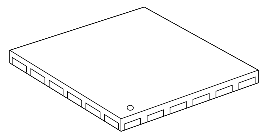
PWM-Embedded 3-Channel Constant Current LED Sink Driver with Bi-directional Transmission

Features

- 3-channel constant current sink driver for RGB LED clusters
- Constant current range: Iout = 5~45mA @V_{DD}=5V; 3~30mA @ V_{DD}= 3.3V
- Only 1 external resistor (R_{EXT}) for current setting
- 8-bit current gain for each channel
- Sustaining voltage at output channels: 17V (max.)
- Supply voltage: 3V~5.5V
- Embedded 12/8-bit PWM generator
  - Gray scale clock generated by the embedded oscillator
  - S-PWM technology
- Two selectable gray scale modes (8/12-bit mode decided by pin)
  - 12-bit gray scale mode (with optional 10-bit dot correction)
  - 8-bit gray scale mode (with optional 8-bit dot correction)
- Reliable data transmission
  - Daisy-chain topology
  - Two-wire only transmission interface
  - Phase-inversed output clock
  - Built-in buffer for long-distance transmission
- Maximum cascaded ICs: 1024
- Maximum CKI frequency: 10MHz
- Support manual-synchronization mode
- Selectable polarity reversion to drive high-power drivers or MOS
- Support open detection (1-bit for R/G/B), leakage detection (1-bit for R/G/B) and external error report pin
- Support transfer-error and CKI/SDI disconnection detection
- Support bi-directional transmission to read back error status
- RoHS-compliant packages: GFN24L

Quad Flat No-Lead



GFN: QFN24L-4*4-0.5

Application

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

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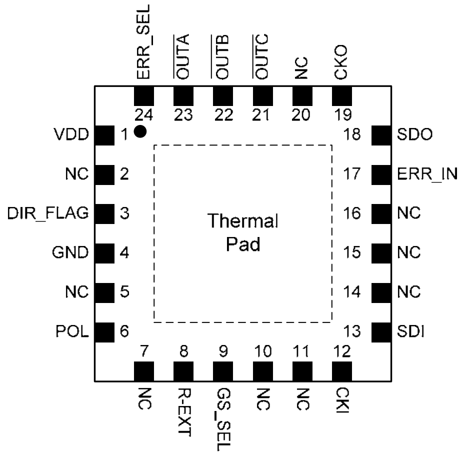
Product Description

MBI6027 is a 3-channel, constant current PWM-embedded LED sink driver with bi-directional transmission. MBI6027 provides constant current range: 5~45mA @V_{DD}=5V; 3~30mA @ V_{DD}= 3.3V for each output channel and three output channels are adjustable with one external resistor. Besides, MBI6027 can support both 3.3V and 5V power systems and sustain 17V at output channels.

With Scrambled-PWM (S-PWM) technology, MBI6027 enhances pulse width modulation by scrambling the "on" time into several "on" periods. Besides, the gray scale clock, GCLK, can be generated by the embedded oscillator. Moreover, MBI6027 provides two selectable gray scale modes: 12-bit gray scale mode and 8-bit gray scale mode. The 12-bit gray scale mode provides 4,096 gray scales for each LED to enrich the color with optional 10-bit dot correction to adjust each LED by 1,024-step dot correction to calibrate the LED brightness. On the other hand, the 8-bit gray scale mode provides 256 gray scales with optional 8-bit dot correction to adjust each LED by 256-step dot correction.

Furthermore, MBI6027 features a two-wire only bi-directional transmission interface to simplify the system controller design. The controller can read back the error status by this bi-directional transmission. MBI6027 supports open detection (1-bit for R/G/B), leakage detection (1-bit for R/G/B), transfer-error and CKI/SDI disconnection detection and an external error report pin. To improve the transmission quality, MBI6027 provides phase-inversed output clock function to enhance long-distance transmission. In addition, MBI6027 preserves selectable polarity reversion to drive high-power drivers or MOSFET as a PWM controller.

Pin Configuration



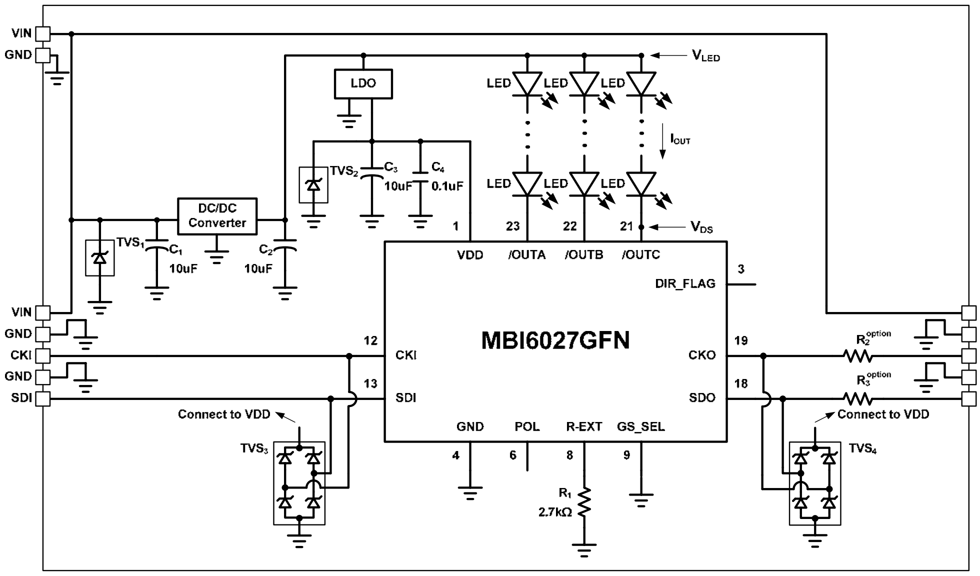
GFN Package
(Top View)

Terminal Description

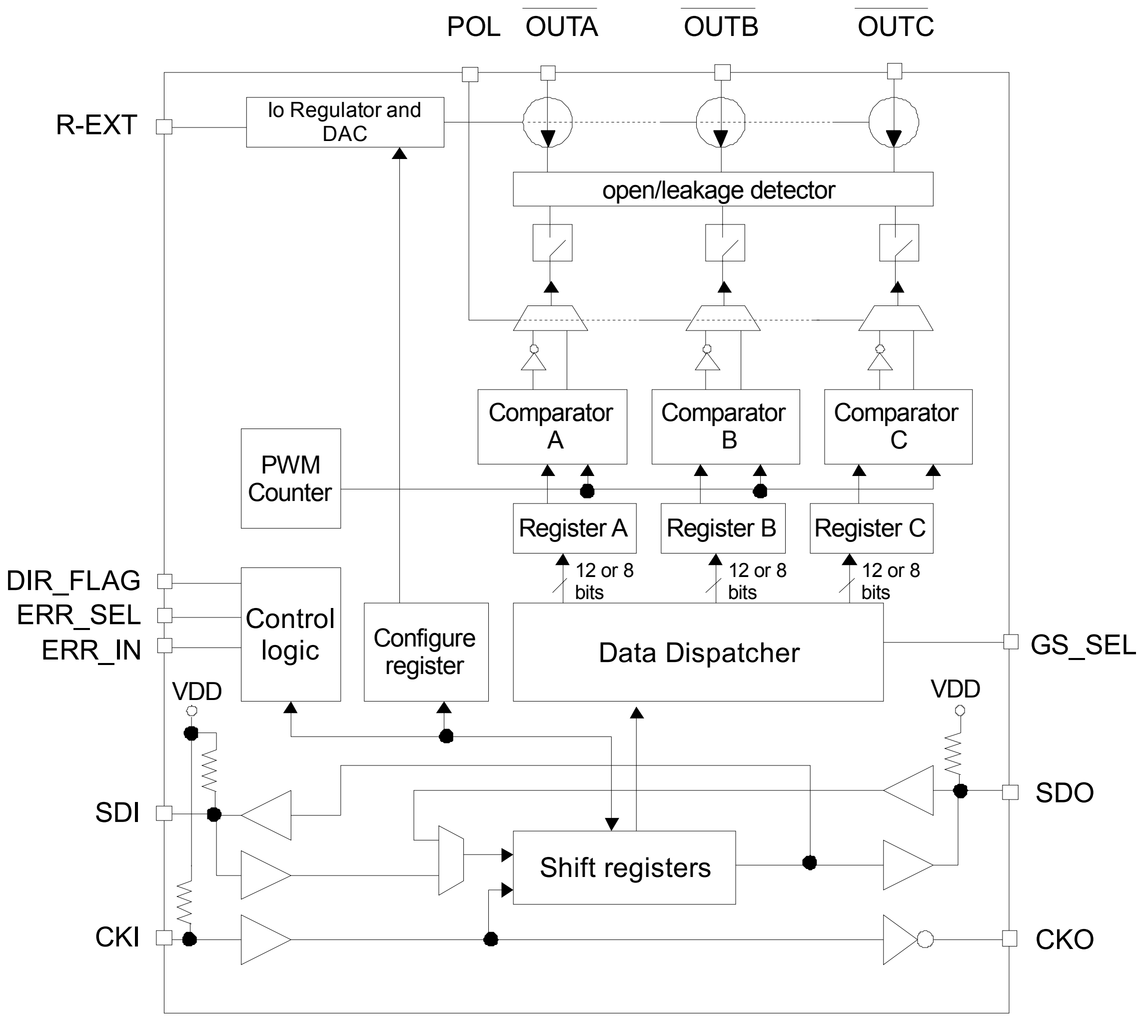
Pin GFN	Name	Description and function
4	GND	Ground terminal for control logic and current sink.
6	POL	Polarity selection. (Default: pull high) To pull low will reverse output for working with MBI182x as a PWM controller. To keep the pin unconnected will work as a sink driver or drive MBI181x.
8	R-EXT	External resistor to setup max. output driving current level.
9	GS_SEL	Select gray scale to be 8 bits or 12 bits High: 8 bit gray scale + 8 bit dot correction (default) Low: 12 bit gray scale + 10 bit dot correction
2,5,7,10,11,14, 15,16,20	NC	Keep unconnected
12	CKI	Serial clock input (Default: pull high)
13	SDI	Serial data input (forward transmission) Serial data output (reverse transmission) (Default: pull high)
18	SDO	Serial data output (forward transmission); Serial data input (reverse transmission); (Default: pull high).
19	CKO	Serial clock output
17	ERR_IN	Receive high power LED driver's error flag High: normal (default) Low: error
23,22,21	$\overline{\text{OUTA}}$, $\overline{\text{OUTB}}$, $\overline{\text{OUTC}}$	Constant current output terminal
3	DIR_FLAG	Transmission direction flag High: forward transmission (default) Low: reverse transmission
1	VDD	Supply voltage terminal
24	ERR_SEL	Select error detect method when pin "POL" is low High: for open detection (default) Low: for short detection
-	Thermal Pad	Heat dissipation pad*. Please connect to GND.

