1MHZ, 3A STEP-DOWN DC-DC BUCK CONVERTER

Description

The AP3441 and AP3441L are 3A step-down DC-DC converters. At heavy load, the constant-frequency PWM control performs excellent stability and transient response. No external compensation components are required.

The AP3441/L supports a range of input voltages from 2.7V to 5.5V allowing the use of a single Li+/Li-polymer cell, multiple Alkaline/NiMH cell, and other standard power sources. The output voltage is adjustable from 0.6V to the input voltage. The AP3441/L employs internal power switch and synchronous rectifier to minimize external part count and realize high efficiency. During shutdown, the input is disconnected from the output and the shutdown current is less than 1μA. Other key features include over-temperature and short circuit protection, and under-voltage lockout to prevent deep battery discharge.

The AP3441/L delivers 3A maximum output current while consuming only 55μA of no-load quiescent current. Ultra-low $R_{DS(ON)}$ integrated MOSFETs and 100% duty cycle operation make the AP3441/L an ideal choice for high output voltage, high current applications which require a low dropout threshold. Pulse skip mode to maintain high efficiency at light-load conditions.

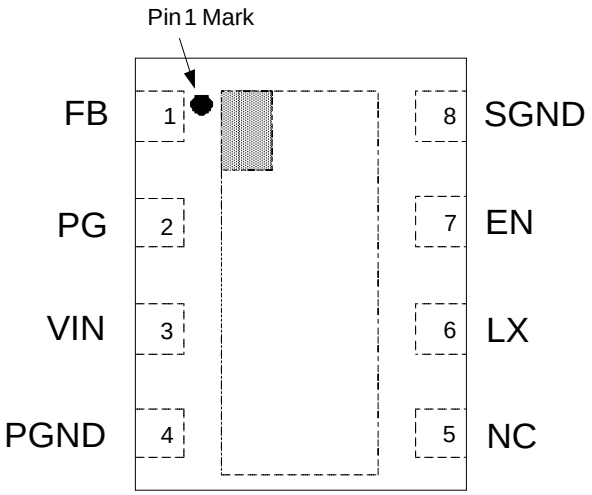
The AP3441/L is available in U-DFN2020-8 (Type E) package.

Features

- Input Voltage: 2.7V to 5.5V
- Output Voltage: 0.6V to V_{IN}
- 0.6V Reference Voltage with ±1.5% Precision
- 55μA (Typical) No Load Quiescent Current
- Shutdown Current: <1μA
- 100% Duty Cycle Operation
- 1MHz Switching Frequency
- No External Compensation Required
- Short Circuit Protection
  - AP3441L: Latch Off Protection
  - AP3441: Hiccup Mode Protection
- Over Voltage Protection
  - AP3441L: Latch Off Protection
  - AP3441: Non Latch Off Protection
- Thermal Shutdown
- U-DFN2020-8 (Type E) Package
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Pin Assignments

(Top View)



U-DFN2020-8 (Type E)

Applications

- Post DC-DC Voltage Regulation
- Set Top Boxes
- Notebook Computer
- PAD

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

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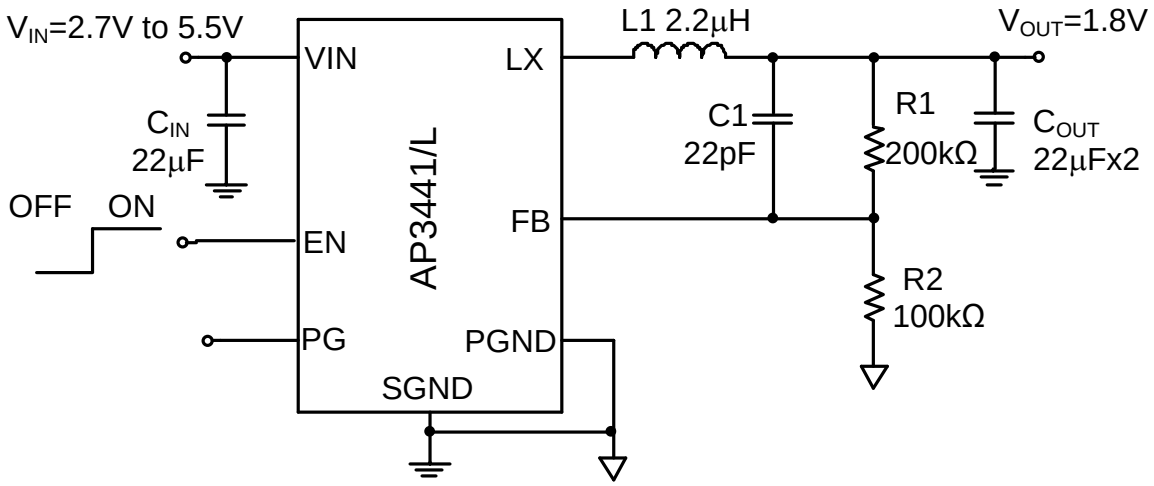
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	FB	Feedback voltage to internal error amplifier, the threshold voltage is 0.6V.
2	PG	Power good indicator, open drain output. PG is pulled up to VIN when the output voltage is within 20% of the regulation level, otherwise it is low.
3	VIN	Bias supply. Chip main power supply pin
4	PGND	Power ground pin
5	NC	No connection
6	LX	The drains of the internal main and synchronous power MOSFET.
7	EN	Enable control input. Force this pin voltage above 1.5V enables the chip, and below 0.4V shuts down the device.
8	SGND	Signal ground pin
EP	Exposed Pad	Exposed metal pad on the underside of the package without any electrical connection to internal circuit. It is recommended to connect this pad to the PC board ground plane in order to improve heat dissipation.

