High Efficiency Selectable Current Limit Synchronous Step-Up DC/DC Converter

FEATURES

- High Efficiency 93% (V_{IN}=2.4V, V_{OUT}=3.3V, I_{OUT}=200mA).
- Output Current up to 500mA. (V_{IN}=2.4V, at V_{OUT}=3.3V, CLSEL=OUT)
- 20μA Quiescent Supply Current.
- Power-Saving Shutdown Mode (0.1μA typical).
- Internal Synchronous Rectifier (no external diode)
- Selectable Current Limit for Reduced Ripple
- Low Noise , Anti-Ringing Feature
- On-Chip Low Battery Detector.
- Low Battery Hysteresis
- Space-Saving Package: MSOP-10

APPLICATIONS

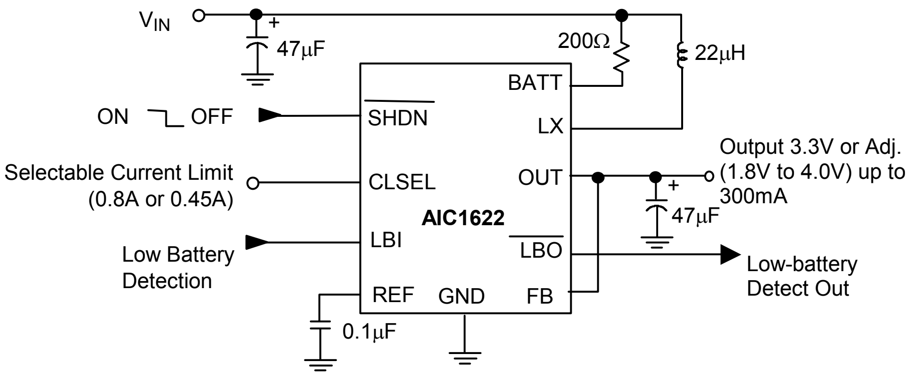
- Palmtop & Notebook Computers.
- PDAs
- Wireless Phones
- Pocket Organizers.
- Digital Cameras.
- Hand-Held Devices with 1 to 2-Cell of NiMH/NiCd Batteries.

DESCRIPTION

The AIC1622 is a high efficiency step up DC-DC converter. The start-up voltage is as low as 0.8V and operate with an input voltage down to 0.7V. Consuming only 20μA of quiescent current. These devices 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 ranging from 1.8V to 4.0V can be easily set by two external resistors, connecting FB to OUT to get 3.3V. In terms of design flexibility, the peak current of internal switch is selectable (0.45A or 0.8A). AIC1622 also features a circuit that eliminates noise due to inductor ringing.

TYPICAL APPLICATION CIRCUIT



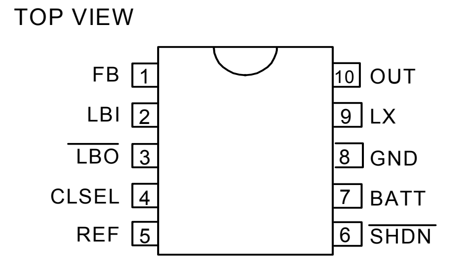
ORDERING INFORMATION

AIC1622XXXX

- PACKING TYPE
  TR: TAPE & REEL
- PACKAGING TYPE
  O: MSOP-10
- C: Commercial
  P: Lead Free Commercial

Example: AIC1622COTR
→ In MSOP-10 Package & Taping & Reel Packing Type
AIC1622POTR
→ In MSOP-10 Lead Free Package & Taping & Reel Packing Type

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS

Supply Voltage (OUT to GND)	8.0V
Switch Voltage (LX to GND)	V_{OUT}+ 0.3V
Battery Voltage (Batt to GND)	6.0V
$\overline{SHDN}$, LBO to GND	6.0V
LBI, REF, FB, CLSEL 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

