NOT RECOMMENDED FOR NEW DESIGN

USE AP3428

AP6015

High Efficiency Step-Down Low Power DC-DC Converter

Features

- High efficiency synchronous step-down converter with greater than 94%
- Current Mode Operation for faster transient response and better loop stabilization
- 2.5V to 5.5V operating input voltage range
- Adjustable output voltage range from 0.8V to V_{IN}
- Fixed output voltage options: 1.8V, 2.5V and 3.3V
- Up to 800mA output current
- High efficiency over a wide range of load currents
- PWM operation mode
- Internal soft-start function
- Typical quiescent current of 150µA
- MSOP-10L: Available in "Green" Molding Compound (No Br, Sb)
- Lead Free Finish/ RoHS Compliant (Note 1)

General Description

The AP6015 is the first device in a family of low-noise current mode synchronous step-down DC-DC converters. It is ideally suited for systems powered by either a 1-cell Li-ion battery or a 2- to 3-cell NiCd/ NiMH/ Alkaline battery.

The AP6015 is a synchronous PWM converter with integrated N- and P-channel power MOSFET switches. Compared to the asynchronous topology, synchronous rectification offers the benefits of higher efficiency and reduced component count. The high operating frequency of 1MHz allows small inductor and capacitor to be used. This results in small pcb area. During shut-down, the standby current drops to 1µA or less. The AP6015 is available in the 10-pin MSOP package. It operates over a free-air temperature range of -40°C to 85°C.

Applications

- Mobile Handsets
- PDAs, Ultra Mobile PCs
- Portable Media Players, Digital Still/Video Cameras
- USB-based DSL Modems
- LAN/WLAN/WPAN/WWAN Modules

Ordering Information

AP 6015 - XX M10 G - 13

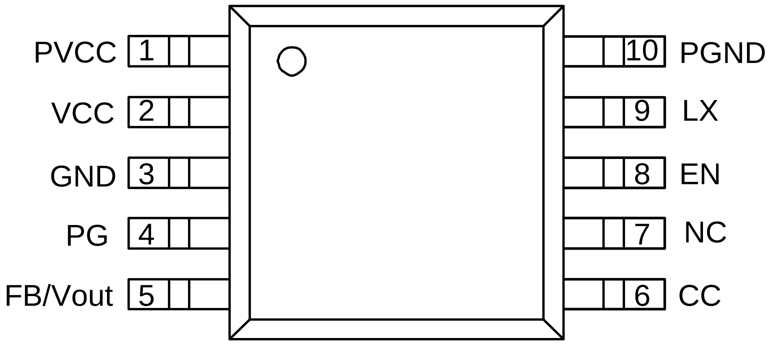
Voltage	Package	Green	Packing
Blank : Adj 18 : 1.8V 25 : 2.5V 33 : 3.3V	M10 : MSOP-10L	G : Green	13 : Tape & Reel

Device	Package Code	Packaging (Note 2)	13" Tape and Reel	
			Quantity	Part Number Suffix
AP6015-XXM10G-13	M10	MSOP-10L	2500/Tape & Reel	-13

Notes: 1. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied, see *EU Directive 2002/95/EC Annex Notes*.
2. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at http://www.diodes.com/datasheets/ap02001.pdf.

Pin Assignment

(Top View)

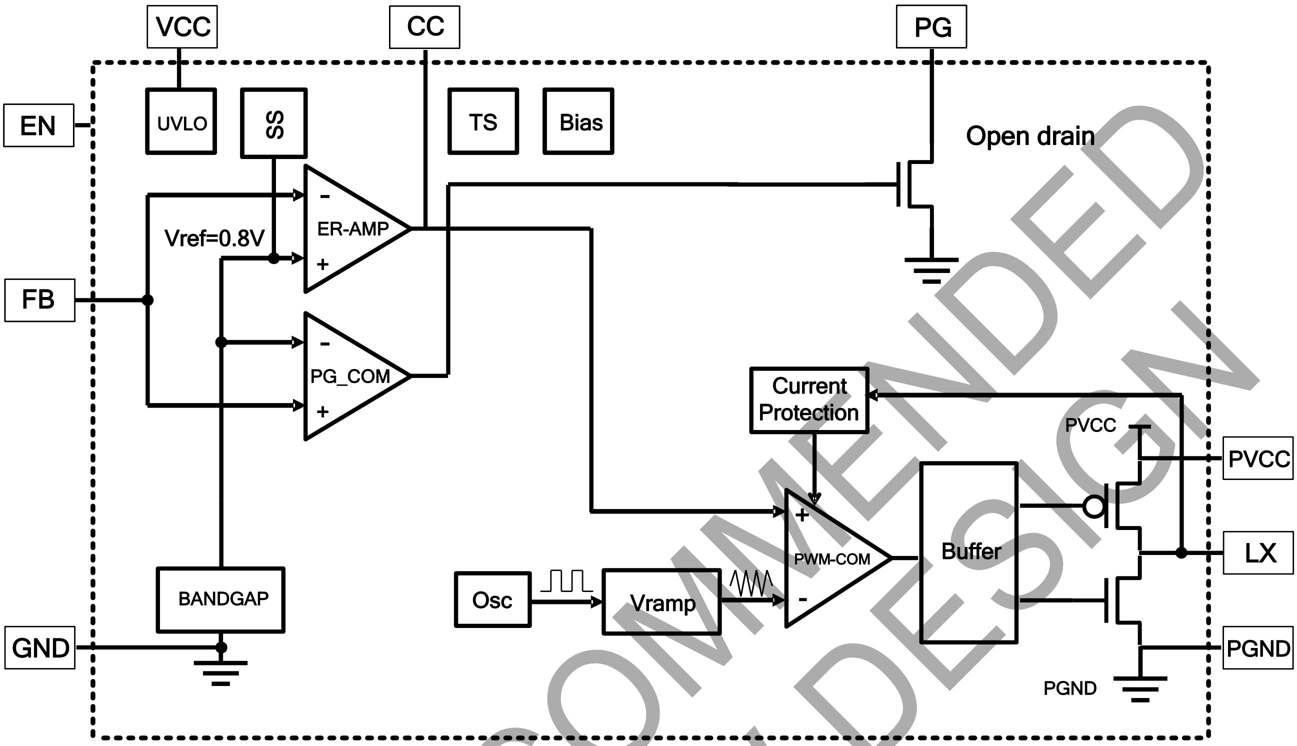


MSOP-10L

Pin Descriptions

Pin Name	Pin NO.	I/O	Description
PVCC	1	I	Supply voltage input
VCC	2		Supply bypass pin. A 1μF coupling capacitor should be connected as close as possible to this pin.
GND	3		Ground
PG	4	O	Power good comparator output. A pull-up resistor should be connected between PG and V_O.
FB	5	I	Feedback pin for the fixed output voltage option.
CC	6	I	Compensation pin
NC	7	NC	No connect
EN	8	I	Enable.Pin, H: Enable. L:shutdown
LX	9	I/O	Connect the inductor to this pin.
PGND	10		Power ground

Block Diagram



Notes: 3. The adjustable output voltage version does not use the internal feedback resistor divider. The FB pin is directly connected to the error amplifier.

