2A, 23V, 340K High-Efficiency Synchronous-Rectified Buck Converter

General Description

The uP1715R is a high-efficiency synchronous-rectified buck converter with internal power switch. With internal low $R_{DS(ON)}$ switches, the high-efficiency buck converter is capable of delivering 2A output current over a wide input voltage range from 4.5V to 23V. The output voltage is adjustable from 0.8V to 20V by a voltage divider. Other features for the buck converter include adjust soft-start, chip enable, over-voltage, under-voltage, over-temperature and over-current protections. It is available in a space saving SOP-8L package.

Applications

- **Battery-Powered Portable Devices**
  - **MP3 Players**
  - **Digital Still Cameras**
  - **Wireless and DSL Modems**
  - **Personal Information Appliances**
- **802.11 WLAN Power Supplies**
- **FPGA/ASIC Power Supplies**
- **Laptop, Palmtops, Notebook Computers**
- **Portable Information Appliances**

Ordering Information

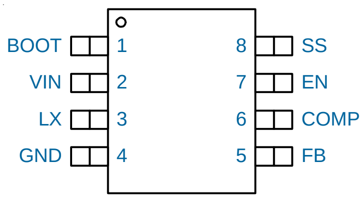
Order Number	Package Type	Top Marking
uP1715RSA8	SOP-8L	uP1715R

Note: uPI products are compatible with the current IPC/ JEDEC J-STD-020 requirement. They are halogen-free, RoHS compliant and 100% matte tin (Sn) plating that are suitable for use in SnPb or Pb-free soldering processes.

Features

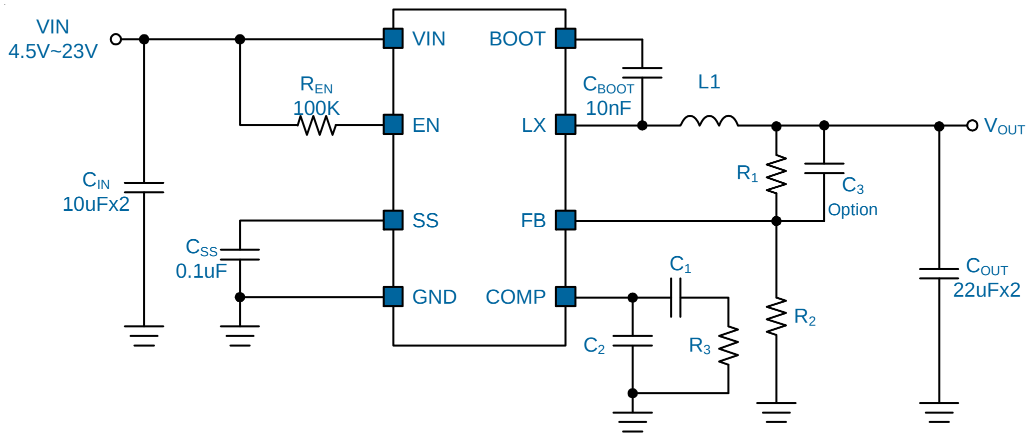
- **4.5V to 23V Input Voltage Range**
- **Adjustable Output from 0.8V to 20V**
- **2A Output Current**
- **Accurate Reference: 0.8V ($\pm$ 1.5%)**
- **Up to 93% Conversion Efficiency**
- **Integrated Low $R_{DS(ON)}$ Upper and Lower MOSFET Switches: 130mΩ**
- **Current Mode PWM Operation**
- **Constant 340kHz Fixed-Frequency Operation**
- **Programmable Soft-Start**
- **Integrated Boot Diode**
- **Over Voltage and Under Voltage Protection**
- **Over Temperature and Over Current Protection**
- **SOP-8L Package**
- **RoHS Compliant and Halogen Free**

