



**THE DATASHEET OF
AP1501A-12K5G-13**



Description

The AP1501A series are monolithic ICs that are designed for a step-down DC/DC converter, and possess the ability to drive a 5A load without additional transistor component. Due to reducing the number of external component, the board space can be saved easily. The external shutdown function can be controlled by logic level and then come into standby mode. The internal compensation makes feedback control have good line and load regulation without external design. Regarding protected function, thermal shutdown is to prevent over temperature operating from damage, and current limit is against over current operating of the output switch. The AP1501A series operates at a switching frequency of 150kHz thus allowing smaller sized filter components than what would be needed 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 includes fixed 3.3V, 5V, 12V and an adjustable type. The packages are available in a standard 5-lead TO263-5, TO220-5 and TO220-5 (R) packages.

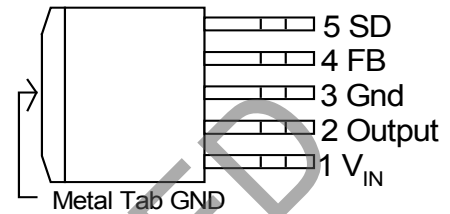
Features

- Output Voltage: 3.3V, 5V, 12V and Adjustable Output Version
- Adjustable Version Output Voltage Range, 1.23V to 37V $\pm 4\%$
- 150kHz $\pm 15\%$ Fixed Switching Frequency
- Voltage Mode Non-synchronous PWM Control
- Thermal-shutdown and Current-limit Protection
- ON/OFF Shutdown Control Input
- Operating voltage can be up to 40V
- Output Load Current: 5A
- Low power Standby Mode
- Built-in Switching Transistor On Chip
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Devices (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative.**
<https://www.diodes.com/quality/product-definitions/>

- 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.

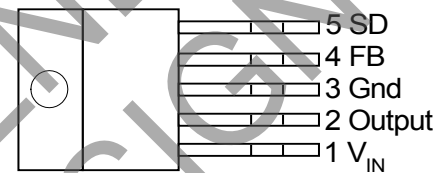
Pin Assignments

(Top View)



TO263-5

(Top View)



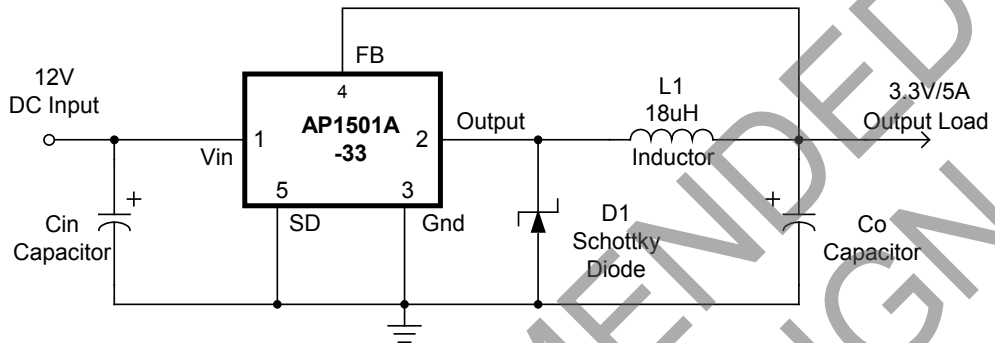
TO220-5/TO220-5 (R)

Applications

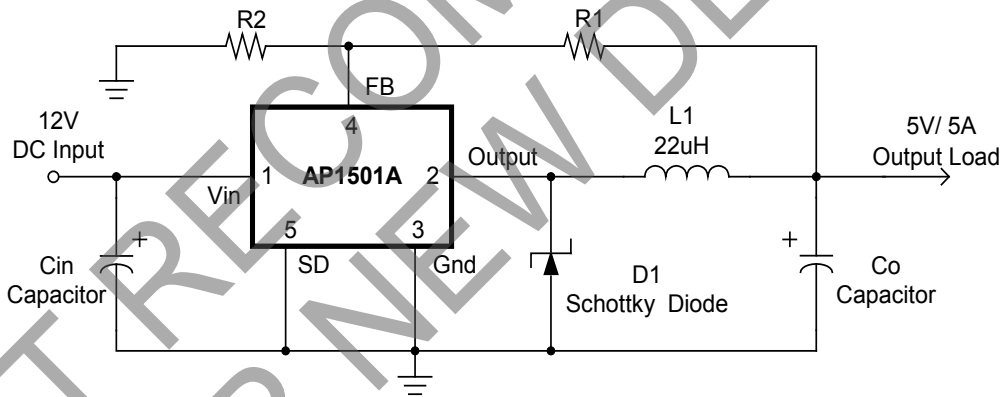
- Simple High-efficiency Step-down Regulator
- On-card Switching Regulators
- Positive to Negative Converter

