User's Guide to BGT24LTR11N16

24GHz Radar

About this document

Scope and purpose

This application note is intended to put flesh on the bones of BGT24LTR11N16's datasheet.
The datasheet gives technical data and limits of the device itself but it is not explaining the device in greater detail. This application note takes care of this issue.
The reader will find here:

- Discussion of all different building blocks
- How to operate the different blocks
- Additional measurement data showing behavior over temperature

Intended audience

Hardware engineers and software engineers working on designs with Infineon's BGT24LTR11N16.

Table of Contents

List of Figures

List of Tables

1 Introduction to BGT24LTR11

BGT24LTR11 is Silicon Germanium radar MMIC for signal generation and reception, operating in the 24.0 GHz to 24.25 GHz ISM band. It is based on a 24 GHz fundamental voltage controlled oscillator (VCO). The device was designed with Doppler-radar applications in mind—as it is capable of keeping the transmit signal inside the ISM band without any external PLL — and may also be used in other types of radar such as FMCW or FSK.

A built-in voltage source delivers a VCO tuning voltage which is proportional to absolute temperature (PTAT). When connected to the VCO tuning pin it compensates for the inherent frequency drift of the VCO over temperature thus stabilizing the VCO within the ISM band eliminating the need for a PLL/Microcontroller. An integrated 1:16 frequency divider also allows for external phase lock loop VCO frequency stabilization.

The receiver section uses a low noise amplifier (LNA) in front of a quadrature homodyne down-conversion mixer in order to provide excellent receiver sensitivity. Derived from the internal VCO signal, a RC-polyphase filter (PPF) generates quadrature LO signals for the quadrature mixer. I/Q IF outputs are available through single-ended terminals.

The device is manufactured in a 0.18 µm SiGe:C technology offering a cutoff frequency of 200 GHz. It is packaged in a 16-pin leadless RoHS compliant TSNP package.

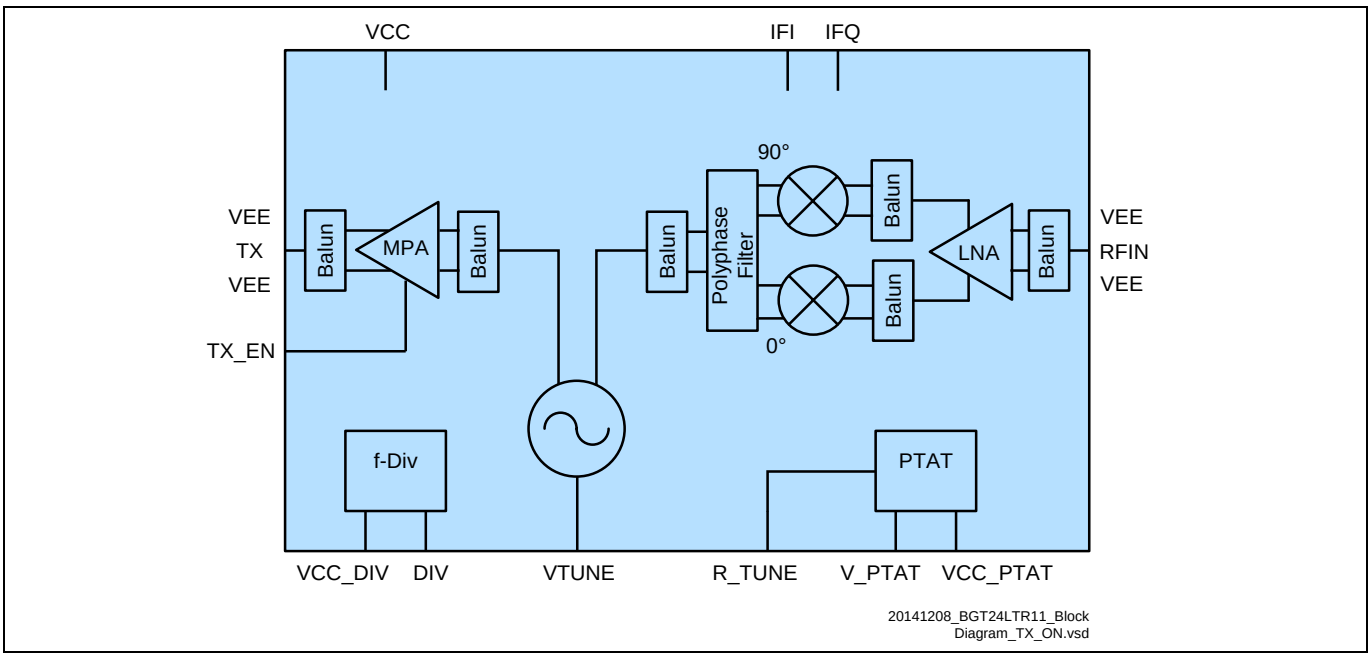

Figure 1 BGT24LTR11N16 Block Diagram

2 Building Blocks

2.1 Transmitter

BGT24LTR11N16 has a single-ended transmitter output TX (pin 11) with a typical output power of 6 dBm. The transmitter's output may be enabled and disabled by applying appropriate voltages to TX_ON (pin 5) as shown in the table below.

Disabling the TX output will not save power as the output will be switched to an internal load while the rest of the chip is still running. This is necessary in case one wants to implement a software controlled oscillator (see section 4.3).

