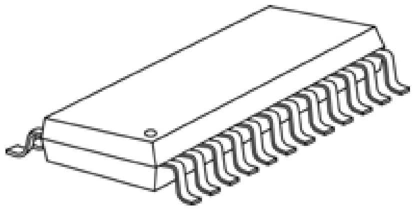
16-Channel Constant Current LED Driver With Silent Error Detection and Power Saving Modes

Features

- Package compatible with MBI5026
- 16 constant-current output channels
  Constant output current range: 3~80mA
  - 10~80mA @ 5V supply voltage
  - 3~60mA @ 3.3V supply voltage
- Compulsory error detection
  - Data-independent full panel detection
  - Error detection current: 0.1mA@700ns
  - Individual LED open- and short-circuit detection
  - Leakage and short to ground diagnosis
  - Pre-settable threshold voltage for short-circuit detection and leakage diagnosis
  - Thermal protection
- Power saving modes to save supply current of LED driver
  - Sleep mode
  - 0-Power mode
- Excellent output current accuracy,
  - Between channels: <±1.5% (typ.);
  - Between ICs: <±3% (typ.)
- Fast response to achieve uniform output current,
  $\overline{OE}$ (min.): 40ns (V_{DD}=5V, I_{OUT}=20mA)
- Staggered delay of output, preventing from current surge
- 30MHz clock frequency
- Schmitt trigger input

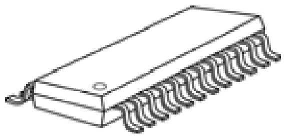
Small Outline Package



GF: SOP24-300-1.00

GD: SOP24-300-1.27

Shrink SOP



GP: SSOP24L-150-0.64

Product Description

MBI5037 is an enhanced 16-channel constant current LED sink driver with advanced error detection functions and smart power-saving modes. MBI5037 succeeds MBI5026 and also exploits **PrecisionDrive™** technology to enhance its output characteristics. Furthermore, MBI5037 uses the concept of **Share-I-O™** technology to make MBI5037 package compatible with MBI5026 and extend its advanced functions, such as silent LED open circuit detection, silent LED short detection, leakage diagnosis, and temperature warning. In addition, MBI5037 features two power saving modes: sleep mode and 0-Power mode to increase the power efficiency.

MBI5037 contains a 16-bit shift register and a 16-bit output latch, which convert serial input data into parallel output format. At MBI5037 output stages, sixteen regulated current output ports are designed to provide uniform and constant current sinks with small current variation between current output ports for driving LEDs within a wide range of forward voltage (V_F) variations. Users may adjust the output current from 3mA to 80mA with an external resistor R_{ext}, which gives users flexibility in controlling the light intensity of LEDs. MBI5037 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.

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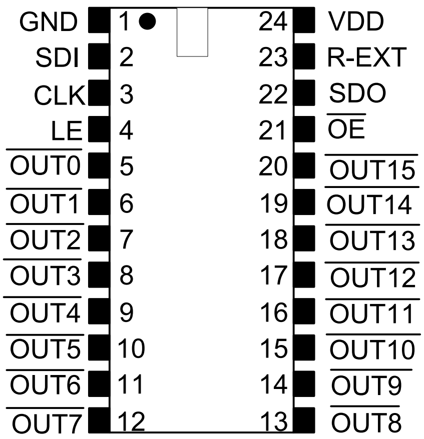
MBI5037 provides “compulsory silent error detection”. Once the dedicated command is issued, all of the current output ports will be turned on in about 700ns interval with current 0.1mA. The image will not be impacted since the turn-on duration and current are so small. All of the current output ports are detected no matter the corresponding data are zero or one, and therefore, users may read the error status and know whether the LEDs are properly lit or not. Moreover, the threshold voltage for short-circuit detection and leakage diagnosis is settable to comply with the variation of different LED forward voltage.

Additionally, to ensure the system reliability, MBI5037 is built with thermal error flag to prevent IC from over temperature (160°C).

MBI5037 also features two power saving modes: sleep mode and 0-Power mode. MBI5037 can enter the sleep mode by command. The sleep mode is suitable for LED display panels when the panels only need to be turned on occasionally or when the system does not have power switch. In the 0-Power mode, if all the output data are 0, MBI5037 will save the power automatically.

With the **Share-I-O™** technique, MBI5037 could be a drop-in replacement of PrecisionDrive™ series LED drivers (16-channel). The printed circuit board originally designed for MBI5026 may be also applicable to MBI5037, if the $\overline{OE}$ is controllable.

Pin Configuration

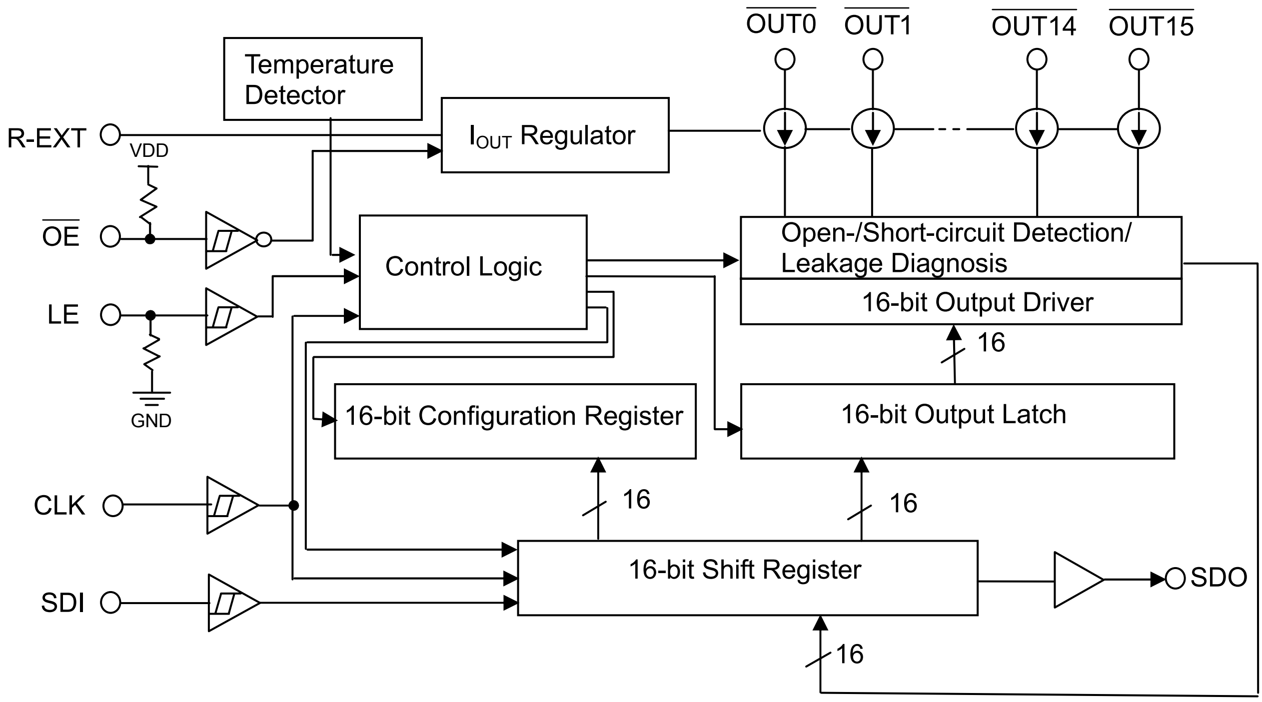


MBI5037GF/GD/GP

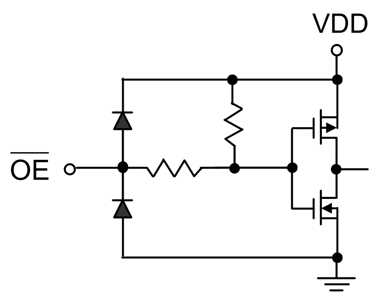
Terminal Description

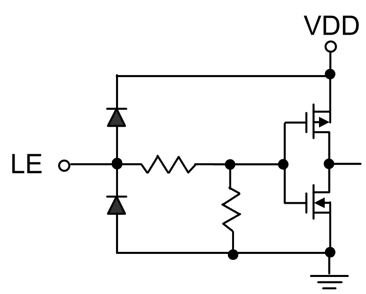
Pin Name	Function
GND	Ground terminal for control logic and current sinks
SDI	Serial-data input to the shift register
CLK	Clock input terminal used to shift data on rising edge and carries command information when LE is asserted.
LE	Data strobe terminal and control command with CLK for extended functions
$\overline{\text{OUT0}}$ ~ $\overline{\text{OUT15}}$	Constant current output ports
$\overline{\text{OE}}$	Enable output ports to sink current. When its level is low (active), the output ports are enabled; when high, all output ports are turned OFF (blanked).
SDO	Serial-data output to the following SDI of the next 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

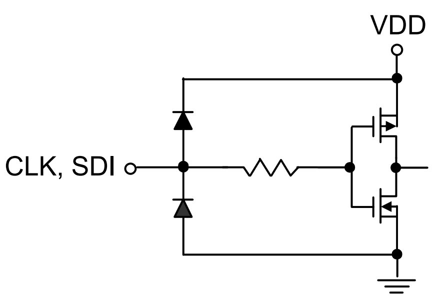
Block Diagram

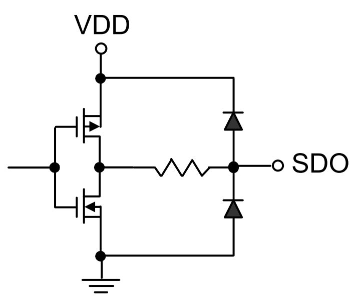


Equivalent Circuits of Inputs and Outputs









Maximum Ratings

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	0~7.0	V
Input Pin Voltage (SDI, $\overline{OE}$, LE, CLK)		V_{IN}	-0.4 to VDD+0.4	V
Output Current ($\overline{OUT0}$ ~ $\overline{OUT15}$)		I_{OUT}	+90	mA
Sustaining Voltage at OUT Port		V_{DS}	-0.5~+17.0	V
GND Terminal Current		I_{GND}	+1440	mA
Power Dissipation (On PCB, Ta=25°C)	GF Type	P_D	2.55	W
	GD Type		2.82	
	GP Type		2.08	
Thermal Resistance (On PCB, Ta=25°C)	GF Type	$R_{th(j-a)}$	49.04	°C/W
	GD Type		44.34	
	GP Type		60.07	
Operating Temperature		T_{opr}	-40 ~ +85	°C
Storage Temperature		T_{stg}	-55 ~ +150	°C
ESD Rating	Human Body Mode (MIL-STD-883G Method 3015.7)	HBM	Class 3A (4000V~7999V)	-
	Machine Mode (JEDEC EIA/JESD22-A115,)	MM	Class B (200V~399V)	-

