3A 17V Synchronous 100% Duty Cycle Step-Down Converter With AOT Control

FEATURES

- Adaptive On Time Control
- 100% Duty Cycle Mode
- Fast Transient Response
- Wide 4.5V to 17V Operating Input Range
- Output Adjustable from 0.9V to 5V
- 3A Continuous Output Current
- Pin-Selectable Output Voltage (Nominal, + 5%)
- Programmable Soft Start
- Quiescent Current of 40μA (Typical)
- Selectable Operating Frequency
- Power Good Output
- Short Circuit Protection
- Over Temperature Protection
- Over Voltage Protection with Latch
- Up to 94% efficiency
- Available in a QFN-16 (3x3x0.75-0.5) Package

APPLICATIONS

- Standard 12-V Rail Supplies
- POL Supplies from Single or Multiple Li-Ion Batteries
- Mobile PC's, Tablets, Modems, Cameras
- Digital TV Power Supply
- Networking Home Terminal
- Set Top Box

DESCRIPTION

The AIC2873B is an easy-to-use synchronous step-down DC-DC converter optimized for applications with high power density. A high switching frequency of typically 1.25MHz allows the use of small inductors and provides fast transient response as well as high output voltage accuracy by use of the AOT control.

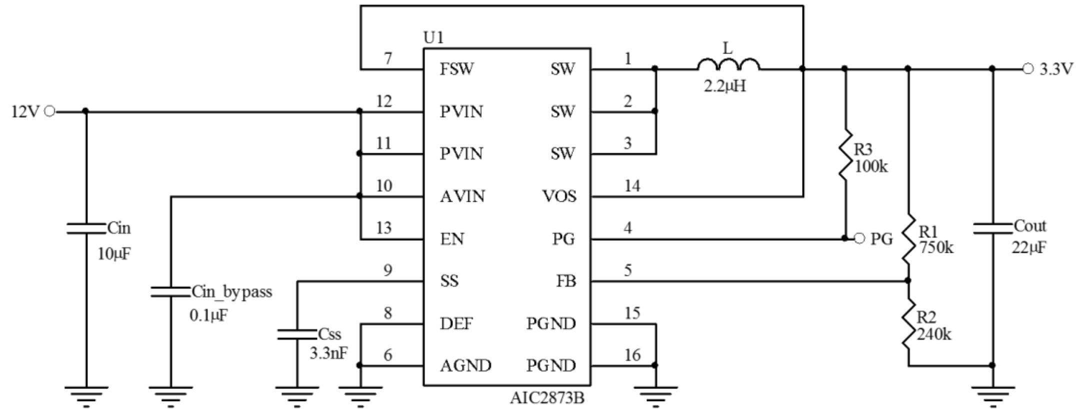
With wide operating input voltage range of 4.5V to 17V, the AIC2873B is ideally suited for systems powered from 5V or 12V intermediate power rails. It supports up to 3A continuous output current at output voltages from 0.9V to 5V (with 100% duty cycle mode).

The output voltage startup ramp can be controlled by the soft-start pin. Power sequencing is also possible by configuring the Enable and open-drain power good pins.

In power save mode, the AIC2873B draws quiescent current of about 40μA from VIN. Power save mode, entered automatically if load is small, maintains high efficiency over the entire load range. In shutdown Mode, the AIC2873B is turned off and shutdown current consumption is less than 2μA.

The AIC2873B is packaged in a QFN-16 (3x3x0.75-0.5).

APPLICATIONS CIRCUIT



AIC2873B Typical Application Circuit

ORDERING INFORMATION

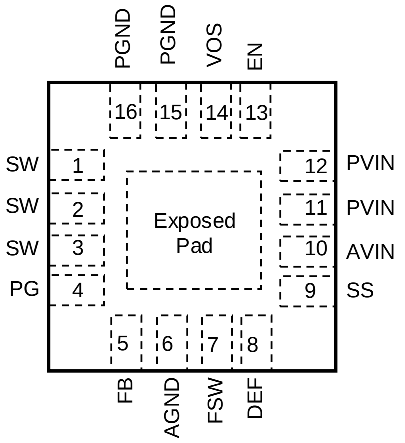
AIC2873BXXXX XX

- PACKING TYPE
  TR: TAPE & REEL
  BG: BAG
- PACKAGING TYPE
  HFC: QFN-16 (3x3x0.75-0.5)
- G: GREEN PACKAGE

Example: AIC2873BGHFCTR
→ Green QFN-16 (3x3x0.75-0.5) Package and TAPE & REEL Packing Type

PIN CONFIGURATION

QFN-16 (3x3x0.75-0.5)
TOP VIEW



Note:
The exposed pad should be connected with GND pin.

ABSOLUTE MAXIMUM RATINGS

PIN Voltage, AVIN, PVIN .... -0.3V to 20V

PIN Voltage, EN .... -0.3V to V_{IN}+0.3V

PIN Voltage, SW .... -0.3V to V_{IN}+0.3V

PIN Voltage, DEF, FSW, FB, PG, VOS, SS .... -0.3V to 7V

Power Good Sink Current, PG 10mA

Junction Temperature .... 125°C

Lead Temperature .... 260°C

Storage Temperature Range .... -65°C to 150°C

Operating Ambient Temperature Range .... -40°C to 85°C

Thermal Resistance Junction to Case QFN-16 (3x3x0.75-0.5)* .... 8°C/W

Thermal Resistance Junction to Ambient QFN-16 (3x3x0.75-0.5)* .... 48°C/W

(Assume no Ambient Airflow)

Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.
*The package is place on a two layers PCB with 2 ounces copper and 2 square inch, connected by 8 vias.

