

# RF137

## Transceiver For GSM Applications

The RF137 Transceiver is a highly integrated device optimized for use in single-band or multi-band Global System for Mobile Communications (GSM) applications.

In the receive path, the device consists of selectable gain Intermediate Frequency (IF) amplifiers and an image reject downconverter with differential IF outputs.

In the transmit path, the device consists of an In-Phase and Quadrature (I/Q) modulator and a frequency translational loop designed to perform frequency up-conversion with high output spectral purity. This loop has a phase/frequency detector, a charge-pump, a mixer, and buffers for the required isolation between RF output, Local Oscillator (LO), and IF inputs.

In addition, the RF137 features an on-chip, dual-loop UHF/VHF frequency synthesizer circuit. It includes two sets of reference dividers, phase/frequency detectors, charge pumps, prescalers, main dividers, and control circuits.

The device package and pinout of the RF137 are shown in Figure 1. A block diagram is shown in Figure 2.

The signal pin assignments and functional pin descriptions are found in Table 1. The absolute maximum ratings of the device are provided in Table 2, and the operating conditions and electrical specifications are provided in Table 3.

### Features

- Image-reject mixer for downconversion to 2nd IF
- 24 dB selectable attenuation on 1st IF amplifier
- 12 dB selectable attenuation on 2nd IF amplifier
- Integrated transmit path with high phase accuracy
- Reduced filtering requirements for the transmit path
- Wide RF and IF range for multi-band operation
- Integrated, fully programmable dual loop synthesizer
- Integrated local oscillator phase shifters
- On-chip second local oscillator
- Low supply voltage down to 2.7 V
- Separate enable lines for transmit, receive, and synthesizer modes for power management
- 48-pin Thin Quad Flat Pack (TQFP) (7mm x 7mm) package

