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

![Typical Application Diagram]

Skyworks Solutions, Inc. • Phone [781] 376-3000 • Fax [781] 376-3100 • sales@skyworksinc.com • www.skyworksinc.com

202008A • Skyworks Proprietary Information • Products and Product Information are Subject to Change Without Notice. • May 28, 2012
Pin Descriptions

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

Pin Configuration

![SC70JW-8 Pin Configuration](image_url)
# AAT2146W

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

### Absolute Maximum Ratings

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

### Thermal Information

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_D$</td>
<td>Maximum Power Dissipation(^2, 3)</td>
<td>625</td>
<td>mW</td>
</tr>
<tr>
<td>$\theta_{JA}$</td>
<td>Thermal Resistance(^2)</td>
<td>160</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

---

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

Electrical Characteristics\(^1\)

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{IN})</td>
<td>Input Voltage</td>
<td>(V_{IN}) Rising</td>
<td>2.7</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>(V_{UVLO})</td>
<td>UVLO Threshold</td>
<td>Hysteresis</td>
<td>100</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_{OUT})</td>
<td>Output Voltage Accuracy</td>
<td>No Load; (T_a = 25^\circ C)</td>
<td>600</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_{OUT})</td>
<td>Output Voltage Tolerance</td>
<td>(I_{OUT} = 0)mA to 600mA, (V_{IN} = 2.7V) to 5.5V</td>
<td>-3.0</td>
<td>+3.0</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>(I_Q)</td>
<td>Quiescent Current</td>
<td>No Load, Not Switching</td>
<td>150</td>
<td>300</td>
<td>(\mu A)</td>
<td></td>
</tr>
<tr>
<td>(I_{S\text{HDDN}})</td>
<td>Shutdown Current</td>
<td>(EN = AGND = PGND)</td>
<td>1.0</td>
<td>(\mu A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(I_{S\text{LIM}})</td>
<td>P-Channel Current Limit</td>
<td></td>
<td>800</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R_{DS\text{HON}})</td>
<td>High Side Switch On Resistance</td>
<td></td>
<td>0.35</td>
<td>(\Omega)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R_{DS\text{LON}})</td>
<td>Low Side Switch On Resistance</td>
<td></td>
<td>0.30</td>
<td>(\Omega)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta V_{\text{Linereg}})</td>
<td>Line Regulation</td>
<td>(V_{IN} = 2.7V) to 5.5V; (I_{OUT} = 600mA)</td>
<td>0.1</td>
<td>%/V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(T_S)</td>
<td>Start-Up Time</td>
<td>From Enable to Output Regulation</td>
<td>150</td>
<td>(\mu s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F_{\text{OSC}})</td>
<td>Oscillator Frequency</td>
<td>(T_a = 25^\circ C)</td>
<td>2.0</td>
<td>MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(T_{SD})</td>
<td>Over-Temperature Shutdown Threshold</td>
<td></td>
<td>140</td>
<td>(^\circ C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(T_{THS})</td>
<td>Over-Temperature Shutdown Hysteresis</td>
<td></td>
<td>15</td>
<td>(^\circ C)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EN**

\(V_{\text{EN(L)}}\) | Enable Threshold Low | | 0.6 | V |
| \(V_{\text{EN(H)}}\) | Enable Threshold High | | 1.4 | V |
| \(I_{\text{EN}}\) | Input Low Current | \(V_{IN} = V_{OUT} = 5.5V\) | -1.0 | 1.0 | \(\mu A\) |

---

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

1. See figure 2 for the application test circuit.
Typical Characteristics

**Line Regulation**
\( V_{\text{out}} = 1.8 \text{V} \)

![Line Regulation Graph](image)

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

![Oscillator Frequency Variation Graph](image)

**Output Voltage Error vs. Temperature**
\( V_{\text{out}} = 1.8 \text{V}; V_{\text{in}} = 3.6 \text{V}; I_{\text{out}} = 400 \text{mA} \)

![Output Voltage Error Graph](image)

**Quiescent Current vs. Input Voltage**

![Quiescent Current Graph](image)

**Load Transient**
\( V_{\text{out}} = 1.8 \text{V}; V_{\text{in}} = 3.6 \text{V}; I_{\text{out}} = 300\text{mA to 400mA}; C_{pf} = 0\text{pF} \)

![Load Transient Graph](image)

**Load Transient**
\( V_{\text{out}} = 1.8 \text{V}; V_{\text{in}} = 3.6 \text{V}; I_{\text{out}} = 300\text{mA to 400mA}; C_{pf} = 100\text{pF} \)

![Load Transient Graph](image)
Typical Characteristics

Load Transient
\( V_{\text{out}} = 1.8V; V_{\text{in}} = 3.6V; I_{\text{out}} = 1\text{mA to 300mA}; C_{\text{ff}} = 100\text{pF} \)

