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SKY65378-11: 860 to 930 MHz RF Front-End Module
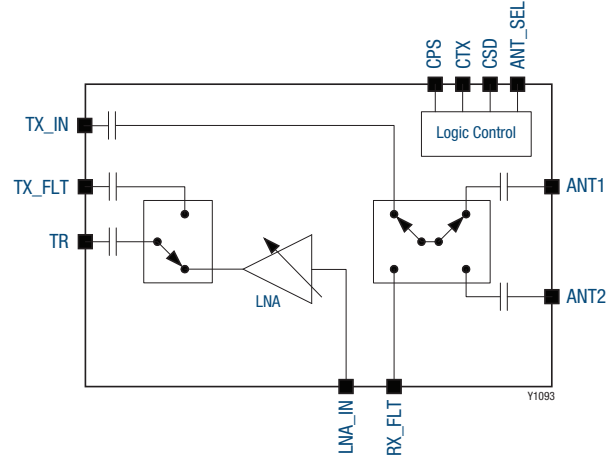
Applications

- Smart meters
- In-home appliances
- Smart thermostats

Features

- Integrated LNA with programmable gain
- Integrated antenna switching with transmit/receive diversity function
- Low FEM noise figure: 2.5 dB typical
- Fast turn-on/turn-off time: <1 μs
- 2.0 to 4.8 V supply operation
- Sleep mode current: <1 μA
- Small QFN (24-pin, 4 x 4 mm) package (MSL1, 260 °C per JEDEC J-STD-020)

Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04–0074.


Figure 1. SKY65378-11 Block Diagram

Description

The SKY65378-11 is a high-performance, highly integrated front-end module (FEM) designed for low power ISM band applications operating in the 860 to 930 MHz band.

The device is designed for ease of use and maximum flexibility, with fully matched 50 Ω input and output, and digital controls compatible with 1.6 to 3.6 V CMOS levels.

The RF blocks operate over a wide supply voltage range from 2.0 to 4.8 V, which allows the SKY65378-11 to be used in battery powered applications over a wide spectrum of the battery discharge curve.

The device is provided in a 4 x 4 mm, 24-pin Quad Flat No-Lead (QFN) package. A functional block diagram is shown in Figure 1. The pin configuration and package are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.
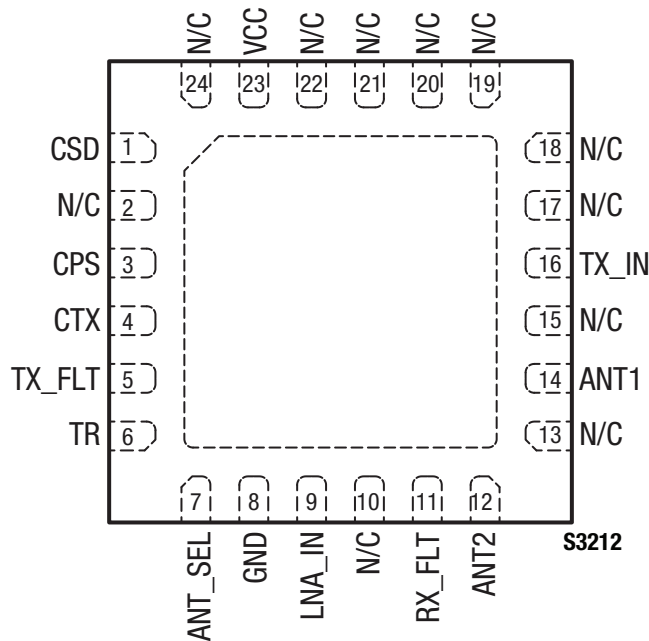
Figure 2. SKY65378-11 Pinout – 24-Pin QFN
(Top View)

