

**Low-Noise, Fast Transient 600mA Step-Down Converter**

**General Description**

The AAT2146W SwitchReg is a 2MHz fixed frequency step-down converter with an input voltage range of 2.7V to 5.5V and output voltage as low as 0.6V. It is optimized to react quickly to a load variation. The AAT2146W is ideal for applications where fixed frequency and low ripple voltage are required over the full range of load conditions.

The AAT2146W is programmable with external feedback resistors. It can deliver 600mA of load current while maintaining a low 150µA no-load quiescent current. The 2MHz switching frequency minimizes the size of external components while keeping switching losses low.

The AAT2146W is designed to maintain high efficiency throughout the operating range, which is critical for portable applications.

The AAT2146W is available in the Pb-free, space-saving 2.0x2.2mm SC70JW-8 package and is rated over the -40°C to +85°C temperature range.

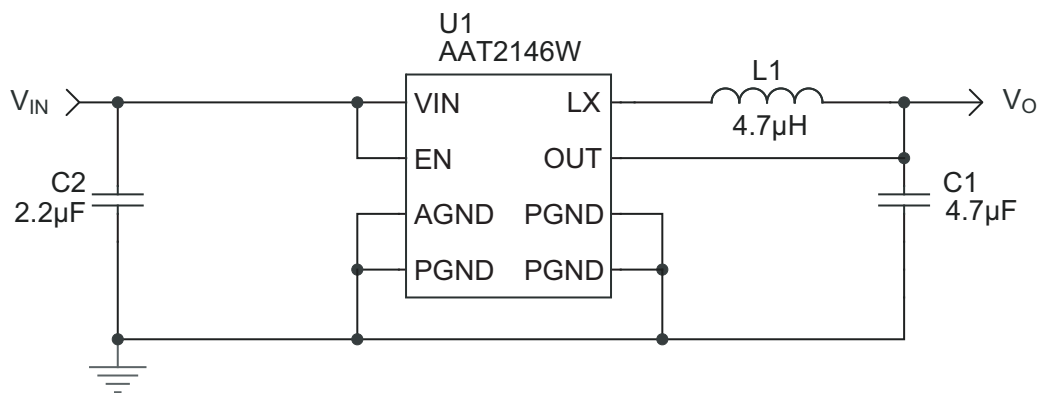
**Features**

- $V_{IN}$  Range: 2.7V to 5.5V
- Low Ripple Voltage Fixed Frequency PWM Mode
- $V_{OUT}$  Adjustable from 0.6V to  $V_{IN}$
- Efficiency up to 96%
- 600mA Max Output Current
- 2MHz Switching Frequency
- 150µs Soft Start
- Fast Load Transient
- Over-Temperature Protection
- Current Limit Protection
- 100% Duty Cycle Low-Dropout Operation
- <1µA Shutdown Current
- SC70JW-8 Package
- Temperature Range: -40°C to +85°C

**Applications**

- Cellular Phones
- Digital Cameras
- Handheld Instruments
- Microprocessor / DSP Core / IO Power
- PDAs and Handheld Computers
- USB Devices

**Typical Application**

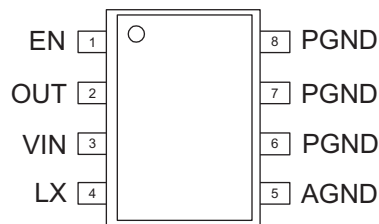


**AAT2146W****Low-Noise, Fast Transient 600mA Step-Down Converter****Pin Descriptions**

Pin #	Symbol	Function
1	EN	Enable pin.
2	OUT	Feedback input pin. This pin is connected either directly to the converter output or to an external resistive divider for an adjustable output.
3	VIN	Input supply voltage for the converter.
4	LX	Switching node. Connect the inductor to this pin. It is internally connected to the drain of both high- and low-side MOSFETs.
5	AGND	Non-power signal ground pin.
6, 7, 8	PGND	Main power ground return pins. Connect to the output and input capacitor return.

**Pin Configuration**

**SC70JW-8  
(Top View)**



**AAT2146W****Low-Noise, Fast Transient 600mA Step-Down Converter****Absolute Maximum Ratings<sup>1</sup>**

Symbol	Description	Value	Units
$V_{IN}$	Input Voltage GND	-0.3 to 6.0	V
$V_{LX}$	LX to GND	-0.3 to $V_{IN} + 0.3$	V
$V_{OUT}$	OUT to GND	-0.3 to $V_{IN} + 0.3$	V
$V_{EN}$	EN to GND	-0.3 to $V_{IN} + 0.3$	V
$T_J$	Junction Temperature Range	-40 to 150	°C
$T_{LEAD}$	Maximum Soldering Temperature (at leads, 10 sec.)	300	°C
$T_A$	Operating Temperature Range	-40 to 85	°C

**Thermal Information**

Symbol	Description	Value	Units
$P_D$	Maximum Power Dissipation <sup>2, 3</sup>	625	mW
$\theta_{JA}$	Thermal Resistance <sup>2</sup>	160	°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 an FR4 board.

3. Derate 6.25mW/°C above 25°C.

**AAT2146W****Low-Noise, Fast Transient 600mA Step-Down Converter****Electrical Characteristics<sup>1</sup>**

$T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ , unless otherwise noted. Typical values are  $T_A = 25^{\circ}\text{C}$ ,  $V_{IN} = 3.6\text{V}$ .

Symbol	Description	Conditions	Min	Typ	Max	Units
<b>Step-Down Converter</b>						
$V_{IN}$	Input Voltage		2.7		5.5	V
$V_{UVLO}$	UVLO Threshold	$V_{IN}$ Rising			2.7	V
		Hysteresis		100		mV
		$V_{IN}$ Falling	1.8			V
$V_{OUT}$	Out Voltage Accuracy	No Load; $T_A = 25^{\circ}\text{C}$		600		mV
$V_{OUT}$	Output Voltage Tolerance	$I_{OUT} = 0\text{mA}$ to $600\text{mA}$ , $V_{IN} = 2.7\text{V}$ to $5.5\text{V}$	-3.0		+3.0	%
$V_{OUT}$	Output Voltage Range		0.6		$V_{IN}$	V
$I_Q$	Quiescent Current	No Load, Not Switching		150	300	$\mu\text{A}$
$I_{SHDN}$	Shutdown Current	EN = AGND = PGND			1.0	$\mu\text{A}$
$I_{LIM}$	P-Channel Current Limit		800			mA
$R_{DS(ON)H}$	High Side Switch On Resistance			0.35		$\Omega$
$R_{DS(ON)L}$	Low Side Switch On Resistance			0.30		$\Omega$
$\Delta V_{Linereg}$	Line Regulation	$V_{IN} = 2.7\text{V}$ to $5.5\text{V}$ ; $I_{OUT} = 600\text{mA}$		0.1		%/V
$I_{OUT}$	Out Leakage Current	0.6V Output			0.2	$\mu\text{A}$
$T_S$	Start-Up Time	From Enable to Output Regulation		150		$\mu\text{s}$
$F_{OSC}$	Oscillator Frequency	$T_A = 25^{\circ}\text{C}$		2.0		MHz
$T_{SD}$	Over-Temperature Shutdown Threshold			140		$^{\circ}\text{C}$
$T_{HYS}$	Over-Temperature Shutdown Hysteresis			15		$^{\circ}\text{C}$
<b>EN</b>						
$V_{EN(L)}$	Enable Threshold Low				0.6	V
$V_{EN(H)}$	Enable Threshold High		1.4			V
$I_{EN}$	Input Low Current	$V_{IN} = V_{OUT} = 5.5\text{V}$	-1.0		1.0	$\mu\text{A}$

