LTC4440A-5
High Speed, High Voltage, High Side Gate Driver

FEATURES
- Wide Operating V_IN Range: Up to 80V
- Rugged Architecture Tolerant of 100V V_IN Transients
- Powerful 1.85Ω Driver Pull-Down (with 6V Supply)
- Powerful 1.1A Peak Current Driver Pull-Up (with 6V Supply)
- 7ns Fall Time Driving 1000pF Load
- 10ns Rise Time Driving 1000pF Load
- Drives Standard Threshold MOSFETs
- TTL/CMOS Compatible Inputs with Hysteresis
- Input Thresholds are Independent of Supply
- Undervoltage Lockout
- Thermally Enhanced 8-Lead MSOP Package

APPLICATIONS
- Automotive Power Systems
- Telecommunications Power Systems
- Distributed Power Architectures
- Server Power Supplies
- High Density Power Modules
- General Purpose Low or High Side Driver

DESCRIPTION
The LTC®4440A-5 is a high frequency high side N-channel MOSFET gate driver that is designed to operate in applications with V_IN voltages up to 80V. The LTC4440A-5 can also withstand and continue to function during 100V VIN transients. The powerful driver capability reduces switching losses in MOSFETs with high gate capacitances. The LTC4440A-5’s pull-up has a peak output current of 1.1A and its pull-down has an output impedance of 1.85Ω.

The LTC4440A-5 features supply independent TTL/CMOS compatible input thresholds with 350mV of hysteresis. The input logic signal is internally level-shifted to the bootstrapped supply, which may function at up to 95V above ground.

The LTC4440A-5 is optimized for driving (5V) logic level FETs and contains an undervoltage lockout circuit that disables the external MOSFET when activated.

The LTC4440A-5 is available in the thermally enhanced 8-lead MSOP package.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>LTC4440A-5</th>
<th>LTC4440-5</th>
<th>LTC4440</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Operating TS</td>
<td>80V</td>
<td>60V</td>
<td>80V</td>
</tr>
<tr>
<td>Absolute Max TS</td>
<td>100V</td>
<td>80V</td>
<td>100V</td>
</tr>
<tr>
<td>MOSFET Gate Drive</td>
<td>4V to 15V</td>
<td>4V to 15V</td>
<td>8V to 15V</td>
</tr>
<tr>
<td>V_CC UV+</td>
<td>3.2V</td>
<td>3.2V</td>
<td>6.3V</td>
</tr>
<tr>
<td>V_CC UV−</td>
<td>3.04V</td>
<td>3.04V</td>
<td>6.0V</td>
</tr>
</tbody>
</table>

TYPICAL APPLICATION
Synchronous Phase-Modulated Full-Bridge Converter

LTC4440A-5 Driving a 1000pF Capacitive Load

For more information www.linear.com/LTC4440A-5
LTC4440A-5

**ABSOLUTE MAXIMUM RATINGS** *(Note 1)*

Supply Voltage

\[ \begin{align*}
V_{CC} & \quad -0.3V \text{ to } 15V \\
\text{BOOST} - \text{TS} & \quad -0.3V \text{ to } 15V \\
\text{INP} & \quad -0.3V \text{ to } 15V \\
\text{BOOST Voltage (Continuous)} & \quad -0.3V \text{ to } 95V \\
\text{TS Voltage (Continuous)} & \quad -5V \text{ to } 80V \\
\text{TS Voltage (100ms)} & \quad -5V \text{ to } 100V \\
\end{align*} \]

Operating Junction Temperature Range *(Notes 2, 3)*

\[ \begin{align*}
\text{LTC4440AI-5} & \quad -40°C \text{ to } 125°C \\
\text{LTC4440AH-5} & \quad -40°C \text{ to } 150°C \\
\text{LTC4440AMP-5} & \quad -55°C \text{ to } 150°C \\
\end{align*} \]

Storage Temperature Range .......... –65°C to 150°C

Lead Temperature (Soldering, 10 sec) ................. 300°C

**ELECTRICAL CHARACTERISTICS** *(Note 2)*

The \( \bullet \) denotes specifications which apply over the specified operating junction temperature range, otherwise specifications are at \( T_A = 25°C \). \( V_{CC} = V_{BOOST} = 6V \), \( V_{TS} = GND = 0V \), unless otherwise noted.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
</table>
| \( I_{VCC} \) | DC Supply Current Normal Operation UVLO | \( \text{INP} = 0V \)
\( \text{INP} = 0V \)
\( V_{CC} < \text{UVLO Threshold (Falling)} - 0.1V \) | 200 | 325 | \( \mu A \) | \( \mu A \) |
| UVLO | Undervoltage Lockout Threshold V\( V_{CC} \) Rising V\( V_{CC} \) Falling Hysteresis | \( \bullet \)
\( \bullet \)
\( \bullet \)
\( \bullet \) | 2.75 | 3.20 | 3.65 | V | V | mV |

