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TRX_120_089

120-GHz IQ Transceiver with Antennas in Package

Preliminary Data Sheet

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Version Control

Version	Changed section	Description of change	Reason for change
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0.2	(all)	Conversion to LGA81 Package	

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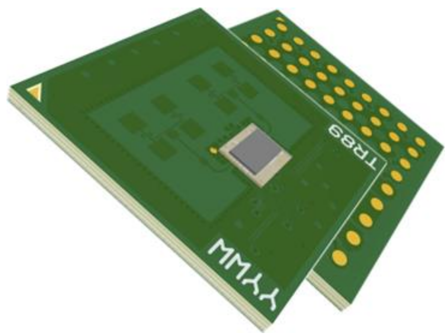
1 Features

- Radar front end (RFE) with antennas in package
- Designed for 122-GHz ISM band applications
- TX, RX frequency range from 119 to 125 GHz
- Wide bandwidth of typical 6 GHz
- Single supply voltage of 3.3 V
- Fully ESD protected device
- Current consumption of 190 mA in continuous operation
- Integrated low phase noise VCO
- Receiver with homodyne quadrature mixer
- RX and TX patch antennas
- LGA81 leadless package, 8 × 8 mm² Package
- Pb-free, RoHS compliant package



1.1 Overview

The TRX_120_089 is an integrated transceiver circuit for the 122-GHz ISM band with antennas in package. The IC comprises integrated VCO, frequency divider, a gain-controlled power amplifier, a gain-controlled low-noise amplifier, a quadrature mixer and a poly-phase filter, and transmit and receive antennas. The VCO frequency can be tuned by two analog inputs - Vfine and Vcoarse. These two tuning inputs combined can be used to obtain the full tuning range of greater than 6 GHz. The RF signal from the oscillator is directed to the RX and TX paths via a local oscillator (LO) amplifier followed by power divider. The RX signal is amplified by LNA and converted to baseband by quadrature mixer.
The on-chip VCO together with integrated frequency divider and external fractional-N PLL can be used for frequency modulated continuous wave (FMCW) radar operation. With a fixed oscillator frequency, it can be used in continuous wave (CW) mode. Other modulation schemes such as FSK can be implemented by utilizing the analog tuning inputs. The IC is fabricated in a SiGe BiCMOS technology.

1.2 Applications

The main field of application for the 120-GHz transceiver radar frontend is in short range radar systems with a range up to about 10 meters. By using dielectric lenses or reflectors, the range can be increased considerably. The TRX_120_089 can be used in FMCW mode as well as in CW mode. Although the chip is intended for use in the ISM band 122 GHz - 123 GHz, it is also possible to extend the bandwidth to the full tuning range of 6.5 GHz. Its high operating frequency and high output power allows measurements with improved range accuracy and maximum detection range.

