AAT1162
12V, 1.5A Step-Down DC/DC Converter

SwitchReg™

General Description

The AAT1162 is an 800kHz high efficiency step-down DC/DC converter. With a wide input voltage range of 4.0V to 13.2V, the AAT1162 is an ideal choice for dual-cell Lithium-ion battery-powered devices and mid-power-range regulated 12V-powered industrial applications. The internal power switches are capable of delivering up to 1.5A to the load.

The AAT1162 is a highly integrated device, simplifying system-level design. Minimum external components are required for the converter.

The AAT1162 optimizes efficiency throughout the entire load range. It operates in a combination PWM/Light Load mode for improved light-load efficiency. The high switching frequency allows the use of small external components. The low current shutdown feature disconnects the load from V_{IN} and drops shutdown current to less than 1µA.

The AAT1162 is available in a Pb-free, space-saving, thermally-enhanced 16-pin TDFN34 package and is rated over an operating temperature range of -40°C to +85°C.

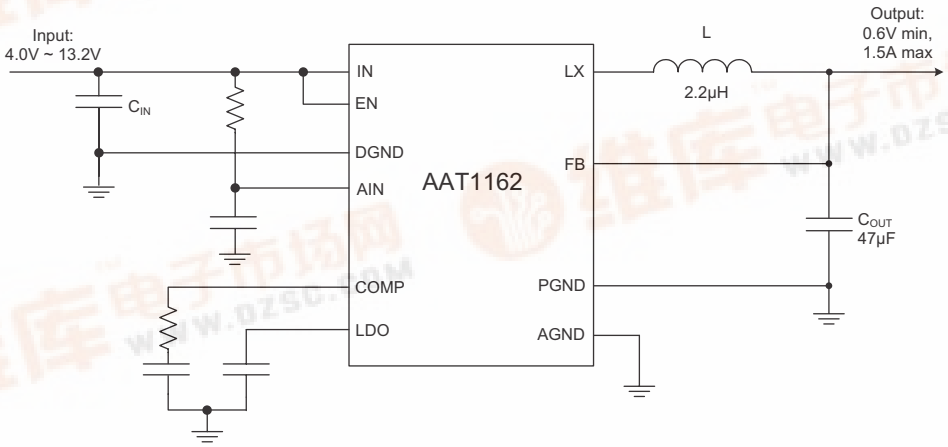
Features

- Input Voltage Range: 4.0V to 13.2V
- Up to 1.5A Load Current
- Fixed or Adjustable Output:
  - Output Voltage: 0.6V to V_{IN}
- Low 115µA No-Load Operating Current
- Less than 1µA Shutdown Current
- Up to 96% Efficiency
- Integrated Power Switches
- 800kHz Switching Frequency
- Soft Start Function
- Short-Circuit and Over-Temperature Protection
- Minimum External Components
- TDFN34-16 Package
- Temperature Range: -40°C to +85°C

Applications

- Distributed Power Systems
- Industrial Applications
- Laptop Computers
- Portable DVD Players
- Portable Media Players
- Set-Top Boxes
- TFT LCD Monitors and HDTVs

Typical Application

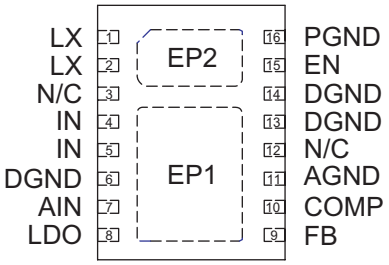


Pin Descriptions

Pin #	Symbol	Function
1, 2, EP2	LX	Power switching node. LX is the drain of the internal P-channel switch and N-channel synchronous rectifier. Connect the output inductor to the two LX pins and to EP2. A large exposed copper pad under the package should be used for EP2.
3, 12	N/C	Not connected.
4, 5	IN	Power source input. Connect IN to the input power source. Bypass IN to DGND with a 22µF or greater capacitor. Connect both IN pins together as close to the IC as possible. An additional 100nF ceramic capacitor should also be connected between the two IN pins and DGND, pin 6
6, 13, 14, EP1	DGND	Exposed Pad 1 Digital Ground, DGND. The exposed thermal pad (EP1) should be connected to board ground plane and pins 6, 13, and 14. The ground plane should include a large exposed copper pad under the package for thermal dissipation (see package outline).
7	AIN	Internal analog bias input. AIN supplies internal power to the AAT1162. Connect AIN to the input source voltage and bypass to AGND with a 0.1µF or greater capacitor. For additional noise rejection, connect to the input power source through a 10Ω or lower value resistor.
8	LDO	Internal LDO bypass node. The output voltage of the internal LDO is bypassed at LDO. The internal circuitry of the AAT1162 is powered from LDO. Do not draw external power from LDO. Bypass LDO to AGND with a 1µF or greater capacitor.
9	FB	Output voltage feedback input. FB senses the output voltage for regulation control. For fixed output versions, connect FB to the output voltage. For adjustable versions, drive FB from the output voltage through a resistive voltage divider. The FB regulation threshold is 0.6V.
10	COMP	Control compensation node. Connect a series RC network from COMP to AGND, R = 51k and C = 270pF.
11	AGND	Analog signal ground. Connect AGND to PGND at a single point as close to the IC as possible.
15	EN	Active high enable input. Drive EN high to turn on the AAT1162; drive it low to turn it off. For automatic startup, connect EN to IN through a 4.7kΩ resistor. EN must be biased high, biased low, or driven to a logic level by an external source. Do not let the EN pin float when the device is powered.
16	PGND	Power ground. Connect AGND to PGND at a single point as close to the IC as possible.

