

INTEGRATED IQ DEMODULATOR

 Check for Samples: [TRF371135](#)

FEATURES

- Frequency Range: 1700 MHz to 6000 MHz
- Integrated Baseband Programmable-Gain Amplifier
- On-Chip Programmable Baseband Filter
- High Out-of-Band IP3: 22 dBm at 3550 MHz
- High Out-of-Band IP2: 52 dBm at 3550 MHz
- Hardware and Software Power Down
- Three-Wire Serial Interface
- Single Supply: 4.5-V to 5.5-V Operation
- Silicon Germanium Technology

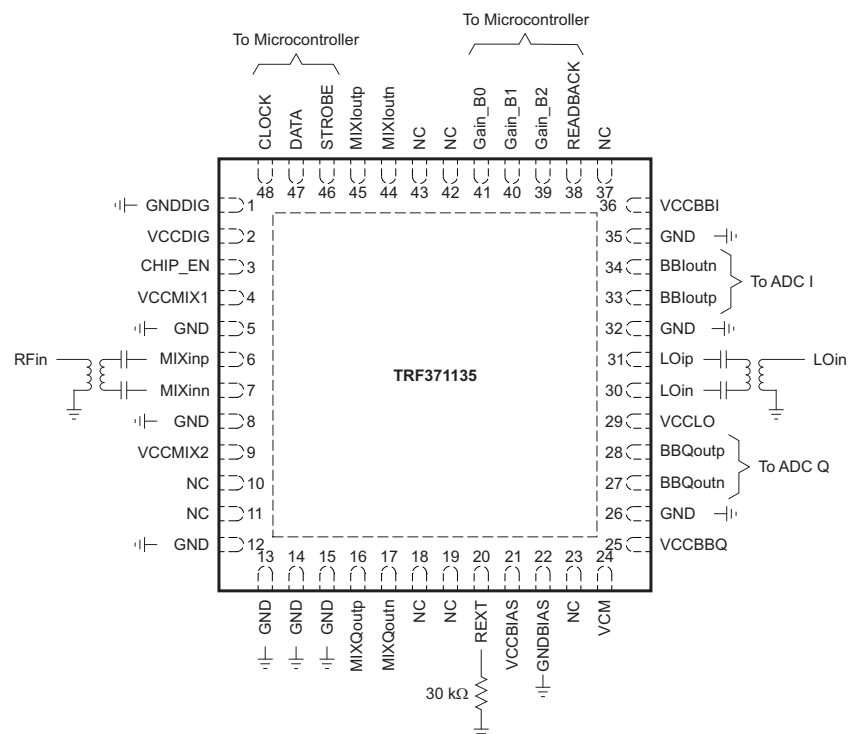
APPLICATIONS

- Multicarrier Wireless Infrastructure
- WiMAX
- High-Linearity Direct-Downconversion Receiver
- LTE (Long Term Evolution)

DESCRIPTION

The TRF371135 is a highly linear and integrated direct-conversion quadrature demodulator. The TRF371135 integrates balanced I and Q mixers, LO buffers, and phase splitters to convert an RF signal directly to I and Q baseband. The on-chip programmable-gain amplifiers allow adjustment of the output signal level without the need for external variable-gain (attenuator) devices. The TRF371135 integrates programmable baseband low-pass filters that attenuate nearby interference, eliminating the need for an external baseband filter.

Housed in a 7-mm × 7-mm QFN package, the TRF371135 provides the smallest and most integrated receiver solution available for high-performance equipment.



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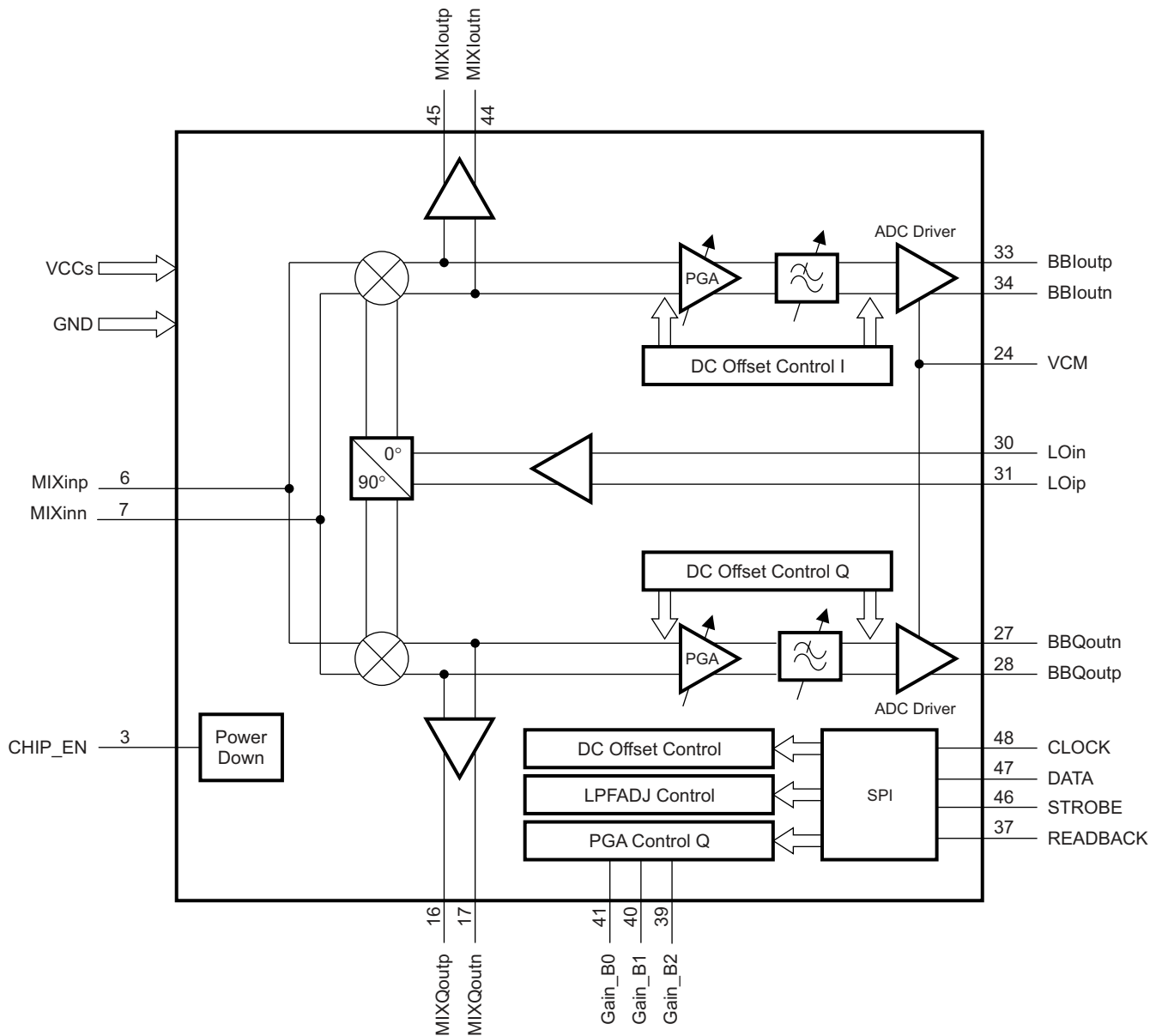


These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

AVAILABLE DEVICE OPTIONS⁽¹⁾

| PRODUCT | PACKAGE LEAD | PACKAGE DESIGNATOR(1) | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKINGS | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|-----------|--------------|-----------------------|-----------------------------|------------------|-----------------|---------------------------|
| TRF371135 | QFN-48 | RGZ | -40°C to 85°C | TRF371135 | TRF371135IRGZR | Tape and reel, 2500 |
| | | | | | TRF371135IRGZT | Tape and reel, 500 |

FUNCTIONAL DIAGRAM

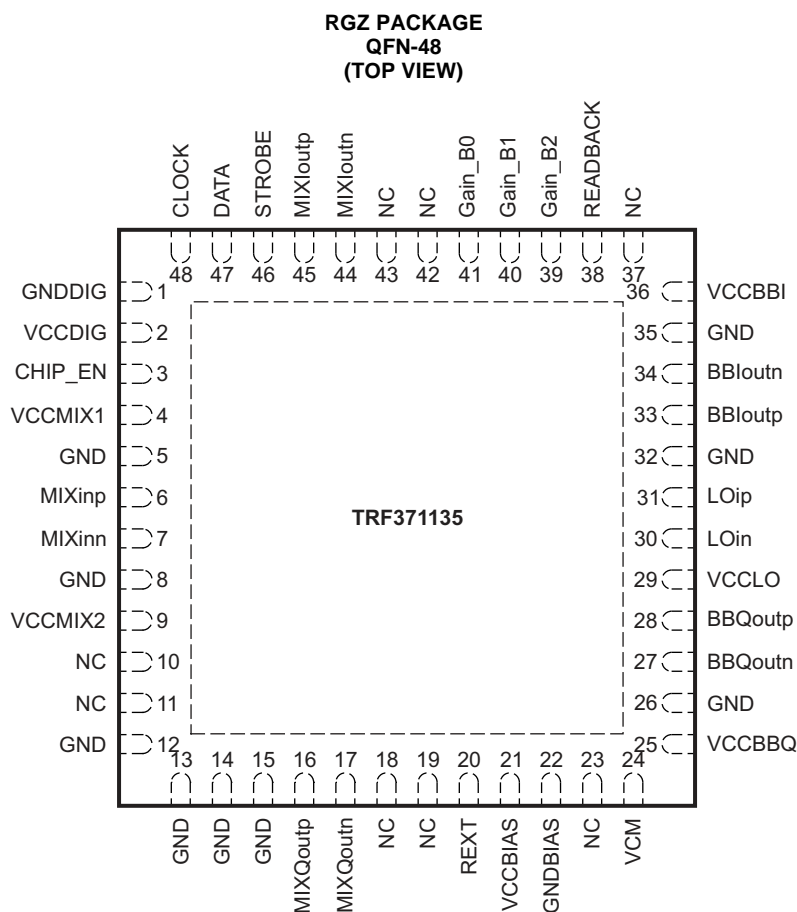


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(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

DEVICE INFORMATION

PIN ASSIGNMENTS



PIN FUNCTIONS

| PIN | | I/O | DESCRIPTION |
|-----|---------|-----|--------------------------------|
| NO. | NAME | | |
| 1 | GNDDIG | | Digital ground |
| 2 | VCCDIG | | Digital power supply |
| 3 | CHIP_EN | I | Chip enable |
| 4 | VCCMIX1 | | Mixer power supply |
| 5 | GND | | Ground |
| 6 | MIXinp | I | Mixer input: positive terminal |
| 7 | MIXinn | I | Mixer input: negative terminal |
| 8 | GND | | Ground |
| 9 | VCCMIX2 | | Mixer power supply |
| 10 | NC | | No connect |
| 11 | NC | | No connect |
| 12 | GND | | Ground |
| 13 | GND | | Ground |
| 14 | GND | | Ground |
| 15 | GND | | Ground |

PIN FUNCTIONS (continued)

| PIN | | I/O | DESCRIPTION |
|-----|----------|-----|--|
| NO. | NAME | | |
| 16 | MIXQoutp | O | Mixer Q output: positive terminal |
| 17 | MIXQoutn | O | Mixer Q output: negative terminal |
| 18 | NC | | No connect |
| 19 | NC | | No connect |
| 20 | REXT | O | Reference bias external resistor |
| 21 | VCCBIAS | | Bias block power supply |
| 22 | GNDBIAS | | Bias block ground |
| 23 | NC | | No connect |
| 24 | VCM | I | Baseband common-mode input voltage |
| 25 | VCCBBQ | | Baseband Q chain power supply |
| 26 | GND | | Ground |
| 27 | BBQoutn | O | Baseband Q (in quadrature) output: negative terminal |
| 28 | BBQoutp | O | Baseband Q (in quadrature) output: positive terminal |
| 29 | VCCLO | | Local oscillator power supply |
| 30 | LOin | I | Local oscillator input: negative terminal |
| 31 | LOip | I | Local oscillator input: positive terminal |
| 32 | GND | | Ground |
| 33 | BBIoutp | O | Baseband I (in-phase) output: positive terminal |
| 34 | BBIoutn | O | Baseband I (in-phase) output: negative terminal |
| 35 | GND | | Ground |
| 36 | VCCBBI | | Baseband I (in phase) power supply |
| 37 | NC | | No connect |
| 38 | READBACK | O | SPI readback data |
| 39 | Gain_B2 | I | PGA fast gain control bit 2 |
| 40 | Gain_B1 | I | PGA fast gain control bit 1 |
| 41 | Gain_B0 | I | PGA fast gain control bit 0 |
| 42 | NC | | No connect |
| 43 | NC | | No connect |
| 44 | MIXIoutn | O | Mixer I output: negative terminal |
| 45 | MIXIoutp | O | Mixer I output: positive terminal |
| 46 | STROBE | I | SPI enable |
| 47 | DATA | I | SPI data input |
| 48 | CLOCK | I | SPI clock input |

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| | VALUE | UNIT |
|--|------------|------|
| Supply voltage range ⁽²⁾ | –0.3 to 6 | V |
| Digital I/O voltage range | –0.3 to 6 | V |
| Operating free-air temperature range, T _A | –40 to 85 | °C |
| Operating virtual junction temperature range, T _J | –40 to 150 | °C |
| Storage temperature range, T _{stg} | –65 to 150 | °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) 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 |
| Power-supply voltage ripple | | | 940 | μV _{PP} |
| T _A Operating free-air temperature range | –40 | | 85 | °C |
| T _J Operating virtual junction temperature range | –40 | | 150 | °C |

THERMAL CHARACTERISTICS

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------------------|---|--------------------------------|-----|------|-----|------|
| R _{θJA} | Thermal resistance, junction-to-ambient | Soldered slug, no airflow | | 26 | | °C/W |
| | | Soldered slug, 200-LFM airflow | | 20.1 | | |
| | | Soldered slug, 400-LFM airflow | | 17.4 | | |
| R _{θJA} ⁽²⁾ | | | | 25 | | |
| R _{θJB} | Thermal resistance, junction-to-board | | | 12 | | °C/W |

(1) Determined using JEDEC standard JESD-51 with high-K board

(2) 16 layers, high-K board

ELECTRICAL CHARACTERISTICS

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETERS | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|---|---------------------|------|---------------------|--------------------|
| DC PARAMETERS | | | | | | |
| I_{CC} | Total supply current | | | 370 | | mA |
| | Power-down current | | | 2 | | mA |
| IQ DEMODULATOR AND BASEBAND SECTION | | | | | | |
| f_{RF} | Frequency range | | 1700 | | 6000 | MHz |
| | Gain range | | 22 | 24 | | dB |
| | Gain step | See ⁽¹⁾ | | 1 | | dB |
| $P_{in_{max}}$ | Max. RF power input | Before damage | | 25 | | dBm |
| OIP3 | Output third-order intercept point | Gain setting = 24 ⁽²⁾ | | 30 | | dBV _{RMS} |
| P1dB _{min} | Min. output compression point | 1 tone ⁽³⁾ | | 3 | | dBV _{RMS} |
| f_{min} | Min. baseband low-pass filter cutoff frequency | 1-dB point ⁽⁴⁾ | | 700 | | kHz |
| f_{max} | Max. baseband low-pass filter cutoff frequency | 3-dB point ⁽⁴⁾ | 15 | | | MHz |
| f_{bypass} | Baseband low-pass filter cutoff frequency in bypass mode | 3-dB point ⁽⁵⁾ | | 30 | | MHz |
| F_{sel} | Baseband relative attenuation at LPF cutoff frequency (f_C) ⁽⁶⁾ | $1 \times f_C$ | | 1 | | dB |
| | | $1.5 \times f_C$ | | 8 | | |
| | | $2 \times f_C$ | | 32 | | |
| | | $3 \times f_C$ | | 54 | | |
| | | $4 \times f_C$ | | 75 | | |
| | | $5 \times f_C$ | | 90 | | |
| | Image suppression | $f_{LO} = 3550\text{ MHz}$ | | -35 | | dB |
| | Output BB attenuator | | | 3 | | dB |
| | Output load impedance | Parallel resistance | | 1 | | k Ω |
| | | Parallel capacitance | | 20 | | pF |
| V_{cm} | Output, common-mode | Measured at I- and Q-channel baseband outputs | | 1.5 | | V |
| | Baseband harmonic level | Second harmonic ⁽⁷⁾ | | -95 | | dBc |
| | | Third harmonic ⁽⁷⁾ | | -103 | | dBc |
| LOCAL OSCILLATOR PARAMETERS | | | | | | |
| | Local oscillator frequency | | 1700 | | 6000 | MHz |
| | LO input level | See ⁽⁸⁾ | -3 | 0 | 6 | dBm |
| | LO leakage | At MIXinn/p at 0-dBm LO drive level | | -58 | | dBm |
| DIGITAL INTERFACE | | | | | | |
| V_{IH} | High-level input voltage | | $0.6 \times V_{CC}$ | 5 | V_{CC} | V |
| V_{IL} | Low-level input voltage | | 0 | | 0.8 | V |
| V_{OH} | High-level output voltage | | $0.8 \times V_{CC}$ | | | V |
| V_{OL} | Low-level output voltage | | | | $0.2 \times V_{CC}$ | V |

- (1) Two consecutive gain settings
- (2) Two CW tones at an offset from LO frequency smaller than the baseband-filter cutoff frequency. Performance is set by baseband circuitry regardless of LO frequency.
- (3) Single CW tone at an offset from LO frequency smaller than the baseband-filter cutoff frequency. Performance is set by baseband circuitry regardless of LO frequency.
- (4) Baseband low-pass filter cutoff frequency is programmable through SPI register LPFADJ. LPFADJ = 0 corresponds to maximum bandwidth; LPFADJ = 255 corresponds to minimum BW.
- (5) Filter Ctrl setting equal to 0
- (6) Attenuation relative to passband gain
- (7) LO frequency set to 3.55 GHz. I or Q output power level -6 dBV_{RMS} differential. Gain setting at 24. DC offset calibration engaged. Input signal set at 1-MHz offset.
- (8) LO power outside of this range is possible but may introduce degraded performance.

ELECTRICAL CHARACTERISTICS

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}^{(1)}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|------------------------------------|-------------------------------------|-----|------|-----|------|
| $f_{LO} = 1740\text{ MHz}$ | | | | | | |
| G_{max} | Maximum gain ⁽²⁾ | Gain setting = 24 | | 45 | | dB |
| NF | Noise figure | Gain setting = 24 | | 10 | | dB |
| IIP3 | Third-order input intercept point | Gain setting = 24 ⁽³⁾⁽⁴⁾ | | 19 | | dBm |
| IIP2 | Second-order input intercept point | Gain setting = 24 ⁽⁴⁾⁽⁵⁾ | | 60 | | dBm |
| $f_{LO} = 1950\text{ MHz}$ | | | | | | |
| G_{max} | Maximum gain ⁽²⁾ | Gain setting = 24 | | 44.3 | | dB |
| NF | Noise figure | Gain setting = 24 | | 10.5 | | dB |
| IIP3 | Third-order input intercept point | Gain setting = 24 ⁽³⁾⁽⁴⁾ | | 20 | | dBm |
| IIP2 | Second-order input intercept point | Gain setting = 24 ⁽⁴⁾⁽⁵⁾ | | 57 | | dBm |
| $f_{LO} = 2025\text{ MHz}$ | | | | | | |
| G_{max} | Maximum gain ⁽²⁾ | Gain setting = 24 | | 44 | | dB |
| NF | Noise figure | Gain setting = 24 | | 11 | | dB |
| IIP3 | Third-order input intercept point | Gain setting = 24 ⁽³⁾⁽⁴⁾ | | 21 | | dBm |
| IIP2 | Second-order input intercept point | Gain Setting = 24 ⁽⁴⁾⁽⁵⁾ | | 57 | | dBm |
| $f_{LO} = 2400\text{ MHz}$ | | | | | | |
| G_{max} | Maximum gain ⁽²⁾ | Gain setting = 24 | | 43 | | dB |
| N3F | Noise figure | Gain setting = 24 | | 12 | | dB |
| IIP3 | Third-order input intercept point | Gain setting = 24 ⁽³⁾⁽⁴⁾ | | 23.5 | | dBm |
| IIP2 | Second-order input intercept point | Gain setting = 24 ⁽⁴⁾⁽⁵⁾ | | 58 | | dBm |
| $f_{LO} = 3550\text{ MHz}$ | | | | | | |
| G_{max} | Maximum gain ⁽²⁾ | Gain setting = 24 | | 40 | | dB |
| NF | Noise figure | Gain setting = 24 | | 13.8 | | dB |
| | | Gain setting = 16 | | 15 | | dB |
| IIP3 | Third-order input intercept point | Gain setting = 24 ⁽³⁾⁽⁴⁾ | | 22 | | dBm |
| IIP2 | Second-order input intercept point | Gain setting = 24 ⁽⁴⁾⁽⁵⁾ | | 52 | | dBm |
| $f_{LO} = 5400\text{ MHz}$ | | | | | | |
| G_{max} | Maximum gain ⁽²⁾ | Gain setting = 24 | | 37.5 | | dB |
| NF | Noise figure | Gain setting = 24 | | 17.5 | | dB |
| IIP3 | Third-order input intercept point | Gain setting = 24 ⁽³⁾⁽⁴⁾ | | 22 | | dBm |
| IIP2 | Second-order input intercept point | Gain setting = 24 ⁽⁴⁾⁽⁵⁾ | | 60 | | dBm |

(1) For broadband frequency sweeps, the Picosecond balun (model #5310A) is used at the RF and LO inputs. For the frequency band between 3300 MHz and 3800 MHz, the Johanson 3600BL14M050E balun is used. For the frequency band between 4900 MHz and 5900 MHz the Johanson 5400BL15B050E balun is used. Performance parameters adjusted for balun insertion loss. Recommended baluns for respective frequency bands are shown as follows:

1740 MHz: Murata LDB211G8005C-001 (or equivalent)

1950 MHz: Murata LDB211G9005C-001 (or equivalent)

2025 MHz: Murata LDB211G9005C-001 (or equivalent)

2500 MHz: Murata LDB212G4005C-001 (or equivalent)

3550 MHz: Johanson 3600BL14M050E (or equivalent)

5400 MHz: Johanson 5400BL15B050E (or equivalent)

(2) Gain defined as voltage gain from Mixin (V_{RMS}) to either baseband output: BBI/Qout (V_{RMS})

(3) Two CW tones of -30 dBm at $f_{RF1} = f_{LO} \pm(2 \times f_C)$ and $f_{RF2} = f_{LO} \pm[(4 \times f_C) + 100\text{ kHz}]$ (f_C = baseband filter 1-dB cutoff frequency).

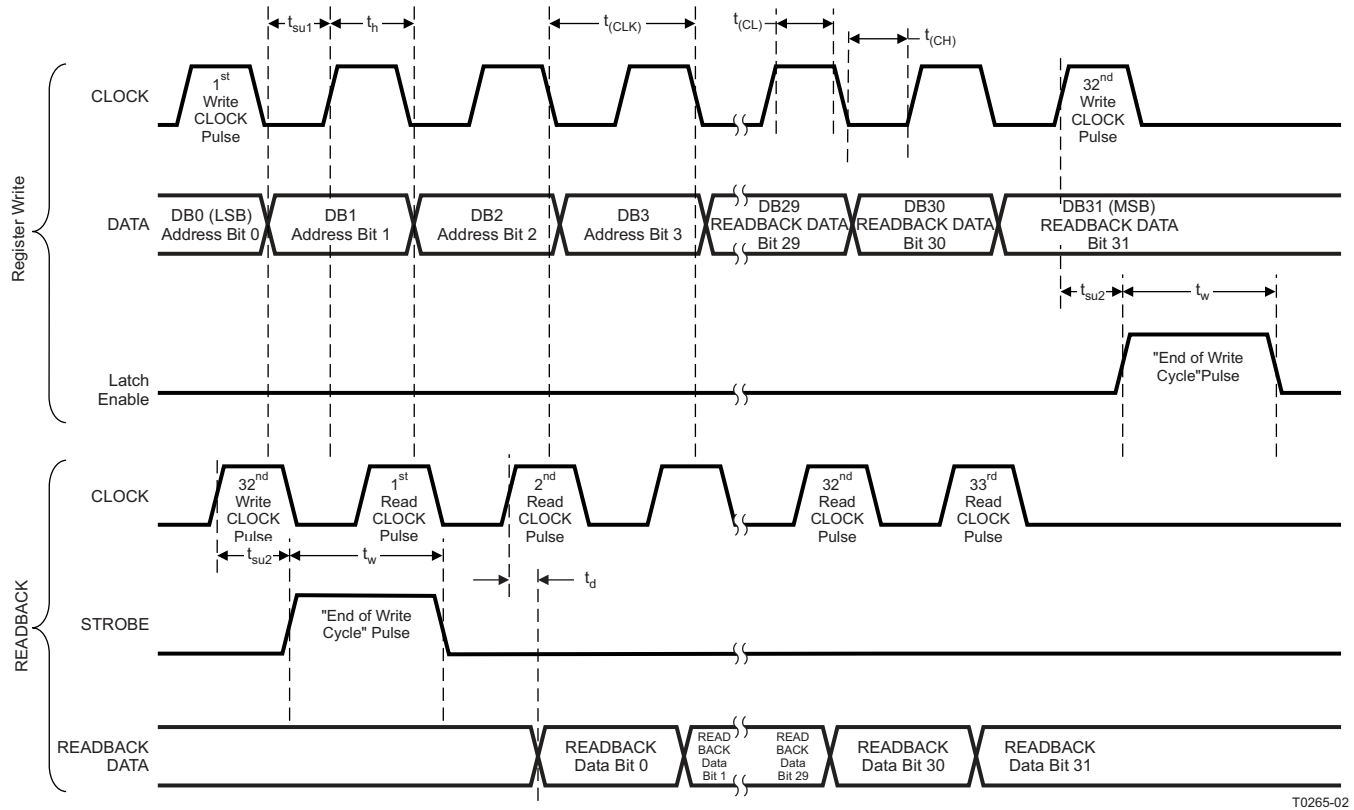
(4) Because the 2-tone interferers are outside of the baseband filter bandwidth, the results are inherently independent of the gain setting. Intermodulation parameters are recorded at maximum gain setting, where measurement accuracy is best.

