TriQuint SEMICONDUCTOR

WIRELESS COMMUNICATIONS DIVISION

TQ9203
DATA SHEET

Low-Current Cellular Band Downconverter IC

Features

- *+5-V single supply*
- *Internal buffer amplifier on mixer LO port*
- *On-chip matching to 50**W***
- *Two selectable RF inputs*
- *Low-cost SO-14 plastic package*
- *21dB system gain*
- *-10dBm typical input intercept point*
- *2.5dB typ. system noise figure*
- *10.5mA typ. operating current*

Product Description

The TQ9203 RFIC Downconverter is a multifunction RF front end designed for the high dynamic range cellular communications standards. The design of the TQ9203 provides a 2.5dB system noise figure for excellent sensitivity, and a good signal range with –10dBm input IP3. Its low current consumption, single +5V operation and small, plastic surface-mount package are ideally suited for cost-competitive, space-limited and portable applications. In addition, two selectable RF inputs simplify implementation of "antenna diversity" in applications such as CDPD. The TQ9203 is specified over a RF frequency range of 800 to 1000MHz, and therefore may be used for any of the cellular and cordless telephony standards.

Electrical Specifications[1]

Parameter	Min	Typ	Max	Units
Frequency	800		1000	MHz
Gain		21.0		dB
Noise Figure		2.5		dB
Input 3rd Order Intercept		-10.0		dBm
DC supply Current		10.5		mA

Note   1. *Test Conditions: Vdd=5V, Ta=25C, filter IL=3.0dB, RF=881MHz, LO=966MHz, IF=85MHz, LO input=-6dBm*

2. *Specified with external noise-matching circuit elements, with image-stripping BPF IL=3dB*

3. *Frequency separation of the two signals is 500KHz; BPF IL=3dB*

Applications

- *Cellular Communications*
- *Spread-Spectrum Receivers*
- *Cordless Phones*

Parameter	Conditions	Min.	Typ/Nom	Max.	Units
RF Frequency	Tuned external match	800		1000	MHz
LO Frequency	Tuned external match	700		1300	MHz
IF Frequency	Tuned external match	30		300	MHz
LO input level			-6		dBm
Supply voltage		4.5	5.0	5.5	V
Gain (LNA IN1)	LO=-6dBm, RF=-35dBm	18.0	21.0		dB
Gain (LNA IN0)	LO=-6dBm, RF=-35dBm		21.0		dB
Noise Figure	LNA IN0 Pin; SSB		2.8		dB
	LNA IN1 Pin; SSB		2.5	3.0	dB
Input 3rd Order Intercept	Frequency Sep. = 500KHz		-10.0		dBm
Return Loss	Mixer RF input		10		dB
	Mixer LO input		10		dB
	LNA OUT Return Loss		20		dB
Supply Current			10.5	12	mA

Note   1. Test Conditions:, Vdd=5.0V, Ta=25C, filter IL=3.0dB, RF=881MHz, LO=966MHz, IF=85MHz, LO input=-6dBm: unless otherwise specified.
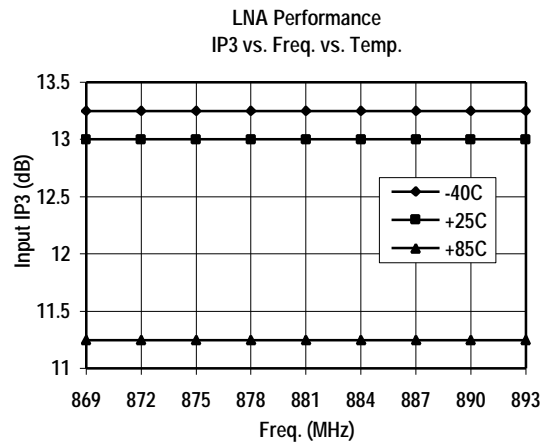
2. Conversion gain, noise figure, and IP3 assume an image stripping band-pass filter between the LNA section and the Mixer section with a 3dB insertion loss.

Electrical Characteristics-LNA section only

Parameter	Conditions	Min.	Typ/Nom	Max.	Units
Gain	RF=-40dBm		18.0		dB
Noise Figure	LNA0 Active		2.1		dB
	LNA1 Active		1.8		dB
Input 3rd Order Intercept	Separation: 500KHz		+13.0		dBm
Output Gain Compression			1.5		dBm
Off Isolation, LNA In1/Out	Select=0V, LNAo On		-7		dB
Off Isolation, LNA In0/Out	Select=5C, LNA1 On		-5		dB
Reverse Isolation			38.0		dB
Supply Voltage		4.5	5.0	5.5	V
Supply Current	Mixer Off[2] Powered down		8.8		mA

Note   1. Test Conditions:, Vdd=5.0V, Ta=25C, RF=881MHz.

