DATA SHEET

# SKY65040-360LF: 1.7-2.4 GHz Low Noise Amplifier

## Applications

- Wireless infrastructure: GSM, CDMA, WCDMA, and TD-SCDMA
- Ultra low-noise applications

## Features

- Ultra-low Noise Figure = 0.65 dB @ 1.95 GHz
- Excellent input and output return loss
- Adjustable gain = 15 to 25 dB @ 1.95 GHz
- High output OIP3 = +34.5 dBm @ 65 mA
- OP1dB = +18 dBm @ 1.95 GHz
- Single, positive DC supply voltage
- Adjustable supply current, 30 to 100 mA
- Small, QFN (8-pin, 2 x 2 mm) Pb-free package (MSL1, 260 °C per JEDEC J-STD-020)

NEW Skyworks Green™ products are RoHS (Restriction of Hazardous Substances)-compliant, conform to the EIA/EICTA/JEITA Joint Industry Guide (JIG) Level A guidelines, are halogen free according to IEC-61249-2-21, and contain <1,000 ppm antimony trioxide in polymeric materials.

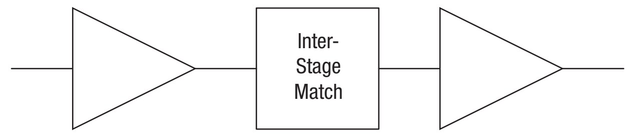


**Figure 1. SKY65040-360LF Block Diagram**

## Description

The SKY65040-360LF is a high performance, two-stage ultra low-noise amplifier. The device is fabricated from Skyworks advanced pHEMT process and is provided in a 2 x 2 mm, 8-pin Quad Flat No-Lead (QFN) package.

The device features excellent input and output return loss, and an integrated interstage matching network. The amplifier's ultra-low Noise Figure (NF), high gain, and excellent 3rd Order Intercept point (IP3) allow it to be used in various receiver and transmitter applications.

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.

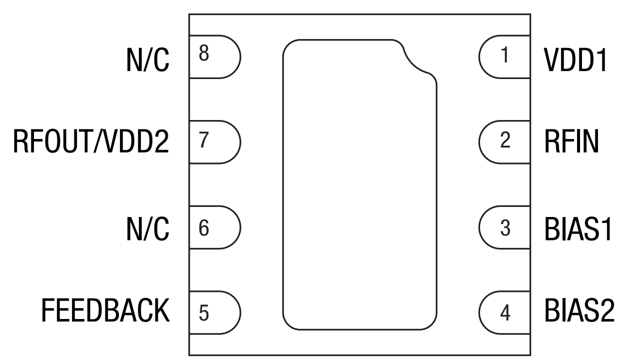


**Figure 2. SKY65040-360LF Pinout – 8-Pin QFN (Bottom View)**

**Table 1. SKY65040-360LF Signal Descriptions**

| Pin # | Name | Description | Pin # | Name | Description |
|---|---|---|---|---|---|
| 1 | VDD1 | 1st stage DC power supply | 5 | FEEDBACK | Connect to RFOUT to reduce gain of 2nd stage transistor |
| 2 | RFIN | RF input | 6 | N/C | No connection |
| 3 | BIAS1 | Source lead for 1st stage transistor | 7 | RFOUT/VDD2 | RF output. Requires a DC bias using an RF choke inductor. |
| 4 | BIAS2 | Source lead for 2nd stage transistor | 8 | N/C | No connection |

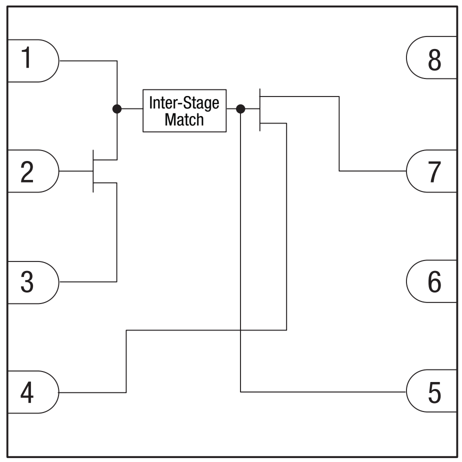


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**Figure 3. SKY65040-360LF On-Die Functional Diagram**

## Functional Description

The SKY65040-360LF is a two stage, low noise amplifier with an integrated interstage matching network. The device has a tested low NF of 0.60 dB and gain of 25 dB. The device allows designers to adjust current and gain without degrading the NF.

The external matching network largely dictates the RF performance of the device. The matching network is required for operation and special care should be taken when designing a circuit board layout for the SKY65040-360LF. There are four separate groups of external components: input, output, biasing, and feedback. Figure 3 illustrates the circuit-on-die inside the 2 x 2 mm QFN package.

### Biasing

To properly bias a depletion mode pHEMT, both the gate and drain of the device must be biased properly. At $V_{GS} = 0$ V and $V_{DS} > 2$ V, the amplifier stage is in its saturated state and draws the maximum amount of current, $I_{DSS}$. A $V_{DS}$ of 5 V is recommended to ensure proper performance.

To eliminate the need for a negative DC supply, self-biasing should be used when a resistor is placed between one of the source leads and ground. A bypass capacitor should be placed in parallel to this resistor to provide an RF ground and to ensure performance remains unchanged at the operating frequency.

When current flows from drain to source and through the resistor, the source voltage becomes biased above DC ground. The gate pin of the device should be left unbiased at 0 V, which creates the desired negative $V_{GS}$ value. This simplifies the design by eliminating the need for a second DC supply. Values for resistor components R1 and R2 can be changed to easily increase or decrease the bias current to a desired level.

The first stage is biased at 20 percent of $I_{DSS}$ to achieve the best NF performance. The gain and current of the 2nd stage amplifier can be adjusted without degrading the overall NF. More current in the 2nd stage yields better IP3 performance.

Components L3 and L4 are the RF bias choke inductors (refer to Figure 18). These are required to block RF power and pass $V_{DD}$ to the drain of each amplifier stage. Components C6, C7, C9, and C10 are RF bypass capacitors. R3 and R5 reduce the voltage presented at the drain of each stage of the device. The resistor values are optimized for 3rd Order Output Intercept Point (OIP3) and P1dB performance.

### Source Inductance

The effect of source inductance varies with frequency. Too little source inductance increases gain and high frequency stability, but at the cost of more in-band instability. Too much source inductance decreases high frequency stability and gain, but improves in-band instability. It is very important to find the optimum tuning of source inductance that balances all variables.