Absolute Maximum Ratings

Symbol	Parameter	Rating	Unit
ESD HBM	Human Body Model ESD Protection	2.5	KV
ESD MM	Machine Model ESD Protection	300	V
PVCC, VCC	Supply Voltage	-0.3 to +5.5	V
	Voltages on pins EN, CC, PG, FB, LX	-0.3 to V_{IN} +0.3	V
$T_{J(MAX)}$	Maximum Junction Temperature Range	+150	^oC
T_{ST}	Storage temperature range	-65 to +150	^oC
T_{OP}	Operating Junction Temperature Range	-40 to +125	^oC

Stresses beyond those listed under “absolute maximum ratings” may 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-rated conditions for extended periods ma affect device reliability.

Recommended Operating Conditions (T$_A$:-40~85°C)

Symbol	Parameter	Rating	Unit
T_A	Operating Ambient Temperature Range	-40 to +85	^oC
V_{IN}	Supply Voltage	2.0 to 5.5	V
V_O	Output voltage range for adjustable output voltage version	0.8 to V_I	V
L	Inductor (see Note 4)	3.3	μH
C_i	Input capacitor (see Note 4)	10	μF
C_o	Output capacitor (see Note 4) $V_O \geq 1.8V$	10	μF

Notes: 4. Refer to application section for further information.

Electrical Characteristics (T$_A$ =25°C)

Over recommended operating free-air temperature range, V_I=3.6V, V_O=2.5V, I_O=300mA, EN=V_{IN}, (unless otherwise noted)

Symbol	Parameter		Conditions	Min	Typ.	Max	Unit
Supply current							
V_{IN}	Input Voltage range	-20 to 85 ^oC	I_O= 0mA to 800mA	2.5	-	5.5	V
			I_O= 0mA to 500mA	2	-	5.5	
		-40 to 85 ^oC	I_O= 0mA to 600mA	2.5		5.5	
			I_O= 0mA to 400mA	2	-	-	
Iccq	Operating quiescent current		I_O= 0mA	-	150	-	μA
I_{STBY}	Standby current		EN= GND	-	0.1	1	μA
Enable							
V_{IH}	EN high-level input voltage		$V_{IN} \leq$ 3V	1.5	-	-	V
			V_{IN}> 3V	2.5	-	-	
V_{IL}	EN low-level input voltage			-	-	0.7	V
I_L	EN input leakage current		EN= GND or V_{IN}	-	0.01	0.1	μA
$V_{(UVLO)}$	Under-voltage-lockout-threshold			1.2	1.6	1.95	V

Electrical Characteristics (Continued)

Over recommended operating free-air temperature range, V_I=3.6V, V_O=2.5V, I_O=300 mA, EN=V_{IN}. (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ.	Max	Unit
Power switch and current limit						
$R_{DS(on)}$	P-channel MOSFET on-resistance	V_I=V_{GS}=3.6V; I=200mA	200	280	410	mΩ
		V_I=V_{GS}=2V; I=200mA	-	480	-	
	P-channel leakage current	V_{DS}=5.5V	-	-	1	μA
	N-channel MOSFET on-resistance	V_I=V_{GS}=3.6V; I_O=200mA	200	280	410	mΩ
		V_I=V_{GS}=2V; I_O=200mA	-	500	-	
	N-channel leakage current	V_{DS}=5.5V	-	-	1	μA
$I_{(LIM)}$	P-channel current limit	2.5V≤V_I≤5.5V	1200	-	1600	mA
Power good output (see Note 5)						
$V_{(PG)}$	Power good threshold	Feedback voltage falling	88% V_O	92% V_O	94% V_O	V
	Power good hysteresis			2.5% V_O		
V_{OL}	PG output low voltage	$V_{(FB)}$=0.8×V_O nominal; $I_{(sink)}$=10μA	-	-	0.3	V
I_{LKG}	PG output leakage current	$V_{(FB)}$=V_O nominal		0.01	1	μA
	Minimum supply voltage for valid power good signal		1.2	-	-	V
Oscillator						
F_S	Oscillator frequency		800	1000	1200	KHz
Output						
V_O	Adjustable output voltage range		0.8		5.5	V
V_{REF}	Reference voltage		0.784	0.8	0.816	V
V_O	Fixed output voltage (see Note 6): AP6015-Adj, AP6015-1.8V	V_I=2.5V to 5.5V; 0mA ≤ I_O ≤ 800mA	−3%	-	4%	V
	AP6015-1.8V	10mA ≤ I_O ≤ 800mA	−3%	-	3%	
	AP6015-2.5V	V_I=2.7V to 5.5V; 0mA ≤ I_O ≤ 800mA	−3%	-	4%	
	AP6015-2.5V	10mA ≤ I_O ≤ 800mA	−3%	-	3%	
	AP6015-3.3V	V_I=3.6V to 5.5V; 0mA ≤ I_O ≤ 800mA	−3%	-	4%	
	AP6015-3.3V	10mA ≤ I_O ≤ 800mA	−3%	-	3%	
	Line regulation	V_I= V_O +0.5V (min.2V) to 6.0V; I_O=10mA		0.3		%/V
	Load regulation	V_I=5.0V; I_O=10mA to 800mA		0.8		%
η	Efficiency	V_I=5V; V_O=3.3V; I_O=300mA V_I=3.6V; V_O=2.5V; I_O=200mA		94		%
	Start-up time	I_O=0mA, time from active EN to V_O	0.4	1	4	ms
$θ_{JA}$	Thermal Resistance Junction-to-Ambient	MSOP-10L (Note 7)		161		°C/W
$θ_{JC}$	Thermal Resistance Junction-to-Case	MSOP-10L (Note 7)		39		°C/W

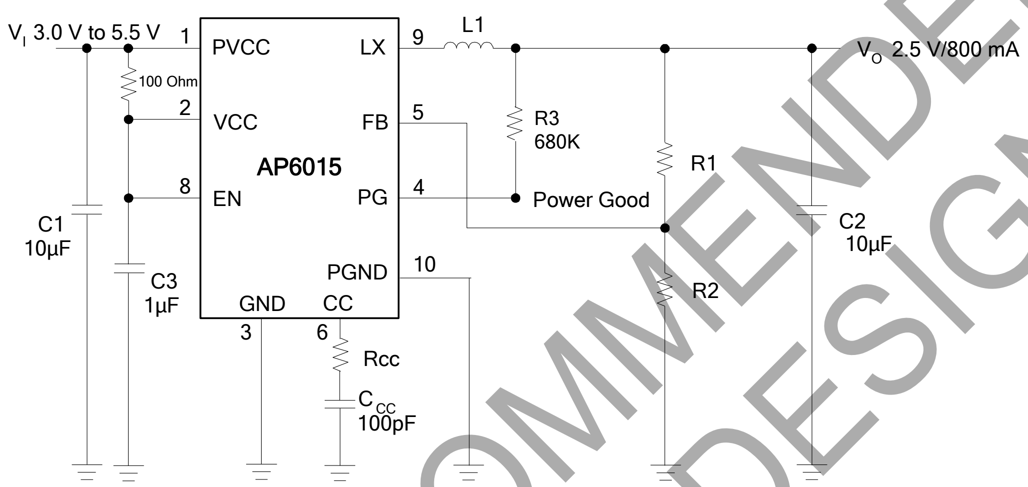
Notes:
5. Power good is not valid for the first 100μs after EN goes high. Please refer to the application section for more information.
6. The output voltage accuracy includes line and load regulation over the full temperature range.
7. Test condition for MSOP-10L: Device mounted on 2oz copper, minimum recommended pad layout on top & bottom layer with thermal vias, double sided FR-4 PCB

Typical Application Circuit

For best transient response we suggest that R_{CC}, C_{CC} and L1 values as below.

