# JW1602

## Multi-topology LED Controller With optimized THD

*Parameters Subject to Change Without Notice*

## DESCRIPTION

The JW®1602 is a multi-topology LED controller with active power factor correction. It is especially designed for LED lighting system. The JW1602 controls the LED current accurately without using an opto-coupler, which can significantly simplify the design of LED lighting system.

The JW1602 achieves high power factor over wide line and load ranges, compared to conventional constant on time control, it also significantly optimized the THD by an improved on time control.

JW1602 integrates an interface for PWM dimming and analog dimming both. The output current can be easily linearly adjusted by an analog signal on ADIM or a PWM signal on DPWM.

The multi-protection function largely enhances the safety and reliability of the system, including over voltage protection, short circuit protection, LED open protection, cycle-by-cycle current limit, VCC UVLO and over-temperature protection.

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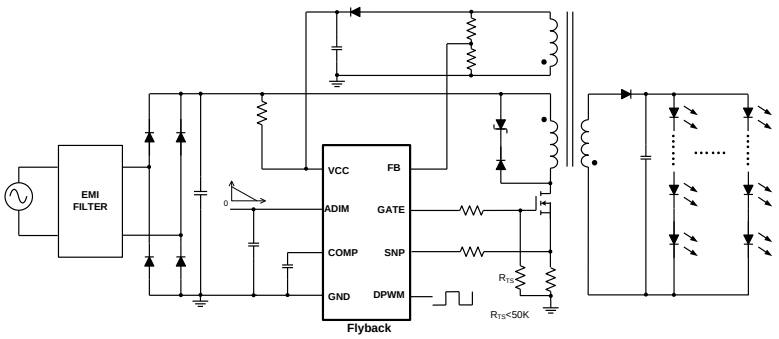
## FEATURES

- Real current control without secondary feedback circuit
- Multi-topology supported
- High current accuracy of line regulation
- Active power factor correction
- Optimized THD
- Compatible with analog dimming
- Compatible with PWM dimming
- Frequency fold-back for deep dimming Range
- CV mode to off the LED
- Valley turn-on to low switching loss
- Cycle-by-cycle current limit
- LED short protection
- LED open protection
- Over-temperature protection
- 8-Pin SOP package