2. Vdd pin supplies connect to both the LNA and the LO buffer amps. Mixer cannot operate without Vdd connection. Mixer Vdd through the IF pin connects only to the mixer FET.

TriQuint
SEMICONDUCTOR

Electrical Characteristics- Mixer section only

Parameter	Conditions	Min.	Typ/Nom	Max.	Units
Conversion Gain			0		dB
Noise Figure			12.0		dB
Output 3rd Order Intercept			10.0		dBm
Mixer RF Return Loss			15.0		dB
Mixer LO Return Loss			10.0		dB
LO Input Power			-6.0		dBm
LO to IF Isolation			40.0		dB
LO to RF Isolation			5.0		dB
RF to IF Isolation			40.0		dB
Supply Current			4.0		mA

Note 1: Test Conditions:, Vdd=5.0V, Ta=25C, filter IL=3.0dB, RF=881MHz, LO=996MHz, IF=85MHz, LO input=-6dBm: unless otherwise specified.
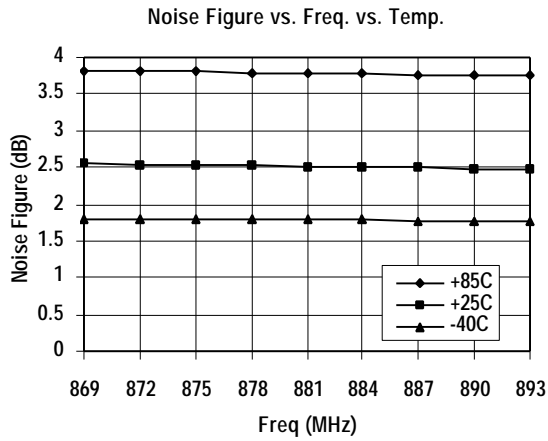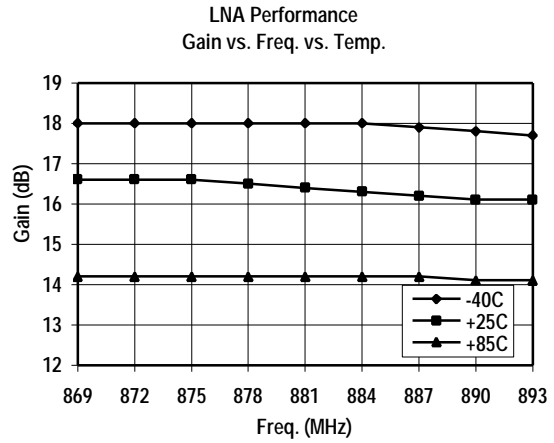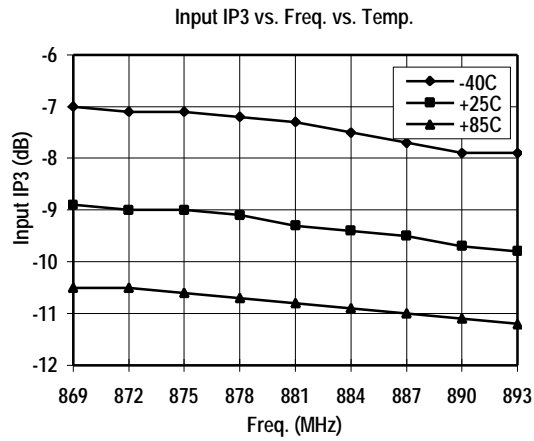
Absolute Maximum Ratings

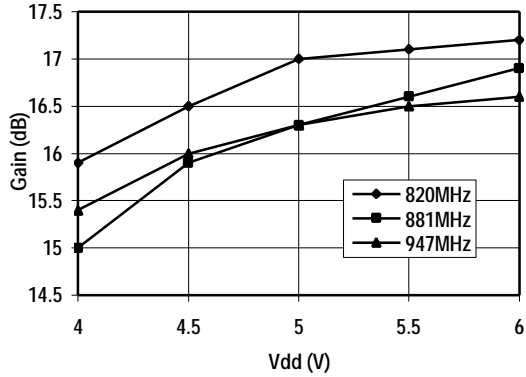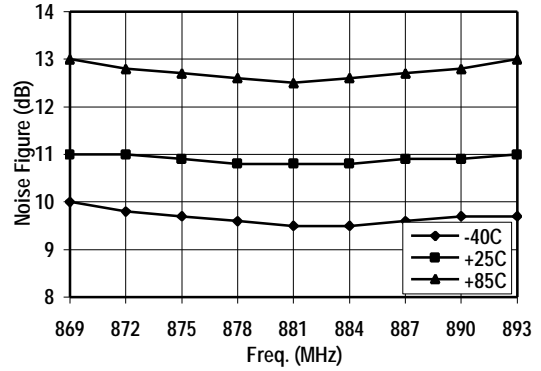| Parameter	Value	Units
DC Power Supply	8.0	V
RF Input Power	+10	dBm
Operating Temperature	-40 to 85	C
Storage Temperature	-55 to 150	C

