EVAL BGT24LTR22

XENSIV™ 24 GHz radar evaluation board

About this document

Scope and purpose

This user guide describes the function, circuitry, and performance of the BGT24LTR22 evaluation board, Infineon's highly integrated multichannel 24 GHz radar transceiver chip. It also provides detailed information on the MMIC (Monolithic Microwave Integrated Circuit) evaluation board and RF impedance matching structures, allowing users to gain a deeper understanding of the chip's capabilities and applications.

Intended audience

The intended audience for this document is design engineers, technicians, and developers of electronic systems, working with Infineon's XENSIV™ 24 GHz radar sensors.

Reference Board/Kit

Product(s) embedded on a PCB with a focus on specific applications and defined use cases that may include software. PCB and auxiliary circuits are optimized for the requirements of the target application.

Boards do not necessarily meet safety, EMI, quality standards (for example UL, CE) requirements.

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Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	**Caution:** *The reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*

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1 Introduction

The last decade has seen tremendous advances in silicon-based integrated circuits (ICs) for radar applications. Monolithic microwave integrated circuits (MMICs) operating in the 24 GHz industrial, scientific, and medical (ISM) band are widely deployed in the market today for several advanced automotive driver assistance systems (ADAS) applications, such as blind spot detection (BSD), lane change assist (LCA), and rear cross traffic alert (RCTA). However, the adaptation of radar technology beyond automotive applications has gained huge momentum. Many emerging industrial and consumer applications have adopted radar technology in recent years due to the numerous benefits offered by this technology.

Recently, there has been a growing interest in millimeter-wave (mm-wave) frequencies higher than 50 GHz for radar applications (e.g., 56 to 66 GHz, 76 to 81 GHz, and above 100 GHz). This is mainly driven by the availability of higher bandwidth at these frequencies, leading to better target detection by the radar, and smaller antenna and MMIC sizes. As devices operating in such mm-wave frequency bands begin to find space in more automotive and industrial applications, the 24 GHz ISM band remains a lucrative option for several evolving low-cost and low-power industrial and consumer applications. The advantages offered by the mm-wave radar technology above 50 GHz, though attractive, come at a high price and design complexity, and it is extremely challenging to adapt them to price- and power-sensitive applications. Also, worldwide frequency regulations are yet to be harmonized with mm-wave radar applications. This makes 24 GHz technology-based radar sensors preferable to their mm-wave counterparts.

Apart from the well-established ADAS automotive segment, a vast majority of industrial and consumer applications, such as motion detectors, door openers, surveillance systems, unmanned aerial vehicles (UAVs), contactless vital-sensing, and simple gesture-recognition systems, are increasingly finding space for 24 GHz radar solutions due to their simplicity [6]. Also, evolving automotive comfort applications, such as hands-free trunk opening and in-cabin lighting, and safety applications, such as child presence detection (CPD), are finding the 24 GHz solutions easily deployable in terms of cost and power consumption requirements. The 24 GHz radar band remains attractive mainly for the following reasons:

- Ability to cover longer distances than mm-wave frequency radar due to lower atmospheric propagation loss
- Lower radome and printed circuit board (PCB) interconnect losses
- Lower impact of PCB tolerances on sensor performance
- Cheaper PCB material
- ISM band leads to harmonized operations almost worldwide without any major regulatory concerns

The feasibility of 24 GHz radar for several automotive, industrial, and consumer applications has led to an increasing demand for highly integrated, low-power, low-noise, and small form-factor MMICs in the 24 GHz ISM band. Simple power-efficient 24 GHz Doppler or frequency-shift keying (FSK) radar systems fulfill many application requirements in the industrial and consumer segment, making them highly attractive for low-power, price-sensitive application scenarios. Though mm-wave frequency (above 50 GHz) based multichannel frequency-modulated continuous wave (FMCW) radar offers a much better target detection in terms of resolution and accuracy, such systems suffer from high power consumption and intensive computation requirements, leading to expensive central processing units (CPUs) and higher system cost. Multichannel FMCW narrowband radar implemented at the 24 GHz ISM band has been successful in mid- to long-range applications in the automotive radar segment for several decades, and the same benefits are now being extended to many industrial and consumer applications with highly integrated and power-efficient MMIC solutions, such as the BGT24LTR22.

2 BGT24LTR22 MMIC

This user guide provides a detailed description of Infineon's next-generation, low-power, highly integrated 24 GHz radar transceiver MMIC BGT24LTR22, designed for industrial radar applications. The chip consists of two transmitters and two receivers with an integrated analog baseband (ABB) for IF signal conditioning designed in Infineon's SiGe:C BiCMOS technology B11HFC. The IC is designed for short- to medium-range low-power sensing applications. The major building blocks of the transceiver are described in detail, and its RF and DC performance as measured on the Infineon evaluation board is provided. A complete description of all the SPI register settings to communicate with the chip is also given. This application note serves as a user manual to quickly get started with the evaluation of the BGT24LTR22 MMIC and implement a radar system using the same.

