

# LM2590HV-AQ-Q1 SIMPLE SWITCHER® Power Converter 150-kHz, 1-A, Step-Down Voltage Regulator With Features

## 1 Features

- Qualified for Automotive Applications
- AEC-Q100 Test Guidance With the Following:
  - Device Temperature Grade 1:  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  Ambient Operating Temperature
  - Device HBM ESD Classification Level 2
  - Device MM ESD Classification Level M3
- 3.3-V, 5-V, and Adjustable Output Versions
- Adjustable Version Output Voltage Range: 1.2 V to 57 V  $\pm 4\%$  Maximum Over Line and Load Conditions
- 1-A Output Load Current
- Available in 7-Pin TO-220 and TO-263 (Surface Mount) Package
- Input Voltage Range up to 60 V
- 150-kHz Fixed Frequency Internal Oscillator
- Shutdown and Soft Start
- Out-of-Regulation Error Flag
- Error Flag Delay
- Low Power Standby Mode,  $I_Q$  Typically 90  $\mu\text{A}$
- High Efficiency
- Thermal Shutdown and Current-Limit Protection

## 2 Applications

- Simple High-Efficiency Step-Down (Buck) Regulators
- Efficient Preregulator for Linear Regulators
- On-Card Switching Regulators
- Positive-to-Negative Converters

## 3 Description

The LM2590HV-AQ-Q1 regulator is a monolithic integrated circuit which provides all the active functions for a step-down (buck) switching regulator, and is capable of driving a 1-A load with excellent line and load regulation. The LM2590HV-AQ-Q1 is available in fixed output voltages of 3.3 V, 5 V, as well as an adjustable output version.

The LM2590HV-AQ-Q1 switching regulator is similar to the LM2591HV with additional supervisory and performance features.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation <sup>(1)</sup>, improved line and load specifications, fixed-frequency oscillator, shutdown or soft start, output error flag, and flag delay.

The LM2590HV-AQ-Q1 operates at a switching frequency of 150 kHz, thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. Available in a standard 7-pin TO-220 package with several different lead bend options, and a 7-pin TO-263 surface mount package.

Other features include a  $\pm 4\%$  tolerance on output voltage under all conditions of input voltage and output load conditions, and  $\pm 15\%$  on the oscillator frequency. External shutdown is included, featuring typically 90- $\mu\text{A}$  standby current. Self-protection features include a two stage current limit for the output switch and an overtemperature shutdown for complete protection under fault conditions.

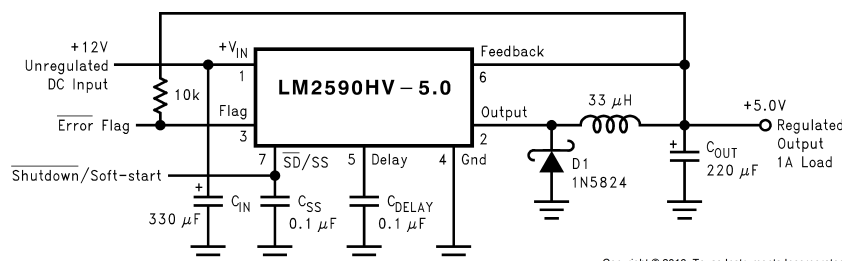
### Device Information (a)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM2590HV-AQ-Q1	DDPAK/TO-263 (7)	10.10 mm x 8.89 mm
	TO-220 (5)	14.986 mm x 10.16 mm

(a) For all available packages, see the orderable addendum at the end of the data sheet.

(1) Patent Number 5,382,918.

### Typical Application (Fixed Output Voltage Versions)



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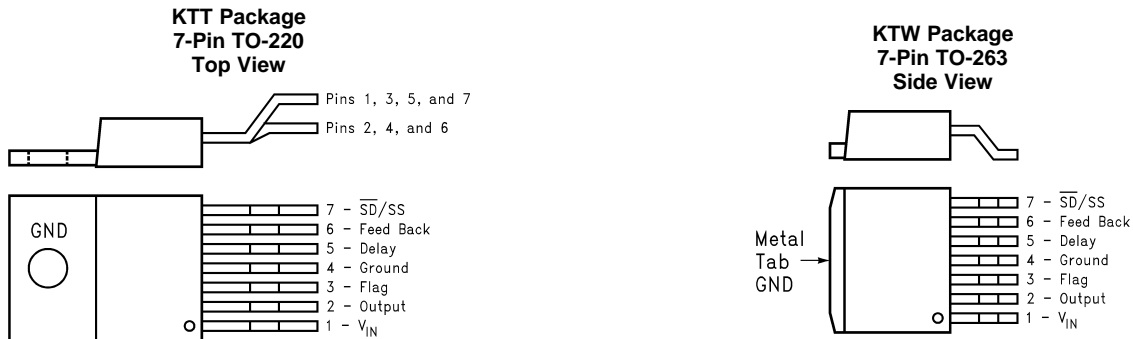
## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision B (April 2013) to Revision C</b>	<b>Page</b>
<ul style="list-style-type: none"> <li>Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section. ....</li> </ul>	<b>1</b>

<b>Changes from Revision A (April 2013) to Revision B</b>	<b>Page</b>
<ul style="list-style-type: none"> <li>Changed layout of National Semiconductor Data Sheet to TI format .....</li> </ul>	<b>22</b>

## 5 Pin Configuration and Functions



### Pin Functions

PIN		I/O <sup>(1)</sup>	DESCRIPTION
NO.	NAME		
1	+V <sub>IN</sub>	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 <sub>IN</sub> – V <sub>SAT</sub> ) and approximately –0.5 V, with a duty cycle of V <sub>OUT</sub> /V <sub>IN</sub> .
3	Error Flag	O	Open-collector output that goes active low ( $\leq 1$ V) when the output of the switching regulator is out of regulation (less than 95% of its nominal value). In this state it can sink maximum 3 mA. When not low, it can be pulled high to signal that the output of the regulator is in regulation (power good). During power up, it can be programmed to go high after a certain delay as set by the Delay pin (Pin 5). The maximum rating of this pin must not be exceeded, so if the rail to which it will be pulled up to is higher than 45 V, a resistive divider must be used instead of a single pullup resistor, as indicated in <a href="#">Figure 25</a> .
4	Ground	G	Circuit ground.
5	Delay	O	This sets a programmable power-up delay from the moment that the output reaches regulation, to the high signal output (power good) on Pin 3. A capacitor on this pin starts charging up by means of an internal ( $\approx 3$ $\mu$ A) current source when the regulated output rises to within 5% of its nominal value. Pin 3 goes high (with an external pullup) when the voltage on the capacitor on Pin 5 exceeds 1.3 V. The voltage on this pin is clamped internally to about 1.7 V. If the regulated output drops out of regulation (less than 95% of its nominal value), the capacitor on Pin 5 is rapidly discharged internally and Pin 3 will be forced low in about 1/1000 <sup>th</sup> of the set power-up delay time.
6	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 <a href="#">Figure 25</a> ). Feedforward capacitor values larger than 0.1 $\mu$ F are not recommended for the same reason, whatever be the DC input voltage.
7	Shutdown / Soft Start	I	The regulator is in shutdown mode, drawing about 90 $\mu$ A, when this pin is driven to a low level ( $\leq 0.6$ V), and is in normal operation when this pin is left floating (internal pullup) or driven to a high level ( $\geq 2$ V). The typical value of the threshold is 1.3 V and the pin is internally clamped to a maximum of about 7 V. If it is driven higher than the clamp voltage, it must be ensured by means of an external resistor that the current into the pin does not exceed 1 mA. The duty cycle is minimum (0%) if this pin is below 1.8 V, and increases as the voltage on the pin is increased. The maximum duty cycle (100%) occurs when this pin is at 2.8 V or higher. So adding a capacitor to this pin produces a soft-start feature. An internal current source charges the capacitor from zero to its internally clamped value. The charging current is about 5 $\mu$ A when the pin is below 1.3 V but is reduced to only 1.6 $\mu$ A above 1.3 V, so as to allow the use of smaller soft-start capacitors.

**NOTE**

If any of the above three features (Shutdown /Soft Start, Error Flag, or Delay) are not used, the respective pins can be left open.

(1) I = Input, O = Output, G = Ground.

## 6 Specifications

### 6.1 Absolute Maximum Ratings<sup>(1)</sup>

		MIN	MAX	UNIT	
Maximum supply voltage ( $V_{IN}$ )			63	V	
$\overline{SD}$ /SS pin input voltage <sup>(2)</sup>			6	V	
Delay pin voltage <sup>(2)</sup>			1.5	V	
Flag pin voltage		-0.3	45	V	
Feedback pin voltage		-0.3	25	V	
Output voltage to ground (steady-state)			-1	V	
Power dissipation		Internally limited			
Lead temperature	S Package	Vapor Phase (60 sec.)		215	°C
		Infrared (10 sec.)		245	°C
	T Package	(Soldering, 10 sec.)		260	°C
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) Voltage internally clamped. If clamp voltage is exceeded, limit current to a maximum of 1 mA.

