PE4152

Mixer in LO Bypass Mode

Application Note 52

Summary

The pSemi PE4152 quad metal-oxide-semiconductor field-effect transistor (MOSFET) mixer supersedes the pSemi PE4150 by offering integrated local oscillator (LO) enable and LO bypass modes. 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 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, set-top box (STB), and CATV systems.

Introduction

The pSemi PE4152 is a high-linearity mixer containing four MOSFETs in a quad configuration. It integrates an LO buffer amplifier that allows LO drive levels of less than 0 dBm to produce third-order IIP3 values like those produced by a quad MOSFET array using a 15-dBm LO drive. This configuration is ideal for portable radio applications. However, the LO buffer amplifier could limit the linearity for cellular infrastructure applications, so the PE4152 features an integrated LO amplifier bypass option, which provides 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 schematic shown in **Figure 2**.

Key Points

- The pSemi PE4152 supersedes the pSemi 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 the LO frequency selectivity.

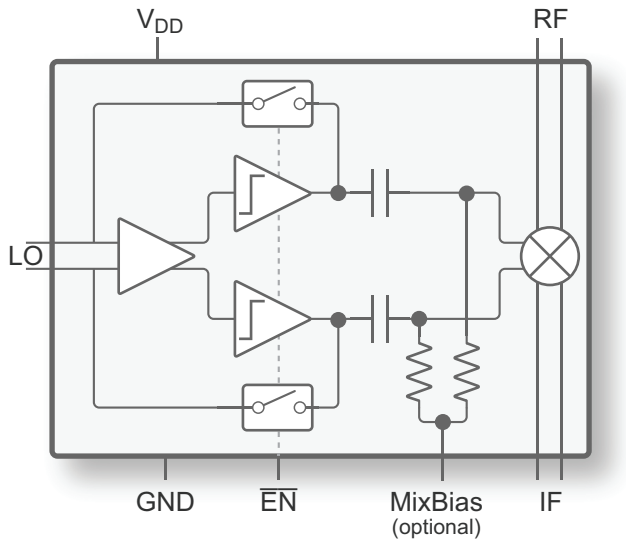
Product Overview

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 using 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, which provides 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 using the pSemi 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

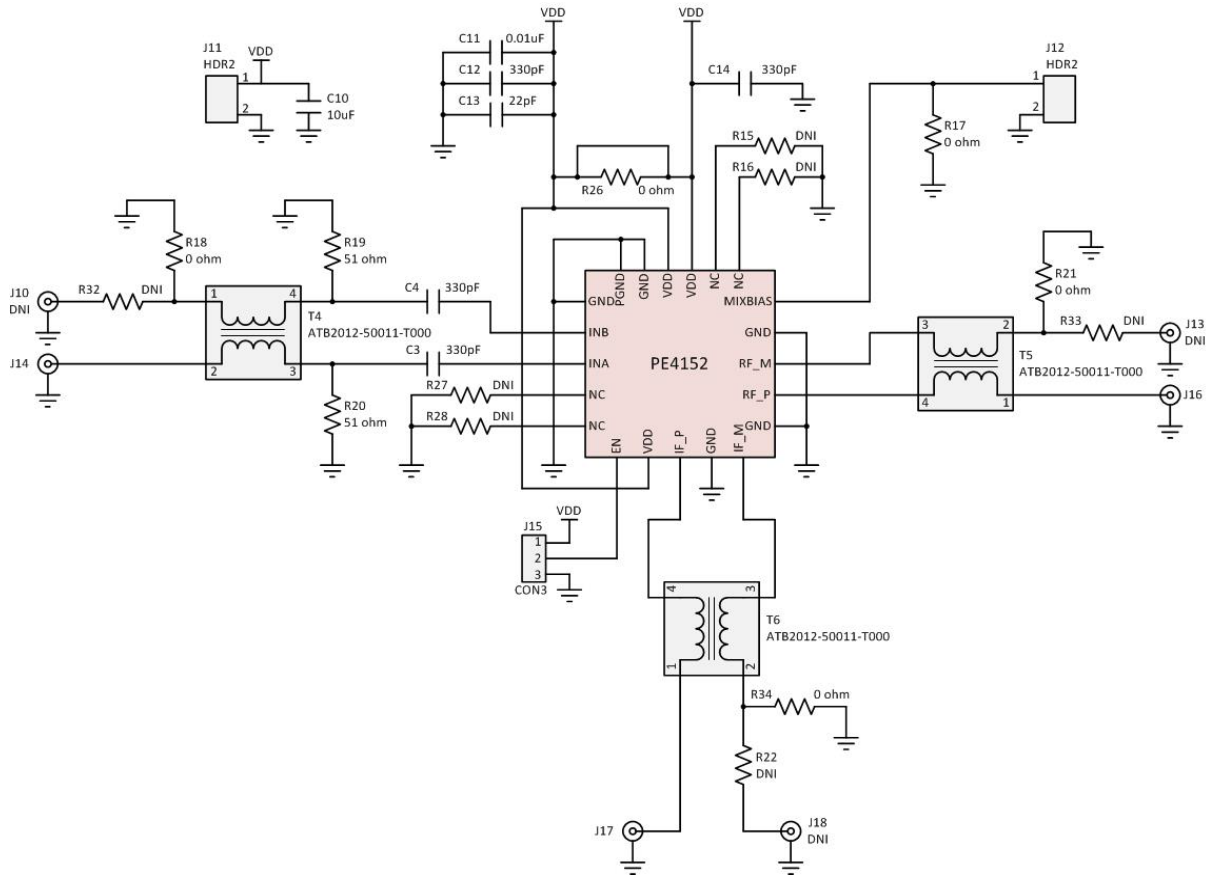
The pSemi PE4152 and PE4150 mixers have been characterized with RF signals from 100 to 1000 MHz, LO signals from 200 to 900 MHz, and yield IF signals from 30 to 130 MHz. Both mixers include an LO buffer amplifier, but the PE4150 has no LO buffer bypass capability. In LO bypass mode, the PE4152 is designed 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, and 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 results in better common mode rejection. A 1:1 balun transformer was used to achieve maximum linearity. A higher-ratio balun can 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 TDK ATB2012-50011 balun transformers. These wire-wound baluns offer acceptable amplitude and phase balance across the 100 to 1000 MHz frequency range, as shown in **Figure 3**. To select LO bypass mode, apply an active high signal to pin 6 (LO enable).

