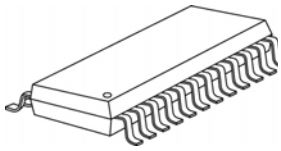
16-Channel Constant Current LED Sink Driver with Full Diagnosis and Power Saving

Features

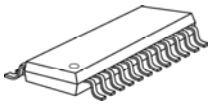
- 3.3V/ 5V supply voltage
- 16 constant current output channels
- Constant output current invariant to load voltage change
- Constant output current range:
  3-45mA@V_{DD}=5V;
  3-30mA@V_{DD}=3.3V
- Excellent output current accuracy:
  - Between channels: ±1.5% (typ.) and ±3% (max.)
  - Between ICs: ±3% (typ.) and ±6% (max.)
- Visual effect control
  - Patented S-PWM technology to improve refresh rate
  - 16-bit gray scale control
  - 6-bit programmable output current gain from 12.5%~200%
- Error detections
  - In-message error detection
    - LED open-circuit detection
  - Compulsory error detection: data-independent full panel and silent error detection in 700ns
    - Programmable LED short-circuit detection
    - LED open-circuit detection
    - Programmable leakage and short to ground diagnosis
  - Current setting resistor open-circuit detection
  - Thermal protection: alert (>140°C) and shutdown (>160°C)
- Flexible operation modes
  - Auto synchronisation mode
  - Manual synchronisation mode
- EMI reduction
  - 2 groups staggered delay of output, preventing from current surge
- Maximum data clock frequency: 20MHz
- Maximum gray scale clock frequency: 20MHz
- 0-power mode
- Watchdog timer (WDT) operation

Small Outline Package



GF: SOP24L-300-1.00

Shrink SOP



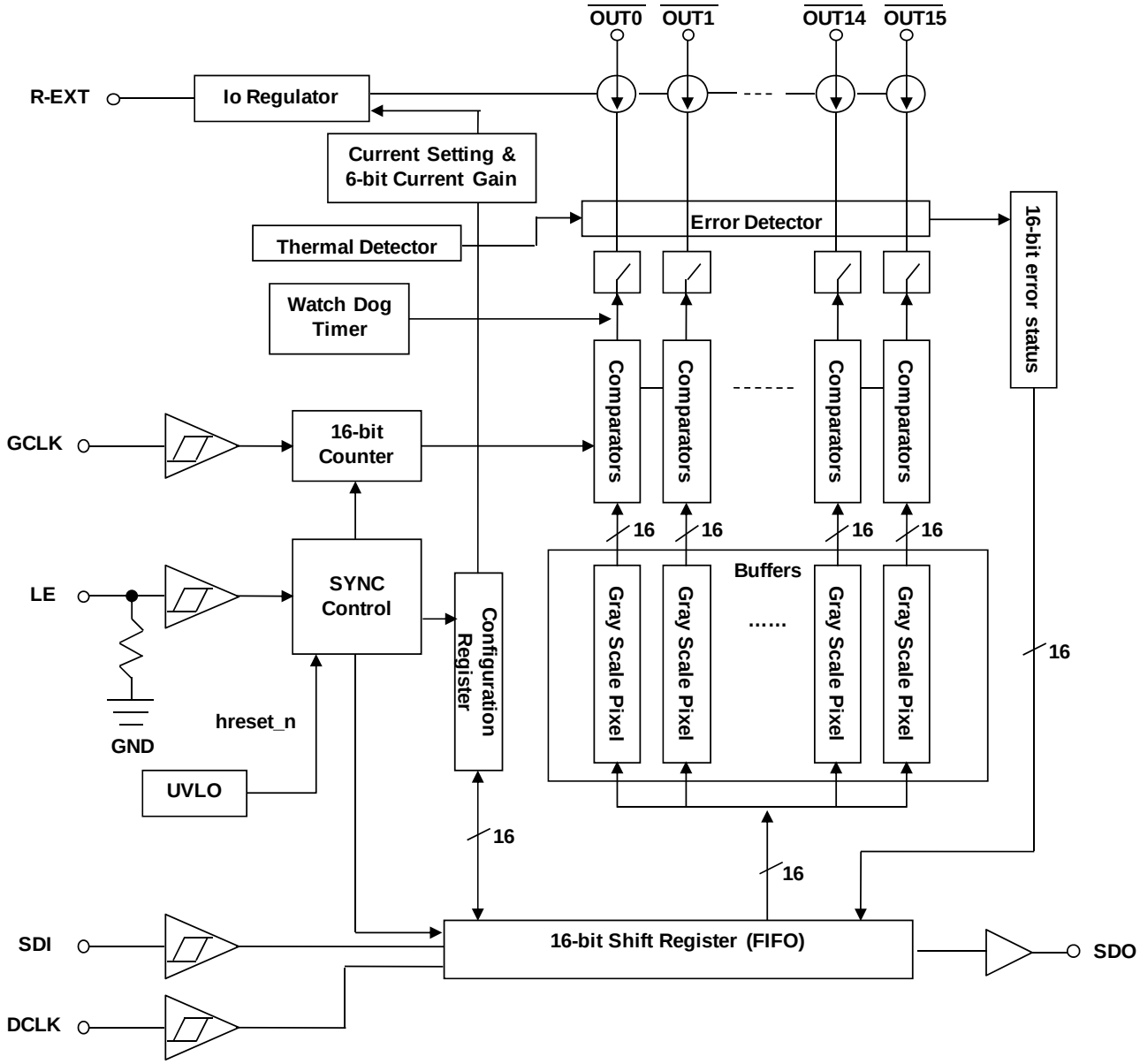
GP: SSOP24L-150-0.64

Product Description

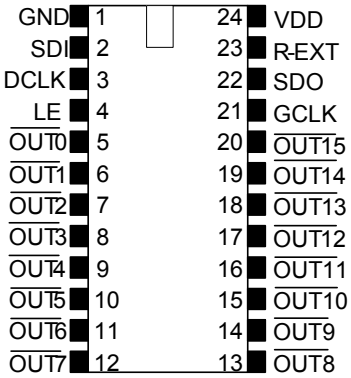
MBI5047 is an enhanced 16-channel constant current LED sink driver with advanced error detection functions and smart power-saving modes. MBI5047 features 0-power mode to reduce the consumed current by chip and increase the power efficiency. Therefore, MBI5047 is especially suitable for LED traffic sign and message sign applications.

MBI5047 provides several kinds of error detections including LED open-circuit (compulsory and in-message), LED short-circuit (compulsory), leakage (compulsory) and over-temperature protection(160°C). This chip integrates a 6-bit current gain which can adjust the output current from 12.5% to 200%.

Block Diagram



Pin Configuration



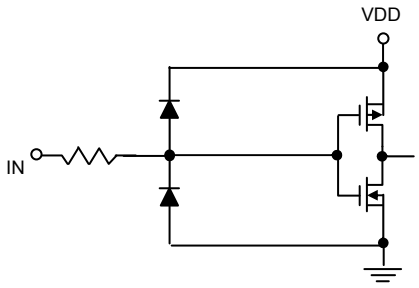
MBI5047GF/GP
Top View

Terminal Description

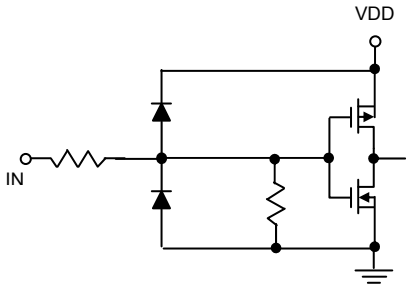
Pin No.	Pin Name	Function
1	GND	Ground terminal for control logic and current sink
2	SDI	Serial-data input to the shift register
3	DCLK	Clock input terminal used to shift data on rising edge and carries command information when LE is asserted.
4	LE	Data strobe input terminal Serial data is transferred to the output latch when LE is high. The data will be latched when LE goes low.
5~20	$\overline{OUT0}$ ~ $\overline{OUT15}$	Constant current output terminals
21	GCLK	Gray scale clock terminal Clock input for gray scale. The gray scale display is counted by gray scale clock comparing with input data.
22	SDO	Serial-data output to the following SDI of next driver IC. SDO signal changes on rising edge of CLK.
23	R-EXT	Input terminal used to connect an external resistor for setting up output current for all output channels
24	VDD	3.3V/5V supply voltage terminal

Equivalent Circuits of Inputs and Outputs

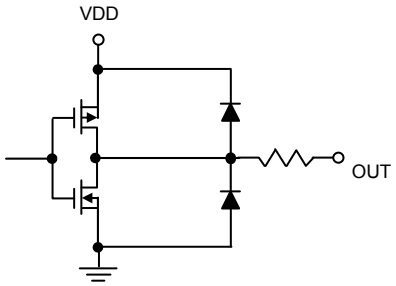
GCLK, DCLK, SDI terminal



LE terminal



SDO terminal



Maximum Ratings

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	0~7.0	V
Input Pin Voltage (SDI,LE, DCLK, GCLK)		V_{IN}	-0.4~V_{DD}+0.4	V
Output Current		I_{OUT}	+50	mA
Sustaining Voltage at /OUT Port		V_{DS}	-0.5~+17.0	V
GND Terminal Current		I_{GND}	+800	mA
Power Dissipation (On PCB*, Ta=25°C)	GF Type	P_D	2.52	W
	GP Type		1.838	
Thermal Resistance (On PCB*, Ta=25°C)	GF Type	$R_{th(j-a)}$	46.69	°C/W
	GP Type		68	
Junction Temperature		$T_{j,max}$	150**	°C
Operating Ambient 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 3B (8000V)
		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.

** 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)

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}	$\overline{OUT0}$~$\overline{OUT15}$		-	-	17.0	V
Output Current		I_{OUT}	Refer to "Test Circuit for Electrical Characteristics"		3	-	45	mA
		I_{OH}	SDO		-	-	-1.0	mA
		I_{OL}	SDO		-	-	1.0	mA
Input Voltage	"H" level	V_{IH}	DCLK, SDI, LE, GCLK Ta =-40~85ºC		0.7xV_{DD}	-	V_{DD}	V
	"L" level	V_{IL}	DCLK, SDI, LE, GCLK Ta =-40~85ºC		GND	-	0.3xV_{DD}	V
Output Leakage Current		I_{OH}	V_{DS}=17.0V		-	-	0.5	µA
Output Voltage	SDO	V_{OL}	I_{OL}=+1.0mA		-	-	0.4	V
		V_{OH}	I_{OH}=-1.0mA		V_{DD}-0.4	-	-	V
Current Skew (Channel)		dI_{OUT1}	I_{OL}=20mA V_{DS}=1V	R_{ext}=680Ω	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OL}=20mA V_{DS}=1V	R_{ext}=680Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		%/dV_{DS}	V_{DS} within 1V and 3V		-	±0.1	±0.5	%/V
Output Current vs. Supply Voltage Regulation*		%/dV_{DD}	V_{DD} within 4.5V and 5.5V		-	±1.0	±2.0	%/V
LED Short-circuit Detection Threshold		$V_{SHORT,TH}$	Programmable by configuration register		2.3 2.8 3.8 4.3	2.5 3.0 4.0 4.5	-	V
Leakage Current & Short to Ground Diagnosis Threshold		$V_{LEAK,TH}$	Programmable by configuration register		1.4 1.8 2.2 2.9	0.4xV_{DD} 0.5xV_{DD} 0.6xV_{DD} 0.7xV_{DD}	-	V
LED Open circuit Detection Threshold		$V_{DS,TH}$	-		-	-	0.3	V
Watchdog Timer Time-out		T_{WDT}	-		70	160	300	ms
0-power Recovery Time Mode		$T_{RECOVERY}$	-		0.55	0.96	1.75	ms
Pull-down Resistor		R_{IN}(down)	LE		250	500	800	KΩ
Supply Current (DCLK= GCLK=0Hz)	"OFF"	I_{DD}(off) 1	R_{ext}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		-	2.8	3.3	mA
		I_{DD}(off) 2	R_{ext}=680Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		-	5.5	6.0	
		I_{DD}(off) 3	R_{ext}=350Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		-	9.0	9.5	
	"ON"	I_{DD}(on) 1	R_{ext}=680Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On		-	5.5	6.0	
		I_{DD}(on) 2	R_{ext}=306Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On		-	9.0	9.5	
	0-power mode	$I_{DD\_0\text{-}Power}$	-		-	130	200	uA
Thermal Flag Temperature1**		T_{TF1}	Junction Temperature		-	140	-	°C
Thermal Flag Temperature2**		T_{TF2}	Junction Temperature		-	160	-	°C

*One channel on.