### 6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge <sup>(1)</sup>	Human-body model (HBM), per AEC Q100-002 <sup>(2)(1)</sup>	±2000	V
	Machine Model (AEC-100-003)	±200	

- (1) The human body model is a 100-pF capacitor discharged through a 1.5-k resistor; the Machine Model is 200 pF discharged through a 0- $\Omega$  resistor.
- (2) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 6.3 Recommended Operating Conditions

	MIN	MAX	UNIT
Ambient temperature	-40	125	°C
Junction temperature	-40	150	°C
Supply voltage	4.5	60	V

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		LM2590HV-AQ-Q1		UNIT
		KTT (TO-220)	KTW (TO-263)	
		7 PINS	7 PINS	
$R_{\theta JA}$ Junction-to-ambient thermal resistance	See <sup>(2)(3)</sup>	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.
- (2) The package thermal impedance is calculated in accordance to JESD 51-7
- (3) Thermal Resistances were simulated on a 4-layer, JEDEC board

## 6.5 Electrical Characteristics – 3.3 V

Specifications are for  $T_J = 25^\circ\text{C}$  unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN <sup>(1)</sup>	TYP <sup>(2)</sup>	MAX <sup>(1)</sup>	UNIT	
<b>SYSTEM PARAMETERS – See <sup>(3)</sup></b>						
$V_{OUT}$ Output voltage	$4.75\text{ V} \leq V_{IN} \leq 60\text{ V}$ , $0.2\text{ A} \leq I_{LOAD} \leq 1\text{ A}$		3.168	3.3	3.432	V
		apply over full operating temperature range	3.135		3.465	
$\eta$ Efficiency	$V_{IN} = 12\text{ V}$ , $I_{LOAD} = 1\text{ A}$		77%			

- (1) All limits at room temperature ( $T_J = 25^\circ\text{C}$ ) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
- (2) Typical numbers are at  $25^\circ\text{C}$  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 LM2590HV-AQ-Q1 is used as shown in the [Figure 24](#) test circuit, system performance will be as shown in system parameters section of [Electrical Characteristics](#).

## 6.6 Electrical Characteristics – 5 V

Specifications are for  $T_J = 25^\circ\text{C}$  unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN <sup>(1)</sup>	TYP <sup>(2)</sup>	MAX <sup>(1)</sup>	UNIT	
<b>SYSTEM PARAMETERS – See <sup>(3)</sup></b>						
$V_{OUT}$ Output voltage	$7\text{ V} \leq V_{IN} \leq 60\text{ V}$ , $0.2\text{ A} \leq I_{LOAD} \leq 1\text{ A}$		4.8	5	5.2	V
		apply over full operating temperature range	4.75		5.25	
$\eta$ Efficiency	$V_{IN} = 12\text{ V}$ , $I_{LOAD} = 1\text{ A}$		82%			

- (1) All limits at room temperature ( $T_J = 25^\circ\text{C}$ ) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
- (2) Typical numbers are at  $25^\circ\text{C}$  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 LM2590HV-AQ-Q1 is used as shown in the [Figure 24](#) test circuit, system performance will be as shown in system parameters section of [Electrical Characteristics](#).

## 6.7 Electrical Characteristics – ADJ

Specifications are for  $T_J = 25^\circ\text{C}$  unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN <sup>(1)</sup>	TYP <sup>(2)</sup>	MAX <sup>(1)</sup>	UNIT	
<b>SYSTEM PARAMETERS – See <sup>(3)</sup></b>						
$V_{FB}$ Feedback voltage	$4.5\text{ V} \leq V_{IN} \leq 60\text{ V}$ , $0.2\text{ A} \leq I_{LOAD} \leq 1\text{ A}$		1.193	1.23	1.267	V
		apply over full operating temperature range	1.18		1.28	
$I_{FB}$ Feedback bias current	$V_{FB} = 1.3\text{ V}$			10	50	nA
		apply over full operating temperature range			300	
$\eta$ Efficiency	$V_{IN} = 12\text{ V}$ , $V_{OUT} = 3\text{ V}$ , $I_{LOAD} = 1\text{ A}$		76%			

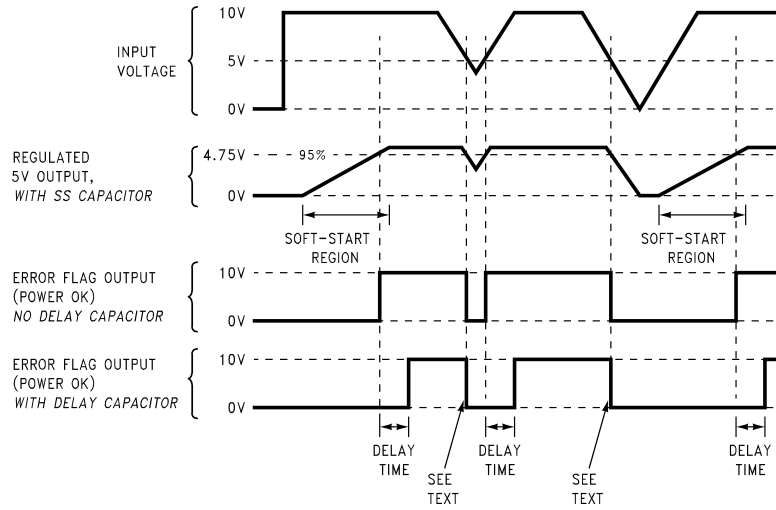
- (1) All limits at room temperature ( $T_J = 25^\circ\text{C}$ ) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
- (2) Typical numbers are at  $25^\circ\text{C}$  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 LM2590HV-AQ-Q1 is used as shown in the [Figure 25](#) test circuit, system performance will be as shown in system parameters section of [Electrical Characteristics](#).

## 6.8 All Output Voltage Versions Electrical Characteristics

Specifications are for  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$  for the 3.3-V, 5-V, and adjustable version, and  $I_{LOAD} = 500\text{ mA}$ , unless otherwise specified. Unless otherwise specified,

PARAMETER		TEST CONDITIONS	MIN <sup>(1)</sup>	TYP <sup>(2)</sup>	MAX <sup>(1)</sup>	UNIT
<b>DEVICE PARAMETERS</b>						
$f_O$	Oscillator frequency	See <sup>(3)</sup>		127	150	173
			apply over full operating temperature range	110		173
$V_{SAT}$	Saturation voltage	$I_{OUT} = 1\text{ A}$ <sup>(4)</sup> <sup>(5)</sup>		0.95	1.2	V
			apply over full operating temperature range		1.3	
DC	Max duty cycle (ON)	See <sup>(5)</sup>		100%		
	Min duty cycle (OFF)	See <sup>(6)</sup>		0%		
$I_{CLIM}$	Switch current limit	Peak current <sup>(4)</sup> <sup>(5)</sup>		1.3	1.9	2.8
			apply over full operating temperature range	1.2		3.0
$I_L$	Output leakage current	Output = 0 V <sup>(4)</sup> <sup>(6)</sup> <sup>(7)</sup>			50	$\mu\text{A}$
		Output = -1 V <sup>(4)</sup> <sup>(6)</sup> <sup>(7)</sup>		5	30	mA
$I_Q$	Operating quiescent current	$\overline{SD}$ /SS pin open <sup>(6)</sup>		5	10	mA
$I_{STBY}$	Standby quiescent current	$\overline{SD}$ /SS pin = 0 V <sup>(7)</sup>		90	200	$\mu\text{A}$
			apply over full operating temperature range		250	
<b>SHUTDOWN/SOFT-START CONTROL – See Figure 25</b>						
$V_{SD}$	Shutdown threshold voltage	Shutdown mode, $I_{STBY} < 250\ \mu\text{A}$		1.3		V
			apply over full operating temperature range	0.6		
$V_{SS}$	Soft-start voltage	$V_{OUT} = 1\%$ of Normal Output Voltage		1.8		V
		$V_{OUT} = 20\%$ of Nominal Output Voltage		2		V
$V_{SS}$	Soft-start voltage	$V_{OUT} = 100\%$ of Nominal Output Voltage		3		V
$I_{SD}$	Shutdown current	$V_{SHUTDOWN} = 0.5\text{ V}$		5	10	$\mu\text{A}$
$I_{SS}$	Soft-start current	$V_{Soft-start} = 2.5\text{ V}$		1.5	5	$\mu\text{A}$
<b>FLAG/DELAY CONTROL – See Figure 25</b>						
	Regulator dropout detector threshold voltage	Low (Flag ON)		92%	96%	98%
$V_{FSAT}$	Flag output saturation voltage	$I_{SINK} = 3\text{ mA}$ $V_{DELAY} = 0.5\text{ V}$		0.3	0.7	V
			apply over full operating temperature range		1	
$I_{FL}$	Flag output leakage current	$V_{FLAG} = 60\text{ V}$		0.3		$\mu\text{A}$
$V_{DTH}$	Delay pin threshold voltage	$V_{OUT}$ Regulated	1.21	1.25	1.29	V
$I_{DELAY}$	Delay pin source current	$V_{DELAY} = 0.5\text{ V}$		3	6	$\mu\text{A}$
$I_{DSAT}$	Delay pin saturation	Low (flag ON)		70	350	mV
			apply over full operating temperature range		400	

- (1) All limits at room temperature ( $T_J = 25^\circ\text{C}$ ) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
- (2) Typical numbers are at  $25^\circ\text{C}$  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)  $V_{IN} = 60\text{ V}$ .



