LM2591HV SIMPLE SWITCHER®電力コンバータ 150kHz、1A降圧型電圧レギュレータ

1 特長

- 3.3V、5V、および可変出力電圧バージョン
- 可変タイプの出力電圧範囲は1.2V～57V、入力と負荷の全条件で±4%の許容誤差
- 1Aの出力負荷電流を保証
- 5ピンのパッケージで提供
- 60Vまでの入力電圧範囲
- 150kHz固定周波数の自己発振器を内蔵
- オン/オフ制御
- 低消費電力のスタンバイ・モード、I_Qの標準値90µA
- 高効率
- サーマル・シャットダウンおよび電流制限保護回路内蔵

2 アプリケーション

- シンプルな高効率降圧型(バック)レギュレータ
- リニア・レギュレータ用の効率的なプリレギュレータ
- オンボードのスイッチング・レギュレータ
- 正負反転コンバータ

3 概要

LM2591HVシリーズのレギュレータは、モノリシックな集積回路で、降圧型(バック)スイッチング・レギュレータのすべてのアクティブ機能を提供し、優れたラインおよび負荷レギュレーションで1Aの負荷を駆動できます。これらのデバイスは、3.3V、5Vの固定出力電圧と、可変出力電圧バージョンで利用可能です。

このシリーズのスイッチング・レギュレータはLM2590HVと似ていますが、一部の監視および制御機能が省略されています。

これらのレギュレータは、必要な外部部品の数が最小限で済み、簡単に使用でき、内部周波数補償、改善されたラインおよび負荷仕様、固定周波数発振器を備えています。

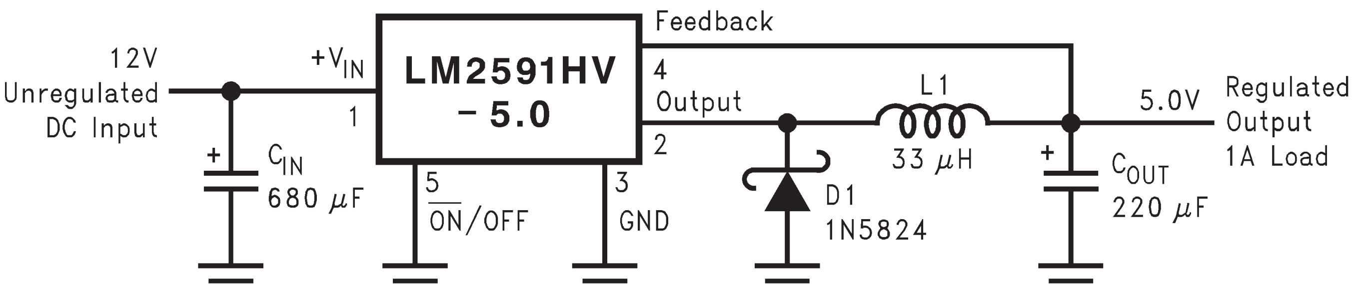
LM2591HVシリーズは150kHzのスイッチング周波数で動作するため、低周波数で動作するスイッチング・レギュレータに比べて、サイズの小さなフィルタ部品を使用できます。標準的な5ピンのパッケージで、いくつかの異なるリード曲げオプションで提供されるほか、5ピンの表面実装パッケージでも提供されます。

製品情報(1)

型番	パッケージ	本体サイズ(公称)
LM2591HV	DDPAK/TO-263 (5)	10.18mm×8.41mm
	TO-220 (5)	14.986mm×10.16mm

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

代表的なアプリケーション



(固定出力電圧のバージョン)

English Data Sheet: SNVS074

目次

4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Revision D (April 2013) から **Revision E** に変更 **Page**

- 「*ESD定格*」の表、「*機能説明*」セクション、「*デバイスの機能モード*」セクション、「*アプリケーションと実装*」セクション、「*電源に関する推奨事項*」セクション、「*レイアウト*」セクション、「*デバイスおよびドキュメントのサポート*」セクション、「*メカニカル、パッケージ、および注文情報*」セクションを追加 ... 1

Revision C (April 2013) から **Revision D** に変更 **Page**

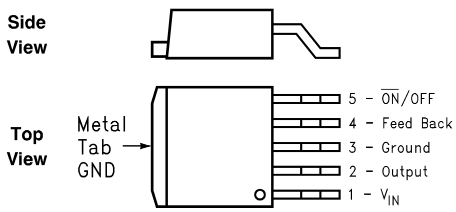
- Changed layout of National Data Sheet to TI format ... 21

5 概要（続き）

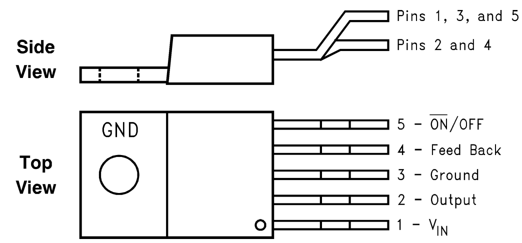
他の特長として、入力電圧と出力負荷のあらゆる条件において、許容誤差が出力電圧について±4%、発振器の周波数について±15%であることが挙げられます。外部シャットダウン機能を備えており、スタンバイ電流は標準値で90µAです。自己保護機能として、出力スイッチには2段の電流制限回路が搭載されており、異常条件では過熱シャットダウンにより完全な保護が行われます。

6 Pin Configuration and Functions

KTT Package
5-Pin DDPAK/TO-26
Top View



NDH Package
5-Pin TO-220
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	$+V_{IN}$	I	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	O	Internal switch. The voltage at this pin switches between approximately ($+V_{IN} - V_{SAT}$) and approximately −0.5 V, with a duty cycle of V_{OUT}/V_{IN}.
3	Ground	—	Circuit ground.
4	Feedback	I	Senses the regulated output voltage to complete the feedback loop. This pin is directly connected to the Output for the fixed voltage versions, but is set to 1.23 V by means of a resistive divider from the output for the Adjustable version. If a feedforward capacitor is used (Adjustable version), then a negative voltage spike is generated on this pin whenever the output is shorted. This happens because the feedforward capacitor cannot discharge fast enough, and because one end of it is dragged to Ground, the other end goes momentarily negative. To prevent the energy rating of this pin from being exceeded, a small-signal Schottky diode to Ground is recommended for DC input voltages above 40 V whenever a feedforward capacitor is present (See *Test Circuits*). Feedforward capacitor values larger than 0.1 µF are not recommended for the same reason, whatever be the DC input voltage.
5	$\overline{ON}$/OFF	I	The regulator is in shutdown mode, drawing about 90 µA, when this pin is driven to a high level (≥ 2 V), and is in normal operation when this Pin is left floating or driven to a low level (≤ 0.6 V). The typical value of the threshold is 1.3 V and the voltage on this pin must not exceed 25 V.

7 Specifications

7.1 Absolute Maximum Ratings[1][2]

			MIN	MAX	UNIT
Maximum supply voltage (V_{IN})				63	V
$\overline{ON}$/OFF pin voltage			−0.3	25	V
Feedback pin voltage			−0.3	25	V
Output voltage to ground	(Steady-state)			−1	V
Power dissipation			Internally limited		
Lead temperature	KTT package	Vapor phase (60 sec.)		215	°C
		Infrared (10 sec.)		245	
	NDH package (Soldering, 10 sec.)			260	
Maximum junction temperature				150	°C
Storage temperature, T_{stg}			−65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1][2]	±2000	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) The human body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin.

7.3 Recommended Operating Conditions

	MIN	MAX	UNIT
Temperature	−40	125	°C
Supply voltage	4.5	60	V

7.4 Thermal Information

THERMAL METRIC[1]			LM2591HV		UNIT
			KTT (DDPAK/TO-263)	NDH (TO-220)	
			5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	See [2][3]	50	50	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance		2	2	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.
(2) The package thermal impedance is calculated in accordance to JESD 51-7
(3) Thermal Resistances were simulated on a 4-layer, JEDEC board

7.5 Electrical Characteristics LM2591HV-3.3

Specifications are for T_J = 25°C unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN[(1)]	TYP[(2)]	MAX[(1)]	UNIT
SYSTEM PARAMETERS – See *Test Circuits*[(3)]							
V_{OUT}	Output Voltage	4.75 V ≤ V_{IN} ≤ 60 V, 0.2 A ≤ I_{LOAD} ≤ 1 A		3.168	3.3	3.432	V
			T_A = –40°C to 125°C	3.135		3.465	
η	Efficiency	V_{IN} = 12 V, I_{LOAD} = 1 A			77%		

(1) All limits ensured at room temperature (T_J = 25°C) unless otherwise noted. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical numbers are at 25°C and represent the most likely norm.
(3) External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance. When the LM2591HV is used as shown in *Test Circuits* test circuit, system performance will be as shown in *Electrical Characteristics*.

7.6 Electrical Characteristics LM2591HV-5.0

Specifications are for T_J = 25°C unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN[(1)]	TYP[(2)]	MAX[(1)]	UNIT
SYSTEM PARAMETERS – See *Test Circuits*[(3)]							
V_{OUT}	Output Voltage	7 V ≤ V_{IN} ≤ 60 V, 0.2 A ≤ I_{LOAD} ≤ 1 A		4.8	5	5.2	V
			T_A = –40°C to 125°C	4.75		5.25	
η	Efficiency	V_{IN} = 12 V, I_{LOAD} = 1 A			82%		

(1) All limits ensured at room temperature (T_J = 25°C) unless otherwise noted. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical numbers are at 25°C and represent the most likely norm.
(3) External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance. When the LM2591HV is used as shown in *Test Circuits* test circuit, system performance will be as shown in *Electrical Characteristics*.

7.7 Electrical Characteristics LM2591HV-ADJ

Specifications are for T_J = 25°C unless otherwise noted

PARAMETER		TEST CONDITIONS		MIN[(1)]	TYP[(2)]	MAX[(1)]	UNIT
SYSTEM PARAMETERS – See *Test Circuits*[(3)]							
V_{FB}	Feedback Voltage	4.5 V ≤ V_{IN} ≤ 60 V, 0.2 A ≤ I_{LOAD} ≤ 1 A V_{OUT} programmed for 3 V. Circuit of Test Circuits.		1.193	1.23	1.267	V
			T_A = –40°C to 125°C	1.18		1.28	
η	Efficiency	V_{IN} = 12 V, V_{OUT} = 3 V, I_{LOAD} = 1 A			76%		

(1) All limits ensured at room temperature (T_J = 25°C) unless otherwise noted. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical numbers are at 25°C and represent the most likely norm.
(3) External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance. When the LM2591HV is used as shown in *Test Circuits* test circuit, system performance will be as shown in *Electrical Characteristics*.