Line Transient
\( V_{\text{out}} = 1.8V; V_{\text{in}} = 3.6\text{ to 4.2V}; I_{\text{out}} = 400\text{mA}; C_{\text{ff}} = 0\text{pF} \)

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

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

Output Voltage Ripple
\( V_{\text{out}} = 1.8V; V_{\text{in}} = 3.6V; I_{\text{out}} = 400\text{mA} \)

Soft Start
\( V_{\text{out}} = 1.8V; V_{\text{in}} = 3.6V; I_{\text{out}} = 400\text{mA} \)
**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 4.7μH inductor and a 4.7μF 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_f) 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.
**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.
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 \(0.24\text{A/}\mu\text{s}\). This equates to a slope compensation that is 75% of the inductor current down slope for a 1.5V output and 4.7\(\mu\text{H}\) inductor.

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

This is the internal slope compensation. When externally programming to 2.5V, the calculated inductance is 7.5\(\mu\text{H}\).

\[
L = \frac{0.75 \cdot V_o}{m} = \frac{0.75 \cdot V_o}{0.24\frac{\text{A}}{\mu\text{s}}} \approx 3\frac{\text{us}}{\text{A}} \cdot V_o
\]

\[
= 3\frac{\text{us}}{\text{A}} \cdot 2.5\text{V} = 7.5\mu\text{H}
\]

In this case, a standard 6.8\(\mu\text{H}\) value is selected.

Table 1 displays inductor values for the AAT2146W.

<table>
<thead>
<tr>
<th>Output Voltage</th>
<th>Inductor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1V, 1.2V</td>
<td>2.2(\mu\text{H})</td>
</tr>
<tr>
<td>1.5V, 1.8V</td>
<td>4.7(\mu\text{H})</td>
</tr>
<tr>
<td>2.5V, 3.3V</td>
<td>6.8(\mu\text{H})</td>
</tr>
</tbody>
</table>

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 4.7\(\mu\text{H}\) CDRH3D16 series inductor selected from Sumida has a 105m\(\Omega\) 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 2.2\(\mu\text{F}\) to 10\(\mu\text{F}\) 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.

\[
C_{IN} = \frac{V_o}{V_{IN}} \cdot \left(1 - \frac{V_o}{V_{IN}}\right) \cdot \frac{1}{ESR \cdot f_{sw}}
\]

For \(V_{IN} = 2 \cdot V_o\)

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

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

Always examine the ceramic capacitor DC voltage coefficient characteristics when selecting the proper value. For example, the capacitance of a 10\(\mu\text{F}\), 6.3V, X5R ceramic capacitor with 5.0V DC applied is actually about 6\(\mu\text{F}\).

The maximum input capacitor RMS current is:

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

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 \(V_{IN} = 2 \cdot V_o\)

\[
I_{RMS(MAX)} = \frac{I_o}{2}
\]
The term \( \frac{V_o}{V_{in}} \) 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:

\[
I_{RMS(max)} = \frac{2}{\sqrt{3}} \cdot \frac{V_{out} \cdot (V_{in(max)} - V_{out})}{L \cdot f_{sw} \cdot V_{in(max)}}
\]

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.
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.

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

The AAT2146W combined with an external feedforward capacitor (C4 in Figure 5), delivers enhanced transient response for extreme pulsed load applications.
## 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 $R_{DS(ON)}$ 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:

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

$I_Q$ is the step-down converter quiescent current. The term $t_{SW}$ 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 $R_{DS(ON)HS}$, 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 $\theta_{JA}$ for the SC70JW-8 package which is 160°C/W.

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

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

<table>
<thead>
<tr>
<th>$V_{OUT}$ (V)</th>
<th>$R2 = 59k\Omega$</th>
<th>$R2 = 221k\Omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R1 (k\Omega)$</td>
<td>$R1 (k\Omega)$</td>
</tr>
<tr>
<td>0.8</td>
<td>19.6</td>
<td>75</td>
</tr>
<tr>
<td>0.9</td>
<td>29.4</td>
<td>113</td>
</tr>
<tr>
<td>1.0</td>
<td>39.2</td>
<td>150</td>
</tr>
<tr>
<td>1.1</td>
<td>49.9</td>
<td>187</td>
</tr>
<tr>
<td>1.2</td>
<td>59.0</td>
<td>221</td>
</tr>
<tr>
<td>1.3</td>
<td>68.1</td>
<td>261</td>
</tr>
<tr>
<td>1.4</td>
<td>78.7</td>
<td>301</td>
</tr>
<tr>
<td>1.5</td>
<td>88.7</td>
<td>332</td>
</tr>
<tr>
<td>1.8</td>
<td>118</td>
<td>442</td>
</tr>
<tr>
<td>1.85</td>
<td>124</td>
<td>464</td>
</tr>
<tr>
<td>2.0</td>
<td>137</td>
<td>523</td>
</tr>
<tr>
<td>2.5</td>
<td>187</td>
<td>715</td>
</tr>
<tr>
<td>3.3</td>
<td>267</td>
<td>1000</td>
</tr>
</tbody>
</table>

