1A, 52KHz, Step-Down Switching Regulator LM2575

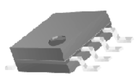
FEATURES

- 3.3V, 5.0V, 12V and Adjustable Output Versions
- Adjustable Version Output Voltage Range
- Wide Input Voltage Range
- Guaranteed 1A Output Current
- 52kHz Fixed Frequency Internal Oscillator
- Voltage mode non-synchronous PWM control
- On/Off shutdown control input
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3 for SMD packages

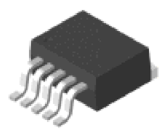
APPLICATION

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

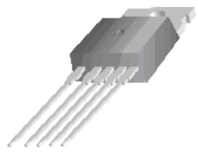
SOP-8PP PKG



TO-263-5L PKG



TO-220-5L PKG



ORDERING INFORMATION

Device	Package
LM2575GDP-X.X	SOP-8PP
LM2575GR-X.X	TO-263-5L
LM2575GT-X.X	TO-220-5L

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

DESCRIPTION

The LM2575 series are monolithic ICs designed for a step-down DC/DC converter, capable of driving 1A load without an additional transistor. It saves a board space. The external shutdown function is controlled by a logic level and then the circuit comes into the standby mode. The internal compensation makes the feedback control with good line and load regulation characteristics without an external design. Regarding the protection functions – the thermal shutdown prevents circuit damage during the over temperature operation and the current limit is against overcurrent operation of the output switch. If the case for the current limiting occurs and VFB is down by 40% of the nominal output voltage, the switching frequency shall be reduced.

The fixed output voltage version includes 3.3V, 5V, 12V devices, while the adjustable version voltages range from 1.23V to 37V. The chips are available in a standard 5-lead TO-220, TO-263 and SOP-8PP package.

ABSOLUTE MAXIMUM RATINGS (Note 1)

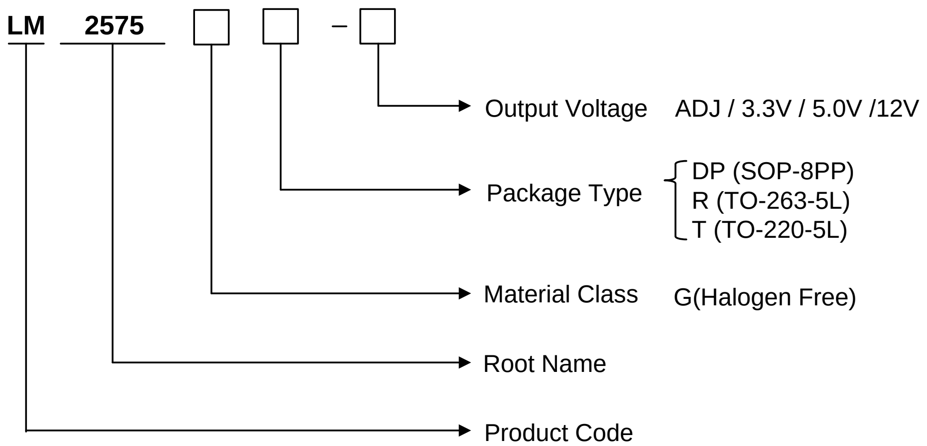
Characteristic	Symbol	Value	Unit
Maximum Input Supply Voltage	V_{IN}	45	V
ON/OFF Pin Input Voltage	$V_{ON/OFF}$	$-0.3 \le V \le 40, \le VIN$	V
Feedback Pin Voltage	V_{FB}	$-0.3 \le V \le 25, \le VIN$	V
Output Voltage to Ground (Steady State)	V_{OUT}	-1	V
Storage Temperature Range	T_{STG}	-65 to +150	^{o}C
Operating Temperature Range	T_J	150	^{o}C

RECOMMENDED OPERATING CONDITIONS

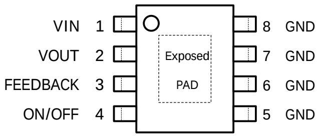
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT
Supply Voltage	V_{IN}	-	40	V
Load Current	I_{LOAD}	-	1	A
Junction Temperature	T_J	-40	125	

ORDERING INFORMATION

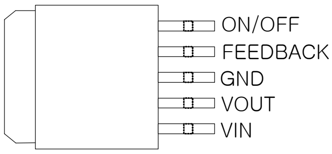
VOUT	Package	Order No.	Description	Status
ADJ	SOP-8PP	LM2575GDP-ADJ	1A, Adjustable, 52kHz, On/off	Active
	TO-263-5L	LM2575GR-ADJ	1A, Adjustable, 52kHz, On/off	Active
	TO-220-5L	LM2575GT-ADJ	1A, Adjustable, 52kHz, On/off	Active
3.3V	SOP-8PP	LM2575GDP-3.3	1A, Fixed, 52kHz, On/off	Active
	TO-263-5L	LM2575GR-3.3	1A, Fixed, 52kHz, On/off	Active
	TO-220-5L	LM2575GT-3.3	1A, Fixed, 52kHz, On/off	Active
5.0V	SOP-8PP	LM2575GDP-5.0	1A, Fixed, 52kHz, On/off	Active
	TO-263-5L	LM2575GR-5.0	1A, Fixed, 52kHz, On/off	Active
	TO-220-5L	LM2575GT-5.0	1A, Fixed, 52kHz, On/off	Active
12V	SOP-8PP	LM2575GDP-12	1A, Fixed, 52kHz, On/off	Active
	TO-263-5L	LM2575GR-12	1A, Fixed, 52kHz, On/off	Active
	TO-220-5L	LM2575GT-12	1A, Fixed, 52kHz, On/off	Active



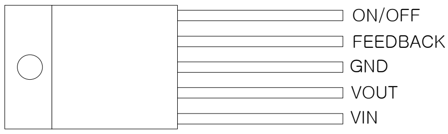
PIN CONFIGURATION



SOP-8PP



TO-263-5L



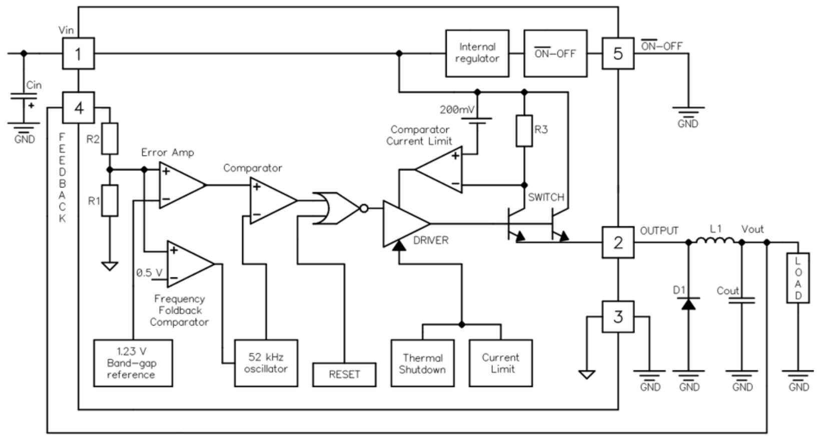
TO-220-5L

PIN DESCRIPTION

Package		Symbol	Description
TO-263-5L TO-220-5L	SOP-8PP		
1	1	VIN	This pin is the positive input supply for the LM2575 step-down switching regulator. In order to minimize voltage transients and to supply the switching currents needed by the regulator, a suitable input bypass capacitor must be present.
2	2	VOUT	This is the emitter of the internal switch. The saturation voltage V_{SAT} of this output switch is typically 1.2V. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry.
3	5, 6, 7, 8	GND	Circuit ground pin. See the information about the printed circuit board layout.
4	3	FEEDBACK	This pin senses regulated output voltage to complete the feedback loop. The signal is divided by the internal resistor divider network R1, R2 and applied to the non–inverting input of the internal error amplifier. In the adjustable version of the LM2575 switching regulator this pin is the direct input of the error amplifier and the resistor network R1, R2 is connected externally to allow programming of the output voltage.
5	4	ON/OFF	It allows the switching regulator circuit to be shutdown using logic level signals, thus dropping the total input supply current to approximately 100uA.

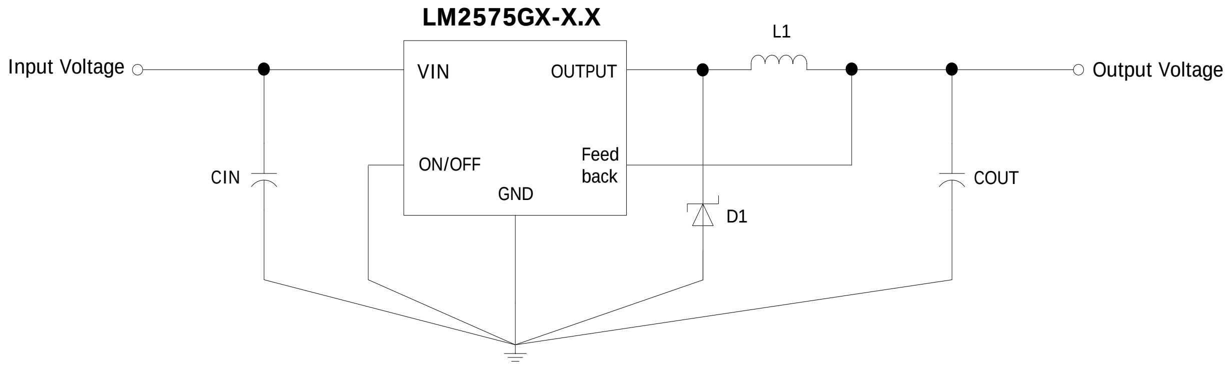
* Exposed Pad of SOP-8PP package should be externally connected to GND.

BLOCK DIAGRAM

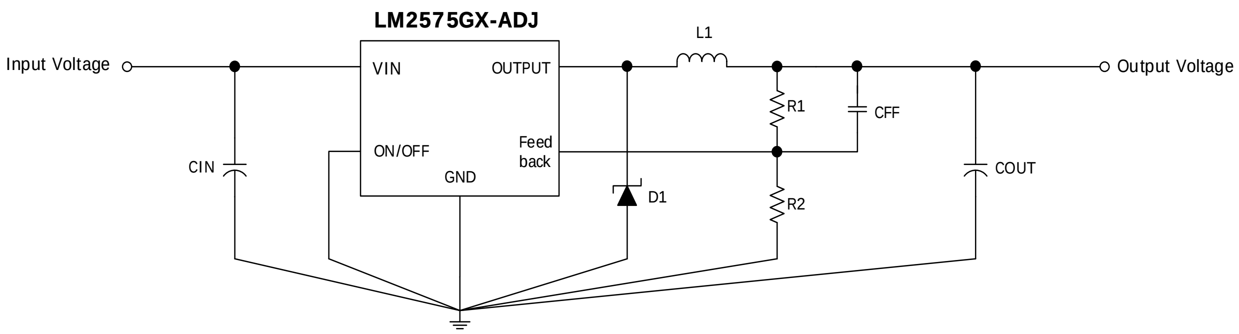


TYPICAL APPLICATION

- Fixed Output Voltage Version



- Adjustable Output Voltage Version



ELECTRICAL CHARACTERISTICS

Specification with standard type face are for T_J=25 , and those with **boldface type** apply over **full Operating Temperature Range**. Unless specified otherwise, V_{IN}=12V for the 3.3V, 5V, and Adjustable versions and V_{IN}=18V for the 12V version. I_{LOAD}=0.2A

Characteristic	Symbol	Test Condition		Min. (Note 3)	Typ. (Note 2)	Max. (Note 3)	Unit
SYSTEM PARAMETERS (Note 4)							
Efficiency	η	LM2575GX-ADJ	V_{IN}=15V, I_{LOAD}=1A		80		%
		LM2575GX-3.3	V_{IN}=12V, I_{LOAD}=1A		75		
		LM2575GX-5.0	V_{IN}=12V, I_{LOAD}=1A		77		
		LM2575GX-12	V_{IN}=15V, I_{LOAD}=1A		85		
Output Voltage	V_{OUT}	LM2575GX-3.3	5.1V ≤ V_{IN} ≤ 40V	3.168	3.3	3.432	V
			0.2A ≤ I_{LOAD} ≤ 1A	**3.135**		**3.465**	
		LM2575GX-5.0	7V ≤ V_{IN} ≤ 40V	4.800	5.0	5.200	
			0.2A ≤ I_{LOAD} ≤ 1A	**4.750**		**5.250**	
		LM2575GX-12	15V ≤ V_{IN} ≤ 40V	11.520	12	12.480	
			0.2A ≤ I_{LOAD} ≤ 1A	**11.400**		**12.600**	
Feedback Voltage	V_{FB}	LM2575GX-ADJ	7V ≤ V_{IN} ≤ 40V	1.193	1.23	1.267	V
			0.2A ≤ I_{LOAD} ≤ 1A	**1.180**		**1.280**	
DEVICE PARAMETERS							
Feedback Bias Current	I_{FB}	Adjustable Version Only, V_{FB}=1.3V			10	50	nA
						100	
Oscillator Frequency	F_{OSC}	(Note 5)		47	52	58	kHz
				42		**63**	
Saturation Voltage	V_{SAT}	I_{OUT}=1A, (Note 6, 7)			1.2	1.4	V
					1.3	**1.5**	
Max. Duty Cycle (ON)	DC	(Note 7)			100		%
Min. Duty Cycle (OFF)		(Note 8)			0		
Current Limit	I_{CL}	Peak Current (Note 6, 7)			3.2		A
Output Leakage Current	I_L	V_{OUT}=0V (Note 6, 8)				-1	mA
		V_{OUT}=-1V (Note 9)				-30	mA
Quiescent Current	I_Q	(Note 8)			5	8	mA
Shutdown Current	$I_{SHUTDOWN}$	$V_{ON/OFF}$=5V(OFF) (Note 9)			100	200	µA
						250	
ON/OFF Control							
ON/OFF Pin Logic Input Threshold voltage	V_{IH}	Low (Regulator ON)				**0.6**	V
	V_{IL}	High (Regulator OFF)		**2.0**			
ON/OFF Pin Logic Input current	I_H	$V_{ON/OFF}$=2.5V (regulator OFF)			-0.1	5	uA
	I_L	$V_{ON/OFF}$=0.5V (regulator ON)			0.01	-1	

ES France - Département Composants & Modules
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
Site Web : www.es-france.com

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

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

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

Note 4: External components such as the schottky diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance. When the LM2575 is used as shown in the typical circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

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

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

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

Note 8: Feedback pin removed from output and connected to 12V for the 3.3V, 5V, and the ADJ version, and 15V for the 12V version, to force the output transistor switch OFF.

Note 9: VIN=40V.

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Tél. 01 47 95 99 89
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TYPICAL OPERATING CHARACTERISTIC

T.B.D.

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Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
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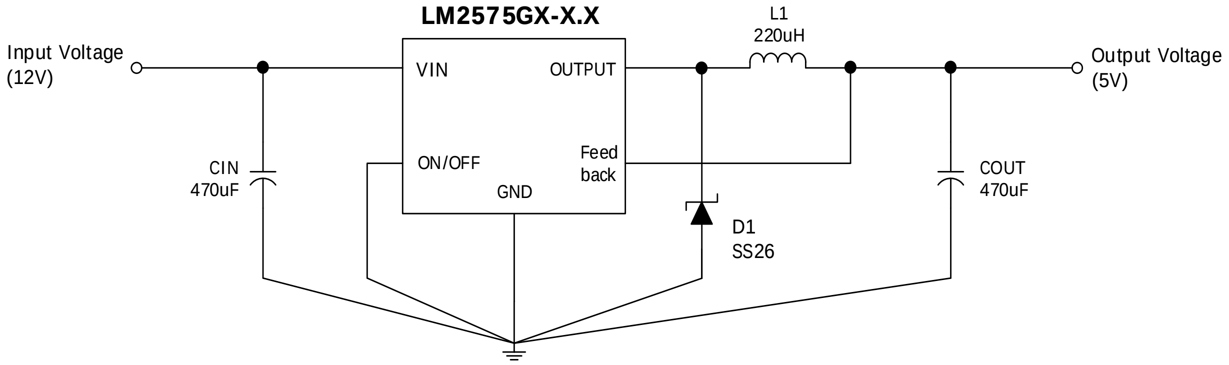
APPLICATION INFORMATION

- TYPICAL APPLICATION

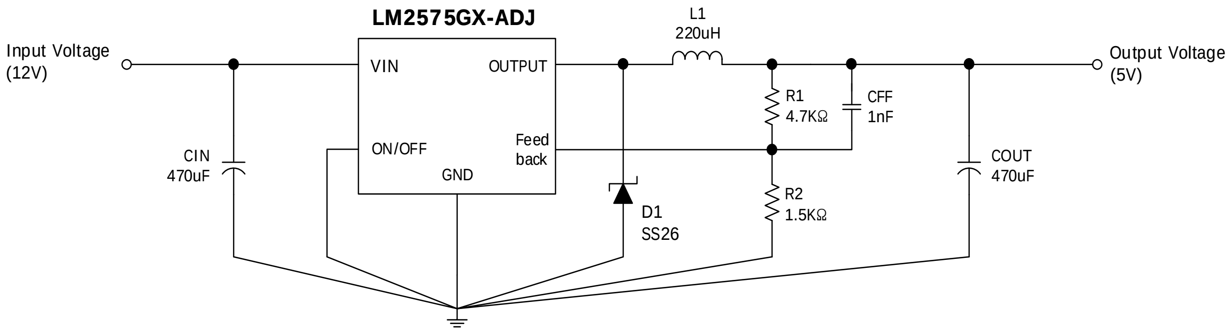
As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance generate voltage transients which can cause problems. For minimal inductance and ground loops, the length of the wires should be kept as short as possible. Single-point grounding or ground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

- Fixed Output Voltage Version (VOUT=5V)



[Figure 1]

- Adjustable Output Voltage Version (VOUT=5V)



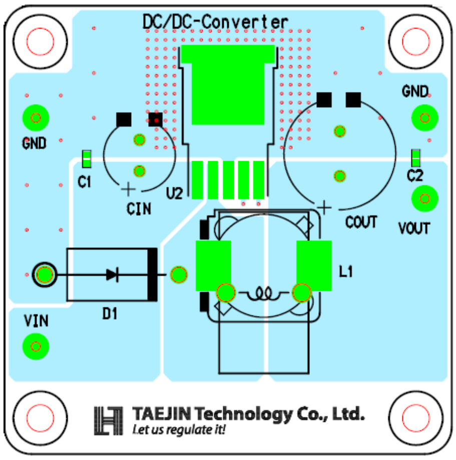
[Figure 2]

* $V_{OUT} = V_{FB}(1+\frac{R1}{R2})$, Where V_{FB}=1.23V, R2 Between 1K and 5K, CFF=1nF

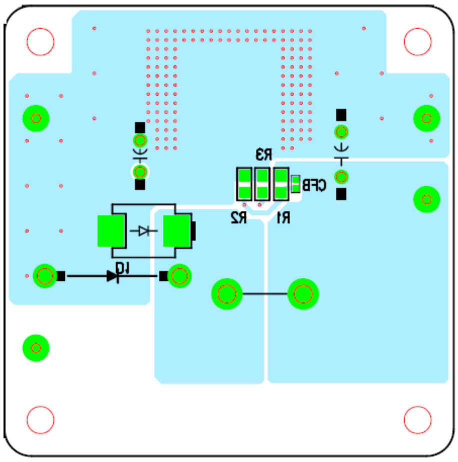
- PCB Layout

Proper layout of the switching power supplies is very important, and sometimes critical for proper function: poor layout design can result in poor line or load regulation and stability issues. Place the high-current paths (GND, IN and SW) very close to the device with short, direct, and wide traces. Place the input capacitor as close as possible to the IN and GND pins. Place the external feedback resistors next to the FB pin.
Keep the switching node SW short and away from the feedback network. The circuit of below PCB layout is shown in Figure.