### Applications

- GSM900/DCS1800/PCS1900 digital cellular telephony

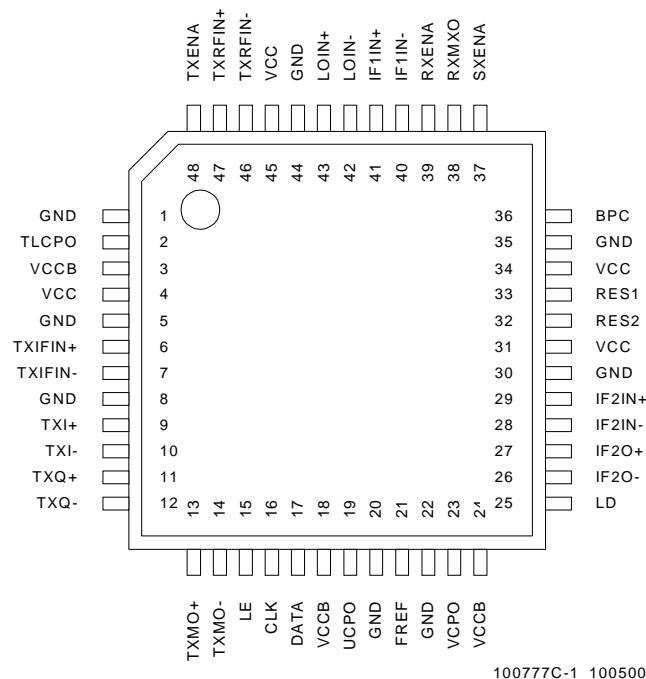


Figure 1. RF137 Pinout – 48-Pin TQFP

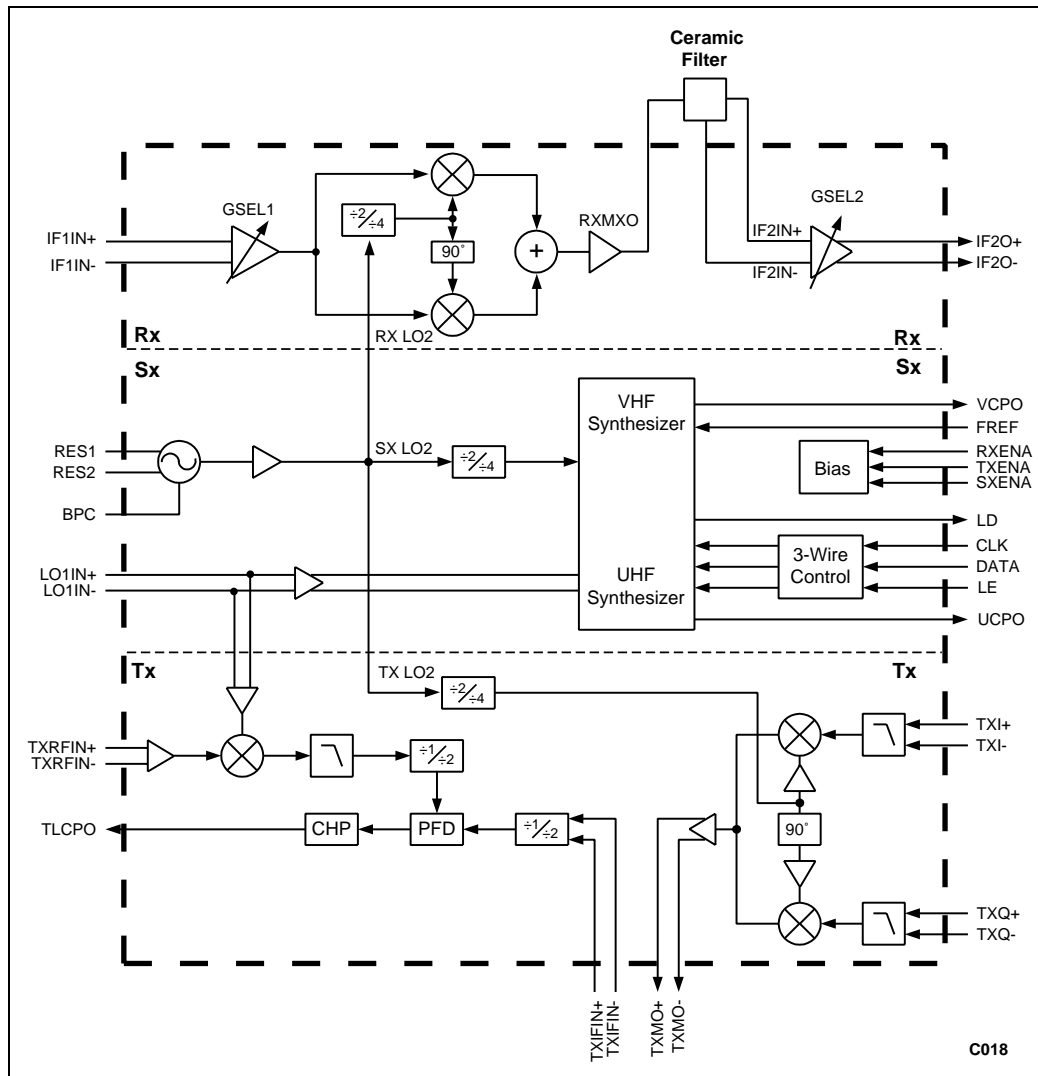


Figure 2. RF137 Block Diagram

## Technical Description

The RF137 Transceiver consists of three main sections:

- Receive (Rx) section
- Transmit (Tx) section
- Synthesizer (Sx) section

The Rx, Tx, and Sx sections can be powered up or down independently by setting RXENA, TXENA, and SXENA high or low.

The signal pin assignments and functional pin descriptions are found in Table 1. Table 2 provides the absolute maximum ratings of the RF137. The general electrical characteristics are provided in Table 3.

**Receive Section.** The receive section consists of the following functional blocks:

- A first IF amplifier (selectable gain step of 24 dB).
- An image reject mixer that downconverts from a first IF to a second IF.
- A buffer amplifier that precedes a second IF ceramic filter.
- A second IF amplifier (selectable gain step of 12 dB) with differential outputs.

The first IF amplifier is a Programmable Gain Amplifier (PGA) with selectable gains of +18 or –6 dB. The amplifier gain is controlled by a three-wire bus. The first IF amplifier is at a high gain state when bit S7 = 1 (Rx Gain Sel1) and CO = 1 or at a low gain state when bit S7 = 0 (Rx Gain Sel1) and CO = 1.

The image reject mixer relaxes the first IF filtering requirements at the image frequency of the second mixer. Image rejection is achieved for a high side/low side injection when bit S9 is set to the appropriate logic level and CO = 1. Table 4 defines the three-wire bus control and output states.

Table 1. RF137 Signal Description

Pin #	Name	Description	Pin #	Name	Description
1	GND	Ground	25	LD	Lock detect output
2	TLCPO	Translational loop charge pump output	26	IF2O–	2nd IF output
3	VCCB	Supply for synthesizers	27	IF2O+	2nd IF output
4	VCC	Supply for transceiver	28	IF2IN–	2nd IF input reference
5	GND	Ground	29	IF2IN+	2nd IF input
6	TXIFIN+	TxIF translation loop input	30	GND	Ground
7	TXIFIN–	TxIF translation loop input	31	VCC	Supply for transceiver
8	GND	Ground	32	RES2	Resonator pin for VHF oscillator
9	TXI+	Tx modulator input	33	RES1	Resonator pin for VHF oscillator
10	TXI–	Tx modulator input	34	VCC	Supply for transceiver
11	TXQ+	Tx modulator input	35	GND	Ground
12	TXQ–	Tx modulator input	36	BPC	Bypass capacitor
13	TXMO+	Positive polarity TX modulator output	37	SXENA	Synthesizer enable
14	TXMO–	Negative polarity TX modulator output	38	RXMXO	Rx mixer output
15	LE	Latch enable input	39	RXENA	Receiver enable
16	CLK	Clock input	40	IF1IN–	1st IF input
17	DATA	Data input	41	IF1IN+	1st IF input
18	VCCB	Supply for synthesizers	42	LOIN–	UHF local oscillator input reference
19	UCPO	UHF loop charge pump output	43	LOIN+	UHF local oscillator input
20	GND	Ground	44	GND	Ground
21	FREF	Reference input	45	VCC	Supply for transceiver
22	GND	Ground	46	TXRFIN–	Transmit input reference
23	VCPO	VHF loop charge pump output	47	TXRFIN+	Transmit input
24	VCCB	Supply for synthesizers	48	TXENA	Transmit enable

Table 2. Absolute Maximum Ratings

Parameter	Minimum	Maximum	Units
Ambient Operating Temperature	–30	+85	°C
Storage Temperature	–40	+125	°C
Power Dissipation		+600	mW
Supply Voltage (Vcc)		+4.0	V
Input Voltage Range	GND	Vcc	V
Supply Voltage (Vccb)		4.0	V