*Thermal conductivity will be improved by soldering a heat-conducting copper foil on PCB with the thermal pad.

Typical Application Circuit

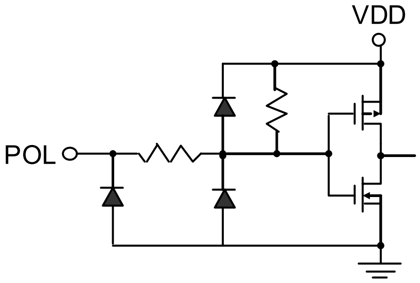


Function Block Diagram

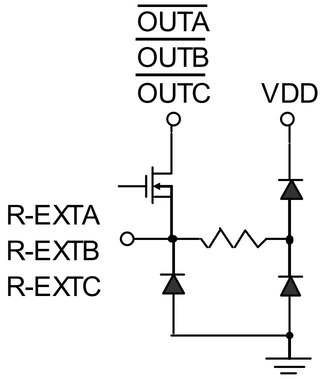


Equivalent Circuits of Inputs and Outputs

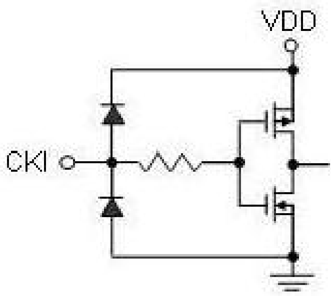
POL terminal



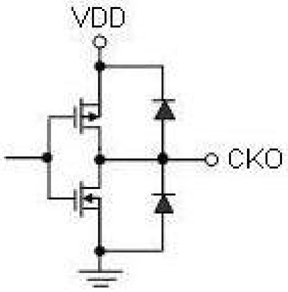
R-EXTA,B,C, $\overline{\text{OUTA,B,C}}$ terminal



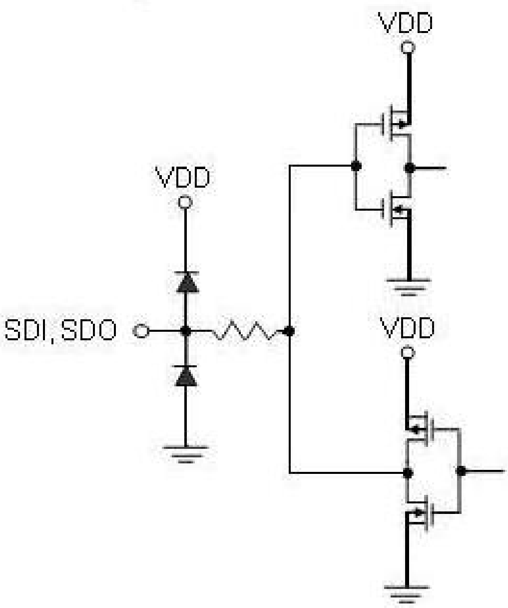
CKI terminal



CKO terminal



SDI, SDO terminal



Maximum Rating

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	7	V
Input Voltage		V_{IN}	-0.4 ~ V_{DD}+0.4	V
Output Current per Output Channel		I_{OUT}	+50	mA
Sustaining Voltage at OUT port		V_{DS}	+17	V
GND Terminal Current		I_{GND}	150	mA
Power Dissipation (By simulation, on 4-layer PCB)*	GFN	P_D	2.83	W
Thermal Resistance (By simulation, on 4-Llayer PCB)*	GFN	$R_{th(j-a)}$	44.10	°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 (V_{DD}=5.0V, Ta=25°C)

Characteristic		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-	4.5	5	5.5	V
Sustaining Voltage		V_{DS}	$\overline{OUTA}$ ~ $\overline{OUTC}$ =Off	-	-	17	V
Input Voltage	"H" level	V_{IH}	-	3.65	-	-	V
	"L" level	V_{IL}	-	-	-	1.4	V
Output Voltage	CKO, SDO	V_{OH}	I_{OH}=-3.0mA	4.8	-	-	V
		V_{OL}	I_{OL}=+3.0mA	-	-	0.2	V
Knee Voltage*		V_{Knee}	R_{EXT}=710Ω	0.75	0.85	1.0	V
Voltage at R-EXT pins		V_{REXT}	-	0.56	0.61	0.66	V
Output Current		I_{OUT}	Refer to "Test Circuit"	5	-	45	mA
		I_{OH}	CKO, SDO at V_{OH}=4.8V	-2	-3	-4.5	mA
		I_{OL}	CKO, SDO at V_{OH}=0.2V	2	3.5	5.5	mA
Supply current**	OFF	I_{DD} (off)	R_{EXT} =710Ω,CKI=Low, CKO, SDO=NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ =Off	-	9.1	-	mA
	ON	I_{DD}(on)	R_{EXT} =710Ω,CKI=Low, CKO, SDO=NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ =On	-	9.1	-	
			R_{EXT} =710Ω,CKI=10MHz, CKO, SDO=NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ =On	-	12	-	
Output Leakage Current		I_{OH}	V_{DS}=17.0V and $\overline{OUTA}$ ~ $\overline{OUTC}$ =Off	-	-	1	μA
Current Skew (Channel)		dI_{OUT1}	I_{OUT}=20mA V_{DS}=1.0V, R_{EXT}=710Ω	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OUT}=20mA V_{DS}=1.0V, R_{EXT}=710Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation		$\%/dV_{DS}$	V_{DS} within 1.0V and 3.0V, I_{OUT} =5mA~45mA	-	±0.1	±0.5	% / V
Output Current vs. Supply Voltage Regulation		$\%/dV_{DD}$	V_{DD} within 4.5V and 5.5V I_{OUT} =5mA~45mA	-	±1	±2	% / V
Pull-up Resistor		R_{IN}(up)	-	-	470	-	KΩ

*One channel turns on.

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

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

Characteristic		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-	3	3.3	3.6	V
Sustaining Voltage		V_{DS}	$\overline{OUTA}$ ~ $\overline{OUTC}$ =Off	-	-	17	V
Input Voltage	"H" level	V_{IH}	-	2.40	-	-	V
	"L" level	V_{IL}	-	-	-	0.92	V
Output Voltage	CKO, SDO	V_{OH}	I_{OL}=+2mA	3.1	-	-	V
		V_{OL}	I_{OH}=-2mA	-	-	0.2	V
Knee Voltage*		V_{Knee}	R_{EXT}=710Ω	0.75	0.85	1.0	V
Voltage at R-EXT pins		V_{REXT}	-	0.56	0.61	0.66	V
Output Current		I_{OUT}	Refer to "Test Circuit"	3	-	30	mA
		I_{OH}	CKO, SDO at V_{OH}=3.1V	-1.5	-2.3	-3.5	mA
		I_{OL}	CKO, SDO at V_{OH}=0.2V	1.5	2.5	4.5	mA
Supply current**	OFF	I_{DD} (off)	R_{EXT} =710Ω , CKI=Low, CKO, SDO=NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ =Off	-	6	-	mA
	ON	I_{DD}(on)	R_{EXT} =710Ω, CKI=Low CKO, SDO=NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ =On	-	6	-	mA
			R_{EXT} =710Ω, CKI=10MHz CKO, SDO=NC, $\overline{OUTA}$ ~ $\overline{OUTC}$ =On	-	8.5	-	mA
Output Leakage Current		I_{OH}	V_{DS}=17.0V and $\overline{OUTA}$ ~ $\overline{OUTC}$ =Off	-	-	1	μA
Current Skew (Channel)		dI_{OUT1}	I_{OUT}=20mA V_{DS}=1.0V; R_{EXT}=710Ω	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OUT}=20mA V_{DS}=1.0V; R_{EXT}=710Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation		$\%/dV_{DS}$	V_{DS} within 1.0V and 3.0V, I_{OUT} =3mA~30mA	-	±0.1	±0.5	% / V
Output Current vs. Supply Voltage Regulation		$\%/dV_{DD}$	V_{DD} within 3.0V and 3.6V I_{OUT} =3mA~30mA	-	±1	±2	% / V
Pull-up Resistor		R_{IN}(up)	-	-	450	-	KΩ

*One channel turns on.

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

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

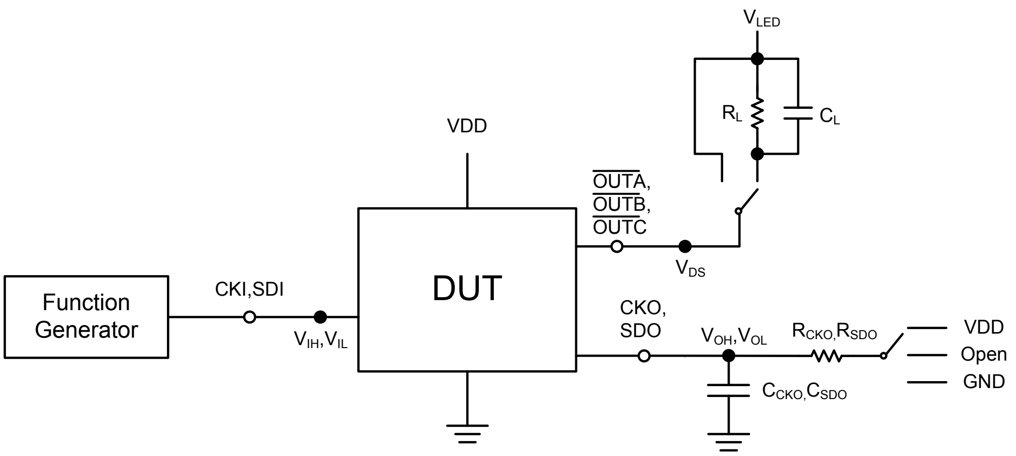
Characteristic		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation delay time ("H" to "L" or "L" to "H")	CKI↑-CKO↓	t_{P1}	R_{EXT} =750ohm R_L =200ohm V_{LED} = 4.5V	11	16	21	ns
	CKO↓-SDO	t_{P2}	Same as t_{P1}	7	12	17	ns
	CKO↓-SDI	t_{P5}	Same as t_{P1}	-1	4	9	ns
	CKO↑-DIR_FLAG	t_{P6}	Same as t_{P1}	-5	0	5	ns
	SDI(n+1) – SDO(n)	t_{P3}	Wire delay and IC internal delay	wd*	wd*	wd*	ns
	CKI(n) – CKI(n+1)	t_{P4}	Wire delay and IC internal delay	t_{P1}+ wd*	t_{P1}+ wd*	t_{P1}+ wd*	ns
Rise Time	CKO/SDO/SDI	t_{CR}	-	2	5	9	ns
	$\overline{\text{OUTA}}$ ~ $\overline{\text{OUTC}}$	t_{OR1}	R_{EXT} =700ohm	-	8.5	-	ns
Fall Time	CKO/SDO/SDI	t_{CF}	-	2	5	9	ns
	$\overline{\text{OUTA}}$ ~ $\overline{\text{OUTC}}$	t_{OF1}	R_{EXT} =700ohm	-	10		ns
Hold Time	SDI-CKI↓	$t_{H(D)}$	-	8	-	-	ns
Setup Time	CKI↓-SDI	$t_{S(D)}$	-	8	-	-	ns
Pulse Width	CKI(WM)	$t_{W(WM)}$	Pulse width of write mode	15	-	-	ns
Pulse Width	CKI(RM)	$t_{W(RM)}$	Pulse width of read mode	50	-	-	ns
Output Stagger Delay	$\overline{\text{OUTA}}$ ~ $\overline{\text{OUTC}}$	t_{SD}	VDD=5V; V_{LED} = 4.5V R_{EXT} =750ohm; R_L =200ohm	-	5	-	ns
Frequency	CKI(WM)	F_{CKI}	Flat(AWG26), 50cm distance	0.2	-	10	MHz
	CKI(RM)	F_{CKI}	Flat(AWG26), 50cm distance	0.2	-	4	MHz
	PWM clock	F_{PCKL}	-	-	5	-	MHz
	Internal oscillator	-	-	14	20	26	MHz

* wd: is wire delay , which is dependent on wire distance and wire material.

