sup> | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$  |     | -50      |                       | dBc      |
| Third baseband harmonic (USB or LSB) <sup>(2)</sup>  |  |     | -60      |                       | dBc      |
| IMD <sub>3</sub>                                     | I, Q <sup>(1)</sup> = 1 Vp-p (two-tone signal, $f_{BB1} = 928\text{ kHz}$ , $f_{BB2} = 992\text{ kHz}$ ) |     | -59      | -53                   | dBc      |
| P1dB (output compression point)                      |  |     | 7        |                       | dBm      |
| NSD Noise spectral density                           | 6-MHz offset from carrier, $P_{out} = 0\text{ dBm}$ , over temperature                                   |     | -148     | -146.5 <sup>(3)</sup> | dBm/Hz   |
| RFOUT pin impedance <sup>(4)</sup>                   |  |     | 28 + j15 |                       | $\Omega$ |
| Carrier suppression                                  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , unadjusted                                     |     | 33       |                       | dBc      |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , optimized                                      |     | 55       |                       |          |
| Sideband suppression                                 | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , unadjusted                                     |     | 35       |                       | dBc      |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , optimized                                      |     | 55       |                       |          |

(1) I, Q = 1 Vp-p implies that the magnitude of the signal at each input pin IVIN, IREF, QVIN, QREF is equal to 500 mVp-p.

(2) USB = upper sideband. LSB = lower sideband.

(3) Maximum noise values are assured by statistical characterization only, not production testing. The values specified are over the entire temperature range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ .

(4) For a listing of impedances at various frequencies, see [Table 1](#).

## RF OUTPUT PERFORMANCE

Over recommended operating conditions,  $V_{CC} = 5\text{ V}$ ,  $V_{CM} = 3.7\text{ V}$ ,  $f_{LO} = 2.1\text{ GHz}$  at 0 dBm (unless otherwise specified)

| PARAMETER  | TEST CONDITIONS   | MIN | TYP      | MAX                   | UNIT     |
|--|---|-----|----------|-----------------------|----------|
| <b>Single and Two-Tone Specifications</b>            |   |     |          |                       |          |
| Output power   |   | -5  | -3       |                       | dBm      |
| Second baseband harmonic (USB or LSB) <sup>(2)</sup> | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$   |     | -50      | -42                   | dBc      |
| Third baseband harmonic (USB or LSB) <sup>(2)</sup>  |   |     | -60      | -51                   | dBc      |
| IMD <sub>3</sub>                                     | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ (two-tone signal, $f_{BB1} = 928\text{ kHz}$ , $f_{BB2} = 992\text{ kHz}$ ) |     | -55      | -47                   | dBc      |
| P1dB (output compression point)                      |   |     | 7        |                       | dBm      |
| NSD Noise spectral density                           | 60-MHz offset from carrier, $P_{out} = 0\text{ dBm}$ , over temperature   |     | -151     | -148.5 <sup>(3)</sup> | dBm/Hz   |
| WCDMA ACPR   | Single carrier, channel power = -14 dBm   |     | 71       |                       | dBc      |
| RFOUT pin impedance <sup>(4)</sup>                   |   |     | 35 + j27 |                       | $\Omega$ |
| Carrier suppression                                  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , unadjusted  |     | 30       |                       | dBc      |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , optimized   |     | 55       |                       |          |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , over temperature <sup>(5)</sup>   |     | 47       |                       |          |
| Sideband suppression                                 | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , unadjusted  |     | 37       |                       | dBc      |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , optimized   |     | 55       |                       |          |
|  | I, Q <sup>(1)</sup> = 1 Vp-p, $f_{BB} = 928\text{ kHz}$ , over temperature <sup>(5)</sup>   |     | 47       |                       |          |

(1) I, Q = 1 Vp-p implies that the magnitude of the signal at each input pin IVIN, IREF, QVIN, QREF is equal to 500 mVp-p.

(2) USB = upper sideband. LSB = lower sideband.

(3) Maximum noise values are assured by statistical characterization only, not production testing. The values specified are over the entire temperature range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ .

(4) For a listing of impedances at various frequencies, see [Table 1](#).

(5) After optimization at room temperature. See the *Definitions of Selected Specifications* section.

## THERMAL CHARACTERISTICS

| PARAMETER  | CONDITION  | NOM  | UNIT                      |
|--|--|------|---------------------------|
| $R_{\theta JA}$ Thermal resistance, junction to ambient          | Soldered pad using four-layer JEDEC board with four thermal vias | 42.8 | $^\circ\text{C}/\text{W}$ |
| $R_{\theta JM}$ Thermal resistance, junction to mounting surface |  | 24.8 | $^\circ\text{C}/\text{W}$ |
| $R_{\theta JC}$ Thermal resistance, junction to case             | Soldered pad using two-layer JEDEC board with four thermal vias  | 67.6 | $^\circ\text{C}/\text{W}$ |

## DEFINITIONS OF SELECTED SPECIFICATIONS

### Unadjusted Carrier Suppression

This specification measures the amount by which the local oscillator component is attenuated in the output spectrum of the modulator relative to the carrier. It is assumed that the baseband inputs delivered to the pins of the TRF3702 are perfectly matched to have the same dc offset ( $V_{CM}$ ). This includes all four baseband inputs: IVIN, QVIN, IREF and QREF. Unadjusted carrier suppression is measured in dBc.

### Adjusted (Optimized) Carrier Suppression

This differs from the unadjusted suppression number in that the dc offsets of the baseband inputs are iteratively adjusted around their theoretical value of  $V_{CM}$  to yield the maximum suppression of the LO component in the output spectrum. Adjusted carrier suppression is measured in dBc.

## DEFINITIONS OF SELECTED SPECIFICATIONS (continued)

### Unadjusted Sideband Suppression

This specification measures the amount by which the unwanted sideband of the input signal is attenuated in the output of the modulator, relative to the wanted sideband. It is assumed that the baseband inputs delivered to the modulator input pins are perfectly matched in amplitude and are exactly 90° out of phase. Unadjusted sideband suppression is measured in dBc.

### Adjusted (Optimized) Sideband Suppression

This differs from the unadjusted sideband suppression in that the baseband inputs are iteratively adjusted around their theoretical values to maximize the amount of sideband suppression. Adjusted sideband suppression 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 at  $T_A = 25^\circ\text{C}$ . This specification then measures the suppression when temperature conditions change after the initial calibration is done.

Figure 1 shows a simulated output and illustrates the respective definitions of various terms used in this data sheet. The graph assumes a baseband input of 50 kHz.

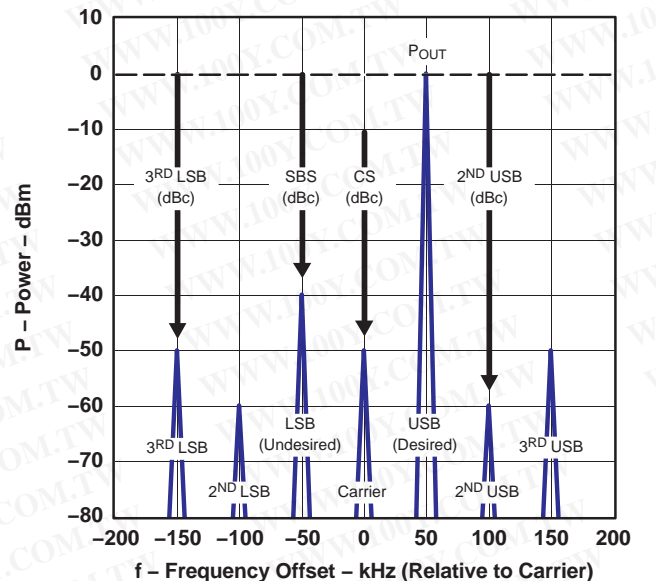


Figure 1. Graphical Illustration of Common Terms

## TYPICAL CHARACTERISTICS

For all the performance plots in this section, the following conditions were used, unless otherwise noted:  $V_{CC} = 5\text{ V}$ ,  $V_{CM} = 3.7\text{ V}$ ,  $P_{LO} = 0\text{ dBm}$ , I and Q inputs driven differentially at a frequency of 50 kHz. In the case of optimized suppressions, the point of optimization is noted and is always at nominal conditions and room temperature. A level of >50 dBc is assumed to be optimized.

TYPICAL CHARACTERISTICS (continued)

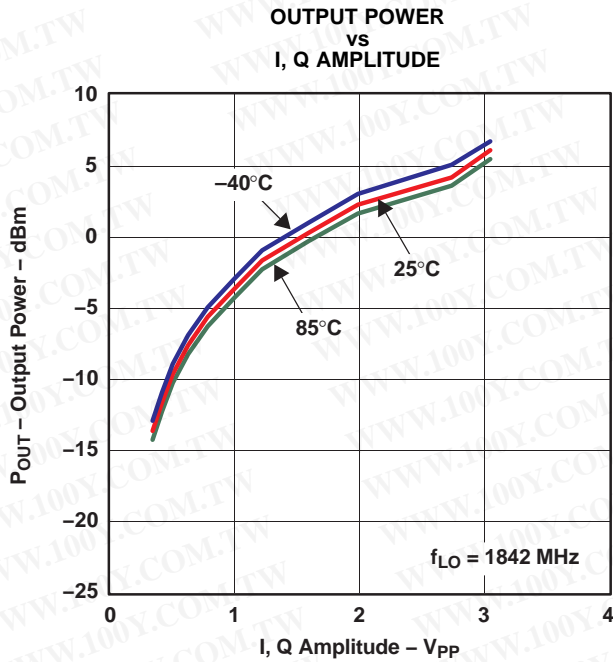


Figure 2.

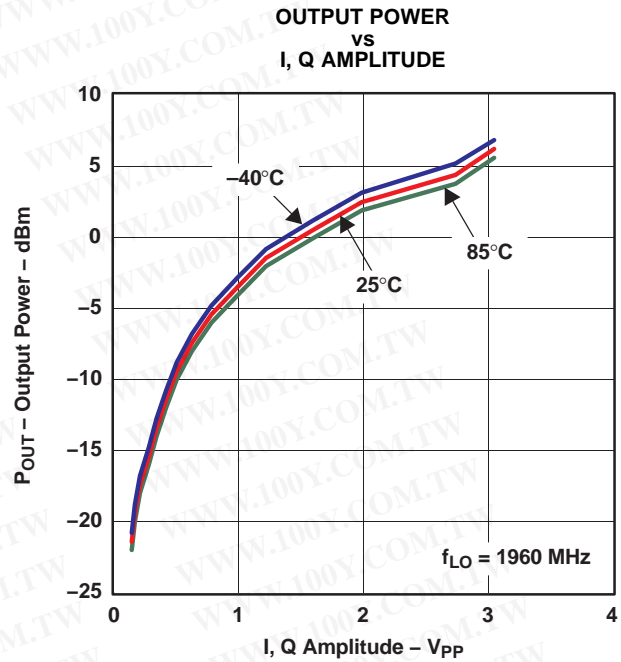


Figure 3.

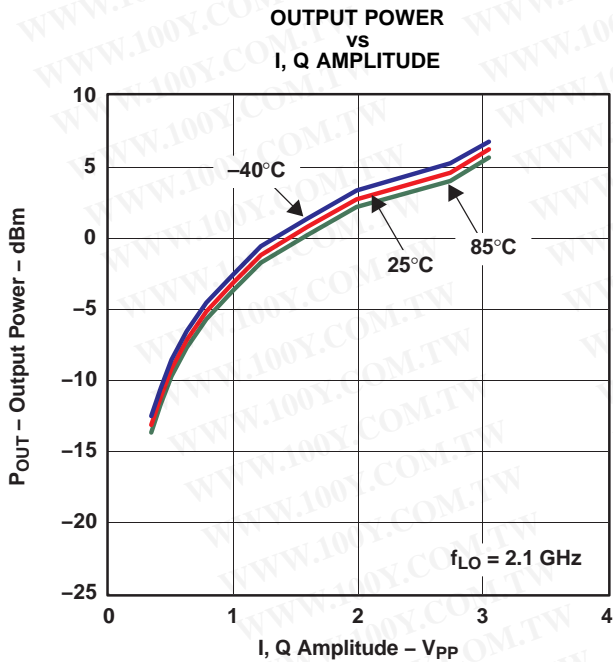


Figure 4.

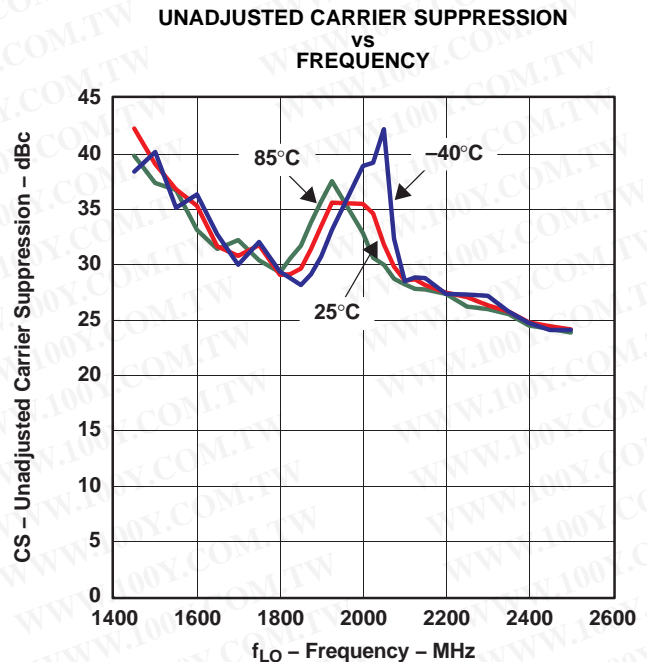


Figure 5.



TYPICAL CHARACTERISTICS (continued)

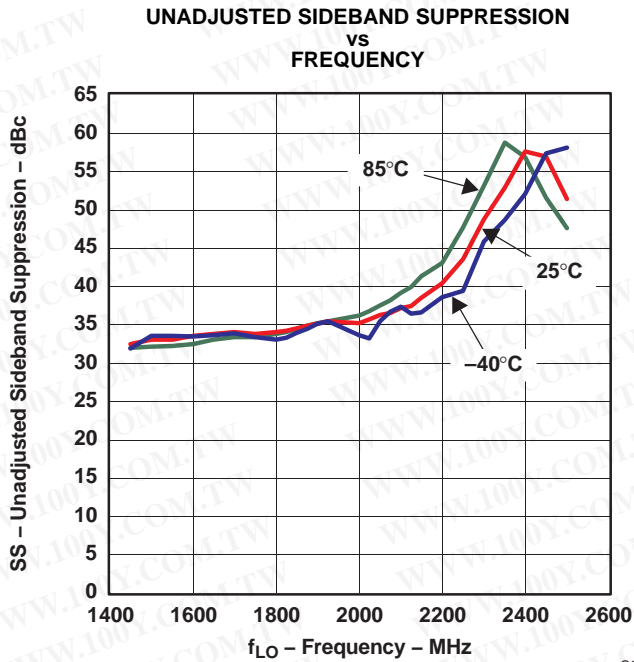


Figure 6.

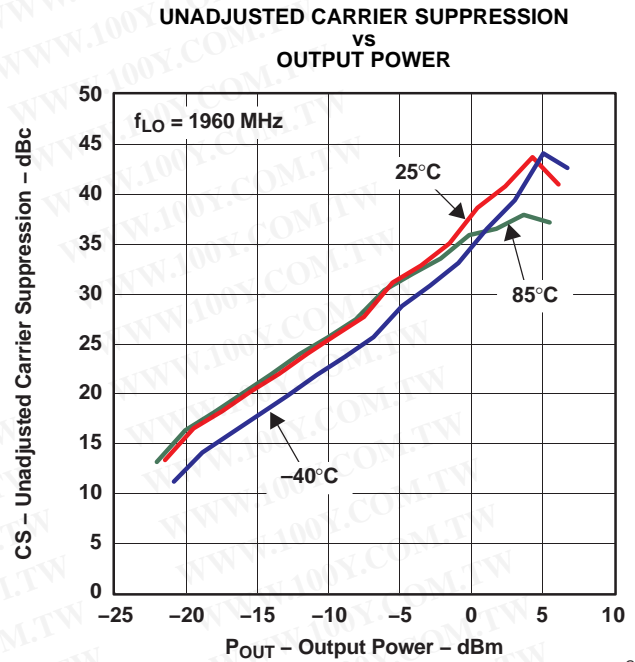


Figure 7.