TriQuint
SEMICONDUCTOR

Typical Performance

Test Conditions *(Unless Otherwise Specified): Vdd=5.0V, Ta=25C, filter IL=3.0dB, RF=881MHz, LO=996MHz, IF=85MHz, LO input=-6dBm*

Conversion Gain vs. Freq. vs. Temp.

**LNA Performance
Noise Figure vs. Freq. vs. Temp.**

Input IP3 vs. Freq. vs. Temp.

**LNA Performance
Gain vs. Freq. vs. Temp.**

Noise Figure vs. Freq. vs. Temp.

**LNA Performance
IP3 vs. Freq. vs. Temp.**

*For additional information and latest specifications, see our website: **www.triquint.com***

TriQuint
SEMICONDUCTOR
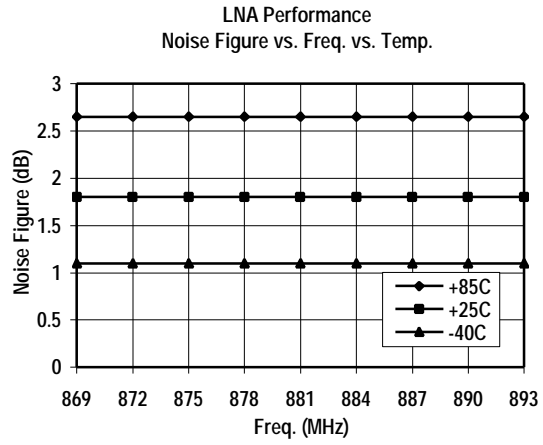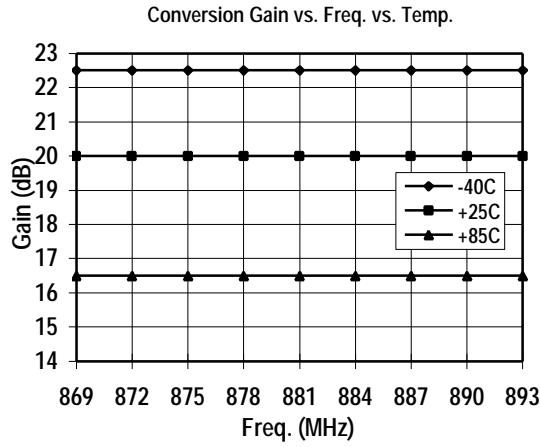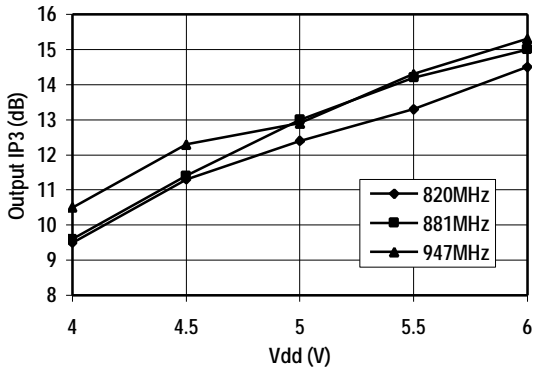
LNA Performance
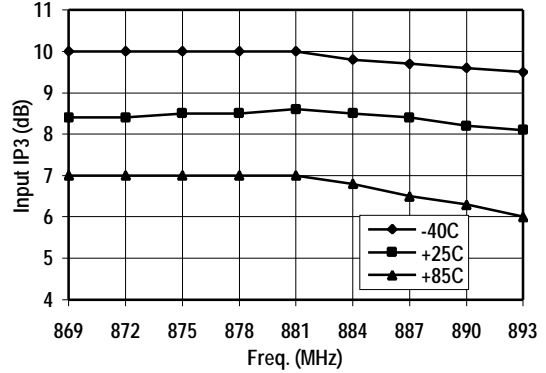### Gain vs. Vdd vs. Freq.

Mixer Performance
Noise Figure vs. Freq. vs. Temp.

