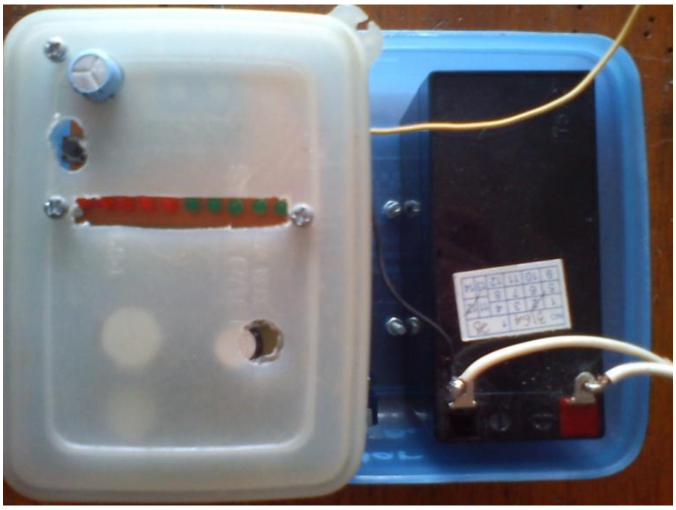
LAMPIRAN A
FOTO ALAT



Tampak Atas

Tampak Depan

Tampak Samping Kanan

Tampak Belakang

Tampak Samping Kiri

LAMPIRAN B

DATASHEET

LM1575/LM2575/LM2575HV
SIMPLE SWITCHER® 1A Step-Down Voltage Regulator

General Description

The LM2575 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 1A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, 15V, and an adjustable output version.

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

The LM2575 series offers a high-efficiency replacement for popular three-terminal linear regulators. It substantially reduces the size of the heat sink, and in many cases no heat sink is required.

A standard series of inductors optimized for use with the LM2575 are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies.

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

Features

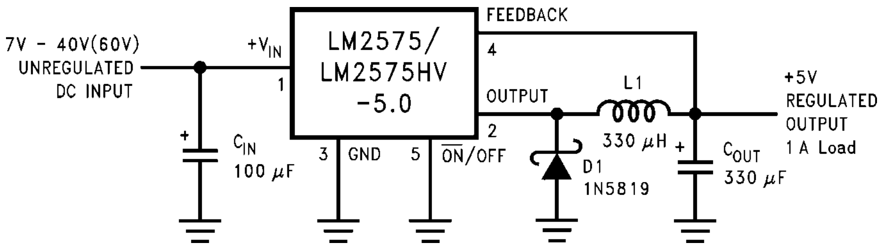
- 3.3V, 5V, 12V, 15V, and adjustable output versions
- Adjustable version output voltage range, 1.23V to 37V (57V for HV version) ±4% max over line and load conditions
- Guaranteed 1A output current
- Wide input voltage range, 40V up to 60V for HV version
- Requires only 4 external components
- 52 kHz fixed frequency internal oscillator
- TTL shutdown capability, low power standby mode
- High efficiency
- Uses readily available standard inductors
- Thermal shutdown and current limit protection
- P+ Product Enhancement tested

Applications

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

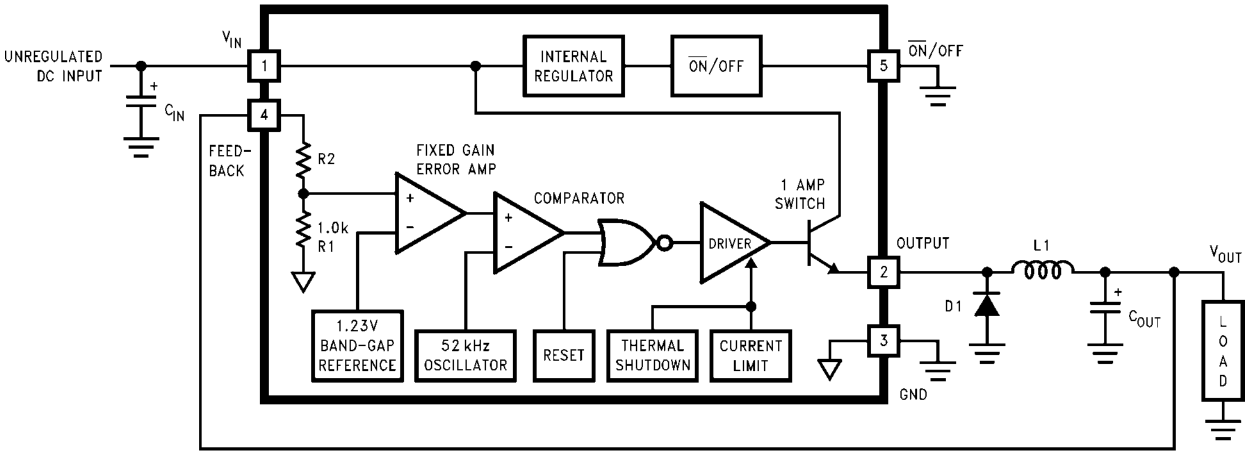
Typical Application

(Fixed Output Voltage Versions)



Note: Pin numbers are for the TO-220 package.

Block Diagram and Typical Application



3.3V, R2 = 1.7k
5V, R2 = 3.1k
12V, R2 = 8.84k
15V, R2 = 11.3k
For ADJ. Version
R1 = Open, R2 = 0Ω

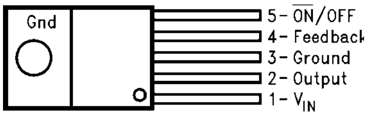
Note: Pin numbers are for the TO-220 package.

FIGURE 1.

Connection Diagrams

(XX indicates output voltage option. See Ordering Information table for complete part number.)

Straight Leads
5–Lead TO-220 (T)



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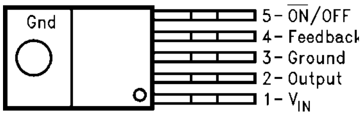
Top View
LM2575T-XX or LM2575HVT-XX
See NS Package Number T05A

Bent, Staggered Leads
5-Lead TO-220 (T)



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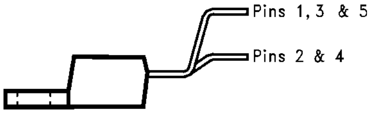
Top View



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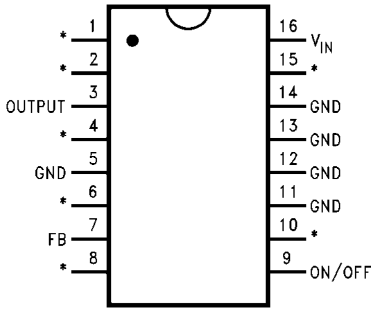
Side View
LM2575T-XX Flow LB03 or
LM2575HVT-XX Flow LB03
See NS Package Number T05D

16–Lead DIP (N or J)

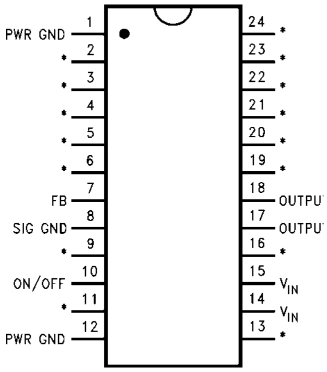


1147525

*No Internal Connection

Top View
LM2575N-XX or LM2575HVN-XX
See NS Package Number N16A
LM1575J-XX-QML
See NS Package Number J16A

24-Lead Surface Mount (M)

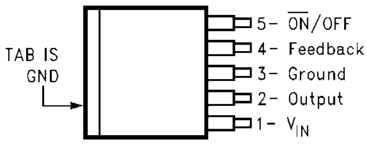


1147526

*No Internal Connection

Top View
LM2575M-XX or LM2575HVM-XX
See NS Package Number M24B

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



1147529

Top View

LM1575-ADJ, LM2575-ADJ, LM2575HV-ADJ Electrical Characteristics

Specifications with standard type face are for T_J= 25°C, and those with **boldface type** apply over **full Operating Temperature Range**.

Symbol	Parameter	Conditions	Typ	LM1575-ADJ Limit (Note 2)	LM2575-ADJ LM2575HV-ADJ Limit (Note 3)	Units (Limits)
SYSTEM PARAMETERS (Note 4) Test Circuit *Figure 2*						
V_{OUT}	Feedback Voltage	V_{IN} = 12V, I_{LOAD} = 0.2A	1.230			V
		V_{OUT} = 5V		1.217	1.217	V(Min)
		Circuit of *Figure 2*		1.243	1.243	V(Max)
V_{OUT}	Feedback Voltage LM1575/LM2575	0.2A ≤ I_{LOAD} ≤ 1A,	1.230			V
		8V ≤ V_{IN} ≤ 40V		1.205/**1.193**	1.193/**1.180**	V(Min)
		V_{OUT} = 5V, Circuit of *Figure 2*		1.255/**1.267**	1.267/**1.280**	V(Max)
V_{OUT}	Feedback Voltage LM2575HV	0.2A ≤ I_{LOAD} ≤ 1A,	1.230			V
		8V ≤ V_{IN} ≤ 60V		1.205/**1.193**	1.193/**1.180**	V(Min)
		V_{OUT} = 5V, Circuit of *Figure 2*		1.261/**1.273**	1.273/**1.286**	V(Max)
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 1A, V_{OUT} = 5V	77			%

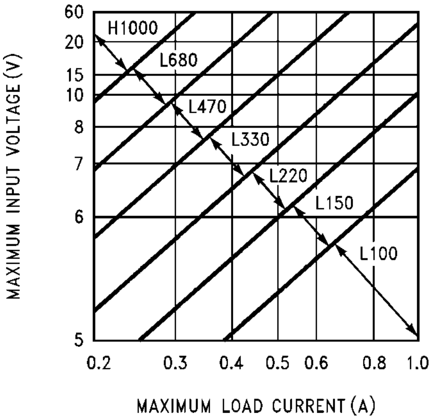
All Output Voltage Versions Electrical Characteristics

Specifications with standard type face are for T_J = 25°C, 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} = 200 mA.