- Top Layout



- Bottom Layout



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Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
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REVISION NOTICE

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

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Fax. 01 47 01 16 22
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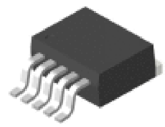
FEATURES

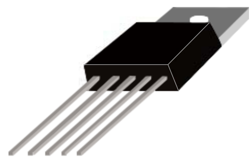
- Step-down Switching Regulator
- Adjustable Version Output Voltage Range, 1.23V to 52V ± 4% Max over Line and Load conditions
- Guaranteed Output Current of 1A
- Fixed Output Voltages : 3.3V, 5.0V, 12V and 15V
- Wide Input Voltage Range 60V
- 52KHz Fixed Frequency Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- Requires only 4 External Components
- High Efficiency
- Use Readily Available Standard Inductors
- Available in TO-220, TO-263 and SOP-8PP Packages
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3

SOP-8PP PKG

TO-263 PKG



TO-220 PKG



ORDERING INFORMATION

Device	Package
LM2575HVDP-ADJ	SOP-8PP 8L
LM2575HVDP-X.X	
LM2575HVR-ADJ	TO-263 5L
LM2575HVR-X.X	
LM2575HVT-ADJ	TO-220 5L
LM2575HVT-X.X	

X.X = Output Voltage = 3.3, 5.0, 12, 15

APPLICATIONS

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

DESCRIPTION

The LM2575HV series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving 1A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V and adjustable output versions.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation and a fixed-frequency oscillator. The LM2575HV series offers a high-efficiency replacement for popular three-terminal linear regulators. It substantially reduces the size of the heat sink, and in some cases no heat sink is required. A standard series of inductors optimized for use with the LM2575HV are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies. Other features include a guaranteed ± 4% tolerance on output voltage within specified input voltages and output load conditions, and ± 10% on the oscillator frequency. External shutdown is included, featuring 50uA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

ABSOLUTE MAXIMUM RATINGS (Note 1)

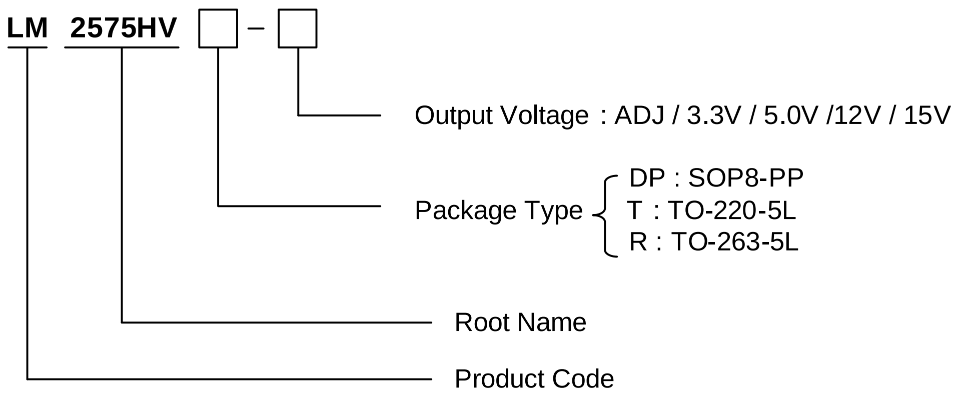
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT
Input Supply Voltage	V_{IN}	-	63	V
ON/OFF Pin Input Voltage	$V_{ON/OFF}$	-0.3	+ V_{IN}	V
Output Voltage to Ground (Steady State)	V_{OUT}	-0.75	-	V
Lead Temperature (Soldering, 5 sec)	T_{SOL}	-	260	℃
Storage Temperature Range	T_{STG}	-65	150	℃
Maximum Junction Temperature Range	T_{JOPR}	-	150	℃

OPERATING RATINGS

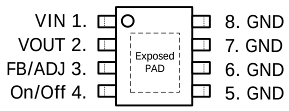
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT
Supply Voltage	V_{IN}	-	60	V
Temperature Range	T_J	-40	125	℃

ORDERING INFORMATION

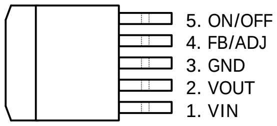
V_{OUT}	Package	Order No.	Description	Supplied As	Status
ADJ	SOP-8PP 8L	LM2575HVDP -ADJ	1A, 52kHz, Adjustable	Reel	Contact us
	TO-263 5L	LM2575HVR -ADJ	1A, 52kHz, Adjustable	Reel	Active
	TO-220 5L	LM2575HVT -ADJ	1A, 52kHz, Adjustable	Tube	Active
3.3V	SOP-8PP 8L	LM2575HVDP -3.3	1A, 52kHz, Fixed	Reel	Contact us
	TO-263 5L	LM2575HVR -3.3	1A, 52kHz, Fixed	Reel	Contact us
	TO-220 5L	LM2575HVT -3.3	1A, 52kHz, Fixed	Tube	Active
5.0V	SOP-8PP 8L	LM2575HVDP -5.0	1A, 52kHz, Fixed	Reel	Contact us
	TO-263 5L	LM2575HVR -5.0	1A, 52kHz, Fixed	Reel	Active
	TO-220 5L	LM2575HVT -5.0	1A, 52kHz, Fixed	Tube	Active
12V	SOP-8PP 8L	LM2575HVDP -12	1A, 52kHz, Fixed	Reel	Contact us
	TO-263 5L	LM2575HVR -12	1A, 52kHz, Fixed	Reel	Active
	TO-220 5L	LM2575HVT -12	1A, 52kHz, Fixed	Tube	Active
15V	SOP-8PP 8L	LM2575HVDP -15	1A, 52kHz, Fixed	Reel	Contact us
	TO-263 5L	LM2575HVR -15	1A, 52kHz, Fixed	Reel	Contact us
	TO-220 5L	LM2575HVT -15	1A, 52kHz, Fixed	Tube	Contact us



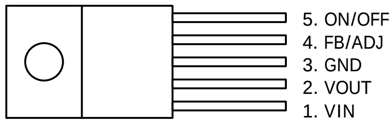
PIN CONFIGURATION



SOP-8PP



TO-263



TO-220

PIN DESCRIPTION

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

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

ELECTRICAL CHARACTERISTICS

Specifications with standard type face are for T_J=25℃ and those with boldface type apply over full operating temperature range. Unless otherwise specified, V_{IN}=12V for the 3.3V, 5V, and Adjustable version, V_{IN}=25V for the 12V version, and V_{IN}=30V for the 15V version, I_{LOAD}=0.5A.

PARAMETER	SYMBOL	TEST CONDITION (Note 2)		MIN.	TYP.	MAX.	UNIT
SYSTEM PARAMETERS (Note 3)							
Feedback Voltage	V_{FB}	LM2575HV-ADJ	V_{IN}=12V, I_{LOAD}=0.5A	1.217	1.230	1.243	V
			0.5A ≤ I_{LOAD} ≤ 1A, 8V ≤ V_{IN} ≤ 55V	1.193 **1.180**	1.230	1.273 **1.286**	V
Output Voltage	V_O	LM2575HV-3.3	V_{IN}=12V, I_{LOAD}=0.5A	3.234	3.300	3.366	V
			0.5A ≤ I_{LOAD} ≤ 1A, 6V ≤ VI_N ≤ 55V	3.168 **3.135**	3.300	3.450 **3.482**	V
		LM2575HV-5.0	V_{IN}=12V, I_{LOAD}=0.5A	4.900	5.000	5.100	V
			0.5A ≤ I_{LOAD} ≤ 1A, 8V ≤ V_{IN} ≤ 55V	4.800 **4.750**	5.000	5.225 **5.275**	V
		LM2575HV-12	V_{IN}=25V, I_{LOAD}=0.5A	11.76	12.00	12.24	V
			0.5A ≤ I_{LOAD} ≤ 1A, 15V ≤ V_{IN} ≤ 55V	11.52 **11.40**	12.00	12.54 **12.66**	V
		LM2575HV-15	V_{IN}=25V, I_{LOAD}=0.5A	14.70	15.00	15.30	V
			0.5A ≤ I_{LOAD} ≤ 1A, 18V ≤ V_{IN} ≤ 55V	14.40 **14.25**	15.00	15.68 **15.83**	V
Efficiency	η	LM2575HV-ADJ	V_{IN}=12V, I_{LOAD}=1A, Vo=5V		77		%
		LM2575HV-3.3	V_{IN}=12V, I_{LOAD}=1A		75		%
		LM2575HV-5.0	V_{IN}=12V, I_{LOAD}=1A		77		%
		LM2575HV-12	V_{IN}=15V, I_{LOAD}=1A		88		%
		LM2575HV-15	V_{IN}=18V, I_{LOAD}=1A		88		%
DEVICE PARAMETERS							
Feedback Bias Current	I_b	V_O=5V (Adjustable Version Only)			50	100 **500**	nA
Oscillator Frequency	f_O	(Note 8)		47 **42**	52	58 **63**	KHZ
Saturation Voltage	V_{SAT}	I_O=1A (Note 4)			1.4	1.55 **1.70**	V
Max Duty Cycle(ON)	DC	(Note 5)		93	98		%
Current Limit	I_{CL}	(Note 4, 8)		4.2 **3.5**	5.8	6.9 **7.5**	A

(Continued)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Output Leakage Current	I_L	(Notes 6, 7) Output=0V		7.5		mA
Quiescent Current	I_Q	(Note 6)		5	10	mA
Standby Quiescent Current	I_{STBY}	ON/OFF Pin=5V (OFF) — V_{IN}=60V		50	200	uA
$\overline{ON}$/OFF CONTROL						
$\overline{ON}$/OFF Pin Logic Input Level	V_{IH}	V_O=0V	2.2 **2.4**	1.4		V
	V_{IL}	V_O=Nominal Output Voltage		1.2	1.0 **0.8**	V
$\overline{ON}$/OFF Pin Input Current	I_{IH}	$\overline{ON}$/OFF Pin=5V (OFF)		12	30	uA
	I_{IL}	$\overline{ON}$/OFF Pin=0V (ON)		0	10	uA

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

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

Note 3. External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance. When the 2575HV is used as shown in the Figure 2 test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

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

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

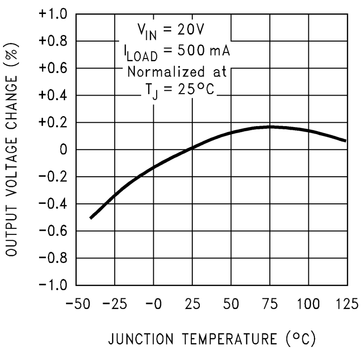
Note 6. Feedback pin removed from output and connected to +12V for the Adjustable, 3.3V, and 5V, versions, and +25V for the 12V and 15V versions, to force the output transistor OFF.

Note 7. V_{IN} =60V.

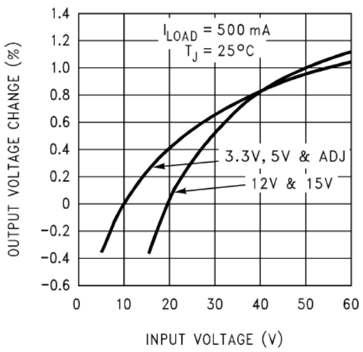
Note 8. The oscillator frequency reduces to approximately 11 kHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage. This self protections feature lowers the average power dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.

TYPICAL OPERATING CHARACTERISTIC

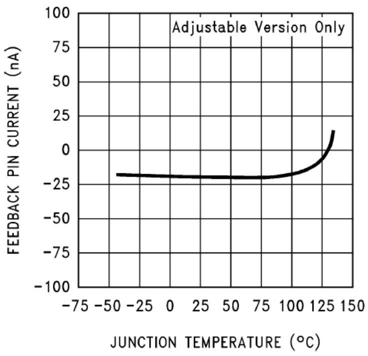
Normalized Output Voltage



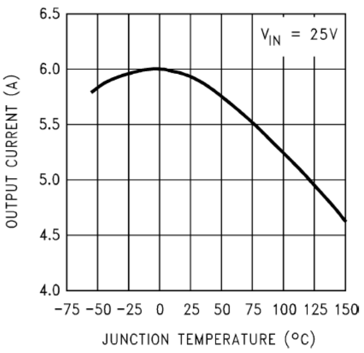
Line Regulation



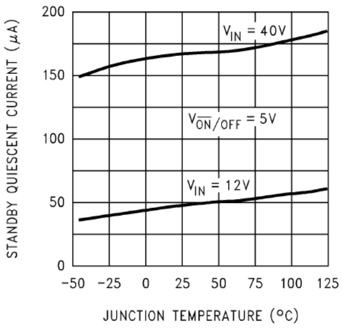
Feedback Pin Current



Current Limit



Standby Quiescent Current



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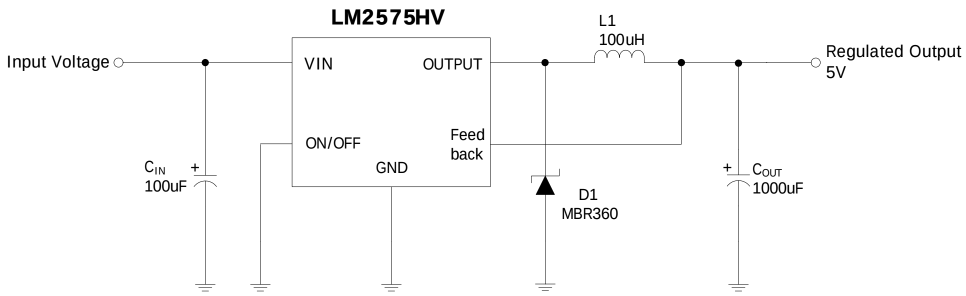
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
Site Web : www.es-france.com

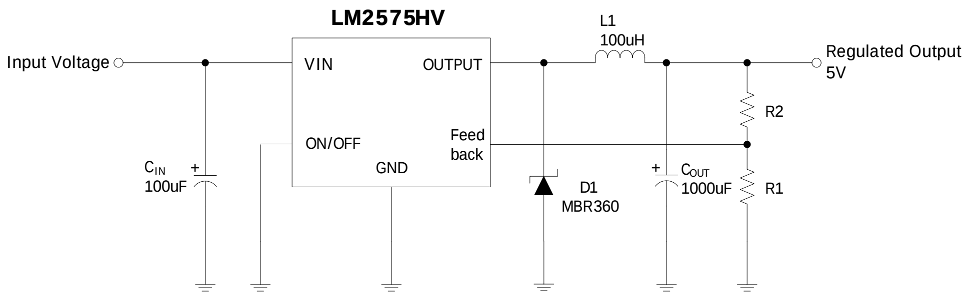
APPLICATION INFORMATION

As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance generate voltage transients which can cause problems. For minimal inductance and ground loops, the length of the leads indicated by heavy lines should be kept as short as possible. Single-point grounding (as indicated) or ground plane construction should be used for best results. When using the Adjustable version, physically locate the programming resistors near the regulator, to keep the sensitive feedback wiring short.

- Fixed Output Voltage Version



- Adjustable Output Voltage Version



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

$$* \quad R2 = R1(\frac{V_{OUT}}{V_{REF}} - 1)$$

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

- C_{IN} : 100uF, Aluminum Electrolytic
- C_{OUT} : 1000uF, Aluminum Electrolytic
- D1 - Schottky Diode
- L1 : 100uH
- R1 : 2K
- R2 : 6.12K

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Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
Site Web : www.es-france.com

REVISION NOTICE

The description in this datasheet can be revised without any notice to describe its electrical characteristics properly.

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127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
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3A, 52kHz, Step-Down Switching Regulator — LM2576

FEATURES

- 3.3V, 5.0V, 12V, 15V, and Adjustable Output Versions
- Adjustable Version Output Voltage Range, 1.23V to 37V ±4% maximum over line and load conditions
- Guaranteed 3.0A Output Current
- Wide Input Voltage Range: Up to 40V
- Requires Only 4 External Components
- 52kHz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- High Efficiency
- Uses Readily Available Standard Inductors
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3 for SMD type packages

APPLICATIONS

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

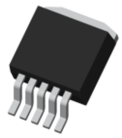
DESCRIPTION

The LM2576 series of regulators are monolithic integrated circuits ideally suited for easy and convenient design of a step-down switching regulator (buck converter). All circuits of this series are capable of driving a 3.0A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V, and an adjustable output version.

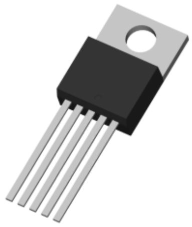
These regulators were designed to minimize the number of external components to simplify the power supply design. Standard series of inductors optimized for use with the LM2576 are offered by several different inductor manufacturers.

The LM2576 features include a ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±10% on the oscillator frequency. External shutdown is included, featuring 50µA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

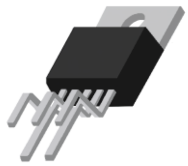
SOP-8PP



TO-263-5



TO-220-5



TO-220TV-5

ORDERING INFORMATION

Device	Package
LM2576DP-x.x	SOP-8PP
LM2576R-x.x	TO-263-5L
LM2576T-x.x	TO-220-5L
LM2576TV-x.x	TO-220TV-5L

x.x: Output Voltage

ABSOLUTE MAXIMUM RATINGS (Note 1)

CHARACTERISTIC	SYMBOL	MIN	MAX	UNIT
Maximum Supply Voltage	V_{IN}	-	45	V
$\overline{\text{ON}}$/OFF Pin Input Voltage	-	−0.3	V_{IN}	V
Output Voltage to Ground	-	−0.8	-	V
Power Dissipation	P_D	-	Internally Limited	W
ESD Rating, HBM	-	2000	-	V
Maximum Junction Temperature	T_J	-	150	°C
Storage Temperature	T_{STG}	−65	150	°C

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

RECOMMENDED OPERATING RATINGS (Note 2)

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

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

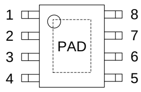
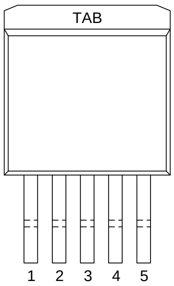
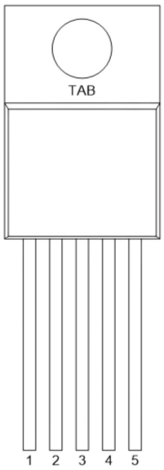
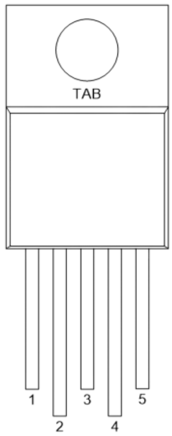
THERMAL INFORMATION

THERMAL METRIC	θ_{JA}	θ_{JC}	UNIT
Thermal Resistance, SOP8-PP	Contact us	15	°C/W
Thermal Resistance, TO-263-5L	70	5	°C/W
Thermal Resistance, TO-220-5L	65	5	°C/W
Thermal Resistance, TO-220TV-5L	65	5	°C/W

ORDERING INFORMATION

VOUT	Package	Order No.	Description	Supplied As	Status
ADJ	SOP8-PP	LM2576DP-ADJ	Adjustable Output	Tape & Reel	Active
	TO-263-5L	LM2576R-ADJ	Adjustable Output	Tape & Reel	Active
	TO-220-5L	LM2576T-ADJ	Adjustable Output	Tube	Active
	TO-220TV-5L	LM2576TV-ADJ	Adjustable Output	Tube	Active
3.3V	SOP8-PP	LM2576DP-3.3	3.3V Fixed Output	Tape & Reel	Contact Us
	TO-263-5L	LM2576R-3.3	3.3V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576T-3.3	3.3V Fixed Output	Tube	Active
5.0V	SOP8-PP	LM2576DP-5.0	5.0V Fixed Output	Tape & Reel	Active
	TO-263-5L	LM2576R-5.0	5.0V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576T-5.0	5.0V Fixed Output	Tube	Active
	TO-220TV-5L	LM2576TV-5.0	5.0V Fixed Output	Tube	Active
12V	SOP8-PP	LM2576DP-12	12V Fixed Output	Tape & Reel	Contact Us
	TO-263-5L	LM2576R-12	12V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576T-12	12V Fixed Output	Tube	Active
	TO-220TV-5L	LM2576TV-12	12V Fixed Output	Tube	Active
15V	SOP8-PP	LM2576DP-15	15V Fixed Output	Tape & Reel	Contact Us
	TO-263-5L	LM2576R-15	15V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576T-15	15V Fixed Output	Tube	Active

