## Description

AP1510 consists of step-down switching regulator with PWM control. These devices include a reference voltage source, oscillation circuit, error amplifier and internal PMOS.

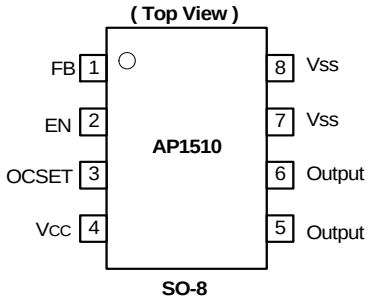
AP1510 provides low-ripple power, high efficiency and excellent transient characteristics. The PWM control circuit is able to vary the duty ratio linearly from 0 up to 100%. This converter also contains an error amplifier circuit. An enable function, an over current protection and a short circuit protection are built inside, when OCP or SCP happens, the operation frequency will be reduced from 300kHz to 30kHz. Also, an internal compensation block is built in to minimum external component count.

With the addition of an internal P-channel Power MOS, a coil, capacitors, and a diode connected externally, these ICs can function as step-down switching regulators. They serve as ideal power supply units for portable devices when coupled with the SO-8 package, providing such outstanding features as low current consumption. Since this converter can accommodate an input voltage up to 23V, it is also suitable for the operation via an AC adapter.

## Features

- Input Voltage: 3.6V to 23V
- Output Voltage: 0.8V to $V_{CC}$
- Duty Ratio: 0% to 100% PWM Control
- Oscillation Frequency: 300kHz Typ
- Current Limit, Enable Function
- Thermal Shutdown Function
- Built-in Internal SW P-channel MOS
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free."Green" Device (Note 3)**

## Pin Assignments



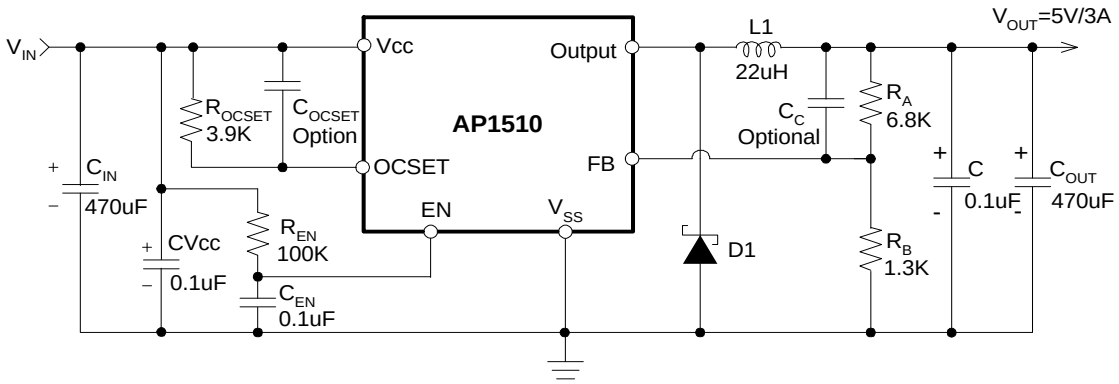

SO-8

## Applications

- Cellular Phones
- PC Motherboard
- LCD Monitor
- Graphic Card
- DVD-Video Player
- Telecom Equipment
- ADSL Modem
- Printer and Other Peripheral Equipment
- Microprocessor Core Supply
- Networking Power Supply

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See http://www.diodes.com/quality/lead_free.html 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