7.8 Electrical Characteristics All Output Voltage Versions

Specifications are for T_J = 25°C, I_{LOAD} = 500 mA, and V_{IN} = 12V for the 3.3-V, 5-V, and adjustable versions, unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN[(1)]	TYP[(2)]	MAX[(1)]	UNIT
DEVICE PARAMETERS							
I_b	Feedback Bias Current	Adjustable Version Only, V_{FB} = 1.3 V			10	50	nA
			T_A = –40°C to 125°C			100	
f_O	Oscillator Frequency	See [(3)]		127	150	173	kHz
			T_A = –40°C to 125°C	110		173	
V_{SAT}	Saturation Voltage	I_{OUT} = 1 A [(4)(5)]			0.95	1.2	V
			T_A = –40°C to 125°C			1.3	
DC	Max Duty Cycle (ON)	See [(5)(6)]			100%		
	Min Duty Cycle (OFF)				0%		
I_{CLIM}	Switch current Limit	Peak Current[(4)(5)]		1.3	1.9	2.8	A
			T_A = –40°C to 125°C	1.2		3.0	
I_L	Output Leakage Current	Output = 0 V			5	50	µA
		Output = −1 V [(4)(6)(7)]			5	30	mA
I_Q	Operating Quiescent Current	$\overline{SD}$/SS Pin Open [(6)]			5	10	mA
I_{STBY}	Standby Quiescent Current	$\overline{SD}$/SS pin = 0 V [(7)]			90	200	µA
			T_A = –40°C to 125°C			250	
ON/OFF CONTROL – See *Test Circuits*							
V_{IH} V_{IL}	$\overline{ON}$/OFF Pin Logic Input Threshold Voltage	Low (Regulator ON) High (Regulator OFF)			1.3		V
			T_A = –40°C to 125°C	2.0		0.6	
I_H	$\overline{ON}$/OFF Pin Input Current	V_{LOGIC} = 2.5 V (Regulator OFF)			5	15	µA
I_L		V_{LOGIC} = 0.5 V (Regulator ON)			0.02	5	µA

(1) All limits ensured at room temperature (T_J = 25°C) unless otherwise noted. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical numbers are at 25°C and represent the most likely norm.
(3) The switching frequency is reduced when the second stage current limit is activated. The amount of reduction is determined by the severity of current overload.
(4) No diode, inductor or capacitor connected to output pin.
(5) Feedback pin removed from output and connected to 0 V to force the output transistor switch ON.
(6) Feedback pin removed from output and connected to 12 V for the 3.3-V, 5-V, and the ADJ. version to force the output transistor switch OFF.
(7) V_{IN} = 60 V.

7.9 Typical Characteristics

(Circuit of *Test Circuits*)

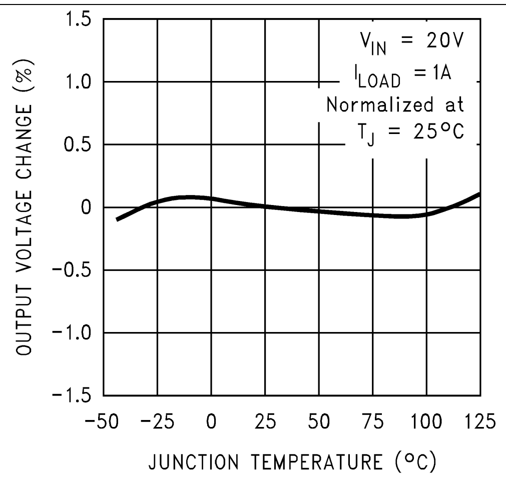


Figure 1. Normalized Output Voltage

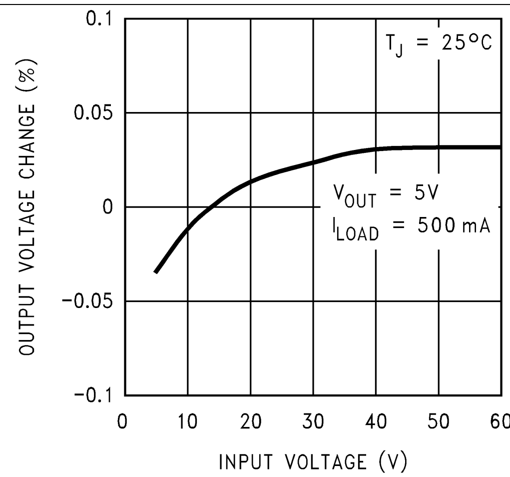


Figure 2. Line Regulation

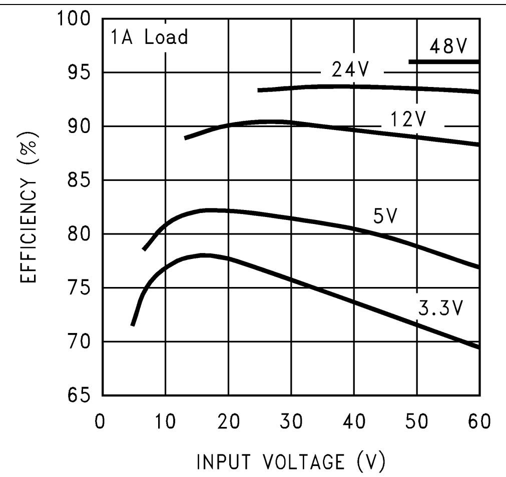


Figure 3. Efficiency

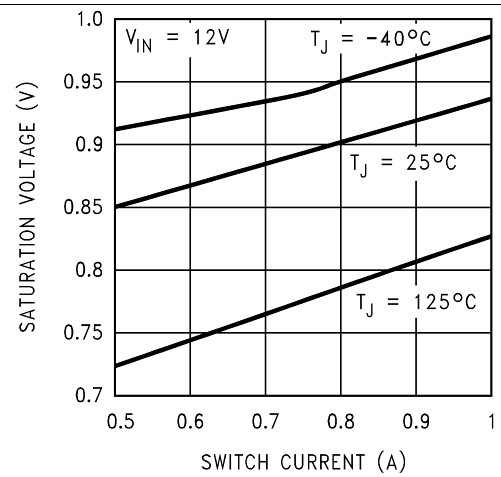


Figure 4. Switch Saturation Voltage

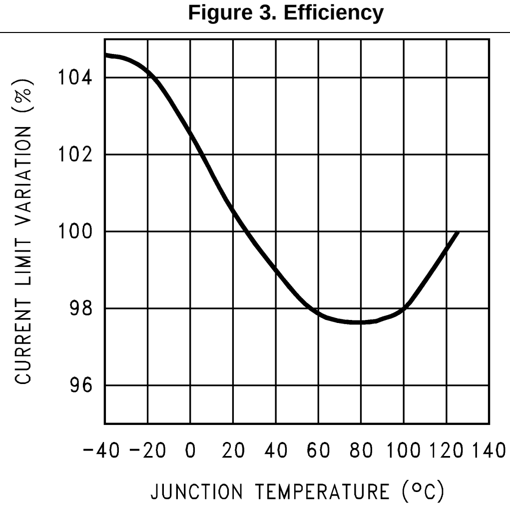


Figure 5. Switch Current Limit

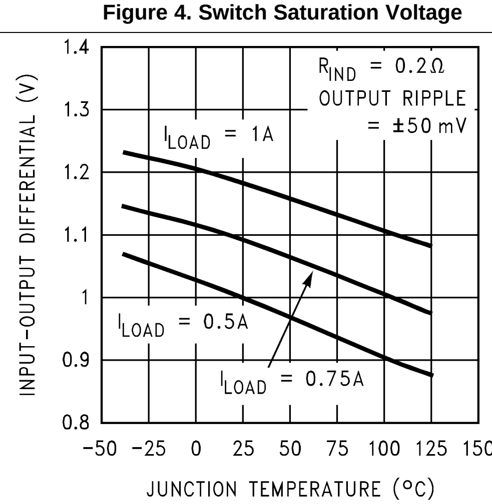


Figure 6. Dropout Voltage

Typical Characteristics (continued)

(Circuit of *Test Circuits*)

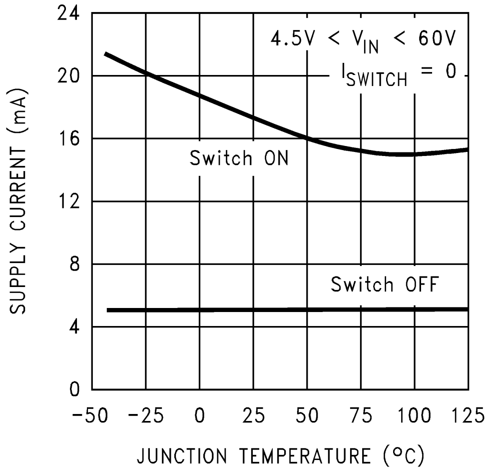


Figure 7. Operating Quiescent Current

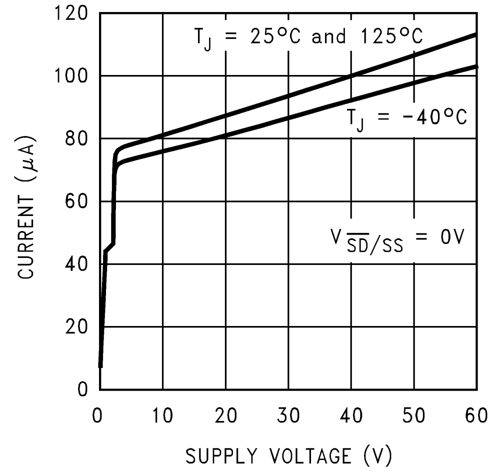


Figure 8. Shutdown Quiescent Current

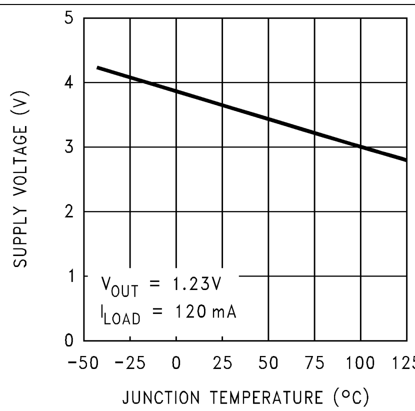


Figure 9. Minimum Operating Supply Voltage

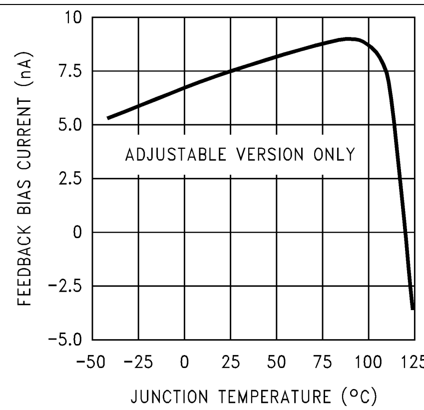


Figure 10. Feedback Pin Bias Current

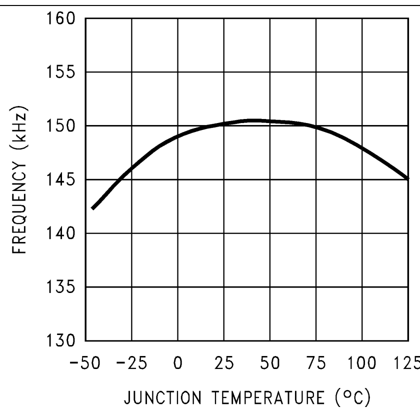


Figure 11. Switching Frequency

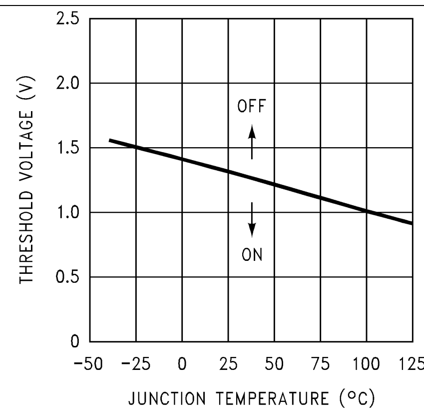


Figure 12. $\overline{ON}$/OFF Threshold Voltage

Typical Characteristics (continued)

(Circuit of *Test Circuits*)