## APPLICATIONS

- Offline LED Driver
- Intelligent dimming of LED driver

## TYPICAL APPLICATION





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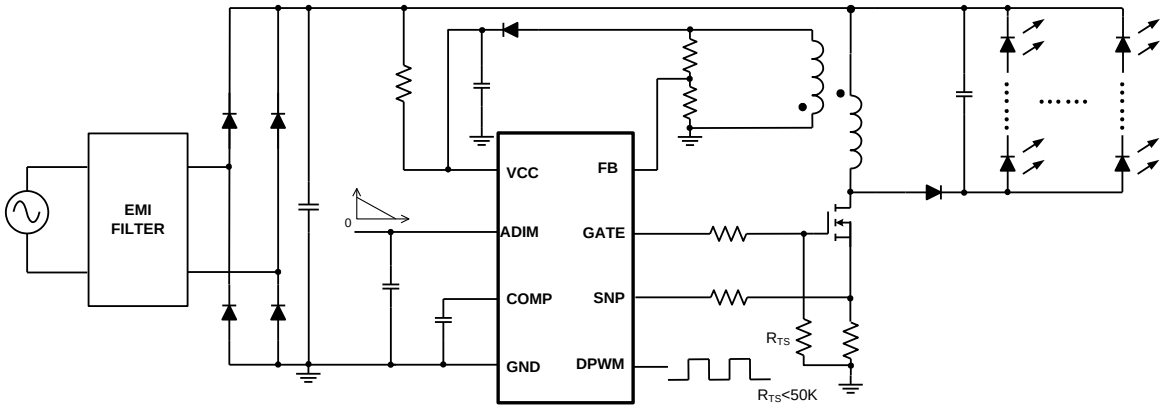
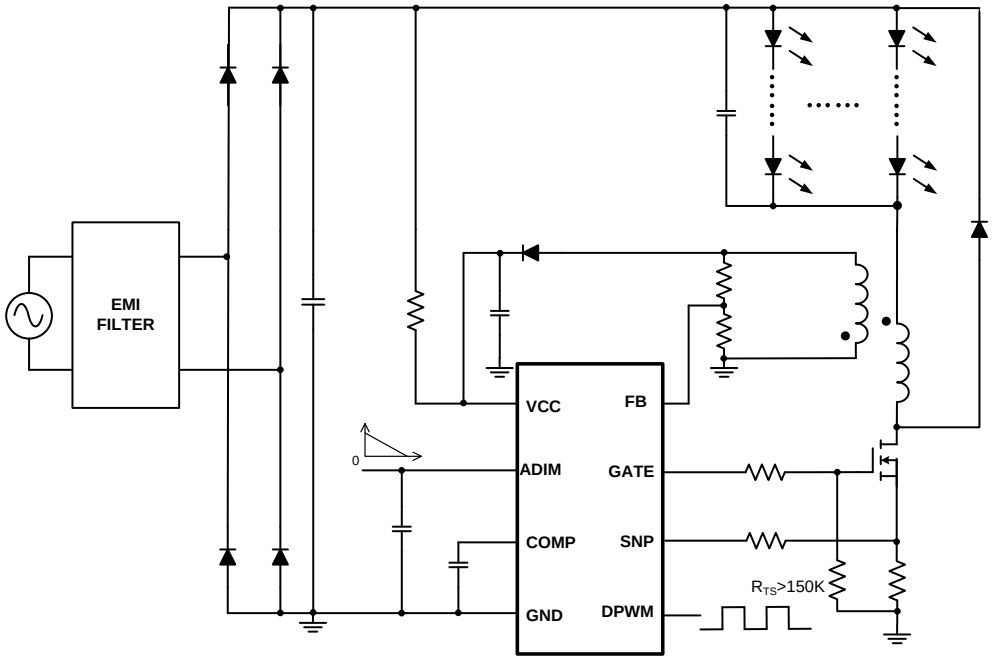
## TYPICAL APPLICATION




Buck-Boost




Buck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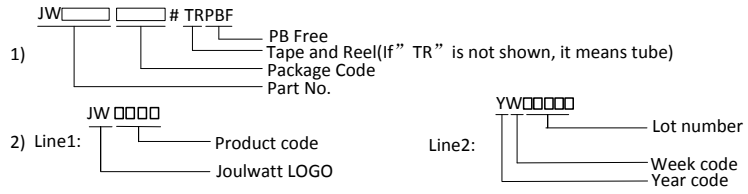
## ORDER INFORMATION

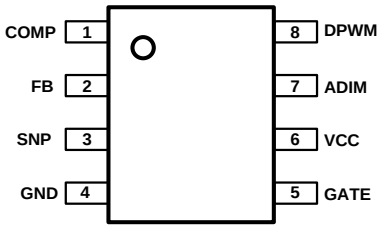
| DEVICE[1)] | PACKAGE | TOP MARKING[2)] |
|---|---|---|
| JW1602SOPB#TRPBF | SOP8 | JW1602<br>YW□□□□□ |

**Notes:**




## PIN CONFIGURATION

**TOP VIEW**




## ABSOLUTE MAXIMUM RATING[1)]

VCC,DPWM PIN .....40V
GATE PIN ..... 24V
All Other Pins ..... -0.3V to 5.5V
Junction Temperature[2) 3)] ..... 150ºC
Lead Temperature.....260ºC
Storage Temperature..... -65ºC to +150ºC

## RECOMMENDED OPERATING CONDITIONS

VCC PIN .....10V to 30V
FB PIN .....1V to 3V
Junction Temperature ($T_J$)..... -40ºC to 125ºC

## THERMAL PERFORMANCE[4)]

| | $\theta_{JA}$ | $\theta_{JC}$ |
|---|---|---|
| SOP8 | 96 | 45ºC/W |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**Note：**

**1)** Exceeding these ratings may damage the device.

**2)** The JW1602 guarantees robust performance from -40°C to 150°C junction temperature. The junction temperature range specification is assured by design, characterization and correlation with statistical process controls.

