High Efficiency Low Start-up Voltage Step-up DC-DC Converter

Features

- **1.0V Low Start-up Input Voltage at 1mA Load**
- **Deliver 3.3V at 100mA with 1V Input Voltage**
- **35μA Quiescent (Switch-off) Supply Current**
- **90% High Efficiency (V_{IN} 3.0V/V_{OUT} 3.3V)**
- **550KHz Fixed Switching Frequency**
- **0.5μA Low Shutdown Current**
- **Flexibility to Use 2A Internal NMOS and External Power Switch**
- **1.0μA Low Shutdown Current**
- **SOT-23-6 Package**
- **RoHS Compliant and 100% Lead (Pb)-Free and Green (Halogen Free with Commercial Standard)**

General Description

The AP9266 is a compact, high-efficiency, step-up DC/DC converter that operates from an input voltage as low as 1Volt. The low start-up input voltage makes the device suitable for 1 to 4 battery cell applications delivering up to 400mA load current.

AP9266 features a voltage mode PWM control loop, providing stable and high-efficiency operation over a broad load current range without external compensation. High frequency 550KHz switching allows the use of small size external components.

The 2.5V to 6V output voltage is set with 2 external resistors. Both internal 2A NMOS power switch and driver or external power switch (NMOS or NPN) are provided for design flexibility. The device is available in SOT-23-6 package

Applications

- DSC, PDA
- MP3 Players
- Electronic Games
- Wireless Equipments
- Camcorders
- Portable Devices
- Single-and Dual-Cell Battery Operated Products
- Battery Backup Supplies

Typical Application Circuit

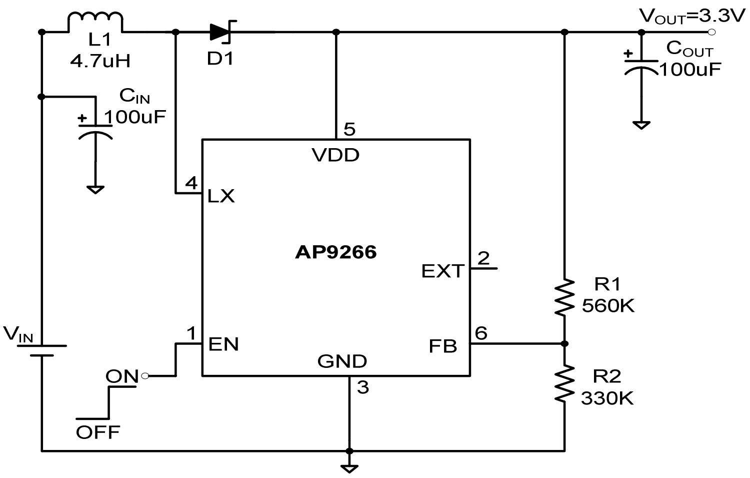
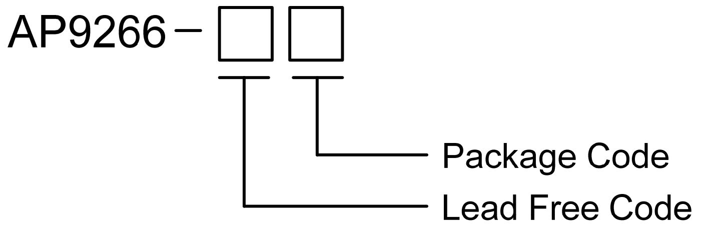


Figure 1. AP9266 Typical Application for 3.3V Output

Ordering Information



Lead Free Code：

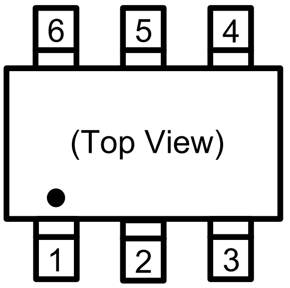
P：Commercial Standard, Lead (Pb) Free And Phosphorous (P) Free Package

G：Green (Halogen Free with Commercial Standard)

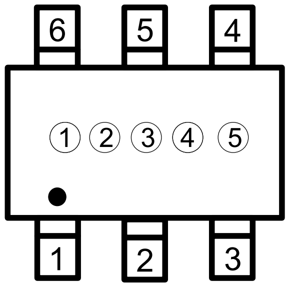
Package Code：

V：SOT-23-6

Pin Description

Part No.	Pin	Symbol	Pin Description
 SOT-23-6	1	EN	Chip Enable. Set CE Pin to low to Shutdown the Device. Must be Set to V_{OUT} or Higher Voltage to enable the Device. Do not Float This Pin.
	2	EXT	Output pin for driving external NMOS or NPN. When driving an NPN, a resistor Should be Added for Limiting Base Current.
	3	GND	Ground pin.
	4	LX	Switch Pin. Connect Inductor/Diode Here.
	5	VDD	Input Power Supply Pin.
	6	FB	Feedback input pin. Internal reference voltage for the error amplifier is 1.25V. Connect resistive divider tap here.

Package Marking Information



SOT-23-6
(Top View)

① 、② **Represents Products Series**

Mark	Products Series
66	AP9266

③ **Represents Type of Regulator**

Mark	Products Series
O	AP9266

④ 、⑤ **Represents Production Date Code**

Note：

* There is an under-line on 1st digit for A type of SOT-26 package.

* There are two under-lines on 4th & 5th digit for Green package.

* There are no under-lines on 4th & 5th digit for Pb-Free package.

Absolute Maximum Ratings

Parameter		Symbol	Ratings	Units
Supply Voltage			-0.3~+6.0	V
LX Pin Switch Voltage			-0.3~V_{OUT}+0.3	V
Others I/O Pin Voltage			-0.3~V_{OUT}+0.3	V
LX Pin Switch Current			2.5	A
EXT Pin Drive Current			30	mA
Junction Temperature		T_J	+150	°C
Thermal Resistance	SOT-23-6	θ_{JA}	160	°C/W
Power Dissipation	SOT-23-6	P_D	450	mW
Operating Ambient Temperature		T_{OPR}	-20 ~ +70	°C
Storage Temperature		T_{STG}	-55 ~ +150	°C
Lead Temperature (soldering, 10sec)			+260	°C
ESD Ratings	Human Body Model, per MIL-STD-883D-3015.7		1.5	KV
	Machine Model, MIL-STM5.2-1999		250	V