2.1 Key features

- Highly integrated 24 GHz radar front-end MMIC in SiGe:C BiCMOS technology for low-power applications
- Fully integrated low phase-noise (PN) voltage-controlled oscillator (VCO)
  - -85 dBc/Hz PN at 100 kHz offset
- Highly integrated frequency divider
  - High-frequency output – /16 – for external hardware PLL
  - Several low-frequency outputs – for software PLL
- Two single-ended transmit (TX) channels with configurable output power
  - Up to +5 dBm typical output power
  - Output power dynamic range greater than 20 dB
  - TX on/off isolation: min. 40 dB
- Two single-ended receive (RX) channels
  - Typical maximum voltage conversion gain (CG) 26 dB, with typical single-sideband noise figure (NFSSB) 8 dB
  - Direct conversion quadrature mixer with differential outputs
- Integrated ABB section for FMCW radar application
  - High-pass filter (HPF) with tunable cut-off frequencies (20 kHz, 50 kHz, 80 kHz and 100 kHz) and gain (18 dB or 30 dB)
  - Variable-gain amplifiers with up to 30 dB gain (5 dB programmable steps)
  - Anti-aliasing filter (AAF) with 600 kHz cut-off frequency
- Integrated ABB bypass mode for Doppler applications
  - DC-coupled mixer output with 3 dB bandwidth above 100 MHz
- Excellent on-chip TX-to-RX isolation above 40 dB
- Integrated PTAT-based tuning voltage generator for Doppler radar applications in the ISM band
- Integrated power and temperature sensors
- One chip supporting all modulation schemes (Doppler, FSK and FMCW)
- Single supply voltage 1.5 V
- Multimode operation with scalable architecture
  - Master mode (single device): 1TX to 1RX, 1TX to 2RX, 2TX to 2RX
  - Slave mode (multiple devices): built-in cascade feature allowing one device to combine with several other devices with a shared LO, and to expand the number of TX and RX for beamforming applications – e.g., 1TX to 4RX and 2TX to 4RX

- SPI transceiver
- Dedicated hardware pin (TX_EN) for fast on/off switching of the transmitters

2.2 Target applications

- Smart lighting (indoor and outdoor)
- Collision avoidance systems for commercial agricultural vehicles (CAVs)
- Industrial automation (robotics)
- Drone landing assist and collision avoidance
- Traffic monitoring
- Security systems (surveillance and alarm)
- Simple presence detection for smart home appliances
- Automatic door openers
- Simple motion detection and speed measurement with ranging
- Vital sensing
- Simple gesture recognition
- Touchless switches

3 BGT24LTR22 evaluation board

All electrical characteristics and functional description of the device presented in this application note are based on the performance of the BGT24LTR22 chip soldered onto a specially designed evaluation board. This section provides a detailed overview of this evaluation board. An overview of the PCB layer stack-up along with RF impedance matching networks and S-parameter measurements are provided, followed by a description of the PCB schematic and bill of materials (BOM).

3.1 Layer stack-up

The evaluation board is based on a four-layer metal stack-up, shown in Figure 1. A Rogers RO-4350B core of 0.250 mm thickness is used as the RF substrate. The matching structures for the transmitter and receiver part are designed based on this stack-up. Blind vias are used beneath the PCB-SMA connectors to improve the return loss.

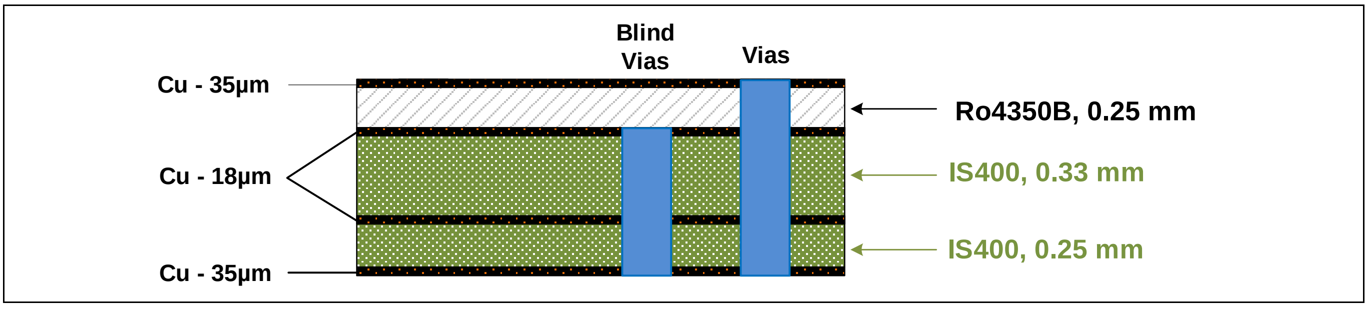


Figure 1 Evaluation board layer stack-up

3.2 Evaluation board layout

Figure 2 shows the BGT24LTR22 evaluation board.