**Figure 1. Timing Diagram for 5-V Output**

## 6.9 Typical Characteristics

(Circuit of [Figure 24](#))

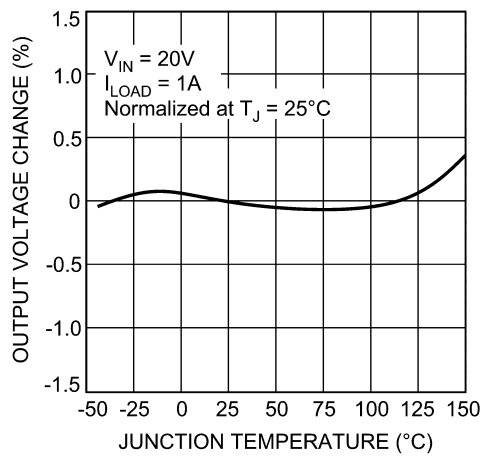


Figure 2. Normalized Output Voltage

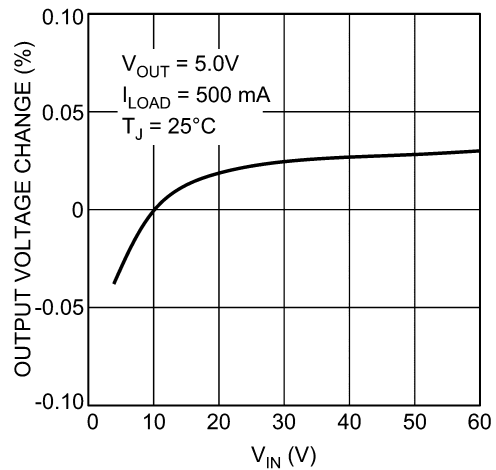


Figure 3. Line Regulation

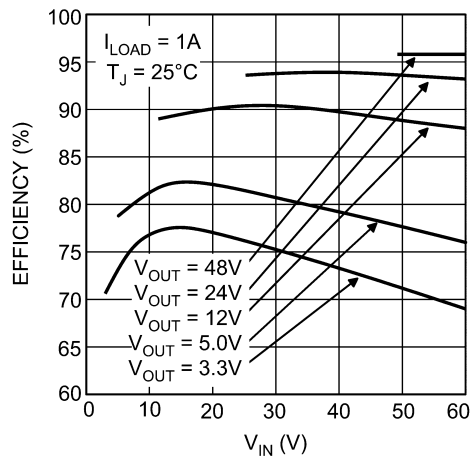


Figure 4. Efficiency

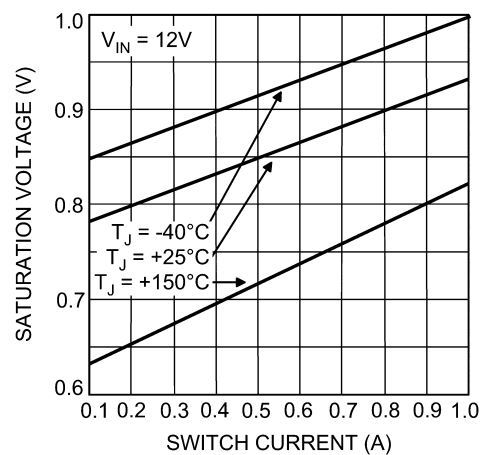


Figure 5. Switch Saturation Voltage

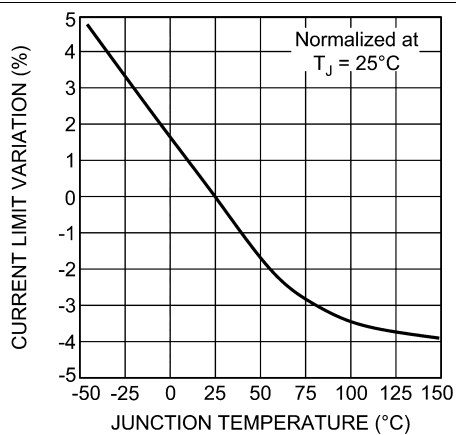


Figure 6. Switch Current Limit

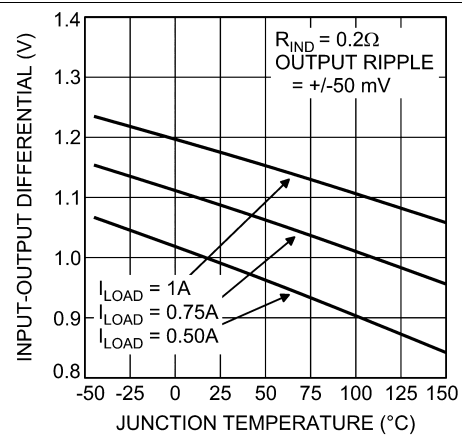


Figure 7. Dropout Voltage



Typical Characteristics (continued)

(Circuit of Figure 24)

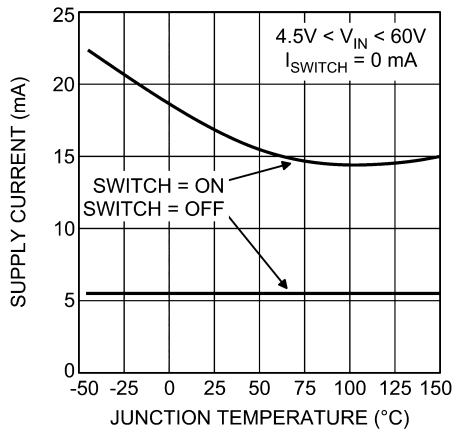


Figure 8. Operating Quiescent Current

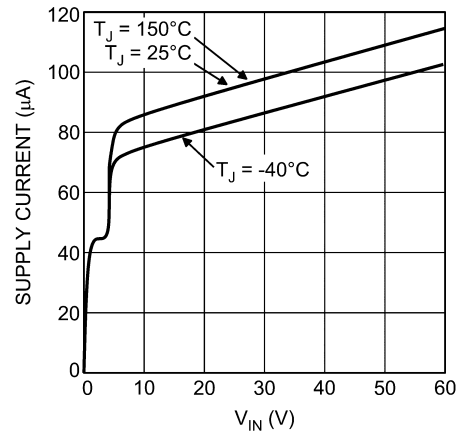


Figure 9. Shutdown Quiescent Current

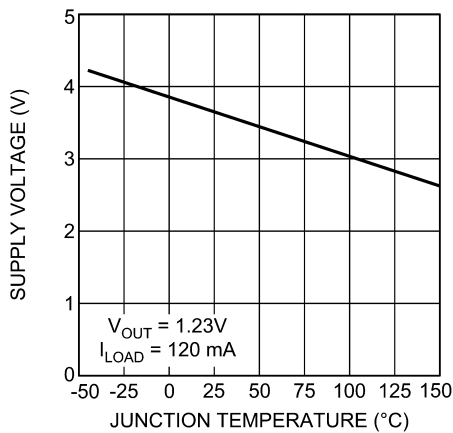


Figure 10. Minimum Operating Supply Voltage

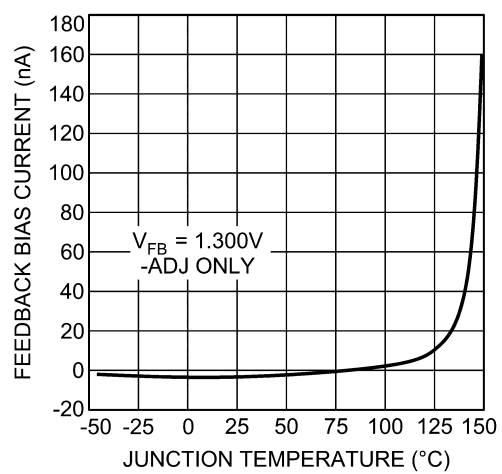


Figure 11. Feedback Pin Bias Current

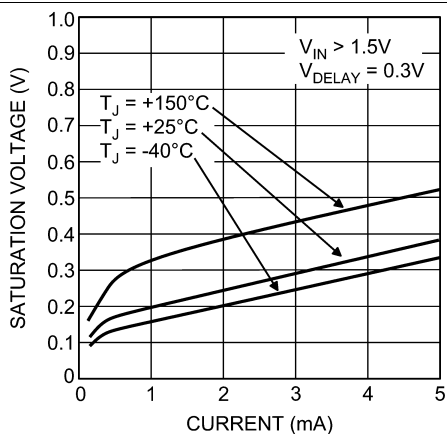


Figure 12. Flag Saturation Voltage

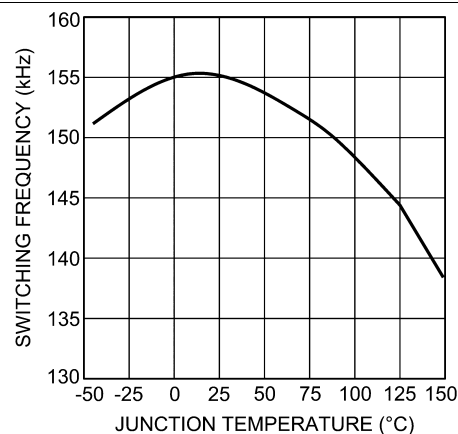


Figure 13. Switching Frequency

Typical Characteristics (continued)

(Circuit of Figure 24)

