

**DATA SHEET**

# SKY65084-360LF: 1.5-2.4 GHz Low Noise Amplifier

## Applications

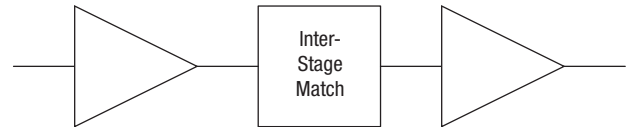
- Wireless infrastructure: GSM, CDMA, WCDMA, and TD-SCDMA
- Ultra low-noise applications

## Features

- Ultra-low Noise Figure = 0.70 dB @ 1.95 GHz
- Excellent input and output return loss
- Adjustable gain = 15 to 25 dB @ 1.95 GHz
- High output OIP3 = +34.0 dBm @ 65 mA
- OP1dB = +16 dBm @ 1.95 GHz
- Single, positive DC supply voltage
- Adjustable supply current, 30 to 100 mA
- Small, QFN (8-pin, 2 x 2 mm) package (MSL1, 260 °C per JEDEC J-STD-020)



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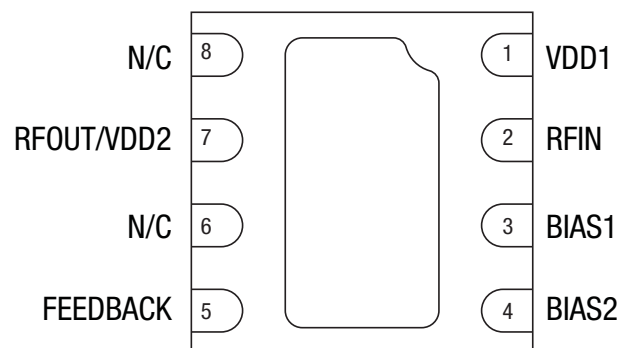
**Figure 1. SKY65084-360LF Block Diagram**

## Description

The SKY65084-360LF 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 3<sup>rd</sup> Order Intercept point (IP3) allow it to be used in various receiver and transmitter applications.

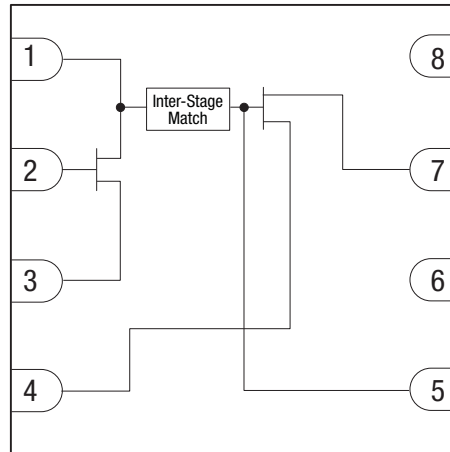
A functional block diagram is shown in Figure 1. The pin configuration and package are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.



**Figure 2. SKY65084-360LF Pinout – 8-Pin QFN (Bottom View)**

**Table 1. SKY65084-360LF Signal Descriptions**

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



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**Figure 3. SKY65084-360LF On-Die Functional Diagram**

### Functional Description

The SKY65084-360LF is a two stage, low noise amplifier with an integrated interstage matching network. The device has a tested low NF of 0.70 dB and gain of 24 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 SKY65084-360LF. 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  $V_{GS} = 0\text{ V}$  and  $V_{DS} > 2\text{ V}$ , 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 2<sup>nd</sup> stage amplifier can be adjusted without degrading the overall NF. More current in the 2<sup>nd</sup> 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 C5, C6, C7, C9, and C10 are RF bypass capacitors. R3 and R4 reduce the voltage presented at the drain of each stage of the device. The resistor values are optimized for 3<sup>rd</sup> 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 SKY65084-360LF, 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. No High-Q components are required for output matching or DC bias.

**Feedback**

Using feedback on the SKY65084-360LF 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 decreased to about 18 dB by adding feedback components.

**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<sub>COLD</sub> 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<sub>COLD</sub> setting to ensure accurate results.

