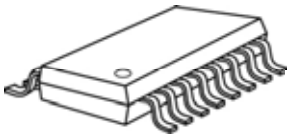
PWM-Embedded 3-Channel Constant Current LED Sink Driver for Small RGB Cluster

Features

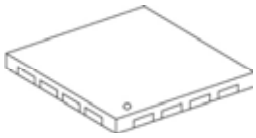
- 3-channel constant current sink driver for RGB LED clusters
- Constant current range 5~50mA
- Individual output current adjusted through external resistors
- Sustaining voltage at output channels: 17V (max.)
- Supply voltage 3V~5.5V
- Embedded 16-bit PWM generator
  - Gray scale clock generated by the embedded oscillator or the external clock
  - PWM counter reset function
  - S-PWM technology
- Two selectable gray scale modes
  - 16-bit gray scale mode (with optional 8-bit dot correction)
  - 10-bit gray scale mode (with optional 6-bit dot correction)
- Reliable data transmission
  - Daisy-chain topology
  - Two-wire only transmission interface
  - Clock reverse
  - Built-in buffer for long-distance transmission
- Flexible operation modes
  - Auto-synchronization mode
  - Manual-synchronization mode
- Selectable polarity reversion to drive high-power drivers or MOS
- RoHS-compliant packages

Shrink SOP



GP: SSOP16L-150-0.64

QFN



GFN: QFN16L-3*3-0.5

Application

- Architecture decorative lighting
- Mesh display, LED strip
- Neon lamp alternative
- PWM generator

Floor 6-4, No.18, Pu-Ting Rd., Hsinchu, Taiwan 30077, ROC.
TEL: +886-3-579-0068, FAX: +886-3-579-7534 E-mail: info@mblock.com.tw

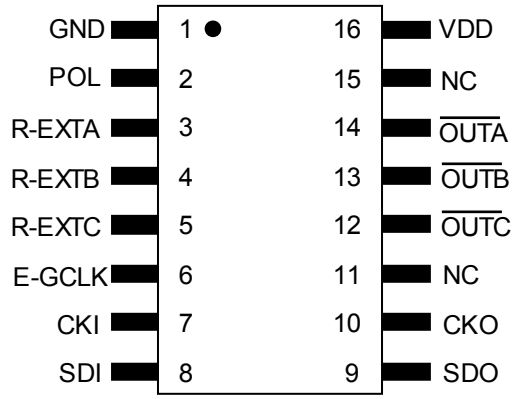
Product Description

MBI6020 is a 3-channel, constant current, PWM-embedded LED sink driver for small RGB LED cluster. MBI6020 provides constant current ranging from 5mA to 50mA for each output channel and three output channels are adjustable with three corresponding external resistors. Besides, MBI6020 can support both 3.3V and 5V power systems and sustain 17V at output channels.

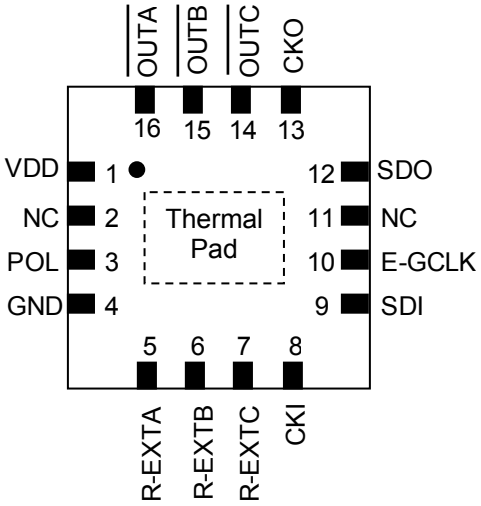
With Scrambled-PWM (S-PWM) technology, MBI6020 enhances pulse width modulation by scrambling the “on” time into several “on” periods, so that MBI6020 reduces the data transmission bandwidth at the same gray scale performance. Besides, the gray scale clock, GCLK, can be generated by either the embedded oscillator or the external clock source. Moreover, MBI6020 provides two selectable gray scale modes: 16-bit gray scale mode and 10-bit gray scale mode. The 16-bit gray scale mode provides 65,536 gray scales for each LED to enrich the color with optional 8-bit dot correction to adjust each LED by 256-step dot correction to calibrate the LED brightness. On the other hand, the 10-bit gray scale mode provides 1,024 gray scales with optional 6-bit dot correction to adjust each LED by 64-step dot correction.

Furthermore, MBI6020 features a two-wire only transmission interface to simplify the system controller design. To improve the transmission quality, MBI6020 provides clock reverse function to enhance long-distance transmission. MBI6020 is flexible for either auto-synchronization or manual-synchronization. In addition, MBI6020 preserves selectable polarity reversion to drive high-power drivers or MOS as a PWM controller.

Pin Configuration



MBI6020GP
Top View



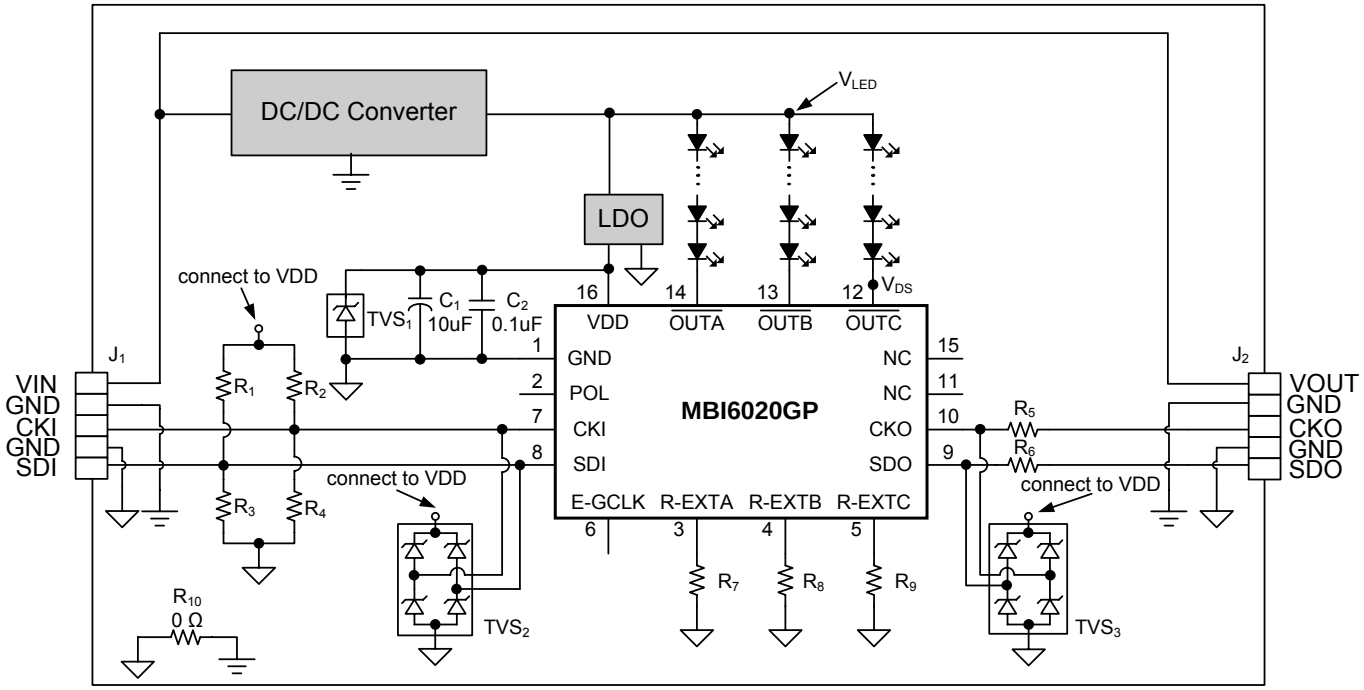
MBI6020GFN
Top View

Terminal Description

Pin		Name	Function
GP	GFN		
1	4	GND	Ground terminal
2	3	POL	Input terminal for selecting output polarity Internal pull-high High: drive LED or low-active regulators or PMOS Low: output reversed to work as a PWM controller to drive high-active regulators or NMOS
3,4,5	5,6,7	R-EXTA,B,C	Input terminals for setting output current by connecting to an external resistor
14,13,12	16,15,14	$\overline{\text{OUTA,B,C}}$	Output terminals for constant current output
6	10	E-GCLK	Input terminal for external GCLK, the clock for PWM counting Internal pull-low
11	11	NC	Keep unconnected Internal pull-low
7	8	CKI	Input terminal for clock input
8	9	SDI	Input terminal for serial data input
10	13	CKO	Output terminal for clock output
9	12	SDO	Output terminal for serial data output
15	2	NC	Keep unconnected Internal pull-high
16	1	VDD	3.3V/5V supply voltage terminal
-	-	Thermal Pad	Heat dissipation pad* 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.

Typical Application Circuit

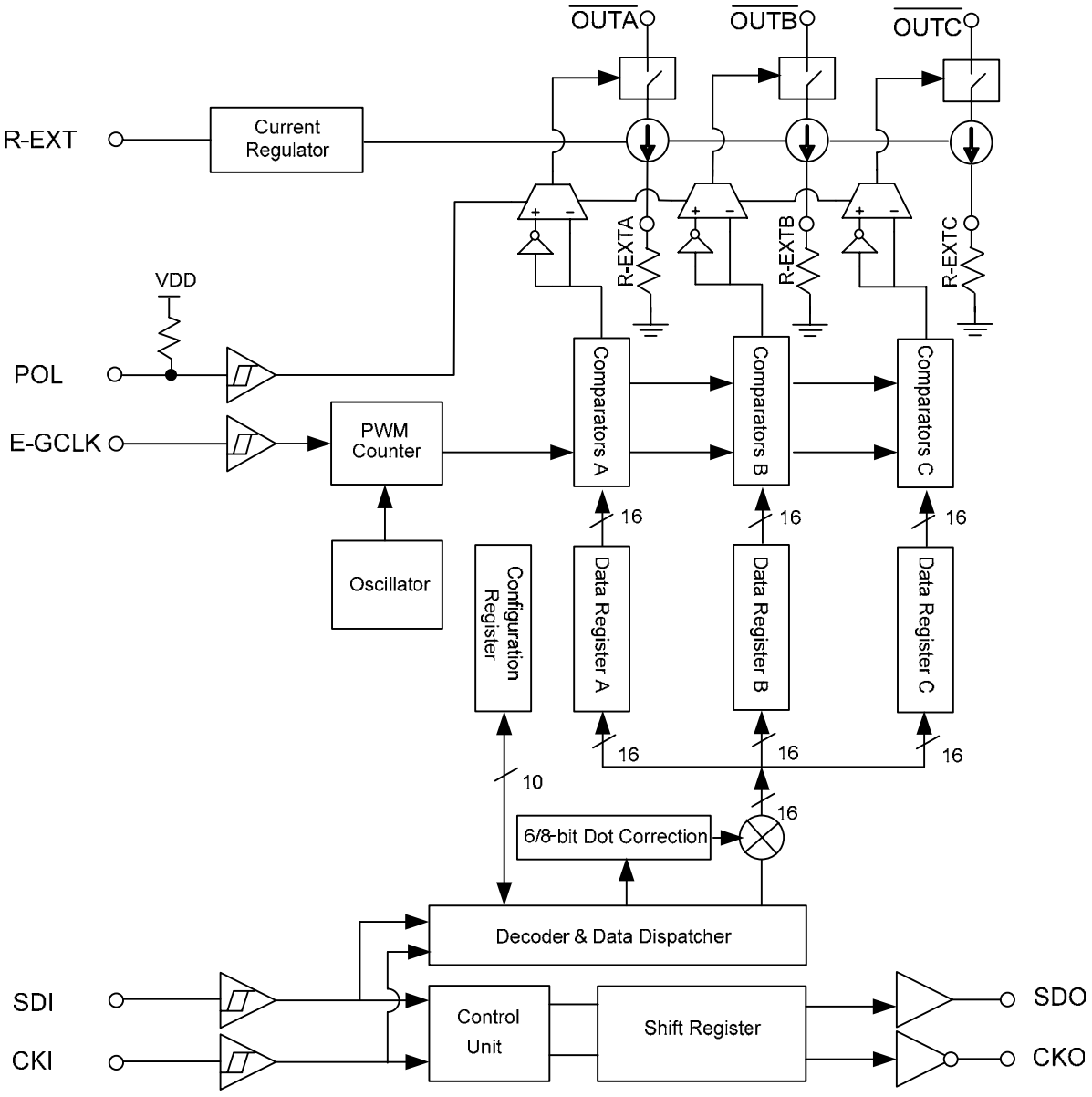


Note:

