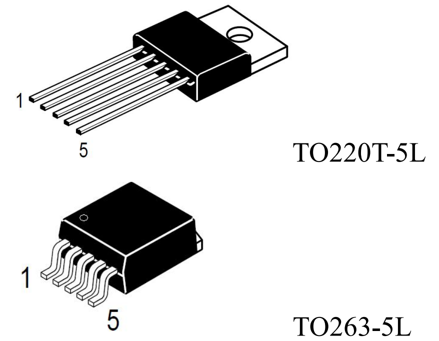
# D2576HV

## 3A Step-Down HV Voltage Regulator

## General Description




The D2576HV series of regulators are monolithic integrated circuit that provides all the active functions for a step-down (buck) switching regulator, capable of driving 3A load with excellent line and load regulation. The D2576HV available in fixed output voltages of 3.3V, 5V, 12Vand an adjustable output version.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation and a fixed-frequency oscillator.

The D2576HV series offers a high-efficiency replacement for popular three-terminal linear regulators. It substantially reduces the size of the heat sink, and in some cases no heat sink is required. A standard series of inductors optimized for use with the D2576HV are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies.

Other features include a guaranteed ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±10% on the oscillator frequency. External shutdown is included, featuring 50 µA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

The D2576HV is available in TO220T-5L and TO263-5L package.

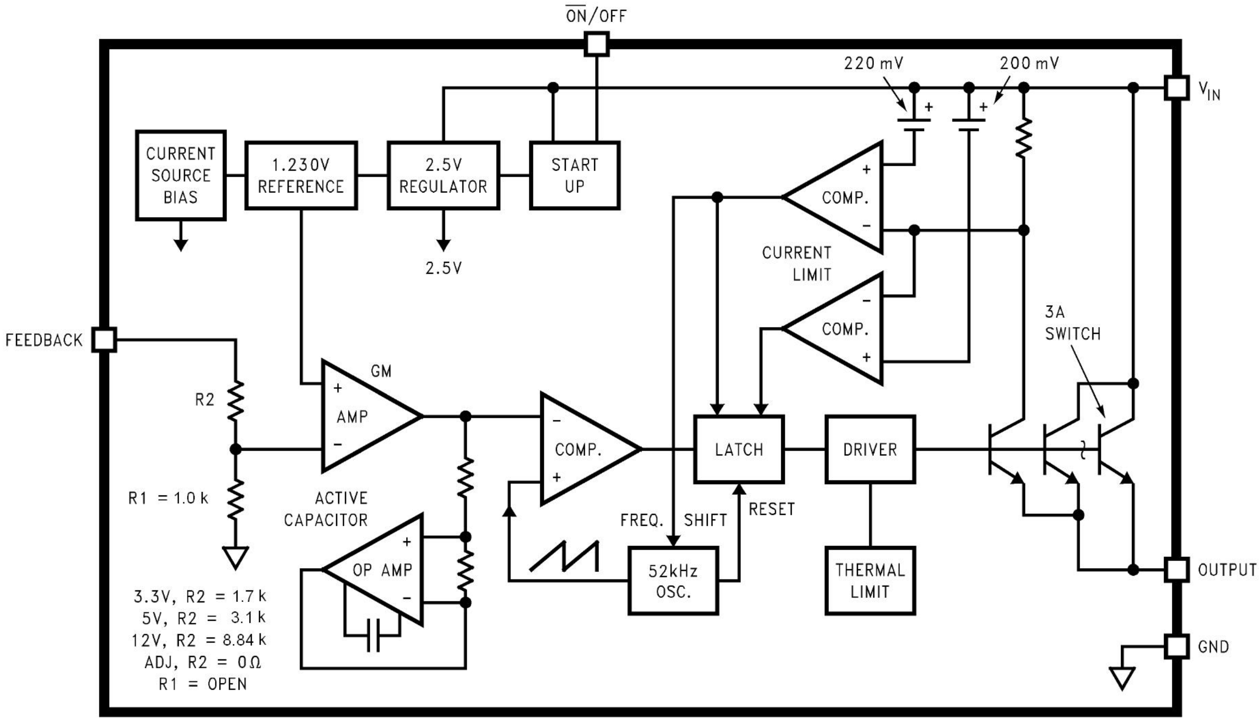
## Features

- 3.3V, 5V, 12V and adjustable output versions
- Wide input voltage range, 40V up to 60V for HV version
- High efficiency
- Specified 3A output current
- 52 kHz fixed frequency internal oscillator
- TTL shutdown capability, low power standby mode
- Uses readily available standard inductors
- Thermal shutdown and current limit protection
- Adjustable version output voltage range, 1.23V to 57V ±4% max over line and load conditions

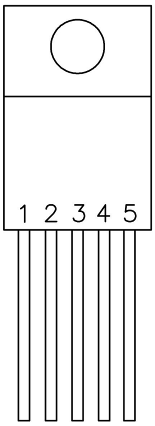
## Applications

- Simple high-efficiency step-down (Buck) regulator
- Efficient pre-regulator for linear regulators
- On-card switching regulators
- Positive to negative converter (Buck-Boost)

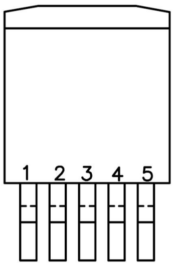
## Functional Block Diagram



## Pin Configuration




TO220T-5L




TO263-5L

## Pin Description

| Pin Number | Pin Name | Function Description |
|---|---|---|
| 1 | VIN | This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be present at this pin to minimize voltage transients and to supply the switching currents needed by the regulator. |
| 2 | OUTPUT | Internal switch, the voltage at this pin switches between (+$V_{IN}$ $V_{SAT}$) and approximately -0.5V. To minimize coupling to sensitive circuitry, the PC board copper area connected to this pin should be kept to a minimum. |
| 3 | GND | Circuit Ground |
| 4 | FEEDBACK | Senses the regulated output voltage to complete the feedback loop. |
| 5 | $\overline{ON}$ / *OFF* | Allows the switching regulator circuit to be shut down using logic level signals |

