THE DATASHEET OF

BGT24ATR11E6433XUMA1

BGT24ATR11

Silicon Germanium 24 GHz Transceiver MMIC

Data Sheet

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BGT24ATR11 Silicon Germanium 24 GHz Transceiver MMIC

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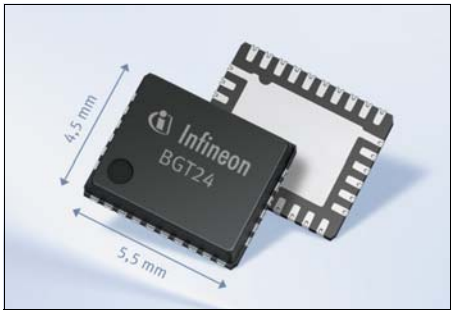
1 Features



- 24 GHz ISM band transceiver MMIC
- Qualified according AEC-Q100
- Fully integrated low phase noise VCO
- Switchable prescaler with 1.5 GHz and 23 kHz output
- On chip power and temperature sensors
- Gilbert based homodyne quadrature receiver
- Single ended RF and LO terminals
- Low noise figure NF_{SSB}: 12 dB
- High conversion gain: 26 dB
- High 1 dB input compression point: -12 dBm
- Single supply voltage 3.3 V
- Low power consumption 500 mW
- 200 GHz bipolar SiGe:C technology b7hf200
- Fully ESD protected device
- VQFN-32-9 leadless plastic package incl. LTI feature
- Pb-free (RoHS compliant) package

RoHS

Description

The BGT24ATR11 is a Silicon Germanium MMIC for signal generation and reception, operating in the 24 GHz ISM band from 24.00 to 24.25 GHz. It is based on a 24 GHz fundamental voltage controlled oscillator. Switchable frequency prescalers are included with output frequencies of 1.5 GHz and 23 kHz. The main RF output delivers typ. 11dBm signal power to feed an antenna and an auxiliary LO output is available to provide LO signal to separate receiver components.
A LNA provides low noise figure and a RC polyphase filter (PPF) is used for LO quadrature phase generation of the homodyne quadrature downconversion mixer. Output power sensors as well as a temperature sensor are implemented for monitoring purposes. The device is controlled via SPI and is manufactured in a 0.18µm SiGe:C technology offering a cutoff frequency of 200 GHz. The MMIC is packaged in a 32 pin leadless RoHs compliant VQFN package.

Product Name	Package	Chip	Marking
BGT24ATR11	VQFN32-9	T1524	BGT24ATR11

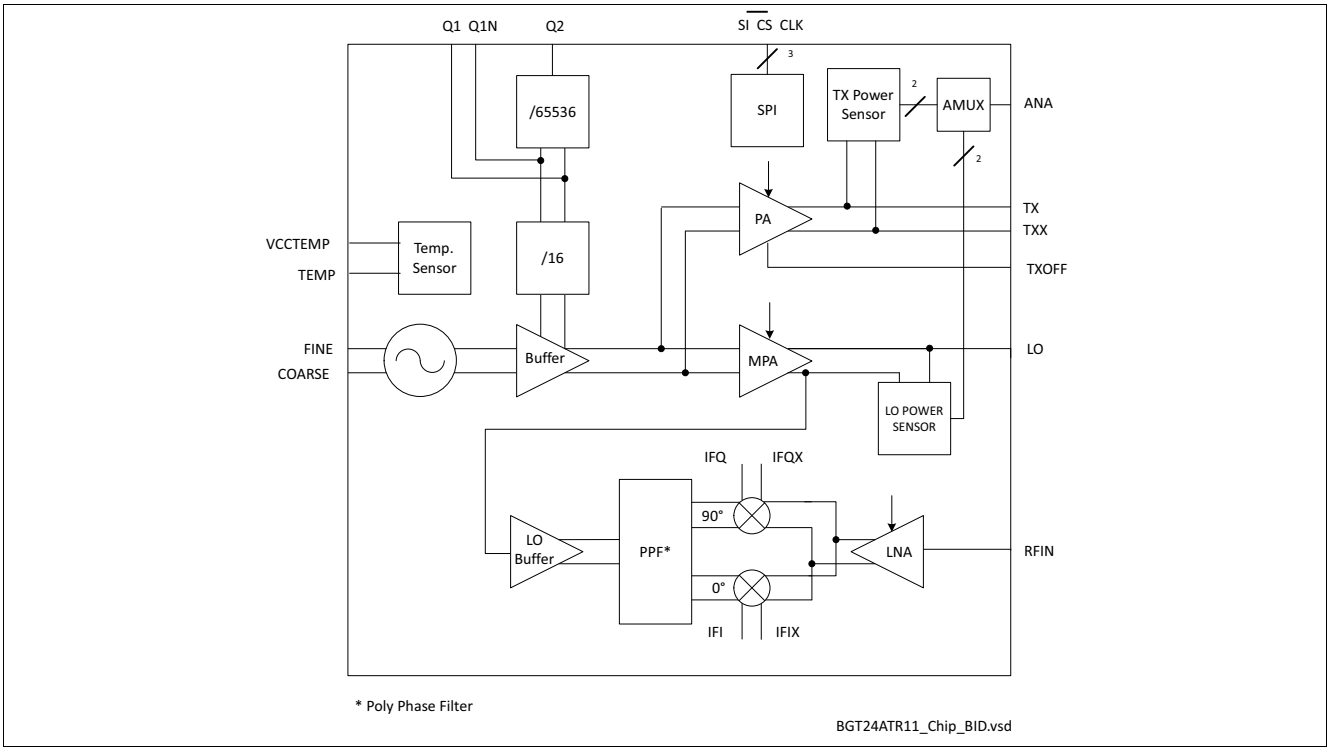


Figure 1 BGT24ATR11 Block Diagram

2 Electrical Characteristics

2.1 Absolute Maximum Ratings

T_A = -40 °C to 125 °C; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)[1)]

Table 1 Absolute Maximum Ratings

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{CC} / V_{CCTEMP}	-0.3	–	3.6	V	–
DC voltage at RF Pins TX, TXX, LO, RFIN1, RFIN2	VDC_{RF}	0	–	0	V	MMIC provides short circuit to GND for all RF pins
DC voltage at Pins IFI, IFIX, IFQ, IFQX	VDC_{IF}	0	–	Vcc	V	–
DC current into Pins IFI, IFIX, IFQ, IFQX	I_{IF}	-8.5	–	3.5	mA	Max. values indicate current due to short circuit to GND and Vcc resp.
DC voltage at Pin ANA	VDC_{ANA}	-0.3	–	3.6	V	–
DC current into Pin ANA (Sink)	$I_{ANA\ SINK}$	125	350	500	µA	Max. values indicate current due to short circuit to GND and Vcc resp.
DC current into Pin ANA (Source)	$I_{ANA\ SOURCE}$	-7	–	–	mA	–
DC current into Pin VCCTEMP	$I_{VCCTEMP}$	–	–	3.5	mA	Max. values indicate current due to short circuit to GND and Vcc resp.
DC voltage at Pin TEMP	VDC_{TEMP}	0	–	Vcc	V	–
DC current into Pin TEMP	I_{TEMP}	-1	–	1.5	mA	Max. values indicate current due to short circuit to GND and Vcc resp.
DC voltage at Pins Q1, Q1N	VDC_{Q1x}	Vcc-0.3	–	Vcc	V	–
DC current into Pins Q1, Q1N	I_{Q1x}	-8	–	12	mA	–
DC voltage at Pin Q2	VDC_{Q2}	-0.3	–	3.6	V	–
DC current into Pin Q2 enabled	I_{Q2EN}	-3	–	3	mA	–
DC current into Pin Q2 disabled	I_{Q2DIS}	-10	–	10	µA	–
DC voltage at SPI input Pins SI, CLK, $\overline{CS}$	VDC_{SPIIN}	-0.3	–	3.6	V	–
DC current into SPI input Pins SI, CLK, $\overline{CS}$	I_{SPIIN}	–	–	3	mA	–
RF input power into Pin RFIN	P_{RF}	–	–	0	dBm	–

1) Not subject to production test, specified by design

Table 1 Absolute Maximum Ratings (cont'd)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
DC voltage at Pins Fine, Coarse	V_F, V_C	0	–	5	V	–
DC current into Pins Fine, Coarse	I_F, I_C	-110	–	110	µA	Positive currents if $V_{TUNE} > V_{CC}$; Negative currents if $0V \leq V_F, V_C \leq Vcc$
DC voltage at Pin TXOFF	VDC_{TXOFF}	-0.3	–	3.6	V	–
Total power dissipation	P_{DISS}	–	–	750	mW	With BIST deactivated
Junction temperature	T_J	-40	–	155	°C	–
Ambient temperature range	T_A	-40	–	125	°C	T_A = temperature at package soldering point
Storage temperature range	T_{STG}	-40	–	150	°C	–

Attention: Stresses exceeding the max. values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the integrated circuit.

