

RFPD-RT-2444-1

mmWave Converter

SC2444

Target Specification

Typical Applications

- 5G NR Frequency Range 2 Development
- Software Defined Radio Applications
- Aerospace and Defense
- Advanced Wireless Communications Research



Summary

The mmWave converter is a stand-alone platform for use in the 24 to 44 GHz range.

The module is designed to interface directly with software-defined radios, such as those commonly implemented using Analog Device's Mixed-Signal Front-End (MxFE), or similar Software Defined Radio, to obtain a complete mmWave system.

Up to four modules can be combined in parallel to create complex MIMO applications.

Description

Power is provided via a 12-volt wall cube which is included with the Development Kit. An embedded fan and temperature monitoring are integrated into the unit to manage heat.

Control of the module is provided via the USB, UART, or SPI interfaces. Most users will find it convenient to control the module using the console interface over USB. Alternatively, embedded controllers may access the UART or SPI interfaces available on the external Control Ports.

Two API protocols are available. The first is ASCII-based, and its commands follow the SCPI structure as defined in IEEE 488.2. The second is a binary protocol, targeted at embedded control applications where speed and timing are critical. Both protocols are detailed in an API Specification.

Up to 4 units can be combined in a vertical stack to create a complex 4 x 4 MIMO radio system. In this scenario, the internal control buses are routed to the cascaded modules over the Expansion Port. In this manner, API commands sent on the primary unit, can be redirected to the downstream modules. This eliminates the need for multiple controllers and simplifies timing and synchronization between units. Module addresses are set using a DIP switch on the Configuration Port.

A Secondary and External Control Port is also available. These ports expose Power, SPI, I2C, UART and GPIO that provide users with a convenient method of interfacing to external front-end modules, such as integrated antenna arrays or switched filter banks.

The low-frequency RF inputs include the IF, I/Q, external LO, and external frequency reference ports on SMA connectors.

The converters can be configured to interface with either IF or I/Q signals. The IF port supports signals between 2

and 6 GHz. The I/Q inputs provide connectivity to external single-ended DACs operating at up to 1 GHz. A low pass filter is included to help with alias and spurious rejection.

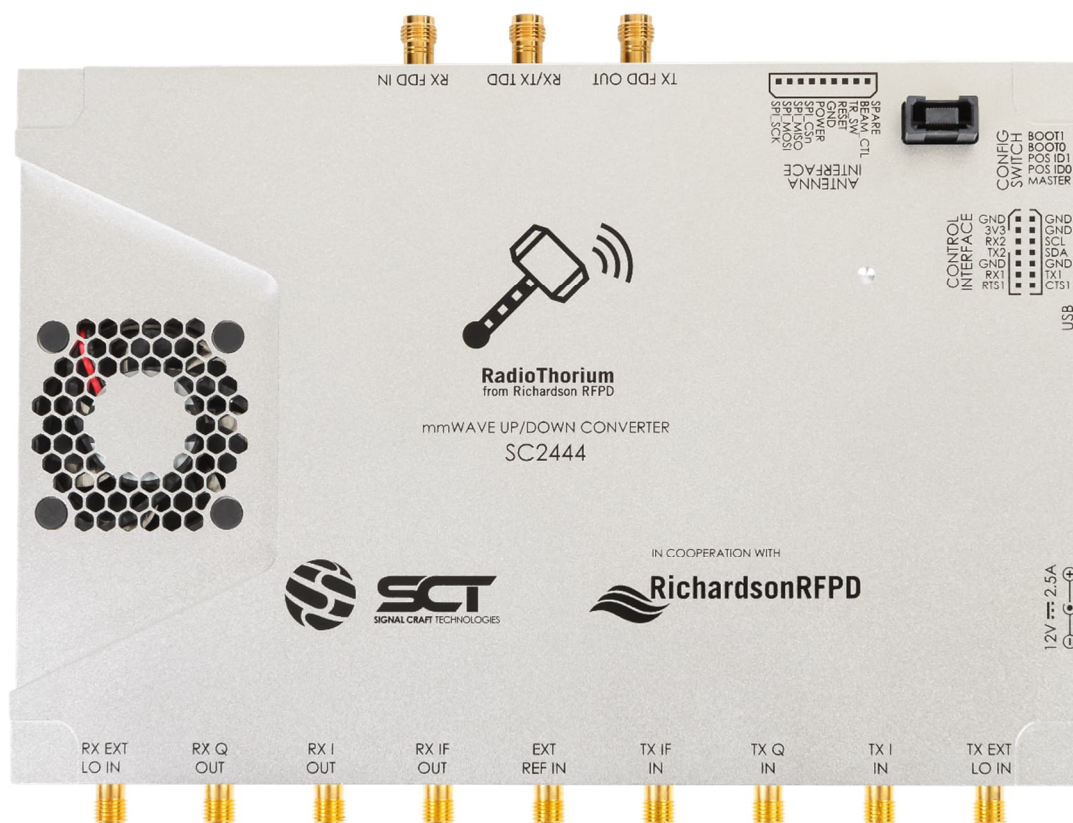
RadioThorium can be used in either Time Division Duplex (TDD) or Frequency Division Duplex (FDD) mode. The mmWave ports include 2.4 mm connectors for the FDD TX and RX functions, in addition to a bidirectional TDD port.

