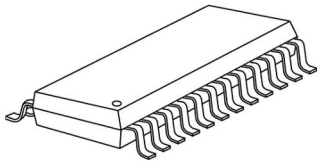
16-Channel Constant Current LED Sink Driver with Silent Error Detection and Current Gain

Features

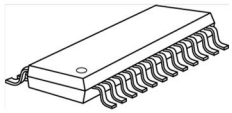
- 16 constant-current output channels
  Constant output current range: 3~90mA
  - 8-90mA @ 5V supply voltage
  - 3-70mA @ 3.3V supply voltage
- In-message error detection
  - Both open-circuit and short-circuit LEDs can be detected
  - On-the-fly error detection
  - Data-in, error-out; both errors are merged and coded with zeros
- Compulsory error detection
  - Full panel, data independent
  - Silent error detection with 0.25mA in 700ns
- Settable threshold voltage for LED short-circuit detection
- Thermal detection
  - Over-temperature report (e.g. temp.>150 °C)
- 64-step programmable current gain: from 12.5% to 200%
- Excellent output current accuracy,
  - Between channels: <±1.5% (typ.), and
  - Between ICs: <±3% (typ.)
- Fast response of output current
  - Min. output pulse width of $\overline{OE}$:
    35ns with good uniformity between output channels
- Staggered delay of output, preventing from current surge
- 30MHz clock frequency
- Schmitt trigger input

Small Outline Package



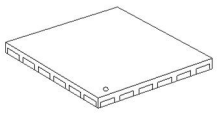
GF: SOP24L-300-1.00

Shrink SOP



GP: SSOP24L-150-0.64

Quad Flat No-Lead



GFN: QFN24L-4*4-0.5

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Product Description

MBI5039 is an enhanced 16-channel constant current LED sink driver with smart error detection and output current gain. MBI5039 succeeds MBI5026 and also exploits **PrecisionDrive™** technology to enhance the output characteristics. Furthermore, MBI5039 adopts **Share-I-O™** technology to be backward compatible with MBI5026, MBI5027 and MBI5029 in pin definition and to extend the functionality for LEDs in-message error detection, compulsory error detection, and current gain control in LED display systems.

MBI5039 contains a 16-bit shift register and a 16-bit output latch, which convert serial input data into parallel output format. At MBI5039 output stages, sixteen regulated current ports are designed to provide uniform and constant current sinks with small skew between ports for driving LEDs within a wide range of forward voltage (V_F) variations. Users may adjust the output current from 5mA to 90mA with an external resistor R_{ext}, which provides users flexibility in controlling the light intensity of LEDs. MBI5039 guarantees to endure maximum 17V at the output ports. Besides, the high clock frequency, up to 30MHz, also satisfies the system requirements of high volume data transmission.

With in-message error detection, MBI5039 can detect individual LED for both open- and short-circuit errors on-the-fly without extra components. The serial data
could be transferred into MBI5039 via the pin SDI, shifted in the shift register, and the outputs perform open- and short-circuit detection simultaneously.

Besides the default in-message error detection, MBI5039 provides compulsory error detection. Once the dedicated command is issued, all of the output ports will be turned on about 700ns interval with current 0.25mA. Since the turn-on duration and current are so small, the image quality will not be impacted. All of the channels are detected no matter the input data is zero or one. The dedicated command is the communication of CLK and LE.

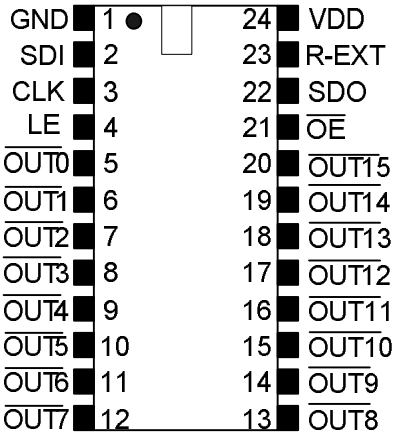
With the above two detections, the system can detect LED errors completely. Moreover, the threshold voltage for short-circuit detection is settable with the variation of different LED forward voltage, and the system controller can easily detect the short-circuit error. Therefore, the error detection is easy to use.

In addition, MBI5039 also allows users to adjust the output current level by setting a programmable configuration code. The code is sent into MBI5039 via the pin SDI. The falling edge of LE would latch the code in the shift register into a built-in 16-bit configuration register, instead of the output latch. The gain code would affect the voltage at the terminal R-EXT and control the output current regulator. The output current can be adjusted finely by a gain ranging from 12.5% to 200% in 64 steps.

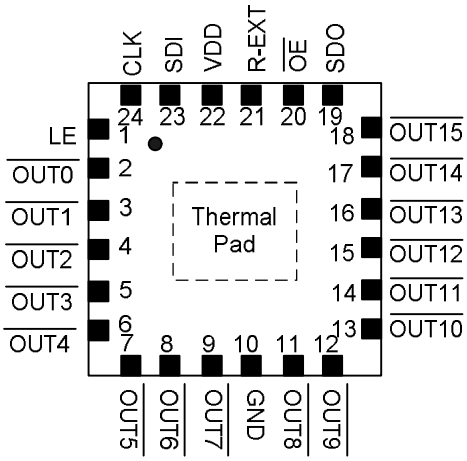
The temperature of the chip itself is also monitored and the thermal warning flag can be read so that the system can adopt essential procedure to protect the system.

With the **Share-I-O™** technique, MBI5039 could be a drop-in replacement of predecessors. The printed circuit board originally designed for MBI5026/7/9 may be also applied to MBI5039 only that the controllers have to be upgraded and $\overline{OE}$ needs to be controllable.

Pin Configuration



MBI5039GF/GP

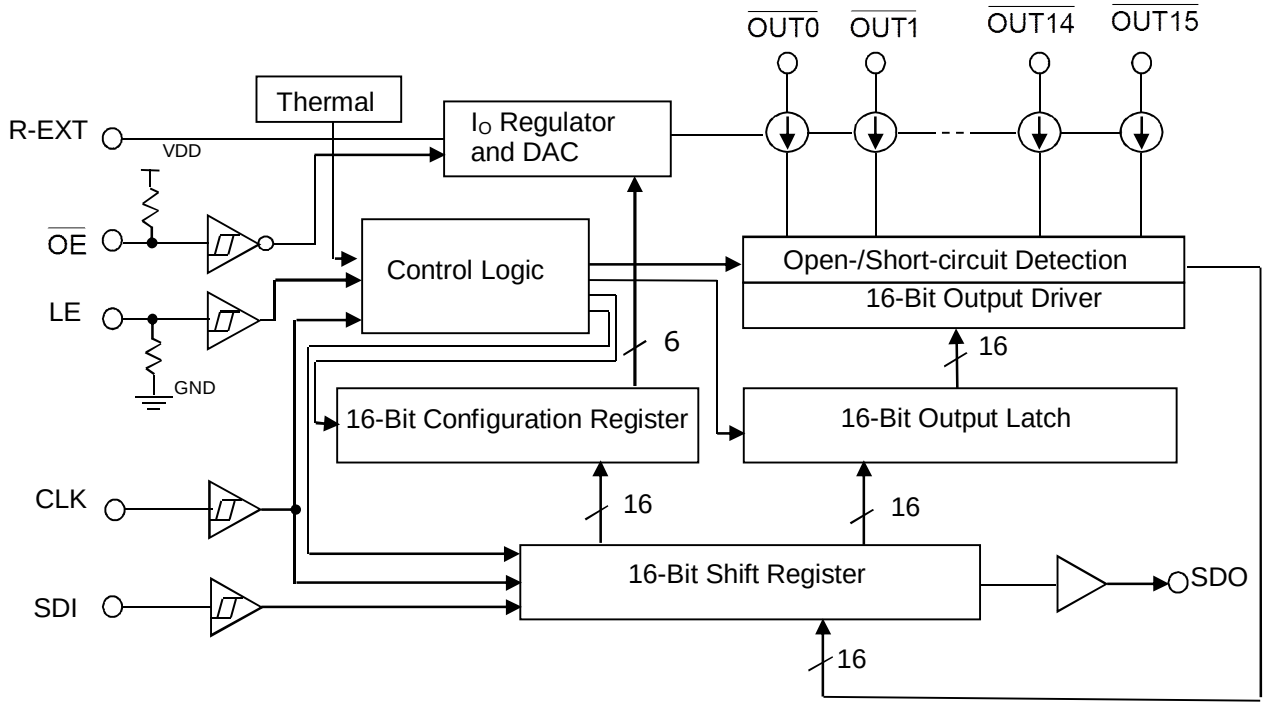


MBI5039GFN

Terminal Description

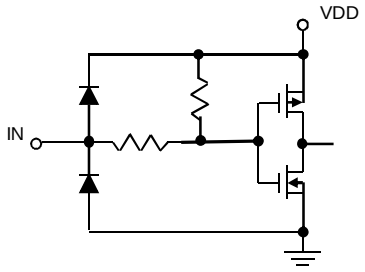
Pin Name	Function
GND	Ground terminal for control logic and current sinks
SDI	Serial-data input to the shift register
CLK	Clock input terminal used to shift data on rising edge and carries command information when LE is asserted.
LE	Data strobe terminal and asserting command with adequate CLK pulses
$\overline{OUT0}$ ~ $\overline{OUT15}$	Constant current output terminals
$\overline{OE}$	Enable output drivers to sink current. When its level is low (active), the output drivers are enabled; when high, all output drivers are turned OFF (blank). The signal is used for error detection. Please refer to error detection sections for further details.
SDO	Serial-data output to the SDI of the following driver IC
R-EXT	Input terminal used for connecting an external resistor in order to set up the current level of all output ports
VDD	3.3/5V supply voltage terminal

Block Diagram

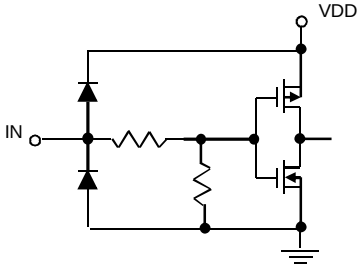


Equivalent Circuits of Inputs and Outputs

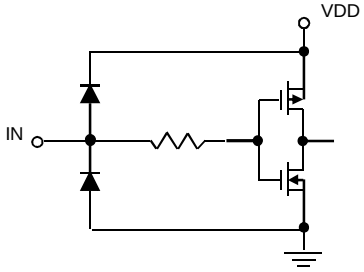
OE Terminal



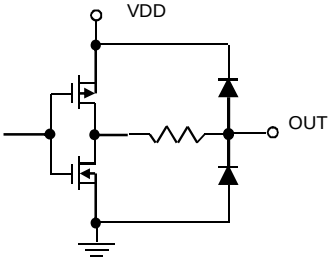
LE terminal



CLK, SDI terminal



SDO terminal



Maximum Ratings

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	0~7	V
Input Pin Voltage (SDI, $\overline{OE}$, LE, CLK, R-EXT)		V_{IN}	-0.4~V_{DD}+0.4	V
Output Current ($\overline{OUT0}$ ~ $\overline{OUT15}$)		I_{OUT}	+100	mA
Sustaining Voltage at OUT Port		V_{DS}	-0.5~17	V
GND Terminal Current		I_{GND}	+1600	mA
Power Dissipation (On PCB, Ta=25°C) *	GF Type	P_D	2.51	W
	GP Type		2.04	
	GFN Type		3.19	
Thermal Resistance (On PCB, Ta=25°C) *	GF Type	$R_{th(j-a)}$	49.86	°C/W
	GP Type		61.20	
	GFN Type		39.15	
Junction Temperature		$T_{j,max}$	150**	°C
Operating Ambient Temperature		T_{opr}	-40~+85	°C
Storage Temperature		T_{stg}	-55~+150	°C
ESD Rating	HBM (MIL-STD-883G Method 3015.7, Human Body Mode)	-	Class 3A (4000V~7999V)	-
	MM (JEDEC EIA/JESD22-A115, Machine Mode)	-	Class B (200V~399V)	-

*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. User should plan for expected thermal dissipation performance by selecting package and arranging layout of the PCB to maximize the capability.