2.2 Thermal Resistance

Table 2 Thermal Resistance

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Junction - soldering point[1)]	R_{thJS}	–	–	40	K/W	–

1) For calculation of R_{thJA} please refer to application note thermal resistance

2.3 ESD Integrity

Table 3 ESD Integrity

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
ESD robustness, HBM[1)]	$V_{ESD-HBM}$	-1	–	1	kV	All pins
ESD robustness, CDM[2)]	$V_{ESD-CDM}$	-500	–	500	V	All pins

1) According to ANSI/ESDA/JEDEC JS-001 (R = 1.5kΩ, C = 100pF) for Electrostatic Discharge Sensitivity Testing, Human Body Model (HBM)-Component Level

2) According to JEDEC JESD22-C101 Field-Induced Charged Device Model (CDM), Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic Components

2.4 Measured RF Characteristics

2.4.1 Power Supply

Table 4 Typical Characteristics T_A = -40 .. 125 °C, SPI-Bit 4 = high

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{CC}	3.135	3.3	3.465	V	–
Supply current	I_{CC}	110	150	190	mA	–
Supply voltage temperature sensor	V_{CCTemp}	3.135	3.3	3.465	V	–
Supply current temperature sensor	I_{CCTemp}	1.3	2.2	3	mA	–

2.4.2 TX Section

Table 5 Typical Characteristics T_A = -40 .. 125 °C, f = 24.0 .. 24.25 GHz, SPI-Bit 4 = high[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
VCO frequency range	f_{VCO}	24.0	–	24.25	GHz	–
VCO fine tuning voltage[2)]	V_F	0.8[3)]	–	3.0	V	0.8V≤V_F≤1.25V for V_{CMIN}=0.75V, 1.25V≤V_F≤3.0V for V_{CMIN}=0.75V+1.7V*(V_F-1.25V)/1.75V, see Figure 2 on Page 12
VCO coarse tuning voltage[2)]	V_C	0.75[3)]	–	3.0	V	0.75V≤V_C≤1.35V for V_{FMIN}=0.8V, 1.35V≤V_C≤3.0V for V_{FMIN}=V_C-0.55V, see Figure 2 on Page 12
VCO tuning slope FINE	$\Delta f / \Delta V_F$	200	–	1000	MHz/V	24GHz≤f≤24.25GHz see Figure 2 on Page 12
VCO tuning slope COARSE	$\Delta f / \Delta V_C$	400	–	2000	MHz/V	24GHz≤f≤24.25GHz see Figure 2 on Page 12
VCO temperature drift	$\Delta f / \Delta T$	-10	-6	0	MHz/K	Min @ T = -40°C
VCO pushing	$\Delta f / \Delta V_{CC}$	-350	60	350	MHz/V	Absolute values

1) Performance based on Application Circuit Figure 3 on Page 16, Cross Section of Application Board, Compensation Structures and Application Board Layout Figure 5 on Page 21ff and Footprint Figure 9 on Page 24

2) At tuning pins chipinternal pull-up of 60kΩ ±20% to VCC; max.- and min. temperature tuning voltage limits are chosen in a way that they can be linearly interpolated within operating temperature range

3) Specified min. value for temperature ≤25°C; min. value for temperatures >25°C is based on following formular V_{CMIN} = V_{FMIN} = 0.8V + 0.4V * (T [°C] - 25°C) / 100°C

