

DATA SHEET

SKY65366-21: 400 MHz Transmit/Receive Front-End Module

Applications

- Automated meter reading
- Advanced metering infrastructure
- ISM systems
- Range extender

Features

- Transmit output power: +30.2 dBm
- High-efficiency PA
- Analog power control
- Receive path NF < 2.2 dB
- PA bypass mode
- LNA low current mode with external resistor
- LNA bypass mode
- Integrated control logic
- Internal RF match and bias circuits
- All RF ports internally DC blocked
- Shutdown mode
- Small footprint, MCM (28-pin, 6 x 6 mm) package (MSL3, 260 °C per JEDEC J-STD-020)



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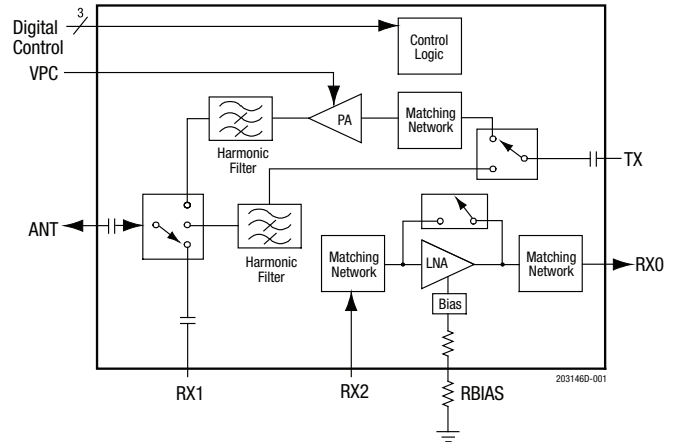


Figure 1. SKY65366-21 Block Diagram

Description

The SKY65366-21 is a high-performance, transmit/receive (T/R) range extender. The device provides a complete T/R chain with T/R switches.

The device transmit chain features +30.2 dBm output. The device receive chain features a low-noise amplifier (LNA) with a 1.8 dB noise figure (NF) and 21 dB gain. The cascaded NF and gain, taking into account the 0.4 dB insertion loss transmit/receive antenna switch, are 2.2 dB and 20.6 dB, respectively.

The module also has a shutdown mode, PA bypass mode, and LNA bypass mode to minimize power consumption.

The device is mounted in a 28-pin, 6 x 6 mm Multi-Chip Module (MCM) surface-mount technology (SMT) package, which allows for a highly manufacturable low-cost solution.

A block diagram of the SKY65366-21 is shown in Figure 1. The device package and pinout for the 28-pin MCM are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

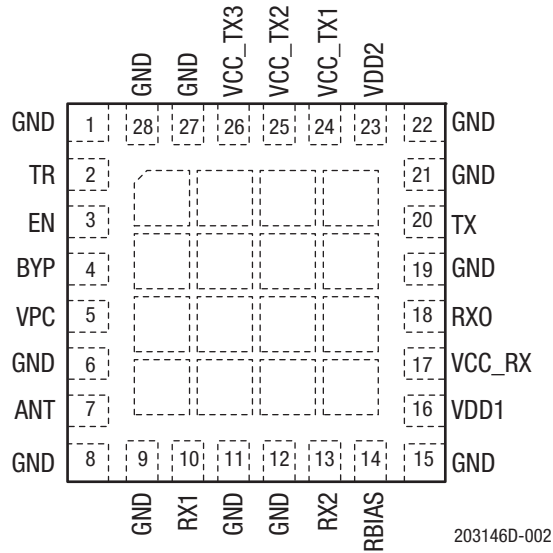


Figure 2. SKY65366-21 Pinout (Top View)

Table 1. SKY65366-21 Signal Descriptions

| Pin | Name | Description | Pin | Name | Description |
|-----|-------|--|-----|---------|---|
| 1 | GND | Ground | 15 | GND | Ground |
| 2 | TR | Digital control input: transmit/receive mode | 16 | VDD1 | 3.3 V power supply |
| 3 | EN | Digital control input: shutdown mode | 17 | VCC_RX | 3.3 V power supply |
| 4 | BYP | Digital control input: receive bypass mode | 18 | RX0 | Receive output |
| 5 | VPC | Transmit output power adjustment | 19 | GND | Ground |
| 6 | GND | Ground | 20 | TX | Transmit path input port. Internally matched to 50 Ω. |
| 7 | ANT | Antenna switch common port. Internally matched to 50 Ω. | 21 | GND | Ground |
| 8 | GND | Ground | 22 | GND | Ground |
| 9 | GND | Ground | 23 | VDD2 | 3.9 V power supply |
| 10 | RX1 | Receive arm of antenna switch. Internally matched to 50 Ω. | 24 | VCC_TX1 | 3.9 V power supply |
| 11 | GND | Ground | 25 | VCC_TX2 | 3.9 V power supply |
| 12 | GND | Ground | 26 | VCC_TX3 | 3.9 V power supply |
| 13 | RX2 | LNA and bypass switch output port. Internally matched to 50 Ω. | 27 | GND | Ground |
| 14 | RBIAS | LNA bias setting resistor | 28 | GND | Ground |

Technical Description

The SKY65366-21 consists of a complete T/R chain with T/R switches contained in the module. A single-pole, triple-throw (SP3T) switch selects between the receive, transmit, and transmit bypass paths. The module has a shutdown mode to minimize power consumption.

Three digital input pins (TR, EN, and BYP) are used to select between transmit, transmit bypass, receive, receive bypass, or shutdown mode.

Transmit Path

The transmit path contains a power amplifier (PA) optimized for saturated performance. The PA output is internally matched for optimum output power and efficiency into a 50 Ω load impedance. The PA output is passed through an harmonic filter before being fed through the SP3T switch. The PA input provides a good return loss into a 50 Ω source impedance.

