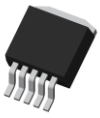
# 3.0A, 150kHz, Step-Down Switching Regulator LM2596

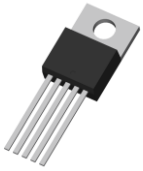
## FEATURES

- 3.3V, 5.0V, 12V, and Adjustable Output version
- Adjustable Output Voltage range, 1.2V to 37V
  ±4% Max. Over Line and Load conditions
- Guaranteed Output Current of 3A
- Available in TO-263, TO-220, SOP-8PP Packages
- Requires Only 4 External Components
- Excellent Line and Load Regulation Specifications
- 150kHz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability
- Low Power Standby Mode, IQ typically 100mA
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3

SOP-8PP



TO-263-5



TO-220-5

TO-220TV-5

## APPLICATION

- Simple High-Efficiency Step-Down(Buck) Regulator
- Efficient Pre-Regulator for Linear Regulators
- On-Card Switching Regulators
- Positive to Negative Converter(Buck-Boost)
- Negative Step-Up Converters
- Power Supply for Battery Chargers

**ORDERING INFORMATION**

| Device | Package |
|---|---|
| LM2596R-X.X | TO-263-5L |
| LM2596T-X.X | TO-220-5L |
| LM2596TV-X.X | TO-220TV-5L |
| LM2596DP-X.X | SOP-8PP |

X.X = Output Voltage = 3.3, 5.0, 12, ADJ

## DESCRIPTION

The LM2596 series of regulators are monolithic integrated circuits ideally suited for easy and convenient design of a step-down switching regulator (buck converter). All circuits of this series are capable of driving a 3.0A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V,12V, and an adjustable output version. These regulators were designed to minimize the number of external components to simplify the power supply design. Standard series of inductors optimized for use with the LM2596 are offered by several different inductor manufacturers. Since the LM2596 converter is a switch-mode power supply, its efficiency is significantly higher in comparison with popular three-terminal linear regulators, especially with higher input voltages. In many cases, the power dissipated is so low that no heatsink is required or its size could be reduced dramatically. A standard series of inductors optimized for use with the LM2596 are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies. The LM2596 features include a guaranteed +/- 4% tolerance on output voltage within specified input voltages and output load conditions, and +/-15% on the oscillator frequency (+/- 2% over 0℃ to 125℃). External shutdown is included, featuring 80㎂ (typical) standby current. Self-protection features include a two stage frequency reducing current limit for output switch and an over temperature shutdown for complete protection under fault conditions.



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## Ordering Information

| $V_{OUT}$ | Package | Order No. | Description | Package Marking | Status |
|---|---|---|---|---|---|
| ADJ | SOP-8PP | LM2596DP-ADJ | 3A, Adjustable, 150kHz, On/off | LM2596-ADJ | Active |
| | TO-220-5L | LM2596T-ADJ | 3A, Adjustable, 150kHz, On/off | LM2596-ADJ | Active |
| | TO-220TV-5L | LM2596TV-ADJ | 3A, Adjustable, 150kHz, On/off | LM2596-ADJ | Active |
| | TO-263-5L | LM2596R-ADJ | 3A, Adjustable, 150kHz, On/off | LM2596-ADJ | Active |
| 3.3V | SOP-8PP | LM2596DP-3.3 | 3A, Fixed, 150kHz, On/off | LM2596-3.3 | Active |
| | TO-220-5L | LM2596T-3.3 | 3A, Fixed, 150kHz, On/off | LM2596-3.3 | Active |
| | TO-263-5L | LM2596R-3.3 | 3A, Fixed, 150kHz, On/off | LM2596-3.3 | Active |
| 5.0V | SOP-8PP | LM2596DP-5.0 | 3A, Fixed, 150kHz, On/off | LM2596-5.0 | Active |
| | TO-220-5L | LM2596T-5.0 | 3A, Fixed, 150kHz, On/off | LM2596-5.0 | Active |
| | TO-220TV-5L | LM2596TV-5.0 | 3A, Fixed, 150kHz, On/off | LM2596-5.0 | Active |
| | TO-263-5L | LM2596R-5.0 | 3A, Fixed, 150kHz, On/off | LM2596-5.0 | Active |
| 12V | SOP-8PP | LM2596DP-12 | 3A, Fixed, 150kHz, On/off | LM2596-12 | Contact Us |
| | TO-220-5L | LM2596T-12 | 3A, Fixed, 150kHz, On/off | LM2596-12 | Active |
| | TO-220TV-5L | LM2596TV-12 | 3A, Fixed, 150kHz, On/off | LM2596-12 | Active |
| | TO-263-5L | LM2596R-12 | 3A, Fixed, 150kHz, On/off | LM2596-12 | Active |



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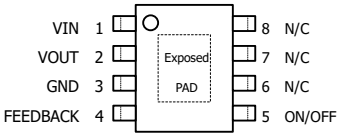
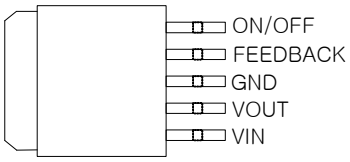
## PIN CONFIGURATION




SOP-8PP


TO-220-5L / TO-220TV-5L




TO-263-5L

## PIN DESCRIPTION

| Package | | Symbol | Description |
|---|---|---|---|
| TO-220-5<br>TO-220TV-5<br>TO-263-5 | SOP-8PP | | |
| 1 | 1 | VIN | This pin is the positive input supply for the LM2596 step–down switching regulator. In order to minimize voltage transients and to supply the switching currents needed by the regulator, a suitable input bypass capacitor must be present. |
| 2 | 2 | VOUT | This is the emitter of the internal switch. The saturation voltage Vsat of this output switch is typically 1.5 V. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry. |
| 3 | 3 | GND | Circuit ground pin. |
| 4 | 4 | FEEDBACK | This pin senses regulated output voltage to complete the feedback loop. The signal is divided by the internal resistor divider network R2, R1 and applied to the non–inverting input of the internal error amplifier. In the Adjustable version of the LM2596 switching regulator this pin is the direct input of the error amplifier and the resistor network R2, R1 is connected externally to allow programming of the output voltage. |
| 5 | 5 | ON/OFF | It allows the switching regulator circuit to be shut down using logic level signals, thus dropping the total input supply current to approximately 80uA. The threshold voltage is typically 1.3V. Applying a voltage above this value (up to +Vin) shuts the regulator off. If the voltage applied to this pin is lower than 1.3V or if this pin is left open, the regulator will be in the "on" condition. |
| - | 6, 7, 8 | N.C. | No Connect. |

* Exposed Pad of SOP8-PP package should be externally connected to GND.



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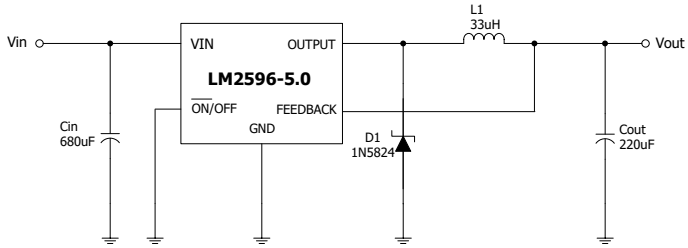
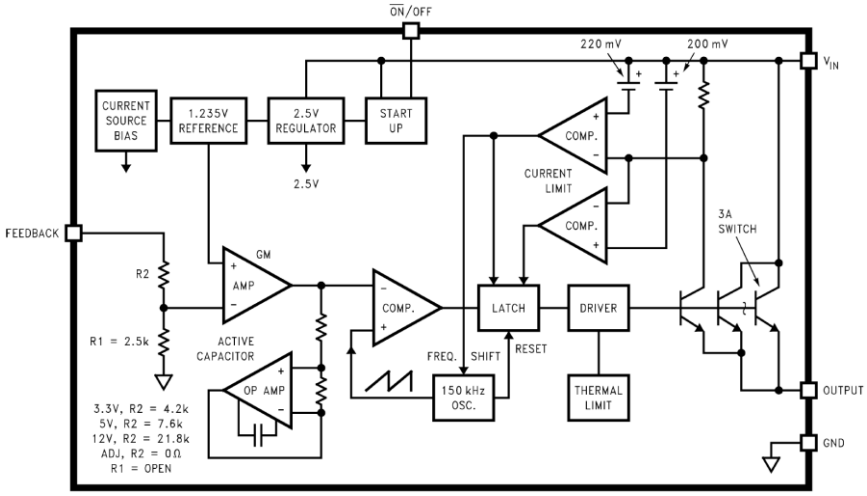
## Typical Application (Fixed Output Voltage Versions)




## Absolute Maximum Ratings

| Rating | Symbol | Value | UNIT |
|---|---|---|---|
| Maximum Supply Voltage | Vin | 45 | V |
| On/Off Pin Input Voltage | - | -0.3V ≤ V ≤ +Vin | V |
| Output Voltage to Ground (Steady-State) | - | -1.0 | V |
| Power Dissipation | | | |
| SOP8-PP-8Lead | $P_D$ | Internally Limited | W |
| Thermal Resistance, Junction to Ambient | $\theta_{JA}$ | Contact us | ℃/W |
| Thermal Resistance, Junction to Case | $\theta_{JC}$ | Contact us | ℃/W |
| TO-220-5Lead | $P_D$ | Internally Limited | W |
| Thermal Resistance, Junction to Ambient | $\theta_{JA}$ | 65 | ℃/W |
| Thermal Resistance, Junction to Case | $\theta_{JC}$ | 5 | ℃/W |
| TO-263-5Lead | $P_D$ | Internally Limited | W |
| Thermal Resistance, Junction to Ambient | $\theta_{JA}$ | 70 | ℃/W |
| Thermal Resistance, Junction to Case | $\theta_{JC}$ | 5 | ℃/W |
| Storage Temperature Range | $T_{STG}$ | -60 to +150 | ℃ |
| Minimum ESD Rating (Human Body Model) | - | 2 | kV |
| Lead Temperature (Soldering, 10seconds) | - | 260 | ℃ |
| Maximum Junction Temperature | $T_J$ | 150 | ℃ |



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**OPERATING RATINGS** (Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications, see the Electrical Characteristics.)

| Rating | Symbol | Value. | Unit |
|---|---|---|---|
| Operating Junction Temperature Range | $T_J$ | -40 to +125 | ℃ |
| Supply Voltage | Vin | 40 | V |

## ELECTRICAL CHARACTERISTICS / SYSTEM PARAMETERS ([Note 1] Test Circuit Figure 2)

(Unless otherwise specified, Vin = 12V for the 3.3V, 5.0V, and Adjustable version, Vin = 25V for the 12V version. $I_{LOAD}$ = 500 mA. For typical values $T_J$ = 25°C, for min/max values $T_J$ is the operating junction temperature range that applies [Note 2], unless otherwise noted.)

| Characteristics | Symbol | Min | TYP | Max | Unit |
|---|---|---|---|---|---|
| **LM2596-3.3V ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (Vin=12V, $I_{LOAD}$=0.5A, $T_J$=25℃) | Vout | 3.234 | 3.3 | 3.366 | V |
| Output Voltage (6.0V≤Vin≤40V, 0.5A≤$I_{LOAD}$≤3.0A | Vout | | | | |
| $T_J$=25℃ | | 3.168 | 3.3 | 3.432 | V |
| $T_J$=-40℃ ~ +125℃ | | 3.135 | - | 3.465 | |
| Efficiency (Vin=12V, $I_{LOAD}$=3.0A) | η | - | 73 | - | % |
| **LM2596-5.0V ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (Vin=12V, $I_{LOAD}$=0.5A, $T_J$=25℃) | Vout | 4.9 | 5.0 | 5.1 | V |
| Output Voltage (8.0V≤Vin≤40V, 0.5A≤$I_{LOAD}$≤3.0A | Vout | | | | |
| $T_J$=25℃ | | 4.8 | 5.0 | 5.2 | V |
| $T_J$=-40℃ ~ +125℃ | | 4.75 | - | 5.25 | |
| Efficiency (Vin=12V, $I_{LOAD}$=3.0A) | η | - | 80 | - | % |
| **LM2596-12V ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (Vin=25V, $I_{LOAD}$=0.5A, $T_J$=25℃) | Vout | 11.76 | 12 | 12.24 | V |
| Output Voltage (15V≤Vin≤40V, 0.5A≤$I_{LOAD}$≤3.0A | Vout | | | | |
| $T_J$=25℃ | | 11.52 | 12 | 12.48 | V |
| $T_J$= -40℃ ~ +125℃ | | 11.4 | - | 12.6 | |
| Efficiency (Vin=12V, $I_{LOAD}$=3.0A) | η | - | 90 | - | % |
| **LM2596-ADJ ([Note 1] Test Circuit Figure 2)** | | | | | |
| Feedback Voltage (Vin=12V, $I_{LOAD}$=0.5A, $T_J$=25℃) | Vout | 1.217 | 1.23 | 1.243 | V |
| Feedback Voltage(8.0V≤Vin≤40V, 0.5A≤$I_{LOAD}$≤3.0A, Vout=5.0V) | Vout | | | | |
| $T_J$=25℃ | | 1.193 | 1.23 | 1.267 | V |
| $T_J$= -40℃ ~ +125℃ | | 1.18 | - | 1.28 | |
| Efficiency (Vin=12V, $I_{LOAD}$=3.0A, Vout=5.0V) | η | - | 73 | - | % |



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| Characteristics | Symbol | Min | TYP | Max | Unit |
|---|---|---|---|---|---|
| **All Output Voltage Versions** | | | | | |
| Feedback Bias Current (Vout=5.0V [Adjustable Version Only]) | Ib | | | | |
| $T_J$=25℃ | | 11.52 | 12 | 12.48 | nA |
| $T_J$= 0 ~ +125℃ | | 11.4 | - | 12.6 | |
| Oscillator Frequency | Fosc | | | | |
| $T_J$=25℃ | | 127 | 150 | 173 | kHz |
| $T_J$= 0 ~ +125℃ | | 110 | - | 173 | |
| Saturation Voltage (Iout=3.0A [note 3]) | Vsat | | | | |
| $T_J$=25℃ | | - | 1.16 | 1.4 | V |
| $T_J$= 0 ~ +125℃ | | - | - | 1.5 | |
| Max Duty Cycle ("0") [Note 4] | DC | - | 100 | - | % |
| Current Limit (Peak Current [Note 3]) | ICL | | | | |
| $T_J$=25℃ | | 3.6 | 4.5 | 6.9 | A |
| $T_J$= 0 ~ +125℃ | | 3.4 | - | 7.5 | |
| Output Leakage Current [Note 5 and 6], $T_J$=25℃ | IL | | | | |
| Output = 0V | | - | - | 25 | μA |
| Output = -1.0V | | - | 2 | 10 | mA |
| Quiescent Current [Note 5] | IQ | | | | |
| $T_J$=25℃ | | - | 5 | - | mA |
| $T_J$= 0 ~ +125℃ | | - | - | 10 | |
| Standby Quiescent Current (ON/OFF Pin = 5.0V ("off")) | ISTBY | | | | |
| $T_J$=25℃ | | - | 80 | 200 | μA |
| $T_J$= 0 ~ +125℃ | | - | - | 250 | |
| ON/OFF Pin Logic Input Level (Test circuit Figure 2) | | | | | |
| Vout=0V | VIH | | | | |
| $T_J$=25℃ | | 2.0 | 1.3 | - | |
| $T_J$= 0 ~ +125℃ | | 2.0 | - | - | V |
| Vout=Nominal Output Voltage | VIL | | | | |
| $T_J$=25℃ | | - | 1.3 | 0.6 | |
| $T_J$= 0 ~ +125℃ | | - | - | 0.6 | |
| ON/OFF Pin Input Current (Test Circuit Figure 2) | | | | | |
| VLOGIC = 2.5V (Regulator OFF) | IIH | - | 5 | 15 | μA |
| VLOGIC = 0.5V (Regulator ON) | IIL | - | 0.02 | 5.0 | |

1. External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance. When the LM2596 is used as shown in the Figure 1 test circuit, system performance will be as shown in system parameters section .
2. Tested junction temperature range for the LM2596 : TLOW = –40°C THIGH = +125°C
3. Output (Pin 2) sourcing current. No diode, inductor or capacitor connected to output pin.
4. Feedback (Pin 4) removed from output and connected to 0 V.
5. Feedback (Pin 4) removed from output and connected to +12V for the Adjustable, 3.3V, and 5.0V versions, and '+25 V for the 12V versions, to force the output transistor “off”.C195
6. Vin = 40 V.