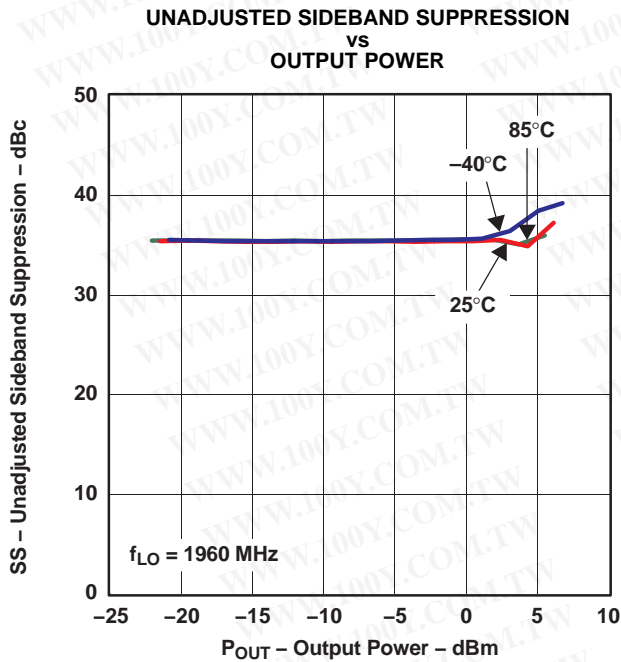


Figure 8.

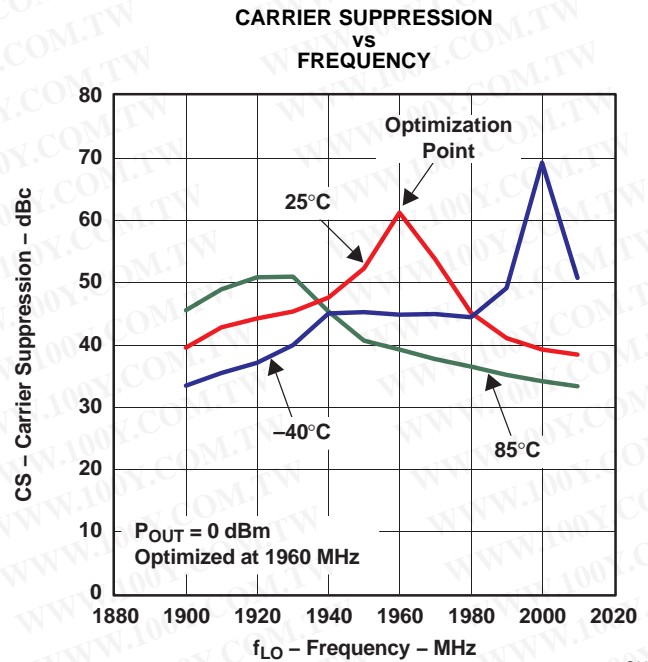


Figure 9.

TYPICAL CHARACTERISTICS (continued)

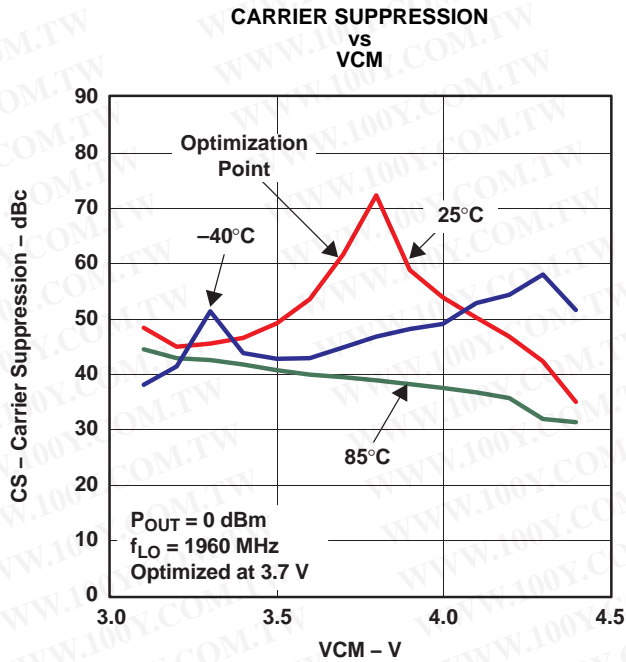


Figure 10.

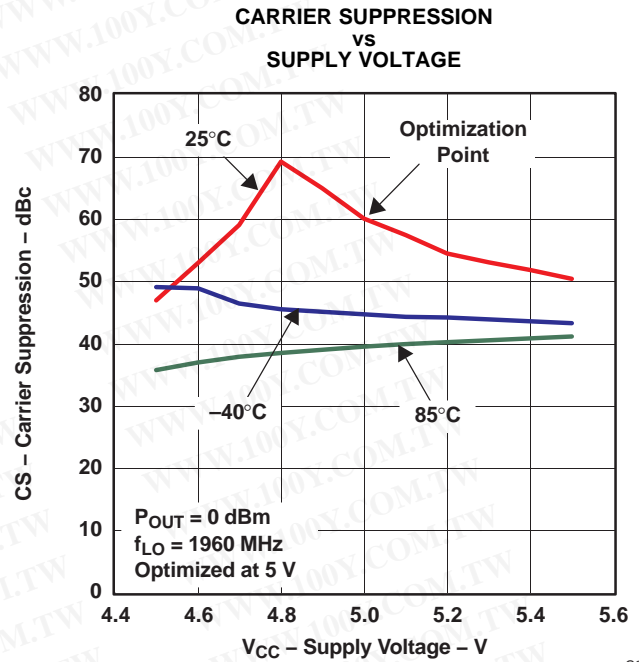


Figure 11.

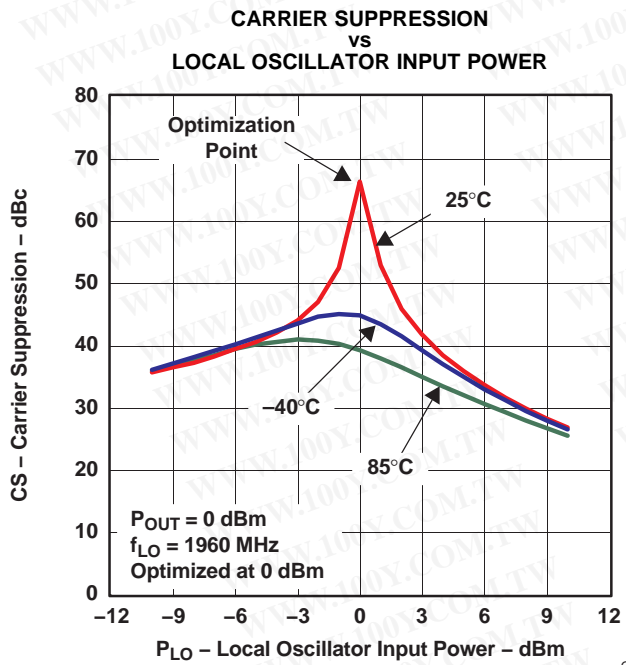


Figure 12.

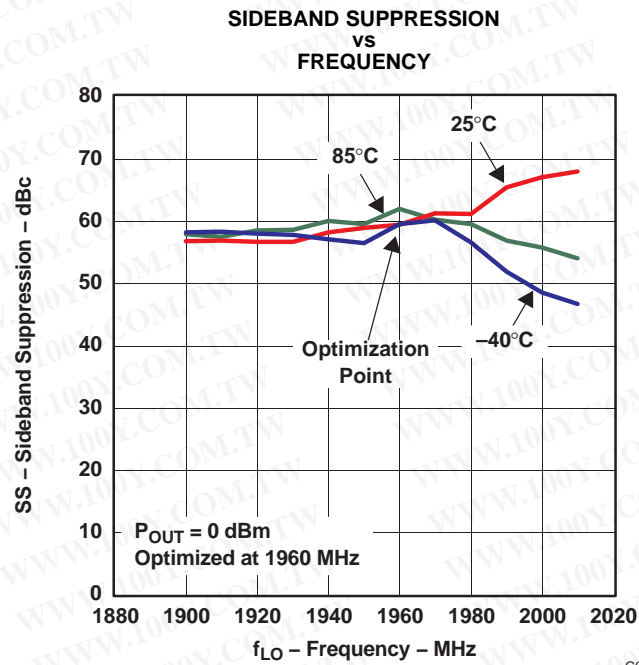


Figure 13.

TYPICAL CHARACTERISTICS (continued)

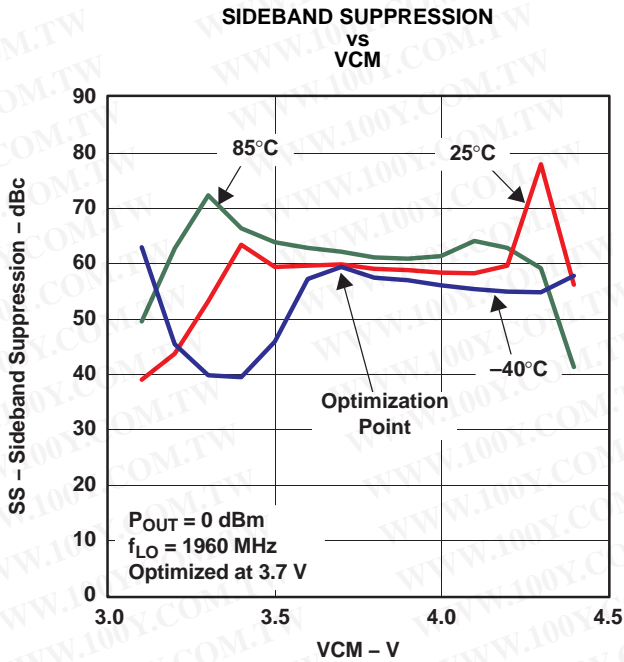


Figure 14.

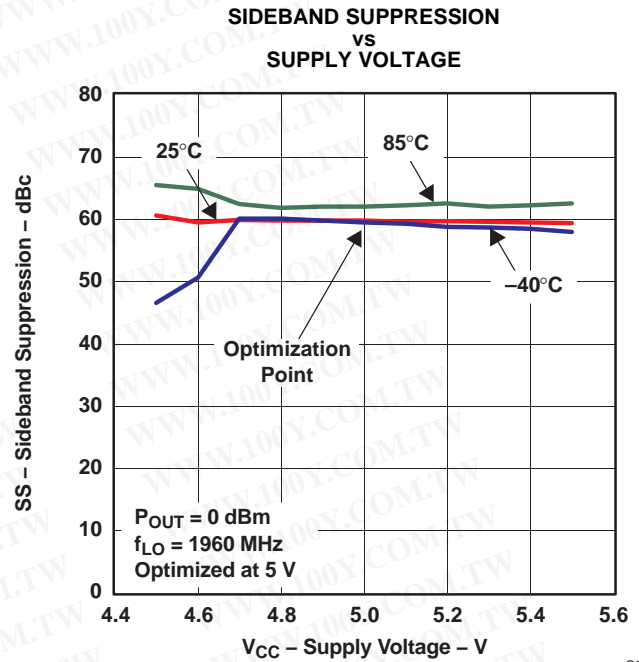


Figure 15.

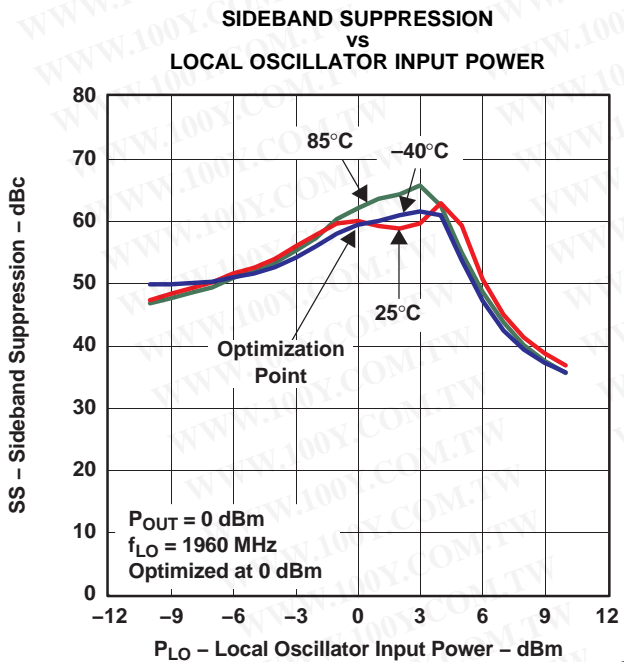


Figure 16.

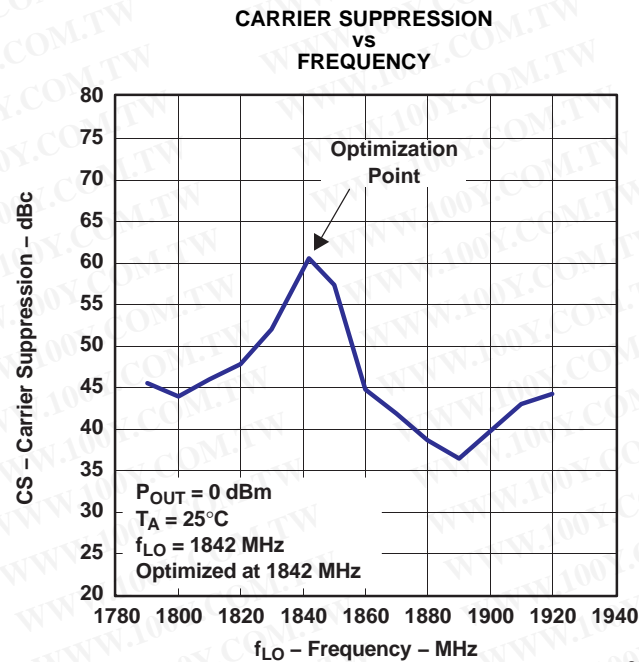


Figure 17.

TYPICAL CHARACTERISTICS (continued)

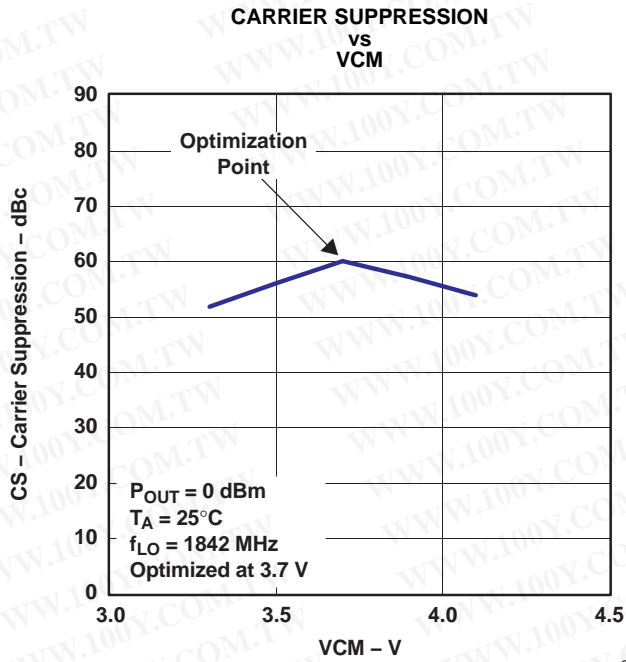


Figure 18.