Typical Applications Circuit

(1) Fixed Type Circuit



(2) Adjustable Type Circuit

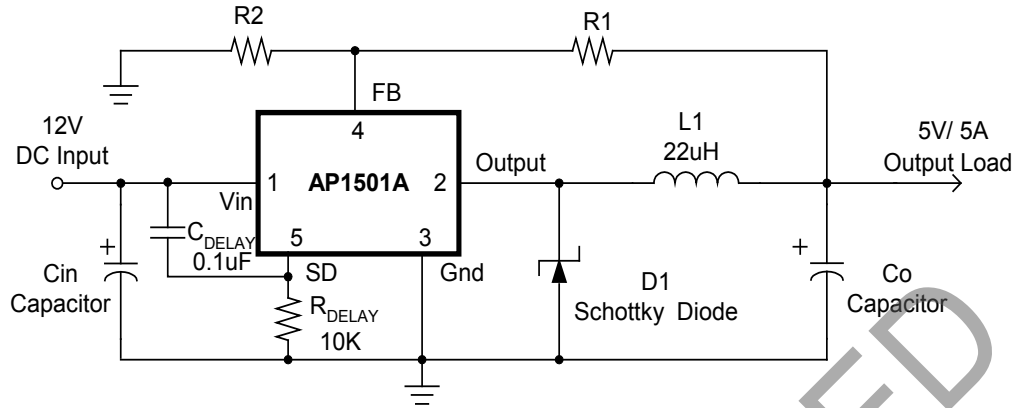


$$V_{OUT} = V_{FB} \times \left(1 + \frac{R1}{R2}\right)$$

$$V_{FB} = 1.23V$$

$$R2 = 1k\Omega \text{ to } 3k\Omega$$

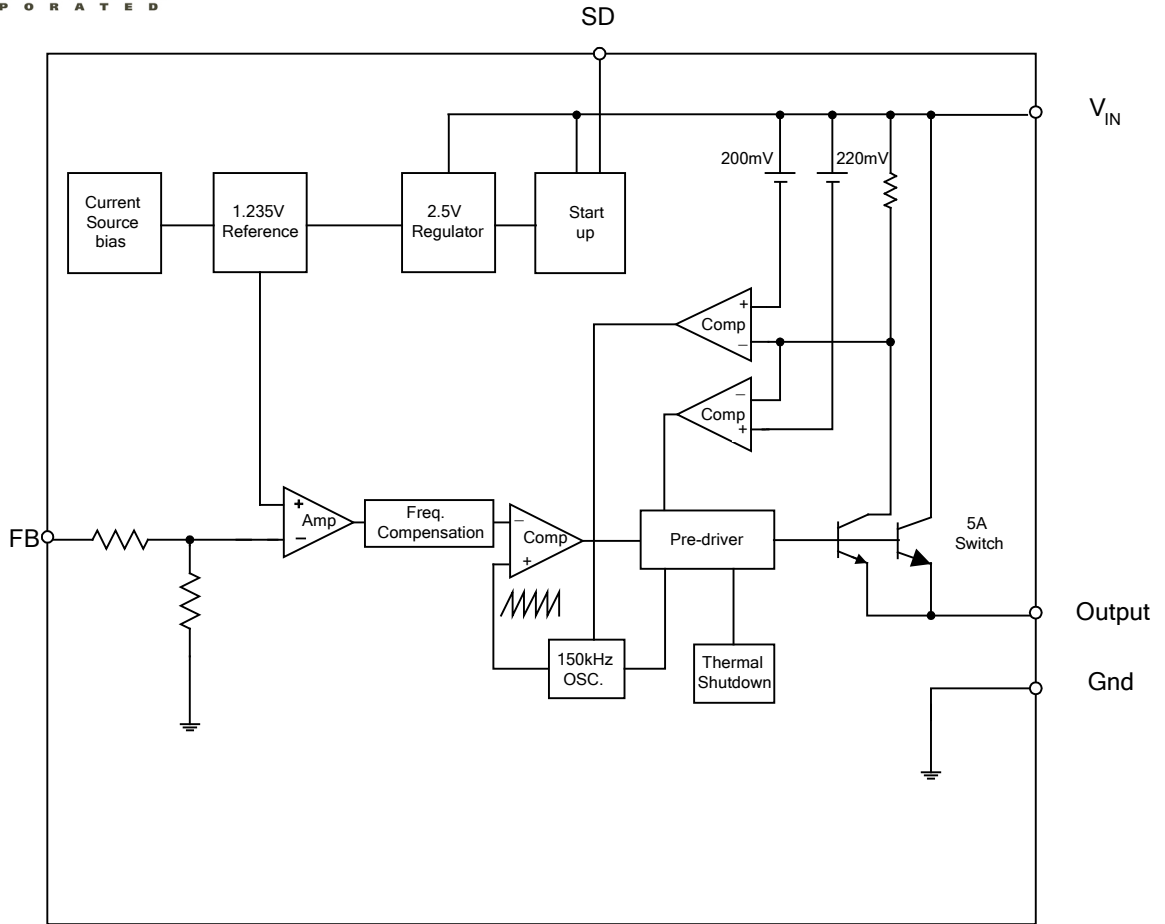
(3) Delay Start Circuit



Pin Descriptions

| Pin Number | Pin Name | Description |
|------------|-----------------|---------------------------------|
| 1 | V _{IN} | Operating voltage input |
| 2 | Output | Switching output |
| 3 | Gnd | Ground |
| 4 | FB | Output voltage feedback control |
| 5 | SD | ON/OFF shutdown |

Functional Block Diagram



Absolute Maximum Ratings

| Symbol | Parameter | Rating | Unit |
|------------------|--------------------------------|--------------------|------|
| ESD MM | Machine Model ESD Protection | 400 | V |
| V _{CC} | Supply Voltage | +45 | V |
| V _{SD} | SD Pin Input Voltage | -0.3 to +40 | V |
| V _{FB} | FB Pin Voltage | -0.3 to +40 | 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 | -20 to +125 | °C |

Recommended Operating Conditions

| Symbol | Parameter | Rating | Unit |
|-----------------|-------------------------------|------------|------|
| V _{OP} | Operating Voltage | 4.5 to 40 | V |
| T _A | Operating Ambient Temperature | -20 to +85 | °C |

NOT RECOMMENDED FOR NEW DESIGN

Electrical Characteristics (All Output Voltage Versions)

Unless otherwise specified, $V_{IN} = 12V$ for 3.3V, 5V, adjustable version and $V_{IN} = 24V$ 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) | — | 40 | 60 100 | nA |
| f_{OSC} | Oscillator Frequency | | — | 127 110 | 150 — | 173 173 | kHz |
