DATA SHEET

SKY87201-11: Low Noise, Fast Transient 600 mA Step-Down Converter with Output Auto Discharge

Applications

- Cellular phones
- Digital cameras
- Handheld instruments
- Microprocessor, DSP Core, I/O power
- PDAs and handheld computers
- USB devices

Features

- Output auto discharge when disabled
- V_{IN} range: 2.7 V to 5.5 V
- Low-noise, light-load mode
- Low ripple power management mode
- Output voltage adjustable from 0.6 V to V_{IN}
- No load quiescent current: 37 µA
- Up to 98% efficiency
- Maximum output current: 600 mA
- Switching Frequency: 2 MHz
- Soft start: 150 µs
- Fast load transient
- Over-temperature protection
- Current limit protection
- 100% duty cycle low-dropout operation
- Shutdown current: <1 µA
- Available in an STDFN (8-pin, 2 x 2 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 SKY87201-11 is a 2 MHz step-down converter with an input voltage range of 2.7 V to 5.5 V and output voltage as low as 0.6 V. It is optimized to react quickly to a load variation. The SKY87201-11 incorporates a unique low-noise architecture that reduces ripple and spectral noise.

The SKY87201-11 is programmable with external feedback resistors. It can deliver 600 mA of load current while maintaining a low 37 µA no-load quiescent current. The 2 MHz switching frequency minimizes the size of external components while keeping switching losses low.

The SKY87201-11 is designed to maintain high efficiency throughout the operating range, which is critical for portable applications.

The device has an output auto discharge feature. This enables the device to quickly discharge the output when the device is disabled ($V_{EN} = V_{IN}$ to 0 V).

The SKY87201-11 is provided in a small, 8-pin, 2 x 2 mm Thin Dual Flat No-Lead (STDFN) package.

A typical application circuit diagram is provided in Figure 1. The pin configuration and package are shown in Figure 2. Signal pin assignment and functional pin descriptions are provided in Table 1. A functional block diagram is shown in Figure 3.

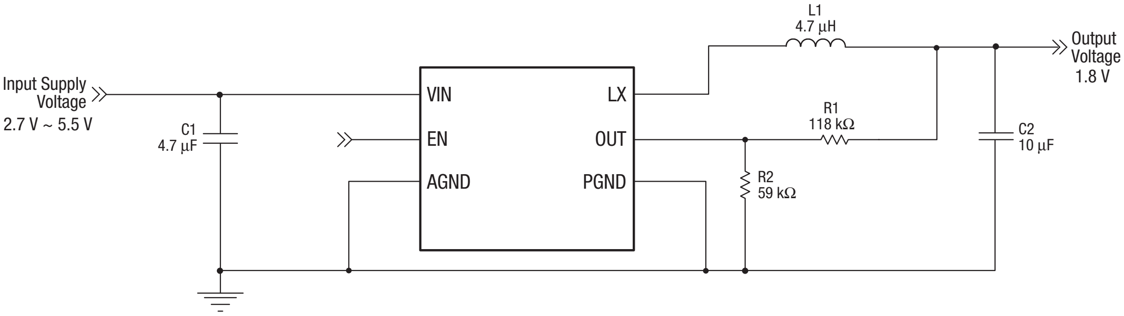


Figure 1. Typical Application Circuit Schematic

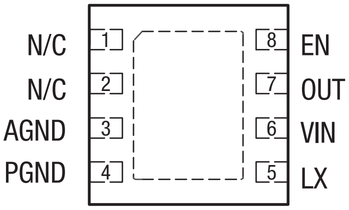


Figure 2. SKY87201-11 Pinout – 8-Pin STDFN Package (Top View)

Table 1. SKY87201-11 Signal Descriptions

Name	Pin #	Description	Name	Pin #	Description
N/C	1	Not connected.	LX	5	Switching node. Connect an inductor to this pin, which is internally connected to the drain of both high- and low-side MOSFETs.
N/C	2	Not connected.	VIN	6	Input supply voltage for the converter.
AGND	3	Non-power signal ground pin.	OUT	7	Feedback input pin. This pin is connected to an external resistive divider.
PGND	4	Main power ground return pin. Connect to the output and input capacitor return.	EN	8	Enable pin

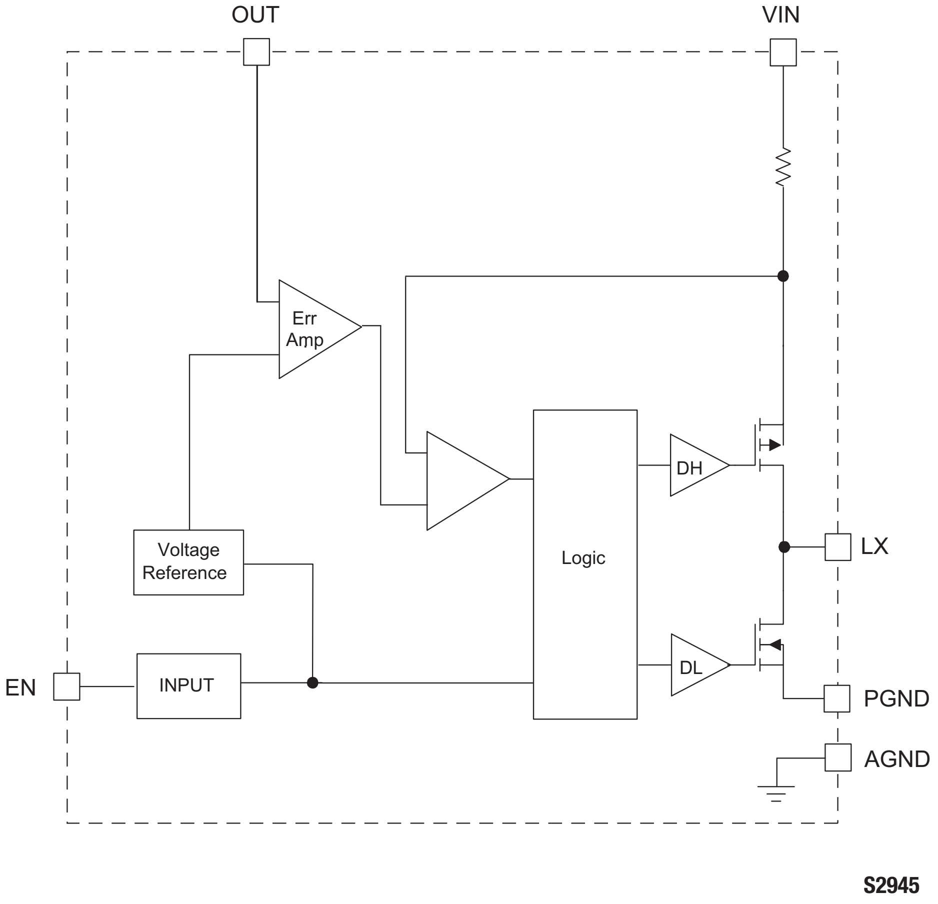


Figure 3. SKY87201-11 Block Diagram

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY87201-11 are provided in Table 2. Electrical specifications are provided in Table 3.

Typical performance characteristics of the SKY87201-11 are illustrated in Figures 4 to 25.

