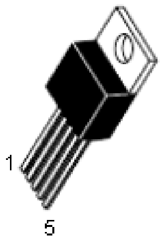
1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

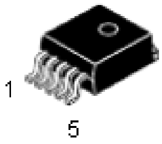
FEATURES

- **Fixed 3.3-V, 5-V, 12-V, and 15-V Options With ±5% Regulation (Max) Over Line, Load, and Temperature Conditions**
- **Adjustable Option With a Range of 1.23 V to 37 V and ±4% Regulation (Max) Over Line, Load, and Temperature Conditions**
- **Specified 1-A Output Current**
- **Wide Input Voltage Range…4.75 V to 40 V**
- **Requires Only Four External Components (Fixed Versions) and Uses Readily Available Standard Inductors**
- **52-kHz (Typ) Fixed-Frequency Internal Oscillator**
- **TTL Shutdown Capability With 50-µA (Typ) Standby Current**
- **High Efficiency…as High as 88% (Typ)**
- **Thermal Shutdown and Current-Limit Protection With Cycle-by-Cycle Current Limiting**



TO−220
T SUFFIX
CASE 314D

Pin 1. V_{in}
2. Output
3. Ground
4. Feedback
5. $\overline{\text{ON}}$/OFF



D^2PAK
D2T SUFFIX
CASE 936A

APPLICATIONS

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

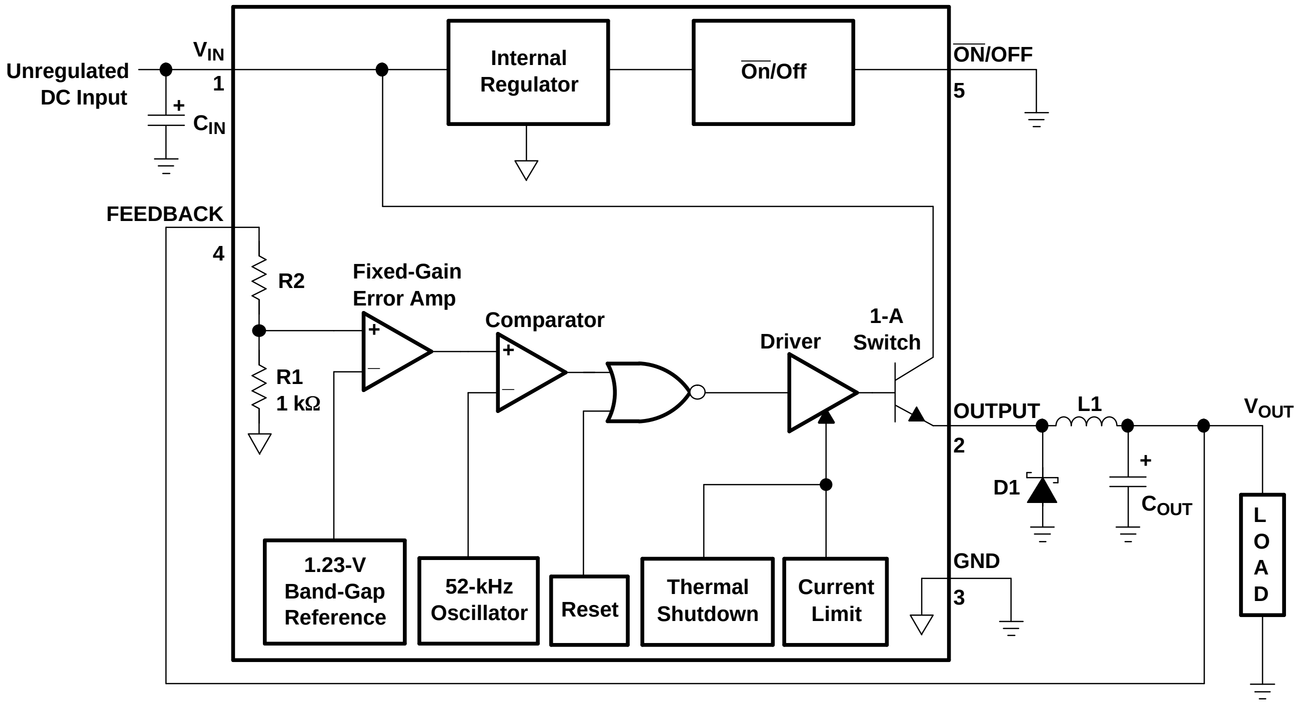
DESCRIPTION/ORDERING INFORMATION

The LM2575 greatly simplifies the design of switching power supplies by conveniently providing all the active functions needed for a step-down (buck) switching regulator in an integrated circuit. Accepting a wide input voltage range and available in fixed output voltages of 3.3 V, 5 V, 12 V, 15 V, or an adjustable output version, the LM2575 has an integrated switch capable of delivering 1 A of load current, with