Pin Configuration



SOP - 8L

Typical Application Circuit

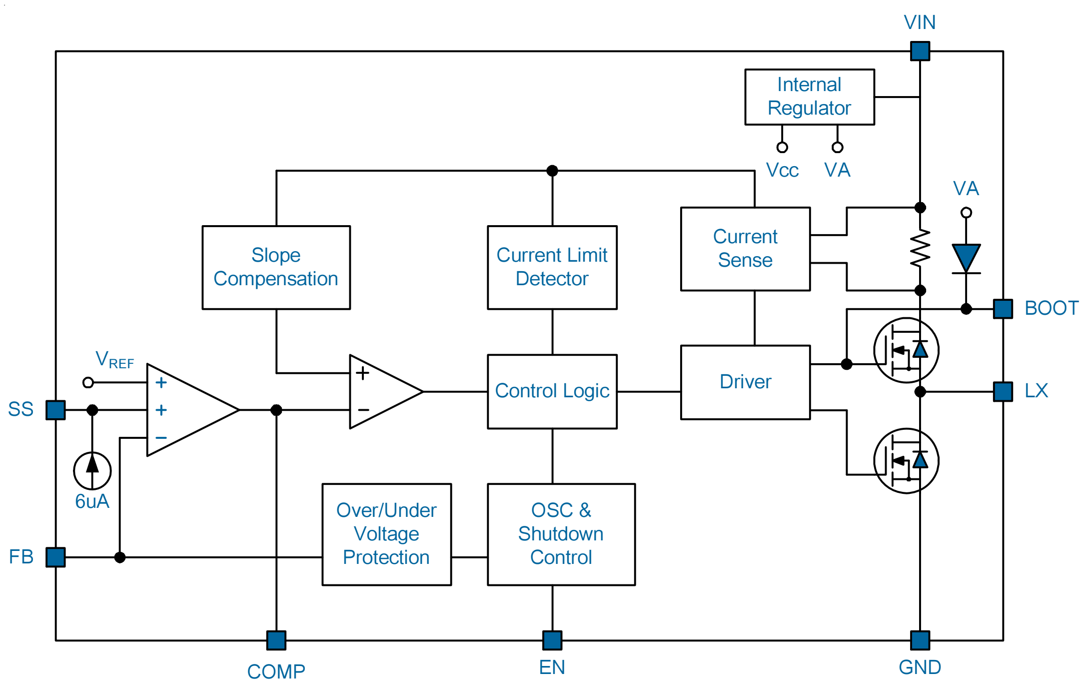


V_{IN}	V_{OUT}	L1	C_{OUT}	R1	R2	R3	C1	C2
12V	1V	3.3uH	22uF*2	1.5K	18K	6.2K	6.8nF	N/A
12V	1.2V	3.3uH	22uF*2	3K	10K	7.5K	6.8nF	N/A
12V	2.5V	6.8uH	22uF*2	16.9K	10K	15K	2.2nF	68pF
12V	3.3V	10uH	22uF*2	26.1K	10K	6.8K	3.9nF	N/A
12V	5V	10uH	22uF*2	45.3K	10K	13K	3.3nF	N/A

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	BOOT	**Bootstrap Supply for the Floating Upper Gate Driver.** Connect the bootstrap capacitor C_{BOOT} between BOOT pin and the LX pin to form a bootstrap circuit. The bootstrap capacitor provides the charge to turn on the upper MOSFET. Typical value for C_{BOOT} is 10nF or greater. Ensure that C_{BOOT} is placed near the IC.
2	VIN	**Power Supply Input.** Input voltage that supplies current to the output voltage and powers the internal control circuit. Bypass the input voltage with a minimum 10uFx2 X5R or X7R ceramic capacitor.
3	LX	**Internal Switches Output.** Connect this pin to the output inductor.
4	GND	**Ground.** Ground of the buck converter.
5	FB	**Switcher Feedback Voltage.** This pin is the inverting input of the error amplifier. FB senses the switcher output through an external resistor divider network.
6	COMP	**Compensation.** This pin is output of the error amplifier. The current comparator threshold increases with this control voltage. Connect a RC network to ground for controlling loop compensation.
7	EN	**Buck Converter Enable (Active High).** A logic low forces the converter into shutdown mode reducing the supply current to less than 1uA. Attach this pin to VIN with a 100kΩ pull up resistor for automatic startup.
8	SS	**Soft-Start Control Pin.** Connect a softstart capacitor C_{SS} to this pin. Leave open for no soft-start application. The softstart capacitor is discharged to ground when EN pin is low.

Functional Block Diagram



Functional Description

The integrated high efficiency synchronous-rectified buck converter with internal power switches. With internal low $R_{DS(ON)}$ switches, it is capable of delivering 2A output current over a wide input voltage range from 4.5V to 23V. The output voltage is adjustable from 0.8V to 20V by a voltage divider. Other features include Programmable soft-start, chip enable, overvoltage, under-voltage, over-temperature and over-current protections.

Input Supply Voltage, VIN

VIN supplies current to internal control circuits and output voltages. The supply voltage range is from 4.5V to 23V. A power on reset (POR) continuously monitors the input supply voltage. The POR level is typically 4.2V at VIN rising. The buck converter draws pulsed current with sharp edges each time the upper switch turns on, resulting in voltage ripples and spikes at supply input. A minimum 10uFx2 ceramic capacitor with shortest PCB trace is highly recommended for bypassing the supply input.

Chip Enable/Disable and Soft Start

Pulling EN pin lower than 0.4V shuts down the buck converter and reduces its quiescent current lower than 1uA. In the shutdown mode, both upper and lower switches are turned off. Pulling EN pin higher than 2.7V enables the buck converter and initiates the soft start cycle.

