150kHz, 2A PWM BUCK DC-DC CONVERTER

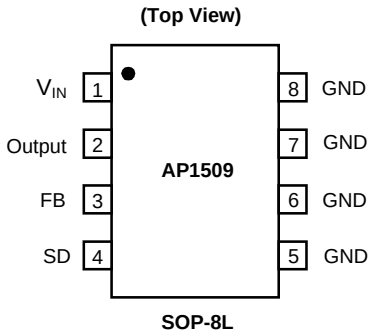
Description

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 ±4% tolerance on output voltage under specified input voltage and output load conditions, and ±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.

Pin Assignments



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)**

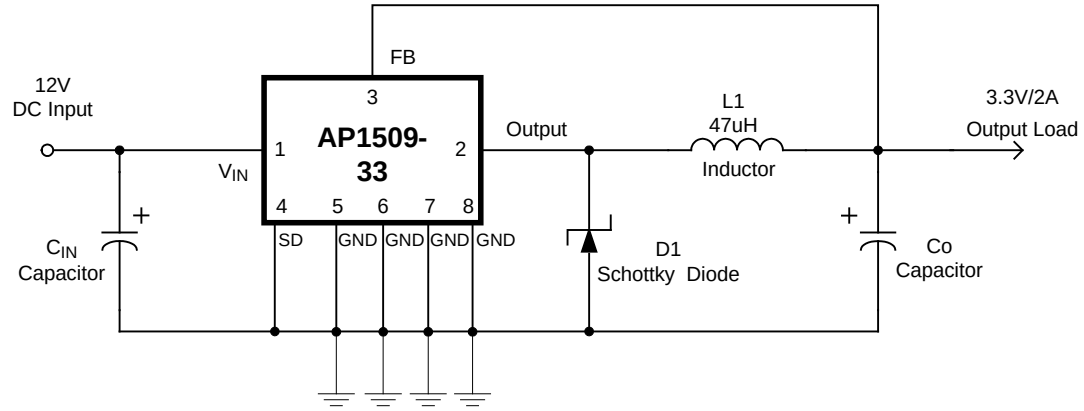
Applications

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

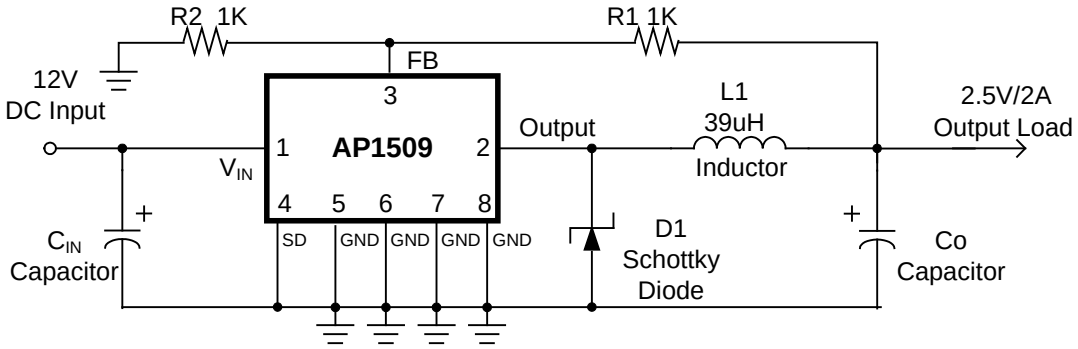
Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen-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