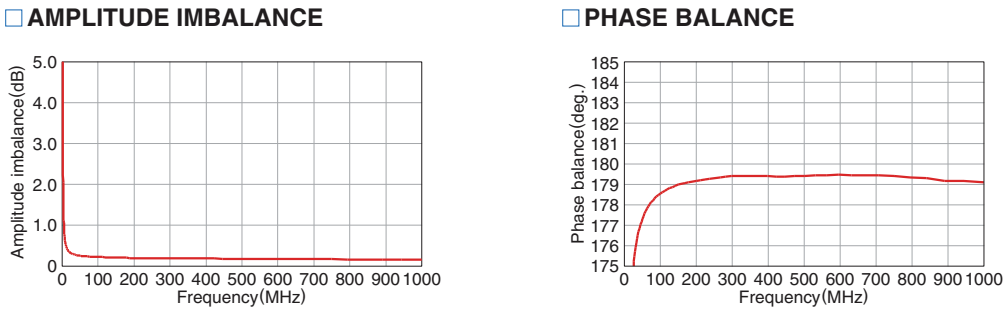
Figure 2 • PE4152 Evaluation Schematic



Notes:

1) For the PCB, use PRT-60631-03.
2) Add a jumper between pins 2 and 3 of J15.
3) Warning: 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[*]