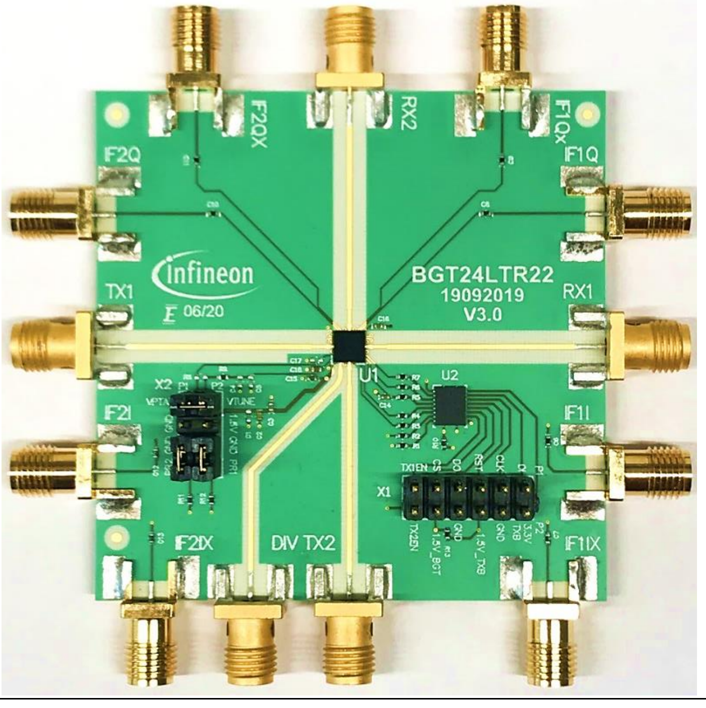


Figure 2 BGT24LTR22 Evaluation board

3.3 Impedance matching structures

Table 2 lists the impedances of all the RF ports of the MMIC defined at the landing pads on the PCB looking into the device pins. For optimum characterization of the device, it is necessary to match these impedances to 50 Ω with proper impedance matching networks.

Table 2 RF port impedances, looking into the device

Frequency (GHz)	RX1 (Ω)	RX2 (Ω)	TX1 (Ω)	TX2 (Ω)
24.000	43.80-j8.29	44.25-j7.29	37.99-j16.57	37.527-j18.858
24.125	43.813-j8.235	44.673-j7.145	38.307-j16.499	36.99-j18.384
24.250	43.827-j8.194	45.233-j7.283	38.67-j16.89	36.71-j17.99

Figure 3 gives the dimensions of the impedance matching network designed on the evaluation board. The layout structures around the ground pins adjacent to each RF pin are important and are highlighted in Figure 4.

