AAT1218

High Current, 1.2MHz Synchronous Boost Converterr

General Description

The AAT1218 is a general purpose DC/DC synchronous boost (step-up) converter providing a tightly regulated DC output voltage for continuous output currents up to 1A (minimum). The maximum peak current in the boost switch is limited to a value of 2A (minimum). Operating input voltage must be less than the output voltage and in the 0.5V to 5.5V range, making the device well suited to portable equipment and consumer appliances.

The boost output voltage is programmed from 2.5V to 5.5V with an external resistor divider. Optimized internal compensation provides fast transient response with no external components.

Synchronous rectification eliminates the need for an external rectifier for output voltage less than 4.5V. Low on-resistance internal switches provide efficiency up to 95%, which minimizes losses and simplifies packaging and circuit board layout. An inductor, two resistors and two ceramic output capacitors are all that are required to implement a DC/DC boost solution.

The switching frequency is internally set to 1.2MHz to minimize external filter size and optimize switching losses.

Integrated soft-start ensures minimal inrush current. The "anti-ring" circuit reduces stray EMI during light load, discontinuous operation. Input quiescent current is less than 400µA at no load.

The device provides cycle-by-cycle current limit and over-temperature protection to prevent device over-stress.

The AAT1218 is available in a Pb-free, 12-pin low profile TDFN33 package with rating from -40°C to 85°C.

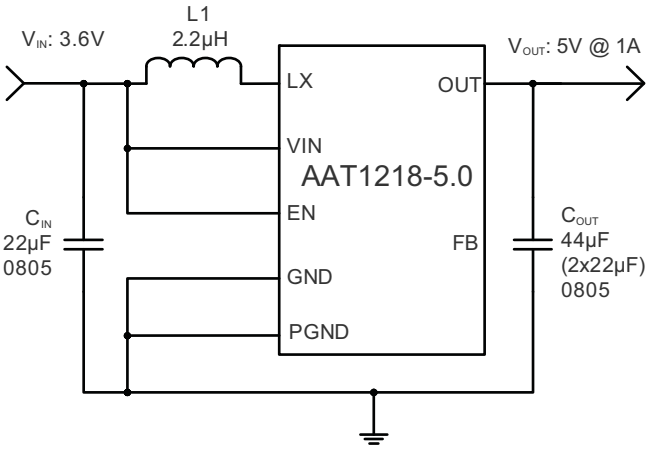
Features

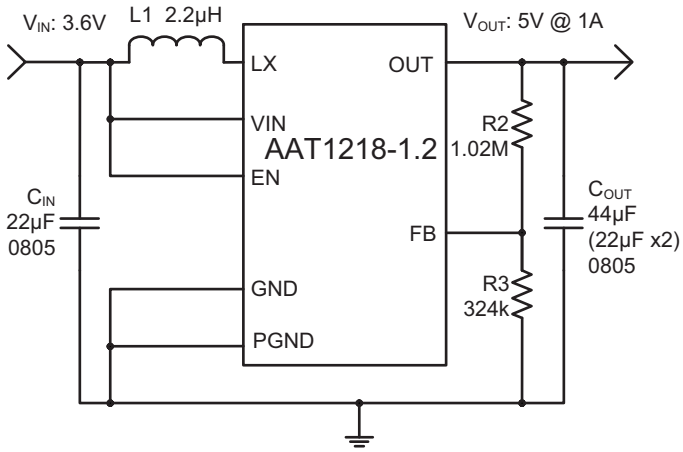
- 2.5V to 5.5V Adjustable Output Voltage
- 0.5V Minimum Input Voltage
- ±2% Output Accuracy
- No Schottky Diode Required (V_{OUT} < 4.5V)
- Up to 95% Efficiency
- 400µA Standby Current
- <1µA Shutdown Current
- Integrated Soft-Start Circuitry Limits Inrush Current
- Constant Frequency 1.2MHz Operation
  - Inductor Height <1.8mm
  - Small Ceramic Capacitors
- Anti-ring Circuit Reduces EMI
- Current Mode Control
  - Fast, Stable Transient Response
  - No External Compensation
  - Cycle-by-Cycle Current Limit
- Low Inrush Current with 0.7ms Soft-start
- Low Output Ripple: <80mVpp for all Loading Conditions (BW = 25MHz)
- Over-Temperature Protection
- Adjustable and Fixed Output Versions Available
- Delivers 1A to 5V Output from a Single Cell Li+ Battery
- Low-profile TDFN33-12 Package

Applications

- DVD Players
- Hard Disk Drive
- MP3 Players
- PDA
- Portable Computers
- Smart Phones

Typical Application



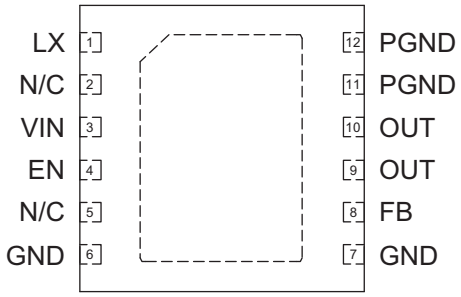


Pin Description

Pin #	Symbol	Description
1	LX	Switching node tied to drain of internal N-channel MOSFET and source of internal P-channel MOSFET. Connect this pin to the external power inductor.
2, 5	NC	No connect.
3	VIN	Input voltage for the controller.
4	EN	Input enable pin.
6, 7	GND	Non-power signal ground pin.
8	FB	Feedback input pin. This pin is connected to an external resistor divider which determines the output voltage setpoint.
9. 10	OUT	Output pin; connected to the positive terminal of the output capacitor and to the external resistor divider.
11, 12	PGND	Power ground pin. Connect this pin directly to input and output capacitors.

