### Why is a Constant Current LED Driver necessary?

When using LEDs in display panels like monochromatic, scrolling message board, or a full color video display, LEDs must share consistent characteristics with respect to brightness to avoid the quilted, patchwork appearance. Proper brightness binning of LEDs is critical to the fabrication of a quality LED display.

The nature of the LED manufacturing process often dominates that the LED manufacturers must ship several brightness bins to satisfy users' demands. Even if a given shipment may be satisfied with a single brightness bin, it could be of no guaranty that the next shipment may be of the same brightness bin. This situation is typical of discrete LED devices, LED numeric displays and LED dot matrix blocks.

Understanding the nature of LEDs, the same current flowing through a class of LEDs will result the same brightness, with very limited variation. To light LEDs with the same brightness, users shall maintain the same current flowing through the class of LEDs. That is why a Constant Current driver is needed.

### What is a Constant Current Driver?

A Constant Current driver is an integrated circuit device designed specifically to work with LEDs in sign and display applications. Through the use of user-settable, constant current outputs, the Constant Current driver regulates the current through LED loads independent of external factors, such as variations in LED Vf, power supply drift, etc. Once a current value is set, the LED driver will continually track that current regardless of the factors mentioned earlier. A unique, integral feedback mechanism actually monitors the current flow in a given LED or string of LEDs and dynamically adjusts the output to maintain the programmed current level.

### How do Constant Current Drivers, MBI5001 and MBI5016, Work?

The Constant Current output stage is an open-drain driver array, which employs an innovative, dynamic, and current regulating scheme. A single resistor tied from MBI5001or MBI5016 to ground sets the desired current (see Fig. 1). Each output of the open-drain array will drive a single LED or series/parallel combinations of LEDs, maintain the desired current on each output string (see Fig. 2 and 3) and typically eliminate the requirement for a current limiting resistor in each string. Each output is equalized to deliver the same current level, even with various LED loads.


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The Constant Current driver actually incorporates several of the functions necessary for the control of LEDs in a dynamic variable message sign application. In addition to the constant current output feature, the device family also addresses the decoding and setup functions by incorporating built-in shift register and latch stages. Serial data, sent directly to the driver, is decoded and latched to the constant current outputs, setting up the desired output sequence.