Symbol	Parameter	Conditions	Typ	LM1575-XX Limit (Note 2)	LM2575-XX LM2575HV-XX Limit (Note 3)	Units (Limits)
DEVICE PARAMETERS						
I_b	Feedback Bias Current	V_{OUT} = 5V (Adjustable Version Only)	50	100/**500**	100/**500**	nA
f_O	Oscillator Frequency	(Note 13)	52			kHz
				47/**43**	47/**42**	kHz(Min)
				58/**62**	58/**63**	kHz(Max)
V_{SAT}	Saturation Voltage	I_{OUT} = 1A (Note 5)	0.9			V
				1.2/**1.4**	1.2/**1.4**	V(Max)
DC	Max Duty Cycle (ON)	(Note 6)	98			%
				93	93	%(Min)
I_{CL}	Current Limit	Peak Current (Notes 5, 13)	2.2			A
				1.7/**1.3**	1.7/**1.3**	A(Min)
				3.0/**3.2**	3.0/**3.2**	A(Max)
I_L	Output Leakage Current	(Notes 7, 8) Output = 0V		2	2	mA(Max)
		Output = −1V	7.5			mA
		Output = −1V		30	30	mA(Max)
I_Q	Quiescent Current	(Note 7)	5			mA
				10/**12**	10	mA(Max)
I_{STBY}	Standby Quiescent Current	ON /OFF Pin = 5V (OFF)	50	200/**500**	200	µA

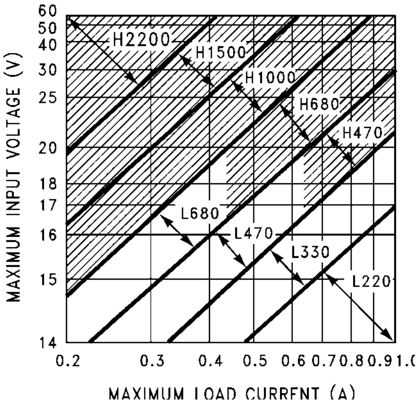
Inductor Value Selection Guides

(For Continuous Mode Operation)



1147510

FIGURE 3. LM2575(HV)-3.3



1147512

FIGURE 5. LM2575(HV)-12

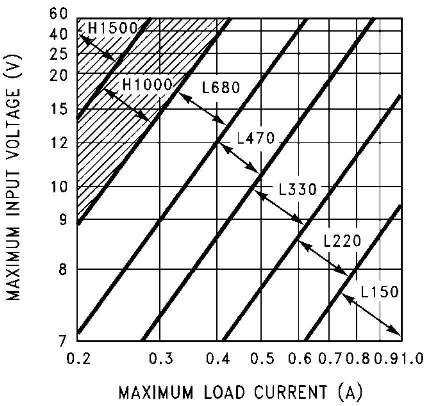


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FIGURE 4. LM2575(HV)-5.0

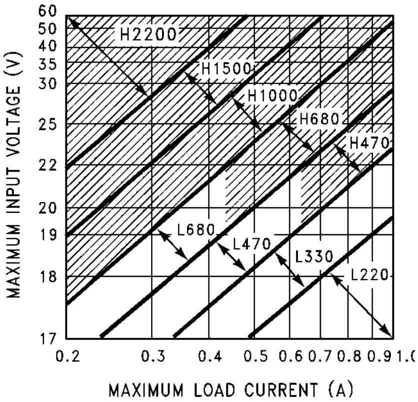

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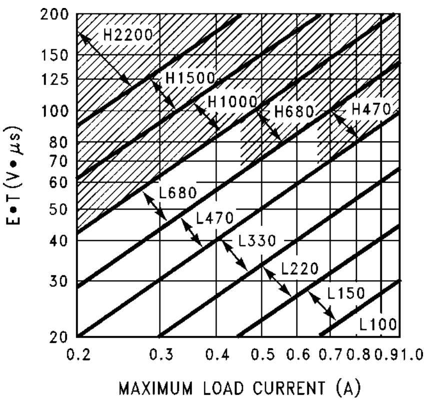
FIGURE 6. LM2575(HV)-15



1147514

FIGURE 7. LM2575(HV)-ADJ

PROCEDURE (Adjustable Output Voltage Versions)	EXAMPLE (Adjustable Output Voltage Versions)
Given: V_{OUT} = Regulated Output Voltage V_{IN}(Max) = Maximum Input Voltage I_{LOAD}(Max) = Maximum Load Current F = Switching Frequency *(Fixed at 52 kHz)*	**Given:** V_{OUT} = 10V V_{IN}(Max) = 25V I_{LOAD}(Max) = 1A F = 52 kHz
1. Programming Output Voltage *(Selecting R1 and R2, as shown in Figure 2)* Use the following formula to select the appropriate resistor values. $$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) \quad \text{where } V_{REF} = 1.23V$$ R_1 can be between 1k and 5k. *(For best temperature coefficient and stability with time, use 1% metal film resistors)* $$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$	**1.Programming Output Voltage** ***(Selecting R1 and R2)*** $$V_{OUT} = 1.23\left(1 + \frac{R2}{R1}\right) \quad \text{Select R1}$$ $$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right) = 1k\left(\frac{10V}{1.23V} - 1\right)$$ R2 = 1k (8.13 − 1) = 7.13k, closest 1% value is 7.15k
2. Inductor Selection (L1) **A.** Calculate the inductor Volt • microsecond constant, E • T (V • μ s), from the following formula: $$E \bullet T = (V_{IN} - V_{OUT})\frac{V_{OUT}}{V_{IN}} \bullet \frac{1000}{F \textit{ (in kHz)}} (V \bullet \mu s)$$ **B.** Use the E • T value from the previous formula and match it with the E • T number on the vertical axis of the **Inductor Value Selection Guide** shown in *Figure 7*. **C.** On the horizontal axis, select the maximum load current. **D.** Identify the inductance region intersected by the E • T value and the maximum load current value, and note the inductor code for that region. **E.** Identify the inductor value from the inductor code, and select an appropriate inductor from the table shown in *Figure 9*. Part numbers are listed for three inductor manufacturers. The inductor chosen must be rated for operation at the LM2575 switching frequency (52 kHz) and for a current rating of 1.15 × I_{LOAD}. For additional inductor information, see the inductor section in the application hints section of this data sheet.	**2. Inductor Selection (L1)** **A.** Calculate E • T (V • μ s) $$E \bullet T = (25 - 10) \bullet \frac{10}{25} \bullet \frac{1000}{52} = 115\ V \bullet \mu s$$ **B.** E • T = 115 V • μ s **C.** I_{LOAD}(Max) = 1A **D.** Inductance Region = H470 **E.** Inductor Value = 470 μ H *Choose from* ***AIE*** *part #430-0634,* ***Pulse Engineering*** *part #PE-53118, or* ***Renco*** *part #RL-1961.*
3. Output Capacitor Selection (C_{OUT}) **A.** 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 require- ment: $$C_{OUT} \geq 7{,}785 \frac{V_{IN}(Max)}{V_{OUT} \bullet L(\mu H)} (\mu F)$$ The above formula yields capacitor values between 10 μ F and 2000 μ F that will satisfy 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 the above formula yields. **B.** The capacitor's voltage rating should be at last 1.5 times greater than the output voltage. For a 10V regulator, a rating of at least 15V	**3. Output Capacitor Selection (C_{OUT})** **A.** $$C_{OUT} > 7{,}785 \frac{25}{10 \bullet 150} = 130\ \mu F$$

PROCEDURE (Adjustable Output Voltage Versions)	EXAMPLE (Adjustable Output Voltage Versions)
4. Catch Diode Selection (D1)	**4. Catch Diode Selection (D1)**
A. 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 LM2575. The most stressful condition for this diode is an overload or shorted output. See diode selection guide in *Figure 8*. **B.** The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage.	**A.** For this example, a 3A current rating is adequate. **B.** Use a 40V MBR340 or 31DQ04 Schottky diode, or any of the suggested fast-recovery diodes in *Figure 8*.
5. Input Capacitor (C_{IN})	**5. Input Capacitor (C_{IN})**
An aluminum or tantalum electrolytic bypass capacitor located close to the regulator is needed for stable operation.	A 100 μ F aluminum electrolytic capacitor located near the input and ground pins provides sufficient bypassing.