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=OUT), R_L=∞, 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		4.0	V
Start-Up Voltage	R_L=3KΩ (Note2)			0.8	1.1	V
Start-Up Voltage Tempco				-2		mV/°C
Output Voltage Range			1.8		4.0	
Output Voltage	FB = V_{OUT}		3.17	3.3	3.43	V
Steady State Output Current (Note 3)	FB=OUT (V_{OUT} =3.3V)	CLSEL=OUT	300	400		mA
		CLSEL=GND	150	220		
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 100 μA			10	30	mV
Reference Line Regulation	V_{OUT} = 1.8V to 4V			5	10	mV/V
FB , LBI Input Threshold			1.199	1.23	1.261	V
Internal switch On-Resistance	I_{LX} = 100mA			0.3		Ω
LX Switch Current Limit	CLSEL=OUT		0.6	0.8	1.0	A
	CLSEL=GND		0.3	0.45	0.6	
LX Leakage Current	V_{LX}=0V, 4V; V_{OUT}=4V			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	1.3	μS
FB Input Current	V_{FB} = 1.4V			0.03	50	nA

ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
LBI Input Current	V_{LBI} = 1.4V		1	50	nA
CLSEL Input Current	CLSEL = OUT		1.4	3	μA
$\overline{SHDN}$ 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	
LBI Hystereisis			50		mV
Damping Switch Resistance	V_{IN} = 2V		50	100	Ω
$\overline{SHDN}$ Input Voltage	V_{IL}			0.2V_{OUT}	V
	V_{IH}	0.8V_{OUT}			
CLSEL 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

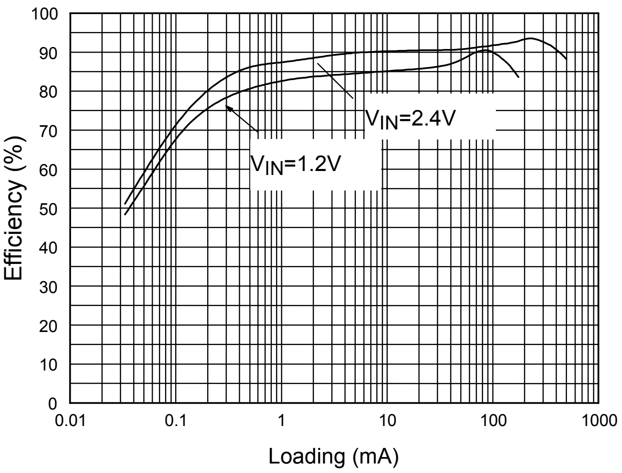


Fig. 1 V_{OUT}=3.3V, CLSEL=OUT (0.8A) (ref. to Fig.16)

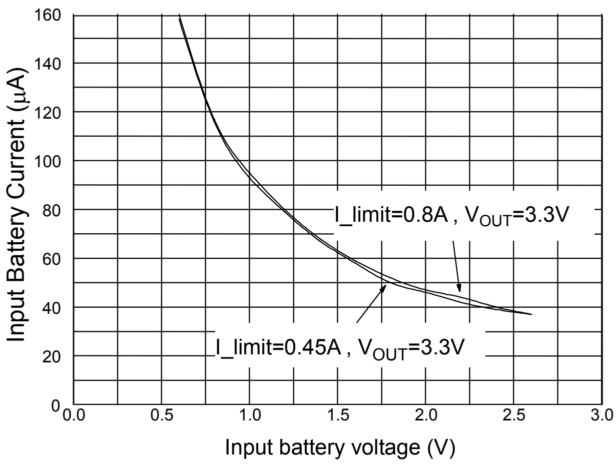


Fig. 2 No-Load Battery Current vs. Input Battery Voltage

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

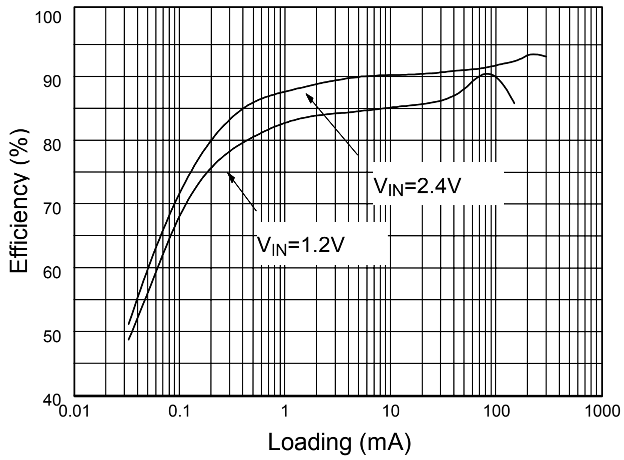


Fig. 3 V_{OUT}=3.3V, CLSEL=GND (0.45A) (ref. to Fig.16)

