19-0728; Rev 4; 2/09

EVALUATION KIT AVAILABLE

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor



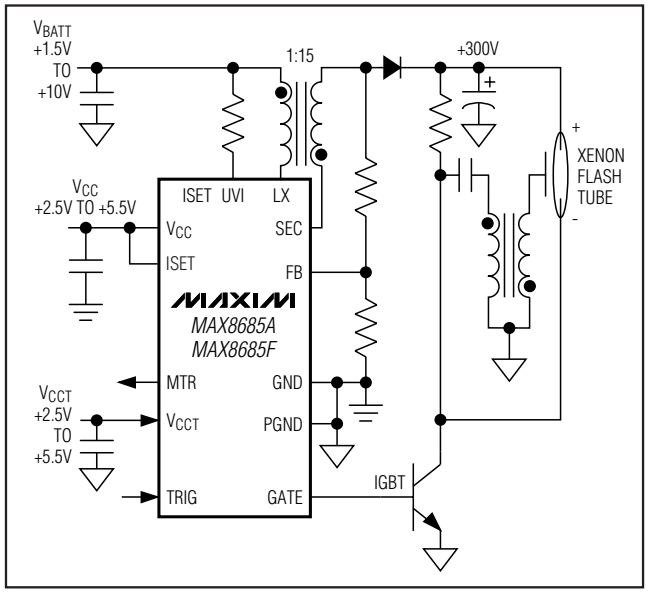
## General Description

The MAX8685 family charges high-voltage photoflash capacitors quickly, while limiting peak drain from the battery, through an efficient flyback switching regulator. The internal n-channel MOSFET improves efficiency over competing bipolar designs by lowering switch-voltage dropout. An integrated insulated gate bipolar transistor (IGBT) driver enables flash discharge and reduces external component count. The device includes an open-drain $\overline{DONE}$ output to indicate when the photoflash voltage has reached regulation. The device automatically refreshes the output voltage every 16s, thus efficiently maintains the capacitor charge level with minimum battery drain.

The MAX8685A/MAX8685F feature an undervoltage input (UVI) monitor. UVI monitors the supply voltage and suspends switching if the input voltage drops below a programmed threshold. The MAX8685A/MAX8685F also feature a voltage-monitor output that provides a scaled replica of the output voltage. The voltage-monitor output is used for interfacing with a microprocessor's internal A/D converter to assist in implementing red-eye reduction.

The MAX8685C/MAX8685D, with fixed peak-primary current limits of 1A and 1.6A, respectively, are offered in a 2mm x 3mm, 8-pin TDFN package. The MAX8685A/MAX8685F, with resistor-programmable current limits of up to 2A (max) and 2.6A (max), respectively, are offered in a 3mm x 3mm, 14-pin TDFN package. All devices operate over the -40°C to +85°C temperature range.

## Typical Operating Circuit




## Features

- **2s to Charge 100µF to 300V**
- **Integrated IGBT Driver**
- **Voltage-Monitor Output***
- **Short-/Open-Circuit Protection**
- **Controlled Inrush Current**
- **Programmable Input Current Limit Up to 2A (MAX8685A) or 2.6A (MAX8685F)***
- **Programmable Input Voltage-Overload Protection***
- **Extended Battery Life with Input-Voltage Monitoring***
- **Internal 2.6A Switch**
- **Robust Architecture Allows Use of Low-Cost Transformers**
- **High Accuracy Not Dependent on Transformer Turns Ratio**
- **Automatic Refresh Mode Draws Minimal Quiescent Current**
- **Charge-Done Indicator**
- **3mm x 3mm, 14-Pin TDFN Package (MAX8685A/MAX8685F)**
- **2mm x 3mm, 8-Pin TDFN Package (MAX8685C/MAX8685D)**

**MAX8685A/MAX8685F only.*

## Ordering Information

| PART | PIN-PACKAGE | TOP MARK |
|---|---|---|
| **MAX8685A**ETD+ | 14 TDFN-EP† 3mm x 3mm | ADD |
| **MAX8685C**ETA+ | 8 TDFN-EP† 2mm x 3mm | AAE |
| **MAX8685D**ETA+ | 8 TDFN-EP† 2mm x 3mm | AAF |
| **MAX8685F**ETD+ | 14 TDFN-EP† 3mm x 3mm | ADY |

***Note:*** *All devices are specified over the -40°C to +85°C operating temperature range.*

*+Denotes a lead(Pb)-free/RoHS-compliant package.*

*†EP= Exposed paddle.*

## Applications

Digital Cameras

Film Cameras

Cell-Phone Cameras

Personal Media Players

***Pin Configurations appear at end of data sheet.***

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

## ABSOLUTE MAXIMUM RATINGS

LX to PGND .....-0.3V to +40V
EN, ISET, MTR, to GND .....-0.3V to ($V_{CC}$ + 0.3V)
UVI to GND .....-0.3V to +12V
$V_{CC}$, $V_{CCT}$, FB, $\overline{DONE}$ to GND .....-0.3V to +6V
GATE, TRIG to PGND (MAX8685A/MAX8685F)
.....-0.3V to ($V_{CCT}$ + 0.3V)
GATE, TRIG to EP
(MAX8685C/MAX8685D).....-0.3V to ($V_{CC}$ + 0.3V)
PGND to GND (Note 1) .....-0.3V to +0.3V
SEC Current..... ±200mA
Current into $\overline{DONE}$.....±10mA

Continuous Power Dissipation
8-Pin TDFN (derate 16.7mW/°C above $T_A$ = +70°C)
(multilayer PCB) .....1333mW
14-Pin TDFN (derate 18.5mW/°C above $T_A$ = +70°C)
(single-layer PCB) .....1481mW
14-Pin TDFN (derate 24.4mW/°C above $T_A$ = +70°C)
(multilayer PCB) .....1951mW
Operating Temperature Range .....-40°C to +85°C
Junction Temperature Range .....-40°C to +150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

**Note 1:** For the MAX8685C/MAX8685D, GND and PGND are internally connected to the exposed paddle (EP). All references to GND or PGND refer to the EP in the MAX8685C/MAX8685D.

*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

($V_{CC}$ = $V_{EN}$ = 3.3V, $V_{CCT}$ = 3.3V (MAX8685A/MAX8685F only); $V_{FB}$ = 0, $R_{ISET}$ = 93.1kΩ (MAX8685A), $R_{ISET}$ = 120kΩ (MAX8685F) $V_{UVI}$ = 1.5V, $T_A$ = -40°C to +85°C, unless otherwise noted.) (Notes 2 and 3)

| PARAMETER | CONDITIONS | | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **$V_{CC}$** | | | | | | | |
| $V_{CC}$ Voltage Range | | | | 2.5 | | 5.5 | V |
| $V_{CC}$ Undervoltage Threshold | $V_{CC}$ rising | | | 2.2 | 2.3 | 2.4 | V |
| | $V_{CC}$ falling | | | 2.1 | 2.2 | 2.3 | |
| $V_{CC}$ Supply Current | Switching at 300kHz | | | | 1.85 | | mA |
| | Not switching | | | | 60 | 100 | µA |
| $V_{CC}$ Shutdown Current (MAX8685A/ MAX8685F) | $V_{EN}$ = 0, $V_{CC}$ = 5.5V, $V_{TRIG}$ = 0 | $V_{CCT}$ = 5.5V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | | $T_A$ = +85°C | | 0.1 | | |
| | | $V_{CCT}$ = 0 | $T_A$ = +25°C | | 0.1 | 1 | |
| | | | $T_A$ = +85°C | | 0.1 | | |
| $V_{CC}$ Shutdown Current (MAX8685C/MAX8685D) | $V_{EN}$ = 0, $V_{CC}$ = 5.5V, $V_{TRIG}$ = 0 | | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | | $T_A$ = +85°C | | 0.1 | | |
| **LX** | | | | | | | |
| LX On-Resistance | $I_{LX}$ = 190mA | | $V_{CC}$ = 3.3V | | 0.18 | 0.4 | Ω |
| | | | $V_{CC}$ = 2.5V | | 0.2 | 0.5 | |
| LX Off-Leakage | $V_{LX}$ = 10V, $V_{EN}$ = 0 | | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | | $T_A$ = +85°C | | 0.1 | | |
| LX Peak Current Limit (MAX8685A Only) | $T_A$ = 0°C to +85°C | | $R_{ISET}$ = 93.1kΩ | 1.44 | 1.60 | 1.76 | A |
| | | | ISET = $V_{CC}$ | | 2.0 | | |
| LX Peak Current Limit (MAX8685F Only) | $T_A$ = 0°C to +85°C | | $R_{ISET}$ = 120kΩ | 1.4625 | 1.625 | 1.7875 | A |
| | | | ISET = $V_{CC}$ | | 2.6 | | |
| LX Peak Current Limit | $T_A$ = 0°C to +85°C | | MAX8685C | | 1.0 | | A |
| | | | MAX8685D | | 1.6 | | |
| LX Switching Frequency | Circuit of Figure 3 or Figure 4, output 90% of final value | | | | 300 | | kHz |

