Silicon Radar GmbH
Im Technologiepark 1
15236 Frankfurt (Oder)
Germany

fon +49.335.557 17 74
fax +49.335.557 10 50
https://www.siliconradar.com

TRX_024_006

24-GHz Highly Integrated IQ Transceiver

Data Sheet

Status:	Date:	Author:	Filename:	
Final	2018-09-28	Silicon Radar GmbH	Datasheet_TRX_024_006_V2.1	
Version: 2.1	Product number: TRX_024_006	Package: QFN20, 3 × 3 mm²	Marking: TRX006 YYWW	Page: 1 of 16

Version Control

Version	Changed section	Description of change	Reason for change
1.6	Product name	Changed from TRX_024_06 to TRX_024_006	New procedure for product nomenclature
	Status	From preliminary to final	Product released to serial production
	Max Ratings	ESD integrity updated	New test results
1.7	Specification	Spec data revised	Routinely revision
1.8	Package Dimensions	IC weight added	Customer request
1.9	Specification	IQ imbalance and thermal resistance values changed	Correction
2.0	Overview	Typos fixed	Routinely revision
	Electrical Characteristics	Level of logic input specified	Correction
	Measurements Results	Diagram TX power vs. Temperature added Description of analog behavior of inputs d0 – d3 added	New test results
2.1	3.2 Pin Description	Table 1: LNA-gain control input voltage corrected	Correction
	6.2 Power Cycling	Application hint added	Update
	6.4 Evaluation Kit	Reference to Silicon Radar's evaluation kit SiRad Easy®	Update
	7 Meas. Results	Figure 10: Name of x-axis corrected, Figure 12: Name of data series corrected	Correction

Table of Contents

1 Features

- Radar transceiver for 24-GHz ISM band
- Single supply voltage of 3.3 V
- Fully ESD protected device
- Low power consumption of 300 mW in continuous operating mode
- Transmitter with power control in two steps
- Receiver with homodyne quadrature mixers
- Low-noise amplifier (LNA) with gain control
- Integrated low phase noise push-push VCO
- Divider division ratio 1:32 (1:8 available in TRX_024_007)
- Single ended TX output
- Single ended RX input
- QFN20 leadless plastic package 3 × 3 mm^2
- Pb-free, RoHS compliant package
- IC is available as bare die as well

1.1 Overview

The IC is an integrated transceiver circuit for the 24-GHz ISM band in the frequency range 24.0 GHz – 24.25 GHz. It includes a low-noise amplifier (LNA) with gain control, quadrature mixers, a poly-phase filter, a voltage controlled oscillator with band switching and a divide-by-32 circuit. The transmitter can be powered down if TX_EN pin is supplied with 0 V. The gain of the receiver can be digitally controlled by Vct pin: Vct = 3.3 V sets the receiver in high gain mode, Vct = 0 V sets the receiver in low gain mode. The output power of the transmitter can be controlled by the pwr1 input. The IC is fabricated in SiGe BiCMOS technology.

Beside the TRX_024_006, an IC variant with a divider division ratio of 1:8 is available as TRX_024_007.

1.2 Applications

The TRX_024_006 can be used in wireless communication systems and in radar systems for the ISM band from 24.0 GHz to 24.25 GHz and for UWB applications between 23 GHz and 26 GHz.

