High Efficiency Synchronous Step-Up DC/DC Converter

FEATURES

- High Efficiency (93% when V_{IN}=2.4V, V_{OUT}=3.3V, I_{OUT}=200mA)
- Output Current up to 500mA. (V_{IN}=2.4V and V_{OUT}=3.3V)
- 20μA Quiescent Supply Current.
- Power-Saving Shutdown Mode (0.1μA typical).
- Internal Synchronous Rectifier (No External Diode Required).
- On-Chip Low Battery Detector.
- Low Battery Hysteresis
- Space-Saving Package: MSOP-8

APPLICATIONS

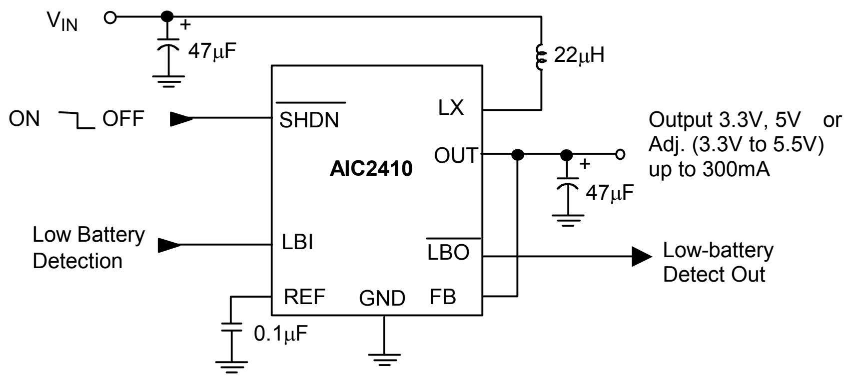
- Hand-Held Devices with 1 to 3-Cell of NiMH/NiCd Batteries.
- Emengency Charger.

DESCRIPTION

The AIC2410 is high efficiency step up DC-DC converters. Simply consuming 20μA of quiescent current. The device offer a built-in synchronous rectifier that reduces size and cost by eliminating the need for an external Schottky diode and improves overall efficiency by minimizing losses.

The switching frequency can range up to 500KHz depending on the load and input voltage. The output voltage can be easily set by two external resistors from 3.3V to 5.5V, connecting FB to OUT to get 3.3V, or connecting to GND to get 5.0V. The peak current of the internal switch is fixed at 1.0A for design flexibility.

TYPICAL APPLICATION CIRCUIT



ORDERING INFORMATION

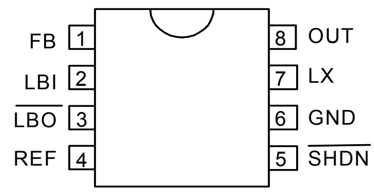
AIC2410X XX XX

- PACKING TYPE
  TR: TAPE & REEL
- PACKAGING TYPE
  O8: MSOP-8
- P: LEAD FREE COMMERCIAL

Example: AIC2410PO8TR
→ In MSOP-8 Lead Free Package & Taping & Reel Packing Type

PIN CONFIGURATION

TOP VIEW



ABSOLUTE MAXIMUM RATINGS

Supply Voltage (OUT to GND)	7.0V
Switch Voltage (LX to GND)	V_{OUT}+ 0.3V
$\overline{SHDN}$, LBO to GND	6.0V
LBI, REF, FB, to GND	V_{OUT}+0.3V
Switch Current (LX)	-1.5A to +1.5A
Output Current (OUT)	-1.5A to +1.5A
Operating Temperature Range	-40°C ~ +85°C
Maximum Junction Temperature	125°C
Storage Temperature Range	-65°C ~150°C
Lead Temperature (Soldering 10 Sec.)	260°C
Thermal Resistance Junction to Case MSOP-8	75°C/W
Thermal Resistance Junction to Ambient MSOP-8	180°C/W

(Assume no ambient airflow, no heatsink)

Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

TEST CIRCUIT

Refer to Typical Application Circuit.

ELECTRICAL CHARACTERISTICS (V_{IN}=2.0V, V_{OUT}=3.3V, FB=V_{OUT}, T_A=25°C, unless otherwise specified.) (Note1)

PARAMETER	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
Minimum Input Voltage			0.7		V
Operating Voltage		1.1		4.5	V
Start-Up Voltage	R_L=3KΩ (Note 2)		0.8	1.1	V
Start-Up Voltage Tempco			-2		mV/°C
Output Voltage Range	V_{IN}<V_{OUT}	3.3		5.5	
Output Voltage	FB = V_{OUT}	3.17	3.3	3.43	V
Steady State Output Current (Note 3)	FB=OUT (V_{OUT} =3.3V)		350		mA
	FB=GND (V_{OUT} =5.0V)		230		
Reference Voltage	I_{REF}= 0	1.199	1.23	1.261	V
Reference Voltage Tempco			0.024		mV/°C
Reference Load Regulation	I_{REF} = 0 to 100μA		10	30	mV
Reference Line Regulation	V_{OUT} = 1.8V to 5.5V		5	10	mV/V
FB , LBI Input Threshold		1.199	1.23	1.261	V
Internal switch On-Resistance	I_{LX} = 100mA		0.3	0.6	Ω
LX Switch Current Limit			1.0		A
LX Leakage Current	V_{LX}=0V~4V; V_{OUT}=5.5V		0.05	1	μA
Operating Current into OUT (Note 4)	V_{FB} = 1.4V , V_{OUT} = 3.3V		20	35	μA
Shutdown Current into OUT	$\overline{SHDN}$ = GND		0.1	1	μA
Efficiency	V_{OUT}= 3.3V ,I_{LOAD} = 200mA		90		%
	V_{OUT} = 2V ,I_{LOAD} = 1mA		85		
LX Switch On-Time	V_{FB} =1V , V_{OUT} = 3.3V	2	4	7	μS
LX Switch Off-Time	V_{FB} =1V , V_{OUT} = 3.3V	0.6	0.9	1.4	μS
FB Input Current	V_{FB} = 1.4V		0.03	50	nA
LBI Input Current	V_{LBI} = 1.4V		1	50	nA
$\overline{SHDN}$ Input Current	$V_{\overline{SHDN}}$ = 0 or V_{OUT}		0.07	50	nA
$\overline{LBO}$ Low Output Voltage	V_{LBI} = 0, I_{SINK} = 1mA		0.2	0.4	μA
$\overline{LBO}$ Off Leakage Current	$V_{\overline{LBO}}$ = 5.5V, V_{LBI} = 5.5V		0.07	1	μA

■ ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
LBI Hystereisis			50		mV
$\overline{SHDN}$ Input Voltage	V_{IL}			$0.2V_{OUT}$	V
	V_{IH}	$0.8V_{OUT}$			

Note 1: Specifications are production tested at T_A=25°C. Specifications over the -40°C to 85°C operating temperature range are assured by design, characterization and correlation with Statistical Quality Controls (SQC).