(5) Two CW tones of -30 dBm at $f_{RF1} = f_{LO} \pm(2 \times f_C)$ and $f_{RF2} = f_{LO} \pm[(2 \times f_C) + 100\text{ kHz}]$; IM2 product measured at 100-kHz output frequency (f_C = baseband filter 1-dB cutoff frequency)

TIMING REQUIREMENTS

V_{CC} = 5 V, LO power = 0 dBm, T_A = 25°C (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|-----------------|-----|-----|-----|------|
| t _(CLK) Clock period | | 50 | | | ns |
| t _(CH) Clock-signal high time | | 20 | | | ns |
| t _(CL) Clock-signal low time | | 20 | | | ns |
| t _{su1} Setup time, data | | 10 | | | ns |
| t _h Hold time, data | | 10 | | | ns |
| t _w Pulse duration, STROBE | | 20 | | | ns |
| t _{su2} Setup time, STROBE | | 10 | | | ns |
| t _d Delay time, clock to readback-data output | | 10 | | | ns |



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Figure 1. Timing Requirements Diagram

TYPICAL CHARACTERISTICS

 $V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

Table of Graphs

| Broadband Data (1700-6000 MHz) | | |
|---------------------------------------|---|---|
| Gain | vs LO frequency ⁽¹⁾ | Figure 2 , Figure 3 , Figure 4 |
| Noise figure | vs LO frequency ⁽¹⁾ | Figure 5 , Figure 6 , Figure 7 |
| IIP3 | vs LO frequency ⁽²⁾⁽³⁾⁽⁴⁾ | Figure 8 , Figure 9 , Figure 10 |
| IIP2 | vs LO frequency ⁽²⁾⁽³⁾⁽⁴⁾ | Figure 11 , Figure 12 , Figure 13 |
| 3.5G Band Data (3300-3800 MHz) | | |
| Gain | vs LO frequency ⁽⁵⁾ | Figure 14 , Figure 15 , Figure 16 |
| IIP3 | vs LO frequency ⁽³⁾⁽⁴⁾⁽⁵⁾ | Figure 17 , Figure 18 , Figure 19 , Figure 20 |
| IIP2 | vs LO frequency ⁽³⁾⁽⁴⁾⁽⁵⁾ | Figure 21 , Figure 22 , Figure 23 , Figure 24 |
| Noise figure | vs LO frequency ⁽⁵⁾ | Figure 25 , Figure 26 , Figure 27 |
| 5G Band Data (4900-5900 MHz) | | |
| Gain | vs LO frequency ⁽⁶⁾ | Figure 28 , Figure 29 , Figure 30 |
| IIP3 | vs LO frequency ⁽³⁾⁽⁴⁾⁽⁶⁾ | Figure 31 , Figure 32 , Figure 33 |
| IIP2 | vs LO frequency ⁽³⁾⁽⁴⁾⁽⁶⁾ | Figure 34 , Figure 35 , Figure 36 |
| Noise figure | vs LO frequency ⁽⁶⁾ | Figure 37 , Figure 38 , Figure 39 |
| Baseband-Related Data | | |
| OIP3 | vs Frequency offset ⁽⁷⁾ | Figure 40 , Figure 41 , Figure 42 , Figure 43 |
| Noise figure | vs BB gain setting | Figure 44 |
| Gain | vs BB gain setting | Figure 45 |
| Gain | vs Frequency offset | Figure 46 , Figure 47 |
| Gain | vs Frequency offset (bypass mode) | Figure 48 , Figure 49 |
| 1-dB LPF corner frequency | vs LPFADJ setting | Figure 50 |
| Relative LPF group delay | Frequency offset ⁽⁸⁾ | Figure 51 |
| Image rejection | vs BB frequency offset | Figure 52 |
| DC offset limit | vs Temperature ⁽⁹⁾ | Figure 53 |
| Out-of-band P1dB | vs Relative offset multiplier to corner frequency ⁽¹⁰⁾ | Figure 54 |

- (1) Measured with broadband Picosecond 5310A balun on the LO input and single-ended connection on the RF input. Performance gain adjusted for the 3-dB differential to single-ended insertion loss.
- (2) Measured with broadband Picosecond 5310A balun on the LO input and RF input. Balun insertion loss is compensated for in the measurement.
- (3) Out-of-band intercept point is defined with tones that are at least 2 times farther out than the programmed LPF corner frequency that generates an intermodulation tone that falls inside the LPF passband.
- (4) Out-of-band intercept point is dependent on the demodulator performance and not the baseband circuitry; the measurement is taken at maximum gain but is valid across all PGA settings.
- (5) Measured with Johanson 3600BL14M050E balun on the LO input and RF input. All dc-blocking and bypass capacitors are 4.7 pF as listed on the EVM schematic.
- (6) Measured with Johanson 5400 BL15B050E balun on the LO input and RF input. All dc-blocking and bypass capacitors are 1.8 pF as listed on the EVM schematic.
- (7) Measured with filter in bypass mode to characterize the pass-band circuitry across baseband frequencies. Tone spacing set to 100 kHz, and tone frequencies are varied from 5/5.1 MHz to 25/25.1 MHz (x-axis of graph).
- (8) Relative to the low-frequency offset group delay in bypass mode
- (9) I_{det} set to 50 μA ; RF signal is off; LO at 2.4 GHz at 0 dBm; Det filter set to 1 kHz; Div set to 1024.
- (10) In-band tone set to 1 MHz; out-of-band jammer tone set to specified relative offset ratio from the programmed corner frequency. Jammer tone is increased until in-band tone compresses 1 dB.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

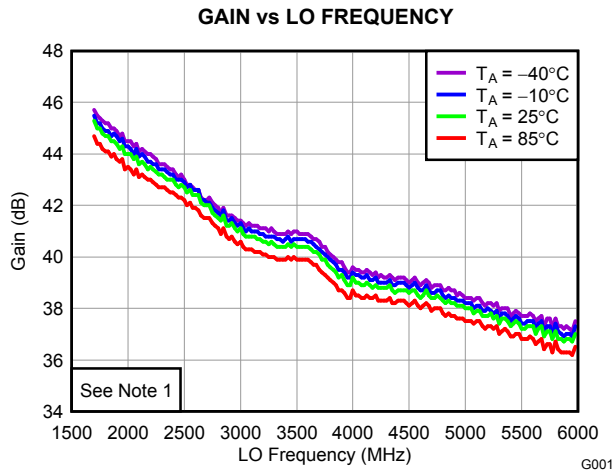


Figure 2.

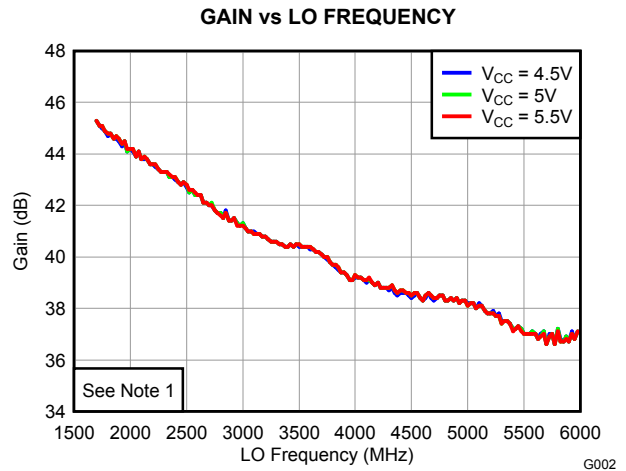


Figure 3.

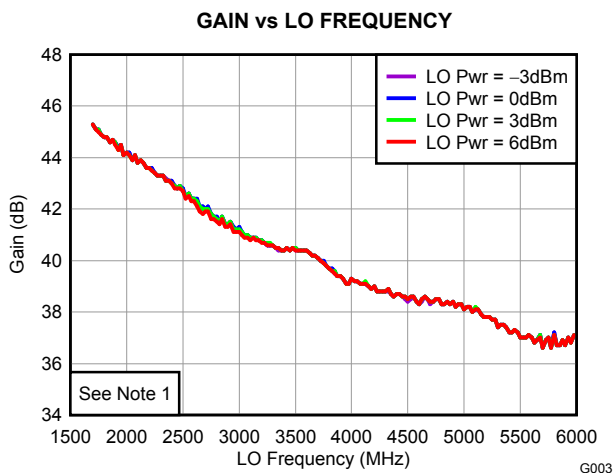


Figure 4.

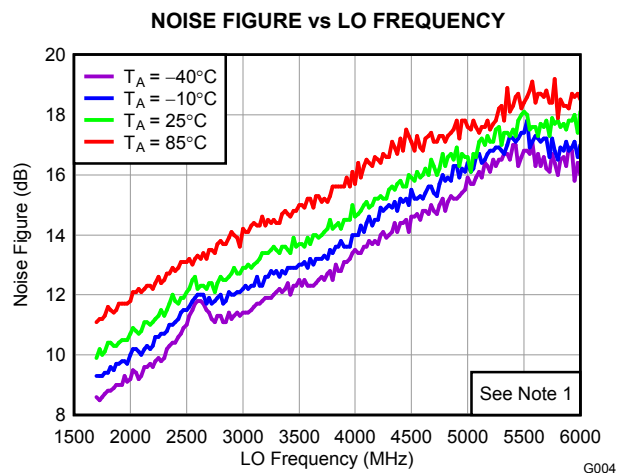


Figure 5.

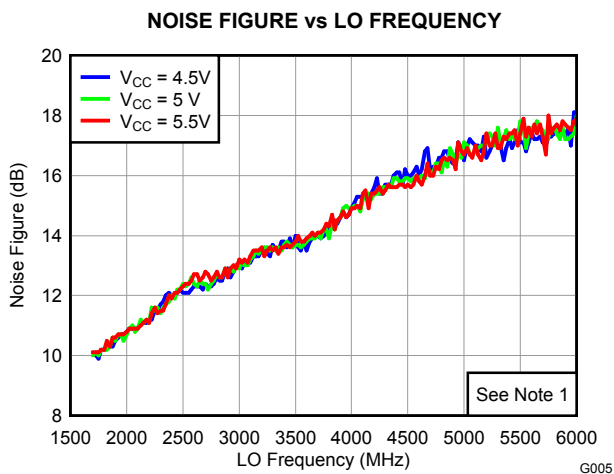


Figure 6.