2 Block Diagram

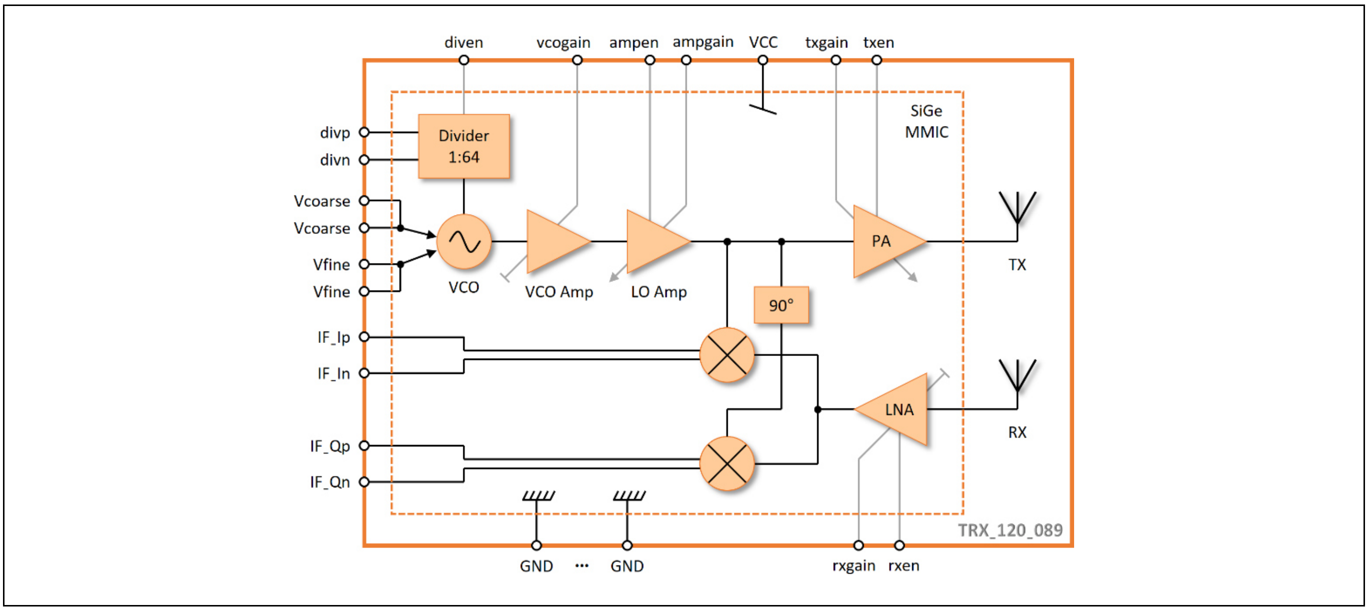


Figure 1 Block Diagram

3 Terminal (Land) Configuration

3.1 Terminal (Land) Assignment

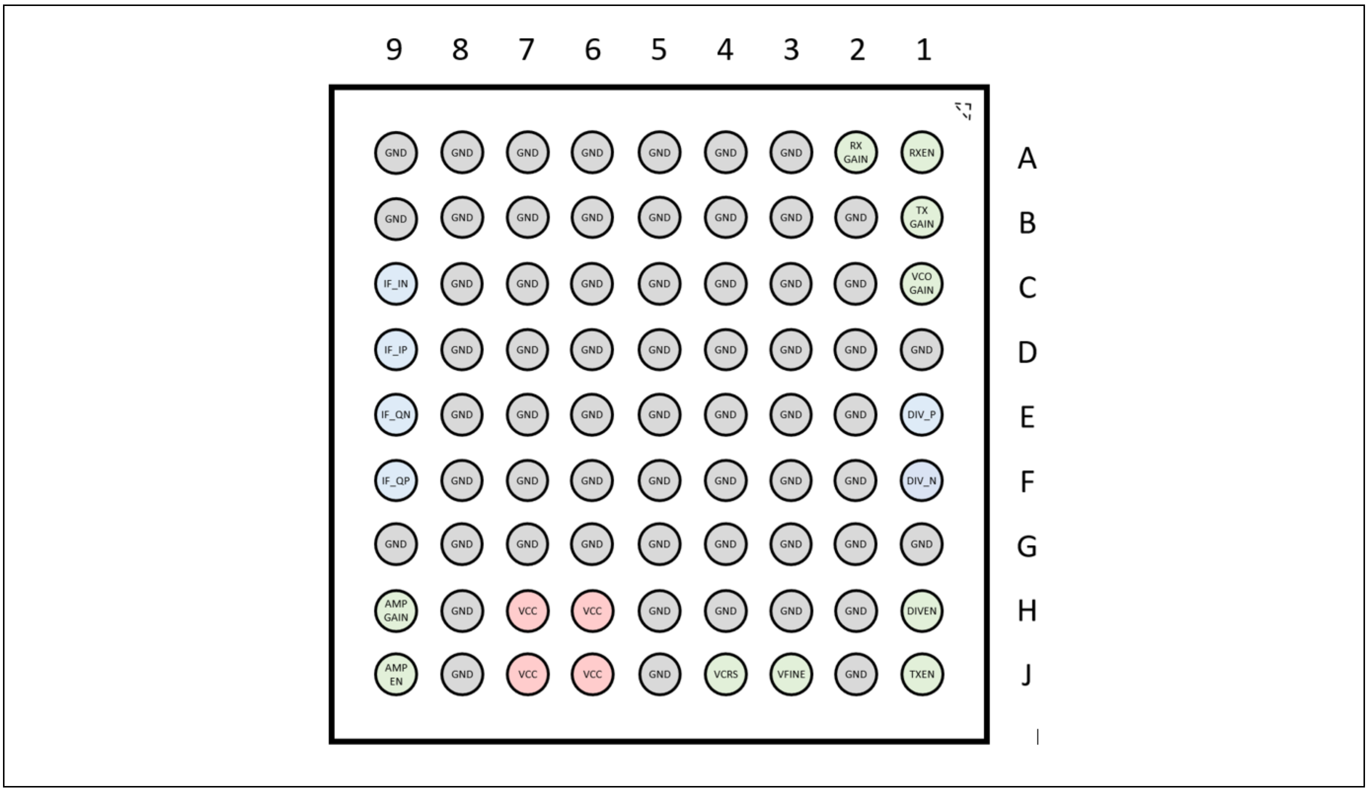


Figure 2 Terminal (Land) Assignment (bottom view)

3.2 Terminal (Land) Description

Table 1 Terminal (Land) Description

Pad		Description
No.	Name	
A1	RXEN	RX enable input: 0 – off, 3.3 V – enable CMOS Schmitt trigger input, no pull resistor at input
A2	RXGAIN	RX gain control input: 0 – low gain, 3.3 V – high gain CMOS Schmitt trigger input, no pull resistor at input
B1	TXGAIN	TX PA gain control input: 0 – low output power), 3.3 V – high output power) The input can also be used for analog output-power control: ≤ 1.3 V (lowest) to ≥ 2.0 V (highest) 100-kΩ pull-down resistor at input
C1	VCOGAIN	VCO gain control input: 0 – low gain, 3.3 V – high gain CMOS Schmitt trigger input, no pull resistor at input
C9	IF_In	IF I output, negative terminal, DC coupled
D9	IF_Ip	IF I output, positive terminal, DC coupled
E9	IF_Qn	IF Q output, negative terminal, DC coupled
