The MBI1812 Application Note

Foreword

The MBI1812 is a LED constant current driver, which allows product developers easily to set the LED current through an external resister, and the LED brightness can be further adjusted by an analog signal, which is connected to $\overline{OE}$. The MBI1812 provides 2 output ports, and each port may drive a string of LEDs. It also features a built-in Thermal Protection (TP) function to protect IC from over temperature damage and thermal shutdown function~~s~~.

Application Circuit

Figure 1 shows the application circuit of the MBI1812. Product developers usually use only one power source for both LED and IC. However, for the MBI1812, the maximum operating voltage of VDD is 14.4V and the sustaining voltage of VDD is only 15V. To avoid the VLED (i.e over 17V) connector to VDD, V_{LED} and VDD should be separated to prevent IC been damaged. Alternatively, a resistor (R0) and a zener diode (D1), with clamping voltage 12V. Following shows the calculation of R0:

$$R0 = (V_{IN}-12V) / I_{DD} \quad (1)$$

where I_{DD} is the supply current of IC.

In general application, the V_{LED} is lower than 17V to avoid the voltage exceeding the sustaining voltage of output port of IC. However, sometimes the V_{IN} may be larger than 17V, and then developers need a linear regulator to clamp voltage under 17V. The linear regulator on Figure 1 is a simple of Low Dropout Regulator (LDO). Developers can get a suitable V_{LED} by zener diode (D2).

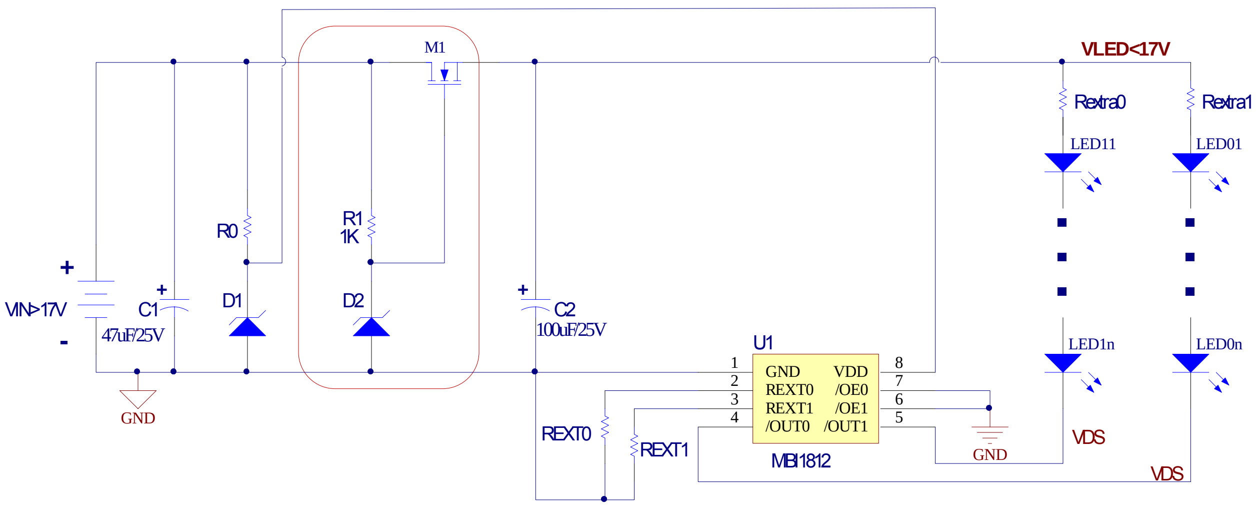

Figure 1. The Application Circuit of the MBI1812

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Circuit Design

How to decide the V_{LED} is usually a concern for product developers when using MBI1812. If V_{LED} is larger than the one it needed, it will cause the overheat problem. However if there is not sufficient voltage for IC, IC cannot keep constant current. Therefore, the following is the suggestions for circuit design.

