Date: 8-Apr-09

# FT6610

## Universal High Brightness LED Driver



FocalTech Systems Co., Ltd

support@focaltech-systems.com

## Index

## 1). Features :

- >90% Efficiency
- 8V to 450V input range
- Constant-current LED driver
- Applications from a few mA to more than 1A Output
- LED string from one to hundreds of diodes
- PWM Low-Frequency Dimming via Enable pin
- Input Voltage Surge ratings up to 700V
- Constant offtime or constant frequency PWM

## 2). Applications :

- DC/DC or AC/DC LED Driver applications
- RGB Backlighting LED Driver
- Back Lighting of Flat Panel Displays
- General purpose constant current source
- Signage and Decorative LED Lighting
- Automotive
- Chargers

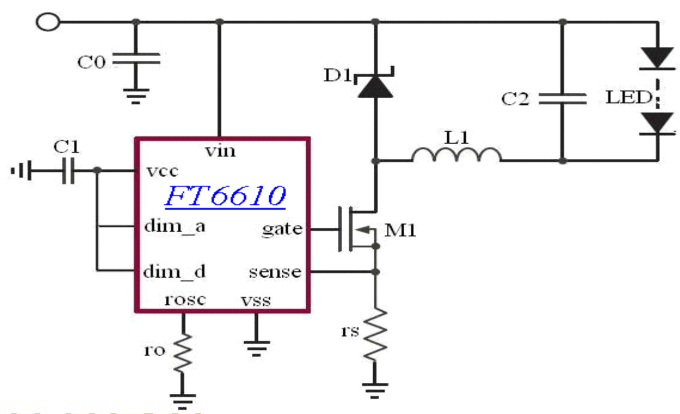



**Fig 1. Typical application**

## 3). Typical Application General Description :

The FT6610 is a PWM high-efficiency LED driver control IC. It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from 8VDC up to 450VDC. The FT6610 controls an external MOSFET at fixed switching frequency up to 300kHz. The frequency *(offtime)* can be programmed using a single resistor. The LED string is driven at constant current rather than constant voltage, thus providing constant light output and enhanced reliability. The output current can be programmed between a few milliamps and up to more than 1.0A.

The FT6610 uses a rugged high voltage junction isolated process that can withstand an input voltage surge of up to 450V. Output current to an LED string can be programmed to any value between zero and its maximum value by applying an external control voltage at the linear dimming control input of the FT6610. The FT6610 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 kHz.

## 4). Block Diagram :

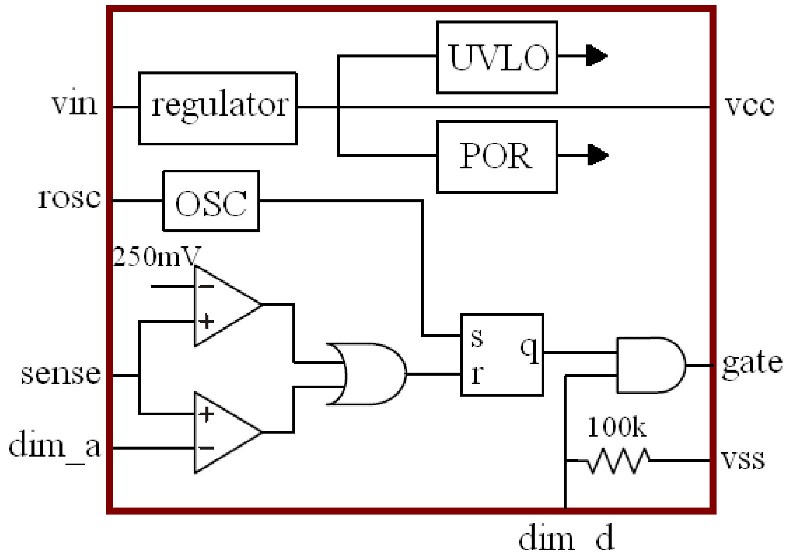



**Fig 2. FT6610 block diagram**

## 5). Pin Description :

| Pin | SOIC-16 | SOIC-8 | Description |
|---|---|---|---|
| VIN | 1 | 1 | Input voltage 8V to 450V DC |
| SENSE | 4 | 2 | Sense LED string current |
| VSS | 5 | 3 | Device ground |
| GATE | 8 | 4 | Drives the gate of the external MOSFET |
| DIM_D | 9 | 5 | Low Frequency PWM Dimming pin, also Enable input. Internal 100kΩ pull-down to VSS |
| VCC | 12 | 6 | Internally regulated supply voltage (7.5V nominal). Can supply up to 1mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossings. |
| DIM_A | 13 | 7 | Linear dimming by changing the current limit threshold at current sense comparator |
| Rosc | 14 | 8 | Oscillator control. A resistor connected between this pin and ground sets the PWM frequency, , Connected between this pin and gate sets the offtime.. |

*No Connects (NC) are not internally connected and may be used for pass-thru PCB traces.*