**Thermal flag 1 is over-temperature alarm, and thermal flag 2 is thermal shutdown.

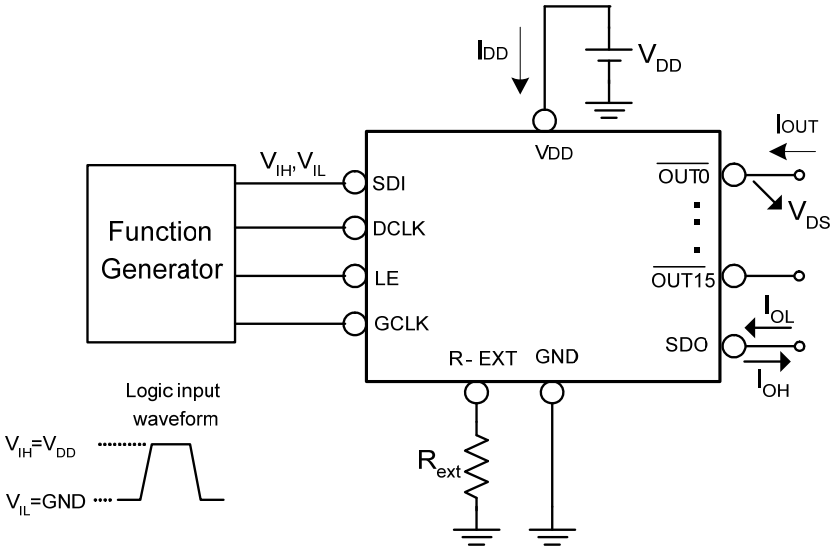
Electrical Characteristics (V_{DD}= 3.3V)

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}	$\overline{OUT0}$~ $\overline{OUT15}$		-	-	17.0	
Output Current		I_{OUT}	Refer to "Test Circuit for Electrical Characteristics"		3	-	30	mA
		I_{OH}	SDO		-	-	-1.0	mA
		I_{OL}	SDO		-	-	1.0	mA
Input Voltage	"H" level	V_{IH}	DCLK, SDI, LE, GCLK Ta =-40~85ºC		0.7xV_{DD}	-	V_{DD}	V
	"L" level	V_{IL}	DCLK, SDI, LE, GCLK Ta =-40~85ºC		GND	-	0.3xV_{DD}	V
Output Leakage Current		I_{OH}	V_{DS}=17.0V		-	-	0.5	µA
Output Voltage	SDO	V_{OL}	I_{OL}=+1.0mA		-	-	0.4	V
		V_{OH}	I_{OH}=-1.0mA		V_{DD}-0.4	-	-	V
Current Skew (Channel)		dI_{OUT1}	I_{OL}=25.7mA V_{DS}=1V	R_{ext}=560Ω	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OL}=25.7mA V_{DS}=1V	R_{ext}=560Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		%/dV_{DS}	V_{DS} within 1V and 3V		-	±0.1	±0.5	%/V
Output Current vs. Supply Voltage Regulation*		%/dV_{DD}	V_{DD} within 3.0V and 3.6V		-	±1.0	±2.0	%/V
LED Short-circuit Detection Threshold		$V_{SHORT,TH}$	Programmable by configuration register		2.3 2.8 3.8 4.3	2.5 3.0 4.0 4.5	-	V
Leakage Current & Short to Ground Diagnosis Threshold		$V_{LEAK,TH}$	Programmable by configuration register		0.8 1.0 1.3 1.7	0.4xV_{DD} 0.5xV_{DD} 0.6xV_{DD} 0.7xV_{DD}	-	V
LED Open-circuit Detection Threshold		$V_{DS,TH}$	-		-	-	0.30	V
Watchdog Timer Time-out		T_{WDT}	-		55	115	250	ms
0-power Recovery Time Mode		$T_{RECOVERY}$	-		0.55	0.69	1.5	ms
Pull-down Resistor		R_{IN}(down)	LE		250	500	800	KΩ
Supply Current (DCLK= GCLK=0Hz)	"OFF"	I_{DD}(off) 1	R_{ext}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		-	2.5	3.0	mA
		I_{DD}(off) 2	R_{ext}=680Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		-	5.1	5.6	
		I_{DD}(off) 3	R_{ext}=490Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		-	6.6	7.1	
	"ON"	I_{DD}(on) 1	R_{ext}=680Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On		-	5.1	5.6	
		I_{DD}(on) 2	R_{ext}=490Ω, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On		-	6.6	7.1	
	0-power mode	$I_{DD\_0\text{-}Power}$	-		-	130	200	uA
Thermal Flag Temperature1**		T_{TF1}	Junction Temperature		-	140	-	°C
Thermal Flag Temperature2**		T_{TF2}	Junction Temperature		-	160	-	°C

*One channel on.

**Thermal flag 1 is over-temperature alarm, and thermal flag 2 is thermal shutdown.

Test Circuit for Electrical Characteristics



Switching Characteristics (V_{DD}= 5.0V)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Setup Time	SDI - DCLK ↑	t_{SU0}	V_{DD}=5.0V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=680Ω V_{DS}=1V R_L=150Ω C_L=10pF C_1=100nF C_2=10μF C_{SDO}=10pF V_{LED}=4.0V	7	-	-	ns
	LE ↑ - DCLK ↑	t_{SU1}		7	-	-	ns
	LE ↓ - DCLK ↑	t_{SU2}		50	-	-	ns
Hold Time	DCLK ↑ - SDI	t_{H0}		7	-	-	ns
	DCLK ↑ - LE ↓	t_{H1}		7	-	-	ns
	LE ↓ - GCLK ↑	t_{H2}		10	-	-	ns
Propagation Delay Time	DCLK - SDO	t_{PD0}		-	25	33	ns
	GCLK - $\overline{OUT2n}$*	t_{PD1}		-	50	-	ns
	LE - SDO	t_{PD2}**		-	30	40	ns
Staggered Delay of Output	$\overline{OUT2n+1}$***	t_{DL1}		-	5	-	ns
Pulse Width	LE	$t_{W(L)}$		15	-	-	ns
	DCLK	$t_{W(DCLK)}$		25	-	-	ns
	GCLK	$t_{W(GCLK)}$		25	-	-	ns
Command to Command		t_{CC}		50	-	-	ns
SDO Rise Time		$t_{r,SDO}$		-	10	-	ns
SDO Fall Time		$t_{f,SDO}$		-	10	-	ns
Output Rise Time of Output Ports		t_{OR}		10	15	30	ns
Output Fall Time of Output Ports		t_{OF}		10	15	30	ns
In-message Error Detection Duration (Count by GCLK)		$1/F_{GCLK}$		10	-	-	$1/F_{GCLK}$
Compulsory Error Detection Operation time****		t_{ERR-C}		700	-	-	ns
Data Clock Frequency (Pure Digital)		F_{DCLK}		-	-	20	MHz
Gray Scale Clock Frequency (Pure Digital)		F_{GCLK}		-	-	20	MHz

*Output waveforms have good uniformity among channels.

**In timing of “configuration read”, “in-message error detection read” and “compulsory error detection read”, the next DCLK rising edge should be t_{PD2} after LE’s falling edge.

***Refer to the Timing Waveform, n=0, 1, 2, 3, 4, 5, 6, 7.

****Users have to leave more time than the maximum error detection time for the error detection.

Switching Characteristics (V_{DD}= 3.3V)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Setup Time	SDI - DCLK ↑	t_{SU0}	V_{DD}=3.3V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=680Ω V_{DS}=1V R_L=150Ω C_L=10pF C_1=100nF C_2=10μF C_{SDO}=10pF V_{LED}=4.0V	8	-	-	ns
	LE ↑ - DCLK ↑	t_{SU1}		8	-	-	ns
	LE ↓ - DCLK ↑	t_{SU2}		50	-	-	ns
Hold Time	DCLK ↑ - SDI	t_{H0}		8	-	-	ns
	DCLK ↑ - LE ↓	t_{H1}		8	-	-	ns
	LE ↓ - GCLK ↑	t_{H2}		12			ns
Propagation Delay Time	DCLK - SDO	t_{PD0}		-	30	40	ns
	GCLK - $\overline{OUT2n}$*			-	60	-	ns
	LE -SDO	t_{PD2}**		-	40	50	ns
Staggered Delay of Output	$\overline{OUT2n+1}$***			-	5	-	ns
Pulse Width	LE	$t_{w(L)}$		15	-	-	ns
	DCLK	$t_{w(DCLK)}$		25	-	-	ns
	GCLK	$t_{w(GCLK)}$		25	-	-	ns
Command to Command		t_{cc}		50	-	-	ns
SDO Rise Time		$t_{r,SDO}$		-	10		ns
SDO Fall Time		$t_{f,SDO}$		-	10		ns
Output Rise Time of Output Ports		t_{OR}		25	30	60	ns
Output Fall Time of Output Ports		t_{OF}		25	30	60	ns
In-message Error Detection Duration (Count by GCLK)		$1/F_{GCLK}$		10	-	-	$1/F_{GCLK}$
Compulsory Error Detection Operation time****		t_{ERR-C}		700	-	-	ns
Data Clock Frequency (Pure Digital)		F_{DCLK}		-	-	20	MHz
Gray Scale Clock Frequency (Pure Digital)		F_{GCLK}		-	-	20	MHz

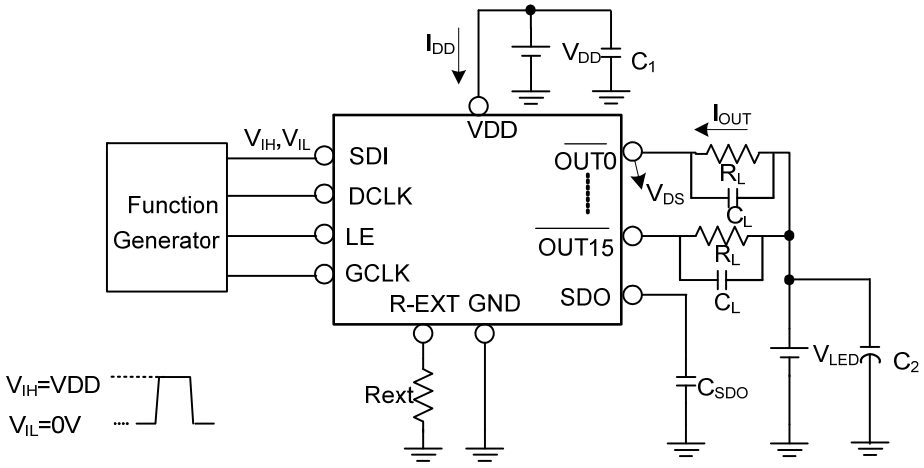
*Output waveforms have good uniformity among channels

**In timing of “configuration read”, “in-message error detection read” and “compulsory error detection read”, the next DCLK rising edge should be t_{PD2} after LE’s falling edge.

***Refer to the Timing Waveform, n=0, 1, 2, 3, 4, 5, 6, 7

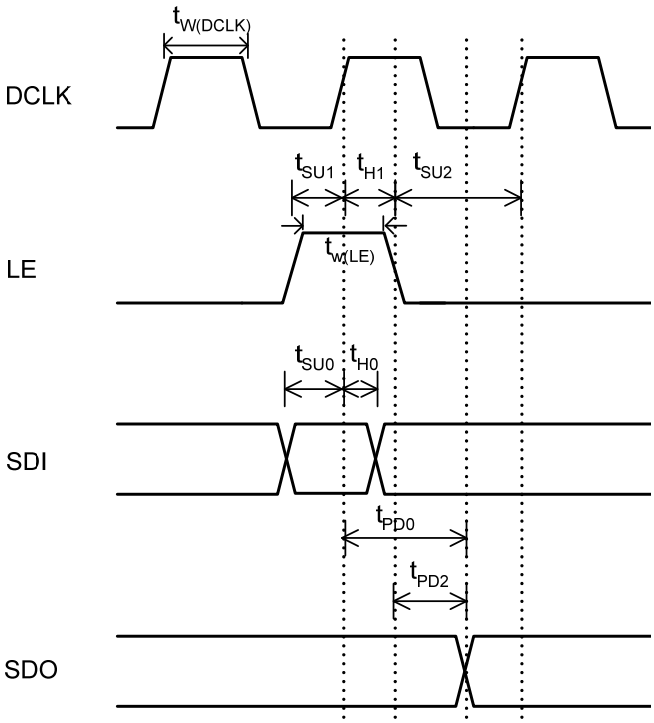
****Users have to leave more time than the maximum error detection time for the error detection.

Test Circuit for Switching Characteristics

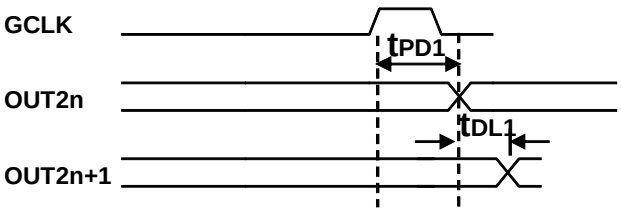


Timing Waveform

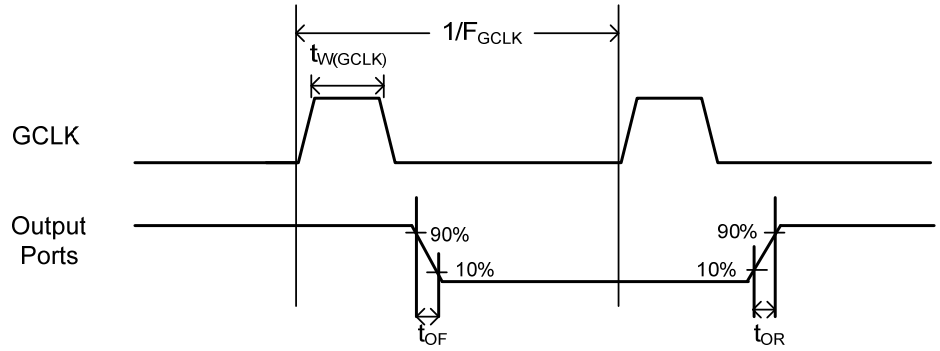
(1)



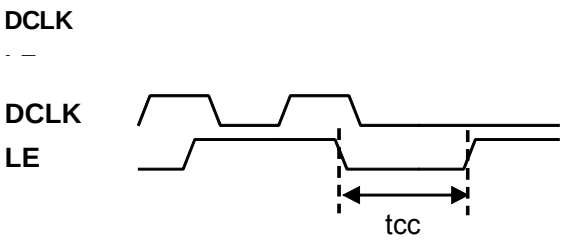
(2)



(3)



(4)



Principle of Operation

Users should set the operation modes in the configuration register through the “write configuration” command before sending gray scale data. The control command and configuration register are summarized in the following two tables.