1. D_1~D_9 are Transient Voltage Suppressor (TVS) for overshoot/undershoot/ESD protection. The suggested maximum off-state capacitance (Co) of TVS is 4pF.
2. C_1~C_2 are required. The values of the C_1~C_2 are reference only. Tantalum capacitors and Ceramic capacitors are recommended.
3. For hot swapping, system grounding, connector design, external ESD protection, or detailed circuit information,

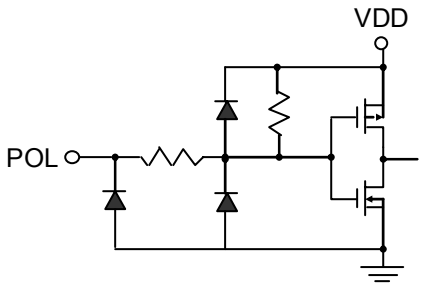
Please refer to the ***"MBI6020 Application Note"*** for detailed information.

Block Diagram

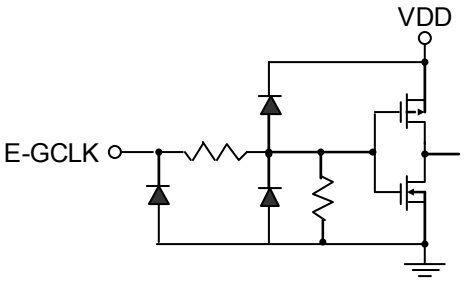


Equivalent Circuits of Inputs and Outputs

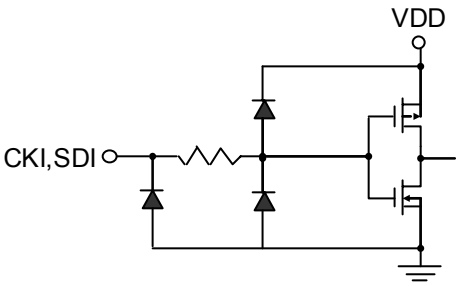
POL terminal



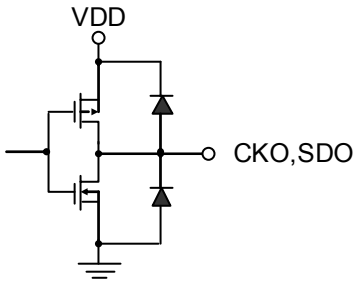
E-GCLK terminal



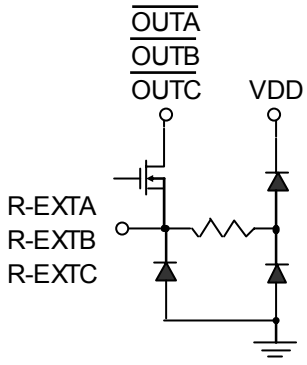
CKI, SDI terminal



CKO, SDO terminal



R-EXTA,B,C, $\overline{\text{OUTA,B,C}}$ terminal



Maximum Rating

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	0~7	V
Sustaining Voltage at CKI, SDI, E-GCLK, POL Pins		V_{IN}	-0.4~V_{DD}+0.4	V
Sustaining Voltage at CKO, SDO Pins		V_{OUT}	-0.4~V_{DD}+0.4	V
Sustaining Voltage at $\overline{OUTA}$ ~ $\overline{OUTC}$		V_{DS}	-0.5~+17	V
Output Current per Output Channel		I_{OUT}	+50	mA
GND Terminal Current		I_{GND}	160	mA
Power Dissipation (On 4 Layer PCB, Ta=25°C)*	GP	P_D	1.66	W
	GFN		2.48	W
Thermal Resistance (By simulation, on 4 Layer PCB)*	GP	$R_{th(j-a)}$	75.33	°C/W
	GFN		50.31	°C/W
Operating Junction Temperature		$T_{j,max}$	150	°C
Operating Temperature		T_{opr}	-40~+85	°C
Storage Temperature		T_{stg}	-55~+150	°C
ESD Rating	Human Body Mode (MIL-STD-883G Method 3015.7)	HBM	Class 3A (4000V~7999V)	-
	Machine Mode (JEDEC EIA/JESD22-A115)	MM	Class C (≧400V)	-

*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.

Electrical Characteristics (V_{DD}=5.0V, Ta=25°C)

Characteristics		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-		4.5	5.0	5.5	V
Sustaining Voltage at OUT Ports		V_{DS}	$\overline{OUTA}$ ~ $\overline{OUTC}$ Off		-	-	17.0	V
Output Current		I_{OUT}	Refer to "Test Circuit for Electrical Characteristics"		5	-	50	mA
Driving Current		I_{OH}	CKO, SDO at V_{OH}=4.8V		2.0	3.0	3.8	mA
		I_{OL}	CKO, SDO at V_{OH}=0.2V		2.0	3.0	4.3	mA
Output Leakage Current		I_{OUT}	V_{DS}=17.0V and channel off		-	-	1.0	μA
Current Skew (Channel)		dI_{OUT}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=20Ω	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=20Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		$\%/dV_{DS}$	V_{DS} within 1.0V and 3.0V		-	±0.1	±0.5	%/V
Output Current vs. Supply Voltage Regulation*		$\%/dV_{DD}$	V_{DD} within 4.5V and5.5V		-	±1.0	±2.0	%/V
Input Voltage of CKI, SDI, E-GCLK, POL Pins	"H" level	V_{IH}	-		$0.73xV_{DD}$	-	V_{DD}	V
	"L" level	V_{IL}	-		GND	-	$0.28xV_{DD}$	V
Output Voltage of CKO, SDO Pins	"H" level	V_{OH}	I_{OH}=-3.0mA		V_{DD}-0.2	-	-	V
	"L" level	V_{OL}	I_{OL}=+3.0mA		-	-	0.2	V
Voltage at R-EXTA,B,C Pins		V_{REXT}	$\overline{OUTA}$ ~ $\overline{OUTC}$ On		0.36	0.41	0.44	V
Knee Voltage		V_{Knee}	R_{ext}=8Ω@50mA		0.75	0.85	1.00	V
Pull-up Resistor at POL Pin		R_{IN}(up)	-		-	470	-	KΩ
Pull-down Resistor at E-GCLK, NC Pins		R_{IN}(down)	-		-	470	-	KΩ
Supply Current**	"Off"	I_{DD}(off)	R_{ext}=10Ω, CKI=Low, CKO, SDO= NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ Off		-	2.0	3.5	mA
	"On"	I_{DD}(on)	R_{ext}=20Ω, CKI=Low, CKO, SDO= NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ On		-	3.0	4.0	
			R_{ext}=20Ω, CKI=10MHz, CKO, SDO= NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ On		-	5.0	6.0	

*One channel turns on.

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

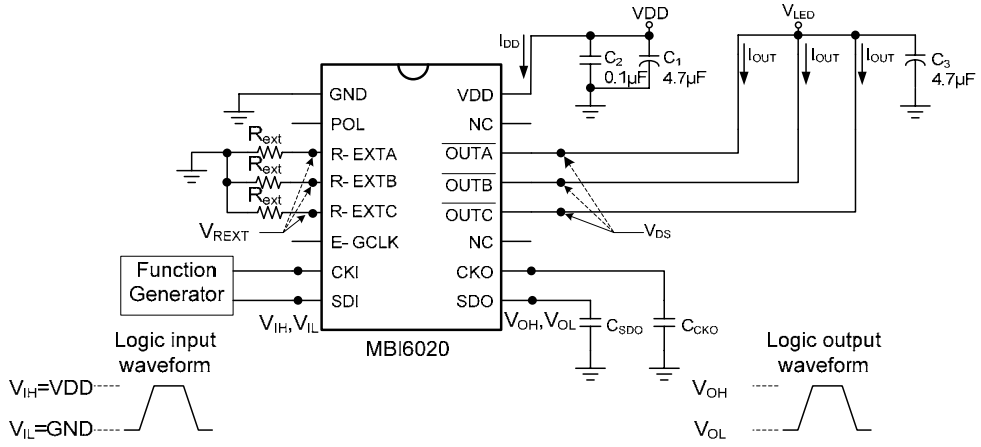
Electrical Characteristics (V_{DD}=3.3V, Ta=25°C)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-	3.0	3.3	3.6	V
Sustaining Voltage at OUT Ports		V_{DS}	$\overline{OUTA}$ ~ $\overline{OUTC}$ Off	-	-	17.0	V
Output Current		I_{OUT}	Refer to "Test Circuit for Electrical Characteristics"	5	-	50	mA
Driving Current		I_{OH}	CKO, SDO at V_{OH}=3.1V	1.8	2.0	2.8	mA
		I_{OL}	CKO, SDO at V_{OH}=0.2V	1.8	2.0	3.4	mA
Output Leakage Current		I_{OUT}	V_{DS}=17.0V and channel off	-	-	1.0	μA
Current Skew (Channel)		dI_{OUT}	I_{OUT}=20mA, V_{DS}=1.0V, R_{ext}=20Ω	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OUT}=20mA, V_{DS}=1.0V, R_{ext}=20Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		$\%/dV_{DS}$	V_{DS} within 1.0V and 3.0V	-	±0.1	±0.5	%/V
Output Current vs. Supply Voltage Regulation*		$\%/dV_{DD}$	V_{DD} within 2.7V and 3.6V	-	±1.0	±2.0	%/V
Input Voltage of CKI, SDI, E-GCLK, POL Pins	"H" level	V_{IH}	-	0.73xV_{DD}	-	V_{DD}	V
	"L" level	V_{IL}	-	GND	-	0.28xV_{DD}	V
Output Voltage of CKO, SDO Pins	"H" level	V_{OH}	I_{OH}=-3.0mA	V_{DD}-0.2	-	-	V
	"L" level	V_{OL}	I_{OL}=+3.0mA	-	-	0.2	V
Voltage at R-EXTA,B,C Pins		V_{REXT}	$\overline{OUTA}$ ~ $\overline{OUTC}$ On	0.36	0.41	0.44	V
Knee Voltage		V_{Knee}	R_{ext}=8Ω@50mA	0.75	0.85	1.00	V
Pull-up Resistor at POL Pin		R_{IN}(up)	-	-	450	-	KΩ
Pull-down Resistor at E-GCLK, NC Pins		R_{IN}(down)	-	-	450	-	KΩ
Supply Current**	"Off"	I_{DD}(off)	R_{ext}=10Ω, CKI=Low, CKO, SDO= NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ Off	-	2.0	3.5	mA
	"On"	I_{DD}(on)	R_{ext}=20Ω, CKI=Low, CKO, SDO= NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ On	-	2.5	3.5	
			R_{ext}=20Ω, CKI=10MHz, CKO, SDO= NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ On	-	4.0	5.0	

*One channel turns on.

