

Product Description

The TQ9222 is a 3-V, RF receiver IC designed specifically for dual-band TDMA applications. Its RF performance meets the requirements of products designed to the IS-136 and GSM standards. The TQ9222 is pin compatible with TQ5121 (cellular band LNA/Mixer) which enables handset designers to use strategic board platform strategy.

The TQ9222 contains two separate LNA+Mixer circuits to handle both the 800 MHz cellular band and the 1900 MHz PCS band. The mixers use a high-side LO frequency, with the IF covering a range of 70-140 MHz. IF frequencies below 120 MHz are possible due to the 1/2-IF spurious signal rejection in the 1900 MHz LNA+Mixer. The IF outputs are designed for use of a common IF frequency. Most RF ports are internally matched to 50Ω, greatly simplifying the design and keeping the number of external components to a minimum. Separate supply voltage connections provide the required flexibility for dual-band operation. The TQ9222 achieves good RF performance with low current consumption, supporting long standby times in portable applications. Coupled with the very small QSOP-24 package, the part is ideally suited for dual-band mobile phones.

Electrical Specifications¹

Parameter		Typ	Units
Gain	800 band	17.5	MHz
	1900 band	17.5	MHz
Noise Figure	800 band	2.7	dB
	1900 band	3.0	dB
Input 3 rd Order Intercept	800 band	-9.0	dBm
	1900 band	-9.0	dBm
DC supply Current	800 band	10.0	mA
	1900 band	22.0	mA

¹Note: Test Conditions: V_{dd}=2.8V, T_a=25C, filter IL=2.5dB, RF¹=881MHz, RF²=1960MHz, LO¹=991MHz, LO²=2070MHz, IF=110MHz, LO Input=-7dBm; unless otherwise specified

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Dual-Band TDMA LNA/Downconverter IC

Features

- Pin compatible with TQ5121
- Single 3 V operation
- Low-current operation
- Low-frequency IF capability
- Excellent 1/2 IF rejection
- IF output combining
- 50 W matched inputs (most ports)
- QSOP-24 plastic package

Applications

- IS-136 dual-band Mobile Phones
- Tri-Mode Phones
- GSM dual-band Mobile Phones
- Wireless local loop

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Electrical Characteristics

Parameter	Conditions	Min.	Typ/Nom	Max.	Units
RF Frequency	Cellular band	869		894	MHz
	PCS band	1930		1990	MHz
LO Frequency	Cellular band	950		1040	MHz
	PCS band	2010		2140	MHz
IF Frequency	Cellular band	85		140	MHz
LO input level		-7	-4	0	dBm
Supply voltage		2.7	2.8	3.0	V
Gain	Cellular band	16.0	17.5		dB
	PCS band	16.0	17.5		dB
Gain Variation vs. Temp.	-40 to 85C	-2.0		+2.0	dB
Noise Figure	Cellular band		2.7	3.5	dB
	PCS band		3.0	3.5	dB
Input 3 rd Order Intercept	Cellular band	-11.0	-9.0		dBm
	PCS band	-11.0	-9.0		dBm
Return Loss	LNA input – external match	10			dB
	Cellular and PCS band	LNA output	10		dB
		Mixer RF input	10		dB
		Mixer LO input	10		dB
Isolation	LO to LNA in	40			dB
	Cellular and PCS bands	LO to IF; after IF match		40	dB
		RF to IF; after IF match		40	dB
IF Output Impedance	Vdd = 2.8V; "ON"		500		Ohm
Cellular and PCS band	Vdd = 0V; "OFF"		<50		Ohm
Supply Current	Cellular band		10	13	mA
	PCS band		22		mA

