1 MHz, 3.0 A, Synchronous Step-Down Converter

General Description

The APS2430 is a high efficiency monolithic synchronous buck regulator using a constant frequency, current mode architecture. Supply current down to 60 μA at no load and < 1 μA at shutdown. The 2.7 V to 6.0 V input voltage range makes the APS2430 ideally suited for single-cell Li-Ion batteries and two to four AA battery-powered applications. 100% duty cycle provides low-dropout operation to extend the battery life of portable systems. PWM pulse skipping mode operation provides very low output ripple voltage for noise sensitive applications. The switching frequency is internally set to 1 MHz, allowing the use of small surface mount inductors and capacitors. Low output voltages are easily supported with the 0.6 V feedback reference voltage.

The built-in soft-start function can eliminates inrush current to avoid damage to the system. Also, a hiccup auto-restart operation can protect the buck regulator once short-circuits occurs. The APS2430 is available in SOT-23-5L and SOT-23-6L IC packages.

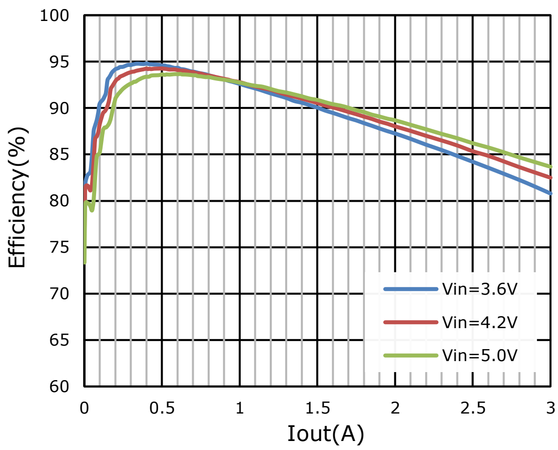
Applications

- Set Top Box
- Portable Instruments
- Battery Powered Equipment
- Wireless Access Point Router and DSL Modems
- Personal and Notebook Computer
- Microprocessors and DSP Core Supplies
- Digital Still and Video Cameras

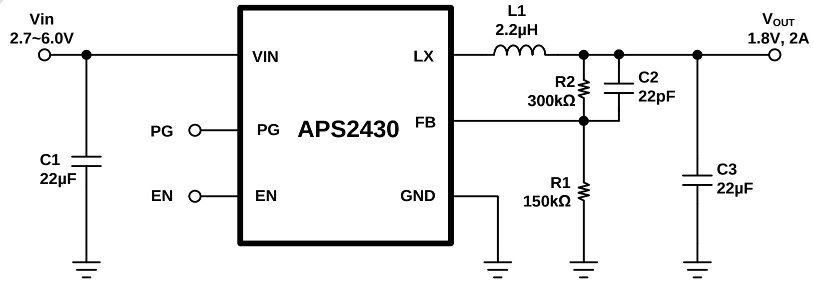
Features

- High Efficiency: Up to 95 %
- 1 MHz Constant Switching Frequency
- 2.7 V to 6.0 V Input Voltage Range
- 3.0 A Output Current at V_{IN} = 3 V
- Quiescent Current: 60 μA (input < 4.2 V)
- Integrated Main Switch and Synchronous Rectifier
- 100% Duty Cycle in Dropout
- Shutdown Current < 1 μA
- Slope Compensated Current Mode Control for Excellent Line and Load Transient Response
- Robust protection features, OCP, TSD
- Same BOM L-C passive components for V_{IN} = 5 to V_{OUT} = 3.3 V, 2.5 V, 1.8 V, 1.2 V and 1.0 V
- Internal Soft Start Circuitry
- Packages: SOT-23-5L, SOT-23-6L.

Efficiency vs. I_{OUT} @ V_{OUT}=1.8 V



Typical Application Circuit

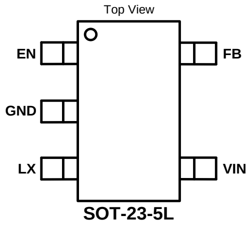


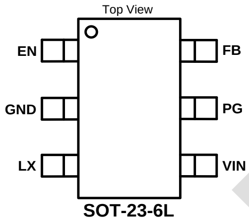
Ordering Information

Order Codes	Max. Cont. I_{OUT}	SCP Modes	Packages	Shipping	Top Markings
APS2430ATBER	3 A	Hiccup	SOT-23-5L	3,000/Reel	S6XYP
APS2430BTCER	3 A	Hiccup	SOT-23-6L	3,000/Reel	S5XYP