Table 1. SKY65378-11 Signal Descriptions

Pin	Name	Description	Pin	Name	Description
1	CSD	Shutdown control pin	13	N/C	Not connected internally
2	N/C	Not connected internally	14	ANT1	Antenna port 1
3	CPS	Receive path select control input	15	N/C	Not connected internally
4	CTX	Transmit enable control input	16	TX_IN	Transmit signal to antennas (from external)
5	TX_FLT	Transmit signal from TR port	17	N/C	Not connected internally
6	TR	Common receive/transmit port	18	N/C	Not connected internally
7	ANT_SEL	Antenna select control input	19	N/C	Not connected internally
8	GND	Ground	20	N/C	Not connected internally
9	LNA_IN	LNA input (from receive filter)	21	N/C	Not connected internally
10	N/C	Not connected internally	22	N/C	Not connected internally
11	RX_FLT	Receive signal from antennas (to receive filter)	23	VCC	Positive power supply
12	ANT2	Antenna port 2	24	N/C	Not connected internally

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY65378-11 are provided in Table 2. The recommended operating conditions are specified in Table 3. Electrical specifications are provided in Tables 4 to 8.

The state of the SKY65378-11 is determined by the logic provided in Table 9. Table 10 provides the logic for the two antenna ports.

Table 2. SKY65378-11 Absolute Maximum Ratings (Note 1)

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage (no RF)	V_{CC}	−0.3	5.5	V
Transmit input power at TX_IN port	$P_{IN\_TX\_MAX}$		+32	dBm
Transmit input power at TR port (Note 2)	$P_{IN\_TR\_MAX}$		+20	dBm
Receive input power at ANT1 or ANT2 ports	$P_{IN\_RX\_MAX}$		+10	dBm
Voltage Standing Wave Ratio	VSWR		10:1	−
Operating temperature	T_A	−40	+85	°C
Storage temperature	T_{STG}	−40	+125	°C
Electrostatic discharge:	ESD			
Charged Device Model (CDM), Class 4			1000	V
Human Body Model (HBM), Class 1C			1000	V
Machine Model (MM), Class A			50	V

Note 1: Exposure to maximum rating conditions for extended periods may reduce device reliability. There is no damage to device with only one parameter set at the limit and all other parameters set at or below their nominal value. Exceeding any of the limits listed here may result in permanent damage to the device.

Note 2: $P_{IN\_TR\_MAX}$ = +12 dBm at worst case where VSWR = 10:1.

CAUTION*: Although this device is designed to be as robust as possible, electrostatic discharge (ESD) can damage this device. This device must be protected at all times from ESD. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD precautions should be used at all times.*

Table 3. SKY65378-11 Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units
Supply voltage	V_{CC}	2.0	4.0	4.8	V
Operating temperature	T_A	−40	+25	+85	°C

Table 4. SKY65378-11 Electrical Specifications: DC Characteristics (Note 1)
(V$_{CC}$ = 4 V, T$_A$ = +25 °C as Measured on Evaluation Board [Not De-Embedded to Device], Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Total supply current	I$_{CQ\_TX}$	Transmit mode		330		µA
	I$_{CQ\_RX\_LOWGAIN}$	Receive low gain mode		4		mA
	I$_{CQ\_RX\_HIGHGAIN}$	Receive high gain mode		8		mA
Sleep supply current	I$_{CC\_OFF}$	Sleep mode		0.3	1.00	µA

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 5. SKY65378-11 Electrical Specifications: Transmit Characteristics (Note 1)
(V$_{CC}$ = 4 V, T$_A$ = +25 °C as Measured on Evaluation Board [Not De-Embedded to Device], All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Frequency	f		860		930	MHz
Insertion loss	S21	TR to ANT1 and ANT2		1.5		dB
Input return loss	S11	Measured at TR		−10		dB
Output return loss	S22	Measured at ANT1 and ANT2		−10		dB
Turn-on time	t$_{ON}$	From 50% of CTX edge to 90% of final RF output power			1	µs
Turn-off time (Note 2)	t$_{OFF}$	From 50% of CTX edge to 10% of final RF output power			1	µs

Note 1: Performance is guaranteed only under the conditions listed in this table.
Note 2: CSD must remain high for 500 ns after CTX is set low.

