# 100mA REGULATED CHARGE PUMP AP3602A/B

## General Description

The AP3602A/B are regulated step-up DC/DC converters based on charge pump technique. These ICs have the ability to supply 100mA constant output current or 250mA peak output current for 100ms from 3.0V to 5V input (2.7V to 4.5 V for AP3602B), so they can be used as white LEDs driver or flash LED driver.

The AP3602A/B have very low power dissipation and high efficiency in typical applications. Other features include over-temperature protection, low temperature coefficient and etc. to meet some special requirements of hand-held battery powered devices.

Only 3 external capacitors are required in applications, which helps to save space and lower cost. These chips also have a disable terminal to turn on or turn off the chip to ease the use.

The AP3602A/B are available in SOT-23-6 package.

## Features

- Low Quiescent Current: 13μA Typical
- Regulated Output Voltage Precision: 4%
- High Output Current:
  100mA when $V_{IN}$≥3.0V
  50mA when $V_{IN}$≥2.7V
- High Frequency: up to 1.2 MHz
- Low Shutdown Supply Current: <1μA
- High Output Peak Current: 250mA for 100ms
- Over Temperature Protection
- Operating Temperature Range: -40°C to 85°C

## Applications

- Mobile Phone Backlight Driver
- Camera Flash LED Driver
- MP3, MP4
- Handheld Device
- Portable Communication Device

SOT-23-6

Figure 1. Package Type of AP3602A/B

## Pin Configuration

K Package
(SOT-23-6)

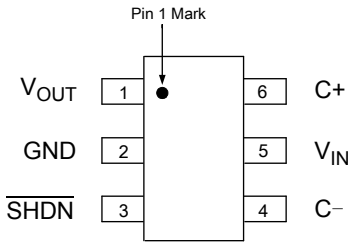



Figure 2. Pin Configuration of AP3602A/B (Top View)

## Pin Description

| Pin Number | Pin Name | Function |
|---|---|---|
| 1 | $V_{OUT}$ | Regulated Output Voltage. $V_{OUT}$ should be bypassed with a 1μF to 22μF low ESR ceramic capacitor which is placed as close to the pin as possible for best performance |
| 2 | GND | Ground. GND should be tied to a ground plane for best performance. The $C_{OUT}$ and $C_{IN}$ should be placed as close to this pin as possible |
| 3 | $\overline{SHDN}$ | Active Low Shutdown Input. A low signal on $\overline{SHDN}$ disables the AP3602A/B, while a high signal enables the AP3602A/B. $\overline{SHDN}$ pin must not be allowed to float |
| 4 | C- | Flying Capacitor Negative Terminal. The flying capacitor should be placed as close to this pin as possible |
| 5 | $V_{IN}$ | Input Supply Voltage. $V_{IN}$ should be bypassed with a 1μF to 22μF low ESR ceramic capacitor which is placed as close to the pin as possible for best performance |
| 6 | C+ | Flying Capacitor Positive Terminal. The flying capacitor should be placed as close to this pin as possible |

## Functional Block Diagram

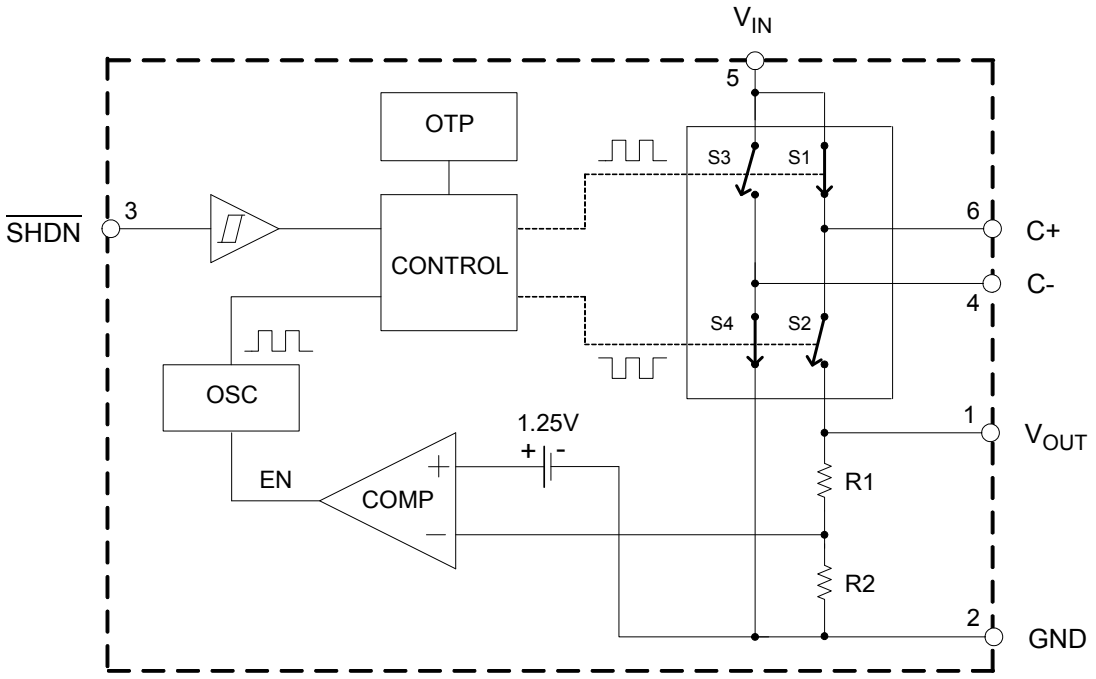
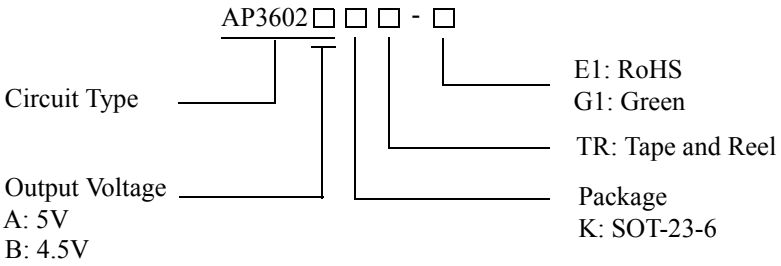



