

## LM2705

# Micropower Step-up DC/DC Converter with 150mA Peak Current Limit

### General Description

The LM2705 is a micropower step-up DC/DC in a small 5-lead SOT-23 package. A current limited, fixed off-time control scheme conserves operating current resulting in high efficiency over a wide range of load conditions. The 21V switch allows for output voltages as high as 20V. The low 400ns off-time permits the use of tiny, low profile inductors and capacitors to minimize footprint and cost in space-conscious portable applications. The LM2705 is ideal for LCD panels requiring low current and high efficiency as well as white LED applications for cellular phone back-lighting. The LM2705 can drive up to 3 white LEDs from a single Li-Ion battery. The low peak inductor current of the LM2705 makes it ideal for USB applications.

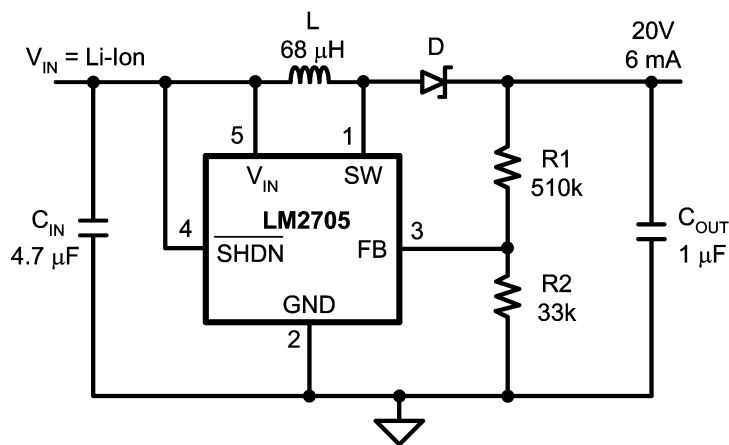
### Features

- 150mA, 0.7 $\Omega$ , internal switch
- Uses small surface mount components
- Adjustable output voltage up to 20V
- 2.2V to 7V input range
- Input undervoltage lockout
- 0.01 $\mu$ A shutdown current
- Small 5-Lead SOT-23 package

### Applications

- LCD Bias Supplies
- White LED Back-Lighting
- Handheld Devices
- Digital Cameras
- Portable Applications

### Typical Application Circuit

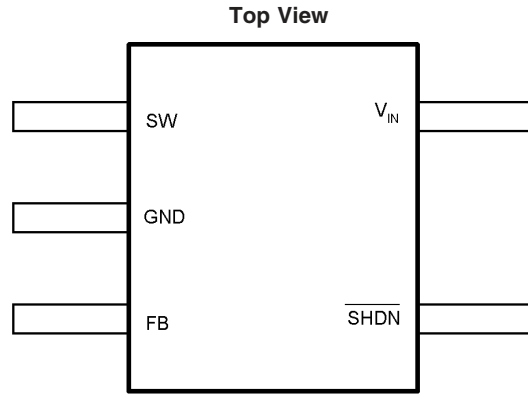


$C_{IN}$ : Taiyo Yuden Ceramic  
 $C_{OUT}$ : Taiyo Yuden Ceramic  
 L: Coilcraft DT1608C-683  
 D: ON Semiconductor MBRM130LT3

20039701

FIGURE 1. Typical 20V Application

## Connection Diagram



20039702

SOT23-5

 $T_{Jmax} = 125^{\circ}\text{C}$ ,  $\theta_{JA} = 220^{\circ}\text{C/W}$  (Note 2)

## Ordering Information

Order Number	Package Type	NSC Package Drawing	Top Mark	Supplied As
LM2705MF-ADJ	SOT23-5	MA05B	S59B	1000 Units, Tape and Reel
LM2705MFX-ADJ	SOT23-5	MA05B	S59B	3000 Units, Tape and Reel

## Pin Description/Functions

Pin	Name	Function
1	SW	Power Switch input.
2	GND	Ground.
3	FB	Output voltage feedback input.
4	SHDN	Shutdown control input, active low.
5	V <sub>IN</sub>	Analog and Power input.

**SW(Pin 1):** Switch Pin. This is the drain of the internal NMOS power switch. Minimize the metal trace area connected to this pin to minimize EMI.

**GND(Pin 2):** Ground Pin. Tie directly to ground plane.

**FB(Pin 3):** Feedback Pin. Set the output voltage by selecting values for R1 and R2 using:

$$R1 = R2 \left( \frac{V_{OUT}}{1.237V} - 1 \right)$$

Connect the ground of the feedback network to an AGND plane which should be tied directly to the GND pin.

**SHDN(Pin 4):** Shutdown Pin. The shutdown pin is an active low control. Tie this pin above 1.1V to enable the device. Tie this pin below 0.3V to turn off the device.

**V<sub>IN</sub>(Pin 5):** Input Supply Pin. Bypass this pin with a capacitor as close to the device as possible.

**Absolute Maximum Ratings** (Note 1)

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

$V_{IN}$	7.5V
SW Voltage	21V
FB Voltage	2V
$\overline{SHDN}$ Voltage	7.5V
Maximum Junction Temp. $T_J$ (Note 2)	150°C
Lead Temperature (Soldering 10 sec.)	300°C
Vapor Phase (60 sec.)	215°C

Infrared (15 sec.)	220°C
ESD Ratings (Note 3)	
Human Body Model	2kV
Machine Model (Note 4)	200V

**Operating Conditions**

Junction Temperature (Note 5)	-40°C to +125°C
Supply Voltage	2.2V to 7V
SW Voltage Max.	20.5V

**Electrical Characteristics**

Specifications in standard type face are for  $T_J = 25^\circ\text{C}$  and those in **boldface type** apply over the full **Operating Temperature Range** ( $T_J = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ ). Unless otherwise specified  $V_{IN} = 2.2\text{V}$ .