Note 2: Start-up voltage operation is guaranteed without the addition of an external Schottky diode between the input and output.

Note 3: Steady-state output current indicates that the device maintains output voltage regulation under load.

Note 4: Device is bootstrapped (power to the IC comes from OUT). This correlates directly with the actual battery supply.

TYPICAL PERFORMANCE CHARACTERISTICS

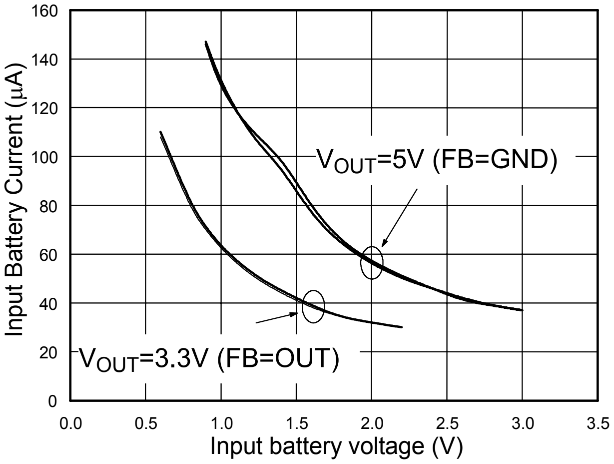


Fig. 1 No-Load Battery Current vs. Input Battery

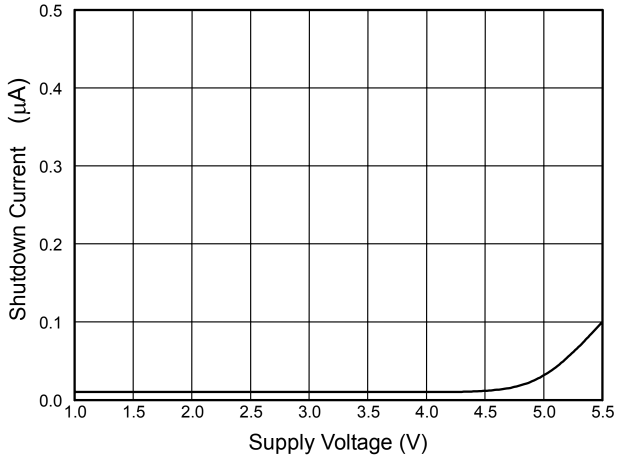


Fig. 2 Shutdown Current vs. Supply Voltage

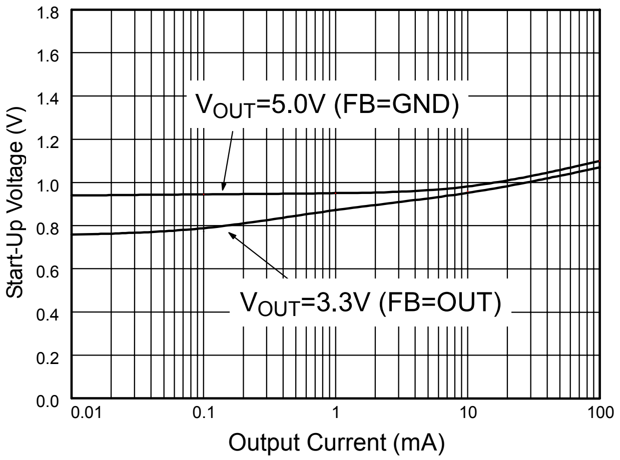


Fig. 3 Start-Up Voltage vs. Output Current

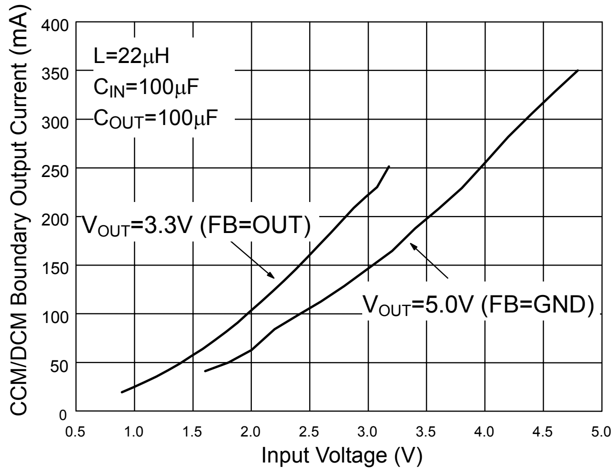


Fig. 4 Turning Point between CCM & DCM

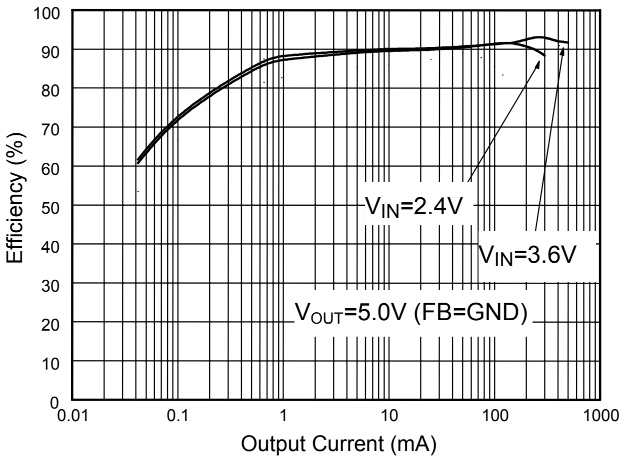


Fig. 5 Efficiency vs. Load Current (ref. to Fig.26)

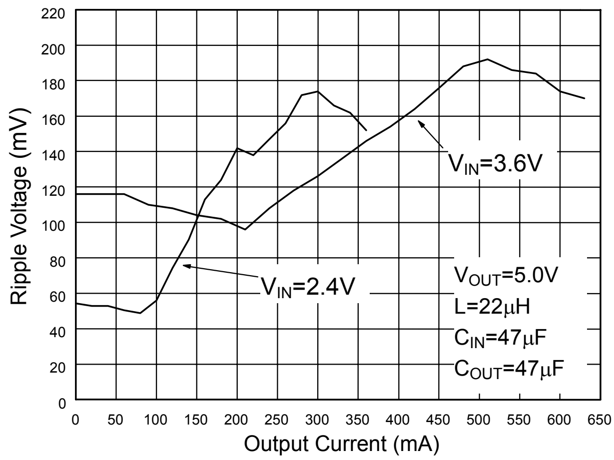


Fig. 6 Ripple Voltage (ref. to Fig.26)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

