RF3404

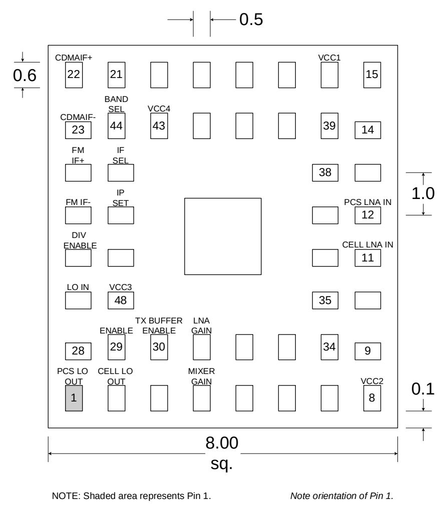
DUAL-BAND/TRI-MODE CDMA
LOW NOISE AMPLIFIER/MIXER MODULE

Typical Applications

- CDMA Cellular/PCS Handsets

Product Description

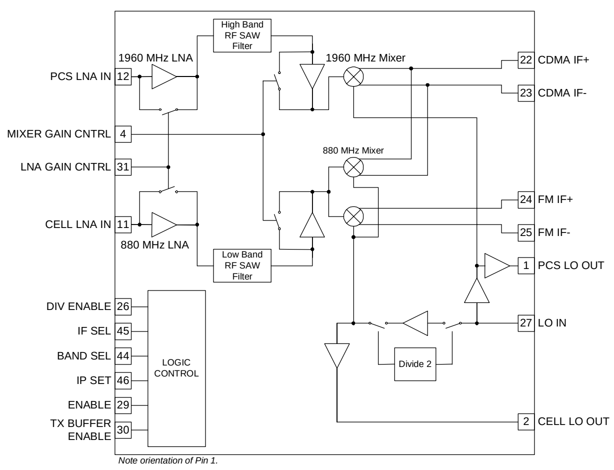
The RF3404 is a fully-functional, integrated dual-band downconverter module for tri-mode CDMA applications. The module, which uses SiGe technology, features two complete RF downconverters with low noise amplifiers, RF SAW filters, TX LO buffers, and RF matching for PCS and cellular band frequencies. Additionally, a divide-by-2 prescaler is integrated to allow the use of a single-band VCO. Multiple gain control options are available to conserve current and meet IS-98B specifications. The mixer design allows for a common IF filter for CDMA cellular and PCS operation, and a second output for the FM output. IF matching is external to the module.



Package Style: 8mmx8mm Module

Optimum Technology Matching® Applied

- ☐ Si BJT
- ☐ GaAs HBT
- ☐ GaAs MESFET
- ☐ Si Bi-CMOS
- ☑ SiGe HBT
- ☐ Si CMOS



Functional Block Diagram

Features

- Complete Dual-Band Receiver Front End
- Integrated RF SAW Filters
- Internal RF Matching and Bias Settings
- Stepped LNA/Mixer Gain Control
- Adjustable LNA Bias Current and IIP3
- Meets IS-98B Specifications

Ordering Information

RF3404	Dual-Band/Tri-Mode CDMA Low Noise Amplifier/ Mixer Module
RF3404 PCBA	Fully Assembled Evaluation Board

RF Micro Devices, Inc.
7628 Thorndike Road
Greensboro, NC 27409, USA
Tel (336) 664 1233
Fax (336) 664 0454
http://www.rfmd.com

Absolute Maximum Ratings

Parameter	Rating	Unit
Supply Voltage	-0.5 to +5.0	V_{DC}
Input LO and RF Levels	+6	dBm
Operating Ambient Temperature	-30 to +85	°C
Storage Temperature	-40 to +150	°C

Caution! ESD sensitive device.