Pin Configuration

TDFN33-12
(Top View)



Absolute Maximum Ratings[1]

Symbol	Description	Value	Units
	LX, VIN, EN, FB Voltage to PGND	-0.3 to 6.0	V
	PGND Voltage to GND	-0.3 to 0.3	V
	Operating Junction Temperature Range	-40 to 150	°C
	Maximum Soldering Temperature (at leads, 10 sec)	300	°C

Thermal Information

Symbol	Description		Value	Units
P_D	Maximum Power Dissipation[2]	TDFN33-12[3]	2000	mW
Θ_{JA}	Maximum Thermal Resistance – Junction to Ambient	TDFN33-12	50	°C/W
Θ_{JC}	Maximum Thermal Resistance – Junction to Case	TDFN33-12	41.68	°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.
2. Mounted on 1.6mm thick FR4 circuit board.
3. Derate 25mW/°C above 25°C ambient temperature.

Electrical Characteristics

V_{IN} = 1.2V, V_{OUT} = 3.3V, C_{OUT} = 44µF, T_A = 25°C unless otherwise noted.

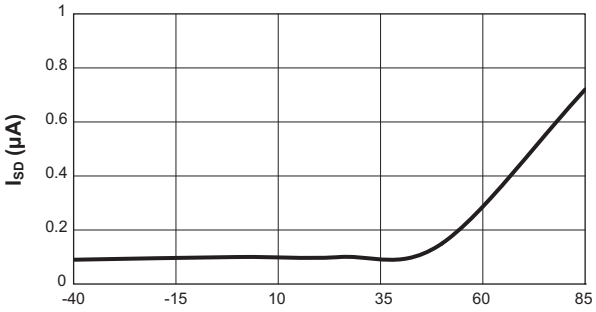
Symbol	Description	Conditions	Min	Typ	Max	Units
V_{IN}	Minimum Start-Up Voltage	I_{LOAD} = 1mA		0.85	1	V
	Minimum Start-Up Voltage Loaded	I_{LOAD} = 300mA (Resistive)		1.4		V
	Operating Input Voltage Range	T_A = -40°C to +85°C	0.5		V_{OUT} - 0.5	V
V_{OUT_RANGE}	Output Voltage Range		2.5		5.5	V
V_{FB}	Feedback Voltage	T_A = -40°C to +85°C	1.164	1.200	1.236	V
I_Q	Quiescent Current Switching, No Load Operation, Measured from V_{OUT}	0.5 < V_{IN} < V_{OUT} - 0.5V, I_{LOAD} = 0mA		300	700	µA
	Quiescent Current Device Disabled (Shut Down)	0.5 < V_{IN} < V_{OUT} - 0.5V, V_{EN} = 0		0.01	1	µA
F_{OSC}	Switching Frequency		0.95	1.2	1.5	MHz
DC	Minimum Operating Duty Cycle				0	%
	Maximum Operating Duty Cycle		80			%
I_{LIMIT}	NMOS Current Limit	T_A = -40°C to +85°C	2.0	2.5		A
T_{SS}	Soft-Start Time	V_{IN} = 3.3V, V_{OUT} = 5V, C_{OUT} = 10µF		0.7		ms
NMOS Leakage	NMOS Switch Leakage			0.1	5.0	µA
PMOS Leakage	PMOS Switch Leakage			0.1	5.0	µA
NMOS On-Resistance	NMOS Switch On-Resistance			180		mΩ
PMOS On-Resistance	PMOS Switch On-Resistance			250		mΩ
ΔV_{OUT}	Line Regulation	V_{IN} = 1.5 - (V_{OUT} - 0.5), I_{LOAD} = 0mA to 1000mA		0.1		%
ΔV_{OUT}	Load Regulation	V_{IN} = 1.5 - (V_{OUT} - 0.5), I_{LOAD} = 0mA to 1000mA		0.5		%
$\Delta V_{OUT(LINE_TRANSIENT)}$	Line Transient Response[1]	V_{IN} = 2.5V - 4.5V, ΔV_{IN} = 1V, dV_{IN}/dt = ±0.2V/µs	-3		3	% V_{OUT}
$\Delta V_{OUT(LOAD_TRANSIENT)}$	Load Transient Response[1]	V_{IN} = 2.5V, I_{LOAD} = 50mA to 500mA, dI_{LOAD}/dt = ±0.5A/µs, C_{FF} = 100pF	-10		10	% V_{OUT}
EN						
$V_{EN(L)}$	Logic Input Low Threshold for EN				0.6	V
$V_{EN(H)}$	Logic Input High Threshold for EN	V_{OUT} = 3.3V	0.85			V
		V_{OUT} = 5.0V	1.0			
I_{EN}	Enable Input Low Current	V_{IN} = V_{OUT} = 5.5V	-1.0		1.0	µA

1. Specifications are guaranteed by design and characterization.

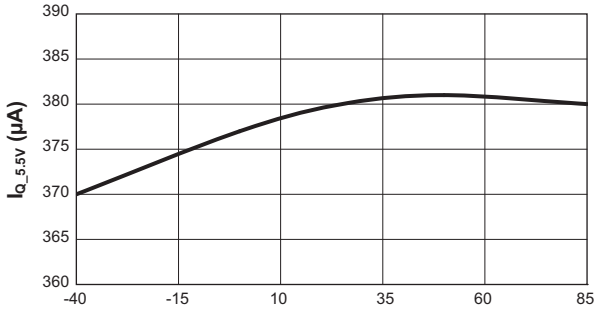
Typical Characteristics

C_{IN} = 22µF, C_{OUT} = 44µF; L = 2.2µH; T_A = 25°C, unless otherwise noted.

