

## DATA SHEET

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

## Applications

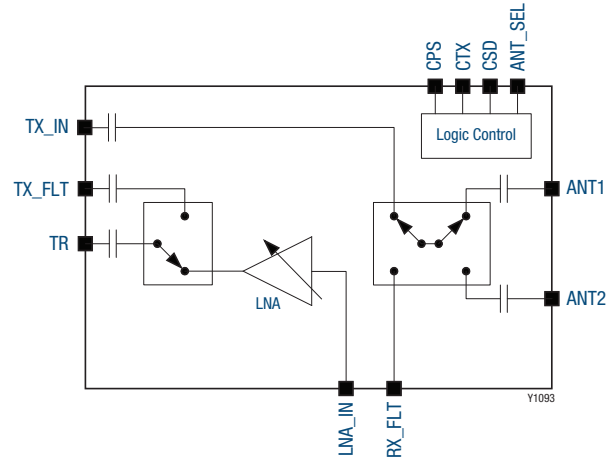
- Smart meters
- In-home appliances
- Smart thermostats

## 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  $\mu$ s
- 2.0 to 4.8 V supply operation
- Sleep mode current: <1  $\mu$ A
- 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**

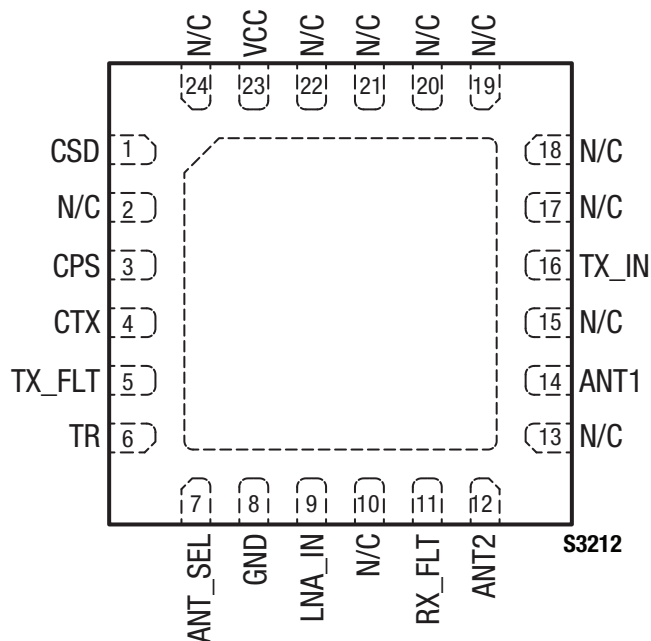
## Description

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  $\Omega$  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)                    | VCC        | −0.3    | 5.5     | V     |
| Transmit input power at TX_IN port        | PIN_TX_MAX |         | +32     | dBm   |
| Transmit input power at TR port (Note 2)  | PIN_TR_MAX |         | +20     | dBm   |
| Receive input power at ANT1 or ANT2 ports | PIN_RX_MAX |         | +10     | dBm   |
| Voltage Standing Wave Ratio               | VSWR       |         | 10:1    | —     |
| Operating temperature                     | TA         | −40     | +85     | °C    |
| Storage temperature                       | TSTG       | −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:** PIN\_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        | VCC    | 2.0     | 4.0     | 4.8     | V     |
| Operating temperature | TA     | −40     | +25     | +85     | °C    |