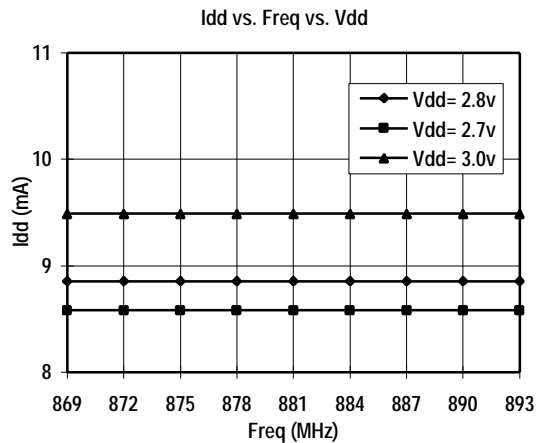
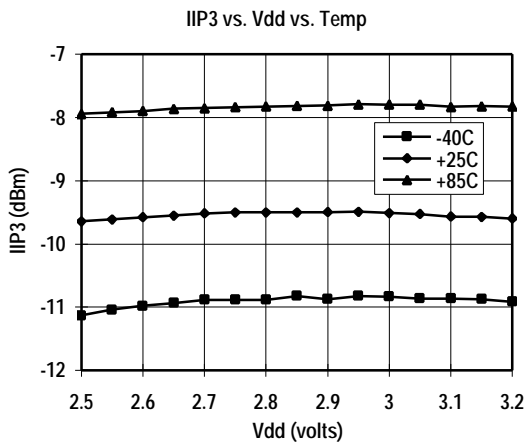
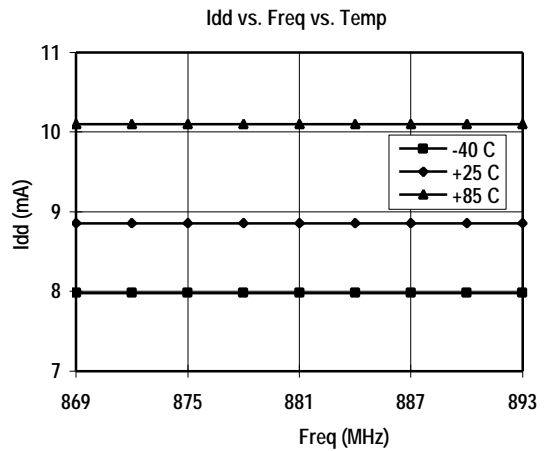
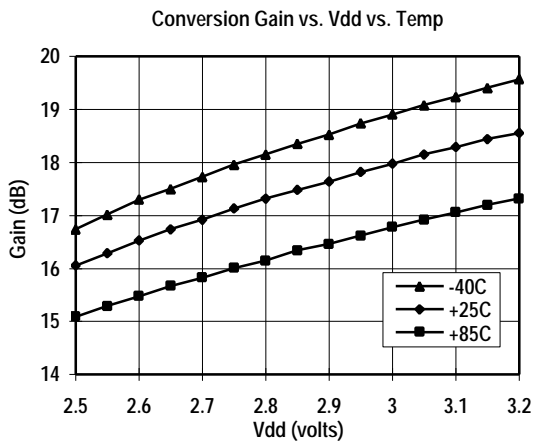
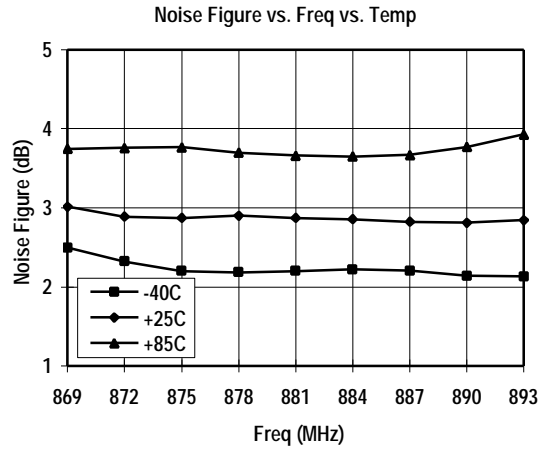
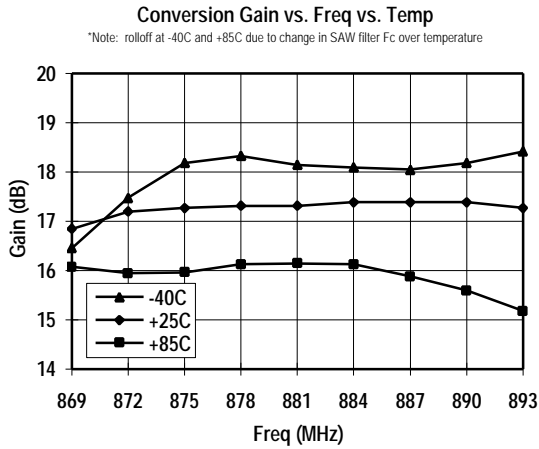
Note 1: Test Conditions: Vdd=2.8V, Ta=25C, filter IL=2.5dB, RF1=881MHz, RF2=1960MHz, LO1=991MHz, LO2= 2070MHz, IF=110MHz, LO Input=-7dBm; unless otherwise specified

Absolute Maximum Ratings

Parameter	Value	Units
DC Power Supply	5.0	V
Power Dissipation	500	mW
Operating Temperature	-40 to 85	C
Storage Temperature	-60 to 150	C
Signal level on inputs/outputs	+20	dBm
Voltage to any non supply pin	-.3 to +.3	V

Typical Performance

Test Conditions: TQ9222 Low Band (Unless Otherwise Specified): Vdd=2.8V, Ta=25C, filter IL=2.5dB, RF=881MHz, LO=991MHz, IF=110MHz, LO input=-7dBm



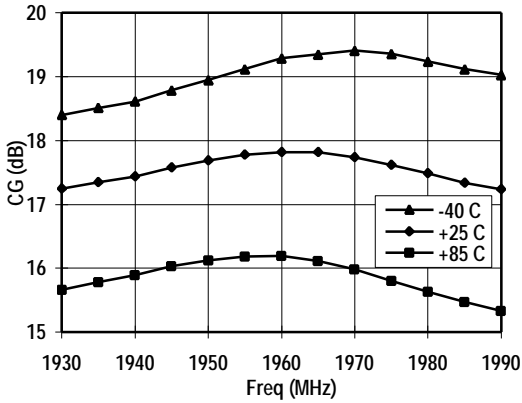
TQ9222

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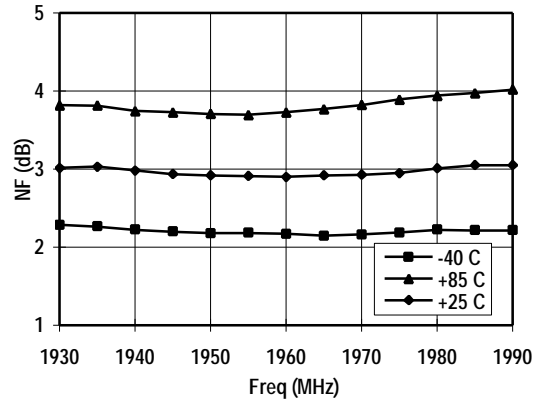
Typical Performance:

Test Conditions: TQ9222 High Band (Unless Otherwise Specified): Vdd=2.8V, Ta=25C, filter IL=2.5dB, RF=1960MHz, LO=2070MHz, IF=110MHz, LO input=-7dBm