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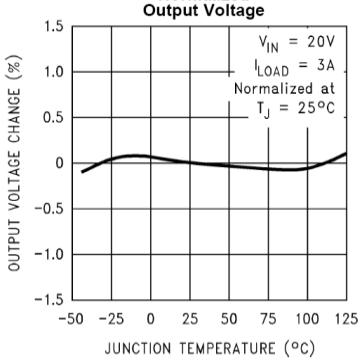
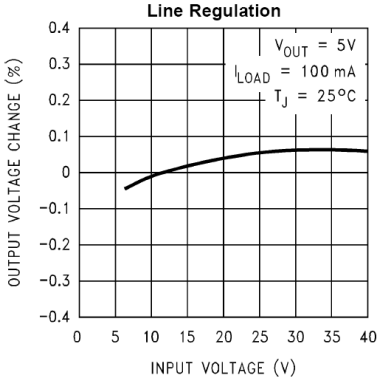
## TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 2)

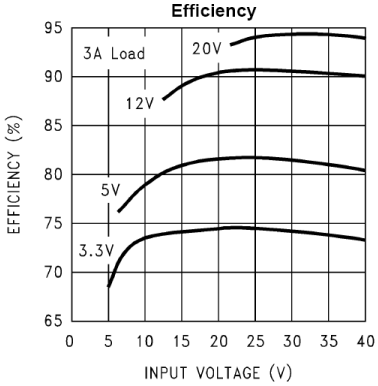
Normalized Output Voltage



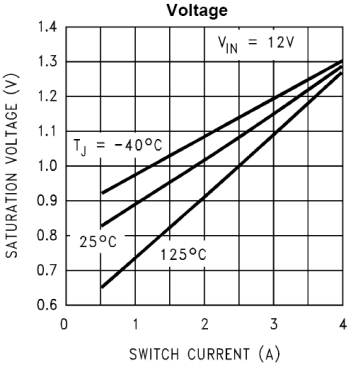

Line Regulation



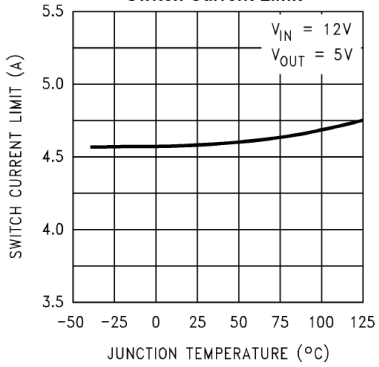

Efficiency



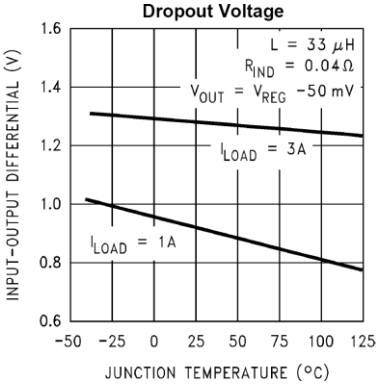

Switch Saturation Voltage



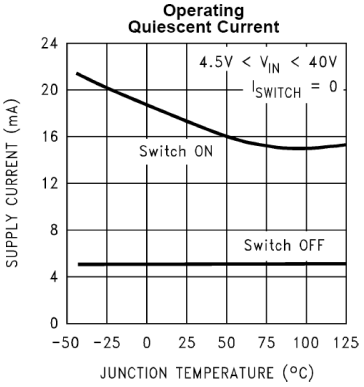

Switch Current Limit



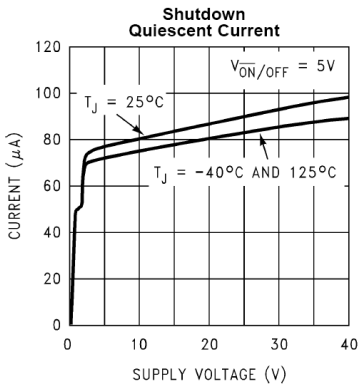

Dropout Voltage



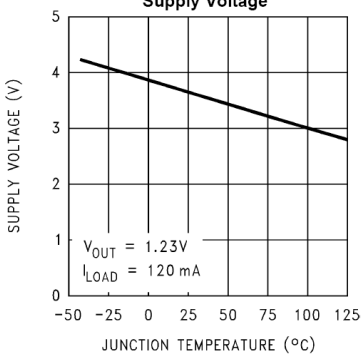

Operating Quiescent Current



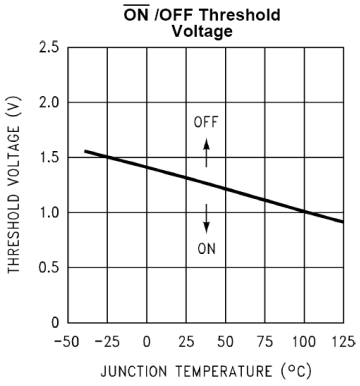

Shutdown Quiescent Current



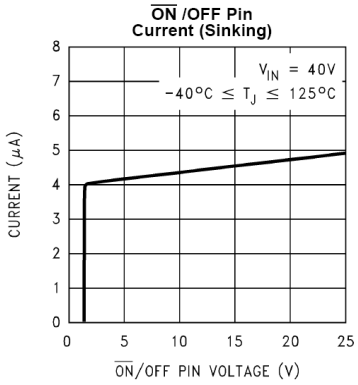

Minimum Operating Supply Voltage



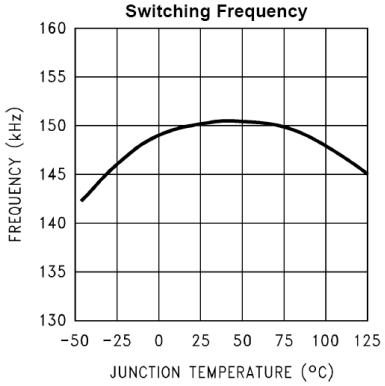

ON /OFF Threshold Voltage




ON /OFF Pin Current (Sinking)




Switching Frequency



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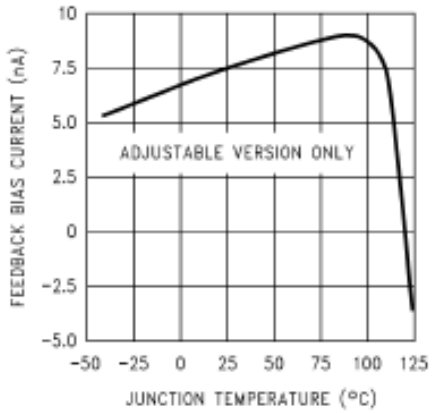
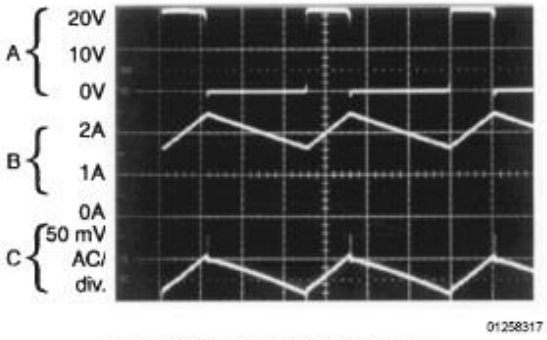
## TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 2)

Feedback Pin
Bias Current



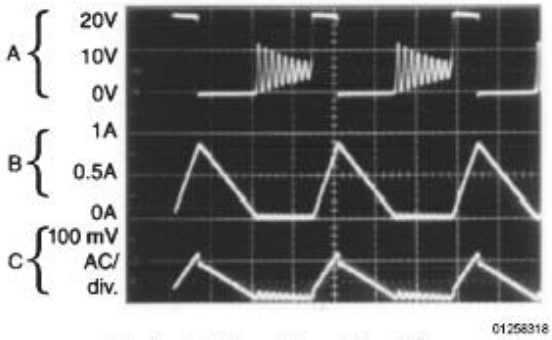

Continuous Mode Switching Waveforms
$V_{IN}$ = 20V, $V_{OUT}$ = 5V, $I_{LOAD}$ = 2A
L = 32 µH, $C_{OUT}$ = 220 µF, $C_{OUT}$ ESR = 50 mΩ




Horizontal Time Base: 2 µs/div.

A: Output Pin Voltage, 10V/div.
B: Inductor Current 1A/div.
C: Output Ripple Voltage, 50 mV/div.

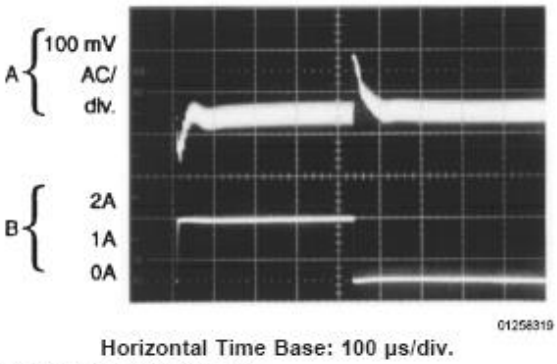
Discontinuous Mode Switching Waveforms
$V_{IN}$ = 20V, $V_{OUT}$ = 5V, $I_{LOAD}$ = 500 mA
L = 10 µH, $C_{OUT}$ = 330 µF, $C_{OUT}$ ESR = 45 mΩ




Horizontal Time Base: 2 µs/div.

A: Output Pin Voltage, 10V/div.
B: Inductor Current 0.5A/div.
C: Output Ripple Voltage, 100 mV/div.

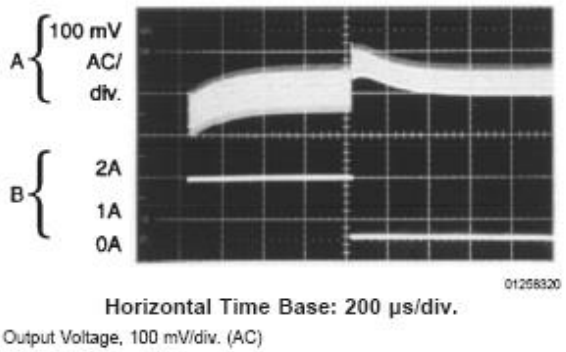
Load Transient Response for Continuous Mode
$V_{IN}$ = 20V, $V_{OUT}$ = 5V, $I_{LOAD}$ = 500 mA to 2A
L = 32 µH, $C_{OUT}$ = 220 µF, $C_{OUT}$ ESR = 50 mΩ




Horizontal Time Base: 100 µs/div.

A: Output Voltage, 100 mV/div. (AC)
B: 500 mA to 2A Load Pulse

Load Transient Response for Discontinuous Mode
$V_{IN}$ = 20V, $V_{OUT}$ = 5V, $I_{LOAD}$ = 500 mA to 2A
L = 10 µH, $C_{OUT}$ = 330 µF, $C_{OUT}$ ESR = 45 mΩ




Horizontal Time Base: 200 µs/div.

A: Output Voltage, 100 mV/div. (AC)
B: 500 mA to 2A Load Pulse



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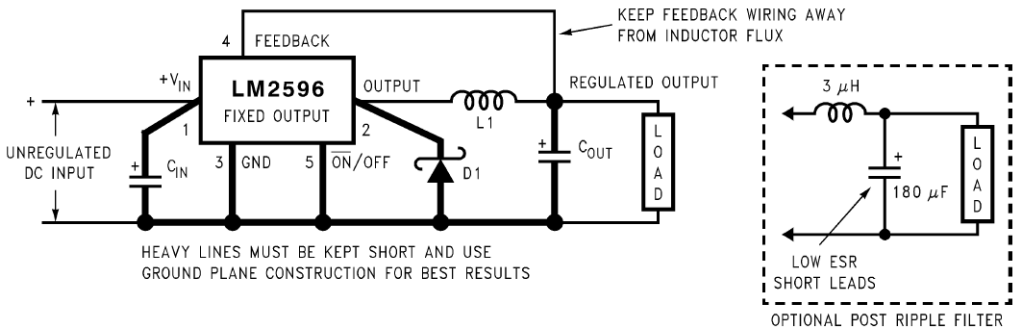
## Test Circuit and Layout Guidelines

**Fixed Output Voltage Versions**

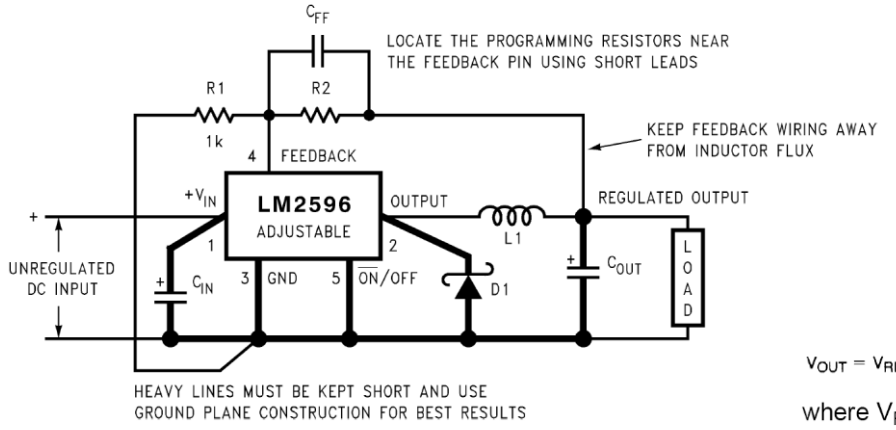



$C_{IN}$ = 470$\mu$F, 50V, $C_{OUT}$ = 220$\mu$F, 25V (Aluminum Electrolytic Nichicon "PL Series"

D1 = 5A, 40V Schottky Rectifier, IN5825

L1 = 68uH, L38

**Adjustable Output Voltage Versions**




$$V_{OUT} = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$

where $V_{REF}$ = 1.23V

Cin = 470 $\mu$F, 50V, Cout = 220 $\mu$F, 35V (Aluminum Electrolytic Nichicon "PL Series"

D1 = 5A, 40V Schottky Rectifier, IN5825

L1 = 68uH, R1 = 1 kΩ, 1%, R2 = R1 x (Vout / Vref - 1)

As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance can generate voltage transients which can cause problems. For minimal inductance and ground loops, the wires indicated by heavy lines should be wide printed circuit traces and should be kept as short as possible. For best results, external components should be located as close to the switching IC as possible using ground plane construction or single point grounding. If open core inductors are used, special care must be taken as to the location and positioning of this type of inductor. Allowing the inductor flux to intersect sensitive feedback, IC ground path and COUT wiring can cause problems. When using the adjustable version, special care must be taken as to the location of the feedback resistors and the associated wiring. Physically locate both resistors near the IC, and route the wiring away from the inductor, especially an open core type of inductor.



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## REVISION NOTICE

The description in this datasheet is subject to change without any notice to describe its electrical characteristics properly.



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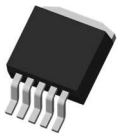
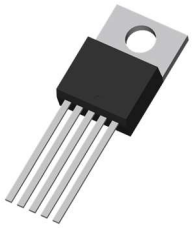
# 3A, 150kHz, Step-Down Switching Regulator LM2596G

## FEATURES

- 3.3V, 5.0V, 12V, and Adjustable Output Versions
- Adjustable Version Output Voltage Range, 1.23V to 37V ±4% maximum over line and load conditions
- Guaranteed 3.0A Output Current
- Wide Input Voltage Range: Up to 40V
- Requires Only 4 External Components
- 150kHz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- High Efficiency
- Uses Readily Available Standard Inductors
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3 for SMD type packages



TO-263-5



TO-220-5

## APPLICATIONS

- Simple High-Efficiency Step-Down (Buck) Regulator
- Efficient Pre-Regulator for Linear Regulators
- On-Card Switching Regulators
- Positive to Negative Converter (Buck-Boost)
- Power Supply for Battery Chargers

## DESCRIPTION

The LM2596G series of regulators are monolithic integrated circuits ideally suited for easy and convenient design of a step-down switching regulator (buck converter). All circuits of this series are capable of driving a 3.0A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, and an adjustable output version.

These regulators were designed to minimize the number of external components to simplify the power supply design. Standard series of inductors optimized for use with the LM2596G are offered by several different inductor manufacturers.

The LM2596G series operates at a switching frequency of 150kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators.

LM2596G features include a ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±15% on the oscillator frequency. External shutdown is included. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

**ORDERING INFORMATION**

| Device | Package |
|---|---|
| LM2596GR-x.x | TO-263-5L |
| LM2596GT-x.x | TO-220-5L |

x.x: Output Voltage



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## ABSOLUTE MAXIMUM RATINGS (Note 1)

| CHARACTERISTIC | SYMBOL | MIN | MAX | UNIT |
|---|---|---|---|---|
| Maximum Supply Voltage | $V_{IN}$ | - | 45 | V |
| $\overline{ON}$/OFF Pin Input Voltage | - | −0.3 | 25 | V |
| FB Pin Input Voltage | - | −0.3 | 25 | V |
| Output Voltage to Ground | - | −1.0 | - | V |
| Power Dissipation | $P_D$ | - | Internally Limited | W |
| ESD Rating, HBM | - | 2 | - | kV |
| Maximum Junction Temperature | $T_J$ | - | 150 | °C |
| Storage Temperature | $T_{STG}$ | −65 | 150 | °C |

Note 1. Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## RECOMMENDED OPERATING RATINGS (Note 2)

| CHARACTERISTIC | SYMBOL | MIN | MAX | UNIT |
|---|---|---|---|---|
| Supply Voltage | $V_{IN}$ | - | 40 | V |
| Operating Junction Temperature | $T_J$ | −40 | 125 | °C |

Note 2. The device is not guaranteed to function outside its operating ratings.