**Table 4. SKY65378-11 Electrical Specifications: DC Characteristics (Note 1)****(V<sub>CC</sub> = 4 V, T<sub>A</sub> = +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 | ICQ_TX          | Transmit mode          |     | 330     |      | μA    |
|                      | ICQ_RX_LOWGAIN  | Receive low gain mode  |     | 4       |      | mA    |
|                      | ICQ_RX_HIGHGAIN | Receive high gain mode |     | 8       |      | mA    |
| Sleep supply current | ICC_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<sub>CC</sub> = 4 V, T<sub>A</sub> = +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           | ton    | From 50% of CTX edge to 90% of final RF output power |     |         | 1   | μs    |
| Turn-off time (Note 2) | toff   | 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<sub>CC</sub> = 4 V, T<sub>A</sub> = +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  | RXLG   | @ 900 to 930 MHz and 860 to 870 MHz, CSD = logic “1,” CPS = CTX = logic “0” |     | 14      |     | dB    |
| Receive high gain mode | RXHG   | @ 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<sub>CC</sub> = 4 V, T<sub>A</sub> = +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          | NFLG      | @ 900 to 930 MHz and 860 to 870 MHz,<br>CSD = logic "1,"<br>CPS = CTX = logic "0" |     | 2.7     | 3.5 | dB    |
| Receive noise figure, high-gain mode         | NFHG      | @ 900 to 930 MHz and 860 to 870 MHz,<br>CPS = CSD = logic "1,"<br>CTX = logic "0" |     | 2.5     | 3   | dB    |
| 1 dB input compression point, low-gain mode  | IP1dBLG   | @ 900 to 930 MHz and 860 to 870 MHz,<br>CSD = logic "1,"<br>CPS = CTX = logic "0" |     | -10     |     | dBm   |
| 1 dB input compression point, high-gain mode | IP1dBHG   | @ 900 to 930 MHz and 860 to 870 MHz,<br>CPS = CSD = logic "1,"<br>CTX = logic "0" | -15 | -12     |     | dBm   |
| Antenna port return loss                     | S11ANT1,2 | @ 900 to 930 MHz and 860 to 870 MHz,<br>into 50 Ω, ANT1 and ANT2 ports            |     | -12     |     | dB    |
| TR port return loss in receive mode          | S22TR     | @ 900 to 930 MHz and 860 to 870 MHz,<br>into 50 Ω                                 |     | -12     |     | dB    |
| Turn-on time                                 | ton       | From 50% of CTX edge to 90% of final RF output power                              |     |         | 1   | μs    |
| Turn-off time                                | toff      | 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<sub>CC</sub> = 4 V, T<sub>A</sub> = +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                | ISOANTSW      |                |     | 30      |     | dB    |
| Isolation between TX_IN and TR ports                 | ISORXTX       |                |     | 20      |     | dB    |
| Insertion loss from TX_IN to ANT1                    | TX_ANT1       |                |     | 0.9     |     | dB    |
| Insertion loss from TX_IN to ANT2                    | TX_ANT2       |                |     | 0.9     |     | dB    |
| Insertion loss from ANT1 to RX_FILT                  | RX_ANT1       |                |     | 0.9     |     | dB    |
| Insertion loss from ANT2 to RX_FILT                  | RX_ANT2       |                |     | 0.9     |     | dB    |
| Antenna 1 to antenna 2 switching time, transmit mode | tANT1/ANT2_TX |                |     | 940     |     | ns    |
| Antenna 1 to antenna 2 switching time, receive mode  | tANT1/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)**  
**(T<sub>A</sub> = +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 <sub>IH</sub> |                | 1.6 |         | V <sub>CC</sub> (Note 2) | V     |
| Low                  | V <sub>IL</sub> |                | 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<br>(Pin 3) | CSD<br>(Pin 1) | CTX<br>(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<br>(Pin 3) | CSD<br>(Pin 1) | CTX<br>(Pin 4) | ANT_SEL<br>(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).