Table 1 Enabling/disabling TX output

Enable TX	Disable TX
Voltage at TX_ON > 2 V	Voltage at TX_ON < 0.8 V

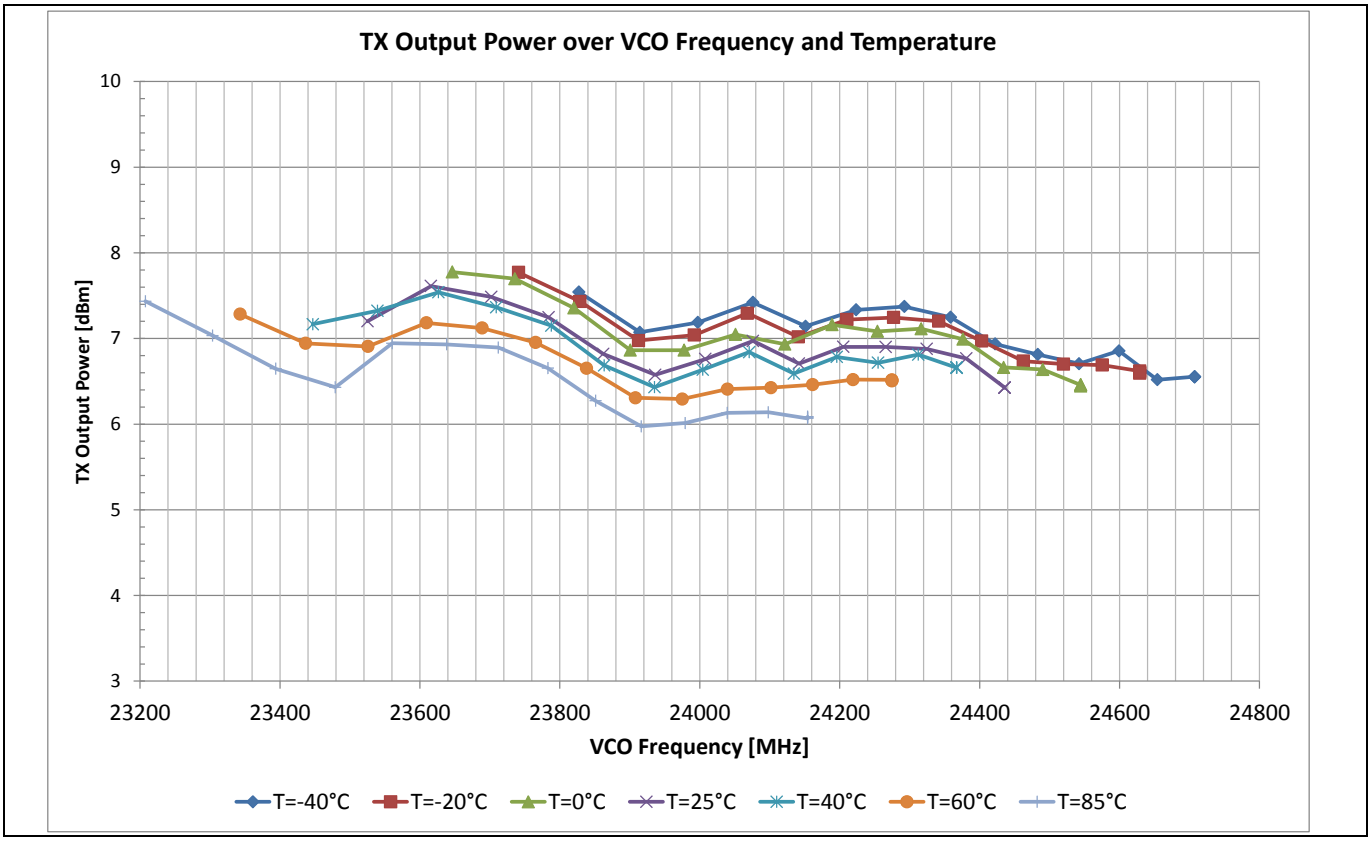

Figure 2 TX output power vs. frequency and temperature

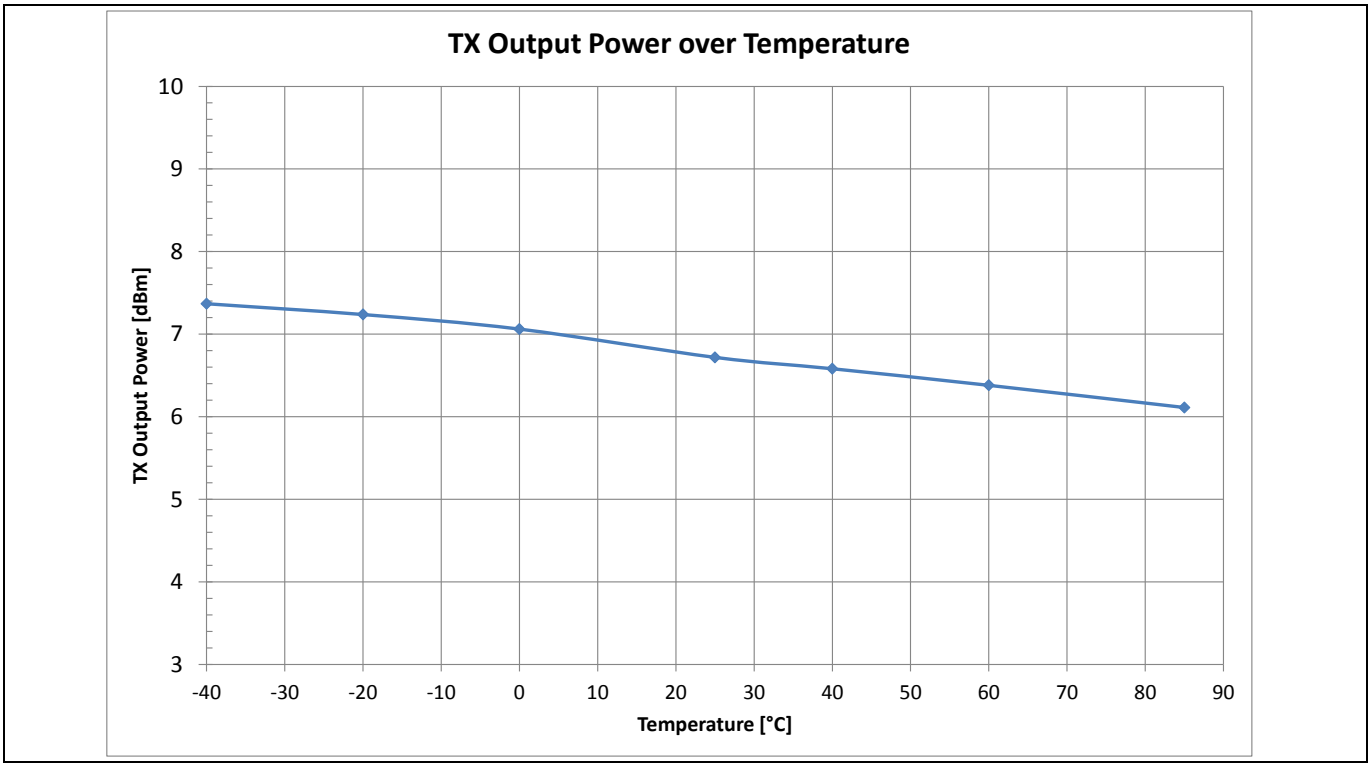

Figure 3 TX output power with VTUNE connected to V_PTAT

2.2 Receiver

The receiver consists of an LNA followed by quadrature direct-conversion mixer. Its input (RX, pin 3) is single-ended. The voltage conversion gain is typically 20 dB with a single side-band noise figure of 10 dB.