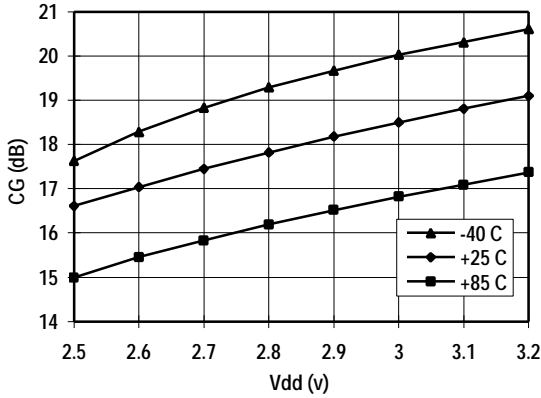
Conversion Gain vs. Freq. vs. Temp.



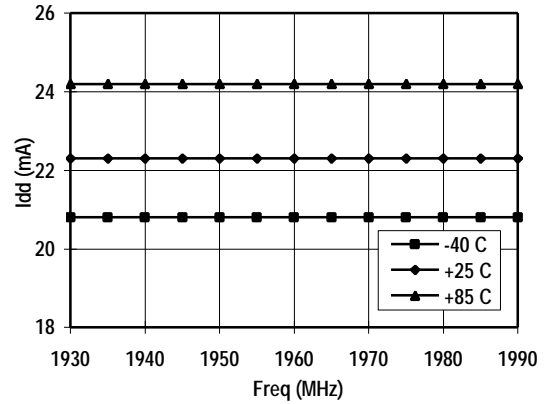
Noise Figure vs. Freq. vs. Temp.



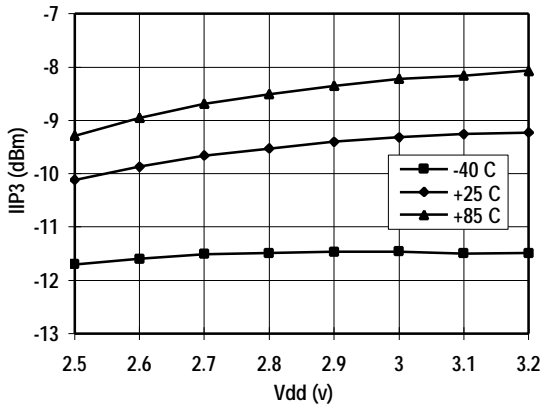
Conversion Gain vs. Vdd vs. TEMP



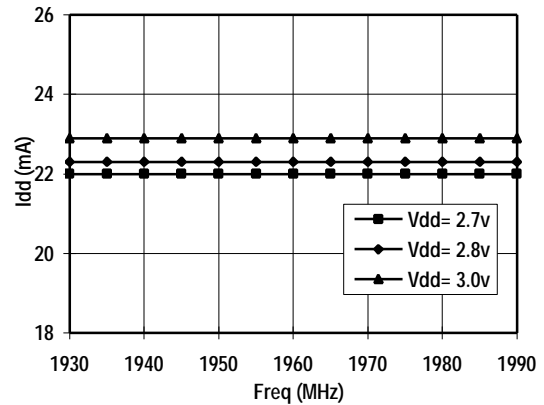
Idd vs Freq. vs Temp.