2 Block Diagram

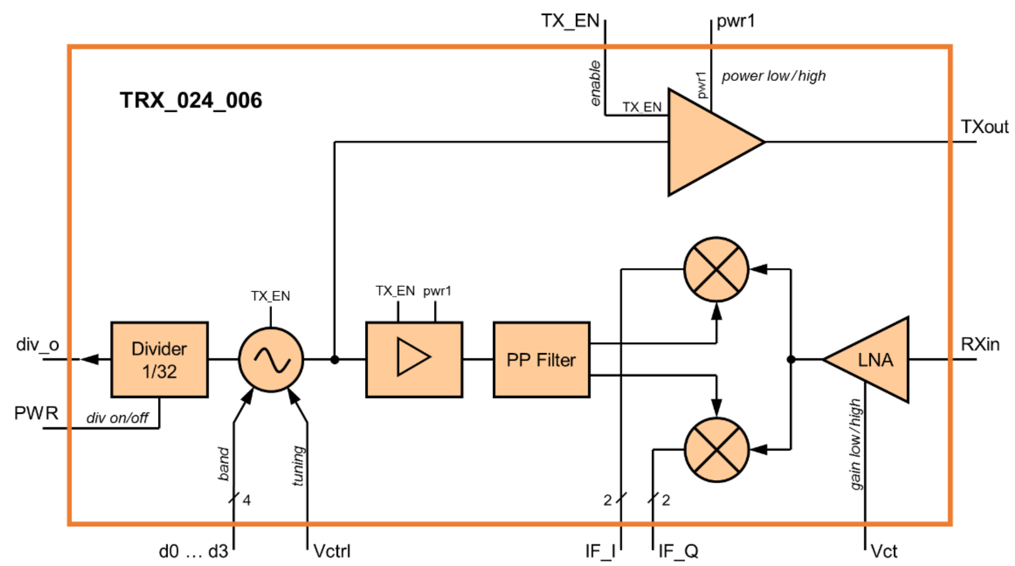


Figure 1 Block Diagram

3 Pin Configuration

3.1 Pin Assignment

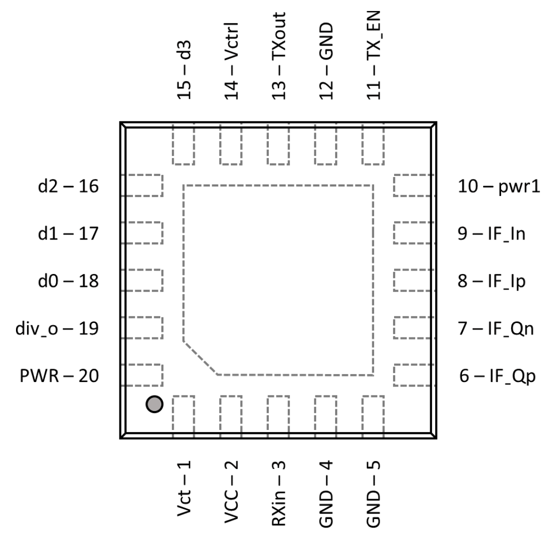


Figure 2 Pin Assignment (QFN20, Top View)

3.2 Pin Description

Table 1 Pin Description

Pin		Description
No.	Name	
1	Vct	LNA gain control input, with internal 100-kΩ pull-up resistor: 3.3 V – high gain mode, 0 – low gain mode
2	VCC	Supply voltage
3	RXin	RF input, 50 Ω
4, 5	GND	Ground
6	IF_Qp	IF outputs, DC coupled, external AC coupling capacitors required
7	IF_Qn	
8	IF_Ip	
9	IF_In	
10	pwr1	Power-amplifier gain control input with internal 100-kΩ pull-up resistor: 3.3 V – P_{OUT_MAX} , 0 – P_{OUT_MAX} - 4 dB
11	TX_EN	TX enable input, high active, with internal 100-kΩ pull-up resistor: 3.3 V – enable, 0 – off
12	GND	Ground
13	TXout	Transmitter output, 50 Ω
14	Vctrl	VCO tuning voltage input
15	d3	VCO band switching inputs, each input with internal 120-kΩ pull-down resistor
16	d2	
17	d1	
18	d0	
19	div_o	Divider output, 50 Ω, DC coupled, external decoupling capacitor required (min. 100 pF)
20	PWR	Divider enable input, with internal 100-kΩ pull-up resistor: 3.3 V – enable, 0 – off
(21)	GND	Exposed die attach pad of the QFN package, must be soldered to ground

4 Specification

4.1 Absolute Maximum Ratings

Attempted operation outside the absolute maximum ratings of the part may cause permanent damage to the part. Actual performance of the IC is only given within the operational specifications, not at absolute maximum ratings.

Table 2 Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit	Condition / Remark
Supply voltage	V_{CC}		3.6	V	to GND
DC voltage at RF pins	V_{DCRF}	0	2	mV	IC provides low ohmic circuit to GND for TXout and RXin
Junction temperature	T_J		150	°C	
Storage temperature range	T_{STG}	-65	150	°C	
DC voltage at control inputs	V_{CTL}	-0.3	V_{CC} + 0.3	V	d0, d1, d2, d3, Vctrl, Vct, pwr1, TX_EN, PWR
Input power into pin RFin	P_{IN}		0	dBm	
ESD robustness	V_{ESD}		500	V	Class 1A, Note 1

Note 1 According to ESDA/JEDEC Joint Standard for Electrostatic Discharge Sensitivity Testing, Human Body Model Component Level, ANSI/ESDA/JEDEC JS-001-2011

4.2 Operating Range

Table 3 Operating Range

Parameter	Symbol	Min	Max	Unit	Condition / Remark
Ambient temperature	T_A	-40	85	°C	
Supply voltage	V_{CC}	3.13	3.47	V	(3.3V ± 5%)
DC voltage at control inputs	V_{CTL}	0	V_{CC}	V	d0, d1, d2, d3, Vctrl, Vct, pwr1, TX_EN, PWR

Note: Do not drive input signals without power supplied to the device.

4.3 Thermal Resistance

Table 4 Thermal Resistance

Parameter	Symbol	Min	Typ	Max	Unit	Condition / Remark
Thermal resistance, junction-to-ambient	R_{thja}			75	K/W	Four-layer PCB according to JEDEC standard JESD-51

4.4 Electrical Characteristics

T_A = -40 °C to +85 °C unless otherwise noted. Typical values measured at T_A = 25 °C and V_{CC} = 3.3 V.