1. **Sorting the forward voltage of LED**

   As above-mentioned, a large V_{LED} may cause the overheat problem. Therefore, reducing the variation of LED forward voltage (V_F) is necessary, and the recommended range of variation should be within 0.2V. (e.g. $V_{F,MIN.}$=3.2V， $V_{F,MAX.}$=3.4V)

2. **Select a suitable R_{ext}.**

   The MBI1812 allows developers to set the LED current (I_{OUT}) by an external resistor, R_{ext}. After developers decide the LED current, R_{ext} can be calculated by the following equations.

   R_{ext} = (1.224 / I_{OUT}) x 720 For MBI1812 .... (2)

3. **Decide V_{DS}.**

   To keep a constant current, a sufficient voltage at output port of IC (V_{DS}) is needed. Figure 2 show the I-V curves of MBI1812, user get a suitable V_{DS} from it. In general, the V_{DS} is slightly greater than the knee voltage.

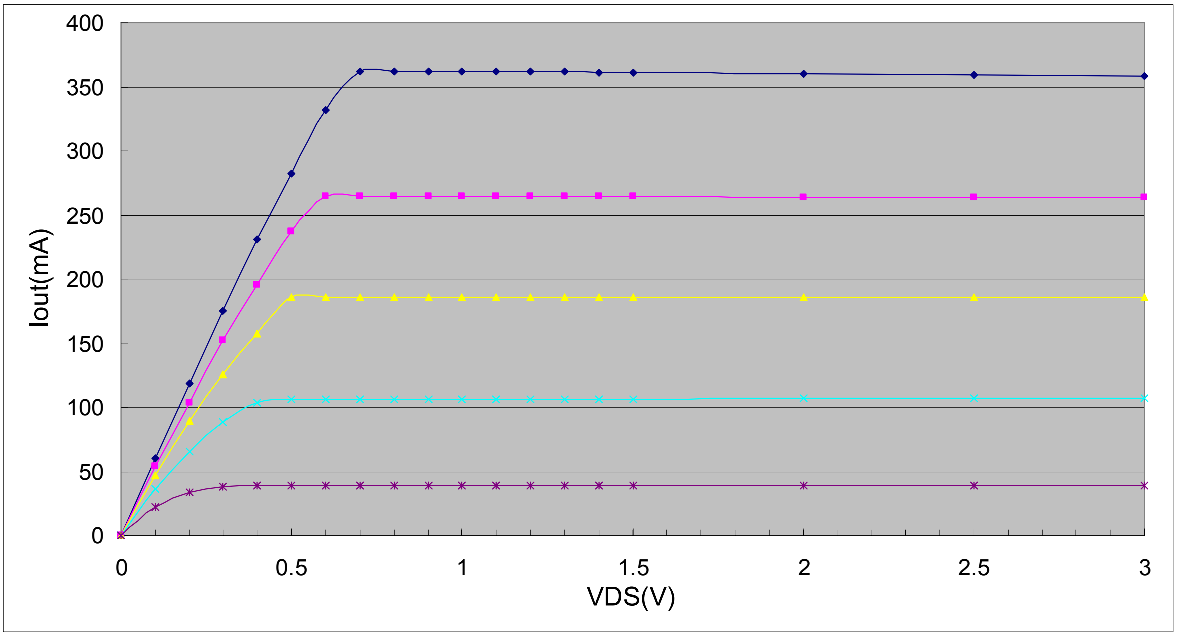

Figure 2. I_{OUT} vs. V_{DS} (MBI1812)

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4. Decide $V_{LED,MIN.}$

After the above conditions are set, the minimum V_{LED} ($V_{LED,MIN}$) can be determined by the following equation (3).

$$V_{LED,MIN.} = (V_{F,MAX.} \times n) + V_{DS} \quad (3)$$

where $V_{F,MAX}$ represents the maximum forward voltage of LED, and n is the cascaded LED count.

