SKY66100-11: 169 to 170 MHz Transmit/Receive Front-End Module

Applications

- Automated meter reading
- Advanced metering infrastructure
- ISM systems

Features

- Transmit output power: >+27 dBm
- High efficiency PA
- Receive loss: <0.4 dB
- Transmit bypass mode with 0.9 dB insertion loss
- Sleep mode current: < 1 µA
- Integrated control logic
- Small footprint MCM (16-pin, 4 x 4 mm) package (MSL3, 260 °C per JEDEC J-STD-020)

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Description

The SKY66100-11 is a high-performance, transmit/receive (Tx/Rx) front-end module (FEM). The device includes a power amplifier (PA) capable of more than +27 dBm of transmit output power at more than 45 percent PAE for the module (55 percent for the standalone PA). For current-sensitive applications, the PA can be bypassed to save battery current.

All functionality can be controlled by a three-wire interface. The FEM can be placed in a deep "sleep" mode, drawing less than 1 µA of current.

The receive chain consists of a low-loss single-pole, triple-throw (SP3T) switch, which provides an insertion loss of approximately 0.4 dB. Three separate V_{CC} pins enable maximum RF isolation.

The SKY66100-11 is packaged in a 16-pin, 4 x 4 mm Multi-Chip Module (MCM), which allows for a highly manufacturable low-cost solution.

A functional block diagram of the SKY66100-11 is shown in Figure 1. The 16-pin MCM package and pinout are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.
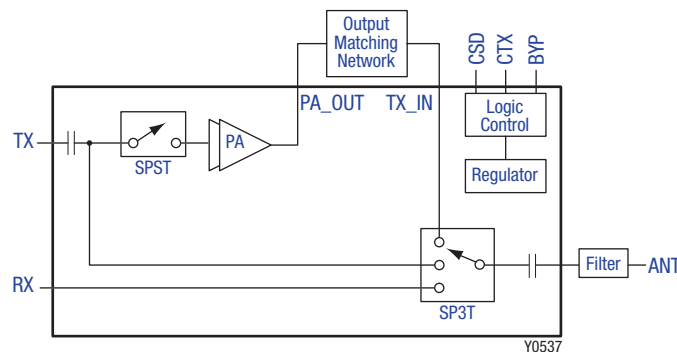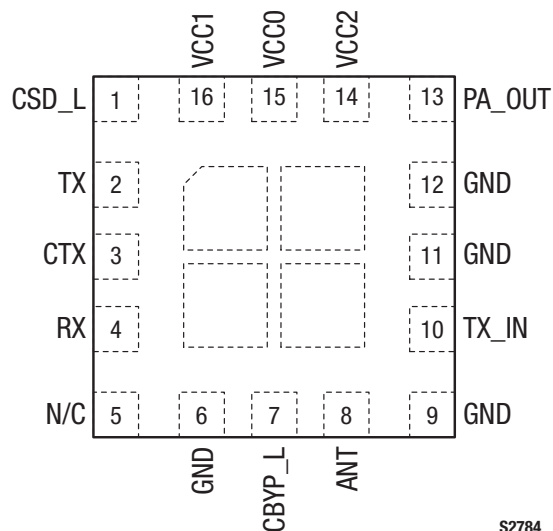

Figure 1. SKY66100-11 FEM Block Diagram

Figure 2. SKY66100-11 Pinout – 16-Pin MCM
(Top View)

Table 1. SKY66100-11 Signal Descriptions

Pin	Name	Description	Pin	Name	Description
1	CSD_L	Control, shutdown/sleep, active low	9	GND	Ground
2	TX	Transmit RF input	10	TX_IN	Transmit input. Externally filtered signal.
3	CTX	Control, transmit modes	11	GND	Ground
4	RX	Receive RF output	12	GND	Ground
5	N/C	No connection	13	PA_OUT	PA output
6	GND	Ground	14	VCC2	Supply for second stage of PA
7	CBYP_L	Control, transmit bypass mode	15	VCC0	Supply for logic, regulator, bias
8	ANT	Antenna I/O	16	VCC1	Supply for first stage of PA

Technical Description

The SKY66100-11 consists of a complete Tx/Rx chain with Tx/Rx switches contained in the module. An SP3T switch selects between receive, transmit, and transmit bypass paths. The module has a shutdown mode to minimize power consumption.

Three digital input control pins (CSD_L, CTX, and CBYP_L) are used to select between shutdown, Tx/Rx, or transmit bypass mode, respectively.

The bypass mode can also be configured to power-down the PA and remove it from the RF path using an internal single-pole, single-throw (SPST) switch.

The transmit path contains a PA optimized for saturated performance. The PA can be passed through an external impedance matching network and harmonic filter before being fed through the SP3T switch. External inductors for each of the two PA stages provide maximum application flexibility.