The board trace present on the first stage transistor (pin 3) is about 60 mils long and 6 mils wide. The electrical length of the line is 9.8 degrees at 1950 MHz. When designing a board for the SKY65040-360LF, these exact dimensions should be used. The board trace length at pin 4 should be minimized.

### Input and Output RF Matching Network

The input band-pass matching network consists of four components. Component C1 serves as the input DC blocking capacitor, C2 provides high frequency stability and improved input return loss, and L1 and L2 are responsible for the best noise match looking into the gate of the first stage amplifier.

Excess board trace should be eliminated at the input of the device to minimize board losses. High-Q components should be used to achieve the best NF of the amplifier. Murata GJM series capacitors and Coilcraft HP series inductors are recommended. Any excess board or component loss on the input of the device directly adds to the total measured NF.

The output matching network is band-pass network optimized for output return loss and OIP3 performance.

### Feedback

Using feedback on the SKY65040-360LF is not necessary, but can be used to reduce gain without affecting other parameters. The default circuit configuration has 25 dB of gain, but can be increased to about 18.5 dB by removing feedback components. Figures 20 and 21 describe the circuit and board layout, respectively, for using feedback with the SKY65040-360LF. The source inductance present on pin 3 has also been increased to 160 mils or 26 degrees at 1950 MHz.

### Measuring NF

Special care should be taken when making < 1 dB NF measurements. Ideally, measurements should be made in an RF shield room. An Agilent MXA N9020A spectrum analyzer with an internal pre-amp paired with an N4001A smart noise source was used for all noise measurements. The smart noise source has an internal thermocouple that automatically sets the $T_{COLD}$ setting on the analyzer. If a smart noise source is unavailable, a standard noise source should be used. Use an external thermocouple to manually adjust the $T_{COLD}$ setting to ensure accurate results.

## Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY65040-360LF are provided in Table 2. The recommended operating conditions are specified in Table 3 and electrical specifications are provided in Table 4.

Performance characteristics for the SKY65040-360LF are illustrated in Figures 4 through 16.

**Table 2. SKY65040-360LF Absolute Maximum Ratings**

| Parameter | Symbol | Minimum | Typical | Maximum | Units |
|---|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | 5.5 | | V |
| Input power | $P_{IN}$ | | +10 | | dBm |
| Supply current stage one | $I_{DS1}$ | | 50 | | mA |
| Supply current stage two | $I_{DS2}$ | | 100 | | mA |
| Power dissipation | $P_{DIS}$ | | 240 | | mW |
| Junction temperature | $T_J$ | | 150 | | °C |
| Storage temperature | $T_{STG}$ | –65 | | +125 | °C |
| Operating temperature | $T_{OP}$ | –40 | | +85 | °C |
| Thermal resistance | $\Theta_{JC}$ | | 47 | | °C/W |

**Note:** 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.

**Table 3. SKY65040-360LF Recommended Operating Conditions**

| Parameter | Symbol | Minimum | Typical | Maximum | Units |
|---|---|---|---|---|---|
| Operating frequency | f | 1.7 | | 2.4 | GHz |
| Supply voltage | $V_{DD}$ | 4.75 | 5.00 | 5.25 | V |
| Supply current | $I_{DD}$ | 30 | 65 | 100 | mA |

**Table 4. SKY65040-360LF Electrical Specifications**
**($T_{OP}$ = +25 °C, Characteristic Impedance [$Z_O$] = 50 Ω, $V_{DD}$ = 5 V, $I_{DD}$ = 65 mA, f = 1950 MHz, Parameters Include Recommended Matching Networks, Unless Otherwise Noted)**

| Parameter | Symbol | Test Condition | Min | Typical | Max | Units |
|---|---|---|---|---|---|---|
| Noise Figure (Note 1) | NF | High gain circuit<br>Feedback circuit | | 0.65<br>0.60 | 1.0 | dB<br>dB |
| Small signal gain | \|S21\| | High gain circuit<br>Feedback circuit | 23.5 | 25.0<br>18.5 | 26.5 | dB<br>dB |
| Input return loss | \|S11\| | High gain circuit<br>Feedback circuit | | –25<br>–25 | | dB<br>dB |
| Output return loss | \|S22\| | High gain circuit<br>Feedback circuit | | –15<br>–11 | | dB<br>dB |
| Reverse isolation | \|S12\| | High gain circuit<br>Feedback circuit | | –34<br>–29 | | dB<br>dB |
| 3rd Order Output Intercept Point | OIP3 | 5 MHz spacing, $P_{IN}$ = –18 dBm per tone<br>High gain circuit<br>Feedback circuit | | <br>+34.5<br>+34.0 | | <br>dBm<br>dBm |
| 1 dB Output Compression Point | OP1dB | High gain circuit<br>Feedback circuit | | +16<br>+18 | | dBm<br>dBm |
| Stability | | Unconditionally stable up to 18 GHz | | >1 | | K |

**Note 1**: Loss from input RF connector and board trace de-embedded from measurement.

## Typical Performance Characteristics

**($T_{OP}$ = +25 °C, Characteristic Impedance [$Z_O$] = 50 Ω, $V_{DD}$ = 5 V, $I_{DD}$ = 65 mA, Parameters Include a Recommended High Gain 1950 MHz Matching Network, Unless Otherwise Noted)**