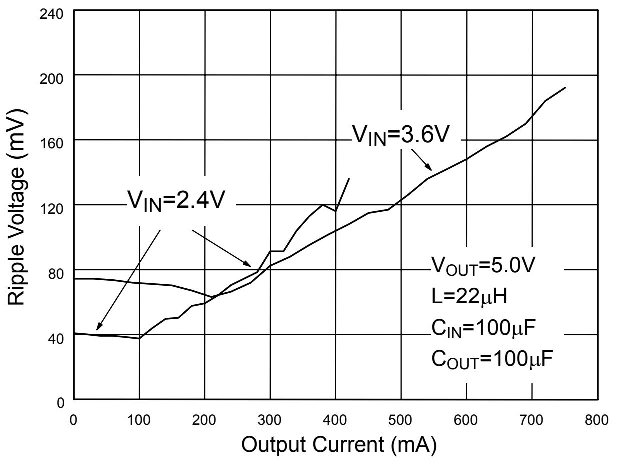


Fig. 7 Ripple Voltage (ref. to Fig.26)

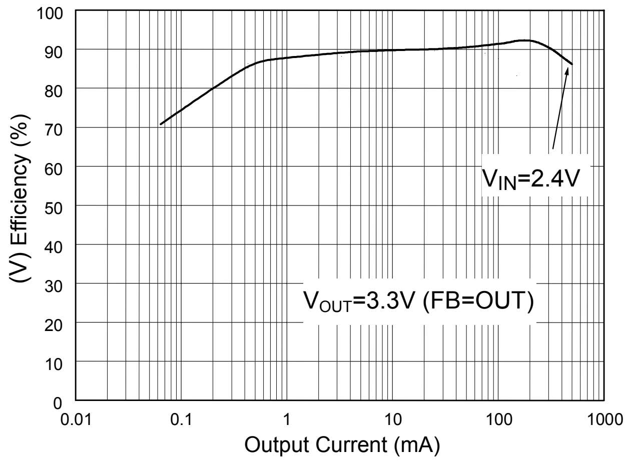


Fig. 8 Efficiency vs. Load Current (ref. to Fig.26)

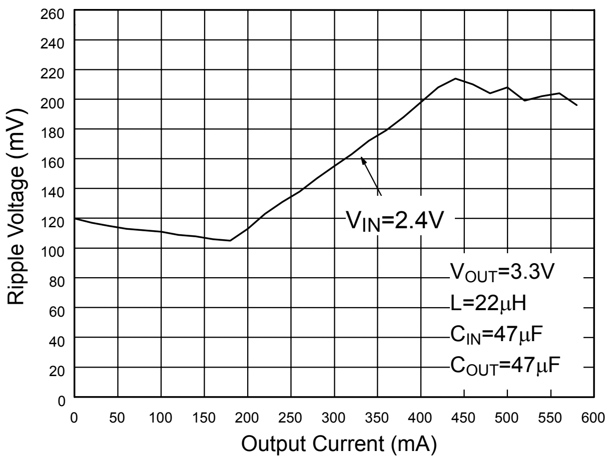


Fig. 9 Ripple Voltage (ref. to Fig.26)

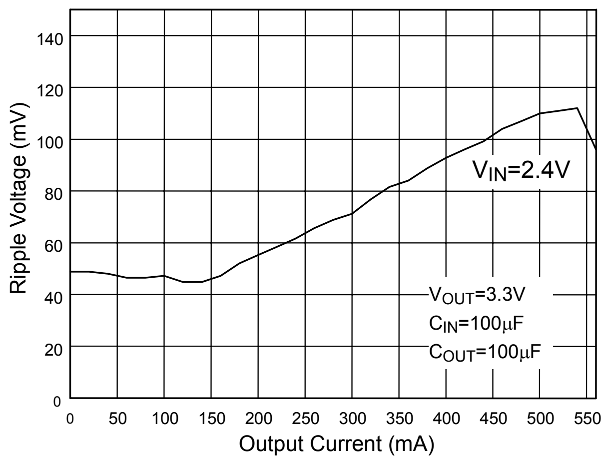


Fig. 10 Ripple Voltage (ref. to Fig.26)

