



**THE DATASHEET OF
AP1509-33SL**



Description

The AP1509 series are monolithic ICs designed for a step-down DC-DC converter and have the ability of driving a 2A load without an additional transistor, which saves board space.

The external shutdown function can be controlled by logic level and then go into standby mode. The internal compensation makes feedback control have good line and load regulation without external design. Regarding protected function, thermal shutdown prevents overtemperature operating from damage, and current limit works against overcurrent operating of the output switch. If current limit function occurs, and V_{FB} is below 0.5V, the switching frequency is reduced. The AP1509 series operates at a switching frequency of 150kHz thus allowing smaller-sized filter components than what is required with lower frequency switching regulators.

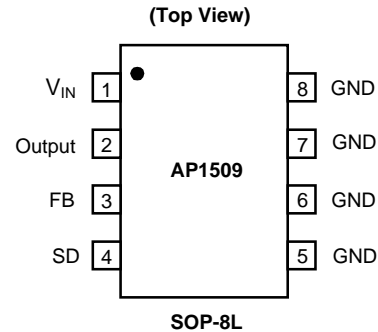
Other features include a guaranteed $\pm 4\%$ tolerance on output voltage under specified input voltage and output load conditions, and $\pm 15\%$ on the oscillator frequency. The output version included fixed 3.3V, 5V, 12V, and an adjustable type. The chips are available in a standard 8-lead SO-8 package.

Features

- Output Voltage: 3.3V, 5V, 12V, and Adjustable Output Version
- Adjustable Version Output Voltage Range of 1.23V to 18V+4%
- 150kHz +15% Fixed Switching Frequency
- Voltage Mode Non-Synchronous PWM Control
- Thermal-Shutdown and Current-Limit Protection
- ON/OFF Shutdown Control Input
- Operating Voltage up to 22V
- Output Load Current: 2A
- Low Power Standby Mode
- Built-in Switching Transistor On Chip
- **Totally Lead-Free & Fully RoHS Compliant (Note 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

- Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
 2. See <https://www.diodes.com/quality/lead-free/> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
 3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Pin Assignments

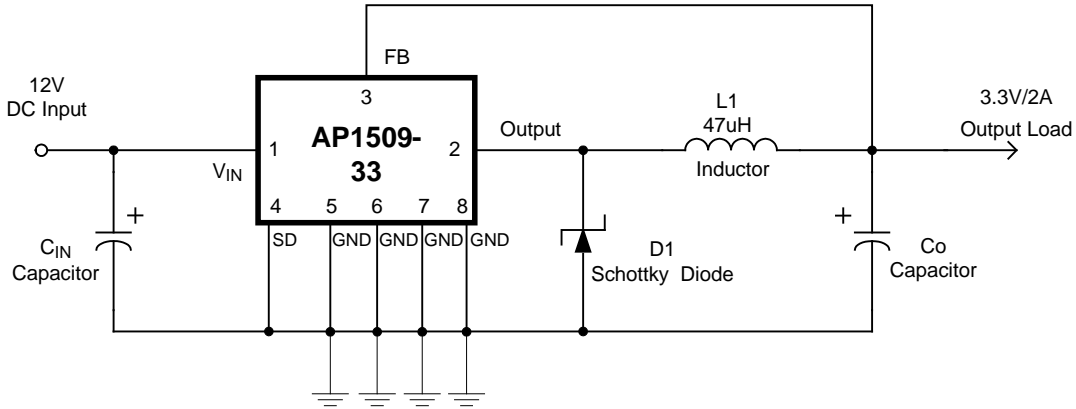


Applications

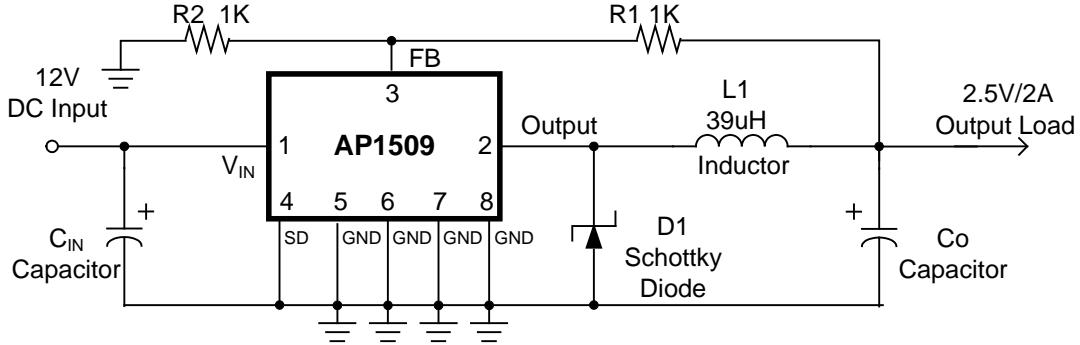
- Simple High-Efficiency Step-Down Regulator
- On-Card Switching Regulators
- Positive to Negative Converter