The uP1715R features programmable soft start function to limit the inrush current from supply input by a soft start capacitor C_{SS} connected to SS pin as shown in Figure 1.The C_{SS} is charged to VIN by a 6uA current source when EN pin is taken high. The V_{SSE} voltage is clamped to V_{SS} with a threshold voltage of NMOSFET.

The error amplifier is a tri-input device. V_{SSE} or V_{REF} whichever is smaller dominates the non-inverting inputs of the error amplifier. The V_{SSE} voltage starts ramping up when V_{SS} is higher than about 0.7V. The V_{FB} voltage will follow the V_{SSE} and ramp up linearly. When V_{SSE} is higher than V_{REF}, the uP1715R asserts soft start end and the V_{FB} voltage is regulated to V_{REF}. Soft start end also initiates the output under voltage protection.

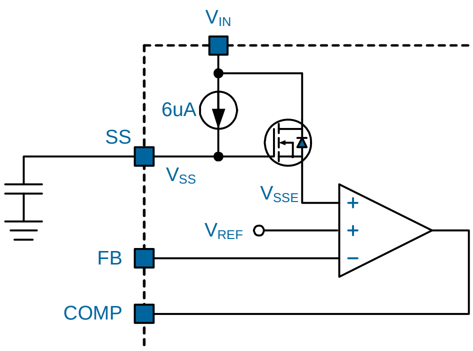


Figure 1. uP1715R Soft Start

Main Control Loop

The uP1715R adopts slope-compensated, current mode PWM control. During normal operation, the uP1715R operates at PWM mode to regulate output voltage by transferring the power to the output voltage cycle by cycle at a constant frequency. The uP1715R turns on the upper switch at each rising edge of the internal oscillator allowing the inductor current to ramp up linearly. The switch remains on until either the current limit is tripped or the PWM comparator turns off the switch for regulating output voltage.

The lower switch turns on with optimal dead time and picks up the inductor current after the upper switch turns off allowing the inductor current to ramp down linearly. The switch remains on until the next rising edge of oscillator turns on the upper switch. The uP1715R regulates the output voltage by controlling the ramp up/down duty cycle of inductor current. The high frequency switching ripple is easily smoothed by the output filter.

The upper switch current is sensed, slope compensated and compared with the error amplifier output COMP to determine the adequate duty cycle. The feedback voltage V_{FB} is sensed through a resistive voltage divider and regulated to internal 0.8V reference voltage. The error amplifier amplifies and compensates voltage variation to get appropriate COMP pin voltage.

When the load current increases, it causes a slight decrease in the feedback voltage relative to the 0.8V reference, which in turn, causes the error amplifier output voltage to increase until the average inductor current matches the new load current.

Output Voltage Setting and Feedback Network

For the adjustable output version, the output voltage can be set from V_{REF} to VIN by a voltage divider as:

$$V_{OUT} = 0.8V \times \frac{R1 + R2}{R2}$$

The internal V_{REF} is 0.8V with 1.5% accuracy. In real applications, a 22pF feed-forward ceramic capacitor is recommended in parallel with R1 for better transient response.

Over Temperature Protection

The OTP is triggered and shuts down the uP1715R if the junction temperature is higher than 160°C. The OTP is a non-latch type protection. The uP1715R automatically initiates another soft start cycle if the junction temperature drops below 130°C.

Absolute Maximum Rating

(Note 1)

Supply Input Voltage, V_{IN} -- -0.3V to +25V

LX Pin Voltage

DC -- -0.3V to +(V_{IN} +0.3V)

<50ns -- -3.5V to +28V

BOOT Pin Voltage -- -0.3V to (LX + 6.0V)

Other Pins -- -0.3V to 6V

Storage Temperature Range -- -65^{O}C to +150^{O}C

Junction Temperature -- 150^{O}C

Lead Temperature (Soldering, 10 sec) -- 260^{O}C

ESD Rating (Note 2)

HBM (Human Body Mode) -- 2kV

MM (Machine Mode) -- 200V

Thermal Information

Package Thermal Resistance (Note 3)

SOP-8L θ_{JA} -- 160°C/W

SOP-8L θ_{JC} -- 39°C/W

Power Dissipation, P_D @ T_A = 25°C

SOP-8L -- 0.62W

Recommended Operation Conditions

(Note 4)

Operating Junction Temperature Range-- -40^{O}C to +125^{O}C

Operating Ambient Temperature Range -- -40^{O}C to +85^{O}C

Electrical Characteristics

(V_{IN} = 12V, T_A = 25^{O}C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Current						
Supply Current		V_{EN} = 3.0V, V_{FB} = 1.0V	0.8	1.3	1.5	mA
Shutdown Supply Current		V_{EN} = 0V	0	0.3	3	uA
Input Under Voltage Lockout Threshold		V_{IN} rising	4	4.2	4.4	V
Input Under Voltage Lockout Threshold Hysteresis			--	350	--	mV
Reference						
Feedback Voltage	V_{FB}	4.75V < V_{IN} < 23V	0.788	0.800	0.812	V
Error Amplifier Voltage Gain	AEA		--	400	--	V/V
Error Amplifier Transconductance	GEA	ΔIC = +/-10uA	600	820	950	uA/V
COMP to Current Sense Transconductance	GCS		--	3.6	--	A/V