F9	IF_Qp	IF Q output, positive terminal, DC coupled
E1	divp	Differential frequency-divider output, positive and negative terminal, matched to 50 Ω load, DC coupled, external decoupling capacitor required
F1	divn	
H1	diven	Frequency-divider enable input: 0 – off, 3.3 V – enable CMOS Schmitt trigger input, no pull resistor at input
J1	txen	TX PA enable input: 0 – off, 3.3 V – enable CMOS Schmitt trigger input, no pull resistor at input
J3	Vfine	Fine VCO-frequency tuning input Identical terminals with a low-ohmic internal connection
J4	Vcoarse	Coarse VCO-frequency tuning input Identical terminals with a low-ohmic internal connection
H6, H7 J6, J7	VCC	Supply voltage (3.3 V)
J9	ampen	LO amplifier enable input: 0 – off, 3.3 V – enable CMOS Schmitt trigger input, no pull resistor at input
H9	ampgain	LO-amplifier gain control input: 0 – low gain, 3.3 V – high The input can also be used for analog gain control: ≤ 1.3 V (lowest) to ≥ 2.0 V (highest) 100-kΩ pull-down resistor at input
A3 - A9; B2 - B9; C2 - C8; D1 - D8, E2 - E8; F2 - F8; G1 - G9; H2 - H5; H8, J2, J5, J8	GND	Ground