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Overall					T=25°C, V_{CC}=2.75V
RF Frequency Range		869 to 894		MHz	
		1930 to 1990		MHz	
IF Frequency Range		0.1 to 400		MHz	
LO Input Level	-10	-7	0	dBm	
Cellular Band (CDMA)					RF Freq=869MHz to 894MHz LO Freq=1053MHz to 1078MHz
LNA On					
Gain	23.0	25.0		dB	LNA set for max IIP3; Mixer RF amp ON
		24.5		dB	LNA set for Nominal IIP3; Mixer RF amp ON
		16.0		dB	LNA set for max IIP3; Mixer RF amp OFF
		15.0		dB	LNA set for Nominal IIP3; Mixer RF amp OFF
Noise Figure		2.0	2.5	dB	LNA set for max IIP3; Mixer RF amp ON
		2.1		dB	LNA set for Nominal IIP3; Mixer RF amp ON
		4.0		dB	LNA set for max IIP3; Mixer RF amp OFF
		4.5		dB	LNA set for Nominal IIP3; Mixer RF amp OFF
Input IP3		-9.0		dBm	LNA set for max IIP3; Mixer RF amp ON
		-8.0		dBm	LNA set for Nominal IIP3; Mixer RF amp ON
		1.5		dBm	LNA set for max IIP3; Mixer RF amp OFF
		2.0		dBm	LNA set for Nominal IIP3; Mixer RF amp OFF
		+10.0		dBm	LNA only, set for max IIP3
LNA Off					
Gain		5		dB	Mixer RF amp ON
		-3		dB	Mixer RF amp OFF
Noise Figure		15		dB	Mixer RF amp ON
		22		dB	Mixer RF amp OFF
Input IP3		+10.0		dBm	Mixer RF amp ON
		+20.0		dBm	Mixer RF amp OFF

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Cellular Band (FM)					RF Freq=869MHz to 894MHz LO Freq=1053MHz to 1078MHz
LNA On					
Gain		23.0		dB	LNA set for max IIP3; Mixer RF amp ON
		23.0		dB	LNA set for Nominal IIP3; Mixer RF amp ON
		13.0		dB	LNA set for max IIP3; Mixer RF amp OFF
		13.0		dB	LNA set for Nominal IIP3; Mixer RF amp OFF
Noise Figure		2.1	2.6	dB	LNA set for max IIP3; Mixer RF amp ON
		2.2		dB	LNA set for Nominal IIP3; Mixer RF amp ON
		5.0		dB	LNA set for max IIP3; Mixer RF amp OFF
		5.0		dB	LNA set for Nominal IIP3; Mixer RF amp OFF
Input IP3		-8.0		dBm	LNA set for max IIP3; Mixer RF amp ON
		-8.0		dBm	LNA set for Nominal IIP3; Mixer RF amp ON
		3.5		dBm	LNA set for max IIP3; Mixer RF amp OFF
		4.0		dBm	LNA set for Nominal IIP3; Mixer RF amp OFF
PCS Band					RF Freq=1930MHz to 1990MHz LO Freq=2114MHz to 2174MHz
LNA On					
Gain	23.0	25.0		dB	LNA set for max IIP3; Mixer RF amplifier ON
		24.0		dB	LNA set for Nominal IIP3; Mixer RF amplifier ON
		16		dB	LNA set for max IIP3; Mixer RF amp OFF
		15		dB	LNA set for Nominal IIP3; Mixer RF amplifier OFF
Noise Figure		2.2	2.7	dB	LNA set for max IIP3; Mixer RF amplifier ON
		2.3		dB	LNA set for Nominal IIP3; Mixer RF amplifier ON
		5.0		dB	LNA set for max IIP3; Mixer RF amp OFF
		6.0		dB	LNA set for Nominal IIP3; Mixer RF amplifier OFF
Input IP3	-12.0	-8.5		dBm	LNA set for max IIP3; Mixer RF amplifier ON
		-7.5		dBm	LNA set for Nominal IIP3; Mixer RF amplifier ON
		2		dBm	LNA set for max IIP3; Mixer RF amp OFF
		1		dBm	LNA set for Nominal IIP3; Mixer RF amplifier OFF
		+10.0		dBm	LNA only, set for max IIP3
LNA Off					
Gain		5		dB	Mixer RF amplifier ON
		-4		dB	Mixer RF amplifier OFF
Noise Figure		15		dB	Mixer RF amplifier ON
		22		dB	Mixer RF amplifier OFF
Input IP3		+10.0		dBm	Mixer RF amplifier ON
		+20.0		dBm	Mixer RF amplifier OFF