## ELECTRICAL CHARACTERISTICS (continued)

($V_{CC}$ = $V_{EN}$ = 3.3V, $V_{CCT}$ = 3.3V (MAX8685A/MAX8685F only); $V_{FB}$ = 0, $R_{ISET}$ = 93.1kΩ (MAX8685A), $R_{ISET}$ = 120kΩ (MAX8685F) $V_{UVI}$ = 1.5V, $T_A$ = -40°C to +85°C, unless otherwise noted.) (Notes 2 and 3)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **SEC** | | | | | | |
| SEC Sense Resistance | | | | 1.1 | | Ω |
| SEC Valley-Current Threshold (MAX8685A Only) | $I_{SEC}$ falling | $R_{ISET}$ = 93.1kΩ | | 21.4 | | mA |
| | | ISET = $V_{CC}$ | | 26.7 | | |
| SEC Valley-Current Threshold (MAX8685F Only) | $I_{SEC}$ falling | $R_{ISET}$ = 120kΩ | | 10 | | mA |
| | | ISET = $V_{CC}$ | | 16 | | |
| SEC Valley-Current Threshold | $I_{SEC}$ falling | MAX8685C | | 16 | | mA |
| | | MAX8685D | | 16 | | |
| **FB** | | | | | | |
| FB Trip Threshold | $V_{FB}$ rising | $T_A$ = +25°C | 1.24 | 1.25 | 1.26 | V |
| | | $T_A$ = -40°C to +85°C | 1.237 | 1.250 | 1.263 | |
| FB Input Current | $V_{FB}$ = 1.25V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| Output Refresh Rate | From $V_{FB}$ > 1.25V to LX switching | | | 16 | | s |
| **UVI (MAX8685A/MAX8685F only)** | | | | | | |
| UVI Trip Threshold Falling | | | 0.98 | 1.00 | 1.02 | V |
| UVI Trip Threshold Rising | | | 1.05 | 1.07 | 1.09 | V |
| UVI Input Current | $V_{EN}$ = 0, $V_{UVI}$ = $V_{CC}$ = 5.5V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| **EN** | | | | | | |
| EN Input Threshold | $V_{EN}$ rising | | | 1.0 | 1.4 | V |
| | $V_{EN}$ falling | | 0.4 | 0.9 | | |
| EN Input Leakage Current | $V_{EN}$ = 5.5V, $V_{CC}$ = 5.5V | $T_A$ = +25°C | | 5.5 | 10 | µA |
| | | $T_A$ = +85°C | | 5.5 | | |
| **VOLTAGE MONITOR (MAX8685A/MAX8685F only)** | | | | | | |
| MTR Output Accuracy | $V_{FB}$ = 1.25V | | 1.94 | 2 | 2.06 | V |
| | $V_{FB}$ = 0.833V | | 1.280 | 1.333 | 1.387 | |
| MTR Output Current | $V_{FB}$ = 1.25V | | | 100 | | µA |
| **THERMAL SHUTDOWN** | | | | | | |
| Thermal-Shutdown Threshold | | | | 170 | | °C |
| Thermal-Shutdown Hysteresis | | | | 15 | | °C |
| **$\overline{DONE}$** | | | | | | |
| $\overline{DONE}$ Output Voltage, Low | $I_{\overline{DONE}}$ = 5mA | | | 100 | 400 | mV |
| $\overline{DONE}$ Output Current, High | $V_{\overline{DONE}}$ = 5.5V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

## ELECTRICAL CHARACTERISTICS (continued)

($V_{CC}$ = $V_{EN}$ = 3.3V, $V_{CCT}$ = 3.3V (MAX8685A/MAX8685F only); $V_{FB}$ = 0, $R_{ISET}$ = 93.1kΩ (MAX8685A), $R_{ISET}$ = 120kΩ (MAX8685F) $V_{UVI}$ = 1.5V, $T_A$ = -40°C to +85°C, unless otherwise noted.) (Notes 2 and 3)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **IGBT DRIVER** | | | | | | |
| TRIG Input Thresholds | $V_{TRIG}$ rising | | | | 1.4 | V |
| | $V_{TRIG}$ falling | | 0.4 | | | |
| TRIG Input Current | $V_{TRIG}$ = 5.5V | $T_A$ = +25°C | | 5.5 | 10 | µA |
| | | $T_A$ = +85°C | | 5.5 | | |
| GATE Source Current | $V_{TRIG}$ = 3.3V | | | 250 | | mA |
| GATE Sink Current | $V_{TRIG}$ = 0 | | | 50 | | mA |
| **$V_{CCT}$ (MAX8685A/MAX8685F only)** | | | | | | |
| $V_{CCT}$ Voltage Range | | | 2.5 | | 5.5 | V |
| $V_{CCT}$ Shutdown Current | $V_{TRIG}$ = 0, $V_{CCT}$ = 5.5V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |

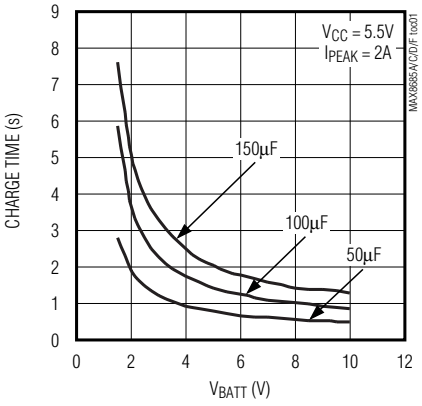
**Note 2:** For the MAX8685C/MAX8685D, GND and PGND are internally connected to the exposed paddle (EP). All references to GND or PGND refer to the EP in the MAX8685C/MAX8685D.

**Note 3:** Devices are 100% production tested at $T_A$ = +25°C. Limits over the operating temperature range are guaranteed by design and characterization.

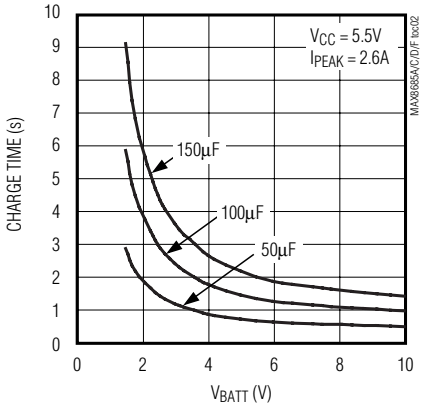
## Typical Operating Characteristics

($V_{EN}$ = $V_{BATT}$ = $V_{ISET}$ = $V_{CC}$ = 3.3V, $V_{CCT}$ = 5.5V, circuits of Figure 3, $T_A$ = +25°C, unless otherwise noted.)

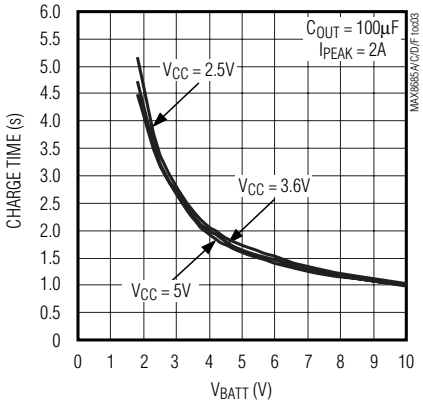
**CHARGE TIME (FROM 30V TO 300V) vs. $V_{BATT}$**




**CHARGE TIME (FROM 30V to 300V) vs. $V_{BATT}$ (MAX8685F)**



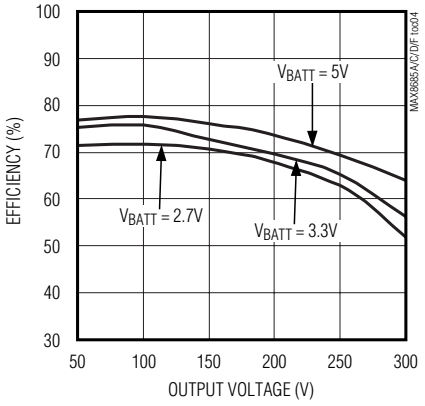

**CHARGE TIME (FROM 30V TO 300V) vs. $V_{BATT}$**



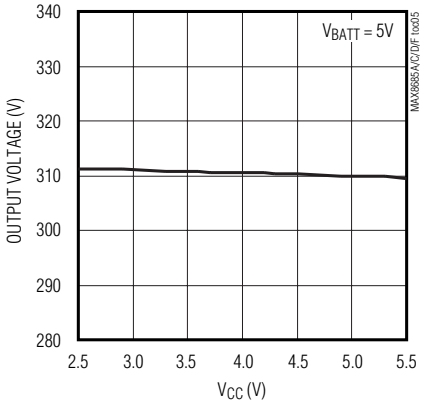
## Typical Operating Characteristics (continued)

($V_{EN}$ = $V_{BATT}$ = $V_{ISET}$ = $V_{CC}$ = 3.3V, $V_{CCT}$ = 5.5V, circuits of Figure 3, $T_A$ = +25°C, unless otherwise noted.)