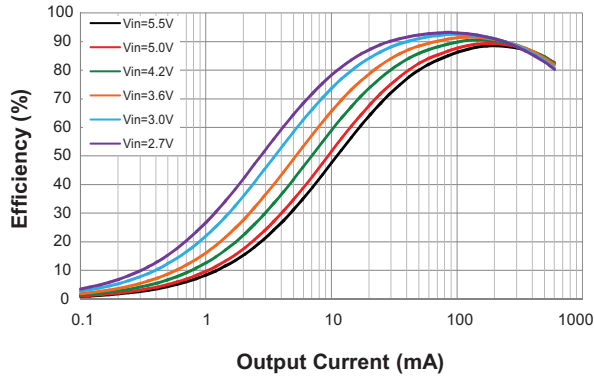
1. The AAT2146W is guaranteed to meet performance specifications over the  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  operating temperature range and is assured by design, characterization, and correlation with statistical process controls.

# AAT2146W

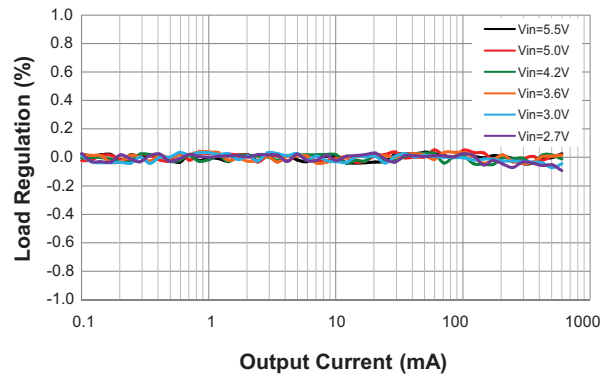
## Low-Noise, Fast Transient 600mA Step-Down Converter

### Typical Characteristics<sup>1</sup>

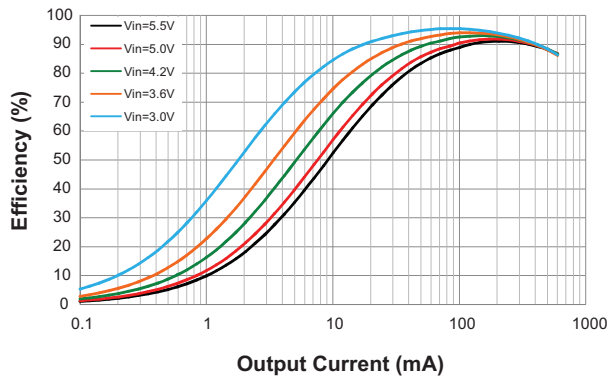
**Efficiency vs. Output Current**  
( $V_{OUT} = 1.8V$ )



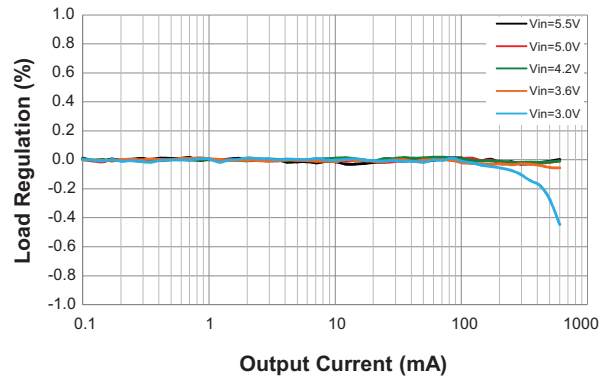
**Load Regulation**  
( $V_{OUT} = 1.8V$ )



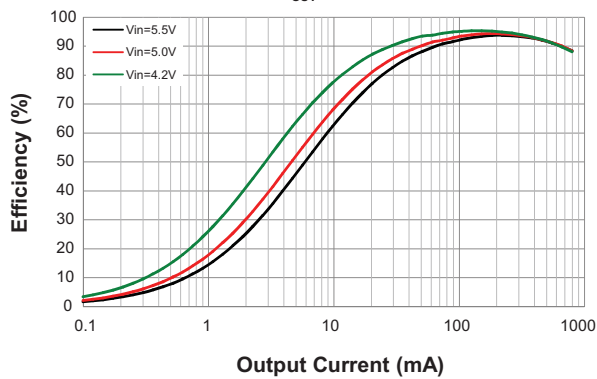
**Efficiency vs. Output Current**  
( $V_{OUT} = 2.5V$ )



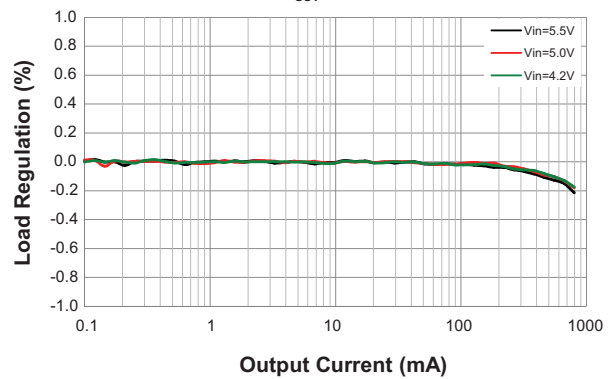
**Load Regulation**  
( $V_{OUT} = 2.5V$ )



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



**Load Regulation**  
( $V_{OUT} = 3.3V$ )



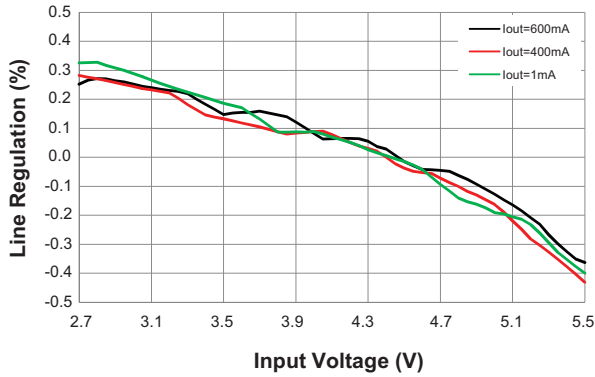
1. See figure 2 for the application test circuit.