## Absolute Maximum Ratings

| Parameter Name | Symbol | Value | Unit |
|---|---|---|---|
| Maximum Supply Voltage | $V_{IN}$ | 63 | V |
| $\overline{ON}$ / *OFF* Pin Input Voltage | $\overline{ON}$ / *OFF* | -0.3V≤V≤+$V_{IN}$ | V |
| Output Voltage to Ground(steady state) | $V_{OUT}$ | -1 | V |
| Power Dissipation | $P_{DMAX}$ | Internally Limited | |
| Storage Temperature Range | Tstg | -65~+150 | ℃ |
| Maximum Junction Temperature | $T_{JA}$ | 150 | ℃ |
| ESD Susceptibility (Human Body Model) | ESD | 2 | kV |
| Lead Temperature (Soldering, 10 Seconds) | $T_L$ | 260 | ℃ |

## Recommended Operating Conditions

| Parameter Name | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{IN}$ | 6~60 | V |
| Operating temperature range | Topr | -40~+125 | ℃ |

## Electrical Characteristics

（Unless otherwise specified: $T_J$ = 25°C）

| Parameter Name | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Device Parameters** | | | | | | |
| Feedback Bias Current | Ib | Adjustable version only, $V_{OUT}$=5V | | 50 | 100 | nA |
| Oscillator Frequency | fo | (Note 1) | 47 | 52 | 58 | kHz |
| $V_{SAT}$ Saturation Voltage | $V_{SAT}$ | $I_{OUT}$=3A | | 1.4 | 1.8 | V |
| Max. Duty Cycle(ON) | DC | | 93 | 98 | | % |
| Current Limit | $I_{CL}$ | (Note 1) | 4.2 | 5.8 | 6.9 | A |
| Output Leakage Current | $I_L$ | Output=0V | | | 2 | mA |
| | | Output=-1V | | 7.5 | 30 | mA |
| Quiescent Current | $I_Q$ | | | 5 | 10 | mA |
| Standby Quiescent Current | $I_{STBY}$ | $\overline{ON}/OFF$ pin=5V(OFF) | | 50 | 200 | µA |
| $\overline{ON}/OFF$ **Control** | | | | | | |
| $\overline{ON}/OFF$ Pin Logic Input Level | $V_{IH}$ | $V_{OUT}$=0V | 2.0 | | | V |
| | $V_{IL}$ | $V_{OUT}$=nominal output voltage | | | 0.8 | V |
| $\overline{ON}/OFF$ Pin Input Current | $I_{IH}$ | $\overline{ON}/OFF$ pin=5V(OFF) | | 12 | 30 | µA |
| | $I_{IL}$ | $\overline{ON}/OFF$ pin=0V(ON) | | 0 | 10 | µA |

**Note 1:** The oscillator frequency reduces to approximately 11 kHz 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 protection feature lowers the average power dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.

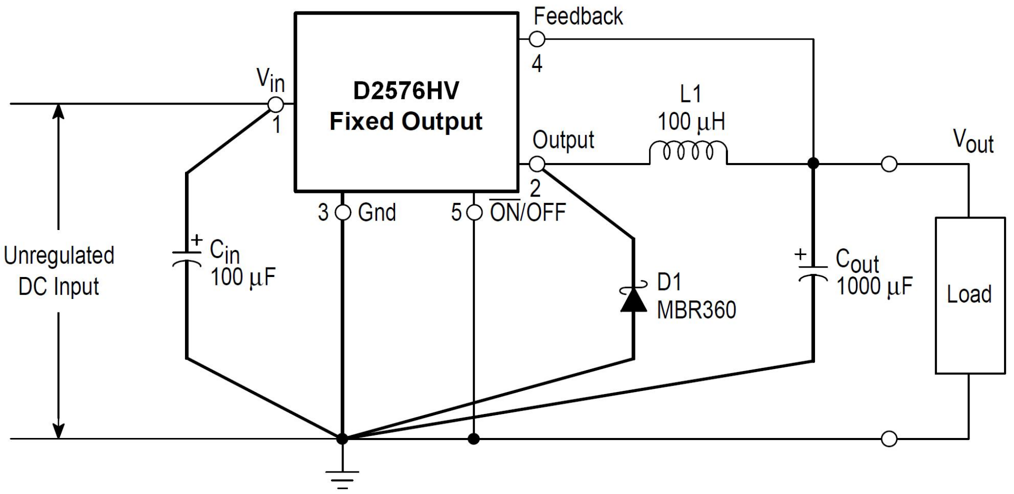
Output pin sourcing current. No diode, inductor or capacitor connected to output.

