Transformerless AC/DC Constant Current Driver

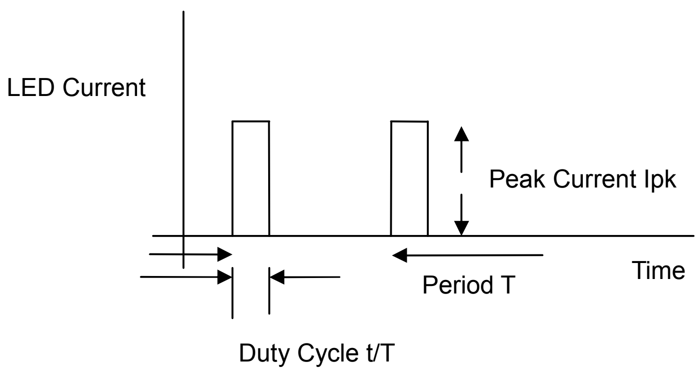
Foreword

This application note is for MBI6001N1N, N1D, N2N and N2D. Based on the *MBI6001 Datasheet* and the attached *MBI6001 Iout Reference Table*, annexed to the product shipment, you may basically light on your LED loads. To further fine tune the operating current at various loads, please refer to this document.

Basics

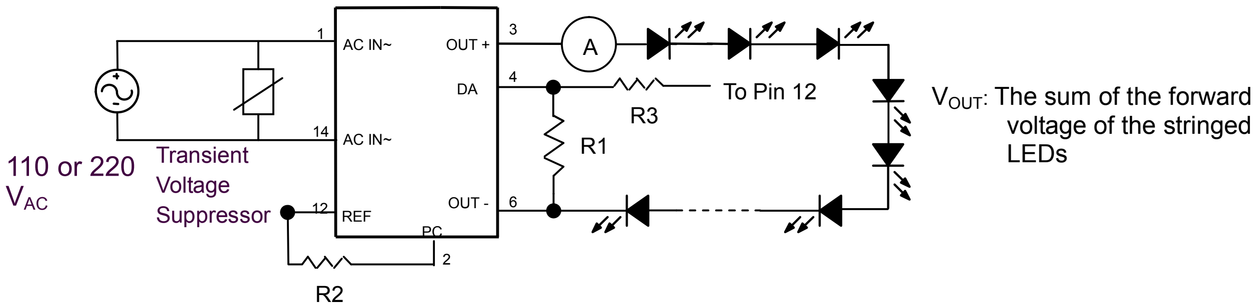
MBI6001 series operate in a manner that they internally convert the incoming AC line power to a rectified and unregulated DC power and the internal circuitry further delivers the pulsed current to light on the LED load. N1x serves for 110 V AC and N2x for 220 V AC. The pulsed current with adequate pulse peak current and associated duty cycle gives a nominal I_{out} of average current that matches your LED load and light on your LEDs.

Refer to the *Typical Application Circuit*, the conceptual LED current could be depicted as:



I_{out} is defined as the average of LED Current, which is close to Ipk x t/T.

Typical Application Circuit



Note: There is no pin being connected to earth ground.

Getting Started

To exploit MBI6001 with your LEDs, the vendor provides a default value of R1, R2, and R3 if any, to make LEDs lit. The following is to help you for fine adjustment by changing R1 and R2.

The Numbers of LED Load

Before applying MBI6001, you need to know the characteristic of your LED load.

The LED load is suggested to be configured to a string of serial LED devices. When the LEDs are connected in series, the current flowing into the LEDs, I_F, must be equal to each other and equal brightness can be achieved. When LEDs are connected in series, the total forward voltage will be the sum of each V_F. When you apply N LEDs, N x V_F will be the total forward voltage, where V_F is provided by LED vendors.

Now you can connect your LED load to MBI6001. Pin 3, OUT+, is connected to the anode of the string and Pin 6, OUT-, to the cathode. Since V_F is different for varieties of LEDs, MBI6001 characterizes the load by V_{OUT} , instead of V_F. For a specific LED, say, Green, White, etc., the V_F is determined. Then, applying N LEDs in series, N x V_F will be perceived by MBI6001 as V_{OUT} .