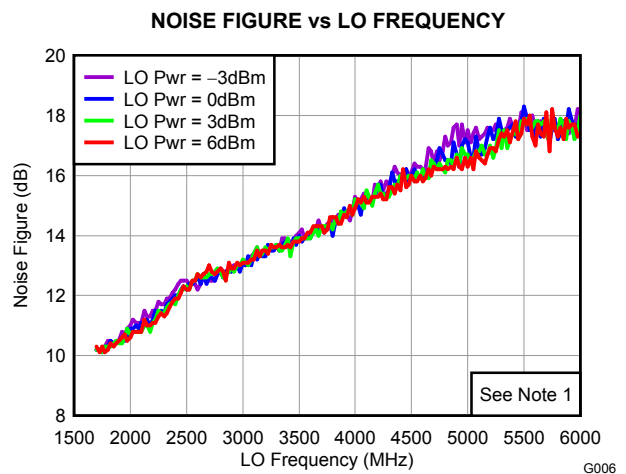


Figure 7.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

IIP3 vs LO FREQUENCY

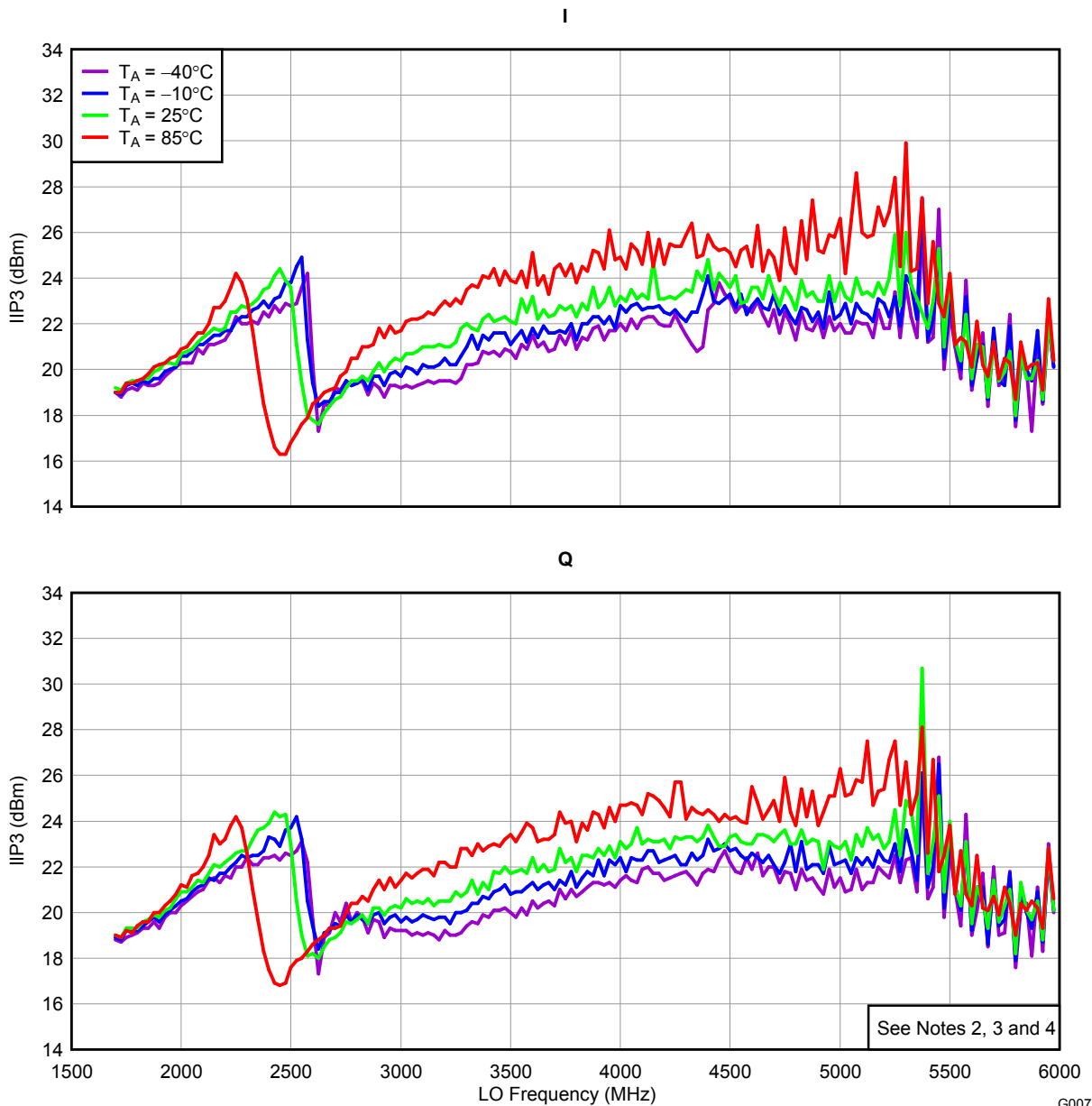


Figure 8.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

IIP3 vs LO FREQUENCY

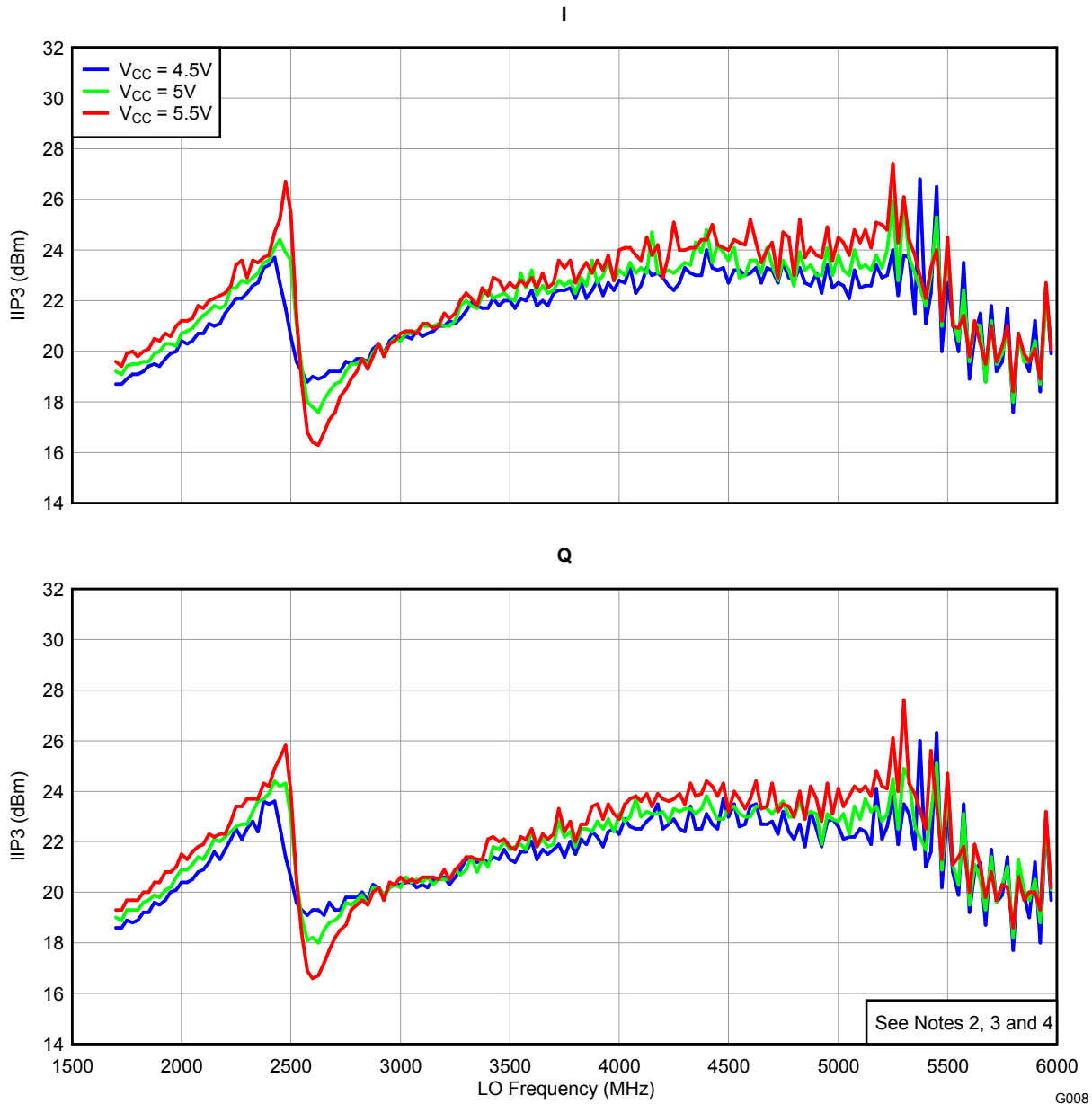


Figure 9.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

IIP3 vs LO FREQUENCY

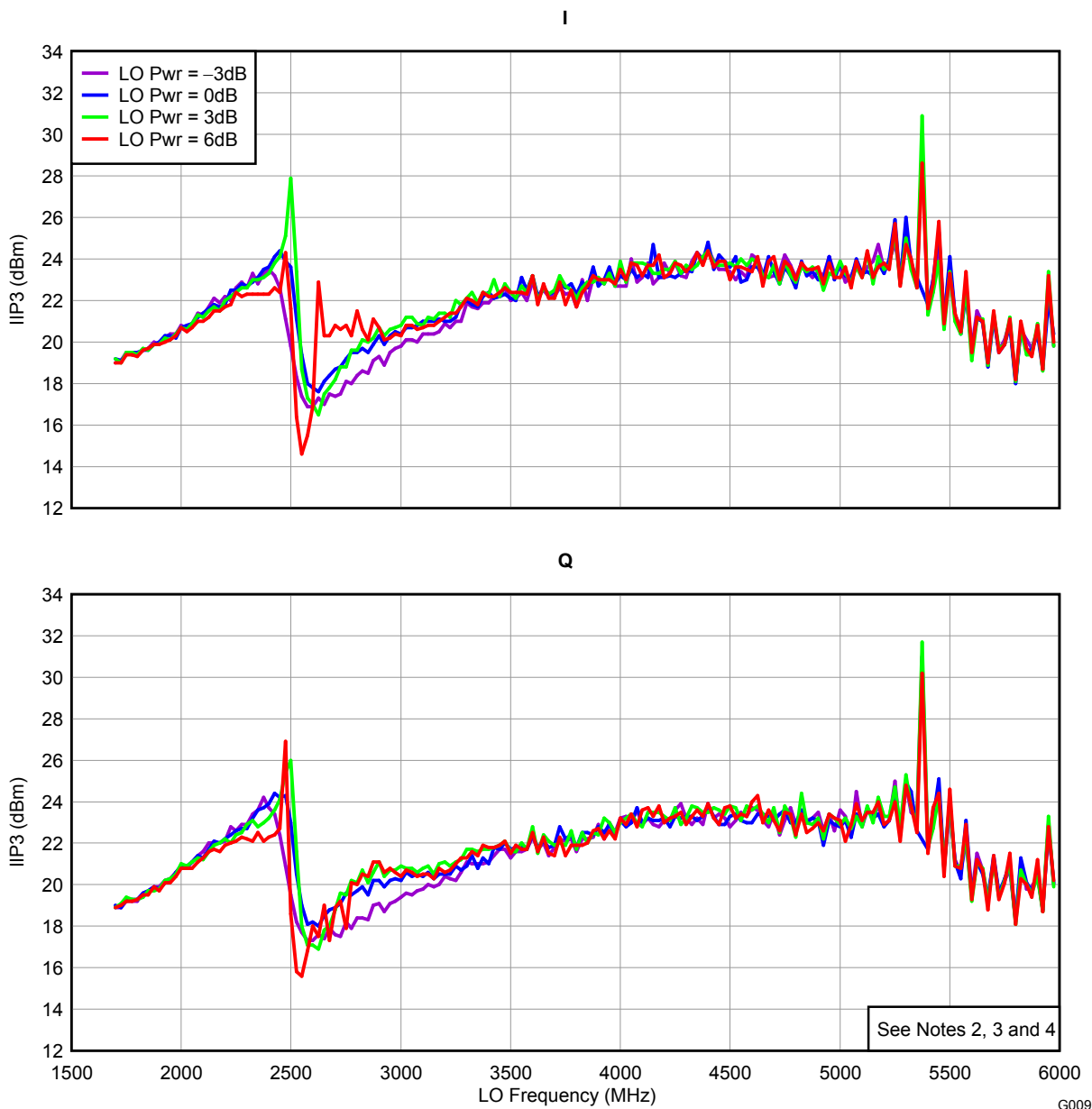


Figure 10.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

IIP2 vs LO FREQUENCY

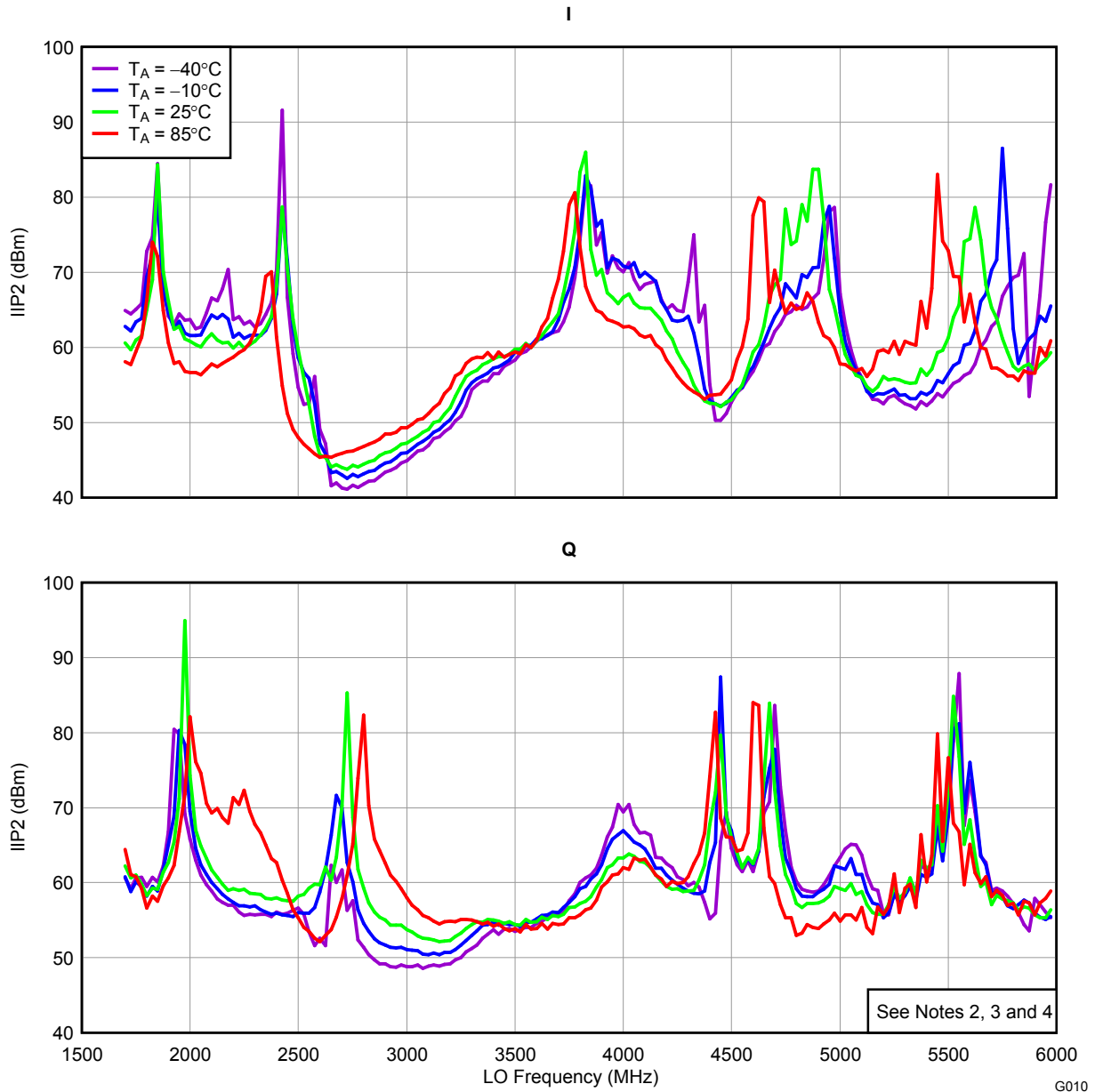


Figure 11.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

IIP2 vs LO FREQUENCY

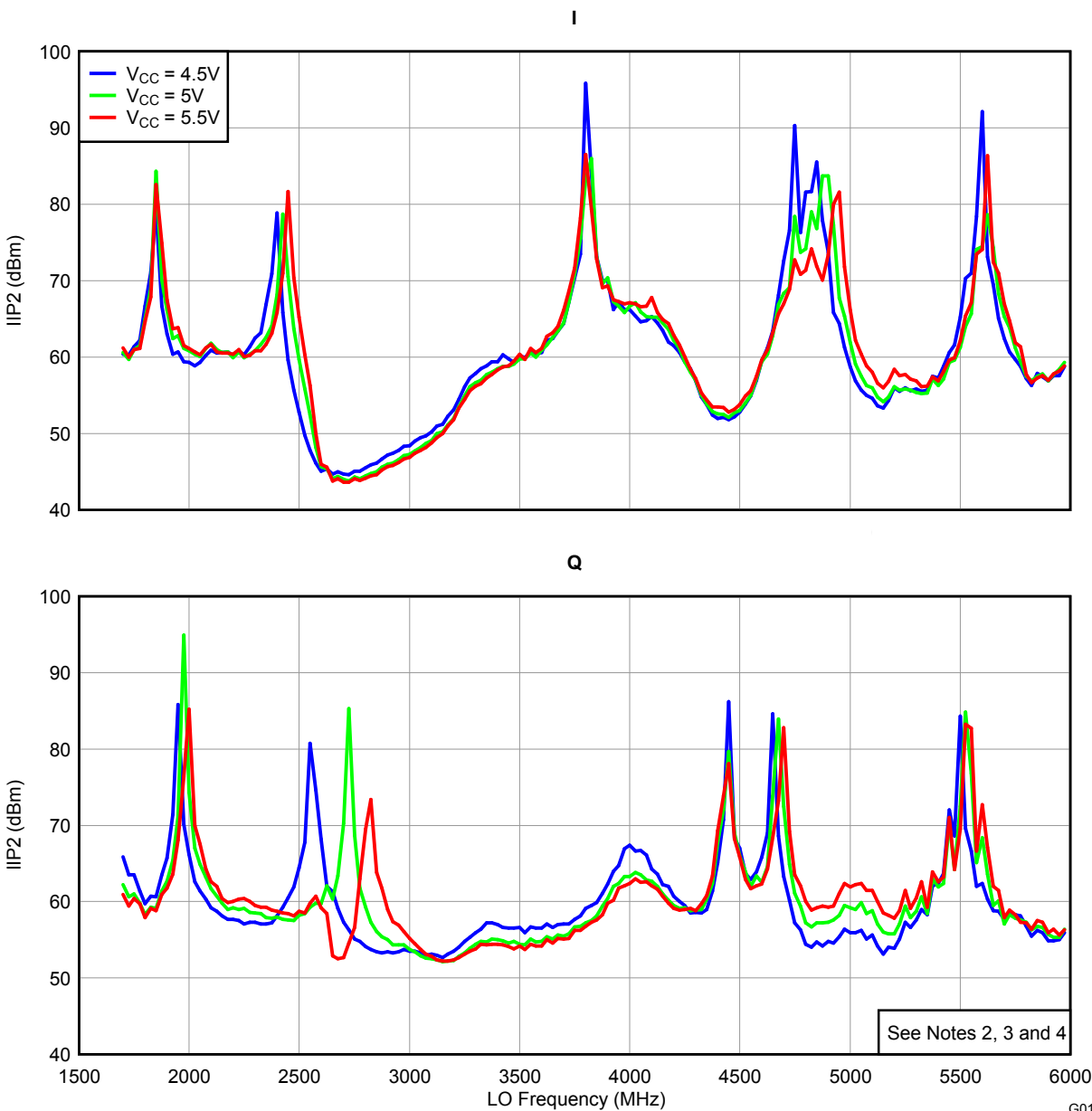


Figure 12.

TYPICAL CHARACTERISTICS, BROADBAND DATA (1700 MHz–6000 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

IIP2 vs LO FREQUENCY

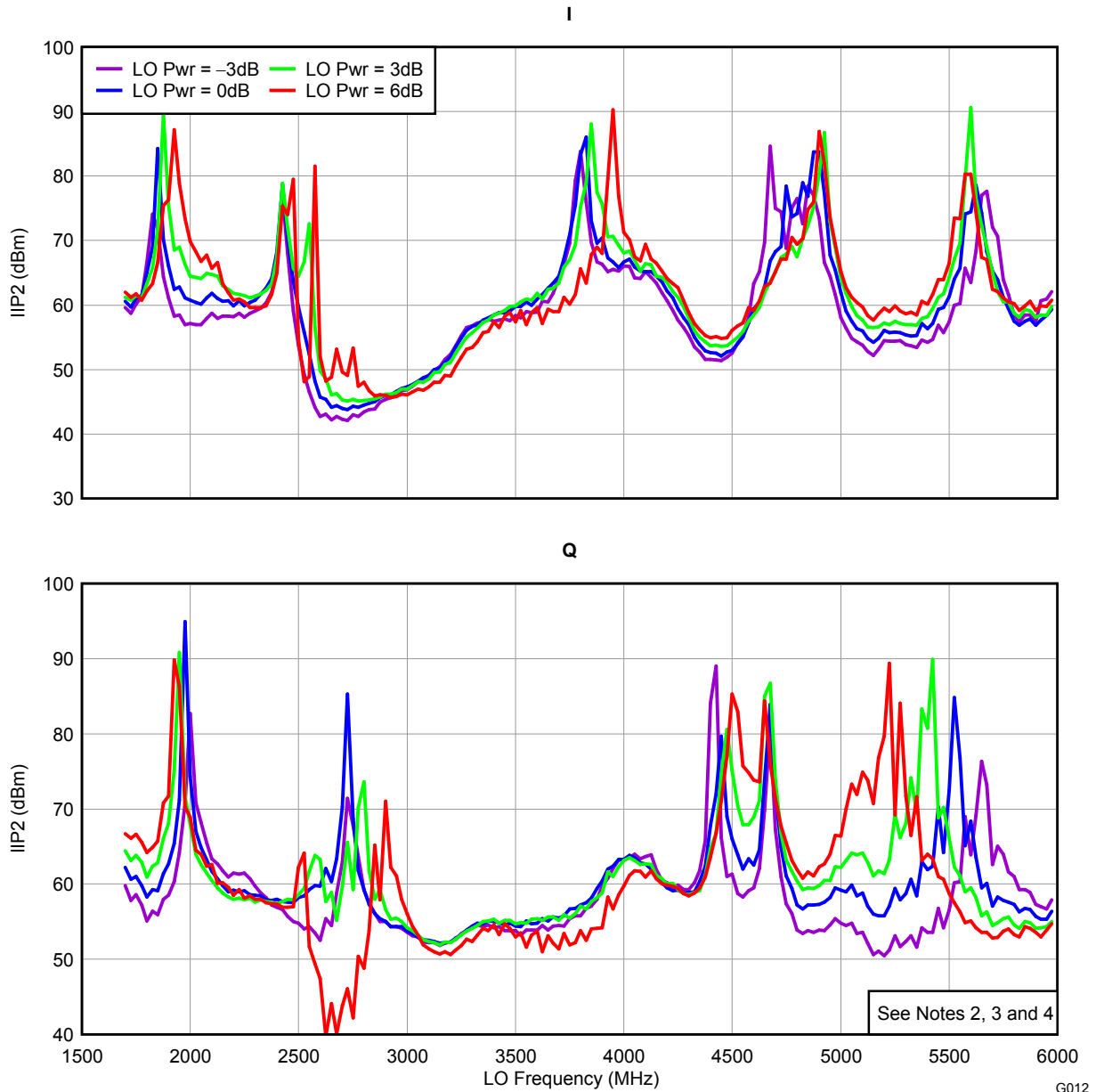


Figure 13.

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TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

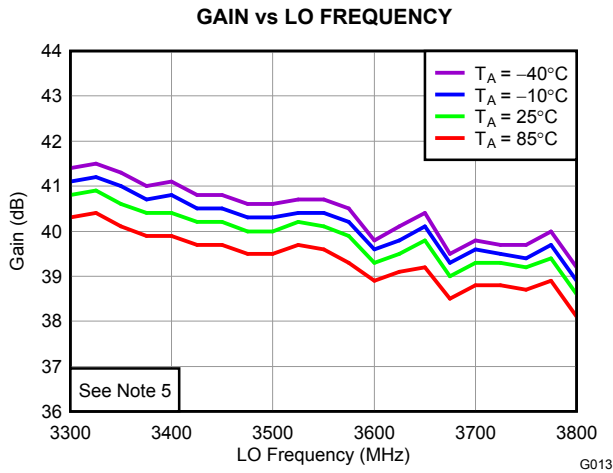


Figure 14.

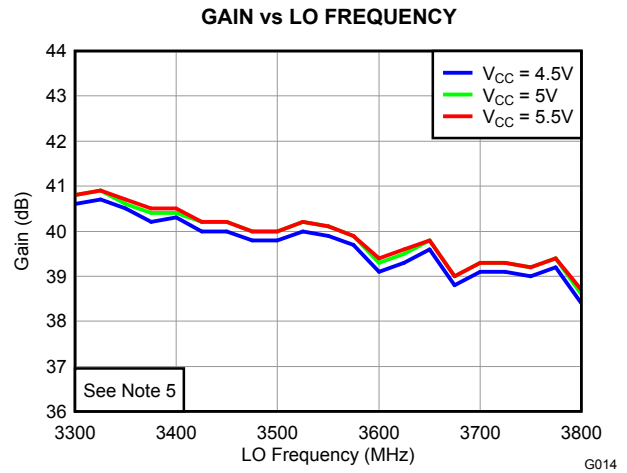


Figure 15.

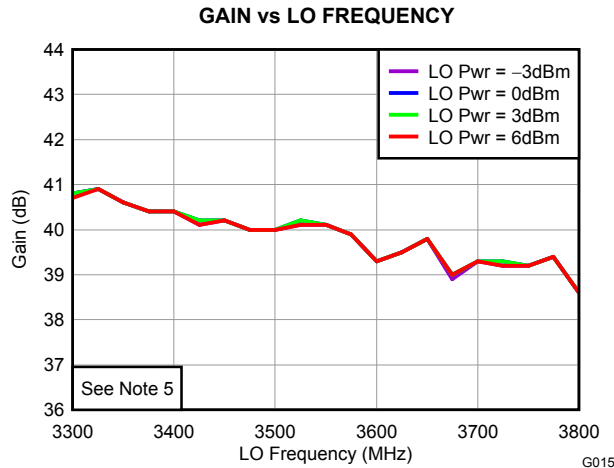


Figure 16.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

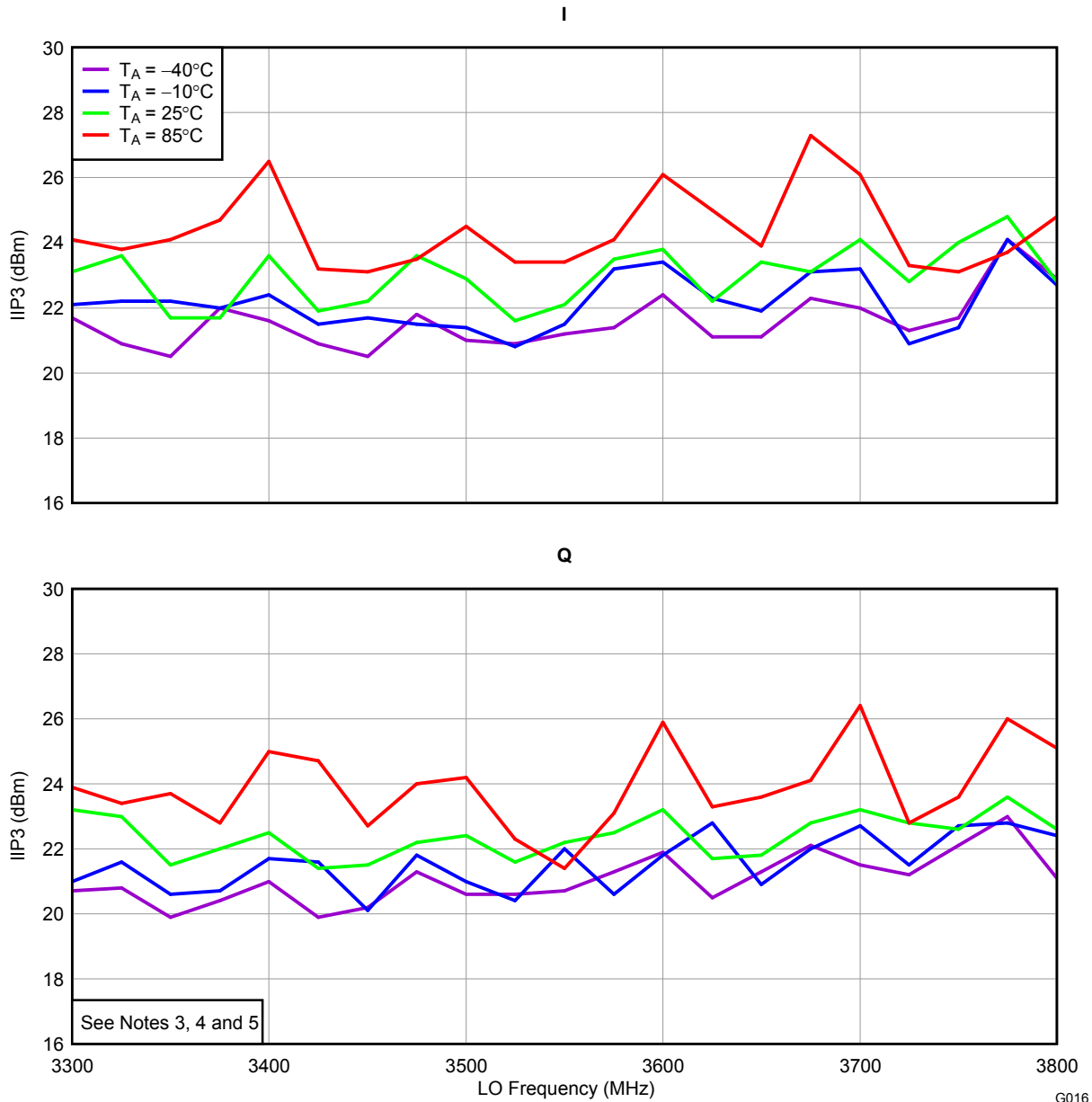


Figure 17.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

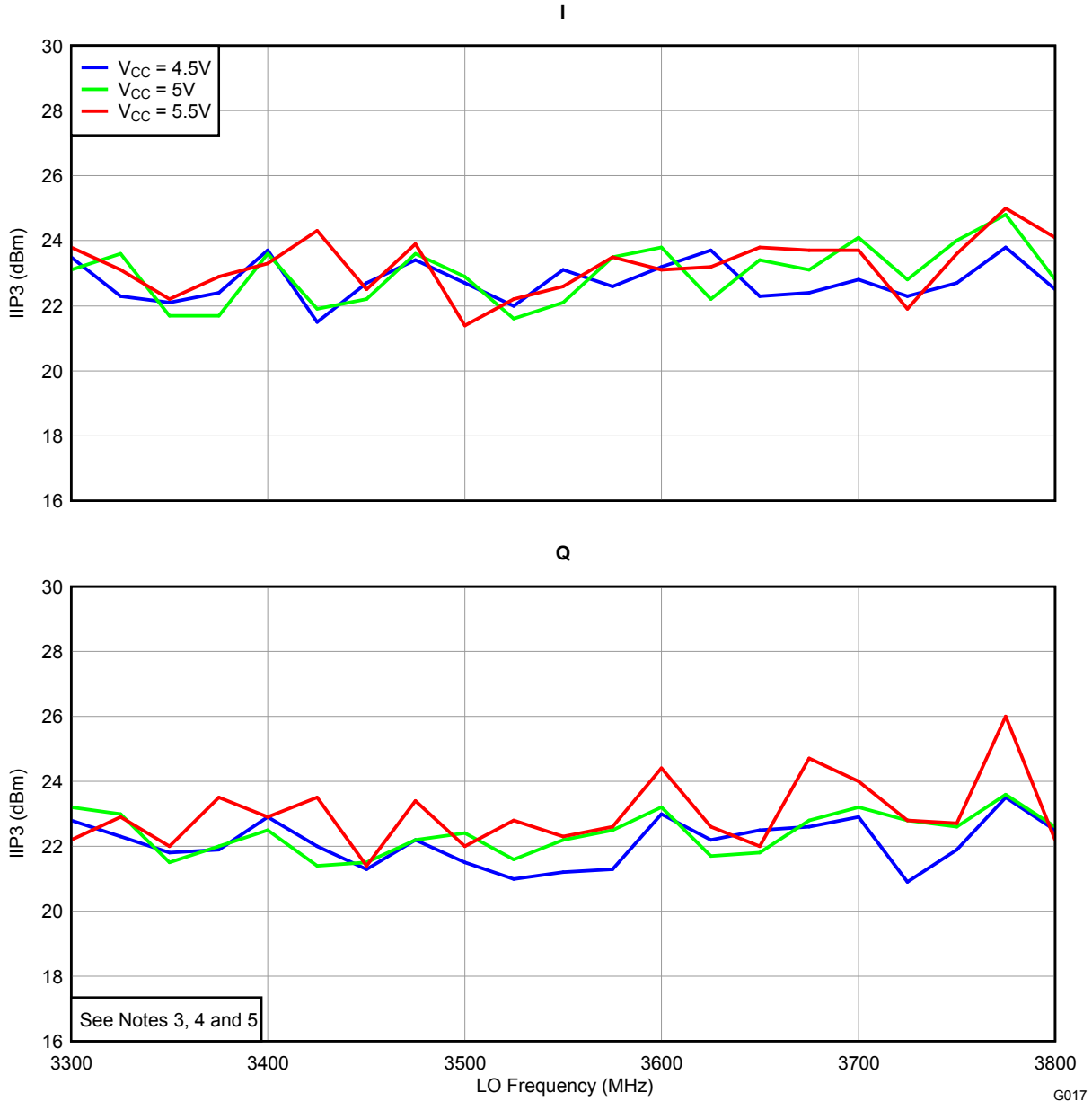


Figure 18.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

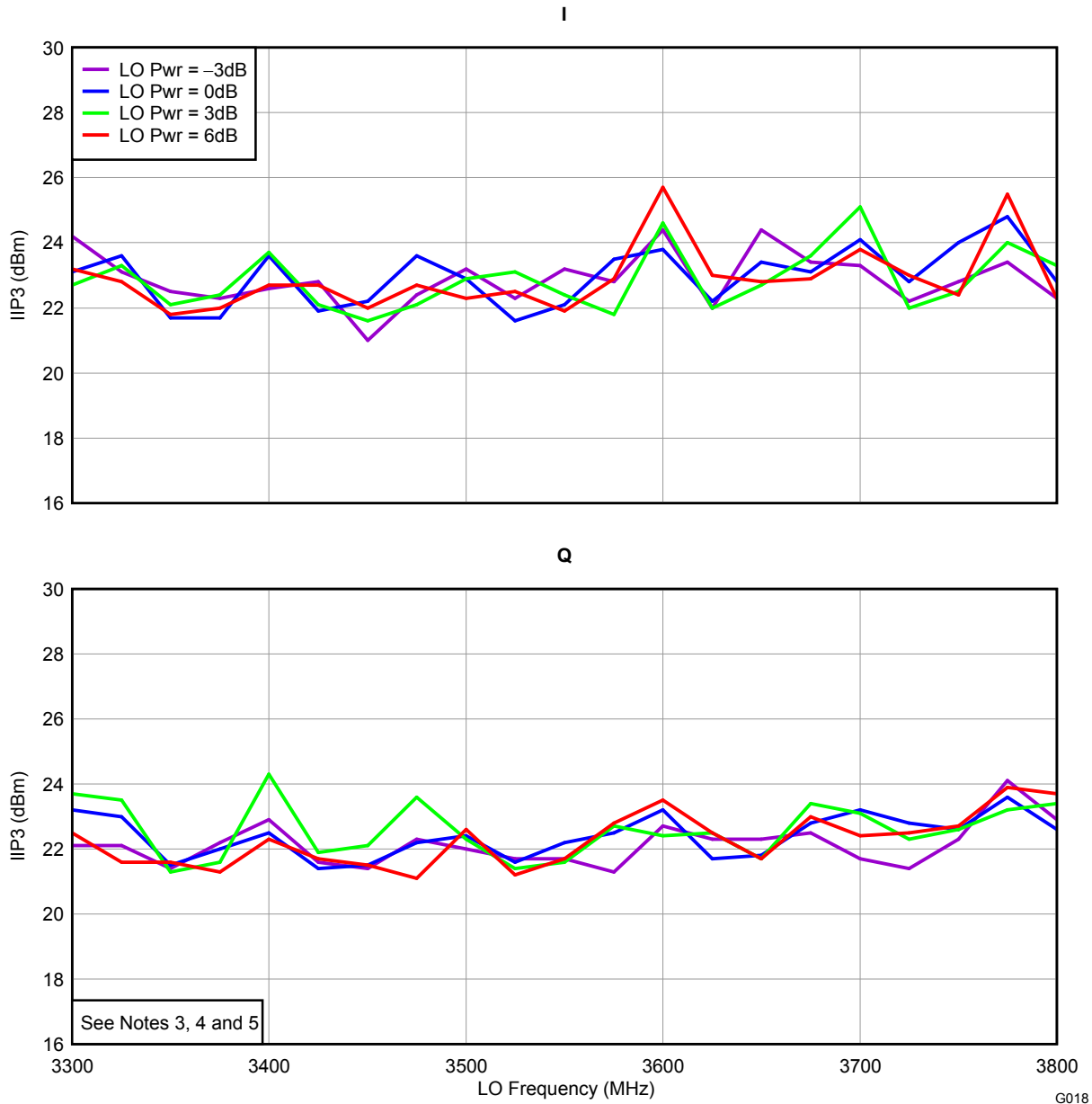


Figure 19.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

V_{CC} = 5 V, LO power = 0 dBm, T_A = 25°C, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