| V_{SAT} | Saturation Voltage | | $I_{OUT} = 5A$ No outside circuit $V_{FB} = 0V$ force driver on | — | 1.5 | 1.6 1.7 | 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 | 5.5 | 6.0 | 6.5 | A |
| | | | No outside circuit $V_{FB} = 0$ force driver on | | | 7.5 | |
| I_L | Output = 0V | Output Leakage Current | No outside circuit $V_{FB} = 12V$ force driver off (Note 4) | — | — | 200 | μA |
| | Output = -1V | | $V_{IN} = 40V$ | — | 2 | 60 | mA |
| I_Q | Quiescent Current | | $V_{FB} = 12V$ force driver off | — | 5 | 10 | mA |
| I_{STBY} | Standby Quiescent Current | | SD pin = 5V | — | 150 | 250 | μA |
| | | | $V_{IN} = 40V$ | — | — | 300 | |
| V_{IL} | SD Pin Logic Input Threshold Voltage | | Low (regulator ON) | — | 1.3 | 0.6 | V |
| V_{IH} | | | High (regulator OFF) | 2.0 | | — | |
| I_H | SD Pin Logic Input Current | | $V_{LOGIC} = 2.5V$ (OFF) | — | 15 | 25 | μA |
| I_L | SD Pin Input Current | | $V_{LOGIC} = 0.5V$ (ON) | — | 0.02 | 5 | |
| θ_{JA} | Thermal Resistance Junction-to-Ambient | | TO263-5 (Note 5) | — | 37 | — | $^{\circ}C/W$ |
| | | | TO220-5(R) (Note 5) | — | 31 | — | |
| θ_{JC} | Thermal Resistance Junction-to-Case | | TO263-5 (Note 5) | — | 6 | — | $^{\circ}C/W$ |
| | | | TO220-5(R) (Note 5) | — | 5 | — | |

Notes: 4. FB pin removed from output and connected to 0V to force the output transistor switch ON. FB pin removed from output and connected to 12V for the 3.3V, 5V, and the ADJ. version, and 15V for the 12V version, to force the output transistor switch OFF.
5. Test condition: Device mounted with copper area of approximately 3in², 1oz, no air flow.

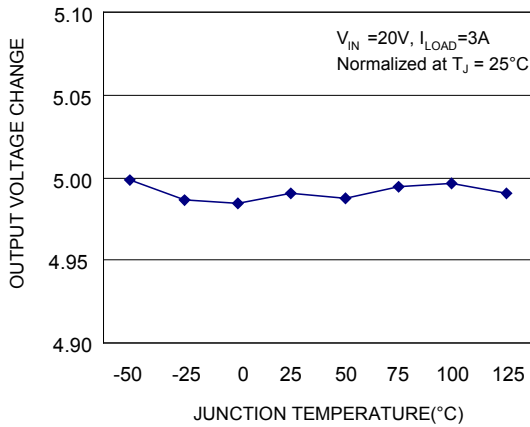
Electrical Characteristics (continued)

Specifications with **boldface type** are for full operating temperature range, the other type are for $T_J = +25^\circ\text{C}$.

