

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

Check for Samples: [LM2590HV-AQ](#)

FEATURES

- Reliability Qualification for Automotive
- 3.3V, 5V, and Adjustable Output Versions
- Adjustable Version Output Voltage Range, 1.2V to 57V $\pm 4\%$ Max Over Line and Load Conditions
- 1A Output Load Current
- Available in 7-pin TO-220 and TO-263 (surface mount) Package
- Input Voltage Range up to 60V
- 150 kHz Fixed Frequency Internal Oscillator
- Shutdown/Soft-Start
- Out of Regulation Error Flag
- Error Flag Delay
- Low Power Standby Mode, I_Q Typically 90 μA
- High Efficiency
- Thermal Shutdown and Current Limit Protection

APPLICATIONS

- Simple High-Efficiency Step-Down (buck) Regulator
- Efficient Pre-Regulator for Linear Regulators
- On-Card Switching Regulators
- Positive to Negative Converter
 - † Patent Number 5,382,918.

DESCRIPTION

The LM2590HV-AQ 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 Amp load with excellent line and load regulation. The LM2590HV-AQ is available in fixed output voltages of 3.3V, 5.0V, as well as an adjustable output version.

The LM2590HV-AQ 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†, improved line and load specifications, fixed-frequency oscillator, Shutdown/Soft-start, output error flag and flag delay.

The LM2590HV-AQ 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-lead TO-220 package with several different lead bend options, and a 7-lead 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 μA standby current. Self protection features include a two stage current limit for the output switch and an over temperature shutdown for complete protection under fault conditions.

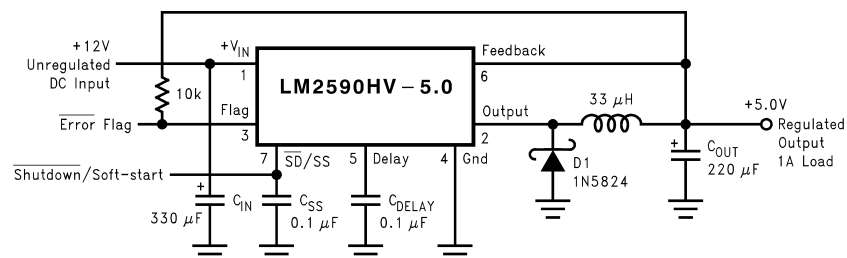


Figure 1. Typical Application (Fixed Output Voltage Versions)



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

SIMPLE SWITCHER is a registered trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 2004–2013, Texas Instruments Incorporated



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.

Absolute Maximum Ratings ⁽¹⁾

Maximum Supply Voltage (V _{IN})			63V
SD /SS Pin Input Voltage ⁽²⁾			6V
Delay Pin Voltage ⁽²⁾			1.5V
Flag Pin Voltage			−0.3 ≤ V ≤45V
Feedback Pin Voltage			−0.3 ≤ V ≤+25V
Output Voltage to Ground (Steady State)			−1V
Power Dissipation			Internally limited
Storage Temperature Range			−65°C to +150°C
ESD Susceptibility ⁽³⁾		Human Body Model (AEC-100-002) ⁽³⁾	2kV
		Machine Model (AEC-100-003)	200V
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

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For specifications and test conditions, see the Electrical Characteristics.
- (2) Voltage internally clamped. If clamp voltage is exceeded, limit current to a maximum of 1 mA.
- (3) The human body model is a 100 pF capacitor discharged through a 1.5k resistor; the Machine Model is 200pF discharged through a 0Ω resistor.

Operating Conditions

Ambient Temperature Range	$-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$
Junction Temperature Range	$-40^{\circ}\text{C} \leq T_J \leq +150^{\circ}\text{C}$
Supply Voltage	$+4.5V \leq V_{IN} \leq +60V$

LM2590HV-3.3-AQ Electrical Characteristics

Specifications with standard type face are for $T_J = 25^{\circ}\text{C}$, and those with **boldface type** apply over **full Operating Temperature Range**.

Symbol	Parameter	Conditions	LM2590HV-3.3-AQ			Units
			Min ⁽¹⁾	Typ ⁽²⁾	Max ⁽¹⁾	
SYSTEM PARAMETERS ⁽³⁾ Test Circuit of Figure 24						
V _{OUT}	Output Voltage	4.75V ≤ V _{IN} ≤ 60V, 0.2A ≤ I _{LOAD} ≤ 1A	3.168 3.135	3.3	3.432 3.465	V V
η	Efficiency	V _{IN} = 12V, I _{LOAD} = 1A		77		%

- (1) All limits at room temperature (standard type face) and at **temperature extremes (bold type face)**. 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°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 is used as shown in the [Figure 24](#) test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

LM2590HV-5.0-AQ Electrical Characteristics

Specifications with standard type face are for $T_J = 25^\circ\text{C}$, and those with **boldface type** apply over **full Operating Temperature Range**.

Symbol	Parameter	Conditions	LM2590HV-5.0-AQ			Units
			Min ⁽¹⁾	Typ ⁽²⁾	Max ⁽¹⁾	
SYSTEM PARAMETERS ⁽³⁾ Test Circuit Figure 24						
V _{OUT}	Output Voltage	7V ≤ V _{IN} ≤ 60V, 0.2A ≤ I _{LOAD} ≤ 1A	4.800 4.750	5	5.200 5.250	V V
η	Efficiency	V _{IN} = 12V, I _{LOAD} = 1A		82		%

- (1) All limits at room temperature (standard type face) and at **temperature extremes (bold type face)**. 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°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 is used as shown in the [Figure 24](#) test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

LM2590HV-ADJ-AQ Electrical Characteristics

Specifications with standard type face are for $T_J = 25^\circ\text{C}$, and those with **boldface type** apply over **full Operating Temperature Range**.

Symbol	Parameter	Conditions	LM2590HV-ADJ-AQ			Units
			Min ⁽¹⁾	Typ ⁽²⁾	Max ⁽¹⁾	
SYSTEM PARAMETERS ⁽³⁾ Test Circuit Figure 25						
V _{FB}	Feedback Voltage	4.5V ≤ V _{IN} ≤ 60V, 0.2A ≤ I _{LOAD} ≤ 1A	1.193 1.180	1.230	1.267 1.280	V V
I _{FB}	Feedback Bias Current	V _{FB} = 1.30V		10	50 300	nA nA
η	Efficiency	V _{IN} = 12V, V _{OUT} = 3V, I _{LOAD} = 1A		76		%

- (1) All limits at room temperature (standard type face) and at **temperature extremes (bold type face)**. 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°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 is used as shown in the [Figure 25](#) test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

All Output Voltage Versions Electrical Characteristics

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

Symbol	Parameter	Conditions	LM2590HV-XXX-AQ			Units
			Min ⁽¹⁾	Typ ⁽²⁾	Max ⁽¹⁾	
DEVICE PARAMETERS						
f _O	Oscillator Frequency	⁽³⁾	127 110	150	173 173	kHz kHz
V _{SAT}	Saturation Voltage	I _{OUT} = 1A ⁽⁴⁾ ⁽⁵⁾		0.95	1.2 1.3	V V
DC	Max Duty Cycle (ON)	⁽⁵⁾		100		%
	Min Duty Cycle (OFF)	⁽⁶⁾		0		%
I _{CLIM}	Switch current Limit	Peak Current, ⁽⁴⁾ ⁽⁵⁾	1.3 1.2	1.9	2.8 3.0	A A
I _L	Output Leakage Current	Output = 0V ⁽⁴⁾ ⁽⁶⁾ ⁽⁷⁾			50	μA
		Output = −1V ⁽⁴⁾ ⁽⁶⁾ ⁽⁷⁾		5	30	mA
I _Q	Operating Quiescent Current	$\overline{\text{SD}}$ /SS Pin Open ⁽⁶⁾		5	10	mA
I _{STBY}	Standby Quiescent Current	$\overline{\text{SD}}$ /SS pin = 0V ⁽⁷⁾		90	200 250	μA μA
θ _{JC}	Thermal Resistance	TO220 or TO263 Package, Junction to Case		2		°C/W
θ _{JA}		TO220 Package, Junction to Ambient ⁽⁸⁾		50		°C/W
θ _{JA}		TO263 Package, Junction to Ambient ⁽⁹⁾		50		°C/W
θ _{JA}		TO263 Package, Junction to Ambient ⁽¹⁰⁾		30		°C/W
θ _{JA}		TO263 Package, Junction to Ambient ⁽¹¹⁾		20		°C/W
SHUTDOWN/SOFT-START CONTROL Test Circuit of Figure 25						
V _{SD}	Shutdown Threshold Voltage	Shutdown Mode, I _{STBY} < 250μA	0.6	1.3	2.0	V
		V _{OUT} = 1% of Normal Output Voltage		1.8		V
V _{SS}	Soft-start Voltage	V _{OUT} = 20% of Nominal Output Voltage		2		V
		V _{OUT} = 100% of Nominal Output Voltage		3		V
I _{SD}	Shutdown Current	V _{SHUTDOWN} = 0.5V		5	10	μA
I _{SS}	Soft-start Current	V _{Soft-start} = 2.5V		1.5	5	μA

