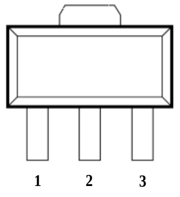
HIGH-VOLTAGE LED DRIVER WITH BUILD-IN MOSFET SWITCH

IK2306

SOT-89



1.Drain
2.GND
3.V_{DD}

FEATURES

- Operating Temperature Range -40...+85 ºc
- ON-Resistance of The MOSFET Switch 210 Ohm
- OFF-State Breakdown Voltage of the MOSFET Switch Not Less 500 V

APPLICATIONS

- Decorative lighting
- Low Power Light Fixtures
- LED Signs and Displays
- Architectural Lighting
- Incandescent Replacement
- Industrial Lighting

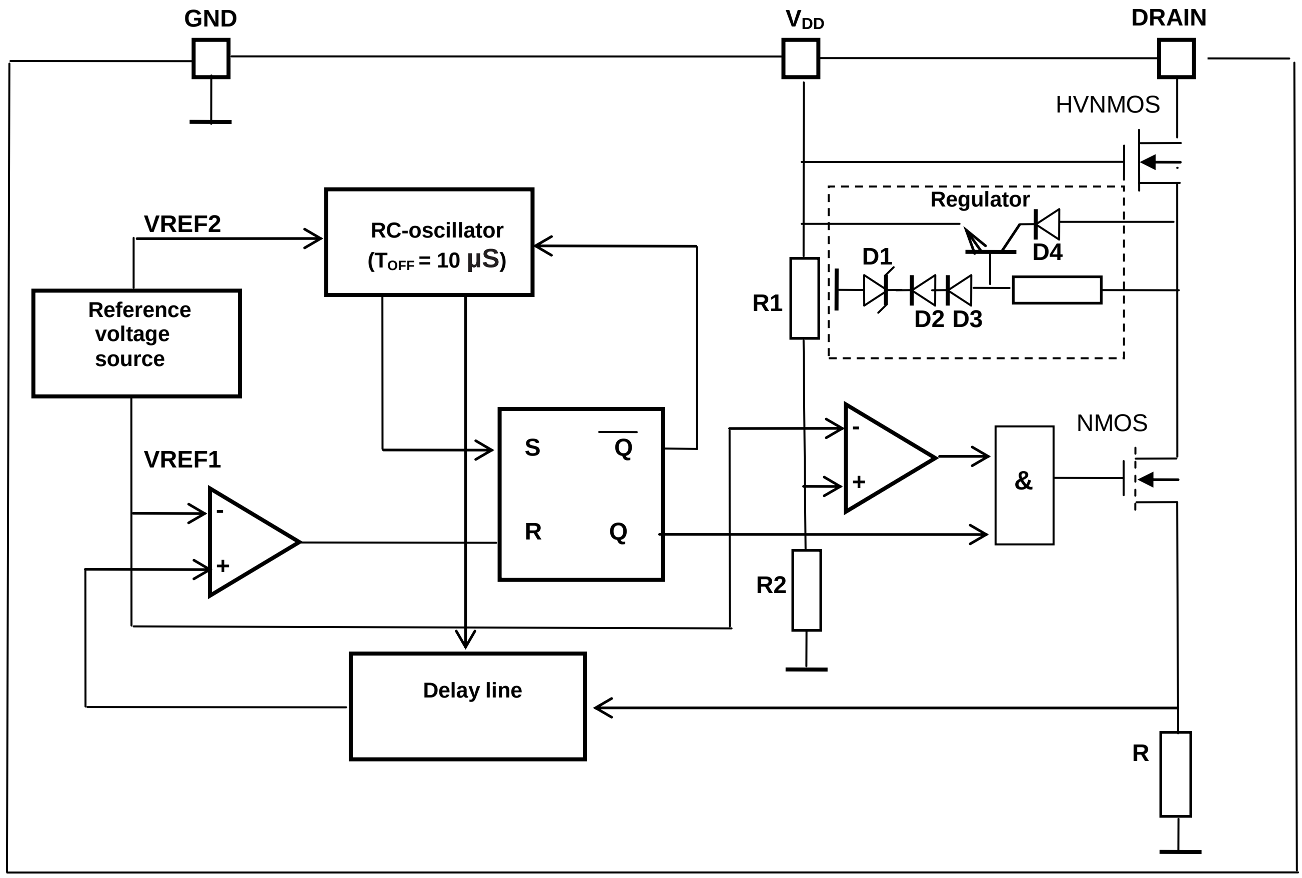
ORDERING INFORMATION

Device	Operating Temperature Range	Package	Packing
IK2306PT	T_A = - 40 ... + 85 °C	SOT-89	Tape & Reel