(1). XY = date code, P = Assembly site

Pin Configurations





Pin Description

Pin Names	Pin No.		Pin Functions
	SOT-23-5L	SOT-23-6L	
EN	1	1	Regulator Enable control input. Drive EN above 1.1 V to turn on the part. Drive EN below 0.6 V to turn it off. In shutdown, all functions are disabled drawing < 1 µA supply current. Do not leave EN floating.
GND	2	2	Ground.
LX	3	3	Power Switch Output. It is the Switch note connection to inductor. This pin connects to the drains of the internal P-CH and N-CH MOSFET switches.
VIN	4	4	Power supply input pin. Must be closely decoupled to PGND with a 22 µF or greater ceramic capacitor.
PG	-	5	Power Good Indicator. This pin is an open drain logic output. Connect PG to an external pull-up resistor and get a high level output. PG is pulled to ground when the output voltage is less than 91.5 % of the target output voltage. Let PG float or connect to ground when don't use PG function.
FB	5	6	Feedback Input Pin. Connect FB to the center point of the external resistor divider. The feedback threshold voltage is 0.6 V.

Functional Block Diagrams

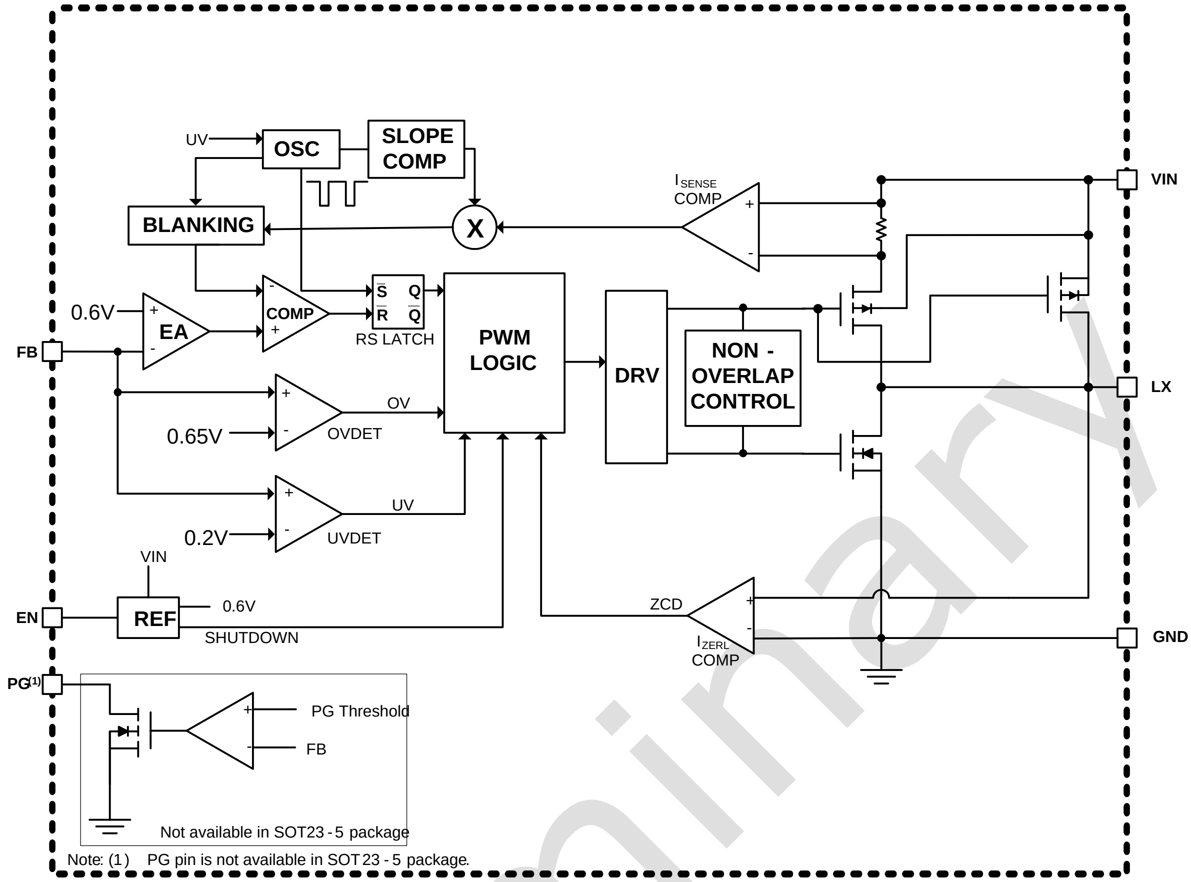


Figure 1. Function Block Diagram

Absolute Maximum Ratings(1)