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Isolation (PCS, Cellular CDMA, Cellular FM)					
LO to IF Isolation	15			dB	
LO to RF Isolation	35			dB	
LO Output to LO Input Isolation	30			dB	
RF to LO Input Isolation	20			dB	
RF to LO Output Isolation	30			dB	
IF to RF Isolation		40		dB	
Transmit Band Rejection		20		dB	
Power Supply					
Supply Voltage	2.7	2.75	3.0	V	Specifications
Logic High	1.8				
Logic Low			0.4		
Cellular					
LNA Current		7		mA	Cellular; LNA On, Max IIP3
		5		mA	Cellular; LNA On, Nominal IIP3
		0		mA	Cellular; LNA Off
Mixer Current		16		mA	Cellular; Mixer RF Amplifier ON
		10		mA	Cellular; Mixer RF Amplifier OFF
PCS					
LNA Current		7		mA	PCS; LNA On, Max IIP3
		5		mA	PCS; LNA On, Nominal IIP3
		0		mA	PCS; LNA Off
Mixer Current		16		mA	PCS; Mixer RF Amplifier ON
		10		mA	PCS; Mixer RF Amplifier OFF
Power Down			1	μA	Enable=0
Local Oscillator Input					
Cellular - CDMA/FM					
Input Power	-10	-7	0	dBm	
Input Frequency		685-710		MHz	IF=184MHz
		1053-1078		MHz	IF=184MHz
		1370-1420		MHz	IF=184MHz with divider enabled.
		2106-2156		MHz	IF=184MHz with divider enabled.
PCS					
Input Power	-10	-7	0	dBm	
Input Frequency		1746-1806		MHz	IF=184MHz
		2114-2174		MHz	IF=184MHz
Local Oscillator Output TX Buffer					
Cellular - CDMA/FM					
Output Power	-12			dBm	Single-ended 50Ω load
Output Frequency		685-710		MHz	IF=184MHz
		1053-1078		MHz	IF=184MHz
		685-710		MHz	IF=184MHz with divider enabled.
		1053-1078		MHz	IF=184MHz with divider enabled.
Current Consumption			2	mA	
PCS					
Output Power	-12			dBm	Single-ended 50Ω load
Output Frequency		1746-1806		MHz	IF=184MHz
		2114-2174		MHz	IF=184MHz
Current Consumption			2	mA	

State Table (Typical Values for V_{CC}=2.75V)

Parameter	Cellular						PCS					
	LNA On				LNA Off		LNA On				LNA Off	
	LNA at Max IIP3		LNA at Nom IIP3				LNA at Max IIP3		LNA at Nom IIP3			
	Mixer Amp On	Mixer Amp Off	Mixer Amp On	Mixer Amp Off	Mixer Amp On	Mixer Amp Off	Mixer Amp On	Mixer Amp Off	Mixer Amp On	Mixer Amp Off	Mixer Amp On	Mixer Amp Off
Gain (dB)	25	16	24.5	15	4	-3	25	15	24	15.5	5	-4
Noise Figure (dB)	2.0	4	2.1	4.5	15	22	2.2	5.0	2.3	6	15	22
Input IP3 (dBm)	-9	1.5	-8	2	+10	+20	-8.5	2	-7.5	1	+10	+20
Total Current	29.5	23.5	28	22	24	18	29.5	23.5	28	22	24	18

RF3404 Control States

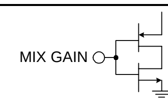
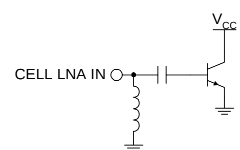
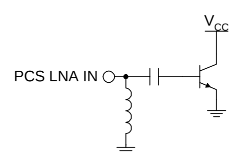
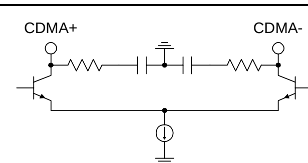
	BAND SEL	IF SEL	LNA GAIN	MIX GAIN	ENABLE
PCS CDMA High Gain	1	0	1	1	1
PCS CDMA Mid1 Gain	1	0	1	0	1
PCS CDMA Mid2 Gain	1	0	0	1	1
PCS CDMA Low Gain	1	0	0	0	1
Cell CDMA High Gain	0	0	1	1	1
Cell CDMA Mid1 Gain	0	0	1	0	1
Cell CDMA Mid2 Gain	0	0	0	1	1
Cell CDMA Low Gain	0	0	0	0	1
Cell FM High Gain	0	1	1	1	1
Cell FM Mid1 Gain	0	1	1	0	1
Cell FM Mid2 Gain	0	1	0	1	1
Cell FM Low Gain	0	1	0	0	1
Shutdown	X	X	X	X	0
Not Defined	1	1	X	X	1