To further simplify the buck regulator design procedure, National Semiconductor is making available computer design software to be used with the Simple Switcher line of switching regulators. ***Switchers Made Simple*** *(version 3.3) is available on a (3½") diskette for IBM compatible computers from a National Semiconductor sales office in your area.*

V_R	Schottky		Fast Recovery	
	1A	3A	1A	3A
20V	1N5817 MBR120P SR102	1N5820 MBR320 SR302	The following diodes are all rated to 100V 11DF1 MUR110 HER102	The following diodes are all rated to 100V 31DF1 MURD310 HER302
30V	1N5818 MBR130P 11DQ03 SR103	1N5821 MBR330 31DQ03 SR303		
40V	1N5819 MBR140P 11DQ04 SR104	IN5822 MBR340 31DQ04 SR304		
50V	MBR150 11DQ05 SR105	MBR350 31DQ05 SR305		
60V	MBR160 11DQ06 SR106	MBR360 31DQ06 SR306		

FIGURE 8. Diode Selection Guide

Inductor Code	Inductor Value	Schott (Note 15)	Pulse Eng. (Note 16)	Renco (Note 17)
L100	100 µ H	67127000	PE-92108	RL2444
L150	150 µ H	67127010	PE-53113	RL1954
L220	220 µ H	67127020	PE-52626	RL1953
L330	330 µ H	67127030	PE-52627	RL1952
L470	470 µ H	67127040	PE-53114	RL1951
L680	680 µ H	67127050	PE-52629	RL1950
H150	150 µ H	67127060	PE-53115	RL2445
H220	220 µ H	67127070	PE-53116	RL2446
H330	330 µ H	67127080	PE-53117	RL2447
H470	470 µ H	67127090	PE-53118	RL1961
H680	680 µ H	67127100	PE-53119	RL1960
H1000	1000	67127110	PE-53120	RL1959
H1500	1500	67127120	PE-53121	RL1958
H2200	2200 µ H	67127130	PE-53122	RL2448

Note 15: Schott Corp., (612) 475-1173, 1000 Parkers Lake Rd., Wayzata, MN 55391.

Note 16: Pulse Engineering, (619) 674-8100, P.O. Box 12236, San Diego, CA 92112.

Note 17: Renco Electronics Inc., (516) 586-5566, 60 Jeffryn Blvd. East, Deer Park, NY 11729.

FIGURE 9. Inductor Selection by Manufacturer's Part Number

Application Hints

INPUT CAPACITOR (C_{IN})

To maintain stability, the regulator input pin must be bypassed with at least a 47 μ F electrolytic capacitor. The capacitor's leads must be kept short, and located near the regulator.

If the operating temperature range includes temperatures below −25°C, the input capacitor value may need to be larger. With most electrolytic capacitors, the capacitance value decreases and the ESR increases with lower temperatures and age. Paralleling a ceramic or solid tantalum capacitor will increase the regulator stability at cold temperatures. For maximum capacitor operating lifetime, the capacitor's RMS ripple current rating should be greater than

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

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

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

INDUCTOR SELECTION

All switching regulators have two basic modes of operation: continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulator performance and requirements.

The LM2575 (or any of the Simple Switcher family) can be used for both continuous and discontinuous modes of operation.

The inductor value selection guides in *Figure 3* through *Figure 7* were 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 will be approximately 20% to 30% of the maximum DC current. With relatively heavy load currents, the circuit operates in the continuous mode (inductor current always flowing), but under light load conditions, the circuit will be forced to the discontinuous mode (inductor current falls to zero for a period of time). This discontinuous mode of operation is perfectly acceptable. For light loads (less than approximately 200 mA) 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. The computer design software ***Switchers Made Simple*** will provide all component circuits, or can give incorrect scope readings because of induced voltages in the scope probe.

The inductors listed in the selection chart include ferrite pot core construction for AIE, powdered iron toroid for Pulse Engineering, and ferrite bobbin core for Renco.

An inductor should not be operated beyond its maximum rated current because it may saturate. When an inductor begins to saturate, the inductance decreases rapidly and the inductor begins to look mainly resistive (the DC resistance of the winding). This will cause the switch current to rise very rapidly. Different inductor types have different saturation characteristics, and this should be kept in mind when selecting an inductor.

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

INDUCTOR RIPPLE CURRENT

When the switcher is operating in the continuous mode, the inductor current waveform ranges from a triangular to a sawtooth type of waveform (depending on the input voltage). For a given input voltage and output voltage, the peak-to-peak amplitude of this inductor current waveform remains constant. As the load current rises or falls, the entire sawtooth current waveform also rises or falls. The average DC value of this waveform is equal to the DC load current (in the buck regulator configuration).

If the load current drops to a low enough level, the bottom of the sawtooth current waveform will reach zero, and the switcher will change to a discontinuous mode of operation. This is a perfectly acceptable mode of operation. Any buck switching regulator (no matter how large the inductor value is) will be forced to run discontinuous if the load current is light enough.

OUTPUT CAPACITOR

An output capacitor is required to filter the output voltage and is needed for loop stability. The capacitor should be located near the LM2575 using short pc board traces. Standard aluminum electrolytics are usually adequate, but low ESR types are recommended for low output ripple voltage and good stability. The ESR of a capacitor depends on many factors, some which are: the value, the voltage rating, physical size and the type of construction. In general, low value or low voltage (less than 12V) electrolytic capacitors usually have higher ESR numbers.

The amount of output ripple voltage is primarily a function of the ESR (Equivalent Series Resistance) of the output capacitor and the amplitude of the inductor ripple current (ΔI_{IND}). See the section on inductor ripple current in Application Hints.

The lower capacitor values (220 μ F–680 μ F) will allow typi- cally 50 mV to 150 mV of output ripple voltage, while larger- value capacitors will reduce the ripple to approximately 20 mV to 50 mV.

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

values for discontinuous (as well as continuous) mode of operation.

Inductors are available in different styles such as pot core, toriod, E-frame, bobbin core, etc., as well as different core materials, such as ferrites and powdered iron. The least expensive, the bobbin core type, consists of wire wrapped on a ferrite rod core. This type of construction makes for an inexpensive inductor, but since the magnetic flux is not completely contained within the core, it generates more electromagnetic interference (EMI). This EMI can cause problems in sensitive readily conducted through the leads to the printed circuit board copper, which is acting as a heat sink

For best thermal performance, the ground pins and all the unconnected pins should be soldered to generous amounts of printed circuit board copper, such as a ground plane. Large areas of copper provide the best transfer of heat to the sur- rounding air. Copper on both sides of the board is also helpful in getting the heat away from the package, even if there is no direct copper contact between the two sides. Thermal resistance numbers as low as 40°C/W for the SO package, and 30°C/W for the N package can be realized with a carefully engineered pc board.

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

Additional Applications

INVERTING REGULATOR

Figure 10 shows a LM2575-12 in a buck-boost configuration to generate a negative 12V output from a positive input voltage. This circuit bootstraps the regulator's ground pin to the negative output voltage, then by grounding the feedback pin, the regulator senses the inverted output voltage and regulates it to −12V.

For an input voltage of 12V or more, the maximum available output current in this configuration is approximately 0.35A. At lighter loads, the minimum input voltage required drops to approximately 4.7V.

The switch currents in this buck-boost configuration are higher than in the 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 1.5A. Using a delayed turn-on or an undervoltage lockout circuit (described in the next section) would allow the input voltage to rise to a high enough level before the switcher 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 can not be used to select the inductor or the output capacitor. The recommended range of inductor values for the buck-boost design is between 68 μ H and 220 μ H, and the output capacitor values must be larger than what is normally required for buck designs. Low input voltages or high output currents require a large 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 from the following formula:

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

Where f_{osc} = 52 kHz. 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 for the LM2575 is +28V, or +48V for the LM2575HV.

The ***Switchers Made Simple*** (version 3.3) design software can be used to determine the feasibility of regulator designs using different topologies, different input-output parameters, different components, etc.

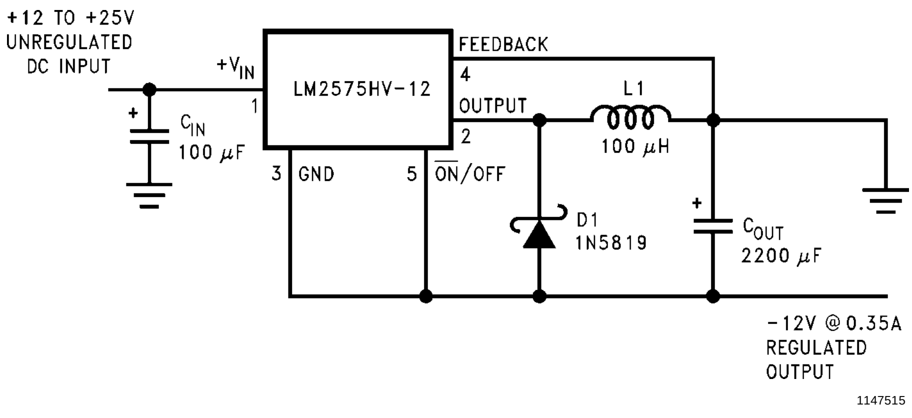


FIGURE 10. Inverting Buck-Boost Develops −12V

April 2005

National Semiconductor

LM1577/LM2577
SIMPLE SWITCHER® Step-Up Voltage Regulator

General Description

The LM1577/LM2577 are monolithic integrated circuits that provide all of the power and control functions for step-up (boost), flyback, and forward converter switching regulators. The device is available in three different output voltage versions: 12V, 15V, and adjustable.

Requiring a minimum number of external components, these regulators are cost effective, and simple to use. Listed in this data sheet are a family of standard inductors and flyback transformers designed to work with these switching regulators.

Included on the chip is a 3.0A NPN switch and its associated protection circuitry, consisting of current and thermal limiting, and undervoltage lockout. Other features include a 52 kHz fixed-frequency oscillator that requires no external components, a soft start mode to reduce in-rush current during start-up, and current mode control for improved rejection of input voltage and output load transients.