ELECTRICAL CHARACTERISTICS

(V_{IN}=12V, T_A=25°C, unless otherwise specified.) (Note1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage	V_{IN}		4.5		17	V
Supply Current						
Shutdown Current	I_{SHDN}	V_{EN}=0V		1.0	4	μA
Quiescent Current	I_Q	V_{EN}=High, I_{OUT}=0mA, device not switching		40		μA
Logic Threshold						
EN High Level Input Voltage	V_{ENH}		2.0			V
EN Low Level Input Voltage	V_{ENL}				0.6	V
DEF, FSW High Level Input Voltage	V_H		1.2			V
DEF, FSW Low Level Input Voltage	V_L				0.3	V
Input Leakage Current (EN, DEF, FSW)	I_{LKG}	EN=V_{IN} or GND; DEF, FSW=V_{OUT} or GND		0.01	1	μA
V_{REF} Voltage and Feedback Input Current						
Feedback Reference Voltage	V_{REF}	4.5V≦V_{IN}≦17V	0.78	0.8	0.82	V
Feedback Input Leakage Current	I_{LKG_FB}	V_{FB}=0.8V		1	100	nA
Output						
Output Voltage Range	V_{OUT}	V_{OUT}≦V_{IN}	0.9		5	V
Output Over Voltage Protection	V_{OUT_OVP}			5.8		V
DEF(Output Voltage Programming)		DEF=Low	V_{OUT}			
		DEF=High	V_{OUT}+5%			
Line Regulation		4.5V≦V_{IN}≦17V, V_{OUT}=3.3V, I_{OUT}=1A, PWM mode operation		0.02		%/V
Load Regulation		V_{IN}=17V, V_{OUT}=3.3V, PWM mode operation		0.05		%A
Switch On Resistance						
High Side Switch On Resistance	$R_{DS(ON)H}$	5.5V≦V_{IN}		90		mΩ
Low Side Switch On Resistance	$R_{DS(ON)L}$	5.5V≦V_{IN}		45		mΩ
Current Limit						
High Side Switch Forward Current Limit	I_{LIMIT}	V_{IN}=5.5V	4	6		A
Thermal Shutdown						
Thermal Threshold	T_{SD}			150		°C
Thermal Shutdown Hysteresis	T_{SD_HYS}			20		°C

■ ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
On-Time Timer Control						
On-Time	t_{ON}	V_{IN}=12V, V_{OUT}=5V, V_{FSW}=High		333		ns
		V_{IN}=12V, V_{OUT}=5V, V_{FSW}=Low		167		ns
Minimum Off-Time	$t_{OFF(MIN)}$			60		ns
Soft Start						
SS/TR Source Current	I_{SS}		0.5	1.6	4	μA
Power Good						
PGOOD Threshold	V_{TH_PG}	Rising (%V_{OUT})	89	94	99	%
PGOOD Hysteresis				6		%
PGOOD Output Low	V_{OL_PG}	I_{PG}=-2mA		0.07	0.3	V
PGOOD Input Leakage Current	I_{LKG_PG}	V_{PG}=1.8V		1	400	nA
Under Voltage Lockout Voltage						
UVLO Threshold	V_{UVLO}	Falling Input Voltage	3.45	3.75	4.10	V
UVLO Hystersis	V_{UVLO_HYS}			250		mV

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).

TYPICAL PERFORMANCE CHARACTERISTICS

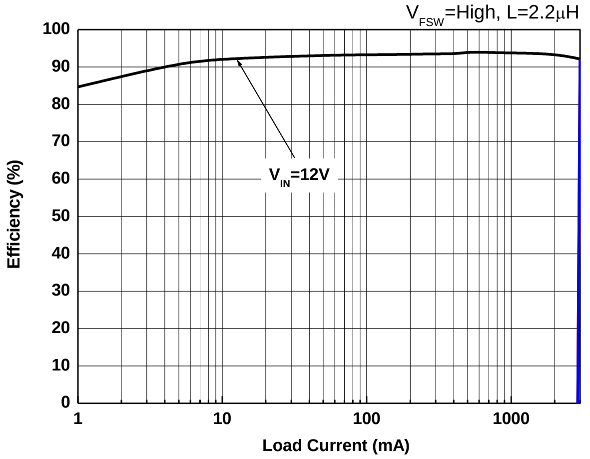


Fig. 1 Efficiency vs. Load Current (V_{OUT}=5V)

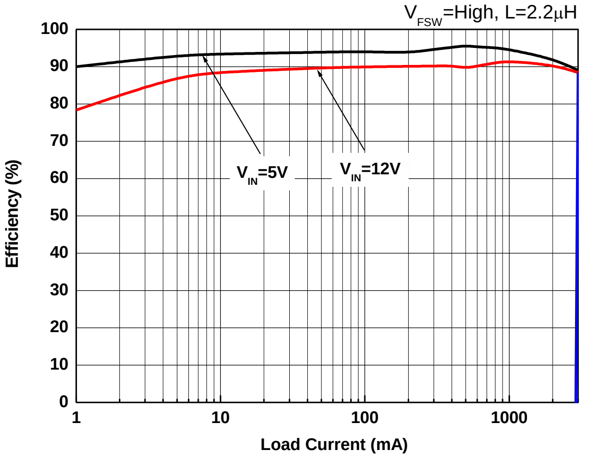


Fig. 2 Efficiency vs. Load Current (V_{OUT}=3.3V)