PRODUCT DESCRIPTION

IK2306 is high-voltage LED driver control ICs with build-in MOSFET switch and purposed for LED lighting control. IC allows efficient operation of LED strings from voltage sources ranging up to 400 VDC. The IK2306 include an internal high-voltage switching MOSFET controlled with fixed off-time T_{OFF} of approximately 10µs. The LED string is driven at constant current, thus providing constant light output and enhanced reliability. The output current is internally fixed 50mA for IK2306. The peak current control scheme provides good regulation of the output current throughout the universal AC line voltage range of 85 to 264V AC or DC input voltage of 20 to 400V.

BLOCK DIAGRAM



Figure

PIN DESCRIPTION

Pin No.	Symbol	Description
1	Drain	This is a drain terminal of the output switching MOSFET and a linear Regulator input.
2	GND	This is a common connection for all circuits
3	V_{DD}	This is a power supply pin for all control circuits. Bypass this pin with a 0.1uF low impedance capacitor.

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Min	Max	Unit
V_{DRAIN}	Input Voltage	-0.3	420	V
V_{DD}	Low-Voltage Part Supply Voltage	-0.3	10	V

* Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device.
These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied.
Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

RECOMMENDED OPERATION MODE RANGE

Symbol	Parameter	Min	Max	Unit
V_{DRAIN}	Input Voltage	20	400	V

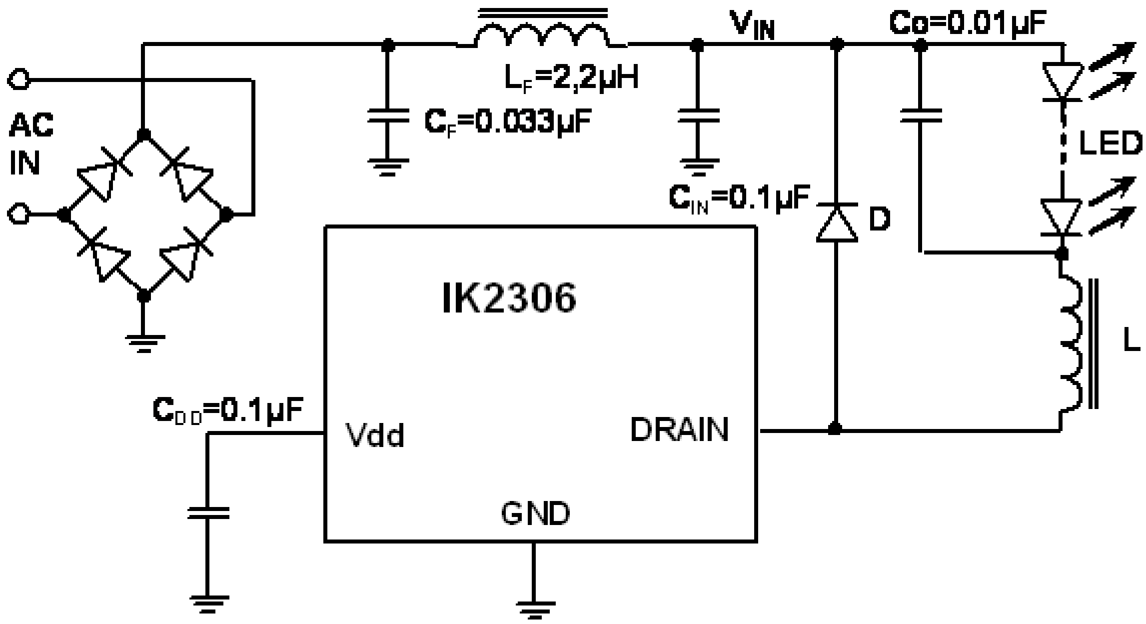
ELECTRICAL CHARACTERISTICS

<table>
<tr><th>Symbol</th><th>Parameter</th><th>Test Conditions</th><th>Min</th><th>Max</th><th>Ambient Temperature, °C</th><th>Unit</th></tr>
<tr><td>V_{DDR}</td><td>Regulator Output Voltage</td><td>V_{IN} = (20÷ 400)V</td><td>5.5</td><td>9.0</td><td rowspan="6">25 ± 10</td><td>V</td></tr>
<tr><td>I_{DD}</td><td>Low-Voltage (Control) Part Of IC Consumption Current</td><td>V_{DD} = 9.5 V
V_{IN} = 40 V</td><td>-</td><td>350</td><td>uA</td></tr>
<tr><td>R_{ON}</td><td>ON-Resistance of The Switch (DRAIN Pin)</td><td>V_{DD} = V_{DDR}
I_{DRAIN} = 20 mA</td><td>-</td><td>210</td><td>Ohm</td></tr>
