

- **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	$\mu\text{W}$
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.

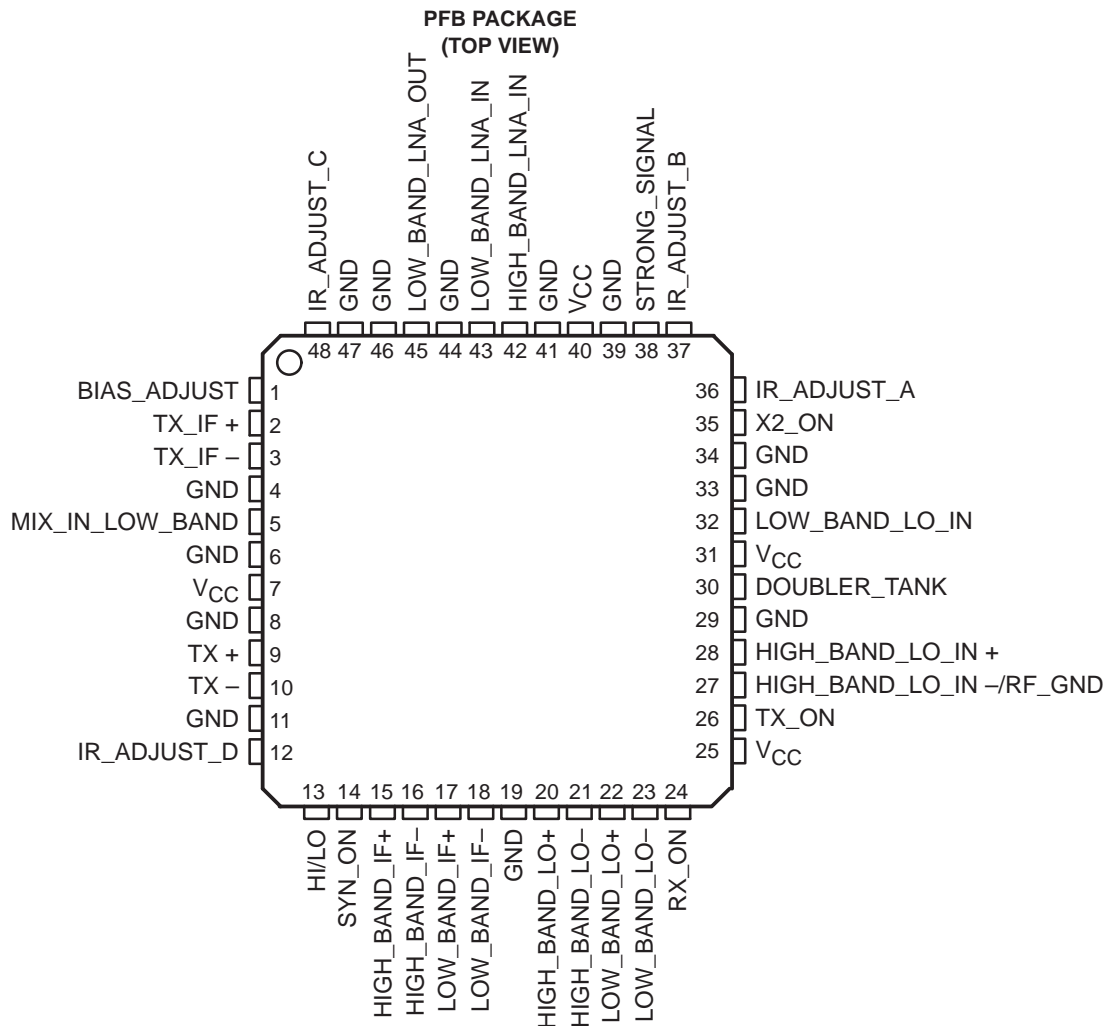


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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