Table 6. SKY65378-11 Electrical Specifications: Receive Characteristics (1 of 2) (Note 1)
(V$_{CC}$ = 4 V, T$_A$ = +25 °C as Measured on Evaluation Board [Not De-Embedded to Device], All Unused Ports Terminated with 50 Ω, Input Port ANT1 or ANT2, Output Port TR, 0 Ω Connected Between the RX_FLT and LNA_IN Pins in Lieu of External Filters, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Frequency	f		860		930	MHz
Receive low gain mode	RX$_{LG}$	@ 900 to 930 MHz and 860 to 870 MHz, CSD = logic "1," CPS = CTX = logic "0"		14		dB
Receive high gain mode	RX$_{HG}$	@ 900 to 930 MHz and 860 to 870 MHz, CPS = CSD = logic "1," CTX = logic "0"		17		dB

Table 6. SKY65378-11 Electrical Specifications: Receive Characteristics (2 of 2) (Note 1)
(V_{CC} = 4 V, T_A = +25 °C as Measured on Evaluation Board [Not De-Embedded to Device], All Unused Ports Terminated with 50 Ω, Input Port ANT1 or ANT2, Output Port TR, 0 Ω Connected Between the RX_FLT and LNA_IN Pins in Lieu of External Filters, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Receive noise figure, low-gain mode	NF_{LG}	@ 900 to 930 MHz and 860 to 870 MHz, CSD = logic "1," CPS = CTX = logic "0"		2.7	3.5	dB
Receive noise figure, high-gain mode	NF_{HG}	@ 900 to 930 MHz and 860 to 870 MHz, CPS = CSD = logic "1," CTX = logic "0"		2.5	3	dB
1 dB input compression point, low-gain mode	$IP1dB_{LG}$	@ 900 to 930 MHz and 860 to 870 MHz, CSD = logic "1," CPS = CTX = logic "0"		−10		dBm
1 dB input compression point, high-gain mode	$IP1dB_{HG}$	@ 900 to 930 MHz and 860 to 870 MHz, CPS = CSD = logic "1," CTX = logic "0"	−15	−12		dBm
Antenna port return loss	$S11_{ANT1,2}$	@ 900 to 930 MHz and 860 to 870 MHz, into 50 Ω, ANT1 and ANT2 ports		−12		dB
TR port return loss in receive mode	$S22_{TR}$	@ 900 to 930 MHz and 860 to 870 MHz, into 50 Ω		−12		dB
Turn-on time	t_{ON}	From 50% of CTX edge to 90% of final RF output power			1	μs
Turn-off time	t_{OFF}	From 50% of CTX edge to 10% of final RF output power			1	μs

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 7. SKY65378-11 Electrical Specifications: Diversity Antenna Characteristics (Note 1)
(V_{CC} = 4 V, T_A = +25 °C, f = 900 to 930 MHz and 860 to 870 MHz, as Measured on Evaluation Board [De-Embedded to Device], All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Isolation between ANT1 and ANT2 ports	ISO_{ANTSW}			30		dB
Isolation between TX_IN and TR ports	ISO_{RXTX}			20		dB
Insertion loss from TX_IN to ANT1	T_{X_ANT1}			0.9		dB
Insertion loss from TX_IN to ANT2	T_{X_ANT2}			0.9		dB
Insertion loss from ANT1 to RX_FILT	R_{X_ANT1}			0.9		dB
Insertion loss from ANT2 to RX_FILT	R_{X_ANT2}			0.9		dB
Antenna 1 to antenna 2 switching time, transmit mode	$t_{ANT1/ANT2\_TX}$			940		ns
Antenna 1 to antenna 2 switching time, receive mode	$t_{ANT1/ANT2\_RX}$			800		ns

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 8. SKY65378-11 Electrical Specifications: Logic Characteristics (Note 1)
(TA = +25 °C as Measured on Evaluation Board [De-Embedded to Device], Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Voltage logic input:						
High	V_{IH}		1.6		Vcc (Note 2)	V
Low	V_{IL}		0		0.3	V

Note 1: Performance is guaranteed only under the conditions listed in this table.