Transmit output power is controlled by the VPC pin, which is normally set to 2.25 V DC voltage. The nominal DC input impedance into the VPC pin is 50 kΩ.

Receive Path

The receive path contains an LNA with bypass switch. The LNA impedance matching networks are internal to the module and have been optimized for a low NF while maintaining good return losses into a 50 Ω source and load impedance. The receive arm of the SP3T switch and the LNA input are connected to module pins to allow an external filter to be inserted into the receive path.

Operation Mode Control

The five SKY65366-21 operating modes are controlled by the three digital pins: TR, EN, and BYP (pins 2, 3, and 4, respectively). The control logic truth table is provided in Table 2.

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY65366-21 are provided in Table 3. Recommended operating conditions are specified in Table 4. Electrical specifications are provided in Tables 5, 6, and 7.

Table 2. SKY65366-21 Operating Modes Truth Table¹

| Operating Mode | Control Voltage | | | Internal States | | | | |
|-----------------------|-----------------|------------|-------------|-----------------|-----|-------------------|------------|------------------|
| | TR (Pin 2) | EN (Pin 3) | BYP (Pin 4) | PA | LNA | LNA Bypass Switch | T/R Switch | PA Bypass Switch |
| Transmit | 1 | 1 | 0 | On | Off | Open | PA | PA |
| Transmit bypass | 1 | 1 | 1 | Off | Off | Open | PA bypass | PA bypass |
| Receive | 0 | 1 | 0 | Off | On | Open | RX1 | Open |
| Receive Bypass | 0 | 1 | 1 | Off | Off | Through | RX1 | Open |
| Shutdown ² | X | 0 | X | Off | Off | Open | Open | Open |

¹ See Table 4 for logic 0 and 1 characteristics. “X” = don't care state, defined as a valid state of logic 1 or 0. Control signals must be a valid logic 1 or 0. Performance is not guaranteed if control inputs are floated.

² In the high state, TR, EN, and BYP have an input current of 33 μA due to an internal 100 kΩ pulldown resistance. For the lowest leakage current, the high state is not recommended for TR and BYP when the device is in shutdown mode (EN = 0).

Table 3. SKY65366-21 Absolute Maximum Ratings¹

| Parameter | Symbol | Minimum | Maximum | Units |
|--|------------------------|---------|------------------------|--------|
| LNA supply voltage | VCC_RX | -0.3 | +5.0 | V |
| LNA supply current | I _{CC_RX} | | 20 | mA |
| PA supply voltage | VCC_TX1/2/3 | -0.3 | +6.0 | V |
| Digital supply voltage | V _{DD1} | -0.5 | +5.5 | V |
| Digital supply voltage | V _{DD2} | -0.5 | +5.5 | V |
| Digital control voltage (TR, EN, BYP) | V _{CTL} | -0.5 | V _{DD1} + 0.3 | V |
| Transmit output power control voltage | VPC | -0.3 | +5.0 | V |
| Receive RF input power (RX2) | P _{IN_RX2} | | +5 | dBm |
| Receive RF input power (ANT) | P _{IN_ANT} | | +33 | dBm |
| Transmit RF input power | P _{IN_TX} | | +15 | dBm |
| Transmit RF input power, bypass mode | P _{IN_TX_BYP} | | +20 | dBm |
| Operating case temperature ² | T _C | -40 | +85 | °C |
| Storage temperature | T _{STG} | -40 | +150 | °C |
| Junction temperature | T _J | | +150 | °C |
| T/R port load VSWR in transmit mode | VSWR | | 10:1 | - |
| Electrostatic discharge: Charged Device Model (CDM), Class C3 Human Body Model (HBM), Class 1A | ESD | | 1000 250 | V V |

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 typical value as provided in Table 4.

² Nominal thermal resistance, junction-to-case, is 18 °C/W.

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 4. SKY65366-21 Recommended Operating Conditions

| Parameter | Symbol | Min | Typ | Max | Units |
|--|---------------------|--------------|-----------------------|--------------|--------|
| Transmit frequency range | f | 400 | | 500 | MHz |
| Receive frequency range | f | 400 | | 500 | MHz |
| LNA supply voltage | VCC_RX | 3.00 | 3.30 | 3.45 | V |
| Digital supply voltage | VDD1 VDD2 | 3.00 3.70 | VCC_RX VCC_TX1/2/3 | 3.45 4.00 | V V |
| PA supply voltage | VCC_TX1/2/3 | 3.70 | 3.90 | 4.00 | V |
| Digital input voltage, logic 0 (TR, EN, BYP) | V _{CTL} | 0 | | 0.7 | V |
| Digital input voltage, logic 1 (TR, EN, BYP) | V _{CTL} | 1.6 | | VDD1 | V |
| Transmit output power control voltage | VPC | 0 | 2.25 | 2.50 | V |
| Receive RF input power (RX2) | P _{IN_RX2} | | | -15 | dBm |
| Transmit RF input power (TX) | P _{IN_TX} | | +10 | +13 | dBm |
| Transmit duty cycle | | | | 50 | % |