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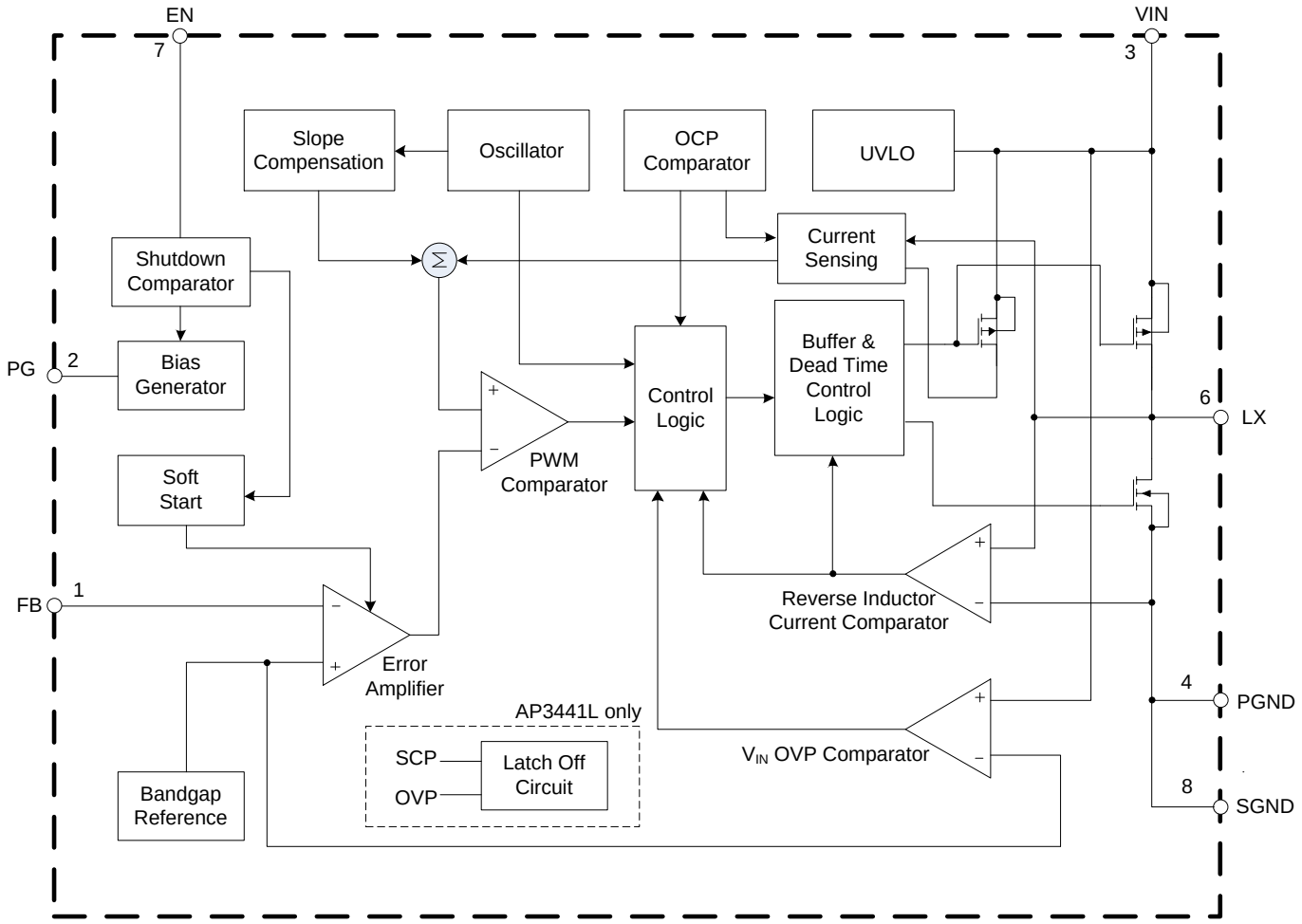
Functional Block Diagram



