PE4152 Mixer in LO Bypass Mode

Application Note 52

Peregrine Semiconductor

Summary

Peregrine Semiconductor's PE4152 quad metal-oxide-semiconductor field-effect transistor (MOSFET) mixer supersedes the PE4150 by offering integrated local oscillator (LO) enable and LO bypass modes. Importantly, the PE4152 provides a one-chip solution to customers who previously would have had to use two separate designs to achieve optimum performance. The PE4152 mixer operates from 100 to 1000 MHz (RF) and 200 to 900 MHz (LO) and delivers high linearity and superior LO-to-RF and LO-to-IF isolation levels of the bypassed LO amplifier relative to the enabled mode. Additionally, LO bypass mode results in lower power consumption. In LO bypass mode, the PE4152 is designed for LO power levels up to +23 dBm and exhibits a typical conversion loss of 8 dB. The PE4152 mixer is ideal for applications such as land-mobile-radio (LMR), portable radio, mobile radio, cellular infrastructure and set-top box (STB)/CATV systems.

Introduction

Peregrine Semiconductor's PE4152 is a high linearity mixer containing four MOSFETs in a quad configuration. It integrates a local oscillator (LO) buffer amplifier that allows LO drive levels of less than 0 dBm to produce third-order IIP3 values similar to those produced by a quad MOSFET array utilizing a 15 dBm LO drive. This configuration is ideal for portable radio applications. However, the LO buffer amplifier may limit the linearity for cellular infrastructure applications. The PE4152 features an integrated LO amplifier bypass option providing additional flexibility for low power or increased linearity operation.

This application note describes the PE4152 integrated LO amplifier bypass option for increased performance and presents test results based on the evaluation circuit shown.

Key Points

- The PE4152 supersedes the PE4150 by featuring an LO (buffer) bypass option.
- LO bypass mode results in lower power consumption.
- LO bypass mode offers improved linearity over non-bypass mode.
- LO bypass mode delivers superior isolation.
- LO bypass mode increases LO frequency selectivity.

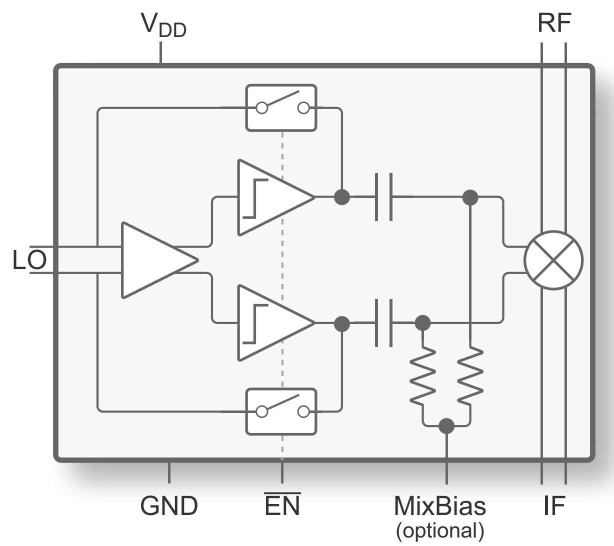
Product Overview

The PE4152 is a high linearity quad MOSFET mixer with an integrated LO amplifier. The LO amplifier allows for LO input drive levels of less than 0 dBm to produce IIP3 values similar to those produced by a quad MOSFET array utilizing a 15 dBm LO drive. The PE4152 operates with differential signals at the RF and IF ports and the integrated LO buffer amplifier drives the mixer core. The PE4152 can be used as an upconverter or a downconverter.

The PE4152 mixer also offers an integrated LO amplifier bypass option providing additional flexibility for low power or increased linearity operation. The bypassed LO amplifier allows superior LO to RF and LO to IF isolation levels relative to the enabled mode.

The PE4152 mixer is manufactured on Peregrine's UltraCMOS® process, a patented variation of silicon-on-insulator (SOI) technology on a sapphire substrate, offering the performance of gallium arsenide (GaAs) with the economy and integration of conventional CMOS.