excellent line and load regulation. The device also offers internal frequency compensation, a fixed-frequency oscillator, cycle-by-cycle current limiting, and thermal shutdown. In addition, a manual shutdown is available via an external $\overline{\text{ON}}$/OFF pin.

The LM2575 represents a superior alternative to popular three-terminal linear regulators. Due to its high efficiency, it significantly reduces the size of the heat sink and, in many cases, no heat sink is required. Optimized for use with standard series of inductors available from several different manufacturers, the LM2575 greatly simplifies the design of switch-mode power supplies by requiring a minimal addition of only four to six external components for operation.

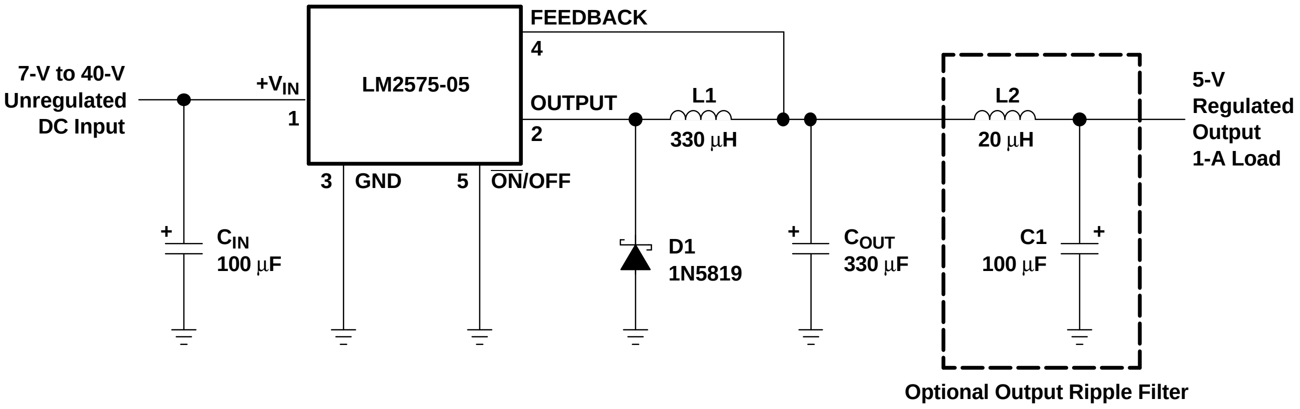
The LM2575 is characterized for operation over the virtual junction temperature range of 0 °C to 85 °C.

FUNCTIONAL BLOCK DIAGRAM



3.3 V: R2 = 1.7 kΩ
5 V: R2 = 3.1 kΩ
12 V: R2 = 8.84 kΩ
15 V: R2 = 11.3 kΩ
ADJ: R1 = Open, R2 = 0 Ω

A. Pin numbers are for the KTT (TO-263) package.



A. Pin numbers are for the KTT (TO-263) package.

Figure 1. Typical Application Circuit (Fixed Version)

Absolute Maximum Ratings(1)

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_{IN}	Supply voltage		42	V
	$\overline{\text{ON}}$/OFF pin input voltage	–0.3	V_{IN}	V
	Output voltage to GND (steady state)		–1	V
T_J	Maximum junction temperature		150	°C
T_{stg}	Storage temperature range	–65	150	°C

(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.