If the V_{LED} is an integer voltage (ex. the voltage of transformer is usually an integer one), the extra voltage (V_{extra}) needs to be consumed by the resistor cascaded with LEDs (R_{extra} as shown in Figure 1). The value of the resistor can be calculated by following equations

$$V_{extra} = V_{LED} - (V_{F,MAX.} \times n) - V_{DS} \quad (4)$$

$$R_{extra} = V_{extra} / I_{OUT} \quad (5)$$

5. Decide R1/ D2.

After deciding V_{LED}, the breakdown voltage of the zener diode (D2) can be calculated as below

$$V_{Z\text{-}D2} = V_{LED} + Vth \quad (6)$$

where the $V_{Z\text{-}D2}$ is the breakdown voltage of D2; Vth is the threshold voltage of MOSFET.

The suggestion value of R1:1K.

6. Decide M1

To select the MOSFET M1, the current of M1 should be larger than the current of LED, and the sustaining voltage of M1 should be larger than that of V_{IN}.

7. Power Dissipation / Heat Dissipation

In general applications, power dissipation is the major factor to cause temperature rising on the IC. The greater power dissipation causes the higher temperature. The power dissipation can be calculated by the following equation (7).

$$P_D = (V_{DD} \times I_{DD}) + (V_{DS} \times I_{OUT}) \times m \quad (7)$$

where m represents the number of the output ports of IC, and then the temperature on IC can be approached by the following equation (8).

$$T_{(jc)} = T_A + Rth_{(ja)} \times P_D \quad (8)$$

where $T_{(jc)}$ means the temperature on IC; T_A is the ambient temperature; and $Rth_{(ja)}$ represents the thermal resistance from junction to ambient temperature.

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Following is an example explaining the design process.

Example:

For lighting 8 pieces of high-power white LEDs, the sorted forward voltage ranges from 3.2V to 3.4V; and LED current is set to 360mA. If we use MBI1812 to be the LED constant current driver, and each port has 4 pieces of LED in cascade. Therefore,

1. **Select the R_{ext}**

   From equation (3), R_{ext} = (1.224V / 330mA) x 720 = 2670Ω, a resistor with 2.7kΩ/0.06W is selected for R_{ext}. Thus, I_{OUT} = (1.224V / 2.7kΩ) x 720 = 326mA.

2. **Decide V_{DS}**

   As shown in Figure 2, the knee voltage is 0.6V when I_{OUT} is 330mA. Therefore, when the I_{OUT} is 326mA, the V_{DS} can be set as 0.6V.

3. **Decide $V_{LED,MIN.}$**

   After the above conditions are set, $V_{LED,MIN}$ can be calculated by equation (3)

   $V_{LED,MIN.}$ = (3.4V x 4) + 0.6V = 14.2V, and thus, the selected V_{LED} must be greater than 14.2V.

4. If the V_{LED} is set as 15V, we need to add a resistor, R_{extra}, to consume the extra voltage drop. The value of the resistor can be calculated by equations (4) and (5):

   V_{extra} = 15V – (3.4V x 4) – 0.6V = 0.8V

   R_{extra} = 0.8V / 326mA = 2.4Ω; thus, we select R_{extra}=2.4Ω

   The sustaining power of R_{extra} is P_{Rextra} = $(326mA)^2$ x 2.4Ω = 0.255W; thus, the recommended R_{extra} is 2.4Ω/0.5W.

5. **Select R1**

   According to the datasheet of MBI1812, when R_{ext}=2.4kΩ, the $I_{DD,MAX}$ is 12mA. From equation (1), R1 is calculated as below:

   R1 = (15V – 12V) / 12mA = 240Ω; thus, we select R1=240Ω. The sustaining power of R1 is P_{R1} = $(12mA)^2$ x 240Ω = 0.035W ; thus, the recommended R1 is 240Ω/0.25W.