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY66100-11 are provided in Table 2. The recommended operating conditions are specified in Table 3, and electrical specifications are provided in Tables 4 through 7.

The state of the SKY66100-11 is determined by the logic provided in Table 8.

Typical performance characteristics are shown in Figures 3 through 11.

Table 2. SKY66100-11 Absolute Maximum Ratings (Note 1)

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage (Pins: VCC0, VCC1, VCC2)	V_{CC}	−0.3	+3.8	V
Digital input voltage (Pins: CSD_L, CTX, CBYP_L)	V_{CTL}	−0.5	V_{CC}	V
Receive mode (Pin: ANT)	P_{IN_ANT}		+15	dBm
Transmit mode (Pin: TX)	P_{IN_TX}		−4	dBm
Transmit RF input power, transmit bypass mode (Pin:TX)	P_{IN_TXB}		+20	dBm
Transmit output power	P_{OUT}		+28	dBm
Voltage Standing Wave Ratio	VSWR		10:1	−
Thermal resistance	Θ_{JC}		14.7	°C/W
Operating temperature	T_C	−40	+85	°C
Storage temperature	T_{STG}	−55	+150	°C
Junction temperature	T_J		+150	°C

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.

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. SKY66100-11 Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units
Operating frequency range	f	169		170	MHz
Supply voltage (Pins: VCC0, VCC1, VCC2)	V_{CC}	2.0	3.3	3.6	V
Receive RF input power (Pin: RX)	P_{IN_RX}			−15	dBm
Transmit RF input power, transmit mode (Pin:TX)	P_{IN_TX}		−6		dBm
Transmit RF input power, transmit bypass mode (Pin: TX)	P_{IN_TX}		+15	+20	dBm
Transmit mode duty cycle				50	%

Table 4. SKY66100-11 DC Electrical Specifications (Note 1)
(V_{CC} = +3.3 V, T_C = +25 °C, with Output Matching Network as Noted, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Receive quiescent current (Pins: VCC0, VCC1, VCC2)	I_{Q_RX}	Rx mode (Note 2)		680		μA
Transmit quiescent current (Pins : VCC0, VCC1, VCC2)	I_{Q_TX}	Tx mode		15		mA
Transmit bypass quiescent current (Pins: VCC0, VCC1, VCC2)	I_{Q_TXBYP}	Tx bypass mode (Note 2)		680		μA
Transmit operating current (Pins: VCC0, VCC1, VCC2)	I_{OP_TX}	TX mode: V_{CC} = 3.3 V, P_{OUT} = +24 dBm (Note 3 and Note 5)		210		mA
		V_{CC} = 3.6 V, P_{OUT} = +27 dBm (Note 4)		325		mA
Shutdown current (Pins: VCC0, VCC1, VCC2) (Note 5, Note 6, and Note 7)	I_{SD}	Shutdown/sleep mode		0.02	1.0	μA

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

Note 2: Does not include control pin currents. See Table 7 for more information.

Note 3: Requires EK1 output match network designed for +24 dBm. See Figure 3. Contact Skyworks Application Support for more information.

Note 4: Requires EK2 output match network designed for +27 dBm. See Figure 4. Contact Skyworks Application Support for more information.

Note 5. Not production tested.

Note 6: Shutdown mode functionally verified in production to be less than 1 mA.

Note 7: All controls must be <0.1 V to achieve the specified sleep current.

Table 5. SKY66100-11 Receive Mode Electrical Specifications (Note 1)
(V_{CC} = +3.3 V, T_C = +25 °C, f = 169 to 170 MHz, Characteristic Source and Load Impedance = 50 Ω, CW Input, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Receive Mode: ANT to RX Output Path (Note 2)						
Insertion loss (Note 3)	IL			0.4		dB
1 dB input compression point (Note 4)	IP1dB		+15			dBm
3rd order input intercept point (Note 4)	IIP3		+29			dBm
Input return loss (Note 4)	|S11|		8			dB
Power-on time, RX (Note 4 and Note 5)	T_{ON_RX}	Final mode = RX (see Table 8)		1		μs

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

Note 2: Mode configured according to logic shown in Table 8.

Note 3: Insertion loss increases to 0.9 dB when using an external antenna filter. See Figure 3.

Note 4: Not production tested.

Note 5: Elapsed time is from sleep mode to the final mode indicated in Table 8. A final mode is considered achieved when its corresponding P_{OUT} is at least 90% of its final value.

