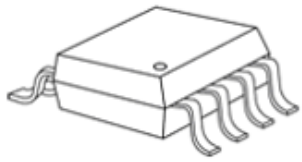
Single-wire 3-Channel Constant Current Sink Driver for Small LED Clusters

Features

- 3-channel constant current sink driver for LED strips
- Constant current range: 3~30mA
- One external resistor only
- Sustaining voltage at output channels: 17V (max.)
- Supply voltage 5V~12V with built-in LDO
- Embedded 12-bit PWM generator
  - Gray scale clock generated by the embedded oscillator
  - S-PWM patented technology
- Reliable data transmission
  - One-wire transmission interface to eliminate clock signal wire
  - Built-in buffer for long distance transmission
- RoHS-compliant package

Small Outline Package



GD: SOP8-150-1.27

Application

- LED strips
- LED guardrail tubes
- Architectural lighting

Product Description

MBI6120 is a 3-channel, constant current, PWM-embedded sink driver for LED strips. MBI6120 provides constant current ranging from 3mA to 30mA for each output channel and the constant output current is adjustable with an external resistor. Besides, MBI6120 can operate with a supply voltage ranging from 5V to 12V and sustain 17V at output channels.

With Scrambled-PWM (S-PWM) technology, MBI6120 enhances pulse width modulation by scrambling the “ON” time into several “ON” periods to increase visual refresh rate at the same gray scale performance. Besides, the gray scale clock (GCLK) is generated by the embedded oscillator. The 12-bit gray scale mode provides 4,096 gray scales for each LED to enrich the color.

In addition, MBI6120 features a one-wire transmission interface to make cluster-to-cluster connection much easier by eliminating the global clock signal. To improve the transmission quality, MBI6120 provides a unique protocol (patent pending) and serial data signal regeneration. MBI6120 is also featured by auto-synchronization.

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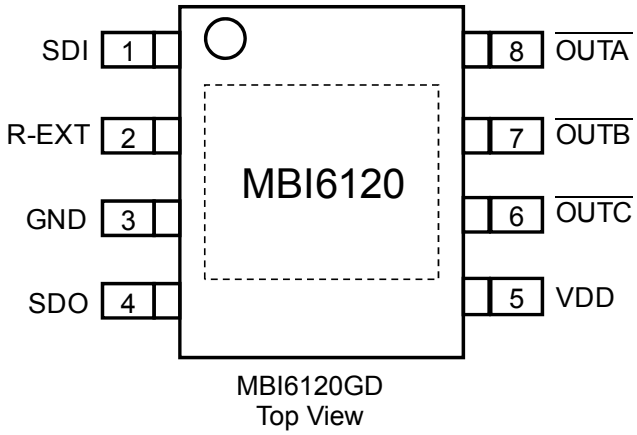
Pin Configuration



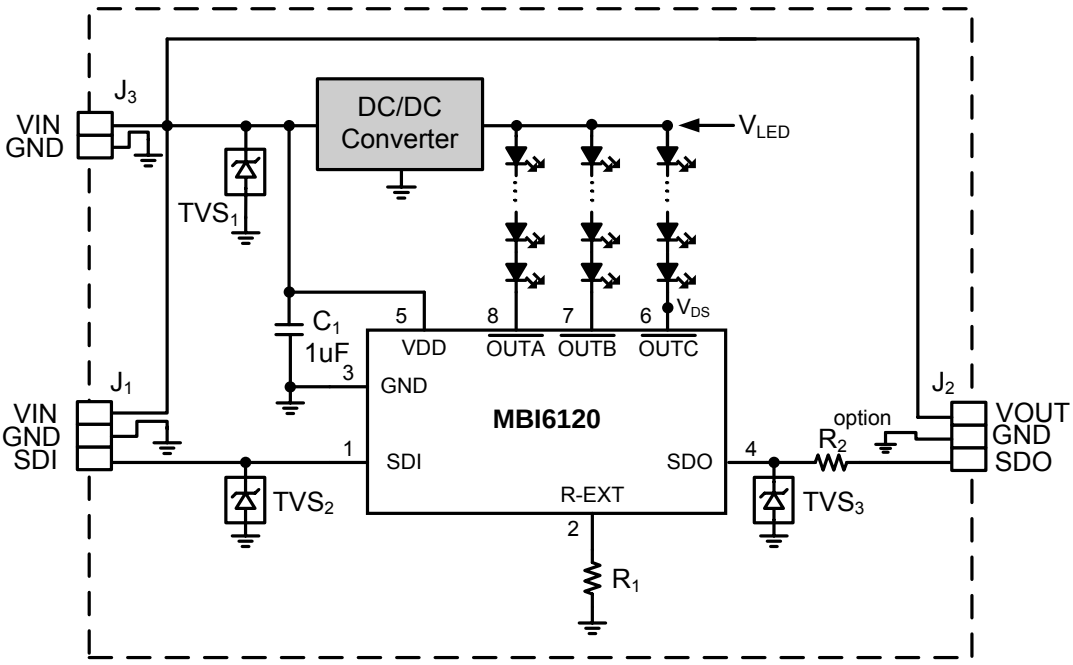
MBI6120GD
Top View

Terminal Description

Pin	Name	Description and function
1	SDI	Input terminal for serial data
2	R-EXT	Input terminal for setting up output current
3	GND	Ground terminal
4	SDO	Output terminal for serial data
5	VDD	Supply voltage terminal
6	$\overline{\text{OUTC}}$	Output terminal for channel C
7	$\overline{\text{OUTB}}$	Output terminal for channel B
8	$\overline{\text{OUTA}}$	Output terminal for channel A
-	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.