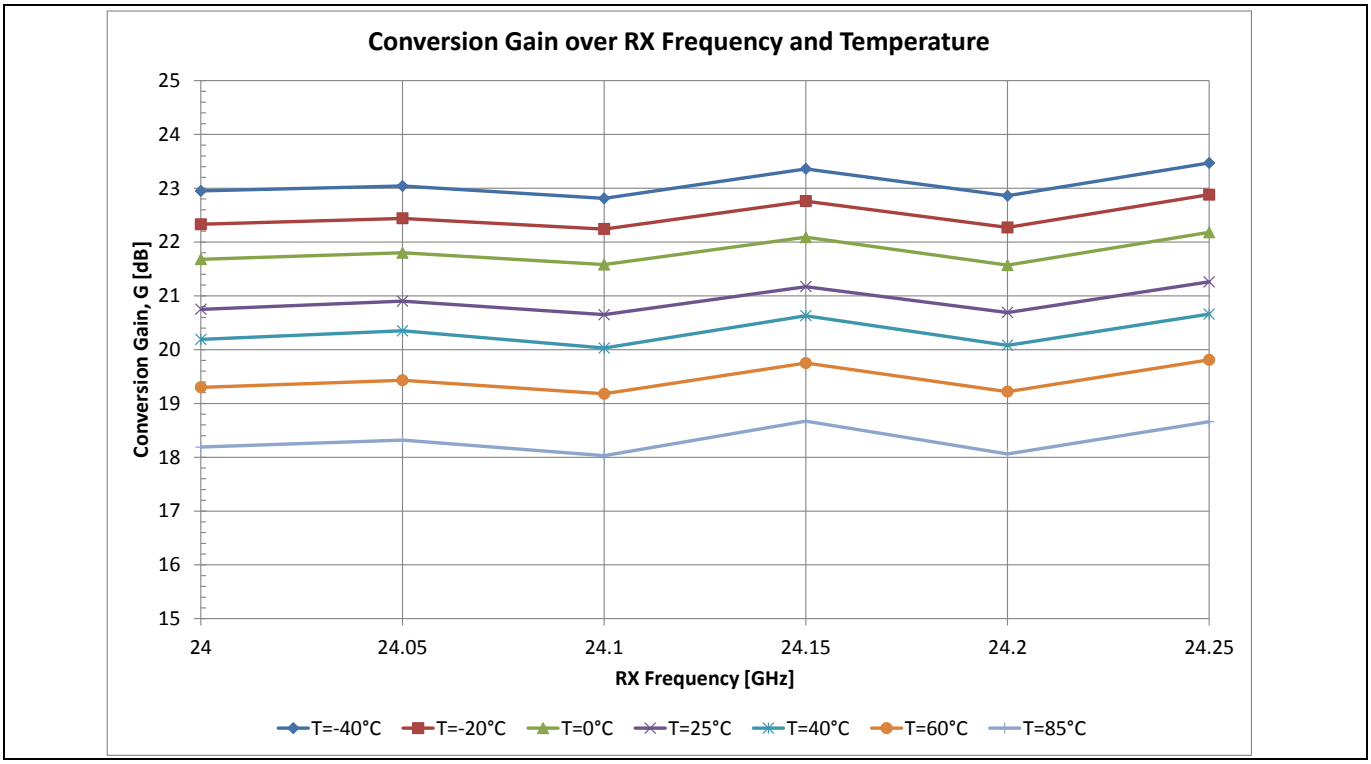

Figure 4 Gain vs. frequency

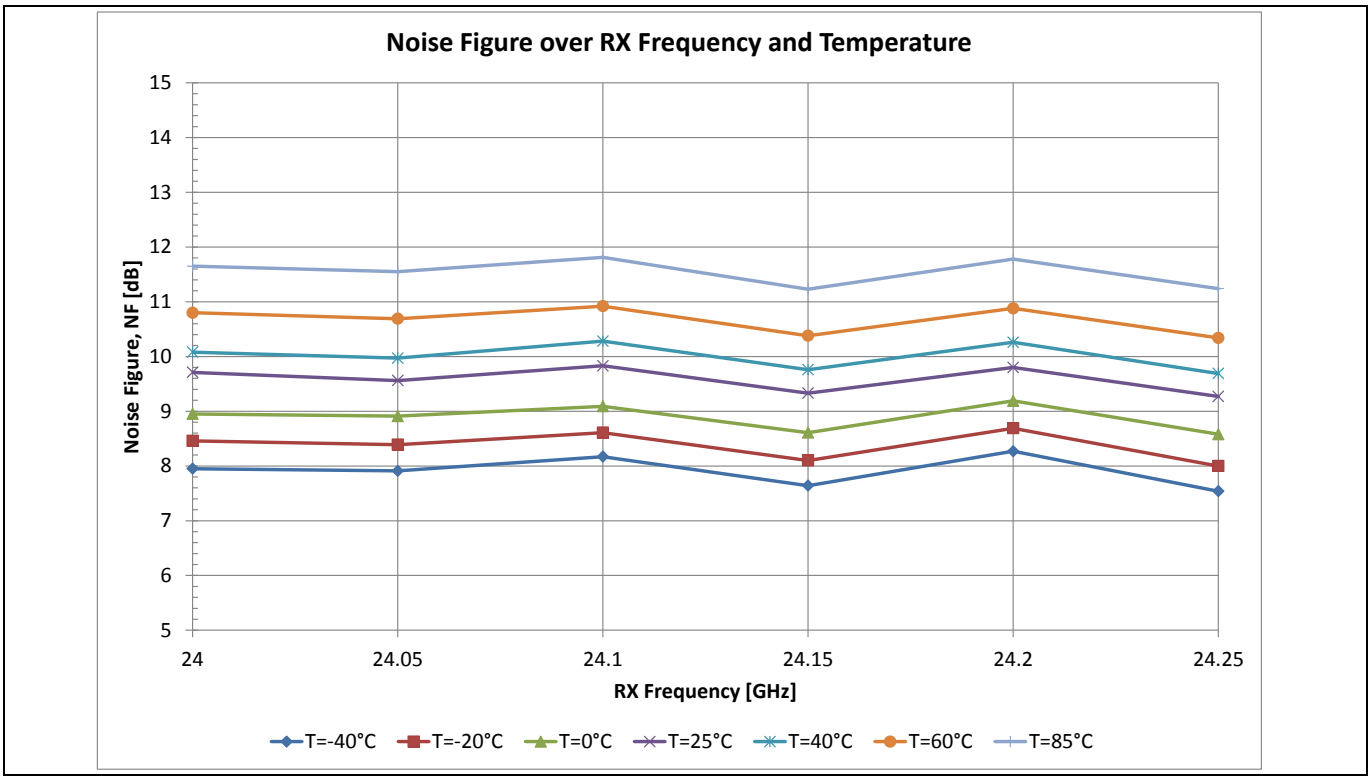

Figure 5 Noise figure vs. frequency

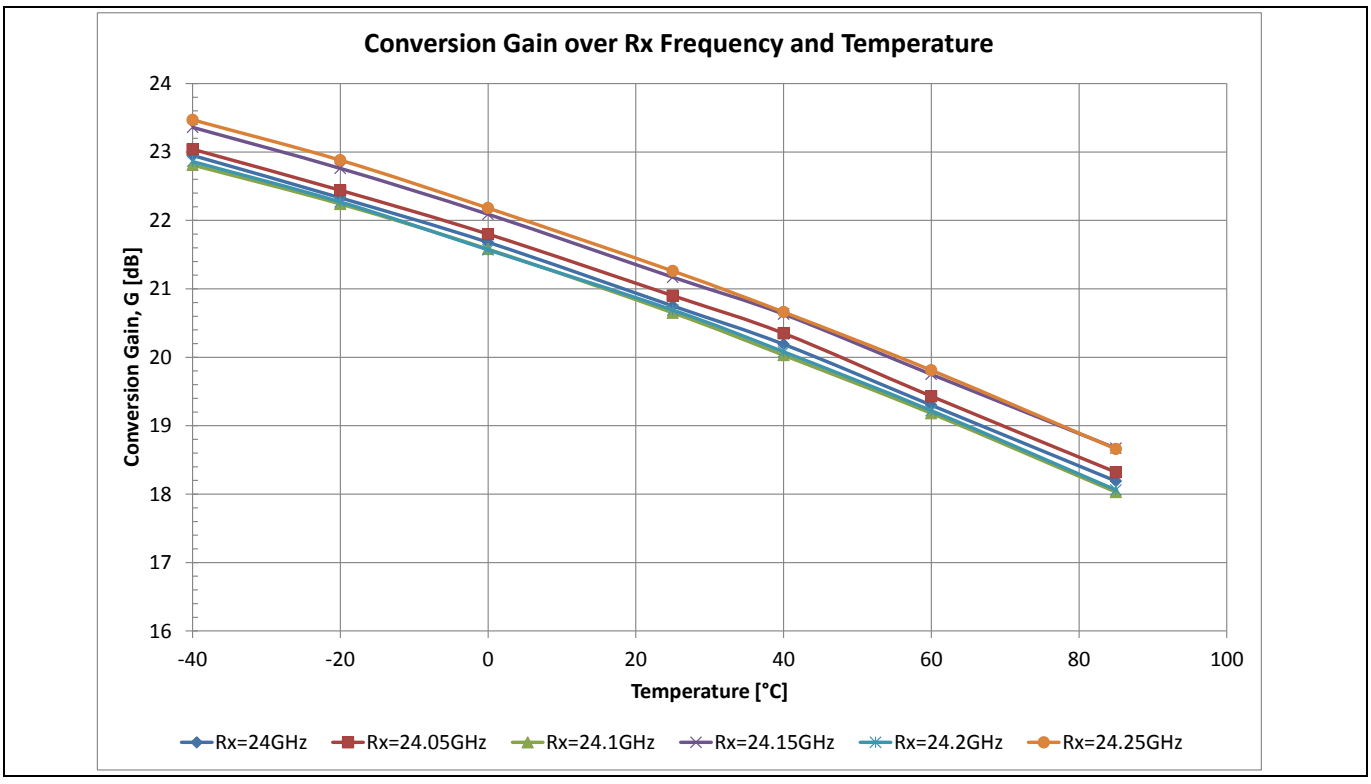

Figure 6 Conversion gain vs. temperature

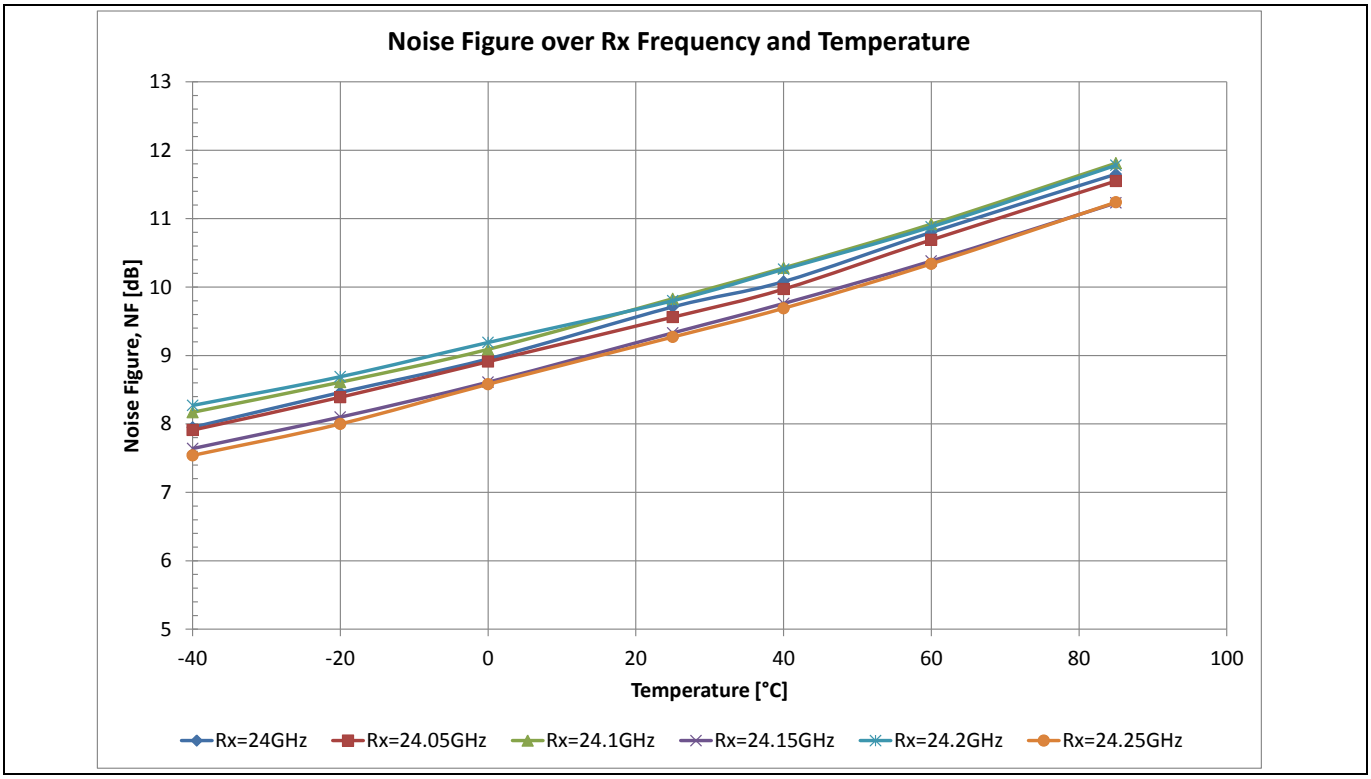

Figure 7 Noise figure vs. temperature

2.3 Voltage Controlled Oscillator (VCO)

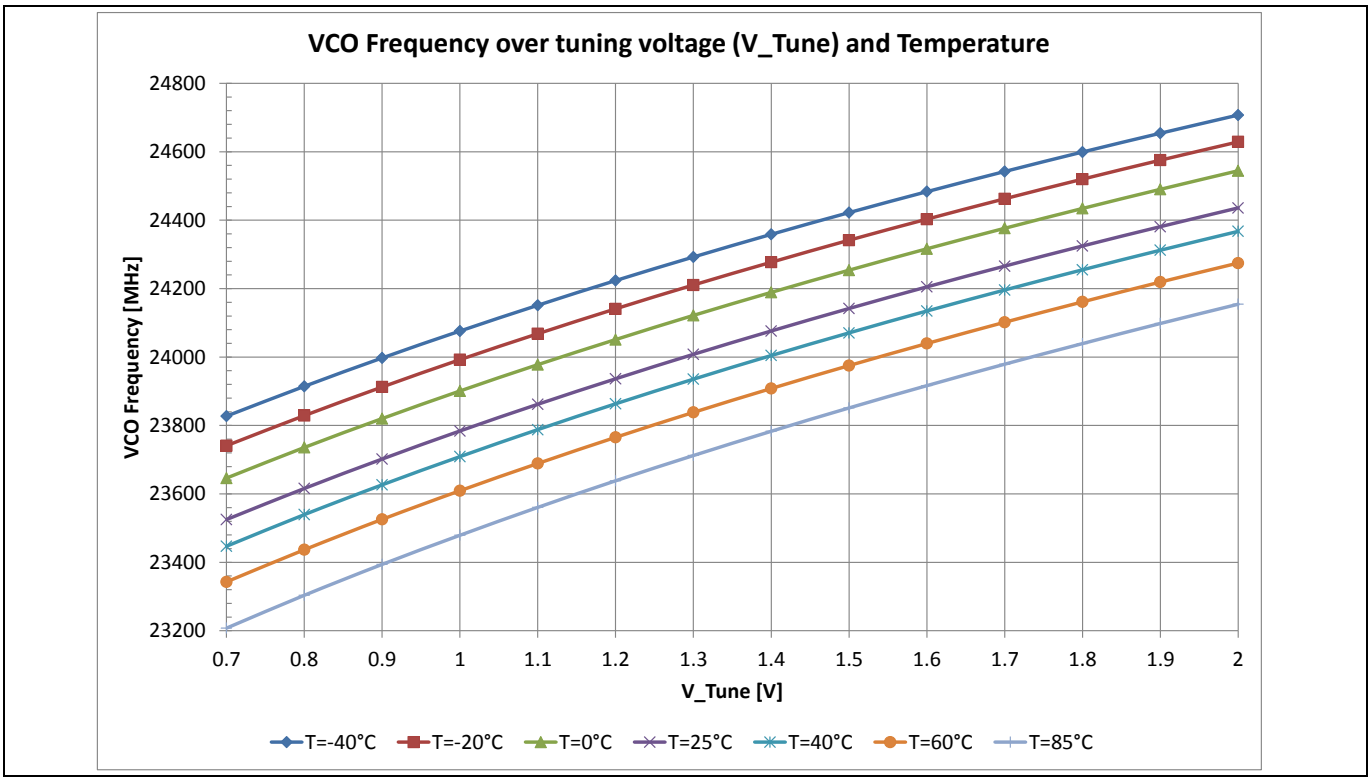

Figure 8 VCO frequency over tuning voltage and temperature

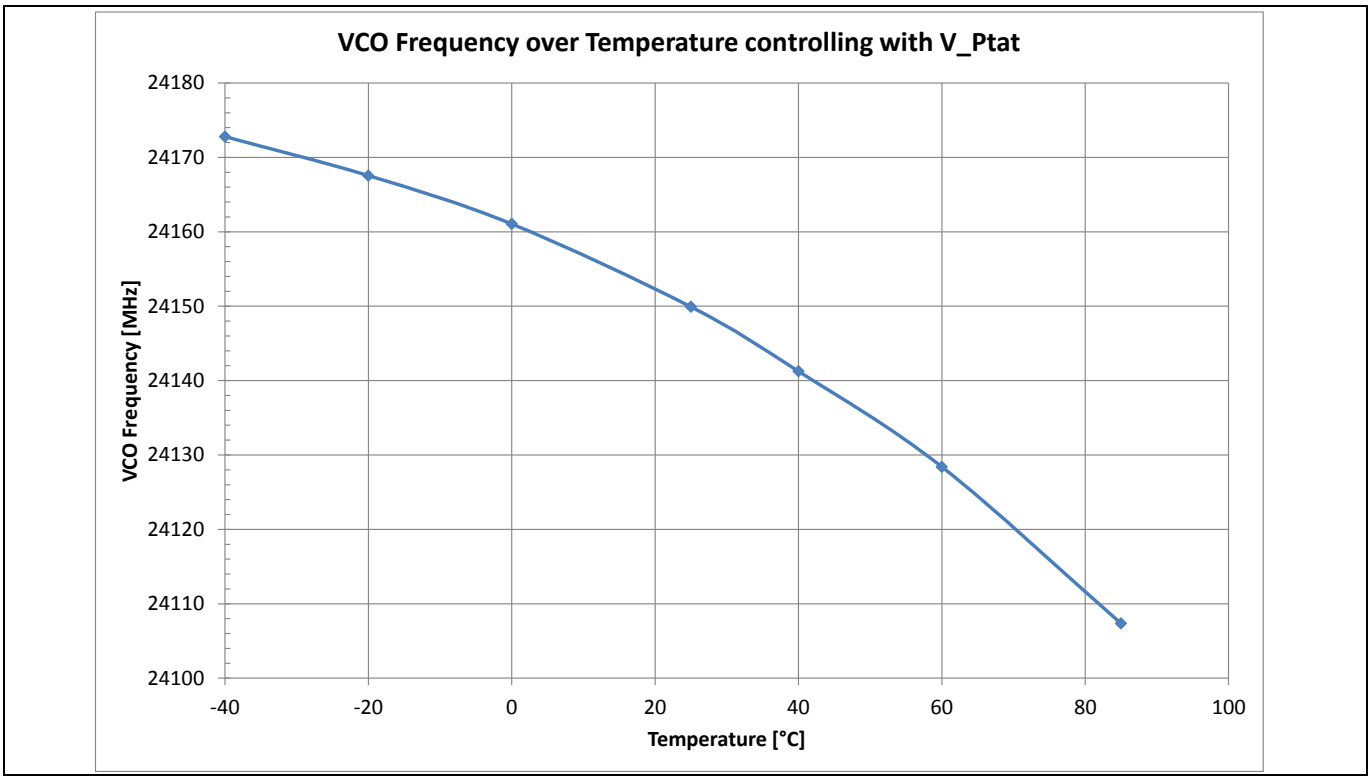

Figure 9 VCO frequency over temperature, VCO controlled by PTAT voltage source

2.4 Proportional to Absolute Temperature (PTAT) Voltage Source

The PTAT voltage source generates a voltage V_{PTAT} at the V_PTAT pin (pin 15) which is proportional to the chip temperature. It is powered separate from VCC via the VCC_PTAT pin (pin 16).