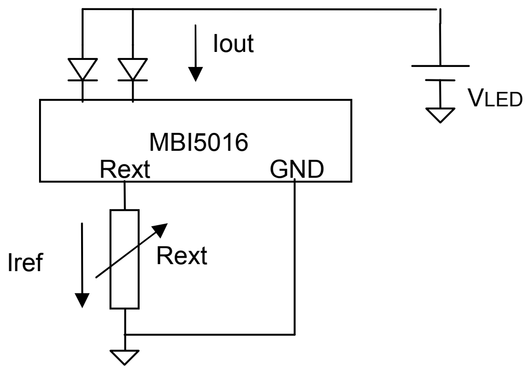


Fig. 1

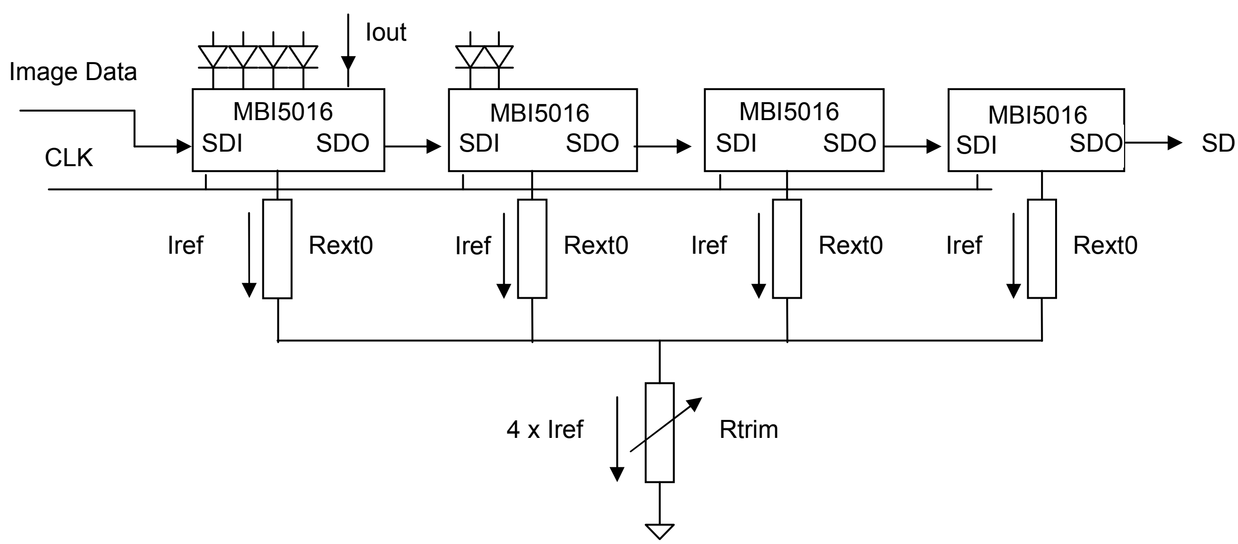


Fig. 2

**Cascading a String of MBI5001 or MBI5016**

All image data could be commanded and shifted from a single source (see Fig. 2). MBI5001 and MBI5016 preserve a data setup time and data hold time to ensure the data shift firmly among the ICs. The wiring delay of the signal of CLK should be matched by the wiring delay of the signal of SDO. The successive MBI5001 and MBI5016 thus receive the correct image data.

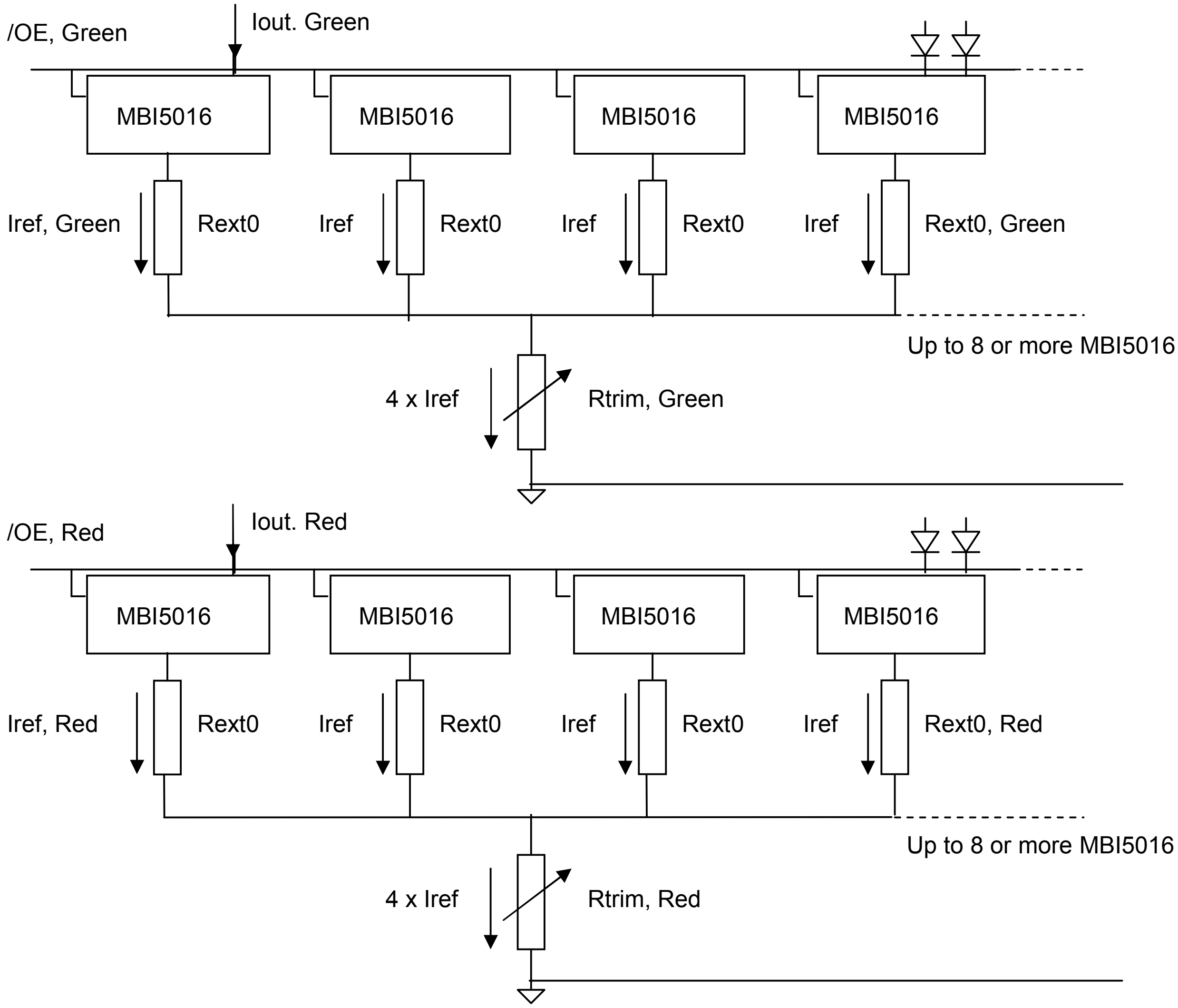
/OE, Green
Iout. Green
MBI5016
MBI5016
MBI5016
MBI5016
Iref, Green
Rext0
Iref
Rext0
Iref
Rext0
Iref
Rext0, Green
Up to 8 or more MBI5016
4 x Iref
Rtrim, Green
/OE, Red
Iout. Red
MBI5016
MBI5016
MBI5016
MBI5016
Iref, Red
Rext0
Iref
Rext0
Iref
Rext0
Iref
Rext0, Red
Up to 8 or more MBI5016
4 x Iref
Rtrim, Red