Typical Application Circuit

(1) Fixed Type Circuit



(2) Adjustable Type Circuit

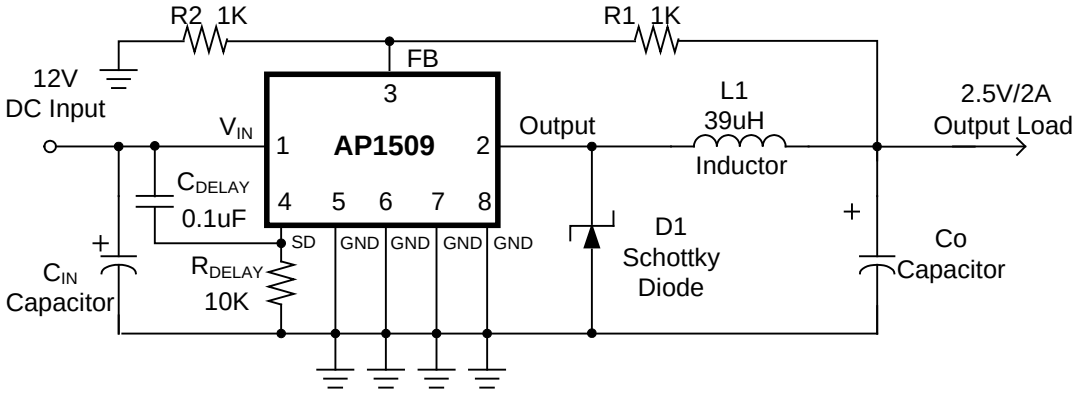


$$V_{OUT} = V_{FB} \times (1 + \frac{R1}{R2})$$

V_{FB} = 1.23V

R2 = 1K ~ 3K

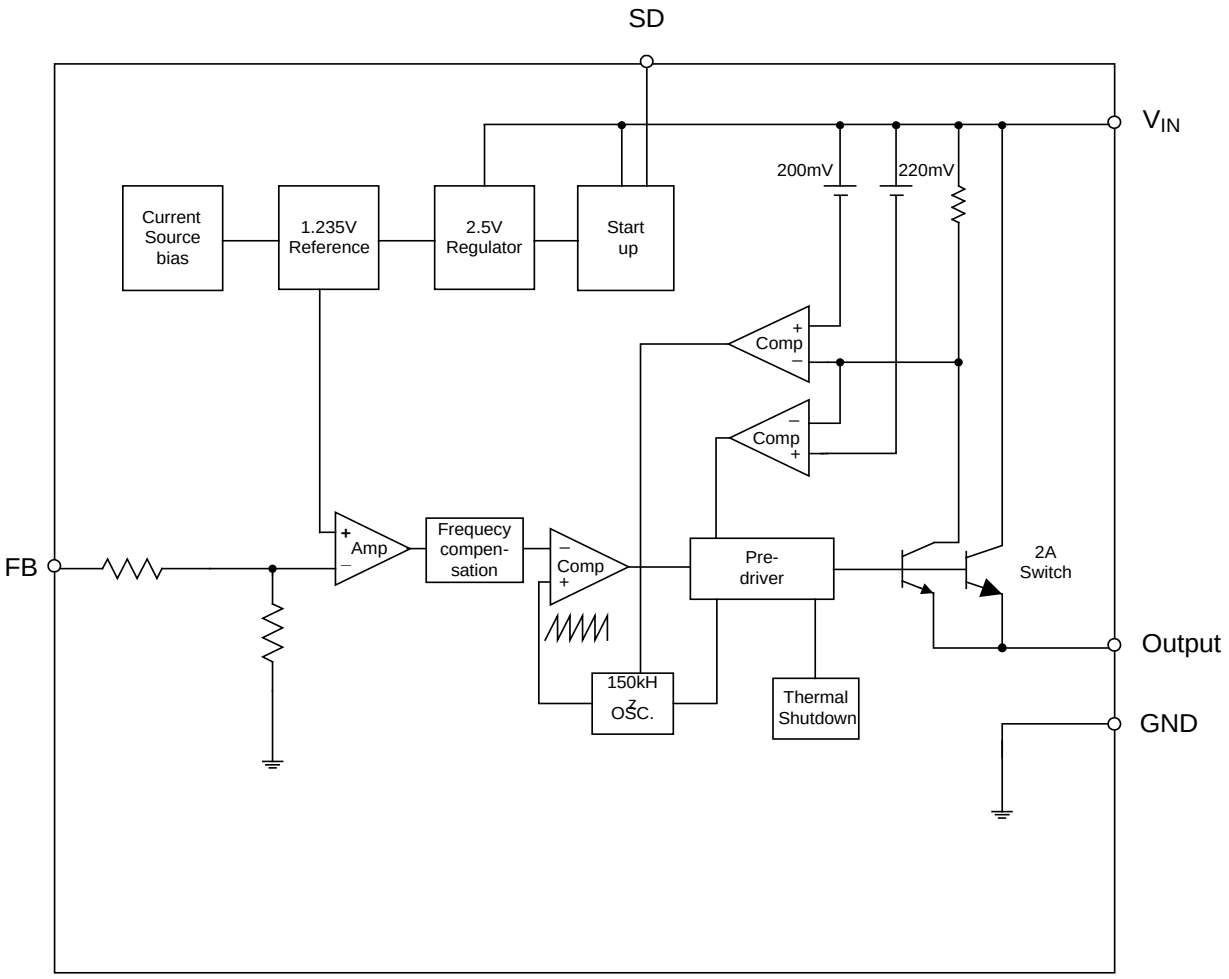
(3) Delay Start Circuit



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

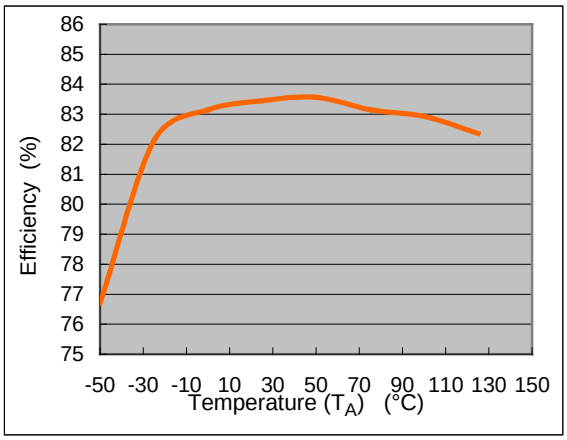
Electrical Characteristics

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°C.

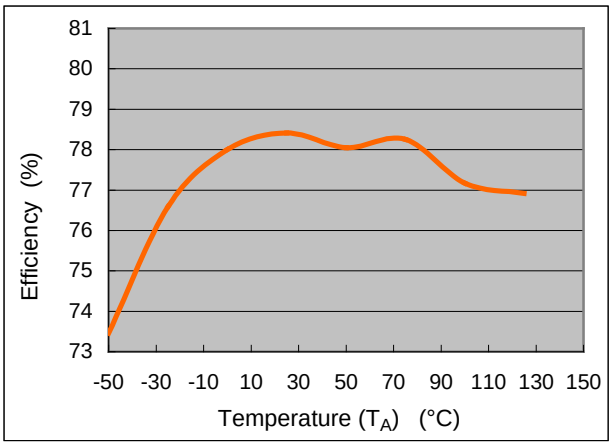
Symbol	Parameter	Conditions		Min	Typ.	Max	Unit
I_{FB}	Feedback Bias Current	V_{FB} = 1.3V (Adjustable Version Only)		—	-10	-50 **-100**	nA
F_{OSC}	Oscillator Frequency	—		127 **110**	150	173 **173**	kHz
F_{SCP}	Oscillator Frequency of Short Circuit Protect	When Current Limit Occurred and V_{FB} < 0.5V, T_a = 25°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 V_{FB} = 12V Force Driver Off		—	—	-200	µA
	Output = -1 (Output Leakage Current)	V_{IN} = 22V		—	-5		mA
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	—	°C/W
Θ_{JC}	Thermal Resistance with a Copper Area of Approximately 3in^2	SO-8	Junction to Ambient	—	70	—	°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