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

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	That assures the IC works properly	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"	10	-	80	mA
		I_{OH}	SDO, V_{OH}=4.6V	-	-	-1.0	mA
		I_{OL}	SDO, V_{OL}=0.4V	-	-	1.0	mA
Input Voltage	"H" level	V_{IH}	Ta=-40~85ºC	0.7xV_{DD}	-	V_{DD}	V
	"L" level	V_{IL}	Ta=-40~85ºC	GND	-	0.3xV_{DD}	V
Output Leakage Current		I_{OH}	V_{DS}=17.0V and all channels off	-	-	0.1	μA
Output Voltage	SDO	V_{OL}	I_{OL}=+1.0mA	-	-	0.4	V
		V_{OH}	I_{OH}=-1.0mA	4.6	-	-	V
Current Skew (Channel)		dI_{OUT1}/I_{OUT}	I_{OUT}=20mA, V_{DS}=1.0V; R_{ext}=7.5KΩ	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}/I_{OUT}	I_{OUT}=20mA, V_{DS}=1.0V; R_{ext}=7.5KΩ	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		%/dV_{DS}	V_{DS} within 1.0V and 3.0V, R_{ext}=7500Ω@20mA	-	±0.1	±0.3	% / V
Output Current vs. Supply Voltage Regulation*		%/dV_{DD}	V_{DD} within 4.5V and 5.5V	-	±1.0	±2.0	% / V
LED Open Detection Threshold Voltage**		$V_{OD,TH}$	-	-	0.35	0.40	V
Pull-down Resistor		R_{IN}(down)	LE	250	500	800	KΩ
Pull-up Resistor		R_{IN}(up)	$\overline{OE}$	250	500	800	KΩ
Supply Current	"Off"	I_{DD}(off) 1	R_{ext}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off	1.9	2.2	3.0	mA
		I_{DD}(off) 2	R_{ext}=7.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off	4.3	4.6	6.0	mA
		I_{DD}(off) 3	R_{ext}=2.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off	6.3	6.6	7.5	mA
	"On"	I_{DD}(on) 1	R_{ext}=7.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On	4.4	5.0	6.5	mA
		I_{DD}(on) 2	R_{ext}=2.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On	7.0	7.4	8.0	mA
	Sleep mode	I_{DD}(sleep)	-	30	50	70	μA
	0-Power mode	I_{DD}(0-Power)	-	30	50	70	μA
Thermal Flag Temperature		T_{TF}	Junction Temperature	-	160	-	°C

*One channel on.

**LED short detection threshold voltage ($V_{SD,TH}$) and leakage diagnosis threshold voltage ($V_{LD,TH}$) are configurable voltages. Please see the "Definition of Configuration Register" for details.

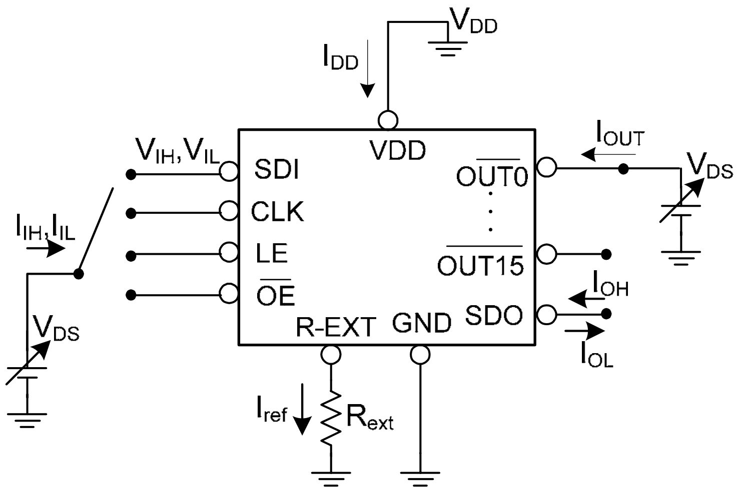
Electrical Characteristics (V_{DD}=3.3V; Ta=25°C)

Characteristics		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	That assures the IC works properly		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 “Test Circuit for Electrical Characteristics”		3	-	60	mA
		I_{OH}	SDO, V_{OH}=2.9V		-	-	-1.0	mA
		I_{OL}	SDO, V_{OL}=0.4V		-	-	1.0	mA
Input Voltage	“H” level	V_{IH}	Ta=-40~85ºC		0.7xV_{DD}	-	V_{DD}	V
	“L” level	V_{IL}	Ta=-40~85ºC		GND	-	0.3xV_{DD}	V
Output Leakage Current		I_{OH}	V_{DS}=17.0V and all channels off		-	-	0.1	μA
Output Voltage	SDO	V_{OL}	I_{OL}=+1.0mA		-	-	0.4	V
		V_{OH}	I_{OH}=-1.0mA		2.9	-	-	V
Current Skew (Channel)		dI_{OUT1}/I_{OUT}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=7.5KΩ	-	±1.5	±3.0	%
Current Skew (IC)		dI_{OUT2}/I_{OUT}	I_{OUT}=20mA V_{DS}=1.0V	R_{ext}=7.5KΩ	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation*		%/dV_{DS}	V_{DS} within 1.0V and 3.0V, R_{ext}=7500Ω@20mA		-	±0.1	±0.3	% / V
Output Current vs. Supply Voltage Regulation*		%/dV_{DD}	V_{DD} within 3.0V and 3.6V		-	±1.0	±2.0	% / V
LED Open Detection Threshold Voltage**		$V_{OD,TH}$	-		-	0.35	0.40	V
Pull-down Resistor		R_{IN}(down)	LE		250	500	800	KΩ
Pull-up Resistor		R_{IN}(up)	$\overline{OE}$		250	500	800	KΩ
Supply Current	“Off”	I_{DD}(off) 1	R_{ext}=Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		1.6	1.8	2.6	mA
		I_{DD}(off) 2	R_{ext}=7.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		4.2	4.4	4.8	mA
		I_{DD}(off) 3	R_{ext}=2.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =Off		5.8	6.2	7.0	mA
	“On”	I_{DD}(on) 1	R_{ext}=7.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On		4.2	4.4	5.0	mA
		I_{DD}(on) 2	R_{ext}=2.5KΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ =On		6.0	6.5	7.0	mA
	Sleep mode	I_{DD}(sleep)	-		30	40	60	μA
	0-Power mode	I_{DD}(0-Power)	-		30	40	60	μA
Thermal Flag Temperature		T_{TF}	Junction Temperature		-	160	-	°C

*One channel on.

**LED short detection threshold voltage ($V_{SD,TH}$) and leakage diagnosis threshold voltage ($V_{LD,TH}$) are configurable voltages. Please see the “Definition of Configuration Register” for details.

Test Circuit for Electrical Characteristics



Switching Characteristics (V_{DD}=5.0V)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	LE-$\overline{OUT0}$	t_{pLH1}	V_{DD}=5.0V, V_{DS}=1.0V, V_{IH}=V_{DD}, V_{IL}=GND, R_{ext}=7.5KΩ, I_{OUT}=20mA, V_{LED}=4V, R_L=150Ω, C_L=10pF, C1=100nF, C2=22uF, C_{SDO}=10pF	-	30	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pLH2}		-	30	-	ns
	CLK-SDO	t_{pLH3}		-	20	30	ns
Propagation Delay Time ("H" to "L")	LE-$\overline{OUT0}$	t_{pHL1}		-	30	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pHL2}		-	30	-	ns
	CLK-SDO	t_{pHL3}		-	20	30	ns
Stagger delay	$\overline{OUTn}$-$\overline{OUTn+1}$	t_{stag}		-	2	3	ns
Pulse Width	CLK	$t_{w(CLK)}$		16.5	-	-	ns
	LE	$t_{w(L)}$		20	-	-	ns
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		$t_{r,SDO}$		-	8	-	ns
SDO Fall Time		$t_{f,SDO}$		-	8	-	ns
Output Rise Time of Output Ports		t_{or}		10	15	-	ns
Output Fall Time of Output Ports		t_{of}		5	10	-	ns
Compulsory error detection operation time**		t_{ERR-C}		-	-	700	ns
$\overline{OE}$ with uniform output***		$t_{w(OE)}$		40	-	-	ns
$\overline{OE}$ with uniform output***		$t_{w(OE)}$	R_{ext}=2.5KΩ, I_{OUT}=60mA	50	-	-	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.
**Users have to leave more time than the maximum error detection time for the error detection.
***With uniform output current of all output ports.

Switching Characteristics (V_{DD}=3.3V)

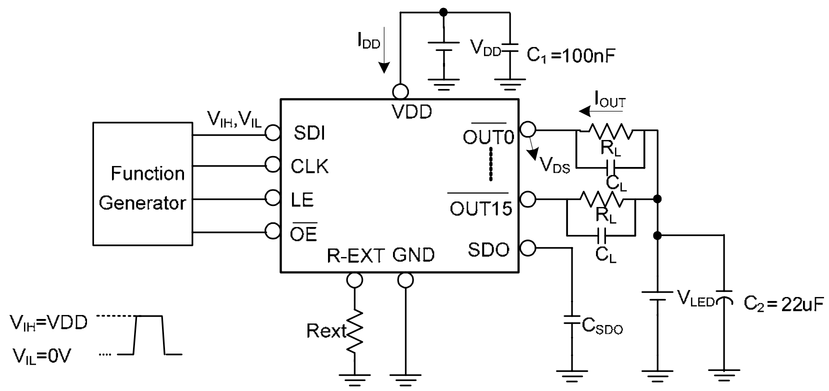
Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	LE-$\overline{\text{OUT0}}$	t_{pLH1}	V_{DD}=3.3V, V_{DS}=1.0V, V_{IH}=V_{DD}, V_{IL}=GND, R_{ext}=7.5KΩ, I_{OUT}=20mA, V_{LED}=4V, R_L=150Ω, C_L=10pF, C1=100nF, C2=22uF, C_{SDO}=10pF	-	30	-	ns
	$\overline{\text{OE}}$-$\overline{\text{OUT0}}$	t_{pLH2}			30	-	ns
	CLK-SDO	t_{pLH3}		-	30	40	ns
Propagation Delay Time ("H" to "L")	LE-$\overline{\text{OUT0}}$	t_{pHL1}		-	50	-	ns
	$\overline{\text{OE}}$-$\overline{\text{OUT0}}$	t_{pHL2}		-	50	-	ns
	CLK-SDO	t_{pHL3}		-	30	40	ns
Stagger delay	$\overline{\text{OUTn}}$-$\overline{\text{OUTn+1}}$	t_{stag}		-	2	3	ns
Pulse Width	CLK	$t_{w(CLK)}$		20	-	-	ns
	LE	$t_{w(L)}$		20	-	-	ns
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		$t_{r,SDO}$		-	8	-	ns
SDO Fall Time		$t_{f,SDO}$		-	8	-	ns
Output Rise Time of Output Ports		t_{or}		15	20	-	ns
Output Fall Time of Output Ports		t_{of}		20	25	-	ns
Compulsory error detection operation time**		t_{ERR-C}		-	-	700	ns
$\overline{\text{OE}}$ with uniform output***		$t_{w(OE)}$		90	-	-	ns
Output Rise Time of Output Ports		t_{or}	R_{ext}=2.5KΩ, I_{OUT}=60mA	-	20	-	ns
Output Fall Time of Output Ports		t_{of}		-	230	-	ns
$\overline{\text{OE}}$ with uniform output***		$t_{w(OE)}$		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.