## 6). Pin configuration :

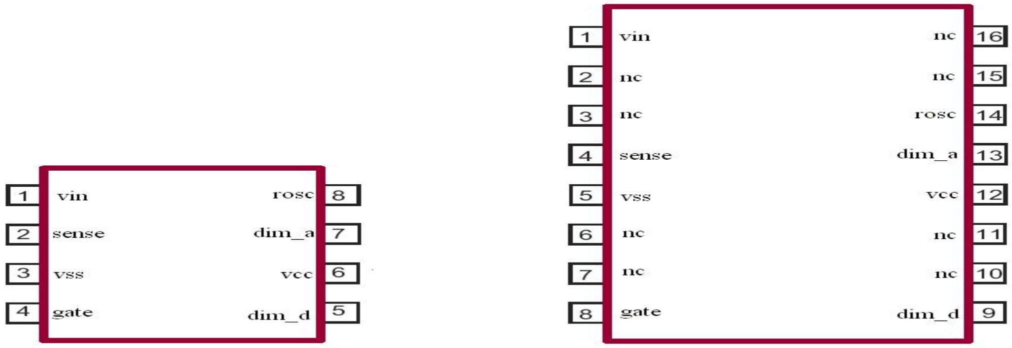



**Fig 3. FT6610 package sop-8 and sop-16**

## 7). Absolute Maximum Ratings :

| Parameter Value | |
|---|---|
| VIN to VSS | -0.5V to +470V |
| SENSE | -0.3V to (VCC + 0.3V) |
| DIM_A, DIM_D to VSS | -0.3V to (VCC - 0.3V) |
| GATE to VSS | -0.3V to (VCC + 0.3V) |
| VCCmax | 13.5V |
| Continuous Power Dissipation (TA = +25°C) | |
| 16-Pin SO (derate 7.5mW/°C above +25°C) | 1300mW |
| 8-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 |

Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied. Continuous operation of the device at the absolute rating level may affect device reliability. All voltages are referenced to device ground.

## 8). Thermal Resistance :

| Package | $\theta_{ja}$ |
|---|---|
| 8-Lead SOIC | 128℃/W |
| 16-Lead SOIC | 82℃/W |

## 9). Electrical Characteristics :

(Over recommended operating conditions unless otherwise specified $T_A = 25°C$)

| Symbol | Parameter | Min | Typ | Max | Units | Conditions |
|---|---|---|---|---|---|---|
| VINDC | Input DC supply voltage range | 8.0 | | 450 | V | DC input voltage |
| IINsd | Shut-down mode supply current | - | 0.5 | 1 | mA | Pin DIM_D to VSS, VIN = 8V |
| VCC | Internally regulated voltage | 7.2 | 7.5 | 7.8 | V | VIN = 8 – 450V, Icc(ext) = 0, GATE open |
| VCCmax | Maximal pin VCC voltage | - | - | 13.5 | V | When an external voltage applied to pin VCC |
| ICC(ext) | VCC current available for external circuitry 1 | - | - | 1.0 | mA | VIN = 8 – 100V |
| UVLO | VCC undervoltage lockout threshold | 6.2 | 6.7 | 7.2 | V | VIN rising |
| ΔUVLO | VCC undervoltage lockout hysteresis | - | 500 | - | mV | VIN falling |
| VEN(lo) | Pin DIM_D input low voltage | - | - | 1.0 | V | VIN = 8 – 450V |
| VEN(hi) | Pin DIM_D input high voltage | 2.4 | - | - | V | VIN = 8 – 450V |
| REN | Pin DIM_D pull-down resistance | 80 | 100 | 120 | kΩ | |
| VSENSE(hi) | Current sense pull-in threshold voltage | 225 | 250 | 275 | mV | |
| VGATE(hi) | GATE high output voltage | VCC-0.3 | - | VCC | V | IOUT = 10mA |
| VGATE(lo) | GATE low output voltage | 0 | - | 0.3 | V | IOUT = -10mA |
| fOSC | Oscillator frequency | | 28<br>78 | | kHz | Rocs=1MΩ to vss<br>Rosc=300kΩ to vss |
| DMAXhf | Maximum PWM duty cycle | - | - | 100 | % | FPWMhf = 25kHz. sense to vss. GBD |
| VDIM_A | Linear dimming pin voltage range | 0 | - | 250 | mV | VIN = 12V |
| TBLANK | Current sense blanking interval | 240 | 300 | 360 | ns | Vsense = 0.55Vdim_a, dim_a=vcc |
| tRISE | GATE output rise time | - | 60 | | ns | CGATE = 270pF |
| tFALL | GATE output fall time | - | 40 | | ns | CGATE = 270pF |
| | | | | | | |

*Note: some parameters are guaranteed by design, not by production test*

## 10). Application Information :

The FT6610 is a low-cost off-line buck(see Fig 5.) or boost (see Fig 6.) converter control IC designed specifically for driving multi-LED stings or arrays. It can be operated from either universal AC line(see fig 4.) or any DC voltage (see fig 1.) between 8-450V. Optionally, a passive power factor correction circuit can be used in order to pass the AC harmonic limits set by EN 61000-3-2 Class C for lighting equipment having input power less than 25W. The FT6610 can drive up to hundreds of High-Brightness (HB) LEDs or multiple strings of HB LEDs. The LED arrays can be configured as a series or series/parallel connection. The FT6610 regulates constant current that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime. The FT6610 features an enable pin (DIM_D) that allows PWM control of brightness.

