DATA SHEET

SKY87020-12: Power Management IC for the SkyBlue™ System

Applications

- Smartphones
- 3G/4G multimode front-end modules
- Tablets, eBook readers
- Wireless data cards

Features

- Input voltage range: 2.5 V to 5.5 V
- High-efficiency converter:
  – Output voltage range optimized for SkyBlue™ PA operation
- 4.5 V, 3 mA PA bias supply output:
  – IC disable VIN bypass
- Over-temperature and short-circuit protection
- Small footprint CSP (16-ball, 2.005 mm × 2.005 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.

Description

The SKY87020-12 is a high-efficiency RF front-end power management IC for APT RF power amplifier (PA) applications in portable battery powered devices. This IC includes a high-efficiency DC-DC voltage converter with a 4.5 V reference supply to provide a user-programmable RF PA APT supply for a 2.5 V to 5.5 V input range.

The SKY87020-12 also provides an additional 4.5 V bias supply for RF PA operation. This bias voltage output can supply load currents up to 3 mA and is available whenever the device is enabled. When the device is disabled, the VIN supply is bypassed to the 4V5 output.

The SKY87020-12 is available in a 16-pin, 2.005 mm × 2.005 mm Chip Scale Package (CSP) package.

A typical application circuit is shown in Figure 1. The pin configuration is shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

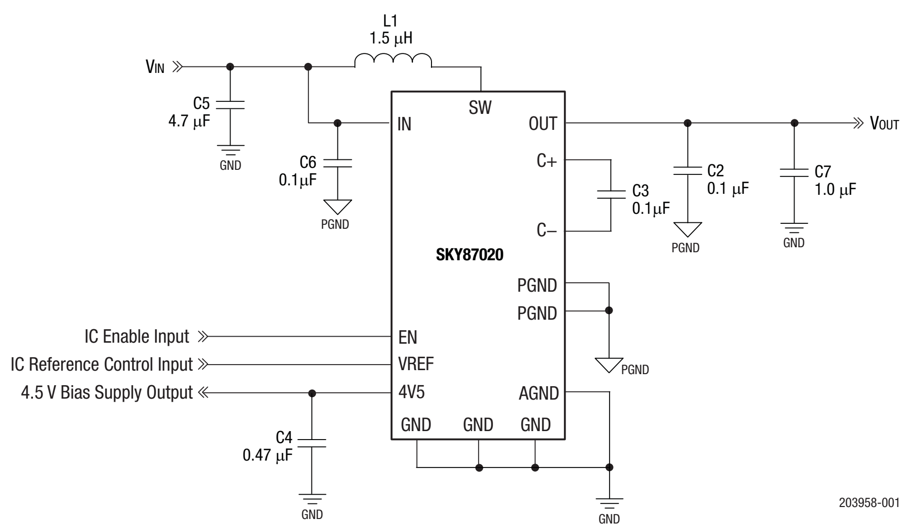

Figure 1. Typical Application Circuit (Programmable Output)

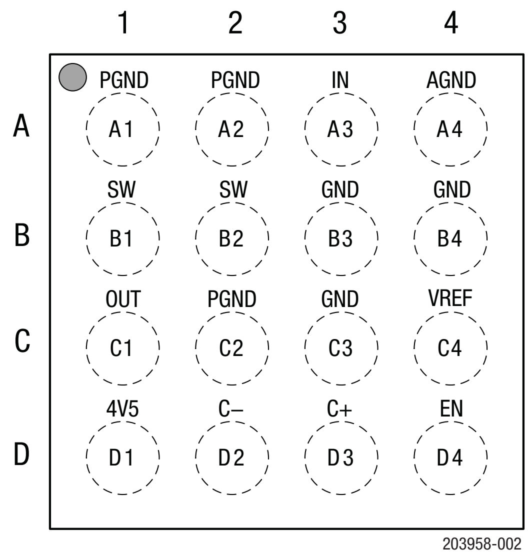

Figure 2. SKY87020-12 Pinout (Top View)

Table 1. SKY87020-12 Signal Pin Assignments and Descriptions

Pin	Name	Description
A1, A2	PGND	Power ground.
A3	IN	Input supply voltage connection. Bypass with a 4.7μF or greater value ceramic capacitor placed between the power supply input to the L1 inductor input and AGND. Place an additional 0.1μF ceramic bypass capacitor between the IN pin and PGND.
A4	AGND	Analog/signal ground.
B1, B2	SW	Inductor connection. Connect a 1.5 or 2.2 μH inductor between this pin and the input source power supply.
B3, B4, C3	GND	Ground termination. Ground pins should be connected to AGND.
C1	OUT	Regulated voltage output pin. Bypass the regulated output supply pin with a 1.0 μF ceramic capacitor to AGND and a 0.1 μF ceramic capacitor to PGND.
C2	PGND	Power ground.
C4	VREF	IC Reference control input pin. Connect this pin to the system VREF control output to set IC operating state.
D1	4V5	4.5 V Regulated bias supply output. Bypass this supply output with a 0.47 μF ceramic capacitor connected between this pin and AGND.
D2	C-	Capacitor connection. Connect a 0.1 μF ceramic capacitor between this pin and C+.
D3	C+	Capacitor connection. Connect a 0.1 μF ceramic capacitor between this pin and C–.
D4	EN	IC Enable input pin. Connect this pin to the system enable control output.

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY87020-12 are provided in Table 2, the thermal information is listed in Table 3, and electrical specifications are provided in Table 4.

The RF front-end system is controlled by the MIPI RFFE control interface. Table 5 shows the register map, which outlines functions and controls that are accessible through the MIPI RFFE control interface to manage the SKY87020-12 PMIC.

Figure 3 shows a functional block diagram of the SKY87020-12.