**3)** The JW1602 includes thermal protection that is intended to protect the device in overload conditions. Thermal protection is active when junction temperature exceeds the maximum operating junction temperature. Continuous operation over the specified absolute maximum operating junction temperature may damage the device.

**4)** Measured on JESD51-7, 4-layer PCB.


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## ELECTRICAL CHARACTERISTICS

| *$V_{CC}$ = 25V, $T_A$ = 25ºC, unless otherwise stated.* | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **Symbol** | **Condition** | **Min.** | **Typ.** | **Max.** | **Units** |
| Vcc Supply(Vcc) | | | | | | |
| $V_{CC}$ Turn-On Voltage | $V_{CC_ON}$ | | 22 | 24 | 27 | V |
| $V_{CC}$ Turn-off Low Voltage | $V_{CC_OFF_L}$ | | 7.0 | 8.0 | 9.5 | V |
| VCC Hysteresis(note1) | $V_{CC_HYS}$ | VCC_ON-VCC_OFF_L | | 16 | | V |
| VCC Shunt Regulator Voltage | $V_{CC_OFF_H}$ | | 31 | 34 | 37 | V |
| VCC Shunt Regulator Pull-Down Current | $I_{CC_PD}$ | VCC =38V | | 4 | | mA |
| VCC Quiescent Current | $I_Q$ | VCC =20V | 14 | 22 | 30 | μA |
| $V_{CC}$ Quiescent Current with Switching | $I_{Q_SW}$ | Switching frequency =60kHz; Min on time; Gate floating | | 700 | | uA |
| Sense Current of Primary(SNP) | | | | | | |
| $V_{REF}$ Voltage | $V_{REF}$ | | 294 | 300 | 306 | mV |
| SNP Offset voltage(note1) | $V_{SNP_OFT}$ | | | 50 | | mV |
| SNP Sense Current Limit(Flyback) | $V_{SNP_H1}$ | | 1.2 | 1.5 | 1.8 | V |
| SNP Sense Current Limit(Buck) | $V_{SNP_H2}$ | | 1.8 | 2.2 | 2.6 | V |
| SNP Inductor Short Current Limit | $V_{IND_SHT}$ | | 2.2 | 2.7 | 3.2 | V |
| Leading Edge Blanking Time(note1) | $T_{LEB}$ | | | 400 | | ns |
| Line compensation factor(note1) | $K_{LC}$ | | | 0.04 | | A/A |
| Output Feedback(FB) | | | | | | |
| FB OVP Threshold | $V_{FB_OVP}$ | | 3.65 | 3.8 | 3.95 | V |
| FB Burst on Threshold in CV | $V_{FB_CVON}$ | | | 1.1 | | V |
| FB Burst off Threshold in CV | $V_{FB_CVOFF}$ | | | 1.2 | | V |
| FB OVP Sensing blanking time | $T_{OVP_BLK1}$ | SNP>0.6V | 1.6 | 2 | 2.4 | us |
| FB OVP Sensing blanking time | $T_{OVP_BLK2}$ | SNP<0.3V | 0.8 | 1 | 1.2 | us |
| Compensation(COMP) | | | | | | |
| Comp Max Sourcing Current | $I_{SOURCE}$ | | | 10 | | uA |
| Max Comp Voltage(note1) | $V_{COMP_H}$ | | | 4 | | V |
| Comp voltage frequency starts to foldback | $V_{COMP_FF}$ | | | 0.65 | | V |
| Maximum Oscillator Frequency high | $f_{MAX_H}$ | COMP=1.5V | 96 | 120 | 145 | kHz |
| Maximum Oscillator Frequency low | $f_{MAX_L}$ | COMP=0.3V | 30 | 35 | 40 | kHz |
| DPWM Dimming(DPWM) | | | | | | |
| DPWM Signal High Level | $V_{PWMH}$ | | 0.88 | | | V |
| DPWM Signal Low Level | $V_{PWML}$ | | | | 0.92 | V |