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Table 6. SKY66100-11 Transmit Mode Electrical Specifications (Note 1) (Note 2)
(V$_{CC}$ = +3.3 V, T$_C$ = +25 °C, f = 169 to 170 MHz, Characteristic Source and Load Impedance = 50 Ω, with Output Matching Network as in Figure 3, CW Input, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Transmit Mode: TX to PA_OUT → TX_IN to ANT Path (Note 3)						
Output power	P$_{OUT}$	V$_{CC}$ = 3.6 V (Note 4) V$_{CC}$ = 3.3 V (Note 5 and Note 6)		+27 +24		dBm dBm
PA power added efficiency (Note 7)	PAE$_{PA}$	At PA_OUT pin (Note 4) At PA_OUT pin (Note 5 and Note 6)		45 55.8		% %
2nd harmonic (Note 6 and Note 8)	2fo				−36	dBm
3rd to 10th harmonics (Note 6 and Note 8)	3fo 4fo 5fo 6fo 7fo 8fo 9fo 10fo				−54 −54 −54 −54 −54 −54 −54 −54	dBm dBm dBm dBm dBm dBm dBm dBm
Input return loss (Note 6 and Note 9)	|S11|	P$_{IN}$ = −30 dBm	8			dB
Output return loss (Note 3 and Note 6)	|S22|	P$_{IN}$ = −30 dBm	6			dB
Non-harmonic spurious power (Note 6, Note 8, and Note 10)		VSWR = 5:1, all phases			−40	dBm
Power-on time (Note 6 and Note 11)	T$_{ON\_TX}$	Final mode = transmit (see Table 8)		2.8		µs
Receive isolation (Note 13)	|S$_{RXTX}$|			12		dB
Transmit Bypass Mode: TX to ANT Path						
Insertion loss (Note 12)	IL	V$_{CC}$ = 3.0 to 3.6 V		0.9		dB
1 dB input compression point (Note 6)	IP1dB		21			dBm
2nd harmonic (Note 6 and Note 8)	2fo	P$_{IN\_TX}$ = +20 dBm			−36	dBm
3rd to 5th harmonics (Note 6 and Note 8)	3fo-5fo	P$_{IN\_TX}$ = +20 dBm			−54	dBm
Input return loss (Note 6 and Note 9)	|S11|		6			dB
Output return loss (Note 3 and Note 6)	|S22|		8			dB
Transition time (Note 6 and Note 11)	t$_{ON}$	Final mode = transmit bypass (see Table 8)		1		µs
Receive isolation	|S$_{RXTX}$|	P$_{IN\_TX}$ = +20 dBm		25		dB

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

Note 2: Mode configured according to logic shown in Table 8.

Note 3: External output matching network and filter located between PA_OUT and TX_IN (pins 13 and 10, respectively).

Note 4: Requires EK2 output match network designed for +27 dBm. See Figure 4. Contact Skyworks Application Support for more information.

Note 5: Requires EK1 output match network designed for +24 dBm. See Figure 3. Contact Skyworks Application Support for more information.

Note 6: Not production tested.

Note 7: Calculated from Evaluation Board test results with loss of output matching network.

Note 8: Final performance dependent on external filter. The 2nd to 10th harmonics are fully characterized but are not production tested.

Note 9: External input matching network.

Note 10: Measurement performed with spectrum analyzer (RBW = 100 kHz for frequencies < 1 GHz and RBW = 1 MHz for frequencies between 1 GHz and 10 GHz).

Note 11: Elapsed time is from sleep mode to the final mode indicated in Table 8. A final mode is considered achieved when its corresponding P$_{OUT}$ is at least 90% of its final value.

Note 12: The insertion loss increases to 2 dB in TX bypass mode with the external input match. The RX bypass is not affected.

Note 13: Includes gain of PA.

Table 7. SKY66100-11 Electrical Specifications: Control Logic Characteristics (Note 1)
(Tc = +25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Control voltage (Note 2): High Low	V_{IH} V_{IL}		1.6 0		V_{CC} 0.7	V V
Input current (Note 3): High Low	I_{IH} I_{IL}	Tc = 25 °C		36 0		μA μA

Note 1: Performance is guaranteed only under the conditions listed in this table. Control logic input signals are: CSD_L, CTX, and CBYP_L.

Note 2: Not production tested.

Note 3: Each control pin has a 100 kΩ pull-down resistor.

Table 8. SKY66100-11 Mode Control Logic (Note 1)

Mode	RF Signal Path Pin → Pin	CSD_L (Pin 1)	CTX (Pin 3)	CBYP_L (Pin 7)
Sleep	(Note 2)	0	X	X
Transmit bypass	TX → ANT	1	1	0
Receive	ANT → RX	1	0	X
Transmit	TX to PA_OUT → TX_IN to ANT	1	1	1

Note 1: "1" = 1.6 to Vcc, "0" = 0 to 0.7 V, "X" = don't care.

Note 2: All I/O are disconnected from internal components.