Typical Application Circuit

(1) Fixed Type Circuit



(2) Adjustable Type Circuit

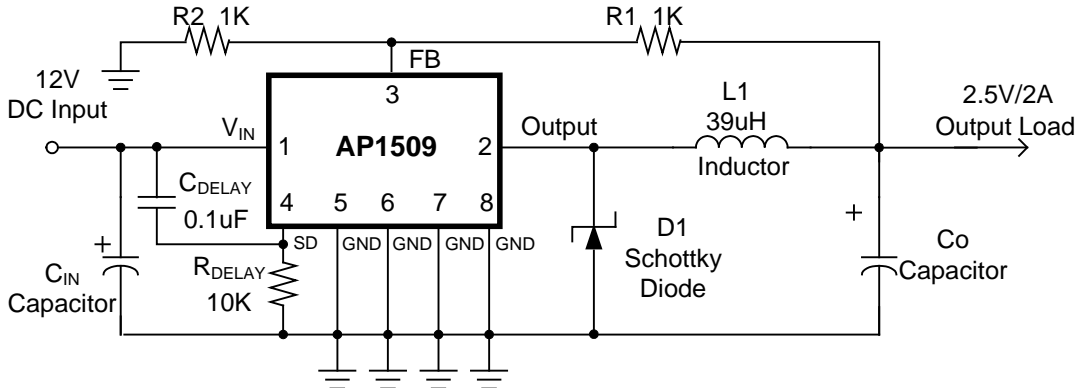


$$V_{OUT} = V_{FB} \times \left(1 + \frac{R1}{R2}\right)$$

$$V_{FB} = 1.23V$$

$$R2 = 1K \sim 3K$$

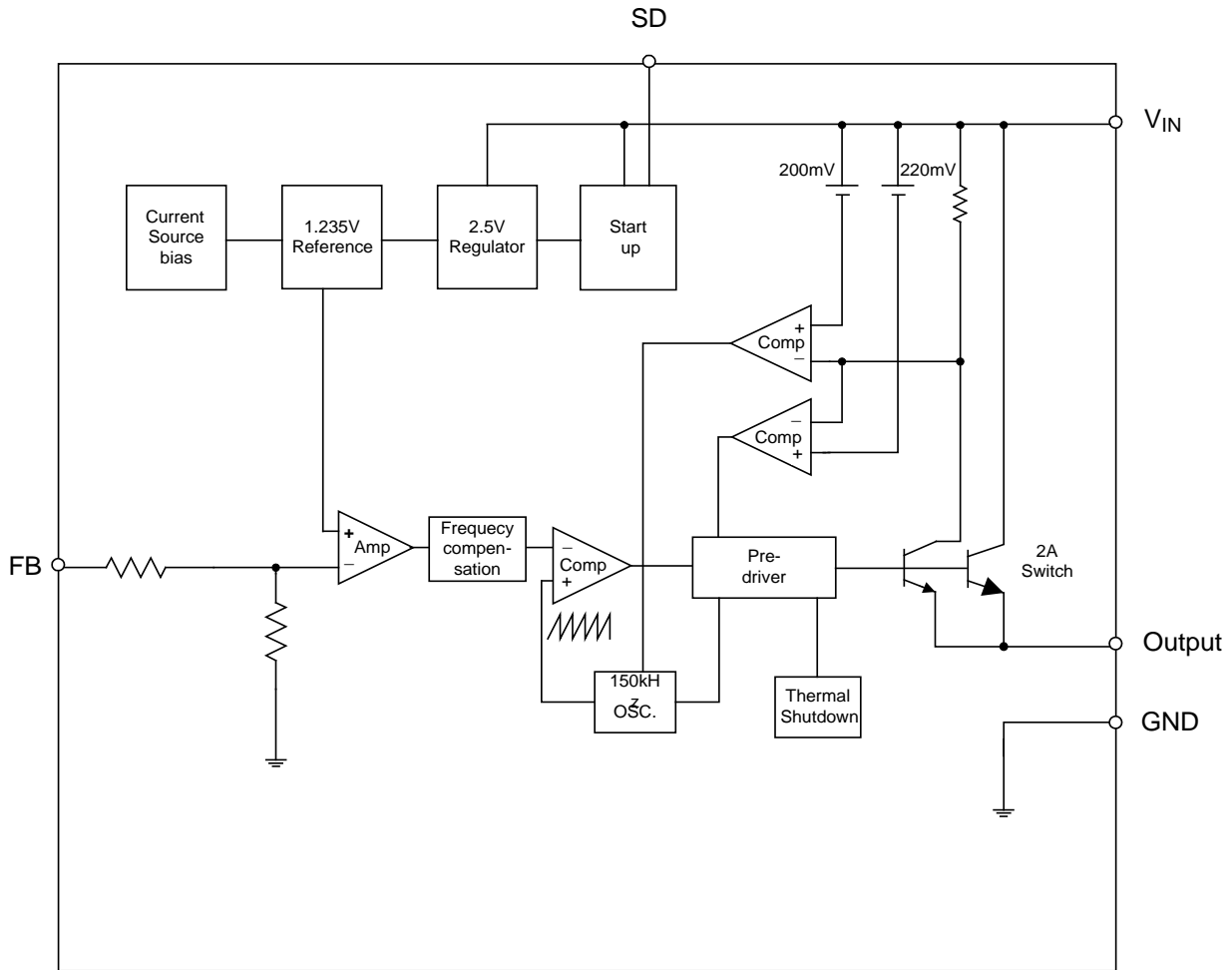
(3) Delay Start Circuit



Pin Descriptions

| Pin Name | Description |
|-----------------|---------------------------------|
| V _{IN} | Operating Voltage Input |
| Output | Switching Output |
| GND | Ground |
| FB | Output Voltage Feedback Control |
| SD | ON/OFF Shutdown |