VIN..-0.3 V to 7 V
EN, FB...........................-0.3 V to V_{IN} + 0.3 V
SW...............................-0.3 V to V_{IN} + 0.3 V
ESD Ratings
Human Body Model.......................±4 kV
Machine Model............................±200 V
Package Thermal Resistance(2)
Θ_{JA} - SOT-23-5L, SOT-23-6L.......220 °C/W
Θ_{JC} - SOT-23-5L, SOT-23-6L........55 °C/W

Operating Temperature............ -40 °C to 85 °C
Junction Temperature(3).........Internally Limited
Storage Temperature............ -65 °C to 150 °C
Lead Temperature (Soldering, 10s)........260 °C

(1). Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.
(2). Thermal Resistance is specified with approximately 1 square of 1 oz copper.
(3). T_J is calculated from the ambient temperature T_A and power dissipation PD according to the following formula: $T_J = T_A + (PD) \times (220\ °C/W)$.

Electrical Characteristics(1)

($V_{IN} = V_{EN} = 3.6$ V, $T_A = 25$ °C, unless otherwise noted.)

Parameters	Conditions	Min	Typ	Max	Unit
Input Supply Voltage					
Input Voltage Range		2.7		6.0	V
Operating Supply Current (non- switching)	V_{FB} = 0.7 V		60	300	μA
Shutdown Supply Current	V_{FB} = 0 V, V_{IN} = 4.2 V		0.1	1.0	μA
Feedback and Output					
Regulated Feedback Voltage	T_A = + 25 °C	0.5880	0.6000	0.6120	V
	T_A = 0 °C ≤ T_A ≤ 85 °C	0.5865	0.6000	0.6135	V
	T_A = -40 °C ≤ T_A ≤ 85 °C	0.5820	0.6000	0.6180	V
Feedback Input Bias Current	V_{FB} = 0.65 V		±30		nA
Reference Voltage Line Regulation	V_{IN} = 2.5 V to 5.5 V, I_{OUT} = 300 mA		0.5	0.60	%/V
Output Voltage Line Regulation	V_{IN} = 2.5 V to 5.5 V I_{OUT} = 300 mA		0.5	0.60	%/V
Output Voltage Load Regulation	I_{OUT} = 300 to 3000 mA		0.5		%/A
Current Limit					
Peak Inductor Current	V_{IN} = 3 V, V_{FB} = 0.5 V or V_{OUT} = 90 % Duty Cycle < 35 %		4.3		A
Oscillator					
Oscillator Frequency	V_{FB} = 0.6 V or V_{OUT} = 100 %	0.8	1.0	1.2	MHz
MOSFET					
$R_{DS(ON)}$ of P-CH MOSFET (SOT-23-6L)	I_{LX} = 300 mA		75		mΩ
$R_{DS(ON)}$ of N-CH MOSFET (SOT-23-6L)	I_{LX} = -300 mA		55		mΩ
LX Leakage	V_{EN} = 0 V, V_{LX} = 0 V or 5 V, V_{IN} = 5 V		±0.01	±1	μA

Electrical Characteristics[1] (continued)

(V_{IN} = V_{EN} = 3.6 V, T_A = 25 °C, unless otherwise noted.)

Parameters	Conditions	Min	Typ	Max	Unit
Soft-start					
Soft start			1		ms
Input UVLO					
UVLO	V_{IN} Rising	2.3	2.5	2.7	V
	V_{IN} Falling	2.0	2.2	2.4	V
Enable Input					
Low Level Input Voltage	-40 °C ≤ T_A ≤ 85 °C			0.6	V
High Level Input Voltage		1.1			
Leakage Current			±0.01	±1	μA
Power Good(NOT available in SOT-23-5L Package)					
Power Good Threshold	Measured at FB pin, With Respect to V_{REF}	85	91.5		%
Thermal Shutdown					
Thermal Shutdown[2]			155		°C

(1). Specifications over the temperature range are guaranteed by design and characterization.
(2). Guaranteed by design and characterization only.

Functional Descriptions

Operation

APS2430 is a monolithic switching mode Step-Down DC-DC converter. It utilizes internal MOSFETs to achieve high efficiency and can generate very low output voltage by using internal reference at 0.6 V. It operates at a fixed switching frequency, and uses the slope compensated current mode architecture. This Step-Down DC-DC Converter supplies 3.0 A output current at V_{OUT} = 1.8 V with input voltage range from 2.7 V to 6.0 V.

Current Mode PWM Control

Slope compensated current mode PWM control provides stable switching and cycle-by-cycle current limit for excellent load and line responses and protection of the internal main switch (P-Ch MOSFET) and synchronous rectifier (N-CH MOSFET). During normal operation, the internal P-Ch MOSFET is turned on for a certain time to ramp the inductor current at each rising edge of the internal oscillator, and switched off when the peak inductor current is above the error voltage. The current comparator, I_{COMP}, limits the peak inductor current. When the main switch is off, the synchronous rectifier will be turned on immediately and stay on until either the inductor current starts to reverse, as indicated by the current reversal comparator, I_{ZERO}, or the beginning of the next clock cycle.