Features

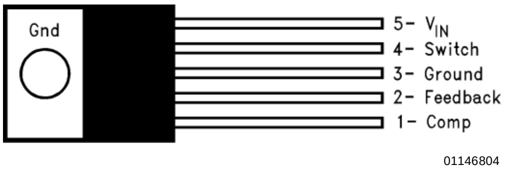
- Requires few external components
- NPN output switches 3.0A, can stand off 65V
- Wide input voltage range: 3.5V to 40V
- Current-mode operation for improved transient response, line regulation, and current limit
- 52 kHz internal oscillator
- Soft-start function reduces in-rush current during start-up
- Output switch protected by current limit, under-voltage lockout, and thermal shutdown

Typical Applications

- Simple boost regulator
- Flyback and forward regulators
- Multiple-output regulator

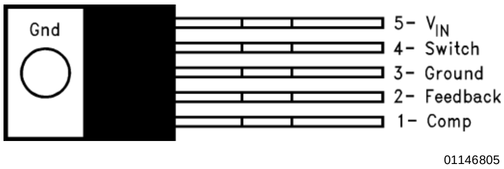
Connection Diagrams

Straight Leads
5-Lead TO-220 (T)



Top View
Order Number LM2577T-12, LM2577T-15, or LM2577T-ADJ
See NS Package Number T05A

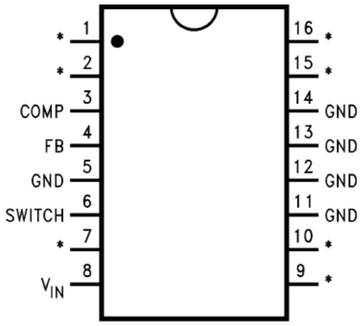
Bent, Staggered Leads
5-Lead TO-220 (T)



Top View
Order Number LM2577T-12 Flow LB03, LM2577T-15 Flow LB03, or LM2577T-ADJ Flow LB03
See NS Package Number T05D

Connection Diagrams (Continued)

16-Lead DIP (N)



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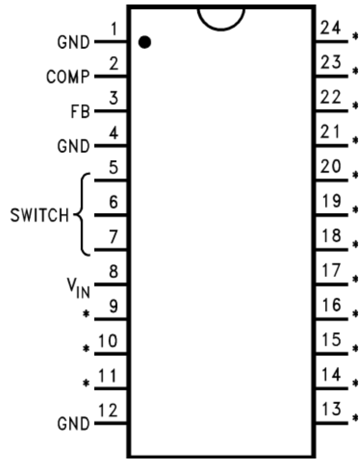
*No internal Connection

Top View
Order Number LM2577N-12, LM2577N-15, or LM2577N-ADJ
See NS Package Number N16A

24-Lead Surface Mount (M)



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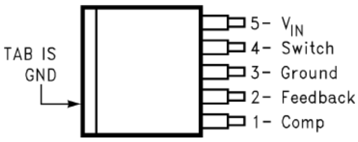
*No internal Connection

Top View
Order Number LM2577M-12, LM2577M-15, or LM2577M-ADJ
See NS Package Number M24B

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



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Top View

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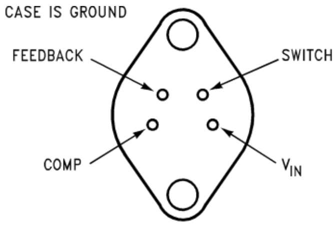
Side View
Order Number LM2577S-12, LM2577S-15, or LM2577S-ADJ
See NS Package Number TS5B

4-Lead TO-3 (K)



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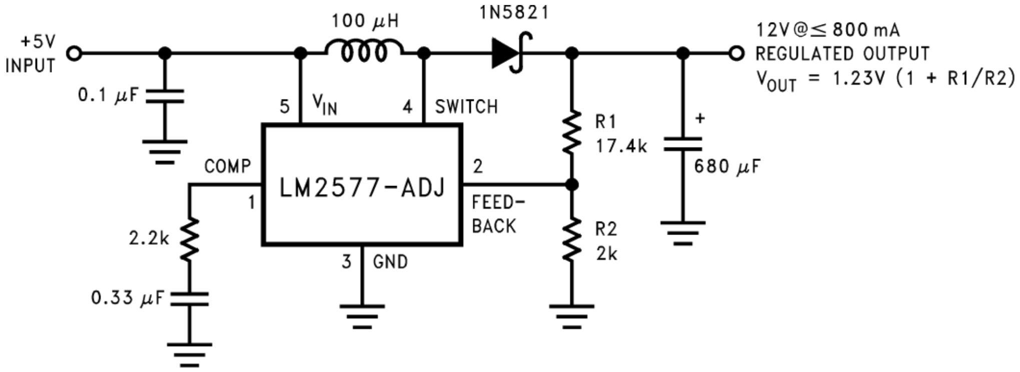
Bottom View
Order Number LM1577K-12/883, LM1577K-15/883, or LM1577K-ADJ/883
See NS Package Number K04A

Ordering Information

Temperature Range	Package Type	Output Voltage 12V	15V	ADJ	NSC Package Drawing	Package
−40˚C ≤ T_A ≤ +125˚C	24-Pin Surface Mount	LM2577M-12	LM2577M-15	LM2577M-ADJ	M24B	SO
	16-Pin Molded DIP	LM2577N-12	LM2577N-15	LM2577N-ADJ	N16A	N
	5-Lead Surface Mount	LM2577S-12	LM2577S-15	LM2577S-ADJ	TS5B	TO-263
	5-Straight Leads	LM2577T-12	LM2577T-15	LM2577T-ADJ	T05A	TO-220
	5-Bent Staggered Leads	LM2577T-12 Flow LB03	LM2577T-15 Flow LB03	LM2577T-ADJ Flow LB03	T05D	TO-220
−55˚C ≤ T_A ≤ +150˚C	4-Pin TO-3	LM1577K-12/883	LM1577K-15/883	LM1577K-ADJ/883	K04A	TO-3

Typical Application



Note: Pin numbers shown are for TO-220 (T) package.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	45V
Output Switch Voltage	65V
Output Switch Current (Note 2)	6.0A
Power Dissipation	Internally Limited
Storage Temperature Range	−65˚C to +150˚C
Lead Temperature	
(Soldering, 10 sec.)	260˚C
Maximum Junction Temperature	150˚C
Minimum ESD Rating	
(C = 100 pF, R = 1.5 kΩ)	2 kV

Operating Ratings

Supply Voltage	$3.5V \le V_{IN} \le 40V$
Output Switch Voltage	$0V \le V_{SWITCH} \le 60V$
Output Switch Current	$I_{SWITCH} \le 3.0A$
Junction Temperature Range	
LM1577	$-55˚C \le T_J \le +150˚C$
LM2577	$-40˚C \le T_J \le +125˚C$

Electrical Characteristics—LM1577-12, LM2577-12

Specifications with standard type face are for T_J = 25˚C, and those in **bold type face** apply over full **Operating Temperature Range**. Unless otherwise specified, V_{IN} = 5V, and I_{SWITCH} = 0.

Symbol	Parameter	Conditions	Typical	LM1577-12 Limit (Notes 3, 4)	LM2577-12 Limit (Note 5)	Units (Limits)
SYSTEM PARAMETERS Circuit of *Figure 1* (Note 6)						
V_{OUT}	Output Voltage	V_{IN} = 5V to 10V	12.0			V
		I_{LOAD} = 100 mA to 800 mA		11.60/**11.40**	11.60/**11.40**	V(min)
		(Note 3)		12.40/**12.60**	12.40/**12.60**	V(max)
$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	Line Regulation	V_{IN} = 3.5V to 10V	20			mV
		I_{LOAD} = 300 mA		50/**100**	50/**100**	mV(max)
$\frac{\Delta V_{OUT}}{\Delta_{LOAD}}$	Load Regulation	V_{IN} = 5V	20			mV
		I_{LOAD} = 100 mA to 800 mA		50/**100**	50/**100**	mV(max)
η	Efficiency	V_{IN} = 5V, I_{LOAD} = 800 mA	80			%
DEVICE PARAMETERS						
I_S	Input Supply Current	$V_{FEEDBACK}$ = 14V (Switch Off)	7.5			mA
				10.0/**14.0**	10.0/**14.0**	mA(max)
		I_{SWITCH} = 2.0A	25			mA
		V_{COMP} = 2.0V (Max Duty Cycle)		50/**85**	50/**85**	mA(max)
V_{UV}	Input Supply	I_{SWITCH} = 100 mA	2.90			V
	Undervoltage Lockout			2.70/**2.65**	2.70/**2.65**	V(min)
				3.10/**3.15**	3.10/**3.15**	V(max)
f_O	Oscillator Frequency	Measured at Switch Pin	52			kHz
		I_{SWITCH} = 100 mA		48/**42**	48/**42**	kHz(min)
				56/**62**	56/**62**	kHz(max)
V_{REF}	Output Reference	Measured at Feedback Pin				V
	Voltage	V_{IN} = 3.5V to 40V	12	11.76/**11.64**	11.76/**11.64**	V(min)
		V_{COMP} = 1.0V		12.24/**12.36**	12.24/**12.36**	V(max)
$\frac{\Delta V_{REF}}{\Delta V_{IN}}$	Output Reference Voltage Line Regulator	V_{IN} = 3.5V to 40V	7			mV
R_{FB}	Feedback Pin Input Resistance		9.7			kΩ
G_M	Error Amp	I_{COMP} = −30 µA to +30 µA	370			µmho
	Transconductance	V_{COMP} = 1.0V		225/**145**	225/**145**	µmho(min)
				515/**615**	515/**615**	µmho(max)

Electrical Characteristics—LM1577-15, LM2577-15 (Continued)

Specifications with standard type face are for T_J = 25˚C, and those in **bold type face** apply over full **Operating Temperature Range**. Unless otherwise specified, V_{IN} = 5V, and I_{SWITCH} = 0.