| Parameter Name | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **D2576HV-3.3V** | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$=12V, $I_O$=500mA | 3.234 | 3.3 | 3.366 | V |
| | | 6V≤$V_{IN}$≤60V<br>0.5A≤$I_{LOAD}$≤3A | 3.168 | 3.3 | 3.450 | V |
| Efficiency | η | $V_{IN}$=12V, $I_{LOAD}$=3A | | 75 | | % |
| **D2576HV-5.0V** | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$=12V, $I_O$=500mA | 4.90 | 5.00 | 5.10 | V |
| | | 8V≤$V_{IN}$≤60V<br>0.5A≤$I_{LOAD}$≤3A | 4.800 | 5.0 | 5.225 | V |
| Efficiency | η | $V_{IN}$=12V, $I_{LOAD}$=3A | | 77 | | % |
| **D2576HV-12V** | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$=25V, $I_O$=500mA | 11.76 | 12.00 | 12.24 | V |
| | | 15V≤$V_{IN}$≤60V<br>0.5A≤$I_{LOAD}$≤3A | 11.52 | 12.00 | 12.54 | V |
| Efficiency | η | $V_{IN}$=25V, $I_{LOAD}$=3A | | 88 | | % |

| Parameter Name | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **D2576HV-ADJ** | | | | | | |
| Output Voltage | $V_{OUT}$ | $V_{IN}$=12V,$I_O$=500mA,<br>$V_{OUT}$=5V | 1.217 | 1.230 | 1.243 | V |
| | | 8V≤$V_{IN}$≤60V, $V_{OUT}$=5V<br>0.5A≤$I_{LOAD}$≤3A | 1.193 | 1.230 | 1.273 | V |
| Efficiency | η | $V_{IN}$=12V,$I_{LOAD}$=3A,<br>$V_{OUT}$=5V | | 77 | | % |

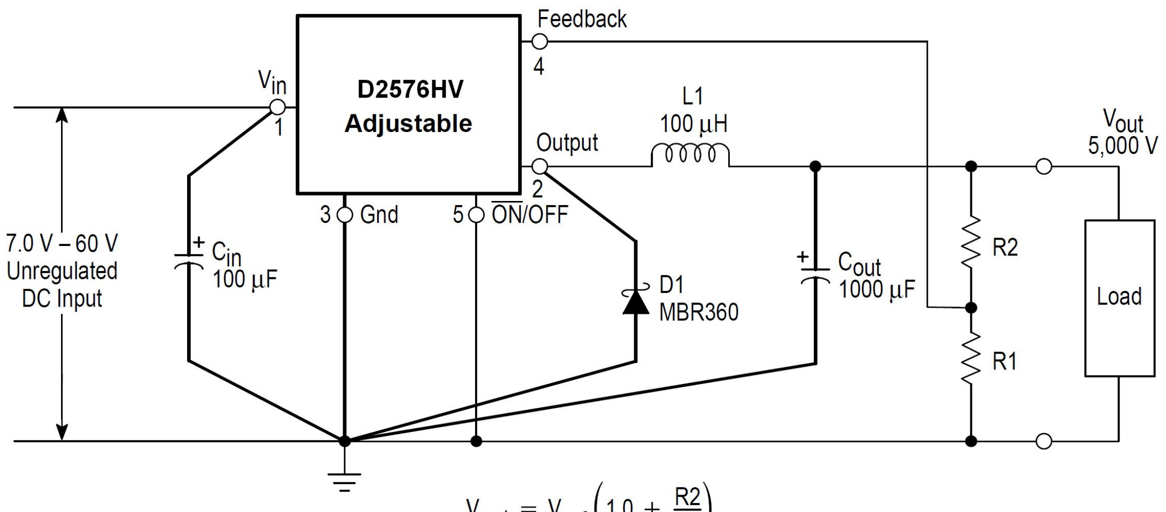
## Test Circuit

### Fixed Output Voltage Versions




| | | |
|---|---|---|
| $C_{in}$ | – | 100 µF, 100 V, Aluminium Electrolytic |
| $C_{out}$ | – | 1000 µF, 25 V, Aluminium Electrolytic |
| D1 | – | Schottky, MBR360 |
| L1 | – | 100 µH, Pulse Eng. PE–92108 |
| R1 | – | 2.0 k, 0.1% |
| R2 | – | 6.12 k, 0.1% |

### Adjustable Output Voltage Versions

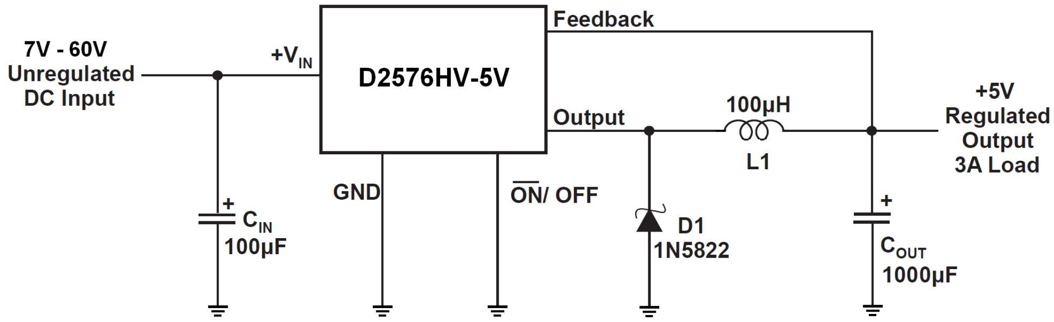



$$V_{out} = V_{ref}\left(1.0 + \frac{R2}{R1}\right)$$

$$R2 = R1\left(\frac{V_{out}}{V_{ref}} - 1.0\right)$$

Where $V_{ref}$ = 1.23 V, R1 between 1.0 k and 5.0 k

## Typical Application




## Application Information

### Input Capacitor ($C_{IN}$)

To maintain stability, the regulator input pin must be bypassed with at least a 100 µF electrolytic capacitor. The capacitor's leads must be kept short, and located 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 will increase the regulator stability at cold temperatures. For maximum capacitor operating lifetime, the capacitor's RMS ripple current rating should 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 D2576HV 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 will be approximately 20% to 30% of the maximum DC current. With relatively heavy load currents, the circuit operates in the continuous mode (inductor current always flowing), but under light load conditions, the circuit will be 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, toriod, E-frame, bobbin core, etc., as well as different core materials, such as ferrites and powdered iron. The least expensive, the bobbin core type, consists of wire wrapped on a ferrite rod core. This type of construction makes for an inexpensive inductor, but since the magnetic flux is not completely contained within the core, it 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. The inductors listed in the selection chart include ferrite pot core construction for AIE, powdered iron toroid for Pulse Engineering, and ferrite bobbin core for Renco.