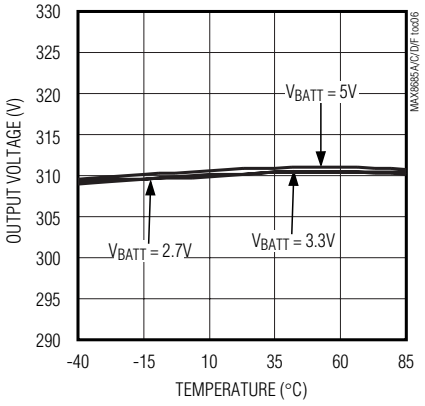
**EFFICIENCY vs. OUTPUT VOLTAGE**



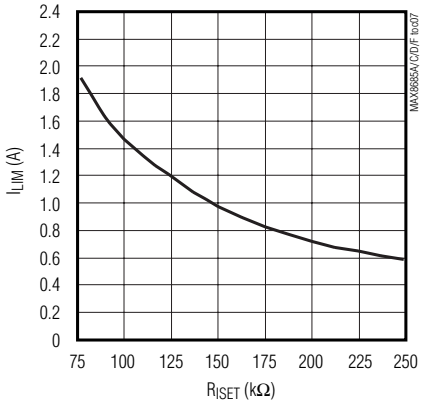

**OUTPUT VOLTAGE vs. $V_{CC}$**



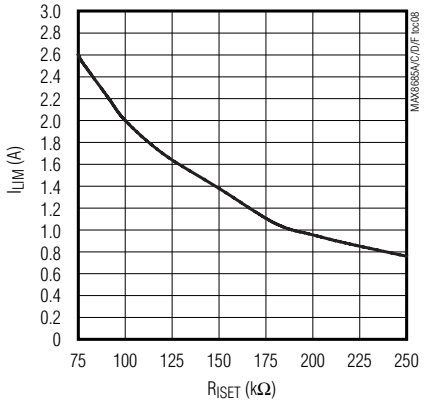

**OUTPUT VOLTAGE vs. TEMPERATURE**



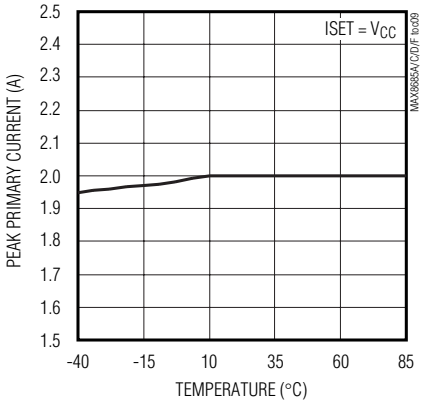

**PRIMARY CURRENT LIMIT vs. $R_{ISET}$**



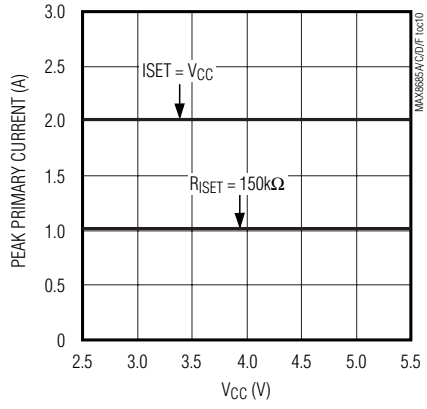

**PRIMARY CURRENT LIMIT vs. $R_{ISET}$ (MAX8685F)**



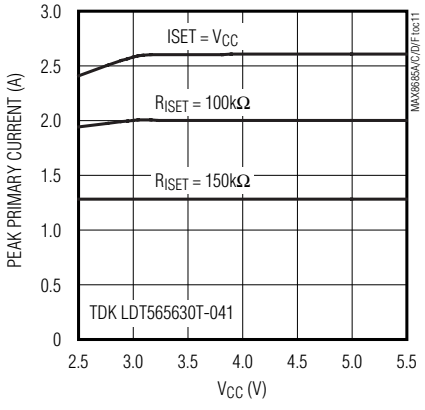

**PEAK PRIMARY CURRENT vs. TEMPERATURE**



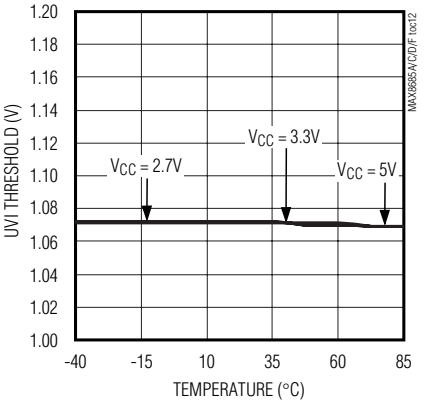

**PEAK PRIMARY CURRENT vs. $V_{CC}$**




**PEAK PRIMARY CURRENT vs. $V_{CC}$ (MAX8685F)**




**UVI RISING THRESHOLD vs. TEMPERATURE**

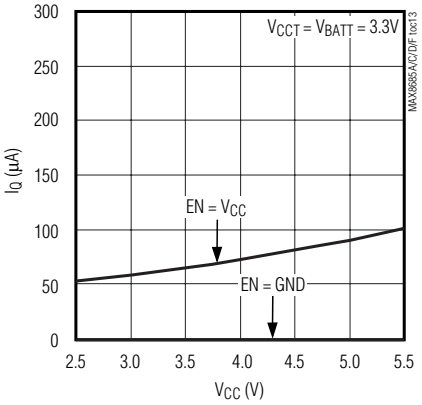


# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

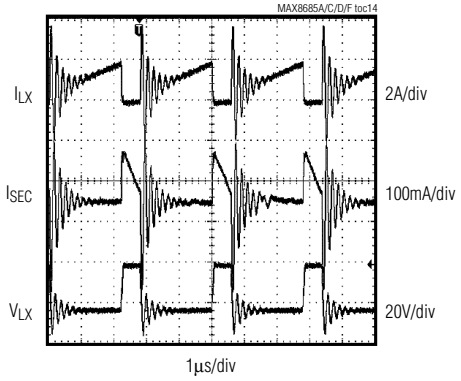
## Typical Operating Characteristics (continued)

($V_{EN}$ = $V_{BATT}$ = $V_{ISET}$ = $V_{CC}$ = 3.3V, $V_{CCT}$ = 5.5V, circuits of Figure 3, $T_A$ = +25°C, unless otherwise noted.)

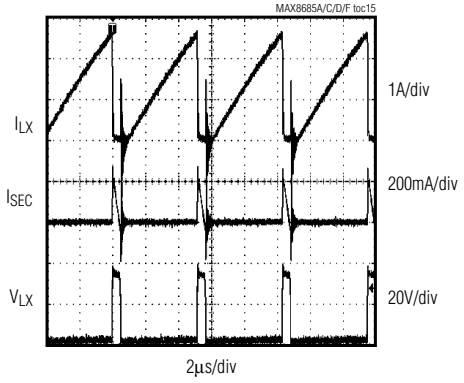
**QUIESCENT CURRENT vs. $V_{CC}$**



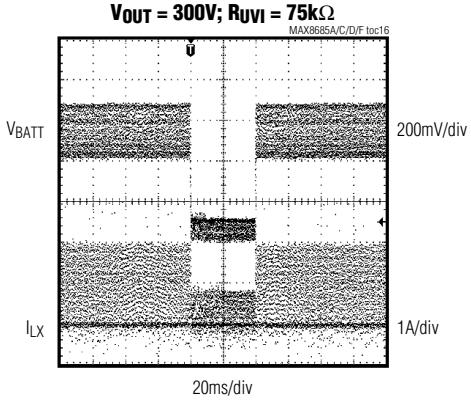

**SWITCHING WAVEFORMS**



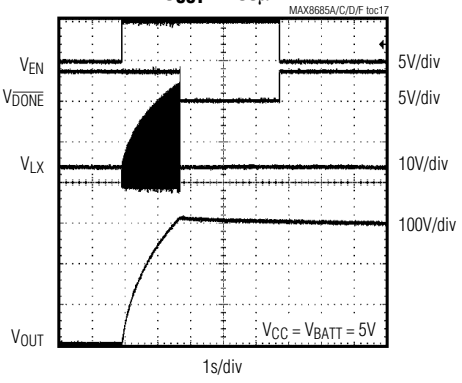

**SWITCHING WAVEFORMS (MAX8685F)**



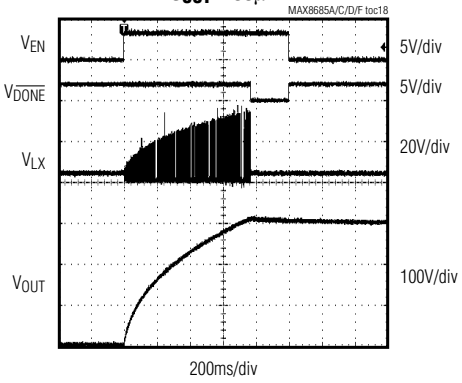

**LINE STEP WITH UVI**
**$V_{OUT}$ = 300V; $R_{UVI}$ = 75kΩ**




**CHARGE PROFILE**
**$C_{OUT}$ = 100µF**



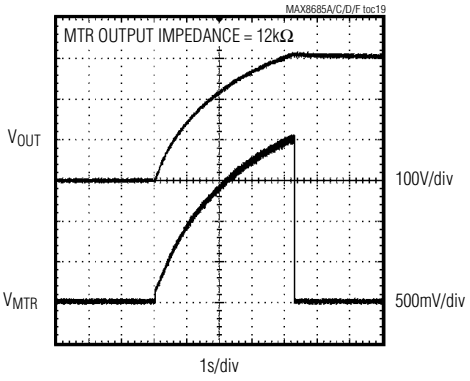

**CHARGE PROFILE (MAX8685F)**
**$C_{OUT}$ = 35µF**



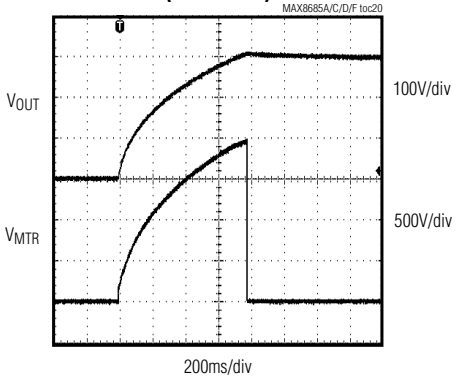
## Typical Operating Characteristics (continued)

($V_{EN}$ = $V_{BATT}$ = $V_{ISET}$ = $V_{CC}$ = 3.3V, $V_{CCT}$ = 5.5V, circuits of Figure 3, $T_A$ = +25°C, unless otherwise noted.)