Symbol	Parameter	Conditions	Typical	LM1577-15 Limit (Notes 3, 4)	LM2577-15 Limit (Note 5)	Units (Limits)
DEVICE PARAMETERS						
	NPN Switch Current Limit	V_{COMP} = 2.0V	4.3			A
				3.7/**3.0**	3.7/**3.0**	A(min)
				5.3/**6.0**	5.3/**6.0**	A(max)

Electrical Characteristics—LM1577-ADJ, LM2577-ADJ

Specifications with standard type face are for T_J = 25˚C, and those in **bold type face** apply over full **Operating Temperature Range**. Unless otherwise specified, V_{IN} = 5V, $V_{FEEDBACK}$ = V_{REF}, and I_{SWITCH} = 0.

Symbol	Parameter	Conditions	Typical	LM1577-ADJ Limit (Notes 3, 4)	LM2577-ADJ Limit (Note 5)	Units (Limits)
SYSTEM PARAMETERS Circuit of *Figure 3* (Note 6)						
V_{OUT}	Output Voltage	V_{IN} = 5V to 10V	12.0			V
		I_{LOAD} = 100 mA to 800 mA		11.60/**11.40**	11.60/**11.40**	V(min)
		(Note 3)		12.40/**12.60**	12.40/**12.60**	V(max)
$\Delta V_{OUT}/$	Line Regulation	V_{IN} = 3.5V to 10V	20			mV
ΔV_{IN}		I_{LOAD} = 300 mA		50/**100**	50/**100**	mV(max)
$\Delta V_{OUT}/$	Load Regulation	V_{IN} = 5V	20			mV
ΔI_{LOAD}		I_{LOAD} = 100 mA to 800 mA		50/**100**	50/**100**	mV(max)
η	Efficiency	V_{IN} = 5V, I_{LOAD} = 800 mA	80			%
DEVICE PARAMETERS						
I_S	Input Supply Current	$V_{FEEDBACK}$ = 1.5V (Switch Off)	7.5			mA
				10.0/**14.0**	10.0/**14.0**	mA(max)
		I_{SWITCH} = 2.0A	25			mA
		V_{COMP} = 2.0V (Max Duty Cycle)		50/**85**	50/**85**	mA(max)
V_{UV}	Input Supply Undervoltage Lockout	I_{SWITCH} = 100 mA	2.90			V
				2.70/**2.65**	2.70/**2.65**	V(min)
				3.10/**3.15**	3.10/**3.15**	V(max)
f_O	Oscillator Frequency	Measured at Switch Pin	52			kHz
		I_{SWITCH} = 100 mA		48/**42**	48/**42**	kHz(min)
				56/**62**	56/**62**	kHz(max)
V_{REF}	Reference Voltage	Measured at Feedback Pin				V
		V_{IN} = 3.5V to 40V	1.230	1.214/**1.206**	1.214/**1.206**	V(min)
		V_{COMP} = 1.0V		1.246/**1.254**	1.246/**1.254**	V(max)
$\Delta V_{REF}/$ ΔV_{IN}	Reference Voltage Line Regulation	V_{IN} = 3.5V to 40V	0.5			mV
I_B	Error Amp Input Bias Current	V_{COMP} = 1.0V	100			nA
				300/**800**	300/**800**	nA(max)
G_M	Error Amp Transconductance	I_{COMP} = −30 µA to +30 µA	3700			µmho
		V_{COMP} = 1.0V		2400/**1600**	2400/**1600**	µmho(min)
				4800/**5800**	4800/**5800**	µmho(max)
A_{VOL}	Error Amp Voltage Gain	V_{COMP} = 1.1V to 1.9V	800			V/V
		R_{COMP} = 1.0 MΩ (Note 7)		500/**250**	500/**250**	V/V(min)

Electrical Characteristics—LM1577-ADJ, LM2577-ADJ (Continued)

Specifications with standard type face are for T_J = 25˚C, and those in **bold type face** apply over full **Operating Temperature Range**. Unless otherwise specified, V_{IN} = 5V, $V_{FEEDBACK}$ = V_{REF}, and I_{SWITCH} = 0.

Symbol	Parameter	Conditions	Typical	LM1577-ADJ Limit (Notes 3, 4)	LM2577-ADJ Limit (Note 5)	Units (Limits)
DEVICE PARAMETERS						
	Error Amplifier Output Swing	Upper Limit $V_{FEEDBACK}$ = 1.0V	2.4	 2.2/**2.0**	 2.2/**2.0**	V V(min)
		Lower Limit $V_{FEEDBACK}$ = 1.5V	0.3	 0.40/**0.55**	 0.40/**0.55**	V V(max)
	Error Amp Output Current	$V_{FEEDBACK}$ = 1.0V to 1.5V V_{COMP} = 1.0V	±200	 ±130/**±90** ±300/**±400**	 ±130/**±90** ±300/**±400**	µA µA(min) µA(max)
I_{SS}	Soft Start Current	$V_{FEEDBACK}$ = 1.0V V_{COMP} = 0V	5.0	 2.5/**1.5** 7.5/**9.5**	 2.5/**1.5** 7.5/**9.5**	µA µA(min) µA(max)
D	Maximum Duty Cycle	V_{COMP} = 1.5V I_{SWITCH} = 100 mA	95	 93/**90**	 93/**90**	% %(min)
$\Delta I_{SWITCH}/\Delta V_{COMP}$	Switch Transconductance		12.5			A/V
I_L	Switch Leakage Current	V_{SWITCH} = 65V $V_{FEEDBACK}$ = 1.5V (Switch Off)	10	 300/**600**	 300/**600**	µA µA(max)
V_{SAT}	Switch Saturation Voltage	I_{SWITCH} = 2.0A V_{COMP} = 2.0V (Max Duty Cycle)	0.5	 0.7/**0.9**	 0.7/**0.9**	V V(max)
	NPN Switch Current Limit	V_{COMP} = 2.0V	4.3	 3.7/**3.0** 5.3/**6.0**	 3.7/**3.0** 5.3/**6.0**	A A(min) A(max)
THERMAL PARAMETERS (All Versions)						
θ_{JA} θ_{JC}	Thermal Resistance	K Package, Junction to Ambient K Package, Junction to Case	35 1.5			˚C/W
θ_{JA} θ_{JC}		T Package, Junction to Ambient T Package, Junction to Case	65 2			
θ_{JA}		N Package, Junction to Ambient (Note 8)	85			
θ_{JA}		M Package, Junction to Ambient (Note 8)	100			
θ_{JA}		S Package, Junction to Ambient (Note 9)	37			

STEP-UP (BOOST) REGULATOR

Figure 4 shows the LM1577-ADJ/LM2577-ADJ used as a Step-Up Regulator. This is a switching regulator used for producing an output voltage greater than the input supply voltage. The LM1577-12/LM2577-12 and LM1577-15/LM2577-15 can also be used for step-up regulators with 12V or 15V outputs (respectively), by tying the feedback pin directly to the regulator output.

A basic explanation of how it works is as follows. The LM1577/LM2577 turns its output switch on and off at a frequency of 52 kHz, and this creates energy in the inductor (L). When the NPN switch turns on, the inductor current charges up at a rate of V_{IN}/L, storing current in the inductor. When the switch turns off, the lower end of the inductor flies above V_{IN}, discharging its current through diode (D) into the output capacitor (C_{OUT}) at a rate of $(V_{OUT} - V_{IN})/L$. Thus, energy stored in the inductor during the switch on time is transferred to the output during the switch off time. The output voltage is controlled by the amount of energy transferred which, in turn, is controlled by modulating the peak inductor current. This is done by feeding back a portion of the output voltage to the error amp, which amplifies the difference between the feedback voltage and a 1.230V reference. The error amp output voltage is compared to a voltage proportional to the switch current (i.e., inductor current during the switch on time).

The comparator terminates the switch on time when the two voltages are equal, thereby controlling the peak switch current to maintain a constant output voltage.

Voltage and current waveforms for this circuit are shown in *Figure 5*, and formulas for calculating them are given in *Figure 6*.

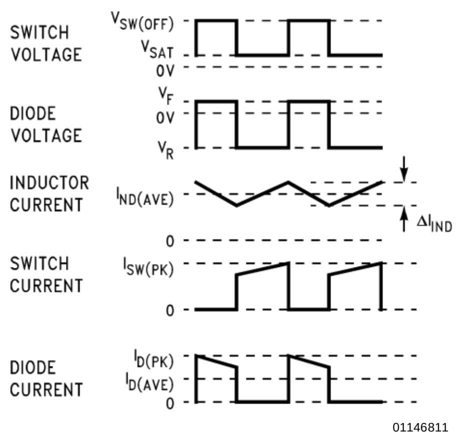


FIGURE 5. Step-Up Regulator Waveforms

Duty Cycle	D	$\frac{V_{OUT} + V_F - V_{IN}}{V_{OUT} + V_F - V_{SAT}} \approx \frac{V_{OUT} - V_{IN}}{V_{OUT}}$
Average Inductor Current	$I_{IND(AVE)}$	$\frac{I_{LOAD}}{1 - D}$
Inductor Current Ripple	ΔI_{IND}	$\frac{V_{IN} - V_{SAT}}{L} \frac{D}{52{,}000}$
Peak Inductor Current	$I_{IND(PK)}$	$\frac{I_{LOAD(max)}}{1 - D_{(max)}} + \frac{\Delta I_{IND}}{2}$
Peak Switch Current	$I_{SW(PK)}$	$\frac{I_{LOAD(max)}}{1 - D_{(max)}} + \frac{\Delta I_{IND}}{2}$
Switch Voltage When Off	$V_{SW(OFF)}$	$V_{OUT} + V_F$
Diode Reverse Voltage	V_R	$V_{OUT} - V_{SAT}$
Average Diode Current	$I_{D(AVE)}$	I_{LOAD}
Peak Diode Current	$I_{D(PK)}$	$\frac{I_{LOAD}}{1 - D_{(max)}} + \frac{\Delta I_{IND}}{2}$
Power Dissipation of LM1577/2577	P_D	$0.25\Omega \left(\frac{I_{LOAD}}{1 - D}\right)^2 D + \frac{I_{LOAD}\, D\, V_{IN}}{50\,(1 - D)}$

V_F = Forward Biased Diode Voltage
I_{LOAD} = Output Load Current

FIGURE 6. Step-Up Regulator Formulas

STEP-UP REGULATOR DESIGN PROCEDURE

The following design procedure can be used to select the appropriate external components for the circuit in *Figure 4*, based on these system requirements.