Figure 3. Functional Block Diagram of AP3602A/B

## Ordering Information




| Package | Temperature Range | Part Number | | Marking ID | | Packing Type |
|---|---|---|---|---|---|---|
| | | RoHS | Green | RoHS | Green | |
| SOT-23-6 | -40 to 85°C | AP3602AKTR-E1 | AP3602AKTR-G1 | E7T | G7T | Tape & Reel |
| | | AP3602BKTR-E1 | AP3602BKTR-G1 | E8T | G8T | Tape & Reel |

BCD Semiconductor's products as designated with "E1" suffix in the part number are RoHS compliant. Products with "G1" suffix are available in green packages.

## Absolute Maximum Ratings (Note 1)

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage | $V_{IN}$ | 7 | V |
| Output Voltage | $V_O$ | 7 | V |
| $\overline{SHDN}$ Pin Voltage | $V_{\overline{SHDN}}$ | 7 | V |
| Thermal Resistance (Junction to Ambient, no Heat sink) | $R_{\theta JA}$ | 300 | °C/W |
| Operating Junction Temperature | $T_J$ | 150 | °C |
| Storage Temperature Range | $T_{STG}$ | -65 to 150 | °C |
| Lead Temperature (Soldering, 10sec) | $T_{LEAD}$ | 260 | °C |
| ESD (Human Body Model) | | 2000 | V |

Note 1: Stresses greater than 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 Ratings" for extended periods may affect device reliability.

## Recommended Operating Conditions

| Parameter | Symbol | | Min | Max | Unit |
|---|---|---|---|---|---|
| Input Voltage | $V_{IN}$ | AP3602A | 2.7 | 5 | V |
| | | AP3602B | 2.7 | 4.5 | |
| Operating Temperature | $T_A$ | | -40 | 85 | °C |

## Electrical Characteristics

($C_{FLY}$=1μF, $C_{IN}$=$C_{OUT}$=10μF, $T_A$=25°C, unless otherwise specified.)

### For AP3602A

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage | $V_{IN}$ | $V_O$=5V | 2.7 | | $V_O$ | V |
| Quiescent Current | $I_Q$ | $V_{IN}$=2.7V to 5.0V, $I_O$=0mA, $V_{\overline{SHDN}}$ =$V_{IN}$, Not Switching | | 13 | 30 | μA |
| Output Voltage | $V_O$ | 2.7V<$V_{IN}$<5V, $I_O$≤50mA | 4.8 | 5.0 | 5.2 | V |
| | | 3.0V<$V_{IN}$<5V, $I_O$≤100mA | 4.8 | 5.0 | 5.2 | |
| Shutdown Supply Current | $I_{\overline{SHDN}}$ | 2.7V<$V_{IN}$<3.6V, $I_O$=0, $V_{\overline{SHDN}}$ =0V | | 0.01 | 1 | μA |
| | | 3.6V<$V_{IN}$<5.0V, $I_O$=0, $V_{\overline{SHDN}}$ =0V | | | 2.5 | |
| Ripple Voltage | $V_{RIPPLE}$ | $V_{IN}$=2.7V, $I_O$=50mA | | 25 | | $mV_{PP}$ |
| | | $V_{IN}$=3V, $I_O$=100mA | | 30 | | |
| Efficiency | η | $V_{IN}$=2.7V, $I_O$=50mA | | 92 | | % |
| Frequency | $f_{OSC}$ | Oscillator free running | | 1.2 | | MHz |
| $\overline{SHDN}$ Input Threshold High | $V_{IH}$ | | 1.4 | | | V |
| $\overline{SHDN}$ Input Threshold Low | $V_{IL}$ | | | | 0.3 | |
| $\overline{SHDN}$ Input Current High | $I_{IH}$ | $V_{\overline{SHDN}}$ =$V_{IN}$ | -1 | | 1 | μA |
| $\overline{SHDN}$ Input Current Low | $I_{IL}$ | $V_{\overline{SHDN}}$ =GND | -1 | | 1 | |
| $V_{OUT}$ Turn-on Time | $t_{ON}$ | $V_{IN}$=3V, $I_O$=0mA | | 0.2 | | ms |
| Short-Circuit Current | $I_{SC}$ | $V_{IN}$=3V, $V_O$=GND, $V_{\overline{SHDN}}$ =3V | | 300 | | mA |

## Electrical Characteristics (Continued)

($C_{FLY}$=1μF, $C_{IN}$=$C_{OUT}$=10μF, $T_A$=25°C, unless otherwise specified.)

