

1MHz 2.5A Step-Down DC/DC Converter

General Description

The AAT1155 is a step-down, SwitchReg™, switching converter ideal for applications where high efficiency, small size, and low ripple are critical. Able to deliver 2.5A with an internal power MOSFET, the current-mode controlled IC provides high efficiency. Fully internally compensated, the AAT1155 simplifies system design and lowers external parts count.

The AAT1155 is available in a Pb-free, MSOP-8 package and is rated over the -40°C to +85°C temperature range.

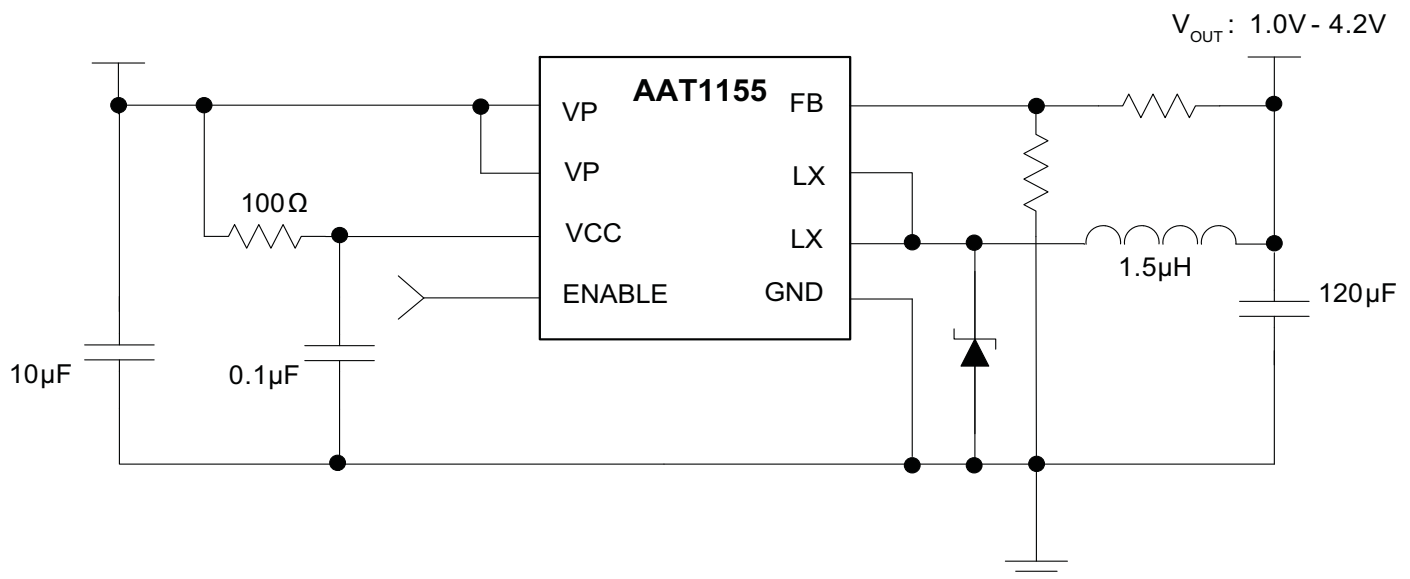
Features

- 5.5V Max Supply Input
- Adjustable V_{OUT}: 1.0V to 4.2V
- 2.5A Output Current
- Up to 95% Efficiency
- Integrated Low On-Resistance Power Switches
- Internally Compensated Current Mode Control
- 1MHz Switching Frequency
- Constant Pulse Width Modulation (PWM) Mode
- Low Output Ripple with Light Load
- Internal Soft Start
- Current Limit Protection
- Over-Temperature Protection
- MSOP-8 Package
- -40°C to +85°C Temperature Range

Applications

- Cable/DSL Modems
- Computer Peripherals
- High Efficiency Conversion from 5V or 3.3V Supply
- Network Cards
- Set-Top Boxes

Typical Application

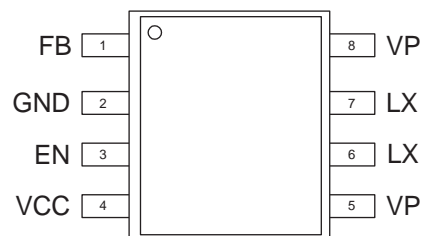


AAT1155**1MHz 2.5A Step-Down DC/DC Converter****Pin Descriptions**

Pin #	Symbol	Function
1	FB	Feedback input pin. This pin is connected to an external resistive divider for an adjustable output.
2	GND	Signal ground.
3	EN	Enable input pin. When connected high, the AAT1155 is in normal operation. When connected low, it is powered down. This pin should not be left floating.
4	VCC	Small signal filtered bias supply.
5, 8	VP	Input supply for converter power stage.
6, 7	LX	Inductor connection pins. These pins should be connected to the output inductor.

Pin Configuration

**MSOP-8
(Top View)**



1MHz 2.5A Step-Down DC/DC Converter**Absolute Maximum Ratings¹**

Symbol	Description	Value	Units
V_{CC}, V_P	VCC, VP to GND	6	V
V_{LX}	LX to GND	-0.3 to $V_P+0.3$	
V_{FB}	FB to GND	-0.3 to $V_{CC}+0.3$	
V_{EN}	EN to GND	-0.3 to $V_{CC}+0.3$	
T_J	Operating Junction Temperature Range	-40 to 150	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec)	300	
V_{ESD}	ESD Rating ² - HBM	3	kV

Thermal Characteristics³

Symbol	Description	Value	Units
Θ_{JA}	Maximum Thermal Resistance	150	°C/W
P_D	Maximum Power Dissipation	833	mW

Recommended Operating Conditions

Symbol	Description	Rating	Units
T	Ambient Temperature Range	-40 to +85	°C

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. Human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.
3. Mounted on a demo board (FR4, in still air).

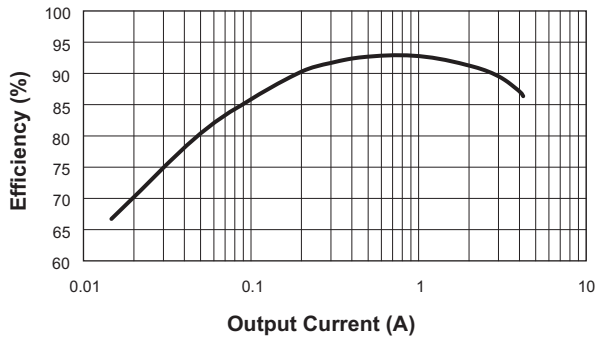
1MHz 2.5A Step-Down DC/DC Converter**Electrical Characteristics**

$V_{IN} = V_{CC} = V_P = 5V$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted. Typical values are $T_A = 25^{\circ}C$.