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| | | | | | | |
|---|---|---|---|---|---|---|
| Analog Dimming(ADIM) | | | | | | |
| ADIM OFF | $V_{ADIM_OFF}$ | | | 0.2 | | V |
| ADIM Low threshold voltage | $V_{ADIM_LOW}$ | | 0.27 | 0.3 | 0.33 | V |
| ADIM HIGH threshold voltage | $V_{ADIM_HIGH}$ | | | 3.3 | | V |
| Gate output(GATE) | | | | | | |
| Gate Output High | $V_{GATE_H}$ | | 9.6 | 12 | 14.4 | V |
| Gate Output Low | $V_{GATE_L}$ | | | | 200 | mV |
| $t_r$ Gate Driver Output Rise Time (note1) | $T_{GATE_R}$ | $C_L$=1nF 1V to 8V | | 50 | | ns |
| $t_f$ Gate Driver Output Fall Time (note1) | $T_{GATE_F}$ | $C_L$=1nF 8V to 1V | | 50 | | ns |
| Maximum turn on time | $T_{on_max}$ | | 30 | 40 | | us |
| Minimum turn on time | $T_{on_min}$ | | 360 | 450 | 540 | ns |
| Maximum turn off time | $T_{off_max}$ | | 160 | 200 | 240 | us |
| Thermal | | | | | | |
| Thermal foldback Temperature(note1) | $T_{OTPFB}$ | | | 140 | | ℃ |

Note1: Guarantee by design.


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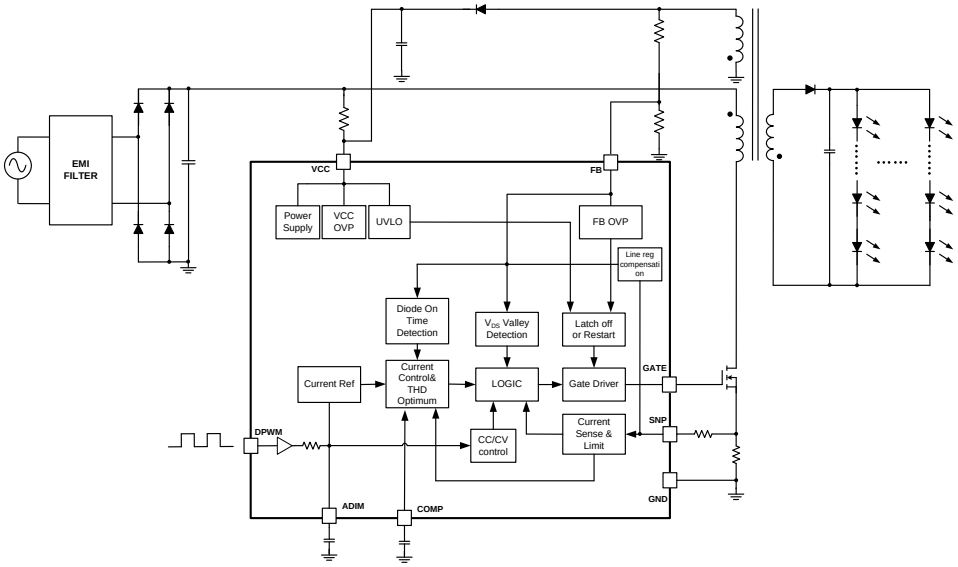
## PIN DESCRIPTION

| Pin | Name | Description |
|---|---|---|
| 1 | COMP | Compensation Pin for Internal Error Amplifier. Connect a capacitor between the pin and GND to compensate the internal feedback loop. |
| 2 | FB | Voltage Loop Feedback Pin. VFB is used to detect open LED conditions by sampling the auxiliary winding voltage. |
| 3 | SNP | Primary current sense Pin. The pin is used for cycle-by-cycle peak current control and limit. |
| 4 | GND | Power Ground. |
| 5 | GATE | Gate Driver for the External Main MOSFET Switch. |
| 6 | VCC | Power Supply Pin. This pin supplies current to the internal start-up circuit. This pin must be bypassed with a capacitor nearby. |
| 7 | ADIM | Apply an analog signal on this pin for analog dimming, CV mode take the control loop if ADIM goes below than 0.2V.<br>An external capacitor should be connected on ADIM to filter out the DPWM to get the internal current reference. |
| 8 | DPWM | Apply a PWM signal on this pin for external PWM dimming. |