Electrical Characteristics

(V_{IN}=2.5V, V_{OUT} =3.3V, Load Current=0, T_A=25˚C, unless otherwise noted.)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{ST}	Start-up Voltage	I_L=1mA	---	0.95	1.10	V
		I_L=100mA	---	1.20	1.30	V
V_{HOLD}	Holding Voltage	I_L=20mA	---	0.60	---	V
V_{DD}	Operating V_{OUT} Range	Start –up I_{DD1}>250μA	2.2	---	6.0	V
I_{DD1}	No Load Current (V_{DD})	V_{DD}=3.3V, EN=1.5V, FB=0.5V	---	210	---	μA
I_{DD2}	Switch Off Current (V_{DD})	V_{DD}=3.3V, EN=1.5V, FB=1.5V	---	35	---	μA
I_{OFF}	Shutdown Current (V_{DD})	V_{DD}=4.5V, EN=0.0V, FB=0.5V	---	0.1	1	μA
V_{REF}	Feedback Reference Voltage		1.225	1.25	1.227	V
V_{EN}	EN Input Voltage Threshold	V_{DD}=3.3V, FB=0.5V	0.2	0.6	1.4	V
F_{SW}	Switching Frequency		440	550	660	KHz
D_{MAX}	Maximum Duty Cycle		---	78	---	%
$R_{DS(ON)}$	Switch on Resistance		---	0.4	---	Ω
V_{LXLIM}	Switch Voltage Limit		---	0.6	---	V
	EXT on Resistance to V_{DD}	V_{DD}=EN=3.3V, FB=0.5V	---	40	45	Ω
	EXT on Resistance to GND	V_{DD}=EN=3.3V, FB=0.5V	---	12	15	Ω
$\triangle V_{LINE}$	Line Regulation	V_{IN} = 1.5~2.5V, I_L=1mA	---	10	---	mV/V
$\triangle V_{LOAD}$	Load Regulation	V_{IN} =1.5V, I_L=1~100mA	---	0.25	---	mV/mA