- (1) All limits at room temperature (standard type face) and at **temperature extremes (bold type face)**. 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°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 0V to force the output transistor switch ON.
- (6) Feedback pin removed from output and connected to 12V for the 3.3V, 5V, and the ADJ. version to force the output transistor switch OFF.
- (7) $V_{IN} = 60\text{V}$.
- (8) Junction to ambient thermal resistance (no external heat sink) for the package mounted TO-220 package mounted vertically, with the leads soldered to a printed circuit board with (1 oz.) copper area of approximately 1 in^2 .
- (9) Junction to ambient thermal resistance with the TO-263 package tab soldered to a single sided printed circuit board with 0.5 in^2 of (1 oz.) copper area.
- (10) Junction to ambient thermal resistance with the TO-263 package tab soldered to a single sided printed circuit board with 2.5 in^2 of (1 oz.) copper area.
- (11) Junction to ambient thermal resistance with the TO-263 package tab soldered to a double sided printed circuit board with 3 in^2 of (1 oz.) copper area on the LM2590HVS-AQ side of the board, and approximately 16 in^2 of copper on the other side of the p-c board. See application hints in this data sheet and the thermal model in **Switchers Made Simple** available at <http://ti.com>.

All Output Voltage Versions Electrical Characteristics (continued)

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

Symbol	Parameter	Conditions	LM2590HV-XXX-AQ			Units
			Min ⁽¹⁾	Typ ⁽²⁾	Max ⁽¹⁾	
FLAG/DELAY CONTROL Test Circuit of Figure 25						
	Regulator Dropout Detector Threshold Voltage	Low (Flag ON)	92	96	98	%
V _F SAT	Flag Output Saturation Voltage	I _{SINK} = 3 mA V _{DELAY} = 0.5V		0.3	0.7 1.0	V
I _F L	Flag Output Leakage Current	V _{FLAG} = 60V		0.3		μA
V _D TH	Delay Pin Threshold Voltage	V _{OUT} Regulated	1.21	1.25	1.29	V
I _{DELAY}	Delay Pin Source Current	V _{DELAY} = 0.5V		3	6	μA
I _D SAT	Delay Pin Saturation	Low (Flag ON)		70	350 400	mV mV

Typical Performance Characteristics

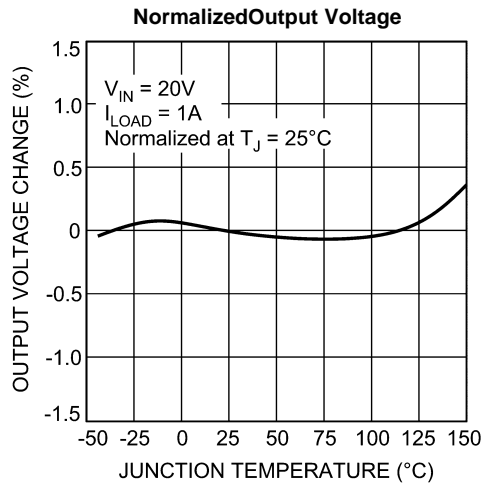
(Circuit of [Figure 24](#))

Figure 2.

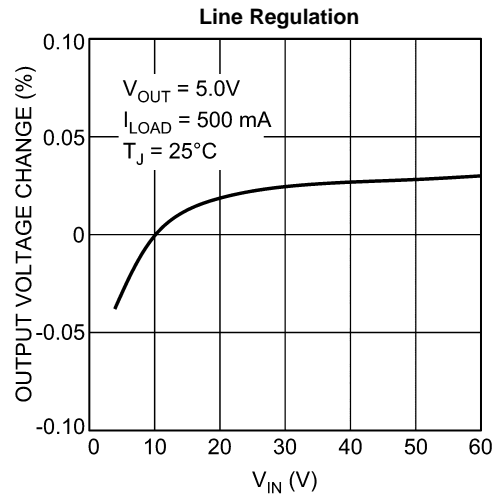


Figure 3.

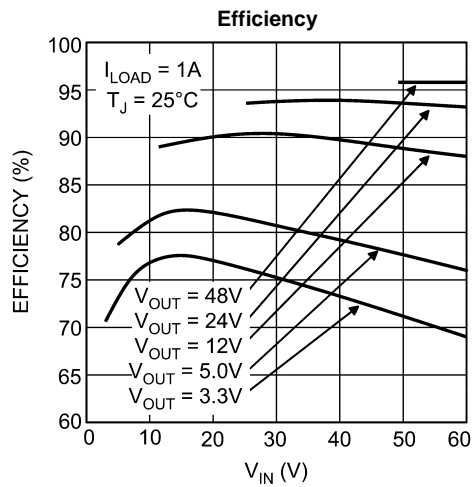


Figure 4.

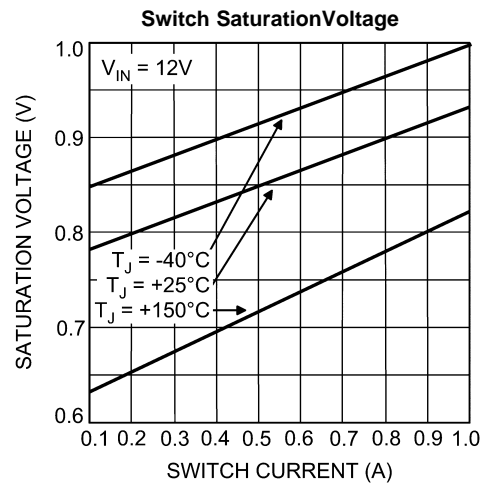


Figure 5.

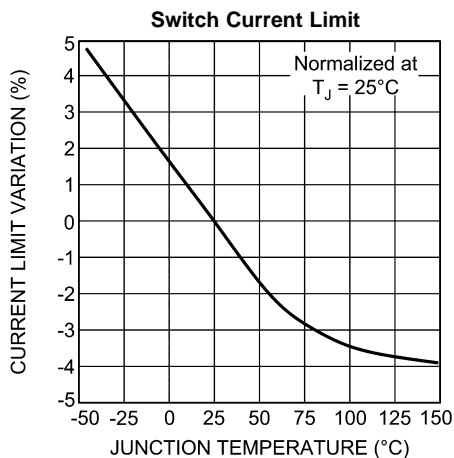


Figure 6.

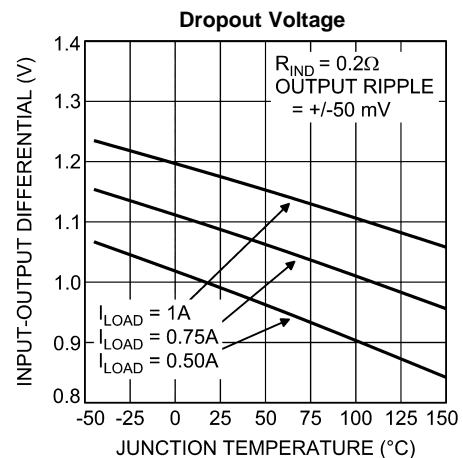


Figure 7.