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

Characteristic		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation delay time ("H" to "L" or "L" to "H")	CKI↑-CKO↓	t_{P1}	R_{EXT} =750ohm R_L =200ohm V_{LED} = 4.5V	18	23	28	ns
	CKO↓-SDO	t_{P2}	Same as t_{P1}	14	18	22	ns
	CKO↓-SDI	t_{P5}	Same as t_{P1}	0	5	10	ns
	CKO↑-DIR_FLAG	t_{P6}	Same as t_{P1}	-5	-1	4	ns
	SDI(n+1) – SDO(n)	t_{P3}	Wire delay and IC internal delay	wd*	wd*	wd*	ns
	CKI(n) – CKI(n+1)	t_{P4}	Wire delay and IC internal delay	t_{P1}+ wd*	t_{P1}+ wd*	t_{P1}+ wd*	ns
Rise Time	CKO/SDO/SDI	t_{CR}	-	3	7	13	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OR1}	R_{EXT} =700ohm	-	10	-	ns
Fall Time	CKO/SDO/SDI	t_{CF}	-	3	7	13	ns
	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{OF1}	R_{EXT} =700ohm	-	12	-	ns
Output stagger delay	$\overline{OUTA}$ ~ $\overline{OUTC}$	t_{SD}	VDD=3.3V ;V_{LED} = 4.5V R_{EXT} =750ohm; R_L =200ohm	-	8	-	ns
Hold Time	SDI-CKI↓	$t_{H(D)}$	VDD=3.3V	10	-	-	ns
Setup Time	CKI↓-SDI	$t_{S\,(D)}$	VDD=3.3V	10	-	-	ns
Pulse Width	CKI(WM)	$t_{W\,(WM)}$	Pulse width of write mode	15	-	-	ns
Pulse Width	CKI(RM)	$t_{W\,(RM)}$	Pulse width of read mode	50	-	-	ns
Frequency	CKI(WM)	F_{CKI}	Flat(AWG26),50cm distance	0.2	-	10	MHz
	CKI(RM)	F_{CKI}	Flat(AWG26),50cm distance	0.2	-	3	MHz
	PWM clock	F_{PCKL}	-	-	5	-	MHz
	Internal oscillator	-	-	14	20	26	MHz

Test Circuit



Note:

R_{CKO}, R_{CKO} = Load resistance for CKO and SDO.

C_{CKO}, C_{CKO} = Load capacitance; includes jig and probe capacitance.

R_L, C_L = Load resistance and load capacitance for $\overline{OUTA}$ ~ $\overline{OUTC}$.

