

# HV9931 Unity Power Factor LED Lamp Driver

## Features

- ❑ Constant Output Current
- ❑ Large Step-Down Ratio
- ❑ Unity Power Factor
- ❑ Low Input Current Harmonic Distortion
- ❑ Fixed Frequency or Fixed Off-Time Operation
- ❑ Internal 450V Linear Regulator
- ❑ Input and output current sensing
- ❑ Input Current limit
- ❑ Enable, PWM and Phase Dimming

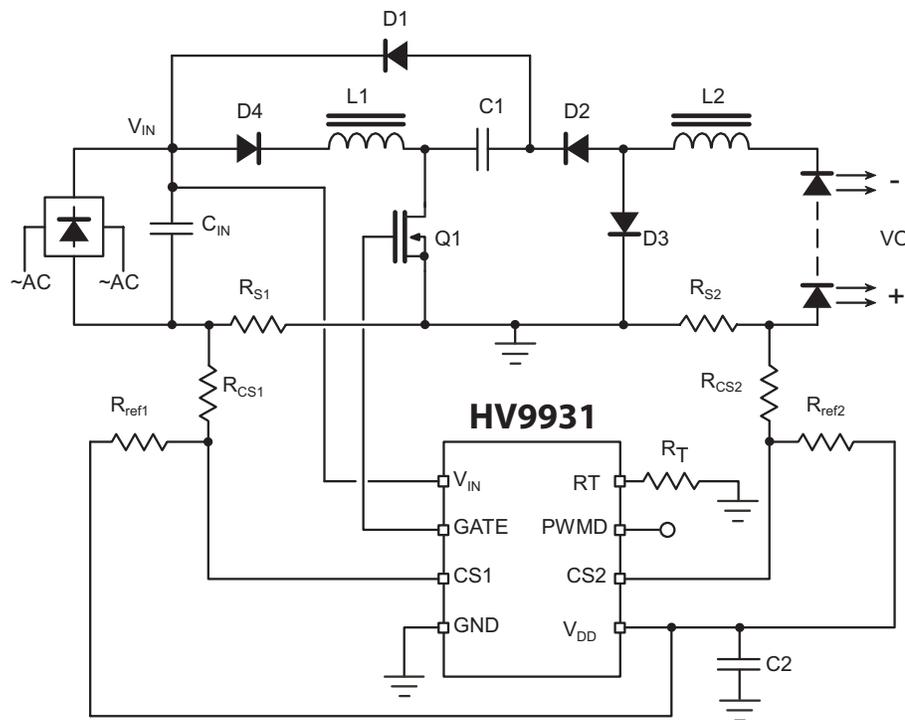
## Applications

- ❑ Offline LED Lamps and Fixtures
- ❑ Street lamps
- ❑ Traffic Signals
- ❑ Decorative Lighting

## General Description

The HV9931 is a fixed frequency PWM controller IC designed to control an LED lamp driver using a single-stage PFC buckboost-buck topology. It can achieve a unity power factor and a very high step-down ratio that enables driving a single high-brightness LED from the 85-264VAC input without a need for a power transformer. This topology allows reducing the filter capacitors and using non-electrolytic capacitors to improve reliability. The HV9931 uses open-loop peak current control to regulate both the input and the output current. This control technique eliminates a need for loop compensation, limits the input inrush current, and is inherently protected from input under-voltage condition. Capacitive isolation protects the LED Lamp from failure of the switching MOSFET. HV9931 provides a low-frequency PWM dimming input that can accept an external control signal with a duty ratio of 0-100% and a frequency of up to a few kilohertz. The PWM dimming capability enables HV9931 phase control solutions that can work with standard wall dimmers.

