

- Low-Noise Amplifier for Each Band
- RF Mixer for Each Band With Image Rejection Configuration for High Band
- IF Amplifier for Both Low and High Bands
- Operates From a Supply Voltage Range of 3.6 V to 4 V
- Suitable for Portable Dual-Band/Dual-Mode Cellular Telephones (IS136)
- 48-Pin Plastic Thin Quad Flatpack Package (TQFP)

description

The TRF1500 is a dual-band/dual-mode personal communications system (PCS) receiver for cellular telephones operating dual mode (analog and digital) in the 800-MHz band and single mode (digital) in the 1900-MHz band. The TRF1500 consists of a low-noise amplifier (LNA) and mixer for each band. The high band uses an image rejection mixer for down conversion while the low band relies on an off-chip image rejection filter between the LNA and mixer.

The local oscillator (LO) inputs additionally have buffered outputs that can be used in either single-ended or differential mode for a phase-locked-loop (PLL) configuration. A state is also available that allows the low-band LO to serve as the high-band LO through a mode-selectable frequency doubler.

A wideband mixer is also available for transmit loop architectures commonly used in advanced mobile phone systems, global systems for mobile communications, and digital cellular systems.

Power consumption is low and can be further reduced by operating the TRF1500 in sleep mode. Typical power consumption for each receiver function is shown in Table 1.

The TRF1500 is available in a 48-pin plastic thin-quad flatpack package (TQFP) and is characterized for operation from -30°C to 85°C operating free-air temperature.

Table 1. Typical Power Consumption at $V_{CC} = 3.75\text{ V}$

| FUNCTION | TYPICAL POWER | UNIT |
|-------------------|---------------|---------------|
| Sleep mode | 38 | μW |
| Low band | 85 | mW |
| High band | 190 | mW |
| Transmit mixer | 50 | mW |
| Frequency doubler | 12 | mW |



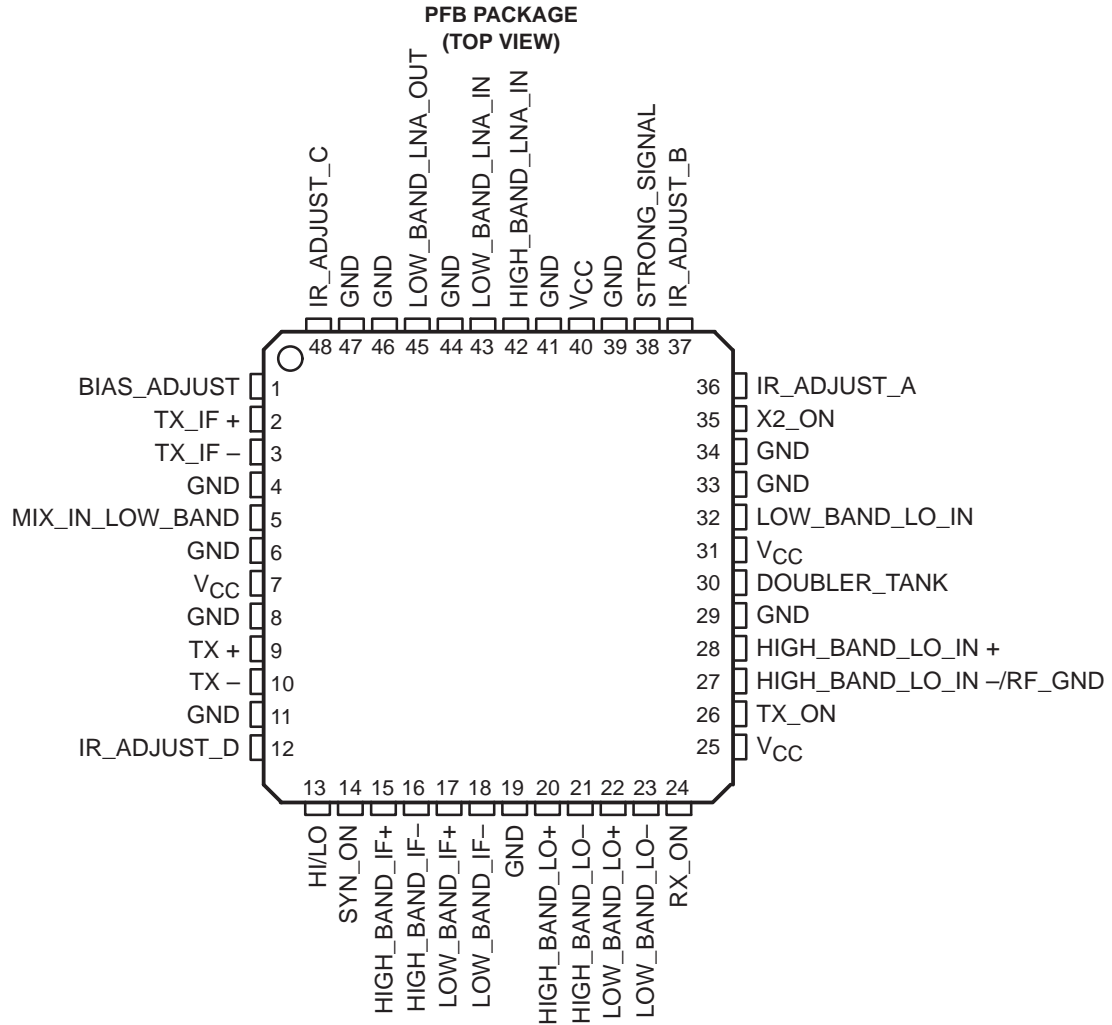
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.



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.