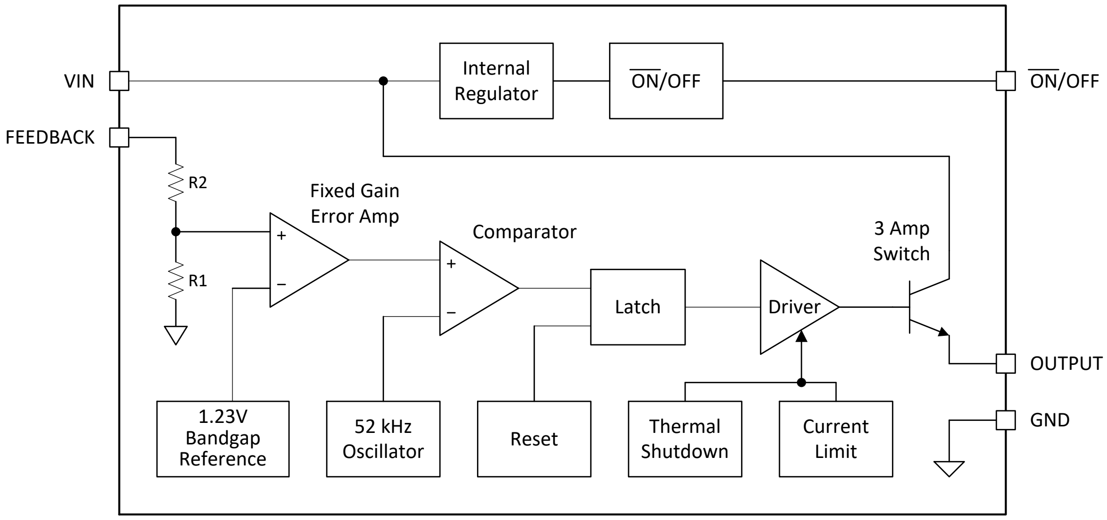
PIN CONFIGURATION

SOP-8PP	TO-263-5	TO-220-5	TO-220TV-5
(Top View) 			

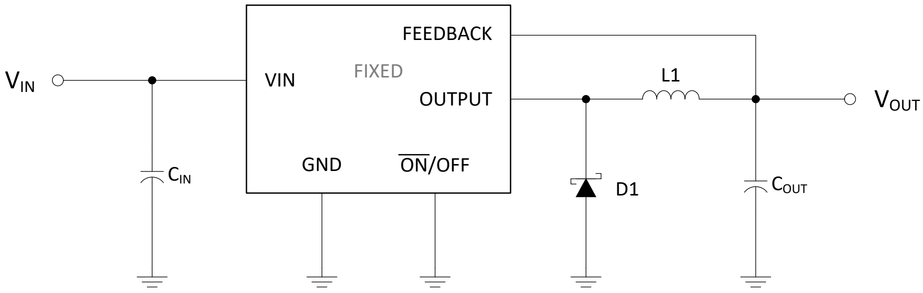
PIN DESCRIPTION

Pin No.			Pin Name	Pin Function
TO-263-5	TO-220-5 TO-220TV-5	SOP-8PP		
1	1	1	VIN	Supply input pin to collector pin of power transistor. Connect to power supply and input bypass capacitors C_{IN}, Path from VIN pin to high frequency bypass C_{IN} and GND must be as short as possible to minimize voltage transients.
2	2	2	OUTPUT	Emitter pin of the power transistor. This is a switching node. Attached this pin to an inductor and the cathode of the external diode. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry.
3	3	6	GND	Ground pin. Path to C_{IN} must be as short as possible.
4	4	3	FEEDBACK	Feedback sense input pin. Connect to the midpoint of feedback divider to set V_{OUT} for ADJ version or connect this pin directly to the output capacitor for a fixed output version.
5	5	4	$\overline{\text{ON}}$/OFF	Enable input to the voltage regulator. It allows the switching regulator circuit to be shutdown using logic level signals. Applying level high shuts the regulator off. If the voltage applied to this pin is level low, the regulator will be in the ON condition. Do not leave this pin float.
-	-	5 / 7 / 8	N.C.	No Connection
TAB	TAB	-	TAB	Connect to GND. Attached to heatsink for thermal relief for TO-220 package or put a copper plane connected to this pin as a thermal relief for TO-263 package.
-	-	PAD	Exposed Pad	Connect to GND. Solder to copper plane for thermal relief.

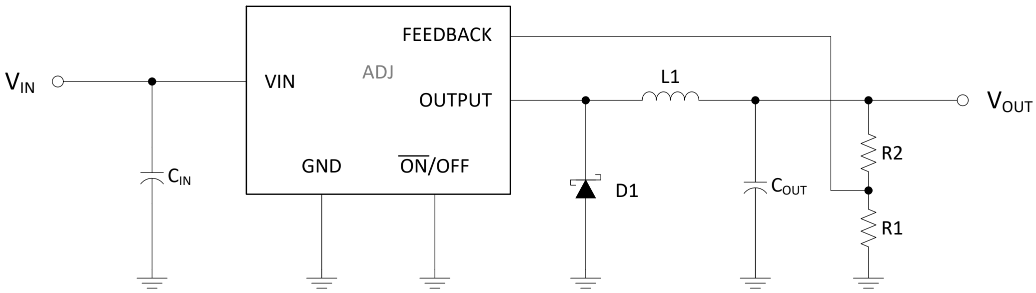
BLOCK DIAGRAM



TYPICAL APPLICATION CIRCUIT



< Fixed Output Voltage Version >



< Adjustable Output Voltage Version >

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

ELECTRICAL CHARACTERISTICS

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

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
3.3V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 12V, I_{LOAD} = 0.5A	3.234	3.3	3.366	V
Output Voltage	V_{OUT}	6.0V ≤ V_{IN} ≤ 40V, 0.5A ≤ I_{LOAD} ≤ 3.0A	3.168 **3.135**	3.3 -	3.432 **3.465**	V
Efficiency	η	V_{IN} = 12V, I_{LOAD} = 3.0A	-	75	-	%
5.0V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 12V, I_{LOAD} = 0.5A	4.900	5.0	5.100	V
Output Voltage	V_{OUT}	8.0V ≤ V_{IN} ≤ 40V, 0.5A ≤ I_{LOAD} ≤ 3.0A	4.800 **4.750**	5.0 -	5.200 **5.250**	V
Efficiency	η	V_{IN} = 12V, I_{LOAD} = 3.0A	-	77	-	%
12V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 25V, I_{LOAD} = 0.5A	11.76	12	12.24	V
Output Voltage	V_{OUT}	15V ≤ V_{IN} ≤ 40V, 0.5A ≤ I_{LOAD} ≤ 3.0A	11.52 **11.40**	12 -	12.48 **12.60**	V
Efficiency	η	V_{IN} = 15V, I_{LOAD} = 3.0A	-	88	-	%
15V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 25V, I_{LOAD} = 0.5A	14.70	15	15.30	V
Output Voltage	V_{OUT}	18V ≤ V_{IN} ≤ 40V, 0.5A ≤ I_{LOAD} ≤ 3.0A	14.40 **14.25**	15 -	15.60 **15.75**	V
Efficiency	η	V_{IN} = 18V, I_{LOAD} = 3.0A	-	88	-	%
Adjustable Output (Note 3)						
Feedback Voltage	V_{FB}	V_{IN} = 12V, I_{LOAD} = 0.5A, V_{OUT} = 5.0V	1.217	1.23	1.243	V
Feedback Voltage	V_{FB}	8.0V ≤ V_{IN} ≤ 40V, 0.5A ≤ I_{LOAD} ≤ 3.0A, V_{OUT} = 5.0V	1.193 **1.180**	1.23 -	1.267 **1.280**	V
Efficiency	η	V_{IN} = 12V, I_{LOAD} = 3.0A, V_{OUT} = 5.0V	-	77	-	%

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

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Fax. 01 47 01 16 22
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ELECTRICAL CHARACTERISTICS (continued)

Specification with standard type face are for T_J = 25°C, and those with **boldface type** apply over full operating temperature range in Recommended Operating Ratings. Unless otherwise specified, V_{IN} = 12V for the 3.3V, 5.0V, and Adjustable version, and V_{IN} = 25V for the 12V and 15V version. I_{LOAD} = 500mA. For typical values, T_J = 25°C, unless otherwise noted.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
All Output Voltage Versions						
Feedback Bias Current	I_B	V_{OUT} = 5.0V (Adjustable Version Only)	- -	50 -	100 **500**	nA
Oscillator Frequency (Note 4)	f_O		47 **42**	52 -	58 **63**	kHz
Saturation Voltage	V_{SAT}	I_{OUT} = 3.0A (Note 5)	- -	1.4 -	1.6 **1.8**	V
Max Duty Cycle (Note 6)	DC		93	98	-	%
Current Limit (Note 4,5)	I_{CL}		4.2 **3.5**	5.8 -	6.9 **7.5**	A
Output Leakage Current (Note 7, 8)	I_L	Output = 0V	-	-	2.0	mA
		Output = −0.8V (Note 7,8)	-	7.5	30	
Quiescent Current (Note 7)	I_Q		-	5.0	10	mA
Standby Quiescent Current	I_{STBY}	$\overline{\text{ON}}$/OFF pin = 5.0V (OFF)	-	50	200	µA
$\overline{\text{ON}}$/OFF Pin Input Level	V_{IH}	V_{OUT} = 0V	2.2 **2.4**	1.4 -	- -	V
	V_{IL}	V_{OUT} = Nominal Output Voltage	- -	1.2 -	1.0 **0.8**	V
$\overline{\text{ON}}$/OFF Pin Input Current	I_{IH}	$\overline{\text{ON}}$/OFF Pin = 5.0V (OFF)	-	12	30	µA
	I_{IL}	$\overline{\text{ON}}$/OFF Pin = 0V (ON)	-	0	10	µA

Note 4. The oscillator frequency reduces to approximately 11 kHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage. This self-protection feature lowers the average power dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.
Note 5. OUTPUT pin sourcing current. No diode, inductor or capacitor connected to OUTPUT.
Note 6. FEEDBACK pin removed from output and connected to 0V.
Note 7. FEEDBACK pin removed from output and connected to +12V for the 3.3V, 5.0V, and Adjustable versions, and 25V for the 12V and 15V versions, to force the output transistor OFF.
Note 8. V_{IN} = 40V.

TYPICAL OPERATING CHARACTERISTICS

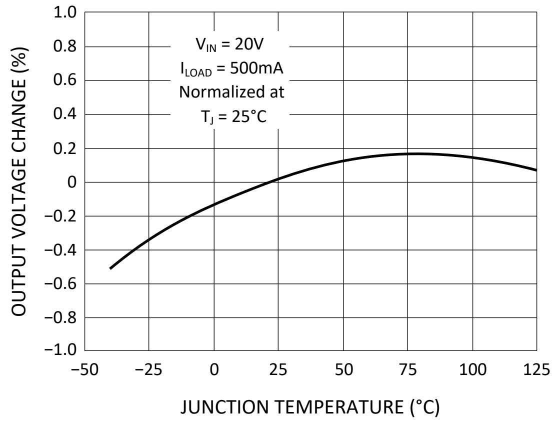

Figure 1. Normalized Output Voltage

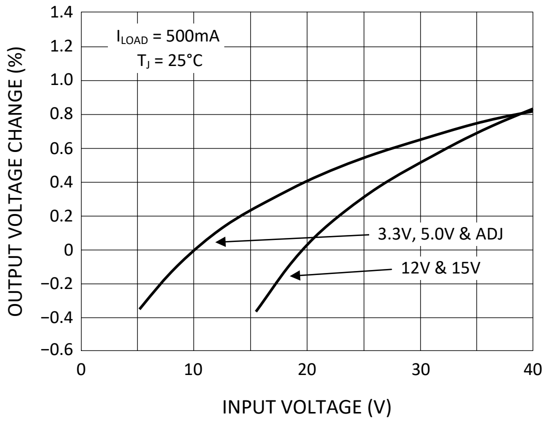

Figure 2. Line Regulation

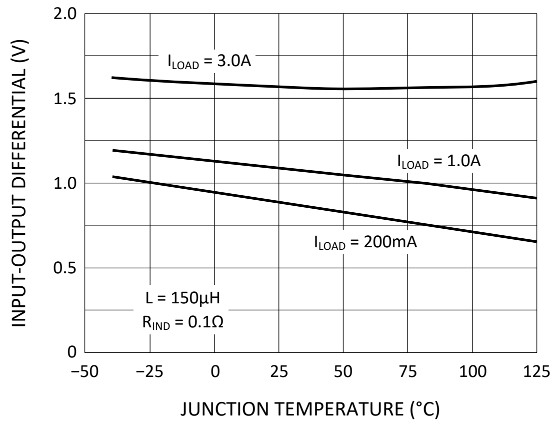

Figure 3. Dropout Voltage

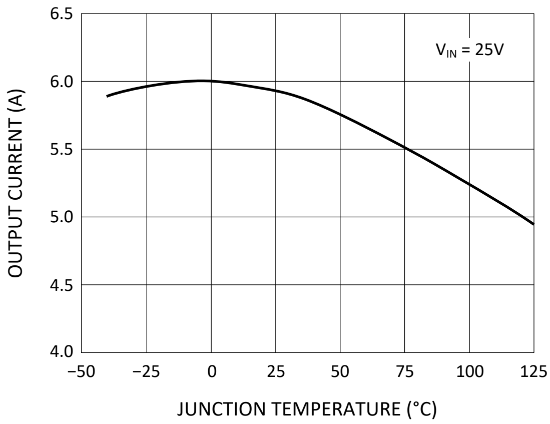

Figure 4. Current Limit

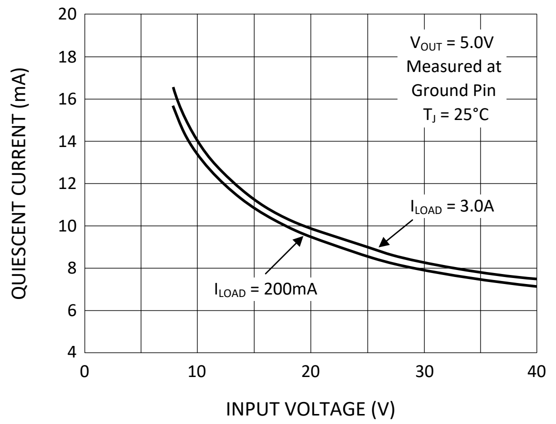

Figure 5. Quiescent Current

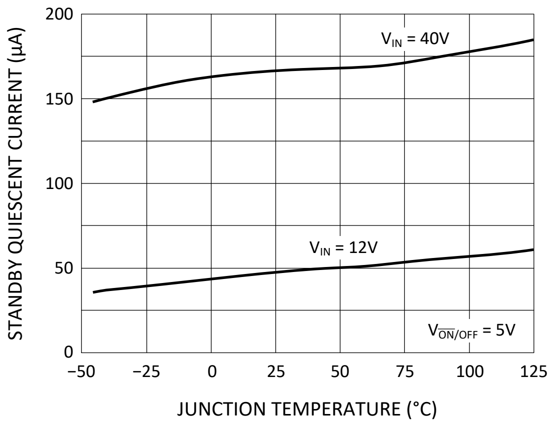

Figure 6. Standby Quiescent Current

TYPICAL OPERATING CHARACTERISTICS (continued)

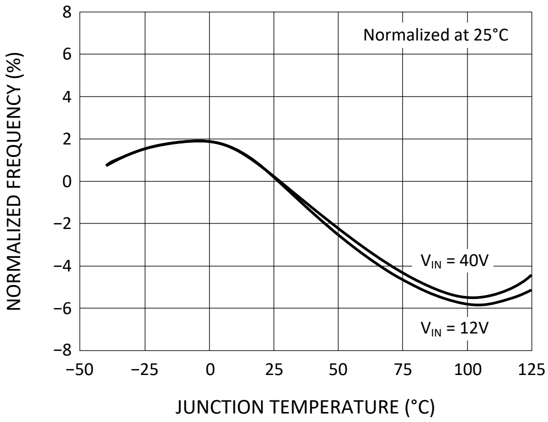

Figure 7. Oscillator Frequency

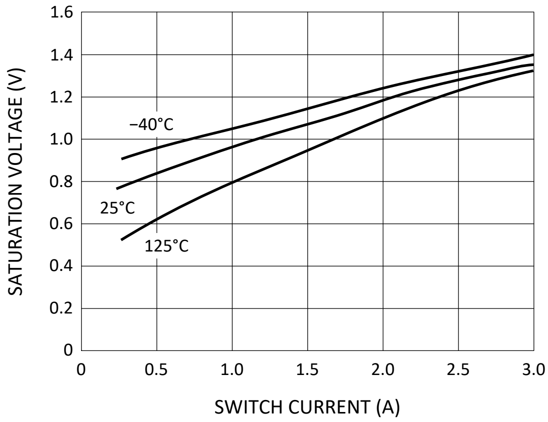

Figure 8. Switch Saturation Voltage

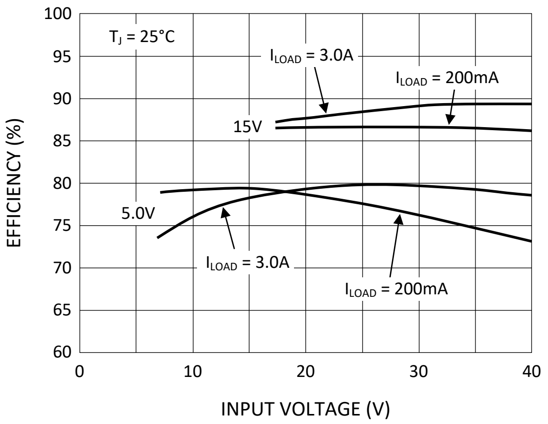

Figure 9. Efficiency

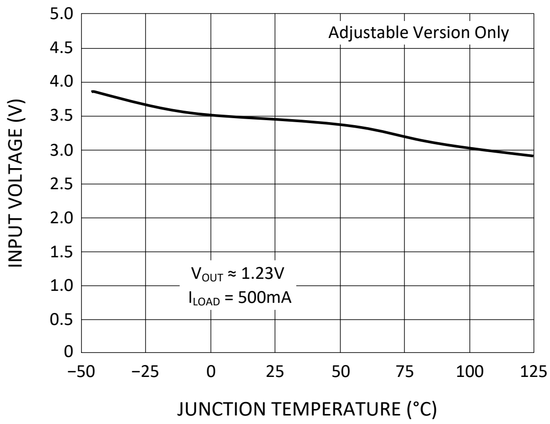

Figure 10. Minimum Operating Voltage

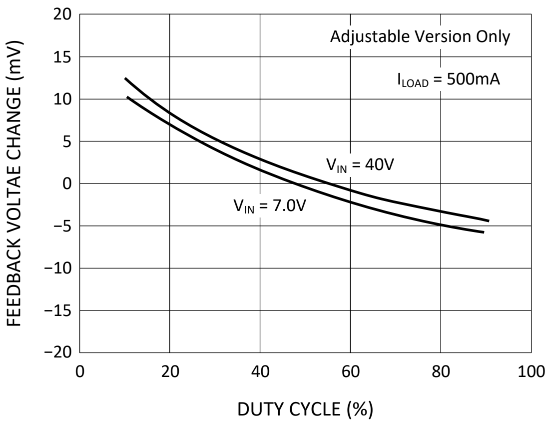

Figure 11. Feedback Voltage vs Duty Cycle

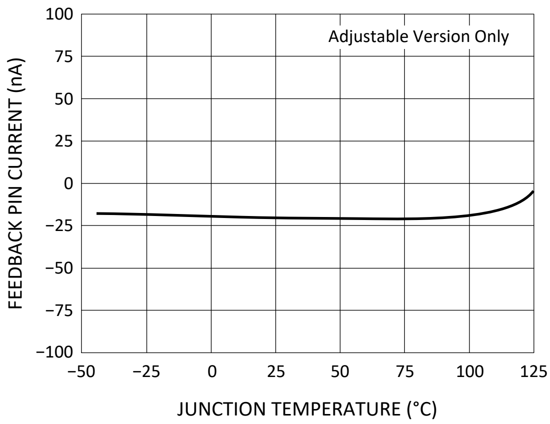

Figure 12. Feedback Pin Current

APPLICATION INFORMATION

OVERVIEW

The LM2576 regulator is an easy-to-use, non-synchronous step-down DC-DC converter with a wide input voltage range up to 40V. It is capable of delivering up to 3.0A DC load current with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V and an adjustable output version. The family requires few external components, and the pin arrangement was designed for simple, optimum PCB layout.