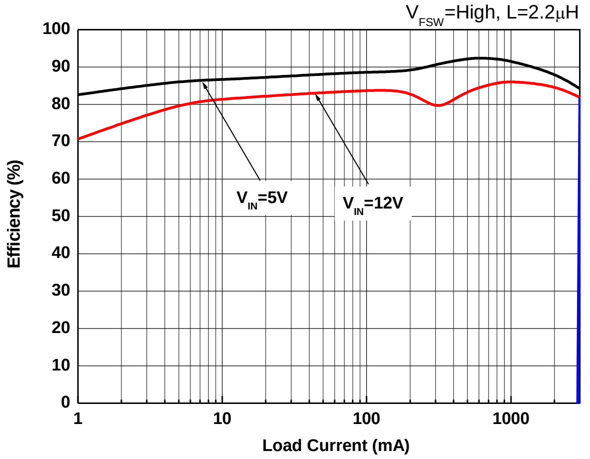


Fig. 3 Efficiency vs. Load Current (V_{OUT}=1.8V)

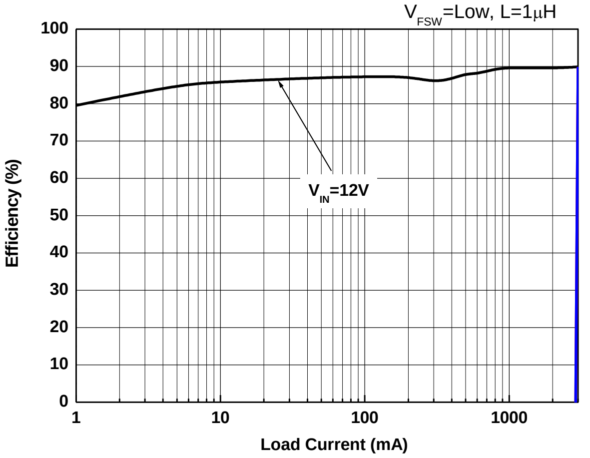


Fig. 4 Efficiency vs. Load Current (V_{OUT}=5V)

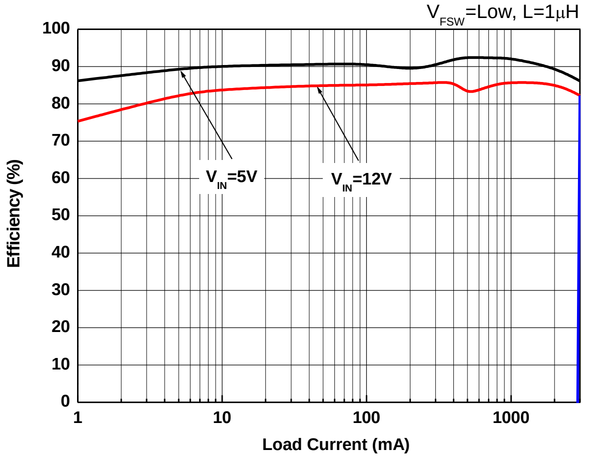


Fig. 5 Efficiency vs. Load Current (V_{OUT}=3.3V)

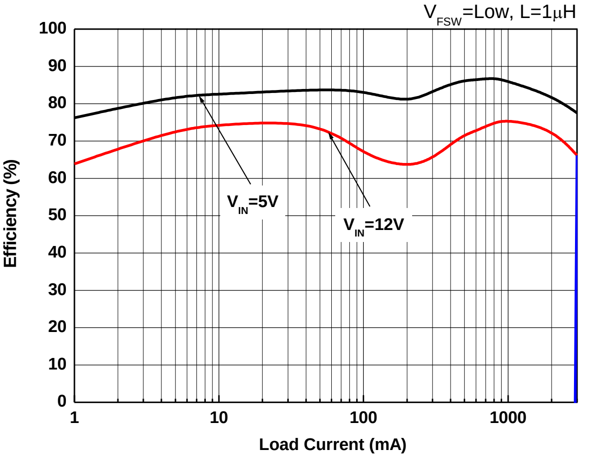


Fig. 6 Efficiency vs. Load Current (V_{OUT}=1.8V)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

