

# TRF1400

## RF TELEMETRY RECEIVERS

### VHF/UHF RZ ASK REMOTE CONTROL RECEIVER

SLWS014E – JUNE 1996 – REVISED APRIL 1998

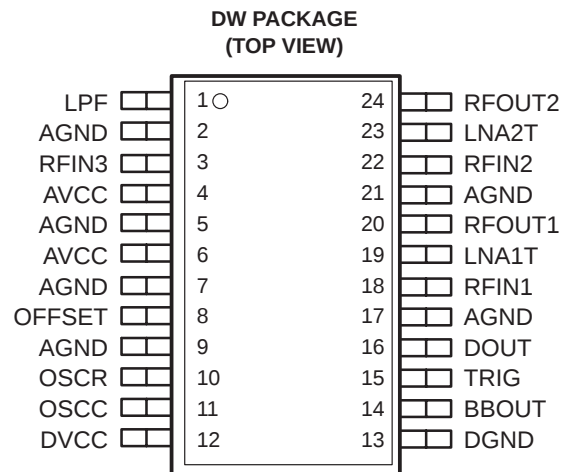
- **Wide VHF/UHF Frequency Range**  
200 MHz to 450 MHz for World-Wide Remote Control Frequency Compatibility
- **High Receiver Sensitivity** . . . -103 dBm at 315 MHz
- **Accepts Baseband Data Rates From 500 Hz to 10 kHz**
- **Manchester-Decoded and Raw Baseband Outputs for Easy Interface to Serial Data Decoders and Microcontrollers**
- **TRF (Tuned Radio Frequency) Design Eliminates Local Oscillator (No Emissions) and Reduces Many Government Type Approvals (Including FCC)**
- **Adjustable Internal Sampling Clock Set By External Components**
- **Internal Amplifier and Comparator for Amplification and Shaping of Low-Level Input Signals With Average-Detecting Autobias Adaptive Threshold Circuitry for Improved Sensitivity**
- **Minimum External Component Count and Surface-Mount Packaging for Extremely Small Circuit Footprint – Typically Replaces More Than 40 Components in an Equivalent Discrete Solution**
- **No Manual Alignment When Using SAW Filters**
- **Advanced Submicron BiCMOS Process Technology for Minimum Power Consumption**

#### description

The TRF1400 VHF/UHF RZ ASK remote control receiver is specifically designed for RZ ASK (return-to-zero amplitude-shift keyed) communications systems operating in the 200-MHz to 450-MHz band. This device is targeted for use in automotive and home security systems, garage door openers, remote utility metering, and other low-power remote control and telemetry systems.

A complete RZ ASK receiver solution on a chip, the TRF1400 requires only a minimum of external components for operation. This significantly reduces the complexity and footprint of new designs compared with current discrete receiver designs. The TRF1400 requires no manual alignment when using external SAW (surface acoustic wave) filters. For a lower-cost solution, the device is also compatible with external LC components.

The TRF1400 also includes several on-chip features that normally require additional circuitry in a receiver system design. These include two low-noise front-end amplifiers, an RF amplifier/comparator for detection and shaping of input signals, and a demodulated RZ ASK baseband TTL-level output that readily interfaces to self-synchronizing devices. Also included is on-chip Manchester decoding logic that provides a specially formatted TTL data output, synchronized with a trigger output, for easy interface to any microcontroller using Manchester-encoded data.



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.



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS  
INSTRUMENTS**

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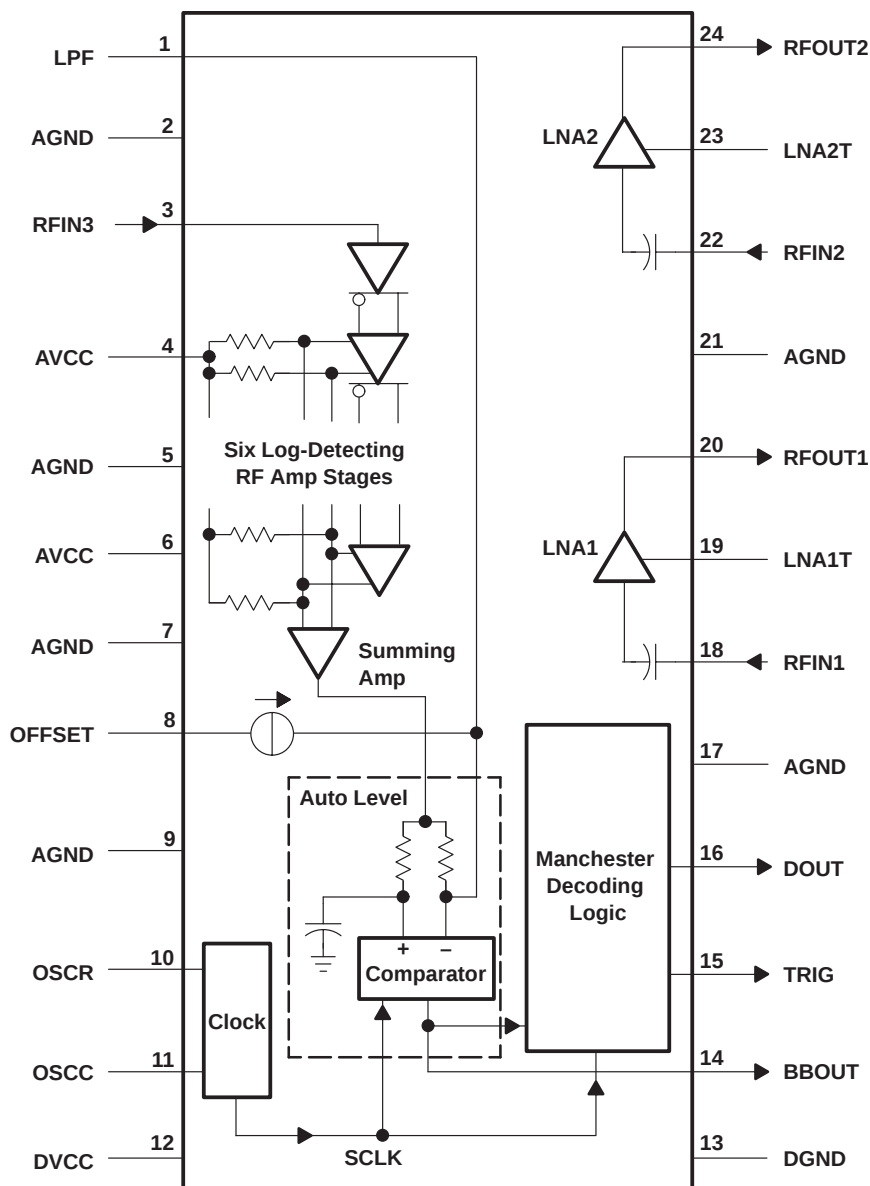
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#### description (continued)

The TRF1400 VHF/UHF RZ ASK remote control receiver is available in a 24-pin SOIC (DW) package, and is characterized for operation over the temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The DW package is available taped and reeled; add R suffix to device type when ordering (e.g., TRF1400DWR).