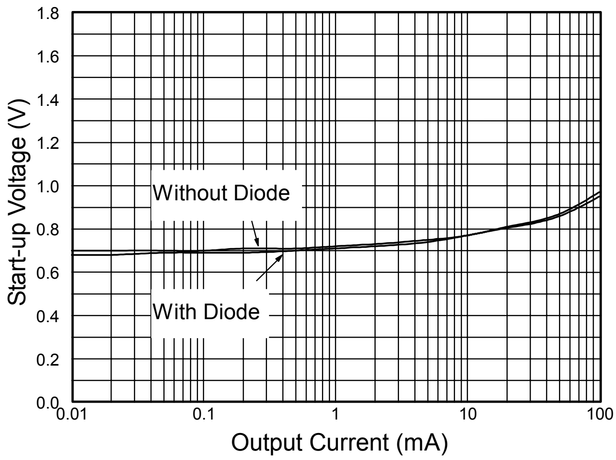


Fig. 4 Start-up Voltage vs. Output Current

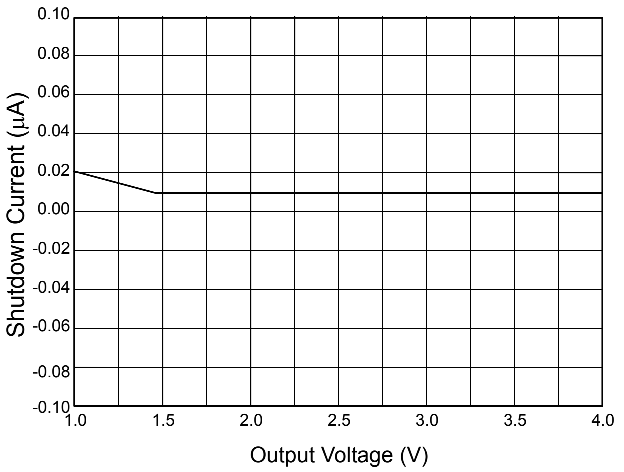


Fig. 5 Shutdown Current vs. Output Voltage

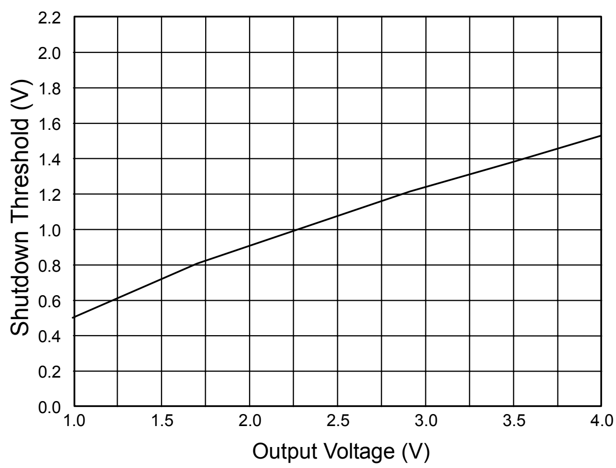


Fig. 6 Shutdown Threshold vs. Output Voltage

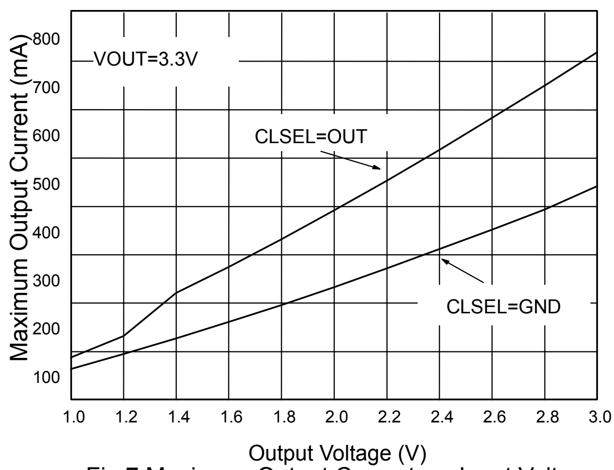


Fig.7 Maximum Output Current vs. Input Voltage

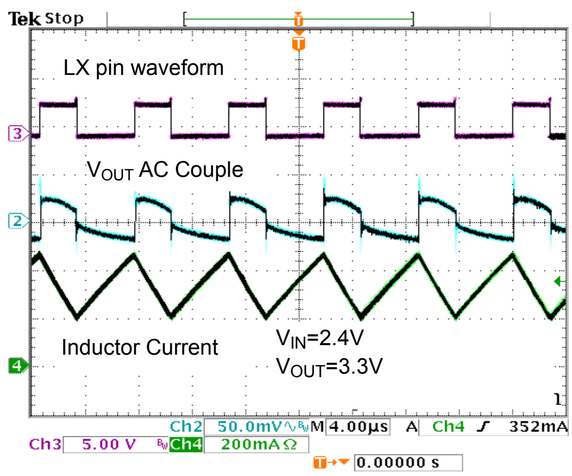


Fig. 8 Heavy Load Waveform

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

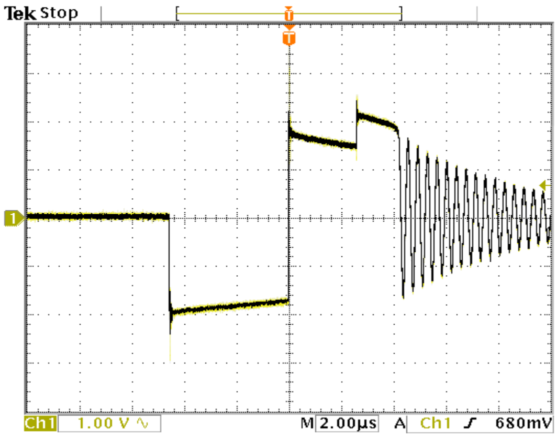


Fig. 9 Without Damping Ringing Function

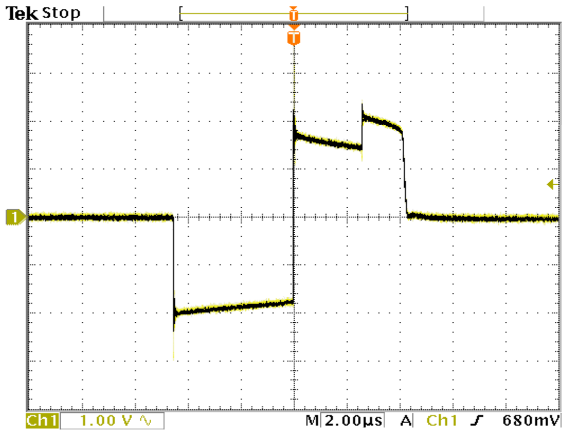


Fig. 10 With Damping Ringing Function

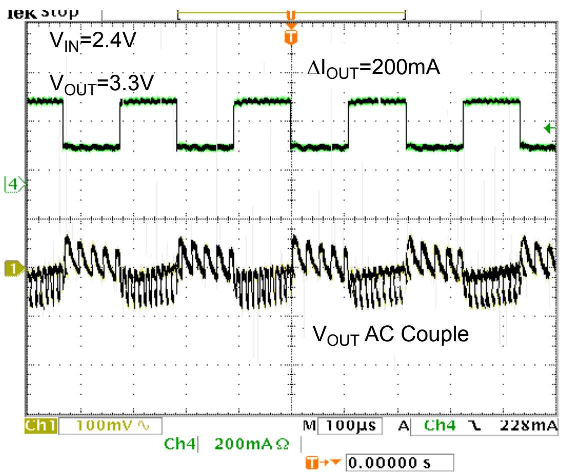
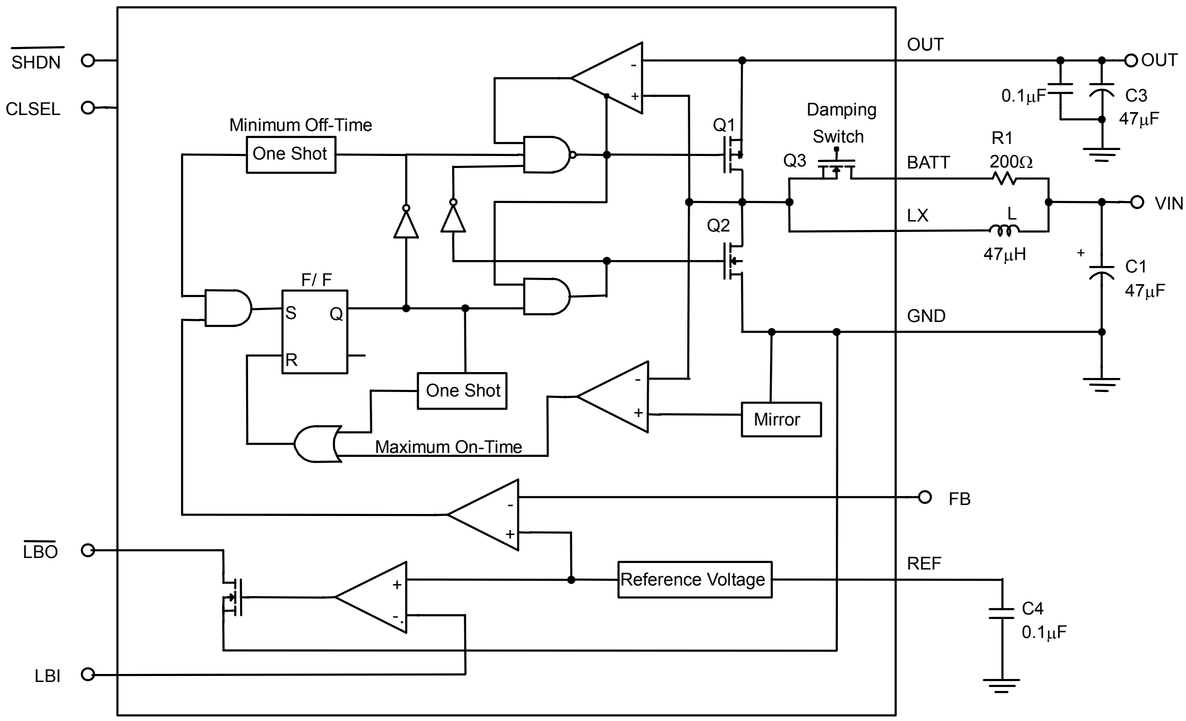


Fig. 11 Load Transient Response

■ BLOCK DIAGRAM



