

# SRK2401

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24GHz 2T4R FMCW Radar Transceiver

Data Sheet

Revision A1.6

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矽杰微电子（厦门）有限公司  
SGR Semiconductors Inc.



## GENERAL DESCRIPTION

The SRK2401 is a fully integrated FMCW radar transceiver based on the state-of-art silicon germanium process. It operates in the 24 GHz ISM band from 24.00 to 24.25 GHz. It consists of a fractional-N frequency synthesizer offering FMCW ramp generation, two transmit chains featuring a 9 dBm output power, and four receive chains with a 29 dB conversion gain, a 9 dB noise figure and a high input compression point up to -8 dBm. A single signal with frequency of about 23 kHz generated from integrated frequency prescaler is also available. On-chip baluns are included to provide single-ended RF interfaces. The device is controlled via SPI interface. The radar transceiver is package in a compact 56-lead, 7 mm x 7 mm QFN package.

## FEATURES

- ♦ 24 GHz ISM band fully integrated FMCW radar transceiver
- ♦ Integrated with 2 transmitters, 4 receivers and a fractional-N frequency synthesizer
- ♦ FMCW ramp generation
- ♦ 26-bit fixed modulus allows sub hertz frequency resolution
- ♦ Programmable charge pump currents
- ♦ RX channel voltage conversion gain: 29 dB
- ♦ RX channel noise figure: 9 dB
- ♦ RX channel input P1dB: -8 dBm
- ♦ TX output power: 9 dBm
- ♦ VCO phase noise: -103 dBc @ 1 MHz offset
- ♦ Integrated balun for single-ended RF interfaces
- ♦ Prescaler with about 23 kHz output
- ♦ On-chip power and temperature sensors
- ♦ DC power rating: 3.3 V and 435 mA
- ♦ 56-lead, 7 mm x 7 mm QFN package
- ♦ Fully ESD protection