Electrical Characteristics

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Power Switches						
Hide-Side Switch On Resistance	$R_{DS(ON)}$		90	130	170	mΩ
Low-Side Switch On Resistance	$R_{DS(ON)}$		90	130	170	mΩ
High-Side Switch Leakage Current		V_{EN} = 0V, V_{SW} = 0V	--	0	10	uA
Upper Switch Current Limit		Minimum Duty Cycle	3.4	4	5.5	A
Lower Switch Current Limit		From Drain to Source	--	1.1	--	A
Oscillator						
Oscillation Frequency	FOSC1		300	340	380	kHz
Short Circuit Oscillation Frequency	FOSC2	V_{FB} = 0V	80	100	120	kHz
Maximum Duty Cycle	DMAX	V_{FB} = 1.0V	85	90	95	%
Minimum On Time	TON		170	220	270	ns
Logic Input						
EN Threshold Voltage		V_{EN} Rising	1.7	1.9	2.1	V
EN Voltage Hysteresis			--	300	--	mV
Soft Start						
Soft-Start Current		V_{SS} = 0V	5.5	6.0	6.5	uA
Soft-Start period		C_{SS} = 0.1uF	--	15	--	ms
Protection						
FB Over Voltage Protection			0.9	1.1	1.3	V
Over-Temperature Protection			--	160	--	^{o}C
Over-Temperature Hysteresis			--	30	--	^{o}C

Note 1. Stresses listed as the above *Absolute Maximum Ratings* may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

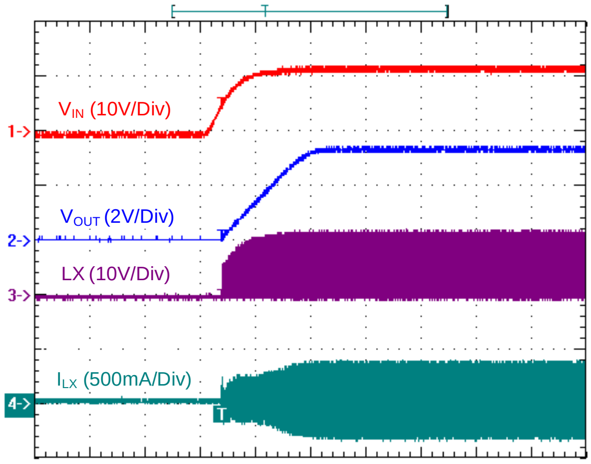
Note 2. Devices are ESD sensitive. Handling precaution recommended.

Note 3. θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 4. The device is not guaranteed to function outside its operating conditions.

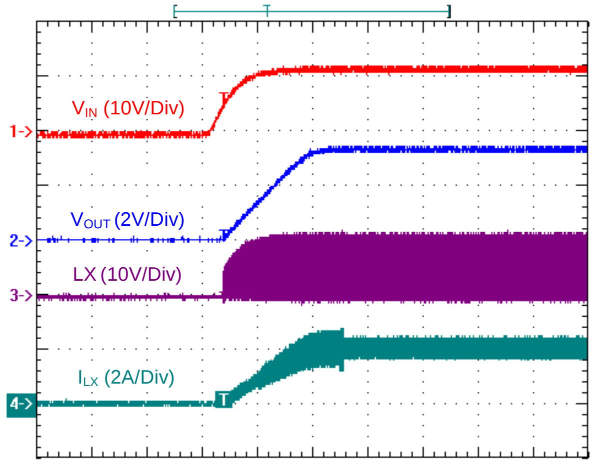
Typical Operation Characteristics

Power On Waveforms



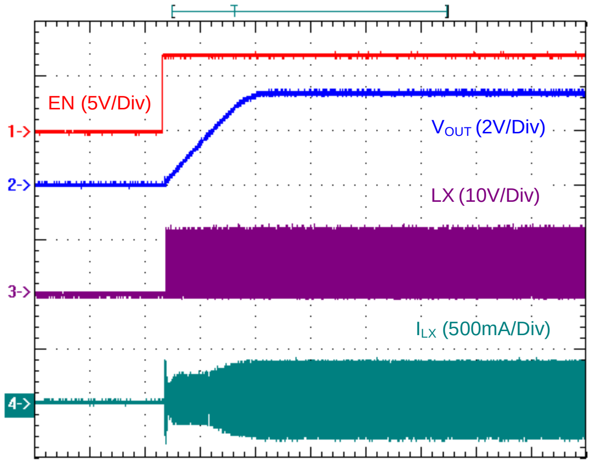
10ms/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A