Table 2. Absolute Maximum Ratings (Note 1)

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage GND	V_{IN}		+6.0	V
LX to GND	V_{LX}	–0.3	VIN + 0.3	V
OUT to GND	V_{OUT}	–0.3	VIN + 0.3	V
EN to GND	V_{EN}	–0.3	VIN + 0.3	V
Junction temperature	T_J	–40	+150	°C
Soldering temperature (@ leads, 10 sec)	T_{LEAD}		+300	°C
Thermal resistance (Note 2)	Θ_{JA}		70	°C/W
Power dissipation (Note 2) (Note 3)	P_D		1.43	W
Electrostatic Discharge:	ESD			
Charged Device Model (CDM), Class 4			1500	V
Human Body Model (HBM), Class 3A			4000	V
Machine Model (MM), Class C			400	V

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.

Note 2: Mounted on an FR4 board.

Note 3: Derate 14.3 mW/°C above 25 °C.

***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. SKY87201-11 Electrical Characteristics (Note 1)
(T_A = –40 °C to +85 °C [Typical Values @ +25 °C, VIN = 3.6 V], Unless Otherwise Noted)

Parameter	Symbol	Test Conditions	Minimum	Typical	Maximum	Units
Step-Down Converter						
Input voltage	V_{IN}		2.7		5.5	V
Under Voltage Lockout threshold	V_{UVLO}	V_{IN} rising			2.7	V
		Hysteresis		100		mV
		V_{IN} falling	1.8			V
Output voltage tolerance	V_{OUT}	I_{OUT} = 0 mA to 600 mA, V_{IN} = 2.7 V to 5.5 V	–3		+3	%
Output voltage range	V_{OUT}		0.6		V_{IN}	V
Quiescent current	I_{CQ}	No load		37	70	µA
Shutdown current	I_{SHDN}	EN = AGND = PGND			1	µA
P-channel current limit	I_{LIM}		800			mA
High side switch on resistance	$R_{DS(ON)H}$			0.35		Ω
Low side switch on resistance	$R_{DS(ON)L}$			0.30		Ω
Line regulation	$\Delta V_{LINEREG}$	V_{IN} = 2.7 V to 5.5 V, I_{OUT} = 600 mA		0.1		%/V
Output threshold voltage accuracy	V_{OUT}	0.6 V output, No load, T_A = 25 °C	591	600	609	mV
Output leakage current	I_{OUT}	0.6 V output			0.2	µA
Output impedance	R_{OUT}	>0.6 V output	250			k Ω
Start-up time	T_S	From enable to output regulation		150		µs
Oscillator frequency	f_{OSC}	T_A = 25 °C	0.9	2.0	2.6	MHz
Over-temperature shutdown threshold	T_{SD}			140		°C
Over-temperature shutdown hysteresis	T_{HYS}			15		°C
Enable						
Enable threshold low	$V_{EN(L)}$				0.6	V
Enable threshold high	$V_{EN(H)}$		1.4			V
Input low current	I_{EN}	V_{IN} = V_{OUT} = 5.5 V	–1		+1	µA
Output discharge time	$T_{DISCHARGE}$	V_{IN} = 3.0 V to 5.5 V, V_{EN} = V_{IN} to 0 V, V_{OUT} = 3.0 V to 0.4 V, L = 4.7 µH C_{OUT} = 22 µF			25	ms

Typical Performance Characteristics

(T_A = +25 °C, Unless Otherwise Noted)

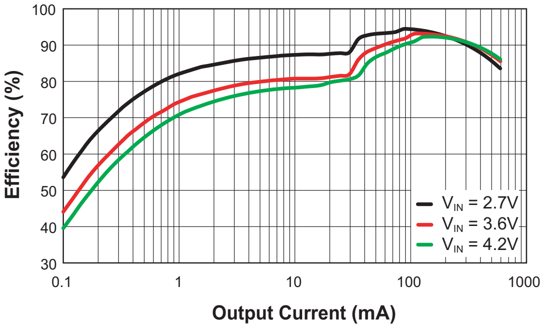


Figure 4. Efficiency vs Output Current (V_{OUT} = 1.8 V)

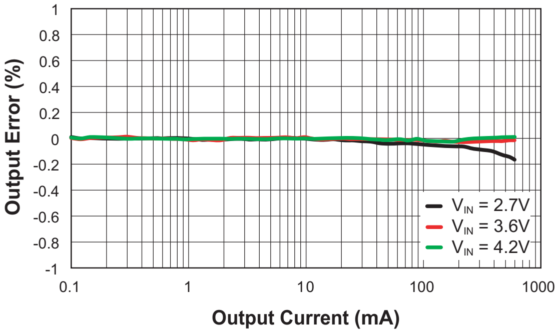


Figure 5. Load Regulation (V_{OUT} = 1.8 V)

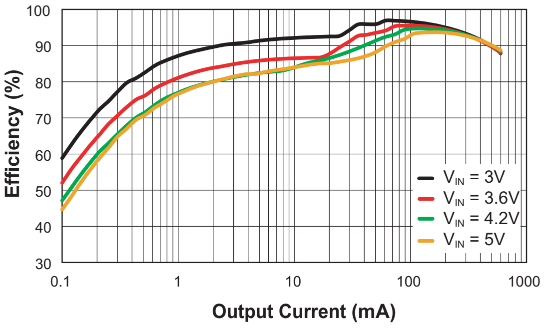


Figure 6. Efficiency vs Output Current (V_{OUT} = 2.5 V)

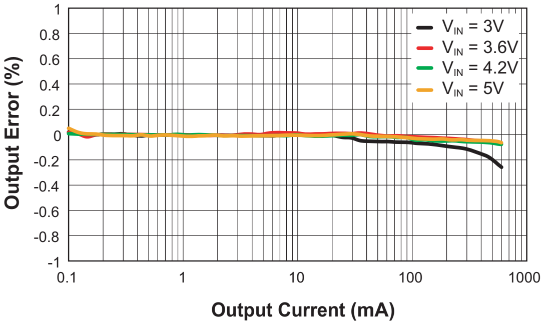


Figure 7. Load Regulation (V_{OUT} = 2.5 V)

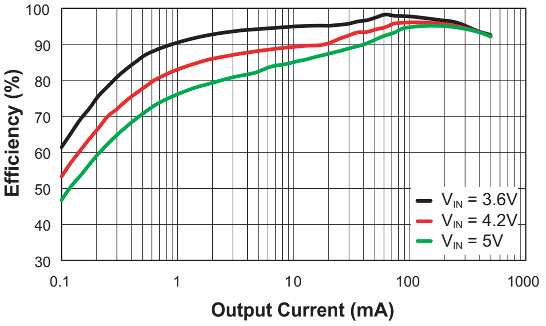


Figure 8. Efficiency vs Output Current (V_{OUT} = 3.3 V)

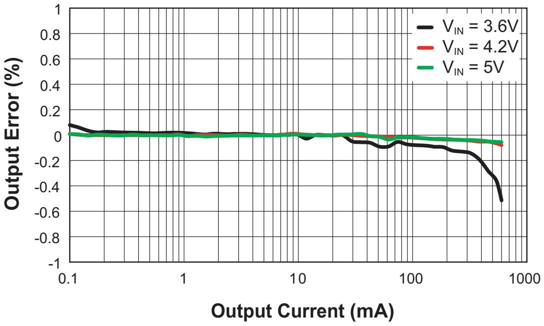


Figure 9. Load Regulation (V_{OUT} = 3.3 V)