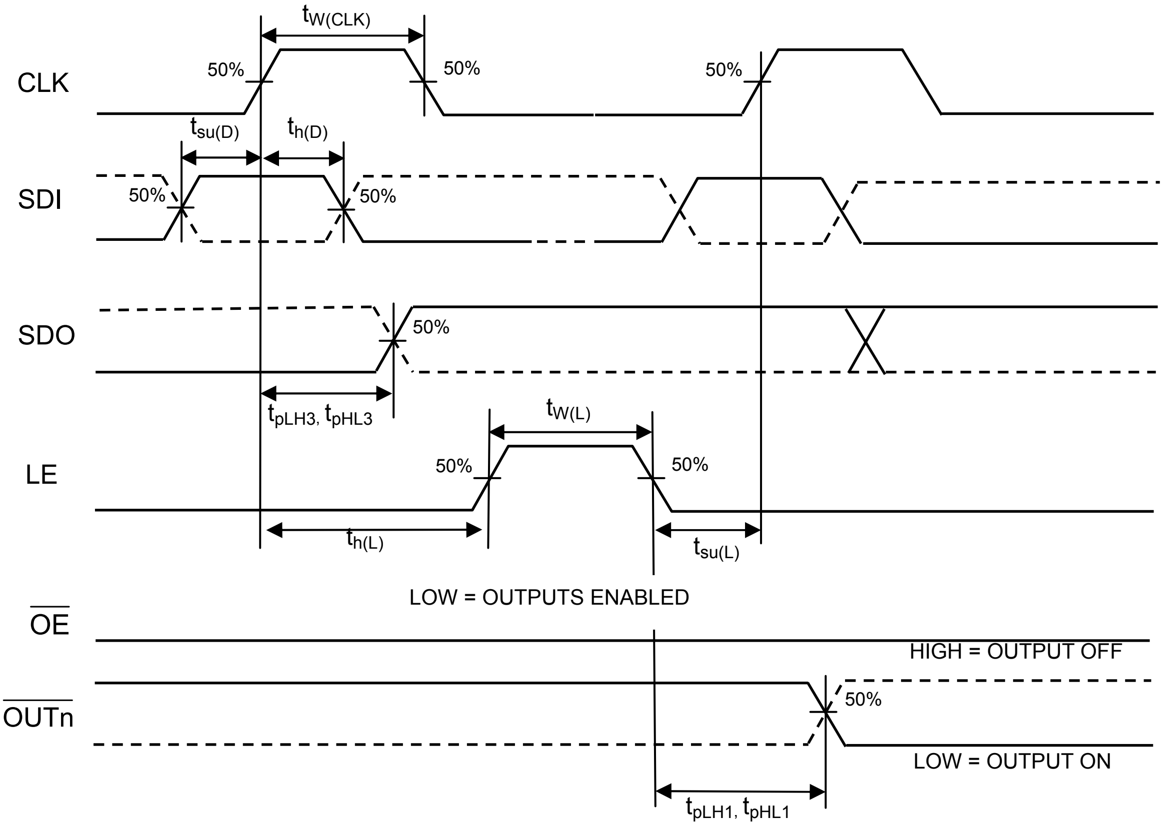
**Users have to leave more time than the maximum error detection time for the error detection.

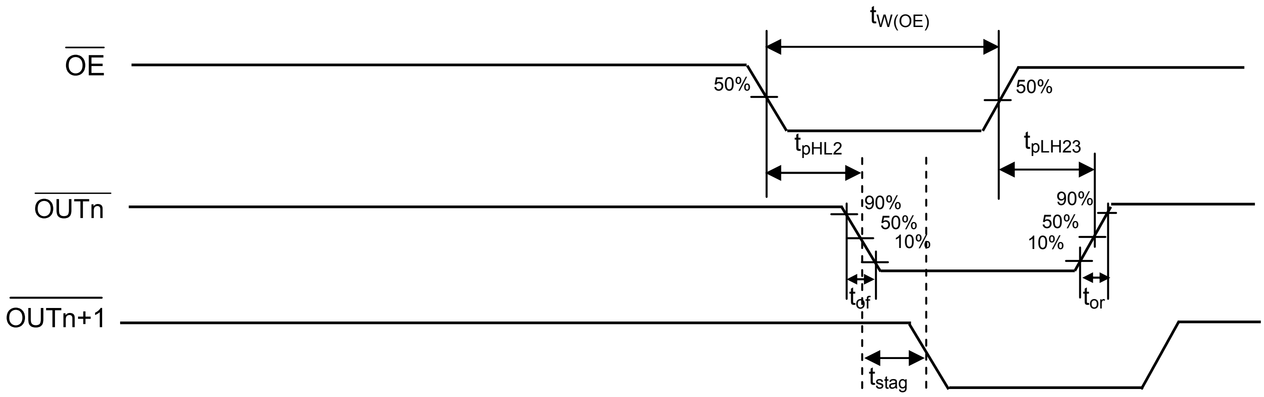
***With uniform output current of all output ports.

Test Circuit for Switching Characteristics



Timing Waveform

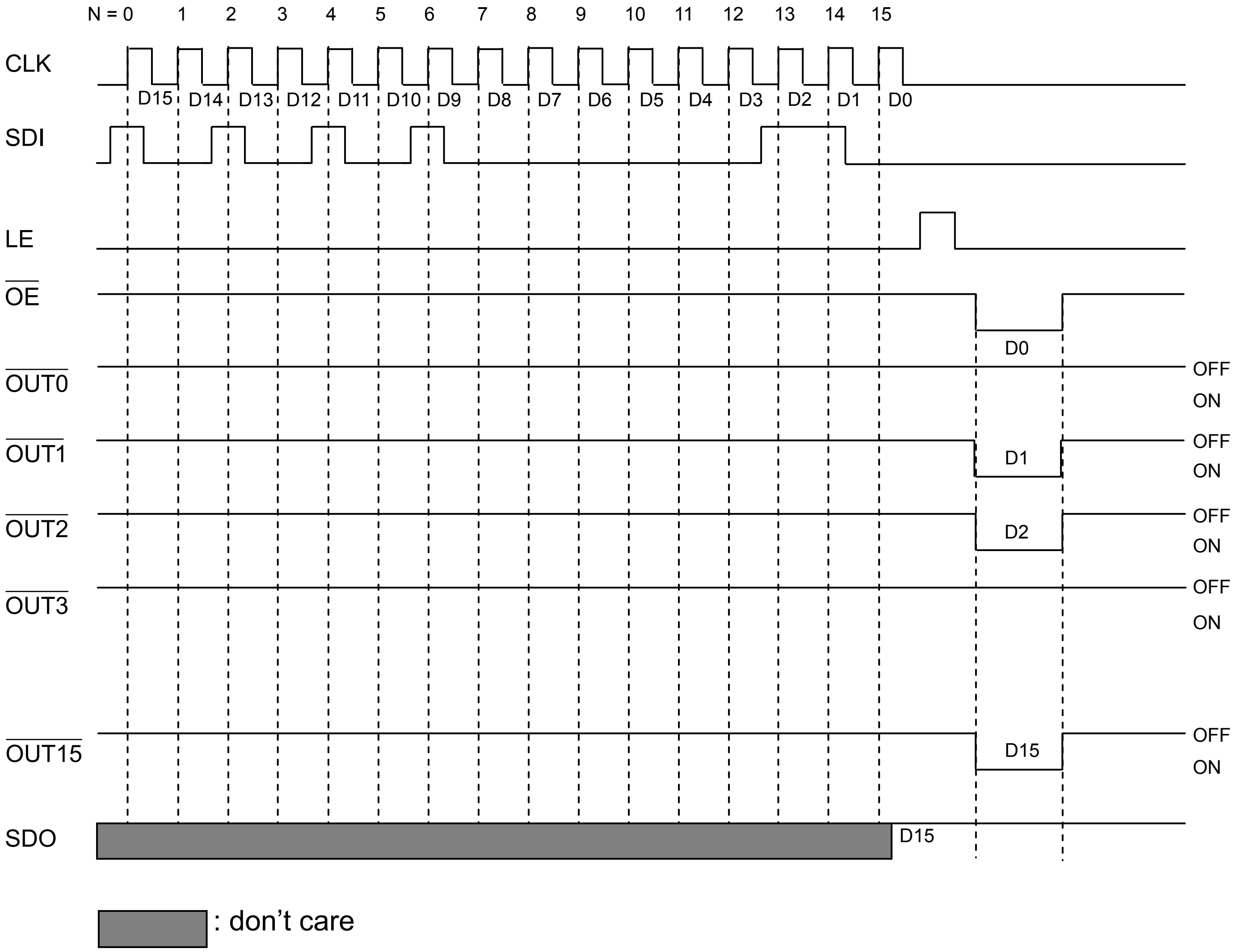




Control the Output Ports

The data are shifted from the SDI to the 16-bit shift register. When the LE is high without CLK toggled, the data in the shift register are latched to the output latch at the falling edge of LE. This is so-called "series-in parallel-out" mechanism.

When the $\overline{OE}$ is low and the data in the output latch are "1", 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.



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
11		0	0	1	0	10'b00 0000 0000									

Bit	Definition	Value	Function
F	Threshold voltage for short-circuit detection or leakage diagnosis	00	0.4 x V_{DD}
		01	0.5 x V_{DD}
E		10	0.6 x V_{DD}
		11(Default)	0.7 x V_{DD}
D	0-Power mode	0 (Default)	Disable 0-power mode
		1	Enable 0-power mode
C	Sleep mode	0 (Default)	Disable sleep mode
		1	Enable sleep mode
B	Detection current for compulsory open/short	00	0.1mA for error detection current
		01	0.5mA for error detection current
A		10(Default)	0.1mA for error detection current
		11	Error detection current set by R_{ext}
9	Compulsory error detection operation time	0 (Default)	Maximum detection operation time to ensure the error detection is correct: 700ns. Users have to leave more than 700ns for error detection.
		1	For short-circuit and open-circuit detections only. Detection operation time: determined by the falling edge of LE to the rising edge of $\overline{OE}$.