4 Specification

4.1 Absolute Maximum Ratings

Attempted operation outside the absolute maximum ratings of the device may cause permanent damage to the device. Actual performance of the IC is only guaranteed 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 enable inputs	V_{en}	-0.3	V_{CC} + 0.3	V	Inputs rxen, txen, diven, ampen
DC voltage at gain control inputs	V_{cntrl}	-0.3	V_{CC} + 0.3	V	Inputs rxgain, txgain, vcogain, ampgain
DC voltage at tuning inputs	V_{tune}	-0.3	V_{CC} + 0.3	V	Inputs Vfine, Vcoarse
Junction temperature	T_J	-50	150	°C	
Storage temperature range	T_{STG}	*tbd*	*tbd*	°C	
ESD robustness	V_{ESD}		*tbd*	kV	Human body model, HBM [1)]

1) CLASS 1C 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	Remarks / Condition
Ambient temperature	T_A	-40	85	°C	
Supply voltage	V_{CC}	3.13	3.47	V	(3.3 V ± 5%)
DC voltage at enable inputs	V_{en}	0	V_{CC}	V	Inputs rxen, txen, diven, ampen
DC voltage at gain control inputs	V_{cntrl}	0	V_{CC}	V	Inputs rxgain, txgain, vcogain, ampgain
DC voltage at tuning inputs	V_{tune}	0	V_{CC}	V	Inputs Vfine, Vcoarse

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

Power-up sequence should be the following:

1. Connect to ground
2. Apply V_{CC}
3. Set all control voltages

Power-down sequence should be the reverse of the above.

4.3 Thermal Resistance

Table 4 Thermal Resistance

Parameter	Symbol	Min	Typ	Max	Unit	Remarks / Condition
Thermal resistance, junction-to-ambient	R_{thja}			*tbd*	K/W	

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	Remarks / Condition
DC Parameters						
Supply current consumption	I_{CC}		190	240	mA	All functions enabled, max. gain, w/o duty cycling.
Input voltages, logic low level for Schmitt trigger input stages	V_{inp1_L}	0		0.6	V	Inputs txen, rxen, diven, ampen, rxgain, vcogain. Typical thresholds: 1.1V/2.1V
Input voltages, logic high level for Schmitt trigger input stages	V_{inp1_H}	V_{CC} - 0.6		V_{CC}	V	
Input voltages, logic low level	V_{inp2_L}	0		0.4	V	Inputs rxen, txen, diven, ampen
Input voltages, logic high level	V_{inp2_H}	V_{CC} - 0.4		V_{CC}	V	
RF Parameters						
TX output start frequency	f_{TX_start}	116.1	*tbd*	121.7	GHz	Vfine = Vcoarse = 0, Note 2
TX output stop frequency	f_{TX_stop}	123.3	*tbd*	128.9	GHz	Vfine = Vcoarse = 3.3 V, Note 2
TX tuning full bandwidth	Δf_{TX}	*tbd*	6.5	*tbd*	GHz	Note 2
VCO tuning slope, coarse	$\Delta f_{TX}/\Delta V_{Vcoarse}$		3.5		GHz/V	For linear region of frequency vs. control voltage curve
VCO tuning slope, fine	$\Delta f_{TX}/\Delta V_{Vfine}$		*tbd*		GHz/V	For linear region of frequency vs. control voltage curve
VCO frequency pushing	$\Delta f_{TX}/\Delta V_{CC}$		374		MHz/V	
Phase noise	P_N		-90		dBc/Hz	at 1 MHz offset
Transmitter output power	P_{TX}		3.0		dBm	Measured without antennas.
Divider output power	P_{div}		-10		dBm	Vfine = Vcoarse = 3.3 V, Note 1
Divider output frequency	f_{div}		1.9		GHz	
Receiver conversion gain	g_{RX}	>10			dB	
Receiver conversion gain control	Δg_{RX}		4		dB	rxgain switched from 0 to 3.3 V
IF frequency range	f_{IF}	0		200	MHz	
IF output impedance	Z_{OUT}		500		Ω	Differential outputs
IQ amplitude imbalance	Aimb		< +/-1.5		dB	Measured, at f_{IF} = 5 MHz
IQ phase imbalance	PHimb	-10		10	deg	
Noise figure (DSB)			12.5		dB	Simulated, at f_{IF} = 1 MHz
Input compression point	IP_{1dB}		-20		dBm	

Note 1: Measured single-ended. Divider outputs are loaded with 50 Ω, external decoupling capacitors are required. No 50-Ω match is required in application.