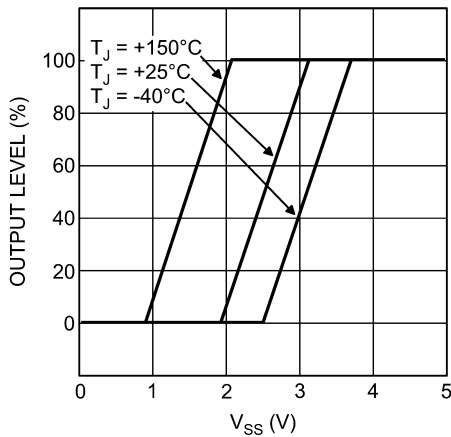


Figure 14. Soft Start

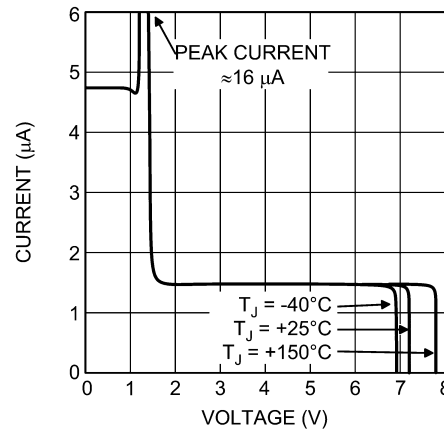


Figure 15. SHUTDOWN and Soft-Start Current

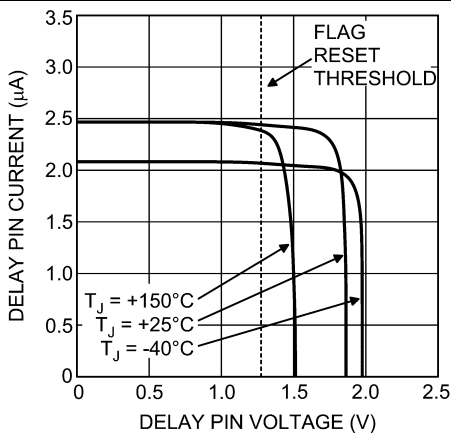


Figure 16. Delay Pin Current

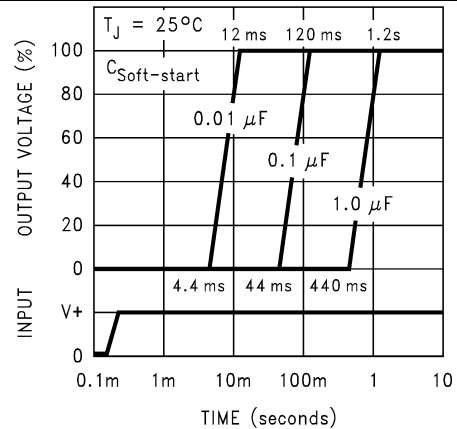


Figure 17. Soft-Start Response

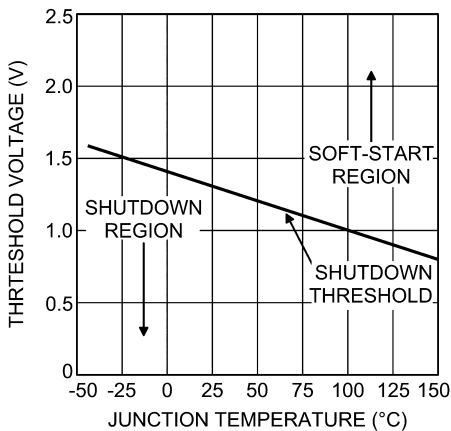


Figure 18. SHUTDOWN and Soft-Start Threshold Voltage

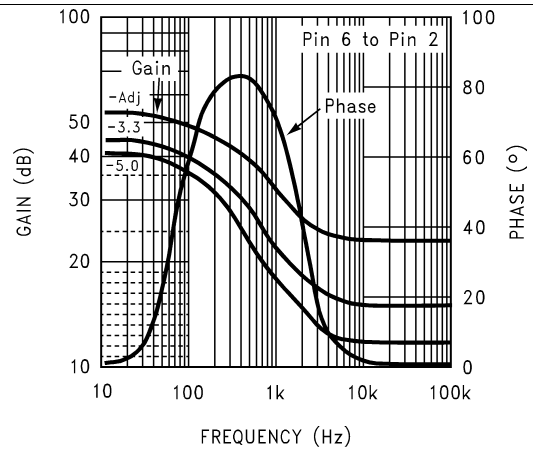
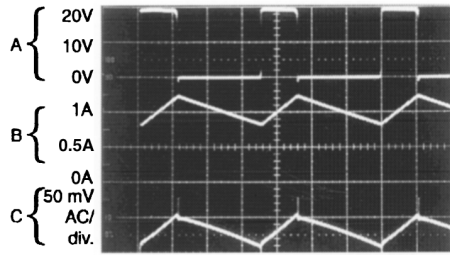


Figure 19. Internal Gain-Phase Characteristics

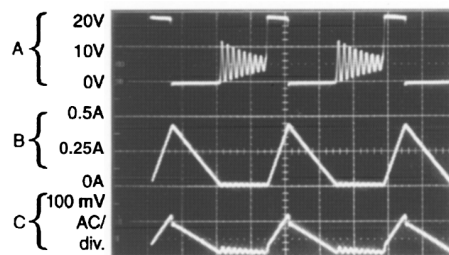
**Typical Characteristics (continued)**

(Circuit of Figure 24)



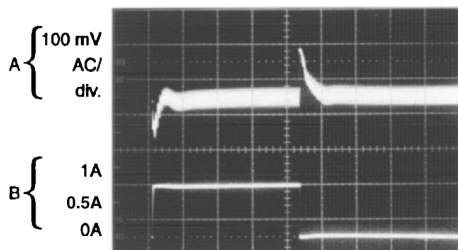
Continuous Mode Switching Waveforms  $V_{IN} = 20\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{LOAD} = 1\text{ A}$ ,  $L = 52\text{ }\mu\text{H}$ ,  $C_{OUT} = 100\text{ }\mu\text{F}$ ,  $C_{OUT}\text{ ESR} = 100\text{ m}\Omega$   
Output Pin Voltage, 10 V/div.  
Inductor Current 0.5 A/div.  
Output Ripple Voltage, 50 mV/div.

**Figure 20. Horizontal Time Base: 2  $\mu\text{s}/\text{div}$**



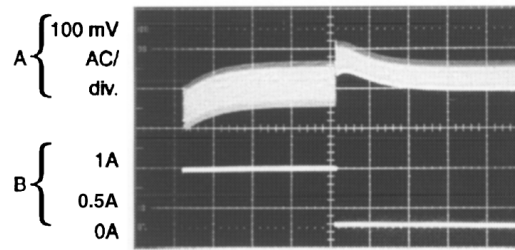
Discontinuous Mode Switching Waveforms  $V_{IN} = 20\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{LOAD} = 250\text{ mA}$ ,  $L = 15\text{ }\mu\text{H}$ ,  $C_{OUT} = 150\text{ }\mu\text{F}$ ,  $C_{OUT}\text{ ESR} = 90\text{ m}\Omega$   
Output Pin Voltage, 10 V/div.  
Inductor Current 0.25 A/div.  
Output Ripple Voltage, 100 mV/div.

**Figure 21. Horizontal Time Base: 2  $\mu\text{s}/\text{div}$**



Load Transient Response for Continuous Mode  $V_{IN} = 20\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{LOAD} = 250\text{ mA}$  to 1 A,  $L = 52\text{ }\mu\text{H}$ ,  $C_{OUT} = 100\text{ }\mu\text{F}$ ,  $C_{OUT}\text{ ESR} = 100\text{ m}\Omega$   
Output Voltage, 100 mV/div. (AC)  
250-mA to 1-A Load Pulse

**Figure 22. Horizontal Time Base: 50  $\mu\text{s}/\text{div}$**

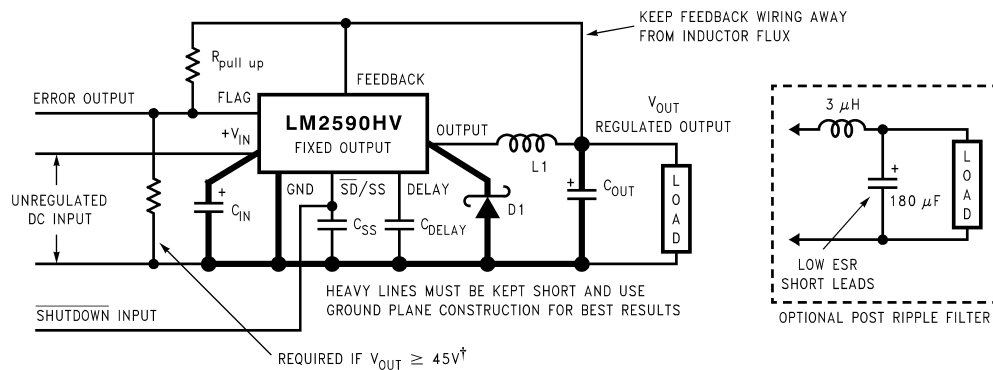


Load Transient Response for Discontinuous Mode  $V_{IN} = 20\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{LOAD} = 250\text{ mA}$  to 1 A,  $L = 15\text{ }\mu\text{H}$ ,  $C_{OUT} = 150\text{ }\mu\text{F}$ ,  $C_{OUT}\text{ ESR} = 90\text{ m}\Omega$   
Output Voltage, 100 mV/div. (AC)  
250-mA to 1-A Load Pulse

**Figure 23. Horizontal Time Base: 200  $\mu\text{s}/\text{div}$**

## 7 Parameter Measurement Information

### 7.1 Test Circuits



Component Values shown are for  $V_{IN} = 15\text{ V}$ ,

$V_{OUT} = 5\text{ V}$ ,  $I_{LOAD} = 1\text{ A}$ .

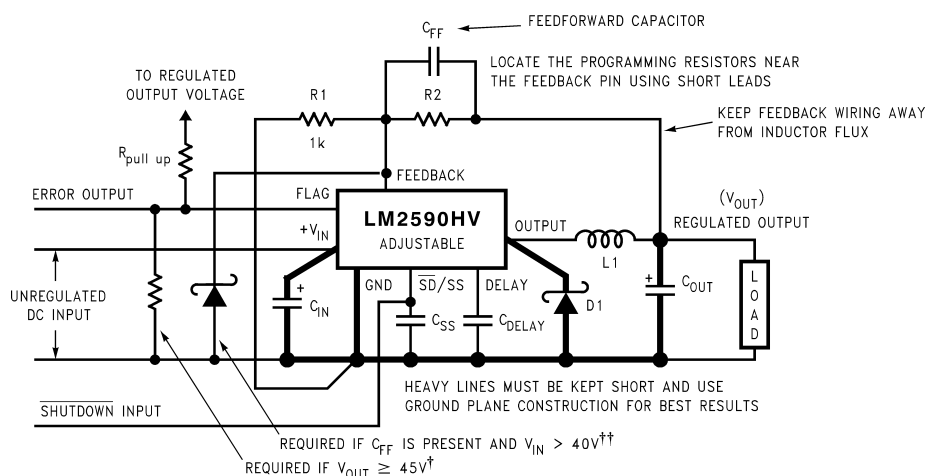
$C_{IN}$  — 470- $\mu\text{F}$ , 50-V, Aluminum Electrolytic Nichicon *PM Series*

$C_{OUT}$  — 220- $\mu\text{F}$ , 25-V Aluminum Electrolytic, Nichicon *PM Series*

D1 — 2-A, 60-V Schottky Rectifier, 21DQ06 (International Rectifier)

L1 — 68  $\mu\text{H}$ , See [Inductor Selection Procedure](#)

**Figure 24. Fixed Output Voltage Versions**



Select  $R_1$  to be approximately 1 k $\Omega$ , use a 1% resistor for best stability.