In FDD Mode, the Up-Conversion (UC) path has approximately 30 dB of gain and an output compression point, or P1dB, of 18 dBm at 40 GHz. In TDD mode, the gain is also 30 dB, but the P1dB reduces to 16 dBm at 40 GHz.

In FDD Mode, the Down-Conversion (DC) path has a maximum gain of approximately 70 dB, noise figure of 10 dB, and an input compression point, or P1dB, of 0 dBm at 40 GHz. In TDD mode, the gain is also close to 70 dB with a noise figure of 12 dB, and an input P1dB of better than 0 dBm at 40 GHz.

Two on-board Local Oscillators (LOs) are provided to facilitate standalone operation. Each LO can be configured independent of the other, providing users with complete control of the RF/LO/IF frequency plan specific to their application.

Optionally, the onboard synthesizers can be disabled when external LOs are supplied by the user.



SC2444 – mmWave Frequency Converter

Definitions

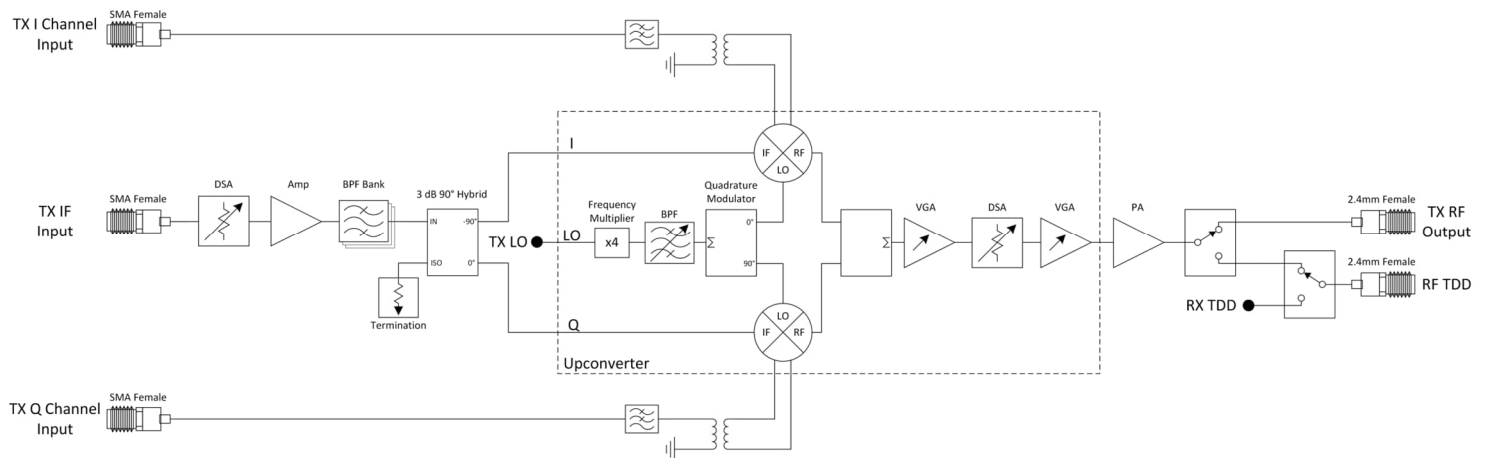
The following definitions apply to these specifications:

- *Typical* values describe the expected performance for the majority of units. Typical values may not be verified on all units shipped from the factory.
- *Minimum (Min)* and *Maximum (Max)* values describe warranted product performance.
- *Device Temperature (T_{device})* is the current device temperature.