## THERMAL INFORMATION

| THERMAL METRIC | $\theta_{JA}$ | $\theta_{JC}$ | UNIT |
|---|---|---|---|
| Thermal Resistance, TO-263-5L | 70 | 5 | °C/W |
| Thermal Resistance, TO-220-5L | 65 | 5 | °C/W |



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## ORDERING INFORMATION

| VOUT | Package | Order No. | Description | Supplied As | Status |
|---|---|---|---|---|---|
| ADJ | TO-263-5L | LM2596GR-ADJ | Adjustable Output | Tape & Reel | Active |
| | TO-220-5L | LM2596GT-ADJ | Adjustable Output | Tube | Contact Us |
| 3.3V | TO-263-5L | LM2596GR-3.3 | 3.3V Fixed Output | Tape & Reel | Contact Us |
| | TO-220-5L | LM2596GT-3.3 | 3.3V Fixed Output | Tube | Contact Us |
| 5.0V | TO-263-5L | LM2596GR-5.0 | 5.0V Fixed Output | Tape & Reel | Active |
| | TO-220-5L | LM2596GT-5.0 | 5.0V Fixed Output | Tube | Contact Us |
| 12V | TO-263-5L | LM2596GR-12 | 12V Fixed Output | Tape & Reel | Contact Us |
| | TO-220-5L | LM2596GT-12 | 12V Fixed Output | Tube | Contact Us |



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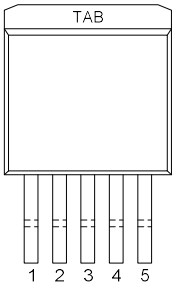
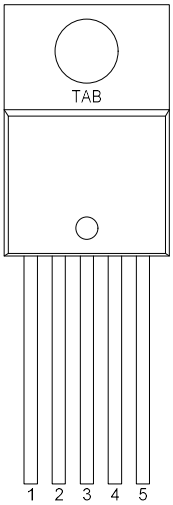
## PIN CONFIGURATION

| TO-263-5 | TO-220-5 |
|---|---|
|  |  |





## PIN DESCRIPTION

| Pin No. | | Pin Name | Pin Function |
|---|---|---|---|
| TO-263-5 | TO-220-5 | | |
| 1 | 1 | VIN | Supply input pin to collector pin of power transistor. Connect to power supply and input bypass capacitors $C_{IN}$, Path from VIN pin to high frequency bypass $C_{IN}$ and GND must be as short as possible to minimize voltage transients. |
| 2 | 2 | OUTPUT | Emitter pin of the power transistor. This is a switching node. Attached this pin to an inductor and the cathode of the external diode. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry. |
| 3 | 3 | GND | Ground pin. Path to $C_{IN}$ must be as short as possible. |
| 4 | 4 | FEEDBACK | Feedback sense input pin. Connect to the midpoint of feedback divider to set $V_{OUT}$ for ADJ version or connect this pin directly to the output capacitor for a fixed output version. |
| 5 | 5 | $\overline{ON}$/OFF | Enable input to the voltage regulator. It allows the switching regulator circuit to be shutdown using logic level signals. Applying level high shuts the regulator off. If the voltage applied to this pin is level low, the regulator will be in the ON condition. Do not leave this pin float. |
| TAB | TAB | TAB | Connect to GND. Attached to heatsink for thermal relief for TO-220 package or put a copper plane connected to this pin as a thermal relief for TO-263 package. |



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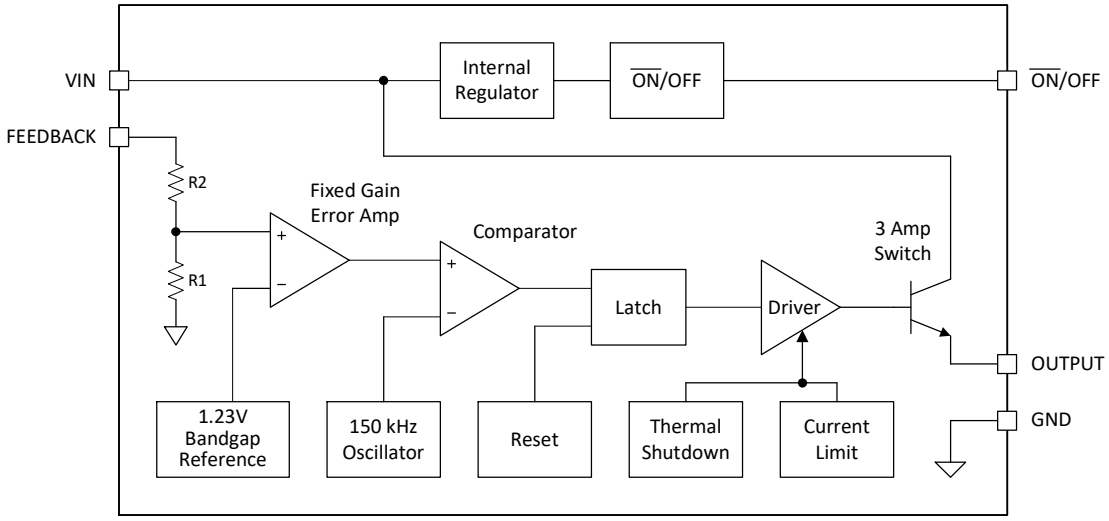
## BLOCK DIAGRAM



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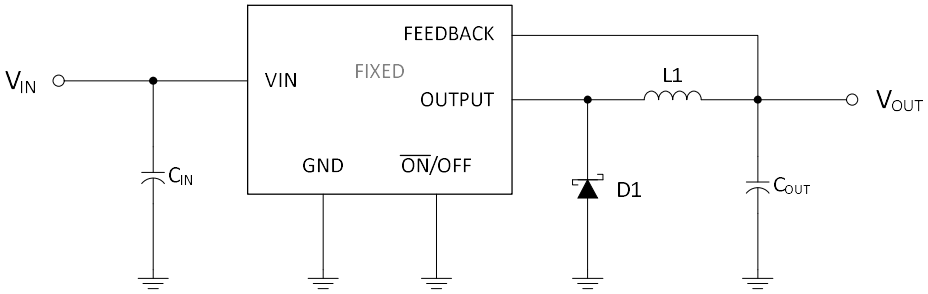
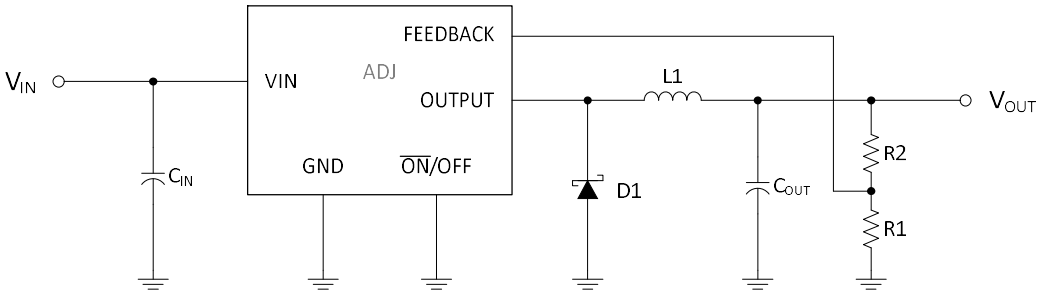
## TYPICAL APPLICATION CIRCUIT




< Fixed Output Voltage Version >




< Adjustable Output Voltage Version >

* External components such as the catch diode (D1), inductor (L1), input and output capacitors and PCB layout can affect switching regulator system performance. For the details, refer to the *Application Information* and *PCB Layout Guidelines*.



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## ELECTRICAL CHARACTERISTICS

Specification with standard type face are for $T_J$ = 25°C, and those with **boldface type** apply over full operating temperature range in the *Recommended Operating Ratings*.

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| 3.3V Output (Note 3) | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$ = 12V, $I_{LOAD}$ = 0.5A | 3.234 | 3.3 | 3.366 | V |
| Output Voltage | $V_{OUT}$ | 6.0V ≤ $V_{IN}$ ≤ 40V, 0.5A ≤ $I_{LOAD}$ ≤ 3.0A | 3.168<br>**3.135** | 3.3<br>- | 3.432<br>**3.465** | V |
| Efficiency | η | $V_{IN}$ = 12V, $I_{LOAD}$ = 3.0A | - | 73 | - | % |
| 5.0V Output (Note 3) | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$ = 12V, $I_{LOAD}$ = 0.5A | 4.900 | 5.0 | 5.100 | V |
| Output Voltage | $V_{OUT}$ | 8.0V ≤ $V_{IN}$ ≤ 40V, 0.5A ≤ $I_{LOAD}$ ≤ 3.0A | 4.800<br>**4.750** | 5.0<br>- | 5.200<br>**5.250** | V |
| Efficiency | η | $V_{IN}$ = 12V, $I_{LOAD}$ = 3.0A | - | 80 | - | % |
| 12V Output (Note 3) | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$ = 25V, $I_{LOAD}$ = 0.5A | 11.76 | 12 | 12.24 | V |
| Output Voltage | $V_{OUT}$ | 15V ≤ $V_{IN}$ ≤ 40V, 0.5A ≤ $I_{LOAD}$ ≤ 3.0A | 11.52<br>**11.40** | 12<br>- | 12.48<br>**12.60** | V |
| Efficiency | η | $V_{IN}$ = 25V, $I_{LOAD}$ = 3.0A | - | 90 | - | % |
| Adjustable Output (Note 3) | | | | | | |
| Feedback Voltage | $V_{FB}$ | $V_{IN}$ = 12V, $I_{LOAD}$ = 0.5A, $V_{OUT}$ = 3.0V | 1.217 | 1.23 | 1.243 | V |
| Feedback Voltage | $V_{FB}$ | 8.0V ≤ $V_{IN}$ ≤ 40V, 0.5A ≤ $I_{LOAD}$ ≤ 3.0A,<br>$V_{OUT}$ = 3.0V | 1.193<br>**1.180** | 1.23<br>- | 1.267<br>**1.280** | V |
| Efficiency | η | $V_{IN}$ = 12V, $I_{LOAD}$ = 3.0A, $V_{OUT}$ = 3.0V | - | 73 | - | % |

Note 3. External components such as catch diode, inductor, input and output capacitors can affect switching regulator system performance.



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## ELECTRICAL CHARACTERISTICS (continued)

Specification with standard type face are for $T_J$ = 25°C, and those with **boldface type** apply over full operating temperature range in Recommended Operating Ratings. Unless otherwise specified, $V_{IN}$ = 12V for the 3.3V, 5.0V, and Adjustable version, and $V_{IN}$ = 24V for the 12V version. $I_{LOAD}$ = 500mA.

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| All Output Voltage Versions | | | | | | |
| Feedback Bias Current | $I_B$ | $V_{OUT}$ = 3.0V (Adjustable Version Only) | - | 15 | 50 | nA |
| Oscillator Frequency | $f_O$ | | 127 | 150 | 173 | kHz |
| Saturation Voltage | $V_{SAT}$ | $I_{OUT}$ = 3.0A (Note 4,5) | - | 1.26 | 1.4 | V |
| Max Duty Cycle (Note 5) | DC | (ON) | - | 100 | - | % |
| Current Limit (Note 4,5) | $I_{CL}$ | Peak Current | 3.4 | 4.5 | 6.0 | A |
| Output Leakage Current (Note 4,5) | $I_L$ | Output = 0V | - | - | 25 | μA |
| | | Output = −1.0V (Note 7) | - | 1.0 | 10 | mA |
| Quiescent Current (Note 6) | $I_Q$ | | - | 5.0 | 10 | mA |
| Standby Quiescent Current | $I_{STBY}$ | $\overline{ON}$/OFF pin = 5.0V (OFF) | - | 100 | 200 | μA |
| $\overline{ON}$/OFF Pin Input Level | $V_{IH}$ | $V_{OUT}$ = 0V | 2.0 | 1.3 | - | V |
| | $V_{IL}$ | $V_{OUT}$ = Nominal Output Voltage | - | 1.3 | 0.6 | V |
| $\overline{ON}$/OFF Pin Input Current | $I_{IH}$ | $\overline{ON}$/OFF Pin = 2.5V (OFF) | - | 5.0 | 15 | μA |
| | $I_{IL}$ | $\overline{ON}$/OFF Pin = 0.5V (ON) | - | - | 5.0 | μA |

Note 4. OUTPUT pin sourcing current. No diode, inductor or capacitor connected to OUTPUT.
Note 5. FEEDBACK pin removed from output and connected to 0V to force the output transistor switch ON.
Note 6. FEEDBACK pin removed from output and connected to +12V for the 3.3V, 5.0V, and Adjustable versions, and 15V for the 12V version, to force the output transistor OFF.
Note 7. $V_{IN}$ = 40V.



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## TYPICAL OPERATING CHARACTERISTICS

T.B.D.



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## APPLICATION INFORMATION

### OVERVIEW

The LM2596G regulator is an easy-to-use, non-synchronous step-down DC-DC converter with a wide input voltage range up to 40V. It is capable of delivering up to 3.0A DC load current with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, and an adjustable output version. The family requires few external components, and the pin arrangement was designed for simple, optimum PCB layout.

### INPUT CAPACITOR

To maintain stability, the regulator input pin must be bypassed with at least a 100μF electrolytic capacitor. The capacitor's leads must be kept short, and placed near the regulator.

If the operating temperature range includes temperatures below 25°C, the input capacitor value may need to be larger. With most electrolytic capacitors, the capacitance value decreases and the ESR increases with lower temperatures and age. Paralleling a ceramic or solid tantalum capacitor increases the regulator stability at cold temperatures. For maximum capacitor operating lifetime, the RMS ripple current rating of the capacitor must be greater than:

$$1.2 \times \left(\frac{t_{ON}}{T}\right) \times I_{LOAD}$$

where $\frac{t_{ON}}{T} = \frac{V_{OUT}}{V_{IN}}$ for a buck regulator

and $\frac{t_{ON}}{T} = \frac{|V_{OUT}|}{|V_{OUT}|+V_{IN}}$ for a buck-boost regulator

### INDUCTOR SELECTION

All switching regulators have two basic modes of operation: continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulator performance and requirements.

The LM2596G can be used for both continuous and discontinuous modes of operation.

When using inductor values shown in the inductor selection guide, the peak-to-peak inductor ripple current is approximately 20% to 30% of the maximum DC current. With relatively heavy load currents, the circuit is forced to the discontinuous mode (inductor current falls to zero for a period of time). This discontinuous mode of operation is perfectly acceptable. For light loads (less than approximately 300mA), it may be desirable to operate the regulator in the discontinuous mode, primarily because of the lower inductor values required for the discontinuous mode.

The selection guide chooses inductor values suitable for continuous mode operation, but if the inductor value chosen is prohibitively high, the designer should investigate the possibility of discontinuous operation.

Inductors are available in different styles such as pot core, toroid, E-frame, bobbin core, and so on, as well as different core materials, such as ferrites and powdered iron. The bobbin core is the least expensive type, and consists of wire wrapped on a ferrite rod core. This type of construction makes for an inexpensive inductor; however, because the magnetic flux is not completely contained within the core, the bobbin core generates more electromagnetic interference (EMI). This EMI can cause problems in sensitive circuits, or can give incorrect scope readings because of induced voltages in the scope probe.



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An inductor must not operate beyond its maximum-rated current because it may saturate. When an inductor begins to saturate, the inductance decreases rapidly, and the inductor begins to look mainly resistive (the DC resistance of the winding), causing the switch current to rise very rapidly. Different inductor types have different saturation characteristics, and this must be considered when selecting an inductor.
The inductor manufacturer's data sheets include and energy limits to avoid inductor saturation.

**INDUCTOR RIPPLE CURRENT**

When the regulator is operating in the continuous mode, the inductor current waveform ranges from a triangular to a sawtooth type of waveform (depending on the input voltage). For a given input voltage and output voltage, the peak-to-peak amplitude of this inductor current waveform remains constant. As the load current rises or falls, the entire sawtooth current waveform also rises or falls. The average DC value of this waveform is equal to the DC load current (in the buck regulator configuration).
If the load current drops to a low enough level, the bottom of the sawtooth current waveform reaches zero, and the regulator changes to a discontinuous mode of operation. This is a perfectly acceptable mode of operation. Any buck switching regulator (no matter how large the inductor value is) is forced to run discontinuous if the load current is light enough.

**OUTPUT CAPACITOR**

An output capacitor is required to filter the output voltage and is needed for loop stability. The capacitor must be placed near the LM2596G using short PCB traces. Standard aluminum electrolytics are usually adequate, but low ESR types is recommended for low output ripple voltage and good stability. The ESR of a capacitor depends on many factors, including: the value, the voltage rating, physical size, and the type of construction. In general, low value or low voltage (less than 12V) electrolytic capacitors usually have higher ESR numbers.
The amount of output ripple voltage is primarily a function of the ESR (Equivalent Series Resistance) of the output capacitor and the amplitude of the inductor ripple current ($\Delta I_{IND}$). See *Inductor Ripple Current*.
The lower capacitor values (220μF to 1000μF) allows typically 50mV to 150mV of output ripple voltage, while larger-value capacitors reduces the ripple to approximately 20mV to 50mV.

$$\text{Output Ripple Voltage} = (\Delta I_{IND})\ (\text{ESR of } C_{OUT})$$

To further reduce the output ripple voltage, several standard electrolytic capacitors may be paralleled, or a higher-grade capacitor may be used. Such capacitors are often called high-frequency, low-inductance, or low-ESR. These reduce the output ripple to 10mV or 20mV. However, when operating in the continuous mode, reducing the ESR below 0.03Ω can cause instability in the regulator.
Tantalum capacitors can have a very low ESR, and must be carefully evaluated if it is the only output capacitor. Because of their good low temperature characteristics, a tantalum can be used in parallel with aluminum electrolytics, with the tantalum making up 10% or 20% of the total capacitance.
The ripple current rating of the capacitor at 150kHz should be at least 50% higher than the peak-to-peak inductor ripple current.

**CATCH DIODE**

Buck regulators require a diode to provide a return path for the inductor current when the switch is off. This diode must be placed closed to the LM2596G using short leads and short printed-circuit traces.
Because of their fast switching speed and low forward voltage drop, Schottky diodes provide the best efficiency, especially in low output voltage switching regulators (less than 5V). Fast-recovery, high-efficiency, or ultra-fast recovery diodes are also suitable, but some types with an abrupt turnoff characteristic may cause instability and EMI problems. A fast-recovery diode with soft recovery characteristics is a better choice. Standard 60Hz diodes



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(for example, 1N4001 or 1N5400, and so on) are also not suitable.

**OUTPUT VOLTAGE RIPPLE AND TRASIENTS**

The output voltage of a switching power supply contains a sawtooth ripple voltage at the regulator frequency, typically about 1% of the output voltages, and may also contain short voltage spikes at the peaks of the sawtooth waveform.

The output ripple voltage is due mainly to the inductor sawtooth ripple current multiplied by ESR of the output capacitor (See *Inductor Selection*).

The voltage spikes are present because of the fast switching action of the output switch, and the parasitic inductance of the output filter capacitor. To minimize these voltage spikes, special low inductance capacitors can be used, and their lead lengths must be kept short. Wiring inductance, stray capacitance, as well as the scope probe used to evaluate these transients, all contribute to the amplitude of these spikes.