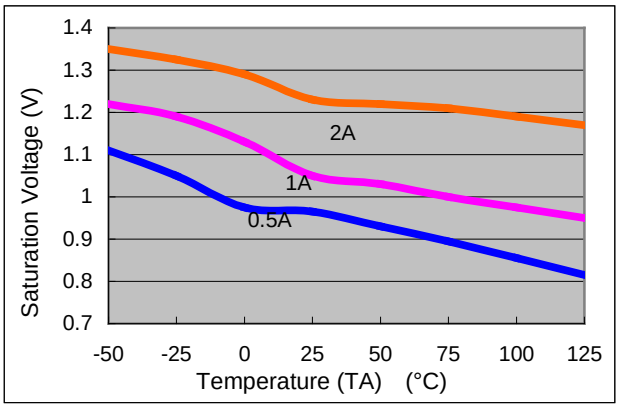
AP1509 Efficiency vs. Temperature
(V_{IN} = 12V, V_{OUT} = 5V, Io = 2A)



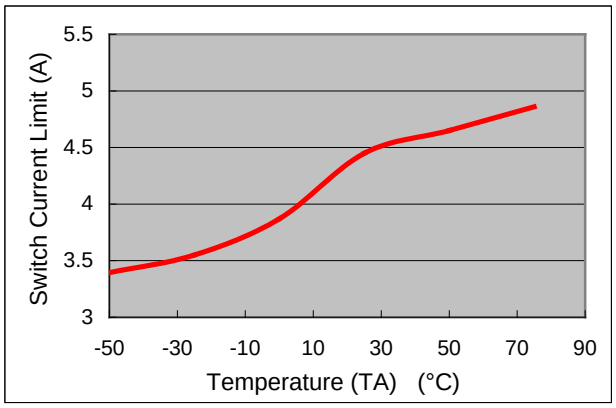
AP1509 Efficiency vs. Temperature
(V_{IN} = 12V, V_{OUT} = 3.3V, Io = 2A)



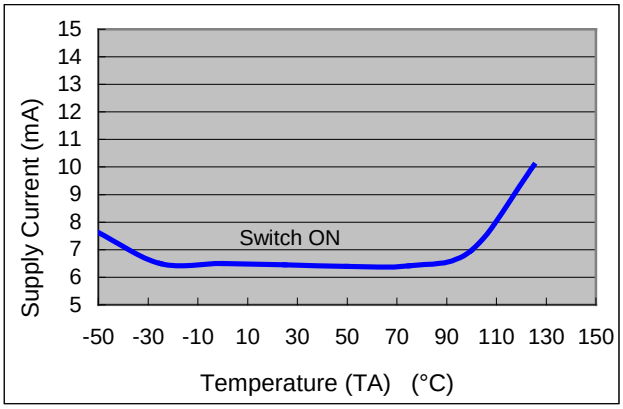
AP1509 Saturation Voltage vs. Temperature
(V_{IN} = 12V, V_{FB} = 0V, VSD = 0)

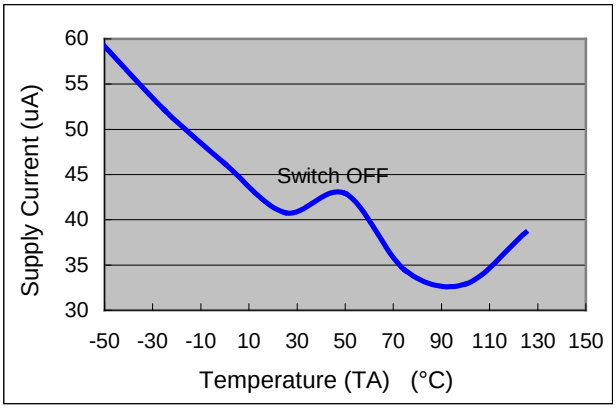


AP1509 Switch Current Limit vs. Temperature
(V_{IN} = 12V, V_{FB} = 0V)



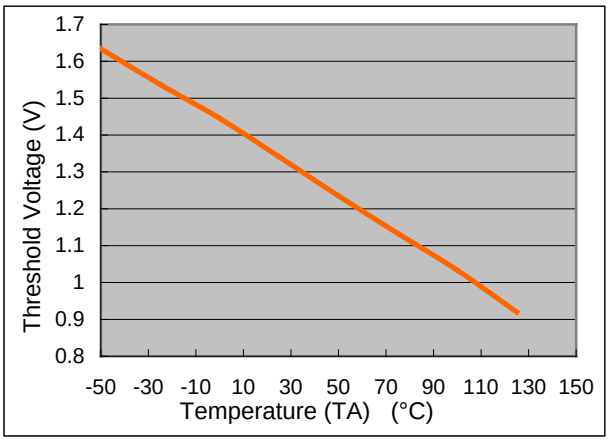
AP1509 Supply Current vs. Temperature
(V_{IN} = 12V, No Load, Von/off = 0V (Switch ON) ,Von/off = 5V (Switch OFF))