Note 2: Preliminary values. Update as larger data base becomes available. f_{TX_start} (Max) and f_{TX_stop} (Min) remains defined to assure an operation within ISM band between 122.0 and 123.0 GHz. Further information on specification of frequency limits on request.

5 Packaging

5.1 Outline Dimensions

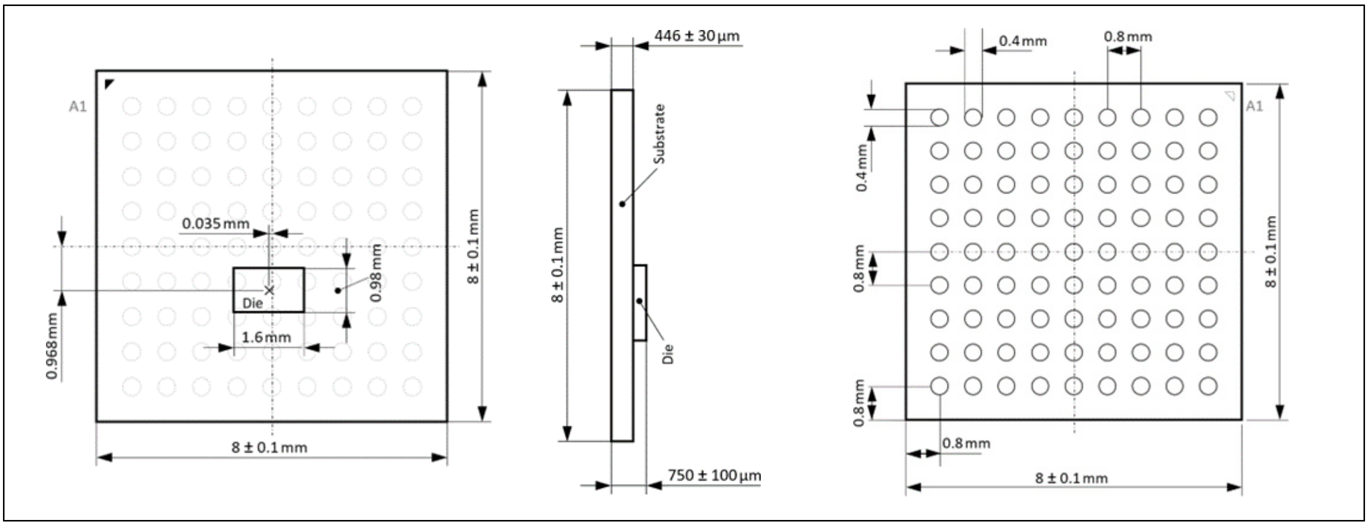


Figure 3 Outline Dimensions (top, side and bottom view). Bare die is placed on top of substrate by flip-chip.

5.2 Package Code

Top-Side Markings: TR89
YYWW

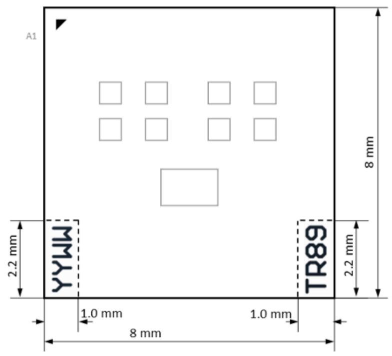


Figure 4 Package Marking

5.3 Antenna Position

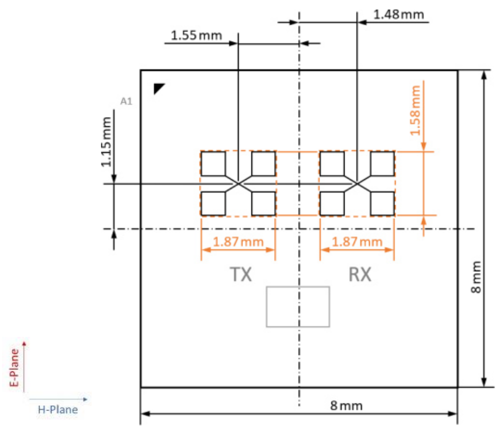


Figure 5 Antenna Position (top view)