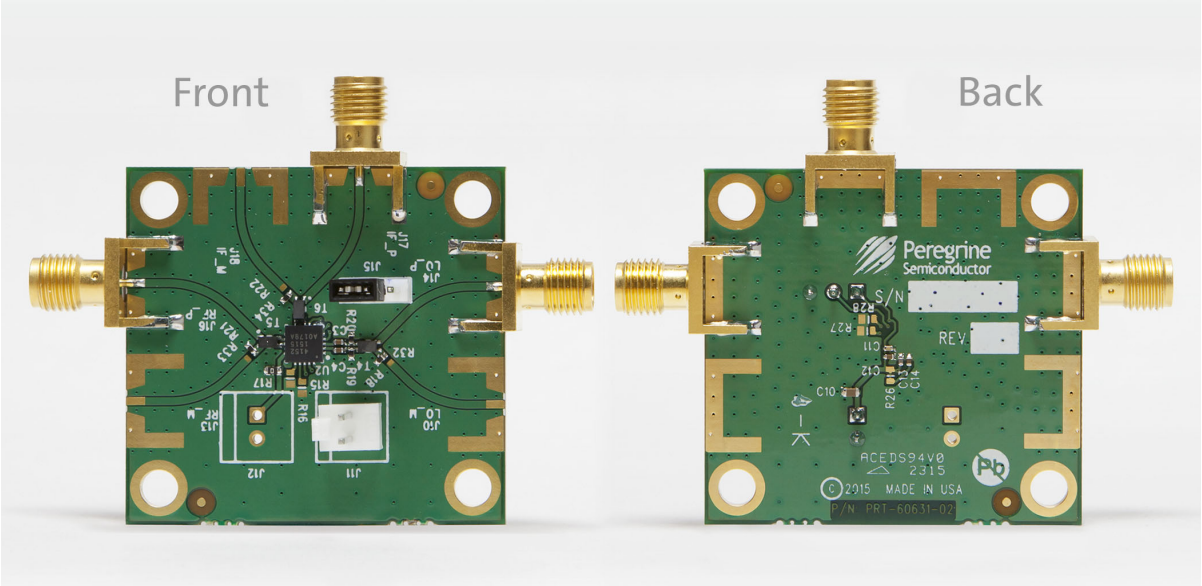


Note: * Graphs are courtesy of the Frequency Characteristics section of the ATB series RF Components data sheet from TDK Corporation.

Evaluation Board

Figure 4 shows the PE4152 evaluation board.

Figure 4 • PE4152 Mixer Evaluation Board



Measured Results

Figure 5 through **Figure 11** show the typical performance over temperature between the PE4152 LO enable and bypass modes. The test conditions for the LO enable mode were the following:

- V_{DD} = 3V
- RF power = 2 dBm
- LO power = –10 dBm
- IF = 109.65 MHz

The same conditions were used for LO bypass mode, except for an LO power of +23 dBm.

Figure 5 shows an improvement in power consumption, and indicates that the LO buffer amplifier typically draws 10 mA of current. **Figure 6** shows the conversion loss. **Figure 7** and **Figure 8** show 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 shown in **Figure 9** and **Figure 10**. **Figure 11** shows the RF-to-IF isolation.