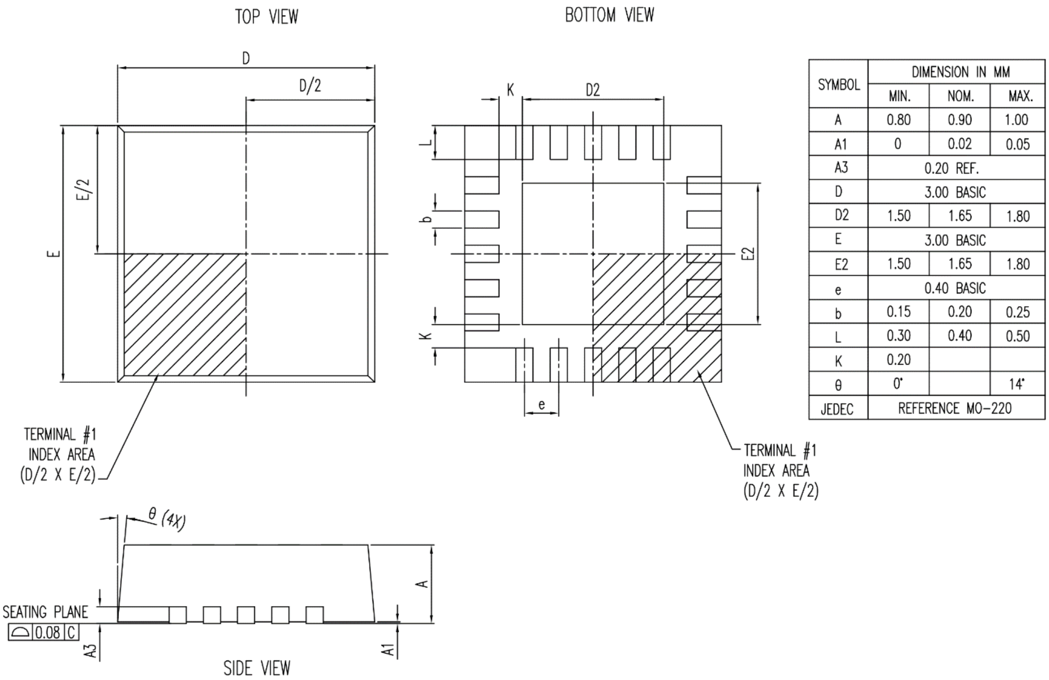
Table 5 Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Condition / Remark
DC Parameters						
Supply current consumption	I_{CC}	80	89	100	mA	TX, divider enabled
Control input voltage, low level	V_{IN_L}	0		0.3 × V_{CC}	V	Inputs TX_EN, pwr1, PWR and Vct
Control input voltage, high level	V_{IN_H}	0.7 × V_{CC}		Vcc	V	
Transmitter Section TX						
Transmitter start frequency	f_{TX}	22.3	22.8	23.3	GHz	
Transmitter stop frequency		25.9	26.4	26.9	GHz	
Divider division ratio	D_{div_o}		32			Note 1
Divider output frequency	f_{div_o}	700		840	MHz	
Tuning voltage VCO	V_{ctrl}	0		3.3	V	
Tuning slope VCO (Vctrl)	$\Delta f_{TX}/\Delta V_{ctrl}$		220		MHz/V	Only Vctrl swept
Number of adjustable frequency bands			16			d0 - d3: VCO band switching, Note 1
Pushing VCO	$\Delta f_{TX}/\Delta V_{CC}$		135		MHz/V	f = 24.15 GHz
Phase noise	P_N	-105	-102		dBc/Hz	at 1 MHz offset
Output impedance	Z_{TXout}		50		Ω	
Transmitter output power	P_{TX}	2.5	4	6	dBm	
Adjustable range output power	P_{TX_ADJ}	0		4	dBm	pwr1 = 0 / 3.3 V
Divider output power	P_{div_o}	-9	-8.5	-8	dBm	Note 2
Spurious power	P_{Sp-}		-40		dBm	$f_{TX} - f_{div}$
	P_{Sp+}		-43		dBm	$f_{TX} + f_{div}$
Harmonics power	P_{Ha12}		-46		dBm	12 GHz
	P_{Ha48}		-40		dBm	48 GHz
Receiver Section RX						
Receiver frequency	f_{RX}	22.3		26.9	GHz	
Receiver input impedance	Z_{RXIN}		50		Ω	
Number of adjustable gain modes			2			Adjustable LNA gain control
Gain high gain mode				18	dB	V_{ct} = 3.3 V
Gain low gain mode				11	dB	V_{ct} = 0
IF frequency range	f_{IF}	0		200	MHz	
IF output impedance	Z_{OUT}		470		Ω	Differential
IQ amplitude imbalance		-1		1	dB	
IQ phase imbalance		-10		10	deg	
Noise figure, high gain mode			4		dB	Simulated (double side band at f_{IF} = 1 MHz)
Noise figure, low gain mode			6		dB	
Input compression point	1dB ICP	-20		-13	dBm	

Note 1 See also chapter “Measurement Results”, Figure 10 and 11.
Note 2 Divider output is loaded with 50 Ω, DC coupled, external decoupling capacitor ≥ 100 pF required.

5 Packaging

5.1 Package Dimensions

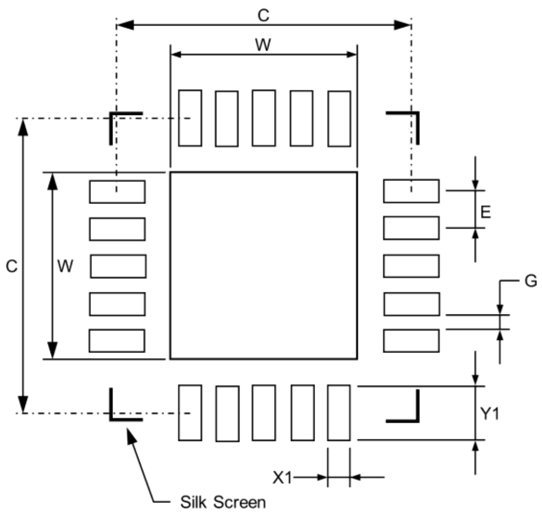


SYMBOL	DIMENSION IN MM		
	MIN.	NOM.	MAX.
A	0.80	0.90	1.00
A1	0	0.02	0.05
A3	0.20 REF.		
D	3.00 BASIC		
D2	1.50	1.65	1.80
E	3.00 BASIC		
E2	1.50	1.65	1.80
e	0.40 BASIC		
b	0.15	0.20	0.25
L	0.30	0.40	0.50
K	0.20		
θ	0°		14°
JEDEC	REFERENCE MO-220		

Figure 3 Outline Dimensions of QFN20, 3 × 3 mm², 0.4 mm Pitch

IC Weight: 0.235 g (typ.)