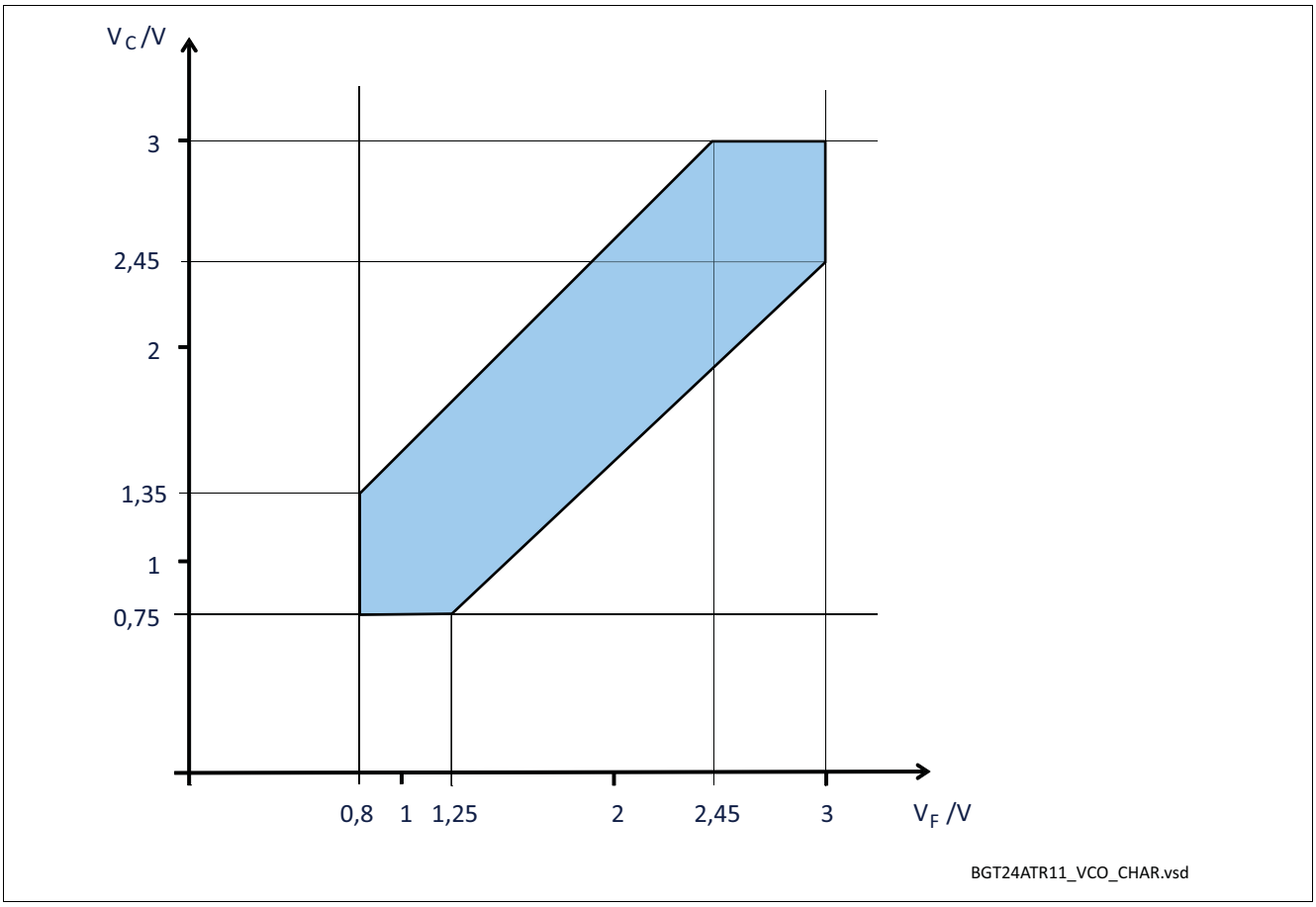


Figure 2 VCO Tuning Window

Table 6 Typical Characteristics T_A = -40 .. 125 °C, f = 24.0 .. 24.25 GHz, SPI-Bit 4 = high[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
VCO phase noise	P_N	–	-85	-75	dBc/Hz	@ 100kHz offset, $V_F = V_C$
TX/TXX load impedance	Z_{TX} Z_{TXX}	–	19.8-j20.9 18-j17.3	–	Ω	Typical value at 24.125GHz and VSWR ≤ 2:1
Max. TX output power	P_{TX}	6	11	15	dBm	–
Max. TX output power for V_{CC} = 3.3V ± 50mV	P_{TX}	6.5	11	14.5	dBm	–
TX ouput power adjustable range	a_{TX}	3	9	–	dB	Adjustable via SPI
TX output power in “off” mode[2)]	P_{TXoff}	–	–	-30	dBm	Parameter based on IFX eval board design

Table 6 Typical Characteristics T_A = -40 .. 125 °C, f = 24.0 .. 24.25 GHz, SPI-Bit 4 = high[1)] (cont'd)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
LO load impedance	Z_{LO}	–	24.4-j25.8	–	Ω	Typical value at 24.125GHz and VSWR ≤ 2:1
LO output power[3)]	P_{LO}	-8	0	6	dBm	SPI-Bit 4 = high
Q1 Prescaler division ratio	D_{Q1}	–	2^4	–	–	–
Q1 Prescaler output power	P_{Q1}	-13	-9	-5	dBm	Q1 loaded with 100 Ohm (AC- coupled)
Q1 load impedance	Z_{Q1}	–	100	–	Ω	–
Q2 Prescaler division ratio	D_{Q2}	–	2^{20}	–	–	–
Q2 Prescaler max. output voltage	V_{maxQ2}	2.4	–	–	V	Test condition: Q2 loaded with high impedance probe (1 MOhm,13 pF)
Q2 Prescaler min. output voltage	V_{minQ2}	–	–	0.8	V	Test condition: Q2 loaded with high impedance probe (1 MOhm, 13 pF)
Q2 Prescaler max. output source current	$I_{maxsource\ Q2}$	1.2	–	–	mA	Test condition: Q2 loaded with 50 Ohm to Vcc
Q2 Prescaler max. output sink current	$I_{maxsink\ Q2}$	1.2	–	–	mA	Test condition: Q2 loaded with 50 Ohm to Vcc
Q2 Prescaler output resistance in disable mode	$R_{Q2,DIS}$	100	–	–	kΩ	–
Voltage at Txoff for disabeling TX output power	$V_{TX,OFF}$	1.5	–	–	V	–
Voltage at Txoff for enabeling TX output power	$V_{TX,ON}$	–	–	0.5	V	–
TXon/off switching time	$t_{ON/OFF}$	–	–	500	ns	–

1) Performance based on Application Circuit Figure 3 on Page 16, Cross Section of Application Board, Compensation Structures and Application Board Layout Figure 5 on Page 21ff and Footprint Figure 9 on Page 24

2) Guaranteed by device design

3) High LO buffer output power in "high" mode otherwise typ. 4dB reduced LO-output power

2.4.3 RX Section

Table 7 Typical Characteristics T_A = -40 .. 125 °C, f = 24.0 .. 24.25 GHz, SPI-Bit 4 = high[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
RFIN frequency range	f_{RFIN}	24.0	–	24.25	GHz	–
RFIN port impedance[2)]	Z_{RFIN}	–	22.9-j14.9	–	Ω	Typical value at 24.125GHz and VSWR ≤ 2:1
RFIN VSWR	$VSWR$	–	–	2:1	–	At load port of off-chip compensation network as proposed
IF frequency range	f_{IF}	0	–	10	MHz	–
IF output impedance	Z_{IF}	850	1000	1150	Ω	–
Leakage LO to RFIN	$L_{LO=>RFIN}$	–	–	-30	dBm	Parameter based on IFX eval board design
Voltage conversion gain[3)]	G_C	19	26	31	dB	$R_{LOAD,IF}$ > 10 kΩ
LNA gain reduction	ΔG_{CLG}	3	5	8	dB	–
SSB noise figure	N_{SSB}	–	12	20	dB	Single sideband at f_{IF} = 100 kHz
IF 1/f corner frequency	f_c	–	10	20	kHz	–
Input compression point	IP_{1dB}	-17	-12	–	dBm	–
Input 3'rd order intercept point	$IIP3$	-8	-4	–	dBm	–
Quadrat. phase imbalance	ε_p	-10	–	10	deg	–
Quadrat. amplitude imbalance	ε_A	-1	–	1	dB	–

1) Performance based on Application Circuit Figure 3 on Page 16, Cross Section of Application Board, Compensation Structures and Application Board Layout Figure 5 on Page 21ff and Footprint Figure 9 on Page 24

2) Guaranteed by device design

3) Lowest gain at high temperature, highest gain at low temperature

2.5 Temperature Sensor

Monitoring of the chip temperature is provided by the on-chip temperature sensor which delivers temperature-proportional voltage to the TEMP output. The temp. sensor can be independently biased through VCCTEMP. Thereby the chip temperature can be monitored while the main supply of the transceiver is switched off.

Table 8 Typical Characteristics Temperature Sensor T_A = -40 .. 125 °C[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Temperature range	T_{TSENS}	-40	–	125	°C	–
Output temperature voltage	$V_{OUT,TEMP}$	–	1.50	–	V	@ 25°C
Sensitivity	S_{TSENS}	–	4.5	–	mV/K	–
Overall accuracy error	Err_{TSENS}	–	–	±15	K	–

1) all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

2.6 Power Detector

For RF output power indication, peak voltage detectors are connected to the output of the TX power amplifier and to the LO medium power amplifier. To eliminate temperature and supply voltage variations, a reference output voltage VREF is available through the ANA output for the TX and LO power sensor. The compensated detector output voltage is given by the difference between VOUT and VREF for both power sensors respectively. This voltage is proportional to the RF voltage swing at the individual amplifier outputs, its characteristic is non-directional.