Pin Configuration

TDFN34-16
(Top View)



Absolute Maximum Ratings[1]

Symbol	Description	Value	Units
$V_{IN,}$ V_{AIN}	Input Voltage	-0.3 to 14	V
V_{LX}	LX to GND Voltage	-0.3 to V_{IN} + 0.3	V
V_{FB}	FB to GND Voltage	-0.3 to V_{IN} + 0.3	V
V_{EN}	EN to GND Voltage	-0.3 to V_{IN} + 0.3	V
T_J	Operating Junction Temperature Range	-40 to 150	°C

Thermal Information[3]

Symbol	Description	Value	Units
P_D	Maximum Power Dissipation[4]	2.7	W
θ_{JA}	Thermal Resistance	37	°C/W

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Based on long-term current density limitation.
3. Mounted on an FR4 board.
4. Derate 2.7mW/°C above 25°C.

Electrical Characteristics[1]

4.0V < V_{IN} < 13.2V. C_{IN} = C_{OUT} = 22µF; L = 4.7µH, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C.

Symbol	Description	Conditions		Min	Typ	Max	Units
V_{IN}	Input Voltage Range			4.0		13.2	V
V_{UVLO}	Input Under-Voltage Lockout	Rising				4.0	V
		Hysteresis			0.3		
I_Q	Supply Current	No Load			115	200	µA
I_{SHDN}	Shutdown Current	V_{EN} = GND				1	µA
V_{OUT}	Output Voltage Range			0.6		0.94 V_{IN}	V
V_{OUT}	Output Voltage Accuracy	I_{OUT} = 0A to 1.5A		-2.5		2.5	%
$\Delta V_{OUT}/V_{OUT}/\Delta V_{IN}$	Line Regulation	V_{IN} = 4.5V to 13.2V			0.023	0.100	%/V
$\Delta V_{OUT}/I_{OUT}$	Load Regulation	V_{IN} = 12V, V_{OUT} = 5V, I_{OUT} = 0A to 1.5A			0.4		%
V_{FB}	Feedback Reference Voltage (adjustable version)	No Load, T_A = 25°C		0.59	0.60	0.61	V
I_{FBLEAK}	FB Leakage Current	V_{OUT} = 1.2V	Adjustable Version			0.2	µA
			Fixed Version		2		
F_{OSC}	PWM Oscillator Frequency			0.6	0.8	1	MHz
	Foldback Frequency				200		kHz
DC	Maximum Duty Cycle					94	%
T_{ON}	Minimum Turn-On Time				100		ns
T_S	Soft-Start Time				200		µs
$R_{DS(ON)H}$	P-Channel On Resistance	V_{IN} = 12V			0.12		Ω
		V_{IN} = 6V			0.15		
$R_{DS(ON)L}$	N-Channel On Resistance	V_{IN} = 12V			0.06		Ω
		V_{IN} = 6V			0.08		
η	Efficiency	V_{IN} = 12V, V_{OUT} = 5V, I_{OUT} = 1.5A			93		%
I_{LIM}	PMOS Current Limit			2.0	3.0		A
I_{LXLEAK}	LX Leakage Current	V_{IN} = 13.2V, V_{LX} = 0 to V_{IN}				1	µA

1. The AAT1162 is guaranteed to meet performance specifications over the -40°C to +85°C operating temperature range and is assured by design, characterization, and correlation with statistical process controls.

Electrical Characteristics[1]

4.0V < V_{IN} < 13.2V. C_{IN} = C_{OUT} = 22µF; L = 4.7µH, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = 25°C.

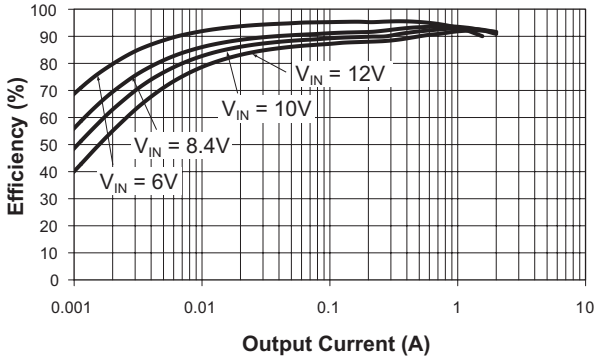
Symbol	Description	Conditions	Min	Typ	Max	Units
T_{SD}	Over-Temperature Shutdown Threshold			140		°C
T_{HYS}	Over-Temperature Shutdown Hysteresis			25		°C
V_{IL}	EN Logic Low Input Threshold				0.4	V
V_{IH}	EN Logic High Input Threshold		1.4			V
I_{EN}	EN Input Current	V_{EN} = 0V, V_{EN} = 13.2V	-1.0		1.0	µA

1. The AAT1162 is guaranteed to meet performance specifications over the -40°C to +85°C operating temperature range and is assured by design, characterization, and correlation with statistical process controls.