<tr><td>V_{UVLO}</td><td>Undervoltage Threshold (Low-Voltage Part of IC)</td><td>V_{DD} = V_{UVLO}
I_{DRAIN} = 50 mA</td><td>3.4</td><td>V_{DDR} – 0.3</td><td>V</td></tr>
<tr><td>I_{SAT}</td><td>MOSFET Saturation Current (DRAIN Pin)</td><td>V_{DD}= V_{DDR}
V_{SAT} = 50 V</td><td>100</td><td>-</td><td>mA</td></tr>
<tr><td>V_{BR}</td><td>OFF-State Breakdown Voltage of The MOSFET Switch (DRAIN Pin)</td><td>V_{DD} = V_{DDR}
I_{DRAIN} = 1 mA</td><td>500</td><td>-</td><td>V</td></tr>
<tr><td>I_{TH}</td><td>Threshold Current</td><td>V_{DD} = V_{DDR}
V_{IN} = 50 V</td><td>52.0</td><td>63.0</td><td>25 ± 10
-40
85</td><td>mA</td></tr>
<tr><td>T_{OFF}</td><td>OFF Time (DRAIN Pin)</td><td rowspan="3">V_{DD} = V_{DDR}
V_{IN} = 50 V</td><td>8.0</td><td>13.0</td><td rowspan="3">25 ± 10</td><td>us</td></tr>
<tr><td>T_{ON}</td><td>Minimun ON-Time of The Switch (DRAIN Pin)</td><td>-</td><td>650</td><td>ns</td></tr>
<tr><td>T_{BLANK}</td><td>Leading Edge Blanking Delay</td><td>200</td><td>400</td><td>ns</td></tr>
</table>

FUNCTIONAL DESCRIPTION

The IK2306 is PWM peak current controllers or controlling a buck converter topology in continuous conduction mode (CCM). The output current is internally preset at 50mA. When the input voltage of 20 to 400V appears at the DRAIN pin, the internal high-voltage linear regulator seeks to maintain a voltage of 7VDC at the VDD pin. Until this voltage exceeds the internally programmed under-voltage threshold, the output DRAIN is non-conductive. When the threshold is exceeded, the DRAIN turns on. The input current begins to flow into the DRAIN pin. Hysteresis is provided in the under-voltage comparator to prevent oscillation. When the input current exceeds the internal preset level, a current sense comparator resets an RS flip-fl op, and the DRAIN turns off. At the same time, a one-shot circuit is activated that determines the duration of the off-state (10 µs typ.). As soon as this time is over, the flip-fl op sets again. The new switching cycle begins. A “blanking” delay of 300ns is provided that prevents false triggering of the current sense comparator due to the leading edge spike caused by circuit parasitics.