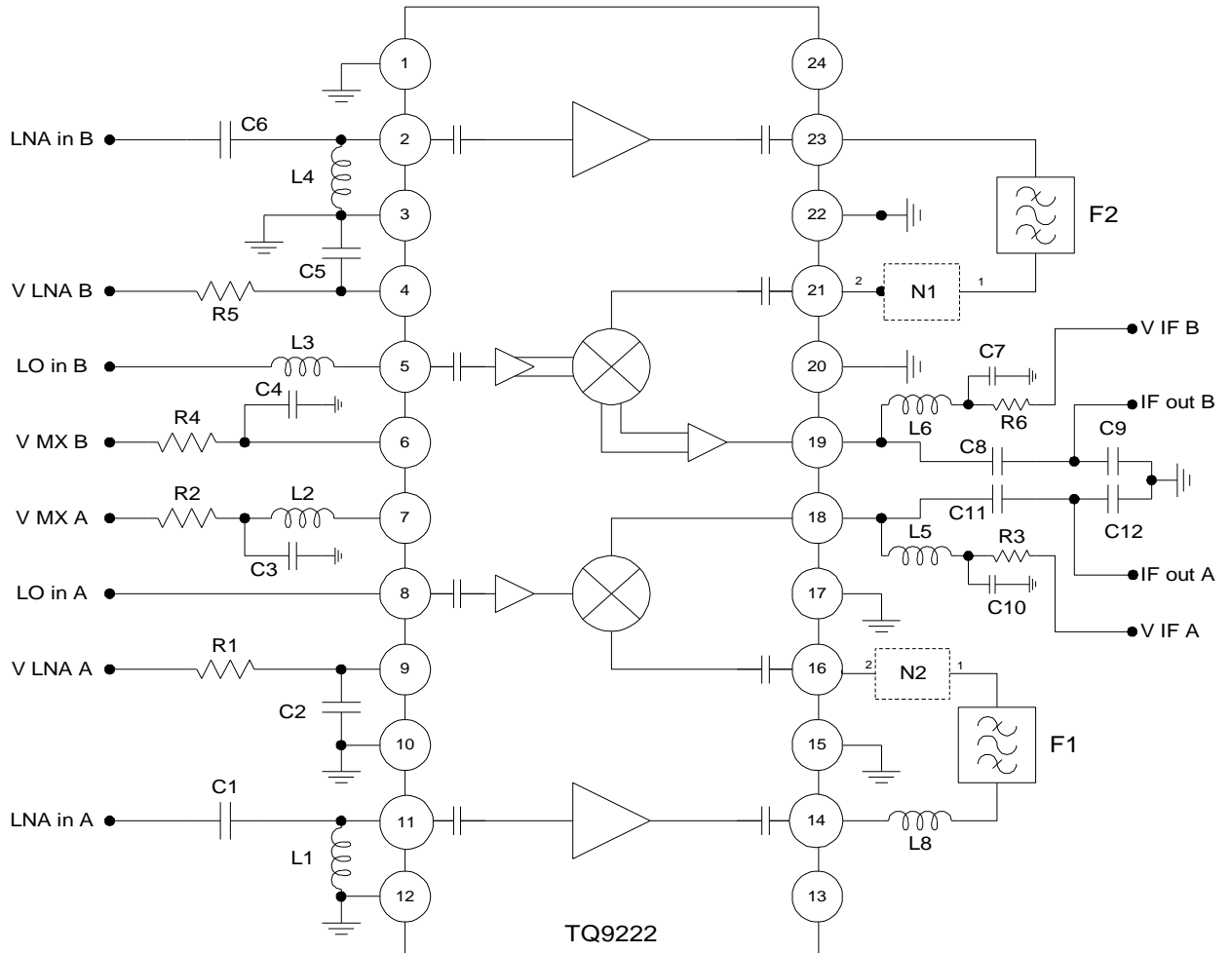
IIP3 vs. Vdd vs. TEMP



Idd vs Freq. vs Vdd



Application/Test circuit



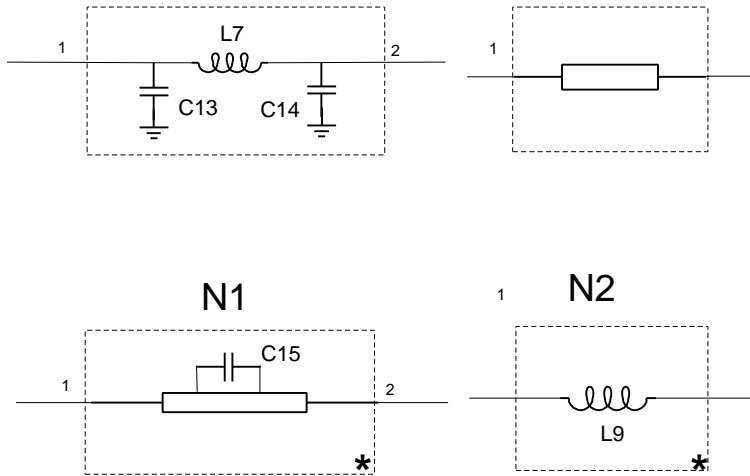
Bill of Material for TQ9222 Receiver Application/Test Circuit

Component	Reference Designator	Part Number	Value	Size	Manufacturer
Receiver IC	U1	TQ9222		QOP-24	TriQuint Semiconductor
Capacitor	C1		1.2pF	0603	
Capacitor	C2, C3, C4, C5		1000pF	0603	
Capacitor	C6		1.5pF	0603	
Capacitor	C7, C10		.01μF	0603	
Capacitor	C9		4.7pF	0603	
Capacitor	C8, C11		12pF, 10pF	0603	
Capacitor	C12		8.2pF	0603	
Capacitor	C13		1.5pF	0603	
Capacitor	C14, C15 (filter dependent)		0.5pF	0603	

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Filter	F1	869-894MHz	
Filter	F2	1930-1990MHz	
Inductor	L1	10nH	0603
Inductor	L2	8.2nH	0603
Inductor	L3	6.8nH	0603
Inductor	L4	2.7nH	0603
Inductor	L5, L6	180nH	0603
Inductor	L7 (filter dependent)	2.7nH	0603
Inductor	L8	10nH	0402
Inductor	L9 (filter dependent)	2.2nH	0603
Resistor	R1-6 (power supply only)	10 Ohm	0603



OPTIONAL FILTER OUTPUT NETWORKS, DEPENDING UPON FILTER TYPE, BOARD LAYOUT, AND IF FREQUENCY

* denotes networks used for data sheet parameters

Introduction

The TQ9222 3V RFIC Downconverter is designed specifically for dual-band TDMA applications. The TQ9222 contains two separate LNA+Mixer circuits to handle both the 800 MHz cellular band and the 1900 MHz PCS band. The IF frequency range covers 70 to 140 MHz. Most of the ports are internally matched to 50 Ω simplifying the design and keeping the number of external components to a minimum. Separate supply voltage connections provide the required flexibility for dual-band operation.

Operation: Please refer to the applications test circuit above.

General Description

Low Noise Amplifier (LNA)

The LNA sections of the TQ9222 consist of two cascaded common source FETs (see Fig 1). Each LNA is designed to operate on supply voltages from 3V to 5V. The main differences between the high and low band LNAs are the bias circuits. The source terminal of the first stage has to be grounded very close to the pin (pin 1 for PCS band and pin 12 for cellular band). This will avoid a significant gain reduction due to degeneration. The LNA requires a matching circuit on the input to provide a good noise, gain and return loss performance. The output is close to 50 Ω for direct connection to a 50 Ω image stripping filter.