6. In this example, under the worst case, the V_{DS} is

   V_{DS} = V_{IN} - V_{extra} - $V_{F,MIN.}$ x n = 15V - 0.8V - 3.4V x 4 = 0.6V

   where $V_{F,MIN.}$ represents the minimum forward voltage of LED. Thus, the power dissipation of one IC can be calculated by equation (7) as below:

   P_D = (V_{DD} x I_{DD}) + (V_{DS} x I_{OUT}) x m =(12V x 12mA) + (0.6V x 326mA) x 2   0.54W

   And the temperature on IC can be approached as below:

   T_{IC} T_A + Rth(ja) x P_D = 25°C + (125°C/W x 0.54)   92.5°C

   where Rth(ja)=125°C/W is the thermal resistance of IC with thermal pad where the heat sink area on PCB layout is 4 times larger than IC's area. (Please refer to page 4 of the datasheet of MBI1812).

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Figure 3 shows the application circuit of this example.

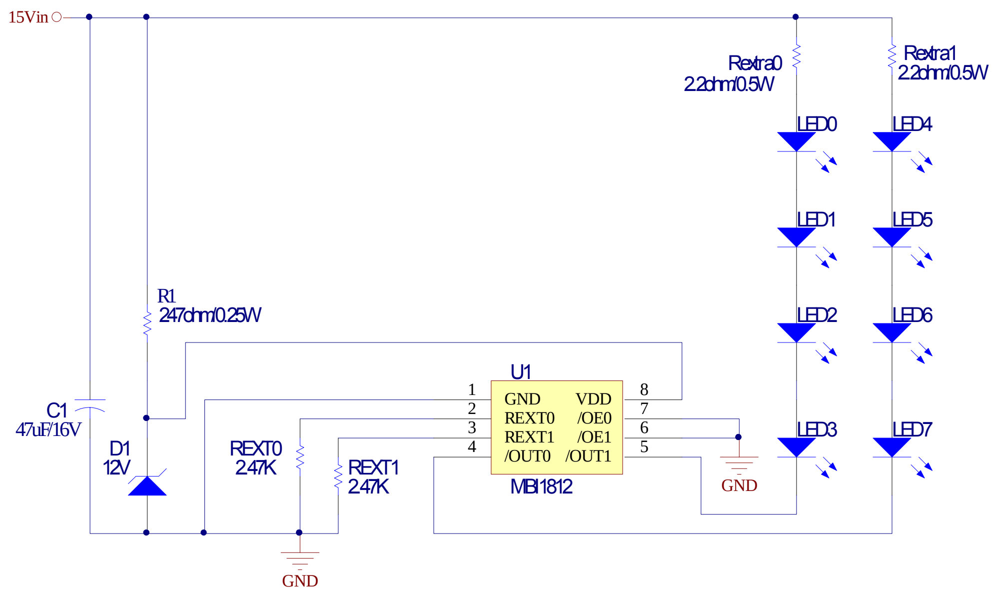

Figure 3. The application circuit using only one MBI1812

The previous example shows the design process by using only one MBI1812, the IC's temperature is 92.5°C. If the temperature is too high for developers, two ICs in parallel can be a solution to reduce it, developers may use two ICs as a solution for that.

The following shows the example of using two MBI1812.

1. **Select the R_{ext}**

   In this solution, each IC lights up 4 LED in cascade and each two output channels in parallel. Thus, the LED current flowing into each port is 330mA/2=165mA. From equation (2), R_{ext} = 4896Ω. Therefore a resistor with 5.1kΩ/0.06W is selected for R_{ext}, and the LED current is I_{OUT} = (1.224V / 5.1kΩ) x 720 = 173mA.

2. **Decide V_{DS}**

   As shown in Figure 2, the knee voltage is 0.5V when I_{OUT} is 165mA. Therefore, when the I_{OUT} is 173mA, the V_{DS} can be set as 0.5V.

3. **Decide $V_{LED,MIN.}$**

   After the above conditions are set, $V_{LED,MIN}$ can be calculated by equation (3)

   $V_{LED,MIN.}$ = (3.4V x 4) + 0.5V = 14.1V, and thus, the selected V_{LED} must be greater than 14.1V.