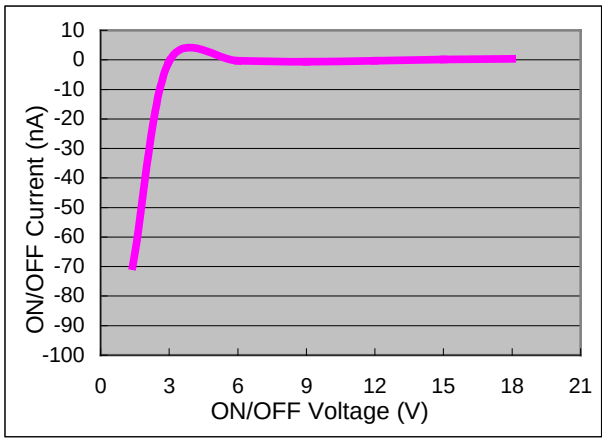


Typical Performance Characteristics (continued)

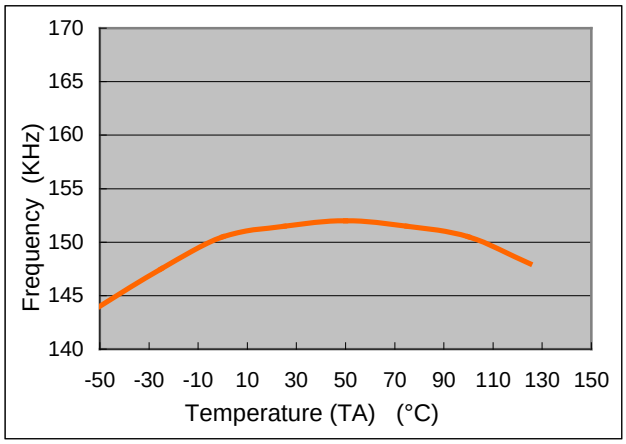
AP1509 Threshold Voltage vs. Temperature
(V_{IN} = 12V, Io = 100mA)



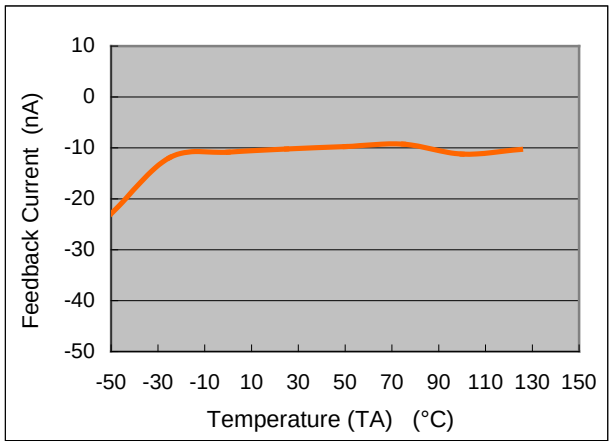
AP1509 ON/OFF Current vs. ON/OFF Voltage
(V_{IN} = 12V)



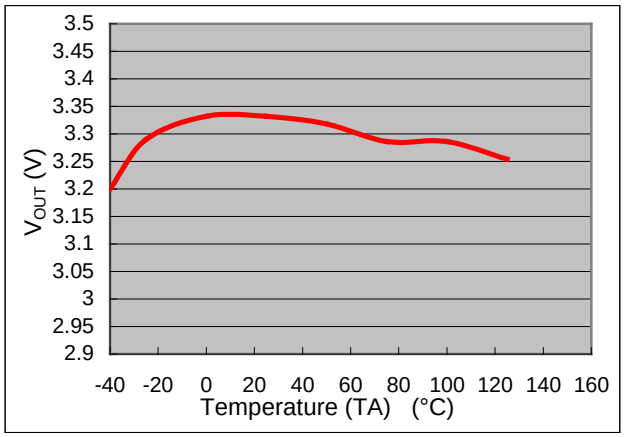
AP1509 Frequency vs. Temperature
(V_{IN} = 12V, Io = 500mA, V_{OUT} = 5V)