**Electrical and Mechanical Specifications**

The absolute maximum ratings of the SKY65084-360LF 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 SKY65084-360LF are illustrated in Figures 4 through 10.

**Table 2. SKY65084-360LF Absolute Maximum Ratings**

Parameter	Symbol	Minimum	Typical	Maximum	Units
Supply voltage	V <sub>DD1</sub> , V <sub>DD2</sub>		5.5		V
Input power	P <sub>IN</sub>		+13		dBm
Supply current stage one	I <sub>DS1</sub>		50		mA
Supply current stage two	I <sub>DS2</sub>		100		mA
Power dissipation	P <sub>DIS</sub>		530		mW
Junction temperature	T <sub>J</sub>		150		°C
Storage temperature	T <sub>STG</sub>	-65		+125	°C
Operating temperature	T <sub>OP</sub>	-40		+85	°C
Thermal resistance	Θ <sub>JC</sub>		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. Exceeding any of the limits listed here may result in permanent damage to the device.

**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. SKY65084-360LF Recommended Operating Conditions**

Parameter	Symbol	Minimum	Typical	Maximum	Units
Operating frequency	f	1.5		2.4	GHz
Supply voltage	V <sub>DD</sub>	4.75	5.00	5.25	V
Supply current	I <sub>DD</sub>	30	65	100	mA

**Table 4. SKY65084-360LF Electrical Specifications (Note 1)**

(T<sub>OP</sub> = +25 °C, Characteristic Impedance [Z<sub>0</sub>] = 50 Ω, V<sub>DD</sub> = 5 V, I<sub>DD</sub> = 65 mA, f = 1950 MHz, Parameters Include Recommended Matching Networks, Unless Otherwise Noted)

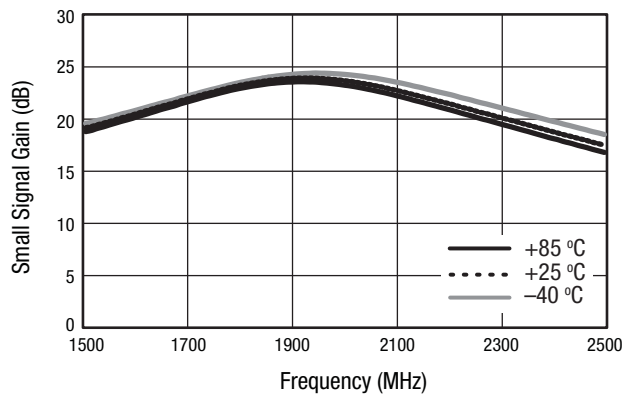
Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Noise Figure (Note 2)	NF			0.7	1.0	dB
Small signal gain	IS21I		23.5	24.0	24.5	dB
Input return loss	IS11I			20		dB
Output return loss	IS22I			20		dB
Reverse isolation	IS12I			36		dB
3 <sup>rd</sup> Order Input Intercept Point	IIP3	5 MHz spacing, P <sub>IN</sub> = -18 dBm per tone, f = 2000 MHz		+10		dBm
3 <sup>rd</sup> Order Output Intercept Point	OIP3	5 MHz spacing, P <sub>IN</sub> = -18 dBm per tone, f = 2000 MHz		+34.0		dBm
1 dB Input Compression Point	IP1dB	f = 2000 MHz		-7		dBm
1 dB Output Compression Point	OP1dB	f = 2000 MHz		+16		dBm
Stability	K	Unconditionally stable up to 18 GHz		>1		-
Supply current	I <sub>DD</sub>	V <sub>DD</sub> = 5 V	58	65	73	mA

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

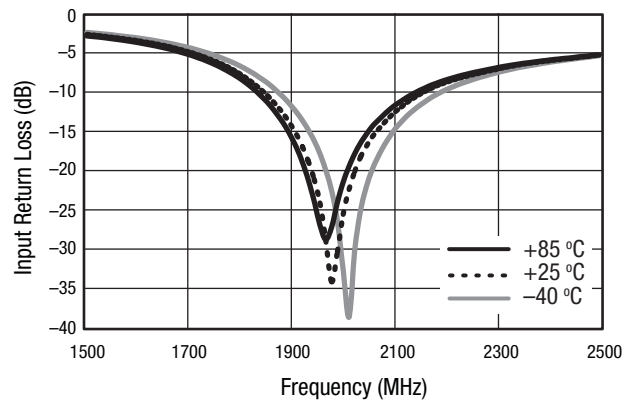
**Note 2:** Loss from input RF connector and board trace de-embedded from measurement.