4. If the V_{LED} is set as 15V, we need to add a resistor, R_{extra}, to consume the extra voltage drop. The value of the resistor can be calculated by equations (4) and (5):

   V_{extra} = 15V – (3.4V x 4) – 0.5V = 0.9V

   R_{extra} = 0.9V / 173mA = 5.2Ω; thus, we select R_{extra}=5.1Ω

   The sustaining power of R_{extra} is P_{Rextra} = $(173mA)^2$ x 5.1Ω = 0.153W; thus, the recommended R_{extra}

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is 5.1Ω/0.5W.

5. **Select R1**

According to the datasheet of MBI1812, when R_{ext}=2.4kΩ and 4.7kΩ, $I_{DD,MAX}$ is 12mA. Therefore, when R_{ext}=4.7kΩ, the $I_{DD,MAX}$ can also be considered as 12mA. Since we use two IC in this example, the current can be considered as 24mA. From equation (1), R1 is calculated as below

R1 = (15V – 12V) / 24mA = 125Ω; thus, we select R1=120Ω. The sustaining power of R1 is P_{R1} = $(24mA)^2$ x 120Ω = 0.069W ; thus, the recommended R1 is 120Ω/0.25W.

6. In this example, under the worst case, the V_{DS} is

$V_{DS.} = V_{IN} - V_{extra} - V_{F,MIN.}$ x n = 15V - 0.9V - 3.4V x 4 = 0.5V

where $V_{F,MIN.}$ represents the minimum forward voltage of LED. Thus, the power dissipation of one IC can be calculated by equation (7) as below:

$P_D = (V_{DD} \times I_{DD}) + (V_{DS} \times I_{OUT}) \times m$ =(12V x 12mA) + (0.5V x 173mA) x 2   0.317W

And the temperature on IC can be approached as below:

T_{IC} T_A + Rth x P_D = 25°C + (125°C/W x 0.317)   65°C

where Rth=125°C/W is the thermal resistance of IC with thermal pad where the heat sink area on PCB layout is 4 times larger than IC's area. (Please refer to page 4 of the datasheet of MBI1812)

Figure 4 shows the application circuit by using two MBI1812.

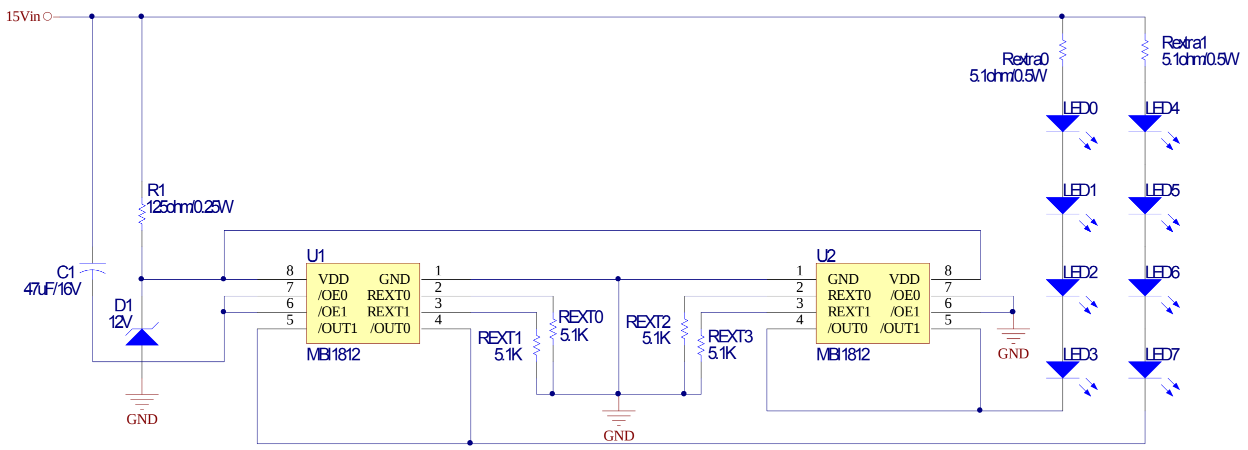

Figure 4. Application circuit using two MBI1812

Hot Plug-In

A behaviors of hot plug-in may cause the inrush current and damage IC. If the hot plug-in application is needed, please don't use the ceramic capacitor to be the input capacitor. However, if the VDD has been isolated by a resistor and zener diode, the input capacitor, where is placed close to VDD, can be used a ceramic capacitor with 0.1uF for noise filter.