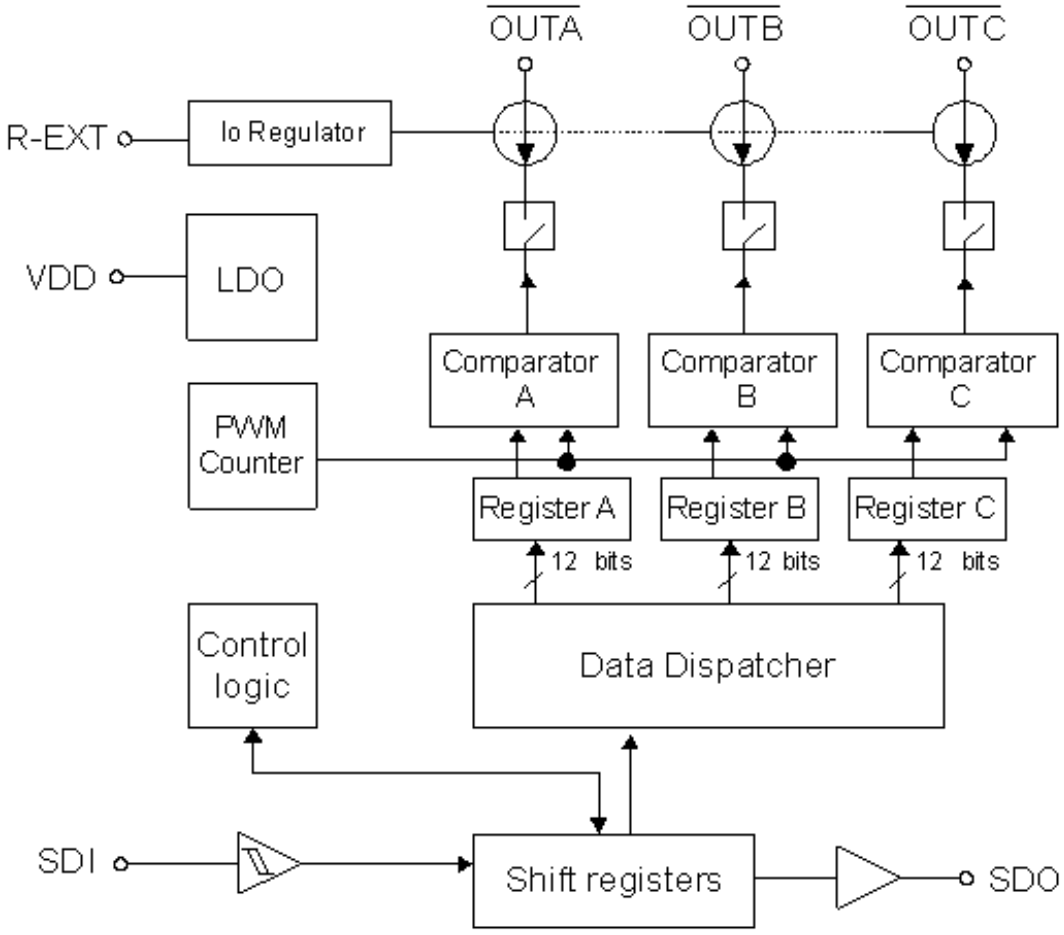
Typical Application Circuit



Note:

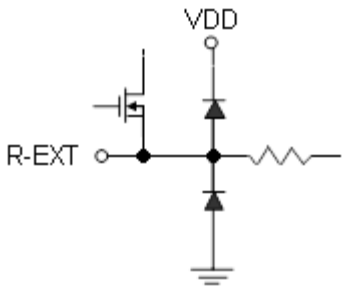
1. TVS_1~TVS_3 are Transient Voltage Suppressor (TVS).
2. C_1 is required and the value of the C_1 is reference only.
3. For hot plug, system grounding, connector design, external ESD protection, or other circuit information, please refer to the ***"MBI6120 Application Note"*** for detailed information.

Block Diagram

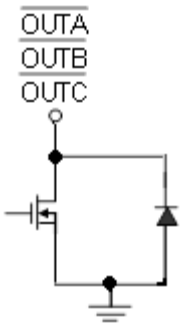


Equivalent Circuits of Inputs and Outputs

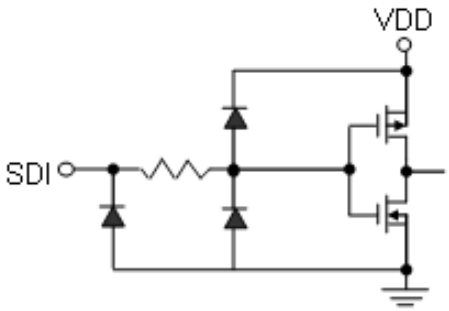
R-EXT terminal



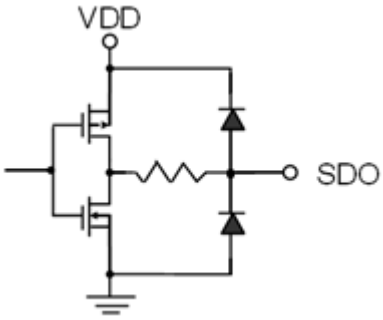
$\overline{\text{OUTA,B,C}}$ terminal



SDI terminal



SDO terminal



Maximum Rating

Characteristic	Symbol	Rating	Unit
Supply Voltage	V_{DD}	12	V
Sustaining Voltage at SDI Pin	V_{SDI}	-0.4~7	V
Sustaining Voltage at Output Pins	V_{DS}	17	V
Output Current per Channel	I_{OUT}	30	mA
GND Terminal Current	I_{GND}	90	mA
Power Dissipation (On 4 Layer PCB, Ta=25°C)*	P_D	3.13	W
Thermal Resistance (By simulation, on 4 Layer PCB)*	$R_{th(j-a)}$	40	°C/W
Junction Temperature	$T_{j,max}$	150**	°C
Operating Ambient Temperature	T_{opr}	-40~+85	°C
Storage Temperature	T_{stg}	-55~+150	°C

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

** Operation at the maximum rating for extended periods may reduce the device reliability; therefore, the suggested junction temperature of the device is under 125°C.

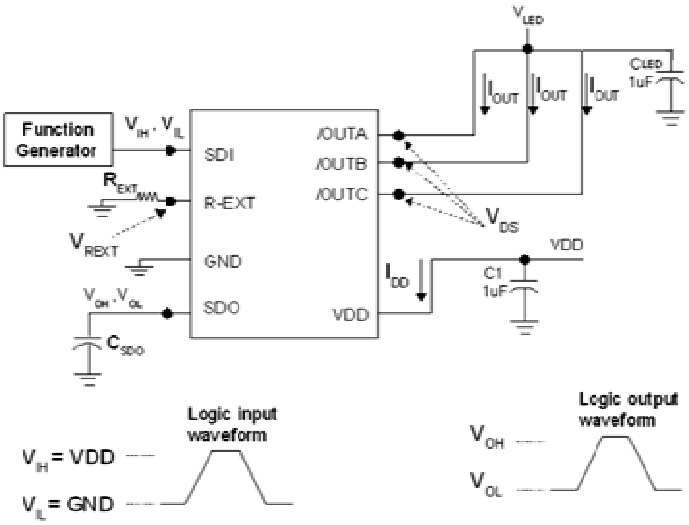
Note: The performance of thermal dissipation is strongly related to the size of thermal pad, thickness and layer numbers of the PCB. The empirical thermal resistance may be different from simulative value. Users should plan for expected thermal dissipation performance by selecting package and arranging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

Electrical Characteristics

Typical values measured at V_{DD}=5~12V, T_A=25°C unless otherwise specified.