Control Command

Command Name	Signals Combination		Description
	LE	Number of CLK rising edge when LE is asserted	The Action after a falling edge of LE
Latch data	High	0	Latch the serial data to the output latch
Open-circuit detection	High	1	Issue "Open-circuit error detection" once
Short-circuit detection	High	2	Issue "Short-circuit error detection" once
Thermal detection	High	3	Issue "IC thermal detection" once
Write configuration	High	4	Serial data are transferred to the "configuration register"
Leakage diagnosis	High	5	Detect the leakage problem on LED driver
Read configuration	High	6	Read out configuration register
Wake-up mode	High	7	Wake up from sleep mode
Sleep mode	High	9	Enter sleep mode by setting bit "C"

Note: Number of CLK = 8 or ≧10: no action.

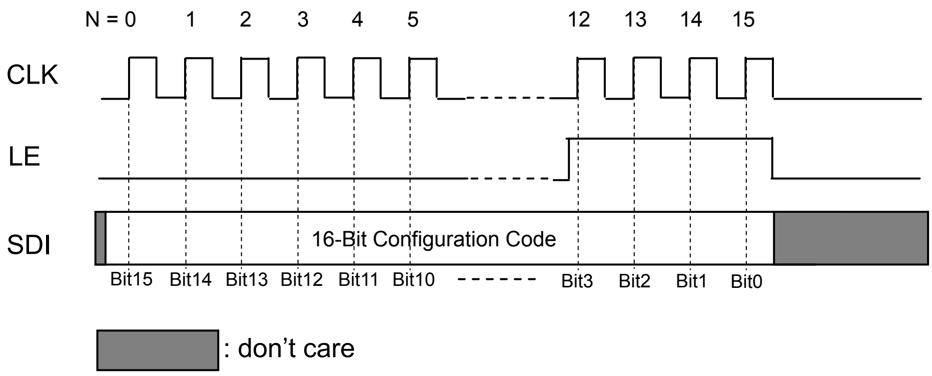
For detailed timing diagrams, please refer to the section of "Principle of Operation".

Error Code

Detection Result	Error flag for the corresponding channel
Open or short error is detected in the channel	0
Neither open nor short error is detected in the channel	1

If the error detection is invalid, the error code remains “1”. Please refer to section of “Principle of Operation” for the condition of valid error detection.

Writing Configuration Code



With the special waveform of writing configuration command, the controller sends a 16-bit configuration setting to the MBI5037’s shift register through MBI5037’s SDI pin. Then the MBI5037 distinguishes the command from the combination of LE and CLK signal and latches the content of the shift register to the 16-bit configuration register rather than to the 16-bit output latch.

Principle of Operation

Compulsory Error Detection

Compulsory error detection includes open-circuit detection, short-circuit detection, and leakage diagnosis by issuing different control commands.

Setting the Detection Time and Detection Current

The detection operation time is set by bit “9” of the configuration register. If bit “9” is set to the default value “0”, the detection operation time will be 700ns (Figure 3). Otherwise, users may determine the detection operation time from the falling edge of LE to the rising edge of $\overline{OE}$ by setting bit “9” to the value “1” (Figure 4). The settings of detection operation time are only applicable for open-circuit and short-circuit detections.

The detection current is set by bit [B:A] of the configuration register. If bit [B:A] is set to the value “10” (default) or “00”, the detection current is 0.1mA. If bit [B:A] is set to the value “01”, the detection current is 0.5mA. If bit [B:A] is set to the value “11”, the detection current is the same as I_{OUT}, which is set by R_{ext}.

For the definition of bit “9”, bit “A”, and bit “B”, please refer to the section of “Definition of Configuration Register”.

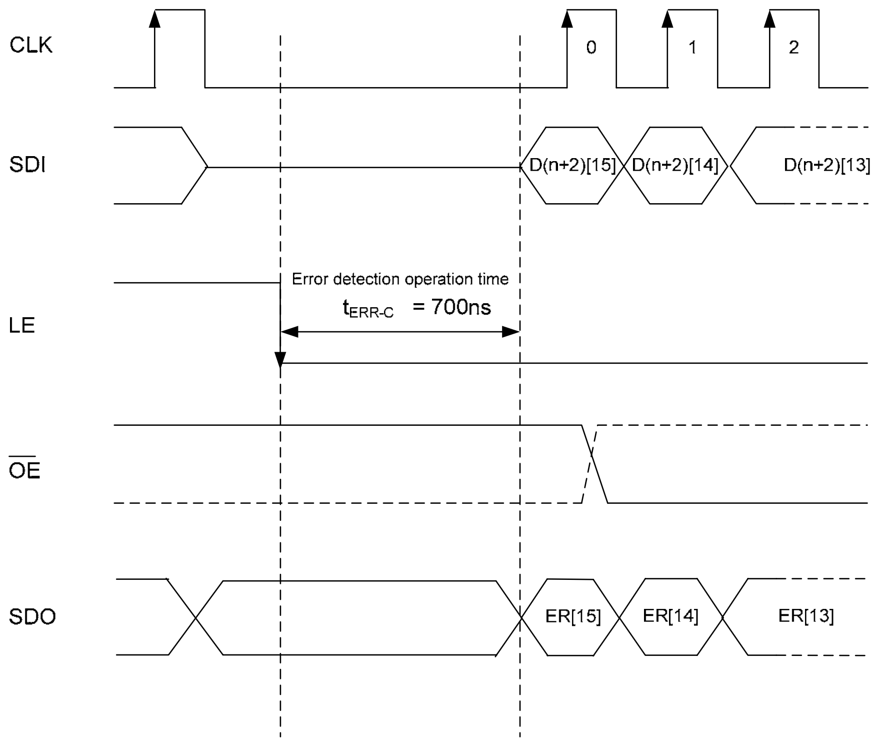


Figure 1

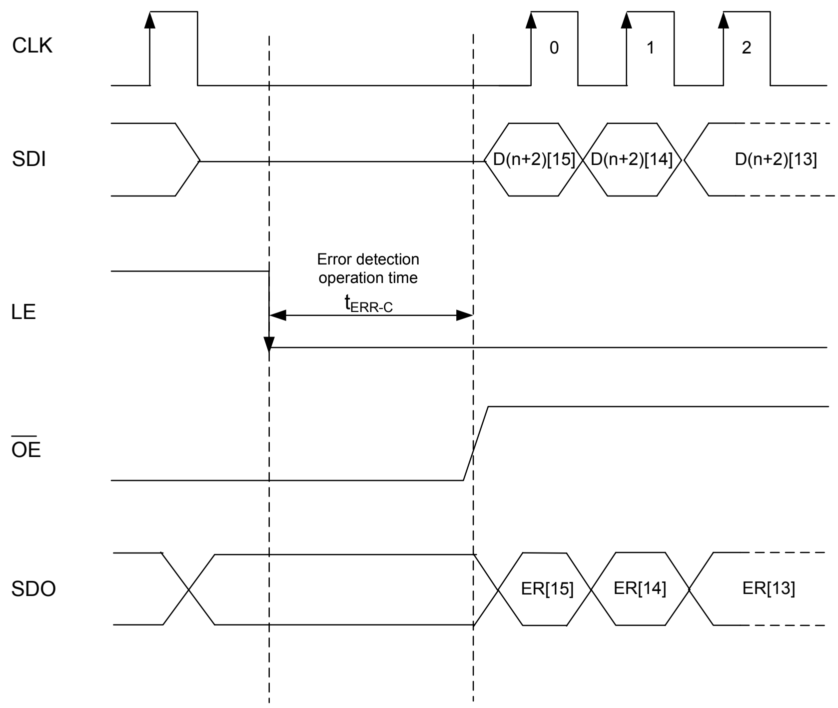


Figure 2

Silent Error Detection (Default)

The default setting of error detection is 0.1mA in 700ns. This is also called “silent error detection” because MBI5037 runs the detection without LED flickers. No matter the data is 1 or 0, the output ports will be turned on with 0.1mA 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 the detection flicker and the quality of the video and image will not be influenced. All the error codes will be “0” and shifted out through SDO once only.

Manual Control of Compulsory Error Detection

The manual control is designed for specific applications. When the output loading is heavy, users can set the detection time and current by setting different values on the configuration register. For detailed information on the setting, please refer to the section of “Definition of Configuration Register”.

There are some conditions that the users may not be able to perform error detection with 0.1ma detection current. For example:

1. The V_F variation of LED is larger. The short detection is based on the difference of V_F of LED in normal and short-circuit conditions. If the V_F variation of LED is significant, it may not be able to find a threshold voltage to perform short detection with small current. To cascade several LEDs in series, the output ports will have the same impact since the accumulated V_F variation becomes larger.
2. The setup time of LED within smaller current is very long, so that the output voltage for error detection cannot be in stable state in time.

Within these concerns, a larger current may be necessary to perform the error detection. There are two benefits for larger LED current applications: (1) the difference of V_F of LED in normal and short-circuit condition is larger (2) the output voltage of LED driver can enter a stable state sooner.

In addition to detecting with 0.1mA, MBI5037 can also run the detection with the current 0.5mA and by R_{ext}, i.e., the normal current in normal operation.

In the configuration register, bit [B:A] are used to set the current for detection. If bits [B:A] are set to "01", the current for detection is 0.5mA. If bits [B:A] is set to "11", the current for detection depend on R_{EXT} setting. The default setting of bits [B:A] is "10"; that is, the default current for detection is small current (0.1mA).

Compulsory Open-Circuit Detection

The principle of MBI5037 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 MBI5037 will be turned on.