Package Thermal Data(1)

PACKAGE	BOARD	θ_{JC}	θ_{JCB}	θ_{JA}
PDIP (N)	High K, JESD 51-7	51°C/W		67°C/W
TO-263 (KTT)	High K, JESD 51-5		TBD	TBD

(1) Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(\text{max}) – T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_{IN}	Supply voltage	4.75	40	V
T_J	Operating virtual junction temperature	0	85	°C

Electrical Characteristics

I_{LOAD} = 200 mA, V_{IN} = 12 V for 3.3-V, 5-V, and adjustable versions, V_{IN} = 25 V for 12-V version, V_{IN} = 30 V for 15-V version (unless otherwise noted) (see Figure 2)

PARAMETER			TEST CONDITIONS	T_J	MIN	TYP	MAX	UNIT
V_{OUT}	Output voltage	LM2575-33	V_{IN} = 12 V, I_{LOAD} = 0.2 A	25°C	3.234	3.3	3.366	V
			4.75 V ≤ V_{IN} ≤ 40 V, 0.2 A ≤ I_{LOAD} ≤ 1 A	25°C	3.168	3.3	3.432	
				Full range	3.135		3.465	
		LM2575-05	V_{IN} = 12 V, I_{LOAD} = 0.2 A	25°C	4.9	5	5.1	
			8 V ≤ V_{IN} ≤ 40 V, 0.2 A ≤ I_{LOAD} ≤ 1 A	25°C	4.8	5	5.2	
				Full range	4.75		5.25	
		LM2575-12	V_{IN} = 25 V, I_{LOAD} = 0.2 A	25°C	11.76	12	12.24	
			15 V ≤ V_{IN} ≤ 40 V, 0.2 A ≤ I_{LOAD} ≤ 1 A	25°C	11.52	12	12.48	
				Full range	11.4		12.6	
		LM2575-15	V_{IN} = 30 V, I_{LOAD} = 0.2 A	25°C	14.7	15	15.3	
			18 V ≤ V_{IN} ≤ 40 V, 0.2 A ≤ I_{LOAD} ≤ 1 A	25°C	14.4	15	15.6	
				Full range	14.25	15	15.75	
	Feedback voltage	LM2575-ADJ	V_{IN} = 12 V, V_{OUT} = 5 V, I_{LOAD} = 0.2 A	25°C	1.217	1.23	1.243	V
			8 V ≤ V_{IN} ≤ 40 V, V_{OUT} = 5 V, 0.2 A ≤ I_{LOAD} ≤ 1 A	25°C	1.193	1.23	1.267	
				Full range	1.18		1.28	
η	Efficiency	LM2575-33	V_{IN} = 12 V, I_{LOAD} = 1 A	25°C		75		%
		LM2575-05	V_{IN} = 12 V, I_{LOAD} = 1 A			77		
		LM2575-12	V_{IN} = 15 V, I_{LOAD} = 1 A			88		
		LM2575-15	V_{IN} = 18 V, I_{LOAD} = 1 A			88		
		LM2575-ADJ	V_{IN} = 12 V, V_{OUT} = 5 V, I_{LOAD} = 1 A			77		
I_{IB}	Feedback bias current		V_{OUT} = 5 V (ADJ version only)	25°C		50	100	nA
				Full range			500	
f_o	Oscillator frequency		(1)	25°C	47	52	58	kHz
				Full range	42		63	
V_{SAT}	Saturation voltage		I_{OUT} = 1 A(2)	25°C		0.9	1.2	V
				Full range			1.4	
	Maximum duty cycle		(3)	25°C	93	98		%
I_{CL}	Peak current		(1)(2)	25°C	1.7	2.8	3.6	A
				Full range	1.3		4	
I_L	Output leakage current		V_{IN} = 40(4), Output = 0 V	25°C			2	mA
			V_{IN} = 40(4), Output = –1 V			7.5	30	
I_Q	Quiescent current		(4)	25°C		5	10	mA
I_{STBY}	Standby quiescent current		OFF ($\overline{ON}$/OFF pin = 5 V)	25°C		50	200	µA
V_{IH}	$\overline{ON}$/OFF logic input level		OFF (V_{OUT} = 0 V)	25°C	2.2	1.4		V
				Full range	2.4			
V_{IL}			ON (V_{OUT} = nominal voltage)	25°C		1.2	1	
				Full range			0.8	
I_{IH}	$\overline{ON}$/OFF input current		OFF ($\overline{ON}$/OFF pin = 5 V)	25°C		12	30	µA
I_{IL}			OFF ($\overline{ON}$/OFF pin = 0 V)			0	10	