Table 5. SKY65366-21 DC Electrical Specifications¹
(VCC_RX = VDD1 = 3.3 V, VCC_TX1/2/3 = VDD2 = 3.9 V, Tc = 25 °C, RBIAS = 0 Ω, VPC = 2.25 V, No RF Input Power, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|--|----------------------|--|-----|-------|------|-------|
| Quiescent current, receive mode ² | I _{Q_RX} | | | 12 | 20.0 | mA |
| Quiescent current, receive bypass mode ² | I _{Q_BYP} | | | 50 | 76 | μA |
| VDD1 quiescent current, transmit mode | I _{Q_VDD1} | VPC = 2.25 V | | 22 | 25 | mA |
| VCC_TX1/2/3 quiescent current, transmit mode | I _{Q_TX} | T _C = 25 °C, VCC_TX1/2/3 = 3.9 V, VPC = 2.25 V | | 26 | | mA |
| VCC_TX1/2/3 operating current, transmit mode | I _{OP_TX} | P _{IN} = +10 dBm, VPC = 2.25 V, f = 418 MHz, VCC_TX1/2/3 = 3.9 V | | 780 | 880 | mA |
| VDD1 quiescent current, transmit bypass mode ³ | I _{DD1} | | | 25 | | μA |
| VCC_TX1/2/3 quiescent current, transmit bypass mode ³ | I _{Q_TXB} | | | 0.5 | | μA |
| VCC_RX quiescent current, shutdown mode ³ | I _{Q_SD_RX} | | | 0.025 | | μA |
| VCC_TX1/2/3 quiescent current, shutdown mode ³ | I _{Q_SD_TX} | | | 0.3 | | μA |
| Digital input current, logic 1 ³ | I _H | | | 33 | | μA |
| Digital input current, logic 0 ³ | I _L | | | 0 | | μA |

¹ Performance is guaranteed only under the conditions listed in this table. Modes are established as indicated in Table 2. Minimum and maximum values are verified in production by measurement at 25 °C under typical operating conditions.

² Total current drawn from VCC_RX and VDD1 supplies.

³ Not production tested.

Table 6. SKY65366-21 Electrical Specifications: Receive and Receive Bypass Mode¹ (1 of 2)
(VCC_RX = VDD1 = 3.3 V, VCC_TX1/2/3 = VDD2 = 3.9 V, Tc = 25 °C, f = 412 to 424 MHz, 50 Ω Source and Load Impedance, CW Input, RBIAS = 0 Ω, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|--------------------|--|-----|------|-----|-------|
| Receive Mode: RX2 to Receive Output Path | | | | | | |
| Small signal gain | G | | 19 | 21 | | dB |
| Noise figure | NF | T _C = 25 °C VCC_RX = 3.3 V | | 1.8 | 2.1 | dB |
| Noise figure variation over temperature | NF _{TEMP} | | | ±0.3 | | dB |
| 1 dB input compression point | IP1dB | 1 dB gain compression | -19 | -17 | | dBm |
| Third order input intercept point | IIP3 | P _{IN} = -30 dBm/tone, 200 kHz spacing | -11 | -8.5 | | dBm |
| Input return loss | S ₁₁ | | | 12 | | dB |
| Output return loss | S ₂₂ | | | 10 | | dB |
| Reverse isolation | S ₁₂ | | | 27 | | dB |
| Non-harmonic spurious ² | P _{SPUR} | VSWR 10:1, all phases, unused port open-circuit | | | -50 | dBm |
| Transition time ² | t | | | 0.5 | | μs |

Table 6. SKY65366-21 Electrical Specifications: Receive and Receive Bypass Mode¹ (2 of 2)
(VCC_RX = VDD1 = 3.3 V, VCC_TX1/2/3 = VDD2 = 3.9 V, Tc = 25 °C, f = 412 to 424 MHz, 50 Ω Source and Load Impedance, CW Input, RBIAS = 0 Ω, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|----------------------|--|-----|-----|-----|-------|
| Receive Bypass Mode: RX2 to Receive Output Path | | | | | | |
| Insertion loss | IL | | | 2 | 3 | dB |
| 1 dB input compression point | IP1dB | 1 dB gain compression | 12 | 14 | | dBm |
| Third order input intercept point | IIP3 | P _{IN} = 0 dBm/tone, 200 kHz spacing | +28 | +34 | | dBm |
| Input return loss | S ₁₁ | | 10 | 16 | | dB |
| Output return loss | S ₂₂ | | 10 | 28 | | dB |
| Transition time ² | t | | | 0.5 | | μs |
| Receive and Receive Bypass Mode: ANT to RX1 Path | | | | | | |
| Insertion loss | IL | | | 0.4 | 0.9 | dB |
| 1 dB input compression point ² | IP1dB _{ANT} | 1 dB gain compression | +24 | | | dBm |
| Third order input intercept point ² | IIP3 _{ANT} | P _{IN} = 0 dBm/tone, 200 kHz spacing | | +35 | | dBm |
| Input return loss | S ₁₁ | | 10 | 18 | | dB |
| Output return loss | S ₂₂ | | 10 | 20 | | dB |
| Transition time ² | t | | | 0.5 | | μs |

¹ Performance is guaranteed only under the conditions listed in this table. Modes are established as indicated in Table 2. Minimum and maximum values are verified in production by measurement at 25 °C and f = 418 MHz under typical operating conditions.

² Not production tested.