Function Block Diagram

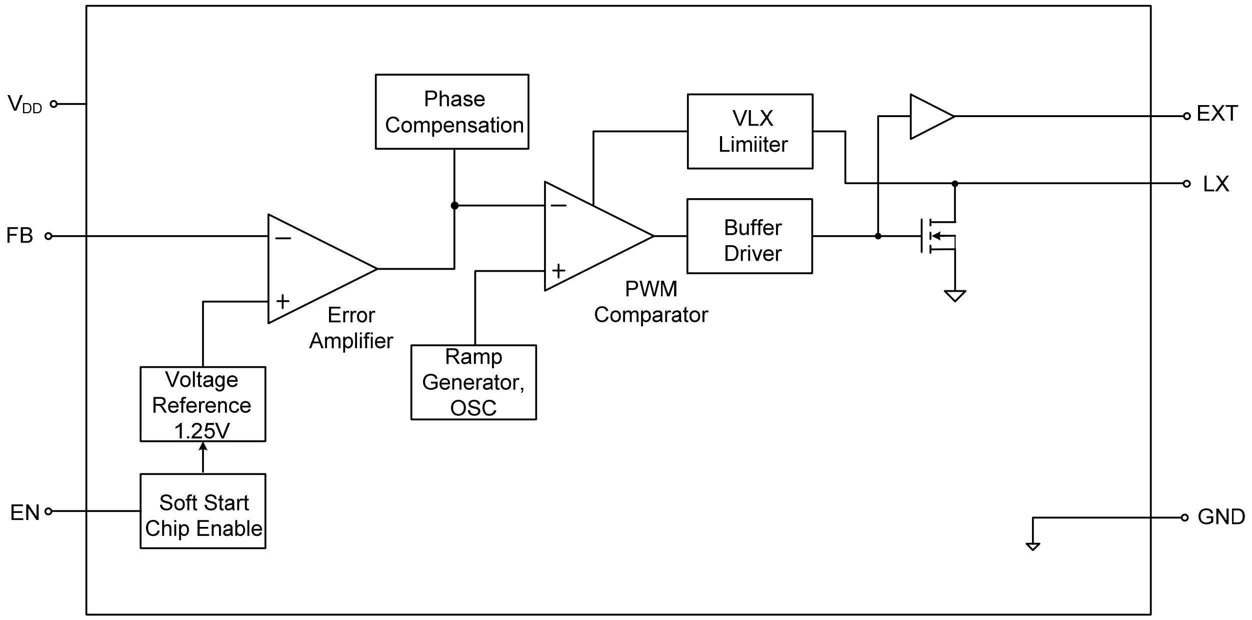


Figure 2. AP9266 Functional Block Diagram

Typical Application Circuit

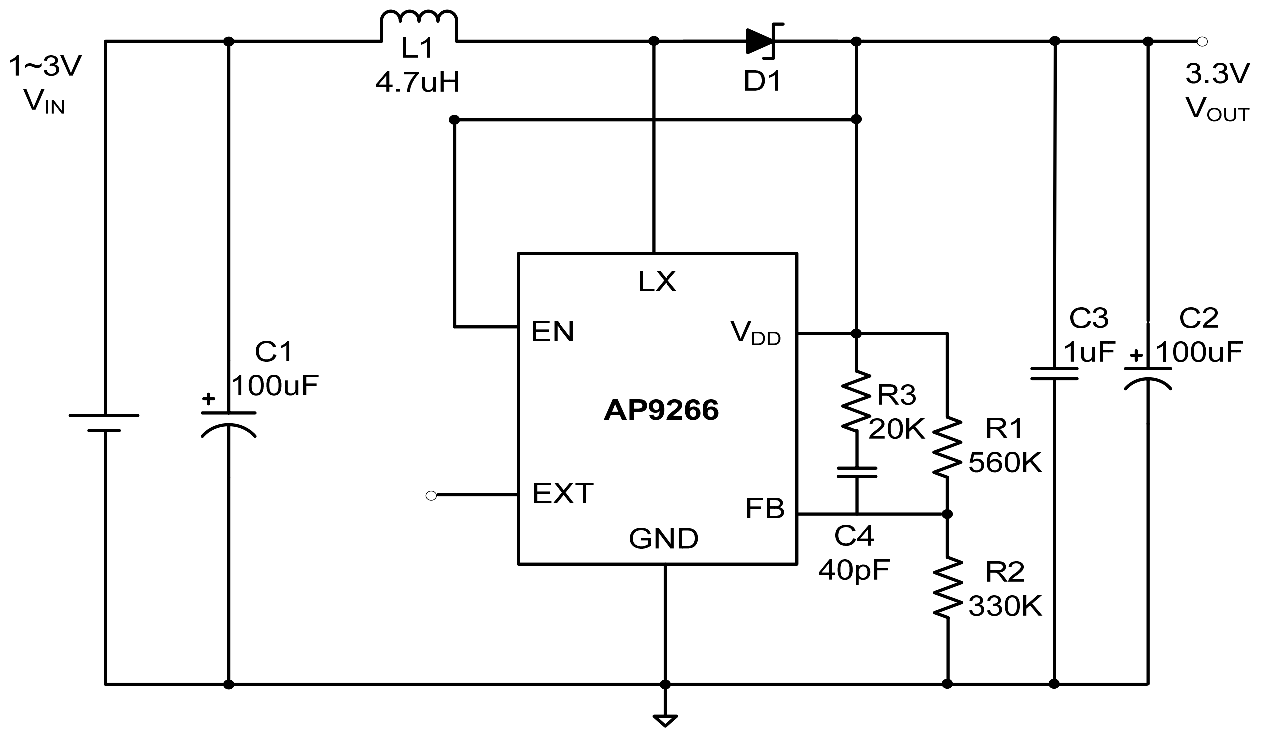


Figure 3. AP9266 Typical Application for 3.3V Output Below 400mA

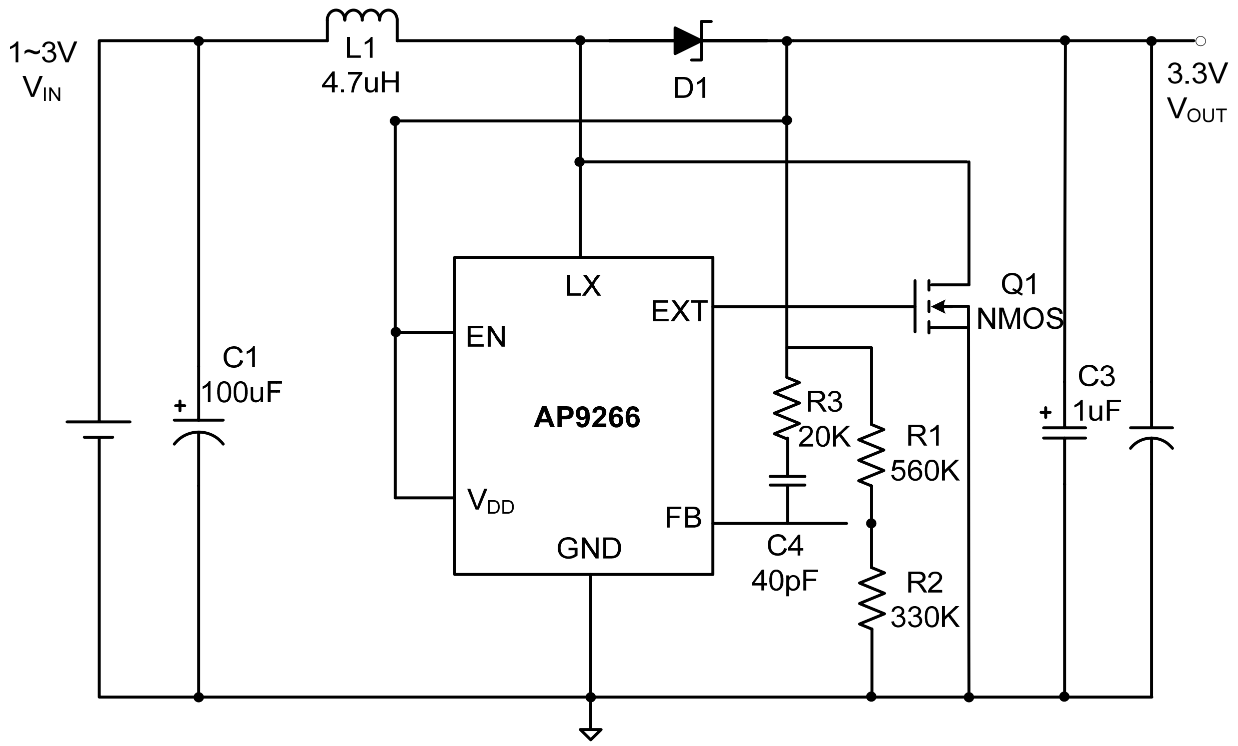


Figure 4. 0.4A~2A Output Current Application

Detail Description

The AP9266 is a high-efficiency, step-up DC-DC converter for portable devices like DSC and PDA. The AP9266 combines a boost switching regulator, 2A/0.25Ω N-channel power MOSFET, 1.25V precision reference, soft start, shutdown control, and a low-battery comparator. The switching DC-DC converter boosts a 1- to 4-cell input to an adjustable output between 2.5V and 6.0V. The AP9266 starts from a low 1.0V input and remains operational down to 0.6V at 20mA load current.

Step-Up Converter

The step-up DC-DC converter operation can be understood by referring to the block diagram in Figure 2. The error amplifier monitors the output voltage by comparing the feedback voltage with the 1.25V reference voltage. When the feedback voltage is lower than the reference voltage, the error amplifier output will decrease. The error amplifier output is then compared with the oscillator ramp voltage at the PWM controller. When the ramp voltage is higher than the error amplifier output, the buffer driver is turned on which will then switch on the internal N-channel MOSFET; and vice versa. As the error amplifier output decreases, the buffer driver turn-on time increases and duty cycle increases. When the feedback voltage is higher than the reference voltage, the error amplifier output increases and the duty cycle decreases.

During the first part of each switching cycle, the internal N-channel MOSFET switch is turned on. This allows current to ramp up in the inductor and store energy in a magnetic field. During the second part of each cycle, the MOSFET is turned off, the voltage across the inductor reverses and forces current through the diode to the output filter capacitor and load. As the energy stored in the inductor is depleted, the current ramps down and the output diode turns off. The output filter capacitor stores the charge while the inductor current is higher than the output current, then sustains the output voltage until the next switching cycle.

Output Voltage Selection

Referring to Fig.3 and Fig.4, select an output voltage for AP9266 by connecting FB to a resistive divider between the output and GND. The V_{OUT} can be set as:

$$V_{OUT} = (1+R1/R2) \times 1.25V$$

Higher R1, R2 values reduce quiescent current, but give bad noise immunity. To keep stable feedback loop operation and better noise immunity, select (R1+R2) value less than 1MΩ

Compensation

An internal compensation circuit is designed to guarantee stability over the full input/output voltage and median output load range. To increase loop stability at heavy output load, an optional RC compensation network can be added between V_{OUT} and FB, as the R3 and C4 shown in Fig.3. Select R3 and C4 values to meet the equation:

$$\sqrt{L1C2} \approx (R1 + R3) \times C4$$

And keep the R6C4 network frequency value

$$1/(2\pi R3C4),$$

between one third and half of switching frequency, i.e. from 183KHz to 275KHz.

Low-Voltage Start-Up Oscillator

The AP9266 use a CMOS, low-voltage start-up oscillator for a 1.0V guaranteed minimum startup input voltage at +25˚C. On start- up, the low-voltage oscillator switches the N-channel MOSFET until the output voltage reaches 2.2V. Above this level, the normal boost-converter feedback and control circuitry take over. Once the device is in regulation, it can operate down to a 0.8V input since internal power for the IC is bootstrapped from the output voltage. Do not apply full load until the output exceeds 2.4V.