Figures 4 through 11 show the typical performance characteristics for the SKY87020-12 at T_A = –30 °C to 85 °C, and typical values are for T_A = 25 °C.

Table 2. Absolute Maximum Ratings[1]

Parameter	Symbol	Minimum	Maximum	Units
IN supply	V_{IN}	–0.3	6.0	V
SW, OUT	V_{SW}, V_{OUT}	–0.3	12	V
C+, C–, 4V5	V_{C+}, V_{C-}, V_{4V5}	–0.3	V_{IN} + 0.3	V
EN, VREF	V_{EN}, V_{VREF}	–0.3	6.0	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 nominal value. Exceeding any of the limits listed may result in permanent damage to the device.

Table 3. SKY87020-12 Thermal Information

Parameter	Symbol	Minimum	Typical	Maximum	Units
Operating junction temperature range	T_J	–30		150	°C
Storage temperature range	T_{STG}	–65		150	°C
Maximum soldering temperature (@ ball, 10 sec)	T_{BALL}			300	°C
16-Ball 2.005 mm × 2.005 mm CSP Thermal Impedance					
Junction to ambient thermal resistance[1]	θ_{JA}		81		°C/W
Junction to package top thermal difference	Ψ_{JT}		6		°C/W
Junction to board thermal difference	Ψ_{JB}		34		°C/W
Maximum power dissipation[2]	P_D		1.54		W

[1] The thermal resistance is measured in accordance with EIA/JESD 51 series.
[2] When T_A = 25 °C

ESD HANDLING: *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 when handling or transporting. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD handling precautions should be used at all times.*

Table 4. SKY87020-12 Device Electrical Characteristics[1] (1 of 2)
(V_{CC} = 3.8 V, V_{OUT} = 9.5 V, C1 = 4.7 µF, C2 = 1.0 µF, C3 = C5 = C6 = 0.1 µF, C4 = 0.47 µF, L1 = 1.5 µH, T_A = –30 °C to +85 °C, Unless Otherwise Noted. T_A = 25 °C [Typical])

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
General Operating Conditions						
Input voltage range	V_{IN}		2.5	3.8	5.5	V
No load supply current	I_Q	Bypass mode, EN = V_{IN}; no load (I_{OUT} = 0 A)		0.45		mA
		Step-Up mode, VREF = 2.00 no load (I_{OUT} = 0 A), Switching		13		
Shutdown current	I_{SHDN}	EN = AGND = PGND		0.1	1	µA
DC-DC Step-Up (Boost) Regulator						
Output voltage range	V_{OUT}	EN = V_{IN}; V_{REF} = 0.52 to 2.32	2.5		11	V
Output voltage accuracy	$V_{OUT[TOL]}$	EN = V_{IN}; V_{REF} = 2.0 V, I_{LOAD} = 110 mA	–1.5		1.5	%
Output load current	I_{OUT}			110	300	mA
Switching current limit	$I_{LIM(SW)}$	T_A = 25 ºC		2.5	2.7	A
Switching frequency	f_{OSC}	No load, T_A = 25 ºC		1.8	2.25	MHz
Maximum boost switching duty cycle	D_{MAX}			90		%
Line regulation	$\Delta V_{OUT}/V_{OUT}/\Delta V_{IN}$	V_{IN} = 5.5 V to 2.5 V, V_{OUT} = 9.5 V (V_{REF} = 2.0 V), I_{LOAD} = 110 mA		0.02		%/V
Load regulation	$\Delta V_{OUT}/V_{OUT}$	V_{IN} = 3.8 V, I_{LOAD} = 30 to 110 mA		1.15	2.0	%
Over voltage protection threshold	V_{OVP}		11.5		11.9	V
PMOS synchronous switch on-resistance	$R_{DS[ON]H}$	V_{IN} = 3.8 V, V_{OUT} = 9.5 V; T_A = 25 °C		280		mΩ
NMOS low-side switch on resistance	$R_{DS[ON]L}$	V_{IN} = 3.8 V,V_{OUT} = 9.5 V; T_A = 25 °C		150		mΩ
Turn-on time	$t_{SS[ON]}$	V_{IN} = 3.8 V; EN transition low to high, V_{OUT} = 0 to 90% of 3.8 V, I_{LOAD} = 10 mA			60	µs
Output switching ripple	V_{OUT_RIPPLE}	V_{IN} = 3.8 V, V_{REF} = 2.0 V, I_{LOAD} = 110 mA			100	mVpp

Table 4. SKY87020-12 Device Electrical Characteristics[1] (2 of 2)
(V_{CC} = 3.8 V, V_{OUT} = 9.5 V, C1 = 4.7 µF, C2 = 1.0 µF, C3 = C5 = C6 = 0.1 µF, C4 = 0.47 µF, L1 = 1.5 µH, T_A = –30 °C to +85 °C, Unless Otherwise Noted. T_A = 25 °C [Typical])