G043

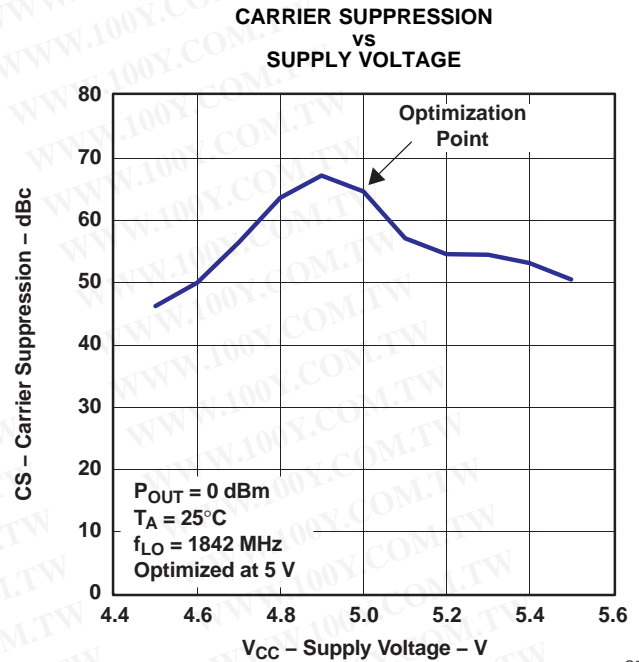


Figure 19.

G044

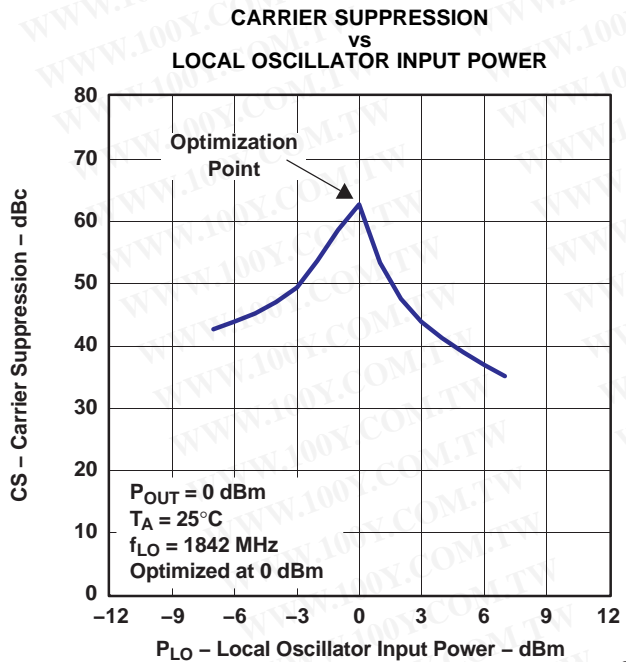


Figure 20.

G018

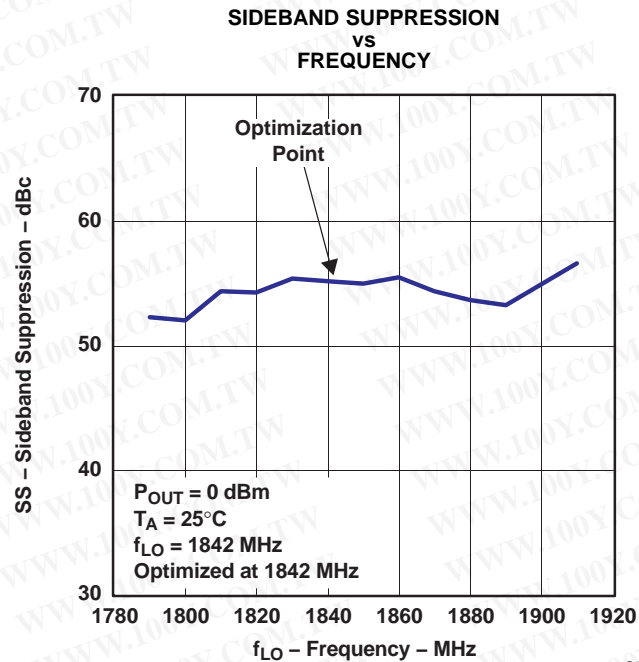


Figure 21.

G045



**TYPICAL CHARACTERISTICS (continued)**

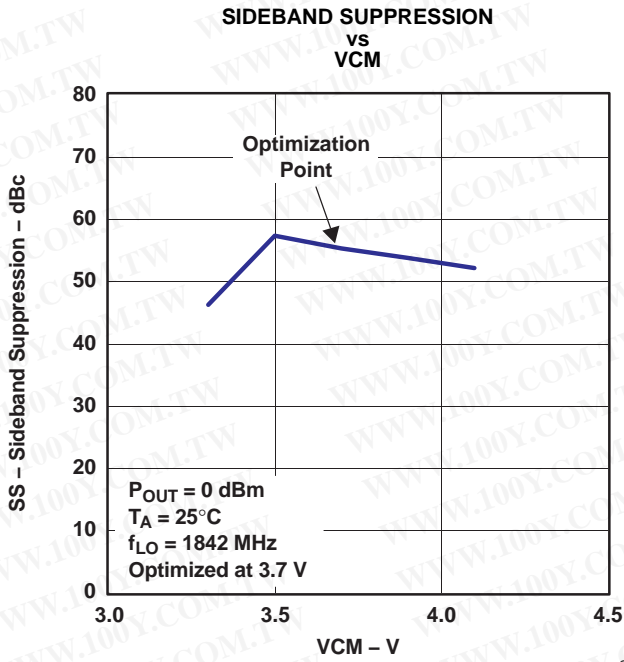


Figure 22.

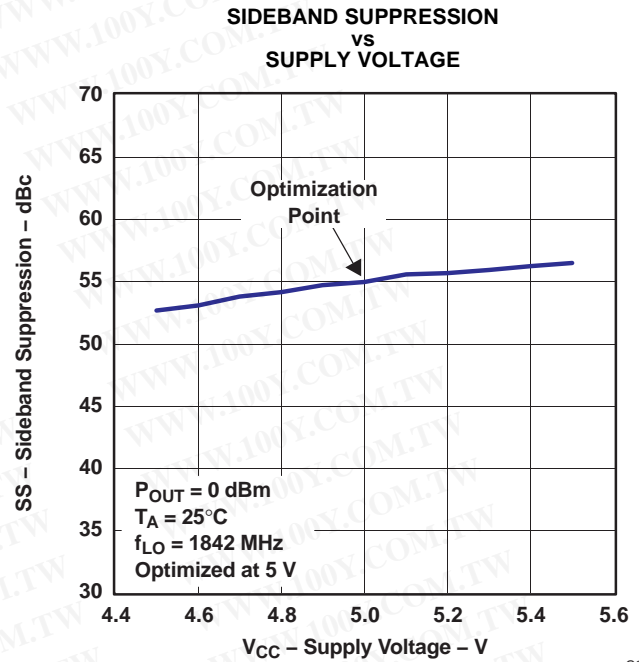


Figure 23.

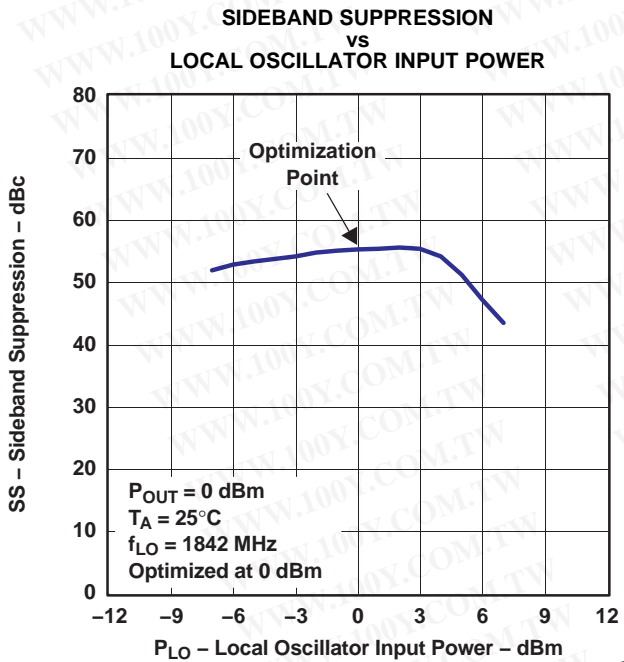


Figure 24.

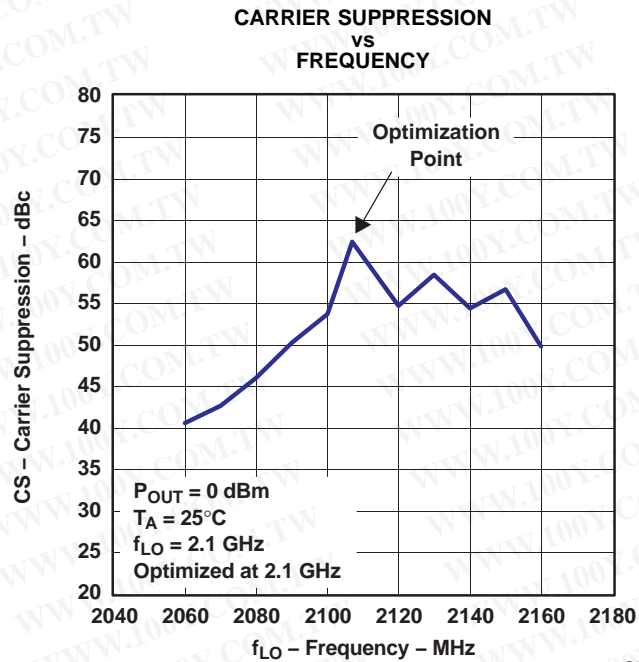


Figure 25.

TYPICAL CHARACTERISTICS (continued)

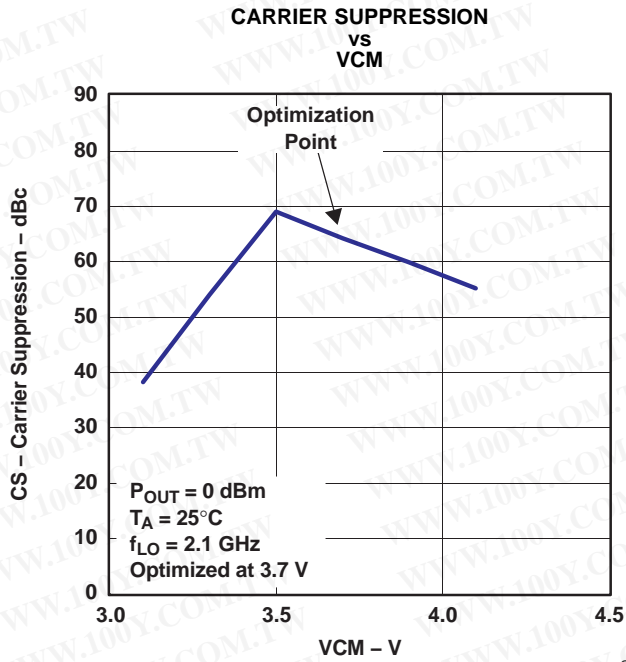


Figure 26.

G056

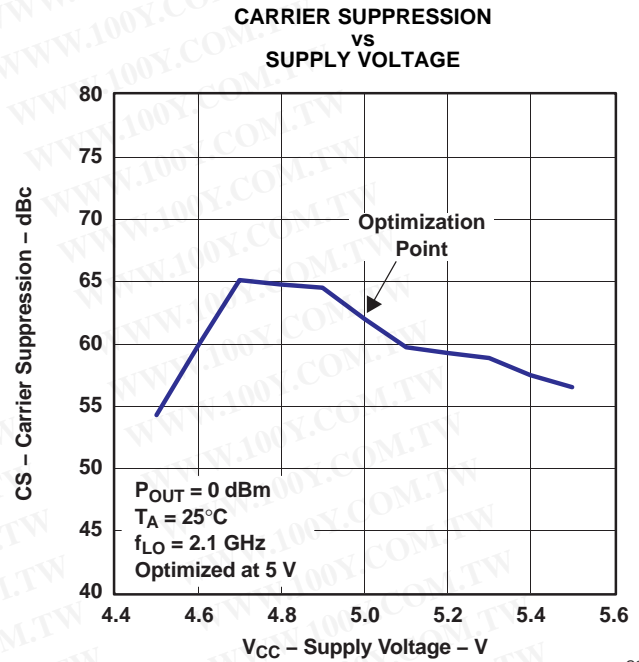


Figure 27.

G057

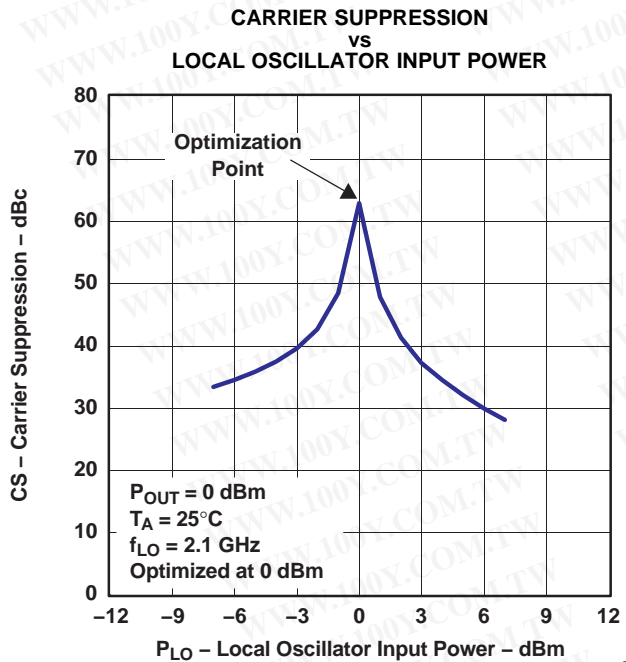


Figure 28.

G055

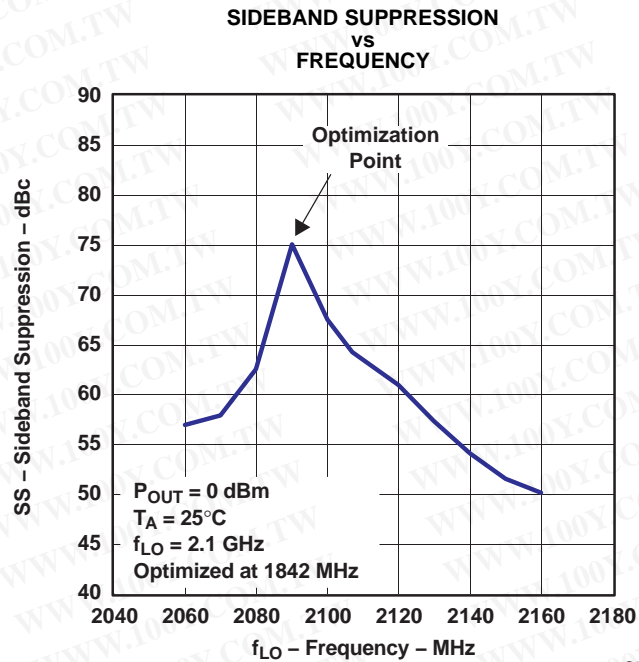


Figure 29.