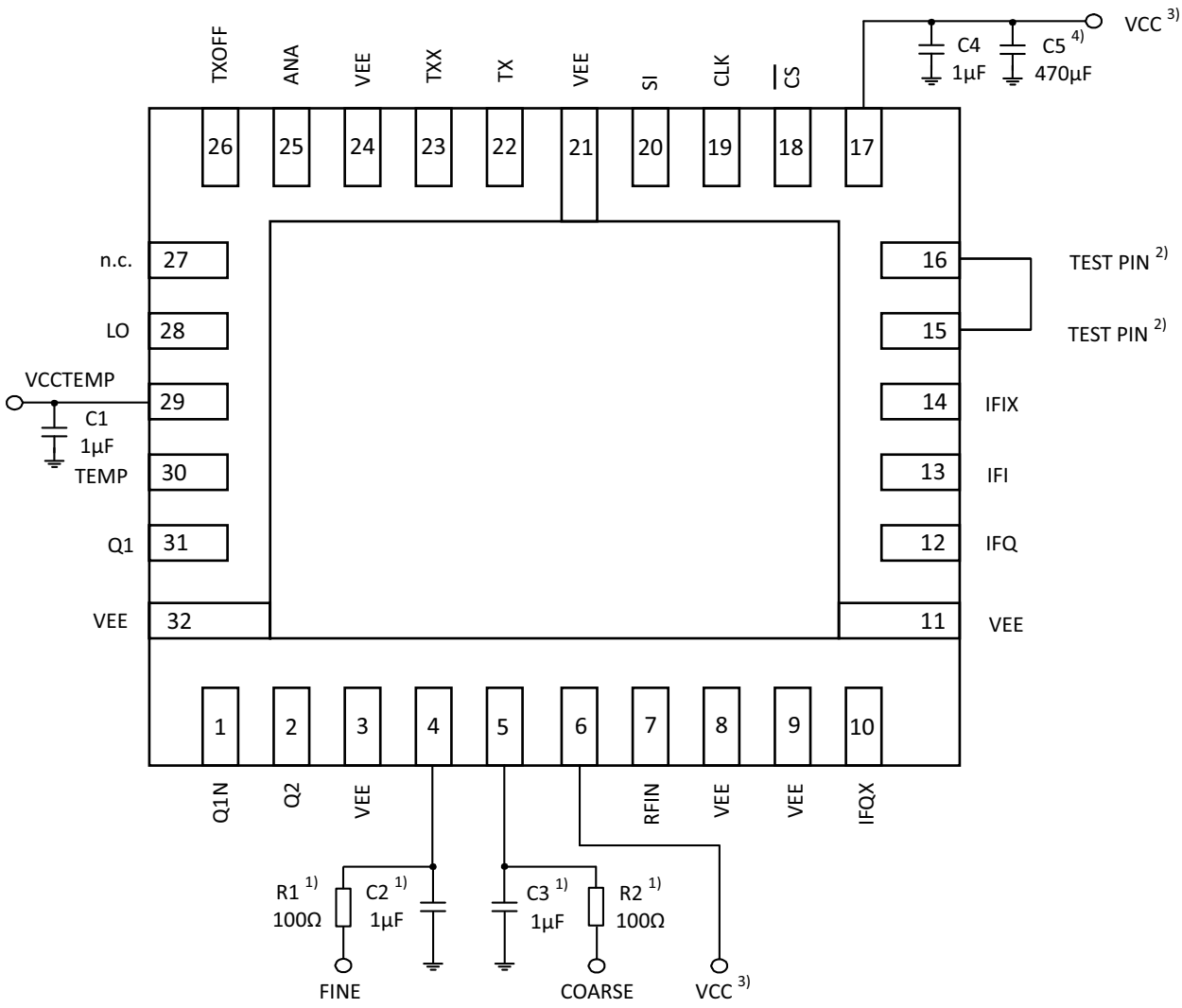
Table 9 Typical Characteristics Power Detector T_A = -40 .. 125 °C, V_{CC} = 3.3 V[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Power range	P_{PSENS}	-10	–	15	dBm	–
TX power sensor output	$V_{OUT,TX}$ - $V_{REF,TX}$	–	550	–	mV	@ P_{TX} = 11 dBm
LO power sensor output	$V_{OUT,LO}$ - $V_{REF,LO}$	–	50	–	mV	@ P_{LO} = 0 dBm

1) all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

3 Application Circuit and Block Diagram

3.1 Application Circuit Schematic



1) RC-time constants to be defined according to modulation requirements.
2) Connect pin 15 and 16
3) Galvanic connection of VCC pins on silicon
4) Optional value: according to quality of supply voltage

BGT24ATR11_Appl_BID.vsd

Figure 3 Application Circuit with Chip Outline (Top View)

Table 10 Bill of Materials

Part Number	Part Type	Manufacturer	Size	Comment
C1 ... C5	Chip capacitor	Various	Various	–
R1 ... R2	Chip resistor	Various	0402	–

3.2 Pin Description

Table 11 Pin Definition and Function

Pin No.	Name	Function
1	Q1N	Complementary prescaler output 1.5GHz
2	Q2	Prescaler output 23kHz
3	VEE	Ground
4	FINE	VCO fine tuning input
5	COARSE	VCO coarse tuning input
6	VCC	Supply voltage; Total current divided equal on both VCC pins
7	RFIN	RF input downconverter
8	VEE	Ground
9	VEE	Ground
10	IFQX	Complementary quadrature phase IF output downconverter
11	VEE	Ground
12	IFQ	Quadrature phase IF output downconverter
13	IFI	In phase IF output downconverter
14	IFIX	Complementary in phase IF output downconverter
15	TEST PIN	Test pin; DC coupled pin
16	TEST PIN	Test pin; DC coupled pin
17	VCC	Supply voltage; Total current divided equal on both VCC pins
18	$\overline{CS}$	Chip select input SPI (inverted)
19	CLK	Clock input SPI interface
20	SI	Data input SPI interface
21	VEE	Ground
22	TX	Transmit output
23	TXX	Complementary transmit output
24	VEE	Ground
25	ANA	Analog output
26	TXOFF	Pulsable Pin / Please connect to VEE in case TXOFF function is controlled via SPI
27	n.c.	Not connected
28	LO	LO output
29	VCCTEMP	Temperature sensor supply voltage
30	TEMP	Temperature sensor output
31	Q1	Prescaler output 1.5GHz
32	VEE	Ground

3.3 SPI

1.) Three signals control the serial peripheral interface of the BGT24ATR11:

SI (Data); CLK (Clock); $\overline{CS}$ (Chip select)

2.) The data bits SI (MSB first) are read in the shift with falling edge of the CLK signal.

Please make sure, that the data is present at least 10 ns before and at least 10 ns after the falling edge of the clock signal.

3.) The CLK and $\overline{CS}$ signals are combined internally.

At least 20 ns before first rising edge of the first CLK signal $\overline{CS}$ needs to be in "low" state.

While the Data is read, $\overline{CS}$ has to remain in "low" state.

4.) When Data read in is finished, the shift register content will be written in the latch at the rising edge of the $\overline{CS}$ signal. The time between the last falling edge of the CLK signal and the rising edge of the $\overline{CS}$ must be at least 20 ns.

Table 12 SPI Data Bit Description

Data Bit	Name	Description (Logic High)	Power ON State
15 (MSB)	GS	LNA Gain reduction	low
14 ..13	–	Not used	low
12	DIS_PA	TX power disabled, in case TXon/off function is controlled via TXOFF pin, this bit needs to be set in low state	high
11	AMUX2	Analog multiplexer control bit 2	high
10	Test Bit	Test bit, must be low otherwise malfunction	low
9	Test Bit	Test bit, must be low otherwise malfunction	low
8	AMUX1	Analog multiplexer control bit 1	low
7	AMUX0	Analog multiplexer control bit 0	low
6	DIS_DIV64k	Disable 64k divider	low
5	DIS_DIV16	Disable 16 divider	low
4	PC2_BUF	High LO buffer output power in “high” mode otherwise typ. 4dB reduced LO-output power	low
3	PC1_BUF	High TX buffer output power	low
2	PC2_PA	TX power reduction bit 2	high
1	PC1_PA	TX power reduction bit 1	high
0	PC0_PA	TX power reduction bit 0	high