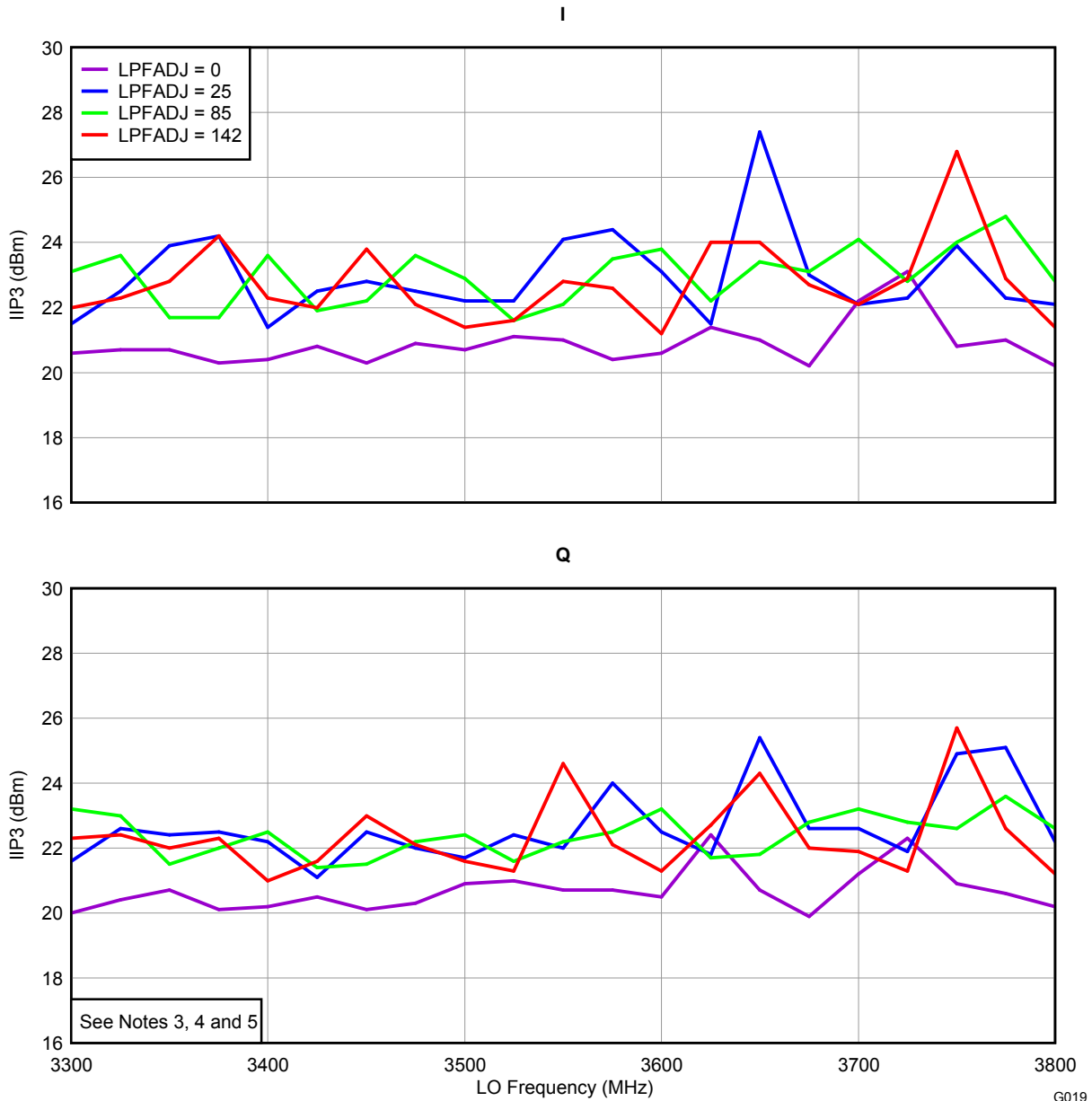


Figure 20.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

V_{CC} = 5 V, LO power = 0 dBm, T_A = 25°C, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

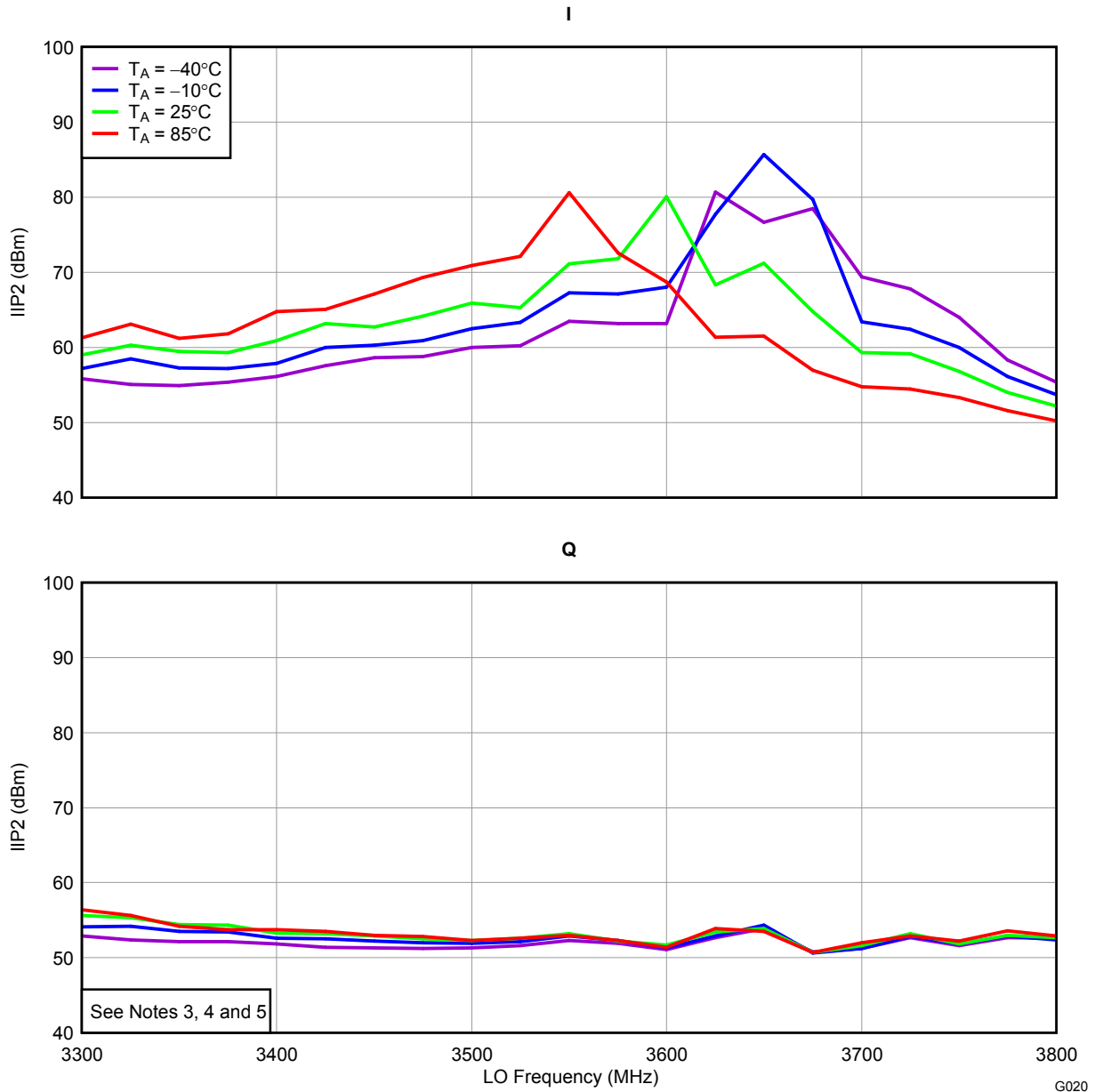


Figure 21.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

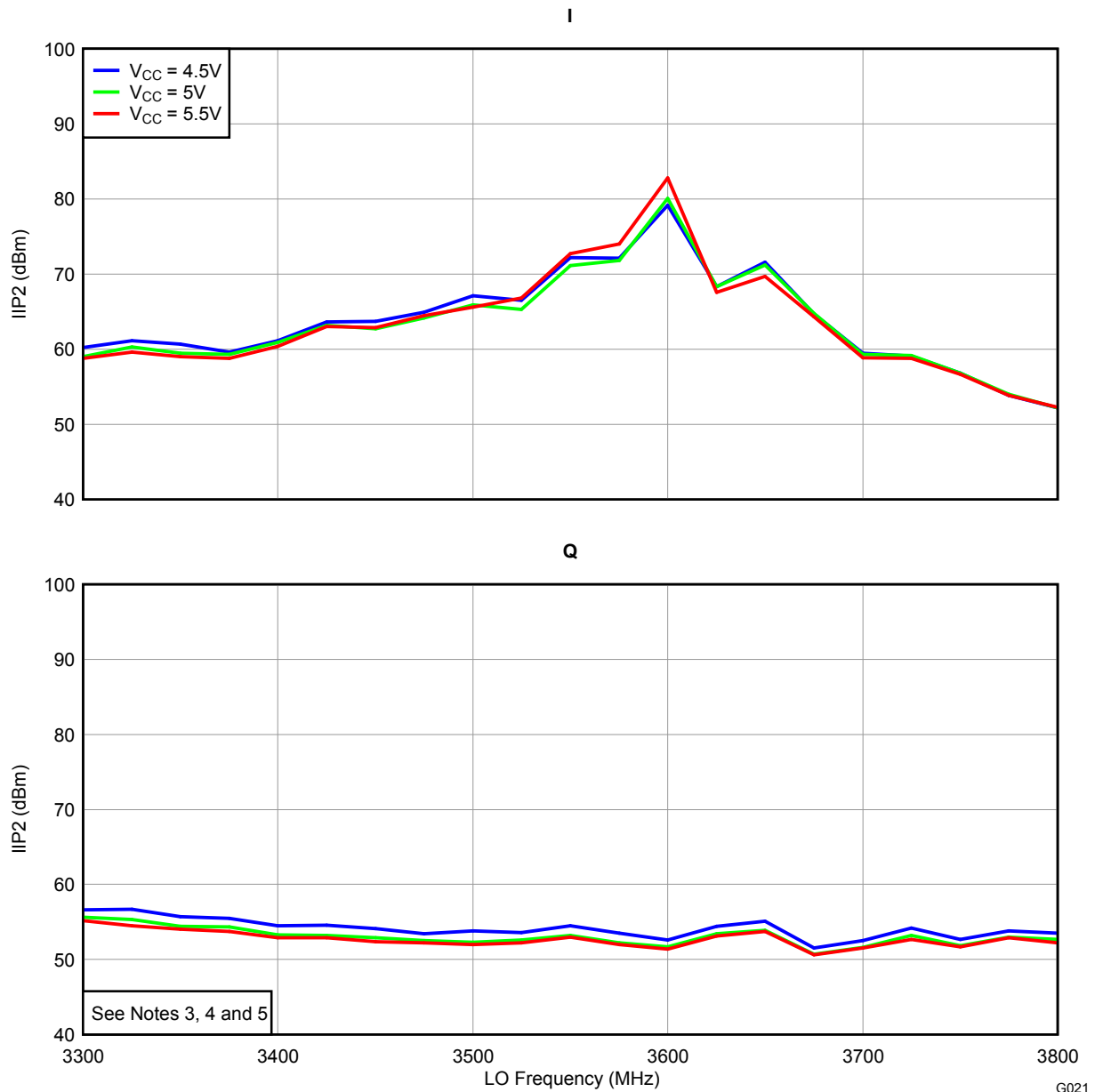


Figure 22.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

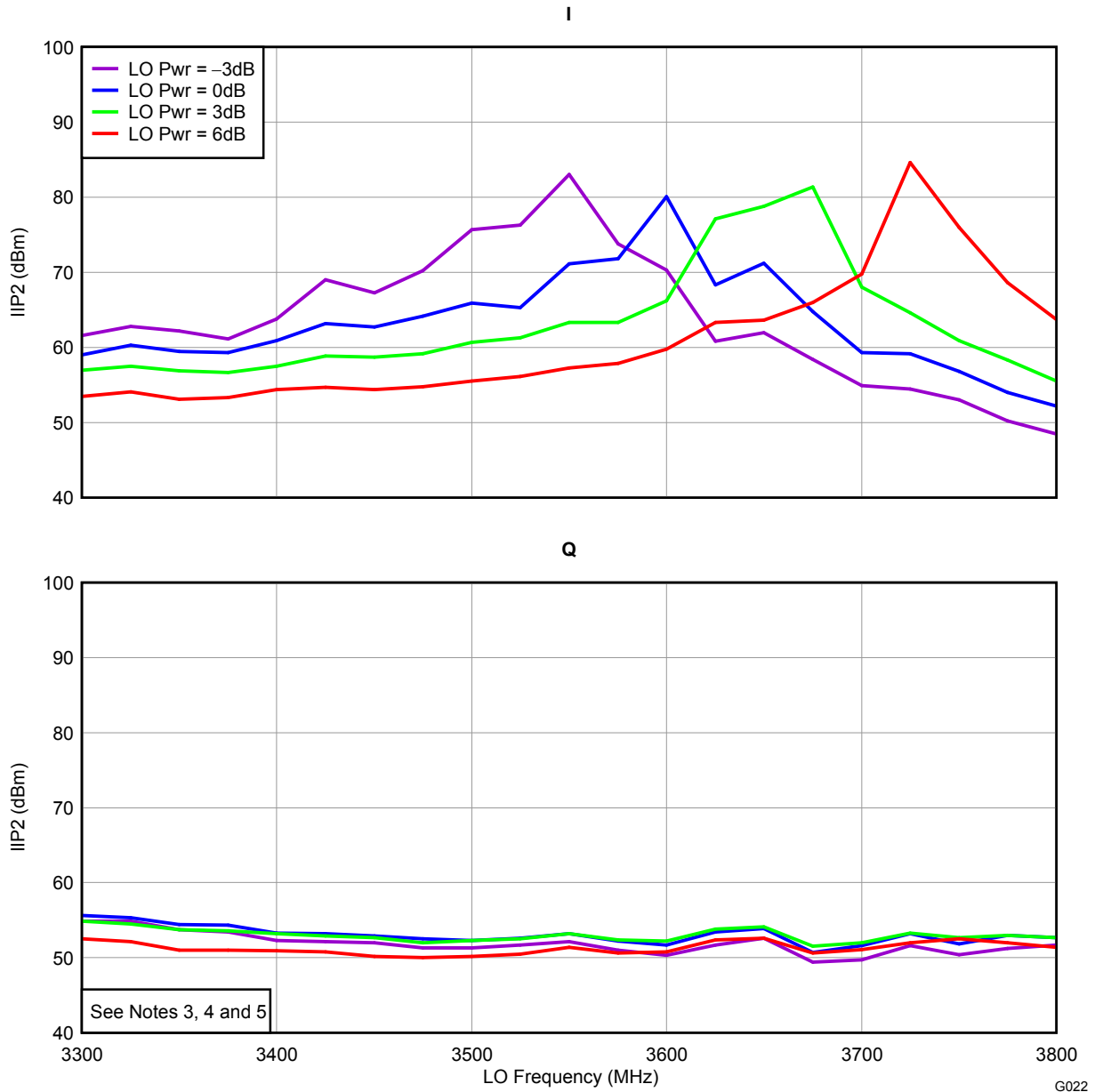


Figure 23.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

V_{CC} = 5 V, LO power = 0 dBm, T_A = 25°C, balun = Johanson 3600BL14M050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

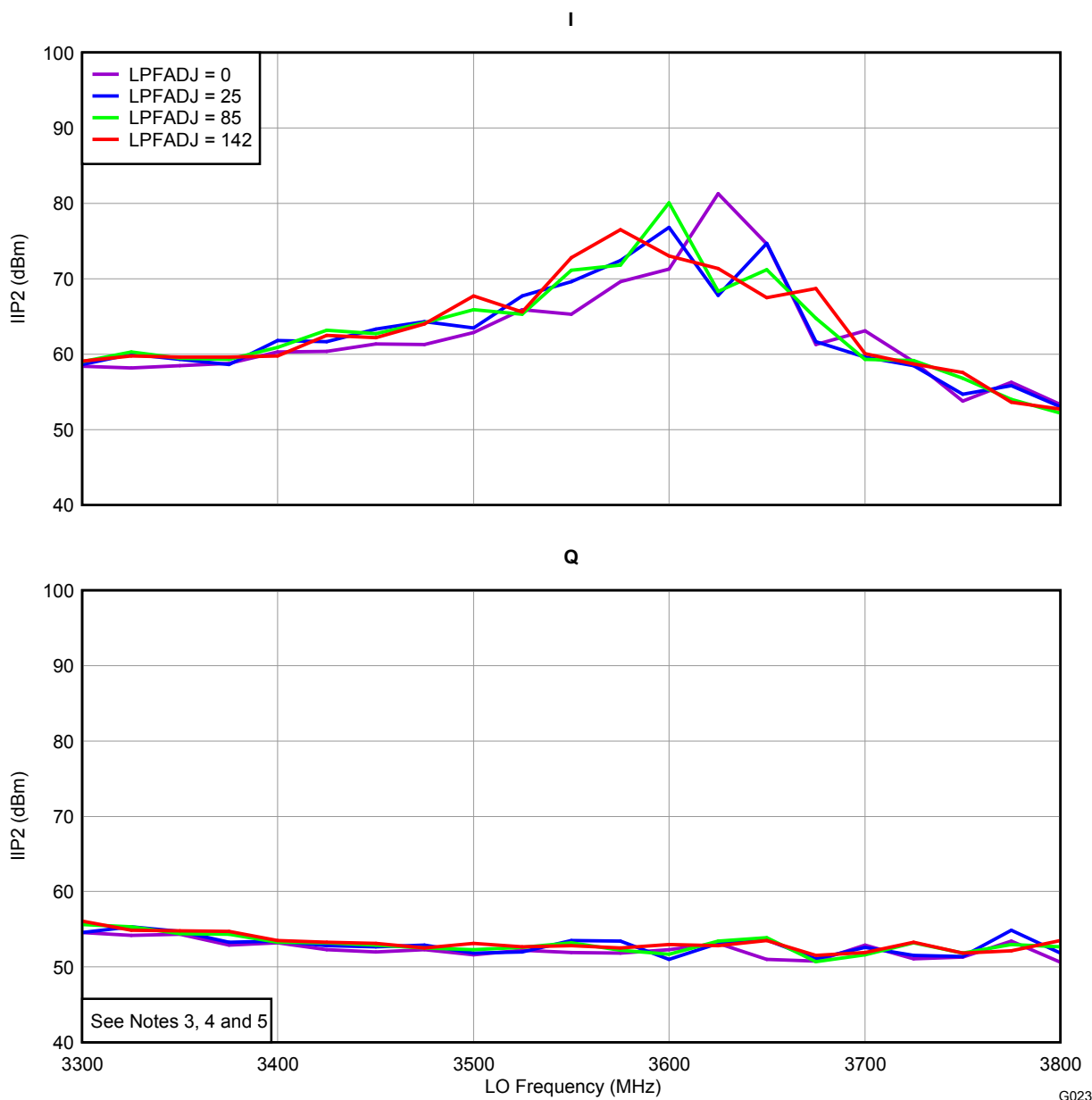


Figure 24.

TYPICAL CHARACTERISTICS, 3.5G BAND DATA (3300 MHz–3800 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 3600BL14M050E (unless otherwise noted)

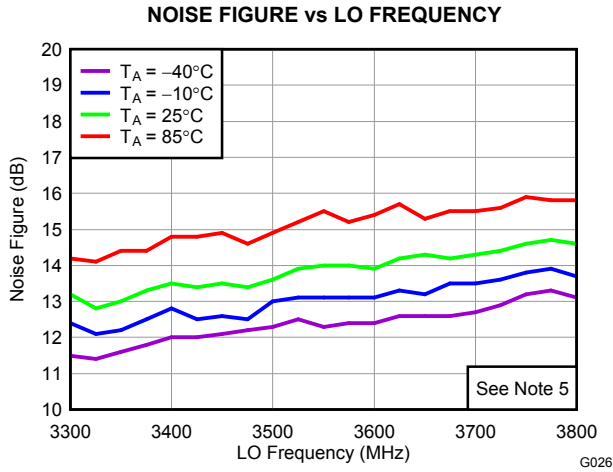


Figure 25.

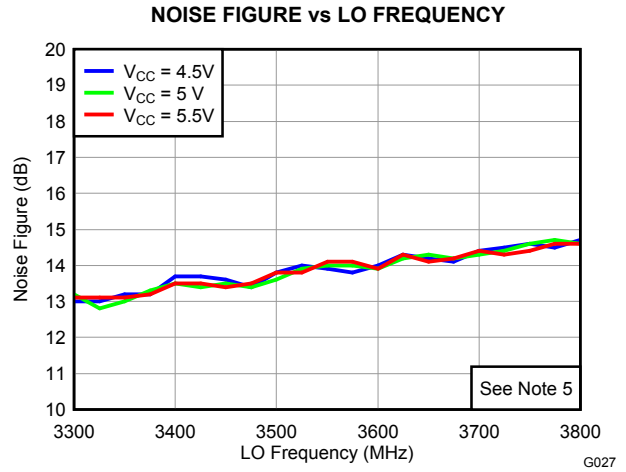


Figure 26.

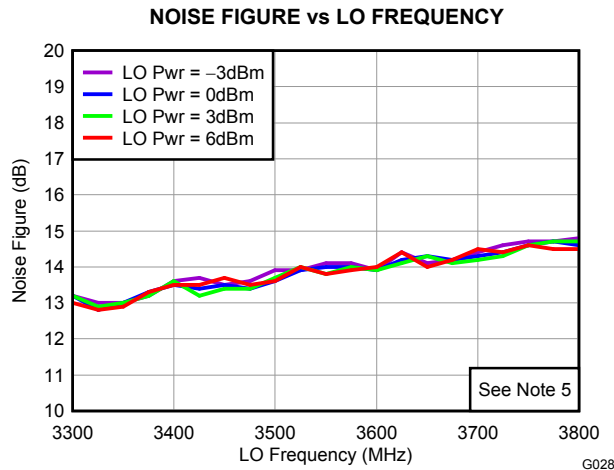


Figure 27.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 5400BL15B050E (unless otherwise noted)

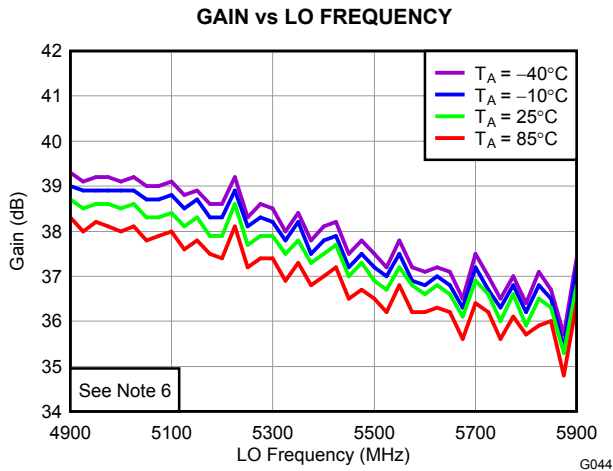


Figure 28.

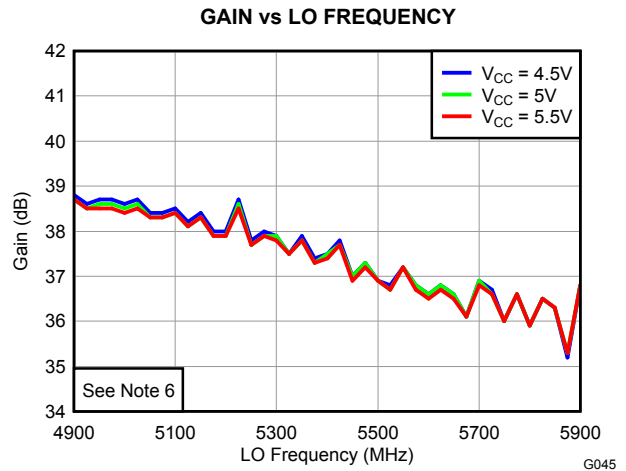


Figure 29.