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max (Note 5)	Units
$I_Q$	Device Disabled	FB = 1.3V		40	<b>70</b>	$\mu\text{A}$
	Device Enabled	FB = 1.2V		235	<b>300</b>	
	Shutdown	$\overline{SHDN} = 0\text{V}$		0.01	2.5	
$V_{FB}$	Feedback Trip Point		<b>1.189</b>	1.237	<b>1.269</b>	V
$I_{CL}$	Switch Current Limit		110 <b>100</b>	150	175 <b>180</b>	mA
$I_B$	FB Pin Bias Current	FB = 1.23V (Note 7)		30	<b>120</b>	nA
$V_{IN}$	Input Voltage Range		<b>2.2</b>		<b>7.0</b>	V
$R_{DSON}$	Switch $R_{DSON}$			0.7	<b>1.6</b>	$\Omega$
$T_{OFF}$	Switch Off Time			400		ns
$I_{SD}$	$\overline{SHDN}$ Pin Current	$\overline{SHDN} = V_{IN}, T_J = 25^\circ\text{C}$		0	80	nA
		$\overline{SHDN} = V_{IN}, T_J = 125^\circ\text{C}$		15		
		$\overline{SHDN} = \text{GND}$		0		
$I_L$	Switch Leakage Current	$V_{SW} = 20\text{V}$		0.05	5	$\mu\text{A}$
UVP	Input Undervoltage Lockout	ON/OFF Threshold		1.8		V
$V_{FB}$ Hysteresis	Feedback Hysteresis			8		mV
$\overline{SHDN}$ Threshold	$\overline{SHDN}$ low			0.7	<b>0.3</b>	V
	$\overline{SHDN}$ High		<b>1.1</b>	0.7		
$\theta_{JA}$	Thermal Resistance			220		$^\circ\text{C/W}$

**Note 1:** Absolute maximum ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions for which the device is intended to be functional, but device parameter specifications may not be guaranteed. For guaranteed specifications and test conditions, see the Electrical Characteristics.

**Note 2:** The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_{J(\text{MAX})}$ , the junction-to-ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . See the Electrical Characteristics table for the thermal resistance. The maximum allowable power dissipation at any ambient temperature is calculated using:  $P_D(\text{MAX}) = (T_{J(\text{MAX})} - T_A)/\theta_{JA}$ . Exceeding the maximum allowable power dissipation will cause excessive die temperature.

**Note 3:** The human body model is a 100 pF capacitor discharged through a 1.5 k $\Omega$  resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.

**Note 4:** ESD susceptibility using the machine model is 150V for SW pin.

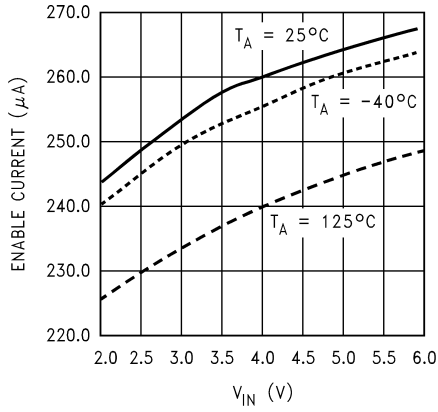
**Note 5:** All limits guaranteed at room temperature (standard typeface) and at temperature extremes (bold typeface). All room temperature limits are 100% production tested or guaranteed through statistical analysis. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

