

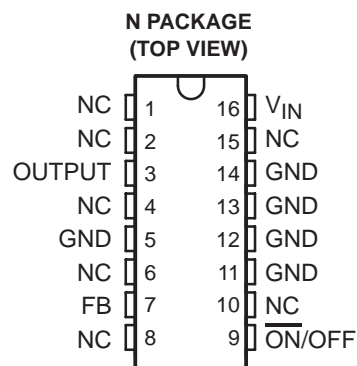
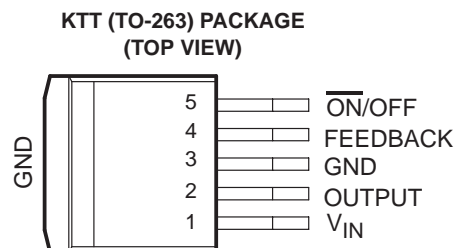
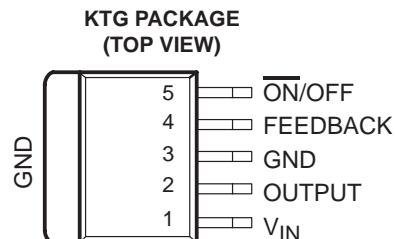
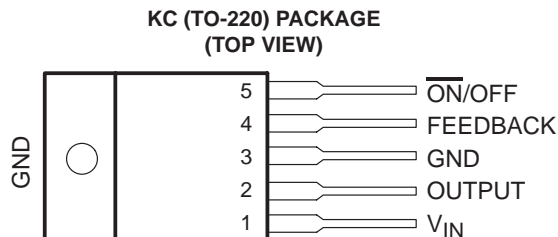
## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

- Fixed 3.3-V, 5-V, 12-V, and 15-V Options With  $\pm 5\%$  Regulation (Max) Over Line, Load, and Temperature Conditions
- Adjustable Option With a Range of 1.23 V to 37 V and  $\pm 4\%$  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- $\mu$ A (Typ) Standby Current
- High Efficiency . . . as High as 88% (Typ)
- Thermal Shutdown and Current Limit Protection With Cycle-by-Cycle Current Limiting
- 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 ON/OFF pin.



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PRODUCT PREVIEW information concerns products in the formative or design phase of development. Characteristic data and other specifications are design goals. Texas Instruments reserves the right to change or discontinue these products without notice.



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PRODUCT PREVIEW

# LM2575

## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

### description/ordering information (continued)

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 now 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  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### ORDERING INFORMATION

$T_J$	$V_O$ (NOM)	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
$-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$	3.3 V	P-DIP (N)	Tube of 25	LM2575-33IN	
	5 V			LM2575-05IN	
	12 V			LM2575-12IN	
	15 V			LM2575-15IN	
	ADJ			LM2575IN	
	3.3 V	PowerFLEX™ (KTG)	Reel of 2000	LM2575-33IKTGR	
	5 V			LM2575-05IKTGR	
	12 V			LM2575-12IKTGR	
	15 V			LM2575-15IKTGR	
	ADJ			LM2575IKTGR	
	3.3 V	TO-220 (KC)	Tube of 50	LM2575-33IKC	
	5 V			LM2575-05IKC	
	12 V			LM2575-12IKC	
	15 V			LM2575-15IKC	
	ADJ			LM2575IKC	
	3.3 V	TO-263 (KTT)	Tube of 50	LM2575-33IKTT	
			Reel of 2000	LM2575-33IKTTR	
	5 V		Tube of 50	LM2575-05IKTT	
			Reel of 2000	LM2575-05IKTTR	
	12 V		Tube of 50	LM2575-12IKTT	
			Reel of 2000	LM2575-12IKTTR	
	15 V		Tube of 50	LM2575-15IKTT	
			Reel of 2000	LM2575-15IKTTR	
	ADJ		Tube of 50	LM2575IKTT	
			Reel of 2000	LM2575IKTTR	