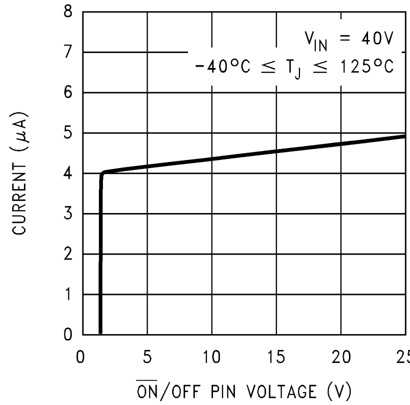


Figure 13. $\overline{ON}$/OFF Pin Current (Sinking)

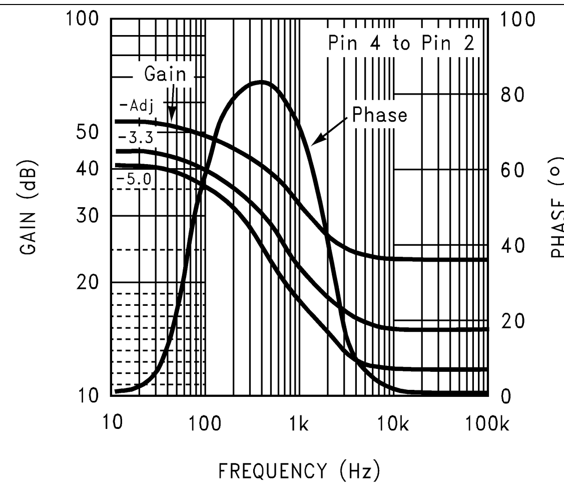
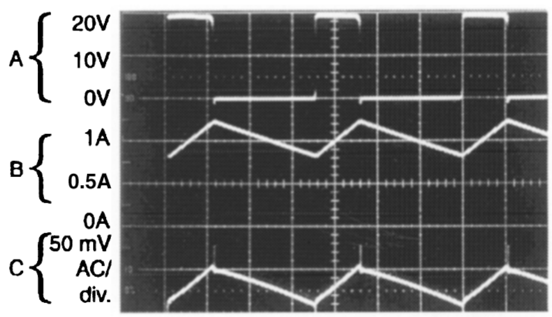


Figure 14. Internal Gain-Phase Characteristics



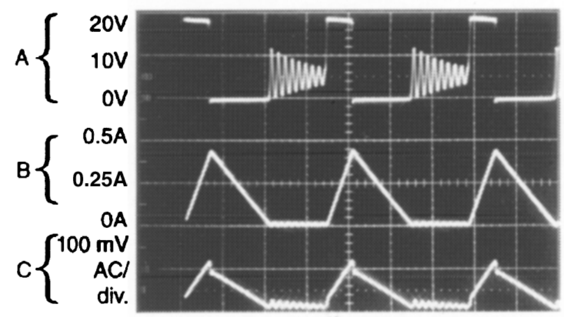
Continuous Mode Switching Waveforms V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 1A L = 52 μH, C_{OUT} = 100 μF, C_{OUT} ESR = 100 mΩ

Output Pin Voltage, 10V/div.

Inductor Current 0.5A/div.

Output Ripple Voltage, 50 mV/div.

Figure 15. Horizontal Time Base: 2 μs/div



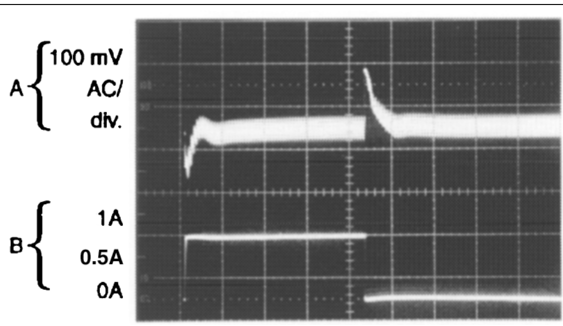
Discontinuous Mode Switching Waveforms V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 250 mA L = 15 μH, C_{OUT} = 150 μF, C_{OUT} ESR = 90 mΩ

Output Pin Voltage, 10V/div.

Inductor Current 0.25A/div.

Output Ripple Voltage, 100 mV/div.

Figure 16. Horizontal Time Base: 2 μs/div

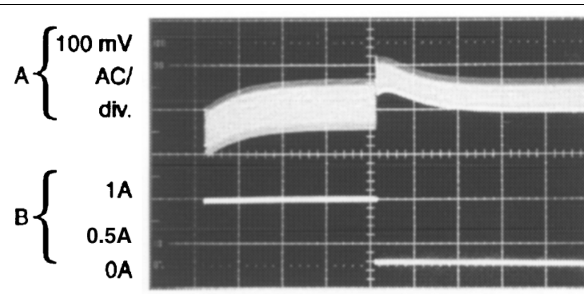


Load Transient Response for Continuous Mode V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 250 mA to 1A L = 52 μH, C_{OUT} = 100 μF, C_{OUT} ESR = 100 mΩ

Output Voltage, 100 mV/div. (AC)

250 mA to 1A Load Pulse

Figure 17. Horizontal Time Base: 50 μs/div



Load Transient Response for Discontinuous Mode V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 250 mA to 1A L = 15 μH, C_{OUT} = 150 μF, C_{OUT} ESR = 90 mΩ

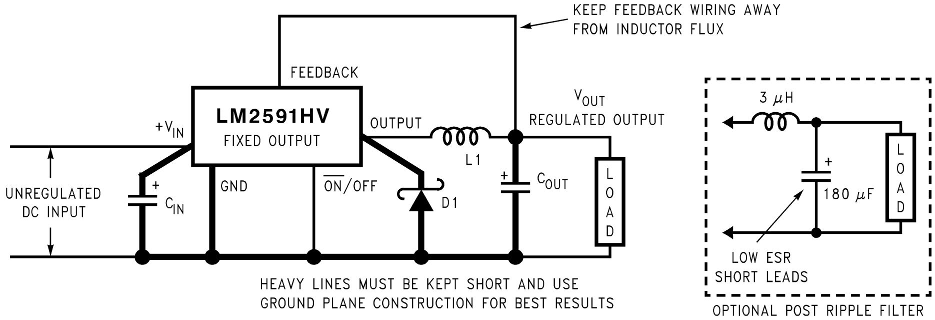
Output Voltage, 100 mV/div. (AC)

250 mA to 1A Load Pulse

Figure 18. Horizontal Time Base: 200 μs/div

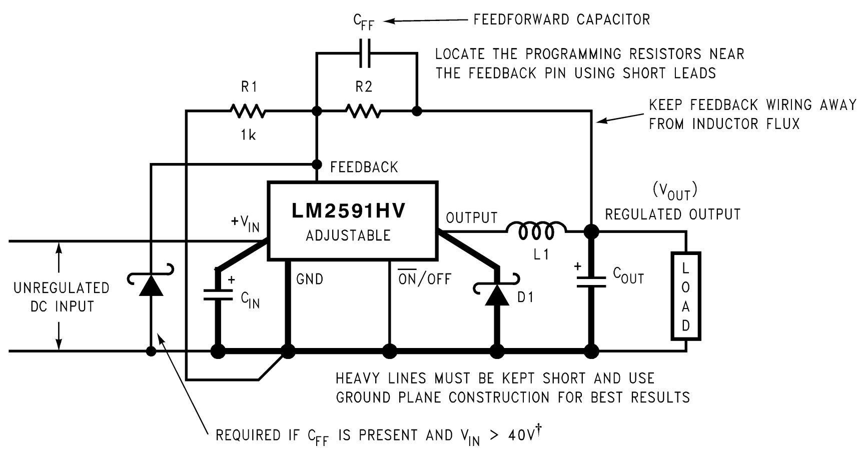
8 Parameter Measurement Information

8.1 Test Circuits



Component Values shown are for V_{IN} = 15V,
V_{OUT} = 5V, I_{LOAD} = 1A.
C_{IN} — 470 µF, 50V, Aluminum Electrolytic Nichicon “PM Series”
C_{OUT} — 220 µF, 25V Aluminum Electrolytic, Nichicon “PM Series”
D1 — 2A, 60V Schottky Rectifier, 21DQ06 (International Rectifier)
L1 — 68 H, See *Inductor Selection Procedure*

Figure 19. Fixed Output Voltage Versions



Select R_1 to be approximately 1 kΩ, use a 1% resistor for best stability.
Component Values shown are for V_{IN} = 20V,
V_{OUT} = 10V, I_{LOAD} = 1A.
C_{IN}: — 470 µF, 35V, Aluminum Electrolytic Nichicon “PM Series”
C_{OUT}: — 220 µF, 35V Aluminum Electrolytic, Nichicon “PM Series”
D1 — 2A, 60V Schottky Rectifier, 21DQ06 (International Rectifier)
See *Inductor Selection Procedure* L1 — 100 µH,
R_1 — 1 kΩ, 1%
R_2 — 7.15k, 1%
C_{FF} — 3.3 nF
Typical Values
C_{SS}—0.1 µF
C_{DELAY}—0.1 µF
$R_{PULL\ UP}$ — 4.7k (use 22k if V_{OUT} is ≥ 45V)
† Small signal Schottky diode to prevent damage to feedback pin by negative spike when output is shorted. Required if V_{IN} > 40V

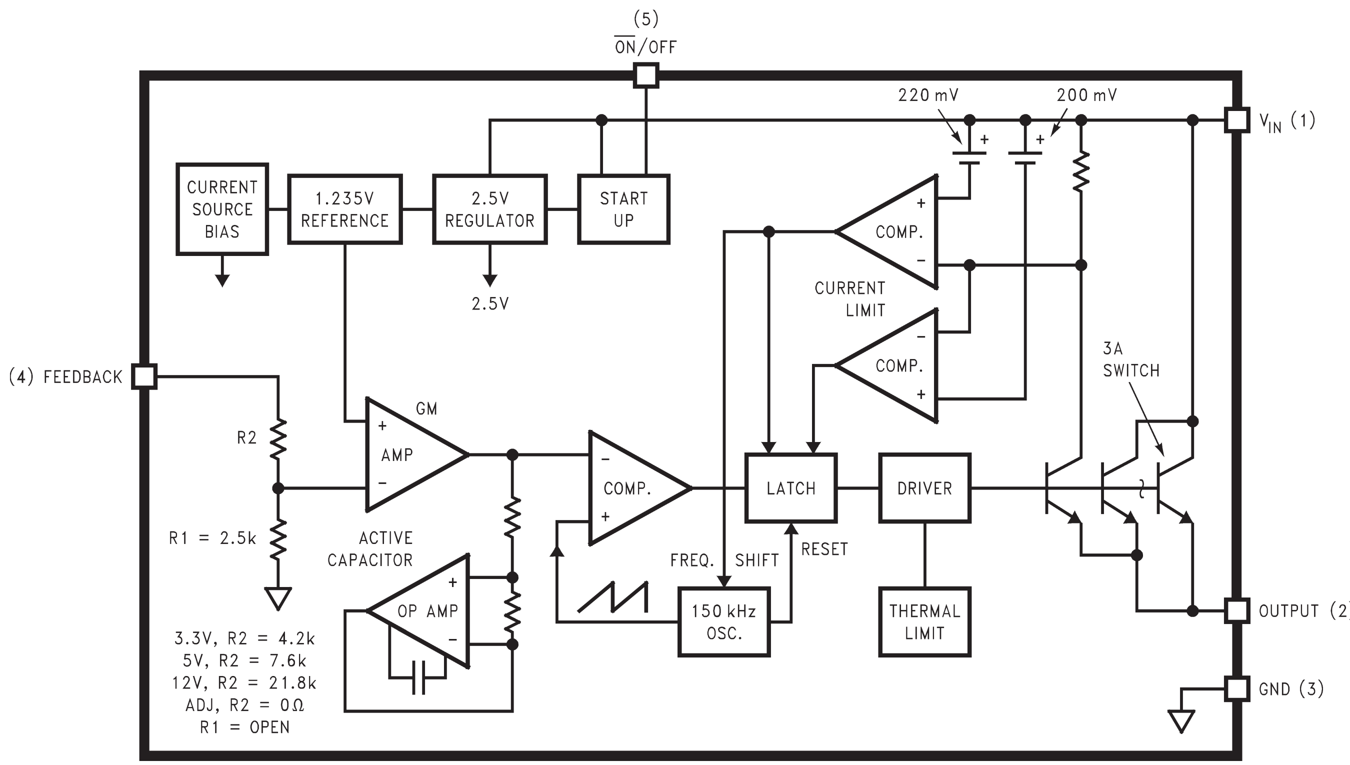
Figure 20. Adjustable Output Voltage Versions