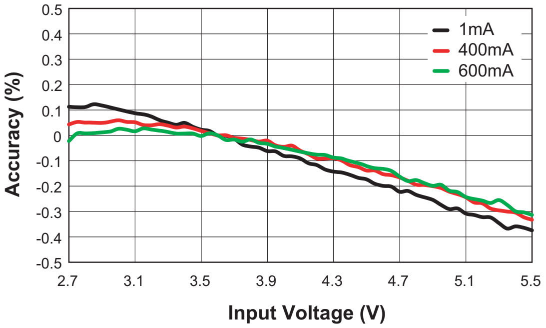


Figure 10. Line Regulation (V_{OUT} = 1.8 V)

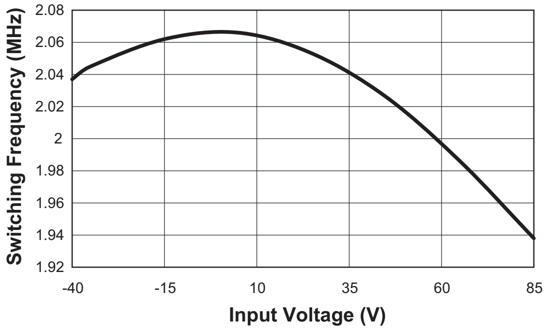


Figure 11. Switching Frequency vs Temperature (V_{OUT} = 1.8 V, I_{OUT} = 1 A)

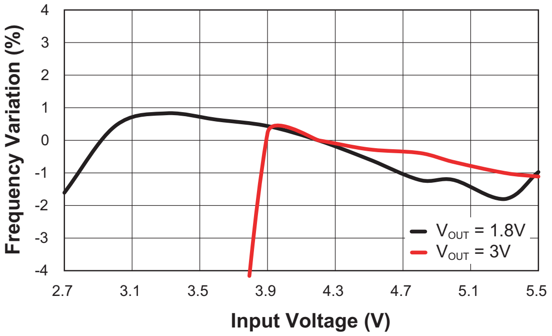


Figure 12. Frequency Variation vs Input Voltage

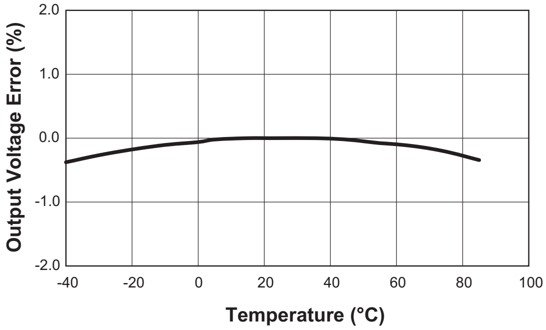


Figure 13. Output Voltage Error vs Temperature (V_{IN}= 3.6 V, V_{OUT} = 1.8 V, I_{OUT} = 400 mA)

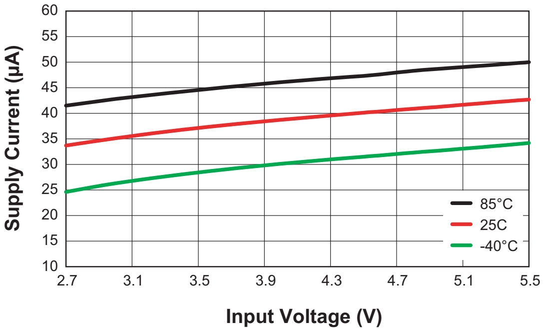


Figure 14. No Load Quiescent Current vs Input Voltage (V_{OUT} = 1.8 V)

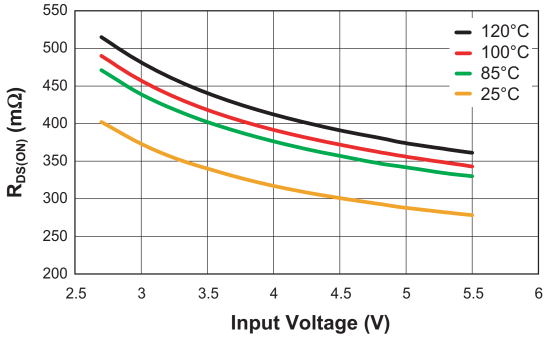


Figure 15. P-Channel $R_{DS(ON)}$ vs Input Voltage

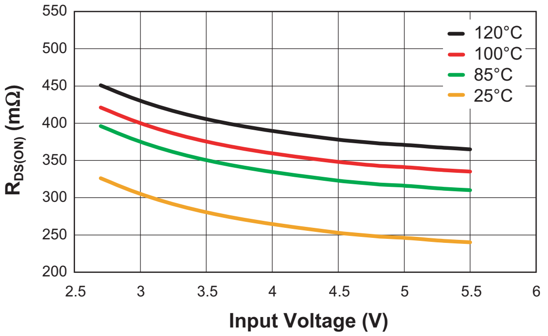


Figure 16. N-Channel $R_{DS(ON)}$ vs Input Voltage

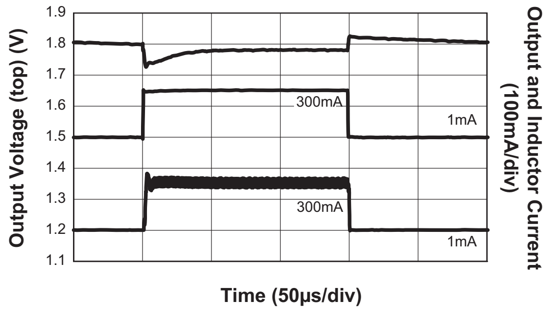


Figure 17. Load Transient (V_{IN}= 3.6 V, V_{OUT} = 1.8 V, C_{OUT} = 10 µF, C_{FF} = 100 pF)

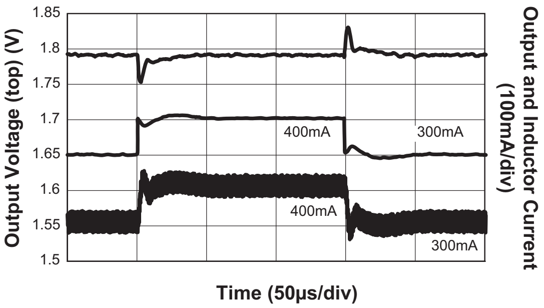


Figure 18. Load Transient (V_{IN}= 3.6 V, V_{OUT} = 1.8 V, C_{OUT} = 4.7 µF, C_{FF} = 0 pF)

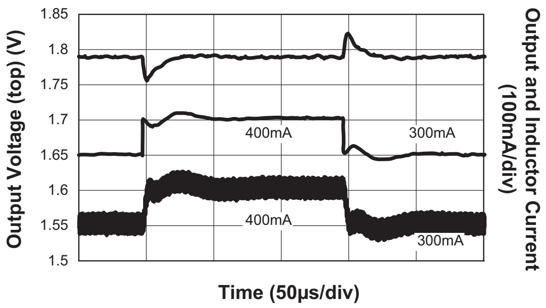


Figure 19. Load Transient (V_{IN}= 3.6 V, V_{OUT} = 1.8 V, C_{OUT} = 10 µF, C_{FF} = 0 pF)