Figure 5 • IDD

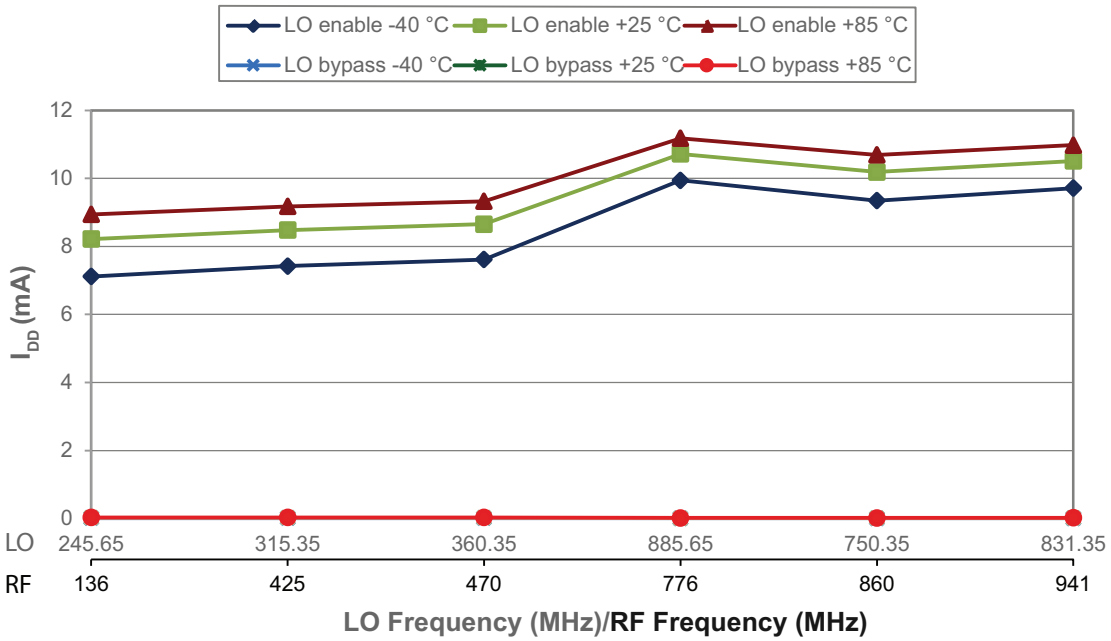


Figure 6 • Conversion Loss

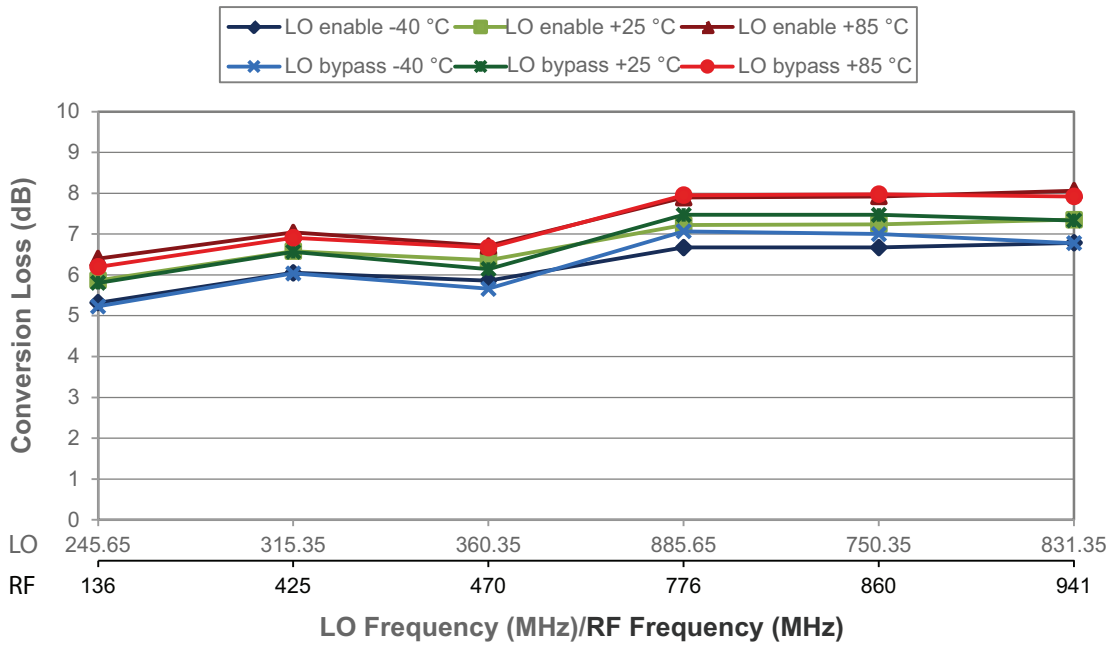


Figure 7 • IIP3