The PTAT voltage source serves two purposes:

- Generating tuning voltage for the VCO in Doppler mode. See section 4.1.
- Temperature sensor measuring chip temperature.

The chip temperature T_{chip} can be calculated from V_{PTAT} using the following equation:

T_{chip} / °C = 158.7 * (V_{PTAT} / V) – 217.0 with VCC_PTAT = VCC =3.3 V and VCC_DIV open.

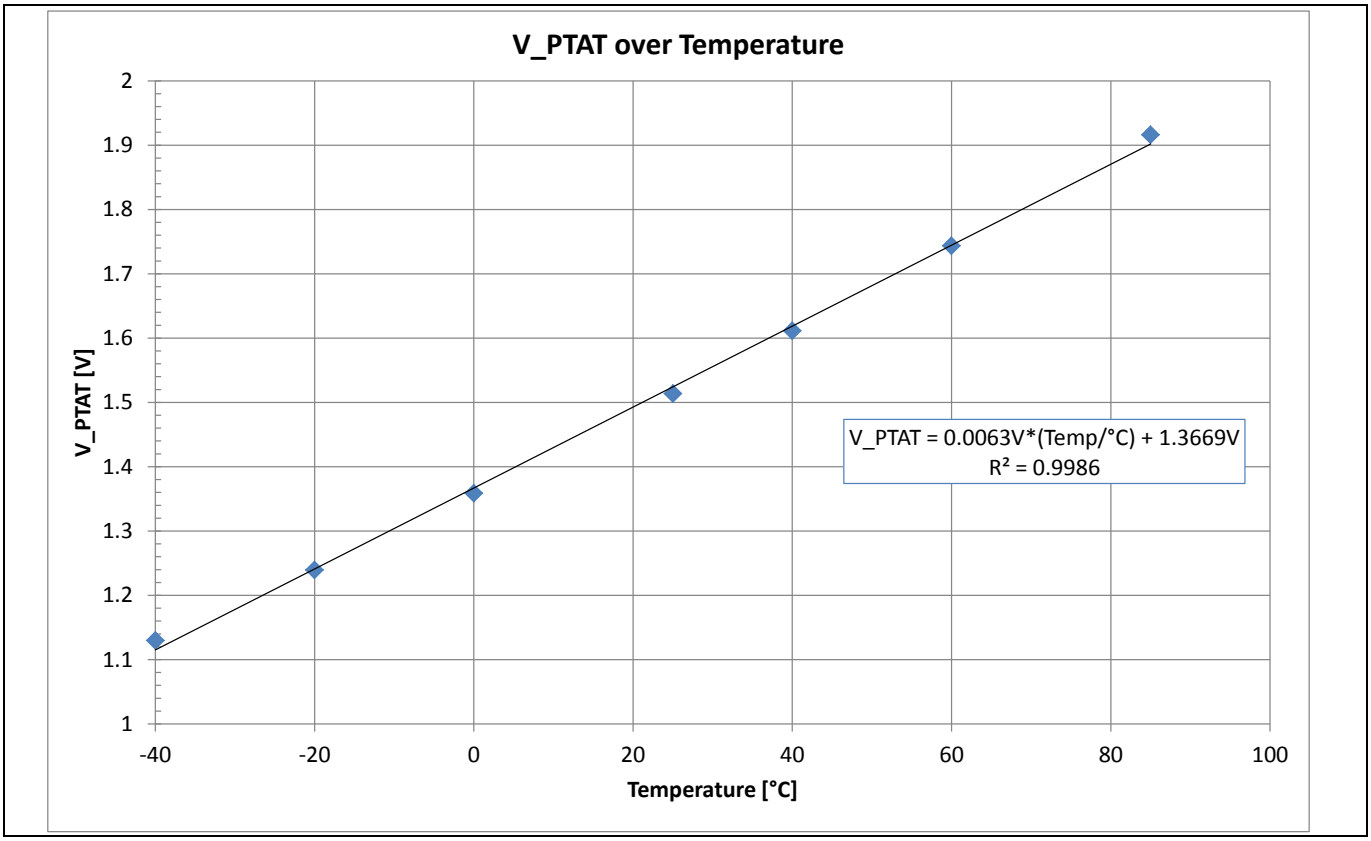

Figure 10 Voltage generated by PTAT voltage source vs. temperature

2.5 Frequency Divider

BGT24LTR11N16's frequency divider has two divider rations, divide by 16 and divide by 8182 which result in output frequencies of 1.5 GHZ and 3 MHz respectively.

