


**Macroblock**

Datasheet

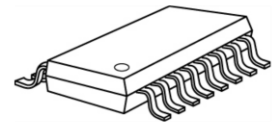
**MBI6030**

# PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Clusters

## Features

- 3-channel constant current LED sink driver for RGB LED clusters
- Constant output current range per channel: 5~150mA
- Excellent output current accuracy,
  - Between channels:  $<\pm 3\%$  (max.);
  - Between ICs:  $<\pm 6\%$  (max.)
- Sustaining voltage at output channels: 40V (max.)
- Embedded 16-bit PWM generator
  - Gray scale clock generated by the embedded oscillator
  - S-PWM technology
- Two selectable modes to trade off between image quality and transmission bandwidth
  - 16-bit gray scale mode
  - 10-bit gray scale mode (with optional 6-bit dot correction)
- Reliable data transmission
  - Daisy-chain topology
  - Two-wire only transmission interface
  - Clock regeneration
  - Built-in buffer for long distance transmission
- Supply voltage range ( $V_{DDH}$ ): 7~30V
- Embedded voltage regulator
- Selectable polarity reversion to drive high-power drivers or MOS
- RoHS-compliant packages

Shrink SOP



GP: SSOP16L-150-0.64

QFN



GFN: QFN24L-4\*4-0.5

## Application

- Architectural lighting
- Mesh display or LED strip
- Neon light replacement
- Channel letter
- Remote PWM generator

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

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## Product Description

MBI6030 is a 3-channel, constant current, PWM-embedded LED sink driver for RGB LED cluster. MBI6030 provides constant current ranging from 5mA to 150mA for each output channel and sustains 40V at output channels. The constant output current of each output channel is adjustable with three corresponding external resistors.

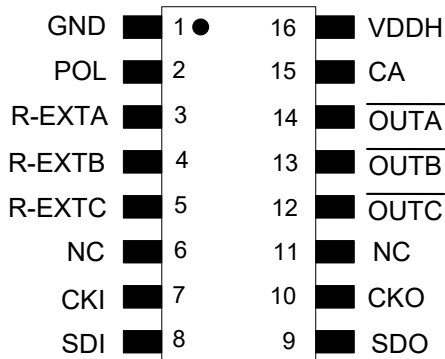
With Scrambled-PWM (S-PWM) technology, MBI6030 enhances pulse width modulation by scrambling the “on” time into several “on” periods, so that MBI6030 reduces the data transmission bandwidth at the same gray scale performance. MBI6030 provides two selectable gray scale modes to trade off between image quality and transmission: 16-bit gray scale mode and 10-bit gray scale mode. 16-bit gray scale mode provides 65,536 gray scales for each LED to enrich the color. Furthermore, 10-bit gray scale mode provides 1,024 gray scales. Subject to 10-bit gray scale mode, 6-bit dot correction may adjust each LED by 64-step gain to compensate the LED brightness.

Furthermore, MBI6030 features a two-wire transmission interface to make cluster-to-cluster connection easier. To improve the transmission quality, MBI6030 provides clock regeneration to recover the clock duty cycle to avoid signal distortion after long-distance transmission.

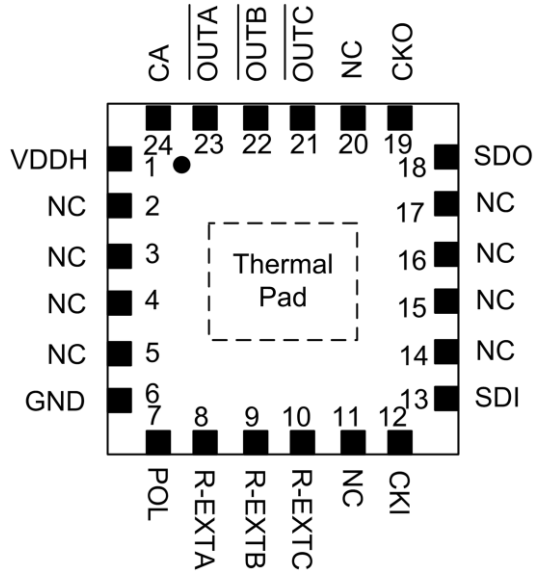
MBI6030 allows wide supply voltage range ( $V_{DDH}$ ) from 7V to 30V, which is suitable for 12V or 24V systems. Additionally, MBI6030 preserves selectable polarity reversion to driver external high-power drivers as a PWM controller.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Pin Configuration



MBI6030GP  
Top View



MBI6030GFN  
Top View

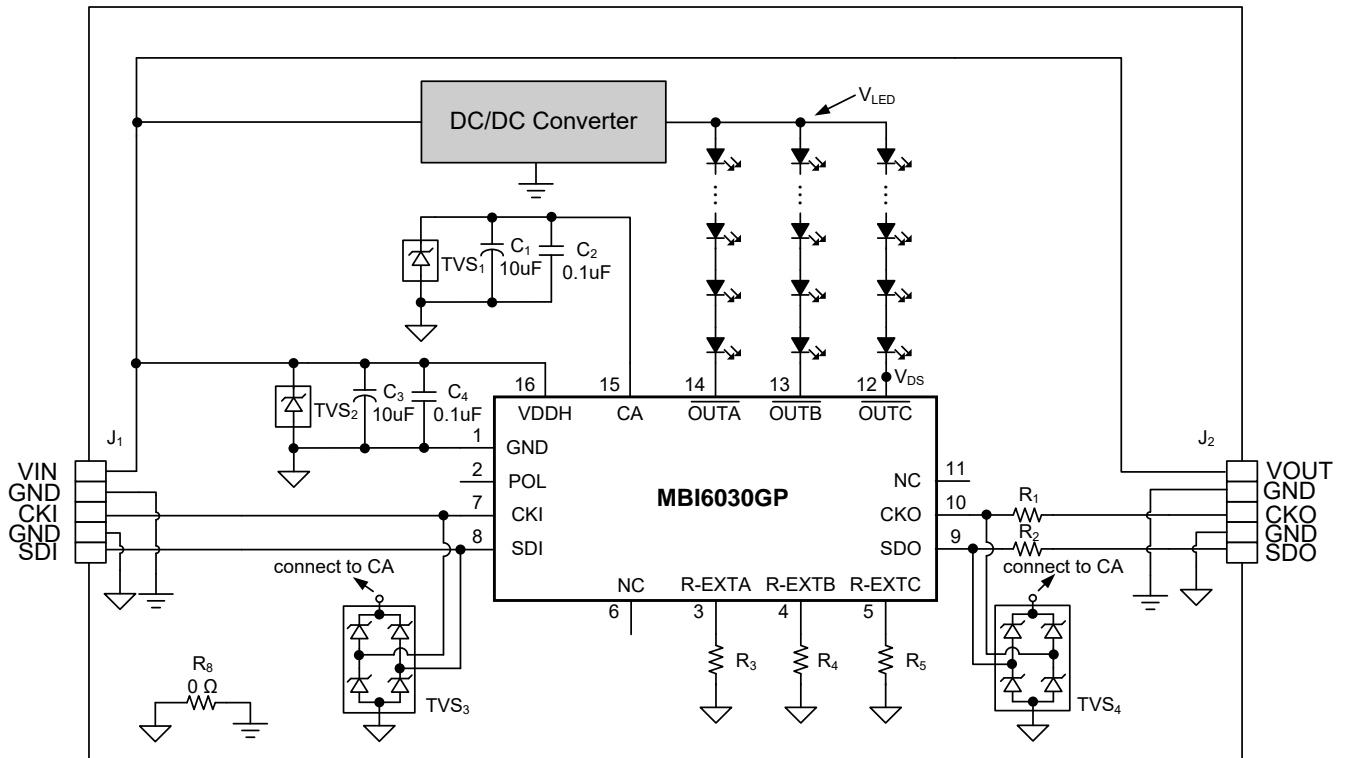
## Terminal Description

| Pin No.  |                           | Pin Name                     | Function  |
|----------|---------------------------|------------------------------|---|
| GP       | GFN                       |                              |   |
| 1        | 6                         | GND                          | Ground terminal   |
| 2        | 7                         | POL                          | Input terminal for selecting output polarity. With internal pull-up resistor connected to CA. High/NC: normal mode to drive low-active regulators or PMOS<br>Low: output reversed to work as a PWM controller to drive high-active regulators or NMOS |
| 3,4,5    | 8,9,10                    | R-EXTA,B,C                   | Input terminal for setting output current by connecting to an external resistor   |
| 14,13,12 | 23,22,21                  | $\overline{\text{OUTA,B,C}}$ | Output terminals for constant current output  |
| 6, 11    | 2,3,4,5,11,14,15,16,17,20 | NC                           | Keep unconnected<br>Internal pulled-down  |
| 7        | 12                        | CKI                          | Input terminal for clock input  |
| 8        | 13                        | SDI                          | Input terminal for serial data input  |
| 10       | 19                        | CKO                          | Output terminal for clock output  |
| 9        | 18                        | SDO                          | Output terminal for serial data output  |
| 15       | 24                        | CA                           | Connecting a capacitor to GND to enhance the stability of CA.   |
| 16       | 1                         | VDDH                         | High supply voltage terminal  |
| -        | -                         | Thermal Pad                  | Heat dissipation pad*<br>Please connect to GND  |

\*The desired thermal conductivity will be improved on condition that a heat-conducting copper foil on PCB is soldered with thermal pad.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Typical Application Circuit