#### functional block diagram



### Terminal Functions

| TERMINAL<br>NAME | NO.                      | I/O | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------|--------------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AGND             | 2, 5,<br>7, 9,<br>17, 21 |     | Analog ground for all internal analog circuits. AGND is not internally connected to digital ground (DGND). All analog signals are referenced to AGND.                                                                                                                                                                                                                                                                                                                                                                                                       |
| AVCC             | 4, 6                     |     | Positive power supply voltage for all analog circuits — 4.5 V to 5.5 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| BBOUT            | 14                       | O   | Baseband data output. BBOUT is the demodulated envelope of the recovered RF signal and is active with any received ASK signal coding format.                                                                                                                                                                                                                                                                                                                                                                                                                |
| DGND             | 13                       |     | Digital ground for all internal logic circuits. DGND is not internally connected to analog ground (AGND).                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| DOUT             | 16                       | O   | Data output. Data appearing at DOUT is a binary, TTL representation of the baseband data, and is only meaningful when Manchester-encoded ASK data is received. DOUT is active high and is internally pulled down.                                                                                                                                                                                                                                                                                                                                           |
| DVCC             | 12                       |     | Positive power supply voltage for all digital circuits. DVCC is 4.5 V to 5.5 V. For best noise performance, DVCC should connect to AVCC at the power supply, not at the TRF1400 device.                                                                                                                                                                                                                                                                                                                                                                     |
| LNA1T            | 19                       |     | Low-noise amplifier (LNA) 1 ground termination. LNA1T should be connected to AGND through a parallel resistor-capacitor bias network. If left unconnected, LNA1 is disabled.                                                                                                                                                                                                                                                                                                                                                                                |
| LNA2T            | 23                       |     | Low-noise amplifier (LNA) 2 ground termination. LNA2T should be connected to AGND through a parallel resistor-capacitor bias network. If left unconnected, LNA2 is disabled.                                                                                                                                                                                                                                                                                                                                                                                |
| LPF              | 1                        |     | Connection for external low-pass capacitor used in the average-detecting adaptive threshold circuitry.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| OFFSET           | 8                        |     | Connection for external offset resistor. A resistor (1 M $\Omega$ suggested) sets the internal threshold detector offset voltage. Lowering the value of this resistor decreases device sensitivity.                                                                                                                                                                                                                                                                                                                                                         |
| OSCC             | 11                       |     | Internal oscillator frequency-setting capacitor. A capacitor, connected between OSCC and ground, in conjunction with a resistor connected between OSCR and OSCC, determines the speed of the internal clock oscillator (SCLK). The SCLK signal is used for processing the demodulated incoming data stream and controls the Manchester decoding and timing recovery logic sections of the device. The internal oscillator must be set to 10 times the received Manchester data rate for valid TRIG and DOUT, or to 5 times the received baseband data rate. |
| OSCR             | 10                       |     | Internal oscillator frequency-setting resistor. A resistor, connected between OSCR and OSCC, in conjunction with a capacitor connected between OSCC and ground determines the speed of the internal oscillator (SCLK). The SCLK signal is used for processing the demodulated incoming data stream and controls the Manchester decoding and timing recovery logic sections of the device. The internal oscillator must be set to 10 times the received Manchester data rate for valid TRIG and DOUT, or to 5 times the received baseband data rate.         |
| RFIN1            | 18                       | I   | RF input to first low-noise, high-gain amplifier stage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| RFIN2            | 22                       | I   | RF input to second low-noise, high-gain amplifier stage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| RFIN3            | 3                        | I   | RF input to the detecting RF amplifier stages. Filtered RF in the form of AM RZ ASK data at frequencies between 200 MHz and 450 MHz, at a baud rate between 500 Hz and 10 kHz can be applied to RFIN3 for detection and decoding.                                                                                                                                                                                                                                                                                                                           |
| RFOUT1           | 20                       | O   | RF output of the first low-noise, high-gain amplifier                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| RFOUT2           | 24                       | O   | RF output of the second low-noise, high-gain amplifier. Typically, the input of an external SAW or LC filter is connected to RFOUT2.                                                                                                                                                                                                                                                                                                                                                                                                                        |
| TRIG             | 15                       | O   | Trigger output. TRIG pulses to indicate each new received data cell and is only meaningful when Manchester-encoded ASK data is received. TRIG is active high and is internally pulled down.                                                                                                                                                                                                                                                                                                                                                                 |

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## RF TELEMETRY RECEIVERS

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#### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

|                                                      |                |
|------------------------------------------------------|----------------|
| Supply voltage range, AVCC, DVCC (see Note 1)        | –0.6 to 6 V    |
| Input voltage range, V <sub>I</sub>                  | –0.6 to 6 V    |
| Continuous total power dissipation                   | 180 mW         |
| Operating free-air temperature range, T <sub>A</sub> | –55°C to 85°C  |
| Storage temperature range, T <sub>stg</sub>          | –65°C to 150°C |
| ESD protection, all terminals: human body model      | 2 kV           |
| machine model                                        | 200 V          |
| JEDEC latchup                                        | 150 mA or 11 V |

<sup>†</sup> 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.

NOTE 1: Voltage values are with respect to GND.

#### recommended operating conditions

|                                                                                            | MIN | NOM | MAX | UNIT |
|--------------------------------------------------------------------------------------------|-----|-----|-----|------|
| Supply voltage, V <sub>CC</sub>                                                            | 4.5 |     | 5.5 | V    |
| Input frequency, f <sub>in</sub>                                                           | 200 |     | 450 | MHz  |
| Operating free-air temperature, T <sub>A</sub>                                             | –40 |     | 85  | °C   |
| Minimum permissible AM modulation of RF envelope applied to RF Input, measured at –101 dBm |     | 25% |     |      |

electrical characteristics as measured in the test circuit detailed in Figures 1 through 6 with f<sub>in</sub> = 315 MHz over recommended ranges of supply voltage and operating free-air temperature, typical values are at V<sub>CC</sub> = 5 V and T<sub>A</sub> = 25°C (unless otherwise noted)

#### current consumption

| PARAMETER                                                   | TEST CONDITIONS                                                                            | MIN | TYP | MAX | UNIT |
|-------------------------------------------------------------|--------------------------------------------------------------------------------------------|-----|-----|-----|------|
| I <sub>CC</sub> Average supply current from V <sub>CC</sub> | I/O pins terminated with typical loads, Signal applied with a 5-kHz baseband data rate     |     | 2.7 | 3.5 | mA   |
|                                                             | I/O pins terminated with typical loads, Signal applied with a 2.5-kHz Manchester data rate |     | 2.7 | 3.5 |      |
|                                                             | I/O pins terminated with typical loads, no data input                                      |     | 2.5 |     |      |

#### digital interface

| PARAMETER                                 | TEST CONDITIONS   | MIN                  | MAX | UNIT |
|-------------------------------------------|-------------------|----------------------|-----|------|
| V <sub>OH</sub> High-level output voltage | DOUT, TRIG, BBOUT | V <sub>CC</sub> –0.5 |     | V    |
| V <sub>OL</sub> Low-level output voltage  |                   |                      | 0.5 | V    |

#### VSWR (voltage standing-wave ratio), ripple rejection

| PARAMETER                                                            | TEST CONDITIONS                                          | MIN | TYP                | MAX | UNIT |
|----------------------------------------------------------------------|----------------------------------------------------------|-----|--------------------|-----|------|
| VSWR into 50 Ω at RFIN1, RFOUT1, RFIN2, RFOUT2, RFIN3                | With external LC matching network                        |     | 2:1                |     | V/V  |
| Ripple rejection at BBOUT while maintaining BER = 1/100 (see Note 2) | 1 MHz injected at AVCC and DVCC, Carrier level = –50 dBm |     | 6% V <sub>CC</sub> |     |      |

NOTE 2: BER (bit error rate = errors/number of bits) is qualified by integration of logic-level pulses (>50% high = 1, <50% low = 0). (See the System Design Considerations Using the TRF1400 RF Telemetry Receivers Application Report, TI literature number SLWA005, for more BER information.)



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#### RF sensitivity/overload

| PARAMETER                                                                                                                                     | TEST CONDITIONS                                                                                                                            | MIN | TYP  | MAX  | UNIT |
|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-----|------|------|------|
| RF input level (average) at test board RF input required for BER 1/100 at 5 kHz baseband data rate, 2.5 kHz Manchester data rate (see Note 2) | $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ ,<br>$f_{in} = 315\text{ MHz}$ ,<br>external SAW preselector bandpass filter (see Note 3) |     | -103 | -101 | dBm  |
| Overload signal level at $f_c$ with BER 1/100 at 5 kHz baseband data rate, 2.5 kHz Manchester data rate (see Note 2)                          | $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ ,<br>$f_{in} = 315\text{ MHz}$                                                            |     | -20  |      | dBm  |

NOTES: 2. BER (bit error rate = errors/number of bits) is qualified by integration of logic-level pulses (> 50% high = 1, < 50% low = 0).  
 3. The SAW bandpass filter must have a rejection level greater than or equal to 50 dB at  $\pm 0.5 f_c$ , an insertion loss of less than or equal to 3 dB, and a -3 dB passband width of 0.2%  $f_c$ , where  $f_c$  is the passband center frequency of the SAW filter.