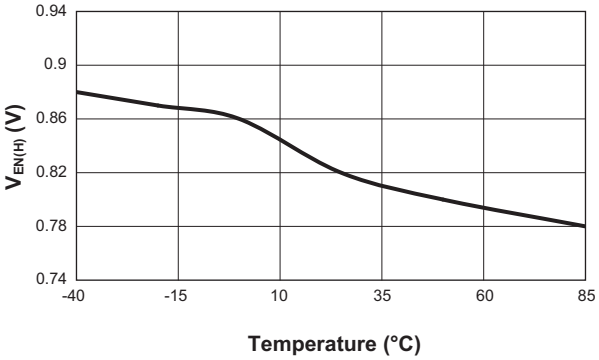
AAT1218 I_{SD} vs. Temperature



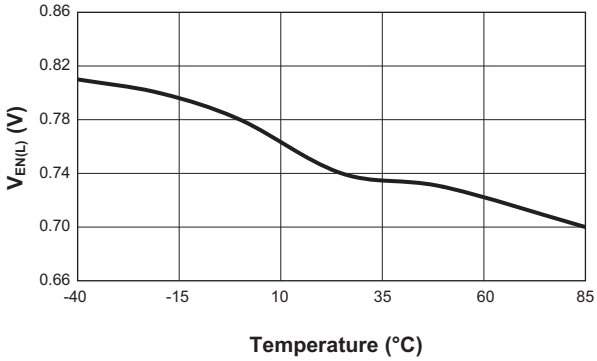
AAT1218 I_Q vs. Temperature
(V_{OUT} = 5.5V, Measured From V_{OUT})



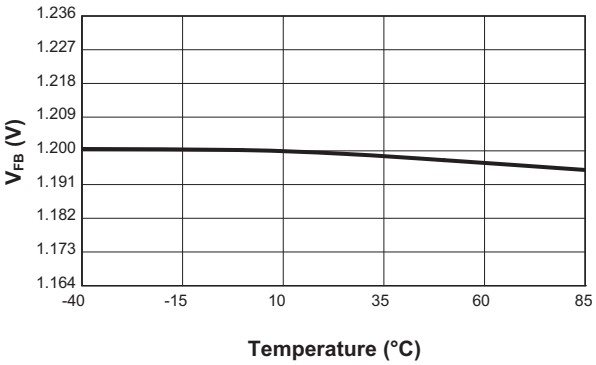
$V_{EN(H)}$ vs. Temperature
(V_{OUT} = 5V)



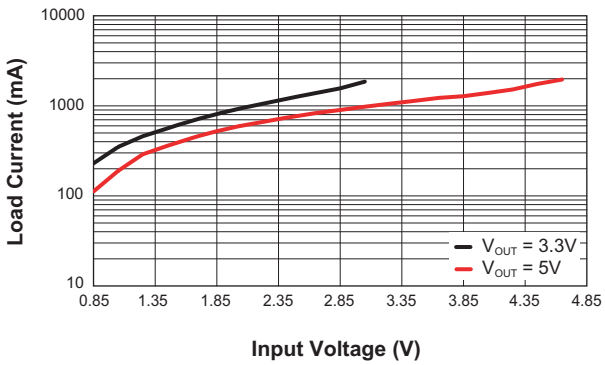
$V_{EN(L)}$ vs. Temperature
(V_{OUT} = 5.0V)



AAT1218 V_{FB} vs. Temperature



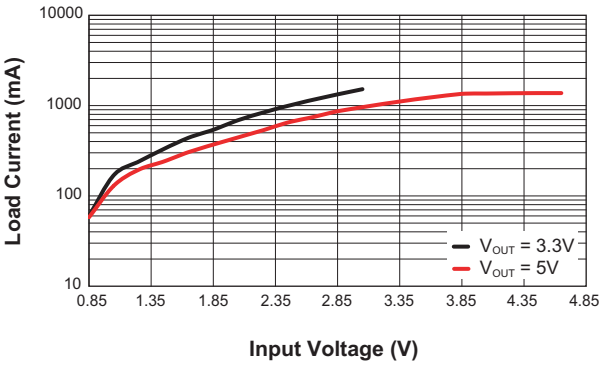
Maximum Load Current vs. V_{IN}



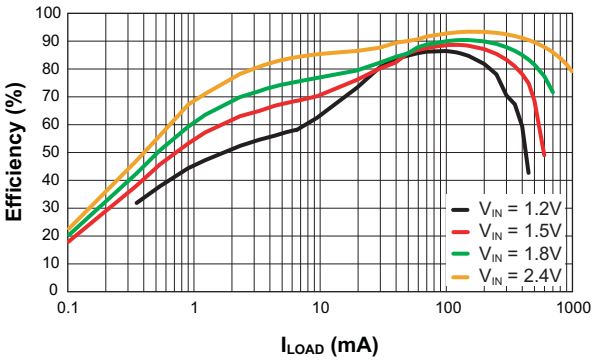
Typical Characteristics

C_{IN} = 22µF, C_{OUT} = 44µF; L = 2.2µH; T_A = 25°C, unless otherwise noted.

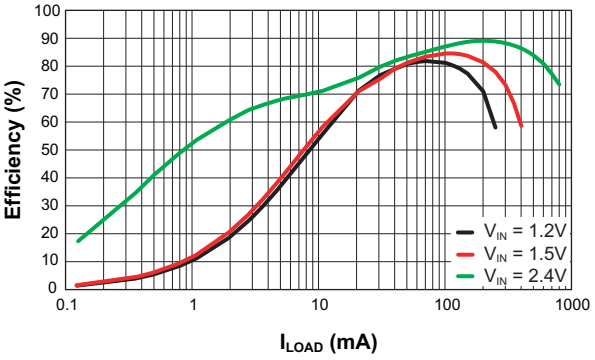
Maximum Load Current at Startup vs. V_{IN}