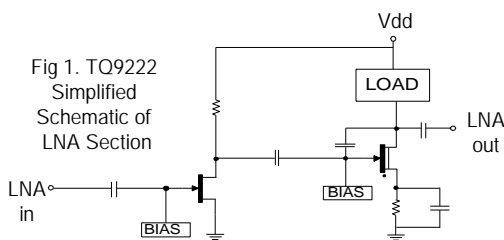


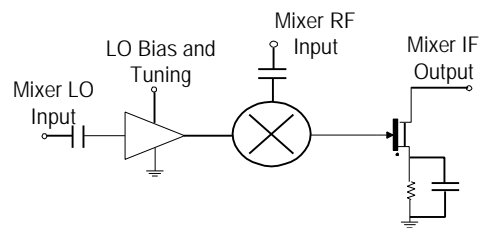
Fig 1. LNA Sections

Cellular Band Mixer

The cellular band mixer of the TQ9222 is implemented by a common source depletion FET. The mixer is designed to operate on supply voltages from 3V to 5V. An on-chip buffer amplifier simplifies direct connection of the LO input to a commercial VCO at drive levels down to -7dBm. The common-

gate LO buffer provides a good input match, and supplies the voltage gain necessary to drive the mixer FET gate. The "open-drain" IF output allows for flexibility in matching to various IF frequencies and filter impedances (see Fig. 2).

Fig 2. Cellular Band Mixer



PCS Band Mixer

The PCS band mixer section of the TQ9222 is a balanced mixer with a single ended output. This balanced mixer topology minimizes the LO leakage out of the RF and IF ports thereby giving excellent LO suppression (see Fig. 3)

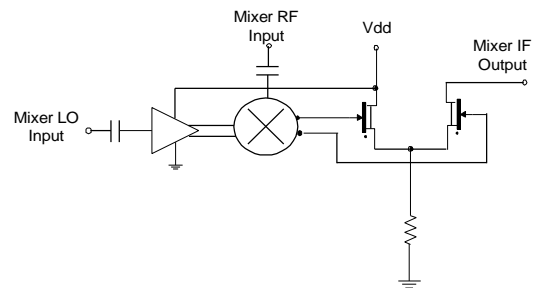


Fig 3. PCS Band Mixer

Low Noise Amplifier Application

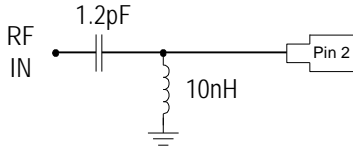
To obtain the best possible combination of performance and flexibility, the high and low band LNAs were designed to be used with off-chip input impedance matching. Based on the system requirements, the designer can make several performance trade-offs and select the best impedance match for the particular application.

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LNA Input Match

The input matching network primarily determines the noise and gain performance. Fig 4 shows a suggested input match for the high band. The low band uses a series 1.2pF capacitor and a shunt 10nH inductor.



Note: These values assume ideal components and neglect board parasitics. The discrepancy between these values and those of the typical application circuit are the board and component parasitics.

Fig 4. LNA Input Match

The LNA gain, noise figure and input return loss are a function of the source impedance (Z_s), or reflection coefficient (Γ_s), presented to the input pin. Highest gain and lowest return loss occur when Γ_s is equal to the complex conjugate of the LNA input impedance. A different source reflection coefficient, Γ_{opt} , which is experimentally determined, will provide the lowest possible noise figure, F_{min} .

The noise resistance, R_n , provides an indication of the sensitivity of the noise performance to changes in Γ_s as seen by the LNA input.

$$F_{LNA} = F_{MIN} + \frac{4R_n}{Z_0} \cdot \frac{|\Gamma_{opt} - \Gamma_s|^2}{|1 + \Gamma_{opt}|^2 \cdot (1 - |\Gamma_s|^2)}$$

Components such as filters and mixers placed after the LNA degrade the overall system noise figure according to the following equation:

$$F_{SYSTEM} = F_{LNA} + \frac{F_2 - 1}{G_{LNA}}$$

where F_{LNA} and G_{LNA} represent the linear noise factor and gain of the LNA and F_2 is the noise factor of the next stage. Thus, the system noise figure depends on the highest gain and minimum noise figure of the LNA.

Designing the input matching network involves a compromise between optimum noise performance and best input return loss. For example, when the TQ9222 LNA is matched for optimum noise figure (1.35dB @ 880 MHz, and 1.45dB @ 1960 MHz), the input return loss is only about 4dB. On the other hand, when the LNA is matched for best return loss, the LNA noise figure is approximately 1.95dB @ 881 MHz and 2.14dB @ 1960MHz (see Table 1.)

Low Band

Freq (MHz)	$ \Gamma_{opt} $	$<\Gamma_{opt}$	Fmin (dB)	Rn (Ω)
835	0.678	33	1.34	61.6
850	0.655	34	1.38	61.1
865	0.652	36	1.36	61.2
880	0.652	38	1.35	60.9
895	0.649	38	1.36	61.3
910	0.659	40	1.35	61.2
925	0.687	41	1.35	65.6

High Band

Freq (MHz)	$ \Gamma_{opt} $	$<\Gamma_{opt}$	Fmin (dB)	Rn (Ω)
1860	0.557	51	1.44	31.1
1960	0.555	54	1.45	31.7
2060	0.532	59	1.61	29.0

Table 1. Noise Parameters

LNA Output Match

The output impedance of the high and low band LNAs, were designed to interface directly with 50 Ω terminations. This internal match serves to reduce the number of external components required at this port. An additional benefit accrues as an improvement in IP3 performance, return loss and power gain.