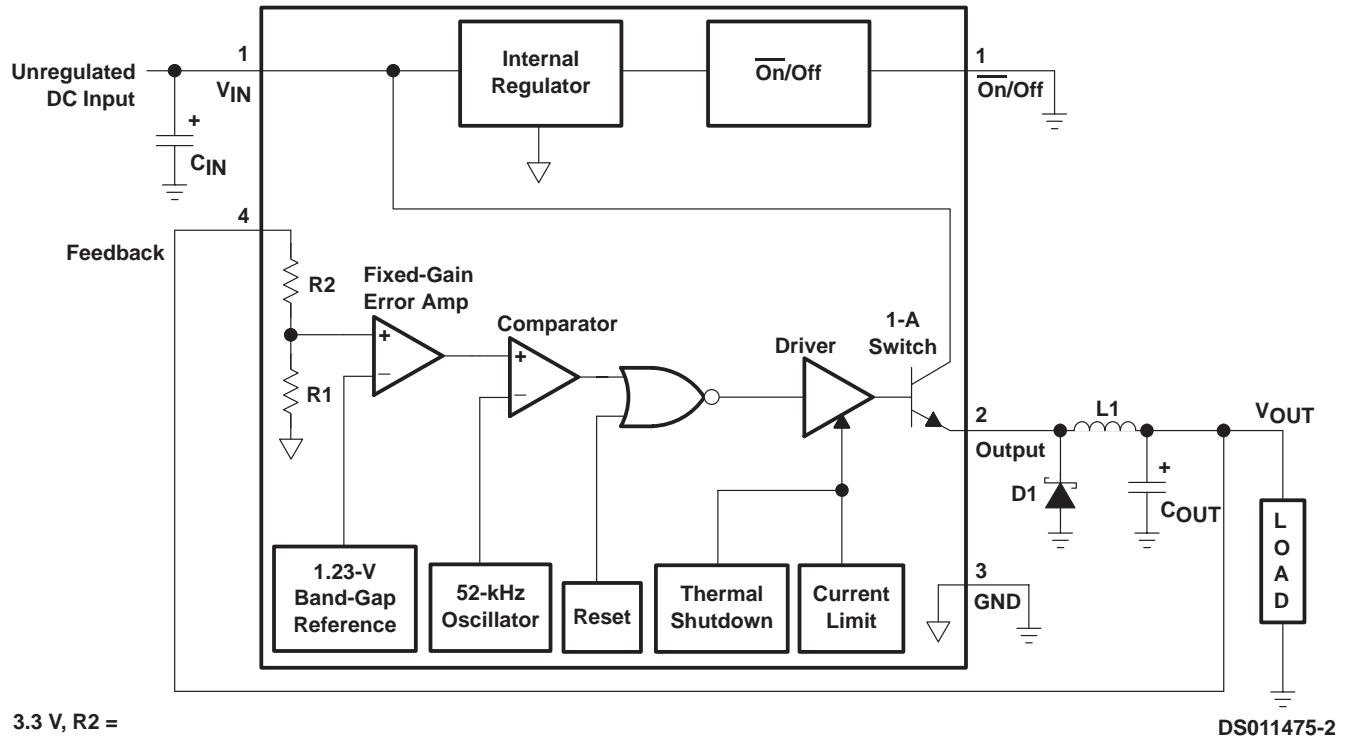
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).

# LM2575

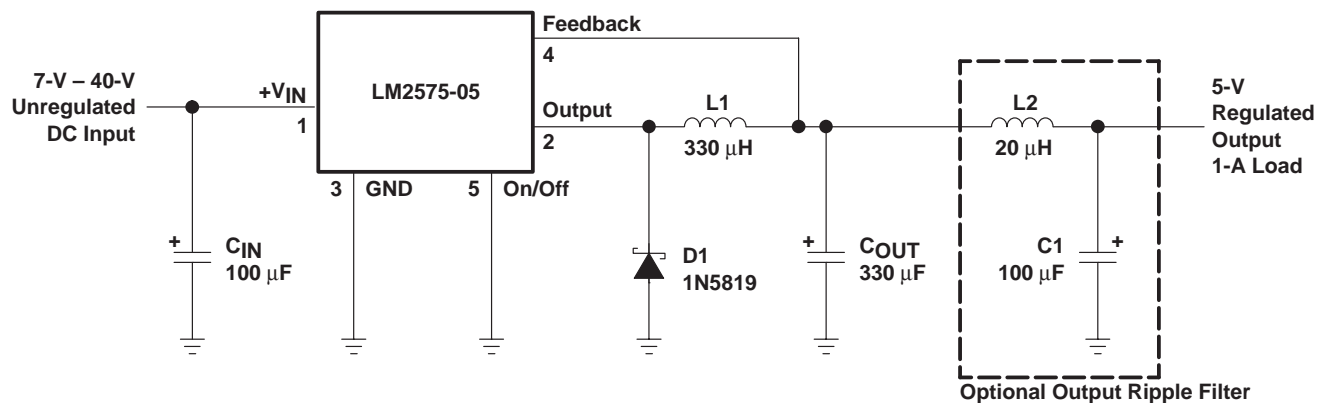
## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