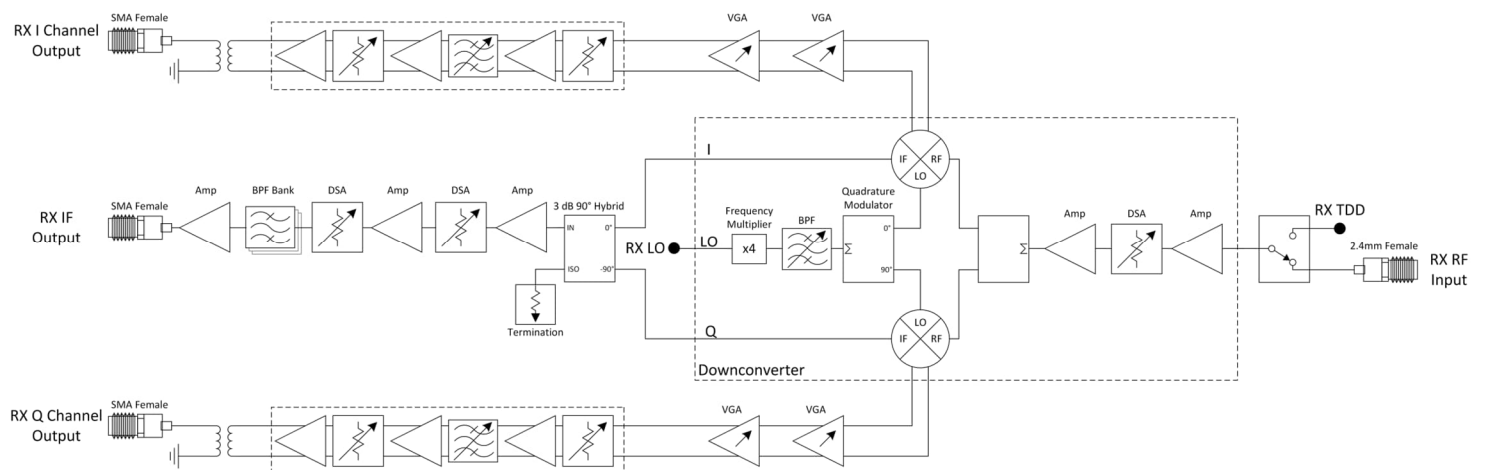
Specifications are subject to change without notice. For the most recent SC2444 specification, visit www.signalcraft.com.