Table 2 Setting the divider ratio

Divider ratio	Voltage at VCC_PTAT (pin 16)
16	< 0.8 V
8192	3.3 V

Setting the divider to a 3 MHz output will cause the PTAT to consume current. This ratio is usually used only in case of a software controlled VCO and for this use cases a temperature sensor is required anyways to check the validity of the used look-up table.

3 Evaluation Board

3.1 Schematic Diagram

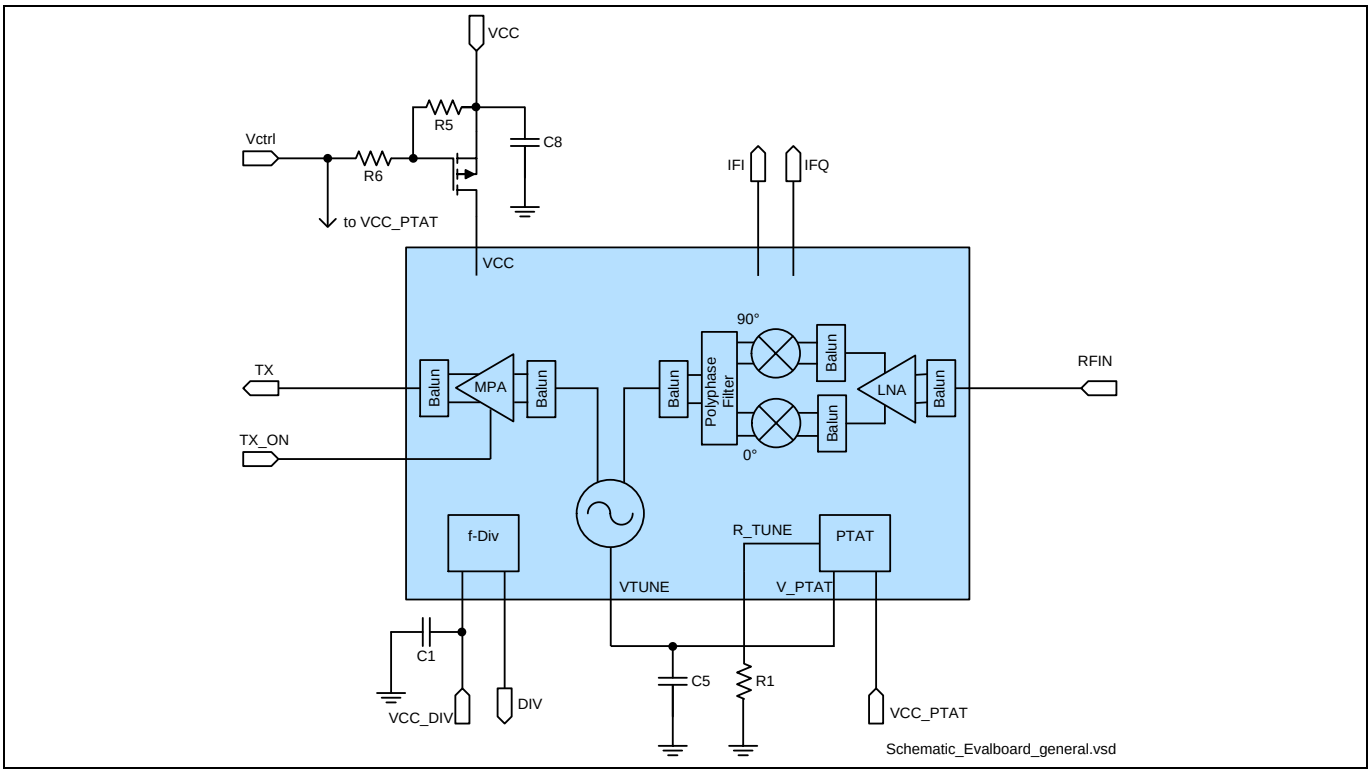

Figure 11 Schematic diagram

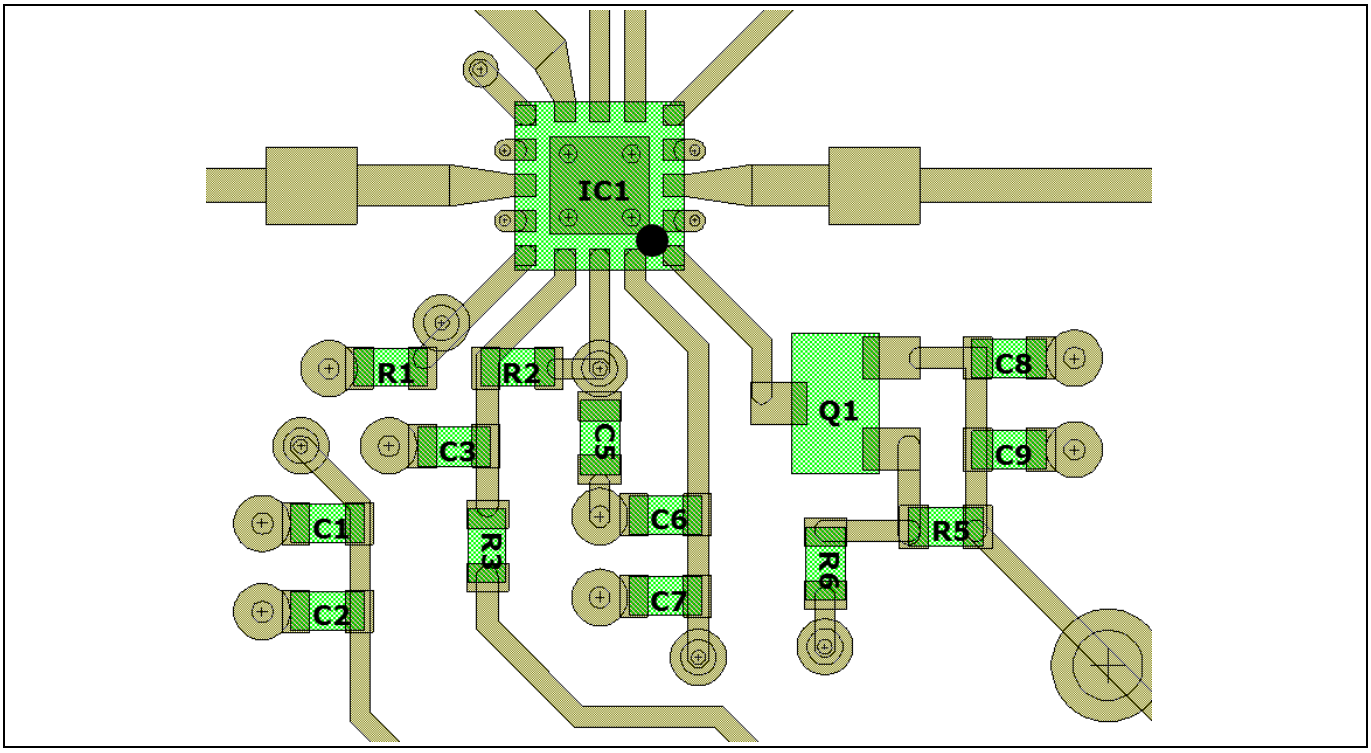

Figure 12 Component placement

Table 3 Bill of materials

Designation	Part type	Value	Package	Manufacturer
C1, C5, C8	Chip capacitor	1 µF	0402	Various
C2, C3, C6, C7, C9		DNP	0402	
R1	Chip resistor	16 kΩ	0402	Various
R2,R3	Chip resistor	0 Ω	0402	Various
R5	Chip resistor	100 kΩ	0402	Various
R6	Chip resistor	1 kΩ	0402	Various
Q1	p-MOSFET	BSS209PW	SOT-323	Infineon
IC1	Radar MMIC	BGT24LTR11N16	TSNP-16-9	Infineon

3.1.1 Matching Structures

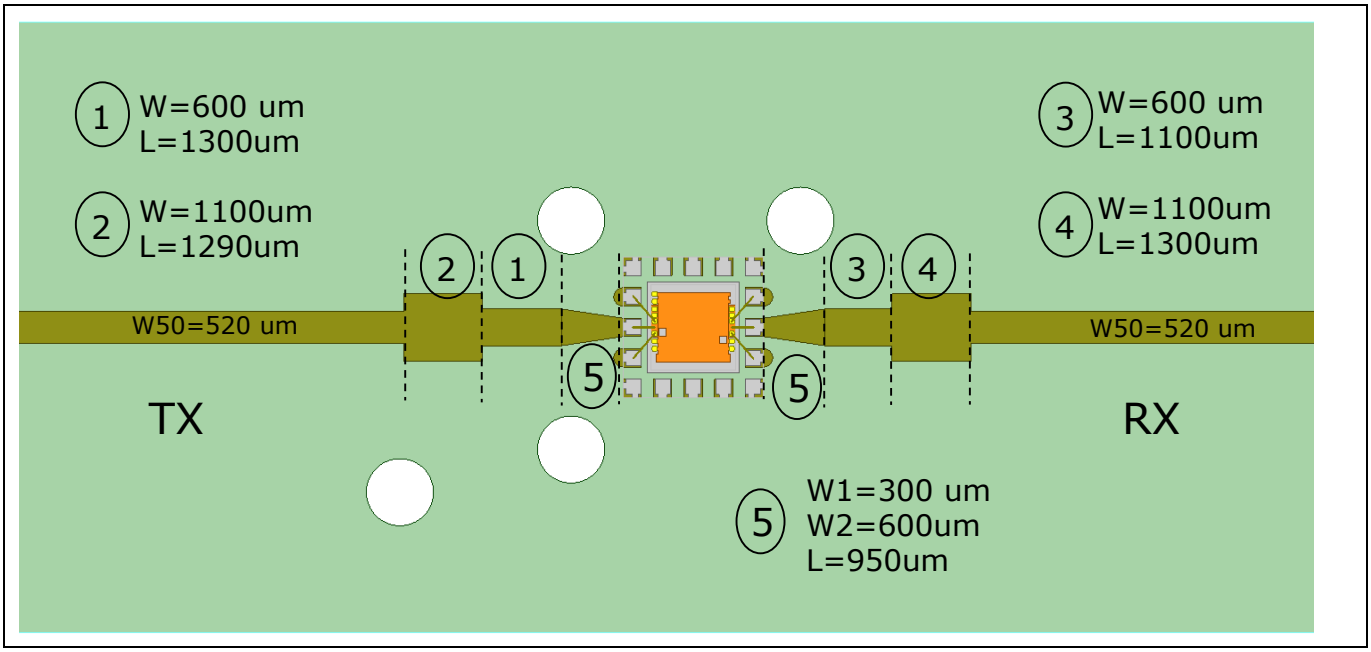

Figure 13 Matching structures to be used on a Ro4350B substrate with a thickness of 0.254 mm