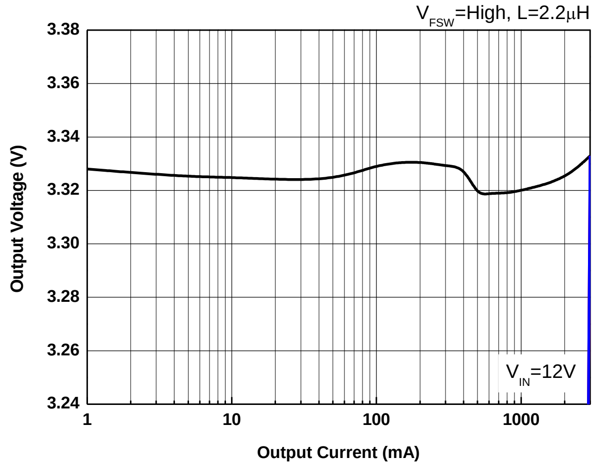


Fig. 7 Output Voltage vs. Output Current

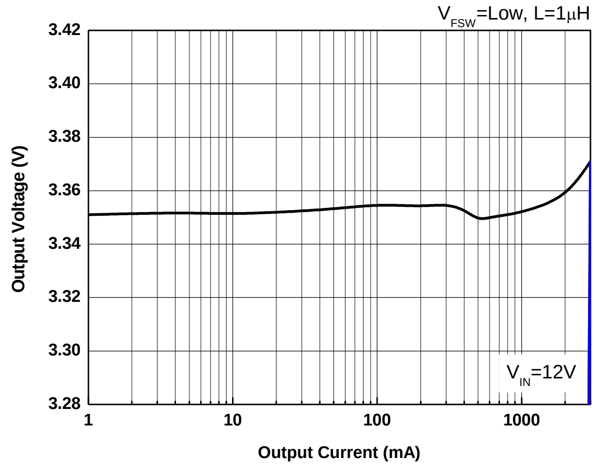


Fig. 8 Output Voltage vs. Output Current

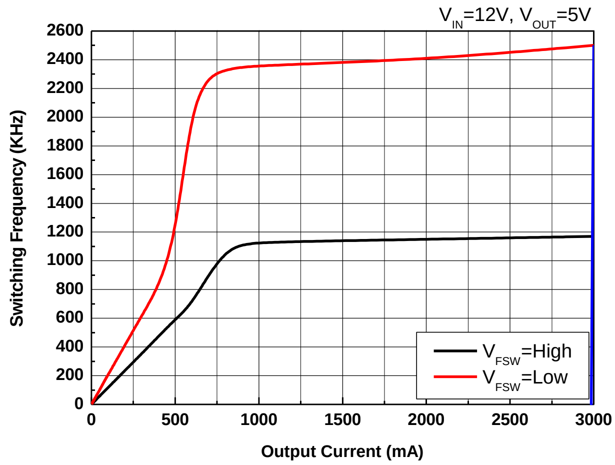


Fig. 9 Switching Frequency vs. Output Current

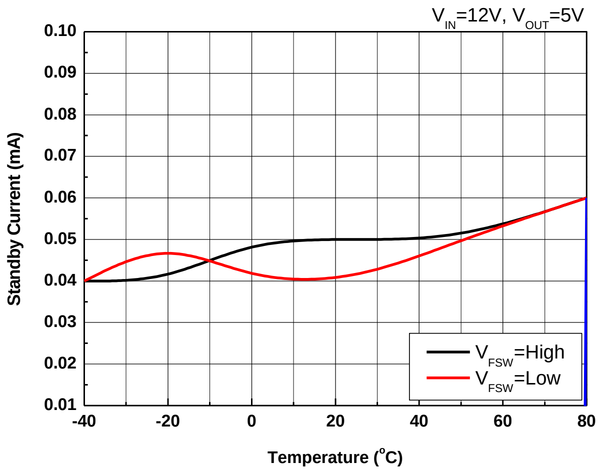


Fig. 10 Standby Current vs. Temperature

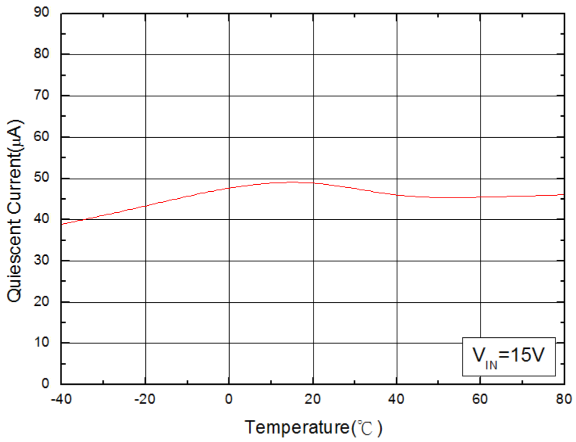


Fig. 11 Quiescent Current vs. Temperature

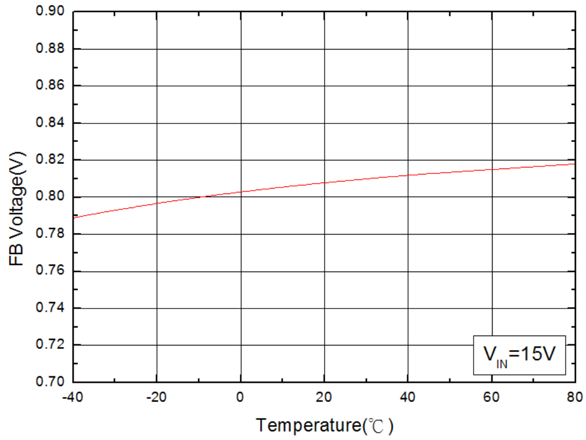


Fig. 12 FB Voltage vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

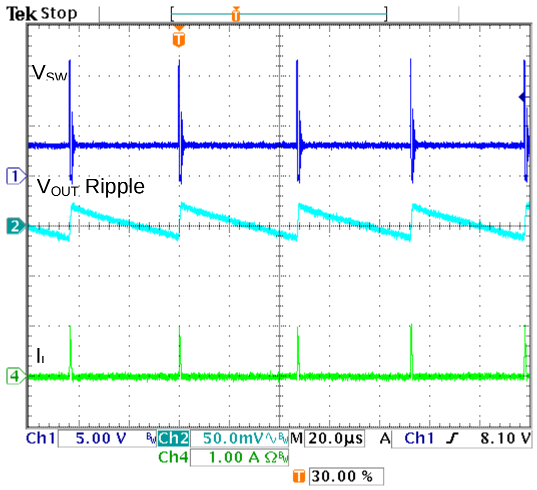


Fig. 13 Output Ripple (V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=10mA)

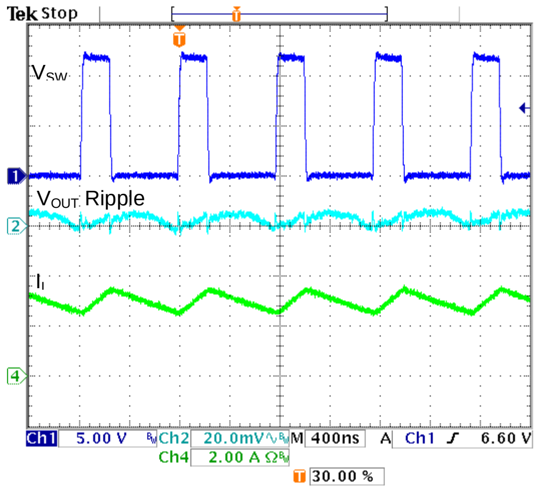


Fig. 14 Output Ripple (V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=3A)