Soft Start

The AP9266 has internal soft start circuit that limits current draw at startup, reducing transients on the input source. Soft-start is particularly useful for higher impedance input sources, such as Li+ and alkaline cells. When power is applied to the device, the soft start circuit first pumps up the output voltage to approximately 2.2 V at a fixed duty cycle. This is the voltage level at which the controller can operate normally. In addition to that, the start up capability with heavy loads is also improved.

Shutdown

The AP9266 enters shutdown to reduce quiescent current to typically 0.1μA when EN pin is low. For normal operation, drive EN high or connect EN to V_{out}. During shutdown, the reference, low-battery comparator, gain block, and all feedback and control circuitry are off. The boost converter's output drops to one Schottky diode voltage drop below the input voltage and LX remains high impedance. The capacitance and load at V_{OUT} determine the rate at which V_{OUT} decays. Shutdown can be pulled as high as 6V, regardless of the voltage at V_{OUT}.

Application Information

Inductor Selection

The AP9266 is designed to work well with a 4.7μH to 10μH inductor in most applications. Low inductance values supply higher output current, butalso increase the ripple and reduce efficiency. Higher inductor values reduce ripple and improve efficiency, but also limit output current. Choose a low DC-resistance inductor, usually less than 1Ω to minimize loss. It is necessary to choose an inductor with saturation current greater than the peak current that the inductor will encounter in the application. Saturation occurs when the inductor's magnetic flux density reaches the maximum level the core can support and inductance falls.

Capacitor Selection

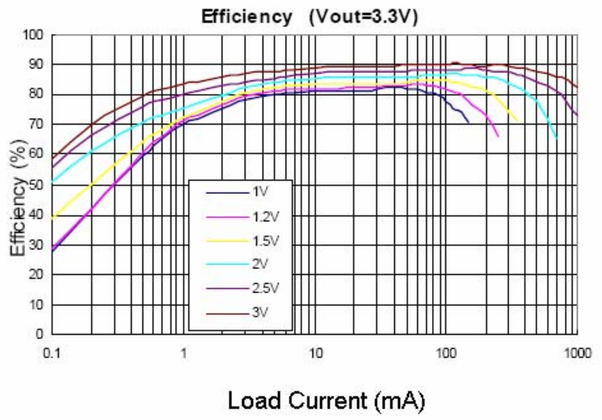
Use a 47uF to 100uF SMT tantalum output capacitor with about 50mΩ to 150mΩ equivalent series resistance (ESR) to provide stable switching while minimizing output ripple. Smaller capacitors are acceptable for light loads or in applications that can tolerate higher output ripple. The input capacitor reduces peak currents and noise at the voltage source. Input capacitors must meet the input ripple requirements and voltage rating. The ESR of both input and output capacitors affects efficiency and output ripple. Output voltage ripple is the product of the peak inductor current and the output capacitor ESR. Use low ESR capacitors for best performance, or connect two or more output capacitors in parallel.

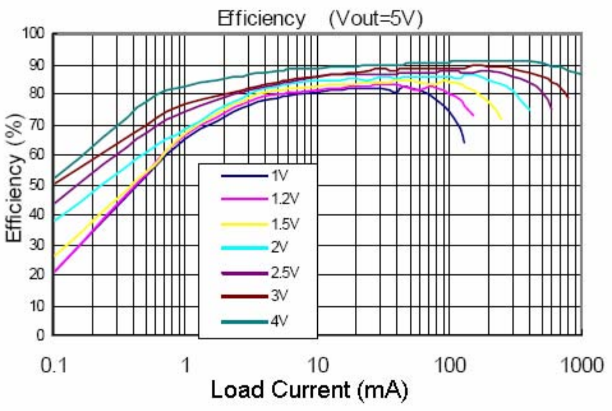
Layout Considerations

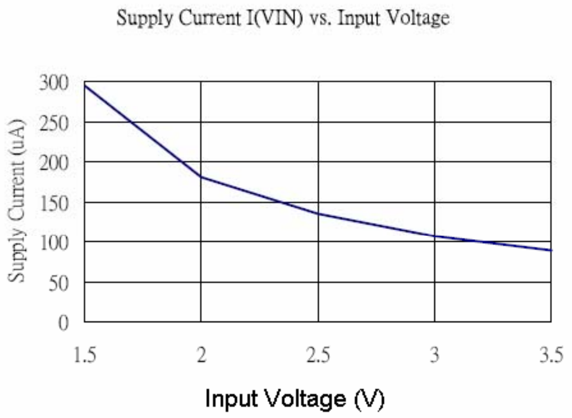
High switching frequencies make PC board layout a very important part of design. Good design minimizes excessive EMI on the feedback paths and voltage gradients in the ground plane, both of which can result in instability or regulation errors. Connect the inductor, input filter capacitor, and output filter capacitor as close to the device as possible, and keep their traces short, direct, and wide to reduce power loss so as to improve efficiency. Connect their ground pins at a single common node in a star ground configuration, or at a full ground plane. The external voltage feedback network should be very close to the FB pin, within 5mm. Keep noisy traces, such as the LX trace, away from the voltage feedback network; also keep them separate, using grounded copper. The output capacitor should be placed close to the output terminals to obtain better smoothing effect on the output ripple. A 1μF bypass capacitor (Fig. 3 & 4) should be placed close to the VOUT pin and GND pin of the AP9266 to filter the switching spikes in the output voltage to provide more stability.

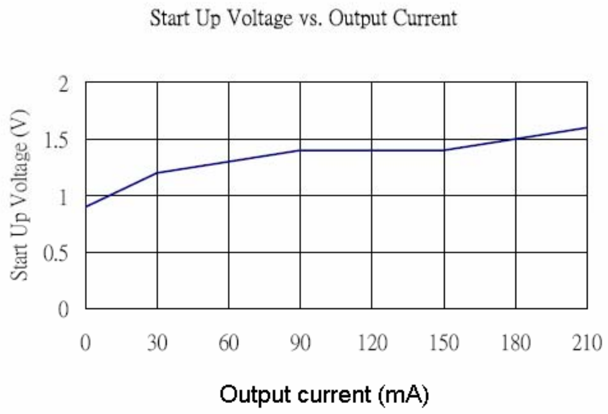
Typical Operating Characteristic

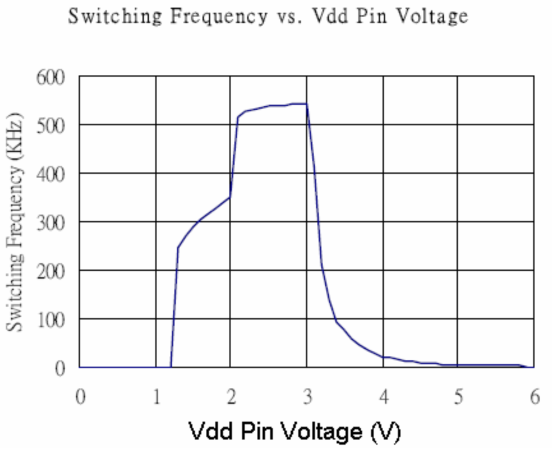
(V_{OUT}=3.3V, L1=10μH, C_{OUT}=100μF, T_A=+25℃, unless otherwise noted.)