3.2 Layout of Evaluation Board

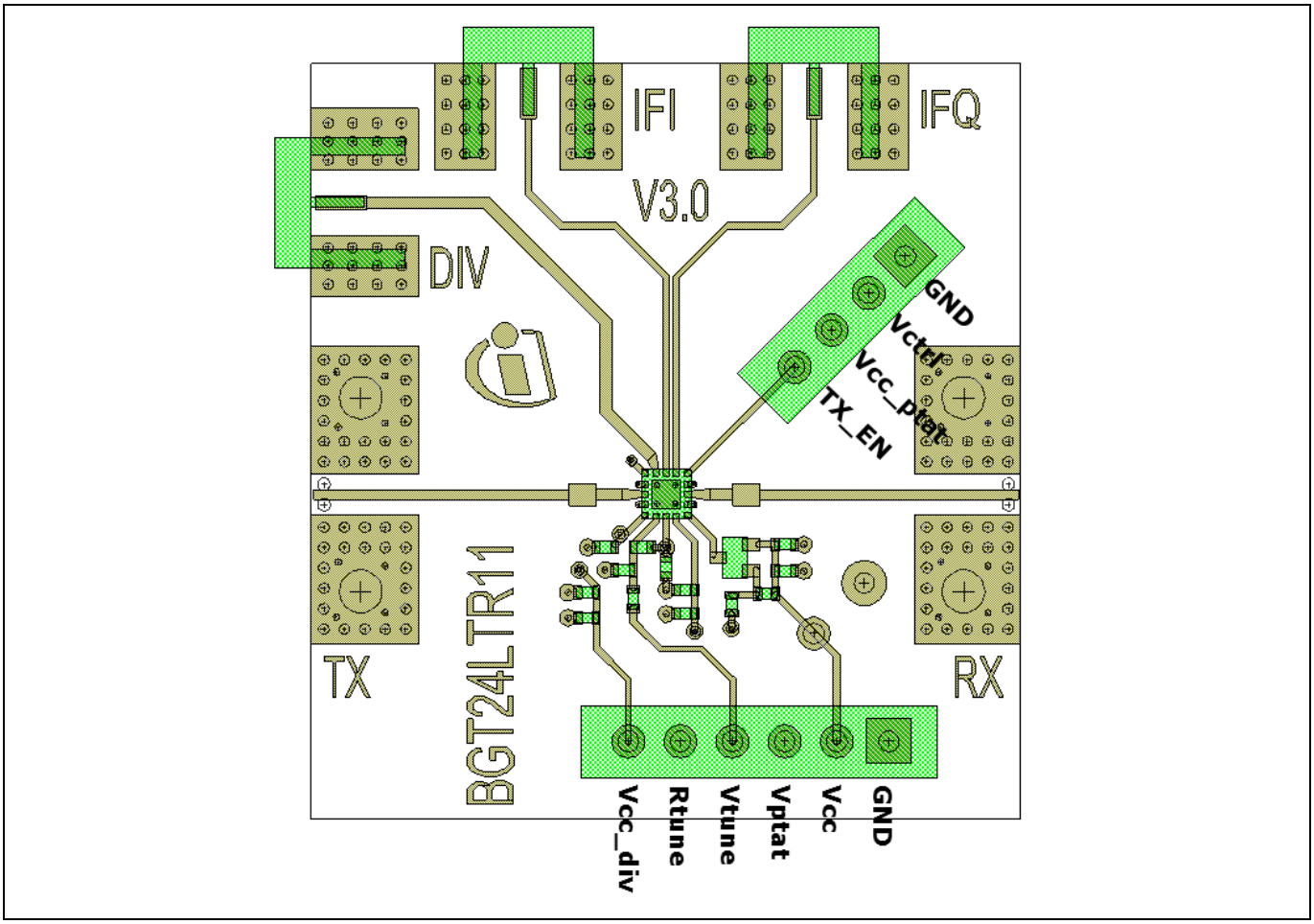

Figure 14 Layout of evaluation board with description of pin headers

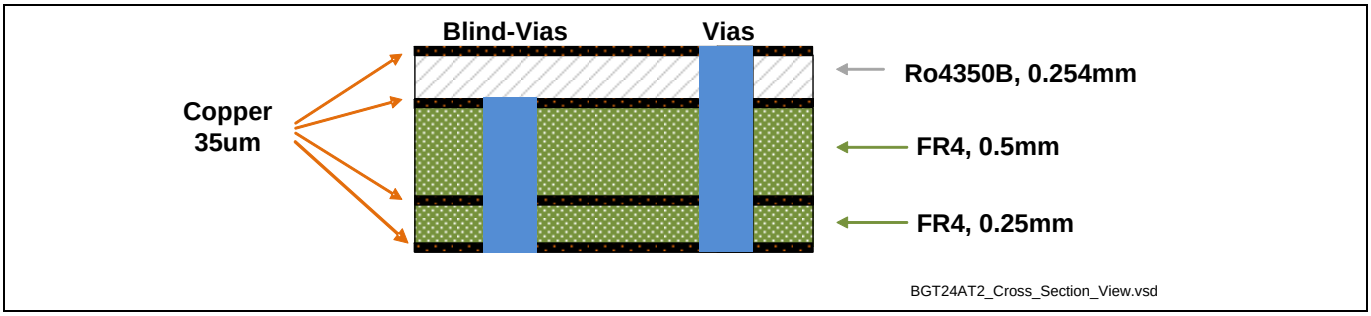

Figure 15 Layer stack

3.3 Layout Version improving TX to RX Isolation

The isolation between the TX port and the RX port on the standard evaluation board is typically about 25 dB. This isolation can be improved to 35dB by adding a grounded length of line at the ground pins next to the TX output pin as shown in Figure 16. Details of the used compensation structures can be found in Figure 17.

Table 4

	Standard evaluation PCB	PCB with compensation structures
TX to RX isolation / dB	25	35

