



## 28V Internal Switch LCD Bias Supply in SOT23

MAX1605

### General Description

The MAX1605 boost converter contains a 0.5A internal switch in a tiny 6-pin SOT23 package. The IC operates from a +2.4V to +5.5V supply voltage but can boost battery voltages as low as 0.8V up to 28V at the output.

The MAX1605 uses a unique control scheme providing the highest efficiency over a wide range of load conditions. An internal 0.5A MOSFET reduces external component count, and a high switching frequency (up to 500kHz) allows for tiny surface-mount components. The current limit can be set to 500mA, 250mA, or 125mA, allowing the user to reduce the output ripple and component size in low-current applications.

Additional features include a low quiescent supply current and a shutdown mode to save power. The MAX1605 is ideal for small LCD panels with low current requirements but can also be used in other applications. A MAX1605EVKIT evaluation kit (EV kit) is available to help speed up design time.

### Applications

LCD Bias Generators  
Cellular or Cordless Phones  
Palmtop Computers  
Personal Digital Assistants (PDAs)  
Organizers  
Handy Terminals

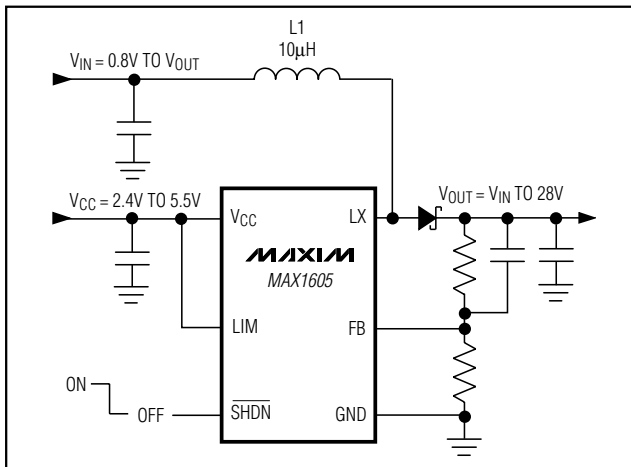
### Features

- ◆ Adjustable Output Voltage up to 28V
- ◆ 20mA at 20V from a Single Li+ Battery
- ◆ 88% Efficiency
- ◆ Up to 500kHz Switching Frequency
- ◆ Selectable Inductor Current Limit (125mA, 250mA, or 500mA)
- ◆ 18μA Operating Supply Current
- ◆ 0.1μA Shutdown Current
- ◆ Small 6-Pin SOT23 Package

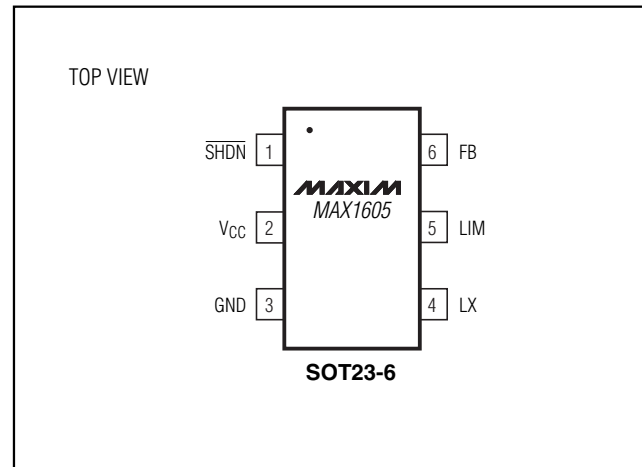
### Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	SOT MARK
MAX1605EUT-T	-40°C to +85°C	6 SOT23-6	AAHP

### Typical Operating Circuit



### Pin Configuration



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## ABSOLUTE MAXIMUM RATINGS

V <sub>CC</sub> , FB, LIM, $\overline{\text{SHDN}}$ to GND.....	-0.3V to +6V	Operating Temperature Range .....	-40°C to +85°C
LX to GND .....	-0.3V to +30V	Junction Temperature .....	+150°C
Continuous Power Dissipation (T <sub>A</sub> = +70°C)		Storage Temperature Range .....	-65°C to +150°C
6-Pin SOT23 (derate 8.7mW/°C above +70°C) .....	696mW	Lead Temperature (soldering, 10s) .....	+300°C