# AAT2146W

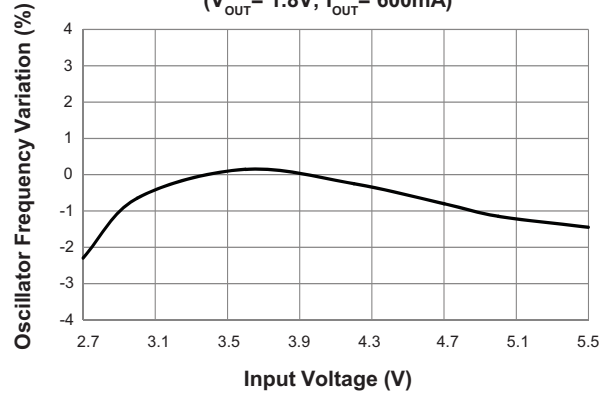
## Low-Noise, Fast Transient 600mA Step-Down Converter

### Typical Characteristics

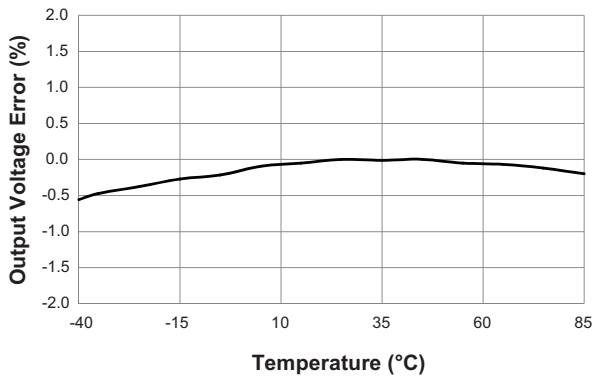
**Line Regulation**  
( $V_{OUT} = 1.8V$ )



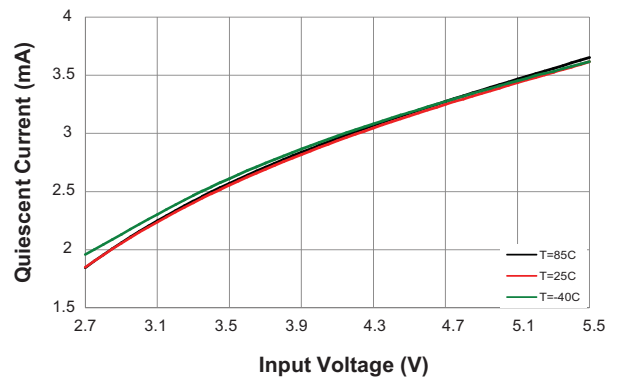
**Oscillator Frequency Variation vs. Input Voltage**  
( $V_{OUT} = 1.8V$ ;  $I_{OUT} = 600mA$ )



**Output Voltage Error vs. Temperature**  
( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6V$ ;  $I_{OUT} = 400mA$ )

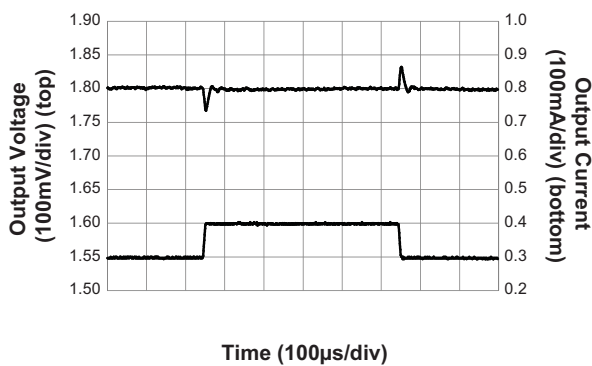


**Quiescent Current vs. Input Voltage**



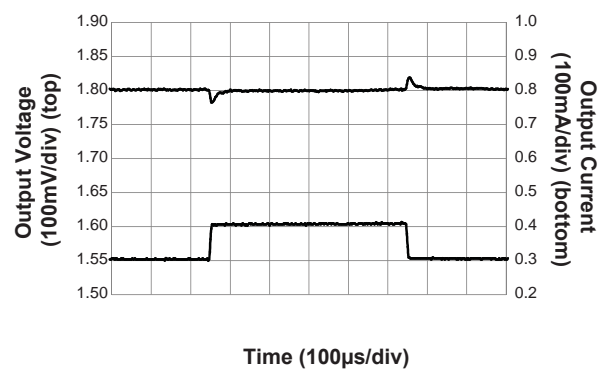
**Load Transient**

( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6V$ ;  $I_{OUT} = 300mA$  to  $400mA$ ;  $C_{FF} = 0pF$ )



**Load Transient**

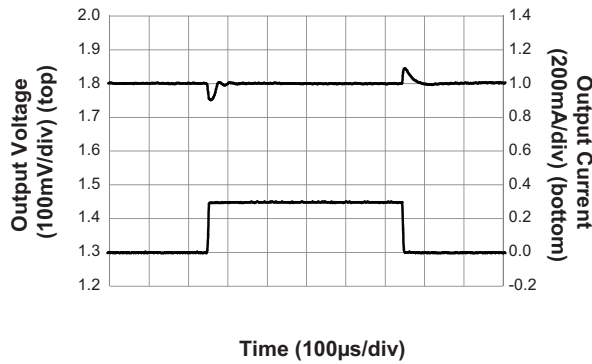
( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6V$ ;  $I_{OUT} = 300mA$  to  $400mA$ ;  $C_{FF} = 100pF$ )



## Typical Characteristics

### Load Transient

( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6V$ ;  $I_{OUT} = 1mA$  to  $300mA$ ;  $C_{FF} = 100pF$ )

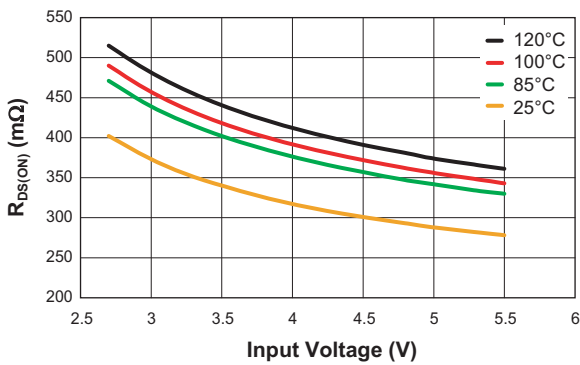


### Line Transient

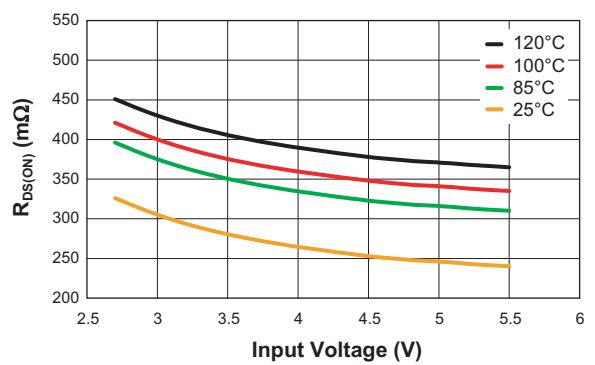
( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6$  to  $4.2V$ ;  $I_{OUT} = 400mA$ ;  $C_{FF} = 0pF$ )