	R_{CC}	C_{CC}	L1-WURTH	C1, C2 (MLCC)
$V_{IN} < 3.0V$, $V_{OUT} < 2.5V$	200KΩ	33PF	1.8µH	10µF
$V_{IN} \geq 3.0V$, $V_{OUT} < 2.5V$	68KΩ	100PF	1.8µH	10µF
$V_{IN} \geq 3.0V$, $V_{OUT} \geq 2.5V$	82KΩ	100PF	3.3µH	10µF

(1) ADJ Output



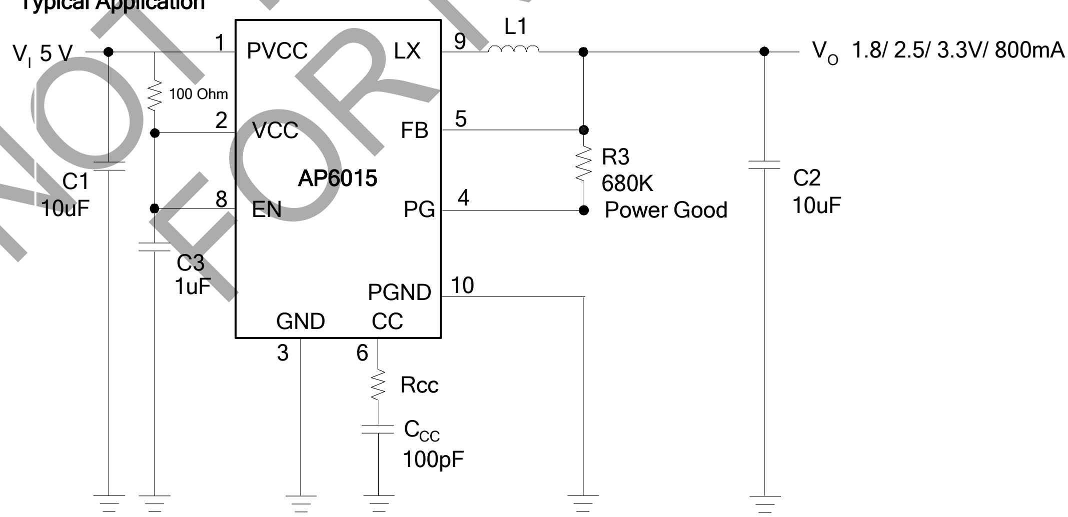
R2: Suggest to be 39K~100K because of stability reasons.

$$V_O = V_{REF} \times (1 + \frac{R_1}{R_2})$$

Typical Application Circuit for Adjustable Output Voltage Option

(2) FIXED Output

Typical Application



Standard 5 V to 1.8/ 2.5/ 3.3V/ 800mA Conversion; High Efficiency

Typical Operating Characteristics

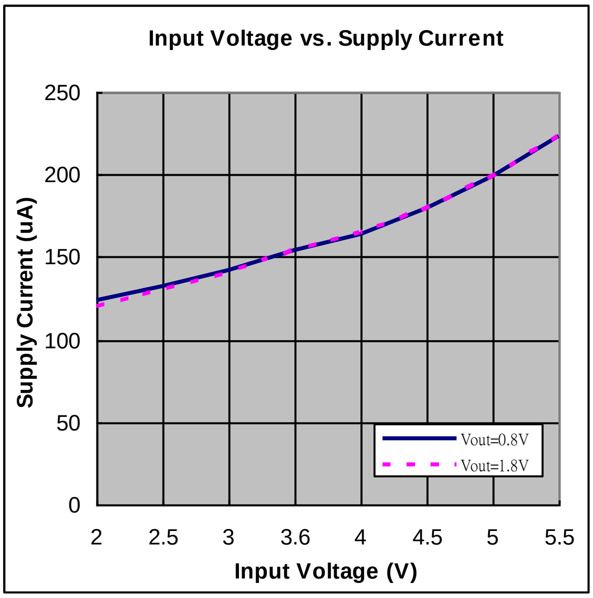


Figure 1

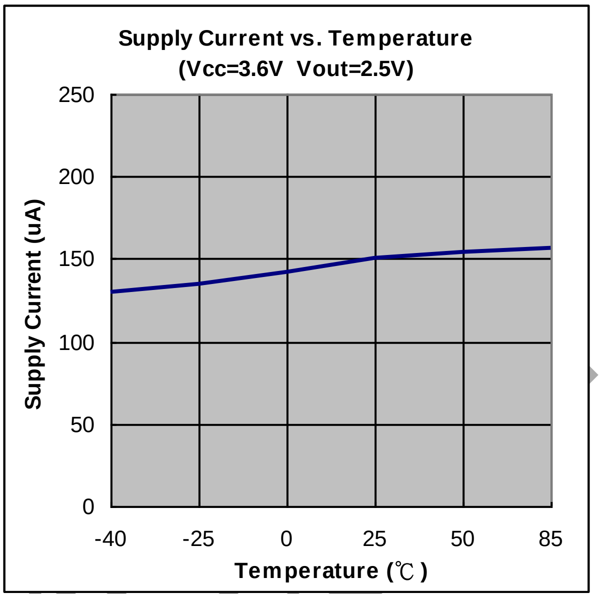


Figure 2

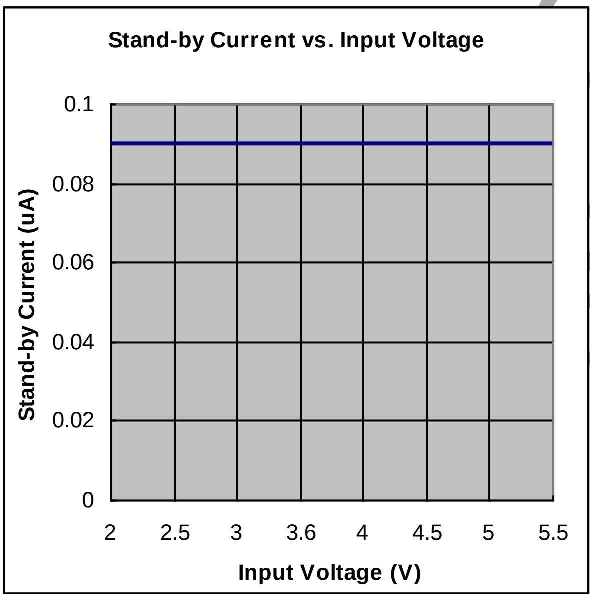


Figure 3

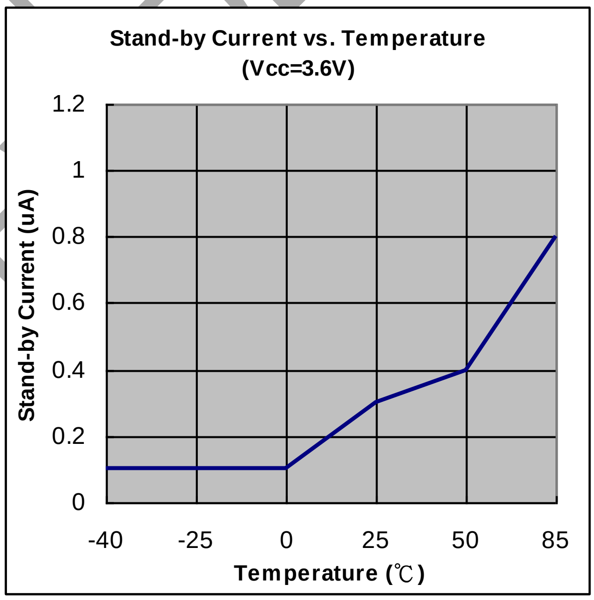


Figure 4

Typical Operating Characteristics (Continued)