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

Characteristics		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-		4.5	5.0	5.5	V
Sustaining Voltage at OUT Ports		VDS	$\overline{OUT0}$ ~ $\overline{OUT15}$		-	-	17.0	V
Output Current		IOUT	Refer to ñTest Circuit for Electrical Characteristicsò		8	-	90	mA
		I_{OH}	SDO		-	-	-1.0	mA
		I_{OL}	SDO		-	-	1.0	mA
Input Voltage	ñHòlevel	V_{IH}	Ta=-40~85ºC		0.7xV_{DD}	-	V_{DD}	V
	ñLòlevel	V_{IL}	Ta=-40~85ºC		GND	-	0.3xV_{DD}	V
Output Leakage Current		I_{OH}	V_{DS}=17.0V and channel off		-	-	0.5	εA
Output Voltage	SDO	V_{OH}	I_{OH}=-1.0mA		V_{DD}-0.4	-	-	V
		V_{OL}	I_{OL}=+1.0mA		-	-	0.4	V
Current Skew (Channel)		dI_{OUT1}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=700Ý	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=700Ý	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		%/dV_{DS}	V_{DS} within 1.0V and 3.0V, R_{ext}=700Ý@20mA		-	±0.1	±0.3	% / V
Output Current vs. Supply Voltage Regulation*		%/dV_{DD}	V_{DD} within 4.5V and 5.5V		-	±0.5	±1.0	% / V
LED Open Detection Threshold Voltage**		$V_{OD,TH}$	-		-	0.35	-	V
Pull-up Resistor		R_{IN}(up)	$\overline{OE}$		250	450	800	Kq
Pull-down Resistor		R_{IN}(down)	LE		250	450	800	Kq
Supply Current	ñOffò	I_{DD}(off) 1	R_{ext}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off,		-	2.2	-	mA
		I_{DD}(off) 2	R_{ext}=700q , $\overline{OUT0}$ ~ $\overline{OUT15}$ = Off,		-	5.4	-	
		I_{DD}(off) 3	R_{ext}=230q , $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off,		-	8.5	-	
	ñOnò	I_{DD}(on) 1	R_{ext}=700q , $\overline{OUT0}$ ~ $\overline{OUT15}$ =On,		-	5.9	-	
		I_{DD}(on) 2	R_{ext}=230q , $\overline{OUT0}$ ~ $\overline{OUT15}$ =On,		-	9.3	-	
Thermal Flag Temperature		T_{TF}	Junction Temperature		135	150	165	°C

*One channel on.

**LED short detection threshold voltage ($V_{SD,TH}$) is a configurable voltage. Please see the ñDefinition of Configuration Registerò for details.

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

Characteristics		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-		3.0	3.3	3.6	V
Sustaining Voltage at OUT Ports		V_{DS}	$\overline{OUT0}$ ~ $\overline{OUT15}$		-	-	17.0	V
Output Current		I_{OUT}	Refer to ñTest Circuit for Electrical Characteristicsò		3	-	70	mA
		I_{OH}	SDO		-	-	-1.0	mA
		I_{OL}	SDO		-	-	1.0	mA
Input Voltage	ñHòlevel	V_{IH}	Ta=-40~85ºC		0.7xV_{DD}	-	V_{DD}	V
	ñLòlevel	V_{IL}	Ta=-40~85ºC		GND	-	0.3xV_{DD}	V
Output Leakage Current		I_{OH}	V_{DS}=17.0V and channel off		-	-	0.5	εA
Output Voltage	SDO	V_{OH}	I_{OH}=-1.0mA		V_{DD}-0.4	-	-	V
		V_{OL}	I_{OL}=+1.0mA		-	-	0.4	V
Current Skew (Channel)		dI_{OUT1}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=700Ý	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=700Ý	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		%/dV_{DS}	V_{DS} within 1.0V and 3.0V, R_{ext}=700Ý@20mA		-	±0.1	±0.3	% / V
Output Current vs. Supply Voltage Regulation*		%/dV_{DD}	V_{DD} within 3.0V and 3.6V		-	±0.5	±1.0	% / V
LED Open Detection Threshold Voltage**		$V_{OD,TH}$	-		-	0.35	-	V
Pull-up Resistor		R_{IN}(up)	$\overline{OE}$		250	450	800	Kq
Pull-down Resistor		R_{IN}(down)	LE		250	450	800	Kq
Supply Current	ñOffò	I_{DD}(off) 1	R_{ext}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off,		-	1.8	-	mA
		I_{DD}(off) 2	R_{ext}=700q, $\overline{OUT0}$ ~ $\overline{OUT15}$ = Off,		-	5.0	-	
		I_{DD}(off) 3	R_{ext}=230q, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off,		-	8.0	-	
	ñOnò	I_{DD}(on) 1	R_{ext}=700q, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On,		-	5.3	-	
		I_{DD}(on) 2	R_{ext}=230q, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On,		-	8.4	-	
Thermal Flag Temperature		T_{TF}	Junction Temperature		135	150	165	°C

*One channel on.

**LED short detection threshold voltage ($V_{SD,TH}$) is a configurable voltage. Please see the ñDefinition of Configuration Registerò for details.

Test Circuit for Electrical Characteristics

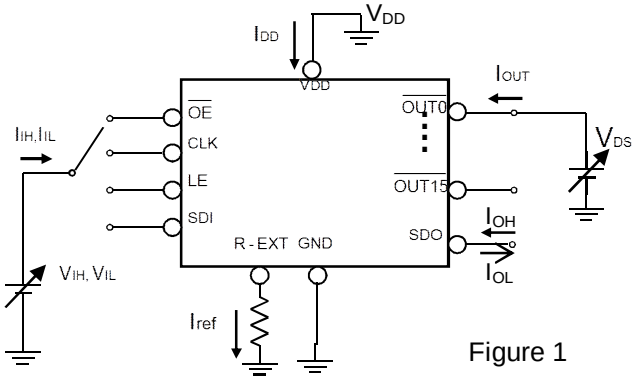


Figure 1

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

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time (ñLòto ñHò)	LE-SDO	t_{pLS}	V_{DD}=5.0V V_{DS}=1.0V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=700Ý R_L=162Ý C_L=10pF I_{OUT}=20mA C_1=100nF C_2=22εF C_{SDO}=10pF	-	55	70	ns
	CLK-SDO	t_{pLH1}		-	25	30	ns
	LE-$\overline{OUT0}$	t_{pLH2}		-	20	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pLH3}		-	20	-	ns
Propagation Delay Time (ñHòto ñLò)	LE-SDO	t_{pLS}		-	55	70	ns
	CLK-SDO	t_{pHL1}		-	25	30	ns
	LE-$\overline{OUT0}$	t_{pHL2}		-	28	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pHL3}		-	28	-	ns
Staggered Delay of Output	$\overline{OUTn}$-$\overline{OUTn+1}$	t_{stag}		-	-	5	ns
Pulse Width	CLK	$t_{w(CLK)}$		15	-	-	ns
	LE	$t_{w(L)}$		15	-	-	ns
Data Clock Frequency		F_{CLK}		-	-	30	MHz
Hold Time for LE		$t_{h(L)}$		10	-	-	ns
Setup Time for LE		$t_{su(L)}$		10	-	-	ns
Hold Time for SDI		$t_{h(D)}$		5	-	-	ns
Setup Time for SDI		$t_{su(D)}$		3	-	-	ns
Maximum CLK Rise Time*		t_r		-	-	500	ns
Maximum CLK Fall Time*		t_f		-	-	500	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}		15	25	-	ns
Output Fall Time of Output Ports		t_{of}		10	15	-	ns
In-message error detection operation time		t_{ERR-I}		300	350	400	ns
Compulsory error detection operation time		t_{ERR-C}		600	650	700	ns
$\overline{OE}$ with uniform output**		$t_{w(OE)}$		-	25	-	ns
Output On-time Error***		t_{ON_ERR}	On-off latch data=all ñ1ò, 25ns $\overline{OE}$ low level one shot pulse input	0	12	25	ns
$\overline{OE}$ with uniform output		$t_{w(OE)}$	R_{ext}=230Ý I_{OUT}=60mA	35	40	-	ns

* If t_r or t_f is large, it may be critical to achieve the timing required for data transfer between two cascaded drivers.

** $\overline{OE}$ =t_{or}+t_{of}.

***Output pulse width= $\overline{OE}$ + t_{ON_ERR}. Users should set the appropriate $\overline{OE}$ pulse width based on the required uniformity of $\overline{OE}$ gray scale.

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

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time (ñLòto ñHò)	LE-SDO	t_{pLS}	V_{DD}=3.3V V_{DS}=1.0V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=700Ý R_L=162Ý C_L=10pF I_{OUT}=20mA C_1=100nF C_2=22ε F C_{SDO}=10pF	-	85	100	ns
	CLK-SDO	t_{pLH1}		-	30	35	ns
	LE-$\overline{OUT0}$	t_{pLH2}			30	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pLH3}		-	30	-	ns
Propagation Delay Time (ñHòto ñLò)	LE-SDO	t_{pLS}		-	85	100	ns
	CLK-SDO	t_{pHL1}		-	30	35	ns
	LE-$\overline{OUT0}$	t_{pHL2}		-	40	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pHL3}		-	40	-	ns
Staggered Delay of Output	$\overline{OUTn}$-$\overline{OUTn+1}$	t_{stag}		-	-	5	ns
Pulse Width	CLK	$t_{w(CLK)}$		20	-	-	ns
	LE	$t_{w(L)}$		15	-	-	ns
Data Clock Frequency		F_{CLK}		-	-	25	MHz
Hold Time for LE		$t_{h(L)}$		10	-	-	ns
Setup Time for LE		$t_{su(L)}$		10	-	-	ns
Hold Time for SDI		$t_{h(D)}$		5	-	-	ns
Setup Time for SDI		$t_{su(D)}$		3	-	-	ns
Maximum CLK Rise Time*		t_r		-	-	500	ns
Maximum CLK Fall Time*		t_f		-	-	500	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}		20	30	-	ns
Output Fall Time of Output Ports		t_{of}		30	40	-	ns
In-message error detection operation time		t_{ERR-I}		300	350	400	ns
Compulsory error detection operation time		t_{ERR-C}		600	650	700	ns
$\overline{OE}$ with uniform output**		$t_{w(OE)}$		-	50	-	ns
Output On-time Error***		t_{ON_ERR}	On/off latch data=all ñ1ò; 50ns $\overline{OE}$ low level one-shot pulse input	0	24	35	ns
$\overline{OE}$ with uniform output		$t_{w(OE)}$	Rext=230Ý I_{OUT}=60mA	-	300	-	ns

*If t_r or t_f is large, it may be critical to achieve the timing required for data transfer between two cascaded drivers.

** $\overline{OE}$ = t_{or}+t_{of}.

***Output pulse width= $\overline{OE}$ + t_{ON_ERR}. Users should set the appropriate $\overline{OE}$ pulse width based on the uniformity of $\overline{OE}$ gray scale.