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

---

Skyworks Solutions, Inc. • Phone [781] 376-3000 • Fax [781] 376-3100 • sales@skyworksinc.com • www.skyworksinc.com

202008A • Skyworks Proprietary Information • Products and Product Information are Subject to Change Without Notice. • May 28, 2012
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.
Step-Down Converter Design Example

Specifications

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

1.8V Output Inductor

\[ L1 = 3 \cdot \frac{\mu s}{A} \cdot V_O = 3 \cdot \frac{\mu s}{A} \cdot 1.8V = 5.4\mu H \text{ (use 4.7}\mu H; \text{ see Table 1)} \]

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

\[ \Delta I_L1 = \frac{V_O}{L1 \cdot f_{sw}} \cdot \left(1 - \frac{V_O}{V_IN}\right) = \frac{1.8V}{4.7\mu H \times 2.0MHz} \cdot \left(1 - \frac{1.8V}{4.2V}\right) = 109mA \]

\[ I_{PKL1} = I_O + \frac{\Delta I_L1}{2} = 0.4A + 0.055A = 0.455A \]

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

1.8V Output Capacitor

\[ V_{DROOP} = 0.1V \]

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

\[ I_{RMS} = \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{(V_O) \cdot (V_{IN(MAX)} - V_O)}{L1 \cdot f_{sw} \cdot V_{IN(MAX)}} = \frac{1}{2 \cdot \sqrt{3}} \cdot \frac{1.8V \cdot (4.2V - 1.8V)}{4.7\mu H \cdot 2.0MHz \cdot 4.2V} = 32mA \text{ (rms)} \]

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

Input Capacitor

Input Ripple Voltage \( V_{PP} = 25mV \)

\[ C_{IN} = \frac{1}{(V_{PP} \cdot I_O) \cdot 4 \cdot f_{sw}} \cdot \frac{1}{(25mV \cdot 0.4A) \cdot 4 \cdot 2.0MHz} = 2.17\mu F; \text{ use 2.2}\mu F \]

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

\[ P_{ESR} = ESR \cdot I_{RMS}^2 = 5m\Omega \cdot (0.2A)^2 = 0.2mW \]
AAT2146W Losses

\[
P_{\text{TOTAL}} = \frac{I_0^2 \cdot (R_{\text{DS(ON)HS}} \cdot V_O + R_{\text{DS(ON)LS}} \cdot [V_{\text{IN}} - V_O])}{V_{\text{IN}}} + (t_{\text{sw}} \cdot f_{\text{sw}} \cdot I_O + I_Q) \cdot V_{\text{IN}}
\]

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

\[
T_{j(\text{MAX})} = T_A + \Theta_{JA} \cdot P_{\text{LOSS}} = 85^\circ C + (160^\circ C/W) \cdot 70.9mW = 96.4^\circ C
\]
AAT2146W
Low-Noise, Fast Transient 600mA Step-Down Converter

<table>
<thead>
<tr>
<th>$V_{\text{out}}$ (V)</th>
<th>R2 = 59kΩ</th>
<th>R2 = 221kΩ</th>
<th>L1 (μH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>19.6</td>
<td>75.0</td>
<td>2.2</td>
</tr>
<tr>
<td>0.9</td>
<td>29.4</td>
<td>113</td>
<td>2.2</td>
</tr>
<tr>
<td>1.0</td>
<td>39.2</td>
<td>150</td>
<td>2.2</td>
</tr>
<tr>
<td>1.1</td>
<td>49.9</td>
<td>187</td>
<td>2.2</td>
</tr>
<tr>
<td>1.2</td>
<td>59.0</td>
<td>221</td>
<td>2.2</td>
</tr>
<tr>
<td>1.3</td>
<td>68.1</td>
<td>261</td>
<td>2.2</td>
</tr>
<tr>
<td>1.4</td>
<td>78.7</td>
<td>301</td>
<td>4.7</td>
</tr>
<tr>
<td>1.5</td>
<td>88.7</td>
<td>332</td>
<td>4.7</td>
</tr>
<tr>
<td>1.8</td>
<td>118</td>
<td>442</td>
<td>4.7</td>
</tr>
<tr>
<td>1.85</td>
<td>124</td>
<td>464</td>
<td>4.7</td>
</tr>
<tr>
<td>2.0</td>
<td>137</td>
<td>523</td>
<td>6.8</td>
</tr>
<tr>
<td>2.5</td>
<td>187</td>
<td>715</td>
<td>6.8</td>
</tr>
<tr>
<td>3.3</td>
<td>267</td>
<td>1000</td>
<td>6.8</td>
</tr>
</tbody>
</table>