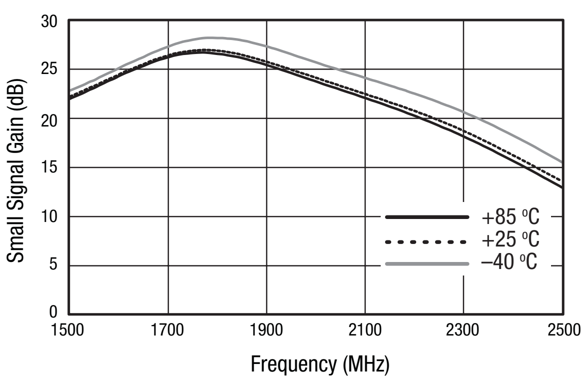



**Figure 4. Small Signal Gain vs Frequency Over Temperature, $P_{IN}$ = –20 dBm**

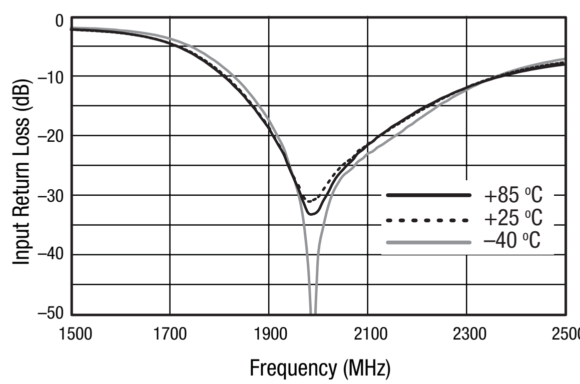



**Figure 5. Intput Return Loss vs Frequency Over Temperature, $P_{IN}$ = –20 dBm**

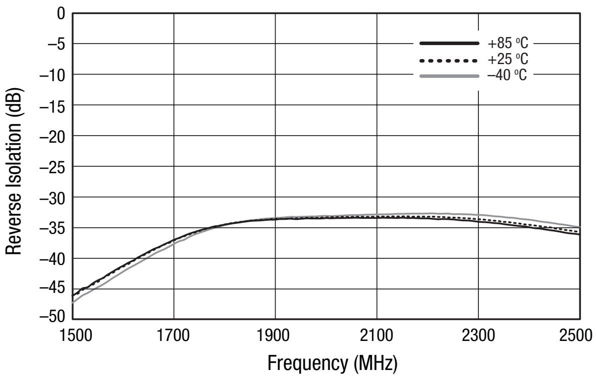



**Figure 6. Reverse Isolation vs Frequency Over Temperature, PIN = –20 dBm**

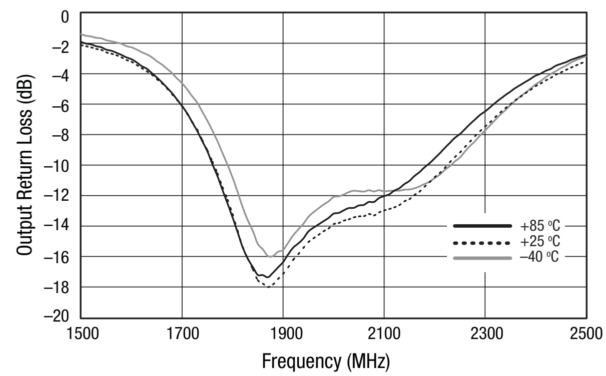



**Figure 7. Output Return Loss vs Frequency Over Temperature, PIN = –20 dBm**

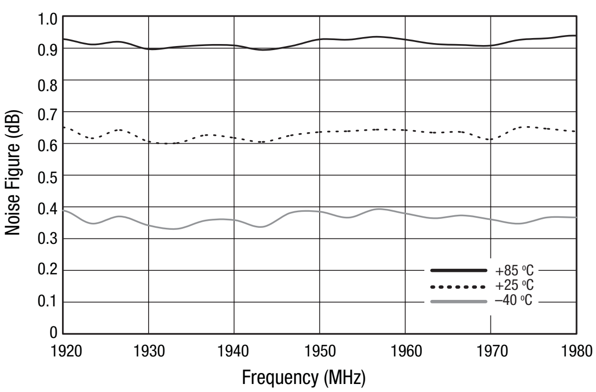



**Figure 8. Noise Figure vs Frequency Over Temperature, Input RF Connector and Board Trace De-Embedded From Measurement**

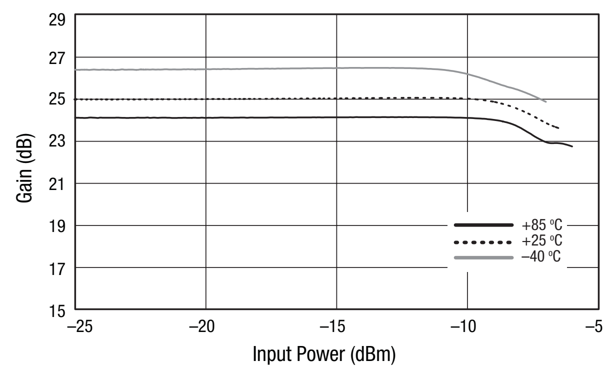



**Figure 9. Gain vs Input Power Over Temperature, f = 1950 MHz**

## Typical Performance Characteristics

**($T_{OP}$ = +25 °C, Characteristic Impedance [$Z_0$] = 50 Ω, $V_{DD}$ = 5 V, $I_{DD}$ = 65 mA, Parameters Include a Recommended 1800-2000 MHz Matching Network With Feedback, Unless Otherwise Noted)**