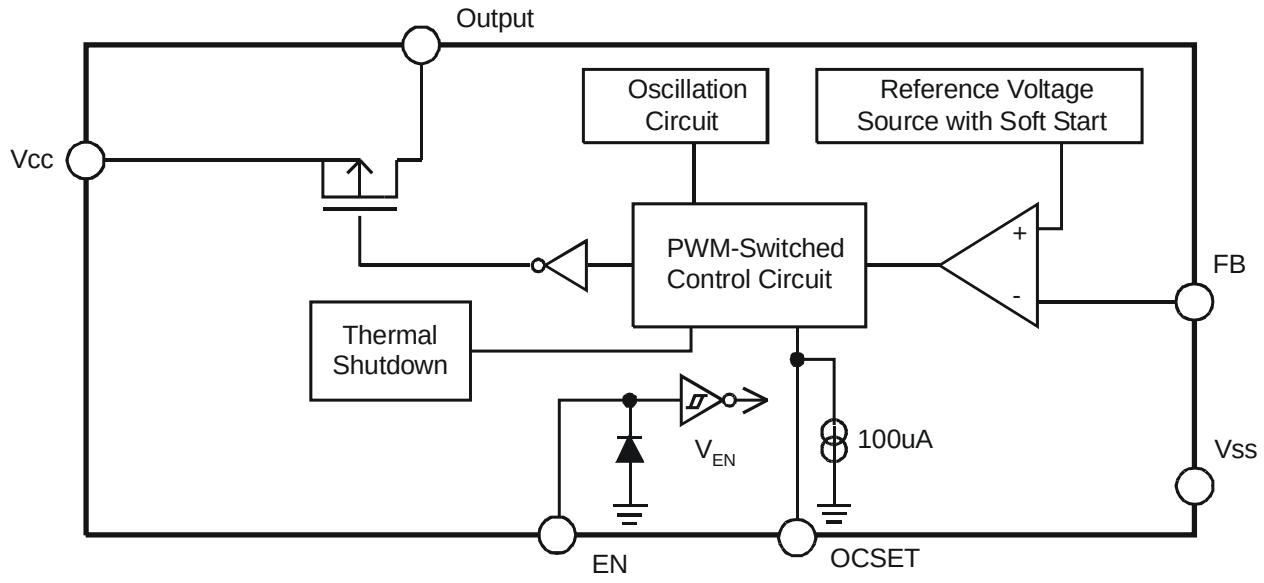

**Note: $V_{OUT} = V_{FB} \times (1+R_A/R_B)$**
**$R_B$=0.7K~5K ohm**


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## Pin Descriptions

| Pin Number | Pin Name | Description |
|---|---|---|
| 1 | FB | Feedback pin |
| 2 | EN | Enable Input pin<br>H: Normal operation<br>(Step-down operation)<br>L: Step-down operation stopped<br>(All circuits deactivated) |
| 3 | OCSET | Add an external resistor to set max output current |
| 4 | $V_{CC}$ | IC power supply pin |
| 5, 6 | Output | Switch Pin. Connect external inductor/diode here. Minimize trace area at this pin to reduce EMI. |
| 7, 8 | $V_{SS}$ | GND Pin |

## Block Diagram





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## Absolute Maximum Ratings

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{CC}$ | $V_{CC}$ Pin Voltage | $V_{SS}$ - 0.3 to $V_{SS}$ + 25 | V |
| $V_{FB}$ | FB Pin Voltage | $V_{SS}$ - 0.3 to $V_{CC}$ | V |
| $V_{EN}$ | EN Pin Voltage | $V_{SS}$ - 0.3 to $V_{IN}$ + 0.3 | V |
| $V_{OUT}$ | Output Pin Voltage | $V_{SS}$ - 0.3 to $V_{IN}$ + 0.3 | V |
| $P_D$ | Power Dissipation | Internally Limited | mW |
| $T_{OP}$ | Operating Junction Temperature Range | -20 to +125 | °C |
| $T_{ST}$ | Storage Temperature Range | -65 to +150 | °C |

Caution: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

## Recommended Operating Conditions

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $V_{IN}$ | Input Voltage | 3.6 | 23 | V |
| $I_{OUT}$ | Output Current | 0 | 3 | A |
| $T_A$ | Operating Ambient Temperature | -25 | +85 | °C |

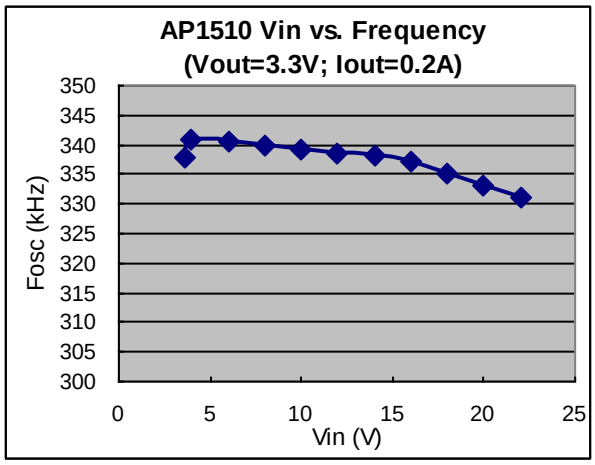
## Electrical Characteristics ($V_{IN}$ = 12V, $T_A$ = +25°C, unless otherwise specified.)