Figure 1 • ***PE4152 Block Diagram***



LO Bypass Mode

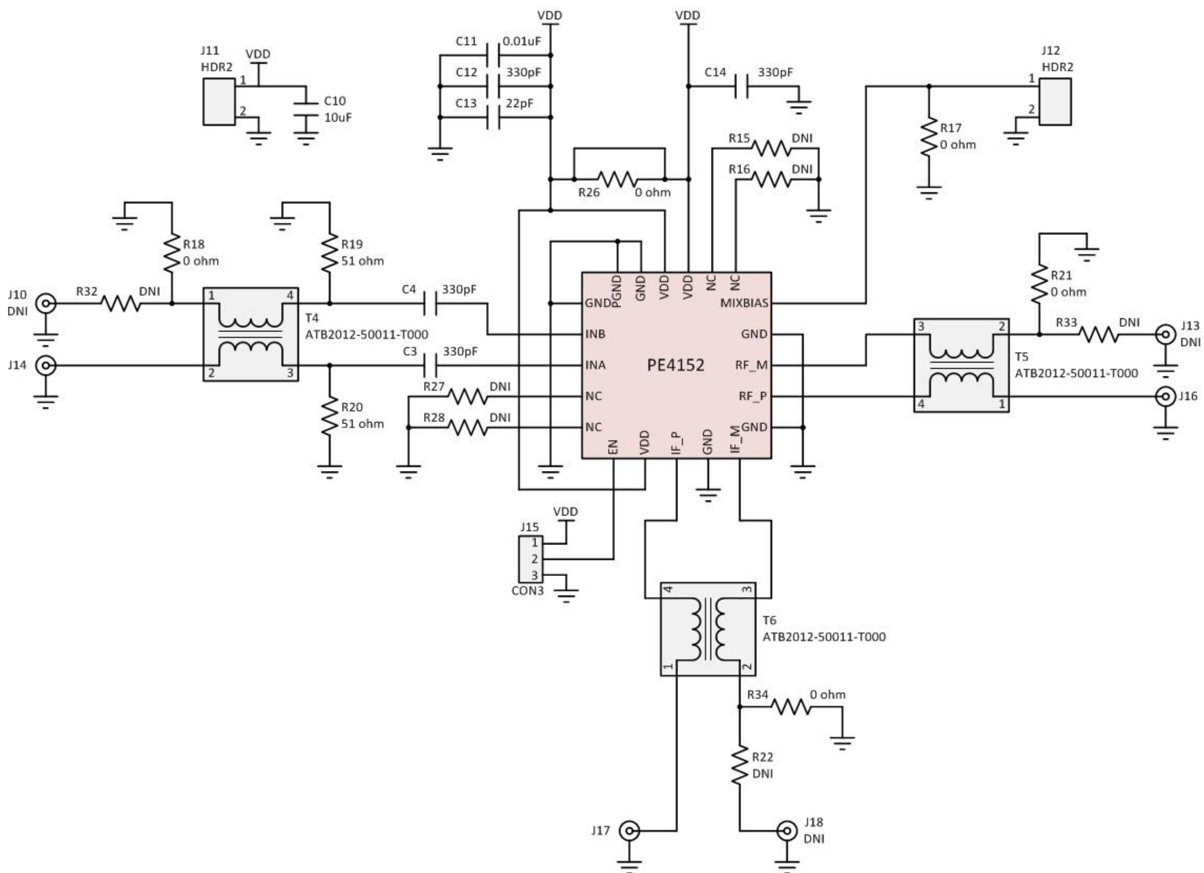
The PE4152 and PE4150 mixers have been characterized with RF signals from 100 to 1000 MHz and LO signals from 200 to 900 MHz and yield IF signals from 30 to 130 MHz. Both mixers include an LO buffer amplifier, but the PE4150 offers no LO buffer bypass capability. In LO bypass mode, the PE4152 is designed for LO power levels up to +23 dBm and exhibits a typical conversion loss of 8 dB. The typical input IP3 performance is +27 dBm. The LO-to-RF and LO-to-IF isolation are typically 60 dB, whereas the RF-to-IF isolation is typically 45 dB.

External baluns are used on the RF, LO and IF pins to provide unbalanced-balanced transformation to the differential ports. Selecting a balun with the best amplitude and phase balance will result in better common mode rejection. A 1:1 balun transformer was used to achieve maximum linearity. A higher-ratio balun may offer better amplitude and phase match, but increases the impedance and, therefore, the voltage to the device, causing compression to occur sooner.

Evaluation Schematic

Figure 2 shows the PE4152 evaluation schematic. The baluns selected are the ATB2012-50011 balun transformers from TDK. These wire-wound baluns offer acceptable amplitude and phase balance across the 100 to 1000 MHz frequency range (**Figure 3**). The LO bypass mode is selected by applying an active high signal to pin 6.

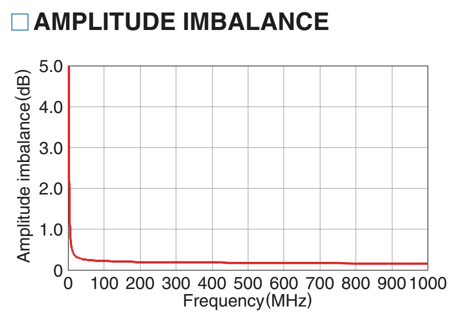
Figure 2 • ***PE4152 Evaluation Schematic***



Notes:

1) For PCB use PRT-60631-03.
2) Add jumper between pins 2 and 3 of J15.
3) Caution: Contains parts and assemblies susceptible to damage by electrostatic discharge (ESD).

Figure 3 • *Amplitude and Phase Balance Across the 100 to 1000 MHz Frequency Range*(*)



Note: * Graphs courtesy of the Frequency Characteristics section of the ATB series RF Components datasheet from TDK Corporation.

Evaluation Board

Figure 4 presents the evaluation board for the PE4152 mixer.

Figure 4 • *PE4152 Mixer Evaluation Board*

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Measured Results

Figure 5 through Figure 11 present the typical performance over temperature between the LO enable and bypass modes for the PE4152. The test conditions for the LO enable mode were V_{DD} = 3V, RF power = 2 dBm, LO power = –10 dBm and IF = 109.65 MHz. The same conditions were used for the LO bypass mode except for LO power of +23 dBm.