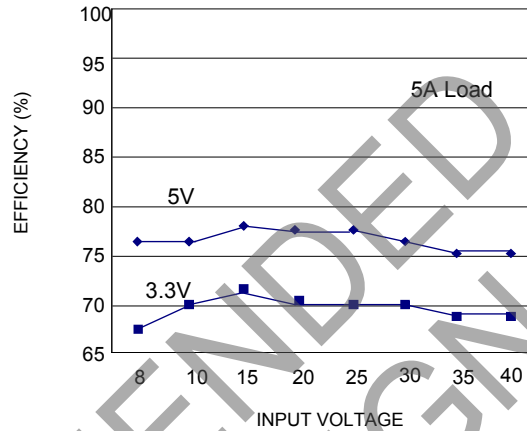
| | Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|--------------|-----------|-----------------|--|---------------------|------|---------------------|------|
| AP1501A-ADJ | V_{FB} | Output Feedback | $5V \leq V_{IN} \leq 40V$ $0.2A \leq I_{LOAD} \leq 5A$ V_{OUT} programmed for 3V | 1.193/ 1.18 | 1.23 | 1.267/ 1.28 | V |
| | η | Efficiency | $V_{IN} = 12V, I_{LOAD} = 5A$ | — | 72 | — | % |
| AP1501A-3.3V | V_{OUT} | Output Voltage | $5.5V \leq V_{IN} \leq 40V$ $0.2A \leq I_{LOAD} \leq 5A$ | 3.168/ 3.135 | 3.3 | 3.432/ 3.465 | V |
| | η | Efficiency | $V_{IN} = 12V, I_{LOAD} = 5A$ | — | 71 | — | % |
| AP1501A-5V | V_{OUT} | Output Voltage | $8V \leq V_{IN} \leq 40V$ $0.2A \leq I_{LOAD} \leq 5A$ | 4.8/ 4.75 | 5 | 5.2/ 5.25 | V |
| | η | Efficiency | $V_{IN} = 12V, I_{LOAD} = 5A$ | — | 78 | — | % |
| AP1501A-12V | V_{OUT} | Output Voltage | $15V \leq V_{IN} \leq 40V$ $0.2A \leq I_{LOAD} \leq 5A$ | 11.52/ 11.4 | 12 | 12.48/ 12.6 | V |
| | η | Efficiency | $V_{IN} = 16V, I_{LOAD} = 5A$ | — | 88 | — | % |

Typical Performance Characteristics

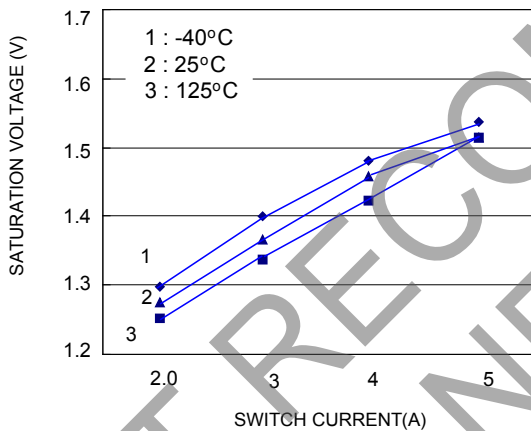
**Typical Performance Characteristics
Normalized Output Voltage**