Table 7. SKY65366-21 Electrical Specifications: Transmit Mode¹
(VCC_RX = VDD1 = 3.3 V, VCC_TX1/2/3 = VDD2 = 3.9 V, P_{IN} = +10 dBm, T_c = 25 °C, f = 412 to 424 MHz, VPC = 2.25 V, 50 Ω Source and Load Impedance, CW Input, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|-------------------|--|-------|-------|-------|-------|
| <i>TX to ANT Path</i> | | | | | | |
| Output power ² | P _{OUT} | T _c = +25 °C VCC_TX1/2/3 = 3.9 V | +29.5 | +30.2 | | dBm |
| | | T _c = -30 to +60 °C VCC_TX1/2/3 = 3.7 to 4 V | +29.2 | | +32.0 | dBm |
| Output power control ³ | P _{CTL} | VPC = 0 V to 2.25 V | 40 | 62 | | dB |
| Power-added efficiency ⁵ | PAE | | | 35 | | % |
| 2 nd to 10 th harmonic ⁴ | 2fo to 10fo | Without external filter | | -70 | -50 | dBc |
| | | With external filter ⁵ | | -86 | -78 | dBc |
| Input return loss | S ₁₁ | | 10 | 16 | | dB |
| Output return loss | S ₂₂ | | | 13 | | dB |
| Non-harmonic spurious ⁵ | P _{SPUR} | VSWR 6:1, all phases | | | -50 | dBm |
| Power on time ⁵ | T | | | 1.0 | | μs |
| <i>TX to ANT Path, Transmit Bypass Mode</i> | | | | | | |
| Insertion loss | IL | | | 2.0 | 2.5 | dB |
| 1 dB input compression point ⁵ | IP1 dB | | +24 | | | dBm |
| Third order input intercept point ⁵ | IIP3 | P _{IN} = 0 dBm | | +38 | | dBm |
| 2 nd harmonic | 2fo | P _{IN} = +12 dBm | | -80 | -40 | dBc |
| 3 rd harmonic | 3fo | P _{IN} = +12 dBm | | -80 | -40 | dBc |
| Transmit bypass path rejection | R _{2fo} | @ 2fo | 22 | 27 | | dB |
| | R _{3fo} | @ 3fo | 30 | 49 | | dB |
| Input return loss | S ₁₁ | | 10 | 24 | | dB |
| Output return loss | S ₂₂ | | 10 | 24 | | dB |
| Transition time ⁵ | T | | | 0.5 | | μs |
| <i>ANT to RX1 Path</i> | | | | | | |
| Isolation | S ₂₁ | | 18 | 33 | | dB |
| <i>ANT to RX1 Path, Transmit Bypass Mode</i> | | | | | | |
| Isolation | S ₂₁ | | 18 | 33 | | dB |

¹ Performance is guaranteed only under the conditions listed in this table. Modes are established as indicated in Table 2. Minimum and maximum values are verified in production by measurement at 25 °C and f = 418 MHz under typical operating conditions.

² Output power rated at the antenna output. PA output power is actually 1.5 dB higher.

³ Output power control is the difference between the output power at VPC = 2.25 V and VPC = 0 V.

⁴ Only the 2nd to 5th harmonics are production tested. The 6th to 10th harmonics are characterized only. Harmonics can be reduced with external filtering, as shown in Figure 3.

⁵ Not production tested.

Evaluation Board Description

The SKY65366-21 Evaluation Board is used to test the performance of the SKY65366-21 Transmit/Receive Range Extender. A typical application schematic diagram is provided in Figure 3. A Low-Pass Filter (LPF) can be incorporated on the ANT port to provide additional rejection of PA output harmonic levels and/or limit unwanted signals from entering the receive path. A three-section LPF is indicated for this function in Figure 3.

An Evaluation Board schematic diagram is provided in Figure 4. Typical part marking appears in Figure 5. An assembly drawing for the Evaluation Board is shown in Figure 6, and the layer detail is provided in Figure 7.

Package Dimensions

The PCB layout footprint for the SKY65366-21 is provided in Figure 8. Package dimensions are shown in Figure 9, and tape and reel dimensions are provided in Figure 10.

Package and Handling Information

Since the device package is sensitive to moisture absorption, it is baked and vacuum packed before shipping. 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 SKY65366-21 is rated to Moisture Sensitivity Level 3 (MSL3) at 260 °C. It can be used for lead or lead-free soldering. For additional information, refer to Skyworks Application Note, *PCB Design and SMT Assembly/Rework Guidelines for MCM-L Packages*, document number 101752.

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.