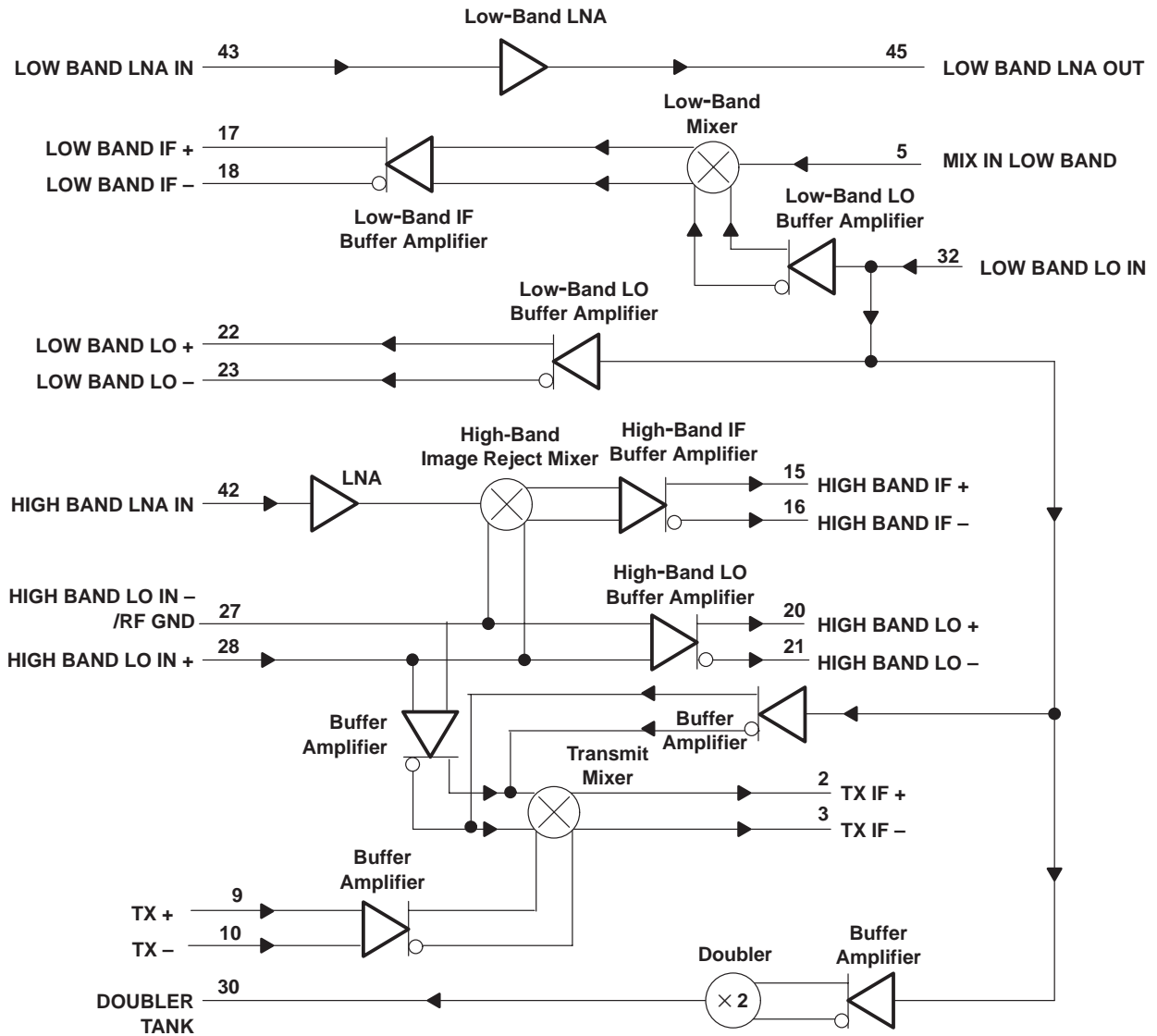
TRF1500 DUAL-BAND/DUAL-MODE PCS RECEIVER

SLWS041A – JANUARY 1998



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

functional block diagram



TRF1500

DUAL-BAND/DUAL-MODE PCS RECEIVER

SLWS041A – JANUARY 1998

Terminal Functions

| TERMINAL | | I/O | DESCRIPTION |
|------------------------------|--|-----|--|
| NAME | NO. | | |
| DOUBLER_TANK | 30† | O | Doubler output |
| HIGH_BAND_IF + | 15† | O | High-band IF noninverting output |
| HIGH_BAND_IF – | 16† | O | High-band IF inverting output |
| HIGH_BAND_LNA_IN | 42† | I | High-band LNA input |
| HIGH_BAND_LO + | 20† | O | Buffered high-band LO noninverting output |
| HIGH_BAND_LO – | 21† | O | Buffered high-band LO inverting output |
| HIGH_BAND_LO_IN – /RF_GND | 27† | I | High-band LO inverting input/RF GND |
| HIGH_BAND_LO_IN + | 28† | I | High-band LO noninverting input |
| HI/LO | 13 | I | High-band/low-band select; 1 = high band, 0 = low band |
| IR_ADJUST_A | 36 | I | Image rejection adjustment |
| IR_ADJUST_B | 37 | I | Image rejection adjustment |
| IR_ADJUST_C | 48 | I | Image rejection adjustment |
| IR_ADJUST_D | 12 | I | Image rejection adjustment |
| GND | 4, 6, 8, 11, 19, 29, 33, 34, 39, 41, 44, 46, 47 | | Ground |
| LOW_BAND_IF + | 17† | O | Low-band IF noninverting output |
| LOW_BAND_IF – | 18† | O | Low-band IF inverting output |
| LOW_BAND_LNA_IN | 43† | I | Low-band LNA input |
| LOW_BAND_LNA_OUT | 45† | O | Low-band LNA output |
| LOW_BAND_LO – | 23† | O | Buffered low-band LO inverting output |
| LOW_BAND_LO_IN | 32† | I | Low-band LO input |
| MIX_IN_LOW_BAND | 5† | I | Low-band mixer input |
| BIAS_ADJUST | 1 | I | Bias adjustment |
| RX_ON | 24 | I | Receiver LNA/mixer power control |
| STRONG_SIGNAL | 38 | I | Strong signal indication |
| SYN_ON | 14 | I | VCO power control |
| TX + | 9† | I | Transmit, noninverting input |
| TX – | 10† | I | Transmit, inverting input |
| TX_IF + | 2† | O | Transmit IF, noninverting output |
| TX_IF – | 3† | O | Transmit IF, inverting output |
| TX_ON | 26 | I | Transmit mixer/driver power control |
| VCC | 7, 25, 31, 40 | I | VCC |
| X2_ON | 35 | I | Doubler power control |

† Pins without internal ESD protection



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

| | |
|--|----------------|
| Supply voltage range, V_{CC} | –0.3 V to 6 V |
| Power dissipation, $T_A = 25^\circ\text{C}$ | 350 mW |
| Maximum operating junction temperature, T_{Jmax} | 150°C |
| Operating free-air temperature range, T_A | –40°C to 85°C |
| Storage temperature range, T_{stg} | –65°C to 150°C |

† 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.