#### oscillator (internal clock)

| PARAMETER                                                                                                | MIN | MAX | UNIT |
|----------------------------------------------------------------------------------------------------------|-----|-----|------|
| Sample clock frequency, SCLK (5× baseband data rate, 10× Manchester data rate)                           | 2.5 | 50  | kHz  |
| Frequency spread (process variation, temperature, $V_{CC}$ ), not including external component tolerance |     | ±5% |      |

#### timing requirements over recommended ranges of supply voltage and operating free-air temperature

##### RF input data (see Figure 7)

|                          | MIN | MAX          | UNIT |
|--------------------------|-----|--------------|------|
| $t_r$ Rise time at RFIN1 |     | $0.1 t_{w3}$ | μs   |
| $t_f$ Fall time at RFIN1 |     | $0.1 t_{w3}$ | μs   |

##### received data

|                                                                                                                         | MIN                   | MAX                    | UNIT |
|-------------------------------------------------------------------------------------------------------------------------|-----------------------|------------------------|------|
| Baseband data frequency, AM RZ ASK                                                                                      | 0.5                   | 10                     | kHz  |
| Manchester data frequency, AM RZ ASK                                                                                    | 0.25                  | 5                      | kHz  |
| Pulse period tolerance for synchronization, valid TRIG and DOUT data                                                    |                       | ±8%                    |      |
| Pulse duty cycle for synchronization, valid TRIG and DOUT data                                                          | 49%                   | 51%                    |      |
| $t_x$ Dead time between wakeup time and frame start time (for synchronization valid, TRIG and DOUT data) (see Figure 8) | $38 \div \text{SCLK}$ | $317 \div \text{SCLK}$ | ms   |
| $t_{w3}$ Duration, modulated RF carrier (see Figure 9)                                                                  | 100                   | 2000                   | μs   |

#### switching characteristics over recommended ranges of supply voltage and operating free-air temperature

##### device latency for BBOUT, TRIG, DOUT (see Figure 9)

| PARAMETER                                                   | MIN | TYP                    | MAX | UNIT |
|-------------------------------------------------------------|-----|------------------------|-----|------|
| Delay time between power applied and output signal at BBOUT |     | 10                     |     | ms   |
| Demodulation delay time across device (RF Input to BBOUT)   |     | 10                     |     | μs   |
| $t_{d1}$ Delay time between BBOUT ↑ and TRIG ↑              |     | $2.5 \div \text{SCLK}$ |     | μs   |
| $t_{d2}$ Delay time between DOUT ↑ and TRIG ↑               |     | $0.5 \div \text{SCLK}$ |     | μs   |

##### RF carrier (see Figure 9)

| PARAMETER                            | MIN | TYP                    | MAX | UNIT |
|--------------------------------------|-----|------------------------|-----|------|
| $t_{w0}$ Duration, logic 0 data cell |     | $2 t_{w3}$             |     | μs   |
| $t_{w1}$ Duration, logic 1 data cell |     | $2 t_{w3}$             |     | μs   |
| $t_{w2}$ Duration, trigger pulse     |     | $0.5 \div \text{SCLK}$ |     | μs   |

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#### PARAMETER MEASUREMENT INFORMATION

TRF1400 electrical characteristics are measured with the device connected in the circuit shown in Figure 1.

As with any RF design, the successful integration of the device into a circuit board relies heavily on the layout of the board and the quality of the external components. Figures 2 through 6 show the layout of the circuit board used to obtain the TRF1400 electrical characteristics. Table 1 lists the parts required to complete the test circuit, which demonstrates TRF1400 performance at 315 MHz. Specified component tolerances (and Q where applicable) should be observed during the selection of parts. Tables 2 through 4 give S parameters for each of the RF signal processing blocks.

A complete set of Gerber photoplotter files for the circuit board can be obtained from any TI Field Sales Office.

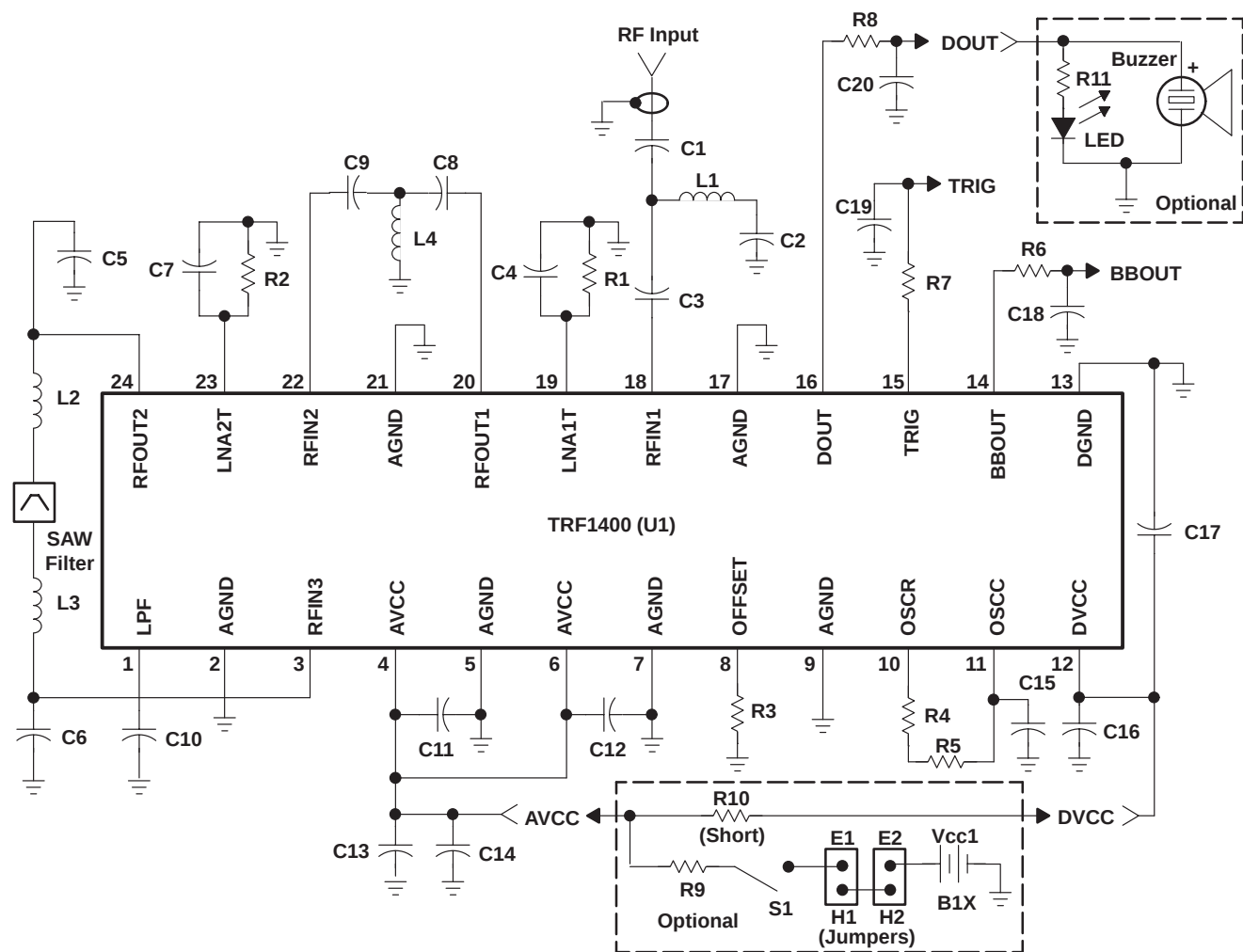
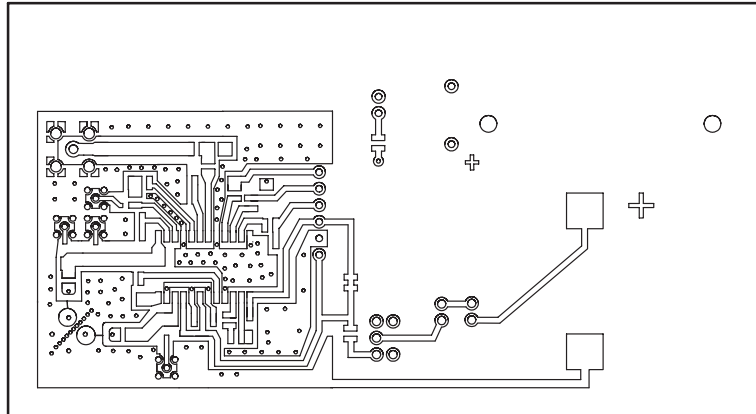


