2A,16V,380KHz Step-Down Converter

DESCRIPTION

The EUP3410/3411 is a current mode, step-down switching regulator capable of driving 2A continuous load with excellent line and load regulation. The EUP3410/3411 can operate with an input voltage range from 4.5V to 16V and the output can be externally set from 1.2V to 12V with a resistor divider.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. In shutdown mode the regulator draws 25µA of supply current.

The EUP3410/3411 requires a minimum number of external components.

FEATURES

- 30V Input Surge Protection
- Up to 2A Output Current
- 0.17Ω Internal DMOS Output Switch
- 4.5V to 16V Input Operating Range
- Output Adjustable from 1.2V to 12V
- Up to 95% Efficiency
- 25µA Shutdown Current
- Fixed 380KHz Frequency
- Thermal Shutdown and Overcurrent Protection
- Input Supply Overvoltage and Undervoltage Lockout
- Available in SOP-8 & MSOP-10 Packages
- RoHS Compliant and 100% Lead(Pb)-Free

APPLICATIONS

- PC Monitors
- Distributed Power Systems
- Networking Systems
- Portable Electronics

Typical Application Circuit

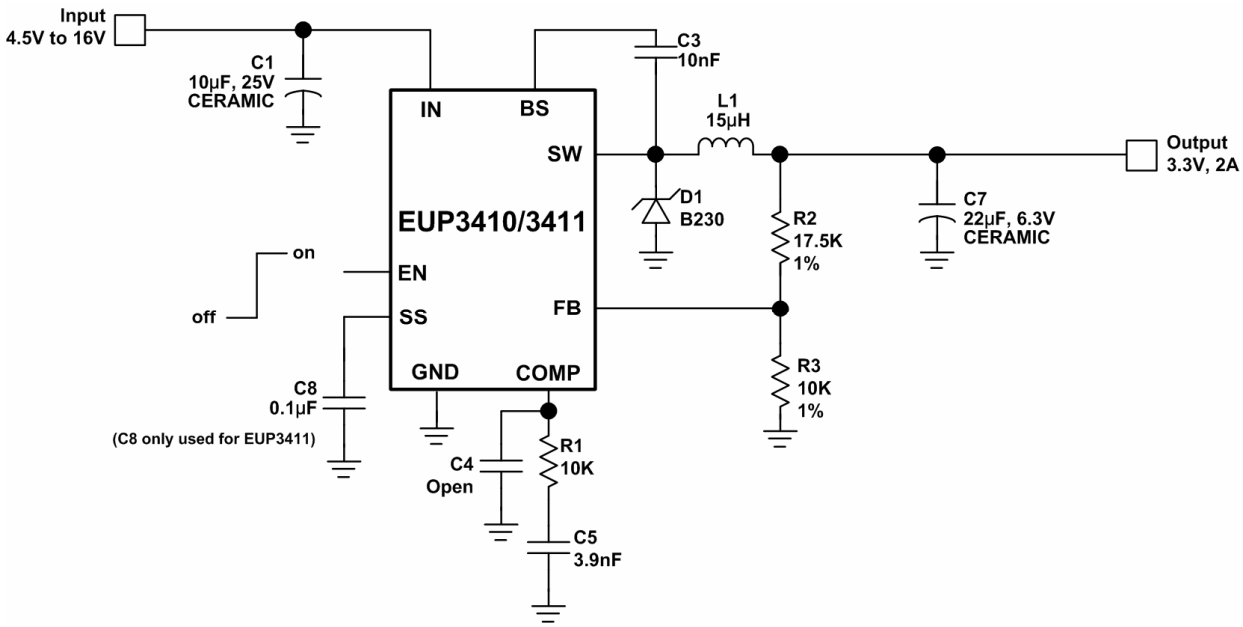


Figure 1. Typical Application Circuit with Ceramic Capacitors

Typical Application Circuit (continued)