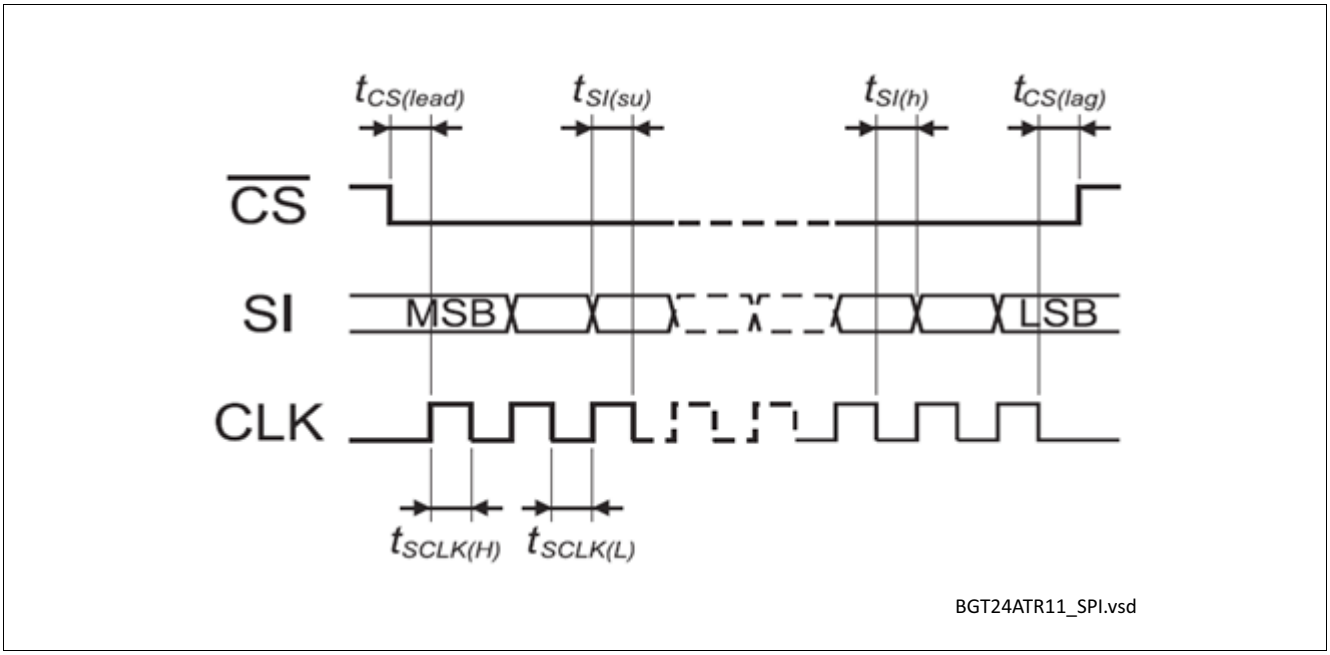


Figure 4 Timing Diagram of the SPI

Table 13 SPI Timing and Logic Levels

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Serial clock frequency	f_{SCLK}	0	–	50	MHz
Serial clock high time	$f_{SCLK(H)}$	10	–	–	ns
Serial clock low time	$t_{SCLK(L)}$	10	–	–	ns
Chip select lead time	$t_{CS(lead)}$	20	–	–	ns
Chip select lag time	$t_{CS(lag)}$	20	–	–	ns
Data setup time	$t_{SI(su)}$	10	–	–	ns
Data hold time	$t_{SI(h)}$	10	–	–	ns
Low level (SI, CLK, $\overline{CS}$)	$V_{IN(L)}$	0	–	0.8	V
High level (SI, CLK, $\overline{CS}$)	$V_{IN(H)}$	2.0	–	V_{CC}	V
Input capacitance (SI, CLK, $\overline{CS}$)	C_{IN}	–	–	2	pF
Input current (SI, CLK, $\overline{CS}$)	I_{IN}	-150	–	150	µA

Table 14 Truth Table AMUX

Output signal ANA	AMUX2	AMUX1	AMUX0
$V_{OUT,TX}$	low	low	low
$V_{REF,TX}$	low	low	high
$V_{OUT,LO}$	low	high	low
$V_{REF,LO}$	low	high	high
V_{TEMP}	high	low	low
Test_Signal1	high	low	high

Table 14 Truth Table AMUX (cont'd)

Output signal ANA	AMUX2	AMUX1	AMUX0
Test_Signal2	high	high	low
Test_Signal2	high	high	high

3.4 Application Board and Reflow Profile

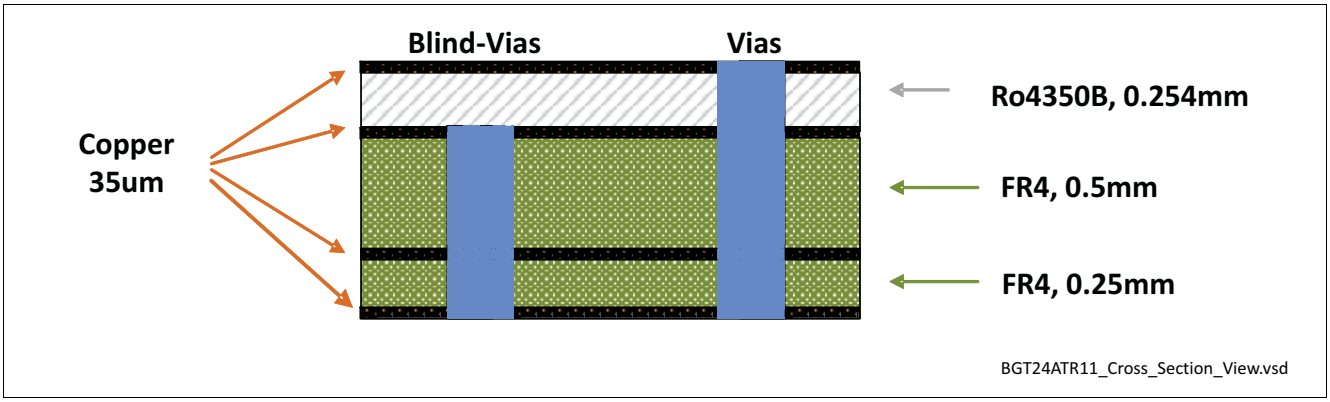


Figure 5 Cross-Section View of Application Board

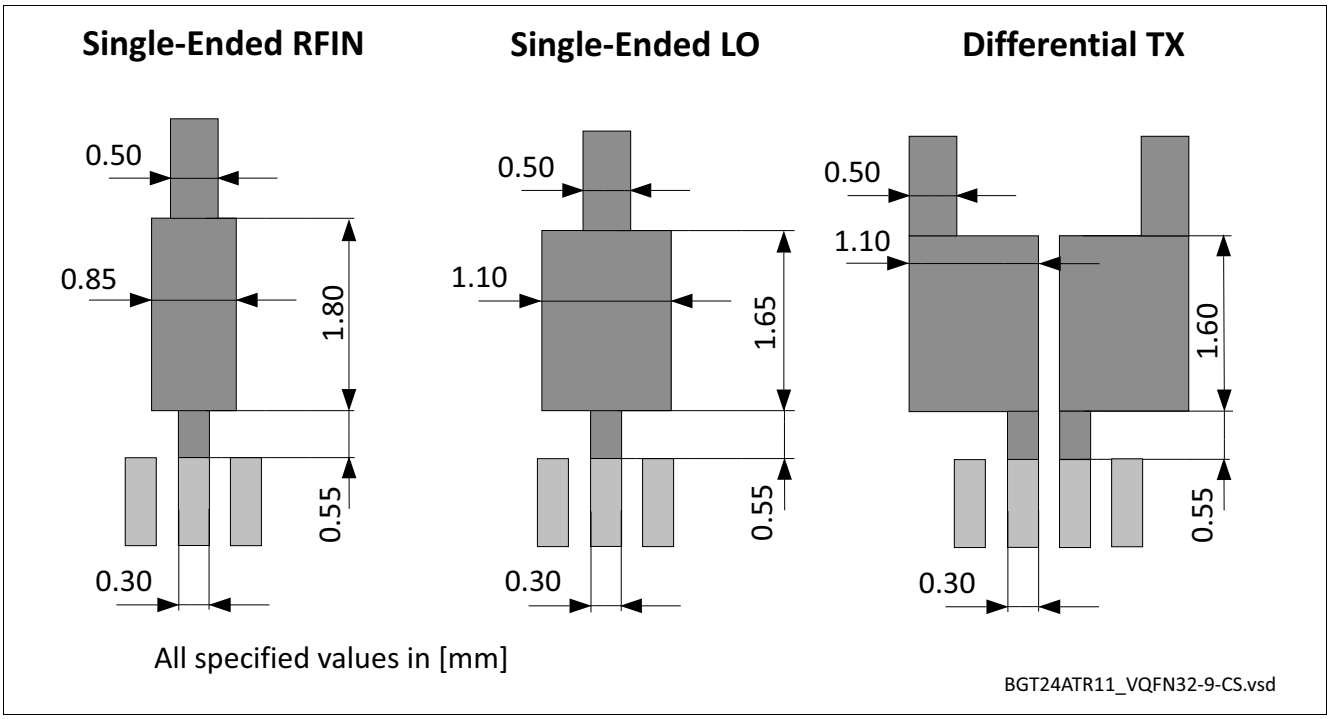


Figure 6 Detail of Compensation Structure (valid for appl. board mat. Ro4350B, 0.254mm acc. to Fig. 5)