**Table 3. RF137 Electrical Specifications (1 of 4)**  
 (TA = 25 °C, Vcc = 3.0 V, except where specified)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
<b>IF Amplifier/Mixer</b>						
Input impedance	ZIN	differential		1000// 0.5		Ω//pF
Input operating frequency	FN		70		450	MHz
Voltage gain: High gain mode Low gain mode	AV	S7 = 1, CO = 1 S7 = 0, CO = 1	+16.5 -7	+18 -6	+19 -5	dB dB
Gain step variation	dAV				0.5	dB
Single-sideband noise figure	NF	High gain mode		7	8	dB
Input 1 dB compression point High gain mode Low gain mode	P1dB		-35 -9	-32 -7		dBV dBV
Mixer spurious level		Pin = -51 dBV			-50	dBc
Image rejection			35	45		dB
Output impedance	ZOUT			330// 2.2		Ω//pF
Output operating frequency	FOUT			14.6		MHz
<b>2nd IF Amplifier</b>						
Input impedance	ZIN			330// 2.2		Ω//pF
Operating frequency	FIF			14.6		MHz
Voltage gain: High gain mode Low gain mode	AV	S8 = 1, CO = 1 S8 = 0, CO = 1	17 5	18 6	19 7	dB dB
Gain step variation versus frequency	dAV				0.5	dB
Noise figure	NF			7		dB
Input P1dB	P1dB	low gain mode	-25	-22		dBV
Output impedance	ZOUT	differential		1000// 1.2		Ω//pF
<b>Receiver</b>						
Gain temperature coefficient		without ceramic filter		0.03	0.04	dB/°C
Power supply rejection ratio				0.5		dB/V
Input common mode rejection ratio		FIN = 400 MHz		65		dB
<b>I/Q Modulator</b>						
Input impedance	ZIN	differential @ 100 kHz		750// 3.3		kΩ//pF
Input common mode voltage range	VCM		0.85	1.35	VCC- 1.35	V
Input offset voltage	VOS			1	5	mV
Input common mode rejection ratio		FIN = 100 kHz FIN = 1 MHz		75 55		dB
Output operating frequency	FOUT		70		425	MHz
Output impedance	ZOUT	differential @400MHz		600// 3.1		Ω//pF

**Table 3. RF137 Electrical Specifications (2 of 4)**  
 (TA = 25 °C, Vcc = 3.0 V, except where specified)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
<b>I/Q Modulator (continued)</b>						
Differential output voltage			-20	-15		dBV
Output noise power	NO	10 MHz offset		-130	-126	dBc/Hz
LO feedthrough				-43	-40	dBc
Sideband suppression				45		dB
Spurious (Note 1)		@200 kHz offset @300 kHz offset		-60 -60	-40 -45	dBc dBc
<b>Translational Loop</b>						
Transmit frequency (input from VCO)	fTX		800		2000	MHz
LO input frequency	fLO		800		2000	MHz
IF frequency: with divide-by-2 with divide-by-1	fIF	S4 = 1, CO = 1 S4 = 0, CO = 1	70 70		425 300	MHz
Transmit input power	PIN	with external 50Ω termination	-13	-10	-7	dBm
Transmit input impedance	ZIN	differential		300// 0.3		Ω pF
LO input power	PIN	With external 50Ω termination	-13	-10	-7	dBm
LO input impedance	ZIN	differential		300// 0.3		Ω pF
Tx output noise	NO	@ 20 MHz offset (Note 2)		-165	-162	dBc/Hz
Charge pump output current source/sink source/sink high impedance output	IOUT	S10 = 0, CO = 1 S10 = 1, CO = 1		±1.0 ±0.5 0.02		mA mA mA
Tx output spurs (Note 3): 2X spurs 3X spurs 4X spurs 5X spurs				-65 -70 -70 <-70		dBc dBc dBc dBc
Device turn-on and lock time (with respect to enable input)		1 MHz loop bandwidth		30	100	μs
<b>VHF VCO</b>						
Operating frequency (depends on external resonator)	FVCO		300		850	MHz
Tuning voltage range: varactor ground referenced varactor supply referenced			0.5		VCC-0.5	V V
Phase noise (Note 4)		10 MHz offset, FVCO = 800 MHz, resonator Q = 20		-145		dBc/Hz

**Table 3. RF137 Electrical Specifications (3 of 4)**  
 (TA = 25 °C, Vcc = 3.0 V, except where specified)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
<b>Synthesizer</b>						
Input frequency (low freq. mode), VHF PLL	f <sub>INL</sub> (IF)		150		260	MHz
Input frequency (high freq. mode), VHF PLL	f <sub>INH</sub> (IF)		250		450	MHz
Input frequency (low freq. mode), UHF PLL	f <sub>INL</sub> (RF)		500		1200	MHz
Input frequency (high freq. mode), UHF PLL	f <sub>INH</sub> (RF)		500		2000	MHz
Reference frequency	f <sub>REF</sub>		1		40	MHz
Reference input sensitivity	R <sub>IN</sub>		500			mVpp
Phase detector frequency	f <sub>PD</sub>		10		10000	kHz
Phase detector output impedance	Z <sub>O</sub>		10			MΩ
Prescaler input sensitivity	P <sub>IN</sub>		100			mVpp
Prescaler input impedance	Z <sub>IN</sub>	@ 1 GHz		100		Ω
PLL contribution to phase jitter (N=11670)	Φ <sub>NMAIN</sub>	UHF only; F <sub>comparison</sub> = 100 kHz, 10 kHz loop BW; integrated from 200 to 270,000 Hz		1.5		Degrees RMS
Main divider phase jitter	Φ <sub>DIV</sub>				0.5	ps
PLL contribution to phase jitter (N=1680)	Φ <sub>NAUX</sub>	VHF only; F <sub>comparison</sub> = 300 kHz, 10 kHz loop BW; integrated from 200 to 270,000 Hz		0.75		Degrees RMS
UHF charge pump current, step 0	I <sub>DOR,0</sub>	t=25°C	0.6	0.8	1.0	mA
UHF charge pump current, step 1	I <sub>DOR,1</sub>	t=25°C	0.9	1.2	1.5	mA
UHF charge pump current, step 2	I <sub>DOR,2</sub>	t=25°C	1.35	1.8	2.25	mA
UHF charge pump current, step 3	I <sub>DOR,3</sub>	t=25°C	2.02	2.7	3.38	mA
VHF charge pump current, step 0	I <sub>DOI,0</sub>	t=25°C	0.4	0.5	0.67	mA
VHF charge pump current, step 1	I <sub>DOI,1</sub>	t=25°C	0.6	0.8	1.0	mA
VHF charge pump current, step 2	I <sub>DOI,2</sub>	t=25°C	0.9	1.2	1.5	mA
VHF charge pump current, step 3	I <sub>DOI,3</sub>	t=25°C	1.35	1.8	2.25	mA
Charge pump current relative step size (current change from any one step to next step in sequence)	I <sub>DOS</sub>		40	50	60	%
Charge pump leakage current	I <sub>DOO</sub>		-5		5	nA
Charge pump output voltage compliance	V <sub>DO</sub>		0.5		V <sub>cc</sub> -0.5	V
Lock detect time constant	I <sub>LOCK</sub>			500		μs
Lock detect phase error threshold				45		degrees
<b>Three-Wire Control (refer to Figure 4)</b>						
Data to clock setup time	t <sub>CS</sub>		50			ns
Data to clock hold time	t <sub>CH</sub>		10			ns
Clock pulse width high	t <sub>CWH</sub>		50			ns
Clock pulse width low	t <sub>CWL</sub>		50			ns
Clock to load enable setup time	t <sub>ES</sub>		50			ns
Load enable pulse width	t <sub>EW</sub>		50			ns
Load enable transition to clock start time	t <sub>ls</sub>		50			ns