An additional small LC filter (20μH and 100μF) can be added to the output to further reduce the amount of output ripple and transients. A reduction by 10 times in output ripple voltage and transients is possible with this filter.

**FEEDBACK CONNECTION**

The LM2596G (fixed voltage versions) FEEDBACK pin must be wired to the output voltage point of the switching power supply. When using the adjustable version, physically locate both output voltage programming resistors near the LM2596G to avoid picking up unwanted noise. Avoid using resistors greater than 100kΩ because of the increased change of noise pickup. Adjustable output voltage can be programmed with the following equation:

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

$$R2 = R1 \left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

where $V_{REF}$ = 1.23V, R1 between 1.0k and 5.0k

**$\overline{ON}$/OFF INPUT**

The $\overline{ON}$/OFF pin provides electrical ON and OFF control for the LM2596G.

For normal operation, the $\overline{ON}$/OFF pin must be grounded or driven with a low-level TTL voltage. When the voltage of the $\overline{ON}$/OFF pin is below 1.2V, the device starts switching, and the output voltage rises until it reaches the normal regulation voltage.

To put the regulator into standby mode, drive this pin with a high-level TTL or CMOS signal. When the voltage of this pin is higher than 1.4V, the device is in shutdown mode. The typical standby current in this mode is 60μA.

The $\overline{ON}$/OFF pin can be safely pulled up to $+V_{IN}$ without a resistor in series with it. The $\overline{ON}$/OFF pin must not be left open.

**CURRENT LIMIT**

The LM2596G device has current limiting to prevent the switch current from exceeding safe values during an accidental overload on the output. This current limit value can be found in *Electrical Characteristics: All Output Voltage Versions* under the heading of $I_{CL}$.

The LM2596G uses cycle-by-cycle peak current limit for overload protection. This helps to prevent damage to the device and external components. The regulator operates in current limit mode whenever the inductor if the load current is greater than 3A or the converter is starting up. Keep in mind that the maximum available load current depends on the input voltage, output voltage, and inductor value.



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**GROUNDING**

To maintain output voltage stability, the power ground connections must be low-impedance. For the 5 lead TO-263 and TO-220 style package, both the tab and pin 3 are ground and either connection may be used, as they are both part of the same copper lead frame.

**HEAT SINK AND THERMAL CONSIDERATIONS**

In many cases, only a small heat sink is required to keep the LM2596G junction temperature within the allowed operating range. For each application, to determine whether or not a heat sink will be required, the following must be identified:

1. Maximum ambient temperature (in the application).
2. Maximum regulator power dissipation (in application).
3. Maximum allowed junction temperature (125°C for the LM2596G). For a safe, conservative design, a temperature approximately 15°C cooler than the maximum temperatures should be selected.
4. LM2596G package thermal resistances $\theta_{JA}$ and $\theta_{JC}$.

Total power dissipated by the LM2596G can be estimated as follows:

$$P_D = (V_{IN})\,(I_Q) + (V_O / V_{IN})\,(I_{LOAD})\,(V_{SAT})$$

where $I_Q$ (quiescent current) and $V_{SAT}$ can be found in *Typical Operating Characteristics* shown previously, $V_{IN}$ is the applied minimum input voltage, $V_O$ is the regulated output voltage, and $I_{LOAD}$ is the load current. The dynamic losses during turn-on and turn-off are negligible if a Schottky type catch diode is used.

When no heat sink is used, the junction temperature rise can be determined by the following:

$$\Delta T_J = (P_D)\,(\theta_{JA})$$

To arrive at the actual operating junction temperature, add the junction temperature rise to the maximum ambient temperature.

$$T_J = \Delta T_J + T_A$$

If the actual operating junction temperature is greater than the selected safe operating junction temperature determined instep 3, then a heat sink is required.

When using a heat sink, the junction temperature rise can be determined by the following:

$$\Delta T_J = (P_D)\,(\theta_{JC} + \theta_{interface} + \theta_{Heatsink})$$

The operating junction temperature will be:

$$T_J = T_A + \Delta T_J$$

As above, if the actual operating junction temperature is greater than the selected safe operating junction temperature, then a larger heat sink is required (one that has a lower thermal resistance).



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## PCB LAYOUT

### PCB LAYOUT GUIDELINES

As in any switching regulator, the layout of the printed circuit board is very important for the operation of switching power supplies. Switch mode converters are very fast switching devices. Rapidly switching currents associated with wiring inductance, stray capacitance and parasitic inductance of the printed circuit board traces can generate unwanted voltage transients which can generate electromagnetic interferences (EMI) and affect the desired operation. Therefore, appropriate guidelines must be followed to reduce the effects of switching noise.

The most important layout rule is to keep the AC current loops as small as possible. Figure 1 shows the current flow in a buck converter. The top schematic shows a dotted line which represents the current flow during the top-switch ON-state. The middle schematic shows the current flow during the top-switch OFF-state. The bottom schematic shows the currents referred to as AC currents. These AC currents are the most critical because they are changing in a very short time period. The dotted lines of the bottom schematic are the traces to keep as short and wide as possible. This also yields a small loop area reducing the loop inductance.

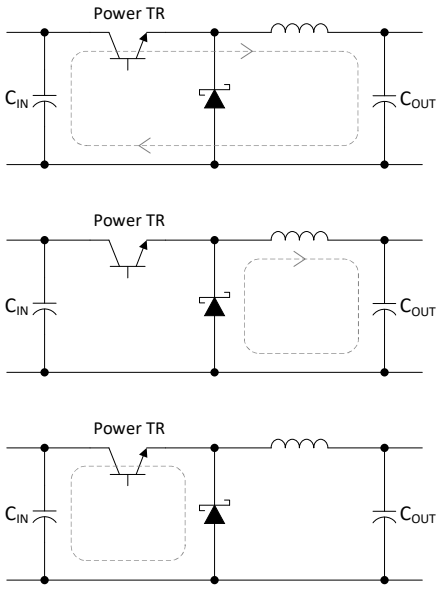


Figure 1. Current Flow in Buck Application

### PCB LAYOUT PROCEDURE

General points of PCB layout procedure are as follows:

1. Place the input capacitor and the catch diode on the same PCB surface layer as the IC terminal and as close as possible to IC.
2. Do not omit placing input decoupling/bypass ceramic capacitor (0.1μF to 0.47μF).
3. Place inductor close to IC but no need to be as close as input capacitor. And do not expand copper area on switching node (OUTPUT) more than needed. The PCB area connected to the OUTPUT of the IC should be kept to a minimum in order to minimize radiation noise from the switching node to sensitive circuitry.
4. Place output capacitor close to inductor.
5. Another sensitive part of the circuit is the feedback. It is important to keep the sensitive feedback wiring short. Route feedback trace away from noise causing sources, such as the inductor and the diode. To assure this, physically locate the programming resistors near to the regulator, when using the adjustable version of the



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regulator.

6. Connect thermal vias to a ground plane if available to improve thermal dissipation.

The ground plane area must be sufficient for thermal dissipation purposes. It is recommended to use at least 2oz copper boards to help thermal dissipation and reduce parasitic inductances of board traces.
Review the PCB layout example as shown in Figure 3.

**PCB LAYOUT EXAMPLE**

Review the PCB layout example as shown in Figure 3.

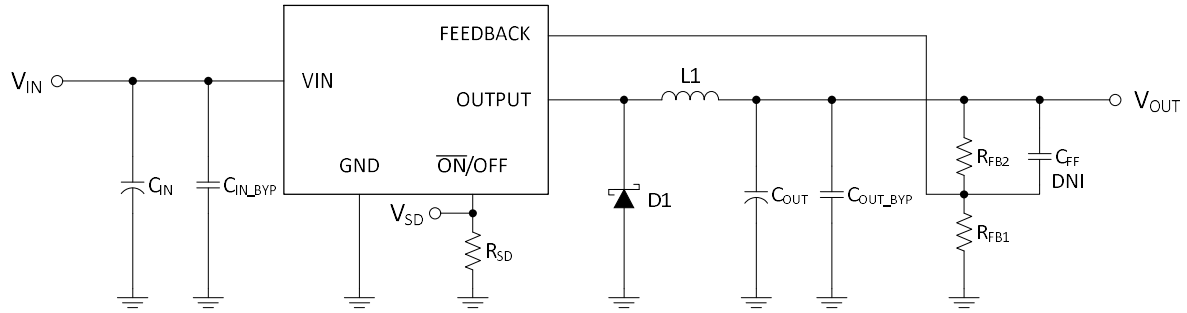


Figure 2. Schematic for PCB Layout Example

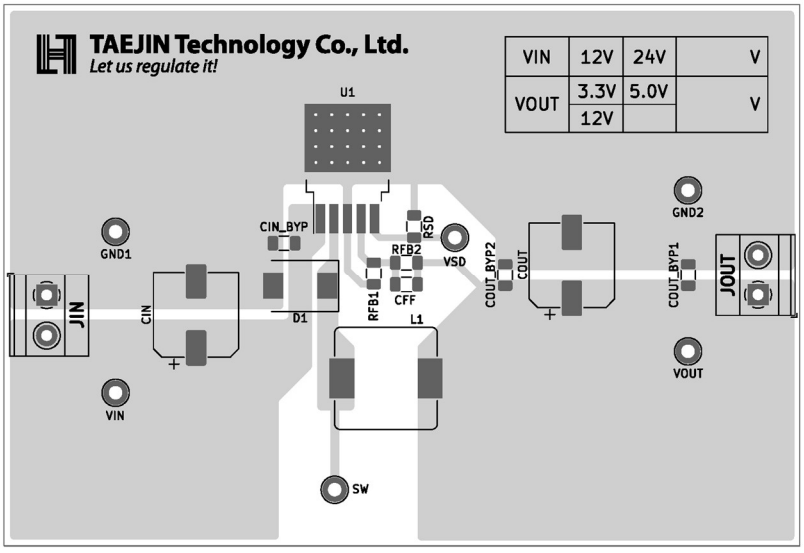


Figure 3. PCB Layout Example



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## REVISION NOTICE

The description in this datasheet is subject to change without any notice to describe its electrical characteristics properly.



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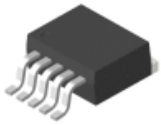
# 60V, 3A, 150kHz, Step-down Switching Regulator LM2596HV

## FEATURES

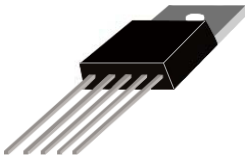
- 3.3V, 5V, 12V and Adjustable output versions
- Adjustable version output voltage range, 1.23V to 57V
- ±4% max over line and load condition
- Available in TO-220, TO-263 and SOP-8PP
- Guaranteed 3A output load current
- Input voltage range up to 60V
- Requires only 4 external components
- Excellent line and load regulation specifications
- 150kHz fixed frequency internal oscillator
- Low power standby mode, $I_{STB}$ typically 30uA
- High efficiency
- Thermal shutdown and current limit protection
- Output short protection by reduction of frequency by 3 times

SOP-8PP PKG

TO-263 PKG



TO-220 PKG



**ORDERING INFORMATION**

| Device | Package |
|---|---|
| LM2596HVGDP-ADJ | SOP-8PP |
| LM2596HVGDP-X.X | |
| LM2596HVGR-ADJ | TO-263 5L |
| LM2596HVGR-X.X | |
| LM2596HVGT-ADJ | TO-220 5L |
| LM2596HVGT-X.X | |

X.X = Output Voltage = 3.3, 5.0, 12

## APPLICATION

- Simple high-efficiency step-down (buck) regulator
- Efficient pre-regulator for linear regulators
- On-card switching regulators

## DESCRIPTION

The LM2596HV series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, and an adjustable output version.
Available in a standard 5-lead TO-220 package and a 5-lead TO-263 surface mount package.
External shutdown is included, featuring typically 30 μA standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown, and protection from output short for full protection under fault conditions.

## Absolute Maximum Ratings (Note 1)

| CHARACTERISTIC | SYMBOL | MIN. | MAX. | UNIT |
|---|---|---|---|---|
| Supply Voltage | $V_{IN}$ | - | 63 | V |
| ON/OFF Pin Input Voltage | $V_{ON/OFF}$ | -0.3 | 60 (or $V_{IN}$) | V |
| FB pin voltage | $V_{FB}$ | -0.3 | 25 (or $V_{IN}$) | V |
| Output voltage to GND | $V_{OUT}$ | -1 | | V |
| Storage Temperature Range | $T_{STG}$ | -65 | 150 | ℃ |
| Maximum Junction Temperature Range | $T_{J,MAX}$ | - | 150 | ℃ |



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## Operating Ratings

| CHARACTERISTIC | SYMBOL | MIN. | MAX. | UNIT |
|---|---|---|---|---|
| Supply Voltage | $V_{IN}$ | 4.5 | 60 | V |
| Load Current | $I_{LOAD}$ | - | 3.0 | A |
| Temperature Range | $T_J$ | -40 | 125 | |

## Ordering Information

| VOUT | Package | Order No. | Description | Supplied As | Status |
|---|---|---|---|---|---|
| ADJ | SOP-8PP-8L | LM2596HVGDP-ADJ | 3A, 150kHz, Adjustable | Reel | Active |
| | TO-263-5L | LM2596HVGR-ADJ | 3A, 150kHz, Adjustable | Reel | Active |
| | TO-220-5L | LM2596HVGT-ADJ | 3A, 150kHz, Adjustable | Tube | Active |
| 3.3V | SOP-8PP-8L | LM2596HVGDP-3.3 | 3A, 150kHz, Fixed | Reel | Contact us |
| | TO-263-5L | LM2596HVGR-3.3 | 3A, 150kHz, Fixed | Reel | Active |
| | TO-220-5L | LM2596HVGT-3.3 | 3A, 150kHz, Fixed | Tube | Contact us |
| 5.0V | SOP-8PP-8L | LM2596HVGDP-5.0 | 3A, 150kHz, Fixed | Reel | Active |
| | TO-263-5L | LM2596HVGR-5.0 | 3A, 150kHz, Fixed | Reel | Active |
| | TO-220-5L | LM2596HVGT-5.0 | 3A, 150kHz, Fixed | Tube | Active |
| 12V | SOP-8PP-8L | LM2596HVGDP-12 | 3A, 150kHz, Fixed | Reel | Contact us |
| | TO-263-5L | LM2596HVGR-12 | 3A, 150kHz, Fixed | Reel | Active |
| | TO-220-5L | LM2596HVGT-12 | 3A, 150kHz, Fixed | Tube | Active |



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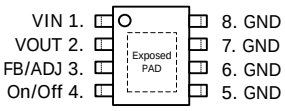
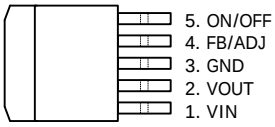
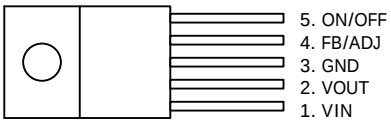
## PIN CONFIGURATION




SOP-8PP




TO-263-5L




TO-220-5L

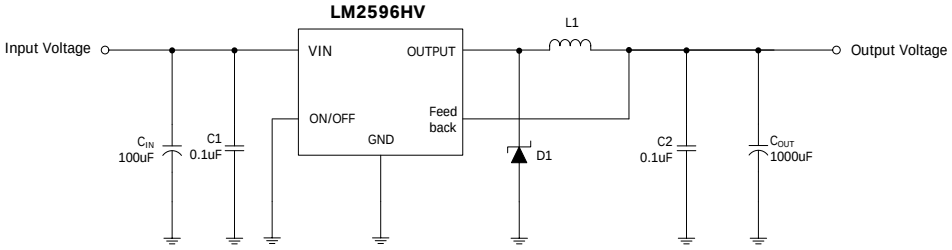
## PIN DESCRIPTION

| Pin No. | TO-263 / TO-220 5 LEAD | | Pin No. | SOP-8PP 8 LEAD | |
|---|---|---|---|---|---|
| | Name | Function | | Name | Function |
| 1 | VIN | Input Supply | 1 | VIN | Input Supply |
| 2 | VOUT | Output Voltage | 2 | VOUT | Output Voltage |
| 3 | GND | Ground | 3 | FB / ADJ | Output Voltage Feedback or Output Adjust |
| 4 | FB / ADJ | Output Voltage Feedback or Output Adjust | 4 | ON/OFF | ON/OFF Shutdown |
| 5 | ON/OFF | ON/OFF Shutdown | 5 / 6 / 7 / 8 | GND | Ground |

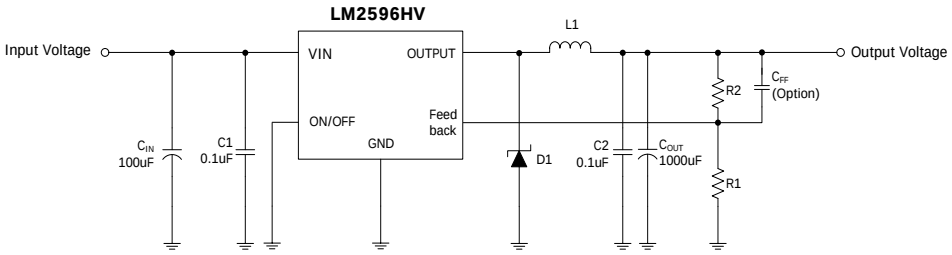
* Exposed Pad of SOP8-PP package should be externally connected to GND.