### For AP3602B

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage | $V_{IN}$ | $V_O$=4.5V | 2.7 | | $V_O$ | V |
| Quiescent Current | $I_Q$ | $V_{IN}$=2.7V to 4.5V, $I_O$=0mA, $V_{\overline{SHDN}}$ =$V_{IN}$, Not Switching | | 13 | 30 | μA |
| Output Voltage | $V_O$ | 2.7V<$V_{IN}$<4.5V, $I_O$<50mA | 4.32 | 4.5 | 4.68 | V |
| | | 3.0V<$V_{IN}$<4.5V, $I_O$<100mA | 4.32 | 4.5 | 4.68 | |
| Shutdown Supply Current | $I_{\overline{SHDN}}$ | 2.7V<$V_{IN}$<3.6V, $I_O$=0, $V_{\overline{SHDN}}$ =0V | | 0.01 | 1 | μA |
| | | 3.6V<$V_{IN}$<4.5V, $I_O$=0, $V_{\overline{SHDN}}$ =0V | | | 2.5 | |
| Ripple Voltage | $V_{RIPPLE}$ | $V_{IN}$=2.7V, $I_O$=50mA | | 25 | | $mV_{PP}$ |
| | | $V_{IN}$=3V, $I_O$=100mA | | 30 | | |
| Efficiency | η | $V_{IN}$=2.7V, $I_O$=50mA | | 83 | | % |
| Frequency | $f_{OSC}$ | Oscillator free running | | 1.2 | | MHz |
| $\overline{SHDN}$ Input Threshold High | $V_{IH}$ | | 1.4 | | | V |
| $\overline{SHDN}$ Input Threshold Low | $V_{IL}$ | | | | 0.3 | |
| $\overline{SHDN}$ Input Current High | $I_{IH}$ | $V_{\overline{SHDN}}$ =$V_{IN}$ | -1 | | 1 | μA |
| $\overline{SHDN}$ Input Current Low | $I_{IL}$ | $V_{\overline{SHDN}}$ =0V | -1 | | 1 | |
| $V_{OUT}$ Turn-on Time | $t_{ON}$ | $V_{IN}$=3V, $I_O$=0mA | | 0.2 | | ms |
| Short-Circuit Current | $I_{SC}$ | $V_{IN}$=3V, $V_O$=GND, $V_{\overline{SHDN}}$ =3V | | 300 | | mA |

## Application Information

### Operating Principles

The AP3602A/B use a switched capacitor charge pump to boost the input voltage to a regulated output voltage. Regulation is achieved by sensing the chip output voltage through an internal resistor divider network. Controlled by an internal comparator (refer to the functional block diagram), the charge pump circuit is enabled when the divided output voltage is below a preset trip point .

The charge pump operates at 1.2MHz with 50% duty cycle. Conversion consists of a two-phase operation. In the first phase, switches S2 and S3 are opened and S1 and S4 are closed. During this time, $C_{FLY}$ charges to the voltage on $V_{IN}$ and load current is supplied by $C_{OUT}$. During the second phase, S2 and S3 are closed, and S1 and S4 are opened. This action connects $C_{FLY}$ low side to $V_{IN}$, $C_{FLY}$ high side to $V_{OUT}$, then a voltage about $2*V_{IN}$ is used to charge $C_{OUT}$ and supply the load current. For each cycle, charges is transported from $V_{IN}$ to $V_{OUT}$ to maintain the output voltage in its nominal value.

This process breaks when the $V_{OUT}$ is high enough for the reason of higher input voltage or lower load, then the divided voltage at the control comparator exceeds the internal trip point high level, which compels the charge pump circuit enter to the idle mode in which the switching cycle stops (pulse skipping) and the output voltage is continually decreased because it is maintained by the discharging of $C_{OUT}$ only. In idle mode, the feedback circuit continues sensing $V_{OUT}$. If the divided voltage at the control comparator drops below the preset trip point, the comparator will start the switching cycle again.

In idle mode, the AP3602A/B's quiescent current is about 13μA. In shutdown mode, all internal circuitry is turned off and the AP3602A/B draw only leakage current from $V_{IN}$, which is less than 1μA. So, the shutdown power loss for AP3602A/B is very low, that is beneficial to the battery supplied systems.

### Short Circuit and Thermal Protection

The AP3602A/B have a thermal protection and shutdown circuit that continuously monitors the IC junction temperature.

When output short circuit occurs, the short circuit current is about 300mA (Typical). Under this condition, the $I_{IN}$ is about 2*Iout, which causes about 1.8W instant power dissipation on AP3602A/B, that will cause a rise in the internal IC junction temperature. If the thermal protection circuit senses the junction temperature exceeding approximately 160°C, the thermal shutdown circuit will disable the charge pump switching circuit. The thermal hysteresis is about 10°C, which means that the charge pump circuit can be active when the short circuit is removed and the junction temperature drops below 150°C.

The thermal shutdown protection will cycle on and off if an output short circuit condition persists. This will allow the AP3602A/B to operate on a short circuit condition without latch up or damage to the device.