**PIN CONFIGURATION**

- **TOP VIEW**
- **MS8E PACKAGE**
- **8-LEAD PLASTIC MSOP**
- **\( T_{J\text{MAX}} = 150°C, \theta_J = 40°C/W \) (NOTE 4)**
- **EXPOSED PAD (PIN 9) IS GND, MUST BE SOLDERED TO PCB**

**ORDER INFORMATION**

<table>
<thead>
<tr>
<th>LEAD FREE FINISH</th>
<th>TAPE AND REEL</th>
<th>PART MARKING *</th>
<th>PACKAGE DESCRIPTION</th>
<th>TEMPERATURE RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC4440AIMS8E-5#PBF</td>
<td>LTC4440AIMS8E-5#TRPBF</td>
<td>LTGKP</td>
<td>8-Lead Plastic MSOP</td>
<td>–40°C to 125°C</td>
</tr>
<tr>
<td>LTC4440AHMS8E-5#PBF</td>
<td>LTC4440AHMS8E-5#TRPBF</td>
<td>LTGKP</td>
<td>8-Lead Plastic MSOP</td>
<td>–40°C to 150°C</td>
</tr>
<tr>
<td>LTC4440AMPMS8E-5#PBF</td>
<td>LTC4440AMPMS8E-5#TRPBF</td>
<td>LTGKP</td>
<td>8-Lead Plastic MSOP</td>
<td>–55°C to 150°C</td>
</tr>
</tbody>
</table>

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for information on nonstandard lead based finish parts.

For more information on lead free part marking, go to: [http://www.linear.com/leadfree/](http://www.linear.com/leadfree/)

For more information on tape and reel specifications, go to: [http://www.linear.com/tapeandreel/](http://www.linear.com/tapeandreel/)
## ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the specified operating junction temperature range, otherwise specifications are at \( T_A = 25 \degree C \). \( V_{CC} = V_{BOOST} = 6 \text{V}, V_{TS} = GND = 0 \text{V}, \) unless otherwise noted. (Note 2)

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Input Signal (INP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{IH} )</td>
<td>High Input Threshold</td>
<td>INP Ramping High</td>
<td>●</td>
<td>1.2</td>
<td>1.55</td>
<td>2</td>
</tr>
<tr>
<td>( V_{IL} )</td>
<td>Low Input Threshold</td>
<td>INP Ramping Low</td>
<td>●</td>
<td>0.8</td>
<td>1.25</td>
<td>1.6</td>
</tr>
<tr>
<td>( V_{IH} - V_{IL} )</td>
<td>Input Voltage Hysteresis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{INP} )</td>
<td>Input Pin Bias Current</td>
<td></td>
<td>±0.01</td>
<td>±2</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>Output Gate Driver (TG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{OH} )</td>
<td>High Output Voltage</td>
<td>( I_{TG} = -10 \text{mA}, V_{OH} = V_{BOOST} - V_{TG} )</td>
<td>●</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{DL} )</td>
<td>Low Output Voltage</td>
<td>( I_{TG} = 100 \text{mA} )</td>
<td>●</td>
<td>185</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>( I_{PU} )</td>
<td>Peak Pull-Up Current</td>
<td></td>
<td>0.7</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{DS} )</td>
<td>Output Pull-Down Resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Switching Timing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{rr} )</td>
<td>Output Rise Time</td>
<td>10% – 90%, ( C_L = 1 \text{nF} )</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10% – 90%, ( C_L = 10 \text{nF} )</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{rf} )</td>
<td>Output Fall Time</td>
<td>10% – 90%, ( C_L = 1 \text{nF} )</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10% – 90%, ( C_L = 10 \text{nF} )</td>
<td></td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{PHL} )</td>
<td>Output High-Low Propagation Delay</td>
<td></td>
<td>●</td>
<td>35</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>( t_{PLH} )</td>
<td>Output Low-High Propagation Delay</td>
<td></td>
<td>●</td>
<td>33</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The LTC4440A-5 is tested under pulsed load conditions such that \( T_J = T_A \). The LTC4440A1-5 is guaranteed over the \(-40 \degree C \) to \(125 \degree C \) operating junction temperature range. The LTC4440AH-5 is guaranteed over the \(-40 \degree C \) to \(150 \degree C \) operating junction temperature range and the LTC4440AMP-5 is tested and guaranteed over the \(-55 \degree C \) to \(150 \degree C \) operating junction temperature range.