LNA Performance
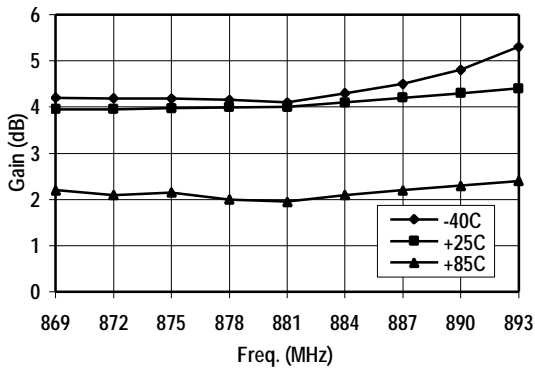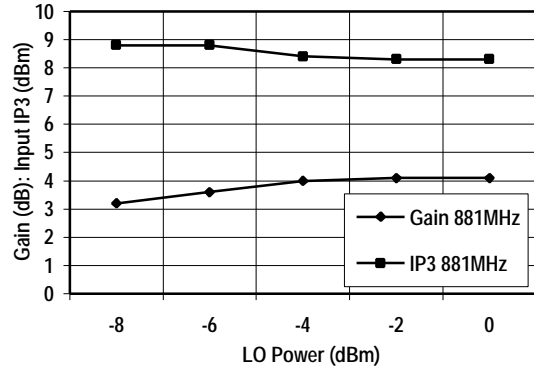### IP3 vs. Vdd vs. Freq.

Mixer Performance
IP3 vs. Freq. vs. Temp.

Mixer Performance
Gain vs. Freq. vs. Temp.

Mixer Performance
Gain vs. Input IP3 vs. LO Power

LNA[0] S-Parameters, VDD=5.0V

Freq	|S11|	<S11	|S21|	<S21	|S12|	<S12	|S22|	<S22
800	0.76	-39	4.30	4	0.0033	-161	0.25	-110
825	0.75	-40	4.42	-2	0.0034	-158	0.16	-120
850	0.74	-41	4.50	-8	0.0038	-160	0.10	-138
875	0.73	-42	4.54	-13	0.0044	-164	0.05	167
900	0.72	-43	4.58	-22	0.0047	-170	0.07	93
925	0.71	-43	4.57	-28	0.0051	-174	0.12	75
950	0.71	-44	4.53	-34	0.0054	-178	0.18	60
975	0.70	-46	4.50	-38	0.0056	178	0.23	52
1000	0.70	-47	4.43	-45	0.0062	174	0.29	47

LNA[1] S-Parameters, Vdd=5.0V

Freq	|S11|	<S11	|S21|	<S21	|S12|	<S12	|S22|	<S22
800	0.82	-40	4.55	17	0.0058	171	0.30	-94
825	0.82	-41	4.70	10	0.0061	166	0.23	-98
850	0.82	-42	4.82	4	0.0067	161	0.16	-100
875	0.81	-43	4.92	-2	0.0069	156	0.09	-99
900	0.81	-45	4.97	-8	0.0075	151	0.03	-69
925	0.80	-46	5.00	-13	0.0078	150	0.05	24
950	0.80	-47	4.99	-19	0.0079	145	0.11	37
975	0.79	-48	4.97	-24	0.0078	142	0.16	37
1000	0.79	-49	4.94	-29	0.0085	142	0.21	36

LNA[0] Noise Parameters, Vdd=5.0V

Freq (MHz)	Fmin (dB)	G_{opt} (mag)	G_{opt} (ang)	Rnoise (Ω)
820	1.51	0.65	26.5	40.1
881	1.54	0.65	29.0	40.0
915	1.57	0.64	30.5	39.9
947	1.60	0.64	32.0	39.9

LNA[1] Noise Parameters, Vdd=5.0V

Freq (MHz)	Fmin (dB)	G_{opt} (mag)	G_{opt} (ang)	Rnoise (Ω)
820	1.30	0.67	27.4	38.9
881	1.33	0.66	30.4	39.9
915	1.36	0.66	31.5	39.9
947	1.39	0.66	32.7	38.7

TriQuint
SEMICONDUCTOR

Mixer S-Parameters, 5.0V

Freq (MHz)	RF IN |S11|	RF IN <S11	LO IN |S11|	LO IN <S11
700	0.36	-42	0.21	-48
750	0.36	-45	0.19	-44
800	0.35	-45	0.17	-40
850	0.34	-46	0.15	-33
900	0.33	-47	0.13	-14
950	0.34	-45	0.17	6
1000	0.40	-47	0.26	0
1050	0.39	-56	0.33	-23
1100	0.39	-60	0.31	-37

Mixer S-Parameters, 5.0V

Freq (MHz)	Mixer IF Out |S11|	Mixer IF Out <S11
50	0.993	-2
75	0.991	-2
100	0.991	-2
125	0.994	-3
150	0.995	-4
175	0.995	-4
200	0.994	-5
225	0.994	-5
250	0.994	-6