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

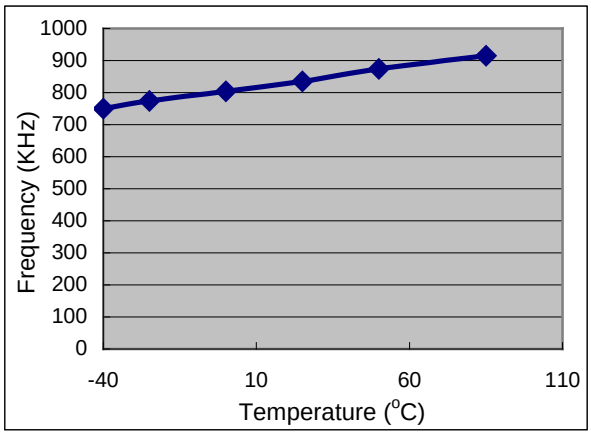


AP1509 Output Voltage vs. Temperature
(V_{IN} = 12V, Io = 2A)

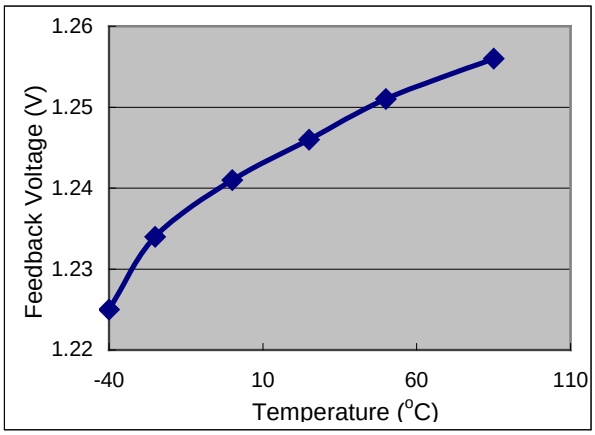


Typical Performance Characteristics (continued)

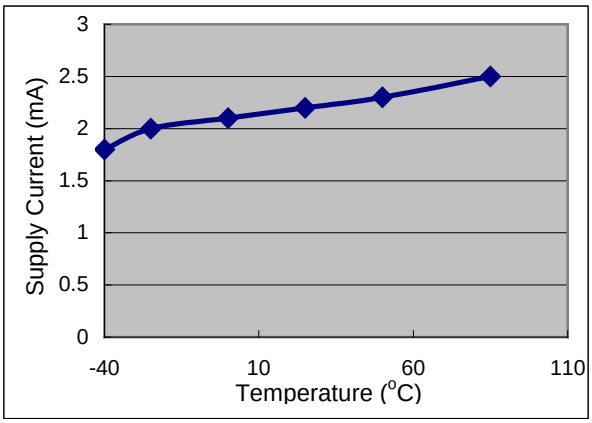
Header Frequency vs. Temperature



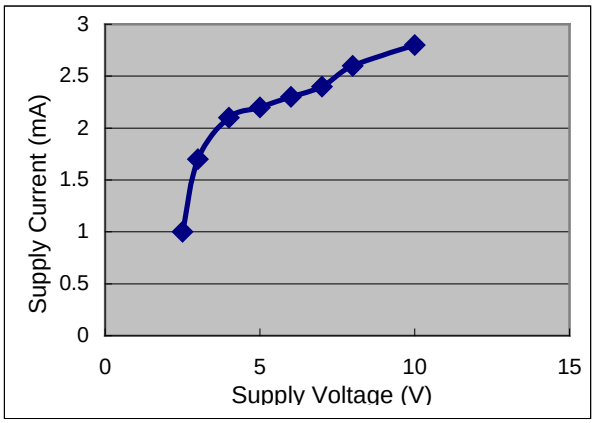
Feedback Voltage vs. Temperature
(V_{IN} = 15V, V_{OUT} = 5V)