**Table 3. RF137 Electrical Specifications (4 of 4)**  
(TA = 25 °C, Vcc = 3.0 V, except where specified)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
<b>Transceiver</b>						
Enable and control VIH	VIH		Vcc-0.4			V
Enable and control VIL	VIL				0.4	V
Enable and control IIH	IIH			20	60	μA
Enable and control IIL	IIL		-10	-1	0	μA
Total supply current: Rx mode Tx mode Synthesizer mode Sleep mode @Vcc = 3.0V	Icc	RXENA = SXENA = high TXENA = SXENA = high SXENA = high RXENA = SXENA = TXENA = low		48 60 27 0.04	0.2	mA mA mA mA
Power supply range	Vcc (Note 5) VCCB		2.7 2.7	3.75 3.75	3.94 3.94	V V
Operating temperature range	TA		-30	+25	+85	°C
<p><b>Note 1:</b> For 1Vp-p, 100 kHz differential signals across Iin and Qin.</p> <p><b>Note 2:</b> For 1 MHz loop bandwidth and external VCO with phase noise of -165 dBc/Hz @ 20 MHz offset from a carrier frequency of 900 MHz.</p> <p><b>Note 3:</b> "NX spurs" denotes the order of the fLO harmonic that can mix with a harmonic of fIF and result in a product at zero frequency.</p> <p><b>Note 4:</b> Using varactors with similar characteristics as Loral part KV1925.</p> <p><b>Note 5:</b> Vcc must not be less than VCCB - 0.4 V if separate supply voltages are used for Vcc and VCCB.</p>						

The buffer amplifier following the image reject mixer has an output impedance of 330 Ω for direct connection to the external ceramic filter.

The second IF amplifier converts the single-ended output from the ceramic filter to a differential signal which may be input to a bandpass sigma-delta A/D converter. The input impedance of the amplifier is a nominal 330 Ω, which matches the external ceramic filter. The nominal gain of the amplifier is 18 dB, but is reduced to 6 dB when bit S8 = 0 (Rx Gain Sel2) and CO = 1.

**Transmit Section.** The transmit section consists of the following functional blocks:

- A baseband to IF quadrature modulator with an output amplifier.
- A translation loop circuit consisting of a phase and frequency detector, a charge pump, a TxRF input buffer, an LO input buffer, a mixer, and a low pass filter.

The I/Q-to-IF modulator takes in differential I and Q baseband signals. The baseband signals are initially low pass filtered and then input to a pair of double balanced mixers. Pins 13 and 14 (TXMO+ and TXMO-, respectively), the modulator output, and Pins 6 and 7 (TXIF+ and TXIF-, respectively), the IF input, allow for any additional filtering required before the signals enter the translation loop.

The translation loop circuit of the RF137, together with a VCO and an external loop filter, forms a Phase-Locked Loop (PLL). The inherent bandpass filtering that occurs in the PLL eliminates the need for a duplexer or a Surface Acoustic Wave (SAW) filter that is usually required to suppress transmission noise. The overall efficiency is increased as a result of the elimination of high loss, post-PA bandpass filters. This results in increased handset talk time.

The VCO output of the translation loop is at the transmit RF frequency. A portion of the VCO output must be fed back to Pin 47 (TXRFIN+) of the device and mixed with a buffered LO signal to create an IF signal. The IF output from the mixer is input to the phase and frequency detector where the IF output from the mixer is compared with the modulated IF input to the device. When CO = 1, the S6 bit on the three-wire bus allows for a high side/low side injection setting.