## APPLICATIONS

- ♦ Industrial radars
- ♦ IoT sensors

## FUNCTIONAL BLOCK DIAGRAM

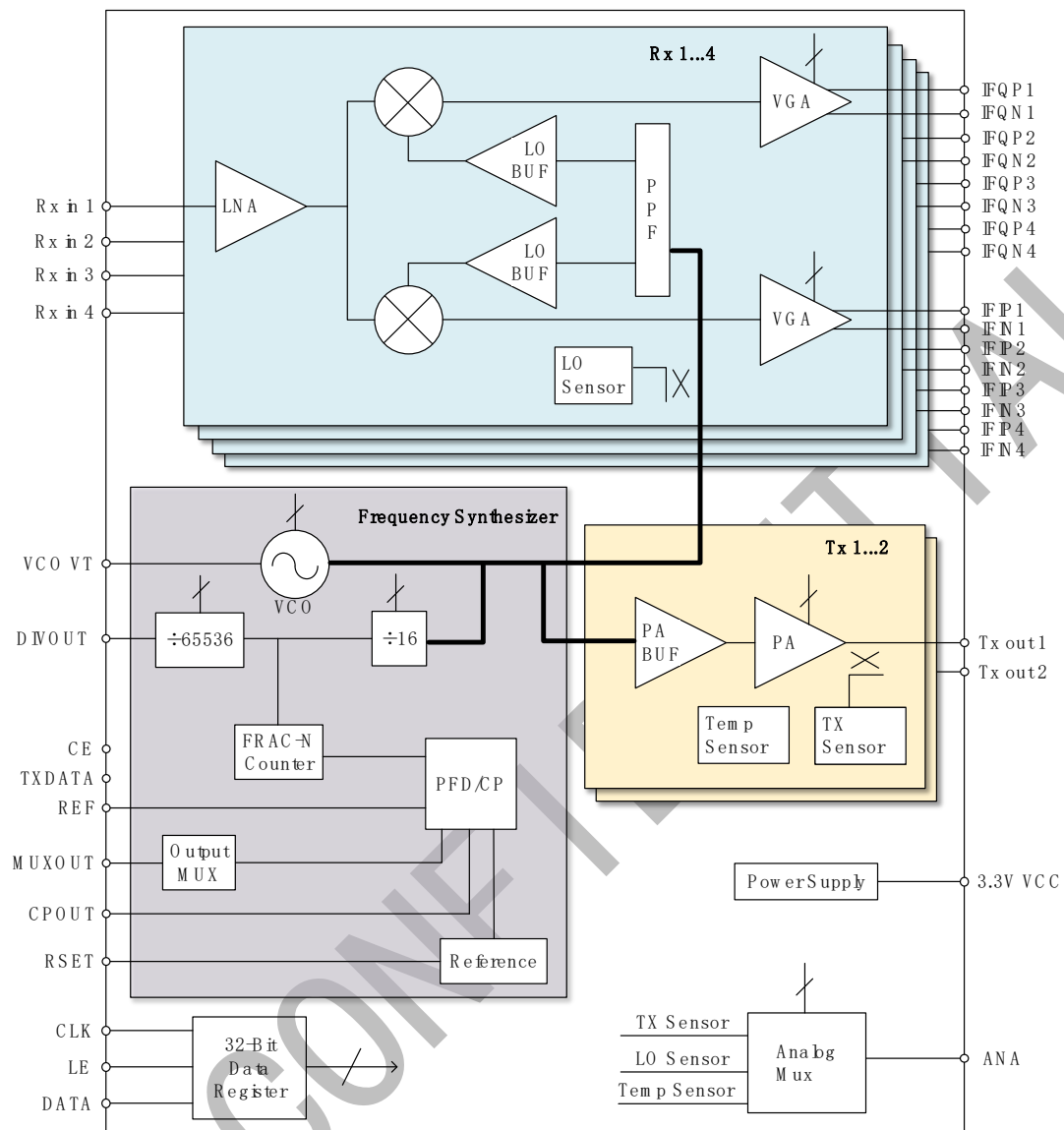


Figure 1 SOC Functional Block Diagram



## SPECIFICATIONS

VCC = 3.3 V, GND = 0 V, dBm referred to 50  $\Omega$ , operating temperature is 25 °C , unless otherwise noted.

## POWER SUPPLY

Table 1 Power Supply Characteristics

| Parameter      | Symbol          | Min   | Typ | Max   | Units | Note                          |
|----------------|-----------------|-------|-----|-------|-------|-------------------------------|
| Supply voltage | V <sub>CC</sub> | 3.135 | 3.3 | 3.465 | V     | AVDD,DVDD,VCCTX/RX,<br>VCCVCO |
| Supply current | I <sub>CC</sub> |       | 435 |       | mA    |                               |

## TX SECTION

Table 2 TX Characteristics

| Parameter                    | Symbol                  | Min   | Typ   | Max   | Units  | Note                                |
|------------------------------|-------------------------|-------|-------|-------|--------|-------------------------------------|
| VCO frequency range          | f <sub>VCO</sub>        | 24.00 |       | 24.25 | GHz    |                                     |
| VCO tuning voltage           | V <sub>T</sub>          | 0.25  |       | 2.75  | V      |                                     |
| VCO tuning slope             | $\Delta f / \Delta V_T$ |       | -0.6  |       | MHz/mV |                                     |
| VCO temperature drift        | $\Delta f / \Delta T$   |       | 1.4   |       | MHz/°C |                                     |
| VCO phase noise              | P <sub>N</sub>          |       | -103  |       | dBc/Hz | @ 1 MHz offset                      |
| TX port return loss          | $\Gamma_{TX}$           |       | -15   |       | dB     | without PCB matching                |
| Max TX output power          | P <sub>TX</sub>         |       | 9     |       | dBm    |                                     |
| TX output power tuning range |                         |       | 18    |       | dB     |                                     |
| TX/TX isolation              |                         |       | -40   |       | dB     | Only one TX ON                      |
| Prescaler1 division ratio    | D <sub>Q1</sub>         |       | 16    |       |        | Output around 1.5GHz                |
| Prescaler2 division ratio    | D <sub>Q2</sub>         |       | 65536 |       |        | Output around 23kHz                 |
| Prescaler2 output voltage    | V <sub>Q2</sub>         |       | 3     |       | V      | DIVOUT is loaded with 1 Mohm, 14 pF |