Control Command

Command name	**LE**	**Number of CLK rising edge when LE is asserted**	**The action after a falling edge of LE**
Stop Compulsory Error Detection	High	0	Stop compulsory1/ compulsory2/ compulsory3/ compulsory4 error detection.
Data Latch	High	1	Serial data are transferred to the buffers
Global Latch	High	2	Buffer data are transferred to the comparators
Read Configuration Register	High	4	Read the configuration register
Compulsory1 Error Detection (Open-circuit)	High	6	Start compulsory error detection (Open-circuit detection)
Compulsory2 Error Detection (Short-circuit)	High	7	Start compulsory error detection (Short-circuit detection)
Compulsory3 Error Detection (R_{ext}-open, the status of thermal protection, the status of 0-power mode and the status of watchdog time-out)	High	8	Start compulsory error detection (R_{ext}-open error detection, the status of thermal protection, the status of 0-power mode and the status of watchdog time-out)
Compulsory4 Error Detection (Leakage or Short to ground diagnosis)	High	9	Start leakage or short to ground diagnosis detection
Write Configuration Register	High	10	Write 16-bit configuration register
Reset PWM Counter	High	11	Reset the PWM counter
Enable Write Configuration	High	12	Enable to write the configuration register
Wake-up	High	13	Wake up from 0-power mode
Software Reset	High	30	Reset IC to initial state except configuration register

Definition of Configuration Register

MSB LSB

F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0

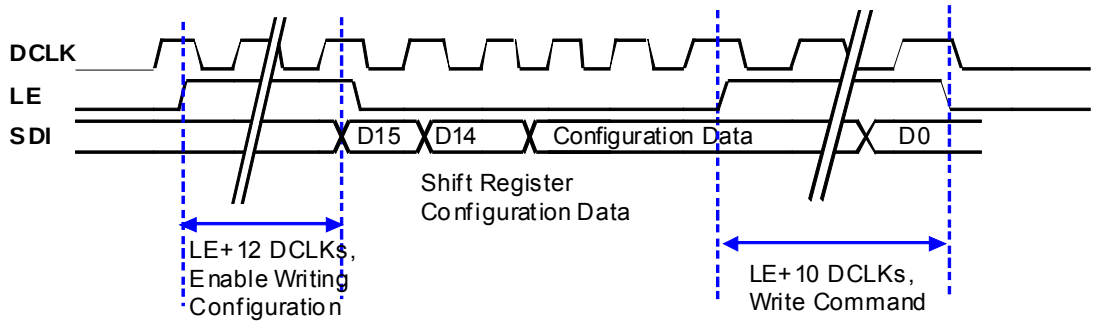
e.g. Default Value

F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
0	0	1	11		11		10		1	000000					

Bit	Attribute	Definition	Value	Function
F	Read/Write	0-power mode	0 (Default)	Disable 0-power mode
			1	Enable 0-power mode
E	Read/Write	PWM data synchronization mode	1	Manual-synchronization. Once the next input data is correctly recognized, MBI5047 will stop the present PWM cycle and restart a new PWM cycle to show the new data immediately.
			0 (Default)	Auto-synchronization, MBI5047 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.
D	Read/Write	Watchdog timer (WDT)	0	Disable WDT
			1 (Default)	Enable WDT
C~B	Read/Write	Threshold voltage of short-circuit detection	00 01 10 11 (Default)	2'b00: 2.5V 2'b01: 3.0V 2'b10: 4.0V 2'b11: 4.5V
A~9	Read/Write	Threshold voltage of leakage detection	00 01 10 11 (Default)	2'b00: 0.4xVdd 2'b01: 0.5xVdd 2'b10: 0.6xVdd 2'b11: 0.7xVdd
8~7	Read/Write	Read SDO Data Type	00 01 10 (Default) 11	2'b00: In-message error status 2'b01: Reserved 2'b10: SDI value 2'b11: Reserved
6	Read/Write	Thermal shutdown	0	Disable thermal shutdown
			1 (Default)	Enable thermal shutdown When the IC temperature is over 160°C, it will turn off the output current of all channels automatically.
5~0	Read/Write	Output current gain adjustment	000000 ~ 111111	6'b000000 (Default),(12.5%)

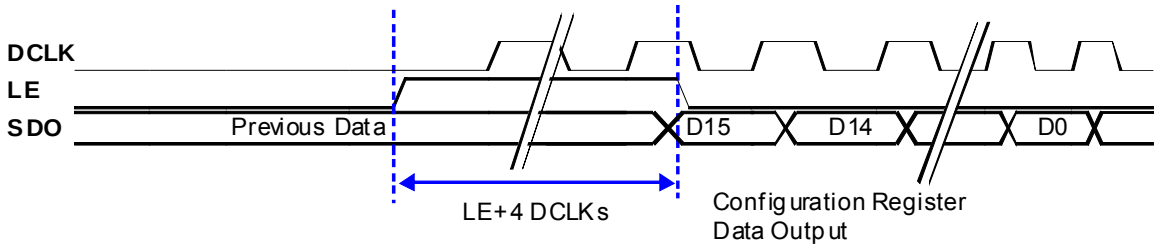
Write Configuration Register

Write the configuration register when receiving one LE pulse containing 12 DCLKs, then send 16-bit configuration setting to each LED driver and send one LE pulse containing 10 DCLKs.



Read Configuration Register

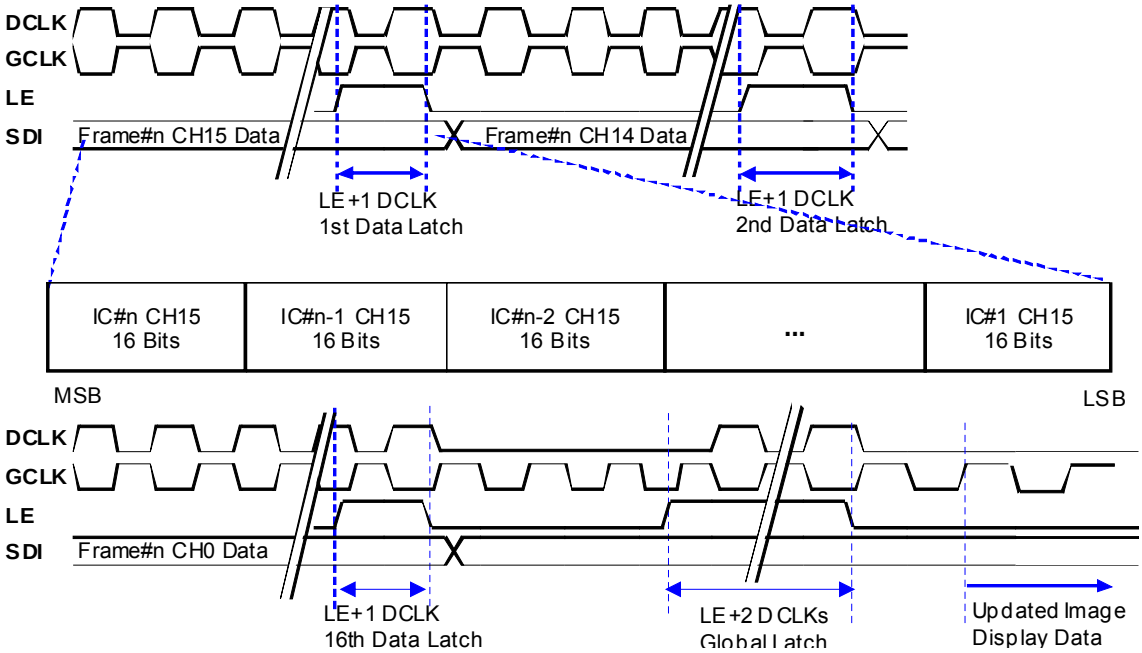
Read the configuration register when receiving one LE pulse containing 4 DCLKs to read the configuration setting. After the command, 16-bit configuration of each chip will be shifted out sequentially from the n^{th} chip to the 1^{st} chip.



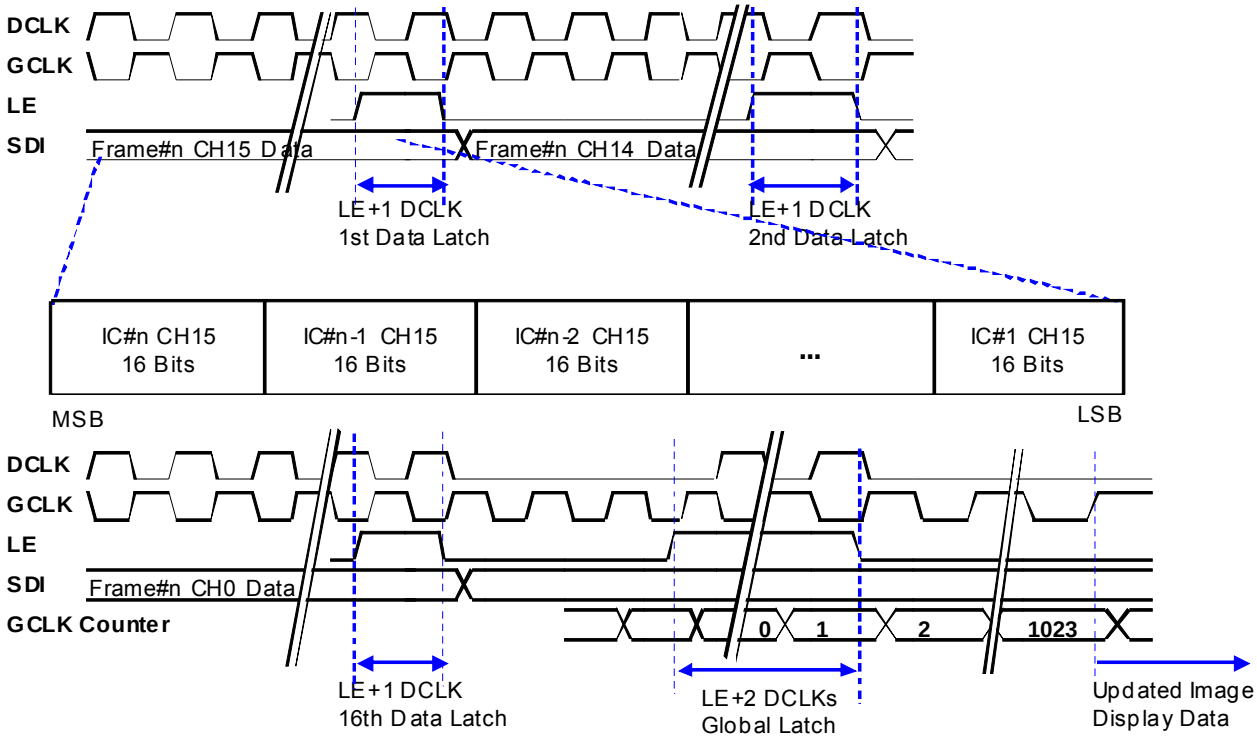
Set the PWM Gray Scale Data

The 16-bit input shift register latches 16 times of the gray scale data into each data buffer with a “data latch” command sequentially. With a “global latch” command for an additional latch, the buffer data are transferred to the comparators.

Manual Sync. Mode



Auto Sync. Mode



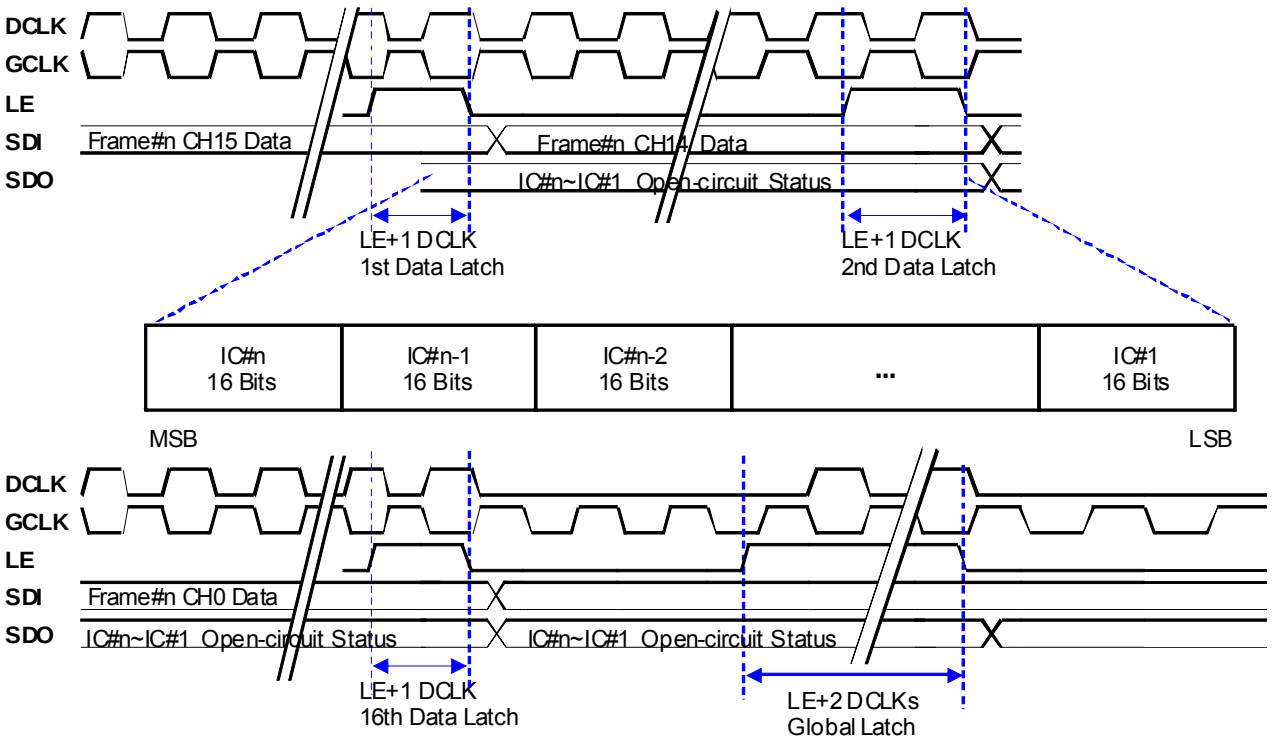
Note: there is no timing relation between DCLK and GCLK.