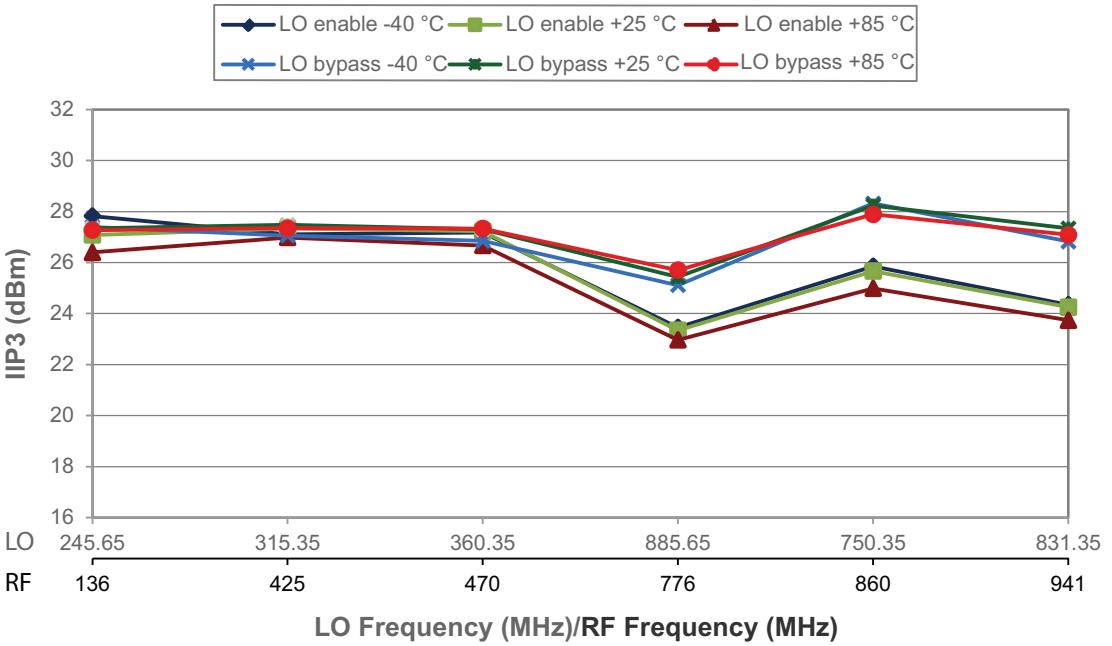


Figure 8 • IIP2

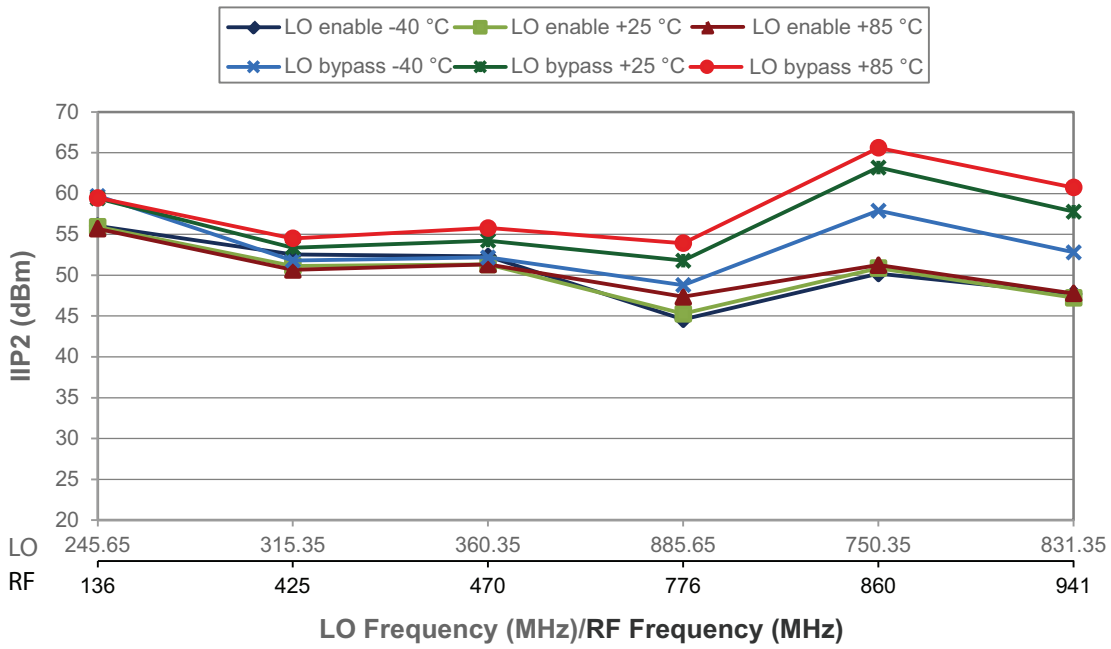


Figure 9 • LO-to-RF Isolation