G058

**TYPICAL CHARACTERISTICS (continued)**

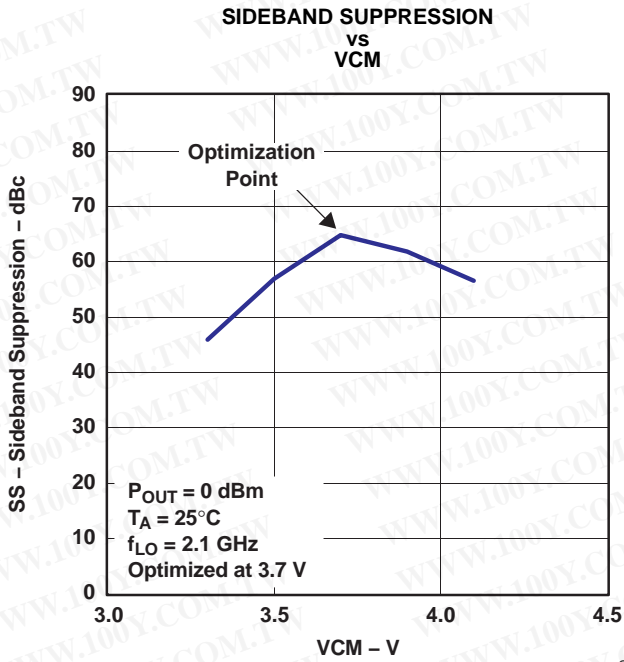


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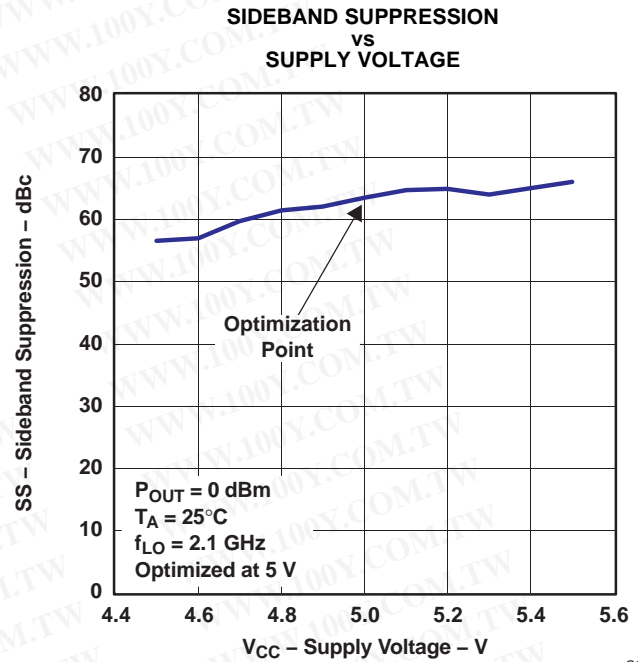


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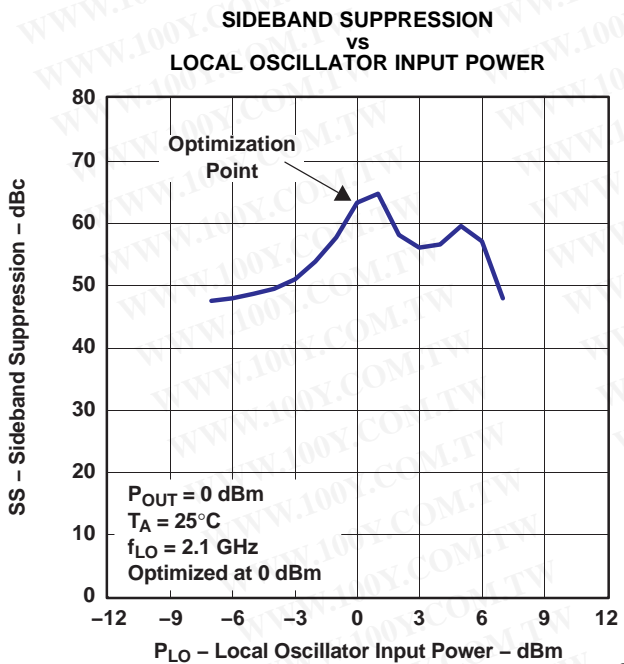


Figure 32.

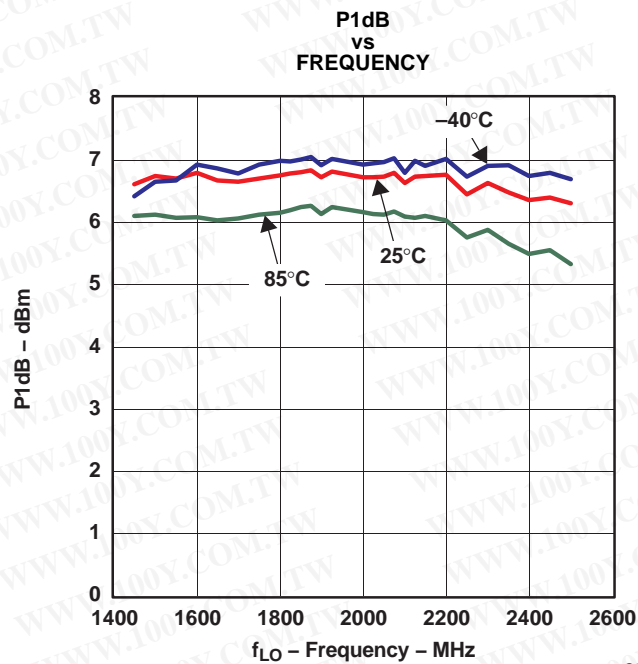


Figure 33.

TYPICAL CHARACTERISTICS (continued)

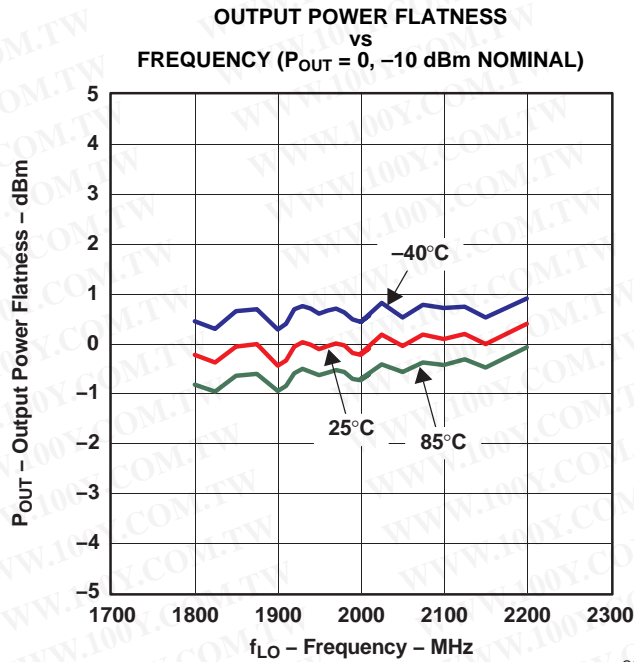


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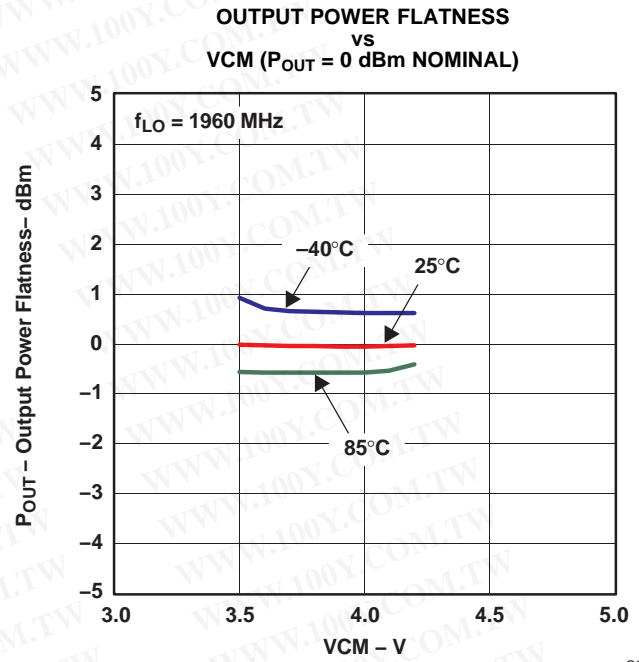


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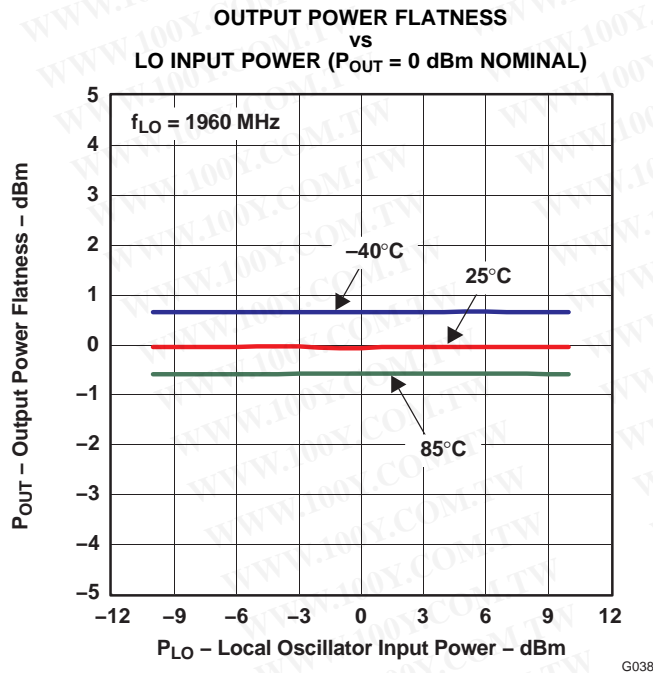


Figure 36.

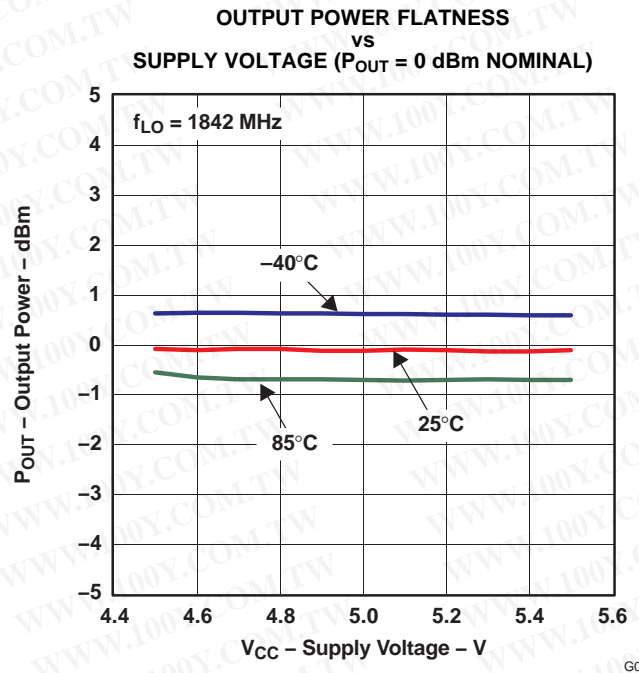


Figure 37.



TYPICAL CHARACTERISTICS (continued)

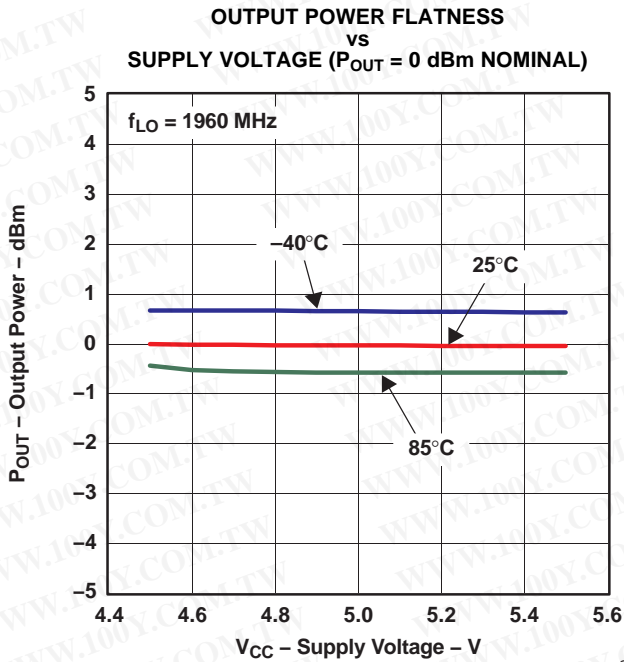


Figure 38.

G033

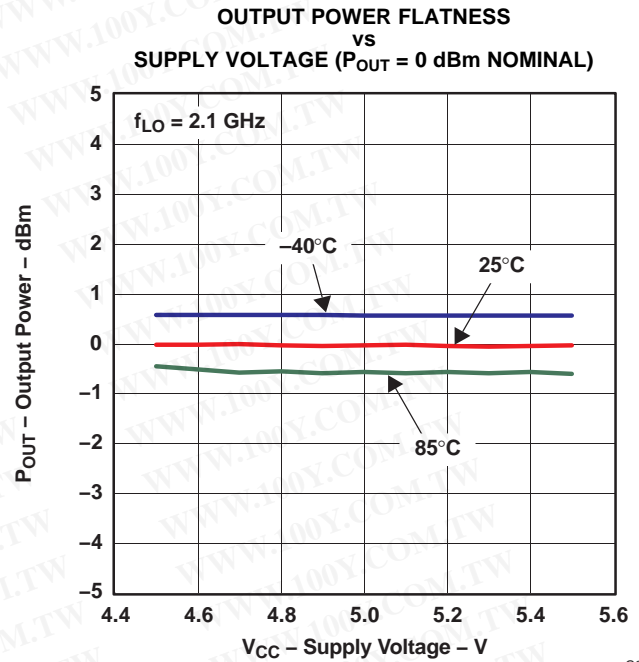


Figure 39.

G053

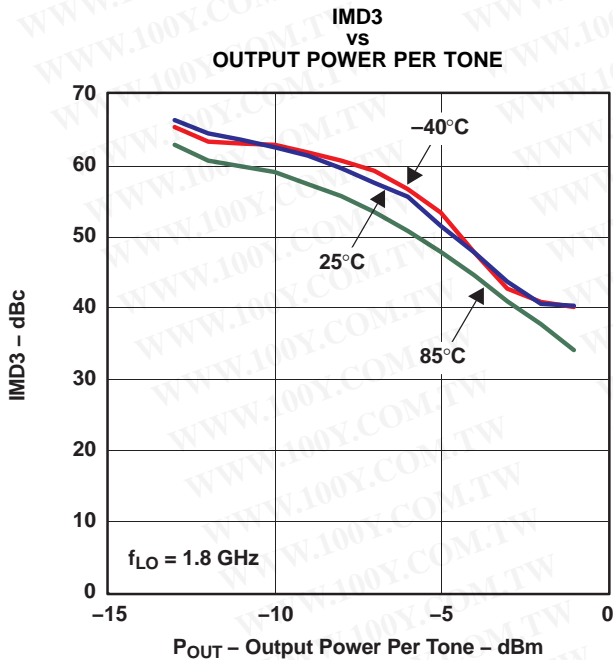


Figure 40.

G016

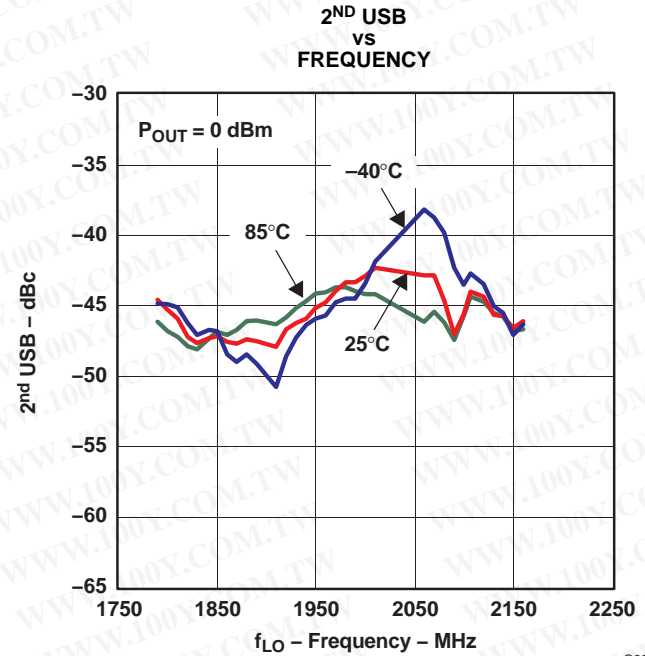


Figure 41.