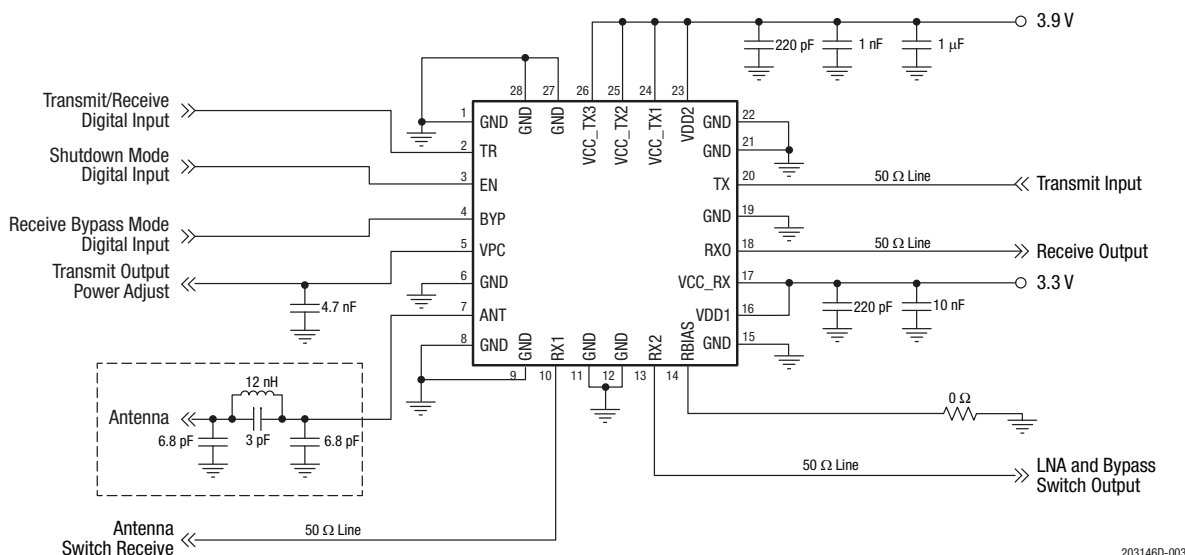
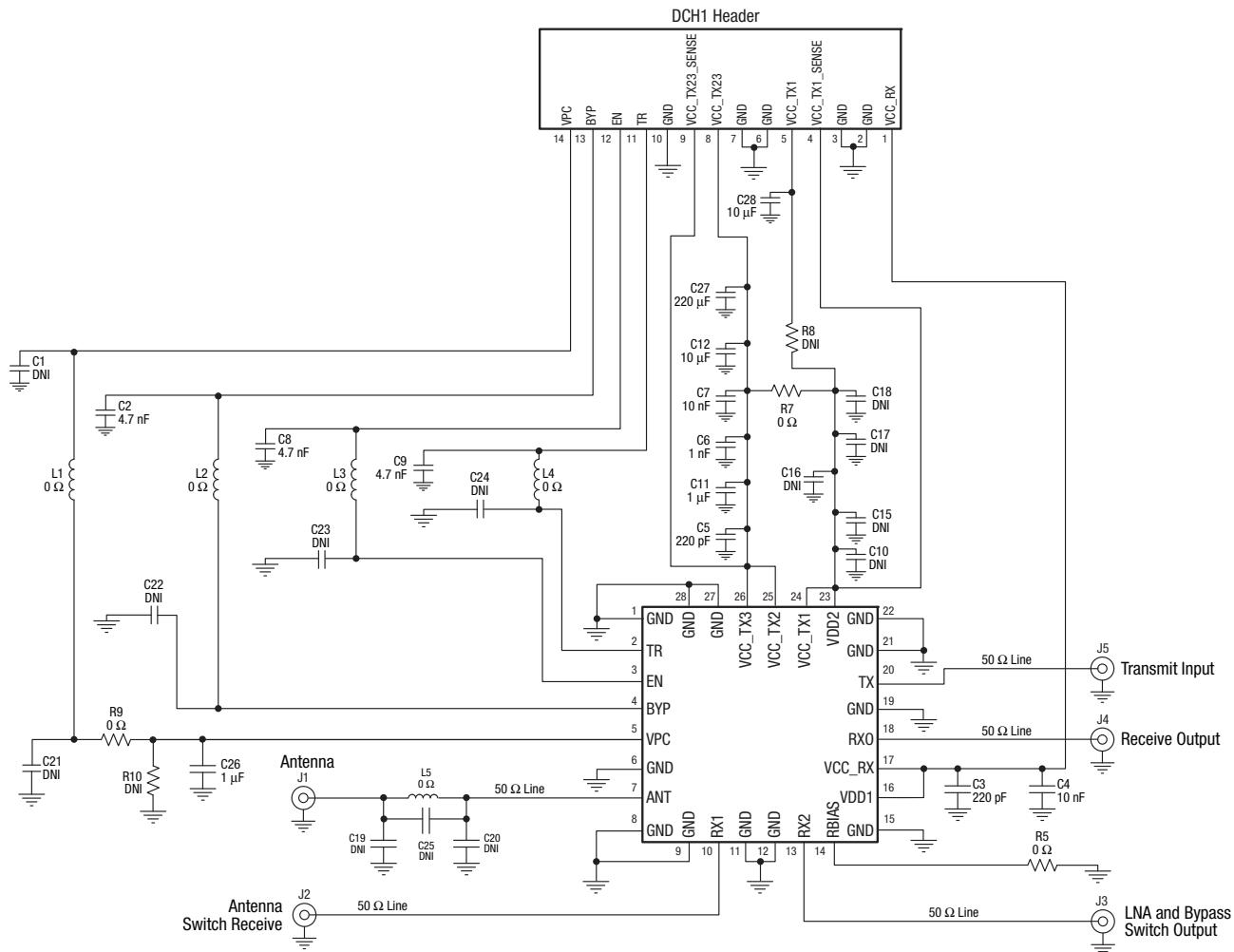


Figure 3. SKY65366-21 Typical Application Schematic



Notes:

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.

PCB Recommendations:

- Metal Layer 1 = RF traces + control lines. Core thickness between top RF layer and ground plane is critical.
- Metal Layer 2 = Solid ground plane. No traces routing.
- Metal Layer 3 and 4 = Control lines + VCC traces (no VCC plane).
- Four copper on each layer connected to the ground plane. Use VCC traces in a star distribution pattern. Always use 4 layers.

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Figure 4. SKY65366-21 Evaluation Board Schematic

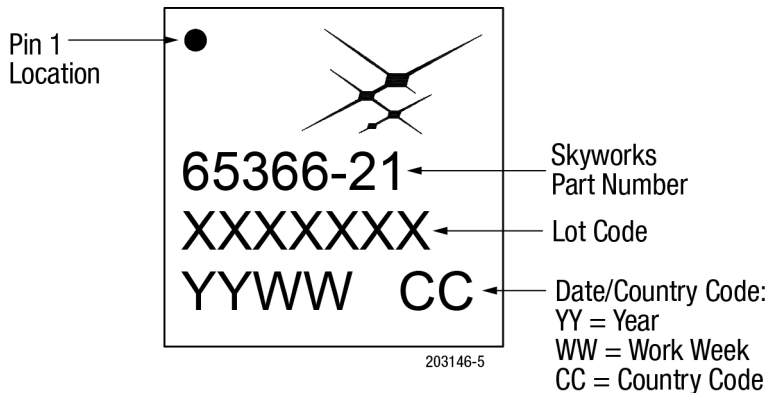


Figure 5. SKY65366-21 Typical Part Marking (Top View)