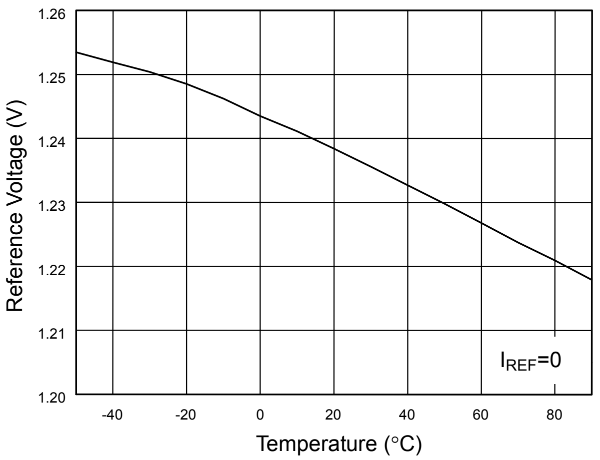


Fig. 11 Reference Voltage vs. Temperature

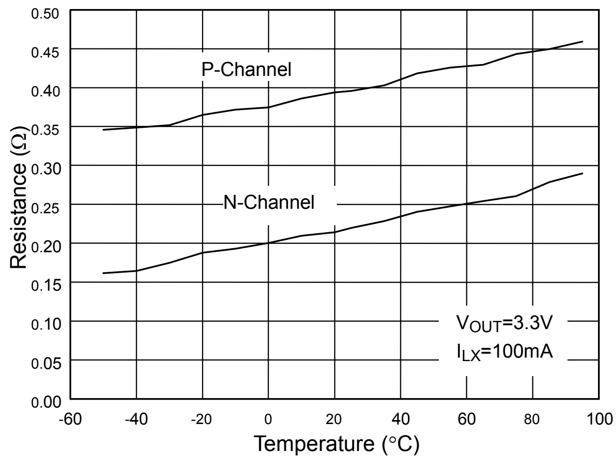


Fig. 12 Switch Resistance vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

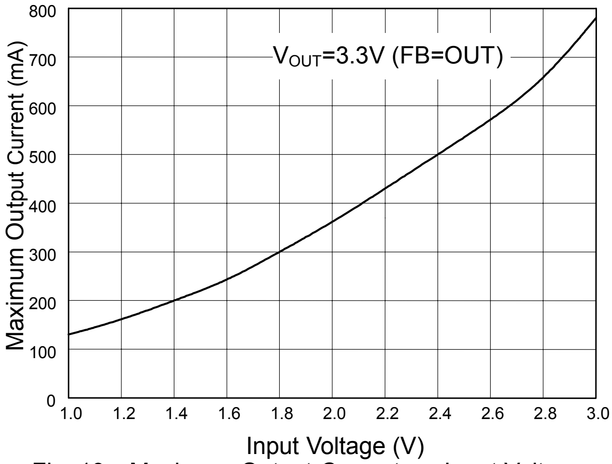


Fig. 13 Maximum Output Current vs. Input Voltage

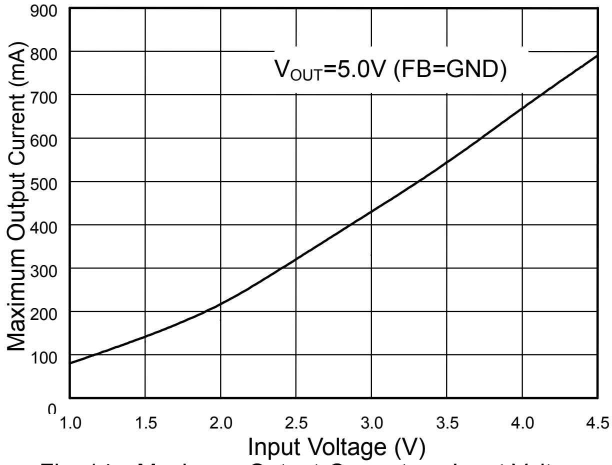


Fig. 14 Maximum Output Current vs. Input Voltage

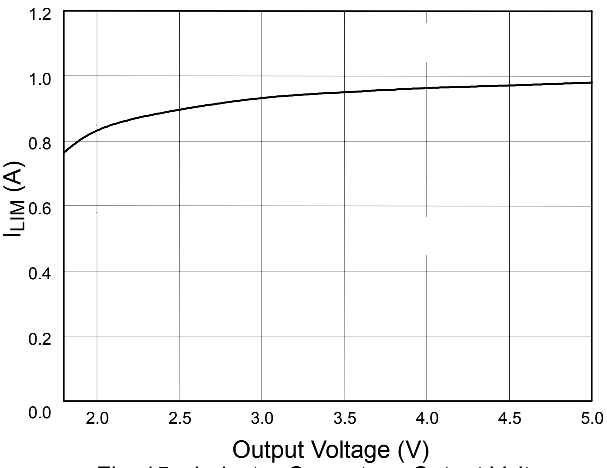


Fig. 15 Inductor Current vs. Output Voltage

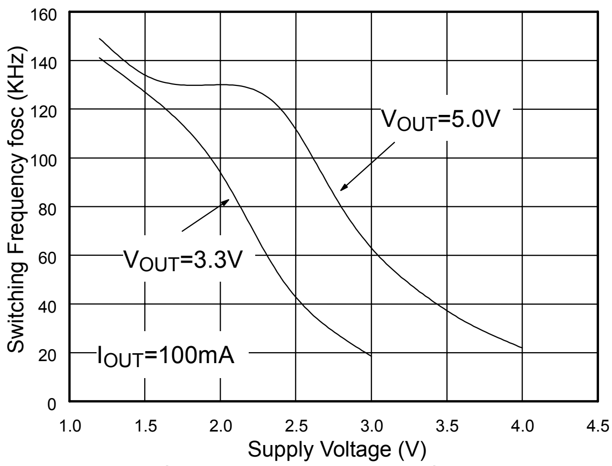


Fig. 16 Switching Frequency vs. Supply Voltage

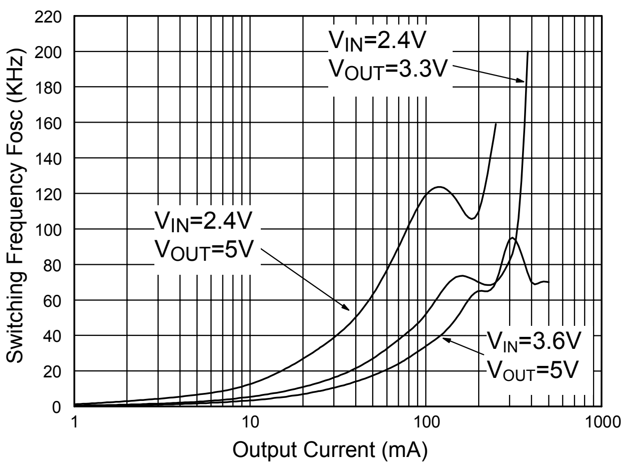


Fig. 17 Switching Frequency vs. Output Current