Functional Block Diagram of AP3441/L

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Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{IN}	Input Voltage	-0.3 to 6	V
V_{EN}	EN Pin Voltage	-0.3 to V_{IN}+0.3	V
V_{FB}	FB Pin Voltage	-0.3 to V_{IN}+0.3	V
V_{LX}	LX Pin Voltage	-0.3 to V_{IN}+0.3	V
V_{LX}	LX Pin Voltage	-3 to V_{IN} +3 for <20ns	V
V_{FB}	Feedback Pin Voltage	-0.3 to V_{IN}+0.3	V
P_D	Power Dissipation (On PCB, T_A = +25°C)	1.4	W
θ_{JA}	Thermal Resistance (Junction to Ambient)	70	°C/W
θ_{JC}	Thermal Resistance (Junction to Case, Simulation)	8.2	°C/W
T_J	Operating Junction Temperature	+150	°C
T_{STG}	Storage Temperature	-55 to +150	°C
V_{HBM}	ESD (Human Body Model, JESD22-A114)	2000	V
V_{CDM}	ESD (Charge Device Mode, JESD22-C101)	1000	V

Note: 4. Stresses greater than those listed under "*Absolute Maximum Ratings"* can cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "*Recommended Operating Conditions*" is not implied. Exposure to "*Absolute Maximum Ratings*" for extended periods can affect device reliability.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{IN}	Supply Voltage	2.7	5.5	V
T_J	Junction Temperature Range	-40	+125	°C
T_A	Operating Ambient Temperature	-40	+85	°C

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Electrical Characteristics (@T_A = +25°C, V_{IN} = 5.0V, V_{OUT} = 2.5V, C_{OUT} = 22μF*2, L = 2.2μH, unless otherwise specified.)

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
VIN Pin						
V_{IN}	Input Voltage Range	—	2.7	—	5.5	V
V_{OUT}	Output Voltage Range	—	0.6	—	V_{IN}	V
I_Q	Quiescent Current	V_{FB} = 0.65V	—	55	—	μA
I_{SD}	Shutdown Current	V_{EN} = 0V	—	0.1	1	μA
V_{UVLO}	Input UVLO Threshold	V_{IN} Rises	—	2.4	2.5	V
V_{HYS}	Input UVLO Hysteresis	V_{IN} Falls	—	0.2	—	V
Feedback Input						
V_{FB}	Regulated Feedback Voltage	—	0.591	0.6	0.609	V
I_{FB}	FB Leakage Current	V_{FB} = 1V	—	—	0.2	μA
I_{LIM}	Peak Inductor Current	—	3.5	—	—	A
Oscillator						
f_{OSC}	Oscillator Frequency	—	0.8	1	1.2	MHz
D_{MAX}	Maximum Duty Cycle	—	100	—	—	%
MOSFET						
$R_{DS(ON)}$	Drain-Source On-State Resistance	I_{LX} = 100mA High Side	—	72	—	mΩ
		I_{LX} = 100mA Low Side	—	53	—	mΩ
R_{DISCH}	Output Discharge Switch On Resister	—	—	50	—	Ω
EN Pin						
V_{ENH}	EN Threshold High	—	1.5	—	—	V
V_{ENL}	EN Threshold Low	—	—	—	0.4	V
I_{EN}	EN Leakage Current	V_{IN}= V_{EN} =5V	-1.0	—	1.0	μA
Protection						
V_{SCP}	Short Circuit Protection Latch Off Threshold	AP3441L only	—	0.42	—	V
t_{DELAY_SCP}	Short Circuit Protection Delay Time	—	—	30	—	μs
T_{OTP}	Over Temperature Protection	—	—	+150	—	°C
T_{DTH}	OTP Hysteresis	—	—	+20	—	°C
V_{OVP}	V_{OUT} Over Voltage Protection	AP3441L only	—	0.72	—	V
V_{IOVP}	V_{IN} Over Voltage Protection	V_{IN} Rises	—	6.3	—	V
V_{IHSY}	IOVP Hysteresis	V_{IN} Falls	—	0.35	—	V
Soft Start						
t_{SS}	Soft-Start Time	—	0.7	1.0	1.3	ms