## Typical Application Circuit



## Ordering Information

DEVICE	Package Options	
	8-Lead SOIC	8-Lead DIP
HV9931	HV9931LG-G	HV9931P-G

-G indicates package is RoHS compliant ('Green')



# HV9931

## Absolute Maximum Ratings

$V_{IN}$ to GND	-0.5V to +470V
$V_{DD}$ to GND	-0.3V to +13.5V
CS1, CS2 to GND	-0.3V to $V_{DD} + 0.3V$
PWMD to GND	-0.3V to ( $V_{DD} + 0.3V$ )
GATE to GND	-0.3V to ( $V_{DD} + 0.3V$ )
<b>Continuous Power Dissipation (TA = +25°C)</b> - Also limited by package power dissipation limit, whichever is lower.	
8-Pin DIP (derate 9mW/°C above +25°C)	900mW
8-Pin and 14-Pin SO (derate 6.3mW/°C above +25°C)	630mW
Operating Temperature Range	-40°C to +85°C
Junction Temperature	+125°C
Storage Temperature Range	-65°C to +150°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

(The \* denotes the specifications which apply over the full operating junction temperature range of  $-40^{\circ}\text{C} < T_A < +85^{\circ}\text{C}$ , otherwise the specifications are at  $T_A = 25^{\circ}\text{C}$ ,  $V_{IN} = 100V$ , unless otherwise noted)

Symbol	Parameter	Min	Typ	Max	Units	Conditions
<b>Input</b>						
$V_{INDC}$	Input DC supply voltage range*	8		450	V	DC input voltage
$I_{INSD}$	Shut-Down mode supply current*		0.5	1	mA	PWMD connected to GND, $V_{IN} = 12V$
<b>Internal Regulator</b>						
$V_{DD}$	Internally regulated voltage*	7.12	7.5	7.88	V	$V_{IN} = 8-450V$ , $I_{DD(ext)} = 0$ , GATE open
UVLO	$V_{DD}$ undervoltage lockout threshold	6.45	6.7	6.95	V	$V_{IN}$ rising
$\Delta UVLO$	$V_{DD}$ undervoltage lockout hysteresis		500		mV	
<b>PWM Dimming</b>						
$V_{PWMD(lo)}$	PWMD input low voltage*			1.0	V	$V_{IN} = 8-450V$
$V_{PWMD(hi)}$	PWMD input high voltage*	2.4			V	$V_{IN} = 8-450V$
$R_{PWMD}$	PWMD pull-down resistance	50	100	150	k $\Omega$	$V_{PWMD} = 5V$
<b>GATE</b>						
$V_{GATE(hi)}$	GATE high output voltage*	$V_{DD} - 0.3$		$V_{DD}$	V	$I_{GATE} = 10mA$
$V_{GATE(lo)}$	GATE low output voltage*	0		0.3	V	$I_{GATE} = -10mA$
$T_{RISE}$	GATE output rise time		30	50	ns	$C_{GATE} = 500pF$
$T_{FALL}$	GATE output fall time		30	50	ns	$C_{GATE} = 500pF$
$T_{DELAY}$	Delay from CS trip to GATE		150	300	ns	$V_{IN} = 12V$ , $V_{CS1}$ , $V_{CS2} = -50mV$
$T_{BLANK}$	Blanking delay	150	215	280	ns	$V_{CS1}$ , $V_{CS2} = -0.15V$

Symbol	Parameter	Min	Typ	Max	Units	Conditions
<b>Oscillator</b>						
$F_{OSC}$	Initial Accuracy	80	100	120	kHz	$RT = 230K$
$\Delta F_T$	Temperature Stability		3		%	$T_j = -40^{\circ}C$ to $+125^{\circ}C$
<b>Comparators</b>						
$V_{OFFSET1}$ $V_{OFFSET2}$	Comparator Input offset voltage*	-12		12	mV	
$\Delta V_{OFFSET1}$ $\Delta V_{OFFSET2}$	Input offset voltage temperature drift		10		$\mu V/^{\circ}C$	$T_j = -40^{\circ}C$ to $+125^{\circ}C$

## Pin Description

**$V_{IN}$**  – This pin is the input of a high voltage regulator.

**$V_{DD}$**  – This is a power supply pin for all internal circuits. It must be bypassed with a low ESR capacitor to GND.

