CC/CV Mode Synchronous Step-Down Converter

DESCRIPTION

The EUP3276A is a synchronous, step-down constant on-time buck regulator capable of driving 5A continuous load current. The EUP3276A operates in either CC (Constant Current) mode or CV (Constant Voltage) mode with an input voltage range from 4.5V to 36V. The EUP3276A provides programmable cable compensation by adjusting external resistor divider. The EUP3276A provides excellent transient response with constant on-time control method while maintaining a nearly constant frequency of 150KHz.

Fault condition protection includes VIN under-voltage lockout, cycle-by-cycle current limiting, short-circuit protection, as well as thermal shutdown. Programmable soft-start minimizes the inrush supply current and the output overshoot at initial startup.

The EUP3276A is available in TQFN-23 package.

FEATURES

- Wide Input Voltage Range: 4.5V to 36V
- Up to 5A Output Current
- Excellent Line and Load Transient Responses
- Integrated 40mΩ N-Channel MOSFET for High Side
- Integrated 15mΩ N-Channel MOSFET for Low Side
- Fixed 150KHz Frequency
- CC/CV Mode Control
- Adjustable Soft-Start
- Programmable Cable Compensation
- Cycle-by-Cycle Current Limit
- Hiccup Short Circuit Protection
- Over-Temperature Protection
- Available in TQFN-23 Package
- RoHS Compliant and 100% Lead(Pb)- Free, Halogen-Free

APPLICATIONS

- Car Charger
- Portable Charger Application
- DC-DC Converter with Current Limit

Typical Application Circuit

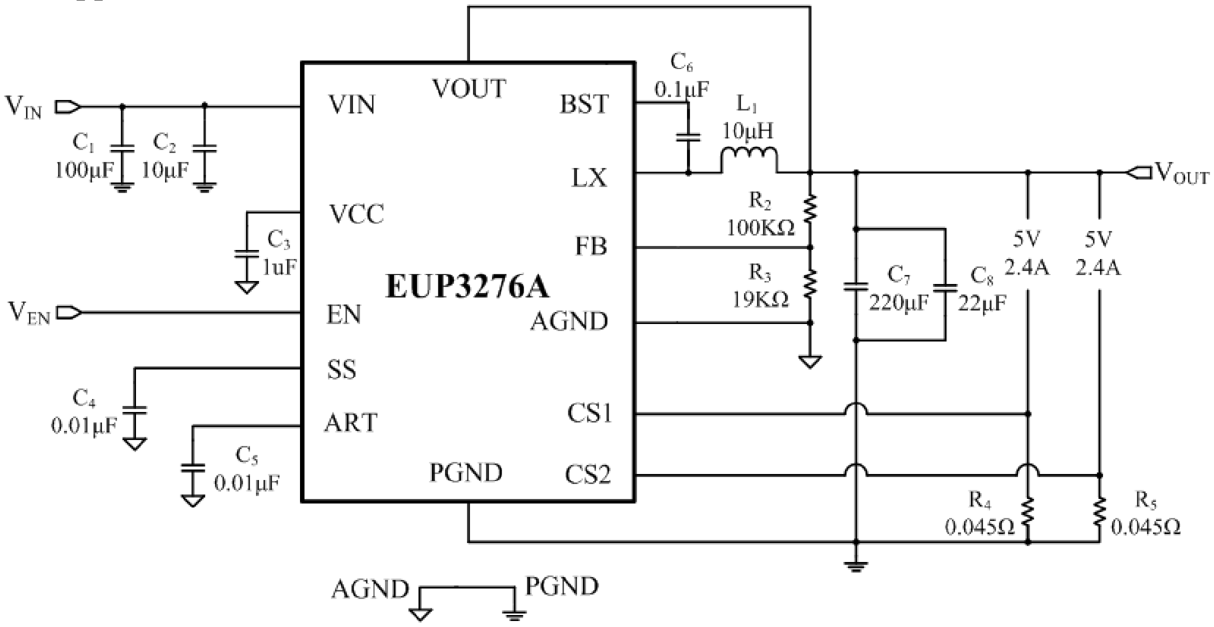
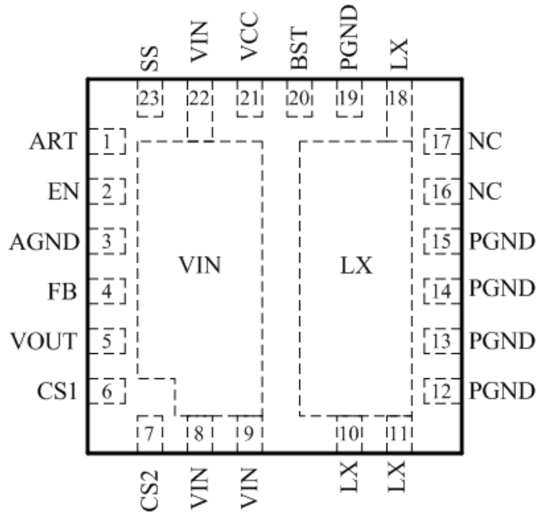