Characteristic		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-	5	-	12	V
Sustaining Voltage		V_{DS}	Corresponding channel off	-	-	17	V
SDI Input Voltage		V_{SDI}	-	3.0	-	5.5	V
SDI Input Threshold	"H" level	V_{IH}	-	2.2	-	-	V
	"L" level	V_{IL}	-	-	-	0.8	V
Output Current		I_{OUT}	Corresponding channel on	3	-	30	mA
		I_{OH}	SDO at V_{OH}=2.9V	-1.0	-2.2	-4.1	mA
		I_{OL}	SDO at V_{OH}=0.2V	1.3	2.2	3.5	mA
Output Leakage Current		I_{OH}	V_{DS}=17.0V, corresponding channel off	-	-	1	μA
Output Voltage	SDO	V_{OL}	I_{OL}=+2.2mA	-	0.2	-	V
		V_{OH}	I_{OH}=-2.2mA	-	2.9	-	V
Voltage at R-EXT Pin		V_{REXT}	-	0.55	0.60	0.65	V
Current Bit Skew		dI_{OUT1}	I_{OUT}=20mA, V_{DS}=1.0V	-	±1.5	±3.0	%
Current Chip Skew		dI_{OUT2}	I_{OUT}=20mA, V_{DS}=1.0V	-	±3.0	±6.0	%
Output Current vs. V_{DS}		$\%/dV_{DS}$	V_{DS} ranged from 1V to 3V	-	±0.1	±0.5	% / V
Output Current vs. V_{DD}		$\%/dV_{DD}$	V_{DD} ranged from 5V to 12V	-	±1	±2	% / V
Knee Voltage		V_{KNEE}	R_{ext}=690Ω, corresponding channel on	0.75	0.85	1.0	V
Pull-down Resistor		R_{IN_SDI}	Pull-down resistance at SDI pin	45	65	85	KΩ
Supply Current	OFF	I_{DD_OFF}	R_{ext}=690Ω,SDO=NC, all channels off	-	8.5	-	mA
	ON	I_{DD_ON}	R_{ext}=690Ω,SDO=NC, all channels on	-	8.5	-	

Test Circuit for Electrical Characteristics

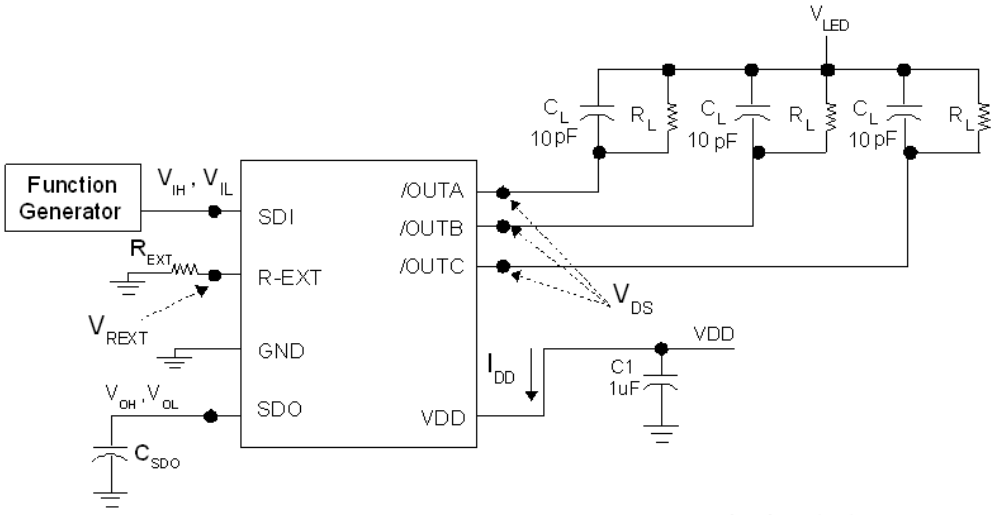


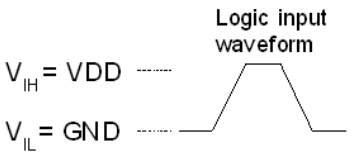
Switching Characteristics

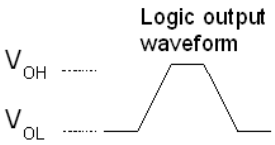
Typical values measured at V_{DD}=5~12V, T_A=25°C unless otherwise specified.

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("H" to "L")	PWMCLK↑– $\overline{OUTA}$ ↓	t_{PHL1}	R_{ext}=690Ω R_L=200Ω C_L =10pF V_{LED} = 5V C_{SDO}=18pF	-	10	-	ns
	PWMCLK↑– $\overline{OUTB}$ ↓	t_{PHL2}		-	20	-	ns
	PWMCLK↑– $\overline{OUTC}$ ↓	t_{PHL3}		-	30	-	ns
Propagation Delay Time ("L" to "H")	PWMCLK↑– $\overline{OUTA}$ ↑	t_{PLH1}		-	10	-	ns
	PWMCLK↑– $\overline{OUTB}$ ↑	t_{PLH2}		-	20	-	ns
	PWMCLK↑– $\overline{OUTC}$ ↑	t_{PLH3}		-	30	-	ns
Frequency	Internal Oscillator	F_{OSC}		50	63	75	MHz
Pulse Width of PWM	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{WDM}		144	-	-	ns
SDO Period	SDO rising to rising period	t_{WSDO}		480	-	-	ns
Rise Time	SDO	t_{OR}		4	7.5	13	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OR1}		15	25	40	ns
Fall Time	SDO	t_{OF}		4	7.5	13	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OF1}		20	30	45	ns