**GATE** – This pin is the output gate driver for an external N-channel power MOSFET.

**GND** – Ground return for all the internal circuitry. This pin must be electrically connected to the ground of the power train.

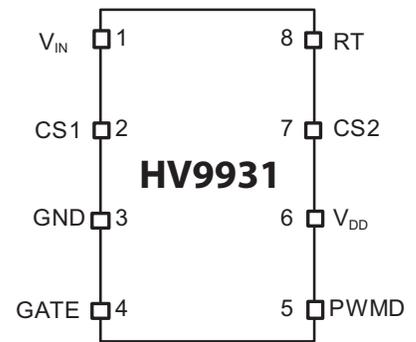
**RT** – Oscillator control. A resistor connected between this pin and GND sets the PWM frequency. A resistor connected between this pin and GATE sets the PWM off-time.

**PWMD** – When this pin is pulled to GND, switching of the HV9931 is disabled. When the PWMD pin is released, or external TTL high level is applied to it, switching will resume. This feature is provided for applications that require PWM dimming of the LED lamp.

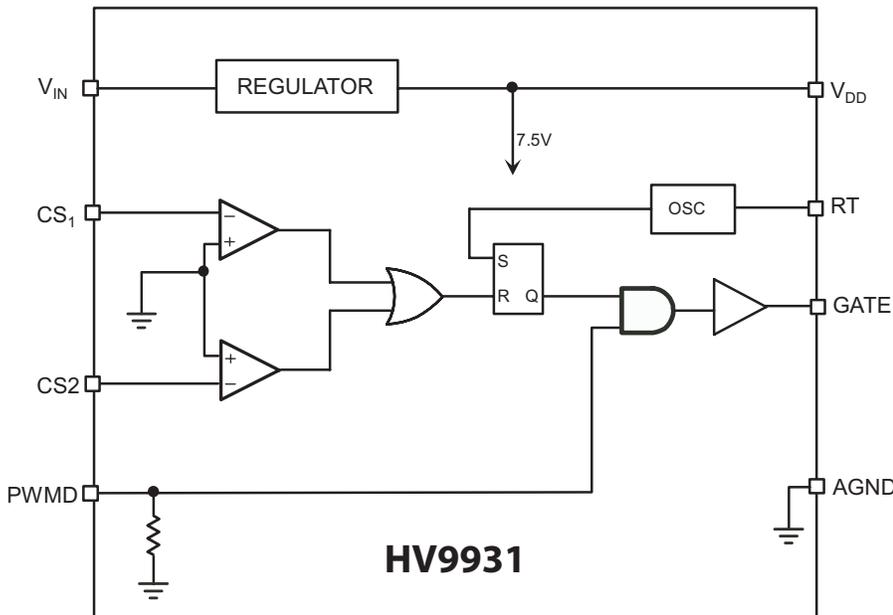
**CS1 and CS2** – These pins are used to sense the input and output currents of the converter. They are the inverting inputs of the internal comparators.