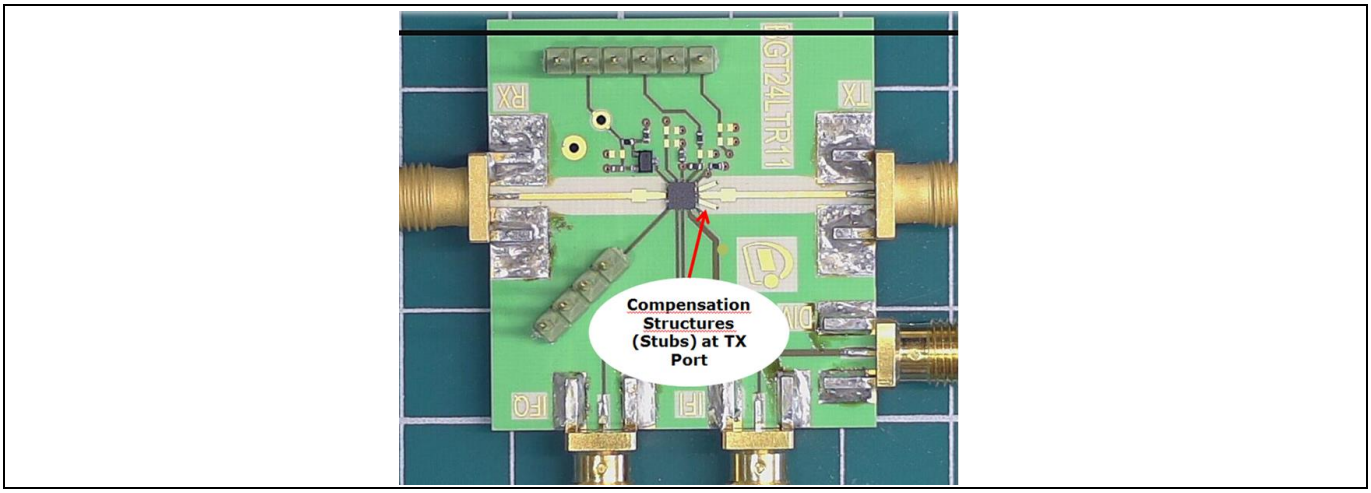

Figure 16 Adding compensation structures will increase TX to RX isolation

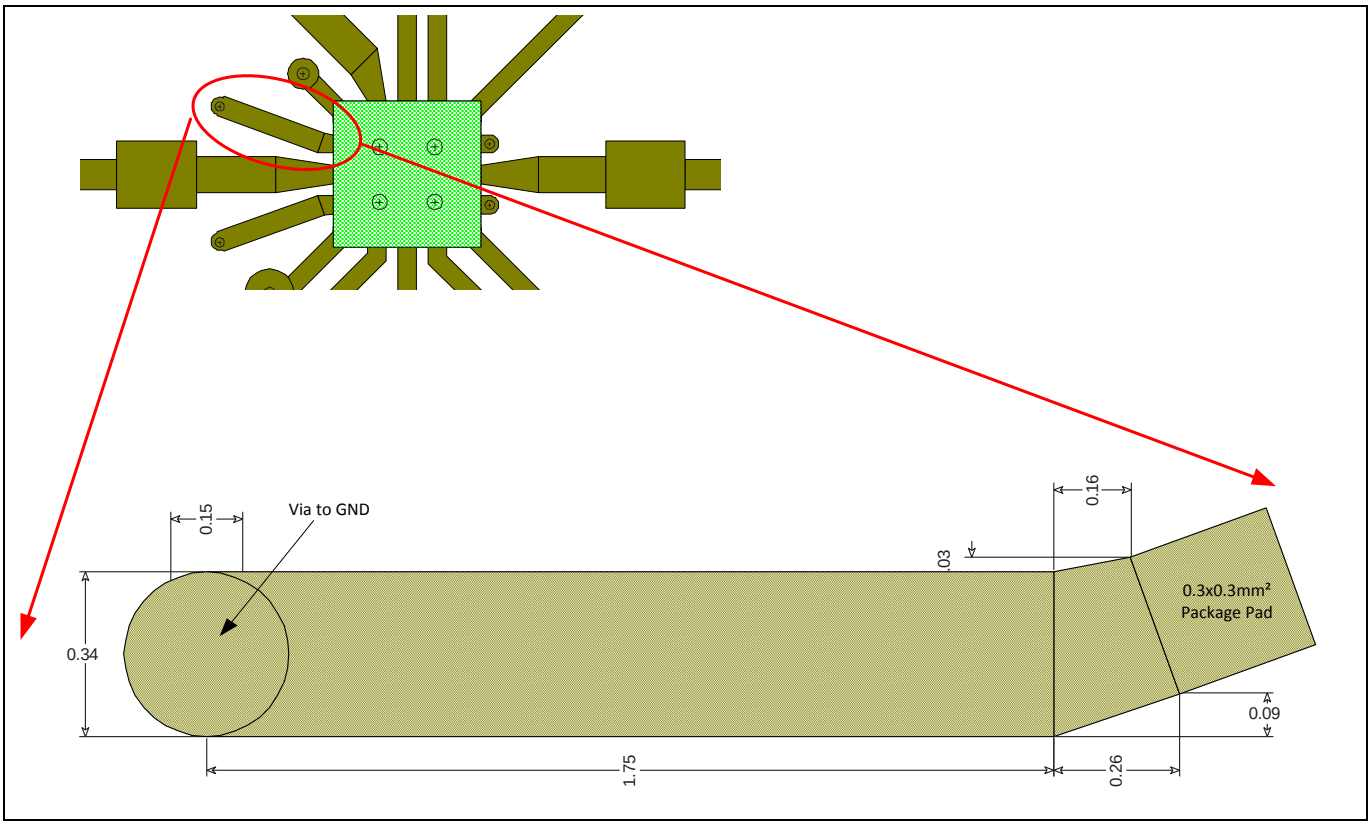

Figure 17 Compensation structures in detail. (Unit is mm)

4 Controlling the VCO

4.1 Controlling the VCO using V_PTAT

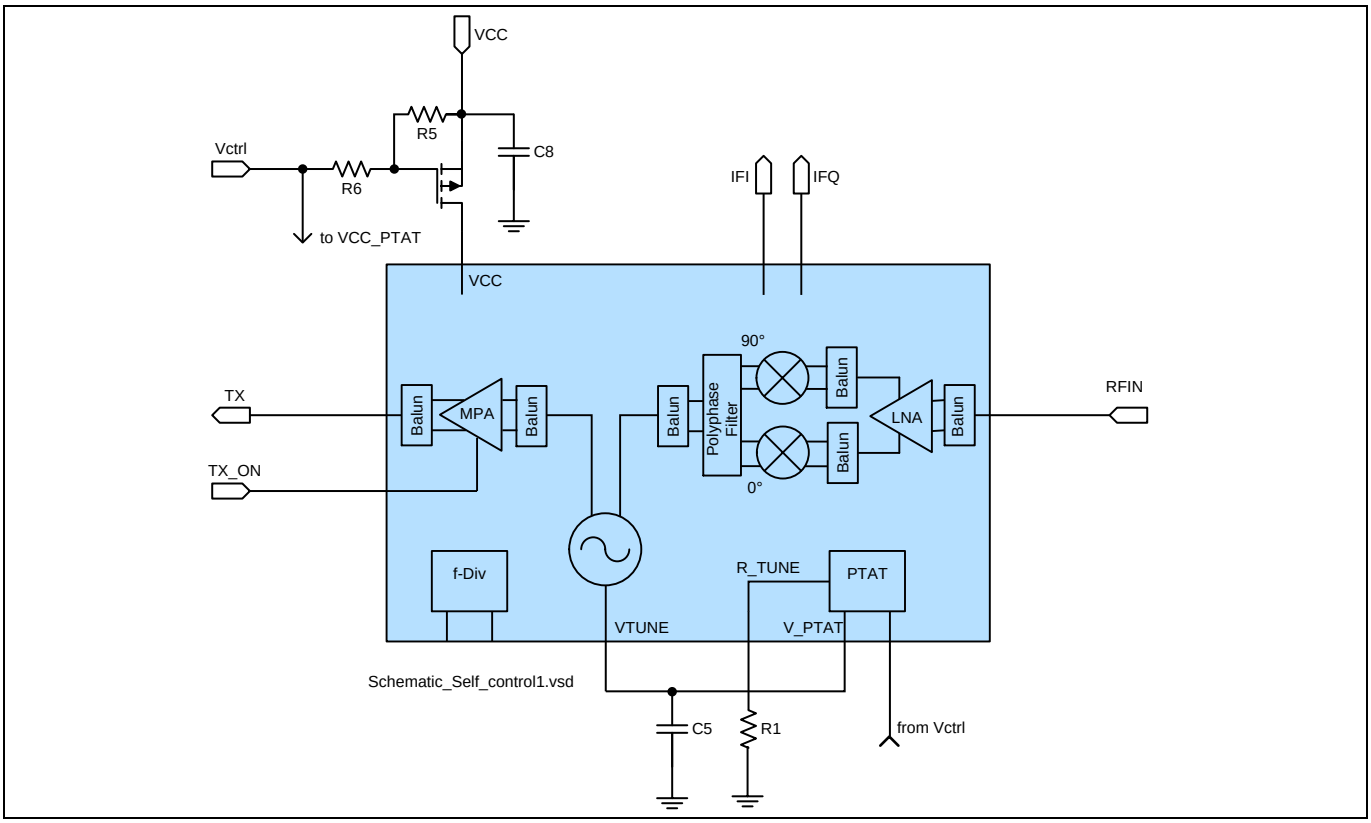

Figure 18 Block diagram: Using V_PTAT to keep BGT24LTR11N16 in the ISM band

Exact frequency control in Doppler radars in the 24 GHz ISM band is not really necessary for most applications. If we assume the transmit frequency to be at the lower edge of the band while it is actually at the upper edge the introduced error is only 0.8 %.

BGT24LTR11N16 was designed to keep its transmit frequency inside the ISM band without the need for a dedicated frequency control circuit like a Phase Locked Loop (PLL) or a look-up table based control of VTUNE.

To achieve this capacitor C5 is charged by V_PTAT while the rest of the chip is turned off to save power. Once C5 is fully charged VCC_PTAT is disconnected while VCC is applied and VTUNE gets its voltage from C5.

There are two reasons for toggling VCC and VCC_PTAT. The first one is obvious: Turning off VCC and VCC_PTAT reduces current consumption (45 mA and 1.5mA, respectively). The second reason for turning off VCC_PTAT is that the PTAT source generates noise at its output when running and this noise on the tuning voltage will degrade the signal to noise ratio (SNR) of the system. Of course for some short range this SNR might still be acceptable.

4.1.1 Controlling the VCO with the PTAT source in detail

One duty-cycle works as follows:

1. TX_ON = 0 V. Disables TX output to prevent out of band emissions.
2. Vctrl = 3.3 V. This turns on the PTAT source (VCC_PTAT = 3.3 V) while VCC is disconnected from power supply.

3. Wait for C5 to be charged. At the start-up of the system when the capacitor is fully discharged this will require a longer time. During normal operation the capacitor is only slightly discharged and will be very quickly recharged.
4. Vctrl = 0 V. Turns off PTAT and turns on the rest of the chip.
5. Wait for VCO to settle its frequency. Settling time of the VCO is maximum 100 ns.
6. TX_ON = 3.3 V. Enables TX output.
7. Sample IF frequency.
8. Goto 1.

Further reduction of the power consumption is possible by introducing a time frame when both VCC and VCC_PTAT are disconnected. This would mean that VCC_PTAT needs to be disconnected from Vctrl and one more GPIO pin needs to be available at the microcontroller in the system.