**Note 6:** Typical numbers are at 25°C and represent the most likely norm.

**Note 7:** Feedback current flows into the pin.

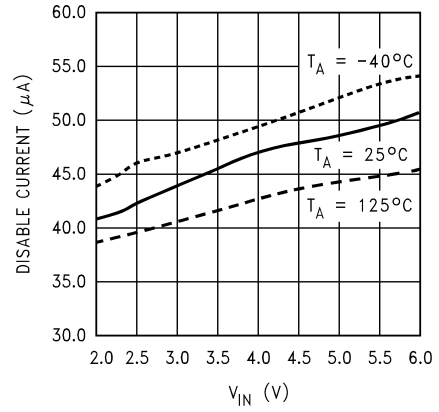
# Typical Performance Characteristics

**Enable Current vs  $V_{IN}$   
(Part Switching)**



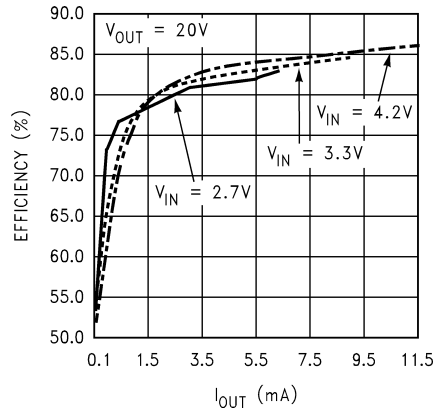
20039705

**Disable Current vs  $V_{IN}$   
(Part Not Switching)**



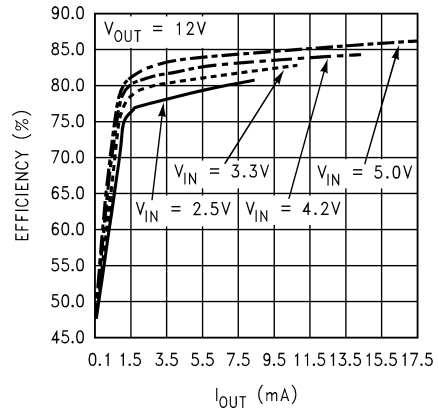
20039706

**Efficiency vs Load Current**



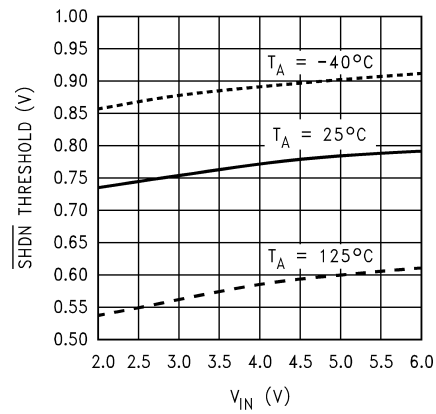
20039724

**Efficiency vs Load Current**



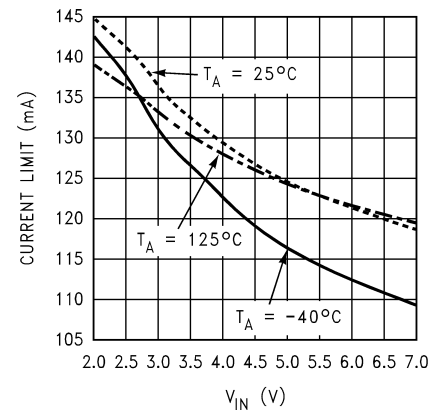
20039725

**SHDN Threshold vs  $V_{IN}$**



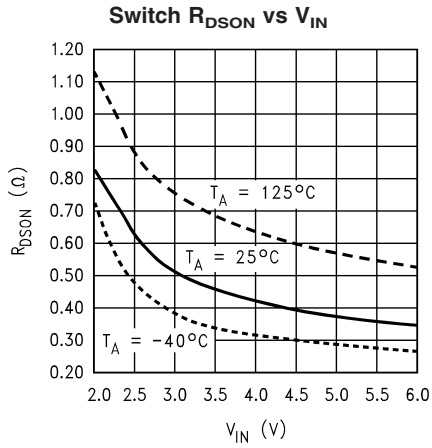
20039713

**Switch Current Limit vs  $V_{IN}$**

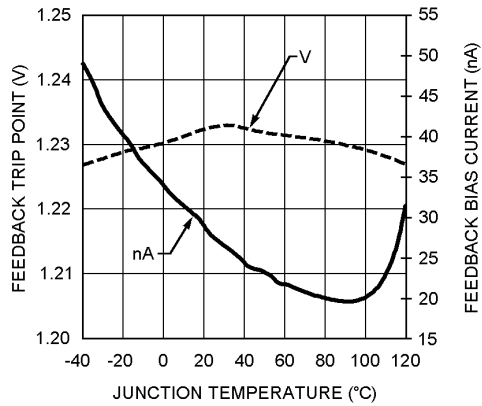


20039737

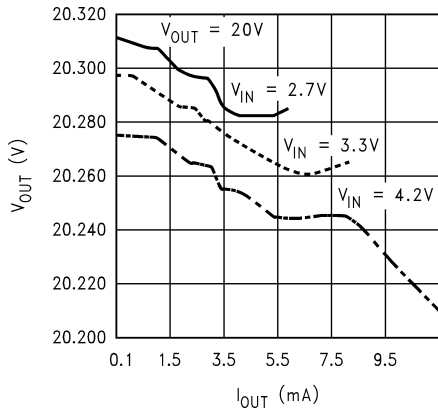
# Typical Performance Characteristics (Continued)



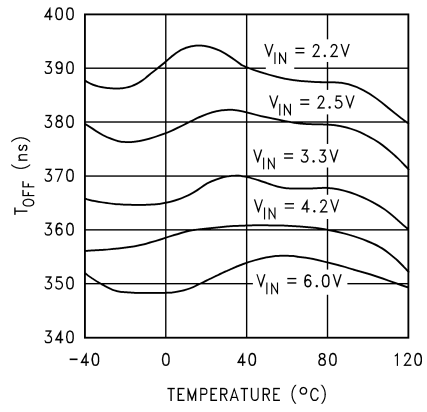
### FB Trip Point and FB Pin Current vs Temperature