Block Diagrams

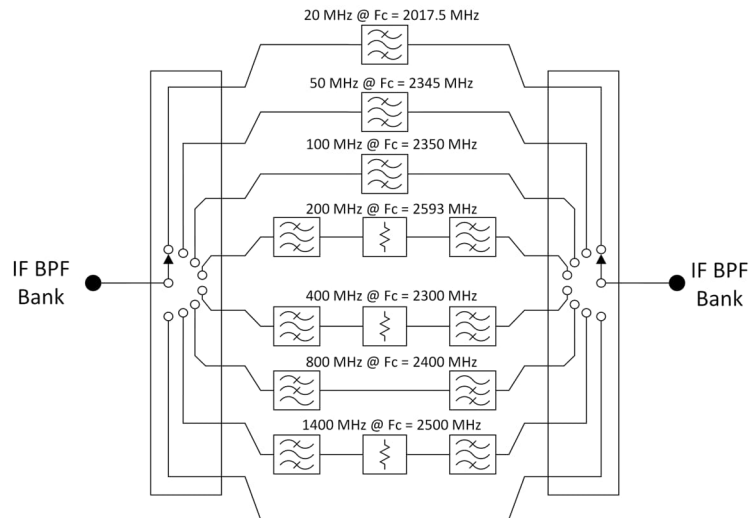
Transmit Channel



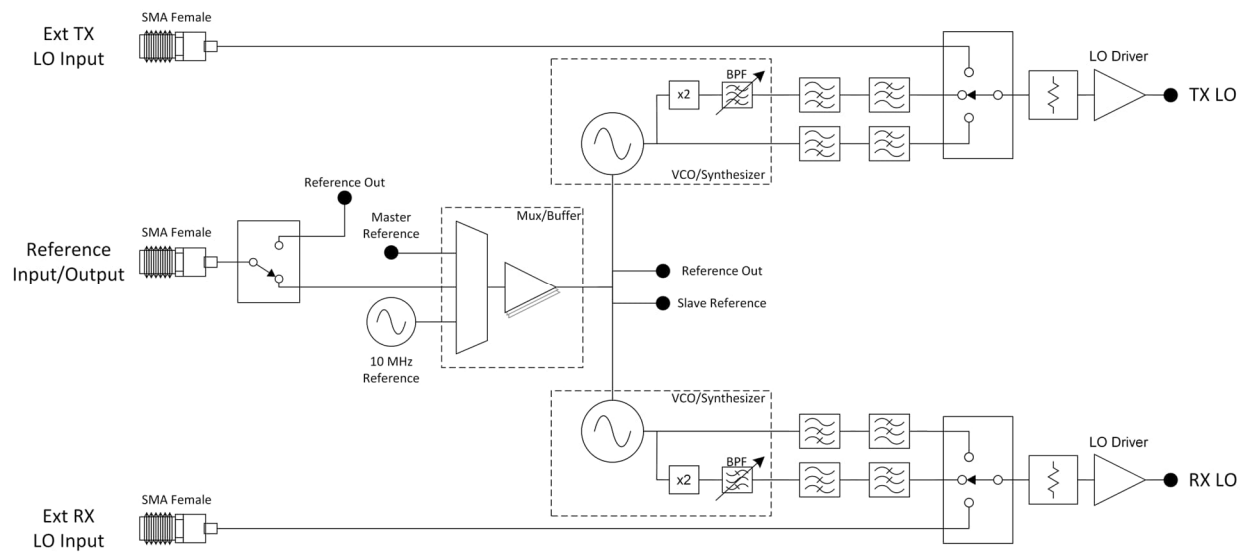
Receive Channel



IF Filter Bank



Local Oscillators



IF Down-Conversion (DC) Path Specifications

General

Parameter	Conditions	Min	Typical	Max	Comments
Input Frequency (MHz)		24000	-	44000	
Output Intermediate Frequency (MHz)		2000	-	6000	
Internal Local Oscillator Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Power (dBm)		-5	-	0	
Gain Control Step Size (dB)		-	0.5	-	
Gain Control Range (dB)	IF Section	-	63	-	
	RF Section	-	19	-	
Max Input Power (dBm)		-	-	0	No damage

DC IF Path - FDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Conversion Gain (dB)	24 GHz $\leq$ F < 29 GHz	-	75	-	Maximum Gain, IF = 4.0 GHz, IF Filter Bypass
	29 GHz $\leq$ F $\leq$ 35 GHz	-	74	-	
	35 GHz < F $\leq$ 40 GHz	-	74	-	
	40 GHz < F $\leq$ 44 GHz	-	71	-	
	24 GHz < F < 29 GHz	-	-6	-	Minimum Gain, IF = 4.0 GHz, IF Filter Bypass
	29 GHz $\leq$ F $\leq$ 35 GHz	-	-7	-	
	35 GHz < F $\leq$ 40 GHz	-	-8	-	
	40 GHz < F $\leq$ 44 GHz	-	-9	-	
Noise Figure (dB)	24 GHz < F < 29 GHz	-	9	-	Maximum Gain, IF = 4.0 GHz, IF Filter Bypass
	29 GHz $\leq$ F $\leq$ 35 GHz	-	11	-	
	35 GHz < F $\leq$ 40 GHz	-	10	-	
	40 GHz < F $\leq$ 44 GHz	-	13	-	
1dB Input Compression (dBm)	24 GHz $\leq$ F < 44 GHz	-	-3	-	Minimum Gain, IF Filter Bypass