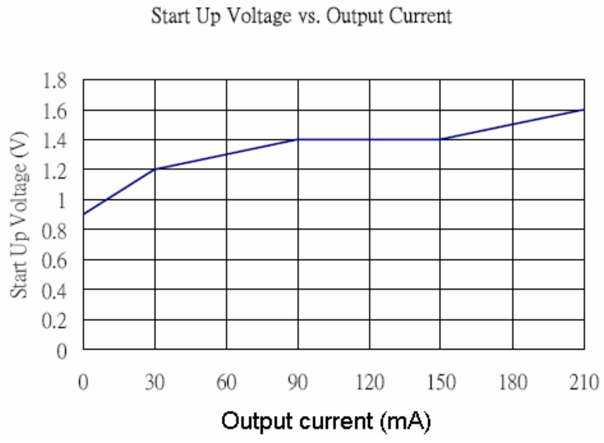

Efficiency (Vout=3.3V)


Efficiency (Vout=5V)

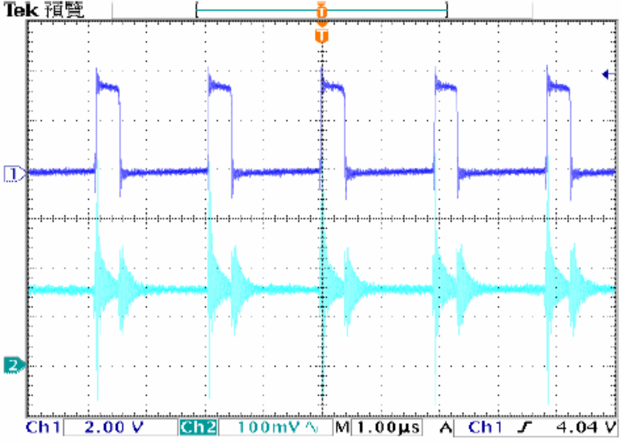

Supply Current I(VIN) vs. Input Voltage


Start Up Voltage vs. Output Current

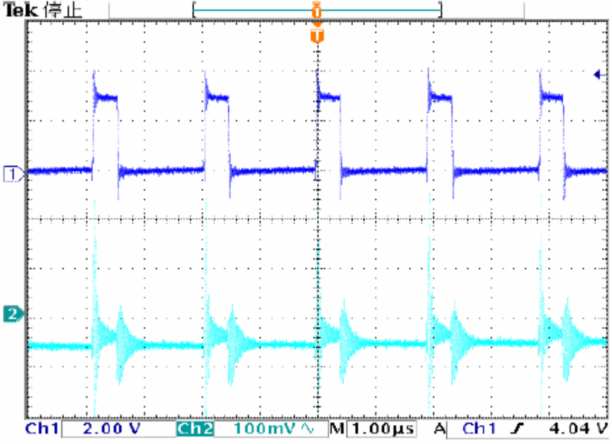

Switching Frequency vs. Vdd Pin Voltage


Start Up Voltage vs. Output Current

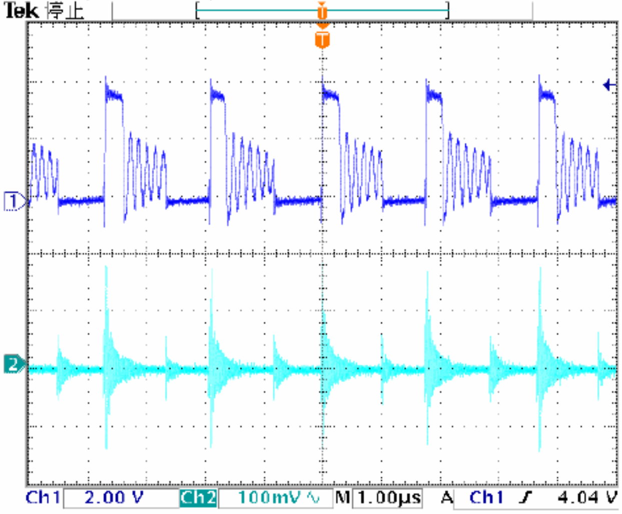
LX& Output Ripple
Vin=1V,Vout=3.3V



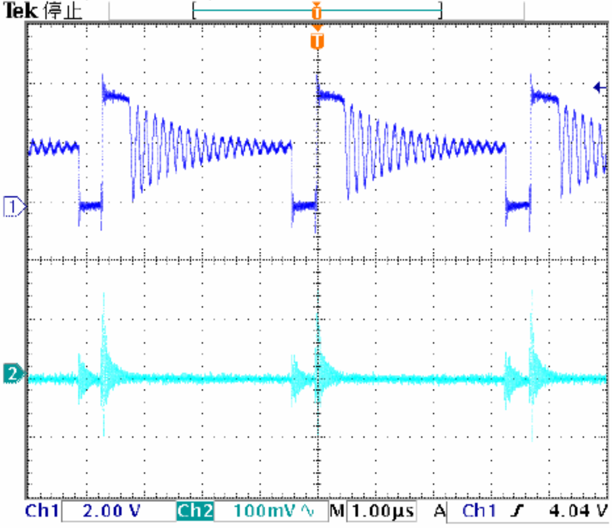
LX& Output Ripple
Vin=2V,Vout=3.3V



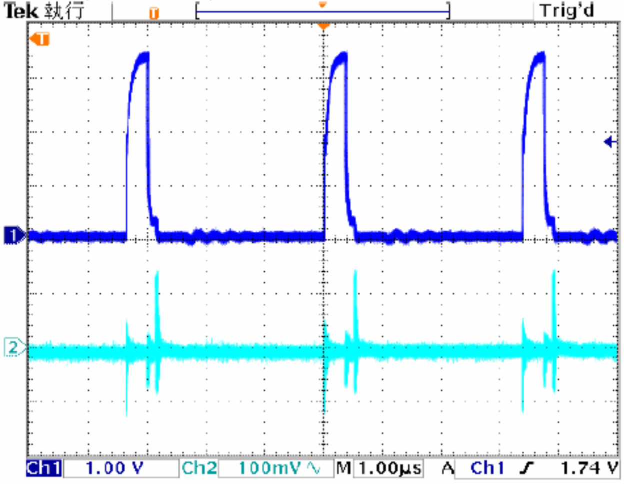
LX& Output Ripple
Vin=1V,Vout=3.3V,Iout=10mA