### P-Channel $R_{DS(ON)}$ vs. Input Voltage (Junction Temperature)

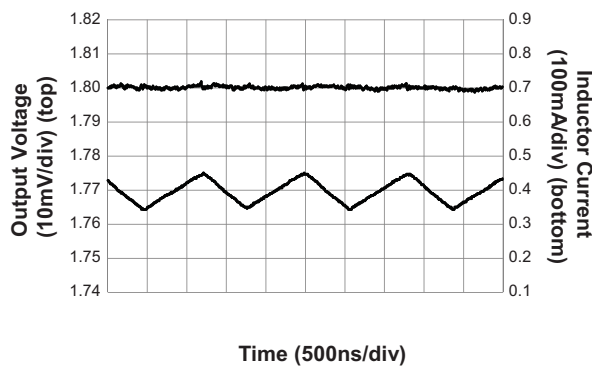


### N-Channel $R_{DS(ON)}$ vs. Input Voltage (Junction Temperature)



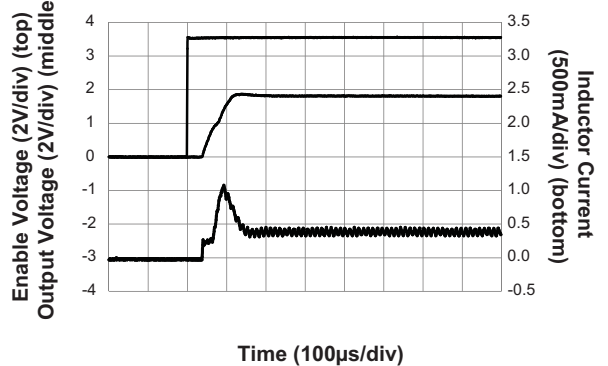
### Output Voltage Ripple

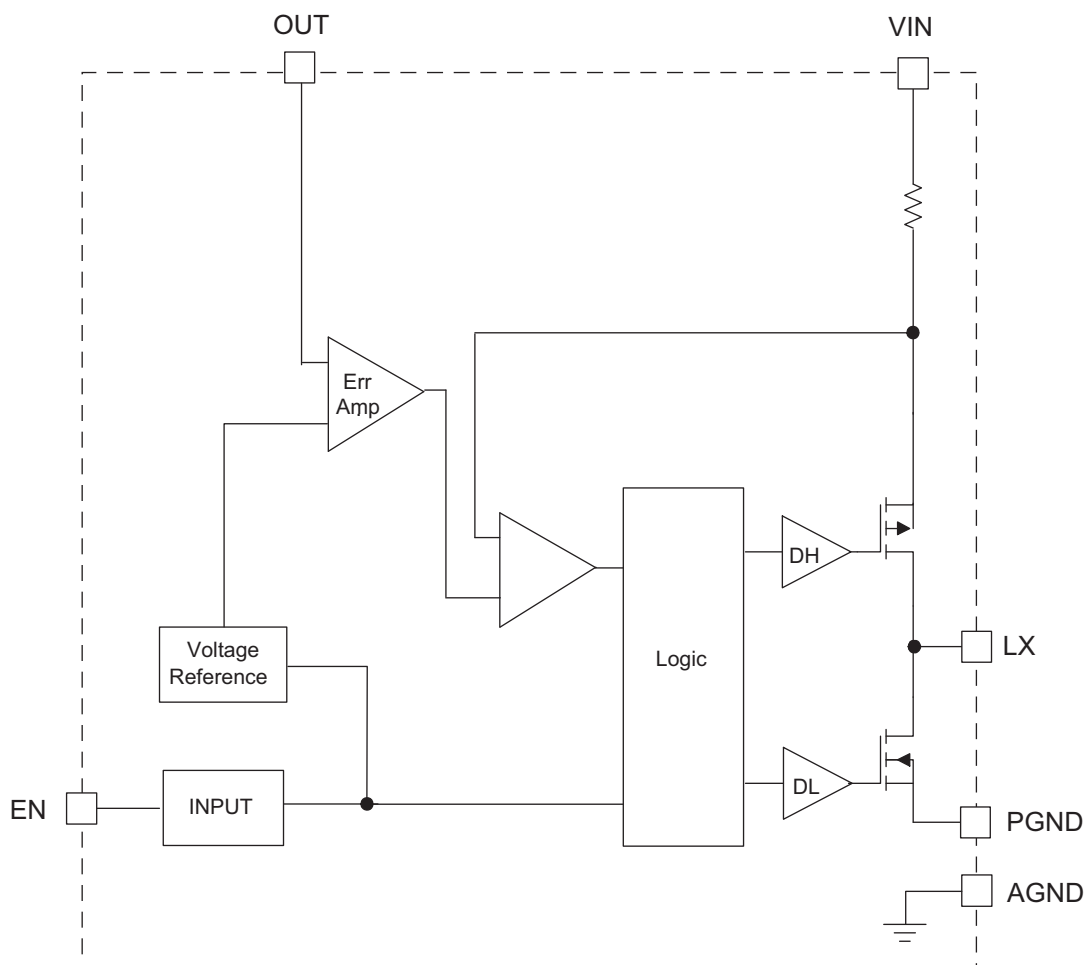
( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6V$ ;  $I_{OUT} = 400mA$ )



### Soft Start

( $V_{OUT} = 1.8V$ ;  $V_{IN} = 3.6V$ ;  $I_{OUT} = 400mA$ )



**AAT2146W****Low-Noise, Fast Transient 600mA Step-Down Converter****Functional Block Diagram****Functional Description**

The AAT2146W is a high performance, fixed frequency, 600mA, 2MHz, monolithic step-down converter. It has been designed with the goal of minimizing external components, size and optimizing efficiency over the complete load range, and produces reduced ripple voltage and spectral noise. Typically, a 4.7 $\mu$ H inductor and a 4.7 $\mu$ F ceramic output capacitor are recommended (see tables 4 and 5).

The adjustable output can be programmed with external feedback to any voltage, ranging from 0.6V to the input voltage. An additional feed-forward capacitor ( $C_{FF}$ ) can also be added to the external feedback to provide improved transient response (see Figure 1).

At dropout, the converter duty cycle increases to 100% and the output voltage tracks the input voltage minus the  $R_{DS(ON)}$  voltage drop of the P-channel high-side MOSFET.

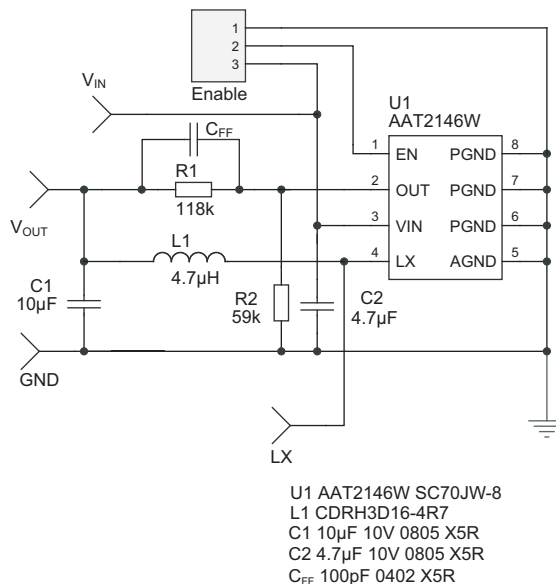
The input voltage range is 2.7V to 5.5V. The converter efficiency has been optimized for all load conditions, ranging from no load to 600mA.