## Pinout

**SOIC-8, DIP-8**

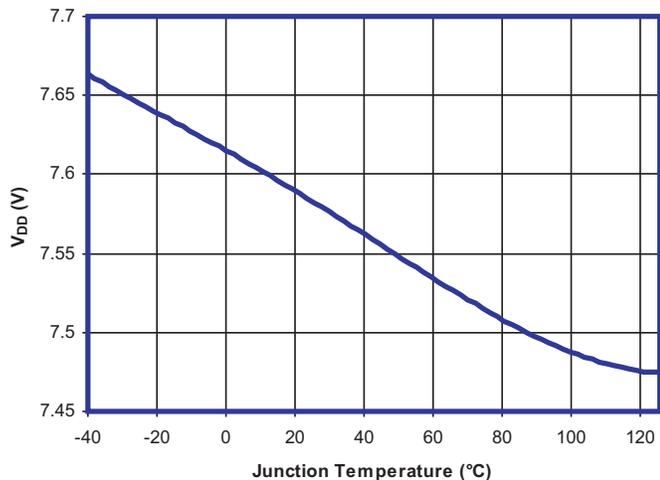


## Functional Block Diagram

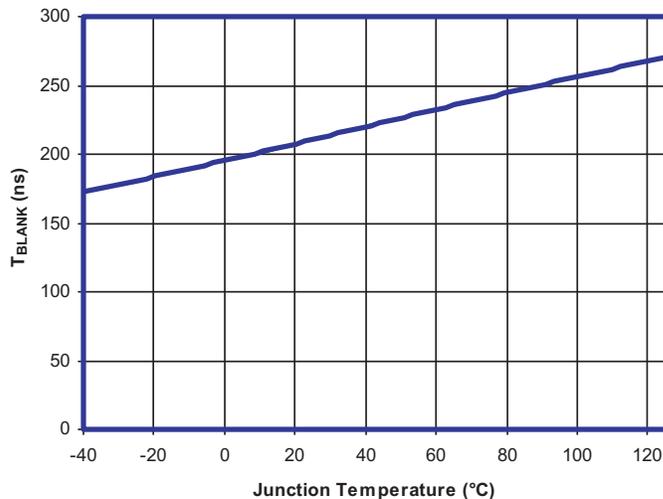


Typical Performance Characteristics ( $T_J = 25^\circ\text{C}$ ,  $V_{IN} = 100\text{V}$  unless otherwise noted)

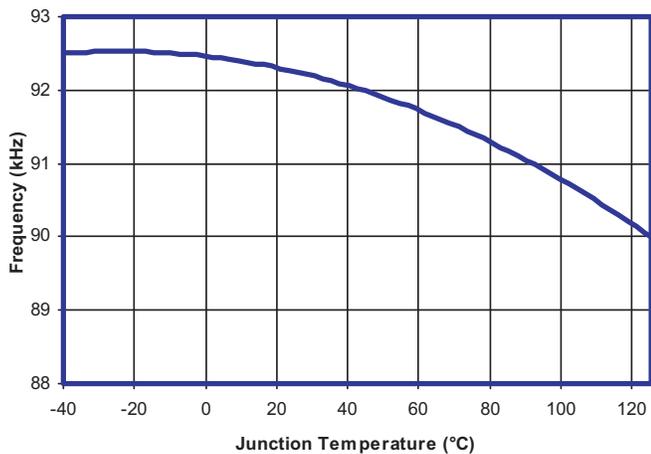
$V_{DD}$  vs. Junction Temperature ( $I_{IN} = 2\text{mA}$ )



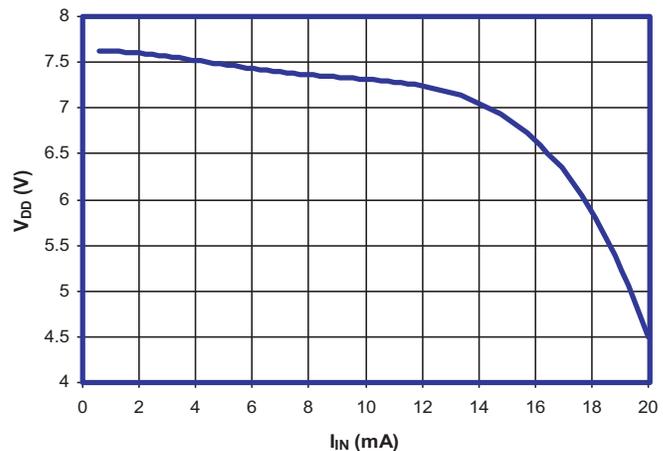
Blanking Delay vs. Junction Temperature



Frequency vs. Junction Temperature ( $R_T = 226\text{K}$ )



$V_{DD}$  vs. Regulator Current ( $V_{IN} = 100\text{V}$ )