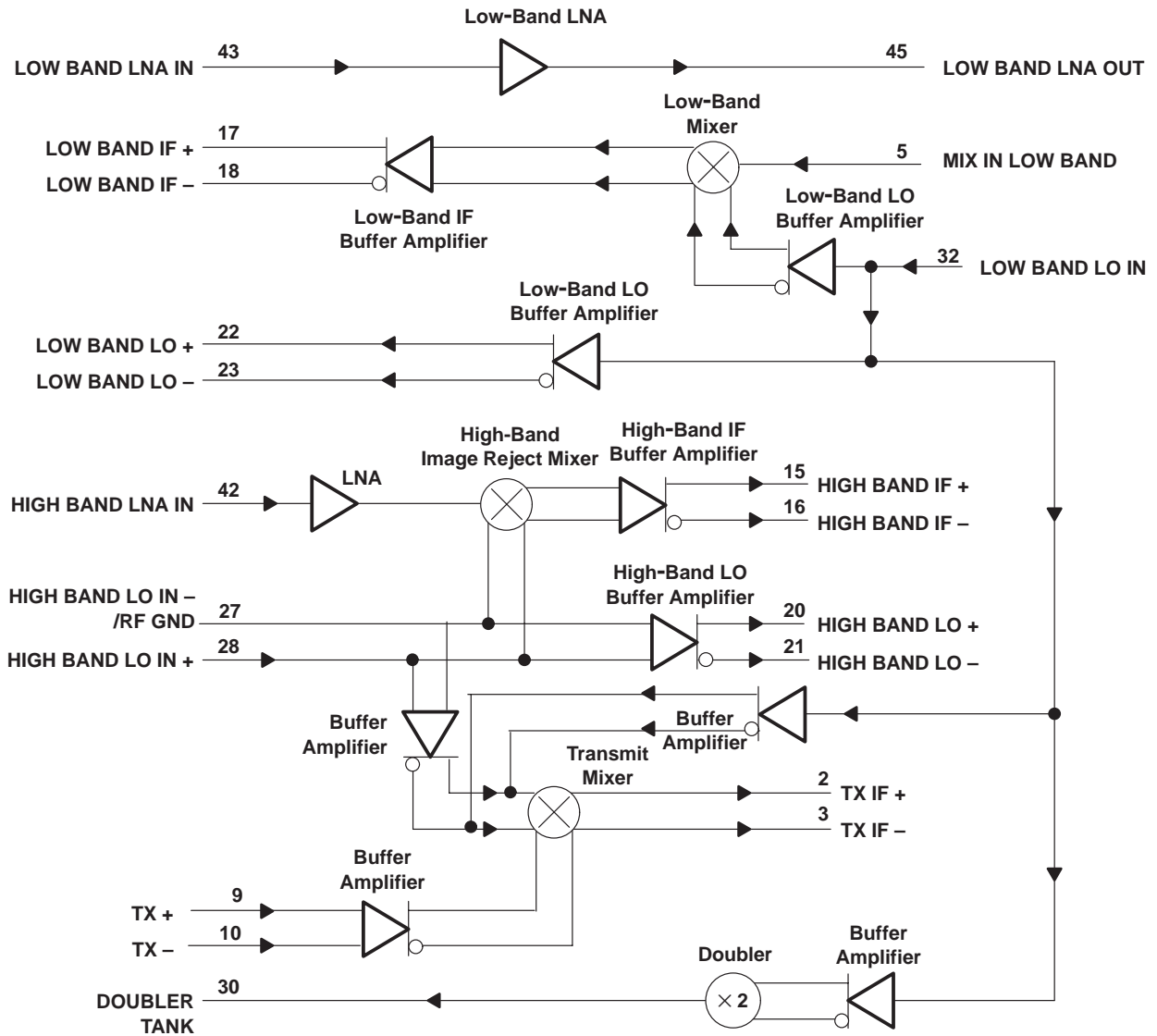
# TRF1500 DUAL-BAND/DUAL-MODE PCS RECEIVER

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functional block diagram



# TRF1500 DUAL-BAND/DUAL-MODE PCS RECEIVER

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## 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