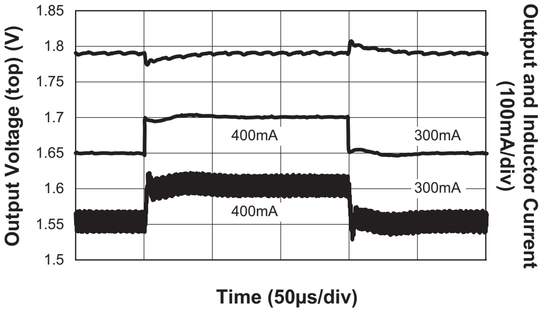


Figure 20. Load Transient (V_{IN}= 3.6 V, V_{OUT} = 1.8 V, C_{OUT} = 10 µF, C_{FF} = 100 pF)

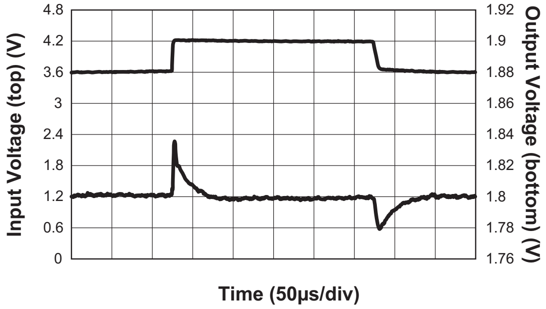


Figure 21. Line Transient (V_{OUT}= 1.8 V, V_{IN} = 3.6 V to 4.2 V, I_{OUT} = 400 mA, C_{FF} = 0 pF)

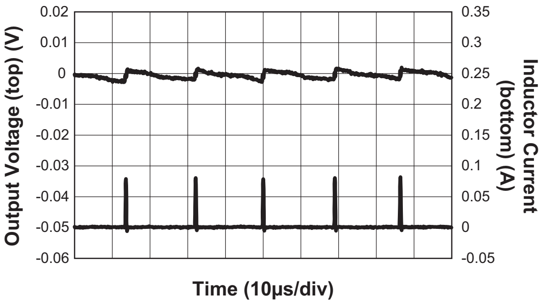


Figure 22. Output Ripple
(V_{OUT}= 1.8 V, V_{IN} = 3.6 V, I_{OUT} = 1 mA, C_{FF} = 0 pF)

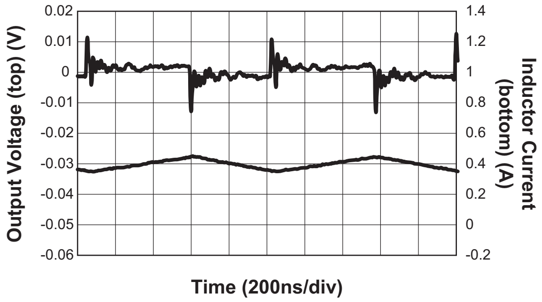


Figure 23. Output Ripple
(V_{OUT}= 1.8 V, V_{IN} = 3.6 V, I_{OUT} = 400 mA, C_{FF} = 0 pF)

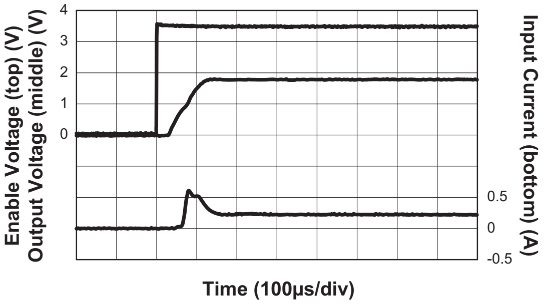


Figure 24. Soft Start
(V_{IN}= 3.6 V, V_{OUT} = 1.8 V, I_{OUT} = 400 mA)

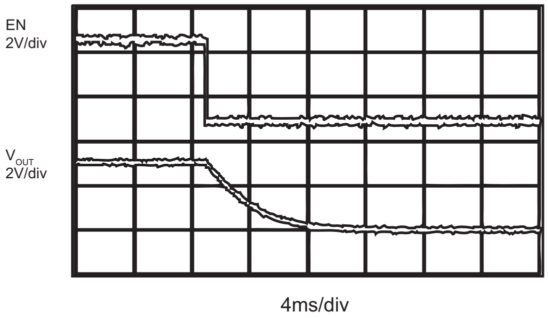


Figure 25. Discharge Time
(C_{IN}= 2.2 µF, C_{OUT} = 2.2 µF, L = 4.7 µH, R1 = 236 kΩ, R2 = 59 kΩ)

Functional Description

The SKY87201-11 is a high performance, 600 mA, 2 MHz monolithic step-down converter. It has been designed to minimize external component size and optimize efficiency over the complete load range with reduced ripple and spectral noise. Apart from the small bypass input capacitor, only a small L-C filter is required at the output. Typically, a 4.7 µH inductor is recommended for a 1.8 V output converter (see Table 4).

The SKY87201-11 can be programmed with external feedback to any voltage, ranging from 0.6 V to the input voltage (V_{IN}). An additional feed-forward capacitor can also be added to the external feedback loop to provide improved transient response.

At dropout, the converter duty cycle increases to 100 percent and the output voltage tracks the input voltage minus the $R_{DS(ON)}$ drop of the P-channel high-side MOSFET.

The input voltage range is 2.7 V to 5.5 V. The converter efficiency has been optimized for all load conditions, ranging from no load to 600 mA.

The internal error amplifier and compensation provides excellent transient response, load, and line regulation. Soft start eliminates any output voltage overshoot when the enable or the input voltage is applied.

Control Loop

The SKY87201-11 is a peak current mode step-down converter. The current through the P-channel MOSFET (high side) is sensed for current loop control, as well as short circuit and overload protection. A fixed slope compensation signal is added to the sensed current to maintain stability for duty cycles greater than 50 percent. The peak current mode loop appears as a voltage-programmed current source in parallel with the output capacitor.

The output of the voltage error amplifier programs the current mode loop for the necessary peak switch current to force a constant output voltage for all load and line conditions. Internal loop compensation terminates the transconductance voltage error amplifier output.

Soft Start/Enable

Soft start limits the current surge seen at the input and eliminates output voltage overshoot. When pulled low, the enable input forces the SKY87201-11 into a low-power, non-switching state. The total input current during shutdown is less than 1 µA.

Current Limit and Over-Temperature Protection

For overload conditions, the peak input current is limited. To minimize power dissipation and stresses under current limit and short-circuit conditions, switching is terminated after entering current limit for a series of pulses. Switching is terminated for seven consecutive clock cycles after a current limit has been sensed for a series of four consecutive clock cycles.

Thermal protection completely disables switching when internal dissipation becomes excessive. The junction over-temperature threshold is 140 °C with 15 °C of hysteresis. Once an over-temperature or over-current fault condition is removed, the output voltage automatically recovers.

Under-Voltage Lockout

Internal bias of all circuits is controlled using the the VIN input. Under-Voltage Lockout (UVLO) guarantees sufficient VIN bias and proper operation of all internal circuitry before activation.

Output Auto Discharge

When the SKY87201-11 is disabled (V_{EN} =V_{IN} to 0 V), the output is quickly discharged (refer to Figure 26).