Test Circuit for Switching Characteristics

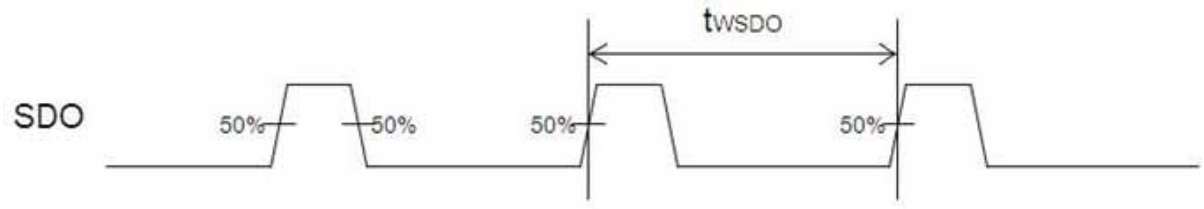




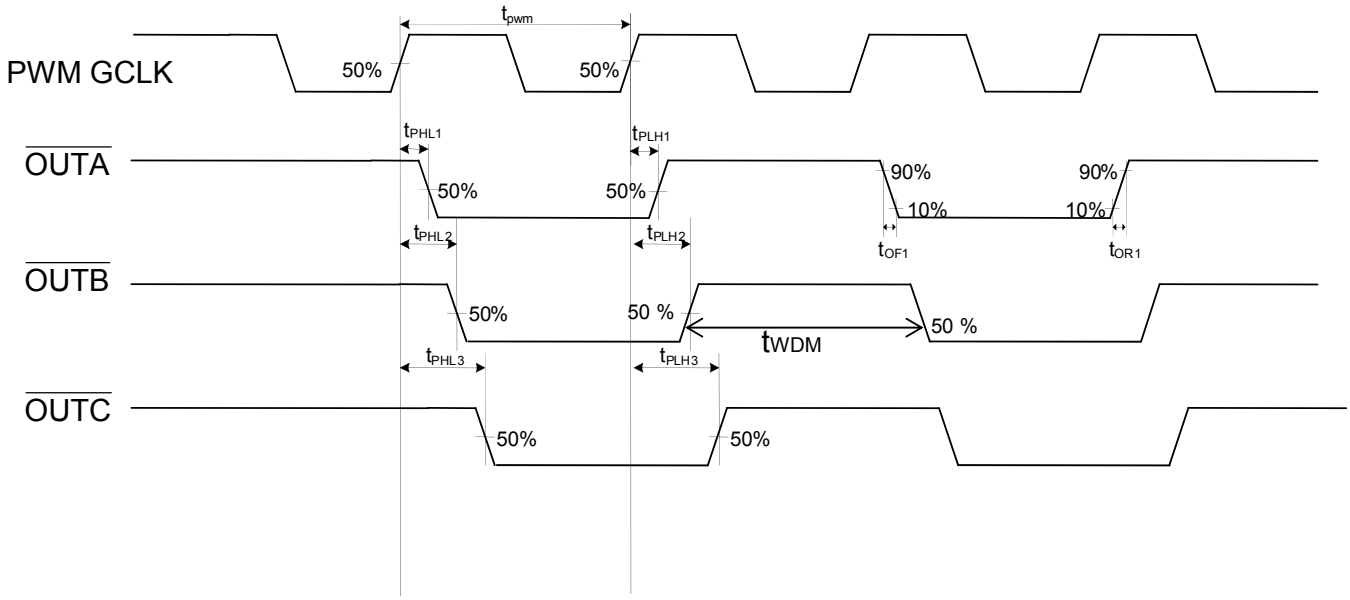


Timing Waveform

SDI/SDO Timing

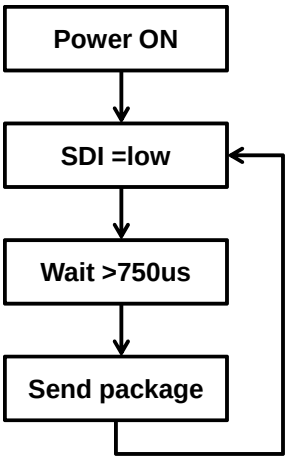


Output Timing



Principle of Operation

MBI6120 provides a single-wire transmission interface to address the data without a latch command. The sequence of operation should follow the steps below:



Step 1. Setup the header information

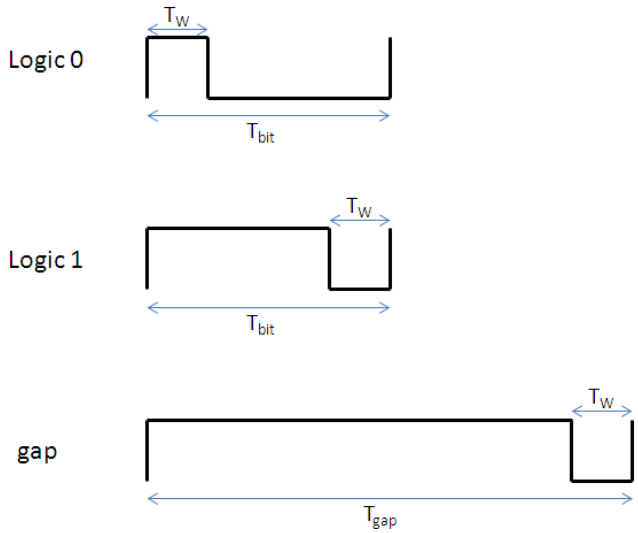
Step 2. Send the gray scale data.

Before sending package, SDI must be pulled-low for longer than 750μs.

MBI6120 receives the data packet containing targeted gray scale (GS) data from the controller, and turns ON the output channels according to the gray scale data. The gray scale clock of PWM generator, GCLK, is generated by the embedded oscillator.

Control Interface: Single-wire Interface

MBI6120 adopts the single-wire interface and samples the data (SDI) between two rising edges of SDI, typical of RZ code protocols. The following waveforms illustrate the definitions logic 0, 1, and a symbol “gap”.



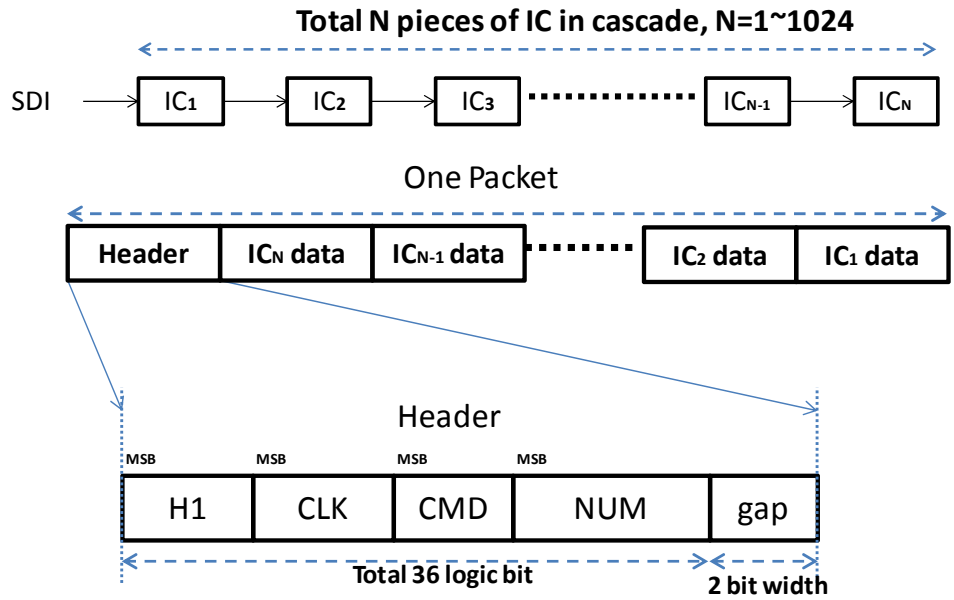
Characteristics		Symbol	Min.	Typ.	Max.	Unit
Logic 0/1 bit width	SDI↑-SDI↑(logic 0/1)	T_{bit}	1		10	us
Minimum pulsewidth	SDI	T_W	0.08		$0.25xT_{bit}$	us
Symbol gap width	SDI↑-SDI↑(gap)	T_{gap}	$T_{gap} = 2xT_{bit}$			us

The Structure of Packet

The data packet of MBI6120 is composed of two parts:

1. Header:
   The header defines the cascaded IC numbers and also contains a command to decide the data type.
2. Data:
   This is the gray scale data for each IC.

Structure of one packet:



Header[35:24] H1: 12-bit strings of '1' as the preamble of the data packet
Header[23:20] CLK: 4-bit GCLK selector
Header[19:12] CMD: 8-bit command
Header[11:0] NUM: 12-bit number of cascaded devices
gap: a symbol defined in the previous page

As for the sequence of the SDI gray scale data, the data of the last IC will be sent first from the controller.