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
2G Mode Output Operation (4.5 V output)						
2G mode output voltage	V_{OUT2G}	2.5 V ≤V_{IN} < 3.2 V, V_{REF} = 0 V, I_{LOAD} = 50 mA	3.0	3.2		V
2G mode output current	I_{OUT2G}	V_{REF} = 0 V			50	mA
2G mode boost supply over voltage protection threshold	OVP_{2G}	V_{IN} = 3.2 V; V_{REF} = 0 V	4.5		5.4	V
Step-Down Voltage Operation						
Output voltage	V_{OUT}	V_{IN} = 3.8 V; I_{LOAD} = 30 mA	1.5	1.8	2.0	V
		V_{IN}≤ 3.2 V (step-down bypass mode)		VIN		
Maximum output load current	I_{LOAD}				30	mA
4.5 V Bias Supply Regulator						
Output voltage range	V_{OUT}	EN = V_{IN}	4.4	4.5	5.5	V
Output operating current	I_{OUT}	2.5 V < V_{IN} ≤ 4.5 V		1.5	3	mA
Line regulation	$\Delta V_{OUT}/V_{OUT}/\Delta V_{IN}$	V_{IN} = 2.5 V to 4.4 V, V_{OUT} = 4.5 V; no load		2		%/V
Load regulation	$\Delta V_{OUT}/V_{OUT}$	V_{IN} = 3.8 V, I_{LOAD} = 0 to 3 mA			3	%
Output switching ripple	V_{OUT_RIPPLE}	V_{IN} = 3.8 V, I_{LOAD} = 3 mA			150	mV_{PP}
Enable and Control						
Enable threshold low	$V_{EN(L)}$	2.5 V ≤ V_{IN} ≤ 5.5 V			0.4	V
Enable threshold high	$V_{EN(H)}$	2.5 V ≤ V_{IN} ≤ 5.5 V	1.4			
Enable input leakage current	$I_{EN[LEAK]}$	EN = V_{IN} = 3.8 V		20		µA
Reference input voltage range	V_{REF}		0		2.32	V
Reference gain	A_{VREF}	V_{REF} to V_{OUT} gain		4.75		V/V
Protection Features						
Under voltage lock-out threshold	$V_{UVLO(TH)}$	V_{IN} rising, latch off			2.49	V
Over temperature shutdown threshold	t_{SHDN}	Temp. rising, latch off		150		ºC

[1] Performance is guaranteed only under the conditions listed in this table.

Table 5. SKY87020-12 MIPI RFFE 2.0 Control (1 of 2)

Register Class	Register Address (hex)	Register Name	Data Bits	Default	Bit Name	Description	
STATIC PMIC CONTROL	0x00	STATIC_ PMIC_ CONFIG0	7	0	Reserved	Reserved per RFFE standard	
			6:3	0000	Reserved	Reserved. Set to 0, not hardware accessible	
			2:0	000	PMIC Operating Mode	0x0: Disable 0x1: Standby (forced bypass) 0x2: Enable 3G/4G Mode 0x3: Enable 2G mode 0x4: Enable 3G/4G Mode 0x5: Disable	
VREF CONTROL	0x01	VREF_ CONFIG0	8	00111000	Vcc_VREF	VREF output select, default value 0x38	0x00-0x22: 0.32 V 0xFF: 100% full scale
RFFE Reserved	0x1A	RFFE STATUS	7	0	Software Reset	Reset all configurable registers to default values except for USID, GSID and PM_TRIG. RFFE status is reset after read	0x0: Normal Operation 0x1: Software Reset
			6	0	COMMAND_FRAME_PARITY_ ERR	Command sequence received with parity error – discard command	0x0: Normal Operation 0x1: Error
			5	0	COMMAND_LENGTH_ERR	Command length error - RFFE status is reset after read	0x0: Normal Operation 0x1: Error
			4	0	ADDRESS_FRAME_PARITY_ ERR	Address frame with parity error - RFFE status is reset after read	0x0: Normal Operation 0x1: Error
			3	0	DATA_FRAME_PARITY_ERR	Data frame with parity error - RFFE status is reset after read	0x0: Normal Operation 0x1: Error
			2	0	READ_UNUSED_REG	Read command to an invalid address - RFFE status is reset after read	0x0: Normal Operation 0x1: Read
			1	0	WRITE_UNUSED_REG	Write command to an invalid address - RFFE status is reset after read	0x0: Normal Operation 0x1: Write
			0	0	BID_GID_ERR	Read command with a BROADCAST_ID or GROUP_ID - RFFE status is reset after read	0x0: Normal Operation 0x1: Read
	0x1B	Group SID	7:4	0000	Reserved		
			3:0	0000	GSID		

Table 5. SKY87020-12 MIPI RFFE 2.0 Control (2 of 2)

Register Class	Register Address (hex)	Register Name	Data Bits	Default	Bit Name	Description
RFFE Reserved	0x1C	RFFE Power Mode and Trigger	7:6	10	Software Reset	0x0: Normal Mode (ACTIVE) 0x1: Default Setting (STARTUP) 0x2: Low Power Mode 0x3: Reserved
			5	0	Trigger Mask 2	0x0: Data writes are masked 0x1: Data writes go directly to register
			4	0	Trigger Mask 1	0x0: Data writes are masked 0x1: Data writes go directly to register
			3	0	Trigger Mask 0	0x0: Data writes are masked 0x1: Data writes go directly to register
			2	0	Trigger 2	0x0: No action 0x1: Data transferred from shadow register to active register
			1	0	Trigger 1	0x0: No action 0x1: Data transferred from shadow register to active register
			0	0	Trigger 0	0x0: No action 0x1: Data transferred from shadow register to active register
	0x1D	Product ID	7:0	10100000	Product ID [7:0]	PROD ID=0xA0 When PMIC is connected to the following PAs: SKY78113 SKY78130 SKY78132 PROD ID=0x00 When PMIC is connected to the following PA: SKY77658-11
	0x1E	Manufacturer ID		10100101	Manufacturer ID LSB [7:0]	MFR ID: 0x1A5
	0x1F	Manufacturer and User ID	7:6	00	Reserved	
			5:4	01	Manufacturer ID MSB [9:8]	MFR ID: 0x1A5
			3:0	0100	USID	USID = 0x04 when PMIC is connected to the following PAs: SKY77658-11 SKY78113 SKY78132
				0101		USID = 0x05 when PMIC is connected the following PA: SKY78130