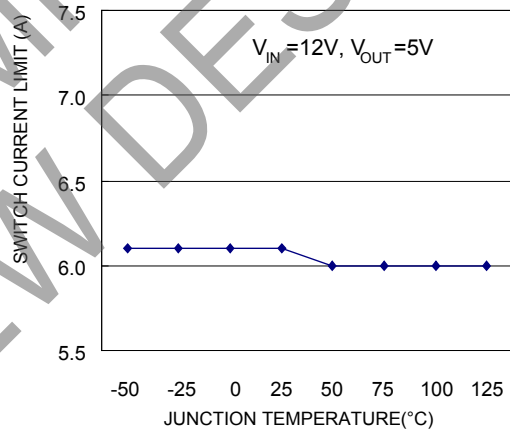
Efficiency



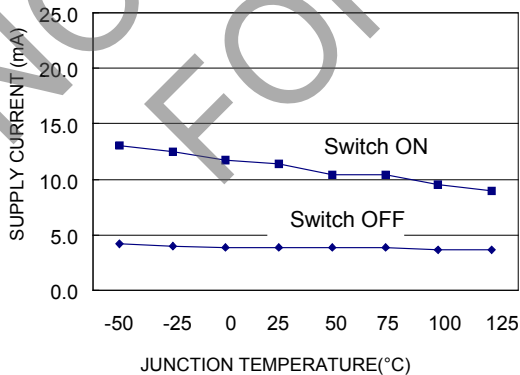
Switch Saturation Voltage



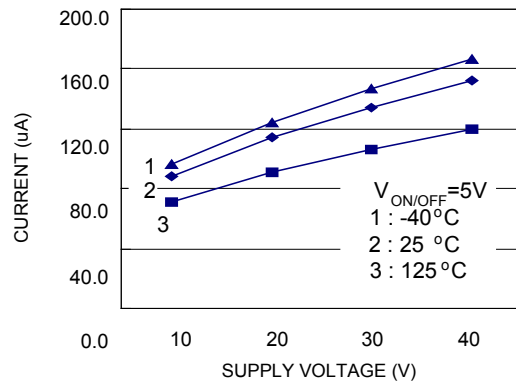
Switch Current Limit



Operating Quiescent Current

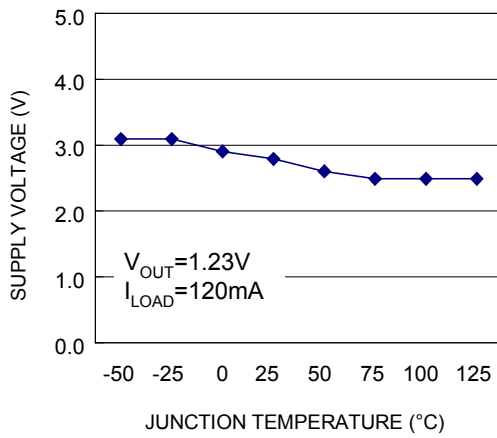


Shutdown Quiescent Current

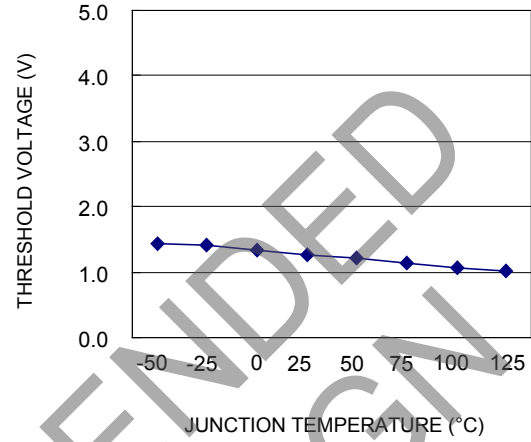


Typical Performance Characteristics (continued)

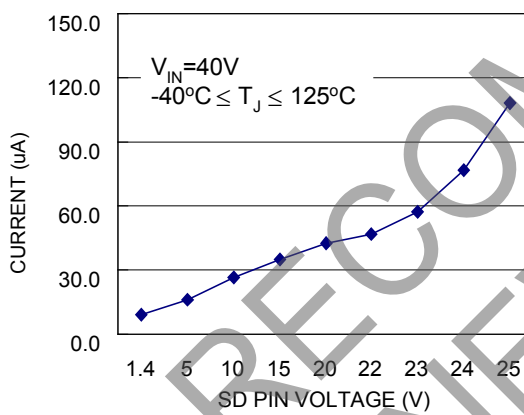
Minimum Operating Supply Voltage



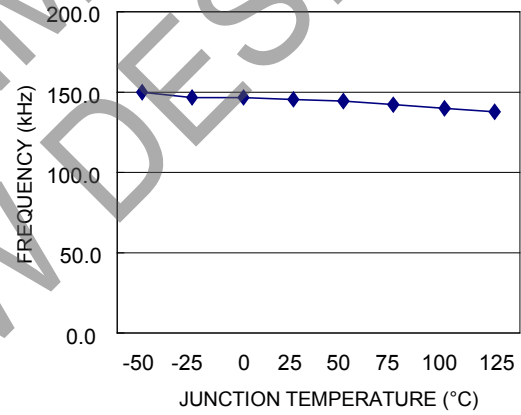
ON/OFF Threshold Voltage



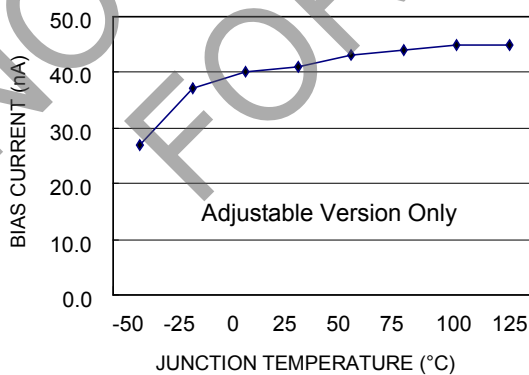
SD Pin Current (Sinking)



Switch Frequency



FB Pin Bias Current



Functional Description

Pin Functions

+V_{IN}

This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be present at this pin to minimize voltage transients and to supply the switching currents needed 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 PC board copper area connected to this pin should be kept a minimum.