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Typical Performance Characteristics
(VCC = 3.6 V, f = 169 MHz CW Signal, Unless Otherwise Noted)
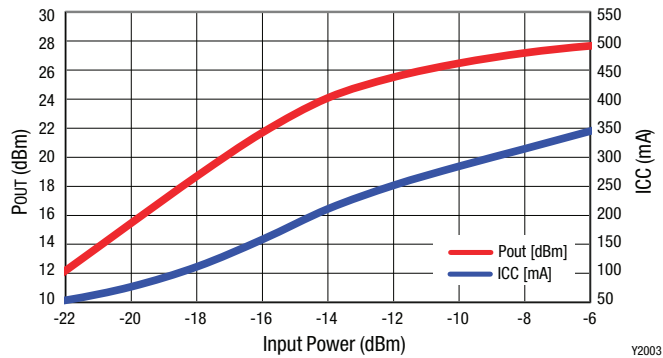
Figure 3. P$_{OUT}$ and ICC vs P$_{IN}$
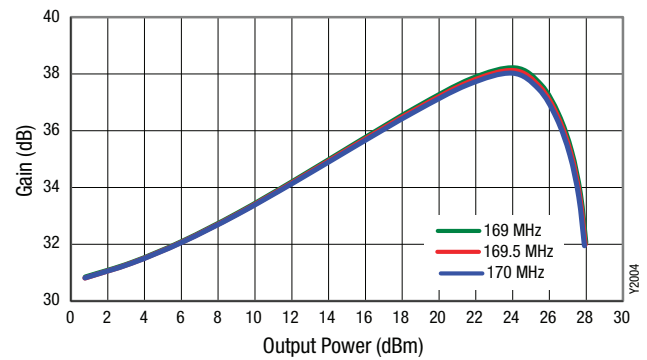
Figure 4. Gain vs. P$_{OUT}$
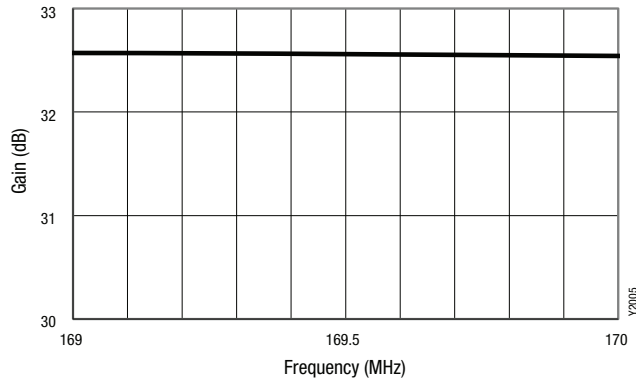
Figure 5. Small Signal Gain vs Frequency
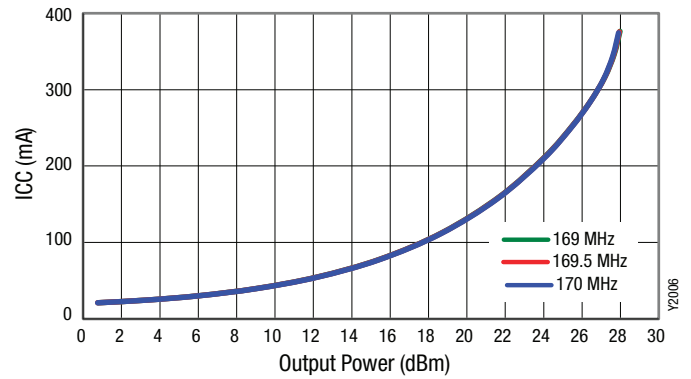