In-message Error Detection - LED Open-circuit

Users can set the in-message error detection by bit “8” and bit “7” of configuration register. To enable the in-message error detection, the bit “8” and bit “7” should be set to “00”.

The open-circuit will be reported only when output channels are turned on in 10 GCLKs, and the error reports will be put into the shift register after the gray scale data (LE+2 DCLKs) is latched.

Users will judge if the turn-on time is enough or not to deliver the error report. If the turn-on time is too short, ACHIILES will report normal state coded as “1”.



Note: there is no timing relation between DCLK and GCLK.

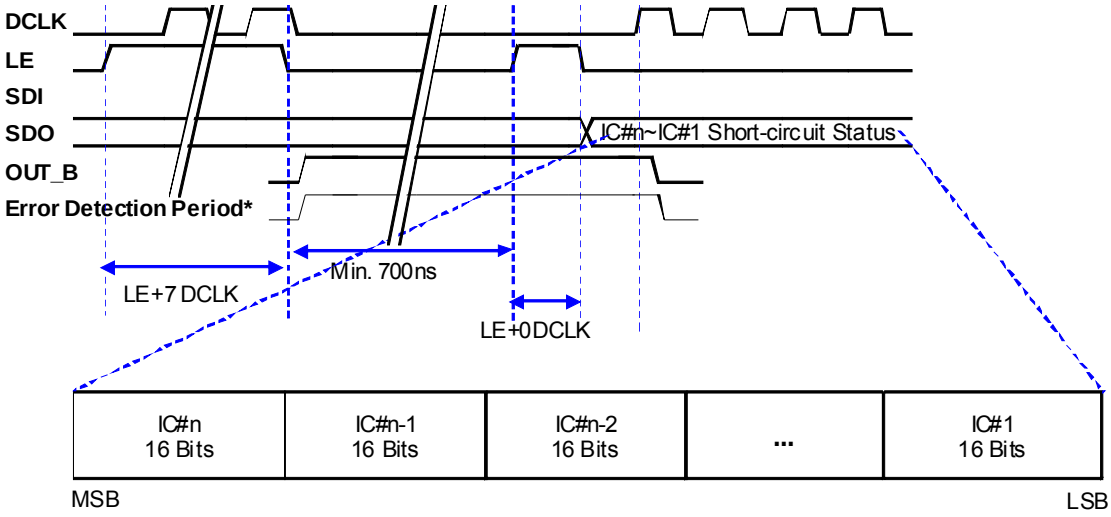
Detection Result	Error Flag for the Corresponding Channel
LED open error detected in the channel	0
No LED open error detected in the channel	1
MBI5047 enters 0-power mode	1

Compulsory1 Error Detection - LED Open-circuit

MBI5047 will perform compulsory1 error detection when receiving one LE pulse with 6 DCLKs and will stop the error detection when receiving one LE pulse with 0 DCLK. Besides, the output channels will be forced to turn off to perform the compulsory1 error detection. The duration is suggested longer than 700ns (between the LE falling edges). The error report will be shifted out after the compulsory1 error detection operation time (LE+0 DCLK). MBI5047 will shift out open-circuit reports from SDO simultaneously.

Error Code

Detection Result	Error Flag for the Corresponding Channel
LED open error detected in the channel	0
No LED open error detected in the channel	1
MBI5047 enters 0-power mode	1



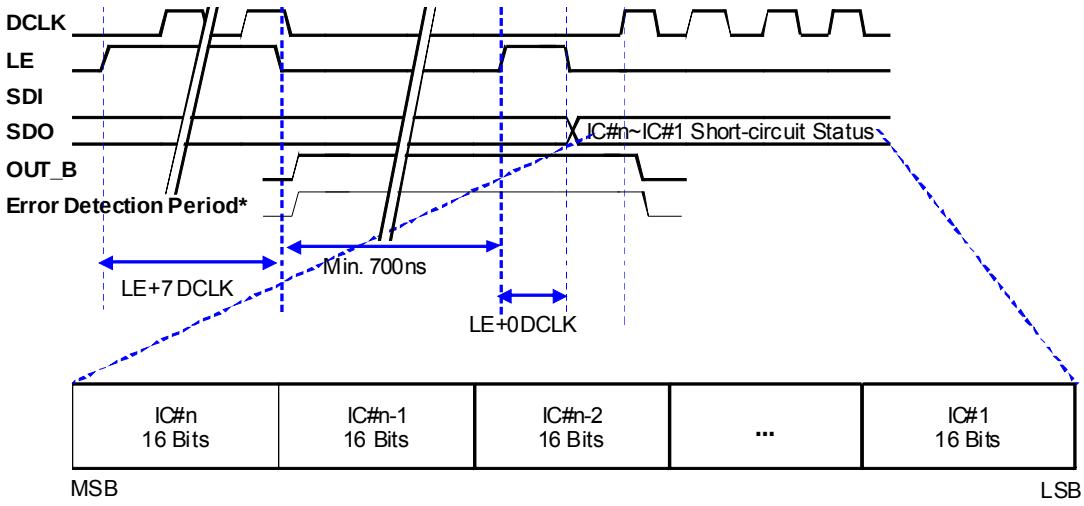
*For the correctness of the error message, MBI5047 releases the error detection period only when receiving one LE pulse containing 0 DCLK and DCLK is active. During the error detection period, MBI5047 will force OUT_B off and perform the compulsory error detection.

Compulsory2 Error Detection - LED Short-circuit

MBI5047 will perform compulsory2 error detection when receiving one LE pulse with 7 DCLKs and will stop the error detection when receiving one LE pulse with 0 DCLK. The output channels will be forced to turn off and then turn on within a small current of 0.25mA. The duration is suggested longer than 700ns (between the LE falling edges) to perform compulsory2 error detection. The error report will be shifted out after the compulsory2 error detection operation time (LE+ 0 DCLK). MBI5047 will shift out short–circuit reports from SDO simultaneously.

Error Code

Detection Result	Error Flag for the Corresponding Channel
LED short error detected in the channel	0
No LED short error detected in the channel	1
MBI5047 enters 0-power mode	1



*For the correctness of the error message, MBI5047 releases the error detection period only when receiving one LE pulse containing 0 DCLK and DCLK is active. During the error detection period, MBI5047 will force OUT_B off and perform the compulsory error detection.

Compulsory3 Error Detection - Fault Status Report

MBI5047 will perform compulsory3 error detection when receiving one LE pulse with 8 DCLKs and will stop the error detection when receiving one LE pulse with 0 DCLK. Besides, the output channels will be forced to turn off to perform the compulsory3 error detection. The duration is suggested longer than 700ns (between the LE falling edges). The error report will be shifted out after the compulsory3 error detection operation time (LE+0 DCLK). MBI5047 will shift out R_{ext}-open, thermal protection error reports, the status of 0-power mode and watchdog timer (WDT) time-out from SDO simultaneously.

Watchdog Timer (WDT) Time-out

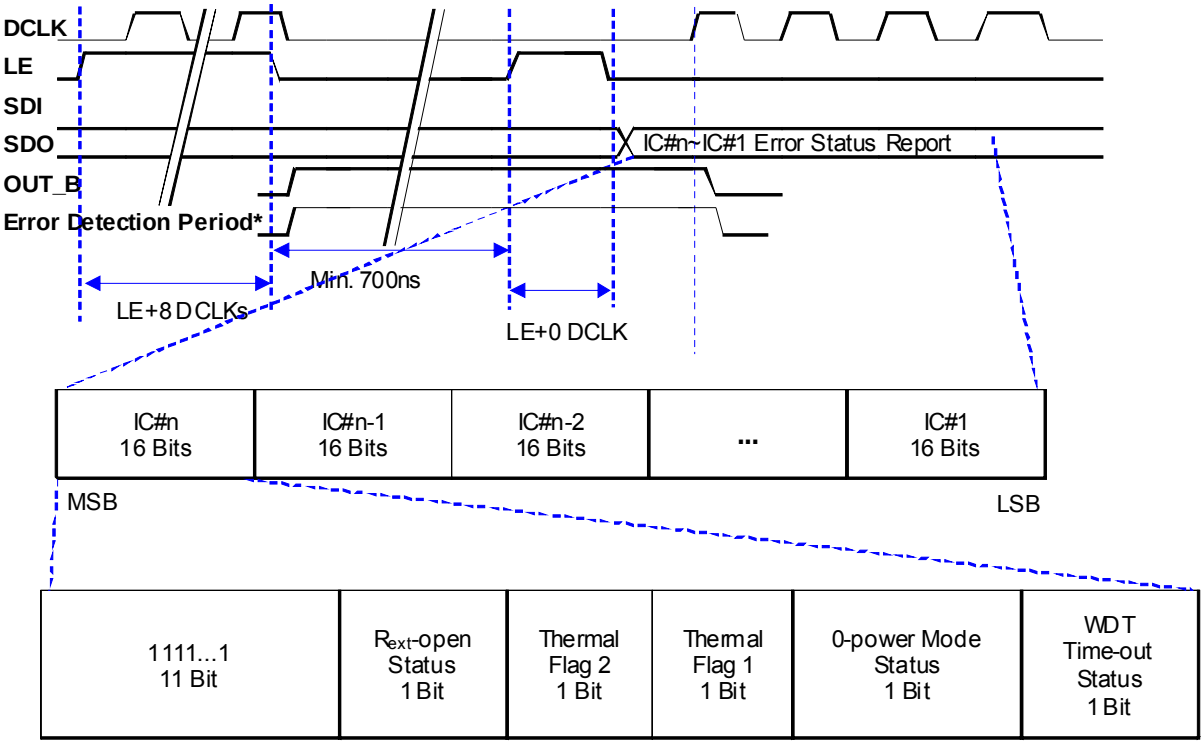
Detection Result	WDT Time-out Status
WDT time-out occurred	1
No time-out	0

0-power Mode

Detection Result	0-power Mode Status
In 0-power Mode	1
Out of 0-power mode	0

Error Code

Detection Result	Error Flag for the Corresponding Chip
R_{ext} open-circuit detected	0
No R_{ext} open-circuit detected	1



*For the correctness of the error message, MBI5047 releases the error detection period only when receiving one LE pulse containing 0 DCLK and DCLK is active. During the error detection period, MBI5047 will force OUT_B off and perform the compulsory error detection.

Thermal Flag

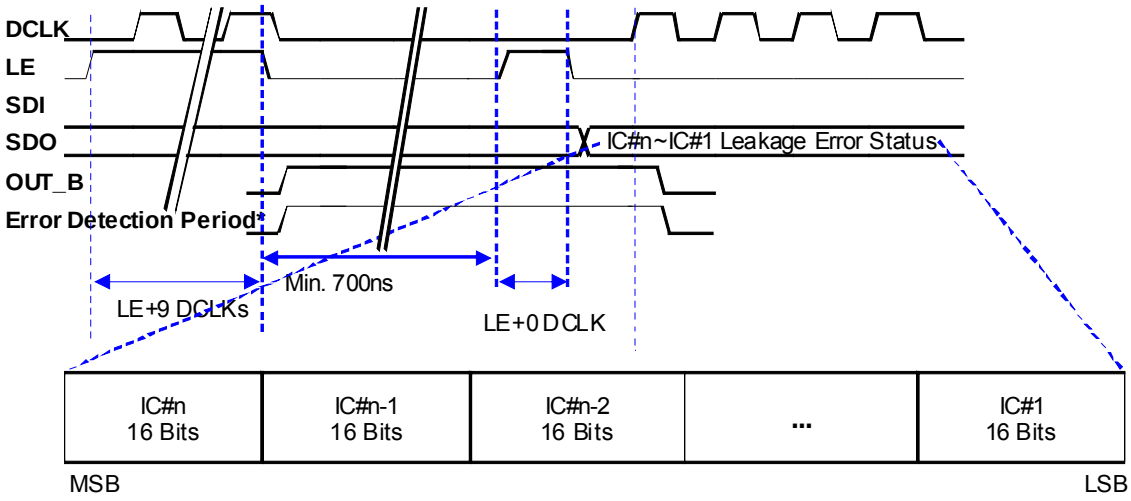
Thermal flag 1 is over-temperature alarm, and thermal flag 2 is thermal shutdown. When the IC temperature is over 140°C, thermal flag 1 will report “0”. When the IC temperature is under 120°C, thermal flag 1 will recover to “1”. When the IC temperature is over 160°C, the thermal flag 2 will become “0”, and the output channels will be shut down. The thermal shutdown status is latched until power cycling or a wakeup command issued from the controller.

Compulsory4 Error Detection - Device Leakage Diagnosis

MBI5047 will perform compulsory4 error detection when receiving one LE pulse with 9 DCLKs and will stop the error detection when receiving one LE pulse with 0 DCLK. Besides, the output channels will be forced to turn off and then turn on within a small current of 0.4uA. The duration is suggested longer than 700ns (between the LE falling edges) to perform compulsory4 error detection. The error report will be shifted out after the compulsory4 error detection operation time (LE+ 0 DCLK). MBI5047 will shift out leakage error reports from SDO simultaneously.