An inductor should not be operated 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) This will cause the switch current to rise very rapidly. Different inductor types have different saturation characteristics, and this should be kept in mind when selecting an inductor.

The inductor manufacturer's data sheets include current and energy limits to avoid inductor saturation.

### Inductor Ripple Current

When the switcher 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 will reach zero, and the switcher will change 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) will be forced to run discontinuous if the load current is light enough.

### Catch Diode

Buck regulators require a diode to provide a return path for the inductor current when the switch is off. This diode should be located close to the D2576HV 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 turn-off characteristic may cause instability and EMI problems. A fast-recovery diode with soft recovery characteristics is a better choice. Standard 60 Hz diodes (e.g., 1N4001 or1N5400, etc.) are also not suitable**.**

## Output Capacitor

An output capacitor is required to filter the output voltage and is needed for loop stability. The capacitor should be located near the D2576HV using short pc board traces. Standard aluminum electrolytics are usually adequate, but low ESR types are recommended for low output ripple voltage and good stability. The ESR of a capacitor depends on many factors, some which are: 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 the section on inductor ripple current in Application Hints. The lower capacitor values (220 µF–1000 µF) will allow typically 50 mV to 150 mV of output ripple voltage, while larger-value capacitors will reduce the ripple to approximately20 mV to 50mV.Output Ripple Voltage = ($\Delta I_{IND}$) (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 will reduce the output ripple to 10 mV or 20 mV. 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 should 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 capacitor’s ripple current rating at 52 kHz should be at least 50% higher than the peak-to-peak inductor ripple current.

## Output Voltage Ripple and Transients

The output voltage of a switching power supply will contain a sawtooth ripple voltage at the switcher frequency, typically about 1% of the output voltage, 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 the ESR of the output capacitor. 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 (20 µH & 100 µF) can be added to the output to further reduce the amount of output ripple and transients. A 10 × reduction in output ripple voltage and transients is possible with this filter.

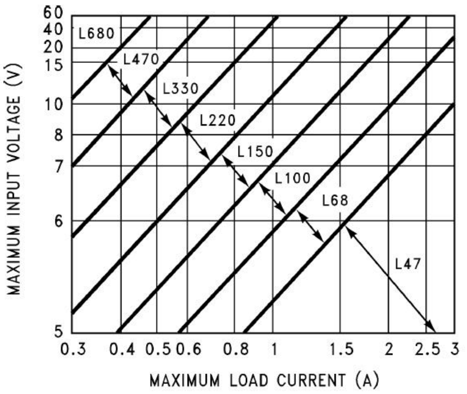
## Feedback Connection

The D2576HV (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 D2576HV to avoid picking up unwanted noise. Avoid using resistors greater than 100kΩ because of the increased chance of noise pickup.

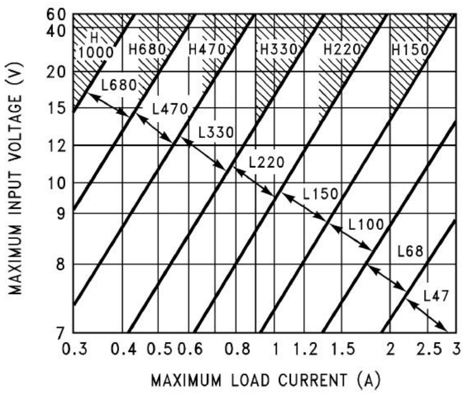
## $\overline{ON}/OFF$ Input

For normal operation, the $\overline{ON}/OFF$ pin should be grounded or driven with a low-level TTL voltage (typically below 1.6V). To put the regulator into standby mode, drive this pin with a high-level TTL or CMOS signal. 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 should not be left open.

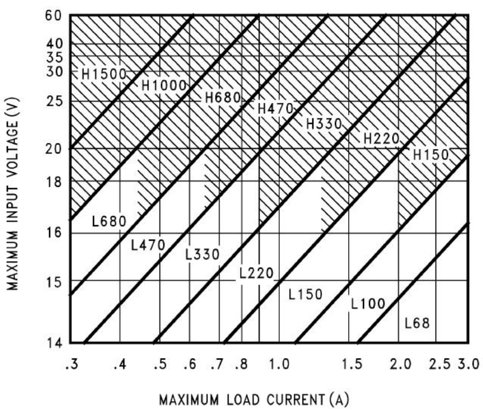
**Inductor Value Selection Guides ( For Continuous Mode Operation)**