Improvement in power consumption is demonstrated in Figure 5, indicating the LO buffer amplifier typically draws 10 mA of current. Figure 6 presents conversion loss. Figure 7 and Figure 8 demonstrate the improvement in linearity. Most notable is the superior LO-to-RF and LO-to-IF isolation levels of the bypassed LO amplifier relative to the enabled mode as indicated in Figure 9 and Figure 10. Figure 11 presents RF-IF isolation.

Figure 5 • *IDD*

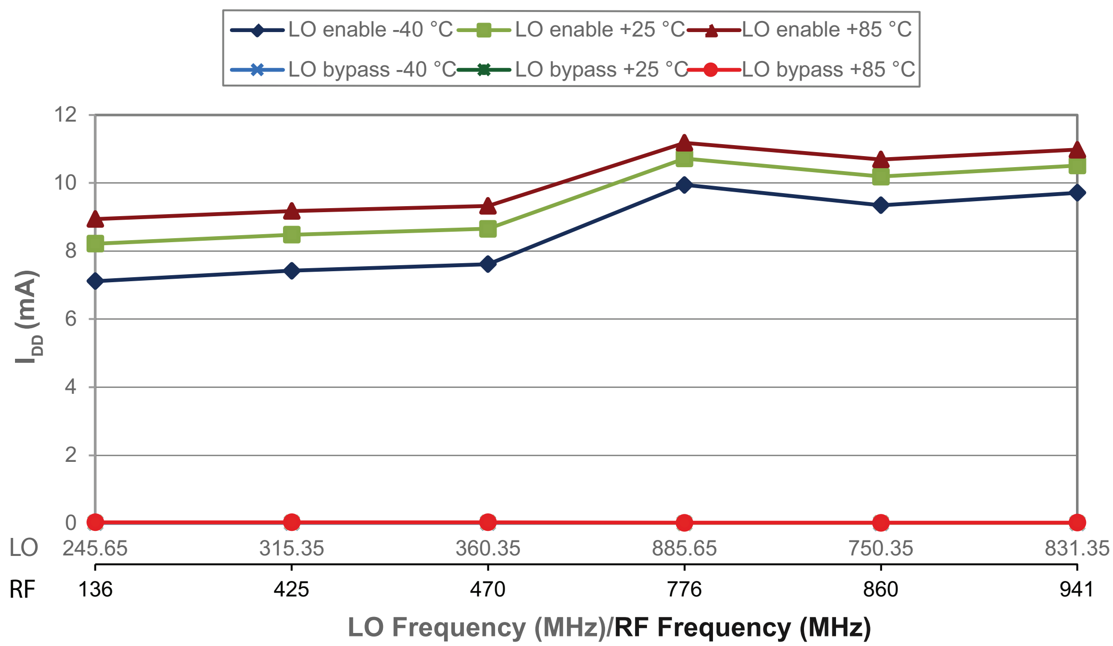


Figure 6 • *Conversion Loss*

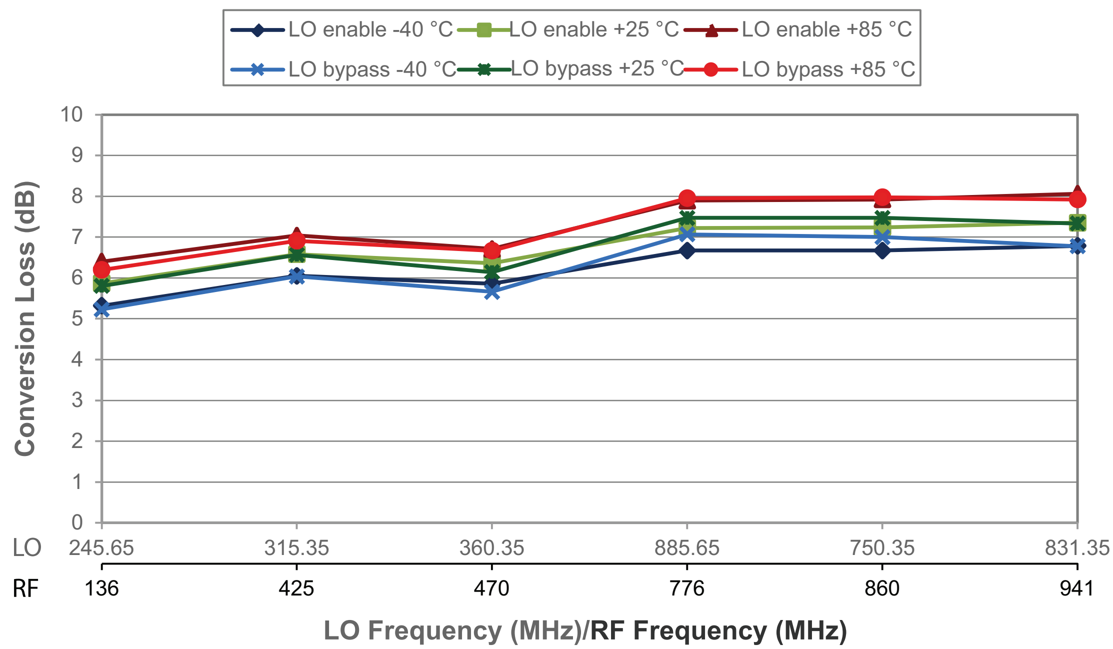


Figure 7 • *IIP3*