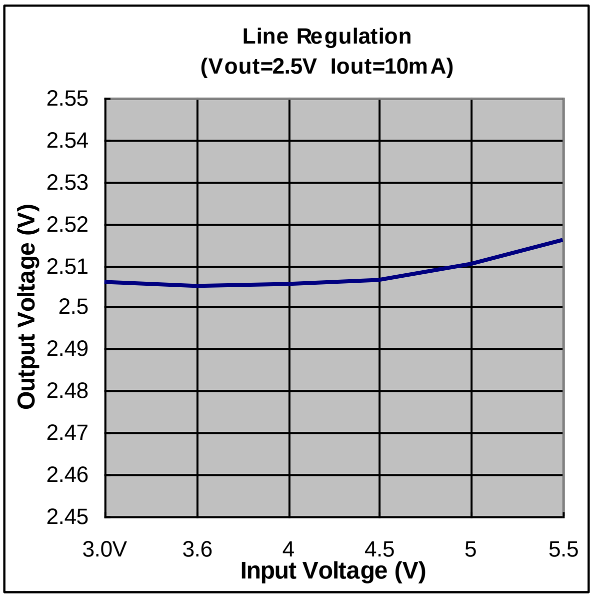


Figure 5

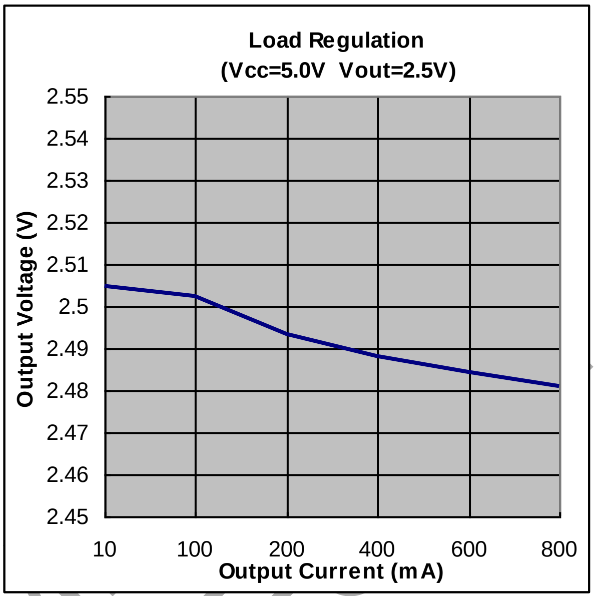


Figure 6

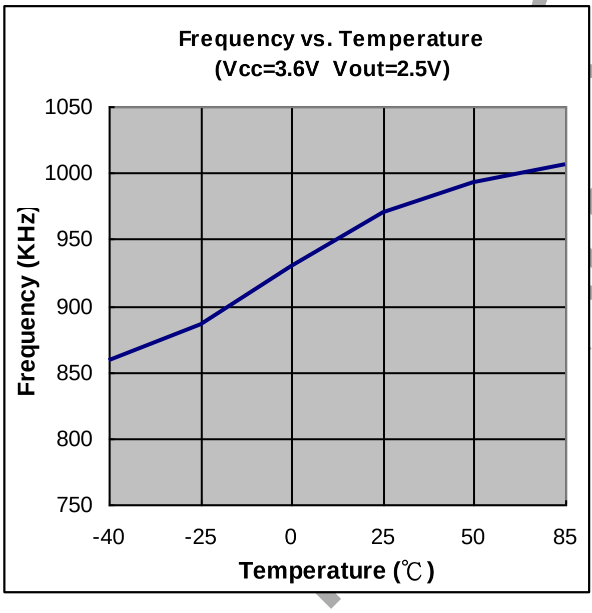


Figure 7

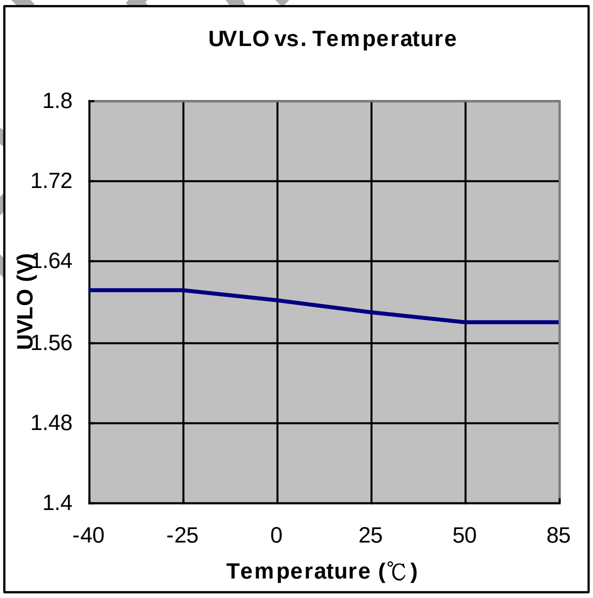


Figure 8

Typical Operating Characteristics (Continued)