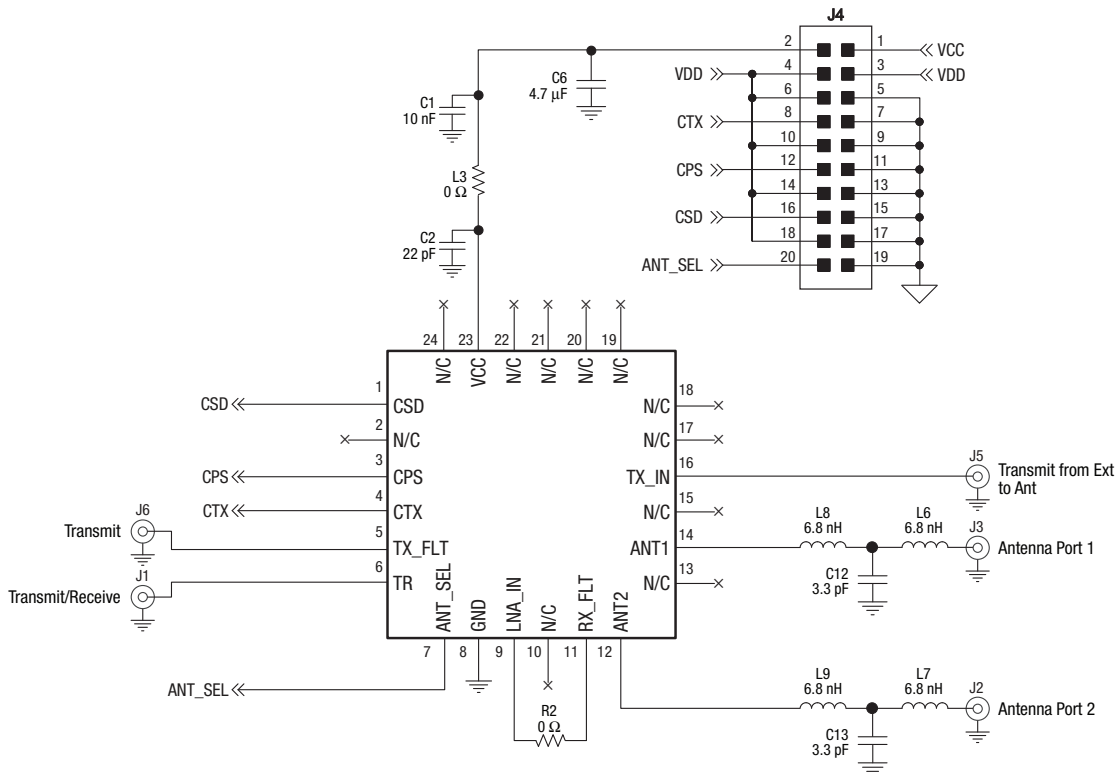
If use of the TR port is desired, the RF signal first enters connector J1 (TR), exits connector J6 (TX\_FLT) through an external PA and filter – or is directly shorted to connector J5 (TX\_IN) – then passed to either J2 (ANT2) or J3 (ANT1).

**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).

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**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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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 $\mu$ F | 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 $\Omega$  | 0402       | Panasonic          | ERJ2GE0R00        | Thick film chip resistor                             |
| L6, L7, L8, L9     | 6.8 nH      | 0603       | Murata             | LQG18HN6N8S00D    | High frequency multilayer inductor                   |
| R2                 | 0 $\Omega$  | 0402       | Panasonic          | ERJ2GEJ0R0        | Thick film chip resistor                             |