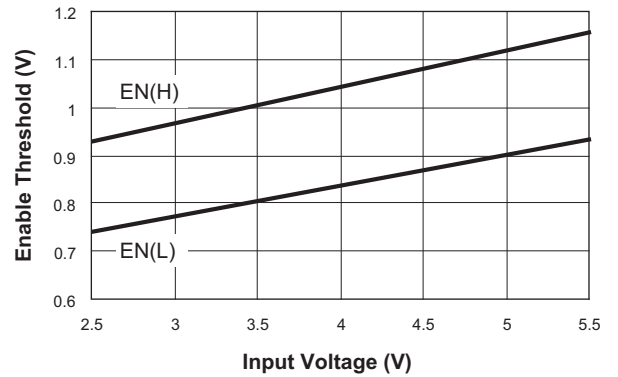
Symbol	Description	Conditions	Min	Typ	Max	Units
V_{IN}	Input Voltage Range		2.7		5.5	V
V_{OUT}	Output Voltage Tolerance	$V_{IN} = V_{OUT} + 0.2$ to $5.5V$, $I_{OUT} = 0.5A$	-2.5		2.5	%
$V_{EN(L)}$	Enable Low Voltage				0.6	V
$V_{EN(H)}$	Enable High Voltage		1.4			
V_{UVLO}	Under-Voltage Lockout	V_{IN} Rising			2.5	
		V_{IN} Falling	1.2			
$V_{UVLO(HYS)}$	Under-Voltage Lockout Hysteresis			250		mV
I_Q	Quiescent Supply Current	No Load, $V_{FB} = 0V$		630	1000	μA
I_{SHDN}	Shutdown Current	$V_{EN} = 0V$, $V_{IN} = 5.5V$			1.0	
I_{LIM}	Current Limit	$T_A = 25^{\circ}C$	4.4			A
$R_{DS(ON)H}$	High Side Switch On Resistance	$T_A = 25^{\circ}C$		60		$m\Omega$
η	Efficiency	$I_{OUT} = 1.0A$		92		%
$\frac{\Delta V_{OUT}}{V_{OUT} * \Delta V_{IN}}$	Load Regulation	$I_{LOAD} = 0A$ to $2.5A$		± 2.3		
$\Delta V_{OUT}/V_{OUT}$	Line Regulation	$V_{IN} = 2.7V$ to $5.5V$		0.75		%/V
f_{OSC}	Oscillator Frequency	$T_A = 25^{\circ}C$		1		MHz
T_{SD}	Over-Temperature Shutdown Threshold			140		$^{\circ}C$
T_{HYS}	Over-Temperature Shutdown Hysteresis			15		

Typical Characteristics

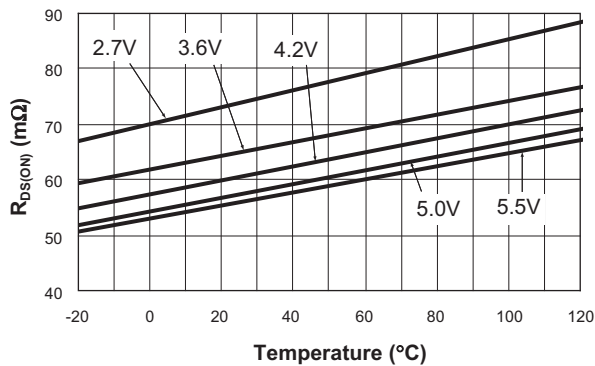
Efficiency vs. Load Current
($V_{IN} = 5.0V$; $V_{OUT} = 3.3V$)



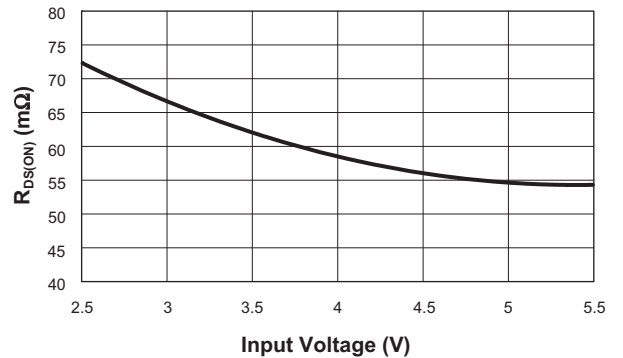
Enable Threshold vs. Input Voltage



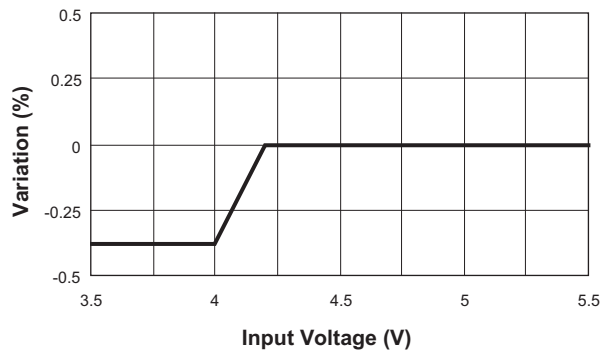
$R_{DS(ON)}$ vs. Temperature



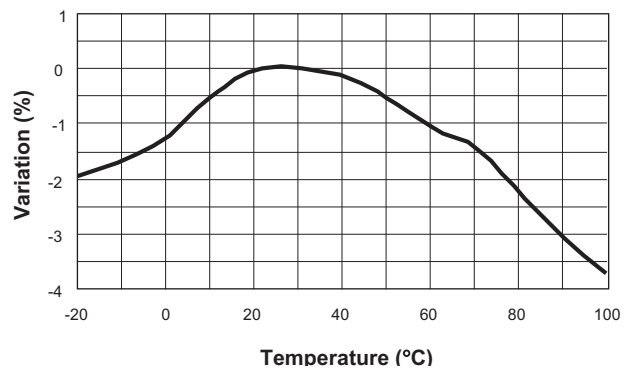
$R_{DS(ON)}$ vs. Input Voltage
($I_{DS} = 1A$)



Oscillator Frequency Variation vs. Input Voltage
($V_{OUT} = 3.3V$)



Oscillator Frequency Variation vs. Temperature
($V_{IN} = 5V$)