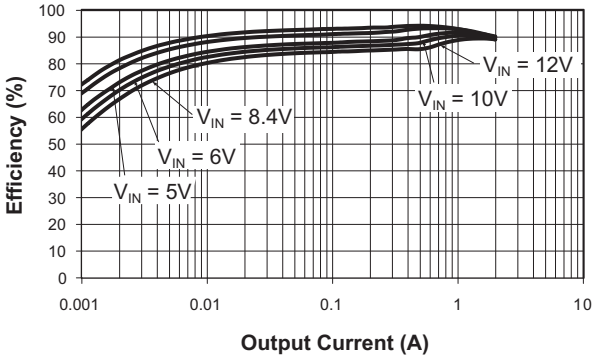
Typical Characteristics

Test circuit of Figure 2, unless otherwise specified.

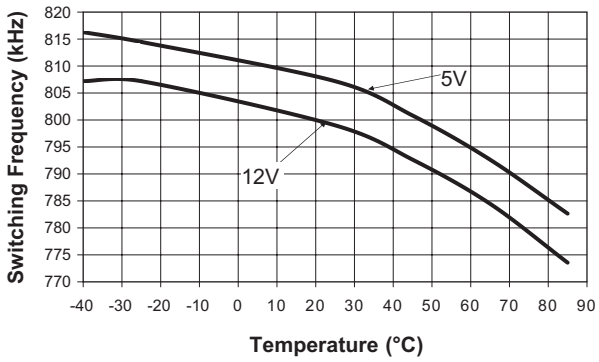
Efficiency vs. Output Current
(V_{OUT} = 5V)



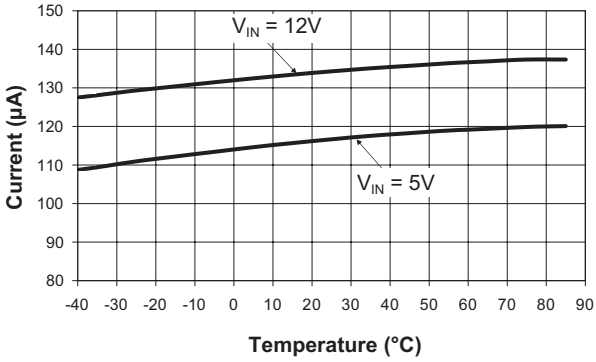
Efficiency vs. Output Current
(V_{OUT} = 3.3V)



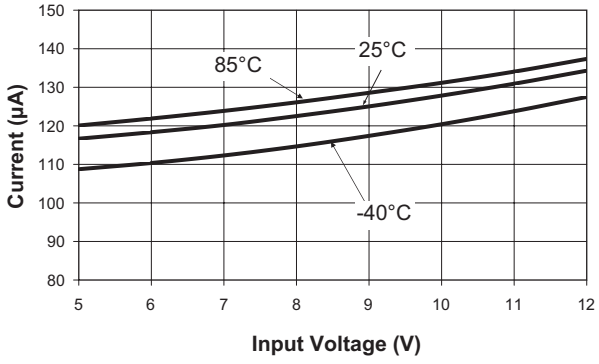
Switching Frequency vs. Temperature



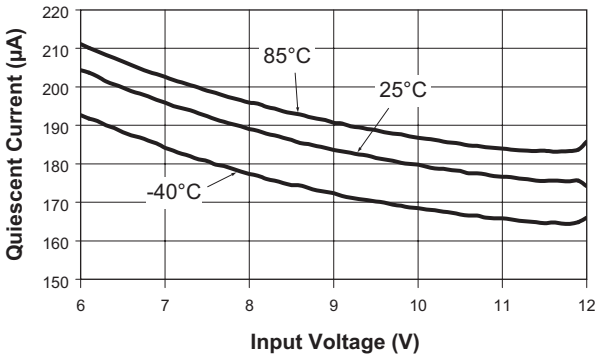
Non-Switching Quiescent Current vs. Temperature



Non-Switching Quiescent Current vs. Input Voltage



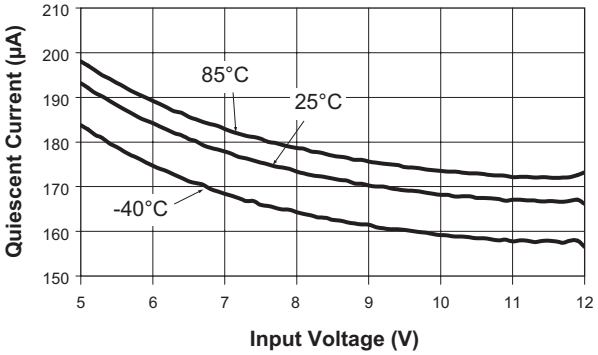
Switching Quiescent Current vs. Input Voltage
(V_{OUT} = 5V)



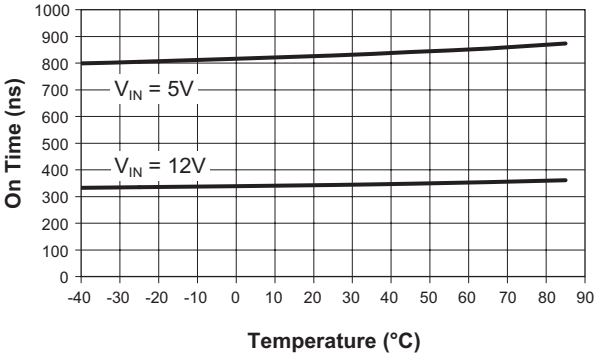
Typical Characteristics

Test circuit of Figure 2, unless otherwise specified.