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

Test Circuit for Electrical Characteristics



Switching Characteristics (V_{DD}=5.0V, Ta=25°C)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Setup Time	SDI–CKI↓	t_{SU}	V_{LED}=4V V_{DS}=1.0V V_{IH}=V_{DD} V_{IL}=GND I_{OUT}=20mA R_L=150Ω C_L=10pF C1=4.7uF C2=0.1uF C3=4.7uF C_{CKO}=8pF C_{SDO}=8pF	7.5	-	-	ns
Hold Time	CKI↓–SDI	t_{HD}		7.5	-	-	ns
Propagation Delay Time ("H" to "L")	CKI↑–CKO↓	t_{PHL1}		25	30	35	ns
	E-GCLK↑–$\overline{OUTA}$↓	t_{PHL3}		25	36	46	ns
Propagation Delay Time ("L" to "H")	SDO↑↓-CKO↑	t_{PHL2}		7	10	14	ns
Staggered Delay of Output	$\overline{OUTA}$ ~ $\overline{OUTB}$	t_{SD}		-	5	-	ns
	$\overline{OUTB}$ ~ $\overline{OUTC}$	t_{SD}		-	5	-	ns
Pulse Width	CKI*	$t_{w(I)}$		15	-	-	ns
Minimum Pulse Width of PWM	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{WDM}		30	35	40	ns
Rise Time	CKO–SDO	t_{OR}		2	6	10	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OR1}		6.0	11.0	16.0	ns
Fall Time	CKO–SDO	t_{OF}		2	6	10	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OF1}		15	20	25	ns
Frequency	CKI*	F_{CKI}		0.2	-	10	MHz
	GCLK	F_{GCLK}		-	-	20	
	Internal Oscillator	F_{OSC}		18.0	20.0	22.0	

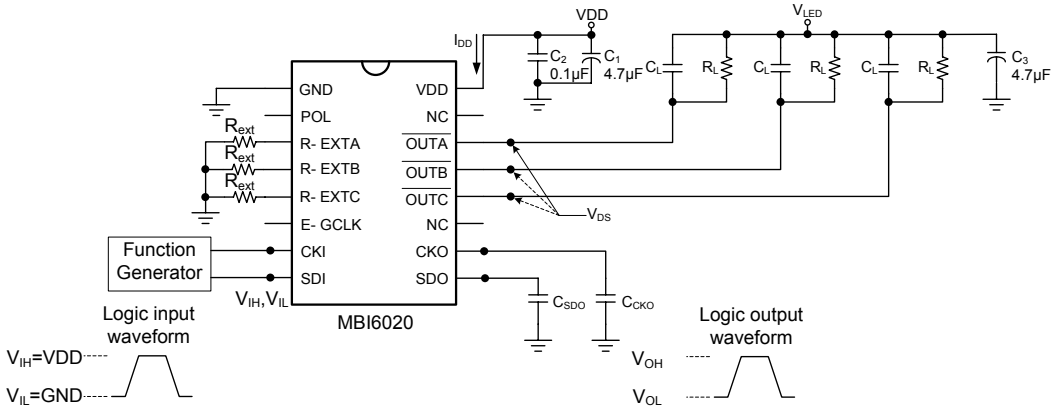
*The maximum frequency may be limited by different application conditions. Please refer to the application note for details.

Switching Characteristics (V_{DD}=3.3V, Ta=25°C)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Setup Time	CKI↓–SDI	t_{SU}	V_{LED}=4V V_{DS}=1.0V V_{IH}=V_{DD} V_{IL}=GND I_{OUT}=20mA R_L=150Ω C_L=10pF C1=4.7uF C2=0.1uF C3=4.7uF C_{CKO}=8pF C_{SDO}=8pF	7.5	-	-	ns
Hold Time	SDI–CKI↓	t_{HD}		7.5	-	-	ns
Propagation Delay Time ("H" to "L")	CKI↑–CKO↓	t_{PHL1}		40	45	50	ns
	E-GCLK↑–$\overline{OUTA}$ ↓	t_{PHL3}		30	42	54	ns
Propagation Delay Time ("L" to "H")	SDO↑↓-CKO↑	t_{PHL2}		8	12	16	ns
Staggered Delay of Output	$\overline{OUTA}$ ~ $\overline{OUTB}$	t_{SD}		-	8	-	ns
	$\overline{OUTB}$ ~ $\overline{OUTC}$	t_{SD}		-	8	-	ns
Pulse Width	CKI	$t_{w(I)}$		15	-	-	ns
Minimum Pulse Width of PWM	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{WDM}		40	55	70	ns
Rise Time	CKO–SDO	t_{OR}		4	10	15	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OR1}		13.0	20.0	25.0	ns
Fall Time	CKO–SDO	t_{OF}		4	10	15	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OF1}		20.0	25.0	30.0	ns
Frequency	CKI*	F_{CKI}		0.2	-	10	MHz
	GCLK	F_{GCLK}		-	-	20	
	Internal Oscillator	F_{OSC}		18.0	20.0	22.0	

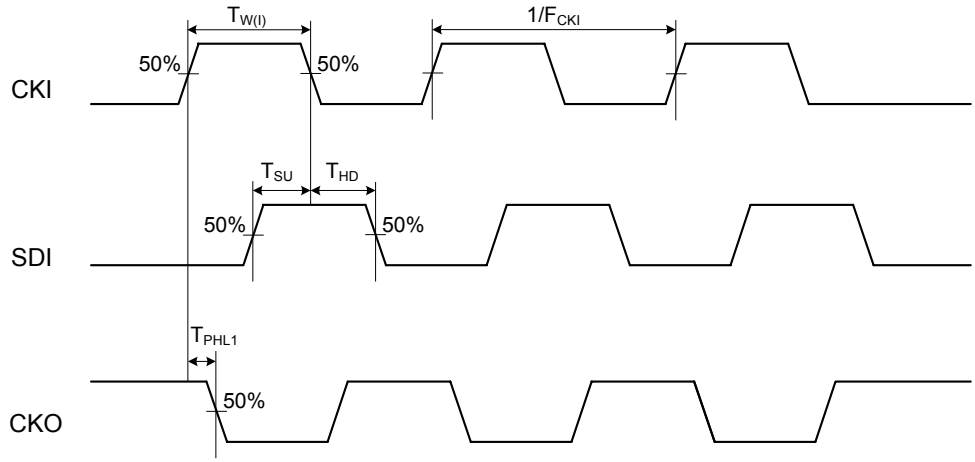
*The maximum frequency may be limited by different application conditions. Please refer to the application note for details.

Test Circuit for Switching Characteristics

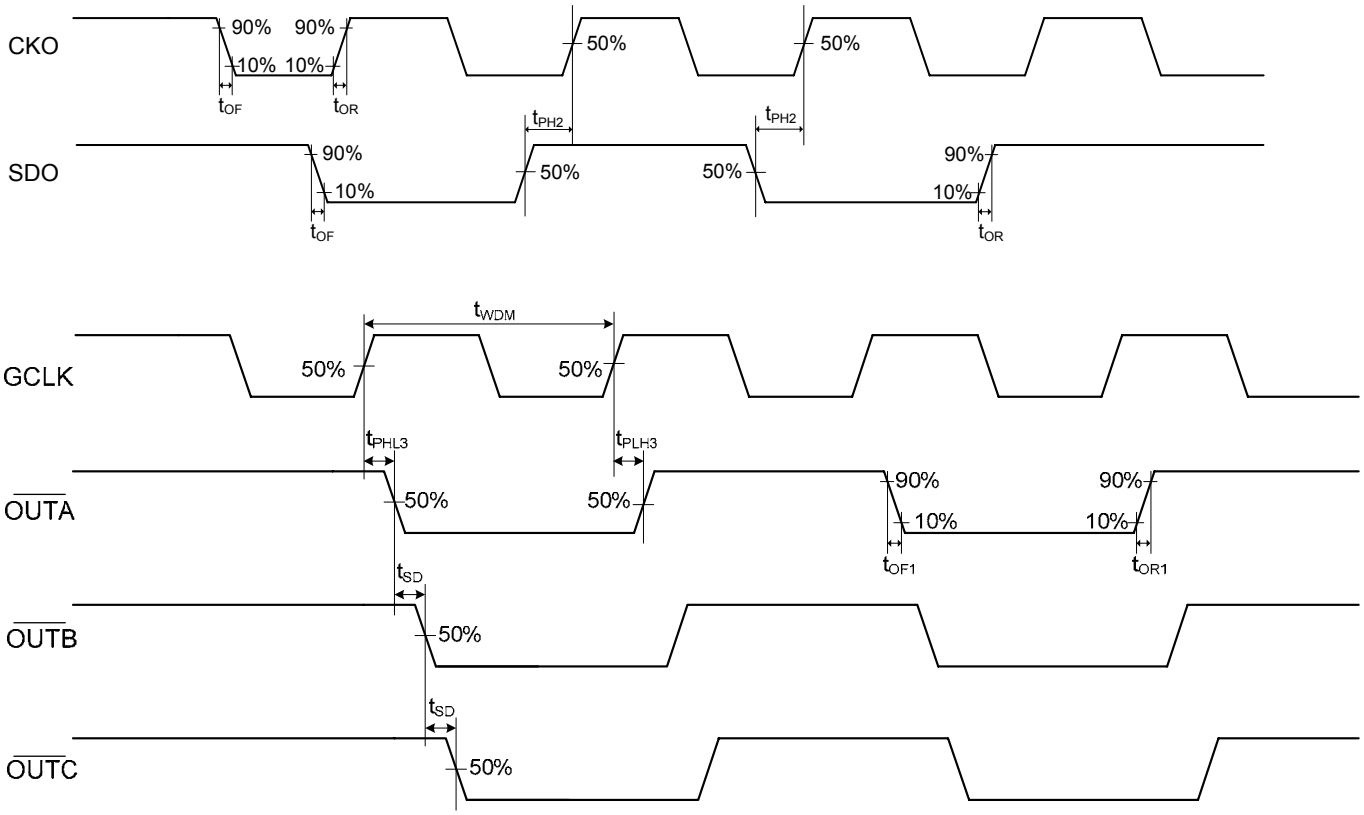


Timing Waveform

Signal Input and Output with Clock Reverse



Output Timing



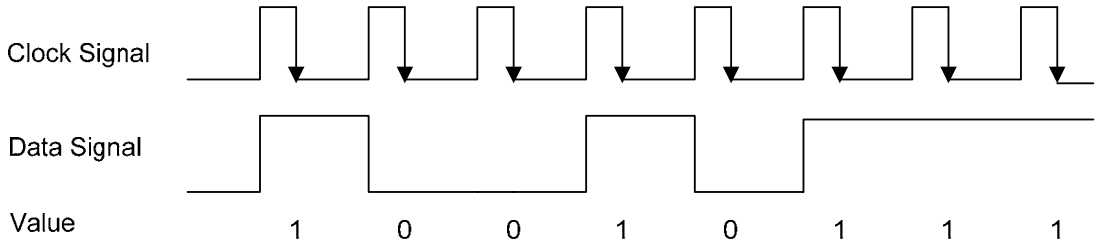
Principle of Operation

MBI6020 receives the data packet containing targeted gray scale data from the controller, and turns on the output channels according to the gray scale data. The gray scale clock of PWM generator, GCLK, can be used as the embedded oscillator or the external clock source. MBI6020 provides SPI-like interface (CKI, SDI), a two-wire only transmission interface, to address the data, so that MBI6020 receives the data directly without latching data.

