Constant Current LED Driver with PWM Dimming Control

GENERAL DESCRIPTION
The NJW4617 is a constant current LED driver with PWM dimming control. The output current can be set by external sensing resistor, and the NJW4617 can set up to 500mA. Because the withstand voltage of the output (LED) pin is 40V, it can series-connect the LED depending on forward voltage of the LED. The LED dimming control can be regulated via PWM duty cycle. It is suitable for back light, light source and so on.

FEATURES
- Operating Voltage Range: 2.5V to 40V
- Output Voltage:  V_{LED}=40V max.
- Output Current:  I_{LED}=20mA to 500mA
- Output Current Accuracy:  ±1.5%
- To 11 of White LED can be operated. (at LED Vf=3.4V)
- Quiescent Current:  450µA max.
- PWM Dimming Control and Enable Control (Common Pin)
- Over Current Protection
- Thermal Shutdown Protection
- LED Short Protection
- Package:  TO-252-5

BLOCK DIAGRAM

![Block Diagram of NJW4617]

V_{DD}  LED
V_{REF} (0.2V)  RS
Current Limit
Thermal Shut Down
LED Short Protection
Control Logic
Standby Timer
GND  EN/PWM

NJW4617DL3
(TO-252-5)
**PIN CONFIGURATION**

1. **V_DD**
2. **EN/PWM**
3. **GND**
4. **R_S**
5. **LED**

**PIN DESCRIPTIONS**

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Pin Name</th>
<th>I/O</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V_DD</td>
<td>-</td>
<td>Power supply pin</td>
</tr>
</tbody>
</table>
| 2       | EN/PWM   | I   | Standby control pin and PWM signal input pin for dimming control.  
[At Standby control]  
Normal operation: High Level.  
Standby mode: Low Level.  
[At PWM signal input]  
The LED dimming control can be regulated by PWM duty cycle.  
In the case without dimming, I_LED becomes the current set by the external resistor (R_S) when High level is input to this pin.  
Note that this pin should not be open. |
| 3       | GND      | -   | Ground pin |
| 4       | R_S      | O   | Resistor connect pin of I_LED setting.  
The LED current can be set with connected resistor (R_S) between R_S pin and GND pin. R_S [Ω] = 0.2 [V] / I_LED [A] |
| 5       | LED      | O   | Constant current circuit output pin  
Connect cathode pin of LED. |
### ABSOLUTE MAXIMUM RATINGS

(\( T_a = 25^\circ C \))

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>RATINGS</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>( V_{DD} )</td>
<td>-0.3 to +45 V</td>
<td>V</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>( V_{LED} )</td>
<td>-0.3 to +45 V</td>
<td>V</td>
</tr>
<tr>
<td>EN/PWM Pin Voltage</td>
<td>( V_{ENPWM} )</td>
<td>-0.3 to +45 V</td>
<td>V</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>( P_D )</td>
<td>1190 (*1) mW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3125 (*2) mW</td>
<td></td>
</tr>
<tr>
<td>Junction Temperature Range</td>
<td>( T_j )</td>
<td>-40 to +150 °C</td>
<td></td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>( T_{opr} )</td>
<td>-40 to +125 °C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>( T_{stg} )</td>
<td>-50 to +150 °C</td>
<td></td>
</tr>
</tbody>
</table>

(*1) Mounted on glass epoxy board. (76.2 × 114.3 × 1.6mm: based on EIA/JEDEC standard size, 2Layers, Cu area 100mm²)

(*2) Mounted on glass epoxy board. (76.2 × 114.3 × 1.6mm: based on EIA/JEDEC standard, 4Layers),

(For 4Layers: Applying 74.2 × 74.2mm inner Cu area and a thermal via hole to a board based on JEDEC standard JESD51-5)

### RECOMMENDED OPERATING CONDITIONS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>( V_{DD} )</td>
<td>2.5 - 40 V</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output Current</td>
<td>( I_{LED} )</td>
<td>20 - 500 mA</td>
<td></td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>( V_{LED} )</td>
<td>- - 40 V</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

### ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, \( V_{DD} = 12V, V_{LED} = 1V, R_S = 2Ω, V_{ENPWM} = V_{DD}, Ta = 25^\circ C \))