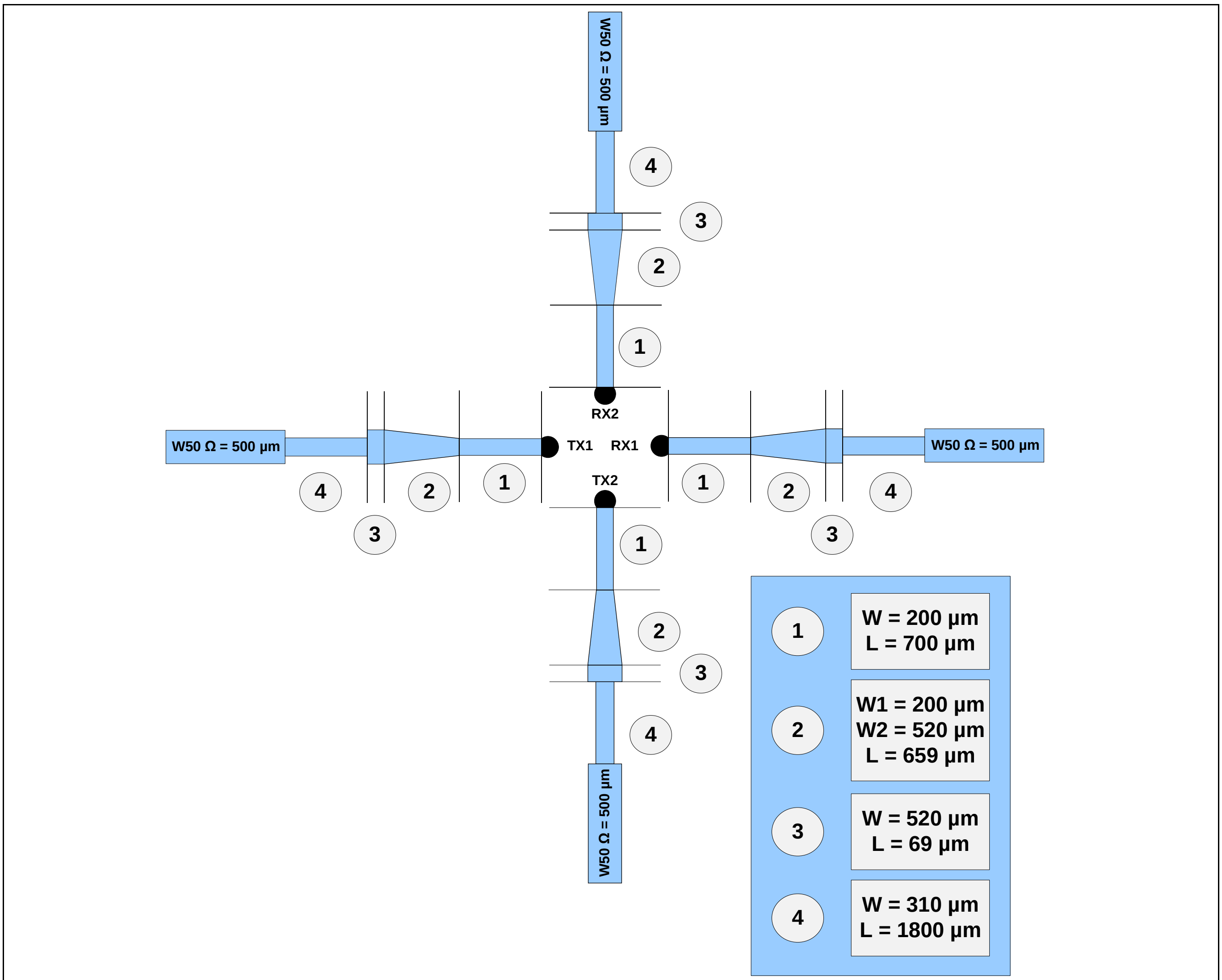


Figure 3 Dimensions of impedance matching structures used on the evaluation board

Figure 4 shows a zoomed-in view of the layout of the PCB below the chip area. It is recommended to follow the layout approach described for all the ground pins surrounding the RF ports to achieve good isolation between the TX and RX ports. These connecting lines around the RF ports are 200 µm wide and the ground vias are all through vias with 200 µm diameter.

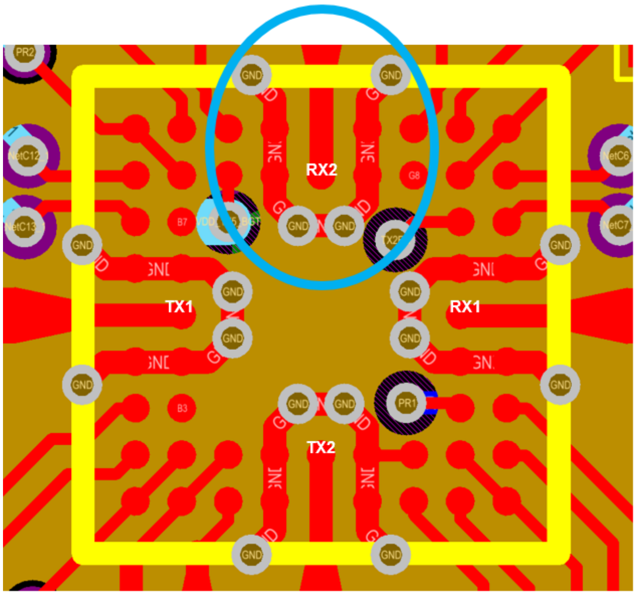


Figure 4 Layout of ground vias and lines around the RF ports for higher TX to RX isolation

Figure 5 shows a zoomed-in view of the fabricated impedance matching structures.