### Typical Performance Characteristics

(T<sub>OP</sub> = +25 °C, Characteristic Impedance [Z<sub>0</sub>] = 50 Ω, V<sub>DD</sub> = 5 V, I<sub>DD</sub> = 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<sub>IN</sub> = -20 dBm**



**Figure 5. Input Return Loss vs Frequency Over Temperature, P<sub>IN</sub> = -20 dBm**

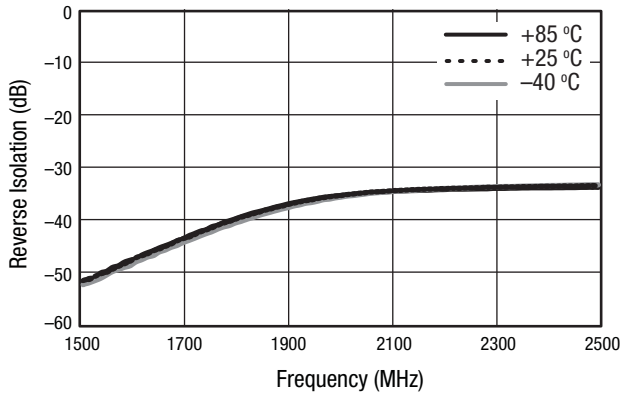


Figure 6. Reverse Isolation vs Frequency Over Temperature,  $P_{IN} = -20$  dBm

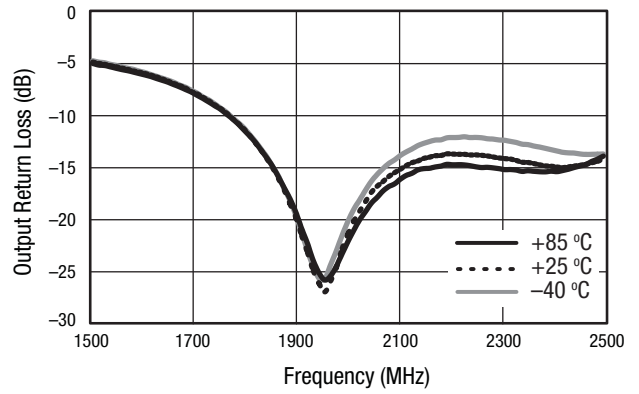


Figure 7. Output Return Loss vs Frequency Over Temperature,  $P_{IN} = -20$  dBm

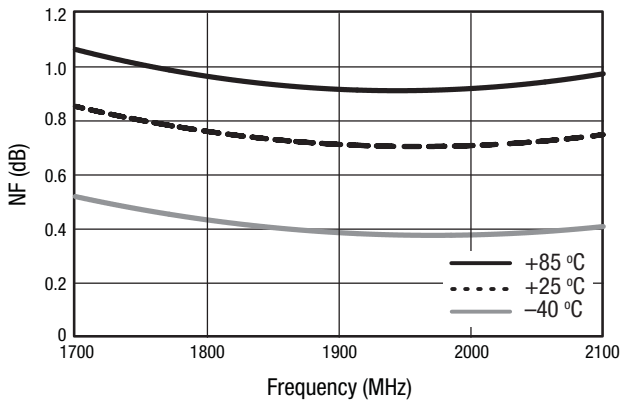


Figure 8. Noise Figure vs Frequency Over Temperature, Input RF Connector and Board Trace De-Embedded From Measurement