■ PIN DESCRIPTIONS

PIN 1: FB- Connecting to OUT to get +3.3V output, or using a resistor network to set output voltage ranging from +1.8V to +4.0V.

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

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

PIN 4: CLSEL- Current-limit selects input. CLSEL= OUT sets the current limit to 0.8A. CLSEL=GND sets the current limit to 0.45A.

PIN 5: REF- 1.23V reference voltage. Bypass with a 0.1μF capacitor.

PIN 6: $\overline{SHDN}$- Shutdown input. High=operating, low=shutdown.

PIN 7: BATT- Battery input and damping switch connection. If damping switch is unused, leave BATT unconnected.

PIN 8: GND- Ground.

PIN 9: LX- N-channel and P-channel power MOSFET drain.

PIN 10: OUT- Power output. OUT provides bootstrap power to the IC.

APPLICATION INFORMATION

Overview

AIC1622 is a high efficiency, step-up DC-DC converter, 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 AIC1622 is as low as 0.8V and it operates with an input voltage down to 0.7V. Quiescent supply current is only 20μA. In addition, AIC1622 features a circuit that eliminates inductor ringing to reduce noise. The internal P-MOSFET on-resistance is typically 0.3Ω to improve overall efficiency by minimizing AC losses. The output voltage ranging from 1.8V to 4.0V can be easily set by two external resistors, connecting FB to OUT to get 3.3V. CLSEL pin of AIC1622 offers a selectable current limit (0.8A or 0.45A). The lower current limit allows the use of a physically smaller inductor in space-sensitive applications.