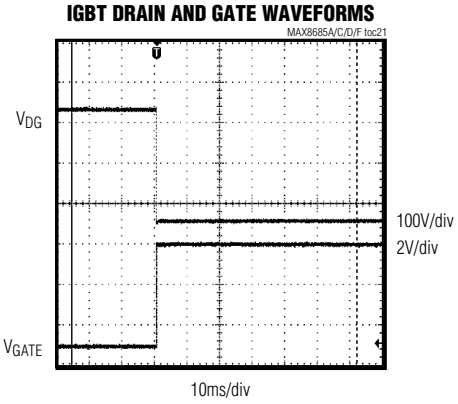
**CHARGE-UP WAVEFORM OF MTR**



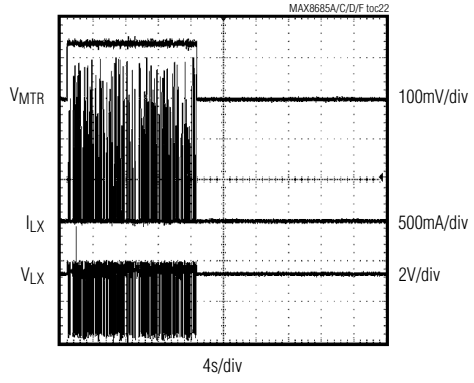

**CHARGE-UP WAVEFORM OF MTR (MAX8685F)**



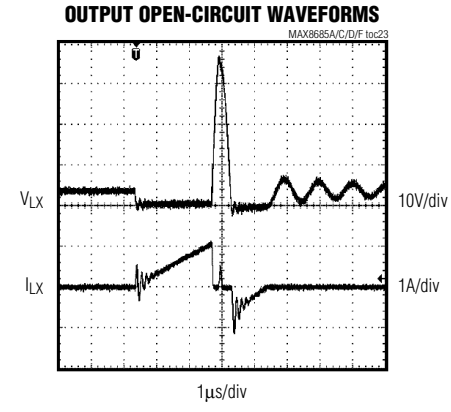

**IGBT DRAIN AND GATE WAVEFORMS**



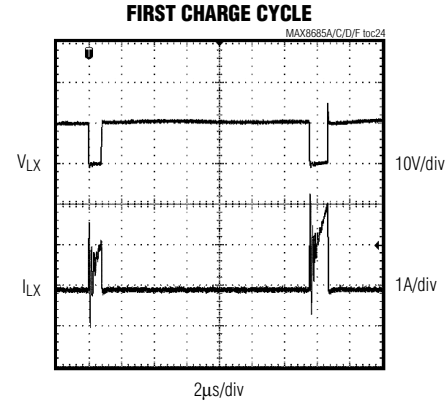

**STARTUP INTO SHORT-CIRCUIT WAVEFORMS**




**OUTPUT OPEN-CIRCUIT WAVEFORMS**




**FIRST CHARGE CYCLE**



# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

## Pin Description

| PIN | | NAME | FUNCTION |
|---|---|---|---|
| MAX8685A/ MAX8685F | MAX8685C/ MAX8685D | | |
| 1 | 1 | EN | Enable Input. Drive EN high to turn on the charger or low to turn it off. EN is internally pulled to GND through a 1MΩ resistor. |
| 2 | — | GND | Analog Ground. Connect GND directly to PGND and the exposed paddle in a star ground configuration. |
| 3 | 2 | TRIG | IGBT Driver Trigger Input. Drive TRIG to $V_{CCT}$ ($V_{CC}$) to trigger GATE. TRIG is internally pulled to PGND through a 1MΩ resistor. |
| 4 | — | $V_{CCT}$ | Supply Voltage Connection for the IGBT Driver. Bypass $V_{CCT}$ to PGND with a 1µF ceramic capacitor. Connect $V_{CCT}$ to $V_{CC}$ or an external supply up to 5.5V maximum. |
| 5 | 3 | GATE | IGBT Driver Output. Connect GATE to the IGBT gate. The GATE output voltage swings between $V_{CCT}$ and PGND (MAX8685A/MAX8685F only). For the MAX8685C/MAX8685D, the GATE output voltage swings between $V_{CC}$ and PGND (EP). |
| 6 | — | PGND | Power Ground. Connect PGND directly to GND and the exposed paddle in a star ground configuration. |
| 7 | 4 | $\overline{DONE}$ | Charge Done Indicator. $\overline{DONE}$ is an open-drain output that is internally pulled low when EN is driven high and the output capacitor is charged. $\overline{DONE}$ is high impedance when EN is driven low (shutdown mode) and while the output capacitor is charging. |
| 8 | 5 | LX | Transformer Primary Connection. Connect LX to the transformer primary as shown in Figure 3 or Figure 4. In shutdown mode, the internal switch is off and LX is connected to the battery voltage through the primary side of the transformer. An internal clamp limits the LX voltage to 34V. |
| 9 | 6 | SEC | Secondary Current-Sense Input. Connect SEC to the return of the secondary winding to measure current. |
| 10 | — | UVI | Battery Input Undervoltage Detect. Connect a resistor from UVI to the battery to make a resistor-divider with an internal 75kΩ resistor to GND. The input current from the battery is reduced when $V_{UVI}$ drops below 1V. Connect UVI to $V_{CC}$ when this feature is not in use. UVI is high impedance when EN is driven low (shutdown mode). |
| 11 | — | ISET | Current-Limit Set. Connect a resistor from ISET to GND to set the peak current limit through the primary winding. For the MAX8685A, $R_{ISET}$ = 2A x 75kΩ / $I_{PEAK}$. For the MAX8685F, $R_{ISET}$ = 2.6A x 75kΩ / $I_{PEAK}$. Connect ISET to $V_{CC}$ to set the current limit to 2A (MAX8685A) or to 2.6A (MAX8685F). |
| 12 | 7 | $V_{CC}$ | Supply Voltage for the IC. Bypass $V_{CC}$ to GND (EP) with a 1µF ceramic capacitor. |
| 13 | 8 | FB | Output Feedback. Connect FB to the center of a resistor-divider connected between the transformer's secondary winding and GND to set the output voltage. $V_{FB}$ regulates to 1.25V. |
| 14 | — | MTR | Voltage-Monitor Output. The sample-and-hold monitor circuitry provides a voltage proportional to the output voltage. MTR provides a 2V output when $V_{FB}$ equals 1.25V. The voltage monitor output is only valid when the part is charging. In shutdown mode, MTR is internally grounded. See the *Output-Voltage Monitoring (MAX8685A/MAX8685F Only)* section. |
| — | — | EP | Exposed Paddle. Connect the exposed paddle, GND, and PGND together. Note that the exposed paddle is the only ground connection for the MAX8685C/MAX8685D. |

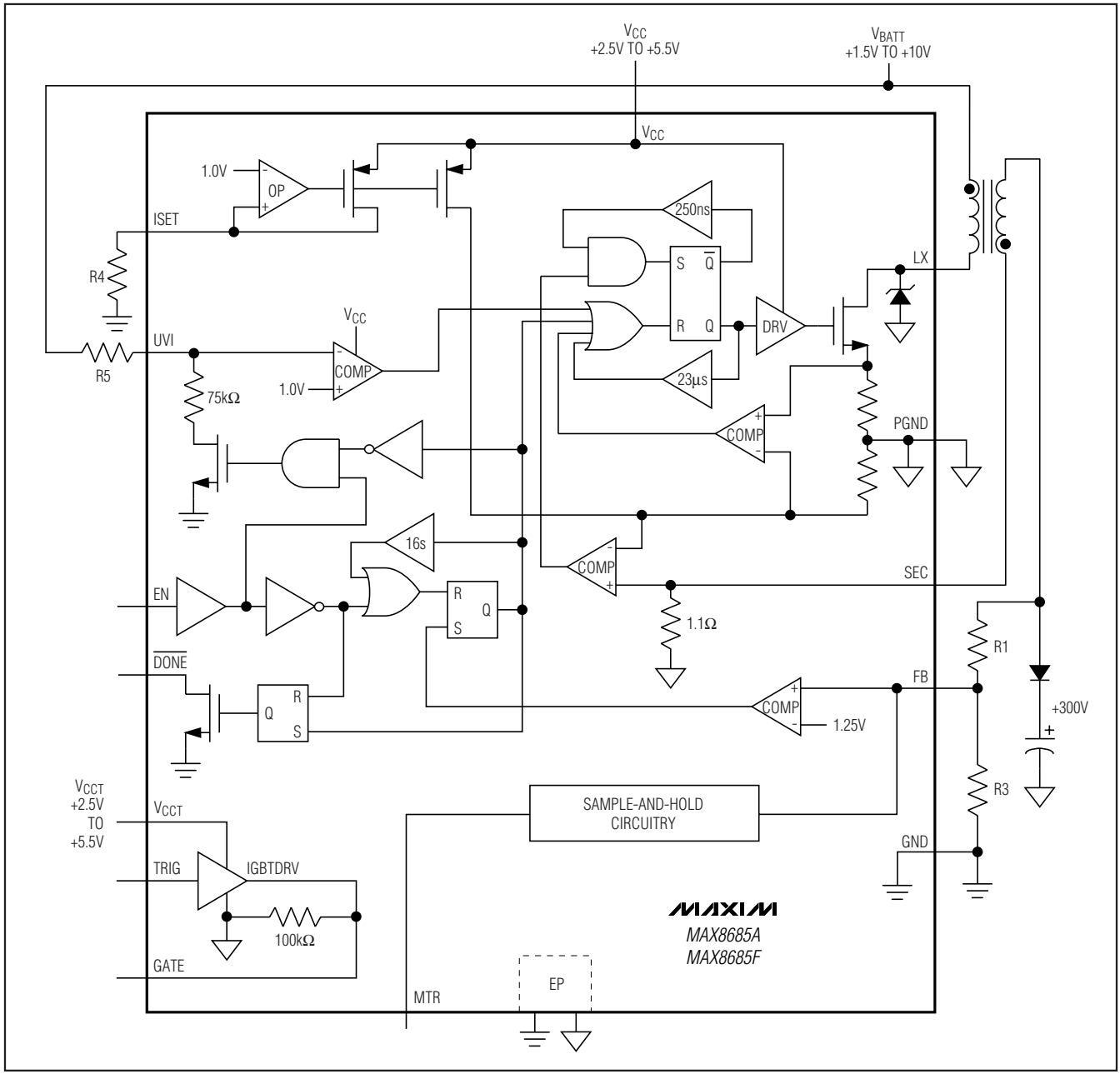



*Figure 1. MAX8685A/MAX8685F Functional Diagram*

## Detailed Description

The MAX8685 family of devices utilizes a flyback DC-DC converter topology with current-limited continuous-mode (CCM) control scheme and internal switch to charge photoflash capacitors quickly and efficiently. Low-battery-detection circuitry monitors the input voltage on a cycle-by-cycle basis and reduces peak primary current if the input voltage decreases below the UVI threshold. An integrated IGBT driver with internal pullup and pulldown resistors safely drives IGBTs for discharging the