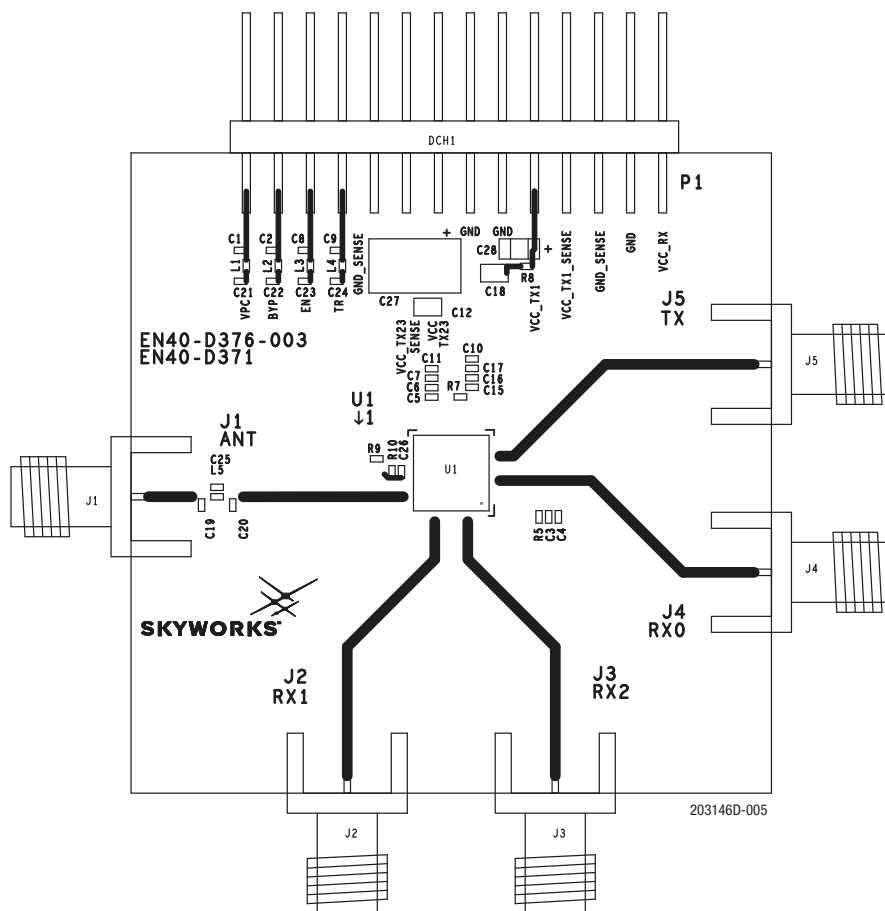
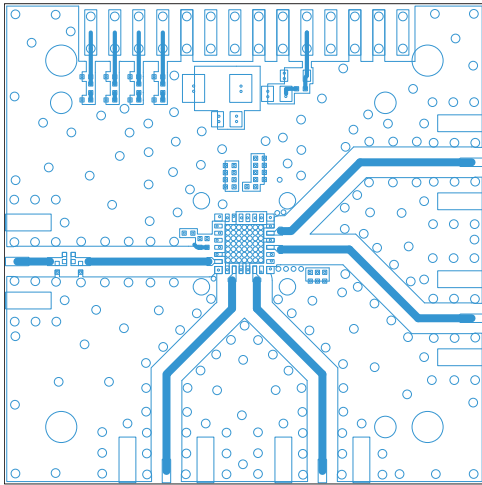
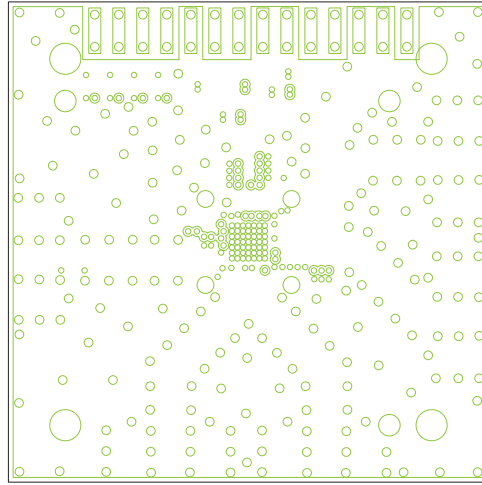


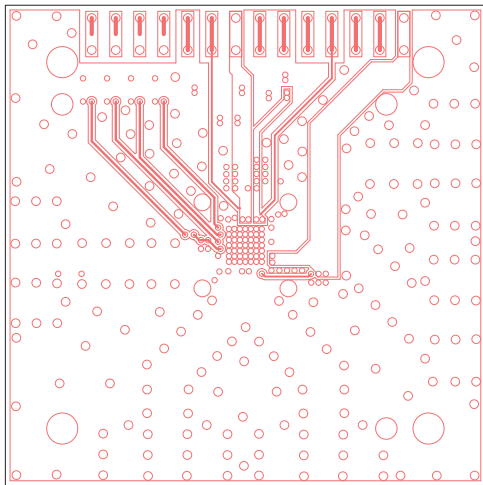
Figure 6. SKY65366-21 Evaluation Board Assembly Diagram