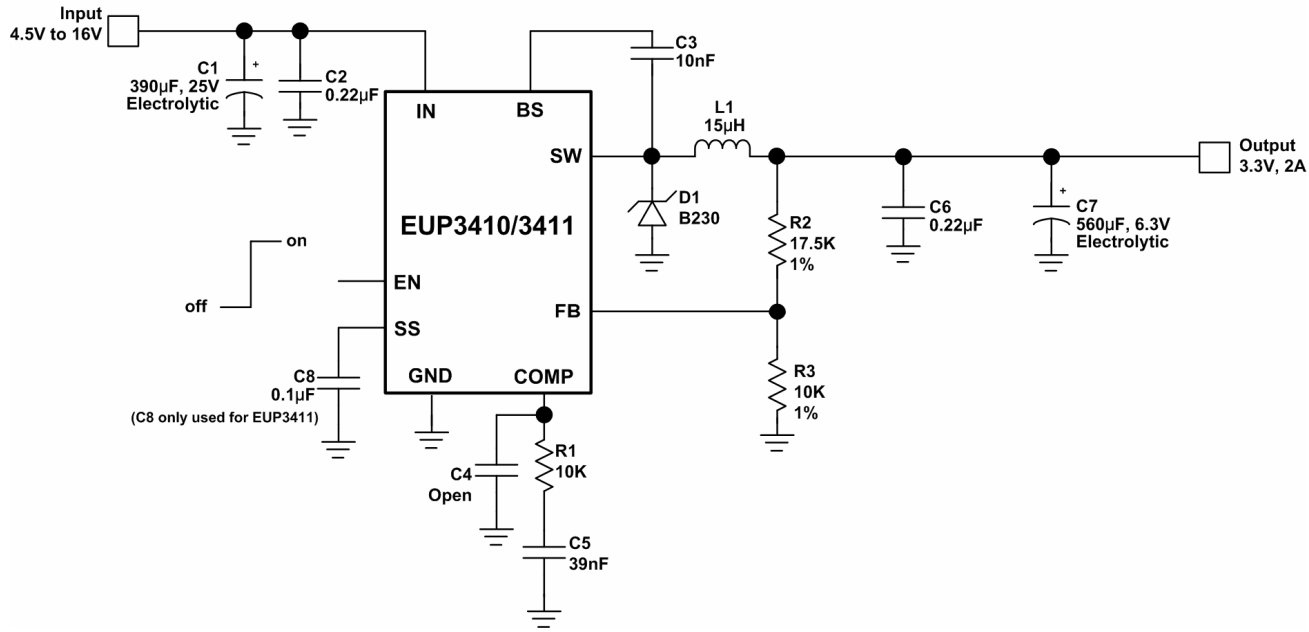


Figure 2. Typical Application Circuit with Electrolytic Capacitors

Block Diagram

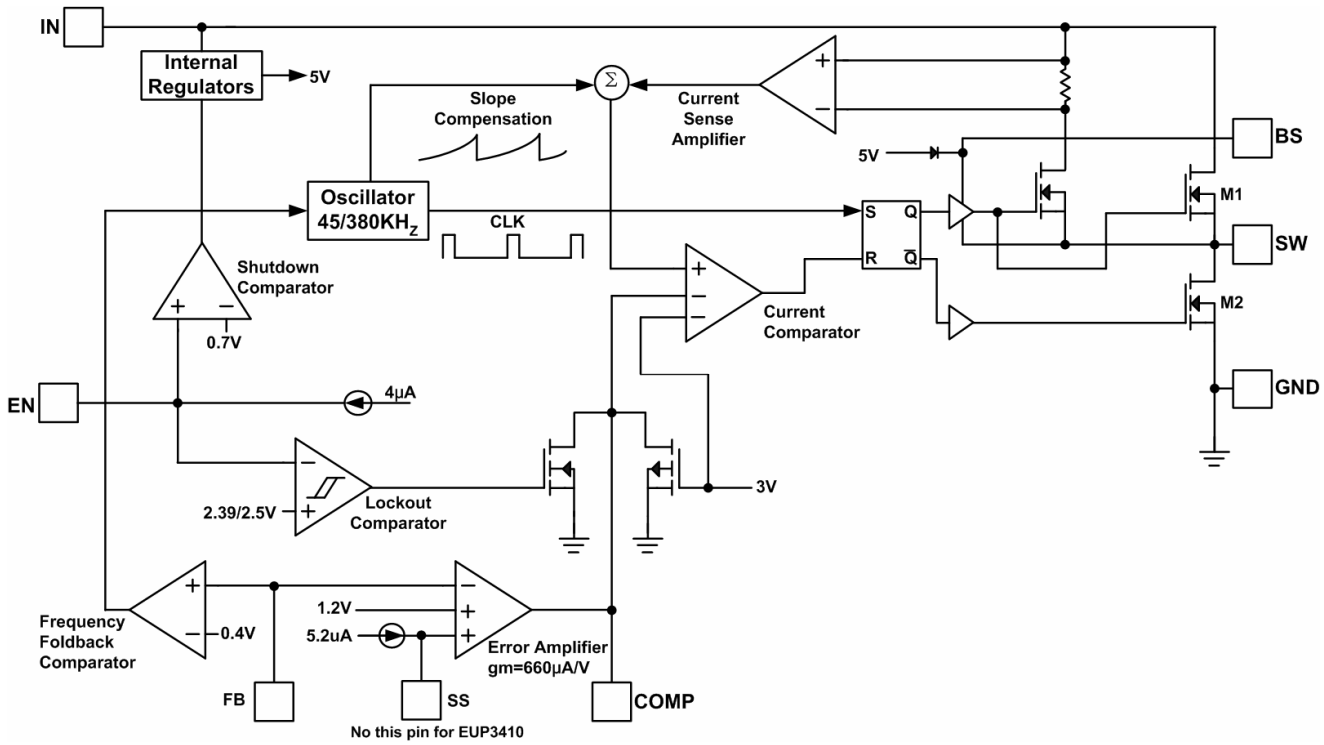
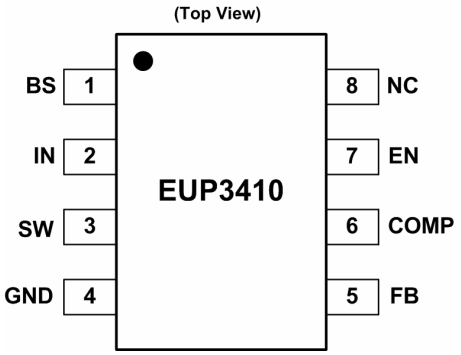
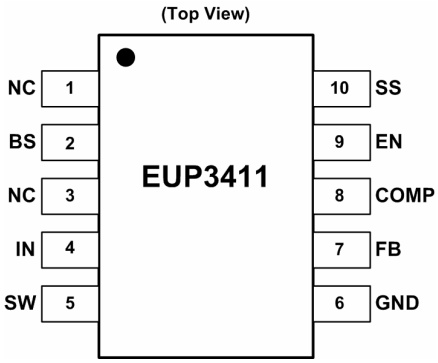