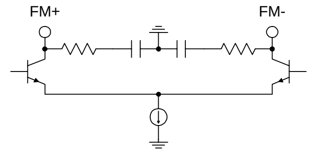
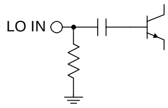
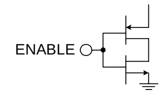
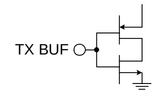
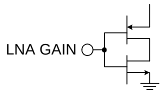
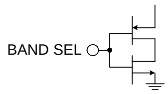
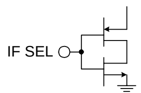
Control Logic

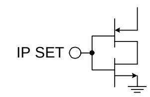
Mode	BAND_SEL	IF_SEL	ENABLE	TX BUF	DIVIDER ENABLE
Cellular FM	0	1	1	X	X
Cellular CDMA	0	0	1	X	X
PCS CDMA	1	0	1	X	X
Power Down	1	1	1	X	X
Power Down 2	X	X	0	X	X
TX Buffer Enabled	X	X	1	1	X
Divider Enabled	X	X	1	X	1

Gain Control Logic

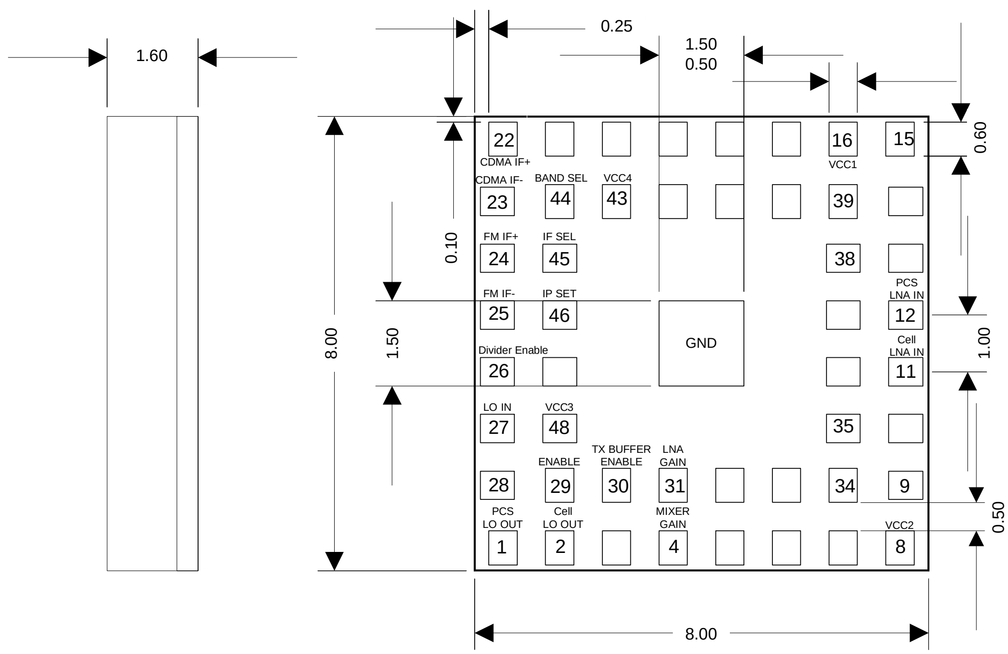
LNA Mode	Mixer Mode	LNA GAIN	MIX GAIN	IP SET
High Gain High Linearity (off-chip)	High Gain	1	1	1
High Gain High Linearity (off-chip)	Low Gain	1	0	1
High Gain Low Linearity (on-chip)	High Gain	1	1	0
High Gain Low Linearity (on-chip)	Low Gain	1	0	0
Low Gain	High Gain	0	1	X
Low Gain	Low Gain	0	0	X