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### 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	$\mu\text{A}$
010000	Low-band LO input buffer on		3.3	4	$\text{mA}$
011000	Low-band receive normal		24	28	$\text{mA}$
110000	High-band LO input buffer on		4	5	$\text{mA}$
111000	High-band receive normal		56	62	$\text{mA}$
111001	High-band receive with doubler on		61	68	$\text{mA}$
010100	Low-band transmit mixer		13	16	$\text{mA}$
110100	High-band transmit mixer		17	21	$\text{mA}$
110101	High-band transmit mixer, doubler on		22	27	$\text{mA}$

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

<sup>†</sup> 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 $\Omega$  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 <sub>FR</sub> =2070.52		4.35		dB
RF input return loss	50 $\Omega$		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

<sup>†</sup> High-band LNA, mixer, and IF amplifier specifications apply for an IF output terminated into a 1-k $\Omega$  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 $\Omega$		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

<sup>‡</sup> Transmit mixer specifications apply for an IF output terminated into a 1-k $\Omega$  resistor load.

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### 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 $\Omega$		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

<sup>†</sup> High-band transmit mixer specifications apply for an IF output terminated into a 1-k $\Omega$  resistor load using the internal frequency doubler.







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## 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).



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**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

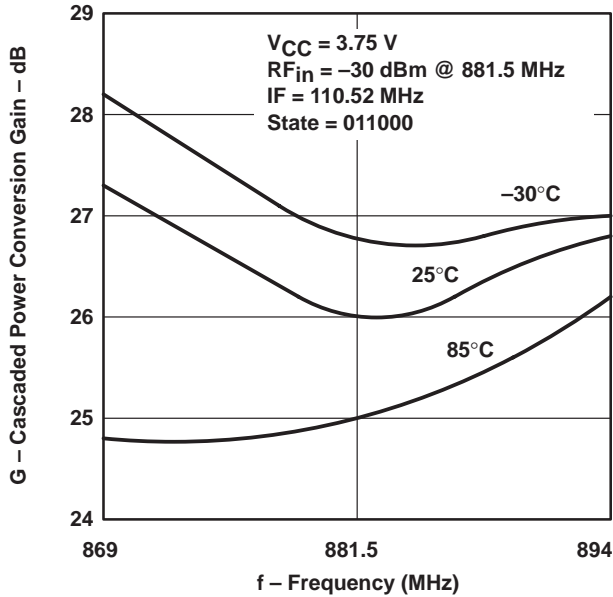


Figure 2

LOW BAND RECEIVER  
 CASCADED NOISE FIGURE  
 VS  
 FREQUENCY

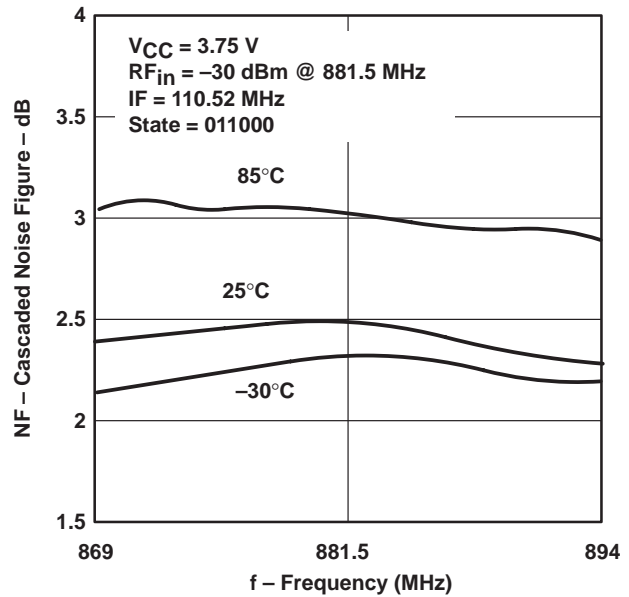


Figure 3

LOW BAND RECEIVER  
 CASCADED THIRD ORDER INPUT INTERCEPT POINT  
 VS  
 FREQUENCY

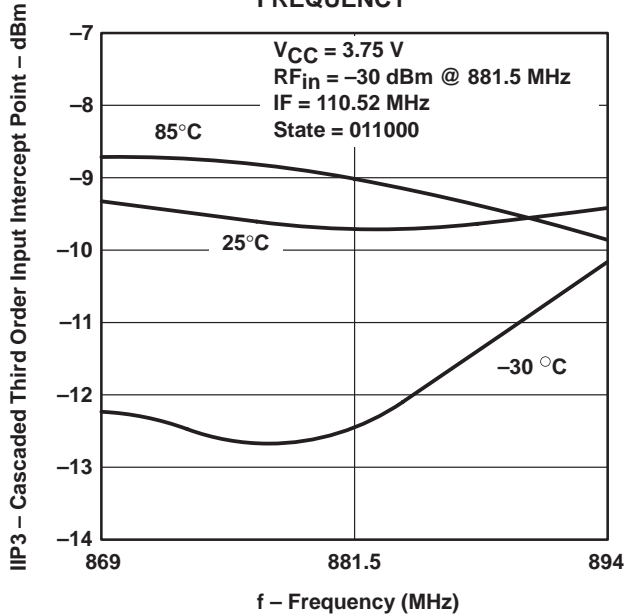


Figure 4

HIGH BAND RECEIVER  
 CASCADED POWER CONVERSION GAIN  
 VS  
 FREQUENCY

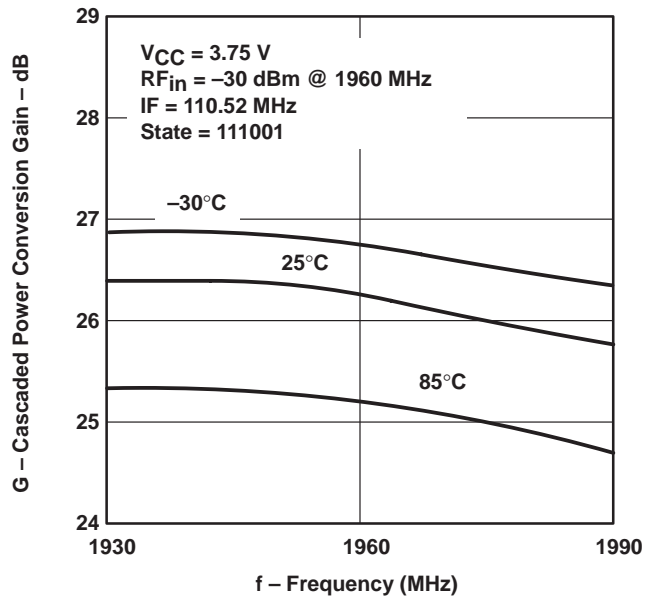


Figure 5

TYPICAL CHARACTERISTICS

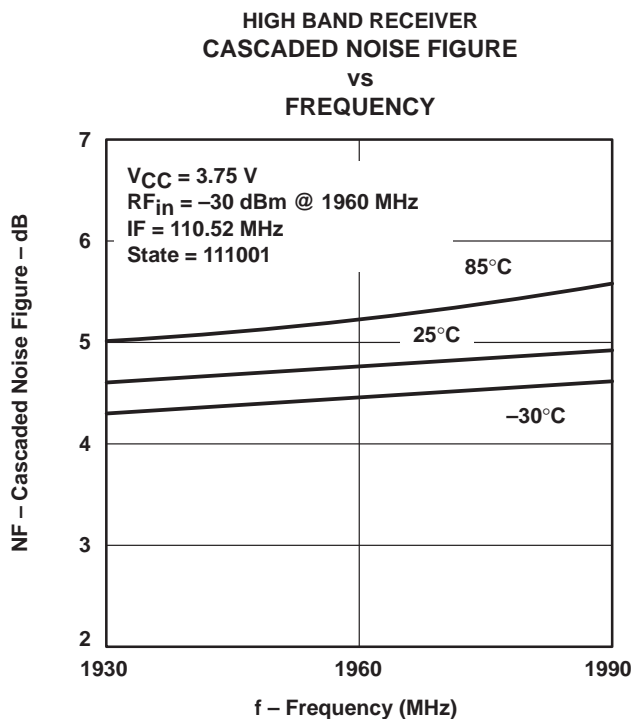


Figure 6

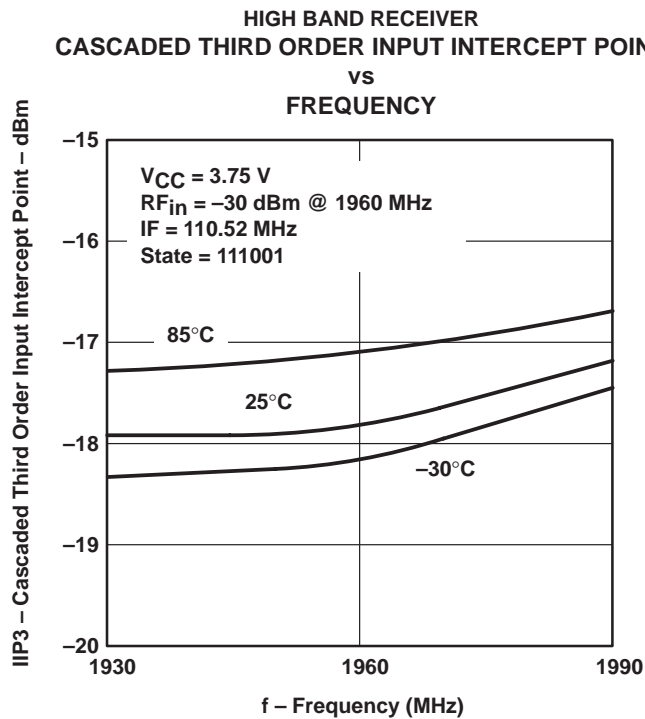


Figure 7

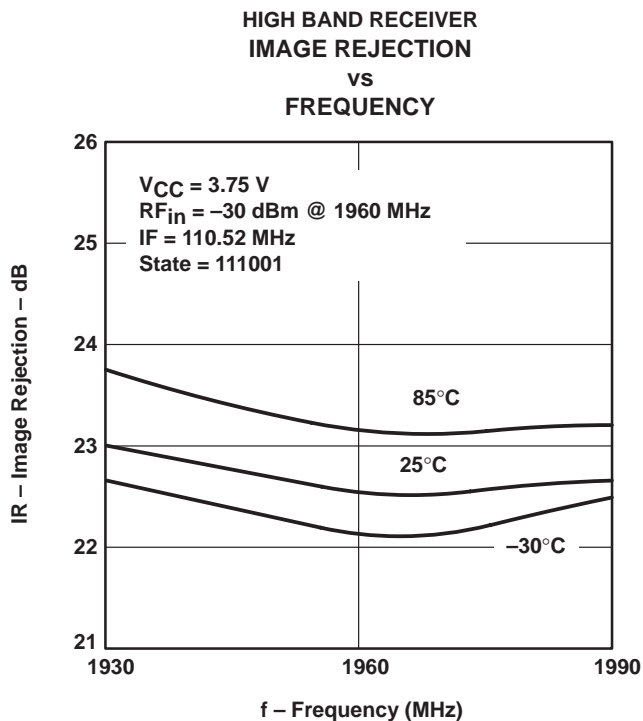


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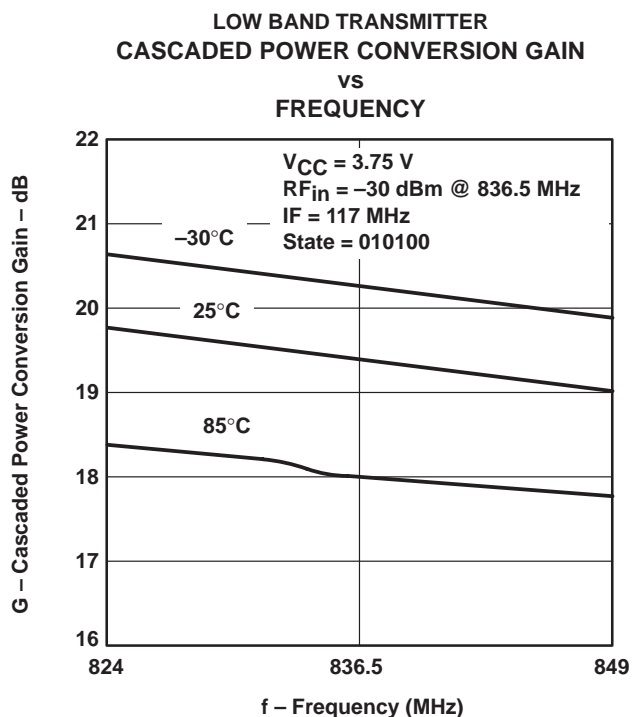