## Typical Performance Characteristics

### Typical Performance Characteristics for AP3602A

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

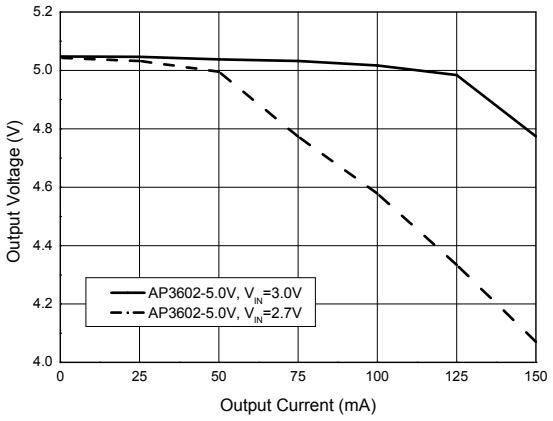



Figure 4. Output Voltage vs. Output Current

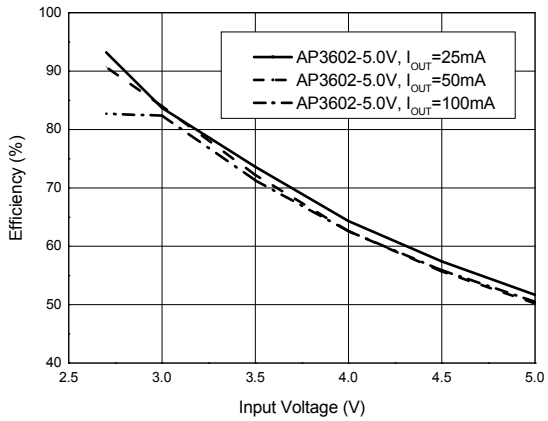



Figure 5. Efficiency vs. Input Voltage

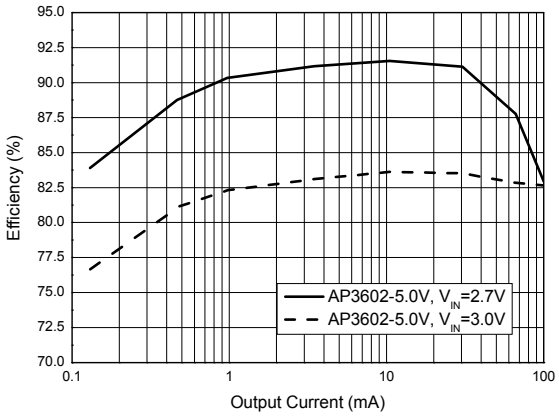



Figure 6. Efficiency vs. Output Current

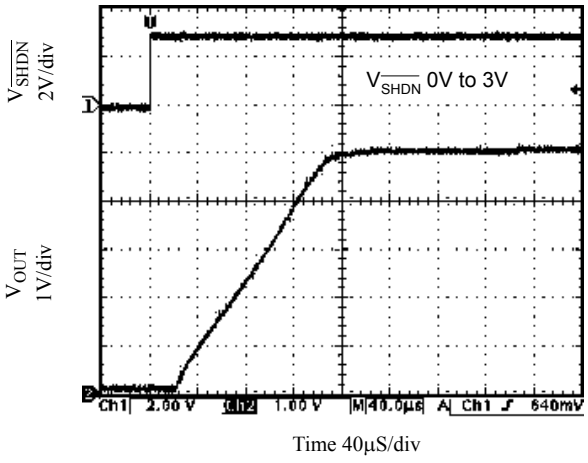



Figure 7. $V_{OUT}$ Start UpTime, @ No Load

## Typical Performance Characteristics (Continued)

### Typical Performance Characteristics for AP3602A (Continued)

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

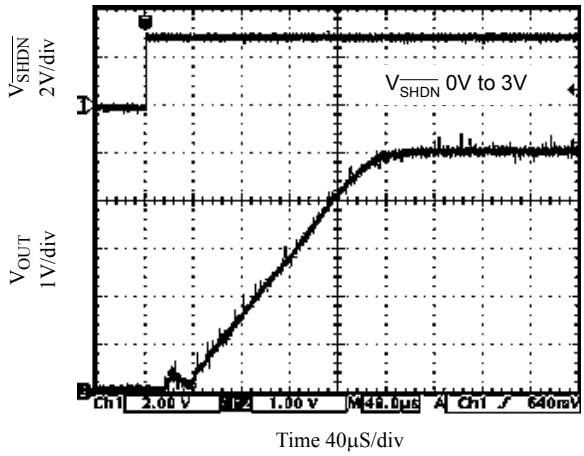



Figure 8. $V_{OUT}$ Start Up Time, @ 50mA Load

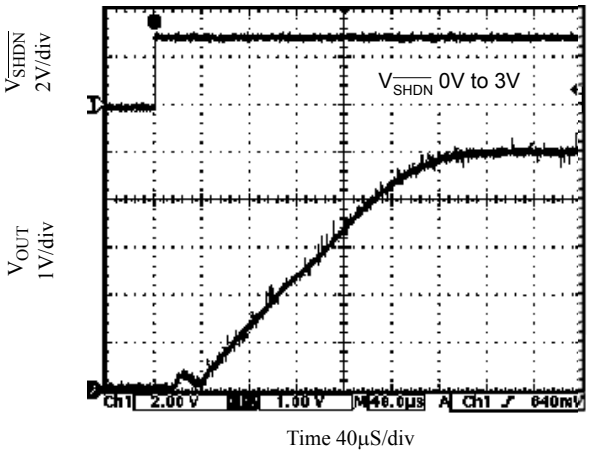



Figure 9. $V_{OUT}$ Start Up Time, @ 100mA Load