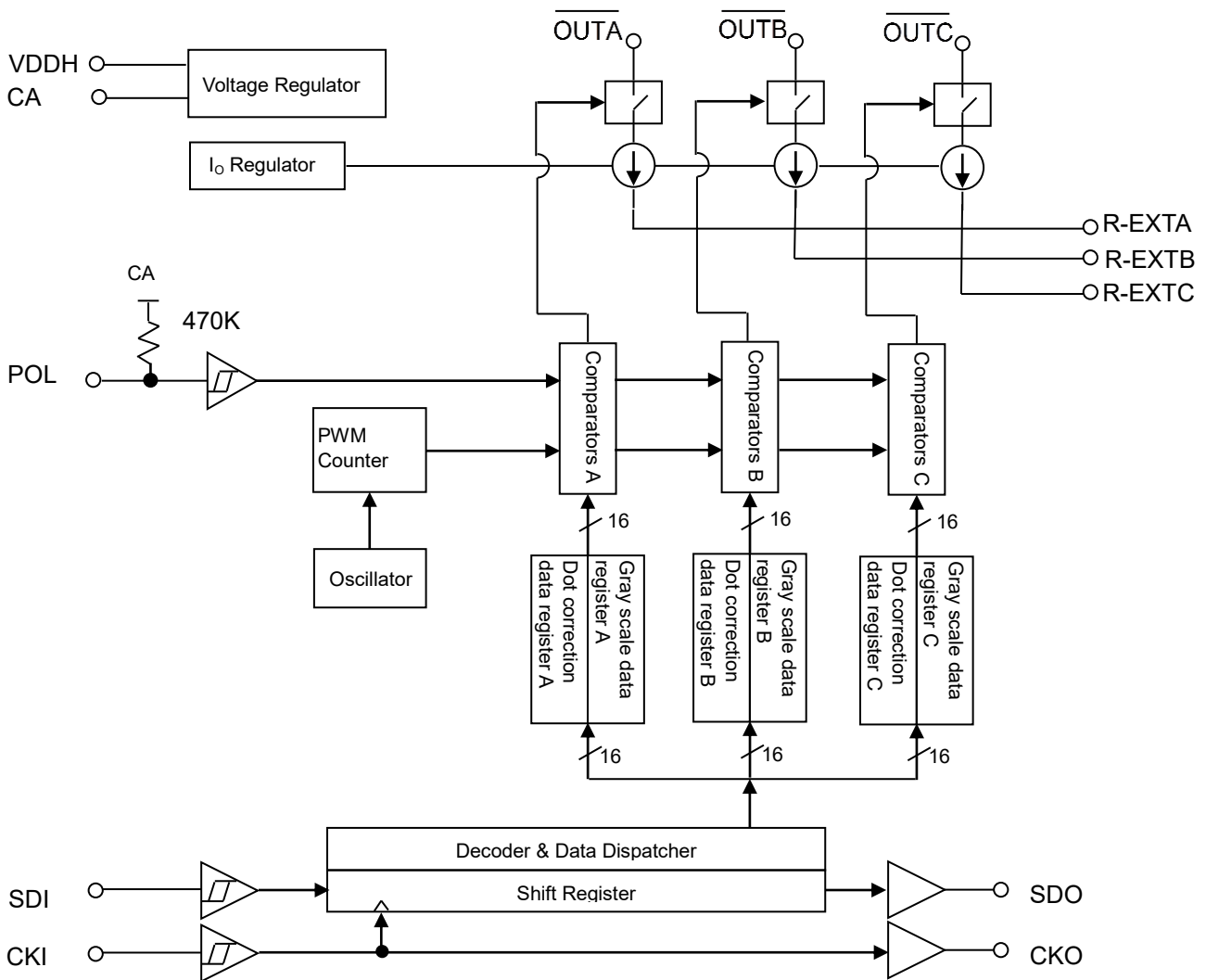


Note:

1. The TVS<sub>1</sub> and TVS<sub>3</sub>, transient voltage suppressors, are used to suppress the overshoot, undershoot and ESD.
2. C<sub>1</sub>~C<sub>4</sub> are required. The values of these capacitors are reference only. Tantalum and ceramic capacitors are recommended.
3. Please locate the C<sub>1</sub>, C<sub>2</sub>, and TVS<sub>1</sub> as close to the pin16, the C<sub>4</sub> as close to pin15 as possible.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

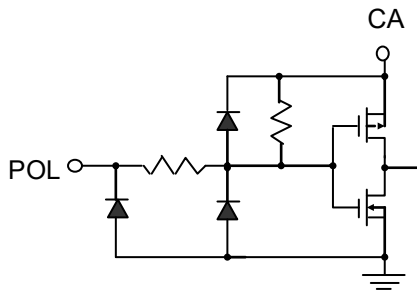
## Block Diagram



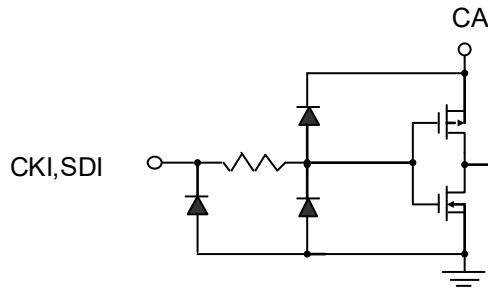
# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Equivalent Circuits of Inputs and Outputs

**POL terminal**

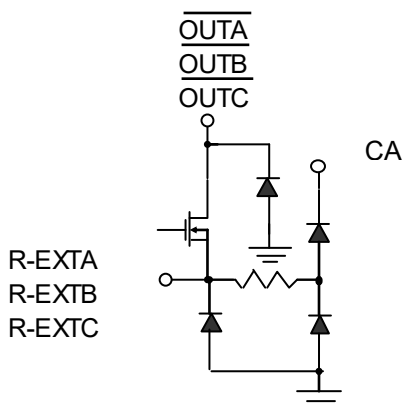


**CKI, SDI terminal**

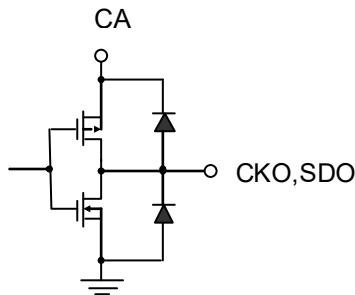


**OUTA, OUTB, OUTC**

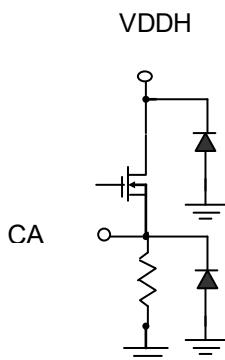
**R-EXTA, R-EXTB, R-EXTC terminal**



**CKO, SDO terminal**



**VDDH, CA terminal**



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Maximum Ratings

| Characteristic  |  | Symbol        | Rating                            | Unit               |
|---|--|---------------|-----------------------------------|--------------------|
| Supply Voltage  |  | $V_{DDH}$     | 0~35                              | V                  |
| Sustaining Voltage at CKI, SDI, E-GCLK, POL Pins                |  | $V_{IN}$      | -0.4~ $V_{CA}+0.4$                | V                  |
| Sustaining Voltage at CKO, SDO Pins                             |  | $V_{OUT}$     | -0.4~ $V_{CA}+0.4$                | V                  |
| Sustaining Voltage at $\overline{OUTA} \sim \overline{OUTC}$    |  | $V_{DS}$      | -0.5~+40                          | V                  |
| Output Current per Output Channel                               |  | $I_{OUT}$     | +170                              | mA                 |
| GND Terminal Current  |  | $I_{GND}$     | 480                               | mA                 |
| Power Dissipation<br>(On 4 Layer PCB, $T_a=25^\circ\text{C}$ )* | MBI6030GP  | $P_D$         | 1.85                              | W                  |
|   | MBI6030GFN   | $P_D$         | 2.97                              | W                  |
| Thermal Resistance<br>(By simulation, on 4 Layer PCB)*          | MBI6030GP  | $R_{th(j-a)}$ | 67.44                             | $^\circ\text{C/W}$ |
|   | MBI6030GFN   |               | 42.10                             | $^\circ\text{C/W}$ |
| Junction Temperature  |  | $T_{j,max}$   | 150                               | $^\circ\text{C}$   |
| Storage Temperature   |  | $T_{stg}$     | -55~+150                          | $^\circ\text{C}$   |
| ESD Rating  | Human Body Mode<br>(MIL-STD-883G<br>Method 3015.7) | HBM           | Class 3A<br>(4000V ~ 7999V)       | -                  |
|   | Machine Mode<br>(JEDEC<br>EIA/JESD22-A115)         | MM            | Class C<br>( $\geq 400\text{V}$ ) | -                  |

\*The PCB size is 76.2mm\*114.3mm in simulation. Please refer to JEDEC JESD51.

Note: The performance of thermal dissipation is strongly related to the size of thermal pad, thickness and layer numbers of the PCB. The empirical thermal resistance may be different from simulative value. Users should plan for expected thermal dissipation performance by selecting package and arranging layout of the PCB to maximize the capability.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Electrical Characteristics (Ta=25°C)