5.2 Package Footprint



Dimension Limits in mm		min	nom	max
Contact Pitch	E		0.4 BSC	
Contact Pad Width	W			1.8
Contact Pad Spacing	C		3.0	
Contact Pad Width	X1		0.2	
Contact Pad Length	Y1			0.7
Distance Between Pads	G	0.20		

Figure 4 Recommended Land Pattern

5.3 Package Code

Top-Side Markings TRX006
YYWW

5.4 Qualification Test

Table 6 Reliability and Environmental Test

Qualification Test	JEDEC Standard	Condition	Pass / Fail
MSL3	J-STD-020E	Reflow simulation 3 times at 260°C	pass

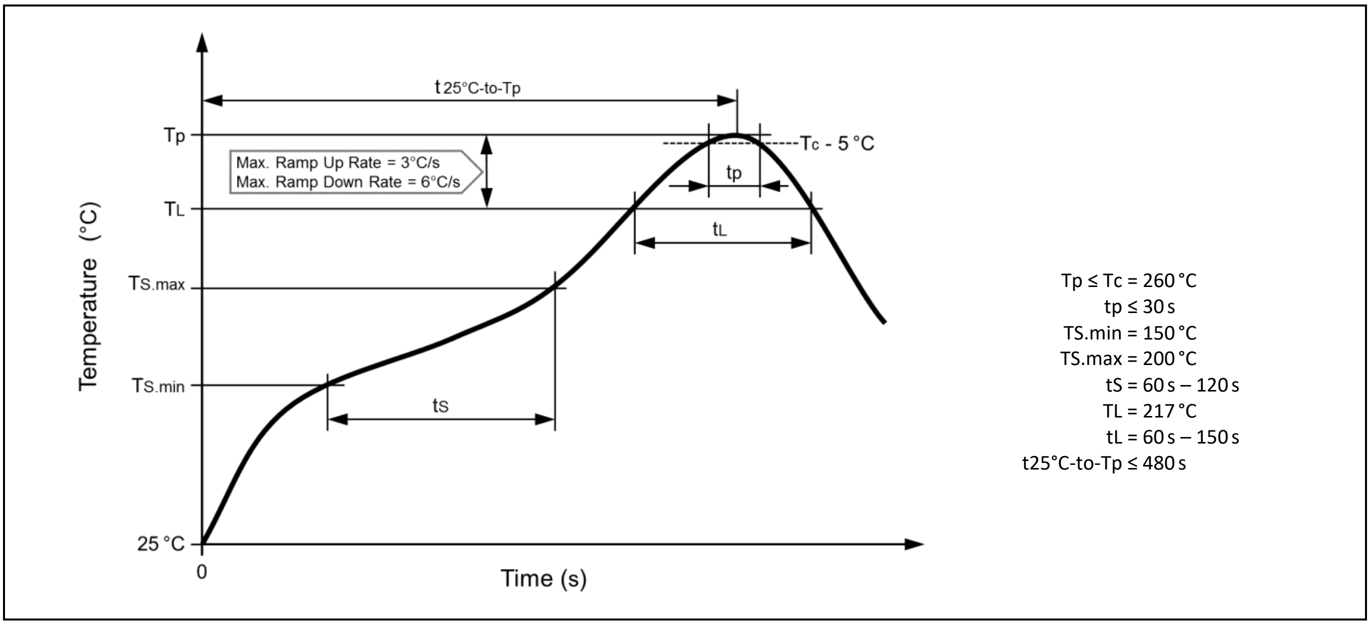


Figure 5 Reflow Profile for Pb-Free Assembly according to JEDEC Standard J-STD-020E