TYPICAL APPLICATION DIAGRAM



Figure

Selecting L and D

There is a certain trade-off to be considered between optimal sizing of the output inductor L and the tolerated output current ripple. The required value of L is inversely proportional to the ripple current dI_O in it.

$$L = \frac{T_{OFF\_MIAX} * V_O}{dI_O} \quad (1)$$

V_O is the forward voltage of the LED string. T_{OFF} is the off time of the IK2306. The output current in the LED string (I_O) is calculated then as:

$$I_O = I_{TH} - \frac{1}{2} dI_O \quad (2)$$

where I_{TH} is the current sense comparator threshold. The ripple current introduces a peak-to-average error in the output current setting that needs to be accounted for. Due to the constant off-time control technique used in the IK2306, the ripple current is independent of the input AC or DC line voltage variation. Therefore, the output current will remain unaffected by the varying input voltage. Adding a filter capacitor across the LED string can reduce the output current ripple even further, thus permitting a reduced value of L. However, one must keep in mind that the peak-to-average current error is affected by the variation of T_{OFF}. Therefore, the initial output current accuracy might be sacrificed at large ripple current in L. Another important aspect of designing an LED driver with the IK2306 is related to certain parasitic elements of the circuit, including distributed coil capacitance of L, junction capacitance and reverse recovery of the rectifier diode D, capacitance of the printed circuit board traces C_{PCB} and output capacitance C_{DRAIN} of the controller itself. These parasitic elements affect the efficiency of the switching converter and could potentially cause false triggering of the current sense comparator if not properly managed. Minimizing these parasitics is essential for efficient and reliable operation of the IK2306. Coil capacitance of inductors is typically provided in the manufacturer's data books either directly or in terms of the self-resonant frequency (SRF).

$$SRF = 1/(2\pi\sqrt{LC_L}) \qquad (3)$$

where L is the inductance value, and C_L is the coil capacitance. Charging and discharging this capacitance every switching cycle causes high-current spikes in the LED string. Therefore, connecting a small capacitor C_O (~10nF) is recommended to bypass these spikes. Using an ultra-fast rectifier diode for D is recommended to achieve high efficiency and reduce the risk of false triggering of the current sense comparator. Using diodes with shorter reverse recovery time t_{RR} and lower junction capacitance C_J achieves better performance. The reverse voltage rating V_R of the diode must be greater than the maximum input voltage of the LED lamp. The total parasitic capacitance present at the DRAIN pin of the IK2306 can be calculated as:

$$C_P = C_{DRAIN} + C_{PCB} + C_L + C_J \qquad (4)$$

where and C_{DRAIN} is the DRAIN capacitance (C_{DRAIN} < 5pF), and C_{PSB} is the printed-circuit board capacitance.

When the switching MOSFET turns on, the capacitance C_P is discharged into the DRAIN pin of the IC. The discharge current is limited to about 150mA typically. However, it may become lower at increased junction temperature. The duration of the leading edge current spike can be estimated as:

$$T_{SPIKE} = t_{RR} + \frac{V_{IN} * C_{\mathrm{P}}}{I_{\mathrm{SAT}}} \qquad (5)$$

In order to avoid false triggering of the current sense comparator, C_P must be minimized in accordance with the following expression:

$$C_P < \frac{I_{SAT} * (T_{\mathrm{BLANK\_MIN}} - t_{RR})}{V_{IN\_MAX}} \qquad (6)$$

where T_{BLANK_MIN} is the minimum blanking time of 200ns, and V_{IN_MAX} is the maximum instantaneous input voltage.

Estimating Power Loss

Discharging the parasitic capacitance C_P into the DRAIN pin of the IK2306 is responsible for the bulk of the switching power loss. It can be estimated using the following equation:

$$P_{SWITCH} = \left(\frac{V_{IN}^{2} * C_{\mathrm{P}}}{2} + V_{IN} * I_{SAT} * t_{RR} \right) * F_S \qquad (7)$$

where Fs is the switching frequency, I_{SAT} is the saturated DRAIN current of the IZ921/22/23. The switching loss is the greatest at the maximum input voltage. The switching frequency is given by the following:

$$F_S \approx \frac{V_{IN} - V_O}{V_{IN} * T_{OFF}} \qquad (8)$$

The switching power loss associated with turn-off transitions of the DRAIN pin can be disregarded. Due to the large amount of parasitic capacitance connected to this switching node, the turn-off transition occurs essentially at zero-voltage. Conduction power loss in the IK2306 can be calculated as:

$$P_{COND} \approx I_O{}^2 * R_{ON} * \frac{V_O}{V_{IN}} + I_{DD} * (V_{IN} - V_O) \qquad (9)$$

where R_{ON} is the ON resistance, I_{DD} is the internal linear regulator current.

$$P_{TOTAL} = P_{SWITCH} + P_{COND} \qquad (10)$$

Layout Considerations

Single Point Grounding

Use a single point ground connection from the input filter capacitor to the area of copper connected to the GND pin.