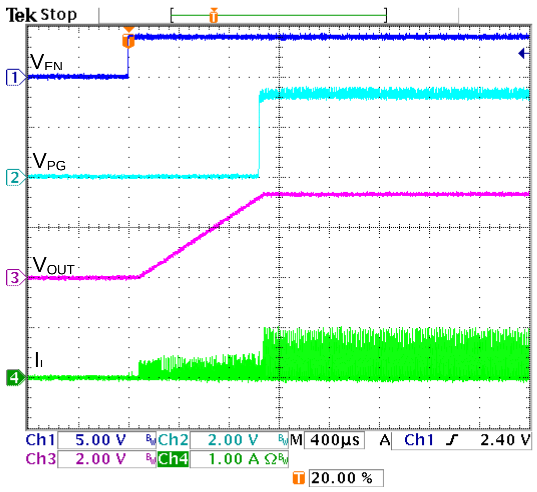


Fig. 15 EN Start Up (V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=100mA)

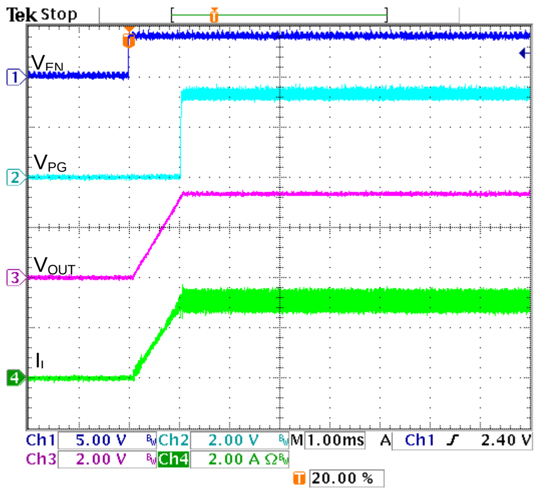


Fig. 16 EN Start Up (V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=3A)

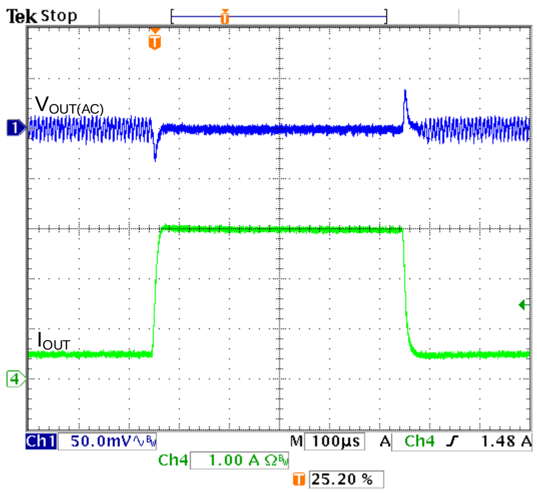


Fig. 17 Load Transient (V_{IN}=12V, V_{OUT}=3.3V, I_O=0.5-3A)

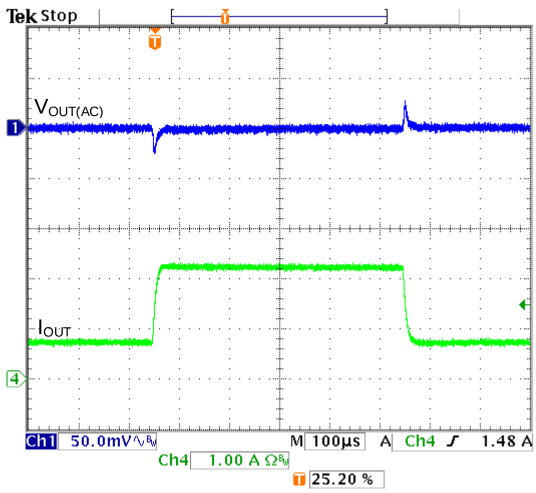
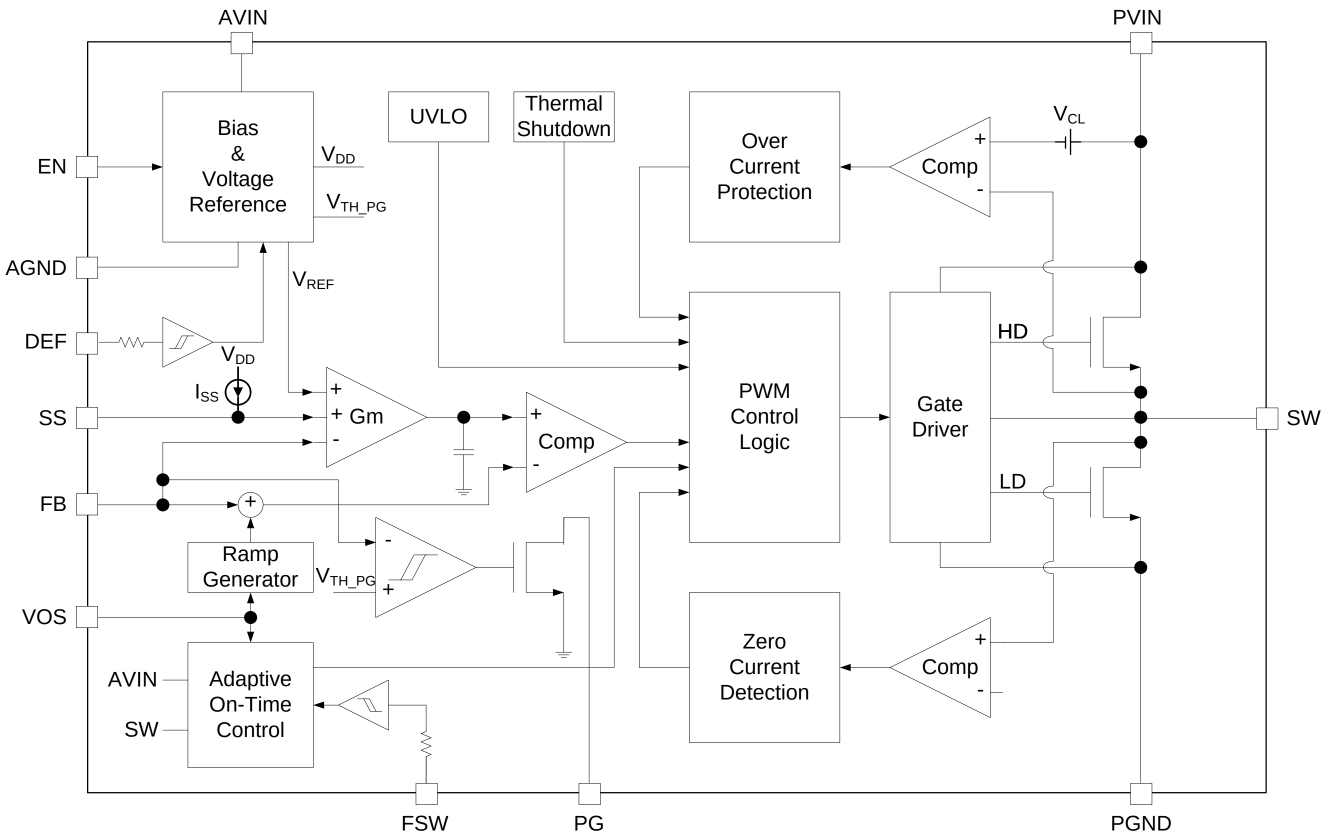