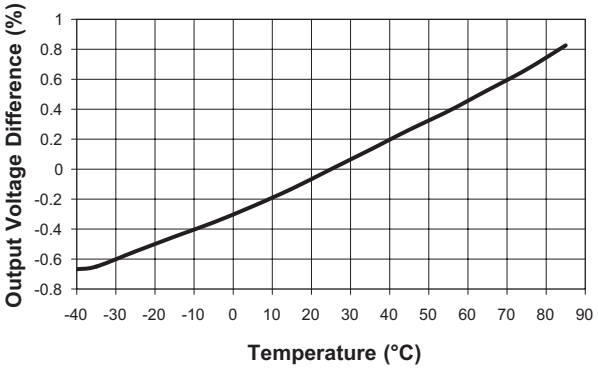
Switching Quiescent Current vs. Input Voltage
(V_{OUT} = 3.3V)



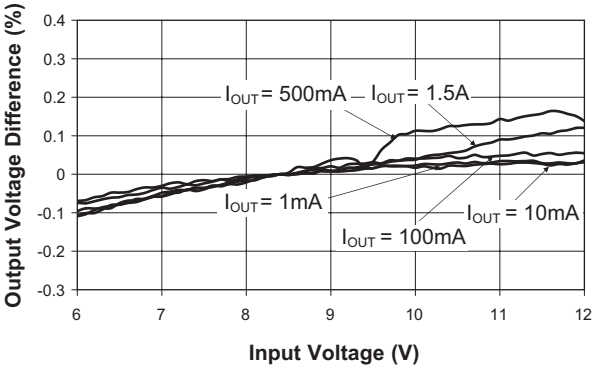
On Time vs. Temperature
(V_{OUT} = 3.3V)



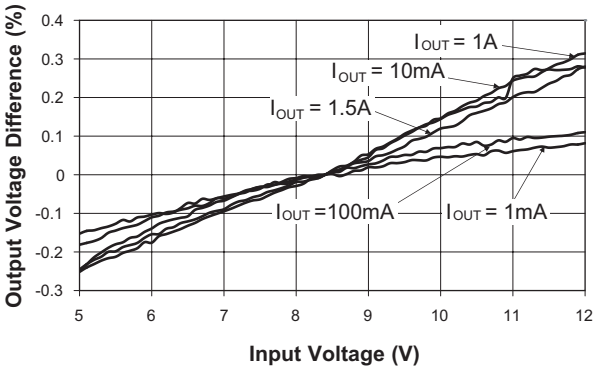
Output Voltage Tolerance vs. Temperature
(V_{OUT} = 3.3V; I_{LOAD} = 1.5A)



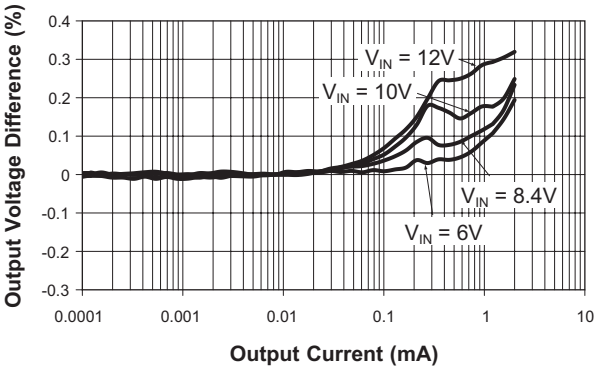
Line Regulation
(V_{OUT} = 5V)



Line Regulation
(V_{OUT} = 3.3V)



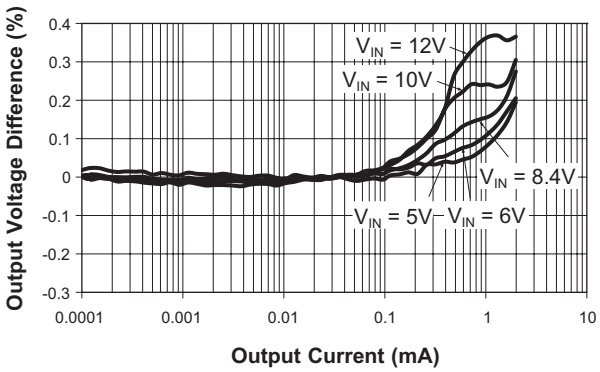
Load Regulation
(V_{OUT} = 5V)



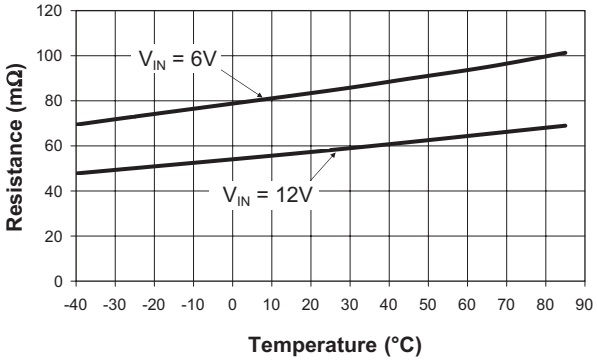
Typical Characteristics

Test circuit of Figure 2, unless otherwise specified.