Functional Block Diagram



Absolute Maximum Ratings

| Symbol | Parameter | Rating | Unit |
|-----------|---------------------------------|--------------------|------|
| ESD HBM | Human Body Model ESD Protection | 2 | KV |
| ESD MM | Machine Model ESD Protection | 200 | V |
| V_{IN} | Supply Voltage | +24 | V |
| V_{SD} | ON/OFF Pin Input Voltage | -0.3 to +18 | V |
| V_{FB} | Feedback Pin Voltage | -0.3 to +18 | V |
| V_{OUT} | Output Voltage to Ground | -1 | V |
| P_D | Power Dissipation | Internally Limited | W |
| T_{ST} | Storage Temperature | -65 to +150 | °C |
| T_J | Operating Junction Temperature | -40 to +125 | °C |

Recommended Operating Conditions

| Symbol | Parameter | Min | Max | Unit |
|-----------|-------------------------------|-----|-----|------|
| I_{OUT} | Output Current | 0 | 2 | A |
| V_{OP} | Operating Voltage | 4.5 | 22 | V |
| T_A | Operating Ambient Temperature | -20 | 85 | °C |

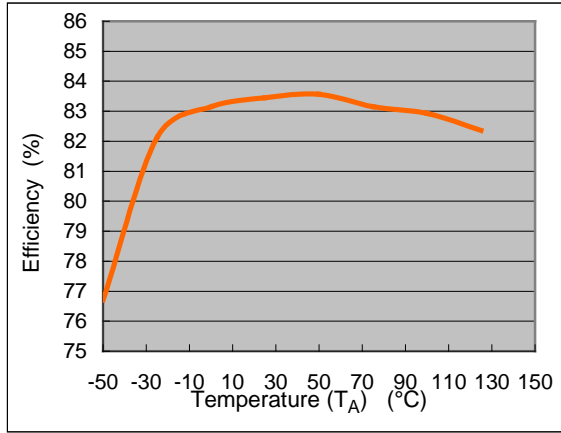
Electrical Characteristics

Unless otherwise specified, $V_{IN} = 12V$ for 3.3V, 5V, adjustable version, and $V_{IN} = 18V$ for the 12V version. $I_{LOAD} = 0.5A$
 Specifications with **boldface type** are for full operating temperature range, the other type are for $T_J = 25^\circ C$.

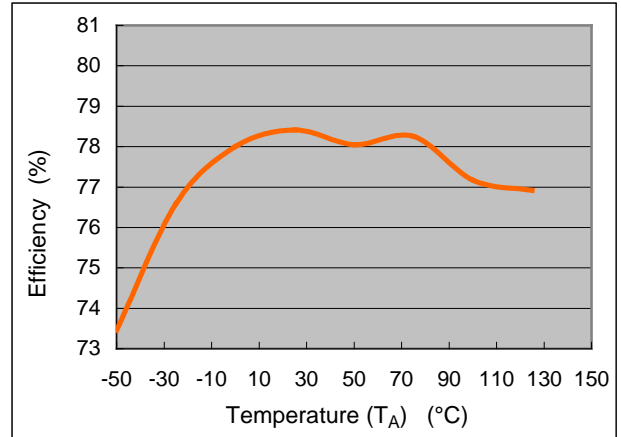
| Symbol | Parameter | | Conditions | Min | Typ. | Max | Unit |
|---------------|--|------------------------|--|-------------------|------|--------------------|--------------|
| I_{FB} | Feedback Bias Current | | $V_{FB} = 1.3V$ (Adjustable Version Only) | — | -10 | -50 -100 | nA |
| F_{OSC} | Oscillator Frequency | | — | 127 110 | 150 | 173 173 | kHz |
| F_{SCP} | Oscillator Frequency of Short Circuit Protect | | When Current Limit Occurred and $V_{FB} < 0.5V$, $T_a = 25^\circ C$ | 10 | 30 | 50 | kHz |
| V_{SAT} | Saturation Voltage | | $I_{OUT} = 2A$ No Outside Circuit $V_{FB} = 0V$ Force Driver On | — | 1.25 | 1.4 1.5 | V |
| DC | Max. Duty Cycle (ON) | | $V_{FB} = 0V$ Force Driver On | — | 100 | — | % |
| | Min. Duty Cycle (OFF) | | $V_{FB} = 12V$ Force Driver Off | — | 0 | — | |
| I_{CL} | Current Limit | | Peak Current No Outside Circuit $V_{FB} = 0V$ Force Driver On | 3 | — | — | A |
| I_L | Output = 0 | Output Leakage Current | No Outside Circuit | — | — | -200 | μA |
| | Output = -1 | | $V_{FB} = 12V$ Force Driver Off | — | -5 | — | |
| I_Q | Quiescent Current | | $V_{FB} = 12V$ Force Driver Off | — | 5 | 10 | mA |
| I_{STBY} | Standby Quiescent Current | | ON/OFF pin = 5V $V_{IN} = 22V$ | — | 70 | 150 200 | μA |
| V_{IL} | ON/OFF Pin Logic Input Threshold Voltage | | Low (Regulator ON) | — | 1.3 | 0.6 | V |
| V_{IH} | | | High (Regulator OFF) | 2.0 | | — | |
| I_H | ON/OFF Pin Logic Input Current | | $V_{LOGIC} = 2.5V$ (OFF) | — | — | -0.01 | μA |
| I_L | ON/OFF Pin Input Current | | $V_{LOGIC} = 0.5V$ (ON) | — | -0.1 | -1 | |
| θ_{JA} | Thermal Resistance | | SO-8 Junction to Case | — | 15 | — | $^\circ C/W$ |
| θ_{JC} | Thermal Resistance with a Copper Area of Approximately $3in^2$ | | SO-8 Junction to Ambient | — | 70 | — | $^\circ C/W$ |
| AP1509 - ADJ | V_{FB} | Output Feedback | $4.5V < V_{IN} < 22V$ $0.2A < I_{LOAD} < 2A$ V_{OUT} Programmed for 3V | 1.193 1.18 | 1.23 | 1.267 1.28 | V |
| | η | Efficiency | $V_{IN} = 12V$, $I_{LOAD} = 2A$ | 76 | 76 | — | % |
| AP1509 - 3.3V | V_{OUT} | Output Voltage | $4.75V < V_{IN} < 22V$ $0.2A < I_{LOAD} < 2A$ | 3.168 3.135 | 3.3 | 3.432 3.465 | V |
| | η | Efficiency | $V_{IN} = 12V$, $I_{LOAD} = 2A$ | 78 | 78 | — | % |
| AP1509 - 5V | V_{OUT} | Output Voltage | $7V < V_{IN} < 22V$ $0.2A < I_{LOAD} < 2A$ | 4.8 4.75 | 5 | 5.2 5.25 | V |
| | η | Efficiency | $V_{IN} = 12V$, $I_{LOAD} = 2A$ | 83 | 83 | — | % |
| AP1509 - 12V | V_{OUT} | Output Voltage | $15V < V_{IN} < 22V$ $0.2A < I_{LOAD} < 2A$ | 11.52 11.4 | 12 | 12.48 12.6 | V |
| | η | Efficiency | $V_{IN} = 15V$, $I_{LOAD} = 2A$ | 90 | 90 | — | % |