Pin	Function	Description	Interface Schematic
1	**PCS LO OUT**	PCS LO output. Internal DC block.	
2	**CELL LO OUT**	Cellular LO output. Internal DC block.	
3	**GND**	Low-inductance ground required.	
4	**MIXER GAIN**	Logic input. Controls switch around mixer preamp. High selects maximum mixer gain.	
5	**GND**	Low-inductance ground required.	
6	**GND**	Low-inductance ground required.	
7	**GND**	Low-inductance ground required.	
8	**VCC2**	PCS LNA VCC. External bypass capacitor between 10pF and 47nF required.	
9	**GND**	Low-inductance ground required.	
10	**GND**	Low-inductance ground required.	
11	**CELL LNA IN**	Cellular LNA input. Internally matched to 50Ω. DC-blocking internal to module.	
12	**PCS LNA IN**	PCS LNA input. Internally matched to 50Ω. DC-blocking internal to module.	
13	**GND**	Low-inductance ground required.	
14	**GND**	Low-inductance ground required.	
15	**GND**	Low-inductance ground required.	
16	**VCC1**	Cellular LNA VCC. External bypass may be required.	
17	**GND**	Low-inductance ground required.	
18	**GND**	Low-inductance ground required.	
19	**GND**	Low-inductance ground required.	
20	**GND**	Low-inductance ground required.	
21	**GND**	Low-inductance ground required.	
22	**CDMA IF+**	CDMA IF output. Open collector. “Current combiner” IF interface to SAW filter recommended.	
23	**CDMA IF-**	CDMA IF output. Open collector. “Current combiner” IF interface to SAW filter recommended.	See pin 22.

Pin	Function	Description	Interface Schematic
24	FM IF+	FM IF output. Open collector. “Current combiner” IF interface to SAW filter recommended.	
25	FM IF-	FM IF output. Open collector. “Current combiner” IF interface to SAW filter recommended.	See pin 24.
26	DIVIDER ENABLE	Logic input. High enable frequency divide by 2 circuitry in cellular mode.	
27	LO IN	LO single-end input. Internal DC block.	
28	GND	Low-inductance ground required.	
29	ENABLE	Logic input. Low level shuts down IC. IC can be shut down by setting pins 44 and 45 high and TX Buffer Enable low as well.	
30	TX BUFFER ENABLE	Logic input. High enables TX LO buffer amplifiers.	
31	LNA GAIN	Logic input. Controls LNA bypass switch. High selects maximum LNA gain.	
32	GND	Low-inductance ground required.	
33	GND	Low-inductance ground required.	
34	GND	Low-inductance ground required.	
35	GND	Low-inductance ground required.	
36	GND	Low-inductance ground required.	
37	GND	Low-inductance ground required.	
38	GND	Low-inductance ground required.	
39	GND	Low-inductance ground required.	
40	GND	Low-inductance ground required.	
41	GND	Low-inductance ground required.	
42	GND	Low-inductance ground required.	
43	VCC4	V_{CC} connection for internal references, logic, and mix preamps. Internal RF bypass capacitor. External bypass capacitor between 1nF and 47nF may be required.	
44	BAND SEL	Logic input. High level selects PCS band; lower level selects cellular band.	
45	IF SEL	Logic input. High selects FM IF outputs in cellular mode; low selects CDMA IF outputs.	

Pin	Function	Description	Interface Schematic
46	**IP SET**	Logic input. High selects maximum IIP3 mode.	
47	**GND**	Low-inductance ground required.	
48	**VCC3**	VCC connection for internal LO amplifiers. Internal RF bypass capacitor. External bypass between 1nF and 47nF may be required.	

Outline Drawing



Overview

Why Design with Receive Modules?

The RF3404 is a fully integrated dual-band, tri-mode module contains an LNA, RF image-rejection SAW filter, mixer, mixer preamplifier, and local oscillator (LO) buffer amplifiers as shown in the block diagram. The module also contains all of the RF matching components, bias-setting components, and decoupling components required. The differential IF output matching is external to the module in part due to the varying range of IFs used by customers and the physical size of IF SAW filters. The module, which measures only 8.0mmx8.0mm and takes up only $64mm^2$ of PCB area, is less than half the size of available alternative solutions, which typically occupy over $200mm^2$ of board area. The RF3404 is control-compatible with existing IF-to-baseband solutions.