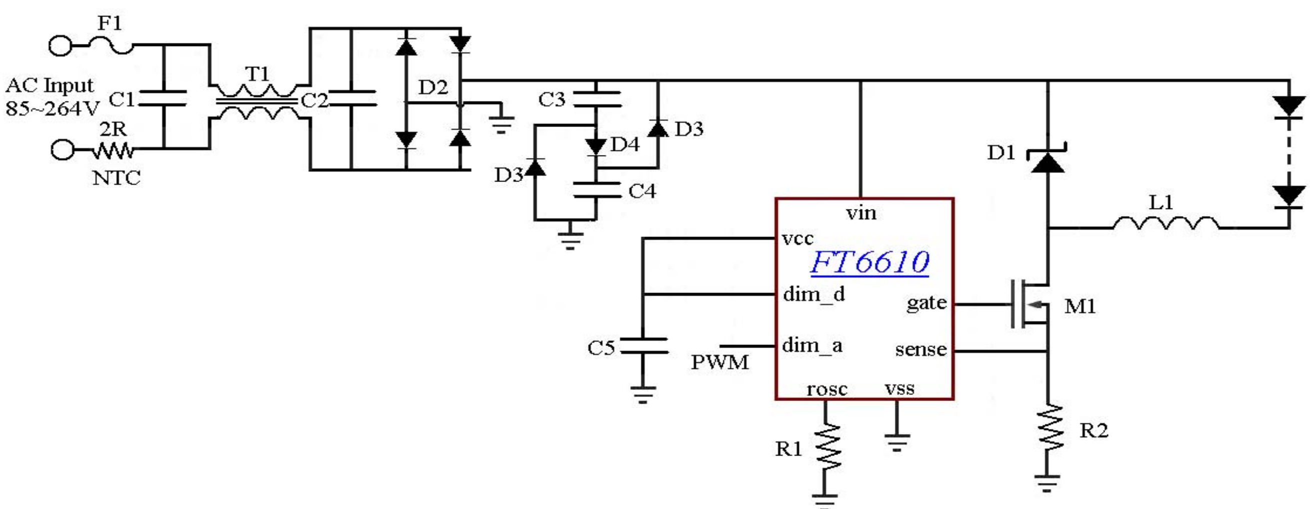
The FT6610 can also control brightness of LEDs by programming continuous output current of the LED driver (so-called linear dimming) when a control voltage is applied to the DIM_A pin.

The FT6610 is offered in a standard 8-pin SOIC package. It is also available in a high voltage rated SO-16 package for applications that require VIN greater than 250V.

The FT6610 includes an internal high-voltage linear regulator that powers all internal circuits and can also serve as a bias supply for low voltage external circuitry.

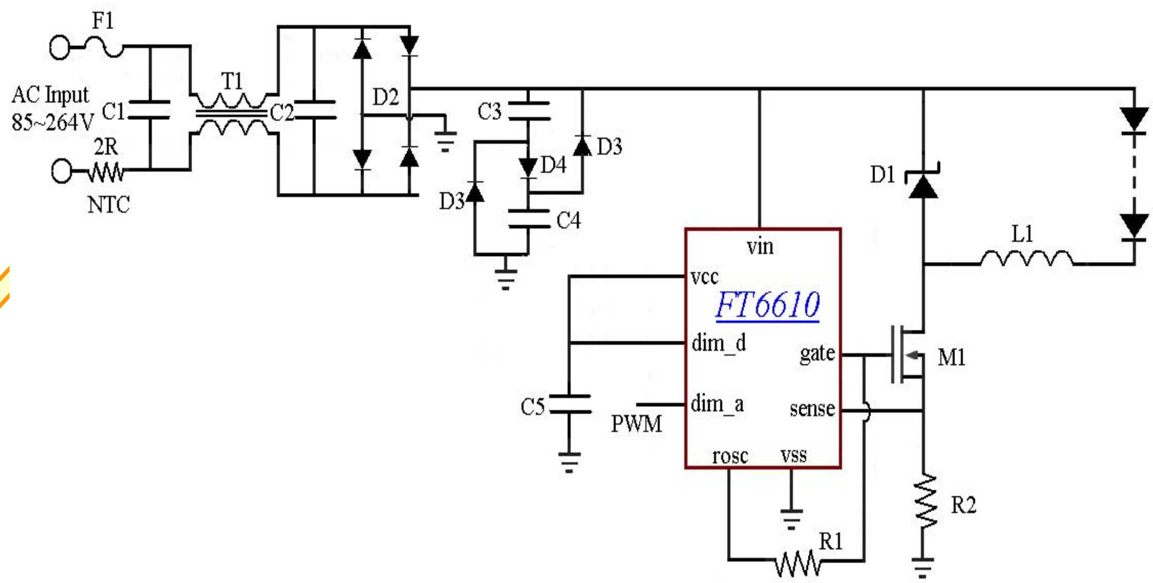
The FT6610 includes two kind of PWM: constant frequency or constant offtime. For the late one, when input power voltage changes in big range the output current will change little.