Idle Mode Operation

At very light loads, the APS2430 automatically enters pulse skipping Mode. In the pulse skipping Mode, the inductor current may reach zero or reverse on each pulse. The PWM control loop will automatically skip pulses to maintain output regulation. The bottom MOSFET is turned off by the current reversal comparator, I_{ZERO}, and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator.

Power Good Output (PG)

PGOOD is an open-drain type output and requires a pullup resistor. PGOOD is actively held low in soft-start, standby, and shutdown. It is released when the output voltage rises above 91.5% of nominal regulation point. The PGOOD signal goes low if the output is turned off or falls below 91.5% of nominal regulation point.

Dropout Operation

When the input voltage decreases toward the value of the output voltage, the APS2430 allows the main switch to remain on for more than one switching cycle and increases the duty cycle[6] until it reaches 100%. The output voltage then is the input voltage minus the voltage drop across the main switch and the inductor. At low input supply voltage, the $R_{DS(ON)}$ of the P-Channel MOSFET increases, and the efficiency of the converter decreases. Caution must be exercised to ensure the heat dissipated not to exceed the maximum junction temperature of the IC.

(6). The duty cycle D of a step-down converter is defined as:

$$D = T_{ON} \times f_{OSC} \times 100\% \approx \frac{V_{OUT}}{V_{IN}} \times 100\%$$

Where T_{ON} is the main switch on time and f_{OSC} is the oscillator frequency (1 MHz).

Maximum Load Current

The APS2430 will operate with input supply voltage as low as 2.7 V, however, the maximum load current decreases at lower input due to large I-R drop on the main switch and synchronous rectifier. The slope compensation signal reduces the peak inductor current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%. Conversely the current limit increases as the duty cycle decreases.

Short-circuit and Overvoltage

When a short circuit occurs, the feedback voltage will be decrease. Once the feedback voltage lower than 0.20V, the short-circuit hiccup protection will be activated. In addition, if the feedback voltage above 0.65V, the feedback overvoltage protection will also be activated and turn off the high side MOSFET.

Layout Guidance

When laying out the PCB board, the following suggestions should be taken to ensure proper operation of the APS2430. These items are also illustrated graphically in Figure 2 (illustrated by APS2430B).

1. The power traces, including the GND trace, the LX trace and the V_{IN} trace should be kept short, direct and wide.
2. The V_{FB} pin should be connected directly to the feedback resistor. The resistive divider R1/R2 must be connected between the (+) plate of C3 and ground.
3. Connect the (+) plate of C1 to the V_{IN} pin as closely as possible. This capacitor provides the AC current to internal power MOSFET.
4. Keep the switching node, LX, away from the sensitive V_{FB} node.
5. Keep the (-) plates of C1 and C3 as close as possible.

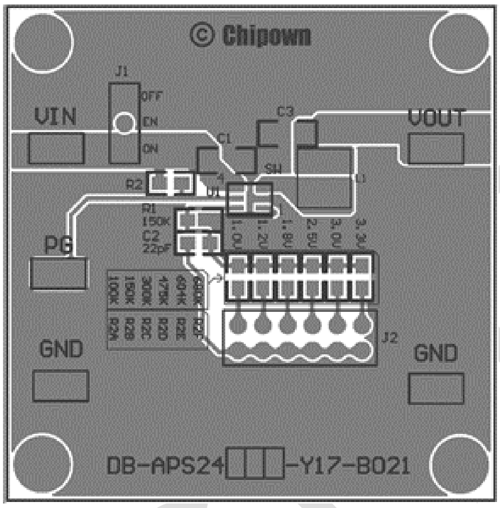


Figure2. APS2430B Recommend Layout

Application Information

Setting the Output Voltage

The external resistors set the output voltage according to the following equation:

$$V_{OUT}=0.6V\times\left(1+\frac{R2}{R1}\right)$$

where

- R1 = 150 kΩ(1%) for all outputs
- R2A = 100 kΩ(1%) for V_{OUT} = 1.0 V
- R2B = 150 kΩ(1%) for V_{OUT} = 1.2 V
- R2C = 300 kΩ(1%) for V_{OUT} = 1.8 V
- R2D = 475 kΩ(1%) for V_{OUT} = 2.5 V
- R2E = 604 kΩ(1%) for V_{OUT} ≈ 3.0 V
- R2F = 680 kΩ(1%) for V_{OUT} ≈ 3.3 V

Inductor Selection

For most designs, the APS2430 operates with inductors of 1 μH to 4.7 μH. Low inductance values are physically smaller but require faster switching, which results in some efficiency loss. The inductor value can be derived from the following equation:

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

Where ΔI_L is inductor Ripple Current. Large value inductors lower ripple current and small value inductors result in high ripple currents. Choose inductor ripple current approximately 35% of the maximum load current 3000 mA, or ΔI_L=1050 mA.