Given:

$V_{IN\ (min)}$ = Minimum input supply voltage

V_{OUT} = Regulated output voltage

$I_{LOAD(max)}$ = Maximum output load current

Before proceeding any further, determine if the LM1577/LM2577 can provide these values of V_{OUT} and $I_{LOAD(max)}$ when operating with the minimum value of V_{IN}. The upper limits for V_{OUT} and $I_{LOAD(max)}$ are given by the following equations.

$V_{OUT} \leq 60V$

and $V_{OUT} \leq 10 \times V_{IN(min)}$

$$I_{LOAD(max)} \leq \frac{2.1A \times V_{IN(min)}}{V_{OUT}}$$

These limits must be greater than or equal to the values specified in this application.

1. Inductor Selection (L)

A. *Voltage Options:*

1. **For 12V or 15V output**

From *Figure 7* (for 12V output) or *Figure 8* (for 15V output), identify inductor code for region indicated by $V_{IN\ (min)}$ and $I_{LOAD\ (max)}$. The shaded region indicates con

Application Hints (Continued)

ditions for which the LM1577/LM2577 output switch would be operating beyond its switch current rating. The minimum operating voltage for the LM1577/LM2577 is 3.5V.

From here, ***proceed to step C***.

2. **For Adjustable version**

Preliminary calculations:

The inductor selection is based on the calculation of the following three parameters:

$D_{(max)}$, the maximum switch duty cycle ($0 \le D \le 0.9$):

$$D_{(max)} = \frac{V_{OUT} + V_F - V_{IN(min)}}{V_{OUT} + V_F - 0.6V}$$

where V_F = 0.5V for Schottky diodes and 0.8V for fast recovery diodes (typically);

E •T, the product of volts x time that charges the inductor:

$$E \bullet T = \frac{D_{(max)} (V_{IN(min)} - 0.6V) 10^6}{52{,}000 \text{ Hz}} \qquad (V \bullet \mu s)$$

$I_{IND,DC}$, the average inductor current under full load;

$$I_{IND,DC} = \frac{1.05 \times I_{LOAD(max)}}{1 - D_{(max)}}$$

B. *Identify Inductor Value:*

1. From *Figure 9*, identify the inductor code for the region indicated by the intersection of E•T and $I_{IND,DC}$. This code gives the inductor value in microhenries. The L or H prefix signifies whether the inductor is rated for a maximum E•T of 90 V•µs (L) or 250 V•µs (H).

2. If D < 0.85, go on to step C. If D ≥ 0.85, then calculate the minimum inductance needed to ensure the switching regulator's stability:

$$L_{MIN} = \frac{6.4 (V_{IN(min)} - 0.6V) (2D_{(max)} - 1)}{1 - D_{(max)}} \qquad (\mu H)$$

If L_{MIN} is smaller than the inductor value found in step B1, go on to step C. Otherwise, the inductor value found in step B1 is too low; an appropriate inductor code should be obtained from the graph as follows:

1. Find the lowest value inductor that is greater than L_{MIN}.

2. Find where E•T intersects this inductor value to determine if it has an L or H prefix. If E•T intersects both the L and H regions, select the inductor with an H prefix.

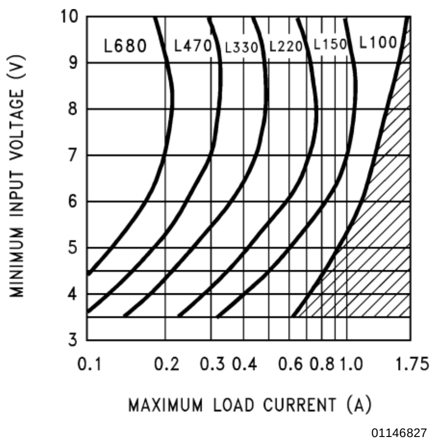


FIGURE 7. LM2577-12 Inductor Selection Guide

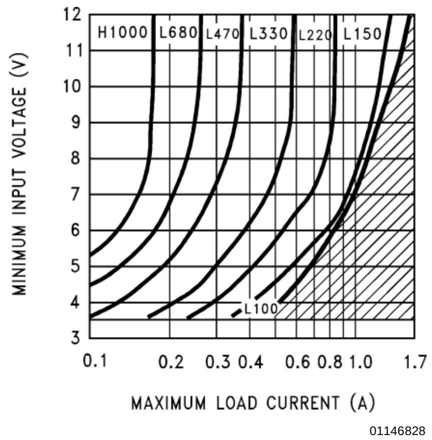
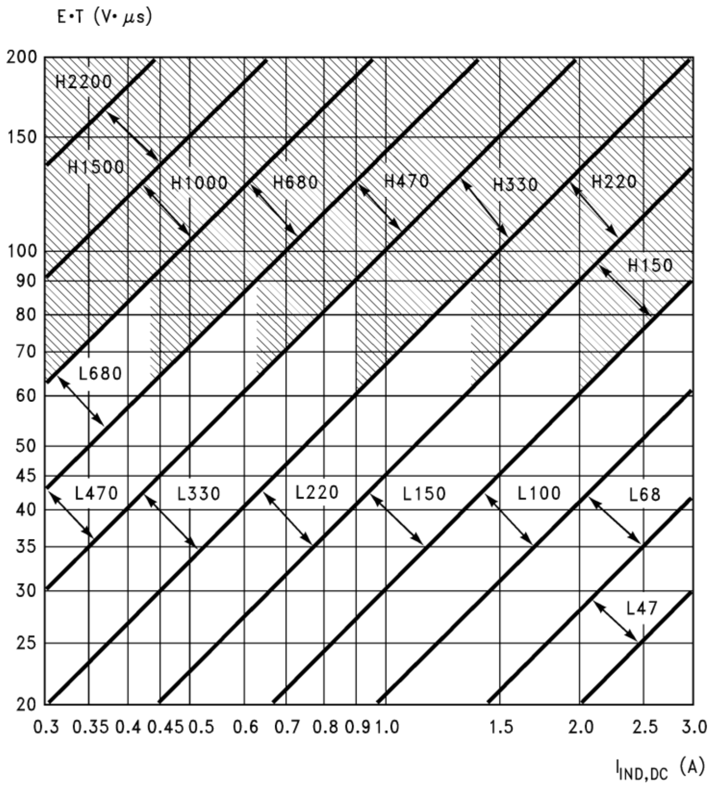


FIGURE 8. LM2577-15 Inductor Selection Guide



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Note: These charts assume that the inductor ripple current inductor is approximately 20% to 30% of the average inductor current (when the regulator is under full load). Greater ripple current causes higher peak switch currents and greater output ripple voltage; lower ripple current is achieved with larger-value
inductors. The factor of 20 to 30% is chosen as a convenient balance between the two extremes.

FIGURE 9. LM1577-ADJ/LM2577-ADJ Inductor Selection Graph

C. *Select an inductor* from the table of *Figure 10* which cross-references the inductor codes to the part numbers of three different manufacturers. Complete specifications for these inductors are available from the respective manufacturers. The inductors listed in this table have the following characteristics:

AIE: ferrite, pot-core inductors; Benefits of this type are low electro-magnetic interference (EMI), small physical size, and very low power dissipation (core loss). Be careful not to operate these inductors too far beyond their maximum ratings for E•T and peak current, as this will saturate the core.

Pulse: powdered iron, toroid core inductors; Benefits are low EMI and ability to withstand E•T and peak current above rated value better than ferrite cores.

Renco: ferrite, bobbin-core inductors; Benefits are low cost and best ability to withstand E•T and peak current above rated value. Be aware that these inductors gener- ate more EMI than the other types, and this may interfere with signals sensitive to noise.