Fig. 18 Load Transient (V_{IN}=12V, V_{OUT}=3.3V, I_O=0.75-2.25A)

BLOCK DIAGRAM



Functional Block Diagram

PIN DESCRIPTIONS

Pin No.	Pin Name	Pin Function
6	AGND	Analog Ground. Must be connected directly to the Exposed Thermal Pad and common ground plane.
10	AVIN	Supply voltage for control circuitry. Connect to same source as PVIN.
8	DEF	Output Voltage Scaling (Low = nominal, High = nominal + 5%)
13	EN	Enable input (High = enabled, Low = disabled)
5	FB	Voltage feedback. Connect resistive voltage divider to this pin.
7	FSW	Switching Frequency Select (Low = 2.5MHz, High = 1.25MHz for typical operation)
4	PG	Output power good (High = VOUT ready, Low = VOUT below nominal regulation) ; open drain (requires pull-up resistor)
15, 16	PGND	Power ground. Must be connected directly to the Exposed Thermal Pad and common ground plane.
11, 12	PVIN	Supply voltage for power stage. Connect to same source as AVIN.
9	SS	Soft-Start Pin. An external capacitor connected to this pin sets the internal voltage reference rise time.
1, 2, 3	SW	Switch node, which is connected to the internal MOSFET switches. Connect inductor between SW and output capacitor.
14	VOS	Output voltage sense pin and connection for the control loop circuitry.
-	Exposed Thermal Pad	Must be connected to AGND. Must be soldered to achieve appropriate power dissipation and mechanical reliability.

APPLICATION INFORMATION

The AIC2873B is an adaptive on time control synchronous step down converter that can maintain almost fixed switching frequency over full input voltage range. It can deliver up to 3A output current from 4.5V to 17V input voltage. Unlike the traditional fixed frequency PWM control, the adaptive on-time control has the simpler control circuit and the faster transient response. During normal operation, the AIC2873B can regulate its output voltage through a feedback control circuit, which is composed of a comparator, a slope generator, a reference generator and several control signal generators. At the beginning of the switching cycle, the main power switch will be turned on and the synchronous power switch will be turned off through anti-short-through block. The main power switch will be turned off after the internal on-time timer expires. When the main power switch is turned off, the synchronous power switch will be turned on until the summing signal of feedback voltage signal and slope signal is lower than reference voltage signal or the inductor current starts to reverse. The AIC2873B will enter discontinuous conduction mode (DCM) operation while working at light load conditions.

Frequency Selection

The AIC2873B's pseudo switching frequency can be selected to be either 1.25MHz or 2.5MHz. The pseudo switching frequency is 1.25MHz while FSW pin is connected to high level voltage, and 2.5MHz while FSW pin is connected to low level voltage.

Pin-Selectable Output Voltage

The AIC2873B's output voltage can be increased by 5% above the setting value while DEF pin is connected to high level voltage, and its output voltage can be regulated to the setting value while DEF pin is connected to low level voltage.

Shutdown

By connecting the EN pin to low level voltage, the AIC2873B can be shut down to reduce the supply current to 1.0μA (typical). At this operation mode, the output voltage of step-down converter is equal to 0V.

Soft-Start

The AIC2873B provides the soft-start function. Initially, the voltage at SS pin is 0V. Then an internal current source of 1.6μA (typ.) charges an external soft-start capacitor. During the soft-start period, the voltage at SS pin will limit the feedback threshold voltage at FB pin. When the voltage at SS pin is higher than reference voltage, the feedback threshold voltage at FB pin reaches the desired value. The soft-start time can be calculated in accordance with the following equation.

$$t_{SS} = C_{SS} \times \frac{V_{REF}}{1.6\mu A}$$

The soft-start capacitor is discharged to GND when the EN pin is connected to low level voltage.