For output voltages above 2.0 V, when light-load efficiency is important, the minimum recommended inductor is 2.2 μH. For optimum voltage-positioning load transients, choose an inductor with DC series resistance in the 50 mΩ to 150 mΩ range. For higher efficiency at heavy loads (above 500 mA), or minimal load regulation (but some transient overshoot), the resistance should be kept below 100 mΩ. The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation. Table 1 lists some typical surface mount inductors that meet target applications for the APS2430.

Vendor	P/N	L (μH)	DCR (mΩ)	I_{RATED} (A)	I_{SAT} (A)	Size(L x W x H) (mm)
Mag.Layers	MMD-05CZ-2R2M-M2	2.2	29	5.5	9	5.7 x 5.4 x 3.0
Sunlord	SWPA5040S2R2NT	2.2	17	3.95	6.5	5.0 x 5.0 x 4.0
Sunlord	WPN4020H2R2MT	2.2	48	5	7.6	4.0 x 4.0 x 2.0

Table 1. Recommended Inductors

Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. The input capacitor impedance at the switching frequency shall be less than input source impedance to prevent high frequency switching current passing to the input. A low ESR input capacitor sized for maximum RMS current must be used. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. A 22 μF ceramic capacitor for most applications is sufficient.

Output Capacitor Selection

The output capacitor is required to keep the output voltage ripple small and to ensure regulation loop stability. The output capacitor must have low impedance at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current. The output ripple ΔV_{OUT} is determined by:

$$\Delta V_{OUT}\leq\frac{V_{OUT}\times(V_{IN}-V_{OUT})}{V_{IN}\times f_{OSC}\times L}\times\left(ESR+\frac{1}{8\times f_{OSC}\times C3}\right)$$

V_{OUT}	R1 (kΩ)	R2 (kΩ)	L1 (µH)	C1 (µF)	C2 (PF)	C3 (µF)
3.3V	150	680	2.2	22	22	22
3.0V	150	604	2.2	22	22	22
2.5V	150	475	2.2	22	22	22
1.8V	150	300	2.2	22	22	22
1.2V	150	150	2.2	22	22	22
1.0V	150	100	2.2	22	22	22

Table 2. Recommended Component Values for Typical Application Circuit

Typical Performance Characteristics

All curves taken at V_{IN} = 5.0V with configuration in typical application circuit for V_{OUT} = 3.3V shown in this datasheet. T_A = 25°C, unless otherwise specified.