The internal error amplifier and compensation provides excellent transient response, load, and line regulation. Soft start eliminates any output voltage overshoot when the enable or the input voltage is applied.



# AAT2146W

## Low-Noise, Fast Transient 600mA Step-Down Converter

**Figure 1: Enhanced Transient Response Schematic.**

### Control Loop

The AAT2146W is a peak current mode step-down converter. The current through the P-channel MOSFET (high side) is sensed for current loop control, as well as short circuit and overload protection. A fixed slope compensation signal is added to the sensed current to maintain stability for duty cycles greater than 50%. The peak current mode loop appears as a voltage-programmed current source in parallel with the output capacitor.

The output of the voltage error amplifier programs the current mode loop for the necessary peak switch current to regulate a constant output voltage for all load and line conditions. Internal loop compensation terminates the transconductance voltage error amplifier output. The error amplifier reference is fixed at 0.6V.

### Soft Start / Enable

Soft start limits the current surge seen at the input and eliminates output voltage overshoot. When pulled low, the enable input forces the AAT2146W into a low-power, non-switching state. The total input current during shutdown is less than 1µA.

### Current Limit and Over-Temperature Protection

For overload conditions, the peak input current is limited cycle by cycle.

Thermal protection completely disables switching when junction temperature becomes excessive. The junction over-temperature threshold is 140°C with 15°C of hysteresis. Once an over-temperature or over-current fault condition is removed, the output voltage automatically recovers.

### Under-Voltage Lockout

Internal bias of all circuits is controlled via the  $V_{IN}$  input. Under-voltage lockout (UVLO) guarantees sufficient  $V_{IN}$  bias and proper operation of all internal circuitry prior to activation.

## AAT2146W

## Low-Noise, Fast Transient 600mA Step-Down Converter

## Applications Information

## Inductor Selection

The step-down converter uses peak current mode control with slope compensation to maintain stability for duty cycles greater than 50%. The output inductor value must be selected so the inductor current down slope meets the internal slope compensation requirements. The internal slope compensation is 0.24A/μs. This equates to a slope compensation that is 75% of the inductor current down slope for a 1.5V output and 4.7μH inductor.

$$m = \frac{0.75 \cdot V_o}{L} = \frac{0.75 \cdot 1.5V}{4.7\mu H} = 0.24 \frac{A}{\mu s}$$

This is the internal slope compensation. When externally programming to 2.5V, the calculated inductance is 7.5μH.

$$L = \frac{0.75 \cdot V_o}{m} = \frac{0.75 \cdot V_o}{0.24A \frac{A}{\mu s}} \approx 3 \frac{\mu s}{A} \cdot V_o$$

$$= 3 \frac{\mu s}{A} \cdot 2.5V = 7.5\mu H$$

In this case, a standard 6.8μH value is selected.

Table 1 displays inductor values for the AAT2146W.

Output Voltage	Inductor
1V, 1.2V	2.2μH
1.5V, 1.8V	4.7μH
2.5V, 3.3V	6.8μH

**Table 1: Inductor Values.**

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.

The 4.7μH CDRH3D16 series inductor selected from Sumida has a 105mΩ DCR and a 900mA DC current rating. At full load, the inductor DC loss is 17mW which gives a 2.8% loss in efficiency for a 400mA, 1.5V output.

## Input Capacitor

Select a 2.2μF to 10μF X7R or X5R ceramic capacitor for the input. To estimate the required input capacitor size, determine the acceptable input voltage ripple level ( $V_{PP}$ ) and solve for  $C_{IN}$ . The calculated value varies with input voltage and is a maximum when  $V_{IN}$  is double the output voltage.

$$C_{IN} = \frac{\frac{V_o}{V_{IN}} \cdot \left(1 - \frac{V_o}{V_{IN}}\right)}{\left(\frac{V_{PP}}{I_o} - ESR\right) \cdot f_{sw}}$$

For  $V_{IN} = 2 \cdot V_o$

$$\frac{V_o}{V_{IN}} \cdot \left(1 - \frac{V_o}{V_{IN}}\right) = \frac{1}{4}$$

$$C_{IN(MIN)} = \frac{1}{\left(\frac{V_{PP}}{I_o} - ESR\right) \cdot 4 \cdot f_{sw}}$$

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

The maximum input capacitor RMS current is:

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

The input capacitor RMS ripple current varies with the input and output voltage and will always be less than or equal to half of the total DC load current.

$$\sqrt{\frac{V_o}{V_{IN}} \cdot \left(1 - \frac{V_o}{V_{IN}}\right)} = \sqrt{D \cdot (1 - D)} = \sqrt{0.5^2} = \frac{1}{2}$$

For  $V_{IN} = 2 \cdot V_o$

$$I_{RMS(MAX)} = \frac{I_o}{2}$$

# AAT2146W

## Low-Noise, Fast Transient 600mA Step-Down Converter

The term  $\frac{V_O}{V_{IN}} \cdot \left(1 + \frac{V_O}{V_{IN}}\right)$  appears in both the input voltage ripple and input capacitor RMS current equations and is a maximum when  $V_O$  is twice  $V_{IN}$ . This is why the input voltage ripple and the input capacitor RMS current ripple are a maximum at 50% duty cycle.

The input capacitor provides a low impedance loop for the edges of pulsed current drawn by the AAT2146W. Low ESR/ESL X7R and X5R ceramic capacitors are ideal for this function. To minimize stray inductance, the capacitor should be placed as closely as possible to the IC. This keeps the high frequency content of the input current localized, minimizing EMI and input voltage ripple.

The proper placement of the input capacitor (C2) can be seen in the evaluation board layout in Figure 2.

A laboratory test set-up typically consists of two long wires running from the bench power supply to the evaluation board input voltage pins. The inductance of these wires, along with the low-ESR ceramic input capacitor, can create a high Q network that may affect converter performance. This problem often becomes apparent in the form of excessive ringing in the output voltage during load transients. Errors in the loop phase and gain measurements can also result.

Since the inductance of a short PCB trace feeding the input voltage is significantly lower than the power leads from the bench power supply, most applications do not exhibit this problem.

In applications where the input power source lead inductance cannot be reduced to a level that does not affect the converter performance, a high ESR tantalum or aluminum electrolytic should be placed in parallel with the low ESR, ESL bypass ceramic. This dampens the high Q network and stabilizes the system.

### Output Capacitor

The output capacitor limits the output ripple voltage and provides holdup during large load transitions. A 4.7 $\mu$ F to 10 $\mu$ F 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 voltage ripple.