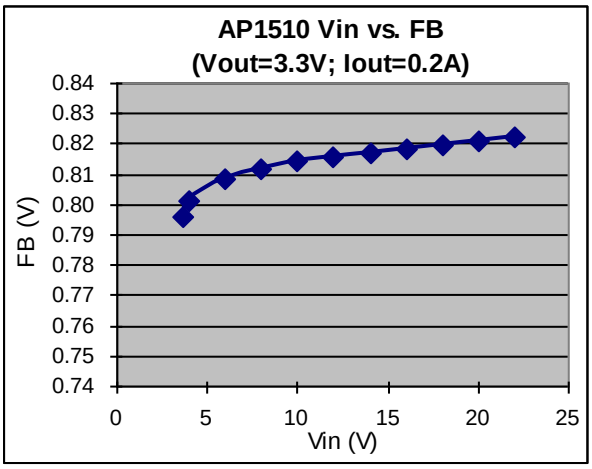
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{FB}$ | Feedback Voltage | $I_{OUT}$ = 0.1A | 0.784 | 0.8 | 0.816 | V |
| $I_{FB}$ | Feedback Bias Current | $I_{OUT}$ = 0.1A | — | 0.1 | 0.5 | μA |
| $I_{SW}$ | Switch Current | — | 3.5 | — | — | A |
| $I_{SHDN}$ | Current Consumption During Power Off | $V_{EN}$ = 0V | — | 10 | — | μA |
| $\Delta V_{OUT}$ /$V_{IN}$ | Line Regulation | $V_{IN}$ = 5V to 23V, $I_{OUT}$ = 0.2A | — | 1 | 2 | % |
| $\Delta V_{OUT}$ /$V_{OUT}$ | Load Regulation | $I_{OUT}$ = 0.1 to 3A | — | 0.2 | 0.5 | % |
| $f_{OSC}$ | Oscillation Frequency | Measure waveform at Output pin | 240 | 300 | 360 | kHz |
| $f_{OSC1}$ | Frequency of Current Limit or Short Circuit Protect | Measure waveform at Output pin | 10 | — | — | kHz |
| $V_{IH}$ | EN Pin Input Voltage | Evaluate oscillation at Output pin | 2.0 | — | — | V |
| $V_{IL}$ | | Evaluate oscillation stop at Output pin | — | — | 0.8 | |
| $I_{ENH}$ | EN Pin Input Leakage Current | — | — | 20 | — | μA |
| $I_{ENL}$ | | — | — | -10 | — | μA |
| $I_{OCSET}$ | OCSET Pin Bias Current | — | 75 | 90 | 105 | μA |
| $t_{SS}$ | Soft-Start Time | — | 0.3 | 2 | 5 | ms |
| $T_{SHDN}$ | Thermal Shutdown Threshold | — | — | +150 | — | °C |
| $T_{HYS}$ | Thermal Shutdown Hysteresis | — | — | +55 | — | °C |
| $R_{DSON}$ | Internal MOSFET $R_{DSON}$ | $V_{IN}$ = 5V, $V_{FB}$ = 0V | — | 110 | 150 | mΩ |
| | | $V_{IN}$ = 12V, $V_{FB}$ = 0V | — | 70 | 100 | |
| EFFI | Efficiency | $V_{IN}$ = 12V, $V_{OUT}$ = 5V $I_{OUT}$ = 3A | — | 91 | — | % |
| $\theta_{JA}$ | Thermal Resistance Junction-to-Ambient | SO-8 (Note 4) | — | 134 | — | °C/W |
| $\theta_{JC}$ | Thermal Resistance Junction-to-Case | SO-8 (Note 4) | — | 22 | — | °C/W |