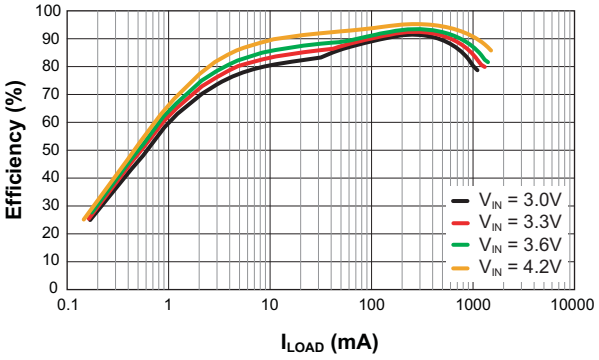
AAT1218 3.3V Output Efficiency



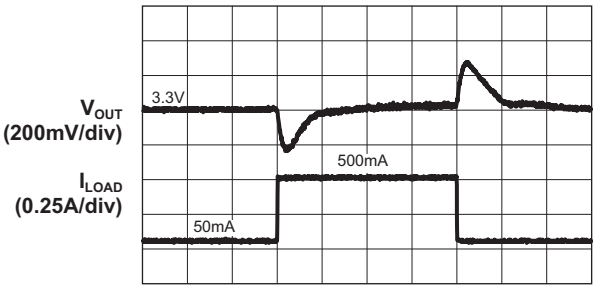
AAT1218 5.0V Output Efficiency



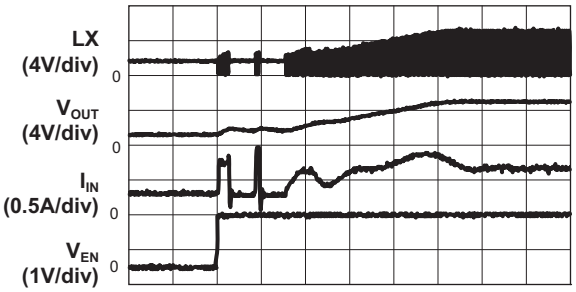
AAT1218 5.0V Output Efficiency



Load Transient
(V_{IN} = 2.0V; V_{OUT} = 3.3V; C_{OUT} = 44µF; C_{FF} = 100pF)



Soft Start Waveform
(V_{IN} = 1.5V; V_{OUT} = 5V; Load = 100mA)



Typical Characteristics

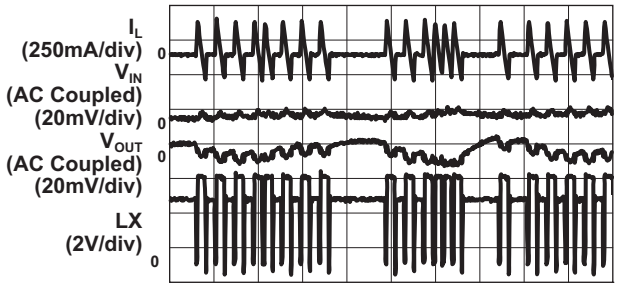
V_{IN} = 3.6V, V_{OUT} = 3.6V, C_{IN} = 22µF, C_{OUT} = 44µF; L = 2.2µH; T_A = 25°C, unless otherwise noted.

Anti-Ringing Operation
(V_{IN} = 3V; V_{OUT} = 5V; Load = 10mA)



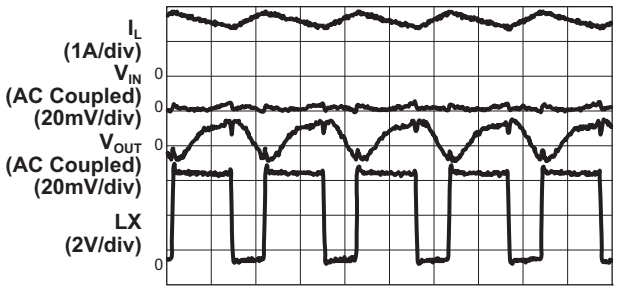
Time (0.2µs/div)

Power Saving Mode Waveform
(V_{IN} = 3.6V; V_{OUT} = 5V; Load = 5mA)



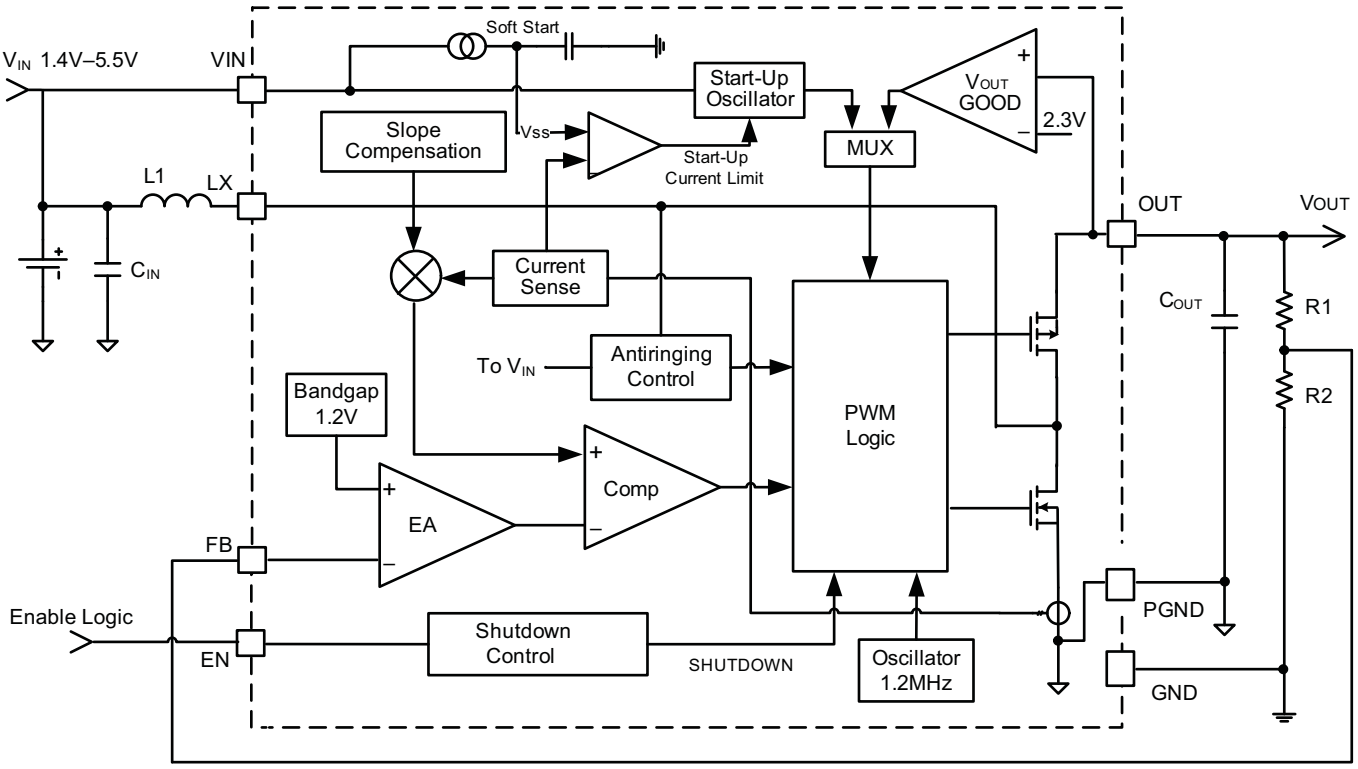
Time (4µs/div)