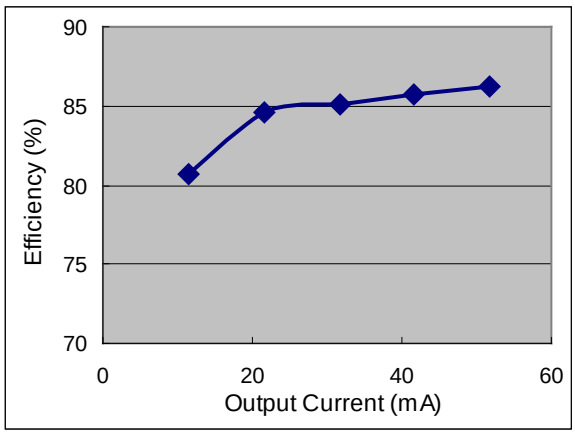
Supply Current vs. Temperature
(V_{IN} = 15V, V_{OUT} = 5V, I_{OUT} = 0A)



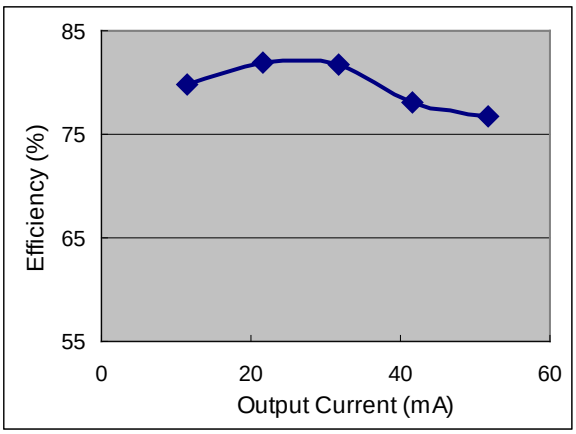
Supply Current vs. Supply Voltage
(V_{IN} = 15V, V_{OUT} = 5V, I_{OUT} = 0A)



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 150µA. 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

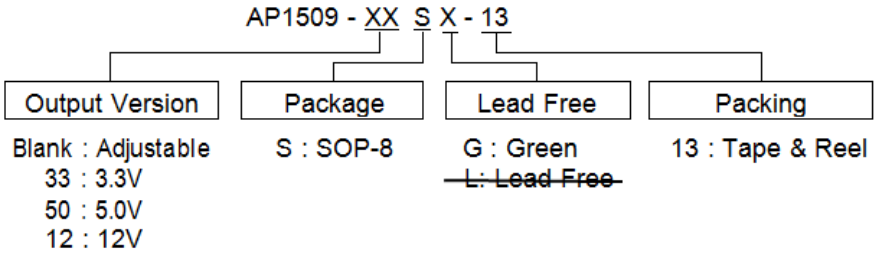
The SO-8 package requires a heat sink under most conditions. The size of the heat sink depends on the input voltage, the output voltage, the load current, and the ambient temperature. The AP1509 junction temperature rises above ambient temperature for a 2A load and different input and output voltages. 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