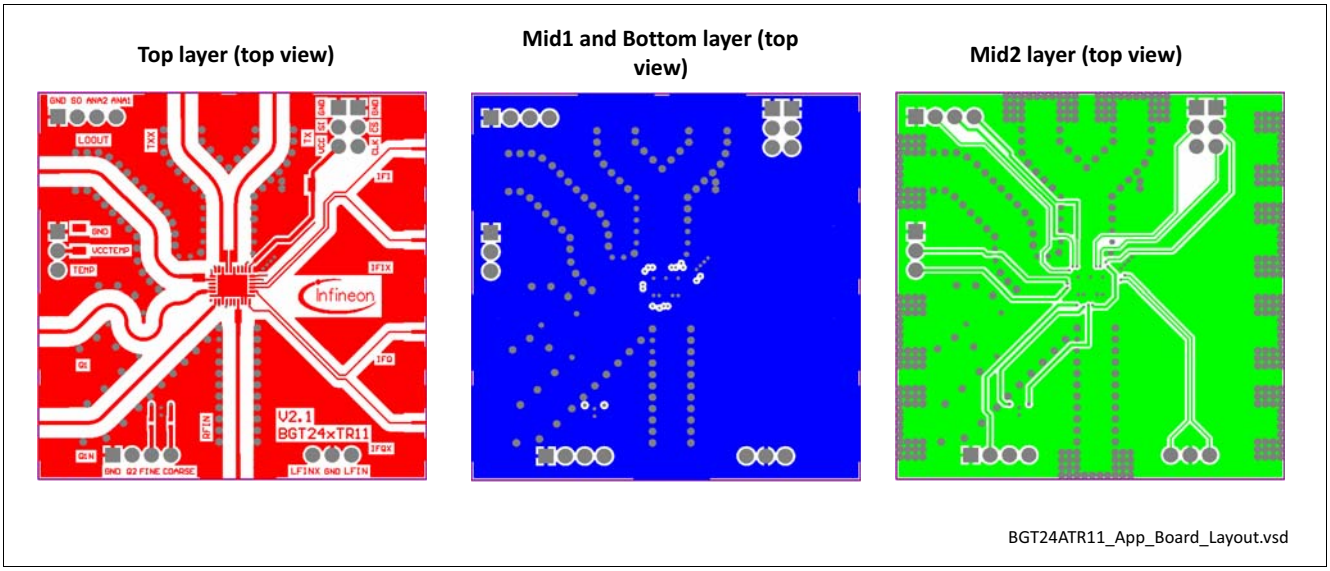


Figure 7 Application Board Layout

Note: In order to achieve the same performance as given in this datasheet please follow the suggested PCB-layout. The compensation structure is critical for RF performance. Via holes as recommended on one of next pages (not shown above).