Timing Waveform

I. Write Mode Direction

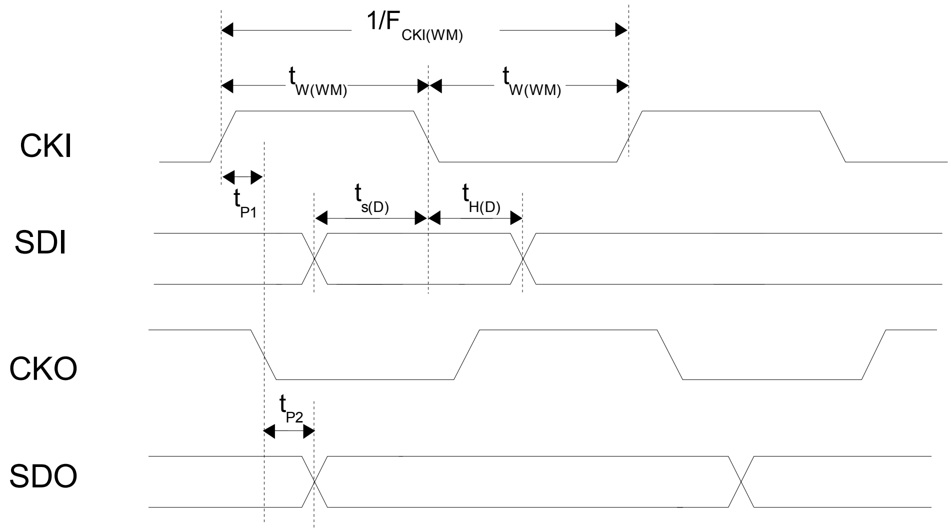


Fig.1 CKI/SDI, CKO/SDO write mode direction for even ICs

Note: Even IC means 0, 2nd, 4th … ICs connected to controller

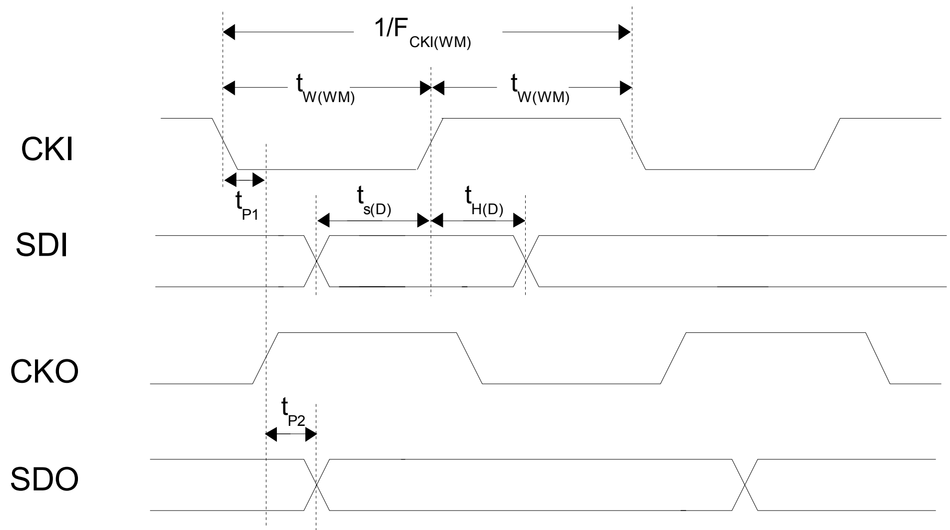


Fig.2 CKI/SDI, CKO/SDO write mode direction for odd ICs

Note: Odd IC means 1st, 3rd, 5th … ICs connected to controller

II. Read Mode Direction

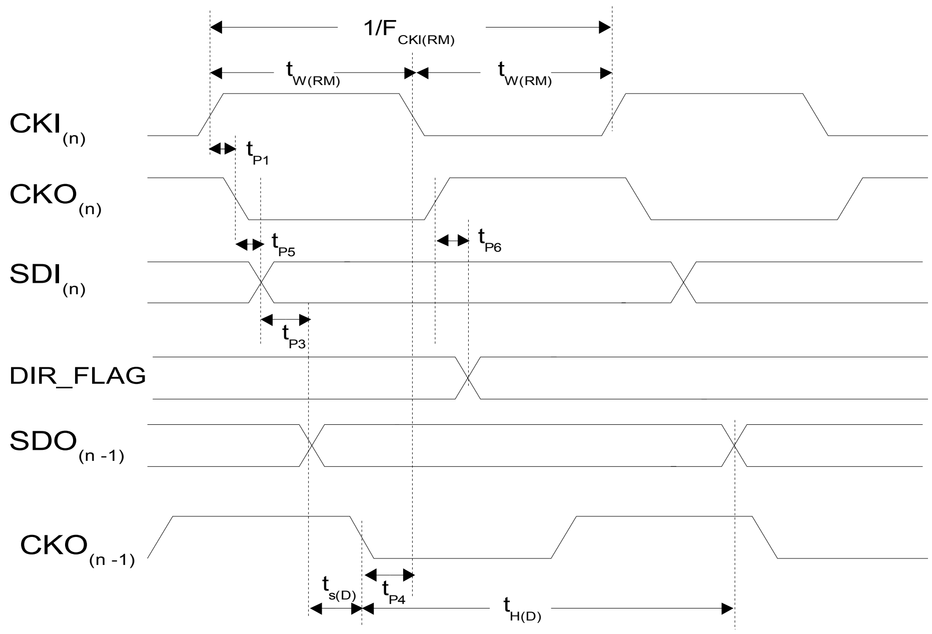


Fig.3 CKI/SDI, CKO/SDO read mode direction for IC(n) is even IC

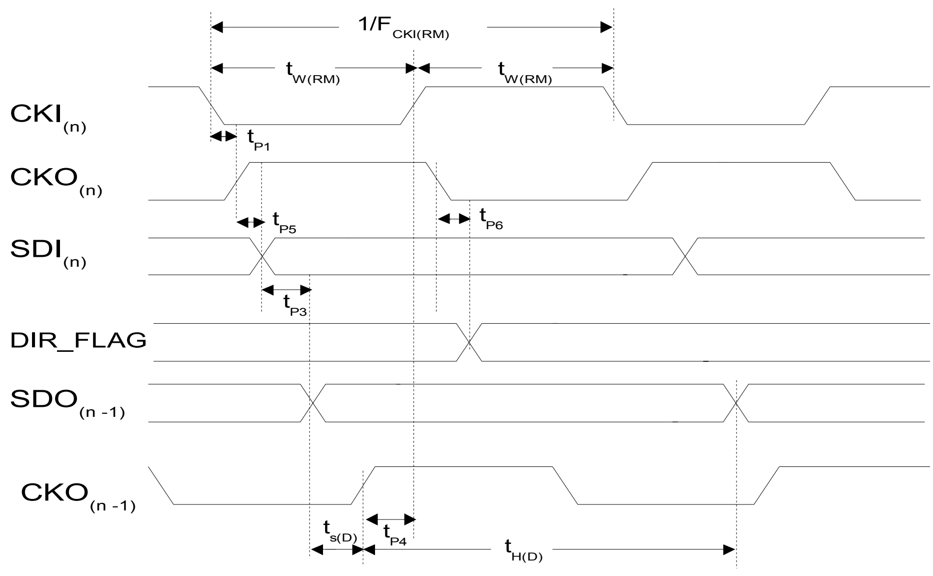


Fig.4 CKI/SDI, CKO/SDO read mode direction for IC(n) is odd IC

III. $\overline{\text{OUTA}}$ ~ $\overline{\text{OUTC}}$

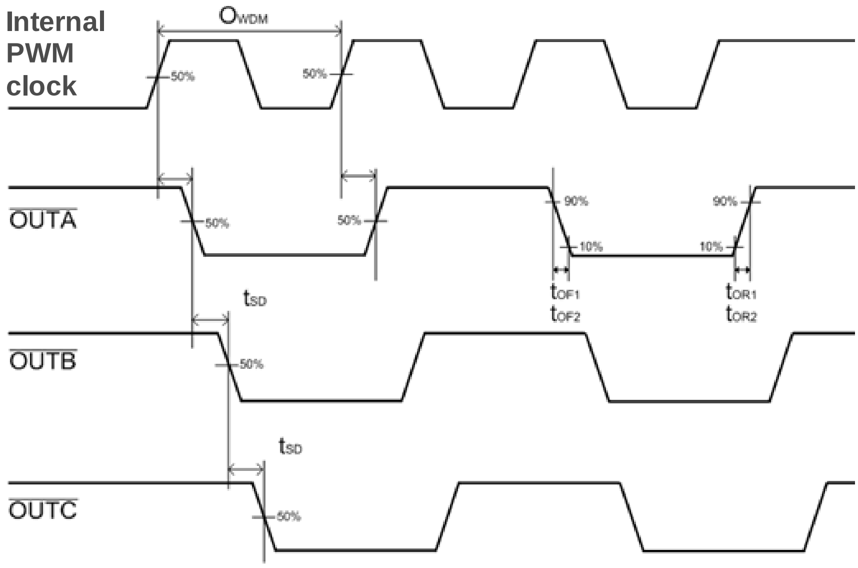


Fig.5 $\overline{\text{OUTA}}$ ~ $\overline{\text{OUTC}}$ timing diagram

IV. Data programming sequence

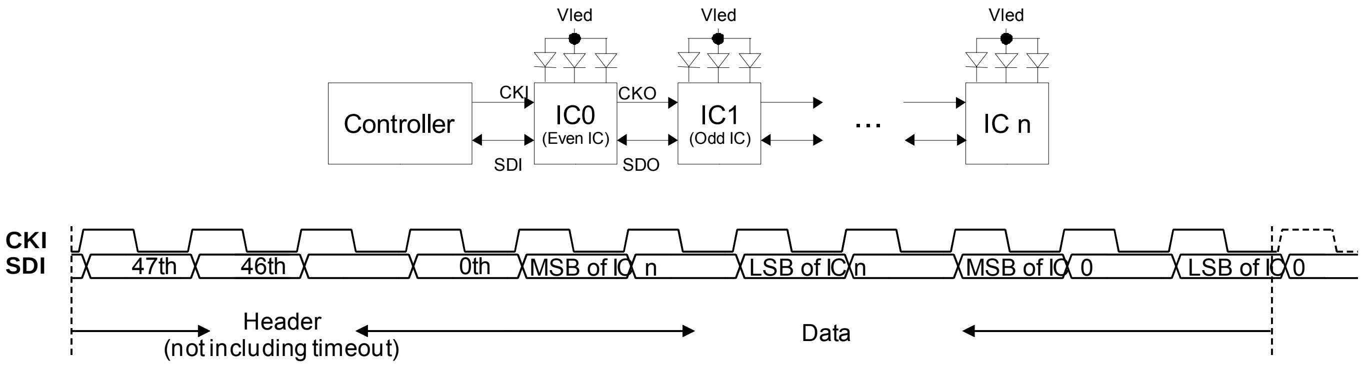


Fig.6 Data programming sequence

The above figure shows an application example of MBI6027. The drivers are connected serially and the data sequence sent by the controller is shown in Fig. 6. All commands are composed of “Header” and “Data”, as shown in the above figure.

The programming data sequence is from ICn, ICn-1, … to IC0 and for each IC, MSB bit is sent first.

(Please also refer to sec. of “Protocol Packet Sequence”)

V. Control Interface

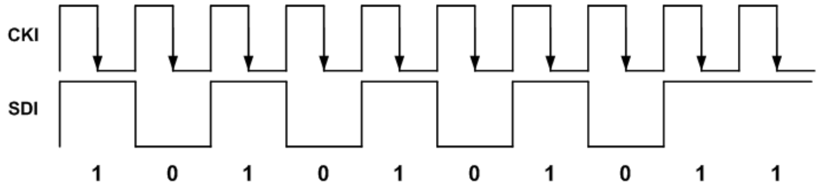


Fig.7 Data sampling scheme

MBI6027 adopts the SPI-like interface (CKI/SDI). By SPI-like interface, MBI6027 samples the data (SDI) at the falling edge of the clock (CKI).The above waveform is the example of the SPI-like interface.

Principle of Operation

MBI6027 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, is generated by the embedded oscillator. MBI6027 provides SPI-like interface (CKI, SDI), a two-wire only transmission interface, to address the data, so that MBI6027 receives the data directly without latching data.

Gray Scale Control

MBI6027 provides two gray scale modes: 12-bit gray scale mode and 8-bit gray scale mode. MBI6027 specifically adopts S-PWM technology in both 12-bit/8-bit gray scale mode to scramble the PWM to 64 segments, so that the visual refresh rate can be increased. For example, with S-PWM, the default PWM clock frequency is 5MHz (the frequency of internal oscillator/4), and therefore, the visual refresh rate of 12-bit gray scale mode will be increased to:
5MHz/4096x64=78,125Hz

MBI6027 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, MBI6027 will stop the present PWM cycle and restart a new PWM cycle to show the new data immediately.

12-bit gray scale data

The following is the equation for the duty cycle of output in 12-bit gray scale mode.

$$\text{The duty cycle of output (\%)} = \frac{\text{12- bit gray scale data}}{4096} \times 100\%$$

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

Table 1. 12-bit gray mode scale output result

Example	Gray scale data	Duty Cycle of Output
1	4095	99.9%
2	2,048	50%
3	1,024	25%
. . .	. . .	. . .

8-bit gray scale

The following is the equation for the duty cycle of output in 8-bit gray scale mode.

$$\text{The duty cycle of output}(\%) = \frac{8\text{-bit gray scale data}}{256} \times 100\%$$

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

Table 2. 8-bit gray scale mode output result

Example	Gray scale data	Duty Cycle of Output
1	255	99.6%
2	128	50%
3	64	25%
. . .	. . .	. . .

Dot Correction Control

MBI6027 also provides 10-bit or 8-bit dot correction control in 12-bit or 8-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, MBI6027 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.

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

For 10-bit dot correction, the default value of dot correction data is 1023.

$$\text{The duty cycle of output}(\%) = \frac{12\text{-bit gray scale data} \times \dfrac{(10\text{-bit dot correction data}+1)}{1024}}{4096} \times 100\%$$

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

Table 3. 10-bit dot correction output result

Example	Gray scale data	Dot correction data	Duty Cycle of Output
1	2,048	1023 (Default)	50%
2	2,048	511	25%
3	1,024	1023	25%
. . .	. . .	. . .	. . .

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

For 8-bit dot correction, the default value of dot correction data is 255.

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

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

Table 4. 8-bit dot correction output result

Example	Gray scale data	Dot correction data	Duty Cycle of Output
1	128	255 (Default)	50%
2	128	63	12.5%
3	64	127	12.5%
. . .	. . .	. . .	. . .

Definition of Configuration Register

Table 5. Configuration register

Bit	Definition	Value	Function
31~25	Reserved	0	7b'000 0000
24	ERR_SEL when pin "POL" is 0	1 (default)	This register bit directly connects to pin ERR_SEL, which selects error detection type when pin "POL" is 0 1: for open detection, 0: for short detection
23~16	Current gain adjustment	0 ~ 255 (default)	Current gain of $\overline{\text{OUTC}}$
15~8	Current gain adjustment	0 ~ 255 (default)	Current gain of $\overline{\text{OUTB}}$
7~0	Current gain adjustment	0 ~ 255 (default)	Current gain of $\overline{\text{OUTA}}$

MBI6027 provides 8-bit current gain for each channel. Current gain adjustment, in contrast to duty-cycle modulation by dot correction, is achieved by current modulation according to the current gain information. Please refer to page 27 for detailed calculation procedures of current gain corresponding to configuration register contents.

Definition of Dot Correction Register

Table 6. 10-bit dot correction register

Bit	Definition	Value	Function
29~20	Dot correction adjustment	0 ~ 1023(default)	Dot correction of $\overline{\text{OUTC}}$
19~10	Dot correction adjustment	0 ~ 1023(default)	Dot correction of $\overline{\text{OUTB}}$
9~0	Dot correction adjustment	0 ~ 1023(default)	Dot correction of $\overline{\text{OUTA}}$

Table 7. 8-bit dot correction register

Bit	Definition	Value	Function
23~16	Dot correction adjustment	0 ~ 255(default)	Dot correction of $\overline{\text{OUTC}}$
15~8	Dot correction adjustment	0 ~ 255(default)	Dot correction of $\overline{\text{OUTB}}$
7~0	Dot correction adjustment	0 ~ 255(default)	Dot correction of $\overline{\text{OUTA}}$

Definition of Gray Scale Register

Table8. 12-bit gray scale register

Bit	Definition	Value	Function
35~24	Gray scale adjustment	0(default) ~ 4095	Gray scale of $\overline{\text{OUTC}}$
23~12	Gray scale adjustment	0(default) ~ 4095	Gray scale of $\overline{\text{OUTB}}$
11~0	Gray scale adjustment	0(default) ~ 4095	Gray scale of $\overline{\text{OUTA}}$

Table9. 8-bit gray scale register

Bit	Definition	Value	Function
23~16	Gray scale adjustment	0(default) ~ 255	Gray scale of $\overline{\text{OUTC}}$
15~8	Gray scale adjustment	0(default) ~ 255	Gray scale of $\overline{\text{OUTB}}$
7~0	Gray scale adjustment	0(default) ~ 255	Gray scale of $\overline{\text{OUTA}}$

Protocol Packet Sequence

Prefix	Header	Data

Prefix

MBI6027 identifies the data as a new packet after time-out. Then users can follow the “time-out” protocol (time-out duration: stop t_{tout} + 1CKI + stop t_{tout}) to re-start packet decoding scheme.
Note that only one CKI pulse can be inserted between two t_{tout} intervals, or “time-out” protocol will be restarted as shown in Fig.10 below.