Component Values shown are for  $V_{IN} = 20\text{ V}$ ,

$V_{OUT} = 10\text{ V}$ ,  $I_{LOAD} = 1\text{ A}$ .

$C_{IN}$ : — 470- $\mu\text{F}$ , 35-V, Aluminum Electrolytic Nichicon *PM Series*

$C_{OUT}$ : — 220- $\mu\text{F}$ , 35-V Aluminum Electrolytic, Nichicon *PM Series*

D1 — 2-A, 60-V Schottky Rectifier, 21DQ06 (International Rectifier)

L1 — 100  $\mu\text{H}$ , See [Inductor Selection Procedure](#)

$R_1$  — 1 k $\Omega$ , 1%

$R_2$  — 7.15k, 1%

$C_{FF}$  — 3.3 nF

*Typical Values*

$C_{SS}$ —0.1  $\mu\text{F}$

$C_{DELAY}$ —0.1  $\mu\text{F}$

$R_{PULL\ UP}$  — 4.7k (use 22k if  $V_{OUT}$  is  $\geq 45\text{ V}$ )

† Resistive divider is required to avoid exceeding maximum rating of 45 V or 3 mA on or into flag pin.

†† Small signal Schottky diode to prevent damage to feedback pin by negative spike when output is shorted ( $C_{FF}$  not being able to discharge immediately will drag feedback pin below ground). Required if  $V_{IN} > 40\text{ V}$

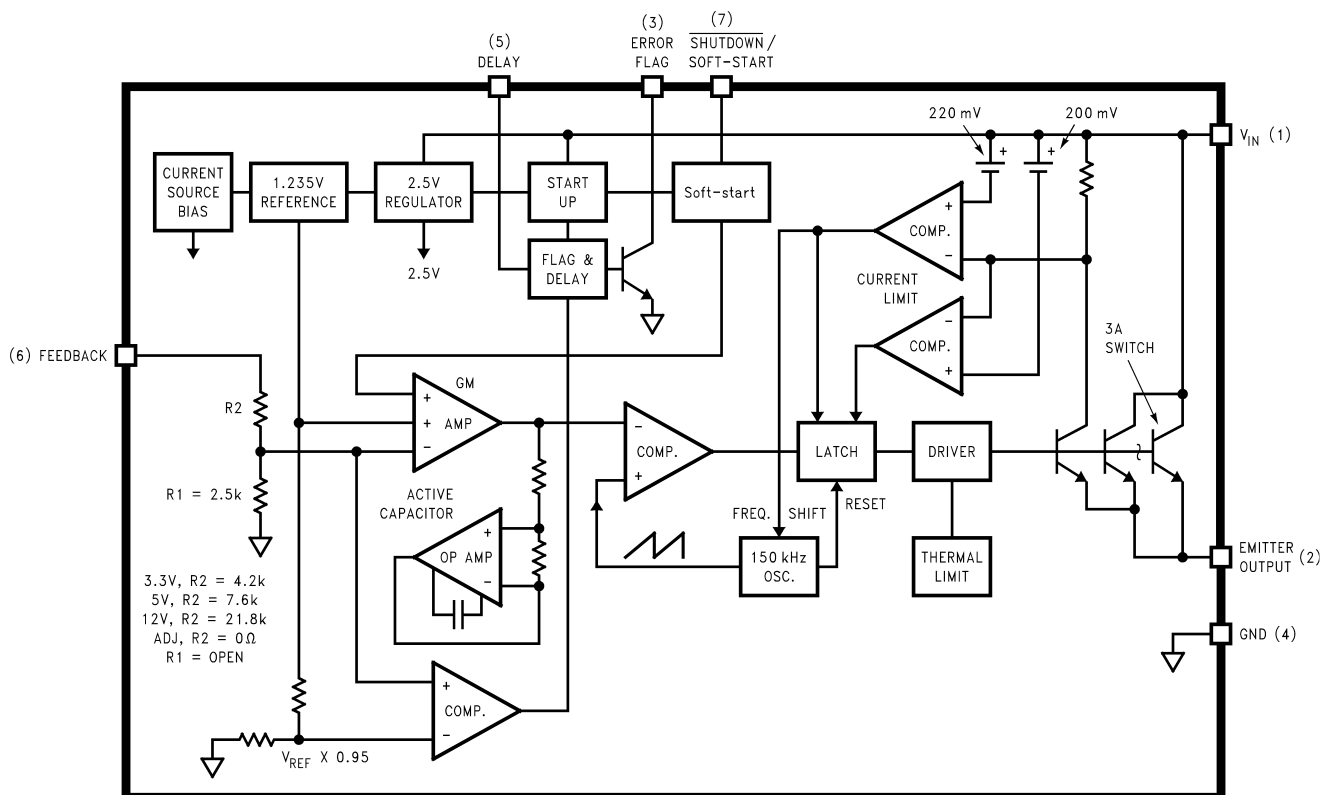
**Figure 25. Adjustable Output Voltage Versions**

## 8 Detailed Description

### 8.1 Overview

The LM2590 SIMPLE SWITCHER® regulator is an easy-to-use non-synchronous step-down DC-DC converter with a wide input voltage range up to 60 V. It 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, 12-V, and an adjustable output version. The family requires few external components and the pin arrangement was designed for simple, optimum PCB layout.

### 8.2 Functional Block Diagram



### 8.3 Feature Description

#### 8.3.1 Undervoltage Lockout

Some applications require the regulator to remain off until the input voltage reaches a predetermined voltage. [Figure 26](#) contains an undervoltage lockout circuit for a buck configuration, while [Figure 27](#) and [Figure 28](#) are for the inverting types (only the circuitry pertaining to the undervoltage lockout is shown). [Figure 26](#) uses a Zener diode to establish the threshold voltage when the switcher begins operating. When the input voltage is less than the Zener voltage, resistors R1 and R2 hold the SHUTDOWN /Soft-start pin low, keeping the regulator in the shutdown mode. As the input voltage exceeds the Zener voltage, the Zener conducts, pulling the SHUTDOWN /Soft-start pin high, allowing the regulator to begin switching. The threshold voltage for the undervoltage lockout feature is approximately 1.5 V greater than the Zener voltage.

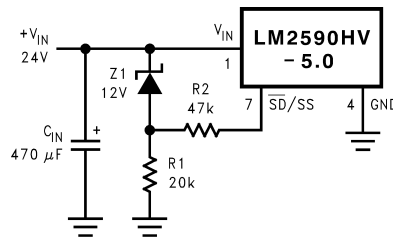
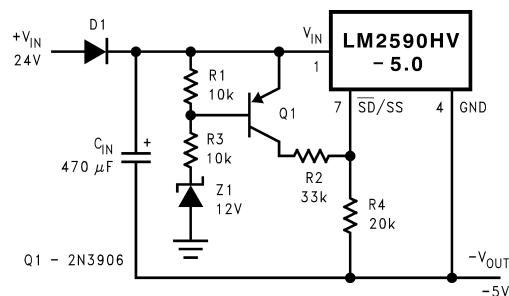
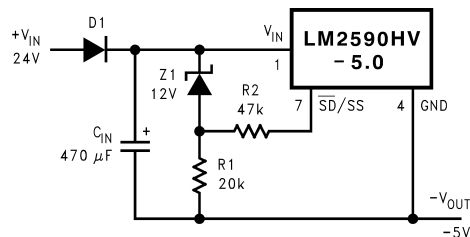
**Feature Description (continued)**

**Figure 26. Undervoltage Lockout for a Buck Regulator**

Figure 27 and Figure 28 apply the same feature to an inverting circuit. Figure 27 features a constant threshold voltage for turnon and turnoff (Zener voltage plus approximately one volt). If hysteresis is needed, the circuit in Figure 28 has a turn ON voltage which is different than the turn OFF voltage. Because the  $\overline{\text{SD/SS}}$  pin has an internal 7-V Zener clamp, R2 is needed to limit the current into this pin to approximately 1 mA when Q1 is on.


**Figure 27. Undervoltage Lockout Without Hysteresis for an Inverting Regulator**

**Figure 28. Undervoltage Lockout With Hysteresis for an Inverting Regulator**
**8.3.2 SHUTDOWN / Soft-Start**

This reduction in start-up current is useful in situations where the input power source is limited in the amount of current it can deliver. In some applications, soft start can be used to replace undervoltage lockout or delayed start-up functions.

If a very slow output voltage ramp is desired, the soft-start capacitor can be made much larger. Many seconds or even minutes are possible.

If only the shutdown feature is needed, the soft-start capacitor can be eliminated.