Figure 9

TYPICAL CHARACTERISTICS

LOW BAND TRANSMITTER  
 CASCADED NOISE FIGURE  
 VS  
 FREQUENCY

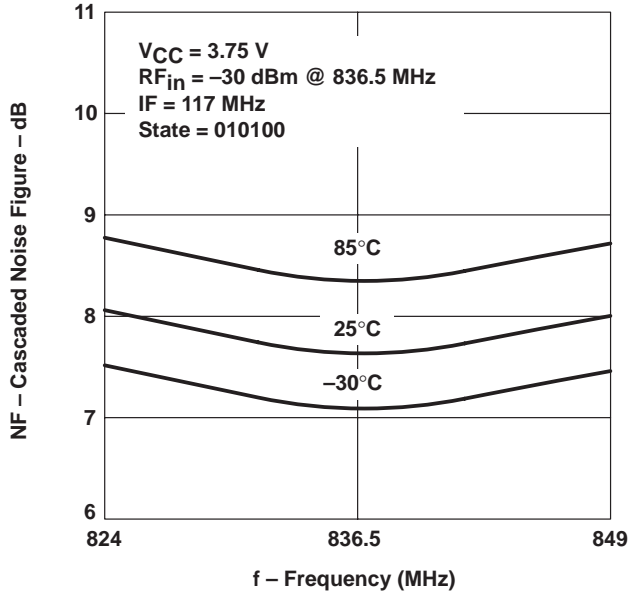


Figure 10

LOW BAND TRANSMITTER  
 CASCADED THIRD ORDER INPUT INTERCEPT POINT  
 VS  
 FREQUENCY

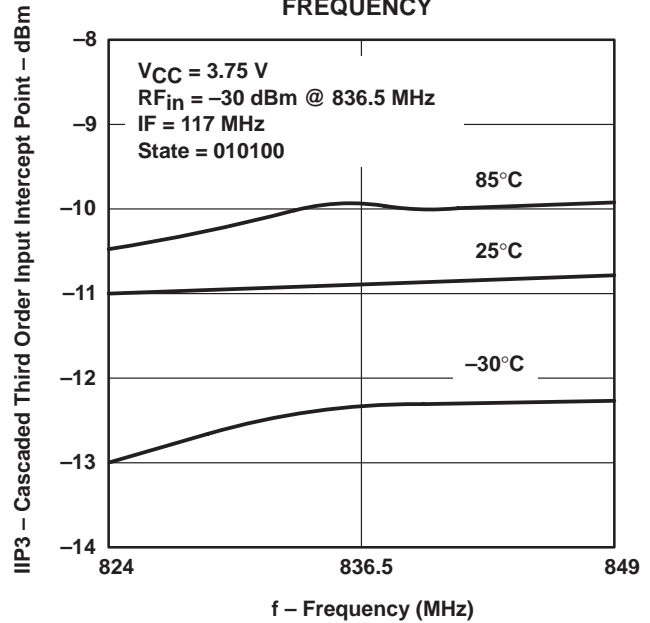


Figure 11

HIGH BAND TRANSMITTER  