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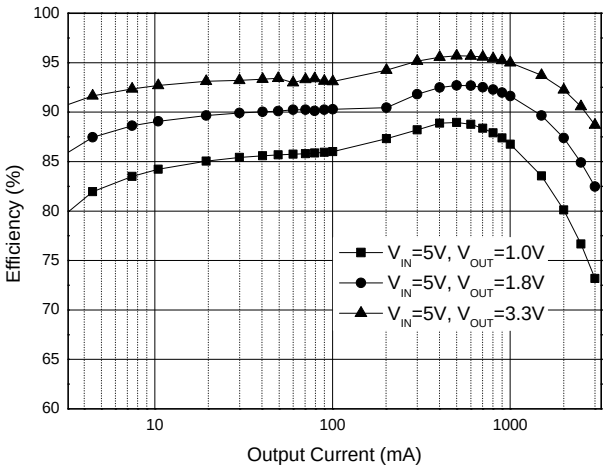
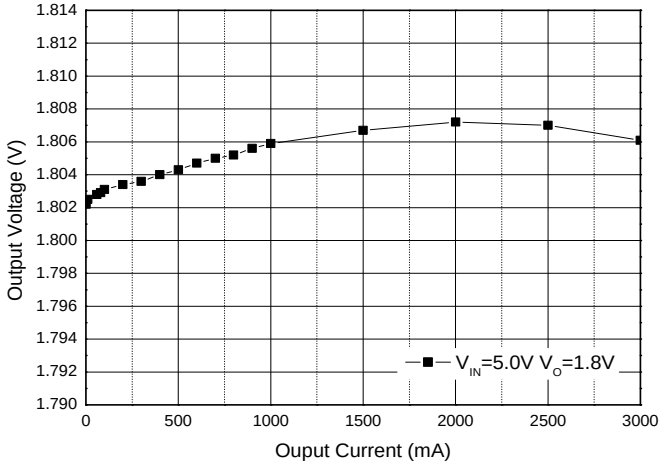
Typical Performance Characteristics (@T_A = +25°C, V_{IN} = 5V, V_{OUT} = 1.8V, unless otherwise specified.)