Note 2: For ANT_SEL, the maximum voltage is 3.6 V.

Table 9. SKY65378-11 Mode Logic Truth Table (Note 1)

Mode	CPS (Pin 3)	CSD (Pin 1)	CTX (Pin 4)
Sleep (all off)	0	0	0
Receive low gain	0	1	0
Receive high gain	1	1	0
Transmit	X	1	1
Shutdown (Note 2)	0	0	1
Shutdown (Note 2)	1	0	0
Shutdown (Note 2)	1	0	1

Note 1: See Table 8 for logic voltage levels. "X" = don't care

Note 2: Expect approximately 15 μA through each control pin that has logic high. For true sleep mode, set CPS, CSD, and CTX low.

Table 10. SKY65378-11 Antenna Port Logic Truth Table

Mode	CPS (Pin 3)	CSD (Pin 1)	CTX (Pin 4)	ANT_SEL (Pin 7)
ANT1 port enabled	X	X	X	0
ANT2 port enabled	X	X	X	1

Note 1: See Table 8 for logic voltage levels. "X" = don't care

Evaluation Board Description

The SKY65378-11 Evaluation Board is used to test the performance of the SKY65378-11 FEM. An Evaluation Board schematic diagram is shown in Figure 3. Table 11 provides the Bill of Materials (BOM) list for Evaluation Board components. A photograph of the Evaluation Board is shown in Figure 4.

Evaluation Board Setup Procedure

1. Connect J1, J2, and J3 to 50 Ω instruments. If applicable, terminate all unused ports with 50 Ω.

2. Connect the supply ground to pin 1 of the J4 header.

3. Connect 3.6 V to pin 3 or 4 of the J4 header. Refer to Tables 9 and 10 for path selection logic.

Transmit Performance. The 860 MHz to 930 MHz (depending on the region) amplifier performance is monitored by applying an RF signal to J5 (TX_IN) and measuring the output power on J2 (ANT2) or J3 (ANT1).

If use of the TR port is desired, the RF signal first enters connector J1 (TR), exits connector J6 (TX_FLT) through an external PA and filter – or is directly shorted to connector J5 (TX_IN) – then passed to either J2 (ANT2) or J3 (ANT1).

Receive Performance. The 860 MHz to 930 MHz LNA performance is monitored by applying an RF signal to J2 (ANT2) or J3 (ANT1) and measuring the output signal on J1 (TR).

CAUTION: Care should be taken not to overdrive the device by applying too much RF on the input. A suitable starting input power is –20 dBm.

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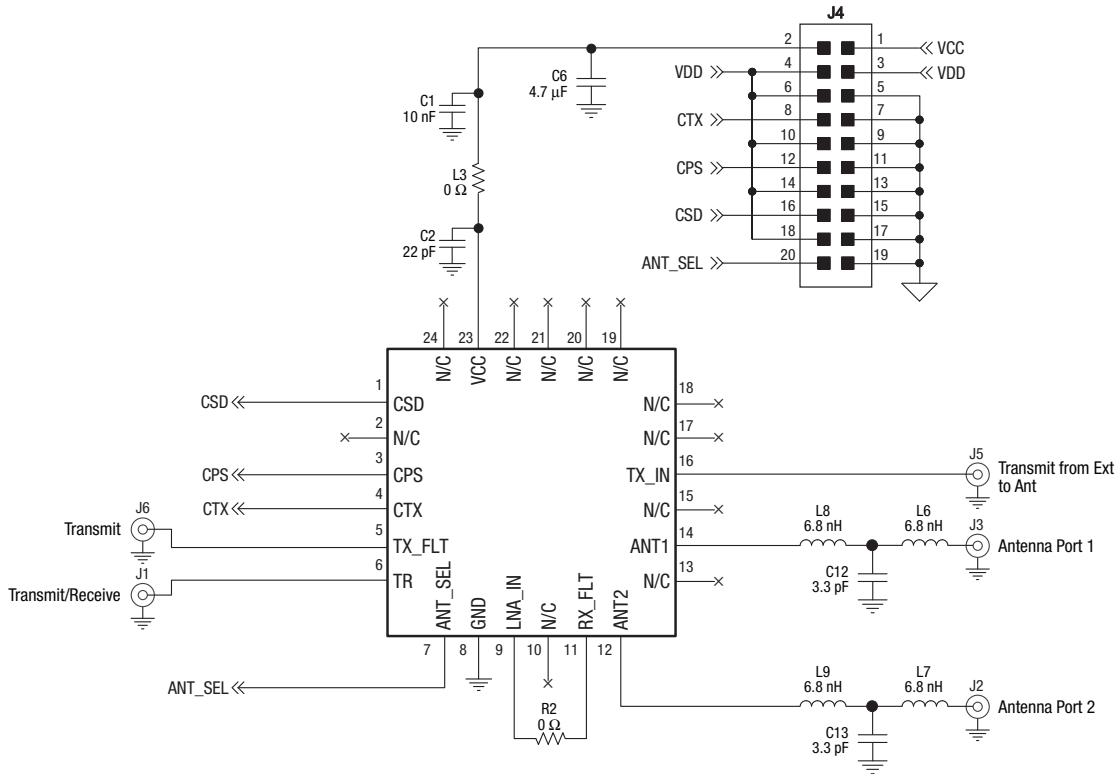
Note: Some component labels may be different from the corresponding component symbol shown here.
Component values, however, are accurate as of the date of this data sheet.