G023

TYPICAL CHARACTERISTICS (continued)

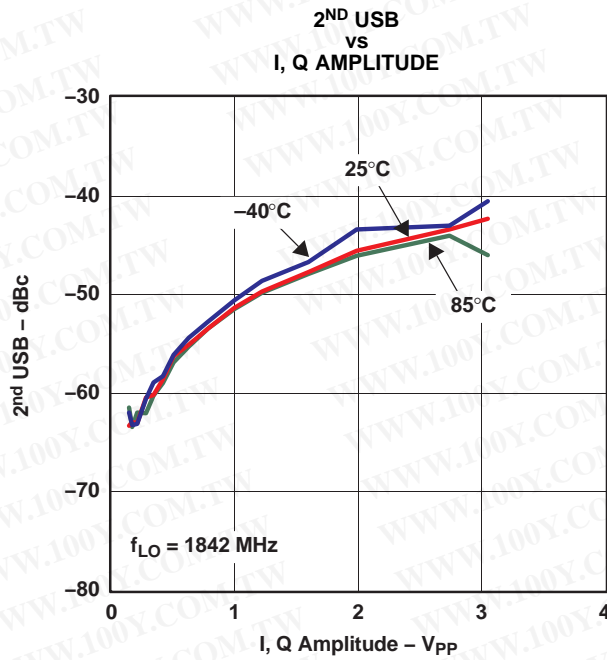


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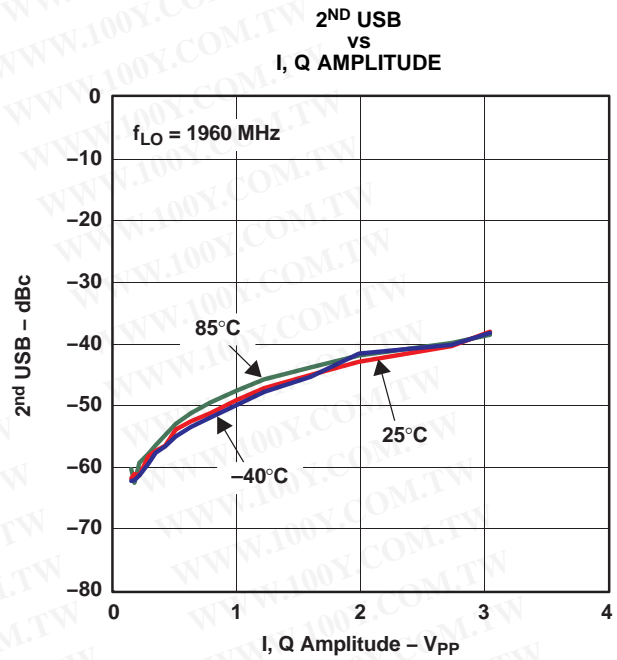


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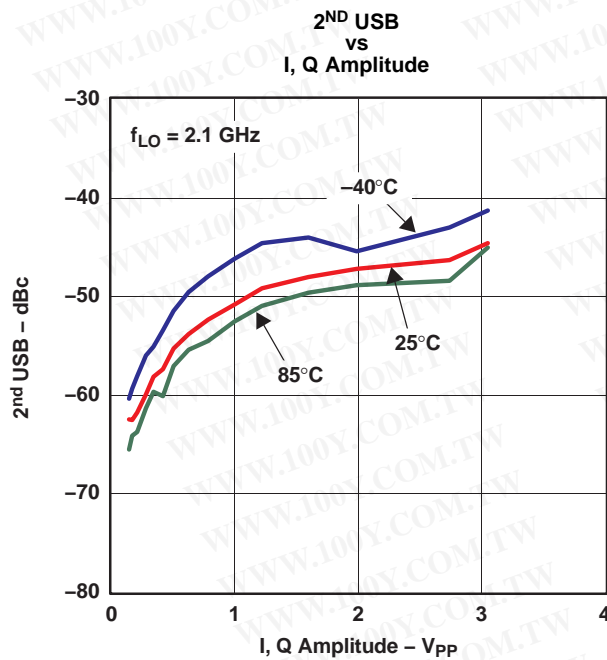


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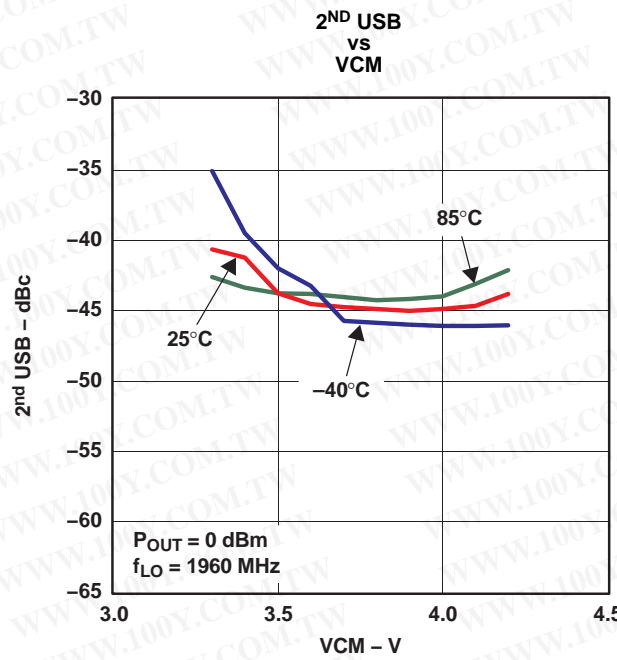


Figure 45.

TYPICAL CHARACTERISTICS (continued)

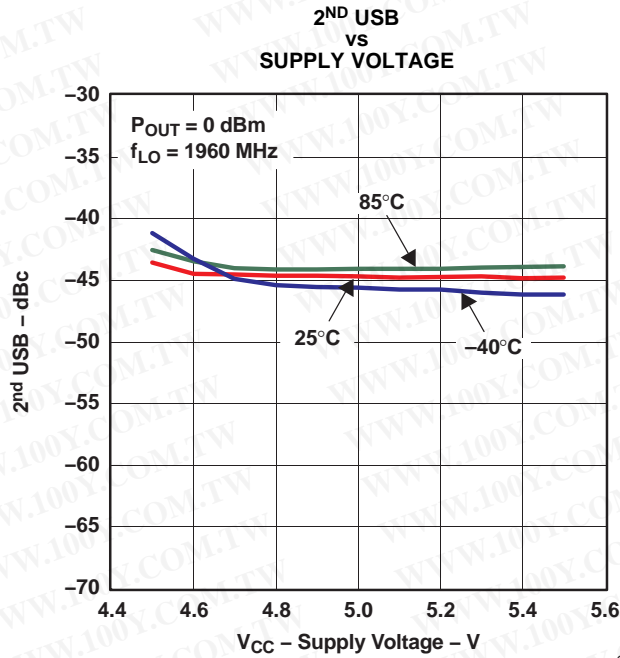


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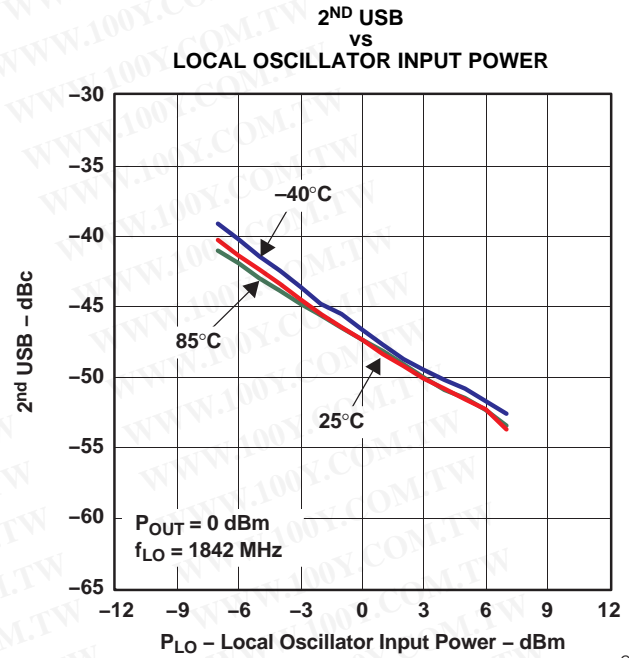


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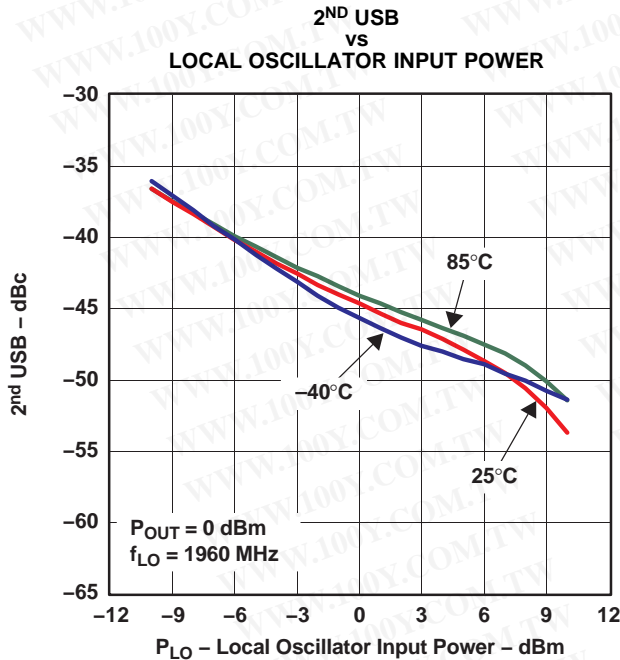


Figure 48.

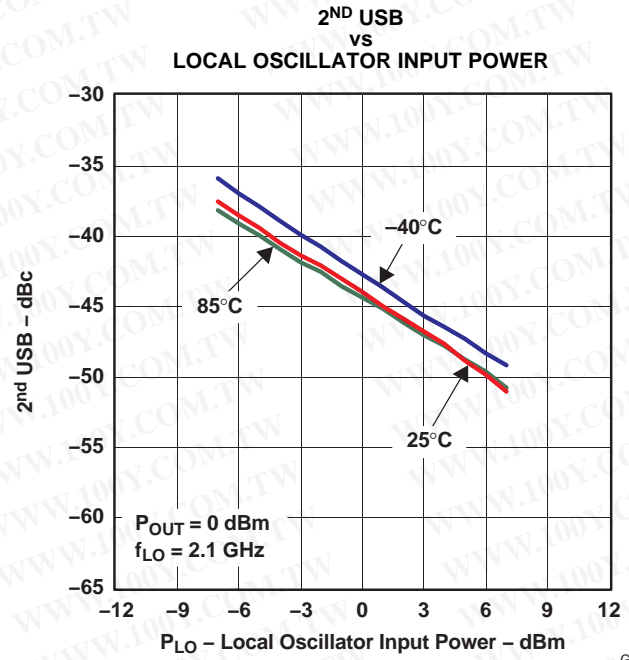


Figure 49.

TYPICAL CHARACTERISTICS (continued)

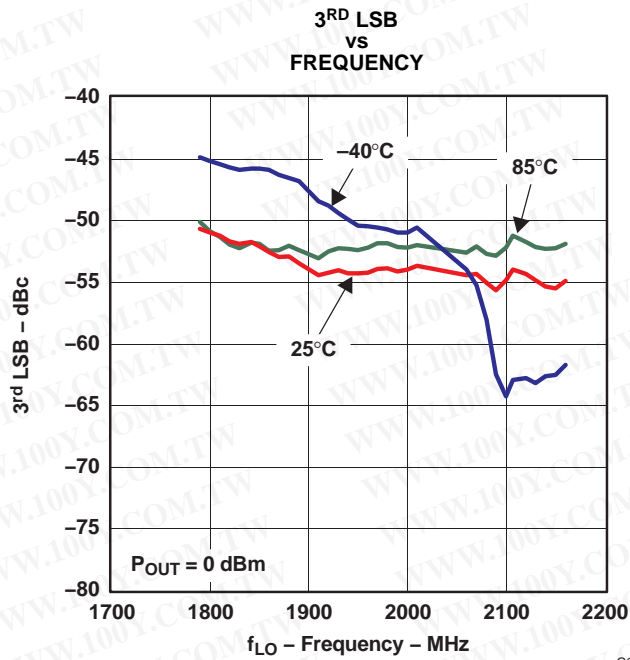


Figure 50.

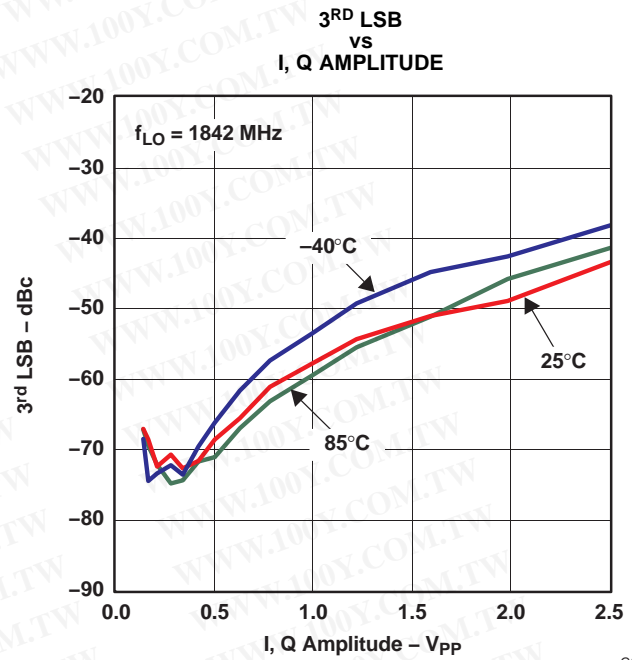


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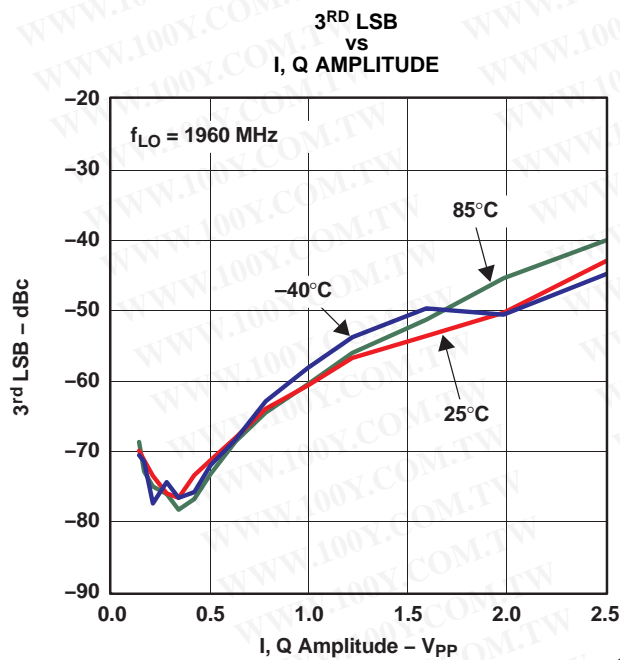


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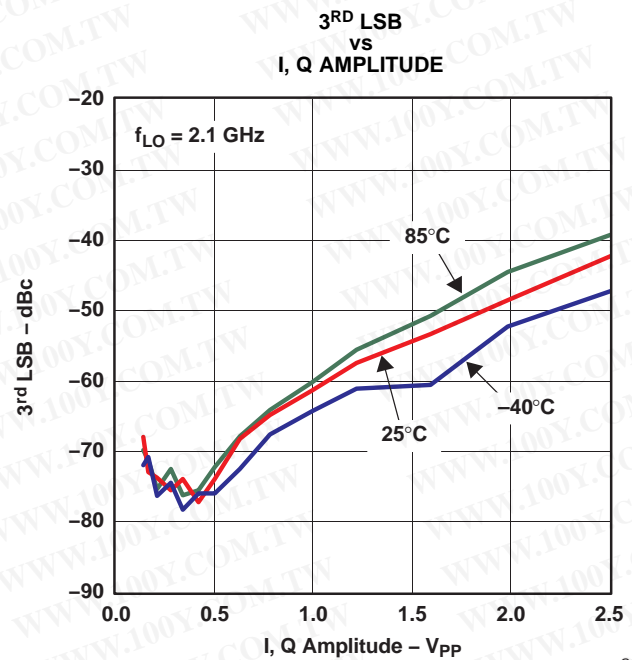


Figure 53.