DC IF Path - TDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Conversion Gain (dB)	$24 \text{ GHz} \leq F < 29 \text{ GHz}$	-	74	-	Maximum Gain, IF = 4.0 GHz, IF Filter Bypass
	$29 \text{ GHz} \leq F \leq 35 \text{ GHz}$	-	72	-	
	$35 \text{ GHz} < F \leq 40 \text{ GHz}$	-	71	-	
	$40 \text{ GHz} < F \leq 44 \text{ GHz}$	-	69	-	
	$24 \text{ GHz} < F < 29 \text{ GHz}$	-	-7	-	Minimum Gain, IF = 4.0 GHz, IF Filter Bypass
	$29 \text{ GHz} \leq F \leq 35 \text{ GHz}$	-	-9	-	
	$35 \text{ GHz} < F \leq 40 \text{ GHz}$	-	-11	-	
	$40 \text{ GHz} < F \leq 44 \text{ GHz}$	-	-11	-	
Noise Figure (dB)	$24 \text{ GHz} < F < 29 \text{ GHz}$	-	10	-	Maximum Gain, IF = 4.0 GHz, IF Filter Bypass
	$29 \text{ GHz} \leq F \leq 35 \text{ GHz}$	-	12	-	
	$35 \text{ GHz} < F \leq 40 \text{ GHz}$	-	11	-	
	$40 \text{ GHz} < F \leq 44 \text{ GHz}$	-	15	-	
1dB Input Compression (dBm)	$24 \text{ GHz} < F < 44 \text{ GHz}$	-	-2	-	Minimum Gain, IF Filter Bypass

I/Q Down-Conversion (DC) Path Specifications

General

Parameter	Conditions	Min	Typical	Max	Comments
Input Frequency (MHz)		24000	-	41000	
I/Q Bandwidth (MHz)		-	-	1400	
Internal Local Oscillator Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Power (dBm)		-5	-	0	
Gain Control Range (dB)	Baseband Section	-	130	-	
	RF Section	-	19	-	
Max Input Power (dBm)		-	-	0	No damage

DC I/Q Path - FDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Conversion Gain (dB)	$24 \text{ GHz} \leq F < 32 \text{ GHz}$	-	78	-	Maximum RF Gain, 70dB Baseband Gain, I/Q Freq = 100 MHz
	$32 \text{ GHz} \leq F \leq 38 \text{ GHz}$	-	74	-	
	$38 \text{ GHz} < F \leq 41 \text{ GHz}$	-	76	-	
	$24 \text{ GHz} < F < 29 \text{ GHz}$	-	-38	-	Minimum Gain, I/Q Freq = 100 MHz
	$29 \text{ GHz} \leq F \leq 35 \text{ GHz}$	-	-41	-	
	$35 \text{ GHz} < F \leq 41 \text{ GHz}$	-	-40	-	
Noise Figure (dB)	$24 \text{ GHz} < F < 32 \text{ GHz}$	-	12	-	Maximum Gain, I/Q Freq = 100 MHz
	$32 \text{ GHz} \leq F \leq 38 \text{ GHz}$	-	14	-	
	$38 \text{ GHz} < F \leq 41 \text{ GHz}$	-	13	-	
1dB Input Compression (dBm)	$24 \text{ GHz} \leq F < 41 \text{ GHz}$	-	-3	-	Minimum Gain