INPUT CAPACITOR

To maintain stability, the regulator input pin must be bypassed with at least a 100µF electrolytic capacitor. The capacitor's leads must be kept short, and placed near the regulator.
If the operating temperature range includes temperatures below 25°C, the input capacitor value may need to be larger. With most electrolytic capacitors, the capacitance value decreases and the ESR increases with lower temperatures and age. Paralleling a ceramic or solid tantalum capacitor increases the regulator stability at cold temperatures. For maximum capacitor operating lifetime, the RMS ripple current rating of the capacitor must be greater than:

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

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

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

INDUCTOR SELECTION

All switching regulators have two basic modes of operation: continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulator performance and requirements.
The LM2576 can be used for both continuous and discontinuous modes of operation.
The inductor value selection guides in Figure 21 through Figure 25 are designed for buck regulator designs of the continuous inductor current type. When using inductor values shown in the inductor selection guide, the peak-to-peak inductor ripple current is approximately 20% to 30% of the maximum DC current. With relatively heavy load currents, the circuit is forced to the discontinuous mode (inductor current falls to zero for a period of time). This discontinuous mode of operation is perfectly acceptable. For light loads (less than approximately 300mA), it may be desirable to operate the regulator in the discontinuous mode, primarily because of the lower inductor values required for the discontinuous mode.
The selection guide chooses inductor values suitable for continuous mode operation, but if the inductor value chosen is prohibitively high, the designer should investigate the possibility of discontinuous operation.
Inductors are available in different styles such as pot core, toroid, E-frame, bobbin core, and so on, as well as different core materials, such as ferrites and powdered iron. The bobbin core is the least expensive type, and consists of wire wrapped on a ferrite rod core. This type of construction makes for an inexpensive inductor; however, because the magnetic flux is not completely contained within the core, the bobbin core generates more electromagnetic interference (EMI). This EMI can cause problems in sensitive circuits, or can give incorrect scope

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

INDUCTOR RIPPLE CURRENT

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

OUTPUT CAPACITOR

An output capacitor is required to filter the output voltage and is needed for loop stability. The capacitor must be placed near the LM2576 using short PCB traces. Standard aluminum electrolytics are usually adequate, but low ESR types is recommended for low output ripple voltage and good stability. The ESR of a capacitor depends on many factors, including: the value, the voltage rating, physical size, and the type of construction. In general, low value or low voltage (less than 12V) electrolytic capacitors usually have higher ESR numbers.
The amount of output ripple voltage is primarily a function of the ESR (Equivalent Series Resistance) of the output capacitor and the amplitude of the inductor ripple current (ΔI_{IND}). See *Inductor Ripple Current*.
The lower capacitor values (220µF to 1000µF) allows typically 50mV to 150mV of output ripple voltage, while larger-value capacitors reduces the ripple to approximately 20mV to 50mV.

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

To further reduce the output ripple voltage, several standard electrolytic capacitors may be paralleled, or a higher-grade capacitor may be used. Such capacitors are often called high-frequency, low-inductance, or low-ESR. These reduce the output ripple to 10mV or 20mV. However, when operating in the continuous mode, reducing the ESR below 0.03Ω can cause instability in the regulator.
Tantalum capacitors can have a very low ESR, and must be carefully evaluated if it is the only output capacitor. Because of their good low temperature characteristics, a tantalum can be used in parallel with aluminum electrolytics, with the tantalum making up 10% or 20% of the total capacitance.
The ripple current rating of the capacitor at 52kHz should be at least 50% higher than the peak-to-peak inductor ripple current.

CATCH DIODE

Buck regulators require a diode to provide a return path for the inductor current when the switch is off. This diode must be placed closed to the LM2576 using short leads and short printed-circuit traces.
Because of their fast switching speed and low forward voltage drop, Schottky diodes provide the best efficiency, especially in low output voltage switching regulators (less than 5V). Fast-recovery, high-efficiency, or ultra-fast

recovery diodes are also suitable, but some types with an abrupt turnoff characteristic may cause instability and EMI problems. A fast-recovery diode with soft recovery characteristics is a better choice. Standard 60Hz diodes (for example, 1N4001 or 1N5400, and so on) are also not suitable. See Table 2 for Schottky and soft fast recovery diode selection guide.

OUTPUT VOLTAGE RIPPLE AND TRASIENTS

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

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

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

An additional small LC filter (20µH and 100µF) can be added to the output (as shown in Figure 18) to further reduce the amount of output ripple and transients. A reduction by 10 times in output ripple voltage and transients is possible with this filter.

FEEDBACK CONNECTION

The LM2576 (fixed voltage versions) FEEDBACK pin must be wired to the output voltage point of the switching power supply. When using the adjustable version, physically locate both output voltage programming resistors near the LM2576 to avoid picking up unwanted noise. Avoid using resistors greater than 100kΩ because of the increased change of noise pickup. Adjustable output voltage can be programmed with the following equation:

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

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

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

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

The $\overline{\text{ON}}$/OFF pin provides electrical ON and OFF control for the LM2576.

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

To put the regulator into standby mode, drive this pin with a high-level TTL or CMOS signal. When the voltage of this pin is higher than 1.4V, the device is in shutdown mode. The typical standby current in this mode is 50µA.

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

CURRENT LIMIT

The LM2576 device has current limiting to prevent the switch current from exceeding safe values during an accidental overload on the output. This current limit value can be found in Electrical Characteristics: All Output Voltage Versions under the heading of I_{CL}.

The LM2576 uses cycle-by-cycle peak current limit for overload protection. This helps to prevent damage to the device and external components. The regulator operates in current limit mode whenever the inductor if the load current is greater than 3A or the converter is starting up. Keep in mind that the maximum available load current depends on the input voltage, output voltage, and inductor value. The regulator also incorporates short-circuit protection to prevent inductor current run-away. When the voltage on FB pin (ADJ) falls below about 0.58V the switching frequency is dropped to about 11 kHz. This allows the inductor current to ramp down sufficiently during the switch OFF-time to prevent saturation.

GROUNDING

To maintain output voltage stability, the power ground connections must be low-impedance (see Figure 19 and Figure 20). For the 5 lead TO-263 and TO-220 style package, both the tab and pin 3 are ground and either connection may be used, as they are both part of the same copper lead frame.

HEAT SINK AND THERMAL CONSIDERATIONS

In many cases, only a small heat sink is required to keep the LM2576 junction temperature within the allowed operating range. For each application, to determine whether or not a heat sink will be required, the following must be identified:

1. Maximum ambient temperature (in the application).
2. Maximum regulator power dissipation (in application).
3. Maximum allowed junction temperature (125°C for the LM2576). For a safe, conservative design, a temperature approximately 15°C cooler than the maximum temperatures should be selected.
4. LM2576 package thermal resistances θ_{JA} and θ_{JC}.

Total power dissipated by the LM2576 can be estimated as follows:

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

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

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

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

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

$$T_J = \Delta T_J + T_A$$

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

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

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

The operating junction temperature will be:

$$T_J = T_A + \Delta T_J$$

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

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Fax. 01 47 01 16 22
e-mail : comp@es-france.com
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ADDITIONAL APPLICATION

INVERTING REGULATOR

Figure 13 shows a LM2576-12 in a buck-boost configuration to generate a negative 12V output from a positive input voltage. This circuit bootstraps the GND pin of the regulator to the negative output voltage, then by grounding the FEEDBACK pin, the regulator senses the inverted output voltage and regulates it to −12V.

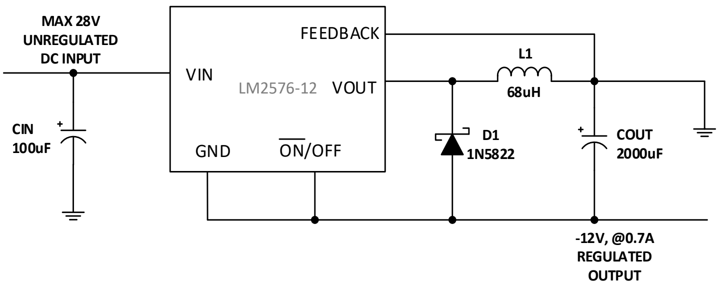

Figure 13. Inverting Buck-Boost Develops −12V

For an input voltage of 12V or more, the maximum input voltage required drops to approximately 4.7V.
The switch currents in this buck-boost configuration are higher than in standard buck-mode design, thus lowering the available output current. Also, the start-up input current of the buck-boost converter is higher than the standard buck-mode regulator, and this may overload an input power source with a current limit less than 5A. Using a delayed turn-on or an undervoltage lockout circuit (described in *Negative Boost Regulator*) would allow the input voltage to rise to a high enough level before the regulator would be allowed to turn on.
Because of the structural differences between the buck and the buck-boost regulator topologies, the buck regulator design procedure section cannot be used to select the inductor or the output capacitor. The recommended range of inductor values for the buck-boost design is between 68µH and 220µH, and the output capacitor values must be larger than what is normally required for buck designs. Low input voltage or high output currents require a larger value output capacitor (in the thousands of micro Farads).
The peak inductor current, which is the same as the peak switch current, can be calculated in the following equation:

$$I_p \approx \frac{I_{LOAD}(V_{IN} + |V_O|)}{V_{IN}} + \frac{V_{IN}|V_O|}{V_{IN} + |V_O|} \times \frac{1}{2L_1 f_{OSC}}$$

where f_{OSC} = 52kHz

Under normal continuous inductor current operating conditions, the minimum V_{IN} represents the worst case. Select an inductor that is rated for the peak current anticipated.
Also, the maximum voltage appearing across the regulator is the absolute sum of the input and output voltage. For a −12V output, the maximum input voltage is +28V.

NEGATIVE BOOST REGULATOR

Another variation on the buck-boost topology is the negative boost configuration. The circuit in Figure 14 accepts an input voltage ranging from −5V to −12V and provides a regulated −12V output. Input voltages greater than −12V causes the output to rise above −12V, but does not damage the regulator.

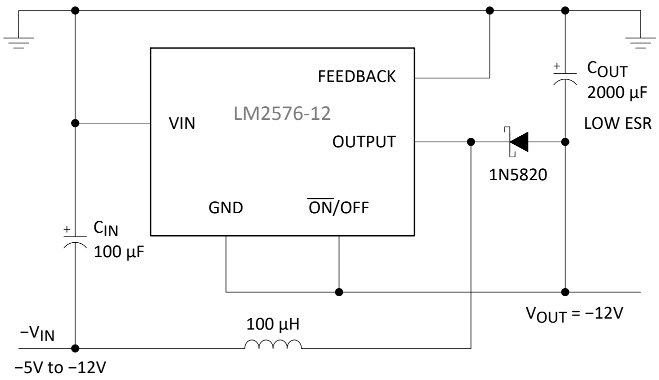

Figure 14. Negative Boost

Because of the boosting function of this type of regulator, the switch current is relatively high, especially at low input voltages. Output load current limitations are a result of the maximum current rating of the switch. Also, boost regulators cannot provide current-limiting load protection in the event of a shorted load, so some other means (such as a fuse) may be necessary.

UNDERVOLTAGE LOCKOUT

In some applications it is desirable to keep the regulator off until the input voltage reaches a certain threshold. An undervoltage lockout circuit which accomplishes this task is shown in Figure 15, while Figure 16 shows the same circuit applied to a buck-boost configuration. These circuits keep the regulator off until the input voltage reaches a predetermined level.

$$V_{TH} \approx V_{Z1} + 2V_{BE}(Q1)$$

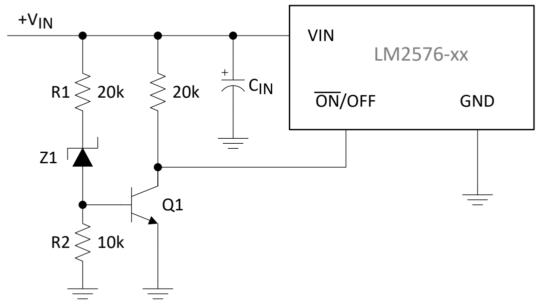

Figure 15. Undervoltage Lockout for Buck Circuit

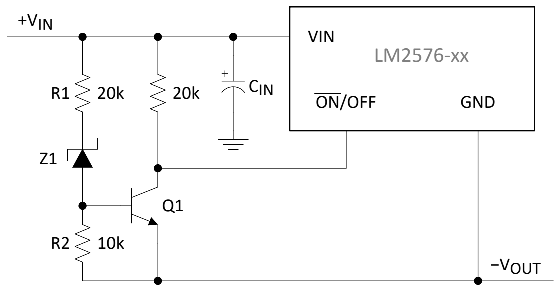

Figure 16. Undervoltage Lockout for Buck-Boost Circuit

DELAYED START-UP

The circuit in Figure 17 uses the $\overline{ON}$/OFF pin to provide a time delay between the time the input voltage is applied and the time the output voltage comes up (only the circuitry pertaining to the delayed start-up is shown). As the input voltage rises, the charging of capacitor C1 pulls the $\overline{ON}$/OFF pin high, keeping the regulator OFF. Once the input voltage reaches its final value and the capacitor stops charging, resistor R2 pulls the $\overline{ON}$/OFF pin low, thus allowing the circuit to start switching. Resistor R1 is included to limit the maximum voltage applied to the $\overline{ON}$/OFF pin, reduces power supply noise sensitivity, and also limits the capacitor C1 discharge current. When high input ripple voltage that is 60Hz (or 50Hz) or 120Hz (or 100Hz) exists, avoid long delay time, because this ripple can be coupled into the $\overline{ON}$/OFF pin and cause problems.

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

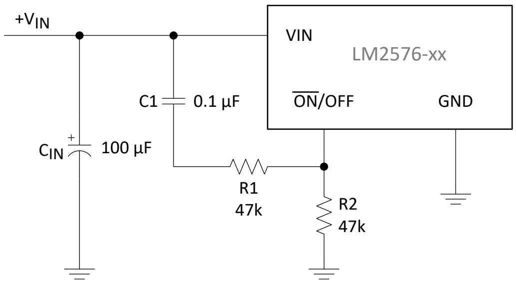

Figure 17. Delayed Start-Up

ADJUSTABLE OUTPUT, LOW-RIPPLE POWER SUPPLY

A 3.0A power supply that features an adjustable output voltage is shown in Figure 18. An additional LC filter that reduces the output ripple by a factor of 10 or more is included in this circuit.

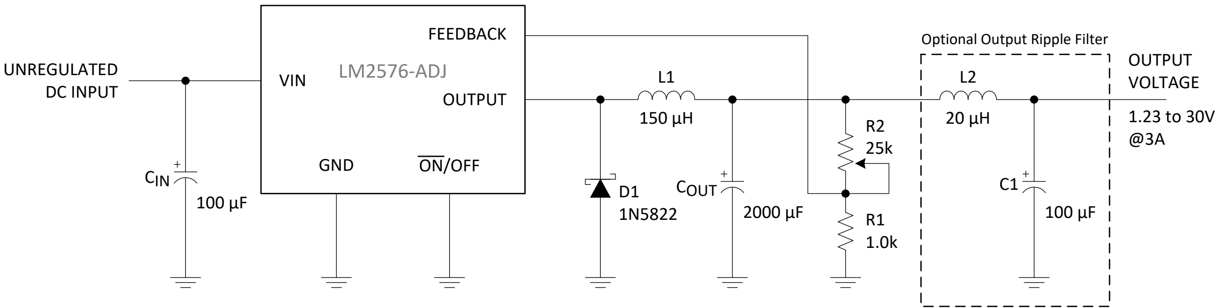

Figure 18. 1.23V to 30V Adjustable 3.0A Power Supply with Low Output Ripple

APPLICATION CIRCUIT DESIGN PROCEDURE

TYPICAL CIRCUITS

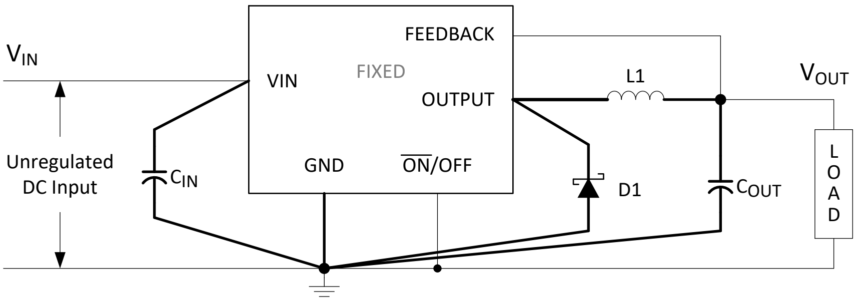

Figure 19. Fixed Output Voltage Version

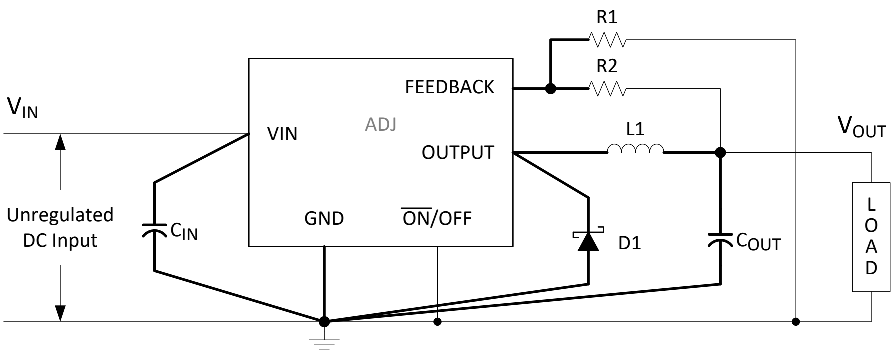

Figure 20. Adjustable Output Voltage Version

As indicated in the Figure 19 and Figure 20, to minimize inductance and ground loops, the length of the leads indicated by heavy lines should be kept as short as possible. For best results, single-point grounding (as indicated) or ground plane construction should be used. For the details, refer to the *PCB Layout Guidelines*.

FIXED OUTPUT VOLTAGE VERSION

Design Requirements

Table 1 lists the design parameters of this example.

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Regulated Output Voltage (3.3V, 5.0V, 12V, or 15V), V_{OUT}	5.0V
Maximum Input Voltage, $V_{IN.MAX}$	15V
Maximum Load Current, $I_{LOAD.MAX}$	3.0A

Design Procedure and Example

1. Inductor Selection (L1)
   1) Select the correct inductor value selection guide from Figure 21, Figure 22, Figure 23, or Figure 24. (Output voltages of 3.3V, 5.0V, 12V or 15V respectively). For other output voltages, see the design procedure for the adjustable version.
      - Use the selection guide shown in Figure 22.
   2) From the inductor value selection guide, identify the inductance region intersected by V_{IN}(max) and I_{LOAD}(max), and note the inductor code for that region.
      - From the selection guide, the inductance area intersected by the 15V line and 3.0A line is L100.
   3) Identify the inductor value from the inductor code, and select an appropriate inductor from the Table 3. The inductor chosen must be rated for operation at the LM2576 switching frequency (52kHz) and for a current rating of 1.15 × I_{LOAD}. For additional inductor information, see *Inductor Selection*.
      - Inductor value required is 100µH from the Table 3.
2. Output Capacitor Selection (C_{OUT})
   1) The value of the output capacitor together with the inductor defines the dominate pole-pair of the switching regulator loop. For stable operation and an acceptable output ripple voltage, (approximately 1% of the output voltage) a value between 100µF and 470µF is recommended.
      - Choose COUT = 680µF to 2000µF standard aluminum electrolytic.
   2) The voltage rating of the capacitor must be at least 1.5 times greater than the output voltage. For a 5.0V regulator, a rating of at least 8.0V is appropriate, and a 10V or 15V rating is recommended. Higher voltage electrolytic capacitors generally have lower ESR numbers, and for this reason it may be necessary to select a capacitor rated for a higher voltage than would normally be needed.
      - Capacitor voltage rating = 20V.
3. Catch Diode Selection (D1)
   1) The catch diode current rating must be at least 1.2 times greater than the maximum load current. Also, if the power supply design must withstand a continuous output short, the diode should have a current rating equal to the maximum current limit of the LM2576. The most stressful condition for this diode is an overload or shorted output condition.
      - For this example, a 3.0A current rating is adequate.
   2) The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage.
      - Use a 20V 1N5823 or SR302 Schottky diode, or any of the suggested fast-recovery diodes shown in Table 2.
4. Input Capacitor (C_{IN})
   1) An aluminum or tantalum electrolytic bypass capacitor located close to the regulator is needed for stable operation.
      - A 100µF, 25V aluminum electrolytic capacitor located near the input and ground pins provides sufficient bypassing.