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|----------|-----|------|
| Supply voltage, V_{CC} | 3.6 | 3.75 | 4 | V |
| High-level input voltage, V_{IH} | 3 | V_{CC} | | V |
| Low-level input voltage, V_{IL} | –0.3 | | 0.5 | V |
| Operating free-air temperature, T_A | –30 | | 85 | °C |
| Operating junction temperature, T_J | –30 | | 105 | °C |

control state

| CONTROL STATE (HI/LO, SYN ON, RX ON, TX ON, STRONG SIGNAL, X2) | ACTIVE CIRCUITS |
|--|---|
| 000000 | Sleep mode |
| 010000 | Low-band LO input buffer on |
| 011000 | Low-band receive normal |
| 011010 | Low-band receive strong signal |
| 010100 | Low-band transmit mixer |
| 011100 | Low-band receive and transmit mixer |
| 011110 | Low-band transmit |
| 010001 | Double on |
| 011001 | LB Receive normal, doubler on |
| 011011 | LB receive strong signal, doubler on |
| 011111 | LB transmit, doubler on |
| 111011 | High–band receive strong signal |
| 110000 | High-band LO input buffer on |
| 111000 | High-band receive normal |
| 111010 | High-band receive strong signal |
| 111001 | High-band receive frequency doubler on |
| 110100 | High-band transmit normal |
| 110101 | High-band transmit frequency doubler on |

TRF1500

DUAL-BAND/DUAL-MODE PCS RECEIVER

SLWS041A – JANUARY 1998

current consumption, $V_{CC} = 3.75\text{ V}$, $T_A = 25^\circ\text{C}$

| CONTROL STATE (HI/LO, SYN ON, RX ON, TX ON, STRONG SIGNAL, X2) | | MIN | TYP | MAX | UNIT |
|--|--------------------------------------|-----|-----|-----|---------------|
| 000000 | Sleep mode | | 20 | 100 | μA |
| 010000 | Low-band LO input buffer on | | 3.3 | 4 | mA |
| 011000 | Low-band receive normal | | 24 | 28 | mA |
| 110000 | High-band LO input buffer on | | 4 | 5 | mA |
| 111000 | High-band receive normal | | 56 | 62 | mA |
| 111001 | High-band receive with doubler on | | 61 | 68 | mA |
| 010100 | Low-band transmit mixer | | 13 | 16 | mA |
| 110100 | High-band transmit mixer | | 17 | 21 | mA |
| 110101 | High-band transmit mixer, doubler on | | 22 | 27 | mA |

electrical characteristics at 881.5 MHz (unless otherwise noted)

low-band LNA, mixer, saw filter, and IF buffer amplifier, $V_{CC} = 3.75\text{ V}^\dagger$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|------------------------------------|--------|--------|---------|---------------|
| RF input frequency range | | 869 | | 894 | MHz |
| LO frequency range | | 979.52 | | 1004.52 | MHz |
| IF frequency | | | 110.52 | | MHz |
| LO input power | | | -5 | | dBm |
| Turn on/off time | | | 65 | | μs |
| Power conversion gain | | 24 | 26 | 28 | dB |
| Power conversion gain reduction | Strong signal condition: LNA off | | 19 | | dB |
| Noise figure | | | 2.5 | 3.0 | dB |
| RF input return loss | $Z = 50\ \Omega$ | | 5.6 | | dB |
| LO input return loss | | | 16.5 | | dB |
| LO buffer output power | | | -10.3 | | dBm |
| Power leakage LO in to RF in | | | -53 | | dBm |
| IIP3 (third-order intermodulation product) | Referenced RF input port | | -9.7 | | dBm |
| 1-dB RF input compression point | Referenced RF input port | | -21 | | dBm |
| 1-dB blocking point | Blocking signal 45 MHz below f_0 | | -18 | | dBm |

[†] Low-band LNA, mixer, and IF amplifier with an external surface-acoustic wave (SAW) filter having 3-dB insertion loss (IL). All specifications apply for an IF output terminated into a 1-k Ω load. Parametric limits apply only when tested using the evaluation board or the recommended application circuit.

electrical characteristics at 1960 MHz (unless otherwise noted)

high-band LNA, mixer, and IF buffer amplifier, doubler, $V_{CC} = 3.75 V^\dagger$, $T_A = 25^\circ C$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|---------|--------|---------|------|
| RF input frequency range | | 1930 | | 1990 | MHz |
| LO frequency range (at doubler input) | | 1020.26 | | 1050.26 | MHz |
| IF frequency | | | 110.52 | | MHz |
| LO input power | | | -5 | | dBm |
| Power conversion gain | | 24 | 26.3 | 29 | dB |
| Power conversion gain reduction | Strong signal condition: LNA off | | 43.5 | | dB |
| Image Rejection | | 20 | 22.5 | | dB |
| Noise figure | | | 4.66 | 5.1 | dB |
| Noise figure | Control state 111000, LO _{FR} =2070.52 | | 4.35 | | dB |
| RF input return loss | 50 Ω | | 14.2 | | dB |
| LO buffer output power | | | -14 | | dBm |
| Power leakage LO in to RF in | | | -50 | | dBm |
| IIP3 (third-order intermodulation product) | Referenced RF input port | -19 | -17.7 | | dBm |
| 1-dB RF input compression point | Referenced RF input port | | -23.7 | | dBm |
| 2 x 2 spur performance | -50 dBm referenced RF input port, LO=1020.13 MHz and RF=1985 | | 69 | | dBc |
| 3 x 3 spur performance | -50 dBm referenced RF input port, LO=1019.92 MHz and RF=2003 | | 81 | | dBc |

[†] High-band LNA, mixer, and IF amplifier specifications apply for an IF output terminated into a 1-k Ω load. Parametric limits apply only when tested using the evaluation board or recommended application circuit using the internal frequency doubler.

electrical characteristics at 836.5 MHz (unless otherwise noted)

low-band transmit mixer, $V_{CC} = 3.75 V^\ddagger$, $T_A = 25^\circ C$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|-----------------------|-----|-------|-----|------|
| TX mixer input frequency | | 824 | | 849 | MHz |
| LO frequency | | 941 | | 966 | MHz |
| TX mixer output frequency | | | 117 | | MHz |
| LO input power | | | -5 | | dBm |
| Conversion power gain | | 17 | 19 | | dB |
| Noise figure | Double sideband | | 7.8 | | dB |
| TX input return loss | Balanced 200 Ω | | 9.8 | | dB |
| Power leakage LO in to TX in | | | -49 | | dBm |
| Power leakage TX in to LO in | TX In = -30 dBm | | -70.6 | | dBm |
| 1-dB input compression point | Referred to TX input | | -20 | | dBm |
| Second-order input intercept point (IIP2) | Referred to TX input | | 29.5 | | dBm |
| Third-order input intercept point (IIP3) | Referred to TX input | | -11.5 | | dBm |

[‡] Transmit mixer specifications apply for an IF output terminated into a 1-k Ω resistor load.