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

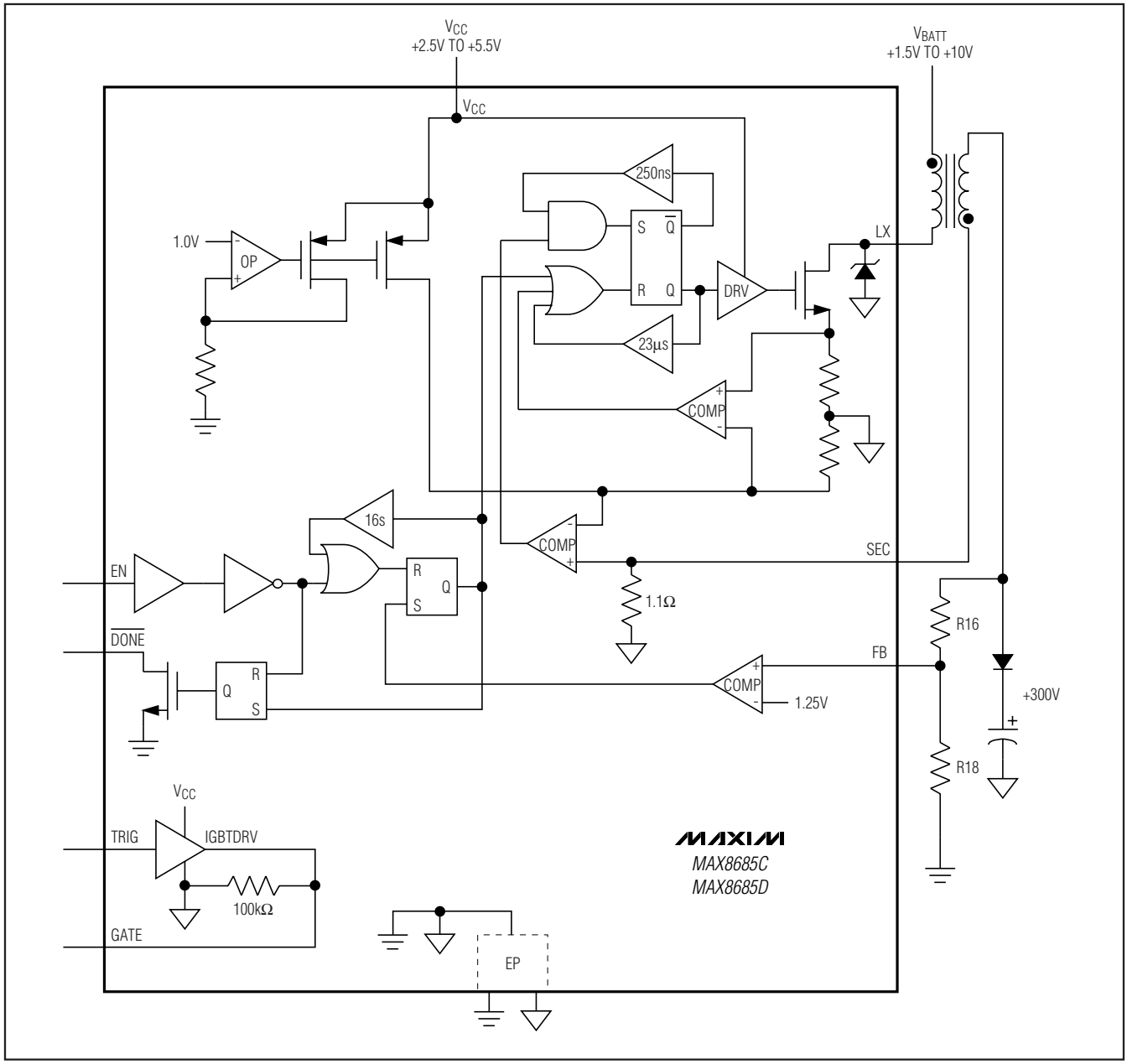



*Figure 2. MAX8685C/MAX8685D Functional Diagram*

output capacitor through a xenon flash bulb. A voltage-monitor output generates a sampled replica of the output voltage to interface with the microprocessor's internal A/D converter to assist in implementing red-eye reduction.

Figure 1 shows the MAX8685A/MAX8685F functional diagram; Figure 2 is the functional diagram for the MAX8685C/MAX8685D.

### Control Scheme

The MAX8685 family uses a constant peak-and-valley current-control scheme to precisely control the photoflash capacitor charging current. The MAX8685A/MAX8685F current limit is set by the ISET resistor (see the *Choosing a Resistor for Lowering the Charge Current (MAX8685A/MAX8685F Only)* section) or by connecting ISET to $V_{CC}$ for a maximum limit of 2A (MAX8685A) or 2.6A (MAX8685F). The resistor at ISET (MAX8685A/MAX8685F) and the transformer turns ratio set the peak charge current.

The MAX8685C/MAX8685D offer fixed peak primary current limits of 1A and 1.6A, respectively. Drive EN high to turn on the LX switch and initiate charging. After the LX switch turns on, the current in the transformer primary winding increases to the peak current limit. When the LX switch turns off, the energy stored in the transformer is delivered to the photoflash capacitor through the transformer secondary and rectifying diode. As the secondary current ramps down, it is monitored through SEC. When the current drops to 1.67% of the primary peak current limit, the LX switch turns on after a 50ns delay (MAX8685C/MAX8685D/MAX8685F) and a new charge cycle begins. There is no delay in the MAX8685A. This cycle repeats itself, adding energy to the photoflash capacitor until the target output voltage is reached. The switching frequency is determined by the time required to ramp the primary-side inductance to the LX peak current limit and the discharge time of the secondary current. The switching frequency increases as the output capacitor charges to the targeted output voltage. Once the target output voltage is reached, the IC automatically refreshes the output every 16s, efficiently maintaining the capacitor charge level with minimum battery drain. The MAX8685 family draws only 60µA (typ) in automatic refresh mode. Automatic refresh can be overridden by driving EN low.

### Secondary-Side Sensing

Output regulation is accomplished using a resistor-divider connected to the anode of the output rectifying diode (see Figure 3 or Figure 4). This connection eliminates DC current drain on the output capacitor while still providing direct output sensing for optimum voltage accuracy that is not dependent on the transformer turns ratio. The MAX8685 samples $V_{FB}$ during the flyback

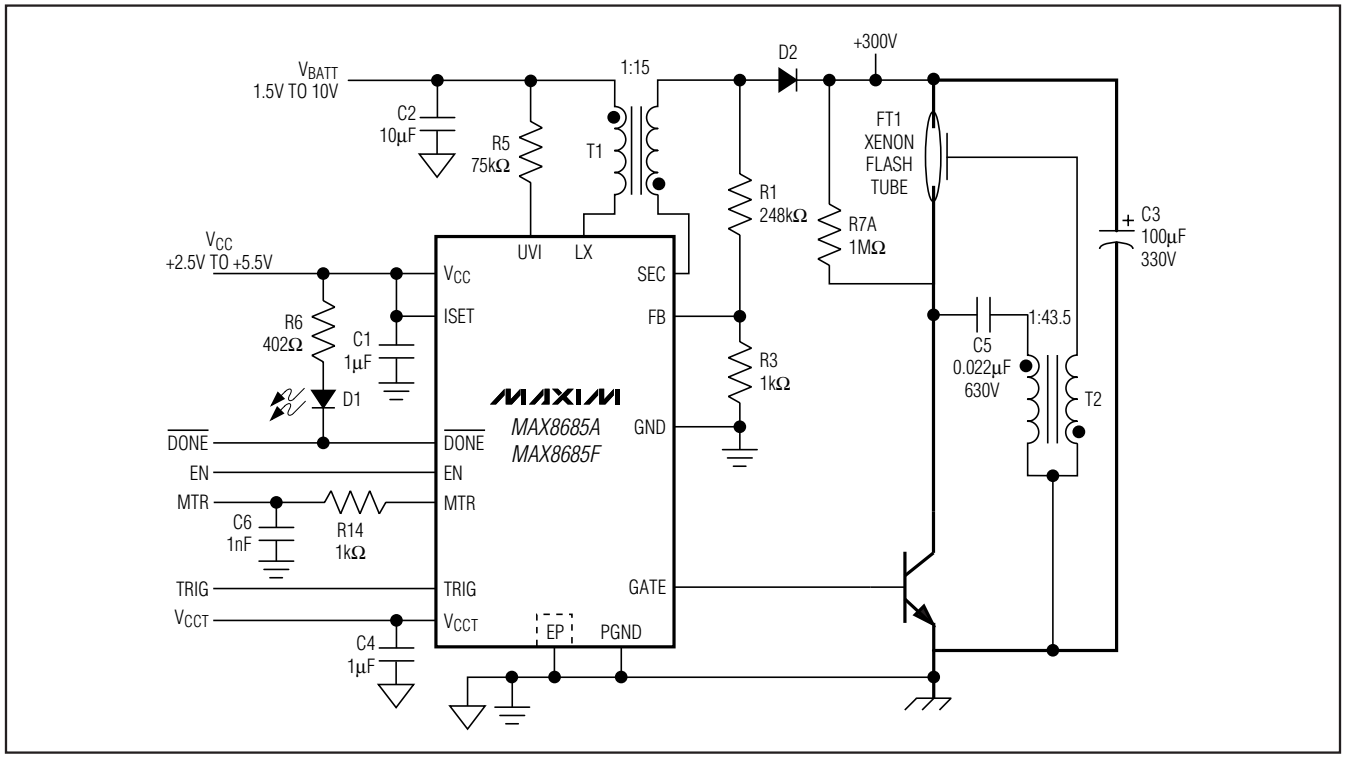



*Figure 3. MAX8685A/MAX8685F Typical Application Circuit*

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

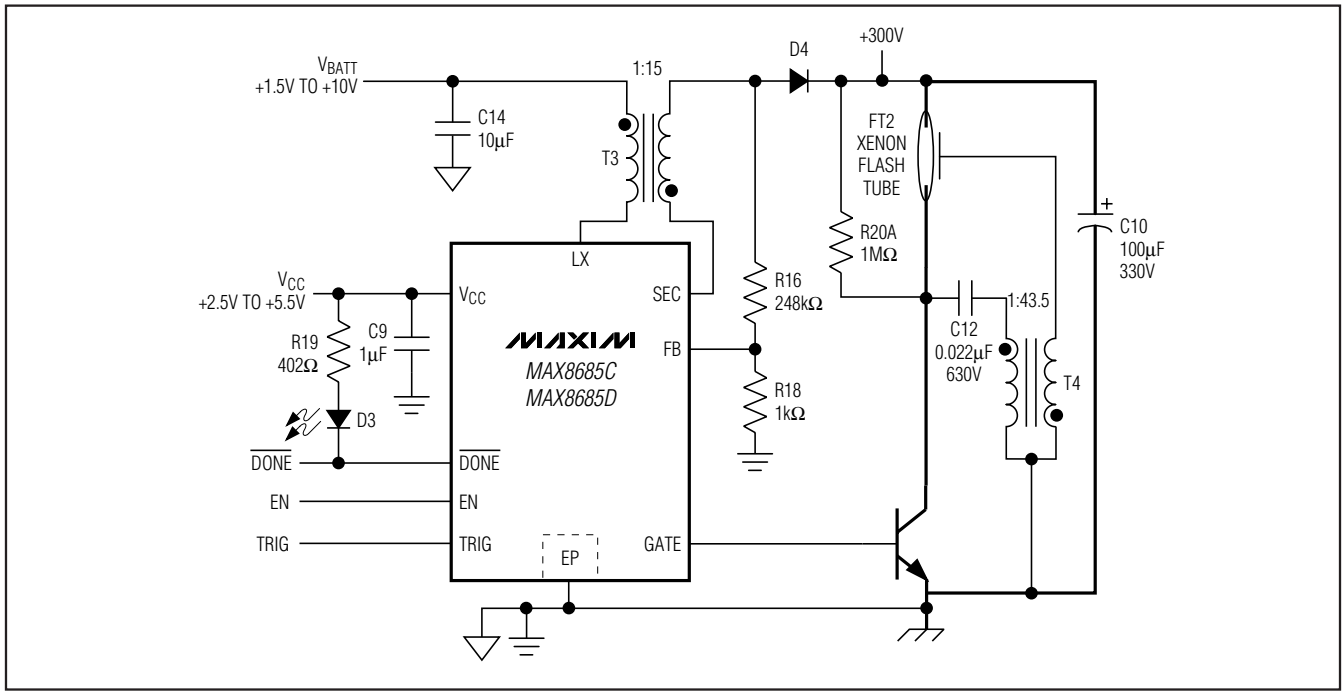



*Figure 4. MAX8685C/MAX8685D Typical Application Circuit*

phase (when the LX switch is off). When $V_{FB}$ rises above 1.25V, charging stops and $\overline{DONE}$ internally pulls low. See the *Adjustable Output Voltage* section for information on selecting values for the resistor-divider.