The output voltage droop due to a load transient is dominated by the capacitance of the ceramic output capacitor. During a step increase in load current, the ceramic output capacitor alone supplies the load current until the loop responds. Within two or three switching cycles, the loop responds and the inductor current increases to match the load current demand. The relationship of the output voltage droop during the three switching cycles to the output capacitance can be estimated by:

$$C_{OUT} = \frac{3 \cdot \Delta I_{LOAD}}{V_{DROOP} \cdot f_{sw}}$$

Once the average inductor current increases to the DC load level, the output voltage recovers. The above equation establishes a limit on the minimum value for the output capacitor with respect to load transients.

The internal voltage loop compensation also limits the minimum output capacitor value to 4.7 $\mu$ F. This is due to its effect on the loop crossover frequency (bandwidth), phase margin, and gain margin. Increased output capacitance will reduce the crossover frequency with greater phase margin.

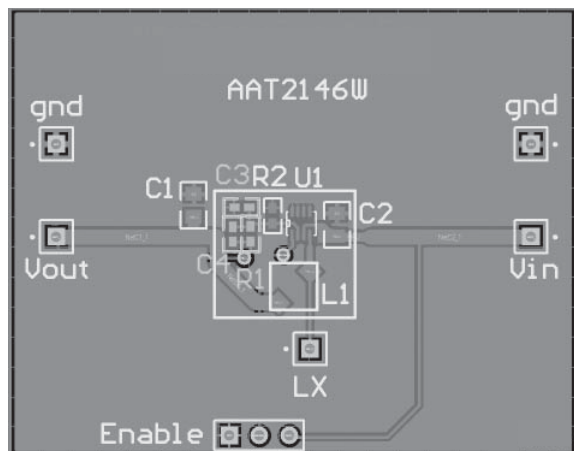
The maximum output capacitor RMS ripple current is given by:

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

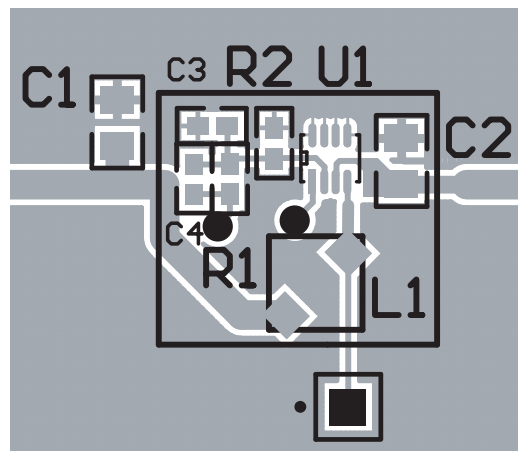
Dissipation due to the RMS current in the ceramic output capacitor ESR is typically minimal, resulting in less than a few degrees rise in hot-spot temperature.

# AAT2146W

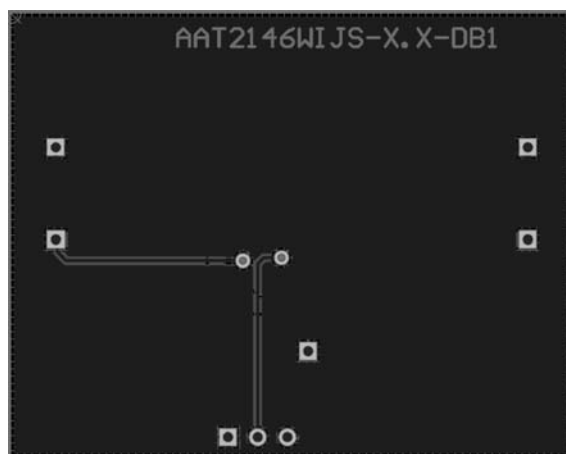
## Low-Noise, Fast Transient 600mA Step-Down Converter



**Figure 2: AAT2146W Evaluation Board Component Side Layout.**



**Figure 3: Exploded View of AAT2146W Evaluation Board Component Side Layout.**



**Figure 4: AAT2146W Evaluation Board Solder Side Layout.**

### Adjustable Output Resistor Selection

Feedback resistors R1 and R2 of Figure 5 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 59kΩ. 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 2 summarizes the resistor values for various output voltages with R2 set to either 59kΩ for good noise immunity or 221kΩ for reduced no load input current.

$$R1 = \left( \frac{V_{OUT}}{V_{REF}} - 1 \right) \cdot R2 = \left( \frac{1.5V}{0.6V} - 1 \right) \cdot 59k\Omega = 88.5k\Omega$$

The AAT2146W combined with an external feedforward capacitor (C4 in Figure 5), delivers enhanced transient response for extreme pulsed load applications.

# AAT2146W

## Low-Noise, Fast Transient 600mA Step-Down Converter

V <sub>OUT</sub> (V)	R2 = 59kΩ	R2 = 221kΩ
	R1 (kΩ)	R1 (kΩ)
0.8	19.6	75
0.9	29.4	113
1.0	39.2	150
1.1	49.9	187
1.2	59.0	221
1.3	68.1	261
1.4	78.7	301
1.5	88.7	332
1.8	118	442
1.85	124	464
2.0	137	523
2.5	187	715
3.3	267	1000

**Table 2: Adjustable Resistor Values For Use With 0.6V Step-Down Converter.**

### Thermal Calculations

There are three types of losses associated with the AAT2146W step-down converter: switching losses, conduction losses, and quiescent current losses. Conduction losses are associated with the R<sub>DS(ON)</sub> characteristics of the power output switching devices. Switching losses are dominated by the gate charge of the power output

switching devices. A simplified form of the losses is given by:

$$P_{TOTAL} = \frac{I_O^2 \cdot (R_{DS(ON)HS} \cdot V_O + R_{DS(ON)LS} \cdot [V_{IN} - V_O])}{V_{IN}} + (t_{sw} \cdot f_{sw} \cdot I_O + I_Q) \cdot V_{IN}$$

I<sub>Q</sub> is the step-down converter quiescent current. The term t<sub>sw</sub> is used to estimate the full load step-down converter switching losses.

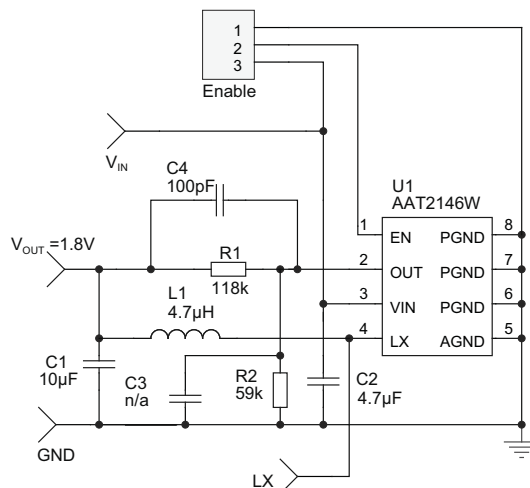
For the condition where the step-down converter is in dropout at 100% duty cycle, the total device dissipation reduces to:

$$P_{TOTAL} = I_O^2 \cdot R_{DS(ON)HS} + I_Q \cdot V_{IN}$$

Since R<sub>DS(ON)</sub>, quiescent current, and switching losses all vary with input voltage, the total losses should be investigated over the complete input voltage range.