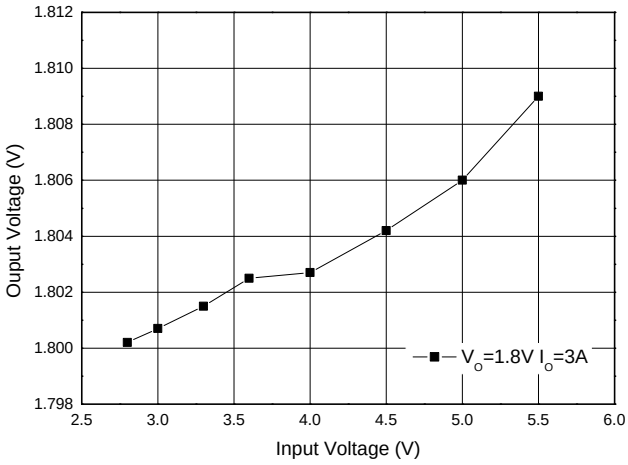
Efficiency vs. Load Current



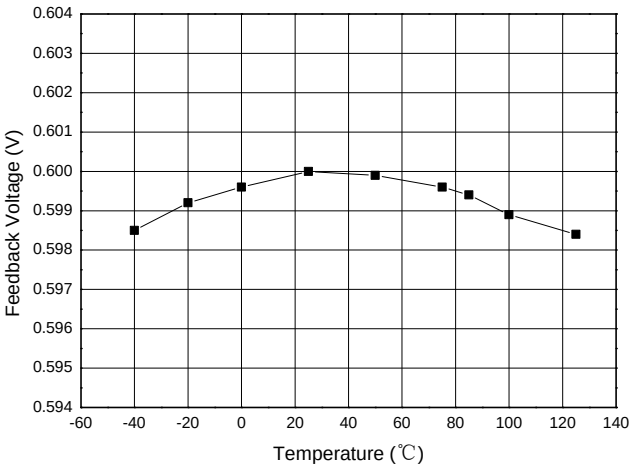
Output Voltage vs. Output Current



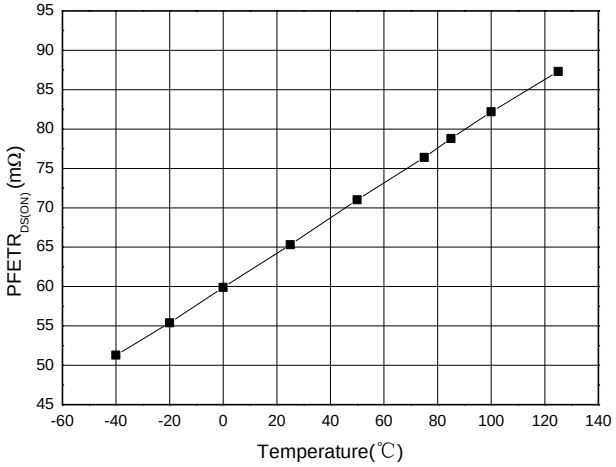
Output Voltage vs. Input Voltage



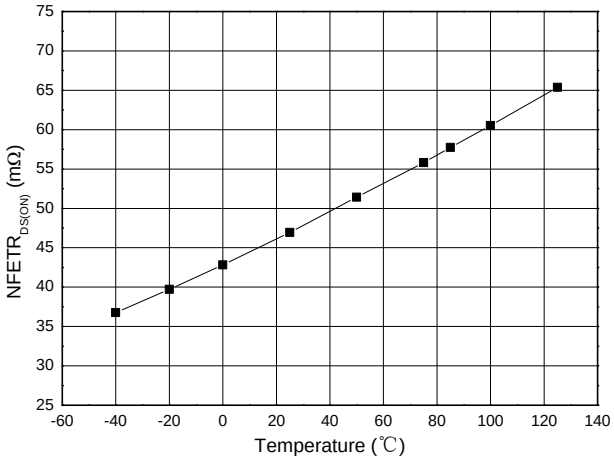
Feedback Reference Voltage vs. Temperature



PFET Drain-Source On-State Resistance vs. Temperature



NFET Drain-Source On-State Resistance vs. Temperature



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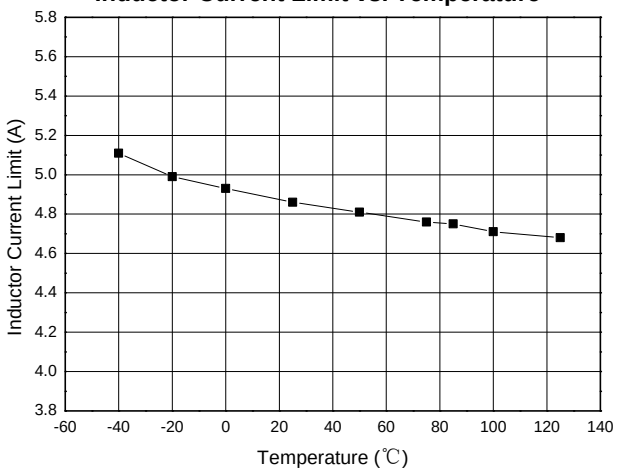
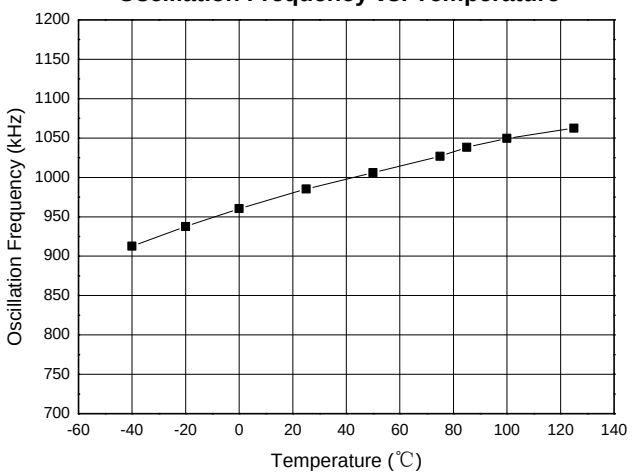
Typical Performance Characteristics (@T_A = +25°C, V_{IN} = 5V, V_{OUT} = 1.8V, unless otherwise specified.)

Inductor Current Limit vs. Temperature



Oscillation Frequency vs. Temperature



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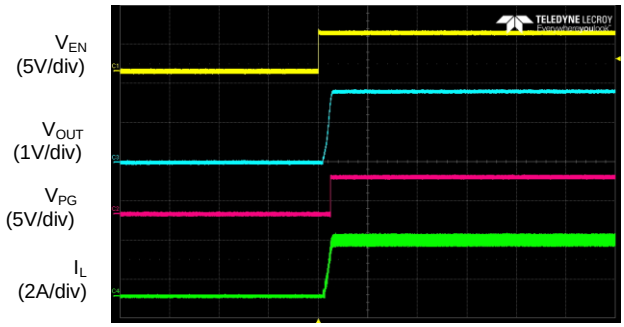
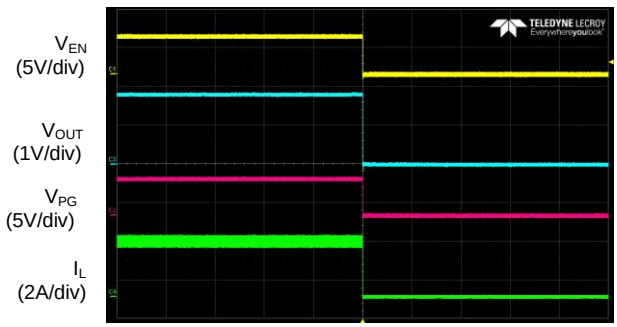
Typical Performance Characteristics (@T_A = +25°C, V_{IN} = 5V, V_{OUT} = 1.8V, unless otherwise specified.)