9 Detailed Description

9.1 Overview

The LM2591HV SIMPLE SWITCHER® regulator is an easy-to-use, nonsynchronous, step-down DC-DC converter with a wide input voltage range up to 60 V. The regulator is capable of delivering up to 1-A DC load current with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, and an adjustable output version. The family requires few external components, and the pin arrangement was designed for simple, optimum PCB layout.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Delayed Start-Up

The circuit in Figure 21 uses the ON/OFF pin to provide a time delay between the time the input voltage is applied and the time the output voltage comes up (only the circuitry pertaining to the delayed start-up is shown). As the input voltage rises, the charging of capacitor C1 pulls the ON/OFF pin high, keeping the regulator off. When the input voltage reaches its final value and the capacitor stops charging, the resistor R_2 pulls the ON/OFF pin low, thus allowing the circuit to start switching. Resistor R_1 is included to limit the maximum voltage applied to the ON/OFF pin (maximum of 25 V), reduces power supply noise sensitivity, and also limits the capacitor, C1, discharge current. When high input ripple voltage exists, avoid long delay time, because this ripple can be coupled into the ON/OFF pin and cause problems.

This delayed start-up feature is useful in situations where the input power source is limited in the amount of current it can deliver. It allows the input voltage to rise to a higher voltage before the regulator starts operating. Buck regulators require less input current at higher input voltages.

Feature Description (continued)

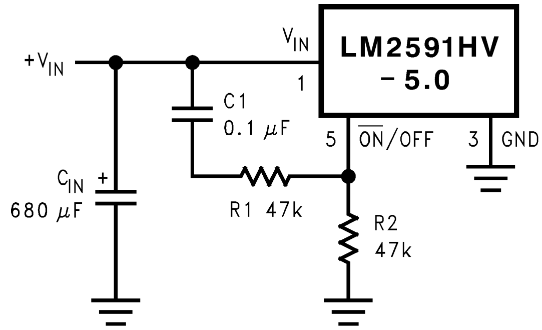


Figure 21. Delayed Start-Up

9.3.2 Undervoltage Lockout

Some applications require the regulator to remain off until the input voltage reaches a predetermined voltage. An undervoltage lockout feature applied to a buck regulator is shown in Figure 22, while Figure 23 and Figure 24 applies the same feature to an inverting circuit. The circuit in Figure 23 features a constant threshold voltage for turnon and turnoff (Zener voltage plus approximately one volt). If hysteresis is needed, the circuit in Figure 24 has a turnon voltage which is different than the turnoff voltage. The amount of hysteresis is approximately equal to the value of the output voltage. If Zener voltages greater than 25 V are used, an additional 47-kΩ resistor is needed from the ON/OFF pin to the ground pin to stay within the 25-V maximum limit of the ON/OFF pin.

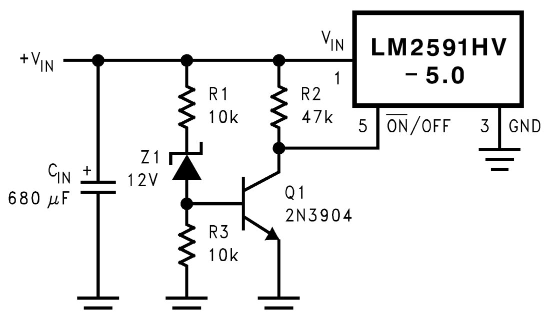
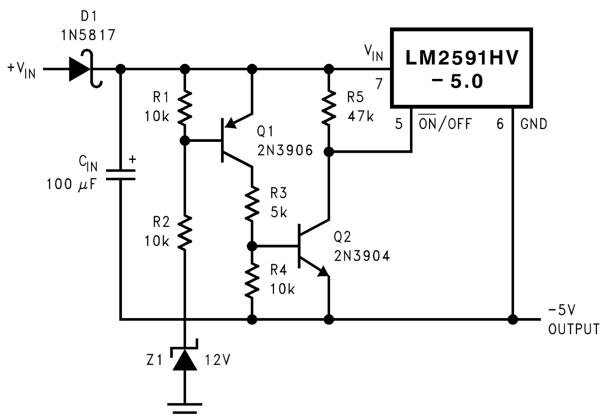


Figure 22. Undervoltage Lockout for Buck Regulator



This circuit has an ON/OFF threshold of approximately 13 V.

Figure 23. Undervoltage Lockout for Inverting Regulator

9.4 Device Functional Modes

9.4.1 Shutdown Mode

The $\overline{\text{ON}}$/OFF pin provides electrical ON and OFF control for the LM2591HV. When the voltage of this pin is higher than 2 V, the device is shutdown mode. The typical standby current in this mode is 90 μA.

9.4.2 Active Mode

When the $\overline{\text{ON}}$/OFF pin is left floating or pull below 0.6 V, the device starts switching and the output voltage rises until it reaches a normal regulation voltage.

10 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information

10.1.1 Feedforward Capacitor

C_{FF} – A feedforward capacitor, shown across R2 in *Test Circuits*, is used when the output voltage is greater than 10 V or when C_{OUT} has a very low ESR. This capacitor adds lead compensation to the feedback loop and increases the phase margin for better loop stability.

If the output voltage ripple is large (>5% of the nominal output voltage), this ripple can be coupled to the feedback pin through the feedforward capacitor and cause the error comparator to trigger the error flag. In this situation, adding a resistor, R_{FF}, in series with the feedforward capacitor, approximately 3 times R1, will attenuate the ripple voltage at the feedback pin.

10.1.2 Input Capacitor

C_{IN} – A low ESR aluminum or tantalum bypass capacitor is needed between the input pin and ground pin. It must be placed near the regulator using short leads. This capacitor prevents large voltage transients from appearing at the input, and provides the instantaneous current needed each time the switch turns on.

The important parameters for the Input capacitor are the voltage rating and the RMS current rating. Because of the relatively high RMS currents flowing in a buck regulator's input capacitor, this capacitor should be chosen for its RMS current rating rather than its capacitance or voltage ratings, although the capacitance value and voltage rating are directly related to the RMS current rating. The voltage rating of the capacitor and its RMS ripple current capability must never be exceeded.

10.1.3 Output Capacitor

C_{OUT} – An output capacitor is required to filter the output and provide regulator loop stability. Low impedance or low ESR Electrolytic or solid tantalum capacitors designed for switching regulator applications must be used. When selecting an output capacitor, the important capacitor parameters are the 100-kHz Equivalent Series Resistance (ESR), the RMS ripple current rating, voltage rating, and capacitance value. For the output capacitor, the ESR value is the most important parameter. The ESR must generally not be less than 100 mΩ or there will be loop instability. If the ESR is too large, efficiency and output voltage ripple are effected, so ESR must be chosen carefully.

10.1.4 Catch Diode

Buck regulators require a diode to provide a return path for the inductor current when the switch turns off. This must be a fast diode and must be placed close to the LM2591HV using short leads and short printed-circuit traces.

Because of their very fast switching speed and low forward voltage drop, Schottky diodes provide the best performance, especially in low output voltage applications (5 V and lower). Ultra-fast recovery, or high-efficiency rectifiers are also a good choice, but some types with an abrupt turnoff characteristic may cause instability or EMI problems. Ultra-fast recovery diodes typically have reverse recovery times of 50 ns or less. The diode must be chosen for its average/RMS current rating and maximum voltage rating. The voltage rating of the diode must be greater than the DC input voltage (not the output voltage).

10.1.5 Inverting Regulator

The circuit in Figure 25 converts a positive input voltage to a negative output voltage with a common ground. The circuit operates by bootstrapping the regulator's ground pin to the negative output voltage, then grounding the feedback pin. The regulator senses and regulates the inverted output voltage.

Application Information (continued)

This example uses the LM2591HV-5.0 to generate a −5-V output, but other output voltages are possible by selecting other output voltage versions, including the adjustable version. Because this regulator topology can produce an output voltage that is either greater than or less than the input voltage, the maximum output current greatly depends on both the input and output voltage.

To determine how much load current is possible before the internal device current limit is reached (and power limiting occurs), the system must be evaluated as a buck-boost configuration rather than as a buck. The peak switch current in amperes, for such a configuration is given as Equation 1:

$$I_{PEAK} = I_{LOAD} \times \left(\frac{V_{IN} + V_{OUT}}{V_{IN}} \right) + \frac{V_{IN} \times V_{OUT} \times 10^6}{2 \times L \times f \times (V_{IN} + V_{OUT})}$$

where

- L is in µH
- and f is in Hz
- The maximum possible load current I_{LOAD} is limited by the requirement that $I_{PEAK} \leq I_{CLIM}$ (1)

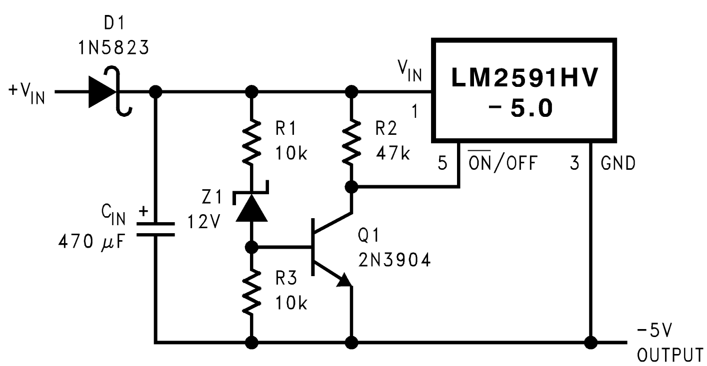
While checking for this, take I_{CLIM} to be the lowest possible current limit value (minimum across tolerance and temperature is 1.2 A for the LM2591HV). Also to account for inductor tolerances, take the minimum value of inductance for L in Equation 1 (typically 20% less than the nominal value). Further, Equation 1 disregards the drop across the switch and the diode. This is equivalent to assuming 100% efficiency, which is never so. Therefore expect I_{PEAK} to be an additional 10% to 20% higher than calculated from Equation 1.

See Application Note AN-1157 (SNVA022) for examples based on positive to negative configuration.

The maximum voltage appearing across the regulator is the absolute sum of the input and output voltage, and this must be limited to a maximum of 60 V. For example, when converting +20 V to −12 V, the regulator would see 32 V between the input pin and ground pin. The LM2591HV has a maximum input voltage spec of 60 V.

Additional diodes are required in this regulator configuration. Diode D1 is used to isolate input voltage ripple or noise from coupling through the C_{IN} capacitor to the output, under light or no load conditions. Also, this diode isolation changes the topology to closely resemble a buck configuration thus providing good closed loop stability. A Schottky diode is recommended for low input voltages, (because of its lower voltage drop) but for higher input voltages, a fast recovery diode could be used.