Application/Test Circuit
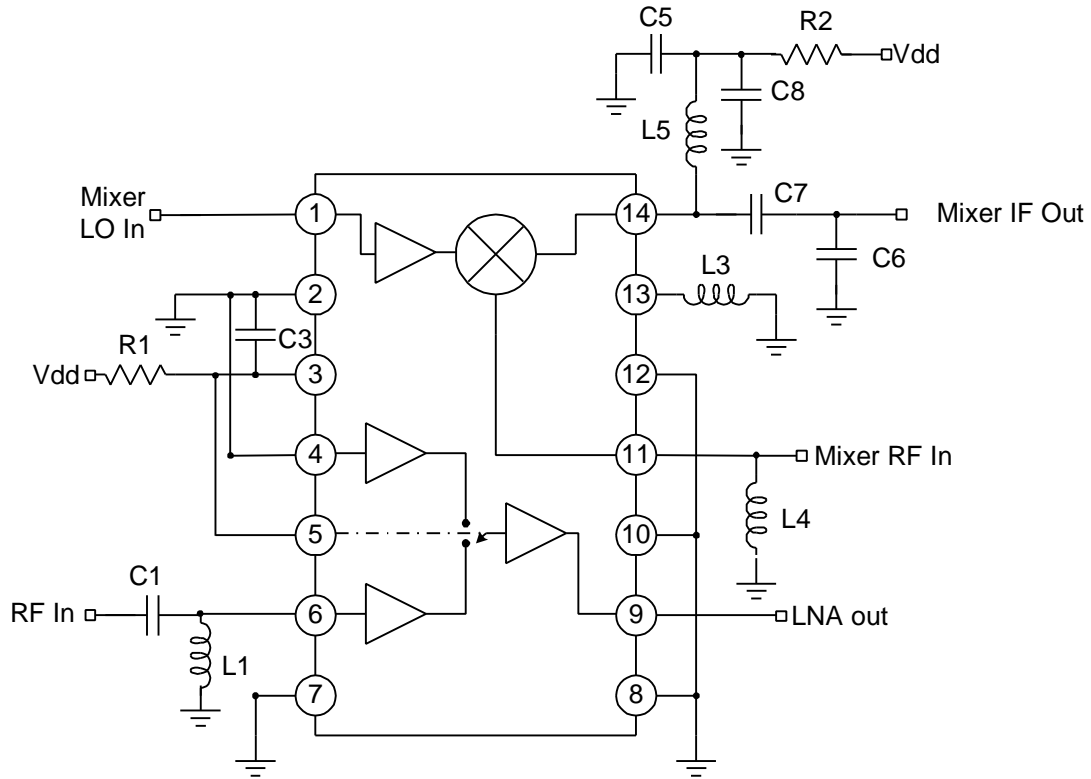
Bill of Material for TQ9203 Receiver Application/Test Circuit

Component	Reference Designator	Part Number	Value	Size	Manufacturer
Receiver IC	U1	TQ9203		SO-14	TriQuint Semiconductor
Capacitor	C1		1.5pF	0402	
Capacitor	C3, C8		0.01μF	0402	
Capacitor	C5, C6		33pF	0402	
Capacitor	C7		5.6pF	0402	
Inductor	L1, L3, L4		12nH	0402	
Inductor	L5		470nH	0402	
Resistor	R1, R2		10 ohm	0603	

*Component values for L5, C6, and C7 depend upon the IF frequency and the IF filter impedance. R1 and R2 are optional. Here they are chosen for an 85MHz IF and 50W load.

TriQuint
SEMICONDUCTOR

TQ9203 Product Description

The TQ9203 efficiently integrates a low-noise amplifier and high-intercept mixer, with performance equal to a discrete implementation, though use of circuit techniques from monolithic and discrete design practices. The LNA consists of two cascaded common-source amplifier stages, using a *"DC-stacked"* topology, in which the same DC current flows through both stages. An external noise match is used to achieve optimum noise figure. Matching is performed with PC board microstrip lines or lumped-elements surface-mount components, using simple, well understood networks. The output on-chip impedance is matched to 50 ohms.

The mixer is implemented as a *"cascode"* stage operating like a dual-gate FET mixer. A common-gate LO buffer provides the necessary gain to drive the mixer FET gate and establishes a good input match. The on-chip buffer amplifier allows for direct connection to a commercial VCO at drive levels down to –6dBm. An *"open collector"* IF output allows for flexibility, matching to various Ifs and filter types.