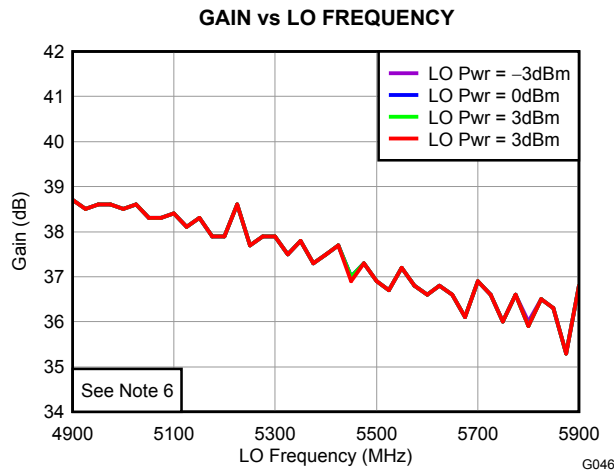


Figure 30.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

V_{CC} = 5 V, LO power = 0 dBm, T_A = 25°C, balun = Johanson 5400BL15B050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

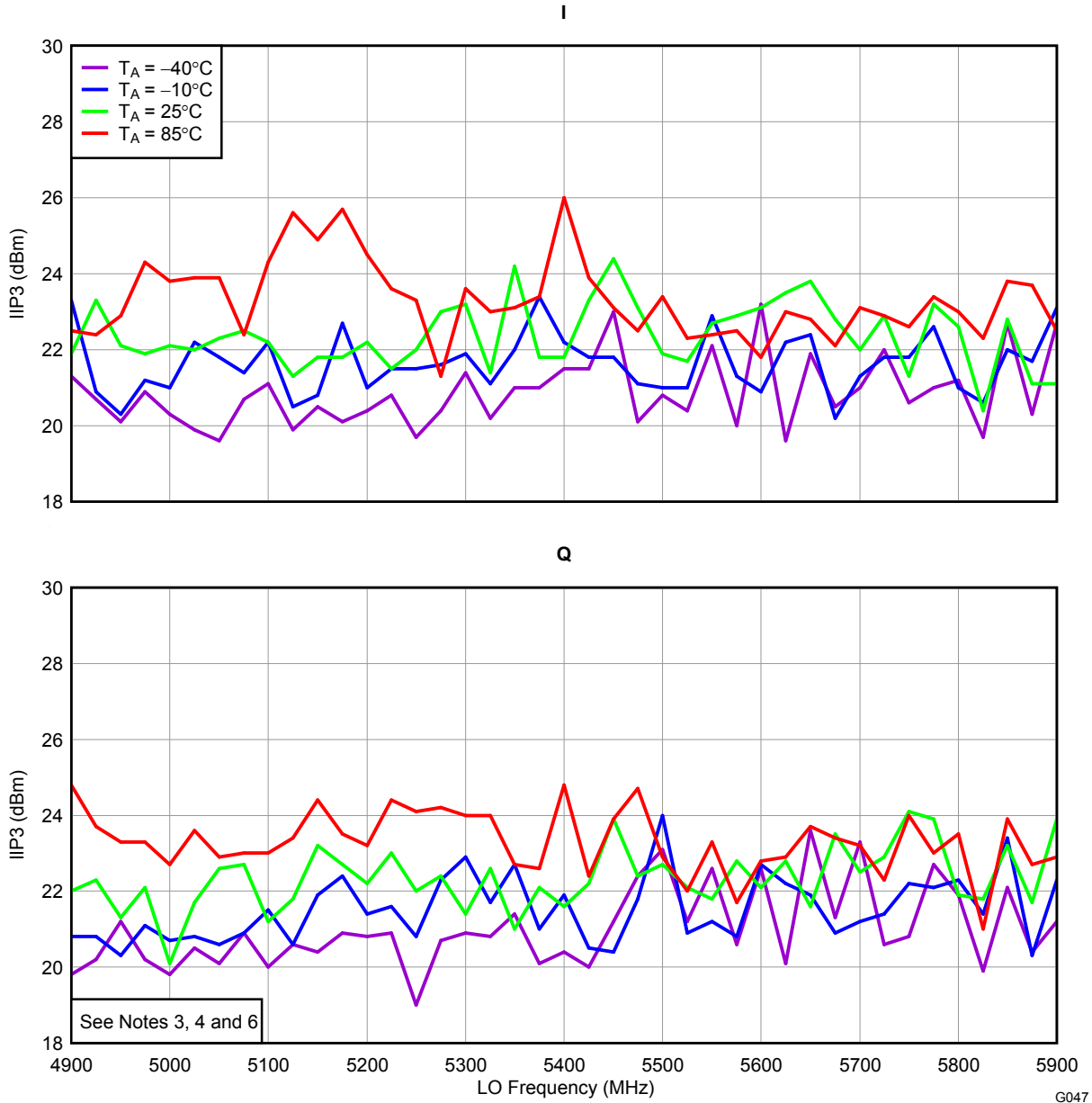


Figure 31.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 5400BL15B050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

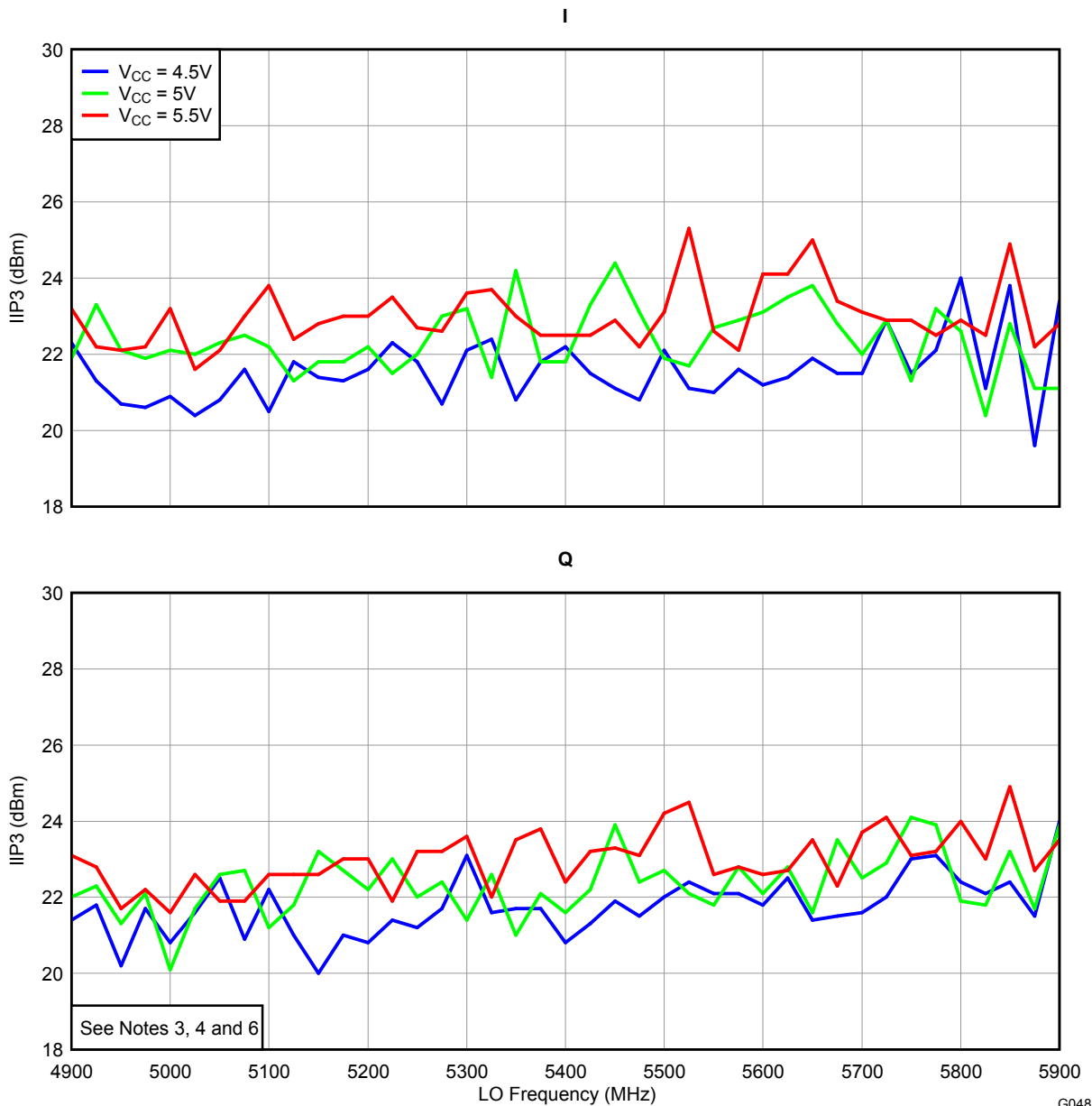


Figure 32.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 5400BL15B050E (unless otherwise noted)

IIP3 vs LO FREQUENCY

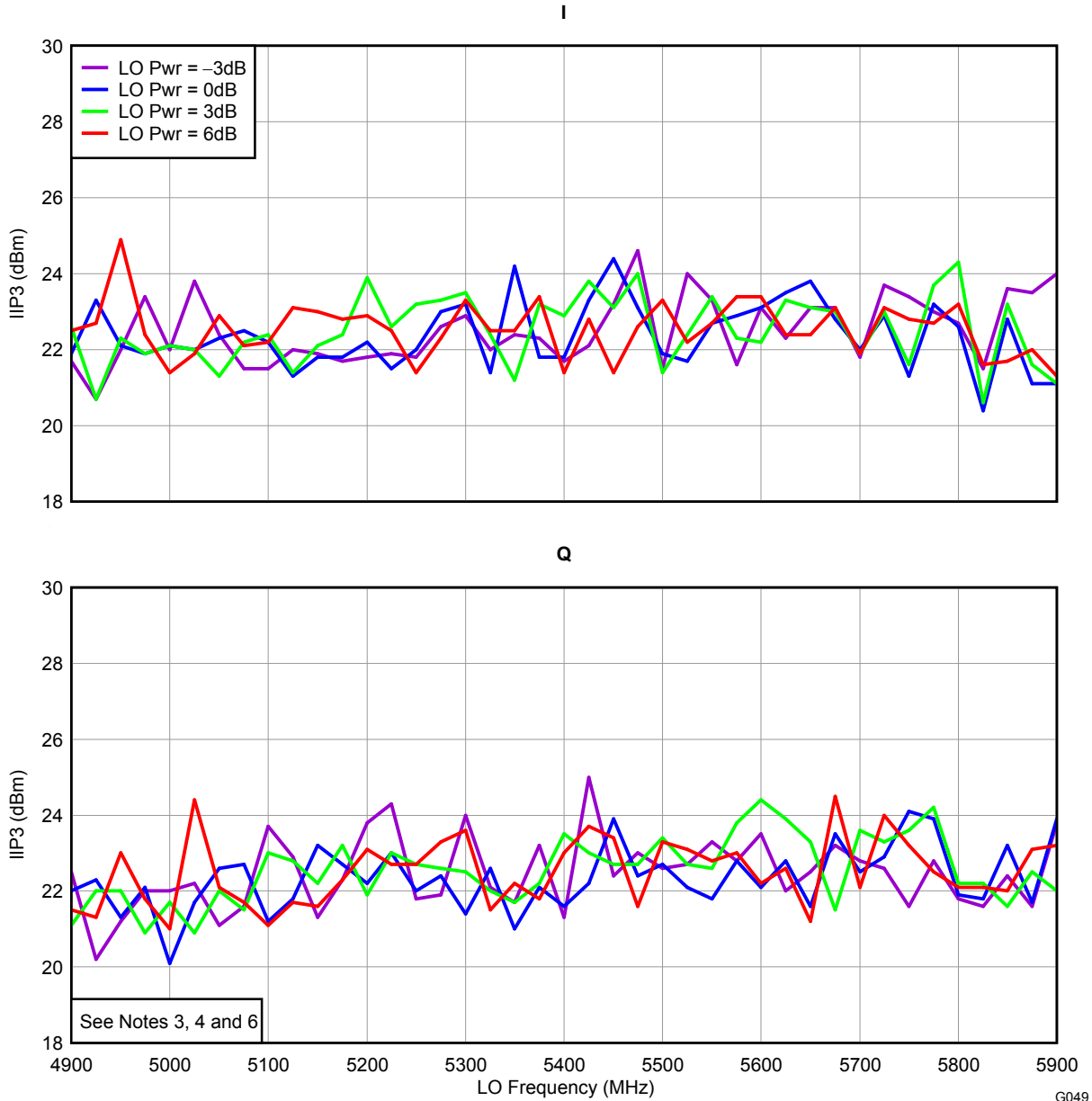


Figure 33.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

V_{CC} = 5 V, LO power = 0 dBm, T_A = 25°C, balun = Johanson 5400BL15B050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

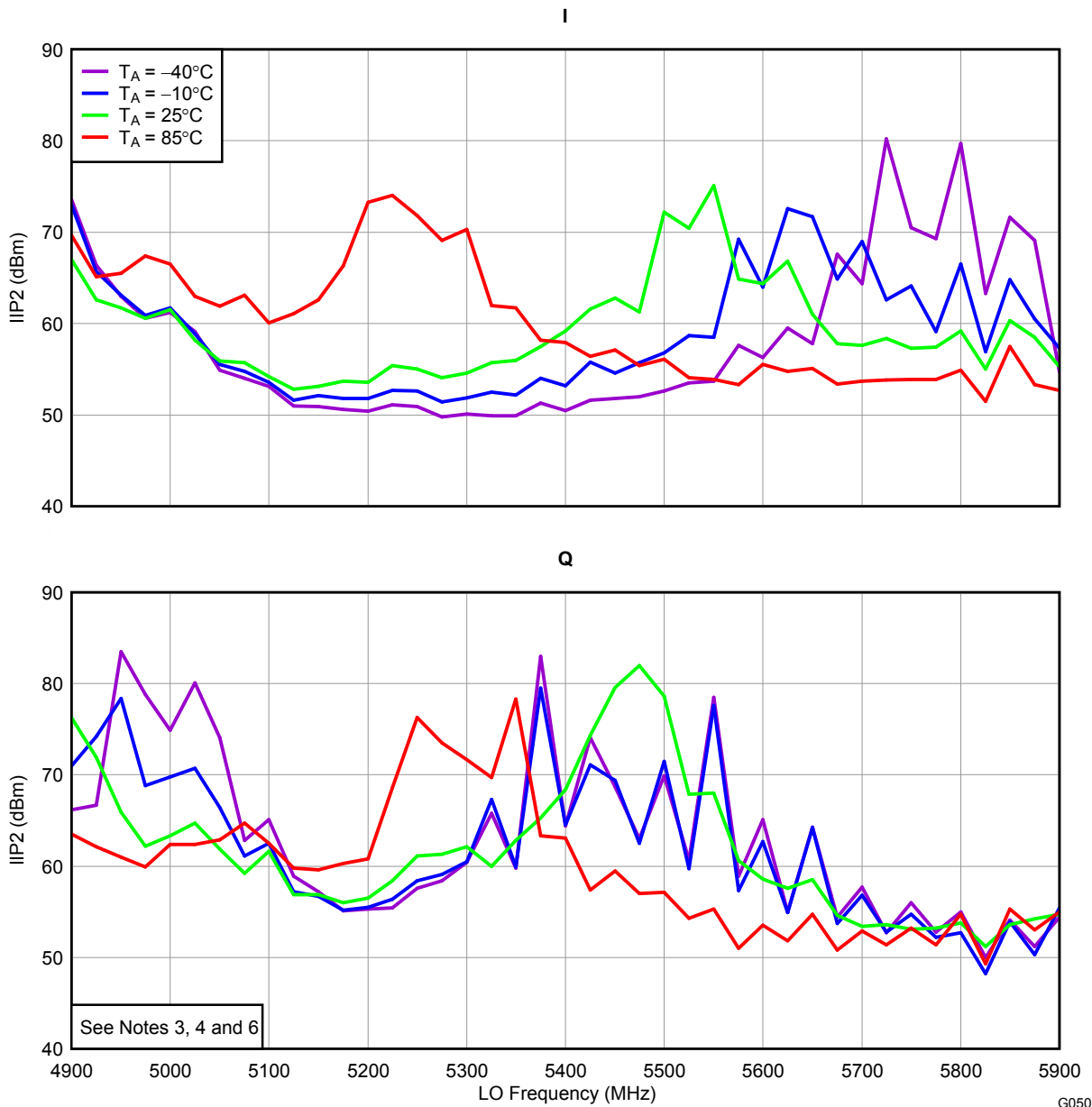


Figure 34.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 5400BL15B050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

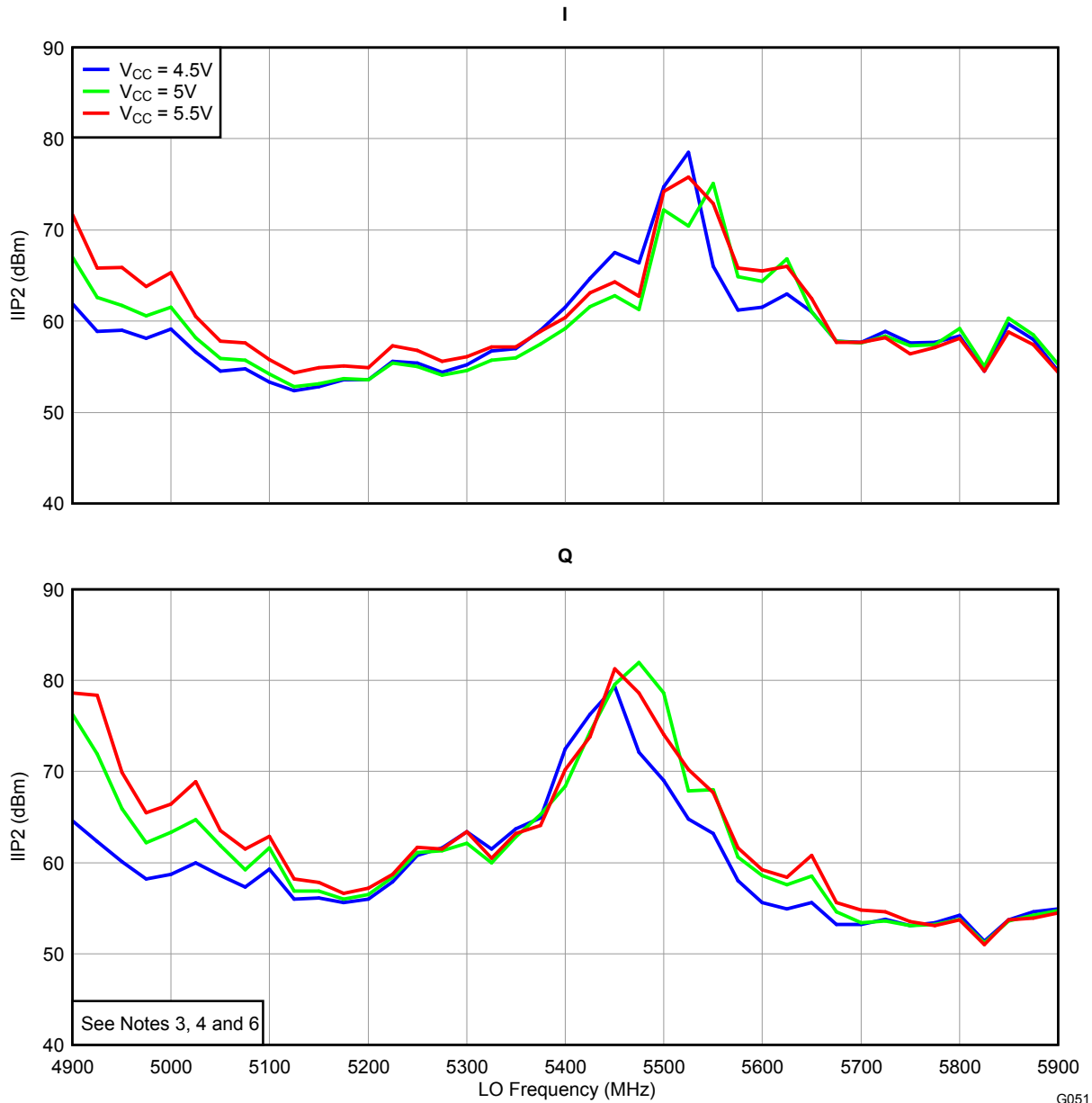


Figure 35.

TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 5400BL15B050E (unless otherwise noted)

IIP2 vs LO FREQUENCY

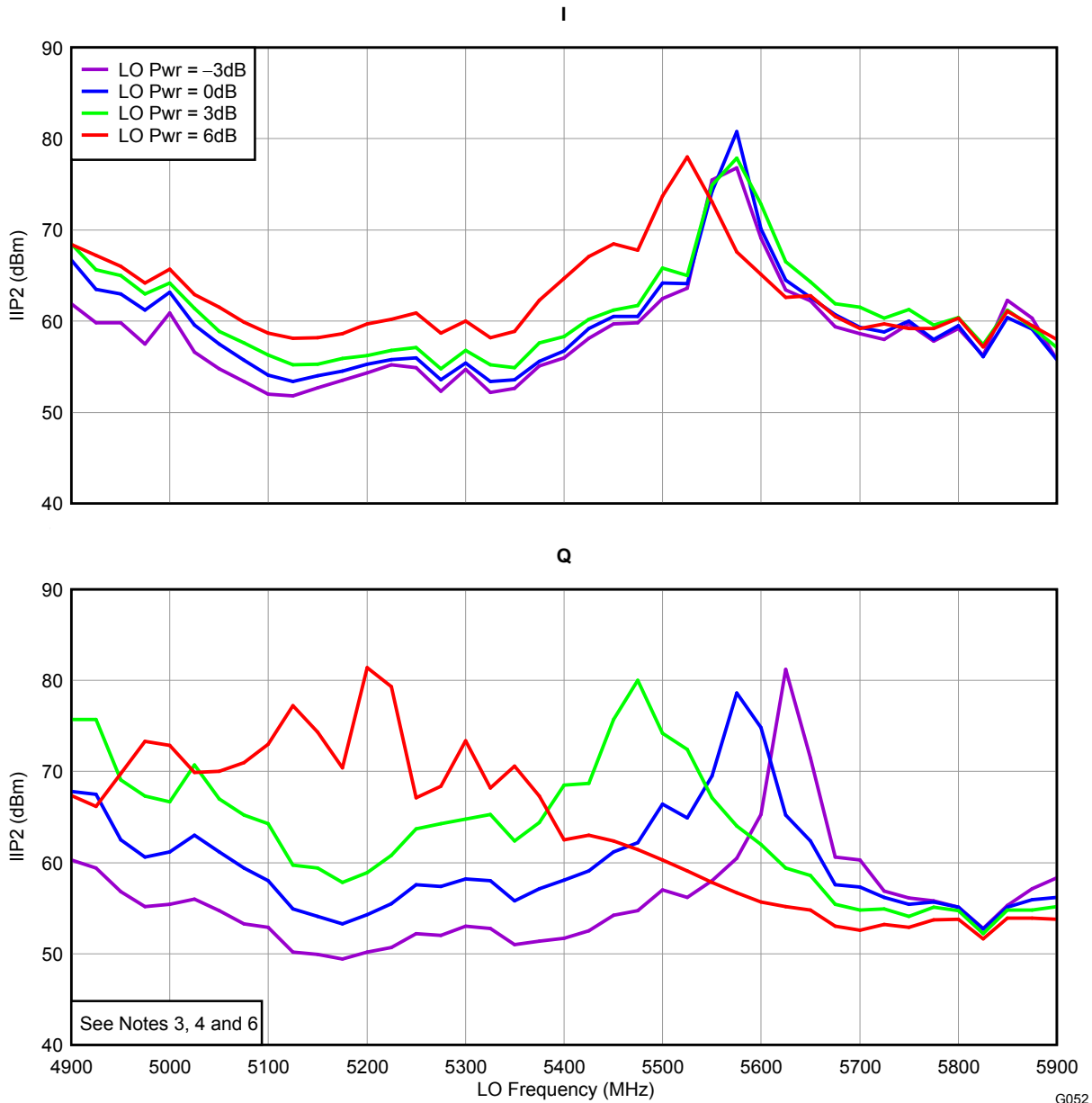


Figure 36.

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TYPICAL CHARACTERISTICS, 5G BAND DATA (4900 MHz–5900 MHz) (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, balun = Johanson 5400BL15B050E (unless otherwise noted)

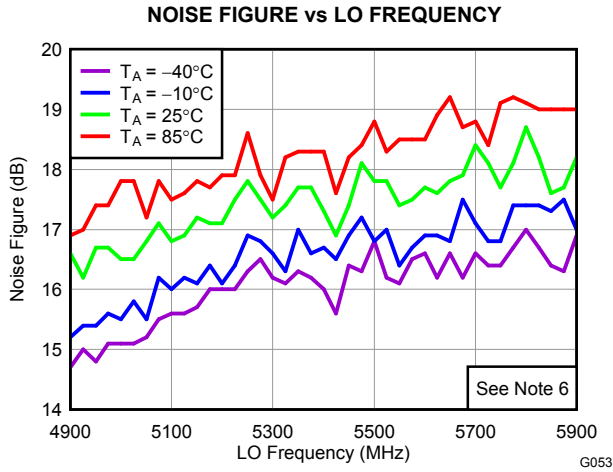


Figure 37.