High junction temperatures degrade operating lifetimes; operating lifetime is derated to junction temperatures greater than \(125 \degree C \). Note that the maximum ambient temperature consistent with these specifications is determined by specific operating conditions in conjunction with board layout, the rated package thermal impedance and other environment factors.

**Note 3:** \( T_J \) is calculated from the ambient temperature \( T_A \) and power dissipation \( PD \) according to the following formula:

\[
T_J = T_A + (PD \cdot 0.4^\circ C/W)
\]

Continuous operation above the specified absolute operating junction temperature may impair device reliability or permanently damage the device.

**Note 4:** Failure to solder the exposed pad of the MS8E package to the PC board will result in a thermal resistance much higher than \(40^\circ C/W\).
# Typical Performance Characteristics

## VCC Supply Quiescent Current vs Voltage

![Graph showing VCC Supply Quiescent Current vs Voltage](image1)

## BOOST-TS Supply Quiescent Current vs Voltage

![Graph showing BOOST-TS Supply Quiescent Current vs Voltage](image2)

## Output Low Voltage (VOL) vs Supply Voltage

![Graph showing Output Low Voltage (VOL) vs Supply Voltage](image3)

## Output High Voltage (VOH) vs Supply Voltage

![Graph showing Output High Voltage (VOH) vs Supply Voltage](image4)

## Input (INP) Thresholds vs Supply Voltage

![Graph showing Input (INP) Thresholds vs Supply Voltage](image5)

## 2MHz Operation

![Graph showing 2MHz Operation](image6)

## VCC Supply Current vs Temperature

![Graph showing VCC Supply Current vs Temperature](image7)

## VCC Undervoltage Lockout Thresholds vs Temperature

![Graph showing VCC Undervoltage Lockout Thresholds vs Temperature](image8)

## BOOST-TS Quiescent Current vs Temperature

![Graph showing BOOST-TS Quiescent Current vs Temperature](image9)
**TYPICAL PERFORMANCE CHARACTERISTICS**

- **Input (INP) Threshold vs Temperature**
- **Input Threshold Hysteresis vs Temperature**
- **Peak Driver (TG) Pull-Up Current vs Temperature**

- **Output Driver Pull-Down Resistance vs Temperature**
- **Propagation Delay vs Temperature**

- **Driving a 3300pF Capacitive Load**

For more information [www.linear.com/LTC4440A-5](http://www.linear.com/LTC4440A-5)
PIN FUNCTIONS

**INP (Pin 1):** Input Signal. TTL/CMOS compatible input referenced to GND (Pin 2).

**GND (Pins 2, 4, Exposed Pad Pin 9):** Ground. The exposed pad must be electrically connected to Pins 2 and 4 and soldered to PCB ground for rated thermal performance.

**VCC (Pin 3):** Chip Supply. This pin powers the internal low side circuitry. A low ESR ceramic bypass capacitor should be tied between this pin and the GND pin (Pin 2).

**NC (Pin 5):** No Connect. No connection required. For convenience, this pin may be tied to Pin 6 (BOOST) on the application board.

**BOOST (Pin 6):** High Side Bootstrapped Supply. An external capacitor should be tied between this pin and TS (Pin 8). Normally, a bootstrap diode is connected between VCC (Pin 3) and this pin. Voltage swing at this pin is from VCC – VD to VIN + VCC – VD, where VD is the forward voltage drop of the bootstrap diode.

**TG (Pin 7):** High Current Gate Driver Output (Top Gate). This pin swings between TS and BOOST.

**TS (Pin 8):** Top (High Side) source connection or GND if used in ground referenced applications.

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**BLOCK DIAGRAM**

![Block Diagram of LTC4440A-5](image)

**TIMING DIAGRAM**

![Timing Diagram of LTC4440A-5](image)
Overview

The LTC4440A-5 receives a ground-referenced, low voltage digital input signal to drive a high side N-channel power MOSFET whose drain can float up to 80V above ground, eliminating the need for a transformer between the low voltage control signal and the high side gate driver. The LTC4440A-5 normally operates in applications with input supply voltages ($V_{IN}$) up to 80V, but is able to withstand and continue to function during 100V, 100ms transients on the input supply.