Test Circuit for Switching Characteristics

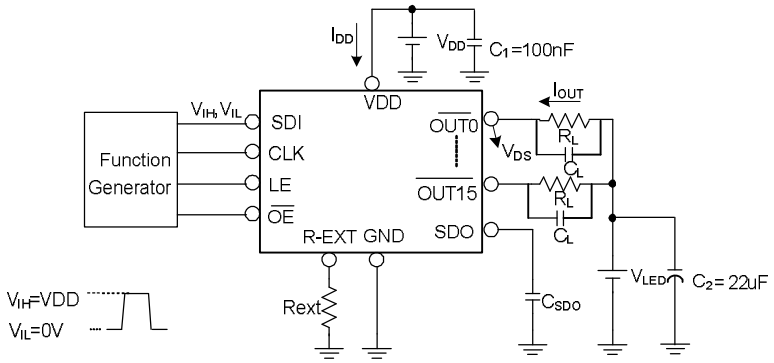
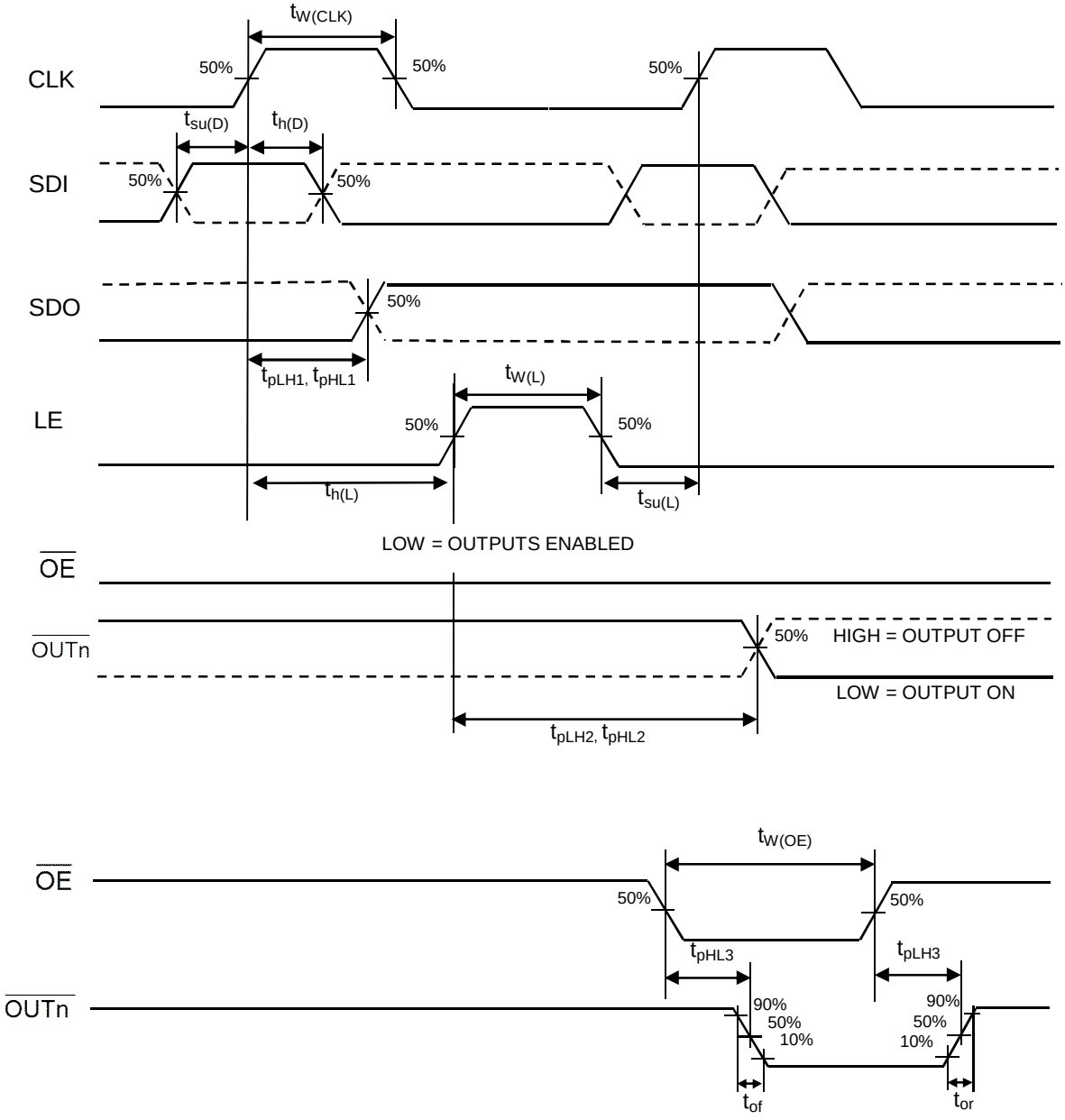
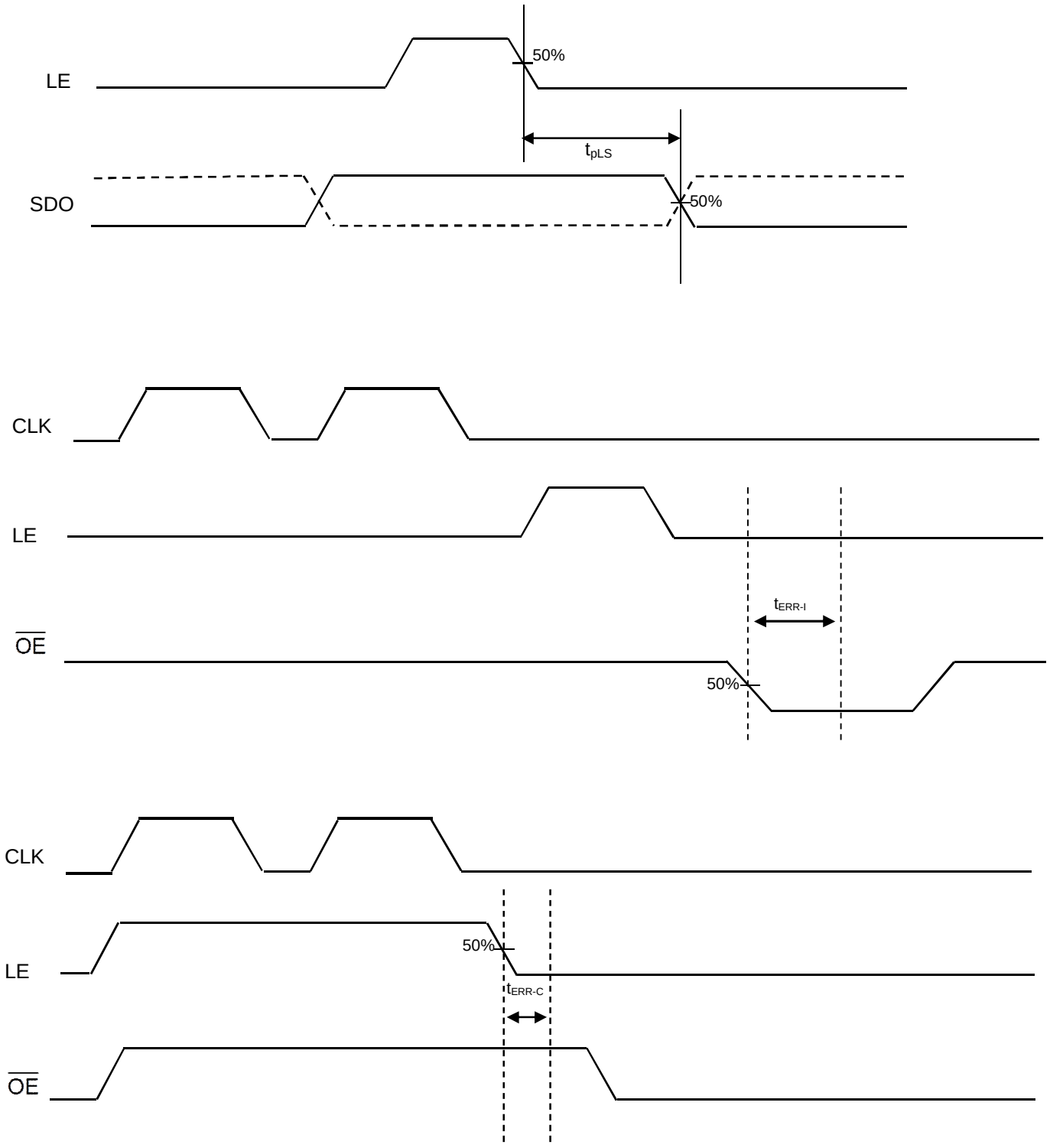


Figure 2

Timing Waveform

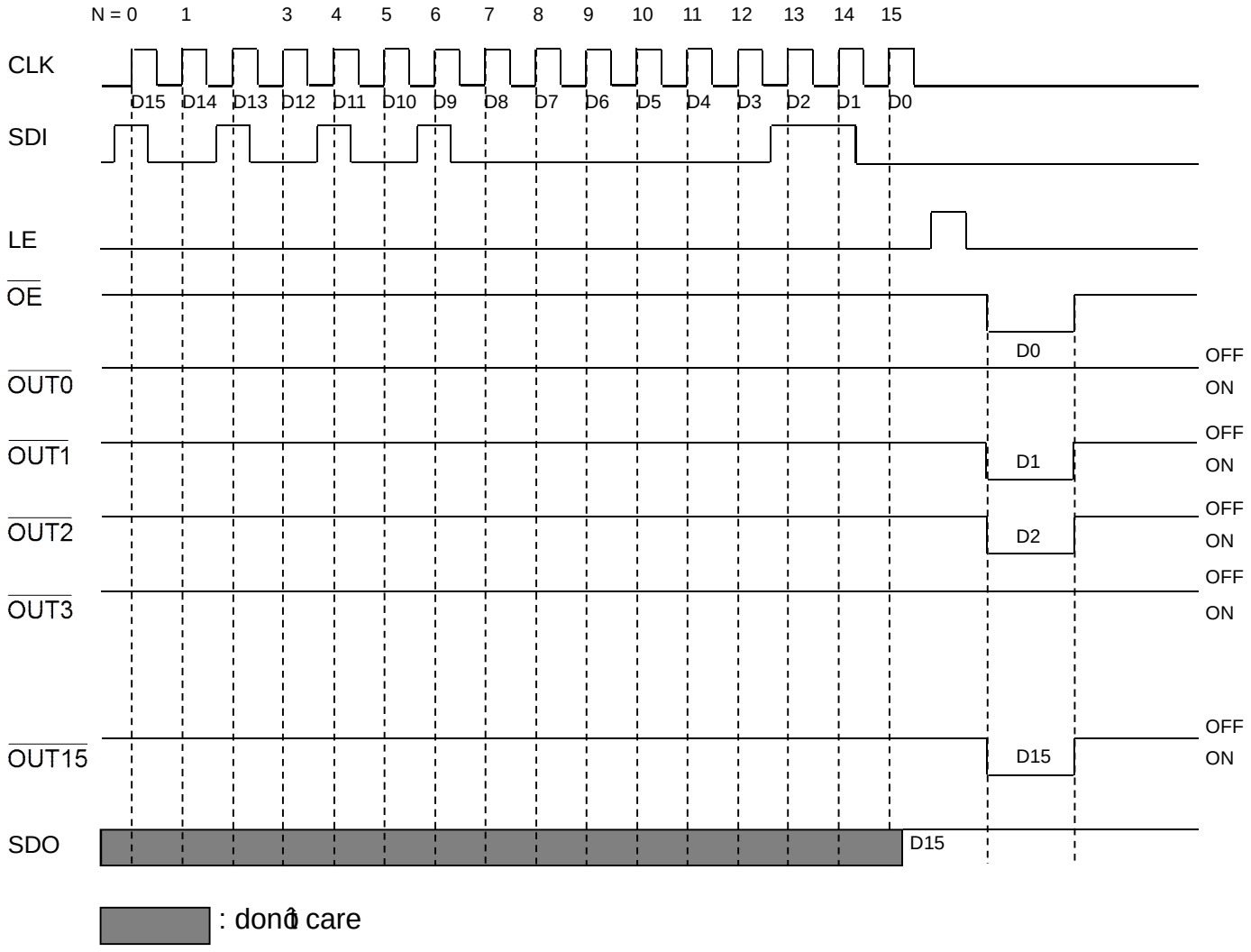



LE
50%
t_{pLS}
SDO
50%
CLK
LE
t_{ERR-I}
$\overline{OE}$
50%
CLK
LE
50%
t_{ERR-C}
$\overline{OE}$

Control the Output Ports

The data is shifted from the SDI to the 16-bits shift registers. When both the LE is asserted and no CLK toggles when the LE is high, the data in the shift register is latched to the output latch. This is so-called ñseries-in parallel outò mechanism.