| Characteristic   | Symbol          | Condition  | Min.               | Typ.                 | Max.                 | Unit       |
|--|-----------------|--|--------------------|----------------------|----------------------|------------|
| Voltage Regulator Input Voltage                          | $V_{DDH}$       | -  | 7                  | -                    | 30                   | V          |
| CA Output Voltage  | $V_{CA}$        | -  | 4.5                | 5                    | 5.5                  | V          |
| Sustaining Voltage at OUT Ports                          | $V_{DS,Max}$    | $\overline{OUTA} \sim \overline{OUTC} = \text{Off}$  | -                  | -                    | 40                   | V          |
| Output Current   | $I_{OUT}$       | Refer to "Test Circuit for Electrical Characteristics"   | 5                  | -                    | 150                  | mA         |
| Driving Current  | $I_{OH}$        | CKO, SDO at $V_O=3.5V$   | -8.5               | -                    | -15.5                | mA         |
|  | $I_{OL}$        | CKO, SDO at $V_O=1.0V$   | 8                  | -                    | 15                   | mA         |
| Output Leakage Current                                   | $I_{OUT}$       | $V_{DS}=40V$ , all channels turn off   | -                  | -                    | 0.2                  | $\mu A$    |
| Current Skew (Channel)                                   | $dI_{OUT1}$     | $I_{OUT}=19.9mA$<br>$V_{DS}=1.0V$   $R_{ext}=20\Omega$   | -                  | $\pm 1.5$            | $\pm 3.0$            | %          |
| Current Skew (IC)  | $dI_{OUT2}$     | $I_{OUT}=19.9mA$<br>$V_{DS}=1.0V$   $R_{ext}=20\Omega$   | -                  | $\pm 3.0$            | $\pm 6.0$            | %          |
| Output Current vs. Output Voltage Regulation             | $\%/dV_{DS}$    | $V_{DS}$ within 1.0 V and 3.0V   | -                  | $\pm 0.1$            | $\pm 0.5$            | % / V      |
| Input Voltage of CKI, SDI Pins                           | "H" level       | $V_{IH}$   | -                  | $0.75 \times V_{CA}$ | $V_{CA}$             | V          |
|  | "L" level       | $V_{IL}$   | -                  | GND                  | $0.26 \times V_{CA}$ | V          |
| Output Voltage of CKO, SDO Pins                          | "H" level       | $V_{OH}$   | $I_{OH}=-1.0mA$    | -                    | 4.5                  | V          |
|  | "L" level       | $V_{OL}$   | $I_{OL}=+1.0mA$    | 0.2                  | -                    | V          |
| Voltage at R-EXTA, R-EXTB, R-EXTC Pins                   | $V_{REXT}$      | $R_{ext}=20\Omega$   | 0.376              | 0.4                  | 0.424                | V          |
| Threshold Temperature for Thermal Shutdown **            | $T_X$           | POL=high   | $R_{ext}=80\Omega$ | -                    | 155                  | °C         |
|  |                 | POL=low  |                    |                      |                      |            |
| Threshold Temperature for Thermal Shutdown Recovering ** | $T_{RECV}$      | POL=high   | $R_{ext}=80\Omega$ | -                    | 130                  | °C         |
|  |                 | POL=low  |                    |                      |                      |            |
| Pull-up Resistor at POL Pin                              | $R_{IN(up)}$    | -  | -                  | 470                  | -                    | K $\Omega$ |
| Supply Current ***                                       | $I_{DD(on) 1}$  | $R_{ext}=20\Omega$ , CKI, SDI=Low, CKO, SDO=NC, $\overline{OUTA} \sim \overline{OUTC} = \text{On}$   | 2.0                | -                    | 5.5                  | mA         |
|  | $I_{DD(off) 2}$ | $R_{ext}=6.8\Omega$ , CKI, SDI=Low, CKO, SDO=NC, $\overline{OUTA} \sim \overline{OUTC} = \text{Off}$ |                    |                      |                      | mA         |

\*One channel turns on.

\*\*Guaranteed by design.

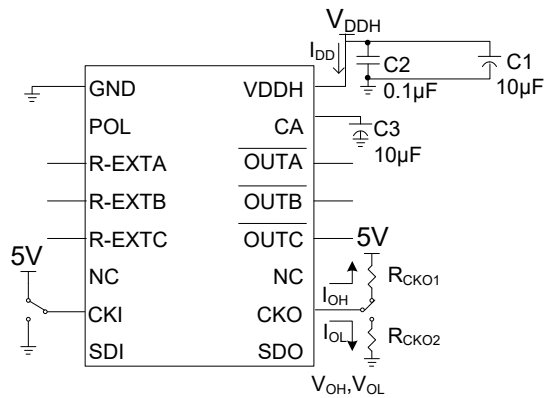
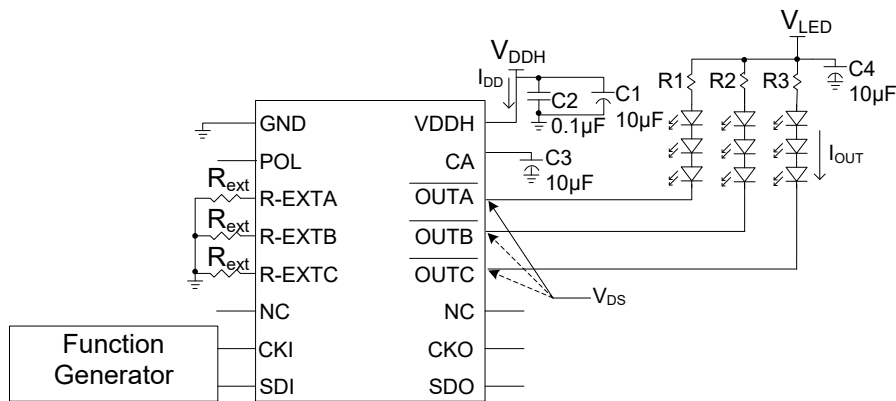
\*\*\* The supply current may vary with the loading conditions.

Note: The above operation range is defined based on the ambient temperature (Ta=25°C). However, the recommended operating temperature range is from -45°C to +85°C, but the operation range may vary accordingly.



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Test Circuit for Electrical Characteristics



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

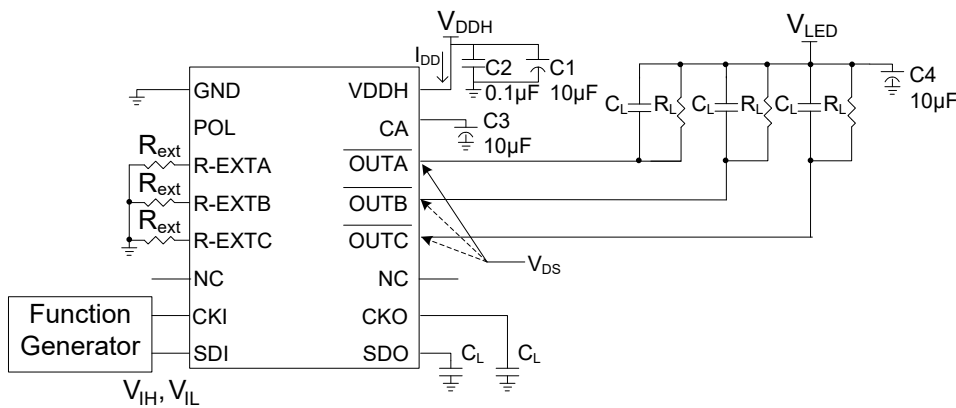
## Switching Characteristics

| Characteristic                   |  | Symbol         | Condition   | Min. | Typ. | Max. | Unit |
|----------------------------------|--|----------------|---|------|------|------|------|
| Setup Time                       | SDI-CKI↓   | $t_{S(D)}$     | $T_A=25^\circ\text{C}$<br>$V_{DDH}=12\text{V}$<br>$V_{DS}=1\text{V}$<br>$V_{IH}=4.5\text{V}$<br>$V_{IL}=0.5\text{V}$<br>$R_{ext}=20\Omega$<br>$(I_{OUT}=20\text{mA})$<br>$R_L=200\Omega$<br>$C_L=10\text{pF}$ | 5    | -    | -    | ns   |
| Hold Time                        | SDI-CKI↓   | $t_{H(D)}$     |   | 5    | -    | -    | ns   |
| Propagation Delay Time           | CKI – CKO  | $t_{P1}$       |   | -    | 25   | -    | ns   |
|                                  | CKO↑ - SDO   | $t_{P2}$       |   | -    | 25   | -    | ns   |
| Pulse Width                      | CKO  | $t_{w(O)}$     |   | 45   | 77   | 90   | ns   |
|                                  | CKI  | $t_{w(I)}$     |   | 17   | -    | -    | ns   |
| Output Rise Time of Output Ports | CKO/SDO  | $t_{cr}$       |   | -    | 2.5  | -    | ns   |
|                                  | $\overline{\text{OUTA}} \sim \overline{\text{OUTC}}$ | $t_{orh}^*$    |   | -    | 60   | -    | ns   |
|                                  |  | $t_{orl}^*$    |   | -    | 125  | -    | ns   |
| Output Fall Time of Output Ports | CKO/SDO  | $t_{cf}$       |   | -    | 2.5  | -    | ns   |
|                                  | $\overline{\text{OUTA}} \sim \overline{\text{OUTC}}$ | $t_{ofh}^*$    | -   | 40   | -    | ns   |      |
|                                  |  | $t_{ofl}^*$    | -   | 135  | -    | ns   |      |
| Frequency                        | CKI**  | $F_{CKI}$      | 0.08  | -    | 8    | MHz  |      |
|                                  | GCLK   | High-frequency | $F_{GCLK}$  | 8.1  | 9.0  | 9.9  | MHz  |
|                                  |  | Low-frequency  | $F_{GCLK}$  | 4.0  | 4.5  | 5.0  | MHz  |
| Maximum CKI Rise Time            |  | $t_r$          | -   | -    | 500  | ns   |      |
| Maximum CKI Fall Time            |  | $t_f$          | -   | -    | 500  | ns   |      |

\* $t_{orh}$ ,  $t_{ofh}$  are for the high-frequency GCLK.  $t_{orl}$ ,  $t_{ofl}$  are for the low-frequency GCLK.