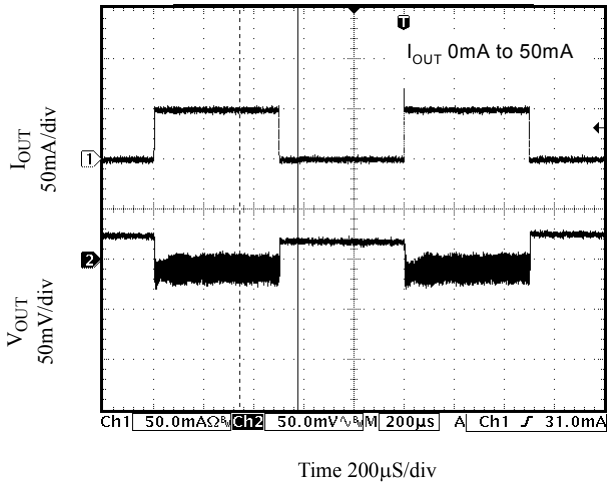



Figure 10. Load Transient Response

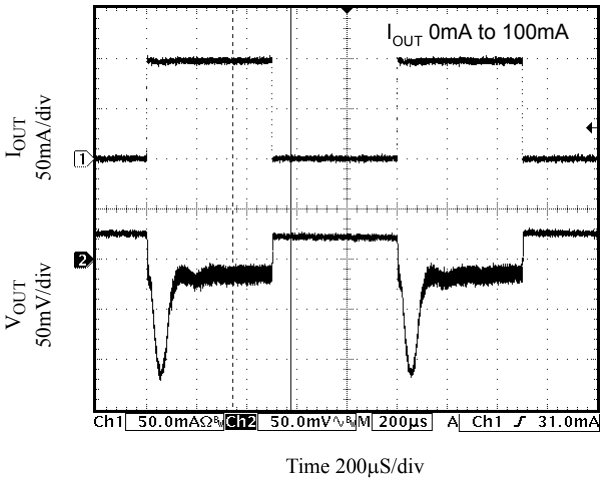



Figure 11. Load Transient Response

## Typical Performance Characteristics (Continued)

### Typical Performance Characteristics for AP3602A (Continued)

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

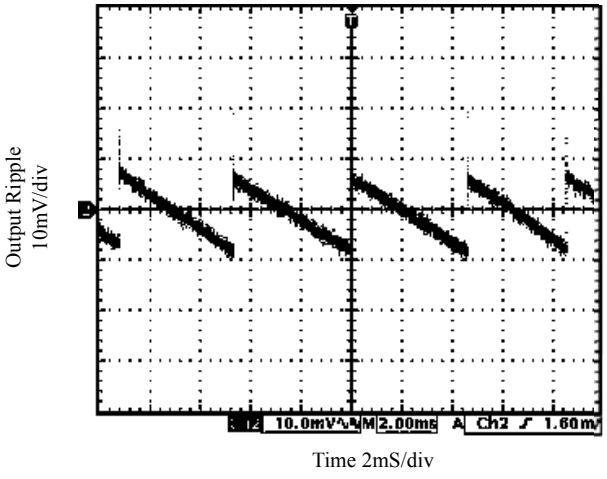



Figure 12. Output Ripple @ $V_{IN}$=2.7V, $I_{OUT}$=0mA

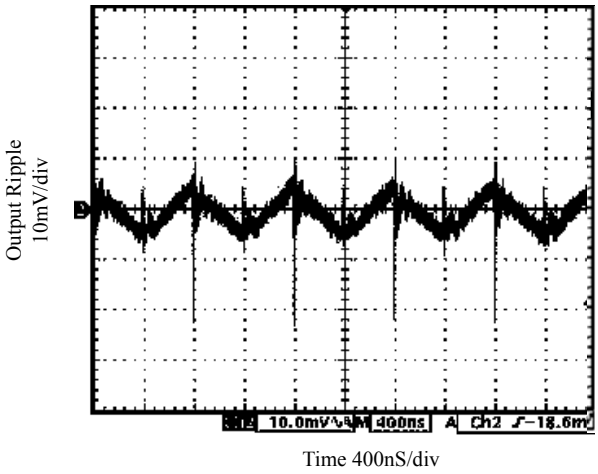



Figure 13. Output Ripple @ $V_{IN}$=2.7V, $I_{OUT}$=50mA

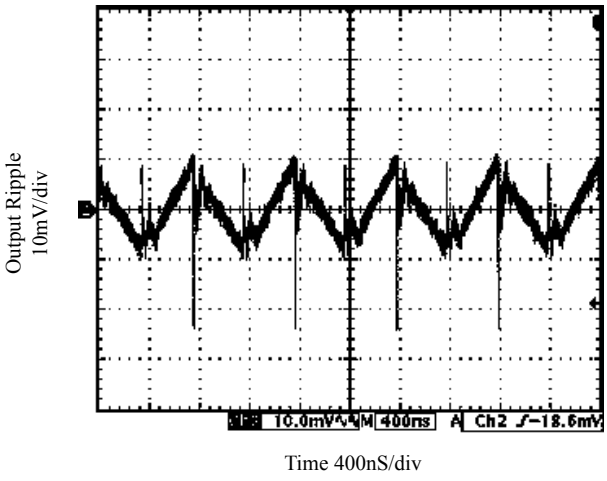



Figure 14. Output Ripple @ $V_{IN}$=2.7V, $I_{OUT}$=100mA

## Typical Performance Characteristics (Continued)

### Typical Performance Characteristics for AP3602B

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