DC I/Q Path - TDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Conversion Gain (dB)	$24 \text{ GHz} \leq F < 32 \text{ GHz}$	-	77	-	Maximum RF Gain, 70dB Baseband Gain I/Q Freq = 100 MHz
	$32 \text{ GHz} \leq F \leq 38 \text{ GHz}$	-	72	-	
	$38 \text{ GHz} < F \leq 41 \text{ GHz}$	-	75	-	
	$24 \text{ GHz} < F < 29 \text{ GHz}$	-	-39	-	Minimum Gain, I/Q Freq = 100 MHz
	$29 \text{ GHz} \leq F \leq 35 \text{ GHz}$	-	-43	-	
	$35 \text{ GHz} < F \leq 40 \text{ GHz}$	-	-42	-	
Noise Figure (dB)	$24 \text{ GHz} < F < 32 \text{ GHz}$	-	14	-	Maximum RF Gain, 70dB Baseband Gain I/Q Freq = 100 MHz
	$32 \text{ GHz} \leq F \leq 38 \text{ GHz}$	-	16	-	
	$38 \text{ GHz} < F \leq 41 \text{ GHz}$	-	14	-	
1dB Input Compression (dBm)	$24 \text{ GHz} \leq F \leq 41 \text{ GHz}$	-	-2	-	Minimum Gain

IF Up-Conversion (UC) Path Specifications

General

Parameter	Conditions	Min	Typical	Max	Comments
Input Frequency (MHz)		2000	-	5000	
Output Frequency (MHz)		24000	-	44000	
Internal Local Oscillator Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Frequency (MHz)	LO x4 Enabled	5400	-	10250	
Input Power (dBm)		-	-	0	Absolute maximum, no damage
External Local Oscillator Input Power (dBm)		-5	-	0	
Gain Control Step Size (dB)		-	0.5	-	
Gain Control Range (dB)	IF Section	-	31.5	-	
	RF Section	-	35	-	

UC IF Path - FDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Gain (dB)	24 GHz < F < 29 GHz	-	38	-	Maximum Gain, IF = 4.0 GHz, IF Filter Bypass
	29 GHz ≤ F ≤ 35 GHz	-	35	-	
	35 GHz < F ≤ 40 GHz	-	33	-	
	40 GHz < F ≤ 44 GHz	-	27	-	
	24 GHz < F < 29 GHz	-	7	-	Minimum Gain to meet output P1dB specification IF = 4.0 GHz, IF Filter Bypass
	29 GHz ≤ F ≤ 35 GHz	-	4	-	
	35 GHz < F ≤ 40 GHz	-	2	-	
	40 GHz < F ≤ 44 GHz	-	-4	-	
1 dB Output Compression (dBm)	24 GHz < F < 29 GHz	-	21	-	Maximum Gain
	29 GHz ≤ F ≤ 35 GHz	-	19	-	
	35 GHz < F ≤ 40 GHz	-	18	-	
	40 GHz < F ≤ 44 GHz	-	15	-	
Noise Figure (dB)	24 GHz < F < 29 GHz	-	18	-	Maximum Gain
	29 GHz ≤ F ≤ 35 GHz	-	19	-	
	35 GHz < F ≤ 40 GHz	-	20	-	
	40 GHz < F ≤ 44 GHz	-	22	-	

UC IF Path - TDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Gain (dB)	24 GHz < F < 29 GHz	-	36	-	Maximum Gain, IF = 4.0 GHz, IF Filter Bypass
	29 GHz ≤ F ≤ 35 GHz	-	33	-	
	35 GHz < F ≤ 40 GHz	-	31	-	
	40 GHz < F ≤ 44 GHz	-	24	-	
	24 GHz < F < 29 GHz	-	6	-	Minimum Gain to meet output P1dB specification IF = 4.0 GHz, IF Filter Bypass
	29 GHz ≤ F ≤ 35 GHz	-	3	-	
	35 GHz < F ≤ 40 GHz	-	0	-	
	40 GHz < F ≤ 44 GHz	-	-7	-	
1 dB Output Compression (dBm)	24 GHz < F < 29 GHz	-	18	-	Maximum Gain
	29 GHz ≤ F ≤ 35 GHz	-	17	-	
	35 GHz < F ≤ 40 GHz	-	16	-	
	40 GHz < F ≤ 44 GHz	-	14	-	
Noise Figure (dB)	24 GHz < F < 29 GHz	-	18	-	Maximum Gain
	29 GHz ≤ F ≤ 35 GHz	-	18	-	
	35 GHz < F ≤ 40 GHz	-	20	-	
	40 GHz < F ≤ 44 GHz	-	22	-	