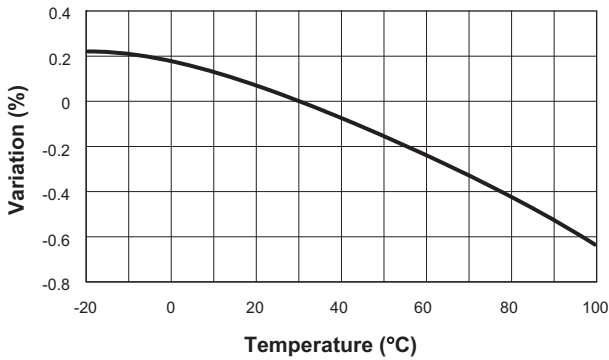


AAT1155

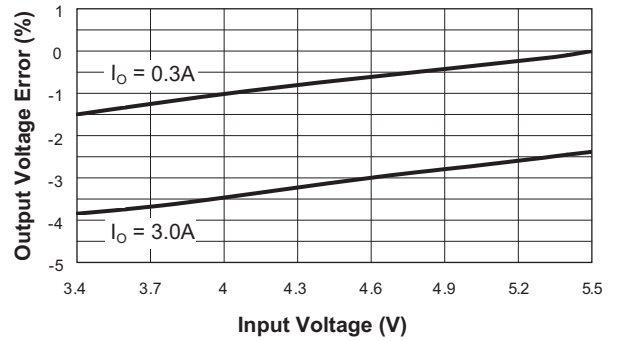
1MHz 2.5A Step-Down DC/DC Converter

Typical Characteristics

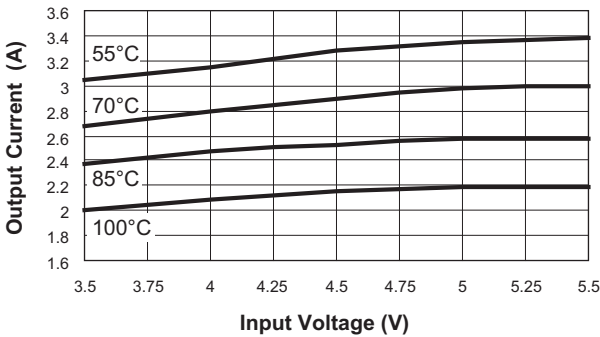
Output Voltage Variation vs. Temperature
($I_{OUT} = 2A$; $V_O = 3.3V$)



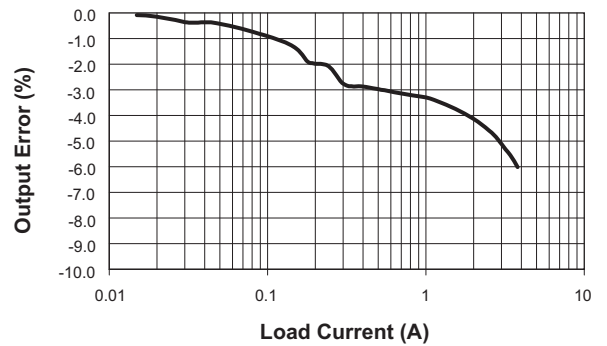
Line Regulation
($V_{OUT} = 3.3V$)



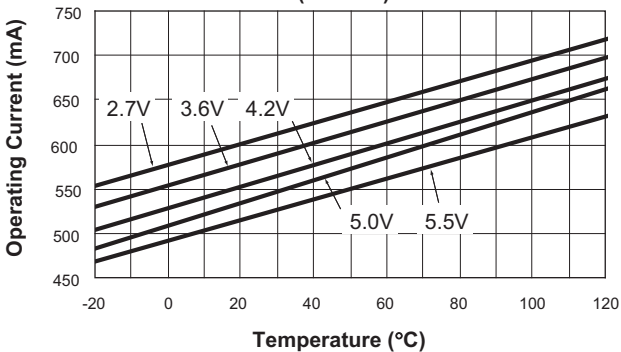
AAT1155 Evaluation Board
Over-Temperature Current vs. Input Voltage
($V_{OUT} = 3.3V$)



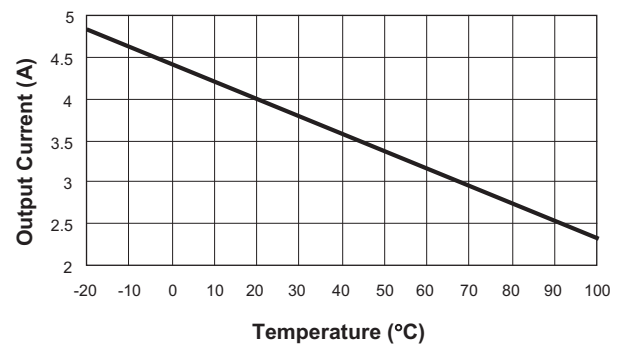
Load Regulation
($V_{IN} = 5.0V$; $V_{OUT} = 3.3V$)



Non-Switching Operating Current vs. Temperature
($FB = 0V$)



Over-Temperature Shutdown Current vs. Temperature
($V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)

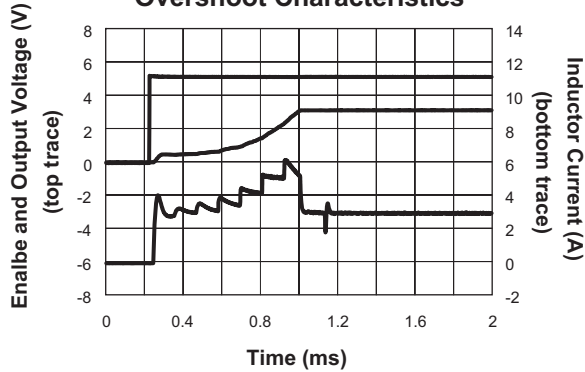


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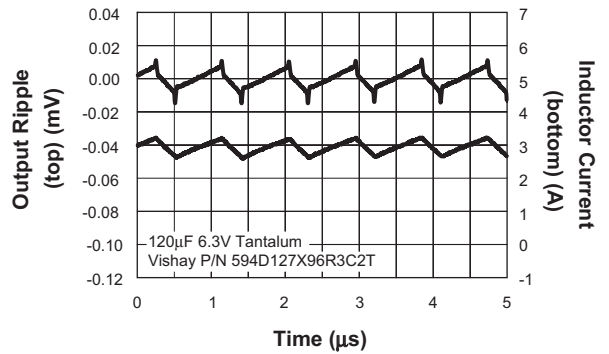
1MHz 2.5A Step-Down DC/DC Converter

Typical Characteristics

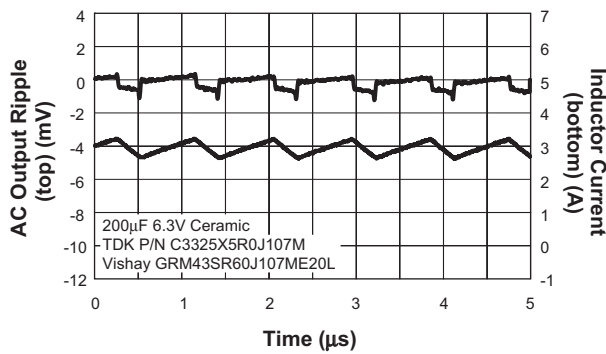
Inrush and Output Overshoot Characteristics



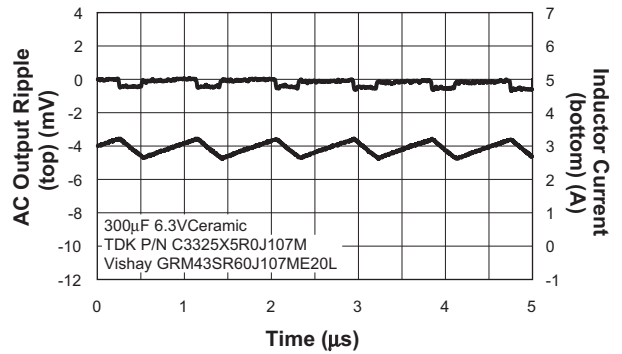
Tantalum Output Ripple
($I_{OUT} = 3.0A$; $V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)