Typical Performance Characteristics (continued)

(Circuit of Figure 24)

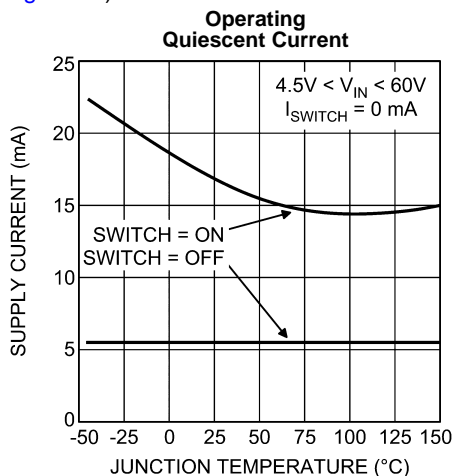


Figure 8.

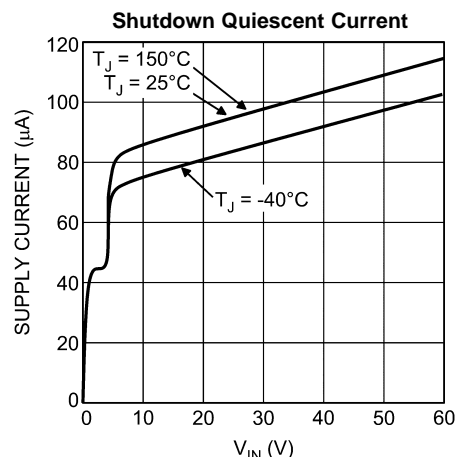


Figure 9.

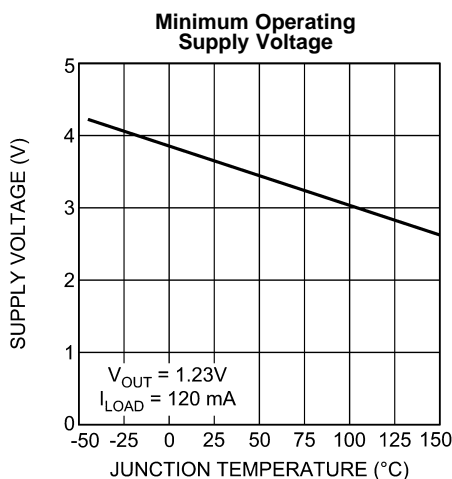


Figure 10.

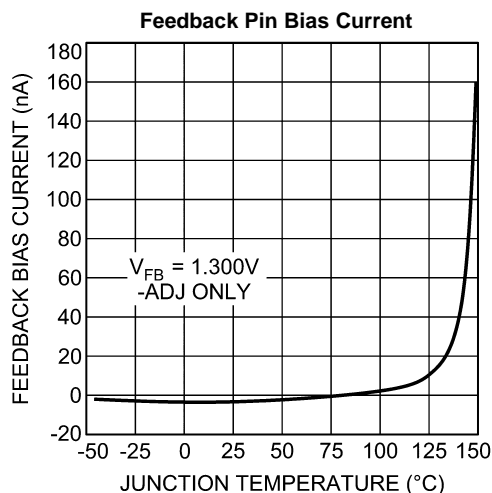


Figure 11.

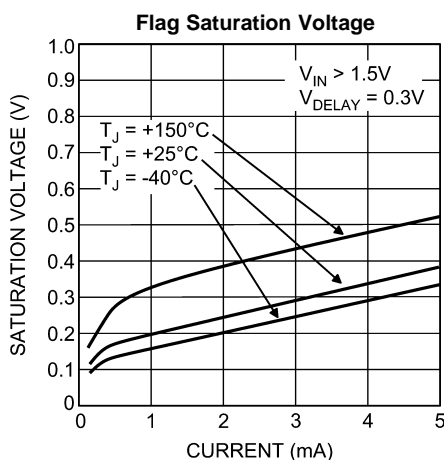


Figure 12.

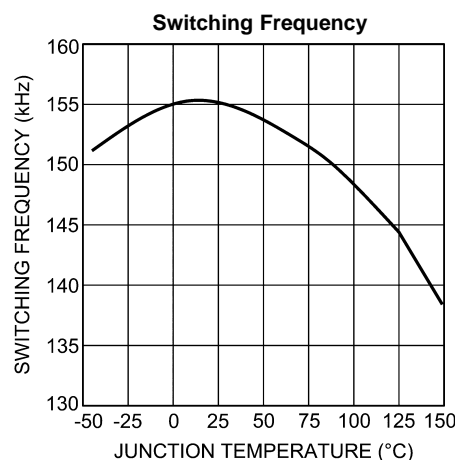


Figure 13.

Typical Performance Characteristics (continued)

(Circuit of [Figure 24](#))

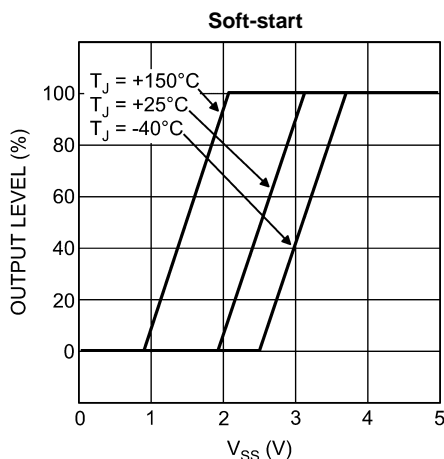


Figure 14.

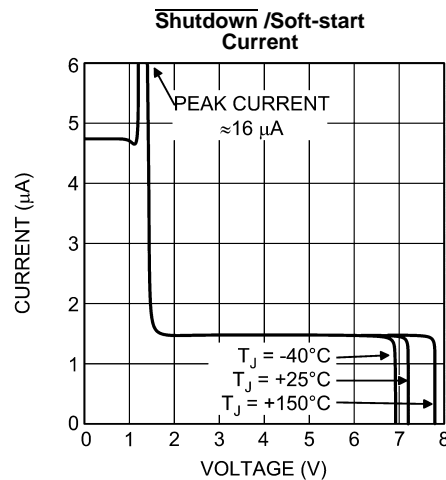


Figure 15.

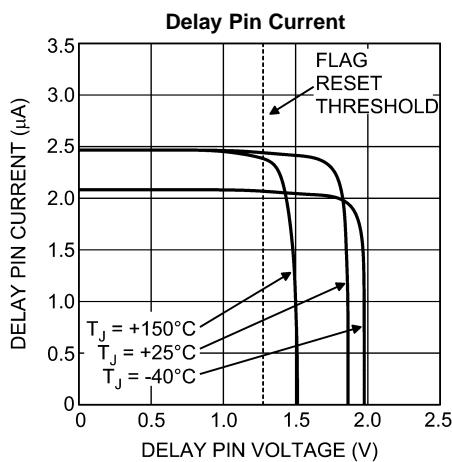


Figure 16.

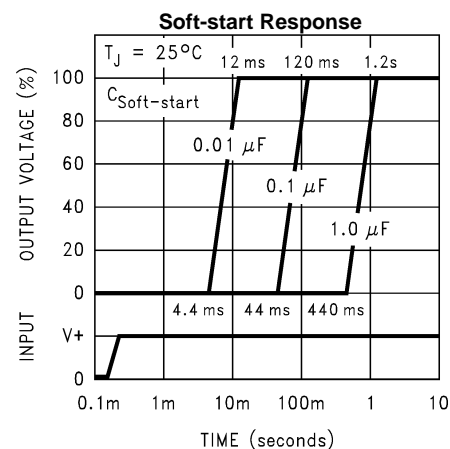


Figure 17.