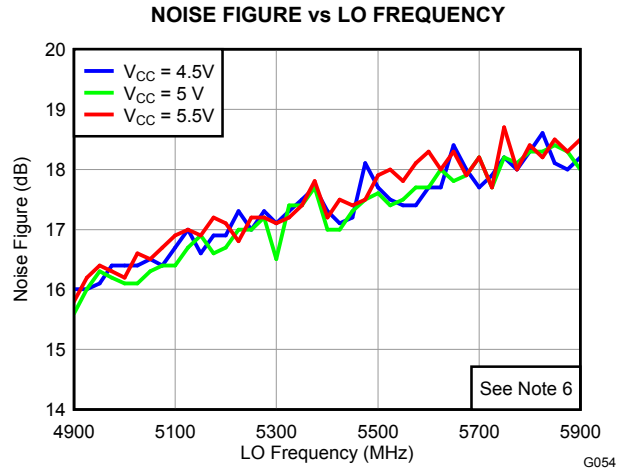


Figure 38.

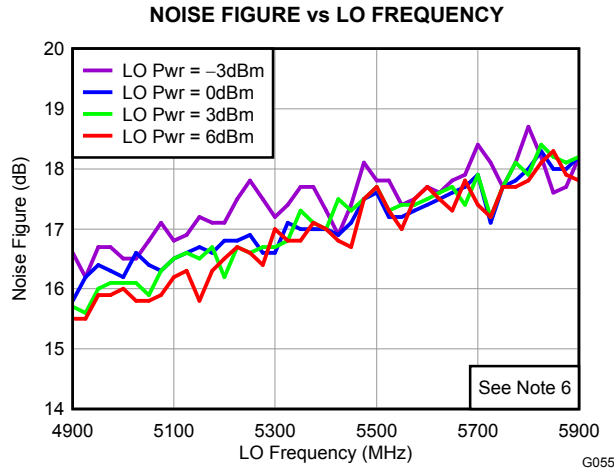


Figure 39.

TYPICAL CHARACTERISTICS, BASEBAND-RELATED DATA

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, independent of balun used (unless otherwise noted)

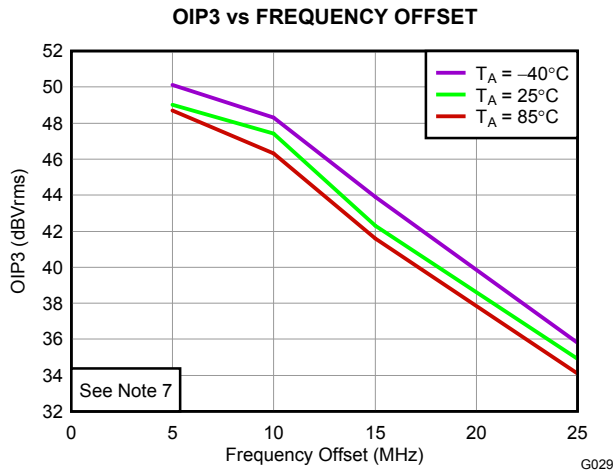


Figure 40.

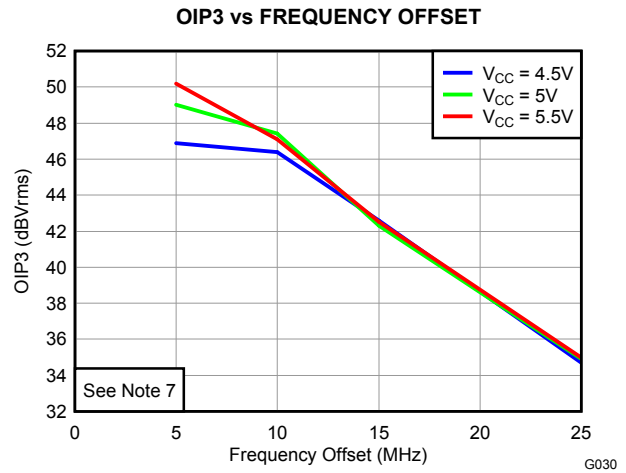


Figure 41.

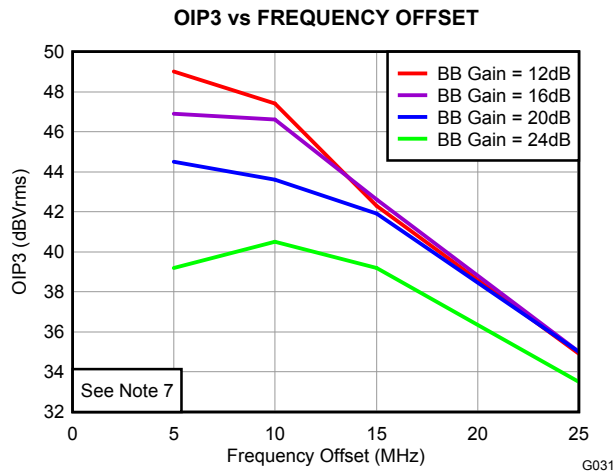


Figure 42.

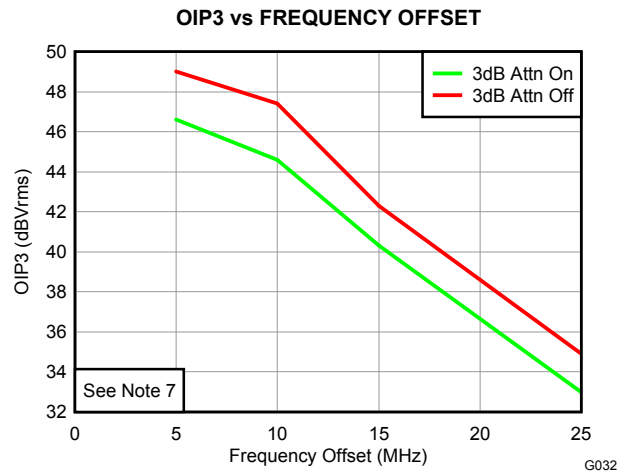


Figure 43.

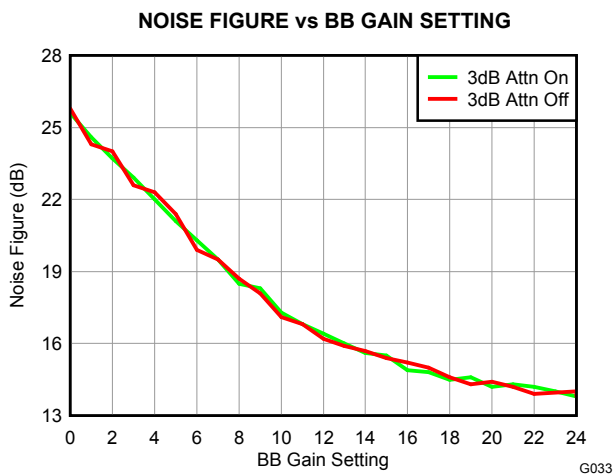


Figure 44.

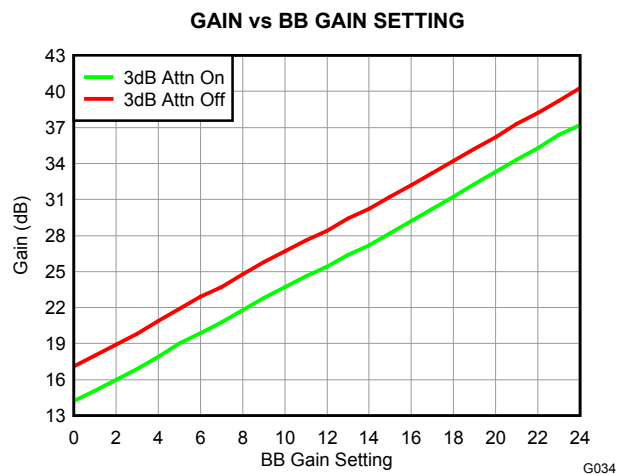


Figure 45.

TYPICAL CHARACTERISTICS, BASEBAND-RELATED DATA (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, independent of balun used (unless otherwise noted)

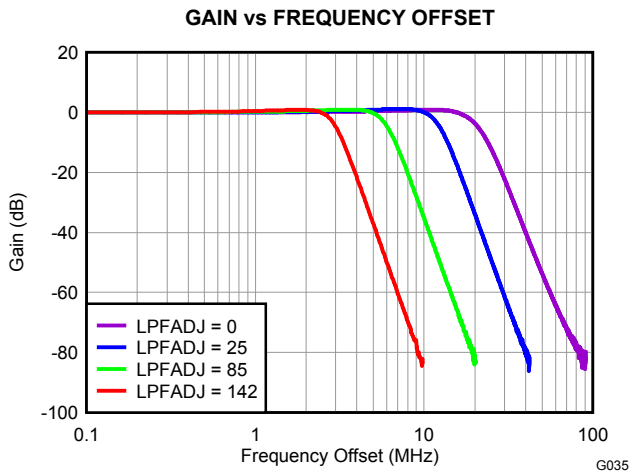


Figure 46.

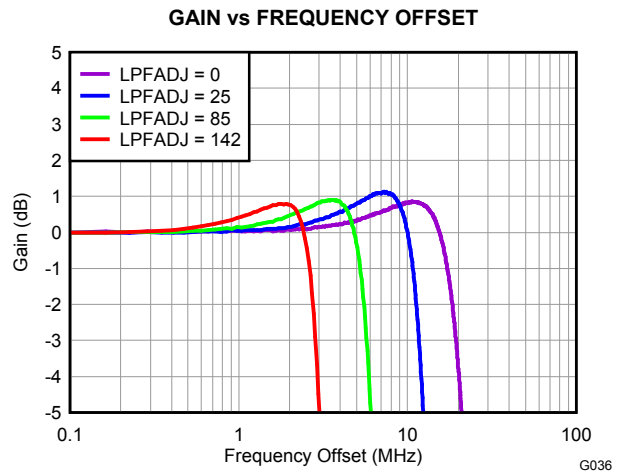


Figure 47.

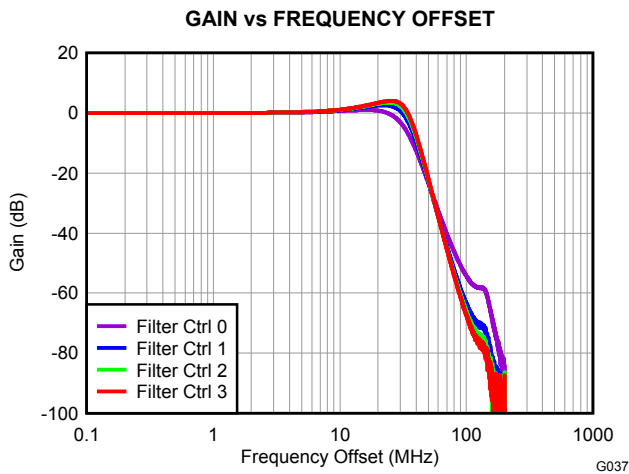


Figure 48. Bypass Mode

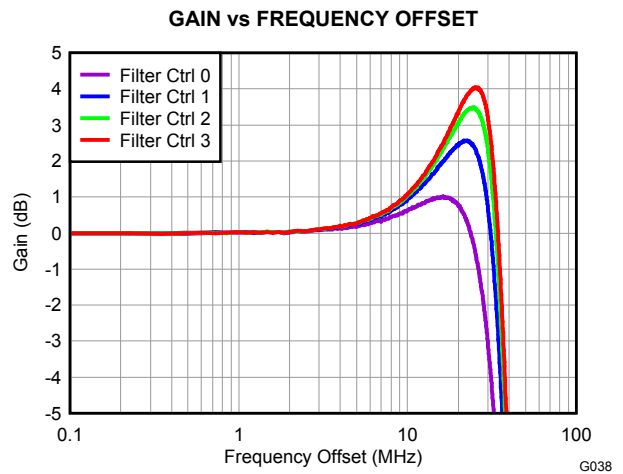


Figure 49. Bypass Mode

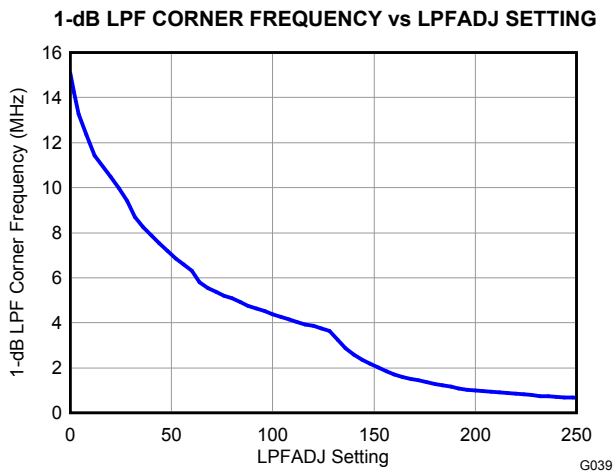


Figure 50.

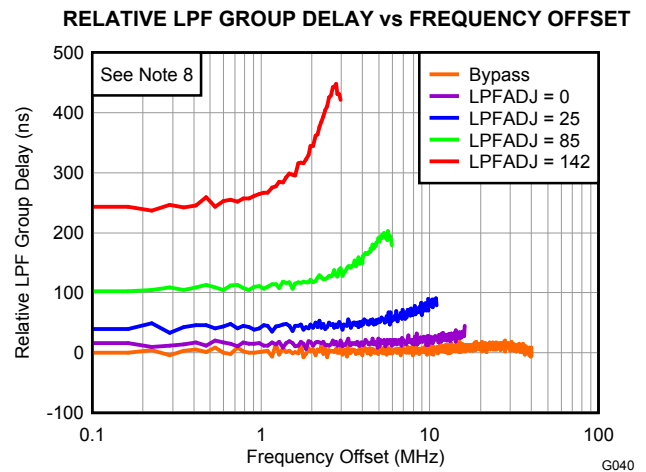


Figure 51.

TYPICAL CHARACTERISTICS, BASEBAND-RELATED DATA (continued)

$V_{CC} = 5\text{ V}$, LO power = 0 dBm, $T_A = 25^\circ\text{C}$, independent of balun used (unless otherwise noted)

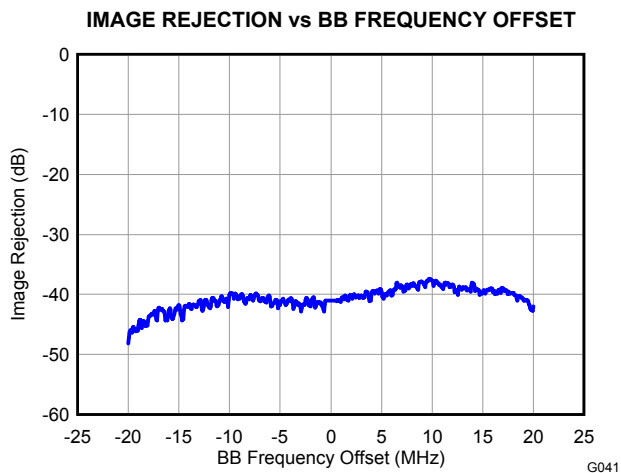


Figure 52.

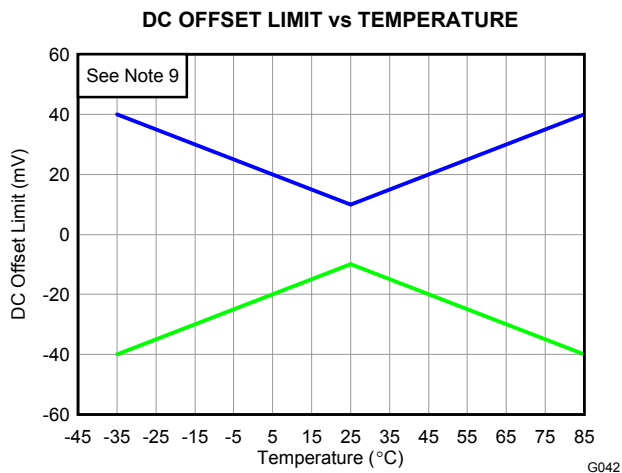


Figure 53.

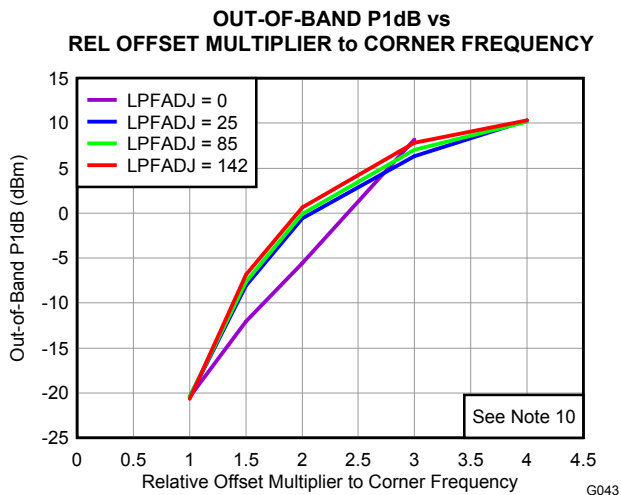


Figure 54.

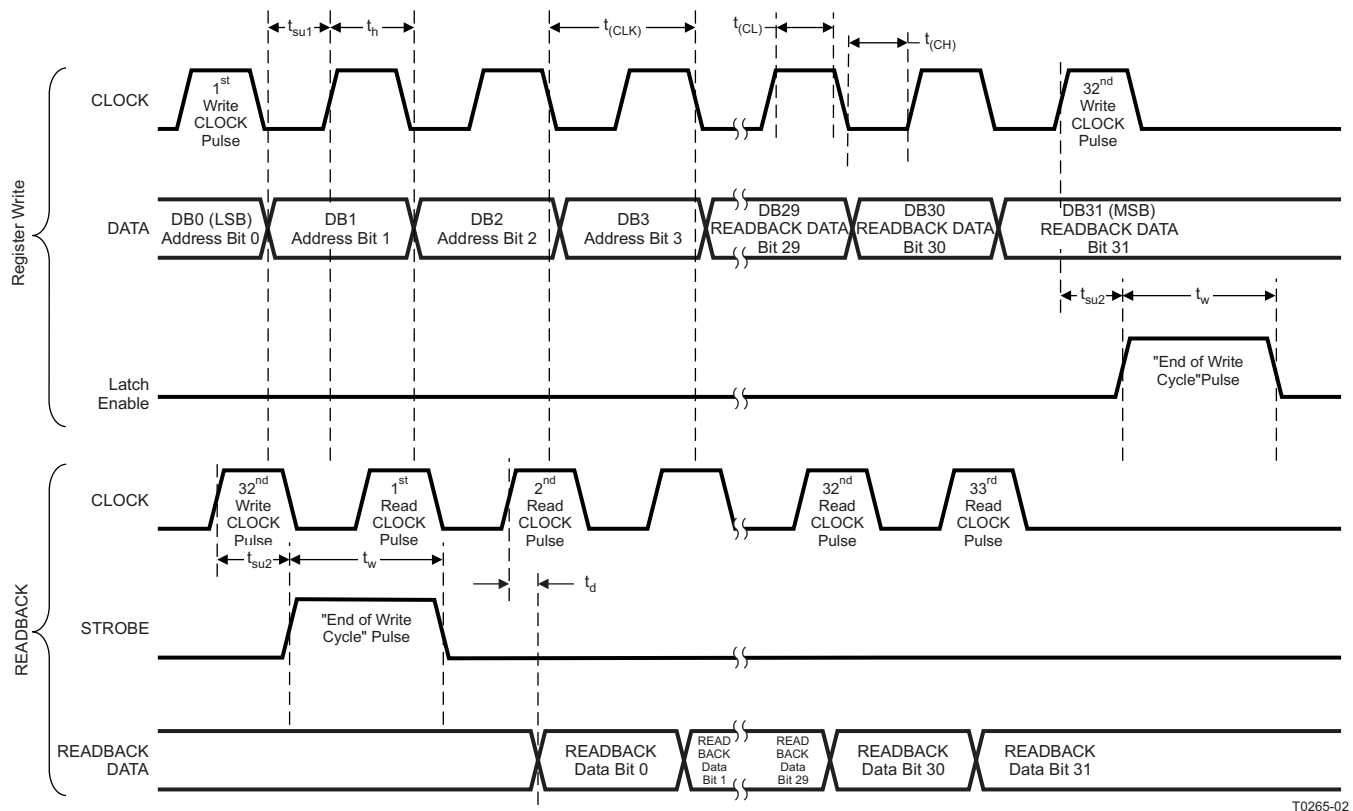
SERIAL INTERFACE PROGRAMMING REGISTERS DEFINITION

The TRF371135 features a three-wire serial programming interface (SPI) that controls an internal 32-bit shift register. There are three signals that must be applied: CLOCK (pin 48), serial DATA (pin 47), and STROBE (pin 46). DATA (DB0–DB31) is loaded LSB-first and is read on the rising edge of CLOCK. STROBE is asynchronous to CLOCK, and at its rising edge the data in the shift register is loaded into the selected internal register. The first two bits (DB0–DB1) are the address to select the available internal registers.

READBACK Mode

The TRF371135 implements the capability to read back the content of the serial programming interface registers. In addition, it is possible to read back the status of the internal DAC registers that are automatically set after an auto dc-offset calibration. Each readback consists of two phases: writing followed by the actual reading of the internal data (refer to timing diagram in [Figure 55](#)).

During the writing phase, a command is sent to the TRF371135 to set it in readback mode and to specify which register is to be read. In the proper reading phase, at each rising clock edge, the internal data is transferred into the READBACK pin and can be read at the following falling edge (LSB first). The first clock after LE goes high (end of writing cycle) is idle, and the following 32 clock pulses transfer the internal register content to the READBACK pin.



T0265-02

Figure 55. Serial Programming Timing Diagram

Table 1. Register Summary⁽¹⁾

| Bit # | Reg 1 | Reg 2 | Bit # | Reg 3 | Reg 5 | Bit # | Reg 0 | |
|-------|----------------|--------------------|-------------|------------------|--------------------|--------------------|------------------|-------|
| Bit0 | ADDR<0,2> | ADDR<0,2> | Bit0 | ADDR<0,2> | ADDR<0,2> | Bit0 | ADDR<0,2> | |
| Bit1 | | | Bit1 | | | Bit1 | | |
| Bit2 | | | Bit2 | | | Bit2 | | |
| Bit3 | ADDR<3,4> | ADDR<3,4> | Bit3 | ADDR<3,4> | ADDR<3,4> | Bit3 | ADDR<3,4> | |
| Bit4 | | | Bit4 | | | Bit4 | | |
| Bit5 | PWD_MIX | EN_AUTOCAL | Bit5 | ILOAD_a<0,5> | MIX_GM_TRIM<0,1> | Bit5 | ID<0,1> | |
| Bit6 | NU | IDAC_BIT<0,7> | Bit6 | | MIX_LO_TRIM<0,1> | Bit6 | NU | |
| Bit7 | PWD_BUF | | Bit7 | | LO_TRIM<0,1> | Bit7 | | |
| Bit8 | PWD_FILT | | Bit8 | | MIX_BUFF_TRIM<0,1> | Bit8 | | |
| Bit9 | NU | | Bit9 | | | Bit9 | | |
| Bit10 | PWD_DC_OFF_DIG | Bit10 | Bit10 | | | | | |
| Bit11 | NU | QDAC_BIT<0,7> | Bit11 | ILOAD_b<0,5> | FLTR_TRIM<0,1> | Bit11 | DC_OFFSET_Q<0,7> | |
| Bit12 | BBGAIN_<0,4> | | Bit12 | | QLOAD_a<0,5> | OUT_BUFF_TRIM<0,1> | | Bit12 |
| Bit13 | | | Bit13 | QLOAD_b<0,5> | | NU | | Bit13 |
| Bit14 | | | Bit14 | | | | | Bit14 |
| Bit15 | | | Bit15 | Bit15 | Bit15 | | | |
| Bit16 | | Bit16 | Bit16 | Bit16 | | | | |
| Bit17 | LPFADJ_<0,7> | IDET_B<0,1> | Bit17 | QLOAD_b<0,5> | NU | Bit17 | DC_OFFSET_I<0,7> | |
| Bit18 | | | Bit18 | | | Bit18 | | |
| Bit19 | | | Bit19 | | | Bit19 | | |
| Bit20 | | | Bit20 | | | Bit20 | | |
| Bit21 | | | Bit21 | | | Bit21 | | |
| Bit22 | EN_FLT_B<0,1> | CAL_SEL | Bit22 | QLOAD_b<0,5> | NU | Bit22 | DC_OFFSET_I<0,7> | |
| Bit23 | | Clk_div_ratio<0,2> | Bit23 | | | Bit23 | | |
| Bit24 | | | Bit24 | | | Bit24 | | |
| Bit25 | EN_FASTGAIN | Cal_clk_sel | Bit25 | Bypass | NU | Bit25 | DC_OFFSET_I<0,7> | |
| Bit26 | | | Bit26 | | | Bit26 | | |
| Bit27 | OSC_TEST | Osc_trim<0,2> | Bit27 | Fltr Ctrl_b<0,1> | NU | Bit27 | DC_OFFSET_I<0,7> | |
| Bit28 | | | Bit28 | | | Bit28 | | |
| Bit29 | NU | Osc_trim<0,2> | Bit29 | Fltr Ctrl_b<0,1> | NU | Bit29 | DC_OFFSET_I<0,7> | |
| Bit30 | | | Bit30 | | | Bit30 | | |
| Bit31 | | | EN 3dB Attn | | | Bit31 | | Bit31 |

(1) Register 4 is not used.