### functional block diagram



### TYPICAL APPLICATION CIRCUIT (FIXED VERSION)



PRODUCT PREVIEW

# LM2575

## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

### absolute maximum ratings over free-air temperature range (unless otherwise noted)<sup>†</sup>

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

<sup>†</sup> 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 (see Note 1)

PACKAGE	BOARD	$\theta_{JC}$	$\theta_{JCB}$	$\theta_{JA}$
P-DIP (N)	High K, JESD 51-7	51°C/W		67°C/W
PowerFLEX™ (KTG)	High K, JESD 51-5		12°C/W	23°C/W
TO-220 (KC)	High K, JESD 51-5		TBD°C/W	TBD°C/W
TO-263 (KTT)	High K, JESD 51-5		TBD°C/W	TBD°C/W

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

### recommended operating conditions

	MIN	MAX	UNIT
$V_{IN}$ Supply voltage	4.75	40	V
$T_J$ Operating virtual junction temperature	–40	125	°C

# LM2575

## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

electrical characteristics at  $I_{LOAD} = 200\text{ mA}$ ;  $V_{IN} = 12\text{ V}$  for the 3.3-V, 5-V, and adjustable versions;  $V_{IN} = 25\text{ V}$  for the 12-V version;  $V_{IN} = 30\text{ V}$  for the 15-V version (unless otherwise noted) (see Figure 2)

PARAMETER		TEST CONDITIONS	T <sub>J</sub>	MIN	TYP†	MAX	UNIT	
V <sub>OUT</sub>	Output voltage	V <sub>IN</sub> = 12 V, I <sub>LOAD</sub> = 0.2 A	25°C	3.234	3.3	3.366	V	
		LM2575-33	4.75 V ≤ V <sub>IN</sub> ≤ 40 V, 0.2 A ≤ I <sub>LOAD</sub> ≤ 1 A	25°C	3.168	3.3		3.432
			Full range	3.135		3.465		
	LM2575-05	V <sub>IN</sub> = 12 V, I <sub>LOAD</sub> = 0.2 A	25°C	4.9	5	5.1		
		8 V ≤ V <sub>IN</sub> ≤ 40 V, 0.2 A ≤ I <sub>LOAD</sub> ≤ 1 A	25°C	4.8	5	5.2		
			Full range	4.75		5.25		
	LM2575-12	V <sub>IN</sub> = 25 V, I <sub>LOAD</sub> = 0.2 A	25°C	11.76	12	12.24		
		15 V ≤ V <sub>IN</sub> ≤ 40 V, 0.2 A ≤ I <sub>LOAD</sub> ≤ 1 A	25°C	11.52	12	12.48		
			Full range	11.4		12.6		
	LM2575-15	V <sub>IN</sub> = 30 V, I <sub>LOAD</sub> = 0.2 A	25°C	14.7	15	15.3		
		18 V ≤ V <sub>IN</sub> ≤ 40 V, 0.2 A ≤ I <sub>LOAD</sub> ≤ 1 A	25°C	14.4	15	15.6		
			Full range	14.25	15	15.75		
Feedback voltage	LM2575-ADJ	V <sub>IN</sub> = 12 V, V <sub>OUT</sub> = 5 V, I <sub>LOAD</sub> = 0.2 A	25°C	1.217	1.23	1.243	V	
		8 V ≤ V <sub>IN</sub> ≤ 40 V, V <sub>OUT</sub> = 5 V, 0.2 A ≤ I <sub>LOAD</sub> ≤ 1 A	25°C	1.193	1.23	1.267		
		Full range	1.18		1.28			
η	Efficiency	LM2575-33	V <sub>IN</sub> = 12 V, I <sub>LOAD</sub> = 1 A	25°C		75	%	
		LM2575-05	V <sub>IN</sub> = 12 V, I <sub>LOAD</sub> = 1 A	25°C		77		
		LM2575-12	V <sub>IN</sub> = 15 V, I <sub>LOAD</sub> = 1 A	25°C		88		
		LM2575-15	V <sub>IN</sub> = 18 V, I <sub>LOAD</sub> = 1 A	25°C		88		
		LM2575-ADJ	V <sub>IN</sub> = 12 V, V <sub>OUT</sub> = 5 V, I <sub>LOAD</sub> = 1 A	25°C		77		
I <sub>IB</sub>	Feedback bias current	V <sub>OUT</sub> = 5 V (ADJ version only)	25°C		50	100	nA	
			Full range			500		
f <sub>o</sub>	Oscillator frequency	See Note 2	25°C	47	52	58	kHz	
			Full range	42		63		
V <sub>SAT</sub>	Saturation voltage	I <sub>OUT</sub> = 1 A (see Note 3)	25°C		0.9	1.2	V	
			Full range			1.4		
Max duty cycle		See Note 4	25°C	93	98		%	
I <sub>CL</sub>	Peak current	See Notes 2 and 3	25°C	1.7	2.2	3	A	
			Full range	1.3		3.2		