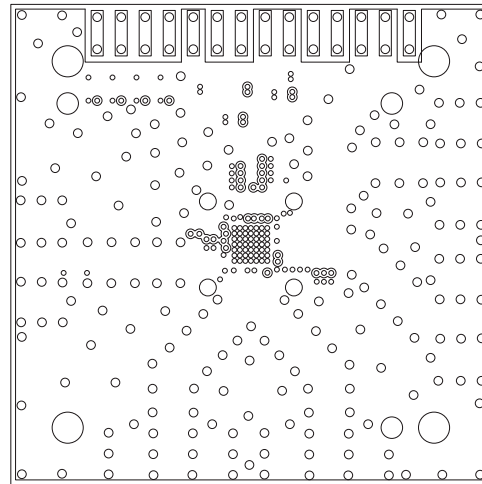
Layer 1: Top – Metal



Layer 2: Ground



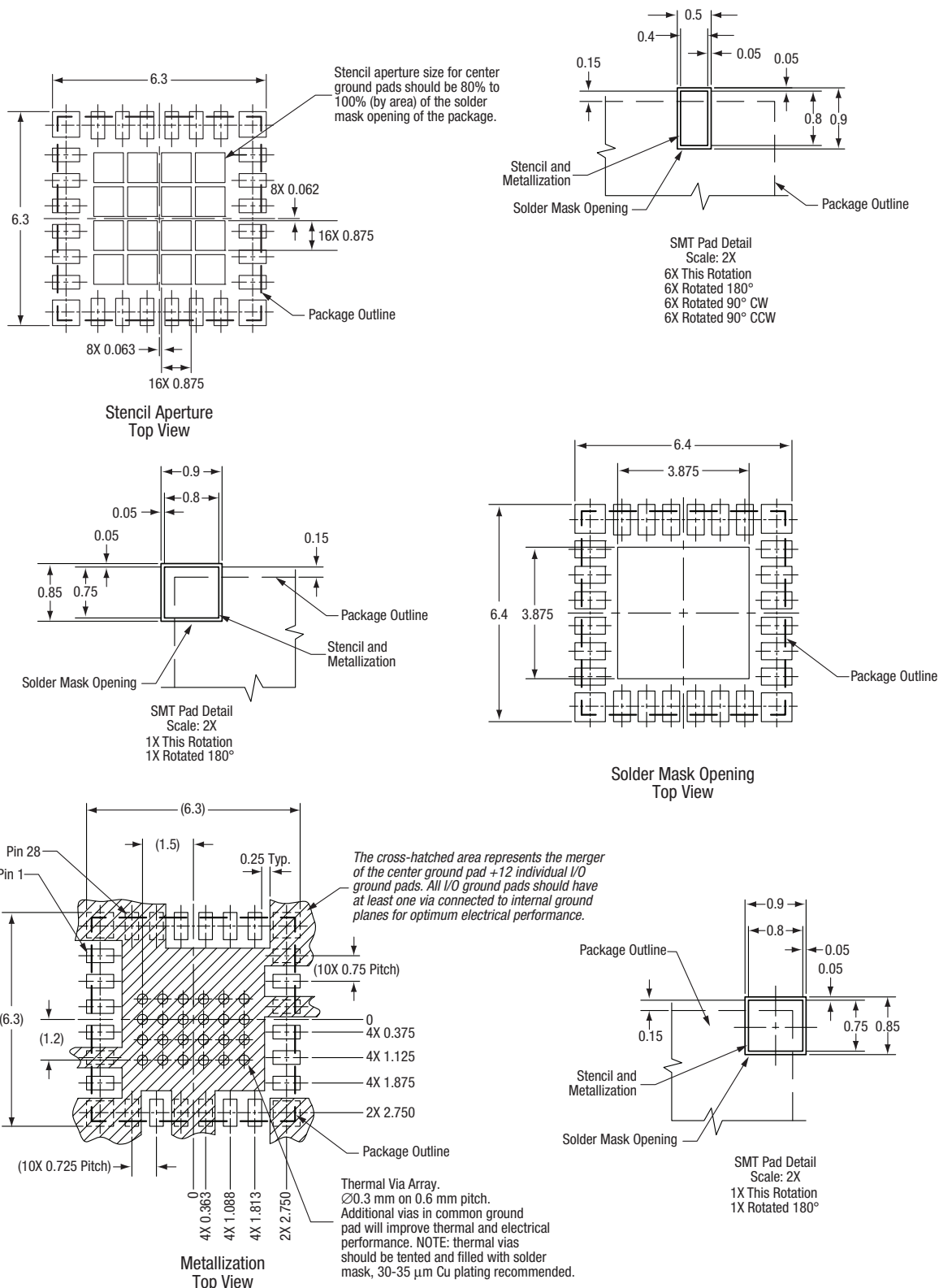
Layer 3: Ground



Layer 4: Solid Ground Plane

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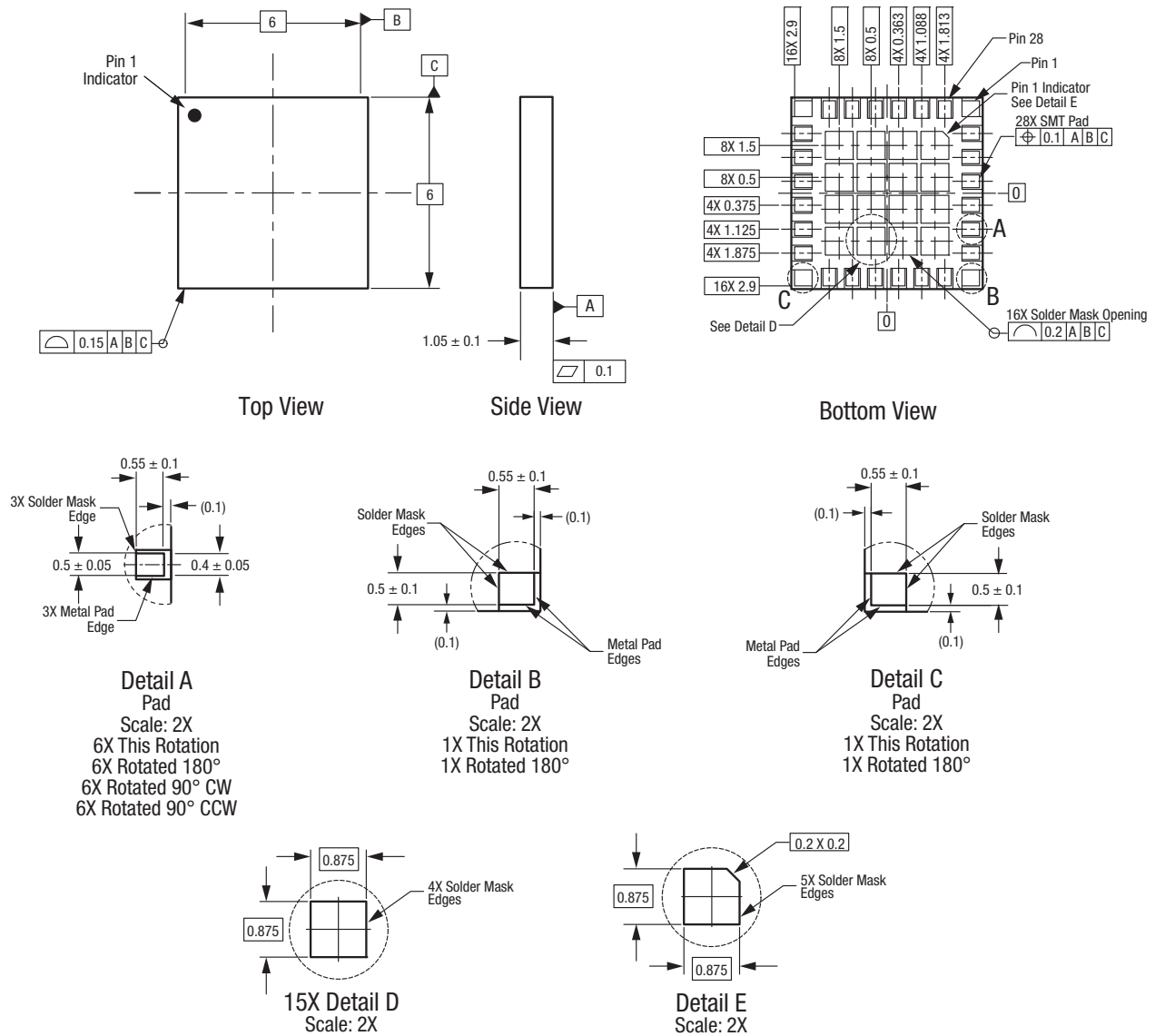
Figure 7. SKY65366-21 Evaluation Board Layer Detail



All measurements are in millimeters