TRF1500

DUAL-BAND/DUAL-MODE PCS RECEIVER

SLWS041A – JANUARY 1998

electrical characteristics at 1910 MHz (unless otherwise noted)

high-band transmit mixer, doubler, $V_{CC} = 3.75 V^\dagger$, $T_A = 25^\circ C$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|-----------------------|-------|-------|--------|------|
| TX mixer input frequency | | 1850 | | 1910 | MHz |
| LO frequency | | 983.8 | | 1013.5 | MHz |
| TX mixer output frequency | | | 117 | | MHz |
| LO input power | | | -5 | | dBm |
| Conversion power gain | | 6 | 9.9 | | dB |
| Noise figure | Double sideband | | 12.7 | | dB |
| TX input return loss | Balanced 200 Ω | | 16.6 | | dB |
| Power leakage LO in to TX in | | | -55.5 | | dBm |
| Power leakage TX in to LO in | TX In = -30 dBm | | -69.5 | | dBm |
| 1-dB input compression point | Referred to TX input | | -15.7 | | dBm |
| Second-order input intercept point (IIP2) | Referred to TX input | | 27 | | dBm |
| Third-order input intercept point (IIP3) | Referred to TX input | | -6.7 | | dBm |

[†] High-band transmit mixer specifications apply for an IF output terminated into a 1-k Ω resistor load using the internal frequency doubler.



APPLICATION INFORMATION

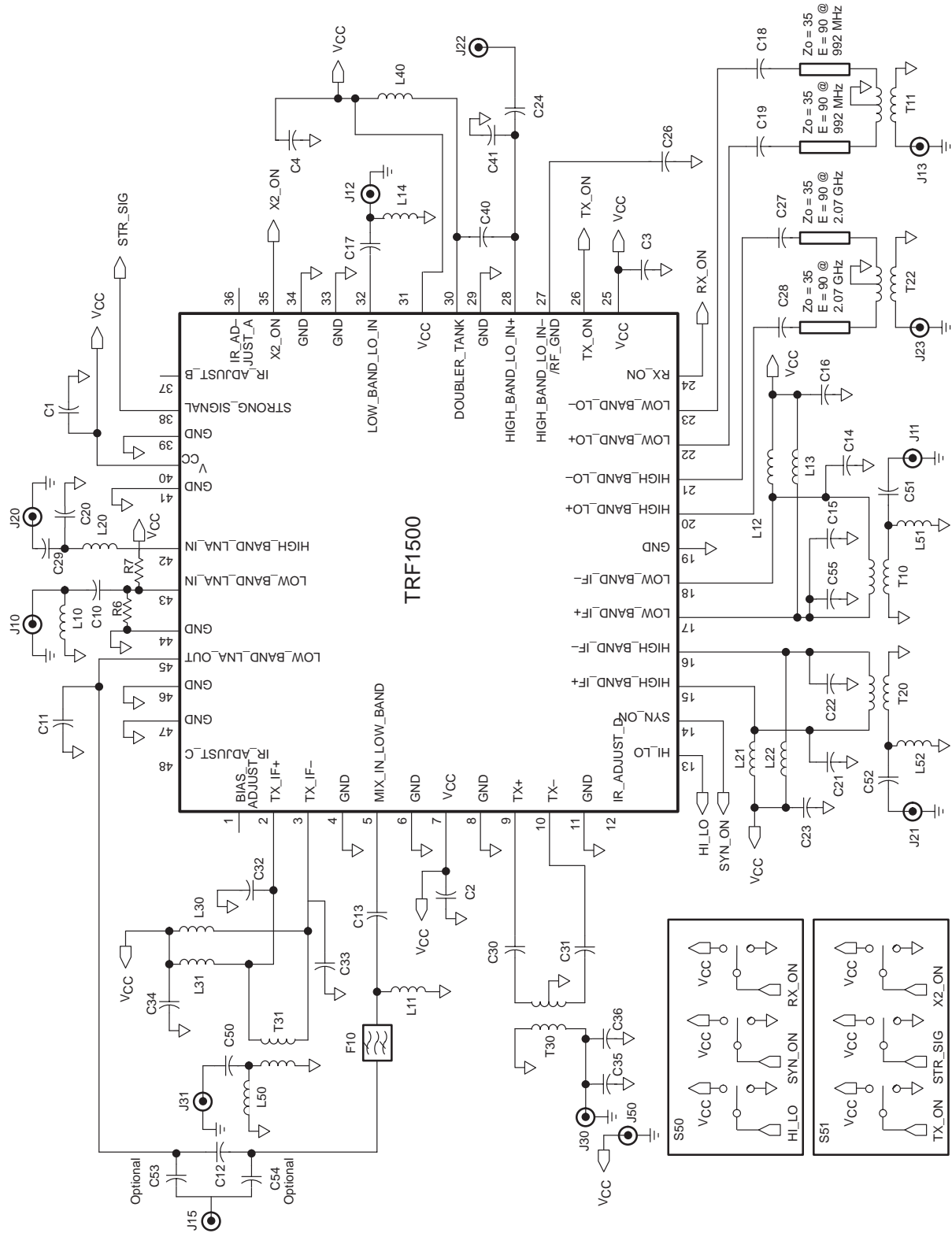


Figure 1. Recommended Application Circuits

TRF1500 DUAL-BAND/DUAL-MODE PCS RECEIVER

SLWS041A – JANUARY 1998

APPLICATION INFORMATION

Table 2. TRF1500 External Component List

| DESIGNATOR | DESCRIPTION (SIZE) | VALUE | MANUFACTURER | PART # |
|------------|--------------------|----------|--------------|-------------------|
| C1 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C2 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C3 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C4 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C10 | Capacitor (0402) | 15000 pF | Murata | GRM36Y5V153Z 16 |
| C11 | Capacitor (0402) | 1 pF | Murata | GRM36COG010C 50s |
| C12† | Capacitor (0402) | 10 pF | Murata | GRM36COG100D 50S |
| C13 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50S |
| C16 | Capacitor (0402) | 1000 pF | Murata | GRM36COG102K 50 |
| C17 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50S |
| C18 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50S |
| C19 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50S |
| C20 | Capacitor (0402) | 1.5 pF | Murata | GRM36COG1R5C 50 |
| C23 | Capacitor (0402) | 1000 pF | Murata | GRM36COG102K 50 |
| C26 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C27 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C28 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C29 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C30 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C31 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C34 | Capacitor (0402) | 47 pF | Murata | GRM36COG470J 50 |
| C40‡ | Capacitor (0402) | 0.5 pF | Murata | GRM36COG0R5C 50S |
| C41‡ | Capacitor (0402) | 0.5 pF | Murata | GRM36COG0R5C 50S |
| C55 | Capacitor (0402) | 1.5 pF | Murata | GRM36COG1R5C 50S |
| L10 | Inductor (0603) | 12 nH | Coilcraft | 0603HS-12NTJBC |
| L11 | Inductor (0805) | 10 nH | Coilcraft | 0603HS-10NTJBC |
| L12 | Inductor (0805) | 150 nH | Coilcraft | 0805HS-150TKBC |
| L13 | Inductor (0805) | 150 nH | Coilcraft | 0805HS-150TKBC |
| L14 | Inductor (0402) | 3.9 nH | Coilcraft | 0603HS-3N9TKBC |
| L20 | Inductor (0603) | 1.8 nH | Coilcraft | 0603HS-1N8TKBC |
| L21 | Inductor (0805) | 150 nH | Coilcraft | 0805HS-151TKBC |
| L22 | Inductor (0805) | 150 nH | Coilcraft | 0805HS-151TKBC |
| L30 | Inductor (0805) | 120 nH | Coilcraft | 0805HS-121TKBC |
| L31 | Inductor (0805) | 120 nH | Coilcraft | 0805HS-121TKBC |
| L40‡ | Inductor (0603) | 1.2 nH | TOKO | LL100S-F12NK |
| R6 | Resistor (0402) | 1.5 M | | |
| R7 | Resistor (0402) | 560K | | |
| F10 | Saw filter | | MA/COM | SAFC881.5MA70N-TC |

† Remove C12 to test the low-band LNA or mixer.