Feedback

Senses the regulated output voltage to complete the feedback loop.

ON/OFF

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 40V) shuts the regulator down. If this shutdown feature is not needed, the SD pin can be wired to the ground pin or it can be left open, in either case the regulator will be in the ON condition.

Thermal Considerations

The AP1501A is available in two packages, a 5-pin surface mount TO263-5, TO220-5 and TO220-5 (R).

The TO220-5 and TO220-5 (R) packages need 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 AP1501A junction temperature rises above ambient temperature for a 5A load and different input and output voltages. The data for these curves was taken with the AP1501A (TO220-5 and TO220-5 (R) packages) operating as a buck switching regulator in an ambient temperature of +25°C (still air). These temperature rise numbers are all approximate and there are many factors that can affect these temperatures. Higher ambient temperatures require more heat sinking.

The TO263-5 surface mount package tab is designed to be soldered to the copper on a printed circuit board. The copper and the board are the heat sink for this package and the other heat producing components, such as the catch diode and inductor. The PC board copper area that the package is soldered to should be at least 0.8 inch², and ideally should have 2 or more square inches of 2 oz. Additional copper area improves the thermal characteristics, but with copper areas greater than approximately 6 inch², only small improvements in heat dissipation are realized. If further thermal improvements are needed, double sided, multilayer PC boards with large copper areas and/or airflow are recommended.

The AP1501A (TO263-5 package) junction temperature rise above ambient temperature with a 2A load for various input and output voltages. This data was taken with the circuit operating as a buck switching regulator with all components mounted on a PC board to simulate the junction temperature under actual operating conditions. This curve can be used for a quick check for the approximate junction temperature for various conditions, but be aware that there are many factors that can affect the junction temperature. When load currents higher than 3A are used, double sided or multilayer PC boards with large copper areas and/or airflow might be needed, especially for high ambient temperatures and high output voltages.

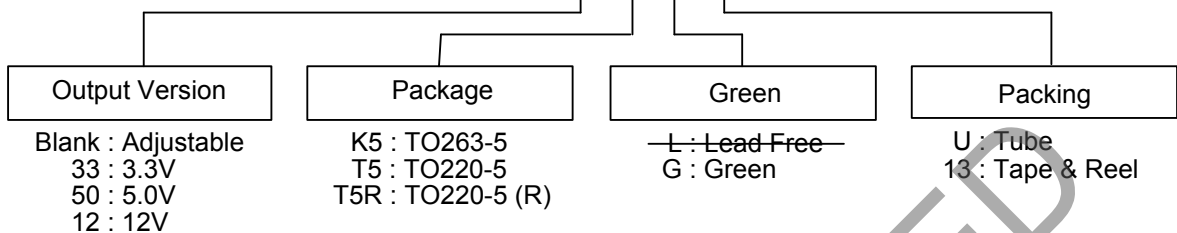
For the best thermal performance, wide copper traces and generous amounts of printed circuit board copper should be used in the board layout. (Once exception to this is the Output pin, which should not have large areas of copper.) Large areas of copper provide the best transfer of heat (lower thermal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

Package thermal resistance and junction temperature rise numbers are all approximate, and there are many factors that will affect these numbers. 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, multilayer board and the amount of solder on the board. The effectiveness of the PC board 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 will add heat to the PC board 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