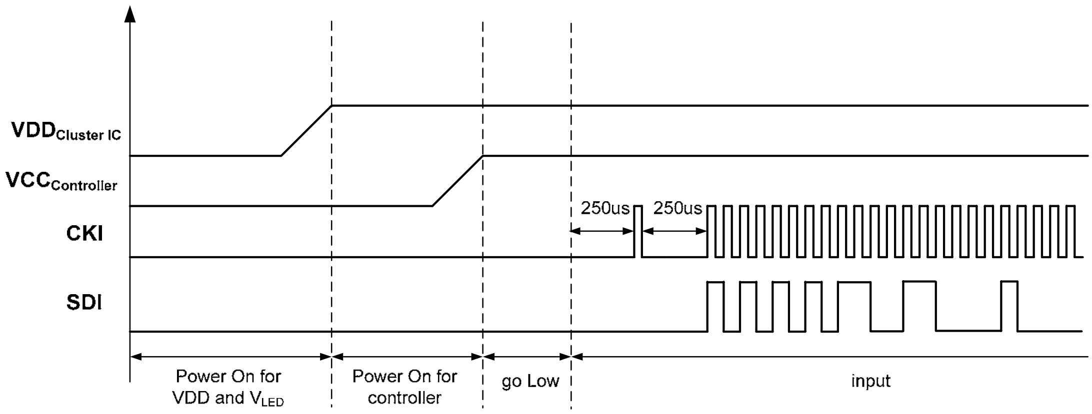


Fig.8 Prefix timing after power-on

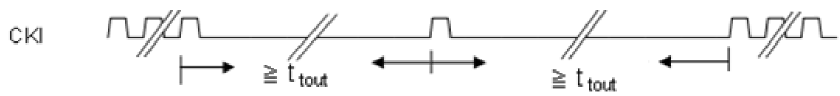


Fig.9 Valid timeout protocol

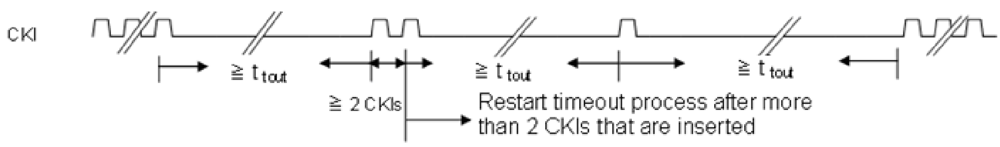


Fig.10 Timeout detection process will be re-started when there are more than 2 CKIs between t_{tout}

t_{tout} : for first timeout command after MBI6027 power on: its value must be more than 250us
for NOT first timeout command after power on: its value must be more than 64 CKIs

Header Packet Format

Preamble	Command	Address	Length	Parity check
16'h AACC	CMD[31:24]	10'b 00 0000 0000	L[13:4]	P[3:0]

CMD[31:24]:

MBI6027 provides seven kinds of command types which are shown as the table below:

Table 10. Command table

CMD[31:24]	CMD Type
8'b 0010 0011	Configuration mode
8'b 0001 0011	Dot correction mode
8'b 0011 1111	Gray scale mode
8'b 0001 0100	Software reset mode
8'b 0010 0000	IC status read mode
8'b 0110 0011	Configuration with status read mode
8'b 0101 0011	Dot correction with status read mode

Note: the 12-/8-bit gray scale mode and 10/8bit dot correction mode are decided by GS_SEL pin

L[13:4]:

Please fill in the binary number of total IC's in cascade. The number to be filled in is N-1, where N is the total number of IC in cascade.

For example: if we have 3 IC's in cascade, Length[13:4]=10'b0000 0000 10

P[3:0]:

P[3] even parity of CMD, P[2] even parity of A, P[1] even parity of L, P[0] even parity of P[3:1].

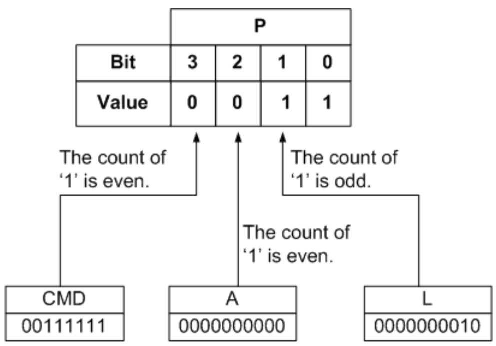


Fig.11 Parity scheme

Configuration Mode(23h)

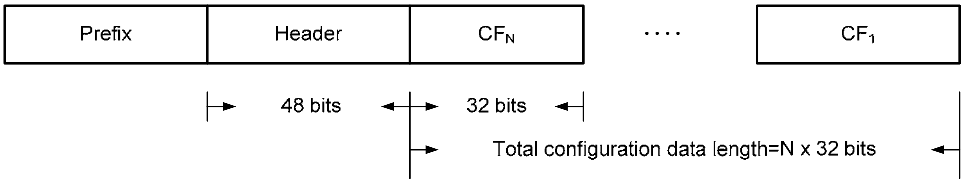


Fig.12 Format of configure write command

Note:

1. N=Number of IC's in cascade.
2. Please refer to "Prefix" for the setup of the prefix.
3. Please refer to "Definition of Configuration Register" in page 16 for the setup of configuration data.
4. The configuration data for the last IC is input first, and the MSB of data is input first.

Dot Correction Mode(13h)

I. 10-bit dot correction

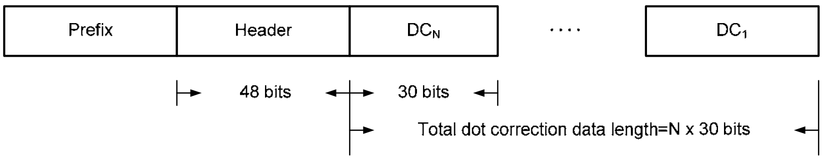


Fig.13 Format of 10-bit dot-correction command

Note:

1. Please connect GS_SEL to GND when applying to the 10-bit dot correction mode.
2. N=Number of IC in cascade
3. Please refer to "Prefix" for the setup of the prefix.
4. Please refer to "Definition of Dot Correction Register" for the setup of dot correction data.
5. The configuration data for the last IC is input first, and the MSB of data is input first.

II. 8-bit dot correction

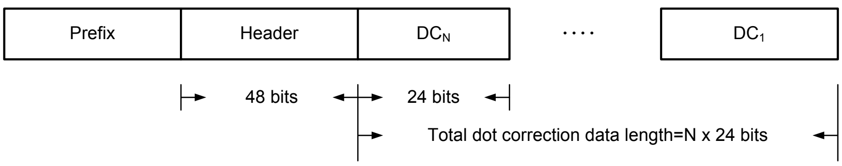


Fig.14 Format of 8-bit dot-correction command

Note:

1. Please connect GS_SEL to VDD when applying to the 8-bit dot correction mode.
2. N=Number of IC in cascade
3. Please refer to "Prefix" for the setup of the prefix.
4. Please refer to "Definition of Dot Correction Register" for the setup of dot correction data.
5. The configuration data for the last IC is input first, and the MSB of data is input first.

Gray Scale Mode(3Fh)

I. 12-bit gray scale

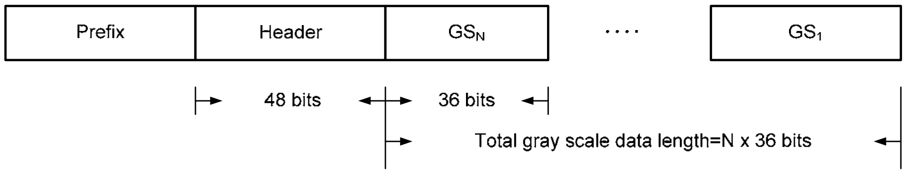


Fig.15 Format of 12-bit gray scale command

Note:

1. Please connect GS_SEL to GND when applying to the 12-bit gray scale mode.
2. N=Number of IC in cascade
3. Please refer to “Prefix” for the setup of the prefix.
4. Please refer to “Definition of Gray Scale Register” for the setup of gray scale data.
5. The configuration data for the last IC is input first, and the MSB of data is input first.

II. 8-bit gray scale

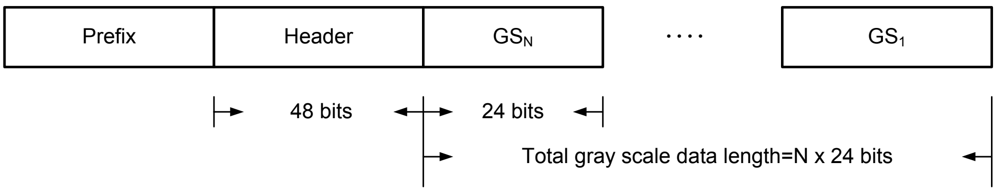


Fig.16 Format of 8-bit gray scale command

Note:

1. Please connect GS_SEL to VDD when applying to the 8-bit gray scale mode.
2. N=Number of IC in cascade
3. Please refer to “Prefix” for the setup of the prefix.
4. Please refer to “Definition of Gray Scale Register” for the setup of gray scale data.
5. The configuration data for the last IC is input first, and the MSB of data is input first.

Here, we use an example to show how to program a 12-bit gray scale, as shown in the following figures.