6 Application

6.1 Application Circuit

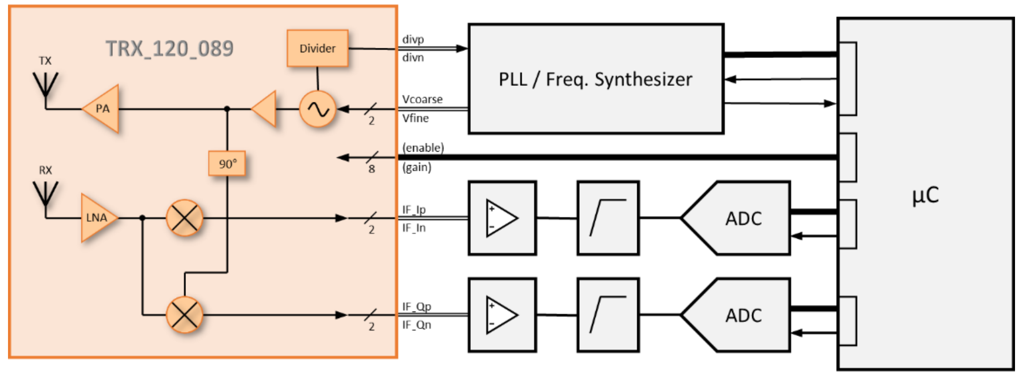


Figure 6 Principle of an Application Circuit

6.2 Evaluation Kit

Silicon Radar offers evaluation kits for speeding up radar development. Please review our website and product sheets for more information: https://www.siliconradar.com/evalkits/.
The *SiRad Easy® r4* platform supports development for many of Silicon Radar's integrated IQ transceivers including radar front end boards for TRX_120_089. It serves as reference hardware and provides a design environment including a graphical user interface for parameter setting. Its functionality and communication protocol are adaptable to development projects.

6.3 Power Cycling

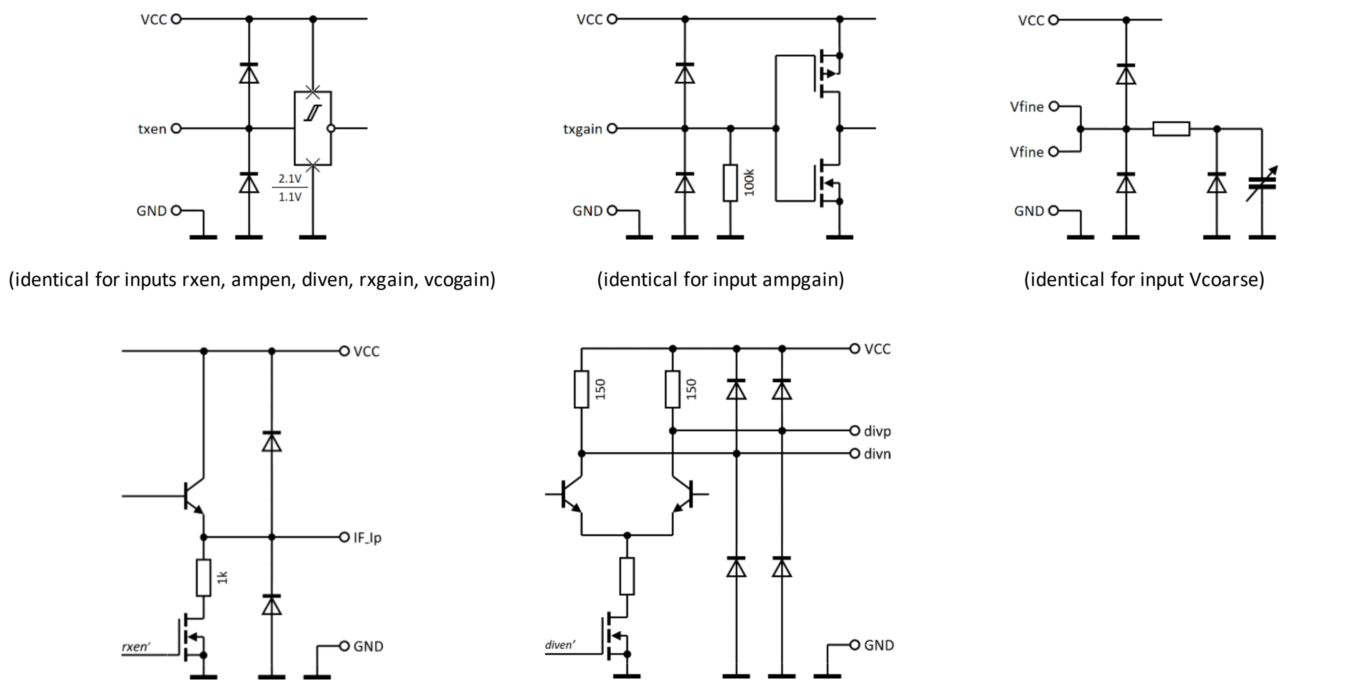
It is possible to reduce power consumption by power cycling the radar front end. Rapid power cycling can be implemented with voltage rise times between 10 and 100 µs. At power-up, it must be ensured that no input signal is driven high before the supply voltage is stable. At power-down, all input signals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