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Inductor Value Selection Guides (For Continuous Mode Operation)

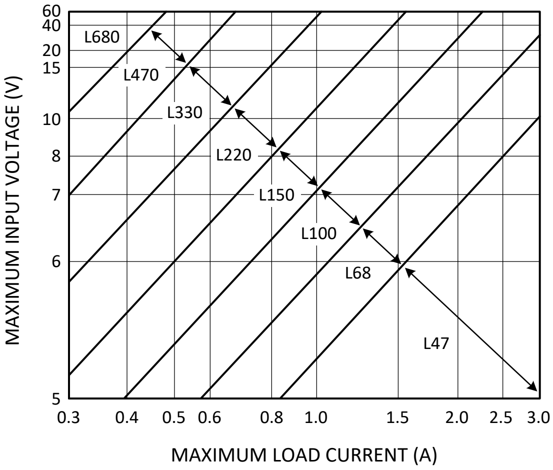

Figure 21. LM2576-3.3

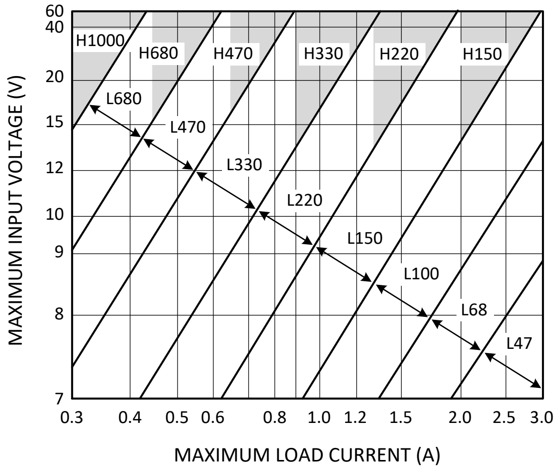

Figure 22. LM2576-5.0

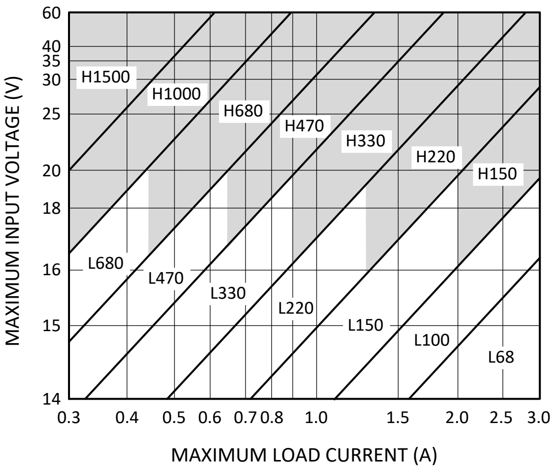

Figure 23. LM2576-12

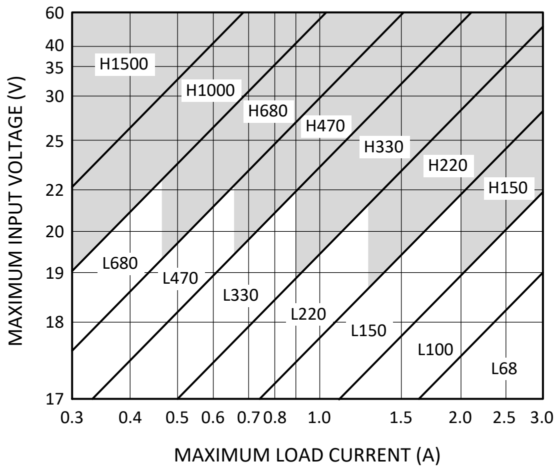

Figure 24. LM2576-15

Table 2. Diode Selection Guide

<table>
<tr><th rowspan="3">V_R</th><th colspan="4">Schottky</th><th colspan="4">Fast Recovery</th></tr>
<tr><th colspan="2">3.0A</th><th colspan="2">4.0A to 6.0A</th><th colspan="2">3.0A</th><th colspan="2">4.0A to 6.0A</th></tr>
<tr><th>Through Hole</th><th>Surface Mount</th><th>Through Hole</th><th>Surface Mount</th><th>Through Hole</th><th>Surface Mount</th><th>Through Hole</th><th>Surface Mount</th></tr>
<tr><td>20V</td><td>1N5820
MBR320P
SR302</td><td>SK32</td><td>1N5823
SR502
SB520</td><td></td><td rowspan="5">MUR320
31DF1
HER302

(all diodes rated to at least 100V)</td><td rowspan="5">MURS320T3
MURD320
30WF10

(all diodes rated to at least 100V)</td><td rowspan="5">MUR420
HER602

(all diodes rated to at least 100V)</td><td rowspan="5">MURD620CT
50WF10

(all diodes rated to at least 100V)</td></tr>
<tr><td>30V</td><td>1N5821
MBR330
SR303
31DQ03</td><td>SK33
30WQ03</td><td>1N5824
SR503
SB530</td><td>50WQ03</td></tr>
<tr><td>40V</td><td>1N5822
MBR340
SR304
31DQ04</td><td>SK34
30WQ04
MBRS340T3
MBRD340</td><td>1N5825
SR504
SB540</td><td>MBRD640CT
50WQ04</td></tr>
<tr><td>50V</td><td>MBR350
31DQ05
SR305</td><td>SK35
30WQ05</td><td>SB550</td><td>50WQ05</td></tr>
<tr><td>60V</td><td>MBR360
DQ06
SR306</td><td>MBRS360T3
MBRD360</td><td>50SQ080</td><td>MBRD660CT</td></tr>
</table>

Table 3. Inductor Selection by Manufacturer's Part Number

Inductor Code	Inductor Value	Pulse	Renco
L47	47 µH	PE-53112	RL2442
L68	68 µH	PE-92114	RL2443
L100	100 µH	PE-92108	RL2444
L150	150 µH	PE-53113	RL1954
L220	220 µH	PE-52626	RL1953
L330	330 µH	PE-52627	RL1952
L470	470 µH	PE-53114	RL1951
L680	680 µH	PE-52629	RL1950
H150	150 µH	PE-53115	RL2445
H220	220 µH	PE-53116	RL2446
H330	330 µH	PE-53117	RL2447
H470	470 µH	PE-53118	RL1961
H680	680 µH	PE-53119	RL1960
H1000	1000 µH	PE-53120	RL1959
H1500	1500 µH	PE-53121	RL1958
H2200	2200 µH	PE-53122	RL2448

ADJUSTABLE OUTPUT VOLTAGE VERSION

Design Requirements

Table 4 lists the design parameters of this example.

Table 4. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Regulated Output Voltage, V_{OUT}	10V
Maximum Input Voltage, $V_{IN.MAX}$	25V
Maximum Load Current, $I_{LOAD.MAX}$	3.0A
Switching Frequency, f (Fixed at 52kHz)	52kHz

Design Procedure and Example

1. Programming Output Voltage (Selecting R1 and R2, as shown in Figure 20)

1) Use the following equation to select the appropriate resistor values.

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) \qquad \text{where } V_{REF} = 1.23V$$

R1 can be between 1k and 5k. (For best temperature coefficient and stability with time, use 1% metal film resistors.)

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

- Select R1 and R2.

$$V_{OUT} = 1.23\left(1 + \frac{R2}{R1}\right) \qquad \text{Select R1} = 1k$$

$$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right) = 1k\left(\frac{10V}{1.23V} - 1\right)$$

R2 = 1K (8.13 − 1) = 7.13k, closest 1% value is 7.15k

2. Inductor Selection (L1)

1) Calculate the inductor Volt microsecond constant, E • T (V • µs), from the following equation:

$$E \bullet T = (V_{IN} - V_{OUT})\frac{V_{OUT}}{V_{IN}} \times \frac{1000}{f \text{ in kHz}} \quad [V \bullet \mu s]$$

- Calculate E × T (V × µs) constant:

$$E \times T = (25 - 10)\frac{10}{25} \times \frac{1000}{52} = (115V \times \mu s)$$

2) Use the E × T value from the previous equation and match it with the E × T number on the vertical axis of the Inductor value selection guide shown in Figure 25.
- E × T = 115V × µs

3) On the horizontal axis, select the maximum load current.
- $I_{LOAD.max}$ = 3.0A

4) Identify the inductance region intersected by the E × T value and the maximum load current value, and note the inductor code for that region.
   - Inductance Region = H150
5) Identify the inductor value from the inductor code, and select an appropriate inductor from the table shown in Table 3. The inductor chosen must be rated for operation at the LM2576 switching frequency (52kHz) and for a current rating of 1.15 × I_{LOAD}. For additional inductor information, see *Inductor Selection*.
   - Proper Inductor Value = 150µH, Choose the inductor from the Table 3.

3. Output Capacitor Selection (C_{OUT})

1) The value of the output capacitor together with the inductor defines the dominate pole-pair of the switching regulator loop. For stable operation, the capacitor must satisfy the following requirement:

$$C_{OUT} \geq 13{,}300 \times \frac{V_{IN}}{V_{OUT} \times L\,[\mu H]}\ [\mu F]$$

The above equation yields capacitor values between 10µF and 2200µF that satisfies the loop requirements for stable operation. But to achieve an acceptable output ripple voltage (approximately 1% of the output voltage) and transient response, the output capacitor may need to be several times larger than above equation yields.
- The capacitor value is:

$$C_{OUT} > 13{,}300 \times \frac{V_{IN}}{10 \times 150} = 221.7\mu F$$

To achieve acceptable output ripple voltage, select $C_{OUT} \geq$ 680µF electrolytic capacitor

2) The capacitor's voltage rating must be at least 1.5 times greater than output voltage. For a 10V regulator, a rating of at least 15V or more is recommended.
   - Capacitor's voltage rating must be at least 1.5 times greater than the output voltage. For a 10V regulator, a rating of at least 15V or more is recommended. Higher voltage electrolytic capacitors generally have lower ESR numbers, and for this reason it may be necessary to select a capacitor rate for a higher voltage than would normally be needed.

4. Catch Diode Selection (D1)

1) The diode current rating must be at least 1.2 times greater than the maximum load current. Also, if the power supply design must withstand a continuous output short, the diode must have a current rating equal to the maximum current limit of the LM2576. The most stressful condition for this diode is an overload or shorted output. See diode selection guide in Table 2.
   - For this example, a 3.3A current rating is adequate.
2) The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage.
   - Use a 30V 1N5821 Schottky diode or any suggested fast-recovery diodes in Table 2.

5. Input Capacitor (C_{IN})

1) An aluminum or tantalum electrolytic bypass capacitor located close to the regulator is needed for stable operation.
   - A 100µF aluminum electrolytic capacitor located near the input and ground pins provides sufficient bypassing.

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Inductor Value Selection Guides (For Continuous Mode Operation)

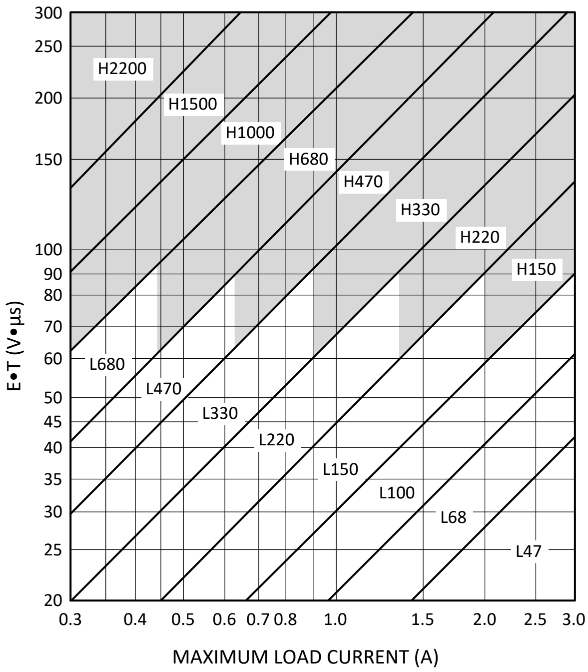

Figure 25. LM2576-ADJ

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PCB LAYOUT

PCB LAYOUT GUIDELINES

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

The most important layout rule is to keep the AC current loops as small as possible. Figure 26 shows the current flow in a buck converter. The top schematic shows a dotted line which represents the current flow during the top-switch ON-state. The middle schematic shows the current flow during the top-switch OFF-state. The bottom schematic shows the currents referred to as AC currents. These AC currents are the most critical because they are changing in a very short time period. The dotted lines of the bottom schematic are the traces to keep as short and wide as possible. This also yields a small loop area reducing the loop inductance.

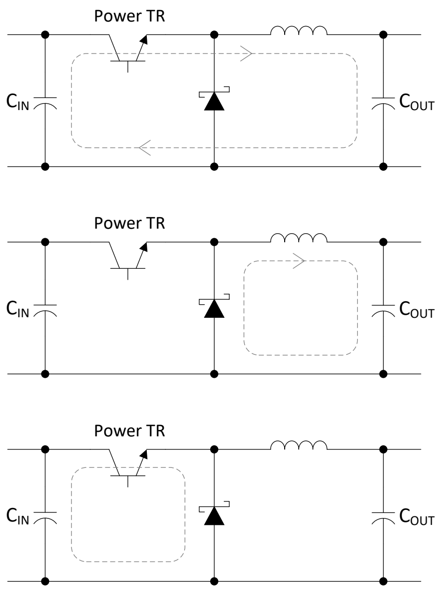


Figure 26. Current Flow in Buck Application

PCB LAYOUT PROCEDURE

General points of PCB layout procedure are as follows:

1. Place the input capacitor and the catch diode on the same PCB surface layer as the IC terminal and as close as possible to IC.
2. Do not omit placing input decoupling/bypass ceramic capacitor (0.1µF to 0.47µF).
3. Place inductor close to IC but no need to be as close as input capacitor. And do not expand copper area on switching node (OUTPUT) more than needed. The PCB area connected to the OUTPUT of the IC should be kept to a minimum in order to minimize radiation noise from the switching node to sensitive circuitry.
4. Place output capacitor close to inductor.

5. Another sensitive part of the circuit is the feedback. It is important to keep the sensitive feedback wiring short. Route feedback trace away from noise causing sources, such as the inductor and the diode. To assure this, physically locate the programming resistors near to the regulator, when using the adjustable version of the regulator.
6. Connect thermal vias to a ground plane if available to improve thermal dissipation.

The ground plane area must be sufficient for thermal dissipation purposes. It is recommended to use at least 2oz copper boards to help thermal dissipation and reduce parasitic inductances of board traces.
Review the PCB layout example as shown in Figure 28.

PCB LAYOUT EXAMPLE

Review the PCB layout example as shown in Figure 28.

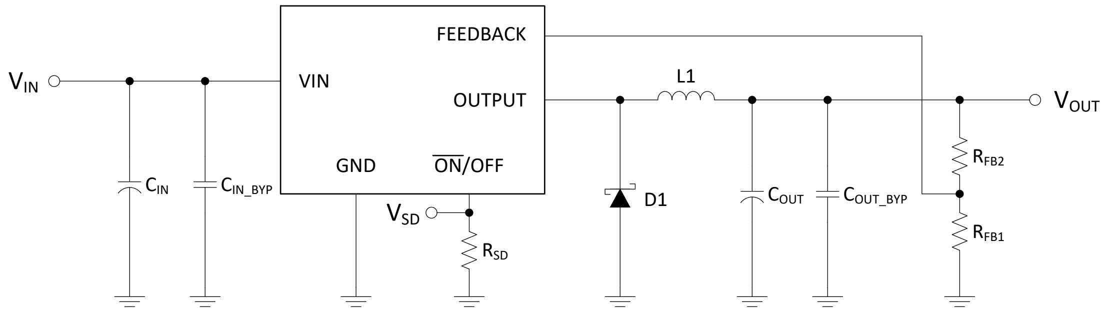


Figure 27. Schematic for PCB Layout Example

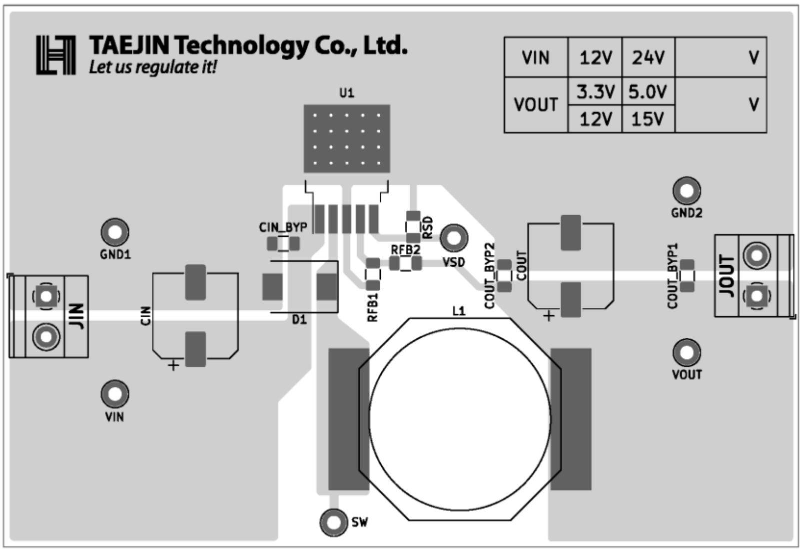


Figure 28. PCB Layout Example

REVISION NOTICE

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

FEATURES

- 3.3V, 5.0V, 12V, 15V, and Adjustable Output Versions
- Adjustable Version Output Voltage Range, 1.23V to 52V ±4% maximum over line and load conditions
- Guaranteed 3.0A Output Current
- Wide Input Voltage Range: Up to 60V
- Requires Only 4 External Components
- 52kHz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- High Efficiency
- Uses Readily Available Standard Inductors
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level 3 for SMD type packages

APPLICATIONS

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

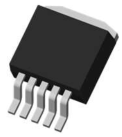
DESCRIPTION

The LM2576HV series of regulators are monolithic integrated circuits ideally suited for easy and convenient design of a step-down switching regulator (buck converter). All circuits of this series are capable of driving a 3.0A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V, and an adjustable output version.

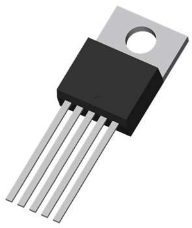
These regulators were designed to minimize the number of external components to simplify the power supply design. Standard series of inductors optimized for use with the LM2576HV are offered by several different inductor manufacturers.