To maintain the designated Iout, the voltage drop between Pin 3 and Pin 6, V_{OUT} , will automatically adopt the V_F change, where V_F is the Forward Voltage of LED devices which usually varies from lot to lot, even for a single type of LED..

However, due to the upper limit of input AC line power, such automatic adoption could only be guaranteed within a range. See *Fig. 1- I_{OUT} vs. V_{OUT}*, MBI6001 Datasheet. Within the range V_{OUT} = 10 to 60 Volt, for MBI6001N1N, I_{OUT} will change less. It may thus be thought constant current.

For example, the V_F changes from 3.6 to 4.0 Volt for a single type of LED. When you connect 15 LEDs in series, V_{OUT} could range from 15 x 3.6 to 15 x 4.0 Volt, where the current is guaranteed invariant to V_F change.

Color	DC Forward Voltage V_F[V]		Optical Power Output P_O[mW]
	Typ.	Max.	Typ.
BLUE	3.6	4.0	6
GREEN	3.5	4.0	4
RED	1.9	2.4	2
WHITE	3.6	4.0	(4)[**]
Condition	I_F=20mA		I_F=20mA

The Selection of LEDs

Usually, the commercial LEDs may work in two modes: DC current mode and pulsed current mode. In MBI6001 application, the LED should work in pulsed current mode. Hence, the maximum peak current should be taken into consideration. To achieve a typical I_{OUT} of 18 mA, a typical I_F(peak) of 90 mA or larger is recommended. (I_F(peak) is also denoted as Pulse Forward Current I_{FP}.) It implies the equivalent Duty Cycle t/T is around 20%. MBI6001 typically drives the LED at a pulse width of 1.66 ms, equivalently.

The reference LED maximum ratings are as below:

Color	DC Forward Current [mA]	Pulse Forward Current[*n] [mA]	DC Reverse Voltage [V]	Power Dissipation [mW]	Operating Temperature [°C]
BLUE **GREEN** **WHITE**	I_F=30	I_{FP}=100	V_R=5	P_D=120	Topr: -30 ~ +85
RED	I_F=50	I_{FP}=200	V_R=5	P_D=120	Topr: -30 ~ +85

※ Pulse width ≦10ms

Setting the LED Currents by R1 and R2

When you have specified your LED, you may fine tune the operation current under MBI6001's limitations.

By adjusting R2, the Ipk is defined. Please refer to the following tables:

For MBI6001N1x:

	Target Ipk	Recommended R2
1.	40 mA	430 Ohm
2.	70 mA	100 Ohm
3.	90 mA	51 Ohm

For MBI6001 N2x:

	Target Ipk	Recommended R2
1.	40 mA	Open
2.	70 mA	162 Ohm
3.	90 mA	91 Ohm

You may start the fine tuning with the recommended resistance of R1. See the Iout Reference Table attached with shipment. Since Iout is close to Ipk x t / T, we may slightly adjust the Duty Cycle t/T to obtain various Iout. To achieve a target Iout, a measurement of Iout is necessary. A simple hand-held multi-meter, which measures the pulsed LED current in a DC averaging manner, is connected in series with the LED string. The positive terminal is connected to Pin 3 OUT+ and the negative terminal to the anode of LED string. (See the Typical Application Circuit.) The reading on the multi-meter is what Iout is defined in the datasheet. Since MBI6001 has a temperature correction in Iout, the reading would only be significant 5 minutes after MBI6001 and LED load are powered.

You may now change slightly the resistance of R1 to adjust your Iout. Usually, the smaller resistance of R1 your give, the smaller Iout you obtain. The resistance range should not be large to adjust the Iout exceeding 23 mA. The maximum load current Iout is suggested to be 23 mA.