‡ Remove C40, L40, and change C41 to 1 pF to test the high-band receive normal mode (doubler turned off).



APPLICATION INFORMATION

Table 3. TRF1500 External Component List For Evaluation Board Test Purposes Only

| DESIGNATOR | DESCRIPTION (SIZE) | VALUE | MANUFACTURER | PART # |
|------------|---------------------|--------|--------------|------------------|
| C14 | Capacitor (0402) | 10 pF | Murata | GRM36COG100D 50S |
| C15 | Capacitor (0402) | 9 pF | Murata | GRM36COG090D 50S |
| C21 | Capacitor (0402) | 9 pF | Murata | GRM36COG090D 50S |
| C22 | Capacitor (0402) | 8 pF | Murata | GRM36COG080D 50S |
| C24† | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C32 | Capacitor (0402) | 12 pF | Murata | GRM36COG120D 50S |
| C33 | Capacitor (0402) | 12 pF | Murata | GRM36COG120D 50S |
| C35 | Capacitor (0402) | 0.5 pF | Murata | GRM36COG0R5C 50S |
| C36 | Capacitor (0402) | 0.5 pF | Murata | GRM36COG0R5C 50S |
| C50 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C51 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C52 | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C53‡ | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| C54§ | Capacitor (0402) | 100 pF | Murata | GRM36COG101J 50 |
| L50 | Inductor (0603) | 68 nH | Coilcraft | 0603HS-68NTJBC |
| L51 | Inductor (0603) | 47 nH | Coilcraft | 0603HS-47NTJBC |
| L52 | Inductor (0603) | 68 nH | Coilcraft | 0603HS-68NTJBC |
| S50 | Triple SPDT switch | | Grayhill | 76SC03 |
| S51 | Triple SPDT switch | | Grayhill | 76SC03 |
| J10 | SMA board connector | | EF Johnson | 142-0701-801 |
| J11 | SMA board connector | | EF Johnson | 142-0701-801 |
| J12 | SMA board connector | | EF Johnson | 142-0701-801 |
| J13 | SMA board connector | | EF Johnson | 142-0701-801 |
| J20 | SMA board connector | | EF Johnson | 142-0701-801 |
| J21 | SMA board connector | | EF Johnson | 142-0701-801 |
| J22 | SMA board connector | | EF Johnson | 142-0701-801 |
| J23 | SMA board connector | | EF Johnson | 142-0701-801 |
| J30 | SMA board connector | | EF Johnson | 142-0701-801 |
| J31 | SMA board connector | | EF Johnson | 142-0701-801 |
| J50 | SMB board connector | | Amphenol | 903-373J-51A |
| T10 | RF 16:1 transformer | | MA/COM | ET16-1 |
| T11 | RF 1:1 transformer | | MA/COM | ETC1-1-13 |
| T20 | RF 16:1 transformer | | MA/COM | ET16-1 |
| T22 | RF 1:1 transformer | | MA/COM | ETC1-1-13 |
| T30 | RF 4:1 transformer | | MA/COM | ETC1.6-4-2-3 |
| T31 | RF 16:1 transformer | | MA/COM | ET16-1 |

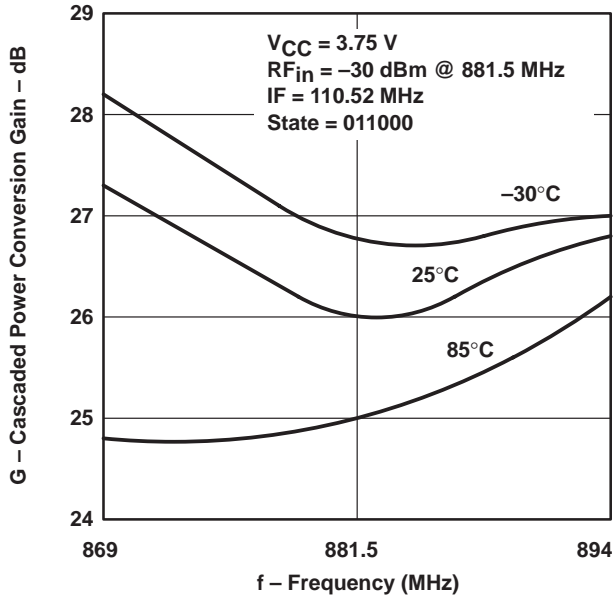
† Populate C24 to test the high-band receive normal mode.

‡ Populate C53 to test the low-band LNA.

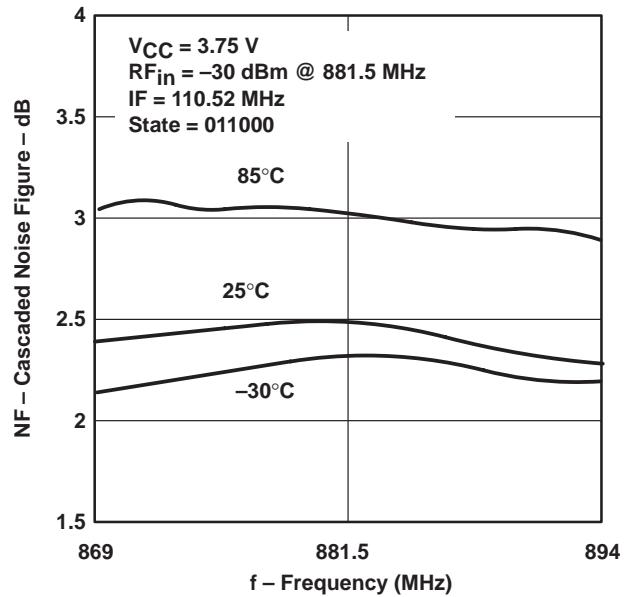
§ Populate C54 to test the low-band mixer.