Figure 1. Application Circuit

Pin Configurations

Package Type	Pin Configurations
TQFN-23	

Pin Description

PIN NAME	TQFN-23	DESCRIPTION
VIN	8,9,22 Left Exposed Pad	Power supply input pin
SS	23	Soft start time setting pin. Connect a capacitor to ground to set the soft start time
ART	1	Hiccup time setting pin. Connect ART to AGND with a capacitor to set hiccup time
EN	2	Enable pin. Chip is enabled when EN=1, shutdown when EN=0
AGND	3	Signal ground pin
FB	4	Output voltage feedback pin
VOUT	5	Output voltage pin
CS1	6	Channel one current sense pin
CS2	7	Channel two current sense pin
LX	10,11,18 Right Exposed Pad	Switching output pin
CGND	NA	Current sense ground pin
LGATE	NA	Low-side switch drive pin
PGND	12,13,14,15,19	Power ground pin
BST	20	Bootstrap capacitor connection pin. BST is power supply for high side gate driver. Connect an external capacitor between BST and LX
VCC	21	5V LDO output pin. Connect a 1µF ceramic capacitor between VCCA and AGND
NC	16,17	Not connected

Ordering Information

Order Number	Package Type	Marking	Quantity per Reel	Operating Temperature Range
EUP3276AJIR1	TQFN-23	xxxxx P3276	2500	-40 °C to +85°C

EUP3276A □ □ □ □

- Lead Free Code
  1: Lead Free, Halogen-Free
- Packing
  R: Tape & Reel
- Operating temperature range
  I: Industry Standard
- Package Type
  J:TQFN-23