4.2 Controlling the VCO using a PLL

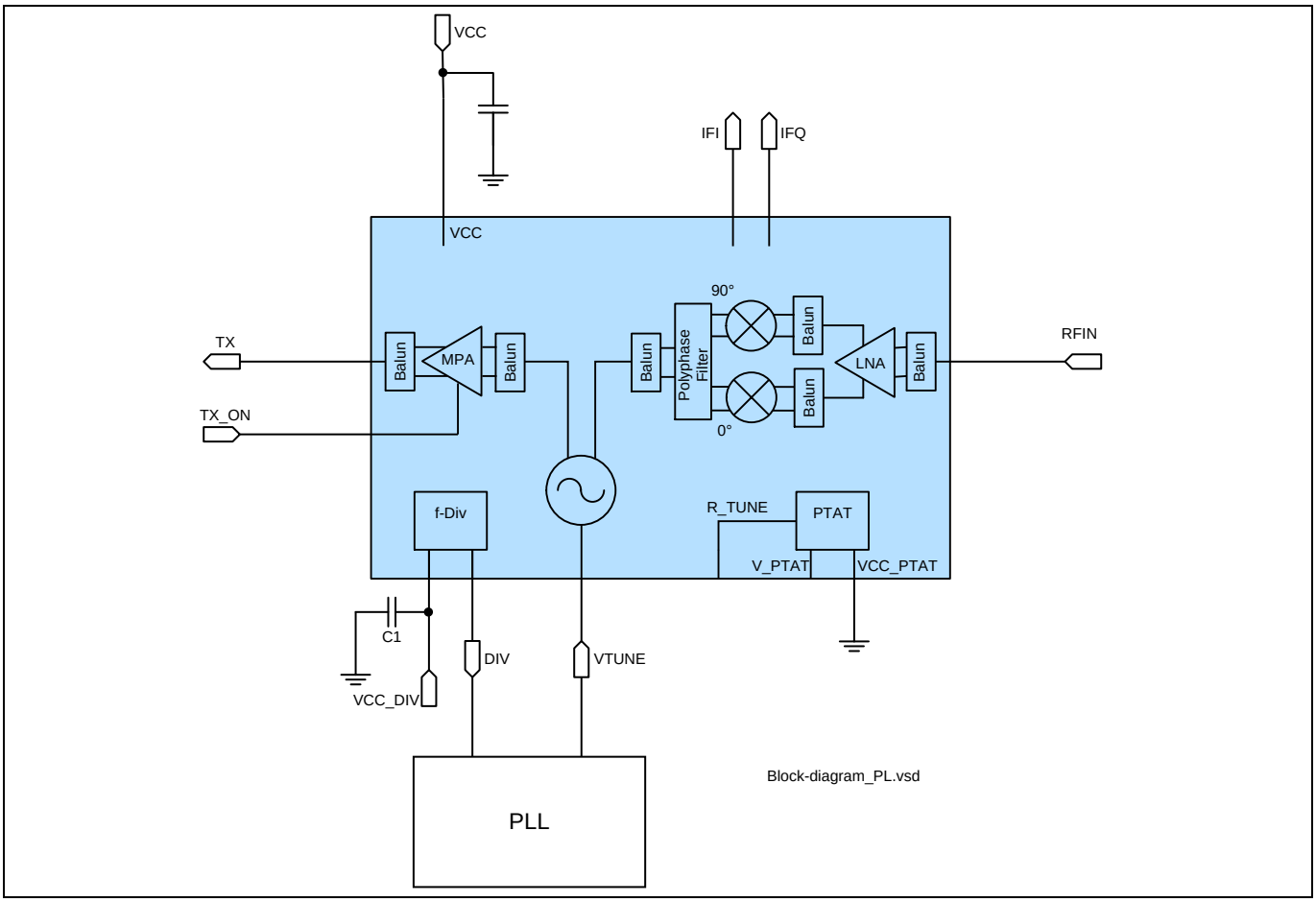

Figure 19 Bock diagram: Controlling BGT24LTR11N16 with a PLL

Controlling BGT24LTR11N16's VCO with a RF Phase Locked Loop (PLL) is straight forward. The frequency divider needs to be set to a ratio of 16 by connecting VCC_PTAT to GND. The 1.5 GHz can then be used to feed the PLL, which in turns generates the tuning voltage.

4.3 Controlling the VCO using a Software Based Open-Loop Concept

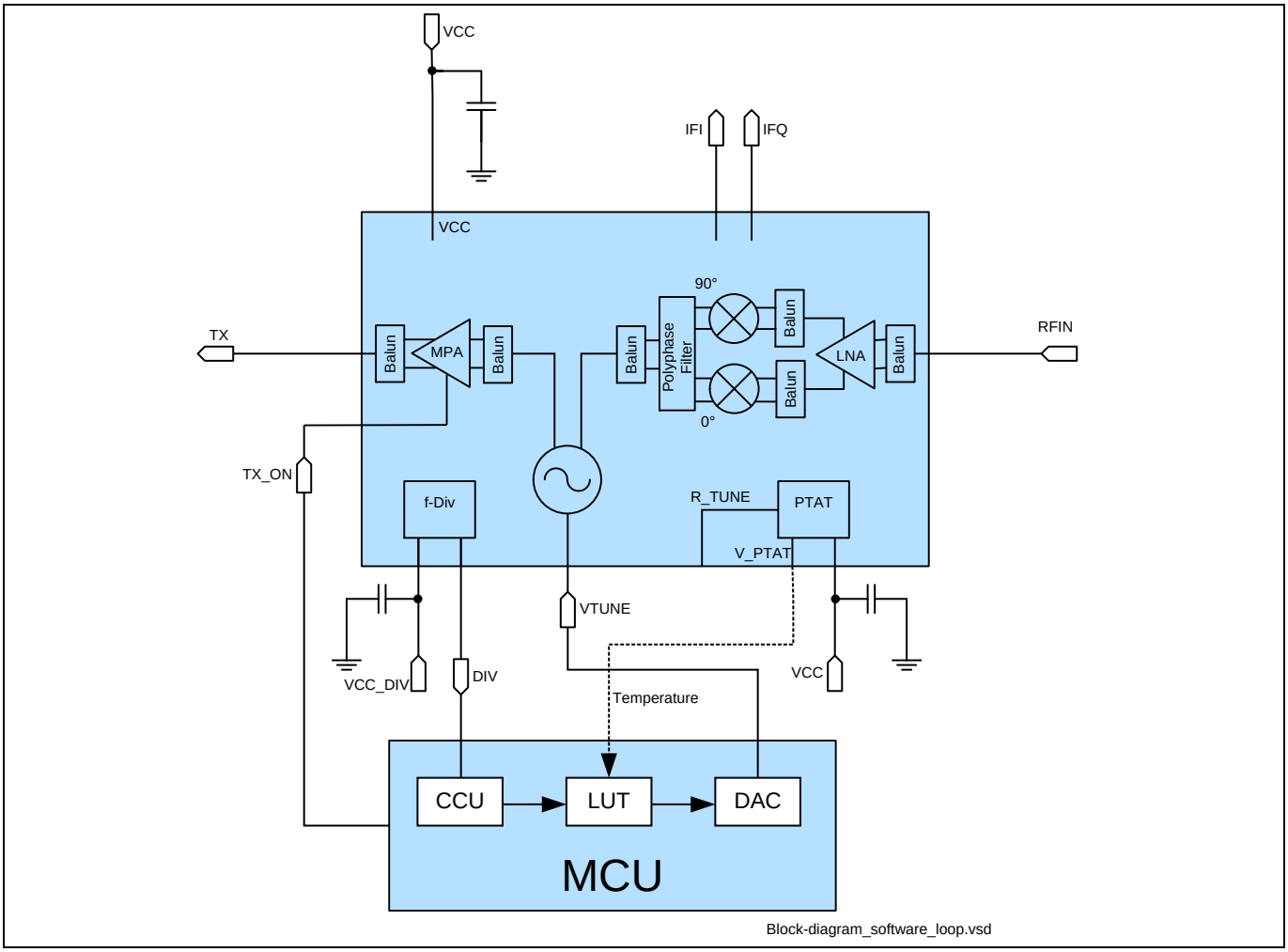

Figure 20 Block diagram: Controlling BGT24LTR11N16 with an Open-Loop concept

It is possible to control BGT24LTR11N16 using an Open-Loop concept, sometimes also called Software-Loop concept. Figure 20 shows a block diagram on how to set-up the system.

- The frequency divider is set to an 8192 division ratio and fed to a Capture Compare Unit (CCU) of the microcontroller to determine the frequency of the oscillator.
- The PTAT source is used as a chip temperature sensor and V_PTAT is fed to an ADC of the microcontroller.
- The microcontroller's DAC is used to generate the tuning voltage of the VCO.
- A GPIO port of the microcontroller enables / disables BGT24LTR11N16's TX output.

Controlling BGT24LTR11N16 with an Open-Loop concept works as follows:

1. Disable TX output
2. Check the chip temperature
3. Generate a Look-Up Table (LUT) that gives the DAC values corresponding to different VCO frequencies. Use this LUT for the modulation of the VCO.
4. Enable TX output
5. Generate transmit signal using DAC
6. Check chip temperature. If chip temperature changed goto 1 else goto 5

5 Authors

Dietmar Stolz, Senior Staff Engineer of Business Unit “Radio Frequency and Sensors”

Revision History

Major changes since the last revision

Page or Reference	Description of change
12 f	Added section on improving TX to RX isolation

Edition 2017-07-11

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN_472_2016_03_PL32_001

IMPORTANT NOTICE

The information contained in this application note is given as a hint for the implementation of the product only and shall in no event be regarded as a description or warranty of a certain functionality, condition or quality of the product. Before implementation of the product, the recipient of this application note must verify any function and other technical information given herein in the real application. Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this application note.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer's technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

For further information on the product, technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies office (www.infineon.com).

WARNINGS

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.