## BLOCK DIAGRAM





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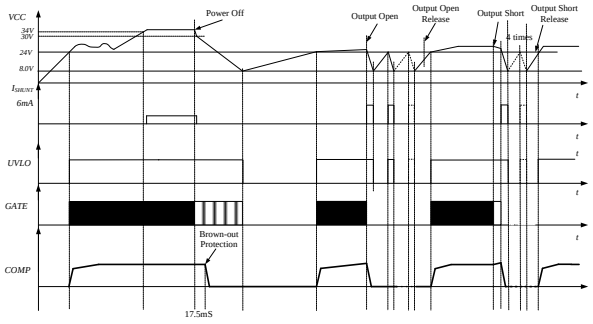
# FUNCTIONAL DESCRIPTION

The JW1602 is a multi-topology LED controller optimized for LED lighting. It uses a novel method to calculate the output current without the need of opto-coupler. The JW1602 achieves high power factor over wide line and load ranges, compared to conventional constant on time control, it also significantly optimized the THD by a improved on time control.

## Start Up

The JW1602 uses a hysteretic start-up to operate from high offline voltages. A resistor connected to the supply voltage protects the part from high voltages. When the DC line charges VCC up to 24V, the gate drive signal begins to switch. The auxiliary winding provides power to the VCC pin along with the resistor in steady state. The gate turns off if VCC goes below than 8V. An internal voltage clamp helps to prevent VCC from being too high. When VCC goes above 34V, an internal shunt current regulates the Vcc voltage. The shunt stops pulling down when VCC is lower than 30V.




Vcc Timing Diagram

## Primary-Side Current Control

The JW1602 controls the output current from the information of inductor current. The output LED means current can be calculated as:

$$I_O = \begin{cases} \dfrac{V_{REF} \cdot N_{PS}}{2R_S} & \text{For Flyback} \\ \dfrac{V_{REF}}{2R_S} & \text{For Buck-Boost} \\ \dfrac{V_{REF}}{R_S} & \text{For Buck} \end{cases}$$

Where

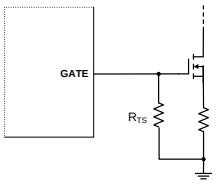
$N_{PS}$ – Turns ratio of primary winding to secondary winding;

$V_{REF}$– Reference voltage, 300mV typically;

$R_S$ – Sensing resistor connected between SNP and ground.

## Multi-Topology Operation Principle

JW1602 supports multi-topology operation with only one resistor $R_{TS}$ that connected between GATE pin and GND pin.




JW1602 works in BUCK mode when $R_{TS}$ is larger than 150Kohm (floating included), and in Buck-Boost/Flyback mode when $R_{TS}$ is smaller than 50Kohm.

## Improved COT control to optimize THD

The JW1602 integrates an improved COT control circuit to optimize THD in BUCK-Boost/Flyback mode.

The average input current can be deduced as,

$$I_{in} = \frac{\sqrt{2} \cdot Vac \cdot \sin(t)}{2L} \cdot T_{on} \cdot D(t)$$

Where Ton is the on-time of GATE, D(t) is the duty cycle.

The dedicated THD improved circuit can modulate input current as a pure sinusoidal wave,

$$I_{in} = k \sin(t)$$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Here k is a constant.

## Line Regulation Compensation Design

The gate turn-off delay is the main reason that causes bad line regulation, the increased voltage on SNP by delay Td can be expressed as,

$$\Delta V_{SNP} = \frac{V_{IN}}{L_m} T_d R_S$$

Here, RS is the sensing resistor. Td is the total turn-off delay of power MOSFET.