Block Diagram

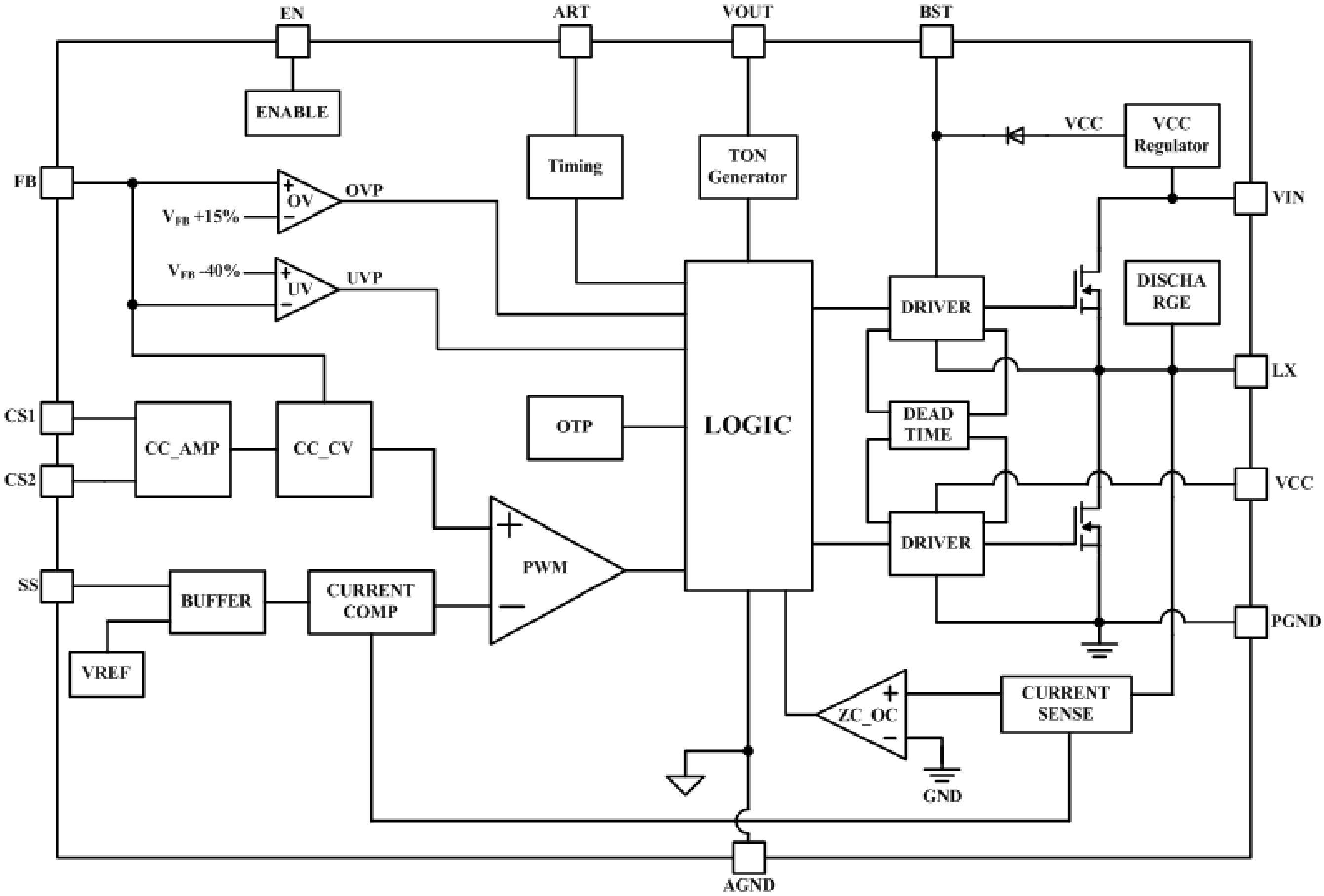


Figure 4.Functional Block Diagram

Absolute Maximum Ratings (1)

- Input Voltage (V_{IN}) --- -0.3V to 40V
- Enable Voltage (V_{EN}) -- -0.3V to 40V
- Switch Voltage (V_{LX}) -- -1V to V_{IN} +0.3V
- Bootstrap Voltage(V_{BST}) -- V_{LX}-0.3V to V_{LX}+6V
- Output Voltage (V_{OUT}) -- -0.3V to 30V
- 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} (TQFN-23) -- 45°C/W
- Thermal Resistance θ_{JC} (TQFN-23) --- 4.5°C/W

Recommend Operating Conditions (2)

- Supply Voltage (V_{IN}) -- 4.5V to 36V
- Ambient Operating Temperature --- -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

(V_{IN}=12V, T_A=+25°C, V_{EN}=5V, unless otherwise specified)

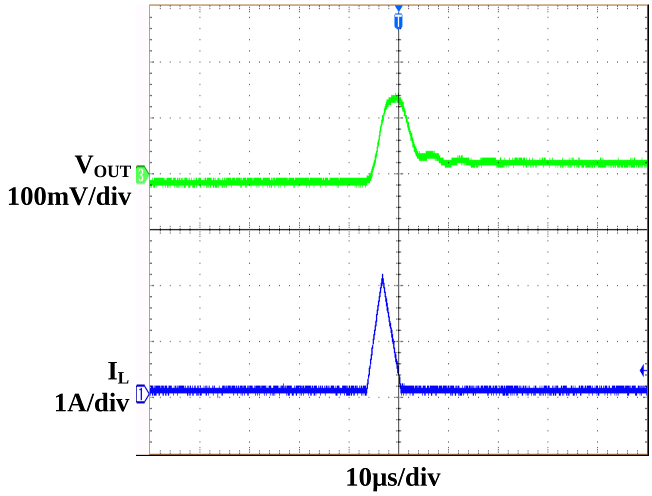
Symbol	Parameter	Conditions	EUP3276A			Unit
			Min.	Typ.	Max.	
General Section						
V_{IN}	Supply voltage		4.5		36	V
I_Q	Quiescent supply current	V_{EN}=5V, V_{FB}=0.85V		1	2	mA
I_{SD}	Shutdown supply current	V_{EN}=0V		1	20	µA
Control Section						
V_{ENH}	Enable threshold	On state	2.5			V
V_{ENL}		Off state			0.5	V
V_{UVLO}	V_{IN} UV lockout threshold	V_{IN} rising		3.9	4.3	V
		V_{IN} falling	3.2	3.6		V
Modulator Section						
F_{OSC}	Operating Frequency	V_{IN}=12V	120	150	180	KHz
T_{ON_MIN}	Minimum on time			100		ns
T_{OFF_MIN}	Minimum off time			400		ns
V_{FB}	Feedback voltage		0.788	0.800	0.812	V
V_{CS}	CS1/CS2 reference voltage		101	108	115	mV
I_{Cable}	Cable compensation	V_{CS}=0.1V		2.7		µA
Power MOS Section						
R_{DSONH}	High side MOS on resistance	V_{IN}=12V		40		mΩ
R_{DSONL}	Low side MOS on resistance	V_{IN}=12V		15		mΩ
Soft Start and Hiccup Section						
I_{SS}	Internal soft start current	V_{SS}=0V		10		µA
I_{ART}	Internal hiccup charging current			2.5		µA
Protection Section						
I_{OCP}	Valley current of I_L		6			A
V_{UV}	UVP threshold	FB falling	55	60	65	%
T_{UV}	UVP delay time	FB falling		1		ms
V_{OV}	OVP threshold	FB rising	112	115	118	%
T_{OV}	OVP delay time	FB rising		10		µs
T_{SD}	Thermal shutdown threshold			160		°C
T_{SD_HYS}	Thermal shutdown hysteresis			60		°C

Typical Operating Characteristics

T_A=25°C, V_{IN}=12V, V_{OUT}=5V, f=150KHz, unless otherwise specified.