Figure 3. Functional Block Diagram

Pin Configurations

Package Type	Pin Configurations	Package Type	Pin Configurations
SOP-8		MSOP-10	

Pin Description

Pin Name	EUP3410	EUP3411	DESCRIPTION
BS	1	2	High-Side Gate Driver Boostrap Supply. BS provides power to the gate driver of high-side n-channel MOSFET switch. Connect a 10nF or greater capacitor from SW to BS.
IN	2	4	Input Supply Pin. IN supplies the power to the IC and the high side power switch. Connect IN to a 4.5V to 16V power source. Bypass IN to GND with a suitably large value capacitor to minimize input ripple to the IC. ***See Input Capacitor Section of the applications notes***.
SW	3	5	Power Switcher Output. Connect the output LC filter from SW to the output.
GND	4	6	Ground.
FB	5	7	Output Feedback Input. FB senses the output voltage to regulate that voltage. Connect FB to an external resistor divider to set the output voltage. The feedback threshold is 1.2V. ***See Setting the Output Voltage.***
COMP	6	8	Loop compensation pin. Connect a series RC network from COMP to GND to compensate the regulation control loop. ***See Compensation.***
EN	7	9	Enable Input. EN is a logic input that controls the regulator on or off. Drive EN logic high to turn on the regulator, and set EN logic low to turn it off. For automatic startup, leave EN unconnected and EN is pulled high by an internal current source to enable the device.
NC	8	1,3	No Connect
SS	-	10	Soft-Start pin. Connect SS to an external capacitor to program the soft-start time. If the pin is not used, leave it open.

Ordering Information

Order Number	Package Type	Marking	Operating Temperature Range
EUP3410DIR1	SOP-8	xxxxx P3410	-40°C to +85°C
EUP3411MIR1	MSOP-10	xxxxx 3411A	-40 °C to +85°C

EUP3410/3411 □ □ □ □

Lead Free Code
1: Lead Free 0: Lead

Packing
R: Tape & Reel

Operating temperature range
I: Industry Standard

Package Type
D: SOP
M: MSOP

Absolute Maximum Ratings (1)

- Input Voltage (V_{IN}) ---------- -0.3V to 30V
- Switch Voltage (V_{SW}) ---------- -1V to V_{IN} +0.3V
- Boot Strap Voltage (V_{BS}) ---------- V_{SW}-0.3V to V_{SW} +6V
- All Other Pins ---------- -0.3V to 6V
- Junction Temperature ---------- 150°C
- Storage Temperature ---------- -65°C to +150°C
- Lead Temp (Soldering, 10sec) ---------- 260°C
- Thermal Resistance θ_{JA} (SOP-8) ---------- 90°C/W
- Thermal Resistance θ_{JA} (MSOP-10) ---------- 61.11°C/W

Recommend Operating Conditions (2)

- Supply Voltage (V_{IN}) ---------- 4.5V to 16V
- Operating Temperature Range ---------- -40°C to +85°C

Note (1): Stress beyond those listed under "Absolute Maximum Ratings" may damage the device.

Note (2): The device is not guaranteed to function outside the recommended operating conditions

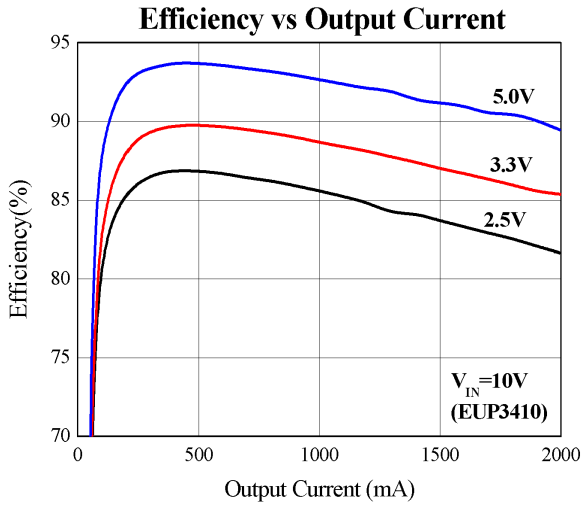
Electrical Characteristics

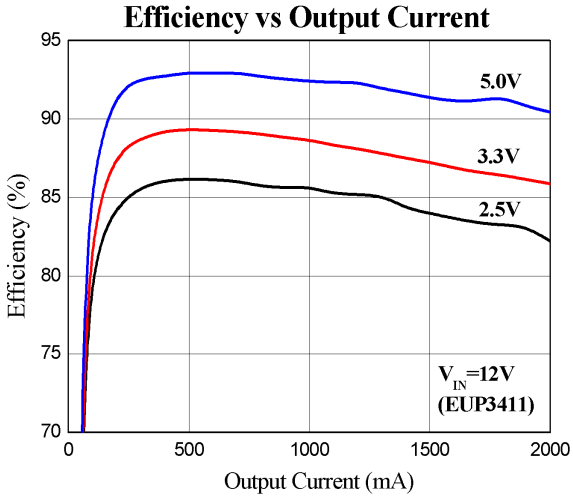
Unless otherwise specified, V_{EN}=5V, V_{IN}=12V ,T_A=+25°C.