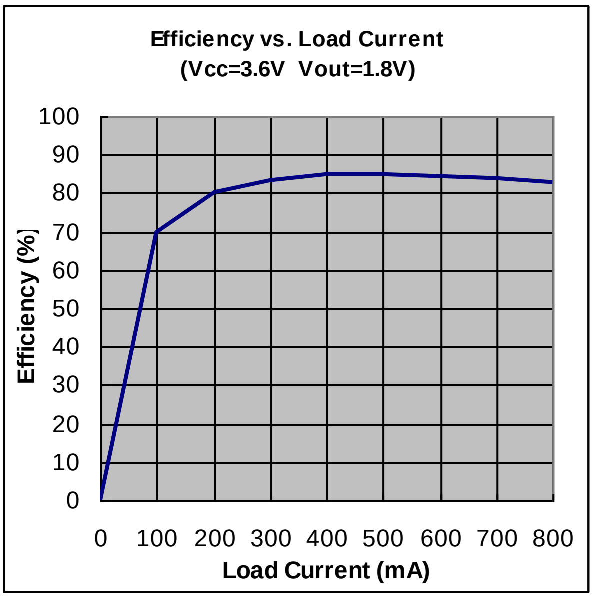


Figure 9

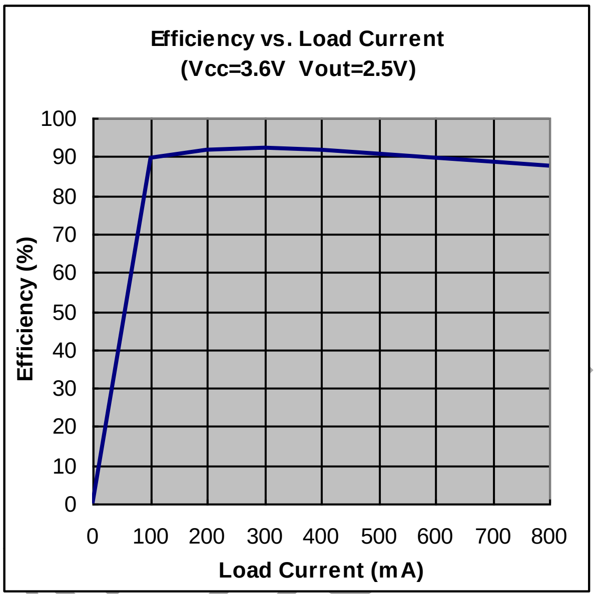


Figure 10

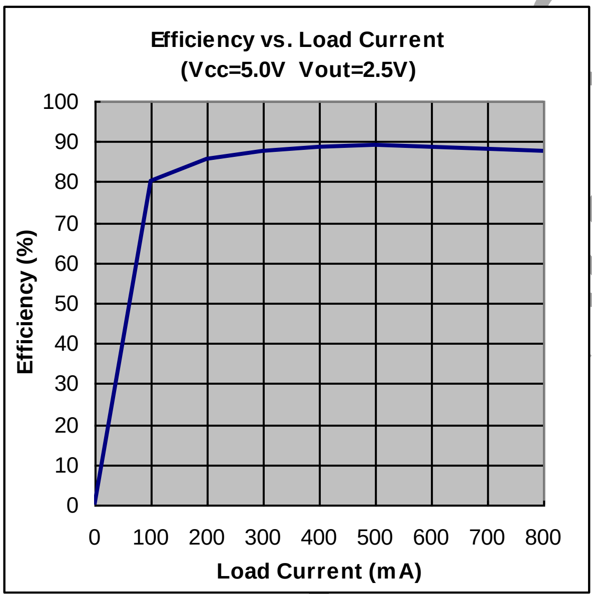


Figure 11

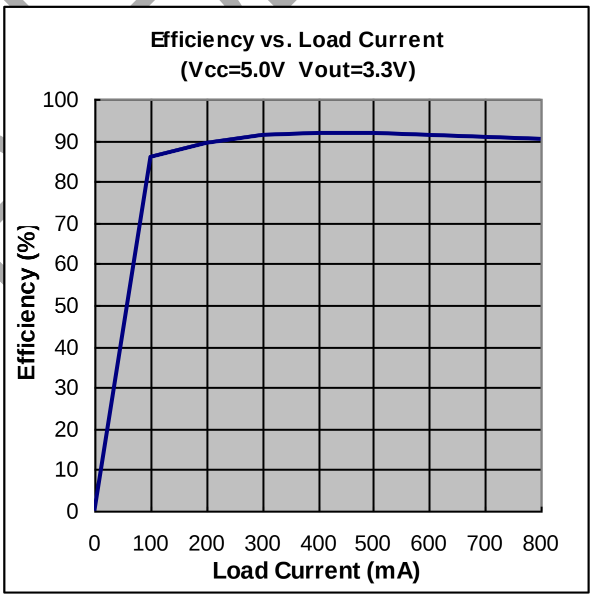


Figure 12

Typical Operating Characteristics (Continued)

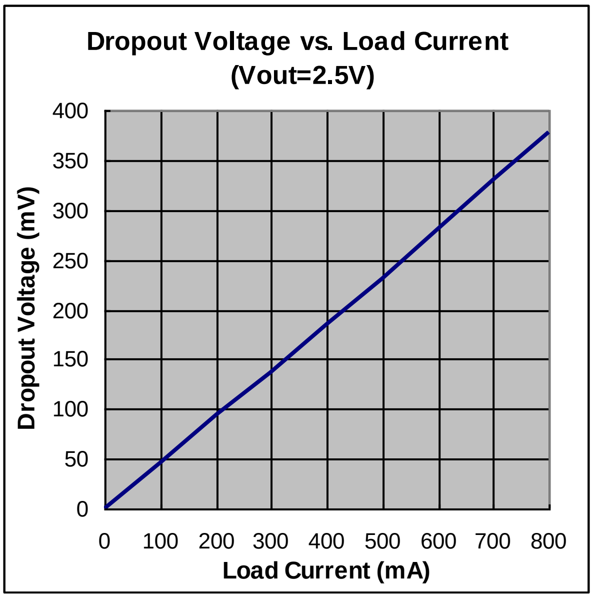


Figure 13

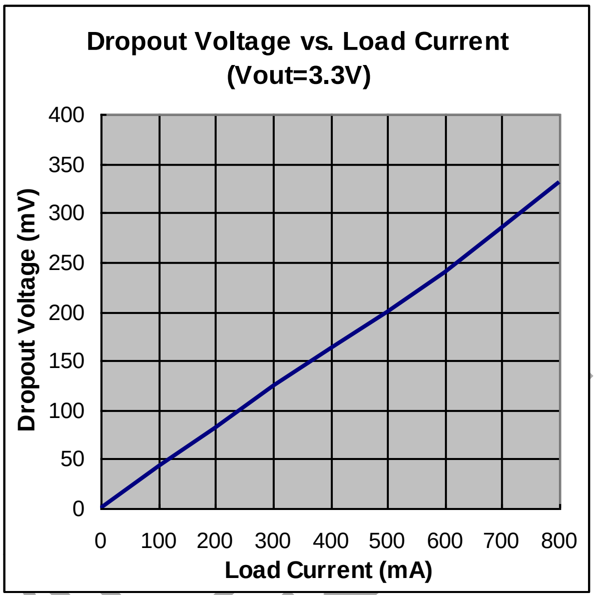


Figure 14

Output Ripple

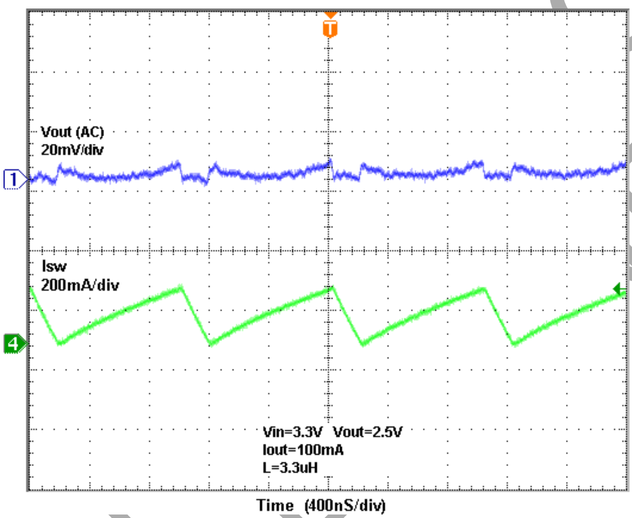


Figure 15

Output Ripple

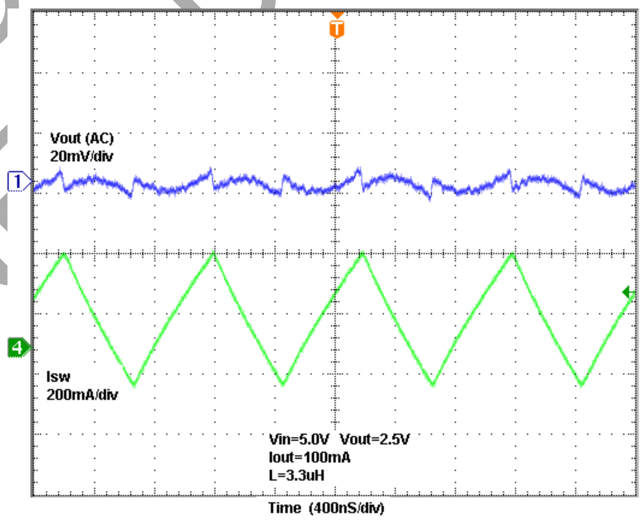


Figure 16

Typical Operating Characteristics (Continued)