## Functional Description

### Power Topology

The HV9931 is optimized to drive Supertex's proprietary single-stage, single-switch, non-isolated topology, cascading an input power factor correction (PFC) buck-boost stage and an output buck converter power stage. This power converter topology offers numerous advantages useful for driving high-brightness light emitting diodes (HB LED). These advantages include unity power factor, low harmonic distortion of the input AC line current, and low output current ripple. The output load is decoupled from the input voltage with a capacitor making the driver inherently failure-safe for the output load. The power converter topology also permits reducing the size of a filter capacitor needed, enabling use of non-electrolytic capacitors. The latter advantage greatly improves reliability of the overall solution.

The HV9931 is a peak current-mode controller that is specifically designed to drive a constant current buckboost-buck power converter. This patent pending control scheme features two identical current sense comparators for detecting negative current signal levels. One of the comparators regulates the output LED current. The other one is used for sensing the input inductor current. The second comparator is mainly responsible for the converter start-up. The control scheme inherently features low inrush current and input under-voltage protection. The HV9931 can operate with programmable constant frequency or constant off-time. In many cases, the constant off-time operating mode is preferred, since it improves line regulation of the output current, reduces voltage stress of the power components and simplifies regulatory EMI compliance. (See Application Note AN-H52.)

### Input Voltage Regulator

The HV9931 can be powered directly from its  $V_{IN}$  pin and takes a voltage from 8V to 450V. When a voltage is applied at the  $V_{IN}$  pin, the HV9931 seeks to maintain a constant 7.5V at the  $V_{DD}$  pin. The  $V_{DD}$  voltage can be also used as a reference for the current sense comparators. The regulator is equipped with an under-voltage protection circuit which shuts off the HV9931 when the voltage at the  $V_{DD}$  pin falls below 6.2V.

The  $V_{DD}$  pin must be bypassed by a low ESR capacitor ( $\geq 0.1\mu F$ ) to provide a low impedance path for the high frequency current of the output gate driver.

The HV9931 can also be operated by supplying a voltage at the  $V_{DD}$  pin greater than the internally regulated voltage. This will turn off the internal linear regulator and the HV9931 will function by drawing power from the external voltage source connected to the  $V_{DD}$  pin.

### PWM Dimming and Wall Dimmer Compatibility

PWM Dimming can be achieved by applying a TTL-compatible square wave signal at the PWMD pin. When the PWMD pin is pulled high, the gate driver is enabled and the circuit operates normally. When the PWMD pin is left open or connected to GND, the gate driver is disabled and the external MOSFET turns off. The HV9931 is designed so that the signal at the PWMD pin inhibits the driver only, and the IC need not go through the entire start-up cycle each time ensuring a quick response time for the output current.

The power topology requires little filter capacitance at the output, since the output current of the buck stage is continuous, and since AC line filtering is accomplished through the middle capacitor rather

than the output one. Therefore, disabling the HV9931 via its PWMD or  $V_{IN}$  pins can interrupt the output LED current in accordance with the phase-controlled voltage waveform of a standard wall dimmer.

### Oscillator

Connecting an external resistor from RT pin to GND programs switching frequency:

$$F_S [kHz] = \frac{25000}{R_T [K\Omega] + 22}$$

Connecting the resistor from RT pin to GATE programs constant off-time:

$$T_{OFF} [\mu s] = \frac{R_T [K\Omega] + 22}{25}$$

### Input and Output Current Feedback

Two current sense comparators are included in the HV9931. Both comparators have their non-inverting inputs internally connected to ground (GND). The CS1 and CS2 inputs are inverting inputs of the comparators. Connecting a resistor divider into either of these inputs from a positive reference voltage and a negative current sense signal programs the current sense threshold of the comparator. The  $V_{DD}$  voltage of the HV9931 can be used as the reference voltage. (If more accuracy is needed, an external reference voltage can be applied.) When either the CS<sub>1</sub> or the CS<sub>2</sub> pin voltage falls below GND, the GATE pulse is terminated. A leading edge blanking delay of 215ns (typ) is added. The GATE voltage becomes high again upon receiving the next clock pulse of the oscillator circuit.