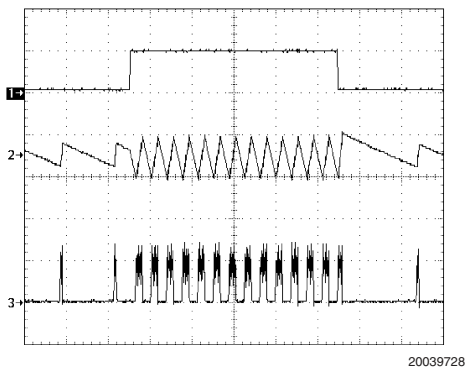
### Output Voltage vs Load Current



### Off Time vs Temperature

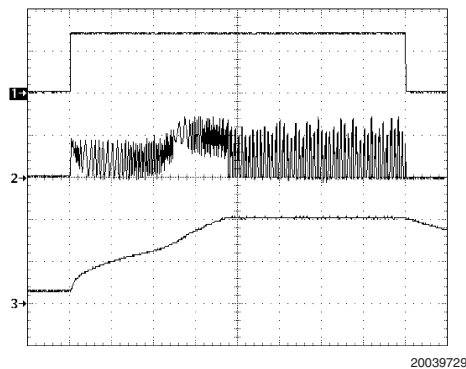


### Step Response



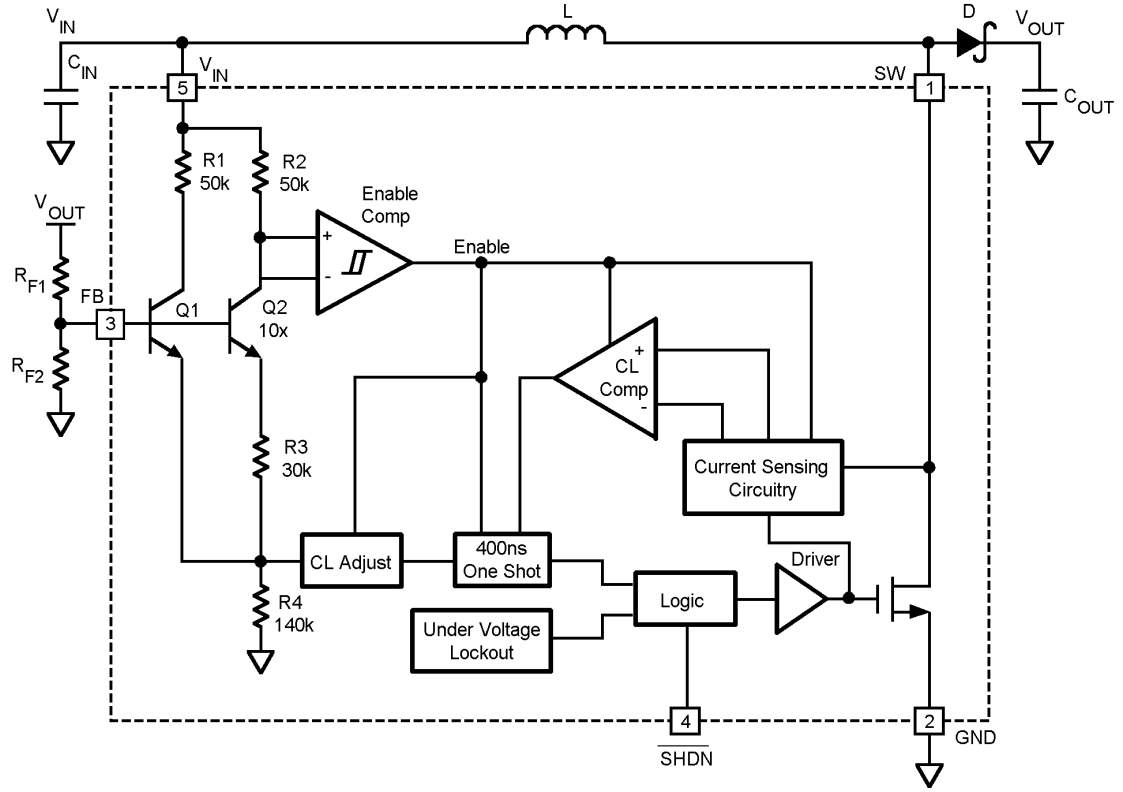
$V_{OUT} = 20V$ ,  $V_{IN} = 3.0V$   
 1) Load, 0.5mA to 5mA to 0.5mA, DC  
 2)  $V_{OUT}$ , 200mV/div, AC  
 3)  $I_L$ , 100mA/div, DC  
 T = 100 $\mu$ s/div

### Start-Up/Shutdown



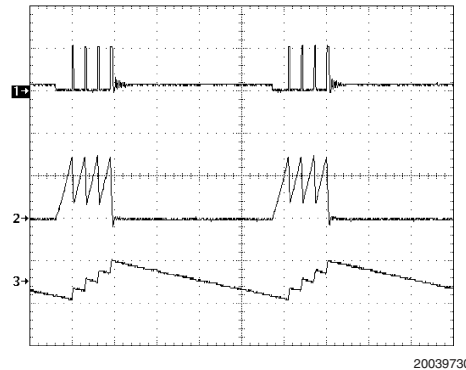
$V_{OUT} = 20V$ ,  $V_{IN} = 3.0V$   
 1) SHDN, 1V/div, DC  
 2)  $I_L$ , 100mA/div, DC  
 3)  $V_{OUT}$ , 10V/div, DC  
 T = 400 $\mu$ s/div  
 $R_L = 3.9k\Omega$

# Operation



20039704

FIGURE 2. LM2705 Block Diagram



20039730

$V_{OUT} = 20V, V_{IN} = 2.7V, I_{OUT} = 2.5mA$   
 1)  $V_{SW}$ , 20V/div, DC  
 2) Inductor Current, 100mA/div, DC  
 3)  $V_{OUT}$ , 200mV/div, AC  
 T = 10 $\mu$ s/div