Table of the Definition of the Header

Definition	Bit	Value	Function
H1	[35:24]	12'b111111111111	Data rate detection
CLK	[23:22]	xx (don't care)	Reserved
	[21:20]	2'b00 (default)	GCLK=5.2MHz (typ.)
		2'b01	GCLK=2.6MHz (typ.)
		2'b10	GCLK=1.3MHz (typ.)
		2'b11	GCLK=650kHz (typ.)
CMD	[19:12]	8'b00000000	Gray scale data
		8'b01010101	Software reset
		Other values	Ineffective, ignored
NUM	[11:10]	xx (don't care)	Reserved
	[9:0]	10'b0000000001~ 10'b1111111111	Number of cascaded IC's

Programming the Header

Once MBI6120 receives 12 bits of consecutive 1's from SDI, MBI6120 will start to configure its register with the sequence of gray scale clock (CLK), data type command (CMD), and number of cascaded IC's (NUM), respectively.

Data rate detection

MBI6120 detects the incoming data rate by internal manipulations on the first 12 bits of 1's, and therefore the 12 bits of 1's must be programmed with the same baud rate as the gray scale data.

Setting up the gray scale clock rate

MBI6120 offers four programmable internal gray scale clock rates to satisfy various requirements of applications. The mapping relation between the Header[21:20] portions and the gray scale clock GCLK is tabulated as follow.

Values of Header[21:20]	Gray Scale Clock Rate
2'b00 (default)	GCLK=5.2MHz (typical)
2'b01	GCLK=2.6MHz (typical)
2'b10	GCLK=1.3MHz (typical)
2'b11	GCLK=650kHz (typical)

Setting up the package type

MBI6120 provides two kinds of input package types, gray scale data package and software reset. For software reset, all following data will be ignored. Aside from these two legal packages, MBI6120 will disregard all other packages due to command mismatch.

Values of Header[19:12]	Package Type
8'b00000000 (8'h00)	12-bit gray scale data
8'b01010101 (8'h55)	Software reset
Others	Invalid command; package disregarded as ineffective data

Setting up the number of cascaded IC's

The maximum allowable cascaded IC's for MBI6120 is 1023, and therefore it takes 10 bits of corresponding registers Header[9:0] (NUM) for properly addressing the input gray scale data to the IC's.

"gap" symbol

MBI6120 is featured by the single-wire transmission, which means the elimination of external global clock signal must appeal other mechanisms for synchronization. The specific gap symbol serves this purpose, and please refer to the ***"MBI6120 Application Note"*** for detailed information.

Gray scale

MBI6120 provides a 12-bit gray scale mode with S-PWM technology to scramble the 12-bit data into 16 segments. The visual refresh rate can be increased. For example, with S-PWM, the default PWM clock (GCLK) frequency is around 5.2MHz (the frequency of internal oscillator divided by twelve), and therefore, the visual refresh rate of 12-bit gray scale mode will be increased to (5.2MHz/4096)x16=20,312Hz

12-bit gray scale with S-PWM

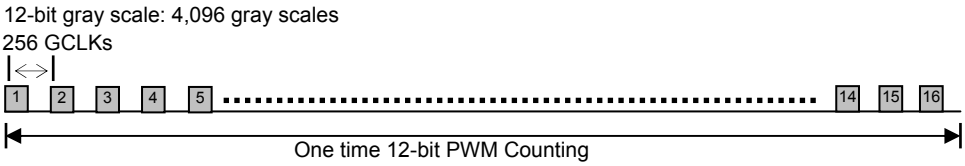
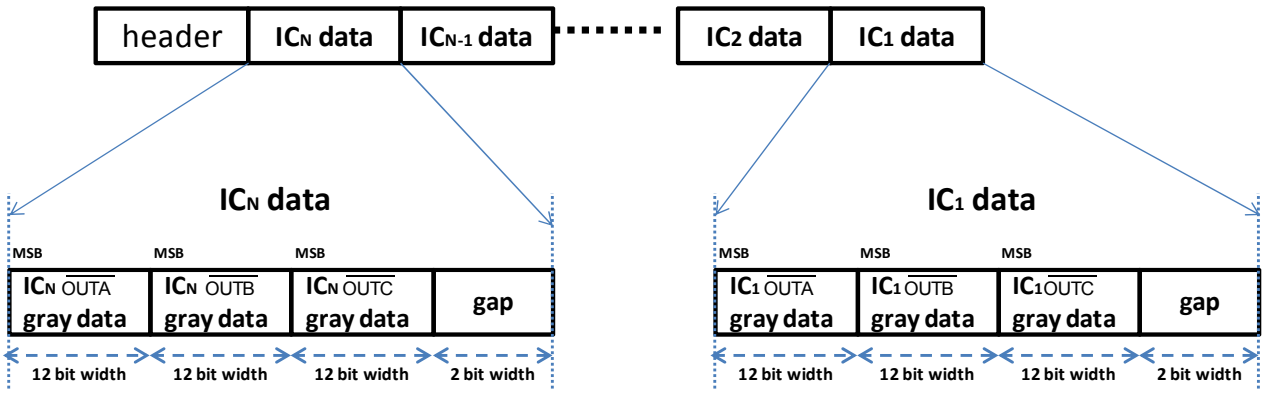


Table of 12-bit Gray Scale Calculation

Gray Scale Data	The Ratio of Output Turn-on Time in a PWM Cycle
0	$0/2^{12}$
1	$1/2^{12}$
2	$2/2^{12}$
⋮	⋮
4095	$4095/2^{12}$

A complete data packet will therefore be illustrated as follow.



The data for each IC contains:

- 12-bit $\overline{OUTA}$ gray scale data
- 12-bit $\overline{OUTB}$ gray scale data
- 12-bit $\overline{OUTC}$ gray scale data
- a gap symbol