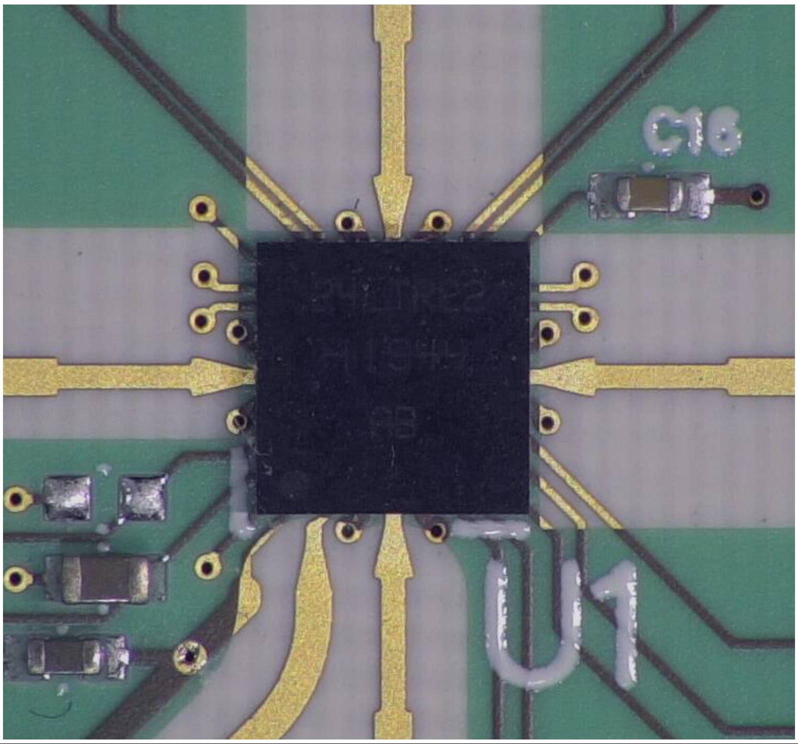


Figure 5 Evaluation board with impedance matching structures

4 S-parameters and PCB loss measurements

The evaluation boards with the proposed impedance matching networks were assembled with the BGT24LTR22 device and SMA connectors for measurement of the S-parameters. This section shows the measured return loss at the receiver and transmitter ports, respectively. The measurements are extremely sensitive to the soldering of the SMA connectors on the evaluation board, and proper care must be taken during the process.