**Synthesizer Section (Sx).** The synthesizer section consists of the following functional blocks:

- Frequency synthesizers
- On-chip oscillator with external resonant circuit
- Three-wire bus control circuit

Table 4. RF137 Control Bits and Output States

Block	C0	Bit	Function	Description
LO	1	S1	RX LO $\div 2/\div 4$	Selects the division ratio for RX LO2 (0 = division ratio is 2; 1 = division ratio is 4)
		S2	SX LO2 $\div 2/\div 4$	Selects the division ratio for SX LO2 (0 = division ratio is 2; 1 = division ratio is 4)
		S3	TX LO $\div 2/\div 4$	Selects the division ratio for TX LO2 (0 = division ratio is 2; 1 = division ratio is 4)
TX	1	S4	TX IF $\div 1/\div 2$	Selects the division ratio for TX IF (0 = division ratio is 1; 1 = division ratio is 2)
		S5	TX MIX OUT $\div 1/\div 2$	Selects the division ratio for TX MIX output signal (0 = division ratio is 1; 1 = division ratio is 2)
		S6	TX LO Injection	Selects between high-side and low-side injection of first LO input with respect to transmit RF (0 = low side; 1 = high side)
Receive	1	S7	RX Gain Select 1	Selects RX 1st IF amplifier gain (0 = low gain; 1 = high gain)
		S8	RX Gain Select 2	Selects RX 2nd IF amplifier gain (0 = low gain; 1 = high gain)
		S9	RX LO Injection	Selects LO injection (0 = low side injection; 1 = high side injection)
TRX	1	S10	TX TL CP Current	Charge pump current in translation loop circuit (0 = low current, 1 = high current)
		S11	Reserved	S11 bit may be programmed as "don't care."
		S12	VHF LO BUF	Selects the state of LO buffer. Needs to be "1" for correct operation (0 = LO buffer off; 1 = LO buffer on)
SX	0	S1	IF/RF	Selects one of the synthesizers, either the VHF or UHF (0 = VHF is selected; 1 = UHF is selected)
		S2	R/N	Selects the R count or N count register within the synthesizer. The N count register also controls the phase detector current and inversion (or phase comparison reference signal) (0 = N counter register selected; 1 = R counter register selected)
		S3	S2=0: Prescaler frequency response	Determines the maximum input frequency at which the prescaler will operate. S1=1 (UHF): 0 = 1.2 GHz, 1 = 2.0 GHz; S1=0 (VHF): 0 = 260 MHz, 1 = 450 MHz
			S2=1: Output invert	Controls polarity of charge pump output (0 = normal operation; 1 = inverted)
		S4	S2=0: Synthesizer power down	Powers down the synthesizers. Only the synthesizer indicated by S1 is affected (0 = Normal operation; 1 = Power down)
			S2=1: Lock detect/Test mode select	Used to select the test mode or lock detect output on pin 25 (0 = selects the test mode output, where S8 and S9 select the signal multiplexed to pin 25; 1 = selects the translational loop lock detect signal for output to pin 25).
		S5-S22	S2=0: N counter	This 18-bit value is loaded into the N counter latch. This value sets the cascaded division ratio of the prescaler and N counter (S22=MSB, S5=LSB). For the VHF N divider (16-bit), bits S21 and S22 are "don't care". The least significant bits (S5-S9 for UHF N divider; S5-S7 for VHF N divider) set the prescaler counter.
		S5-S6	S2=1: Output current	These bits set the charge pump output current. S1=1 UHF: 00=0.8, 01=1.2, 10=1.8, 11=2.7 [mA] S1=0 VHF: 00=0.5, 01=0.8, 10=1.2, 11=1.8 [mA]
		S7	S2=1: CP output impedance	The charge pump output is changed to a high impedance output. Only the charge pump output selected by S1 bit is affected (0 = Normal operation; 1 = output impedance)
		S8-S9	S2=1, S4 = 0: Test mode	These bits select which signal is output at pin 25 (LD) when the test mode output is selected (S2 = 1, S4 = 0). 00 = (Lock detect of VHF) AND (lock detect of UHF) 01 = Output of R divider 10 = Output of N divider 11 = Output of lock detect VHF (S1=0) or UHF (S1=1)
		S10-S22	S2=1: R counter	These 13 bits set the reference divider value (S22=MSB, S10=LSB).



There are two frequency synthesizers on the chip, one UHF and one VHF. The UHF synthesizer can provide frequencies from 500 MHz to 2 GHz. It consists of a 32/33 modulus prescaler, a 13-bit R counter, an 18-bit N counter, a phase detector with lock detection, and a charge pump. The VHF synthesizer, with a frequency range from 150 MHz to 450 MHz, consists of an 8/9 modulus prescaler, a 13-bit R counter, a 16-bit N counter, a phase detector with lock detection, and a charge pump. Each synthesizer has four charge pump current settings for optimal performance.

The on-chip oscillator together with a few external components as resonant elements, form a VHF VCO (Figure 3 shows the VCO configuration). The differential VCO output is buffered and then fed to three dividers (Rx, Tx, Sx) with a selectable divide ratio of either 2 or 4. The Rx and Tx dividers are both quadrature dividers, which generates in-phase and quadrature phase LOs.

The on-chip oscillator with the on-chip VHF synthesizer, provides complete VHF frequency synthesis for the Rx VHF LO and Tx VHF LO.

The three-wire bus control allows the RF137 to be optimized for any desired frequency plan. It also programs the two on-chip

frequency synthesizers. To ensure that the data remains latched, one of the signals TXENA, RXENA, or SXENA must stay enabled.

When bit C0 is set to 1, it allows for divider selections in the translation loop, high-side/low-side injection for the image reject mixer and the receive IF amplifiers' gain setting. When bit C0 is set to 0, it programs the UHF/VHF synthesizer, the R/N counter, charge pump polarity, charge pump output current, and prescaler setting.

The three-wire bus timing diagram is provided in Figure 4. Figure 5 illustrates a typical RF137 application circuit. Figure 6 provides the package dimensions for the 48-pin TQFP RF137 transceiver and Figure 7 provides the tape and reel dimensions.

### ESD Sensitivity

Because the RF137 is a static-sensitive electronic device, proper ESD precautions must be taken when using the RF137. Do not operate or store the RF137 near strong electrostatic fields.