Without diode D3, when the input voltage is first applied, the charging current of C_{IN} can pull the output positive by several volts for a short period of time. Adding D3 prevents the output from going positive by more than a diode voltage.



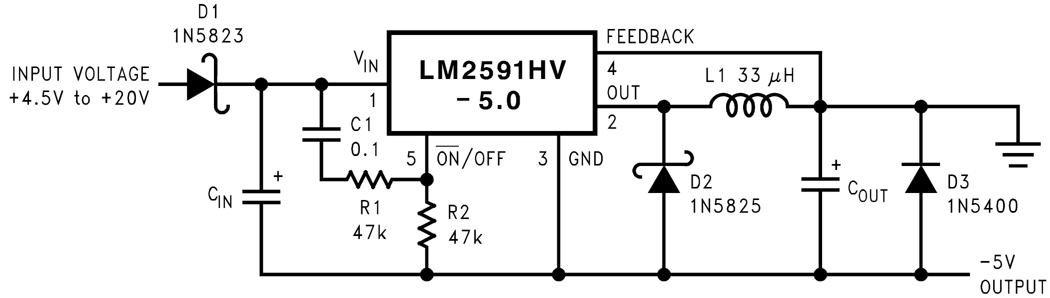
This circuit has hysteresis

Regulator starts switching at V_{IN}= 13 V

Regulator stops switching at V_{IN}= 8 V

Figure 24. Undervoltage Lockout With Hysteresis for Inverting Regulator

Application Information (continued)



C_{IN} —68-µF, 25-V Tant. Sprague 595D

470 µF/50V Elec. Panasonic HFQ

C_{OUT}—47-µF, 20-V Tant. Sprague 595D

220-µF, 25-V Elec. Panasonic HFQ

Figure 25. Inverting −5-V Regulator With Delayed Start-Up

Because of differences in the operation of the inverting regulator, the standard design procedure is not used to select the inductor value. In the majority of designs, a 33-µH, 3-A inductor is the best choice. Capacitor selection can also be narrowed down to just a few values.

This type of inverting regulator can require relatively large amounts of input current when starting up, even with light loads. Input currents as high as the LM2591HV current limit (approx 4 A) are needed for at least 2 ms or more, until the output reaches its nominal output voltage. The actual time depends on the output voltage and the size of the output capacitor. Input power sources that are current-limited or sources that can not deliver these currents without getting loaded down, may not work correctly. Because of the relatively high start-up currents required by the inverting topology, the delayed start-up feature (C1, R_1, and R_2) shown in Figure 25 is recommended. By delaying the regulator start-up, the input capacitor is allowed to charge up to a higher voltage before the switcher begins operating. A portion of the high input current needed for start-up is now supplied by the input capacitor (C_{IN}). For severe start-up conditions, the input capacitor can be made much larger than normal.

Application Information (continued)

10.1.6 Inverting Regulator Shutdown Methods

Using the ON/OFF pin in a standard buck configuration is simple. To turn the regulator ON, pull the ON/OFF pin below 1.3 V (at 25°C, referenced to ground). To turn regulator OFF, pull the ON/OFF pin above 1.3 V. With the inverting configuration, some level shifting is required, because the ground pin of the regulator is no longer at ground, but is now setting at the negative output voltage level. Two different shutdown methods for inverting regulators are shown in Figure 26 and Figure 27.

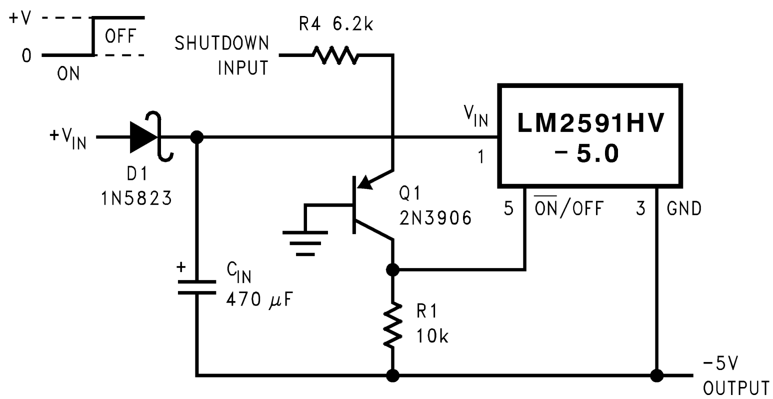


Figure 26. Inverting Regulator Ground Referenced Shutdown

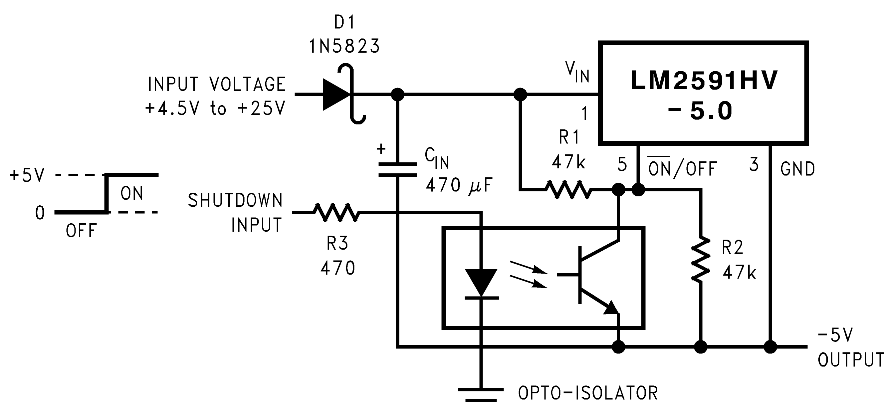


Figure 27. Inverting Regulator Ground Referenced Shutdown Using Opto Device

10.2 Typical Application

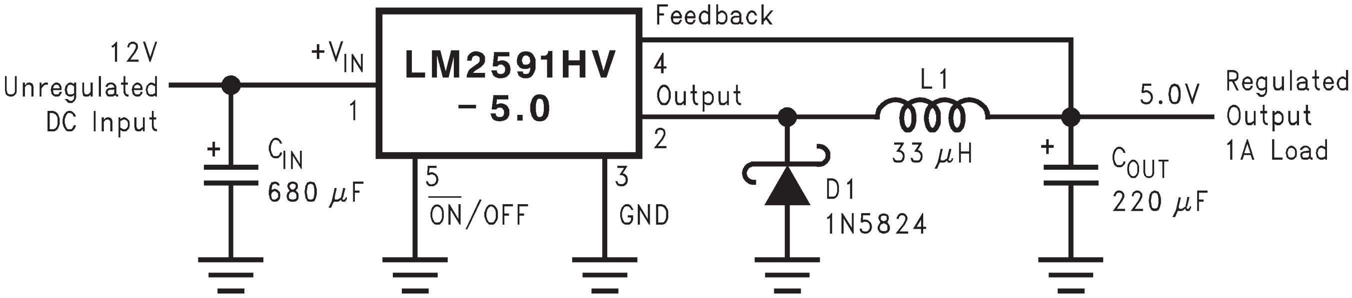


Figure 28. Typical Application

10.2.1 Design Requirements

Table 1 lists the parameters for this design example.

Table 1. Example Parameters

PARAMETER	EXAMPLE VALUE
Regulated output voltage, V_{OUT}	20 V
Maximum input voltage, V_{IN}(max)	24 V
Maximum load current, I_{LOAD}(max)	1 A
Switching frequency, F	Fixed at a nominal 150 kHz

10.2.2 Detailed Design Procedure

10.2.2.1 Inductor Selection Procedure

See Application Note AN-1197 (SNVA038) for detailed information on selecting inductors for buck converters. For a quick-start, the designer may refer to the nomographs provided in Figure 29 to Figure 31. To give designers more options of available inductors, the nomographs provide the required inductance and also the energy in the core expressed in microjoules (µJ), as an alternative to just prescribing custom parts. The following points must be highlighted:

1. The energy values shown on the nomographs apply to steady operation at the corresponding x-coordinate (rated maximum load current). However, under start-up, without soft start, or a short circuit on the output, the current in the inductor will momentarily or repetitively hit the current limit I_{CLIM} of the device, and this current could be much higher than the rated load, I_{LOAD}. This represents an overload situation, and can cause the inductor to saturate (if it has been designed only to handle the energy of steady operation). However, most types of core structures used for such applications have a large inherent air gap (for example, powdered iron types or ferrite rod inductors), so the inductance does not fall off too sharply under an overload. The device is usually able to protect itself by preventing the current from exceeding I_{CLIM}. However, if the DC input voltage to the regulator is over 40 V, the current can slew up so fast under core saturation that the device may not be able to act fast enough to restrict the current. The current can then rise without limit until the device is destroyed.

NOTE

To ensure reliability, TI recommends that, if the DC Input Voltage exceeds 40 V, the inductor must be sized to handle an instantaneous current equal to I_{CLIM} without saturating, irrespective of the type of core structure or material

2. The energy under steady operation is given in Equation 2:

$$e = \frac{1}{2} \text{ x L x } I_{PEAK}^2 \ \ \mu J$$

where

- L is in µH
- I_{PEAK} is the peak of the inductor current waveform with the regulator delivering I_{LOAD}. (2)

These are the energy values shown in the nomographs. See Example 1.

3. The energy under overload is given in Equation 3:

$$e_{CLIM} = \frac{1}{2} \text{ x L x } I_{CLIM}^2 \ \ \mu J \qquad (3)$$

If V_{IN} > 40 V, the inductor must be sized to handle e_{CLIM} instead of the steady energy values. The worst case I_{CLIM} for the LM2591HV is 3 A. The energy rating depends on the inductance. See Example 2.

4. The nomographs were generated by allowing a greater amount of percentage current ripple in the inductor as the maximum rated load decreases (see Figure 32). This was done to allow smaller inductors to be used at light loads. However, Figure 32 shows only the *median* value of the current ripple. In reality there may be a great spread around this because the nomographs approximate the exact calculated inductance to standard available values. It is a good idea to refer to AN-1197 (SNVA038) for detailed calculations if a certain maximum inductor current ripple is required for various possible reasons. Also consider the rather wide tolerance on the nominal inductance of commercial inductors.
5. Figure 31 shows the inductor selection curves for the Adjustable version. The y-axis is 'Et', in Vµsecs. It is the applied volts across the inductor during the ON time of the switch (V_{IN} – V_{SAT} – V_{OUT}) multiplied by the time for which the switch is on in µs. See Example 3.

Example 1: (V_{IN} ≤ 40 V) LM2591HV-5.0, V_{IN} = 24 V, Output 5 V at 0.8 A

1. A first pass inductor selection is based upon *inductance and rated max load current*. Choose an inductor with the inductance value indicated by the nomograph (see Figure 30) and a current rating equal to the maximum load current. Therefore, quick-select a 100-µH, 0.8-A inductor (designed for 150-kHz operation) for this application.
2. Confirm that it is rated to handle 50 µJ (see Figure 30) by either estimating the peak current or by a detailed calculation as shown in AN-1197 (SNVA038). Also, confirm that the losses are acceptable.