Example of 12-bit Gray Scale

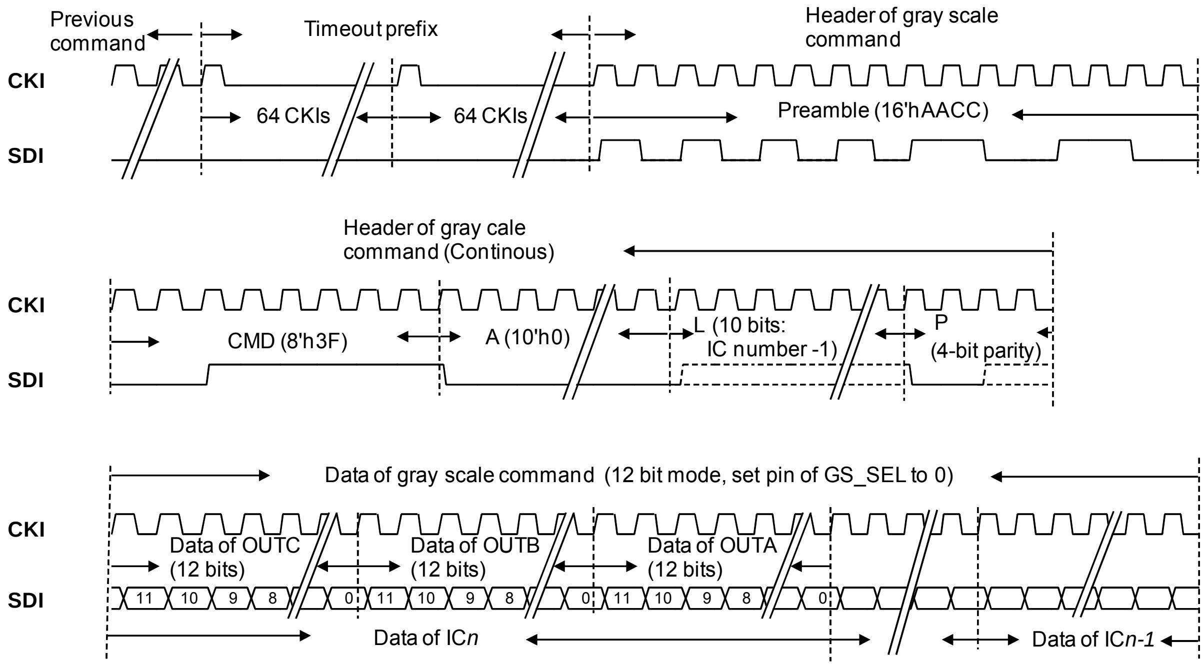


Fig.17 Example of 12-bit gray scale command

Software Reset Mode(14h)

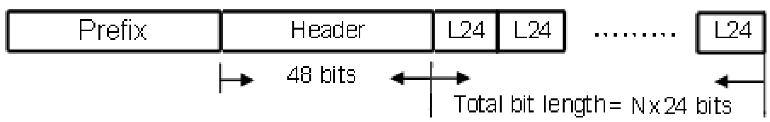


Fig.18 Format of software reset command

Note:

1. L24: 24bit 0's
2. When the software reset command is sent, the IC will be reset EXCEPT:
   a.) configuration register
   b.) dot-correction value

IC Status Read Mode(20h)

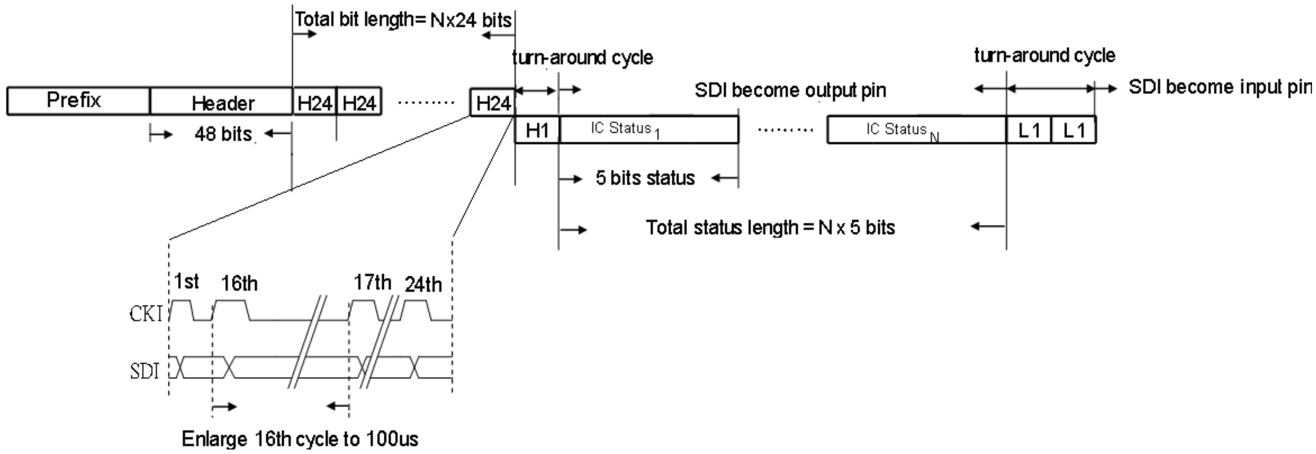


Fig.19 Format of IC status read command

Note:

1. H1: 1 bit 1.
2. L1: 1 bit 0.
3. Please refer to “Switching Characteristics” for the limitation of clock frequency.
4. CKI of the last H24 must be greater than 100μs, and all outputs are disabled during detection.
5. The first IC is output first; the MSB of IC Status is output first.
6. IC Status is defined as follow.

Bit	Status Name	Description
4	Transfer wire status	10 : normal
3		00, 01, 11 : error
2	Open detection status	0 : normal 1 : error
1	Leakage detection status	0 : normal 1 : error
0	Parity check	Even parity of Bit[4:1]

Configuration Status Read Mode(63h)

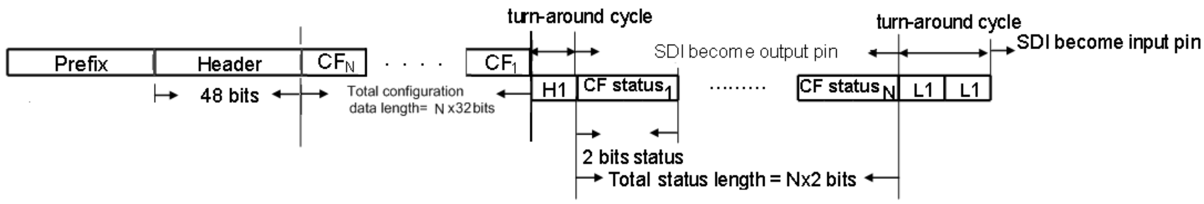


Fig.20 Format of configuration status read command

Note:

1. H1: 1 bit 1
2. Please refer to “Switching Characteristics” for the limitation of clock frequency.
3. Please refer to “Configuration Mode” for the transmission of CF_N~CF_1.
4. The first IC is output first, and the MSB of CF Status is output first.
5. CF Status is defined as follow.

Bit	Status Name	Description
1	Configuration status	0 : normal 1 : error
0	Parity check	Odd parity of configuration status

Dot Correction Status Read Mode(53h)

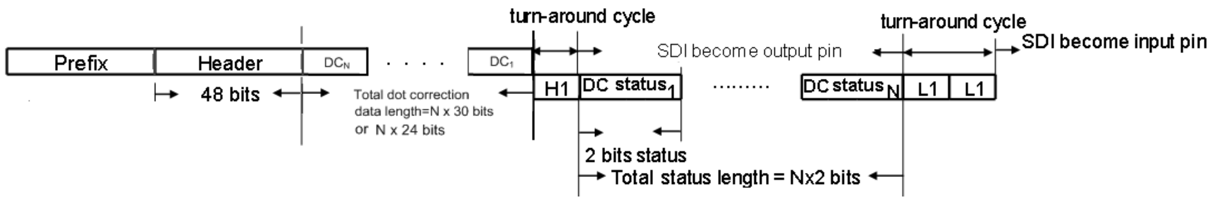


Fig.21 Format of dot correction status read mode command

Note:

1. H1: 1 bit 1’s.
2. L1: 1 bit 0’s.
3. Please refer to “Switching Characteristics” for the limitation of clock frequency.
4. Please refer to “Dot Correction Mode” for the transmission of DC_N~DC_1.
5. The first IC is output first; the MSB of DC Status is output first.
6. DC Status is defined as follow.

Bit	Status Name	Description
1	Dot Correction status	0 : normal 1 : error
0	Parity check	Odd parity of Bit[1]

Programming sequence

I. Initialization:

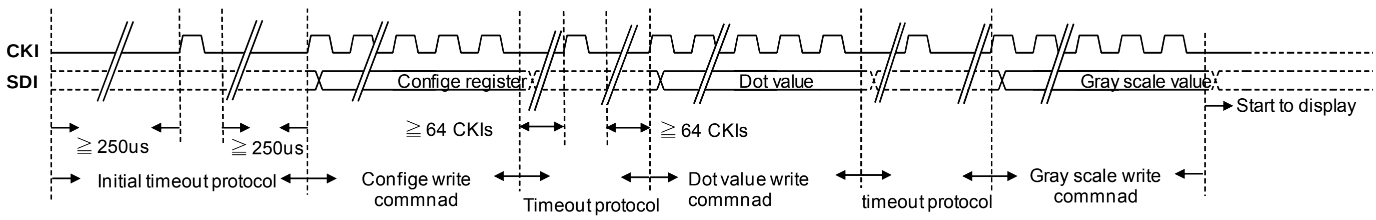


Fig.22 Programming sequence of initialization

The above waveform shows the initialization programming sequence, the configure mode must be sent first, and the output ports ($\overline{\text{OUTA}}$ ~ $\overline{\text{OUTC}}$) will start display after end of gray scale write command. dot correction value write command can be sent or not, if not be sent, the default value are 10'h3FF or 8'hFF (depend on 12bit or 8bit mode) will be used for display. Timeout protocol is need before every header, but note that the first timeout after power up, "250us + 1CKI + 250us" is needed else the first frame data will be ignored

II. Gray scale display:

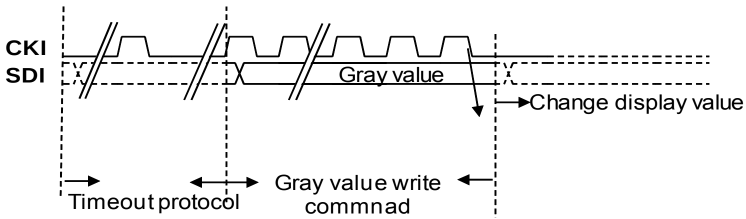


Fig.23 Programming sequence of gray scale display

The above waveform illustrates normal display sequence, for frame rate issue, the gray scale write command must be write inside 1/60 sec., every time that command be finish, the display value will be updated.

III. Dot correction value update sequence:
Following waveform shows the dot correction update sequence, note that the dot correction value will not be updated after dot value write command, it will be updated after next gray scale write command is sent.

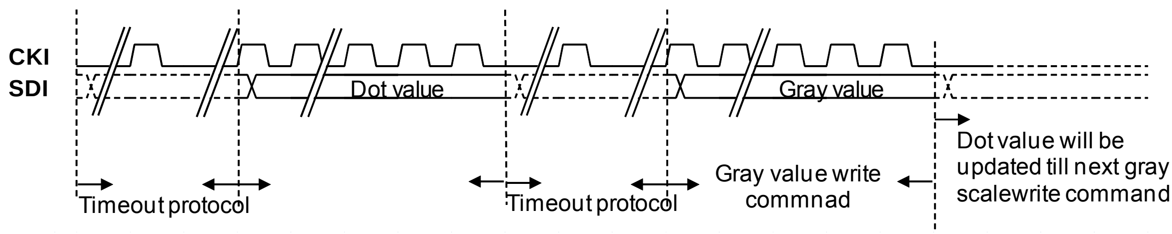


Fig.24 Programming sequence of dot correction

Constant Current

1) MBI6027 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 that the LED shows the same brightness regardless of the variations of LED forward voltages (V_F).