## RX SECTION

Table 3 RX Characteristics

| Parameter               | Symbol            | Min   | Typ  | Max   | Units    | Note                 |
|-------------------------|-------------------|-------|------|-------|----------|----------------------|
| RFIN frequency range    | f <sub>RFIN</sub> | 24.00 |      | 24.25 | GHz      |                      |
| RFIN port return loss   | $\Gamma_{RFIN}$   |       | -15  |       | dB       | without PCB matching |
| IF frequency range      | f <sub>IF</sub>   | 0     |      | 10    | MHz      |                      |
| IF output impedance     | Z <sub>IF</sub>   |       | 1000 |       | $\Omega$ |                      |
| TX/RX isolation         |                   |       | -40  |       | dB       | Based on SP test     |
| RX/RX isolation         |                   |       | -35  |       | dB       | Based on SP test     |
| Voltage conversion gain | G <sub>c</sub>    |       | 29   |       | dB       |                      |
| DSB noise figure        | NF                |       | 9    |       | dB       |                      |
| Input compression point | IP <sub>1dB</sub> |       | -8   |       | dBm      |                      |



|                        |  |   |        |  |
|------------------------|--|---|--------|--|
| IQ phase imbalance     |  | 5 | Degree |  |
| IQ amplitude imbalance |  | 1 | dB     |  |

## TEMPERATURE SENSOR

Table 4 Temperature Sensor Characteristics

| Parameter                  | Symbol         | Min | Typ  | Max | Units | Note    |
|----------------------------|----------------|-----|------|-----|-------|---------|
| Temperature range          | $T_A$          | -40 |      | 105 | °C    |         |
| Output temperature voltage | $V_{OUT,TEMP}$ |     | 1.68 |     | V     | @ 25 °C |
| Sensitivity                |                |     | 4.6  |     | mV/°C |         |
| Overall accuracy error     |                |     |      | ±15 | °C    |         |

## POWER SENSOR

Table 5 Power Sensor Characteristics

| Parameter       | Symbol | Min | Typ  | Max | Units | Note    |
|-----------------|--------|-----|------|-----|-------|---------|
| Power range     |        | -10 |      | 15  | dBm   |         |
| LO power sensor |        |     | 1.18 |     | V     | @ 2 dBm |

## FREQUENCY SYNTHESIZER

Table 6 Frequency Synthesizer Characteristics

| Parameter                    | Symbol       | Min | Typ | Max      | Units      | Note                |
|------------------------------|--------------|-----|-----|----------|------------|---------------------|
| REF input frequency          |              |     | 20  |          | MHz        |                     |
| REF input sensitivity        |              |     |     | $V_{CC}$ | $V_{P-P}$  |                     |
| RSET                         |              |     | 5.1 |          | k $\Omega$ |                     |
| CP current high value        | $I_{CPH}$    |     | 2.5 |          | mA         | RSET=5.1 k $\Omega$ |
| CP current low value         | $I_{CPL}$    |     | 0.3 |          | mA         | RSET=5.1 k $\Omega$ |
| Input high voltage           | $V_{INH}$    | 1.4 |     |          | V          |                     |
| Input low voltage            | $V_{INL}$    |     |     | 0.6      | V          |                     |
| Output high voltage          | $V_{OH}$     |     |     | $V_{CC}$ | V          |                     |
| Normalized phase noise floor | $PN_{SYNTH}$ |     | 215 |          | dBc/Hz     |                     |



## ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS

GND = 0 V, dBm referred to 50  $\Omega$ , operating temperature is 25  $^{\circ}\text{C}$ , unless otherwise noted.