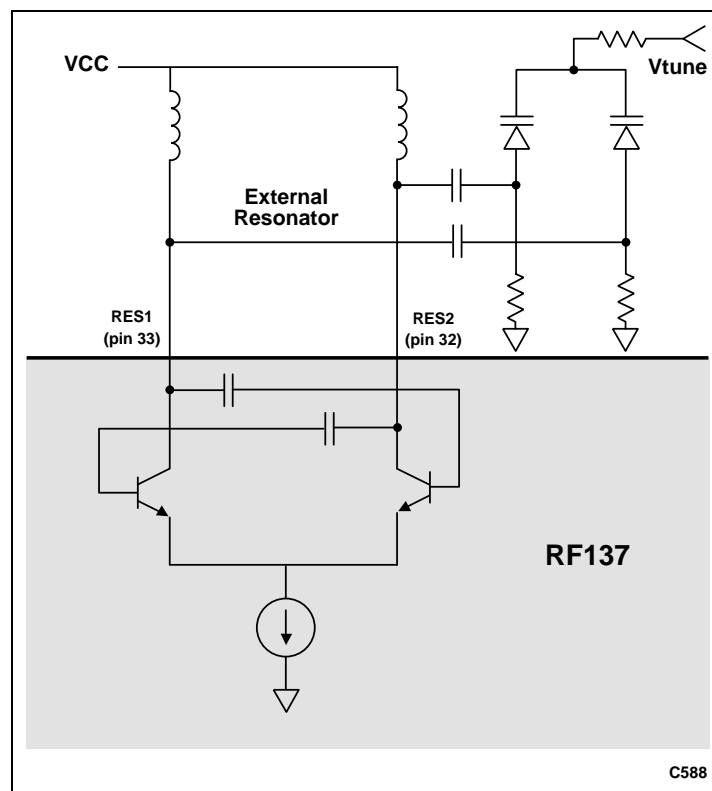


Figure 3. RF137 Internal VCO

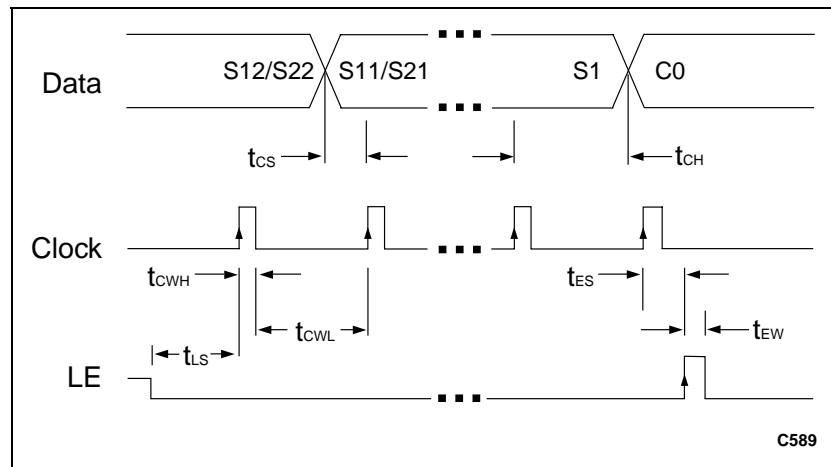
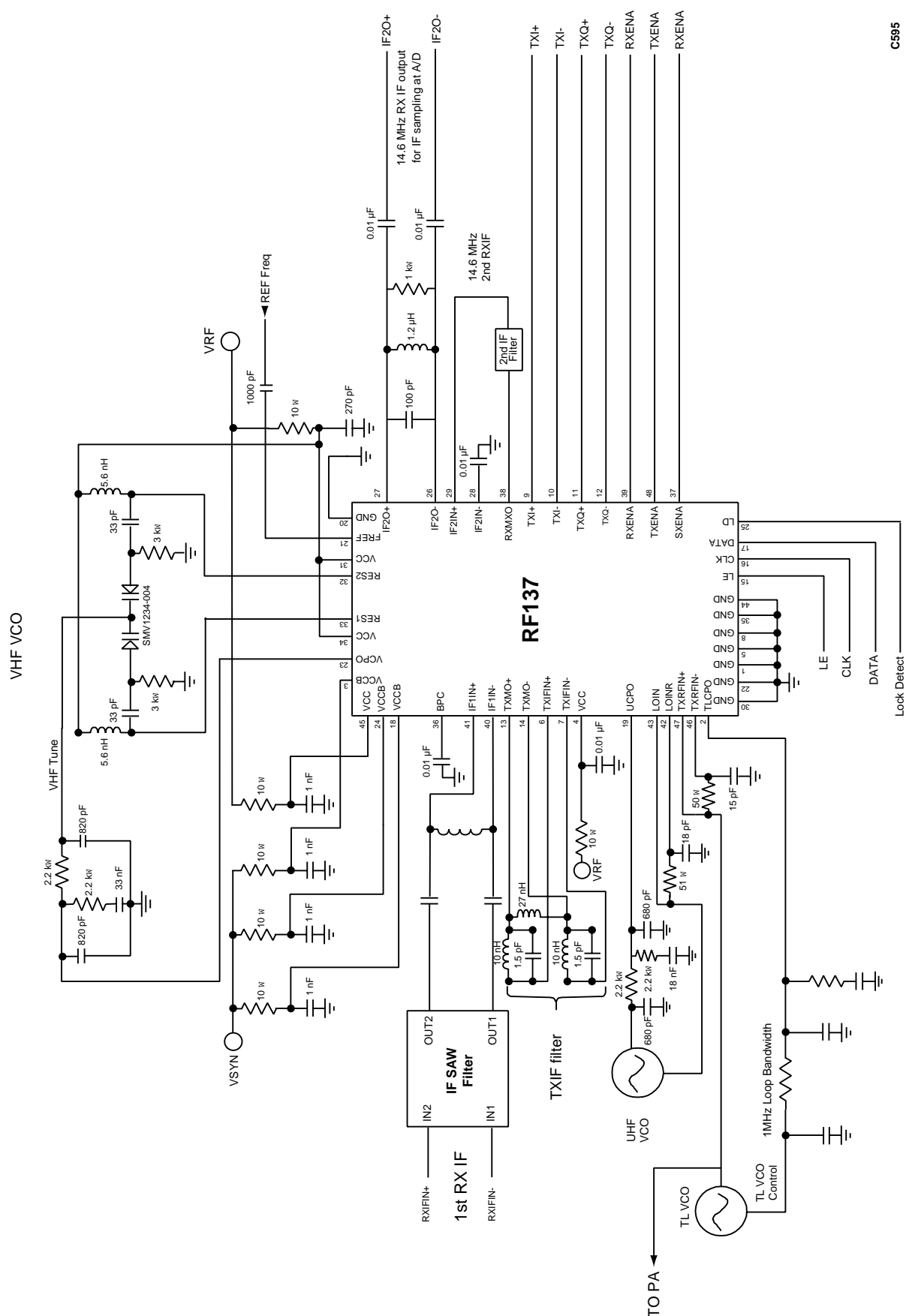