(PWM in constant frequency)

**Fig 4.a. Typical AC input application circuit**




PWM in constant offtime

**Fig 4.b. Typical AC input application circuit**

## 11). LED Driver Operation :

The FT6610 can control all basic types of converters, isolated or non-isolated, operating in continuous or discontinuous conduction mode. When the gate signal enhances the external power MOSFET, the LED driver stores the input energy in an inductor or in the primary inductance of a transformer and, depending on the converter type, may partially deliver the energy directly to LEDs. The energy stored in the magnetic component is further delivered to the output during the off-cycle of the power MOSFET producing current through the string of LEDs (Flyback mode of operation).

When the voltage at the VCC pin exceeds the UVLO threshold the gate drive is enabled. The output current is controlled by means of limiting peak current in the external power MOSFET. A current sense resistor is connected in series with the source terminal of the MOSFET. The voltage from the sense resistor is applied to the SENSE pin of the FT6610. When the voltage at SENSE pin exceeds a peak current sense voltage threshold, the gate drive signal terminates, and the power MOSFET turns off. The threshold is internally set to 250mV, or it can be programmed externally by applying voltage to the DIM_A pin. When soft start is required, a capacitor can be connected to the DIM_A pin to allow this voltage to ramp at a desired rate, therefore, assuring that output current of the LED ramps gradually.

## 12). Supply Current :

A current of 1mA is needed to start the FT6610, this current is internally generated in the FT6610 without using bulky startup resistors typically required in the offline applications. Moreover, in many applications the FT6610 can be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits.

## 13). Setting Light Output :

When the buck converter topology of Figure 1 is selected, the peak SENSE voltage is a good representation of the average current in the LED. However, there is a certain error associated with this current sensing method that needs to be accounted for. This error is introduced by the difference between the peak and the average current in the inductor. For example if the peak-to-peak ripple current in the inductor is 150mA, to get a 500mA LED current, the sense resistor should be 250mV/(500mA+ 0.5*150mA) = 0.43Ω.

## 14). Dimming :

Dimming can be accomplished in two ways, separately or combined, depending on the application. Light output of the LED can be controlled either by linear change of its current, or by switching the current on and off while maintaining it constant. The second dimming method (so-called PWM dimming) controls the LED brightness by varying the duty ratio of the output current.

The linear dimming can be implemented by applying a control voltage from 0 to 250mV to the DIM_A pin. This control voltage overrides the internally set 250mV threshold level of the SENSE pin and programs the output current accordingly. For example, a potentiometer connected between VCC and ground can program the control voltage at the SENSE pin. Applying a control voltage higher than 250mV will not change the output current setting. When higher current is desired, select a smaller sense resistor. The PWM dimming scheme can be implemented by applying an external PWM signal to the DIM_D pin. The PWM signal can be generated by a microcontroller or a pulse generator with a duty cycle proportional to the amount of desired light output. This signal enables and disables the converter modulating the LED current in the PWM fashion. In this mode, LED current can be in one of the two states: zero or the nominal current set by the current sense resistor. It is not possible to use this method to achieve average brightness levels higher than the one set by the current sense threshold level of the FT6610. By using the PWM control method of the FT6610, the light output can be adjusted between zero and 100%. The accuracy of the PWM dimming method is limited only by the minimum gate pulse width, which is a fraction of a percent of the low frequency duty cycle.

## 15). Programming Operating Frequency :

The operating frequency of the oscillator is programmed between 25 and 300kHz using an external resistor connected to the Rosc pin to vss shown in Fig 4 a:

Fosc= 25000/(Rosc[kΩ] + 22) [kHz]

And the operating offtime of the oscillator is programmed too using an external resistor connected to the Rosc pin to gate shown in Fig 4 b:

Toff=(Rosc[kΩ] + 22)/25[us]

## 16). Power Factor Correction :

When the input power to the LED driver does not exceed 25W, a simple passive power factor correction circuit can be added to the FT6610 typical application circuit in Fig 4. In order to pass the AC line harmonic limits of the EN61000-3-2 standard for Class C equipment. The typical application circuit diagram shows how this can be done without affecting the rest of the circuit significantly. A simple circuit consisting of 3 diodes and 2 capacitors is added across the rectified AC line input to improve the line current harmonic distortion and to achieve a power factor greater than 0.85.

## 17). Inductor Design :

Referring to the typical buck application circuit in Fig 5. , the value can be calculated from the desired peak-to-peak LED ripple current in the inductor. Typically, such ripple current is selected to be 30% of the nominal LED current. In the example given here, the nominal current Iled is 350mA.