6 Application

6.1 Application Circuit Schematic

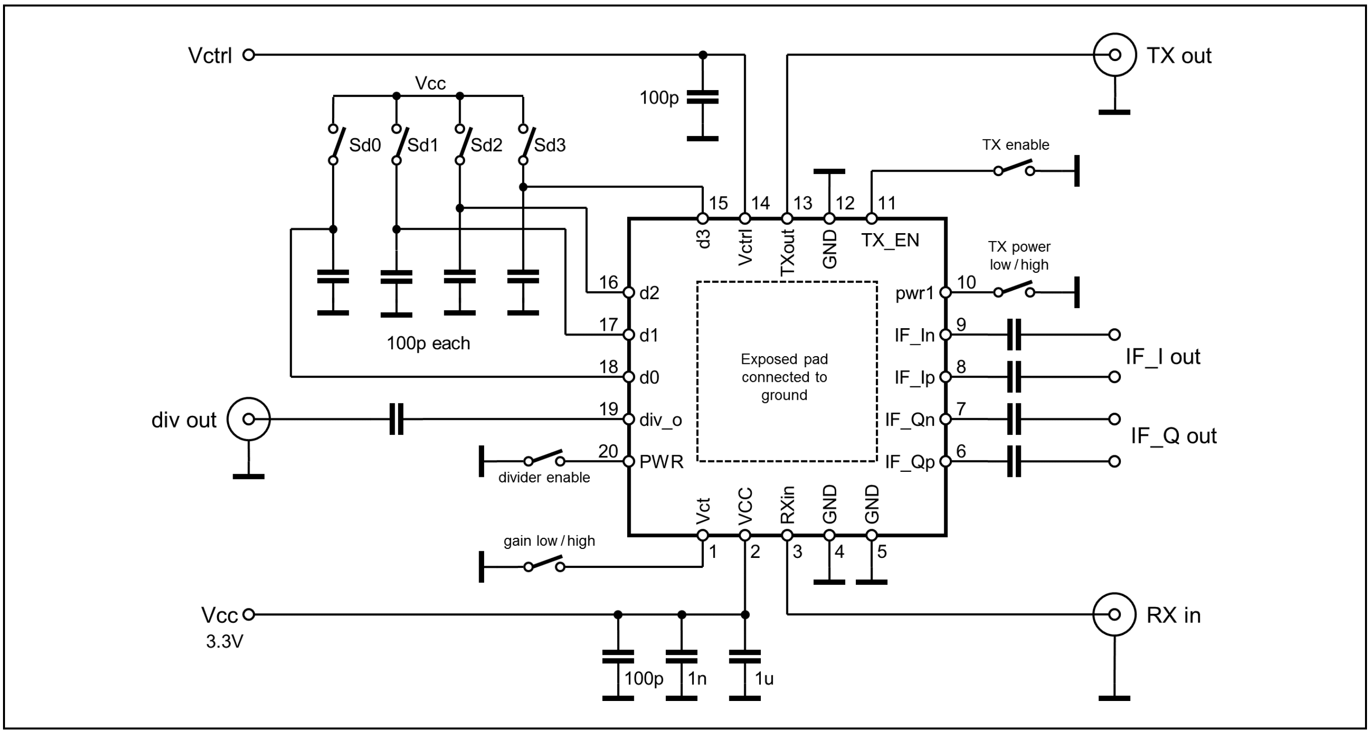


Figure 6 Application Circuit for Band Switching

6.2 Power Cycling

It is possible to reduce power consumption by power cycling the radar front end. Rapid power cycling with voltage rise times between 10 and 100 µs is possible. At power-up, it must be ensured that no input signal is driven high before the supply voltage is stable. At power-down, all input signals must be pulled low before the supply voltage is switched off.

6.3 Evaluation Board

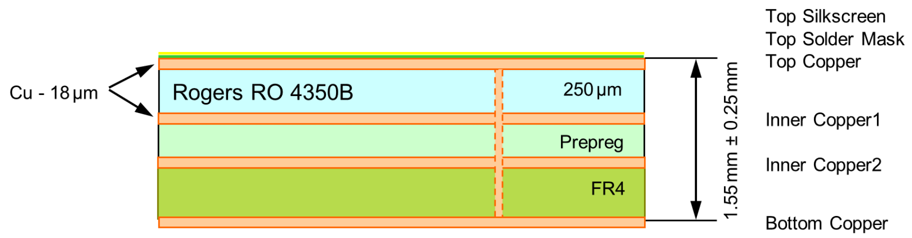


Figure 7 Evaluation Board Stack-up

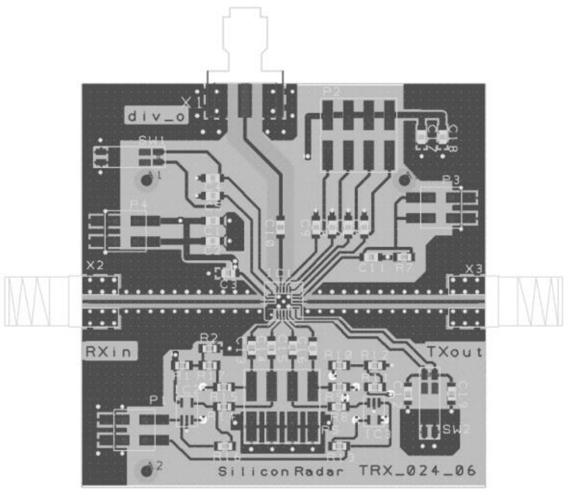


Figure 8 Evaluation Board Layout Including Via Holes (50 mm × 50 mm, Top View)

6.4 Evaluation Kit

For a quick and easy start into radar development Silicon Radar offers SiRad Easy®. It is an evaluation board system for many of our integrated IQ transceivers with antennas in package or on PCB. It comes with a reference hardware and provides a complete design environment which can be configured via a browser-based graphical interface. Its rich functionality and the open communication protocol make it a versatile tool – also for enhanced development projects.
It features:

- Distance measurement
- Velocity measurement
- Frequency modulated continuous wave mode (FMCW)
- Continuous wave mode (CW)

For more information about the features of SiRad Easy® see:
https://www.siliconradar.com/evalkits_e.html

6.5 Input / Output Stages

The following figures show the simplified circuits of the input and output stages. It is important that the voltage applied to the input pins never exceeds V_{CC} by more than 0.3 V. Otherwise, the supply current may be conducted through the upper ESD protection diode connected at the pin.