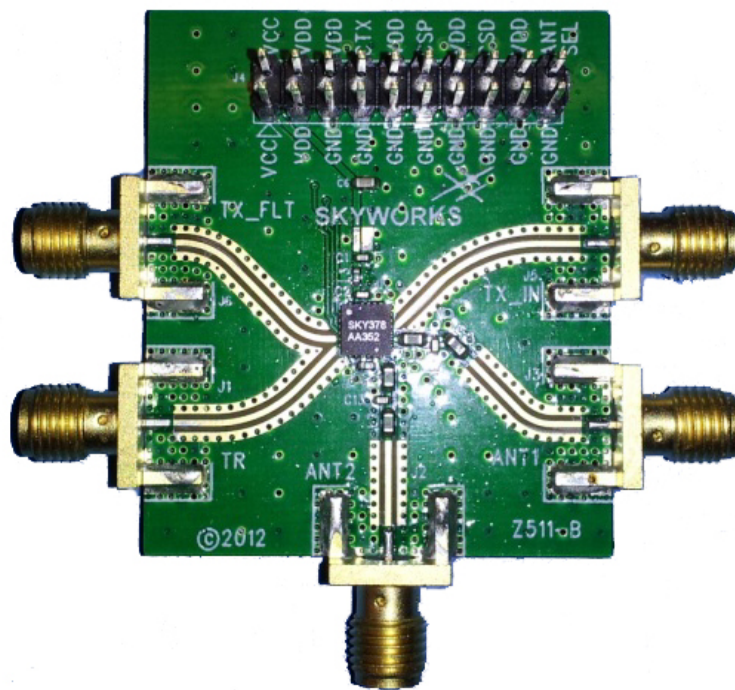


Figure 4. SKY65378-11 Evaluation Board

## Package Dimensions

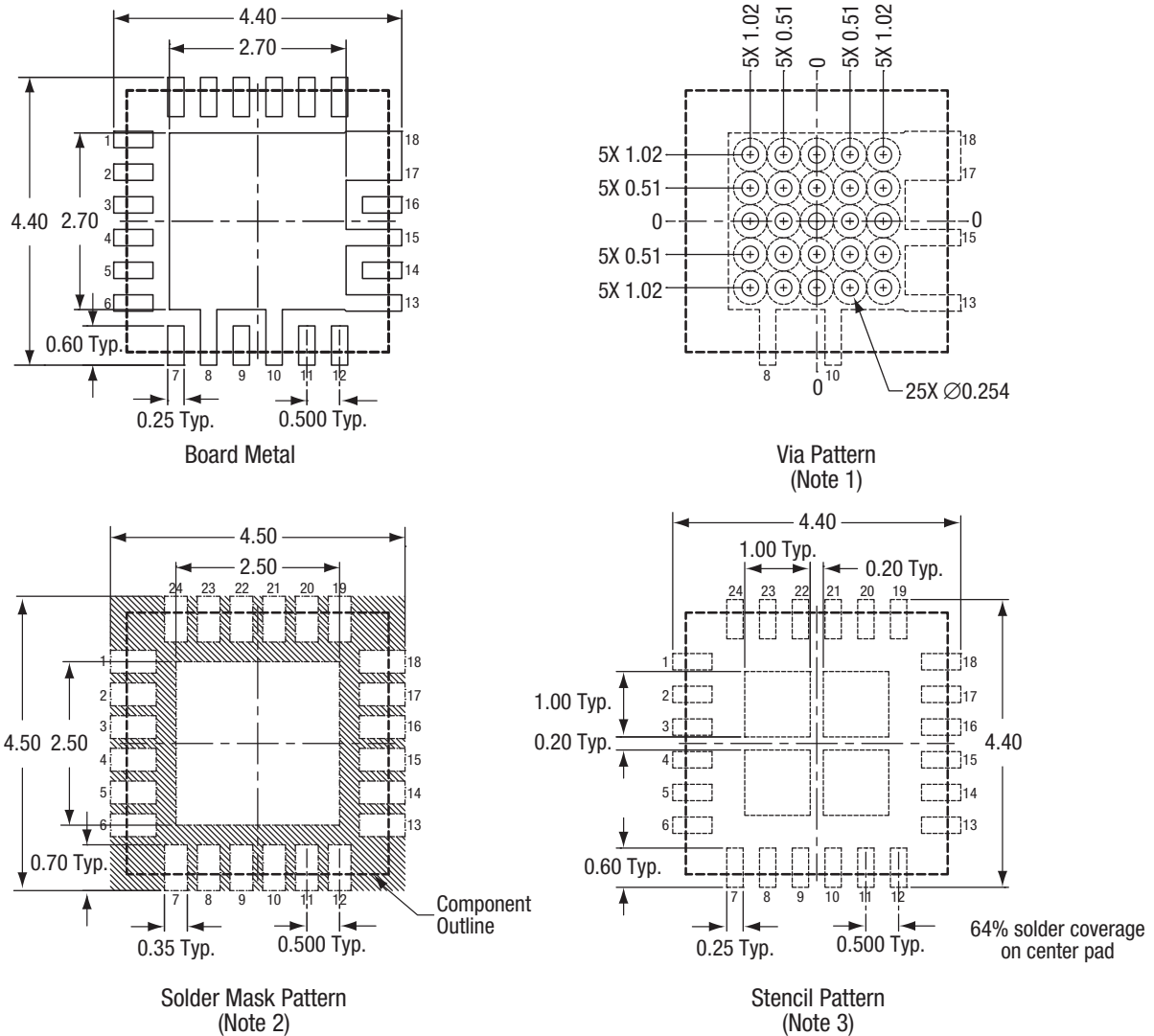
The PCB layout footprint for the SKY65378-11 is shown in Figure 5. Typical part markings are noted in Figure 6. Package dimensions for the 24-pin QFN are shown in Figure 7, and tape and reel dimensions are provided in Figure 8.