Power Good Indictor

AIC2873B contains an on-chip comparator for power good detection. If the output voltage is lower than power good low threshold, the PG pin (an open-drain output) sinks current to GND. When the device is turned off by enable function, UVLO function or thermal shutdown function, the AIC2873B pulls the PG pin low. By connecting PG pin to output capacitor through a resistor, the output capacitor can be discharge in those cases (as shown in figure 19). For reliability, the maximum current into the PG pin should be less than 10mA.

Over Current Protection

The AIC2873B has a cycle-by-cycle current limit to protect the internal power switches. The cycle-by-cycle current limit protection directly limits inductor peak current. While the current limitation function is activated, the duty cycle will be reduced to limit the output power to protect the internal power switches.

Over Temperature Protection

The AIC2873B includes a thermal-limiting circuit, which is designed to protect the device from excessive temperature. When the junction temperature exceeds T_J=150ºC, the thermal-limiting circuit turns the internal power switches off and allows the IC to cool. The hysteretic of the over temperature protection is 20°C (typ).

Output Over Voltage Protection

If the feedback resistor is floating or other situation is happened to make the output voltage is higher than output over voltage protection threshold V_{OUT_OVP}, the output over voltage protection function will be activated. While the output over voltage protection function is activated, the AIC2873B will stops switching and the output voltage will reduce to 0V. The typical output over voltage protection threshold V_{OUT_OVP} is 5.8V.

100% Duty Cycle Operation

When the input voltage approaches the output voltage, the AIC2873B smoothly transits to 100% duty cycle operation. This allows AIC2873B to regulate the output voltage until AIC2873B completely enters 100% duty cycle operation. In 100% duty cycle mode, the output voltage is equal to the input voltage minus the voltage, which is the drop across the main power switch.

The AIC2873B achieves 100% duty cycle operation by extending the turn-on time of the main power switch. While the input voltage approaches the output voltage, the switching frequency of power switches reduces gradually to smoothly transit to 100% duty cycle operation.

If input voltage is very close to output voltage, the switching mode goes from adaptive on-time control mode to 100% duty cycle operation. During this transient state mentioned above, large output ripple voltage may appear on output terminal.

Inductor

The inductor selection depends on the current ripple of inductor, the input voltage and the output voltage.

$$L \geq \frac{V_{OUT}}{f_{SW} \cdot \Delta I_L}\left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Accepting a large current ripple of inductor allows the use of a smaller inductance. However, higher current ripple of inductor can cause higher output ripple voltage and large core loss. By setting an acceptable current ripple of inductor, a suitable inductance can be obtained from above equation.

In addition, it is important to ensure the inductor saturation current exceeds the peak value of inductor current in application to prevent core saturation. The peak value of inductor current can be calculated according to the following equation.

$$I_{PEAK} = I_{OUT(max)} + \frac{V_{OUT}}{2 \times f_{SW} \cdot L}\left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Input Capacitor and Output Capacitor

To prevent the high input voltage ripple and noise resulted from high frequency switching, the use of low ESR ceramic capacitor for the maximum RMS current is recommended. The approximated RMS current of the input capacitor can be calculated according to the following equation.

$$I_{CINRMS} \approx \sqrt{I^2_{OUT(MAX)} \times \frac{V_{OUT}\left(V_{IN} - V_{OUT}\right)}{V^2_{IN}} + \frac{\Delta I^2_L}{12}}$$

At least a 10μF ceramic capacitor is suggested for the input capacitor.

In order to avoid the high input voltage spike to damage the device and noise coupling, a 0.1μF input bypass capacitor must be placed from VIN to GND. The

0.1μF input bypass capacitor and the input capacitor should be placed as close to the IC as possible for the best.

The selection of output capacitor depends on the required output voltage ripple. The output voltage ripple can be expressed as:

$$\Delta V_{OUT} = \frac{\Delta I_L}{8 \times f_{OSC} \cdot C_{OUT}} + ESR \cdot \Delta I_L$$

For lower output voltage ripple, the use of low ESR ceramic capacitor is recommended. The tantalum capacitor can also be used well, but its ESR is larger than that of ceramic capacitor. 22μF ceramic capacitor will be needed for the output capacitor.

When choosing the input and output ceramic capacitors, X5R and X7R types are recommended because they retain their capacitance over wider ranges of voltage and temperature than other types.

Setting the Output Voltage

The output voltage is set using a resistive voltage divider connected from the output voltage to FB. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \frac{R_2}{R_1 + R_2}$$

Thus the output voltage is:

$$V_{OUT} = V_{REF} \times \frac{R_1 + R_2}{R_2}$$

For example, for a 3.3V output voltage and V_{REF}=0.8V, R_2 is 240kΩ, and R_1 is 750kΩ.

Layout Consideration

In order to ensure a proper operation of AIC2873B, the following points should be managed comprehensively.

1. The 0.1μF input bypass capacitor, input capacitor and VIN should be placed as close as possible to each other to reduce the input voltage ripple and noise.
2. The output loop, which is consisted of the inductor, the internal power switch and the output capacitor, should be kept as small as possible.
3. The routes with large current should be kept short and wide.
4. Logically the large current on the converter should flow at the same direction.
5. In order to prevent the effect from noise, the IC's GND pin should be placed close to the ground of the input bypass capacitor.
6. The FB pin should be connected to the feedback resistors directly and the route should be away from the noise sources.