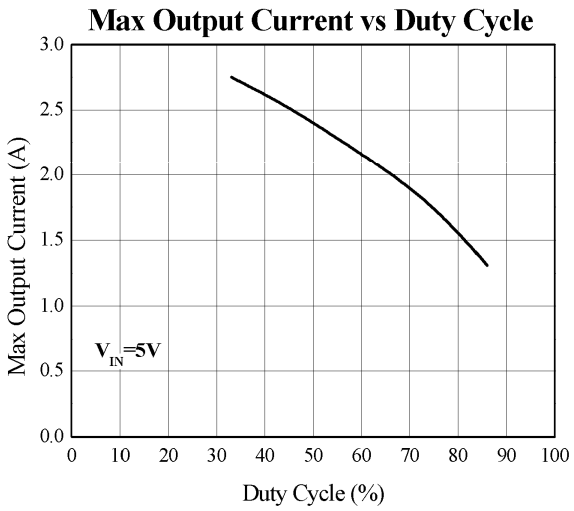
Parameter	Conditions	EUP3410/3411			Unit
		Min	Typ	Max	
Feedback Voltage	4.5V ≤ V_{IN} ≤ 16V	1.162	1.200	1.236	V
Upper Switch On Resistance			0.17		Ω
Lower Switch On Resistance			6.8		Ω
Upper Switch Leakage	V_{EN}=0V, V_{SW}=0V			5	μA
Switch Peak Current Limit		2.4	3		A
Oscillator Frequency		320	380	440	KHz
Short Circuit Frequency	V_{FB}=0V		45		KHz
Maximum Duty Cycle	V_{FB}=1V		90		%
Minimum Duty Cycle	V_{FB}=1.5V		0		%
Enable Threshold		0.7	0.95	1.4	V
Input Undervoltage Lockout Threshold Rising		2	2.5	3	V
Input Undervoltage Lockout Threshold Hysteresis			110		mV
Input Overvoltage Lockout Threshold			22		V
Shutdown Supply Current	V_{EN}=0V		25	36	μA
Operating Supply Current	V_{FB}=1.4V		0.45	0.7	mA
Soft-Start Current (EUP3411)	V_{SS}=0V		5.2		uA
Thermal Shutdown			160		°C

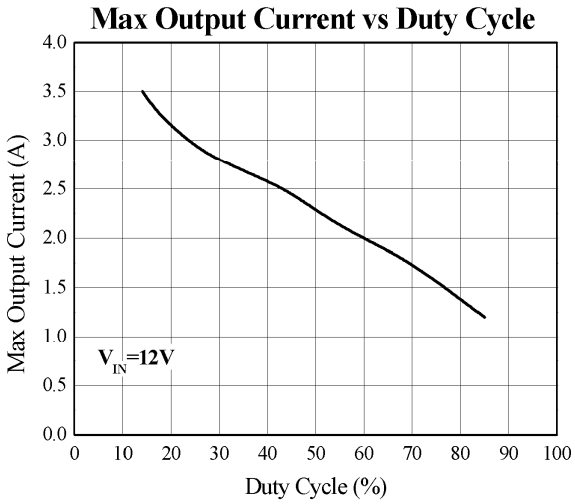
Typical Operating Characteristics

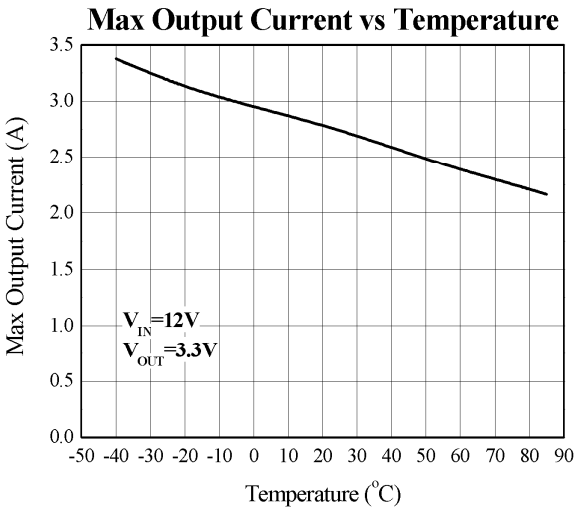
See Figure 2.C1=390uF, C2=0.22uF, C6=0.22uF, C7=560uF, L=15uH, T_A= +25°C.

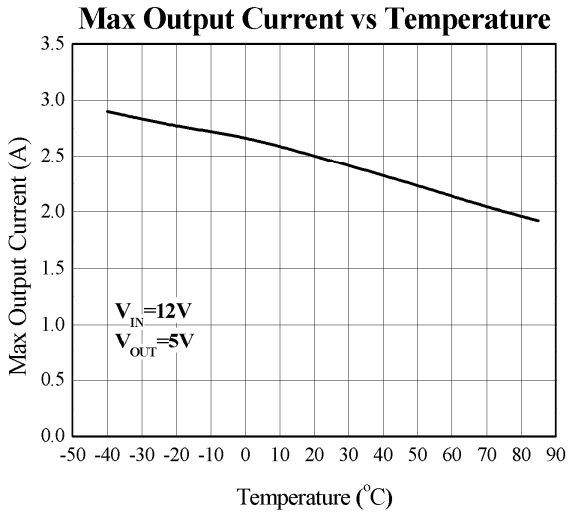










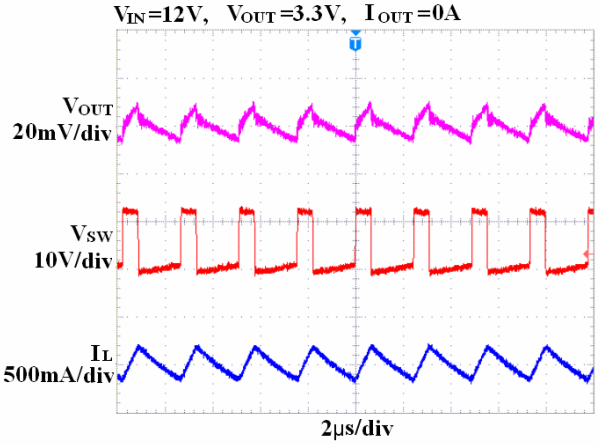


Typical Operating Characteristics

See Figure 2.C1=390uF, C2=0.22uF, C6=0.22uF, C7=560uF, L=15uH, T_A= +25℃.