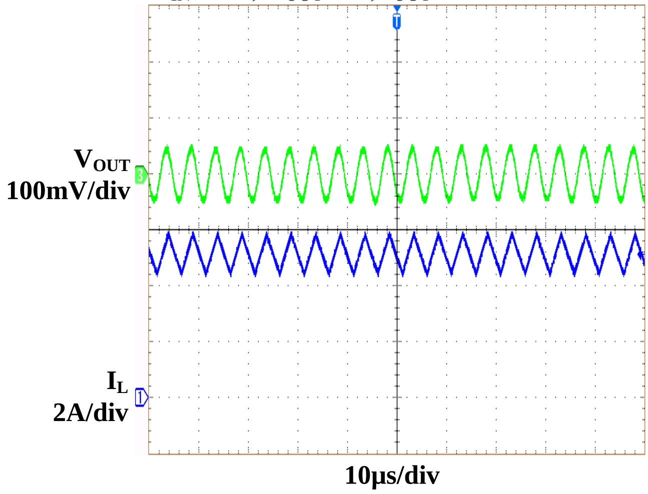
Steady State

V_{IN}=12V, V_{OUT}=5V, No Load



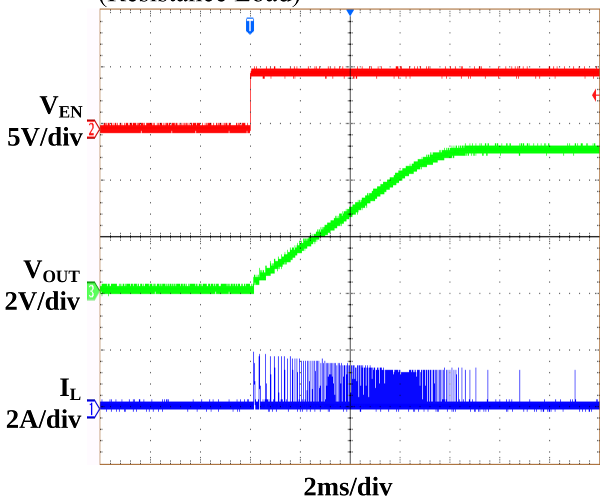
Steady State

V_{IN}=12V, V_{OUT}=5V, I_{OUT}=5A



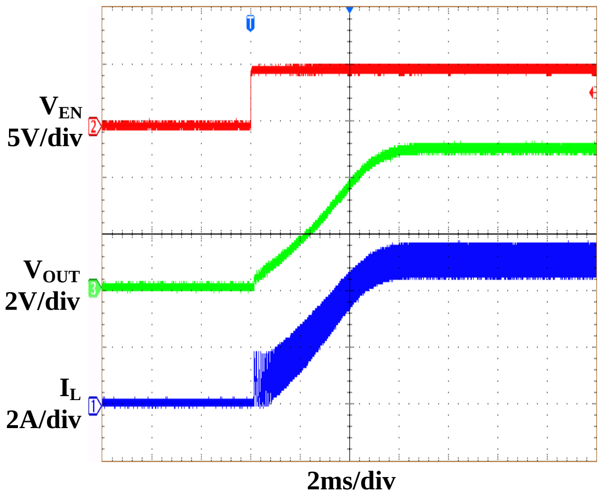
Startup through Enable

V_{IN}=12V, V_{OUT}=5V, C_{SS}=100nF, I_{OUT}=0A (Resistance Load)



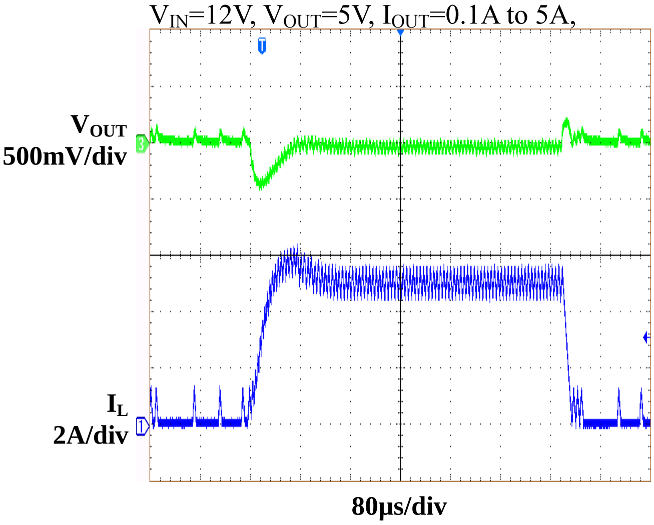
Startup through Enable

V_{IN}=12V, V_{OUT}=5V, C_{SS}=100nF, I_{OUT}=5A (Resistance Load)