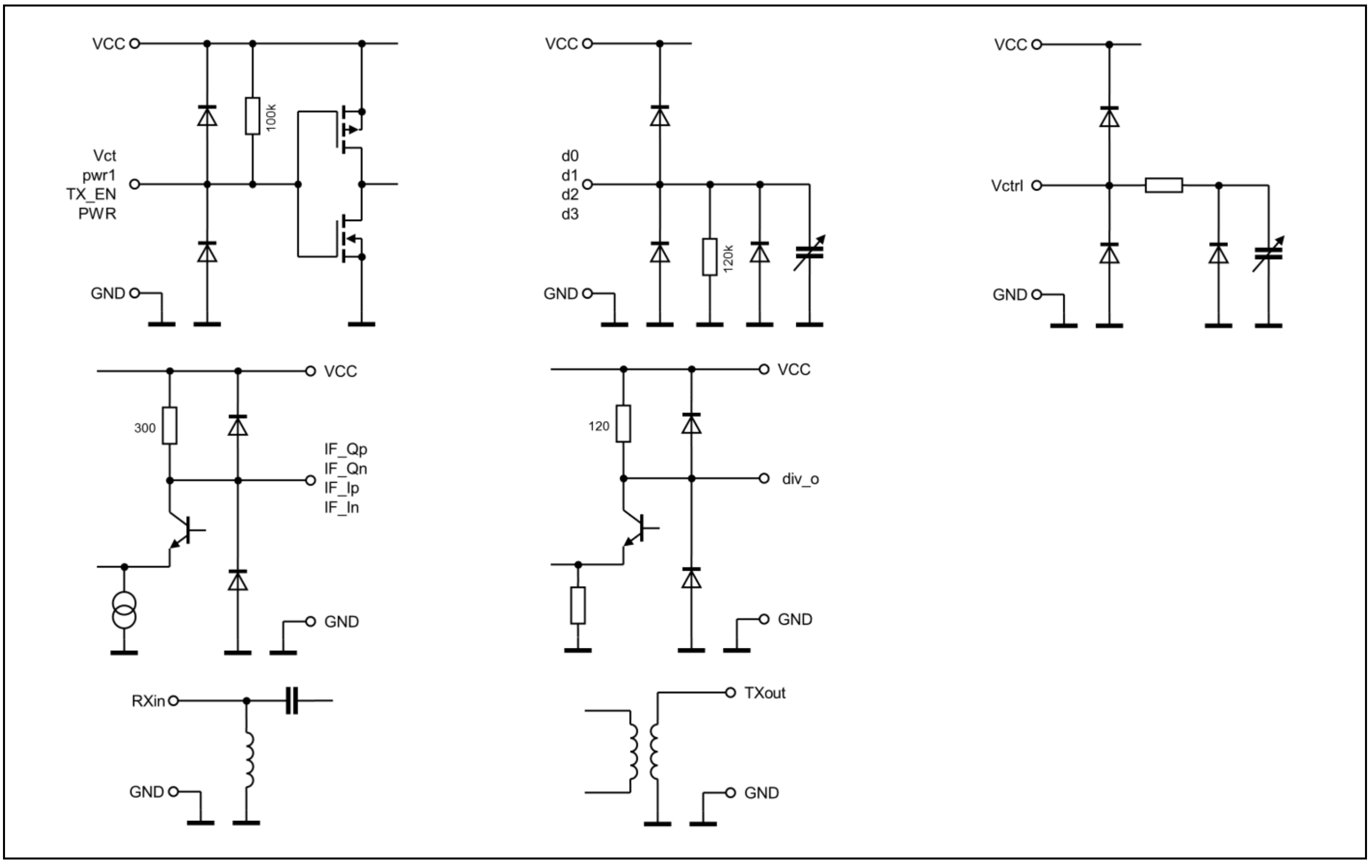


Figure 9 Equivalent I/O Circuits

7 Measurement Results

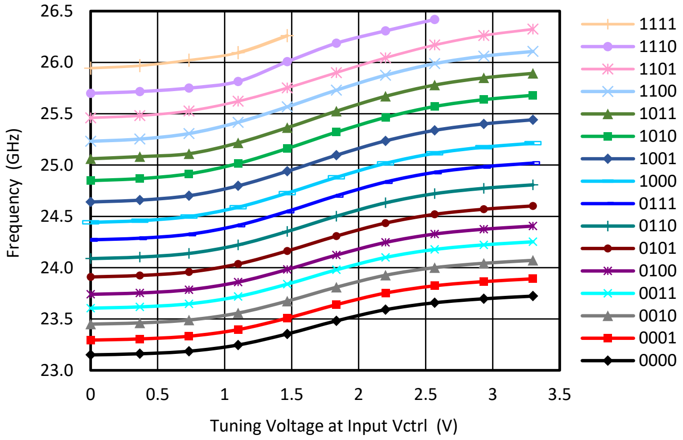


Figure 10 VCO Tuning Band with Switching (d0 - d3)