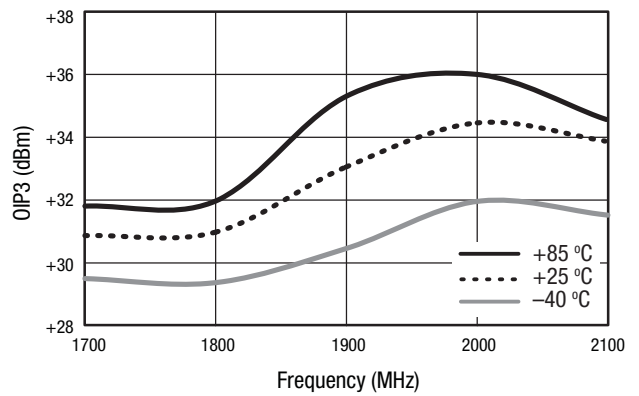


Figure 9. Third Order Output Intercept Point vs Frequency Over Temperature,  $P_{IN} = -18$  dBm/Tone, 5 MHz Tone Spacing

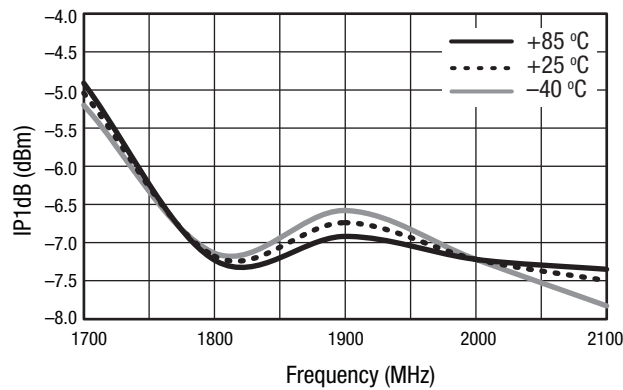


Figure 10. Input 1 dB Compression vs Frequency Over Temperature

## Evaluation Board Description

The SKY65084-360LF Evaluation Board is used to test the performance of the SKY65084-360LF low noise amplifier. An assembly drawing for the Evaluation Board is shown in Figure 11 and an Evaluation Board schematic diagram is shown in Figure 12. Table 5 provides the Evaluation Board Bill of Materials (BOM) list.

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  $\Omega$  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