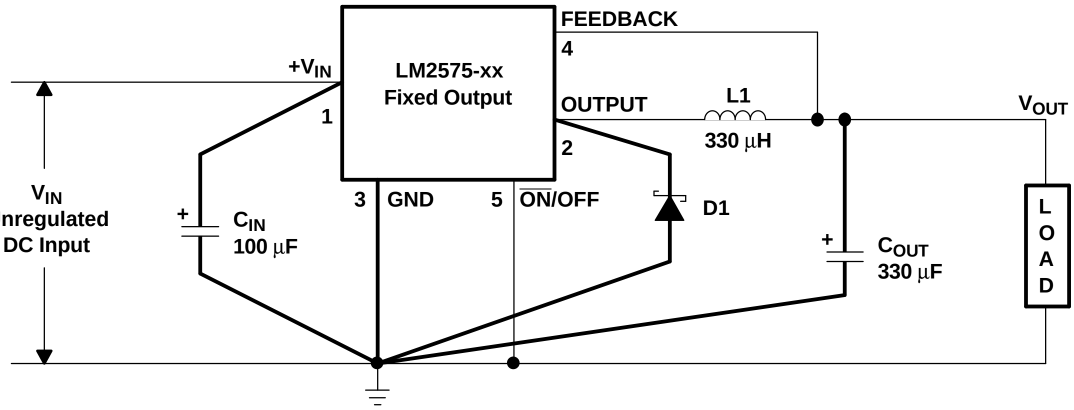
(1) In the event of an output short or an overload condition, self-protection features lower the oscillator frequency to ~18 kHz and the minimum duty cycle from 5% to ~2%. The resulting output voltage drops to ~40% of its nominal value, causing the average power dissipated by the IC to lower.
(2) Output is not connected to diode, inductor, or capacitor. Output is sourcing current.
(3) Feedback is disconnected from output and connected to 0 V.
(4) To force the output transistor off, FEEDBACK is disconnected from output and connected to 12 V for the adjustable, 3.3-V, and 5-V versions; and 25 V for the 12-V and 15-V versions.

APPLICATION INFORMATION

Layout Guidelines

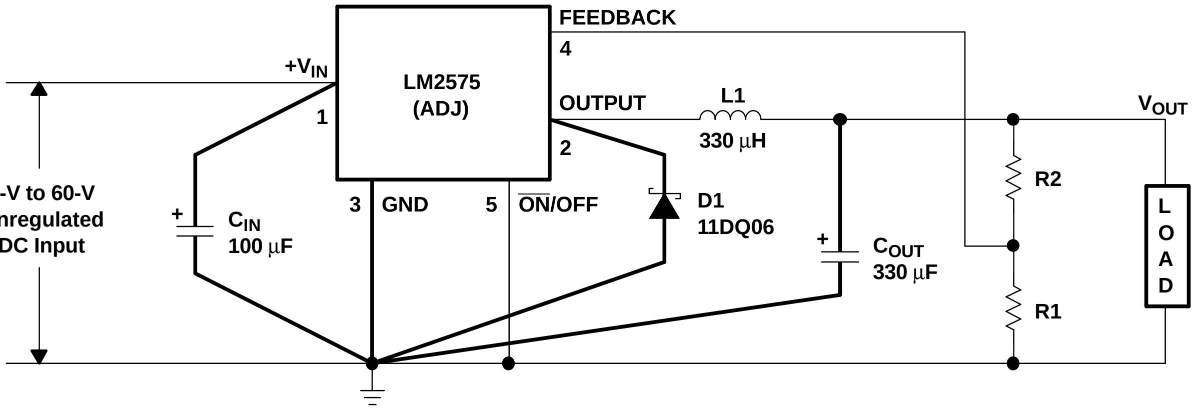
With any switching regulator, circuit layout plays an important role in circuit performance. Wiring and parasitic inductances, as well as stray capacitances, are subjected to rapidly switching currents, which can result in unwanted voltage transients. To minimize inductance and ground loops, the length of the leads indicated by heavy lines should be minimized. Optimal results can be achieved by single-point grounding (see Figure 2) or by ground-plane construction. For the same reasons, the two programming resistors used in the adjustable version should be located as close as possible to the regulator to keep the sensitive feedback wiring short.