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Figure 8. SKY65366-21 PCB Footprint Drawing

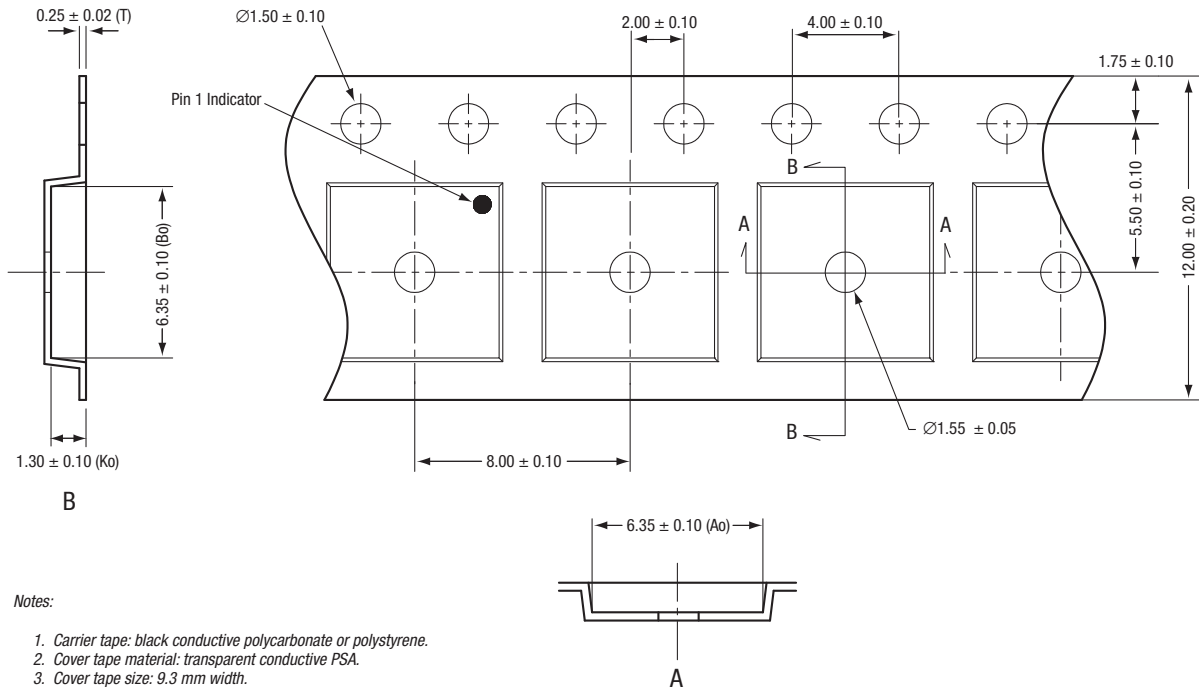


All measurements are in millimeters.
Dimensions and tolerances according to ASME Y14.5M-1994.

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Figure 9. SKY65366-21 Package Dimensions

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203146D-009

Figure 10. SKY65366-21 Tape and Reel Dimensions