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

MBI6020 adopts the SPI-like interface (CKI/SDI). By SPI-like interface, MBI6020 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)



Gray Scale Control

MBI6020 provides two gray scale modes: 16-bit gray scale mode and 10-bit gray scale mode. MBI6020 specifically 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, the default PWM clock frequency is 10MHz (the frequency of internal oscillator/2), and therefore, the visual refresh rate of 16-bit gray scale mode will be increased to: 10MHz/65536x64=9,766Hz

On the other hand, MBI6020 provides 10-bit gray scale mode by traditional PWM. In 16-bit gray scale mode, MBI6020 achieves 65,536 gray scales for each LED, and in 10-bit gray scale mode, MBI6020 achieves 1,024 gray scales.

MBI6020 continuously repeats the PWM cycle and turns on the output ports according to the image data until the next image data is correctly recognized. Once the next input data is correctly recognized, MBI6020 will stop the present PWM cycle and restart a new PWM cycle to show the new data immediately.

Dot Correction Control

MBI6020 also provides 8-bit or 6-bit dot correction control in 16-bit or 10-bit gray scale mode respectively. Dot correction control helps calibrate LED brightness and reduces the loading of calculation in controllers. In addition, designed with S-PWM technology, MBI6020 operates dot correction without sacrificing the visual refresh rate.

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

16-bit gray scale data with 8-bit dot correction data

The following is the equation for the duty cycle of output in 16-bit gray scale mode. For 8-bit dot correction, the default value of dot correction data is 255.

$$\text{The duty cycle of output (\%)} = \frac{\text{16-bit gray scale data} \times \frac{(\text{8-bit dot correction data} + 1)}{256}}{65{,}536} \times 100\%$$

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

Example	Gray scale data	Dot correction data	Duty Cycle of Output
1	32,768	255 (Default)	50%
2	32,768	127	25%
3	16,384	255	25%
. . .	. . .	. . .	. . .

10-bit gray scale with 6-bit dot correction data

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.

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

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

Example	Gray scale data	Dot correction data	Duty Cycle of Output
1	512	63 (Default)	50%
2	512	15	12.5%
3	256	31	12.5%
. . .	. . .	. . .	. . .

Setting the Data Types by the Header

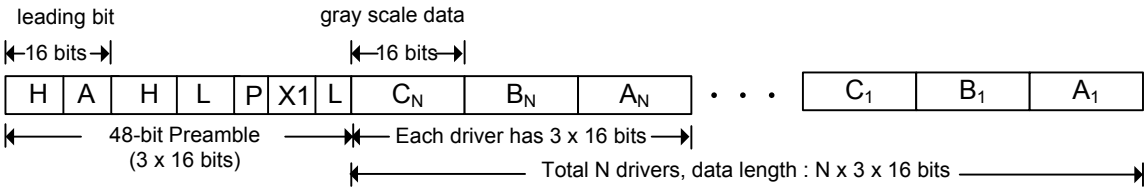
MBI6020 provides six kinds of headers and input data types shown as the table below:

Header H[5:0]	**Data Type**
6'b11 1111	16-bit gray scale data
6'b10 1011	10-bit gray scale data
6'b11 0011	8-bit dot correction data
6'b10 0111	6-bit dot correction data
6'b10 0011	16-bit configuration data
6'b11 0111	10-bit configuration data

Once MBI6020 receives the SDI=1 (1'b1), MBI6020 will start to check if the data is a valid header or not. If the 6-bit data is a valid header, the driver will latch the specific data according to the protocol. If the 6-bit data is not a valid header, MBI6020 will wait for another SDI=1 (1'b1) to check the validity of the next header.

16-bit Gray Scale Data

For 16-bit gray scale data, each word is 16 bits. Each MBI6020 needs 3 words (3x16=48 bits) for the gray scale data of $\overline{OUTC}$, $\overline{OUTB}$ and $\overline{OUTA}$. Prior to the gray scale data, there is a 48-bit preamble. MBI6020 provides parity check function to check the count of bit to prevent the data transmission error. The data format is shown below:



48-bit preamble

Bit	Definition	Value	Function
47:42	H[5:0]	111111	The header of 16-bit gray scale data
41:32	A[9:0]	0000000000	Address. Always send 10'b 0000000000
31:26	H[5:0]	111111	Double check the header
25:16	L[9:0]	N -1. N=Number of IC in series	Set the number of IC in series
15:12	P[3:0]	0000~1111	P[0] is the parity check bit of L[9:0] P[0]=1 if the count of "1" within L[9:0] is odd; P[0]=0 if the count of "1" within L[9:0] is even. P[1] is the parity check bit of A[9:0] P[1]=1 if the count of "1" within A[9:0] is odd; P[1]=0 if the count of "1" within A[9:0] is even. P[2] is the parity check bit of H[5:0] P[2]=1 if the count of "1" within H[5:0] is odd; P[2]=0 if the count of "1" within H[5:0] is even. P[3] is the parity check bit of P[2:0] P[3]=1 if the count of "1" within P[2:0] is odd; P[3]=0 if the count of "1" within P[2:0] is even.
11:10	X1[1:0]	XX	Don't care
9:0	L[9:0]	N-1. N=Number of IC in series	Double check the number of IC in series

48-bit gray scale data

Bit	Definition	Value	Function
47:32	C_N[15:0]	0000000000000000~1111111111111111	16 bits gray scale data of the nth $\overline{OUTC}$ The ratio of $\overline{OUTC}$ turn-on time will be $C_N[15:0]/2^{16}$.
31:16	B_N[15:0]	0000000000000000~1111111111111111	16 bits gray scale data of the nth $\overline{OUTB}$ The ratio of $\overline{OUTB}$ turn-on time will be $B_N[15:0]/2^{16}$.
15:0	A_N[15:0]	0000000000000000~1111111111111111	16 bits gray scale data of the nth $\overline{OUTA}$ The ratio of $\overline{OUTA}$ turn-on time will be $A_N[15:0]/2^{16}$.

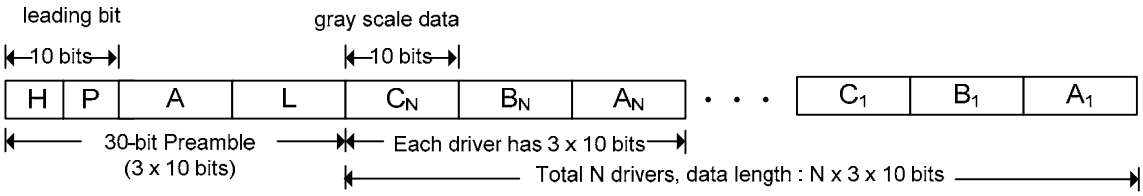
The gray scale data of the last IC is sent first, followed by the previous ICs, and the first IC's gray scale data is sent in the end of the packet.

Example:

Gray scale data	The ratio of output turn-on time
0	$0/2^{16}$
1	$1/2^{16}$
2	$2/2^{16}$
⋮	⋮
65535	$65535/2^{16}$

10-bit Gray Scale Data

For 10-bit gray scale data, each word is 10 bits. Each MBI6020 needs 3 words (3x10=30 bits) for the gray scale data of $\overline{OUTC}$, $\overline{OUTB}$ and $\overline{OUTA}$. Prior to the gray scale data, there is a 30-bit preamble. MBI6020 provides parity check function to check the count of bit to prevent the data transmission error. The data format is shown below:



30-bit preamble

Bit	Definition	Value	Function
29:24	H[5:0]	101011	The header of 10-bit gray scale data
23:20	P[3:0]	0000~1111	P[0] is the parity check bit of L[9:0]. P[0]=1 if the count of "1" within L[9:0] is odd; P[0]=0 if the count of "1" within L[9:0] is even. P[1] is the parity check bit of A[9:0] P[1]=1 if the count of "1" within A[9:0] is odd; P[1]=0 if the count of "1" within A[9:0] is even. P[2] is the parity check bit of H[5:0] P[2]=1 if the count of "1" within H[5:0] is odd; P[2]=0 if the count of "1" within H[5:0] is even. P[3] is the parity check bit of P[2:0] P[3]=1 if the count of "1" within P[2:0] is odd; P[3]=0 if the count of "1" within P[2:0] is even.
19:10	A[9:0]	0000000000	Address. Always send 10'b 0000000000
9:0	L[9:0]	N-1. N=Number of IC in series	Set the number of IC in series

30-bit gray scale data

Bit	Definition	Value	Function
29:20	C_N[9:0]	0000000000~1111111111	10 bits gray scale data of the nth $\overline{OUTC}$ The ratio of $\overline{OUTC}$ turn-on time will be $C_N[9:0]/2^{10}$.
19:10	B_N[9:0]	0000000000~1111111111	10 bits gray scale data of the nth $\overline{OUTB}$ The ratio of $\overline{OUTB}$ turn-on time will be $B_N[9:0]/2^{10}$.
9:0	A_N[9:0]	0000000000~1111111111	10 bits gray scale data of the nth $\overline{OUTA}$ The ratio of $\overline{OUTA}$ turn-on time will be $A_N[9:0]/2^{10}$.

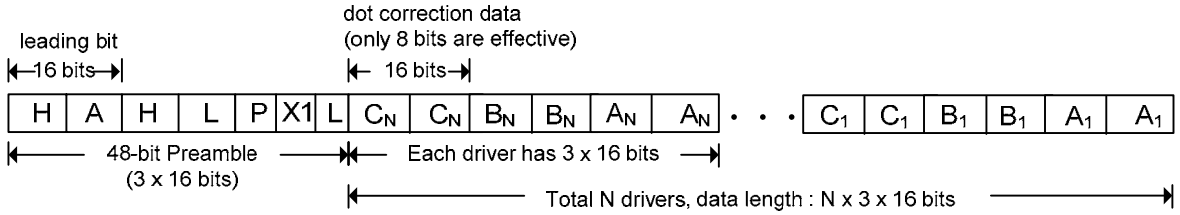
The gray scale data of the last IC is sent first, followed by the previous ICs, and the first IC's gray scale data is sent in the end of the packet.