### Extending Battery Life with UVI (MAX8685A/MAX8685F Only)

The UVI circuit allows the output to charge as fast as possible without causing the input voltage to drop below a programmed voltage level. This feature permits the current limit to be set for a faster charge rate under typical conditions, rather than a level dictated by worst-case discharge state of the battery. The UVI comparator determines if the input source is being pulled low as a result of the input current drawn by photoflash charging or some other process in the camera. When UVI drops below the UVI falling threshold, the LX control latch is reset and the internal MOSFET is immediately turned off. The LX switch remains off until the current in the transformer secondary drops to the valley trip threshold, or for 1µs, whichever occurs first. To reduce average charge current, the LX switch only turns on if the input is above the UVI rising threshold.

### Photoflash Capacitor Fault Protection

The MAX8685 family features protection circuitry to detect an open- or short-circuited output capacitor. During a normal charge cycle, after EN is driven high, the MAX8685 devices generate the first LX pulse with a peak primary current limit equal to one-half the programmed peak current limit with all subsequent pulses equal to the programmed peak current limit.

In the event that the output capacitor is open circuited (see the Output Open-Circuit Waveforms diagram in the *Typical Operating Characteristics*), the first LX pulse charges up the parasitic capacitance at the transformer secondary above the targeted output voltage. Since the FB error amplifier is satisfied, no other switching cycles occur until the autorefresh timer expires after 16s. At this point, if EN is still high, the MAX8685 generates another LX pulse with half the peak current limit. This feature helps to protect the main switch when the output capacitor is open circuited.

In the event that the output capacitor is short circuited (see the Startup into Short-Circuit Waveforms diagram in the *Typical Operating Characteristics*), the first (half-amplitude) LX pulse does not increase the output voltage, so normal LX switching occurs for the full 16s. If the output voltage has not reached its expected final voltage at this point, the MAX8685 stops switching, but the internal reference circuit remains on. This feature helps limit battery drain in the event the output capacitor is short circuited. Cycling EN or $V_{CC}$ allows another charge cycle to occur.

### UVLO

The MAX8685 family of devices provides a UVLO threshold for the $V_{CC}$ power-supply input. When $V_{CC} < V_{UVLO}$, the device cannot turn on. All switching behavior is locked out until $V_{CC}$ increases above the UVLO threshold.

Operation near the UVLO threshold can result in slight overcharge of the output capacitor. Additionally, the voltage-monitor output ($V_{MTR}$) may not provide a proper output voltage when $V_{CC}$ is near the UVLO threshold and less than the minimum valid $V_{CC}$ voltage in the *Electrical Characteristics* table. To ensure that this does not occur, always connect the MAX8685 family of devices to a valid $V_{CC}$ voltage in accordance with the *Electrical Characteristics*.

## Applications Information

### IGBT Driver

The MAX8685 family provides an integrated IGBT driver to trigger and control the discharge of the photoflash capacitor through a xenon flash bulb. Internal pullup and pulldown resistors control the turn-on and turn-off rate of the IGBT. The MAX8685A/MAX8685F provides a separate power input ($V_{CCT}$) for the IGBT driver, while the IGBT drivers of the MAX8685C/MAX8685D use $V_{CC}$ as their power source.

Drive TRIG high to turn on the IGBT gate. Drive TRIG low to turn off the IGBT gate. An internal 1MΩ pulldown resistor on TRIG prevents indeterminate states on the input, while an internal 100kΩ pulldown resistor on GATE prevents indeterminate states on the IGBT gate in the event that $V_{CCT}$ is not present.

The IGBT driver circuitry remains active when EN is pulled low and $V_{CC}$ is valid. This allows a reduction in battery-power consumption, while the photoflash capacitor is being discharged through the xenon flash tube. However, EN may be left high so that multiple flashes at maximum intensity can occur in rapid succession, if needed.

### IGBT Selection

IGBT selection is important for long-term reliability of the photoflash-discharge circuitry. Ensure that the IGBT's $V_{CE}$ maximum voltage rating exceeds the maximum expected output voltage at the photoflash capacitor. Additionally, choose an IGBT that can withstand peak currents in excess of 150A.

Choose an IGBT such that its $V_{GE}$ specification over the expected $V_{CCT}$ (or $V_{CC}$) voltage range is met. Failure to observe these specifications can result in damage to the IGBT. Observe the grounding recommendations in the IGBT data sheet because many IGBTs have a separate emitter connection for the GATE drive only.

### Output-Voltage Monitoring (MAX8685A/MAX8685F Only)

A voltage monitor provides a scaled replica of the output voltage in real time. The scaled output voltage interfaces with a microprocessor's internal A/D converter. MTR provides a 2V output when $V_{FB}$ equals 1.25V. The voltage-monitor output is only valid when the part is charging. In shutdown mode, MTR is internally grounded.

### Transformer Design

The transformer is a key element in any transformer flyback design. The switching elements are subject to significantly large voltage and current stresses, depending on the transformer design. The transformer also plays a key role in the noise performance of the circuit. Proper selection, design, and construction of the transformer are crucial to the performance of a photoflash charger.

#### Minimum Transformer Turns Ratio

The transformer turns ratio needs to be high enough so that the transformer's peak primary voltage does not exceed the voltage rating (34V) of the clamp on the internal MOSFET. The minimum transformer turns ratio is determined by:

$$N = \frac{V_{OUT} + V_D}{34V - V_{BATT}}$$

where $V_{OUT}$ is the output voltage, $V_D$ is the diode voltage drop, and $V_{BATT}$ is the battery voltage. For example, $V_{OUT}$ = 300V, $V_D$ = 2.0V, $V_{BATT}$ = 1.5V. The equation above provides a minimum turns ratio of 1:10. A transformer with a turns ratio of 1:15 is typically recommended for most applications.

#### Primary Inductance

The MAX8685 family operates either in discontinuous-conduction mode (DCM) or in continuous-conduction mode (CCM). Generally, CCM operation offers a higher efficiency and lower ripple currents for the same output power as compared to DCM operation. The capacitive switching losses in the DMOS switch are minimal at the boundary of DCM and CCM operation. The primary inductance is therefore estimated based on this CCM assumption. The MAX8685 devices have a maximum on-time limit ($t_{ON(MAX)}$), typically 23µs, and a typical peak current limit ($I_{LIM}$). The maximum inductance for a minimum battery voltage ($V_{BATT(MIN)}$) is given by:

$$L_{PRI(MAX)} = \frac{V_{BATT(MIN)} \times t_{ON(MAX)}}{I_{LIM}}$$

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

### Secondary Inductance

The boundary of DCM and CCM operation is determined by monitoring the secondary valley current. The secondary current-sensing circuit in the MAX8685 family has a blanking time of approximately 250ns, resulting in a minimum off-time ($t_{OFF(MIN)}$). Since the minimum discharge time occurs at the target output voltage $V_{OUT(MAX)}$, the minimum secondary inductance is given by:

$$L_{SEC(MIN)} = \frac{V_{OUT(MAX)} \times N \times t_{OFF(MIN)}}{I_{LIM}}$$

where N is the transformer turns ratio. This in turn implies a minimum primary inductance $L_{PRI(MIN)}$ given by:

$$L_{PRI(MIN)} = \frac{L_{SEC(MIN)}}{N^2}$$

Choose a value between $L_{PRI(MIN)}$ and $L_{PRI(MAX)}$ based on other considerations for the leakage inductance and the transformer capacitance. A transformer with a primary inductance of 6µH is recommended for most applications.

### Leakage Inductance

A particularly important transformer parameter is leakage inductance. In a practical transformer construction, all windings cannot be equally well-coupled to the core because of physical separation. If the primary inductance is high, the transformer may need multiple windings for the primary. A small amount of energy is stored in the leakage inductance. If the primary inductance is too small, the primary windings may not cover the width of the core and result in poor coupling to the secondary. This also increases the leakage inductance. Leakage inductance does not participate in the primary to secondary energy transfer. Since the leakage inductance does not find a path for the current built up during the switch on-time, it results in voltage spikes and ringing at the drain of the MAX8685 internal power switch (LX) when it turns off.

The MAX8685 family's internal switch is designed to be robust to withstand these voltage spikes; however, voltage overshoot needs to be minimized because it reduces total efficiency. Leakage inductance also delays the transfer of power from input to output, causing an increase in charge time. In addition, transformer secondary leakage inductance may couple with the reverse recovery current of the output rectifier diode to cause ringing when the diode turns off. The transformer secondary leakage inductance and the capacitance of the rectifier determine this resonant frequency. There is typically very little loss in the resonant circuit, so this network can generate many cycles of ringing after the spike. The ringing can therefore affect the peak primary current-sense signal.

The transformer secondary leakage inductance is a function of the primary leakage inductance. Care must be taken during transformer design while applying techniques such as sandwiching the secondary between two primary windings to minimize leakage inductance. This can cause high winding-to-winding capacitance, reducing the efficiency of the circuit, and increasing the charge time.