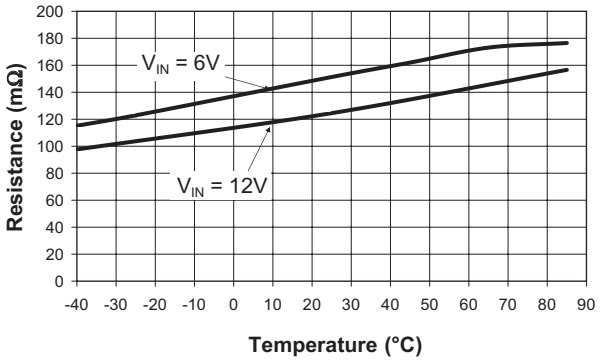
Load Regulation
(V_{OUT} = 3.3V)



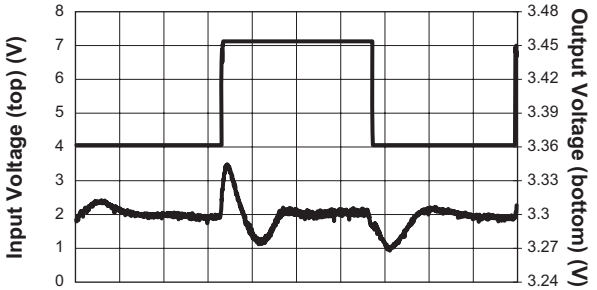
N-Channel $R_{DS(ON)}$ vs. Temperature



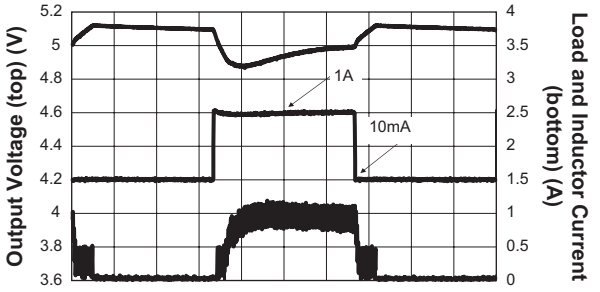
P-Channel $R_{DS(ON)}$ vs. Temperature



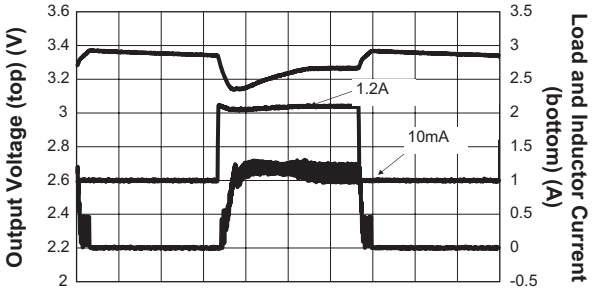
Line Transient
(V_{OUT} = 3.3V; C_{FF} = 100pF)



Load Transient
(V_{OUT} = 5V; C_{FF} = 100pF)



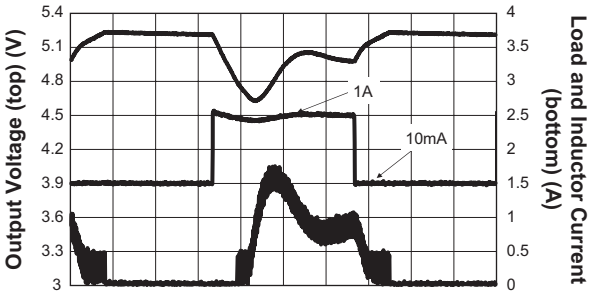
Load Transient
(V_{OUT} = 3.3V; C_{FF} = 100pF)



Typical Characteristics

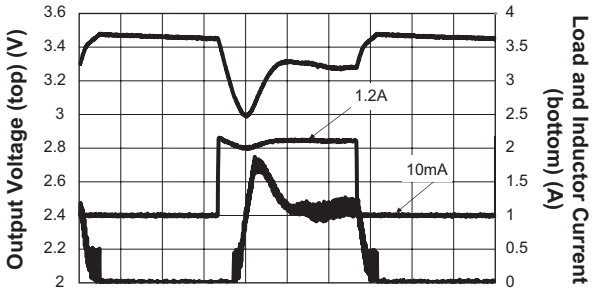
Test circuit of Figure 2, unless otherwise specified.

Load Transient
(V_{OUT} = 5V; No C_{FF})