Example:

Gray scale data	The ratio of output turn-on time
0	$0/2^{10}$
1	$1/2^{10}$
2	$2/2^{10}$
⋮	⋮
1023	$1023/2^{10}$

8-bit Dot Correction Data

For 8-bit dot correction data, each word is 16 bits. Each MBI6020 needs 3 words (3x16=48 bits) for the dot correction data of $\overline{OUTC}$, $\overline{OUTB}$ and $\overline{OUTA}$. However, each dot correction data has only 8 bits, and the first 8 bits of each word are checking bits of dot correction. Prior to the dot correction data, there is a 48-bit preamble. MBI6020 provides parity check function to check the count of bit to prevent the data transmission error. The data format is shown below:



48-bit preamble

Bit	Definition	Value	Function
47:42	H[5:0]	110011	The header of 8-bit dot correction data
41:32	A[9:0]	0000000000	Address. Always send 10'b 0000000000
31:26	H[5:0]	110011	Double check the header
25:16	L[9:0]	N-1. N=Number of IC in series	Set the number of IC in series
15:12	P[3:0]	0000~1111	P[0] is the parity check bit of L[9:0]. P[0]=1 if the count of "1" within L[9:0] is odd; P[0]=0 if the count of "1" within L[9:0] is even. P[1] is the parity check bit of A[9:0] P[1]=1 if the count of "1" within A[9:0] is odd; P[1]=0 if the count of "1" within A[9:0] is even. P[2] is the parity check bit of H[5:0] P[2]=1 if the count of "1" within H[5:0] is odd; P[2]=0 if the count of "1" within H[5:0] is even. P[3] is the parity check bit of P[2:0] P[3]=1 if the count of "1" within P[2:0] is odd; P[3]=0 if the count of "1" within P[2:0] is even.
11:10	X1[1:0]	XX	Don't care
9:0	L[9:0]	N-1. N=Number of IC in series	Double check the number of IC in series

48-bit dot correction data

Bit	Definition	Value	Function
47:40	C_N[7:0]	00000000~11111111	Double check the dot correction data of $\overline{OUTC}$. It should be the same as bit [39:32]; otherwise, the dot correction data will not be latched.
39:32	C_N[7:0]	00000000~11111111	8 bits, dot correction data of $\overline{OUTC}$ The ratio of $\overline{OUTC}$ turn-on time will be (C_N[7:0]+1)/256 x gray scale data C_N.
31:24	B_N[7:0]	00000000~11111111	Double check the dot correction data of $\overline{OUTB}$. It should be the same as bit[23:16]; otherwise, the dot correction data will not be latched.
23:16	B_N[7:0]	00000000~11111111	8 bits, dot correction data for $\overline{OUTB}$ The ratio of $\overline{OUTB}$ turn-on time will be (B_N[7:0]+1)/256 x gray scale data B_N.
15:8	A_N[7:0]	00000000~11111111	Double check the dot correction data of $\overline{OUTA}$ .It should be the same as bit[7:0]; otherwise, the dot correction data will not be latched.
7:0	A_N[7:0]	00000000~11111111	8 bits, dot correction data for $\overline{OUTA}$ The ratio of $\overline{OUTA}$ turn-on time will be (A_N[7:0]+1)/256 x gray scale data A_N.

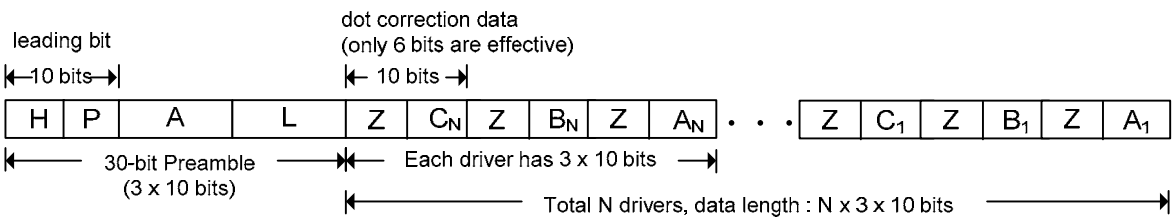
The dot correction data of the last IC is sent first, followed by the previous ICs, and the first IC's dot correction data is sent in the end of the packet.

Example:

Dot correction data	Number of turn-on GCLK
0	1/256 x gray scale data
1	2/256 x gray scale data
2	3/256 x gray scale data
. . .	. . .
255	256/256 x gray scale data

6-bit Dot Correction Data

For 6-bit dot correction data, each word is 10 bits. Each MBI6020 needs 3 words (3x10=30 bits) for the dot correction data of $\overline{OUTC}$, $\overline{OUTB}$ and $\overline{OUTA}$. 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 preamble. MBI6020 provides parity check function to check the count of bit to prevent the data transmission error. The data format is shown below:



30-bits preamble

Bit	Definition	Value	Function
29:24	H[5:0]	100111	The header of 6-bit dot correction data
23:20	P[3:0]	0000~1111	P[0] is the parity check bit of L[9:0]. P[0]=1 if the count of "1" within L[9:0] is odd; P[0]=0 if the count of "1" within L[9:0] is even. P[1] is the parity check bit of A[9:0] P[1]=1 if the count of "1" within A[9:0] is odd; P[1]=0 if the count of "1" within A[9:0] is even. P[2] is the parity check bit of H[5:0] P[2]=1 if the count of "1" within H[5:0] is odd; P[2]=0 if the count of "1" within H[5:0] is even. P[3] is the parity check bit of P[2:0] P[3]=1 if the count of "1" within P[2:0] is odd; P[3]=0 if the count of "1" within P[2:0] is even.
19:10	A[9:0]	0000000000	Address. Always send 10'b 0000000000
9:0	L[9:0]	N-1. N=Number of IC in series	Set the number of IC in series

30-bit dot correction data

Bit	Definition	Value	Function
29:26	Z[3:0]	0000	Check bits of C_N[5:0]. Please send 4b'0000; otherwise, the dot correction data will not be latched.
25:20	C_N[5:0]	000000~111111	6 bits dot correction data for $\overline{OUTC}$ The ratio of $\overline{OUTC}$ turn-on time will be (C_N[5:0]+1)/64 x gray scale data C_N.
19:16	Z[3:0]	0000	Check bits of B_N[5:0]. Please send 4b'0000; otherwise, the dot correction data will not be latched.
15:10	B_N[5:0]	000000~111111	6 bits dot correction data for $\overline{OUTB}$ The ratio of $\overline{OUTB}$ turn-on time will be (B_N[5:0]+1)/64 x gray scale data B_N.
9:6	Z[3:0]	0000	Check bits of A_N[5:0]. Please send 4b'0000; otherwise, the dot correction data will not be latched.
5:0	A_N[5:0]	000000~111111	6 bits dot correction data for $\overline{OUTA}$ The ratio of $\overline{OUTA}$ turn-on time will be (A_N[5:0]+1)/64 x gray scale data A_N.

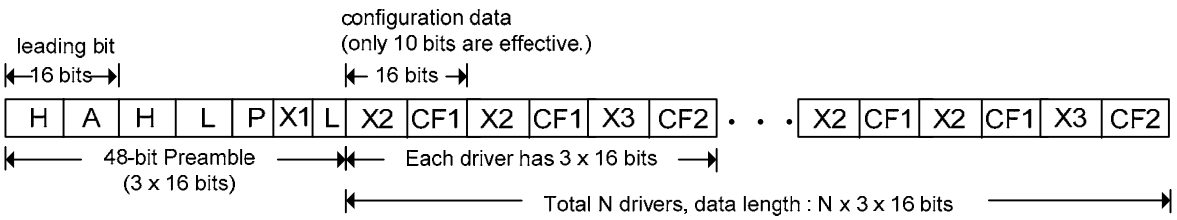
The dot correction data of the last IC is sent first, followed by the previous ICs, and the first IC's dot correction data is sent in the end of the packet.

Example:

Dot correction data	Number of turn-on GCLK
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

16-bit Configuration Data

For 16-bit configuration data, each word is 16 bits. Each MBI6020 needs 3 words (3x16=48 bits) for the configuration data. However, each configuration data has only 10 bits, and the MSB 6 bits of each word are invalid. Prior to the configuration data, there is a 48-bit preamble. MBI6020 provides parity check function to check the count of bit to prevent the data transmission error. The data format is shown below:



48-bits preamble

Bit	Definition	Value	Function
47:42	H[5:0]	100011	The header of 16-bit configuration data
41:32	A[9:0]	0000000000	Address. Always send 10'b 0000000000
31:26	H[5:0]	100011	Double check the header
25:16	L[9:0]	N-1. N=Number of IC in series	Set the number of IC in series
15:12	P[3:0]	0000~1111	P[0] is the parity check bit of L[9:0] P[0]=1 if the count of "1" within L[9:0] is odd; P[0]=0 if the count of "1" within L[9:0] is even. P[1] is the parity check bit of A[9:0] P[1]=1 if the count of "1" within A[9:0] is odd; P[1]=0 if the count of "1" within A[9:0] is even. P[2] is the parity check bit of H[5:0] P[2]=1 if the count of "1" within H[5:0] is odd; P[2]=0 if the count of "1" within H[5:0] is even. P[3] is the parity check bit of P[2:0] P[3]=1 if the count of "1" within P[2:0] is odd; P[3]=0 if the count of "1" within P[2:0] is even.
11:10	X1[1:0]	XX	Don't care
9:0	L[9:0]	N-1. N=Number of IC in series	Double check the number of IC in series

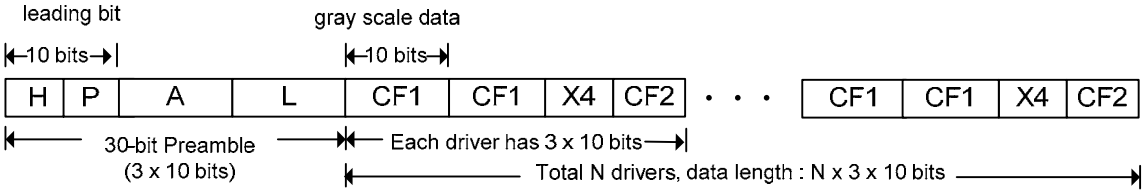
48-bit configuration data

Bit	Definition	Value	Function
47:42	X2[5:0]	XXXXXX	Don't care
41:32	CF1[9:0]	0000000000~1111111111	10 bits data of configuration register bank 1 (CF1)
31:26	X2[5:0]	XXXXXX	Don't care
25:16	CF1[9:0]	0000000000~1111111111	Double check the data of configuration register bank 1 (CF1). It should be the same as bit[41:32], otherwise the data will not be written into register.
15:3	X3[12:0]	XXXXXXXXXXXXX	Don't care.
2:0	CF2[2:0]	000~111	3 bits data of configuration register bank 2 (CF2)

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

10-bit Configuration Data

For 10-bit configuration data, each word is 10 bits. Each MBI6020 needs 3 words (3x10=30 bits) for the configuration data. Prior to the configuration data, there is a 30-bit preamble. MBI6020 provides parity check function to check the count of bit to prevent the data transmission error. The data format is shown below:



30-bit preamble

Bit	Definition	Value	Function
29:24	H[5:0]	110111	The header of 10-bit configuration data
23:20	P[3:0]	0000~1111	P[0] is the parity check bit of L[9:0]. P[0]=1 if the count of "1" within L[9:0] is odd; P[0]=0 if the count of "1" within L[9:0] is even. P[1] is the parity check bit of A[9:0] P[1]=1 if the count of "1" within A[9:0] is odd; P[1]=0 if the count of "1" within A[9:0] is even. P[2] is the parity check bit of H[5:0] P[2]=1 if the count of "1" within H[5:0] is odd; P[2]=0 if the count of "1" within H[5:0] is even. P[3] is the parity check bit of P[2:0] P[3]=1 if the count of "1" within P[2:0] is odd; P[3]=0 if the count of "1" within P[2:0] is even.
19:10	A[9:0]	0000000000	Address. Always send 10'b 0000000000
9:0	L[9:0]	N-1. N=Number of IC in series	Set the number of IC in series

30-bit configuration data

Bit	Definition	Value	Function
29:20	CF1[9:0]	0000000000~1111111111	10 bits data of configuration register bank 1 (CF1)
19:10	CF1[9:0]	0000000000~1111111111	Double check the data of configuration register bank 1(CF1). It should be the same as bit[29:20]; otherwise, the data will not be written into register.
9:3	X4[6:0]	XXXXXXX	Don't care
2:0	CF2[2:0]	000~111	3 bits data of configuration register bank 2 (CF2)

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

Definition of Configuration Register

MBI6020 provides two configuration register banks: configuration register bank 1 (CF1) and configuration register bank 2 (CF2) as defined in the tables below.