Given the total losses, the maximum junction temperature can be derived from the θ<sub>JA</sub> for the SC70JW-8 package which is 160°C/W.

$$T_{J(MAX)} = P_{TOTAL} \cdot Q_{JA} + T_A$$



U1 AAT2146W SC70JW-8  
 L1 CDRH3D16-4R7  
 C2 4.7μF 10V 0805 X5R  
 C1 10μF 6.3V 0805 X5R

**Figure 5: AAT2146W Adjustable Evaluation Board Schematic.**

# AAT2146W

## *Low-Noise, Fast Transient 600mA Step-Down Converter*

### **Layout**

The suggested PCB layout for the AAT2146W is shown in Figures 2, 3, and 4. The following guidelines should be used to help ensure a proper layout.

1. Connect the input capacitor (C2) as close as possible to VIN (Pin 3) and PGND (Pins 6-8).
2. Connect C1 and L1 as close as possible to the device pins. The connection of L1 to the LX pin should be as short as possible.
3. Separate the feedback trace or OUT pin (Pin 2) from any power trace and connect as close as possible to the load point. Sensing along a high-current load trace will degrade DC load regulation. If external feedback resistors are used, place them as close as possible to the OUT pin (Pin 2) to minimize the length of the high impedance feedback trace.

4. Keep the resistance of the trace from the load return to the PGND (Pins 6-8) 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.

A high density, small footprint layout can be achieved using an inexpensive, miniature, non-shielded, high DCR inductor. More care must be taken when laying out the copper board. For example, a non-shielded inductor will have a larger radiated magnetic field than a shielded inductor. Comparatively, the feedback trace must be placed further away from the non-shielded inductor.

**Low-Noise, Fast Transient 600mA Step-Down Converter****Step-Down Converter Design Example****Specifications**

$V_O = 1.8V @ 400mA$ , Pulsed Load  $\Delta I_{LOAD} = 300mA$   
 $V_{IN} = 2.7V$  to  $4.2V$  (3.6V nominal)  
 $f_{sw} = 2MHz$   
 $T_A = 85^\circ C$

**1.8V Output Inductor**

$$L_1 = 3 \frac{\mu S}{A} \cdot V_O = 3 \frac{\mu S}{A} \cdot 1.8V = 5.4\mu H \text{ (use } 4.7\mu H; \text{ see Table 1)}$$

For Sumida inductor CDRH3D16,  $4.7\mu H$ ,  $DCR = 105m\Omega$ .

$$\Delta I_{L1} = \frac{V_O}{L_1 \cdot f_{sw}} \cdot \left(1 - \frac{V_O}{V_{IN}}\right) = \frac{1.8V}{4.7\mu H \times 2.0MHz} \cdot \left(1 - \frac{1.8V}{4.2V}\right) = 109mA$$

$$I_{PKL1} = I_O + \frac{\Delta I_{L1}}{2} = 0.4A + 0.055A = 0.455A$$

$$P_{L1} = I_O^2 \cdot DCR = (0.4A)^2 \cdot 105m\Omega = 17mW$$

**1.8V Output Capacitor**

$$V_{DROOP} = 0.1V$$

$$C_{OUT} = \frac{3 \cdot \Delta I_{LOAD}}{V_{DROOP} \cdot f_{sw}} = \frac{3 \cdot 0.3A}{0.1V \cdot 2.0MHz} = 4.5\mu F; \text{ use } 4.7\mu F$$

$$I_{RMS} = \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{(V_O) \cdot (V_{IN(MAX)} - V_O)}{L_1 \cdot f_{sw} \cdot V_{IN(MAX)}} = \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{1.8V \cdot (4.2V - 1.8V)}{4.7\mu H \cdot 2.0MHz \cdot 4.2V} = 32mA \text{ (rms)}$$

$$P_{ESR} = ESR \cdot I_{RMS}^2 = 5m\Omega \cdot (32mA)^2 = 5.1\mu W$$

**Input Capacitor**

Input Ripple Voltage  $V_{PP} = 25mV$

$$C_{IN} = \frac{1}{\left(\frac{V_{PP}}{I_O} - ESR\right) \cdot 4 \cdot f_{sw}} = \frac{1}{\left(\frac{25mV}{0.4A} - 5m\Omega\right) \cdot 4 \cdot 2.0MHz} = 2.17\mu F; \text{ use } 2.2\mu F$$

$$I_{RMS} = \frac{I_O}{2} = 0.2A \text{ (rms)}$$

$$P_{ESR} = ESR \cdot I_{RMS}^2 = 5m\Omega \cdot (0.2A)^2 = 0.2mW$$

**AAT2146W****Low-Noise, Fast Transient 600mA Step-Down Converter****AAT2146W Losses**

$$P_{\text{TOTAL}} = \frac{I_O^2 \cdot (R_{\text{DS(ON)HS}} \cdot V_O + R_{\text{DS(ON)LS}} \cdot [V_{\text{IN}} - V_O])}{V_{\text{IN}}} + (t_{\text{sw}} \cdot f_{\text{sw}} \cdot I_O + I_Q) \cdot V_{\text{IN}}$$

$$= \frac{0.4^2 \cdot (0.38\Omega \cdot 1.8V + 0.30\Omega \cdot [4.2V - 1.8V])}{4.2V} + (5\text{ns} \cdot 2.0\text{MHz} \cdot 0.4A + 150\mu\text{A}) \cdot 4.2V = 70.9\text{mW}$$

$$T_{\text{J(MAX)}} = T_{\text{A}} + \Theta_{\text{JA}} \cdot P_{\text{LOSS}} = 85^\circ\text{C} + (160^\circ\text{C/W}) \cdot 70.9\text{mW} = 96.4^\circ\text{C}$$



**AAT2146W****Low-Noise, Fast Transient 600mA Step-Down Converter**

$V_{OUT}$ (V)	R2 = 59k $\Omega$ R1 (k $\Omega$ )	R2 = 221k $\Omega$ <sup>1</sup> R1 (k $\Omega$ )	L1 ( $\mu$ H)
0.8	19.6	75.0	2.2
0.9	29.4	113	2.2
1.0	39.2	150	2.2
1.1	49.9	187	2.2
1.2	59.0	221	2.2
1.3	68.1	261	2.2
1.4	78.7	301	4.7
1.5	88.7	332	4.7
1.8	118	442	4.7
1.85	124	464	4.7
2.0	137	523	6.8
2.5	187	715	6.8
3.3	267	1000	6.8