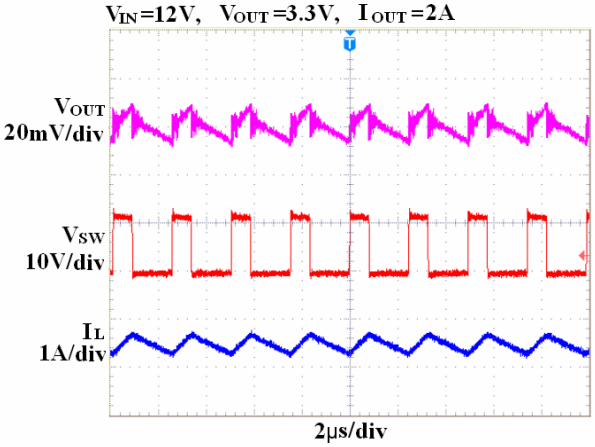
Steady State Test Waveforms

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



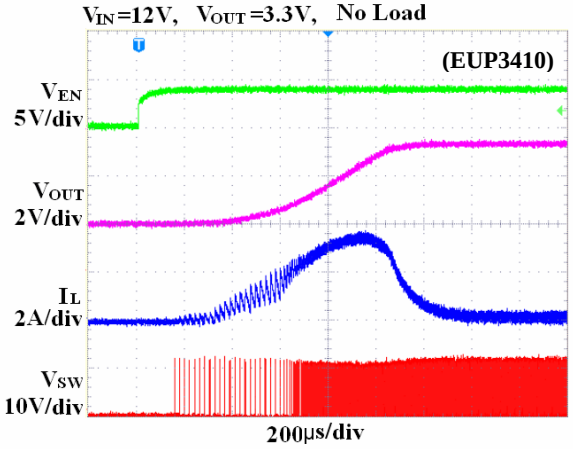
Steady State Test Waveforms

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



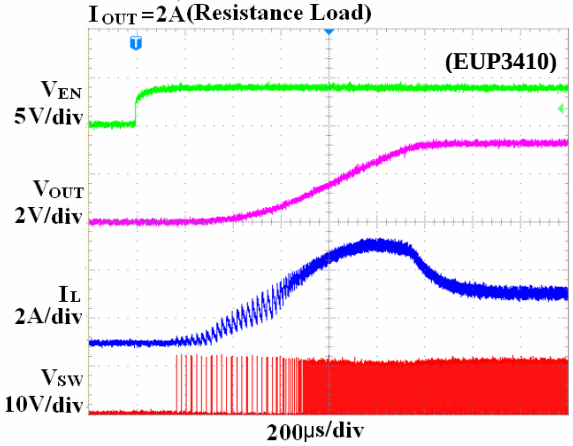
Startup through Enable Waveforms

V_{IN}=12V, V_{OUT}=3.3V, No Load



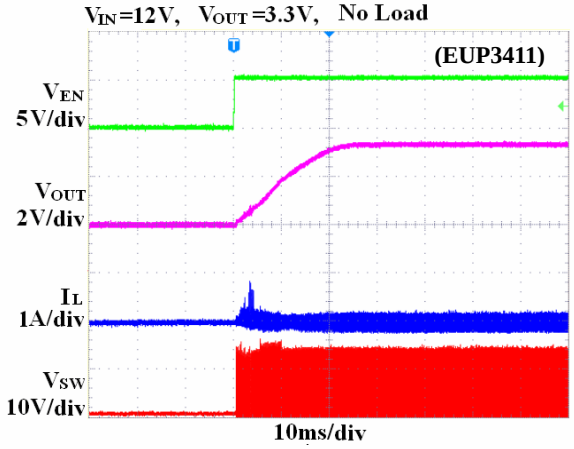
Startup through Enable Waveforms

V_{IN}=12V, V_{OUT}=3.3V,
I_{OUT}=2A(Resistance Load)



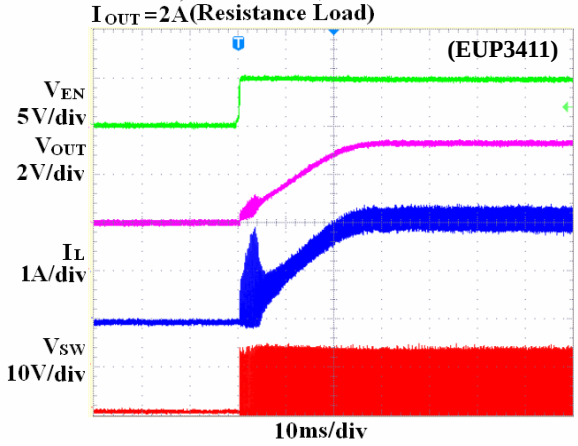
Startup through Enable Waveforms

V_{IN}=12V, V_{OUT}=3.3V, No Load



Startup through Enable Waveforms

V_{IN}=12V, V_{OUT}=3.3V,
I_{OUT}=2A(Resistance Load)

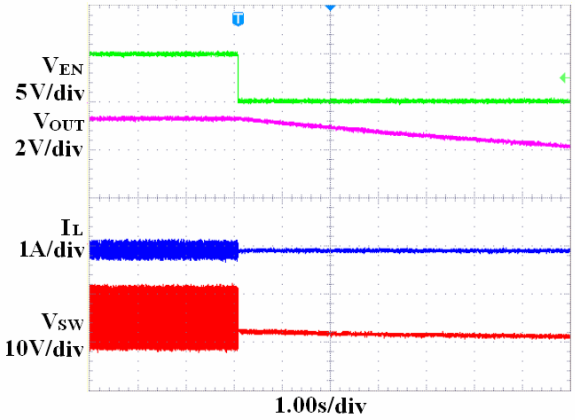


Typical Operating Characteristics

See Figure 2.C1=390uF, C2=0.22uF, C6=0.22uF, C7=560uF, L=15uH, T_A= +25℃.