3.5 Equivalent Circuit Diagram of MMIC Interfaces

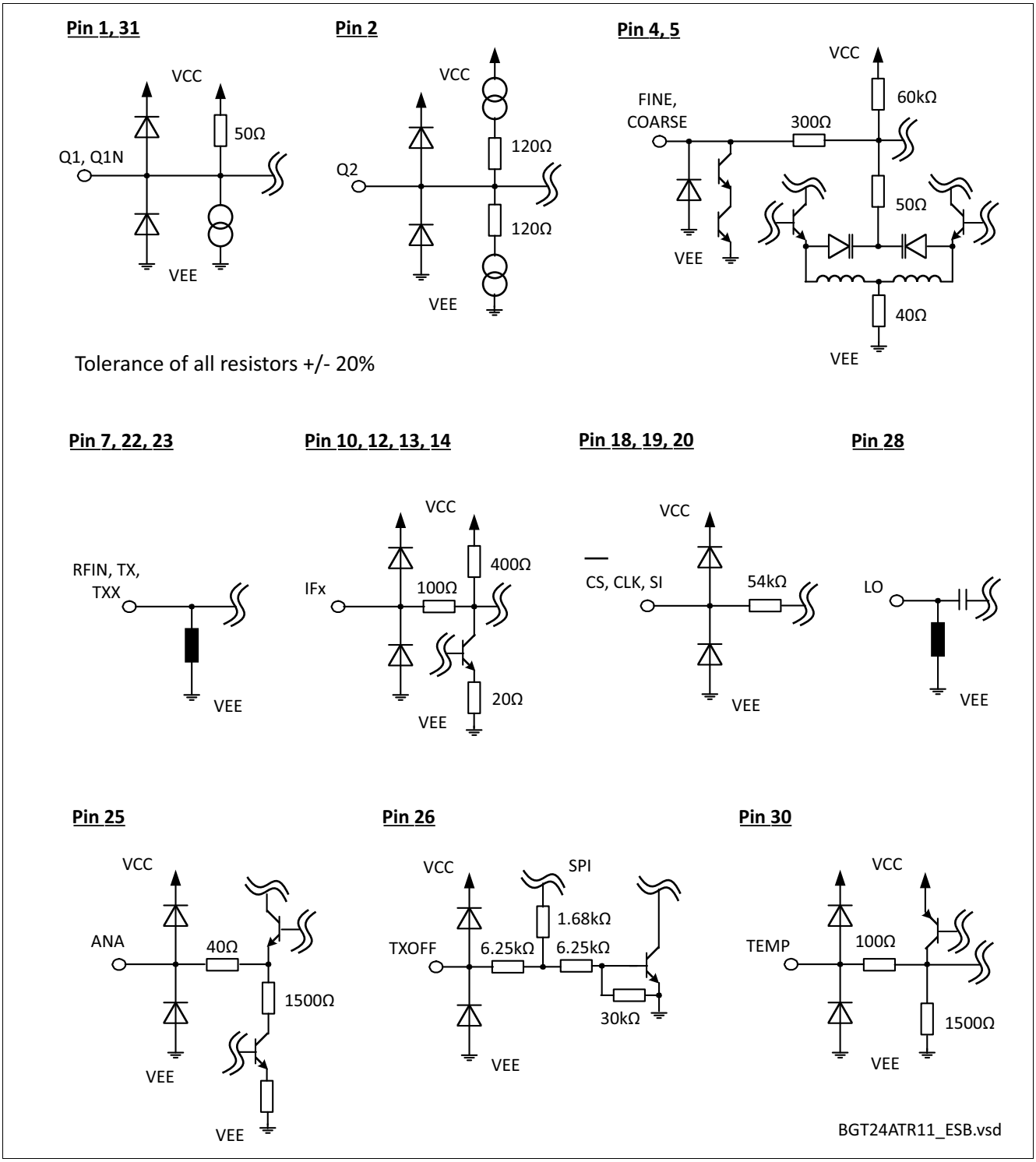


Figure 8 Equivalent Circuit Diagram of MMIC Interfaces

4 Physical Characteristics

4.1 Package Footprint

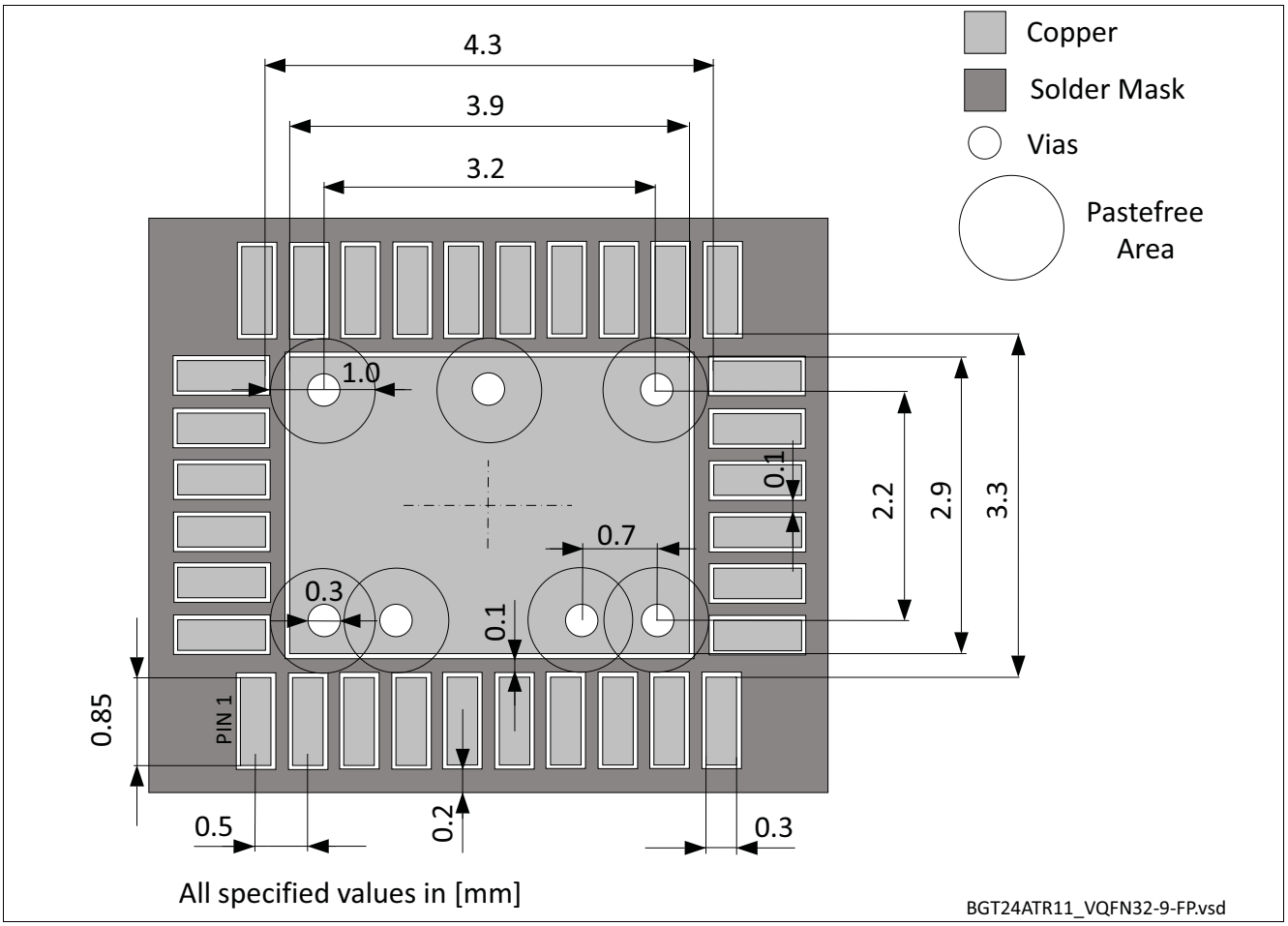


Figure 9 Recommended Footprint and Stencil Layout for the VQFN32-9 Package

4.2 Reflow Profile

Soldering process qualified during qualification with “Preconditioning MSL-3: 30°C. 60%r.h., 192h, according to JEDEC JSTD20”.

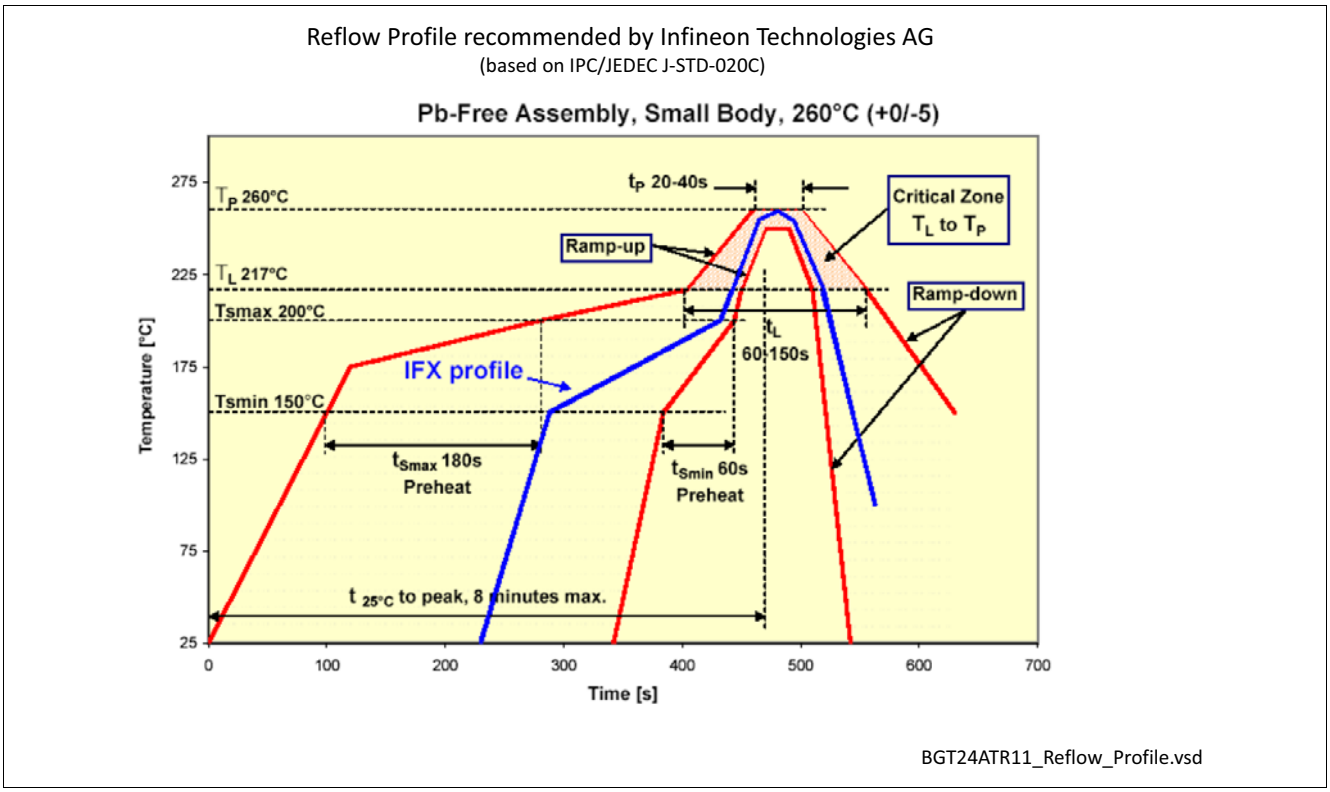


Figure 10 Reflow Profile for BGT24ATR11 (VQFN32-9)