Fixed Output Voltage Versions



C_{IN} = 100 µF, Aluminum Electrolytic
C_{OUT} = 330 µF, Aluminum Electrolytic
D1 = Schottky
L1 = 330 µH

Adjustable Output Voltage Versions



$V_{OUT} = V_{REF}(1 + R2/R1) = 5$ V

Where,
V_{REF} = 1.23 V
R1 = 2 kΩ
R2 = 6.12 kΩ

A. Pin numbers are for the KTT (TO-263) package.

Figure 2. Test Circuit and Layout Guidelines

APPLICATION INFORMATION (continued)

Input Capacitor (C_{IN})

For stability concerns, an input bypass capacitor (electrolytic, $C_{IN} \geq 47\ \mu F$) needs to be located as close as possible to the regulator. For operating temperatures below –25°C, C_{IN} may need to be larger in value. In addition, since most electrolytic capacitors have decreasing capacitances and increasing ESR as temperature drops, adding a ceramic or solid tantalum capacitor in parallel increases the stability in cold temperatures.

To extend the capacitor operating lifetime, the capacitor RMS ripple current rating should be:

$I_{C,RMS} > 1.2(\frac{t_{on}}{T})\ I_{LOAD}$, where:

$$\frac{t_{on}}{T} = \frac{V_{OUT}}{V_{IN}}\ \{\text{buck regulator}\},\ \text{and}$$

$$\frac{t_{on}}{T} = \frac{|V_{OUT}|}{(|V_{OUT}| + V_{IN})}\ \{\text{buck−boost regulator}\}$$

Output Capacitor (C_{OUT})

For both loop stability and filtering of ripple voltage, an output capacitor also is required, again in close proximity to the regulator. For best performance, low-ESR aluminum electrolytics are recommended, although standard aluminum electrolytics may be adequate for some applications. Based on the following equation:

Output Ripple Voltage = (ESR of C_{OUT}) × (inductor ripple current)

Output ripple of 50 mV to 150 mV typically can be achieved with capacitor values of 220 µF to 680 µF. Larger C_{OUT} can reduce the ripple 20 mV to 50 mV peak-to-peak. To improve further on output ripple, paralleling of standard electrolytic capacitors may be used. Alternatively, higher-grade capacitors such as “high frequency”, “low inductance”, or “low ESR” can be used.

The following should be taken into account when selecting C_{OUT}:

- At cold temperatures, the ESR of the electrolytic capacitors can rise dramatically (typically 3× nominal value at –25°C). Because solid tantalum capacitors have significantly better ESR specifications at cold temperatures, they should be used at operating temperature lower than –25°C. As an alternative, tantalums also can be paralleled to aluminum electrolytics and should contribute 10% to 20% to the total capacitance.
- Low ESR for C_{OUT} is desirable for low output ripple. However, the ESR should be greater than 0.05 Ω to avoid the possibility of regulator instability. Hence, a sole tantalum capacitor used for C_{OUT} is most susceptible to this occurrence.
- The capacitor’s ripple current rating of 52 kHz should be at least 50% higher than the peak-to-peak inductor ripple current.

Catch Diode

As with other external components, the catch diode should be placed close to the output to minimize unwanted noise. Schottky diodes have fast switching speeds and low forward voltage drops and, thus, offer the best performance, especially for switching regulators with low output voltages ($V_{OUT} < 5$ V). If a high-efficiency, fast-recovery, or ultra-fast-recovery diode is used in place of a Schottky, it should have a soft recovery (versus abrupt turn-off characteristics) to avoid the chance of causing instability and EMI. Standard 50-/60-Hz diodes, such as the 1N4001 or 1N5400 series, are NOT suitable.