Configuration Register Bank 1 (CF1):

	MSB									LSB
Bit	9	8	7	6	5	4	3	2	1	0
Default Value	10		0	11		1	1	11		0

Note: Bit [15:10] should be set as “0” to avoid signal misjudgment.

Bit	Definition	Value	Function
9:8	PWM clock frequency selection	11	PWM clock=frequency of internal oscillator
		10(default)	PWM clock=frequency of internal oscillator divided by two
		01	PWM clock=frequency of internal oscillator divided by four
		00	PWM clock=frequency of internal oscillator divided by eight
7	Reserved	0	Reserved
6:5	GCLK source selection	11(default)	Internal oscillator
		10	E-GCLK pin
		01	CKI pin
		00	Reserved
4	PWM counter reset	1(default)	PWM counter reset after configuring control register
		0	PWM counter does not reset after configuring control register
3	PWM data synchronization	1(default)	Automatic synchronization
		0	Manual synchronization
2:1	Clock reverse	11	The waveform is reversed from CKI to CKO; other combinations are reserved for internal tests.
0	Parity check	1	Enable
		0(default)	Disable

PWM Clock Frequency

MBI6020 provides four kinds of internal GCLK frequency, which is the internal oscillator frequency divided by 1, 2, 4, and 8, for different applications according to the bits of CF1[9:8].

GCLK Source Selection

MBI6020 provides flexibility to select GCLK source by setting the bits of CF1[6:5].

PWM Counter Reset

MBI6020 can optionally reset the PWM counter by setting the bit of CF1[4] after programming configuration data.

PWM Data Synchronization

MBI6020 is also flexible for either manual-synchronization or auto-synchronization by setting the bit of CF1[3]. For auto-synchronization, the bit of CF1[3] is set to “1” (default). MBI6020 will automatically process the synchronization of previous data and next data for PWM counting. The next image data will be updated to output buffers and start PWM counting when the previous data finishes one internal PWM cycle.

For manual-synchronization, the bit of CF1[3] is set to “0”. Once the next input data is correctly recognized, MBI6020 will stop the present PWM cycle and restart a new PWM cycle to show the new data immediately.

Clock Reverse

MBI6020 enhances the capability of cascading MBI6020 from clock reverse function by setting the bits of CF1[2:1]. The waveform will be reversed from CKI to CKO to balance the duty of the clock signal. This improves the signal integrity of data transmission.

Configuration Register Bank 2 (CF2):

Default Value

	MSB		LSB
Bit	2	1	0
Value	111		

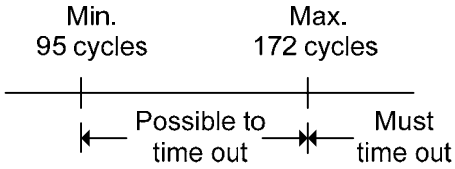
Note: Bit [15:3] should be set as “0” to avoid signal misjudgment.

Bit	Definition	Value	Function
2	Time-out	1 (default)	Enable
		0	Disable
1:0	CKI time-out period selection	11(default)	95~172 cycles
		10	47~86 cycles
		01	23~44 cycles
		00	11~22 cycles

Time-Out Protection

The time-out protection can be enabled or disabled by the bit of CF2[2]. In addition, the time-out period can be set by the bits of CF2[1:0]. The default value is 95~172 cycles. If the CKI pulled-low for more than the preset period, MBI6020 may identify the wires as disconnection. To prevent from misreading, MBI6020 will ignore the present input data and continuously show the previous image data until the next image data is correctly recognized. Users may choose a suitable time-out period depending on the timing of the control system.

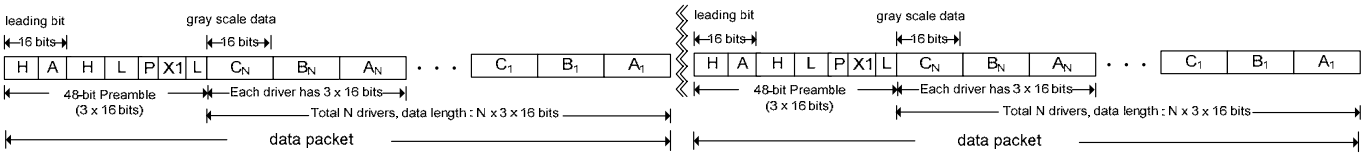
Take the default CKI time-out period (CF2[1:0]=11) for example, MBI6020 may recognize the input data as a new packet during the CKI time-out period (95~172 cycles). To prevent from time-out, users should limit the period shorter than 95 cycles. The illustration is as below:



The Interval between Two Data Packets

MBI6020 identifies the data as a new packet after time-out, so the interval between two data packets should be larger than the maximum value of the CKI time-out period. For example, if the CF2[1:0]=11 (default), the interval between two data packets should be larger than 172 cycles.

If CKI is pulled-low and stops for more than the setting of CKI time-out period, MBI6020 will start to check the valid header of the next data packet. The time-out interval between two data packets helps MBI6020 identify the data stream correctly. The following timing diagram illustrates the interval between two data packets in 16-bit gray scale mode.

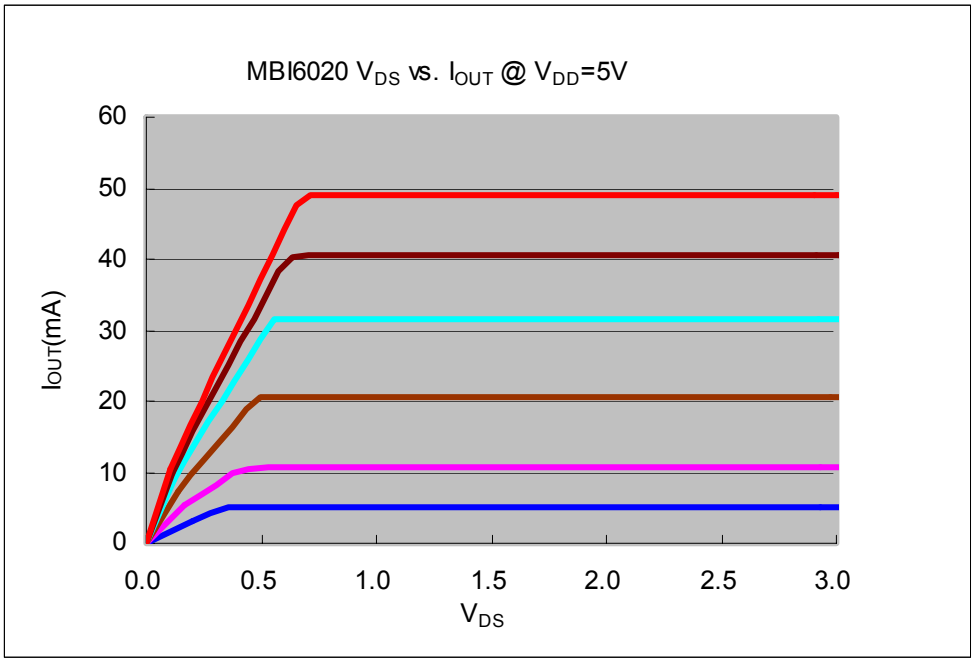


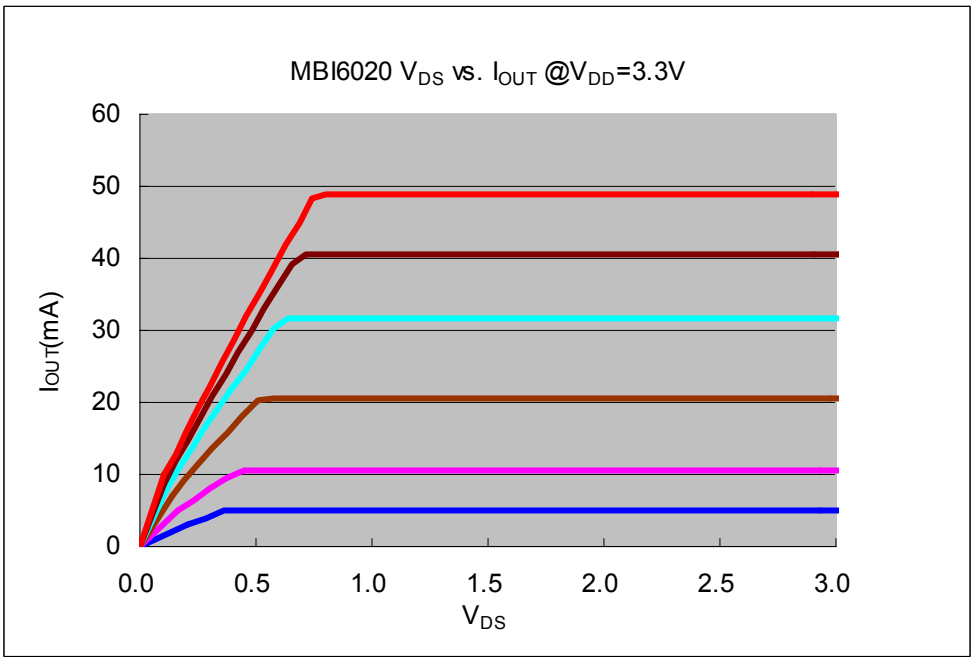
The interval between two data packets > maximum value of CKI time-out period (172 / 86 / 44 / 22 clocks).

Constant Current

1) MBI6020 performs excellent current skew: the maximum current variation between channels is less than ±3%, and that between ICs is less than ±6%.