Figure 4. RF137 Wire Bus Timing Diagram



### Figure 5. RF137 Typical Application Schematic

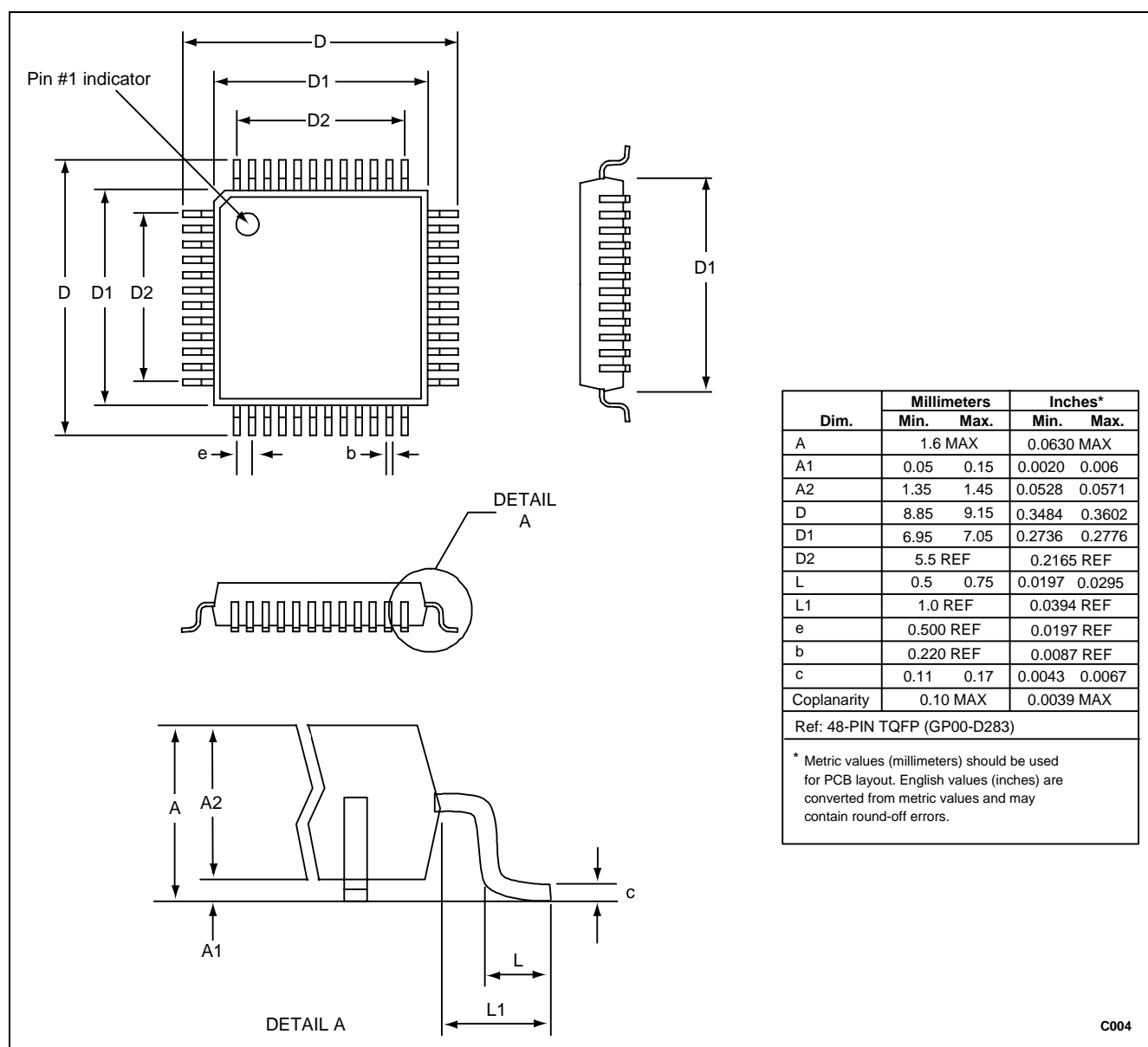


Figure 6. RF137 Package Dimensions – 48-Pin TQFP

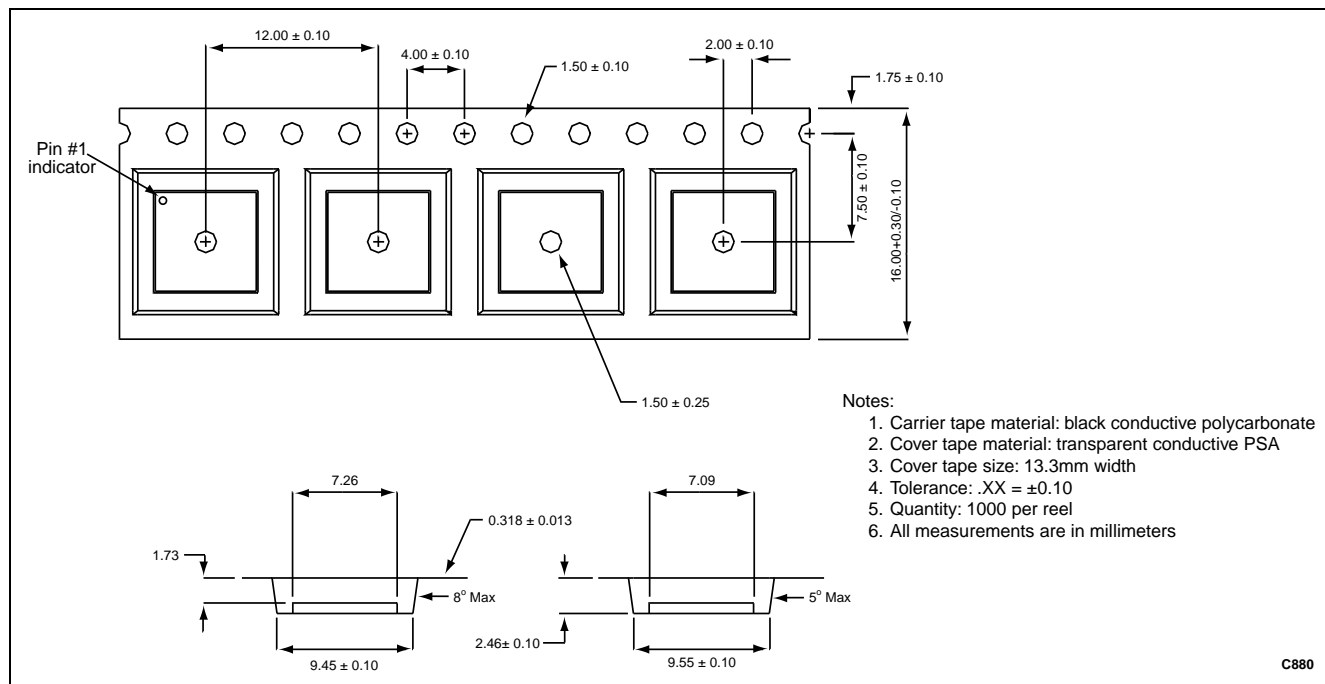


Figure 7. RF137 Tape and Reel Dimensions

## Ordering Information

Model Name	Manufacturing Part Number	Product Revision
GSM Transceiver	RF137	

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Fax 2: (949) 483-4391

**Americas****U.S. Northwest/**

Pacific Northwest – Santa Clara  
Phone: (408) 249-9696  
Fax: (408) 249-7113

**U.S. Southwest – Los Angeles**

Phone: (805) 376-0559  
Fax: (805) 376-8180

**U.S. Southwest – Orange County**

Phone: (949) 483-9119  
Fax: (949) 483-9090

**U.S. Southwest – San Diego**

Phone: (858) 713-3374  
Fax: (858) 713-4001

**U.S. North Central – Illinois**

Phone: (630) 773-3454  
Fax: (630) 773-3907

**U.S. South Central – Texas**

Phone: (972) 733-0723  
Fax: (972) 407-0639

**U.S. Northeast – Massachusetts**

Phone: (978) 367-3200  
Fax: (978) 256-6868

**U.S. Southeast – North Carolina**

Phone: (919) 858-9110  
Fax: (919) 858-8669

**U.S. Southeast – Florida/  
South America**

Phone: (727) 799-8406  
Fax: (727) 799-8306

**U.S. Mid-Atlantic – Pennsylvania**

Phone: (215) 244-6784  
Fax: (215) 244-9292