TYPICAL CHARACTERISTICS (continued)

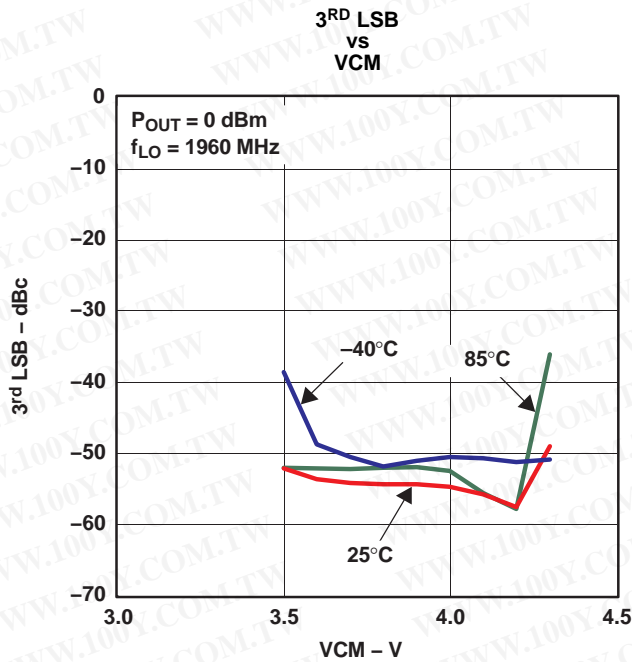


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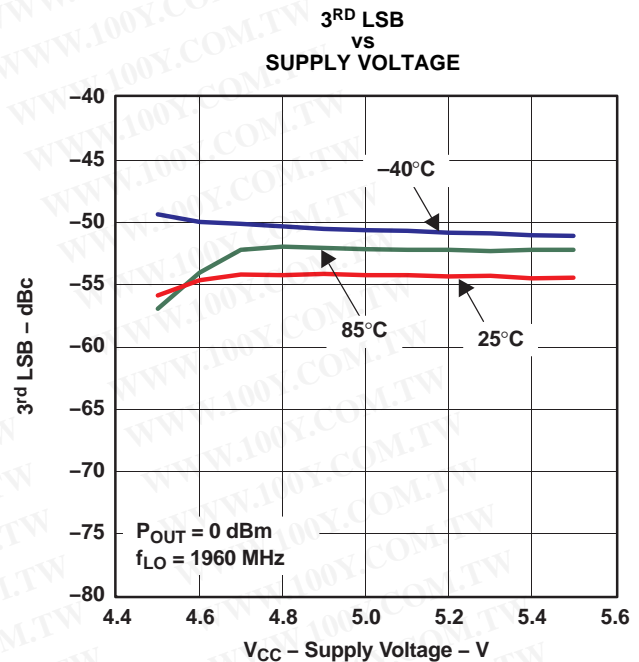


Figure 55.

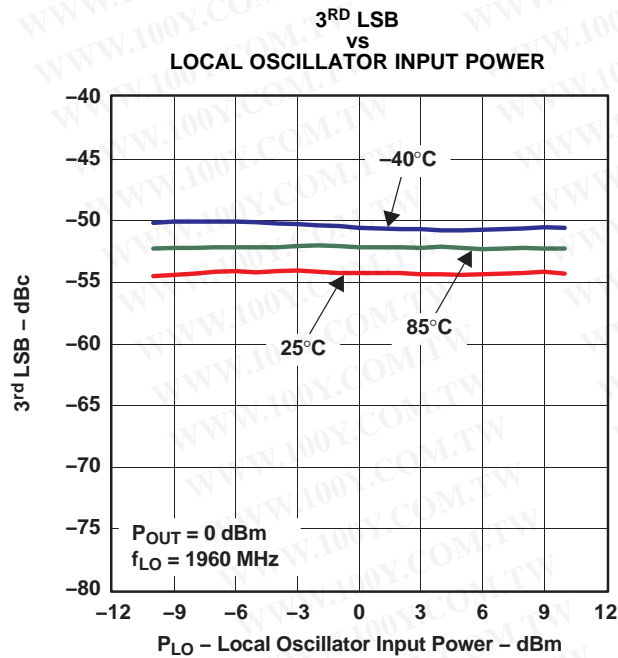


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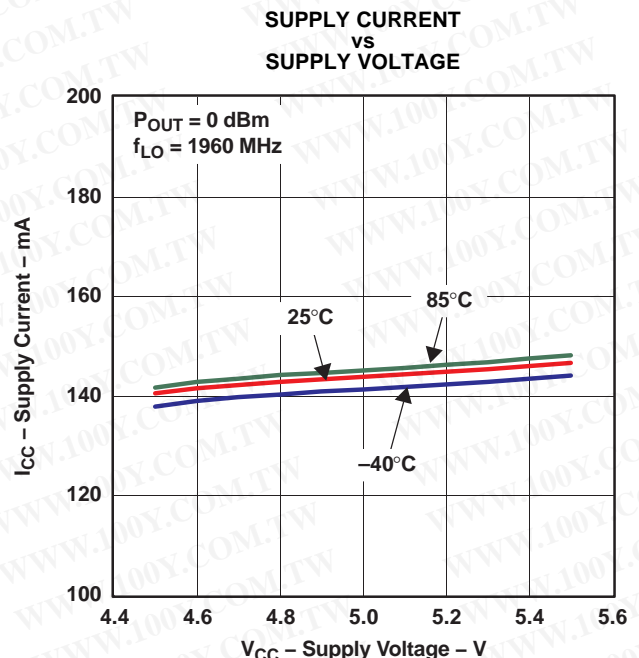


Figure 57.

TYPICAL CHARACTERISTICS (continued)

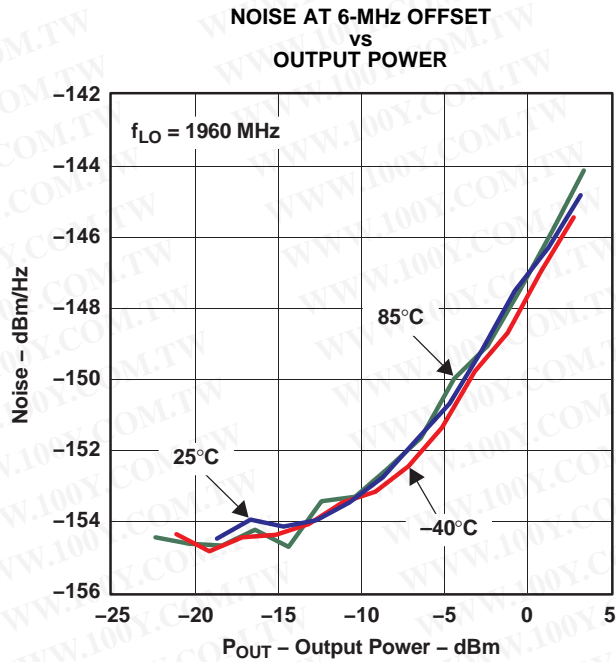


Figure 58.

G046

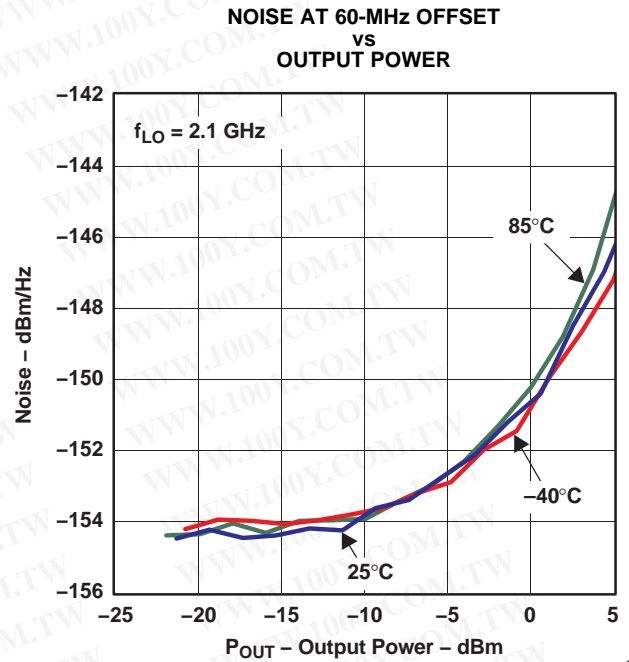


Figure 59.

G063

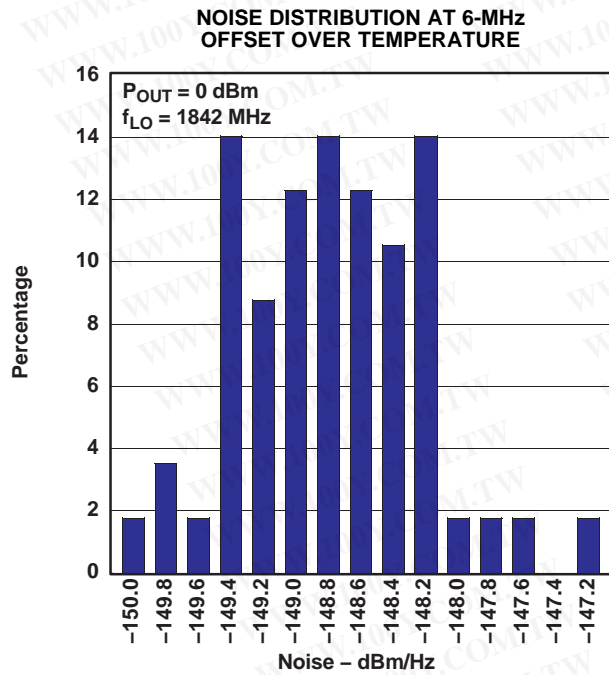


Figure 60.

G065

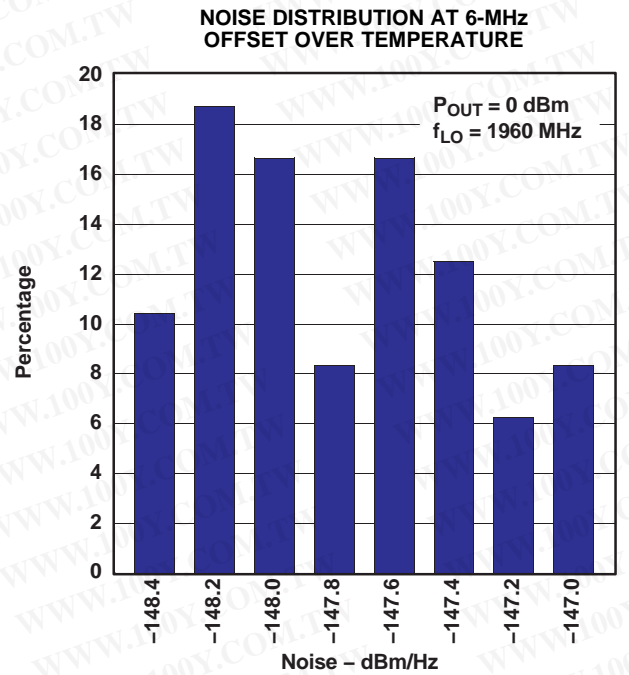


Figure 61.

G064

**TYPICAL CHARACTERISTICS (continued)**

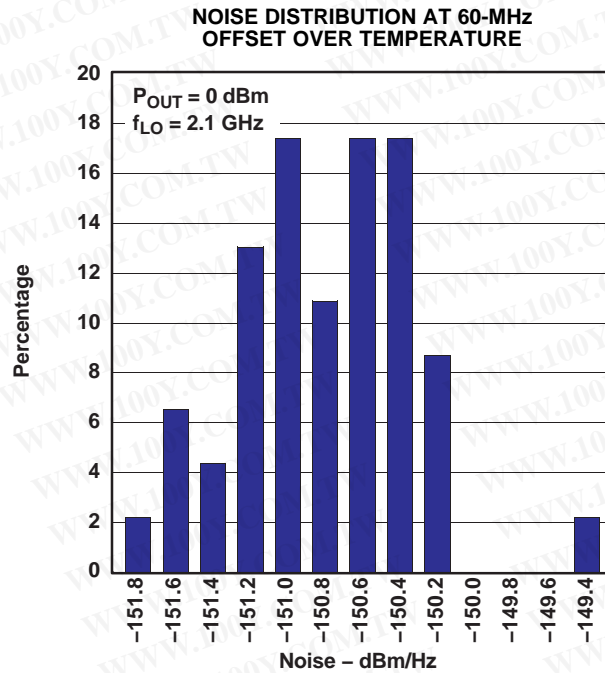


Figure 62.

**THEORY OF OPERATION**

The TRF3702 employs a double-balanced mixer architecture in implementing the direct I, Q upconversion. The I, Q inputs can be driven single-endedly or differentially, with comparable performance in both cases. The common mode level (VCM) of the four inputs (IVIN, IREF, QVIN, QREF) is typically set to 3.7 V and needs to be driven externally. These inputs go through a set of differential amplifiers and through a V-I converter to feed the double-balanced mixers. The ac-coupled LO input to the device goes through a phase splitter to provide the in-phase and quadrature signals that in turn drive the mixers. The outputs of the mixers are then summed, converted to single-ended signals, and amplified before they are fed to the output port RFOUT. The output of the TRF3702 is ac-coupled and can drive 50-Ω loads.

### EQUIVALENT CIRCUITS

Figure 63 through Figure 66 show equivalent schematics for the main inputs and outputs of the device.

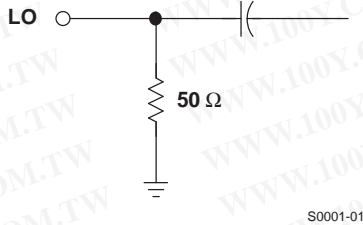


Figure 63. LO Equivalent Input Circuit

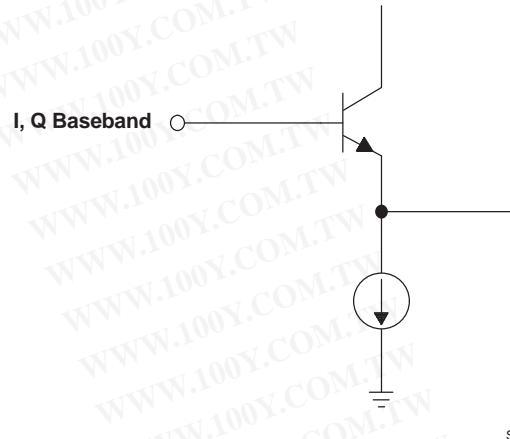


Figure 64. IVIN, QVIN, IREF, QREF Equivalent Circuit

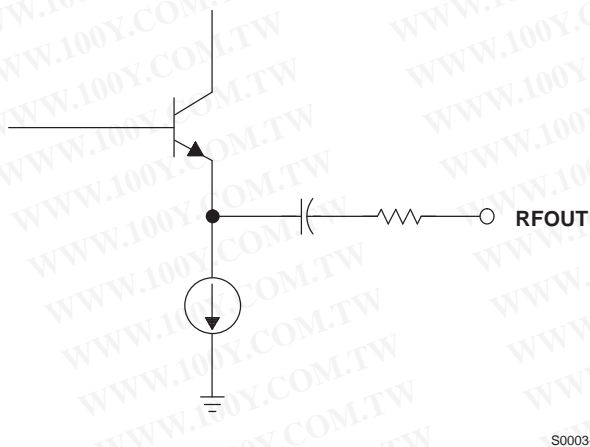


Figure 65. RFOUT Equivalent Circuit

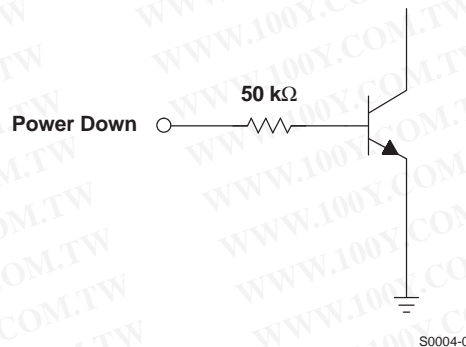


Figure 66. Power-Down (PWD) Equivalent Circuit

## APPLICATION INFORMATION

### DRIVING THE I, Q INPUTS

There are several ways to drive the four baseband inputs of the TRF3702 to the required amplitude and dc offset. The optimal configuration depends on the end application requirements and the signal levels desired by the designer.