Power On Waveforms



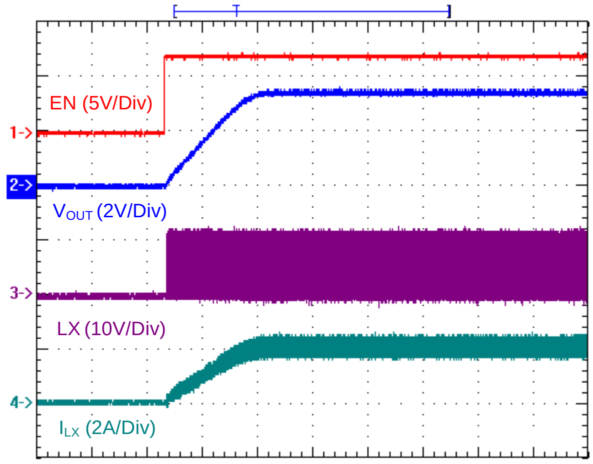
10ms/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 2A

Turn On Waveforms



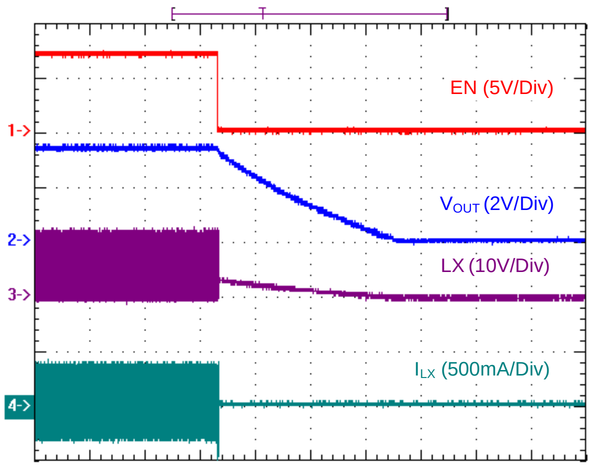
10ms/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A

Turn On Waveforms



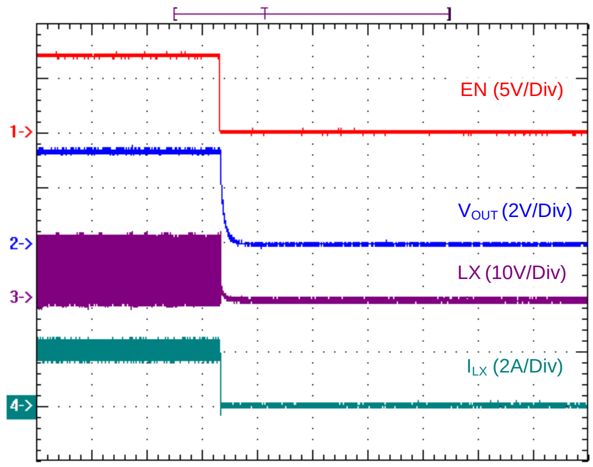
10ms/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 2A