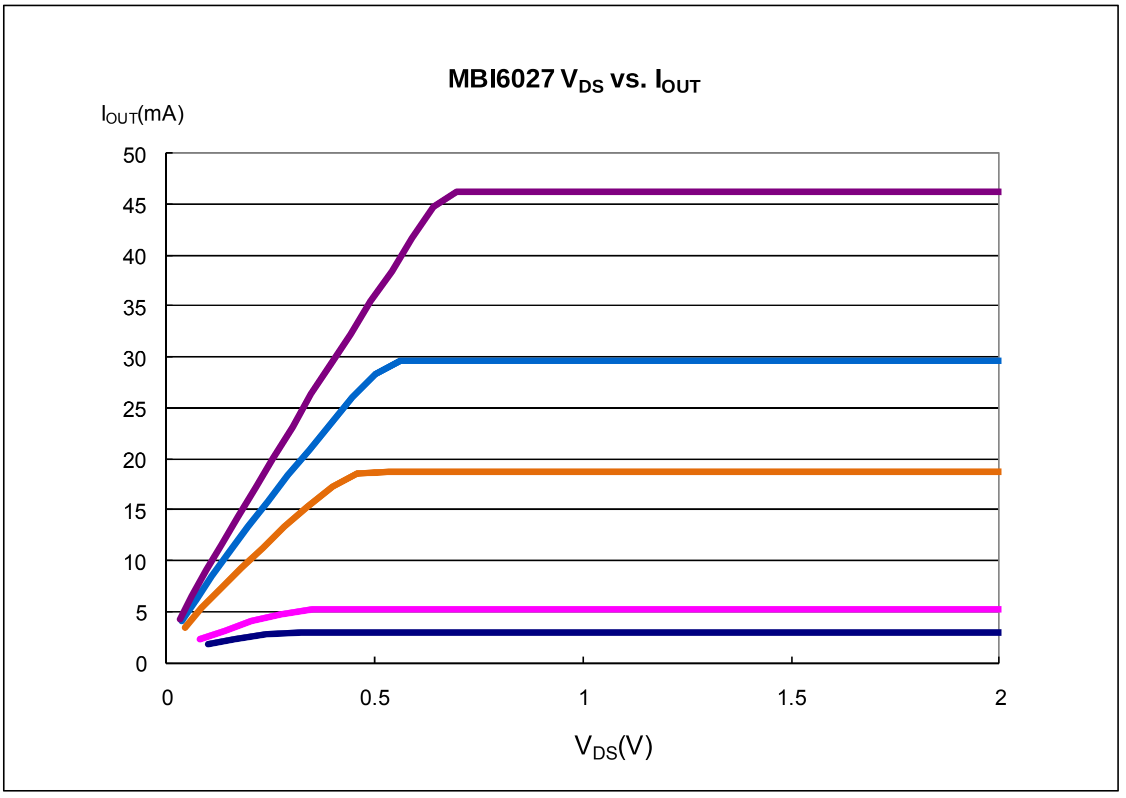


Fig.25 Constant current characteristics of MBI6027

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.

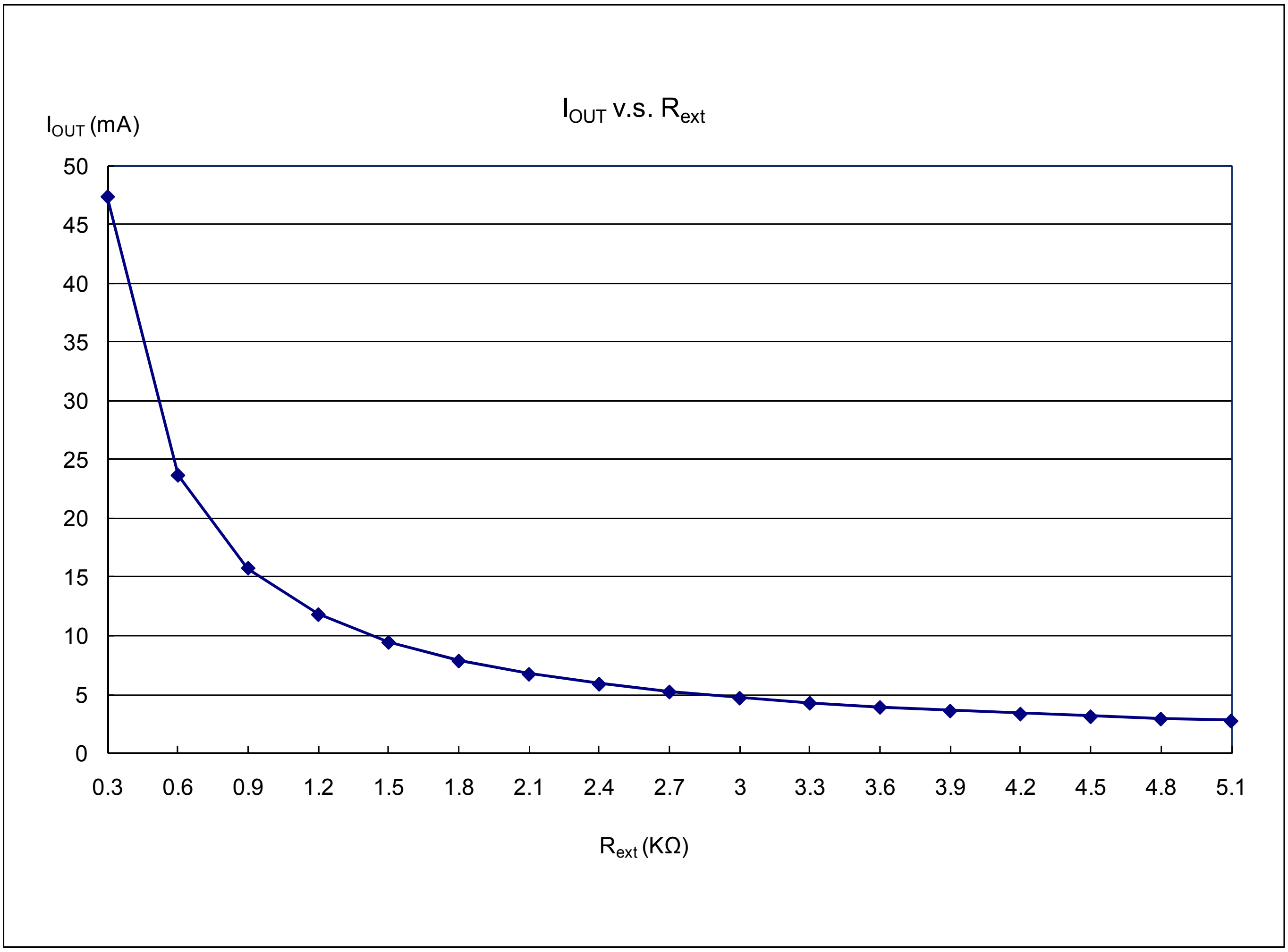


Fig.26 I_{OUT} adjustment by R_{EXT}

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 0.617V. The relationship between I_{OUT} and R_{EXT} is shown in the above figure.

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

$I_{OUT} = 23*0.617 / R_{EXT}$

$R_{EXT} = 23*0.617 / I_{OUT}$

$I_{OUT}=V_{REXT}/R_{EXT}$

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

Current Gain Adjustment

Current gain is used to dynamically adjust output current according to the configuration register. For example, users can program the current gain setup according to ambient light intensity detected by an external sensor. In MBI6027, current gain of each channel can be set separately; please refer to table 5 in page 16 for detailed information about configuration register setup.

Current gain can be calculated by the following equations

$CG_A= A7x2^7+ A6x2^6+ A5x2^5+ A4x2^4+ A3x2^3+ A2x2^2+ A1x2^1+ A0x2^0$

$CG_B= B7x2^7+ B6x2^6+ B5x2^5+ B4x2^4+ B3x2^3+ B2x2^2+ B1x2^1+ B0x2^0$

$CG_C= C7x2^7+ C6x2^6+ C5x2^5+ C4x2^4+ C3x2^3+ C2x2^2+ C1x2^1+ C0x2^0$

Output current of each channel is calculated as follows.

$I_{OUTA}=(23\times 0.617\div R_{EXT}) \times (CG_A\div 255)$

$I_{OUTB}=(23\times 0.617\div R_{EXT}) \times (CG_B\div 255)$

$I_{OUTC}=(23\times 0.617\div R_{EXT}) \times (CG_C\div 255)$

Table 11. Current gain bit – output current level conversion

Current gain bits	Output current level
8b' 0000 0000	0/255
8b' 0000 0001	1/255
8b' 0000 0010	2/255
. . .	. . .
8b' 1111 1110	254/255
8b' 1111 1111 (default)	255/255

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 MBI6027 is calculated by the equation:

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

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

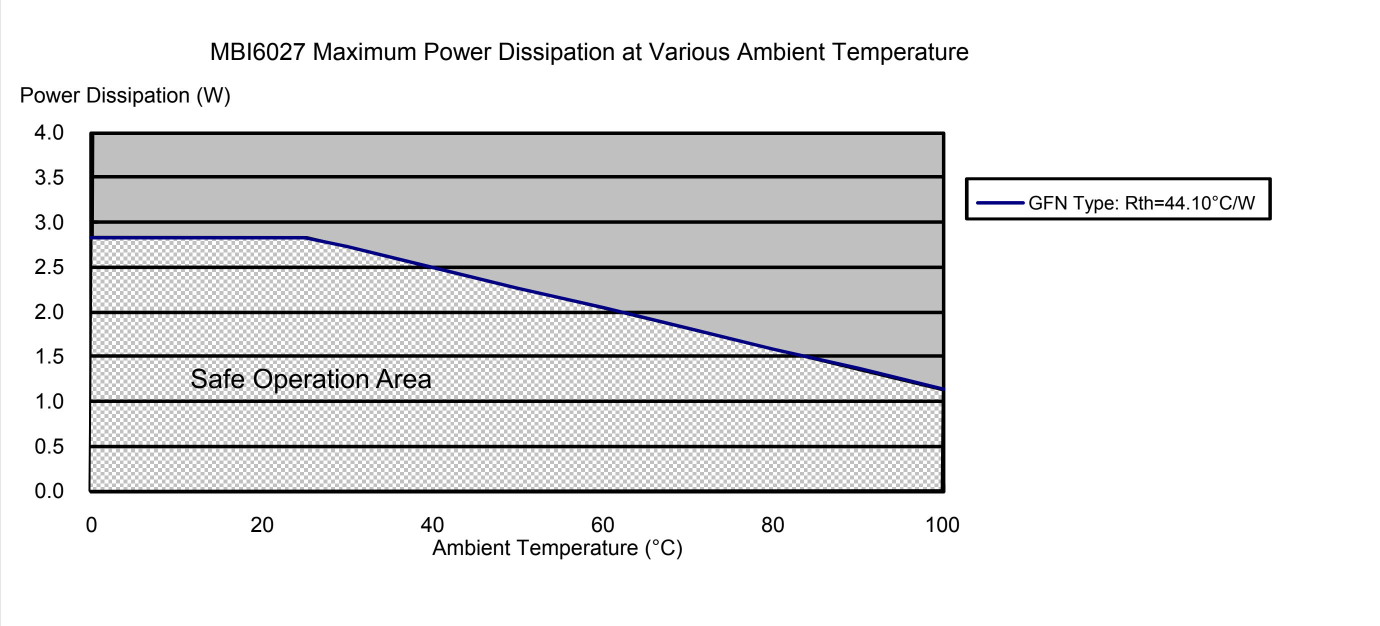


Fig.27 Package power dissipation of MBI6027

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.