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(V<sub>CC</sub> =  $\overline{\text{SHDN}}$  = 3.3V, T<sub>A</sub> = 0°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V <sub>CC</sub>	(Note 2)	2.4		5.5	V
Inductor Input Voltage Range	V <sub>IN</sub>	(Note 2)	0.8		V <sub>OUT</sub>	V
V <sub>CC</sub> Undervoltage Lockout	V <sub>UVLO</sub>	V <sub>CC</sub> falling, 50mV typical hysteresis	2.0	2.2	2.37	V
Quiescent Supply Current	I <sub>CC</sub>	V <sub>FB</sub> = 1.3V		18	35	μA
Shutdown Supply Current		$\overline{\text{SHDN}}$ = GND		0.1	1	μA
V <sub>CC</sub> Line Regulation	ΔV <sub>LNR</sub>	V <sub>OUT</sub> = 18V, I <sub>LOAD</sub> = 1mA, V <sub>IN</sub> = 5V, V <sub>CC</sub> = V <sub>LIM</sub> = 2.4V to 5.5V		0.1		%/V
V <sub>IN</sub> Line Regulation	ΔV <sub>LNR</sub>	V <sub>OUT</sub> = 18V, I <sub>LOAD</sub> = 1mA, V <sub>CC</sub> = V <sub>LIM</sub> = 5V, V <sub>IN</sub> = 2.4V to 12V		0.15		%/V
Load Regulation	ΔV <sub>LDR</sub>	V <sub>OUT</sub> = 18V, V <sub>CC</sub> = V <sub>IN</sub> = V <sub>LIM</sub> = 5V, I <sub>LOAD</sub> = 0mA to 20mA		0.1		%/mA
Efficiency		L1 = 100μH, V <sub>IN</sub> = 3.6V, I <sub>LOAD</sub> = 10mA		88		%
Feedback Set Point	V <sub>FB</sub>		1.225	1.25	1.275	V
Feedback Input Bias Current	I <sub>FB</sub>	V <sub>FB</sub> = 1.3V		5	100	nA
<b>LX</b>						
LX Voltage Range	V <sub>LX</sub>				28	V
LX Switch Current Limit	I <sub>LX(MAX)</sub>	LIM = V <sub>CC</sub>	0.40	0.50	0.56	A
		LIM = floating	0.20	0.25	0.285	
		LIM = GND	0.10	0.125	0.15	
LX On-Resistance	R <sub>LX</sub>	V <sub>CC</sub> = 5V, I <sub>LX</sub> = 100mA		0.8		Ω
		V <sub>CC</sub> = 3.3V, I <sub>LX</sub> = 100mA		1	2	
LX Leakage Current		V <sub>LX</sub> = 28V			2	μA
Maximum LX On-Time	t <sub>ON</sub>		10	13	16	μs
Minimum LX Off-Time	t <sub>OFF</sub>	V <sub>FB</sub> > 1.1V	0.8	1.0	1.2	μs
		V <sub>FB</sub> < 0.8V (soft-start)	3.9	5.0	6.0	
<b>CONTROL INPUTS</b>						
$\overline{\text{SHDN}}$ Input Threshold	V <sub>IH</sub>	2.4V ≤ V <sub>CC</sub> ≤ 5.5V	0.8 × V <sub>CC</sub>			V
	V <sub>IL</sub>	2.4V ≤ V <sub>CC</sub> ≤ 5.5V		0.2 × V <sub>CC</sub>		
$\overline{\text{SHDN}}$ Input Bias Current	I $\overline{\text{SHDN}}$	V <sub>CC</sub> = 5.5V, V $\overline{\text{SHDN}}$ = 0 to 5.5V	-1		1	μA

# 28V Internal Switch LCD Bias Supply in SOT23

MAX1605

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = \overline{SHDN} = 3.3V$ ,  $T_A = 0^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
LIM Input Low Level		$2.4V \leq V_{CC} \leq 5.5V$			0.4	V
LIM Input Float Level		$2.4V \leq V_{CC} \leq 5.5V$ , $I_{LIM} = \pm 0.5\mu A$	$(V_{CC}/2) - 0.2V$		$(V_{CC}/2) + 0.2V$	V
LIM Input High Level		$2.4V \leq V_{CC} \leq 5.5V$	$V_{CC} - 0.4V$			V
LIM Input Bias Current	$I_{LIM}$	$\overline{SHDN} = V_{CC}$ , LIM = GND or $V_{CC}$	-2		2	$\mu A$
		$\overline{SHDN} = GND$		0.1	1	

## ELECTRICAL CHARACTERISTICS

( $V_{CC} = \overline{SHDN} = 3.3V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
Supply Voltage	$V_{CC}$	(Note 2)	2.4	5.5	V
Inductor Input Voltage Range	$V_{IN}$	(Note 2)	0.8	$V_{OUT}$	V
$V_{CC}$ Undervoltage Lockout	$V_{UVLO}$	$V_{CC}$ falling, 50mV typical hysteresis	2.0	2.37	V
Quiescent Supply Current	$I_{CC}$	$V_{FB} = 1.3V$		35	$\mu A$
Shutdown Supply Current		$\overline{SHDN} = GND$		1	$\mu A$
Feedback Set Point	$V_{FB}$		1.215	1.285	V
Feedback Input Bias Current	$I_{FB}$	$V_{FB} = 1.3V$		100	nA
<b>LX</b>					
LX Voltage Range	$V_{LX}$			28	V
LX Switch Current Limit	$I_{LX(MAX)}$	LIM = $V_{CC}$	0.35	0.58	A
		LIM = floating	0.18	0.30	
		LIM = GND	0.08	0.17	
LX On-Resistance	$R_{LX}$	$V_{CC} = 3.3V$ , $I_{LX} = 100mA$		2	$\Omega$
LX Leakage Current		$V_{LX} = 28V$		2	$\mu A$
Maximum LX On-Time	$t_{ON}$		9	17	$\mu s$
Minimum LX Off-Time	$t_{OFF}$	$V_{FB} > 1.1V$	0.75	1.25	$\mu s$
		$V_{FB} < 0.8V$	3.8	6.0	
<b>CONTROL INPUTS</b>					
$\overline{SHDN}$ Input Threshold	$V_{IH}$	$2.4V \leq V_{CC} \leq 5.5V$	$0.8 \times V_{CC}$		V
	$V_{IL}$	$2.4V \leq V_{CC} \leq 5.5V$	$0.2 \times V_{CC}$		
$\overline{SHDN}$ Input Bias Current	$I_{\overline{SHDN}}$	$V_{CC} = 5.5V$ , $V_{\overline{SHDN}} = 0$ to $5.5V$	-1	1	$\mu A$

# 28V Internal Switch LCD Bias Supply in SOT23

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = \overline{SHDN} = 3.3V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted.) (Note 1)