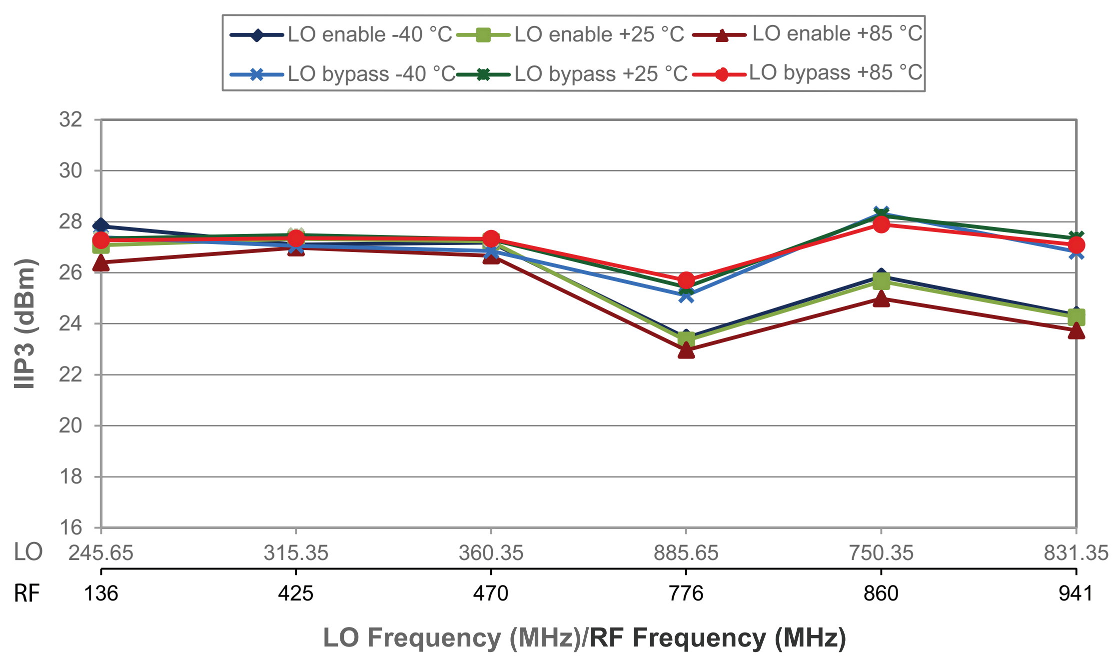


Figure 8 • *IIP2*

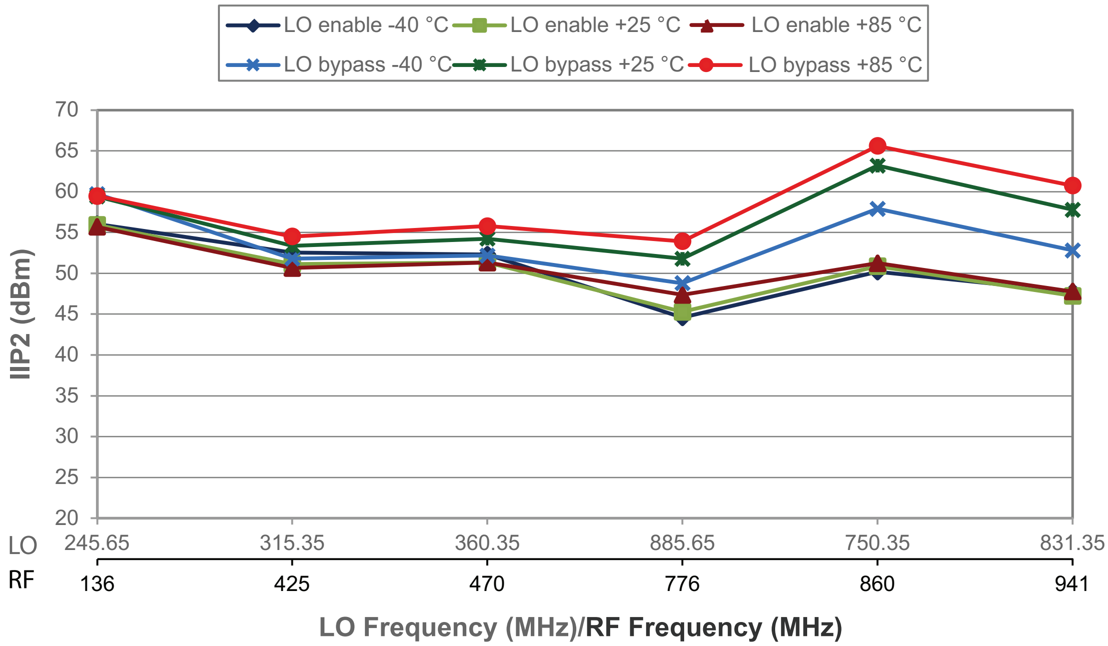


Figure 9 • *LO to RF Isolation*

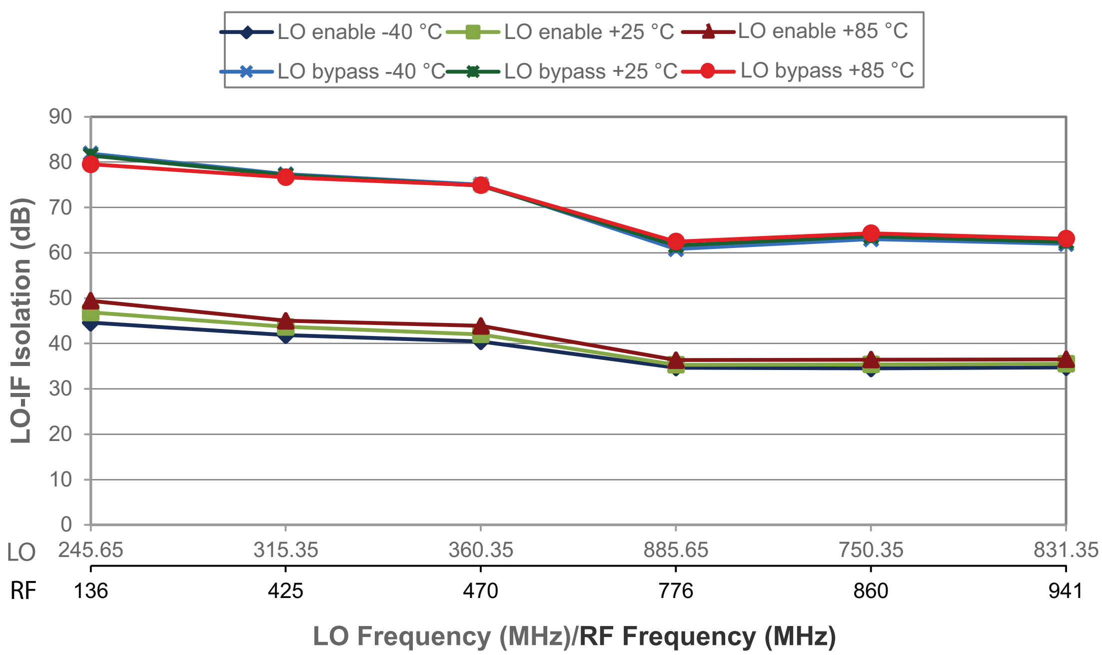


Figure 10 • *LO to IF Isolation*

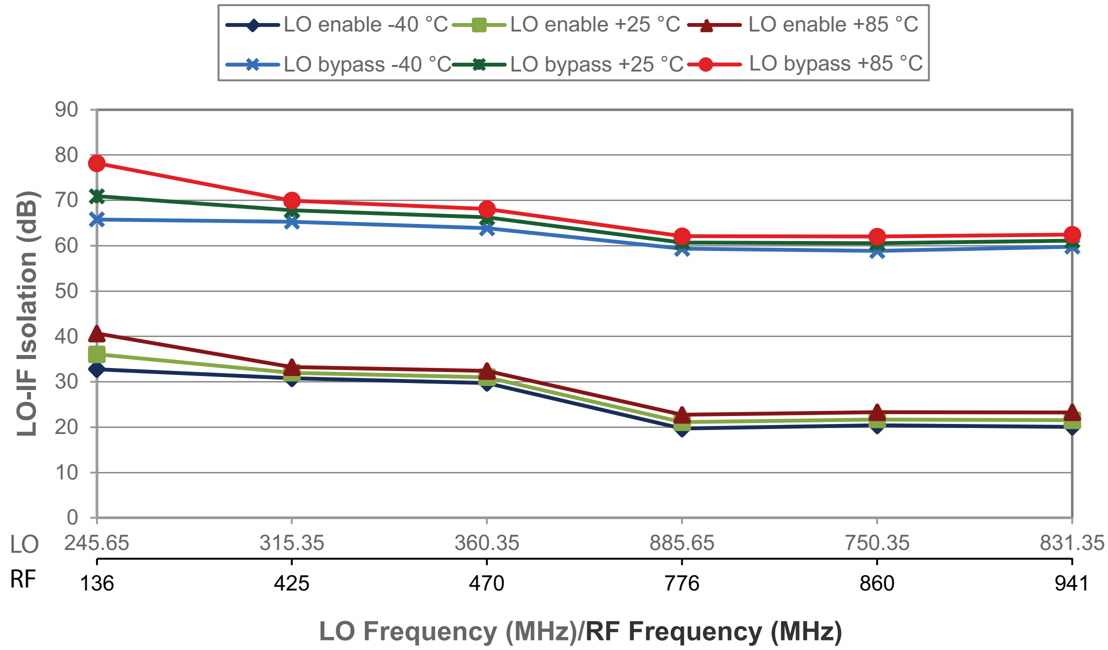
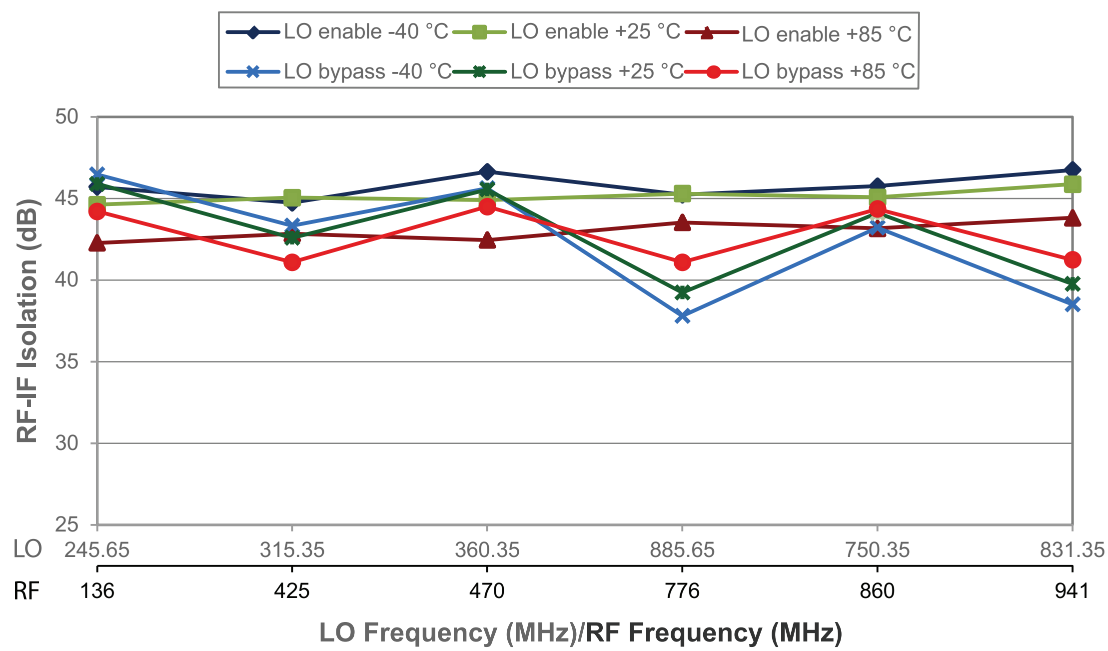