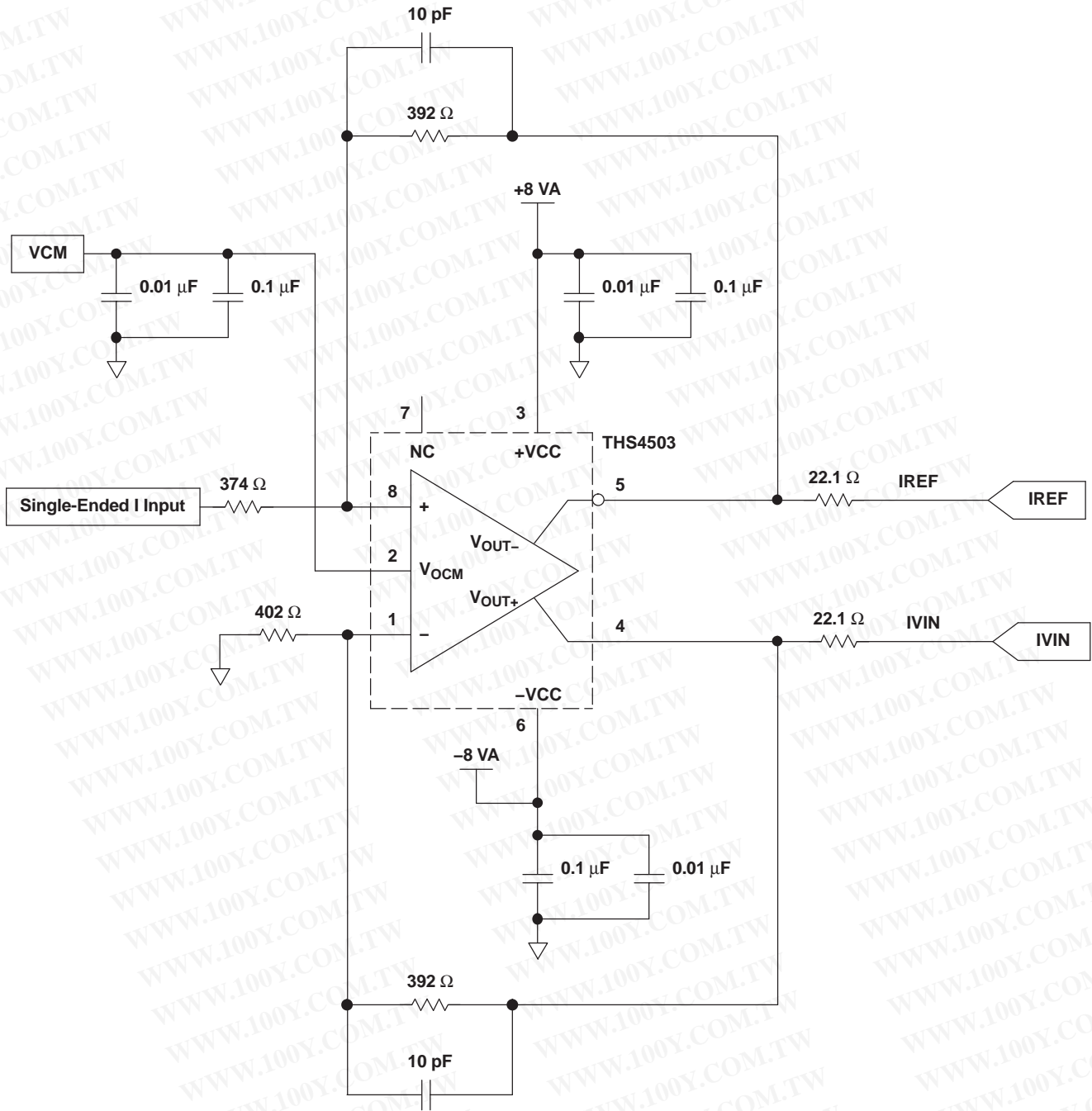
The TRF3702 is by design a differential part, meaning that ideally the user should provide fully complementary signals. However, similar performance in every respect can be achieved if the user only has single-ended signals available. In this case, the IREF and QREF pins just need to have the VCM dc offset applied.

#### Implementing a Single-to-Differential Conversion for the I, Q inputs

In case differential I, Q signals are desired but not available, the THS4503 family of wideband, low-distortion, fully differential amplifiers can be used to provide a convenient way of performing this conversion. Even if differential signals are available, the THS4503 can provide gain in case a higher voltage swing is required. Besides featuring high bandwidth and high linearity, the THS4503 also provides a convenient way of applying the VCM to all four inputs to the modulator through the VOCM pin (pin 2). The user can further adjust the dc levels for optimum carrier suppression by injecting extra dc at the inputs to the operational amplifier, or by individually adding it to the four outputs. [Figure 67](#) shows a typical implementation of the THS4503 as a driver for the TRF3702. Gain can be easily incorporated in the loop by adjusting the feedback resistors appropriately. For more details, see the THS4503 data sheet at [www.ti.com](http://www.ti.com).



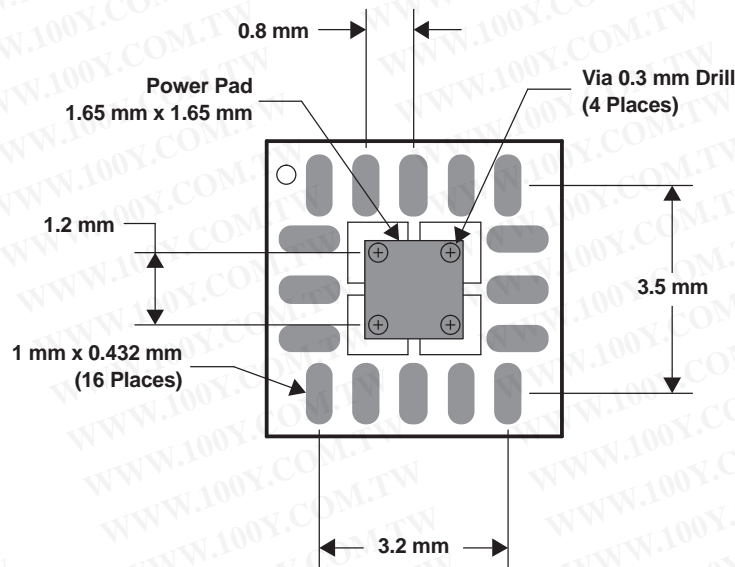
APPLICATION INFORMATION (continued)



S0005-02

Figure 67. Using the THS4503 to Condition the Baseband Inputs to the TRF3702 (I Channel Shown)



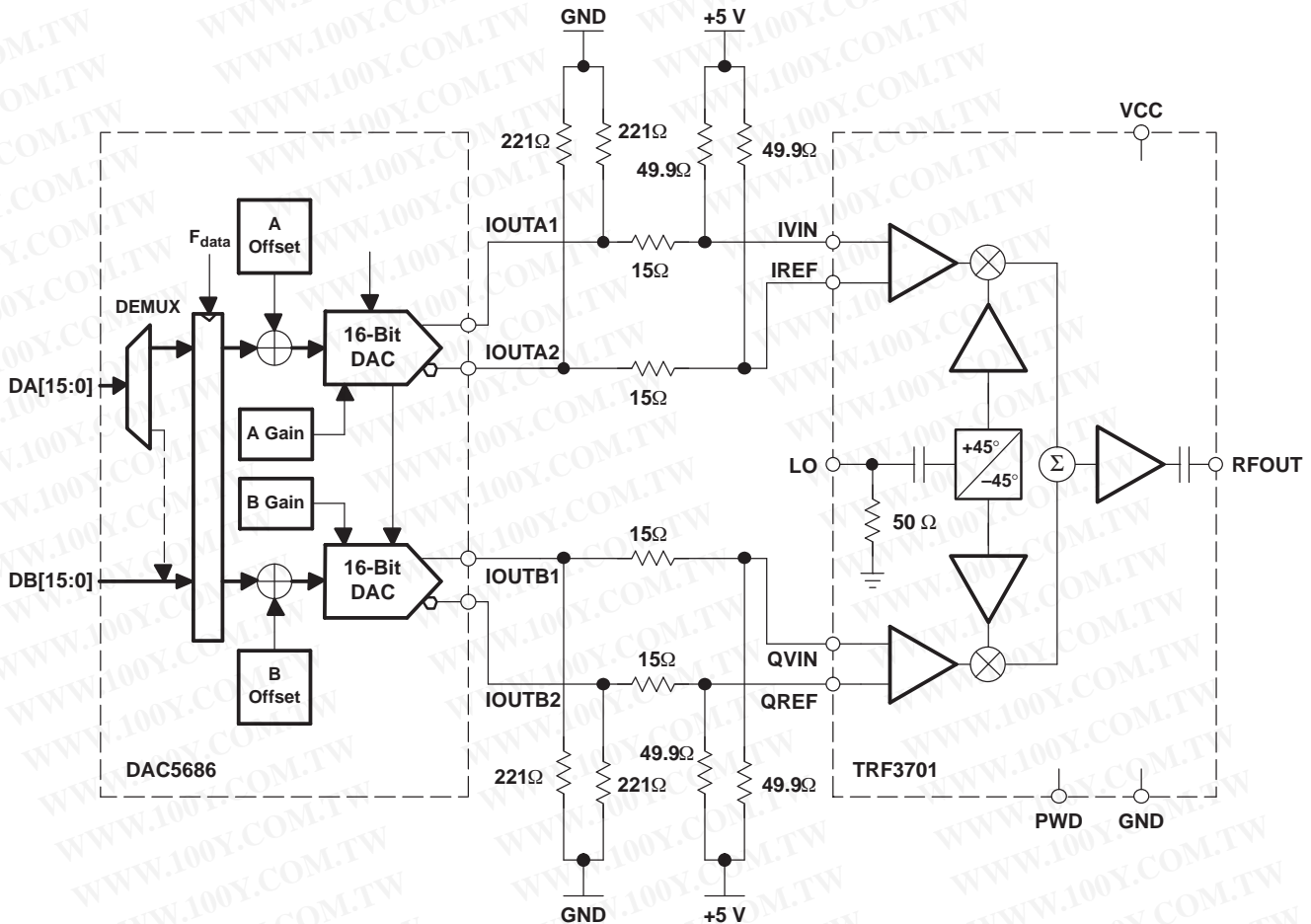
**APPLICATION INFORMATION (continued)****Figure 69. Board Layout for the TRF3702 Device****IMPLEMENTING A DIRECT UPCONVERSION TRANSMITTER USING A TI DAC**

The TRF3702 is ideal for implementing a direct upconversion transmitter, where the input I, Q data can originate from an ASIC or a DAC. Texas Instruments' line of digital-to-analog converters (DAC) is ideally suited for interfacing to the TRF3702. Such DACs include, among others, the DAC290x series, DAC5672, and DAC5686.

This section illustrates the use of the DAC5686, which offers a unique set of features that make interfacing to the TRF3702 easy and convenient. The DAC5686 is a 16-bit, 500 MSPS,  $2\times$ – $16\times$  interpolating dual-channel DAC, and it features I, Q adjustments for optimal interface to the TRF3702. User-selectable, 11-bit offset and 12-bit gain adjustments can optimize the carrier and sideband suppression of the modulator, resulting in enhanced performance and relaxed filtering requirements at RF. The preferred mode of operation of the DAC5686 for direct interface with the TRF3702 at baseband is the dual-DAC mode. The user also has the flexibility of selecting any one of the four possible complex spectral bands to be fed into the TRF3702. For details on the available modes and programming, see the DAC5686 data sheet available at [www.ti.com](http://www.ti.com).

Figure 70 shows the DAC5686 in dual-DAC mode, which is best-suited for zero-IF interface to the TRF3702. In this mode, a seamless, passive interface between the DAC output and the input to the modulator is used, so that no extra components are needed between the two devices. The optimum dc offset level for the inputs to the TRF3702 (VCM) is approximately 3.7 V. The output of the DAC should be centered around 3.3 V or less (depending on signal swing), in order to ensure that its output compliance limits are not exceeded. The resistive network shown in Figure 70 allows for this dc offset transition while still providing a dc path between the DAC output and the modulator. This ensures that the dc offset adjustments on the DAC5686 can still be applied to optimize the carrier suppression at the modulator output. The combination of the DAC5686 and the TRF3702 provides a unique signal-chain solution with state-of-the-art performance for wireless infrastructure applications.

**APPLICATION INFORMATION (continued)**



S0010-01

**Figure 70. DAC5686 in Dual-DAC Mode With Quadrature Modulator**

**GSM Applications**

The TRF3702 is ideally suited for GSM applications, because it combines high linearity with low noise levels. [Figure 60](#) and [Figure 61](#) show the distribution of noise vs output power for the TRF3702 over the entire recommended temperature range. The level of noise attained in combination with the superior IMD3 performance shown in [Figure 40](#) means that the user can reach superior levels of C/N while maintaining high linearity. This combination offers the capability of delivering low levels of EVM, meeting the stringent requirements imposed by the GSM/EDGE standards. [Figure 71](#) shows the spectral mask compliance for the device versus channel power, for both 400-kHz and 600-kHz offsets.



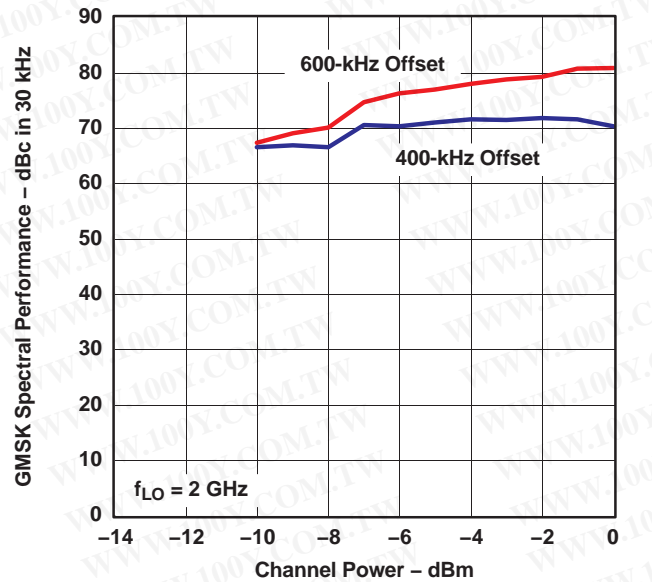
**APPLICATION INFORMATION (continued)**
**GMSK SPECTRAL PERFORMANCE  
vs  
CHANNEL POWER**


Figure 71.

G047

**WCDMA Applications**

The TRF3702 is also optimized for WCDMA applications, where both adjacent-channel power ratio (ACPR) and noise density are critically important. Figure 62 shows the noise performance of the modulator at a 60-MHz offset over temperature. In addition, Figure 72 shows the 60-MHz offset noise measured at the output of the TRF3702 versus WCDMA channel power. Using Texas Instruments' DAC568x series of high-performance digital-to-analog converters in the configuration depicted in Figure 70, state-of-the-art levels of ACPR have been measured. In each case, test model 1 was used with 64 active channels as the baseband input to the TRF3702. Figure 73 shows the performance attained for a single WCDMA carrier at 2.14 GHz, with a measured ACPR of 71.2 dBc for a channel power of -14 dBm. This unprecedented level of ACPR along with the low levels of noise at 60-MHz offset makes the TRF3702 an optimum choice for such applications. Figure 74 shows the single-carrier WCDMA ACPR performance versus channel power; it is important to note that even at high output power levels, the TRF3702 maintains great linearity, offering 64 dBc of ACPR at an output-channel power of -8 dBm.



**APPLICATION INFORMATION (continued)**

**NOISE AT 60-MHz OFFSET  
VS  
WCDMA CHANNEL POWER**

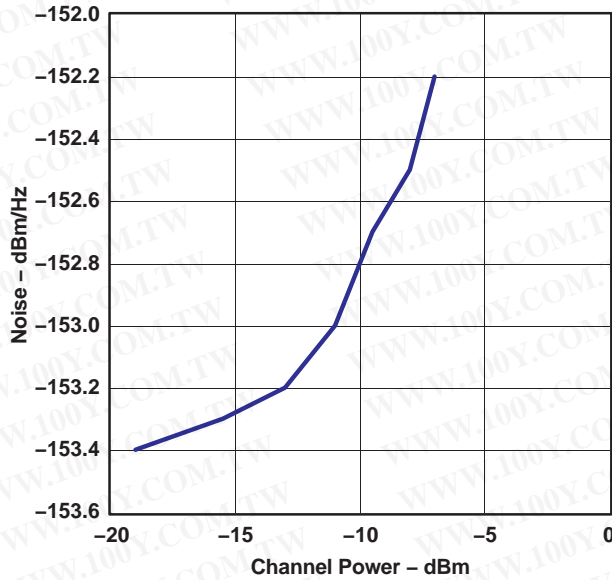


Figure 72.