Fig. 3

**Selections of Rext (Current-setting Resistor)**

The value of the resistor, $R_{ext}$, determines the current that the outputs of a constant current driver will maintain. A resistor $R_{ext}$ becomes a part of a reference circuit and results a reference current, Iref, which is mapped to each output of the device.

$R_{ext}$ is selected from the graph $R_{ext}$ - Iout (see Fig. 4, an example of MBI5001) which is included in the device shipment. To determine the value of $R_{ext}$, the desired current value (Iout) must first be located along the vertical axis of the graph. This point is then transferred horizontally to the intercept point on the curve. The corresponding point on the horizontal axis of the graph will yield the value of $R_{ext}$ required to program the device for the desired current.

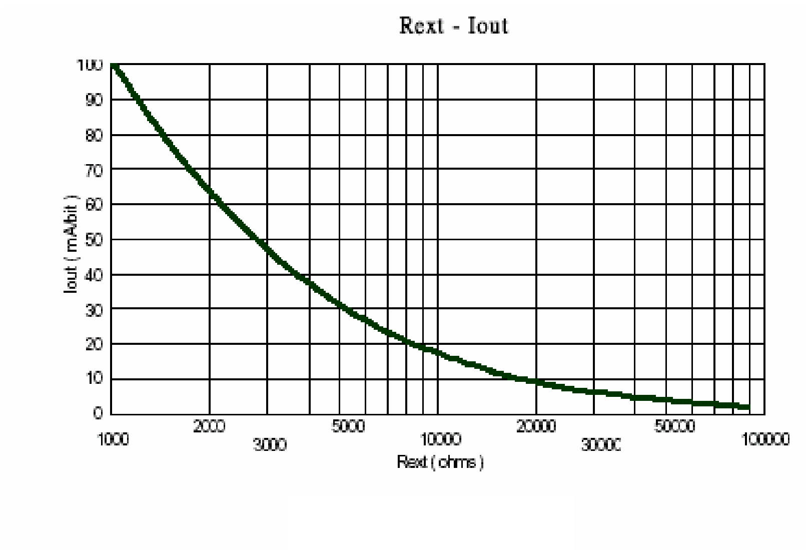


Fig. 4

The effective $R_{ext}$ is the total resistance perceived from Pin 23, R-EXT, to Pin 1, GND.

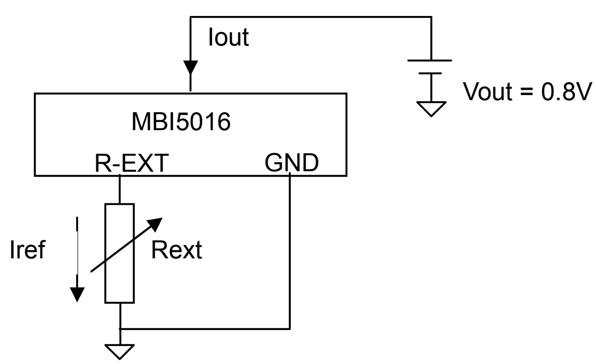


Fig. 5

The current, Iout, shown in the graph $R_{ext}$ - Iout is obtained when Vout = 0.8V.