The LM2576HV features include a ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±10% on the oscillator frequency. External shutdown is included, featuring 50μA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

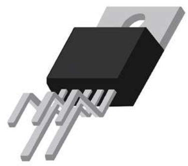
SOP-8PP



TO-263-5



TO-220-5



TO-220TV-5

ORDERING INFORMATION

Device	Package
LM2576HVDP-x.x	SOP-8PP
LM2576HVR-x.x	TO-263-5L
LM2576HVT-x.x	TO-220-5L
LM2576HVTV-x.x	TO-220TV-5L

x.x: Output Voltage

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ABSOLUTE MAXIMUM RATINGS (Note 1)

CHARACTERISTIC	SYMBOL	MIN	MAX	UNIT
Maximum Supply Voltage	V_{IN}	-	63	V
$\overline{ON}$/OFF Pin Input Voltage	-	−0.3	V_{IN}	V
Output Voltage to Ground	-	−0.75	-	V
Power Dissipation	P_D	-	Internally Limited	W
ESD Rating, HBM	-	2000	-	V
Maximum Junction Temperature	T_J	-	150	°C
Storage Temperature	T_{STG}	−65	150	°C

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

RECOMMENDED OPERATING RATINGS (Note 2)

CHARACTERISTIC	SYMBOL	MIN	MAX	UNIT
Supply Voltage	V_{IN}	-	60	V
Operating Junction Temperature	T_J	−40	125	°C

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

THERMAL INFORMATION

THERMAL METRIC	θ_{JA}	θ_{JC}	UNIT
Thermal Resistance, SOP8-PP	Contact us	15	°C/W
Thermal Resistance, TO-263-5L	70	5	°C/W
Thermal Resistance, TO-220-5L	65	5	°C/W
Thermal Resistance, TO-220TV-5L	65	5	°C/W

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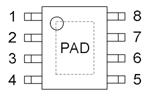
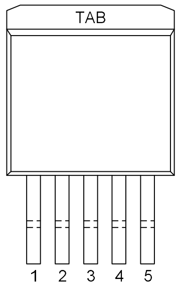
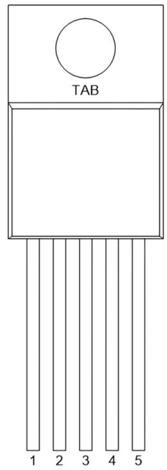
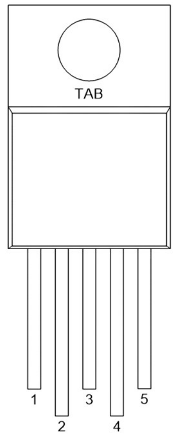
ORDERING INFORMATION

VOUT	Package	Order No.	Description	Supplied As	Status
ADJ	SOP8-PP	LM2576HVDP-ADJ	Adjustable Output	Tape & Reel	Active
	TO-263-5L	LM2576HVR-ADJ	Adjustable Output	Tape & Reel	Active
	TO-220-5L	LM2576HVT-ADJ	Adjustable Output	Tube	Active
	TO-220TV-5L	LM2576HVTV-ADJ	Adjustable Output	Tube	Active
3.3V	SOP8-PP	LM2576HVDP-3.3	3.3V Fixed Output	Tape & Reel	Contact Us
	TO-263-5L	LM2576HVR-3.3	3.3V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576HVT-3.3	3.3V Fixed Output	Tube	Active
5.0V	SOP8-PP	LM2576HVDP-5.0	5.0V Fixed Output	Tape & Reel	Active
	TO-263-5L	LM2576HVR-5.0	5.0V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576HVT-5.0	5.0V Fixed Output	Tube	Active
	TO-220TV-5L	LM2576HVTV-5.0	5.0V Fixed Output	Tube	Contact Us
12V	SOP8-PP	LM2576HVDP-12	12V Fixed Output	Tape & Reel	Active
	TO-263-5L	LM2576HVR-12	12V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576HVT-12	12V Fixed Output	Tube	Active
15V	SOP8-PP	LM2576HVDP-15	15V Fixed Output	Tape & Reel	Contact Us
	TO-263-5L	LM2576HVR-15	15V Fixed Output	Tape & Reel	Active
	TO-220-5L	LM2576HVT-15	15V Fixed Output	Tube	Active

PIN CONFIGURATION

SOP-8PP	TO-263-5	TO-220-5	TO-220TV-5
(Top View) 			

PIN DESCRIPTION

Pin No.			Pin Name	Pin Function
TO-263-5	TO-220-5 TO-220TV-5	SOP-8PP		
1	1	1	VIN	Supply input pin to collector pin of power transistor. Connect to power supply and input bypass capacitors C_{IN}, Path from VIN pin to high frequency bypass C_{IN} and GND must be as short as possible to minimize voltage transients.
2	2	2	OUTPUT	Emitter pin of the power transistor. This is a switching node. Attached this pin to an inductor and the cathode of the external diode. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry.
3	3	5 / 6 / 7 / 8	GND	Ground pin. Path to C_{IN} must be as short as possible.
4	4	3	FEEDBACK	Feedback sense input pin. Connect to the midpoint of feedback divider to set V_{OUT} for ADJ version or connect this pin directly to the output capacitor for a fixed output version.
5	5	4	$\overline{\text{ON}}$/OFF	Enable input to the voltage regulator. It allows the switching regulator circuit to be shutdown using logic level signals. Applying level high shuts the regulator off. If the voltage applied to this pin is level low, the regulator will be in the ON condition. Do not leave this pin float.
TAB	TAB	-	TAB	Connect to GND. Attached to heatsink for thermal relief for TO-220 package or put a copper plane connected to this pin as a thermal relief for TO-263 package.
-	-	PAD	Exposed Pad	Connect to GND. Solder to copper plane for thermal relief.

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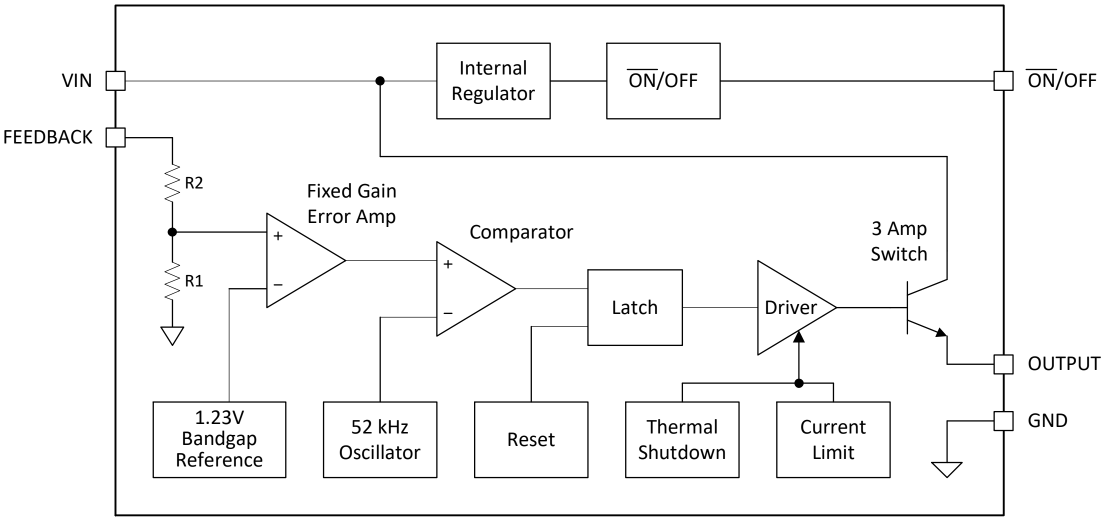
BLOCK DIAGRAM



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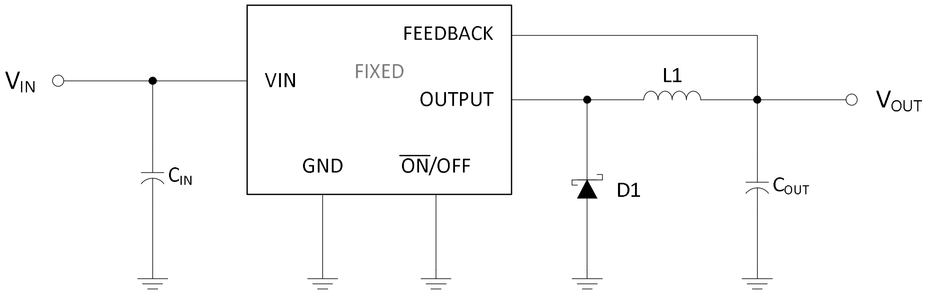
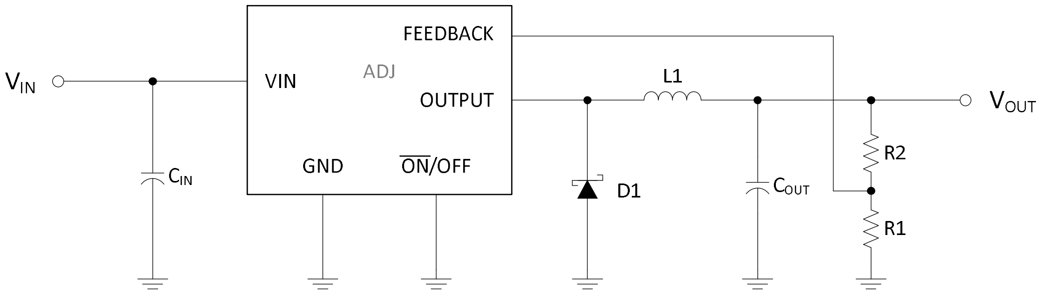
TYPICAL APPLICATION CIRCUIT



< Fixed Output Voltage Version >



< Adjustable Output Voltage Version >

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

ELECTRICAL CHARACTERISTICS

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

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
3.3V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 12V, I_{LOAD} = 0.5A	3.234	3.3	3.366	V
Output Voltage	V_{OUT}	6.0V ≤ V_{IN} ≤ 60V, 0.5A ≤ I_{LOAD} ≤ 3.0A	3.168 **3.135**	3.3 -	3.450 **3.482**	V
Efficiency	η	V_{IN} = 12V, I_{LOAD} = 3.0A	-	75	-	%
5.0V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 12V, I_{LOAD} = 0.5A	4.900	5.0	5.100	V
Output Voltage	V_{OUT}	8.0V ≤ V_{IN} ≤ 60V, 0.5A ≤ I_{LOAD} ≤ 3.0A	4.800 **4.750**	5.0 -	5.225 **5.275**	V
Efficiency	η	V_{IN} = 12V, I_{LOAD} = 3.0A	-	77	-	%
12V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 25V, I_{LOAD} = 0.5A	11.76	12	12.24	V
Output Voltage	V_{OUT}	15V ≤ V_{IN} ≤ 60V, 0.5A ≤ I_{LOAD} ≤ 3.0A	11.52 **11.40**	12 -	12.54 **12.66**	V
Efficiency	η	V_{IN} = 15V, I_{LOAD} = 3.0A	-	88	-	%
15V Output (Note 3)						
Output Voltage	V_{OUT}	V_{IN} = 25V, I_{LOAD} = 0.5A	14.70	15	15.30	V
Output Voltage	V_{OUT}	18V ≤ V_{IN} ≤ 60V, 0.5A ≤ I_{LOAD} ≤ 3.0A	14.40 **14.25**	15 -	15.68 **15.83**	V
Efficiency	η	V_{IN} = 18V, I_{LOAD} = 3.0A	-	88	-	%
Adjustable Output (Note 3)						
Feedback Voltage	V_{FB}	V_{IN} = 12V, I_{LOAD} = 0.5A, V_{OUT} = 5.0V	1.217	1.23	1.243	V
Feedback Voltage	V_{FB}	8.0V ≤ V_{IN} ≤ 60V, 0.5A ≤ I_{LOAD} ≤ 3.0A, V_{OUT} = 5.0V	1.193 **1.180**	1.23 -	1.273 **1.286**	V
Efficiency	η	V_{IN} = 12V, I_{LOAD} = 3.0A, V_{OUT} = 5.0V	-	77	-	%

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

ELECTRICAL CHARACTERISTICS (continued)

Specification with standard type face are for T_J = 25°C, and those with **boldface type** apply over full operating temperature range in Recommended Operating Ratings. Unless otherwise specified, V_{IN} = 12V for the 3.3V, 5.0V, and Adjustable version, V_{IN} = 25V for the 12V version, and V_{IN} = 30V for the 15V version. I_{LOAD} = 500mA. For typical values, T_J = 25°C, unless otherwise noted.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
All Output Voltage Versions						
Feedback Bias Current	I_B	V_{OUT} = 5.0V (Adjustable Version Only)	- -	50 -	100 **500**	nA
Oscillator Frequency (Note 4)	f_O		47 **42**	52 -	58 **63**	kHz
Saturation Voltage	V_{SAT}	I_{OUT} = 3.0A (Note 5)	- -	1.4 -	1.55 **1.7**	V
Max Duty Cycle (Note 6)	DC		93	98	-	%
Current Limit (Note 4,5)	I_{CL}		4.2 **3.5**	5.8 -	6.9 **7.5**	A
Output Leakage Current (Note 7, 8)	I_L	Output = 0V	-	-	2.0	mA
		Output = −0.75V (Note 7,8)	-	7.5	30	
Quiescent Current (Note 7)	I_Q		-	5.0	10	mA
Standby Quiescent Current	I_{STBY}	$\overline{ON}$/OFF pin = 5.0V (OFF)	-	50	200	μA
$\overline{ON}$/OFF Pin Input Level	V_{IH}	V_{OUT} = 0V	2.2 **2.4**	1.4 -	- -	V
	V_{IL}	V_{OUT} = Nominal Output Voltage	- -	1.2 -	1.0 **0.8**	V
$\overline{ON}$/OFF Pin Input Current	I_{IH}	$\overline{ON}$/OFF Pin = 5.0V (OFF)	-	12	30	μA
	I_{IL}	$\overline{ON}$/OFF Pin = 0V (ON)	-	0	10	μA

Note 4. The oscillator frequency reduces to approximately 11 kHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage. This self-protection feature lowers the average power dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.
Note 5. OUTPUT pin sourcing current. No diode, inductor or capacitor connected to OUTPUT.
Note 6. FEEDBACK pin removed from output and connected to 0V.
Note 7. FEEDBACK pin removed from output and connected to +12V for the 3.3V, 5.0V, and Adjustable versions, and 25V for the 12V and 15V versions, to force the output transistor OFF.
Note 8. V_{IN} = 60V.

TYPICAL OPERATING CHARACTERISTICS

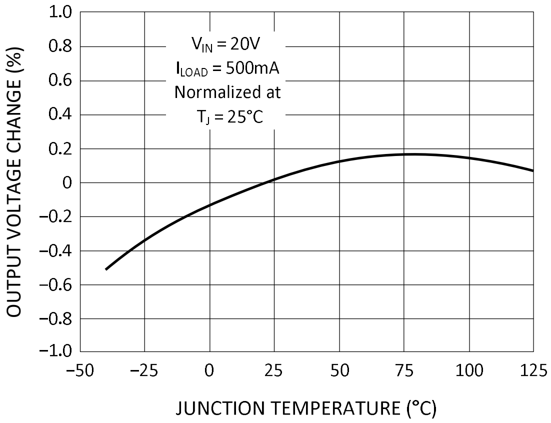


Figure 1. Normalized Output Voltage

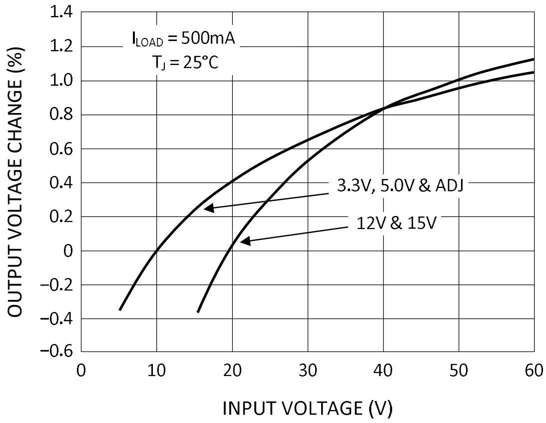


Figure 2. Line Regulation

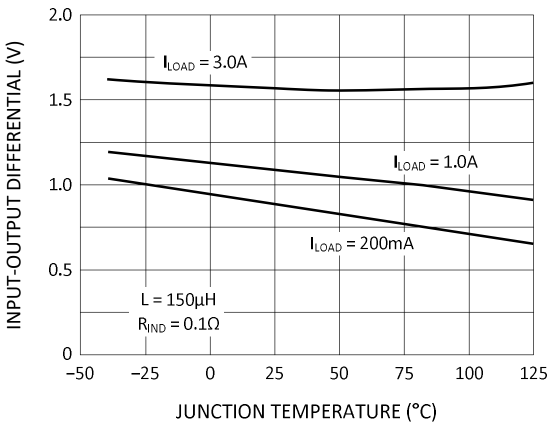


Figure 3. Dropout Voltage

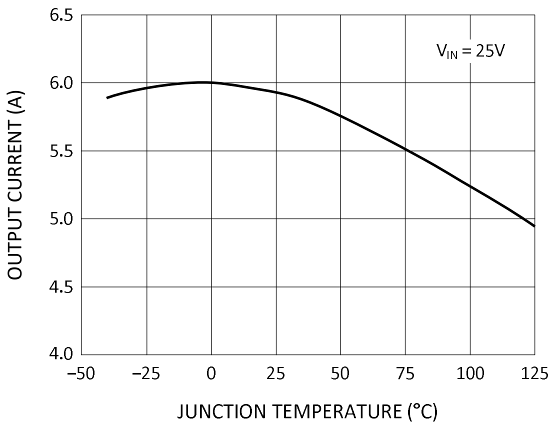


Figure 4. Current Limit

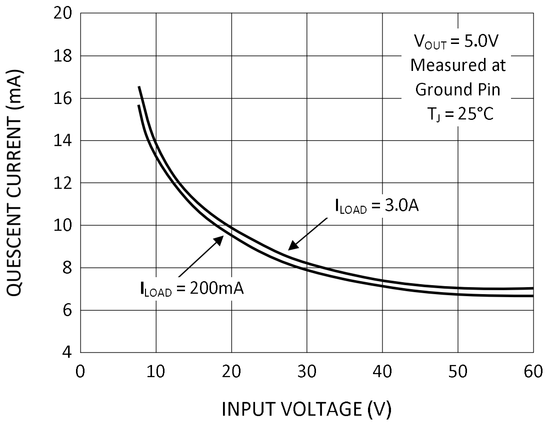


Figure 5. Quiescent Current

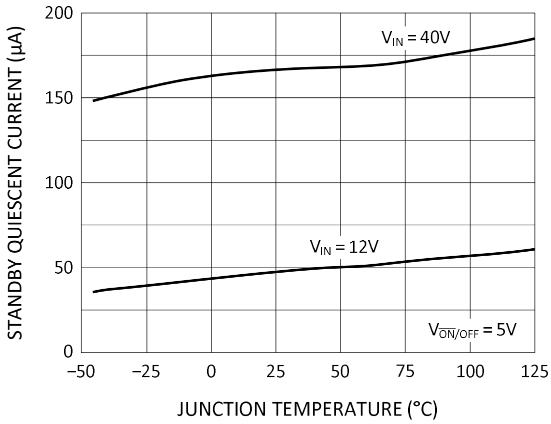


Figure 6. Standby Quiescent Current

TYPICAL OPERATING CHARACTERISTICS (continued)

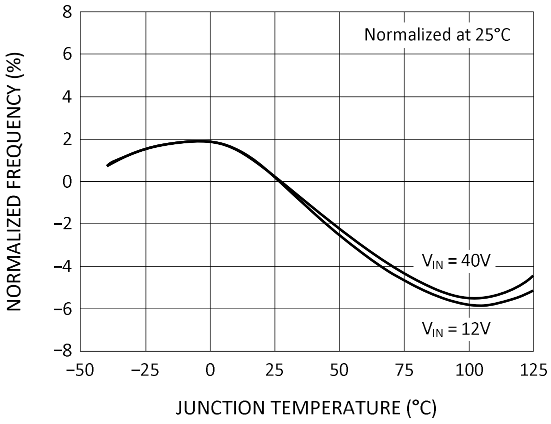


Figure 7. Oscillator Frequency

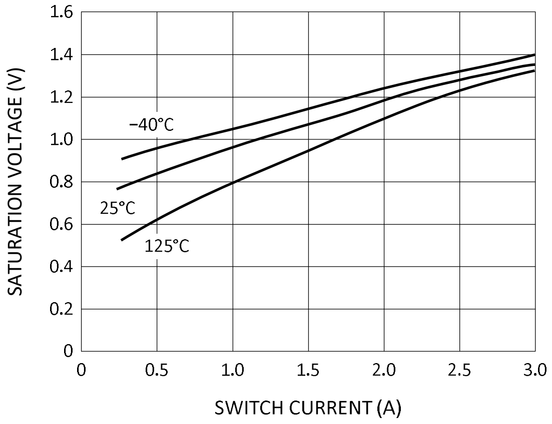


Figure 8. Switch Saturation Voltage

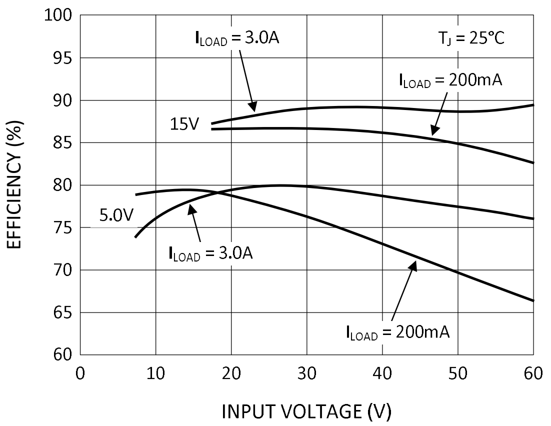


Figure 9. Efficiency

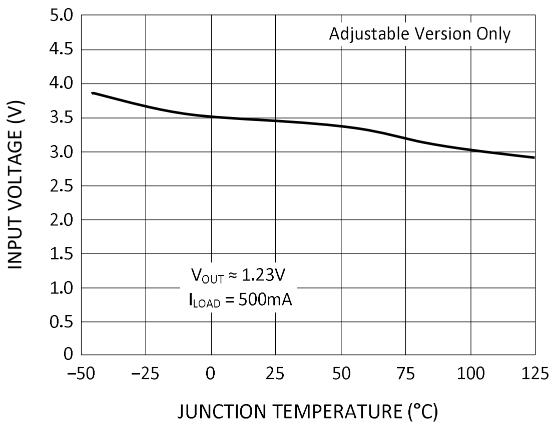


Figure 10. Minimum Operating Voltage

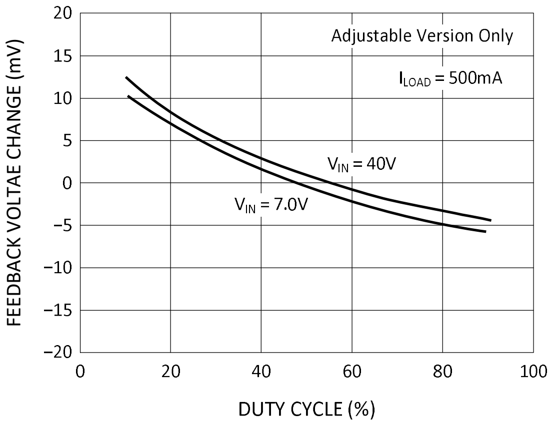


Figure 11. Feedback Voltage vs Duty Cycle

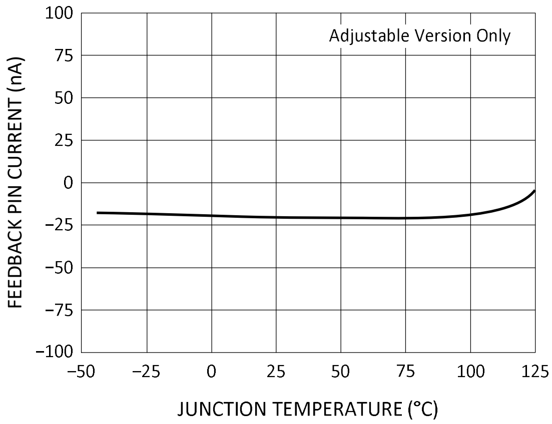


Figure 12. Feedback Pin Current

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APPLICATION INFORMATION

OVERVIEW

The LM2576HV regulator is an easy-to-use, non-synchronous step-down DC-DC converter with a wide input voltage range up to 60V. It is capable of delivering up to 3.0A DC load current with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V and an adjustable output version. The family requires few external components, and the pin arrangement was designed for simple, optimum PCB layout.