4.3 Package Dimensions

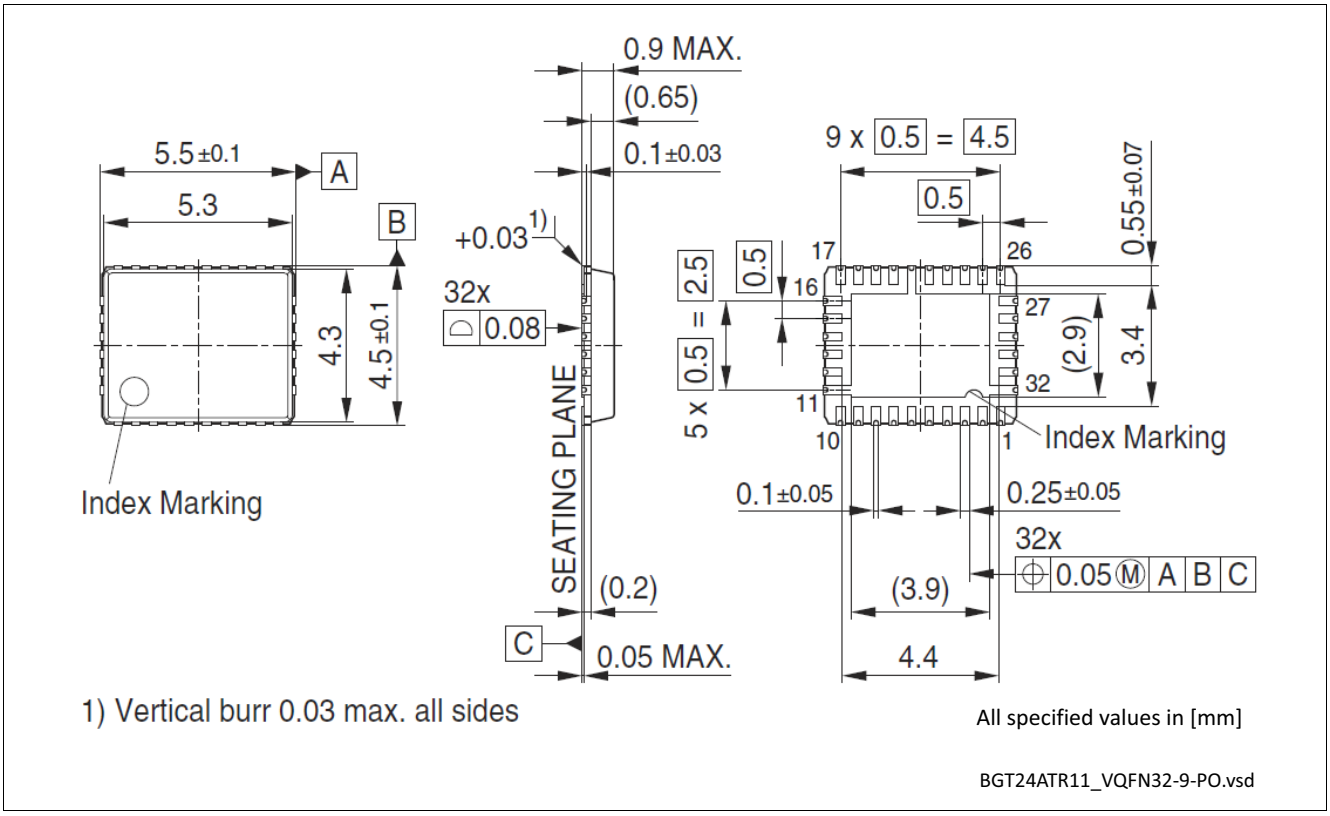


Figure 11 Package Outline (Top, Side and Bottom View) of VQFN32-9

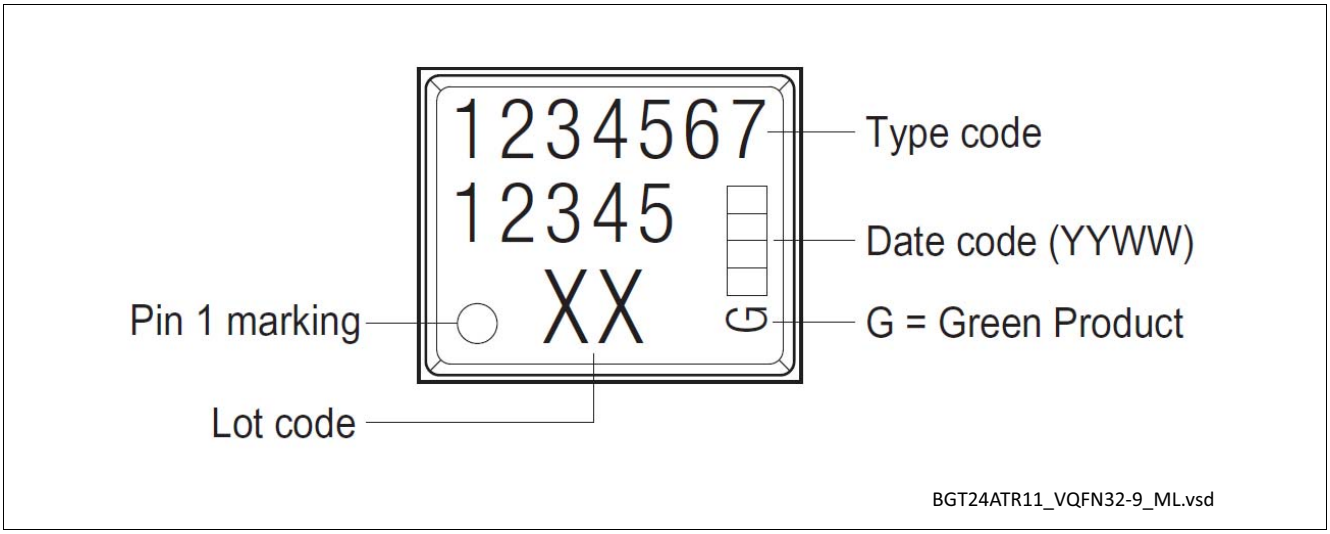


Figure 12 Marking Layout VQFN32-9

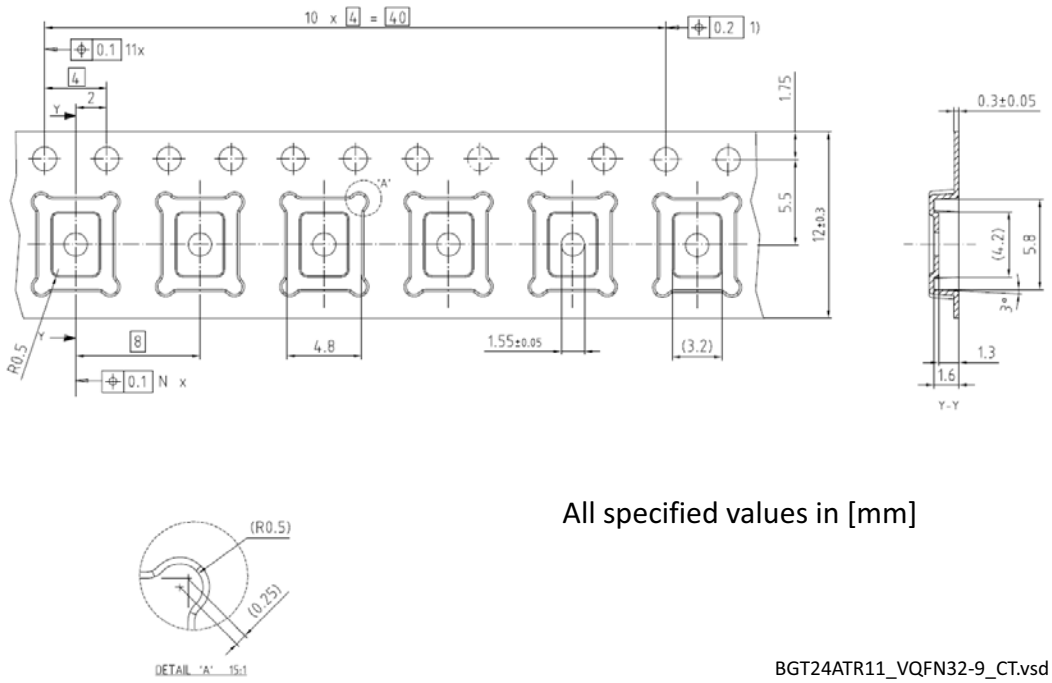


Figure 13 Tape of VQFN32-9

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