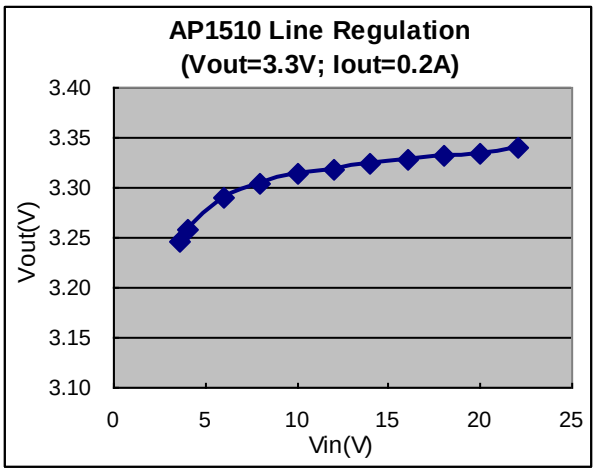
Note: 4. Test condition: Device mounted on FR-4 substrate 2oz copper, minimum recommended pad layout, single side.
For better thermal performance, please arrange larger copper pad of layout for heatsink.

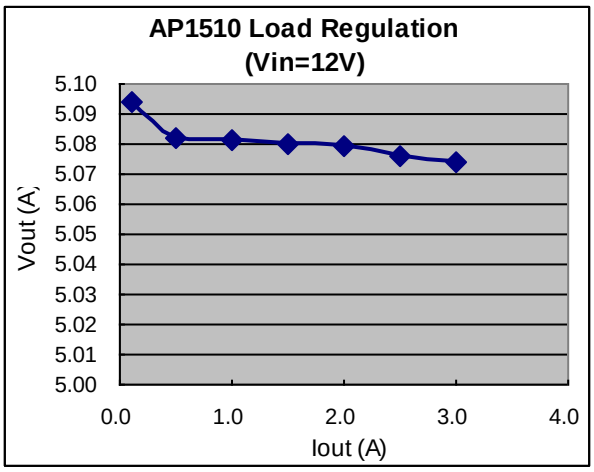

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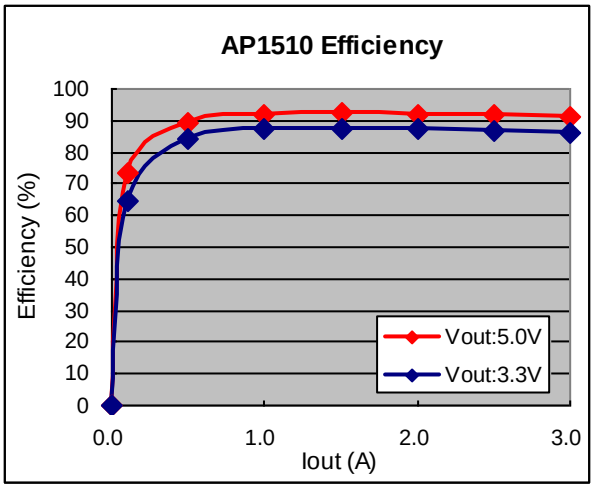
## Typical Performance Characteristics