INPUT CAPACITOR

To maintain stability, the regulator input pin must be bypassed with at least a 100μF electrolytic capacitor. The capacitor's leads must be kept short, and placed near the regulator.
If the operating temperature range includes temperatures below 25°C, the input capacitor value may need to be larger. With most electrolytic capacitors, the capacitance value decreases and the ESR increases with lower temperatures and age. Paralleling a ceramic or solid tantalum capacitor increases the regulator stability at cold temperatures. For maximum capacitor operating lifetime, the RMS ripple current rating of the capacitor must be greater than:

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

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

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

INDUCTOR SELECTION

All switching regulators have two basic modes of operation: continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulator performance and requirements.
The LM2576HV can be used for both continuous and discontinuous modes of operation.
The inductor value selection guides in Figure 21 through Figure 25 are designed for buck regulator designs of the continuous inductor current type. When using inductor values shown in the inductor selection guide, the peak-to-peak inductor ripple current is approximately 20% to 30% of the maximum DC current. With relatively heavy load currents, the circuit is forced to the discontinuous mode (inductor current falls to zero for a period of time). This discontinuous mode of operation is perfectly acceptable. For light loads (less than approximately 300mA), it may be desirable to operate the regulator in the discontinuous mode, primarily because of the lower inductor values required for the discontinuous mode.
The selection guide chooses inductor values suitable for continuous mode operation, but if the inductor value chosen is prohibitively high, the designer should investigate the possibility of discontinuous operation.
Inductors are available in different styles such as pot core, toroid, E-frame, bobbin core, and so on, as well as different core materials, such as ferrites and powdered iron. The bobbin core is the least expensive type, and consists of wire wrapped on a ferrite rod core. This type of construction makes for an inexpensive inductor; however, because the magnetic flux is not completely contained within the core, the bobbin core generates more electromagnetic interference (EMI). This EMI can cause problems in sensitive circuits, or can give incorrect scope

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

INDUCTOR RIPPLE CURRENT

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

OUTPUT CAPACITOR

An output capacitor is required to filter the output voltage and is needed for loop stability. The capacitor must be placed near the LM2576HV using short PCB traces. Standard aluminum electrolytics are usually adequate, but low ESR types is recommended for low output ripple voltage and good stability. The ESR of a capacitor depends on many factors, including: the value, the voltage rating, physical size, and the type of construction. In general, low value or low voltage (less than 12V) electrolytic capacitors usually have higher ESR numbers.
The amount of output ripple voltage is primarily a function of the ESR (Equivalent Series Resistance) of the output capacitor and the amplitude of the inductor ripple current (ΔI_{IND}). See *Inductor Ripple Current*.
The lower capacitor values (220µF to 1000µF) allows typically 50mV to 150mV of output ripple voltage, while larger-value capacitors reduces the ripple to approximately 20mV to 50mV.

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

To further reduce the output ripple voltage, several standard electrolytic capacitors may be paralleled, or a higher-grade capacitor may be used. Such capacitors are often called high-frequency, low-inductance, or low-ESR. These reduce the output ripple to 10mV or 20mV. However, when operating in the continuous mode, reducing the ESR below 0.03Ω can cause instability in the regulator.
Tantalum capacitors can have a very low ESR, and must be carefully evaluated if it is the only output capacitor. Because of their good low temperature characteristics, a tantalum can be used in parallel with aluminum electrolytics, with the tantalum making up 10% or 20% of the total capacitance.
The ripple current rating of the capacitor at 52kHz should be at least 50% higher than the peak-to-peak inductor ripple current.

CATCH DIODE

Buck regulators require a diode to provide a return path for the inductor current when the switch is off. This diode must be placed closed to the LM2576HV using short leads and short printed-circuit traces.
Because of their fast switching speed and low forward voltage drop, Schottky diodes provide the best efficiency, especially in low output voltage switching regulators (less than 5V). Fast-recovery, high-efficiency, or ultra-fast recovery diodes are also suitable, but some types with an abrupt turnoff characteristic may cause instability and

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EMI problems. A fast-recovery diode with soft recovery characteristics is a better choice. Standard 60Hz diodes (for example, 1N4001 or 1N5400, and so on) are also not suitable. See Table 2 for Schottky and soft fast recovery diode selection guide.

OUTPUT VOLTAGE RIPPLE AND TRASIENTS

The output voltage of a switching power supply contains a sawtooth ripple voltage at the regulator frequency, typically about 1% of the output voltages, and may also contain short voltage spikes at the peaks of the sawtooth waveform.
The output ripple voltage is due mainly to the inductor sawtooth ripple current multiplied by ESR of the output capacitor (See *Inductor Selection*).
The voltage spikes are present because of the fast switching action of the output switch, and the parasitic inductance of the output filter capacitor. To minimize these voltage spikes, special low inductance capacitors can be used, and their lead lengths must be kept short. Wiring inductance, stray capacitance, as well as the scope probe used to evaluate these transients, all contribute to the amplitude of these spikes.
An additional small LC filter (20µH and 100µF) can be added to the output (as shown in Figure 18) to further reduce the amount of output ripple and transients. A reduction by 10 times in output ripple voltage and transients is possible with this filter.

FEEDBACK CONNECTION

The LM2576HV (fixed voltage versions) FEEDBACK pin must be wired to the output voltage point of the switching power supply. When using the adjustable version, physically locate both output voltage programming resistors near the LM2576HV to avoid picking up unwanted noise. Avoid using resistors greater than 100kΩ because of the increased change of noise pickup. Adjustable output voltage can be programmed with the following equation:

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

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

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

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

The $\overline{\text{ON}}$/OFF pin provides electrical ON and OFF control for the LM2576HV.
For normal operation, the $\overline{\text{ON}}$/OFF pin must be grounded or driven with a low-level TTL voltage. When the voltage of the $\overline{\text{ON}}$/OFF pin is below 1.2V, the device starts switching, and the output voltage rises until it reaches the normal regulation voltage.
To put the regulator into standby mode, drive this pin with a high-level TTL or CMOS signal. When the voltage of this pin is higher than 1.4V, the device is in shutdown mode. The typical standby current in this mode is 50µA.
The $\overline{\text{ON}}$/OFF pin can be safely pulled up to $+V_{IN}$ without a resistor in series with it. The $\overline{\text{ON}}$/OFF pin must not be left open.

CURRENT LIMIT

The LM2576HV device has current limiting to prevent the switch current from exceeding safe values during an accidental overload on the output. This current limit value can be found in *Electrical Characteristics: All Output Voltage Versions* under the heading of I_{CL}.
The LM2576HV uses cycle-by-cycle peak current limit for overload protection. This helps to prevent damage to

the device and external components. The regulator operates in current limit mode whenever the inductor if the load current is greater than 3A or the converter is starting up. Keep in mind that the maximum available load current depends on the input voltage, output voltage, and inductor value. The regulator also incorporates short-circuit protection to prevent inductor current run-away. When the voltage on FB pin (ADJ) falls below about 0.58V the switching frequency is dropped to about 11 kHz. This allows the inductor current to ramp down sufficiently during the switch OFF-time to prevent saturation.

GROUNDING

To maintain output voltage stability, the power ground connections must be low-impedance (see Figure 19 and Figure 20). For the 5 lead TO-263 and TO-220 style package, both the tab and pin 3 are ground and either connection may be used, as they are both part of the same copper lead frame.

HEAT SINK AND THERMAL CONSIDERATIONS

In many cases, only a small heat sink is required to keep the LM2576HV junction temperature within the allowed operating range. For each application, to determine whether or not a heat sink will be required, the following must be identified:

1. Maximum ambient temperature (in the application).
2. Maximum regulator power dissipation (in application).
3. Maximum allowed junction temperature (125°C for the LM2576HV). For a safe, conservative design, a temperature approximately 15°C cooler than the maximum temperatures should be selected.
4. LM2576HV package thermal resistances θ_{JA} and θ_{JC}.

Total power dissipated by the LM2576HV can be estimated as follows:

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

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

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

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

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

$$T_J = \Delta T_J + T_A$$

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

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

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

The operating junction temperature will be:

$$T_J = T_A + \Delta T_J$$

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

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ADDITIONAL APPLICATION

INVERTING REGULATOR

Figure 13 shows a LM2576HV-12 in a buck-boost configuration to generate a negative 12V output from a positive input voltage. This circuit bootstraps the GND pin of the regulator to the negative output voltage, then by grounding the FEEDBACK pin, the regulator senses the inverted output voltage and regulates it to −12V.

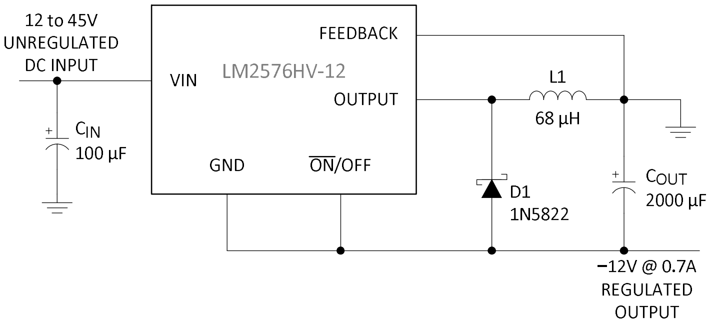

Figure 13. Inverting Buck-Boost Develops −12V

For an input voltage of 12V or more, the maximum input voltage required drops to approximately 4.7V.
The switch currents in this buck-boost configuration are higher than in standard buck-mode design, thus lowering the available output current. Also, the start-up input current of the buck-boost converter is higher than the standard buck-mode regulator, and this may overload an input power source with a current limit less than 5A. Using a delayed turn-on or an undervoltage lockout circuit (described in *Negative Boost Regulator*) would allow the input voltage to rise to a high enough level before the regulator would be allowed to turn on.
Because of the structural differences between the buck and the buck-boost regulator topologies, the buck regulator design procedure section cannot be used to select the inductor or the output capacitor. The recommended range of inductor values for the buck-boost design is between 68µH and 220µH, and the output capacitor values must be larger than what is normally required for buck designs. Low input voltage or high output currents require a larger value output capacitor (in the thousands of micro Farads).
The peak inductor current, which is the same as the peak switch current, can be calculated in the following equation:

$$I_p \approx \frac{I_{LOAD}(V_{IN} + |V_O|)}{V_{IN}} + \frac{V_{IN}|V_O|}{V_{IN} + |V_O|} \times \frac{1}{2L_1 f_{OSC}}$$

where f_{OSC} = 52kHz

Under normal continuous inductor current operating conditions, the minimum V_{IN} represents the worst case. Select an inductor that is rated for the peak current anticipated.
Also, the maximum voltage appearing across the regulator is the absolute sum of the input and output voltage. For a −12V output, the maximum input voltage is +28V.

NEGATIVE BOOST REGULATOR

Another variation on the buck-boost topology is the negative boost configuration. The circuit in Figure 14 accepts an input voltage ranging from −5V to −12V and provides a regulated −12V output. Input voltages greater than −12V causes the output to rise above −12V, but does not damage the regulator.

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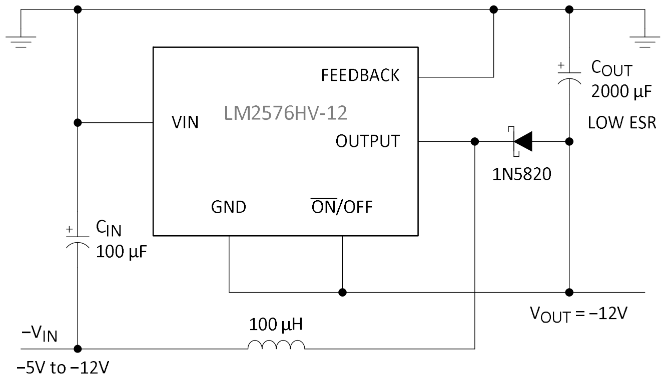

Figure 14. Negative Boost

Because of the boosting function of this type of regulator, the switch current is relatively high, especially at low input voltages. Output load current limitations are a result of the maximum current rating of the switch. Also, boost regulators cannot provide current-limiting load protection in the event of a shorted load, so some other means (such as a fuse) may be necessary.

UNDERVOLTAGE LOCKOUT

In some applications it is desirable to keep the regulator off until the input voltage reaches a certain threshold. An undervoltage lockout circuit which accomplishes this task is shown in Figure 15, while Figure 16 shows the same circuit applied to a buck-boost configuration. These circuits keep the regulator off until the input voltage reaches a predetermined level.

$V_{TH} \approx V_{Z1} + 2V_{BE}(Q1)$

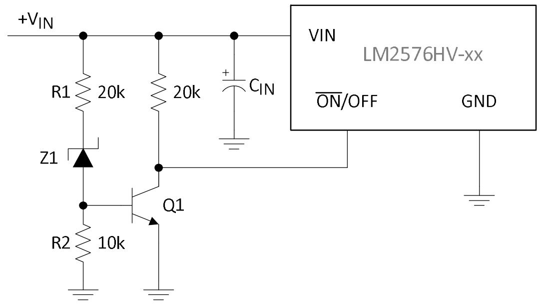

Figure 15. Undervoltage Lockout for Buck Circuit

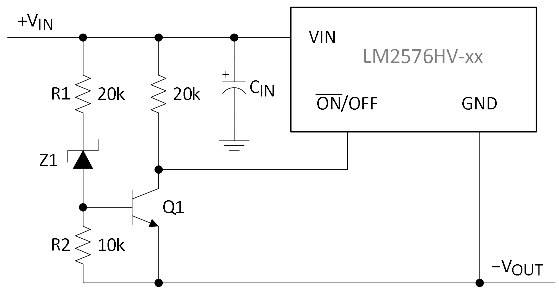

Figure 16. Undervoltage Lockout for Buck-Boost Circuit

DELAYED START-UP

The circuit in Figure 17 uses the $\overline{\text{ON}}$/OFF pin to provide a time delay between the time the input voltage is applied and the time the output voltage comes up (only the circuitry pertaining to the delayed start-up is shown). As the input voltage rises, the charging of capacitor C1 pulls the $\overline{\text{ON}}$/OFF pin high, keeping the regulator OFF. Once the input voltage reaches its final value and the capacitor stops charging, resistor R2 pulls the $\overline{\text{ON}}$/OFF pin low, thus allowing the circuit to start switching. Resistor R1 is included to limit the maximum voltage applied to the $\overline{\text{ON}}$/OFF pin, reduces power supply noise sensitivity, and also limits the capacitor C1 discharge current. When high input ripple voltage that is 60Hz (or 50Hz) or 120Hz (or 100Hz) exists, avoid long delay time, because this ripple can be coupled into the $\overline{\text{ON}}$/OFF pin and cause problems.

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

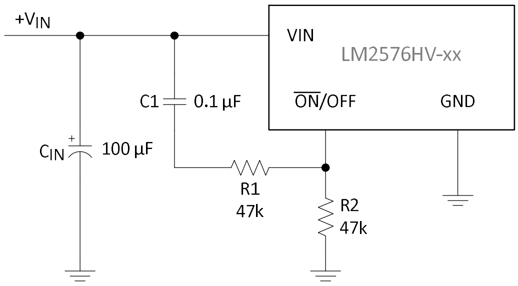

Figure 17. Delayed Start-Up

ADJUSTABLE OUTPUT, LOW-RIPPLE POWER SUPPLY

A 3.0A power supply that features an adjustable output voltage is shown in Figure 18. An additional LC filter that reduces the output ripple by a factor of 10 or more is included in this circuit.

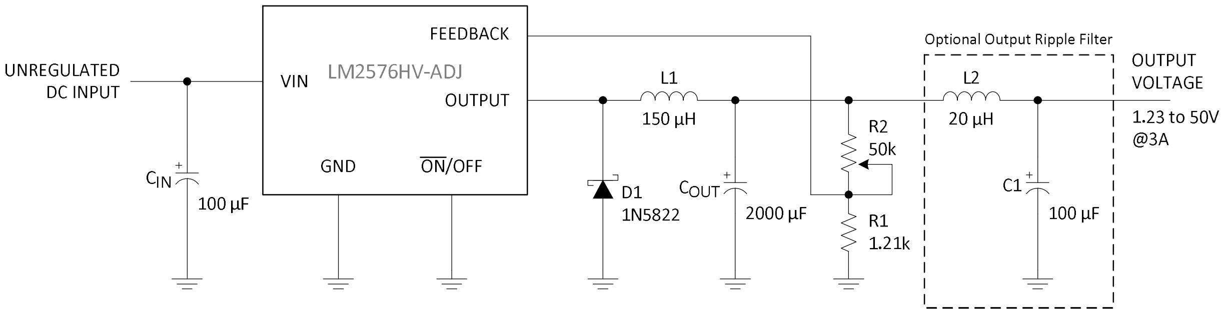

Figure 18. 1.23V to 50V Adjustable 3.0A Power Supply with Low Output Ripple

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APPLICATION CIRCUIT DESIGN PROCEDURE

TYPICAL CIRCUITS

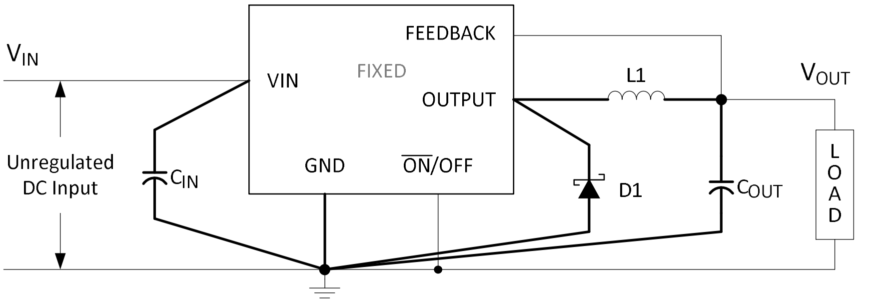

Figure 19. Fixed Output Voltage Version

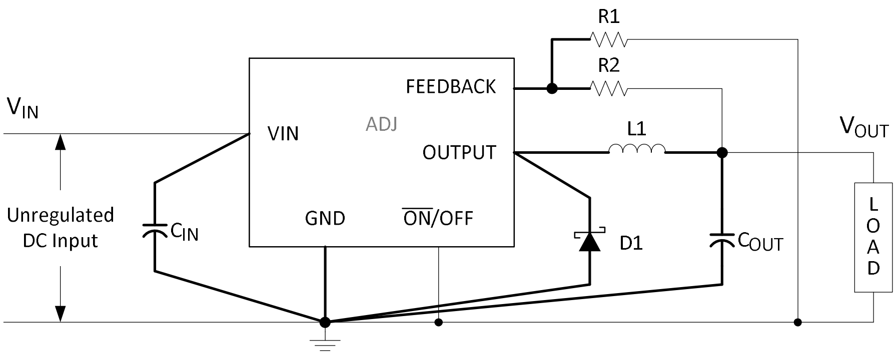

Figure 20. Adjustable Output Voltage Version

As indicated in the Figure 19 and Figure 20, to minimize inductance and ground loops, the length of the leads indicated by heavy lines should be kept as short as possible. For best results, single-point grounding (as indicated) or ground plane construction should be used. For the details, refer to the *PCB Layout Guidelines*.