Error Code

Detection Result	Error Flag for the Corresponding Channel
Leakage error detected in the channel	0
No leakage error detected in the channel	1
MBI5047 enters 0-power mode	1

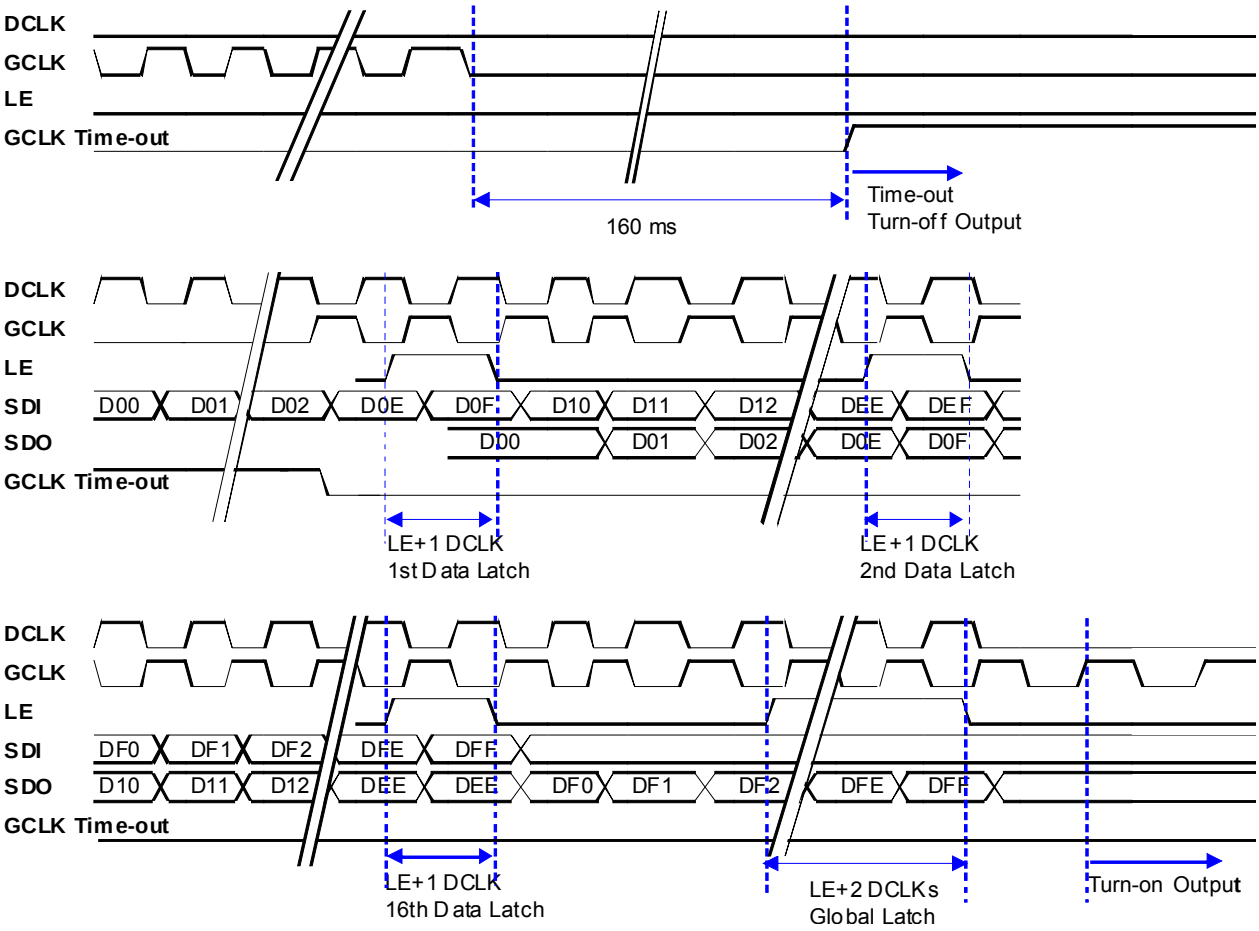


*For the correctness of the error message, MBI5047 releases the error detection period only when receiving one LE pulse containing 0 DCLK and DCLK is active. During the error detection period, MBI5047 will force OUT_B off and perform the compulsory error detection.

Watchdog Timer (WDT) Time-out

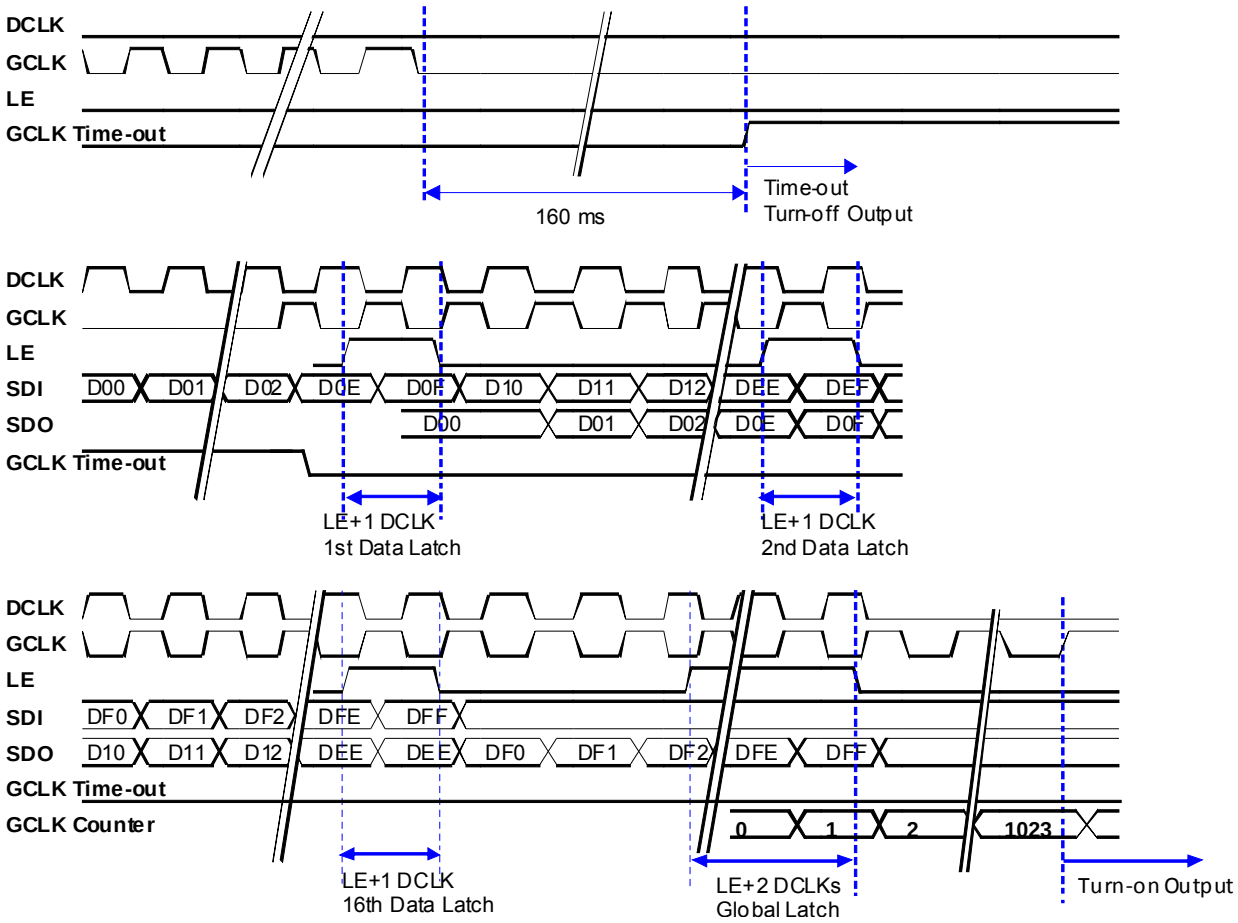
In the following figures, if WDT time-out occurs, the output will turn off when the GCLK is not present. Until the user set PWM gray scale data, global latch command is executed and GCLK is present, the output will turn on again.

PWM Data Manual Sync. Mode



Note: there is no timing relation between DCLK and GCLK.

PWM Data Auto Sync. Mode



Note: there is no timing relation between DCLK and GCLK.

Setting the Threshold Voltage for Compulsory Short-circuit Detection

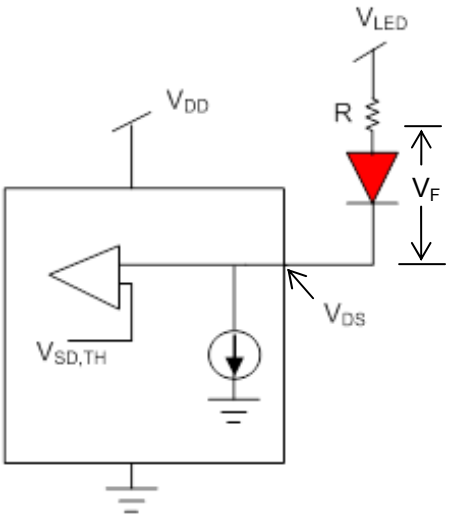
Users can set the threshold voltage ($V_{SHORT.TH}$) for compulsory short-circuit detection by bit [C:B] of configuration register are summarized below:

2'b00: 2.5V

2'b01: 3.0V

2'b10: 4.0V

2'b11: 4.5V (default)



MBI5047 provides settable $V_{SHORT.TH}$ for different LED configuration. If the detected voltage is larger than $V_{SHORT.TH}$, the chip identifies the LED as short-circuit. For example, if each output channel of this chip drives one red LED, the $V_{SHORT.TH}$ should be set smaller. If each output channel of this chip drives several white LEDs, the $V_{SHORT.TH}$ should be set larger. The system should be considered the accumulated V_F of the LEDs when setting a suitable $V_{SHORT.TH}$.

Compulsory Leakage Diagnosis

Another failure phenomenon of LED display is that the LED is always in the on-state caused by a leakage path (or short-to-ground) on the PCB or LED driver. Therefore, this chip adds in the leakage diagnosis to help easily detect the LED driver leakage problem.

When the LED driver leakage problem occurs, the voltage for the leakage current (V_F) will increase, and according to the equation below:

V_{LED}-V_F=V_{DS}

The voltage of the output ports (V_{DS}) will be lower than the original V_{DS} in the off-state (LED driver turns off the output ports).

MBI5047 sinks 400nA while executing leakage diagnosis. If V_F@(400nA+leakage current) is still less than 0.3xV_{DD} or, V_F@400nA is very closed to V_F@(400nA+leakage current), it may cause erroneous determination of leakage diagnosis.

Considering the above variation, this chip allows users to select the suitable voltage as the threshold voltage of the leakage diagnosis. Users can set the threshold voltage ($V_{LEAK.TH}$) for compulsory leakage detection by bit [A:9] of

configuration register as summarized below:

2'b00: 0.4 x V_{DD}

2'b01: 0.5 x V_{DD}

2'b10: 0.6 x V_{DD}

2'b11: 0.7 x V_{DD} (default)

R_{ext}-open Detection

If the R-EXT pin is open, the output current will be turned off. The R-EXT flag will become "0" until the problem is fixed. Users can read the related bit in the error report.

Thermal Protection

Users can set the thermal protection by bit "6" of configuration register. To enable the thermal shutdown function, the bit "6" is set to "1" (default). To disable the thermal shutdown function, the bit "6" is set to "0".

This chip provides two thermal flags:

Thermal flag 1 is over-temperature alarm, and thermal flag 2 is thermal shutdown. When the IC temperature is over 140°C, thermal flag 1 will report "0". When the IC temperature is under 120°C, thermal flag 1 will recover to "1".

When the IC temperature is over 160°C, the thermal flag 2 will become "0" and this chip will turn off the output current of all channels automatically. It will not turn on the output channels until power cycling or a wakeup command issued from the controller.

0-power Mode

By setting bit "F" of the configuration register, the 0-power mode of this chip will be effective. When all the output data of this chip are "0", MBI5047 will enter the 0-power mode automatically. When the non-zero data is latched, this chip will leave 0-power mode automatically. Users may also force this chip to leave the 0-power mode by command. The output recovery time from 0-power mode is 0.96ms typically.

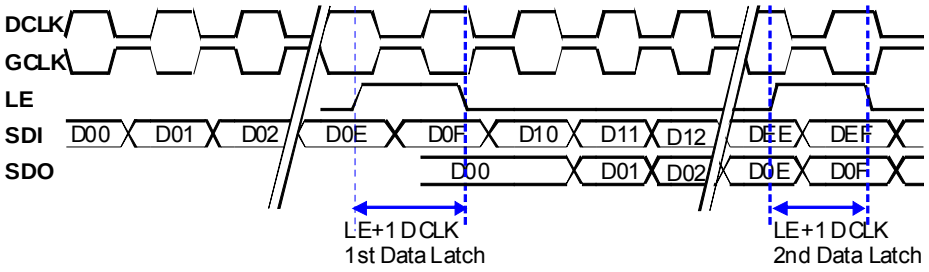
To optimize the power saving of the 0-power mode, it is recommended to categorize LEDs along with LED drivers into groups when designing PCBs in order to allow this chip to turn on or turn off the cascaded LEDs in the group simultaneously. Therefore, the 0-power mode of this chip is especially useful for LED message signs to save the power of LED drivers since many LEDs of an LED message sign are usually not in use.

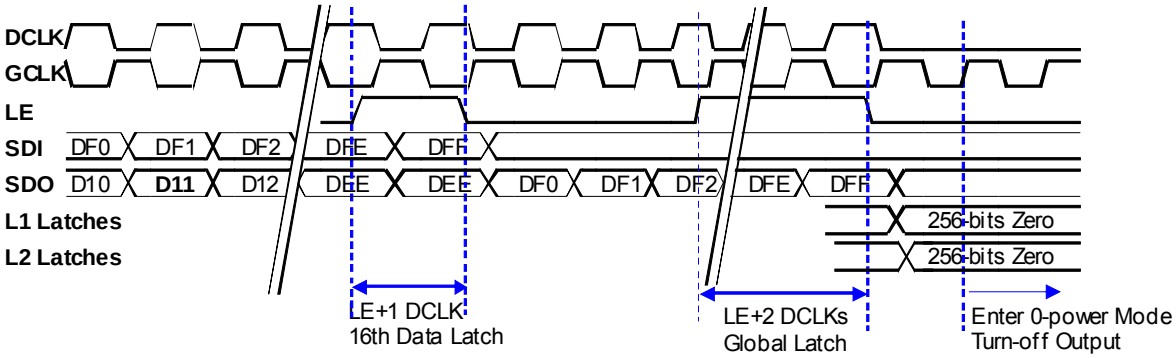
When 0-power mode is enabled, all error detection commands (open-circuit, short-circuit, leakage, thermal detection, R_{ext}-open) will not perform and return to "1", but the other commands (write and read configurations) are still active.