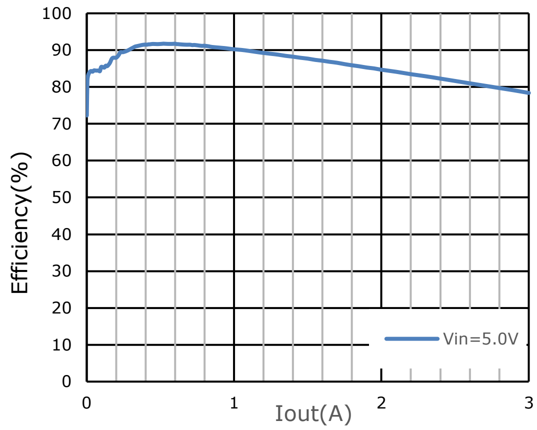


Figure 3. Efficiency, V_{OUT} = 1.2 V

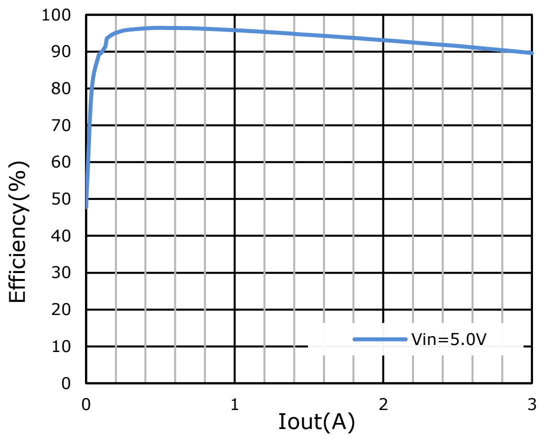


Figure 4. Efficiency, V_{OUT} = 3.3 V

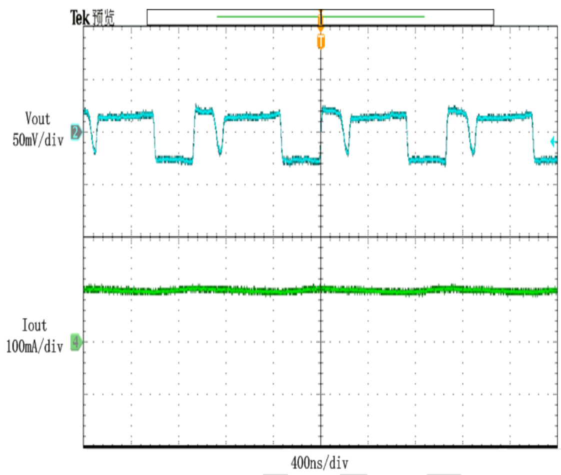


Figure 5. V_{OUT} Ripple,
V_{IN} = 5.0 V, V_{OUT} = 3.3 V, I_{OUT}=100mA

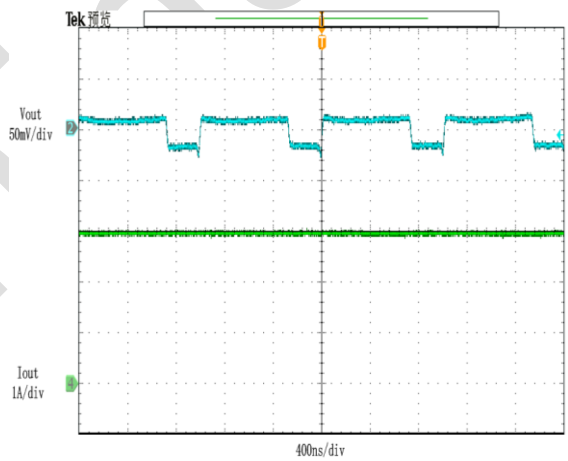


Figure 6. V_{OUT} Ripple,
V_{IN} = 5.0 V, V_{OUT} = 3.3 V, I_{OUT} = 3 A

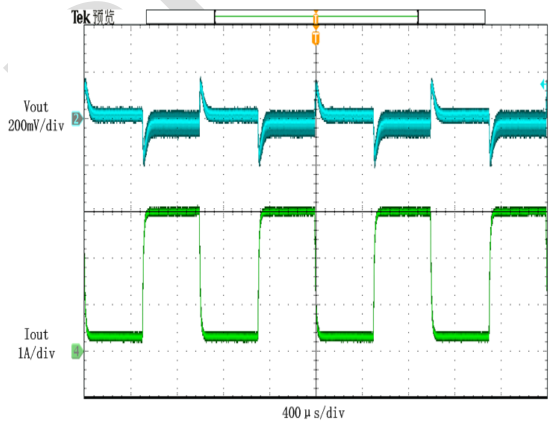


Figure 7. Load Transient,
V_{IN} = 5 V, V_{OUT} = 3.3 V, I_{OUT} = 0.3 A to 3.0 A

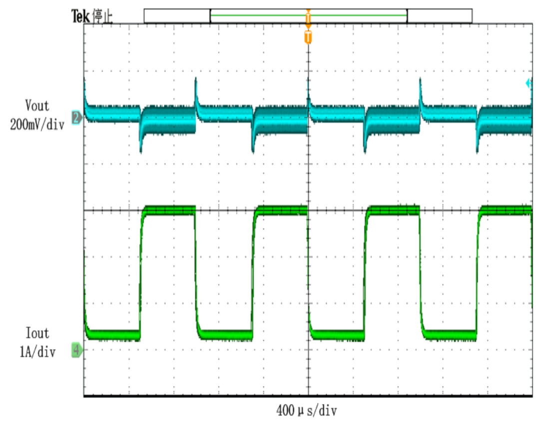


Figure 8. Load Transient,
V_{IN} = 5 V, V_{OUT} = 1.2 V, I_{OUT} = 0.3 A to 3.0 A