**Table 3: Evaluation Board Component Values.**

Manufacturer	Part Number	Inductance ( $\mu$ H)	Max DC Current (A)	DCR ( $\Omega$ )	Size (mm) LxWxH	Type
Sumida	CDRH3D16-2R2	2.2	1.20	0.072	3.8x3.8x1.8	Shielded
	CDRH3D16-4R7	4.7	0.90	0.105	3.8x3.8x1.8	Shielded
	CDRH3D16-6R8	6.8	0.73	0.170	3.8x3.8x1.8	Shielded
Murata	LQH2MCN4R7M02	4.7	0.40	0.80	2.0x1.6x0.95	Non-Shielded
	LQH32CN4R7M23	4.7	0.45	0.20	2.5x3.2x2.0	Non-Shielded
Coilcraft	LPO3310-472	4.7	0.80	0.27	3.2x3.2x1.0	1mm
Coiltronics	SD3118-4R7	4.7	0.98	0.122	3.1x3.1x1.85	Shielded
	SD3118-6R8	6.8	0.82	0.175	3.1x3.1x1.85	Shielded
	SDRC10-4R7	4.7	1.30	0.122	5.7x4.4x1.0	1mm Shielded
TDK	VLS3015T-4R7MR99	4.7	0.99	0.136	3.0x3.0x1.5	Shielded
	VLS3015T-6R8MR86	6.8	0.86	0.176	3.0x3.0x1.5	Shielded
Würth	744042006	6.8	1.25	0.100	4.8x4.8x1.8	Shielded

**Table 4: Recommended Typical Surface Mount Inductors.**

Manufacturer	Part Number	Value	Voltage	Temp. Co.	Case
Murata	GRM219R61A475KE19	4.7 $\mu$ F	10V	X5R	0805
Murata	GRM21BR60J106KE19	10 $\mu$ F	6.3V	X5R	0805
Murata	GRM21BR60J226ME39	22 $\mu$ F	6.3V	X5R	0805

**Table 5: Recommended Surface Mount Capacitors.**1. For reduced quiescent current, R2 = 221k $\Omega$ .

# AAT2146W

## Low-Noise, Fast Transient 600mA Step-Down Converter

### Ordering Information

Output Voltage <sup>1</sup>	Package	Marking <sup>2</sup>	Part Number (Tape and Reel) <sup>3</sup>
Adj $\geq 0.6$	SC70JW-8	Q9XYY	<b>AAT2146WIJS-0.6-T1</b>

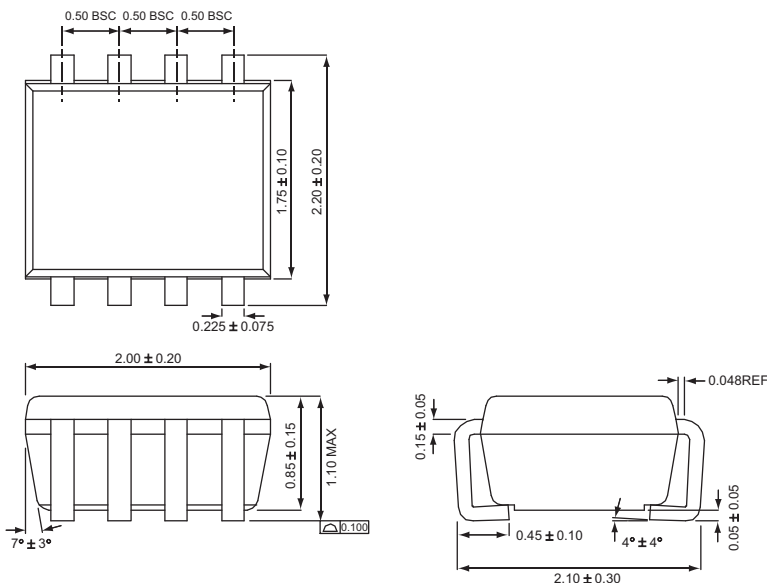


Skyworks Green™ products are compliant with all applicable legislation and are halogen-free.

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

### Package Information

#### SC70JW-8



All dimensions in millimeters.

- Contact Sales for other voltage options.
- XXX = assembly and date code.
- Sample stock is typically held on part numbers listed in **BOLD**.

Copyright © 2012 Skyworks Solutions, Inc. All Rights Reserved.

Information in this document is provided in connection with Skyworks Solutions, Inc. ("Skyworks") products or services. These materials, including the information contained herein, are provided by Skyworks as a service to its customers and may be used for informational purposes only by the customer. Skyworks assumes no responsibility for errors or omissions in these materials or the information contained herein. Skyworks may change its documentation, products, services, specifications or product descriptions at any time, without notice. Skyworks makes no commitment to update the materials or information and shall have no responsibility whatsoever for conflicts, incompatibilities, or other difficulties arising from any future changes.

No license, whether express, implied, by estoppel or otherwise, is granted to any intellectual property rights by this document. Skyworks assumes no liability for any materials, products or information provided hereunder, including the sale, distribution, reproduction or use of Skyworks products, information or materials, except as may be provided in Skyworks Terms and Conditions of Sale.

THE MATERIALS, PRODUCTS AND INFORMATION ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, WHETHER EXPRESS, IMPLIED, STATUTORY, OR OTHERWISE, INCLUDING FITNESS FOR A PARTICULAR PURPOSE OR USE, MERCHANTABILITY, PERFORMANCE, QUALITY OR NON-INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHT; ALL SUCH WARRANTIES ARE HEREBY EXPRESSLY DISCLAIMED. SKYWORKS DOES NOT WARRANT THE ACCURACY OR COMPLETENESS OF THE INFORMATION, TEXT, GRAPHICS OR OTHER ITEMS CONTAINED WITHIN THESE MATERIALS. SKYWORKS SHALL NOT BE LIABLE FOR ANY DAMAGES, INCLUDING BUT NOT LIMITED TO ANY SPECIAL, INDIRECT, INCIDENTAL, STATUTORY, OR CONSEQUENTIAL DAMAGES, INCLUDING WITHOUT LIMITATION, LOST REVENUES OR LOST PROFITS THAT MAY RESULT FROM THE USE OF THE MATERIALS OR INFORMATION, WHETHER OR NOT THE RECIPIENT OF MATERIALS HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Skyworks products are not intended for use in medical, lifesaving or life-sustaining applications, or other equipment in which the failure of the Skyworks products could lead to personal injury, death, physical or environmental damage. Skyworks customers using or selling Skyworks products for use in such applications do so at their own risk and agree to fully indemnify Skyworks for any damages resulting from such improper use or sale.

Customers are responsible for their products and applications using Skyworks products, which may deviate from published specifications as a result of design defects, errors, or operation of products outside of published parameters or design specifications. Customers should include design and operating safeguards to minimize these and other risks. Skyworks assumes no liability for applications assistance, customer product design, or damage to any equipment resulting from the use of Skyworks products outside of stated published specifications or parameters.

Skyworks, the Skyworks symbol, and "Breakthrough Simplicity" are trademarks or registered trademarks of Skyworks Solutions, Inc., in the United States and other countries. Third-party brands and names are for identification purposes only, and are the property of their respective owners. Additional information, including relevant terms and conditions, posted at [www.skyworksinc.com](http://www.skyworksinc.com), are incorporated by reference.