4.1 Measured S-parameters – receiver ports

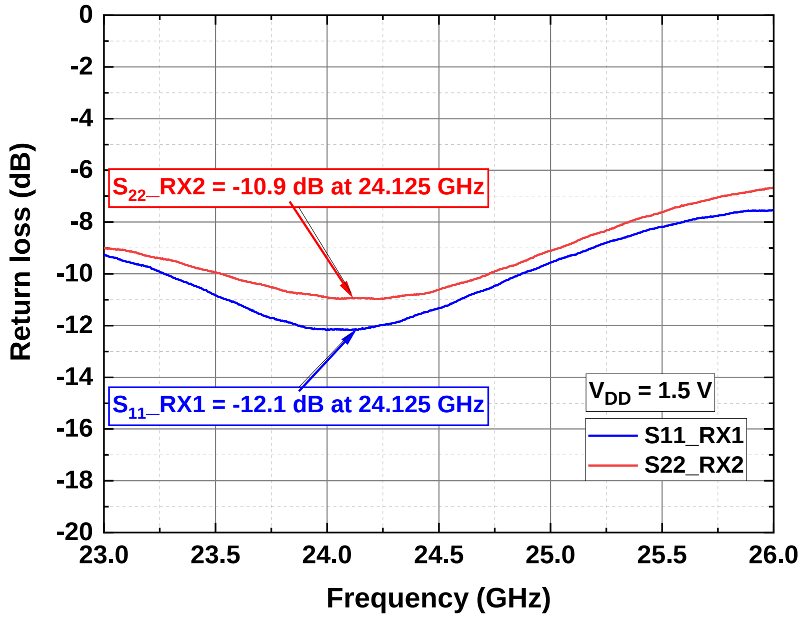


Figure 6 S-parameters – RX ports

4.2 Measured S-parameters – transmitter ports

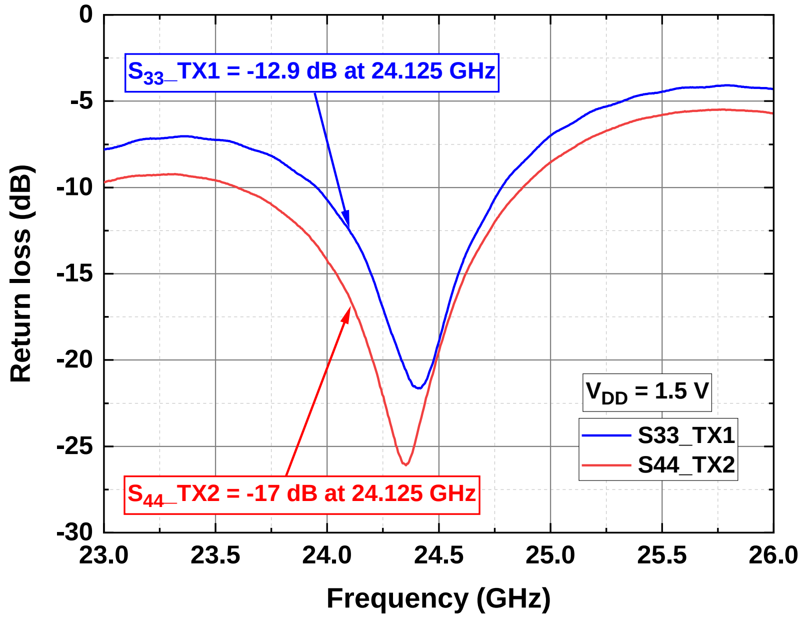
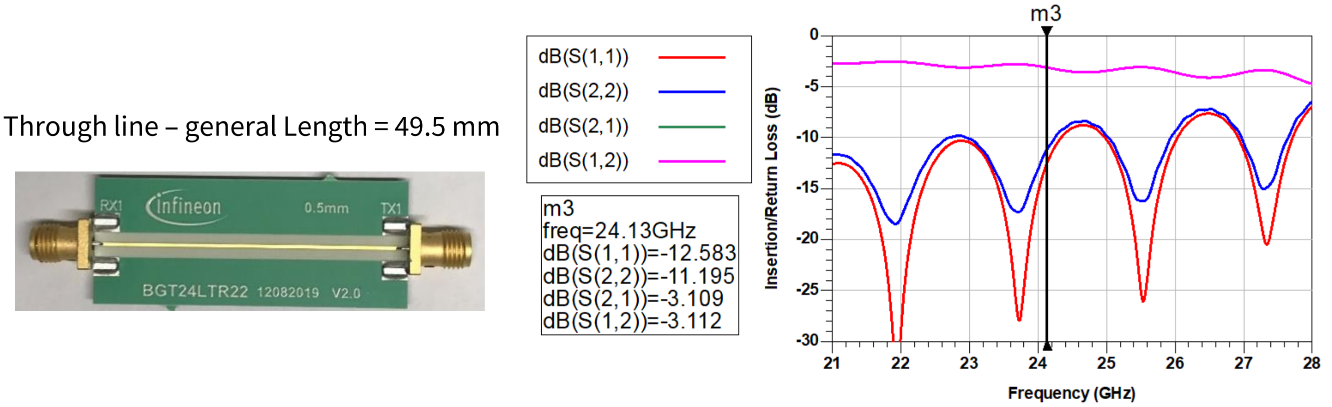


Figure 7 S-parameters – TX ports

4.3 PCB loss measurement

The loss of all the RF transmission line interconnects on the PCB was measured using special through-line calibration structures, as shown in Figure 8. The calibration structures were approximately twice the length of each transmission line section connecting the corresponding RF port to its SMA connector. All four RF ports have the same length of transmission lines from the edge of the matching networks to the SMA interface.

Based on the measurement of the calibration structures, a loss of approximately 1.5 dB was compensated for on all the RF ports (TX1, TX2, RX1 and RX2) for all the measurements presented in this application note unless otherwise mentioned. The loss of the impedance matching networks itself and any other SMA connector mismatch losses were not compensated. On a typical PCB, this can be approximated to an additional 0.5 dB.



a) Line description b) Measurement results

Figure 8 Calibration structures for PCB loss characterization

5 System design

5.1 Schematics

Figure 9 and Figure 10 show the schematics of the evaluation board, and Table 3 lists the BOM.