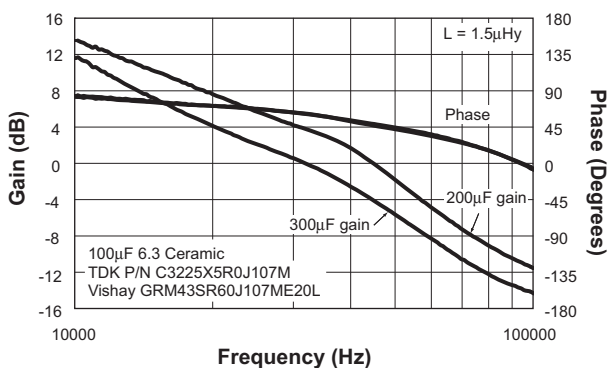
Output Ripple
($I_{OUT} = 3.0A$; $V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)



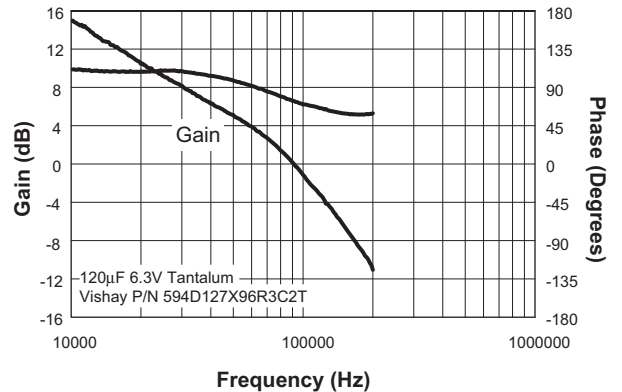
Output Ripple
($I_{OUT} = 3.0A$; $V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)



Loop Crossover Gain and Phase

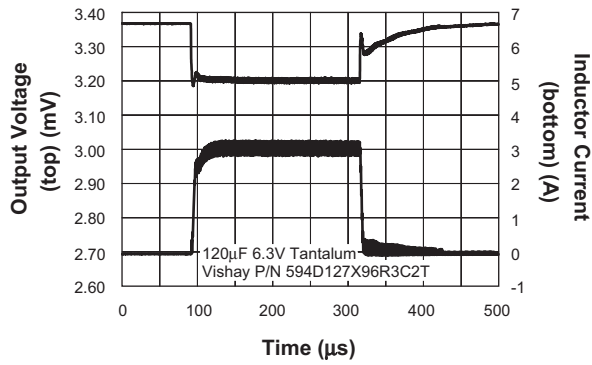


Loop Crossover Gain and Phase

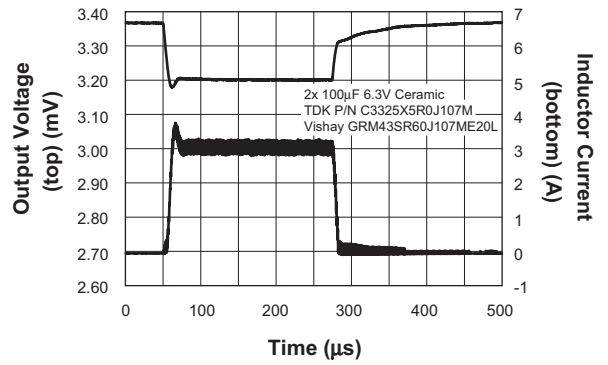


Typical Characteristics

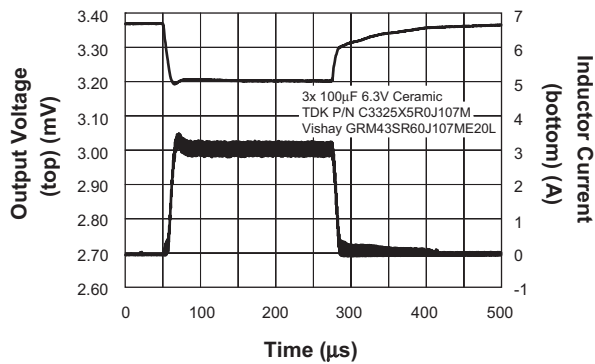
Tantalum Transient Response
 ($I_{OUT} = 0$ to $3.0A$; $V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)



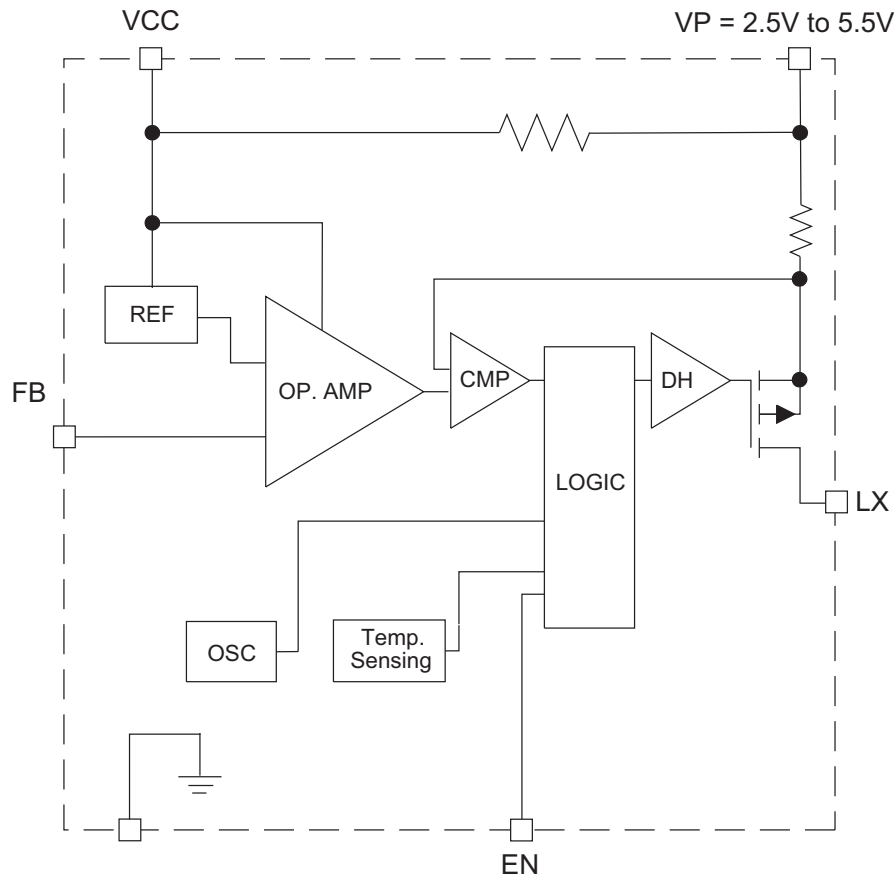
Transient Response
 ($I_{OUT} = 0$ to $3.0A$; $V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)



Transient Response
 ($I_{OUT} = 0$ to $3.0A$; $V_{OUT} = 3.3V$; $V_{IN} = 5.0V$)



Functional Block Diagram



Applications Information

Main Control Loop

The AAT1155 is a peak current mode step-down converter. The inner wide bandwidth loop controls the inductor peak current. The inductor current is sensed as it flows through the internal P-channel MOSFET. A fixed slope compensation signal is then added to the sensed current to maintain stability for duty cycles greater than 50%. The inner loop appears as a voltage-programmed current source in parallel with the output capacitor.