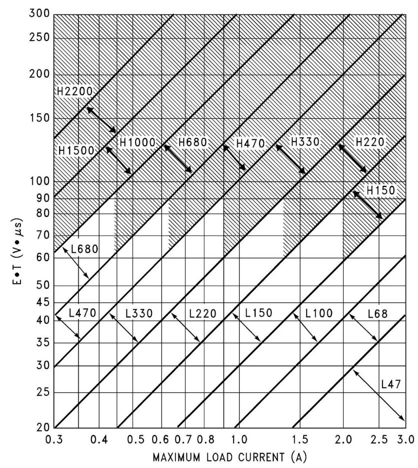

D2576HV-3.3




D2576HV-5.0




D2576HV-12




D2576HV-ADJ

| Inductor Code | Inductor Value | Schott | Pulse Eng. | Renco |
|---|---|---|---|---|
| L47 | 47 µH | 671 26980 | PE-53112 | RL2442 |
| L68 | 68 µH | 671 26990 | PE-92114 | RL2443 |
| L100 | 100 µH | 671 27000 | PE-92108 | RL2444 |
| L150 | 150 µH | 671 27010 | PE-53113 | RL1954 |
| L220 | 220 µH | 671 27020 | PE-52626 | RL1953 |
| L330 | 330 µH | 671 27030 | PE-52627 | RL1952 |
| L470 | 470 µH | 671 27040 | PE-53114 | RL1951 |
| L680 | 680 µH | 671 27050 | PE-52629 | RL1950 |
| H150 | 150 µH | 671 27060 | PE-53115 | RL2445 |
| H220 | 220 µH | 671 27070 | PE-53116 | RL2446 |
| H330 | 330 µH | 671 27080 | PE-53117 | RL2447 |
| H470 | 470 µH | 671 27090 | PE-53118 | RL1961 |
| H680 | 680 µH | 671 27100 | PE-53119 | RL1960 |
| H1000 | 1000 µH | 671 27110 | PE-53120 | RL1959 |
| H1500 | 1500 µH | 671 27120 | PE-53121 | RL1958 |
| H2200 | 2200 µH | 671 27130 | PE-53122 | RL2448 |

Inductor Selection Guide

<table>
<tr><th rowspan="2">$V_R$</th><th colspan="2">Schottky</th><th colspan="2">Fast Recovery</th></tr>
<tr><th>3A</th><th>4A–6A</th><th>3A</th><th>4A–6A</th></tr>
<tr><td>20V</td><td>1N5820<br>MBR320P<br>SR302</td><td>1N5823</td><td rowspan="5">The following diodes are all rated to 100V<br><br>31DF1<br>HER302</td><td rowspan="5">The following diodes are all rated to 100V<br><br>50WF10<br>MUR410<br>HER602</td></tr>
<tr><td>30V</td><td>1N5821<br>MBR330<br>31DQ03<br>SR303</td><td>50WQ03<br>1N5824</td></tr>
<tr><td>40V</td><td>1N5822<br>MBR340<br>31DQ04<br>SR304</td><td>MBR340<br>50WQ04<br>1N5825</td></tr>
<tr><td>50V</td><td>MBR350<br>31DQ05<br>SR305</td><td>50WQ05</td></tr>
<tr><td>60V</td><td>MBR360<br>DQ06<br>SR306</td><td>50WR06<br>50SQ060</td></tr>
</table>

Diode Selection Guide

## Grounding

To maintain output voltage stability, the power ground connections must be low-impedance. For the 5-lead TO-220T and TO-263 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/Thermal Considerations

In many cases, only a small heat sink is required to keep the D2576HV 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 D2576HV). For a safe, conservative design, a temperature approximately 15°C cooler than the maximum temperatures should be selected.
4. D2576HV package thermal resistances $\theta_{JA}$ and $\theta_{JC}$.

Total power dissipated by the D2576HV 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 Performance 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. (3)

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:

$\Delta T_J = (P_D)\ (\theta_{JA})$ (4)

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

$T_J = \Delta T_J + T_A$ (5)

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

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

$\Delta T_J = (P_D)\ (\theta_{JC} + \theta_{interface} + \theta_{Heat\ sink})$ (6)

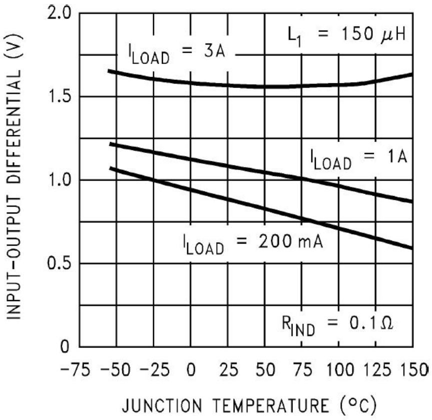
The operating junction temperature will be:

$T_J = T_A + \Delta T_J$ (7)

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). Included on the Switcher Made Simple design software is a more precise (non-linear) thermal model that can be used to determine junction temperature with different input-output parameters or different component values. It can also calculate the heat sink thermal resistance required to maintain the regulators junction temperature below the maximum operating temperature.

## Characteristic Curves

**Dropout Voltage**

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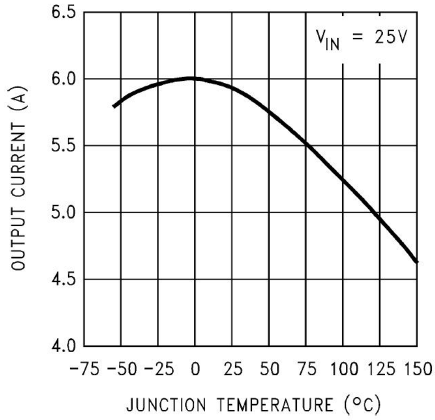
**Current Limit**

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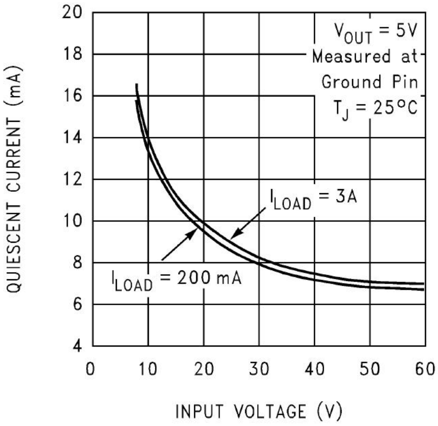
**Quiescent Current**