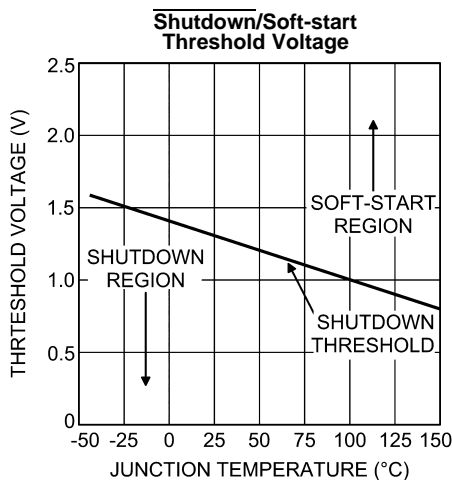


Figure 18.

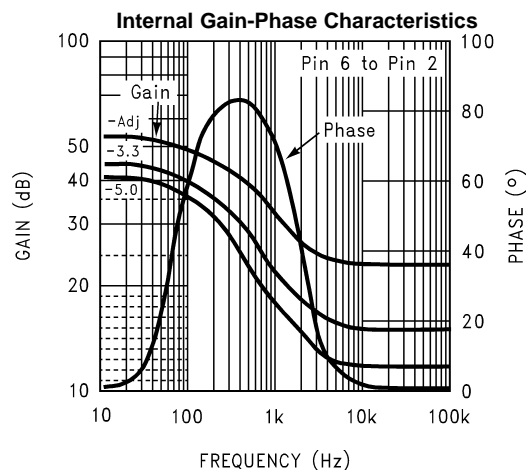
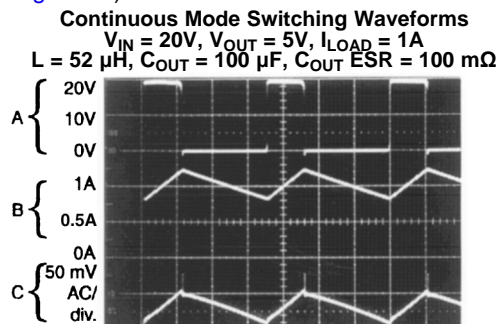


Figure 19.

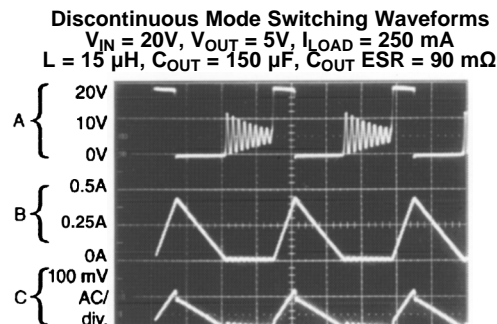
Typical Performance Characteristics (continued)

(Circuit of [Figure 24](#))



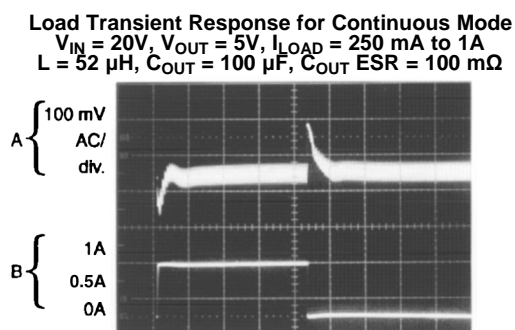
C. Output Ripple Voltage, 50 mV/div.

Figure 20. Horizontal Time Base: 2 μs /div.



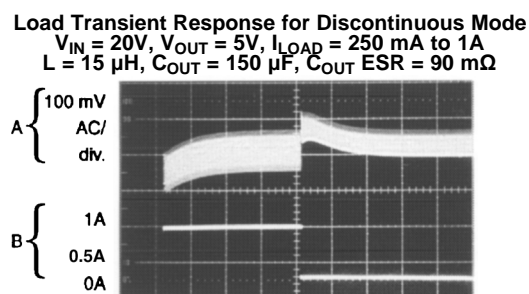
C. Output Ripple Voltage, 100 mV/div.

Figure 21. Horizontal Time Base: 2 μs /div.



B. 250 mA to 1A Load Pulse

Figure 22. Horizontal Time Base: 50 μs /div.

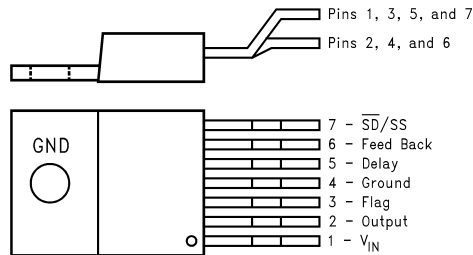


B. 250 mA to 1A Load Pulse

Figure 23. Horizontal Time Base: 200 μs /div.

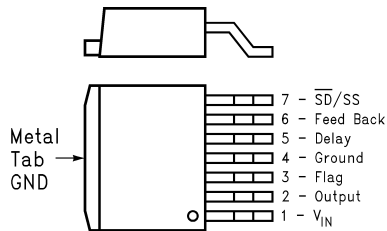
CONNECTION DIAGRAMS AND ORDER INFORMATION

Bent and Staggered Leads, Through Hole Package 7-Lead TO-220 (T)



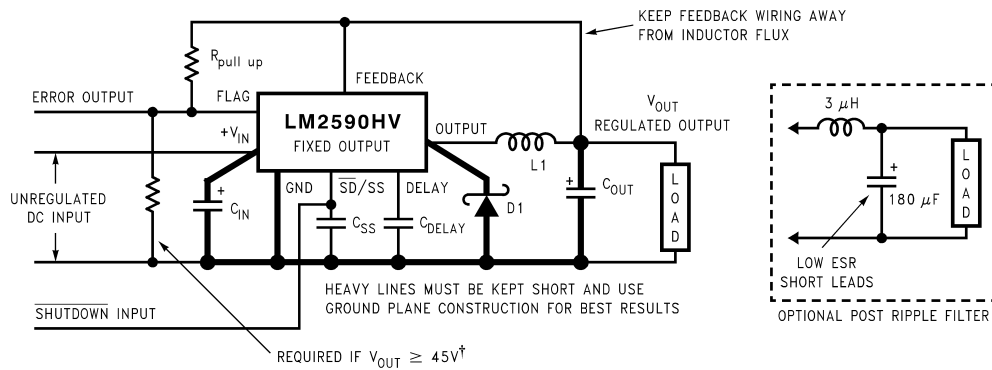
See Package Number NDZ0007B

Surface Mount Package 7-Lead TO-263 (S)



See Package Number KTN007B

Test Circuit and Layout Guidelines



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

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

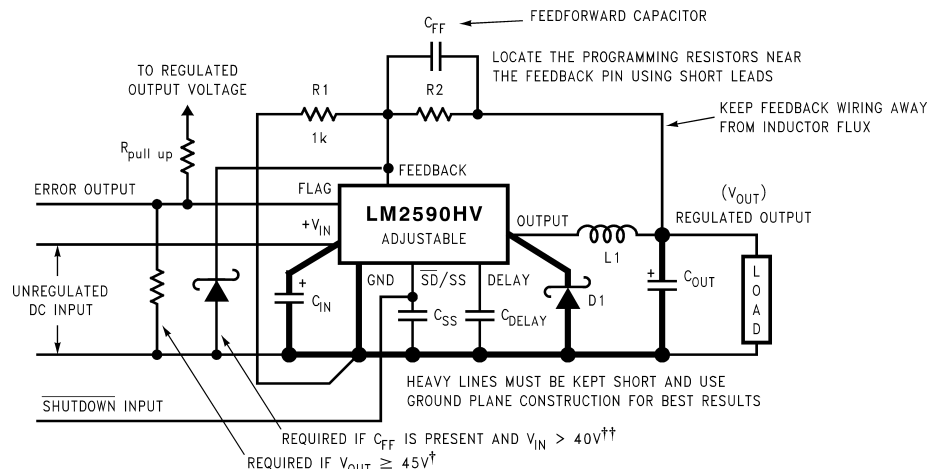
C_{IN} — 470 μF , 50V, Aluminum Electrolytic Nichicon "PM Series"

C_{OUT} — 220 μF , 25V Aluminum Electrolytic, Nichicon "PM Series"