Figure 6. ICC vs P$_{OUT}$
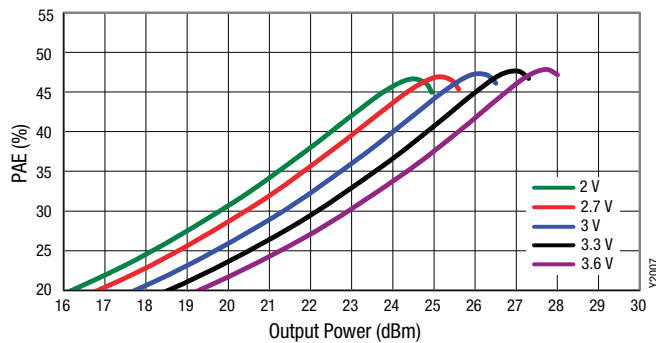
Figure 7. PAE vs P$_{OUT}$ and VCC
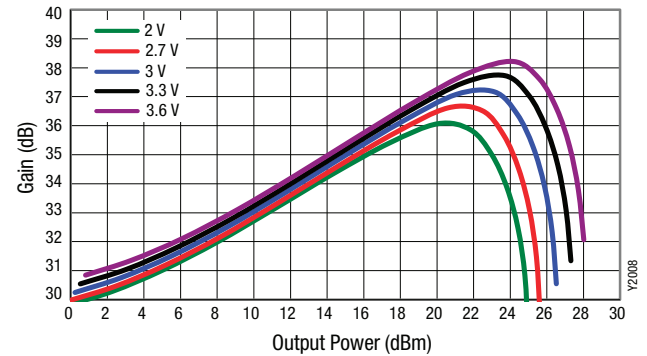
Figure 8. Gain vs P$_{OUT}$ and VCC
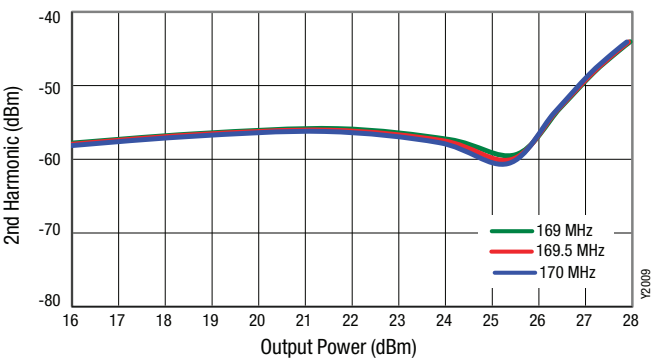
Figure 9. 2nd Harmonic vs POUT
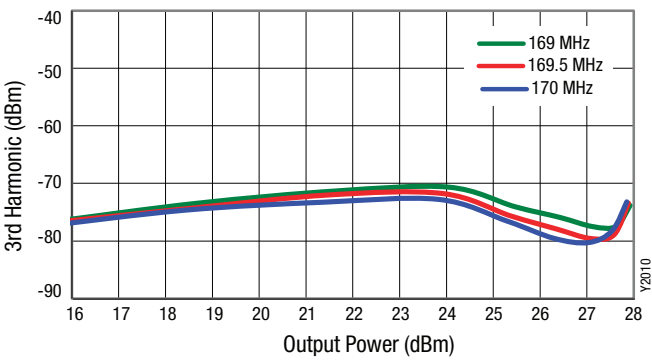
Figure 10. 3rd Harmonic vs POUT
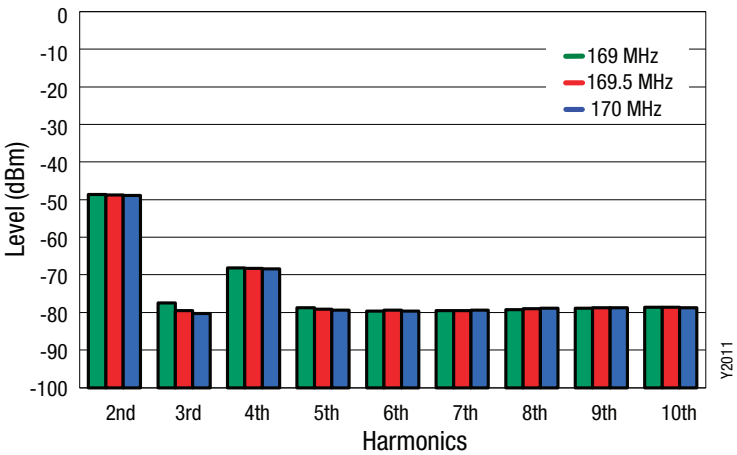
Figure 11. Harmonics at POUT = +27 dBm