Figure 11 • *RF to IF Isolation*



Reciprocal Mixing and Blocker Noise Performance

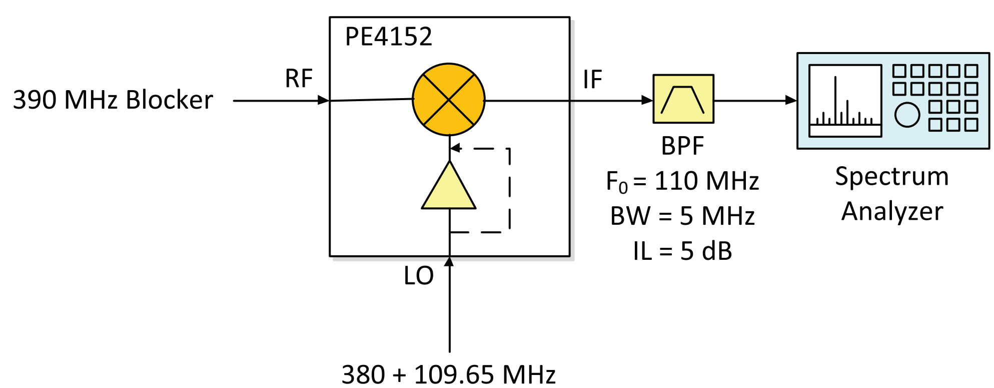
Reciprocal mixing occurs when a blocker enters the mixer and mixes with the LO phase noise that is near the frequency of the blocker. Reciprocal mixing can increase noise and distortion, thus reducing the SNR performance of the receiver.

Desensitization is the measure of a receiver's ability to reject signals that are offset from the desired signal's frequency.[1] Receiver desensitization as a result of an interfering signal is an important parameter for any receiver. In order to meet the TIA[2] interference reference standards, the input referred noise at the mixer must remain less than a specified level in the presence of a blocker. The PE4152 offers excellent blocker rejection performance.

The test setup for the PE4152 in Figure 12 is used to demonstrate the noise floor increase as a result of reciprocal mixing from the LO into the IF band with a blocking signal 10 MHz away from the main signal. The IF power measurements are made on a spectrum analyzer downstream from the band pass filter (BPF), which is used at the IF port to suppress the 99.65 MHz tone from the mixer output. A worst-case mixer conversion loss of 8 dB is used to refer the IF power back to the RF input.

Notes:
1) Motorola's Interference Technical Appendix, Issue 1.41 (February 2002).
2) Telecommunications Industry Association.

Figure 12 • ***PE4152 Test Setup of IF Output with Blocker Interferer Present at RF Port*** [*]



Note: * +10 MHz CW Blocker, LO = 489.65 MHz, IF = 109.65 MHz.

Table 1 shows the increase in the noise floor as a result of the blocker signal for different power levels. Note that the filter insertion loss has been included in the spectrum analyzer offset.

Table 1 • *PE4152 Noise Performance Results in the Presence of a Blocker* (*)

Mode	LO Power (dBm)	RF/Blocker (dBm)	IF Power (dBm)	RF Referred (dBm)
LO Enable	OFF	OFF	–167	
	–7	–19 –16 –13 –10 –7 –4 –1 2	–152.8 –151.6 –151.2 –148.9 –147.4 –147.1 –144.5 –142.4	–144.8 –143.6 –143.2 –140.9 –139.4 –139.1 –136.5 –134.4
LO Bypass	23	–19 –16 –13 –10 –7 –4 –1 2	–151.1 –149.9 –148.2 –147.8 –147.9 –144.2 –144.9 –140.8	–143.1 –141.9 –140.2 –139.8 –139.9 –136.2 –136.9 –132.8

Note: * Noise performance results in the presence of a blocker @ +25 °C, V_{DD} = 3V, unless otherwise specified.