Turn Off Waveforms



200ms/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A

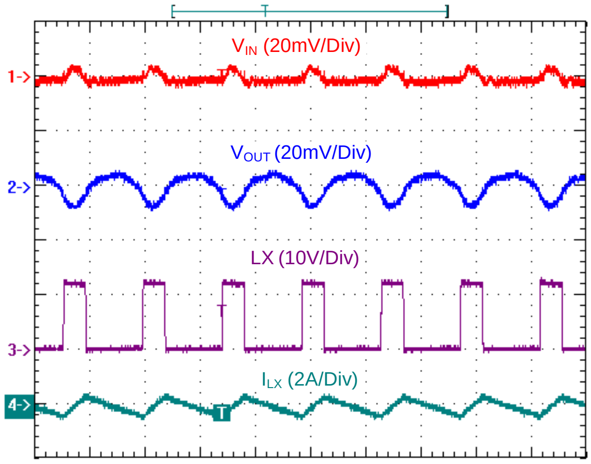
Turn Off Waveforms



20us/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 2A

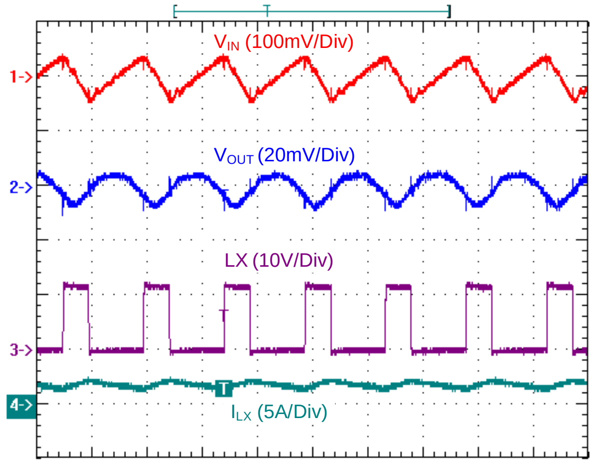
Typical Operation Characteristics

Steady State Waveforms



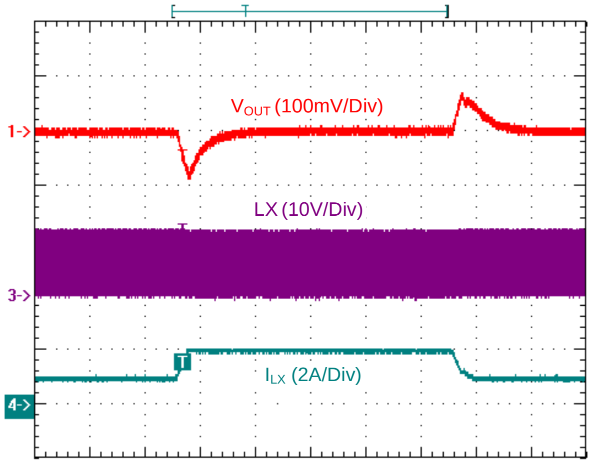
2us/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A

Steady State Waveforms



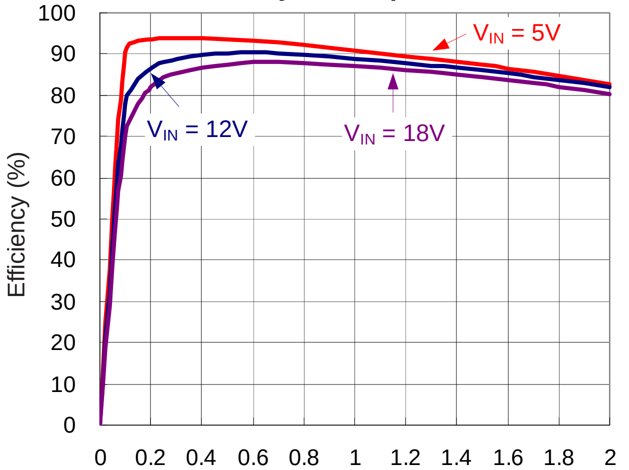
2us/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 2A

Load Transient Test Waveforms



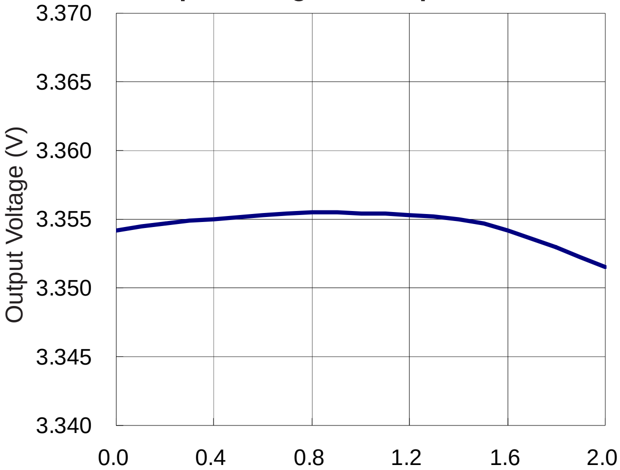
100us/Div
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 1A~2A

Efficiency vs. Output Current



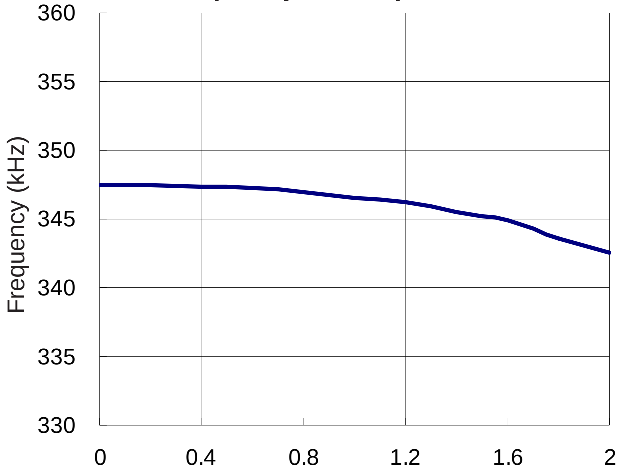
V_{IN} = 5V~18V, V_{OUT} = 3.3V, I_{OUT} = 0A~2A

Output Voltage vs. Output Current



V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A~2A

Frequency vs. Output Current



V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A~2A

Output Inductor Selection

Output inductor selection is usually based the considerations of inductance, rated current value, size requirements and DC resistance (DCR).