The voltage error amplifier output programs the current loop for the necessary inductor current to force a constant output voltage for all load and line conditions. The feedback resistive divider is external, dividing the output voltage to the error amplifier reference voltage of 1.0V. The error amplifier has a limited DC gain. This eliminates

the need for external compensation components, while still providing sufficient DC loop gain for good load regulation. The crossover frequency and phase margin are set by the output capacitor value.

Duty cycle extends to 100% as the input voltage approaches the output voltage. Thermal shutdown protection disables the device in the event of a short-circuit or overload condition.

Soft Start/Enable

Soft start controls the current limit when the input voltage or enable is applied. It limits the current surge seen at the input and eliminates output voltage overshoot.

When pulled low, the enable input forces the device into a low-power, non-switching state. The total input current during shutdown is less than 1 μ A.

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Power and Signal Source

Separate small signal ground and power supply pins isolate the internal control circuitry from switching noise. In addition, the low pass filter R1 and C3 (shown in Figure 1) filters noise associated with the power switching.

Current Limit and Over-Temperature Protection

Over-temperature and current limit circuitry protects the AAT1155 and the external Schottky diode during overload, short-circuit, and excessive ambient temperature conditions. The junction over-temperature threshold is 140°C nominal and has 15°C of hysteresis. Typical graphs of the over-temperature load current vs. input voltage and ambient temperature are shown in the Typical Characteristics section of this document.

Inductor

The output inductor is selected to limit the ripple current to 20% to 40% of the full load current at the maximum input voltage. 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 inductor saturation characteristics. The inductor should not show any appreciable saturation under normal load conditions. During overload and short-circuit conditions, the inductor can exceed its peak current rating without affecting the converter performance. Some inductors may have sufficient peak and average current ratings yet result in excessive losses due to a high DCR. The losses associated with the DCR and its effect on the total converter efficiency must be considered.

For a 2.5A load and the ripple current set to 40% at the maximum input voltage, the maximum peak-to-peak ripple current is 1A. Assuming a 5V ±5% input voltage and 40% ripple, the output inductance required is:

$$L = \frac{V_{OUT}}{I_{OUT} \cdot k \cdot f_s} \cdot \left(1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right)$$

$$= \frac{3.3V}{2.5A \cdot 0.4 \cdot 1MHz} \cdot \left(1 - \frac{3.3V}{5.25V}\right)$$

$$= 1.23\mu H$$

The factor "k" is the fraction of the full load (40%) selected for the ripple current at the maximum input voltage.

The corresponding inductor RMS current is:

$$I_{RMS} = \sqrt{\left(I_{OUT}^2 + \frac{\Delta I^2}{12}\right)} \approx I_{OUT} = 2.5A$$

ΔI is the peak-to-peak ripple current which is fixed by the inductor selection above. For a peak-to-peak current of 40% of the full load current, the peak current at full load will be 120% of the full load. The 1.5μH inductor selected from the Sumida CDRH6D38 series has a 11mΩ DCR and a 4.0A DC current rating with a height of 4mm. At full load, the inductor DC loss is 70mW for a 0.84% loss in efficiency.

Schottky Freewheeling Diode

The Schottky average current is the load current multiplied by one minus the duty cycle.

$$\left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

For V_{IN} at 5V and V_{OUT} at 3.3V, the average diode current is:

$$I_{AVG} = I_{OUT} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right) = 2.5A \cdot \left(1 - \frac{3.3V}{5.0V}\right) = 0.85A$$

With a 125°C maximum junction temperature and a 120°C/W thermal resistance, the maximum average current is:

$$I_{AVG} = \frac{T_{J(MAX)} - T_{AMB}}{\theta_{JA} \cdot V_F} = \frac{125^\circ C - 70^\circ C}{120^\circ C/W \cdot 0.4V} = 1.14A$$

V_F is the forward voltage drop of the Schottky diode.

For overload, short-circuit, and excessive ambient temperature conditions, the AAT1155 enters over-temperature shutdown mode protecting the AAT1155 as well as the output Schottky. In this mode, the output current is limited internally until the junction temperature reaches the temperature limit (see over-temperature characteristics graphs). The diode reverse voltage must be rated to withstand the input voltage.

Input Capacitor Selection

The primary function of the input capacitor is to provide a low impedance loop for the edges of pulsed current

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drawn by the AAT1155. A low ESR/ESL ceramic capacitor is ideal for this function. To minimize stray inductance, the capacitor should be placed as closely as possible to the IC. This also keeps the high frequency content of the input current localized, minimizing the radiated and conducted EMI while facilitating optimum performance of the AAT1155. Proper placement of the input capacitor C1 is shown in the layout in Figure 1. Ceramic X5R or X7R capacitors are ideal. The size required will vary depending on the load, output voltage, and input voltage source impedance characteristics. Typical values range from 1μF to 10μF. The input capacitor RMS current varies with the input voltage and the output voltage. It is highest when the input voltage is double the output voltage where it is one half of the load current.

$$I_{RMS} = I_{OUT} \cdot \sqrt{\frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

A high ESR tantalum capacitor with a value about 10 times the input ceramic capacitor may also be required when using a 10μF or smaller ceramic input bypass capacitor. This dampens any input oscillations that may occur due to the source inductance resonating with the converter input impedance.

Output Capacitor

With no external compensation components, the output capacitor has a strong effect on the loop stability. Larger output capacitance will reduce the crossover frequency with greater phase margin. A 200μF ceramic capacitor provides sufficient bulk capacitance to stabilize the output during large load transitions and has ESR and ESL characteristics necessary for very low output ripple. The RMS ripple current is given by:

$$I_{RMS} = \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{(V_{OUT} - V_F) \cdot (V_{IN} - V_{OUT})}{L \cdot f_S \cdot V_{IN}}$$

For a ceramic output capacitor, the dissipation due to the RMS current and associated output ripple are negligible.

Tantalum capacitors with sufficiently low ESR to meet output ripple requirements generally have an RMS current rating much greater than that actually seen in this application. The maximum tantalum output capacitor ESR is:

$$ESR \leq \frac{V_{RIPPLE}}{\Delta I}$$

where ΔI is the peak-to-peak inductor ripple current.