Table 2. Register 1 Device Setup

| REGISTER 1 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|----------------|-------------|--|
| Bit0 | ADDR<0> | 1 | Register address |
| Bit1 | ADDR<1> | 0 | |
| Bit2 | ADDR<2> | 0 | |
| Bit3 | ADDR<3> | 1 | SPI bank address |
| Bit4 | ADDR<4> | 0 | |
| Bit5 | PWD_MIX | 0 | Mixer power down (Off = 1) |
| Bit6 | NU | 0 | Not used |
| Bit7 | PWD_BUF | 1 | Mixer out test buffer power down (Off = 1) |
| Bit8 | PWD_FILT | 0 | Baseband filter power down (Off = 1) |
| Bit9 | NU | 0 | Not used |
| Bit10 | PWD_DC_OFF_DIG | 1 | DC offset calibration power down (Off = 1) |

Table 2. Register 1 Device Setup (continued)

| REGISTER 1 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|-------------|-------------|---|
| Bit11 | NU | 1 | Not used |
| Bit12 | BBGAIN_0 | 1 | Baseband gain setting. Default = 15. Range is from 0 (minimum gain setting) to 24 (maximum gain setting). See the Application Information section for more information on gain setting and fast gain control options. |
| Bit13 | BBGAIN_1 | 1 | |
| Bit14 | BBGAIN_2 | 1 | |
| Bit15 | BBGAIN_3 | 1 | |
| Bit16 | BBGAIN_4 | 0 | |
| Bit17 | LPFADJ_0 | 0 | Sets programmable low-pass filter corner frequency. Range = 255 (lowest corner frequency) to 0 (highest corner frequency). Default value is 128. |
| Bit18 | LPFADJ_1 | 0 | |
| Bit19 | LPFADJ_2 | 0 | |
| Bit20 | LPFADJ_3 | 0 | |
| Bit21 | LPFADJ_4 | 0 | |
| Bit22 | LPFADJ_5 | 0 | |
| Bit23 | LPFADJ_6 | 0 | |
| Bit24 | LPFADJ_7 | 1 | |
| Bit25 | EN_FLT_B0 | 0 | Selects dc offset detector filter bandwidth. Setting {00, 01, 11} = {10 MHz, 10 kHz, 1 kHz} |
| Bit26 | EN_FLT_B1 | 0 | |
| Bit27 | EN_FASTGAIN | 0 | Enable external fast-gain control |
| Bit28 | GAIN_SEL | 0 | Fast-gain control multiplier bit (x2 = 1) |
| Bit29 | OSC_TEST | 0 | Enables OSC out on readback pin if = 1 |
| Bit30 | NU | 0 | Not used |
| Bit31 | EN 3dB Attn | 0 | Enables output 3-dB attenuator |

EN_FLT_B0/1: These bits control the bandwidth of the detector used to measure the dc offset during the automatic calibration. There is an RC filter in front of the detector that can be fully bypassed. EN_FLT_B0 controls the resistor (bypass = 1), while EN_FLT_B1 controls the capacitor (bypass = 1). The typical 3-dB cutoff frequencies of the detector bandwidth are summarized in the following table (see the [Application Information](#) section for more detail on the dc offset calibration and the detector bandwidth).

| EN_FLT_B1 | EN_FLT_B0 | TYPICAL 3-dB CUTOFF FREQ | NOTES |
|-----------|-----------|--------------------------|--------------------------------|
| X | 0 | 10 MHz | Maximum bandwidth, bypass R, C |
| 0 | 1 | 10 kHz | Enable R |
| 1 | 1 | 1 kHz | Minimum bandwidth, enable R, C |

Table 3. Register 2 Device Setup

| REGISTER 2 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|------------|-------------|--|
| Bit0 | ADDR<0> | 0 | Register address |
| Bit1 | ADDR<1> | 1 | |
| Bit2 | ADDR<2> | 0 | |
| Bit3 | ADDR<3> | 1 | SPI bank address |
| Bit4 | ADDR<4> | 0 | |
| Bit5 | EN_AUTOCAL | 0 | Enable autocal when = 1; reset to 0 when done. |

Table 3. Register 2 Device Setup (continued)

| REGISTER 2 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|------------------|-------------|--|
| Bit6 | IDAC_BIT0 | 0 | I-DAC bits to be set during manual dc offset cal |
| Bit7 | IDAC_BIT1 | 0 | |
| Bit8 | IDAC_BIT2 | 0 | |
| Bit9 | IDAC_BIT3 | 0 | |
| Bit10 | IDAC_BIT4 | 0 | |
| Bit11 | IDAC_BIT5 | 0 | |
| Bit12 | IDAC_BIT6 | 0 | |
| Bit13 | IDAC_BIT7 | 1 | Q-DAC bits to be set during manual dc offset cal |
| Bit14 | QDAC_BIT0 | 0 | |
| Bit15 | QDAC_BIT1 | 0 | |
| Bit16 | QDAC_BIT2 | 0 | |
| Bit17 | QDAC_BIT3 | 0 | |
| Bit18 | QDAC_BIT4 | 0 | |
| Bit19 | QDAC_BIT5 | 0 | |
| Bit20 | QDAC_BIT6 | 0 | |
| Bit21 | QDAC_BIT7 | 1 | |
| Bit22 | IDET_B0 | 1 | Set reference current for digital calibration; Settings {00 to 11} = {50 μ A to 200 μ A}. Setting 00 = highest resolution. |
| Bit23 | IDET_B1 | 1 | |
| Bit24 | CAL_SEL | 1 | DC offset calibration select. 0 = manual cal; 1 = autocal. |
| Bit25 | Clk_div_ratio<0> | 0 | Clk divider ratio. Setting {000 to 111} = {1, 8, 16, 128, 256, 1024, 2048, 16,684}. A higher div ratio (slower clk) improves cal accuracy and reduces speed. |
| Bit26 | Clk_div_ratio<1> | 0 | |
| Bit27 | Clk_div_ratio<2> | 0 | |
| Bit28 | Cal_clk_sel | 1 | Select internal oscillator when 1, SPI clk when 0 |
| Bit29 | Osc_trim<0> | 1 | Internal oscillator frequency trimming; setting {000} = ~300 kHz; Setting {111} = ~1.8 MHz. Nominal setting {110} = ~900 kHz. |
| Bit30 | Osc_trim<1> | 1 | |
| Bit31 | Osc_trim<2> | 0 | |

Table 4. Register 3 Device Setup

| REGISTER 3 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|------------|-------------|-----------------------|
| Bit0 | ADDR<0> | 1 | Register address |
| Bit1 | ADDR<1> | 1 | |
| Bit2 | ADDR<2> | 0 | |
| Bit3 | ADDR<3> | 1 | SPI bank address |
| Bit4 | ADDR<4> | 0 | |
| Bit5 | ILOAD_a<0> | 0 | I mixer offset side A |
| Bit6 | ILOAD_a<1> | 0 | |
| Bit7 | ILOAD_a<2> | 0 | |
| Bit8 | ILOAD_a<3> | 0 | |
| Bit9 | ILOAD_a<4> | 0 | |
| Bit10 | ILOAD_a<5> | 0 | I mixer offset side B |
| Bit11 | ILOAD_b<0> | 0 | |
| Bit12 | ILOAD_b<1> | 0 | |
| Bit13 | ILOAD_b<2> | 0 | |
| Bit14 | ILOAD_b<3> | 0 | |
| Bit15 | ILOAD_b<4> | 0 | |
| Bit16 | ILOAD_b<5> | 0 | |

Table 4. Register 3 Device Setup (continued)

| REGISTER 3 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|----------------|-------------|--|
| Bit17 | QLOAD_a<0> | 0 | Q mixer offset side A |
| Bit18 | QLOAD_a<1> | 0 | |
| Bit19 | QLOAD_a<2> | 0 | |
| Bit20 | QLOAD_a<3> | 0 | |
| Bit21 | QLOAD_a<4> | 0 | |
| Bit22 | QLOAD_a<5> | 0 | |
| Bit23 | QLOAD_b<0> | 0 | Q mixer offset side B |
| Bit24 | QLOAD_b<1> | 0 | |
| Bit25 | QLOAD_b<2> | 0 | |
| Bit26 | QLOAD_b<3> | 0 | |
| Bit27 | QLOAD_b<4> | 0 | |
| Bit28 | QLOAD_b<5> | 0 | |
| Bit29 | Bypass | 0 | Engage filter bypass |
| Bit30 | Fltr Ctrl_b<0> | 1 | Used to adjust for filter peaking response; set to 0 in bypass mode, 1 otherwise |
| Bit31 | Fltr Ctrl_b<1> | 0 | |

I/Q Mixer Load A/B: These bits adjust the load on the mixer output. All values should be 0. No modification is necessary.

Register 4: No programming required for register 4

Table 5. Register 5 Device Setup

| REGISTER 5 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|------------------|-------------|-----------------------------------|
| Bit0 | ADDR<0> | 1 | Register address |
| Bit1 | ADDR<1> | 0 | |
| Bit2 | ADDR<2> | 1 | |
| Bit3 | ADDR<3> | 1 | SPI bank address |
| Bit4 | ADDR<4> | 0 | |
| Bit5 | MIX_GM_TRIM<0> | 1 | Mixer gm current trim |
| Bit6 | MIX_GM_TRIM<1> | 0 | |
| Bit7 | MIX_LO_TRIM<0> | 1 | Mixer switch core VCM trim |
| Bit8 | MIX_LO_TRIM<1> | 0 | |
| Bit9 | LO_TRIM<0> | 1 | LO buffers current trim |
| Bit10 | LO_TRIM<1> | 0 | |
| Bit11 | MIX_BUFF_TRIM<0> | 1 | Mixer output buffer current trim |
| Bit12 | MIX_BUFF_TRIM<1> | 0 | |
| Bit13 | FLTR_TRIM<0> | 1 | Filter current trim |
| Bit14 | FLTR_TRIM<1> | 0 | |
| Bit15 | OUT_BUFF_TRIM<0> | 1 | Filter output buffer current trim |
| Bit16 | OUT_BUFF_TRIM<1> | 0 | |

Table 5. Register 5 Device Setup (continued)

| REGISTER 5 | NAME | RESET VALUE | WORKING DESCRIPTION |
|------------|------|-------------|---------------------|
| Bit17 | NU | 0 | Not used |
| Bit18 | | 0 | |
| Bit19 | | 0 | |
| Bit20 | | 0 | |
| Bit21 | | 0 | |
| Bit22 | | 0 | |
| Bit23 | | 0 | |
| Bit24 | | 0 | |
| Bit25 | | 0 | |
| Bit26 | | 0 | |
| Bit27 | | 0 | |
| Bit28 | | 0 | |
| Bit29 | | 0 | |
| Bit30 | | 0 | |
| Bit31 | 0 | | |

Trims: the trim values allow for minor bias adjustments of internal stages. Generally it is recommended to leave all trim values at the default value of 1. Linearity performance improvement over a small band of frequencies is possible by selective adjustment of the trim values. Optimized intercept point within the band 2.5 GHz to 2.7 GHz is achieved by setting trim values MIX_GM_TRIM<0,1>, MIX_LO_TRIM<0,1>, LO_TRIM<0,1>, MIX_BUFF_TRIM<0,1>, FLTR_TRIM<0,1>, OUT_BUFF_TRIM<0,1> to: 2, 3, 0, 1, 2, 1, respectively.

Readback (Write Command)

| | | | | | | | | | | | | | | | |
|-----------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|------------------|-------|-------|-------|
| 0 | 0 | 0 | 1 | 0 | Zero Fill | | | | | | | | | | |
| Bit0 | Bit1 | Bit2 | Bit3 | Bit4 | Bit5 | Bit6 | Bit7 | Bit8 | Bit9 | Bit10 | Bit11 | Bit12 | Bit13 | Bit14 | Bit15 |
| Zero fill | | | | | | | | | | | | Register address | | 1 | |
| Bit16 | Bit17 | Bit18 | Bit19 | Bit20 | Bit21 | Bit22 | Bit23 | Bit24 | Bit25 | Bit26 | Bit27 | Bit28 | Bit29 | Bit30 | Bit31 |

Reg 0: DAC/Device ID Readback

| Register Address | | | SPI Bank Addr | | ID | | NU | | | | | | | | |
|------------------|-------|-------|---------------|-------|-------|-------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Bit0 | Bit1 | Bit2 | Bit3 | Bit4 | Bit5 | Bit6 | Bit7 | Bit8 | Bit9 | Bit10 | Bit11 | Bit12 | Bit13 | Bit14 | Bit15 |
| DC offset Q DAC | | | | | | | DC offset I DAC | | | | | | | | |
| Bit16 | Bit17 | Bit18 | Bit19 | Bit20 | Bit21 | Bit22 | Bit23 | Bit24 | Bit25 | Bit26 | Bit27 | Bit28 | Bit29 | Bit30 | Bit31 |

Table 6. Register 0 Device Setup (Read-Only)

| READBACK REGISTER | NAME | RESET VALUE | WORKING DESCRIPTION |
|-------------------|---------|-------------|------------------------|
| Bit0 | ADDR<0> | 0 | Select SPI reg 1 to 5 |
| Bit1 | ADDR<1> | 0 | |
| Bit2 | ADDR<2> | 0 | |
| Bit3 | ADDR<3> | 1 | Select SPI bank 1 to 3 |
| Bit4 | ADDR<4> | 0 | |
| Bit5 | ID<0> | 1 | Version ID: 01 = -25 |
| Bit6 | ID<1> | 0 | |

Table 6. Register 0 Device Setup (Read-Only) (continued)

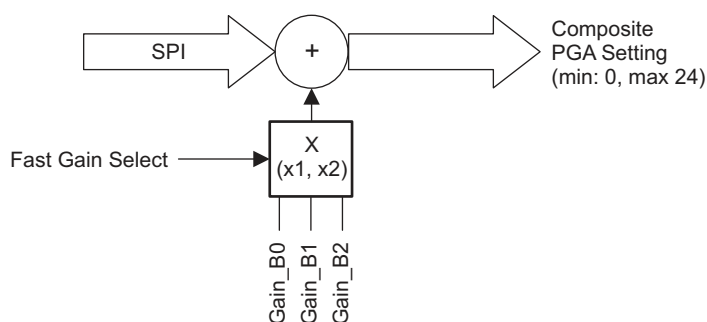
| READBACK REGISTER | NAME | RESET VALUE | WORKING DESCRIPTION |
|-------------------|----------------|----------------|--------------------------|
| Bit7 | NU | 0 | Not used |
| Bit8 | | 0 | |
| Bit9 | | 0 | |
| Bit10 | | 0 | |
| Bit11 | | 0 | |
| Bit12 | | 0 | |
| Bit13 | | 0 | |
| Bit14 | | 0 | |
| Bit15 | | 0 | |
| Bit16 | | DC_OFFSET_Q<0> | |
| Bit17 | DC_OFFSET_Q<1> | 0 | |
| Bit18 | DC_OFFSET_Q<2> | 0 | |
| Bit19 | DC_OFFSET_Q<3> | 0 | |
| Bit20 | DC_OFFSET_Q<4> | 0 | |
| Bit21 | DC_OFFSET_Q<5> | 0 | |
| Bit22 | DC_OFFSET_Q<6> | 0 | |
| Bit23 | DC_OFFSET_Q<7> | 1 | DC offset DAC I register |
| Bit24 | DC_OFFSET_I<0> | 0 | |
| Bit25 | DC_OFFSET_I<1> | 0 | |
| Bit26 | DC_OFFSET_I<2> | 0 | |
| Bit27 | DC_OFFSET_I<3> | 0 | |
| Bit28 | DC_OFFSET_I<4> | 0 | |
| Bit29 | DC_OFFSET_I<5> | 0 | |
| Bit30 | DC_OFFSET_I<6> | 0 | |
| Bit31 | DC_OFFSET_I<7> | 1 | |

APPLICATION INFORMATION

Gain Control

The TRF371135 integrates a baseband programmable-gain amplifier (PGA) that provides 24 dB of gain range with 1-dB steps. The PGA gain is controlled through SPI by a 5-bit word (register 1 bits <12,16>). Alternatively, the PGA can be programmed by a combination of five bits programmed through the SPI and three parallel external bits (pins Gain_B2, Gain_B1, Gain_B0). The external bits are used to reduce the PGA setting quickly without having to reprogram the SPI registers. The fast gain control multiplier bit (register 1 bit 28) sets the step size of each bit to either 1 dB or 2 dB. This allows a fast gain reduction of 0 dB to 7 dB in 1-dB steps or 0 dB to 14 dB in 2-dB steps.

The PGA gain control word (BBGAIN<0,4>) can be programmed to a setting between 0 and 24. This word is the SPI programmed gain (register 1 bits <12,16>) minus the parallel external 3 bits as shown in Figure 56. Note that the PGA gain setting rails at 0 and does not go any lower. Typical applications set the nominal PGA gain setting to 17 and use the fast-gain control bits to protect the analog-to-digital converter in the event of a strong input jammer signal.



B0386-01

Figure 56. PGA Gain Control Word

For example, if a PGA gain setting of 19 is desired, then the SPI can be programmed directly to a value of 19. Alternatively, the SPI gain register can be programmed to 24 and the parallel external bits set to 101 (binary) corresponding to 5-dB reduction.

Automated DC Offset Calibration

The TRF371135 provides an automatic calibration procedure for adjusting the dc offset in the baseband I/Q paths. The internal calibration requires a clock in order to function. The TRF371135 can use the internal relaxation oscillator or the external SPI clock. Using the internal oscillator is the preferred method, which is selected by setting the Cal_clk_sel (register 2, bit 28) to 1. The internal oscillator frequency is set through the Osc_trim bits (register 2, bits <29,31>). The frequency of the oscillator is detailed in Table 7; however, it is expected the actual frequency of operation can vary plus or minus 35% due to process variations. The oscillator frequency can be monitored on the READBACK pin when the Osc_test register (register 1, bit 29) is set to 1.

Table 7. Internal Oscillator Frequency Control

| Osc_trim<2> | Osc_trim<1> | Osc_trim<0> | FREQUENCY |
|-------------|-------------|-------------|-----------|
| 0 | 0 | 0 | 300 kHz |
| 0 | 0 | 1 | 500 kHz |
| 0 | 1 | 0 | 700 kHz |
| 0 | 1 | 1 | 900 kHz |
| 1 | 0 | 0 | 1.1 MHz |
| 1 | 0 | 1 | 1.3 MHz |
| 1 | 1 | 0 | 1.5 MHz |
| 1 | 1 | 1 | 1.8 MHz |

The default setting of these registers corresponds to a 900-kHz oscillator frequency. This is sufficient for autocalibration; modification is not required except for faster calibration convergence.

The output full-scale range of the internal dc offset correction DACs is programmable (IDET_B<0,1>, register 2 bits<22,23>). The range is shown in [Table 8](#).

Table 8. DC Offset Correction DAC Programmable Range

| IDET_B0 | IDET_B1 | Full Scale |
|---------|---------|-------------|
| 0 | 0 | 50 μ A |
| 0 | 1 | 100 μ A |
| 1 | 0 | 150 μ A |
| 1 | 1 | 200 μ A |

The I- and Q-channel output maximum dc offset correction range can be calculated by multiplying the values in the table by the baseband PGA gain. The LSB of the digital correction is dependent on the programmed maximum correction range. For optimum resolution and best correction, the dc offset DAC range should be set to 50 μ A with the PGA gain set for the nominal condition. The dc offset correction DAC output is affected by a change in the PGA gain, but if the initial calibration yields optimum results, then the adjustment of the PGA gain during normal operation does not significantly impair the dc offset balance. For example, if the optimized calibration yields a dc offset balance of 2 mV at a gain setting of 17, then the dc offset maintains less than 10 mV balance as the gain is adjusted ± 7 dB.

The dc offset correction DACs are programmed from the internal registers when the CAL_SEL bit (register 2, bit 24) is set to 1. At start-up, the internal registers are loaded at half-scale, corresponding to a decimal value of 128. The auto-cal is initiated by toggling the EN_AUTO CAL bit (register 2, bit 5) to 1. When the calibration is over, this bit is automatically reset to 0. During calibration, the RF local oscillator must be applied. The dc offset DAC state is stored in the internal registers and maintained as long as the power supply is kept on or until a new calibration is started.

The required clock speed for the optimum calibration is determined by the internal detector behavior (integration bandwidth, gain, sensitivity). The input bandwidth of the detector can be adjusted by changing the cutoff frequency of the RC low-pass filter in front of the detector (register 1, bits 25–26). EN_FLT_B0 controls the resistor (bypass = 1) and EN_FLT_B1 controls the capacitor (bypass = 1). The typical 3-dB cutoff frequencies of the detector bandwidth are summarized in [Table 9](#). The speed of the clock can be slowed down by selecting a clock divider ratio (register 2, bits 25–27).

Table 9. Detector Bandwidth Settings

| EN_FLT_B1 | EN_FLT_B0 | TYPICAL 3-dB CUTOFF FREQUENCY | NOTES |
|-----------|-----------|-------------------------------|--------------------------------|
| X | 0 | 10 MHz | Maximum bandwidth, bypass R, C |
| 0 | 1 | 10 kHz | Enable R |
| 1 | 1 | 1 kHz | Minimum bandwidth, enable R, C |

The detector has more averaging time with a slower clock; hence, it is desirable to slow down the clock speed for a given condition to achieve optimum results. For example, if there is no RF present on the RF input port, the detection filter can be left wide (10 MHz) and the clock divider can be left at div-by-128. The autocalibration yields a dc offset balance between the differential baseband output ports (I and Q) that is less than 15 mV. Some minor improvement may be obtained by increasing the averaging of the detector by increasing the clock divider up to 256 or 1024.

On the other hand, if there is a modulated RF signal present at the input port, it is desirable to reduce the detector bandwidth to filter out most of the modulated signal. The detector bandwidth can be set to a 1-kHz corner frequency. With the modulated signal present and with the detection bandwidth reduced, additional averaging is required to get the optimum results. A clock divider setting of 1024 yields optimum results.

Of course, an increase in the averaging is possible by increasing the clock divider at the expense of longer converging time. The convergence time can be calculated by the following:

$$\tau_c = \frac{(\text{Auto_Cal_Clk_Cycles}) \times (\text{Clk_Divider})}{\text{Osc_Freq}} \quad (1)$$

The dc offset calibration converges in approximately nine cycles. For the case with a clock divider of 1024 and with the nominal oscillator frequency of 900 kHz, the convergence time is:

$$\tau_c = \frac{(9) \times (1024)}{900 \text{ kHz}} = 10.24 \text{ ms} \quad (2)$$

Alternate Method for Adjusting DC Offset

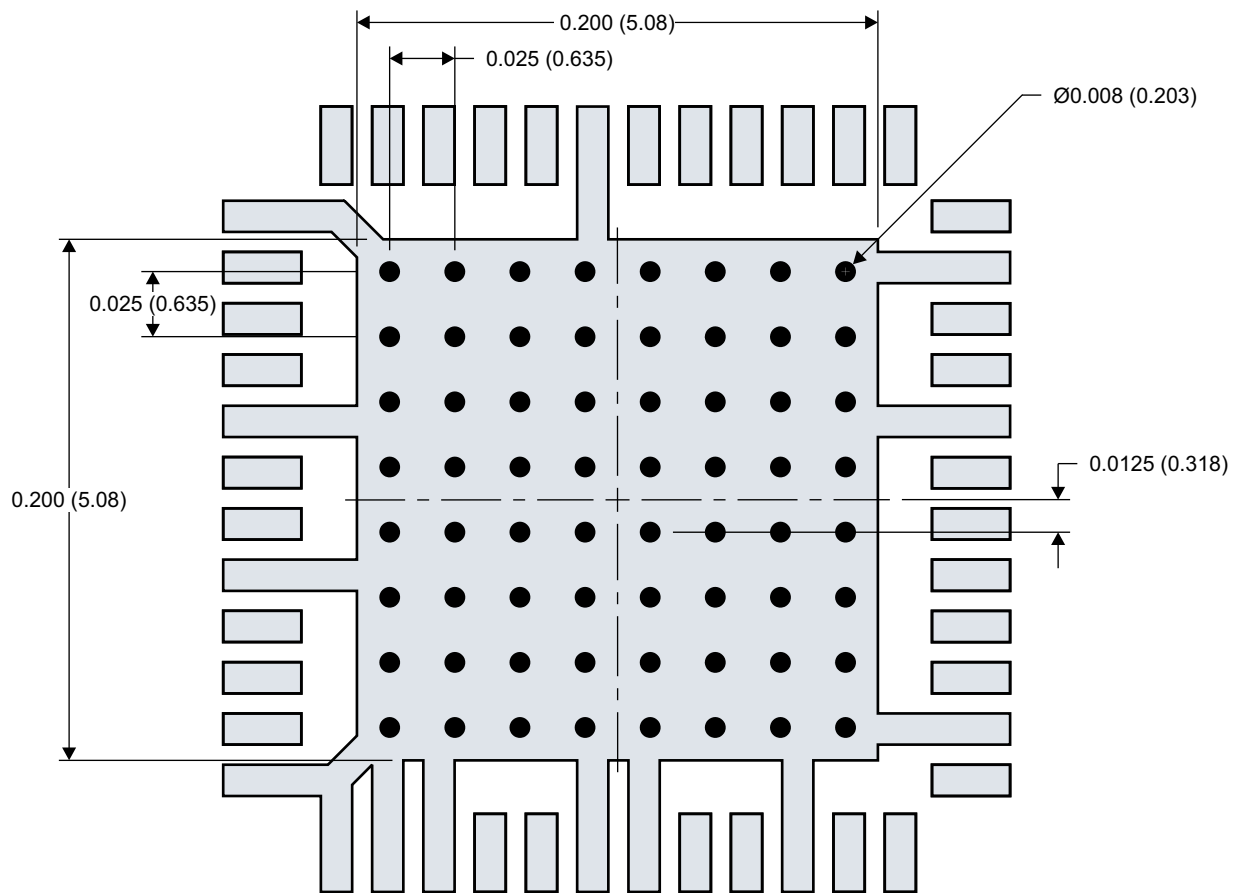
The internal registers controlling the internal dc current DAC are accessible through the SPI, providing a user-programmable method for implementing the dc offset calibration. To employ this option the CAL_SEL bit must be set to 0. During this calibration, an external instrument monitors the output dc offset between the I/Q differential outputs and programs the internal registers (IDAC_BIT<0,7> and QDAC_BIT<0,7> bits) to cancel the dc offset.