The two topologies efficiently use the supply current for low-power operation, approximately 10mA with a 5V supply. The overall circuit provides a distinct performance edge over silicon monolithic designs in terms of input intercept, noise figure and gain. Specifically, the circuit was intended for use in the following applications: cellular (AMPS, NADC, GSM, JDC, ETACS, etc.) and ISM band (902 – 928MHz).

In addition, two selectable LNA inputs are available. They are implemented through the use of two independent first stages, each connected to the second-stage input. A SELECT pin controls which input is active by steering the current through the selected input stage and cutting it off from the other. This provides the optional functionality of a diversity switch in front of the LNA, but without the insertion loss and noise figure penalty from the switch.

Operation

Please refer to the test circuit above.

Power Supply Connection

The TQ9203 was designed to operate within specifications over the power supply range of 4.5 to 5.5V, although it will function over a range of 4.0 to 6.0V. The internal biasing maintains stable operating points with varying supply voltage. However, the electrical parameters do vary slightly with supply voltage. Internally, the downconverter has 50pF of capacitance from Vdd to ground for RF decoupling of the supply line. This should be augmented with additional decoupling capacitance: 1000pF connected externally within 5mm of the package pin. A 10-ohm series resistor in the Vdd line may also be added (optionally) to provide some filtering of supply line noise. Connections to ground should go directly to a low-impedance ground plane. Therefore, it is recommended that multiple via holes to the ground plane occur within 2mm on the inside of the package pins.

LNA Input Interfacing

The TQ9203 LNA was designed for low-noise operation. It makes use of an optimum noise-matching network at the input, not a conjugate match, as would be used for maximum power transfer (although gamma optimum is near the conjugate match). Gamma optimum is referenced from the LNA input into the noise-match network in series with 50 ohms. The gamma optimum and the noise parameters for selected frequencies are shown in the LNA Noise Parameters table.

There are several options for the physical realization of gamma optimum: a series-shunt microstrip transmission line network, a series capacitor/shunt inductor, and a series inductor. Ideal values for these components are included in the Noise Parameters table. The microstrip transmission lines can easily be constructed on FR-4 or G-10 circuit boards, using standard design techniques. The lumped-element components are surface-mount elements designed for RF use. Slight adjustments in the actual values of the elements are likely, due to the effects of component parasitics. It is important that the board-level circuit establishes an impedance of gamma optimum, measure at the solder pad of pin 6. Proper board design for gamma optimum eliminates the need for tuning adjustments and produces a low-noise circuit, which is tolerant of component variations.

LNA Output (Pin 9)

The LNA output is internally matched to 50 ohms over the 800 to 1000MHz frequency band and it is internally DC-blocked. Therefore, direct connections may be made to pin 9.

Mixer RF Input

The mixer RF input is matched close to 50 ohms and is internally DC-blocked. Pin 11 may be directly connected to the filter output. The filter must be as close as possible to the mixer RF input to maintain the proper termination impedance at the LO frequency. Include a shunt inductor of 22nH at the mixer RF input to improve the mixer noise performance by providing a short to ground at the IF frequency. This provides a secondary benefit of slightly improved input match.

Mixer LO Input

The mixer LO input is matched close to 50 ohms and is internally DC-blocked. Pin 1 may be directly connected to the LO input signal. A level greater than –6dBm is recommended. Standard VCO outputs of –2dBm work well.

LO Tuning (Pin 13)

A shunt L on pin 13 resonates with some internal capacitance to produce a bandpass frequency response of the LO buffer amplifier. This attenuates noise at +/- one IF frequency away from the LO frequency. The approximate value of L is determined by the following equation:
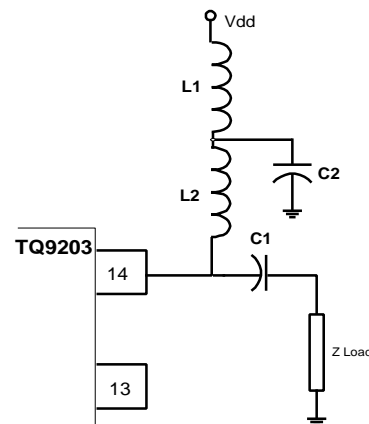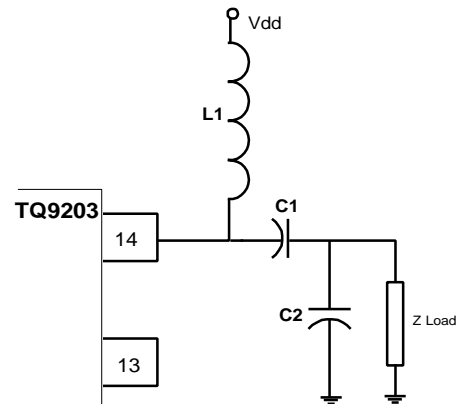
$$L = 1/C \, (2\pi f)^2, \text{ where } C = 2.2pF$$