For example, MBI6001N1N with V_{OUT}= 35 Volt, 110 Volt, under the condition R2 = 51 Ohm and Ipk = 90 mA, you may result:

	R1	Iout
1.	910K Ohm	19.18 mA
2.	953K Ohm	19.66 mA
3.	1000K Ohm	20.28 mA

The exact resistance of R1 (or R3) should be referred to the attached Iout Reference Table, annexed to the product shipment

Please layout a vacancy for R3 on your PCB (printed circuit board), even you don't use R3 now. The R3 is reserved for extending the adjustment range of I_{out}. For MBI6001N1N, it is open-circuit.

For another example, MBI6001N2N with V_{OUT}= 70 Volt, 220 Volt, under the condition R2 = 91 Ohm and Ipk = 90 mA, you may result:

	R3	I_{out}
1.	100K Ohm	15.5 mA
2.	51K Ohm	16.5 mA
3.	43K Ohm	17.1 mA

In this case, you use R3 instead of R1. R1 is left open-circuit.

The Limitation of MBI6001

Although you may adjust the resistance of R2, the maximum load current I_{out} is suggested to be 23 mA. Beyond 23 mA, additional heat is a concern.

Theoretically, MBI6001 may serve with wide ranges of Peak Current Ipk and Duty Cycle t/T. However, a physical limit gives a constraint, the heat dissipation. MBI6001 endures a large voltage drop across the AC line power and the LED loads. The voltage drop and the current passed through cause a power dissipation which releases in a form of heat. Larger the current is delivered, hotter MBI6001 will be. Typically, MBI6001 dissipates 0.6 Watt to 1 Watt. You have to estimate the application environment that can dissipate the same heat to maintain an adequate temperature around the surface of MBI6001. In our typical application, the temperature at the surface of package under the free air, Ta = 25°C, is measured as below 55°C, for MBI6001N1N, where a thermal couple with a multi-meter is applied. Please refer to *Fig. 2- Temp. vs.* V_{OUT} in MBI6001 Datasheet. Likewise, 70°C is for MBI6001N2N.

Sometimes, Ta = 25°C cannot be provided in your application. Then you will need to condition the heat dissipation.

To achieve conditioned heat dissipation, thermally conductive adhesives or silicone are recommended to fill the clearance between the MBI6001 package and the outer thermal conducting surface. The clearance is usually a poor thermal conductor. When the clearance is filled with the thermally conductive adhesive, the thermal conductivity is thus enhanced and suppresses the temperature increase on the MBI6001.

For example, http://www.loctite.com/, thermally conductive adhesive vendor is referenced. See also KE4560G and BB-1000 from http://www.sunnico.com.tw/index_a.htm.

When the thermally conductive adhesive is applied and your product is sealed, it will be hard to rework your product. You should carefully test the reliability before mass production.

The safety

MBI6001 series are certified by UL and CE.

To prevent from electrical shock from the outdoor AC line power, a surge absorber or transient voltage suppressor is necessary to connected in parallel to the Pin 1 and Pin 14. The maximum rating for AC line input is 400V, transient. The referenced surge absorbers or transient voltage suppressors (TVS) are:

P4KE Series from http://www.panjit.com.tw/products.html, or, from http://www.ts.com.tw/semi/index.html.