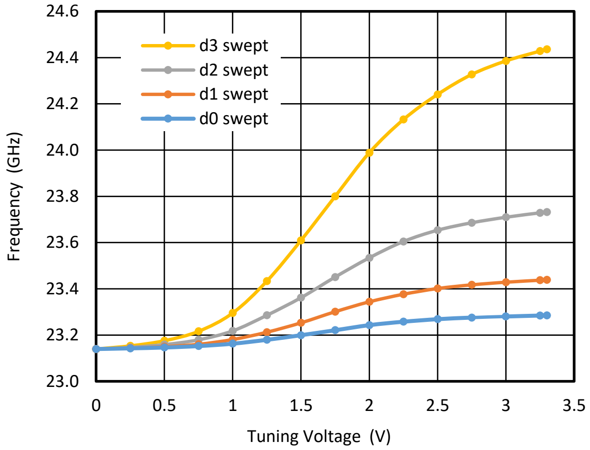


Figure 11 VCO Tuning, d3 - d0 swept, Vctrl = 0 = constant

VCO band switching inputs d3 to d0 can be used to switch the output frequency band as in Figure 10. As an example, input combination "0101" with d3, d1 = 3.3 V and d2, d0 = 0 includes the 24-GHz ISM band. However, the designer should take into account that output frequency bands may shift from chip to chip (see Figure 12), and same switch settings may not give the same output band.

Note, VCO band switching inputs d0 - d3 are analog inputs and can be used to control the output frequency. The bandwidth of the switching inputs increases from d0 to d3. Any of these pins can be interconnected to each other and / or to pin Vctrl to use different bandwidth capabilities of the VCO.

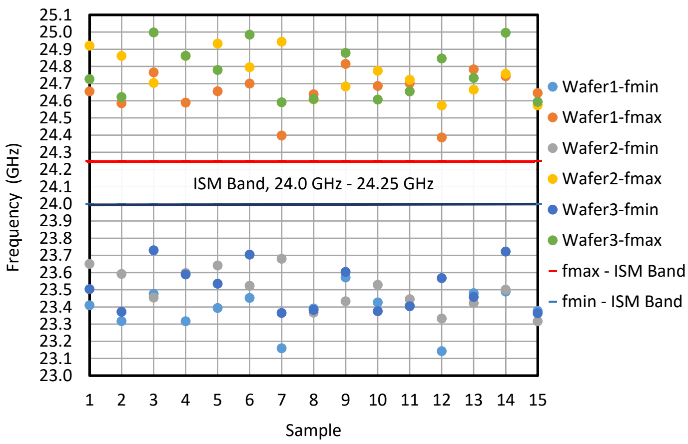


Figure 12 Output Frequency Range in Relation to ISM Band for Several Chips (f_{min}, f_{max} measurement)

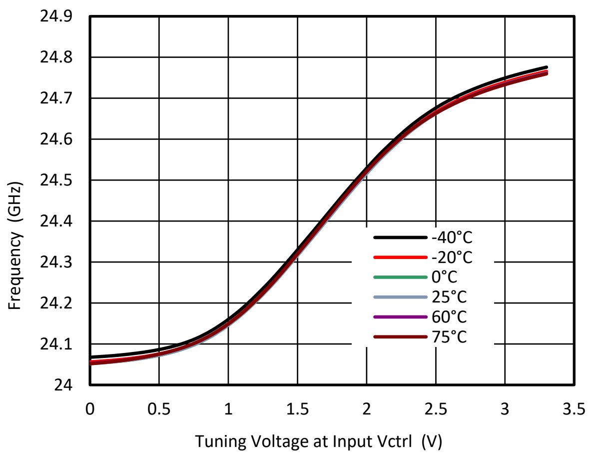


Figure 13 VCO Tuning at Various Temperatures (tuning voltage Vctrl)

The input settings for the measurement shown in Figure 12 are d3 = 0 (0 V), d2 = 1 (3.3 V). Inputs d0, d1, and Vctrl are interconnected and swept together.