S3213

Figure 3. SKY65378-11 Evaluation Board Schematic Diagram

Table 11. SKY65378-11 Evaluation Board Bill of Materials

Component	Value	Size	Manufacturer	Mfr Part Number	Description
C1	10 nF	0402	Murata	GRM155R71E103KA01	Multilayer ceramic capacitor
C2	22 pF	0402	Murata	GRM1555C1H220JZ01	Multilayer ceramic capacitor
C6	4.7 µF	0603	Murata	GRM188R60J475KE19	Multilayer ceramic capacitor
C12, C13	3.3 pF	0402	Murata	GRM1555C1H3R3CZ01	Multilayer ceramic capacitor
J1, J2, J3, J5, J6	SMA	End launch	Johnson Components	142-0701-851	SMA end launch straight jack receptacle, tab contact
J4	10x2	100 mil	Samtec	TSW-110-07-G-D	100 mil header
L3	0 Ω	0402	Panasonic	ERJ2GE0R00	Thick film chip resistor
L6, L7, L8, L9	6.8 nH	0603	Murata	LQG18HN6N8S00D	High frequency multilayer inductor
R2	0 Ω	0402	Panasonic	ERJ2GEJ0R0	Thick film chip resistor
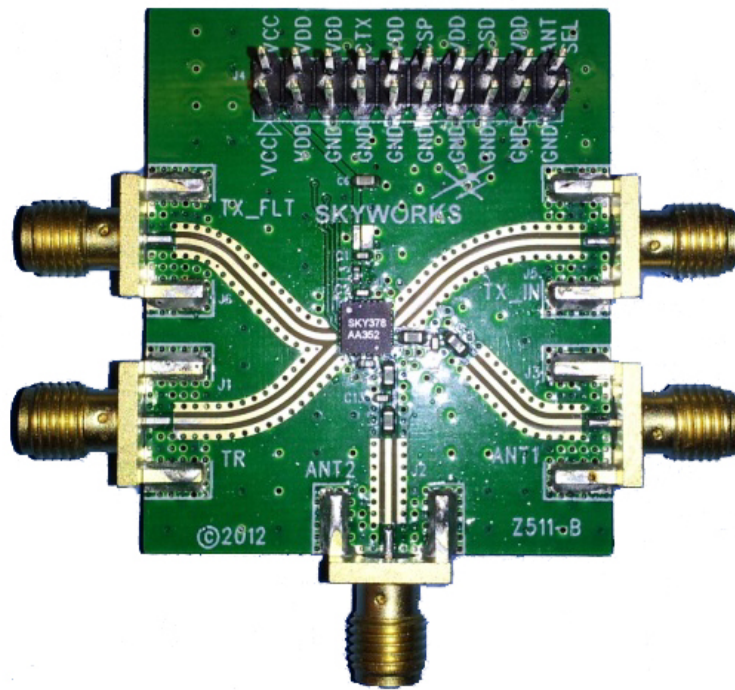
Figure 4. SKY65378-11 Evaluation Board