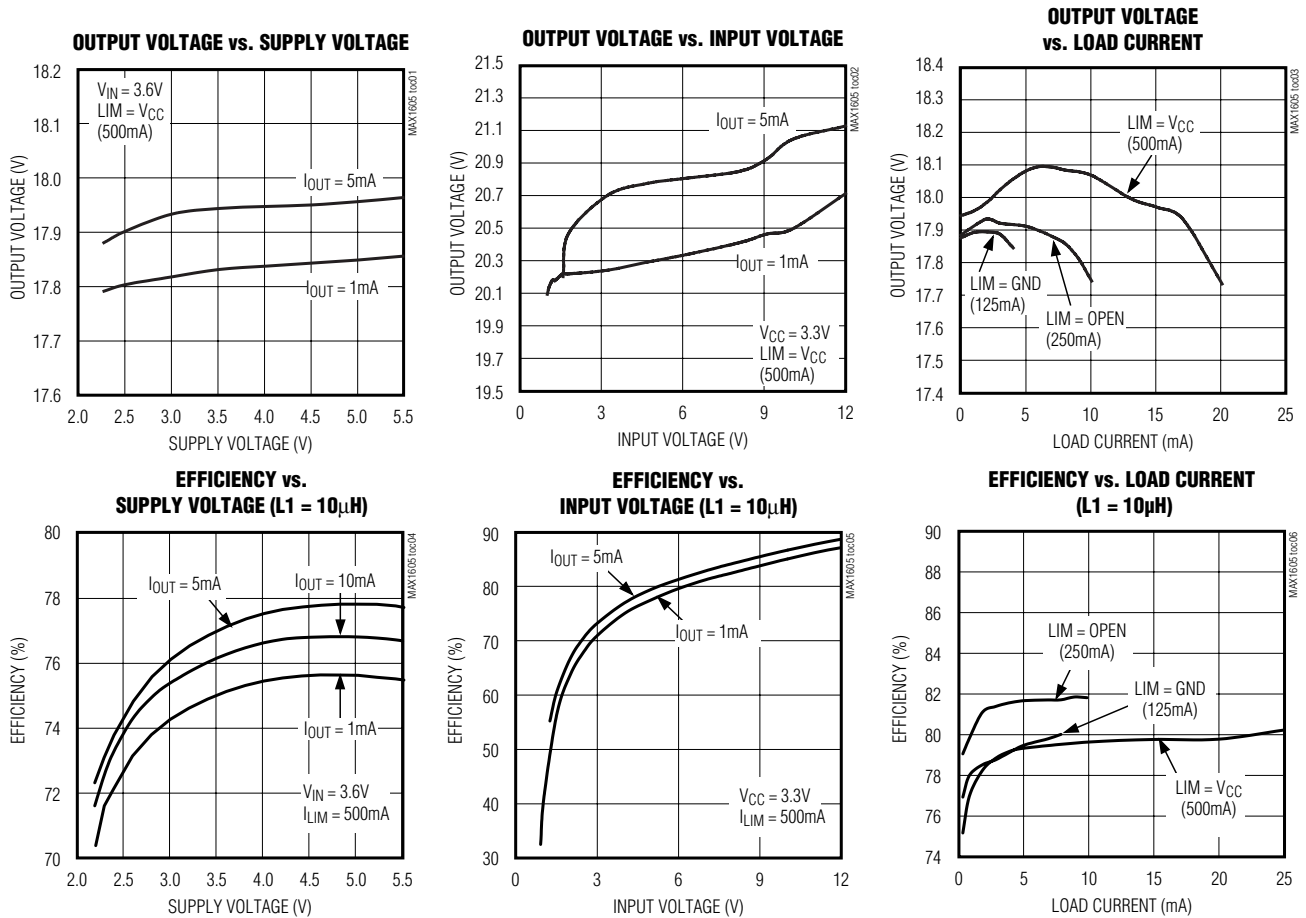
PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
LIM Input Low Level		$2.4V \leq V_{CC} \leq 5.5V$		0.4	V
LIM Input Float Level		$2.4V \leq V_{CC} \leq 5.5V$ , $I_{LIM} = \pm 0.5\mu A$	$(V_{CC} / 2) - 0.25V$	$(V_{CC} / 2) + 0.25V$	V
LIM Input High Level		$2.4V \leq V_{CC} \leq 5.5V$	$V_{CC} - 0.4V$		V
LIM Input Bias Current	$I_{LIM}$	$\overline{SHDN} = V_{CC}$ , LIM = GND or $V_{CC}$	-2	2	$\mu A$
		$\overline{SHDN} = GND$		1	

**Note 1:** All devices are 100% tested at  $T_A = +25^{\circ}C$ . All limits over the temperature range are guaranteed by design.

**Note 2:** The MAX1605 requires a supply voltage between +2.4V and +5.5V; however, the input voltage used to power the inductor can vary from +0.8V to  $V_{OUT}$ .

## Typical Operating Characteristics

( $V_{CC} = 3.3V$ ,  $V_{IN} = 3.6V$ ,  $L1 = 10\mu H$ ,  $\overline{SHDN} = LIM = V_{CC}$ ,  $V_{OUT(NOM)} = 18V$  (Figure 3),  $T_A = +25^{\circ}C$ , unless otherwise noted.)