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiescent Current</td>
<td>( I_{OD} )</td>
<td>-</td>
<td>300</td>
<td>450</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>Quiescent Current at OFF State</td>
<td>( I_{OD,\text{OFF}} )</td>
<td>( V_{ENPWM} = \text{GND} )</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>Output Current Accuracy</td>
<td>( \Delta I_{LED} )</td>
<td>-1.5</td>
<td>-</td>
<td>+1.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Output (LED) Pin Leak Current</td>
<td>( I_{LEAK} )</td>
<td>( V_{ENPWM} = \text{GND}, V_{DD} = V_{LED} = 40V )</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>OFF Delay Time</td>
<td>( t_{D,\text{OFF}} )</td>
<td>10</td>
<td>25</td>
<td>45</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>EN/PWM Pin ON Voltage1</td>
<td>( V_{ENPWM\text{ON1}} )</td>
<td>( V_{DD} &lt; 5V, I_{LED} = \text{OFF} \rightarrow \text{ON} )</td>
<td>0.7 ( V_{DD} )</td>
<td>-</td>
<td>( V_{DD} )</td>
<td>V</td>
</tr>
<tr>
<td>EN/PWM Pin ON Voltage2</td>
<td>( V_{ENPWM\text{ON2}} )</td>
<td>( V_{DD} \geq 5V, I_{LED} = \text{OFF} \rightarrow \text{ON} )</td>
<td>3.5</td>
<td>-</td>
<td>( V_{DD} )</td>
<td>V</td>
</tr>
<tr>
<td>EN/PWM Pin OFF Voltage</td>
<td>( V_{ENPWM\text{OFF}} )</td>
<td>( I_{LED} = \text{ON} \rightarrow \text{OFF} )</td>
<td>0</td>
<td>-</td>
<td>0.5</td>
<td>V</td>
</tr>
<tr>
<td>EN/PWM Pin Input Current</td>
<td>( I_{ENPWM} )</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>R_S Pin Output Current</td>
<td>( I_{OUT\text{RS}} )</td>
<td>( \text{LED} = \text{OPEN} )</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>μA</td>
</tr>
<tr>
<td>PWM Dimming ON Delay Time</td>
<td>( t_{PWM\text{ON}} )</td>
<td>( R_S = 0.4Ω, V_{ENPWM} = L \rightarrow H )</td>
<td>-</td>
<td>13</td>
<td>-</td>
<td>μs</td>
</tr>
<tr>
<td>PWM Dimming OFF Delay Time</td>
<td>( t_{PWM\text{OFF}} )</td>
<td>( R_S = 0.4Ω, V_{ENPWM} = H \rightarrow L )</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>μs</td>
</tr>
<tr>
<td>LED Short Protection Detect Voltage</td>
<td>( V_{LED\text{SHORT}} )</td>
<td>-</td>
<td>18</td>
<td>21</td>
<td>24</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>( I_{LED\text{MAX}} )</td>
<td>( R_S = 0Ω )</td>
<td>500</td>
<td>850</td>
<td>-</td>
<td>mA</td>
</tr>
</tbody>
</table>
**TYPICAL APPLICATION**

![Diagram of NJW4617 Typical Application](image)

- **VDD / V⁺**
- **VDD**
- **VREF (0.2V)**
- **LED**
- **EN/PWM**
- **Control Logic**
- **Current Limit**
- **Thermal Shut Down**
- **LED Short Protection**
- **Standby Timer**
- **GND**
- **Rₛ : Current Sense Resistor**

The Rs Resistance Setting formula: \( Rₛ (\Omega) = \frac{0.2(V)}{I_{LED} (A)} \)

(*3) If the wiring from the power supply to the LED anode pin is long, the voltage may change due to the influence of the parasitic elements.

As the countermeasure, it should connect a decoupling capacitor as close to the LED as possible.
TYPICAL CHARACTERISTICS

Quiescent Current vs. Supply Voltage

Quiescent Current vs. Temperature

Quiescent Current at OFF State vs. Temperature

Output Pin Leak Current vs. Temperature

OFF Delay Time vs. Temperature
TYPICAL CHARACTERISTICS

EN/PWM Pin ON Voltage vs. Supply Voltage

\[ V_{\text{EN/PWM,ON}} \] vs. \[ V_{\text{DD}} \]

EN/PWM Pin ON Voltage vs. Temperature

\[ V_{\text{EN/PWM,ON}} \] vs. \[ T \]

EN/PWM Pin OFF Voltage vs. Supply Voltage

\[ V_{\text{EN/PWM,OFF}} \] vs. \[ V_{\text{DD}} \]

EN/PWM Pin OFF Voltage vs. Temperature

\[ V_{\text{EN/PWM,OFF}} \] vs. \[ T \]