**SINGLE-CARRIER WCDMA PERFORMANCE**

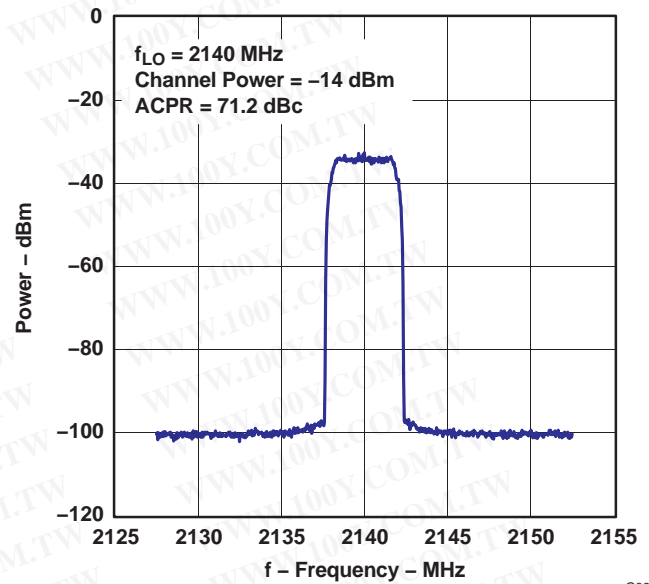


Figure 73.

**SINGLE-CARRIER WCDMA ACPR  
VS  
CHANNEL POWER**

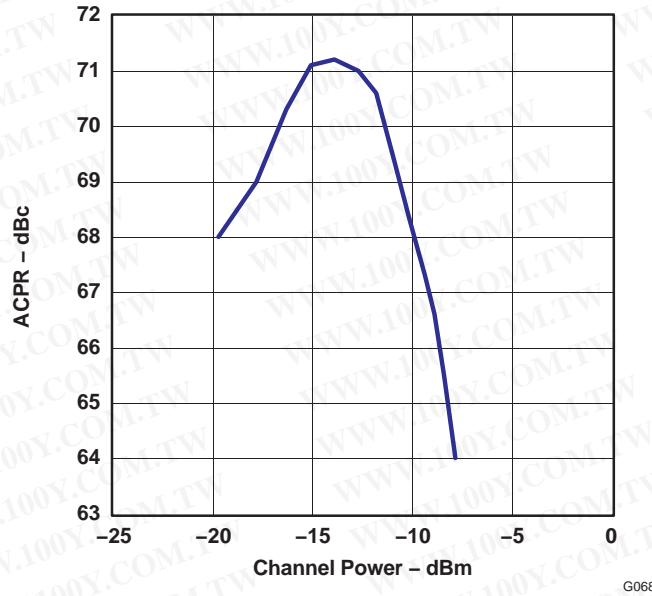


Figure 74.

**APPLICATION INFORMATION (continued)**

The TRF3702 can also be used for multicarrier applications, as is illustrated in Figure 75. For a 4-carrier case at a total output power of  $-16.7$  dBm, an ACPR of almost 63 dBc can be reached. Figure 76 shows the ACPR profile for a 4-carrier WCDMA application versus per-carrier channel power. Further improvements in performance can be achieved by including a low-pass filter between the output of the DAC and the input to the TRF3702, based on the frequency planning and specific requirements of a given design. The combination of the TRF3702, the DAC568x, and the TRF3750 provides a unique signal-chain chipset capable of delivering state-of-the-art levels of performance for the most challenging WCDMA applications.

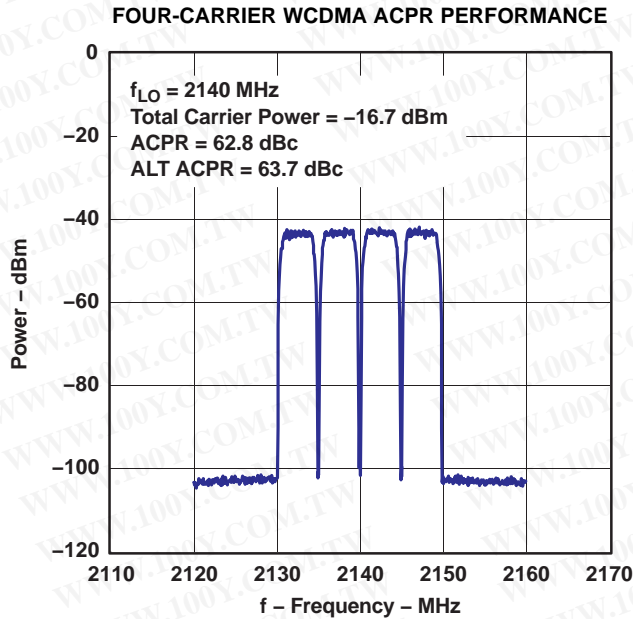


Figure 75.

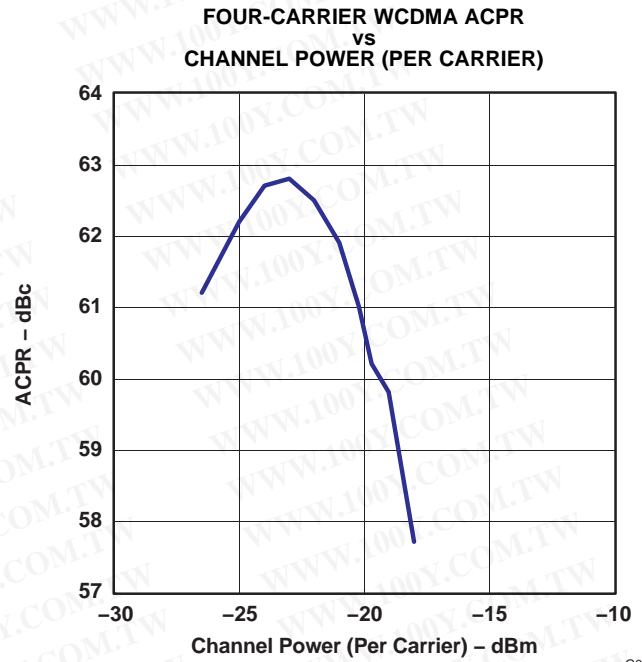


Figure 76.

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TRF3702IRHC      | ACTIVE                | VQFN         | RHC             | 16   | 92          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| TRF3702IRHCG4    | ACTIVE                | VQFN         | RHC             | 16   | 92          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| TRF3702IRHCR     | ACTIVE                | VQFN         | RHC             | 16   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| TRF3702IRHCRG4   | ACTIVE                | VQFN         | RHC             | 16   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |

<sup>(1)</sup> 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.

<sup>(2)</sup> 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)

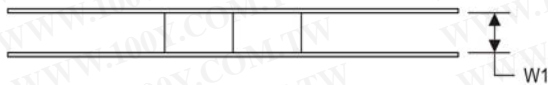
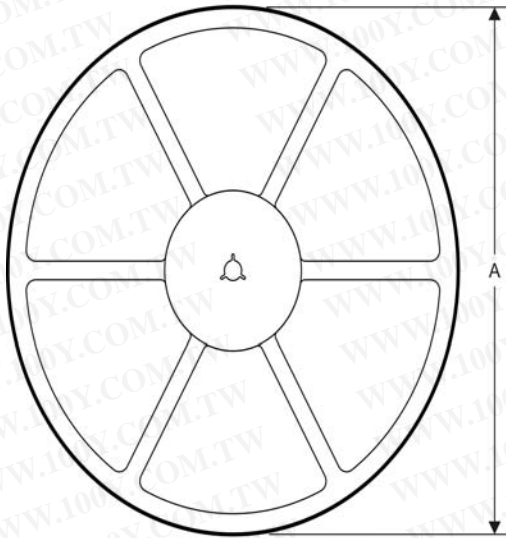
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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TAPE AND REEL INFORMATION

REEL DIMENSIONS

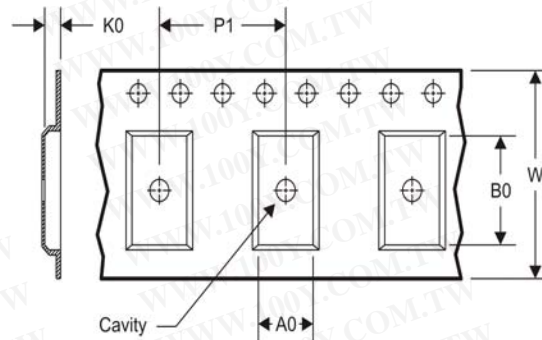


TAPE AND REEL INFORMATION

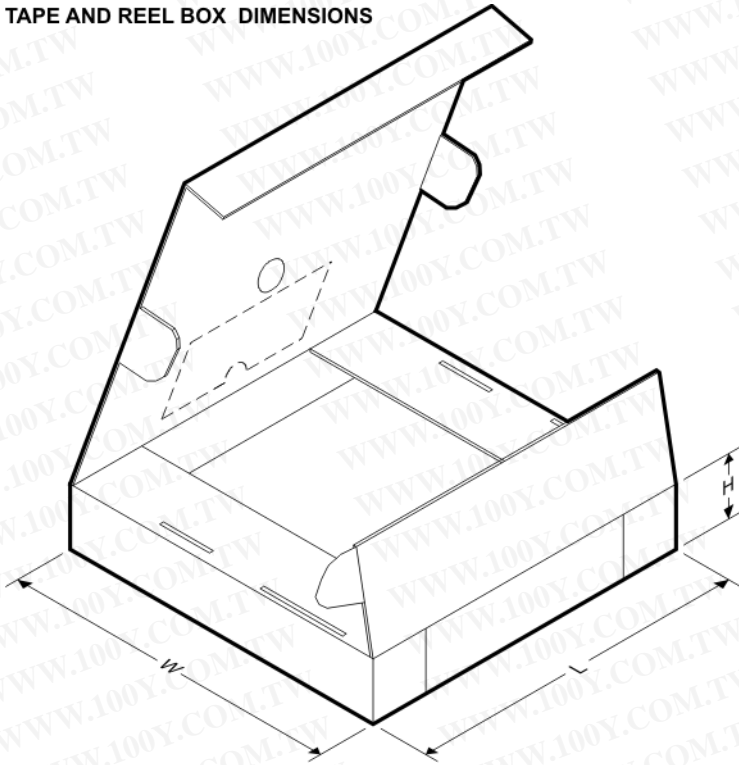
\*All dimensions are nominal

| 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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TRF3702IRHCR | VQFN         | RHC             | 16   | 3000 | 330.0              | 12.4               | 4.3     | 4.3     | 1.5     | 8.0     | 12.0   | Q1            |

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                   |

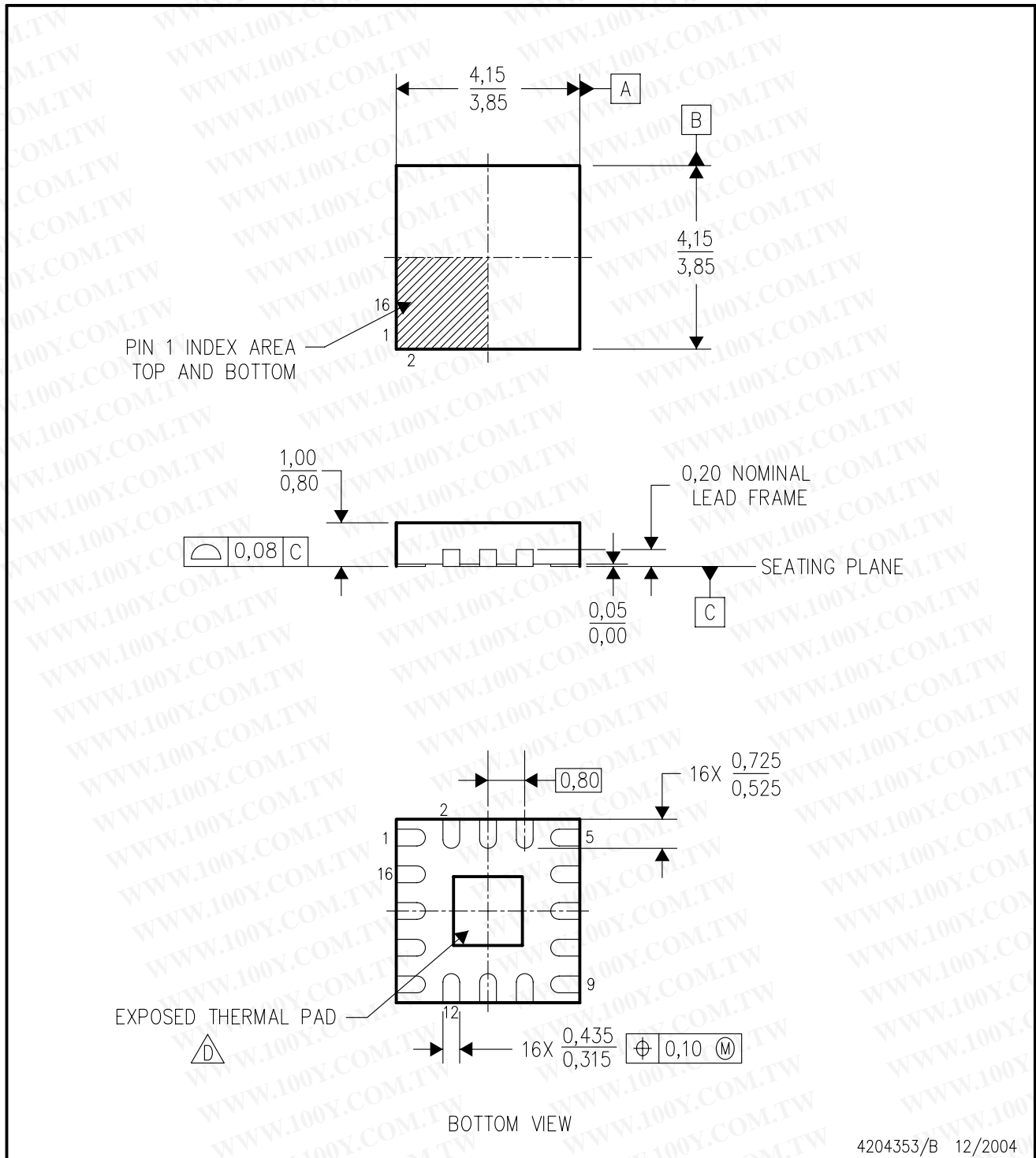
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal


| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TRF3702IRHCR | VQFN         | RHC             | 16   | 3000 | 338.1       | 338.1      | 20.6        |



RHC (S-PQFP-N16) (CUSTOM PACKAGE) PLASTIC QUAD FLATPACK



4204353/B 12/2004

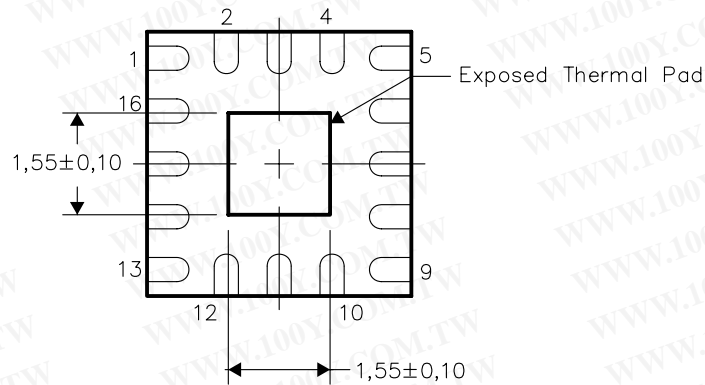
- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. QFN (Quad Flatpack No-Lead) Package configuration.
  -  The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.

**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, Quad Flatpack No-Lead Logic Packages, Texas Instruments Literature No. SCBA017. This document is available at [www.ti.com](http://www.ti.com).

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



Bottom View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

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勝特力电子(上海) 86-21-34970699  
勝特力电子(深圳) 86-755-83298787  
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