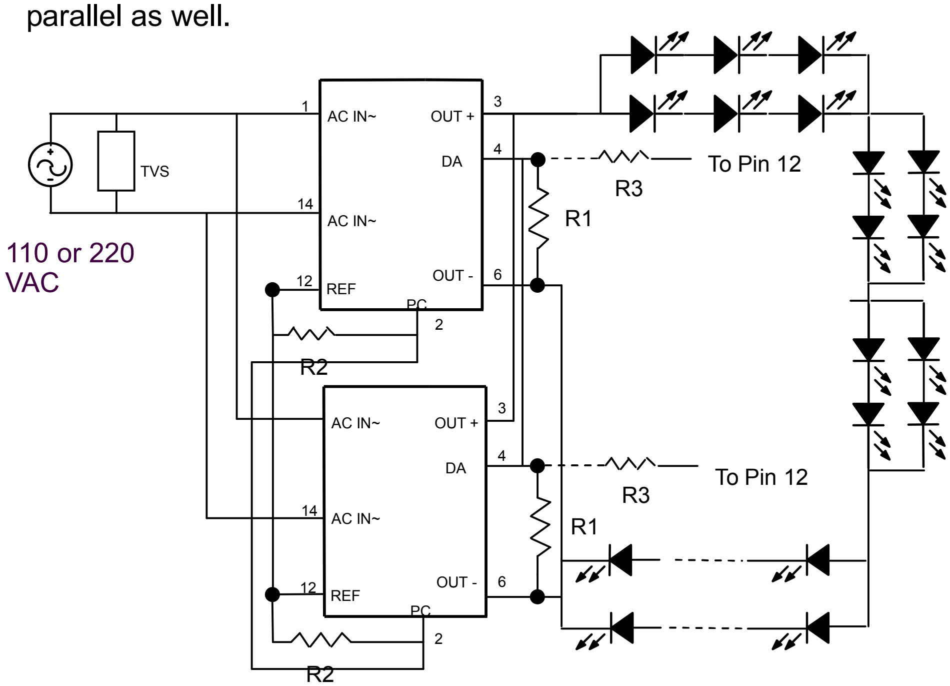
The Maximum Clamping Voltage, Vc, or Maximum Breakdown Voltage, Vbr, is chosen as less than 400V (Transient). The Stand-off Voltage is chosen as larger than 170V (120V x 1.414) for 110V line power and 340 (240V x 1.414) for 220V line power.

You may use PK4E200A for nominal 110VAC and PK4E400A for nominal 220VAC.

Since MBI6001 is not isolated from the AC line power, it is strictly forbidden for connecting any portion of the application circuit to the global earth ground. This is especially critical for any measurement instruments which are powered by AC line. Hand-held or portable multi-meters are recommended.

Extended Application

In some cases, the configuration of LED load will not be a simple string. To extend for larger Iout or to avoid the accidental LED failure, usually open-circuit, that disables the current path for whole LED string, you could purposely select a sort of LED of higher I_F (peak) which endures larger Ipk, or you may connect your LED string in parallel and connect MBI6001 in parallel as well.



The selection of R1, and R2 is as defined as in the case of single string. Equivalently, the two MBI6001s are connected like piggy-back.

For example, when your target Iout is 54 mA, three times of recommended 18mA, you may connect 3 MBI6001 ICs in parallel. The selection of R1 and R2, is just the same as you select for 18 mA for each MBI6001. When total Iout is 54 mA, the total Peak Current Ipk will usually be 90 mA x 3 = 270 mA. Accordingly, you shall select adequate I_F(peak) of LEDs, which is larger than 270 mA.

In the case of using single LED string of I_F(peak) = 80 mA while expecting Iout = 28 mA, the target Iout exceeds the upper limit, 23 mA. You may use two MBI6001 ICs in parallel and make each MBI6001 deliver Iout = 14 mA by setting R1 or R3. Iout = 14 mA is beneath MBI6001 limit. The Ipk for each would be set to 40 mA not 80 mA. (Concerning the LEDs, the equivalent duty cycle would be 28 / 80 = 35% which is usually not guarantied by LED vendors and is larger than our suggestion, 20%.)

Measuring the load current by using Oscilloscopes

It is not suggested to measure the I_{out} by using oscilloscopes. It is always a hazard if you erroneously connect the reference claps to the application circuit.

If you have to know the current flowing through the LED load, a current probe is the most common means.

If you have to know the current flowing through the LED load and you don't have a current probe, you may insert a 1-Ohm resistor in series with LED string and measure the voltage across the 1-Ohm resistor. When measuring the voltage with a regular voltage probe, you put the probe tip on one end of the resistor and put the reference clap on the other. You may obtain the voltage waveform and thus the current waveform.

Caution: Never measure your application circuit by using more than two channels from your oscilloscope simultaneously. It will be a risk to falsely connect your two reference claps to two nodes with very high voltage drop. The false connection will cause either the damage of your scope or your application circuit.