PWM Mode Waveform
(V_{IN} = 3.6V; V_{OUT} = 5V; Load = 1A)



Time (0.4µs/div)

Functional Block Diagram



Functional Description

The AAT1218 is a synchronous step-up DC-DC converter. It utilizes internal MOSFETs to achieve high efficiency over the full load current range. It operates at a fixed switching frequency of 1.2MHz, and uses the slope compensated current mode architecture. The device can operate at 0.5V input after start up. The typical start-up voltage is 0.85V.

Synchronous Rectification

The AAT1218 integrates a synchronous rectifier to improve efficiency and eliminate the external rectifier diode if output voltage is lower than 4.5V. The synchronous rectifier is used to reduce conduction loss contributed by the forward voltage of the external rectifier diode. It is implemented by a PMOS driven by a gate driver with break-before-make timing. When the output voltage is greater than 4.5V, an external rectifier diode is necessary for proper operation.

Low Voltage Start-Up

The AAT1218 can start up at supply voltages as low as 1V. During the start-up phase, the internal low voltage start-up circuitry controls the NMOS switch to soft-start the device. A comparator (V_{OUT} GOOD Comp) monitors the output voltage. If V_{OUT} exceeds 2.3V, the device exits start-up phase and enters normal operation mode. The internal circuitry power supply of the device is connected to V_{IN} during start-up phase and automatically switches to V_{OUT} during normal operation.

Integrated Soft-Start

During start-up, the AAT1218's integrated soft-start circuitry gradually increases the peak inductor current until it reaches normal operating value. The inrush current during start-up can thus be minimized.

Current Mode PWM Control

The AAT1218 is based on a slope compensated current mode control topology. It operates at a fixed frequency of 1.2MHz. At the beginning of each clock cycle, the main switch (NMOS) is turned on and the inductor current starts to ramp up. After the maximum duty cycle or if the sense current signal is equal to the error amplifier (EA) output, the main switch is turned off and the synchronous switch (PMOS) is turned on. This control scheme has intrinsic cycle-by-cycle current limiting, which can prevent the main switch from overstress and prevent saturation of the external inductor.

Power Saving Mode

At very light load, the AAT1218 automatically switches into Power Saving Mode to improve efficiency. In this mode, the PWM control will skip some pulses to maintain regulation. If load increases and output voltage drops, the device will automatically switch back to regular PWM mode and maintain regulation.

Anti-ringing Control

Anti-ringing circuitry is included to remove the high frequency ringing that appears on the LX pin when the inductor current decreases to zero. In this case, ringing on the LX pin is caused by energy stored in parasitics of the MOSFETs and the inductor. The anti-ringing circuitry clamps the voltage to battery voltage internally and thus dampens the ringing.

Device Enable

When EN is set logic high, the AAT1218 begins operation. If EN is set logic low, the device is goes into shutdown mode and consumes less than 1µA current. After start-up, the internal circuitry is supplied by V_{OUT} during normal operation. However, if shutdown mode is enabled, the internal circuitry will again be supplied by the battery.

Application Information

Setting the Output Voltage

An external resistor divider is used to set the output voltage. The output voltage of the switching regulator (V_{OUT}) is determined by the following equation:

$$V_{OUT} = 1.20V \cdot \left(1 + \frac{R1}{R2}\right)$$

V_{OUT}	R1 (Ω)	R2 (Ω)
3.3V	1.02M	576k
5.0V	1.02M	324k

Table 1: Resistor Selection Example for Output Voltage Setting.

Fixed output voltage devices are also available for 3.3V and 5V outputs. These devices integrate the feedback network into the die and can save two external resistors. Do not connect any component to the FB pin and leave it floating.

Inductor Selection

The AAT1218's high switching frequency of 1.2MHz allows for small surface mount inductors. For most designs, the AAT1218 operates with inductors of 2.2µH to 10µH depending on input/output voltage and load current. First determine the worst case V_{IN}, V_{OUT}, and I_{OUT}. Then use the equation below to select the proper inductor value; assume the converter is operating in continuous current mode and is in steady state:

$$D = 1 - \frac{V_{IN}}{V_{OUT}}$$

$$I_{PEAK} = I_{RMS} + \frac{\Delta I}{2}$$

$$\Delta I = \frac{V_{IN} \cdot D}{L \cdot f_{SW}}$$

η is the converter efficiency, I_{PEAK} is the peak inductor current, ΔI is the peak-peak inductor ripple current, I_{RMS} is the RMS current of the inductor current. f_{sw} is the switching frequency, L is the inductance value and D is the steady state duty cycle.