## 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.



**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**

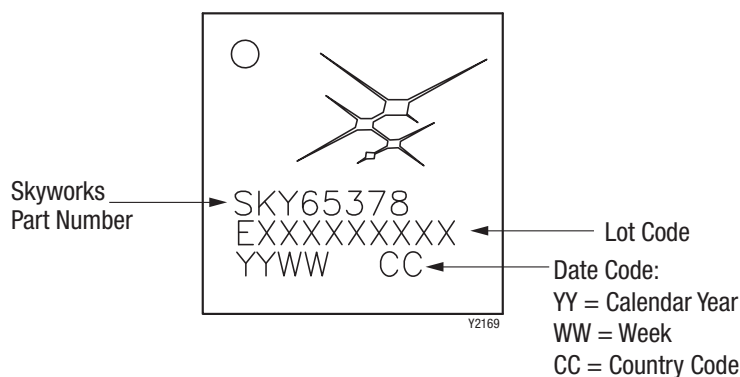
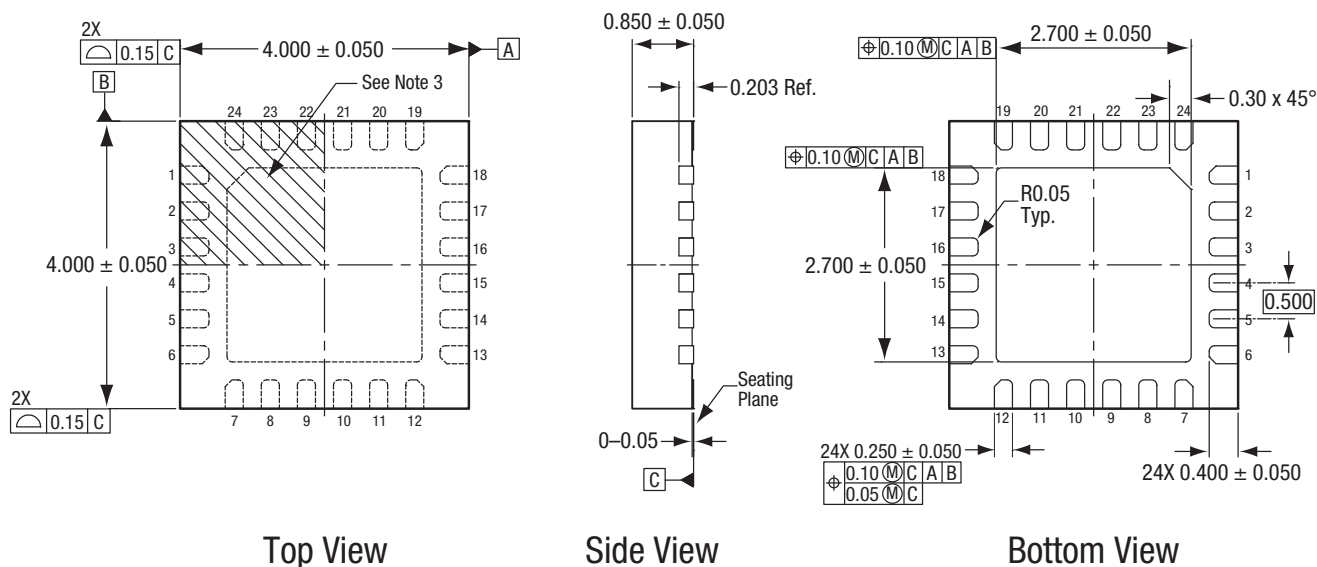


Figure 6. Typical Part Marking

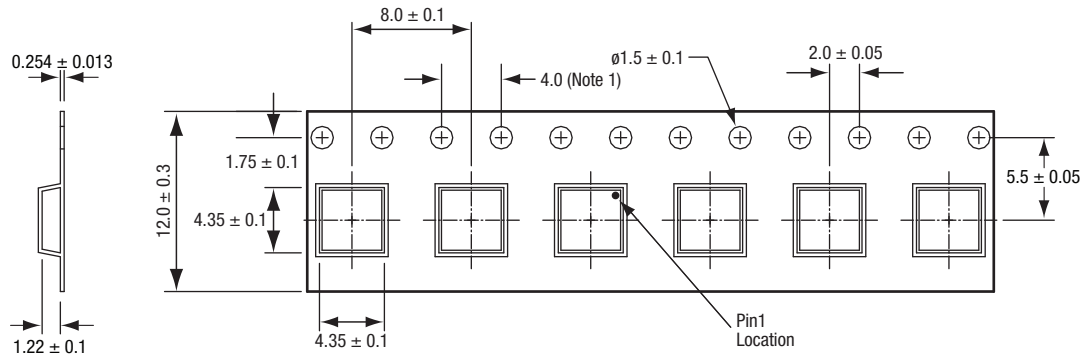


NOTES:

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



**Notes:**

1. 10 sprocket hole pitch cumulative tolerance  $\pm 0.2$ .
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               |

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