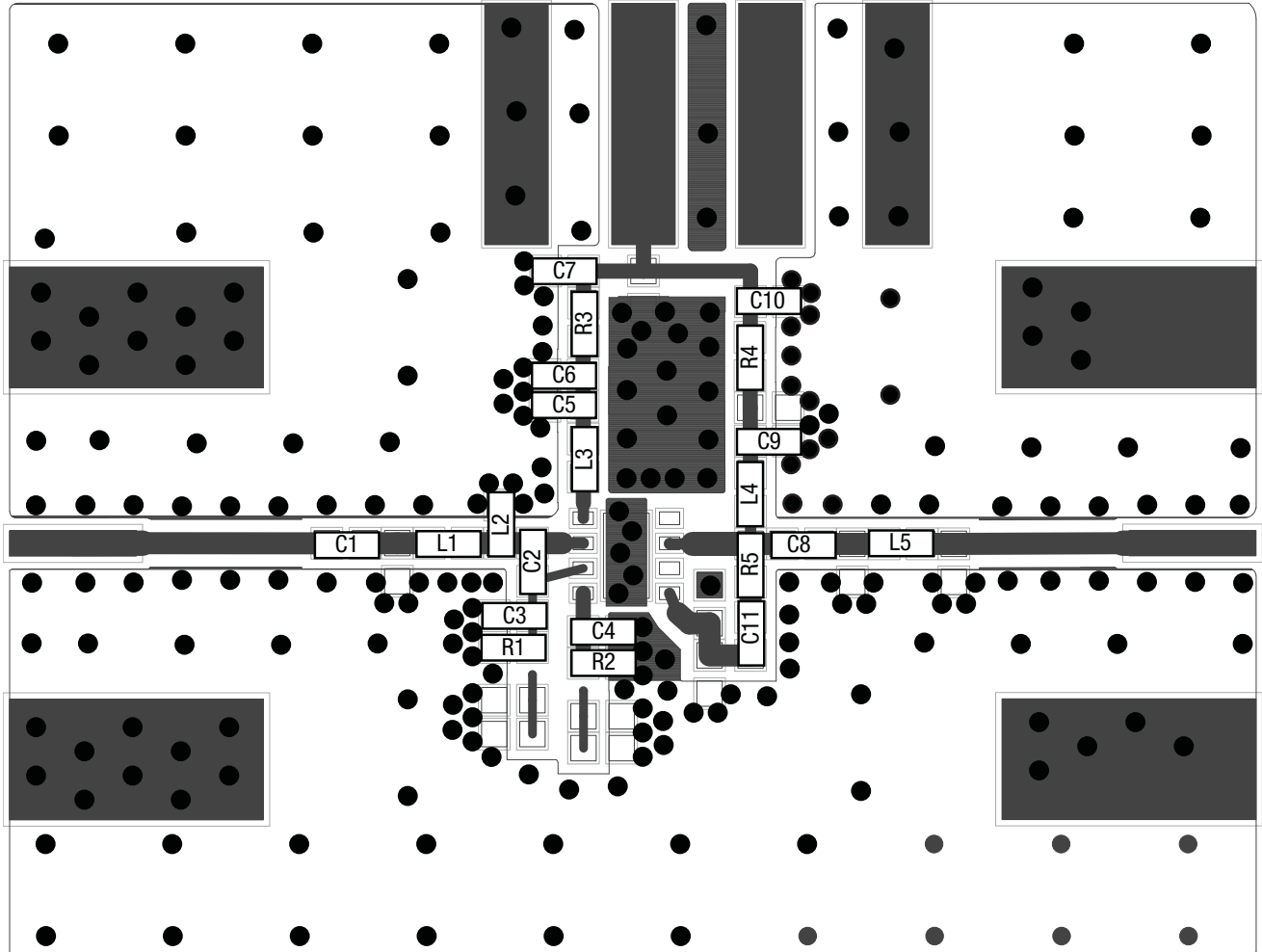
The PCB layout footprint for the SKY65084-360LF is shown in Figure 13. Typical case markings are noted in Figure 14. Package dimensions for the 8-pin QFN are shown in Figure 15, and tape and reel dimensions are provided in Figure 16.

## 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 SKY65084-360LF 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.