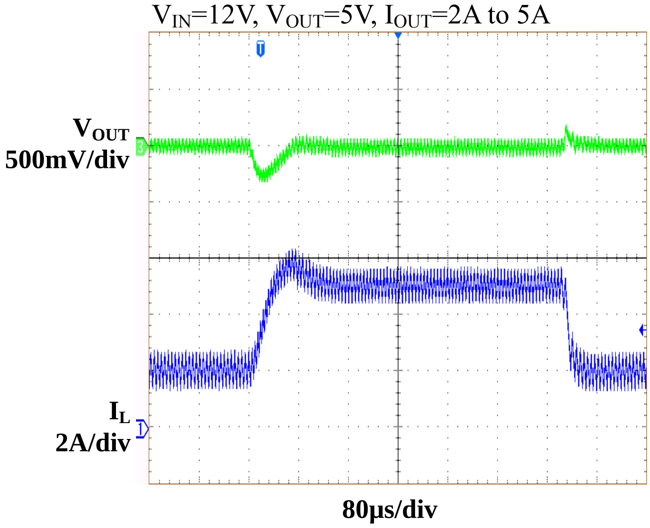
Load Transient Response

V_{IN}=12V, V_{OUT}=5V, I_{OUT}=0.1A to 5A,



Load Transient Response

V_{IN}=12V, V_{OUT}=5V, I_{OUT}=2A to 5A

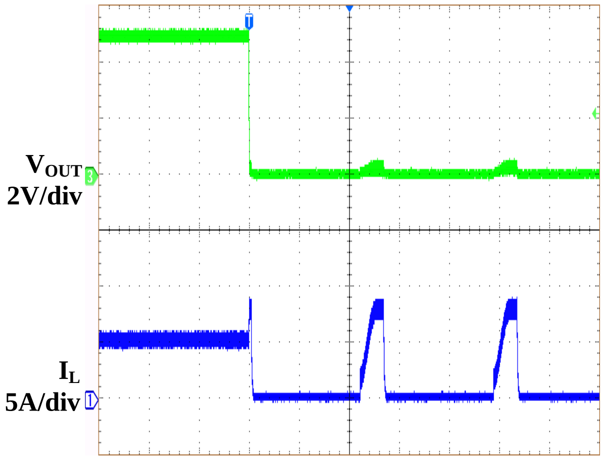


Typical Operating Characteristics

T_A=25°C, V_{IN}=12V, V_{OUT}=5V, f=150KHz, unless otherwise specified.