PFM Control Scheme

The key feature of AIC1622 is a unique minimum-off-time, constant-on-time, current-limited, pulse-frequency-modulation (PFM) control scheme (see BLOCK DIAGRAM) with ultra-low quiescent current. The peak current of the internal N-MOSFET power switch is selectable. 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 is reduced. During the cycle of off-time, P-MOSFET turns on and shunts N-MOSFET. Due to the low turn-on resistance of MOSFET, the synchronous rectifier significantly improves efficiency without the addition of an external component. 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 the body diode of 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.

Current Limit Select Pin

AIC1622 allows a selectable inductor current limit of either 0.45A or 0.8A. The flexibility contributes to designs for higher current or smaller applications. CLSEL draws 1.4μA when connecting to OUT.

BATT/Damping Switch

AIC1622 is designed with an internal damping switch (Fig. 15) to reduce ringing at LX. The damping switch supplies a path to quickly dissipate the energy stored in inductor and reduces the ringing at LX. Damping LX ringing does not reduce V_{OUT} ripple, but does reduce EMI. R1=200Ω works well for most applications while reducing efficiency by only

1%. Larger R1 value provides less damping, but less impact on efficiency. In principle, lower value of R1 is needed to fully damp LX when V_{OUT} /V_{IN} ratio is high.

Selecting the Output Voltage

V_{OUT} can be simply set to 3.3V by connecting the FB pin to OUT due to internal resistor divider (Fig. 16). In order to adjust the output voltage, a resistor divider is connected to V_{OUT}, FB, GND (Fig. 17). Use the following equation to calculate:

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

Where V_{REF} =1.23V and V_{OUT} may range from 1.8V to 4V. The recommended R6 is 240KΩ.

Low-Battery Detection

AIC1622 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 AIC1620 series also work with inductors in the 10μH to 47μH range. An inductor with higher peak inductor current tends a higher output voltage ripple (I_{PEAK}×output filter capacitor ESR). The inductor's DC resistance significantly affects efficiency. We can calculate the maximum output current as follows:

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

   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}=0.45A or 0.8A

2. **Capacitor Selection**
   The output voltage ripple relates with the peak inductor current and the output capacitor ESR. Besides output ripple voltage, the output ripple current also needs to be concerned. The smaller the capacitor ESR is, the higher the ripple current will be. A filter capacitor with low ESR is helpful to the efficiency and steady state output current of AIC1622. Therefore NIPPON tantalum capacitor MCM series with 100μF/6V is recommended. A smaller capacitor (down to 47 μF with higher ESR) is acceptable for light loads or in applications that can tolerate higher output ripple.

3. **PCB Layout and Grounding**
   Since AIC1622 switching frequency can range up to 500kHz, it makes AIC1622 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. Following are the recommended layout diagrams.