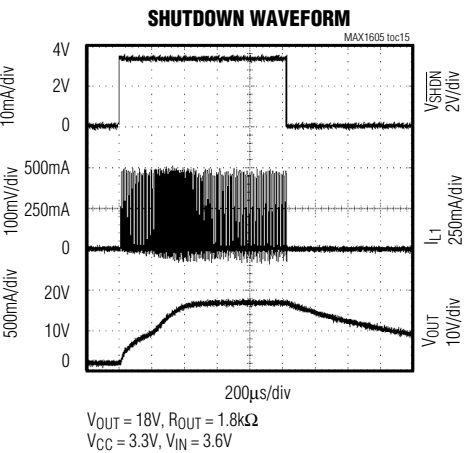
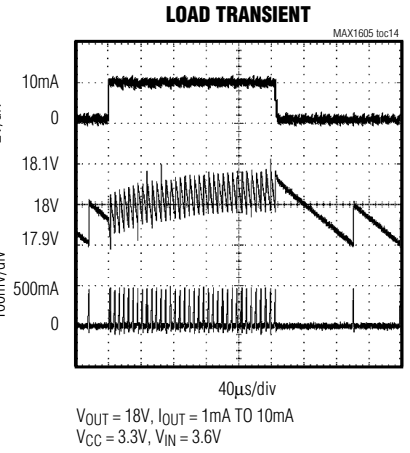
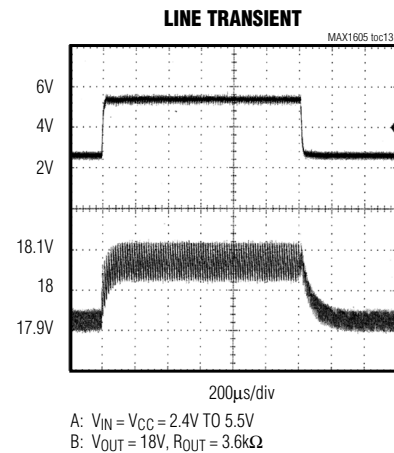
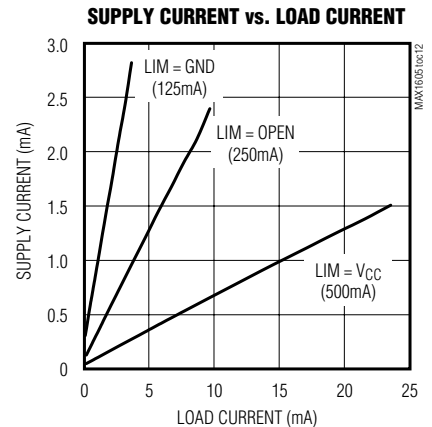
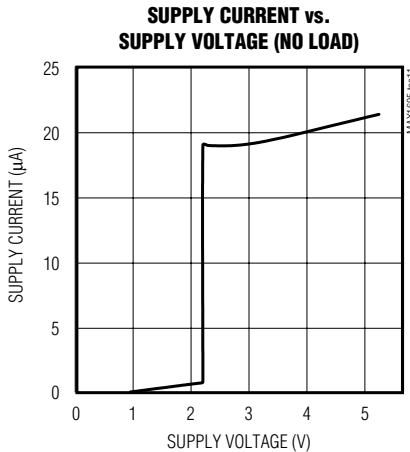
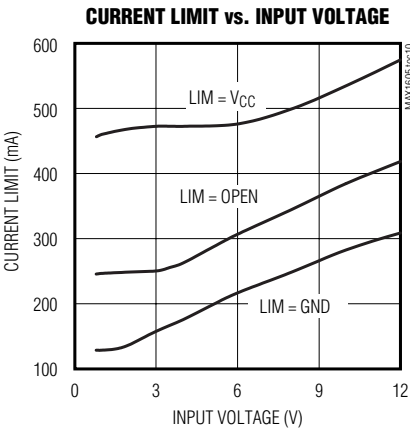
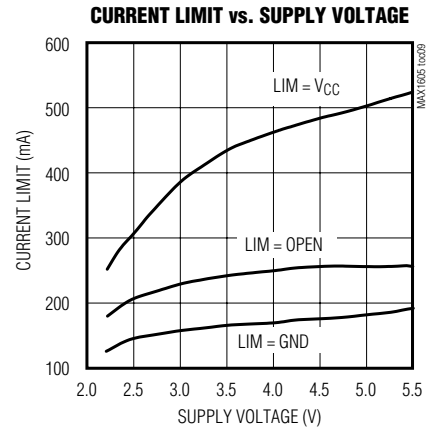
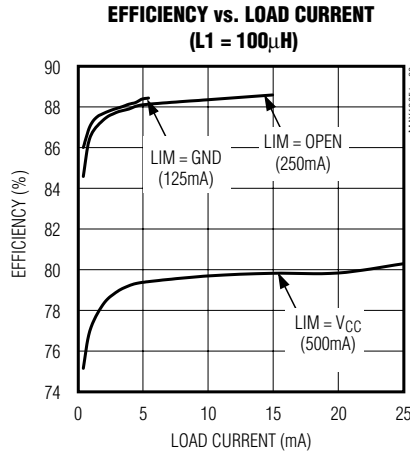
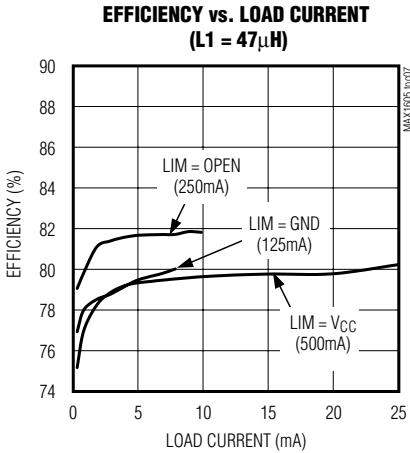


# 28V Internal Switch LCD Bias Supply in SOT23

MAX1605

## Typical Operating Characteristics (continued)

( $V_{CC} = 3.3V$ ,  $V_{IN} = 3.6V$ ,  $L1 = 10\mu H$ ,  $\overline{SHDN} = LIM = V_{CC}$ ,  $V_{OUT(NOM)} = 18V$  (Figure 3),  $T_A = +25^\circ C$ , unless otherwise noted.)