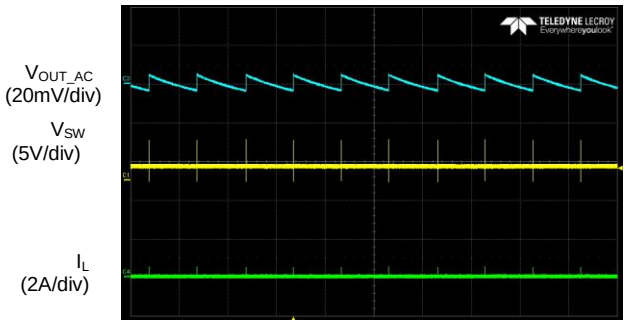
Enable Turn on Characteristic (I_{OUT}=3A)



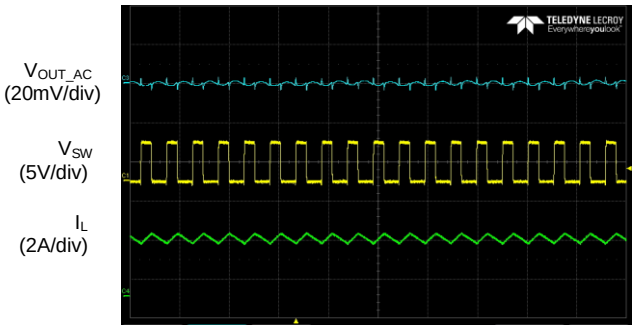
Enable Turn off Characteristic (I_{OUT}=3A)



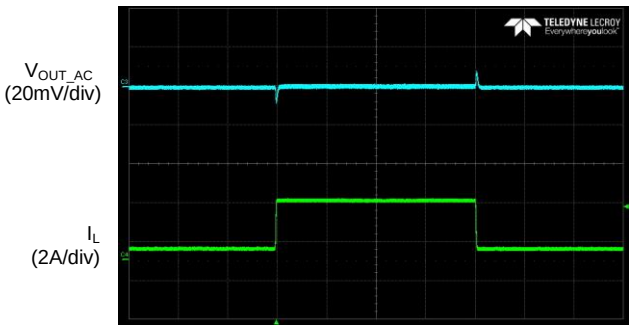
Output Ripple (I_{OUT}=0A)



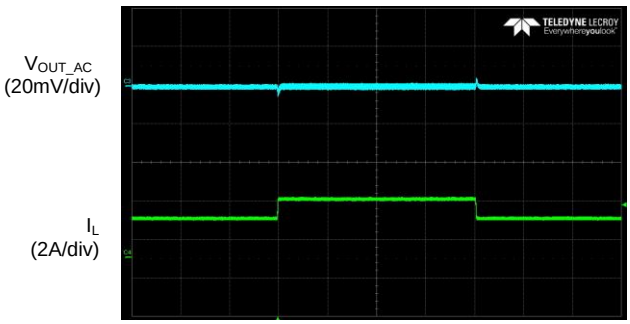
Output Ripple (I_{OUT}=3A)



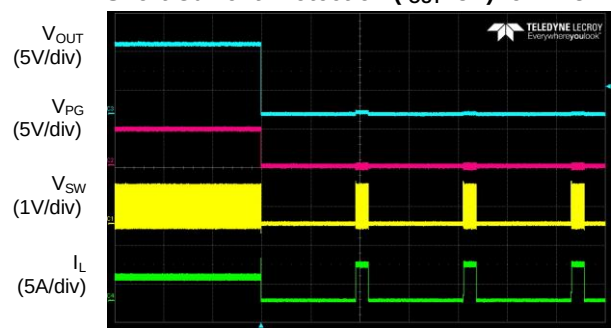
Load Transient (I_{OUT}=0.5A to 3A)



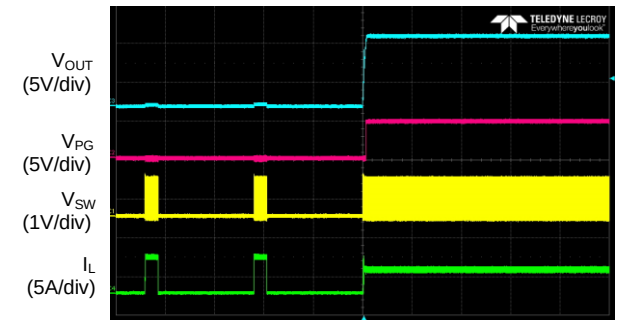
Load Transient (I_{OUT}=2A to 3A)



Short Current Protection (I_{OUT}=3A) for AP3441



SCP Recovery (I_{OUT}=3A) for AP3441



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Application Information

The AP3441/L is a **3**A current mode control, synchronous buck regulator with integrated power MOSFETs. Current mode control assures excellent line regulation, load regulation, and a wide loop bandwidth for fast response to load transients. See the *Typical Applications Circuit* and *Functional Block Diagram* of AP344**1**/L for more details. The buck controller drives the internal high side P-FETs. The buck regulator can operate from an unregulated DC source, such as a battery, with a voltage ranging from 2.7V to 5.5V. The converter output can be regulated as low as 0.**6**V to as high as V_{IN}. The feedback loop is compensated internally.