In a panel application, several MBI5016 ICs are individually controlled by separate resistors and are commonly controlled by a trimming resistor. The following is the case for four MBI5016 sharing a common Rtrim.

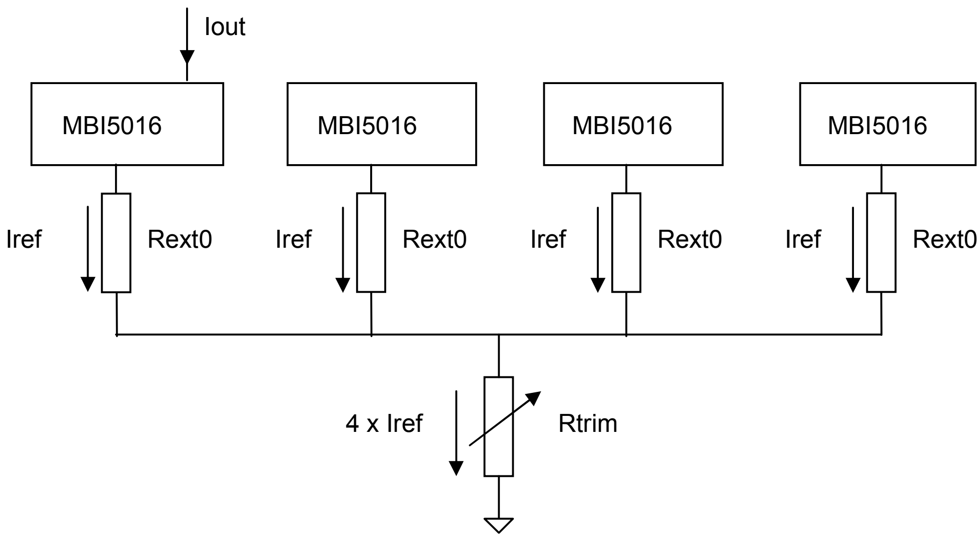


Fig. 6

The Effective $R_{ext}$ will be Rext0 + 4 x Rtrim, considering a single MBI5016 case. The following table is a comparison for single $R_{ext}$ and Rext0 with Rtrim when obtaining the same current.

| $R_{ext}$t for a single MBI5016 | Output Current, Iout, measured with customer's LED load | Rtrim is tuned to obtain the same Iout when Rext0 is fixed at 1.3 KΩ. | Effective $R_{ext}$ |
|---|---|---|---|
| 4297 Ω | 10 mA | Rtrim = 789 Ω | 1.3K + 4 x 789 = 4456 |
| 3240 Ω | 12. 96 mA | 504 Ω | 1.3K + 4 x 504 = 3316 |
| 2760 Ω | 15 mA | 381 Ω | 1.3K + 4 x 381 = 2824 |
| 2265 Ω | 18 mA | 249 Ω | 1.3K + 4 x 249 = 2296 |
| 2009 Ω | 20 mA | 181 Ω | 1.3K + 4 x 181 = 2024 |
| 1805 Ω | 22 mA | 126 Ω | 1.3K + 4 x 126 = 1804 |

The Effective $R_{ext}$ to obtain the same Iout is very close to $R_{ext}$ for a single MBI5016.The above experimental data are randomly selected from our inventory. The summary is thus popular and conclusive.

Likewise, when 8 MBI5016 ICs are connected to share a single Rtrim, the multiplication should be 8 instead of 4.

| $R_{ext}$ for a single MBI5016 | Output Current, Iout, measured with customer's LED load | Rtrim is tuned to obtain the same Iout when Rext0 is fixed at 1.3 KΩ. | Effective $R_{ext}$ |
|---|---|---|---|
| 4297 Ω | 10 mA | Rtrim = 394 Ω | 1.3K + 8 x 394 = 4452 |
| 3240 Ω | 12. 96 mA | 252 Ω | 1.3K + 8 x 252 = 3316 |
| 2760 Ω | 15 mA | 190 Ω | 1.3K + 8 x 190 = 2820 |
| 2265 Ω | 18 mA | 124 Ω | 1.3K + 8 x 124 = 2292 |
| 2009 Ω | 20 mA | 90 Ω | 1.3K + 8 x 90 = 2020 |
| 1805 Ω | 22 mA | 63 Ω | 1.3K + 8 x 63 = 1804 |

If $R_{ext}$ = 1805 Ω could result Iout = 22 mA for a single MBI5016, Rtrim = 63 Ω (shared by 8 MBI5016) plus individual $R_{ext}0$ = 1.3 KΩ will also result Iout= 22 mA.
Rtrim = 63 Ω is obtained by ($R_{ext}$ (1805 Ω) - 1.3 KΩ)/8 = 63 Ω.