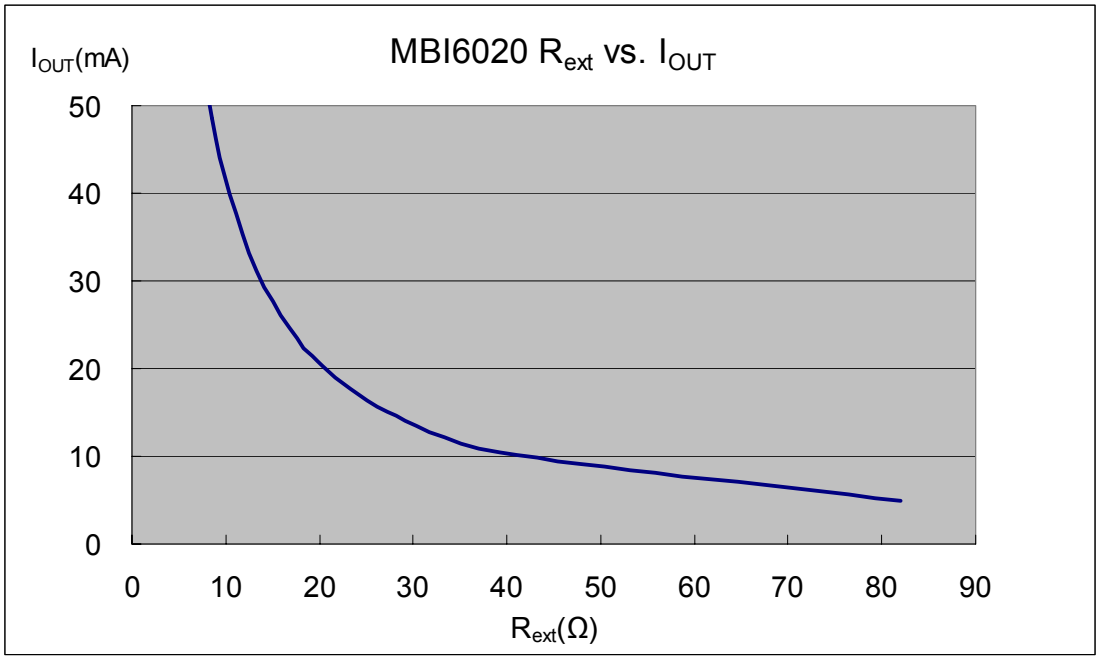
2) In addition, in the saturation region, the output current keeps constant when the output voltage (V_{DS}) is changed. This characteristic guarantees the LED show the same brightness regardless of the variations of LED forward voltages (V_F).





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.



The output current of each channel (I_{OUT}) is set by an external resistor, R_{ext}. When output channels are turned on, V_{REXT} is around 0.4V. The relationship between I_{OUT} and R_{ext} is shown in the following figure.

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

$I_{OUTA}=V_{REXT}/R_{extA}$

$I_{OUTB}=V_{REXT}/R_{extB}$

$I_{OUTC}=V_{REXT}/R_{extC}$

Where R_{extA}, R_{extB}, and R_{extC} are the resistances of the external resistors connected to R-EXTA, R-EXTB, R-EXTC terminals.

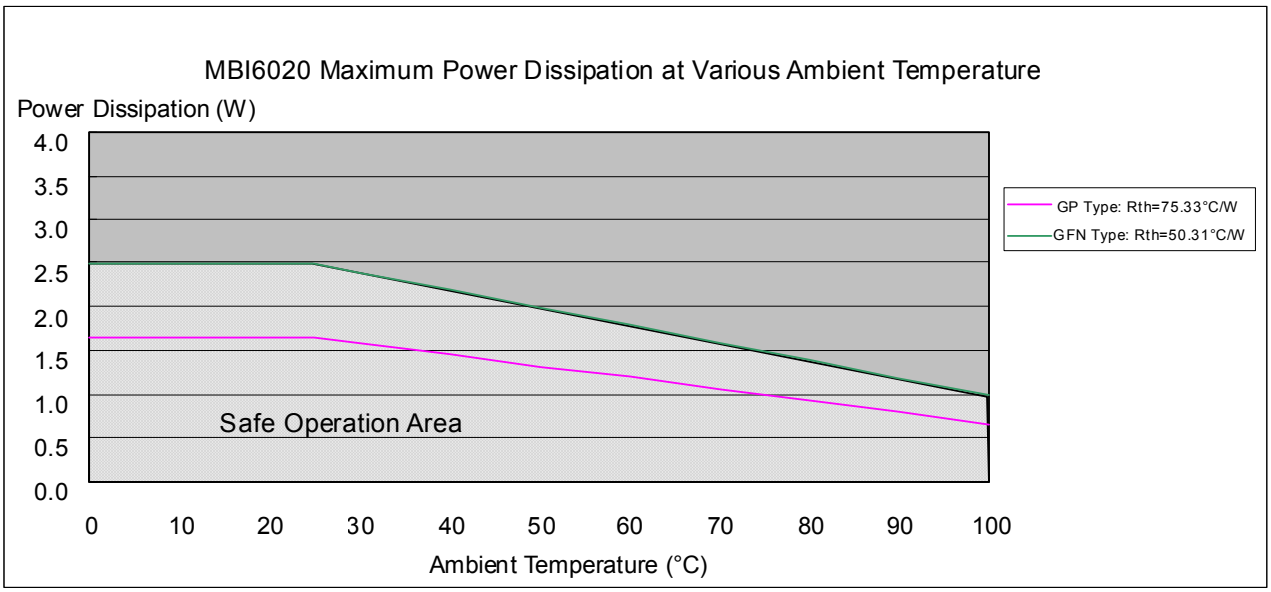
Package Power Dissipation (P_D)

The maximum power dissipation, $P_D(max)=(T_{j,max}–T_a)/R_{th(j-a)}$, decreases as the ambient temperature increases.

The power dissipation (P_D) of MBI6020 is calculated by the equation:

$P_D=(V_{DD}xI_{DD})+[I_{OUTA}x(V_{DSA}–V_{REXTA})]+[I_{OUTB}x(V_{DSB}–V_{REXTB})]+[I_{OUTC}x(V_{DSC}–V_{REXTC})]$

Please refer to the following figure to design within the safe operation area.



Load Supply Voltage (V_{LED})

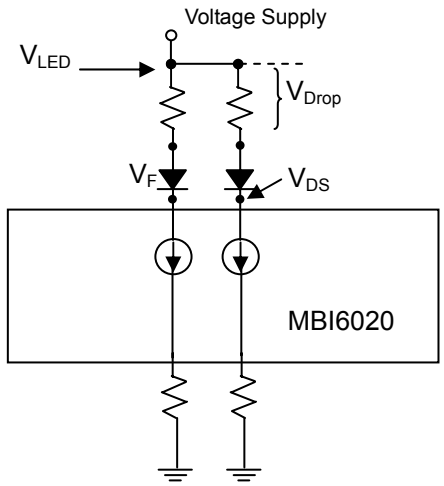
The design of V_{LED} should fulfill two targets:

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

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 resister.

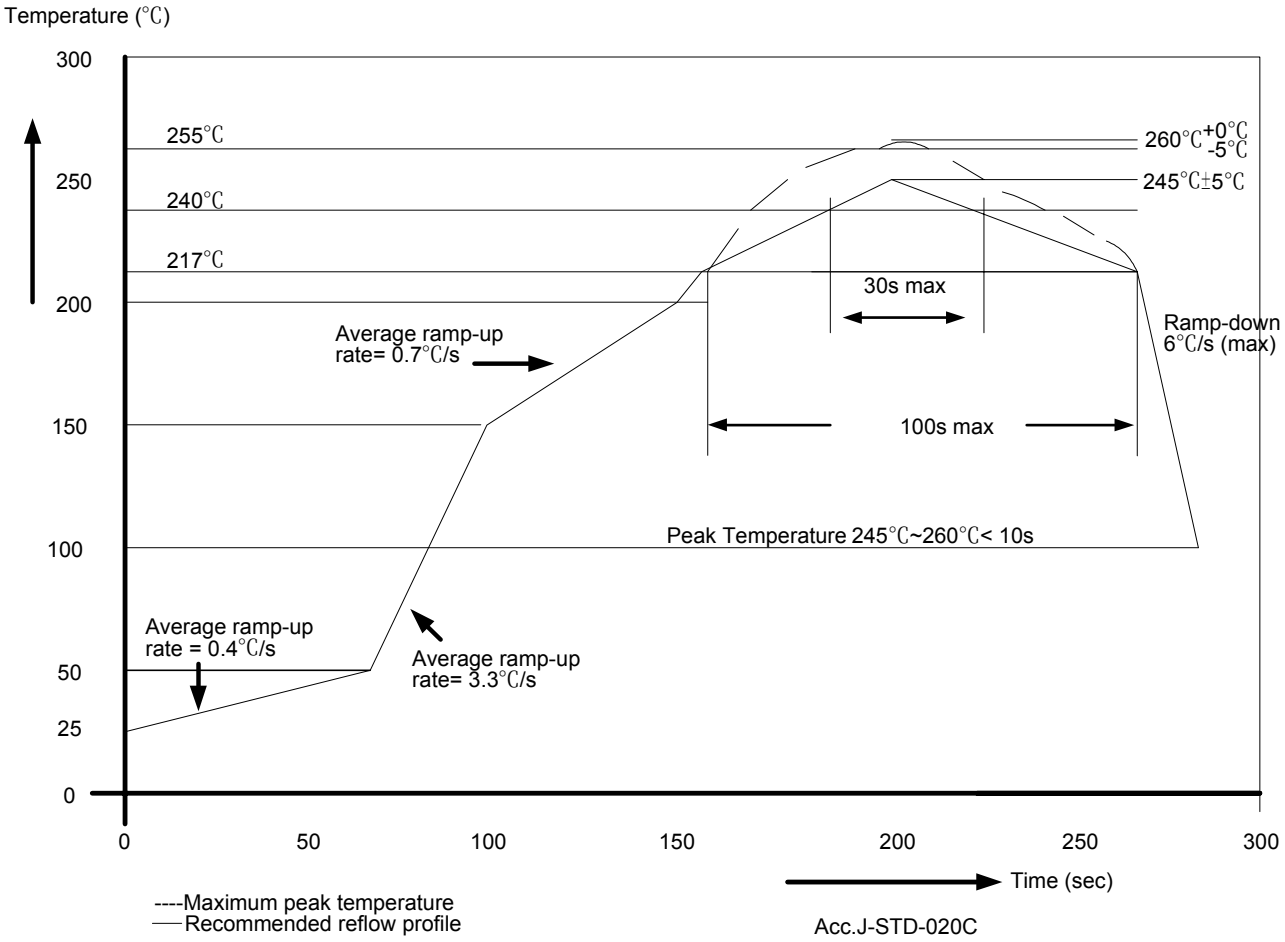


Switching Noise Reduction

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"***.