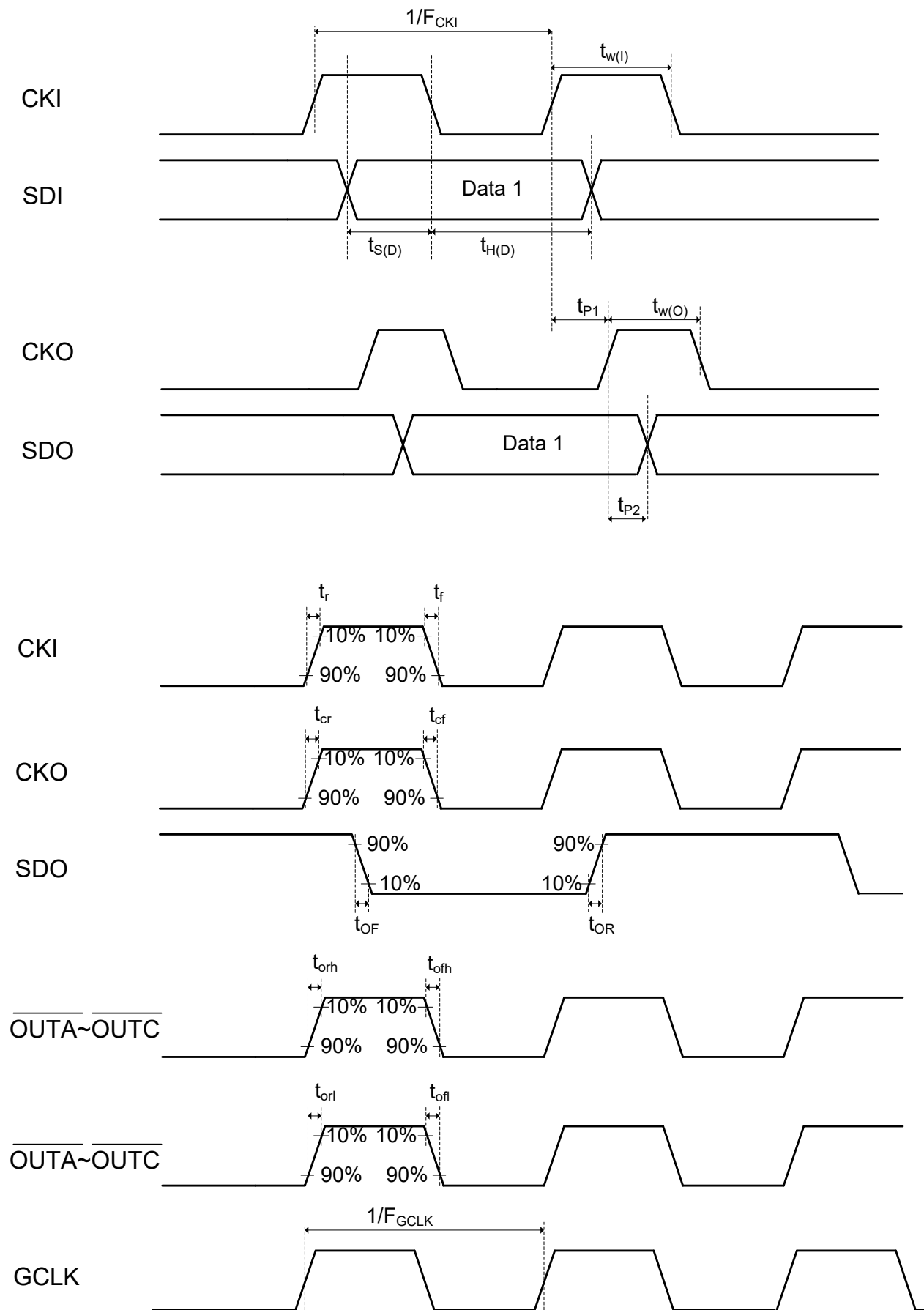
\*\*The maximum frequency may be limited by different application conditions. Please refer to the application note for details.

## Test Circuit for Switching Characteristics



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Timing Waveform



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Principle of Operation

MBI6030 provides SPI-like interface (CKI, SDI), a two-wire transmission interface, to address the data, so that MBI6030 receives the data directly without a latch command. The sequence of operation should follow the steps below:

Step 1. Send the dot correction data (Optional)

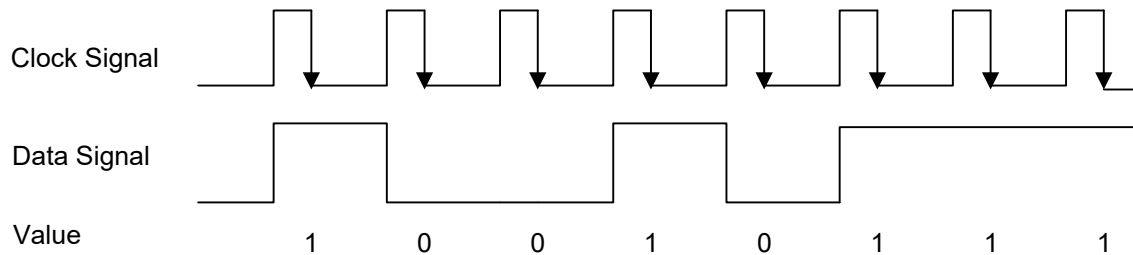
Step 2. Send the gray scale data

MBI6030 receives the data packet containing targeted gray scale data from the controller, and turns on the output channels according to the gray scale data.

## Control Interface: SPI-Like Interface (CKI, SDI)

MBI6030 adopts the SPI-like interface (CKI/SDI). By SPI-like interface, MBI6030 samples the data (SDI) at the falling edge of the clock (CKI). The following waveforms is the example of the SPI-like interface.

### SPI-Like Interface (CKI, SDI)



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## The Structure of Data Packet

MBI6030's data packet contains three parts:

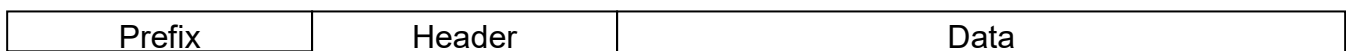
1. Prefix:
 

The prefix is a symbol of "Silent-to-Reset", i.e. a time period for MBI6030 to distinguish two data packets. During the prefix, both CKI and SDI should be tied-low and stop for more than 44 CKI cycles.
2. Header:
 

The header defines the cascaded IC numbers and also contains a command to decide the data type.
3. Data:
 

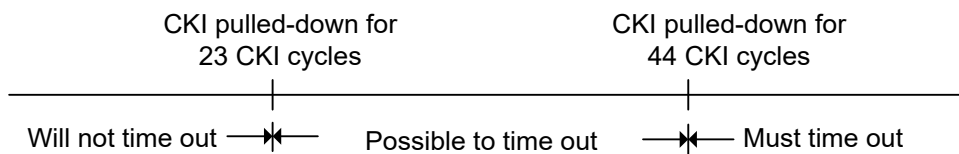
This is the data for each IC. It may be gray scale data or dot correction data.

Structure of a data packet:



## Time-Out Reset for Transmission Abort

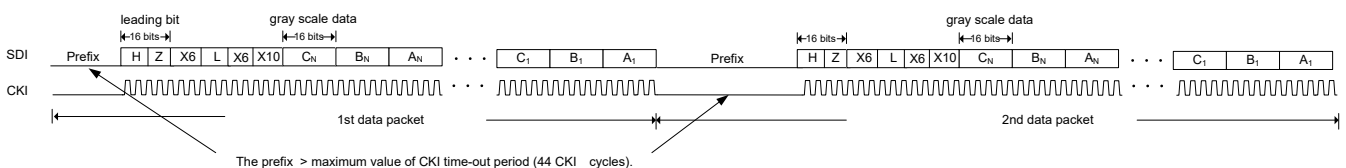
Time-out reset is to prevent ICs from misreading during the data transmission. The time-out period is 23~44 CKI cycles. If the CKI is tied-low for more than the preset period, MBI6030 may identify the wires as disconnection. To prevent from misreading, MBI6030 will ignore the present input data and continuously show the previous image data until the next image data is correctly recognized. That is, MBI6030 may recognize the input data as a new packet during the CKI time-out period (23~44 CKI cycles). To prevent from time-out, users should limit the period shorter than 23 CKI cycles. The illustration is as below:



## The Prefix in the Beginning of a Data Packet

MBI6030 identifies the data as a new data packet after time-out, so the prefix in the beginning of a data packet should be larger than 44 CKI cycles.

If both CKI and SDI are tied-low and stop for more than 44 CKI time-out cycles, MBI6030 will start to check the valid command of the next data packet. The prefix between two data packets helps MBI6030 identify the data packet correctly. The following timing diagram illustrates the interval between two data packets in 16-bit gray scale mode.



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Setting the Data Types by the Command

MBI6030 provides three kinds of commands and input data types shown as the table below:

| Command H[5:0] | Data Type                 |
|----------------|---------------------------|
| 6'b11 111s     | 16-bit gray scale data    |
| 6'b10 101s     | 10-bit gray scale data    |
| 6'b10 011s     | 6-bit dot correction data |

bit "s": 1, high-frequency GCLK (9MHz±10%)

bit "s": 0, low-frequency GCLK (4.5MHz±10%)

Once MBI6030 receives the SDI=1 (1'b1), MBI6030 will start to check if the data is a valid command or not. If the 6-bit data is a valid command, the driver will latch the specific data according to the protocol. If the 6-bit data is not a valid command, MBI6030 will wait for another SDI=1 (1'b1) to check the validity of the next command.

## GCLK Frequency

MBI6030 is embedded with an oscillator as the clock of PWM counter (GCLK) to turn on output ports according to the gray scale data sent from the system controller.

When bit "s" is "1", MBI6030 works at high-frequency GCLK; when bit "s" is "0", MBI6030 works at low-frequency GCLK. The high-frequency GCLK is 9MHz±10%, and the low-frequency GCLK is 4.5MHz±10%.

Low-frequency GCLK is recommended for  $I_{OUT} > 40\text{mA}$ , or when MBI6030 drives external high-power LED drivers, because lower GCLK frequency and switching speed is more suitable for these two applications. In contrast, high-frequency is suitable for  $I_{OUT} < 40\text{mA}$  to enhance the visual refresh rate.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Dot Correction

MBI6030 also provides 6-bit dot correction in 10-bit gray scale mode. Dot correction control helps compensate LED brightness.

For valid dot correction control, users have to program dot correction data before sending gray scale data.

### 10-bit gray scale with 6-bit dot correction:

The following is the equation for the duty cycle of output in 10-bit gray scale mode. For 6-bit dot correction, the default value of dot correction data is 63.

$$\text{The duty cycle of output (\%)} = \frac{10\text{-bit gray scale data} \times \frac{(6\text{-bit dot correction data} + 1)}{64}}{1,024} \times 100\%$$

According to the above equation, the following table shows the examples:

Example:

| Dot correction data | The ratio of output turn-on time |
|---------------------|----------------------------------|
| 0                   | 1/64 x gray scale data           |
| 1                   | 2/64 x gray scale data           |
| 2                   | 3/64 x gray scale data           |
| .                   | .                                |
| .                   | .                                |
| .                   | .                                |
| 63                  | 64/64 x gray scale data          |

### The algorithm of PWM counting with dot correction data

When adopting 6-bit dot correction in 10-bit gray scale mode, MBI6030 will has a 16-bit PWM period, which is also scrambled into 64 segments. The duty ratio of each segment is decided by the 10-bit gray scale data, and the numbers of turned-on segments is decided by the 6-bit dot correction data. The turned-on segments are distributed evenly to increase the visual refresh rate.

The chart below shows the PWM output.