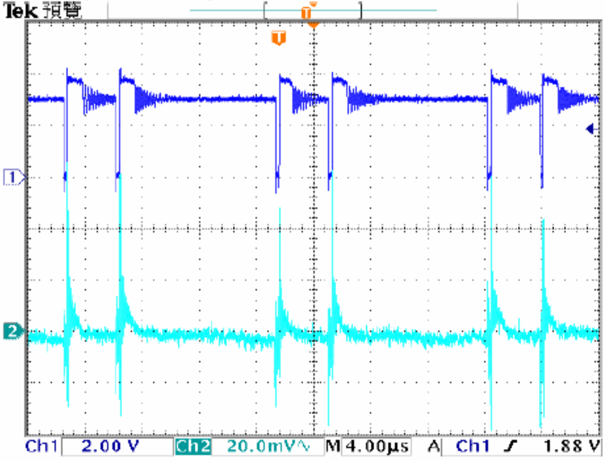
LX& Output Ripple
Vin=2V,Vout=3.3V,Iout=10mA



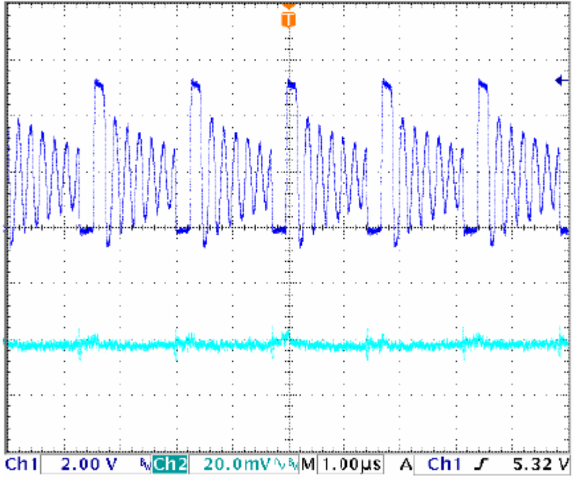
LX& Output Ripple
Vin=2V,Vout=3.3V,Iout=10mA



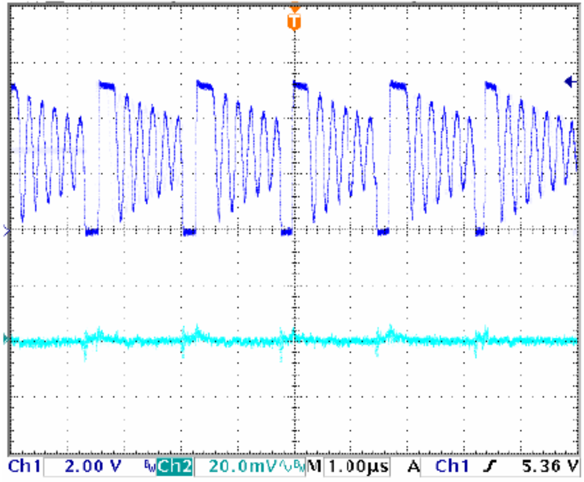
LX& Output Ripple
Vin=3V,Vout=3.3V,Iout=10mA



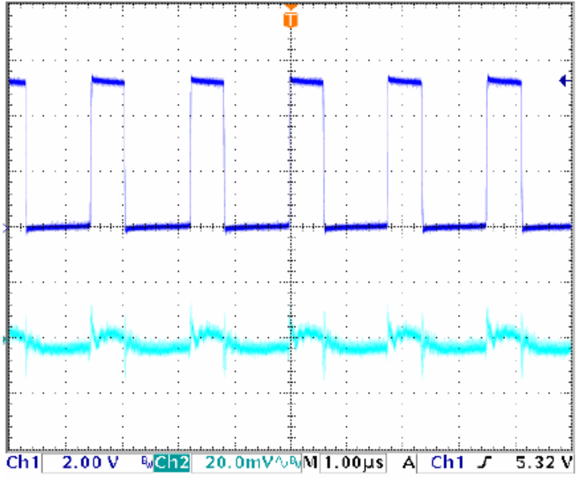
LX& Output Ripple
Vin=2V,Vout=5V



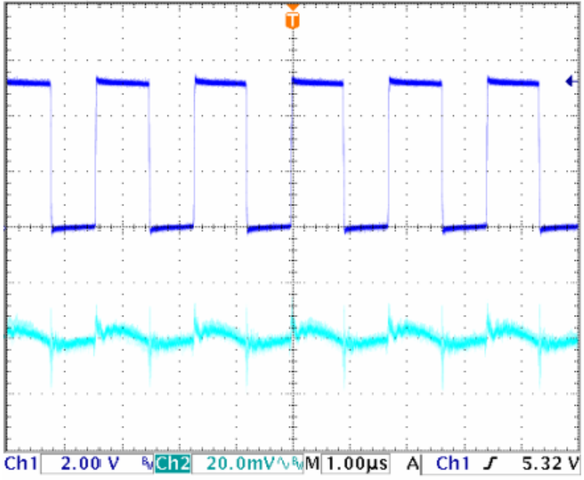
LX& Output Ripple
Vin=3V,Vout=5V



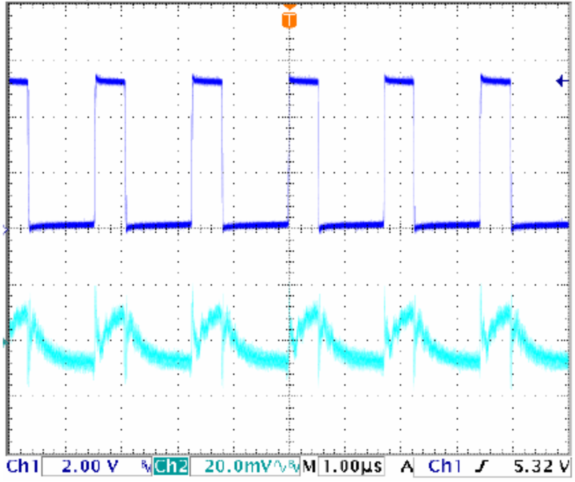
LX& Output Ripple
Vin=2V,Vout=5V Iout=100mA