Typical Performance Characteristics

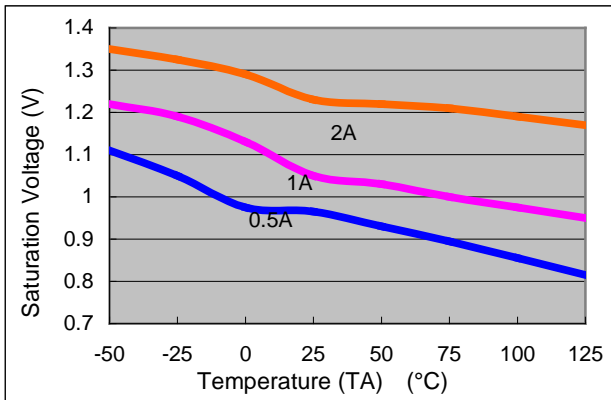
AP1509 Efficiency vs. Temperature
($V_{IN} = 12V, V_{OUT} = 5V, I_o = 2A$)



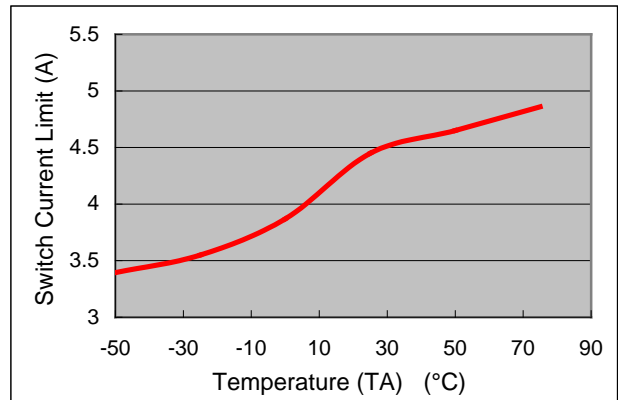
AP1509 Efficiency vs. Temperature
($V_{IN} = 12V, V_{OUT} = 3.3V, I_o = 2A$)



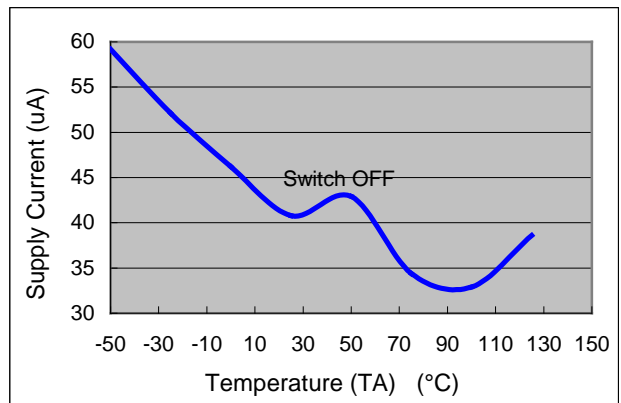
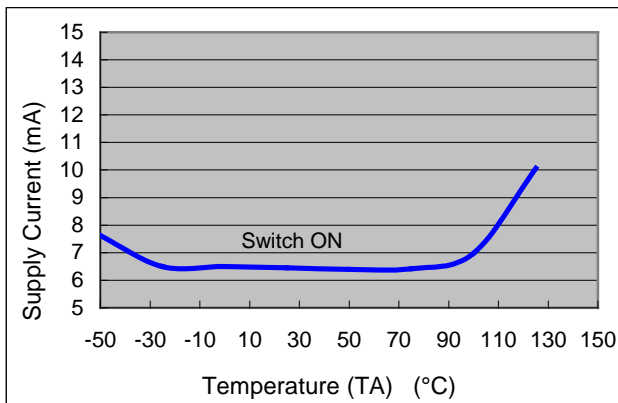
AP1509 Saturation Voltage vs. Temperature
($V_{IN} = 12V, V_{FB} = 0V, V_{SD} = 0$)