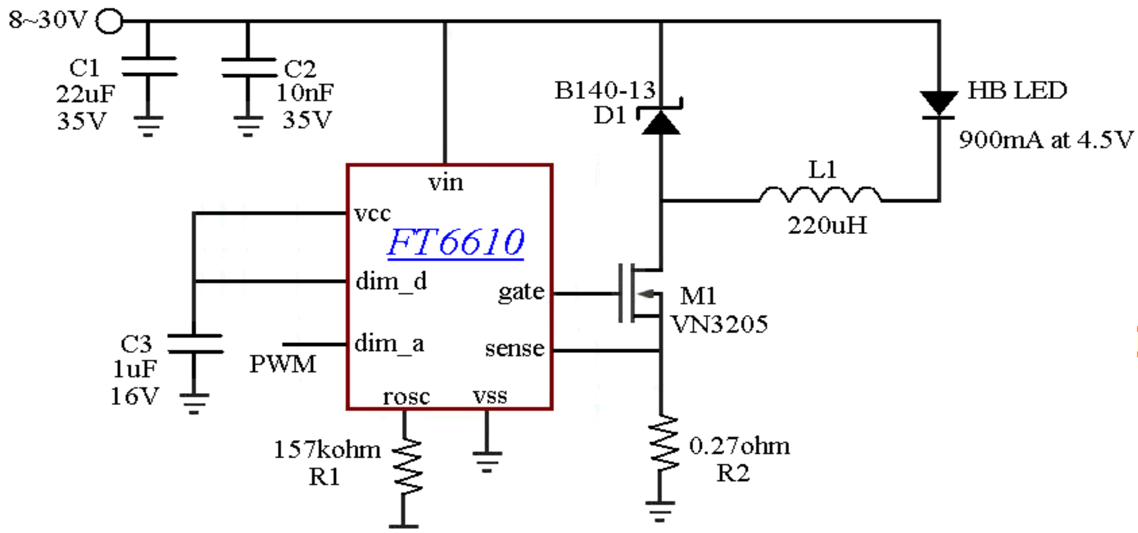



**Fig 5. Buck Driver for a single 900mA HB LED(vin=8~30V)**

The next step is determining the total voltage drop across the LED string. For example, when the string consists of 10 High-Brightness LEDs and each diode has a forward voltage drop of 3.0V at its nominal current; the total LED voltage Vled is 30V.

Knowing the nominal rectified input voltage VIN = 120V*1.41 = 169V, the switching duty ratio can be determined, as:

D = Vled/VIN = 30/169 = 0.177

Then, given the switching frequency, in this example Fosc= 50KHz, the required on-time of the MOSFET transistor can be calculated:

Ton= D/Fosc = 3.5 microsecond

The required value of the inductor is given by:

L = (VIN - Vled) * Ton /(0.3 * Iled) = 4.6mH

In the buck-boost application circuit in Fig 6., the energy from the input source is first stored in the inductor or a Flyback transformer when the switching transistor is ON, The energy is then delivered to the output during the OFF time of the transistor. When the energy stored in the Flyback inductor is not fully depleted by the next switching cycle*continuous conduction mode) the DC conversion between input and ouput voltage is given by:

Vout=-vin*D/(1-D)

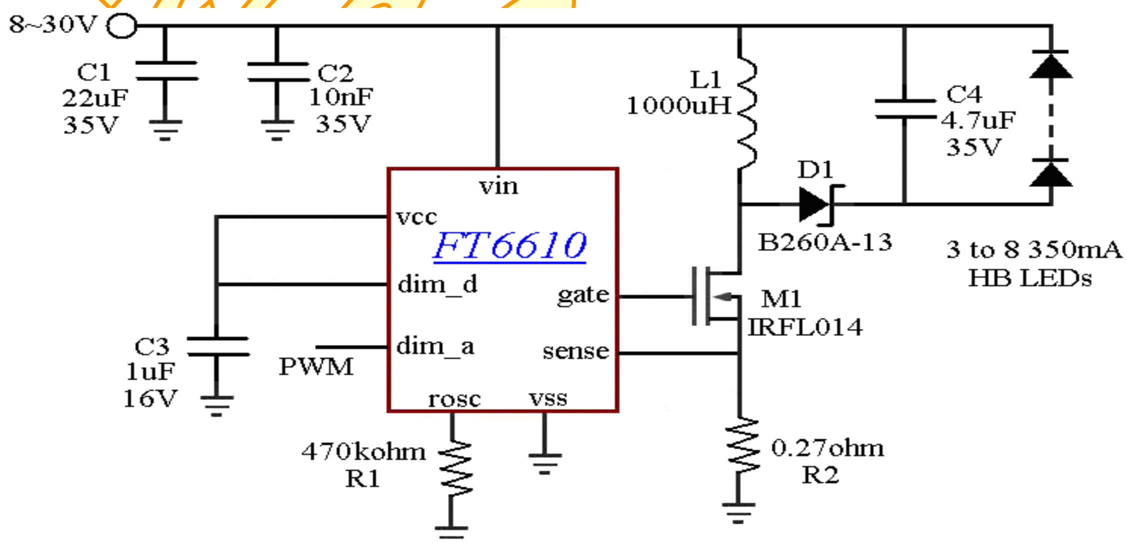



**Fig 6. Buck-Boost driver powering 3 to 8,350mA HB LEDs (Vin=8~30V)**

The output voltage can be either higher or lower than the input voltage, depending on duty ratio. Aassumed the load current is 350mA and vin is equal to 12V, that:

D=vled/(vin+vled)=9/21=0.43

Then, given the switching frequency, in this example fosc=50kHz, the required on-time of the MOS can be calculated:

Ton=D/Fosc=9.6microsecond

The required value of the inductor is given by:

L=vin*Ton/(0.3*Iled)=0.98mH, can use 1mH.

## 18). Input Bulk Capacitor :

An input filter capacitor should be designed to hold the rectified AC voltage above twice the LED string voltage throughout the AC line cycle. Assuming 15% relative voltage ripple across the capacitor, a simplified formula for the minimum value of the bulk input capacitor is given by:

Cmin= Iled*Vled*0.06/vin^2

Cmin= 22 μF, a value 22μF/250V can be used.