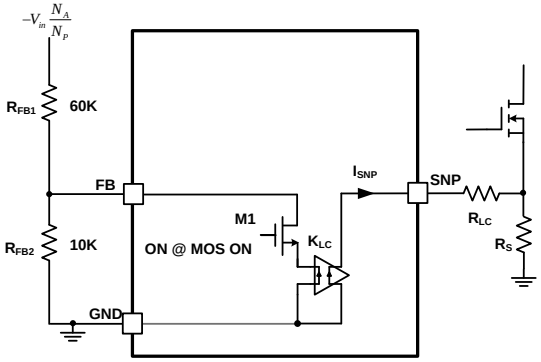
To compensate this increased current of primary side, a current $I_{SNP}$ which is proportional to the voltage on auxiliary winding, sourced from the SNP pin and flows through resistor $R_{LC}$, the sourcing current is,

$$I_{SNP} = K_{LC} \frac{N_A \cdot V_{in}}{N_P \cdot R_{FB1}}$$

Where, $N_A$ is the turns of auxiliary winding, $N_P$ is the turns of primary winding and $K_{LC}$ is current factor, 0.04A/A.

The RLC can be designed as,

$$R_{LC} = \frac{\Delta V_{SNP}}{I_{SNP}} = \frac{T_d \cdot R_S \cdot N_P \cdot R_{FB1}}{K_{LC} \cdot N_A \cdot L_m}$$



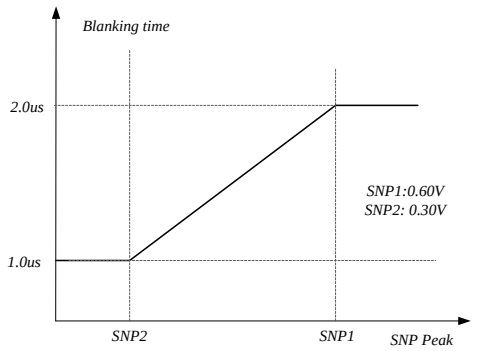

Line regulation compensation circuit

## Critical Conduction Mode Operation

Critical conduction mode is a variable frequency switching scheme that always returns the secondary current to zero in each cycle. The JW1602 relies on this mode to calculate the output current. When the external MOSFET turns off, the energy stored in the inductor forces the secondary freewheeling diode to turn on, and the current of the inductor begins to decrease linearly from peak to zero. When the current decreases to zero, the resonance, caused by the inductor and all the parasitic capacitance, makes the MOSFET drain-source voltage decreases, this decreasing can also be reflected at the auxiliary winding. The turn on signal is generated when the drain-source voltage is approximately at the valley. This switching technique can reduce the MOSFET turn-on losses and diode reverse recovery losses, thus improves efficiency and decreases EMI noise.

## Adaptive Blanking Time for FB Voltage Sensing

To filter out the noise on FB and to get an accurate FB voltage via the auxiliary winding, a blanking time is inserted after the MOSFET turns off. The blanking time is modulated by the SNP peak. The minimum blanking time is about 1us, the maximum is about 2.0us.




## Maximum Frequency Fold-back

JW1602 integrates a maximum frequency fold-back mechanism based on COMP voltage, which ensures a deep dimming. It starts to reduce the maximum frequency when COMP <0.8V and ends at 30KHz when COMP goes down to 0.3V.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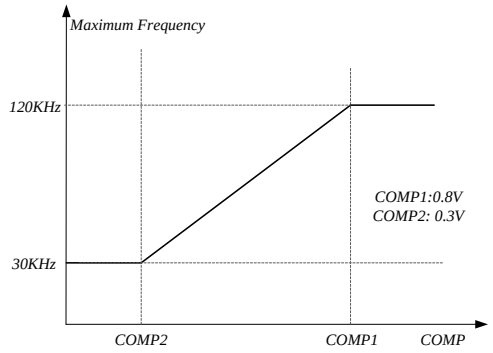
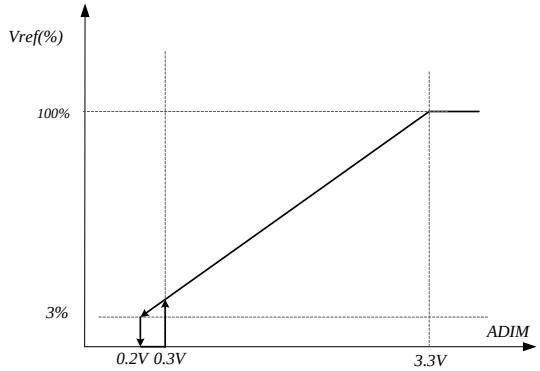



## Loop Compensation

An integrator is applied to the output current feedback loop with a capacitor connected to the COMP. For offline applications, the crossover frequency should be set much less than the line frequency of 120Hz or 100Hz. To have a good PFC performance, a capacitor of 1μF connected to COMP is recommended.