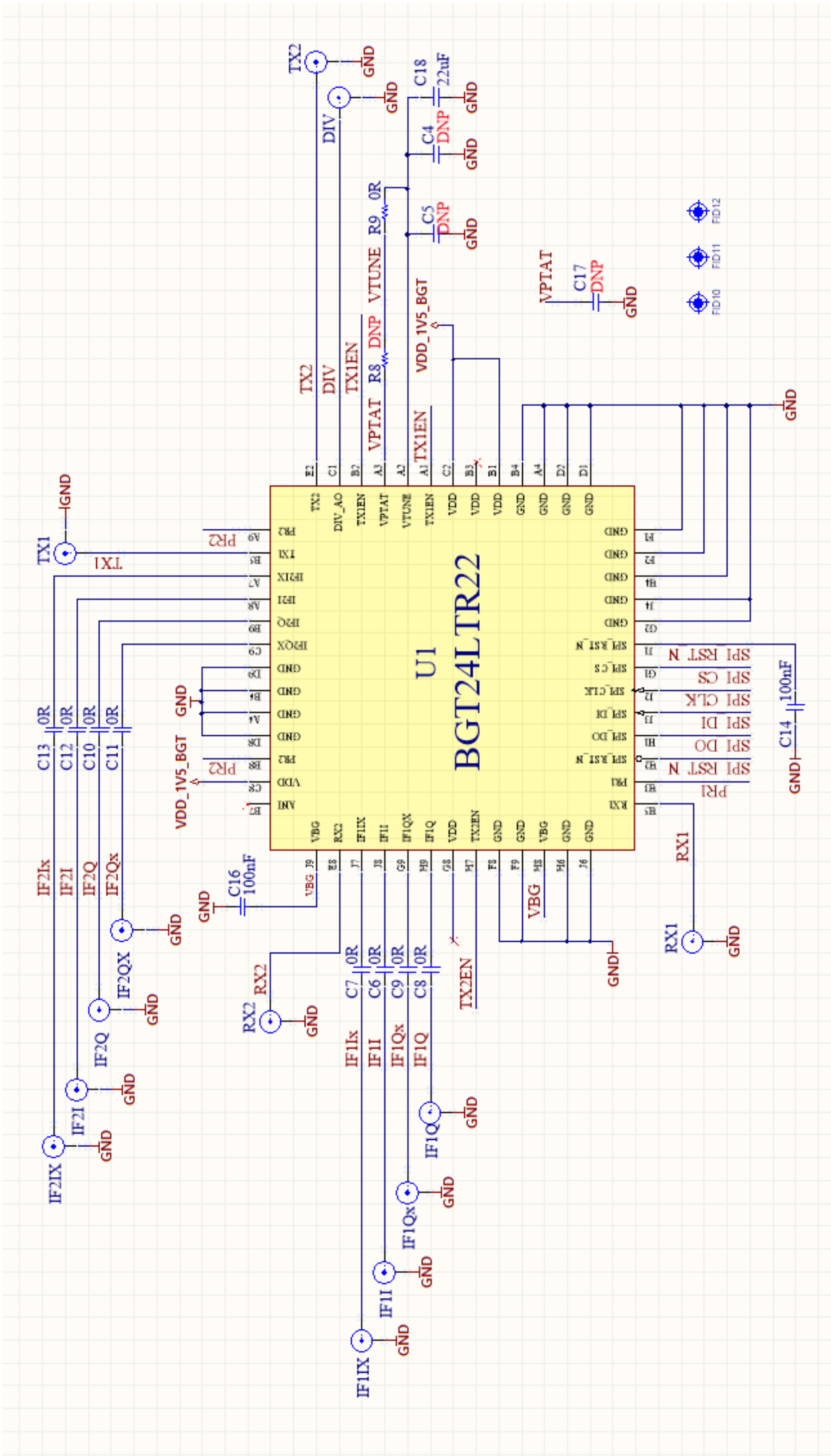
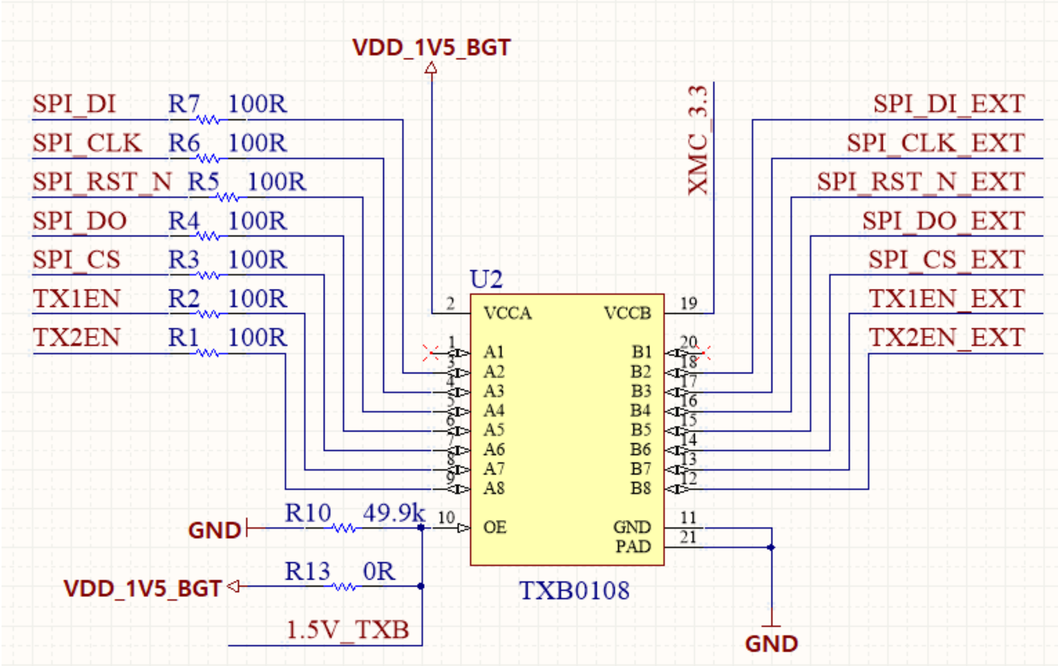
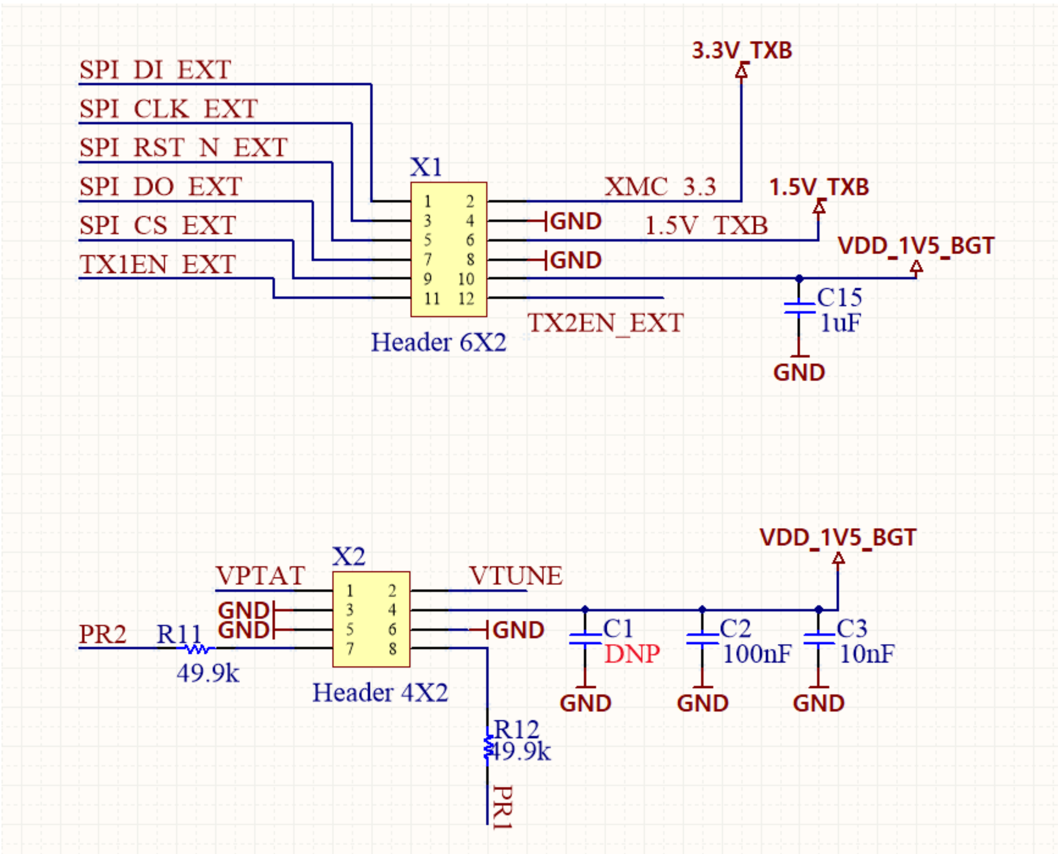