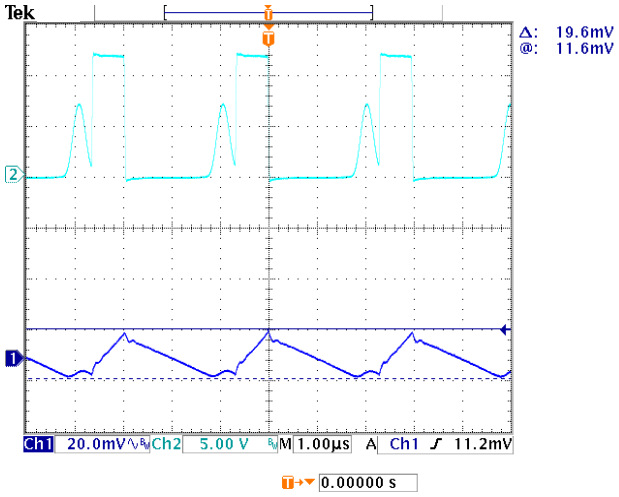





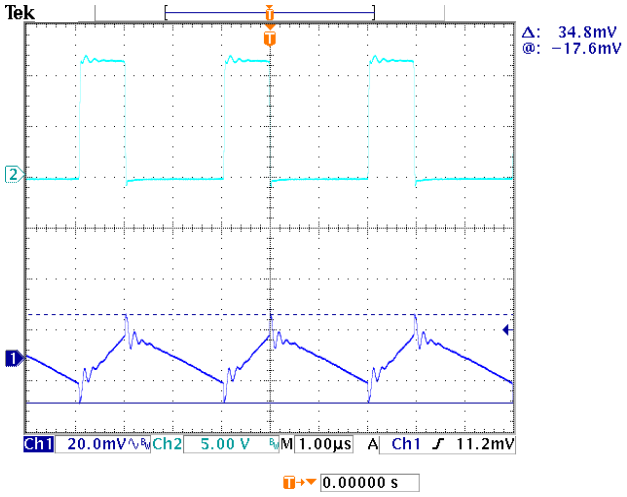
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## Typical Performance Characteristics (Cont.)

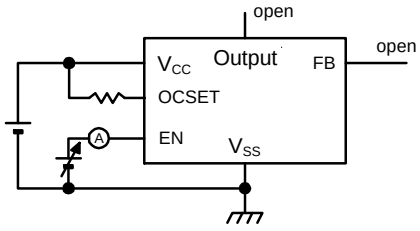
**AP1510 $V_{OUT}$ Ripple**
**($V_{IN}$=12V; $V_{OUT}$=3.3V; $I_{OUT}$=0.1A)**



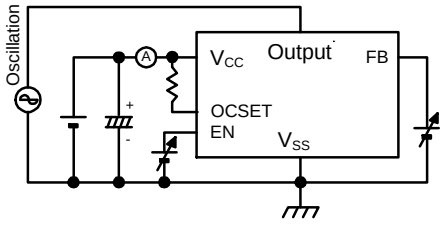

**AP1510 $V_{OUT}$ Ripple**
**($V_{IN}$=12V; $V_{OUT}$=3.3V; $I_{OUT}$=3A)**



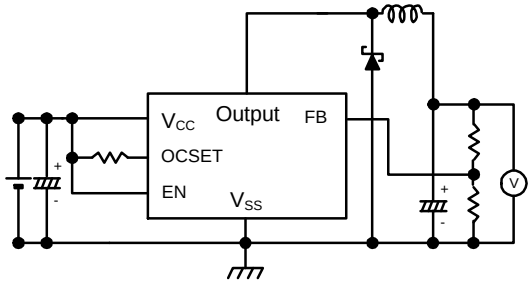

## Test Circuit




**Enable function test**




**Feedback function test**




**Operation function test**


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## Functional Description

**PWM Control**

The AP1510 is a DC/DC converter that employs pulse width modulation (PWM) scheme. Its pulse width varies in the range of 0% to 99%, based on the output current loading. The output ripple voltage caused by the PWM high frequency switching can easily be reduced through an output filter. Therefore, this converter provides a low ripple output supply over a broad range of input voltage & output current loading.

**Under Voltage Lockout**

The under voltage lockout circuit of the AP1510 assures that the high-side MOSFET driver remains in the off state whenever the supply voltage drops below 3.3V. Normal operation resumes once $V_{CC}$ rises above 3.5V.

**Current Limit Protection**

The current limit threshold is set by external resistor $R_{OCSET}$ connected from $V_{CC}$ supply to OCSET pin. The internal sink current $I_{OCSET}$ (90μA typical) across this resistor sets the voltage at OCSET pin. When the PWM voltage is less than the voltage at OCSET, an over-current condition is triggered.