I/Q Up-Conversion (UC) Path Specifications

General

Parameter	Conditions	Min	Typical	Max	Comments
Input Frequency (MHz)		24000	-	41000	
I/Q Bandwidth (MHz)		-	-	1400	
Internal Local Oscillator Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Frequency (MHz)	LO x4 Enabled	5400	-	10250	
External Local Oscillator Input Power (dBm)		-5	-	0	
Gain Control Range (dB)	RF Section	-	30	-	
Max Input Power (dBm)		-	-	+5	No damage

UC I/Q Path - FDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Gain (dB)	24 GHz < F < 29 GHz	-	26	-	Maximum Gain, I/Q Freq = 100 MHz
	29 GHz ≤ F ≤ 35 GHz	-	23	-	
	35 GHz < F ≤ 41 GHz	-	20	-	
1 dB Output Compression (dBm)	24 GHz < F < 29 GHz	-	21	-	Maximum Gain, I/Q Freq = 100 MHz
	29 GHz ≤ F ≤ 35 GHz	-	19	-	
	35 GHz < F ≤ 40 GHz	-	18	-	
	40 GHz < F ≤ 41 GHz	-	15	-	
Noise Figure (dB)	24 GHz < F < 29 GHz	-	28	-	Maximum Gain, I/Q Freq = 100 MHz
	29 GHz ≤ F ≤ 38 GHz	-	28	-	
	38 GHz < F ≤ 41 GHz	-	30	-	

UC I/Q Path - TDD Operation

Parameter	Conditions	Min	Typical	Max	Comments
Gain (dB)	24 GHz < F < 29 GHz	-	24	-	Maximum Gain, I/Q Freq = 100 MHz
	29 GHz ≤ F ≤ 35 GHz	-	21	-	
	35 GHz < F ≤ 41 GHz	-	18	-	
1 dB Output Compression (dBm)	24 GHz < F < 29 GHz	-	18	-	Maximum Gain, I/Q Freq = 100 MHz
	29 GHz ≤ F ≤ 35 GHz	-	17	-	
	35 GHz < F ≤ 40 GHz	-	16	-	
	40 GHz < F ≤ 41 GHz	-	14	-	
Noise Figure (dB)	24 GHz < F < 29 GHz	-	28	-	Maximum Gain, I/Q Freq = 100 MHz
	29 GHz ≤ F ≤ 38 GHz	-	28	-	
	38 GHz < F ≤ 41 GHz	-	30	-	

Interfaces

Power Supply Input

- 110-220 V_{AC} to 12 V_{DC} Adaptor Included (AC Cable Not Included)
- 23 W @ 12 V_{DC}

Control Inputs

- USB-C - Console API
- Auxiliary Control Interface - Console API via UART (TTL Levels)
 - Compatible Mating Cable: [Samtec SFSDT-07-28-G-08.00-DL-NDX](#)
- Expansion Port - Binary via SPI (Mode 1), Console API via RS485
 - Compatible Mating Connector: [Hirose FX20 Series](#) FX20-20P-0.5SV15
- Antenna Interface – Binary via SPI
 - Compatible Mating Cable: [Samtec FCF8-10-01-L-08.00-S-1](#)

Up-Conversion

LO IN	
Connector	SMA (female)
Impedance	50 Ω
Coupling	AC
IF IN	
Connector	SMA (female)
Impedance	50 Ω
Coupling	AC
I/Q IN	
Connectors	SMA (female)
Impedance	50 Ω
Coupling	AC
RF OUT (FDD)	
Connector	2.4 mm (female)
Impedance	50 Ω
Coupling	AC
RF OUT (TDD)	
Connector	2.4 mm (female)
Impedance	50 Ω
Coupling	AC

Down-Conversion

LO IN	
Connector	SMA (female)
Impedance	50 Ω
Coupling	AC
IF OUT	
Connector	SMA (female)
Impedance	50 Ω
Coupling	AC
I/Q OUT	
Connectors	SMA (female)
Impedance	50 Ω
Coupling	AC
RF IN	
Connector	2.4 mm (female)
Impedance	50 Ω
Coupling	AC