## TYPICAL APPLICATION

- Fixed Output Voltage Version




- Adjustable Output Voltage Version



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## ELECTRICAL CHARACTERISTICS

Unless specified otherwise, $V_{IN}$ = 12V for the 3.3V, 5V and adjustable versions, $I_{LOAD}$ = 0.5A, $V_{IN}$ = 18V for 12V version.
The boldface type denotes the specifications, which apply over full operating temperature range $T_J$ = -40 to +125°C.

| PARAMETER | SYMBOL | TEST CONDITION (Note 2) | | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|---|
| **SYSTEM PARAMETERS** (Note 3) | | | | | | | |
| Feedback Voltage | $V_{FB}$ | LM2596HV-ADJ | 8V ≤ $V_{IN}$ ≤ 60V,<br>0.2A ≤ $I_{LOAD}$ ≤ 3A | 1.193<br>**1.180** | 1.230 | 1.273<br>**1.285** | V |
| Output Voltage | $V_O$ | LM2596HV-3.3 | 5.5V ≤ $V_{IN}$ ≤ 60V,<br>0.2A ≤ $I_{LOAD}$≤ 3A | 3.185<br>**3.152** | 3.30 | 3.432<br>**3.465** | V |
| | | LM2596HV-5.0 | 8V ≤ $V_{IN}$ ≤ 60V,<br>0.2A ≤ $I_{LOAD}$ ≤ 3A | 4.825<br>**4.775** | 5.00 | 5.20<br>**5.25** | V |
| | | LM2596HV-12 | 15V ≤ $V_{IN}$ ≤ 60V,<br>0.2A ≤ $I_{LOAD}$ ≤ 3A | 11.58<br>**11.46** | 12.00 | 12.48<br>**12.60** | V |
| Line Regulation | Line Reg | 8 ≤ $V_{IN}$ ≤ 60V, $I_{LOAD}$ = 0.2A | | | 0.3 | | % |
| Load Regulation | Load Reg | 10mA ≤ $I_{LOAD}$ ≤ 3A, $V_{IN}$ = 12V | | | 0.3 | | % |
| Efficiency | η | LM2596HV-ADJ | $V_{IN}$ =12V, $I_{LOAD}$ =3A,<br>$V_{OUT}$ = 5V | | 79 | | % |
| | | LM2596HV-3.3 | $V_{IN}$ =12V, $I_{LOAD}$ =3A | | 77 | | % |
| | | LM2596HV-5.0 | $V_{IN}$ =12V, $I_{LOAD}$ =3A | | 79 | | % |
| | | LM2596HV-12 | $V_{IN}$ =15V, $I_{LOAD}$ =3A | | 83 | | % |
| **DEVICE PARAMETERS** | | | | | | | |
| Quiescent Current | $I_Q$ | $V_{FB}$=12V force driver off (Note 6) | | | 5 | 8 | mA |
| Feedback Bias Current | $I_{FB}$ | $V_{FB}$=1.3V (Adjustable version only) | | -250<br>**-450** | -70 | | nA |
| Shutdown Supply Current | $I_{STB}$ | $V_{ON/OFF}$=5V, $V_{IN}$=60V | | | 30 | 220<br>**280** | uA |
| Oscillator Frequency | $F_{OSC}$ | (Note 8) | | 133<br>**120** | 150 | 168<br>**180** | KHz |
| Oscillator Frequency of short Circuit Protect | $F_{SCP}$ | When $V_{OUT}$ < 40% from nominal,<br>$I_{OUT}$=CL (Note 8) | | | 50 | | KHz |
| Max. duty Cycle | $DC_{(MAX.)}$ | $V_{FB}$=0V force driver on (Note 5) | | **100** | | | % |
| Min. duty Cycle | $DC_{(MIN.)}$ | $V_{FB}$=12V force driver off<br>($V_{FB}$=15V, For 12V Version) | | | | **0** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Current Limit | CL | Peak Current. No outside circuit.<br>$V_{FB}$=0V (Note 4, 8) | 4.1<br>**3.8** | 5.3 | 6.7<br>**7.0** | A |
| Saturation Voltage | $V_{SAT}$ | $I_{OUT}$=3A. No outside circuit.<br>$V_{FB}$=0V (Note 4) | | 1.35 | 1.50<br>**1.70** | V |
| Output Leakage Current | $I_L$ | $V_{OUT}$=0V. No outside circuit.<br>$V_{FB}$=12V (Note 6, 7) | -300 | -50 | | uA |
| Output Leakage Current | $I_{L1}$ | $V_{OUT}$=-1V. No outside circuit.<br>$V_{FB}$=12V (Note 6, 7) | -30 | -3 | | mA |
| ON/OFF Input Threshold | $V_{TH}$ | | **0.6** | **1.3** | **2.0** | V |
| ON/OFF Input Current | $I_H$ | $V_{ON/OFF}$=2.5V | -5 | -0.1 | 5 | uA |
| | $I_L$ | $V_{ON/OFF}$=0.5V | -1 | -0.01 | 1 | uA |
| Thermal Shutdown Temperature | $T_{SD}$ | $T_J$ | | 160 | | |

Note 1. Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2, All limits guaranteed at room temperature (standard type face) and at temperature extremes (bold type face).

Note 3, External components such as the schottky diode, inductor, input and output capacitors can affect switching regulator system performance. When the 2596HV is used as shown in the Figure 2 test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

Note 4. Output pin sourcing current. No diode, inductor or capacitor connected to output.

Note 5. Feedback pin removed from output and connected to 0V.

Note 6. Feedback pin removed from output and connected to +12V for the Adjustable, 3.3V, and 5V, versions, and +25V for the 12V and 15V versions, to force the output transistor OFF.

Note 7. $V_{IN}$ =60V.

Note 8. The oscillator frequency reduces to approximately 50KHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage. This self protections feature lowers the average power dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.



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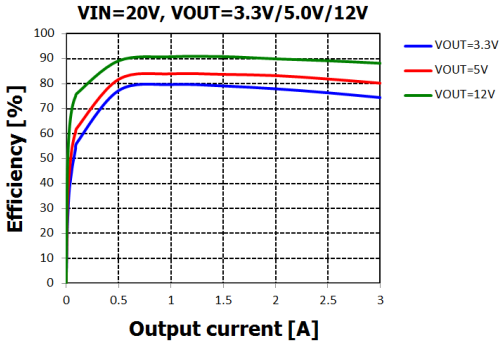
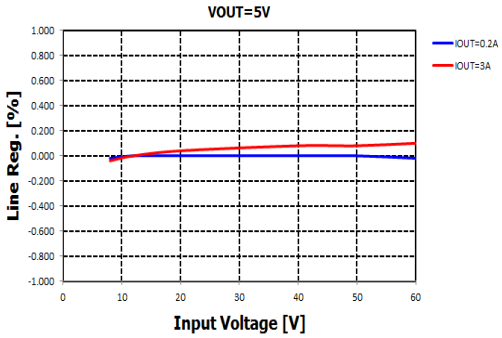
## TYPICAL OPERATING CHARACTERISTIC

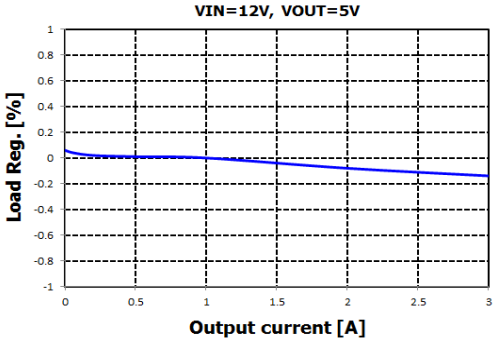
Efficiency vs. IOUT



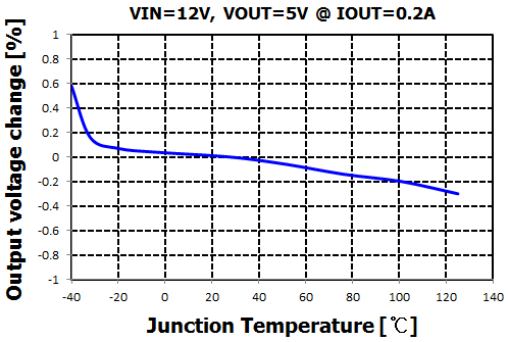

Line Regulation vs. VIN



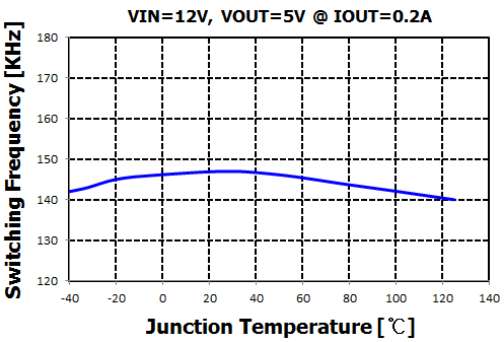

Load Regulation vs. IOUT



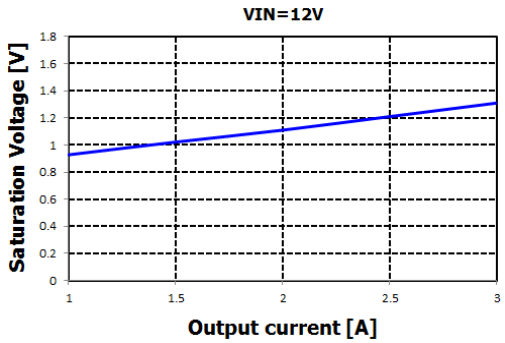

VOUT vs. TJ




FOSC vs. TJ




VSAT vs. IOUT



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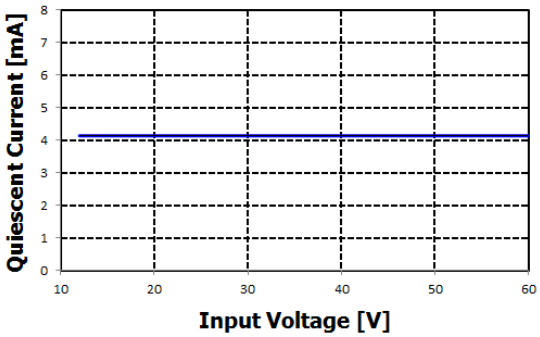
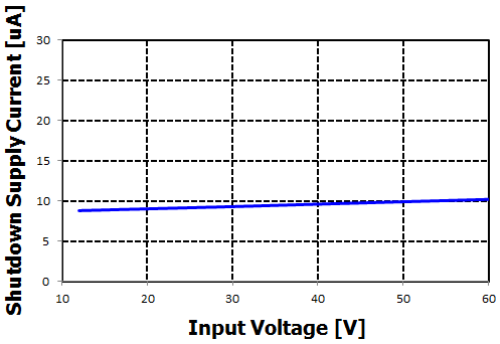
IQ vs. VIN




ISTB vs. VIN



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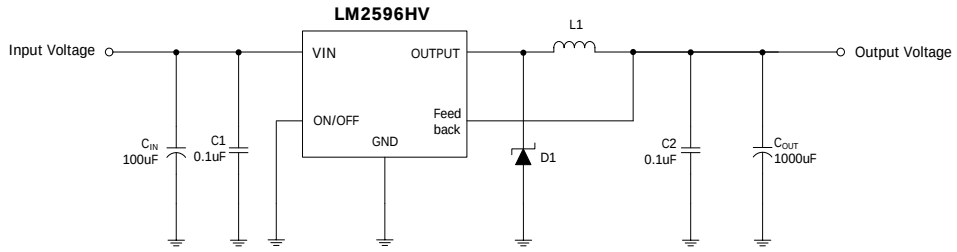
## APPLICATION INFORMATION

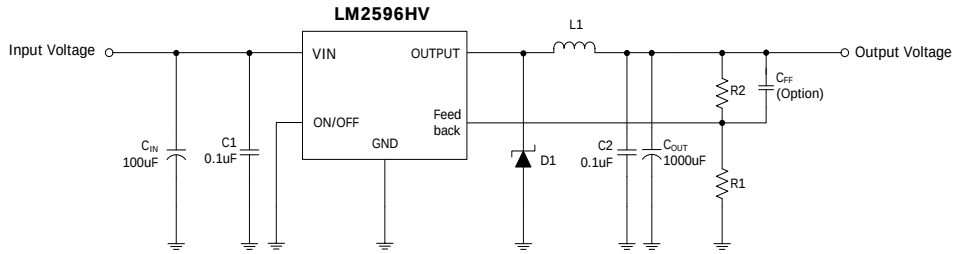
As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance generate voltage transients which can cause problems. For minimal inductance and ground loops, the length of the wires should be kept as short as possible. Single-point grounding or ground plane construction should be used for best results. Keep the feedback wiring away from the inductor flux

- Fixed Output Voltage Version




[Figure 1]

- Adjustable Output Voltage Version




[Figure 2]

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

where $V_{FB}$ = 1.23V, R1 between 1KΩ and 5KΩ.



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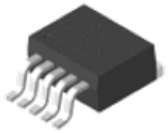
# 3A, 300kHz, Step-Down Switching Regulator LM4576

## FEATURES

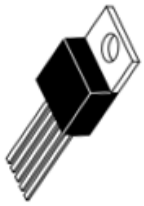
- 3.3V, 5.0V, 12V, 15V and Adjustable Output Versions
- Adjustable Version Output Voltage Range, 1.23V to 37V +/- 4% maximum over line and load conditions
- Guaranteed 3A Output Current
- Wide Input Voltage Range
- Requires Only 4 External Components
- 300KHz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- Uses Readily Available Standard Inductors
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3 for SMD packages

SOP-8PP PKG

TO-263-5L PKG



TO-220-5L PKG



## APPLICATION

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

**ORDERING INFORMATION**

| Device | Marking | Package |
|---|---|---|
| LM4576DP-X.X | LM4576-X.X | SOP-8PP |
| LM4576R-X.X | LM4576-X.X | TO-263-5L |
| LM4576T-X.X | LM4576-X.X | TO-220-5L |

## DESCRIPTION

The LM4576 series of regulators are monolithic integrated circuits that provide all the active functional for a step-down (buck) switching regulator, capable of driving 3A load with excellent line and load regulation.
These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V and an adjustable output versions. Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation, and a fixed-frequency oscillator.
The LM4576 series operates at a switching frequency of 300KHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators.
Some features include a guaranteed +/- 4% tolerance on output voltage under specified input voltage and output load conditions, and +/- 15% on the oscillator frequency. External shutdown is included, featuring typically 60uA standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions. The oscillator frequency is reduced in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage.



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## ORDERING INFORMATION

| $V_{OUT}$ | Package | Order No. | Description | Package Marking | Status |
|---|---|---|---|---|---|
| ADJ | SOP-8PP | LM4576DP-ADJ | 3A, Adjustable, 300kHz, On/off | LM4576-ADJ | Active |
| | TO-263-5L | LM4576R-ADJ | 3A, Adjustable, 300kHz, On/off | LM4576-ADJ | Active |
| | TO-220-5L | LM4576T-ADJ | 3A, Adjustable, 300kHz, On/off | LM4576-ADJ | Active |
| 3.3V | SOP-8PP | LM4576DP-3.3 | 3A, Fixed, 300kHz, On/off | LM4576-3.3 | Contact Us |
| | TO-263-5L | LM4576R-3.3 | 3A, Fixed, 300kHz, On/off | LM4576-3.3 | Contact Us |
| | TO-220-5L | LM4576T-3.3 | 3A, Fixed, 300kHz, On/off | LM4576-3.3 | Contact Us |
| 5.0V | SOP-8PP | LM4576DP-5.0 | 3A, Fixed, 300kHz, On/off | LM4576-5.0 | Active |
| | TO-263-5L | LM4576R-5.0 | 3A, Fixed, 300kHz, On/off | LM4576-5.0 | Active |
| | TO-220-5L | LM4576T-5.0 | 3A, Fixed, 300kHz, On/off | LM4576-5.0 | Active |
| 12V | SOP-8PP | LM4576DP-12 | 3A, Fixed, 300kHz, On/off | LM4576-12 | Contact Us |
| | TO-263-5L | LM4576R-12 | 3A, Fixed, 300kHz, On/off | LM4576-12 | Contact Us |
| | TO-220-5L | LM4576T-12 | 3A, Fixed, 300kHz, On/off | LM4576-12 | Contact Us |
| 15V | SOP-8PP | LM4576DP-15 | 3A, Fixed, 300kHz, On/off | LM4576-15 | Contact Us |
| | TO-263-5L | LM4576R-15 | 3A, Fixed, 300kHz, On/off | LM4576-15 | Contact Us |
| | TO-220-5L | LM4576T-15 | 3A, Fixed, 300kHz, On/off | LM4576-15 | Contact Us |



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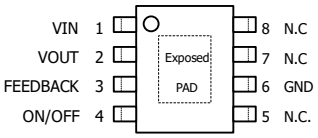
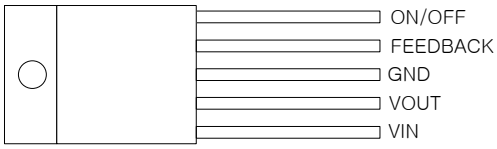
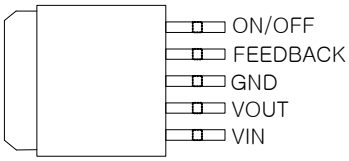
## PIN CONFIGURATION




SOP-8PP




TO-220-5L




TO-263-5L

## PIN DESCRIPTION

| Package | | Symbol | Description |
|---|---|---|---|
| TO-263-5L<br>TO-220-5L | SOP-8PP | | |
| 1 | 1 | VIN | This pin is the positive input supply for the LM4576 step–down switching regulator. In order to minimize voltage transients and to supply the switching currents needed by the regulator, a suitable input bypass capacitor must be present. (Cin in Figure 1). |
| 2 | 2 | VOUT | This is the emitter of the internal switch. The saturation voltage $V_{SAT}$ of this output switch is typically 1.4V. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry. |
| 3 | 6 | GND | Circuit ground pin. See the information about the printed circuit board layout. |
| 4 | 3 | FEEDBACK | This pin senses regulated output voltage to complete the feedback loop. The signal is divided by the internal resistor divider network R1, R2 and applied to the non–inverting input of the internal error amplifier. In the adjustable version of the LM4576 switching regulator this pin is the direct input of the error amplifier and the resistor network R1, R2 is connected externally to allow programming of the output voltage. |
| 5 | 4 | ON/OFF | It allows the switching regulator circuit to be shutdown using logic level signals, thus dropping the total input supply current to approximately 60uA.<br>The threshold voltage is typically 1.4V. Applying a voltage above this value (up to +Vin) shuts the regulator off. If the voltage applied to this pin is lower than 1.4V or if this pin is left open, the regulator will be in the "on" condition |
| - | 5, 7, 8 | N.C. | No Connect. |

* Exposed Pad of SOP-8PP package should be externally connected to GND.