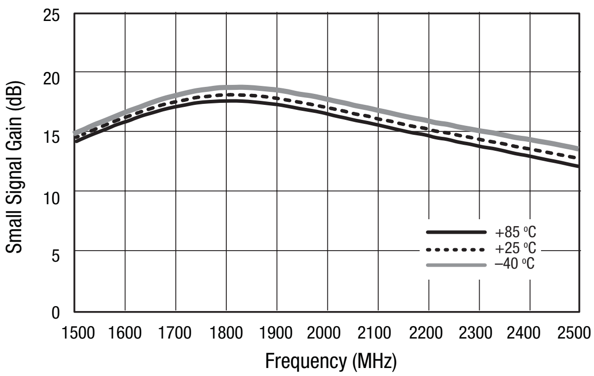



**Figure 10. Small Signal Gain vs Frequency Over Temperature, $P_{IN}$ = –20 dBm**

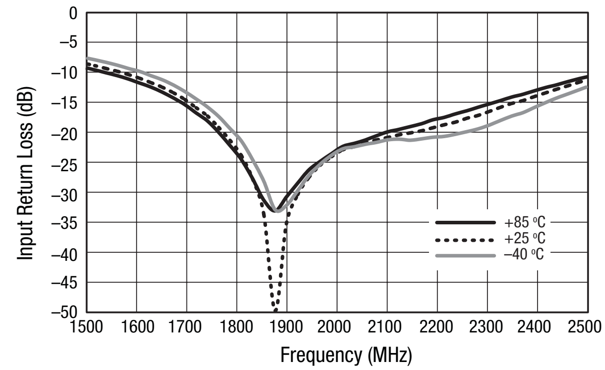



**Figure 11. Input Return Loss vs Frequency Over Temperature, $P_{IN}$ = –20 dBm**

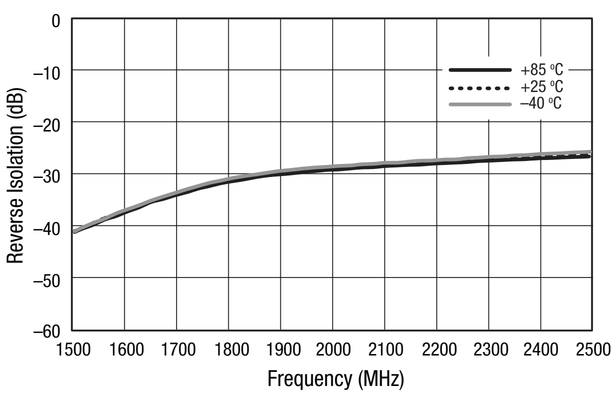



**Figure 12. Reverse Isolation vs Frequency Over Temperature, $P_{IN}$ = –20 dBm**

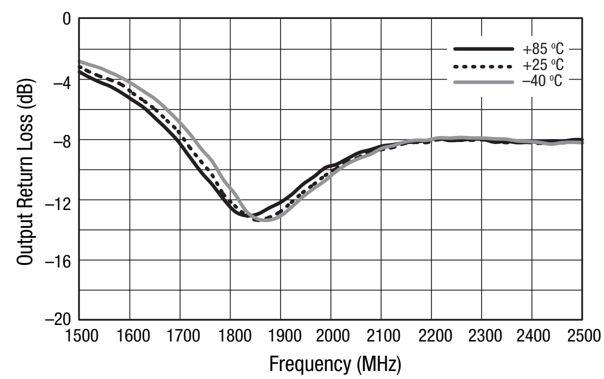



**Figure 13. Output Return Loss vs Frequency Over Temperatures, $P_{IN}$ = –20 dBm**

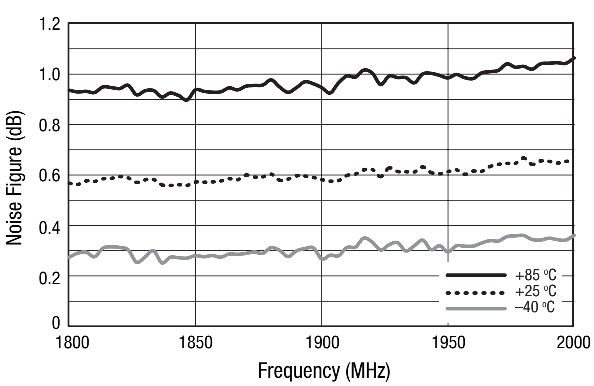



**Figure 14. Noise Figure vs Frequency Over Temperature, Input RF Connector and Board Trace De-Embedded From Measurement**

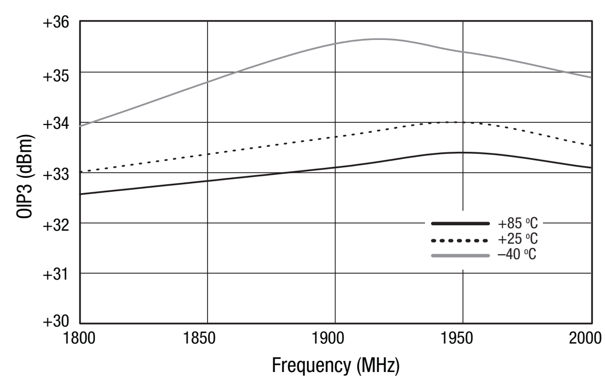



**Figure 15. OIP3 vs Frequency Over Temperature, $P_{IN}$ = –18 dBm/Tone, 5 MHz Tone Spacing**

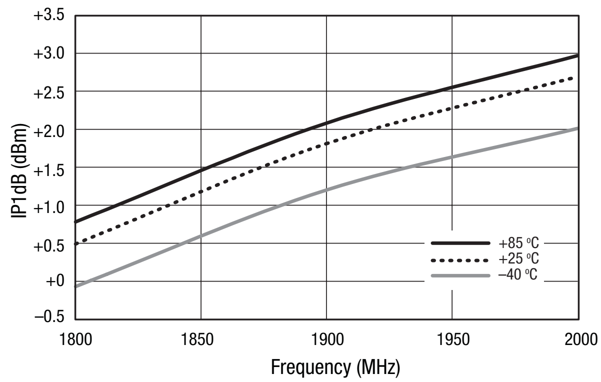



**Figure 16. IP1dB vs Frequency Over Temperature**

## Evaluation Board Description

The SKY65040-360LF Evaluation Board is used to test the performance of the SKY65040-360LF low noise amplifier. An assembly drawing for the Evaluation Board is shown in Figure 17 (high gain circuit) and an Evaluation Board schematic diagram for a high gain circuit is shown in Figure 18. A corresponding Evaluation Board assembly drawing and schematic diagram for a feedback circuit are shown in Figures 19 and 20, respectively.

Tables 5 and 6 provide the Evaluation Board Bill of Materials (BOM) list for high gain circuit components and feedback circuit components, respectively.

Input and output traces have been minimized to reduce losses. All surface mount components are 0402-sized to reduce component parasitics. The use of 0603 or larger components is not recommended. Component spacing has also been minimized. The board is provisioned with two RF connectors and a DC launch. The RF connector and board loss up to component C1 is approximately 0.1 dB at 1.95 GHz.

It is very important to place multiple ground vias as close to shunt components as possible. This ensures proper grounding and circuit performance.

Board material is 10 mil thick VT47 FR4 with 1 oz. copper cladding. RF traces are 50 Ω with a 17.5 mil trace width and a 10 mil gap to ground.

### Evaluation Board Test Procedure

Step 1: Connect RF test equipment to amplifier input/output SMA connectors.

Step 2: Connect DC ground.

Step 3: Connect VDD to a +5 V supply with a current limit of 100 mA. Verify that the board draws approximately 65 mA.

Step 4: Apply RF signal or noise source.

## Package Dimensions

The PCB layout footprint for the SKY65040-360LF is shown in Figure 21. Typical case markings are noted in Figure 22. Package dimensions for the 8-pin QFN are shown in Figure 23, and tape and reel dimensions are provided in Figure 24.