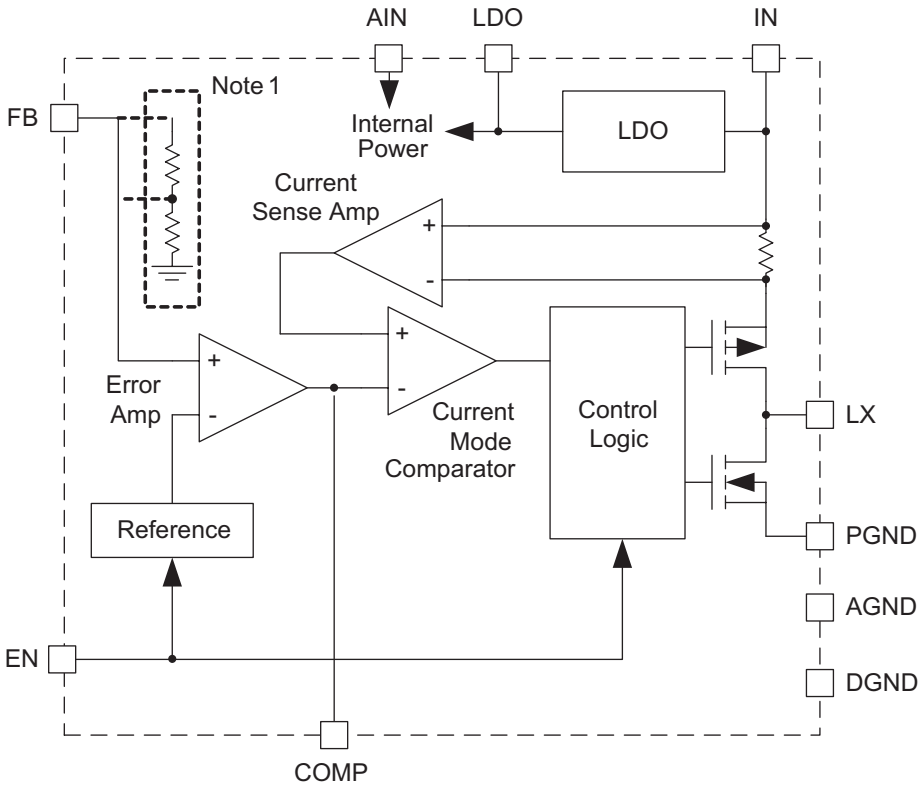
Time (50µs/div)

Load Transient
(V_{OUT} = 3.3V; No C_{FF})



Time (50µs/div)

Functional Block Diagram



Note 1: For fixed output voltage versions, FB is connected to the error amplifier through the resistive voltage divider shown.

Functional Description

The AAT1162 is a current-mode step-down DC/DC converter that operates over a wide 4V to 13.2V input voltage range and is capable of supplying up to 1.5A to the load with the output voltage regulated as low as 0.6V. Both the P-channel power switch and N-channel synchronous rectifier are internal, reducing the number of external components required. The output voltage is adjusted by an external resistor divider; fixed output voltage versions are available upon request. The regulation system is externally compensated, allowing the circuit to be optimized for each application. The AAT1162 includes cycle-by-cycle current limiting, frequency foldback for improved short-circuit performance, and thermal overload protection to prevent damage in the event of an external fault condition.

Control Loop

The AAT1162 regulates the output voltage using constant frequency current mode control. The AAT1162 monitors current through the high-side P-channel MOSFET and uses that signal to regulate the output voltage. This provides improved transient response and eases compensation. Internal slope compensation is included to ensure the current "inside loop" stability.

High efficiency is maintained under light load conditions by automatically switching to variable frequency Light Load control. In this condition, transition losses are reduced by operating at a lower frequency at light loads.

Short-Circuit Protection

The AAT1162 uses a cycle-by-cycle current limit to protect itself and the load from an external fault condition. When the inductor current reaches the internally set 3.0A current limit, the P-channel MOSFET switch turns off and the N-channel synchronous rectifier is turned on, limiting the inductor and the load current.

During an overload condition, when the output voltage drops below 50% of the regulation voltage (0.3V at FB), the AAT1162 switching frequency drops by a factor of 4. This gives the inductor current ample time to reset during the off time to prevent the inductor current from rising uncontrolled in a short-circuit condition.

Thermal Protection

The AAT1162 includes thermal protection that disables the regulator when the die temperature reaches 140ºC. It automatically restarts when the temperature decreases by 25ºC or more.

Applications Information

Setting the Output Voltage

Figure 1 shows the basic application circuit for the AAT1162 and output setting resistors. Resistors R1 and R2 program the output to regulate at a voltage higher than 0.6V. To limit the bias current required for the external feedback resistor string while maintaining good noise immunity, the minimum suggested value for R2 is 5.9kΩ. Although a larger value will further reduce quiescent current, it will also increase the impedance of the feedback node, making it more sensitive to external noise and interference. Table 1 summarizes the resistor values for various output voltages with R2 set to either 5.9kΩ for good noise immunity or 59kΩ for reduced no load input current.

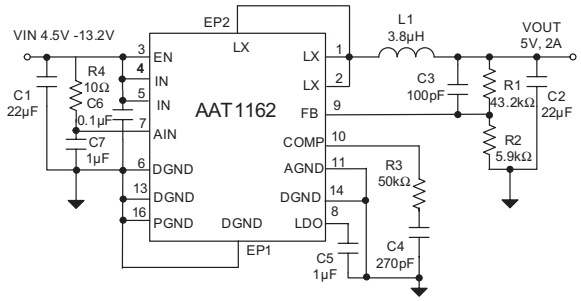


Figure 1: Typical Application Circuit.

The adjustable feedback resistors, combined with an external feed forward capacitor (C3 in Figure 1), deliver enhanced transient response for extreme pulsed load applications. The addition of the feed forward capacitor typically requires a larger output capacitor C2 for stability. Larger C3 values reduce overshoot and undershoot during startup and load changes. However, do not exceed 470pF to maintain stable operation.

The external resistors set the output voltage according to the following equation:

$$V_{OUT} = 0.6V \left(1 + \frac{R1}{R2}\right)$$

or

$$R1 = \left(\frac{V_{OUT}}{V_{REF}} - 1\right) \cdot R2$$

Table 1 shows the resistor selection for different output voltage settings.