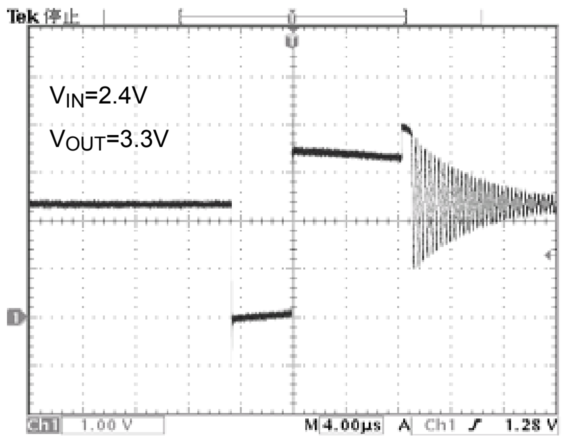


Fig. 18 LX Switching Waveform

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

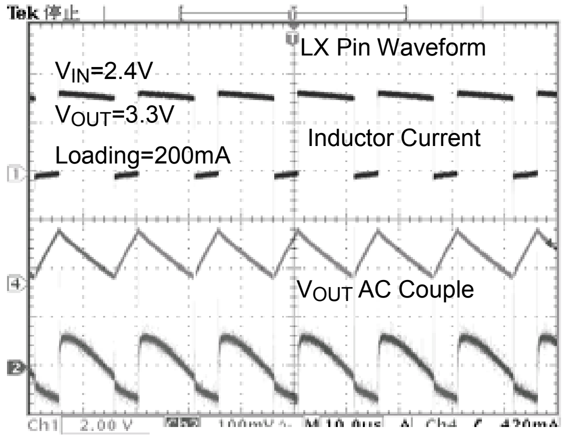


Fig. 19 Heavy Load Waveform

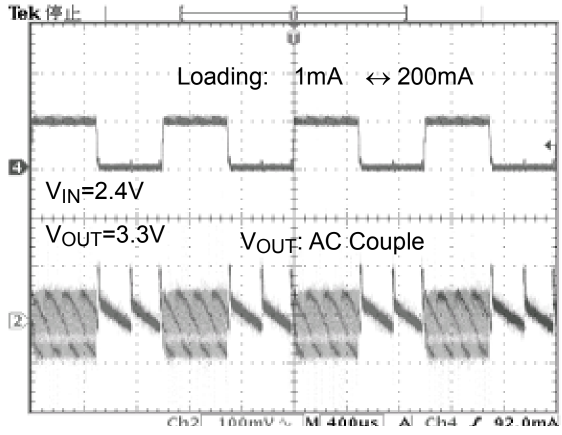


Fig. 20 Load Transient Response

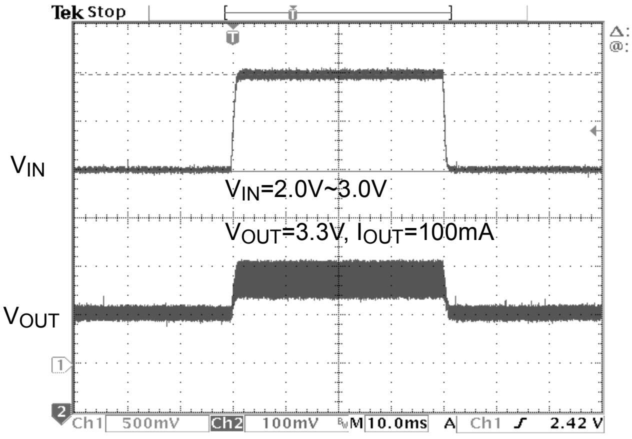


Fig. 21 Line Transient Response

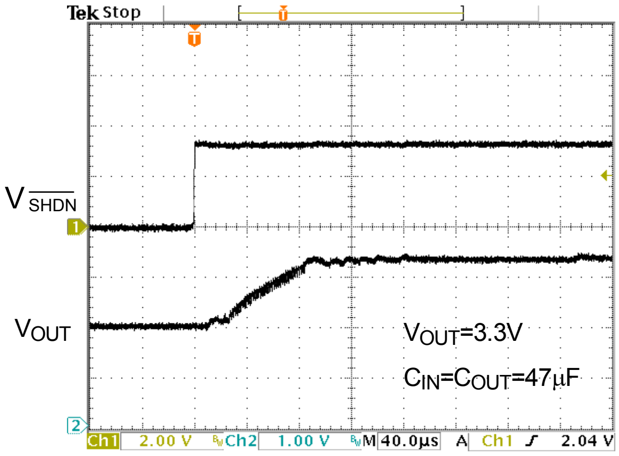


Fig. 22 Exiting Shutdown

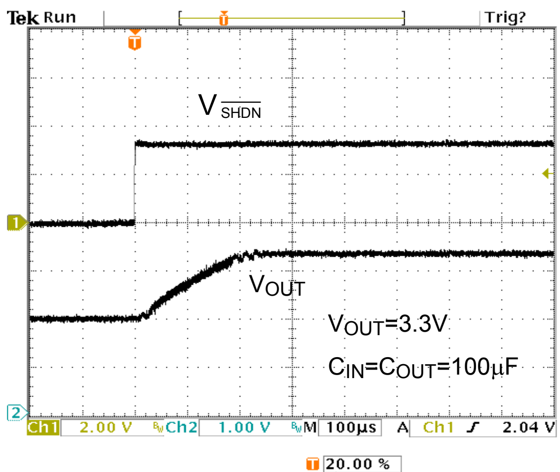


Fig. 23 Exiting Shutdown

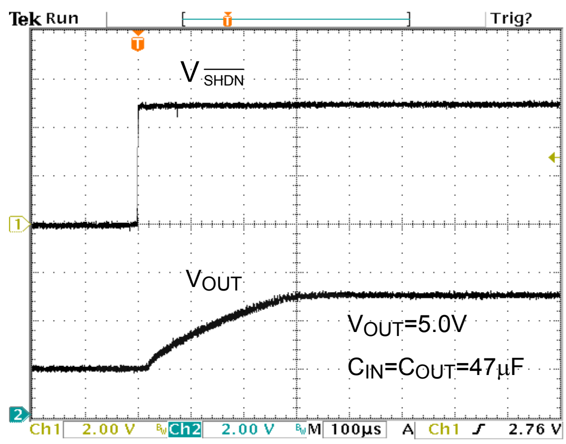


Fig. 24 Exiting Shutdown

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

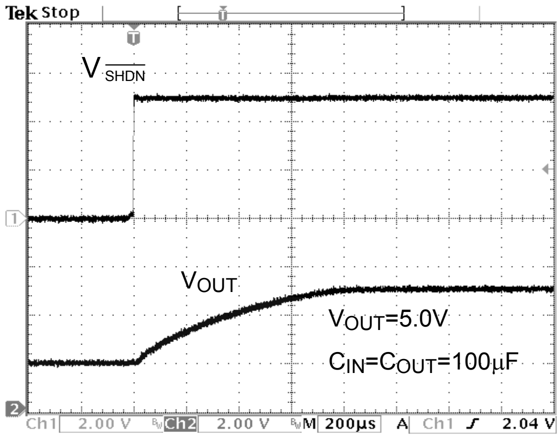
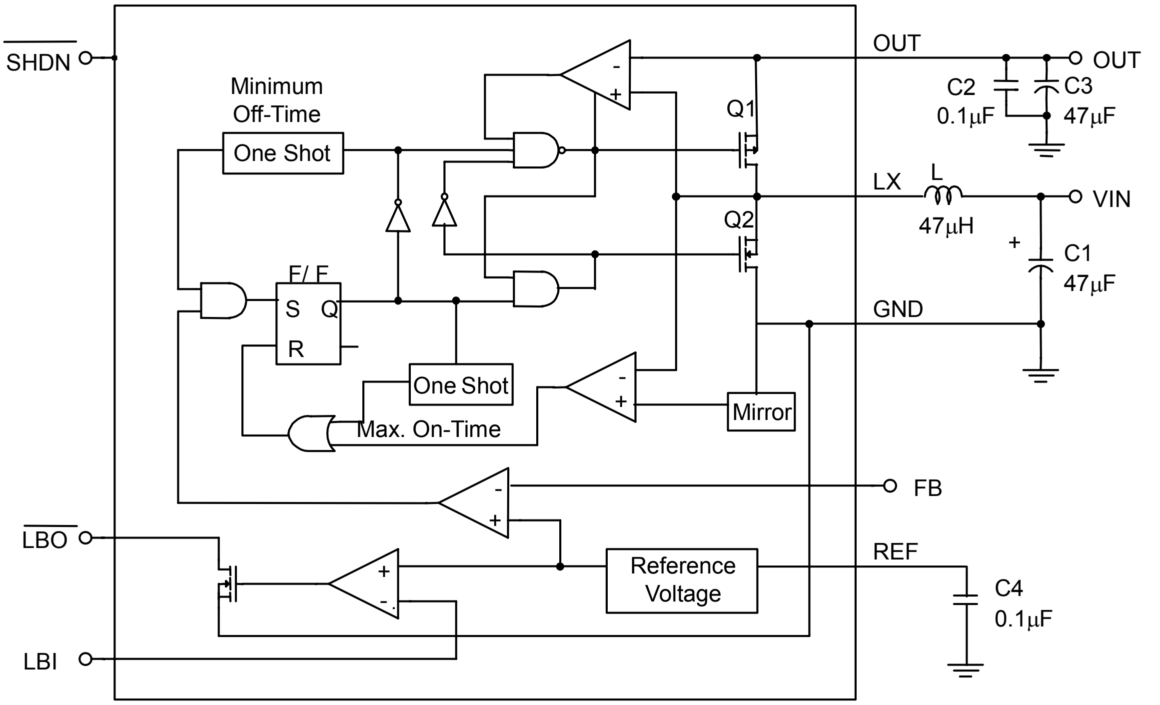