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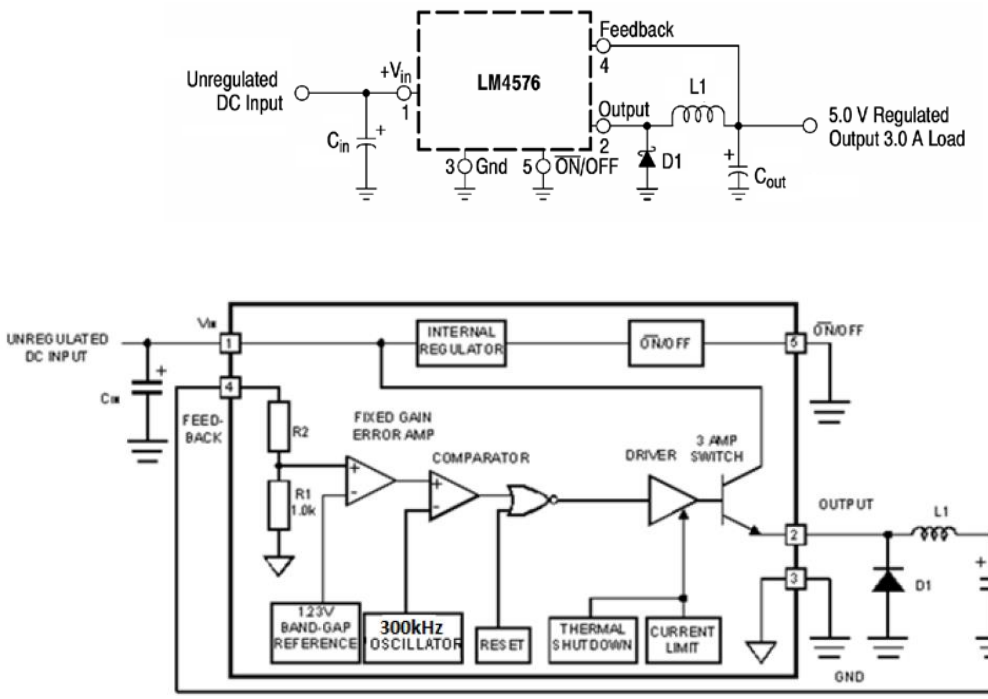
## TYPICAL APPLICATION (Fixed Output Voltage Versions)




3.3V, R2 =1.7K
5V, R2 = 3.1K
12V, R2 = 8.84K
15V, R2 =11.3K
For ADJ Version R1 = Open, R2 =0Ω

**Figure 1. Block Diagram and Typical Application**



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## ABSOLUTE MAXIMUM RATINGS

(Absolute Maximum Ratings indicate limits beyond which damage to the device may occur)

| Rating | Symbol | Value | UNIT |
|---|---|---|---|
| Maximum Supply Voltage | $V_{IN}$ | 45 | V |
| On/Off Pin Input Voltage | $V_{ON/OFF}$ | -0.3V ≤ V ≤ +Vin | V |
| FB Pin Voltage | $V_{FB}$ | -0.3V ≤ V ≤ +Vin | V |
| Output Voltage to Ground (Steady-State) | $V_{OUT}$ | -0.8 | V |
| Power Dissipation<br>SOP-8PP<br>Thermal Resistance, Junction to Ambient<br>Thermal Resistance, Junction to Case | <br>$P_D$<br>$\theta_{JA}$<br>$\theta_{JC}$ | <br>Internally Limited<br>Contact us<br>Contact us | <br>W<br>℃/W<br>℃/W |
| TO-263-5L<br>Thermal Resistance, Junction to Ambient<br>Thermal Resistance, Junction to Case | $P_D$<br>$\theta_{JA}$<br>$\theta_{JC}$ | Internally Limited<br>70<br>5 | W<br>℃/W<br>℃/W |
| TO-220-5L<br>Thermal Resistance, Junction to Ambient<br>Thermal Resistance, Junction to Case | $P_D$<br>$\theta_{JA}$<br>$\theta_{JC}$ | Internally Limited<br>65<br>5 | W<br>℃/W<br>℃/W |
| TO-220V-5L<br>Thermal Resistance, Junction to Ambient<br>Thermal Resistance, Junction to Case | $P_D$<br>$\theta_{JA}$<br>$\theta_{JC}$ | Internally Limited<br>65<br>5 | W<br>℃/W<br>℃/W |
| Storage Temperature Range | $T_{STG}$ | -65 to +150 | ℃ |
| Maximum Junction Temperature | $T_J$ | 150 | ℃ |

**OPERATING RATINGS** (Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications, see the Electrical Characteristics.)

| Rating | Symbol | Value. | Unit |
|---|---|---|---|
| Operating Junction Temperature Range | $T_J$ | -40 to +125 | ℃ |
| Maximum Supply Voltage | $V_{IN}$ | 40 | V |
| Output Current | $I_{OUT}$ | 3 | A |



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**ELECTRICAL CHARACTERISTICS** / System Parameters [Note 1]
(Unless otherwise specified, $V_{IN}$ = 12V for the 3.3V, 5.0V, and Adjustable version, $V_{IN}$ = 25V for the 12V and 15V version. $I_{LOAD}$ = 500 mA. For typical values $T_J$ = 25°C, for min/max values $T_J$ is the operating junction temperature range that applies [Note 2], unless otherwise noted.)

| Characteristics | Symbol | Min | TYP | Max | Unit |
|---|---|---|---|---|---|
| **LM4576-3.3 ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (5.5V ≤ $V_{IN}$ ≤ 40V, 0.2A ≤ $I_{LOAD}$ ≤ 3A)<br>$T_J$=25℃<br>$T_J$= -40℃ ~ +125℃ | $V_{OUT}$ | <br>3.168<br>3.135 | <br>3.3<br>- | <br>3.432<br>3.465 | V |
| Efficiency ($V_{IN}$=12V, $I_{LOAD}$=3A) | η | - | 73 | - | % |
| **LM4576-5.0 ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (8V ≤ $V_{IN}$ ≤ 40V, 0.2A ≤ $I_{LOAD}$ ≤ 3A)<br>$T_J$=25℃<br>$T_J$= -40℃ ~ +125℃ | $V_{OUT}$ | <br>4.800<br>4.750 | <br>5.0<br>- | <br>5.200<br>5.250 | V |
| Efficiency ($V_{IN}$=12V, $I_{LOAD}$=3A) | η | - | 75 | - | % |
| **LM4576-12 ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (15V ≤ $V_{IN}$ ≤ 40V, 0.2A ≤ $I_{LOAD}$ ≤ 3A)<br>$T_J$=25℃<br>$T_J$= -40℃ ~ +125℃ | $V_{OUT}$ | <br>11.520<br>11.400 | <br>12<br>- | <br>12.480<br>12.600 | V |
| Efficiency ($V_{IN}$=15V, $I_{LOAD}$=3A) | η | - | 86 | - | % |
| **LM4576-15 ([Note 1] Test Circuit Figure 2)** | | | | | |
| Output Voltage (18V ≤ $V_{IN}$ ≤ 40V, 0.2A ≤ $I_{LOAD}$ ≤ 3A)<br>$T_J$=25℃<br>$T_J$= -40℃ ~ +125℃ | $V_{OUT}$ | <br>14.400<br>14.250 | <br>15<br>- | <br>15.600<br>15.750 | V |
| Efficiency ($V_{IN}$=18V, $I_{LOAD}$=3A) | η | - | 86 | - | % |
| **LM4576-ADJ ([Note 1] Test Circuit Figure 2)** | | | | | |
| Feedback Voltage (8V ≤ $V_{IN}$ ≤ 40V, 0.2A ≤ $I_{LOAD}$ ≤ 3A, $V_{OUT}$ programmed for 5V)<br>$T_J$=25℃<br>$T_J$= -40℃ ~ +125℃ | $V_{OUT}$ | <br>1.193<br>1.180 | <br>1.230<br>- | <br>1.267<br>1.280 | V |
| Efficiency ($V_{IN}$=12V, $I_{LOAD}$=3A, $V_{OUT}$=5V) | η | - | 75 | - | % |

1. External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance.
2. Tested junction temperature range for the LM4576 : $T_{LOW}$ = –40°C, $T_{HIGH}$ = +125°C



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## ELECTRICAL CHARACTERISTICS / Device Parameters

(Unless otherwise specified, $V_{IN}$ = 12V for the 3.3V, 5.0V, and Adjustable version, $V_{IN}$ = 25V for the 12V and 15V version. $I_{LOAD}$ = 500 mA. For typical values $T_J$ = 25°C, for min/max values $T_J$ is the operating junction temperature range that applies [Note 2], unless otherwise noted.)

| Characteristics | Symbol | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|
| **All Output Voltage Versions** | | | | | |
| Feedback Bias Current ($V_{OUT}$=5.0V [Adjustable Version Only])<br>$T_J$=25℃<br>$T_J$= -40 to +125℃ | $I_b$ | -<br>- | 50<br>- | 100<br>500 | nA |
| Oscillator Frequency [Note 3]<br>$T_J$=25℃<br>$T_J$= -40 to +125℃ | $F_{OSC}$ | 255<br>230 | 300<br>- | 345<br>370 | KHz |
| Saturation Voltage ($I_{OUT}$=3.0A [note 4])<br>$T_J$= 25℃<br>$T_J$= -40 to +125℃ | $V_{SAT}$ | -<br>- | 1.4<br>- | 1.6<br>1.8 | V |
| Max Duty Cycle (“0”) [Note 5] | D/C | 93 | 98 | - | % |
| Current Limit (Peak Current [Note 3 and 4])<br>$T_J$= 25℃<br>$T_J$= -40 to +125℃ | $I_{CL}$ | 4.0<br>3.5 | 5.7<br>- | 6.9<br>7.5 | A |
| Output Leakage Current [Note 6 and 7]<br>Output = 0V<br>Output = -0.8V | $I_L$ | -<br>- | 0.4<br>10 | 2<br>30 | mA |
| Quiescent Current [Note 6]<br>$T_J$= 25℃ | $I_Q$ | - | 5 | 10 | mA |
| Standby Quiescent Current (ON/OFF Pin = 5.0V ("off"))<br>$T_J$=25℃ | $I_{STBY}$ | - | 60 | 200 | µA |
| ON/OFF Pin Logic Input Level ($V_{OUT}$=0V)<br>$T_J$=25℃<br>$T_J$= -40 to +125℃ | $V_{IH}$ | 2.2<br>2.4 | 1.4<br>- | -<br>- | V |
| $V_{OUT}$=Nominal Output Voltage<br>$T_J$=25℃<br>$T_J$= -40 to +125℃ | $V_{IL}$ | -<br>- | 1.2<br>- | 1.0<br>0.8 | V |
| ON/OFF Pin Input Current<br>ON/OFF Pin = 5.0V (Regulator OFF), $T_J$=25℃<br>ON/OFF Pin = 0V (Regulator ON), $T_J$=25℃ | $I_{IH}$<br>$I_{IL}$ | -<br>- | 12<br>0 | 30<br>10 | µA |

3. The oscillator frequency reduces to approximately 75 KHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal voltage. This self protection feature lowers the average dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%
4. Output pin sourcing current. No diode, inductor or capacitor connected to output.
5. Feedback pin removed from output and connected to 0V.
6. Feedback pin removed from output and connected to +12V for the Adjustable, 3.3V, and 5.0V versions, and +25V for the 12V and 15V version, to force the output transistor “off”.
7. Vin = 40V.



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## TYPICAL PERFORMANCE CHARACTERISTICS

T.B.D.



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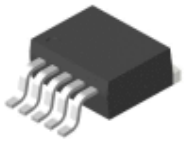
# 5A, 150KHz, Step-Down Switching Regulator LM1501AG

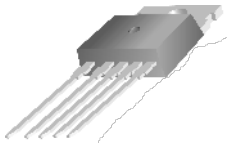
## FEATURES

- 3.3V, 5V, 12V, and adjustable output versions
- Adjustable version output voltage range
- Guaranteed 5A output load current
- Input voltage range up to 40V
- 150KHz fixed frequency internal oscillator
- Excellent line and load regulation
- Thermal shutdown and current limit protection

TO-263-5L PKG



TO-220-5L PKG



## APPLICATION

- Simple high-efficiency step-down regulator
- On-card switching regulators
- Positive to negative converter

**ORDERING INFORMATION**

| Device | Package |
|---|---|
| LM1501AGR-X.X | TO-263-5L |
| LM1501AGT-X.X | TO-220-5L |

X.X = Output Voltage = 3.3, 5.0, 12, ADJ

## DESCRIPTION

The LM1501AG series of regulators are monolithic integrated circuits that provide all the active functions for a step-down switching regulator, capable of driving a 5A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and they include internal frequency compensation and a fixed-frequency oscillator. The LM1501AG 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 ±4% tolerance on output voltage under specified input voltage and output load conditions, and ± 15% on the oscillator frequency. External shutdown is included, featuring typically 80uA standby current. Self-protection features include a two stage frequency reducing current limit for output switch and an over temperature shutdown for complete protection under fault conditions.

## ABSOLUTE MAXIMUM RATINGS (Note 1)

| CHARACTERISTIC | SYMBOL | VALUE | UNIT |
|---|---|---|---|
| Maximum Input Supply Voltage | $V_{IN\_MAX}$ | 45 | V |
| ON/OFF Pin Input Voltage | $V_{ON/OFF}$ | -0.3 ≤ V ≤ +25 | V |
| Feedback Pin Voltage | $V_{FB}$ | -0.3 ≤ V ≤ +25 | V |
| Output Voltage to Ground (Steady State) | $V_{OUT}$ | -1 | V |
| Power Dissipation | $P_D$ | Internally limited | W |
| Storage Temperature Range | $T_{STG}$ | -65 to +150 | °C |
| Operating Temperature Range | $T_J$ | 150 | °C |



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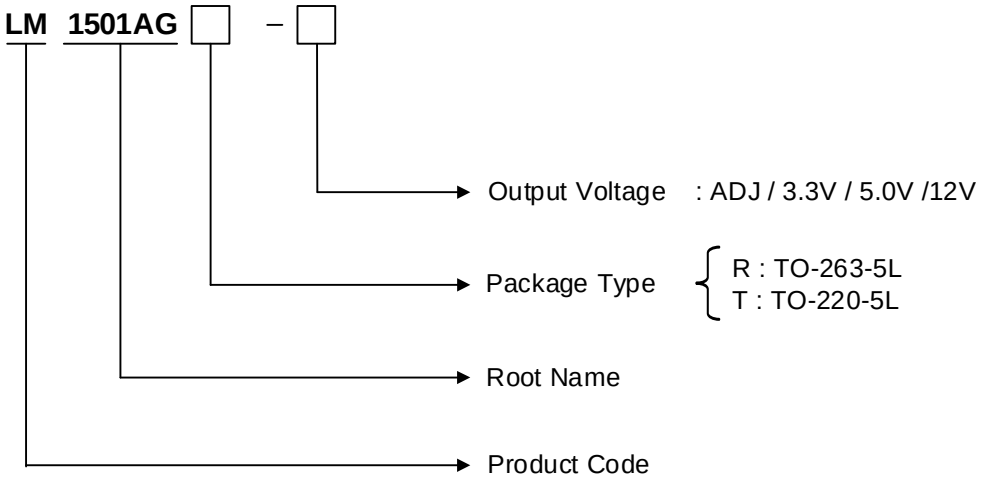
Site Web : www.es-france.com

## RECOMMENDED OPERATING CONDITIONS

| CHARACTERISTIC | SYMBOL | MIN. | MAX. | UNIT |
|---|---|---|---|---|
| Supply Voltage | $V_{IN}$ | - | 40 | V |
| Load Current | ILOAD | - | 5 | A |
| Junction Temperature | $T_J$ | -40 | 125 | °C |

## ORDERING INFORMATION

| VOUT | PACKAGE | ORDER NO. | DESCRIPTION | STATUS |
|---|---|---|---|---|
| ADJ | TO-263-5L | LM1501AGR-ADJ | 5A, 150KHz | Active |
| | TO-220-5L | LM1501AGT-ADJ | 5A, 150KHz | Active |
| 3.3V | TO-263-5L | LM1501AGR-3.3 | 5A, 150KHz | Active |
| | TO-220-5L | LM1501AGT-3.3 | 5A, 150KHz | Active |
| 5.0V | TO-263-5L | LM1501AGR-5.0 | 5A, 150KHz | Active |
| | TO-220-5L | LM1501AGT-5.0 | 5A, 150KHz | Active |
| 12V | TO-263-5L | LM1501AGR-12 | 5A, 150KHz | Active |
| | TO-220-5L | LM1501AGT-12 | 5A, 150KHz | Active |



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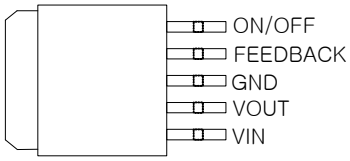
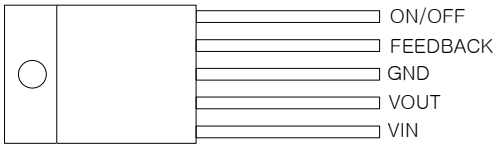
## PIN CONFIGURATION