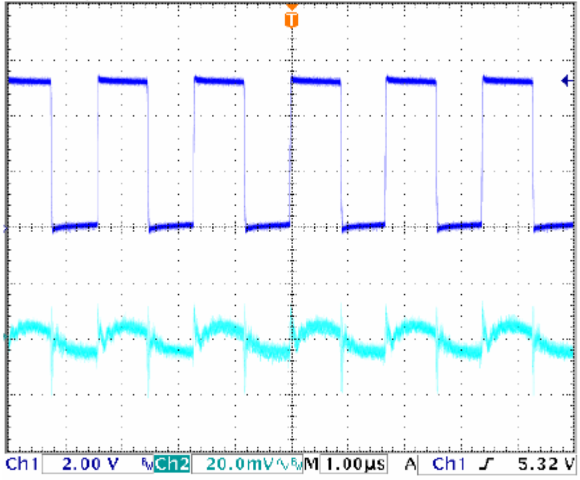
LX& Output Ripple
Vin=3V,Vout=5V Iout=100mA

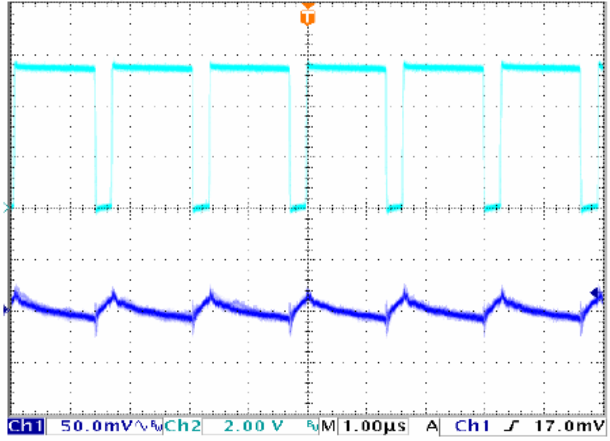


LX& Output Ripple
Vin=2V,Vout=5V Iout=200mA

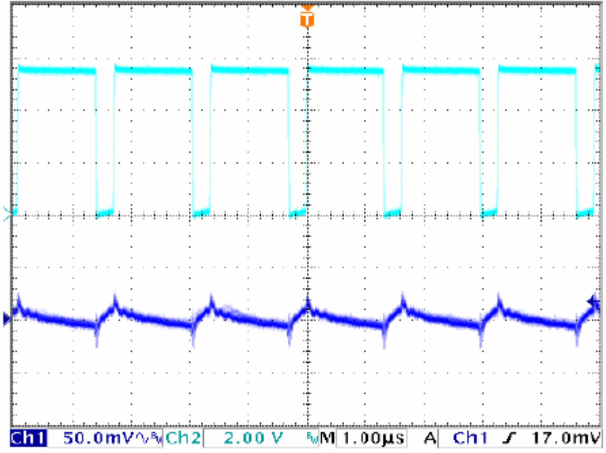


LX& Output Ripple
Vin=3V,Vout=5V Iout=200mA

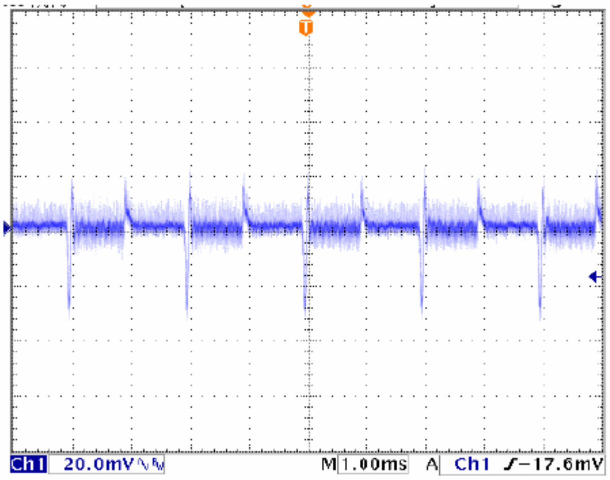




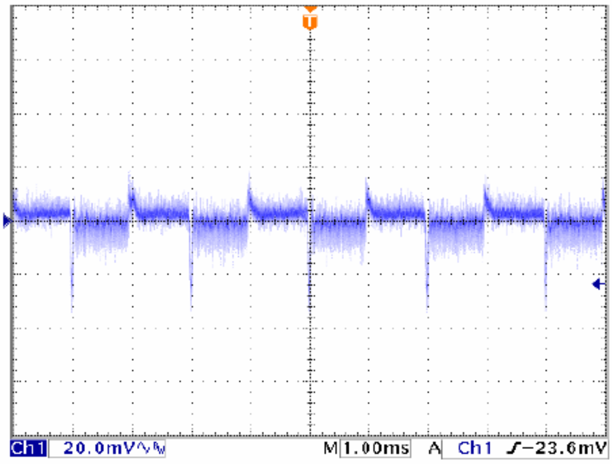
LX& Output Ripple
Vin=4.5V,Vout=5V Iout=100mA



LX& Output Ripple
Vin=4.5V,Vout=5V Iout=100mA



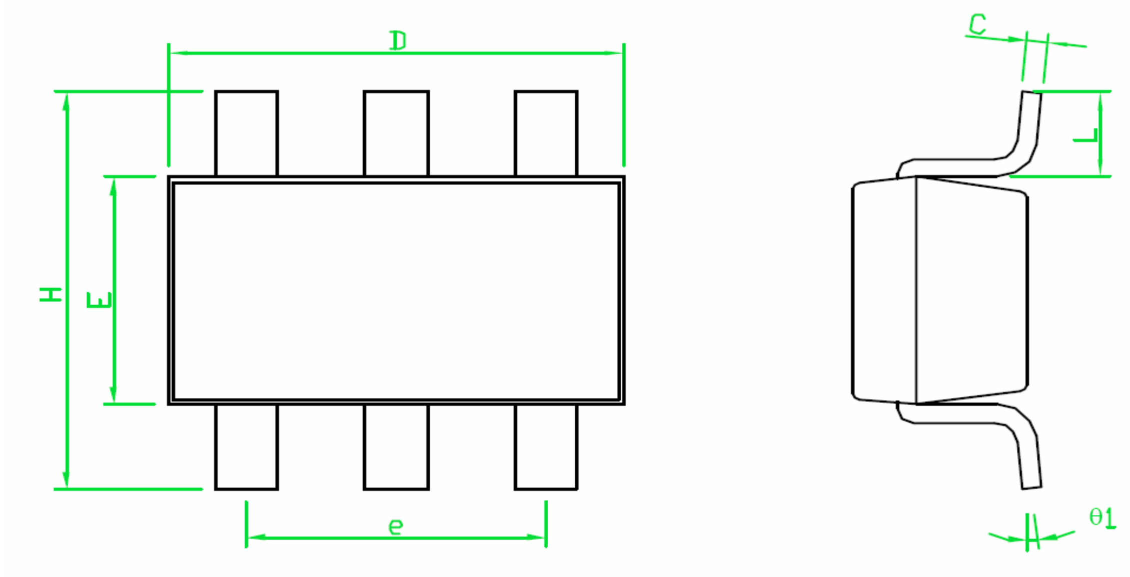
Transient Response
Vin=3V,Vout=3.3V
Iout=10mA → 200mA