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

L1 — 68 μH , See Inductor Selection Procedure

Figure 24. Fixed Output Voltage Versions



Select R_1 to be approximately 1 k Ω , 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)

L1 — 100 μH , See Inductor Selection Procedure

R_1 — 1 k Ω , 1%

R_2 — 7.15k, 1%

C_{FF} — 3.3 nF

Typical Values

C_{SS} —0.1 μF

C_{DELAY} —0.1 μF

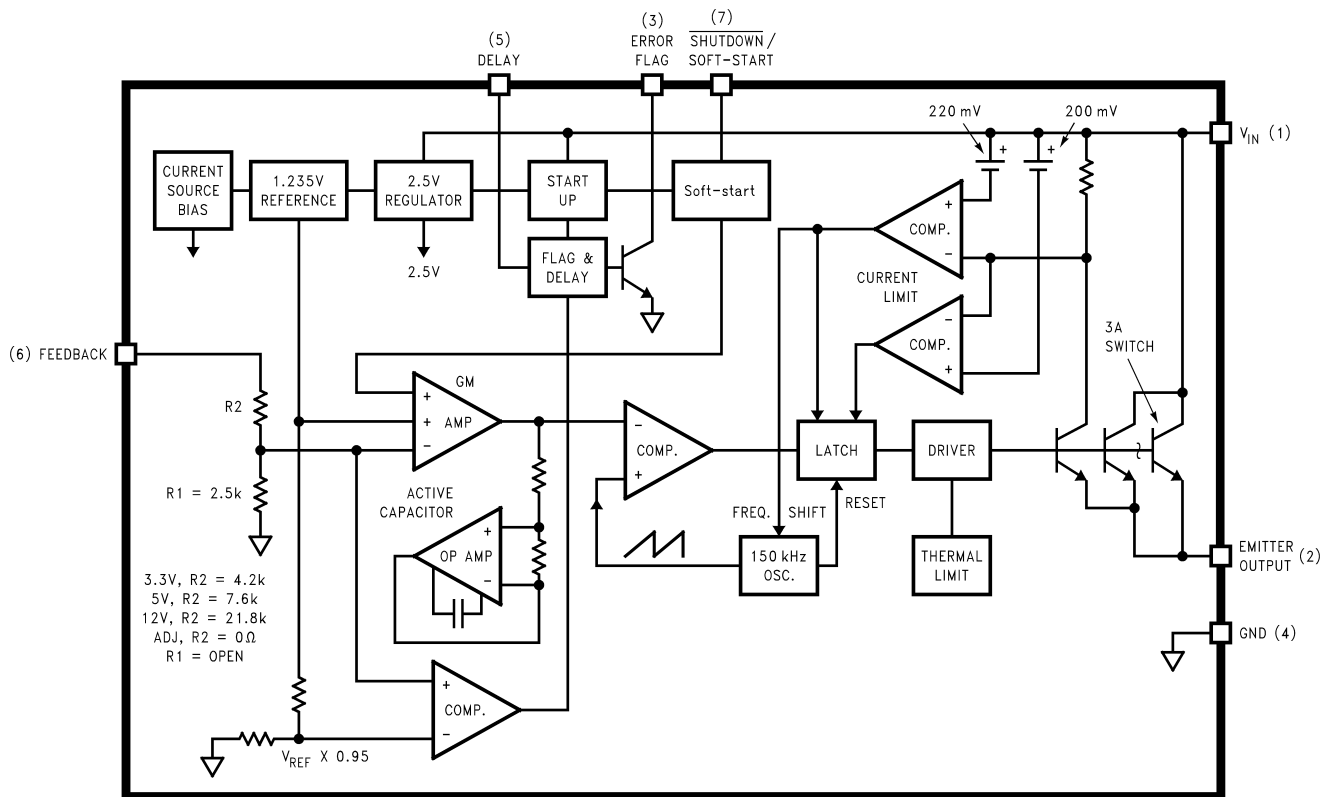
$R_{PULL UP}$ — 4.7k (use 22k if V_{OUT} is $\geq 45V$)

† Resistive divider is required to avoid exceeding maximum rating of 45V/3mA on/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 $V_{IN} > 40V$

Figure 25. Adjustable Output Voltage Versions

Block Diagram



Pin Functions

+ V_{IN} (Pin 1)—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.

Output (Pin 2)—Internal switch. The voltage at this pin switches between approximately $(+V_{IN} - V_{SAT})$ and approximately $-0.5V$, with a duty cycle of V_{OUT}/V_{IN} .

Error Flag (Pin 3)—Open collector output that goes active low ($\leq 1.0V$) 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 3mA. 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 should not be exceeded, so if the rail to which it will be pulled-up to is higher than 45V, a resistive divider must be used instead of a single pull-up resistor, as indicated in [Figure 25](#).

Ground (Pin 4)—Circuit ground.

Delay (Pin 5)—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 on 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 pull-up) when the voltage on the capacitor on Pin 5 exceeds 1.3V. The voltage on this pin is clamped internally to about 1.7V. 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 1/1000th of the set power-up delay time.

Feedback (Pin 6)—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 1.23V 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 since 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 40V whenever a feedforward capacitor is present (See Figure 25). Feedforward capacitor values larger than 0.1 μF are not recommended for the same reason, whatever be the DC input voltage.

Shutdown /Soft-start (Pin 7)—The regulator is in shutdown mode, drawing about 90 μA , when this pin is driven to a low level ($\leq 0.6\text{V}$), and is in normal operation when this Pin is left floating (internal-pullup) or driven to a high level ($\geq 2.0\text{V}$). The typical value of the threshold is 1.3V and the pin is internally clamped to a maximum of about 7V. 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 1mA. The duty cycle is minimum (0%) if this Pin is below 1.8V, and increases as the voltage on the pin is increased. The maximum duty cycle (100%) occurs when this pin is at 2.8V or higher. So adding a capacitor to this pin produces a softstart feature. An internal current source will charge the capacitor from zero to its internally clamped value. The charging current is about 5 μA when the pin is below 1.3V but is reduced to only 1.6 μA above 1.3V, so as to allow the use of smaller softstart capacitors.

NOTE

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.

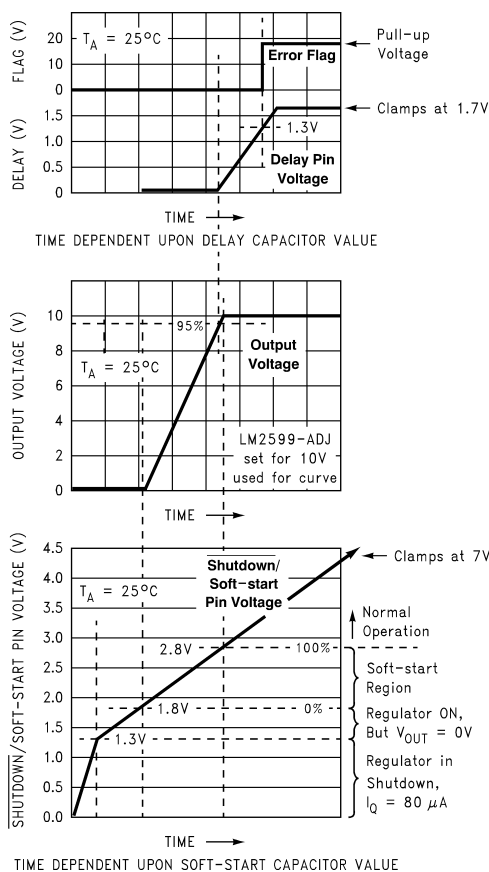


Figure 26. Soft-Start, Delay, Error Output

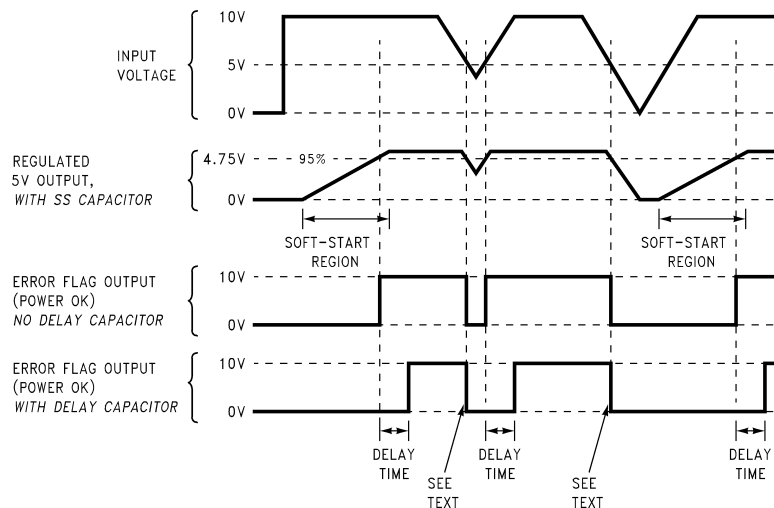


Figure 27. Timing Diagram for 5V Output

Inductor Value Selection Guides

(For Continuous Mode Operation)