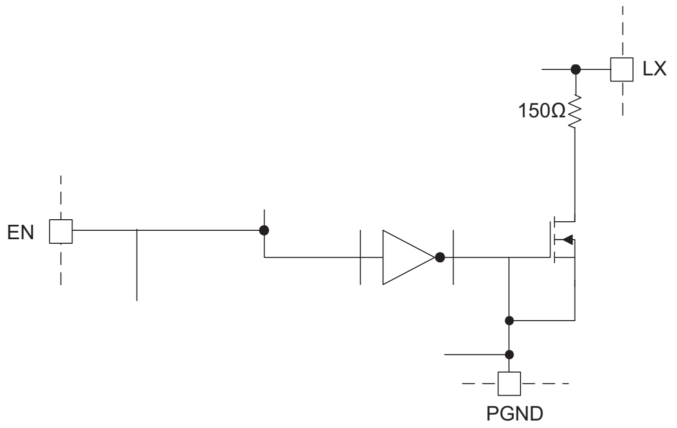


Figure 26. Output Auto Discharge Circuit

Evaluation Board Layout

The SKY87201-11 Evaluation Board is used to test the performance of the SKY87201-11 Step-Down Converter. An Evaluation Board schematic diagram is provided in Figure 27. Component values for the SKY87201-11 Evaluation Board are listed in Table 4. Typical surface mount inductors and capacitors are listed in Tables 5 and 6, respectively. Table 7 provides the Bill of Materials (BOM) for Evaluation Board components.

The suggested PCB layout for the SKY87201-11 is shown in Figures 28 and 29. The following guidelines should be used to help ensure a proper layout.

1. The input capacitor (C1) should connect as close as possible to VIN and PGND.
2. C2 and L1 should be connected as close as possible. The connection of L1 to the LX pin should be as short as possible.
3. The feedback trace or OUT pin should be separate from any power trace and connected as close as possible to the load point. Sensing along a high-current load trace degrades DC load regulation. If external feedback resistors are used, they should be placed as close as possible to the OUT pin to minimize the length of the high impedance feedback trace.
4. The resistance of the trace from the load return to PGND should be kept to a minimum. This helps to minimize any error in DC regulation due to differences in the potential of the internal signal ground and the power ground. A high density, small footprint layout can be achieved using an inexpensive, miniature, non-shielded, high DCR inductor.

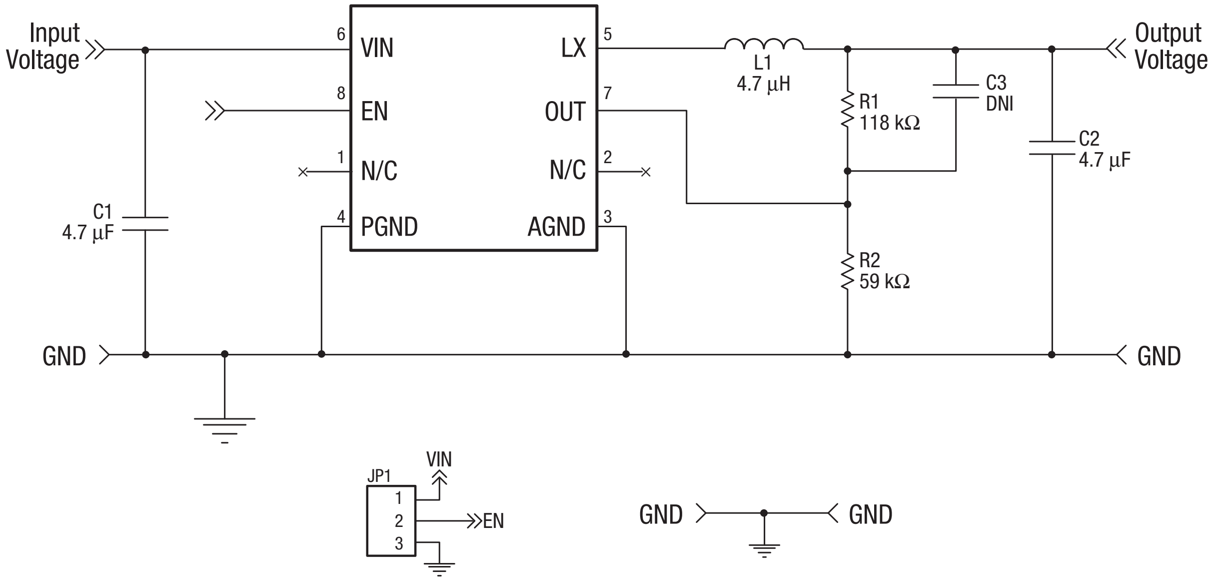


Figure 27. SKY87201-11 Evaluation Board Schematic

Table 4. Evaluation Board Component Values

V_{OUT} (V)	R2 = 59 kΩ R1 (kΩ)	R2 =221 kΩ R1 (kΩ)	L1 (µH)
0.80	19.6	75.0	2.2
0.90	29.4	113	2.2
1.00	39.2	150	2.2
1.10	49.9	187	2.2
1.20	59.0	221	2.2
1.30	68.1	261	2.2
1.40	78.7	301	4.7
1.50	88.7	332	4.7
1.80	118.0	442	4.7
1.85	124.0	464	4.7
2.00	137.0	523	6.8
2.50	187.0	715	6.8
3.30	267.0	1000	6.8

Table 5. Typical Surface Mount Inductors

Manufacturer	Part #	Inductance (µH)	Max DC Current (A)	DCR (Ω)	Size, l x w x h (mm)	Type
Sumida	CDRH3D16-2R2	2.2	1.20	0.072	3.8x3.8x1.8	Shielded
	CDRH3D16-4R7	4.7	0.90	0.105	3.8x3.8x1.8	Shielded
	CDRH3D16-6R8	6.8	0.73	0.170	3.8x3.8x1.8	Shielded
Coiltronics	SD3118-4R7	4.7	0.98	0.122	3.1x3.1x1.85	Shielded
	SD3118-6R8	6.8	0.82	0.175	3.1x3.1x1.85	Shielded
TDK	VLS3015T-4R7MR99	4.7	0.99	0.136	3.0x3.0x1.5	Shielded
	VLS3015T-6R8MR86	6.8	0.86	0.176	3.0x3.0x1.5	Shielded
Wurth	744042006	6.8	1.25	0.100	4.8x4.8x1.8	Shielded
Taiyo Yuden	MAKK2016T4R7M	4.7	1.20	0.308	2.0x1.6x1.0	Shielded

Table 6. Surface Mount Capacitors

Manufacturer	Part #	Value (µF)	Voltage (V)	Temp. Coefficient	Case
Murata	GRM219R61A475KE19	4.7	10	X5R	0805
	GRM21BR60J106KE19	10	6.3	X5R	0805
	GRM188R60J475KE19	4.7	6.3	X5R	0603
	GRM219R61A106KE44	10	10	X5R	0805

Table 7. Evaluation Board Bill of Materials (STDFN Package)

Component	Part Number	Manufacturer	Description
C1, C2	GRM188R60J475KE19	Murata	Ceramic capacitors, 4.7 µF, 0603, X5R, 6.3 V, 10%
L1	CDRH3D16-4R7	Sumida	4.7 µH inductor, 105 mΩ, 0.9 A, 20%
R1	RC0603FR-0759KL	Yageo	59 kΩ resistor, 1/10 W, 1%, 0603, SMD
R2	RC0603FR-07118KL	Yageo	118 kΩ resistor, 1/10 W, 1%, 0603, SMD