When the $\overline{OE}$ is low and the data in the output latch is ñ1ò, the output channel is turned on and the current sinks into the output port. If LEDs are connected to the output port with adequate power source, the LEDs will be lit up with the pre-set current.



Control Command

	Signals Combination*	Description
Command Name	**Number of CLK Rising Edge when LE is asserted**	**The Action after a Falling Edge of LE**
Latch data (In-message error detection)	0	Latch the serial data to the output latch. Perform the in-message error detection if it is enabled in the setting of configuration register. In-message error detection includes open-circuit detection and short-circuit detection.
Compulsory open-circuit detection	1	Issue "open-circuit error detection" once. The data latching will not occur.
Compulsory short-circuit detection	2	Issue "short-circuit error detection" once. The data latching will not occur.
Compulsory thermal detection	3	Issue "IC thermal detection" once. The data latching will not occur.
Write configuration	4	Serial data are transferred to the "configuration register"
Read configuration	5	"Configuration register" is shifted out to SDO.

*See section of "Principle of Operation" for detail timing diagram.
Note: If the number of CLK rising edge is ≧6 when LE is asserted, LED drivers will ignore the command.

Data output from SDO

Command	**SDO after a falling edge of LE**
Latch data, in-message error detection is enabled	Error code of in-message error detection; it needs wait t_{pLS} after the falling edge of LE.
Latch data, in-message error detection is disabled	Serial data input ; the data is latched into output buffer
Compulsory open-circuit detection	Error code of Compulsory open-circuit detection. it needs wait t_{ERR-C} *, after the falling edge of LE.
Compulsory short-circuit detection	Error code of Compulsory short-circuit detection t needs wait t_{ERR-C} *, after the falling edge of LE.
Compulsory thermal detection	Thermal report; it needs wait t_{pLS} after the falling edge of LE.
Write configuration	Serial data input ; the data is latched into configuration register
Read configuration	Shift out data from configuration register

*See section of "Principle of Operation" for detail timing diagram

Error code

Command	**Error flag for corresponding bit in the shift register**
Open or short error is detected in the channel	0
Neither open nor short error is detected in the channel (Or detection is suppressed)	1

If the condition of valid error detection is not matched, the detection is suppressed. Please refer to section of "Principle of Operation" for the condition of valid error detection.

Principle of Operation

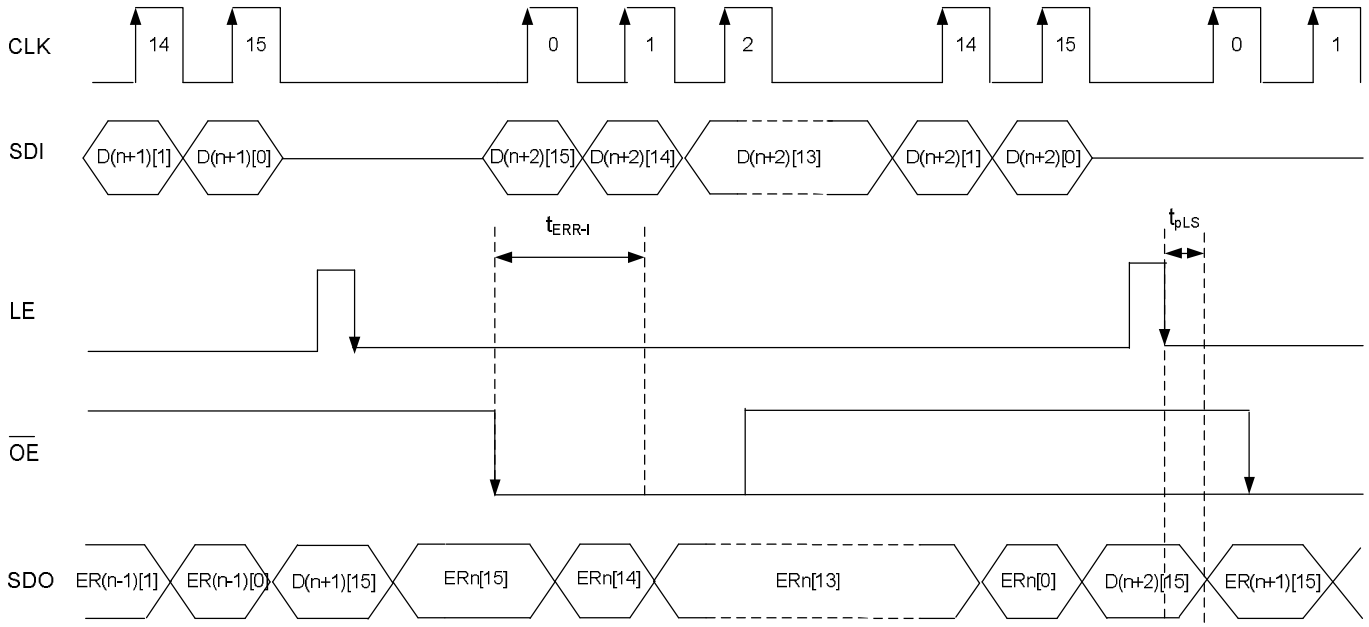
In-Message Error Detection

If the in-message error detection is enabled in the configuration register, the in-message error detection will perform on-the-fly open- and short-circuit detection as data-in and error-out sequentially. The errors are merged and coded with zeros.

The output is detected only when the output data is ñ1ò and $\overline{OE}$ pulse width is larger than t_{ERR-I} , preventing from false error report. This is because the detection result is correct only if the LED is lit up. The error code showed as ñ0ò helps the system identify the errors precisely without comparing data ñ0ò or data ñ1ò.

If the in-message error detection is disabled in the configuration register, the error detection will not be performed and the SDO shifts out the data from the shift register which the SDI is shifted into.

With the in-message error detection, the controller just checked if the data from SDO is ñ0ò to identify the error location without considering the input data, $\overline{OE}$ status and issuing any extra command.



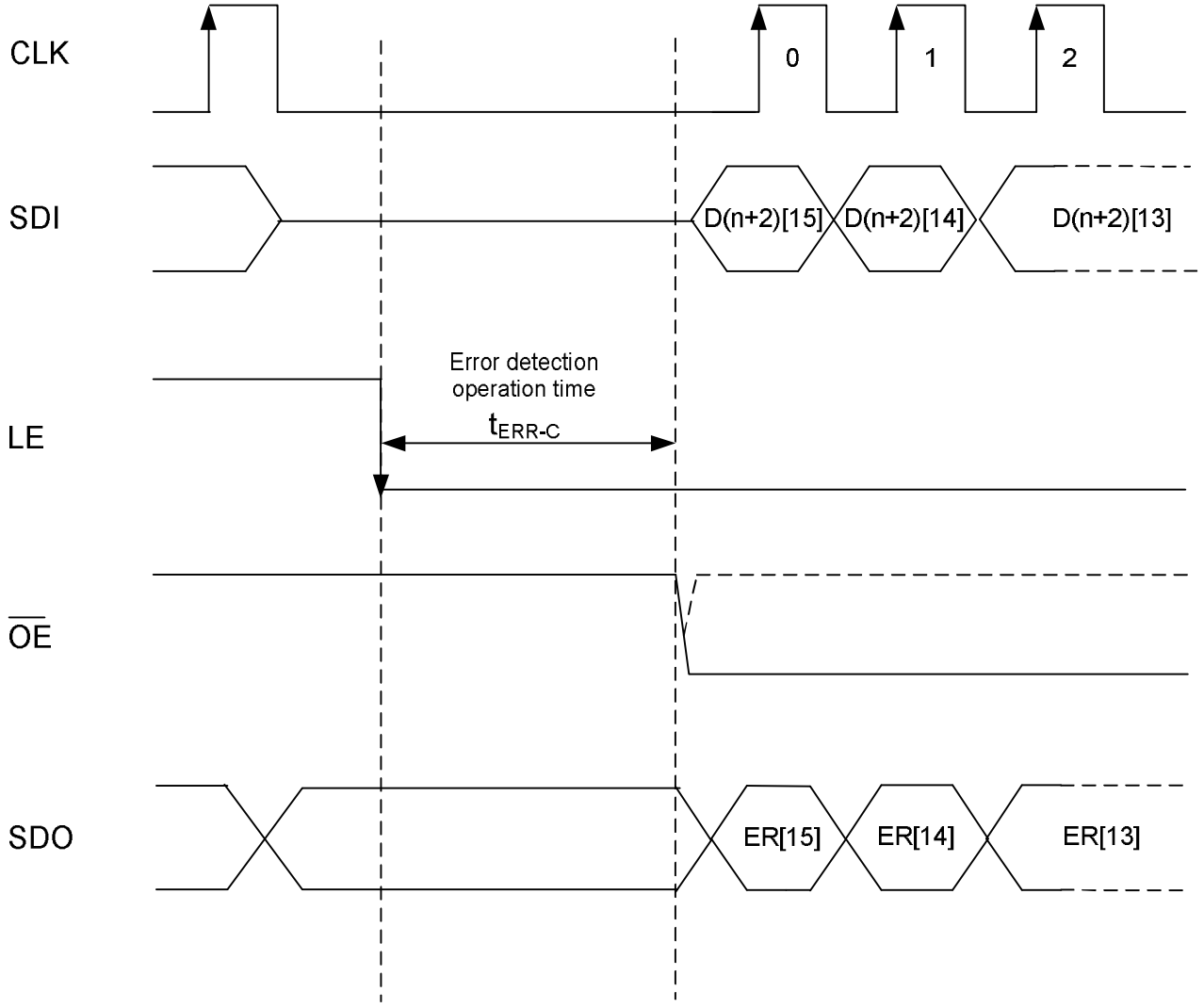
1. Condition of valid error detection: (1) Data =ò1ò(2) $\overline{OE}$ (low) > t_{ERR-I}

Note: If the above condition is not matched, the error detection is suppressed and error codes remain ñ1ò

2. After the falling edge of the LE, the time required for the driver to deliver the error report to the shift register is $t_{pLS.}$

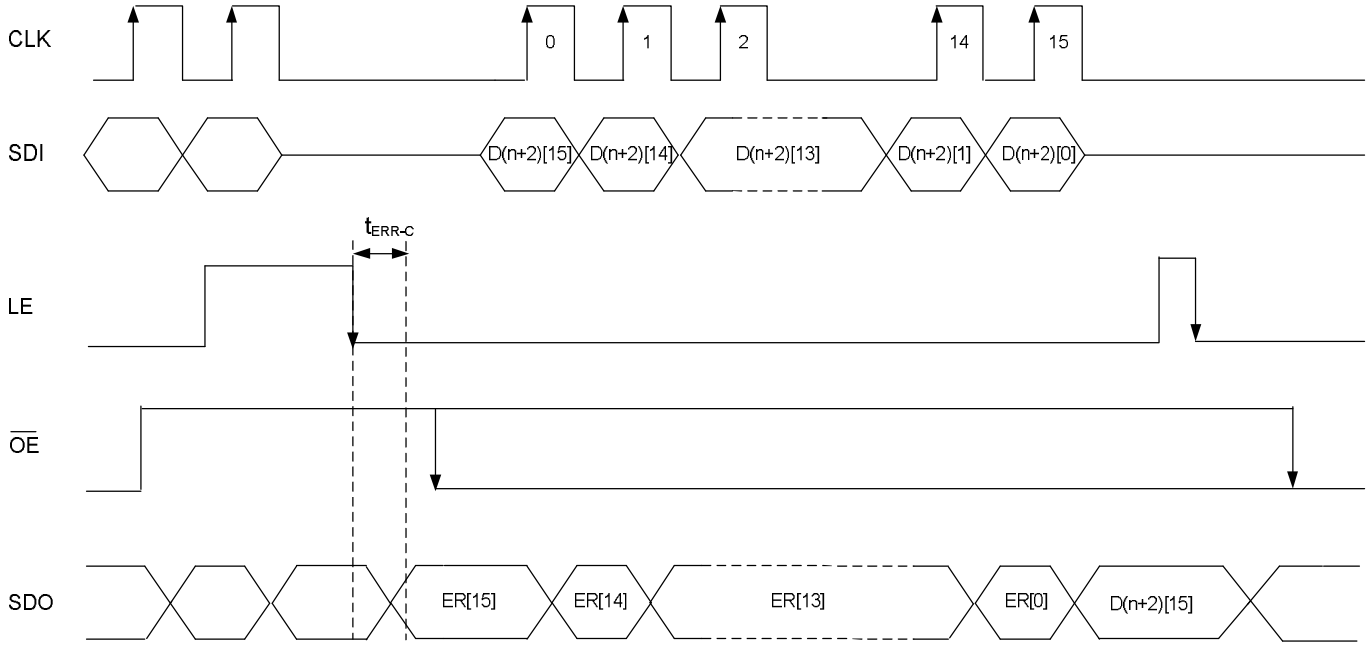
Compulsory Error Detection

Compulsory error detection is ñsilent error detectionò, also named as ñdarkò or ñblindò error detection. No matter the data is 1 or 0, the output will be turned on with 0.25mA in 700ns in the compulsory error detection mode. The turn-on time and turn-on current are short and small, so that the human eye will not perceive detection and the quality of the video and image are not influenced. According to the issued ñcontrol commandsò, the compulsory ñsilentò error detection will run open-circuit or short-circuit detection separately. If an LED has open- or short-circuit, the error code will be ñ0ò and shifted out through SDO once only.