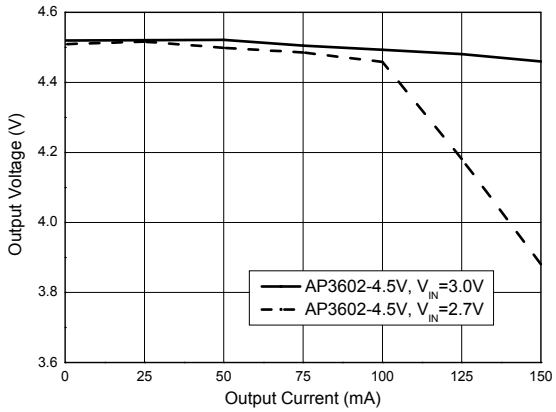



Figure 15. Output Voltage vs. Output Current

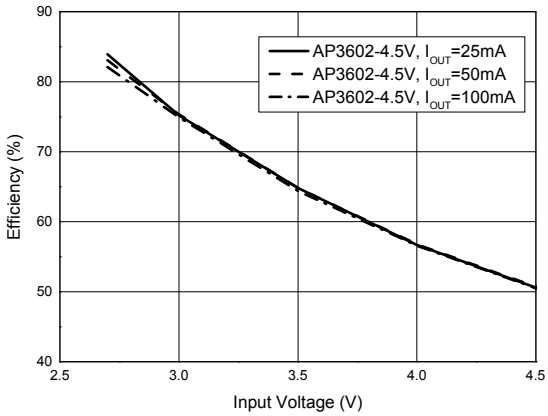



Figure 16. Efficiency vs. Input Voltage

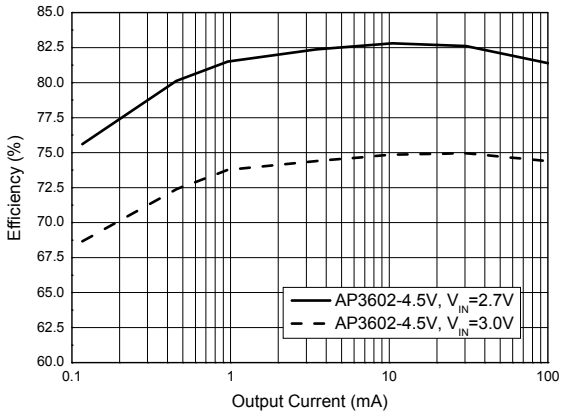



Figure 17. Efficiency vs. Output Current

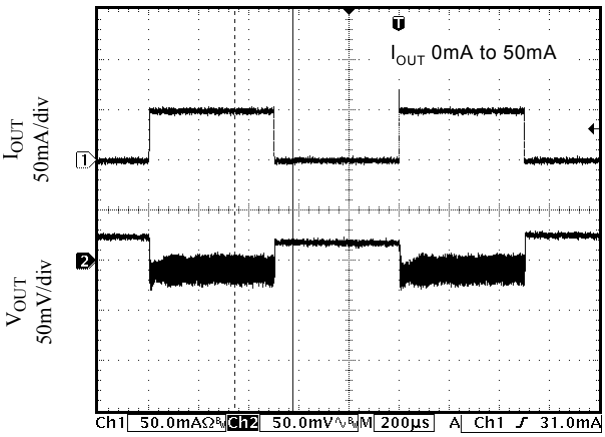



Figure 18. Load Transient Response

## Typical Performance Characteristics (Continued)

### Typical Performance Characteristics for AP3602B (Continued)

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

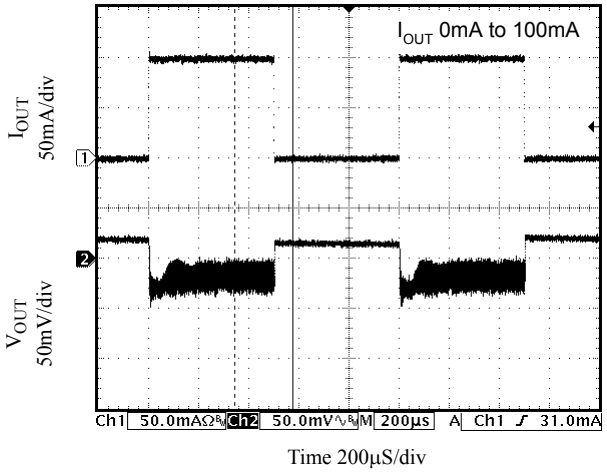



Figure 19. Load Transient Response

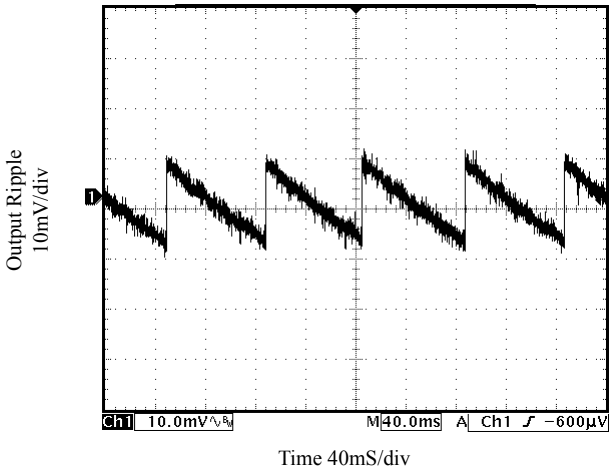



Figure 20. Output Ripple @ $V_{IN}$=2.7V, $I_{OUT}$=0mA

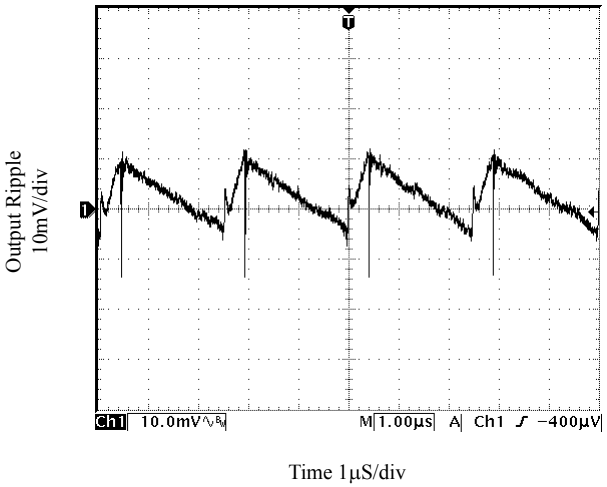



Figure 21. Output Ripple @ $V_{IN}$=2.7V, $I_{OUT}$=50mA

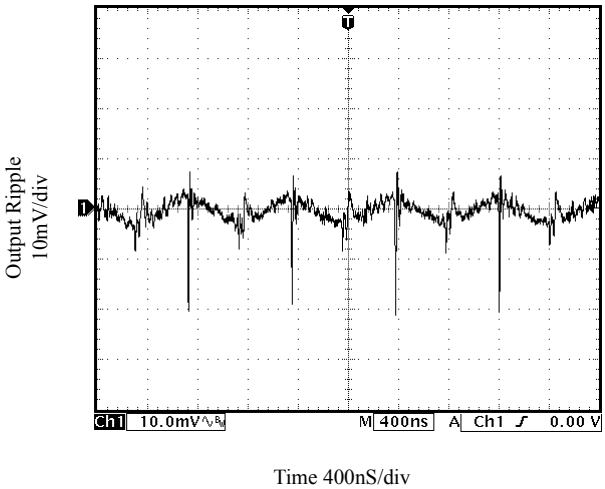