Due to the ESR zero associated with the tantalum capacitor, smaller values than those required with ceramic capacitors provide more phase margin with a greater loop crossover frequency.

Thermal

Losses associated with the AAT1155 output switching MOSFET are due to switching losses and conduction losses. The conduction losses are associated with the $R_{DS(ON)}$ characteristics of the output switching device. At the full load condition, assuming continuous conduction mode (CCM), an accurate calculation of the $R_{DS(ON)}$ losses can be derived from the following equations:

$$P_{ON} = I_{RMS}^2 \cdot R_{DS(ON)}$$

$R_{DS(ON)}$ losses

$$I_{RMS} = \sqrt{\left(I_{OUT}^2 + \frac{\Delta I^2}{12}\right) \cdot D}$$

where, I_{RMS} is internal switch RMS current.

D is the duty cycle and V_F is the forward voltage drop of the Schottky diode.

$$D = \frac{V_{OUT} + V_F}{V_{IN} + V_F}$$

ΔI is the peak-to-peak inductor ripple current. A simplified form of calculating the $R_{DS(ON)}$ and switching losses is given by:

$$P = \frac{I_{OUT}^2 \cdot R_{DS(ON)} \cdot V_{OUT}}{V_{IN}} + (t_{SW} \cdot f_S \cdot I_{OUT} + I_Q) \cdot V_{IN}$$

where I_Q is the AAT1155 quiescent current.

Once the total losses have been determined, the junction temperature can be derived. The thermal resistance (Θ_{JA}) for the MSOP-8 package mounted on an FR4 printed circuit board in still air is 150°C/W.

$$T_J = P \cdot \Theta_{JA} + T_{AMB}$$

T_{AMB} is the maximum ambient temperature and T_J is the resultant maximum junction temperature.

AAT1155**1MHz 2.5A Step-Down DC/DC Converter**

Part Number	Manufacturer	Capacitance (μF)	Voltage (V)	Temp Co.	Case
C4532X5ROJ107M	TDK	100	6.3	X5R	1812
GRM43-2 X5R 107M 6.3	Murata				
GRM43-2 X5R 476K 6.3		47			
GRM42-6 X5R 106K 6.3		10			
594D127X_6R3C2T	Vishay	120	16		C
595D107X0016C		100			

Table 1: AAT1155 Recommended Capacitors.

Part Number	Manufacturer	Inductance (μH)	I (A)	DCR (Ω)	Height (mm)	Type
CDRH6D38-4763-T055	Sumida	1.5	4.0	0.014	4.0	Shielded
N05D B1R5M	Taiyo Yuden		3.2	0.025	2.8	Non-Shielded
NP06DB B1R5M			3.0	0.022	3.2	Shielded
LQH55DN1R5M03	Murata		3.7		0.016	4.7
LQH66SN1R5M03			3.8	Shielded		

Table 2: AAT1155 Recommended Inductors.

Manufacturer	Part Number	V_F
Diodes Inc.	B340LA	0.45V @ 3A
ROHM	RB050L-40	0.45 @ 3A
Micro Semi	5820SM	0.46V @ 3A

Table 3: AAT1155 Recommended Diodes.

1MHz 2.5A Step-Down DC/DC Converter**Evaluation Board Description**

The AAT1155 evaluation board demonstrates the performance, along with the suggested size and placement of external components for the AAT1155 integrated buck regulator. The external components are selected for minimum size and optimum operation up to 2.5A output current.

Components Summary

Capacitor C4 is a high equivalent series resistance (ESR) tantalum capacitor for damping the high Q input network associated with the inductance of the leads feeding the input power to the evaluation board and the low ESR 10 μ F ceramic input capacitor (C1). R2 is a pull-up resistor to allow the enable pin to be used to enable and disable the IC by either shorting the enable pin to GND or leaving the pin open. Both R2 and C4 are for demonstration purposes only and are not necessary in the final solution. Resistors R3 and R4 are used with the 1V model to set the output voltage to any desired value from 1.0V to as high as 200mV below the minimum input voltage. They are not required for the fixed output voltage versions of the AAT1155. For fixed output voltage versions, R4 is omitted and R3 is replaced with a short.

Layout

Figure 1 shows the evaluation board schematic. Figures 2 and 3 display the suggested PCB layout for the AAT1155. The following guidelines should be used to help ensure a proper layout. Table 4 and 5 provide the AAT1155 evaluation board specifications and the component list respectively.

1. The connection from the input capacitor to the Schottky anode should be as short as possible.
2. The input capacitor should connect as closely as possible to VP (Pins 5 and 8) and GND (Pin 2).
3. C1, L1, and CR1 should be connected as closely as possible. The connection from the cathode of the Schottky to the LX node should be as short as possible.
4. The feedback trace (Pin 1) should be separate from any power trace and connect as closely as possible to the load point. Sensing along a high-current load trace can degrade DC load regulation.
5. The resistance of the trace from the load return to GND (Pin 2) 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 reference ground and the load return.
6. R1 and C3 are required in order to provide a cleaner power source for the AAT1155 control circuitry.

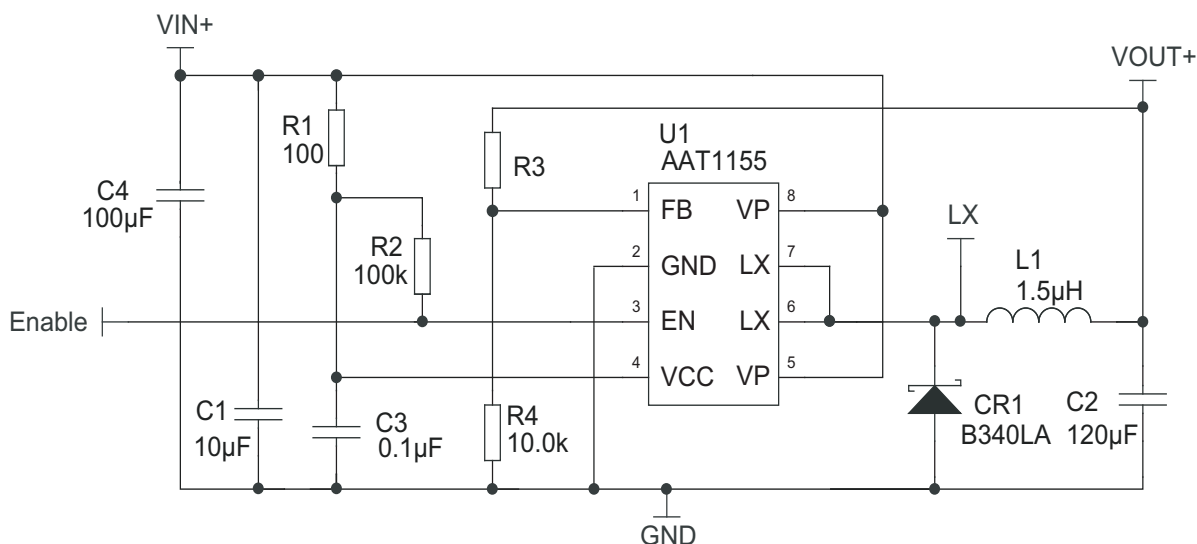


Figure 1: AAT1155 Evaluation Board with Adjustable Output.