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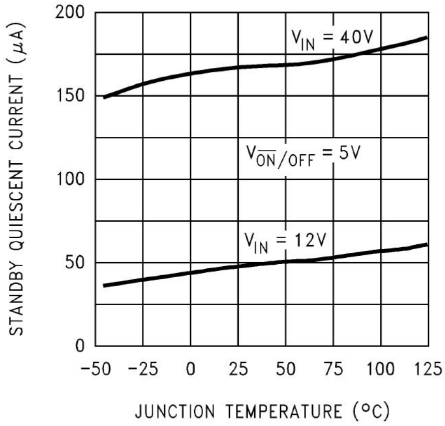
**Standby Quiescent Current**

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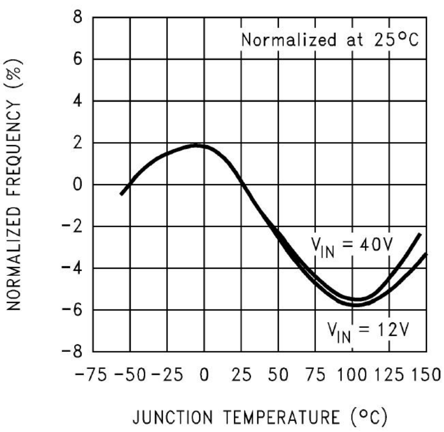
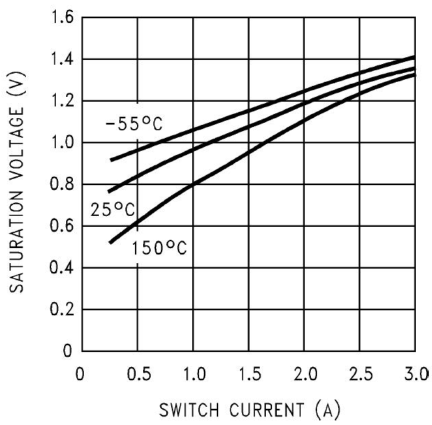
**Oscillator Frequency**