Referring to the Functional Circuit Diagram, the CS2 comparator is responsible for regulating output current. The output LED current can be programmed using the following equation:

$$R_{CS2} = \frac{I_O + \frac{1}{2} \Delta I_{L2}}{7.5V} \cdot R_{REF2} \cdot R_{S2}$$

where  $\Delta I_{L2}$  is the peak-to-peak current ripple in L2. The CS1 comparator limits the current in the input inductor L1. There is no charge in the capacitor C1 upon the start-up of the converter. Therefore, L2 cannot develop the output current, and the HV9931 starts-up in the input current limiting mode. The CS1 current threshold must be programmed such that no input current limiting occurs in normal steady-state operation. The CS1 threshold can be programmed in accordance with a similar equation:

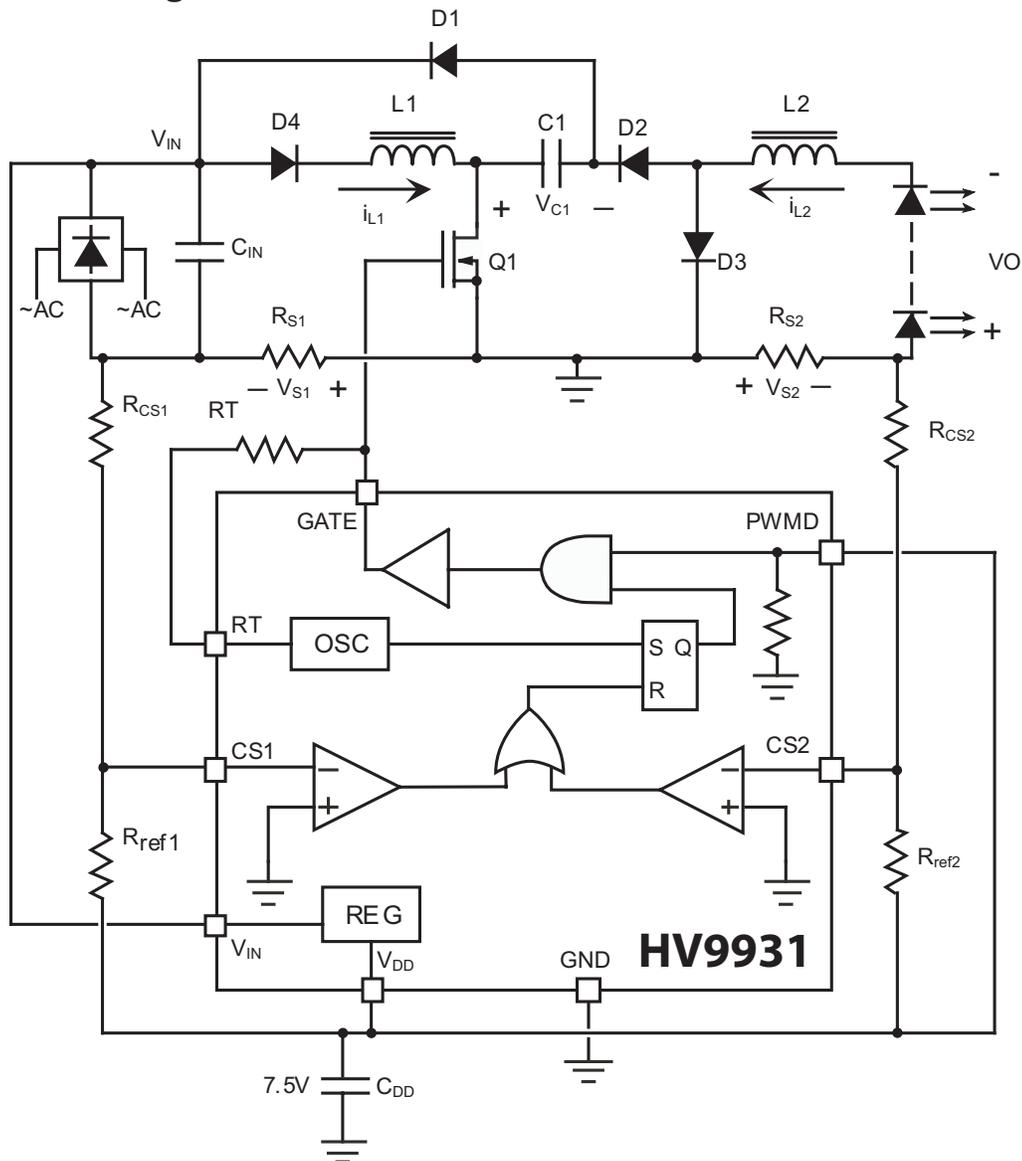
$$R_{CS1} = \frac{I_{L1(PK)}}{7.5V} \cdot R_{REF1} \cdot R_{S1}$$