Feature Description (continued)

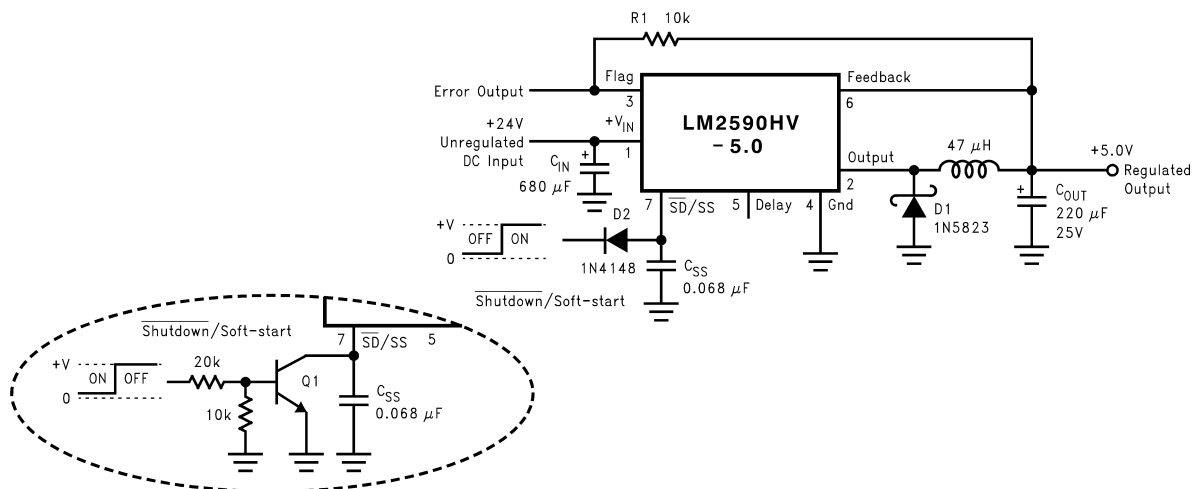
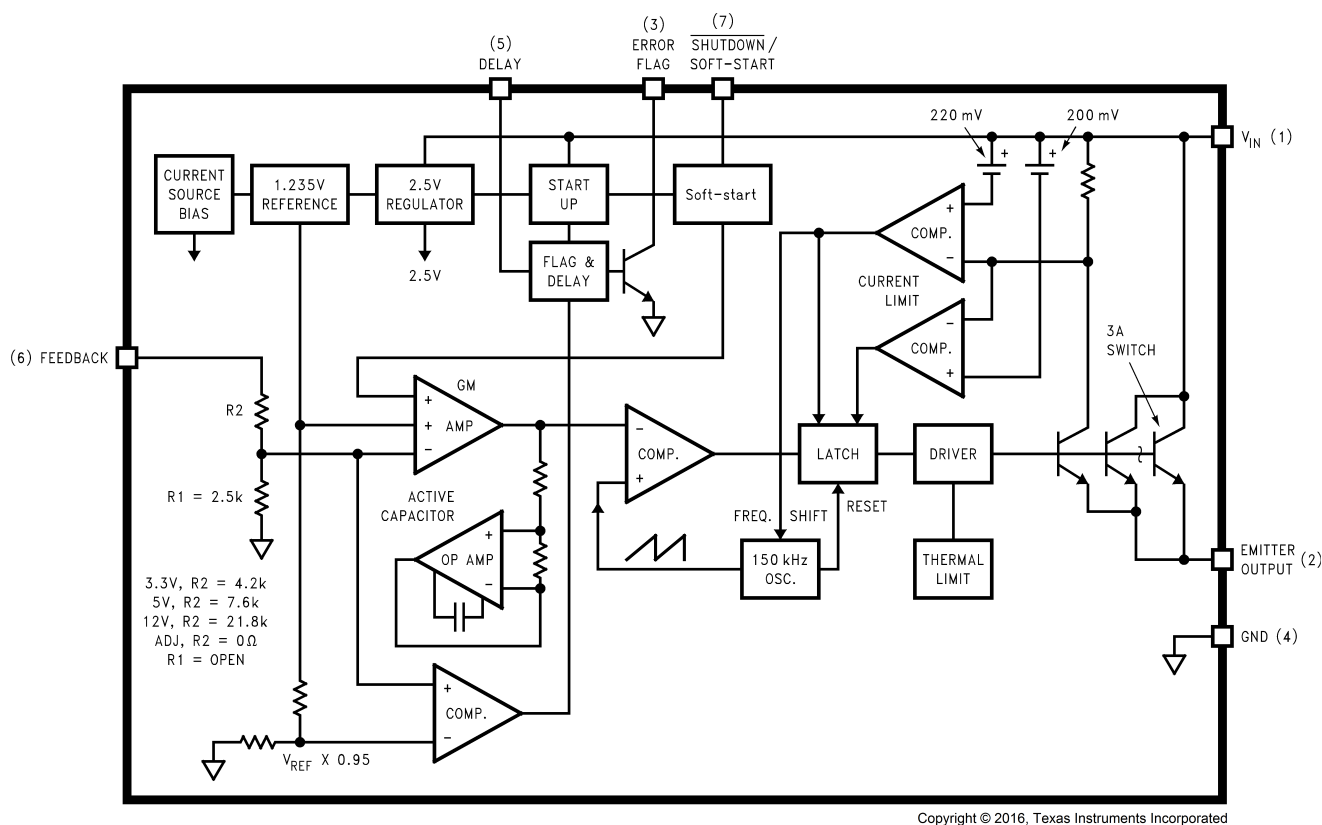


Figure 29. Typical Circuit Using SHUTDOWN /Soft Start and Error Flag Features



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Figure 30. Inverting -5-V Regulator With SHUTDOWN and Soft Start

## Feature Description (continued)

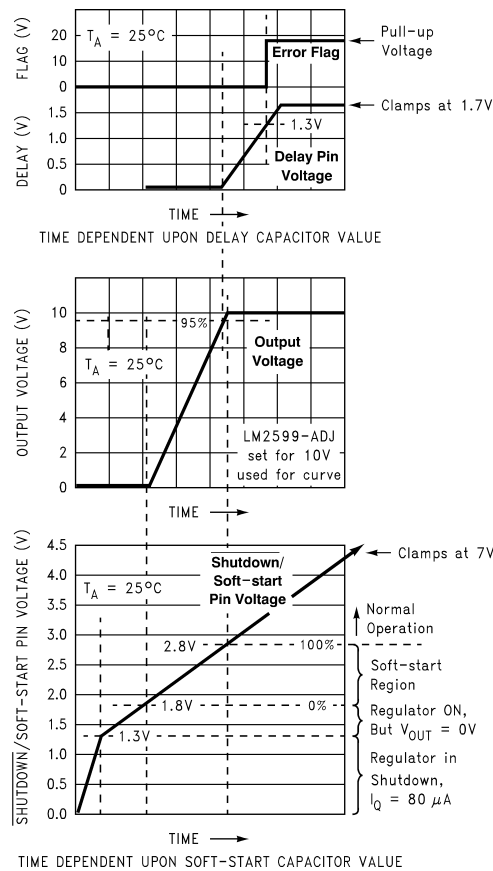


Figure 31. Soft Start, Delay, Error Output

## 8.4 Device Functional Modes

### 8.4.1 Shutdown Mode

The SHUTDOWN / Soft-start pin provides electrical ON and OFF control for the LM2590. When the voltage of this pin is less than 0.6 V, the device is shutdown mode. The typical standby current in this mode is 90  $\mu A$ .

### 8.4.2 Active Mode

When the SHUTDOWN / Soft-start pin is left floating or pull above 2 V, the device starts switching and the output voltage rises until it reaches a normal regulation voltage.



## 9 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.

### 9.1 Application Information

#### 9.1.1 Feedforward Capacitor

(Adjustable Output Voltage Version)

$C_{FF}$  - A Feedforward Capacitor  $C_{FF}$ , shown across R2 in [Figure 25](#) 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.

#### 9.1.2 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 must 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.

#### 9.1.3 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 m $\Omega$  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.

#### 9.1.4 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 located close to the LM2590HV-AQ-Q1 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).

## Application Information (continued)

### 9.1.5 Inverting Regulator

The circuit in [Figure 30](#) 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 the inverted output voltage and regulates it.

This example uses the LM2590HV-5.0-AQ 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:

$$I_{PEAK} = I_{LOAD} \times \left( \frac{V_{IN} + V_{OUT}}{V_{IN}} \right) + \frac{V_{IN} \times V_{OUT} \times 10^9}{2 \times L \times f \times (V_{IN} + V_{OUT})}$$

where

- L is in  $\mu$ H and f is in Hz. (1)

The maximum possible load current  $I_{LOAD}$  is limited by the requirement that  $I_{PEAK} \leq I_{CLIM}$ . 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 LM2590HV-AQ-Q1). Also to account for inductor tolerances, the user must 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 10-20% higher than calculated from [Equation 1](#).

See application note [AN-1157 Positive-to-Negative Buck-Boost Converter Using LM267x SIMPLE SWITCHER](#) 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. In this example, when converting +20 V to -5 V, the regulator would see 25 V between the input pin and ground pin. The LM2590HV-AQ-Q1 has a maximum input voltage rating of 60 V.

An additional diode is 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 1N5400 diode could be used.

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- $\mu$ H, 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 LM2590HV-AQ-Q1 current limit (approximately 3 A) are needed for 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 soft-start feature shown in [Figure 30](#) is recommended.

Also shown in [Figure 30](#) are several shutdown methods for the inverting configuration. With the inverting configuration, some level shifting is required, because the ground pin of the regulator is no longer at ground, but is now at the negative output voltage. The shutdown methods shown accept ground-referenced shutdown signals.

## 9.2 Typical Application

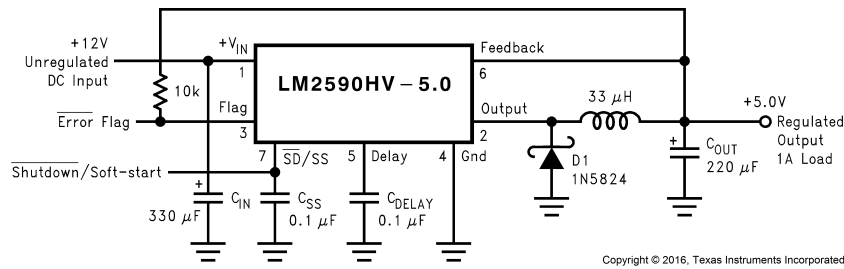


Figure 32. Typical Application

### 9.2.1 Design Requirements

Table 1 lists the parameters for this design example.