EN/PWM Pin Input Current vs. EN/PWM Pin Voltage

\[ I_{\text{EN/PWM}} \] vs. \[ V_{\text{EN/PWM}} \]
TYPICAL CHARACTERISTICS

PWM Dimming ON Delay Time vs. Output Current

$[V_{DD}=12V, V_{LED}=1V]$  

PWM Dimming OFF Delay Time vs. Output Current

$[V_{DD}=12V, V_{LED}=1V]$  

PWM Dimming ON Delay Time vs. Temperature

$[V_{DD}=12V, V_{LED}=1V]$  

PWM Dimming OFF Delay Time vs. Temperature

$[V_{DD}=12V, V_{LED}=1V]$  

Output Current vs. Output Pin Voltage

$[V_{DD}=12V, V_{ENPWM}=V_{DD}]$  

Output Current vs. Temperature

$[V_{DD}=12V, V_{LED}=1V, R_S=2\Omega, V_{ENPWM}=V_{DD}]$  

Output Current vs. Output Pin Voltage

$[V_{DD}=12V, V_{ENPWM}=V_{DD}]$  

Output Current vs. Temperature

$[V_{DD}=12V, V_{ENPWM}=V_{DD}]$
TYPICAL CHARACTERISTICS

LED Short Protection Voltage vs. Temperature

Maximum Output Current vs. Output Pin Voltage

Maximum Output Current vs. Temperature

Output Current vs. Current Sense Resistance
The number of LED series connection

It is necessary to drive LED that is the LED forward voltage (Vf) or more. When the LED was series connected, the supply voltage should be input sum of LED Vf (ΣLED Vf) the series connected or more. In NJW4617, it is necessary as minimum V* that is ΣLED Vf + NJW4617 output voltage (V_{LED} = 1V). The maximum LED connected number that NJW4617 can drive is limited by the recommended output voltage maximum value (40V). Moreover, it should be used with ΣLED Vf within 39V that is subtracted the V_{LED} = 1V.

The table below shows maximum LED number at each Vf. (All LED Vf assumes ideally same)

<table>
<thead>
<tr>
<th>LED Vf is up to</th>
<th>Maximum LED number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0V</td>
<td>up to 13 lights</td>
</tr>
<tr>
<td>3.2V</td>
<td>up to 12 lights</td>
</tr>
<tr>
<td>3.5V</td>
<td>up to 11 lights</td>
</tr>
<tr>
<td>3.9V</td>
<td>up to 10 lights</td>
</tr>
<tr>
<td>4.3V</td>
<td>up to 9 lights</td>
</tr>
</tbody>
</table>

\[ V_{DD} \times n \text{ pcs.} = \sum \text{LEDVf} \leq 39V \]

\[ V^* \leq 40V \]

(*4) If the wiring from the power supply to the V_{DD} pin is long, the voltage may change due to the influence of the parasitic elements.

As the countermeasure, it should connect a decoupling capacitor as close to the V_{DD} pin as possible.
PWM input pulse and PWM dimming accuracy

The $I_{LED}$ transient behavior corresponding to PWM input pulse has some delay at rise/fall time.

If enter a PWM signal with short pulse width, for the output current pulse width error becomes larger against the PWM input pulse width, it is incapable of accurate PWM dimming. The Output current pulse width error rate ($\varepsilon_t$) becomes the following value. ($\varepsilon_t=t_{PWM\_ON}-t_{PWM\_OFF}$)

$$\varepsilon_t = \text{approx. } 12\mu\text{s} \quad (\text{Output Current: } I_{LED} = 500\text{mA}, T_a=25^\circ\text{C typ. <Reference Value>})$$

The actual value of the output current pulse width error rate can calculate by above error rate ($\varepsilon_t$) and the frequency and Duty of the PWM input pulse. ($f_{PWM}$: PWM input pulse frequency, $D$: PWM input pulse Duty)

Based on the allowable value of the output current pulse width error rate, you should determine the frequency and Duty of the PWM input pulse.