TYPICAL CHARACTERISTICS

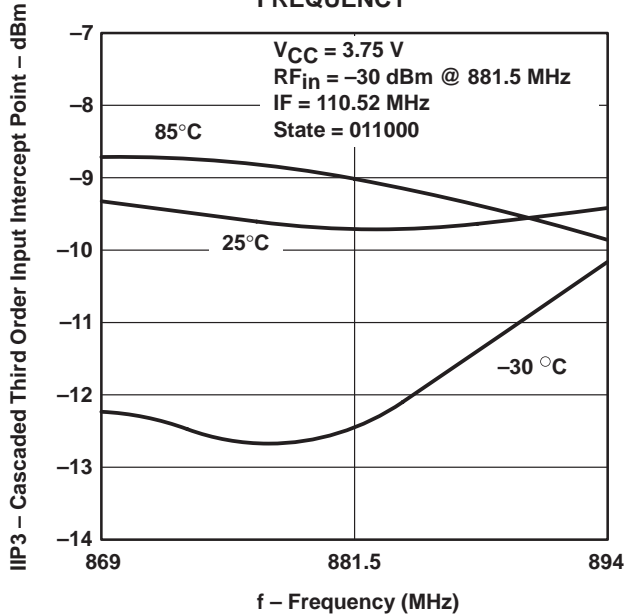
LOW BAND RECEIVER
 CASCADED POWER CONVERSION GAIN
 VS
 FREQUENCY



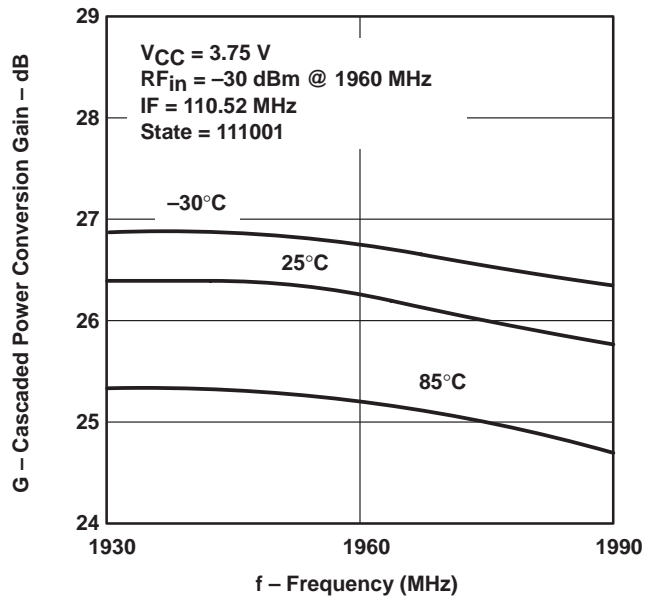
LOW BAND RECEIVER
 CASCADED NOISE FIGURE
 VS
 FREQUENCY