6.4 VCO Tuning Inputs

The VCO tuning inputs Vfine and Vcoarse are of analog nature but can be switched digitally as well. The tuning inputs differ in their tuning ranges (tuning bandwidth) and slopes, where Vcoarse has wider tuning range, and Vfine, narrower.
If only the input Vfine or only the input Vcoarse is used for tuning, the other one must be set to a defined voltage between 0 and V_{CC}. For reasons of compatibility to predecessors of the TRX_120_089, the tuning inputs are duplicated. Two inputs with the same name are connected internally with low impedance.

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.



(identical for inputs rxen, ampen, diven, rxgain, vcogain)

(identical for input ampgain)

(identical for input Vcoarse)

(identical for outputs IF_In, IF_Qp, IF_Qn)

Figure 7 Equivalent I/O Circuits

7 Measurement Results

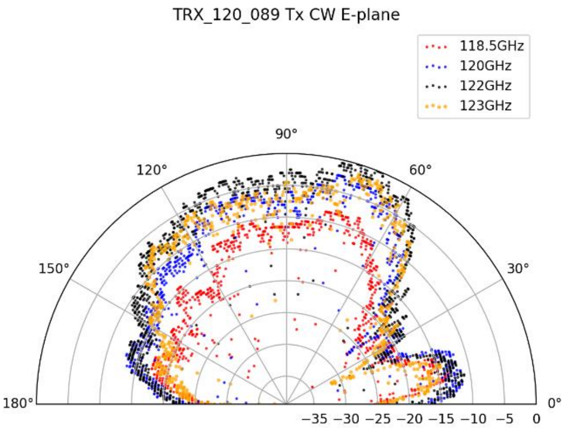


Figure 8 TX Antenna Characteristics in E-plane, measured without lens in CW-Mode of operation.

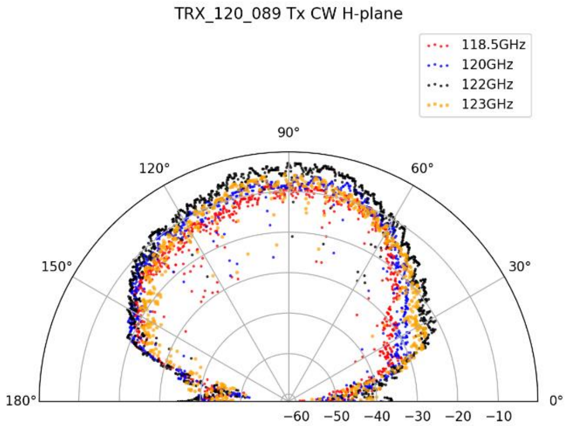


Figure 9 TX Antenna Characteristics in H-plane, measured without lens in CW-Mode of operation.