Fit the proper L into the equations to meet the following criteria:

1. The DC current rating of the inductor must be higher than I_{PEAK} to avoid magnetic saturation. Cored inductor devalues when core temperature increases, so verify the inductor of choice with its temperature characteristics in mind.
2. The inductor ripple current ΔI is typically set for 20% to 40% of the peak inductor current.

Higher inductance means less inductor ripple current; larger size inductors can handle more power. However, larger size inductors also have higher profiles and are more expensive. For optimum load transient and efficiency performance, low DCR inductors should be selected. Table 2 lists some surface mount inductors which are suitable for typical AAT1218 applications.

Input Capacitor

Select a 4.7µF to 10µF X7R or X5R ceramic capacitor for the input. The input capacitor provides a low impedance loop for the edges of pulsed current drawn by the AAT1218. Low ESR/ESL X7R and X5R ceramic capacitors are ideal for this function. To minimize stray inductance, the capacitor should be placed as close as possible to the IC. This keeps the high frequency content of the input current localized, minimizing EMI and input voltage ripple.

Always examine the ceramic capacitor DC voltage coefficient characteristics to derive the proper value. For example, the capacitance of a 10µF, 6.3V, X5R ceramic capacitor with 5.0V DC applied is actually about 6µF.

Output Capacitor

The output capacitor limits the output ripple and provides holdup during large load transitions. When choosing the output capacitor, first consider the acceptable output ripple level (ΔV_{toatal}) and solve for C_{OUT} from the equations below; assume that output current remains constant in steady state:

$$\Delta V_{TOTAL} = \Delta V + \Delta V_{ESR} = \Delta V + I_{OUT} \cdot R_{ESR}$$

$$\Delta V = \frac{I_{OUT} \cdot D}{C_{OUT} \cdot F_{SW}}$$

A 10µF to 47µF X5R or X7R ceramic capacitor typically provides sufficient bulk capacitance to stabilize the output during large load transitions and has the ESR and ESL characteristics necessary for low output ripple.

In addition, the output voltage droop during load transient is related to the capacitance of the ceramic output capacitor. A larger output capacitor helps to reduce voltage droop.

Rectifier Diode Selection

A rectifier diode must be added (D1 in Figure 1) when the output voltage is greater than 4.5V. The Schottky diode is optional for output voltages less than 4.5V, but can improve efficiency by about 2% to 3%. A low forward voltage Schottky diode is recommended. Its voltage rating should be higher than the output voltage. Thus, diodes with 10V or more reverse voltage are recommended. The diode rated current can be slightly less than the peak inductor current to save cost and board space.

Manufacturer	Part Number	L (µH)	Max DCR (mΩ)	Rated DC Current (A)	Size WxLxH (mm)
Sumida	2D14	2.2	94	1.50	3.2x3.2x1.55
		3.3	125	1.2	
		4.7	169	1.0	
	CR54	2.2	23.4	3.84	5.6x6.1x4.85
		3.3	28.6	3.20	
		5.0	44.2	2.60	
	CDRH4D22/HP	2.2	44.3	3.2	5.0x5.0x2.4
		3.5	65.1	2.5	
		4.7	82.6	2.2	
	CDRH5D14/HP	2.0	57	3.2	6.0x6.3x1.5
		3.3	96	2.6	
		5.1	140	2.0	

Table 2: AAT1218 Typical Surface Mount Inductors.

Load Disconnect in Shutdown

In a conventional synchronous step-up converter, a conduction path exists from battery to output through the body diode of the PMOS during shutdown. To avoid output side circuitry drawing current from V_{IN}, special application circuitry such as that shown in Figure 1 is necessary to disconnect the output from V_{IN} during shutdown.

PCB Layout Guidance

The AAT1218 typically operates at 1.2MHz. Since this is a high frequency for DC-DC converters, PCB layout is critical to guarantee satisfactory performance. It is recommended to make traces of the power loop as short and wide as possible, especially where the switching node is involved. First, the inductor and input and output capacitors should be placed close to the IC. Feedback and shutdown traces should avoid proximity to large AC signals, e.g. the power inductor and switching nodes. The optional rectifier diode (D1 in Figure 1 and Figure 2) can improve efficiency and alleviate the stress on the integrated PMOS device. The diode should also be close to the inductor and the chip to form the shortest possible switching loop. While the two layer PCB shown in Figures 3 and 4 is sufficient for low to moderate power applications, large and integral multi-layer ground planes are ideal for high power applications since the large area of copper has lower resistance and higher thermal dissipation capability. The converter's grounds should join at one point only. Figure 1 illustrates the schematic for a typical AAT1218 application.

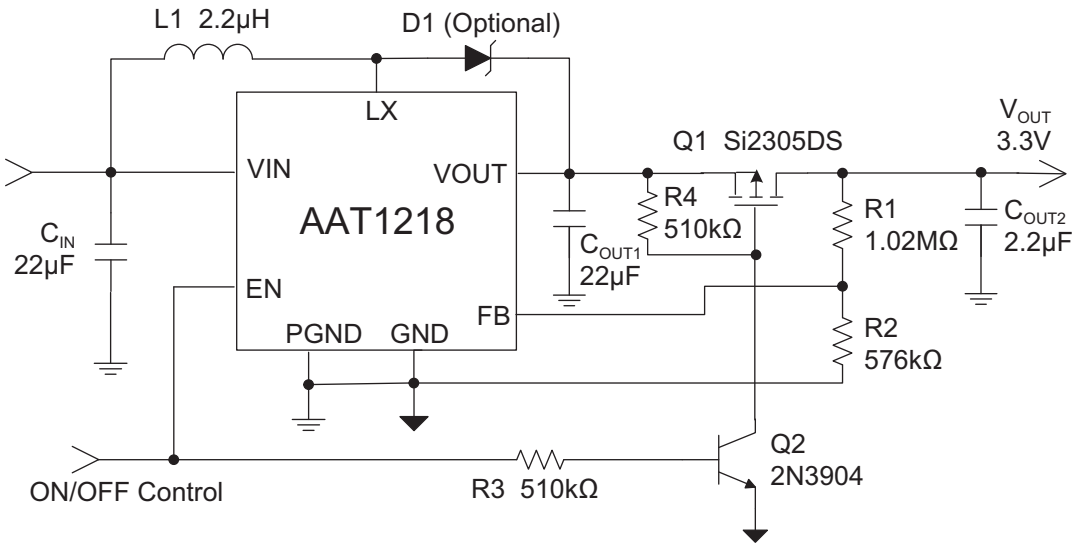


Figure 1: AAT1218 Application Schematic with Load Disconnect Circuit.