Compulsory Open-Circuit Detection

The principle of MBI5039 LED open-circuit detection is based on the fact that the LED loading status is judged by comparing the effective voltage value (V_{DS}) of each output port with the target voltage ($V_{OD,TH}$ = 0.35V). Thus, after the command of "compulsory open-circuit detection", the output ports of MBI5039 will be turned on with 0.25mA in 700ns. Then, the error status saved in the built-in register is shifted out through SDO pin bit by bit while receiving the new data simultaneously. If the compulsory open-circuit detection mode is enabled while running the in-message error detection, MBI5039 will go back to the in-message error detection mode after the compulsory open-circuit detection is finished. Meanwhile, the in-message error detection mode resumes working after the next LE is asserted without any clock toggled.



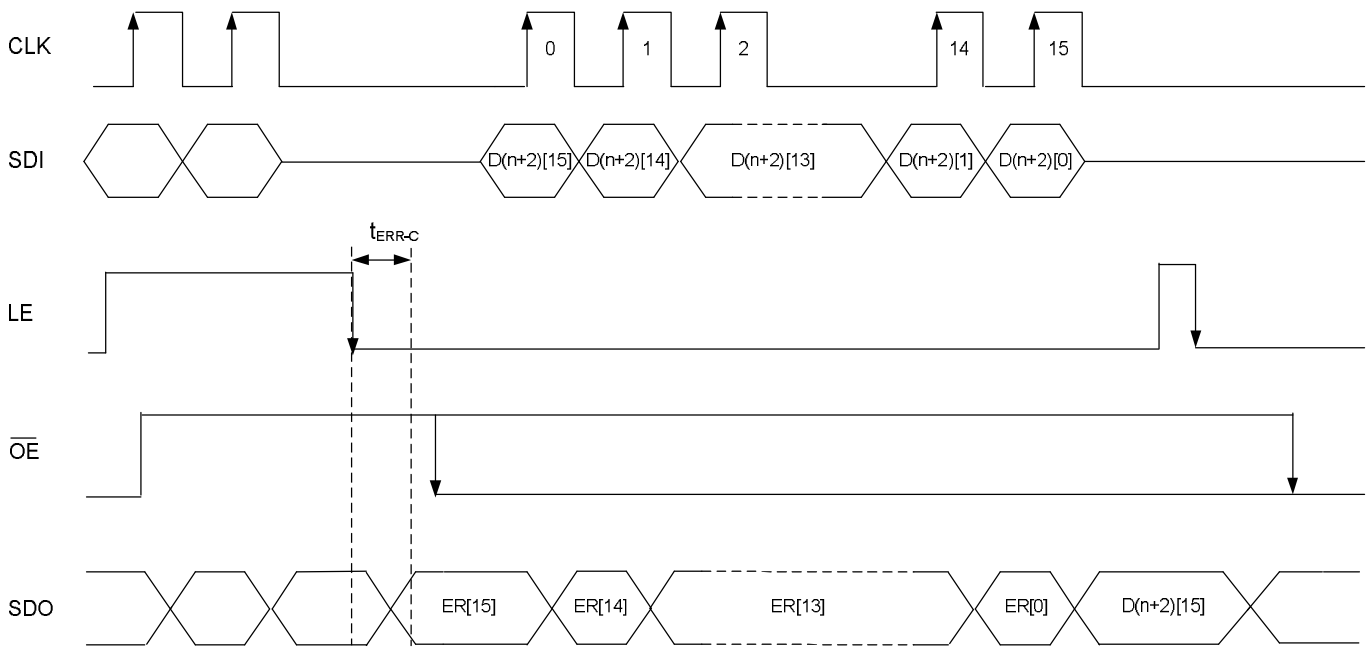
1. Conditions required to activate the open-circuit detection: (1) falling edge of LE and (2) $\overline{OE}$ =High
2. Condition of valid error detection: (1) $\overline{OE}$ =high during t_{ERR-C}

Note: If the above condition is not matched, the error detection is suppressed and error codes remain "1".

3. At the falling edge of LE, all output channels are turned on within 0.25mA.
4. The error detection starts and then loads error result to shift register in t_{ERR-C} duration.
5. If the $\overline{OE}$ is asserted during t_{ERR-C}, the error detection process will be aborted.
6. If CLK is toggled before t_{ERR-C}, the shifted-in data in the shift register will be destroyed at t_{ERR-C}.

Compulsory Short-Circuit Detection

When LED is damaged, a short-circuit error may occur. To effectively detect the short-circuit error, the principle of MBI5039 LED short-circuit detection is based on the fact that the LED voltage drop is judged by comparing the effective voltage value (V_{DS}) of each output port with the target voltage ($V_{SD.TH}$ = 0.45xV_{DD}, default). Please refer to the ñSetting the Threshold Voltage for Short-Circuit Detectionòfor details. Thus, after the command of ñcompulsory short-circuit detectionò, the output ports of MBI5039 will be turned on with 0.25mA in 700ns. Then, the error status saved in the built-in register is shifted out through SDO pin bit by bit while receiving the new data simultaneously. If the compulsory short-circuit detection mode is enabled while running the in-message error detection, MBI5039 will go back to the in-message error detection mode after the compulsory short-circuit detection is finished. Meanwhile, the in-message error detection mode resumes working after the next LE is asserted without any clock toggled. For the short-circuit detection, users need to consider the response time of LEDs to distinguish the LED error status. Please refer to the *MBI5039 Application Note* about how to test whether the response time of LEDs is fast enough or not.



1. Conditions required to activate the short-circuit detection: (1) falling edge of LE and (2) $\overline{OE}$ =High
2. Condition of valid error detection: (1) $\overline{OE}$ =high during t_{ERR-C}

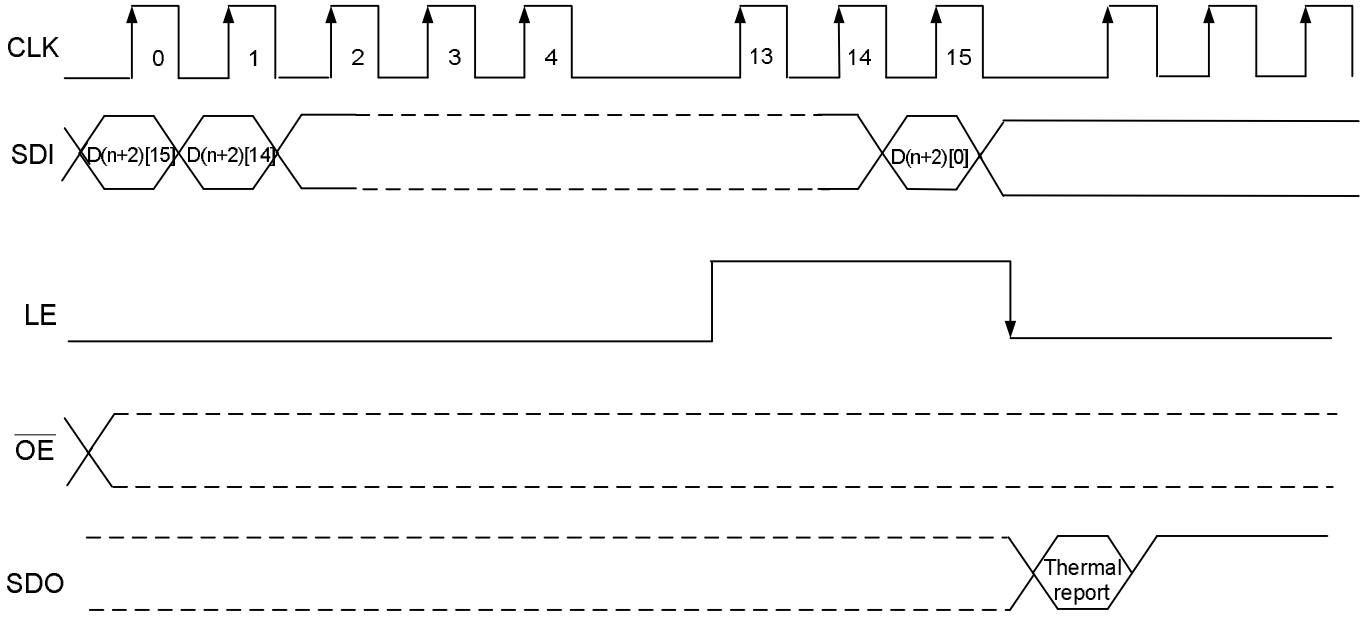
Note: If the above condition is not matched, the error detection is suppressed and error codes remain ñ1ò

3. At the falling edge of LE, all output channels are turned on within 0.25mA.
4. The error detection starts and then loads error result to shift register in t_{ERR-C} duration
5. If the $\overline{OE}$ is asserted during t_{ERR-C}, the error detection process will be aborted.
6. If CLK is toggled before t_{ERR-C}, the shifted-in data in the shift register will be destroyed at $t_{ERR-C.}$

Compulsory Thermal Detection

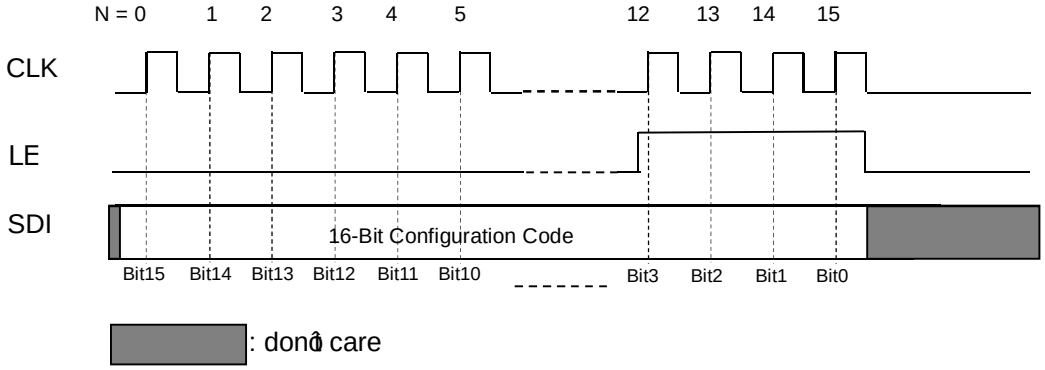
The thermal error flag indicates an overheating condition. When IC's junction temperature is over 150°C (typ.), the bit 15 of the shift register is set to "0".