Soldering Process of "Pb-free" Package Plating*

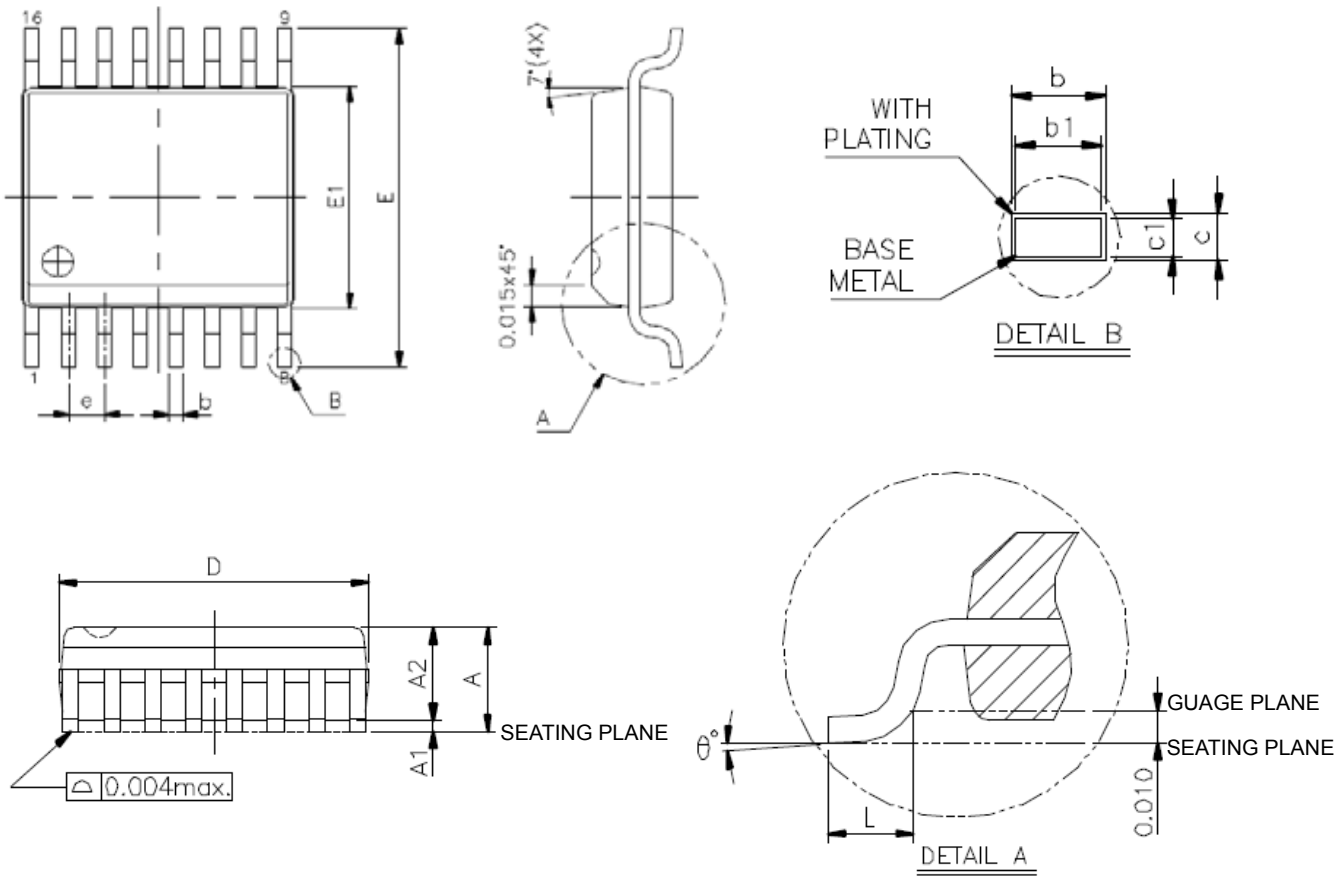
Macroblock has defined "Pb-Free" to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free processes. 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 215ºC to 240ºC 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 J-STD-020C as shown below.



Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 ≧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

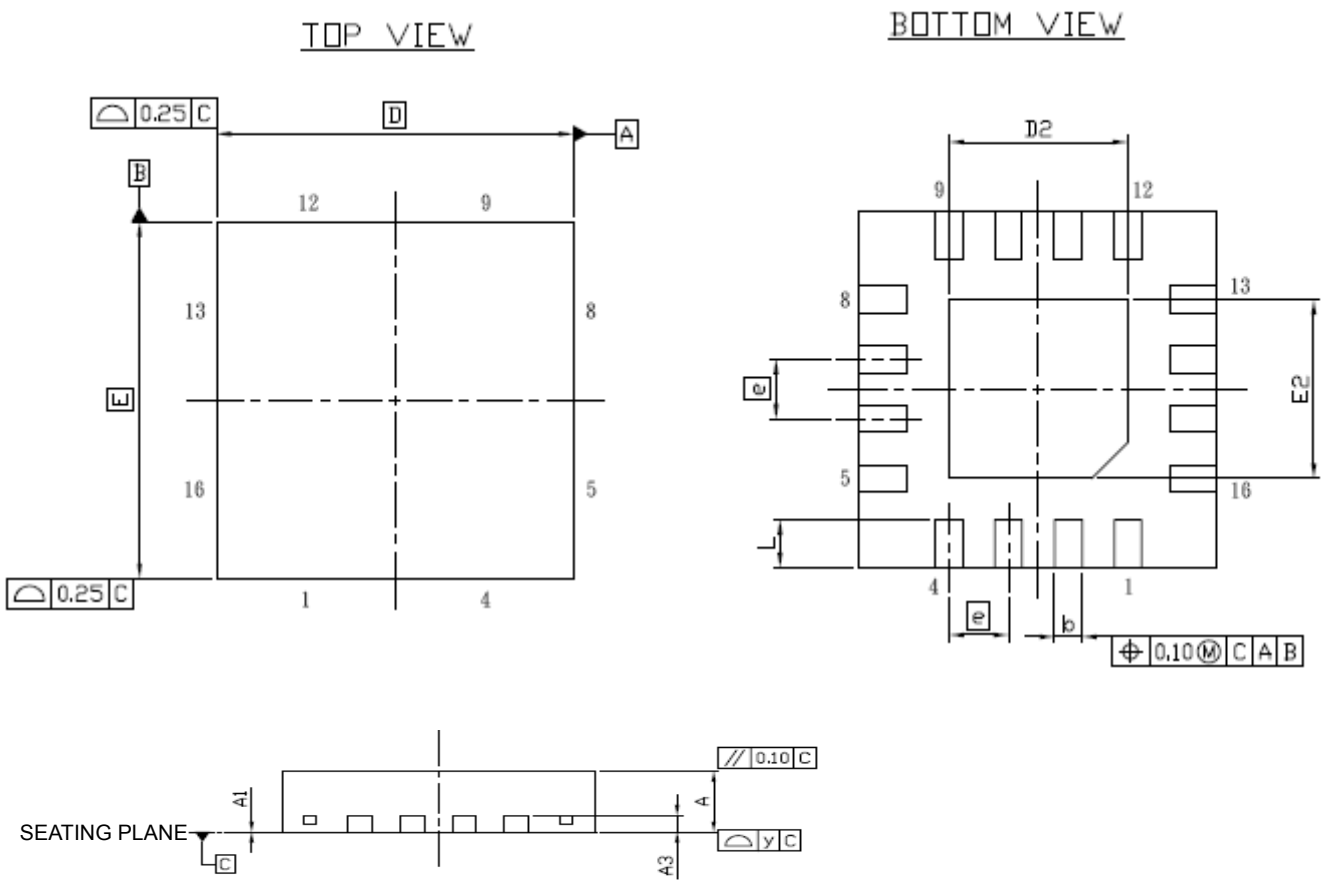
*Note: For details, please refer to Macroblock's "Policy on Pb-free & Green Package".

Package Outline



SYMBOLS	Dimensions shown in inchs			Dimensions shown in millimeters		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.053	—	0.069	1.346	—	1.753
A1	0.004	—	0.010	0.102	—	0.254
A2	0.049	—	0.059	1.245	—	1.499
b	0.008	—	0.012	0.203	—	0.305
b1	0.008	0.010	0.011	0.203	0.254	0.279
c	0.007	—	0.010	0.178	—	0.254
c1	0.007	0.008	0.009	0.178	0.203	0.229
D	0.189	0.193	0.197	4.801	4.902	5.004
E1	0.150	0.154	0.157	3.810	3.912	3.988
E	0.228	0.236	0.244	5.791	5.994	6.198
L	0.016	—	0.050	0.406	—	1.270
e	0.025 BASIC			0.635 BASIC		
Θ°	0	—	8	0	—	8

MBI6020GP Outline Drawing



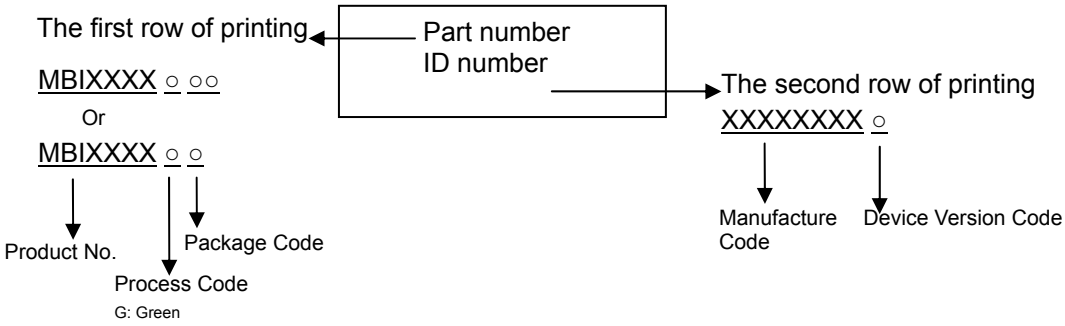
SYMBOL	DIMENSION (MM)			DIMENSION (MIL)		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	27.6	29.5	31.5
A1	0	0.02	0.05	0	0.79	1.97
A3	0.203 REF			8.00 REF		
b	0.18	0.23	0.30	7.09	9.06	11.81
D	2.90	3.00	3.10	114.17	118.11	122.05
D2	1.40	1.50	1.60	55.12	59.06	62.99
E	2.90	3.00	3.10	114.17	118.11	122.05
E2	1.40	1.50	1.60	55.12	59.06	62.99
e	0.50 BSC			19.69 BSC		
L	0.30	0.40	0.50	11.81	15.75	19.69
y	0.08			3.15		

MBI6020GFN Outline Drawing

Note 1: The unit for the outline drawing is mm.

Note 2: Please use the maximum dimensions for the thermal pad layout. To avoid the short circuit risk, the vias or circuit traces shall not pass through the maximum area of thermal pad.

Product Top Mark Information



Product Revision History

Datasheet version	Device Version Code
V1.00	A
V1.01	A

Product Ordering Information

Part Number	RoHS Compliant Package Type	Weight (g)
MBI6020GP	SSOP16L-150-0.64	0.067g
MBI6020GFN	QFN16L-3*3-0.5	0.038g

Disclaimer

Macroblock reserves the right to make changes, corrections, modifications, and improvements to their products and documents or discontinue any product or service. Customers are advised to consult their sales representative for the latest product information before ordering. All products are sold subject to the terms and conditions supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.
Macroblock's products are not designed to be used as components in device intended to support or sustain life or in military applications. Use of Macroblock's products in components intended for surgical implant into the body, or other applications in which failure of Macroblock's products could create a situation where personal death or injury may occur, is not authorized without the express written approval of the Managing Director of Macroblock.
Macroblock will not be held liable for any damages or claims resulting from the use of its products in medical and military applications.