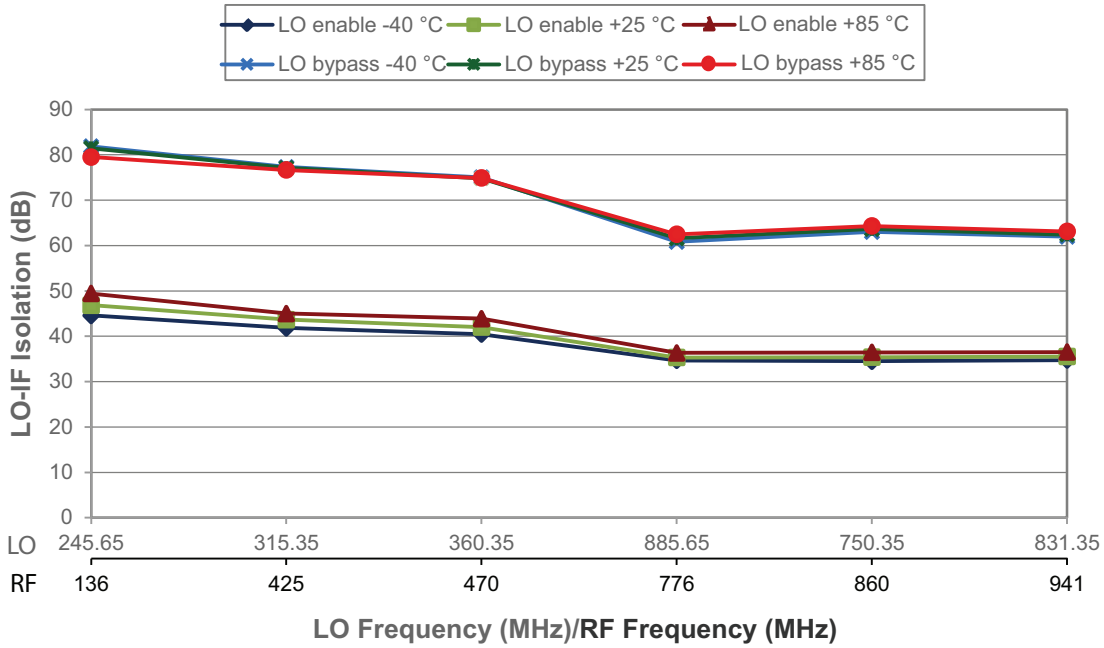


Figure 10 • LO-to-IF Isolation

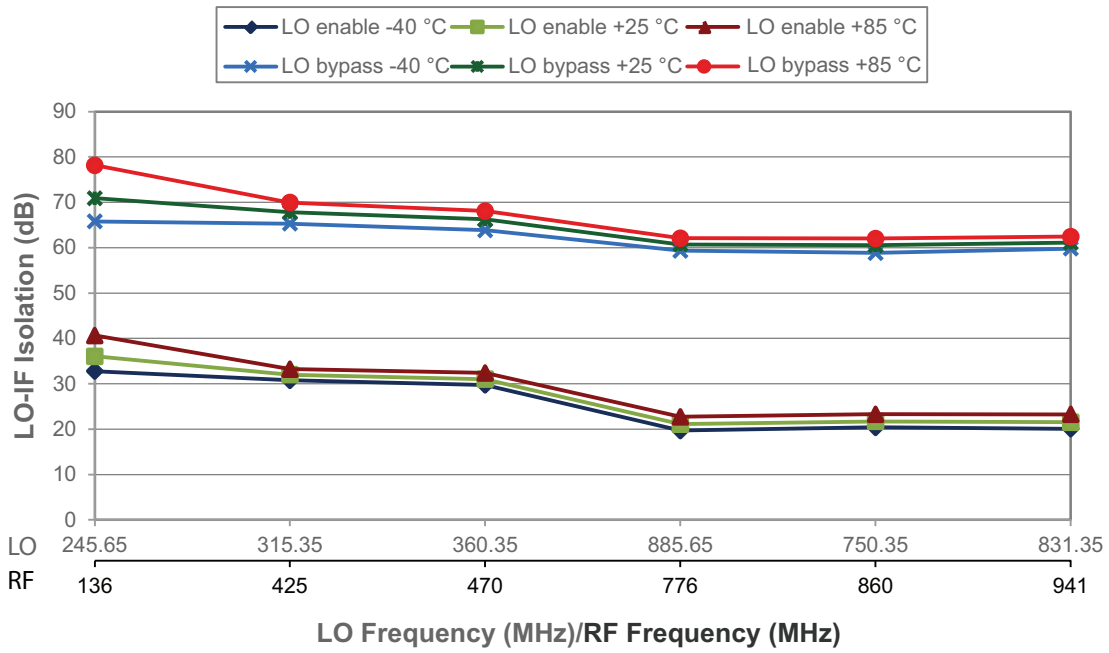
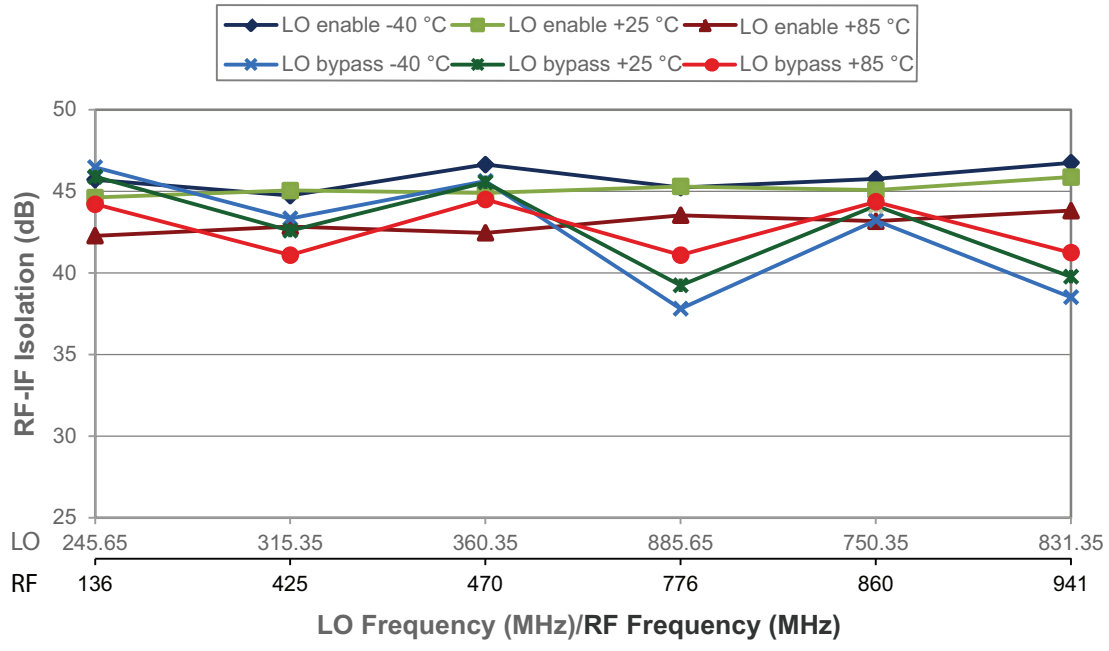