In practice, the value (and/or placement) of L should be empirically determined for a particular layout, since stray capacitance on the PCB layout can move the resident frequency from the expected ideal. The actual value of L should be adjusted until the buffer response (pin 1-> pin 13) produces a peak at the LO frequency. A measurement of the response may be accomplished with a simple coaxial probe "sniffer," in which the end is positioned 50 – 100 mils from the inductor at pin 13. The frequency response of the LO buffer amplifier (pin 13) is directly measured on the network analyzer as the LO input (pin 1) is swept in frequency. The LO drive level should be set at approximately the operating level (-6 to 3dBm) for this measurement. This "tuning" needs to be done only in design, not in production.
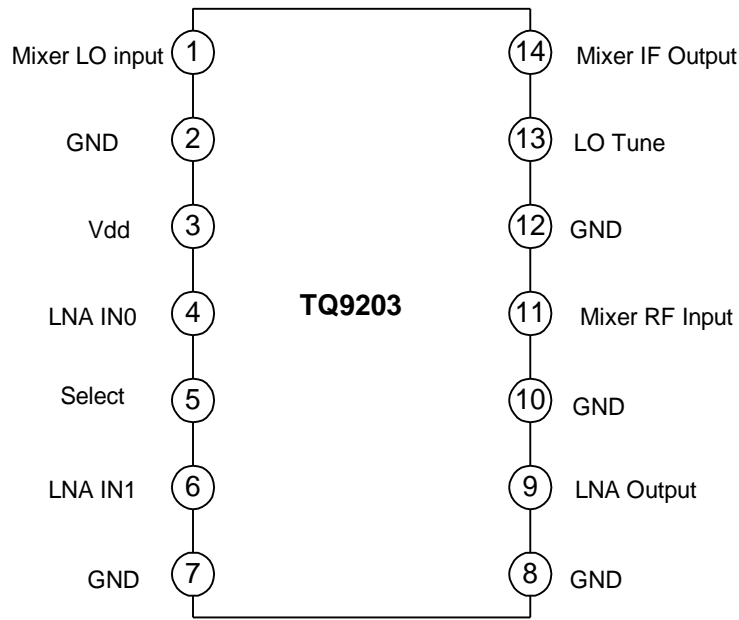
Mixer IF Interfacing

The mixer IF port is a high-impedance, open-drain output. The impedance is a few K ohms in parallel with less than 1pF capacitance. The IF port S-parameters (S11) are listed in the table over the frequency range of 45MHz to 250MHz. It is possible to use Ifs above and below this range: however, at low frequencies the noise increases, and at high frequencies the LO/IF, RF/IF isolation decreases.