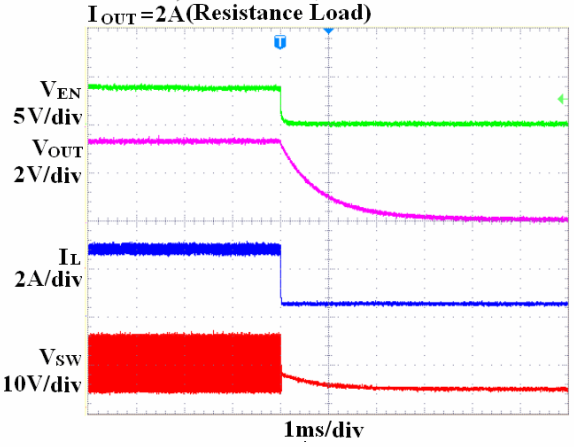
Shutdown through Enable Waveforms

V_{IN}=12V, V_{OUT}=3.3V, No Load



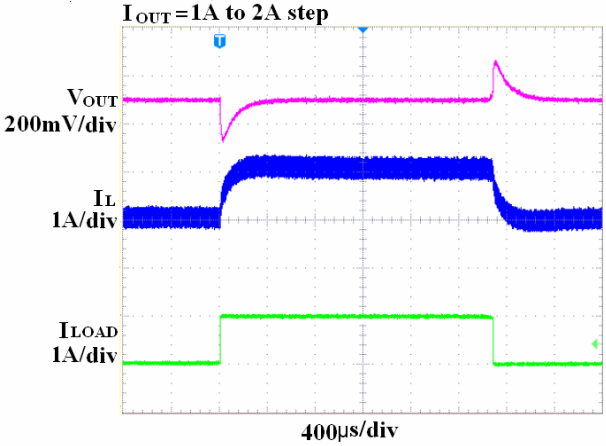
Shutdown through Enable Waveforms

V_{IN}=12V, V_{OUT}=3.3V,
I_{OUT}=2A(Resistance Load)



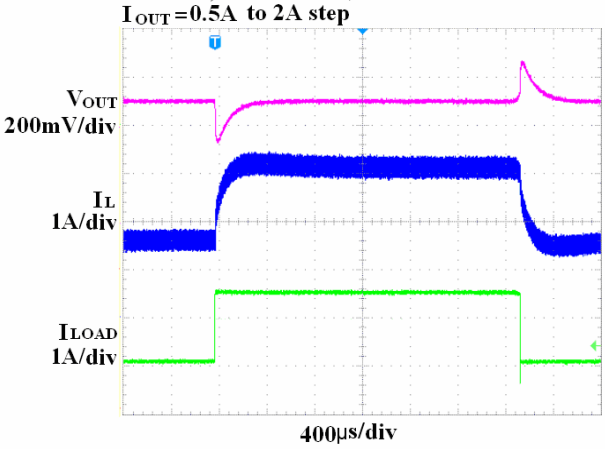
Load Transient Test Waveforms

V_{IN}=12V, V_{OUT}=3.3V,
I_{OUT}=1A to 2A step



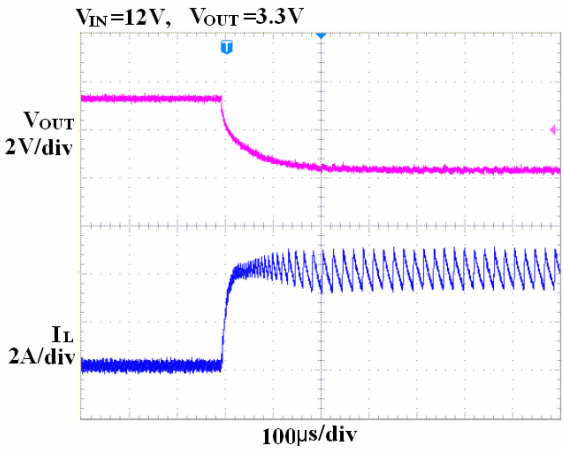
Load Transient Test Waveforms

V_{IN}=12V, V_{OUT}=3.3V,
I_{OUT}=0.5A to 2A step



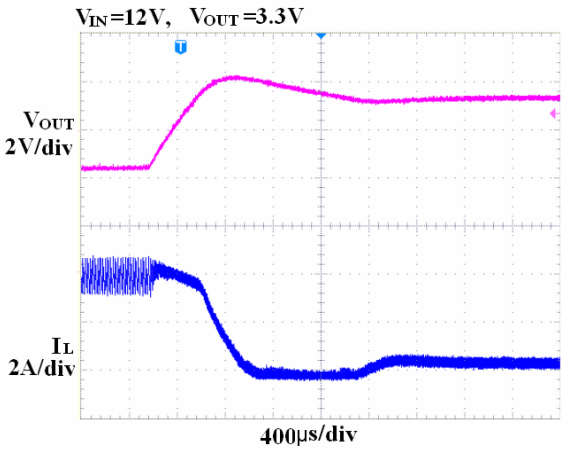
Short Circuit Test Waveforms

V_{IN}=12V, V_{OUT}=3.3V



Short Circuit Recovery Waveforms

V_{IN}=12V, V_{OUT}=3.3V



Functional Description

The EUP3410/3411 is a current-mode step-down switching regulator. The device regulates an output voltage as low as 1.2V from a 4.5V to 16V input power supply. The device can provide up to 2Amp continuous current to the output. The EUP3410/3411 uses current-mode architecture to control the regulator loop. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal error amplifier. The output current of the transconductance error amplifier is presented at COMP pin where a RC network compensates the regulator loop. Slope compensation is internally added to eliminate subharmonic oscillation at high duty cycle. The slope compensation adds voltage ramp to the inductor current signal which reduces maximum inductor peak current at high duty cycles.