LOW BAND RECEIVER
 CASCADED THIRD ORDER INPUT INTERCEPT POINT
 VS
 FREQUENCY



HIGH BAND RECEIVER
 CASCADED POWER CONVERSION GAIN
 VS
 FREQUENCY



TYPICAL CHARACTERISTICS

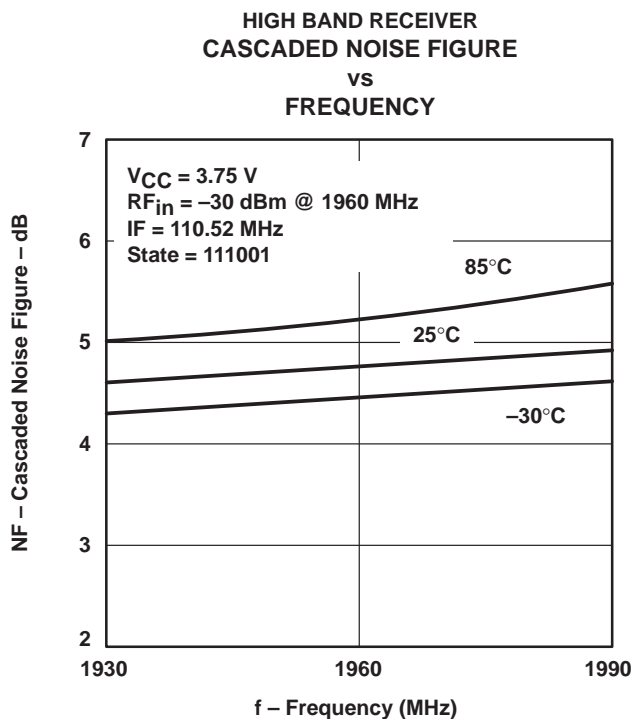


Figure 6

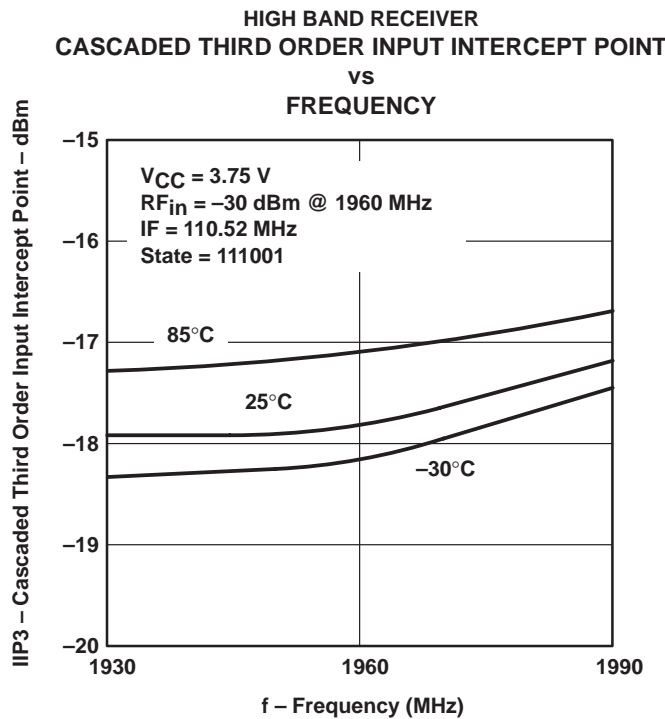


Figure 7

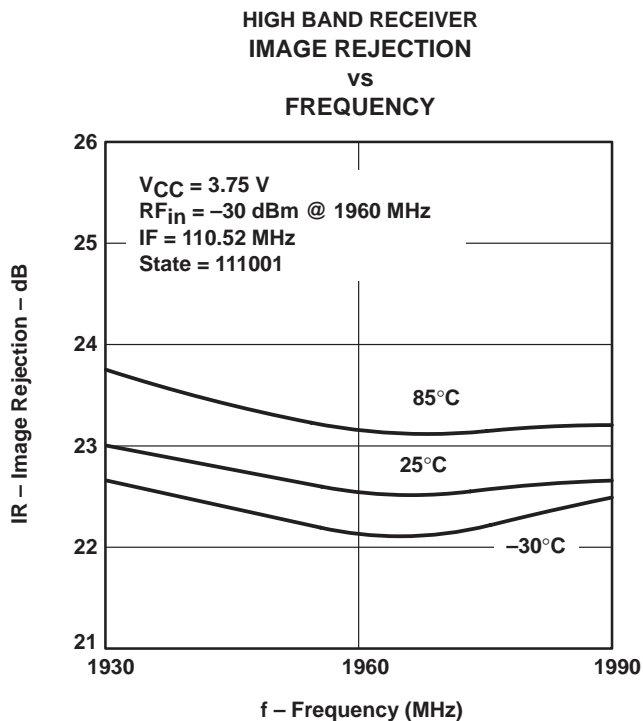


Figure 8

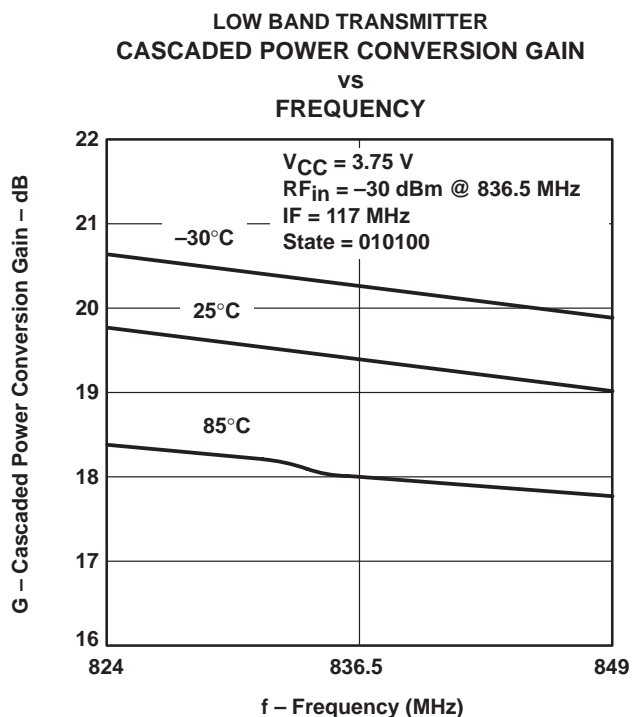


Figure 9

TYPICAL CHARACTERISTICS

LOW BAND TRANSMITTER
 CASCADED NOISE FIGURE
 VS
 FREQUENCY

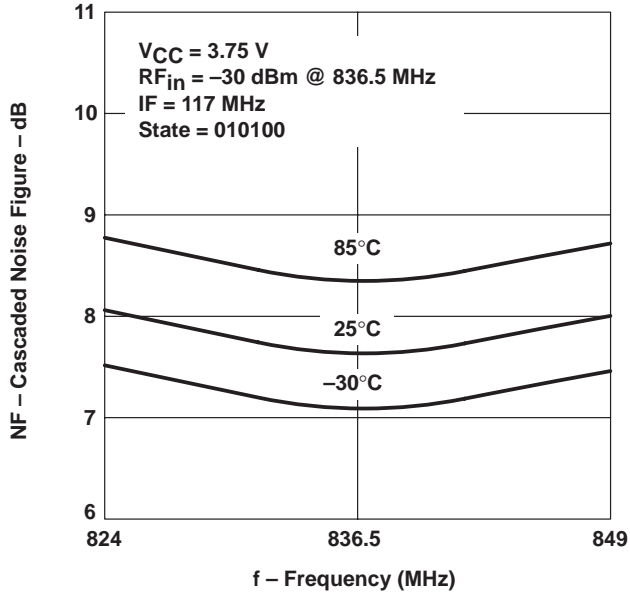


Figure 10

LOW BAND TRANSMITTER
 CASCADED THIRD ORDER INPUT INTERCEPT POINT
 VS
 FREQUENCY

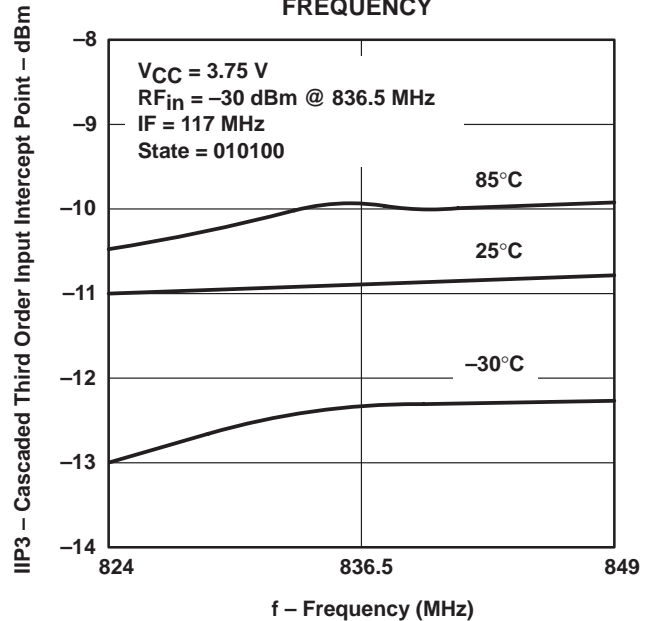


Figure 11

HIGH BAND TRANSMITTER