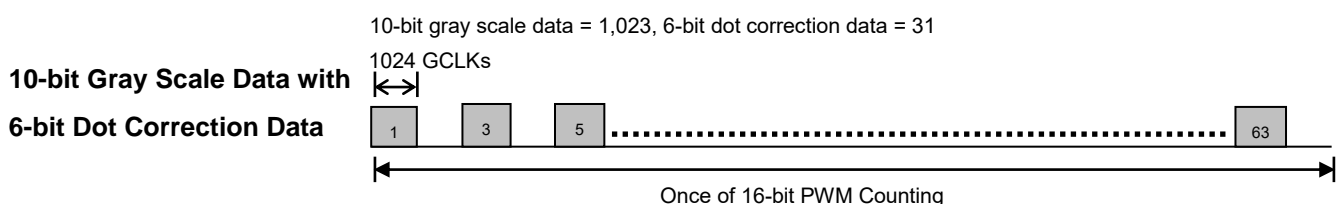
Assume:

the 10-bit grayscale data=1023,

6-bit dot correction data=31 (50%).

The 16-bit PWM output period is scramble into 64 segments,

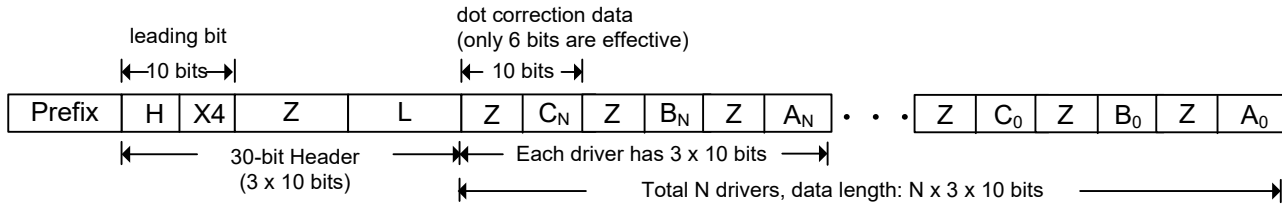
but only 32 segments of the 64 segments are turned on with ~99.9% (1023/1024) duty ratio.



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## 6-bit Dot Correction Data

For 6-bit dot correction data, each word is 10 bits. Each MBI6030 needs 3 words (3x10=30 bits) for the dot correction data of each output channel of one MBI6030. However, each dot correction data has only 6 bits, and the first 4 bits of each word should be set as "0". Prior to the dot correction data, there is a 30-bit header. The data format is shown below:



### Prefix

Both CKI and SDI should be tied-low and stop for more than 44 CKI cycles.

### 30-bits header

| Bit   | Definition | Value                           | Function                                  |
|-------|------------|---------------------------------|---|
| 29:24 | H[5:0]     | 10011s                          | The command of 6-bit dot correction data  |
| 23:20 | X4[3:0]    | 0000                            | Must be 0                                 |
| 19:10 | A[9:0]     | 0000000000                      | Address data. Always send 10'b 0000000000 |
| 9:0   | L[9:0]     | N-1<br>N=Number of IC in series | Set the number of IC in series            |

### 30-bit dot correction data

| Bit   | Definition   | Value  | Function  |
|-------|--|--|---|
| 29:20 | Z[3:0]~C <sub>N</sub> [5:0]                        | 10b'0000000000~<br>10b'0000111111                                | 6-bit x 1 channel dot correction data of the Nth MBI6030. The data of $\overline{OUTC}$ is sent first. The 4 MSB bits, Z[3:0], are not used, and please send 4b'0000. |
| 19:0  | Z[3:0]~B <sub>N</sub> [5:0]...A <sub>N</sub> [5:0] | The range of the data value is the same as the previous 10 bits. | 6-bit x 2 channels dot correction data of the Nth MBI6030. The data format is the same as the prior 10 bits.  |

The dot correction data of the last IC is sent first, followed by the previous ICs, and the first IC's dot correction data is sent in the end of the packet. The ratio of output turn-on time will be (dot correction data+1)/256 x gray scale data.



# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

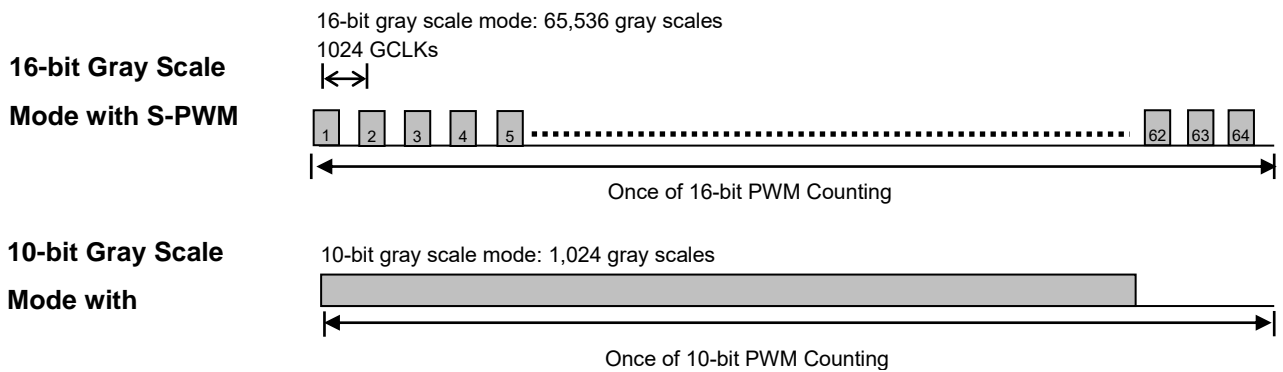
## Gray Scale

MBI6030 provides two gray scale modes: 16-bit gray scale mode and 10-bit gray scale mode by adopting S-PWM or conventional PWM algorithm respectively. MBI6030 adopts S-PWM technology in 16-bit gray scale mode to scramble the 16-bit PWM to 64 segments, so that the visual refresh rate can be increased. For example, with S-PWM, if PWM clock (GCLK) frequency is around 9MHz, and therefore, the visual refresh rate of 16-bit gray scale mode will be increased to:  $9\text{MHz}/65536 \times 64 = 8,789\text{Hz}$

On the other hand, MBI6030 provides 10-bit gray scale mode by conventional PWM. In 16-bit gray scale mode, MBI6030 achieves 65,536 gray scales for each LED, and in 10-bit gray scale mode, MBI6030 achieves 1,024 gray scales. The following illustrations explain the PWM counting by S-PWM and conventional PWM algorithms.

### PWM counting by S-PWM or conventional PWM algorithm

With S-PWM technology, the total PWM cycles can be broken down into MSB (Most Significant Bits) and LSB (Least Significant Bits) of gray scale cycles, and the MSB information can be dithered across 63 refresh cycles 64 segments.



Example of 16-bit Gray Scale Data:

| Gray scale data | The ratio of output turn-on time in a PWM cycle |
|-----------------|---|
| 0               | $0/2^{16}$                                      |
| 1               | $1/2^{16}$                                      |
| 2               | $2/2^{16}$                                      |
| .               | .   |
| .               | .   |
| .               | .   |
| 65535           | $65535/2^{16}$                                  |

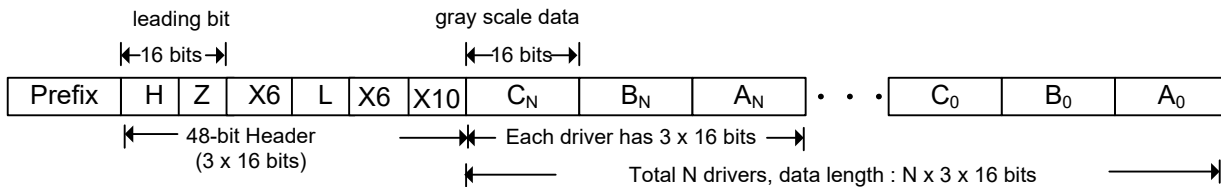
Example of 10-bit Gray Scale Data:

| Gray scale data | The ratio of output turn-on time in a PWM cycle |
|-----------------|---|
| 0               | $0/2^{10}$                                      |
| 1               | $1/2^{10}$                                      |
| 2               | $2/2^{10}$                                      |
| .               | .   |
| .               | .   |
| .               | .   |
| 1023            | $1023/2^{10}$                                   |

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## 16-bit Gray Scale Data

For 16-bit gray scale data, each word is 16 bits. Each MBI6030 needs 3 words (3x16=48 bits) for the gray scale data of each output channel of one MBI6030. Prior to the gray scale data, there is a 48-bit header. The data format is shown below:



### Prefix

Both CKI and SDI should be tied-low and stop for more than 44 CKI cycles.

### 48-bit header

| Bit   | Definition | Value                             | Function                                  |
|-------|------------|-----------------------------------|---|
| 47:42 | H[5:0]     | 11111s                            | The command of 16-bit gray scale data     |
| 41:32 | A[9:0]     | 0000000000                        | Address data. Always send 10'b 0000000000 |
| 31:26 | X6[5:0]    | 000000                            | Must be 0                                 |
| 25:16 | L[9:0]     | N - 1<br>N=Number of IC in series | Set the number of IC in series            |
| 15:10 | X6[5:0]    | 000000                            | Must be 0                                 |
| 9:0   | X10[9:0]   | 0000000000                        | Must be 0                                 |

### 48-bit gray scale data

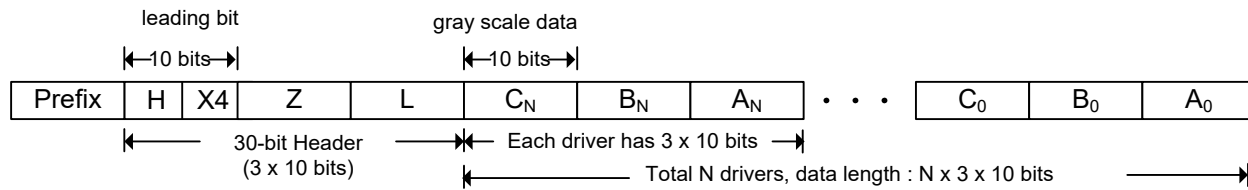
| Bit  | Definition                                  | Value       | Function   |
|------|---|-------------|--|
| 47:0 | C <sub>N</sub> [15:0]~A <sub>N</sub> [15:0] | 48b'0~48b'1 | 16-bit x 3 channels gray scale data of the Nth MBI6030. The data of $\overline{OUTC}$ is sent first. |

The gray scale data of the last IC is sent first, followed by the previous ICs, and the first IC's gray scale data is sent in the end of the packet.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## 10-bit Gray Scale Data

For 10-bit gray scale data, each word is 10 bits. Each MBI6030 needs 3 words (3x10=30 bits) for the gray scale data of each output channel of one MBI6030. Prior to the gray scale data, there is a 30-bit header. The data format is shown below:



### Prefix

Both CKI and SDI should be tied-low and stop for more than 44 CKI cycles.