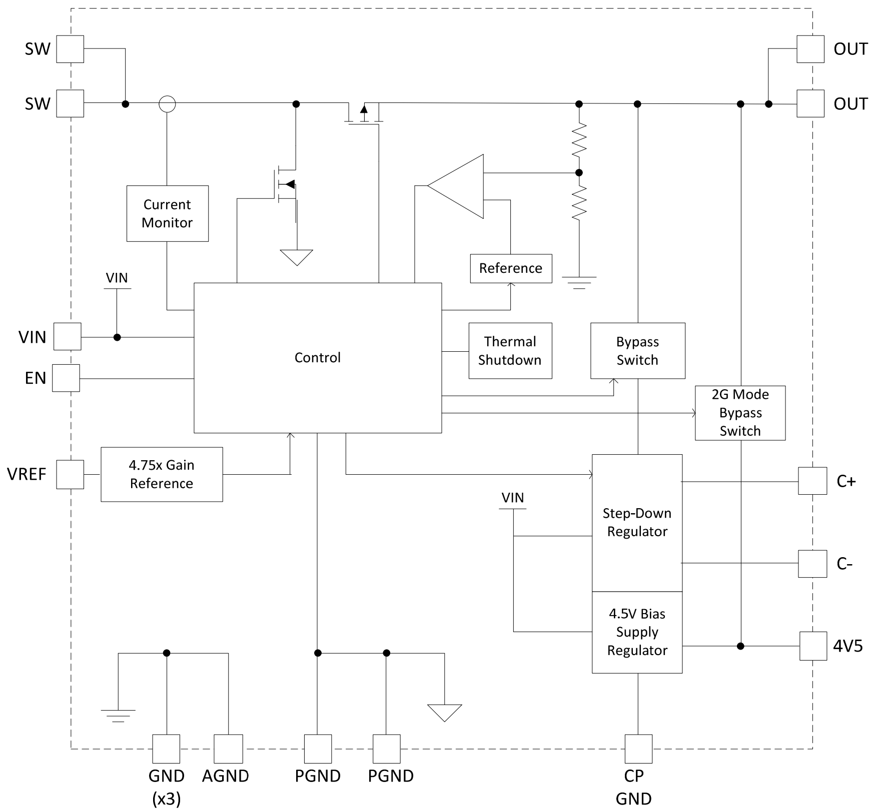

Figure 3. SKY87020-12 Functional Block Diagram

Functional Description

The SKY87020-12 has three main functional blocks, a DC-DC boost converter, a 4.5 V charge pump boost converter and a non-regulating charge pump voltage divider. The operation of each block is conditional on the applied input supply voltage (VIN) and the controlling reference input signal level (VREF). There are output operating voltage states that can be set by the applied VREF signal that cannot be supported by either the DC-DC boost or divide-by-2 charge pump. In these cases, the device output will default to bypass the input supply from VIN to OUT. The theory of the device and system operation is to always supply the requested voltage or greater to the load circuit (SkyBlue™ PA). To support 2G PA operation, the SKY87020-12can supply a 3.2 V bias supply when the system supply voltage drops to or below 3.2 V.

DC-DC Boost Converter Section

DC-DC boost converter can supply a boost output voltage from 2.5 V to 11.0 V from a 2.5 V to 5.5V input supply range and supports load current levels up to 300 mA. Step-Up power conversion is achieved through a multimode PFM/PWM control architecture to achieve the maximum possible boost mode efficiency over the varied input and output voltage and load current conditions. The high 1.8 MHz switching frequency operation permits fast transient response and is capable of wide duty cycle ranges up to 90%. The switching frequency is reduced to 1.4 MHz (typical) when VOUT is set to levels below 7 V to save IC operating quiescent current at low output voltage/light load conditions to improve power conversion efficiency. To simplify the operation and use, the switching regulator is internally compensated to eliminate the need for additional external compensation network components. The high switching frequency is optimized to reduce external components sizes and values (1.5 µH inductor typical with 4.7 uF input/1.0 uF output capacitors) for space constrained applications. Upon IC enable, the output capacitor will be charged to the level of VIN in less than 60 µs to aid in fast output voltage step response timing.

The Boost converter has a quick-start circuit to support fast voltage step response at IC start-up and at any time the applied VREF signal causes the boost output step-up to increase by 1V or more. To achieve <20 µs voltage step timing with a 1.0 µF output capacitor, the boost quick-start circuit allows peak inductor current to flow at the over current limit threshold (2.5 A typical, 2.7 A maximum) level for several switch mode clock cycles to speed charging of the output capacitor. For this reason an inductor must be used with a saturation current rating equal to or greater than the specified over current protection threshold level (2.7 A maximum).

Typical Performance Characteristics

(V_{CC} = 3.8 V, V_{OUT} = 9.5 V, C1 = 4.7 µF, C2 = 1.0 µF, C3 = C5 = C6 = 0.1 µF, C4 = 0.47 µF, L1 = 1.5 µH, T_A = –30 °C to +85 °C, Unless Otherwise Noted. T_A = 25 °C (Typical))

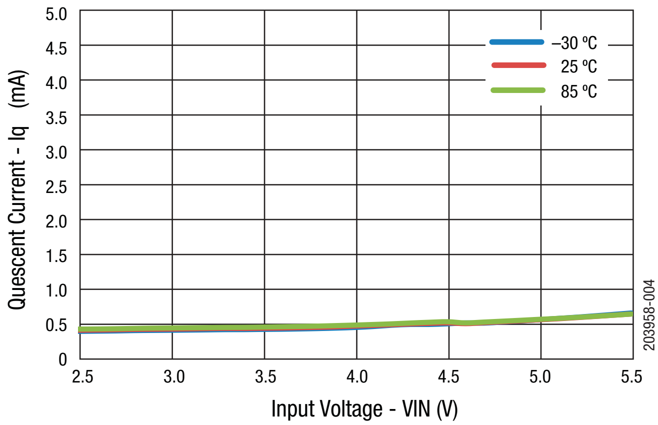

Figure 4. Bypass Mode Quiescent Current vs Input Voltage over Temperature (V_{OUT} = V_{IN})