Table 1. Example Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Regulated output voltage, $V_{OUT}$	5 V
Maximum input voltage, $V_{IN(max)}$	24 V
Maximum load current, $I_{LOAD(max)}$	0.8 A
Switching frequency, F	Fixed at a nominal 150 kHz

### 9.2.2 Detailed Design Procedure

#### 9.2.2.1 Inductor Selection Procedure

For a quick-start the designer may refer to the nomographs provided in Figure 33 to Figure 35. To widen the choice of the Designer to a more general selection of available inductors, the nomographs provide the required inductance and also the energy in the core expressed in microjoules ( $\mu\text{J}$ ), as an alternative to just prescribing custom parts. The following points need to be highlighted:

- 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 momentarily or repetitively hits 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), and so the inductance does not fall off too sharply under an overload. The device is usually able to protect itself by not allowing the current to ever exceed  $I_{CLIM}$ . But 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 till destruction of the device takes place. *Therefore to ensure reliability, TI recommends that, if the DC Input Voltage exceeds 40 V, the inductor must ALWAYS be sized to handle an instantaneous current equal to  $I_{CLIM}$  without saturating, irrespective of the type of core structure/material.*
- The Energy under steady operation is:

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

where

- L is in  $\mu\text{H}$
- and  $I_{PEAK}$  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.

- The Energy under overload is If  $V_{IN} > 40$  V, the inductor should be sized to handle  $e_{CLIM}$  instead of the steady energy values. The worst case  $I_{CLIM}$  for the LM2590HV-AQ-Q1 is 3 A. The Energy rating depends on the Inductance. See Example 2.
- The nomographs were generated by allowing a greater amount of percentage current ripple in the Inductor

as the maximum rated load decreases (see [Figure 36](#)). This was done to permit the use of smaller inductors at light loads. [Figure 36](#) however 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 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.

- [Figure 35](#) shows the inductor selection curves for the adjustable version. The y-axis is  $Et$ , in  $V\mu s$ . 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  $\mu s$ . See Example 3.

**Example 1:** ( $V_{IN} \leq 40$  V) LM2590HV-5.0-AQ,  $V_{IN} = 24$  V, Output 5 V at 0.8 A

- 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 ([Figure 34](#)) and a current rating equal to the maximum load current. We therefore quick-select a 100- $\mu H$ , 0.8-A inductor (designed for 150-kHz operation) for this application.
- Confirm that it is rated to handle 50  $\mu J$  (see [Figure 34](#)) by either estimating the peak current or by a detailed calculation as shown in [AN-1197 Selecting Inductors for Buck Converters](#), and also that the losses are acceptable.

**Example 2:** ( $V_{IN} > 40$  V) LM2590HV-5.0-AQ,  $V_{IN} = 48$  V, Output 5 V at 1 A

- A first pass inductor selection is based upon *Inductance and the switch current limit*. Choose an inductor with the Inductance value indicated by the nomograph ([Figure 34](#)) and a current rating equal to  $I_{CLIM}$ . Therefore quick-select a 10- $\mu H$ , 3-A inductor (designed for 150-kHz operation) for this application.
- Confirm that it is rated to handle  $e_{CLIM}$  by the procedure shown in [AN-1197 Selecting Inductors for Buck Converters](#) and that the losses are acceptable. Here  $e_{CLIM}$  is:

$$e_{CLIM} = \frac{1}{2} \times 100 \times 3^2 = 450 \mu J \quad (3)$$

**Example 3:** ( $V_{IN} \leq 40$  V) LM2590HV-ADJ-AQ,  $V_{IN} = 20$  V, Output 10 V at 1 A

- Because input voltage is less than 40 V, a first pass inductor selection is based upon Inductance and rated maximum load current. Choose an inductor with the Inductance value indicated by the nomograph [Figure 35](#) and a current rating equal to the maximum load. But first calculate  $Et$  for the given application. The Duty cycle is

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

where

- $V_D$  is the drop across the Catch Diode ( $\approx 0.5$  V for a Schottky)
- and  $V_{SAT}$  the drop across the switch ( $\approx 1.5$  V).

So

$$D = \frac{10 + 0.5}{20 - 1.5 + 0.5} = 0.55 \quad (5)$$

And the switch ON time is

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

where

- $f$  is the switching frequency in Hz

So

$$\begin{aligned} Et &= (V_{IN} - V_{SAT} - V_{OUT}) \times t_{ON} \\ &= (20 - 1.5 - 10) \times \frac{0.55}{150000} \times 10^6 V\mu s \\ &= 31.3 V\mu s \end{aligned} \quad (7)$$

Therefore, looking at [Figure 33](#) we quick-select a 100-μH, 1-A inductor (designed for 150-kHz operation) for this application.

2. Confirm that it is rated to handle 100 μJ (see [Figure 35](#)) by the procedure shown in [AN-1197 Selecting Inductors for Buck Converters](#) and that the losses are acceptable. (If the DC Input voltage had been greater than 40 V, consider e<sub>CLIM</sub> as in Example 2).

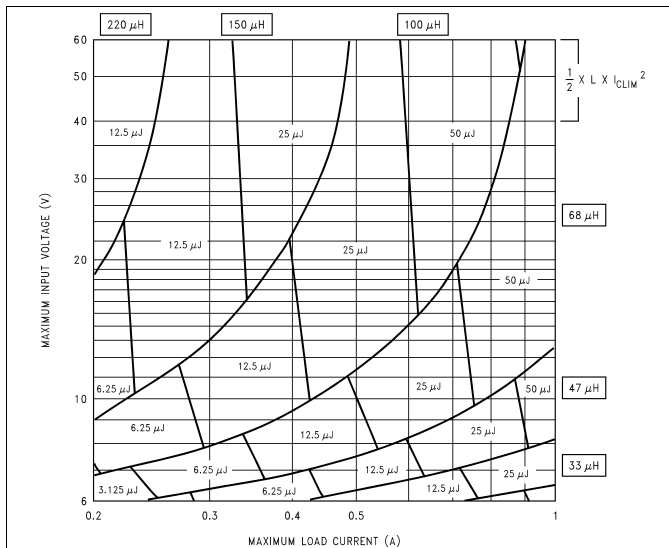
**NOTE**

Take V<sub>SAT</sub> as 1.5 V which includes an estimated resistive drop across the inductor.

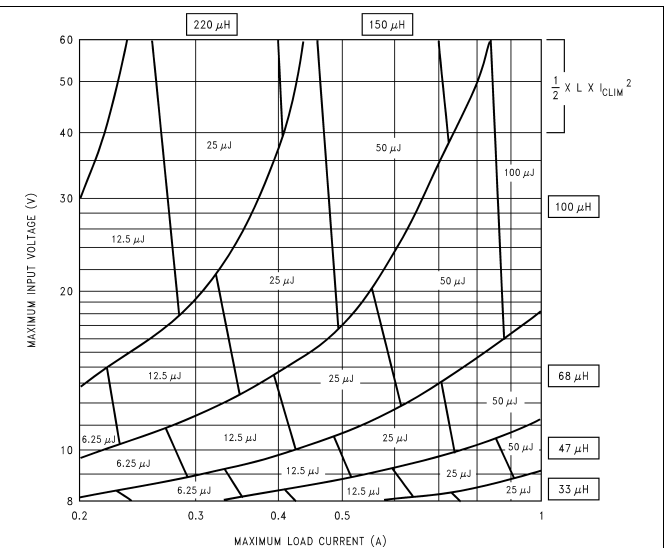
This completes the simplified inductor selection procedure. For more general applications and better optimization, the designer should refer to [AN-1197 Selecting Inductors for Buck Converters](#). provides helpful contact information on suggested Inductor manufacturers who may be able to recommend suitable parts, if the requirements are known.

**9.2.3 Application Curves**

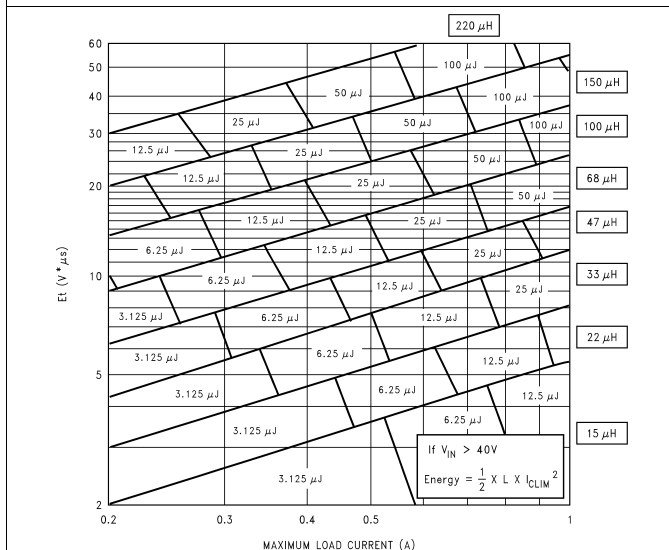
(For Continuous Mode Operation)



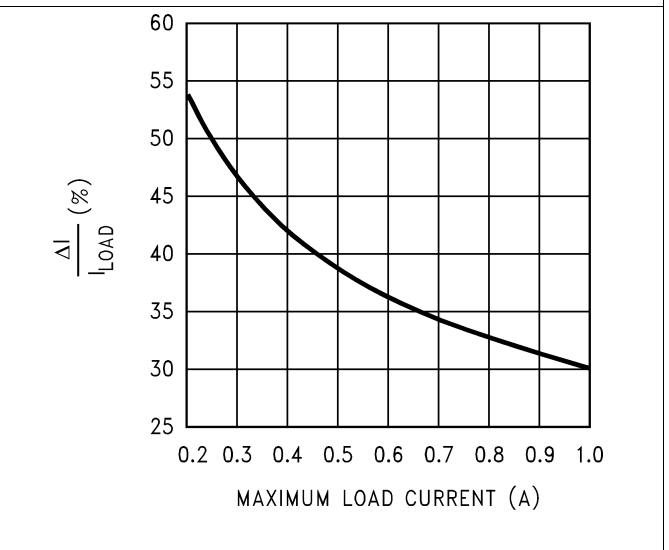
**Figure 33. LM2590HV-3.3-AQ**



**Figure 34. LM2590HV-5.0-AQ**



**Figure 35. LM2590HV-ADJ-AQ**



**Figure 36. Current Ripple Ratio**

## 10 Power Supply Recommendations

The LM2590HV is designed to operate from an input voltage supply up to 60 V. This input supply must be well regulated and able to withstand maximum input current and maintain a stable voltage.