Fig. 25 Exiting Shutdown

BLOCK DIAGRAM



PIN DESCRIPTIONS

PIN 1: FB- Connecting to OUT to get +3.3V output, connecting to GND to get +5.0V output, or using a resistor network to set the output voltage from +3.3V to +5.5V.

PIN 2: LBI- Low-battery comparator input. Internally set at +1.23V to trip.

PIN 3: $\overline{LBO}$- Open-drain low battery comparator output. Output is low when V_{LBI} is <1.23V. $\overline{LBO}$ is high impedance during shutdown.

PIN 4: REF- 1.23V reference voltage. Bypass with a 0.1μF capacitor.

PIN 5: $\overline{SHDN}$- Shutdown input. High=operating, low=shutdown.

PIN 6: GND- Ground

PIN 7: LX- N-channel and P-channel power MOSFET drain.

PIN 8: OUT- Power output. OUT provides bootstrap power to the IC.

APPLICATION INFORMATION

Overview

AIC2410 is high efficiency, step-up DC-DC converters, designed to feature a built-in synchronous rectifier, which reduces size and cost by eliminating the need for an external Schottky diode. The start-up voltage of AIC2410 is as low as 0.8V and it operates with an input voltage down to 0.7V. Quiescent supply current is only 20μA. The internal P-MOSFET on-resistance is typically 0.3Ω to improve overall efficiency by minimizing AC losses. The output voltage can be easily set by two external resistors from 3.3V to 5.5V, connecting FB to OUT to get 3.3V, or connecting to GND to get 5.0V. The peak current of the internal switch is fixed at 1.0A for design flexibility.

PFM Control Scheme

The key feature of the AIC2410 is a unique minimum-off-time, constant-on-time, current-limited, pulse-frequency-modulation (PFM) control scheme (see BLOCK DIAGRAM) with the ultra-low quiescent current. The peak current of the internal N-MOSFET power switch can be fixed at 1.0A. The switch frequency depends on either loading condition or input voltage, and can range up to 500KHz. It is governed by a pair of one-shots that set a minimum off-time (1μS) and a maximum on-time (4μS).

Synchronous Rectification

Using the internal synchronous rectifier eliminates the need for an external Schottky diode. Therefore, the cost and board space are reduced. During the cycle of off-time, P-MOSFET turns on and shunts N-MOSFET. Due to the low turn-on resistance of MOSFET, synchronous rectifier significantly improves efficiency without an additional external Schottky diode. Thus, the conversion efficiency can be as high as 93%.

Reference Voltage

The reference voltage (REF) is nominally 1.23V for excellent T.C. performance. In addition, REF pin can source up to 100μA to external circuit with good load regulation (<10mV). A bypass capacitor of 0.1μF is required for proper operation and good performance

Shutdown

The whole circuit is shutdown when $V_{\overline{SHDN}}$ is low. At shutdown mode, the current can flow from battery to output due to body diode of the P-MOSFET. V_{OUT} falls to approximately Vin-0.6V and LX remains high impedance. The capacitance and load at OUT determine the rate at which V_{OUT} decays. Shutdown can be pulled as high as 6V. Regardless of the voltage at OUT.

Selecting the Output Voltage

V_{OUT} can be simply set to 3.3V/5.0V by connecting FB pin to OUT/GND due to the use of internal resistor divider in the IC (Fig.26 and Fig.27). In order to adjust output voltage, a resistor divider is connected to V_{OUT}, FB, GND (Fig.28). Vout can be calculated by the following equation:

$R5=R6\,[(V_{OUT}\,/\,V_{REF})-1]$ ....(1)

Where V_{REF} =1.23V and V_{OUT} ranging from 1.8V to 5.5V. The recommended R6 is 240KΩ.

Low-Battery Detection

AIC2410 contains an on-chip comparator with 50mV internal hysteresis (REF, REF+50mV) for low battery detection. If the voltage at LBI falls below the internal reference voltage. LBO (an open-drain output) sinks current to GND.

Component Selection

1. **Inductor Selection**

   An inductor value of 22μH performs well in most applications. The AIC2410 also works with inductors in the 10μH to 47μH range. An inductor with higher peak inductor current tends a higher output voltage ripple ($I_{PEAK}\times$output filter capacitor ESR). The inductor's DC resistance significantly affects efficiency. We can calculate the maximum output current as follows:

   $$I_{OUT(MAX)}=\frac{V_{IN}}{V_{OUT}}\left[I_{LIM}-t_{OFF}\left(\frac{V_{OUT}-V_{IN}}{2\times L}\right)\right]\eta$$

   ……………………………………………………(2)

   where $I_{OUT(MAX)}$=maximum output current in amps

   V_{IN}=input voltage

   L=inductor value in μH

   η =efficiency (typically 0.9)

   t_{OFF}=LX switch' off-time in μS

   I_{LIM}=1.0A

2. **Capacitor Selection**

   The output ripple voltage relates with the peak inductor current and the output capacitor ESR. Besides output ripple voltage, the output ripple current also needs to be concerned. A filter capacitor with low ESR is helpful to the efficiency and steady state output current of AIC2410. Therefore NIPPON tantalum capacitor MCM series with 100μF/6V is recommended. A smaller capacitor (down to 47μF with higher ESR) is acceptable for light loads or in applications that can tolerate higher output ripple.