AP1509 Switch Current Limit vs. Temperature
($V_{IN} = 12V, V_{FB} = 0V$)

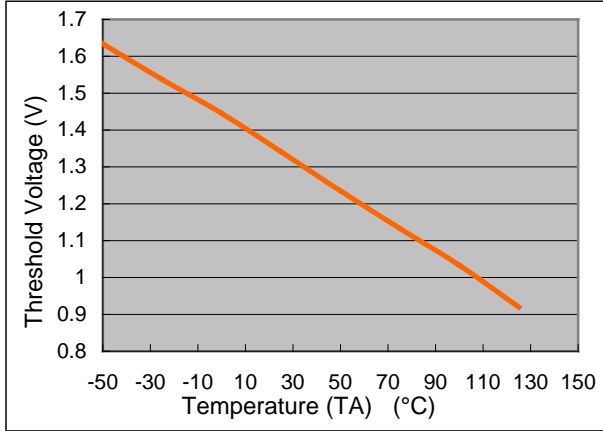


AP1509 Supply Current vs. Temperature
($V_{IN} = 12V, \text{No Load}, V_{on/off} = 0V \text{ (Switch ON)}, V_{on/off} = 5V \text{ (Switch OFF)}$)

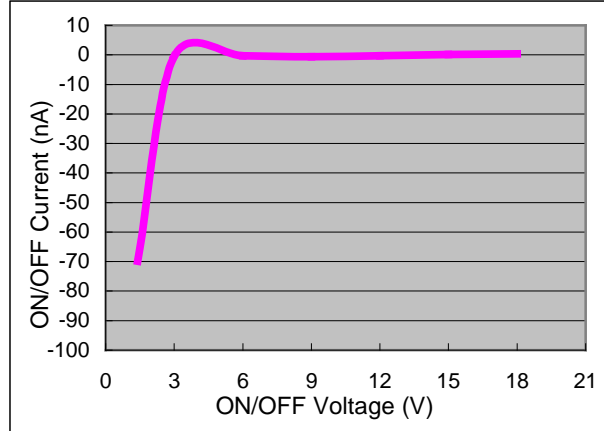


Typical Performance Characteristics (continued)

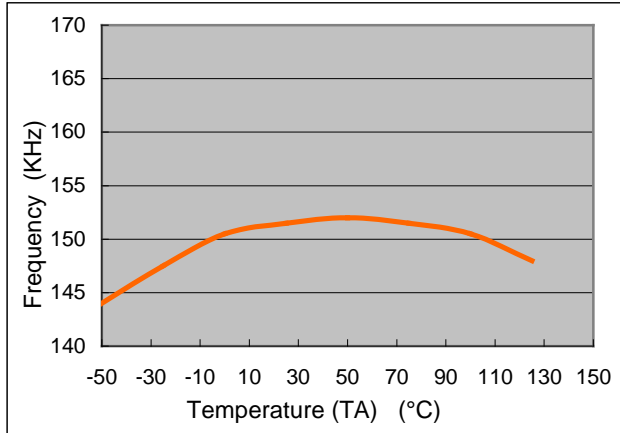
AP1509 Threshold Voltage vs. Temperature
($V_{IN} = 12V$, $I_o = 100mA$)



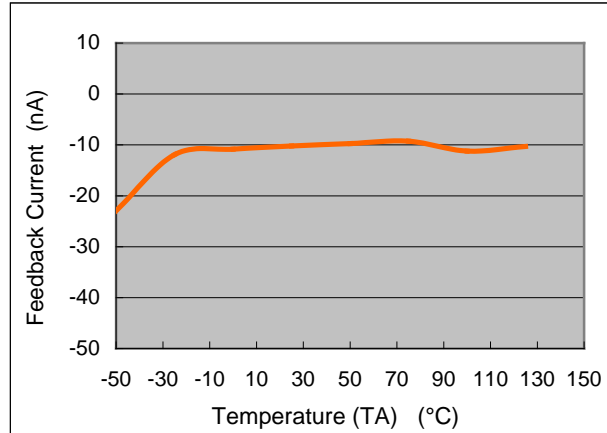
AP1509 ON/OFF Current vs. ON/OFF Voltage
($V_{IN} = 12V$)



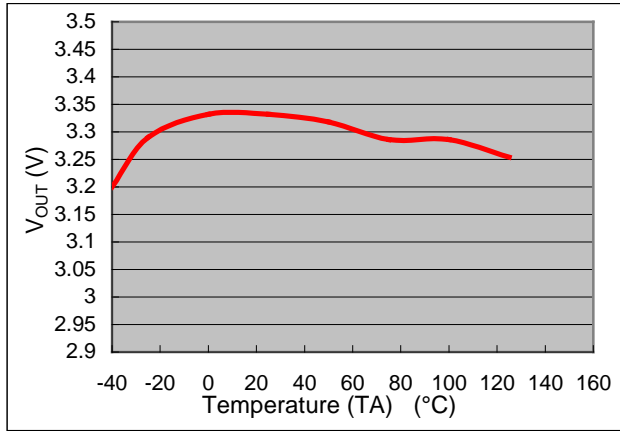
AP1509 Frequency vs. Temperature
($V_{IN} = 12V$, $I_o = 500mA$, $V_{OUT} = 5V$)