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Evaluation Board Description

The SKY66100-11 Evaluation Board is used to test the performance of the SKY66100-11 FEM. Evaluation Board schematic diagrams are provided in Figure 12 (EK-1 board, +24 dBm) and in Figure 13 (EK-2 board, +27 dBm). An assembly drawing for the Evaluation Board is shown in Figure 14.

Package Dimensions

The typical part marking for the SKY66100-11 is shown in Figure 15. The PCB layout footprint for the SKY66100-11 is provided in Figure 16. Figure 17 shows the package dimensions for the 16-pin MCM, and Figure 18 provides the tape and reel dimensions.

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 SKY66100-11 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 the 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.
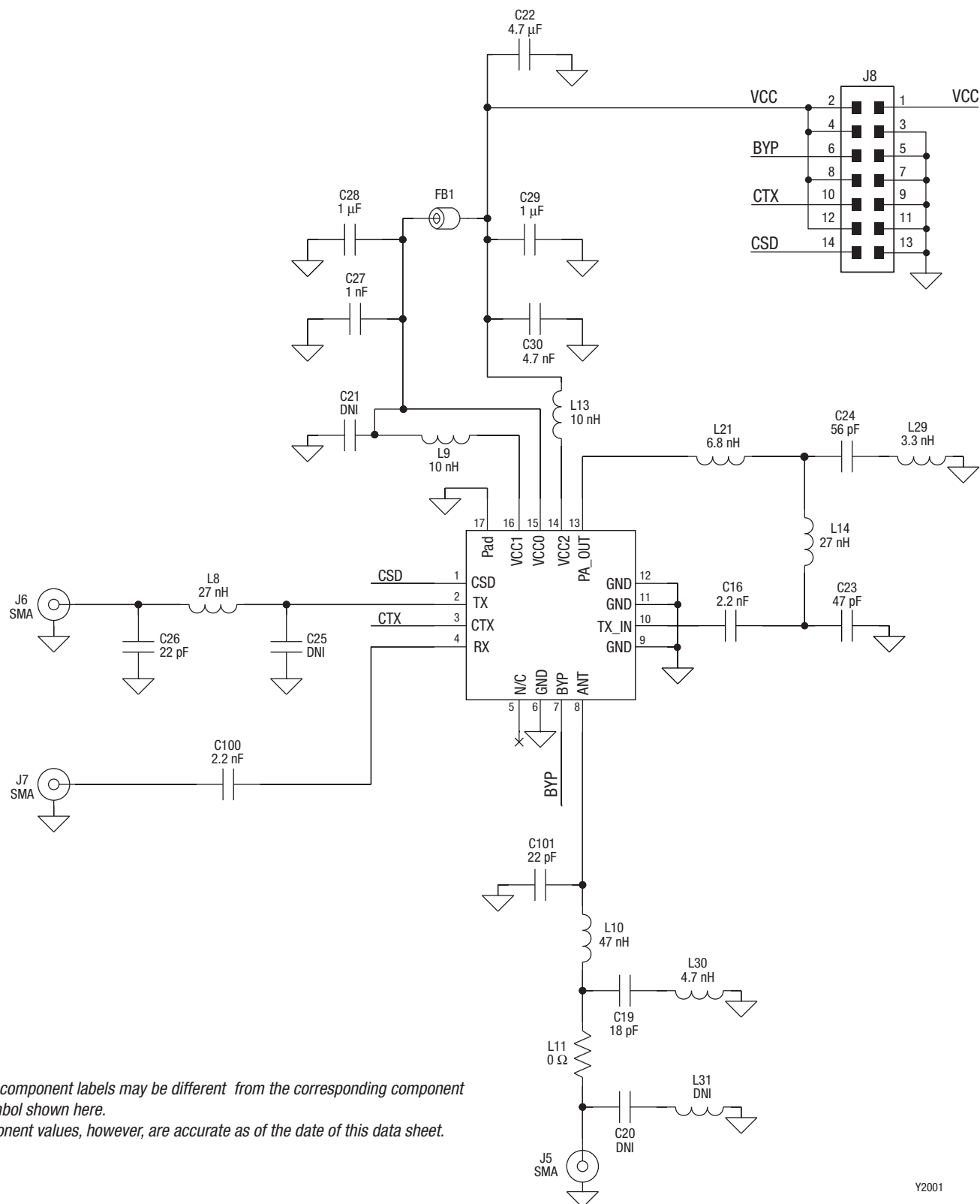
Figure 12. SKY66100-11 EK-1 Evaluation Board Schematic (+24 dBm)

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.

Y2001

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Figure 13. SKY66100-11 EK-2 Evaluation Board Schematic (+27 dBm)

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.

Y2002
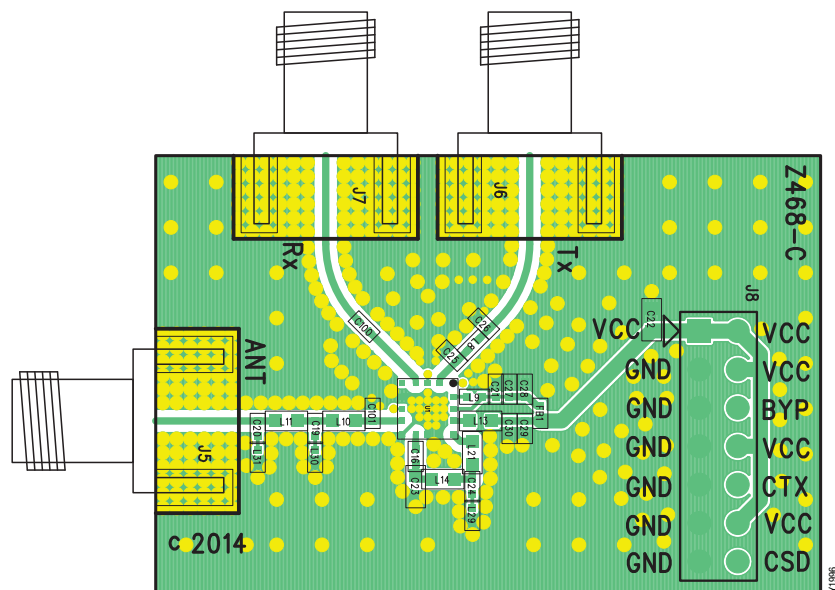
**Figure 14. SKY66100-11 Evaluation Board Assembly Drawing
(Applies to both EK-1 and EK-2 Evaluation Boards)**

PCB Recommendations

Recommendations for 4-layer PCB:

- Metal Layer 1 = RF traces + control lines.