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## Pin Description

PIN	NAME	FUNCTION
1	$\overline{\text{SHDN}}$	Active-Low Shutdown Input. A logic low shuts down the device and reduces the supply current to 0.1 $\mu\text{A}$ . Connect SHDN to $V_{\text{CC}}$ for normal operation.
2	$V_{\text{CC}}$	IC Supply Voltage (+2.4V to +5.5V). Bypass $V_{\text{CC}}$ to GND with a 0.1 $\mu\text{F}$ or greater capacitor.
3	GND	Ground
4	LX	Inductor Connection. The drain of an internal 28V N-channel MOSFET. LX is high impedance in shutdown.
5	LIM	Inductor Current Limit Selection. Connect LIM to $V_{\text{CC}}$ for 500mA, leave LIM floating for 250mA, or connect LIM to GND for 125mA.
6	FB	Feedback Input. Connect to a resistive-divider network between the output ( $V_{\text{OUT}}$ ) and FB to set the output voltage between $V_{\text{IN}}$ and 28V. The feedback threshold is 1.25V.

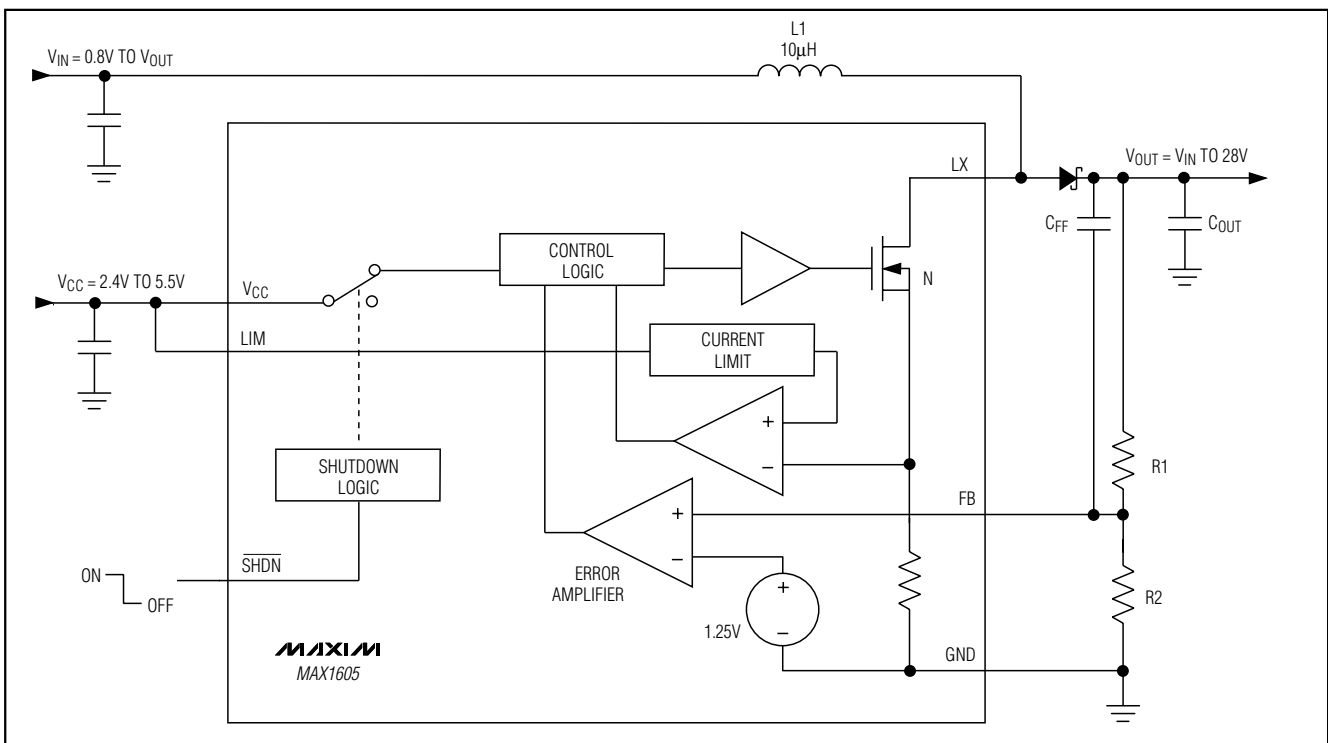


Figure 1. Functional Diagram

### Detailed Description

The MAX1605 compact, step-up DC-DC converter operates from a +2.4V to +5.5V supply. Consuming only 18 $\mu\text{A}$  of supply current, the device includes an internal switching MOSFET with 1 $\Omega$  on-resistance and selectable current limit (Figure 1). During startup, the MAX1605 extends the minimum off-time, limiting initial

surge current. The MAX1605 also features a shutdown mode.