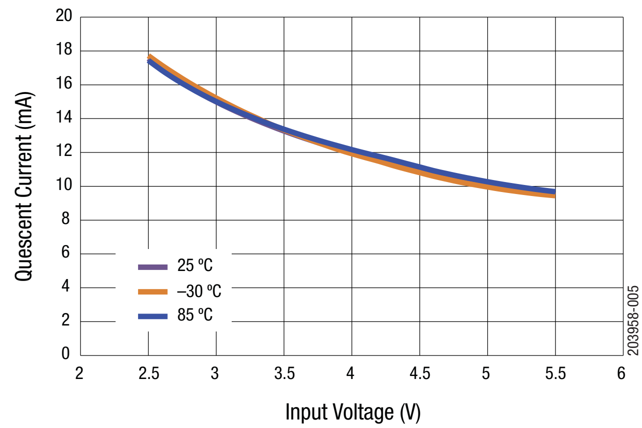

Figure 5. Switch Mode Quiescent Current vs Input Supply over Temperature (V_{OUT} = 9.5 V)

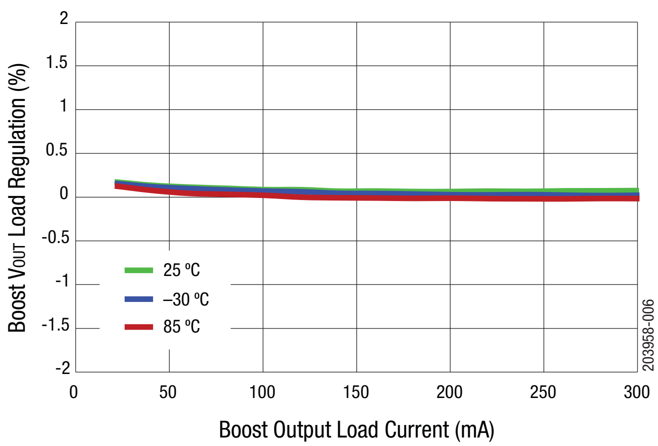

Figure 6. DC-DC Boost Regulator Load Regulation over Temperature

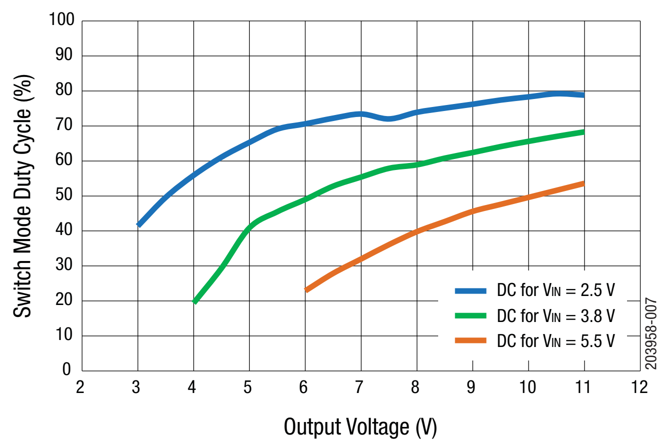

Figure 7. DC-DC Boost Switching Duty Cycle vs Output Voltage over Temperature

Typical Performance Characteristics

(V_{CC} = 3.8 V, V_{OUT} = 9.5 V, C1 = 4.7 μF, C2 = 1.0 μF, C3 = C5 = C6 = 0.1 μF, C4 = 0.47 μF, L1 = 1.5 μH, T_A = –30 °C to +85 °C, Unless Otherwise Noted. T_A = 25 °C (Typical))

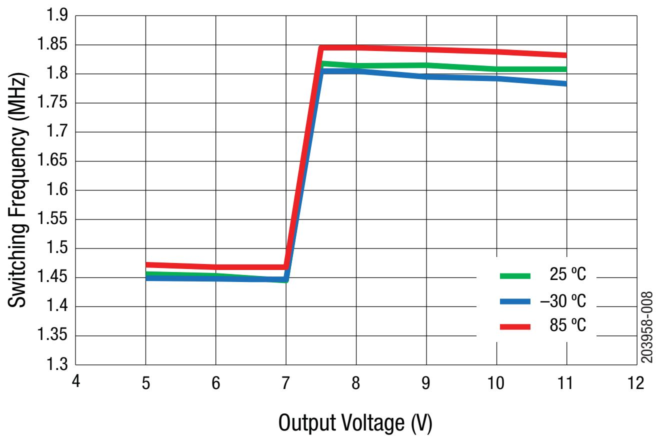

Figure 8. Switching Frequency vs Output Voltage over Temperature (V_{IN} = 3.8 V, I_{LOAD} = 100 mA)

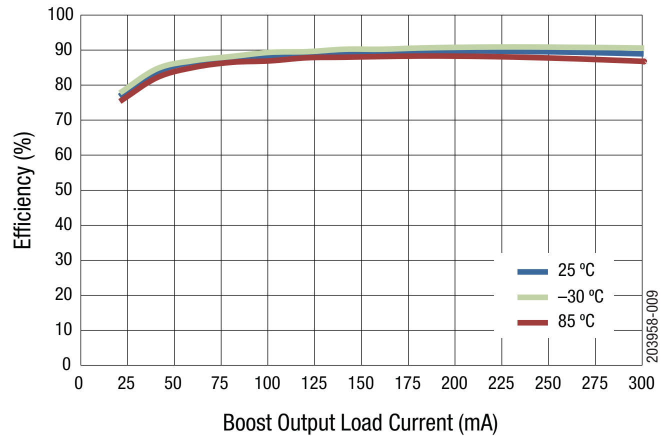

Figure 9. DC-DC Boost Efficiency vs Load Current over Temperature (V_{IN} = 3.8 V, V_{OUT} = 9.5 V)