Low Band LNA Output

The output of the low band LNA will most often be connected to an image stripping filter. Depending on the filter type, additional components might be needed to present a better match to the LNA output. The TQ9222 general applications circuit shows a TOYOCOM (637-881A) saw filter for the low band. A series inductor "L8" of 10nH is added to the filter input to improve the match. This series inductor also smoothes out excessive ripple in the filter passband improving the overall performance of the circuit.

High Band LNA Output

The output of the high band LNA can also be connected directly to the image stripping filter. However, it has been found that some SAW filters can cause low image rejection in the circuit as a whole, even as their individual characteristics show rejection of 30-40dB. It appears that the very low impedance of the SAW filter at the image frequency can be reflected back to the LNA output pin, lessening the effectiveness of the ground, and leaking into the mixer input.

The optimum solution would be to include a 1/4 wavelength transmission line between the LNA output and SAW input in order to invert the impedance. However, a more compact solution is to bridge a small capacitor across a much shorter transmission line, giving a much longer effective length. (refer to Fig 9). It may also be possible to entirely use lumped components to accomplish the same. On the evaluation board, the transmission line is looped to that the capacitor can be varied in its positioning, thus facilitating tuning.

Low Band Mixer: LO Port

As mentioned earlier, a common gate buffer amplifier is positioned between the LO port and the mixer FET gate in order to provide a good impedance to the VCO and to allow operation at lower LO drive levels. The buffer amplifier provides the voltage gain needed to drive the gate of the mixer FET while consuming very little current (approximately 1.5mA).

Because of the broadband 50Ω input impedance of the buffer amplifier and the internal DC blocking capacitor, the user's VCO can be directly connected to the LO input via a 50Ω line with no additional components.

Low Band Mixer Input

Although the low band mixer input port has been designed with a 50Ω impedance, it has been found that LO leakage out through the pin can in some cases reflect off the SAW filter and travel back to the mixer input out of phase, causing some degradation in conversion gain and system noise figure. Sensitivity to the phenomena depends on the particular filter model and SAW-mixer transmission line length. On the

evaluation board, a small inductance "L8" is added on the SAW output to compensate. With certain longer line lengths it is possible to omit "L8".

Low Band LO Buffer Tune

While the broadband input match of the LO buffer amplifier makes interfacing easy, the broadband gain means that thermal and induced noise at other frequencies can be amplified and injected directly into the LO port of the mixer. Noise at the IF frequency, and at LO +/- IF will be downconverted and emerge at the IF port, degrading the downconverter noise figure.

As indicated on the diagram of Fig 5, in order to test the LO response to these spurious signals, a two-tone signal was injected into the LO port with the RF port terminated in 50Ω. One signal generator is set to the LO frequency at its normal LO drive level usually (-7 dBm). The second signal generator (spurious signal) is set to the LO +/- IF frequency. The combined input power at mixer LO port has to be less than -50 dBm. The results shown in Table 2 indicate a good suppression of the interfering signals.

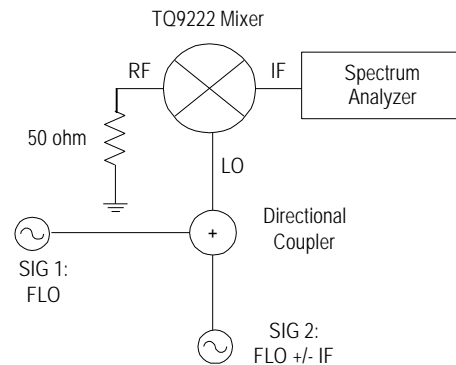


Fig. 5 LO Spurious Response Diagram

LO/Spurious (MHz)	Mixer LO Port Input Power	C/V (dB)
991/1101	-57	-71.7
991/1101	-58.9	-71.8

Table 2. LO Spurious Response Data

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Calculation of Nominal L Value

The node between the LO buffer amplifier and the mixer FET is brought out to Pin 7 (L_tune) and connected to a shunt inductor to AC ground. This inductor is selected to resonate with internal capacitance at the LO frequency in order to suppress out-of-band gain and improve noise performance.

The internal capacitance of the LO amplifier output plus the stray capacitance on the board surrounding Pin 7 is approximately 1.8 pF. The inductor is selected to resonate with the total capacitance at the LO frequency using the following equation:

$$L = \frac{1}{C(2\pi f)^2}, \text{ where } C = 1.5 \text{ pF}$$

but must be confirmed with measurements on a board approximating the final layout.

Measuring the LO Frequency Response

The frequency response of the LO driver amplifier can be measured using a semi-rigid probe (see Fig. 6) and a network analyzer.

Connect port 1 to the LO input (Pin 8) of the TQ9222 with the source power set to deliver -7 dBm. Connect the coaxial probe to Port 2 and place the probe tip approximately 0.1 inch away from either Pin 7 or the inductor.

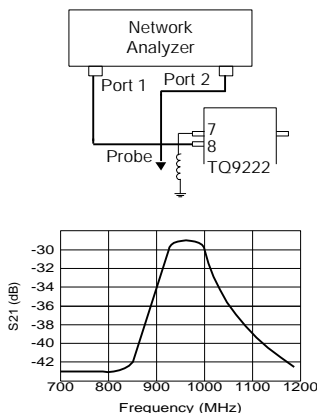


Fig 6. LO Buffer Amplifier Tuning

If the calculated shunt inductor (L2) is not a standard value, the AC ground, implemented with C3, can be slide along the transmission line to adjust for the right inductance (see Fig 7). Once this is completed, the peak of the response should be centered at the center of the LO frequency band.