- NOTES: 2. In the event of an output short or an overload condition, self-protection features lower the oscillator frequency to  $\sim 18\text{ kHz}$  and the minimum duty cycle from 5% to  $\sim 2\%$ . The resulting output voltage drops to  $\sim 40\%$  of its nominal value, causing the average power dissipated by the IC to lower.
3. Output is not connected to diode, inductor, or capacitor. Output is sourcing current.
4. Feedback is disconnected from output and connected to 0 V.

PRODUCT PREVIEW



LM2575  
1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

electrical characteristics at  $I_{LOAD} = 200\text{ mA}$ ;  $V_{IN} = 12\text{ V}$  for the 3.3-V, 5-V, and adjustable versions;  $V_{IN} = 25\text{ V}$  for the 12-V version;  $V_{IN} = 30\text{ V}$  for the 15-V versions (unless otherwise noted) (continued) (see Figure 2)

PARAMETER		TEST CONDITIONS	$T_J$	MIN	TYP†	MAX	UNIT
$I_L$	Output leakage current	$V_{IN} = 40$ (see Note 5), Output = 0 V	25°C			2	mA
		$V_{IN} = 40$ (see Note 5), Output = -1 V			7.5	30	
$I_Q$	Quiescent current	See Note 5	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 ( $V_{OUT} = 0\text{ V}$ )	25°C	2.2	1.4		V
			Full range	2.4			
$V_{IL}$	$\overline{ON/OFF}$ logic input level	ON ( $V_{OUT} = \text{nominal voltage}$ )	25°C		1.2	1	V
			Full range			0.8	
$I_{IH}$	$\overline{ON/OFF}$ input current	OFF ( $\overline{ON/OFF}$ pin = 5 V)	25°C		12	30	μA
$I_{IL}$		ON ( $\overline{ON/OFF}$ pin = 0 V)	25°C		0	10	μA

NOTE 5: 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.