 CASCADED POWER CONVERSION GAIN
 VS
 TEMPERATURE

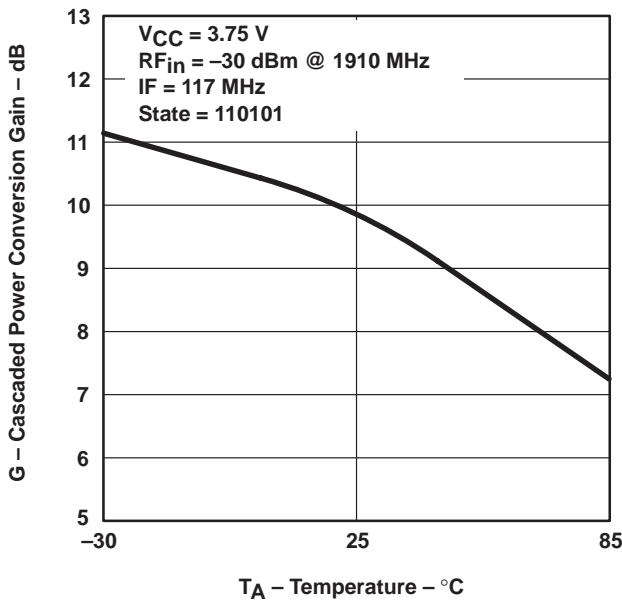


Figure 12

HIGH BAND TRANSMITTER
 CASCADED NOISE FIGURE
 VS
 TEMPERATURE

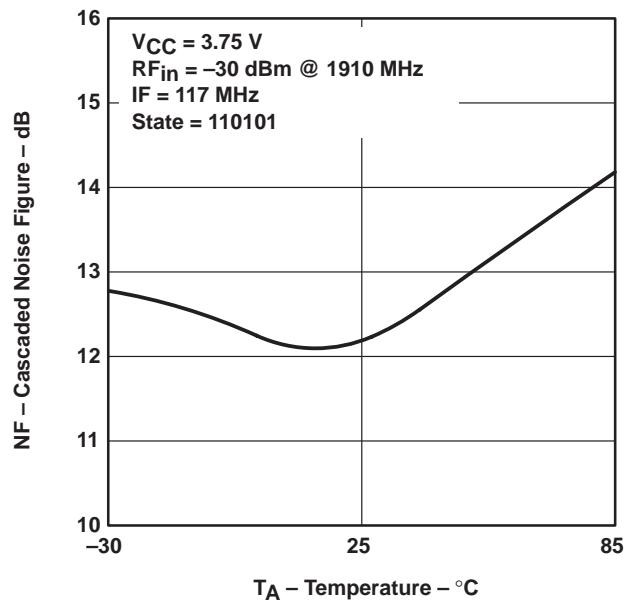


Figure 13

TYPICAL CHARACTERISTICS

HIGH BAND TRANSMITTER
CASCADED THIRD ORDER INPUT INTERCEPT POINT
vs
TEMPERATURE

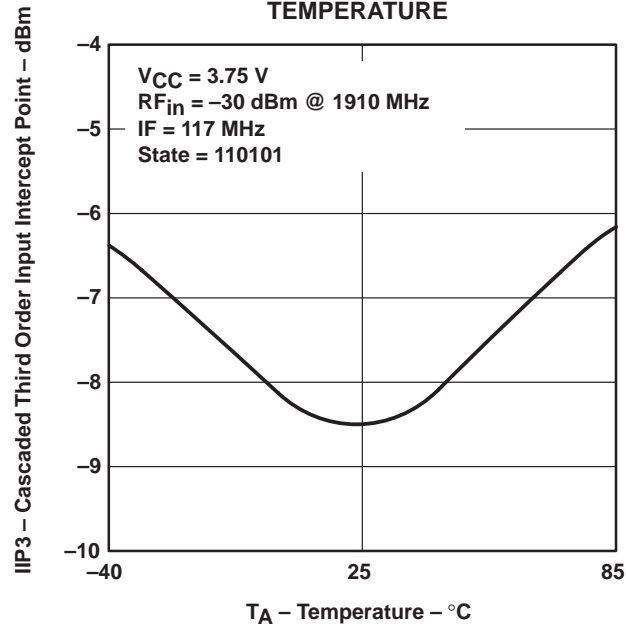


Figure 14

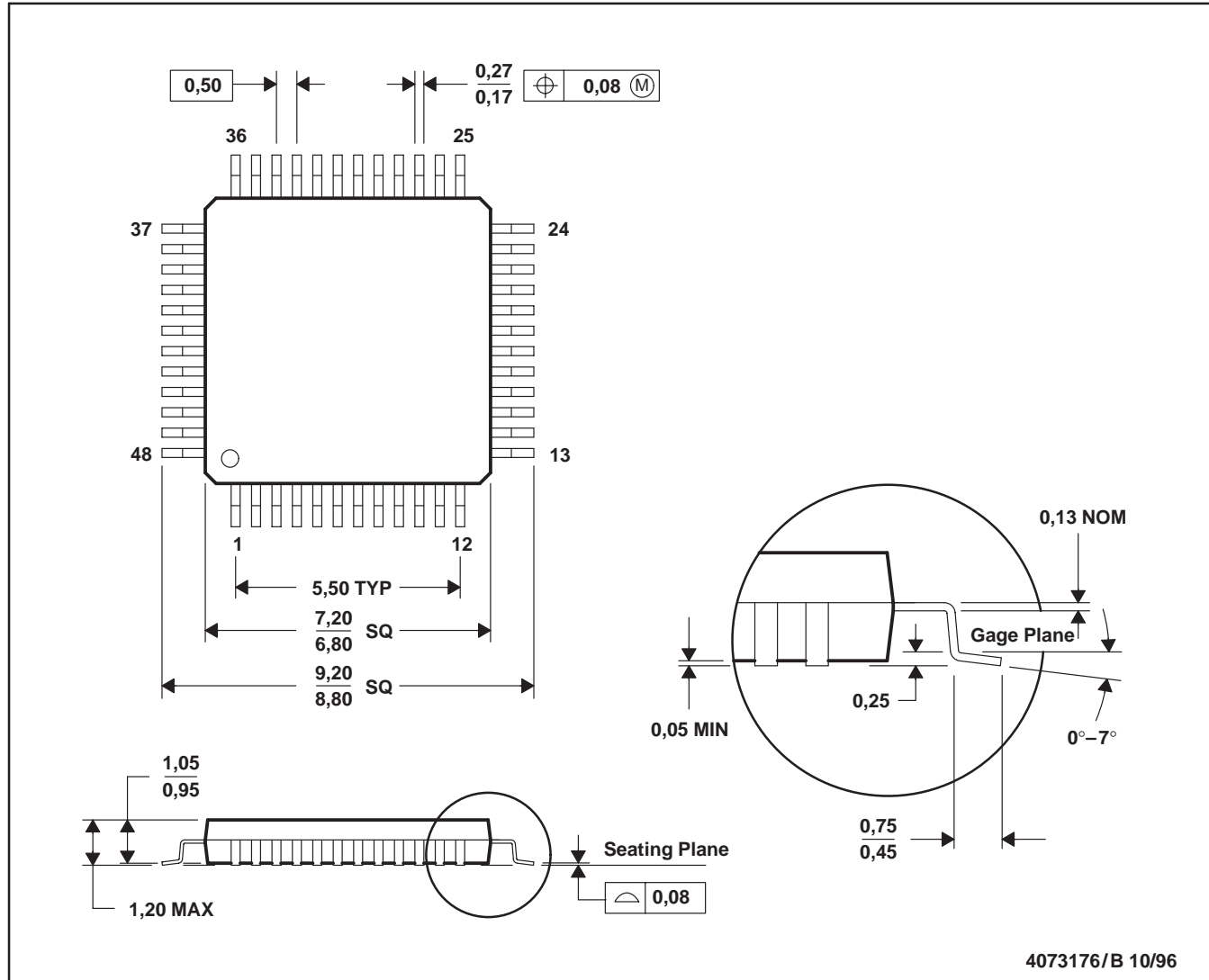
TRF1500 DUAL-BAND/DUAL-MODE PCS RECEIVER

SLWS041A – JANUARY 1998

MECHANICAL DATA

PFB (S-PQFP-G48)

PLASTIC QUAD FLATPACK



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-026

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.