Load Transient Response

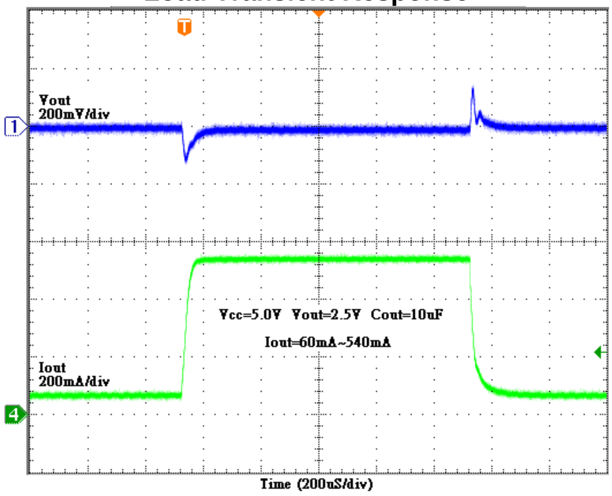


Figure 17

Load Transient Response

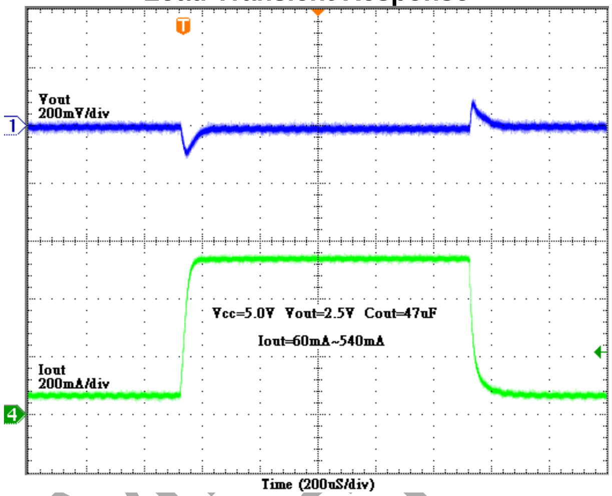


Figure 18

Load Transient Response

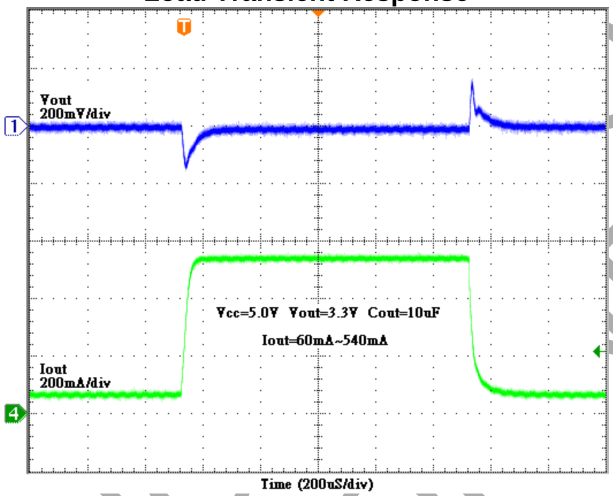


Figure 19

Load Transient Response

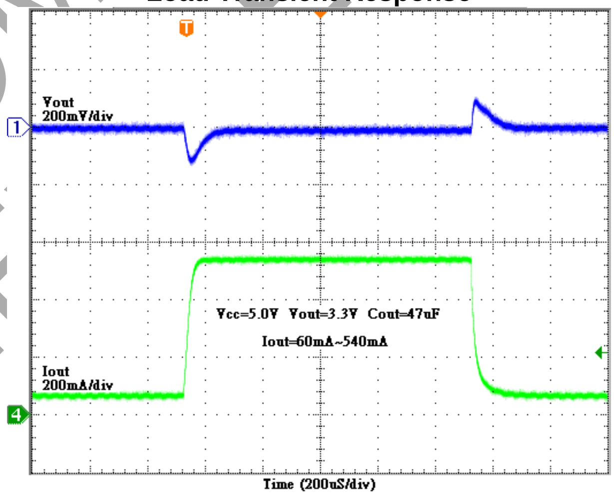


Figure 20

Application Information

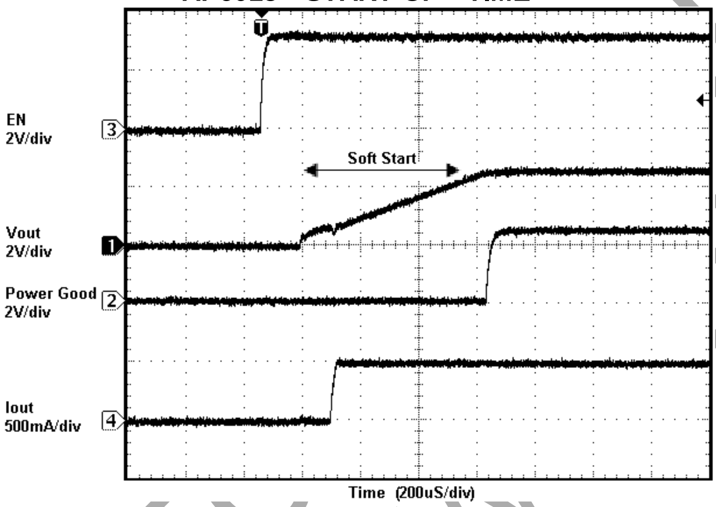
■ Enable (EN)

When EN is on logic low, the AP6015 goes into shutdown mode. In shutdown, all other functions are turned off. The supply current is reduced to 1uA (Typ.).

■ Soft Start

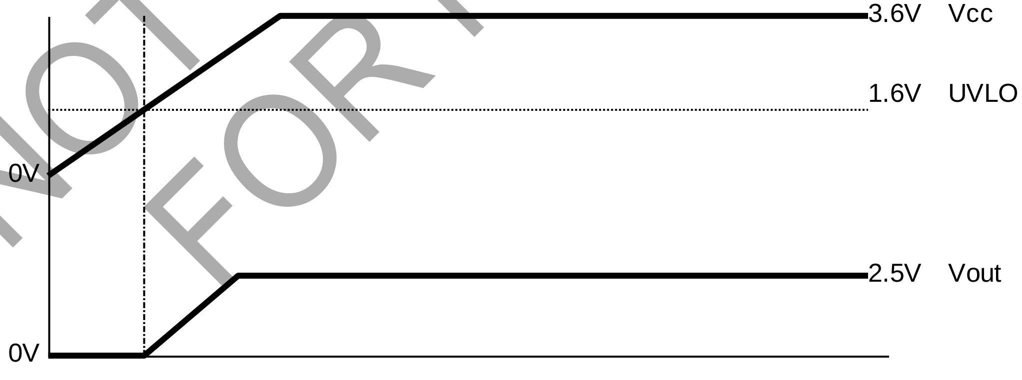
As the enable pin goes high, the soft-start function generates an internal voltage ramp. This causes the start-up current to slowly raise preventing output voltage overshoot and high inrush currents. The soft-start duration is typical 1mSec.