# LM2575

## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

### test circuit and layout guidelines

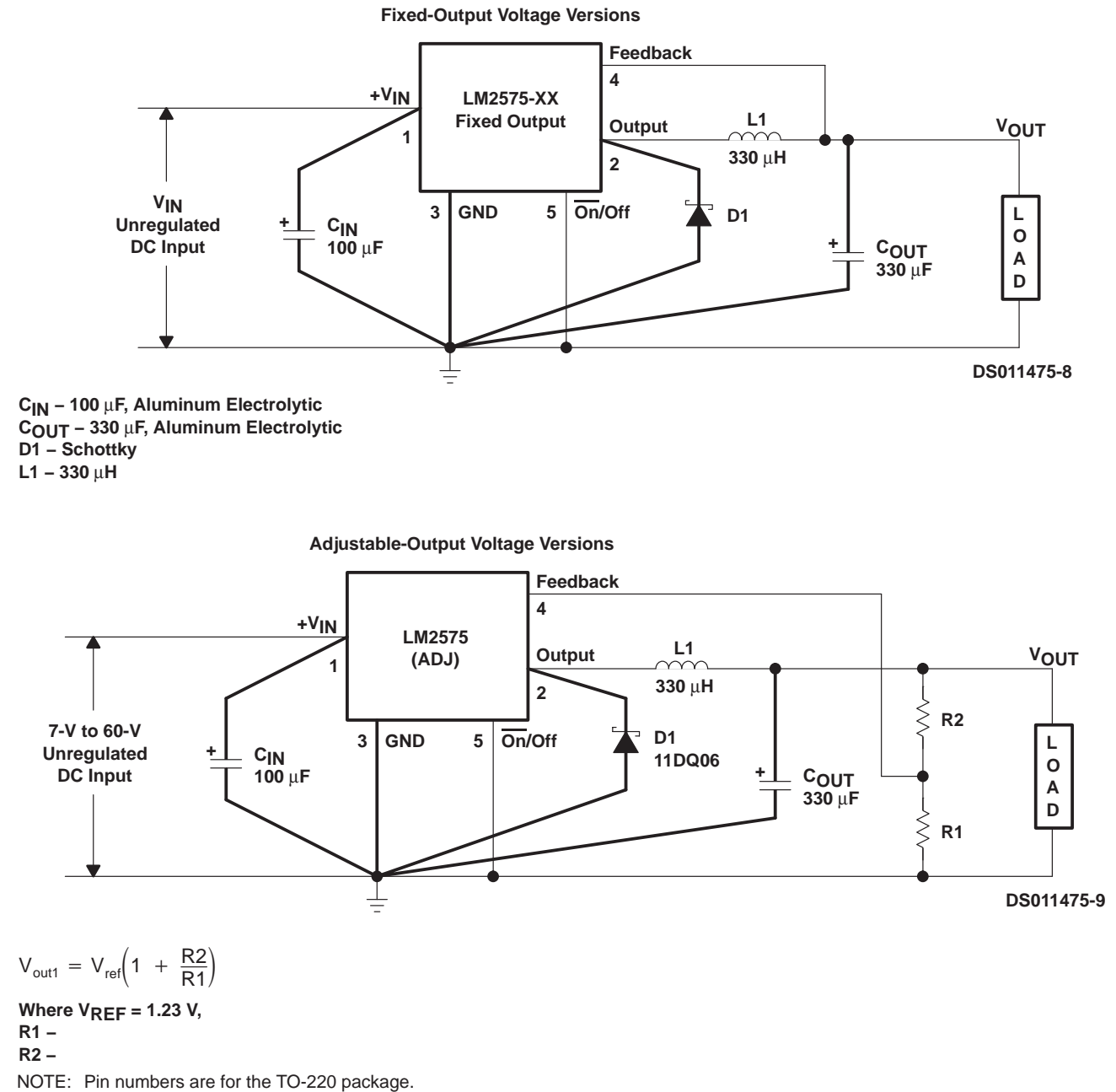


Figure 2

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# **LM2575**

## **1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR**

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

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### **TYPICAL OPERATING CHARACTERISTICS**

**$T_A = 25^\circ\text{C}$  (unless otherwise noted)**

**Figure 3. Normalized Output Voltage**

**Figure 4. Line Regulation**

**Figure 5. Dropout Voltage**

**Figure 6. Current Limit**

**Figure 7. Quiescent Current**

**Figure 8. Standby Quiescent Current**

**Figure 9. Quiescent Current vs. Duty Cycle**

**Figure 10. Oscillator Frequency**

**Figure 11. Switch Saturation Voltage**

**Figure 12. Efficiency**

**Figure 13. Minimum Operating Voltage (Adjustable Version)**

**Figure 14. Feedback Voltage vs. Duty Cycle**

**Figure 15. Feedback Pin Current (Adjustable Version)**

**Figure 16. Switching Waveforms**

**Figure 17. Load Transient Response**

**PRODUCT PREVIEW**





## APPLICATION INFORMATION

## layout guidelines (see Figure 2)

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 (as illustrated) 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.

input capacitor ( $C_{IN}$ )

For stability concerns, an input bypass capacitor (electrolytic,  $C_{IN} \geq 47 \mu\text{F}$ ) needs to be located as close as possible to the regulator. For operating temperatures below  $-25^{\circ}\text{C}$ ,  $C_{IN}$  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 will increase the stability in cold temperatures.