## Analog Dimming

JW1602 incorporates the analog dimming function. An analog signal can be applied to ADIM pin, it can linearly change the internal current reference according to the ADIM which is between $V_{ADIM_LOW}$ and $V_{ADIM_HIGH}$. It can achieve about 3%~100% dimming range.

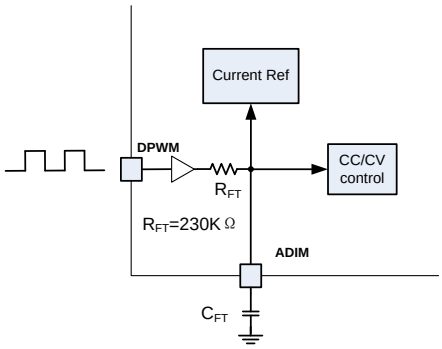



The output current decreases linearly when the ADIM voltage decreases from 3.3V to 0.2V. As soon as ADIM<0.2V, CV loop takes the control loop thus makes the LED in totally off state. When ADIM voltage increases from <0.2V, CC mode will not take the control loop until ADIM≥0.3V.

For non-dimming applications, a bypass ceramic cap should be applied to ADIM pin, <10nF in usual.

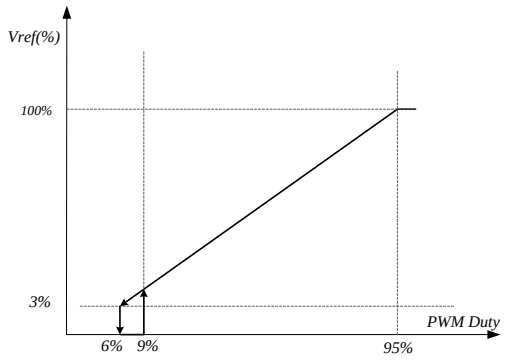
## PWM Dimming

When the PWM signal is injected to DPWM, The PWM signal is conditioned and filtered by a bypass capacitor on ADIM. The internal current reference is adjusted by ADIM, so that the output current is proportional to the PWM duty cycle.




To have a higher PF, lower THD the time constant of $R_{FT}C_{FT}$ should be larger enough to filter the PWM signal to a DC value.

$$R_{FT}C_{FT} \approx 3\sim5\ T_{PWM}$$




The output current decreases linearly when the PWM duty cycle decreases from 100% to 6%. As soon as duty <6%, CV loop takes the control loop thus makes the LED in totally off state. When the PWM duty increases from <6%, CC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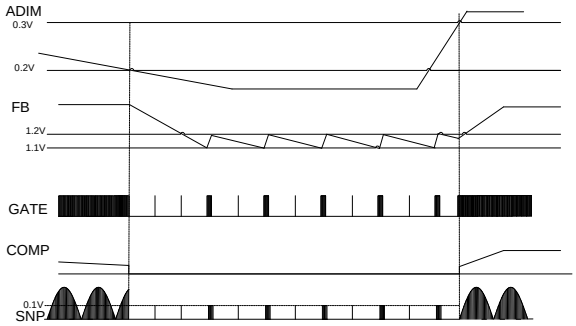
mode will not take the control loop until the duty ≥9%.

## CV mode

CV mode takes the control loop if ADIM goes below than 0.2V, and returns to CC control when ADIM is over than 0.3V.
When FB voltage goes below 1.1V, it starts to switch with peak current control, and the SNP peak voltage is controlled at 0.1V. It stops switching for 1.7mS when detected FB ramp up over 1.2V.