AP1509 Feedback Current vs. Temperature
($V_{IN} = 12V$, $V_{OUT} = 5V$, $V_{fb} = 1.3V$)

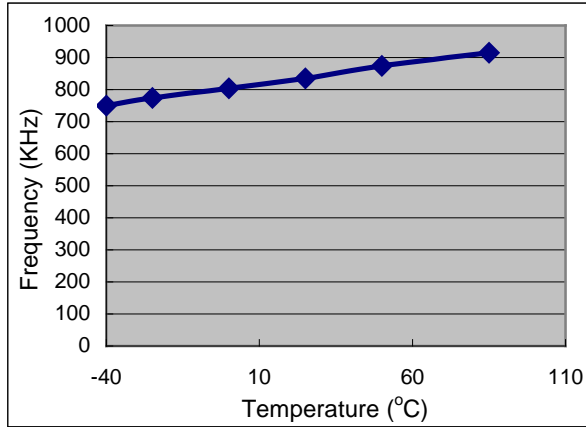


AP1509 Output Voltage vs. Temperature
($V_{IN} = 12V$, $I_o = 2A$)

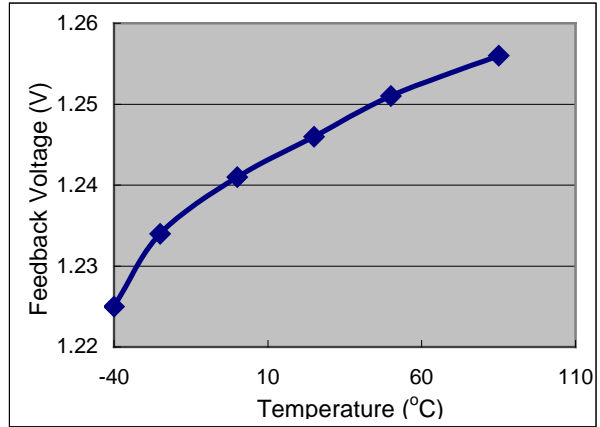


Typical Performance Characteristics (continued)

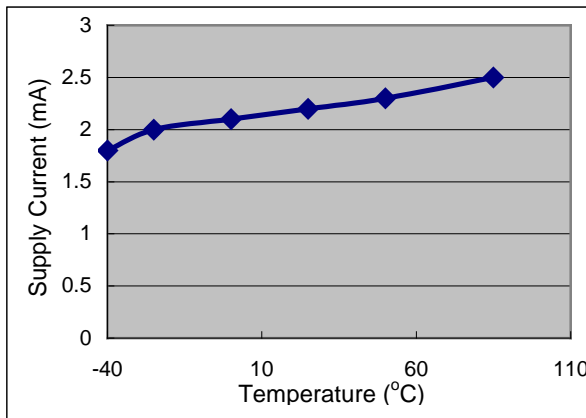
Header Frequency vs. Temperature



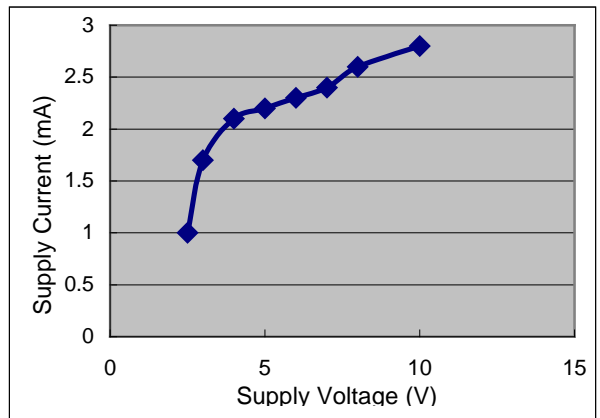
Feedback Voltage vs. Temperature
($V_{IN} = 15V, V_{OUT} = 5V$)



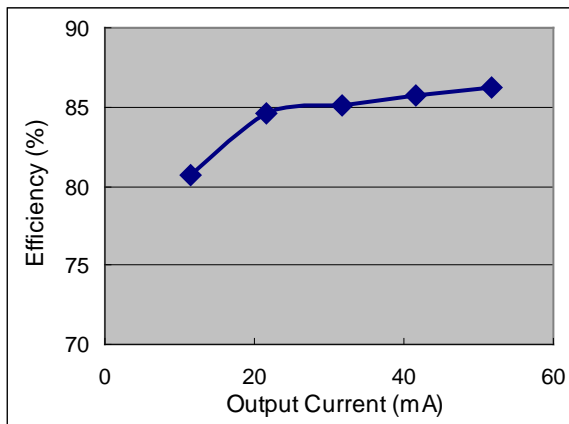
Supply Current vs. Temperature
($V_{IN} = 15V, V_{OUT} = 5V, I_{OUT} = 0A$)