Inductor

Proper inductor selection is key to the performance-switching power-supply designs. One important factor to consider is whether the regulator will be used in continuous (inductor current flows continuously and never drops to zero) or in discontinuous mode (inductor current goes to zero during the normal switching cycle). Each mode has distinctively different operating characteristics and, therefore, can affect the regulator performance and requirements. In many applications, the continuous mode is the preferred mode of operation, since it offers greater output power with lower peak currents, and also can result in lower output ripple voltage. The advantages of continuous mode of operation come at the expense of a larger inductor required to keep inductor current continuous, especially at low output currents and/or high input voltages.

APPLICATION INFORMATION (continued)

The LM2575 can operate in either continuous or discontinuous mode. With heavy load currents, the inductor current flows continuously and the regulator operates in continuous mode. Under light load, the inductor fully discharges and the regulator is forced into the discontinuous mode of operation. For light loads (approximately 200 mA or less), this discontinuous mode of operation is perfectly acceptable and may be desirable solely to keep the inductor value and size small. Any buck regulator eventually will operate in discontinuous mode when the load current is light enough.

The type of inductor chosen can have advantages and disadvantages. If high performance/quality is a concern, then more-expensive toroid core inductors are the best choice, as the magnetic flux is contained completely within the core, resulting in less EMI and noise in nearby sensitive circuits. Inexpensive bobbin core inductors, however, generate more EMI as the open core will not confine the flux within the core. Multiple switching regulators located in proximity to each other are particularly susceptible to mutual coupling of magnetic fluxes from each other's open cores. In these situations, closed magnetic structures (such as a toroid, pot core, or E-core) are more appropriate.

Regardless of the type and value of inductor used, the inductor never should carry more than its rated current. Doing so may cause the inductor to saturate, in which case the inductance quickly drops, and the inductor looks like a low-value resistor (from the dc resistance of the windings). As a result, switching current rises dramatically (until limited by the current-by-current limiting feature of the LM2575) and can result in overheating of the inductor and the IC itself. Note that different types of inductors have different saturation characteristics.

Output Voltage Ripple and Transients

As with any switching power supply, the output of the LM2575 will have a sawtooth ripple voltage at the switching frequency. Typically about 1% of the output voltage, this ripple is due mainly to the inductor sawtooth ripple current and the ESR of the output capacitor (see note on C_{OUT}). Furthermore, the output also may contain small voltage spikes at the peaks of the sawtooth waveform. This is due to the fast switching of the output switch and the parasitic inductance of C_{OUT}. These voltage spikes can be minimized through the use of low-inductance capacitors.

There are several ways to reduce the output ripple voltage: a larger inductor, a larger C_{OUT}, or both. Another method is to use a small LC filter (20 µH and 100 µF) at the output. This filter can reduce the output ripple voltage by a factor of 10 (see Figure 2).

Feedback Connection

For fixed voltage options, FEEDBACK must be wired to V_{OUT}. For the adjustable version, FEEDBACK must be connected between the two programming resistors. Again, both of these resistors should be in close proximity to the regulator, and each should be less than 100 kΩ to minimize noise pickup.

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

$\overline{\text{ON}}$/OFF should be grounded or be a low-level TTL voltage (typically <1.6 V) for normal operation. To shut down the LM2575 and put it in standby mode, a high-level TTL or CMOS voltage should be supplied to this pin. $\overline{\text{ON}}$/OFF should not be left open and safely can be pulled up to V_{IN} with or without a pullup resistor.

Grounding

The power and ground connections of the LM2575 must be low impedance to help maintain output stability. For the 5-pin packages, both pin 3 and tab are ground, and either connection can be used as they are both part of the same lead frame. With the 16-pin and 24-pin packages, all the ground pins (including signal and power grounds) should be soldered directly to wide PCB copper traces to ensure low-inductance connections and good thermal dissipation.