FIXED OUTPUT VOLTAGE VERSION

Design Requirements

Table 1 lists the design parameters of this example.

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Regulated Output Voltage (3.3V, 5.0V, 12V, or 15V), V_{OUT}	5.0V
Maximum Input Voltage, $V_{IN.MAX}$	15V
Maximum Load Current, $I_{LOAD.MAX}$	3.0A

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Design Procedure and Example

1. Inductor Selection (L1)
   1) Select the correct inductor value selection guide from Figure 21, Figure 22, Figure 23, or Figure 24. (Output voltages of 3.3V, 5.0V, 12V or 15V respectively). For other output voltages, see the design procedure for the adjustable version.
      - Use the selection guide shown in Figure 22.
   2) From the inductor value selection guide, identify the inductance region intersected by V_{IN}(max) and I_{LOAD}(max), and note the inductor code for that region.
      - From the selection guide, the inductance area intersected by the 15V line and 3.0A line is L100.
   3) Identify the inductor value from the inductor code, and select an appropriate inductor from the Table 3. The inductor chosen must be rated for operation at the LM2576HV switching frequency (52kHz) and for a current rating of 1.15 × I_{LOAD}. For additional inductor information, see *Inductor Selection*.
      - Inductor value required is 100μH from the Table 3.
2. Output Capacitor Selection (C_{OUT})
   1) The value of the output capacitor together with the inductor defines the dominate pole-pair of the switching regulator loop. For stable operation and an acceptable output ripple voltage, (approximately 1% of the output voltage) a value between 100μF and 470μF is recommended.
      - Choose COUT = 680μF to 2000μF standard aluminum electrolytic.
   2) The voltage rating of the capacitor must be at least 1.5 times greater than the output voltage. For a 5.0V regulator, a rating of at least 8.0V is appropriate, and a 10V or 15V rating is recommended. Higher voltage electrolytic capacitors generally have lower ESR numbers, and for this reason it may be necessary to select a capacitor rated for a higher voltage than would normally be needed.
      - Capacitor voltage rating = 20V.
3. Catch Diode Selection (D1)
   1) The catch diode current rating must be at least 1.2 times greater than the maximum load current. Also, if the power supply design must withstand a continuous output short, the diode should have a current rating equal to the maximum current limit of the LM2576HV. The most stressful condition for this diode is an overload or shorted output condition.
      - For this example, a 3.0A current rating is adequate.
   2) The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage.
      - Use a 20V 1N5823 or SR302 Schottky diode, or any of the suggested fast-recovery diodes shown in Table 2.
4. Input Capacitor (C_{IN})
   1) An aluminum or tantalum electrolytic bypass capacitor located close to the regulator is needed for stable operation.
      - A 100μF, 25V aluminum electrolytic capacitor located near the input and ground pins provides sufficient bypassing.

Inductor Value Selection Guides (For Continuous Mode Operation)

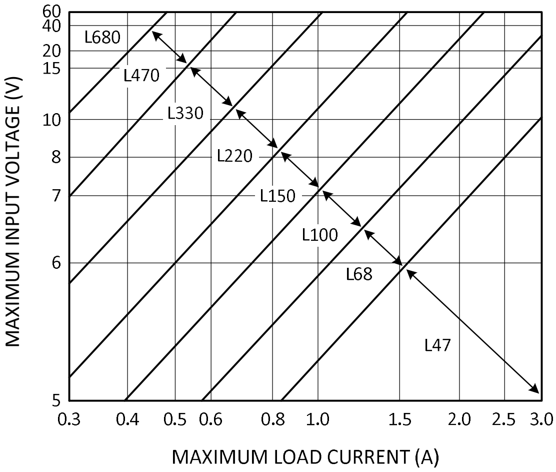

Figure 21. LM2576HV-3.3

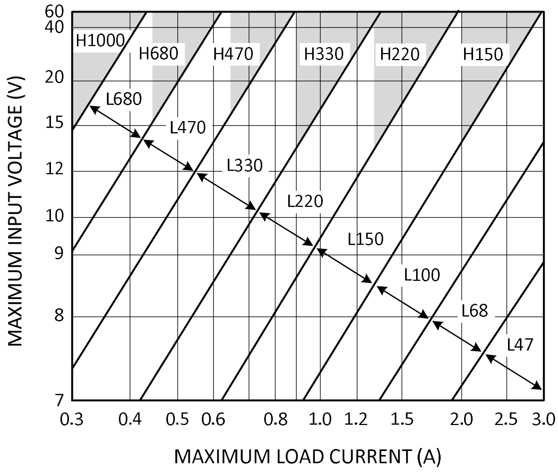

Figure 22. LM2576HV-5.0

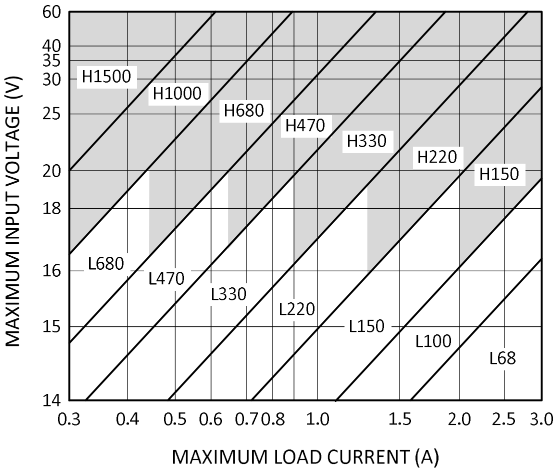

Figure 23. LM2576HV-12

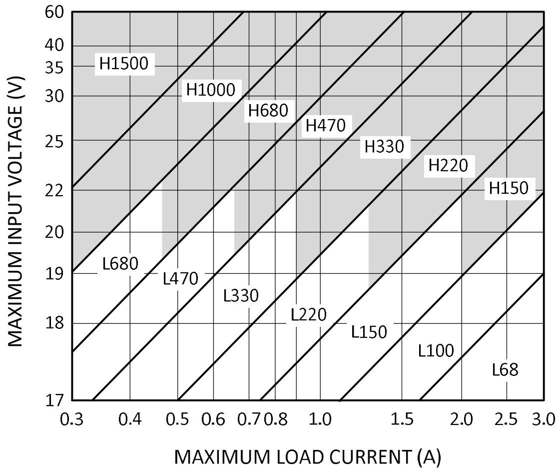

Figure 24. LM2576HV-15

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Table 2. Diode Selection Guide

V_R	Schottky				Fast Recovery			
	3.0A		4.0A to 6.0A		3.0A		4.0A to 6.0A	
	Through Hole	Surface Mount	Through Hole	Surface Mount	Through Hole	Surface Mount	Through Hole	Surface Mount
20V	1N5820 MBR320P SR302	SK32	1N5823 SR502 SB520		MUR320 31DF1 HER302 (all diodes rated to at least 100V)	MURS320T3 MURD320 30WF10 (all diodes rated to at least 100V)	MUR420 HER602 (all diodes rated to at least 100V)	MURD620CT 50WF10 (all diodes rated to at least 100V)
30V	1N5821 MBR330 SR303 31DQ03	SK33 30WQ03	1N5824 SR503 SB530	50WQ03				
40V	1N5822 MBR340 SR304 31DQ04	SK34 30WQ04 MBRS340T3 MBRD340	1N5825 SR504 SB540	MBRD640CT 50WQ04				
50V	MBR350 31DQ05 SR305	SK35 30WQ05	SB550	50WQ05				
60V	MBR360 DQ06 SR306	MBRS360T3 MBRD360	50SQ080	MBRD660CT				

Table 3. Inductor Selection by Manufacturer's Part Number

Inductor Code	Inductor Value	Pulse	Renco
L47	47 µH	PE-53112	RL2442
L68	68 µH	PE-92114	RL2443
L100	100 µH	PE-92108	RL2444
L150	150 µH	PE-53113	RL1954
L220	220 µH	PE-52626	RL1953
L330	330 µH	PE-52627	RL1952
L470	470 µH	PE-53114	RL1951
L680	680 µH	PE-52629	RL1950
H150	150 µH	PE-53115	RL2445
H220	220 µH	PE-53116	RL2446
H330	330 µH	PE-53117	RL2447
H470	470 µH	PE-53118	RL1961
H680	680 µH	PE-53119	RL1960
H1000	1000 µH	PE-53120	RL1959
H1500	1500 µH	PE-53121	RL1958
H2200	2200 µH	PE-53122	RL2448

ADJUSTABLE OUTPUT VOLTAGE VERSION

Design Requirements

Table 4 lists the design parameters of this example.

Table 4. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Regulated Output Voltage, V_{OUT}	10V
Maximum Input Voltage, $V_{IN.MAX}$	25V
Maximum Load Current, $I_{LOAD.MAX}$	3.0A
Switching Frequency, f (Fixed at 52kHz)	52kHz

Design Procedure and Example

1. Programming Output Voltage (Selecting R1 and R2, as shown in Figure 20)

1) Use the following equation to select the appropriate resistor values.

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) \qquad \text{where } V_{REF} = 1.23V$$

R1 can be between 1k and 5k. (For best temperature coefficient and stability with time, use 1% metal film resistors.)

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

- Select R1 and R2.

$$V_{OUT} = 1.23\left(1 + \frac{R2}{R1}\right) \qquad \text{Select R1 = 1k}$$

$$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right) = 1k\left(\frac{10V}{1.23V} - 1\right)$$

R2 = 1K (8.13 − 1) = 7.13k, closest 1% value is 7.15k

2. Inductor Selection (L1)

1) Calculate the inductor Volt microsecond constant, E • T (V • μs), from the following equation:

$$E \bullet T = (V_{IN} - V_{OUT})\frac{V_{OUT}}{V_{IN}} \times \frac{1000}{\text{f in kHz}} \quad [V \bullet \mu s]$$

- Calculate E × T (V × μs) constant:

$$E \times T = (25 - 10)\frac{10}{25} \times \frac{1000}{52} = (115V \times \mu s)$$

2) Use the E × T value from the previous equation and match it with the E × T number on the vertical axis of the Inductor value selection guide shown in Figure 25.
- E × T = 115V × μs

3) On the horizontal axis, select the maximum load current.
- $I_{LOAD.max}$ = 3.0A

4) Identify the inductance region intersected by the E × T value and the maximum load current value, and note the inductor code for that region.

- Inductance Region = H150

5) Identify the inductor value from the inductor code, and select an appropriate inductor from the table shown in Table 3. The inductor chosen must be rated for operation at the LM2576HV switching frequency (52kHz) and for a current rating of 1.15 × I_{LOAD}. For additional inductor information, see *Inductor Selection*.
   - Proper Inductor Value = 150μH, Choose the inductor from the Table 3.

3. Output Capacitor Selection (C_{OUT})

1) The value of the output capacitor together with the inductor defines the dominate pole-pair of the switching regulator loop. For stable operation, the capacitor must satisfy the following requirement:

$$C_{OUT} \geq 13{,}300 \times \frac{V_{IN}}{V_{OUT} \times L\ [\mu H]}\ [\mu F]$$

The above equation yields capacitor values between 10μF and 2200μF that satisfies the loop requirements for stable operation. But to achieve an acceptable output ripple voltage (approximately 1% of the output voltage) and transient response, the output capacitor may need to be several times larger than above equation yields.

- The capacitor value is:

$$C_{OUT} > 13{,}300 \times \frac{V_{IN}}{10 \times 150} = 221.7\mu F$$

To achieve acceptable output ripple voltage, select C_{OUT} ≥ 680μF electrolytic capacitor

2) The capacitor's voltage rating must be at least 1.5 times greater than output voltage. For a 10V regulator, a rating of at least 15V or more is recommended.
   - Capacitor's voltage rating must be at least 1.5 times greater than the output voltage. For a 10V regulator, a rating of at least 15V or more is recommended. Higher voltage electrolytic capacitors generally have lower ESR numbers, and for this reason it may be necessary to select a capacitor rate for a higher voltage than would normally be needed.

4. Catch Diode Selection (D1)

1) The diode current rating must be at least 1.2 times greater than the maximum load current. Also, if the power supply design must withstand a continuous output short, the diode must have a current rating equal to the maximum current limit of the LM2576HV. The most stressful condition for this diode is an overload or shorted output. See diode selection guide in Table 2.
   - For this example, a 3.3A current rating is adequate.

2) The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage.
   - Use a 30V 1N5821 Schottky diode or any suggested fast-recovery diodes in Table 2.

5. Input Capacitor (C_{IN})

1) An aluminum or tantalum electrolytic bypass capacitor located close to the regulator is needed for stable operation.
   - A 100μF aluminum electrolytic capacitor located near the input and ground pins provides sufficient bypassing.

ES France - Département Composants & Modules
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
Site Web : www.es-france.com

Inductor Value Selection Guides (For Continuous Mode Operation)

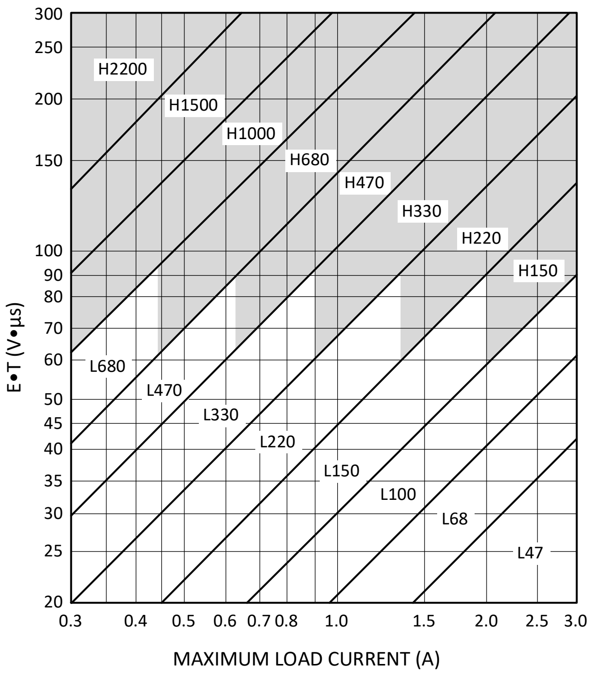

Figure 25. LM2576HV-ADJ

ES France - Département Composants & Modules
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
Site Web : www.es-france.com

PCB LAYOUT

PCB LAYOUT GUIDELINES

As in any switching regulator, the layout of the printed circuit board is very important for the operation of switching power supplies. Switch mode converters are very fast switching devices. Rapidly switching currents associated with wiring inductance, stray capacitance and parasitic inductance of the printed circuit board traces can generate unwanted voltage transients which can generate electromagnetic interferences (EMI) and affect the desired operation. Therefore, appropriate guidelines must be followed to reduce the effects of switching noise.
The most important layout rule is to keep the AC current loops as small as possible. Figure 26 shows the current flow in a buck converter. The top schematic shows a dotted line which represents the current flow during the top-switch ON-state. The middle schematic shows the current flow during the top-switch OFF-state. The bottom schematic shows the currents referred to as AC currents. These AC currents are the most critical because they are changing in a very short time period. The dotted lines of the bottom schematic are the traces to keep as short and wide as possible. This also yields a small loop area reducing the loop inductance.

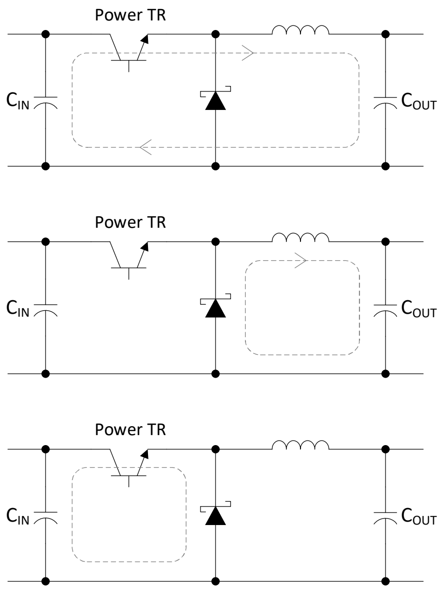

Figure 26. Current Flow in Buck Application

PCB LAYOUT PROCEDURE

General points of PCB layout procedure are as follows:

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

regulator.

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

The ground plane area must be sufficient for thermal dissipation purposes. It is recommended to use at least 2oz copper boards to help thermal dissipation and reduce parasitic inductances of board traces.
Review the PCB layout example as shown in Figure 28.

PCB LAYOUT EXAMPLE

Review the PCB layout example as shown in Figure 28.

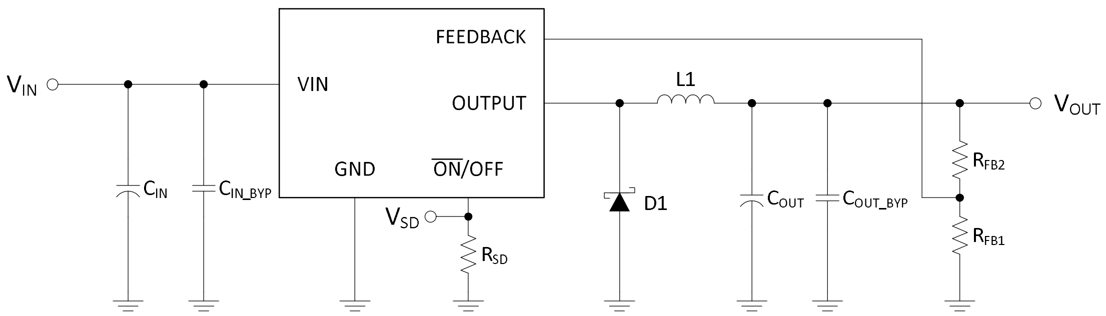

Figure 27. Schematic for PCB Layout Example

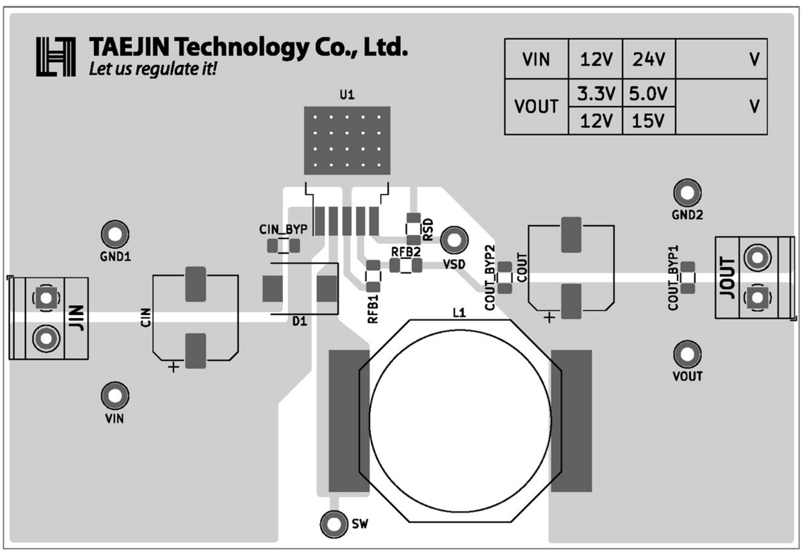

Figure 28. PCB Layout Example

REVISION NOTICE

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

ES France - Département Composants & Modules
127 rue de Buzenval BP 26 - 92380 Garches
Tél. 01 47 95 99 89
Fax. 01 47 01 16 22
e-mail : comp@es-france.com
Site Web : www.es-france.com