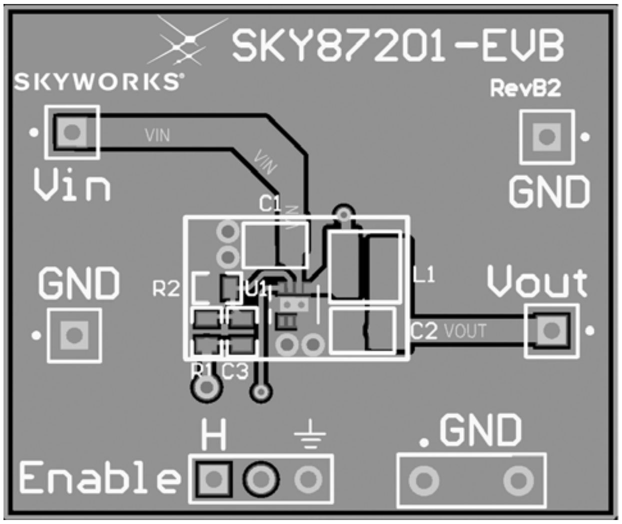


Figure 28. SKY87201-11 Evaluation Board Component Side Layout

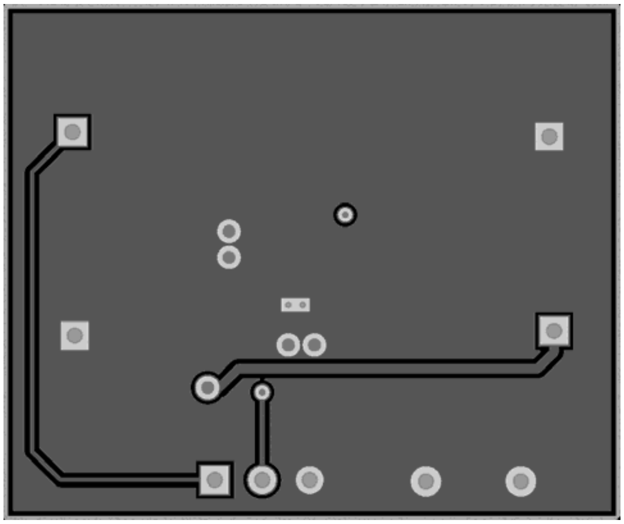


Figure 29. SKY87201-11 Evaluation Board Solder Side Layout

Application Information

Inductor Selection

The step-down converter uses peak current mode control with slope compensation to maintain stability for duty cycles greater than 50 percent. The output inductor value must be selected so the inductor current down-slope meets the internal slope compensation requirements. The internal slope compensation of the SKY87201-11 is 0.24 A/µs (see Equation 1). This equates to a slope compensation that is 75 percent of the inductor current down-slope for a 1.5 V output and 4.7 µH inductor.

$$m = \frac{0.75 \times V_o}{L} = \frac{0.75 \times 1.5V}{4.7\ \mu H} = 0.24\ A/\mu s \qquad (1)$$

This is the internal slope compensation for the SKY87201-11. When externally programming the output voltage to 2.5 V, the calculated inductance is 7.5 µH (from Equation 2).

$$L = \frac{0.75 \times V_O}{m} = \frac{0.75 \times V_O}{0.24\ A/\mu s} \approx \left(3\ \mu s/A\right) \times V_O \qquad (2)$$

$$= \left(3\ \mu s/A\right) \times 2.5V = 7.5\ \mu H$$

In this case, a standard 6.8 µH values is selected.

Table 4 displays inductor values for the SKY87201-11.

Manufacturer specifications list both the inductor DC current rating, which is a thermal limitation, and the peak current rating, which is determined by the saturation characteristics. The inductor should not show any appreciable saturation under normal load conditions. Some inductors may meet the peak and average current ratings yet result in excessive losses due to a high Direct Current Resistance (DCR). Always consider the losses associated with DCR and the affect on the total converter efficiency when selecting an inductor.

The 4.7 µH CDRH3D16 series inductor selected from Sumida has a 105 mW DCR and a 900 mA DC current rating. At full load, the inductor DC loss is 17 mW, which gives a 2.8 percent loss in efficiency for a 400 mA, 1.5 V output.

Input Capacitor

Select a 2.2 µF to 10 µF X7R or X5R ceramic capacitor for the input. To estimate the required input capacitor size, determine the acceptable input ripple level (V_{PP}) and solve for C_{IN} (see Equations 3, 4, and 5). The calculated value varies with input voltage and is a maximum when V_{IN} is double the output voltage.

$$C_{IN} = \frac{\frac{V_o}{V_{IN}} \times \left(1 - \frac{V_O}{V_{IN}}\right)}{\left(\frac{V_{PP}}{I_O} - ESR\right) \times F_S} \qquad (3)$$

$$\frac{V_o}{V_{IN}} \times \left(1 - \frac{V_o}{V_{IN}}\right) = \frac{1}{4}\ \ for\ V_{IN} = 2 \times V_O \qquad (4)$$

$$C_{IN} = \frac{1}{\left(\frac{V_{PP}}{I_O} - ESR\right) \times 4 \times F_S} \qquad (5)$$

Always examine the ceramic capacitor DC voltage coefficient characteristics when selecting the proper value. For example, the capacitance of a 10 µF, 6.3 V, X5R ceramic capacitor with 5.0 V DC applied is actually about 6 µF.

The maximum input capacitor RMS current is calculated using Equation 6:

$$I_{RMS} = I_O \times \sqrt{\frac{V_O}{V_{IN}} \times \left(1 - \frac{V_O}{V_{IN}}\right)} \qquad (6)$$

The input capacitor RMS ripple current varies with the input and output voltage and is always less than or equal to half of the total DC load current as follows:

$$\sqrt{\frac{V_O}{V_{IN}} \times \left(1 - \frac{V_O}{V_{IN}}\right)} = \sqrt{D \times \left(1 - D\right)} = \sqrt{0.5^2} = \frac{1}{2}$$

For $V_{IN} = 2 \times V_O$:

$$I_{RMS(MAX)} = \frac{I_O}{2}$$

The term V_O/V_{IN} x (1 – V_O/V_{IN}) appears in both the input voltage ripple and input capacitor RMS current equations and is a maximum when V_O is twice V_{IN}. This is why the input voltage ripple and the input capacitor RMS current ripple are a maximum at a 50 percent duty cycle.

The input capacitor provides a low impedance loop for the edges of pulsed current drawn by the SKY87201-11. Low ESR/ESL X7R and X5R ceramic capacitors are ideal for this function. To minimize stray inductance, the capacitor should be placed as closely as possible to the device. This keeps the high frequency content of the input current localized, minimizing EMI and input voltage ripple.

The proper placement of the input capacitor (C1) can be seen in the Evaluation Board layout in Figure 28.

A laboratory test setup typically consists of two long wires running from the bench power supply to the Evaluation Board input voltage pins. The inductance of these wires, along with the low-ESR ceramic input capacitor, can create a high Q network that may affect converter performance. This problem often becomes apparent in the form of excessive ringing in the output voltage during load transients. Errors in the loop phase and gain measurements can also result.

Since the inductance of a short PCB trace feeding the input voltage is significantly lower than the power leads from the bench power supply, most applications do not exhibit this problem.

In applications where the input power source lead inductance cannot be reduced to a level that does not affect the converter performance, a high ESR tantalum or aluminum electrolytic should be placed in parallel with the low ESR/ESL bypass ceramic. This dampens the high Q network and stabilizes the system.