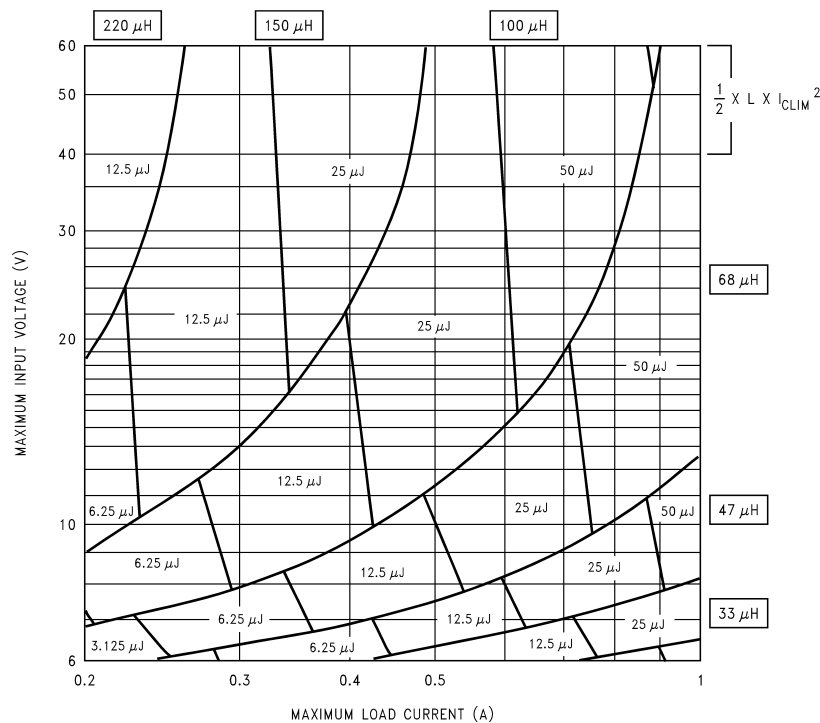


Figure 28. LM2590HV-3.3-AQ

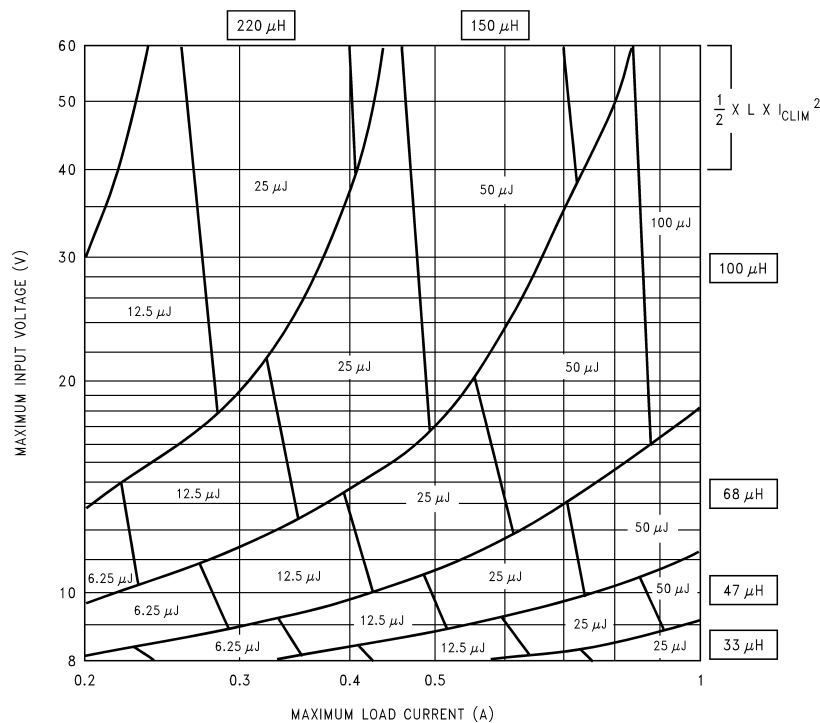


Figure 29. LM2590HV-5.0-AQ

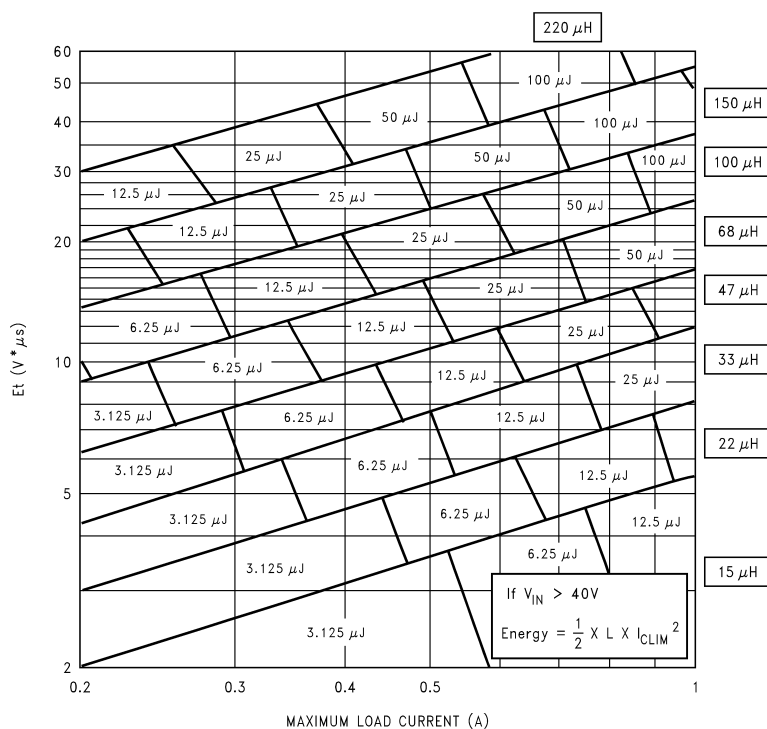
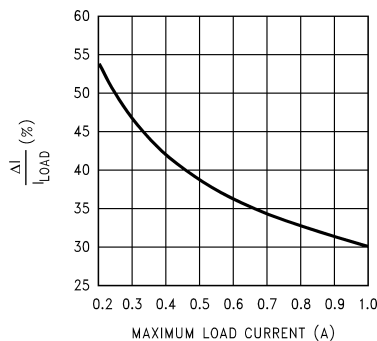


Figure 30. LM2590HV-ADJ-AQ

**Figure 31. Current Ripple Ratio****Table 1. Contact Information for Suggested Inductor Manufacturers**

Coilcraft Inc.	Phone	(USA): 1-800-322-2645
	Web Address	http://www.coilcraft.com
Coilcraft Inc., Europe	Phone	(UK): 1-236-730595
	Web Address	http://www.coilcraft-europe.com
Pulse Engineering Inc.	Phone	(USA): 1-858-674-8100
	Web Address	http://www.pulseeng.com
Pulse Engineering Inc., Europe	Phone	(UK): 1-483-401700
	Web Address	http://www.pulseeng.com
Renco Electronics Inc.	Phone	(USA): 1-321-637-1000
	Web Address	http://www.rencousa.com
Schott Corp.	Phone	(USA): 1-952-475-1173
	Web Address	http://www.shottcorp.com
Cooper Electronic Tech. (Coiltronics)	Phone	(USA): 1-888-414-2645
	Web Address	http://www.cooperet.com
TDK	Phone	(USA): 1-847-803-6100
	Web Address	http://www.componet.tdk.com