## Package and Handling Information

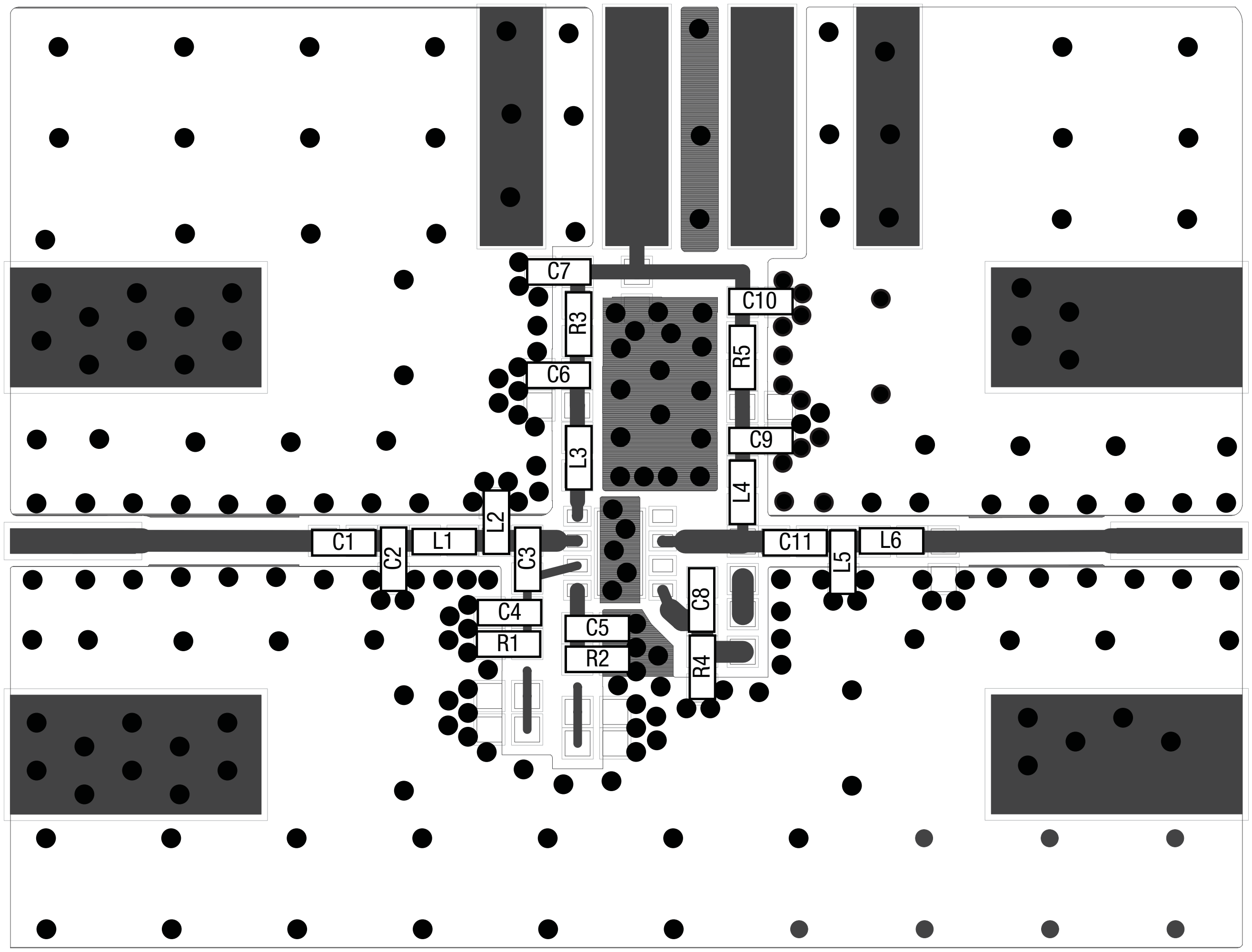
Since the device package is sensitive to moisture absorption, it is baked and vacuum packed before shipping. Instructions on the shipping container label regarding exposure to moisture after the container seal is broken must be followed. Otherwise, problems related to moisture absorption may occur when the part is subjected to high temperature during solder assembly.

THE SKY65040-360LF is rated to Moisture Sensitivity Level 1 (MSL1) at 260 °C. It can be used for lead or lead-free soldering.

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. For packaging details, refer to the Skyworks Application Note, *Discrete Devices and IC Switch/Attenuators Tape and Reel Package Orientation*, document number 200083.

## Electrostatic Discharge (ESD) Sensitivity

The SKY65040-360LF is a static-sensitive electronic device. Do not operate or store near strong electrostatic fields. Take proper ESD precautions.




C1, C2, L1, and L2 comprise the input matching network
C11, L5, and L6 comprise the output matching network.
R1, R3, and C4 are the bias components for the 1st stage amplifier.
R2, R5, and C5 are the bias components for the 2nd stage amplifier.
C6, C7, C9, and C10 are RF bypass capacitors.
L3 and L4 are RF choke inductors.
R4 and C8 provide DC grounding and high frequency stability when feedback isn't used.

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**Figure 17. SKY65040-360LF Evaluation Board Assembly Diagram (High Gain Circuit)**