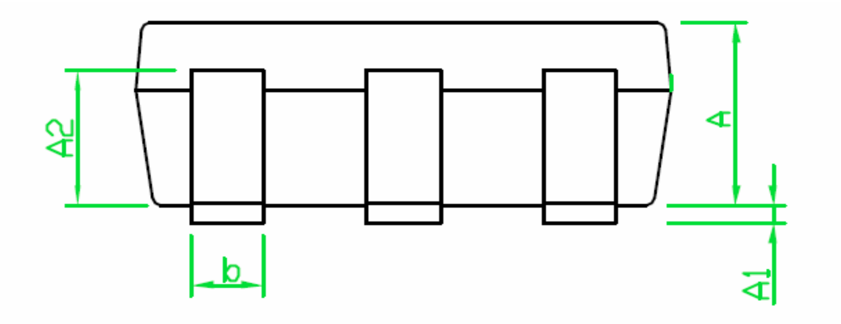


Transient Response
Vin=4.5V,Vout=5V
Iout=10mA → 200mA

Package Outline

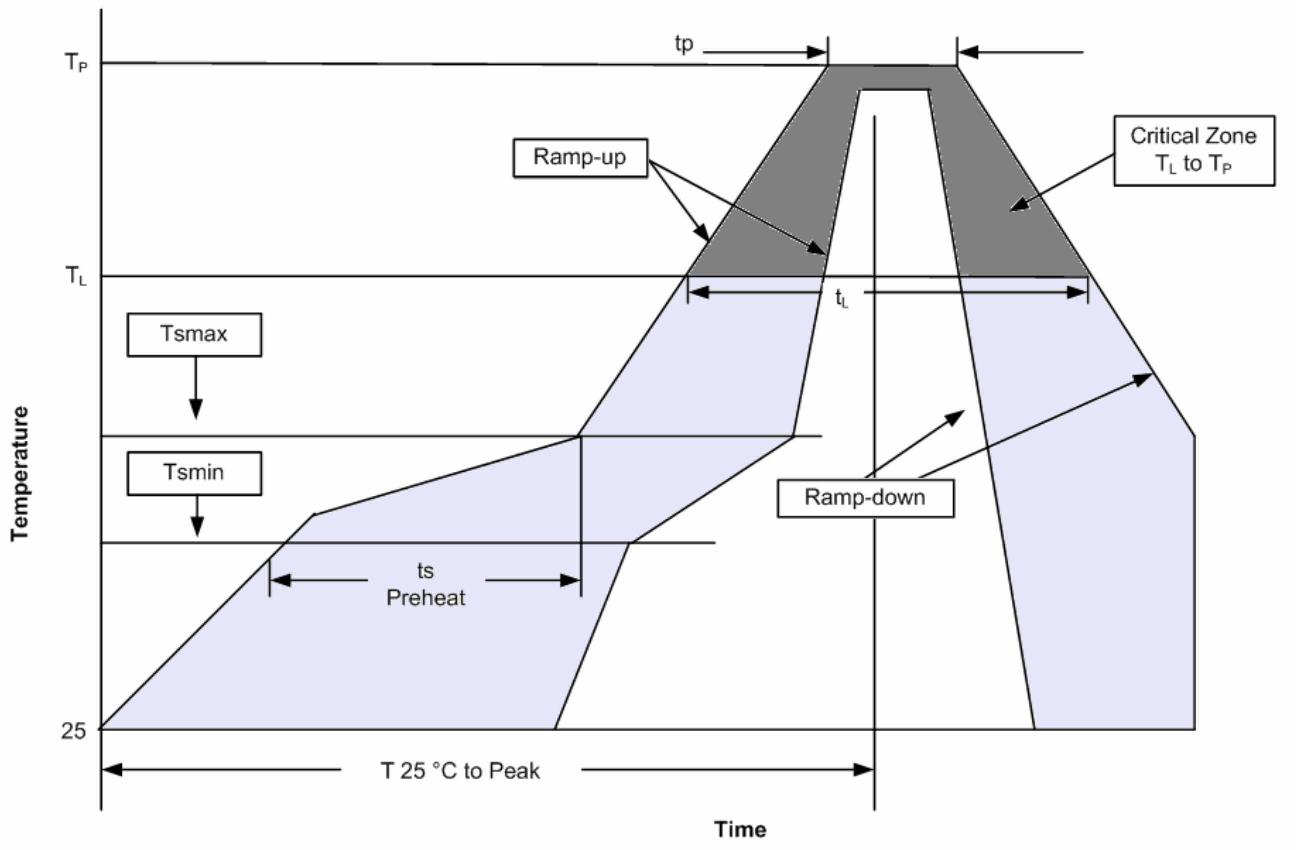
A) SOT-23-6





SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	1.00	1.10	1.30
A1	0.00	–––	0.10
A2	0.70	0.80	0.90
b	0.35	0.40	0.50
C	0.10	0.15	0.25
D	2.70	2.90	3.10
E	1.40	1.60	1.80
e	–––	1.90(TYP)	–––
H	2.60	2.80	3.00
L	0.37	–––	–––
θ1	1°	5°	9°

Reflow Condition (IR/Convection or VPR Reflow)



Classification Reflow Profiles

Profile Feature	Pb-Free / Green Assembly
Average ramp-up rate (T_L to T_P)	3°C/second max
Preheat - Temperature Min (Tsmin) - Temperature Max (Tsmax) - Time (min to max) (ts)	150°C 200°C 60-180 seconds
Time maintained above: - Temperature (T_L) - Time (t_L)	217°C 60-150 seconds
Peak/Classification Temperature (Tp)	See table 1
Time within 5°C of actual Peak Temperature (tp)	20-40 seconds
Ramp-down Rate	6°C/second max
Time 25°C to Peak Temperature	8 minutes max

Notes：
1) All temperatures refer to topside of the package.
2) Measured on the body surface.

Table 2. Pb-free / Green Process – Package Classification Reflow Temperatures

Package Thickness	**Volume mm³ <350**	**Volume mm³ 350~2000**	**Volume mm³ ≧2000**
<2.5 mm	260 +0°C*	260 +0°C*	260 +0°C*
1.6-2.5 mm	260 +0°C*	250 +0°C*	245 +0°C*
≧2.5 mm	250 +0°C*	245 +0°C*	245 +0°C*

Notes：

* Tolerance: The device manufacturer/supplier shall assure process compatibility up to and including the stated classification temperature (this means Peak reflow temperature +0°C. For example 260°C+0°C) at the rated MSL level.