The customer could still use the equation to obtain the Rtrim = (Rext - 1.3 KΩ)/8.

The Rtrim does not consider the serial resistance on customer's application board. There will be slight modification when concerning the serial resistance.

**Selections of the LED Voltage Supply**

A constant current driver regulates the current flow through LEDs by effectively absorbing the excess voltage as required to maintain the programmed current level.

The LED power supply voltage is determined by the following formula:

$V_{LED}$ (total supply voltage) = $Vf_{LED}$ + $\Delta Vf_{LED}$ + $V_{CE}$,

where

$Vf_{LED}$ = minimum forward voltage of LEDs,

$\Delta Vf_{LED}$ = the maximum deviation of $Vf_{LED}$ in the LED class, and

$V_{CE}$ = voltage drop from the driver output to ground.

$V_{LED}$ must be selected high enough so that $V_{CE} \geqq 0.8V$ to maintain the constant current invariant to $\Delta Vf_{LED}$.

**Power Dissipation Considerations**

The power dissipation may be minimized by selecting an adequate LED voltage supply.

The anticipated power dissipation of the device may be calculated by the following formula:

PD1 = # outputs x $I_{OUT}$(ave) x ($V_{OL}$ + $\Delta Vf_{LED}$)+ $V_{DD}$ x $I_{DD}$,

where

# outputs = the number of outputs of the device,

$I_{OUT}$(ave) = the average output current,

$V_{OL}$ = voltage drop from the driver output to ground,

$V_{DD}$ = logic supply voltage, and

$I_{DD}$ = device logic supply current.

Excess $V_{LED}$ will cause excess $V_{OL}$ and thus excess power dissipation.

$I_{OUT}$(ave) = the average output current = $I_{OUT}$ (set by $R_{ext}$) x Duty Cycle (set by /OE).

Considering the package limitation, it is important to know the $R_{th(j-a)}$ values of different kinds of package. Suppose, allowing Tj (max) = 150 °C (max. junction temperature), then the maximum power dissipation capability PD2,

PD2 (at Ta = 0X°C) = (150°C – X°C) / $R_{th(j-a)}$ ------- <1>

When in thermal equilibrium at room temperature, PD1 =< PD2 (at Ta = 25°C).

Macroblock's LED Drivers

| Model | $PD_{max,}$ @ Ta =25°C | $R_{th(j-a)}$ | $PD_{max,}$ @ Ta =85°C |
|---|---|---|---|
| MBI5001CN (DIP) | 1.64 W (on PCB) | 76 °C/W, Ta = 25°C | 0.85 W (on PCB) |
| MBI5001CD (SOP) | 1.06 W (on PCB) | 117 °C/W, Ta = 25°C | 0.54 W (on PCB) |
| MBI5001CP (SSOP) | 0.88 W (on PCB) | 141 °C/W, Ta = 25°C | 0.45W (on PCB) |
| MBI5016CNS (DIP) | 1.52 W (on PCB) | 82 °C/W, Ta = 25°C | 0.79 W (on PCB) |
| MBI5016CF (SOP) | 1.30 W (on PCB) | 96 °C/W, Ta = 25°C | 0.67 W (on PCB) |
| MBI5016CP (SSOP) | 1.11 W (on PCB) | 112 °C/W, Ta = 25°C | 0.57 W (on PCB) |

$PD_{max,}$ @ Ta =25°C is calculated from equation <1>.

**Application Brief-Printed Circuit Board- Layout Considerations**

The constant current drivers utilize one pin for both logic ground and power ground. Care should be taken to minimize inductance and impedance within the ground pattern to avoid switching-noise induced erroneous operation. The Rtrim does not consider the serial resistance on customer's application board. There will be slight modification when concerning the serial resistance.