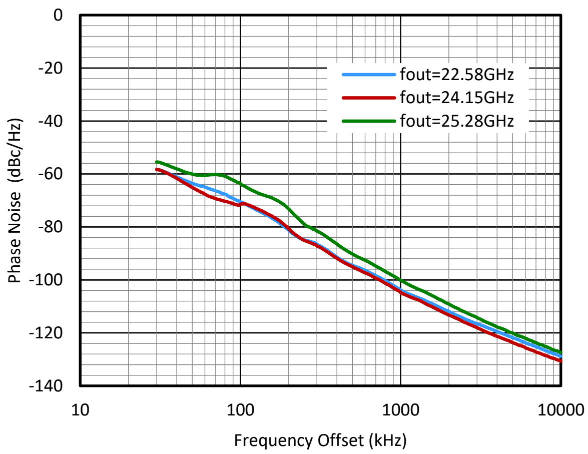


Figure 14 Phase Noise of the Free-Running VCO

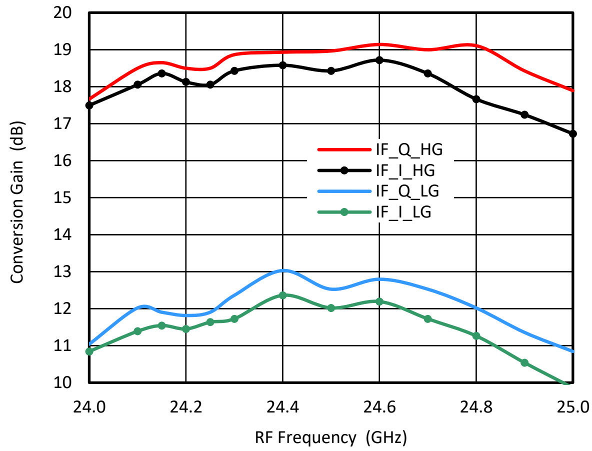


Figure 15 Conversion Gain of the Receiver in High-Gain and Low-Gain Mode

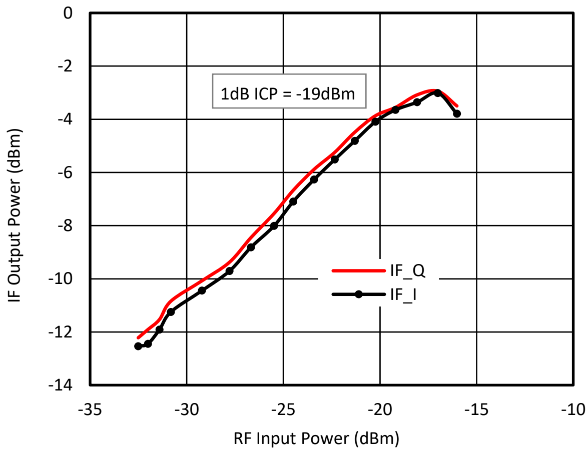


Figure 16 Conversion Gain of the Receiver in High-Gain Mode

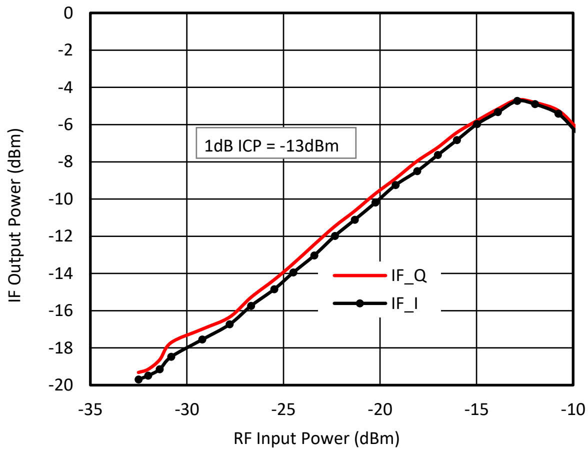


Figure 17 Conversion Gain of the Receiver in Low-Gain Mode

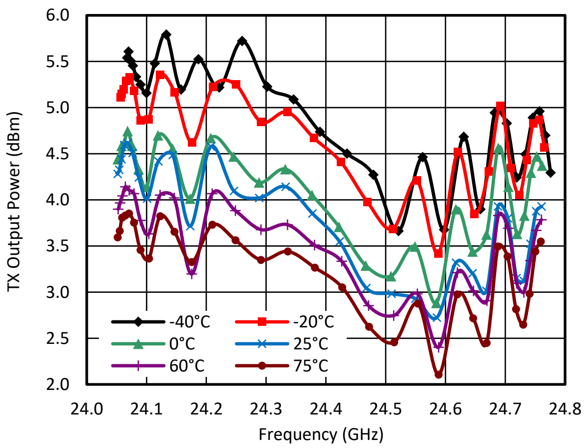


Figure 18 TX Power vs. Frequency at Various Temperatures

Disclaimer

Silicon Radar GmbH 2018. The information contained herein is subject to change at any time without notice.
Silicon Radar GmbH assumes no responsibility or liability for any loss, damage or defect of a product which is caused in whole or in part by

- (i) use of any circuitry other than circuitry embodied in a Silicon Radar GmbH product,
- (ii) misuse or abuse including static discharge, neglect, or accident,
- (iii) unauthorized modifications or repairs which have been soldered or altered during assembly and are not capable of being tested by Silicon Radar GmbH under its normal test conditions, or
- (iv) improper installation, storage, handling, warehousing, or transportation, or
- (v) being subjected to unusual physical, thermal, or electrical stress.

Disclaimer: Silicon Radar GmbH makes no warranty of any kind, express or implied, with regard to this material, and specifically disclaims any and all express or implied warranties, either in fact or by operation of law, statutory or otherwise, including the implied warranties of merchantability and fitness for use or a particular purpose, and any implied warranty arising from course of dealing or usage of trade, as well as any common-law duties relating to accuracy or lack of negligence, with respect to this material, any Silicon Radar product and any product documentation. Products sold by Silicon Radar are not suitable or intended to be used in a life support applications or components, to operate nuclear facilities, or in other mission critical applications where human life may be involved or at stake. All sales are made conditioned upon compliance with the critical uses policy set forth below.

CRITICAL USE EXCLUSION POLICY: BUYER AGREES NOT TO USE SILICON RADAR GMBH'S PRODUCTS FOR ANY APPLICATIONS OR IN ANY COMPONENTS USED IN LIFE SUPPORT DEVICES OR TO OPERATE NUCLEAR FACILITIES OR FOR USE IN OTHER MISSION-CRITICAL APPLICATIONS OR COMPONENTS WHERE HUMAN LIFE OR PROPERTY MAY BE AT STAKE.