AP1501A XX XXX X - XX

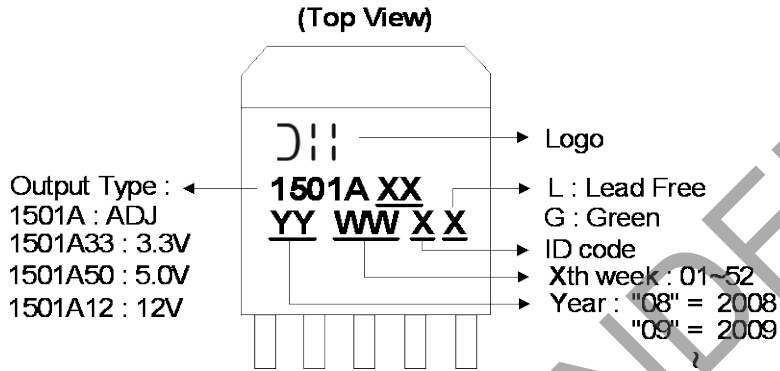


| Device | Voltage | Package code | Package (Note 6) | Lead Free/ Green | Quantity | Part Number Suffix | | Status |
|------------------|---------|--------------|------------------|------------------|----------|--------------------|-------------------|-------------|
| | | | | | | Tube | 13" Tape and reel | |
| AP1501A-33K5G-13 | 33 | K5 | TO263-5 | Green | 800 | NA | -13 | End of Life |
| AP1501A-12K5G-13 | 12 | K5 | TO263-5 | Green | 800 | NA | -13 | NRND |
| AP1501A-50K5G-13 | 50 | K5 | TO263-5 | Green | 800 | NA | -13 | NRND |
| AP1501A-K5G-13 | ADJ | K5 | TO263-5 | Green | 800 | NA | -13 | NRND |
| AP1501A-12T5RG-U | 12 | T5R | TO220-5 (R) | Green | 50 | -U | NA | End of Life |
| AP1501A-33T5RG-U | 33 | T5R | TO220-5 (R) | Green | 50 | -U | NA | End of Life |
| AP1501A-50T5RG-U | 50 | T5R | TO220-5 (R) | Green | 50 | -U | NA | End of Life |
| AP1501A-T5RG-U | ADJ | T5R | TO220-5 (R) | Green | 50 | -U | NA | End of Life |
| AP1501A-12T5G-U | 12 | T5 | TO220-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-33T5G-U | 33 | T5 | TO220-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-50T5G-U | 50 | T5 | TO220-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-T5G-U | ADJ | T5 | TO220-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-12K5G-U | 12 | K5 | TO263-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-33K5G-U | 33 | K5 | TO263-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-50K5G-U | 50 | K5 | TO263-5 | Green | 50 | -U | NA | End of Life |
| AP1501A-K5G-U | ADJ | K5 | TO263-5 | Green | 50 | -U | NA | End of Life |

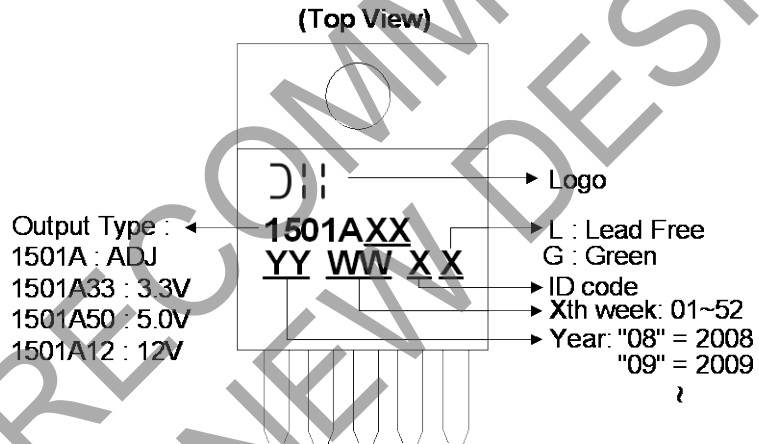
Notes: 6. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.

Marking Information (Note 6)

(1) TO263-5



(2) TO220-5/TO220-5 (R)

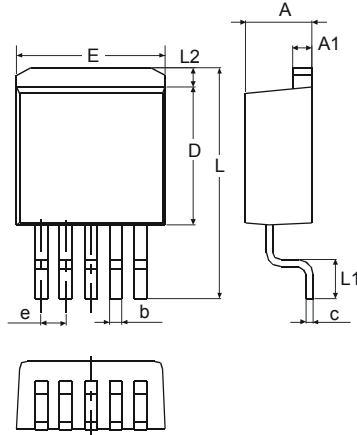


NOT RECOMMENDED FOR NEW DESIGN

Package Outline Dimensions

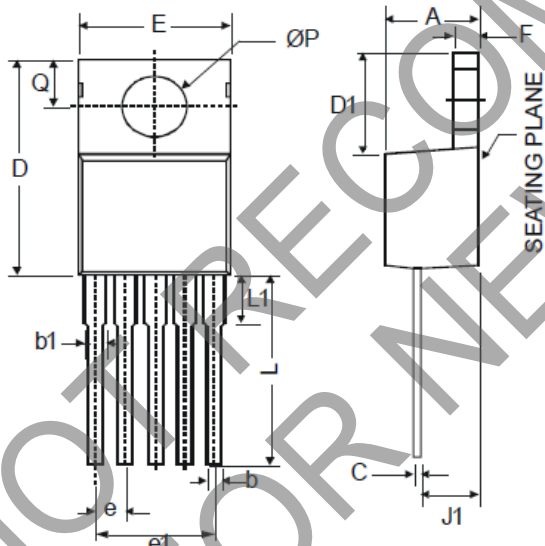
Please see <http://www.diodes.com/package-outlines.html> for the latest version.