The inductance is chosen based on the desired ripple current. Large value inductors result in lower ripple currents and small value inductors result in higher ripple currents. Higher V_{IN} or V_{OUT} also increases the ripple current as shown in the equation below. A reasonable starting point for setting ripple current is ΔIL = 900mA (30% of 3000mA). For most applications, the value of the inductor will fall in the range of 1uH to 10uH.

$$\Delta I_L = \frac{1}{f_{OSC} \times L_{OUT}} \times V_{OUT}(1 - \frac{V_{OUT}}{V_{IN}})$$

Maximum current ratings of the inductor are generally specified in two methods: permissible DC current and saturation current. Permissible DC current is the allowable DC current that causes $40^{O}C$ temperature raise. The saturation current is the allowable current that causes 10% inductance loss. Make sure that the inductor will not saturate over the operation conditions including temperature range, input voltage range, and maximum output current. If possible, choose an inductor with rated current higher than 3.4A so that it will not saturate even under current limit condition.

The size requirements refer to the area and height requirement for a particular design. For better efficiency, choose a low DC resistance inductor. DCR is usually inversely proportional to size.

Different core materials and shapes will change the size, current and price/current relationship of an inductor. Toroid or shielded pot cores in ferrite or permalloy materials are small and don't radiate much energy, but generally cost more than powdered iron core inductors with similar electrical characteristics. The choice of which style inductor to use often depends on the price vs. size requirements and any radiated field/EMI requirements.

Input Capacitor Selection

The buck converter draws pulsed current with sharp edges from the input capacitor resulting in ripple and noise at the input supply voltage. A minimum 10uFx2 X5R or X7R ceramic capacitor is highly recommended to filter the pulsed current. The input capacitor should be placed as near the device as possible to avoid the stray inductance along the connection trace. Y5V dielectrics, aside from losing most of their capacitance over temperature, they also become resistive at high frequencies. This reduces their ability to filter out high frequency noise.

The capacitor with low ESR (equivalent series resistance) provides the small drop voltage to stabilize the input voltage during the transient loading. For input capacitor selection, the ceramic capacitor larger than 10uFx2 is recommend. The capacitor must conform to the RMS current requirement. The maximum RMS ripple current is calculated as:

$$I_{IN(RMS)} = I_{OUT(MAX)} \times \frac{\sqrt{V_{OUT} \times (V_{IN} - V_{OUT})}}{V_{IN}}$$

This formula has a maximum at V_{IN} = 2xV_{OUT}, where $I_{IN(RMS)} = I_{OUT(MAX)}/2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. Note that the capacitor manufacturer's ripple current ratings are often based on 2000 hours of life. This makes it advisable to further derate the capacitor, or choose a capacitor rated at a higher temperature than required. Always consult the manufacturer if there is any question.

Output Capacitor Selection

The integrated buck converter is specifically design to operate with minimum 22uFx2 X5R or X7R ceramic capacitor. The value can be increased to improve load/line transient performance. Y5V dielectrics, aside from losing most of their capacitance over temperature, they also become resistive at high frequencies. This reduces their ability to filter out high frequency noise.

The ESR of the output capacitor determines the output ripple voltage and the initial voltage drop following a high slew rate load transient edge. The output ripple voltage can be calculated as:

$$\Delta V_{OUT} = \Delta I_C \times (ESR + \frac{1}{8 \times f_{OSC} \times C_{OUT}})$$

where f_{OSC} = operating frequency, C_{OUT} = output capacitance and $\Delta I_C = \Delta I_L$ = ripple current in the inductor.

The ceramic capacitor with low ESR value provides the low output ripple and low size profile. Connect a 1uF/10uF ceramic capacitor at output terminal for good performance and place the input and output capacitors as close as possible to the device.

Using Ceramic Capacitors

Higher value, lower cost ceramic capacitors are now available in smaller case sizes. Their high ripple current, high voltage rating and low ESR make them ideal for switching regulator applications. Because the control loop does not depend on the output capacitor's ESR for stable operation, ceramic capacitors can be used to achieve very low output ripple and small circuit size.

However, care must be taken when these capacitors are used at the input and the output. When a ceramic capacitor is used at the input and the power is supplied by a wall adapter through long wires, a load step at the output can induce ringing at the input, V_{IN}. At best, this ringing can couple to the output and be mistaken as loop instability. At worst, a sudden inrush of current through the long wires can potentially cause a voltage spike at V_{IN}, large enough to damage the part. When choosing the input and output ceramic capacitors, choose the X5R or X7R dielectric formulations. These dielectrics have the best temperature and voltage characteristics of all the ceramics for a given value and size.

Checking Transient Response

The regulator loop response can be checked by looking at the load transient response. Switching regulators take several cycles to respond to a step in load current. When a load step occurs, V_{OUT} immediately shifts by an amount equal to (ΔI_{OUT} x ESR), where ESR is the effective series resistance of C_{OUT}. ΔI_{OUT} also begins to discharge or charge C_{OUT}, which generates a feedback error signal. The regulator loop then acts to return V_{OUT} to its steady state value. During this recovery time V_{OUT} can be monitored for overshoot or ringing that would indicate a stability problem.