Figure 9 Evaluation board schematic – part 1



a) Level shifter



b) Pin headers for external connections

Figure 10 **Evaluation board schematic – part 2**

5.2 Bill of materials

The complete bill of materials (BOM) is available on the Design Support section of the EVAL BGT24LTR22 product webpage.

Table 3 Bill of materials (BOM)

Designation	Part type	Value	Package	Manufacturer
C1	Chip capacitor	DNP	0402	Murata
C2	Chip capacitor	100 nF	0402	Murata
C3	Chip capacitor	10 nF	0402	Murata
C4 to C5	Chip capacitor	DNP	0402	Murata
C6-C13	Chip resistor	0 R	0402	Various
C14	Chip capacitor	100 nF	0402	Murata
C15	Chip capacitor	1 µF	0402	Murata
C16	Chip capacitor	100 nF	0402	Murata
C17	Chip capacitor	DNP	0402	Murata
C18	Chip capacitor	22 µF	0402	Murata
R1 to R7	Chip resistor	100 R	0402	Various
R8	Chip resistor	DNP	0402	Various
R9	Chip resistor	0 R	0402	Various
R10 to R12	Chip resistor	49.9 kΩ (optional)	0402	Various
R13	Chip resistor	0 R	0402	Various
IF1I, IF1Ix, IF1Q, IF1Qx, IF2I, IF2Ix, IF2Q, IF2Qx	SMA connector	SMA8400M6-0000	–	Jyebao
TX1, TX2, RX1, RX2, DIV	SMA connector	PSF-S01-002	–	GigaLane
U1	24 GHz radar MMIC	BGT24LTR22	–	Infineon
U2	Level shifter – IC	TXB0108RGYR	–	Texas Instruments
X1	Pin header	2 x 6 pin 2.54 mm	–	Various
X2	Pin header	2 x 4 pin 2.54 mm	–	Various

References

[1] Infineon Technologies AG: *BGT24LTR22 MMIC datasheet;* Available online

[2] Infineon Technologies AG: *UG172630: User guide to BGT24LTR22;* Available online

[3] Chakraborty et al., “A Scalable Multimode 24 GHz Radar Transceiver for Industrial and Consumer Applications in a 0.13 µm SiGe BiCMOS Technology” in Proc. IEEE BCICTS Conf. Nashville, Tennessee, USA, Nov. 2019PL; Available online

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