Example 2: (V_{IN} > 40 V) LM2591HV-5.0, V_{IN} = 48 V, Output 5 V at 1 A

1. A first pass inductor selection is based upon *inductance and the switch currrent limit*. We choose an inductor with the inductance value indicated by the nomograph (Figure 30) and a current rating equal to I_{CLIM}. Therefore, quick-select a 100-µH, 3-A inductor (designed for 150-kHz operation) for this application.
2. Confirm that it is rated to handle e_{CLIM} by the procedure shown in AN-1197 (SNVA038) and that the losses are acceptable. Here e_{CLIM} is calculated using Equation 4:

$$e_{CLIM} = \frac{1}{2} \text{x } 100 \text{ x } 3^2 = 450 \ \mu J \qquad (4)$$

Example 3: (V_{IN} ≤ 40 V) LM2591HV-ADJ, V_{IN} = 20 V, Output 10 V at 1 A

1. Because input voltage is less than 40 V, a first pass inductor selection is based upon inductance and rated maximum load current. We choose an inductor with the inductance value indicated by the nomograph Figure 31 and a current rating equal to the maximum load. First, calculate Et for the given application. The duty cycle is calculated with Equation 5:

$$D = \frac{V_{OUT} + V_D}{V_{IN} - V_{SAT} + V_D}$$

where

- V_D is the drop across the catch diode (≅ 0.5 V for a Schottky)
- V_{SAT} the drop across the switch (≅ 1.5 V) (5)

Substituting in the values gives Equation 6:

$$D = \frac{10 + 0.5}{20 - 1.5 + 0.5} = 0.55 \quad (6)$$

And the switch ON time is calculated with Equation 7:

$$t_{ON} = \frac{D}{f} \times 10^6 \ \mu s \quad (7)$$

where

- f is the switching frequency in Hz

So

$$Et = (V_{IN} - V_{SAT} - V_{OUT}) \times t_{ON}$$
$$= (20 - 1.5 - 10) \times \frac{0.55}{150000} \times 10^6 \ V\mu secs$$
$$= 31.3 \ V\mu secs \quad (8)$$

Therefore, looking at Figure 29, quick-select a 100-µH, 1-A inductor (designed for 150-kHz operation) for this application.

2. Confirm that the inductor is rated to handle 100 µJ (see Figure 31) by the procedure shown in AN-1197 (SNVA038) and that the losses are acceptable. (If the DC input voltage is greater than 40 V, consider e_{CLIM} as shown in Example 2).

NOTE

Take V_{SAT} as 1.5 V which includes an estimated resistive drop across the inductor.

This completes the simplified inductor selection procedure. See AN-1197 (SNVA038), for more general applications and better optimization.

10.2.3 Application Curves

(For Continuous Mode Operation)

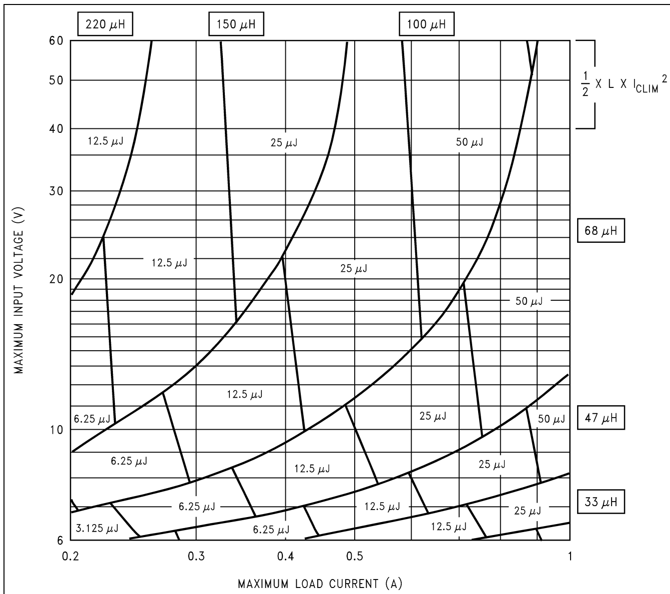


Figure 29. LM2591HV-3.3

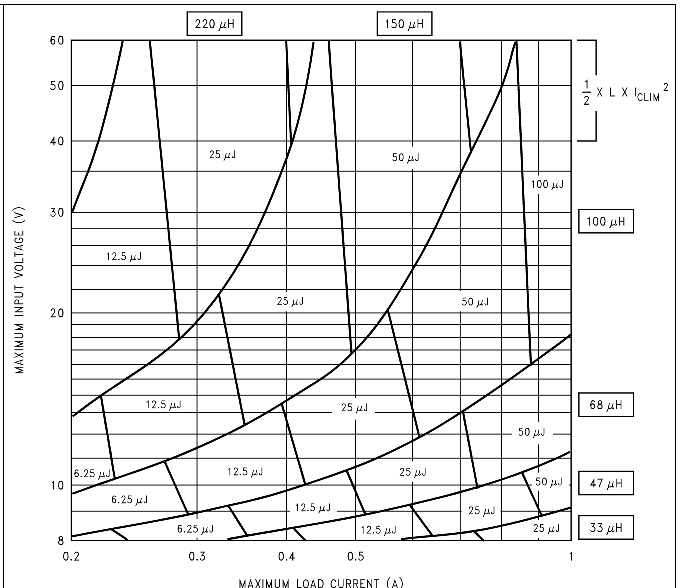


Figure 30. LM2591HV-5.0

(For Continuous Mode Operation)

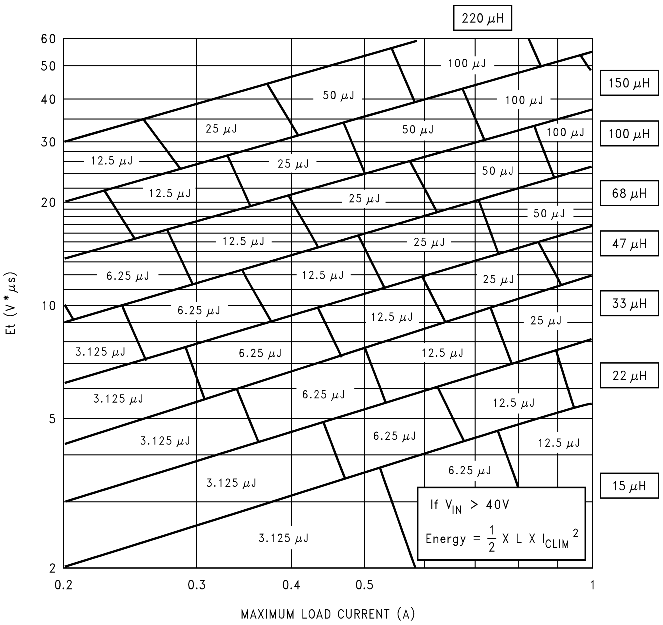


Figure 31. LM2591HV-ADJ

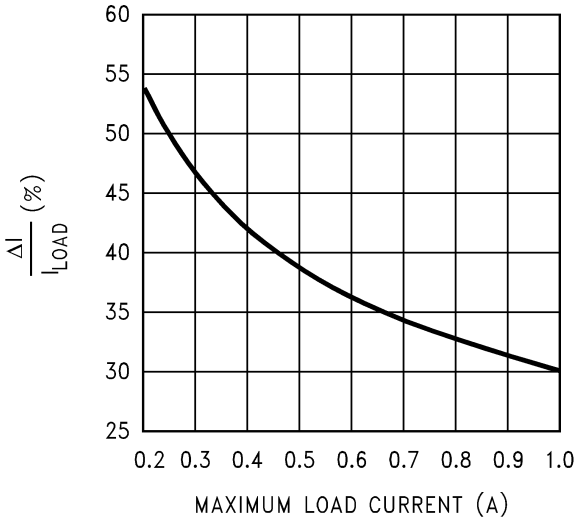


Figure 32. Current Ripple Ratio

11 Power Supply Recommendations

The LM2591HV is designed to operate from an input voltage supply up to 60 V. This input supply must be well regulated, able to withstand maximum input current, and maintain a stable voltage.

12 Layout

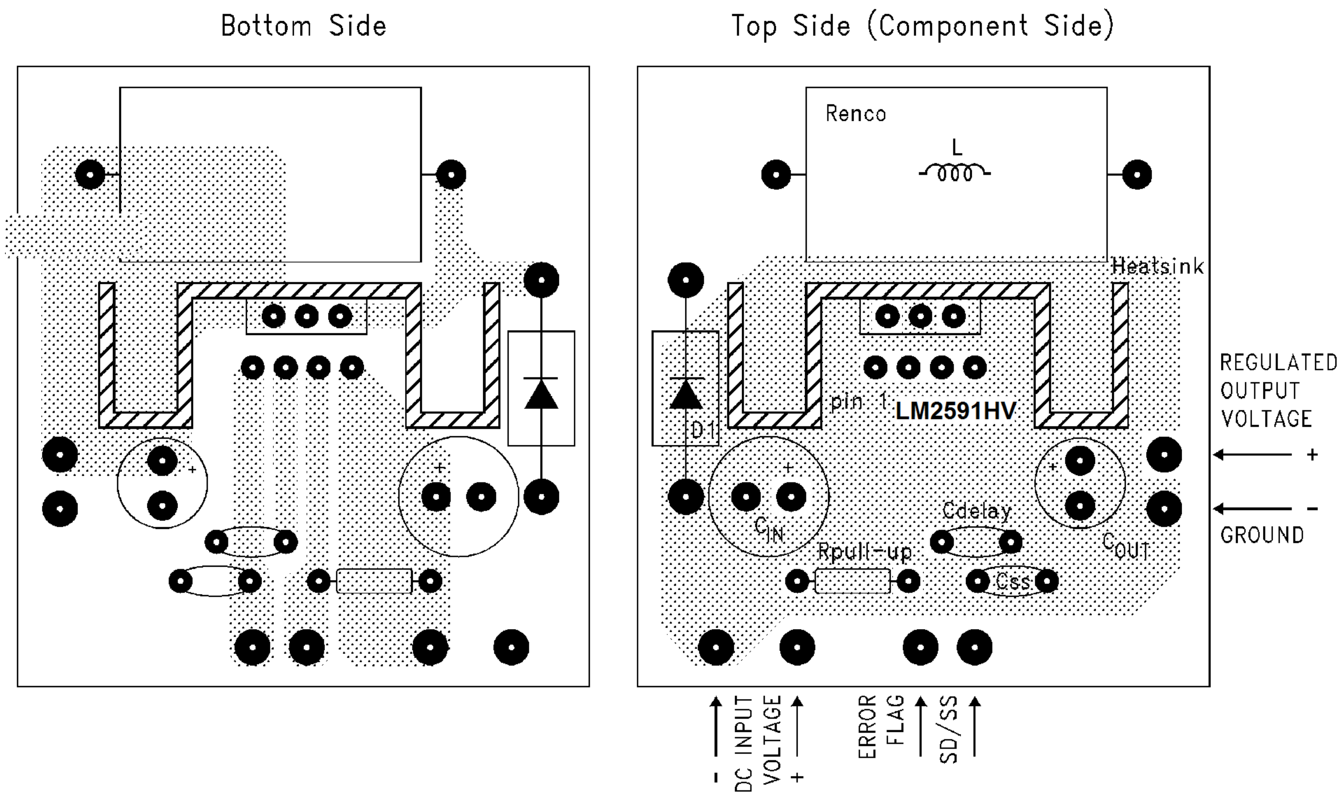
12.1 Layout Guidelines

As in any switching regulator, layout is very important. Rapid switching currents associated with wiring inductance can generate voltage transients, which can cause problems. For minimal inductance and ground loops (see *Test Circuits*), the wires indicated by heavy lines must be wide printed-circuit traces and must be kept as short as possible. For best results, external components must be placed as close to the switcher IC as possible using ground plane construction or single-point grounding.