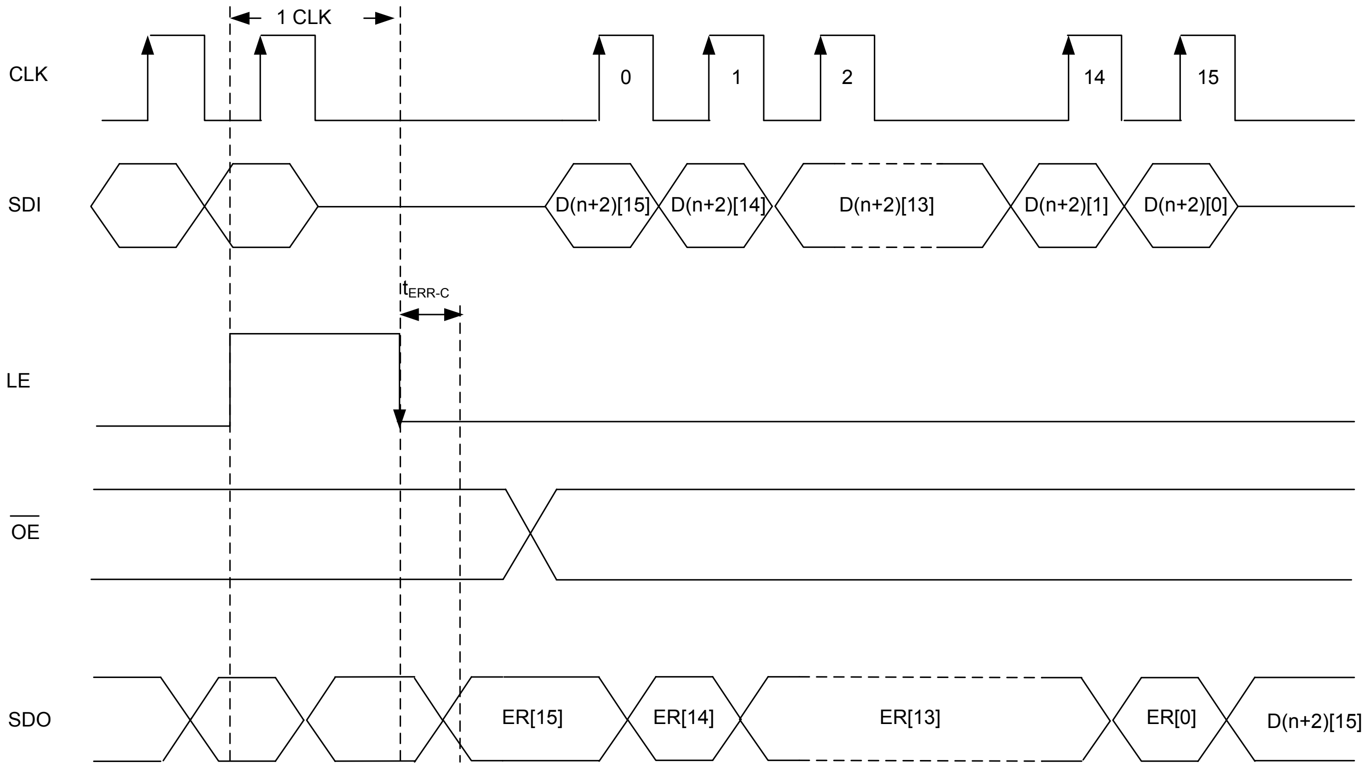


Figure 3

1. Condition required to activate the open-circuit detection: falling edge of LE.
2. At the falling edge of LE, all output channels are turned on based on the detection current set by the user.
3. The error detection starts and then loads error result to shift register during t_{ERR-C}.
4. If CLK is toggled during t_{ERR-C}, the data in the shift register will be overwritten at t_{ERR-C}.

Then, the error status saved in the built-in register is shifted out bit by bit through SDO while receiving the new data.

Compulsory Short-Circuit Detection

When LED is damaged, a short-circuit error may occur. To effectively detect the short-circuit error, the principle of MBI5037 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 ($V_{SD.TH}$ = 0.70xV_{DD}, default). For the selection of a suitable threshold voltage, please refer to the "Setting the Threshold Voltage for Short-Circuit Detection". Thus, after the command of "compulsory short-circuit detection", the output ports of MBI5037 will be turned on. Then, the error status saved in the built-in register is shifted out bit by bit through SDO while receiving the new data.

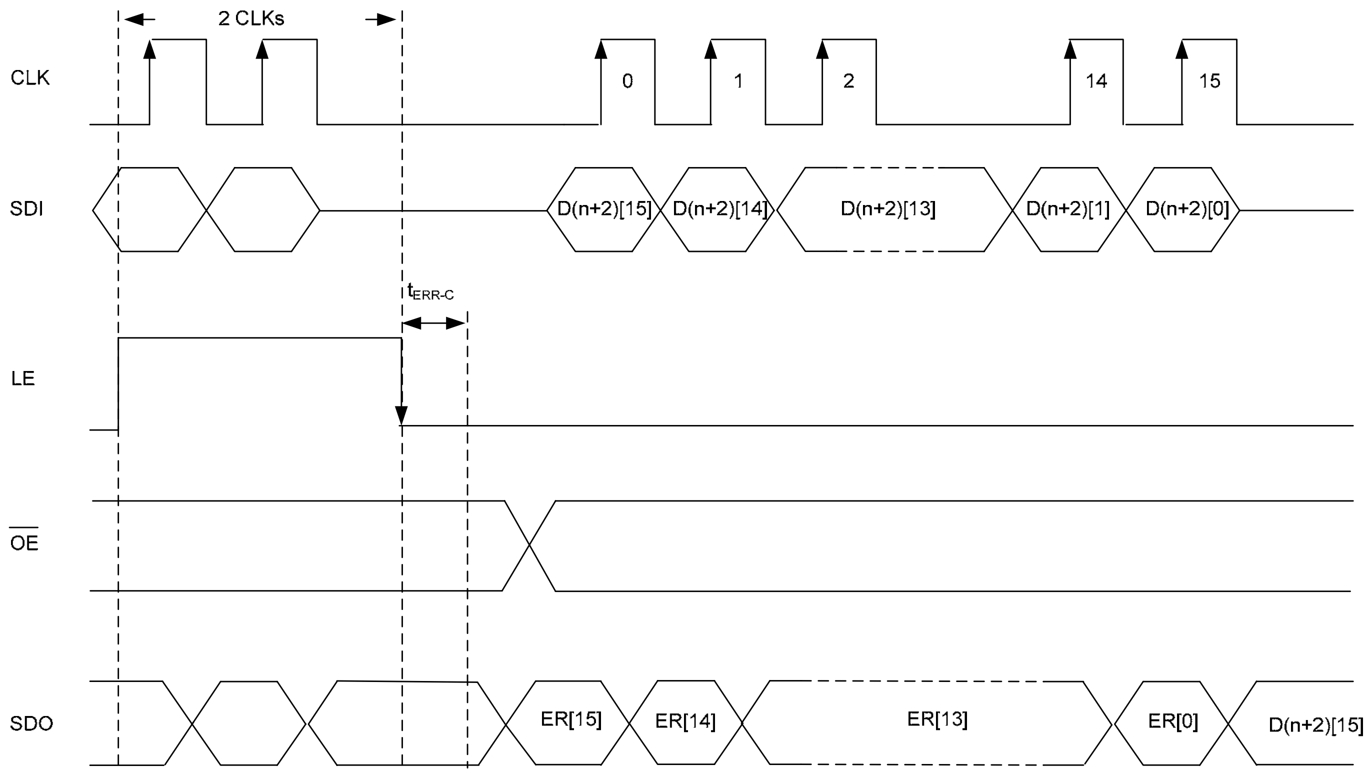


Figure 4

1. Condition required to activate the short-circuit detection: falling edge of LE.
2. At the falling edge of LE, all output channels are turned on based on the detection current set by the user.
3. The error detection starts and then loads error result to shift register in t_{ERR-C} duration.
4. If CLK is toggled during t_{ERR-C}, the data in the shift register will be overwritten at t_{ERR-C}.

Setting the threshold voltage for short-circuit detection

The default threshold voltage for short-circuit detection ($V_{SD,TH}$) equals to 0.7xV_{DD}. If the detected voltage is larger than $V_{SD.TH}$, the MBI5037 identifies the LED as short-circuit.

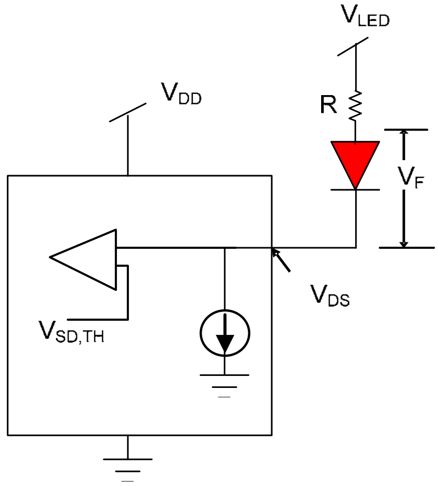


Figure 5

The MBI5037 provides settable $V_{SD,TH}$ for different LED configuration. For example, if each output port of MBI5037 drives one red LED, the $V_{SD,TH}$ shall be set smaller. If each output port of MBI5037 drives several white LEDs, the $V_{SD,TH}$ shall be set larger. The system shall consider accumulated V_F of the LED to set suitable $V_{SD,TH}$.

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, MBI5037 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).

Considering the above variation, MBI5037 allows users to select the suitable voltage as the threshold voltage of the leakage diagnosis. However, the setting of the threshold voltage of the leakage diagnosis is shared with that of the threshold voltage of the short-circuit detection; therefore, users need to set different settings for different detections. The following table compares the different results under the short-circuit detection and leakage diagnosis conditions.

Detection	Condition	Code	Result
Short-Circuit Detection (Detect while turn-on)*	V_{DS}>$V_{SD,TH}$	0	Short-circuit
	V_{DS}<$V_{SD,TH}$	1	Normal
Leakage Diagnosis (Detect while turn-off)*	V_{DS}>$V_{LD,TH}$**	1	Normal
	V_{DS}<$V_{LD,TH}$	0	Leakage

*The LED is turned-on or turned off by the control of MBI5037.

** Threshold voltage of short detection ($V_{SD,TH}$) and threshold voltage of leakage diagnosis ($V_{LD,TH}$) are set by the same configuration register. Users need to reset the configuration register for leakage diagnosis.