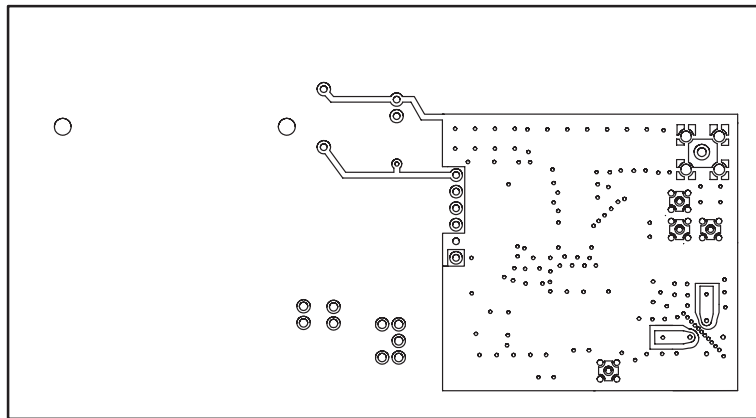
Figure 1. TRF1400 Test Circuit for 315-MHz Operation

## PARAMETER MEASUREMENT INFORMATION

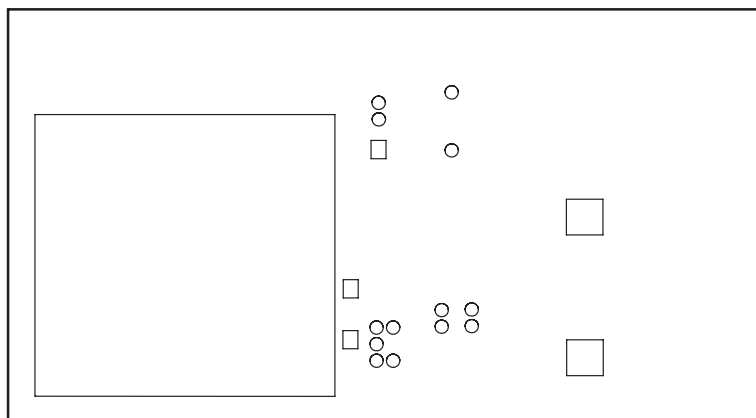


NOTE A: Circuit board material is 62 mil G-10 with 1-oz copper, dielectric constant = 4.5

**Figure 2. TRF1400 Test Circuit Board Layout — Top Side**



**Figure 3. TRF1400 Test Circuit Board Layout — Bottom Side**



**Figure 4. TRF1400 Test Circuit Board Solder Mask — Top Side**

## PARAMETER MEASUREMENT INFORMATION

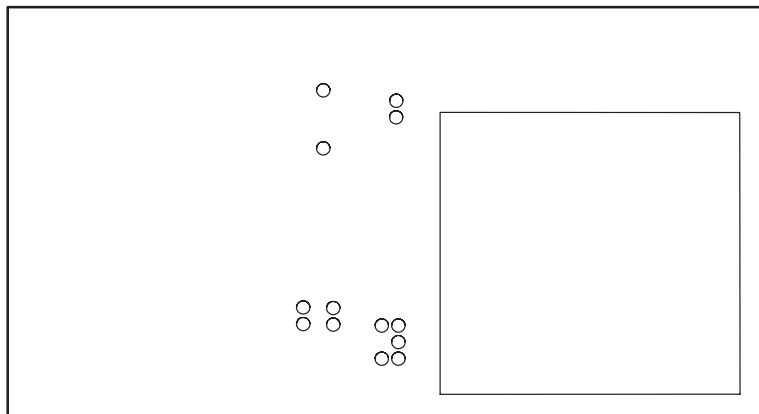


Figure 5. TRF1400 Test Circuit Board Solder Mask — Bottom Side

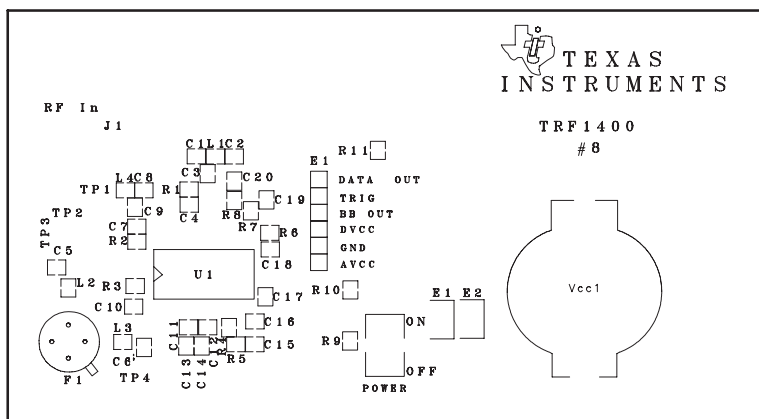


Figure 6. TRF1400 Test Circuit Board Silk Screen

## PARAMETER MEASUREMENT INFORMATION

**Table 1. TRF1400 315-MHz Test Circuit Parts List**

| DESIGNATORS           | DESCRIPTION                      | VALUE                   | MANUFACTURER | MANUFACTURER P/N  |
|-----------------------|----------------------------------|-------------------------|--------------|-------------------|
| C1                    | Capacitor                        | 4 pF                    | Murata       | GRM40C0G040C050V  |
| C2, C3                | Capacitor                        | 22 pF                   | Murata       | GRM40C0G220J050BD |
| C4, C7                | Capacitor                        | 100 pF                  | Murata       | GRM40C0G101J050BD |
| C5                    | Capacitor                        | 5 pF                    | Murata       | GRM40C0G050D050BD |
| C6                    | Capacitor                        | 1.5 pF                  | Murata       | GRM40C0G1R5C050BD |
| C8                    | Capacitor                        | 3 pF                    | Murata       | GRM40C0G030C050BD |
| C9                    | Capacitor                        | 18 pF                   | Murata       | GRM40C0G180J050BD |
| C10                   | Capacitor                        | 0.047 $\mu$ F           | Murata       | GRM40X7R473K050   |
| C11, C12, C17,<br>C19 | Capacitor                        | 2200 pF                 | Murata       | GRM40X7R222K050BD |
| C13, C18, C20         | Capacitor                        | 0.022 $\mu$ F           | Murata       | GRM40X7R223K050BL |
| C14, C16              | Capacitor, Tantalum <sup>†</sup> | 4.7 $\mu$ F @ 6.3 V     | Panasonic    | ECS-T1AY475R      |
| C15                   | Capacitor                        | 220 pF, 5%              | Murata       | GRM40C0G221J050BD |
| E1                    | 2-Pin Connector                  |                         | 3M           | 2340-6111-TN      |
| E2                    | 2-Pin Connector                  |                         | 3M           | 2340-6111-TN      |
| E3                    | 6-Pin Connector                  |                         | 3M           | 2340-6111-TN      |
| H1, H2                | Header Shunts                    |                         | 3M           | 929952-10         |
| F1                    | SAW Filter                       | RFM 1211                | RFM          | RFM 1211          |
| L1                    | Inductor                         | 47 nH                   | Coilcraft    | 0805HS470TMBC     |
| L2                    | Inductor                         | 82 nH                   | Coilcraft    | 0805HS820TKBC     |
| L3                    | Inductor                         | 120 nH                  | Coilcraft    | 0805HS121TKBC     |
| L4                    | Inductor                         | 39 nH                   | Coilcraft    | 0805HS390TMBC     |
| P1                    | RF SMA Connector                 |                         | Johnson      | 142-0701-201      |
| R1                    | Resistor                         | 1.2 K $\Omega$          |              |                   |
| R2                    | Resistor                         | 1.2 K $\Omega$          |              |                   |
| R3                    | Resistor                         | 3 M $\Omega$            |              |                   |
| R4                    | Resistor                         | 130 K $\Omega$ , 1%     |              |                   |
| R5                    | Resistor                         | 0 $\Omega$              |              |                   |
| R6, R8                | Resistor                         | 1K $\Omega$             |              |                   |
| R7                    | Resistor                         | 100 $\Omega$            |              |                   |
| R9                    | Resistor                         | 680 $\Omega$            |              |                   |
| R10                   | Resistor                         | short                   |              |                   |
| R11                   | Resistor                         | 330 $\Omega$            |              |                   |
| S1                    | Switch                           |                         | NKK          | G-12AP            |
| Vcc1                  | Battery Clip                     |                         | Keystone     | 1061              |
| B1X                   | Battery, Lithium                 | 3.3-V Coin Cell (2 ea.) | Panasonic    | CR2016            |
| U1                    | Receiver IC                      | TRF1400                 | TI           | TRF1400           |

<sup>†</sup> Tantalum capacitors are rated at 6.3 Vdc minimum.