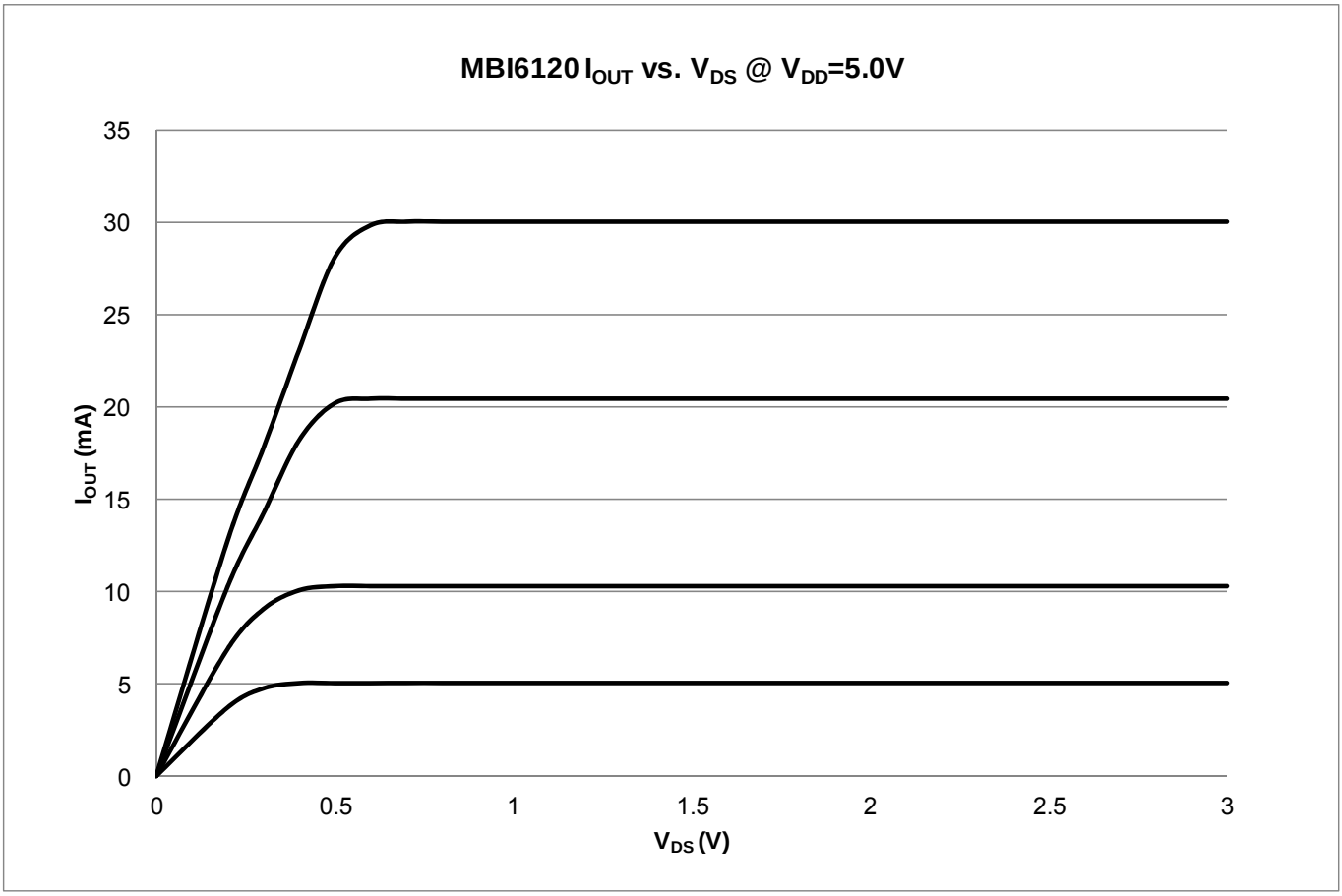
Table of Definition of 12-bit Gray Scale Data

Definition	Bit	Value	Function
$\overline{OUTA}$ gray scale	[11:0]	12'b000000000000~12'b111111111111	12-bit $\overline{OUTA}$ gray scale data
$\overline{OUTB}$ gray scale	[11:0]	12'b000000000000~12'b111111111111	12-bit $\overline{OUTB}$ gray scale data
$\overline{OUTC}$ gray scale	[11:0]	12'b000000000000~12'b111111111111	12-bit $\overline{OUTC}$ gray scale data

Constant Current

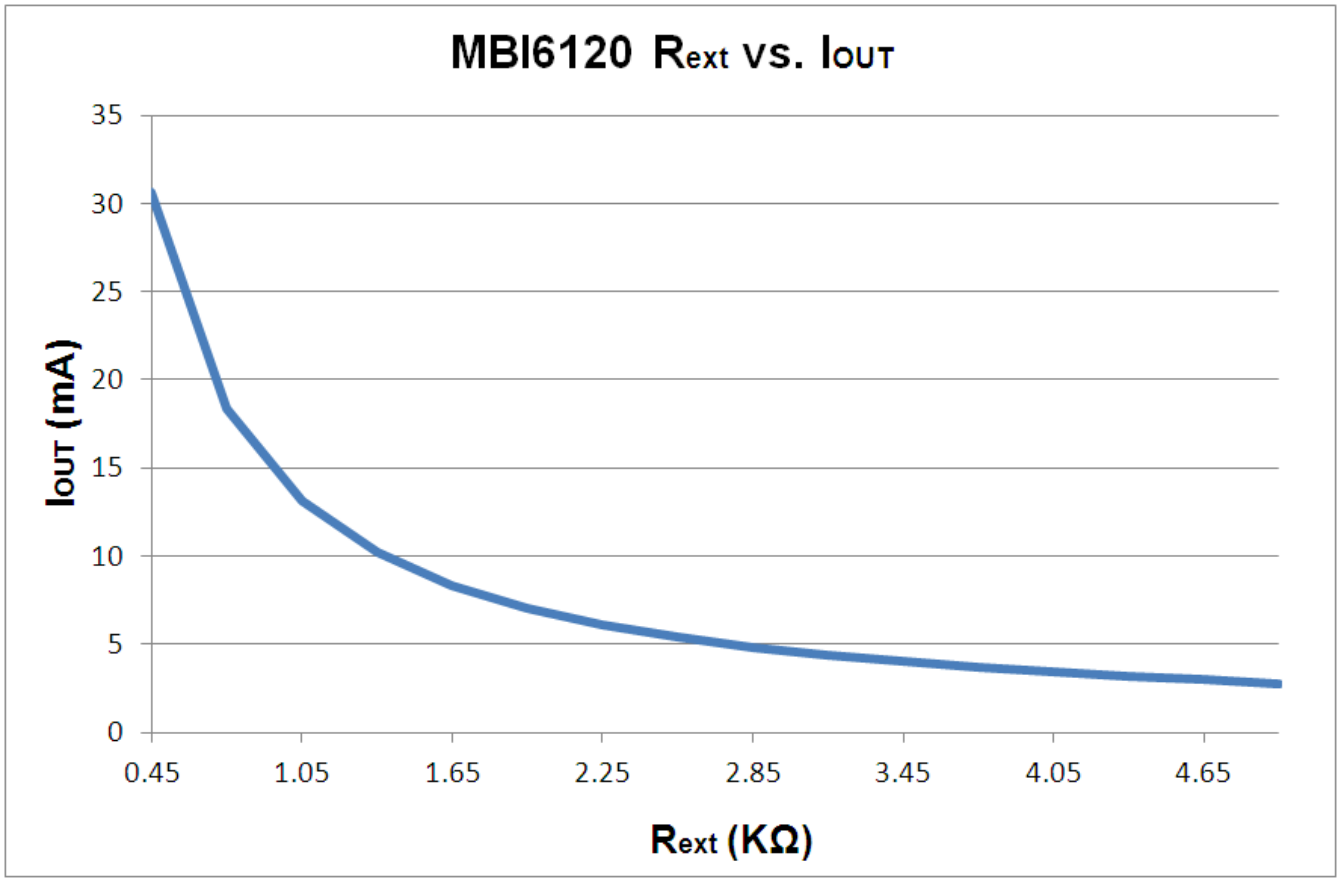
1) MBI6120 performs excellent current skew: the maximum current variation between channels is less than ±3%, and that between ICs is less than ±6%.

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).



Setting the 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 0.6V. The relationship between I_{OUT} and R_{ext} is shown in the following figure.