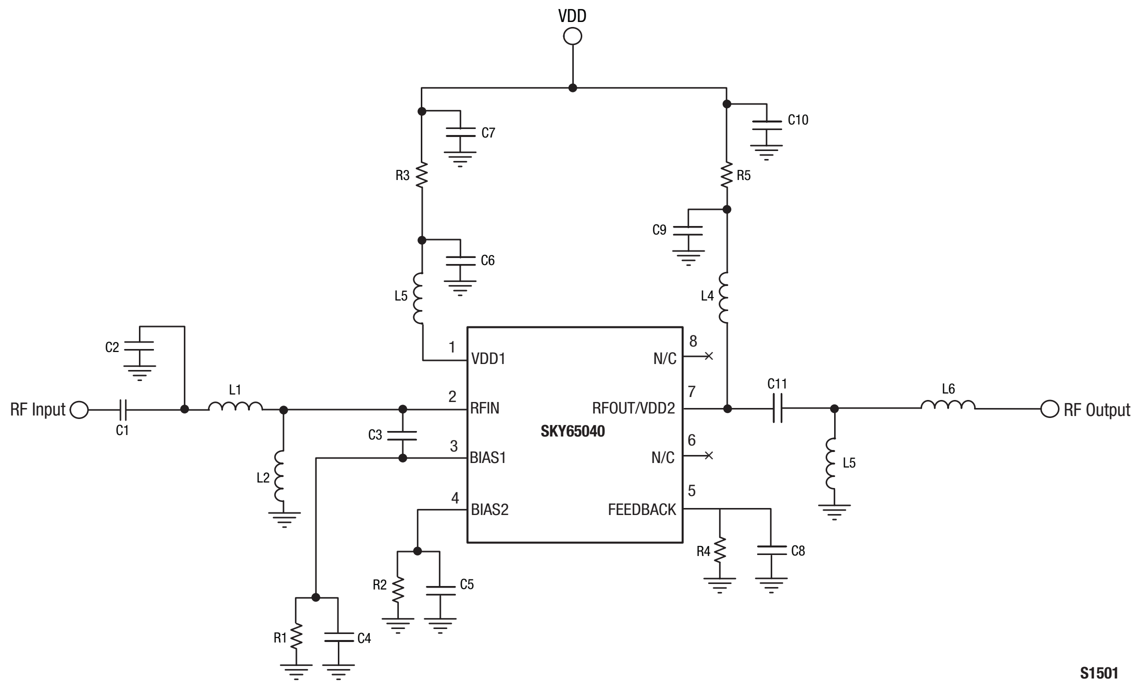
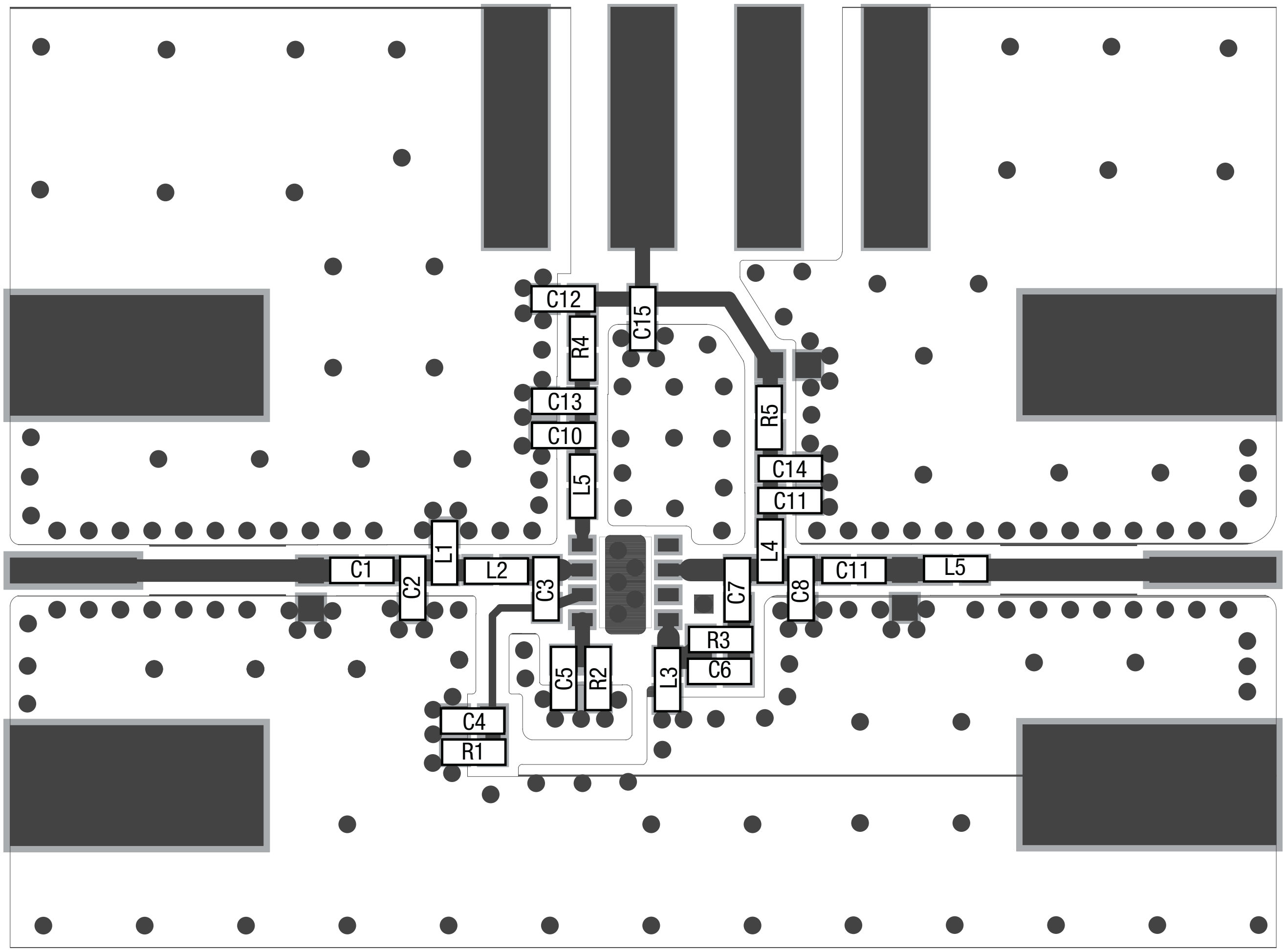



**Figure 18. SKY65040-360LF Evaluation Board Schematic Diagram (High Gain Circuit)**

**Table 5. Recommended Evaluation Board Bill of Materials (High Gain Circuit)**

| Component | Value | Size | Manufacturer | Component | Value | Size | Manufacturer |
|---|---|---|---|---|---|---|---|
| C1 | 20 pF | 0402 | Murata GJM series | L1 | 3.6 nH | 0402 | Coilcraft HP series |
| C2 | 0.5 pF | 0402 | Murata GJM series | L2 | 11 nH | 0402 | Coilcraft HP series |
| C3 | 0.2 pF | 0402 | Murata GJM series | L3 | 10 nH | 0402 | TDK MLG series |
| C4 | 4700 pF | 0402 | Murata GRM series | L4 | 7.5 nH | 0402 | TDK MLG series |
| C5 | 4700 pF | 0402 | Murata GRM series | L5 | 6.8 nH | 0402 | TDK MLG series |
| C6 | 82 pF | 0402 | Murata GRM series | L6 | 3.9 nH | 0402 | TDK MLG series |
| C7 | 4700 pF | 0402 | Murata GRM series | R1 | 22 Ω | 0402 | Panasonic |
| C8 | 0.3 pF | 0402 | Murata GJM series | R2 | 9.1 Ω | 0402 | Panasonic |
| C9 | 4700 pF | 0402 | Murata GRM series | R3 | 120 Ω | 0402 | Panasonic |
| C10 | 0.3 pF | 0402 | Murata GJM series | R4 | 3 kΩ | 0402 | Panasonic |
| C11 | 8.2 pF | 0402 | Murata GRM series | R5 | 20 Ω | 0402 | Panasonic |




C1, C2, L1, and L2 comprise the input matching network
C11, L5, and L6 comprise the output matching network.
R1, R3, and C4 are the bias components for the 1st stage amplifier.
R2, R5, and C5 are the bias components for the 2nd stage amplifier.
C6, C7, C9, and C10 are RF bypass capacitors.
L3 and L4 are RF choke inductors.
R4 and C8 provide DC grounding and high frequency stability when feedback isn't used.