V_{OUT} (V)	R2 = 5.9(kΩ) R1 (kΩ)	R2 = 59(kΩ) R1 (kΩ)
0.8	1.96	19.6
0.9	2.94	29.4
1.0	3.92	39.2
1.1	4.99	49.9
1.2	5.90	59.0
1.3	6.81	68.1
1.4	7.87	78.7
1.5	8.87	88.7
1.8	11.8	118
1.85	12.4	124
2.0	13.7	137
2.5	18.7	187
3.3	26.7	267
5.0	43.2	432

Table 1: Resistor Selection for Different Output Voltage Settings. Standard 1% Resistors are Substituted for Calculated Values.

Inductor Selection

For most designs, the AAT1162 operates with inductors of 2µH to 4.7µH. For output voltages above 3.3V, the minimum recommended inductor is 3.8µH. For 3.3V and below, use a 2 to 2.2µH inductor. For optimum voltage-positioning load transients, choose an inductor with DC series resistance in the 15mΩ to 20mΩ range. For higher efficiency at heavy loads (above 1A), or minimal load regulation (but some transient overshoot), the resistance should be kept below 18mΩ. The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation (1.5A + 263mA). Table 2 lists some typical surface mount inductors that meet target applications for the AAT1162.

Manufacturer's specifications list both the inductor DC current rating, which is a thermal limitation, and the peak current rating, which is determined by the saturation characteristics. The inductor should not show any appreciable saturation under normal load conditions. Some inductors may meet the peak and average current ratings yet result in excessive losses due to a high DCR. Always consider the losses associated with the DCR and its effect on the total converter efficiency when selecting an inductor. For example, the 3.7µH CDR7D43 series inductor selected from Sumida has an 18.9mΩ DCR and a 4.3ADC current rating. At full load, the inductor DC loss is 28mW which gives only a 0.4% loss in efficiency for a 1.5A, 5V output.

Compensation

The AAT1162 step-down converter uses peak current mode control with slope compensation scheme to maintain stability with lower value inductors for duty cycles greater than 50%. The regulation feedback loop in the IC is stabilized by the components connected to the COMP pin, as shown in Figure 1.

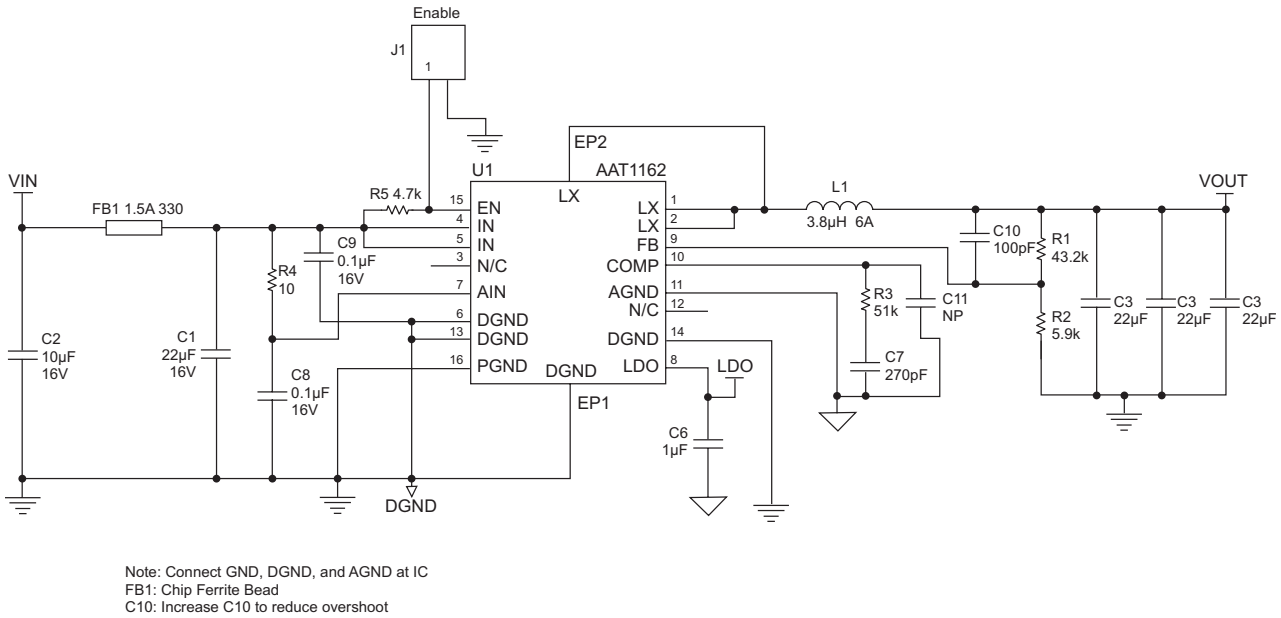
Manufacturer	Part Number	L (µH)	Max DCR (mΩ)	Rated DC Current (A)	Size WxLxH (mm)
Sumida	CDRH103RNP-2R2N	2.2	16.9	5.10	10.3x10.5x3.1
Sumida	CDR7D43MNNP-3R7NC	3.7	18.9	4.3	7.6x7.6x4.5
Coilcraft	MSS1038-382NL	3.8	13	4.25	10.2x7.7x3.8

Table 2: Typical Surface Mount Inductors.