FIGURE 3. Typical Switching Waveform

## Operation (Continued)

The LM2705 features a constant off-time control scheme. Operation can be best understood by referring to *Figure 2* and *Figure 3*. Transistors Q1 and Q2 and resistors R3 and R4 of *Figure 2* form a bandgap reference used to control the output voltage. When the voltage at the FB pin is less than 1.237V, the Enable Comp in *Figure 2* enables the device and the NMOS switch is turned on pulling the SW pin to ground. When the NMOS switch is on, current begins to flow through inductor L while the load current is supplied by the output capacitor  $C_{OUT}$ . Once the current in the inductor reaches the current limit, the CL Comp trips and the 400ns One Shot turns off the NMOS switch. The SW voltage will then rise to the output voltage plus a diode drop and the inductor current will begin to decrease as shown in *Figure 3*. During this time the energy stored in the inductor is transferred to  $C_{OUT}$  and the load. After the 400ns off-time the NMOS switch is turned on and energy is stored in the inductor again. This energy transfer from the inductor to the output causes a stepping effect in the output ripple as shown in *Figure 3*.

This cycle is continued until the voltage at FB reaches 1.237V. When FB reaches this voltage, the enable comparator then disables the device turning off the NMOS switch and reducing the  $I_q$  of the device to 40 $\mu$ A. The load current is then supplied solely by  $C_{OUT}$  indicated by the gradually decreasing slope at the output as shown in *Figure 3*. When the FB pin drops slightly below 1.237V, the enable comparator enables the device and begins the cycle described previously. The SHDN pin can be used to turn off the LM2705 and reduce the  $I_q$  to 0.01 $\mu$ A. In shutdown mode the output voltage will be a diode drop lower than the input voltage.

## Application Information

### INDUCTOR SELECTION - BOOST REGULATOR

The appropriate inductor for a given application is calculated using the following equation:

$$L = \left( \frac{V_{OUT} - V_{IN(min)} + V_D}{I_{CL}} \right) T_{OFF}$$

where  $V_D$  is the schottky diode voltage,  $I_{CL}$  is the switch current limit found in the *Typical Performance Characteristics* section, and  $T_{OFF}$  is the switch off time. When using this equation be sure to use the minimum input voltage for the application, such as for battery powered applications. For the LM2705 constant-off time control scheme, the NMOS power switch is turned off when the current limit is reached. There is approximately a 200ns delay from the time the current limit is reached in the NMOS power switch and when the internal logic actually turns off the switch. During this 200ns delay, the peak inductor current will increase. This increase in inductor current demands a larger saturation current rating for the inductor. This saturation current can be approximated by the following equation:

$$I_{PK} = I_{CL} + \left( \frac{V_{IN(max)}}{L} \right) 200ns$$

Choosing inductors with low ESR decrease power losses and increase efficiency.

Care should be taken when choosing an inductor. For applications that require an input voltage that approaches the

output voltage, such as when converting a Li-Ion battery voltage to 5V, the 400ns off time may not be enough time to discharge the energy in the inductor and transfer the energy to the output capacitor and load. This can cause a ramping effect in the inductor current waveform and an increased ripple on the output voltage. Using a smaller inductor will cause the  $I_{PK}$  to increase and will increase the output voltage ripple further.

For typical curves and evaluation purposes the DT1608C series inductors from Coilcraft were used. Other acceptable inductors would include, but are not limited to, the SLF6020T series from TDK, the NP05D series from Taiyo Yuden, the CDRH4D18 series from Sumida, and the P1166 series from Pulse.

### INDUCTOR SELECTION - SEPIC REGULATOR

The following equation can be used to calculate the approximate inductor value for a SEPIC regulator:

$$L2 = 2 \left( \frac{V_{OUT} + V_D}{I_{CL}} \right) T_{OFF}$$

The boost inductor,  $L1$ , can be smaller or larger but is generally chosen to be the same value as  $L2$ . See *Figure 8* and *Figure 9* for typical SEPIC applications.

### DIODE SELECTION

To maintain high efficiency, the average current rating of the schottky diode should be larger than the peak inductor current,  $I_{PK}$ . Schottky diodes with a low forward drop and fast switching speeds are ideal for increasing efficiency in portable applications. Choose a reverse breakdown of the schottky diode larger than the output voltage.

### CAPACITOR SELECTION

Choose low ESR capacitors for the output to minimize output voltage ripple. Multilayer ceramic capacitors are the best choice. For most applications, a 1 $\mu$ F ceramic capacitor is sufficient. For some applications a reduction in output voltage ripple can be achieved by increasing the output capacitor. Output voltage ripple can further be reduced by adding a 4.7pF feed-forward capacitor in the feedback network placed in parallel with RF1, see *Figure 2*.

Local bypassing for the input is needed on the LM2705. Multilayer ceramic capacitors are a good choice for this as well. A 4.7 $\mu$ F capacitor is sufficient for most applications. For additional bypassing, a 100nF ceramic capacitor can be used to shunt high frequency ripple on the input.