Figure 22. Output Ripple @ $V_{IN}$=2.7V, $I_{OUT}$=100mA

## Typical Performance Characteristics (Continued)

### Typical Performance Characteristics for AP3602A/B

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

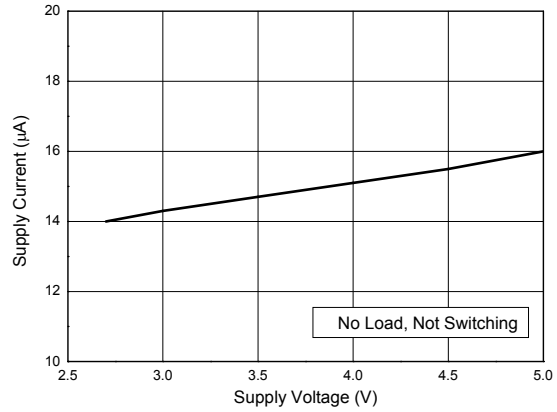



Figure 23. Supply Current vs. Supply Voltage

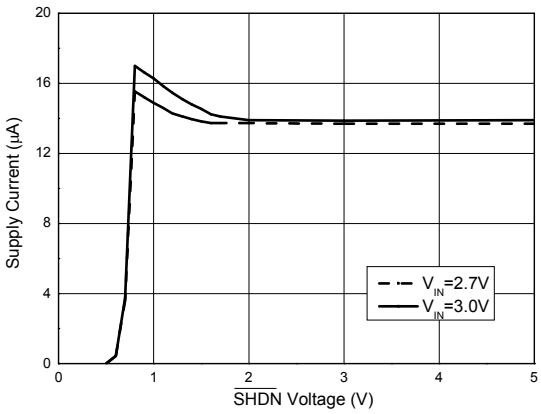



Figure 24. Supply Current vs. $\overline{SHDN}$ Voltage

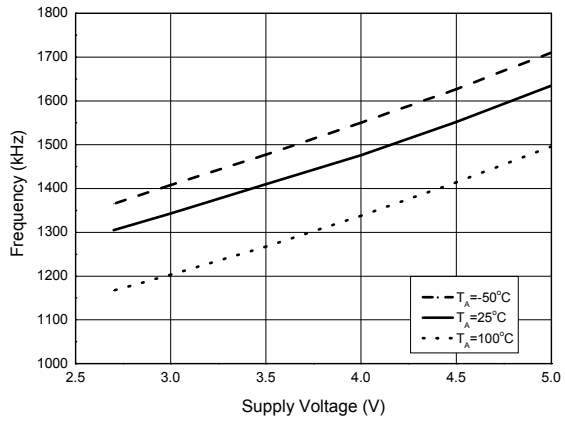



Figure 25. Oscillator Frequency vs. Supply Voltage

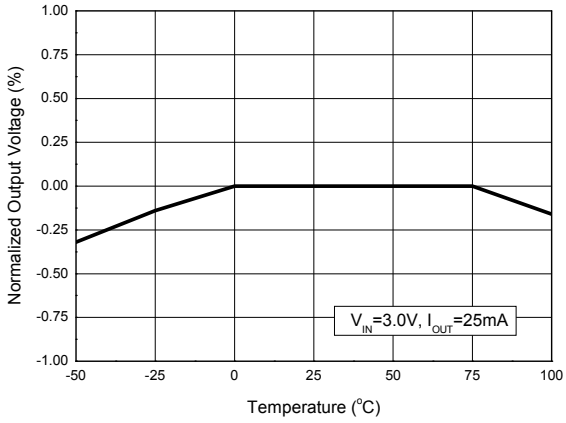



Figure 26. Normalized Output Voltage vs. Temperature

## Typical Performance Characteristics (Continued)

### Typical Performance Characteristics for AP3602A/B (Continued)

(Unless otherwise noted, $V_{IN}$=3.0V, $C_{IN}$=$C_{OUT}$=10μF, $C_{FLY}$=1μF Ceramic Cap, $T_A$=25°C)