Figure 11 • RF-to-IF Isolation



Reciprocal Mixing and Blocker Noise Performance

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

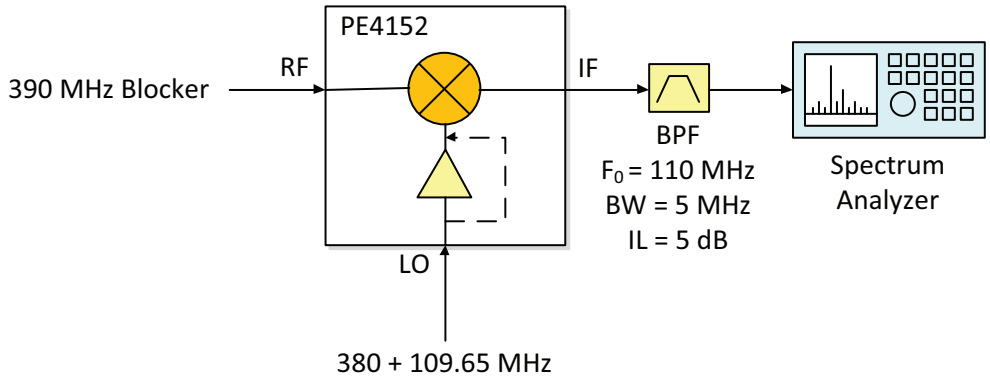
Desensitization is the measure of a receiver's ability to reject signals offset from the preferred signal's frequency.(1) Receiver desensitization as a result of an interfering signal is an important parameter for any receiver. To meet the TIA(2) interference reference standards, the input referred noise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

The PE4152 test setup in **Figure 12** shows 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 the 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. The filter insertion loss was 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	–152.8	–144.8
		–16	–151.6	–143.6
		–13	–151.2	–143.2
		–10	–148.9	–140.9
		–7	–147.4	–139.4
		–4	–147.1	–139.1
		–1	–144.5	–136.5
		2	–142.4	–134.4
LO Bypass	23	–19	–151.1	–143.1
		–16	–149.9	–141.9
		–13	–148.2	–140.2
		–10	–147.8	–139.8
		–7	–147.9	–139.9
		–4	–144.2	–136.2
		–1	–144.9	–136.9
		2	–140.8	–132.8

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

Absolute Maximum Ratings

Exceeding the absolute maximum ratings listed in **Table 2** could cause permanent damage. Restrict operation to the limits listed in **Table 3**. Operation between the operating range maximum and the absolute maximum for extended periods could 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, do not exceed the rating specified in **Table 2**.

Latch-Up Immunity

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

Table 2 • PE4152 Absolute Maximum Ratings

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 PE4152 recommending operating conditions. Do not operate the PE4152 outside these parameters.

Table 3 • PE4152 Recommended Operating Conditions

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** list the PE4152 key electrical specifications at +25 °C and V_{DD} = 3.0V, unless otherwise specified.

Table 4 • PE4152 Electrical Specifications for LO Enable Mode

Parameter	Condition	Min	Typ	Max	Unit
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
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
IF output frequency	–	–	109.65	–	MHz
LO input power	–	–10	–	–6	dBm
RF input power	–	–	–	2	dBm
Conversion loss(1)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	–	6.5 7.5	8.0 8.7	dB
Input IP3(2)	–	20	25	–	dBm
Input IP2(3)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	41 35	52 50	–	dBm
RF to IF isolation(4)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	35 25	45 45	–	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 with 100 kHz spacing.
3) Measured using the half-IF method.
4) Measured with an input frequency equal to the IF.