Bypass Capacitor (C_{DD})

The V_{DD} pin bypass capacitor C_{DD} should be located as near as possible to the V_{DD} and GND pins.

Switching Loop Areas

The area of the switching loop connecting the input filter capacitor C_{IN}, the diode D and the IK2306 together should be kept as small as possible. The switching loop area connecting the output filter capacitor $_{CO}$, the inductor L and the diode D together should be kept as small as possible.

Thermal Considerations vs. Radiated EMI

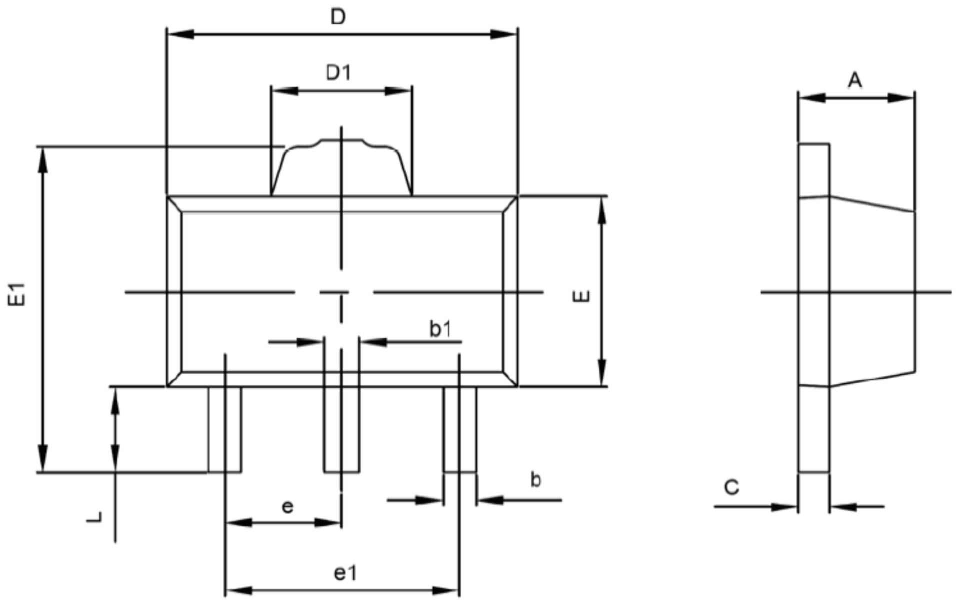
The copper area where GND pin is connected acts not only as a single point ground, but also as a heat sink. This area should be maximized for good heat sinking. The same applies to the cathode of the freewheeling diode D. Both nodes are quiet and therefore, will not cause radiated RF emission. The switching node copper area connected to the DRAIN pin of the IK2306, the anode of D and the inductor L needs to be minimized. A large switching node area can increase high frequency radiated EMI.

Input Filter Layout Considerations

The input circuits of the EMI filter must not be placed in the direct proximity to the inductor L in order to avoid magnetic coupling of its leakage fields. This consideration is especially important when unshielded construction of L is used. When an axial input EMI filter inductor LIN is selected, it must be positioned orthogonal with respect to L. The loop area formed by C_F, L_F and C_{IN} should be minimized. The input lead wires must be twisted together.

PACKAGE DIMENSION

SOT-89-3L



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.400	1.600	0.055	0.063
b	0.320	0.520	0.013	0.020
b1	0.360	0.560	0.014	0.022
c	0.350	0.440	0.014	0.017
D	4.400	4.600	0.173	0.181
D1	1.400	1.800	0.055	0.071
E	2.300	2.600	0.091	0.102
E1	3.940	4.250	0.155	0.167
e	1.500TYP		0.060TYP	
e1	2.900	3.100	0.114	0.122
L	0.900	1.100	0.035	0.043