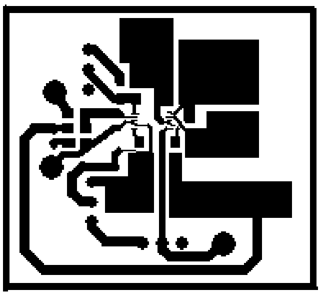


Fig.12 Top layer

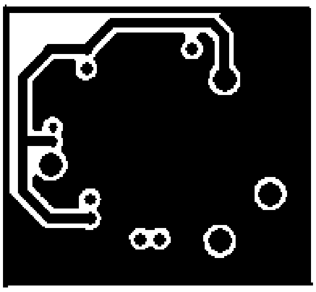


Fig.13 Bottom layer

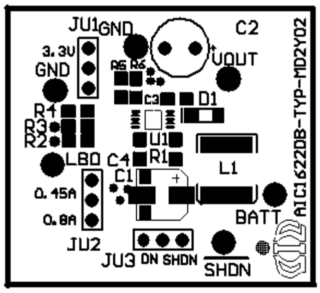


Fig.14 Placement

APPLICATION EXAMPLES

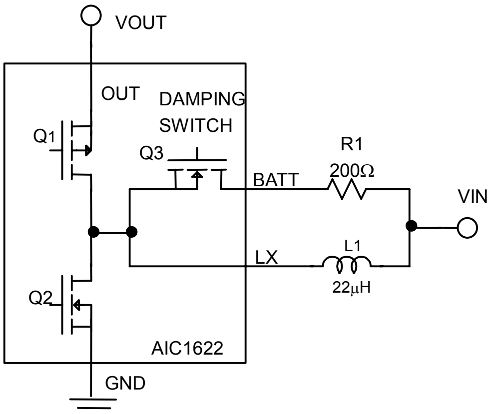
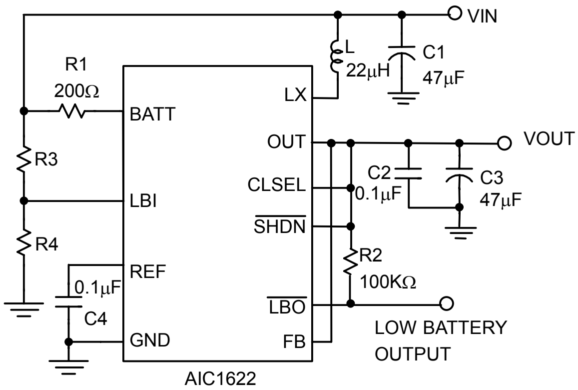


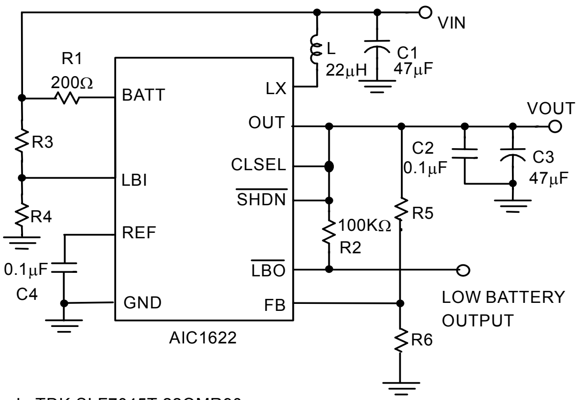
Fig.15 Simplified Damping Switch Diagram



L: TDK SLF7045T-22OMR90

C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

Fig.16 V_{OUT} = 3.3V Application Circuit.



L: TDK SLF7045T-22OMR90

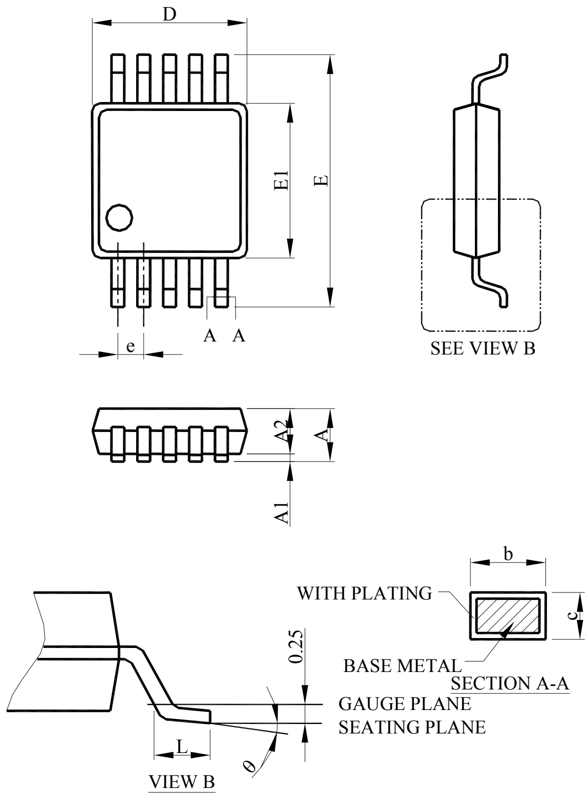
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

$V_{OUT}=V_{REF}*(1+R5/R6)$

Fig.17 An Adjustable Output Application Circuit

■ PHYSICAL DIMENSION (unit: mm)

- **MSOP-10**



SYMBOL	MSOP-10	
	MILLIMETERS	
	MIN.	MAX.
A		1.10
A1	0.05	0.15
A2	0.75	0.95
b	0.15	0.30
c	0.13	0.23
D	2.90	3.10
E	4.90 BSC	
E1	2.90	3.10
e	0.50 BSC	
L	0.40	0.70
θ	0°	6°

Note:

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