- Metal Layer 2 = Solid ground plane. No traces routing. Use vias to ground under the FEM as recommended in Figure 5.

- Metal Layer 3 and 4 = Control lines + VCC traces (no VCC plane).

- Pour copper on each layer connected to the ground plane. Use VCC traces in a star distribution pattern.

Recommendations for 2-layer PCB:

- Metal Layer 1 = RF traces + control lines + VCC.

- Metal Layer 2 = Solid ground plane between the transceiver and the FEM up to the antenna, no traces routing in that area. Use vias to ground under the FEM as recommended in Figure 5.

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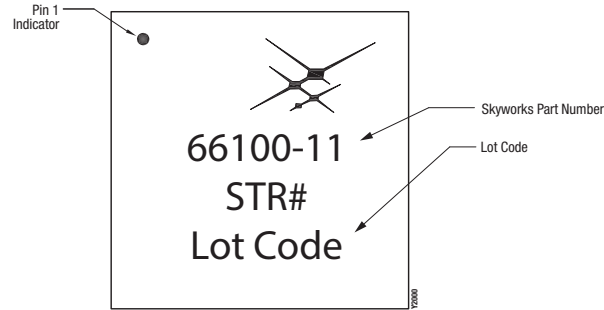
Figure 15. Typical Part Marking

Stencil aperture size for center ground pads should be 80% to 100% (by area) of the solder mask opening of the package.

Stencil Aperture
Top View

SMT Pad Detail
Scale: 2X
3X This Rotation
3X Rotated 180°
5X Rotated 90° CW
5X Rotated 90° CCW

Thermal Via Array. ∅0.3 mm on 0.6 mm pitch. Additional vias in common ground pad improve thermal and electrical performance.

Metallization
Top View

Solder Mask Opening
Top View

Notes:

1. The cross-hatched area represents the merger of the center ground pad +4 individual I/O ground pads. All I/O ground pads should have at least one via connected to internal ground planes for optimum electrical performance.

2. Thermal vias should be tented with solder mask, 30 to 35 mm Cu plating recommended.

3. All measurements are in millimeters

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Figure 16. PCB Layout Footprint for the SKY66100-11 4 x 4 mm MCM
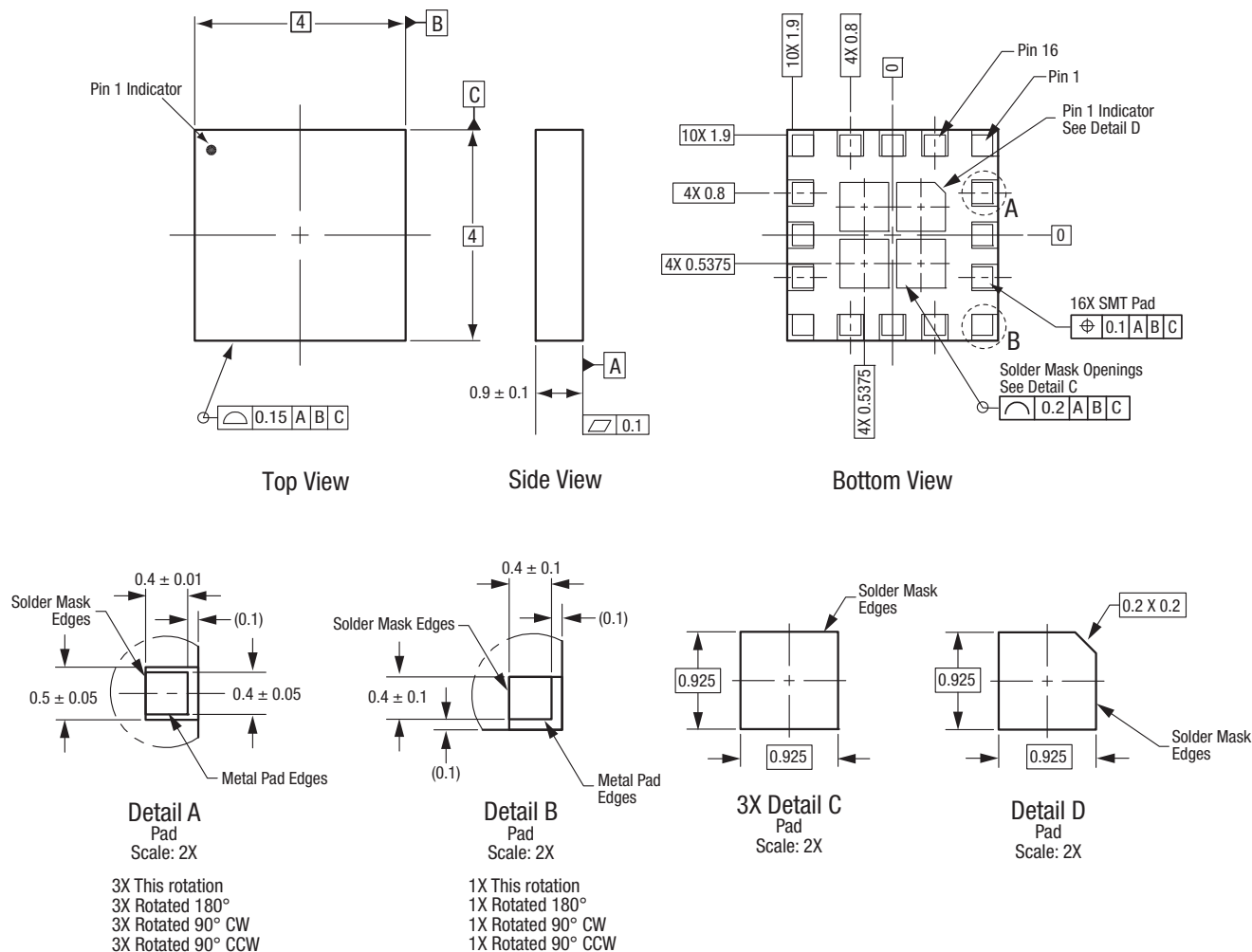
Figure 17. SKY66100-11 16-Pin MCM Package Dimensions