Absolute Maximum Ratings

Exceeding absolute maximum ratings listed in Table 2 may cause permanent damage. Operation should be restricted to the limits listed in Table 3. Operation between operating range maximum and absolute maximum for extended periods may reduce reliability.

ESD Precautions

When handling the PE4152 UltraCMOS device, observe the same precautions as with any other ESD-sensitive device. Although the PE4152 mixer contains circuitry to protect it from damage owing to ESD, precautions should be taken to avoid exceeding the rating specified in Table 2.

Latch-Up Immunity

Unlike conventional CMOS devices, UltraCMOS devices are immune to latch-up.

Table 2 • *Absolute Maximum Ratings for PE4152*

Parameter/Condition	Min	Max	Unit
Supply voltage, V_{DD}		4.0	V
Maximum DC plus peak AC across drain-source		±3.3	V
Maximum DC current across drain-source		6	mA
Maximum AC current across drain-source		36	mA_{P-P}
Storage temperature range	–65	+150	°C
Operating junction temperature		+125	°C
ESD voltage HBM, all pins(*)		1000	V
Note: * Human body model (MIL-STD 883 Method 3015).			

Recommended Operating Conditions

Table 3 lists the recommending operating conditions for the PE4152 mixer. The PE4152 mixer should not be operated outside these parameters.

Table 3 • *Recommended Operating Conditions for PE4152*

Parameter	Min	Typ	Max	Unit
Supply voltage, V_{DD}	2.9		3.1	V
Operating temperature range	–40		+85	°C
LO input power (LO enable)	–10		–6	dBm
LO input power (LO bypass)			23	dBm
RF input power (LO enable)			2	dBm
RF input power (LO bypass)			2	dBm

Electrical Specifications

Table 4 and Table 5 provide the PE4152 key electrical specifications @ +25 °C, V_{DD} = 3.0V, unless otherwise specified.

Table 4 • *PE4152 Electrical Specifications—LO Enable Mode*

Parameter	Condition	Min	Typ	Max	Unit
LO enable mode					
Current drain	A function of frequency		9.5	13.5	mA
Off state leakage current				20	µA
RF input frequency	VHF band UHF1 band UHF2 band 700 MHz 800 MHz 900 MHz	136 380 450 764 851 935		174 470 520 776 870 941	MHz MHz MHz MHz MHz MHz
LO frequency	VHF band UHF1 band UHF2 band 700 MHz 800 MHz 900 MHz	245.65 270.35 340.35 873.65 741.35 825.35		283.65 360.35 410.35 885.65 760.35 831.35	MHz MHz MHz MHz MHz MHz
IF output frequency			109.65		MHz
LO input power		–10		–6	dBm
RF input power				2	dBm
Conversion loss(1)	VHF, UHF1, UHF2 700, 800 and 900 MHz		6.5 7.5	8.0 8.7	dB dB
Input IP3(2)		20	25		dBm
Input IP2(3)	VHF, UHF1, UHF2 700, 800 and 900 MHz	41 35	52 50		dBm dBm
RF to IF isolation(4)	VHF, UHF1, UHF2 700, 800 and 900 MHz	35 25	45 45		dB dB
LO to IF isolation		18	30		dB
LO to RF isolation		25	30		dB

Notes:
1) Measured with a 1:1 balun on the RF and IF ports.
2) Measured with two tones at 2 dBm, 100 kHz spacing.
3) Measured with half-IF method.
4) Measured with an input frequency equal with IF.

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Table 5 • *PE4152 Electrical Specifications—LO Bypass Mode*

Parameter	Condition	Min	Typ	Max	Unit
LO bypass mode					
Off state leakage current			20		µA
RF input frequency	VHF band UHF1 band UHF2 band 700 MHz 800 MHz 900 MHz	136 380 450 764 851 935		174 470 520 776 870 941	MHz MHz MHz MHz MHz MHz
LO frequency	VHF band UHF1 band UHF2 band 700 MHz 800 MHz 900 MHz	245.65 270.35 340.35 873.65 741.35 825.35		283.65 360.35 410.35 885.65 760.35 831.35	MHz MHz MHz MHz MHz MHz
IF output frequency			109.65		MHz
LO input power				23	dBm
RF input power				2	dBm
Conversion loss(1)	VHF, UHF1, UHF2 700, 800 and 900 MHz		6.5 7.5	8.0 8.7	dB dB
Input IP3(2)	VHF, UHF1, UHF2 700, 800 and 900 MHz	24 19	26 24		dBm dBm
Input IP2(3)	VHF, UHF1, UHF2 700, 800 and 900 MHz		46 46		dBm dBm
RF to IF isolation(4)	VHF, UHF1, UHF2 700, 800 and 900 MHz		38 38		dB dB
LO to IF isolation		30	58		dB
LO to RF isolation		35	60		dB

Notes:

1) Measured with a 1:1 balun on the RF and IF ports.
2) Measured with two tones at 2 dBm, 100 kHz spacing.
3) Measured with half-IF method.
4) Measured with an input frequency equal with IF.