	Thermal code
The junction temperature of MBI5039 $\geqq T_{TF}$	0
The junction temperature of MBI5039 $< T_{TF}$	1



At the falling edge of LE, if the driver is overheated, the code "7FFF(HEX)" is delivered to SDO; otherwise, the code "FFFF(HEX)" is latched to sift register.
The data "D(n+2) [ ]" will not be latched into the output buffer.

Writing Configuration Code



After entering the writing configuration mode, the system controller sends a 16-bit configuration register setting which must include check bits (bit9~bit6 = 0101) to the 16-bit shift register through the SDI pin. Then the falling edge of LE will transfer the contents in the shift register to a 16-bit configuration register rather than the 16-bit output latch. If the check bits are not equal to "0101", the data will not be updated to the 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	1	1	1	0	0	0	1	0	1	6'b101011					

Bit	Definition	Value	Function
F~E	Voltage thresholds for short-circuit detection($V_{SD,TH}$)	00	$0.33xV_{DD}\pm0.1V$
		01 (Default)	$0.45xV_{DD}\pm0.1V$
		10	$0.58xV_{DD}\pm0.1V$
		11*	$0.73xV_{DD}\pm0.1V$
D~C	Operation of in-message error detection	00	Reserved bits
		01	Enable LE to trigger in-message error detection; SDO shift out error code as "Error Code" section.
		10	Enable $\overline{OE}$ to trigger in-message error detection; SDO shift out error code as "Error Code" section.
		11 (Default)	Enable $\overline{OE}$ or LE to trigger in-message error detection; SDO shift out error code as "Error Code" section.
B~A	Activation of in-message error detection	00 (Default)	Disable in-message error detection
		01	Enable in-message error detection
		10	
		11	
9~6	Check bits	0101	Write in configuration register
5~0	Current gain	000000 ~ 111111	6'b101011 (Default): allow 64-step programmable current gain from 12.5 % to 200%

*Configuration register=11: when both V_{DD}=5V and in the in-message error detection mode, the $V_{SD,TH}$=0.73x V_{DD}+0.4V. In other conditions, $V_{DS,TH}$ is $0.73xV_{DD}$.

Setting the Threshold Voltage for Short-Circuit Detection

The default threshold voltage for short-circuit detection ($V_{SD,TH}$) equals to 0.45xV_{DD}. If the detected voltage is larger than $V_{SD.TH}$, the MBI5039 identifies the LED as short-circuit.

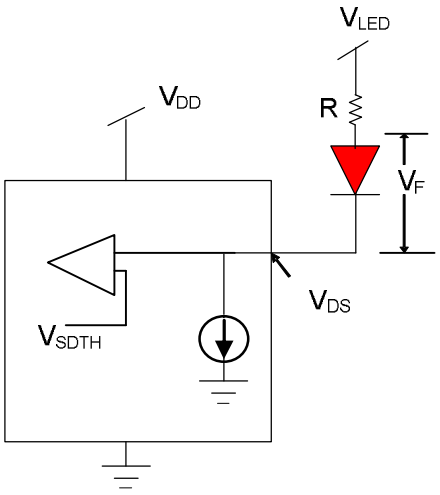


Figure 3

MBI5039 provides settable $V_{SD,TH}$ for different LED configuration. For example, if each output port of MBI5039 drives one red LED, the $V_{SD,TH}$ shall be set larger. If each output port of MBI5039 drives one blue LED, the $V_{SD,TH}$ shall be set smaller. In addition, the system shall consider accumulated V_F of the LED to set the suitable $V_{SD,TH}$.

The system needs to set the suitable $V_{SD,TH}$, V_{LED}, and V_{DD} for different color LEDs.

Consider:

Normal condition : $V_{DS}=V_{LED} - I \times R - V_{F(normal)}$

Short-circuit condition: $V_{DS}=V_{LED} - I \times R - V_{F(short)}$; $V_{F\ (short)}<V_{F\ (normal)}$

Select $V_{SD.TH}$ to meet:

$V_{LED} - I \times R - V_{F(normal)}<V_{SD,TH}<V_{LED} - I \times R - V_{F(short)}$

V_F and I are the values with detection current: 0.25mA (Compulsory error detection) or normal current (in-message error detection)

The variation of each value should be considered.

For example,

a green LED,

$V_{F\ (normal)}$ =3.5~3.7V,

$V_{F\ (short)}$ < 1.5 V,

and R is not used (R=0),

V_{LED} = 4.7~5.3V,

Therefore, in the normal condition, V_{DS}=1~1.8V,

and in the short-circuit condition = V_{DS}>3.2V

If V_{DD}=5V, $V_{DS,\ TH}$ = 0.45xV_{DD} =2.25V is a good choice;

if V_{DD}=3.3V, $V_{DS,\ TH}$ =0.73xV_{DD}=2.41V is a good choice.

In some cases, the V_{DD}, V_{LED}, and R may need to be optimized for different color LEDs. With the adjustable $V_{SD.TH,}$ the selections of these values can be more flexible and reduce the necessity of using dual voltage for operation and error detection.

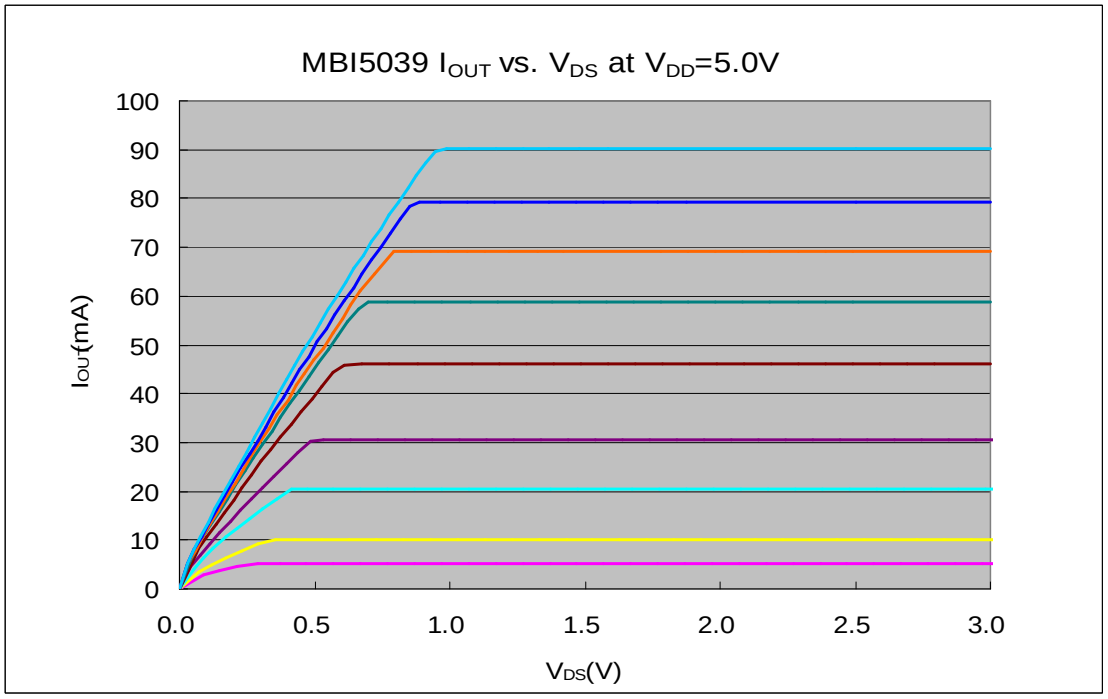
For the compulsory error detection, the $V_{F(normal)}$ and $V_{F(short)}$ shall consider the LED current to be 0.25mA. These two values will be smaller than those in the normal current.

Constant Current

In LED display applications, MBI5039 provides nearly no current variations from channel to channel and from IC to IC. This can be achieved by:

1) While $I_{OUT} \leqq$ 90mA, V_{DD}=5V, the maximum current skew between channels is less than ±1.5% (typical) and that between ICs is less than ±3% (typical).

2) In addition, the characteristics curve of output stage in the saturation region is flat and users can refer to the charts as shown below. Thus, the output current keeps constant regardless of the variations of LED forward voltages (V_F). The output current level in the saturation region is defined as output target current $I_{out,target}$.



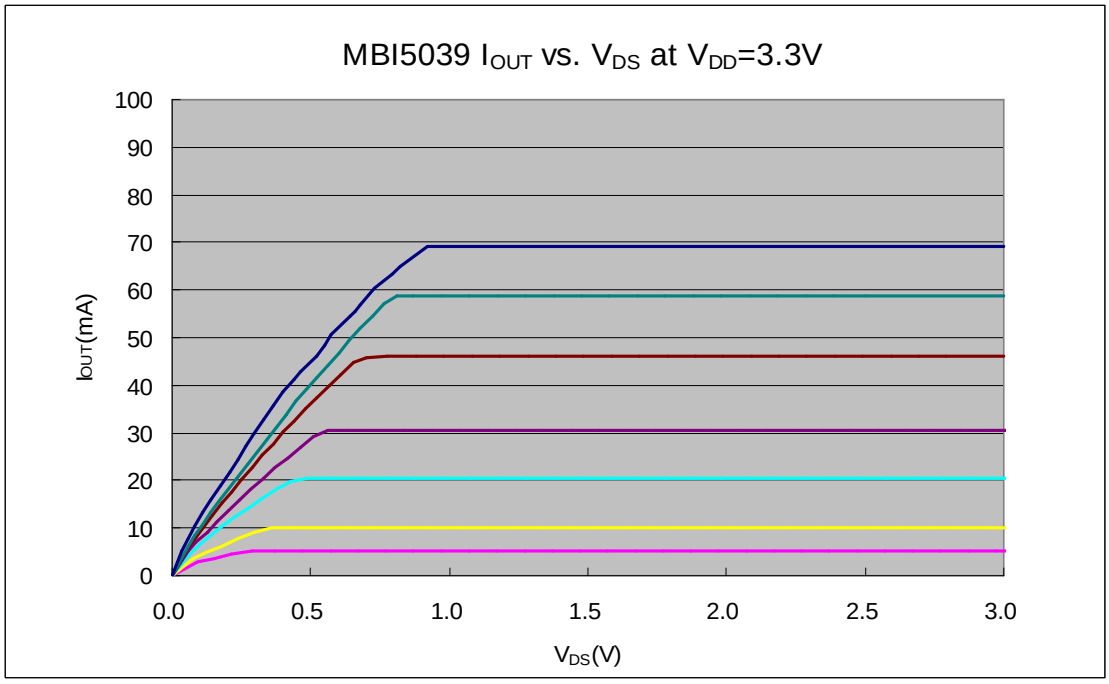


Figure 4

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.