Table 7 Absolute Maximum Ratings

| Parameter                  | Symbol       | Min  | Typ | Max      | Units              | Note                         |
|----------------------------|--------------|------|-----|----------|--------------------|------------------------------|
| Supply voltage             | $V_{CC}$     | -0.3 |     | 3.6      | V                  | AVDD, DVDD, VCCTX/RX, VCCVCO |
| Analog I/O voltage to GND  |              | -0.3 |     | $V_{CC}$ | V                  |                              |
| Digital I/O voltage to GND |              | -0.3 |     | $V_{CC}$ | V                  |                              |
| DC voltage at VT to GND    | $V_{DC\_VT}$ | -0.3 |     | $V_{CC}$ | V                  |                              |
| REF to GND                 | $V_{REF}$    | -0.3 |     | $V_{CC}$ | V                  |                              |
| Input power into RF ports  | $P_{RF}$     |      |     | 0        | dBm                | RX1RF, RX2RF                 |
| Storage temperature        | $T_{STG}$    | -40  |     | 150      | $^{\circ}\text{C}$ |                              |
| Reflow soldering           |              |      |     |          |                    |                              |
| Peak temperature           |              |      |     | 260      | $^{\circ}\text{C}$ |                              |
| Time at peak temperature   |              |      |     | 40       | sec                |                              |

Attention: Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### ESD INTEGRITY

Table 8 ESD Integrity

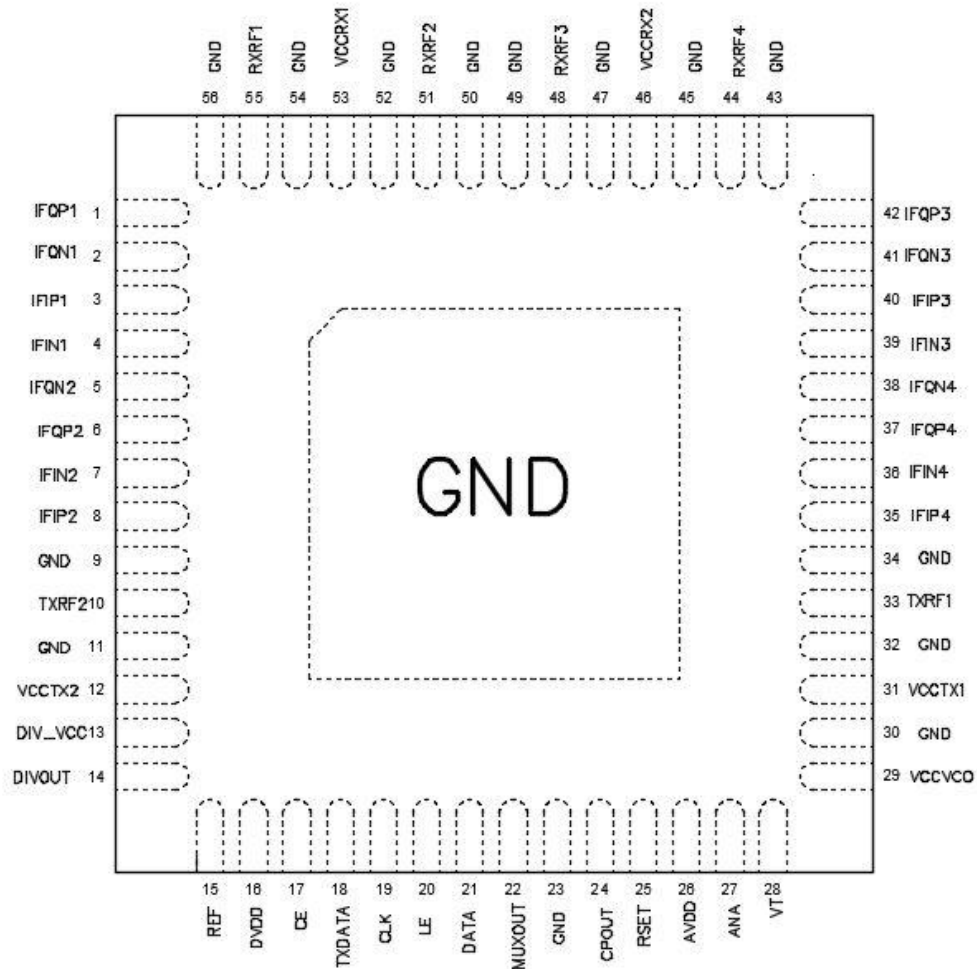
| Parameter                         | Symbol         | Min  | Typ | Max | Units | Note     |
|-----------------------------------|----------------|------|-----|-----|-------|----------|
| ESD robustness, HBM <sup>1)</sup> | $V_{ESD\_HBM}$ | -2   |     | 2   | kV    | All pins |
| ESD robustness, CDM <sup>2)</sup> | $V_{ESD\_CDM}$ | -500 |     | 500 | V     | All pins |