### Control Scheme

The MAX1605 features a minimum off-time, current-limited control scheme. The duty cycle is governed by a pair of one-shots that set a minimum off-time and a maximum on-time. The switching frequency can be up

# 28V Internal Switch LCD Bias Supply in SOT23

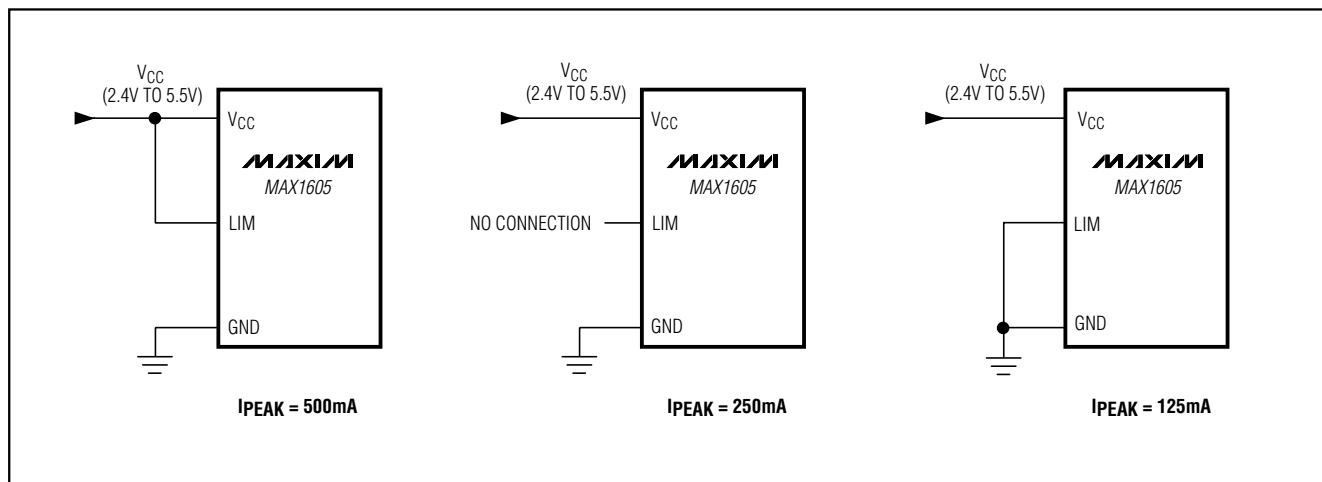


Figure 2. Setting the Peak Inductor Current Limit

to 500kHz and depends upon the load and input voltage. The peak current limit of the internal N-channel MOSFET is pin selectable and may be set at 125mA, 250mA, or 500mA (Figure 2).

### Setting the Output Voltage (FB)

Adjust the output voltage by connecting a voltage-divider from the output ( $V_{OUT}$ ) to FB (Figure 3). Select R2 between 10k $\Omega$  to 200k $\Omega$ . Calculate R1 with the following equation:

$$R1 = R2 [(V_{OUT} / V_{FB}) - 1]$$

where  $V_{FB} = 1.25V$  and  $V_{OUT}$  may range from  $V_{IN}$  to 28V. The input bias current of FB has a maximum value of 100nA, which allows large-value resistors to be used. For less than 1% error, the current through R2 should be greater than 100 times the feedback input bias current ( $I_{FB}$ ).

### Current Limit Select Pin (LIM)

The MAX1605 allows a selectable inductor current limit of 125mA, 250mA, or 500mA (Figure 2). This allows flexibility in designing for higher current applications or for smaller, compact designs. The lower current limit allows the use of a physically smaller inductor in space-sensitive, low-power applications. Connect LIM to VCC for 500mA, leave floating for 250mA, or connect to GND for 125mA.

### Shutdown (SHDN)

Pull SHDN low to enter shutdown. During shutdown, the supply current drops to 0.1 $\mu A$  and LX enters a high-impedance state. However, the output remains connected to the input through the inductor and output rectifier, holding the output voltage to one diode drop

below  $V_{IN}$  when the MAX1605 is shut down. The capacitance and load at OUT determine the rate at which  $V_{OUT}$  decays. SHDN can be pulled as high as 6V, regardless of the input and output voltages.

### Separate/Same Power for L1 and Vcc

Separate voltage sources can supply the inductor ( $V_{IN}$ ) and the IC ( $V_{CC}$ ). This allows operation from low-voltage batteries as well as high-voltage sources (0.8V to 28V) because chip bias is provided by a logic supply (2.4V to 5.5V) while the output power is sourced directly from the battery to L1. Conversely,  $V_{IN}$  and  $V_{CC}$  can also be supplied from one supply if it remains within VCC's operating limits (+2.4V to +5.5V).

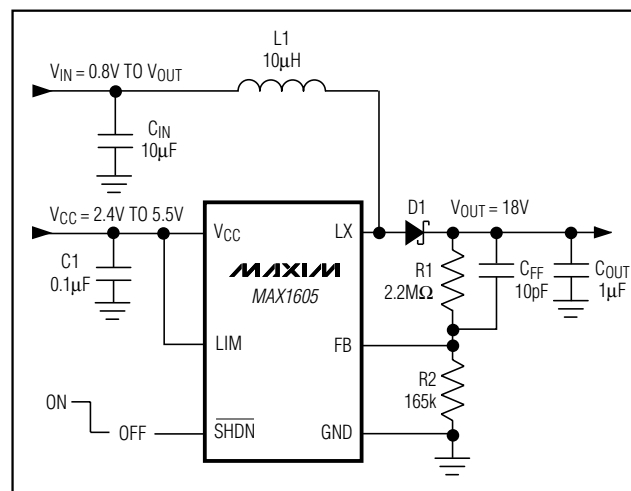


Figure 3. Typical Application Circuit

# 28V Internal Switch LCD Bias Supply in SOT23

## Design Procedure

### Inductor Selection

Smaller inductance values typically offer smaller physical size for a given series resistance or saturation current. Circuits using larger inductance values may start up at lower input voltages and exhibit less ripple, but also provide reduced output power. This occurs when the inductance is sufficiently large to prevent the maximum current limit from being reached before the maximum on-time expires. The inductor's saturation current rating should be greater than the peak switching current. However, it is generally acceptable to bias the inductor into saturation by as much as 20%, although this will slightly reduce efficiency.