Evaluation Board Schematic

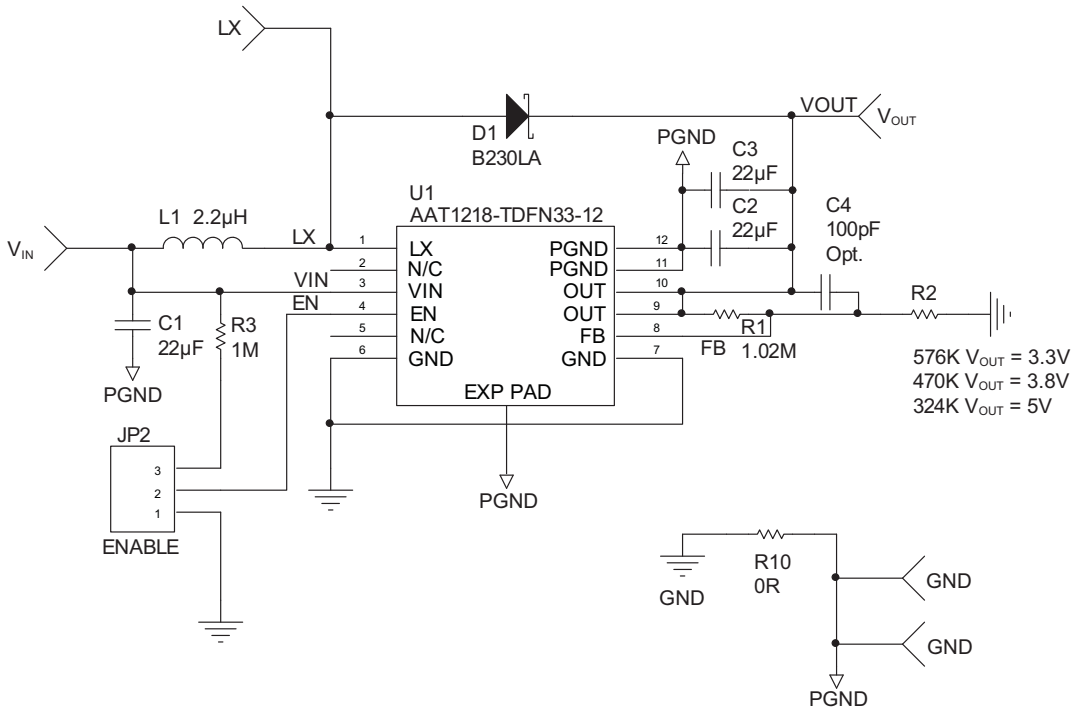


Figure 2: AAT1218 Evaluation Board Schematic.

Evaluation Board Layout

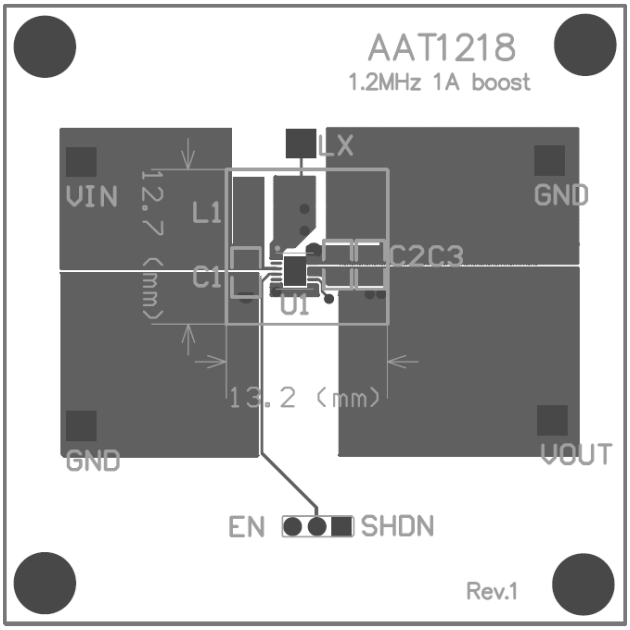


Figure 3: AAT1218 Evaluation Board Top Side Layout.

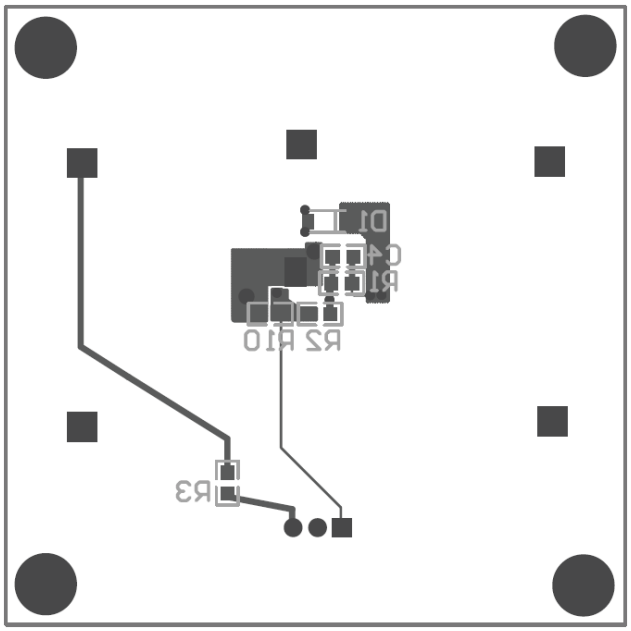


Figure 4: AAT1218 Evaluation Board Bottom Side Layout.