### Transformer Secondary Capacitance

The total capacitance on the secondary must be minimized for both efficient and proper operation. Since the secondary of the transformer undergoes large voltage swings, capacitance on the secondary is a significant detriment to efficiency. This capacitance is reflected on the primary as an effective capacitance proportional to the square of the transformer turns ratio. It therefore dominates the resulting capacitance on the primary. Both the leakage inductance and the secondary capacitance of the transformer need to be minimized for efficient operation.

## Rectifying Diode

The rectifying diode(s) must have sufficient reverse voltage and forward-current ratings. The peak-reverse voltage $V_{R(PEAK)}$ seen by the diode(s) is given by:

$$V_{R(PEAK)} = V_{OUT(MAX)} + N \times V_{BATT}$$

The peak current of the diode $I_{S(PEAK)}$ is determined by the peak primary current as:

$$I_{S(PEAK)} = \frac{I_{LIM}}{N}$$

Rectifier capacitance and transformer secondary leakage inductance couple to cause ringing when the diode turns off. The overshoot caused by this ringing can exceed the diode voltage rating and cause damage to the diode. The ringing can also affect the current-sense signal in the MAX8685 devices. Therefore, it is recommended that the rectifying diode have very low capacitance of 5pF or less. The transition from the conduction to the blocking state recovery time is trr.

The reverse recovery time must be as small as possible to reduce losses due to this reverse current. The reverse recovery voltage spikes also generate noise that can interfere with the current-sense signal. The MAX8685C/MAX8685D/MAX8685F add a 50ns delay

on each switching cycle to reduce losses during reverse recovery. The slope of the voltage spike for recovery from the peak reverse current to 0A is used to characterize the diode as a soft recovery type if the slope is small, or a hard recovery type if the slope is steep. A soft recovery diode exhibits significantly lower switching noise than a hard recovery type. Snubbers can be used to make the reverse recovery waveform soft, but they also lower efficiency. A diode with a small trr and soft recovery is definitely an advantage. Recommended diodes are listed in Table 1.

## Table 1. Recommended Diodes

| PART | SUPPLIER | MAXIMUM REVERSE VOLTAGE (V, EACH) | CAPACITANCE (pF, EACH) |
|---|---|---|---|
| BAV23S (Dual) | Philips | 250 | 5 |
| BAW101S (Dual) | Philips | 300 | 2 |
| CMPD2004S (Single) | Central | 240 | 5 |
| CMPD20055 (Single) | Central | 300 | 5 |

### Adjustable Output Voltage

The MAX8685 family uses secondary feedback to sense the output voltage (see Figure 3 or Figure 4). The output voltage is set by the ratio of a resistor voltage-divider. Choose the lower resistor (R3 in Figure 3 or R18 in Figure 4), connected from FB to GND, less than 2kΩ. A typical value for R3 (R18) is 1kΩ. Larger resistor values combined with parasitic capacitance at FB can slow the rise time of the FB voltage during each cycle. This can prevent the feedback circuitry from detecting when the output has reached the desired level.

The value for the upper resistor (R1 in Figure 3 or R16 in Figure 4) is found from:

$$R1 = R3\left(\frac{V_{OUT}}{V_{FB}} - 1\right)$$

where $V_{FB}$ is 1.25V. Make sure the voltage rating of the resistors is sufficient. It may be necessary to use two resistors in series for the upper resistor so as not to exceed the resistor voltage rating.

### Capacitor Selection

The $V_{CC}$, $V_{CCT}$, and $V_{BATT}$ decoupling capacitors are preferred to be multilayer ceramic type with X5R or X7R dielectric for use across a wide temperature range. Use of Y5V and Z5U dielectrics is strongly discouraged due to the higher voltage and temperature coefficient of these materials.

### Choosing a Resistor for Lowering the Charge Current (MAX8685A/MAX8685F Only)

Set the default for the peak-primary current limit in the MAX8685A/MAX8685F by connecting ISET to $V_{CC}$. The default peak current limit is 2A for the MAX8685A and 2.6A for the MAX8685F. This current limit works well for most applications where the fastest photoflash charge time is desired. If a lower current is required, connect a resistor (R4 in Figure 1) from ISET to GND. Select R4 as follows:

$$R4 = \frac{2.0A}{I_{LIMIT}} \times 75k\Omega \text{ (MAX8685A)}$$

$$R4 = \frac{2.6A}{I_{LIMIT}} \times 75k\Omega \text{ (MAX8685F)}$$

### Adjusting the Battery Threshold for Lowering Charge Current (MAX8685A/MAX8685F Only)

The UVI circuit allows a camera to be ready to flash in a short time when the battery is fresh, while still allowing flash pictures when the battery is at low capacity by extending the charge time to limit the battery surge current. If the UVI input voltage drops below the falling threshold (1.0V typ), the LX switch turns off. On a cycle-by-cycle basis, the input current decreases so that the input remains at or above the UVI threshold until charging is complete. Set the UVI falling threshold by connecting a resistor (R5 in Figure 3) between UVI and the battery input to form a voltage-divider with an internal 75kΩ resistor. Select the UVI resistor value as follows:

$$R5 = 75k\Omega \times \left(\frac{V_{BATT(MIN)}}{V_{UVI}} - 1\right)$$

where $V_{UVI}$ is 1V and $V_{BATT(MIN)}$ is the desired minimum operating battery voltage. When $V_{CC}$ is connected to $V_{BATT}$, the UVI falling threshold must be set to 2.5V or higher. The operational range of R5 is from 37.5kΩ to 675kΩ.

### $\overline{DONE}$ Output

$\overline{DONE}$ is an open-drain output that internally pulls low when EN is high and the circuit has finished charging the output capacitor. Once the output capacitor is charged, $\overline{DONE}$ remains low until EN or $V_{CC}$ goes low. To use $\overline{DONE}$ as a logic-level output, connect a pullup

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

resistor (typically 100kΩ) from $\overline{DONE}$ to the logic supply rail. $\overline{DONE}$ can also drive an LED by placing it in series with a resistor (Figures 3 and 4). When driving an LED, select the series resistor value so that the current into $\overline{DONE}$ is less than 10mA. Note that when the output capacitor is fully charged, the MAX8685 family autorefreshes every 16s as long as EN is high.

### Layout Guidelines

**Warning: Lethal voltages are present in this circuit. Use caution when working with this circuit.**

The high-voltage/high-current operation of this application demands careful attention to board layout. Larger than minimum space between traces in the high-voltage area is recommended. This is essential to meet the voltage-breakdown specifications of the board. To minimize the high-frequency noise generated by switching, high dV/dt paths must be made as short as possible to reduce radiated noise. A high di/dt loop creates noise due to radiated magnetic fields. To reduce high di/dt loop-generated noise, make the loop as small as possible. Keep the area for the high-voltage end of the secondary as small as possible. Refer to the MAX8685 evaluation kit for a layout example.

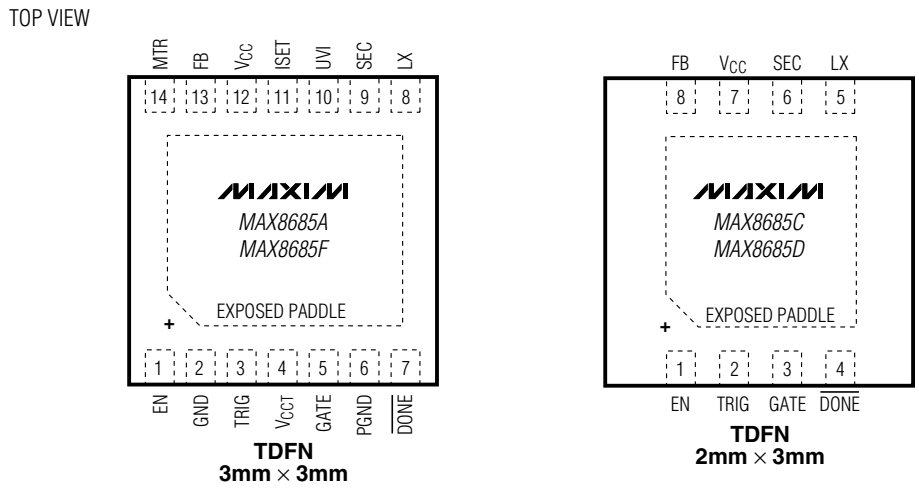
A proper grounding scheme is critical for overall performance and long-term reliability of the MAX8685 family of devices. Create separate ground planes for GND, PGND, and the photoflash discharge ground. First, create a GND plane close to the MAX8685 for the feedback resistor connection, $V_{CC}$ bypass capacitor, ISET resistance (MAX8685A/MAX8685F only), and MTR (MAX8685A/MAX8685F only) output filter. Connect this ground plane to the GND pin (MAX8685A/MAX8685F only) and the exposed paddle of the device. In the case of the MAX8685C/MAX8685D, the exposed paddle is the only ground connection on the device.

Next, create a power ground plane for the photoflash capacitor charging components. Bypass $V_{CCT}$ (MAX8685A/MAX8685F only) and battery ground return to this power ground plane and connect to the PGND pin of the device (MAX8685A/MAX8685F only). In the case of the MAX8685C/MAX8685D, the exposed paddle also serves as the PGND connection. Connect PGND to GND using a single point near the MAX8685.

Lastly, create a separate power ground for the high-current discharge path. The photoflash capacitor, IGBT emitter (pins 1 and 2), and trigger transformer ground connection should all connect to the discharge ground plane. Connect the discharge ground plane to PGND near the MAX8685 PGND pin using the Kelvin-sense emitter connection provided on the IGBT (pin 3). This forces a single-point ground for the discharge path and provides a good return path for the IGBT driver currents and photoflash capacitor charging currents.

It is important to note that when the photoflash capacitor is discharged, there is a very fast di/dt that induces a voltage spike on the ground plane. Failure to observe proper grounding techniques can result in damage to the MAX8685 or other components in the circuit.