Package Dimensions

The PCB layout footprint for the SKY65378-11 is shown in Figure 5. Typical part markings are noted in Figure 6. Package dimensions for the 24-pin QFN are shown in Figure 7, and tape and reel dimensions are provided in Figure 8.

Package and Handling Information

Instructions on the shipping container label regarding exposure to moisture after the container seal is broken must be followed. Otherwise, problems related to moisture absorption may occur when the part is subjected to high temperature during solder assembly.

The SKY65378-11 is rated to Moisture Sensitivity Level 1 (MSL1) at 260 °C. It can be used for lead or lead-free soldering. For additional information, refer to the Skyworks Application Note, *Solder Reflow Information*, document number 200164.

Care must be taken when attaching this product, whether it is done manually or in a production solder reflow environment. Production quantities of this product are shipped in a standard tape and reel format.

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Board Metal

Via Pattern
(Note 1)

25X ⌀0.254

Solder Mask Pattern
(Note 2)

Component
Outline

Stencil Pattern
(Note 3)

64% solder coverage
on center pad

NOTES:
1. Via hole recommendations:
   0.025 mm Cu via wall plating (minimum),
   soldermask on the far side should tent
   or plug via holes.
2. Soldermask recommendations:
   Contact board fabricator for recommended
   soldermask offset and tolerance.
3. Stencil recommendations:
   0.125 mm stencil thickness, laser cut apertures,
   trapezoidal walls and rounded corners offer
   better paste release.

Dimension and tolerancing according to ASME Y14.5M-1994.
Unless specified, dimensions are symmetrical about center lines.
All dimensions are in millimeters.