AAT1155

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Specification	Test Conditions	Min	Typ	Max	Units
Input Voltage		2.7	3.6	5.5	V
Output Error Voltage			±3		%
Output Current		0		2.5	A

Table 4: AAT1155 Evaluation Board Specifications.

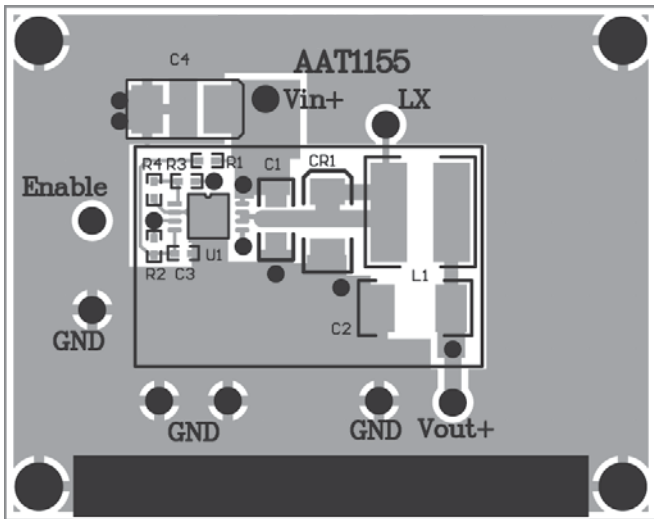


Figure 2: Evaluation Board Top Side.

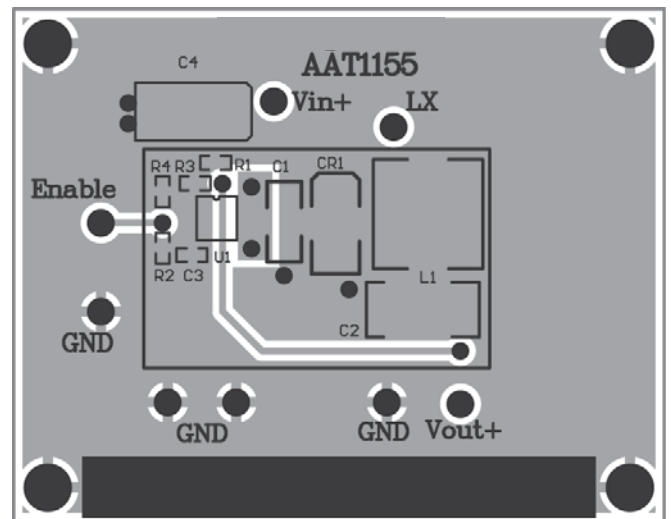


Figure 3: Evaluation Board Bottom Side.

Component	Part#	Description	Manufacturer	
U1	AAT1155IKS-1.0-T1	1.0V 850kHz 2.5A Buck Converter	Skyworks	
U1	AAT1155IKS-1.8-T1	1.8V 850kHz 2.5A Buck Converter	Skyworks	
U1	AAT1155IKS-2.5-T1	2.5V 850kHz 2.5A Buck Converter	Skyworks	
U1	AAT1155IKS-3.3-T1	3.3V 850kHz 2.5A Buck Converter	Skyworks	
CR1	B340LA	Low V_f 3A, 40V Schottky Diode	Diodes Inc.	
C2	594D127X96R6R3C2T	120 μ F, 6.3V, Tantalum	Vishay	
C4	565D107X0016C	100 μ F, 16V, Tantalum	Vishay	
C1	GRM319R60J106KE01	10 μ F, 6.3V, X5R, 10%, 1206	MuRata	
C3	GRM155R61A104KA01	0.1 μ F, 25V, X5R, 10%, 0402	MuRata	
R1	Chip Resistor	100k Ω , 5%, 1/16W, 0402	Vishay	
R2	Chip Resistor	100k Ω , 5%, 1/16W, 0402	Vishay	
L1	CDRH6D28-1R5	1.5 μ H Shielded	Sumida	
R3	Chip Resistor	AAT1155IKS-1.0-T1	see Table 6, 1%, 1/16W, 0402	Vishay
		AAT1155IKS-1.1-T1 thru AAT1155IKS-3.3-T1	0 Ω , 0402	
R4	Chip Resistor	AAT1155IKS-1.0-T1 (when output is > 1.0V only, otherwise not needed)	10k Ω , 1%, 1/16W; 0402	Vishay
		AAT1155IKS-1.1-T1 thru AAT1155IKS-3.3-T1		N/A

Table 5: AAT1155 Evaluation Board Component Listing.

1MHz 2.5A Step-Down DC/DC Converter

For an adjustable output, set R4 to 10k Ω and select R3 according to table 6.

Vo (V)	R3 (kΩ)
1.0	0.00 (short)
1.1	1.00
1.2	2.00
1.25	2.55
1.3	3.01
1.4	4.02
1.5	4.99
1.6	6.04
1.7	6.98
1.8	8.06
1.85	8.45
1.9	9.09
2.0	10.0
2.1	11.0
2.2	12.1
2.3	13.0
2.4	14.0
2.5	15.0
3.3	23.2

Table 6. Resistor selection for adjustable output voltage (R4=10.0k Ω)

1MHz 2.5A Step-Down DC/DC Converter**Design Example**

I_{OUT} 2.5A
 I_{RIPPLE} 40% of Full Load at Max V_{IN}
 V_{OUT} 2.5V
 V_{IN} 5V $\pm 5\%$
 f_S 1MHz
 T_{MAX} 70°C

Inductor Selection

$$\begin{aligned}
 L &= \frac{V_{OUT}}{I_{OUT} \cdot k \cdot f_S} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \\
 &= \frac{3.3V}{2.5A \cdot 0.4 \cdot 1MHz} \cdot \left(1 - \frac{3.3V}{5.25V}\right) \\
 &= 1.23\mu H
 \end{aligned}$$

Use standard value of 1.5 μ H

Sumida inductor Series CDRH6D38.

$$\begin{aligned}
 \Delta I &= \frac{V_{OUT}}{L \cdot f_S} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \\
 &= \frac{3.3V}{1.5\mu H \cdot 1MHz} \cdot \left(1 - \frac{3.3V}{5.25V}\right) \\
 &= 0.82A
 \end{aligned}$$

$$\begin{aligned}
 I_{PK} &= I_{OUT} + \frac{\Delta I}{12} \\
 &= 2.5A + 0.41A \\
 &= 2.91A
 \end{aligned}$$

I_{PK} is the peak current.