TO-263-5L



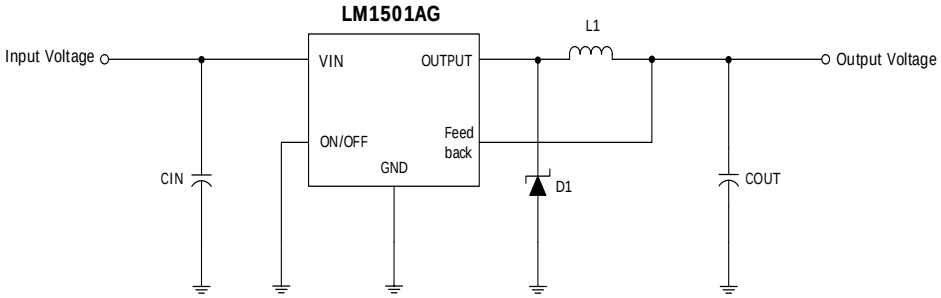

TO-220-5L

## PIN DESCRIPTION

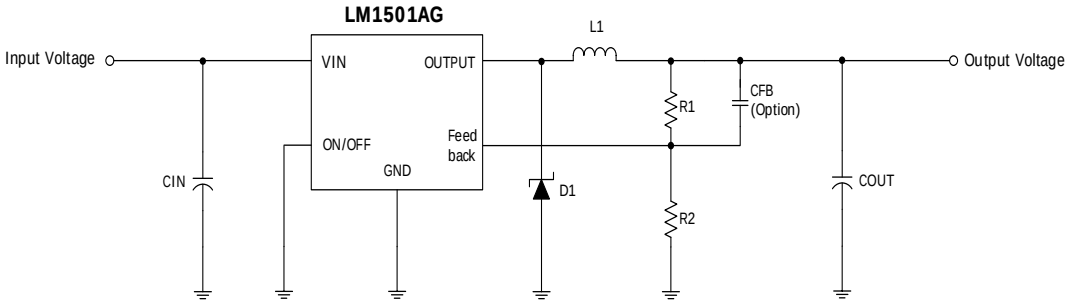
| PIN NO. | TO-263-5L / TO-220-5L PKG | |
|---|---|---|
| | NAME | FUNCTION |
| 1 | VIN | Operating Input Voltage |
| 2 | OUTPUT | Switching Output Voltage |
| 3 | GND | Ground |
| 4 | FB | Output Voltage Feedback Control |
| 5 | ON/OFF | ON/OFF Shutdown |

## TYPICAL APPLICATION

- Fixed Output Voltage Version




- Adjustable Output Voltage Version



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## ELECTRICAL CHARACTERISTICS

Specification with standard type face are for $T_J$=25 , and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, $V_{IN}$=12V for the 3.3V, 5V, and Adjustable version and $V_{IN}$=24V for the 12V version. $I_{LOAD}$=500mA

| CHARACTERISTIC | SYMBOL | TEST CONDITION | | MIN. (Note 3) | TYP. (Note 2) | MAX. (Note 3) | UNIT |
|---|---|---|---|---|---|---|---|
| **SYSTEM PARAMETERS (Note 4)** | | | | | | | |
| Efficiency | η | LM1501AG-ADJ | $V_{IN}$=12V, $I_{LOAD}$=5A | | 68 | | % |
| | | LM1501AG-3.3 | $V_{IN}$=12V, $I_{LOAD}$=5A | | 68 | | |
| | | LM1501AG-5.0 | $V_{IN}$=12V, $I_{LOAD}$=5A | | 75 | | |
| | | LM1501AG-12 | $V_{IN}$=18V, $I_{LOAD}$=5A | | 84 | | |
| Output Voltage | $V_{OUT}$ | LM1501AG-3.3 | 5.5V ≤ $V_{IN}$ ≤ 40V | 3.168 | 3.3 | 3.432 | V |
| | | | 0.2A ≤ $I_{LOAD}$ ≤ 5A | **3.135** | | **3.465** | |
| | | LM1501AG-5.0 | 8V ≤ $V_{IN}$ ≤ 40V | 4.800 | 5.0 | 5.200 | |
| | | | 0.2A ≤ $I_{LOAD}$ ≤ 5A | **4.750** | | **5.250** | |
| | | LM1501AG-12 | 15V ≤ $V_{IN}$ ≤ 40V | 11.520 | 12 | 12.480 | |
| | | | 0.2A ≤ $I_{LOAD}$ ≤ 5A | **11.400** | | **12.600** | |
| Feedback Voltage | $V_{FB}$ | LM1501AG-ADJ | 5.2V ≤ $V_{IN}$ ≤ 40V<br>0.2A ≤ $I_{LOAD}$ ≤ 5A<br>$V_{OUT}$ programmed for 3V | 1.193<br>**1.180** | 1.23 | 1.267<br>**1.280** | V |
| **DEVICE PARAMETERS** | | | | | | | |
| Feedback Bias Current | $I_{FB}$ | Adjustable Version Only, $V_{FB}$=1.3V | | | 15 | 50 | nA |
| | | | | | | **100** | |
| Oscillator Frequency | $F_O$ | (Note 5) | | 127 | 150 | 173 | kHz |
| | | | | **120** | | **180** | |
| Saturation Voltage | $V_{SAT}$ | $I_{OUT}$=5A (Note 6, 7) | | | 1.65 | 1.85 | V |
| | | | | | | **2.00** | |
| Max Duty Cycle (ON) | DC | (Note 7) | | | 100 | | % |
| Max Duty Cycle (ON) | | $I_{LOAD}$ ≥ 4A | | | 50 | | |
| Min Duty Cycle (OFF) | | (Note 8) | | | 0 | | |
| Current Limit | $I_{CL}$ | Peak Current (Note 6, 7) | | | 6.9 | | A |
| Thermal Shutdown Temperature | $T_{SD}$ | (Note 10) | | | 185 | | ℃ |
| Output Leakage Current | $I_L$ | Output=0V (Note 6, 8) | | | | 50 | μA |
| | | Output=-1V (Note 9) | | | 10 | 30 | mA |
| Quiescent Current | $I_Q$ | (Note 8) | | | 5 | 10 | mA |
| Shutdown Current | $I_{SHUTDOWN}$ | ON/OFF pin = 5V(OFF) (Note 9) | | | 80 | 200 | μA |
| | | | | | | **250** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| **ON/OFF CONTROL** | | | | | | |
| ON/OFF Pin Logic Input Threshold voltage | | | | 1.3 | | V |
| | $V_{IH}$ | Low (Regulator ON) | | | 0.6 | |
| | $V_{IL}$ | High (Regulator OFF) | 2.0 | | | |
| ON/OFF Pin Logic Input current | $I_H$ | $V_{LOGIC}$ = 2.5V (regulator OFF) | | 5 | 15 | uA |
| | $I_L$ | $V_{LOGIC}$ = 0.5V (regulator ON) | | 0.02 | 5 | |

Note 1. Absolute Maximum Rating indicate limits beyond which damage to the device may occur. Operating Ratings indicate condition for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2: Typical numbers are at 25 and represent the most likely norm.

Note 3: All limits guaranteed at room temperature (standard type face) and at temperature extremes (bold type face).

Note 4: External components such as the schottky diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance. When the LM1501AG is used as shown in the typical circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

Note 5: The switching frequency is reduced when the second stage current limit is activated. The amount of reduction is determined by the severity of current over-load.

Note 6: No diode, inductor or capacitor connected to output pin.

Note 7: Feedback pin removed from output and connected to 0V to force the output transistor switch ON.

Note 8: Feedback 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.

Note 9: VIN = 40V.

Note 10: Guaranteed by design, not tested.



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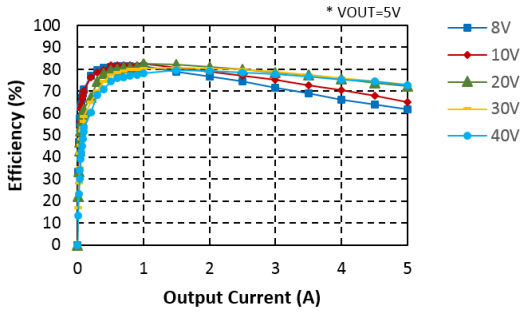
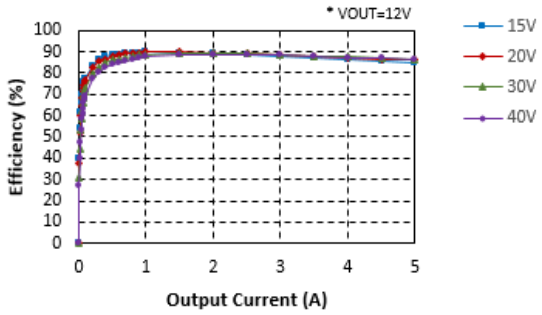
## TYPICAL OPERATING CHARACTERISTIC

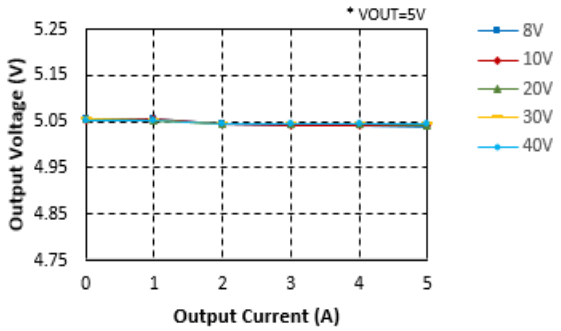
Efficiency vs. IOUT



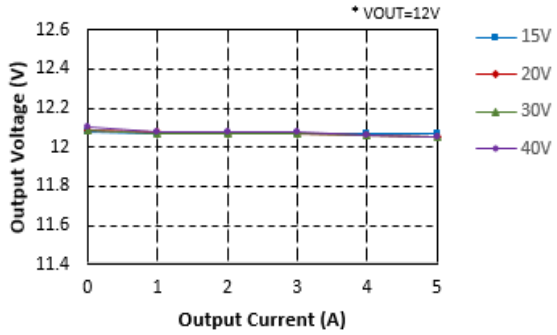

Efficiency vs. IOUT



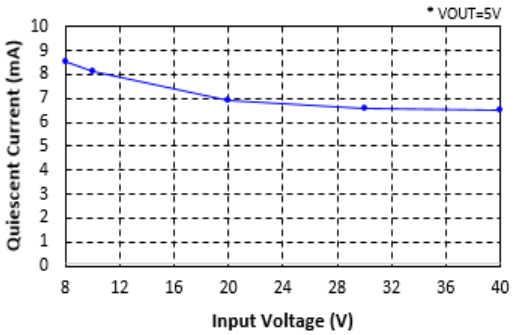

VOUT vs. IOUT



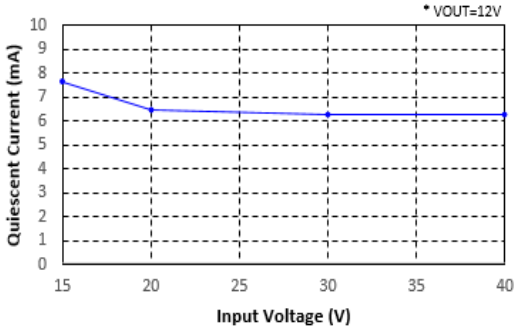

VOUT vs. IOUT




IQ vs. VIN




IQ vs. VIN



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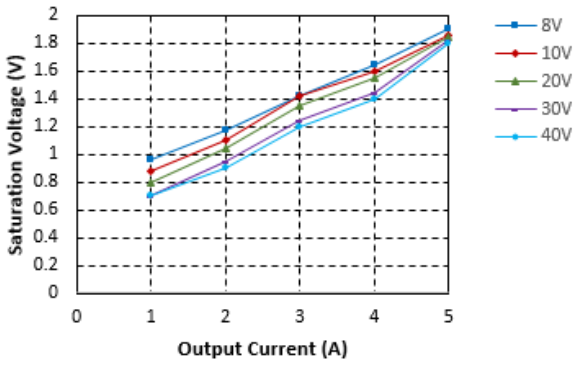
VSAT vs. IOUT



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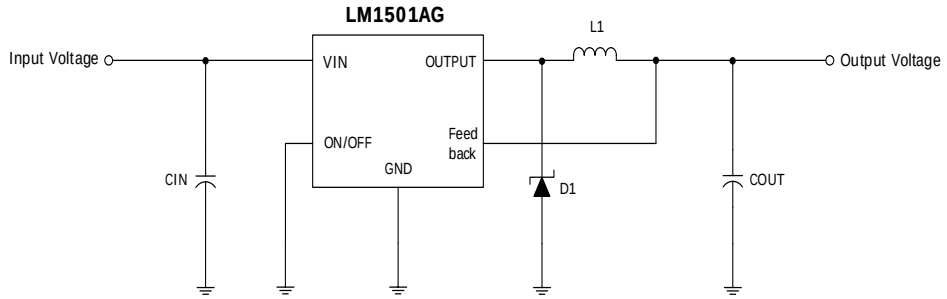
## APPLICATION INFORMATION

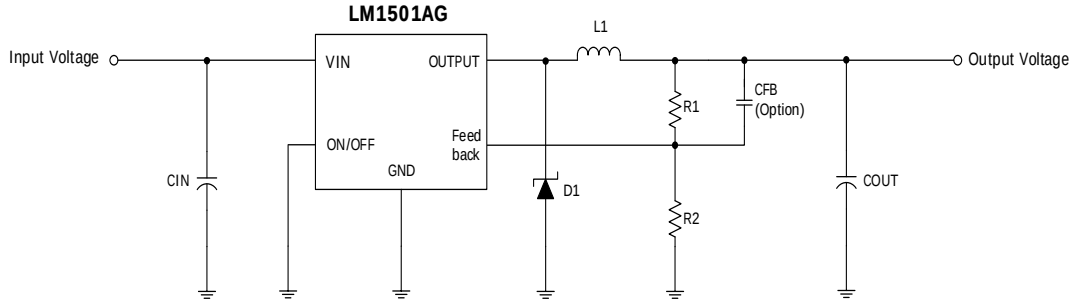
As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance generate voltage transients which can cause problems. For minimal inductance and ground loops, the length of the wires should be kept as short as possible. Single-point grounding or ground plane construction should be used for best results. Keep the feedback wiring away from the inductor flux

- Fixed Output Voltage Version




[Figure 1]

- Adjustable Output Voltage Version




[Figure 2]

* $V_{OUT} = V_{FB}(1+\frac{R1}{R2})$, Where $V_{FB}$ = 1.23V



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## REVISION NOTICE

The description in this datasheet is subject to change without any notice to describe its electrical characteristics properly.



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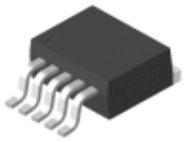
# 5A, 300KHz, Step-Down Switching Regulator LM1501BG

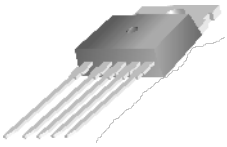
## FEATURES

- 3.3V, 5V, 12V, and adjustable output versions
- Adjustable version output voltage range
- Guaranteed 5A output load current
- Input voltage range up to 40V
- 300KHz fixed frequency internal oscillator
- Excellent line and load regulation
- Thermal shutdown and current limit protection

TO-263-5L PKG



TO-220-5L PKG



## APPLICATION

- Simple high-efficiency step-down regulator
- On-card switching regulators
- Positive to negative converter

**ORDERING INFORMATION**

| Device | Package |
|---|---|
| LM1501BGR-X.X | TO-263-5L |
| LM1501BGT-X.X | TO-220-5L |

X.X = Output Voltage = 3.3, 5.0, 12, ADJ

## DESCRIPTION

The LM1501BG series of regulators are monolithic integrated circuits that provide all the active functions for a step-down switching regulator, capable of driving a 5A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and they include internal frequency compensation and a fixed-frequency oscillator. The LM1501BG series operates at a switching frequency of 300kHz thus allowing smaller sized filter components than what would be needed 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. External shutdown is included, featuring typically 80uA standby current. Self-protection features include a two stage frequency reducing current limit for output switch and an over temperature shutdown for complete protection under fault conditions.

