

is now



indie Semiconductor FFO GmbH

To learn more about indie Semiconductor, please visit our website at <u>www.indiesemi.com</u>

For customer support, please contact us at: <u>dfo.support@indiesemi.com</u>

indie and the indie logo are trademarks of Ay Dee Kay LLC dba indie Semiconductor in the United States and in other countries. Silicon Radar GmbH was acquired by indie Semiconductor and is now indie Semiconductor FFO GmbH. Purchase of products is governed by indie Semiconductor FFO GmbH's Terms and Conditions.



TRX_120_089

120-GHz IQ Transceiver with Antennas in Package

Preliminary Data Sheet

Status:	Date:	Author:	Filename:			
Preliminary	08-Sep-23	Indie Semiconductor FFO GmbH	Data_Sheet_TRX_120_089_V0.2			
Version:	Product number:	Package:	Marking:	Page:		
0.2	TRX_120_089	LGA81, $8 \times 8 \mathrm{mm^2}$	TR89 1 of 13			
			YYWW			
Document:	Annex to VA_U03_01	Anlage 8_Template_Datenblatt_RevE	Date: 19-May-2020	Rev E		



Version Control

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

120-GHz IQ Transceiver TRX_120_089 Preliminary Data Sheet Version 0.2 08-Sep-23



Table of Contents

1	Features	4
1.1	Overview	4
1.2	Applications	4
2	Block Diagram	5
3	Terminal (Land) Configuration	5
3.1	Terminal (Land) Assignment	5
3.2	Terminal (Land) Description	6
4	Specification	7
4.1	Absolute Maximum Ratings	7
4.2	Operating Range	7
4.3	Thermal Resistance	7
4.4	Electrical Characteristics	8
5	Packaging	9
5.1	Outline Dimensions	9
5.2	Package Code	9
5.3	Antenna Position	9
6	Application	
6.1	Application Circuit	
6.2	Evaluation Kit	
6.3	Power Cycling	
6.4	VCO Tuning Inputs	
6.5	Input / Output Stages	
7	Measurement Results	



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 <u>Overview</u>

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 <u>Applications</u>

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.

120-GHz IQ Transceiver TRX_120_089 Preliminary Data Sheet Version 0.2 08-Sep-23



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	l) 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_lp	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,
F1	divn	DC coupled, external decoupling capacitor required
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)
19	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.

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	TJ	-50	150	°C			
Storage temperature range	T _{STG}	tbd	tbd	°C			
ESD robustness	V _{ESD}		tbd	kV	Human body model, HBM ¹⁾		

 Table 2
 Absolute Maximum Ratings

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 <u>Thermal Resistance</u>

Table 4 Thermal Resistance

Parameter	Symbol	Min	Тур	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 5Electrical Characteristics

Parameter	Symbol	Min	Тур	Max	Unit	Remarks / Condition
DC Parameters						
Supply current consumption	Icc		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.
Input voltages, logic high level for Schmitt trigger input stages	V _{inp1_H}	V _{CC} - 0.6		V _{cc}	V	Typical thresholds: 1.1V/2.1V
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		Vcc	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	\mathbf{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 50Ω , external decoupling capacitors are required. No $50-\Omega$ 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 <u>Outline Dimensions</u>



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

5.2 Package Code



Figure 4 Package Marking

5.3 <u>Antenna Position</u>



Figure 5 Antenna Position (top view)



6 Application

6.1 Application Circuit



Figure 6 Principle of an Application Circuit

6.2 <u>Evaluation Kit</u>

Silicon Radar offers evaluation kits for speeding up radar development. Please review our website and product sheets for more information: <u>https://www.siliconradar.com/evalkits/</u>.

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 <u>Power Cycling</u>

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.





Measurement Results 7



TX Antenna Characteristics in E-plane, measured Figure 8 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.

TRX_120_089 FMCW BW=1GHz, different start frequencies H-plane



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

TRX_120_089 FMCW BW=1GHz, different start frequencies E-plane



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



Disclaimer

Indie Semiconductor FFO GmbH 2023. The information contained herein is subject to change at any time without notice.

Indie Semiconductor FFO 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 Indie Semiconductor FFO 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 Indie Semiconductor FFO 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: Indie Semiconductor FFO 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 INDIE SEMICONDUCTOR FFO 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.

Indie Semiconductor FFO GmbH owns all rights, titles and interests to the intellectual property related to Indie Semiconductor FFO GmbH's products, including any software, firmware, copyright, patent, or trademark. The sale of Indie Semiconductor FFO GmbH's products does not convey or imply any license under patent or other rights. Indie Semiconductor FFO GmbH retains the copyright and trademark rights in all documents, catalogs and plans supplied pursuant to or ancillary to the sale of products or services by Indie Semiconductor FFO GmbH. Unless otherwise agreed to in writing by Indie Semiconductor FFO GmbH, any reproduction, modification, translation, compilation, or representation of this material shall be strictly prohibited.