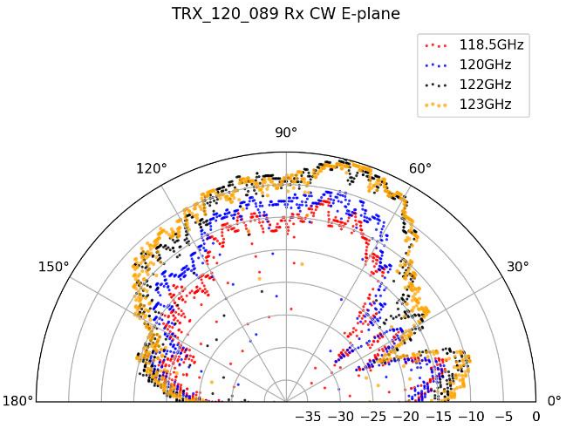


Figure 10 RX Antenna Characteristics in E-plane, measured without lens in CW-Mode of operation.

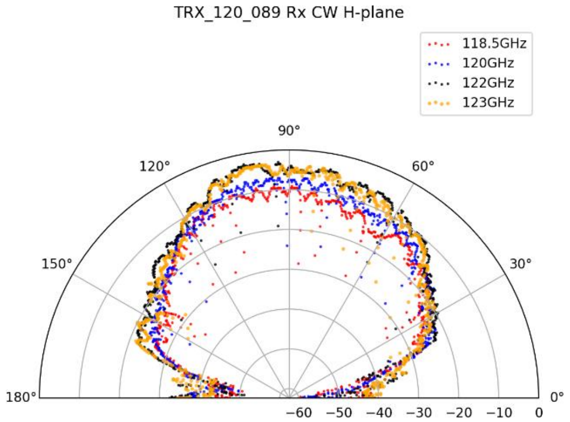


Figure 11 RX Antenna Characteristics in H-plane, measured without lens in CW-Mode of operation.

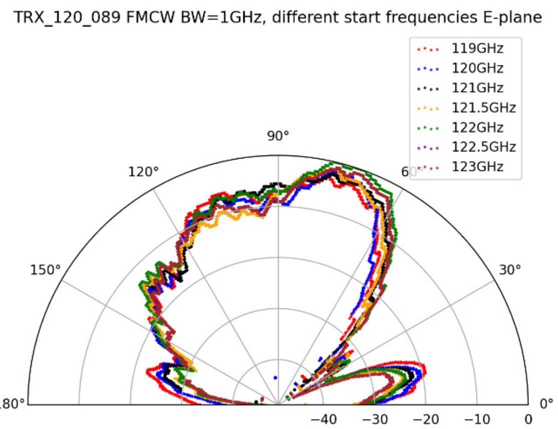


Figure 12 TRX Antenna Characteristics in E-plane, measured without lens in FMCW-Mode of operation with a bandwidth of 1 GHz.

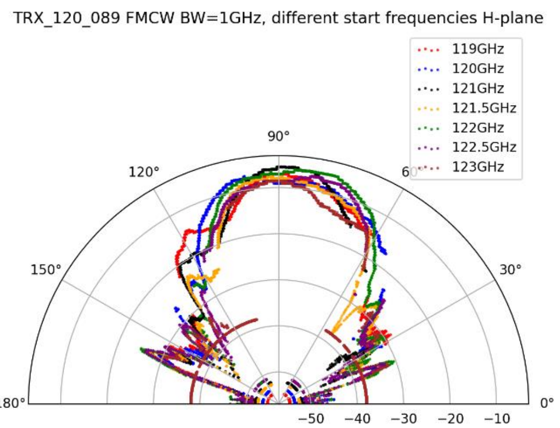


Figure 13 TRX Antenna Characteristics in H-plane, measured without lens in FMCW-Mode of operation with a bandwidth of 1 GHz.

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