Automatically Enter and Leave the 0-power Mode

Automatically enter the 0-power saving mode when PWM gray scale data are all zero and the global latch command is executed at PWM data manual synchronization. In 0-power saving mode, the output is disabled.

Manual Sync. Mode

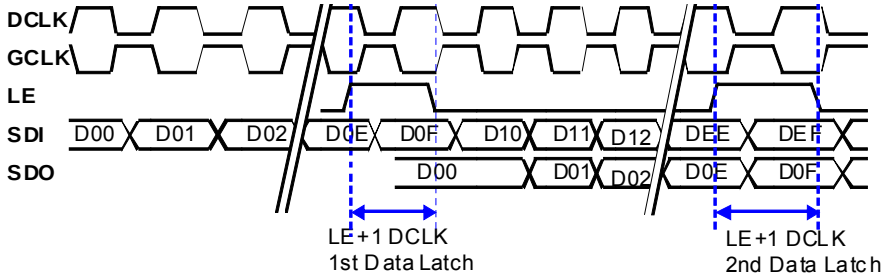


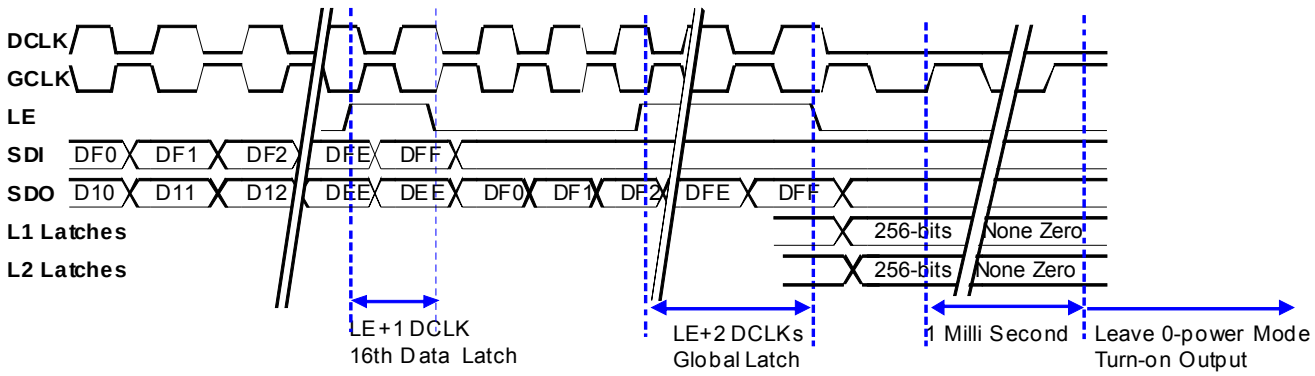


Note: there is no timing relation between DCLK and GCLK.

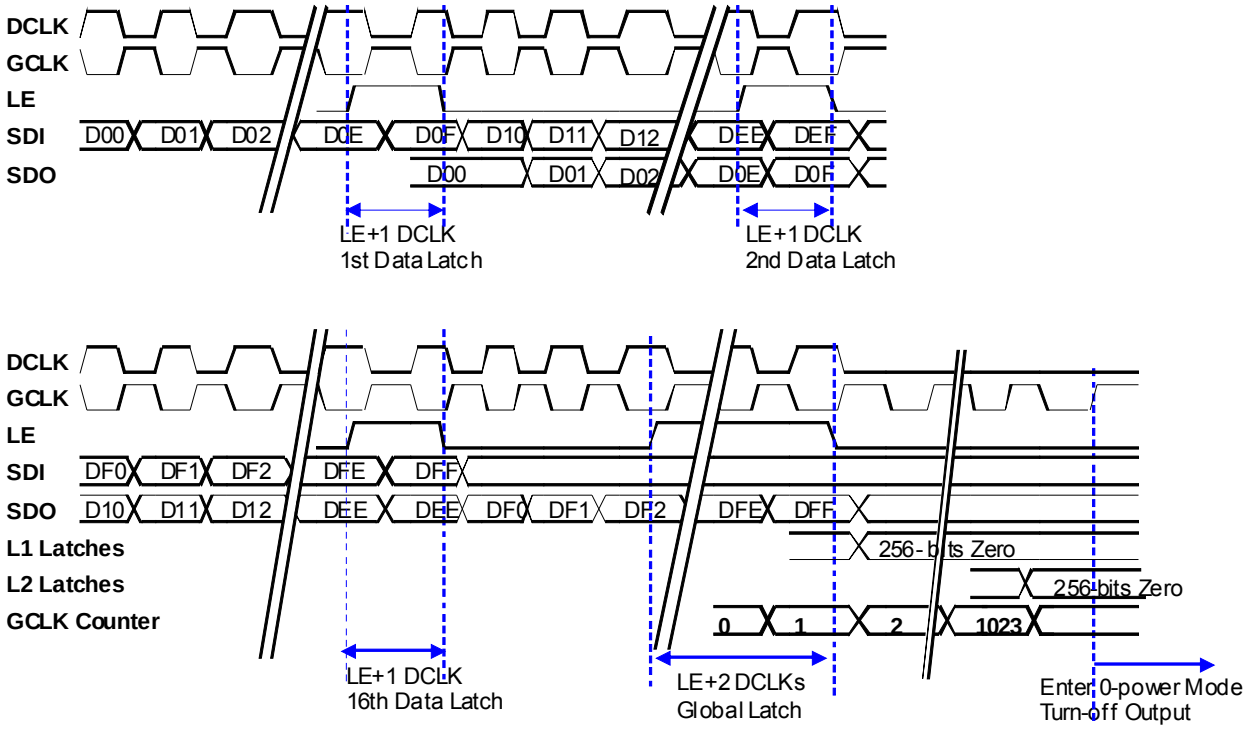
Until the PWM gray scale data are none all zero and the global latch command is executed and must wait 1 ms at PWM data manual synchronization, the output will be enabled and automatically leave the 0-power mode.

Automatically enter the 0-power saving mode when PWM gray scale data are all zero, the global latch command is executed and 1024 GCLKs at PWM data auto synchronization. In 0-power saving mode, the output is disabled.

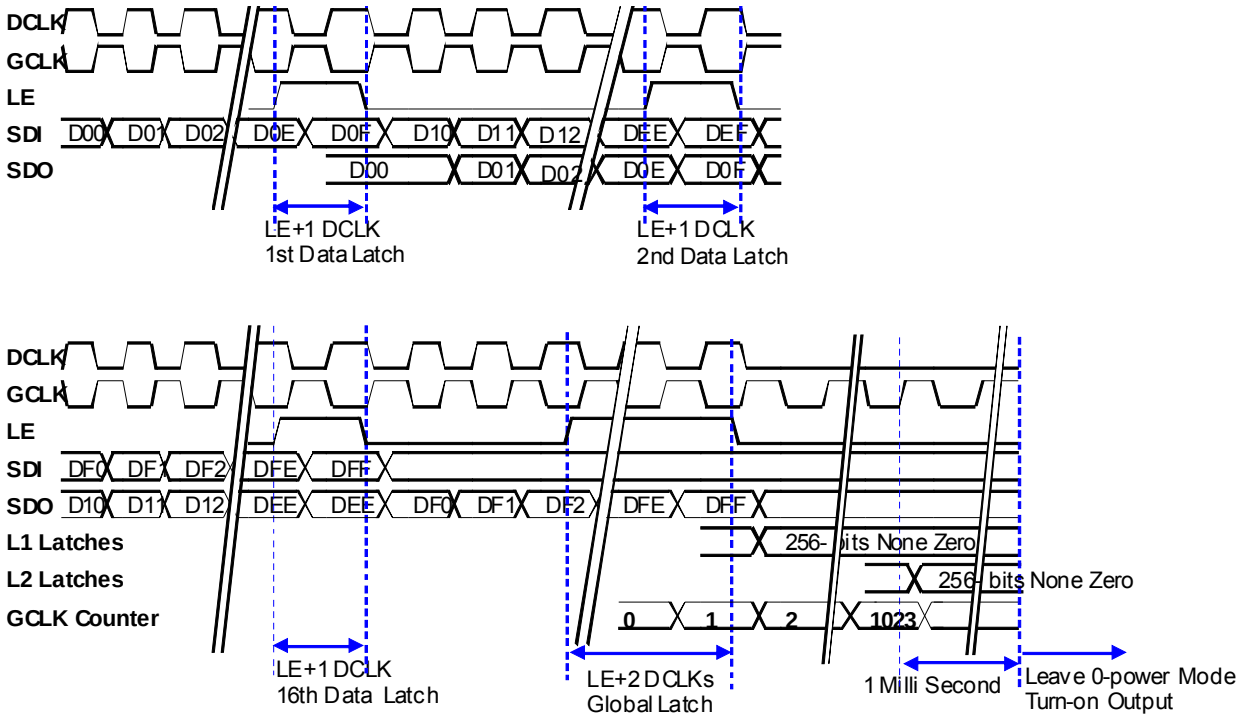




Auto Sync. Mode



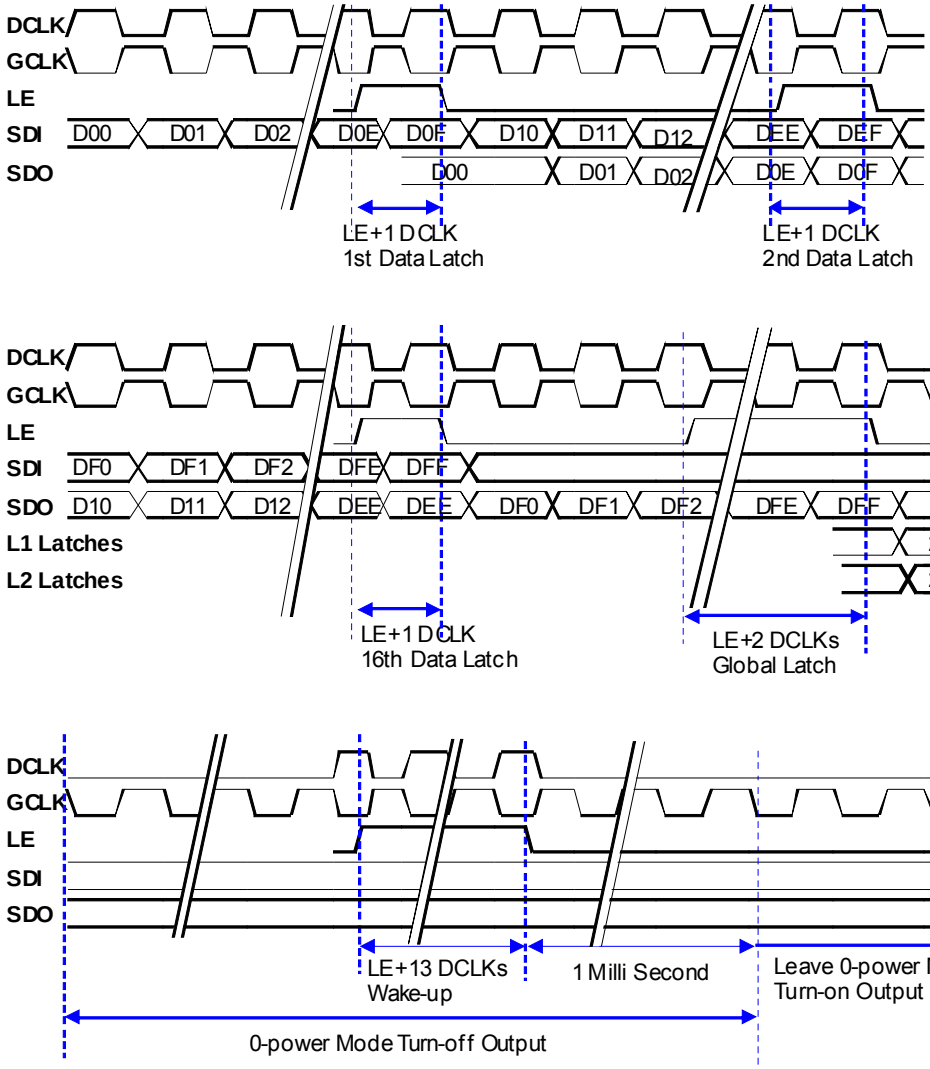
Until the PWM gray scale data are none all zero and the global latch command is executed and must wait 1024 GCLKs + 1ms at PWM data auto synchronization, the output will be enabled and automatically leave the 0-power mode.