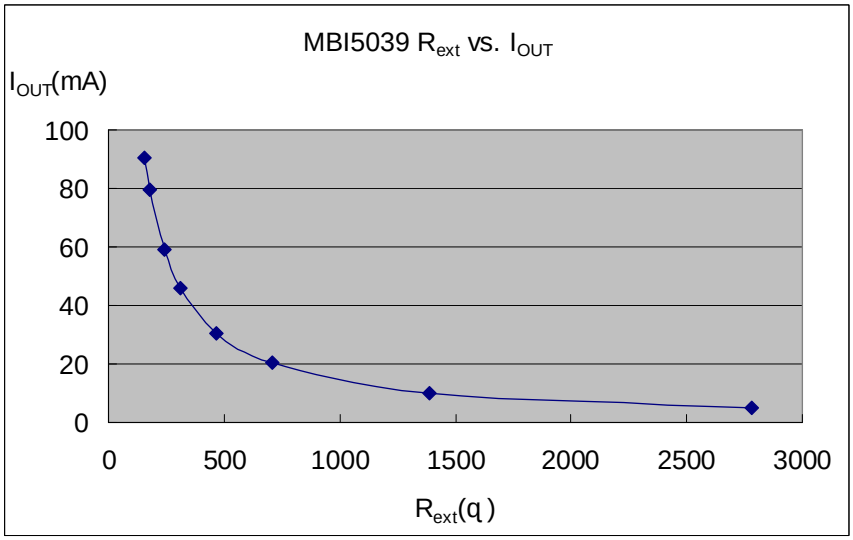


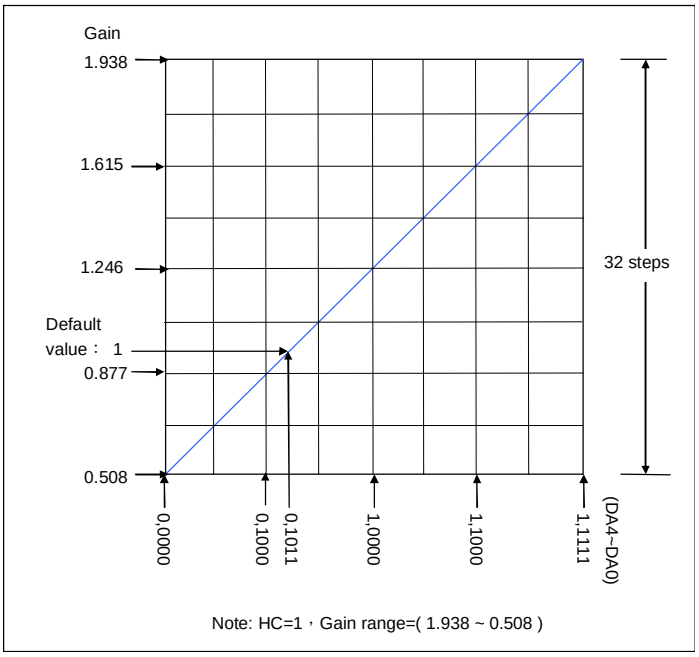
Figure 5

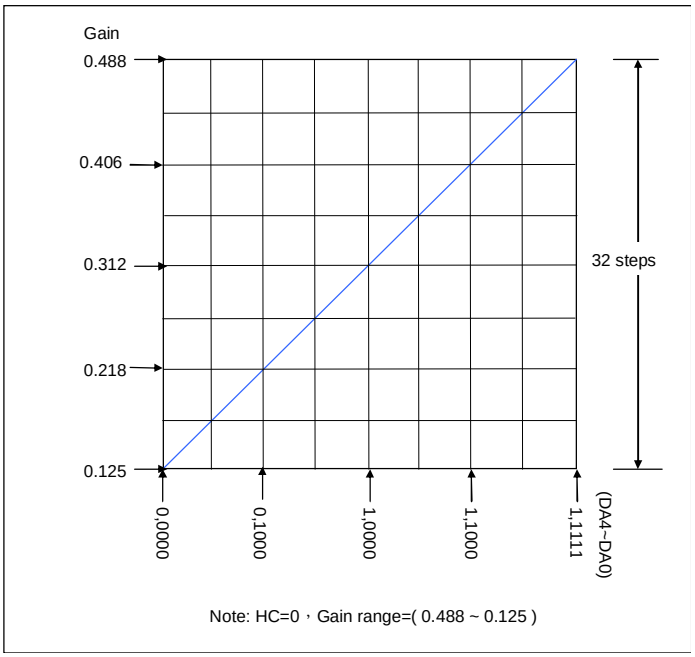
Also, the output current can be calculated from the equation:

$V_{R\text{-}EXT}$=0.61xG; I_{OUT}=($V_{R\text{-}EXT}$/R_{ext})x23.0

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 bit 5 to bit 0 of the configuration register. The default value of G is 1. For your information, the output current is about 20.04mA when R_{ext}=700q and 61mA when R_{ext}=230q if G is set to default value 1. The formula and the setting for G are described in the 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=(65xG-33)/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=(65x1.246-33)/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

MBI5039 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.

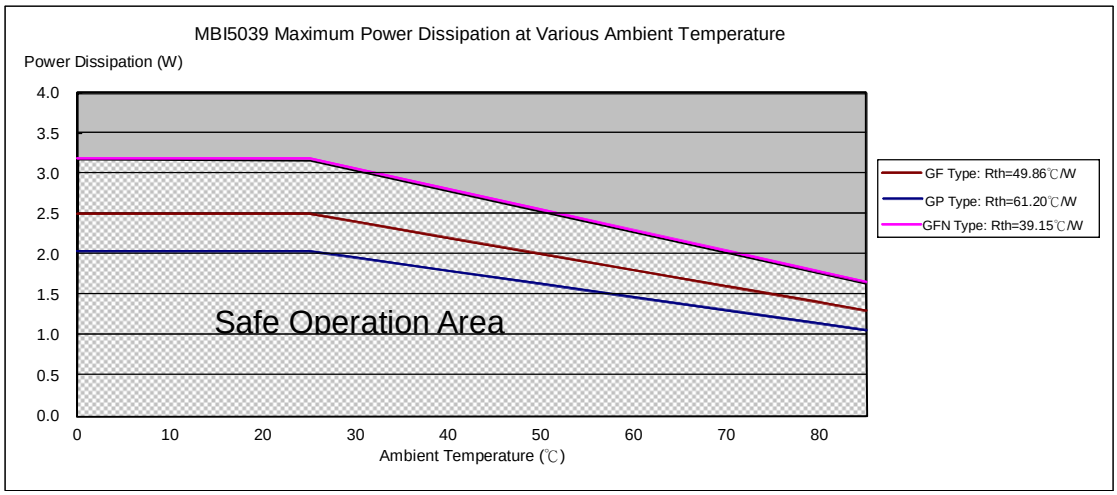
Package Power Dissipation (P_D)

The allowable maximum package heat dissipation is determined as $P_D(max)=(Tj\ddot{i}\ Ta)/R_{th(j-a)}$. 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 $P_D(act) \leqq P_D(max)$, the allowable maximum output current as a function of duty cycle is:

$I_{OUT} =\{[(Tj\ddot{i}\ Ta)/R_{th(j-a)}]\ddot{i}\ (I_{DD}xV_{DD})\}/V_{DS}/Duty/16,$

where Tj = 150°C.

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



Load Supply Voltage (V_{LED})

MBI5039 is designed to operate with V_{DS} ranging from 0.4V to 1.0V, 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 $V_{DS}=V_{LED}$ï 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 $V_{DS}=(V_{LED}$ï $V_F)$ï V_{DROP}.

Resisters or zener diode can be used in the applications as shown in the following figures.