Table 3: Evaluation Board Component Values.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Part Number</th>
<th>Inductance (μH)</th>
<th>Max DC Current (A)</th>
<th>DCR (Ω)</th>
<th>Size (mm)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumida</td>
<td>CDRH3D16-2R2</td>
<td>2.2</td>
<td>1.20</td>
<td>0.072</td>
<td>3.8x3.8x1.8</td>
<td>Shielded</td>
</tr>
<tr>
<td></td>
<td>CDRH3D16-4R7</td>
<td>4.7</td>
<td>0.90</td>
<td>0.105</td>
<td>3.8x3.8x1.8</td>
<td>Shielded</td>
</tr>
<tr>
<td></td>
<td>CDRH3D16-6R8</td>
<td>6.8</td>
<td>0.73</td>
<td>0.170</td>
<td>3.8x3.8x1.8</td>
<td>Shielded</td>
</tr>
<tr>
<td>Murata</td>
<td>LH2MCN4R7M02</td>
<td>4.7</td>
<td>0.40</td>
<td>0.80</td>
<td>2.0x1.6x0.95</td>
<td>Non-Shielded</td>
</tr>
<tr>
<td></td>
<td>LH32CN4R7M23</td>
<td>4.7</td>
<td>0.45</td>
<td>0.20</td>
<td>2.5x3.2x2.0</td>
<td>Non-Shielded</td>
</tr>
<tr>
<td>Colicraft</td>
<td>LPO3310-472</td>
<td>4.7</td>
<td>0.80</td>
<td>0.27</td>
<td>3.2x3.2x1.0</td>
<td>1mm</td>
</tr>
<tr>
<td>Coiltronics</td>
<td>SD3118-4R7</td>
<td>4.7</td>
<td>0.98</td>
<td>0.122</td>
<td>3.1x3.1x1.85</td>
<td>Shielded</td>
</tr>
<tr>
<td></td>
<td>SD3118-6R8</td>
<td>6.8</td>
<td>0.82</td>
<td>0.175</td>
<td>3.1x3.1x1.85</td>
<td>Shielded</td>
</tr>
<tr>
<td></td>
<td>SDRC10-4R7</td>
<td>4.7</td>
<td>1.30</td>
<td>0.122</td>
<td>5.7x4.4x1.0</td>
<td>1mm Shielded</td>
</tr>
<tr>
<td>TDK</td>
<td>VLS3015T-4R7MR99</td>
<td>4.7</td>
<td>0.99</td>
<td>0.136</td>
<td>3.0x3.0x1.5</td>
<td>Shielded</td>
</tr>
<tr>
<td></td>
<td>VLS3015T-6R8MR86</td>
<td>6.8</td>
<td>0.86</td>
<td>0.176</td>
<td>3.0x3.0x1.5</td>
<td>Shielded</td>
</tr>
<tr>
<td>Wurth</td>
<td>744042006</td>
<td>6.8</td>
<td>1.25</td>
<td>0.100</td>
<td>4.8x4.8x1.8</td>
<td>Shielded</td>
</tr>
</tbody>
</table>

Table 4: Recommended Typical Surface Mount Inductors.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Part Number</th>
<th>Value</th>
<th>Voltage</th>
<th>Temp. Co.</th>
<th>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murata</td>
<td>GRM219R61A475KE19</td>
<td>4.7μF</td>
<td>10V</td>
<td>X5R</td>
<td>0805</td>
</tr>
<tr>
<td>Murata</td>
<td>GRM218R60J106KE19</td>
<td>10μF</td>
<td>6.3V</td>
<td>X5R</td>
<td>0805</td>
</tr>
<tr>
<td>Murata</td>
<td>GRM218R60J226ME39</td>
<td>22μF</td>
<td>6.3V</td>
<td>X5R</td>
<td>0805</td>
</tr>
</tbody>
</table>

Table 5: Recommended Surface Mount Capacitors.

1. For reduced quiescent current, R2 = 221kΩ.
**AAT2146W**

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

### Ordering Information

<table>
<thead>
<tr>
<th>Output Voltage</th>
<th>Package</th>
<th>Marking</th>
<th>Part Number (Tape and Reel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adj ≥ 0.6</td>
<td>SC70JW-8</td>
<td>Q9XY</td>
<td>AAT2146WIJS-0.6-T1</td>
</tr>
</tbody>
</table>

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.

1. Contact Sales for other voltage options.
2. XYY = assembly and date code.
3. 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, are incorporated by reference.