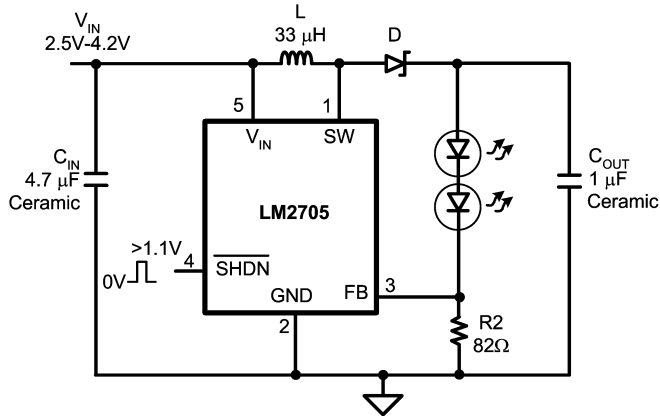
### LAYOUT CONSIDERATIONS

The input bypass capacitor  $C_{IN}$ , as shown in *Figure 1*, must be placed close to the IC. This will reduce copper trace resistance which effects input voltage ripple of the IC. For additional input voltage filtering, a 100nF bypass capacitor can be placed in parallel with  $C_{IN}$  to shunt any high frequency noise to ground. The output capacitor,  $C_{OUT}$ , should also be placed close to the IC. Any copper trace connections for the  $C_{OUT}$  capacitor can increase the series resistance, which directly effects output voltage ripple. The feedback network, resistors R1 and R2, should be kept close to the FB pin to minimize copper trace connections that can inject noise into the system. The ground connection for the feedback resistor network should connect directly to an analog ground plane. The analog ground plane should tie directly to the GND pin. If no analog ground plane is available, the

## Application Information (Continued)

ground connection for the feedback network should tie di-

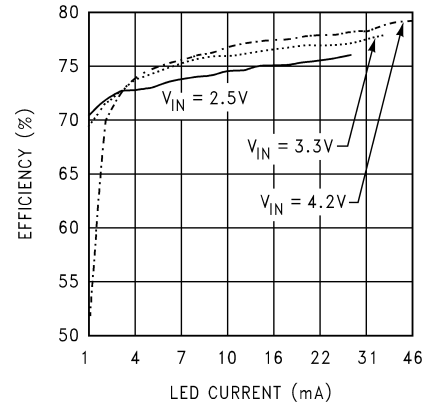
rectly to the GND pin. Trace connections made to the inductor and schottky diode should be minimized to reduce power dissipation and increase overall efficiency.



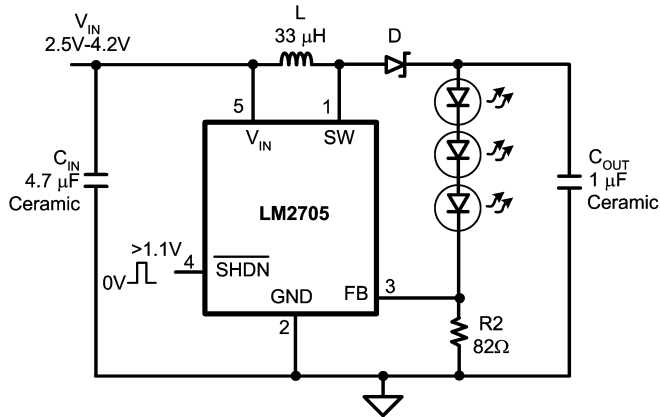
$C_{IN}$ : Taiyo Yuden Ceramic  
 $C_{OUT}$ : Taiyo Yuden Ceramic  
 L: Coilcraft DT1608C-333  
 D: ON Semiconductor MBRM130LT3

20039709

FIGURE 4. 2 White LED Application and Efficiency



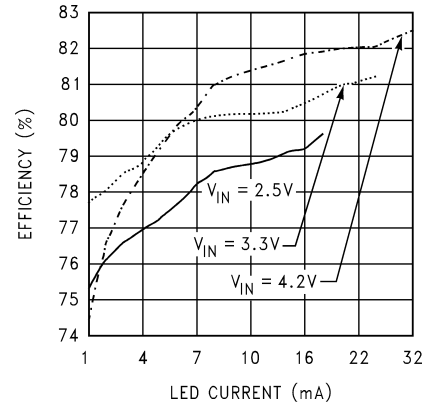
20039742



$C_{IN}$ : Taiyo Yuden Ceramic  
 $C_{OUT}$ : Taiyo Yuden Ceramic  
 L: Coilcraft DT1608C-333  
 D: ON Semiconductor MBRM130LT3

20039734

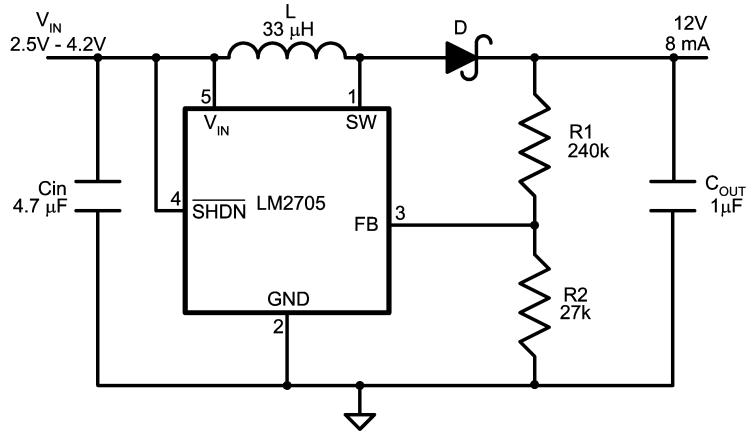
FIGURE 5. 3 White LED Application and Efficiency