The open-drain output permits matching to any chosen filter impedance. In general, a conjugate impedance match is recommended on this port to achieve best power gain, noise figure and output 3rd-order intercept. It is also important to properly center the tuned circuit at the desired IF. This maximizes circuit robustness to component tolerances. For proper mixer operation, pin 14, the open-drain output, must also be biased to Vdd. A practical matching network, which includes biasing, is shown.
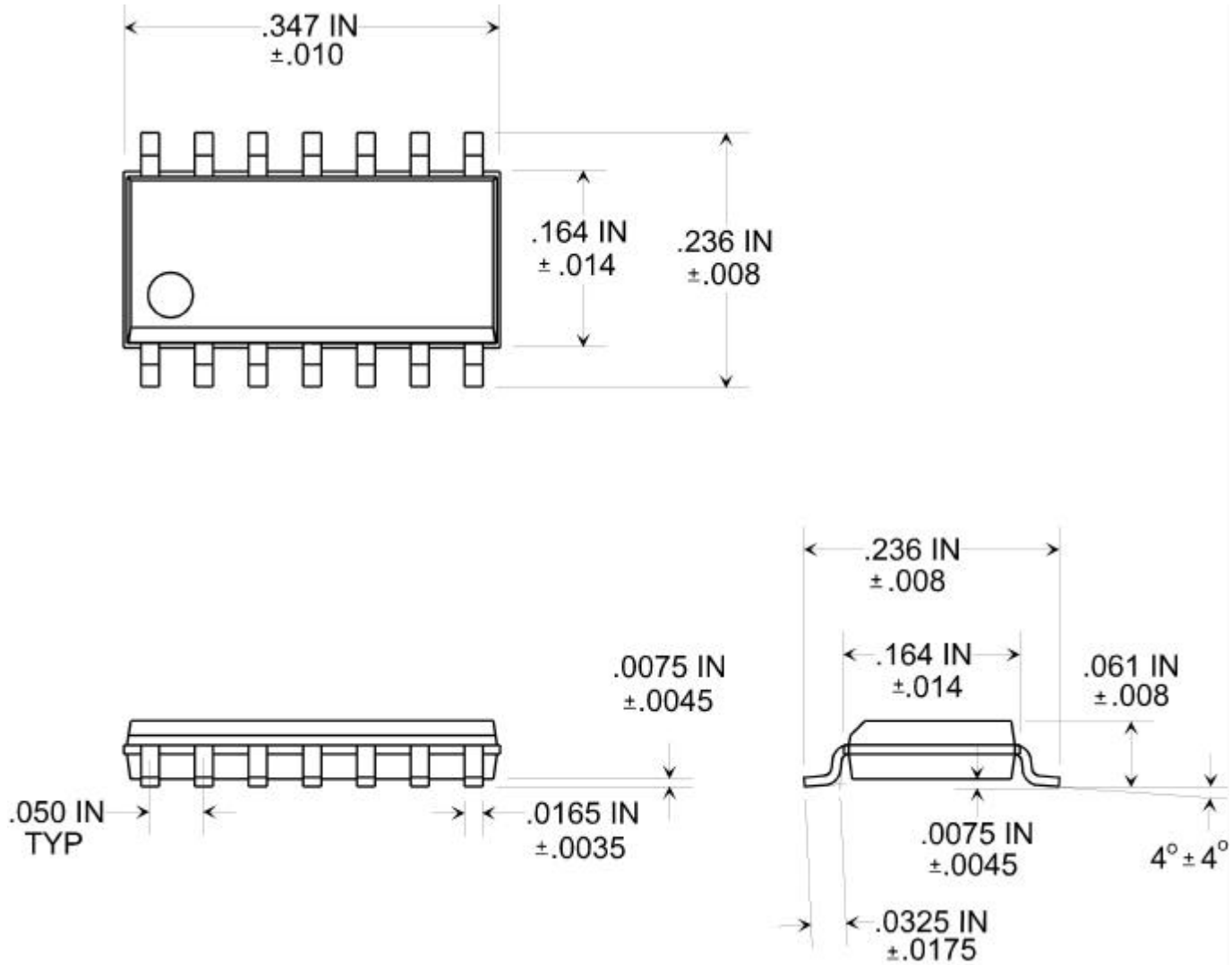
TriQuint
SEMICONDUCTOR

Package Pinout

```
        Mixer LO input  (1)              (14)  Mixer IF Output

              GND       (2)              (13)  LO Tune

              Vdd       (3)              (12)  GND

           LNA IN0      (4)     TQ9203   (11)  Mixer RF Input

            Select      (5)              (10)  GND

           LNA IN1      (6)              (9)   LNA Output

              GND       (7)              (8)   GND
```

Pin Descriptions

Pin Name	Pin #	Description and Usage
Mixer LO IN	1	Buffered LO port. There is an internal DC block on this port, which is matched to 50Ω.
Vdd	3	Supply voltage for bias circuitry and LNA. This pin draws 8mA, typically. Decouple with 0.01uF within 0.25 inch of package.
LNA IN0	4	LNA IN0 is an auxiliary input and has characteristics similar to the LNA IN1 input port. Best performance is achieved with external noise-matching network. Internally DC blocked.
Select	5	Input port selection switch. CMOS-compatible drive, switches input ports from LNA IN1 to LNA IN0. Low=IN0, High=IN1.
LNA IN1	6	LNA IN1 is the primary input port. Best performance is achieved with external noise-matching network. Internally DC blocked.
LNA Out	9	Output port from switched LNA section. Internally matched to 50Ω. Internally DC blocked.
Mixer RF IN	11	Mixer RF Input port. Image stripping band pass filtering before Mixer section improves noise and spurious performance. No return to ground is required. Shunt L recommended for IF suppression.
LO Tune	13	LO buffer tuning, inductor to ground.
Mixer IF Out	14	Mixer IF signal port. Open "collector-" type output requires connection to Vdd and impedance matching to load.
GND	2,7,8, 10,12	Ground connection. Keep physically short for stability and performance. Use several via holes immediately adjacent to the pins down to backside ground plane.

Package Type: SO-14 Plastic Package

Additional Information

For latest specifications, additional product information, worldwide sales and distribution locations, and information about TriQuint:

Web: www.triquint.com   **Tel: (503) 615-9000**

Email: info_wireless@tqs.com   **Fax: (503) 615-8900**

For technical questions and additional information on specific applications:

Email: info_wireless@tqs.com

Revision F, March 23, 1999

TriQuint
SEMICONDUCTOR