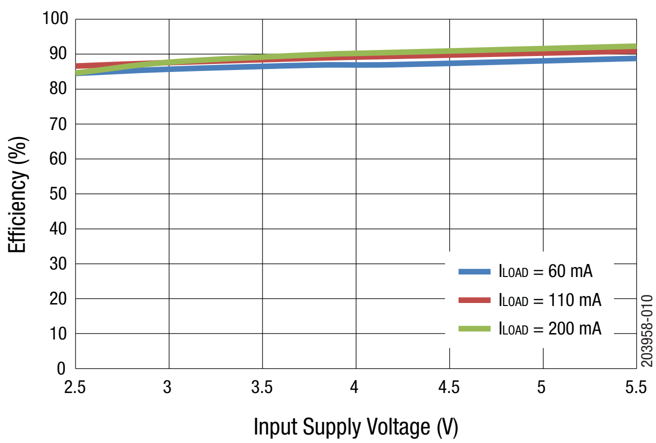

Figure 10. DC-DC Boost Efficiency vs Input Supply (V_{OUT} = 9.5 V)

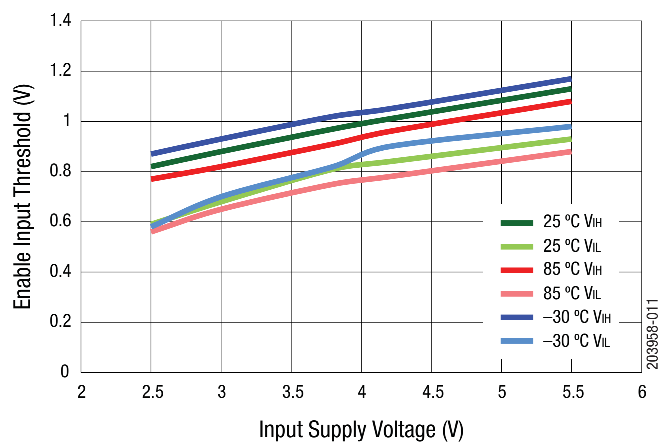

Figure 11. Enable Input Threshold vs Input Supply Voltage over Temperature

Application Connection Schematic Description

A typical application connection schematic diagram is provided in Figure 12. Component values for the SKY87020-12 application connection schematic are listed in Table 6.