A passive PFC circuit at the input requires using two series connected capacitors at the place of calculated Cmin. Each of these identical capacitors should be rated for ½ of the input voltage and have twice as much capacitance.

## 19). Enable :

The FT6610 can be turned off by pulling the DIM_D pin to ground. When disabled, the FT6610 draws quiescent current of less than 1mA.

## 20). Output Open Circuit Protection :

When the buck topology is used, and the LED is connected in series with the inductor, there is no need for any protection against an open circuit condition in the LED string. Open LED connection means no switching and can be continuous. However, in the case of the buck-boost or the flyback topology the FT6610 may cause excessive voltage stress of the switching transistor and the rectifier diode and potential failure. In this case, the FT6610 can be disabled by pulling the DIM_D pin to ground when the over voltage condition is detected.

## 21). Typical application wave :

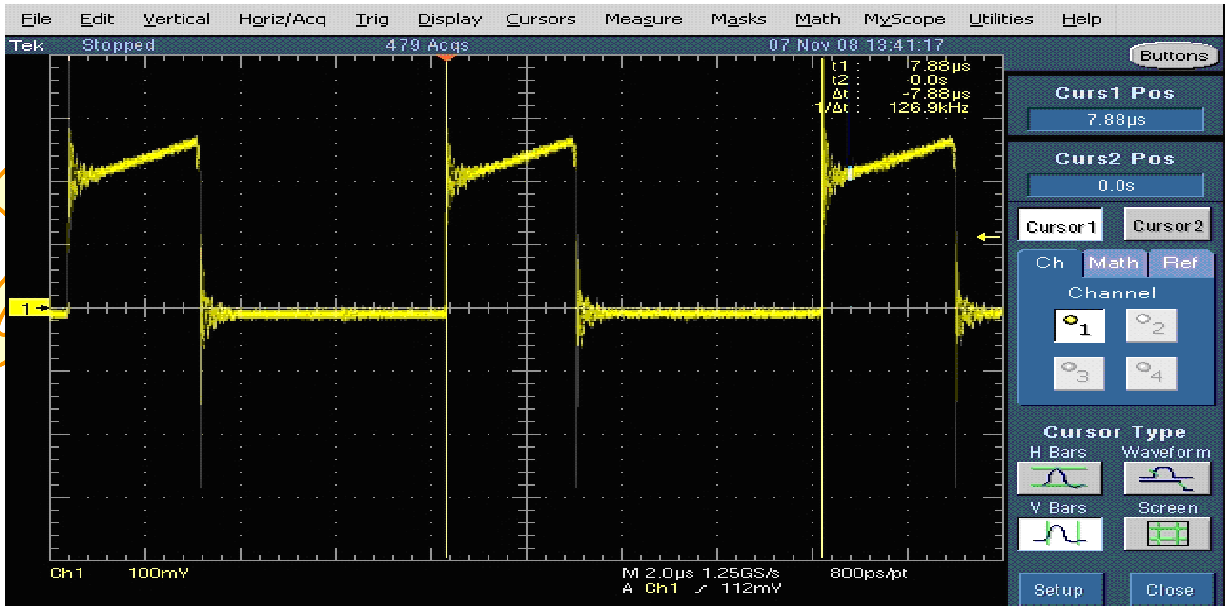


Fig 7. Sense wave in typical application

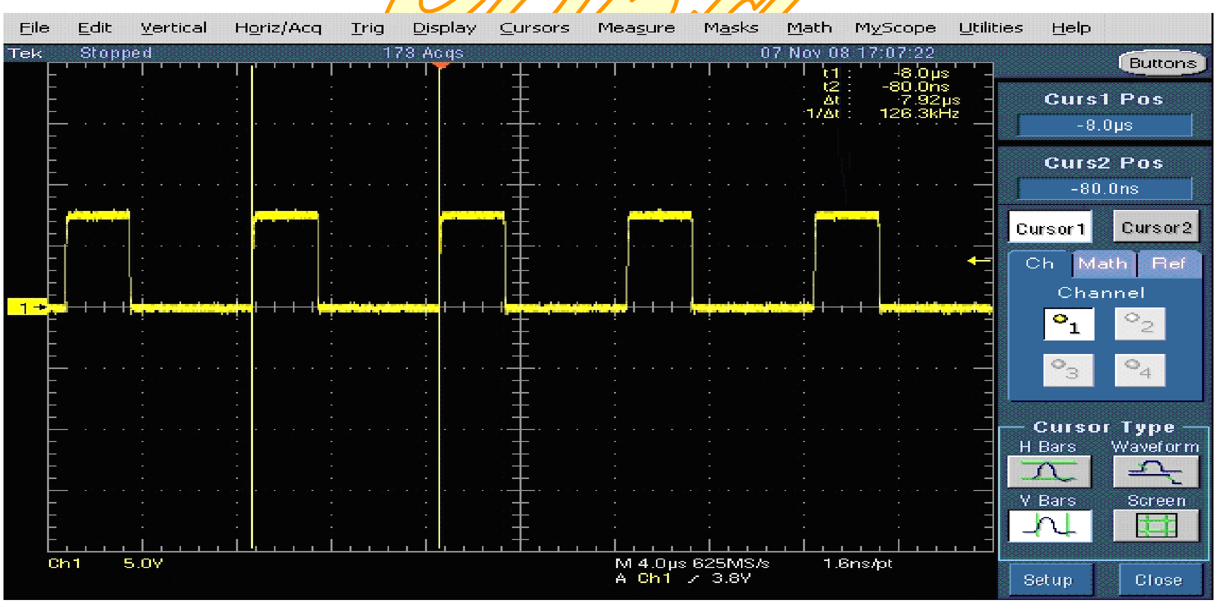


Fig 8. gate wave in typical application

Test condition: *Rosc=180kohm to vss, Rsense=0.33ohm, L=220uH, Vin=20VDC with two LEDs*
*Please refer to Fig 1.*