Electrical Design Overview

The heart of the module is the RF2489 SiGe monolithic microwave integrated circuit (MMIC) based on a high-performance silicon germanium (SiGe) process. The SiGe process is capable of fabricating transistors with an Ft of 47GHz. The module achieves 30dB of gain control in the 880MHz band. The gain-control range is obtained with switches around the LNA and mixer preamplifier. By itself, the cellular LNA features 15dB small-signal gain and a typical noise figure of 1.1dB when drawing 6mA current from a +2.75V_{DC} supply.

A CMOS-enabled control line makes it possible to select an increased LNA input third-order intercept point of +10dBm to meet the cross modulation requirements of the IS-95B CDMA specification. The RF3404's LNA is followed by a miniature RF SAW filter. It provides RF image rejection as well as transmit-band rejection. All impedance matching to the RF SAW filter is contained within the module. The module's RF2489 SiGe MMIC contains two high-frequency mixers that handle downconversion of the CDMA and AMPS signals at 880MHz. The module provides a common IF port for the CDMA cellular and PCS band output signal and a separate IF output port for the AMPS-band IF signal. The mixers and their integrated preamplifiers achieve a noise figure of 7dB, gain of 14dB, and input third-order intercept point of +3dBm. A bypass switch around the mixer preamplifier is integrated to support those systems using a two-step gain approach for meeting the three test conditions of IS-95B intermodulation performance

The 1960MHz PCS CDMA signal path is similar to the cellular path in many ways. The PCS LNA has a typical gain of 16dB with a noise figure of 1.3dB. The LNA can also be bypassed and also has a setting for high input third-order intercept point of +8dBm. The PCS mixer features 13dB gain, 7dB noise figure, and input third-order intercept point of +3dBm. Again, all of the RF impedance matching to the LNA and SAW filters is included in the module.

The RF3404 module is flexible enough to accommodate either single or dual voltage-controlled-oscillator (VCO) architectures. The cellular band has the selectable option of running the LO directly to the cellular mixers or routed through a divide-by-2 frequency prescaler for systems that have migrated to a single VCO architecture. A buffered transmit LO output with -12dBm output power is also supplied for both the PCS and cellular bands. The RF3404 requires an input LO power range of -10dBm to -4dBm. The LO input port is matched to 50Ω. The LO outputs can be tied together externally to support single transmit LO applications and each is matched to 50Ω.

Mechanical Layout Overview

The RF3404 is built around a laminate module technology geared to high-volume manufacturing and the low cost structure mandated by the wireless industry. RF Micro Devices has already built millions of power amplifier (PA) modules using the same materials sets, supply chain, and manufacturing rules used for the RF3404.

The module is overmolded with a compound that has a finished overall thickness of 1.6mm. The backside pattern of the 8.0mmx8.0mm module is a 48-pin land grid array (LGA) with a double row of input/output (I/O) connections to ease trace routing as shown in the interface outline drawing. A total of 21 of these I/O pads are actual signal interconnections, with the remainder being ground connections.

The I/O pads are a generous 0.5mmx0.6mm in size on a 1.0mm pitch. The outer ring of I/O pads contains all of the RF connections along with the voltage supply and some control lines. The inner ring of I/Os contains only DC control signal lines and V_{CC} connections. A 1.5mm square ground pad in the center of the module backplane supplies additional RF grounding and also assures a very robust mechanical attachment to the cellular/PCS telephone PCB. The dual row I/Os aid in the telephone PCB layout by reducing the number of traces required to converge on the perimeter of the module. Routing is eased by viaholes that can be placed between the inner row of connections and the center ground pad in the cellular/PCS telephone PCB.

Why Use Integrated Modules?

Decreased Board Area

Table A shows a comparison between the leading four design approaches for dual-band/tri-mode CDMA front ends:

1. discrete LNAs and discrete mixers with off-chip matching for each component,
2. single band cellular and PCS LNA/Mixer MMICs with off-chip matching,
3. single MMIC dual band chips with off-chip matching and finally
4. fully integrated modules like the RF3404.

Table A summarizes the number of SMD components for each approach as well as the typical amount of phone board space required for a complete layout.The RF3404 represents a 50 percent to 70 percent reduction in the amount of board space required when compared with the most highly integrated chip solutions on the market today. Furthermore, it represents the largest percentage improvement in board space savings for any of the other increased integration gains in recent years.