## 11 Layout

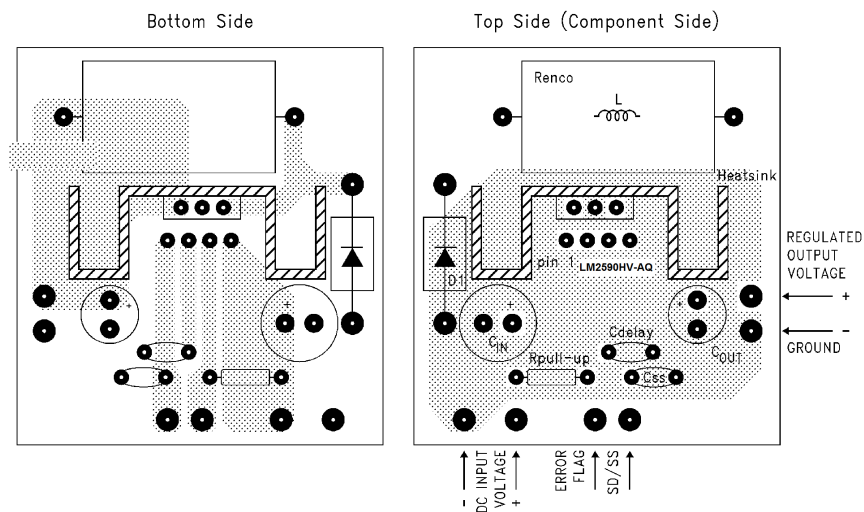
### 11.1 Layout Guidelines

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, with reference to [Figure 24](#) and [Figure 25](#), 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 locate both resistors near the IC, and route the wiring away from the inductor, especially an open-core type of inductor.

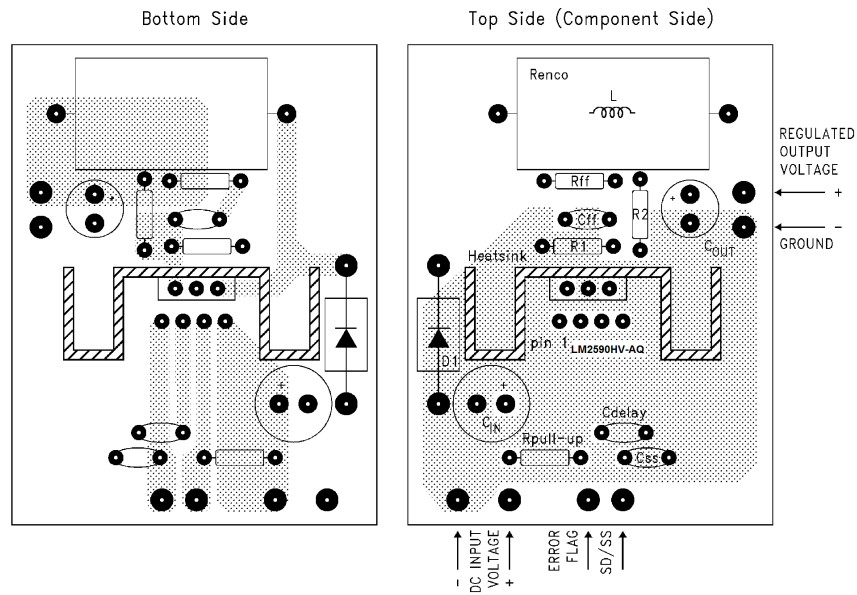
### 11.2 Layout Examples



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

**Figure 37. Typical Through-Hole PCB Layout, Fixed Output (1x Size), Double-Sided**

Layout Examples (continued)



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

Figure 38. Typical Through-Hole PCB Layout, Adjustable Output (1x Size), Double-Sided



## 12 Device and Documentation Support

### 12.1 Documentation Support

#### 12.1.1 Related Documentation

For related documentation, see the following:

- [AN-1157 Positive-to-Negative Buck-Boost Converter Using LM267x SIMPLE SWITCHER](#) (SNVA022)
- [AN-1197 Selecting Inductors for Buck Converters](#) (SNVA038)

### 12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 12.3 Community Resources

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.

### 12.4 Trademarks

E2E is a trademark of Texas Instruments.  
SIMPLE SWITCHER is a registered trademark of Texas Instruments.  
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### 12.5 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 12.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.



**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM2590HVSX5.0AQ	LIFEBUY	DDPAK/ TO-263	KTW	7	500	TBD	Call TI	Call TI	-40 to 125	LM2590HVS 5.0AQ P+	
LM2590HVSX5.0AQ/NOPB	LIFEBUY	DDPAK/ TO-263	KTW	7	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2590HVS 5.0AQ P+	

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

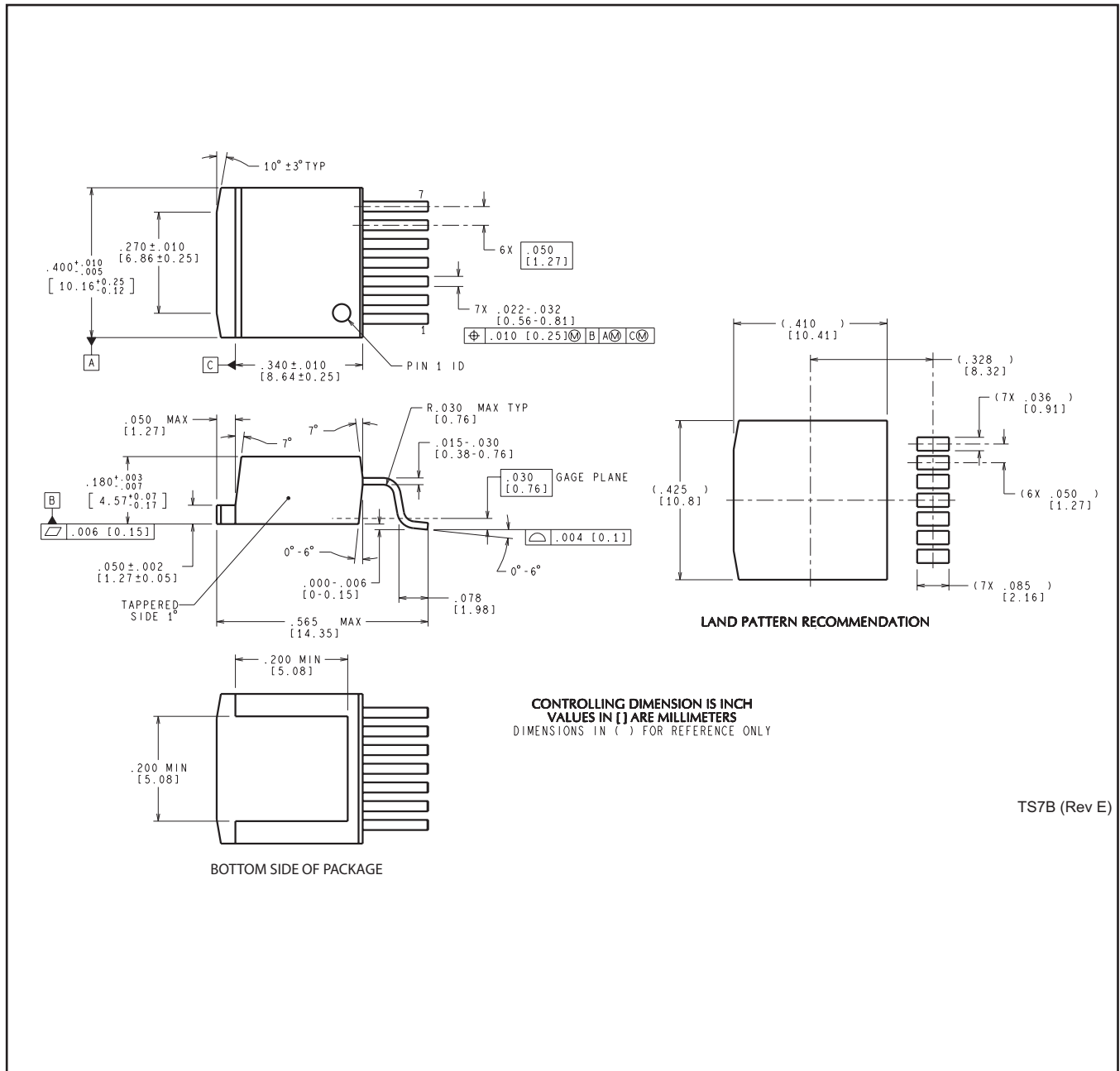
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2590HVSX5.0AQ	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2590HVSX5.0AQ/NOP B	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2590HVSX5.0AQ	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0
LM2590HVSX5.0AQ/NOP B	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0

KTW0007B



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Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
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