Inductor Code	Manufacturer's Part Number		
	Schott	Pulse	Renco
L47	67126980	PE - 53112	RL2442
L68	67126990	PE - 92114	RL2443
L100	67127000	PE - 92108	RL2444
L150	67127010	PE - 53113	RL1954
L220	67127020	PE - 52626	RL1953
L330	67127030	PE - 52627	RL1952
L470	67127040	PE - 53114	RL1951
L680	67127050	PE - 52629	RL1950
H150	67127060	PE - 53115	RL2445
H220	67127070	PE - 53116	RL2446
H330	67127080	PE - 53117	RL2447
H470	67127090	PE - 53118	RL1961
H680	67127100	PE - 53119	RL1960
H1000	67127110	PE - 53120	RL1959
H1500	67127120	PE - 53121	RL1958
H2200	67127130	PE - 53122	RL2448

Schott Corp., (612) 475-1173
1000 Parkers Lake Rd., Wayzata, MN 55391
Pulse Engineering, (619) 268-2400
P.O. Box 12235, San Diego, CA 92112
Renco Electronics Inc., (516) 586-5566
60 Jeffryn Blvd. East, Deer Park, NY 11729

FIGURE 10. Table of Standardized Inductors and Manufacturer's Part Numbers

2. Compensation Network (R_C, C_C) and Output Capacitor (C_{OUT}) Selection

R_C and C_C form a pole-zero compensation network that stabilizes the regulator. The values of R_C and C_C are mainly dependant on the regulator voltage gain, $I_{LOAD(max)}$, L and C_{OUT}. The following procedure calculates values for R_C, C_C, and C_{OUT} that ensure regulator stability. Be aware that this procedure doesn't necessarily result in R_C and C_C that provide optimum compensation. In order to guarantee optimum compensation, one of the standard procedures for testing loop stability must be used, such as measuring V_{OUT} transient response when pulsing I_{LOAD} (see *Figure 15*).

A. *First, calculate the maximum value for R_C.*

$$R_C \le \frac{750 \times I_{LOAD(max)} \times V_{OUT}^2}{V_{IN(min)}^2}$$

Select a resistor less than or equal to this value, and it should also be no greater than 3 kΩ.

B. *Calculate the minimum value for* C_{OUT} using the following two equations.

$$C_{OUT} \ge \frac{0.19 \times L \times R_C \times I_{LOAD(max)}}{V_{IN(min)} \times V_{OUT}}$$

and

$$C_{OUT} \ge \frac{V_{IN(min)} \times R_C \times (V_{IN(min)} + (3.74 \times 10^5 \times L))}{487{,}800 \times V_{OUT}^3}$$

The larger of these two values is the minimum value that ensures stability.

C. *Calculate the minimum value of C_C.*

$$C_C \ge \frac{58.5 \times V_{OUT}^2 \times C_{OUT}}{R_C^2 \times V_{IN(min)}}$$

The compensation capacitor is also part of the soft start circuitry. When power to the regulator is turned on, the switch duty cycle is allowed to rise at a rate controlled by this capacitor (with no control on the duty cycle, it would immediately rise to 90%, drawing huge currents from the input power supply). In order to operate properly, the soft start circuit requires $C_C \ge 0.22$ µF.

The value of the output filter capacitor is normally large enough to require the use of aluminum electrolytic capacitors. *Figure 11* lists several different types that are recommended for switching regulators, and the following parameters are used to select the proper capacitor.

Working Voltage (WVDC): Choose a capacitor with a working voltage at least 20% higher than the regulator output voltage.

Ripple Current: This is the maximum RMS value of current that charges the capacitor during each switching cycle. For step-up and flyback regulators, the formula for ripple current is

$$I_{RIPPLE(RMS)} = \frac{I_{LOAD(max)} \times D_{(max)}}{1 - D_{(max)}}$$

Choose a capacitor that is rated at least 50% higher than this value at 52 kHz.

Equivalent Series Resistance (ESR) : This is the primary cause of output ripple voltage, and it also affects the values of R_C and C_C needed to stabilize the regulator. As a result, the preceding calculations for C_C and R_C are only valid if ESR doesn't exceed the maximum value specified by the following equations.

$$ESR \le \frac{0.01 \times V_{OUT}}{I_{RIPPLE(P\text{-}P)}} \text{ and } \le \frac{8.7 \times (10) - 3 \times V_{IN}}{I_{LOAD(max)}}$$

where

$$I_{RIPPLE(P\text{-}P)} = \frac{1.15 \times I_{LOAD(max)}}{1 - D_{(max)}}$$

Select a capacitor with ESR, at 52 kHz, that is less than or equal to the lower value calculated. Most electrolytic capacitors specify ESR at 120 Hz which is 15% to 30% higher than at 52 kHz. Also, be aware that ESR increases by a factor of 2 when operating at −20˚C.

In general, low values of ESR are achieved by using large value capacitors (C ≥ 470 µF), and capacitors with high WVDC, or by paralleling smaller-value capacitors.

Application Hints (Continued)

3. Output Voltage Selection (R1 and R2)

This section is for applications using the LM1577-ADJ/ LM2577-ADJ. Skip this section if the LM1577-12/LM2577-12 or LM1577-15/LM2577-15 is being used.

With the LM1577-ADJ/LM2577-ADJ, the output voltage is given by

$$V_{OUT} = 1.23V\,(1 + R1/R2)$$

Resistors R1 and R2 divide the output down so it can be compared with the LM1577-ADJ/LM2577-ADJ internal 1.23V reference. For a given desired output voltage V_{OUT}, select R1 and R2 so that

$$\frac{R1}{R2} = \frac{V_{OUT}}{1.23V} - 1$$

4. Input Capacitor Selection (C_{IN})

The switching action in the step-up regulator causes a trian- gular ripple current to be drawn from the supply source. This in turn causes noise to appear on the supply voltage. For proper operation of the LM1577, the input voltage should be decoupled. Bypassing the Input Voltage pin directly to ground with a good quality, low ESR, 0.1 µF capacitor (leads as short as possible) is normally sufficient.

Cornell Dublier —Types 239, 250, 251, UFT, 300, or 350
P.O. Box 128, Pickens, SC 29671
(803) 878-6311

Nichicon —Types PF, PX, or PZ
927 East Parkway, Schaumburg, IL 60173
(708) 843-7500

Sprague —Types 672D, 673D, or 674D Box 1, Sprague Road, Lansing, NC 28643
(919) 384-2551

United Chemi-Con —Types LX, SXF, or SXJ
9801 West Higgins Road, Rosemont, IL 60018
(708) 696-2000

FIGURE 11. Aluminum Electrolytic Capacitors Recommended for Switching Regulators

If the LM1577 is located far from the supply source filter capacitors, an additional large electrolytic capacitor (e.g. 47 µF) is often required.

5. Diode Selection (D)

The switching diode used in the boost regulator must with-stand a reverse voltage equal to the circuit output voltage, and must conduct the peak output current of the LM2577. A suitable diode must have a minimum reverse breakdown voltage greater than the circuit output voltage, and should be rated for average and peak current greater than $I_{LOAD(max)}$ and $I_{D(PK)}$. Schottky barrier diodes are often favored for use in switching regulators. Their low forward voltage drop allows higher regulator efficiency than if a (less expensive) fast recovery diode was used. See *Figure 12* for recommended part numbers and voltage ratings of 1A and 3A diodes.

V_{OUT}	Schottky		Fast Recovery	
(max)	1A	3A	1A	3A
20V	1N5817 MBR120P	1N5820 MBR320P		
30V	1N5818 MBR130P 11DQ03	1N5821 MBR330P 31DQ03		
40V	1N5819 MBR140P 11DQ04	1N5822 MBR340P 31DQ04		
50V	MBR150 11DQ05	MBR350 31DQ05	1N4933 MUR105	
100V			1N4934 HER102 MUR110 10DL1	MR851 30DL1 MR831 HER302

FIGURE 12. Diode Selection Chart

BOOST REGULATOR CIRCUIT EXAMPLE

By adding a few external components (as shown in *Figure 13*), the LM2577 can be used to produce a regulated output voltage that is greater than the applied input voltage. Typical performance of this regulator is shown in *Figure 14* and *Figure 15*. The switching waveforms observed during the operation of this circuit are shown in *Figure 16*.

Application Hints (Continued)

FLYBACK REGULATOR

A Flyback regulator can produce single or multiple output voltages that are lower or greater than the input supply voltage. *Figure 18* shows the LM1577/LM2577 used as a flyback regulator with positive and negative regulated outputs. Its operation is similar to a step-up regulator, except the output switch contols the primary current of a flyback transformer. Note that the primary and secondary windings are out of phase, so no current flows through secondary when current flows through the primary. This allows the primary to charge up the transformer core when the switch is on. When the switch turns off, the core discharges by sending current through the secondary, and this produces voltage at the outputs. The output voltages are controlled by adjusting the peak primary current, as described in the step-up regulator section.

Voltage and current waveforms for this circuit are shown in *Figure 17*, and formulas for calculating them are given in *Figure 19*.

FLYBACK REGULATOR DESIGN PROCEDURE

1. Transformer Selection

A family of standardized flyback transformers is available for creating flyback regulators that produce dual output voltages, from ±10V to ±15V, as shown in *Figure 18*. *Figure 20*lists these transformers with the input voltage, output voltages and maximum load current they are designed for.

2. Compensation Network (C_C, R_C) and Output Capacitor (C_{OUT}) Selection

As explained in the Step-Up Regulator Design Procedure, C_C, R_C and C_{OUT} must be selected as a group. The following procedure is for a dual output flyback regulator with equal turns ratios for each secondary (i.e., both output voltages have the same magnitude). The equations can be used for a single output regulator by changing $\Sigma I_{LOAD(max)}$ to $I_{LOAD(max)}$ in the following equations.

A. **First, calculate the maximum value for R_C.**

$$R_C \leq \frac{750 \times \Sigma I_{LOAD(max)} \times (15V + V_{IN(min)}N)^2}{V_{IN(min)}{}^2}$$

Where $\Sigma I_{LOAD(max)}$ is the sum of the load current (magni- tude) required from both outputs. Select a resistor less than or equal to this value, and no greater than 3 kΩ.