where  $I_{L1(PK)}$  is the maximum peak current in L1.

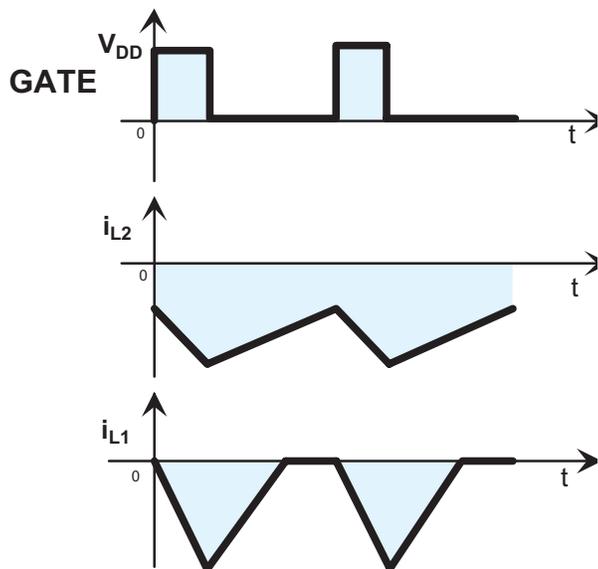
### MOSFET Gate Driver

Typically, the gate driving capability of the HV9931 is limited by the amount of power dissipation in its linear regulator. Thus, care must be taken selecting a switching MOSFET to be used in the circuit. An optimal trade-off must be found between the gate charge and the on-resistance of the MOSFET to minimize the input regulator current.