## ABSOLUTE MAXIMUM RATINGS (Note 1)

| CHARACTERISTIC | SYMBOL | VALUE | UNIT |
|---|---|---|---|
| Maximum Input Supply Voltage | $V_{IN\_MAX}$ | 45 | V |
| ON/OFF Pin Input Voltage | $V_{ON/OFF}$ | $-0.3 \le V \le +25$ | V |
| Feedback Pin Voltage | $V_{FB}$ | $-0.3 \le V \le +25$ | V |
| Output Voltage to Ground (Steady State) | $V_{OUT}$ | -1 | V |
| Power Dissipation | $P_D$ | Internally limited | W |
| Storage Temperature Range | $T_{STG}$ | -65 to +150 | °C |
| Operating Temperature Range | $T_J$ | 150 | °C |



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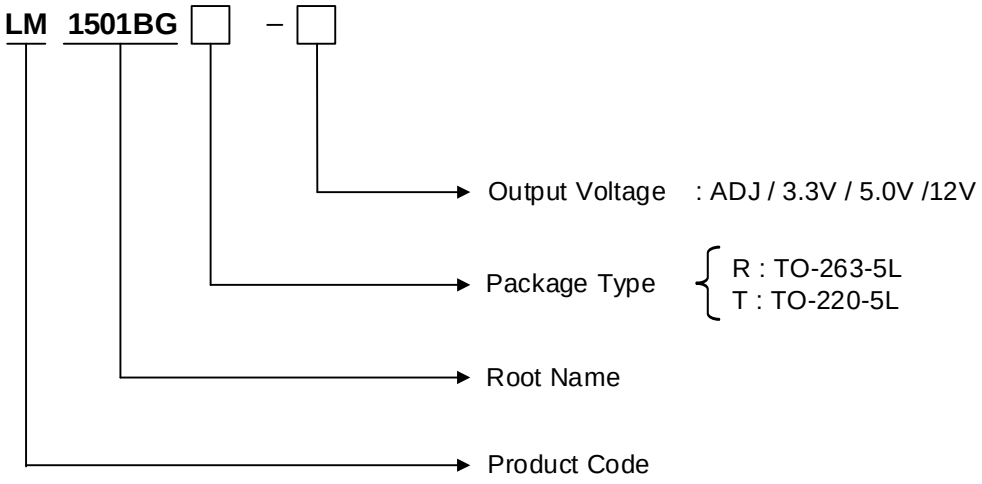
## RECOMMENDED OPERATING CONDITIONS

| CHARACTERISTIC | SYMBOL | MIN. | MAX. | UNIT |
|---|---|---|---|---|
| Supply Voltage | $V_{IN}$ | - | 40 | V |
| Load Current | ILOAD | - | 5 | A |
| Junction Temperature | $T_J$ | -40 | 125 | |

## ORDERING INFORMATION

| VOUT | PACKAGE | ORDER NO. | DESCRIPTION | STATUS |
|---|---|---|---|---|
| ADJ | TO-263-5L | LM1501BGR-ADJ | 5A, 300KHz | Active |
| | TO-220-5L | LM1501BGT-ADJ | 5A, 300KHz | Active |
| 3.3V | TO-263-5L | LM1501BGR-3.3 | 5A, 300KHz | Active |
| | TO-220-5L | LM1501BGT-3.3 | 5A, 300KHz | Active |
| 5.0V | TO-263-5L | LM1501BGR-5.0 | 5A, 300KHz | Active |
| | TO-220-5L | LM1501BGT-5.0 | 5A, 300KHz | Active |
| 12V | TO-263-5L | LM1501BGR-12 | 5A, 300KHz | Active |
| | TO-220-5L | LM1501BGT-12 | 5A, 300KHz | Active |



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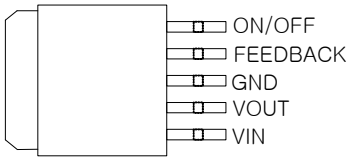
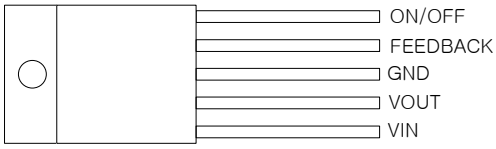
## PIN CONFIGURATION




TO-263-5L



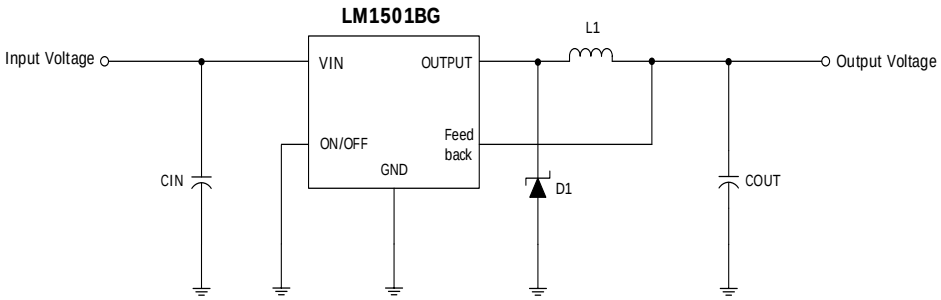

TO-220-5L

## PIN DESCRIPTION

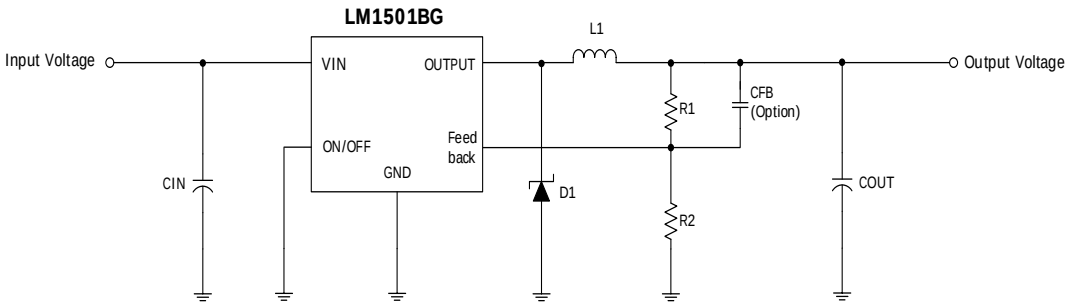
| PIN NO. | TO-263-5L / TO-220-5L PKG | |
|---|---|---|
| | NAME | FUNCTION |
| 1 | VIN | Operating Input Voltage |
| 2 | OUTPUT | Switching Output Voltage |
| 3 | GND | Ground |
| 4 | FB | Output Voltage Feedback Control |
| 5 | ON/OFF | ON/OFF Shutdown |

## TYPICAL APPLICATION

- Fixed Output Voltage Version




- Adjustable Output Voltage Version



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## ELECTRICAL CHARACTERISTICS

Specification with standard type face are for $T_J$=25 , and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, $V_{IN}$=12V for the 3.3V, 5V, and Adjustable version and $V_{IN}$=24V for the 12V version. $I_{LOAD}$=500mA

| CHARACTERISTIC | SYMBOL | TEST CONDITION | | MIN. (Note 3) | TYP. (Note 2) | MAX. (Note 3) | UNIT |
|---|---|---|---|---|---|---|---|
| **SYSTEM PARAMETERS (Note 4)** | | | | | | | |
| Efficiency | η | LM1501BG-ADJ | $V_{IN}$=12V, $I_{LOAD}$=5A | | 80 | | % |
| | | LM1501BG-3.3 | $V_{IN}$=12V, $I_{LOAD}$=5A | | 70 | | |
| | | LM1501BG-5.0 | $V_{IN}$=12V, $I_{LOAD}$=5A | | 75 | | |
| | | LM1501BG-12 | $V_{IN}$=18V, $I_{LOAD}$=5A | | 85 | | |
| Output Voltage | $V_{OUT}$ | LM1501BG-3.3 | 5.5V ≤ $V_{IN}$ ≤ 40V | 3.168 | 3.3 | 3.432 | V |
| | | | 0.2A ≤ $I_{LOAD}$ ≤ 5A | **3.135** | | **3.465** | |
| | | LM1501BG-5.0 | 8V ≤ $V_{IN}$ ≤ 40V | 4.800 | 5.0 | 5.200 | |
| | | | 0.2A ≤ $I_{LOAD}$ ≤ 5A | **4.750** | | **5.250** | |
| | | LM1501BG-12 | 15V ≤ $V_{IN}$ ≤ 40V | 11.520 | 12 | 12.480 | |
| | | | 0.2A ≤ $I_{LOAD}$ ≤ 5A | **11.400** | | **12.600** | |
| Feedback Voltage | $V_{FB}$ | LM1501BG-ADJ | 5.2V ≤ $V_{IN}$ ≤ 40V<br>0.2A ≤ $I_{LOAD}$ ≤ 5A<br>$V_{OUT}$ programmed for 3V | 1.193<br>**1.180** | 1.23 | 1.267<br>**1.280** | V |
| **DEVICE PARAMETERS** | | | | | | | |
| Feedback Bias Current | $I_{FB}$ | Adjustable Version Only, $V_{FB}$=1.3V | | | 15 | 50 | nA |
| | | | | | | **100** | |
| Oscillator Frequency | $F_O$ | (Note 5) | | 255 | 300 | 345 | kHz |
| | | | | **235** | | **365** | |
| Saturation Voltage | $V_{SAT}$ | $I_{OUT}$=5A (Note 6, 7) | | | 1.65 | 1.85 | V |
| | | | | | | **2.00** | |
| Max Duty Cycle (ON) | DC | (Note 7) | | | 100 | | % |
| Max Duty Cycle (ON) | | $I_{LOAD}$ ≥ 4A | | | 50 | | |
| Min Duty Cycle (OFF) | | (Note 8) | | | 0 | | |
| Current Limit | $I_{CL}$ | Peak Current (Note 6, 7) | | | 6.9 | | A |
| Thermal Shutdown Temperature | $T_{SD}$ | (Note 10) | | | 185 | | ℃ |
| Output Leakage Current | $I_L$ | Output=0V (Note 6, 8) | | | | 50 | μA |
| | | Output=-1V (Note 9) | | | 10 | 30 | mA |
| Quiescent Current | $I_Q$ | (Note 8) | | | 5 | 10 | mA |
| Shutdown Current | $I_{SHUTDOWN}$ | ON/OFF pin = 5V(OFF) (Note 9) | | | 80 | 200 | μA |
| | | | | | | **250** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| **ON/OFF CONTROL** | | | | | | |
| ON/OFF Pin Logic Input Threshold voltage | | | | 1.3 | | V |
| | $V_{IH}$ | Low (Regulator ON) | | | 0.6 | |
| | $V_{IL}$ | High (Regulator OFF) | 2.0 | | | |
| ON/OFF Pin Logic Input current | $I_H$ | $V_{LOGIC}$ = 2.5V (regulator OFF) | | 5 | 15 | uA |
| | $I_L$ | $V_{LOGIC}$ = 0.5V (regulator ON) | | 0.02 | 5 | |

**Note 1.** Absolute Maximum Rating indicate limits beyond which damage to the device may occur. Operating Ratings indicate condition for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

**Note 2:** Typical numbers are at 25℃ and represent the most likely norm.

**Note 3:** All limits guaranteed at room temperature (standard type face) and at temperature extremes (**bold type face).**

**Note 4:** External components such as the schottky diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance. When the LM1501BG is used as shown in the typical circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

**Note 5:** The switching frequency is reduced when the second stage current limit is activated. The amount of reduction is determined by the severity of current over-load.

**Note 6:** No diode, inductor or capacitor connected to output pin.

**Note 7:** Feedback pin removed from output and connected to 0V to force the output transistor switch ON.

**Note 8:** Feedback 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.

**Note 9:** VIN = 40V.

**Note 10:** Guaranteed by design, not tested.



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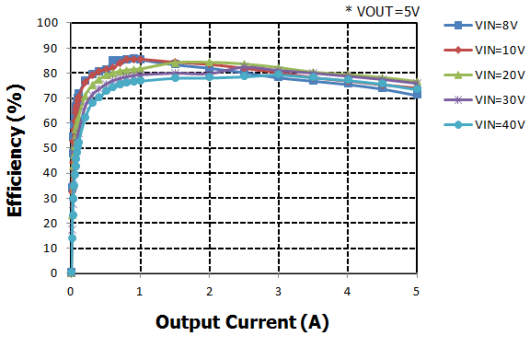
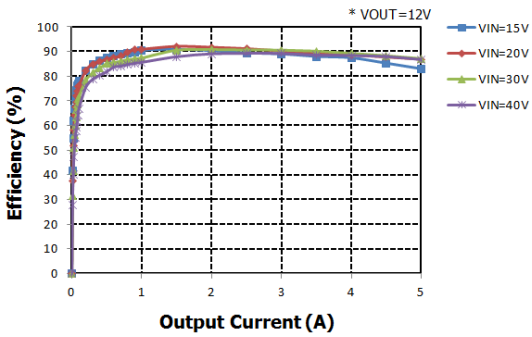
## TYPICAL OPERATING CHARACTERISTIC

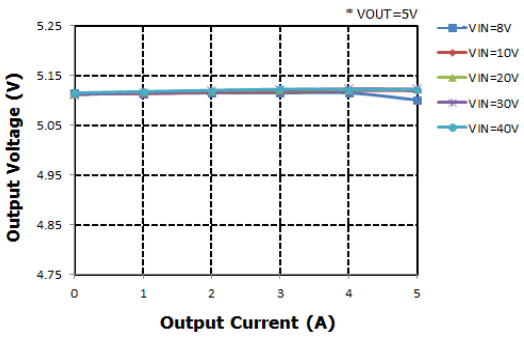
Efficiency vs. IOUT



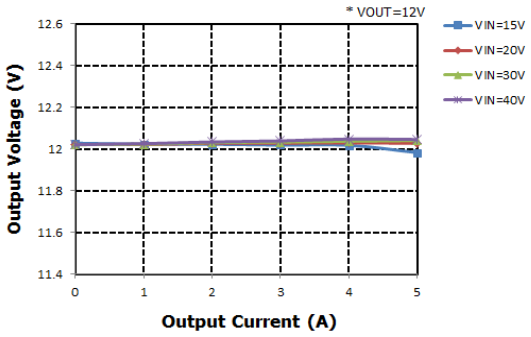

Efficiency vs. IOUT



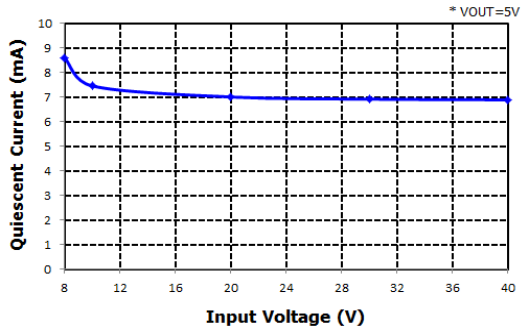

VOUT vs. IOUT



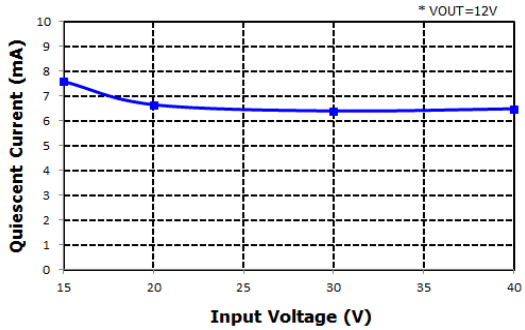

VOUT vs. IOUT




IQ vs. VIN




IQ vs. VIN



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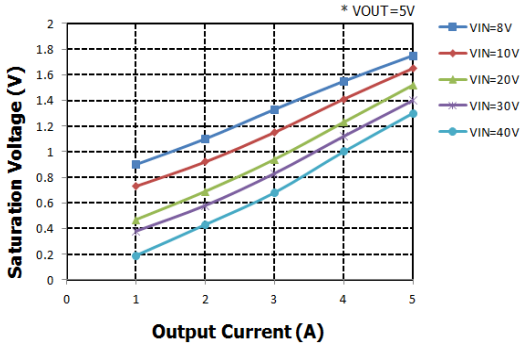
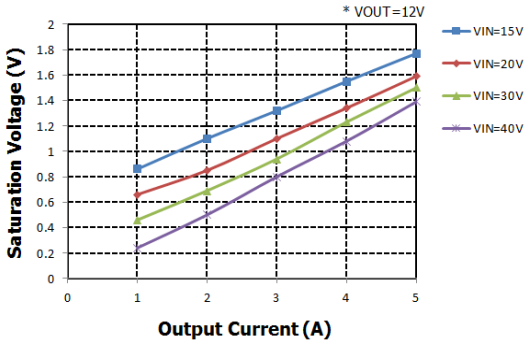
VSAT vs. IOUT




VSAT vs. IOUT



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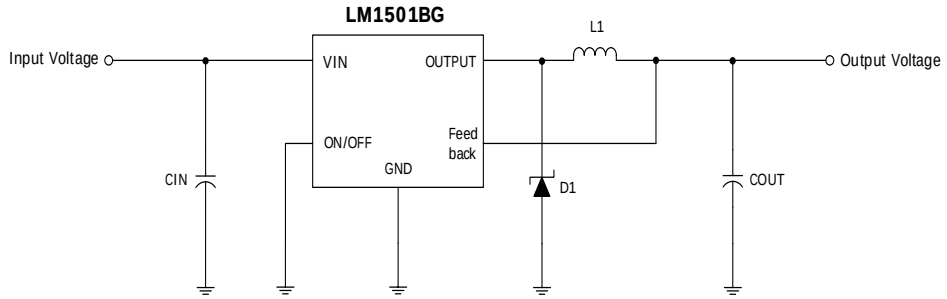
## APPLICATION INFORMATION

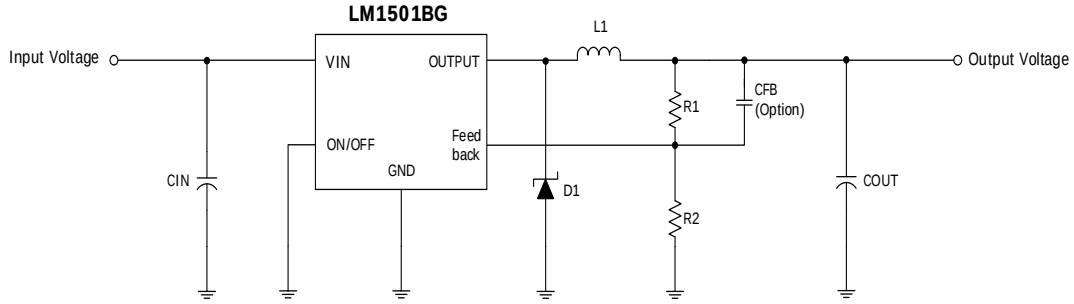
As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance generate voltage transients which can cause problems. For minimal inductance and ground loops, the length of the wires should be kept as short as possible. Single-point grounding or ground plane construction should be used for best results. Keep the feedback wiring away from the inductor flux

- Fixed Output Voltage Version




[Figure 1]

- Adjustable Output Voltage Version




[Figure 2]

* $V_{OUT} = V_{FB}(1+\frac{R1}{R2})$, Where $V_{FB}$ = 1.23V



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## REVISION NOTICE

The description in this datasheet is subject to change without any notice to describe its electrical characteristics properly.



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