If open core inductors are used, take special care as to the location and positioning of this type of inductor. Allowing the inductor flux to intersect sensitive feedback, IC groundpath, and C_{OUT} wiring can cause problems.

When using the adjustable version, take special care as to the location of the feedback resistors and the associated wiring. Physically place both resistors near the IC, and route the wiring away from the inductor, especially an open core type of inductor.

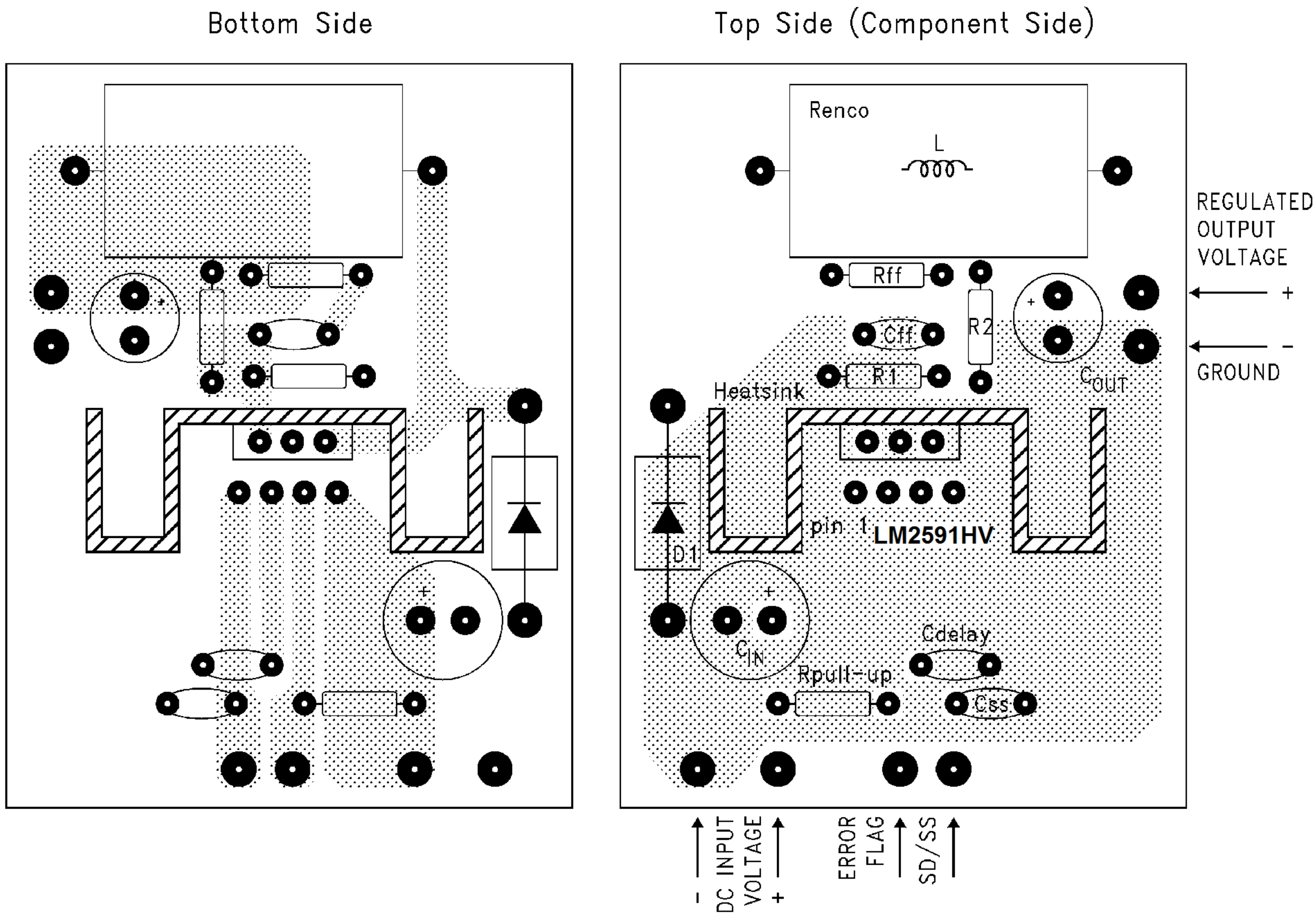
12.2 Layout Examples



C_{IN} = 470-µF, 50-V, aluminum electrolytic Panasonic *HFQ Series*
C_{OUT} = 330-µF, 35-V, aluminum electrolytic Panasonic *HFQ Series*
D1 = 5-A, 40-V Schottky rectifier, 1N5825
L1 = 47-µH, L39, Renco through hole
$R_{PULL\ UP}$ = 10k
C_{DELAY} = 0.1 µF
$C_{SD/SS}$ = 0.1 µF
Thermalloy heat sink #7020

Figure 33. Typical Through-Hole PCB Layout, Fixed Output (1x Size), Double-Sided

Layout Examples (continued)



C_{IN} = 470-µF, 50-V, aluminum electrolytic Panasonic, *HFQ Series*
C_{OUT} = 220-µF, 35-V, aluminum electrolytic Panasonic, *HFQ Series*
D1 = 5-A, 40-V Schottky Rectifier, 1N5825
L1 = 47-µH, L39, Renco, through-hole
R_1 = 1 kΩ, 1%
R_2 = Use formula in *Detailed Design Procedure*
R_{FF} = See *Feedforward Capacitor*
$R_{PULL\ UP}$ = 10k
C_{DELAY} = 0.1 µF
$C_{\overline{SD}/SS}$= 0.1 µF
Thermalloy heat sink #7020

Figure 34. Typical Through-Hole PCB Layout, Adjustable Output (1x Size), Double-Sided

13 デバイスおよびドキュメントのサポート

13.1 コミュニティ・リソース

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

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13.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

14 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。これらの情報は、指定のデバイスに対して提供されている最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LM2591HVS-3.3/NOPB	Active	Production	DDPAK/ TO-263 (KTT) | 5	45 | TUBE	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -3.3 P+
LM2591HVS-3.3/NOPB.B	Active	Production	DDPAK/ TO-263 (KTT) | 5	45 | TUBE	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -3.3 P+
LM2591HVS-5.0/NOPB	Active	Production	DDPAK/ TO-263 (KTT) | 5	45 | TUBE	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -5.0 P+
LM2591HVS-5.0/NOPB.B	Active	Production	DDPAK/ TO-263 (KTT) | 5	45 | TUBE	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -5.0 P+
LM2591HVS-ADJ/NOPB	Active	Production	DDPAK/ TO-263 (KTT) | 5	45 | TUBE	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -ADJ P+
LM2591HVS-ADJ/NOPB.B	Active	Production	DDPAK/ TO-263 (KTT) | 5	45 | TUBE	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -ADJ P+
LM2591HVSX-3.3/NOPB	Active	Production	DDPAK/ TO-263 (KTT) | 5	500 | LARGE T&R	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -3.3 P+
LM2591HVSX-5.0/NOPB	Active	Production	DDPAK/ TO-263 (KTT) | 5	500 | LARGE T&R	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -5.0 P+
LM2591HVSX-ADJ/NOPB	Active	Production	DDPAK/ TO-263 (KTT) | 5	500 | LARGE T&R	ROHS Exempt	SN	Level-3-245C-168 HR	-40 to 125	LM2591HVS -ADJ P+
LM2591HVT-3.3/NOPB	Active	Production	TO-220 (NDH) | 5	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	-40 to 125	LM2591HVT -3.3 P+
LM2591HVT-3.3/NOPB.B	Active	Production	TO-220 (NDH) | 5	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	-40 to 125	LM2591HVT -3.3 P+
LM2591HVT-5.0/NOPB	Active	Production	TO-220 (NDH) | 5	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	-40 to 125	LM2591HVT -5.0 P+
LM2591HVT-5.0/NOPB.B	Active	Production	TO-220 (NDH) | 5	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	-40 to 125	LM2591HVT -5.0 P+
LM2591HVT-ADJ/NOPB	Active	Production	TO-220 (NDH) | 5	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	-40 to 125	LM2591HVT -ADJ P+
LM2591HVT-ADJ/NOPB.B	Active	Production	TO-220 (NDH) | 5	45 | TUBE	Yes	SN	Level-1-NA-UNLIM	-40 to 125	LM2591HVT -ADJ P+

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

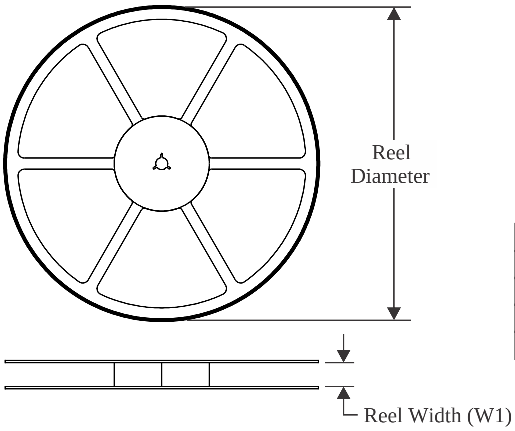
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

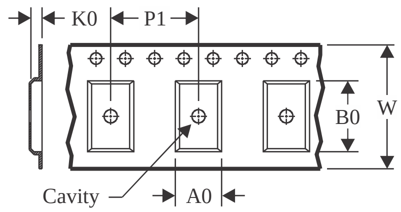
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

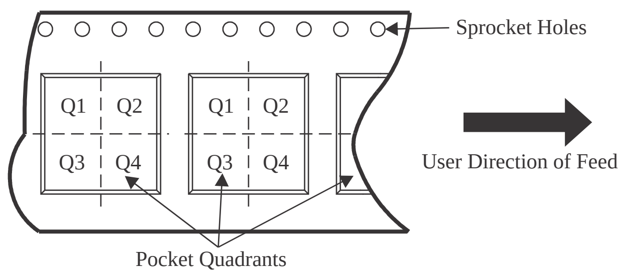


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

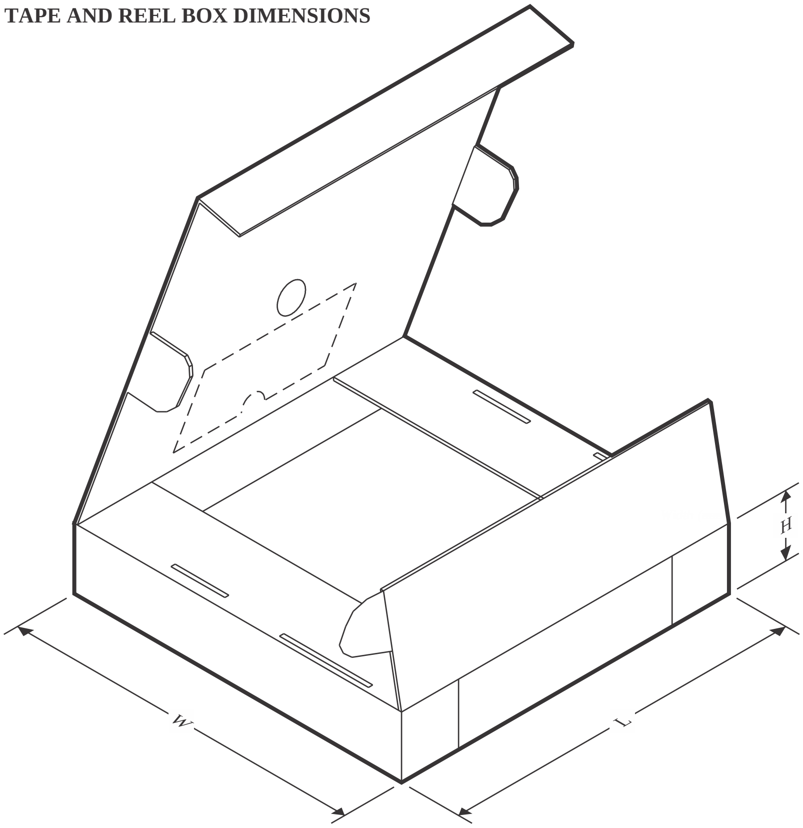
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2591HVSX-3.3/NOPB	DDPAK/ TO-263	KTT	5	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2591HVSX-5.0/NOPB	DDPAK/ TO-263	KTT	5	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2591HVSX-ADJ/NOPB	DDPAK/ TO-263	KTT	5	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