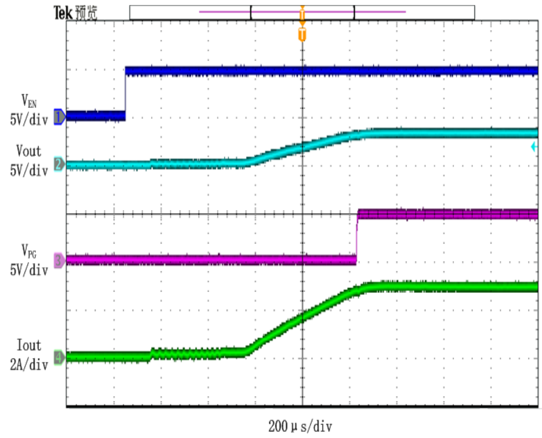


Figure 9. Soft-start with EN
V_{IN} = 5.0 V, V_{OUT} = 3.3 V, I_{OUT} = 3.0 A

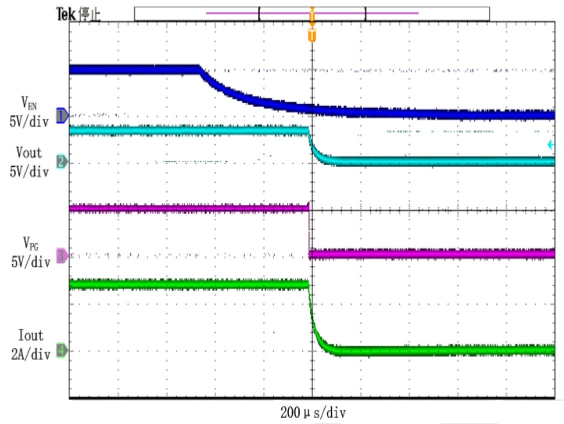


Figure 10. Power down with EN
V_{IN} = 5.0 V, V_{OUT} = 3.3 V, I_{OUT} = 3.0 A

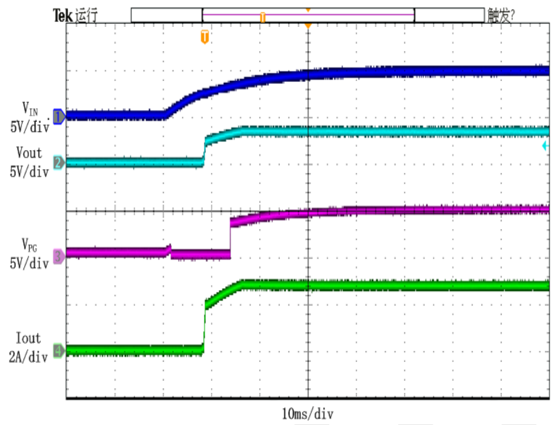


Figure 11. Soft-start
V_{IN} =5.0 V, V_{OUT} = 3.3 V, I_{OUT} = 3.0 A

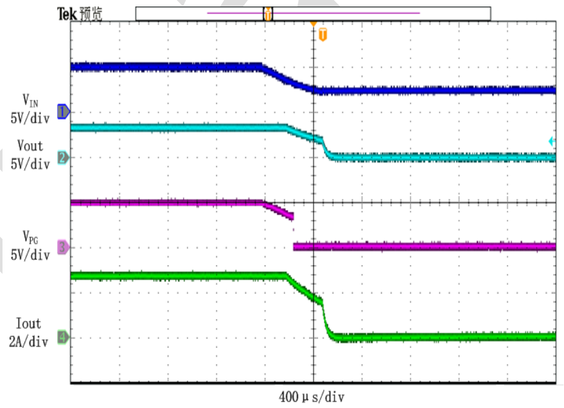
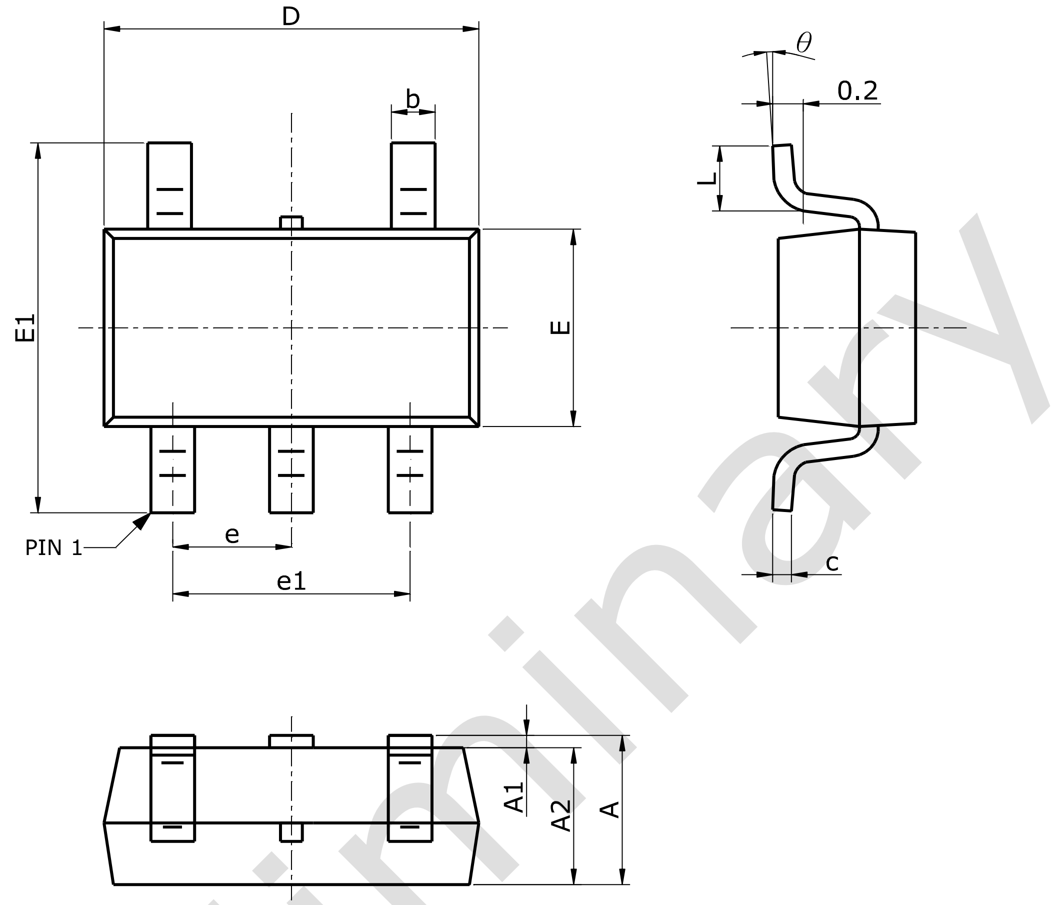