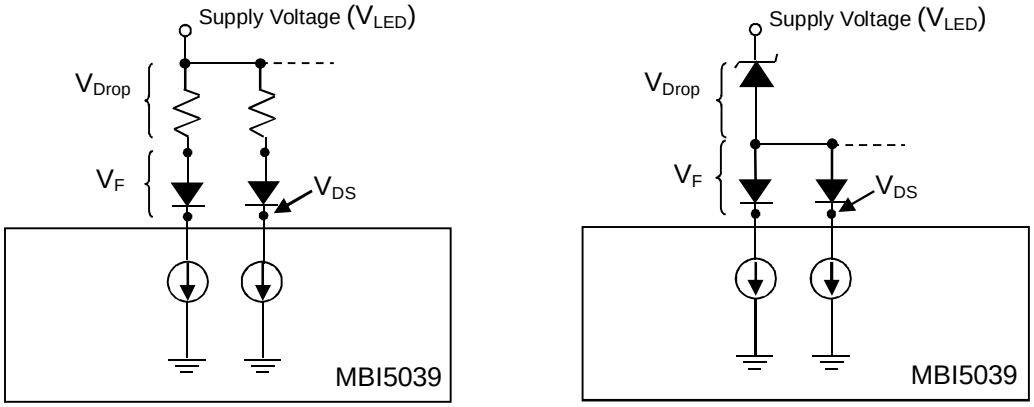


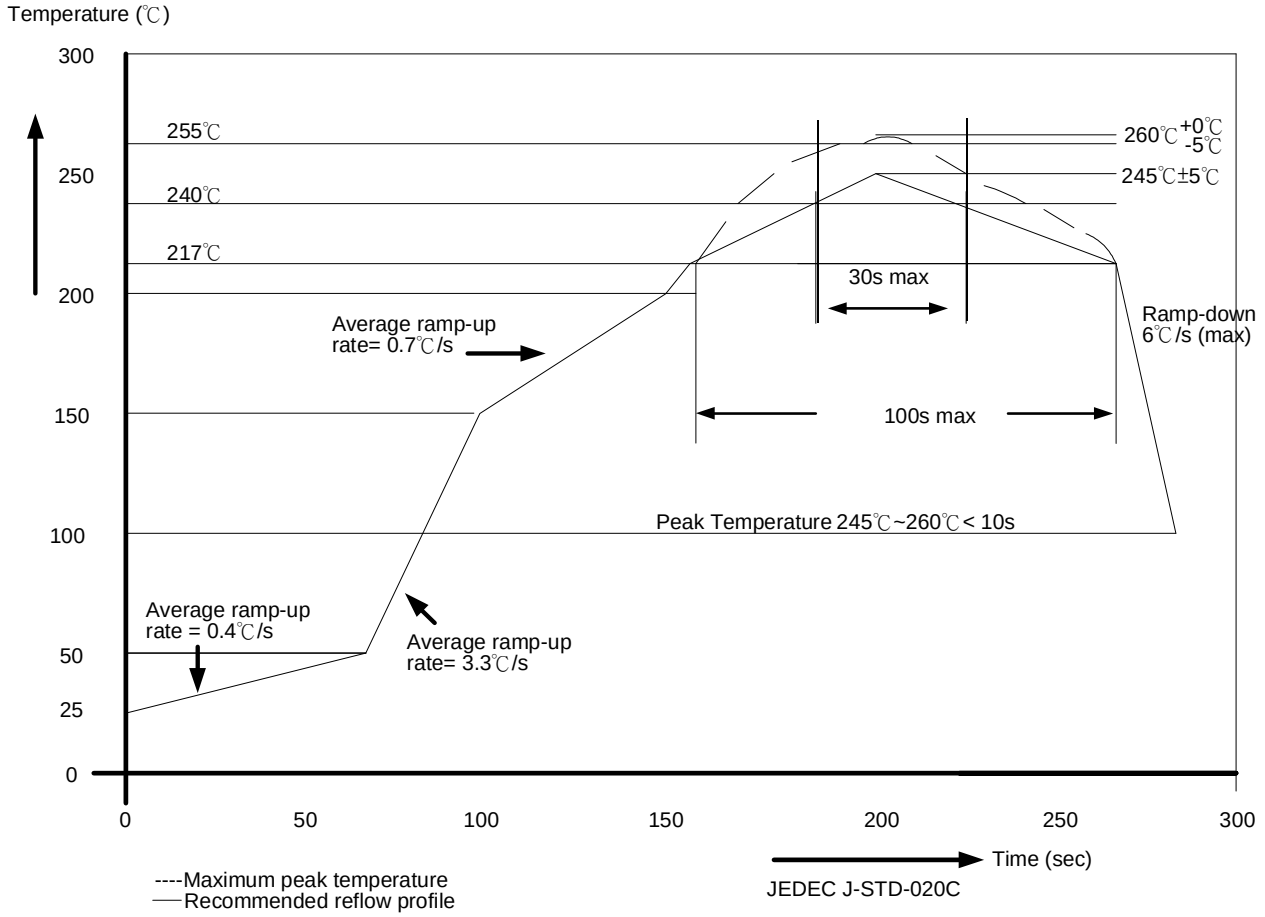
Figure 6

Switching Noise Reduction

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

Soldering Process of “Pb-free & Green” Package Plating*

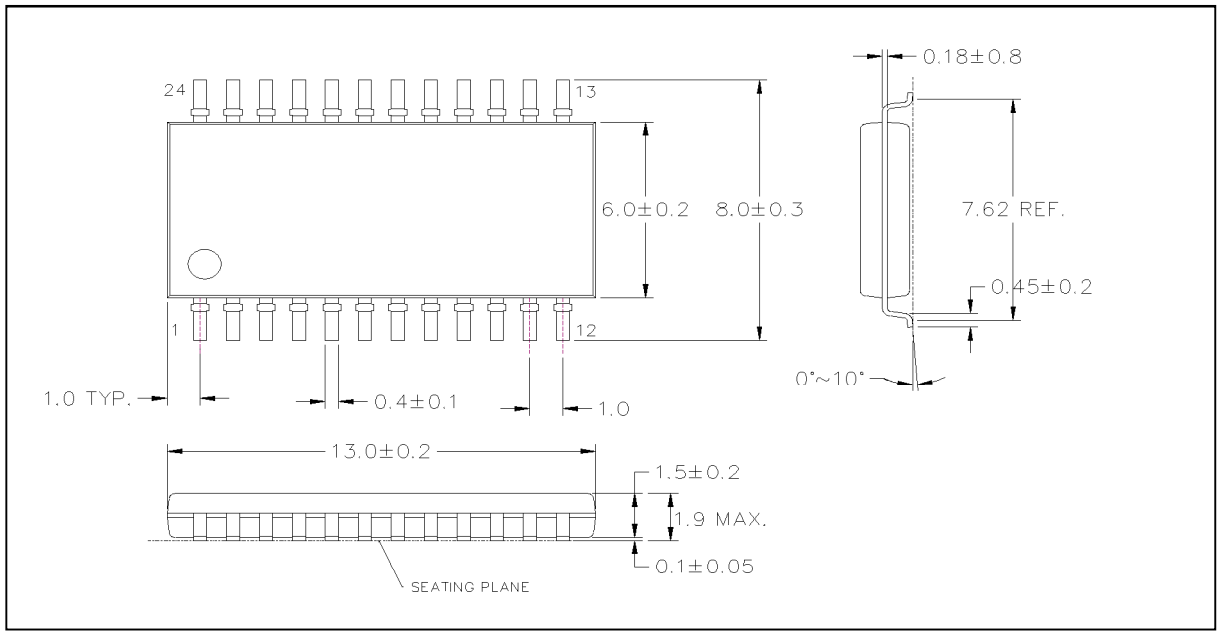
Macroblock has defined "Pb-Free & Green " to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free 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 ï 2.5mm	260 +0 °C	250 +0 °C	245 +0 °C
≧2.5mm	250 +0 °C	245 +0 °C	245 +0 °C

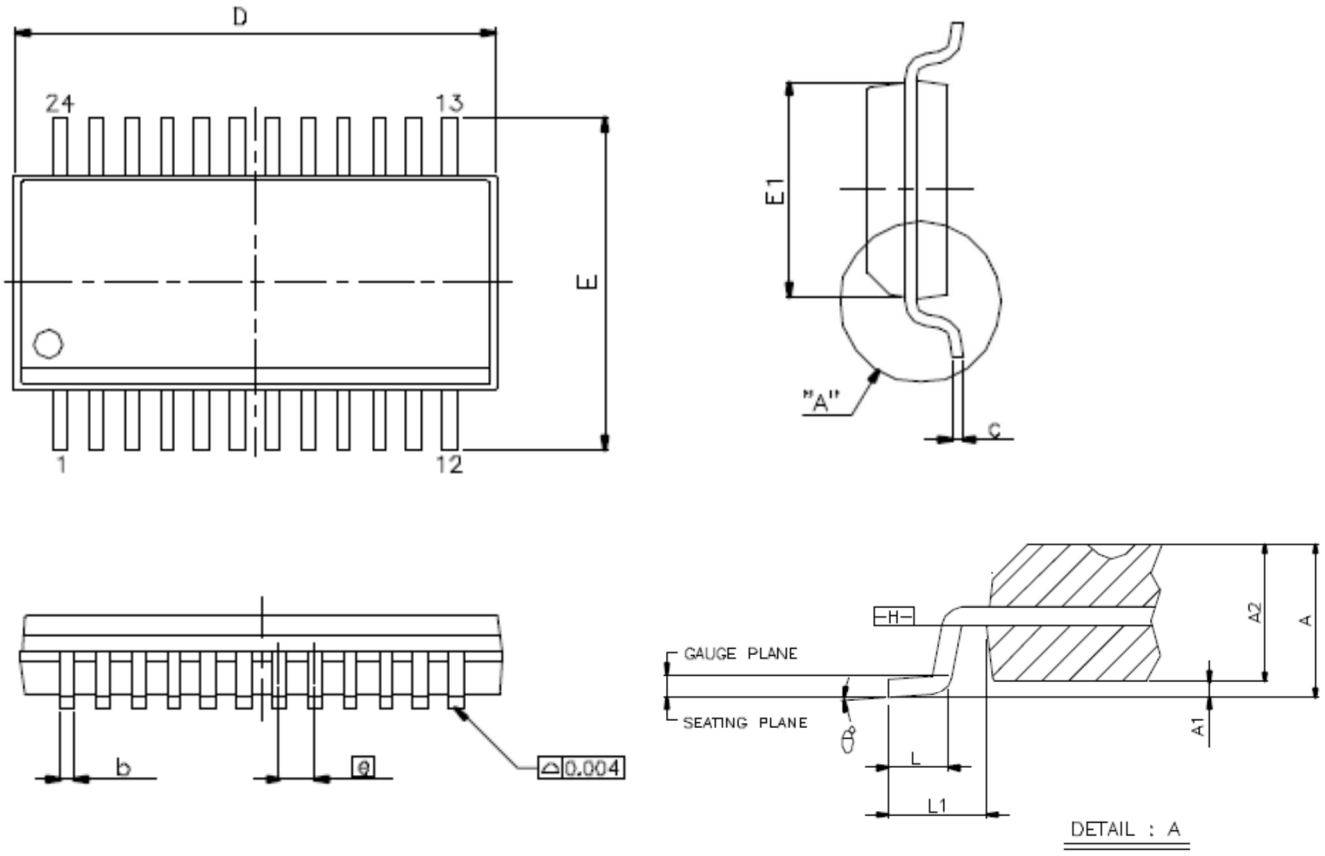
*Note: For details, please refer to Macroblockŝ ñPolicy on Pb-free & Green Packageò

Package Outline



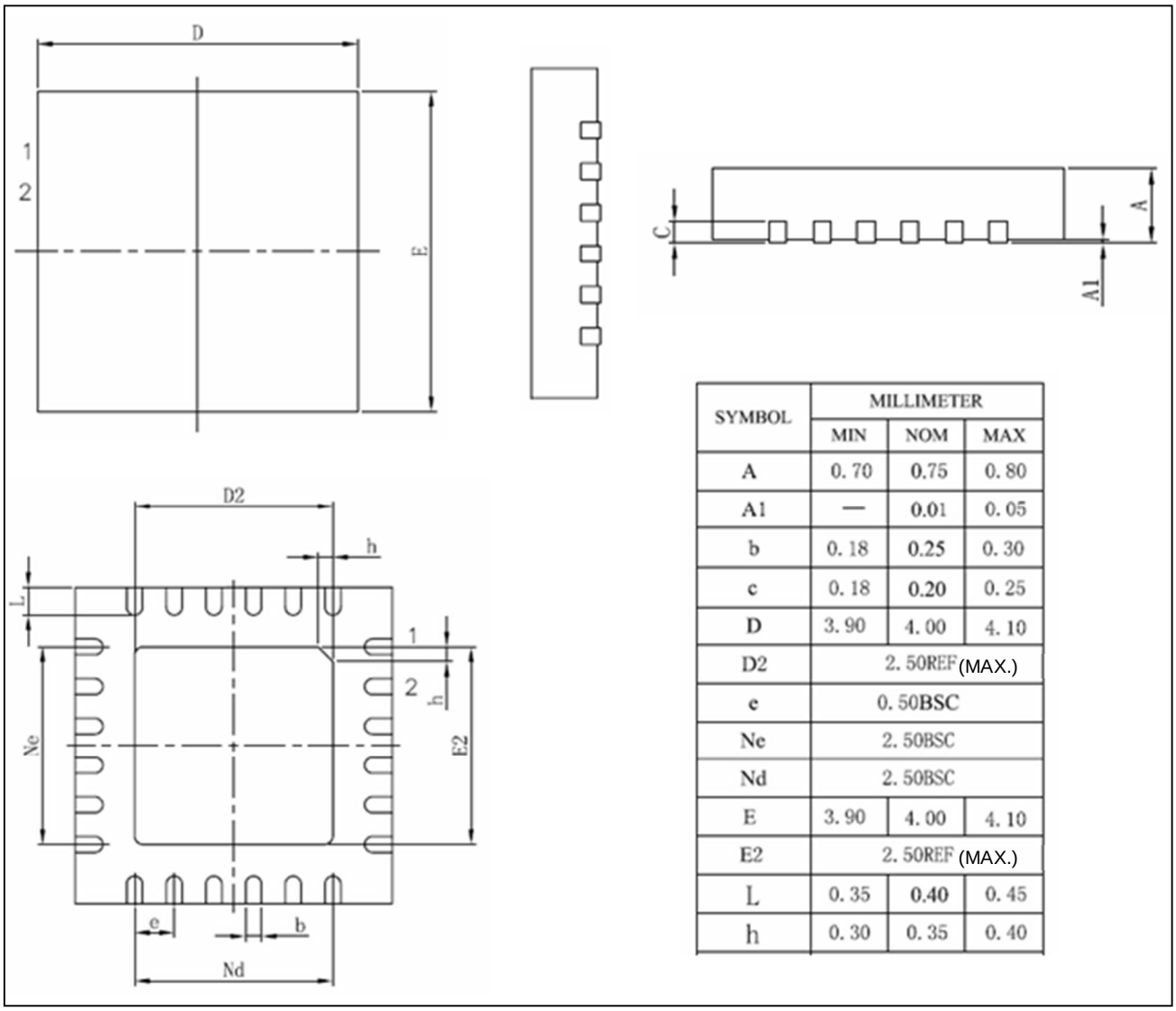
Note: The unit for the outline drawing is mm.

MBI5039GF 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

MBI5039 GP Outline Drawing

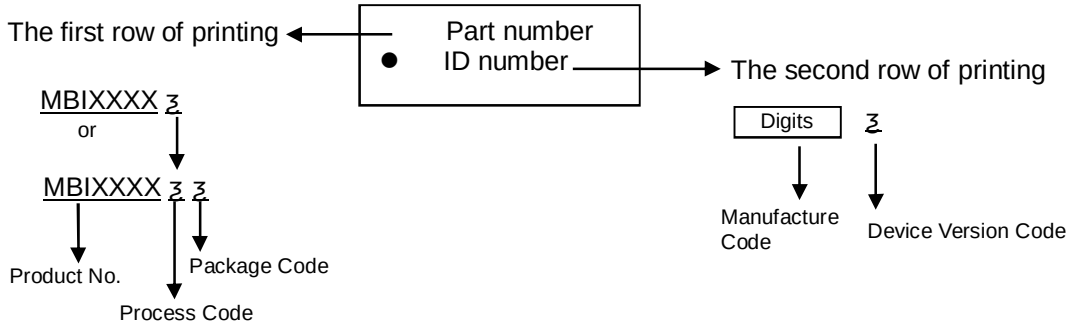


SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	—	0.01	0.05
b	0.18	0.25	0.30
c	0.18	0.20	0.25
D	3.90	4.00	4.10
D2	2.50REF (MAX.)		
e	0.50BSC		
Ne	2.50BSC		
Nd	2.50BSC		
E	3.90	4.00	4.10
E2	2.50REF (MAX.)		
L	0.35	0.40	0.45
h	0.30	0.35	0.40

MBI5039 GFN 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
V2.00	B
VA.00	B
VA.01	B
VA.02	B

Product Ordering Information

Part Number	**RoHS Compliant Package Type**	**Weight (g)**
MBI5039GF-B	SOP24L-300-1.00	0.28
MBI5039GP-B	SSOP24L-150-0.64	0.11
MBI5039GFN-B	QFN24L-4*4-0.5	0.0379

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

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