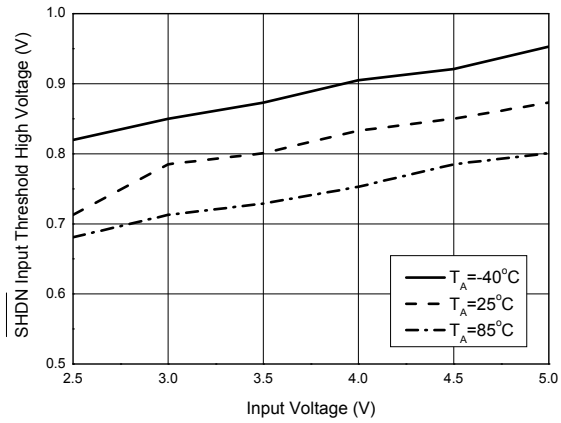



Figure 27. $V_{IH}$ vs. $V_{IN}$

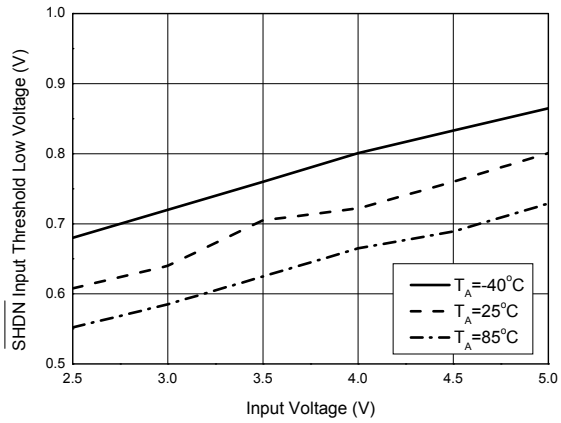



Figure 28. $V_{IL}$ vs. $V_{IN}$

## Typical Application

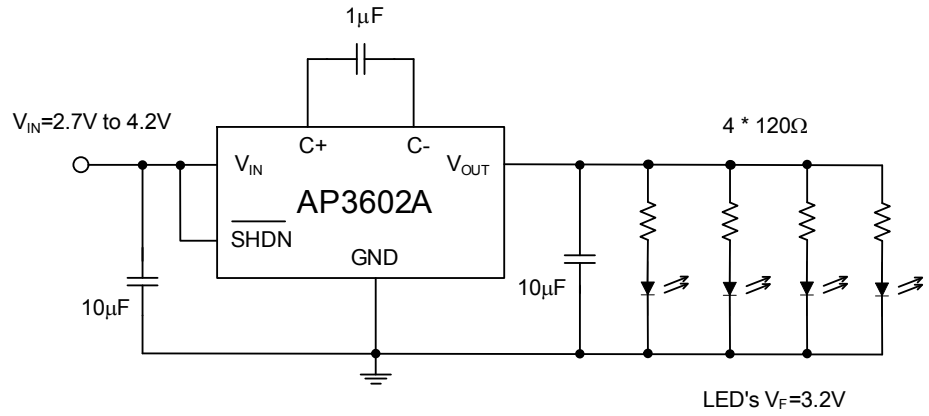



Figure 29. AP3602A Typical Application Circuit

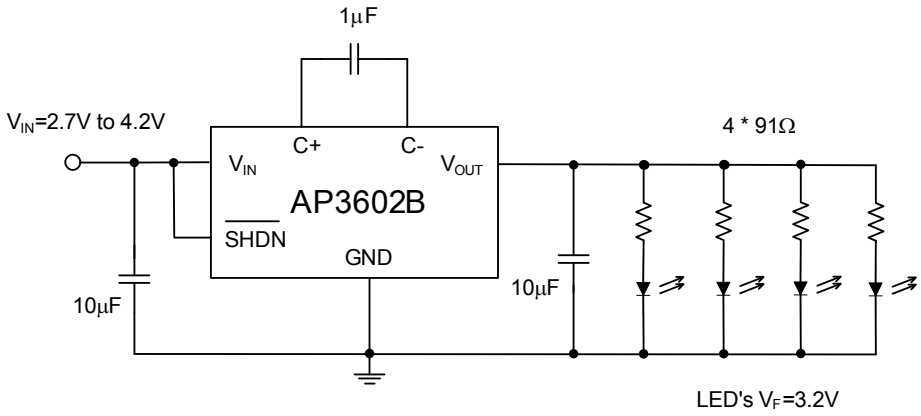
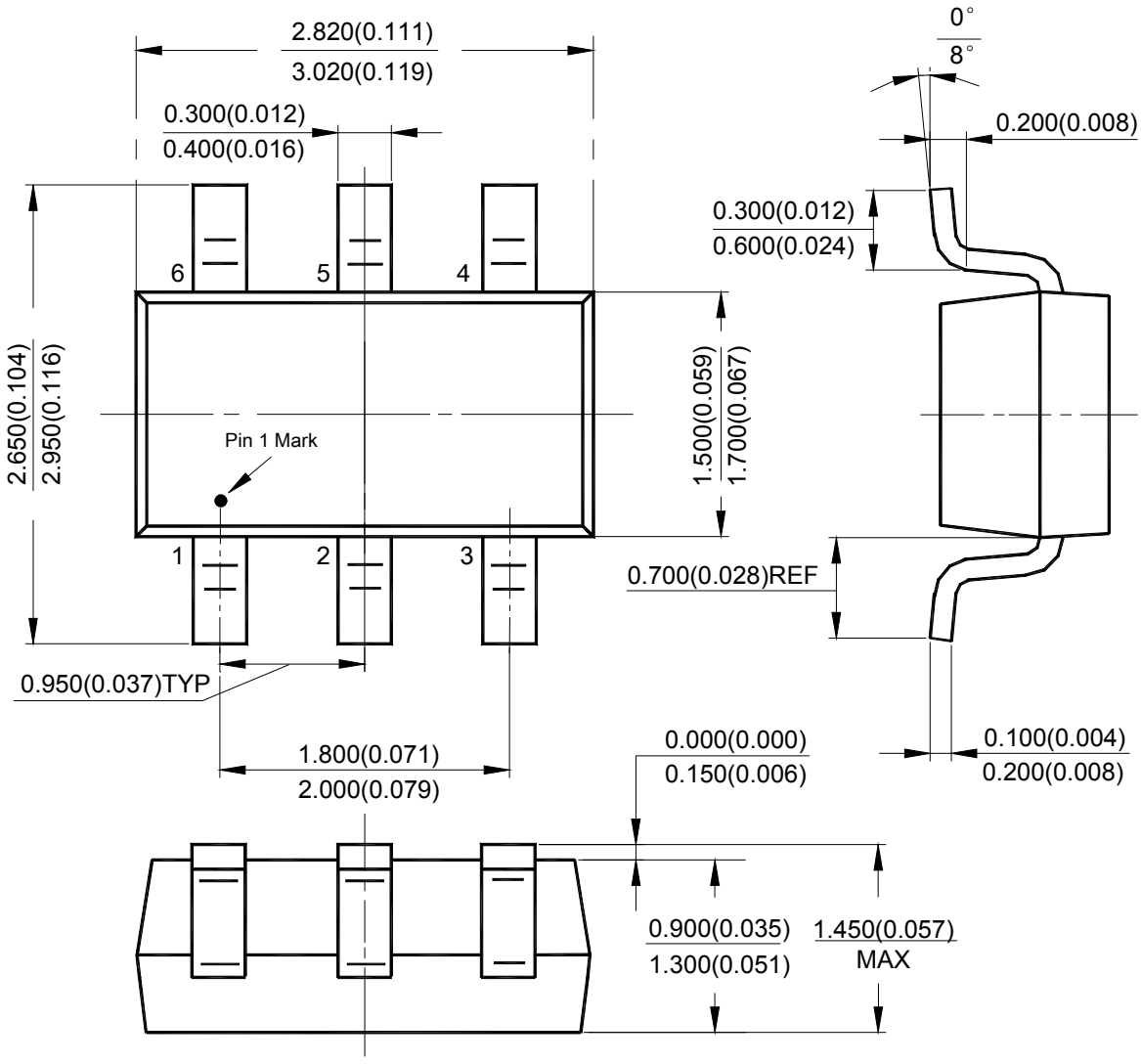



Figure 30. AP3602B Typical Application Circuit

## Mechanical Dimensions

**SOT-23-6** **Unit: mm(inch)**



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