**Canada – Ontario**

Phone: (613) 271-2358  
Fax: (613) 271-2359

**Europe****Europe Central – Germany**

Phone: +49 89 829-1320  
Fax: +49 89 834-2734

**Europe North – England**

Phone: +44 1344 486444  
Fax: +44 1344 486555

**Europe – Israel/Greece**

Phone: +972 9 9524000  
Fax: +972 9 9573732

**Europe South – France**

Phone: +33 1 41 44 36 51  
Fax: +33 1 41 44 36 90

**Europe Mediterranean – Italy**

Phone: +39 02 93179911  
Fax: +39 02 93179913

**Europe – Sweden**

Phone: +46 (0) 8 5091 4319  
Fax: +46 (0) 8 590 041 10

**Europe – Finland**

Phone: +358 (0) 9 85 666 435  
Fax: +358 (0) 9 85 666 220

**Asia – Pacific****Taiwan**

Phone: (886-2) 2-720-0282  
Fax: (886-2) 2-757-6760

**Australia**

Phone: (61-2) 9869 4088  
Fax: (61-2) 9869 4077

**China – Central**

Phone: 86-21-6361-2515  
Fax: 86-21-6361-2516

**China – South**

Phone: (852) 2 827-0181  
Fax: (852) 2 827-6488

**China – South (Satellite)**

Phone: (86) 755-518-2495

**China – North**

Phone: (86-10) 8529-9777  
Fax: (86-10) 8529-9778

**India**

Phone: (91-11) 692-4789  
Fax: (91-11) 692-4712

**Korea**

Phone: (82-2) 565-2880  
Fax: (82-2) 565-1440

**Korea (Satellite)**

Phone: (82-53) 745-2880  
Fax: (82-53) 745-1440

**Singapore**

Phone: (65) 737 7355  
Fax: (65) 737 9077

**Japan**

Phone: (81-3) 5371 1520  
Fax: (81-3) 5371 1501