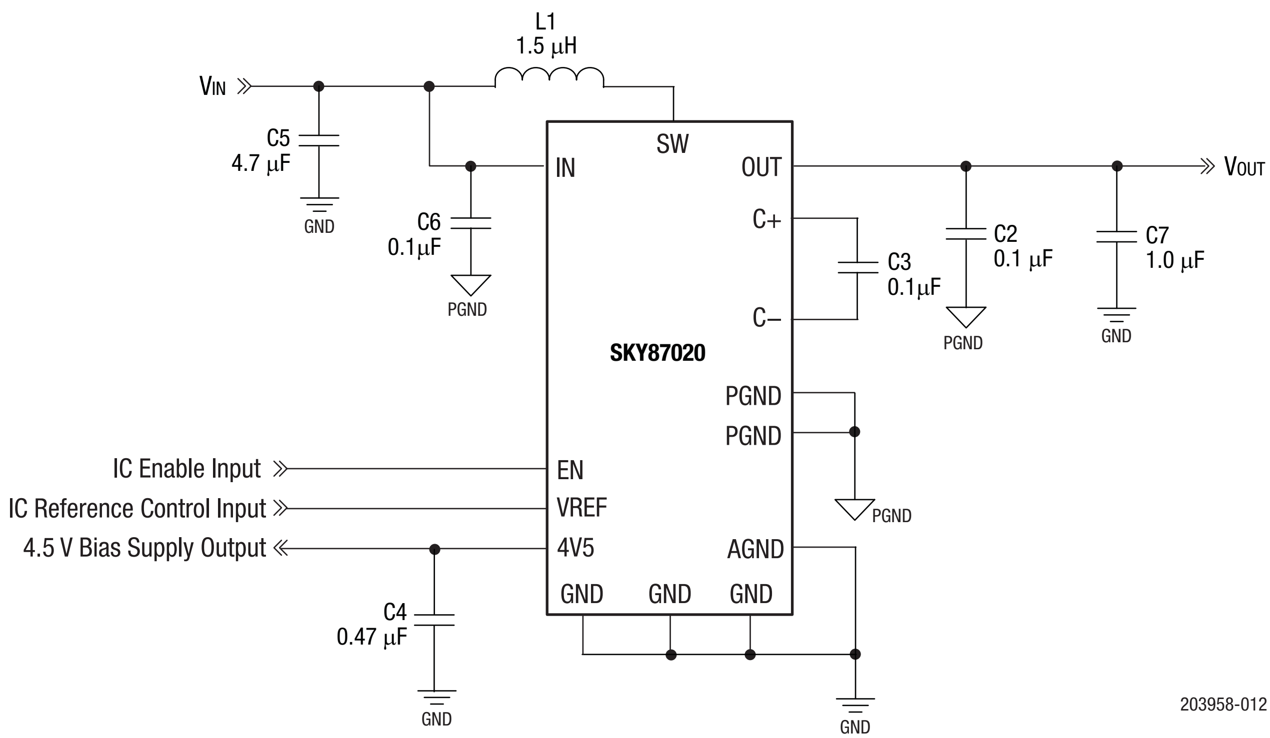

Figure 12. SKY87020-12 Typical Application Connection Schematic

Table 6. Recommended Components Selection

Component	Reference Designator	Details	Part Number
Power inductor	L1	1.5 µH, 76 mΩ (or lower) DCR, 2520	TFM252010GHM-1R5MTAA (TDK) or DFE252010F-1R5M (TOKO)
		2.2 µH, 97 mΩ (or lower) DCR, 2520	DFE252010F-2R2M (TOKO)
OUT bypass capacitor	C2	0.1 µF, 0402, X5R, 25 V	C1005X5R1E104K050BC (TDK)
Flying capacitor	C3	0.1 µF, 0402, X5R, 10 V	C1005X5R1A104K050BA (TDK)
4.5 V supply capacitor	C4	0.47 µF, 0402, X5R, 10 V	C1005X5R1A474K050BB (TDK)
Input capacitor	C5	4.7 µF, 0603, X5R, 10 V	C1608X5R1A475K080AC (TDK)
IN bypass capacitor	C6	0.1 µF, 0201, X5R, 10 V	C0603X5R1A104K030BC (TDK)
Output capacitor	C7	1.0 µF, 0603, X6S, 25 V	C1608X6S1E105K080AB (TDK)

PCB Layout Recommendations

The DC-DC converter PCB layout should follow these recommendations to achieve optimum performance for the system:

- The IC pinout and external component placement has been arranged so the power flow is from left to right on the layout and all RF PA interconnections can be made from the right side on the IC on the top layer
- All external components should be placed as close as possible to the IC pin connections.
- Power ground must be placed on a bottom, middle layer, or power ground layer on a multi-layer PCB Layout. It is preferable to have the power ground plane/layer on the mid/inner layer 1 right below the top layer.
- The IC PGND, input capacitor (C6), and output capacitor (C2) should all be connected to a power ground island with as many interconnecting vias as possible to achieve the lowest connection impedance between the circuit nodes.
- The power ground island should then be connected to the system power return at a single point to maintain maximum switching noise isolation to adjacent circuits.
- The input capacitor (C5), 4V5 capacitor (C4), and output capacitor (C7) should be connected to the system ground plane common with the RF PA system grounding.
- Ferrite beads may also be added in series with the VBATT supply input, output (OUT) and bias supply output (4V5 output) to further reduce high frequency noise into and out of this power supply circuit.

Figure 13 shows the recommended PCB layout with components.

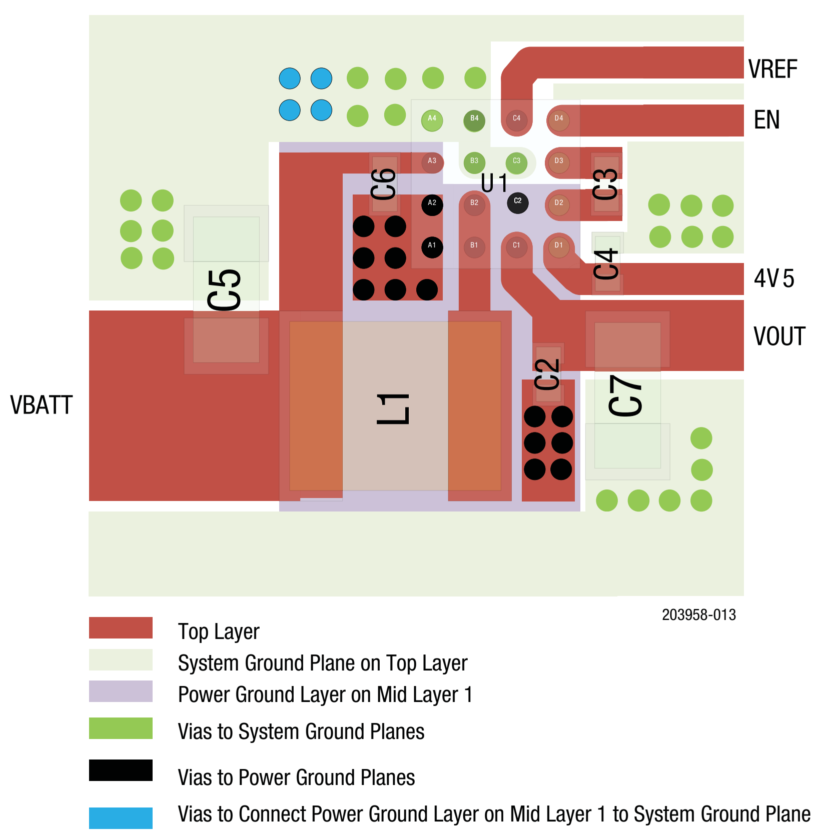

Figure 13. Recommended PCB Layout with Components

Package Dimensions

The PCB layout footprint for the SKY87020-12 is provided in Figure 14. Typical part markings for the SKY87020-12 are shown in Figure 15. Package dimensions are shown in Figure 16. Tape and reel dimensions are shown in Figure 17.

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 SKY87020-12 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*, and 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.