The current limit threshold is given by the following equation:

$$I_{PEAK} \times R_{DS(ON)} = I_{OCSET} \times R_{OCSET}$$

$$I_{PEAK} > I_{OUT(MAX)} + \frac{(\Delta I)}{2}$$

where,

$$\Delta I = \frac{V_{IN} - V_{OUT}}{fs \times L} \times \frac{V_{OUT}}{V_{IN}}$$

$I_{PEAK}$ is the output peak current; $R_{DS(ON)}$ is the MOSFET ON resistance; $f_S$ is the PWM frequency (300kHz typical). Also, the inductor value will affect the ripple current ΔI.

The above equation is recommended for input voltage range of 5V to 18V. For input voltage lower than 5V or ambient temperature over +100°C, higher $R_{OCSET}$ is recommended.

**Inductor Selection**

For most designs, the operation range with inductors is from 22μH to 33μH. The inductor value can be derived from the following equation:

$$L = \frac{V_{IN} - V_{OUT}}{fs \times \Delta I} \times \frac{V_{OUT}}{V_{IN}}$$

Where $\Delta I_L$ is inductor Ripple Current. Large value inductors lower ripple current and small value inductors result in high ripple current. Choose inductor ripple current approximately 15% of the maximum load current 3A, $\Delta I_L$=0.45A. The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation (3A+0.225A).

**Input Capacitor Selection**

This capacitor should be located close to the IC using short leads and the voltage rating should be approximately 1.5 times the maximum input voltage. The RMS current rating requirement for the input capacitor of a buck regulator is approximately 1⁄2 the DC load current. A low ESR input capacitor sized for maximum RMS current must be used. A 470μF low ESR capacitor for most applications is sufficient.

**Output Capacitor Selection**

The output capacitor is required to filter the output voltage and provides regulator loop stability. The important capacitor parameters are the 100kHz Equivalent Series Resistance (ESR), the RMS ripples current rating, voltage rating and capacitance value. For the output capacitor, the ESR value is the most important parameter. The output ripple can be calculated from the following formula.


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## Functional Description (Cont.)

$$V_{RIPPLE} = \Delta I_L \times ESR$$

The bulk capacitor's ESR will determine the output ripple voltage and the initial voltage drop after a high slew-rate transient.

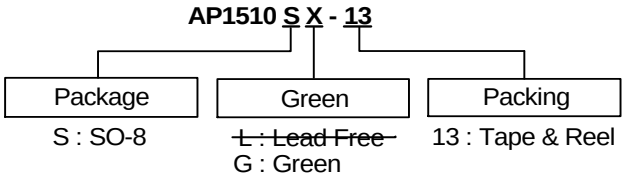
An aluminum electrolytic capacitor's ESR value is related to the capacitance and its voltage rating. In most case, higher voltage electrolytic capacitors have lower ESR values. Most of the time, capacitors with much higher voltage ratings may be needed to provide the low ESR values required for low output ripple voltage.

**PCB Layout Guide**

If you need low $T_C$ & $T_J$ or large $P_D$ (Power Dissipation), the dual Output pins (5 & 6) and $V_{SS}$ pins (7 & 8) on the SO-8 package are internally connected to die pad, the evaluation board should be allowed for maximum copper area at output pins.

1. Connect FB circuits as closely as possible and keep away from inductor flux for pure $V_{FB}$.
2. Connect input capacitor to $V_{CC}$ and $V_{SS}$ pin as closely as possible to get good power filter effect.
3. Connect $R_{OCSET}$ to $V_{CC}$ and OCSET pin as closely as possible.
4. Connect ground side of the input capacitor & Schottky & output capacitor as closely as possible and use ground plane for best performance.