PCB Layout Guidelines

The TRF371135 device is fitted with a ground slug on the back of the package that must be soldered to the PCB ground with adequate ground vias to ensure a good thermal and electrical connection. The recommended via pattern and ground pad dimensions are shown in Figure 57. The recommended via diameter is 8 mils (0.2 mm). The ground pins of the device can be directly tied to the ground slug pad for a low-inductance path to ground. Additional ground vias may be added if space allows. The no-connect (NC) pins can also be tied to the ground plane.

Decoupling capacitors at each of the supply pins is recommended. The high-frequency decoupling capacitors for the RF mixers (VCCMIX) should be placed close to their respective pins. The value of the capacitor should be chosen to provide a low-impedance RF path to ground at the frequency of operation. Typically, this value is around 10 pF or lower. The other decoupling capacitors at the other supply pins should be kept as close to their respective pins as possible.

The device exhibits symmetry with respect to the quadrature output paths. It is recommended that the PCB layout maintain that symmetry in order to ensure the quadrature balance of the device is not impaired. The I/Q output traces should be routed as differential pairs and their lengths all kept equal to each other. Decoupling capacitors for the supply pins should be kept symmetrical where possible. The RF differential input lines related to the RF input and the LO input should also be routed as differential lines with their respective lengths kept equal. If an RF balun is used to convert a single-ended input to a differential input, then the RF balun should be placed close to the device. Implement the RF balun layout per the manufacturer's guidelines to provide best gain and phase balance to the differential outputs. On the RF traces, maintain proper trace widths to keep the characteristic impedance of the RF traces at a nominal 50 Ω .



Note: Dimensions are in inches (mm)

M0177-01

Figure 57. PCB Layout Guidelines

Application Schematic

The typical application schematic is shown in Figure 58. The RF bypass capacitors and coupling capacitors on the supply pins should be adjusted to provide the best high-frequency bypass based on the frequency of operation.

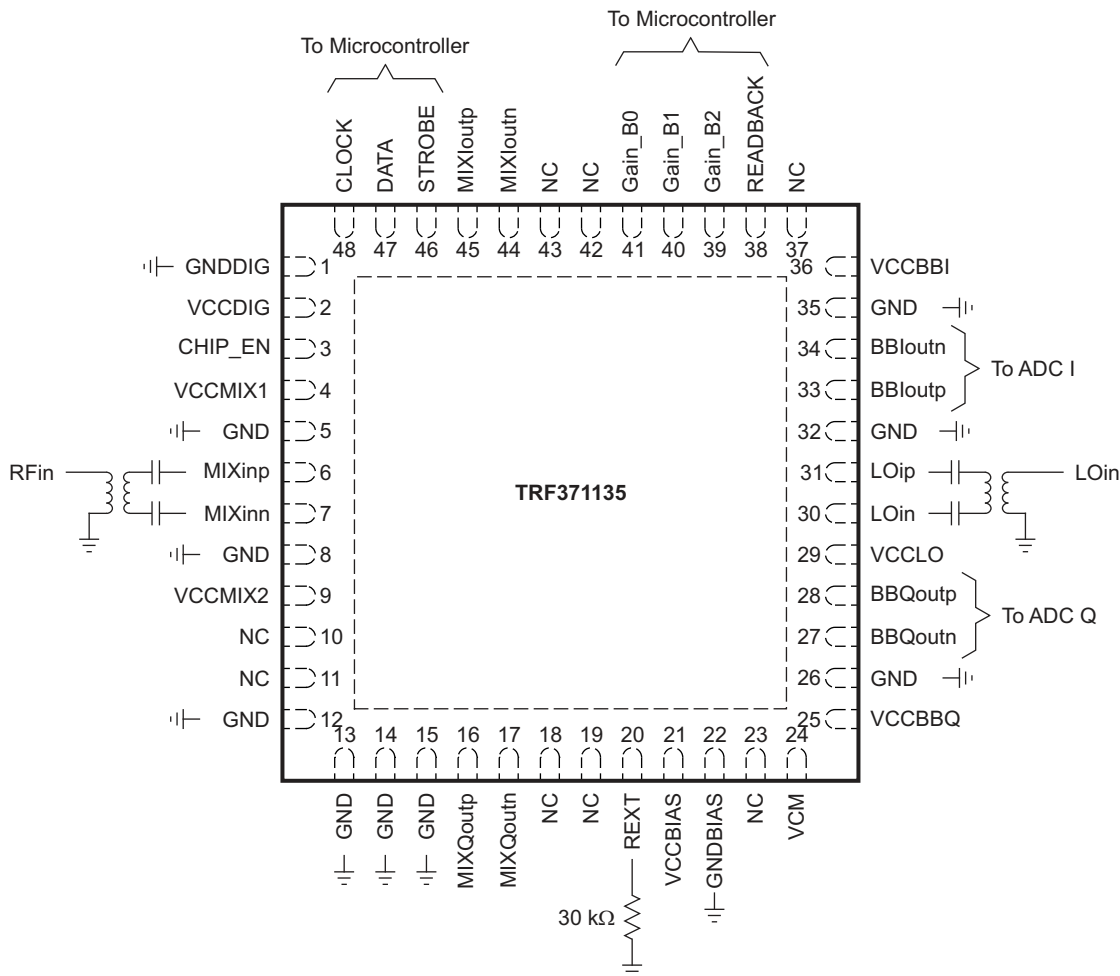


Figure 58. TRF371135 Application Schematic

The RF input port and the RF LO port require differential input paths. Single-ended RF inputs to these ports can be converted with an RF balun that is centered at the band of interest. Linearity performance of the TRF371135 is dependent on the amplitude and phase balance of the RF balun; hence, care should be taken with the selection of the balun device and with the RF layout of the device. The recommended RF balun devices are listed in Table 10.

Table 10. RF Balun Devices

| MANUFACTURER | PART NUMBER | FREQUENCY RANGE | UNBALANCE IMPEDANCE | BALANCE IMPEDANCE |
|--------------|------------------|--------------------|---------------------|-------------------|
| Murata | LDB211G8005C-001 | 1800 MHz ±100 MHz | 50 Ω | 50 Ω |
| Murata | LDB211G9005C-001 | 1900 MHz ±100 MHz | 50 Ω | 50 Ω |
| Murata | LDB212G4005C-001 | 2.3 GHz to 2.7 GHz | 50 Ω | 50 Ω |
| Johanson | 3600BL14M050E | 3.3 GHz to 3.8 GHz | 50 Ω | 50 Ω |
| Johanson | 5400BL15B050E | 4.9 GHz to 5.9 GHz | 50 Ω | 50 Ω |

Application for a High-Performance RF Receiver Signal Chain

The TRF371135 is the centerpiece component in a high-performance direct-downconversion receiver. The device is a highly integrated direct-downconversion demodulator that requires minimal additional devices to complete the signal chain. A signal chain block diagram example is shown in Figure 59.

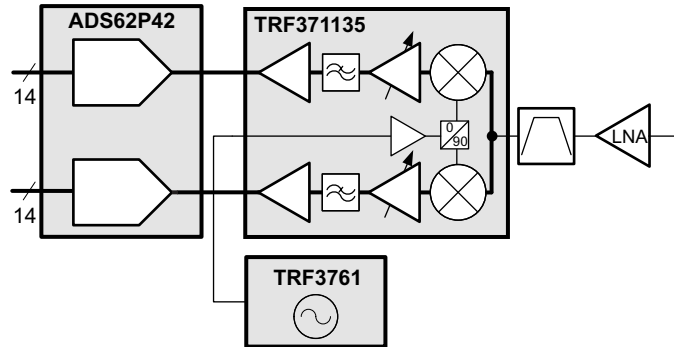


Figure 59. Block Diagram of Direct-Downconvert Receiver

The lineup requires a low-noise amplifier (LNA) that operates at the frequency of interest with typical 1- to 2-dB noise figure (NF) performance. An RF band-pass filter (BPF) is selected at the frequency band of interest to eliminate unwanted signals and images outside the band from reaching the demodulator. The TRF371135 incorporates the direct-downconvert demodulation, baseband filtering, and baseband gain-control functions. An external synthesizer, such as the TRF3761, is used to provide the local oscillator (LO) source to the TRF371135. The differential outputs of the TRF3761 directly mate with LO input of the TRF371135. The quadrature outputs (I/Q) of the TRF371135 directly drive the input to the analog-to-digital converter (ADC). A dual ADC like the ADS62P42 14-bit 65-MSPS ADC mates perfectly with the differential I/Q output of the TRF371135. The baseband output pins (pins 27, 28, 33, 34) can be connected directly to the corresponding input pins of typical ADCs. The positive and negative terminal connections between the TRF371135 and the ADC can be swapped to facilitate a clean routing layout. The swapped connection can be reversed by flipping the signals in the digital domain, if desired. In addition, the common-mode output voltage generated by the ADC is fed directly into the common-mode port (pin 24) to ensure the optimum dynamic range of the ADC is maintained.

EVALUATION TOOLS



An evaluation module is available to test the TRF371135 performance. The TRF371135EVM can be configured with different baluns to enable operation in various frequency bands. The TRF371135EVM is available for purchase through the Texas Instruments web site at www.ti.com.

REVISION HISTORY

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

| Changes from Original (February, 2010) to Revision A | Page |
|--|-------------|
| • Corrected product name discussed throughout document | 1 |
| • Added Evaluation Tools | 50 |

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|---|
| TRF371135IRGZR | ACTIVE | VQFN | RGZ | 48 | 2500 | RoHS & Green | NIPDAUAG | Level-2-260C-1 YEAR | -40 to 85 | TRF 371135IRGZ |  |
| TRF371135IRGZT | ACTIVE | VQFN | RGZ | 48 | 250 | RoHS & Green | NIPDAUAG | Level-2-260C-1 YEAR | -40 to 85 | TRF 371135IRGZ |  |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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

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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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TRF371135IRGZR | VQFN | RGZ | 48 | 2500 | 330.0 | 16.4 | 7.3 | 7.3 | 1.5 | 12.0 | 16.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TRF371135IRGZR | VQFN | RGZ | 48 | 2500 | 350.0 | 350.0 | 43.0 |

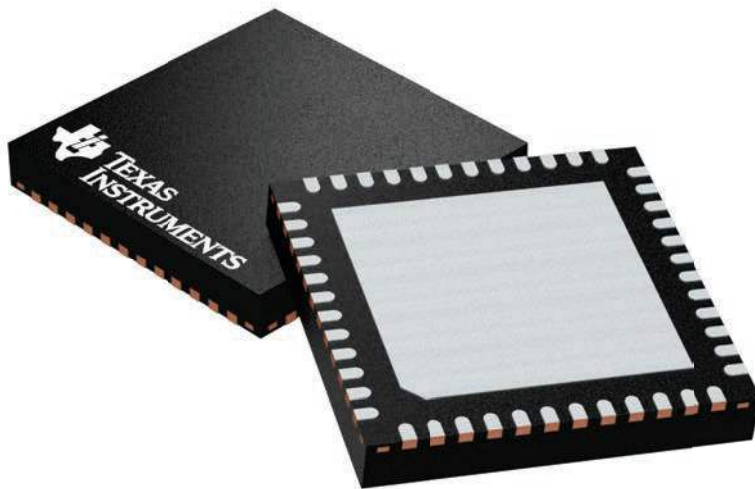
GENERIC PACKAGE VIEW

RGZ 48

VQFN - 1 mm max height

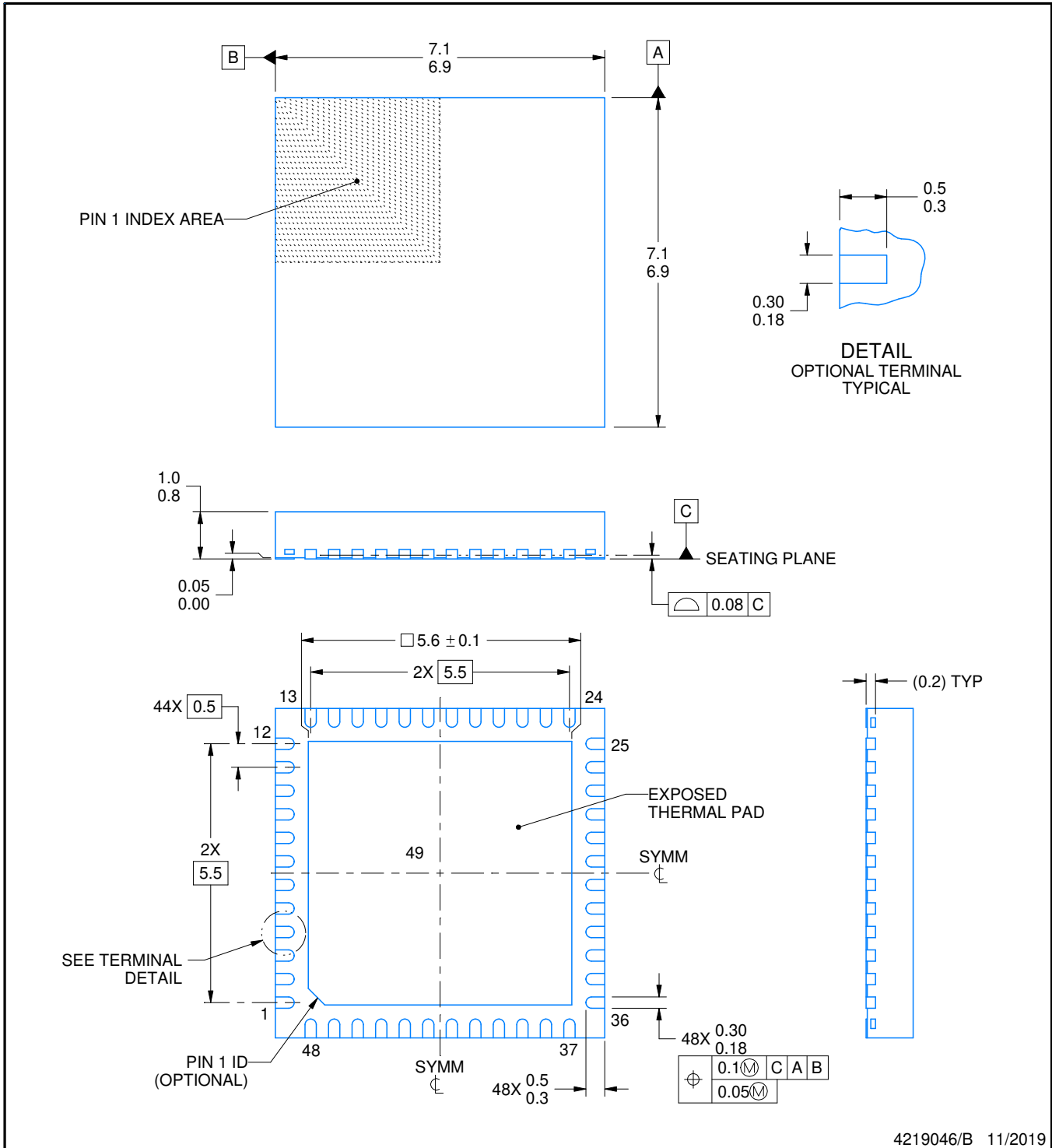
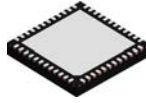
7 x 7, 0.5 mm pitch

PLASTIC QUADFLAT PACK- NO LEAD



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

4224671/A



4219046/B 11/2019

NOTES:

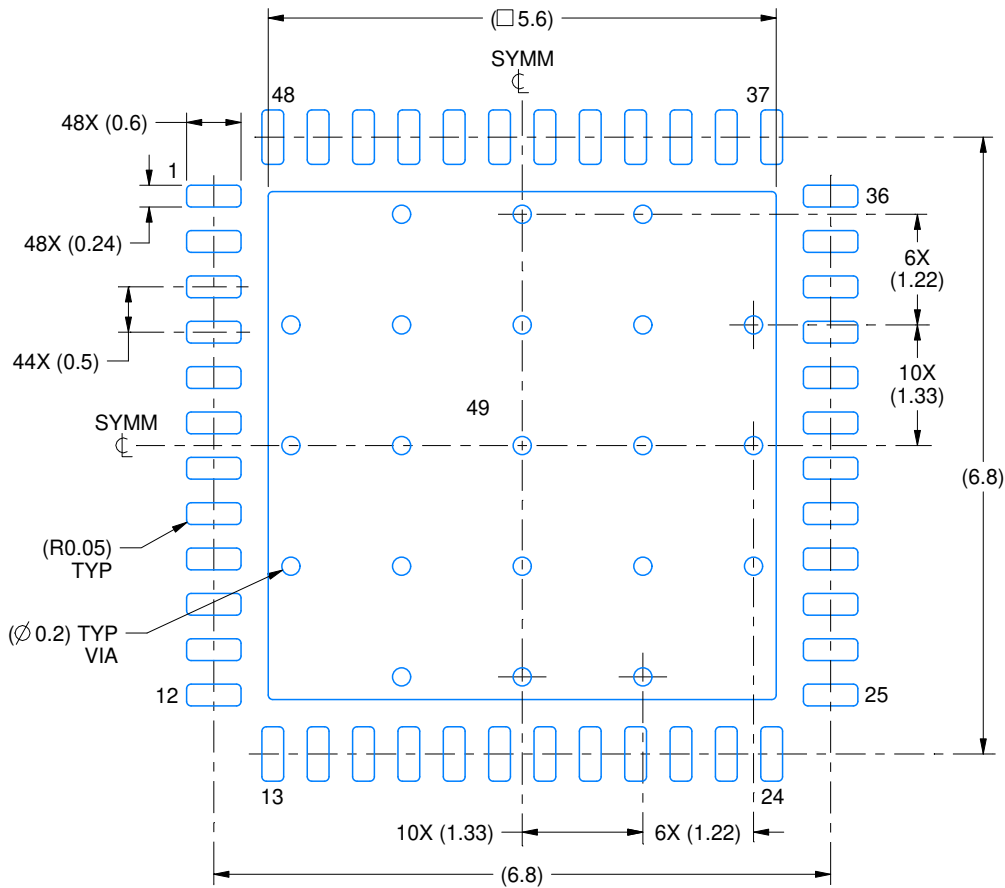
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

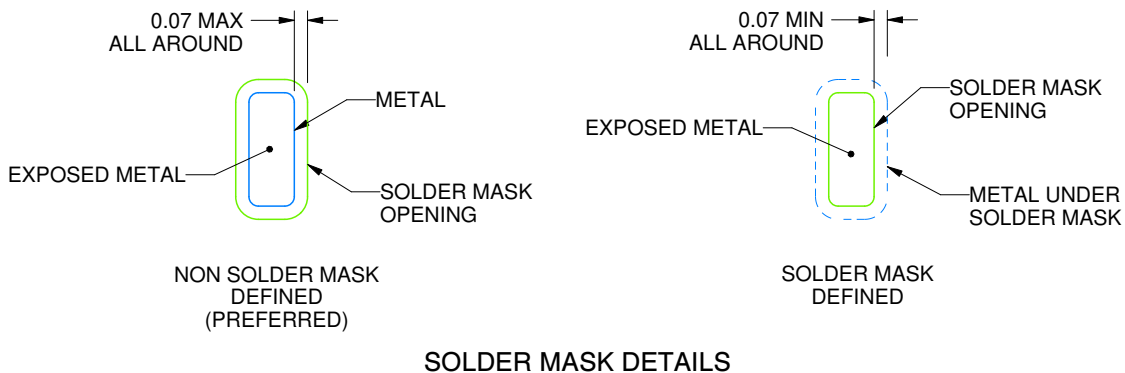
RGZ0048D

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:12X



SOLDER MASK DETAILS

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NOTES: (continued)

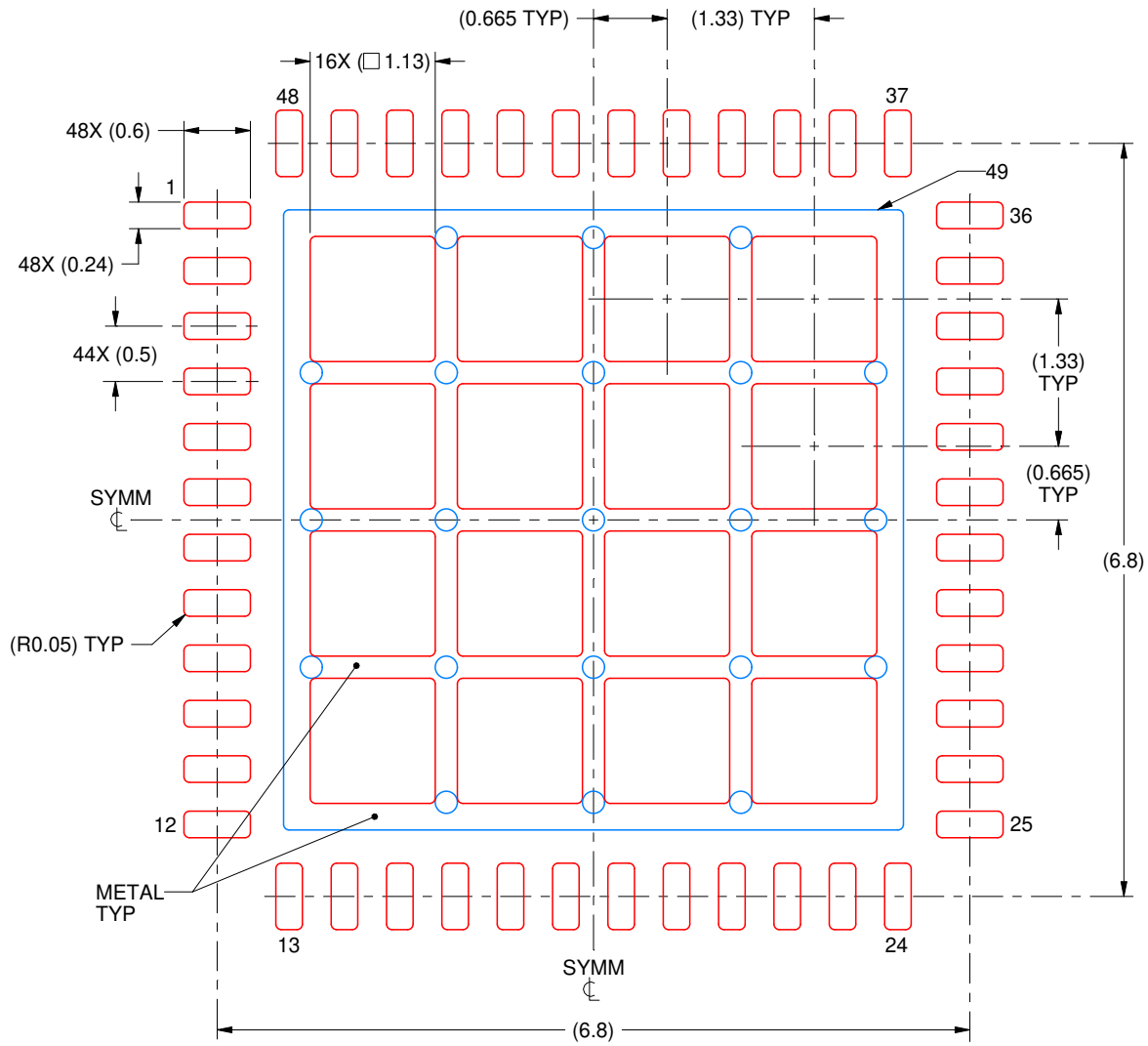
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sluea271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RGZ0048D

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
 BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 49
 66% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
 SCALE:15X

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NOTES: (continued)

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

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