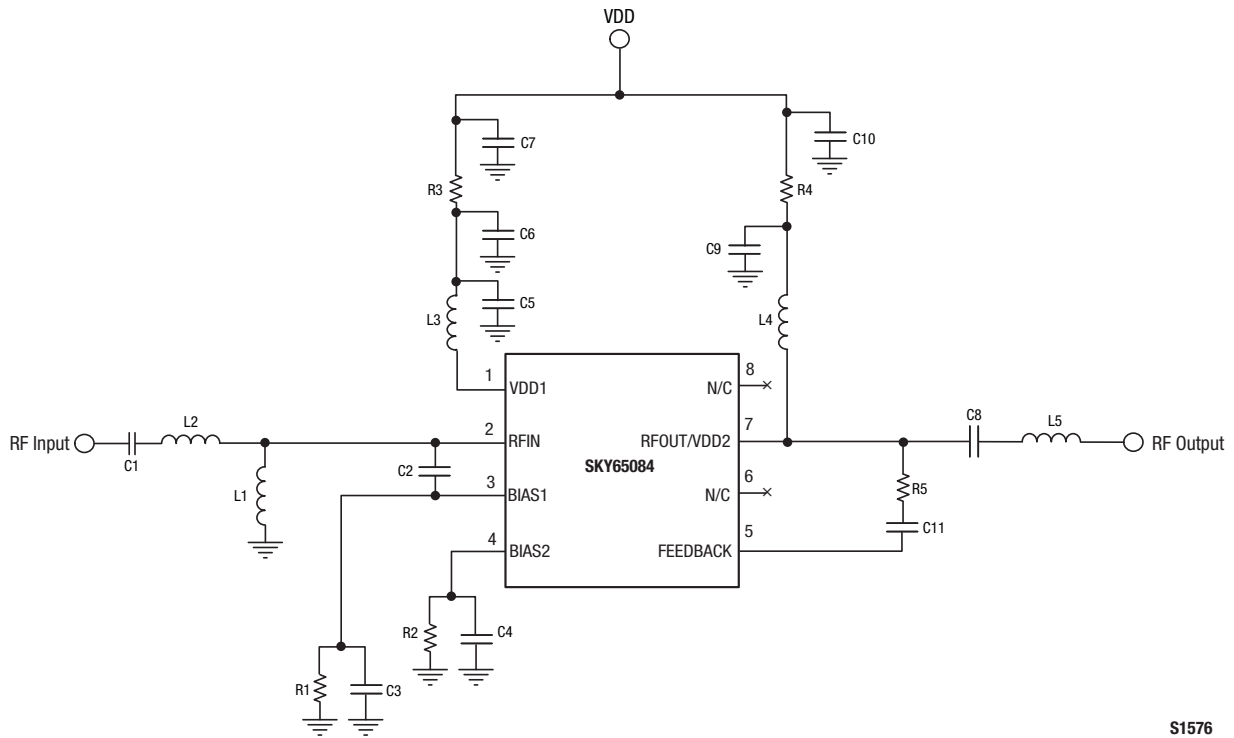
Care must be taken when attaching this product, whether it is done manually or in a production solder reflow environment. Production quantities of this product are shipped in a standard tape and reel format. For packaging details, refer to the Skyworks Application Note, *Discrete Devices and IC Switch/Attenuators Tape and Reel Package Orientation*, document number 200083.



C1, L1, and L2 comprise the input matching network  
 C8, L4, and L5 comprise the output matching network.  
 R1, R3, and C3 are the bias components for the 1st stage transistor.  
 R2, R4, and C4 are the bias components for the 2nd stage transistor.  
 C3, C4, C6, C7, C9, and C10 are RF decoupling capacitors.  
 L3 and L4 are RF choke inductors.  
 R5 and C11 provide RF feedback to adjust gain

S1577

**Figure 11. SKY65084-360LF Evaluation Board Assembly Diagram**



S1576

Figure 12. SKY65084-360LF Evaluation Board Schematic Diagram

Table 5. Recommended Evaluation Board Bill of Materials

Component	Value	Size	Manufacturer	Component	Value	Size	Manufacturer
C1	20 pF	0402	Murata GJM series	L1	5.6 nH	0402	Coilcraft HP series
C2	0.4 pF	0402	Murata GJM series	L2	7.5 nH	0402	Coilcraft CS series
C3	1000 pF	0402	Murata GRM series	L3	6.8 nH	0402	TDK MLG series
C4	1000 pF	0402	Murata GRM series	L4	18 nH	0402	TDK MLG series
C5	8.2 pF	0402	Murata GRM series	L5	4.7 nH	0402	TDK MLG series
C6	0.3 pF	0402	Murata GJM series	R1	20 Ω	0402	Panasonic
C7	1000 pF	0402	Murata GRM series	R2	9.1 Ω	0402	Panasonic
C8	47 pF	0402	Murata GRM series	R3	120 Ω	0402	Panasonic
C9	1000 pF	0402	Murata GRM series	R4	36 Ω	0402	Panasonic
C10	0.3 pF	0402	Murata GJM series	R5	1.1 kΩ	0402	Panasonic
C11	0.3 pF	0402	Murata GJM series				