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Brightness Adjustment

MBI1812 has analog dimming function for brightness adjustment. The LED brightness can be further adjusted by analog signal, which is connected to $\overline{OE}$ .The voltage levels of /OE are divided to four segments:0~1V,1V~2V,2V~3V,3V upward, that are correspond to 100%,50%,25%,0% of I_{OUT}, as figure 7 shows. The /OE Pin of MBI1812 can not be floating ,if the /OE pin doesn't be used, please connect a pull up resistance to VDD.

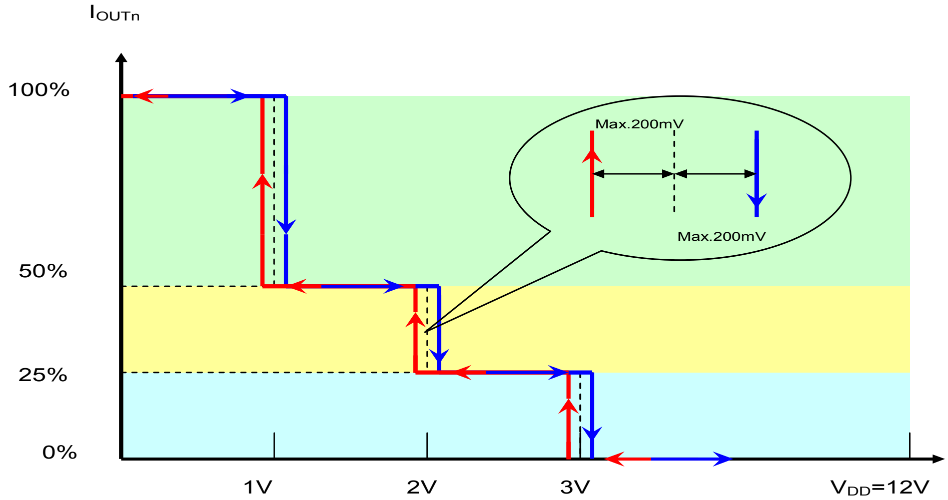

Figure 7 MBI1812 Analog Adjustable Dimming Control

The MBI1812 also accepts a digital signal for dimming control. The less duty cycle , the higher brightness. The highest frequency of the PWM signal is 400kHz.

Thermal Protection (TP)

The MBI1812 features a built-in thermal protection function. When the junction tempereture of IC exceeds 160°C, the thermal protection starts to function and turns off the output current. As soon as the IC cools down below 130°C, the output current will be turned on again. When overheating happens, the peak power dissipation would affect the IC turn on time. The larger peak power dissipation leads to the shorter turn on time, and vice versa. This ensures that IC's junction temperature will not exceed 160°C.

PCB Layout

Following is the notices for product developers when making the PCB layout of MBI1812 To connect a ceramic capacitor with 0.1μF as close to the VDD pin of the IC as possible to avoid the interference from high frequency, and get a stable input voltage.

1. To connect an electrolysis capacitor with 47μF to the input terminal of the LED. It can provide a stable voltage for LED and avoid the oscillation, which is caused by the parasitic inductor of long wire.
2. Rext should be placed as close to IC as possible to avoid the interference of noise, which will result unstable LED current.
3. Increasing the area of IC's heat sink on PCB is helpful to reduce the temperature on IC.

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4. To avoid the interference of heat conduction, do not put the heat sink of IC together with LED's.

5. Putting the thermal pad of IC together with GND not only helps reduce the temperature on IC, but also provides a stable ground system to IC.

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