Enter the 0-power Mode Automatically but Leave by the Command

Automatically enter the 0-power saving mode when PWM gray scale data are all zero. In 0-power saving mode, the output is turn off. Until the wake up command is executed and must wait 1ms, the output will be enabled and leave the 0-power mode

Manual Sync. Mode



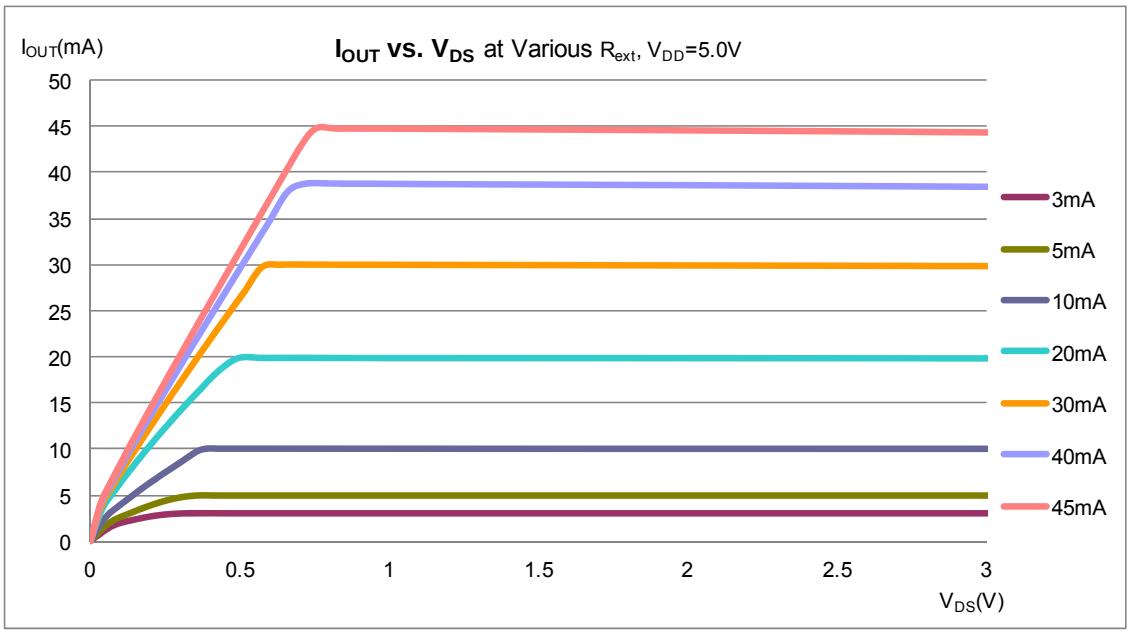
Application Information

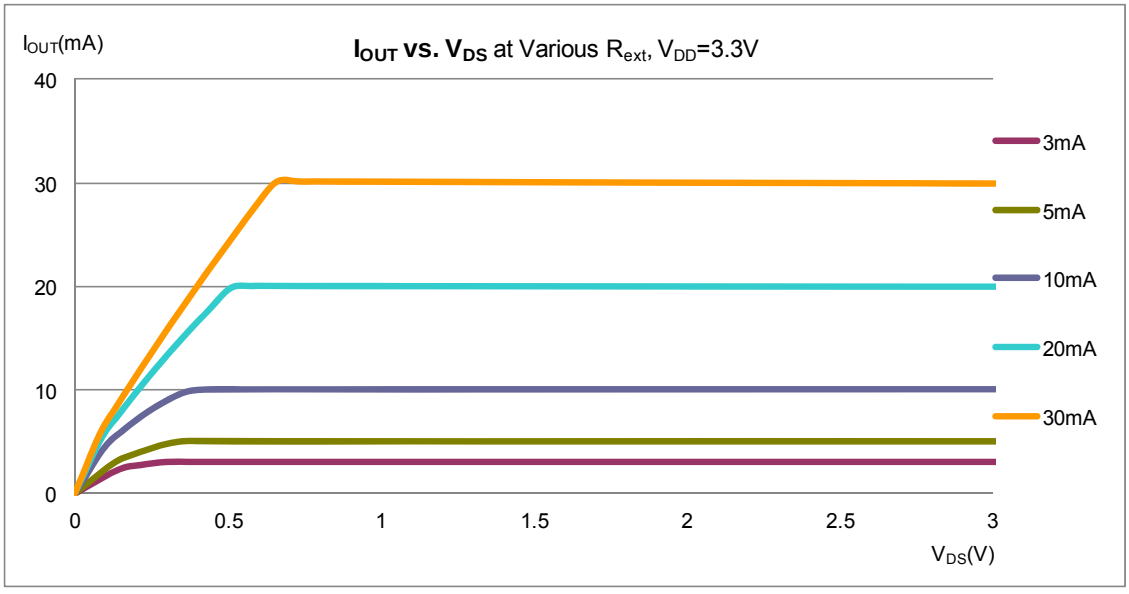
Constant Current

To design LED displays, MBI5047 provides nearly no variations in current from channel to channel and from IC to IC. This can be achieved by:

1) The maximum current variation between channels is less than ±3%, and that between ICs is less than ±6%.

2) In addition, the current characteristic of output stage is flat and users can refer to the figure as shown below. The output current can be kept constant regardless of the variations of LED forward voltages (V_F). This performs as a perfection of load regulation.





Setting Output Current

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

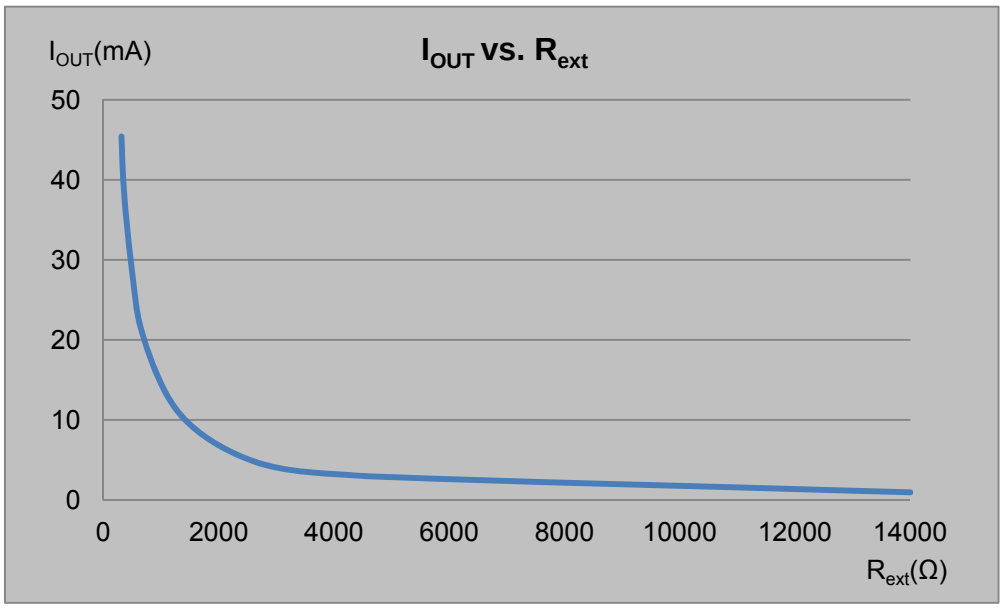
Also, the output current can be calculated from the equation:

$V_{R\text{-}EXT}$=0.6Volt x G x H; $I_{OUT}=V_{R\text{-}EXT}/(R_{ext}$ x H)x23.0

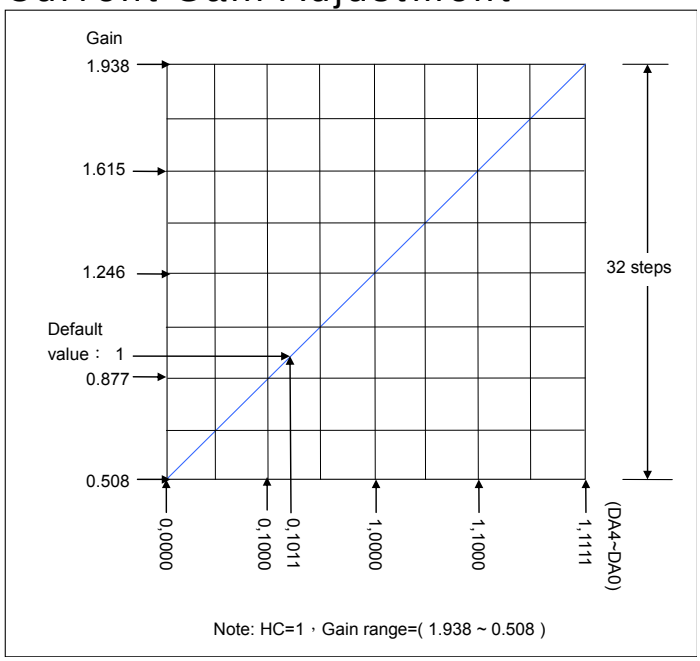
HC=1=>H=1 (Please refers to Current Gain Adjustment section on next page for “HC” description)

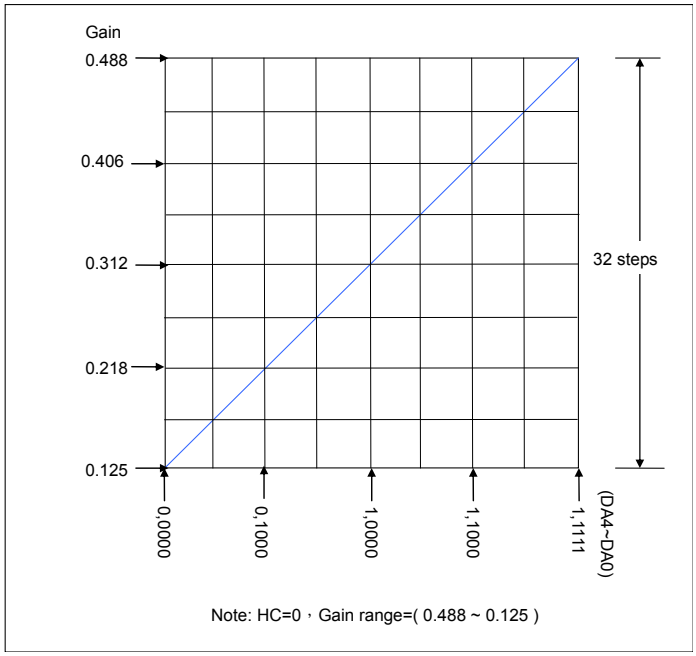
HC=0=>H=4

Whereas R_{ext} is the resistance of the external resistor connected to R-EXT terminal and $V_{R\text{-}EXT}$ is its voltage. G is the digital current gain, which is set by the bit5 – bit0 of the configuration register. The default value of G is 12.5%. For your information, the output current is about 3mA when R_{ext}=575Ω if G is set to default value 12.5%. The formula and setting for G are described in next section.



Current Gain Adjustment





The 6 bits (bit 5~bit 0) of the configuration register set the gain of output current, i.e., G. As total 6-bit in number, i.e., ranged from 6'b000000 to 6'b111111, these bits allow the user to set the output current gain up to 64 levels.
These bits can be further defined inside configuration register as follows:

F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	-	-	HC	DA4	DA3	DA2	DA1	DA0

1. Bit 5 is HC bit. The setting is in low current band when HC=0, and in high current band when HC=1.
2. Bit 4 to bit 0 are DA4 ~ DA0.

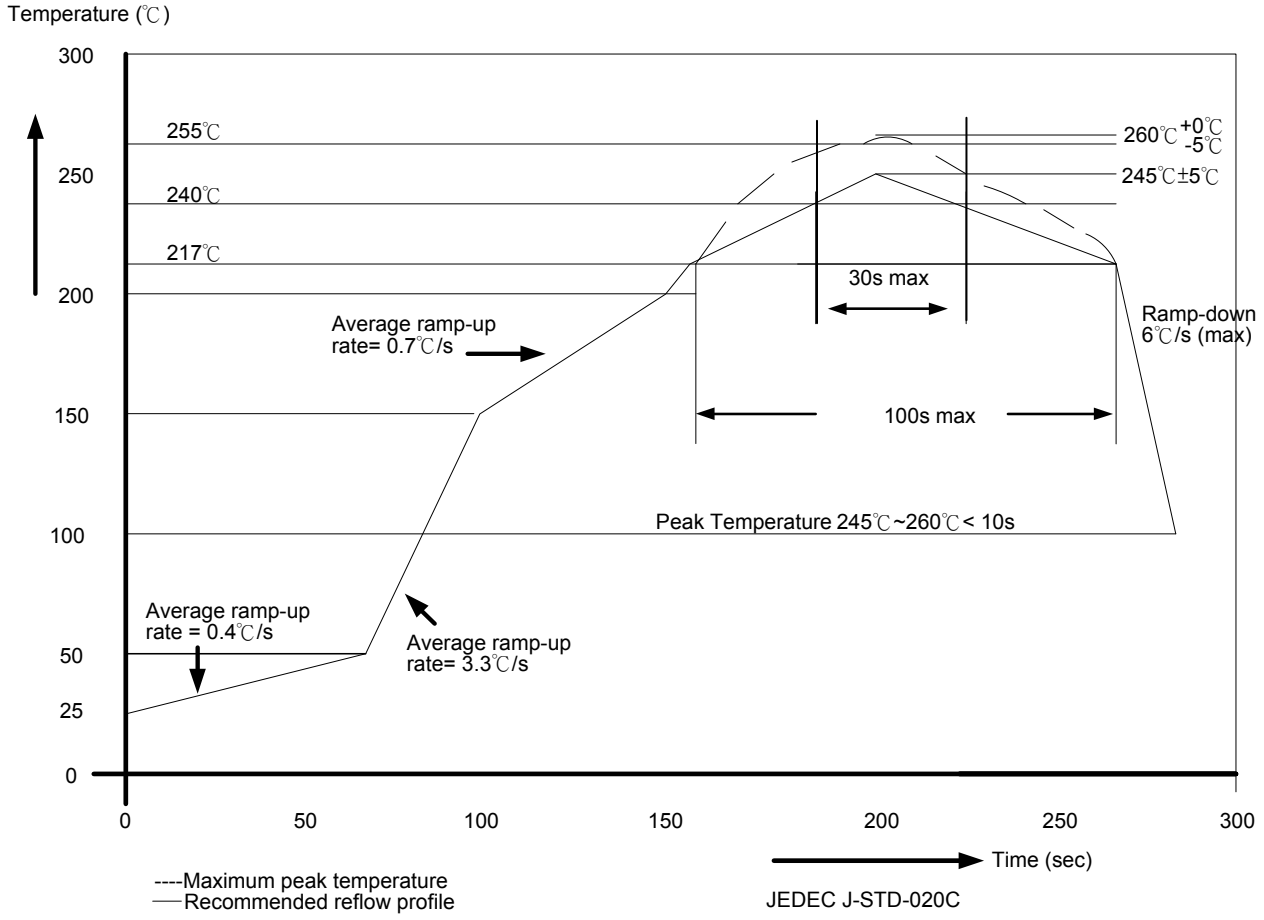
The relationship between these bits and current gain G is:
HC=1, D=(64xG-32)/3
HC=0, D=(256xG-32)/3
and D in the above decimal numeration can be converted to its equivalent in binary form by the following equation:
$D= DA4x2^4+DA3x2^3+DA2x2^2+DA1x2^1+DA0x2^0$
In other words, these bits can be looked as a floating number with 1-bit exponent HC and 5-bit mantissa DA4~DA0.
For example,
HC=1, G=1.246, D=(64x1.246-32)/3=16
the D in binary form would be:
$D=16=1x2^4+0x2^3+0x2^2+0x2^1+0x2^0$
The 6 bits (bit 5~bit 0) of the configuration register are set to 6'b110000.