B. **Calculate the minimum value for ΣC_{OUT}** (sum of C_{OUT} at both outputs) using the following two equations.

$$C_{OUT} \geq \frac{0.19 \times R_C \times L_P \times \Sigma I_{LOAD(max)}}{15V \times V_{IN(min)}}$$

and

$$C_{OUT} \geq \frac{V_{IN(min)} \times R_C \times N^2 \times (V_{IN(min)} + (3.74 \times 10^5 \times L_P))}{487{,}800 \times (15V)^2 \times (15V + V_{IN(min)} \times N)}$$

The larger of these two values must be used to ensure regulator stability.

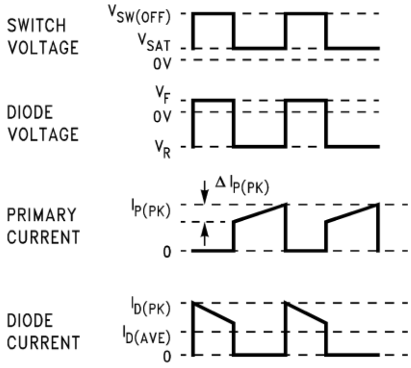


FIGURE 17. Flyback Regulator Waveforms

February
2003

LM3914
Dot/Bar Display Driver

General Description

The LM3914 is a monolithic integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display. A single pin changes the display from a moving dot to a bar graph. Current drive to the LEDs is regulated and programmable, eliminating the need for resistors. This feature is one that allows operation of the whole system from less than 3V.

The circuit contains its own adjustable reference and accurate 10-step voltage divider. The low-bias-current input buffer accepts signals down to ground, or V^{-}, yet needs no protection against inputs of 35V above or below ground. The buffer drives 10 individual comparators referenced to the precision divider. Indication non-linearity can thus be held typically to ½%, even over a wide temperature range.

Versatility was designed into the LM3914 so that controller, visual alarm, and expanded scale functions are easily added on to the display system. The circuit can drive LEDs of many colors, or low-current incandescent lamps. Many LM3914s can be “chained” to form displays of 20 to over 100 segments. Both ends of the voltage divider are externally available so that 2 drivers can be made into a zero-center meter.

The LM3914 is very easy to apply as an analog meter circuit. A 1.2V full-scale meter requires only 1 resistor and a single 3V to 15V supply in addition to the 10 display LEDs. If the 1 resistor is a pot, it becomes the LED brightness control. The simplified block diagram illustrates this extremely simple external circuitry.

When in the dot mode, there is a small amount of overlap or “fade” (about 1 mV) between segments. This assures that at no time will all LEDs be “OFF”, and thus any ambiguous display is avoided. Various novel displays are possible.

Much of the display flexibility derives from the fact that all outputs are individual, DC regulated currents. Various effects can be achieved by modulating these currents. The indi- vidual outputs can drive a transistor as well as a LED at the same time, so controller functions including “staging” control can be performed. The LM3914 can also act as a programmer, or sequencer.

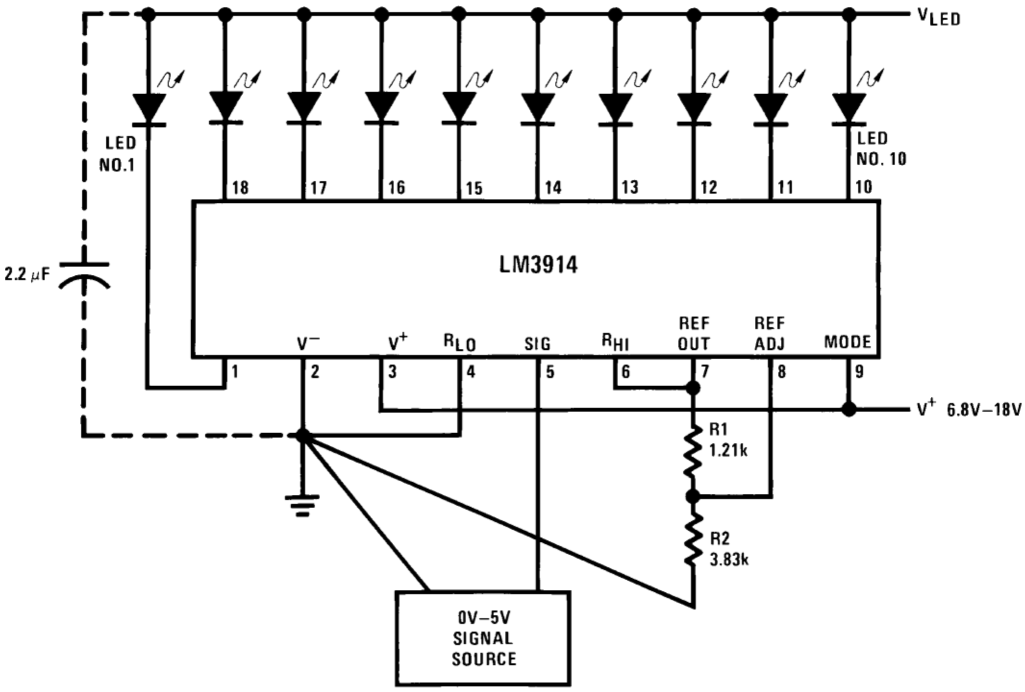
The LM3914 is rated for operation from 0˚C to +70˚C. The LM3914N-1 is available in an 18-lead molded (N) package. The following typical application illustrates adjusting of the reference to a desired value, and proper grounding for accurate operation, and avoiding oscillations.

Features

- Drives LEDs, LCDs or vacuum fluorescents
- Bar or dot display mode externally selectable by user
- Expandable to displays of 100 steps
- Internal voltage reference from 1.2V to 12V
- Operates with single supply of less than 3V
- Inputs operate down to ground
- Output current programmable from 2 mA to 30 mA
- No multiplex switching or interaction between outputs
- Input withstands ±35V without damage or false outputs
- LED driver outputs are current regulated, open-collectors
- Outputs can interface with TTL or CMOS logic
- The internal 10-step divider is floating and can be referenced to a wide range of voltages

Typical Applications

0V to 5V Bar Graph Meter



00797001

$$\text{Ref Out V} = 1.25\left(1 + \frac{R2}{R1}\right)$$

$$I_{LED} \cong \frac{12.5}{R1}$$

Note: Grounding method is typical of *all* uses. The 2.2µF tantalum or 10 µF aluminum electrolytic capacitor is needed if leads to the LED supply are 6" or
longer.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Dissipation (Note 6)	
Molded DIP (N)	1365 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 4)	±35V
Divider Voltage	−100 mV to V^+
Reference Load Current	10 mA
Storage Temperature Range	−55˚C to +150˚C
Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260˚C
Plastic Chip Carrier Package	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 2, 4)

Parameter	Conditions (Note 2)		Min	Typ	Max	Units
COMPARATOR						
Offset Voltage, Buffer and First Comparator	0V ≤ V_{RLO} = V_{RHI} ≤ 12V, I_{LED} = 1 mA			3	10	mV
Offset Voltage, Buffer and Any Other Comparator	0V ≤ V_{RLO} = V_{RHI} ≤ 12V, I_{LED} = 1 mA			3	15	mV
Gain ($\Delta I_{LED}/\Delta V_{IN}$)	$I_{L(REF)}$ = 2 mA, I_{LED} = 10 mA		3	8		mA/mV
Input Bias Current (at Pin 5)	0V ≤ V_{IN} ≤ V^+ − 1.5V			25	100	nA
Input Signal Overvoltage	No Change in Display		−35		35	V
VOLTAGE-DIVIDER						
Divider Resistance	Total, Pin 6 to 4		8	12	17	kΩ
Accuracy	(Note 3)			0.5	2	%
VOLTAGE REFERENCE						
Output Voltage	0.1 mA ≤ $I_{L(REF)}$ ≤ 4 mA, V^+ = V_{LED} = 5V		1.2	1.28	1.34	V
Line Regulation	3V ≤ V^+ ≤ 18V			0.01	0.03	%/V
Load Regulation	0.1 mA ≤ $I_{L(REF)}$ ≤ 4 mA, V^+ = V_{LED} = 5V			0.4	2	%
Output Voltage Change with Temperature	0˚C ≤ T_A ≤ +70˚C, $I_{L(REF)}$ = 1 mA, V^+ = 5V			1		%
Adjust Pin Current				75	120	µA
OUTPUT DRIVERS						
LED Current	V^+ = V_{LED} = 5V, $I_{L(REF)}$ = 1 mA		7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	V_{LED} = 5V	I_{LED} = 2 mA		0.12	0.4	mA
		I_{LED} = 20 mA		1.2	3	
LED Current Regulation	2V ≤ V_{LED} ≤ 17V	I_{LED} = 2 mA		0.1	0.25	mA
		I_{LED} = 20 mA		1	3	
Dropout Voltage	$I_{LED(ON)}$ = 20 mA, V_{LED} = 5V, ΔI_{LED} = 2 mA				1.5	V
Saturation Voltage	I_{LED} = 2.0 mA, $I_{L(REF)}$ = 0.4 mA			0.15	0.4	V
Output Leakage, Each Collector	(Bar Mode) (Note 5)			0.1	10	µA
Output Leakage	(Dot Mode) (Note 5)	Pins 10–18		0.1	10	µA
		Pin 1	60	150	450	µA
SUPPLY CURRENT						
Standby Supply Current (All Outputs Off)	V^+ = 5V, $I_{L(REF)}$ = 0.2 mA			2.4	4.2	mA