## PARAMETER MEASUREMENT INFORMATION

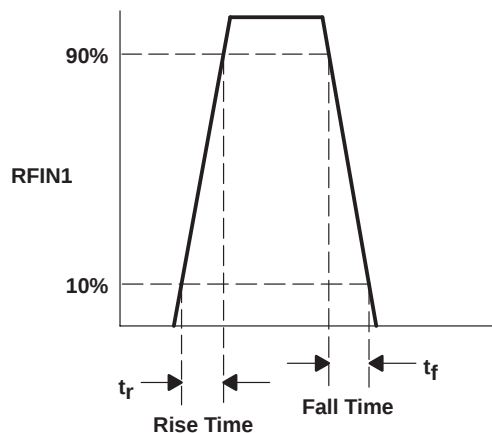


Figure 7. RFIN1 Rise and Fall Times

Table 2. TRF1400 LNA1 S Parameters

| FREQ<br>(MHz) | S11    | ∠ S11    | S21    | ∠ S21    | S12    | ∠ S12     | S22    | ∠ S22    |
|---------------|--------|----------|--------|----------|--------|-----------|--------|----------|
| 300           | 0.9541 | –25.6217 | 4.7618 | 105.1213 | 0.0042 | 135.6601  | 0.6699 | –17.8126 |
| 304           | 0.9555 | –25.8350 | 4.7299 | 103.9028 | 0.0041 | 82.5760   | 0.6722 | –17.5588 |
| 310           | 0.9569 | –26.7244 | 4.6670 | 102.3880 | 0.0033 | 74.4905   | 0.6670 | –18.0246 |
| 315           | 0.9474 | –26.9720 | 4.6271 | 100.8973 | 0.0024 | 108.9183  | 0.6760 | –17.9033 |
| 318           | 0.9543 | –27.3058 | 4.6075 | 99.8886  | 0.0028 | 95.0878   | 0.6724 | –17.9506 |
| 390           | 0.9391 | –32.3782 | 3.8948 | 81.7216  | 0.0044 | –108.3656 | 0.6911 | –20.9576 |
| 418           | 0.9341 | –34.8677 | 3.6575 | 75.8867  | 0.0019 | 165.4227  | 0.6965 | –22.0900 |
| 434           | 0.9270 | –35.8675 | 3.5286 | 72.4715  | 0.0043 | 113.6352  | 0.6991 | –22.8623 |

NOTE 4: Input at RFIN1, output at RFOUT1,  $Z_O = 50 \Omega$ ,  $R_{bias} = 1.2 \text{ k}\Omega$

## PARAMETER MEASUREMENT INFORMATION

**Table 3. TRF1400 LNA2 S Parameters**

| FREQ<br>(MHz) | S11    | ∠ S11    | S21    | ∠ S21    | S12    | ∠ S12     | S22    | ∠ S22    |
|---------------|--------|----------|--------|----------|--------|-----------|--------|----------|
| 300           | 0.9607 | -26.6188 | 4.8712 | 100.9061 | 0.0078 | 122.6680  | 0.6534 | -24.4258 |
| 304           | 0.9655 | -27.1490 | 4.8380 | 99.8060  | 0.0057 | 65.9066   | 0.6555 | -24.5020 |
| 310           | 0.9554 | -27.4384 | 4.7870 | 97.8264  | 0.0030 | 137.0205  | 0.6567 | -25.1169 |
| 315           | 0.9612 | -27.8929 | 4.7239 | 96.5227  | 0.0014 | 31.2221   | 0.6572 | -24.8942 |
| 318           | 0.9615 | -28.4482 | 4.7065 | 95.5964  | 0.0047 | 109.2950  | 0.6571 | -25.0606 |
| 390           | 0.9461 | -33.8905 | 3.9755 | 76.2949  | 0.0054 | 48.3449   | 0.6803 | -28.0870 |
| 418           | 0.9389 | -35.8847 | 3.7411 | 69.8410  | 0.0041 | -119.9136 | 0.6811 | -29.5353 |
| 434           | 0.9406 | -36.8175 | 3.6130 | 66.0262  | 0.0046 | 102.9654  | 0.6839 | -30.4657 |

NOTE 5: Input at RFIN2, output at RFOUT2,  $Z_O = 50 \Omega$ ,  $R_{bias} = 1.2 k\Omega$

**Table 4. TRF1400 RSSI S Parameters**

| FREQ.<br>(MHz) | S11    | ∠ S11    |
|----------------|--------|----------|
| 300            | 0.7937 | -23.6001 |
| 304            | 0.7895 | -24.0484 |
| 310            | 0.7923 | -24.4377 |
| 315            | 0.7931 | -24.5069 |
| 318            | 0.7934 | -24.8835 |
| 390            | 0.7851 | -30.0440 |
| 418            | 0.7736 | -31.2657 |
| 434            | 0.7805 | -32.5896 |

NOTE 6: Input at RFIN3,  $Z_O = 50 \Omega$

## PARAMETER MEASUREMENT INFORMATION

### Manchester data format and timing

The TRF1400 requires specific Manchester data formatting and timing to decode and output Manchester serial data. For the TRF1400 to output meaningful function data at the TRIG and DOUT terminals, the incoming RF signal must have the Manchester-encoded binary format and timing shown in Figure 8 (for 50-kHz SCLK). A wakeup time and frame-start time is required for the device to synchronize with the incoming data. The wakeup time is designated by a data-bit 0 and data-bit 1 sequence repeated five times.

Figure 9 shows Manchester-encoded function data timing.