APPLICATION EXAMPLES

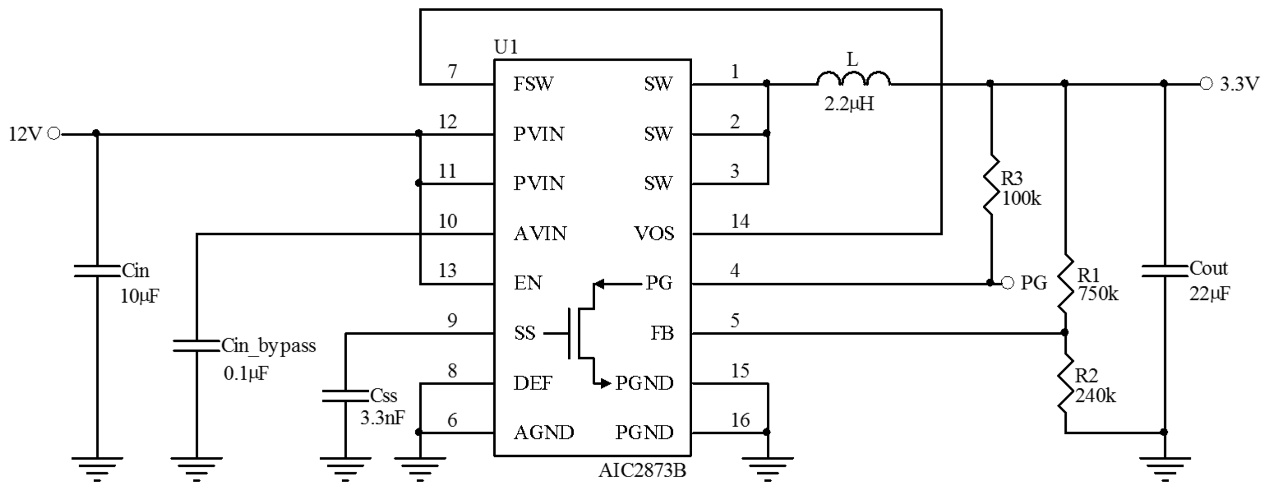
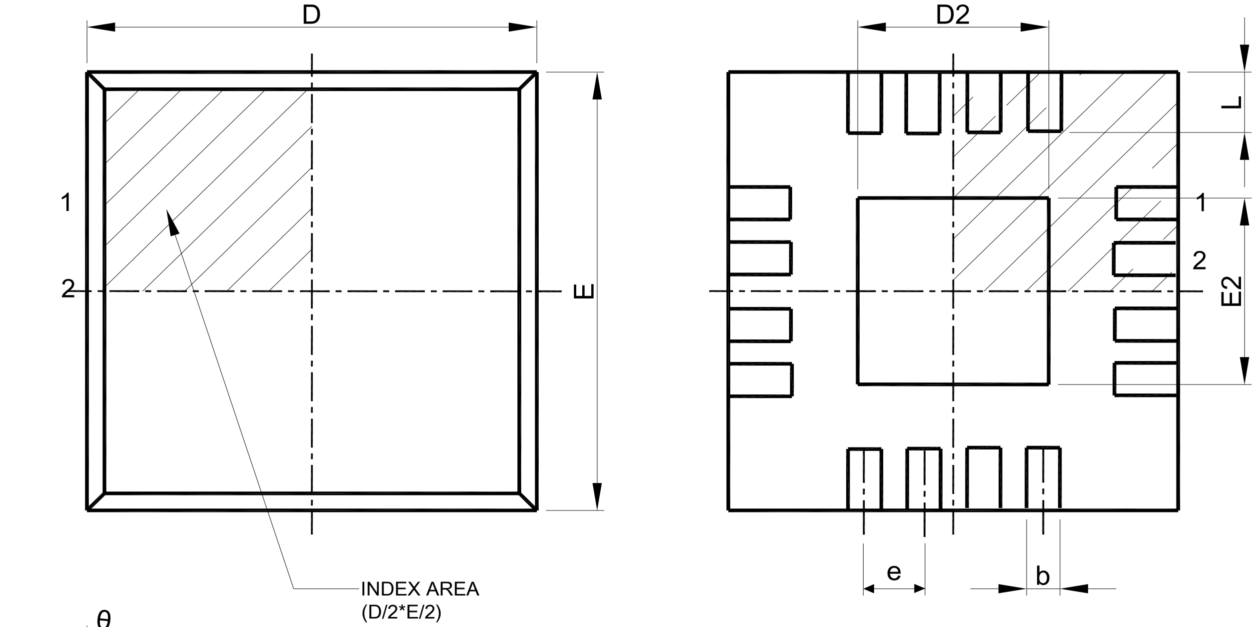
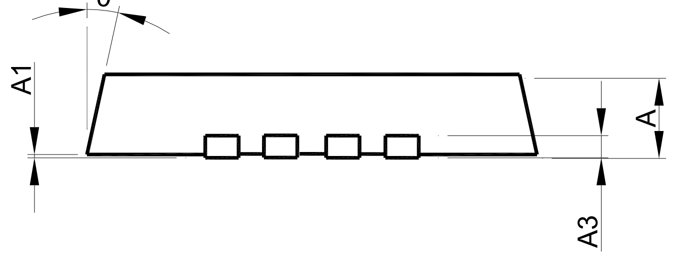


Fig. 19 Discharge Output Capacitor Through PG Pin

■ PHYSICAL DIMENSIONS

● **QFN-16 (3x3x0.75-0.5)**





SYMBOL	QFN-16 (3x3x0.75-0.5)	
	MILLIMETERS	
	MIN.	MAX.
A	0.70	0.80
A1	0.00	0.05
A3	0.20 REF	
b	0.18	0.30
D	2.90	3.10
D2	1.05	1.80
E	2.90	3.10
E2	1.05	1.80
e	0.50 BSC	
L	0.30	0.55
θ	0	14

Note: 1. Refer to JEDEC MO-220 WEED-4,6,7
2. All dimensions are in millimeters, θ is in degrees.