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**Figure 19. SKY65040-360LF Evaluation Board Assembly Diagram (Feedback Circuit)**

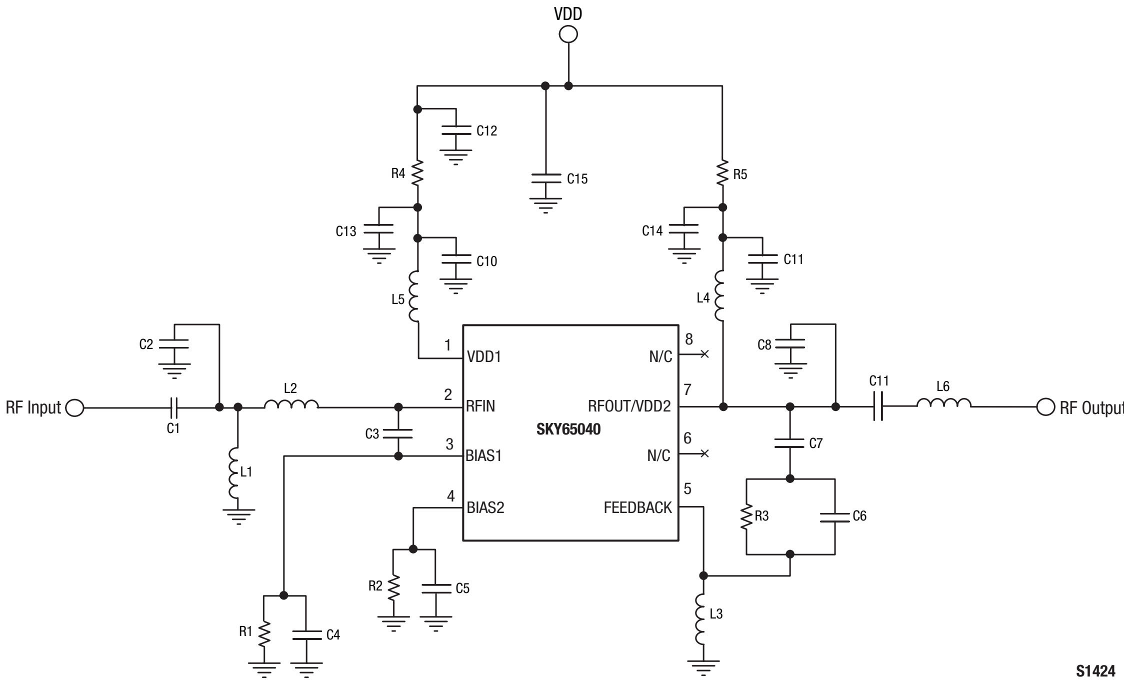


**Figure 20. SKY65040-360LF Evaluation Board Schematic Diagram (Feedback Circuit)**

**Table 6. Recommended Evaluation Board Bill of Materials (Feedback Circuit)**

| Component | Value | Size | Manufacturer | Component | Value | Size | Manufacturer |
|---|---|---|---|---|---|---|---|
| C1 | 20 pF | 0402 | Murata GJM series | C14 | 20 pF | 0402 | Murata GJM series |
| C2 | 0.5 pF | 0402 | Murata GJM series | C15 | 0.1 µF | 0402 | Murata GRM series |
| C3 | 0.2 pF | 0402 | Murata GJM series | L1 | 7.5 nH | 0402 | Coilcraft HP series |
| C4 | 4700 pF | 0402 | Murata GRM series | L2 | 5.6 nH | 0402 | Coilcraft HP series |
| C5 | 1000 pF | 0402 | Murata GRM series | L3 | 15 nH | 0402 | Taiyo Yuden HK series |
| C6 | 0.5 pF | 0402 | Murata GRM series | L4 | 2.2 nH | 0402 | Taiyo Yuden HK series |
| C7 | 1 pF | 0402 | Murata GRM series | L5 | 8.2 nH | 0402 | Taiyo Yuden HK series |
| C8 | 0.75 pF | 0402 | Murata GJM series | L6 | 1.5 nH | 0402 | Taiyo Yuden HK series |
| C9 | 8.2 pF | 0402 | Murata GRM series | R1 | 20 Ω | 0402 | Panasonic |
| C10 | 0.2 pF | 0402 | Murata GJM series | R2 | 8.2 Ω | 0402 | Panasonic |
| C11 | 10 pF | 0402 | Murata GRM series | R3 | 300 Ω | 0402 | Panasonic |
| C12 | 1000 pF | 0402 | Murata GRM series | R4 | 100 Ω | 0402 | Panasonic |
| C13 | 2.2 pF | 0402 | Murata GRM series | R5 | 20 Ω | 0402 | Panasonic |