- **PWM Input pulse width**
  \[ = \frac{D}{100} \times \left( \frac{1}{f_{PWM}} \right) \]

- **Output Current pulse width**
  \[ = \text{PWM Input pulse width} - \varepsilon_t \]

- **Output Current pulse width error rate**
  \[ = \left( \text{Output Current pulse width} - \text{PWM Input pulse width} \right) / \text{PWM Input pulse width} \times 100 \]
  \[ = -\varepsilon_t / \text{PWM Input pulse width} \times 100 \% \]

**Output current pulse width error rate calculation example:**

- **operation with PWM input pulse frequency 200Hz and Duty 1%**
  \[ \text{PWM Input pulse width} = 1 \% / 100 \times (1 / 200[\text{Hz}]) = 50 \mu\text{s} \]
  \[ \text{Output Current pulse width error rate} = -12 \mu\text{s} / 50 \mu\text{s} \times 100 \]
  \[ = -24 \% \]

**Output Current Duty vs. PWM Input Pulse Duty**

**Measurement Conditions**

- Output Current ($I_{LED}$) 20mA ($R_s=10\Omega$)
- 100mA ($R_s=2\Omega$)
- 500mA ($R_s=0.4\Omega$)
- Supply Voltage 12V
- Output (LED) pin Input Voltage at 1V
- PWM Input Pulse 200Hz, 0 to 5V
- Output Current $I_{LED}$ Pulse Width: The time is more than 90% of set current.
- Ambient Temperature $T_a=25^\circ\text{C}$
Protection Circuit

- Over Current Protection (Refer to Maximum Output Current vs. Output Pin Voltage)
  This protection function limits the output current, when the R\(_\text{S}\) pin and GND pin was shorted. The limited current is dependent on output (LED) pin voltage.
  When the output (LED) pin voltage is less than "LED Short Protection Detect Voltage", maximum output current is limited to approx. 850mA (output (LED) pin voltage=1V, Ta=25°C).
  The output current returns to set current, when the short status is release.

- LED Short Protection (Refer to Maximum Output Current vs. Output Pin Voltage)
  This protection function limits the output current, when the output (LED) pin rises as in LED shorten at output FET ON.
  The output current is limited to approx. 400mA when the output (LED) pin voltage rose to approx. 21V.

- Thermal Shutdown Function (Refer to Output Current vs. Temperature)
  When junction temperature of the NJW4617 exceeds the 160°C*, internal thermal shutdown circuit function stops the device function.
  When junction temperature decreases to 140°C* or less, the device operation returns to normal operation.
  The purpose of this function is to prevent malfunctioning of IC at the high junction temperature. Therefore it is not something that urges positive use. It should make sure to operate within the junction temperature range rated (≤+150°C).
  *) Design value
The Loss of Constant Current Driver

The power consumption of the LED lighting circuit is classified as "the power consumption of the constant current driver" "the power consumption of the LED" and "the power consumption of the current sense resistor ($R_s$)".

The loss of constant current driver is caused mainly by quiescent current ($I_{DD}$) and output current ($I_{LED}$).

The power dissipation of the device can be calculated by the following equation.

$$P_D \approx V_{DD} \times I_{DD} + (V_{LED} - V_{RS}) \times I_{LED}$$

where $V_{DD}$ is the supply voltage, $I_{DD}$ is the quiescent current, $V_{LED}$ is the LED driving voltage, $V_{RS}$ is the pin voltage, $I_{LED}$ is the output current.

As shown in the above equation, the loss of constant current driver will increase in proportion to the voltage difference between the LED driving voltage $V^+$ and $\Sigma LED Vf$.

The device power dissipation must be below the power dissipation rate of the device package including thermal derating to ensure correct operation. It should set the LED operating Voltage ($V^+$) and output current ($I_{LED}$) with consideration of $P_D$.

![NJW4617DL3 (TO-252-5) Power Dissipation](image)

The device power dissipation must be below the power dissipation rate of the device package including thermal derating to ensure correct operation.

- **(1)**: Mounted on glass epoxy board. (76.2 x 114.3 x 1.6mm: based on EIAJEDEC standard size, 2Layers, Cu area 100mm²)
- **(2)**: Mounted on glass epoxy board. (76.2 x 114.3 x 1.6mm: based on EIAJEDEC standard, 4Layers, applying 74.2 x 74.2mm inner Cu area and a thermal via hole to a board based on JEDEC standard JESD51-5)
Parallel Drive of NJW4617

For applications that require more than 500mA, it can correspond by parallel connecting two or more NJW4617. The LED current becomes sum of LED current of each NJW4617. Each device accepts different set current.

\[ I_{\text{LED}} [\text{A}] = I_{\text{LED1}} + I_{\text{LED2}} = \frac{0.2}{R_s1} \Omega + \frac{0.2}{R_s2} \Omega \]

(e.g. \( I_{\text{LED}} = 750 \text{ mA} \) setting: \( R_s1 = 0.4 \Omega, \ R_s2 = 0.8 \Omega \))
[CAUTION]
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