The device uses an internal Hside n-channel switch to step down the input voltage to the regulated output voltage. Since the Hside n-channel switch requires gate voltage greater than the input voltage, a boostrap BS capacitor is connected between SW and BS to drive the n-channel gate. The BS capacitor is internally charged while the switch is off. An internal 6.8Ω switch from SW to GND is added to insure that SW is pulled to GND when the switch is off to fully charge the BS capacitor.

Application Information

Setting the Output Voltage

The output voltage is set through a resistive voltage divider (see Figure1 or 2). The voltage divider divides the output voltage down by the ratio:

$$V_{FB} = V_{OUT} * R3/(R2+R3) = 1.2V$$

Thus the output voltage is :

$$V_{OUT} = 1.2V * (R2+R3)/R3$$

Choose R3 value in the range 10k to 100k, R2 is determined by :

$$R2 = (V_{OUT}/1.2 - 1) * R3$$

For example, for a 3.3V output voltage, R3 is 10KΩ, and R2 is 17.5KΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor results in less ripple current and lower output ripple voltage. However, the larger value inductor has a larger physical size, higher series resistance, and lower saturation current. Choose an inductor that does not saturate under the worst-case load conditions. A good rule for determining the inductance is to allow the peak-to- peak ripple current in the inductor to be approximately 30% of the maximum load current. Also, make sure that the peak inductor current (the load current plus half the peak-to-peak inductor ripple current) is below the 2.4A minimum peak current limit.

The inductance value can be calculated by the equation:

$$L = (V_{OUT}) * (V_{IN} - V_{OUT}) / (V_{IN} * f * \Delta I)$$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f is the switching frequency, and ΔI is the peak-to-peak inductor ripple current.

Input Capacitor

The input current to the step-down converter is discontinuous, and therefore an input capacitor C1 is required to supply the AC current to the step-down converter while maintaining the DC input voltage. A low ESR capacitor is required to keep the noise minimum at the IC. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice. The input capacitor value should be greater than 10μF, and the RMS current rating should be greater than approximately 1/2 of the DC load current. In Figure 2, for insuring stable operation C2 should be placed as close to the IC as possible. Alternately a smaller high quality ceramic 0.1μF capacitor may be placed closer to the IC and a larger capacitor placed further away. If using this technique, it is recommended that the larger capacitor type are either tantalum or electrolytic. In Figure 1, all ceramic capacitors should be placed close to the EUP3410/3411.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Low ESR capacitors are preferred to keep the output voltage ripple low. The characteristics of the output capacitor also affect the stability of the regulator control loop. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is estimated to be:

$$V_{RIPPLE} \sim= 1.4 * V_{IN} * (f_{LC}/f)\hat{}2$$

Where V_{RIPPLE} is the output ripple voltage, V_{IN} is the input voltage, f_{LC} is the resonant frequency of the LC filter, f is the switching frequency. In the case of tanatalum or low ESR electrolytic capacitors, the ESR dominates the impedance at the switching frequency, and so the output ripple is calculated as:

$$V_{RIPPLE} \sim= \Delta I * R_{ESR}$$

Where V_{RIPPLE} is the output voltage ripple, ΔI is the inductor ripple current, and R_{ESR} is the equivalent series resistance of the output capacitors.

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the high-side switch is off. A schottky diode is recommended to reduce losses due to the diode forward voltage and recovery times.

Loop Compensation

The system stability is controlled through the COMP pin. COMP is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the feedback loop.

The DC loop gain is:

$$A_{VDC} = (V_{FB} / V_{OUT}) * A_{VEA} * G_{CS} * R_{LOAD}$$

Where:

V_{FB} is the feedback threshold voltage, 1.2V

V_{OUT} is the desired output regulation voltage

A_{VEA} is the transconductance error amplifier voltage gain, 400 V/V

G_{CS} is the current sense gain, (roughly the output current divided by the voltage at COMP), 2A/V

R_{LOAD} is the load resistance (V_{OUT} / I_{OUT} where I_{OUT} is the output load current)

The system has 2 poles. One is due to the compensation capacitor (C5), and the other is due to the output capacitor (C7). These are:

$$f_{P1} = G_{EA} / (2\pi * A_{VEA} * C5)$$

Where P1 is the first pole, and G_{EA} is the error amplifier transconductance (660μA/V).

and

$$f_{P2} = 1 / (2\pi * R_{LOAD} * C7)$$

The system has one zero of importance, due to the compensation capacitor (C5) and the compensation resistor (R1). The zero is:

$$f_{Z1} = 1 / (2\pi * R1 * C5)$$

If a large value capacitor (C7) with relatively high equivalent-series-resistance (ESR) is used, the zero due to the capacitance and ESR of the output capacitor can be compensated by a third pole set by R1 and C4. The pole is:

$$f_{P3} = 1 / (2\pi * R1 * C4)$$

The system crossover frequency (the frequency where the loop gain drops to 1, or 0dB) is important. A good rule of thumb is to set the crossover frequency to approximately 1/10 of the switching frequency. In this case, the switching frequency is 380KHz, therefore use a crossover frequency, f_C, of 40KHz. Lower crossover frequency results in slower loop response and poor load transient performance. Higher crossover frequency can result in loop instability.