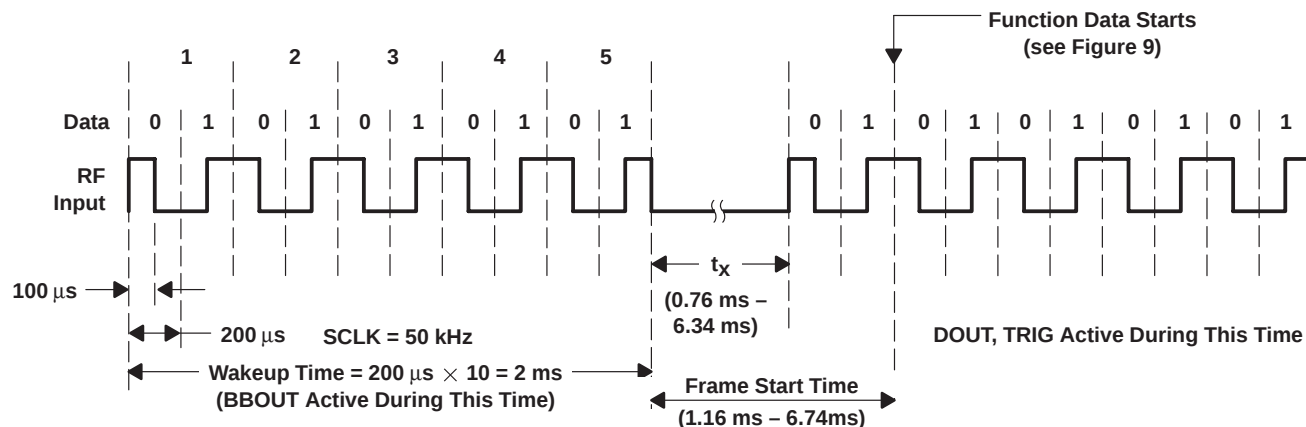


Figure 8. Manchester-Encoded RF Binary Data Format at RF Input

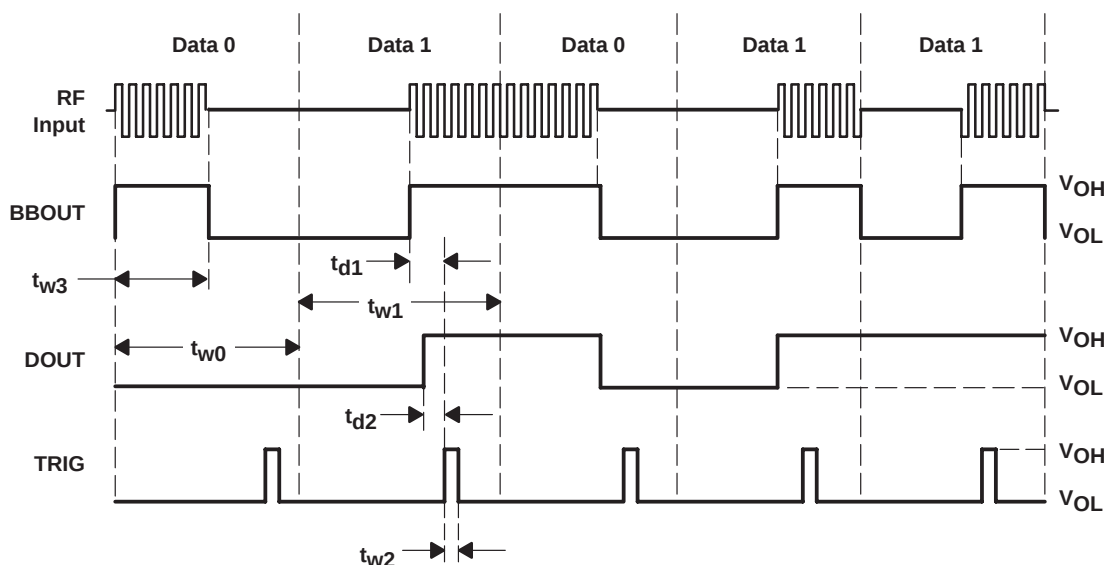
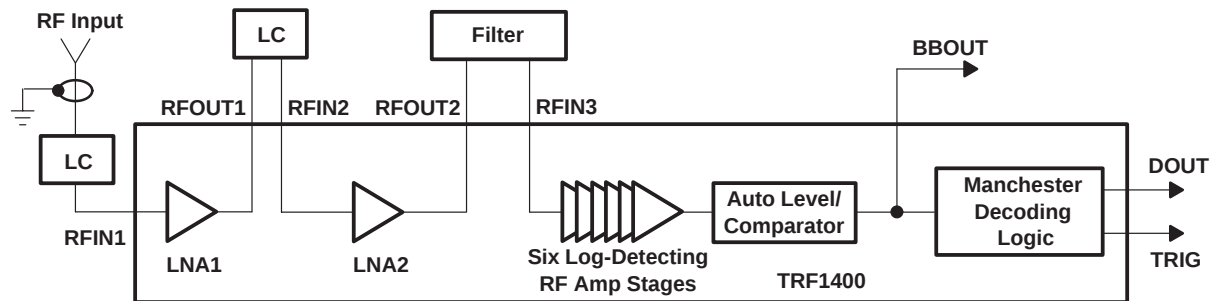


Figure 9. Manchester-Encoded Function Data Timing Diagram

## PRINCIPLES OF OPERATION

### general

The TRF1400 VHF/UHF RZ ASK remote control receiver demodulates AM RZ ASK modulated RF carriers between 200 MHz and 450 MHz with a 500-Hz to 10-kHz baseband data rate or a 250-Hz to 5-kHz Manchester data rate. A general signal flow is shown in Figure 10.



**Figure 10. TRF1400 Signal Flow**

### signal reception

The RF signal is collected by an antenna and then passed through an external LC matching network to bandpass filter the signal and compensate for various antenna loading impedances. The signal is then input to the RFIN1 terminal of the TRF1400.

### signal path through device

The RF signal applied to the RFIN1 terminal is amplified by LNA1 and typically passed through an external LC matching network before being applied to the input of LNA2. The combined gain of the two LNAs is 40 dB, with an input 1-dB compression point of  $-80$  dBm and a noise figure of 5 dB (nominal). The amplified signal is output at RFOUT2 and passed through an external preselector bandpass filter before being applied to the third stage of amplification at terminal RFIN3.

The third stage of amplification consists of an amplifier with a single-ended input and differential outputs followed by six high-gain differential log-detecting amplifier stages with an equivalent gain of 60 dB (nominal), which forms a detector circuit. First, the signal is converted to a differential signal for increased noise immunity. Next, the differential signal is passed through the six high-gain differential log-detecting amplifiers. Each log-detecting amplifier is biased such that when an RF signal is present, an imbalance is caused in its bias circuit. The imbalance in each of the six stages is converted to a voltage that is then summed into a baseband envelope representation of the RF signal. This signal then passes through an autoleveling circuit before being applied to a comparator to produce the TTL-level baseband signal output that appears at BBOUT. An external low-pass filter connected to BBOUT attenuates high-frequency transients in the output signal.

The demodulated signal is also applied to the Manchester decoding and timing recovery logic section of the TRF1400. The Manchester Decoding Logic section has two outputs, TRIG and DOUT, which should be externally low-pass filtered to attenuate high-frequency transients. The signals appearing at these outputs are meaningful only when the received Manchester-encoded data is formatted and timed as shown in Figure 9.

When Manchester-encoded data is received and demodulated, Manchester serial data is output at DOUT and a trigger pulse is output at TRIG. The TRIG pulse rises at the start of each decoded data bit appearing at DOUT.

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## **PRINCIPLES OF OPERATION**

### **frequency adjustment**

The TRF1400 requires no manual alignment. The receive frequency is dependent only on the choice of external matching networks and preselecting filters used. In that respect, the user has only to stock a different set of external components for each frequency, and no manual alignment or end-of-line frequency programming is required. Although the combination of the TRF1400 and test circuit/demo board (Figures 1 – 6) is optimized for frequencies below 360 MHz, operation at reduced performance levels is possible at higher frequencies.

### **external components and device performance**

Whereas the TRF1400 uses a minimum of external components in the typical application, the choice of those components greatly affects the performance of the device. When a SAW (surface acoustic wave) preselector is used, the selectivity (out-of-band rejection) and sensitivity of the TRF1400 are optimized as a result of the high Q of SAW devices. If an LC preselector is used, these parameters change and the overall performance of the TRF1400 is reduced, but can still meet the requirements of many end-equipment applications.

An external resistor connected between OFFSET and ground adjusts the internal offset voltage of the receiver decoding section to maximize the noise rejection of the device. While a 3-M $\Omega$  resistor is suggested, this value can be changed to minimize toggling of outputs DOUT, TRIG, and BBOUT during periods of nonvalid received code.

### **decoder interface**

For baseband operation, a decoder can be interfaced directly to the TRF1400 using the baseband-data output (BBOUT) of the device.

For Manchester operation, a standard microcontroller decoder must know when to poll its input for data. The TRF1400 provides an output terminal (TRIG) for this purpose that pulses on each valid received data cell. In this system configuration, Manchester-encoded binary data must be used in the format described in the following paragraphs to allow the TRF1400 to synchronize properly and produce the TRIG and DOUT outputs.

### **internal clock/synchronization**

An internal clock (SCLK) is used by the TRF1400 for processing the demodulated incoming data stream and for controlling the Manchester-decoding and timing-recovery logic sections of the device. The frequency of SCLK is set by an external resistor connected between the OSCR and OSCC terminals and an external capacitor connected between OSCC and ground, and is adjustable between 2.5 kHz and 50 kHz.