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

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

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

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

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 equation below:

$$\text{Output Ripple Voltage} = (\text{ESR of } C_{OUT}) \times (\text{inductor ripple current})$$

50 mV to 150 mV of output ripple typically can be achieved with capacitor values of 220  $\mu\text{F}$  to 680  $\mu\text{F}$ . Larger  $C_{OUT}$  can reduce the ripple 20 mV – 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  $C_{OUT}$ :

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

# LM2575

## 1-A SIMPLE STEP-DOWN SWITCHING VOLTAGE REGULATOR

SLVS569A – JANUARY 2005 – REVISED FEBRUARY 2005

### APPLICATION INFORMATION

#### 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 ( $V_{OUT} < 5\text{ V}$ ). 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.

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 will drop and the inductor will look like a low-value resistor (from the dc resistance of the windings). As a result, switching current will rise 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.

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## APPLICATION INFORMATION

**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  $\mu$ H and 100  $\mu$ F) at the output; this filter can reduce the output ripple voltage by a factor of 10 (see typical application circuit, Figure 1).

**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 k $\Omega$  to minimize noise pickup.

 **$\overline{ON/OFF}$  input**

$\overline{ON/OFF}$  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.  $\overline{ON/OFF}$  should not be left open and safely can be pulled up to  $V_{IN}$  with or without a pullup resistor.

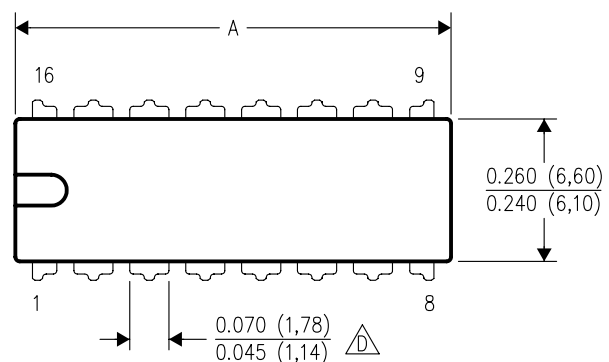
**grounding**

The power and ground connections of the LM2575 need to 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.

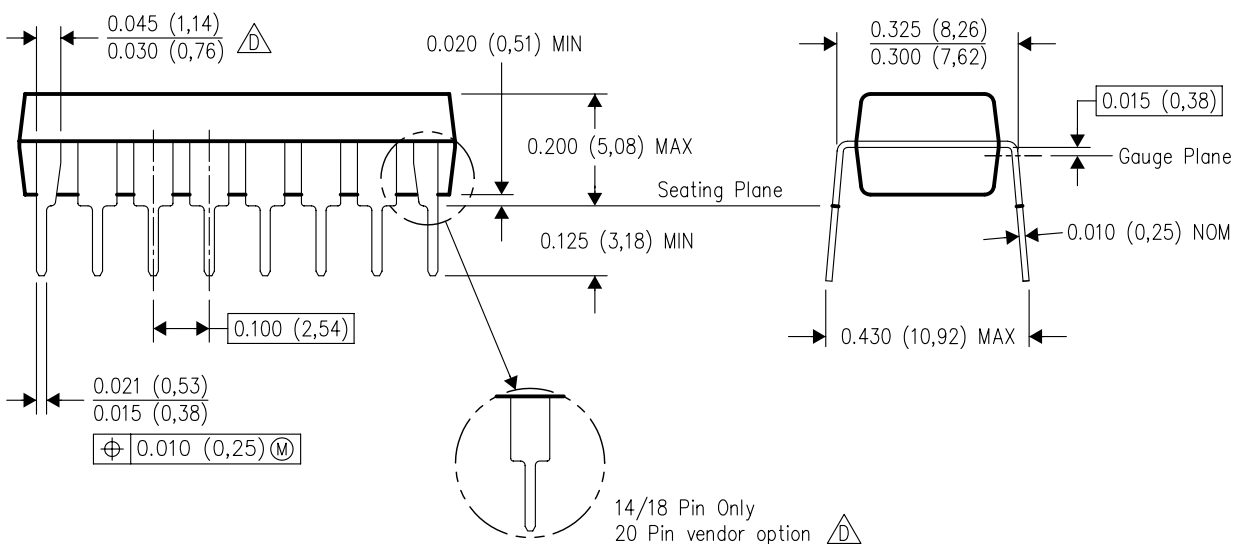
N (R-PDIP-T\*\*)

16 PINS SHOWN

## PLASTIC DUAL-IN-LINE PACKAGE





PINS ** DIM	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-001 VARIATION	AA	BB	AC	AD