Pin Information

This section provides pinout information for the PE4152 mixer. Figure 13 shows the PE4152 pin configuration map for the available package. Table 6 provides a description for each pin.

Figure 13 • *Pin Configuration (Top View)*

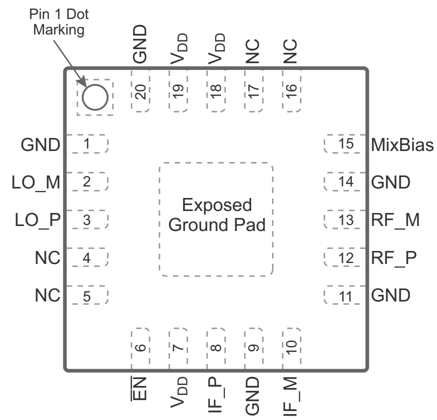


Table 6 • *Pin Descriptions for PE4152*

Pin No.	Pin Name	Description
1, 9, 11, 14, 20	GND	Ground
2	LO_M	Minus LO output
3	LO_P	Positive LO output
4, 5, 16, 17	NC	No connect
6	$\overline{EN}$	LO enable (active low)
7, 18, 19	V_{DD}	Supply voltage
8	IF_P	Positive IF port
10	IF_M	Minus IF port
12	RF_P	Positive RF input
13	RF_M	Minus RF port
15	MixBias(*)	External mixer bias
Pad	GND	Exposed pad: ground for proper operation

Note: * For applications where the DC level of the RF and IF ports are not at 0V, the MixBias pin can be set to the equivalent DC bias level. For example, if the RF and IF signals are biased at 1 VDC, a 1V level can be applied to the MixBias pin. This will maintain the RF performance similar to the 0V case. The MixBias pin can be used in both LO states.

Packaging Information

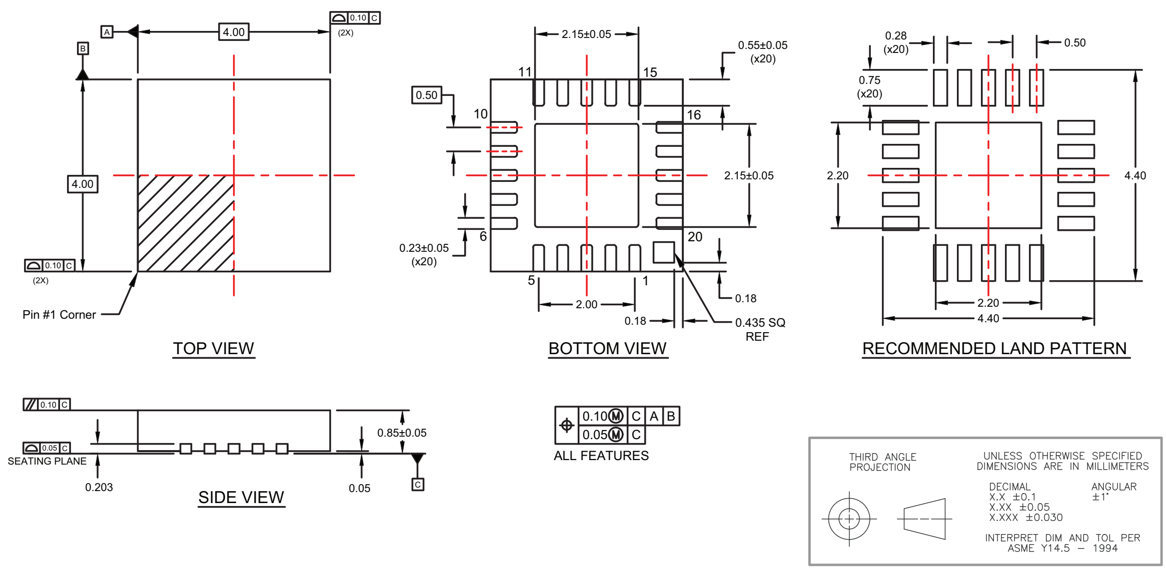
This section provides packaging data including the moisture sensitivity level, package drawing and package marking information.

Moisture Sensitivity Level

The moisture sensitivity level rating for the PE4152 in the green 20-lead 4 × 4 × 0.85 mm QFN package is MSL3.

Package Drawing

Figure 14 • *Package Mechanical Drawing for Green 20-lead 4 × 4 × 0.85 mm QFN*



Top Marking Specification

Figure 15 • *Package Marking Specifications for PE4152*

● = Pin 1 indicator
YY = Last two digits of assembly year
WW = Assembly work week
ZZZZZZ = Assembly lot code (maximum six characters)

Conclusion

Peregrine Semiconductor's PE4152 Quad MOSFET mixer supersedes the PE4150 by offering integrated LO enable and LO bypass modes. Importantly, the PE4152 provides a one-chip solution to customers who previously would have had to use two separate designs to achieve optimum performance. The PE4152 mixer delivers high linearity and superior LO-to-RF and LO-to-IF isolation levels of the bypassed LO amplifier relative to the enabled mode. The PE4152 is ideal for applications such as LMR, portable radio, mobile radio, cellular infrastructure and STB/CATV systems.

Sales Contact

For additional information, contact Sales at sales@psemi.com.