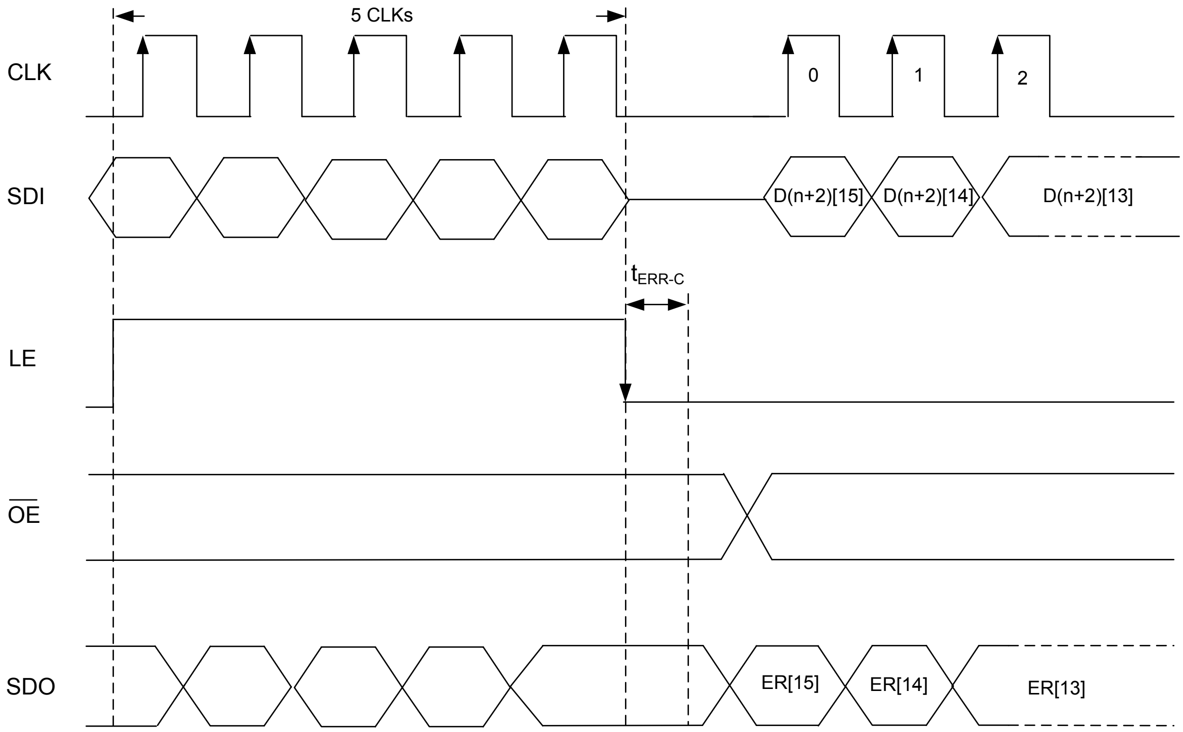


Figure 6

1. Conditions required to activate the leakage diagnosis: (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: Please see the section “Detection conditions” for details.

3. At the falling edge of LE, all output channels are turned off.
4. The error detection starts and then loads error result to shift register in t_{ERR-C} duration.
5. If the $\overline{OE}$ is toggled during t_{ERR-C}, the error codes remain “1”.
6. If CLK is toggled during t_{ERR-C}, the data in the shift register will be overwritten at t_{ERR-C}.

Thermal Detection

The thermal error flag indicates an overheating condition. When IC's junction temperature is over 160°C (typ.), the MSB of SDO is set to "0". The data in the shift register will not be latched into the output buffer.

Detection	Code	Result
The junction temperature of MBI5037≧T_{TF}	0 (SDO=7FFF(HEX))	Overheating
The junction temperature of MBI5037<T_{TF}	1 (SDO=FFFF)	Normal

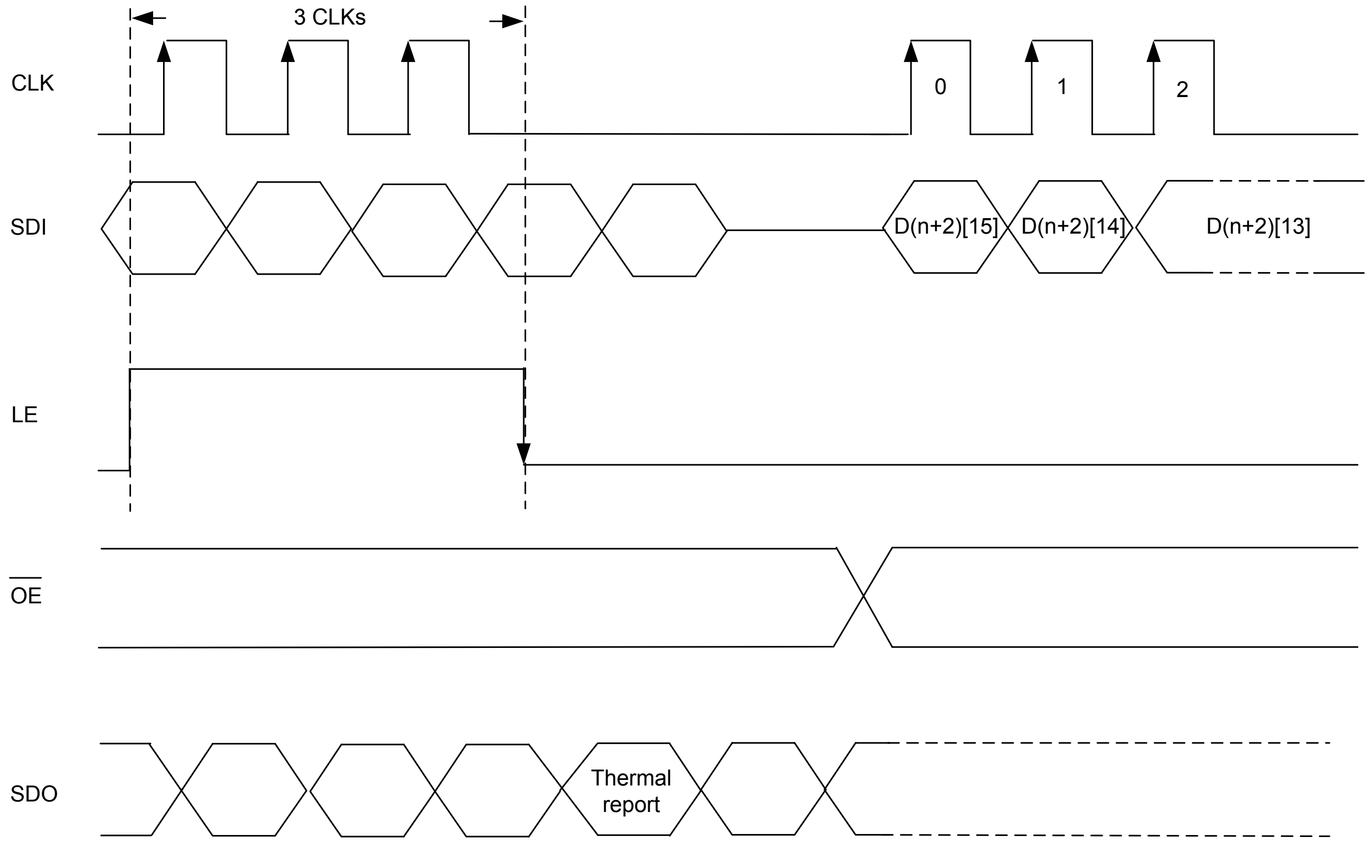


Figure 7

At the falling edge of LE, if MBI5037 is overheated, the code "7FFF(HEX)" is delivered to SDO; otherwise, the code "FFFF(HEX)" is latched to sift register.

Power Saving Modes

There are two power saving modes to save the system power:

Power saving mode	Description	Application
Sleep mode	Set the MBI5037 to enter / leave the sleep mode by commands.	For LED display panels that are sometimes blanked, but the power of the system is not turned off.
0-Power mode	MBI5037 enters/leaves the 0-Power mode automatically, if all the data are zero. Bit "D" shall be set to 1 to enable this mode.	For LED message sign, which partial of the LEDs are always turned-off.

Sleep Mode

MBI5037 will enter the sleep mode when users issue the sleep mode command: LE + 9 CLK. To escape the sleep mode, users have to send the wake-up command: LE+7 CLK. In the sleep mode, the I_{DD} of MBI5037 will be reduced to about 1% of the I_{DD} in the normal mode (see "Electrical Characteristics" for details). In addition, MBI5037 takes 1ms to wake up from the sleep mode.

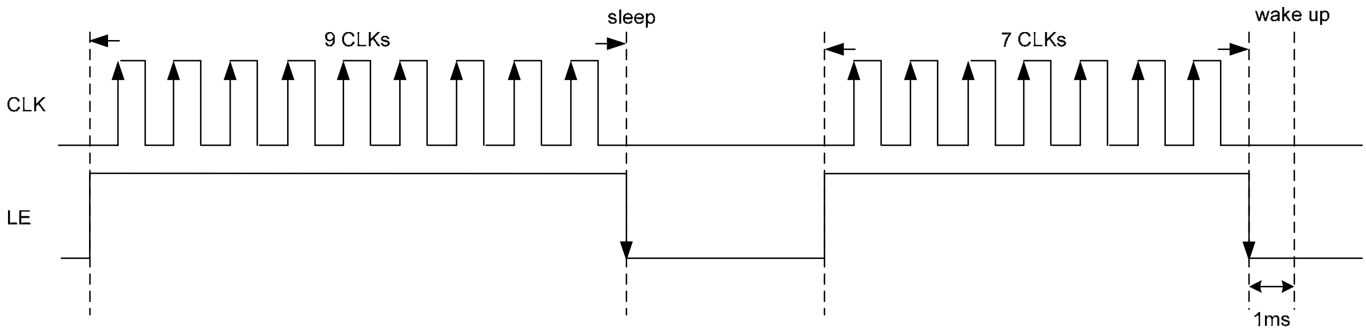


Figure 8

In the sleep mode, MBI5037 will not execute any error detection command except the wakeup command, but the shift register still keeps shifting data with the clock. In other words, it is possible that only parts of the LED drivers on the same display panels are in the sleep mode and others are not, if the control signals are independent.

0-Power Mode

By setting bit "D" of the configuration register, the 0-Power mode of MBI5037 will be effective. When all the output data of the MBI5037 are "0", MBI5037 will enter the 0-Power mode automatically. When the non-zero data is latched, the MBI5037 will leave 0-Power mode automatically.

In the 0-Power mode, the I_{DD} of MBI5037 will be close to the current in the sleep mode. 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 MBI5037 to turn on or turn off the cascaded LEDs in the group simultaneously. Therefore, the 0-Power mode of MBI5037 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.