## Ordering Information

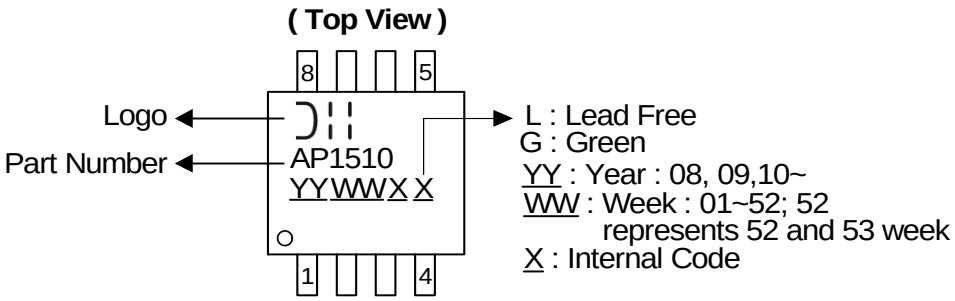



| Device (Note 5) | Package Code | Package (Note 6) | Green | Quantity | Part Number Suffix | | Status (Note 5) |
|---|---|---|---|---|---|---|---|
| | | | | | Tube | 13''Tape and reel | |
| AP1510SG-13 | S | SO-8 | Green | 2500 | NA | -13 | In production |

Notes: 5. All Lead-Free variants are End of life without replacement.
6. 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 (Note 5)

**(1) SO-8**



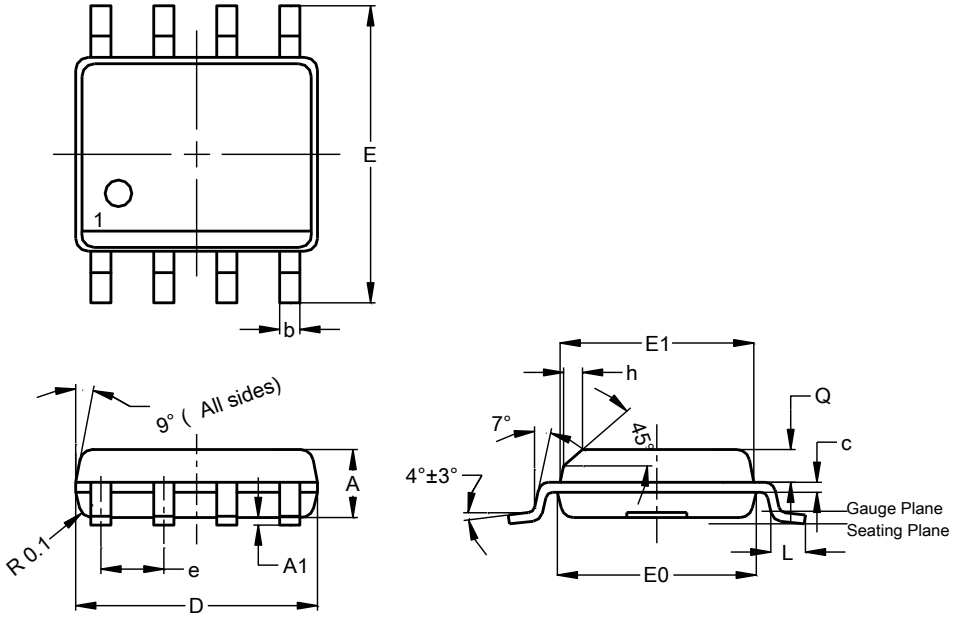


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## Package Outline Dimensions

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

**SO-8**

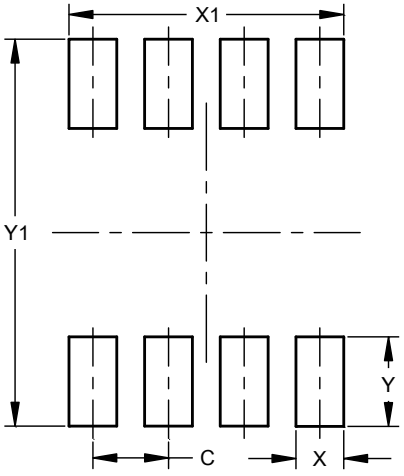



| SO-8 | | | |
|---|---|---|---|
| **Dim** | **Min** | **Max** | **Typ** |
| **A** | 1.40 | 1.50 | 1.45 |
| **A1** | 0.10 | 0.20 | 0.15 |
| **b** | 0.30 | 0.50 | 0.40 |
| **c** | 0.15 | 0.25 | 0.20 |
| **D** | 4.85 | 4.95 | 4.90 |
| **E** | 5.90 | 6.10 | 6.00 |
| **E1** | 3.80 | 3.90 | 3.85 |
| **E0** | 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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