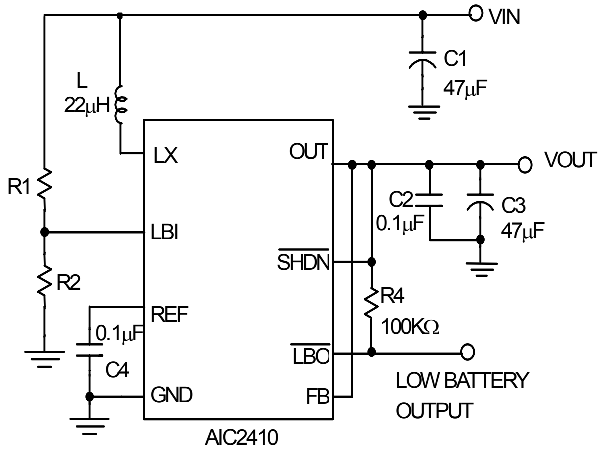
3. **PCB Layout and Grounding**

   Since AIC2410's switching frequency can range up to 500kHz, it makes AIC2410 become very sensitive. So careful printed circuit layout is important for minimizing ground bounce and noise. IC's OUT pin should be as clear as possible. And the GND pin should be placed close to the ground plane. Keep the IC's GND pin and the ground leads of the input and output filter capacitors less than 0.2in (5mm) apart. In addition, keep all connection to the FB and LX pins as short as possible. In particular, when using external feedback resistors, locate them as close to the FB as possible. To maximize output power and efficiency and minimize output ripple voltage, use a ground plane and solder the IC's GND directly to the ground plane.

Ripple Voltage Reduction

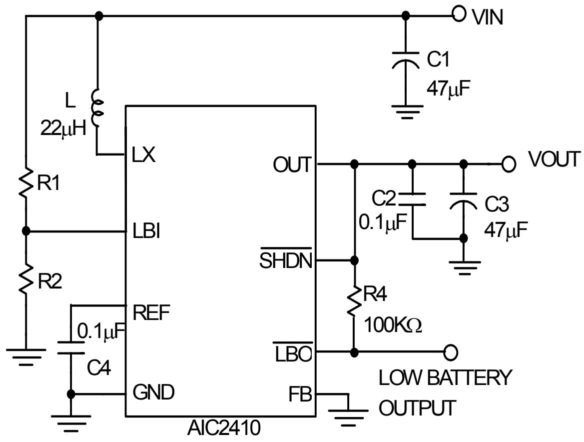
Two or three parallel output capacitors can significantly improve output ripple voltage of AIC2410. The addition of an extra input capacitor results in a stable output voltage. Fig.31 shows the application circuit with the above features. Fig.32 to Fig.35 are the performances of Fig. 31.

APPLICATION EXAMPLES



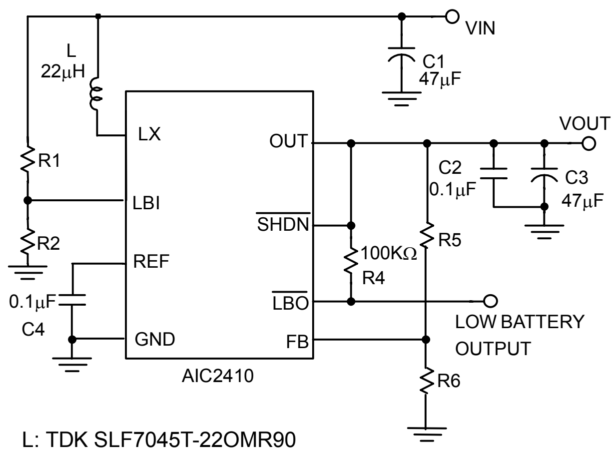
L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

Fig. 26 V_{OUT} = 3.3V Application Circuit.



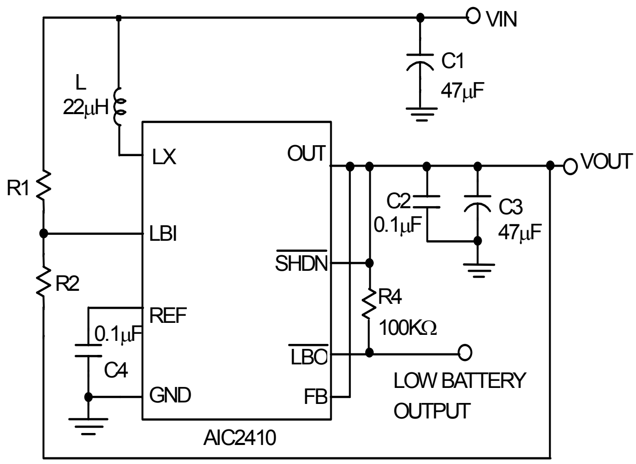
L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

Fig. 27 V_{OUT} = 5.0V Application Circuit.



L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER
$V_{OUT}=V_{REF}*(1+R5/R6)$

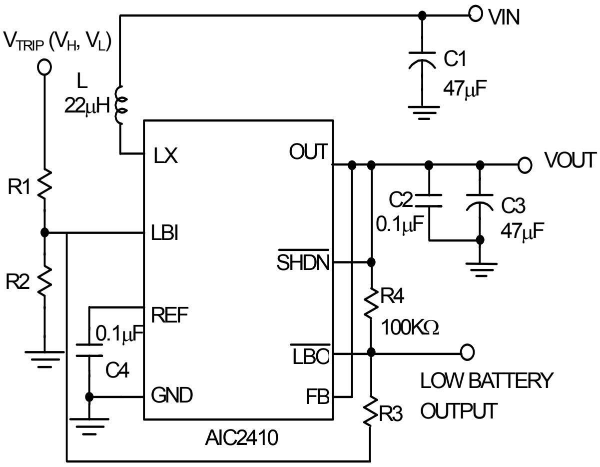
Fig. 28 An Adjustable Output Application Circuit



L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

Fig. 29 Low Battery Detection for V_{IN} < 1.23

APPLICATION EXAMPLES (Continued)



L: TDK SLF7045T-22OMR90

C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

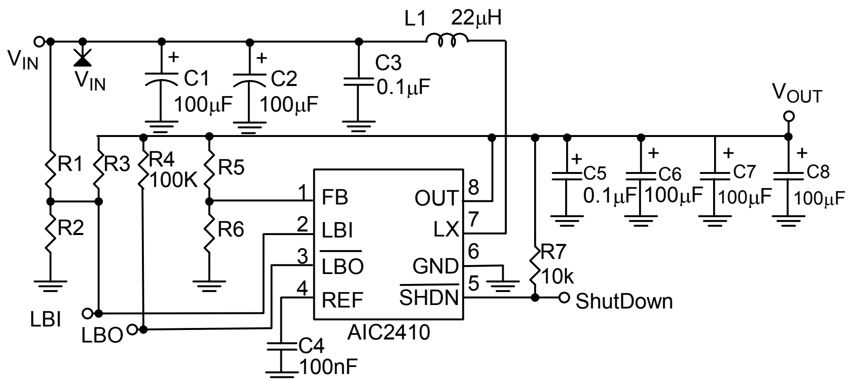
$V_H=1.23(1+R_1/R_2+R_1/R_3)$

$V_L=1.23[1+R_1/R_2-R_1(V_{OUT}-1.23)/1.23(R_3+R_4)]$

Where V_H is the upper trip level

V_L is the lower trip level

Fig. 30 Adding External Hysteresis to Low Battery Detection



R5=0Ω, R6=open; for V_{OUT}=3.3V

R5=open, R6=0Ω; for V_{OUT}=5.0V

$V_{OUT}=1.23(1+R5/R6)$; for adjustable output voltage

L1: TDK SLF7045T-22OMR90

C1~C2, C6~8: NIPPON Tantalum Capacitor 6MCM107MCTER

Fig. 31 AIC2410 application circuit with small ripple voltage.