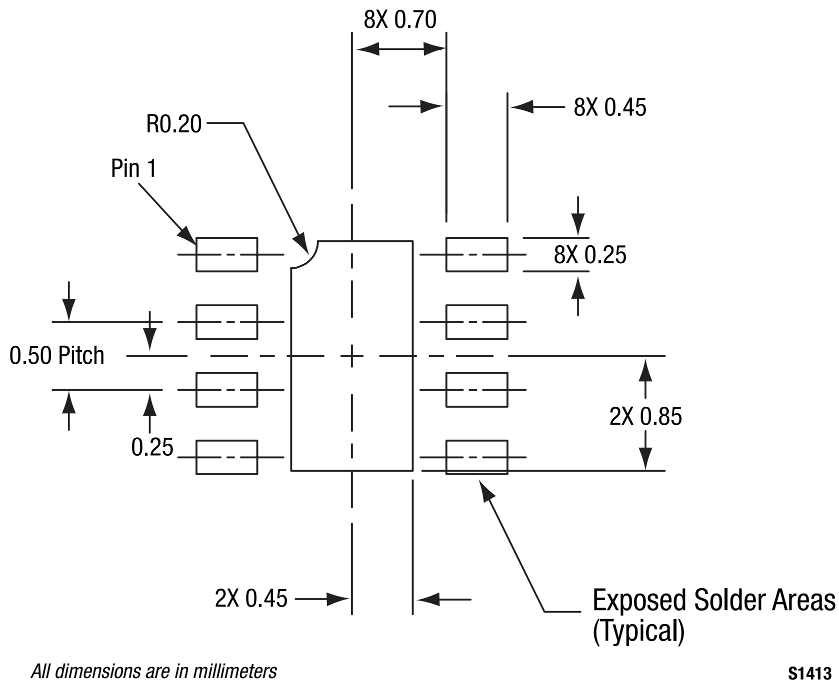


**Figure 21. SKY65040-360LF PCB Layout Footprint**

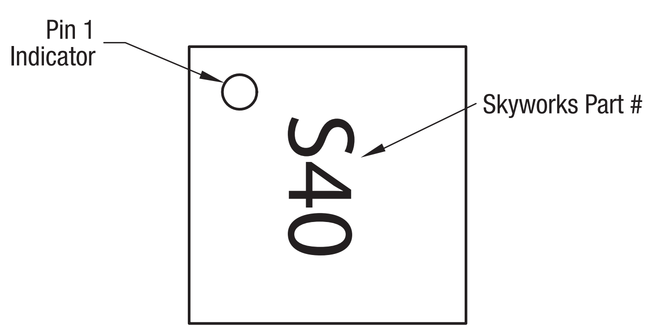


**Figure 22. Typical Case Markings**

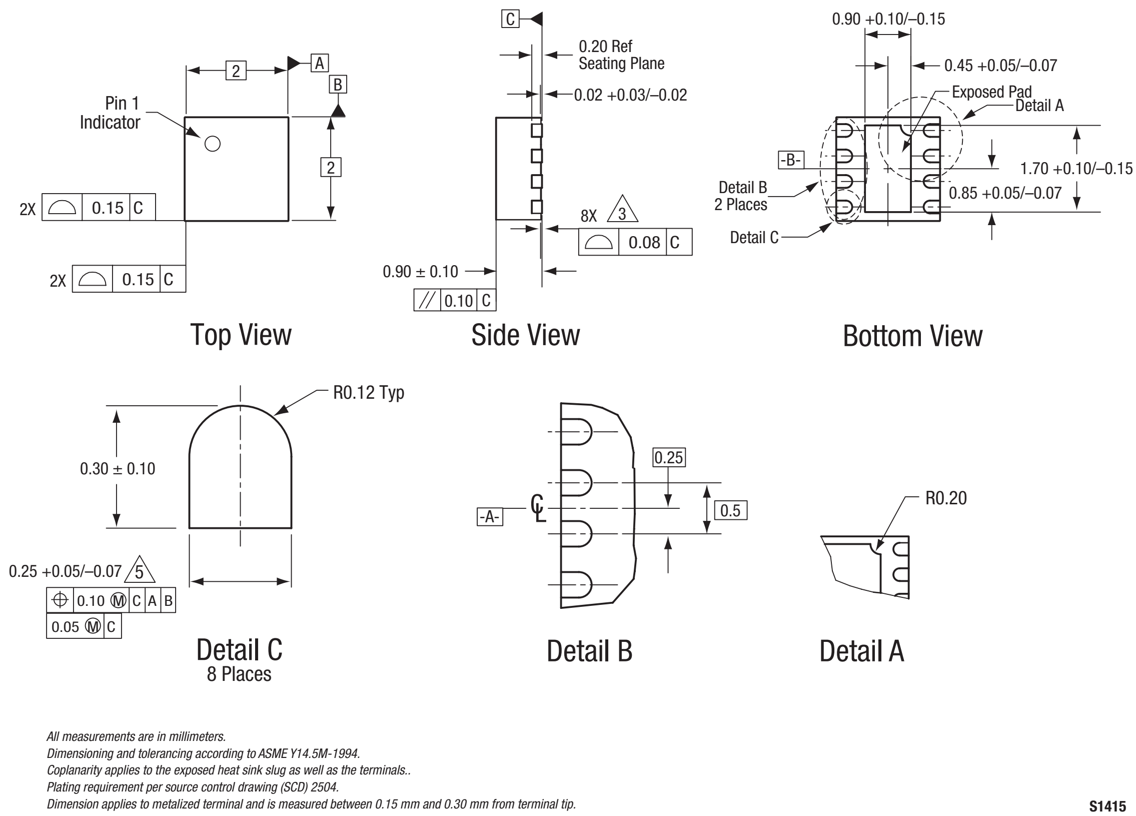


**Figure 23. SKY65040-360LF 8-Pin QFN Package Dimensions**

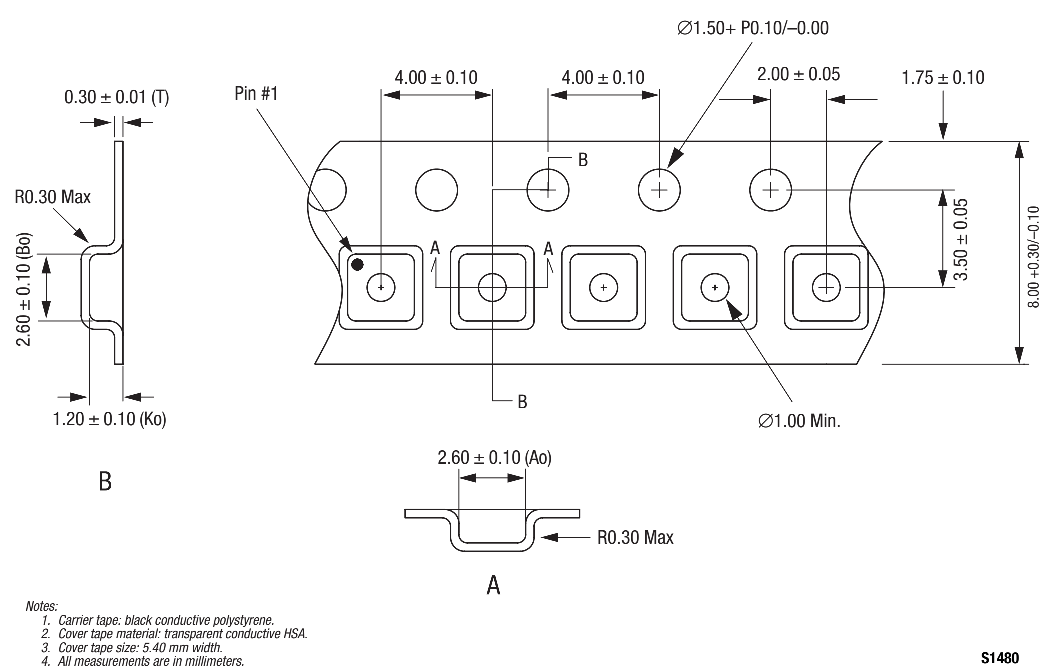


**Figure 24. SKY65040-360LF Tape and Reel Dimensions**

## Ordering Information

| Model Name | Manufacturing Part Number | Evaluation Kit Part Numbers |
|---|---|---|
| SKY65040-360LF Low Noise Amplifier | SKY65040-360LF (Pb-free package) | SKY65040-360LF (High Gain, No Feedback, 1950 MHz)<br>SKY65040-360LF (Low Gain, Feedback, 1800-2000 MHz) |