For baseband output, SCLK is set to 5 times the received baseband data rate (500 Hz to 10 kHz). Incoming baseband data is then sampled at 5 times its transmitted data rate. TTL-level baseband data is output at BBOUT whenever the TRF1400 receives ASK-modulated data in any format. This provides compatibility with systems that use other code formatting, and whose serial data decoders do not require the DOUT or TRIG outputs from the receiver.

For Manchester data output, SCLK must be set to 10 times the received Manchester-encoded data rate (250 Hz to 5 kHz) for the output signals at TRIG and DOUT to be meaningful. The high sampling rate (10 $\times$ ) ensures accurate correlation of the received signal.

The received Manchester data rate (set by a clock on the transmitter/encoder end) can vary as much as  $\pm 8\%$  and TRF1400 synchronization still results. This allows for frequency drift due to external component tolerances and temperature changes on the transmitter end. At the TRF1400 end, a  $\pm 8\%$  frequency variation is also allowed. Thus, the total permissible frequency variation from transmitter clock to receiver clock can be as much as  $\pm 16\%$ . For example, if a serial Manchester data rate of 1.5 kHz is used at the encoder/transmitter end, then the TRF1400 sample clock oscillator (SCLK) must be set to 10 times the transmitted data rate, or 15 kHz. SCLK is allowed to vary  $\pm 8\%$  in frequency, from 13.8 kHz to 16.2 kHz in this case, and the TRF1400 synchronizes successfully to the incoming data.



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## PRINCIPLES OF OPERATION

### internal clock/synchronization (continued)

The data rate of the incoming data itself can also vary the same amount. It is left to the user to design the system such that the transmitter/encoder data rate drifts  $\pm 8\%$  or less. The TRF1400 can introduce as much as a  $\pm 5\%$  frequency variation due to its internal tolerances and semiconductor process variations, so the external resistor and capacitor values used with the TRF1400 can have up to a  $\pm 3\%$  value tolerance.

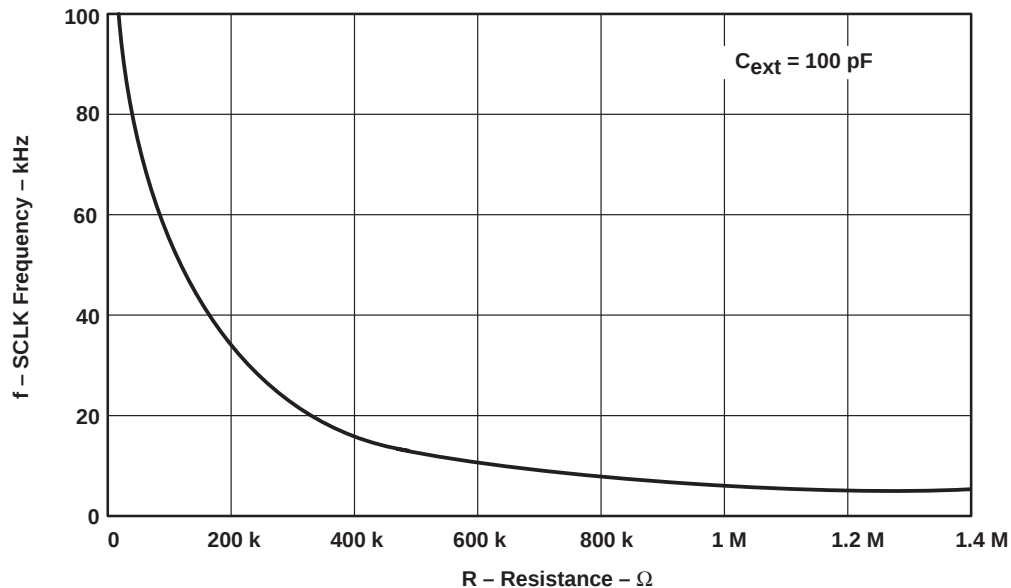
The frequency of the internal clock oscillator is set by connecting a resistor between OSC<sub>R</sub> and OSC<sub>C</sub> and a capacitor between OSC<sub>C</sub> and ground. The following equation defines the oscillator frequency (SCLK speed) as a function of the external resistor and capacitor:

$$F_{\text{osc}} = \frac{1}{1.386 \times (R_{\text{ext}} + R_s) \times (C_{\text{ext}} + C_p)}$$

Where:

- $R_{\text{ext}}$  is the external resistor connected between OSC<sub>R</sub> and OSC<sub>C</sub>.
- $R_s$  is the internal series resistance, typically 1.9 k $\Omega$  or less.
- $C_{\text{ext}}$  is the external capacitor connected between OSC<sub>C</sub> and ground.
- $C_p$  is parasitic capacitance and is dependent on board layout — typical value is 8.5 pF.

For minimum current draw, large values (in the thousands of ohms) for  $R_{\text{ext}}$  should be used. Typical  $R_{\text{ext}}$  values and the resulting SCLK frequency when  $C_{\text{ext}} = 100$  pF are shown in Figure 11.



**Figure 11. External Resistance Versus Sample Clock Frequency**

# TRF1400

## RF TELEMETRY RECEIVERS

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#### APPLICABLE REGULATIONS

Receiver design, as well as transmitter design, is regulated throughout the world. Since the TRF1400 is targeted for world-wide sales, the applicable standard for each region must be considered when the device is to be used in systems to be successfully marketed in that region. For this reason, the TRF1400 conforms to all requirements shown in Figure 12 and Table 5. The primary specifications of most of the standards address carrier frequency and spurious emissions.