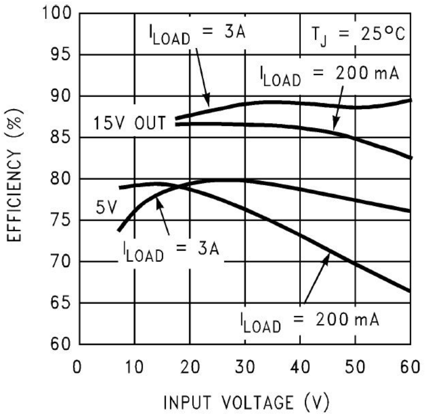



**Switch Saturation Voltage**

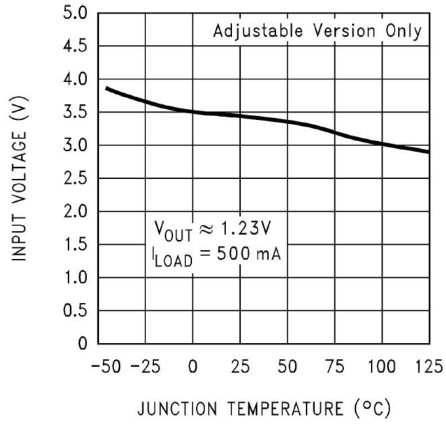


## Characteristic Curves (Continued)

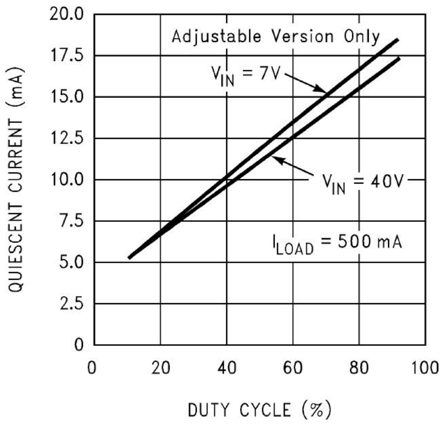
**Efficiency**



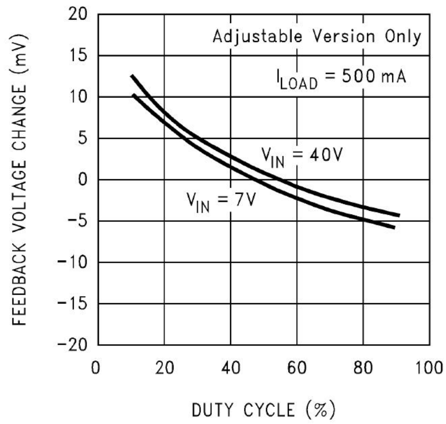

**Minimum Operating Voltage**



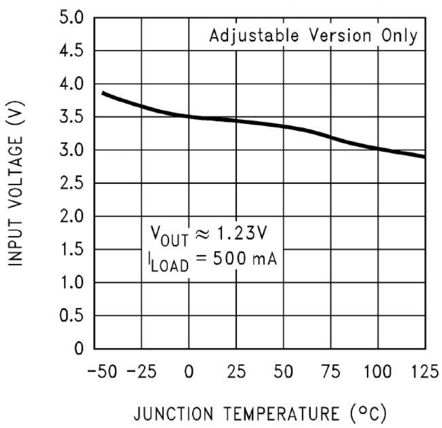

**Quiescent Current vs Duty Cycle**



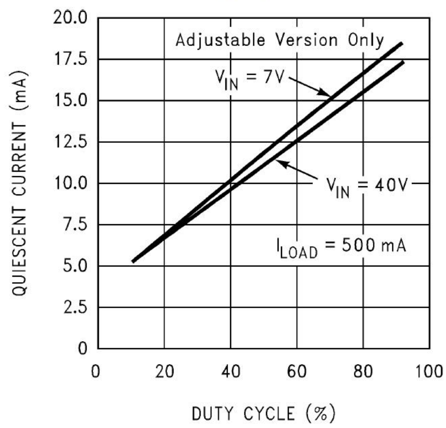

**Feedback Voltage vs Duty Cycle**




**Minimum Operating Voltage**

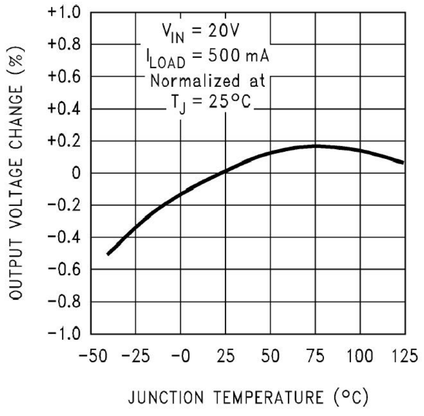



**Quiescent Current vs Duty Cycle**

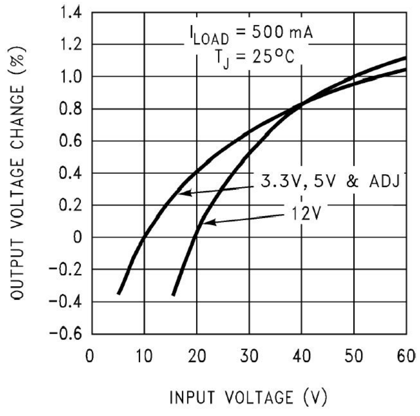


## Characteristic Curves (Continued)

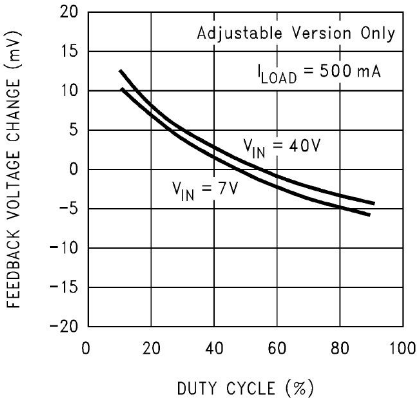
**Normalized Output Voltage**



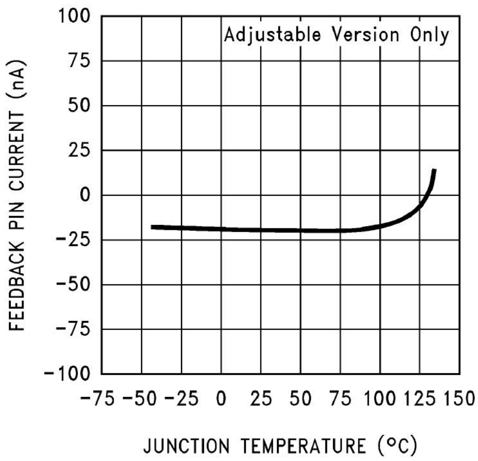

**Line Regulation**



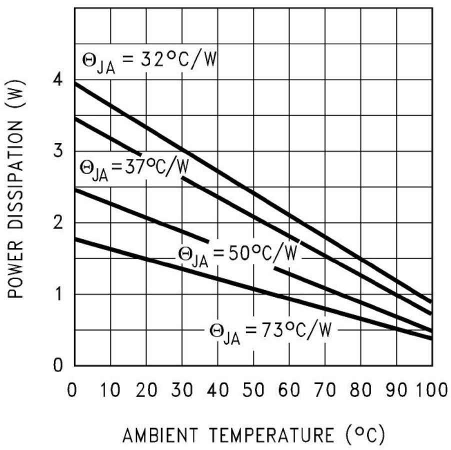