Reduced BOM Counts

Another area where one can see marked improvement is in BOM reduction. The RF3404 reduces the BOM from the most highly integrated alternatives available today that contain approximately 25 components to only three. The three are VCC-bypassing capacitors that depend on the frequency response of the phone board power supply and a resistor.

Simplify the Supply Chain

The supply chain can be significantly simplified with the elimination of two dozen components that would not need to be source selected, qualified, purchased, received, stored, coordinated or delivered to the factory floor.

Decreased Engineering and Product Cycle Time

With a single module solution the RF engineering required to design the front end is significantly reduced. The RF3404 module allows for a design-in solution meeting all of the IS95B requirements, which requires significantly less engineering.

Decreased Assembly Costs

Accordingly, assembly costs are also reduced. With SMD placement costs running in the range of 1.0cents to 1.3cents per placement and with the placement of die packages, SAWs, and modules costing even more per placement, one can eliminate somewhere around 35cents from the cost of assembly with modules and improve factory throughput.

Improve Phone Level Yield

Known good RF performance at the module level is available with integrated modules that have been RF tested. Phone level yield can be improved, in addition to the improvement in yield from placing two dozen fewer components.

Improved Reliability

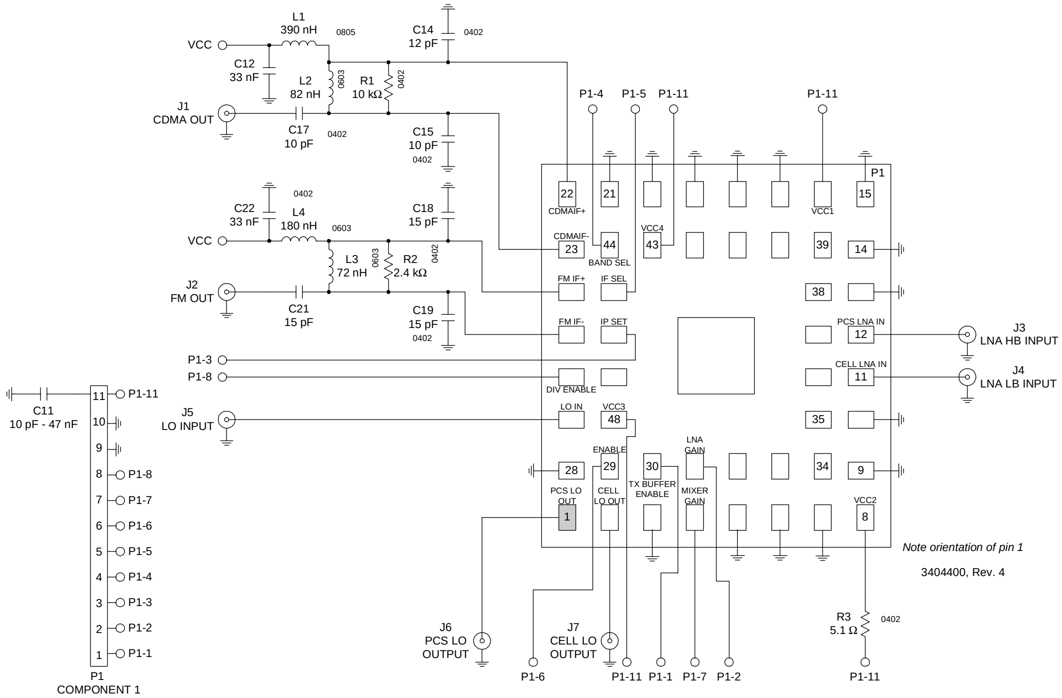
Mechanical attachment and reliability is improved with this module technology due to a variety of factors. The first is the elimination of numerous components and thus solder joints, which directly aids overall phone reliability. Another important factor is the matched coefficient of thermal expansion (CTE) between the laminate module and the cellular/PCS telephone PCB that eliminates much of the solder stress potential found in low-temperature-cofired-ceramic (LTCC) or chip-scale modules and should provide the most robust solution for the stringent mechanical shock and drop tests that mobile telephone hardware must survive.