## 22). Order Information :

| Package Type | SOP | SOP |
|---|---|---|
| | 8 Pin | 16 Pin |
| Product Name | FT6610BE | FT6610CE |

Note:

1). The packages type are available in the top marking “B” (i.e. FTxxxxBx).

2). The packages lead pitch is available in the top marking “E” (i.e. FTxxxxxE).

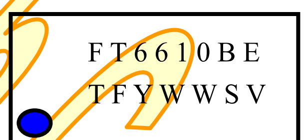
**T** : Track Code

**F** : **”F” for Lead Free process.**

**Y** : Year Code

**WW** : Week Code

**SV** : Lot Code

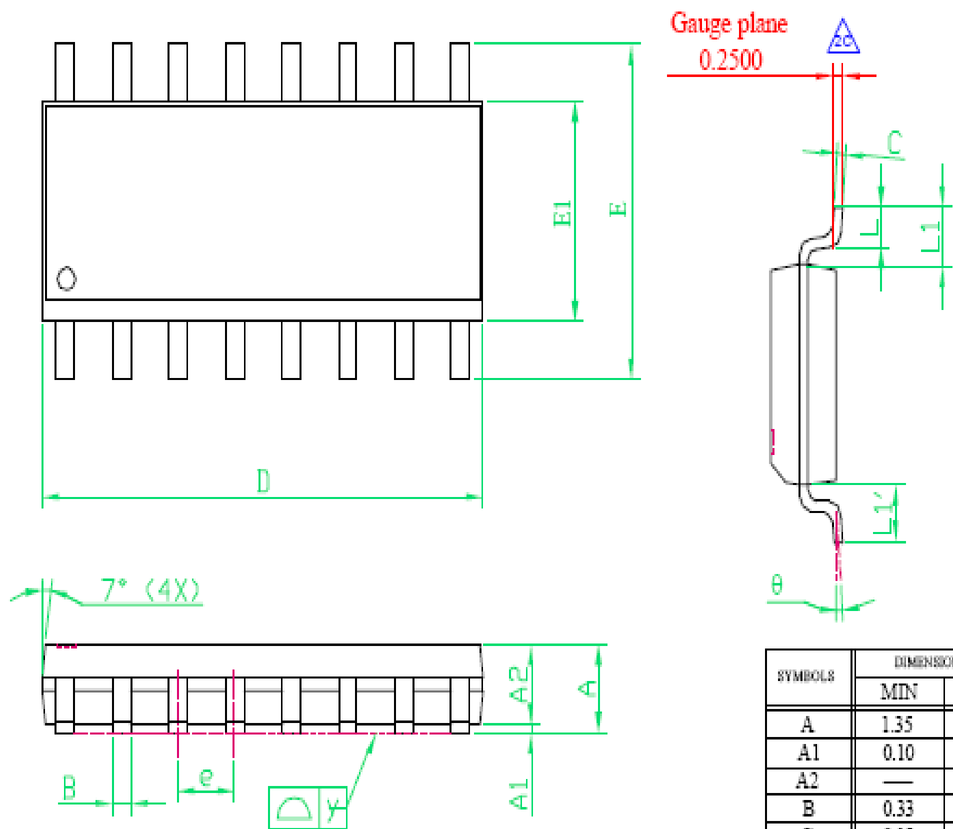


## 23). Package information :

### 23.1). Sop16 L outline information

16-Lead SOIC(Narrow Body) Package Outline(NG)

9.90*3.90mm body,1.75mm height(max),1.27mm pitch



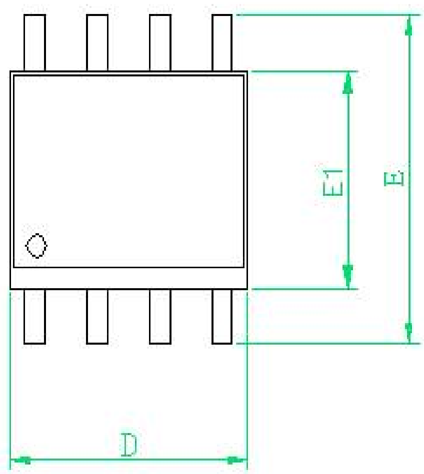

NOTE
1. PACKAGE BODY SIZES EXCLUDE MOLD FLASH AND GATE BURRS
2. DIMENSION L IS MEASURED IN GAGE PLANE
3. TOLERANCE 0.10 mm UNLESS OTHERWISE SPECIFIED
4. CONTROLLING DIMENSION IS MILLIMETER. CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.
5. FOLLOWED FROM JEDEC MS-012