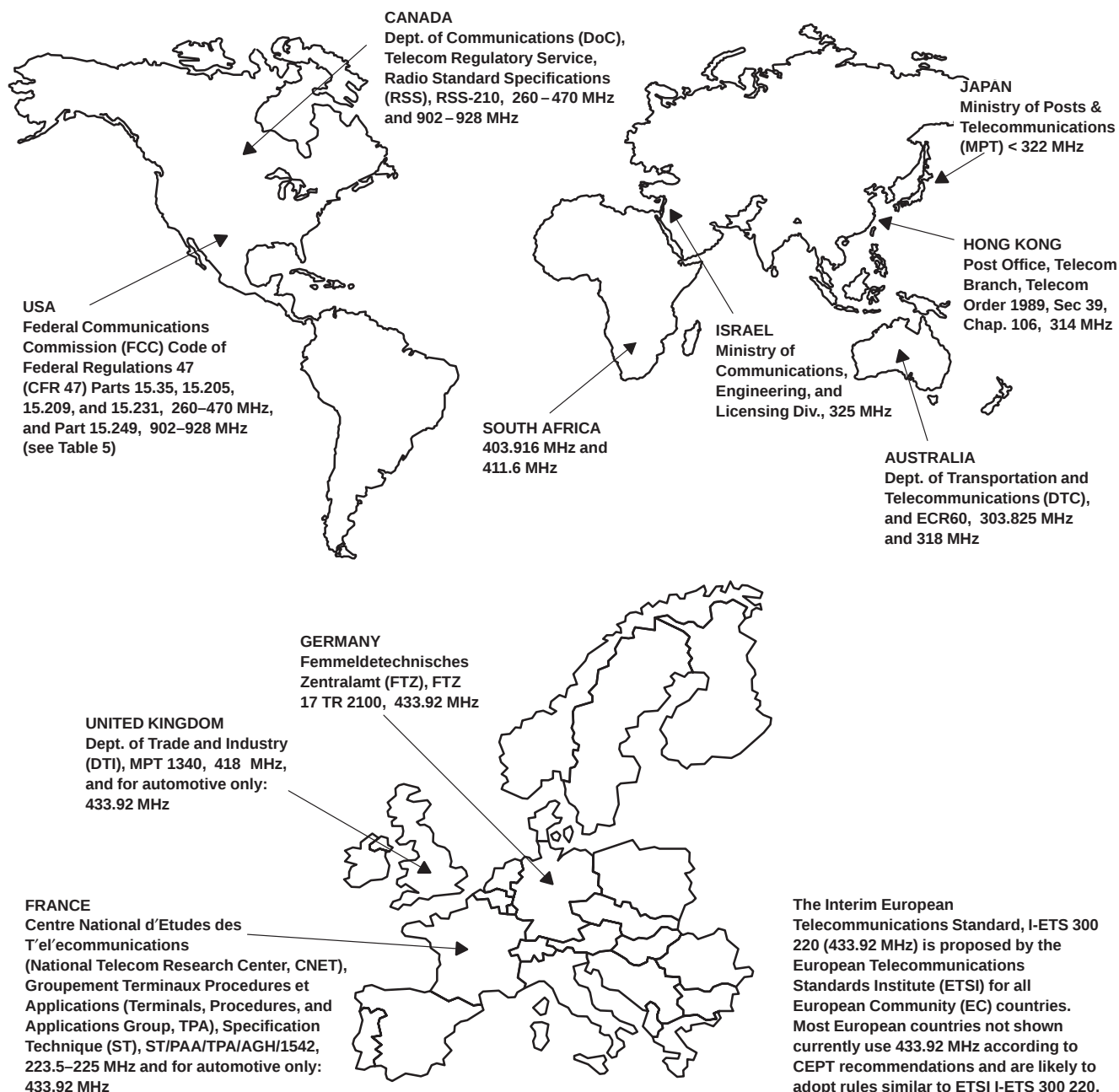


Figure 12. World-Wide Receiver Regulations

## APPLICABLE REGULATIONS

**Table 5. World-Wide Regulations**

| REGION         | REGULATION                                                                                                                                                                                                                                        | FREQUENCY                                                                                     |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| USA            | Federal Communications Commission (FCC) Code of Federal Regulations 47 (CFR 47) Parts 15.35, 15.205, 15.209, 15.231, and 15.249 (see Note 7)                                                                                                      | 260 MHz – 470 MHz (Part 15.35, 15.205, 15.209)<br>902 MHz – 928 MHz (Part 15.249, see Note 4) |
| Germany        | Femmeldetechnisches Zentralamt (FTZ), FTZ 17 TR2100                                                                                                                                                                                               | 433.92 MHz                                                                                    |
| France         | Centre National d'Etudes des T'el'ecomunications (National Telecom Research Center, CNET), Groupement Terminaux Procedures et Applications (Terminals, Procedures and Applications Group, TPA), Specification Technique (ST), ST/PAA/TPA/AGH/1542 | 223.5 MHz – 225 MHz (automotive only)                                                         |
| United Kingdom | Dept. of Trade and Industry (DTI), MPT 1340                                                                                                                                                                                                       | 418 MHz<br>433.92 MHz (automotive only)                                                       |
| Japan          | Ministry of Posts and Telecommunications (MPT)                                                                                                                                                                                                    | < 322 MHz                                                                                     |
| Canada         | Dept. of Communications (DoC), Telecom Regulatory Service, Radio Standard Specifications (RSS), RSS-210                                                                                                                                           | 260 MHz – 470 MHz (RSS-210)<br>902 MHz – 928 MHz                                              |
| Hong Kong      | Post Office, Telecom Branch, Telecom Order 1989, Sec 39, Cap. 106                                                                                                                                                                                 | 314 MHz                                                                                       |
| Australia      | Dept. of Transportation and Telecommunications (DTC), and ECR60                                                                                                                                                                                   | 303.825 MHz and 318 MHz                                                                       |
| Israel         | Ministry of Communications, Engineering & Licensing Div.                                                                                                                                                                                          | 325 MHz                                                                                       |
| South Africa   |                                                                                                                                                                                                                                                   | 403.916 MHz and 411.6 MHz                                                                     |

NOTE 7: Although the FCC Part 15.231 allows low-power unlicensed radios in the range of 260 MHz to 470 MHz, not all frequencies in this range are desirable. This is due to emission restrictions applying to fundamentals and harmonics in various forbidden bands as defined in Parts 15.205 and 15.209. USA frequencies shown above conform to these additional restrictions and are commonly used in the USA. Under Part 15.249, transmitters may continuously radiate 50 000  $\mu\text{V/m}$  at 3 meters with simple modulation. Part 15.247 permits still higher power, but must use true spread-spectrum modulation. See FCC CFR 47, Part 47, Part 15 for details.

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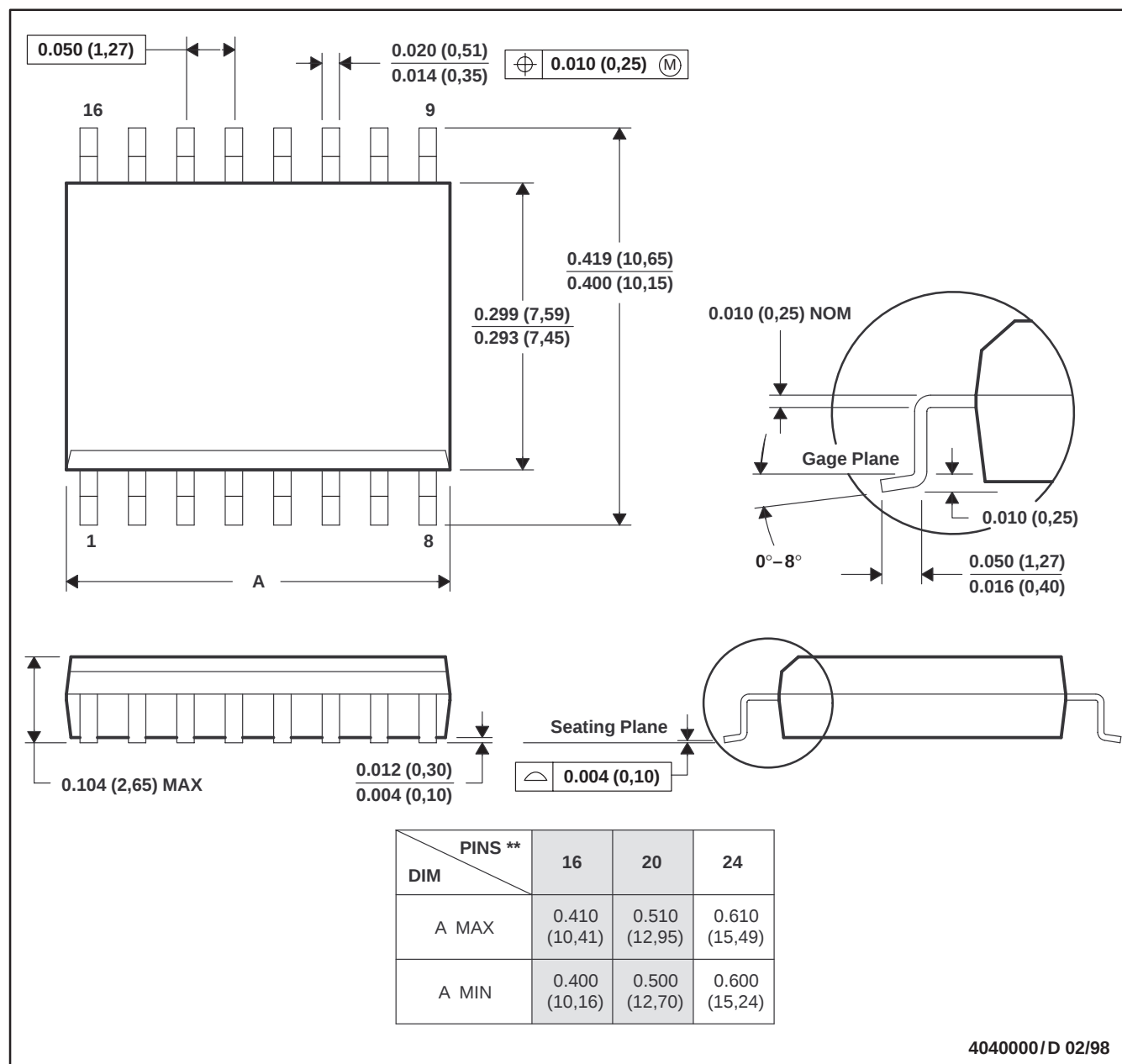
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**MECHANICAL DATA**

**DW (R-PDSO-G\*\*)**

**PLASTIC SMALL-OUTLINE PACKAGE**

16 PIN SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).  
 D. Falls within JEDEC MS-013

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