**Feedback Voltage vs Duty Cycle**




**Feedback Pin Current**

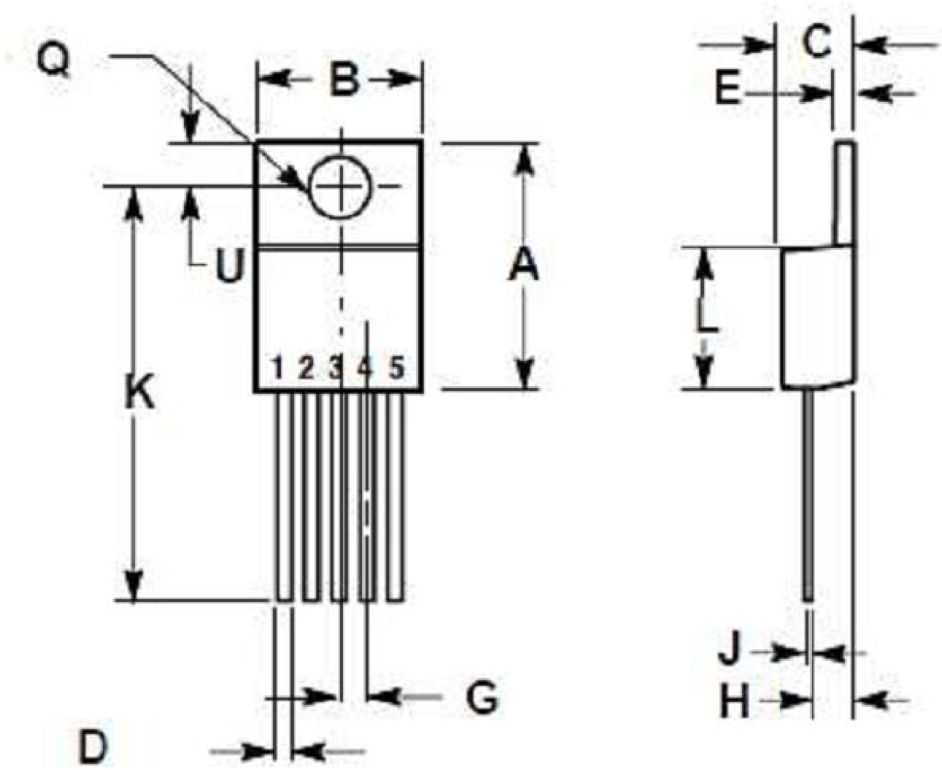



**Maximum Power Dissipation (TO-263)**



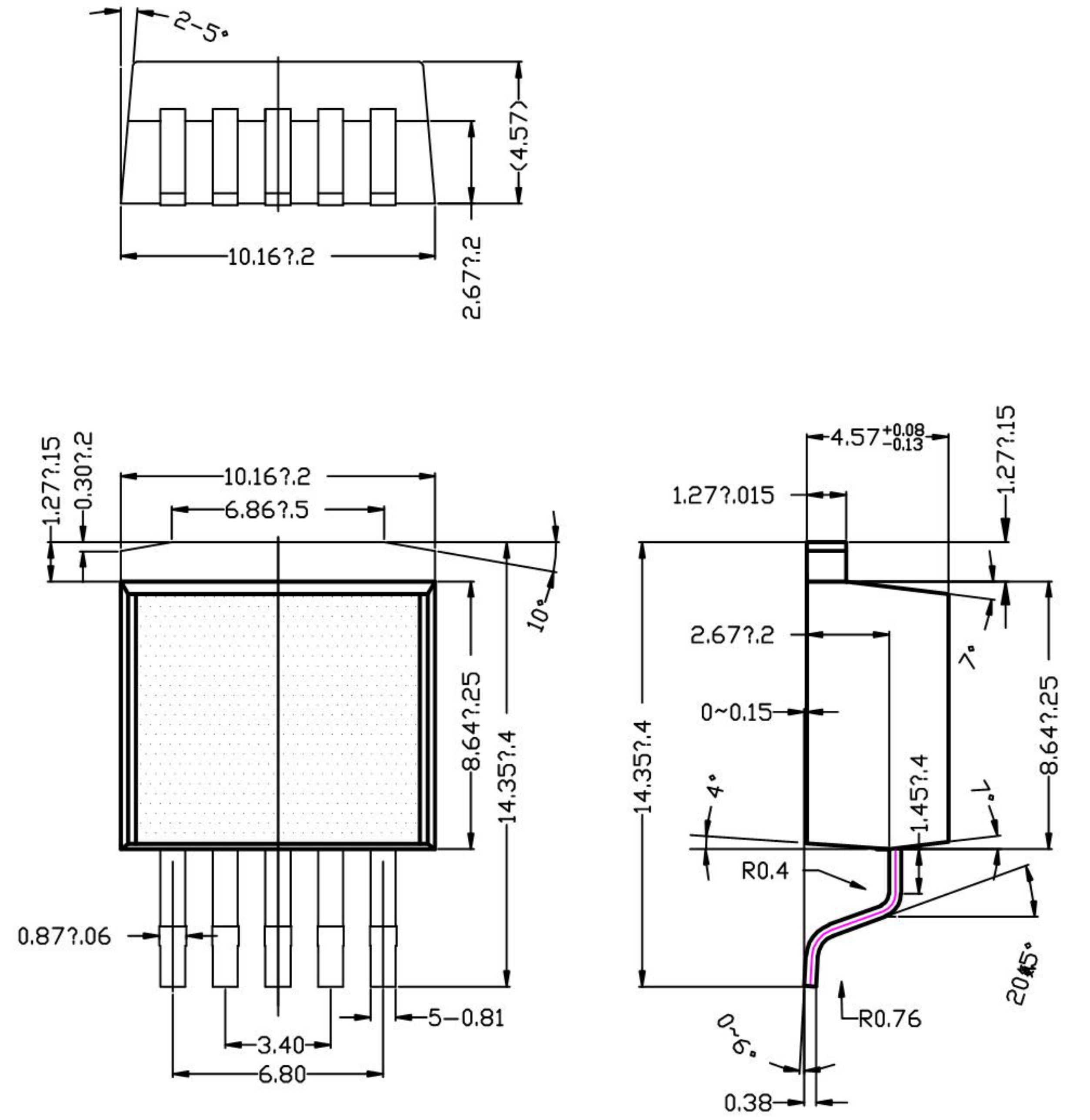
## Outline Dimensions

| TO220T-5L: | Unit：mm |
|---|---|




| 项目 | 规范（mm） | |
|---|---|---|
| | Min | Min |
| A | 15. 500 | 15. 900 |
| B | 9. 804 | 10. 236 |
| C | 4. 318 | 4. 572 |
| D | 0. 66 | 0. 914 |
| E | 1. 143 | 1. 397 |
| G | 1. 702BSC | |
| H | 2. 235 | 2. 591 |
| J | 0. 356 | 0. 406 |
| K | 26. 100 | 26. 500 |
| L | 9. 042 | 9. 347 |
| Q | 3. 790 | 3. 890 |
| U | 2. 600 | 2. 700 |

| TO263-5L: | Unit:mm |
|---|---|



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- The product upgrades without end, Silicore Technology will wholeheartedly provide customers integrated circuits that have better performance and better quality.