### 30-bit header

| Bit   | Definition | Value                           | Function                                  |
|-------|------------|---------------------------------|---|
| 29:24 | H[5:0]     | 10101s                          | The command of 10-bit gray scale data     |
| 23:20 | X4[3:0]    | 0000                            | Must be 0                                 |
| 19:10 | A[9:0]     | 0000000000                      | Address data. Always send 10'b 0000000000 |
| 9:0   | L[9:0]     | N-1<br>N=Number of IC in series | Set the number of IC in series            |

### 30-bit gray scale data

| Bit  | Definition                                | Value       | Function   |
|------|---|-------------|--|
| 29:0 | C <sub>N</sub> [9:0]~A <sub>N</sub> [9:0] | 30b'0~30b'1 | 10-bit x 3 channels gray scale data of the Nth MBI6030. The data of $\overline{OUTC}$ is sent first. |

The gray scale data of the last IC is sent first, followed by the previous ICs, and the first IC's gray scale data is sent in the end of the packet.

## Embedded Voltage Regulator

MBI6030 has an embedded voltage regulator to regulate the high input supply voltage to 5V supply voltage for internal use. The input voltage is ranging from 7~30V, which is suitable for 12V/24V system. The high supply voltage is connected to VDDH, and the output of the regulator is connected to CA. An external capacitor of 10uF should be connected between CA and ground to stabilize the output voltage. Please refer to the application circuit section or MBI6030 application note for further details on circuit design.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Constant Current

- 1) MBI6030 performs excellent current skew: the maximum current variation between channels is less than  $\pm 3\%$ , and that between ICs is less than  $\pm 6\%$ .
- 2) In addition, in the saturation region, the output current keeps constant when the output voltage ( $V_{DS}$ ) is changed. . This characteristic guarantees the LED show the same brightness regardless of the variations of LED forward voltages ( $V_F$ )

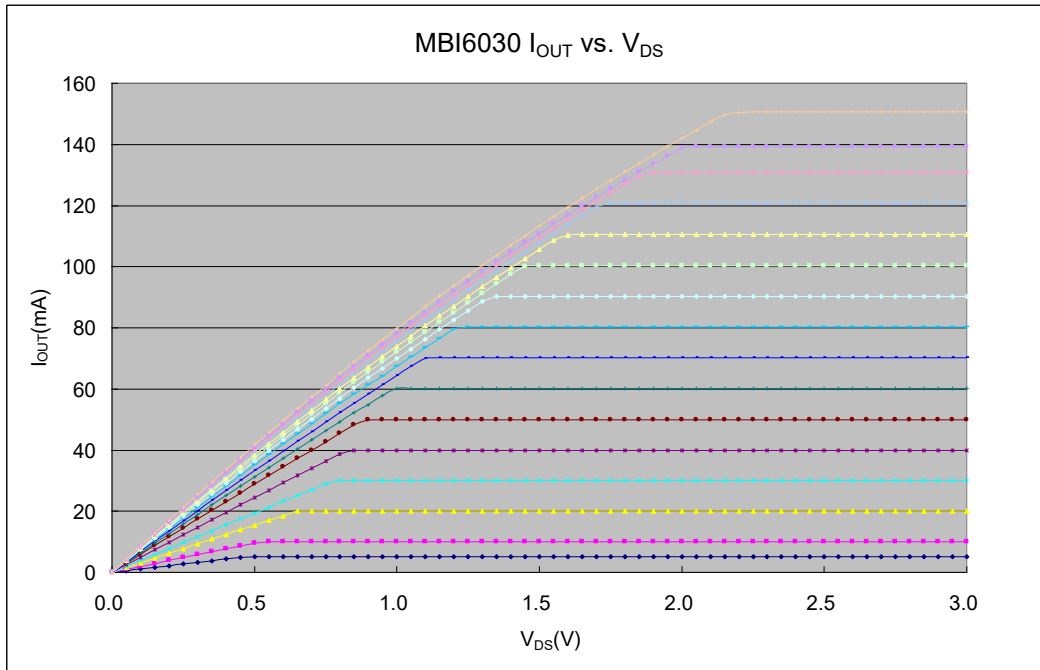


Fig. 1 GCLK=9MHz

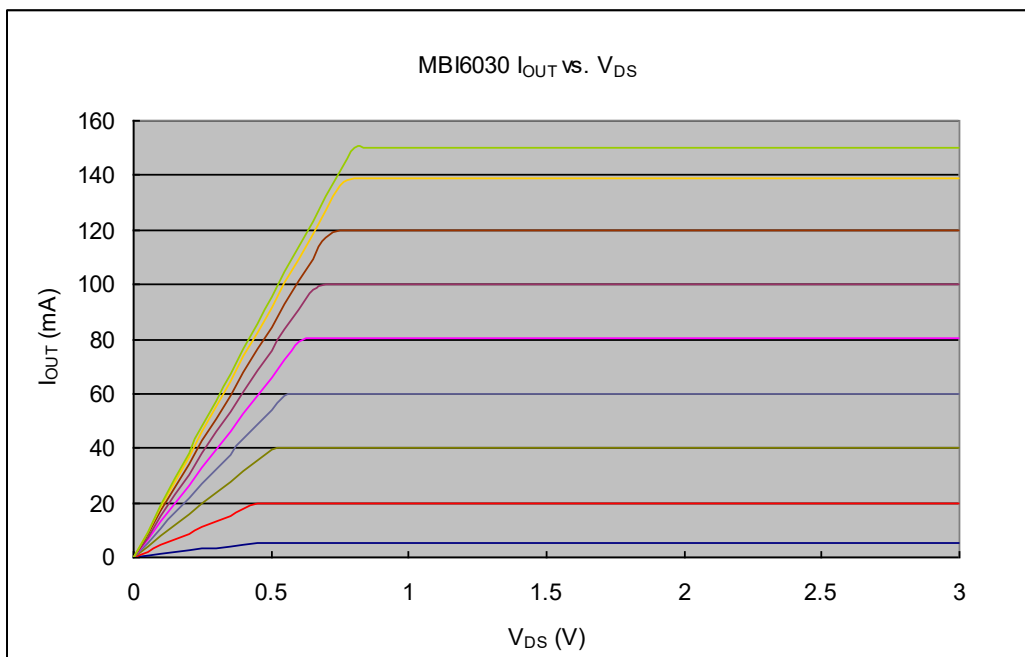
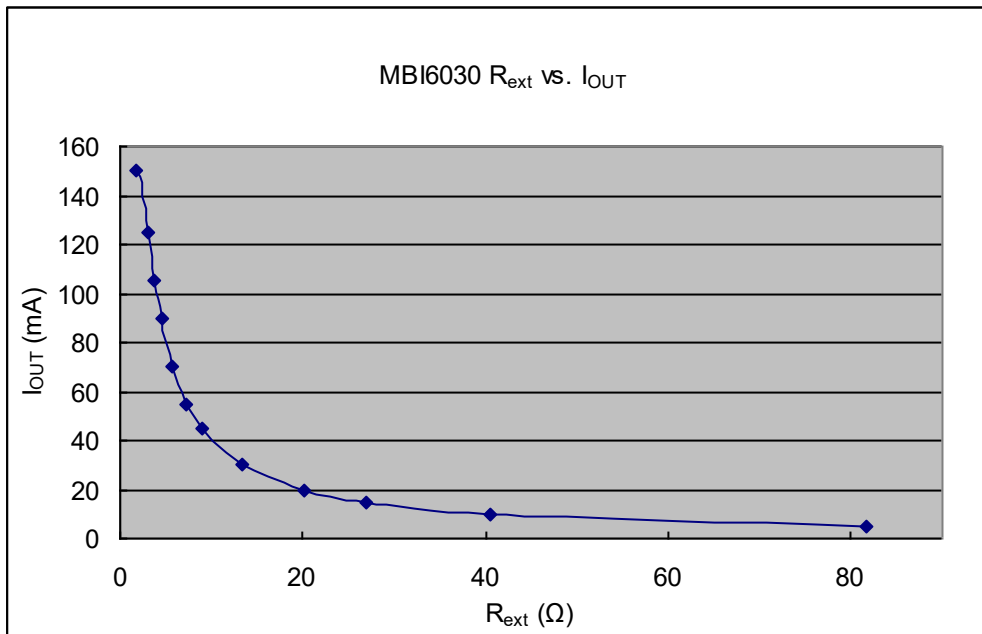


Fig. 2 GCLK=4.5MHz

**MBI6030****PWM Embedded 3-Channel Constant Current  
LED Sink Driver for RGB LED Cluster****Adjusting Output Current**

The output current of each channel ( $I_{OUT}$ ) is set by an external resistor,  $R_{ext}$ . The relationship between  $I_{OUT}$  and  $R_{ext}$  is shown in the following figure.