1): According to AEC-Q100-002-Rev-E

2): According to AEC-Q100-011-Rev-D



## PIN CONFIGURATION AND FUNCTION DESCRIPTIONS



Top View

Figure 2 Pin Configuration

Table 9 Pin Function Descriptions

| Pin No.                                        | Mnemonic | Description                                     |
|------------------------------------------------|----------|-------------------------------------------------|
| 1                                              | IFQP1    | Quadrature phase IF output at RX1               |
| 2                                              | IFQN1    | Complementary quadrature phase IF output at RX1 |
| 3                                              | IFIP1    | In phase IF output at RX1                       |
| 4                                              | IFIN1    | Complementary in phase IF output at RX1         |
| 5                                              | IFQN2    | Complementary quadrature phase IF output at RX2 |
| 6                                              | IFQP2    | Quadrature phase IF output at RX2               |
| 7                                              | IFIN2    | Complementary in phase IF output at RX2         |
| 8                                              | IFIP2    | In phase IF output at RX2                       |
| 9,11,23,30,32<br>34,43,45,47,49<br>50,52,54,56 | GND      | RF or DC ground                                 |
| 10                                             | TXRF2    | RF output at TX2                                |



Table 9 Pin Function Descriptions (continued)

| Pin No. | Mnemonic | Description                                                                                    |
|---------|----------|------------------------------------------------------------------------------------------------|
| 12      | VCCTX2   | Supply voltage for TX2 and $\div 16$ Prescaler1                                                |
| 13      | DIV_VCC  | Supply voltage for Prescaler1 and Prescaler2                                                   |
| 14      | DIVOUT   | $\div 65536$ Prescaler2 output                                                                 |
| 15      | REF      | Reference input                                                                                |
| 16      | DVDD     | Supply voltage for the digital modulator in frequency synthesizer                              |
| 17      | CE       | Chip enable                                                                                    |
| 18      | TXDATA   | TX data pin                                                                                    |
| 19      | CLK      | Serial clock input                                                                             |
| 20      | LE       | SPI load enable, low active                                                                    |
| 21      | DATA     | Serial data input                                                                              |
| 22      | MUXOUT   | Multiplexer output                                                                             |
| 24      | CPOUT    | Charge pump output                                                                             |
| 25      | RSET     | Connecting a resistor between this pin and ground sets the maximum charge pump output current. |
| 26      | AVDD     | Supply voltage for the analog part in frequency synthesizer                                    |
| 27      | ANA      | Analog output                                                                                  |
| 28      | VT       | VCO tuning input                                                                               |
| 29      | VCCVCO   | Supply voltage for VCO                                                                         |
| 31      | VCCTX1   | Supply voltage for TX1                                                                         |
| 33      | TXRF1    | RF output at TX1                                                                               |
| 35      | IFIP4    | In phase IF output at RX4                                                                      |
| 36      | IFIN4    | Complementary in phase IF output at RX4                                                        |
| 37      | IFQP4    | Quadrature phase IF output at RX4                                                              |
| 38      | IFQN4    | Complementary quadrature phase IF output at RX4                                                |
| 39      | IFIN3    | Complementary in phase IF output at RX3                                                        |
| 40      | IFIP3    | In phase IF output at RX3                                                                      |
| 41      | IFQN3    | Complementary quadrature phase IF output at RX3                                                |
| 42      | IFQP3    | Quadrature phase IF output at RX3                                                              |
| 44      | RXRF4    | RF input at RX4                                                                                |
| 46      | VCCRX2   | Supply voltage for RX3 and RX4                                                                 |
| 48      | RXRF3    | RF input at RX3                                                                                |
| 51      | RXRF2    | RF input at RX2                                                                                |
| 53      | VCCRX1   | Supply voltage for RX1 and RX2                                                                 |
| 55      | RXRF1    | RF input at RX1                                                                                |