Table A. Comparison of Alternate CDMA Front-End Solution Approaches

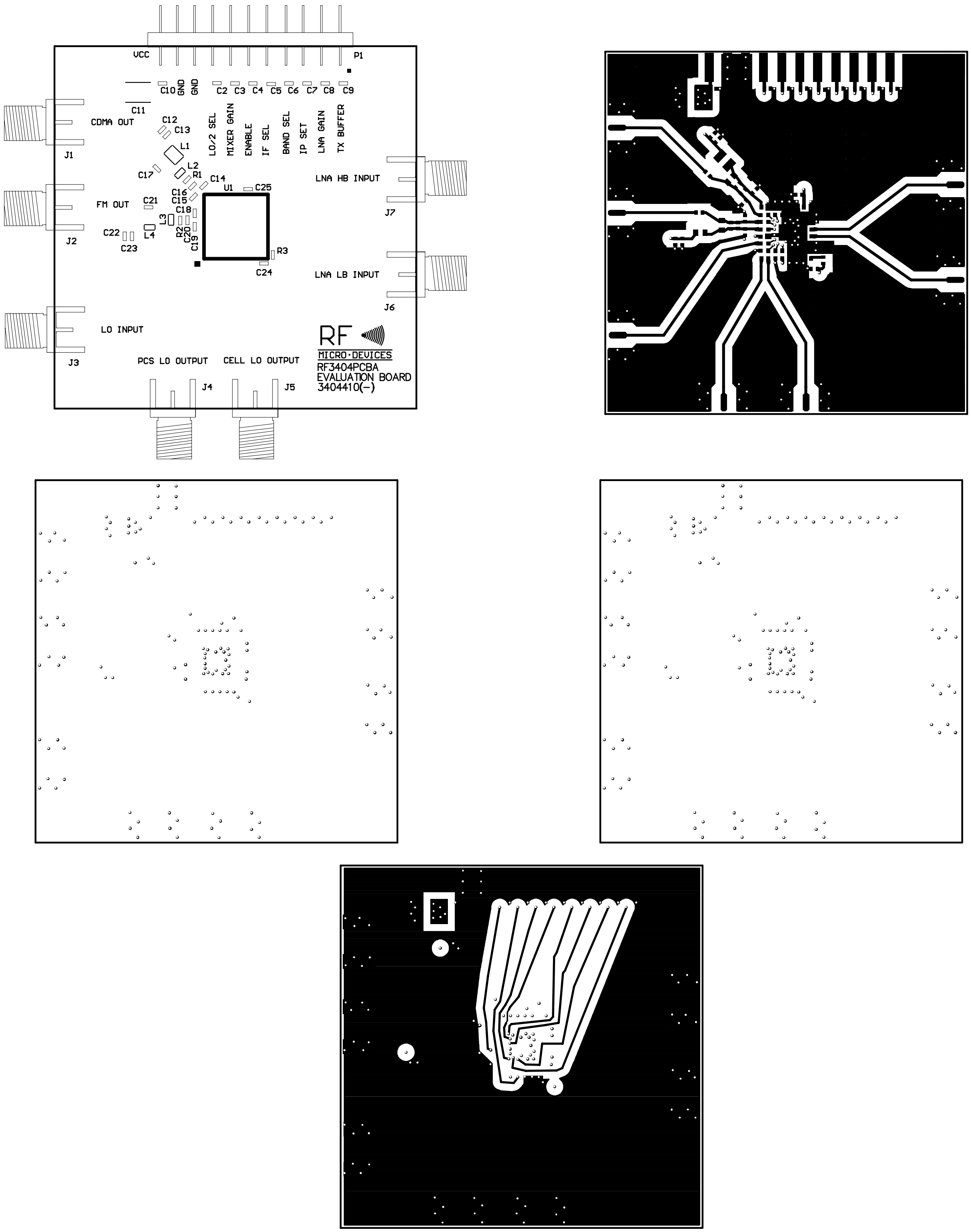
	Number of Components*					
Level of Integration	**Caps**	**Resistors**	**Inductors**	**Saws**	**Total Components**	**Board Area (sq. mm)**
RF3404 Module	2	1	0	0	3	67
Dual Band Integrated MMIC	11	4	7	2	24	~200
Single Band Integrated MMIC	19	8	6	2	35	~280
LNA/Mixer Discrete Solution	24	8	6	2	40	~350

**Does not include IF matching components to IF SAW filters.*

Evaluation Board Schematic



Evaluation Board Layout
Board Size 2.0” x 2.0”
Board Thickness 0.030”, Board Material FR-4, Multi



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FRONT-ENDS