### Picking the Current Limit

The peak LX current limit ( $I_{LX(MAX)}$ ) required for the application may be calculated from the following equation:

$$I_{LX(MAX)} \geq \frac{V_{OUT} \times I_{OUT(MAX)}}{V_{IN(MIN)}} + \frac{(V_{OUT} - V_{IN(MIN)}) \times t_{OFF(MIN)}}{2 \times L}$$

where  $t_{OFF(MIN)} = 0.8\mu s$ , and  $V_{IN(MIN)}$  is the minimum voltage used to supply the inductor. The set current limit must be greater than this calculated value. Select the appropriate current limit by connecting LIM to VCC, GND, or leaving it unconnected (see *Current Limit Select Pin* and Figure 2).

### Diode Selection

The high maximum switching frequency of 500kHz requires a high-speed rectifier. Schottky diodes, such as the Motorola MBRS0530 or the Nihon EP05Q03L, are recommended. To maintain high efficiency, the average current rating of the Schottky diode should be greater than the peak switching current. Choose a reverse breakdown voltage greater than the output voltage.

### Output Filter Capacitor

For most applications, use a small ceramic surface-mount output capacitor, 1 $\mu F$  or greater. For small ceramic capacitors, the output ripple voltage is dominated by the capacitance value. If tantalum or electrolytic capacitors are used, the higher ESR increases the output ripple voltage. Decreasing the ESR reduces the output ripple voltage and the peak-to-peak transient voltage. Surface-mount capacitors are generally preferred because they lack the inductance and resistance of their through-hole equivalents.

### Input Bypass Capacitor

Two inputs, VCC and  $V_{IN}$ , require bypass capacitors. Bypass VCC with a 0.1 $\mu F$  ceramic capacitor as close to the IC as possible. The input supplies high currents to the inductor and requires local bulk bypassing close to the inductor. A 10 $\mu F$  low-ESR surface-mount capacitor is sufficient for most applications.

### PC Board Layout and Grounding

Careful printed circuit layout is important for minimizing ground bounce and noise. Keep the MAX1605's ground pin and the ground leads of the input and output capacitors less than 0.2in (5mm) apart. In addition, keep all connections to FB and LX as short as possible. In particular, when using external feedback resistors, locate them as close to FB as possible. To minimize output voltage ripple, and to maximize output power and efficiency, use a ground plane and solder GND directly to the ground plane. Refer to the MAX1605EVKIT evaluation kit for a layout example.

## Applications Information

### Negative Voltage for LCD Bias

The MAX1605 can also generate a negative output by adding a diode-capacitor charge-pump circuit (D1, D2, and C3) to the LX pin as shown in Figure 4. Feedback is still connected to the positive output, which is not loaded, allowing a very small capacitor value at C4. For best stability and lowest ripple, the time constant of the R1-R2 series combination and C4 should be near or less than that of C2 and the effective load resistance. Output load regulation of the negative output is somewhat looser than with the standard positive output circuit, and may rise at very light loads due to coupling through the capacitance of D2. If this is objectionable, reduce the resistance of R1 and R2, while maintaining their ratio, to effectively preload the output with a few hundred microamps. This is why the R1-R2 values shown in Figure 3 are about 10-times lower than typical values used for a positive-output design. When loaded, the negative output voltage will be slightly lower (closer to ground by approximately a diode forward voltage) than the inverse of the voltage on C4.

### Output Disconnected in Shutdown

When the MAX1605 is shut down, the output remains connected to the input (Figure 3), so the output voltage falls to approximately  $V_{IN} - 0.6V$  (the input voltage minus a diode drop). For applications that require output isolation during shutdown, add an external PNP transistor as shown in Figure 4. When the MAX1605 is active, the voltage set at the transistor's emitter exceeds the input voltage, forcing the transistor into the