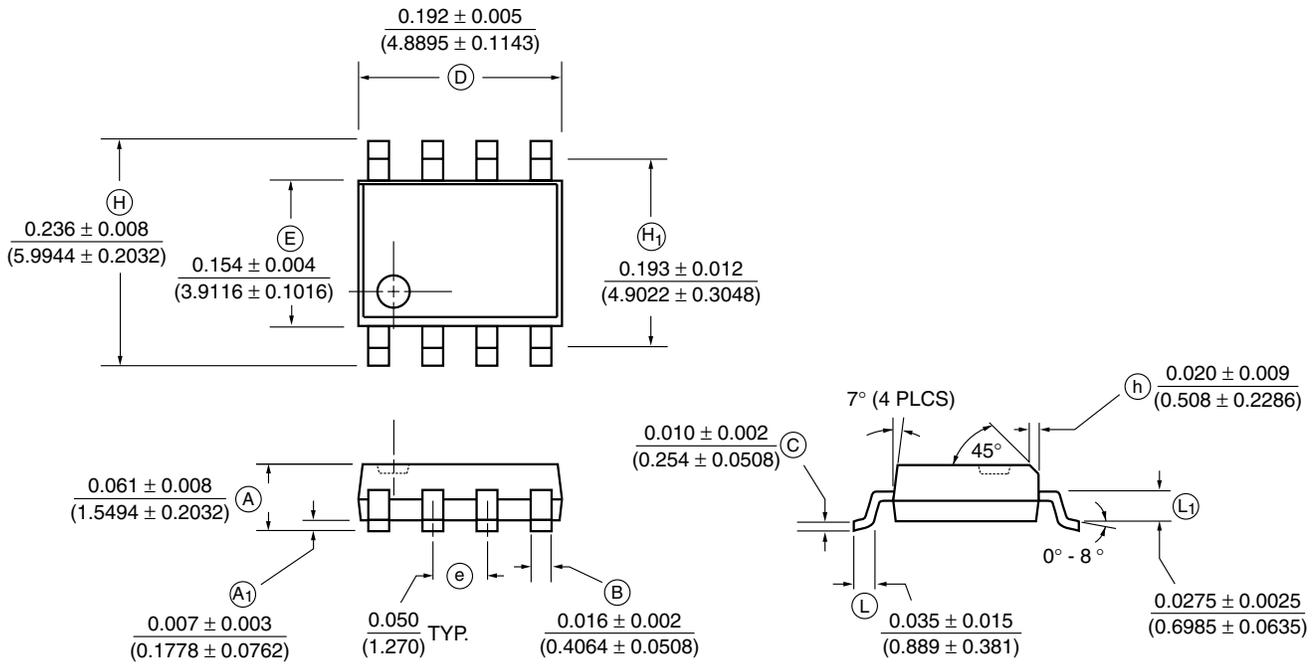
Functional Circuit Diagram



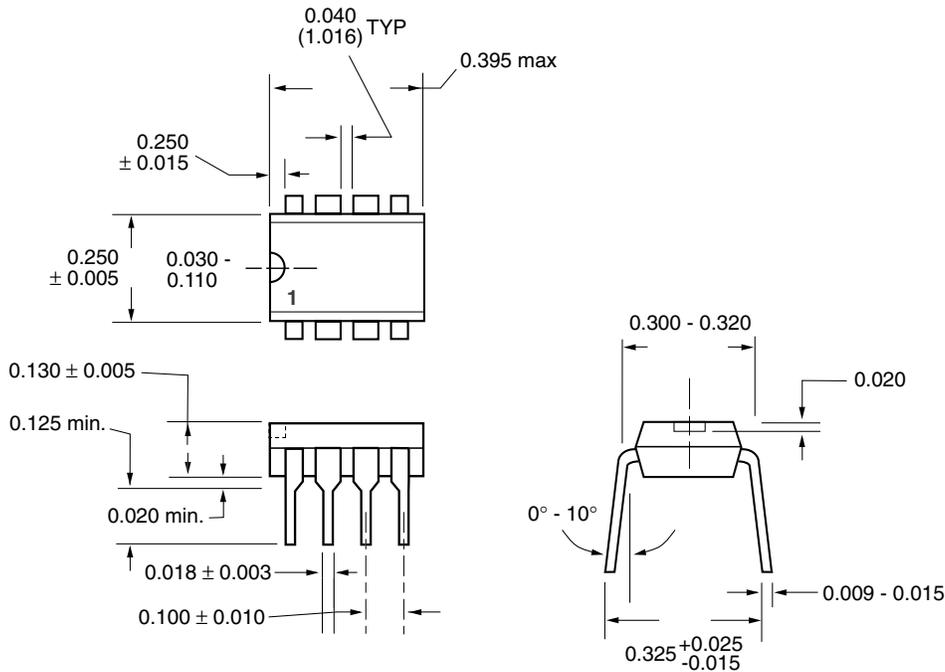
Switching Waveform



### 8-Lead Small Outline Package (LG)



### 8-Lead Plastic Dual In-Line Package (P)



Note: Circle (e.g. **B**) indicates JEDEC Reference.

Measurement Legend =  $\frac{\text{Dimensions in Inches}}{\text{(Dimensions in Millimeters)}}$

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