Staggered Delay of Output

MBI5047 has a built-in delay circuit to perform delay mechanism. Among output ports exist a graduated 5ns delay time among $\overline{OUTn}$ and $\overline{OUTn+1}$, by which the output ports will be turned on at a different time so that the instant current from the power line will be lowered.

Soldering Process of "Pb-free & Green" 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 Pb-free soldering processes and materials, 100% pure tin (Sn) will all require from 245 °C to 260°C for proper soldering on boards, referring to JEDEC J-STD-020C as shown below.



Package Thickness	Volume mm^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".

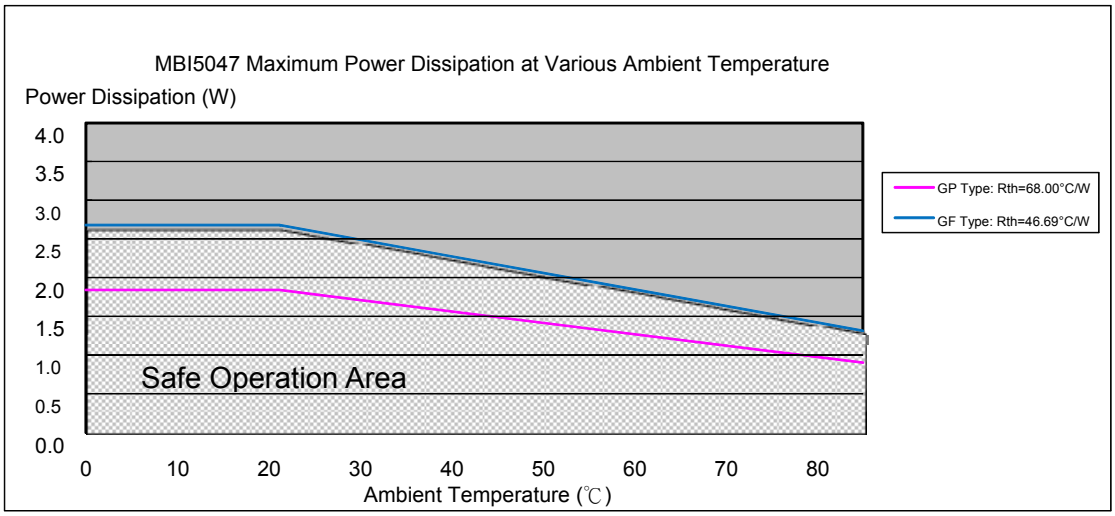
Package Power Dissipation (PD)

The maximum allowable package power dissipation is determined as $P_D(max)=(Tj–Ta)/R_{th(j-a)}$. When 16 output channels are turned on simultaneously, the actual package power dissipation is $P_D(act)=(I_{DD}xV_{DD})+(I_{OUT}xDutyxV_{DS}x16)$. Therefore, to keep $P_D(act)\leq P_D(max)$, the allowable maximum output current as a function of duty cycle is:

$I_{OUT}=\{[(Tj–Ta)/R_{th(j-a)}]–(I_{DD}xV_{DD})\}/V_{DS}/Duty/16$, where Tj=150°C.

Device Type	$R_{th(j-a)}$ (°C/W)
GF	46.69
GP	68.00

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

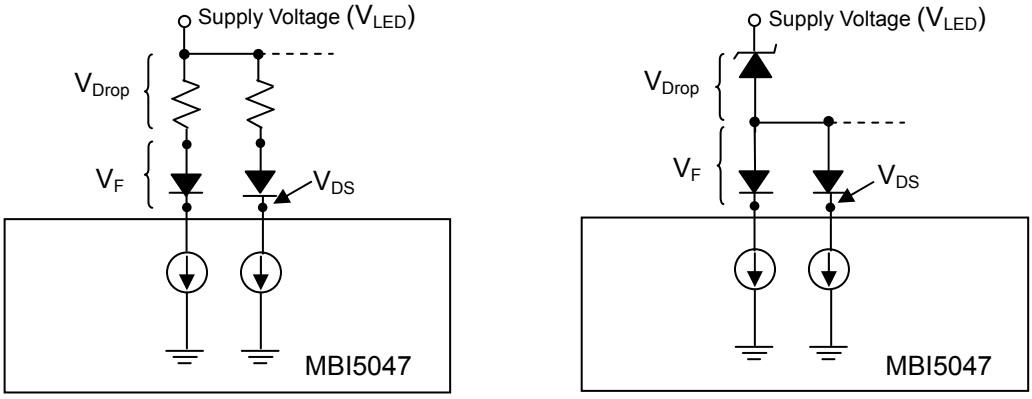


Load Supply Voltage (V_{LED})

MBI5047 is designed to operate with V_{DS} ranging from 0.4V to 1.0V (depending on I_{OUT}=3~45mA) considering the package power dissipating limits. V_{DS} may be higher enough to make $P_{D(act)}$ >$P_{D(max)}$ when V_{LED}=5V and V_{DS}=V_{LED}–V_F, in which V_{LED} is the load supply voltage. In this case, it is recommended to use the lowest possible supply voltage or to set an external voltage reducer, V_{DROP}.

A voltage reducer lets V_{DS}=(V_{LED}–V_F)–V_{DROP}.

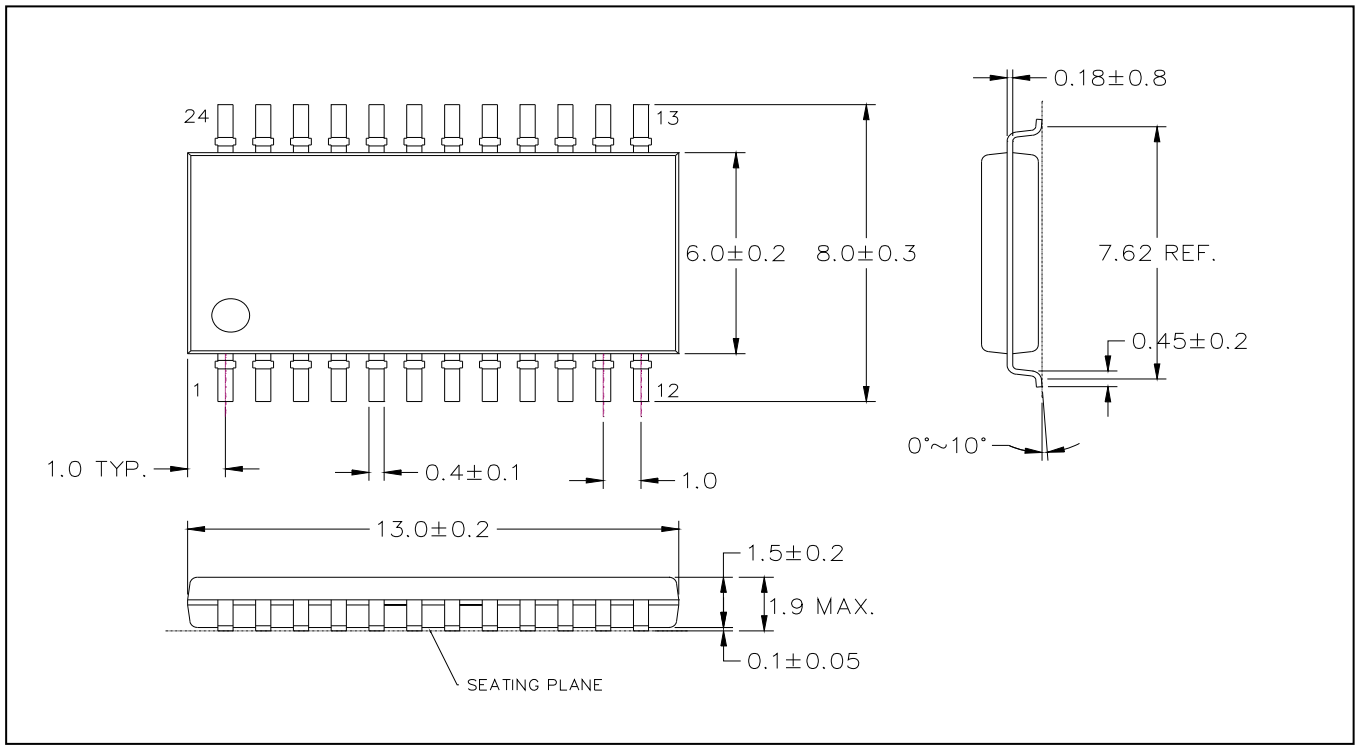
Resistors or Zener diode can be used in the applications as shown in the following figures.



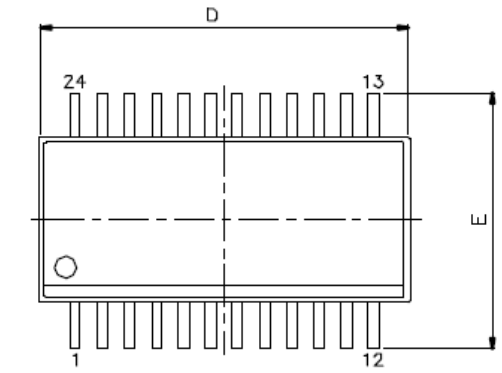
Switching Noise Reduction

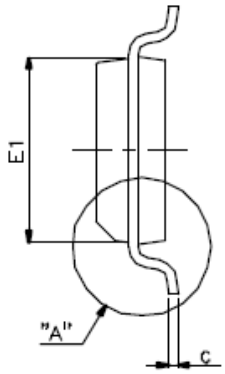
LED driver ICs are frequently used in switch-mode applications which always behave with switching noise due to the parasitic inductance on PCB. To eliminate switching noise, refer to “Application Note for 8-bit and 16-bit LED Drivers- Overshoot”.

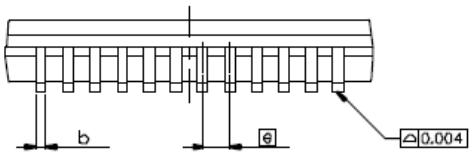
Package Outline

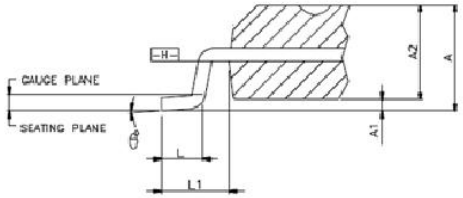


MBI5047GF Outline Drawing







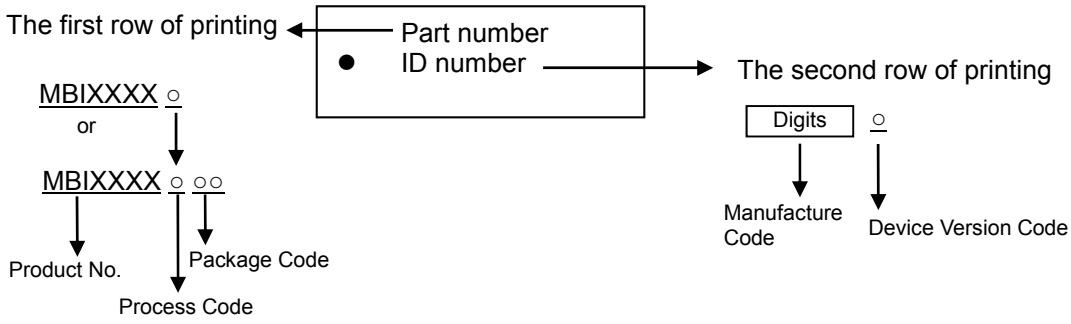


SYMBOLS	Dimensions shown in inches			Dimensions shown in millimeters		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.053	0.064	0.069	1.346	1.626	1.753
A1	0.004	0.006	0.010	0.102	0.152	0.254
A2	—	—	0.059	—	—	1.499
D	0.337	0.341	0.344	8.560	8.661	8.738
E	0.228	0.236	0.244	5.791	5.994	6.198
E1	0.150	0.154	0.157	3.810	3.912	3.988
b	0.008	—	0.012	0.203	—	0.305
c	0.007	—	0.010	0.178	—	0.254
L	0.016	0.025	0.050	0.406	0.635	1.270
e	0.025 BASIC			0.635 BASIC		
L1	0.041 BASIC			1.0414 BASIC		
θ°	0	—	8	0	—	8

MBI5047GP Outline Drawing

Note: The unit for the outline drawing is mm.

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)
MBI5047GF-A	SOP24L-300-1.00	0.28
MBI5047GP-A	SSOP24L-150-0.64	0.11

*Please place your order with the ***"product ordering number"*** information on your purchase order (PO).

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