# 28V Internal Switch LCD Bias Supply in SOT23

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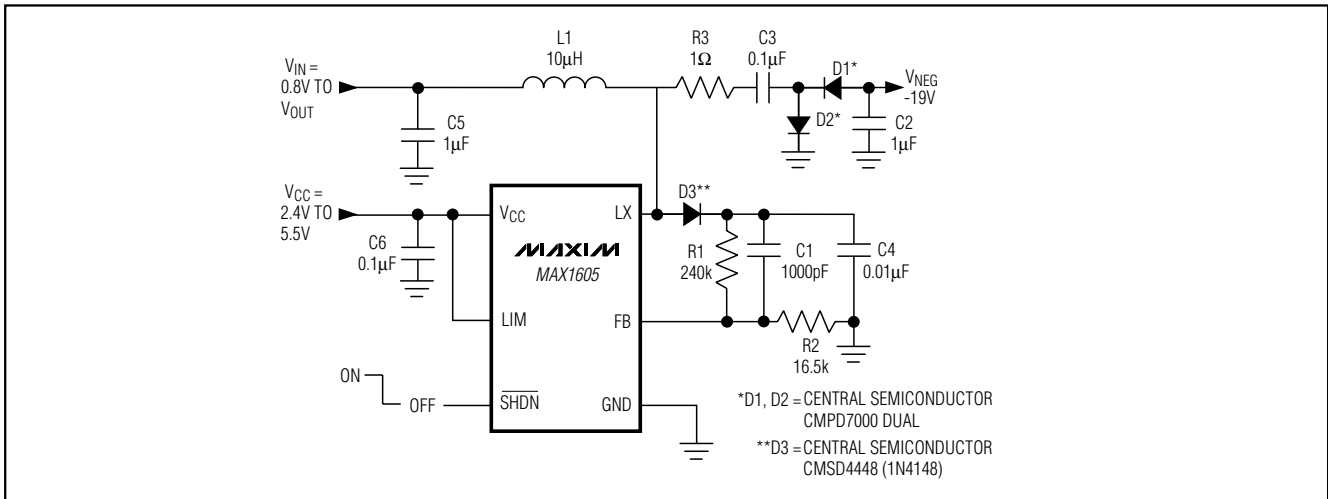


Figure 4. Negative Voltage for LCD Bias

saturation region. When shut down, the input voltage exceeds the emitter voltage so the inactive transistor provides high-impedance isolation between the input and output. Efficiency will be slightly degraded due to the PNP transistor saturation voltage and base current.

## Chip Information

TRANSISTOR COUNT: 2329

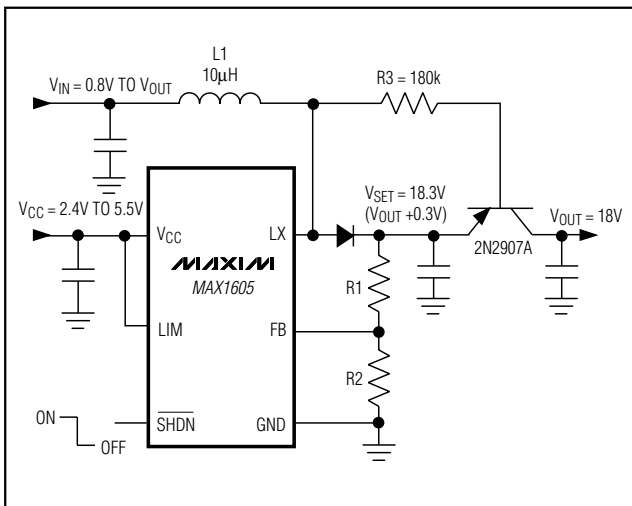
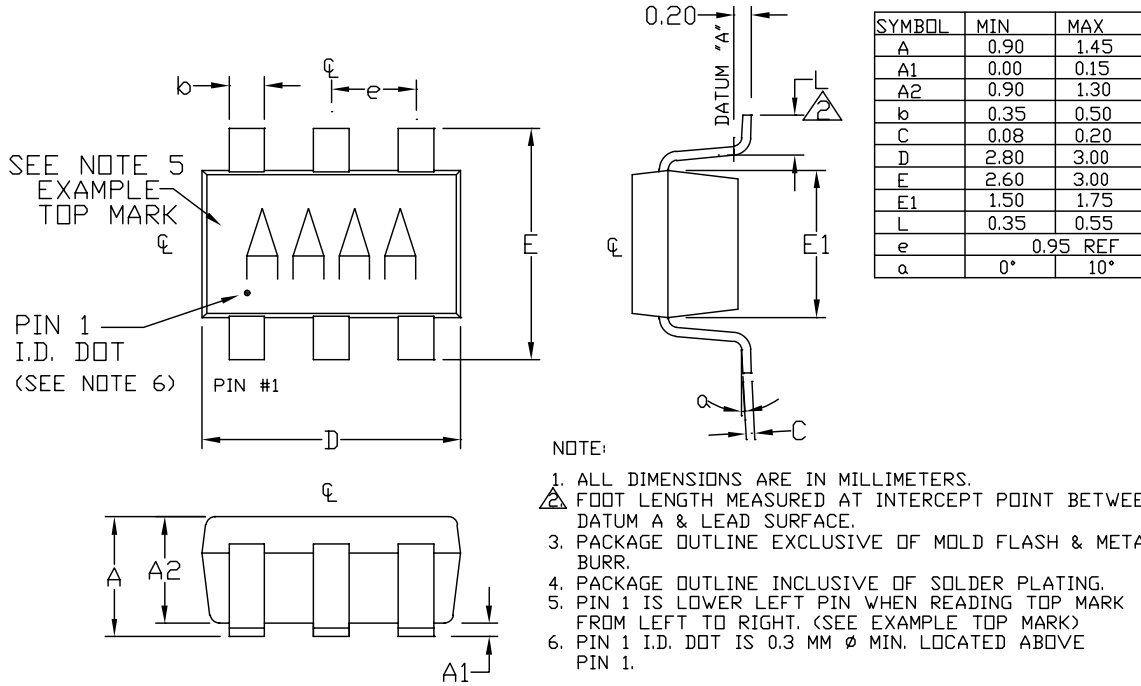


Figure 5. Output Disconnected in Shutdown

# 28V Internal Switch LCD Bias Supply in SOT23

## Package Information

6LSOT23



**MAXIM**  
 PROPRIETARY INFORMATION  
 TITLE:  
 PACKAGE OUTLINE, SOT23, 6L  
 APPROVAL: \_\_\_\_\_ DOCUMENT CONTROL NO. 21-0058 REV D 1/1

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NOTES

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## NOTES

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