The powerful output driver of the LTC4440A-5 reduces the switching losses of the power MOSFET, which increase with transition time. The LTC4440A-5 is capable of driving a 1nF load with 10ns rise and 7ns fall times using a bootstrapped supply voltage $V_{BOOST-TS}$ of 6V.

Input Stage

The LTC4440A-5 employs TTL/CMOS compatible input logic level or thresholds that allow a low voltage digital signal to drive standard threshold power MOSFETs. The LTC4440A-5 contains an internal voltage regulator that biases the input buffer, allowing the input thresholds ($V_{IH} = 1.6V$, $V_{IL} = 1.25V$) to be relatively independent of variations in $V_{CC}$. The 350mV hysteresis between $V_{IH}$ and $V_{IL}$ eliminates false triggering due to noise during switching transitions. However, care should be taken to keep this pin from any noise pickup, especially in high frequency, high voltage applications. The LTC4440A-5 input buffer has a high input impedance and draws negligible input current, simplifying the drive circuitry required for the input.

Output Stage

A simplified version of the LTC4440A-5’s output stage is shown in Figure 1. The pull-down device is an N-channel MOSFET (N1) and the pull-up device is an NPN bipolar junction transistor (Q1). The output swings from the lower rail (TS) to within an NPN $V_{BE}$ (~0.7V) of the positive rail (BOOST). This large voltage swing is important in driving external power MOSFETs, whose $R_{DS(ON)}$ is inversely proportional to its gate overdrive voltage ($V_{GS} - V_{TH}$).

The LTC4440A-5’s peak pull-up (Q1) current is 1.1A while the pull-down (N1) resistance is 1.85Ω, with a BOOST-TS supply of 6V. The low impedance of N1 is required to discharge the power MOSFET’s gate capacitance during high-to-low signal transitions. When the power MOSFET's gate is pulled low (gate shorted to source through N1) by the LTC4440A-5, its source (TS) is pulled low by its load (e.g., an inductor or resistor). The slew rate of the source/gate voltage causes current to flow back to the MOSFET's gate through the gate-to-drain capacitance ($C_{GD}$). If the MOSFET driver does not have sufficient sink current capability (low output impedance), the current through the power MOSFET's $C_{GD}$ can momentarily pull the gate high, turning the MOSFET back on.

A similar scenario exists when the LTC4440A-5 is used to drive a low side MOSFET. When the low side power MOSFET's gate is pulled low by the LTC4440A-5, its drain voltage is pulled high by its load (e.g., inductor or resistor). The slew rate of the drain voltage causes current to flow back to the MOSFET's gate through its gate-to-drain capacitance. If the MOSFET driver does not have sufficient sink current capability (low output impedance), the current through the power MOSFET's $C_{GD}$ can momentarily pull the gate high, turning the MOSFET back on.

Rise/Fall Time

Since the power MOSFET generally accounts for the majority of the power loss in a converter, it is important to quickly turn it on or off, thereby minimizing the transition time in its linear region. The LTC4440A-5 can drive a 1nF load with a 10ns rise time and 7ns fall time.

The LTC4440A-5’s rise and fall times are determined by the peak current capabilities of Q1 and N1. The predriver that drives Q1 and N1 uses a nonoverlapping transition scheme to minimize cross-conduction currents. N1 is fully turned off before Q1 is turned on and vice versa.
Power Dissipation

To ensure proper operation and long-term reliability, the LTC4440A-5 must not operate beyond its maximum temperature rating. Package junction temperature can be calculated by:

\[ T_J = T_A + PD \times (\theta_{JA}) \]

where:

- \( T_J \) = Junction Temperature
- \( T_A \) = Ambient Temperature
- \( PD \) = Power Dissipation
- \( \theta_{JA} \) = Junction-to-Ambient Thermal Resistance

Power dissipation consists of standby and switching power losses:

\[ PD = P_{STDBY} + P_{AC} \]

where:

- \( P_{STDBY} \) = Standby Power Losses
- \( P_{AC} \) = AC Switching Losses

The LTC4440A-5 consumes very little current during standby. The DC power loss at \( V_{CC} = 6V \) and \( V_{BOOST–TS} = 6V \) is only \((200\mu A)(6V) = 1.2mW\) with \( INP = 0V \).