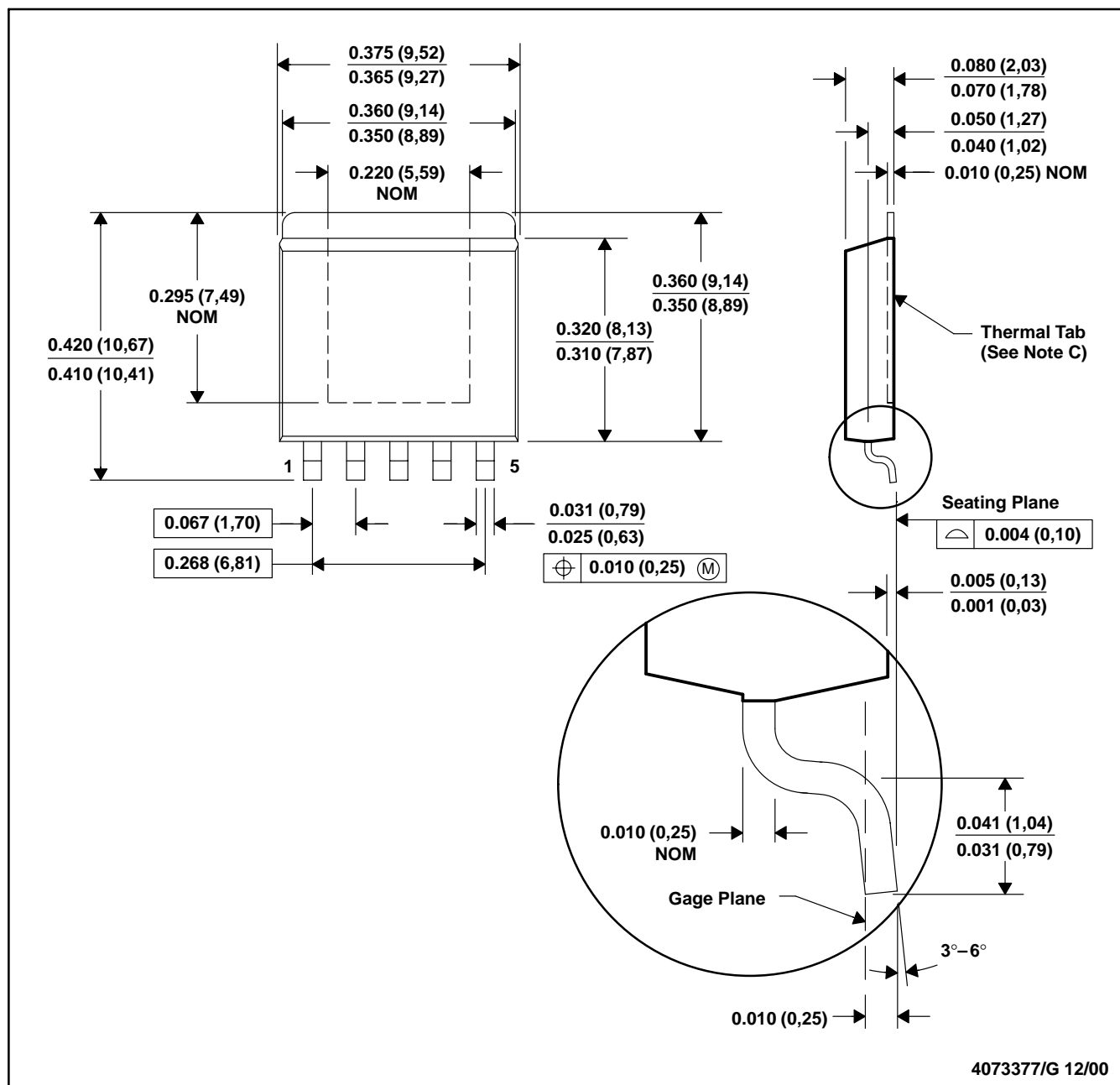
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NOTES:

- A. All linear dimensions are in inches (millimeters).  
B. This drawing is subject to change without notice.
-  Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).  
 The 20 pin end lead shoulder width is a vendor option, either half or full width.