AP6015 START-UP TIME



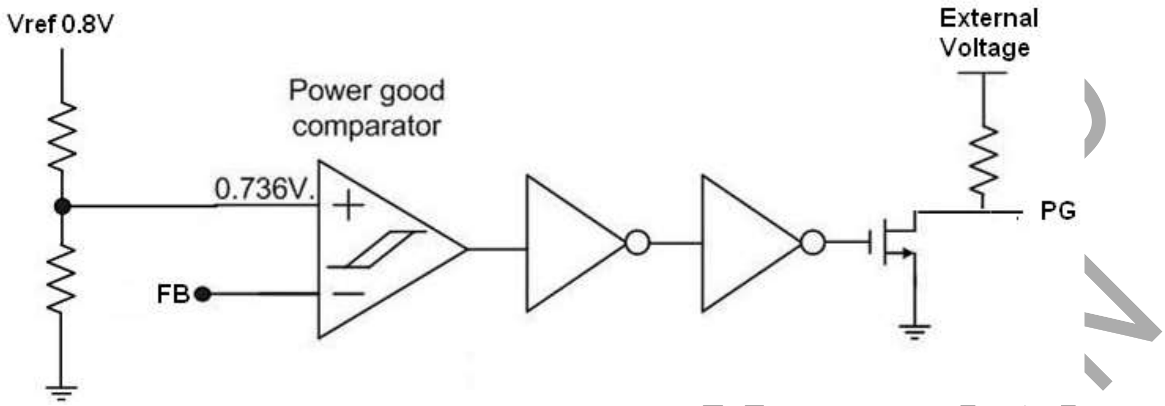
■ Under Voltage Lock Out (UVLO)

The UVLO prevents the converter from turning on when the voltage on V_{CC} is less than typically 1.6V.

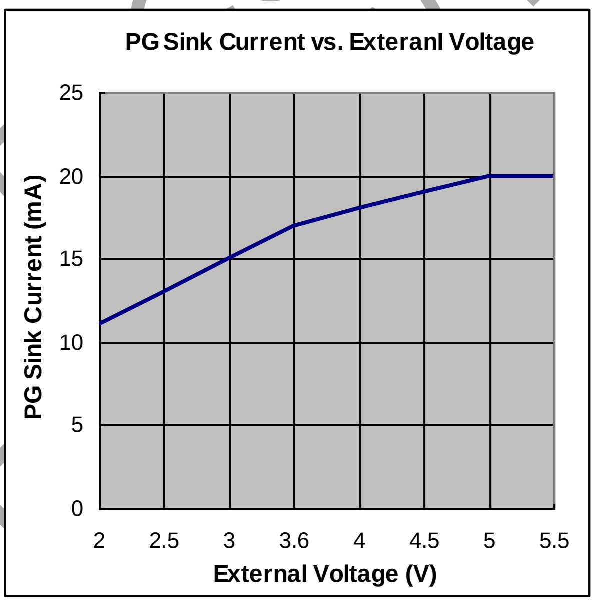


Application Information (Continued)

■ **Power Good (PG)**



The PG comparator has an open drain output capable of sinking typically 10mA. The PG is only active when the AP6015 is enable (EN=high). When the AP6015 is disable (EN=low), the PG pin is high impedance.
If the PG pin is connected to the output of the AP6015 with a pull-up resistor, no initial spike occurs and precautions have to be taken during start-up.
The PG pin becomes active high when the output voltage exceeds typically 92% of its nominal value. Leave the PG pin unconnected when not used.



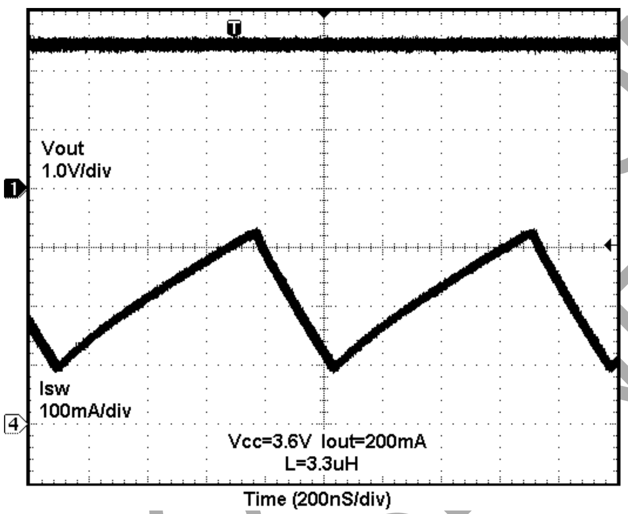
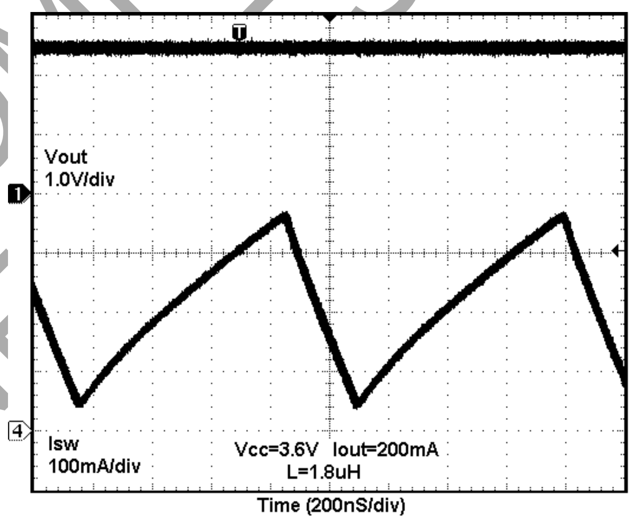
Application Information (Continued)

- **Inductor Selection**

In order to avoid saturation of the inductor, the inductor should be rated at least for the maximum output current plus the inductor ripple current which is calculated as:

$$\Delta I_L = V_O \times \frac{1-(\frac{V_O}{V_{CC}})}{L \times f} \qquad I_{L(MAX)} = I_{O(MAX)} + \frac{\Delta I_L}{2}$$

Where:
f= Switching frequency (1MHz typical)
L = Inductor value
$\triangle I_L$ = Peak-to-peak inductor ripple current
I_L(max) = Maximum inductor current

Vcc=3.6V Vout=2.5V f=1MHz L=3.3uH ➔ $\triangle I_L$ ≒230mA	Vcc=3.6V Vout=2.5V f=1MHz L=1.8uH ➔ $\triangle I_L$ ≒360mA
	

Application Information (Continued)

■ Input Capacitor Selection

Though there is no special requirement for the ESR (Equivalent Series Resistance) of the input capacitor, due attention should be paid to the tolerance and temperature coefficient of the capacitor used. A 10uF or larger capacitance is required between the PVCC and the GND pins. The input capacitor should be placed as close as possible to the PVCC pin in order to achieve good overall system performance.

■ Output Capacitor Selection

Ripple at the voltage output pin is caused by the charge-and-discharge of the output capacitor. For the best performance, a low ESR output capacitor should be used. The equation below demonstrates how the size of the ripple can be calculated.

$$\Delta V_O = V_O \times \frac{1-(\frac{V_O}{V_{CC}})}{L \times f} \times (\frac{1}{8 \times C_O \times f} + ESR) = \Delta I_L \times (\frac{1}{8 \times C_O \times f} + ESR)$$

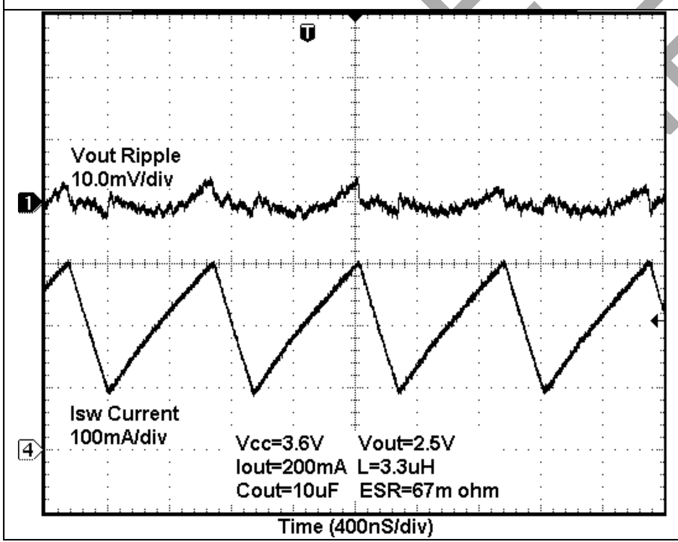
Where:

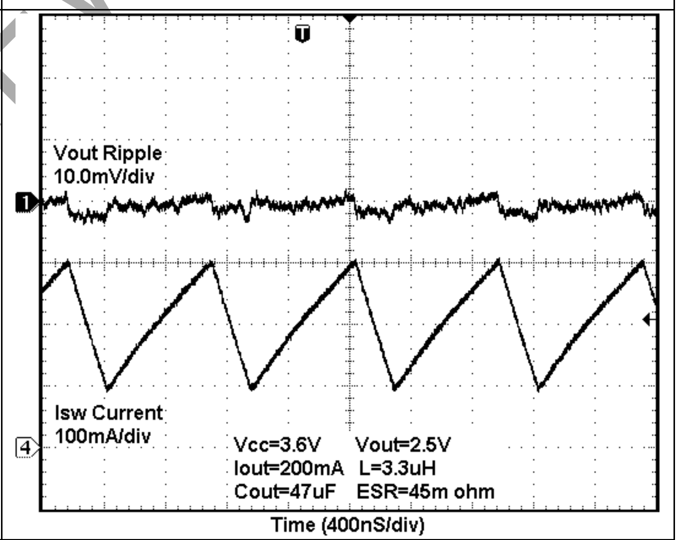
△Vo= Output voltage ripple

L = Inductor value

f = Switching frequency (1MHz typical)

$\triangle I_L$ = Peak-to-peak inductor ripple current

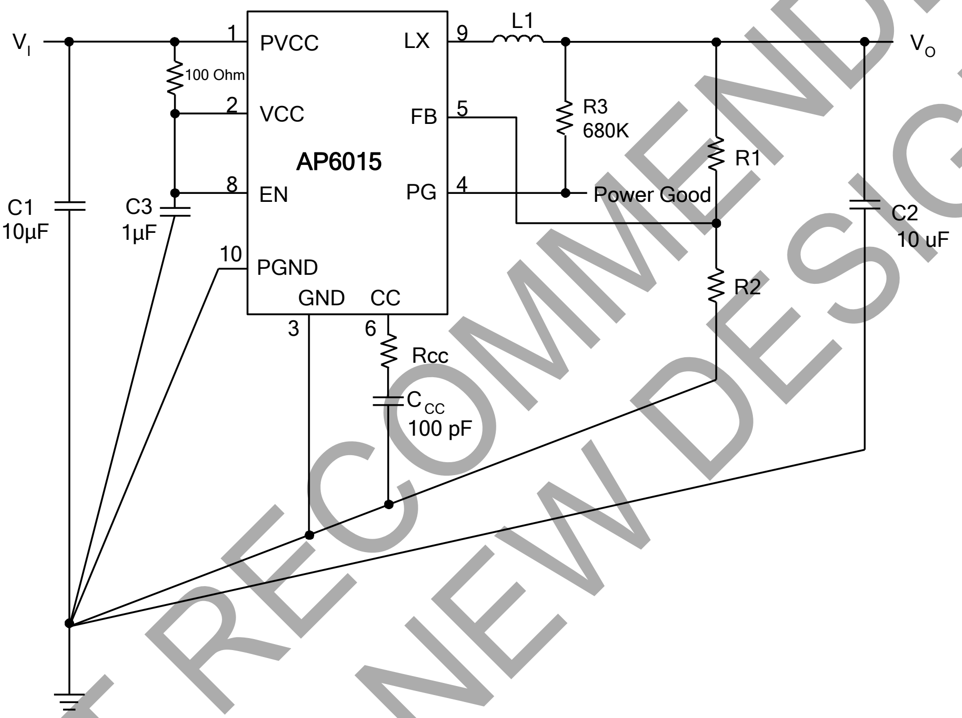




Application Information (Continued)

■ Layout Considerations

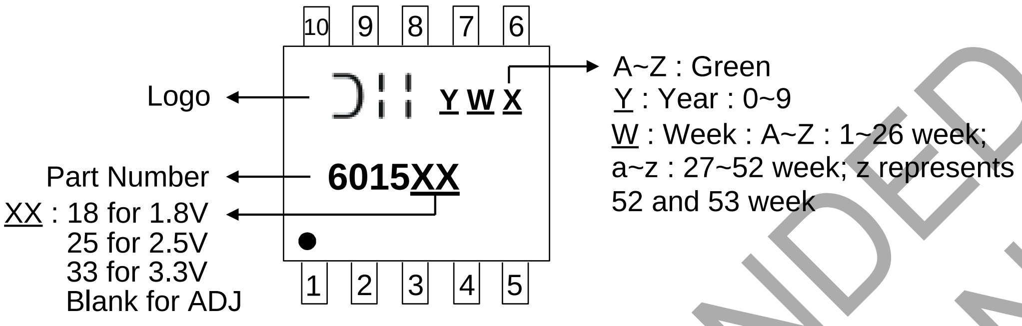
A good board layout practice can significantly improve the stability of the application circuit and reduce the system noise. The feedback path must be as short as possible. The input capacitor and bypass capacitor must be placed close to the PVCC and the VCC pins for optimal performance. It is recommended that the ground planes for System Ground / Power Ground / Analog Ground are isolated from each others, while they should all be joined together at a common point. An example drawing of a circuit with good ground noise performance is shown below.



The external inductor must be placed as close as possible to the switching node, i.e. the LX pin. The copper traces on the pcb, where high peak switching current may flow through, should be kept 'wide' and 'short'. This results in low inductance and capacitance in the current path, hence ground shift problem is avoided and system stability stay within bound.

Marking Information

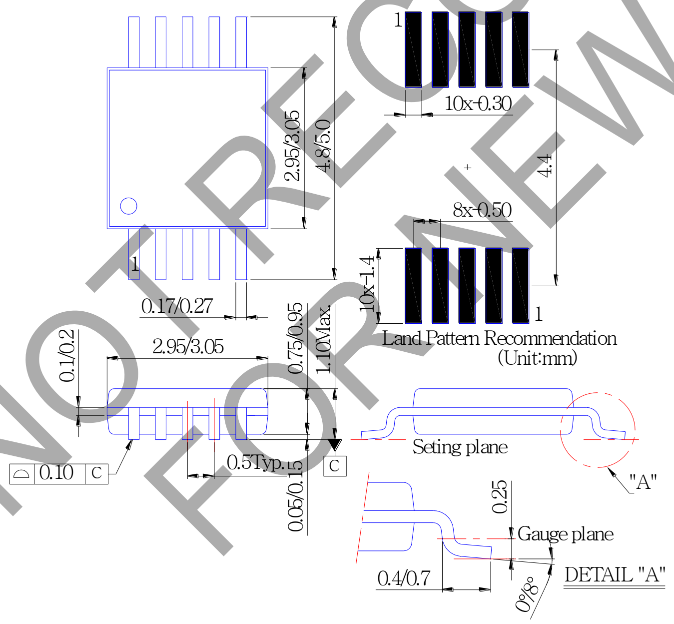
(Top View)



MSOP-10L

Package Information (All Dimensions in mm)

(1) Package type: MSOP-10L



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