Short Circuit

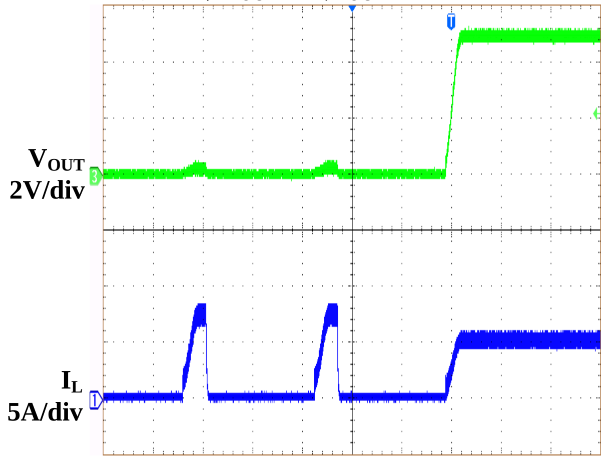
V_{IN}=12V, V_{OUT}=5V, I_{OUT}=5A



20ms/div

Short Circuit Recovery

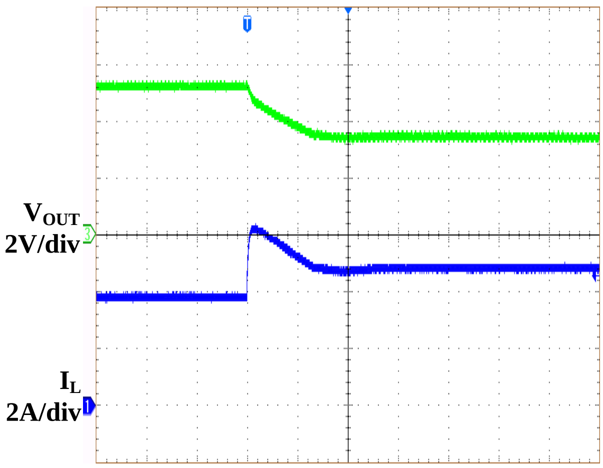
V_{IN}=12V, V_{OUT}=5V, I_{OUT}=5A



20ms/div

CV mode to CC mode

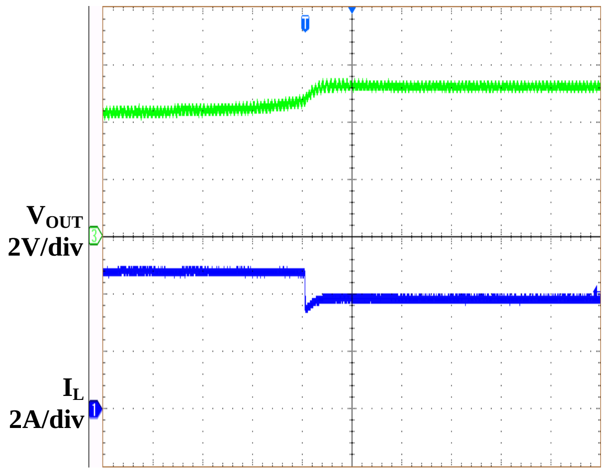
V_{IN}=12V, V_{OUT}=5V, R_{CS}=45mΩ, I_{OUT}=2A



2ms/div

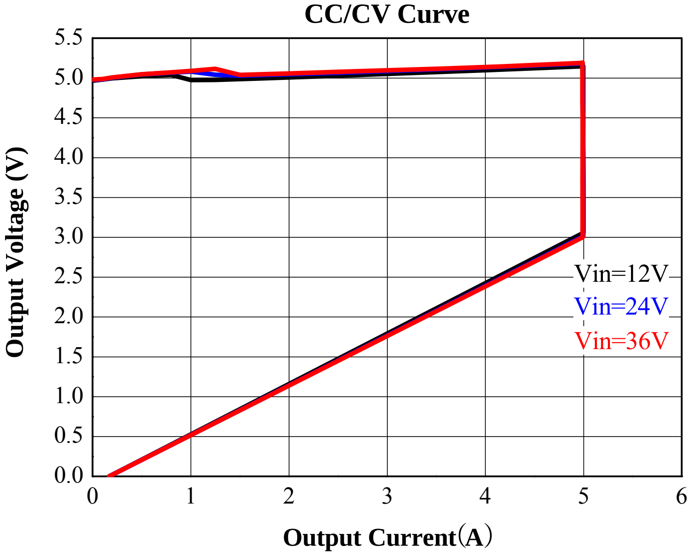
CC mode to CV mode

V_{IN}=12V, V_{OUT}=5V, R_{CS}=45mΩ, I_{OUT}=2A

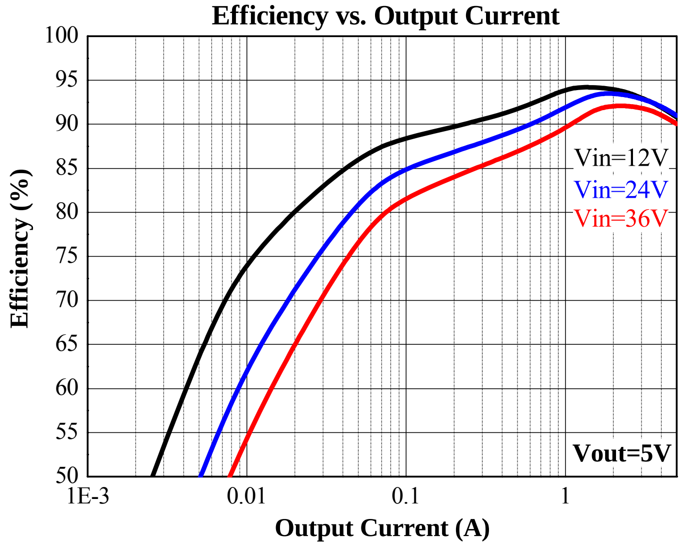


2ms/div

CC/CV Curve



Efficiency vs. Output Current



Functional Description

The EUP3276A is a constant on-time synchronous step-down converter with 4.5V to 36V input power supply. The device can provide up to 5A continuous current to the output. This architecture provides very fast on-time response to output load transients. The switching frequency is 150KHz.

The converter uses internal N-Channel MOSFET switches to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between LX and BST is needed to drive the high side gate. The bootstrap capacitor is charged from the internal 5V rail when LX is low. At light loads, the inductor current may reach zero or reverse on each pulse. The bottom MOS is turned off by the current reversal comparator and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator. At light load, the EUP3276A will automatically skip pulses in pulse skipping mode operation to maintain output regulation and increases efficiency.