Output Capacitor

The output capacitor limits the output ripple and provides holdup during large load transitions. A 4.7 µF to 10 µF X5R or X7R ceramic capacitor typically provides sufficient bulk capacitance to stabilize the output during large load transitions and has the ESR and ESL characteristics necessary for low output ripple.

The output voltage droop due to a load transient is dominated by the capacitance of the ceramic output capacitor. During a step increase in load current, the ceramic output capacitor alone supplies the load current until the loop responds. Within two or three switching cycles, the loop responds and the inductor current increases to match the load current demand. The relationship of the output voltage droop during the three switching cycles to the output capacitance can be estimated by Equation 7:

$$C_{OUT} = \frac{3 \times \Delta I_{LOAD}}{V_{DROOP} \times F_S} \tag{7}$$

Once the average inductor current increases to the DC load level, the output voltage recovers. Equation 7 establishes a limit on the minimum value for the output capacitor with respect to load transients.

The internal voltage loop compensation also limits the minimum output capacitor value to 4.7 µF. This is due to its effect on the loop crossover frequency (bandwidth), phase margin, and gain margin. Increased output capacitance reduces the crossover frequency with greater phase margin.

The maximum output capacitor RMS ripple current is given by Equation 8:

$$I_{RMS(MAX)} = \frac{1}{2 \times \sqrt{3}} \times \frac{V_{OUT} \times \left(V_{IN(MAX)} - V_{OUT}\right)}{L \times F \times V_{IN(MAX)}} \tag{8}$$

Dissipation due to the RMS current in the ceramic output capacitor ESR is typically minimal, resulting in less than a few degrees rise in hot-spot temperature.

Adjustable Output Resistor Selection

For applications that require an adjustable output voltage, the SKY87201-11 can be externally programmed. Resistors R1 and R2 shown in the schematic diagram (see Figure 27) program the output to regulate at a voltage higher than 0.6 V.

To limit the bias current required for the external feedback resistor string while maintaining good noise immunity, the minimum suggested value for R2 is 59 kΩ (see Equation 9). Although a larger value will further reduce quiescent current, it will also increase the impedance of the feedback node, making it more sensitive to external noise and interference. Table 8 summarizes the resistor values for various output voltages with R2 set to either 59 kΩ for good noise immunity or 221 kΩ for reduced, no-load input current.

$$R1 = \left(\frac{V_{OUT}}{V_{REF}} - 1\right) \times R2 = \left(\frac{1.5\,V}{0.6\,V} - 1\right) \times 59\,k\Omega = 88.5\,k\Omega \tag{9}$$

The SKY87201-11, combined with an external feed-forward capacitor (C3 in Figure 27), delivers enhanced transient response for extreme pulsed load applications. The addition of the feed-forward capacitor typically requires a larger C2 output capacitor for stability.

Thermal Calculations

There are three types of losses associated with the SKY87201-11 step-down converter: switching losses, conduction losses, and quiescent current losses.

Conduction losses are associated with the RDS(ON) characteristics of the power output switching devices. Switching losses are dominated by the gate charge of the power output switching devices. At full load, assuming Continuous Conduction Mode (CCM), a simplified form of the losses is given by Equation 10:

$$P_{TOTAL} = \frac{I_O^{\,2} \times (R_{DSON(HS)} \times V_O + R_{DSON(LS)} \times [V_{IN} - V_O])}{V_{IN}} \tag{10}$$

$$+ (t_{SW} \times F \times I_O + I_Q) \times V_{IN}$$

Where I_Q is the step-down converter quiescent current. The term t_{SW} is used to estimate the full load step-down converter switching losses.

For the condition where the step-down converter is in dropout at 100 percent duty cycle, the total device dissipation reduces to:

$$P_{TOTAL} = I_O^{\,2} \times R_{DSON(HS)} + I_Q \times V_{IN}$$

Since $R_{DS(ON)}$, the quiescent current, and switching losses all vary with input voltage, the total losses should be investigated over the complete input voltage range.

Given the total losses, the maximum junction temperature can be derived from the thermal resistance (Θ_{JA}), which is 70 °C/W as shown by Equation 11:

$$T_{J(MAX)} = P_{TOTAL} \times \Theta_{JA} + T_A \tag{11}$$

Table 8. Resistor Selection for Different Output Voltage Settings

V_{OUT} (V)	R2 = 59 kΩ	R2 = 221 kΩ
	R1 (kΩ)	R1
0.80	19.6	75K
0.90	29.4	113K
1.00	39.2	150K
1.10	49.9	187K
1.20	59.0	221K
1.30	68.1	261K
1.40	78.7	301K
1.50	88.7	332K
1.80	118.0	442K
1.85	124.0	464K
2.00	137.0	523K
2.50	187.0	715K
3.30	267.0	1.00M

Step-Down Converter Design Example

Specifications

V_O = 1.8 V @ 400 mA (adjustable using 0.6 V version), pulsed load ΔI_{LOAD} = 300 mA

V_{IN} = 2.7 V to 4.2 V (3.6 V nominal)

F_S = 2 MHz

T_A = 85 °C

1.8 V Output Inductor

L1 = 3 µs/A x V_O2 = 3 µs/A x 1.8 V = 5.4 µH (use 4.7 µH, see Table 4)

For Sumida inductor CDRH3D16, 4.7 µH, DCR = 105 mΩ

$$\Delta I_{L1} = \frac{V_O}{L1 \times F_S} \times \left(1 - \frac{V_O}{V_{IN}}\right) = \frac{1.8V}{4.7\,\mu H \times 2.0\,MHz} \times \left(1 - \frac{1.8V}{4.2V}\right) = 109\,mA$$

$$I_{PKL1} = I_O + \frac{\Delta I_{L1}}{2} = 0.4\,A + 0.055\,A = 0.455\,A$$

$$P_{L1} = I_O{}^2 \times DCR = 0.4\,A^2 \times 105\,m\Omega = 17\,mW$$

1.8 V Output Capacitor

V_{DROOP} = 0.1 V

$$C_{OUT} = \frac{3 \times \Delta I_{LOAD}}{V_{DROOP} \times F_S} = \frac{3 \times 0.3\,A}{0.1V \times 2\,MHz} = 4.5\,\mu F \quad \text{(use 4.7 µF)}$$

$$I_{RMS} = \frac{1}{2 \times \sqrt{3}} \times \frac{V_{OUT} \times \left(V_{IN(MAX)} - V_{OUT}\right)}{L1 \times F \times V_{IN(MAX)}} =$$

$$\frac{1}{2 \times \sqrt{3}} \times \frac{1.8V \times \left(4.2V - 1.8V\right)}{4.7\,\mu H \times 2.0\,MHz \times 4.2V} = 32\,mArms$$

$$Pesr = esr \times I_{RMS}{}^2 = 5\,m\Omega \times \left(32\,mA\right)^2 = 6\,\mu W$$

Input Capacitor

Input ripple V_{PP} = 25 mV

$$C_{IN} = \frac{1}{\left(\frac{V_{PP}}{I_O} - ESR\right) \times 4 \times F_S} = \frac{1}{\left(\frac{25\,mV}{0.4\,A} - 5\,m\Omega\right) \times 4 \times 2.0\,MHz} = 2.17\,\mu F$$

(use 2.2 µF)

$$I_{RMS} = \frac{I_O}{2} = 0.2\,Arms$$

$$P_{esr} = esr \times I_{RMS}{}^2 = 5\,m\Omega \times \left(0.2\,A\right)^2 = 0.2\,mW$$

SKY87201-11 Losses

$$P_{TOTAL} = \frac{I_O{}^2 \times (R_{DSON(HS)} \times V_O + R_{DSON(LS)} \times [V_{IN} - V_O])}{V_{IN}}$$

$$+ (t_{sw} \times F \times I_O + I_Q) \times V_{IN}$$

$$= \frac{0.4^2 \times (0.725\,\Omega \times 1.8V + 0.7\,\Omega \times [4.2V - 1.8V]}{4.2V}$$

$$+ (5\,ns \times 2.0\,MHz \times 0.4\,A + 70\,\mu A) \times 4.2V = 131\,mW$$

$$T_{J(MAX)} = T_A + \Theta_{JA} \times P_{LOSS} = 85\,{}^oC + \left(70\,{}^oC/W\right) \times 131\,mW = 94.2\,{}^oC$$

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 SKY87201-11 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.