(1) Package Type: TO263-5



| TO263-5 | | |
|----------------------|-------|-------|
| Dim | Min | Max |
| A | 4.07 | 4.85 |
| A1 | 1.14 | 1.40 |
| b | 0.66 | 1.02 |
| c | 0.36 | 0.64 |
| D | 8.65 | 9.65 |
| E | 9.78 | 10.54 |
| e | 1.57 | 1.85 |
| L | 14.61 | 15.88 |
| L1 | 2.29 | 2.79 |
| L2 | - | 2.92 |
| All Dimensions in mm | | |

(2) Package Type: TO220-5

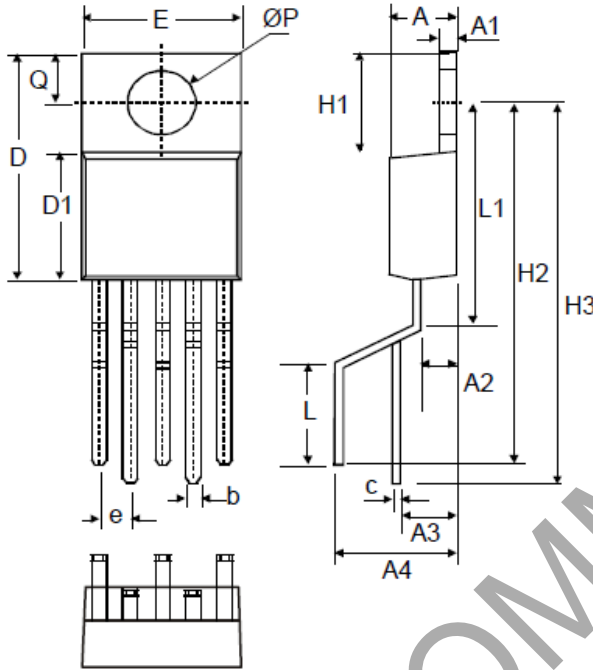


| TO220-5 | | |
|----------------------|-------|-------|
| Dim | Min | Max |
| A | 3.55 | 4.85 |
| b | 0.51 | 1.14 |
| b1 | 1.14 | 1.78 |
| C | 0.31 | 1.14 |
| D | 14.20 | 16.50 |
| D1 | 5.84 | 6.86 |
| E | 9.78 | 10.54 |
| e | 1.6 | 1.8 |
| e1 | 6.6 | 7.0 |
| F | 0.51 | 1.40 |
| J1 | 2.03 | 2.92 |
| L | 12.72 | 14.72 |
| L1 | 3.66 | 6.35 |
| P | 3.53 | 4.09 |
| Q | 2.54 | 3.43 |
| All Dimensions in mm | | |

Package Outline Dimensions (continued)

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

(3) Package Type: TO220-5 (R)

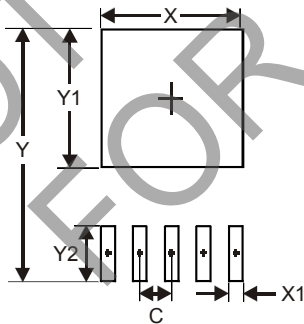


| TO220-5(R) | | | |
|----------------------|-------|-------|-------|
| Dim | Min | Typ | Max |
| A | 4.37 | 4.57 | 4.77 |
| A1 | 1.12 | 1.27 | 1.40 |
| A2 | 2.45 | 2.65 | 2.85 |
| A3 | 4.10 | 4.40 | 4.70 |
| A4 | 7.95 | 8.25 | 8.55 |
| b | 0.64 | 0.79 | 0.94 |
| c | 0.35 | 0.38 | 0.55 |
| D | 14.80 | 15.00 | 15.20 |
| D1 | 8.50 | 8.70 | 8.90 |
| e | - | 1.70 | - |
| E | 9.96 | 10.16 | 10.36 |
| H1 | 6.10 | 6.30 | 6.50 |
| H2 | 21.32 | 22.12 | 22.92 |
| H3 | 24.15 | 24.95 | 25.75 |
| L | - | 6.30 | - |
| L1 | 13.10 | 13.50 | 13.90 |
| P | 3.64 | 3.84 | 4.04 |
| Q | 2.55 | 2.75 | 2.95 |
| All Dimensions in mm | | | |

Suggested Pad Layout

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

(1) Package Type: TO263-5



| Dimensions | Value (in mm) |
|------------|---------------|
| X | 10.9 |
| X1 | 1.05 |
| Y | 15.7 |
| Y1 | 9.1 |
| Y2 | 2.5 |
| C | 1.7 |

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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.

Customers represent that they have all necessary expertise in the safety and regulatory ramifications of their life support devices or systems, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of Diodes Incorporated products in such safety-critical, life support devices or systems, notwithstanding any devices- or systems-related information or support that may be provided by Diodes Incorporated. Further, Customers must fully indemnify Diodes Incorporated and its representatives against any damages arising out of the use of Diodes Incorporated products in such safety-critical, life support devices or systems.

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