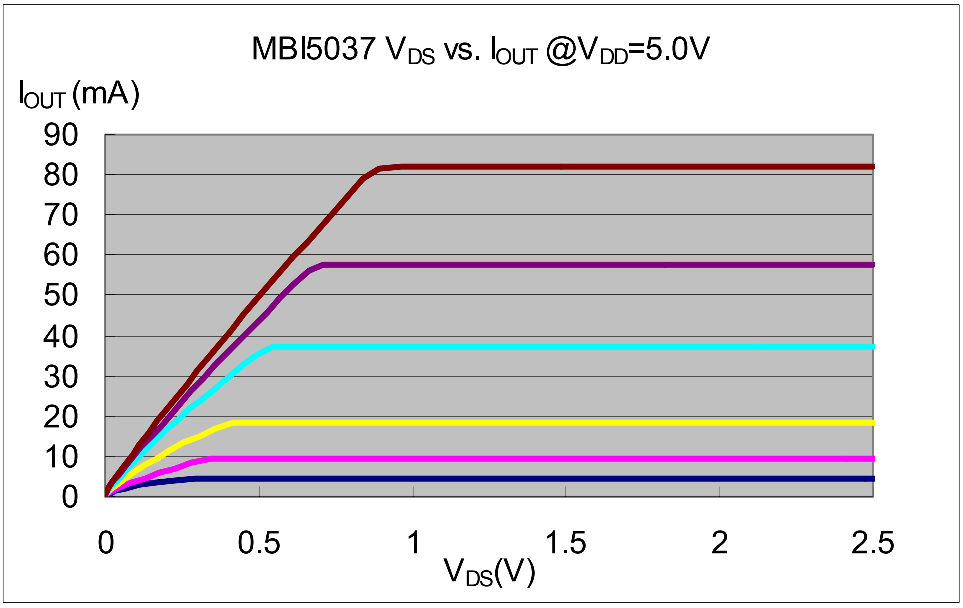
However, the compulsory error detection commands will not be performed when 0-Power mode is enabled, and therefore, all of the output channels will always report data as "1". The system needs to disable the 0-Power mode to activate the compulsory error detection again.

Constant Current

In LED display applications, MBI5037 provides nearly no current variations from channel to channel and from IC to IC. This can be achieved by:

1) While $I_{OUT} \leqq$ 80mA, 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 figure as shown below. Thus, the output current can be kept constant regardless of the variations of LED forward voltages (Vf). The output current level in the saturation region is defined as output target current $I_{out,target}$.



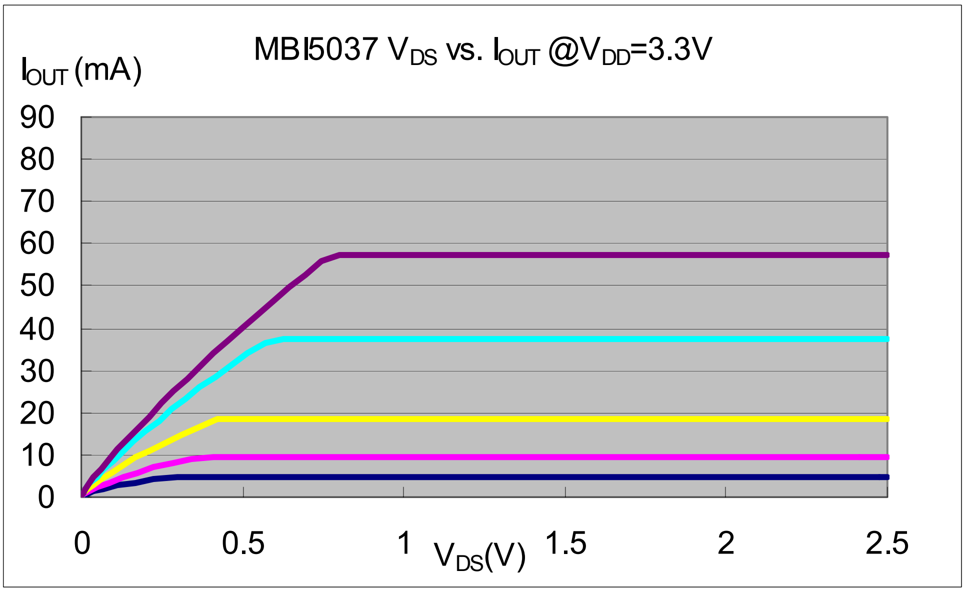


Figure 9

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.

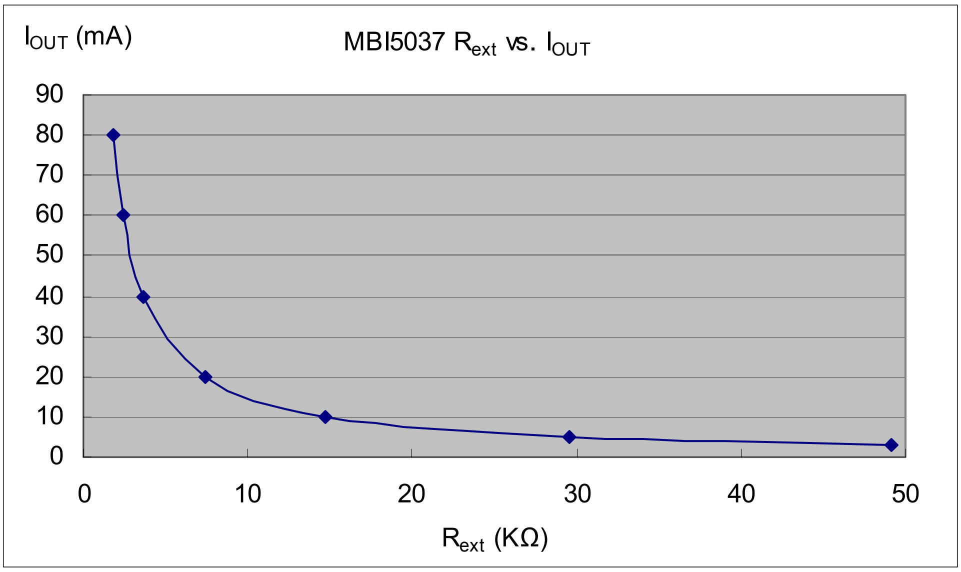


Figure 10

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

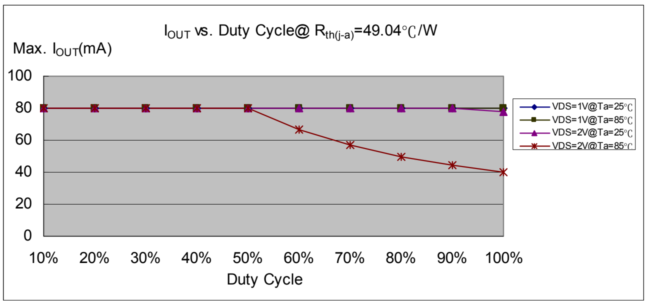
$V_{R\text{-}EXT}$=1.23Volt ; $I_{OUT}=(V_{R\text{-}EXT}/R_{ext})\times 120$

Whereas R_{ext} is the resistance of the external resistor connected to R-EXT terminal and $V_{R\text{-}EXT}$ is its voltage, and the output current is about 20mA when R_{ext}=7.5 KΩ and 60mA when R_{ext}=2.5KΩ.

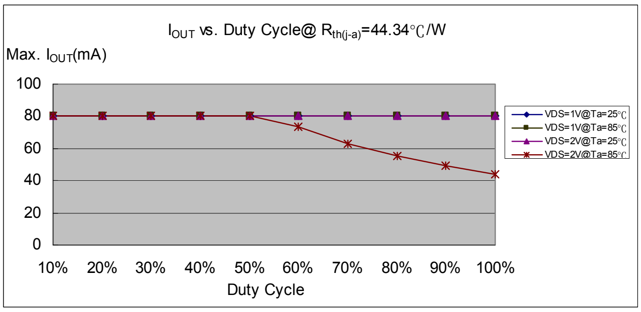
Package Power Dissipation (PD)

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 $P_D(act) \le P_D(max)$, the allowable maximum output current as a function of duty cycle is:

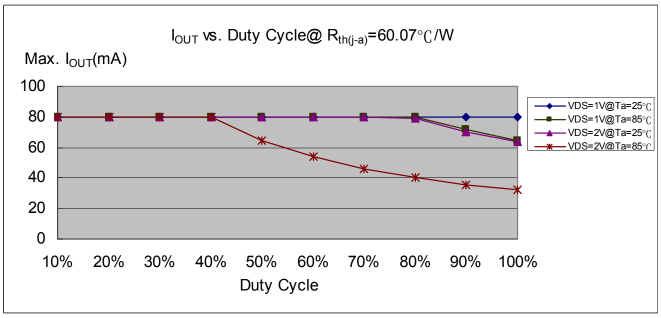
$I_{OUT}=\{[(Tj–Ta)/R_{th(j-a)}]–(I_{DD}xV_{DD})\}/V_{DS}/Duty/16$, where Tj=150°C.



MBI5037GF



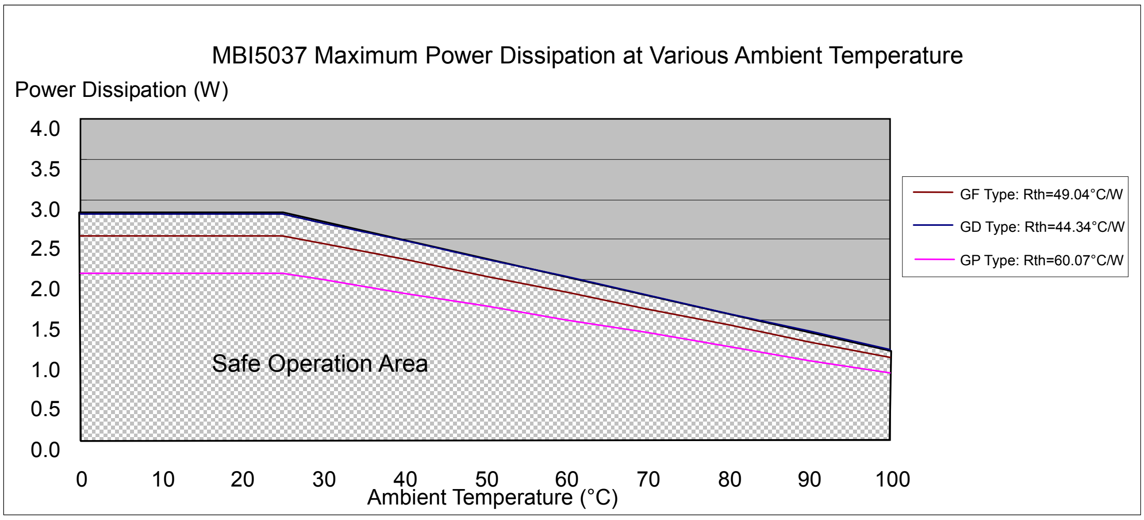
MBI5037GD



MBI5037GP

Condition: I_{OUT}=80mA, 16 output channels	
Device Type	$R_{th(j-a)}$ (°C/W)
GF	49.04
GD	44.34
GP	60.07

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



Load Supply Voltage (V_{LED})

MBI5037 are 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 $V_{DS} = V_{LED} – Vf$, 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 $V_{DS} = (V_{LED} – Vf) – V_{DROP}$.

Resisters, or Zener diode can be used in the applications as the following figure.