CC/CV mode control

The EUP3276A operates in either CC mode or CV mode. The CV mode regulates the output voltage. When output current reaches the CC threshold, the device enters CC mode to limit the output current.

The accurate CC current is implemented by the CS1 and CS2 pins, which can be set by the following equation:

$$I_{CS}(A) = 108(mV)/R_4(m\Omega)$$

Programmable cable compensation

The EUP3276A provides programmable cable compensation by adjusting the external resistor divider to compensate resistive voltage drop across the charger's output cable. The cable compensation voltage can be expressed as:

$$\Delta V_{OUT}(mV) = 0.037 \times \left(I_{OUT}(A) \times R_4(\Omega)\right) \times R_2(\Omega)$$

By adjust the value of R_2, the cable compensation voltage can be programmed.

Soft Start

The EUP3276A has external soft start feature to minimize the inrush supply current and the output overshoot at initial startup. An internal current source, which is typical 10μA, charges the external soft-start capacitor. The soft-start time (T_{SS}) and can be calculated by the following formula:

$$T_{SS}(ms) = 0.1 \times C_4(nF)$$

Over Current Protection

If the sensed current value is above the OC setting, the converter delays the next ON pulse until the current drops below the OC limit. Current limiting occurs on a pulse-by-pulse basis. The EUP3276A uses a valley current limiting scheme where the DC current point is the OC limit plus half of the inductor ripple current. The minimum valley OC limit is 6A over process and temperature.

$$I_{OC}(DC) = I_{OC}(valley) + \frac{1}{2} \times I_{Peak-to-Peak}$$

Over Voltage Protection

OVP (over voltage protection) function with fixed OV (over voltage) threshold set by the internal resistor divider is provided. When the FB pin voltage exceeds 15% of the nominal regulation value of 0.8V, the high-side switch turns off and low-side switch turns on cycle-by-cycle until the output over voltage is released.

Under Voltage Protection

UVP (under voltage protection) function continually monitors the FB voltage after soft-start is completed. If output voltage is lower than 60% of the nominal output voltage by over current or short circuit, the device will wait 1ms and enters hiccup mode. In hiccup mode, there is a delay time period before restart, which can be set by connecting a capacitor from ART pin to AGND pin. A current will charge the capacitor from ground level to a preset level. The delay time is calculated by the following equation:

$$T_{HICCUP}(ms) = 0.445 \times C_5(nF)$$

Thermal Shutdown

The EUP3276A stops switching when its junction temperature exceeds 160°C and resumes when the temperature has dropped by 60°C to protect the device.

Application Information

Setting the Output Voltage

The output voltage is set through a resistive voltage divider and can be expressed by the equation as follows

$$V_{OUT} = 0.8 \times \frac{R3 + R4}{R4}$$

Inductor

The inductor is required to supply constant current to the load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will in turn result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining

inductance is to allow the peak-to-peak ripple current to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit.
The inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_{LX} \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f_{LX} is the switching frequency, and ΔI_L is the peak-to-peak inductor ripple current. Choose an inductor that will not saturate under the maximum inductor peak current, calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_{LX} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where I_{LOAD} is the load current. The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI constraints.

Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors will also suffice. Choose X5R or X7R dielectrics when using ceramic capacitors. Since the input capacitor (C_1) absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, where $I_{C1} = I_{LOAD}/2$. For simplification, use an input capacitor with a RMS current rating greater than half of the maximum load current. The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, or a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple for low ESR capacitors can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{C_1 \times f_{LX}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where C_1 is the input capacitance value. For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

Output Capacitor

The output capacitor (C_5) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{LX} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{LX} \times C_5}\right)$$

Where C_5 is the output capacitance value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor. When using ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance which is the main cause for the output voltage ripple. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f^2{}_{LX} \times L \times C_5} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

When using tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{LX} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The EUP3276A can be optimized for a wide range of capacitance and ESR values.

Thermal Considerations

To avoid the EUP3276A from exceeding the maximum junction temperature, the user will need to do a thermal analysis. The goal of the thermal analysis is to determine whether the operating conditions exceed the maximum junction temperature of the part. The temperature rise is given by:

$$T_R = P_D \times \theta_{JA}$$
$$= \left(V_{IN} \times I_{IN} - V_{OUT} \times I_{OUT} - I^2{}_{OUT} \times R_{DCR}\right) \times \theta_{JA}$$

Where P_D is the power dissipated by the regulator; θ_{JA} is the thermal resistance from the junction of the die to the ambient temperature; R_{DCR} is resistor of inductor.
Then the junction temperature, T_J, is given by:

$$T_J = T_A \times T_R$$

Where T_A is the ambient temperature.