AC switching losses are made up of the output capacitive load losses and the transition state losses. The capacitive load losses are primarily due to the large AC currents needed to charge and discharge the load capacitance during switching. Load losses for the output driver driving a pure capacitive load \( C_{OUT} \) would be:

\[ \text{Load Capacitive Power} = (C_{OUT})(f)(V_{BOOST–TS})^2 \]

The power MOSFET’s gate capacitance seen by the driver output varies with its \( V_{GS} \) voltage level during switching. A power MOSFET’s capacitive load power dissipation can be calculated using its gate charge, \( Q_G \). The \( Q_G \) value corresponding to the MOSFET’s \( V_{GS} \) value (\( V_{CC} \) in this case) can be readily obtained from the manufacturer’s \( Q_G \) vs \( V_{GS} \) curves:

\[ \text{Load Capacitive Power (MOS)} = (V_{BOOST–TS})(Q_G)(f) \]

Transition state power losses are due to both AC currents required to charge and discharge the driver’s internal nodal capacitances and cross-conduction currents in the internal gates.

Undervoltage Lockout (UVLO)

The LTC4440A-5 contains an undervoltage lockout detector that monitors \( V_{CC} \). When \( V_{CC} \) falls below 3.04V, the internal buffer is disabled and the output pin TG is pulled down to TS.

Bypassing and Grounding

The LTC4440A-5 requires proper bypassing on the \( V_{CC} \) and \( V_{BOOST–TS} \) supplies due to its high speed switching (nanoseconds) and large AC currents (Amperes). Careless component placement and PCB trace routing may cause excessive ringing and under/overshoot.

To obtain the optimum performance from the LTC4440A-5:

A. Mount the bypass capacitors as close as possible between the \( V_{CC} \) and GND pins and the BOOST and TS pins. The leads should be shortened as much as possible to reduce lead inductance.

B. Use a low inductance, low impedance ground plane to reduce any ground drop and stray capacitance. Remember that the LTC4440A-5 switches >2A peak currents and any significant ground drop will degrade signal integrity.

C. Plan the power/ground routing carefully. Know where the large load switching current is coming from and going to. Maintain separate ground return paths for the input pin and the output power stage.

D. Keep the copper trace between the driver output pin and the load short and wide.

E. When using the MS8E package, be sure to solder the exposed pad on the back side of the LTC4440A-5 package to the board. Correctly soldered to a 2500mm² double-sided 1oz copper board, the LTC4440A-5 has a thermal resistance of approximately 40°C/W. Failure to make good thermal contact between the exposed back side and the copper board will result in thermal resistances far greater than 40°C/W.
For more information www.linear.com/LTC4440A-5

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.
TYPICAL APPLICATION

240W 42V-56VIN to Unregulated 12V Half-Bridge Converter

PART NUMBER DESCRIPTION COMMENTS

LTC4444/LTC4444-5 High Voltage Synchronous N-Channel MOSFET Driver with Shoot-Through Protection
Up to 100V Supply Voltage, 7.2V ≤ VCC ≤ 13.5V, 3A Peak Pull-Up/0.55Ω Peak Pull-Down

LTC4446 High Voltage Synchronous N-Channel MOSFET Driver without Shoot-Through Protection
Up to 100V Supply Voltage, 7.2V ≤ VCC ≤ 13.5V, 3A Peak Pull-Up/0.55Ω Peak Pull-Down

LTC4441/LTC4441-1 N-Channel MOSFET Gate Driver
Up to 25V Supply Voltage, 5V ≤ VCC ≤ 25V, 6A Peak Output Current

LTC3900 Synchronous Rectifier Driver for Forward Converters
Programmable Time Out, Reverse Inductor Current Sense

LTC3901 Synchronous Rectifier Driver for Push-Pull and Full-Bridge Converters
Programmable Time Out, Reverse Inductor Current Sense

LTC3722-1/LTC3722-2 Synchronous Dual Mode Phase Modulated Full-Bridge Controllers
Adaptive Zero Voltage Switching, High Output Power Levels (Up to Kilowatts)

LTC3723-1/LTC3723-2 Synchronous Push-Pull PWM Controllers
Current Mode or Voltage Mode Controllers

LTC3765/LTC3766 Isolated Synchronous Forward Controller Chip Set
Active Clamp Reset, Direct Flux Limit™ with Onboard Gate Drivers Ideal for Medium Power 24V and 48V Input Applications

LT1952/LT1952-1 Synchronous Forward Active Clamp Controllers
Ideal for Medium Power 24V and 48V Input Applications