 CASCADED POWER CONVERSION GAIN  
 VS  
 TEMPERATURE

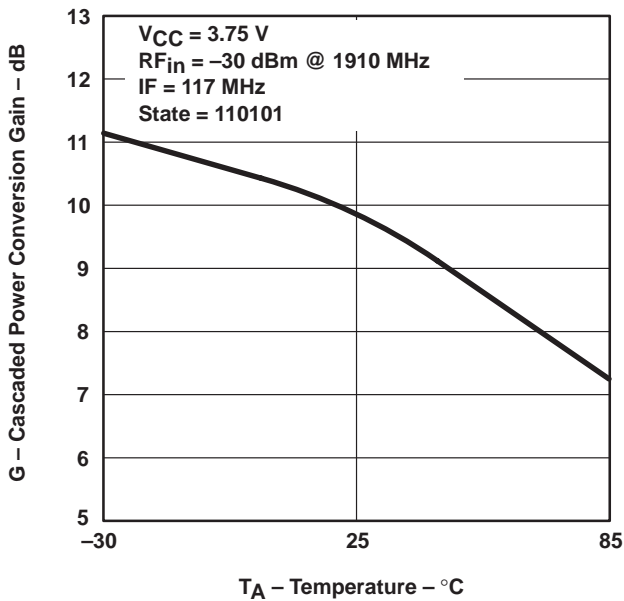


Figure 12

HIGH BAND TRANSMITTER  
 CASCADED NOISE FIGURE  
 VS  
 TEMPERATURE

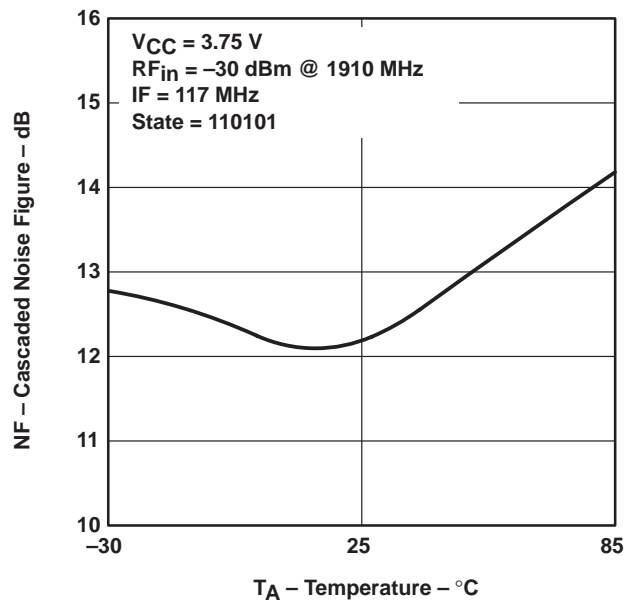


Figure 13

TYPICAL CHARACTERISTICS

HIGH BAND TRANSMITTER  
CASCADED THIRD ORDER INPUT INTERCEPT POINT  