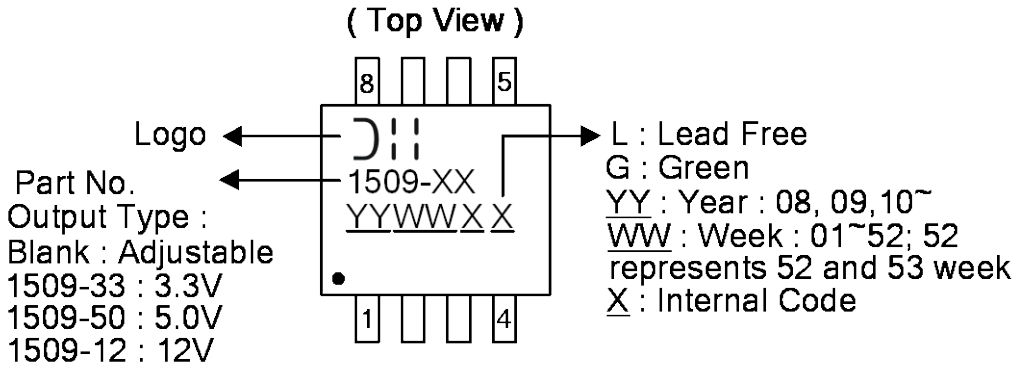


Device	Voltage (V)	Package Code	Package (Note 5)	Lead Free/Green	Quantity	Part Number Suffix		Status (Note 4)	Alternative
						Tube	13" Tape and Reel		
AP1509-12SG-13	12	S	SO-8	Green	2500	NA	-13	In production	
AP1509-33SG-13	3.3	S	SO-8	Green	2500	NA	-13	In production	
AP1509-50SG-13	5.0	S	SO-8	Green	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

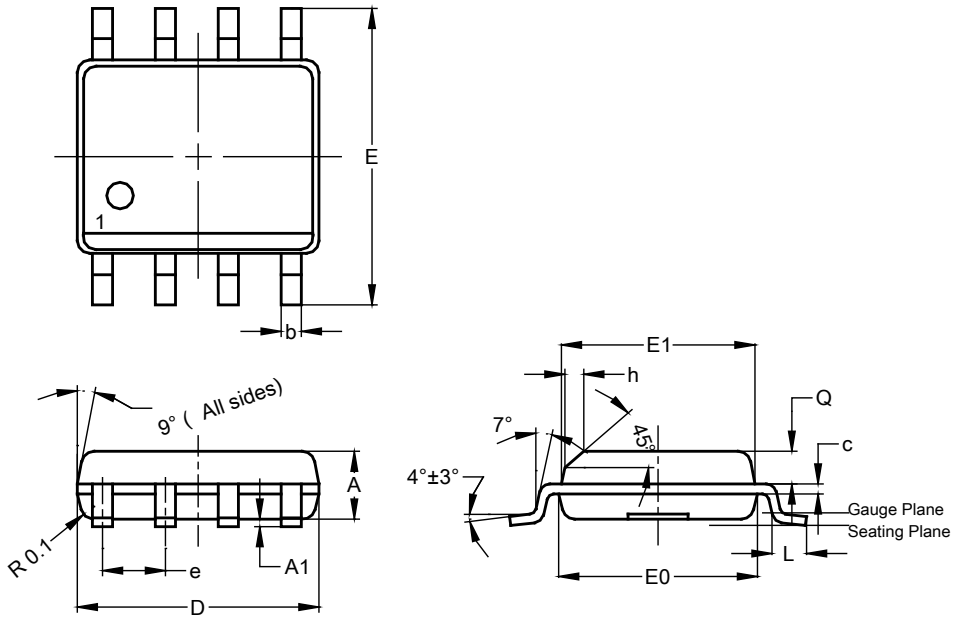
(1) SO-8



Package Outline Dimensions (All Dimensions in mm)

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

SO-8

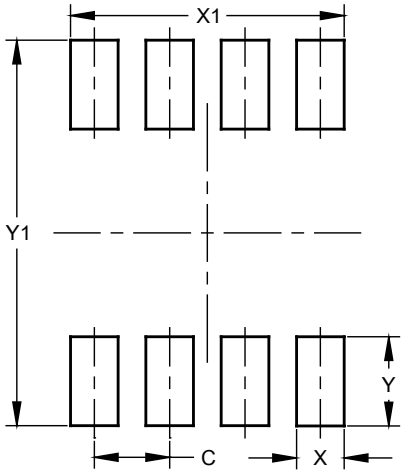


SO-8			
Dim	**Min**	**Max**	**Typ**
A	1.40	1.50	1.45
A1	0.10	0.20	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E0	3.85	3.95	3.90
e	--	--	1.27
h	-	--	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

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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2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

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