Table 5 • PE4152 Electrical Specifications for LO Bypass Mode

Parameter	Condition	Min	Typ	Max	Unit
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
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
IF output frequency	–	–	109.65	–	MHz
LO input power	–	–	–	23	dBm
RF input power	–	–	–	2	dBm
Conversion loss(1)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	–	6.5 7.5	8.0 8.7	dB
Input IP3(2)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	24 19	26 24	–	dBm
Input IP2(3)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	–	46 46	–	dBm
RF to IF isolation(4)	VHF, UHF1, and UHF2 700, 800, and 900 MHz	–	38 38	–	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 with 100 kHz spacing.
3) Measured using the half-IF method.
4) Measured with an input frequency equal to the IF.

Pin Information

Figure 13 shows the PE4152 pin configuration map for the 20-lead 4 × 4 × 0.85 mm QFN package, and **Table 6** lists the description for each pin.

Figure 13 • Pin Configuration (Top View)

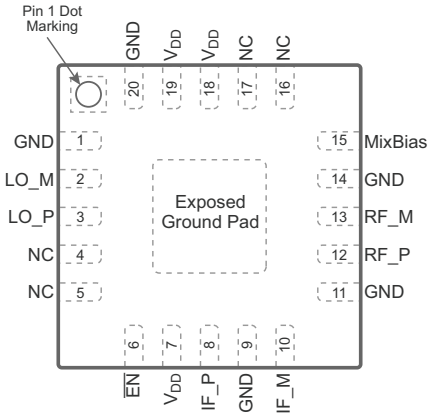


Table 6 • PE4152 Pin Descriptions

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 in which the DC level of the RF and IF ports are not at 0V, the MixBias (pin 15) 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 maintains the RF performance like the 0V case. The MixBias pin can be used in both LO states.

Packaging Information

This section provides the following packaging data:

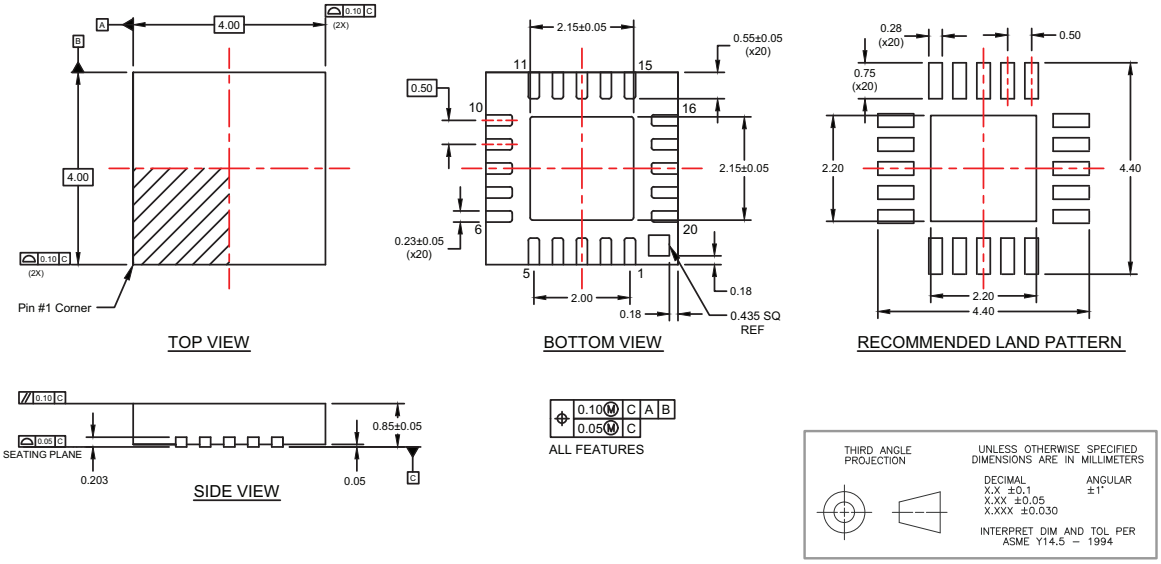
- Moisture sensitivity level
- Package drawing
- Package marking information

Moisture Sensitivity Level

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

Package Drawing

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



Top Marking Specification

Figure 15 • PE4152 Package Marking Specifications

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

Conclusion

The pSemi PE4152 Quad MOSFET mixer supersedes the pSemi PE4150 by offering integrated LO enable and LO bypass modes. 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, STB, and CATV systems.

Sales Contact

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

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