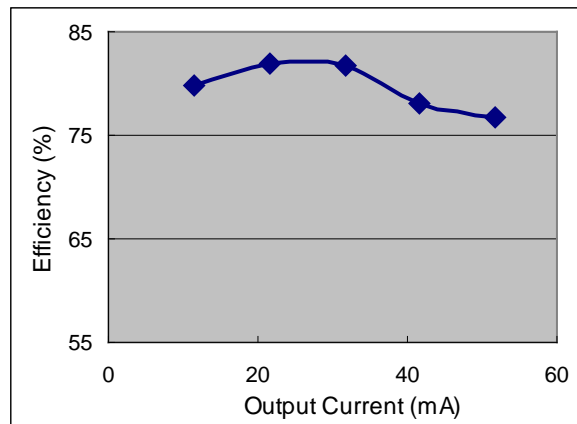
Supply Current vs. Supply Voltage
($V_{IN} = 15V, V_{OUT} = 5V, I_{OUT} = 0A$)



Efficiency vs. Output Current
($V_{IN} = 15V, V_{OUT} = 5V$)



Efficiency vs. Output Current
($V_{IN} = 15V, V_{OUT} = 3.3V$)



Functions Description

Pin Functions

+V_{IN}

This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be presented at this pin to minimize voltage transients and to supply the switching currents required by the regulator.

Ground

Circuit ground.

Output

Internal switch. The voltage at this pin switches between $(+V_{IN} - V_{SAT})$ and approximately -0.5V with a duty cycle of approximately V_{OUT}/V_{IN} . To minimize coupling to sensitive circuitry, the PCB copper area connected to this pin should be minimized.

Feedback

This pin senses the regulated output voltage to complete the feedback loop.

SD

Allows the switching regulator circuit to be shutdown using logic level signals thus dropping the total input supply current to approximately 150 μ A. Pulling this pin below a threshold voltage of approximately 1.3V turns the regulator on, and pulling this pin above 1.3V (up to a maximum of 18V) shuts the regulator down. If this shutdown feature is not required, the SD pin can be wired to the ground pin.

Thermal Considerations

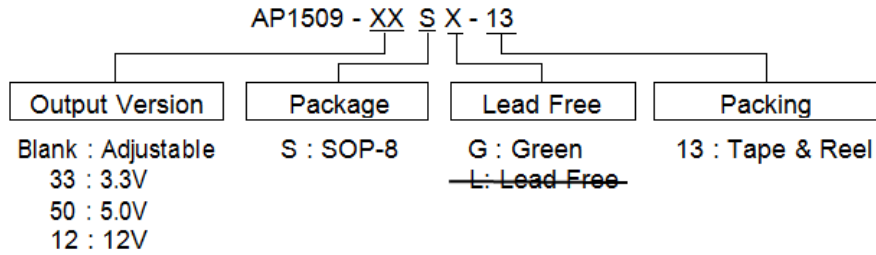
The SO-8 package requires a heat sink under most conditions. The size of the heat sink depends on the input voltage, the output voltage, the load current, and the ambient temperature. The AP1509 junction temperature rises above ambient temperature for a 2A load and different input and output voltages. The data for these curves was taken with the AP1509 (SO-8 package) operating as a buck-switching regulator in an ambient temperature of 25°C (still air). These temperature increments are all approximate and are affected by many factors. Higher ambient temperatures require more heat sinker.

For the best thermal performance, wide copper traces and generous amounts of PCB copper should be used in the board layout; one exception is the output (switch) pin, which should not have large areas of copper. Large areas of copper provide the best transfer of heat (lower thermal resistance) to the surrounding air and moving air lowers the thermal resistance even further.

Package thermal resistance and junction temperature increments are all approximate. The increments are affected by a lot of factors. Some of these factors include board size, shape, thickness, position, location, and even board temperature. Other factors are, trace width, total printed circuit copper area, copper thickness, single or double-sided, multi-layer board, and the amount of solder on the board.

The effectiveness of the PCB to dissipate heat also depends on the size, quantity, and spacing of other components on the board, as well as whether the surrounding air is still or moving. Furthermore, some of these components, such as the catch diode, add heat to the PCB, and the heat can vary as the input voltage changes. For the inductor, depending on the physical size, type of core material, and the DC resistance, it could either act as a heat sink taking heat away from the board, or it could add heat to the board.