■ APPLICATION EXAMPLES (Continued)

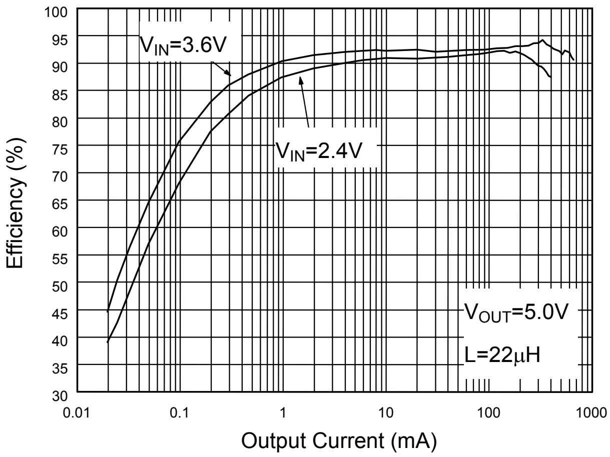


Fig. 32 Efficiency (ref. to Fig.31)

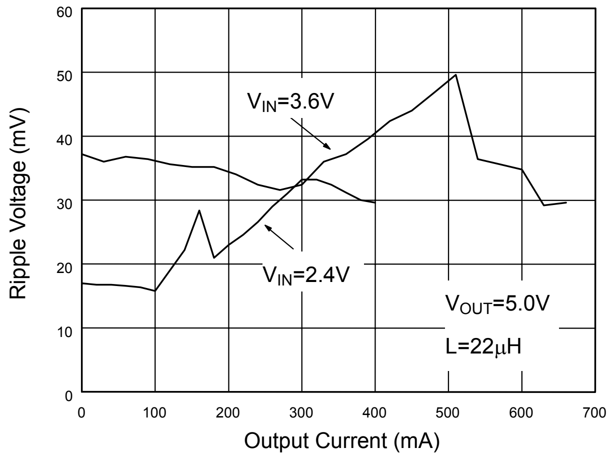


Fig. 33 Ripple Voltage (ref. to Fig.31)

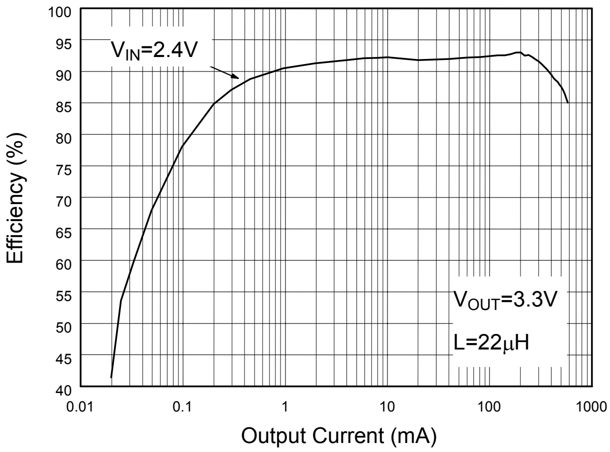


Fig. 34 Efficiency (ref. to Fig.31)

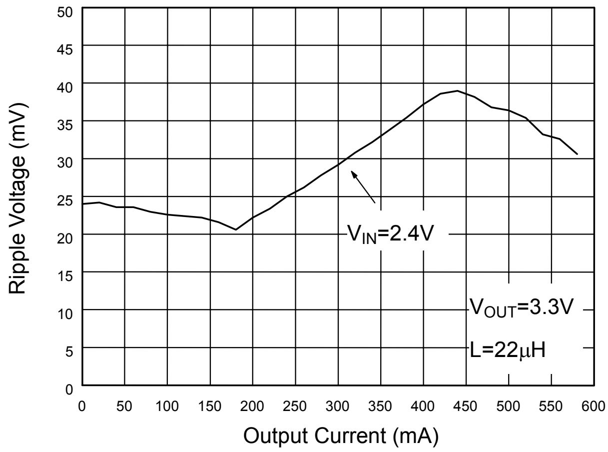
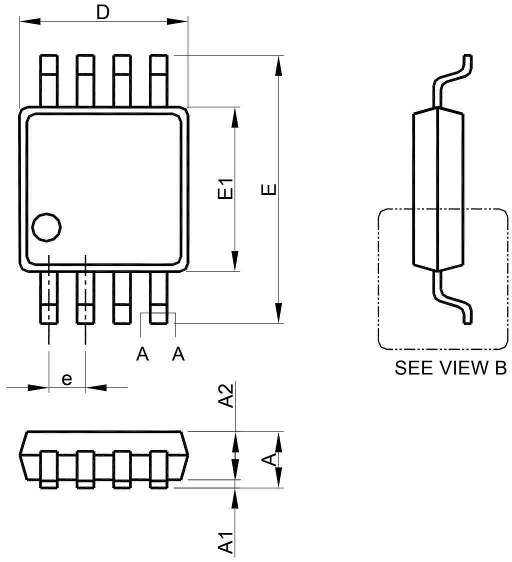


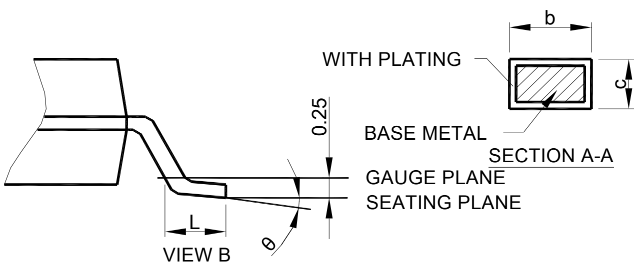
Fig. 35 Ripple Voltage (ref. to Fig.31)

■ PHYSICAL DIMENSION (unit: mm)

- **MSOP-8**



SYMBOL	MSOP-8	
	MILLIMETERS	
	MIN.	MAX.
A		1.10
A1	0.05	0.15
A2	0.75	0.95
b	0.25	0.40
c	0.13	0.23
D	2.90	3.10
E	4.90 BSC	
E1	2.90	3.10
e	0.65 BSC	
L	0.40	0.70
q	0°	6°



Note: 1. Refer to JEDEC MO-187AA.
2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side .
3. Dimension "E1" does not include inter-lead flash or protrusions.
4. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.