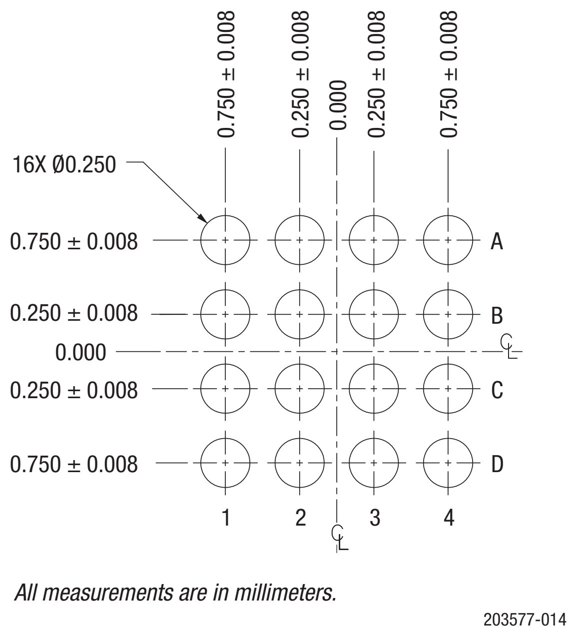

Figure 14. SKY87020-12 PCB Layout Footprint

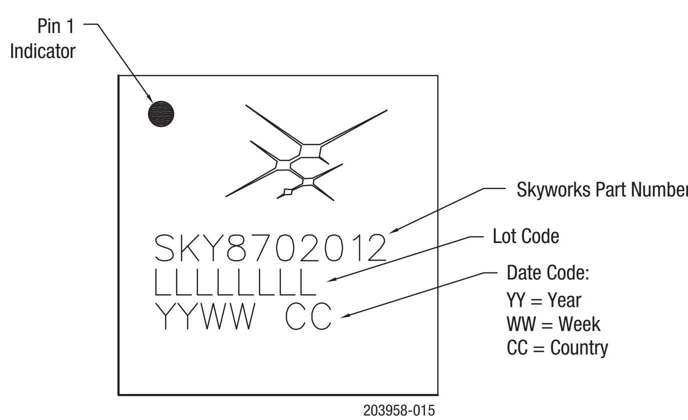

Figure 15. SKY87020-12 Typical Part Markings

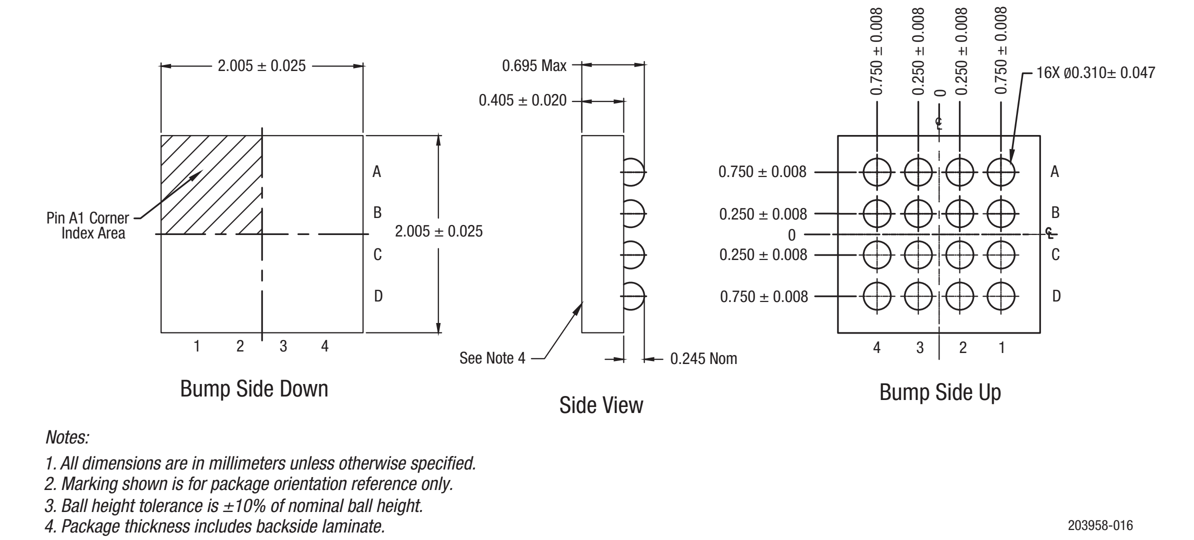

Figure 16. SKY87020-12 Package Dimensions

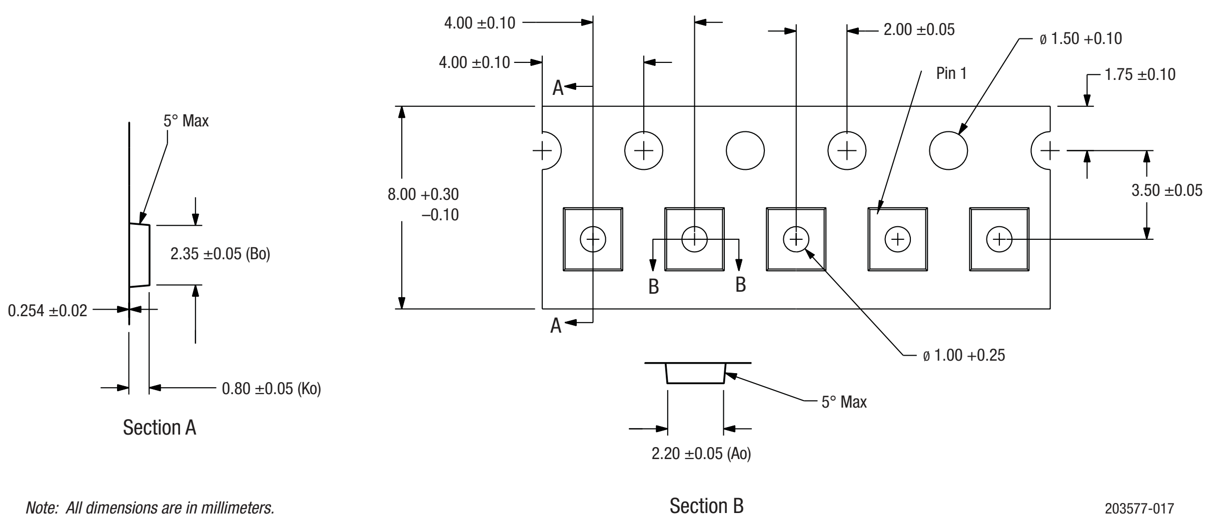

Figure 17. SKY87020-12 Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Number
SKY87020-12: Power Management IC for the SkyBlue™ System	SKY87020-12-001	SKY87020-12-EVB