APPLICATION INFORMATION

INDUCTOR SELECTION PROCEDURE

Application Note AN-1197 titled "Selecting Inductors for Buck Converters" provides detailed information on this topic. For a quick-start the designer may refer to the nomographs provided in [Figure 28](#) to [Figure 30](#). 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 (μJ), as an alternative to just prescribing custom parts. The following points need to 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/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), 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 40V, 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, it is recommended, that if the DC Input Voltage exceeds 40V, 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.*
2. The Energy under steady operation is $e = \frac{1}{2} \times L \times I_{PEAK}^2 \mu J$ where L is in μH and I_{PEAK} is the peak of the inductor current waveform with the regulator delivering I_{LOAD} . These are the energy values shown in the nomographs. See *Example 1* below.
3. The Energy under overload is $e_{CLIM} = \frac{1}{2} \times L \times I_{CLIM}^2 \mu J$ If $V_{IN} > 40V$, the inductor should be sized to handle e_{CLIM} instead of the steady energy values. The worst case I_{CLIM} for the LM2590HV-AQ is 3A. The Energy rating depends on the Inductance. See *Example 2* below.
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 31](#)). This was done to permit the use of smaller inductors at light loads. [Figure 31](#) 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.
5. [Figure 30](#) 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 μsecs. See *Example 3* below.

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

1. A first pass inductor selection is based upon *Inductance and rated max load current*. We choose an inductor with the Inductance value indicated by the nomograph ([Figure 29](#)) and a current rating equal to the maximum load current. We therefore quick-select a 100μH/0.8 A inductor (designed for 150 kHz operation) for this application.
2. We should confirm that it is rated to handle 50 μJ (see [Figure 29](#)) by either estimating the peak current or by a detailed calculation as shown in AN-1197, and also that the losses are acceptable.

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

1. A first pass inductor selection is based upon *Inductance and the switch current limit*. We choose an inductor with the Inductance value indicated by the nomograph ([Figure 29](#)) and a current rating equal to I_{CLIM} . We therefore quick-select a 100μH/3A inductor (designed for 150 kHz operation) for this application.
2. We should confirm that it is rated to handle e_{CLIM} by the procedure shown in AN-1197 and that the losses are acceptable. Here e_{CLIM} is:

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

(1)

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

1. Since input voltage is less than 40V, a first pass inductor selection is based upon Inductance and rated max load current. We choose an inductor with the Inductance value indicated by the nomograph [Figure 30](#) and a current rating equal to the maximum load. But we first need to calculate Et for the given application. The Duty cycle is

$$D = \frac{V_{OUT} + V_D}{V_{IN} - V_{SAT} + V_D} \quad (2)$$

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

$$D = \frac{10 + 0.5}{20 - 1.5 + 0.5} = 0.55 \quad (3)$$

And the switch ON time is

$$t_{ON} = \frac{D}{f} \times 10^6 \mu s \quad (4)$$

where f is the switching frequency in Hz. So

$$\begin{aligned} Et &= (V_{IN} - V_{SAT} - V_{OUT}) \times t_{ON} \\ &= (20 - 1.5 - 10) \times \frac{0.55}{150000} \times 10^6 V\mu secs \\ &= 31.3 V\mu secs \end{aligned} \quad (5)$$

Therefore, looking at [Figure 28](#) we quick-select a 100 μ H/1A inductor (designed for 150 kHz operation) for this application.

2. We should confirm that it is rated to handle 100 μ J (see [Figure 30](#)) by the procedure shown in AN-1197 and that the losses are acceptable. (If the DC Input voltage had been greater than 40V we would need to consider e_{CLIM} as in Example 2 above).

Note that we have taken V_{SAT} as 1.5V 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 ([SNVA038](#)). [Table 1](#) provides helpful contact information on suggested Inductor manufacturers who may be able to recommend suitable parts, if the requirements are known.

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 10V 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.

INPUT CAPACITOR

C_{IN} —A low ESR aluminum or tantalum bypass capacitor is needed between the input pin and ground pin. It must be located 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.

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 should 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.

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 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 (5V 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).

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 startup 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.

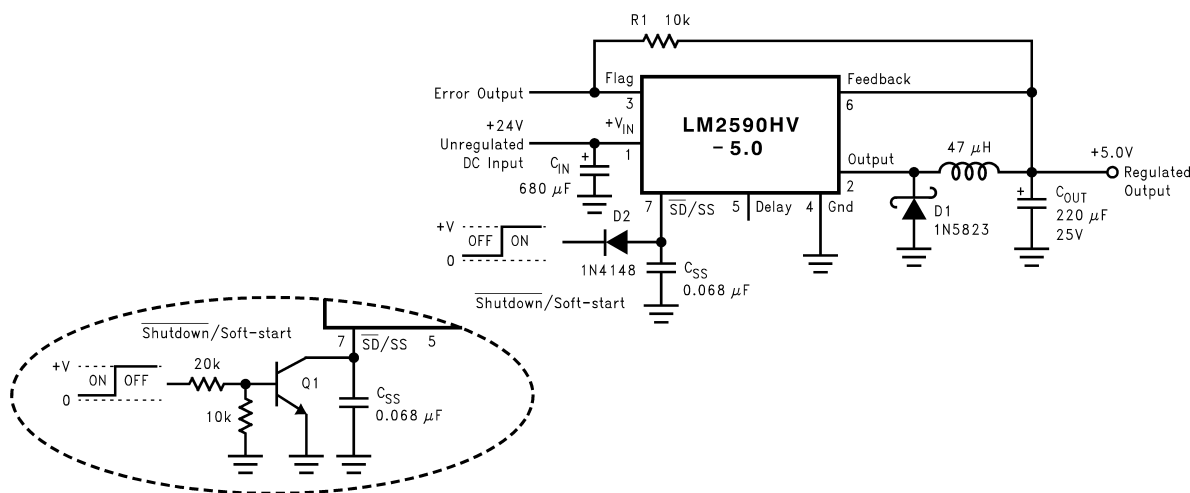


Figure 32. Typical Circuit Using Shutdown /Soft-start and Error Flag Features

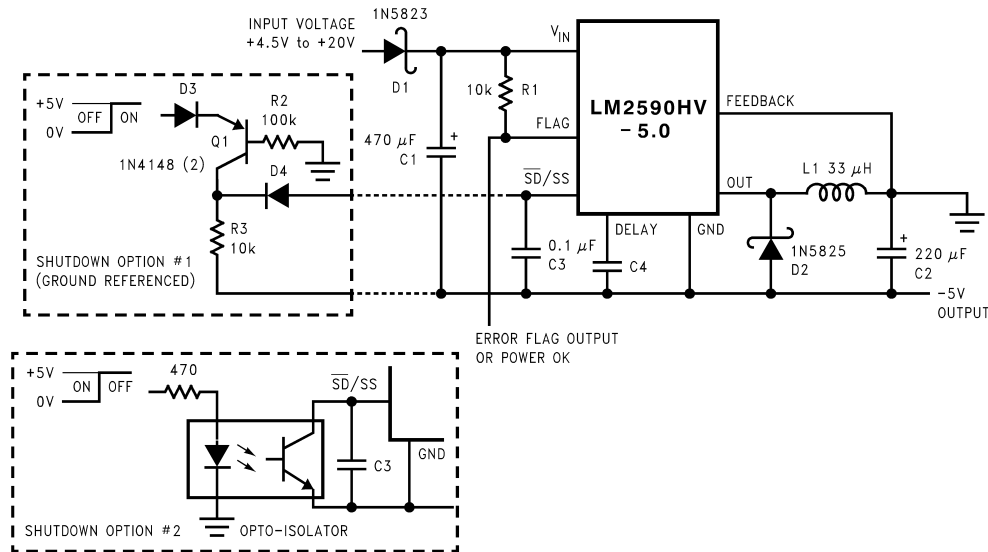


Figure 33. Inverting -5V Regulator With Shutdown and Soft-start

INVERTING REGULATOR

The circuit in [Figure 33](#) 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 -5V output, but other output voltages are possible by selecting other output voltage versions, including the adjustable version. Since 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:

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

where L is in µH and f is in Hz. The maximum possible load current I_{LOAD} is limited by the requirement that $I_{PEAK} \leq I_{CLIM}$. While checking for this, take I_{CLIM} to be the lowest possible current limit value (min across tolerance and temperature is 1.2A for the LM2590HV-AQ). Also to account for inductor tolerances, we should take the min value of Inductance for L in the equation above (typically 20% less than the nominal value). Further, the above equation 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 the above equation.