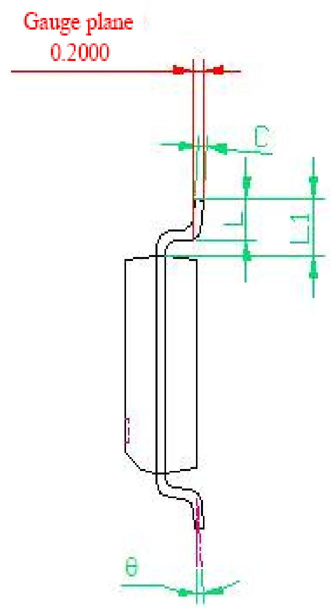
| SYMBOLS | DIMENSIONS IN MILLIMETERS | | | DIMENSIONS IN INCHES | | |
|---|---|---|---|---|---|---|
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | 1.35 | 1.60 | 1.75 | 0.053 | 0.063 | 0.069 |
| A1 | 0.10 | --- | 0.25 | 0.004 | --- | 0.010 |
| A2 | --- | 1.45 | --- | --- | 0.057 | --- |
| B | 0.33 | --- | 0.51 | 0.013 | --- | 0.020 |
| C | 0.19 | --- | 0.25 | 0.007 | --- | 0.010 |
| D | 9.80 | --- | 10.00 | 0.386 | --- | 0.394 |
| E1 | 3.80 | 3.90 | 4.00 | 0.150 | 0.153 | 0.157 |
| e | --- | 1.27 | --- | --- | 0.050 | --- |
| E | 5.80 | 6.00 | 6.20 | 0.228 | 0.236 | 0.244 |
| L | 0.40 | --- | 1.27 | 0.016 | --- | 0.050 |
| y | --- | --- | 0.10 | --- | --- | 0.004 |
| θ | 0° | --- | 8° | 0° | --- | 8° |
| L1-L1' | --- | --- | 0.12 | --- | --- | 0.005 |
| L1 | 1.04REF | | | 0.041REF | | |

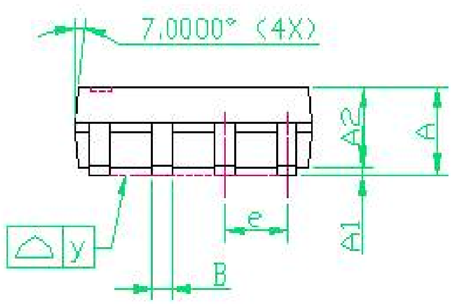
## 23.2). Sop 8L outline information

8-Lead SOIC(Narrow Body) Package Outline(LG)

4.90*3.90mm body,1.75mm height(max),1.27mm pitch




NOTE
1. PACKAGE BODY SIZES EXCLUDE MOLD FLASH AND GATE BURRS
2. DIMENSION L IS MEASURED IN GAGE PLANE
3. TOLERANCE 0.10 mm UNLESS OTHERWISE SPECIFIED
4. CONTROLLING DIMENSION IS MILLIMETER. CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.
5. FOLLOWED FROM JEDEC MS-012

| SYMBOLS | DIMENSIONS IN MILLIMETER | | | DIMENSIONS IN INCH | | |
|---|---|---|---|---|---|---|
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | 1.35 | 1.60 | 1.75 | 0.053 | 0.063 | 0.069 |
| A1 | 0.10 | —— | 0.25 | 0.004 | —— | 0.010 |
| A2 | —— | 1.45 | —— | —— | 0.057 | —— |
| B | 0.33 | —— | 0.51 | 0.013 | —— | 0.020 |
| C | 0.19 | —— | 0.25 | 0.007 | —— | 0.010 |
| D | 4.80 | —— | 5.00 | 0.189 | —— | 0.197 |
| E1 | 3.80 | 3.90 | 4.00 | 0.150 | 0.153 | 0.157 |
| e | —— | 1.27 | —— | —— | 0.050 | —— |
| E | 5.80 | 6.00 | 6.20 | 0.228 | 0.236 | 0.244 |
| L | 0.40 | —— | 1.27 | 0.016 | —— | 0.050 |
| y | —— | —— | 0.10 | —— | —— | 0.004 |
| θ | 0° | —— | 8° | 0° | —— | 8° |
| L1 | 0.95 | 1.05 | 1.15 | 0.037 | 0.041 | 0.045 |

## REVISION TABLE

| DDCN | version | Revisions | Date |
|---|---|---|---|
| DC-0812002 | 1.0 | Initial create | 2009-12-18 |
| DC-0903003 | 2.0 | **1).** page 3- ratings up to 450V→ ratings up to 700V<br>**2).** Page6 - Oscillator frequency Change to 24 、78KHZ<br>**3).** Page10- Fosc= 25000/(Rosc[kΩ] + 21) [kHz]→ Fosc= 25000/(Rosc[kΩ] + 22) [kHz]<br>Toff=(Rosc[kΩ] + 21)/25[us]→ Toff=(Rosc[kΩ] + 22)/25[us]<br>**4).** Page13- *Rosc=100kohm*→ *Rosc=180kohm*<br>**5).** Current sense blanking interval Change to 240~360 ns | 2009-04-06 |
| | | | |

**END OF DATABOOK**