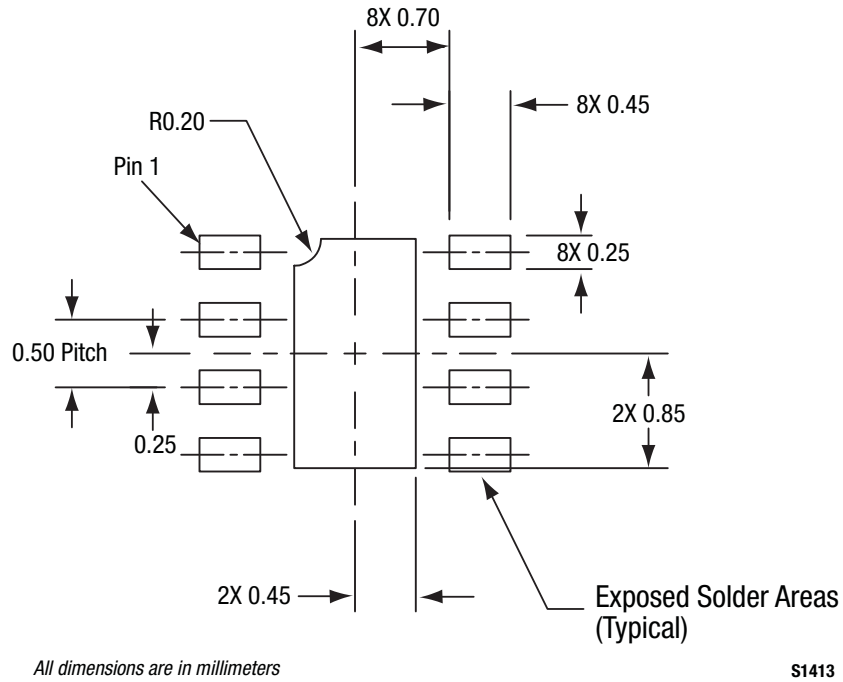


Figure 13. SKY65084-360LF PCB Layout Footprint

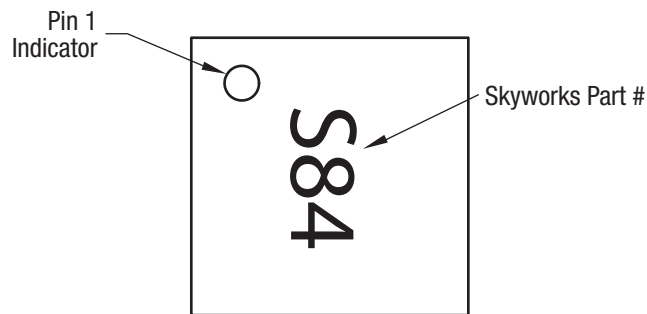
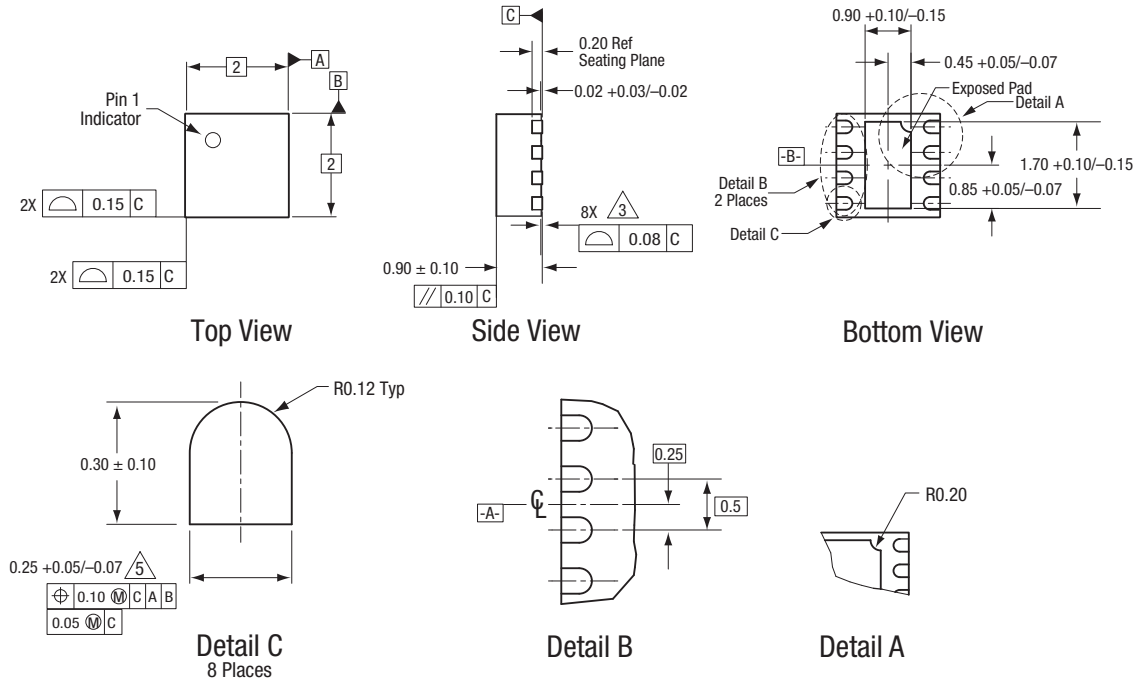