Figure 12. Power down
V_{IN} = 5.0 V, V_{OUT} = 3.3 V, I_{OUT} = 3.0 A

Package Information

SOT-23-5L Package Outline and Dimensions

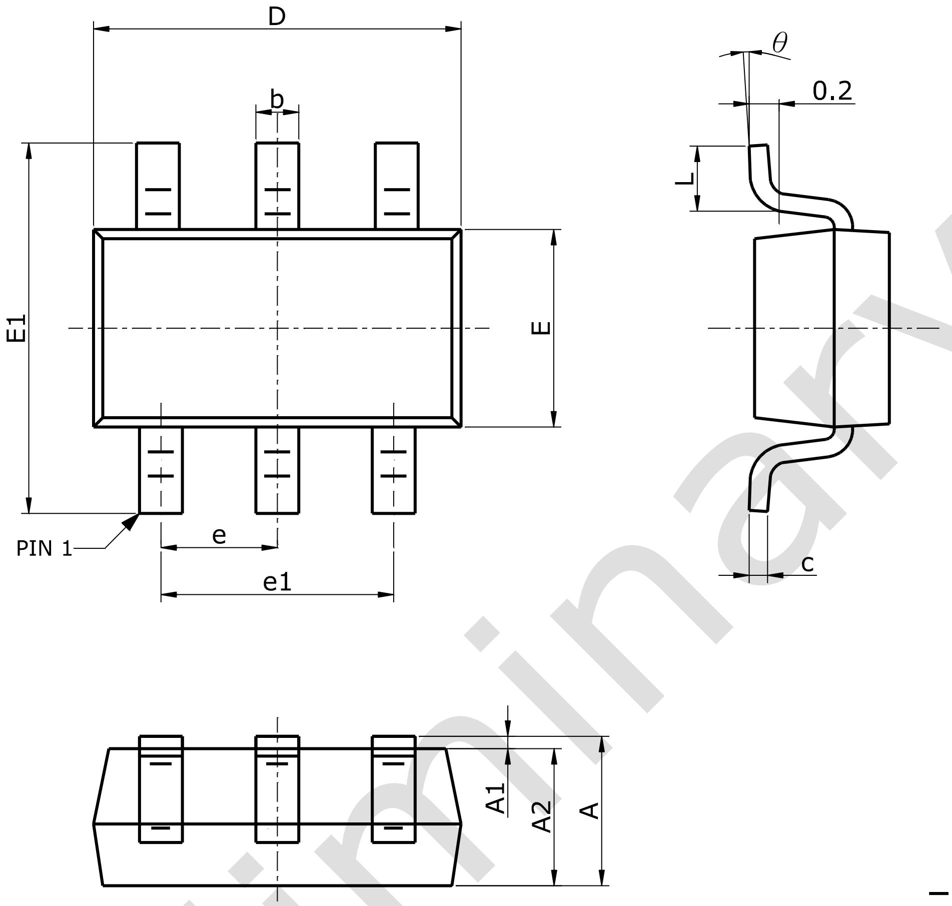


Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

Notes:
1. This drawing is subjected to change without notice.
2. Body dimensions do not include mold flash or protrusion.
3. This package conforms to JEDEC MO-178, variation AA.

Package Information (continued)

SOT-23-6L Package Outline and Dimensions



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

Notes:
1. This drawing is subjected to change without notice.
2. Body dimensions do not include mold flash or protrusion.
3. This package conforms to JEDEC MO-178, variation AB.

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