Under Voltage Lockout (UVLO) Circuit

When the V_{IN} drops lower than the UVLO detector threshold, the UVLO circuit starts to operate, V_{REF} stops, and high-side switch and low-side switch built-in switch transistors turn "OFF". As a result, V_{OUT} drops according to the C_{OUT} capacitance value and the load. When the V_{IN} is rising higher than UVLO released voltage, the IC will restart the operation.

Short Circuit Protection and Recovery

When the AP3441/L output node is shorted to GND that V_{FB} drops under 0.42V, the AP3441 will enter hiccup mode to protect itself and the AP3441L will enter latch-off mode. If short condition is removed, and V_{FB} rises over 0.42V, the AP3441 will recover to normal operation again. The AP3441L will remain in this state until VIN or EN pin voltage is recycled. If the AP3441/L reaches OCP threshold while short circuit, the AP3441 will enter cycle by cycle current limit mode until the current under OCP threshold.

Over Voltage Protection (AP3441L Only)

The AP3441L has internal output OVP circuits. When V_{OUT} is exceeds 120% of the regulation level for more than 40µs, the power switches will be turned off. The AP3441L enters latch off mode and will restart until VIN or EN pin voltage is recycled.

Over Temperature Protection

The internal thermal temperature protection circuitry is provided to protect the integrated circuit in the event that the maximum junction temperature is exceeded. When the junction temperature exceeds +150°C, it shuts down the internal control circuit and switching power MOSFET. The AP3441/L will restart automatically under the control of soft start circuit when the junction temperature decreases to +130°C.

Setting the Output Voltage

Choose R1 and R2 to program the proper output voltage. Resistor R1 is selected based on a design tradeoff between efficiency and output voltage accuracy. For high values of R1 there is less current consumption in the feedback network. However the tradeoff is output voltage accuracy due to the bias current in the error amplifier. Table 1 shows a list of resistors selection for common output voltages. An optional C1 of 10pF to 470pF used to boost the phase margin and improve stability. R2 in Figure 1 can be determined by the following equation:

$$R_2 = \frac{R_1 \cdot 0.6}{V_{OUT} - 0.6}$$

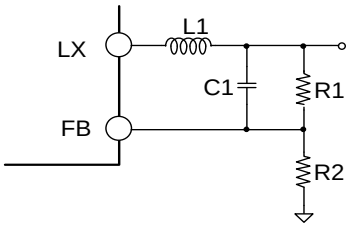

Figure 1. Feedback Divider Network

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	C1 (pF)	L1 (µH)
1.0V	68kΩ	100kΩ	22pF	1.0µH
1.2V	100kΩ	100kΩ	22pF	1.0µH
1.5V	150kΩ	100kΩ	22pF	1.5 to 2.2µH
1.8V	200kΩ	100kΩ	22pF	1.5 to 2.2µH
2.5V	317kΩ	100kΩ	22pF	2.2µH
2.8V	367kΩ	100kΩ	22pF	2.2µH

Table 1. Recommended Component Selection

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Application Information (continued)

Input Capacitor

The input capacitor reduces the surge current drawn from the input supply and the switching noise from the device. The input capacitor has to sustain the ripple current produced during the on time on the upper MOSFET. It must hence have a low ESR to minimize the losses.

The RMS current rating of the input capacitor is a critical parameter that must be higher than the RMS input current. As a rule of thumb, select an input capacitor which has RMs rating that is greater than half of the maximum load current.

Due to large di/dt through the input capacitors, electrolytic or ceramics should be used. If a tantalum must be used, it must be surge protected. Otherwise, capacitor failure could occur. For most applications, a 22µF ceramic capacitor is sufficient.

Output Capacitor

The output capacitor keeps the output voltage ripple small, ensures feedback loop stability and reduces the overshoot of the output voltage. The output capacitor is a basic component for the fast response of the power supply. In fact, during load transient, for the first few microseconds it supplies the current to the load. The converter recognizes the load transient and sets the duty cycle to maximum, but the current slope is limited by the inductor value.