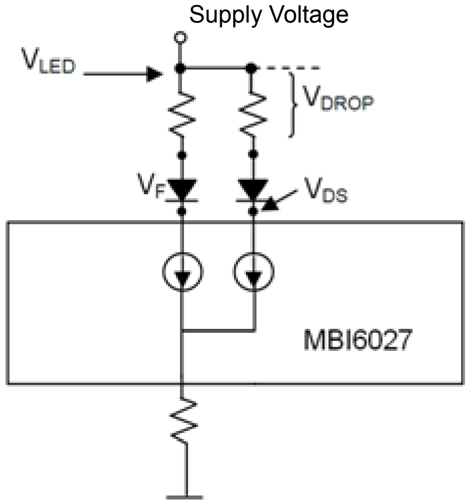


Fig.28 Application of the resistor for V_{LED} adjustment

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 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 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.

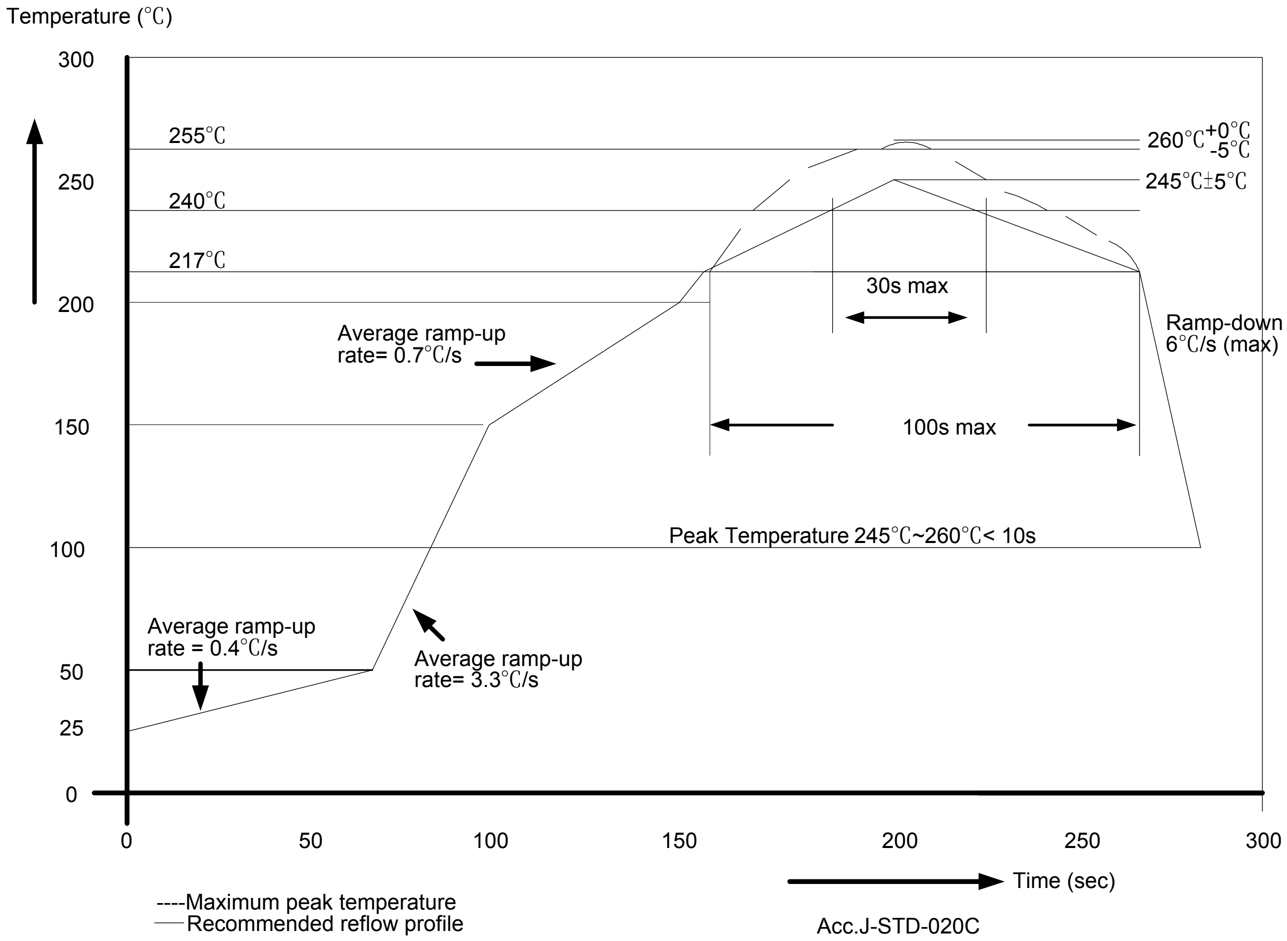
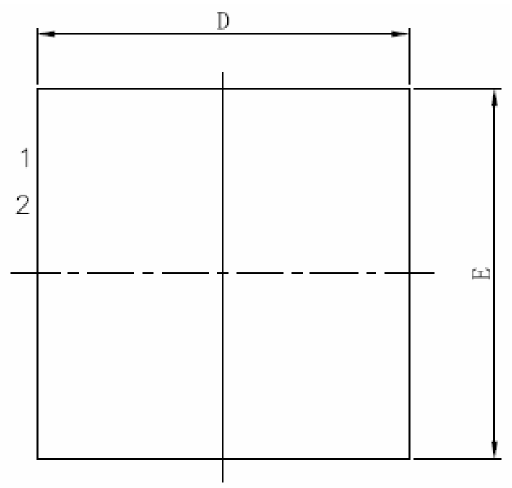


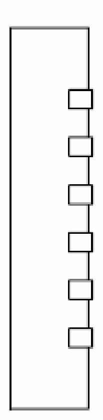
Figure 33. Soldering process of MBI6027

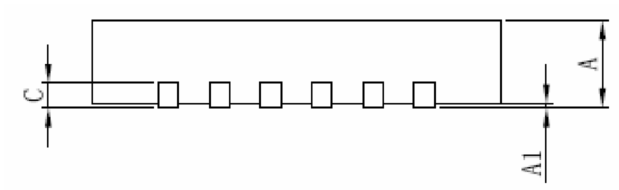
Package Thickness	Volume mm³ <350	Volume mm³ 350-2000	Volume mm³ ≧2000
<1.6mm	260 +0 °C	260 +0 °C	260 +0 °C
1.6mm – 2.5mm	260 +0 °C	250 +0 °C	245 +0 °C
≧2.5mm	250 +0 °C	245 +0 °C	245 +0 °C

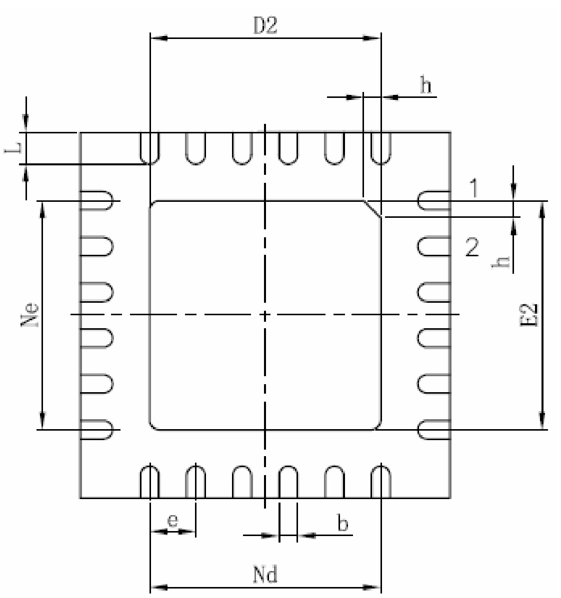
* For details, please refer to Macroblock’s “Policy on Pb-free & Green Package”.

Package Outline









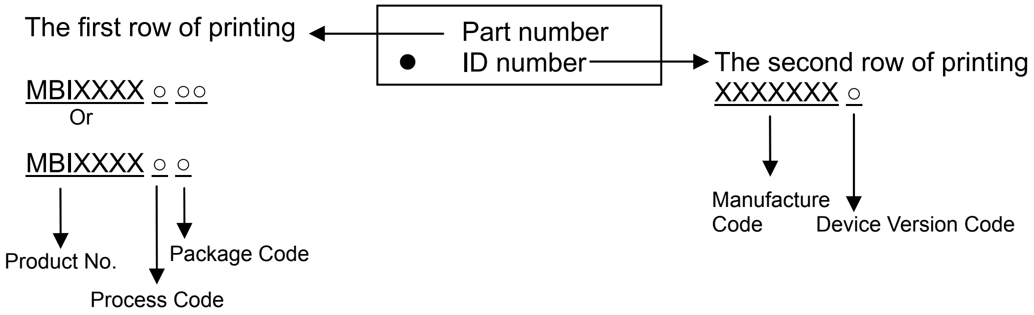
SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0. 70	0.75	0. 80
A1	—	0.01	0. 05
b	0. 18	0.25	0. 30
c	0. 18	0.20	0. 25
D	3. 90	4. 00	4. 10
D2	2. 50REF		
e	0. 50BSC		
Ne	2. 50BSC		
Nd	2. 50BSC		
E	3. 90	4. 00	4. 10
E2	2. 50REF		
L	0. 35	0.40	0. 45
h	0. 30	0. 35	0. 40

MBI6027GFN Outline Drawing

Remark: The thermal pad size may exist a tolerance due to the manufacturing process, please use the maximum dimensions-D2(max. 2.50mm) x E2(max. 2.50mm) 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).

Product Top Mark Information



Product Revision History

Datasheet version	Device Version Code
V1.00	A
V1.01	A
V1.02	A

Product Ordering Information

Part Number	RoHS Compliant Package Type	Weight (g)
MBI6027GFN	QFN24L-4*4- 0.5	0.0379g

Disclaimer