vs  
TEMPERATURE

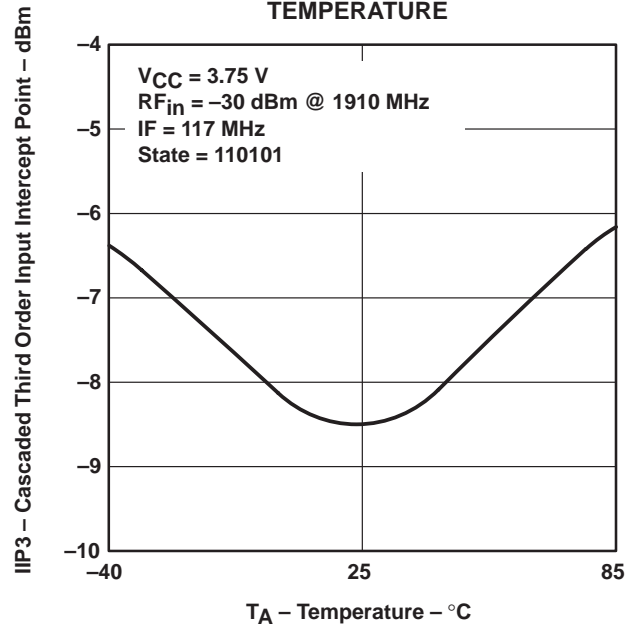


Figure 14

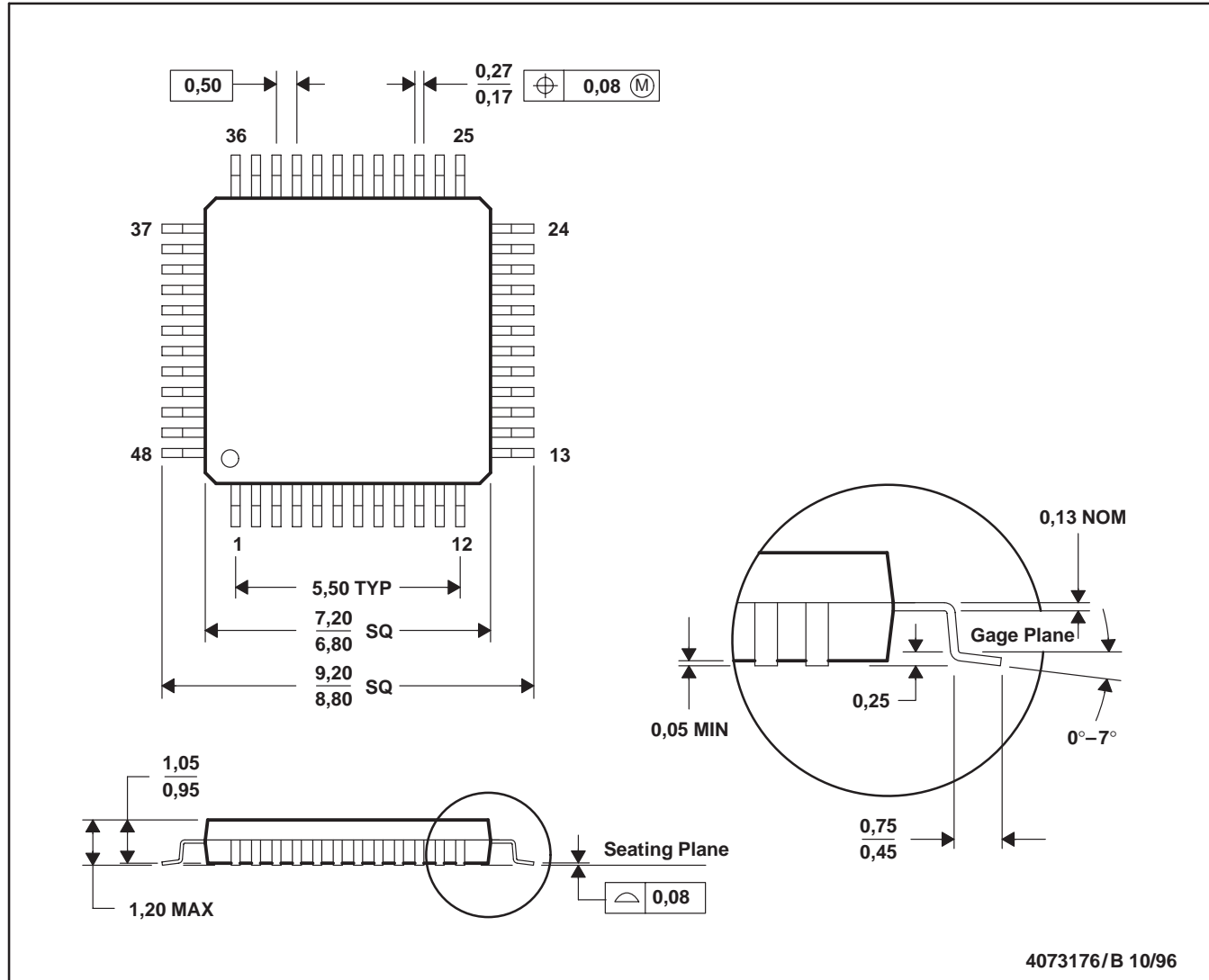
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## MECHANICAL DATA

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



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