## PACKAGE DIMENSIONS

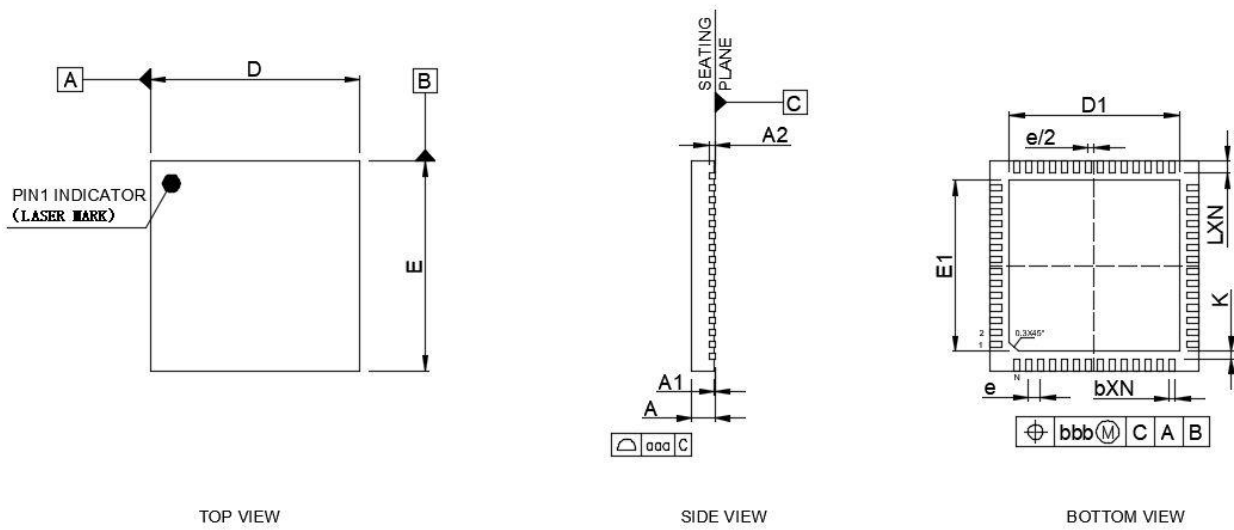


Figure 3 56-Lead QFN Package Dimensions

Table 10 Package Dimensions

|                              |   | SYMBOL | MIN      | NOM  | MAX  |
|------------------------------|---|--------|----------|------|------|
| TOTAL THICKNESS              |   | A      | 0.7      | 0.75 | 0.8  |
| STAND OFF                    |   | A1     | 0.00     | 0.02 | 0.05 |
| L/F THICKNESS                |   | A2     | 0.20 REF |      |      |
| LEAD WIDTH                   |   | b      | 0.15     | 0.2  | 0.25 |
| BODY SIZE                    | X | D      | 6.95     | 7.00 | 7.05 |
|                              | Y | E      | 6.95     | 7.00 | 7.05 |
| LEAD PITCH                   |   | e      | 0.40 BSC |      |      |
| EP SIZE                      | X | D1     | 5.60     | 5.70 | 5.80 |
|                              | Y | E1     | 5.60     | 5.70 | 5.80 |
| LEAD LENGTH                  |   | L      | 0.30     | 0.40 | 0.50 |
| LEAD TIP TO EXPOSED PAD EDGE |   | K      | 0.25 REF |      |      |
|                              |   | N      | 56       |      |      |
| PACKAGE EDGE TOLERANCE       |   | aaa    | 0.10     |      |      |
|                              |   | bbb    | 0.07     |      |      |