## LED Over Temperature Protection

When JW1602 is hotter than 140°C, the internal current reduces linearly in order to reduce the output current. When the temperature is higher than 160°C, the output current reduces to <30% of the rated.

## Brown-out Protection

When the peak SNP voltage is lower than 50mV and lasts for 17.5ms, Brown-out protection could be triggered, then COMP is pulled down zero.

## LED Open Protection

The output voltage can reflect on the auxiliary winding when the main power switch is off. A resistor divider from the auxiliary winding is connected to the FB pin. FB voltage could be detected with an OVP blanking time after the main MOSFET turns off. If the FB voltage is higher than 3.8V, LED open protection could be triggered and the GATE stops switching, and Vcc is pulled down to 8V by an internal sink current and then charged to 24V by the external resistor, which repeats for four times of discharging and charging of Vcc before the next detection cycle.

## LED Short Protection

When the output is shorted, the auxiliary winding voltage comes to zero. JW1602 counts this state for 100ms, if short goes on, it stops switching and set a FAULT flag. Vcc is pulled down to 8V by an internal sink current and then is charged to 24V by the external resistor, which repeats for four times of discharging and charging of Vcc before the next detection cycle.

## PCB Guidelines

1. The bypass ceramic capacitor of VCC should be nearby the VCC and GND as close as possible.
2. To reduce EMI noise, the power loop area should be as small as possible.
3. JW1602 should be kept away from noisy and heating components, such as MOSFET, transformer and diode.
4. FB pin should be kept away from sources of interference; a 20pF capacitor could be paralleled if necessary.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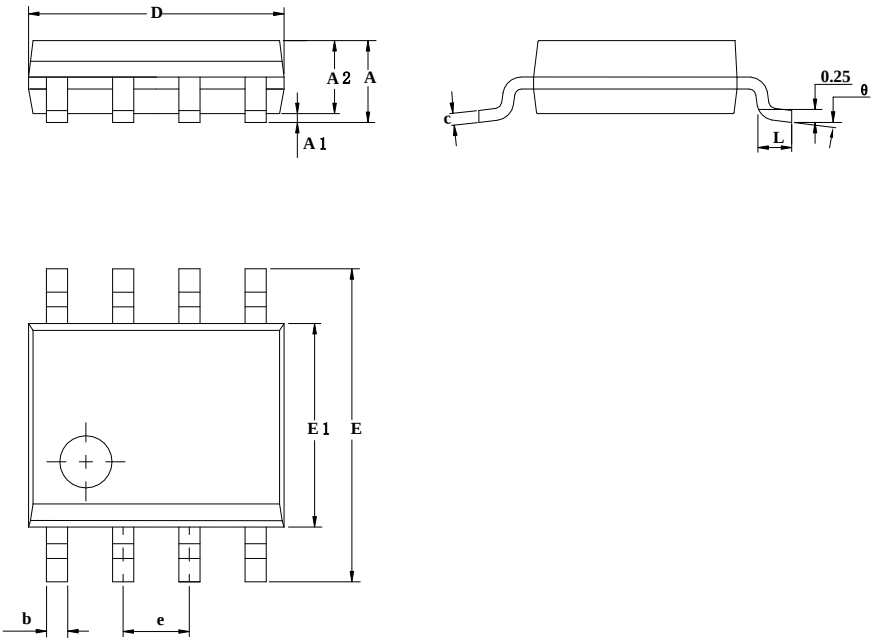
## PACKAGE OUTLINE

SOP8 UNIT: mm




| Symbol | MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | — | — | 1.75 |
| A1 | 0.05 | 0.15 | 0.25 |
| A2 | 1.25 | 1.40 | 1.65 |
| b | 0.32 | 0.42 | 0.52 |
| c | 0.10 | 0.20 | 0.30 |
| D | 4.50 | 5.00 | 5.50 |
| E | 5.50 | 6.00 | 6.50 |
| E1 | 3.50 | 3.90 | 4.30 |
| e | 1.27TYP | | |
| L | 0.40 | — | 1.27 |
| θ | 0° | — | 8° |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