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

$I_{OUT}=(V_{REXT}/R_{ext})x23$

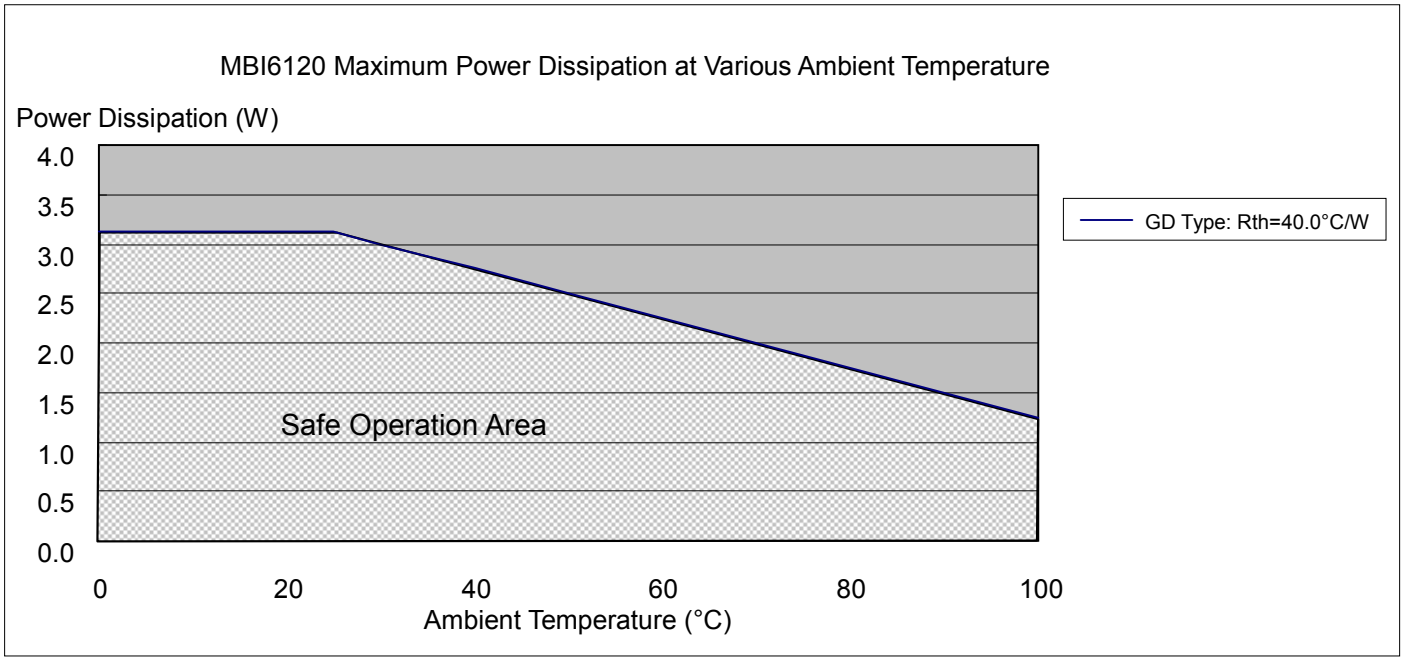
Where R_{ext}, is the resistance of the external resistor connected to the R-EXT terminal.

Package Heat Dissipation (P_D)

The maximum heat dissipation, $P_{D(max)}=(T_{j,max}–T_a)/R_{th(j-a)}$, decreases as the ambient temperature increases.
The heat dissipation (P_D) of MBI6120 is calculated by the equation:

$$P_D=(V_{DD} \times I_{DD}) + (I_{OUTA} \times V_{DSA} \times Duty_A + I_{OUTB} \times V_{DSB} \times Duty_B + I_{OUTC} \times V_{DSC} \times Duty_C)$$

For the calculation of duty cycles, please refer to the “Gray Scale” section.
Please refer to the following figure to design within the safe operation area.



Load Supply Voltage (V_{LED})

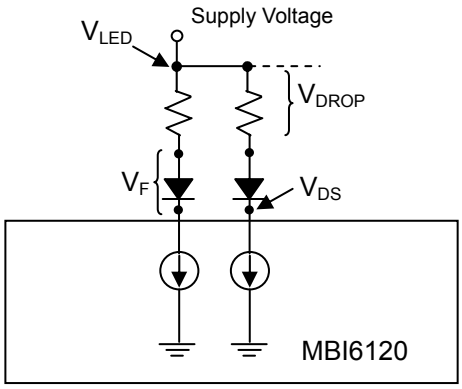
The design of V_{LED} should fulfill two targets:

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 excessive V_{DS} drops on the IC to cause heat issue. In this case, it is recommended to use the lowest possible supply voltage or to set an external resistor to reduce the V_{DS} by adjusting V_{DROP}.