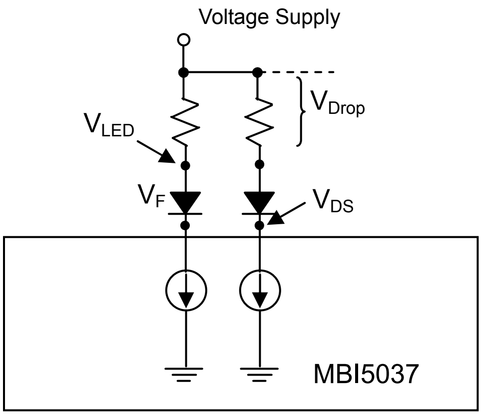
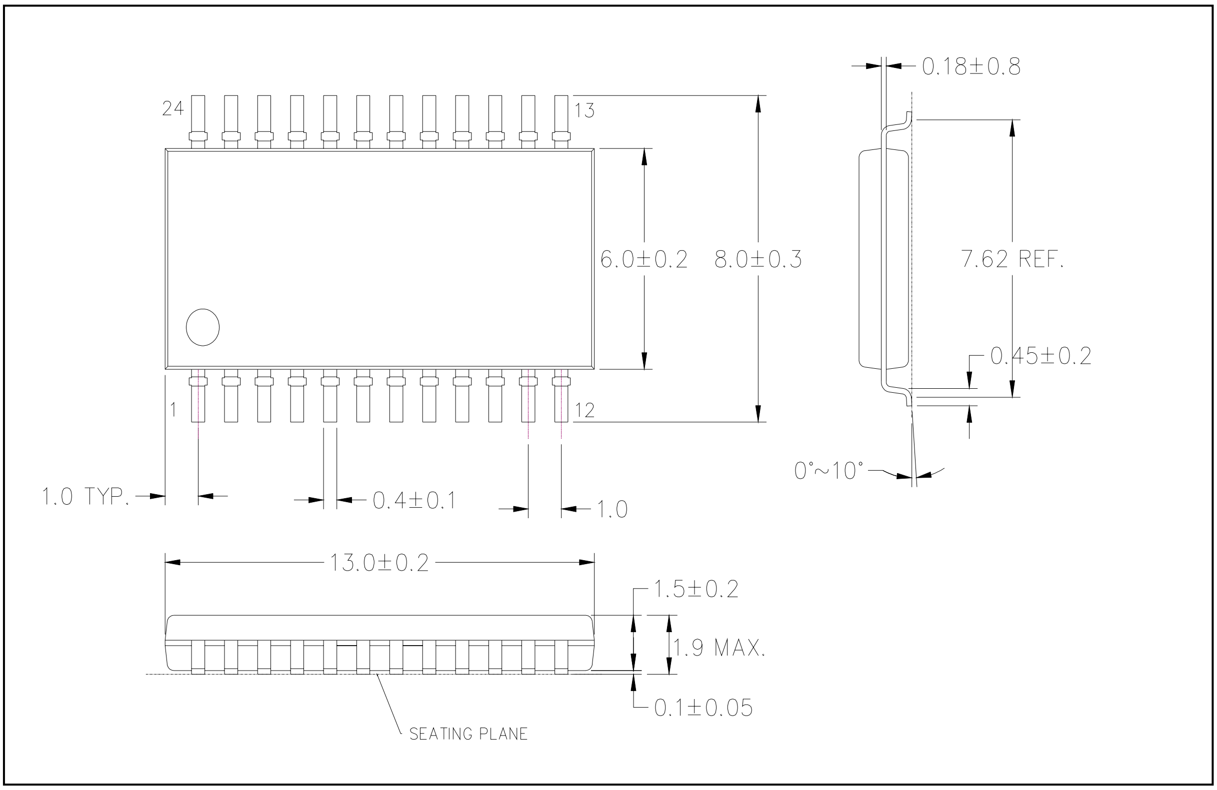


Figure 11

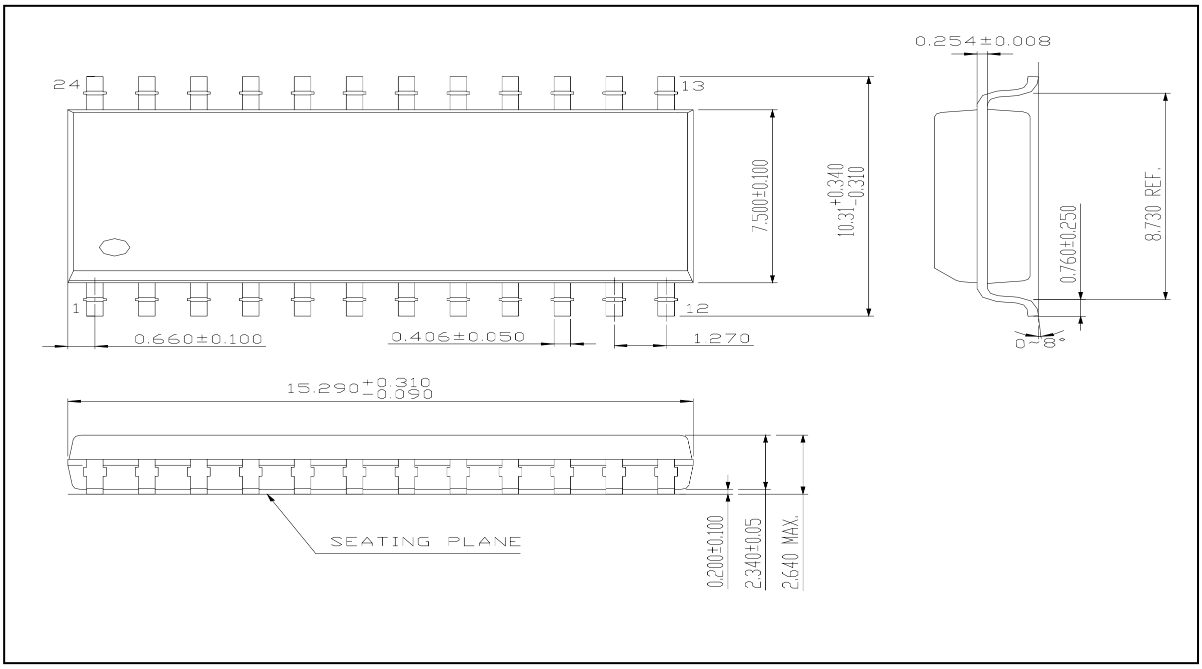
Switching Noise Reduction

LED drivers 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 “Application Note for 8-bit and 16-bit LED Drivers-Overshoot”.

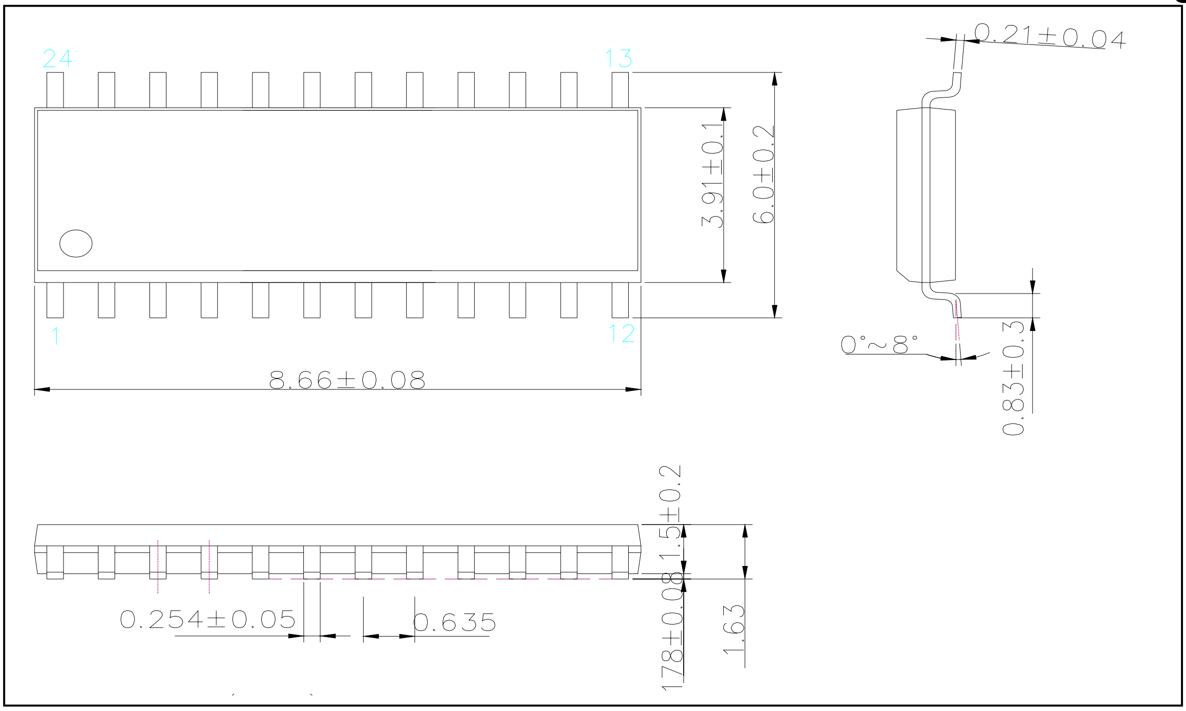
Package Outline



MBI5037GF Outline Drawing



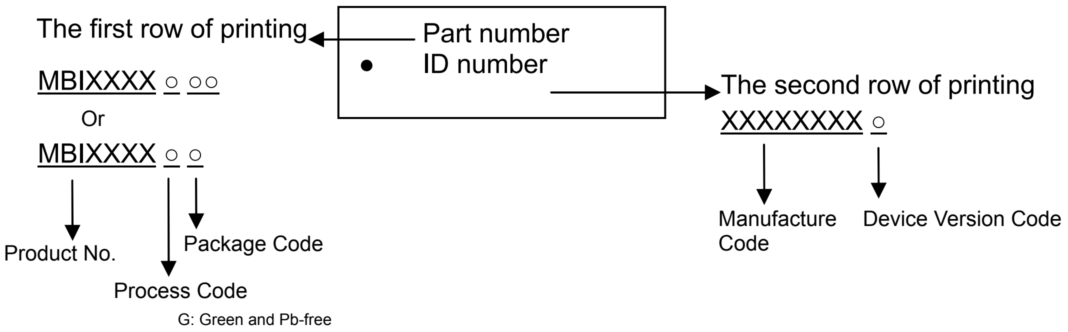
MBI5037GD Outline Drawing



MBI5037GP 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
V2.00	B

Product Ordering Information

Part Number	**RoHS Compliant Package Type**	**Weight (g)**
MBI5037GF	SOP24-300-1.00	0.282
MBI5037GD	SOP24-300-1.27	0.617
MBI5037GP	SSOP24-150-0.64	0.11

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