The reader is also referred to Application Note AN-1157 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 60V. In this example, when converting +20V to -5V, the regulator would see 25V between the input pin and ground pin. The LM2590HV-AQ has a maximum input voltage rating of 60V.

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 μH , 3A 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 current limit (approximately 3.0A) 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 startup currents required by the inverting topology, the Soft-Start feature shown in Figure 33 is recommended.

Also shown in Figure 33 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.

UNDERVOLTAGE LOCKOUT

Some applications require the regulator to remain off until the input voltage reaches a predetermined voltage. Figure 34 contains a undervoltage lockout circuit for a buck configuration, while Figure 35 and Figure 36 are for the inverting types (only the circuitry pertaining to the undervoltage lockout is shown). Figure 34 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 1.5V greater than the zener voltage.

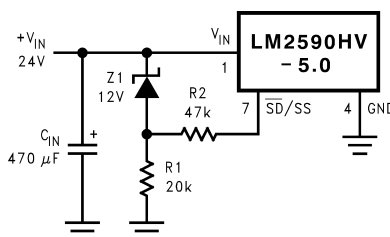


Figure 34. Undervoltage Lockout for a Buck Regulator

Figure 35 and Figure 36 apply the same feature to an inverting circuit. Figure 35 features a constant threshold voltage for turn on and turn off (zener voltage plus approximately one volt). If hysteresis is needed, the circuit in Figure 36 has a turn ON voltage which is different than the turn OFF voltage. The amount of hysteresis is approximately equal to the value of the output voltage. Since the $\overline{\text{SD}}/\text{SS}$ pin has an internal 7V zener clamp, R2 is needed to limit the current into this pin to approximately 1 mA when Q1 is on.

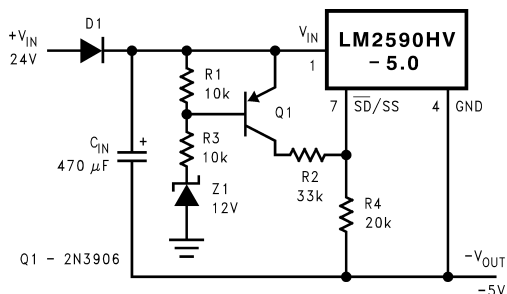


Figure 35. Undervoltage Lockout Without Hysteresis for an Inverting Regulator

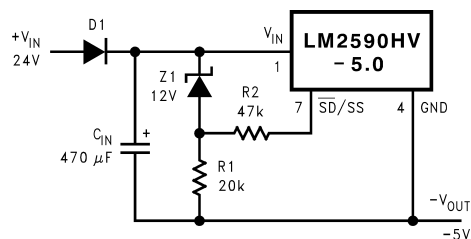


Figure 36. Undervoltage Lockout With Hysteresis for an Inverting Regulator

LAYOUT SUGGESTIONS

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 should be wide printed circuit traces and should be kept as short as possible**. For best results, external components should be located as close to the switcher IC as possible using ground plane construction or single point grounding.

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

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

REVISION HISTORY

Changes from Revision A (April 2013) to Revision B

Page

- Changed layout of National Data Sheet to TI format [22](#)

PACKAGING INFORMATION

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

(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.

OBSOLETE: 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) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side 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


*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/NOPB	DDPAK/TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

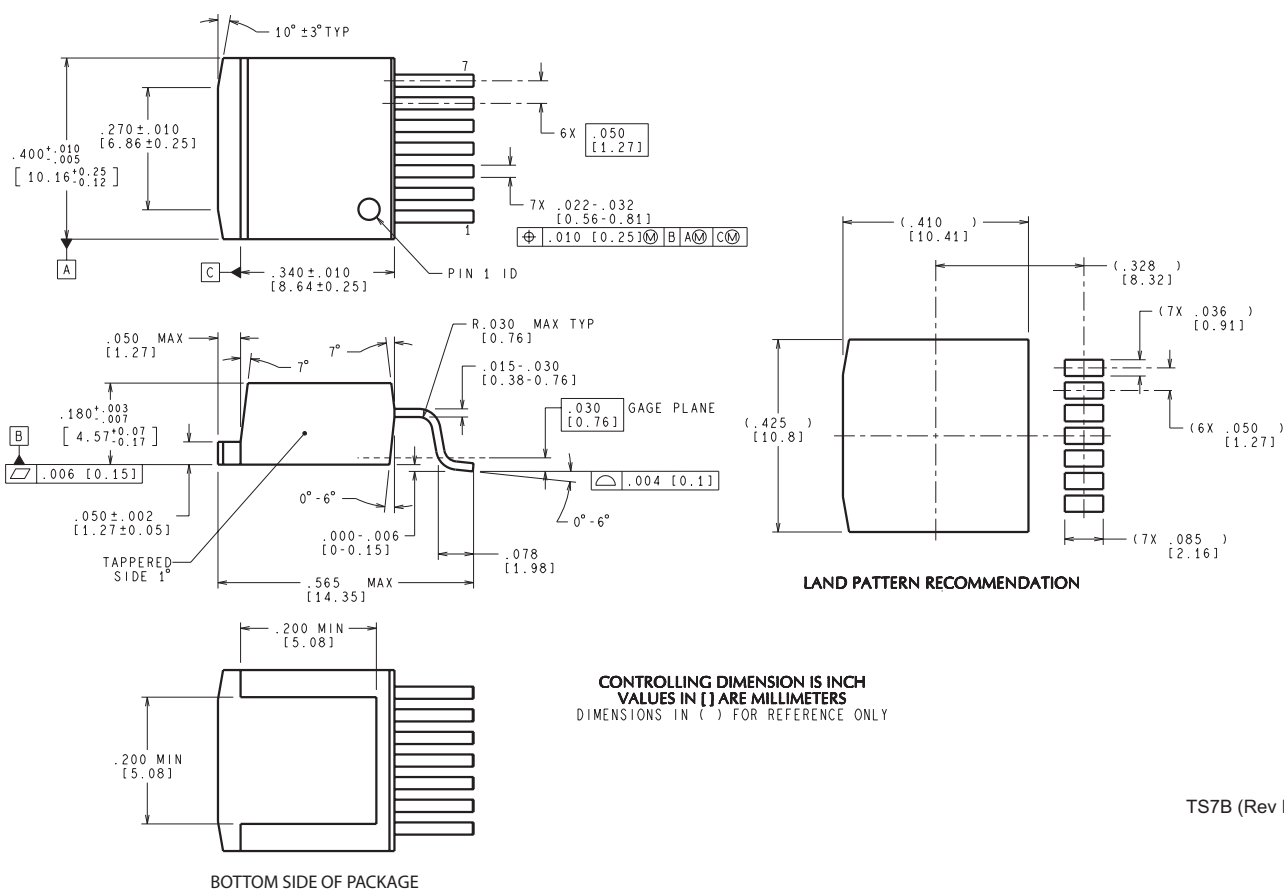
TAPE AND REEL BOX DIMENSIONS



*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



IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com