$V_{DS}=(V_{LED}–V_F)–V_{DROP}$

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

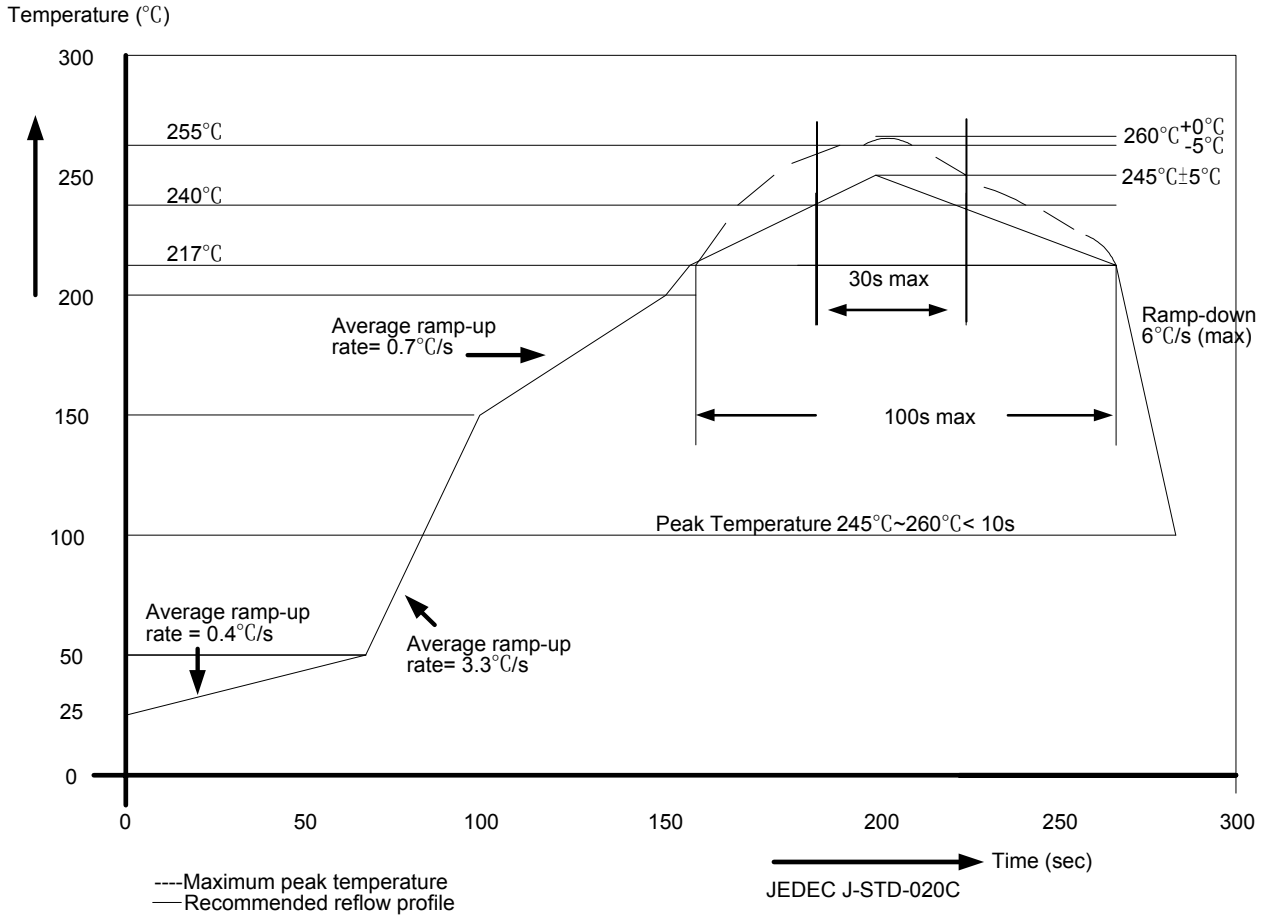


Switching Noise Reduction

The output ports of LED drivers are frequently switching in typical applications. This behavior usually causes 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*

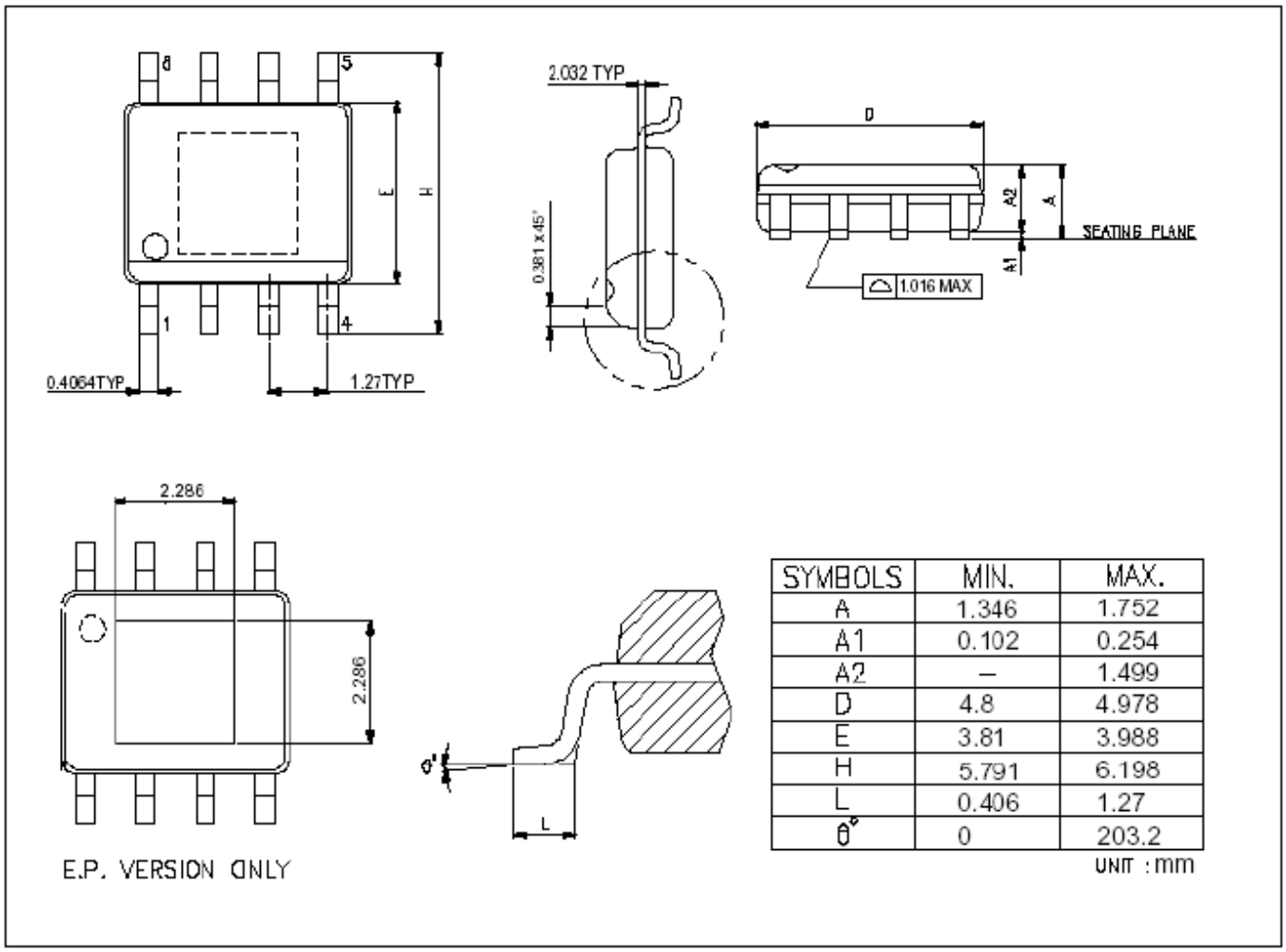
Macroblock has defined "Pb-Free & Green" to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free 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 adopts tin/lead (SnPb) solder paste, and please refer to the JEDEC J-STD-020C for the temperature of solder bath. However, in the whole Pbfree 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^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

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

Package Outline



SYMBOLS	MIN.	MAX.
A	1.346	1.752
A1	0.102	0.254
A2	–	1.499
D	4.8	4.978
E	3.81	3.988
H	5.791	6.198
L	0.406	1.27
θ°	0	203.2

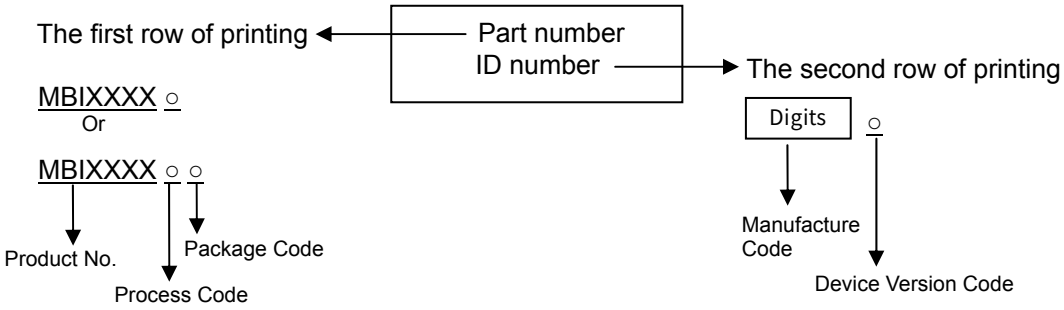
UNIT : mm

MBI6120GD 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

Product Ordering Information

Part Number	**RoHS-Compliant Package Type**	**Weight (g)**
MBI6120GD	SOP8L-150-1.27	0.079

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