PCB Layout Considerations

The physical design of the PCB is the final stage in the design of power converter. If designed improperly, the PCB could radiate excessive EMI and contribute instability to the power converter. Therefore, follow the PCB layout guidelines below can ensure better performance of uP1715.

1 The bold lines of AP Circuit below show the main power current paths. Keep the traces short and wide.

2 To reduce resistive of voltage drops and the number of via, uP1715 power components (C_{IN}, C_{OUT} and L) should be placed on the component side of the board and power current traces routed on its component layer.

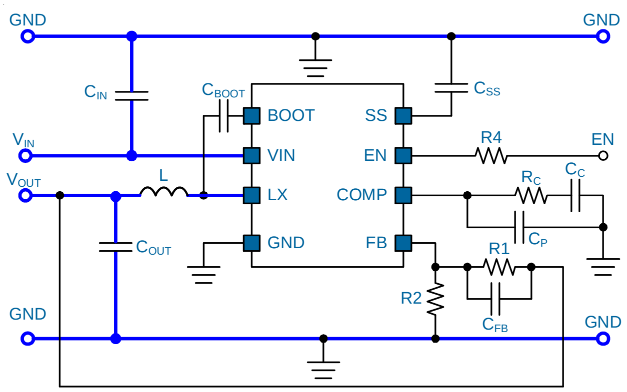
3 LX node supports high frequency voltage swing (dv/dt). It should be routed small area.

4 Place input capacitor as close as possible to the IC pins (VIN and GND).

5 Place feedback components (R1, R2, C_{FB}) behind the output capacitor and near the uP1715. Keep the feedback loop area small and away from LX node.

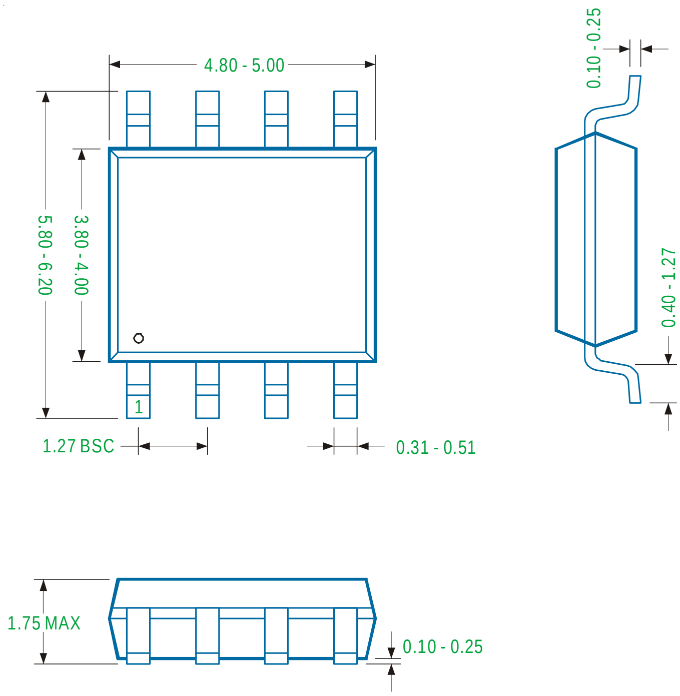
6 Place components (R_C, C_C, C_P, C_{SS} and R4) as close as possible to the IC pins and away from LX node.

7 To minimize parasitical capacitor couplings and magnetic field-to-loop couplings, the power converter should be located away from other circuitry, especially from sensitive analog circuitry.



Package Information

SOP-8L



Note
1. Package Outline Unit Description:
   BSC: Basic. Represents theoretical exact dimension or dimension target
   MIN: Minimum dimension specified.
   MAX: Maximum dimension specified.
   REF: Reference. Represents dimension for reference use only. This value is not a device specification.
   TYP. Typical. Provided as a general value. This value is not a device specification.
2. Dimensions in Millimeters.
3. Drawing not to scale.
4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.

Important Notice

uPI and its subsidiaries reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

uPI products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment. However, no responsibility is assumed by uPI or its subsidiaries for its use; nor for any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of uPI or its subsidiaries.

uPI Semiconductor Corp.

Headquarter
9F.,No.5, Taiyuan 1st St. Zhubei City,
Hsinchu Taiwan, R.O.C.
TEL : 886.3.560.1666 FAX : 886.3.560.1888

Sales Branch Office
12F-5, No. 408, Ruiguang Rd. Neihu District,
Taipei Taiwan, R.O.C.
TEL : 886.2.8751.2062 FAX : 886.2.8751.5064