## KTG (R-PSFM-G5)

## PowerFLEX™ PLASTIC FLANGE-MOUNT PACKAGE



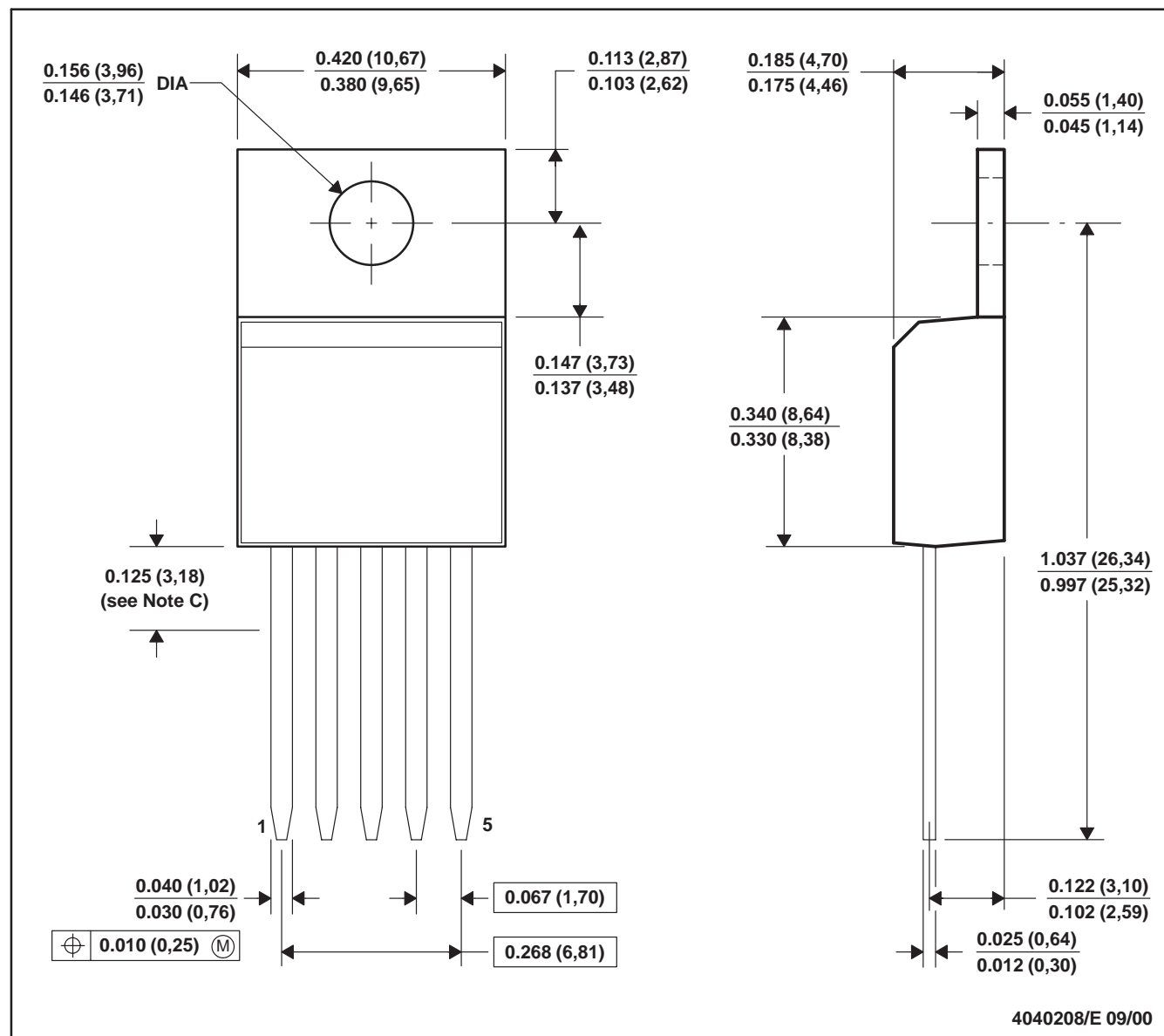
- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - The center lead is in electrical contact with the thermal tab.
  - Dimensions do not include mold protrusions, not to exceed 0.006 (0,15).
  - Falls within JEDEC MO-169

PowerFLEX is a trademark of Texas Instruments.



## KC (R-PSFM-T5)

## PLASTIC FLANGE-MOUNT



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Lead dimensions are not controlled within this area.  
 D. All lead dimensions apply before solder dip.  
 E. The center lead is in electrical contact with the mounting tab.

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