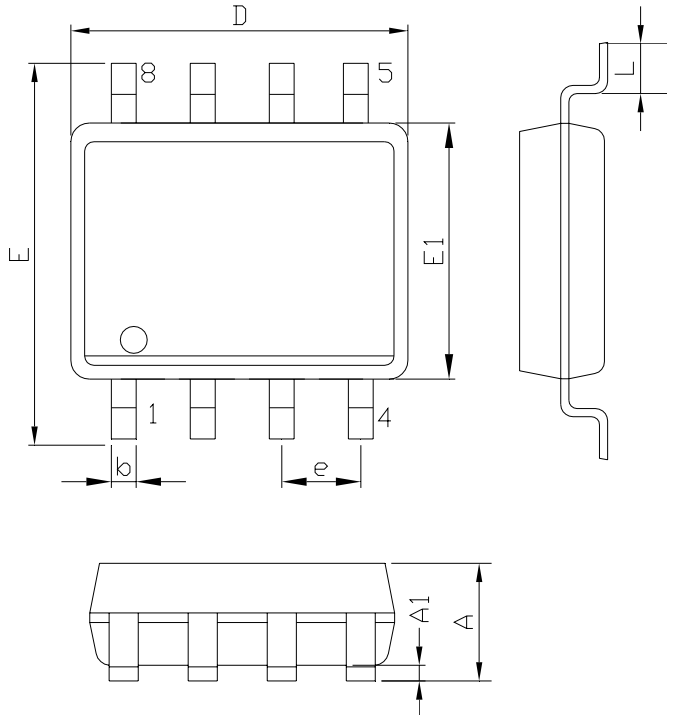
Table 1. Compensation Values for Typical Output Voltage /Capacitor Combinations

VOUT	C7	R1	C5	C4
2.5V	22μF Ceramic	10KΩ	3.9nF	None
3.3V	22μF Ceramic	10KΩ	3.9nF	None
5V	22μF Ceramic	10KΩ	3.9nF	None
12V	22μF Ceramic	10KΩ	3.9nF	None
2.5V	560μF/6.3V (30mΩ ESR)	10KΩ	30nF	None
3.3V	560μF/6.3V (30mΩ ESR)	10KΩ	39nF	None
5V	470μF/10V (30mΩ ESR)	10KΩ	47nF	None
12V	220μF/25V (30mΩ ESR)	10KΩ	56nF	None

The values of the compensation components listed in Table 1 yield a stable control loop for the given output voltage.

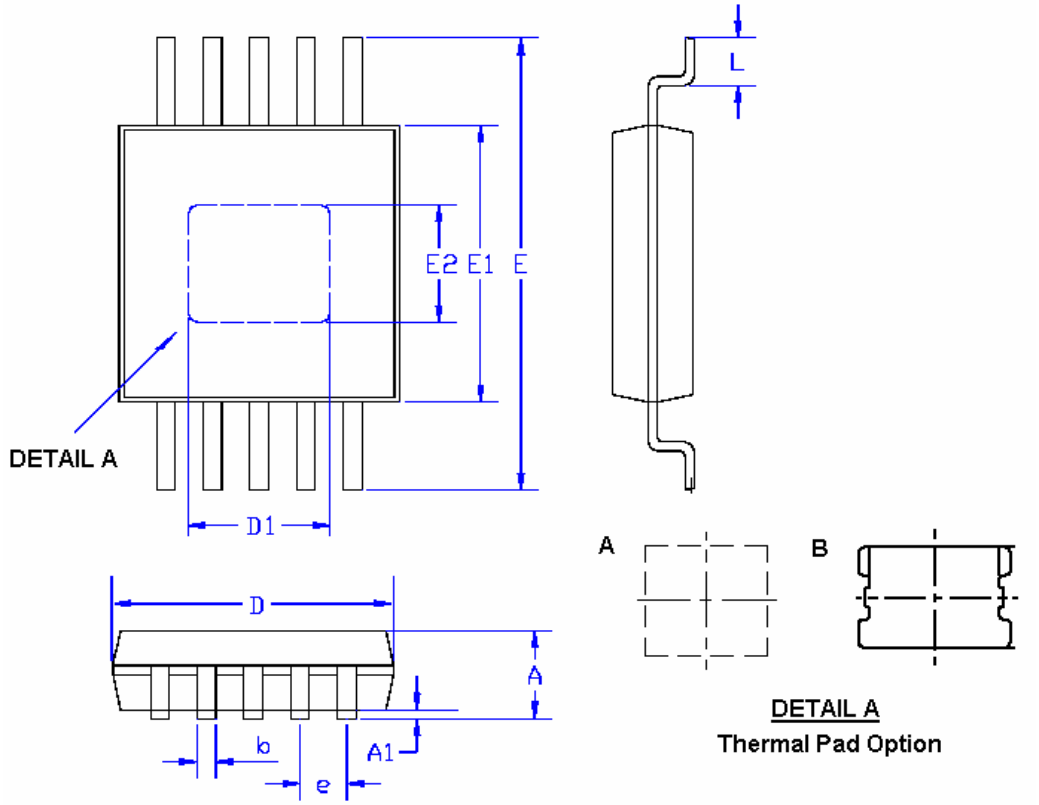
Packaging Information

SOP-8



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
D	4.90		0.193	
E	5.80	6.20	0.228	0.244
E1	3.90		0.153	
L	0.40	1.27	0.016	0.050
b	0.31	0.51	0.012	0.020
e	1.27		0.050	

MSOP-10



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	-	1.10	-	0.043
A1	0.00	0.15	0.000	0.006
D	3.00		0.118	
E1	3.00		0.118	
E	4.70	5.10	0.185	0.201
L	0.40	0.80	0.016	0.031
b	0.17	0.33	0.006	0.013
e	0.50		0.020	
D1	1.80		0.071	
E2	1.66		0.065	