20039743



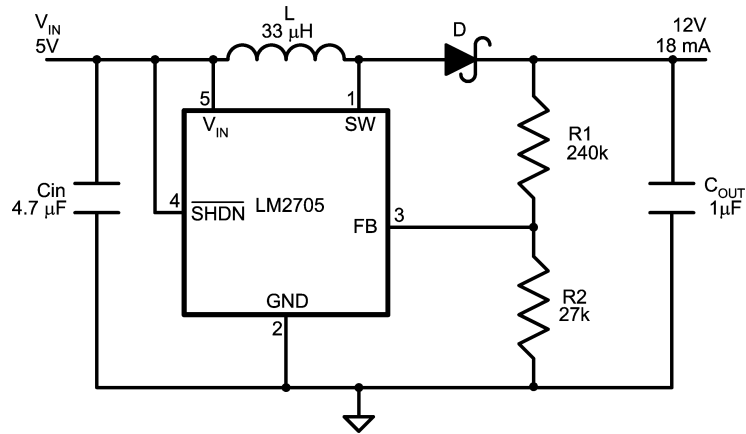
**Application Information** (Continued)



C<sub>IN</sub>: Taiyo Yuden Ceramic  
 C<sub>OUT</sub>: Taiyo Yuden Ceramic  
 L: Coilcraft DT1608C-333  
 D: ON Semiconductor MBRM130LT3

20039735

**FIGURE 6. Li-Ion 12V Application**

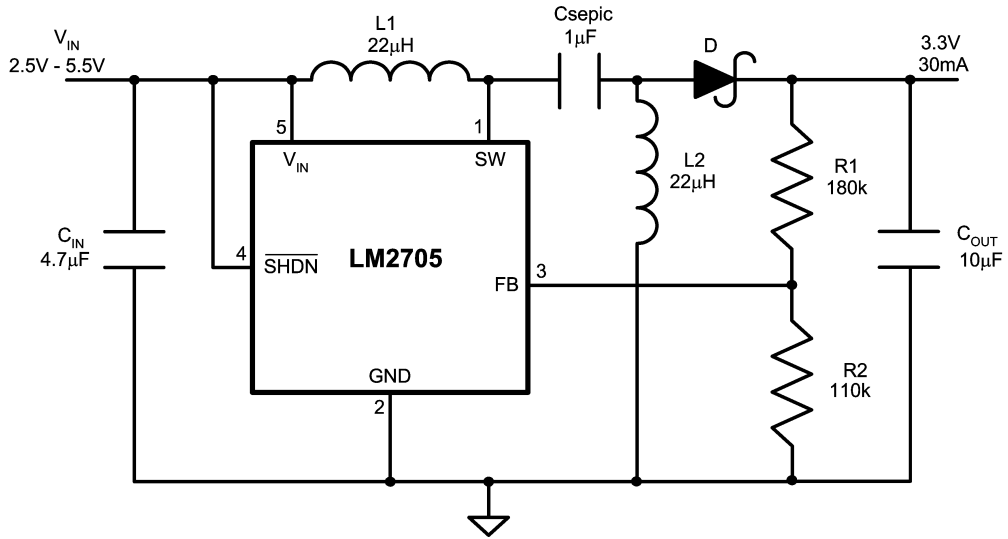


C<sub>IN</sub>: Taiyo Yuden Ceramic  
 C<sub>OUT</sub>: Taiyo Yuden Ceramic  
 L: Coilcraft DT1608C-333  
 D: ON Semiconductor MBRM130LT3

20039736

**FIGURE 7. 5V to 12V Application**

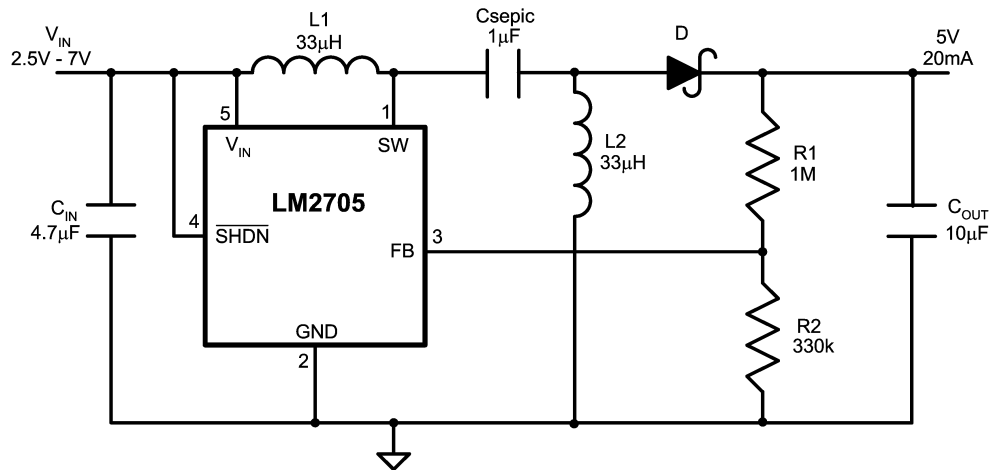
Application Information (Continued)



Csepic: Taiyo Yuden Ceramic  
 C<sub>IN</sub>: Taiyo Yuden Ceramic  
 C<sub>OUT</sub>: Taiyo Yuden Ceramic  
 L1, L2: Coilcraft DT1608C-223  
 D: ON Semiconductor MBRM130LT3