Also, the output current can be calculated by the equation:

$$I_{OUTA} = V_{REXT} / (R_{extA} + 0.116)$$

$$I_{OUTB} = V_{REXT} / (R_{extB} + 0.116)$$

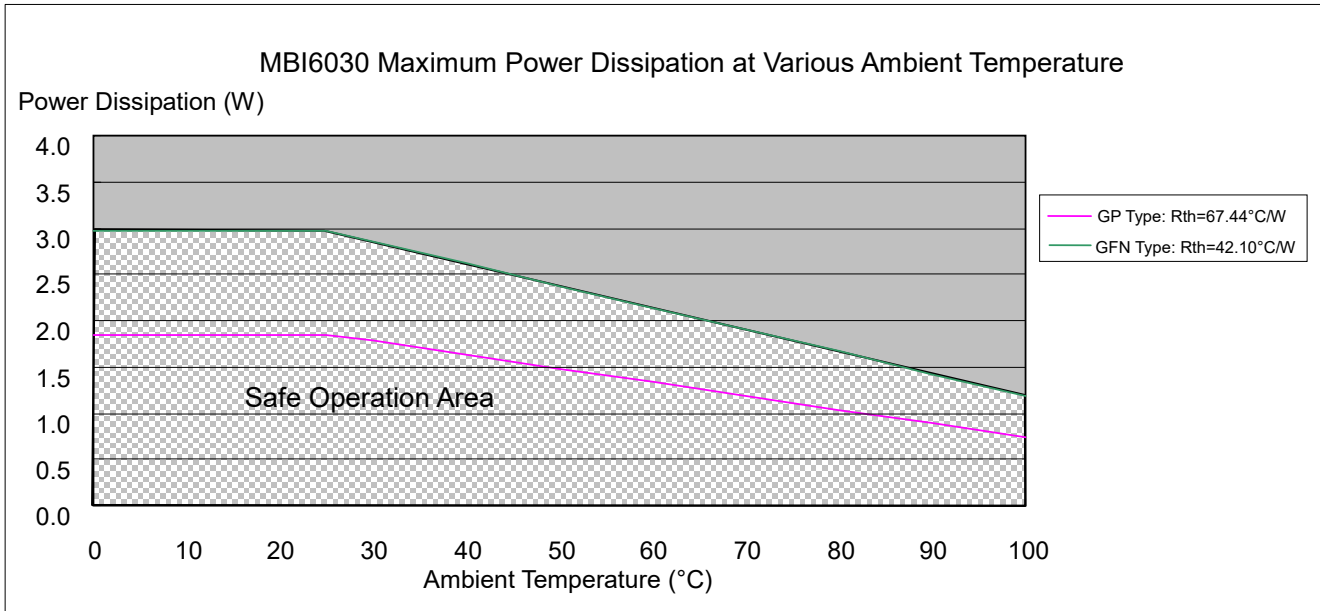
$$I_{OUTC} = V_{REXT} / (R_{extC} + 0.116)$$

Where  $V_{REXT}$  is around 0.4 V, and  $R_{extA}$ ,  $R_{extB}$ ,  $R_{extC}$  are the resistances of the external resistors connected to R-EXTA, R-EXTB, R-EXTC terminals. The current (as a function of  $R_{ext}$ ) is around 97mA when  $R_{extA}$ ,  $R_{extB}$ , or  $R_{extC} = 4\Omega$ , and 19.9mA when  $R_{extA}$ ,  $R_{extB}$ , or  $R_{extC} = 20\Omega$ .

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Package Power Dissipation ( $P_D$ )

The maximum power dissipation,  $P_D(max)=(T_{j,max}-T_a)/R_{th(j-a)}$ , decreases as the ambient temperature increases. Please refer to the following figure to design within the safe operation area.



## TP Function (Thermal Protection)

MBI6030 will automatically protect IC from overheating when the junction temperature exceeds the threshold,  $T_x$  (typ. 155°C). If the POL is pulled up, the output current will be turned off, but SDO and CKO is still work. Thus, the junction temperature starts to decrease. When the temperature is decreased to  $T_{RECV}$  (typ. 130°C), the output current will be turned on again.

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Load Supply Voltage ( $V_{LED}$ )

The design of  $V_{LED}$  should fulfill two targets:

1. Less power consumption and heat
2. Sufficiently headroom for the LED and driver IC to operate in the constant current region.

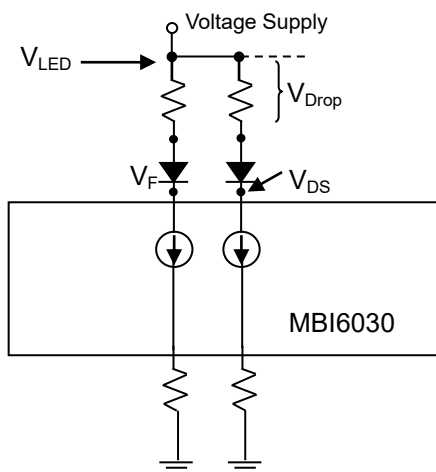
The power dissipation ( $P_D$ ) of MBI6030 is calculated by the equation:

$$P_D = (V_{DDH} \times I_{DD}) + [I_{OUTA} \times (V_{DSA} - V_{REXTA})] + [I_{OUTB} \times (V_{DSB} - V_{REXTB})] + [I_{OUTC} \times (V_{DSC} - V_{REXTC})]$$

From the figure below,  $V_{DS} = V_{LED} - V_F$ , which  $V_{LED}$  is the supply voltage of LED.  $P_{D( act)}$  will be greater than  $P_{D( max)}$ , if  $V_{DS}$  drops too much voltage on the driver. In this case, it is recommended to use the lowest possible supply voltage or to set an external resistor to reduce the by  $V_{DROP}$ .

$$V_{DS} = (V_{LED} - V_F) - V_{DROP}$$

Please refer to the following figure for the application of the resistor.



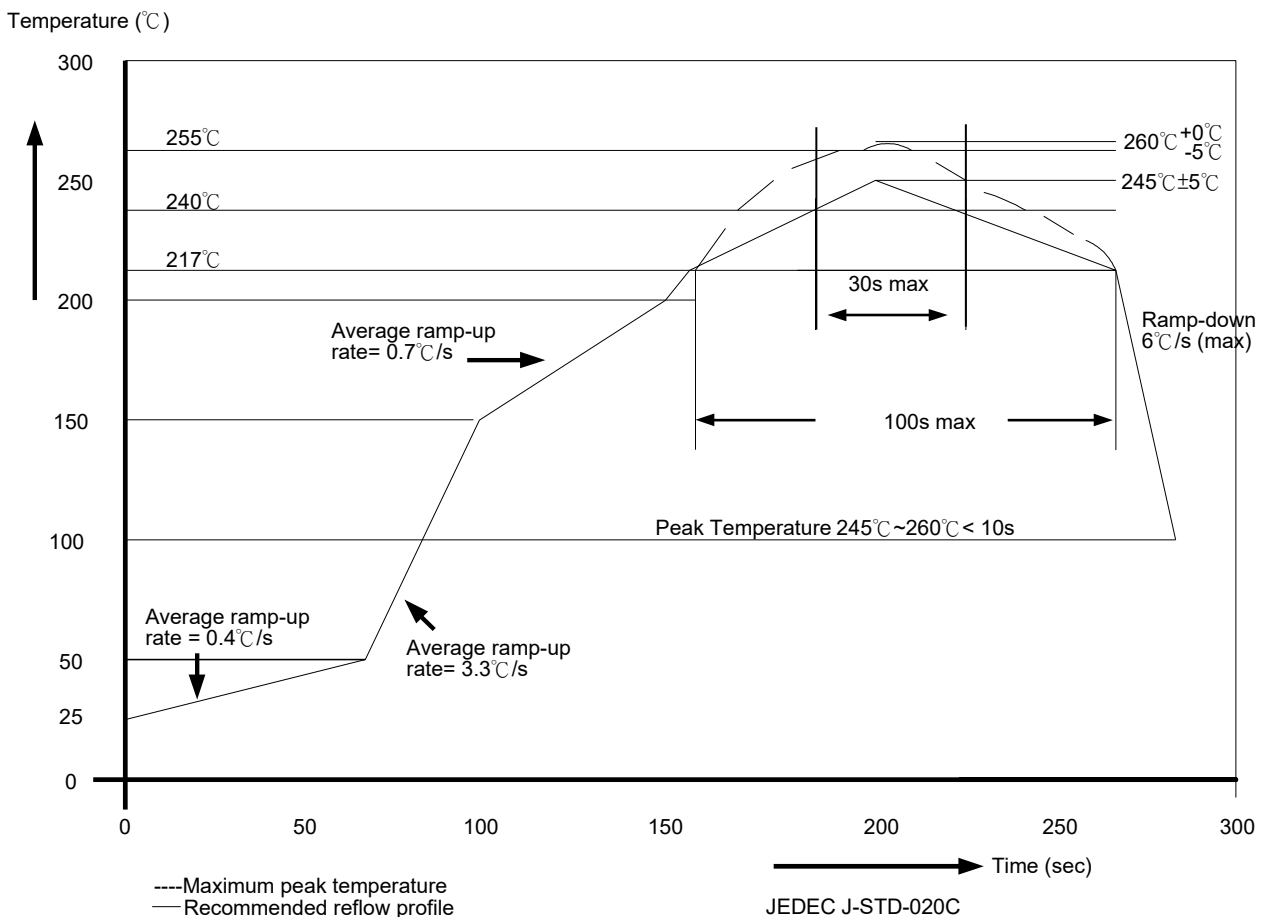
## Switching Noise Reduction

LED drivers are frequently used in switch-mode applications which always behave with switching noise due to the parasitic inductance on PCB. To eliminate switching noise, please refer to "Application Note for 8-bit and 16-bit LED Drivers-Overshoot".

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Soldering Process of "Pb-free" Package Plating\*

Macroblock has defined "Pb-Free" to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free processes. Pure tin is widely accepted by customers and suppliers of electronic devices in Europe, Asia and the US as the lead-free surface finish of choice to replace tin-lead. Also, it is backward compatible to standard 215°C to 240°C reflow processes which adopt tin/lead (SnPb) solder paste. However, in the whole Pb-free soldering processes and materials, 100% pure tin (Sn) will all require from 245 °C to 260°C for proper soldering on boards, referring to JEDEC J-STD-020C as shown below.