Package Dimensions

Typical case markings are shown in Figure 30. Package dimensions for the 8-pin STDFN package are shown in Figure 31. Tape and reel dimensions are provided in Figure 32.

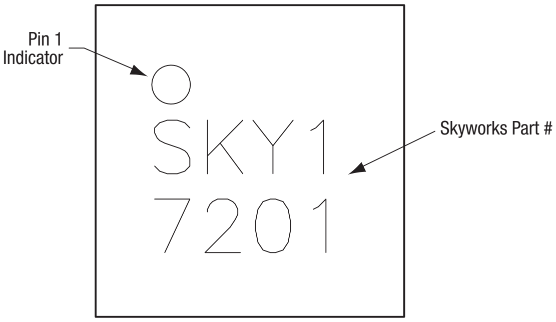
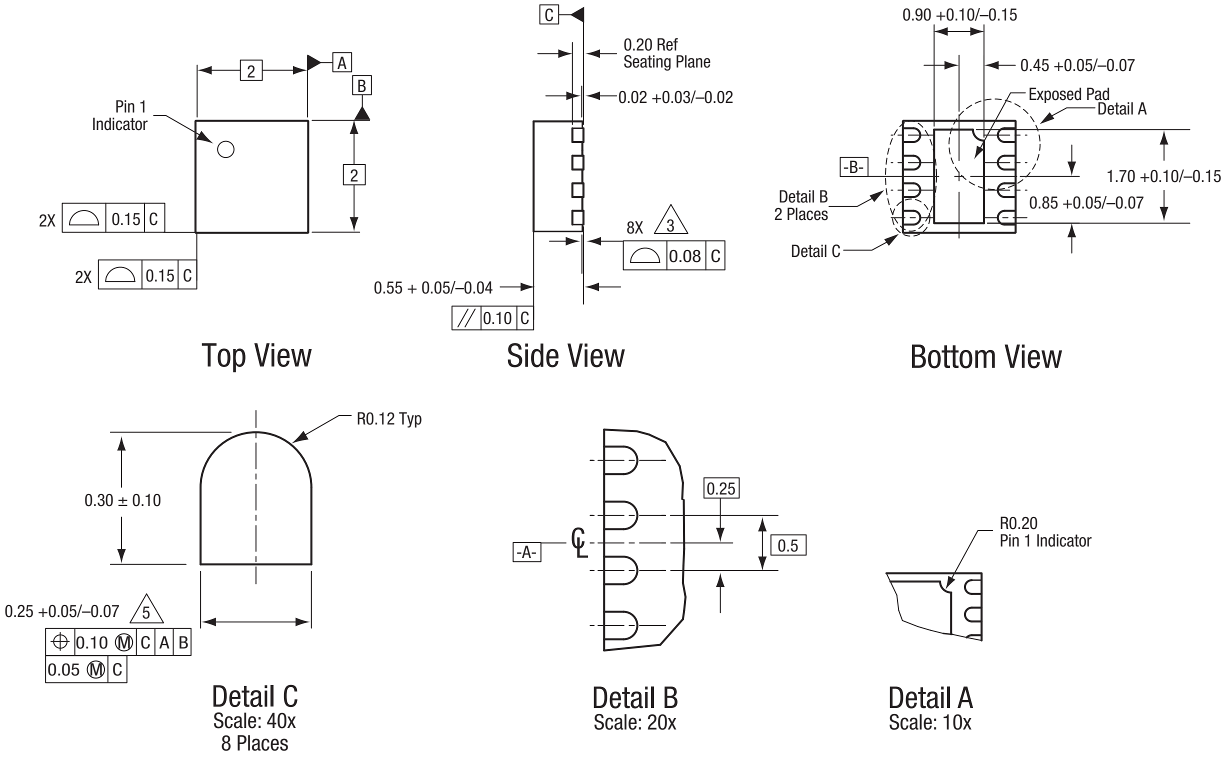


Figure 30. Typical Case Markings (Top View)



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..
Dimension applies to metalized terminal and is measured between 0.15 mm and 0.30 mm from terminal tip.

Figure 33. SKY87201-11 8-Pin STDFN Package Dimensions

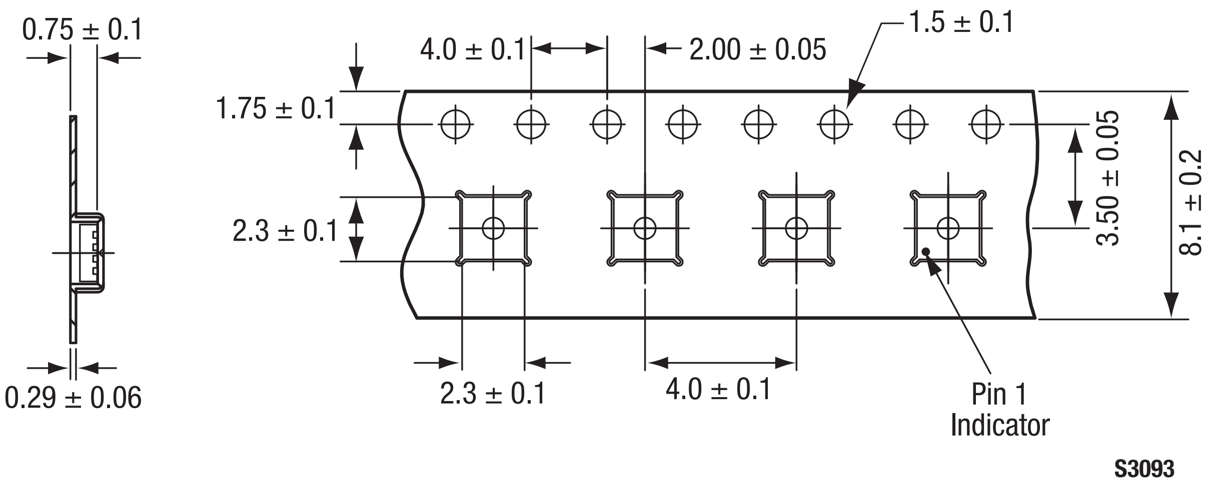


Figure 34. SKY87201-11 Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Number
SKY87201-11 Low-Noise, Step-Down Converter with Output Auto Discharge	SKY87201-11-370LF	SKY87201-11-370LF-EVB

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