## Pin Configurations




**NOTE:** EXPOSED PADDLE IS GND FOR THE MAX8685C/MAX8685D.

## Chip Information

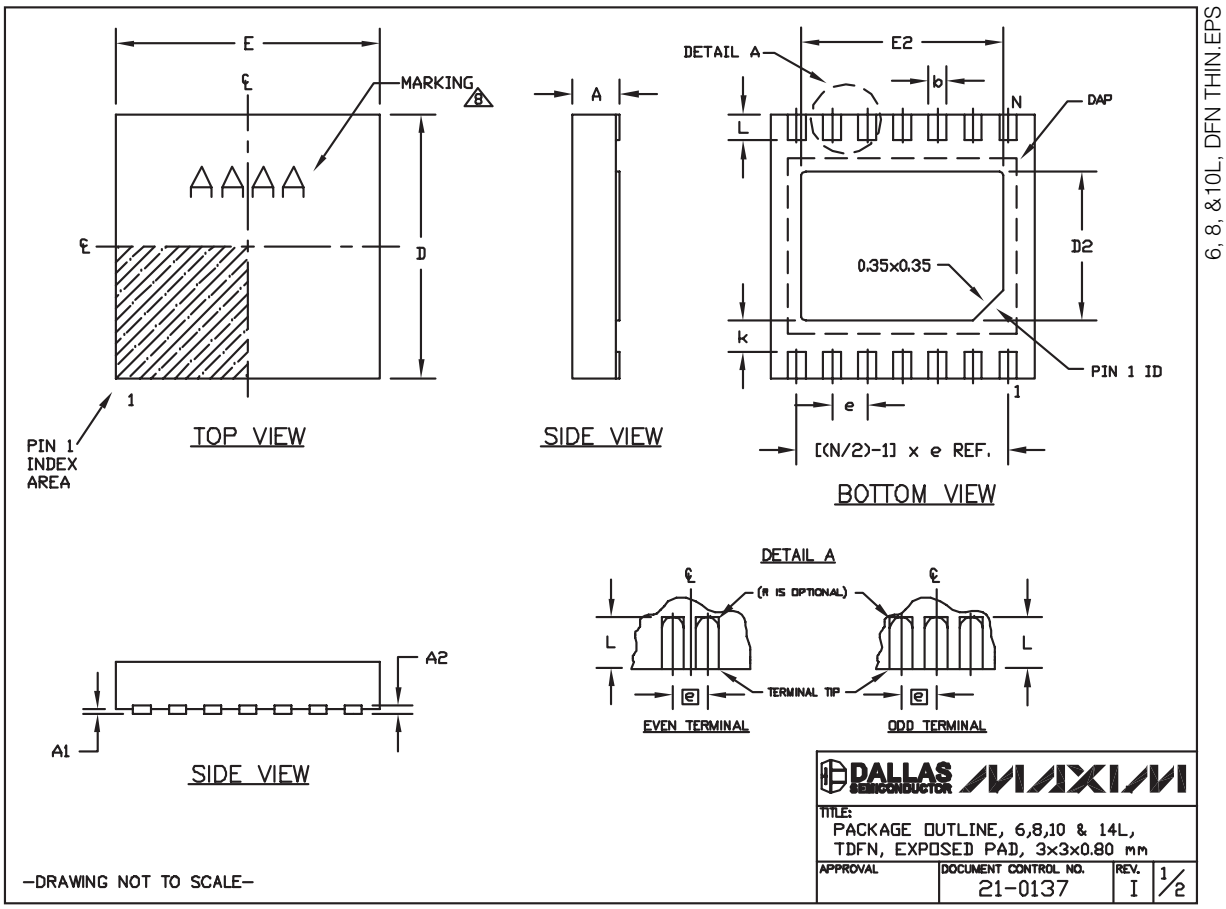
PROCESS: BiCMOS

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

## Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. |
|---|---|---|
| 14 TDFN-EP | T1433-2 | **21-0137** |
| 8 TDFN-EP | T823-1 | **21-0174** |



## Package Information (continued)

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

| COMMON DIMENSIONS | | |
|---|---|---|
| SYMBOL | MIN. | MAX. |
| A | 0.70 | 0.80 |
| D | 2.90 | 3.10 |
| E | 2.90 | 3.10 |
| A1 | 0.00 | 0.05 |
| L | 0.20 | 0.40 |
| k | 0.25 MIN. | |
| A2 | 0.20 REF. | |

| PACKAGE VARIATIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| PKG. CODE | N | D2 | E2 | e | JEDEC SPEC | b | [(N/2)-1] x e |
| T633-2 | 6 | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA | 0.40±0.05 | 1.90 REF |
| T833-2 | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T833-3 | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T1033-1 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033-2 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1433-1 | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ---- | 0.20±0.05 | 2.40 REF |
| T1433-2 | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ---- | 0.20±0.05 | 2.40 REF |

NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY SHALL NOT EXCEED 0.08 mm.
3. WARPAGE SHALL NOT EXCEED 0.10 mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. DRAWING CONFORMS TO JEDEC MO229, EXCEPT DIMENSIONS "D2" AND "E2", AND T1433-1 & T1433-2.
6. "N" IS THE TOTAL NUMBER OF LEADS.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
8. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 6,8,10 & 14L, TDFN, EXPOSED PAD, 3x3x0.80 mm

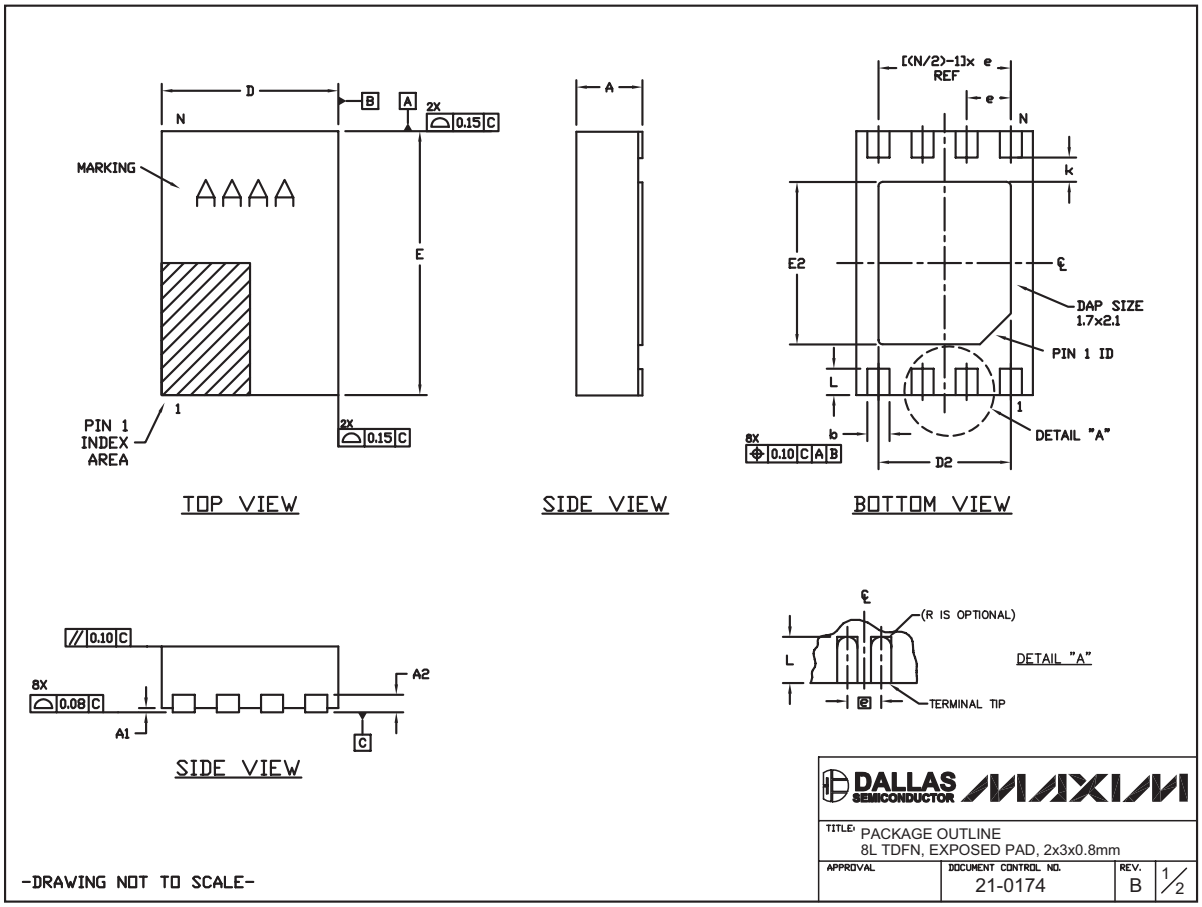
| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0137 | I | 2/2 |

-DRAWING NOT TO SCALE-

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

## Package Information (continued)

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.



## Package Information (continued)

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

| | DIMENSIONS | | |
|---|---|---|---|
| SYMBOL | MIN. | NOM. | MAX. |
| A | 0.70 | 0.75 | 0.80 |
| E | 2.95 | 3.00 | 3.05 |
| D | 1.95 | 2.00 | 2.05 |
| A1 | 0.00 | 0.02 | 0.05 |
| L | 0.30 | 0.40 | 0.50 |
| k | 0.20 MIN. | | |
| A2 | 0.20 REF. | | |
| N | 8 | | |
| e | 0.50 BSC | | |
| b | 0.18 | 0.25 | 0.30 |

| | EXPOSED PAD PACKAGE | | | | | |
|---|---|---|---|---|---|---|
| PKG. CODE | E2 | | | D2 | | |
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| T823-1 | 1.60 | 1.75 | 1.90 | 1.50 | 1.63 | 1.75 |

NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS. COPLANARITY SHALL NOT EXCEED 0.08mm.
3. WARPAGE SHALL NOT EXCEED 0.10mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. COMPLY TO JEDEC MO229, TYPE 1, VERSION WCED-2.
6. "N" IS THE TOTAL NUMBER OF LEADS.
7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
8. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
9. MATERIAL MUST COMPLY WITH BANNED AND RESTRICTED SUBSTANCES SPEC #10-0131.

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE
8L TDFN, EXPOSED PAD, 2x3x0.8mm

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0174 | B | 2/2 |

# Xenon Photoflash Charger with IGBT Driver and Voltage Monitor

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 4 | 2/09 | Added information regarding the clamp on LX | 8, 9, 10, 13 |

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