Designator	Description	Footprint	Comment
C1	Capacitor, Ceramic, Murata, GRM21BR60J226ME39, X5R, 22µF, ±20%, 6.3V	0805	22µF
C2	Capacitor, Ceramic, Murata, GRM21BR60J226ME39, X5R, 22µF, ±20%, 6.3V	0805	22µF
C3	Capacitor, Ceramic, Murata, GRM21BR60J226ME39, X5R, 22µF, ±20%, 6.3V	0805	22µF
C4	Capacitor, Ceramic, Murata, GRM1885C1H101JA01B, C0G, 100pF, ±5%, 50V	0603	100pF
D1	Schottky Diode, Vishay, B230LA	Diode	
JP2	Header, 3-Pin	SMALLHDR1X3	
L1	Inductor, Sumida	CDRH4D28	2.2µH
R1	Chip Resistor, Panasonic, 1.02M, 1/16W, 1%	0603	1.02M
R2	Chip Resistor, Panasonic, 590K, 1/16W, 1%	0603	590K
R3	Chip Resistor, Panasonic, 1M, 1/16W, 5%	0603	1M
R10	Chip Resistor, Panasonic, 0R, 1/16W, 5%	0603	0R
U1	AAT1218-TDFN33-12, AnalogicTech	TDFN33-12	Boost Reg.

Table 3: AAT1218 Evaluation Board Bill of Materials.

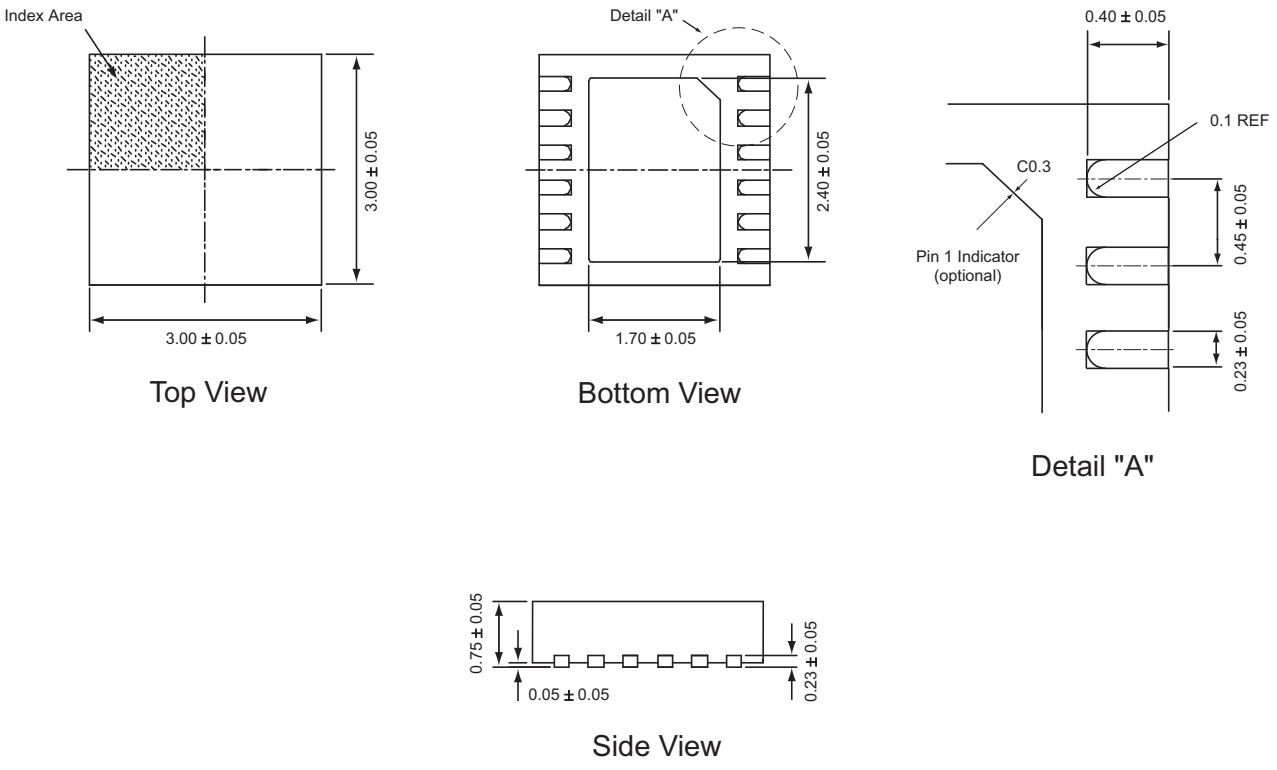
Ordering Information

Description	Package	Marking[1]	Part Number (Tape and Reel)[2]
Adjustable Output Voltage	TDFN33-12	2EXYY	**AAT1218IWP-1.2-T1**
Fixed 3.3V Output Voltage	TDFN33-12	5PXYY	**AAT1218IWP-3.3-T1**
Fixed 5V Output Voltage	TDFN33-12	5RXYY	**AAT1218IWP-5.0-T1**

Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

Package Information

TDFN33-12[3]



All dimensions in millimeters.

1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.
3. The leadless package family, which includes QFN, TQFN, DFN, TDFN and STDFN, has exposed copper (unplated) at the end of the lead terminals due to the manufacturing process. A solder fillet at the exposed copper edge cannot be guaranteed and is not required to ensure a proper bottom solder connection.

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