Ordering Information

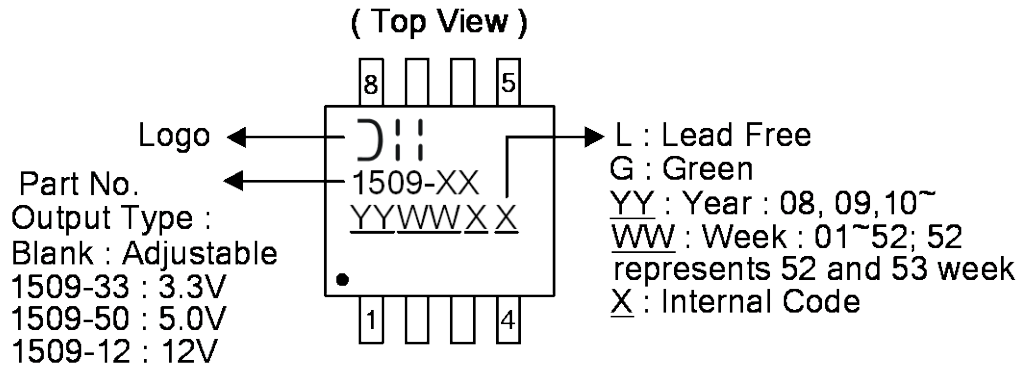


| Device | Voltage (V) | Package Code | Package (Note 5) | Lead Free/Green | Quantity | Part Number Suffix | | Status (Note 4) | Alternative |
|-----------------|-------------|--------------|------------------|-----------------|----------|--------------------|-------------------|-----------------|-------------|
| | | | | | | Tube | 13" Tape and Reel | | |
| AP1509-12SG-13 | 12 | S | SO-8 | Green | 2500 | NA | -13 | In production | |
| AP1509-33SG-13 | 3.3 | S | SO-8 | Green | 2500 | NA | -13 | In production | |
| AP1509-50SG-13 | 5.0 | S | SO-8 | Green | 2500 | NA | -13 | In production | |
| AP1509-SG-13 | ADJ | S | SO-8 | Green | 2500 | NA | -13 | In production | |
| AP1509-12SGL-13 | 12 | S | SO-8 | Green | 2500 | NA | -13 | End of life | None |
| AP1509-33SGL-13 | 3.3 | S | SO-8 | Green | 2500 | NA | -13 | End of life | None |
| AP1509-50SGL-13 | 5.0 | S | SO-8 | Green | 2500 | NA | -13 | End of life | None |
| AP1509-SGL-13 | ADJ | S | SO-8 | Green | 2500 | NA | -13 | End of life | None |

- Notes:
4. All Lead-free versions are End of Life (EOL) with no replacement.
 5. For packaging details, go to our website at:
<https://www.diodes.com/design/support/packaging/diodes-packaging/diodes-package-outlines-and-pad-layouts/>

Marking Information

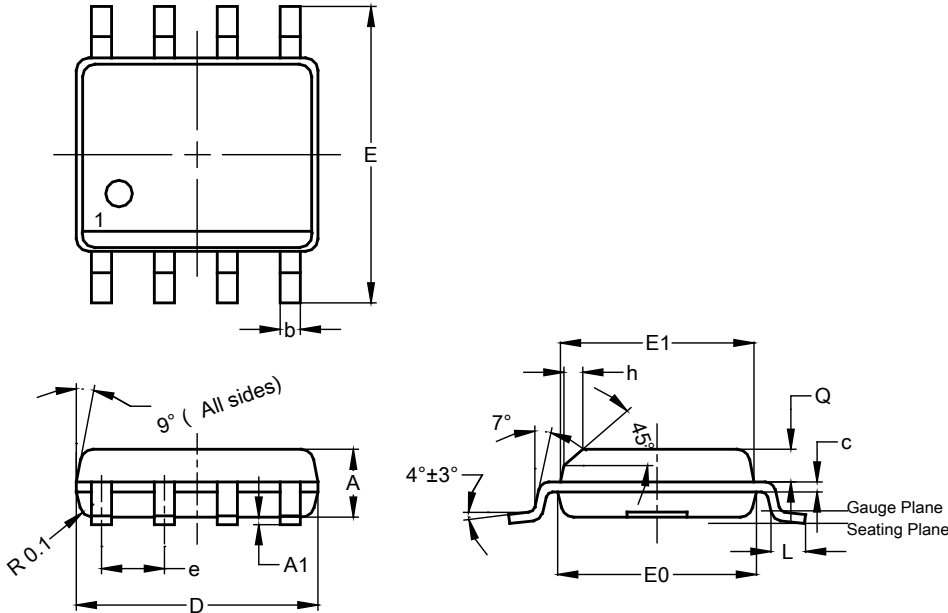
(1) SO-8



Package Outline Dimensions (All Dimensions in mm)

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

SO-8

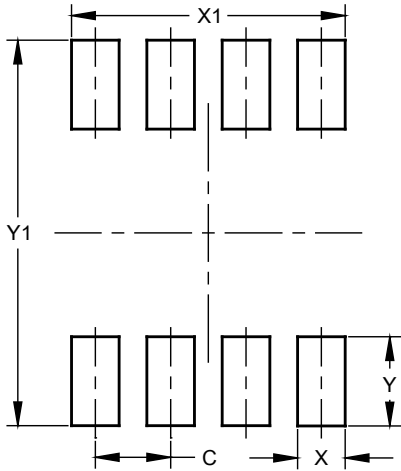


| SO-8 | | | |
|----------------------|------|------|------|
| Dim | Min | Max | Typ |
| A | 1.40 | 1.50 | 1.45 |
| A1 | 0.10 | 0.20 | 0.15 |
| b | 0.30 | 0.50 | 0.40 |
| c | 0.15 | 0.25 | 0.20 |
| D | 4.85 | 4.95 | 4.90 |
| E | 5.90 | 6.10 | 6.00 |
| E1 | 3.80 | 3.90 | 3.85 |
| E0 | 3.85 | 3.95 | 3.90 |
| e | -- | -- | 1.27 |
| h | - | -- | 0.35 |
| L | 0.62 | 0.82 | 0.72 |
| Q | 0.60 | 0.70 | 0.65 |
| All Dimensions in mm | | | |

Suggested Pad Layout

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

SO-8



| Dimensions | Value (in mm) |
|------------|---------------|
| C | 1.27 |
| X | 0.802 |
| X1 | 4.612 |
| Y | 1.505 |
| Y1 | 6.50 |

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