20039739

FIGURE 8. 3.3V SEPIC Application



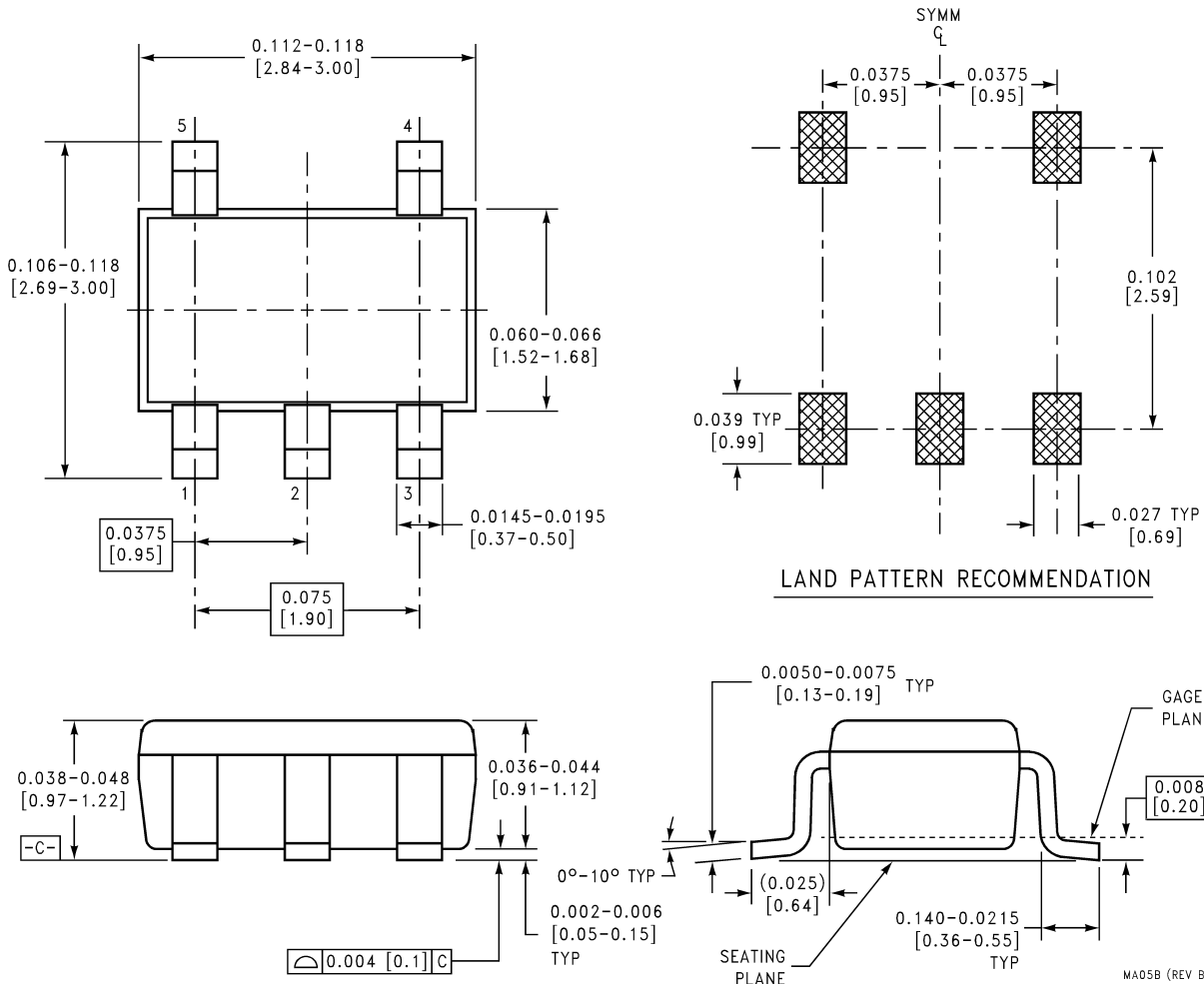
Csepic: Taiyo Yuden Ceramic  
 C<sub>IN</sub>: Taiyo Yuden Ceramic  
 C<sub>OUT</sub>: Taiyo Yuden Ceramic  
 L1, L2: Coilcraft DT1608C-333  
 D: ON Semiconductor MBRM130LT3

20039740

FIGURE 9. 5V SEPIC Application

## Physical Dimensions inches (millimeters)

unless otherwise noted



**5-Lead Small Outline Package (M5)**  
**For Ordering, Refer to Ordering Information Table**  
**NS Package Number MA05B**

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



**National Semiconductor**  
**Americas Customer**  
**Support Center**  
 Email: new.feedback@nsc.com  
 Tel: 1-800-272-9959

**National Semiconductor**  
**Europe Customer Support Center**  
 Fax: +49 (0) 180-530 85 86  
 Email: europe.support@nsc.com  
 Deutsch Tel: +49 (0) 69 9508 6208  
 English Tel: +44 (0) 870 24 0 2171  
 Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor**  
**Asia Pacific Customer**  
**Support Center**  
 Fax: +65-6250 4466  
 Email: ap.support@nsc.com  
 Tel: +65-6254 4466

**National Semiconductor**  
**Japan Customer Support Center**  
 Fax: 81-3-5639-7507  
 Email: jpn.feedback@nsc.com  
 Tel: 81-3-5639-7560

www.national.com