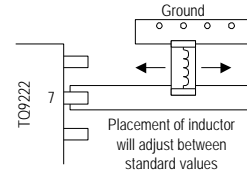


Fig 7. Adjusting AC Ground

Mixer IF Port

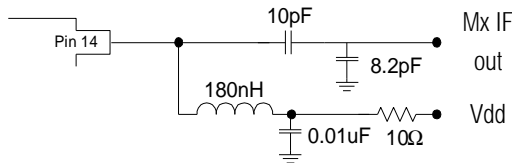
The Mixer IF output is an "open-drain" configuration, allowing for flexibility in efficient matching to various filter types and at various IF frequencies.

For evaluation of the LNA and mixer, it is usually necessary to impedance match the IF port to the 50Ω test systems. When verifying or adjusting the matching circuit on the prototype circuit board, the LO drive should be injected at pin 8 for the Low Band and pin 5 for the High Band at the nominal power level of -7 dBm, since the LO level does have an impact on the IF port impedance.

There are several networks that can be used to properly match the IF port to the SAW or crystal IF filter. The mixer supply voltage is applied through the IF port, so the matching circuit topology must contain either an RF choke or shunt inductor. An extra DC blocking capacitor is not necessary if the output will be attached directly to a SAW or crystal bandpass filters.

Figure 8 shows the IF matching network for the low band. A shunt L, series C, shunt C, is the simplest and requires the fewest components. The only difference with the high band is the series capacitor value of 10pF as opposed to 8.2pF. DC current can be easily injected through the shunt inductor and the series C provides a DC block, if needed. The shunt C, is used to reduce the LO leakage.

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Note: These values assume ideal components and neglect board parasitics. The discrepancy between these values and those of the typical application circuit are the board and component parasitics

Fig. 8 Suggested IF Match

Half-IF Application

When the intermediate frequency is less than twice the bandwidth of the receiver, Half-IF intermodulation spurs will fall within the frequency of operation. The image filter and mixer are the main circuit blocks that influence Half-IF spur suppression. However, it was shown experimentally that the preselector filter plays an important role as well in suppressing half-IF and image spurious signals. The preselector filter eliminates out of band spurs that could get amplified and degrade the performance.

A narrow band pass filter and a high IF frequency are best to eliminate Half-IF problems. The other major contribution is mixer balance which is affected by two factors. First, the LO signal that leaks into the mixer inputs via parasitics. The second major contribution is the source impedance presented at the mixer RF input port. Depending on the board layout, the optimum mixer source impedance may shift which will degrade the Half-IF performance.

It is possible to optimize mixer source impedance for Half-IF rejection at the LO frequency only. This will avoid affecting the desired signal to a large degree. Experience with the TQ9222, has shown that optimum mixer source impedance results in a significant mismatch causing gain reduction. Therefore, a trade-off has to be made between optimum Half-IF performance and conversion gain.

The standard TQ9222 evaluation board uses a Toko TDFM1B-1960L-11 dielectric filter in the high band. It was found that an L-network, comprised of a series 1.8 nH inductor and a shunt 1.8 pF capacitor on the mixer input, produces the best Half-IF rejection and conversion gain. To a lesser extent, it was found

that the length of the transmission line in the filter input also has an effect on Half-IF performance.

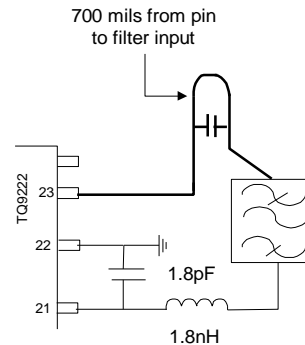


Fig. 9 Image and Half-IF circuit

Note that if the final board layout is significantly different from our evaluation board, the network shown will only be useful as a guideline for development or to show what performance is possible with the TQ9222. A SAW filter will probably require a totally different type of network; and network component values vary widely between SAW filter models.

Usually only a portion of the frequency band will be of concern for half-IF interference. It will depend on the injection mode of the LO signal and the IF frequency being used. For example If the LO is a high side injection such as the case of the TQ9222 and the IF = 110 MHz then (theoretically) we worry about the first 5 MHz of the band (1930-1935) only if we have ideal filters. Unfortunately most of the image stripping filters roll-off around 2000 MHz or higher hence the need to optimize performance up to 1945 MHz. The opposite occurs for low side LO.

Since the frequency response of the preselector and image stripping filter help the performance at the high end of the band, the TQ9222 was tuned to give good half-IF rejection at the low end of the band over a wide temperature range (-40 °C to +85 °C). That was accomplished with a Pi-network* (between the filter output and the mixer input) comprise of a series L = 2.2 nH, shunt C = 1.0 and 0.5 pF. As expected this tuning network degraded the half-IF performance from 1970 to 1990 MHz specially at the extremes temperatures. However, once the

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downconverter was tested with the preselector filter, the performance improved significantly. The results are shown in Table 3.