Layout Guidance

Figure 2 is the schematic for the evaluation board. When laying out the PC board, the following layout guideline should be followed to ensure proper operation of the AAT1162:

1. Exposed pad EP1 must be reliably soldered to PGND/DGND/AGND. The exposed thermal pad should be connected to board ground plane and pins 6, 11, 13, 14 and 16. The ground plane should include a large exposed copper pad under the package for thermal dissipation.
2. The power traces, including GND traces, the LX traces and the VIN trace should be kept short, direct and wide to allow large current flow. The L1 connection to the LX pins should be as short as possible. Use several via pads when routing between layers.
3. Exposed pad pin EP2 must be reliably soldered to the LX pins 1 and 2. The exposed thermal pad should be connected to the board LX connection and the inductor L1 and also pins 1 and 2. The LX plane should include a large exposed copper pad under the package for thermal dissipation.
4. The input capacitors (C9 and C1) should be connected as close as possible to IN (Pins 4 and 5) and DGND (Pin 6) to get good power filtering.
5. Keep the switching node LX away from the sensitive FB node.
6. The feedback trace for the FB pin should be separate from any power trace and connected as closely as possible to the load point. Sensing along a high-current load trace will degrade DC load regulation. The feedback resistors should be placed as close as possible to the FB pin (Pin 9) to minimize the length of the high impedance feedback trace.
7. The output capacitors C3, 4, and 5 and L1 should be connected as close as possible and there should not be any signal lines under the inductor.
8. The resistance of the trace from the load return to the PGND (Pin 16) should be kept to a minimum. This will help to minimize any error in DC regulation due to differences in the potential of the internal signal ground and the power ground.



Note: Connect GND, DGND, and AGND at IC
FB1: Chip Ferrite Bead
C10: Increase C10 to reduce overshoot

Figure 2: AAT1162 Evaluation Board Schematic.

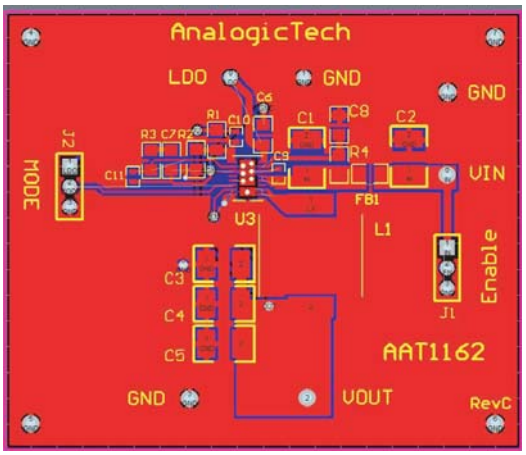


Figure 3: AAT1162 Evaluation Board Component Side Layout.

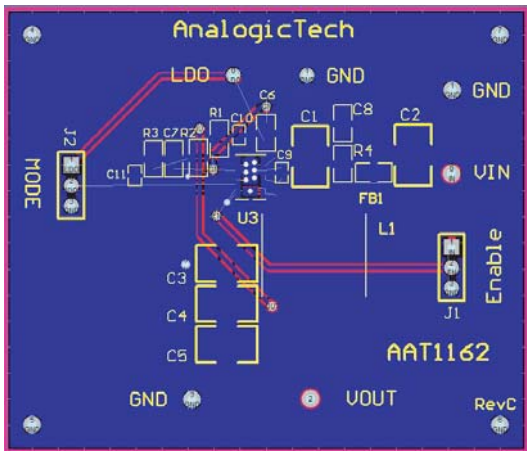


Figure 4: AAT1162 Evaluation Board Solder Side Layout.

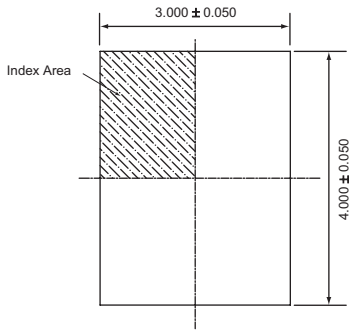
Ordering Information

Package	Marking[1]	Part Number (Tape and Reel)[2]
TDFN34-16	YYXYY	**AAT1162IRN-0.6-T1**

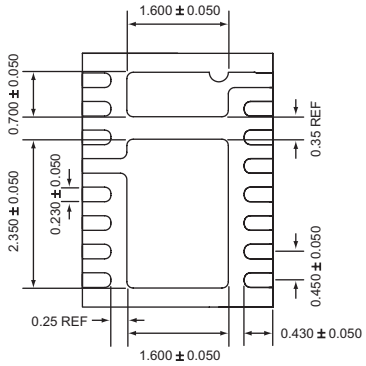
All AnalogicTech products are offered in Pb-free packaging. The term "Pb-free" means semiconductor products that are in compliance with current RoHS standards, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. For more information, please visit our website at http://www.analogictech.com/pbfree.

Package Information

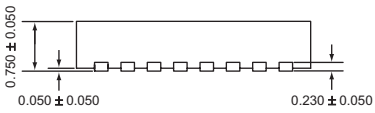
TDFN34-16



Top View



Bottom View



Side View

All dimensions in millimeters.

1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.

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