Efficiency vs. Load Current
($V_{IN} = 5.0V$; $V_{OUT} = 3.3V$)

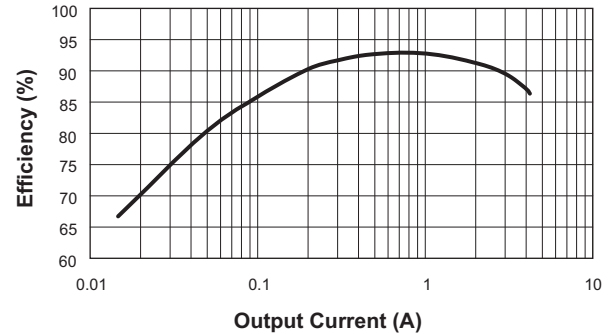


Figure 4: 5V Input, 3.3V Output.

AAT1155 Junction Temperature

$$\begin{aligned}
 P_{ON} &= \frac{I_{OUT}^2 \cdot R_{DS(ON)} \cdot V_{OUT}}{V_{IN}} + \left(\frac{t_{SW} \cdot F_S \cdot I_{OUT}}{2} + I_Q\right) \cdot V_{IN} \\
 &= \frac{(2.5A)^2 \cdot 70m\Omega \cdot 3.3V}{5V} + \left(\frac{20ns \cdot 1MHz \cdot 2.5A}{2} + 690\mu A\right) \cdot 5V \\
 &= 0.42W
 \end{aligned}$$

$$\begin{aligned}
 T_{J(MAX)} &= T_{AMB} + \Theta_{JA} \cdot P_{ON} \\
 &= 70^\circ C + 150^\circ C/W \cdot 0.42W \\
 &= 133^\circ C
 \end{aligned}$$

Diode

$$\begin{aligned}
 I_{DIODE} &= I_{OUT} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \\
 &= 2.5A \cdot \left(1 - \frac{3.3V}{5.25V}\right) = 0.93A
 \end{aligned}$$

$$\begin{aligned}
 P_{DIODE} &= V_F \cdot I_{DIODE} \\
 &= 0.35V \cdot 0.93A = 0.33W
 \end{aligned}$$

Given an ambient thermal resistance of 120°C/W from the manufacturer's datasheet, $T_{J(MAX)}$ of the diode is:

$$\begin{aligned}
 T_{J(MAX)} &= T_{AMB} + \Theta_{JA} \cdot P \\
 &= 70^\circ C + 120^\circ C/W \cdot 0.33W \\
 &= 109^\circ C
 \end{aligned}$$

1MHz 2.5A Step-Down DC/DC Converter**Output Capacitor**

The output capacitor value required for sufficient loop phase margin depends on the type of capacitor selected. For a low ESR ceramic capacitor, a minimum value of 200 μ F is required. For a low ESR tantalum capacitor, lower values are acceptable. While the relatively higher ESR associated with the tantalum capacitor will give more phase margin and a more dampened transient response, the output voltage ripple will be higher.

The 120 μ F Vishay 594D tantalum capacitor has an ESR of 85m Ω and a ripple current rating of 1.48Arms in a C case size. Although smaller case sizes are sufficiently rated for this ripple current, their ESR level would result in excessive output ripple.

The ESR requirement for a tantalum capacitor can be estimated by :

$$ESR \leq \frac{V_{RIPPLE}}{\Delta I} = \frac{100mV}{0.9A} = 111m\Omega$$

$$I_{RMS} = \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{(V_{OUT} + V_F) \cdot (V_{IN} + V_{OUT})}{L \cdot f_S \cdot V_{IN}}$$

$$= \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{3.65V \cdot 1.7V}{1.5\mu H \cdot 1MHz \cdot 5V} = 240mArms$$

Two or three 1812 X5R 100 μ F 6.3V ceramic capacitors in parallel also provide sufficient phase margin. The low ESR and ESL associated with ceramic capacitors also reduces output ripple significantly over that seen with tantalum capacitors. Temperature rise due to ESR ripple current dissipation is also reduced.

Input Capacitor

The input capacitor ripple is:

$$I_{RMS} = I_{OUT} \cdot \sqrt{\frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} = 1.82Arms$$

In the examples shown, C1 is a ceramic capacitor located as closely to the IC as possible. C1 provides the low impedance path for the sharp edges associated with the input current. C4 may or may not be required, depending upon the impedance characteristics looking back into the source. It serves to dampen any input oscillations that may arise from a source that is highly inductive. For most applications, where the source has sufficient bulk capacitance and is fed directly to the AAT1155 through large PCB traces or planes, it is not required. When operating the AAT1155 evaluation board on the bench, C4 is required due to the inductance of the wires running from the laboratory power supply to the evaluation board.

Adjustable Output

For applications requiring an output other than 1V, the AAT1155 can be externally programmed. Resistors R3 and R4 of Figure 1 force the output to regulate higher than 1V. For accurate results (less than 1% error for all outputs), select R4 to be 10k Ω . Once R4 has been selected, R3 can be calculated. For a 1.25V output with R4 set to 10k Ω , R3 is 2.5k Ω .

$$R3 = (V_{OUT} - 1) \cdot R4 = 0.25 \cdot 10k\Omega = 2.5k\Omega$$

1MHz 2.5A Step-Down DC/DC Converter

Ordering Information

Output Voltage	Package	Marking ¹	Part Number (Tape & Reel) ²
1.0V (Adj. $V_{OUT} \geq 1.0V$)	MSOP-8	KXXYY	AAT1155IKS-1.0-T1



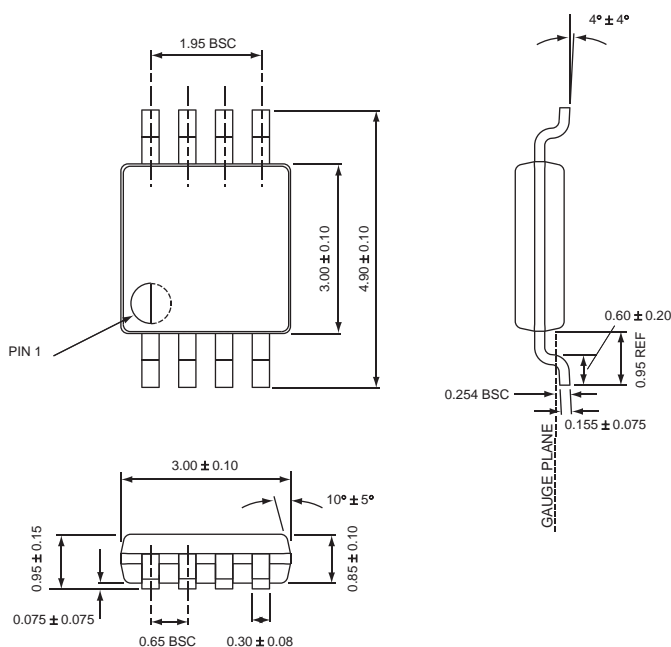
Skyworks Green™ products are compliant with all applicable legislation and are halogen-free.



For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

Package Information

MSOP-8



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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