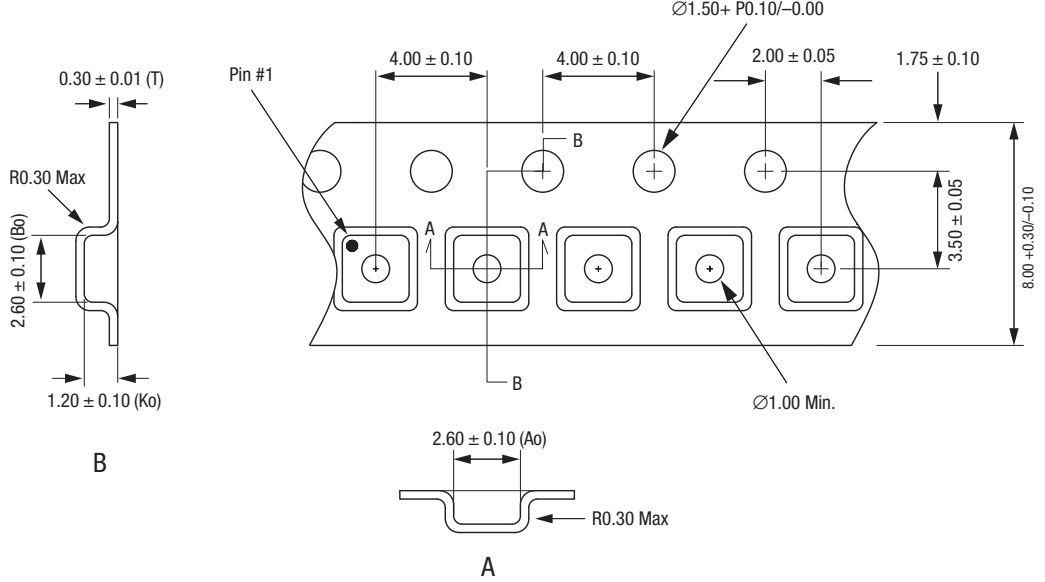
Figure 14. Typical Case Markings



All measurements are in millimeters.  
 Dimensioning and tolerancing according to ASME Y14.5M-1994.  
 Coplanarity applies to the exposed heat sink slug as well as the terminals.  
 Plating requirement per source control drawing (SCD) 2504.  
 Dimension applies to metallized terminal and is measured between 0.15 mm and 0.30 mm from terminal tip.

S1415

Figure 15. SKY65084-360LF 8-Pin QFN Package Dimensions



Notes:  
 1. Carrier tape: black conductive polystyrene.  
 2. Cover tape material: transparent conductive HSA.  
 3. Cover tape size: 5.40 mm width.  
 4. All measurements are in millimeters.

S1480

Figure 16. SKY65084-360LF Tape and Reel Dimensions

**Ordering Information**

Model Name	Manufacturing Part Number	Evaluation Board Part Numbers
SKY65084-360LF Low Noise Amplifier	SKY65084-360LF	SKY65084-360LF EVB

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