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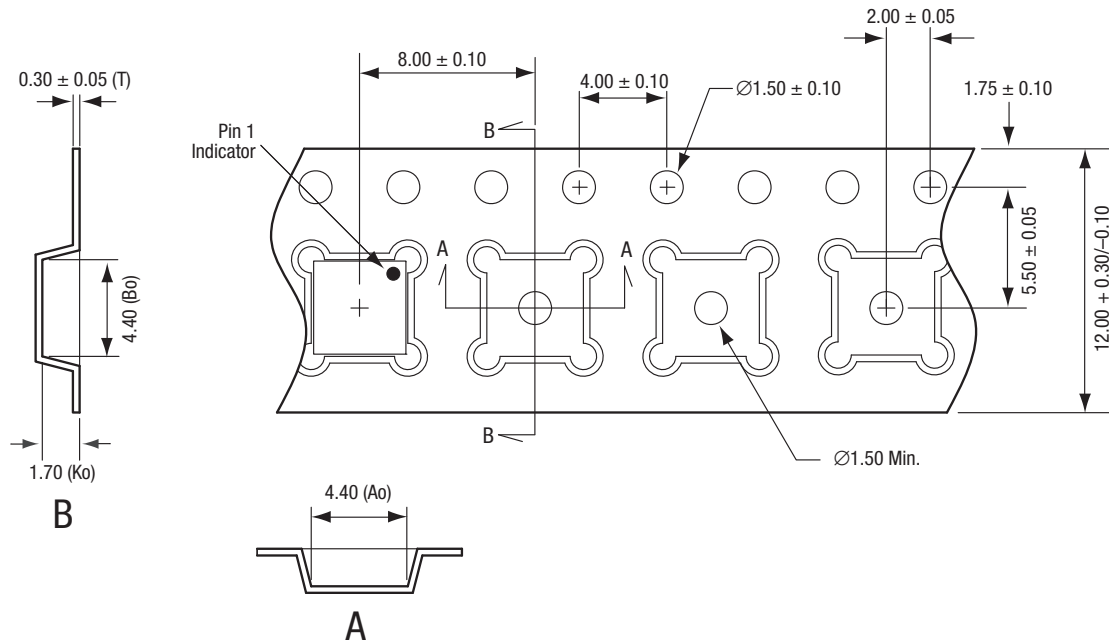
Notes:
1. Carrier tape material: black conductive polycarbonate or polystyrene.
2. Cover tape material: transparent conductive PSA.
3. Cover tape size: 9.3 mm width.
4. Ten sprocket hole pitch cumulative tolerance: ±0.20 mm.
5. Ao and Bo measured on plane 0.30 mm above the bottom of the pocket.
6. Typical ESD surface resistivity is ≤1 x 10^{10} Ohms/square per EIA, JEDEC tape and reel specification.
7. All measurements are in millimeters

S2031

Figure 18. SKY66100-11 Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Number
SKY66100-11 TX/RX FEM (+24 dBm)	SKY66100-11	SKY66100-11-EK1
SKY66100-11 TX/RX FEM (+27 dBm)	SKY66100-11	SKY66100-11-EK2