ESR of the output capacitor dominates the output voltage ripple. The amount of ripple can be calculated from the equation below:

$$VOUT_{CAPACITOR} = \Delta I_{INDUCTOR} * ESR$$

An output capacitor with ample capacitance and low ESR is the best option. For most applications, 2x22µF ceramic capacitor will be sufficient.

$$C_O = \frac{L(I_{OUT} + \frac{\Delta I_{INDUCTOR}}{2})^2}{(\Delta V + V_{OUT})^2 - V_{OUT}^2}$$

Where ΔV is the maximum output voltage overshoot.

Inductor Selection

The inductor is used to supply smooth current to output when it is driven by a switching voltage. Its value is determined based on the operating frequency, load current, ripple current, and duty cycle. For most application, the value of the inductor will fall in the range of 1.0µH to 2.2µH. Choose an inductor that has small DC resistance, has enough current rating and is hard to cause magnetic saturation.

Vo	L(µH)
1.0V	1.0µH
1.2V	1.0µH
1.5V	1.5 to 2.2µH
1.8V	1.5 to 2.2µH
2.5V	2.2µH
2.8V	2.2µH
3.3V	2.2µH

Table 2. Recommended Inductor Selection Table

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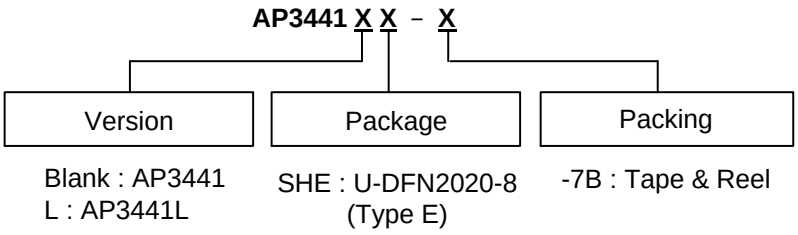
Ordering Information

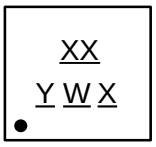


Package	Temperature Range	Part Number	Marking ID	Packing
U-DFN2020-8 (Type E)	-40 to +85°C	AP3441SHE-7B	9B	-7B
U-DFN2020-8 (Type E)	-40 to +85°C	AP3441LSHE-7B	9C	-7B

Marking Information

(1) U-DFN2020-8 (Type E)

(Top View)



XX : Identification Code
Y : Year : 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week; z represents
52 and 53 week
X : Internal Code

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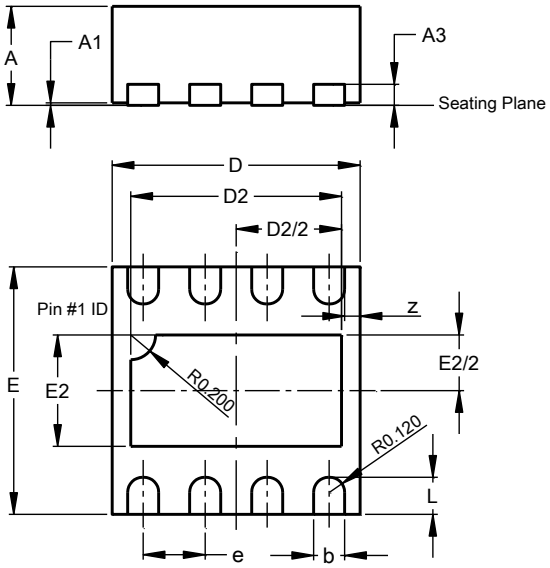
Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) Package Type: U-DFN2020-8 (Type E)

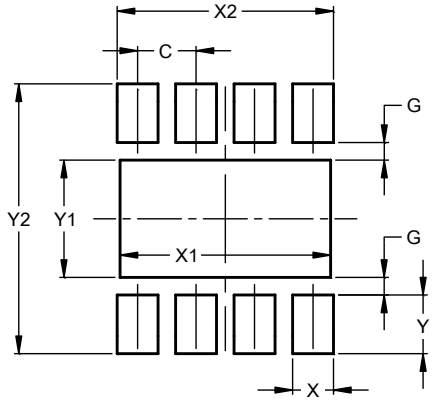


U-DFN2020-8 (Type E)			
Dim	**Min**	**Max**	**Typ**
A	0.50	0.60	0.56
A1	0.00	0.05	0.02
A3	-	-	0.203
b	0.20	0.30	0.25
D	1.950	2.075	2.00
D2	1.60	1.80	1.70
e	0.500 BSC		
E	1.950	2.075	2.00
E2	0.80	1.00	0.90
L	0.25	0.35	0.30
z	-	-	0.125
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) Package Type: U-DFN2020-8 (Type E)



Dimensions	Value (in mm)
C	0.500
G	0.150
X	0.350
X1	1.800
X2	1.850
Y	0.500
Y1	1.000
Y2	2.300

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