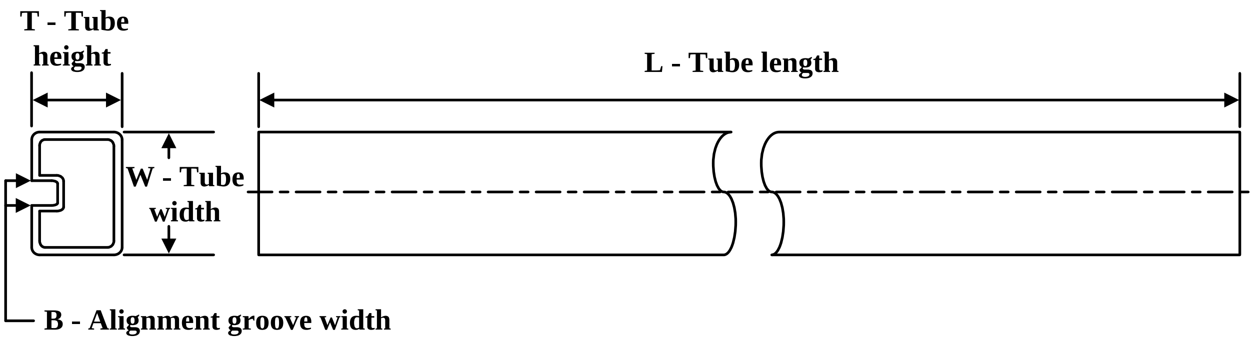
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2591HVSX-3.3/NOPB	DDPAK/TO-263	KTT	5	500	356.0	356.0	45.0
LM2591HVSX-5.0/NOPB	DDPAK/TO-263	KTT	5	500	356.0	356.0	45.0
LM2591HVSX-ADJ/NOPB	DDPAK/TO-263	KTT	5	500	356.0	356.0	45.0

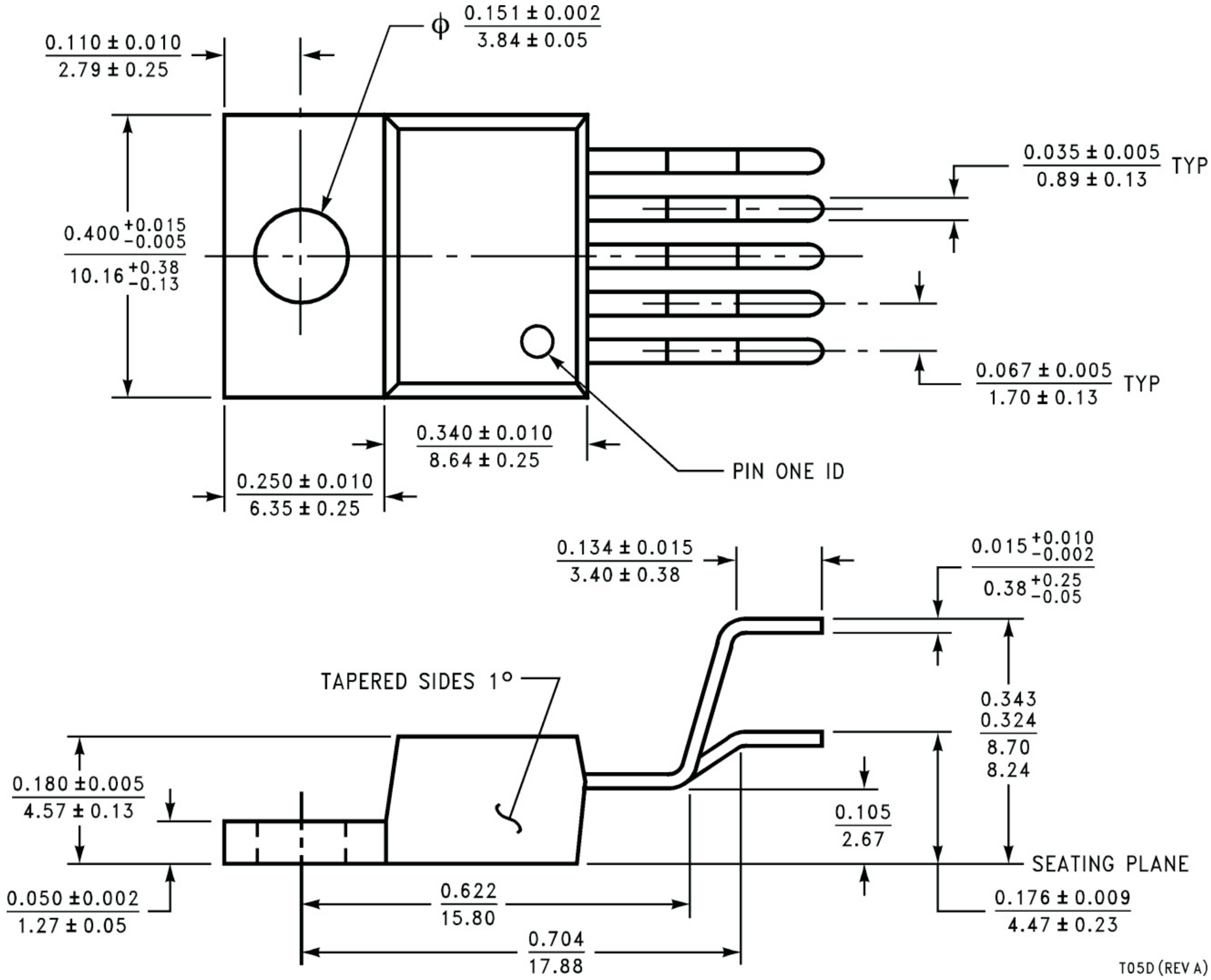
TUBE



*All dimensions are nominal

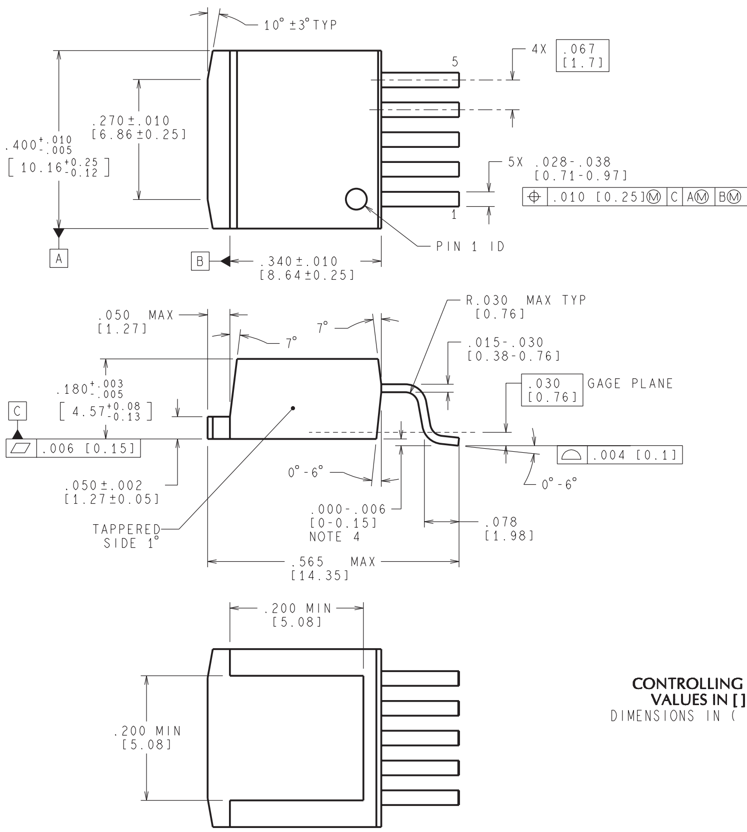
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM2591HVS-3.3/NOPB	KTT	TO-263	5	45	502	25	8204.2	9.19
LM2591HVS-3.3/NOPB.B	KTT	TO-263	5	45	502	25	8204.2	9.19
LM2591HVS-5.0/NOPB	KTT	TO-263	5	45	502	25	8204.2	9.19
LM2591HVS-5.0/NOPB.B	KTT	TO-263	5	45	502	25	8204.2	9.19
LM2591HVS-ADJ/NOPB	KTT	TO-263	5	45	502	25	8204.2	9.19
LM2591HVS-ADJ/NOPB.B	KTT	TO-263	5	45	502	25	8204.2	9.19
LM2591HVT-3.3/NOPB	NDH	TO-220	5	45	502	30	30048.2	10.74
LM2591HVT-3.3/NOPB.B	NDH	TO-220	5	45	502	30	30048.2	10.74
LM2591HVT-5.0/NOPB	NDH	TO-220	5	45	502	30	30048.2	10.74
LM2591HVT-5.0/NOPB.B	NDH	TO-220	5	45	502	30	30048.2	10.74
LM2591HVT-ADJ/NOPB	NDH	TO-220	5	45	502	30	30048.2	10.74
LM2591HVT-ADJ/NOPB.B	NDH	TO-220	5	45	502	30	30048.2	10.74

NDH0005D

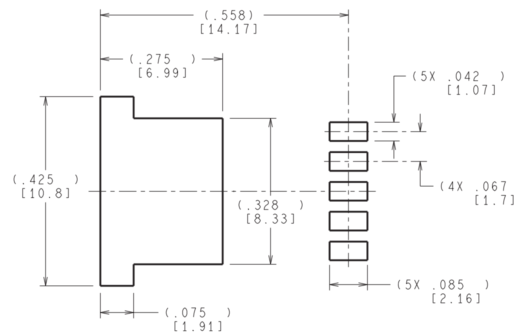


0.151 ± 0.002 / 3.84 ± 0.05
0.110 ± 0.010 / 2.79 ± 0.25
0.035 ± 0.005 / 0.89 ± 0.13 TYP
0.400 +0.015 −0.005 / 10.16 +0.38 −0.13
0.067 ± 0.005 / 1.70 ± 0.13 TYP
0.340 ± 0.010 / 8.64 ± 0.25
PIN ONE ID
0.250 ± 0.010 / 6.35 ± 0.25
0.134 ± 0.015 / 3.40 ± 0.38
0.015 +0.010 −0.002 / 0.38 +0.25 −0.05
TAPERED SIDES 1°
0.343 / 0.324 / 8.70 / 8.24
0.180 ±0.005 / 4.57 ± 0.13
0.105 / 2.67
SEATING PLANE
0.050 ±0.002 / 1.27 ± 0.05
0.622 / 15.80
0.176 ± 0.009 / 4.47 ± 0.23
0.704 / 17.88
T05D (REV A)

KTT0005B



BOTTOM SIDE OF PACKAGE



LAND PATTERN RECOMMENDATION

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

TS5B (Rev D)