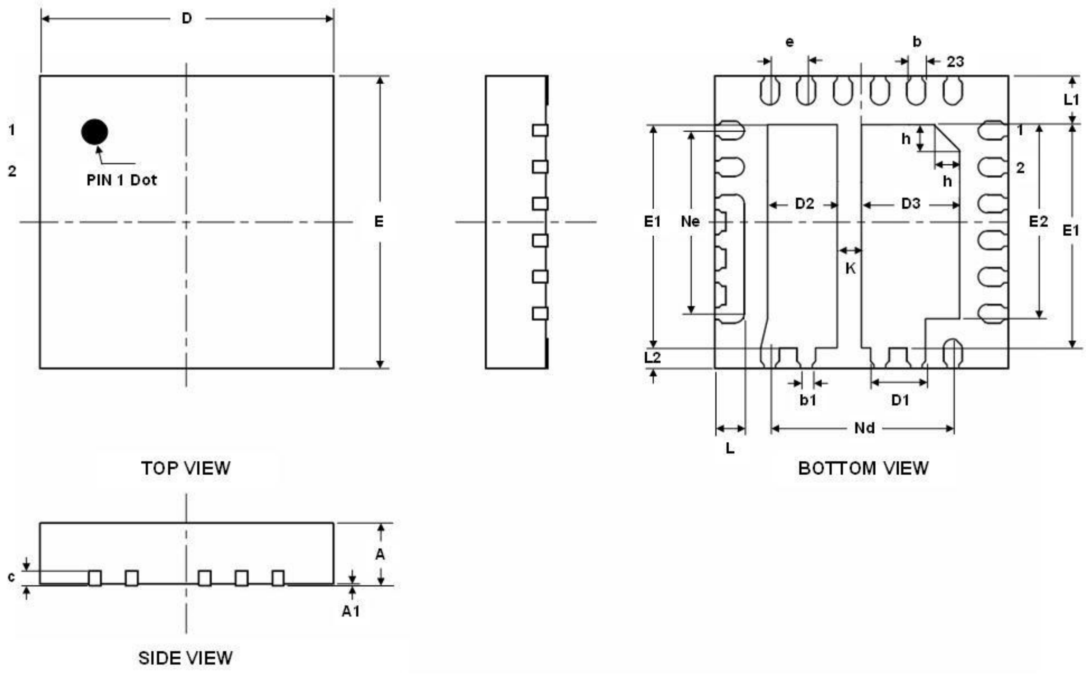
PC Board Layout Checklist

For all switching power supplies, the layout is an important step in the design especially at high peak currents and switching frequencies. If the layout is not carefully done, the regulator might show stability problems as well as EMI problems. When laying out the printed circuit board, the following guidelines should be used to ensure proper operation of the EUP3276A.

1. The input capacitor C_1 should connect to VIN as closely as possible. This capacitor provides the AC current to the internal power MOSFETs.
2. The power traces, consisting of the PGND trace, the LX trace and the VIN trace should be kept short, direct and wide.
3. The VOUT pin should connect directly to the inductor output. The resistive divider R2/R3 must be connected as close as possible between the FB and AGND.
4. Keep the switching node, LX, away from the sensitive VOUT/FB node.

Packaging Information

TQFN-23



Note: The exposed pad outline drawing is for reference only.

SYMBOLS	MILLIMETERS			INCHES		
	MIN.	Normal	MAX.	MIN.	Normal	MAX.
A	0.70	0.75	0.80	0.028	0.030	0.032
A1	0.00	0.02	0.05	0.000	0.001	0.002
b	0.20	0.25	0.30	0.008	0.010	0.012
b1	0.16 REF			0.006 REF		
D	3.90	4.00	4.10	0.154	0.157	0.161
D1	0.65	0.75	0.85	0.026	0.030	0.033
D2	0.85	0.95	1.05	0.033	0.037	0.041
D3	1.24	1.34	1.44	0.049	0.053	0.057
e	0.50 REF			0.020 REF		
Ne	2.50 REF			0.098 REF		
Nd	2.50 REF			0.098REF		
E	3.90	4.00	4.10	0.154	0.157	0.161
E1	2.95	3.05	3.15	0.116	0.120	0.124
E2	2.60	2.65	2.70	0.102	0.104	0.106
L	0.35	0.40	0.45	0.014	0.016	0.018
L1	0.57	0.62	0.67	0.022	0.024	0.026
L2	0.23	0.28	0.33	0.009	0.011	0.013
K	0.33	-	-	0.013	-	-
h	0.30	0.35	0.40	0.012	0.014	0.016