S3214

Figure 5. SKY65378-11 PCB Layout Footprint

Skyworks
Part Number

SKY65378
EXXXXXXXXX
YYWW   CC

Lot Code

Date Code:
YY = Calendar Year
WW = Week
CC = Country Code

Y2169
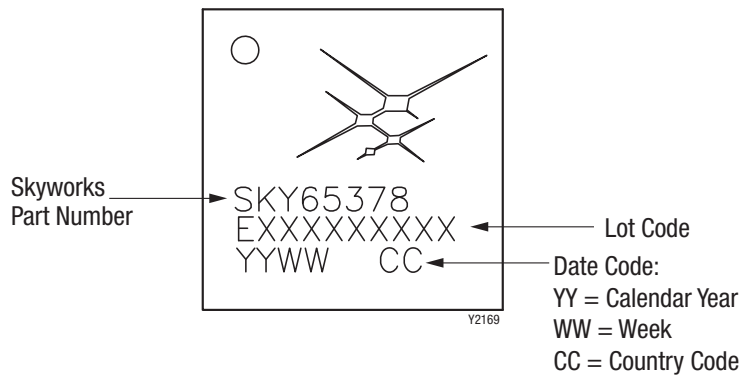
Figure 6. Typical Part Marking

Top View

Side View

Bottom View
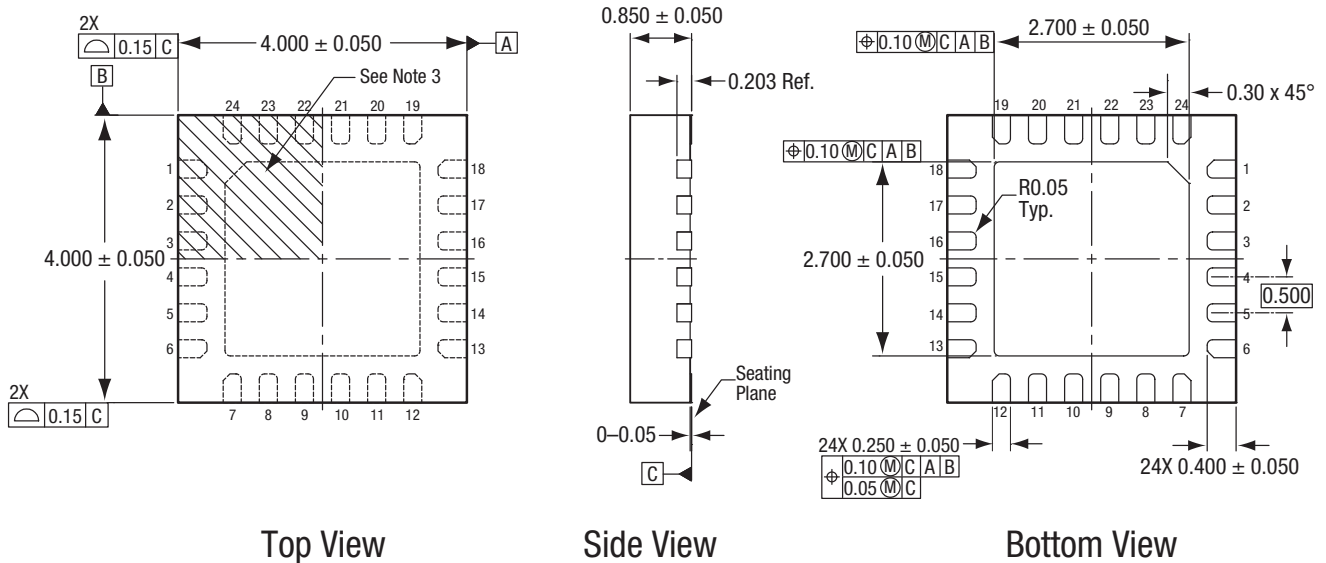
NOTES:
1. All measurements are in millimeters.
2. Dimensioning and tolerancing according to ASME Y14.5M-1994.
   Unless otherwise specified the following values apply:
   Decimal Tolerance: Angular Tolerance:
   X.X (1 place) ± 0.1 mm   ±1°
   X.XX (2 places) ± 0.05 mm
   X.XXX (3 places) ± 0.025 mm
3. Terminal #1 identification mark located within marked area.
4. Unless specified, dimensions are symmetrical about center lines.

S3210

Figure 7. SKY65378-11 24-Pin QFN Package Dimensions

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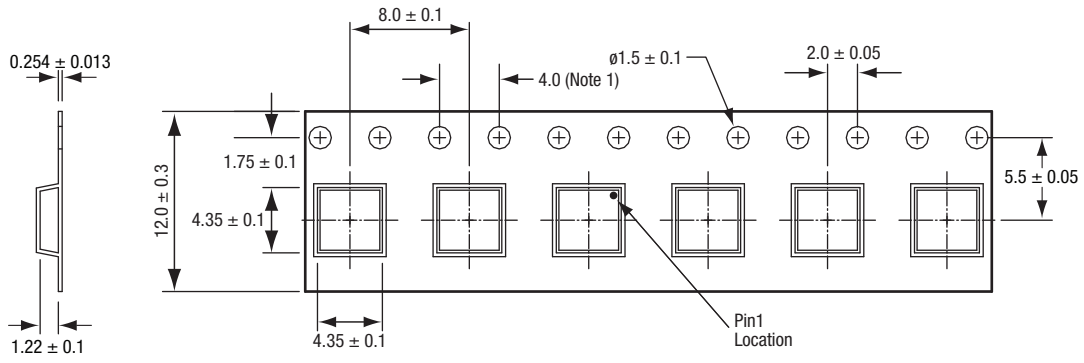
Notes:
1. 10 sprocket hole pitch cumulative tolerance ±0.2.
2. Camber in compliance with EIA-481.
3. All measurements are in millimeters.

S3211

Figure 8. SKY65378-11 Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Numbers
SKY65378-11: RF FEM	SKY65378-11	SKY65378-11-EK1