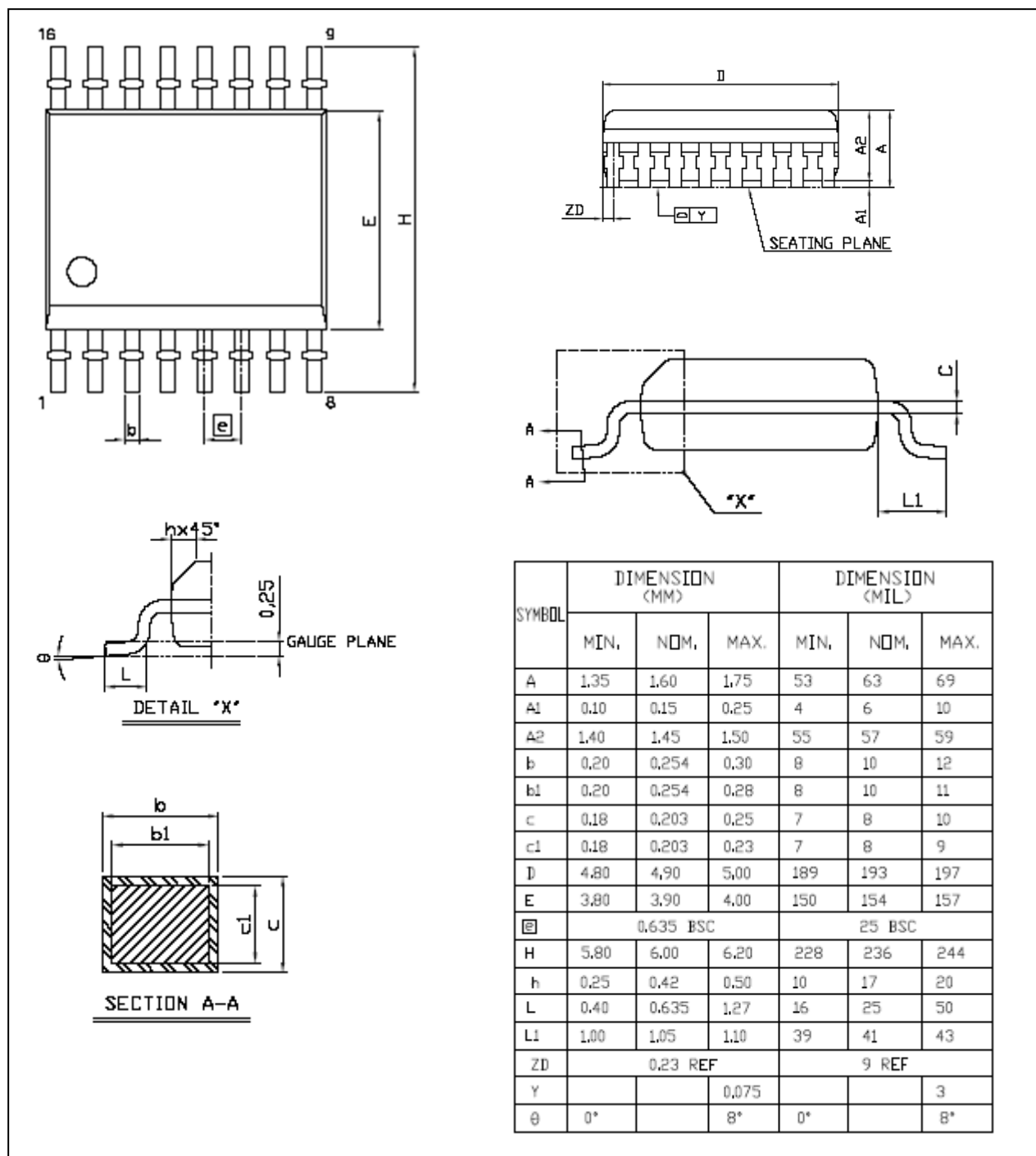
| Package Thickness | Volume mm <sup>3</sup><br><350 | Volume mm <sup>3</sup><br>350-2000 | Volume mm <sup>3</sup><br>≥ 2000 |
|-------------------|--------------------------------|------------------------------------|----------------------------------|
| <1.6mm            | 260 +0 °C                      | 260 +0 °C                          | 260 +0 °C                        |
| 1.6mm – 2.5mm     | 260 +0 °C                      | 250 +0 °C                          | 245 +0 °C                        |
| ≥ 2.5mm           | 250 +0 °C                      | 245 +0 °C                          | 245 +0 °C                        |

\*Note: For details, please refer to Macroblock's "Policy on Pb-free & Green Package".



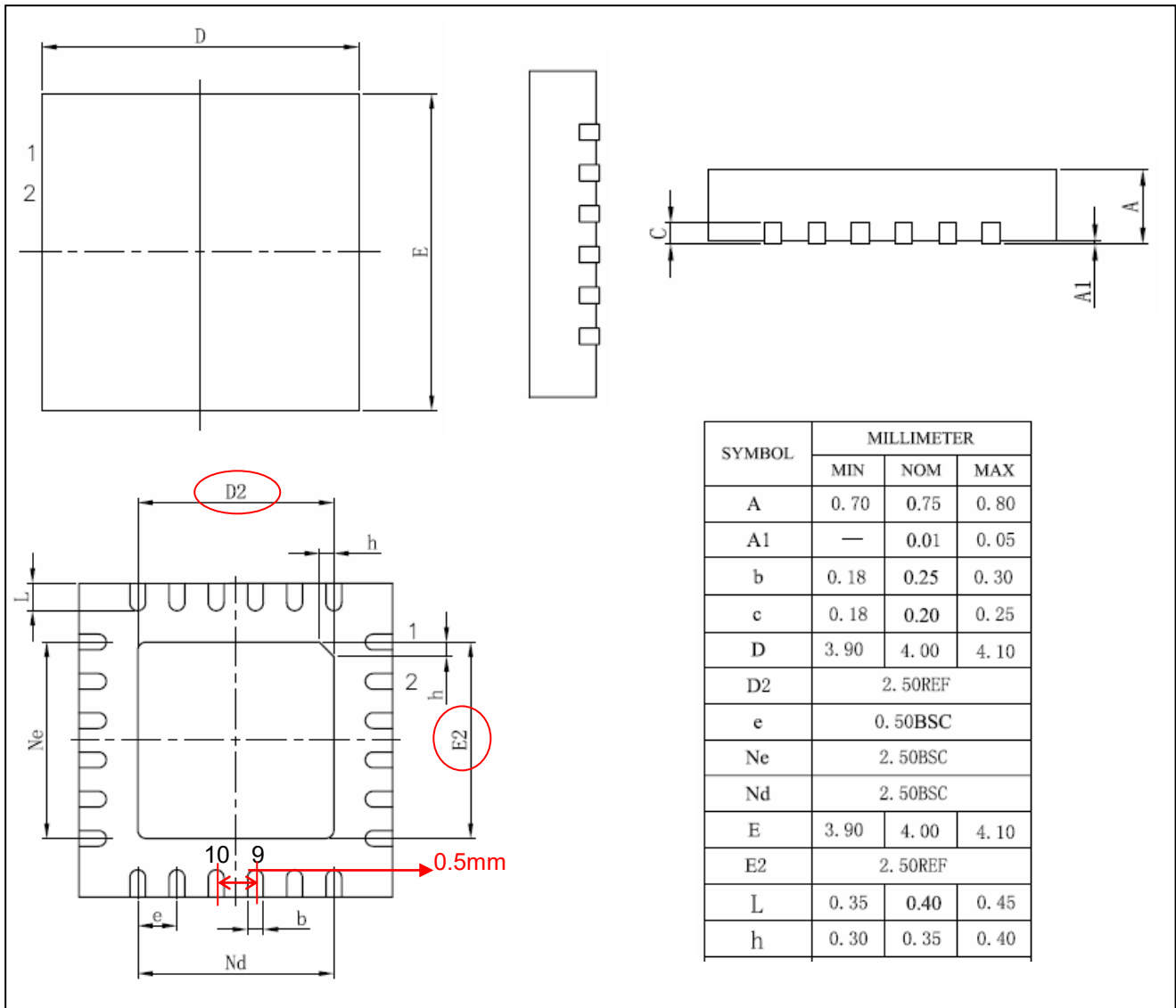
# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Package Outline



**MBI6030**

**PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster**



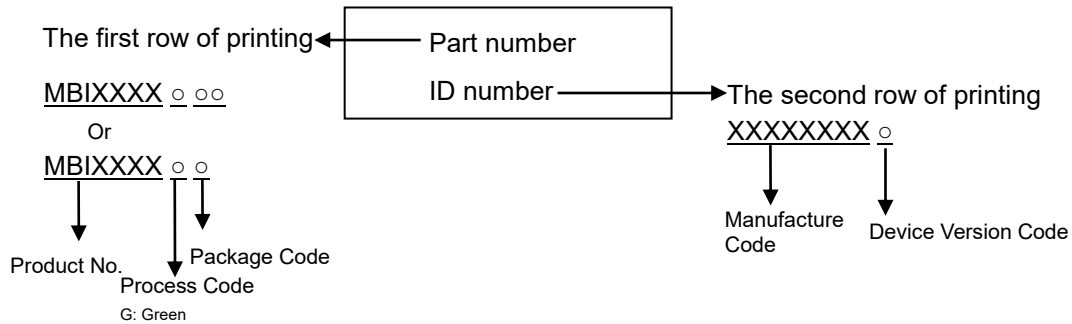
MBI6030 GFN Outline Drawing

Remark: The thermal pad size may exist a tolerance due to the manufacturing process, please use the maximum dimensions-D2(max.) x E2(max.) for the thermal pad layout. In addition, to avoid the short circuit risk, the vias or circuit traces shall not pass through the maximum area of thermal pad.

Note: The unit of the outline drawing is millimeter (mm).

# MBI6030 PWM Embedded 3-Channel Constant Current LED Sink Driver for RGB LED Cluster

## Product Top-mark Information



## Product Revision History

| Datasheet version | Device version code |
|-------------------|---------------------|
| V1.00             | A                   |
| V1.01             | A                   |
| V2.00             | B                   |
| V3.00             | B                   |
| V3.01             | B                   |
| VA.00             | B                   |

## Product Ordering Information

| Part Number | RoHS Compliant Package Type | Weight (g) |
|-------------|-----------------------------|------------|
| MBI6030GP   | SSOP16L-150-0.64            | 0.111g     |
| MBI6030GFN  | QFN24L-4*4-0.5              | 0.038g     |

**MBI6030****PWM Embedded 3-Channel Constant Current  
LED Sink Driver for RGB LED Cluster**

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