Calibration

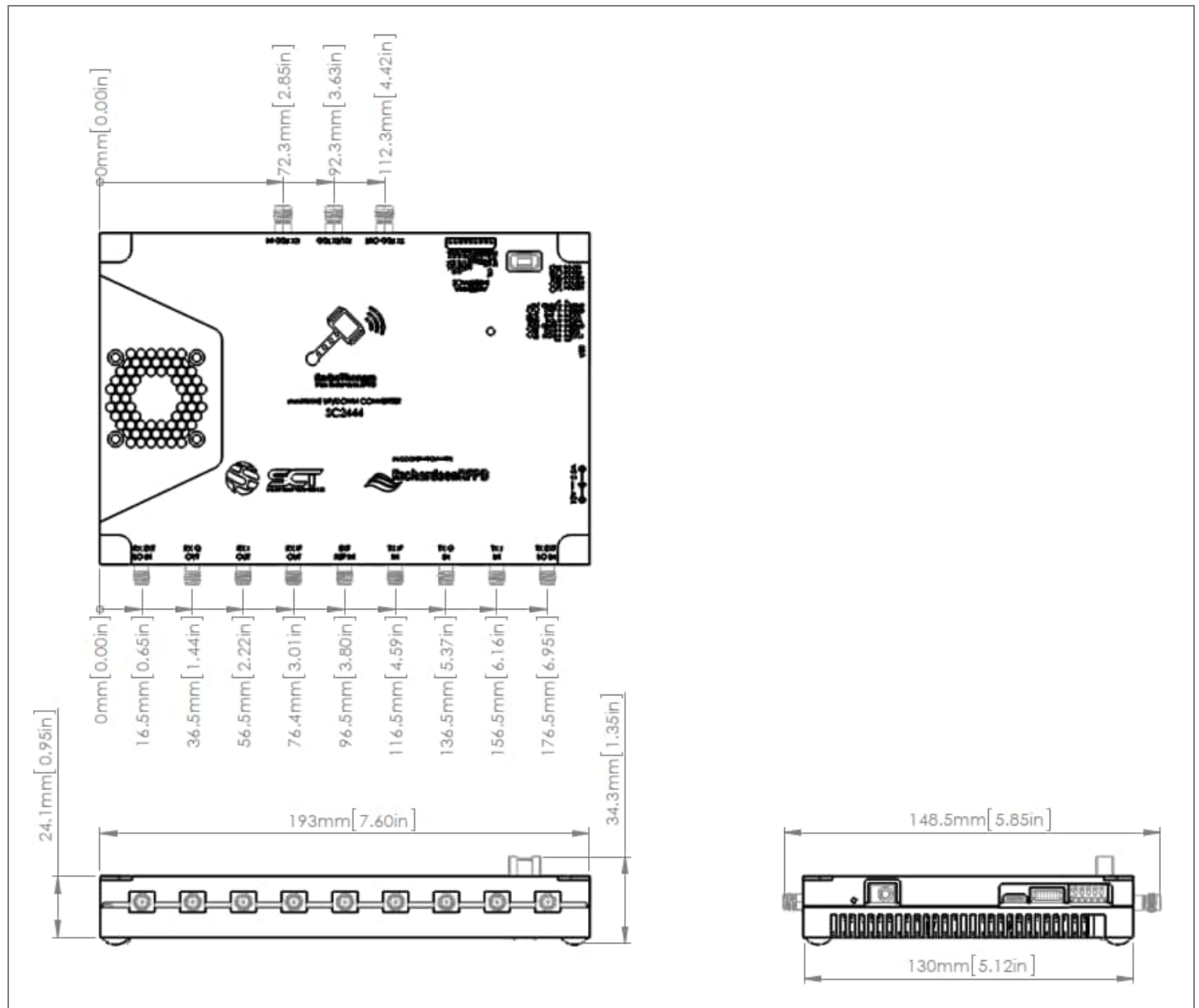
Due to the large number of operating conditions and user configurations, calibration will not be provided on this product.

Physical Characteristics

Weight

1.1 kilograms (2.4 pounds)

Mechanical Dimensions



Environment

Operating

Ambient Temperature Range	0 to 55 °C
Relative Humidity Range	10 – 90% Non-condensing

Storage

Ambient Temperature Range	-40 to 70 °C
Relative Humidity Range	5 – 95% Non-condensing