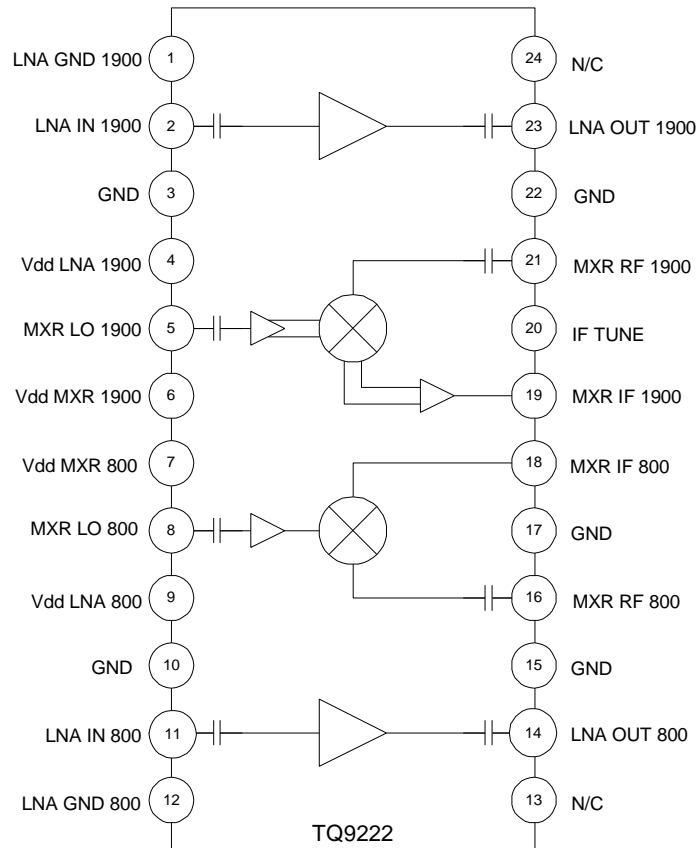
Freq (MHz)	Temp (°C)	Half-IF (dB)
1930	-40	70.30
1940	-40	71.72
1980	+85	72.46
1990	+85	70.21

Table 3. TQ9222 Performance with Preselector Filter (IF = 110 MHz, PLO = -7 dBm, Vdd = 2.8v)

The preselector filter not only improved the half-IF performance but also the image rejection up to 70 dB, RF to IF isolation up to 33dB, and LO to IF isolation up to 43dB.

*This is one of many different circuit topologies that could give similar results. The circuit selected that gives the best performance will depend on the PCB layout.

Package Pinout



Pin Descriptions

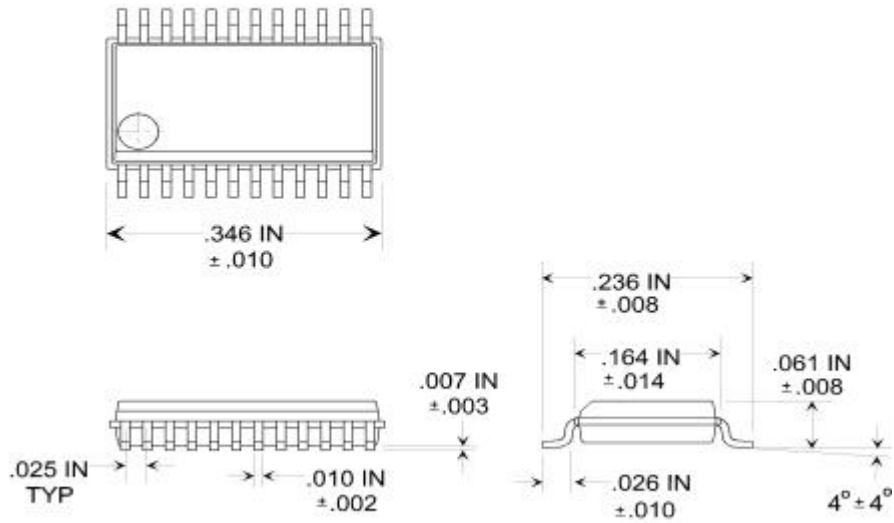
Pin Name	Pin #	Description and Usage
LNA GND 1900	1	High-band LNA first-stage ground connection. Direct connection to ground.
LNA IN 1900	2	High-band LNA input. DC blocked, requires external matching elements for noise match and match to 50Ω.
Vdd LNA 1900	4	High-band LNA supply voltage. Local bypass cap required.
MXR LO 1900	5	High-band Mixer LO input. Internally DC blocked. L3 required for 50Ω match.
Vdd MXR 1900	6	High-band Mixer LO buffer supply voltage. Local bypass cap required.
Vdd MXR 800	7	Low-band Mixer LO buffer supply voltage. Local bypass cap required.
MXR LO 800	8	Low-band Mixer LO input. Matched to 50Ω. Internally DC blocked.
Vdd LNA 800	9	Low-band LNA supply voltage. Local bypass cap required.
LNA IN 800	11	Low-band LNA input. DC blocked, requires external matching elements for noise match and match to 50Ω.
GND LNA 800	12	Low-band LNA first-stage ground connection. Connection to ground.
N/C	13	Open pin. No connection.
LNA OUT 800	14	Low-band LNA output. Matched to 50Ω. Internally DC blocked.

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MXR RF 800	16	Low-band Mixer RF input. Matched to 50 Ω , internally DC blocked.
MXR IF 800	18	Low-band Mixer IF output. Open-drain output. Connection to Vdd required, external matching is required.
MXR IF 1900	19	High-band Mixer IF output. Open-drain output. Connection to Vdd required, external matching is required.
IF TUNE	20	Half-IF tuning inductor to ground for optimum half-IF performance in the high-band mixer.
MXR RF 1900	21	High-band Mixer RF input. Matched to 50 Ω , internally DC blocked.
LNA OUT 1900	23	High-band LNA output. Matched to 50 Ω , internally DC blocked.
N/C	24	Open pin. No connection.
GND	3, 10, 15, 17, 22	Ground connection. Use several via holes immediately adjacent to the pins down to backside ground plane.

Package Type: Power QSOP-24 plastic Package

QSOP-24



Note: Dimensions include flash and mold mismatch.

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Data Sheet

Additional Information

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

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