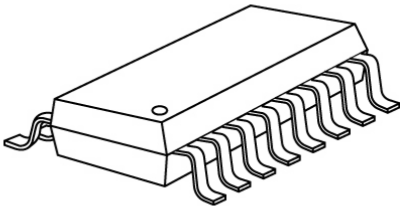
8-Channel Constant Current LED Driver With Silent Error Detection and Power Saving Modes

Features

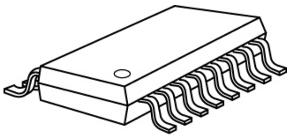
- Package compatible with MBI5168
- 8 constant-current output channels
  Constant output current range: 3~80mA
  - 5~80mA @ 5V supply voltage
  - 3~60mA @ 3.3V supply voltage
- Compulsory error detection
  - Data-independent full panel detection
  - Error detection current: small current during 700ns
  - 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 reduce supply current of LED driver to 200uA
  - 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.): 50ns (V_{DD}=5V, I_{OUT}=20mA)
- Staggered delay of output, preventing from current surge
- 30MHz clock frequency
- Schmitt trigger input

Small Outline Package



GD: SOP16L-150-1.27

Shrink SOP



GP: SSOP16L-150-0.64

Applications

- LED traffic signs
- LED message signs

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Product Description

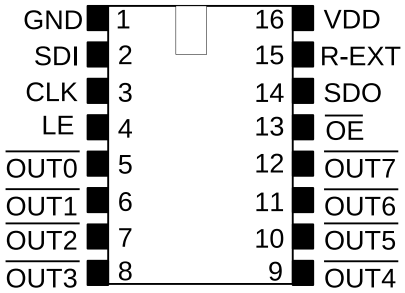
MBI5137 is an enhanced 8-channel constant current LED sink driver with advanced error detection functions and smart power-saving modes. MBI5137 succeeds MBI5168 and also exploits **PrecisionDrive™** technology to enhance its output characteristics. Furthermore, MBI5137 uses the concept of **Share-I-O™** technology to make MBI5137 package compatible with MBI5168 and extend its advanced functions, such as silent LED open circuit detection, silent LED short detection, leakage diagnosis, and temperature warning. With the **Share-I-O™** technique, the printed circuit board originally designed for MBI5168 may be also applicable to MBI5137, if the $\overline{OE}$ is controllable. In addition, MBI5137 features two power saving modes: sleep mode and 0-Power mode to increase the power efficiency. Therefore, MBI5137 is especially suitable for LED traffic sign and message sign applications.

MBI5137 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 small current. The image will not be impacted since the turn-on duration and current are so small. MBI5137 may detect all of the current output ports and report the LED error status without comparing original data. Moreover, the settable threshold voltages for short-circuit detection and leakage diagnosis may comply with the variation of different LED forward voltage. Additionally, to ensure the system reliability, MBI5137 is built with thermal error flag to prevent IC from over temperature (160°C).

MBI5137 also features two power saving modes: sleep mode and 0-Power mode. Both modes reduce the supply current of MBI5137 to 200uA to save the power. Flexible for different applications, sleep mode can be issued by command, while 0-power mode is automatically activated when all the output data are 0. For the power saving purposes, MBI5137 is especially designed to save the supply current of LED drivers when most LEDs on LED traffic signs and message signs are usually turned off.

MBI5137 contains a 8-bit shift register and a 8-bit output latch, which convert serial input data into parallel output format. At MBI5137 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. MBI5137 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.

Pin Configuration

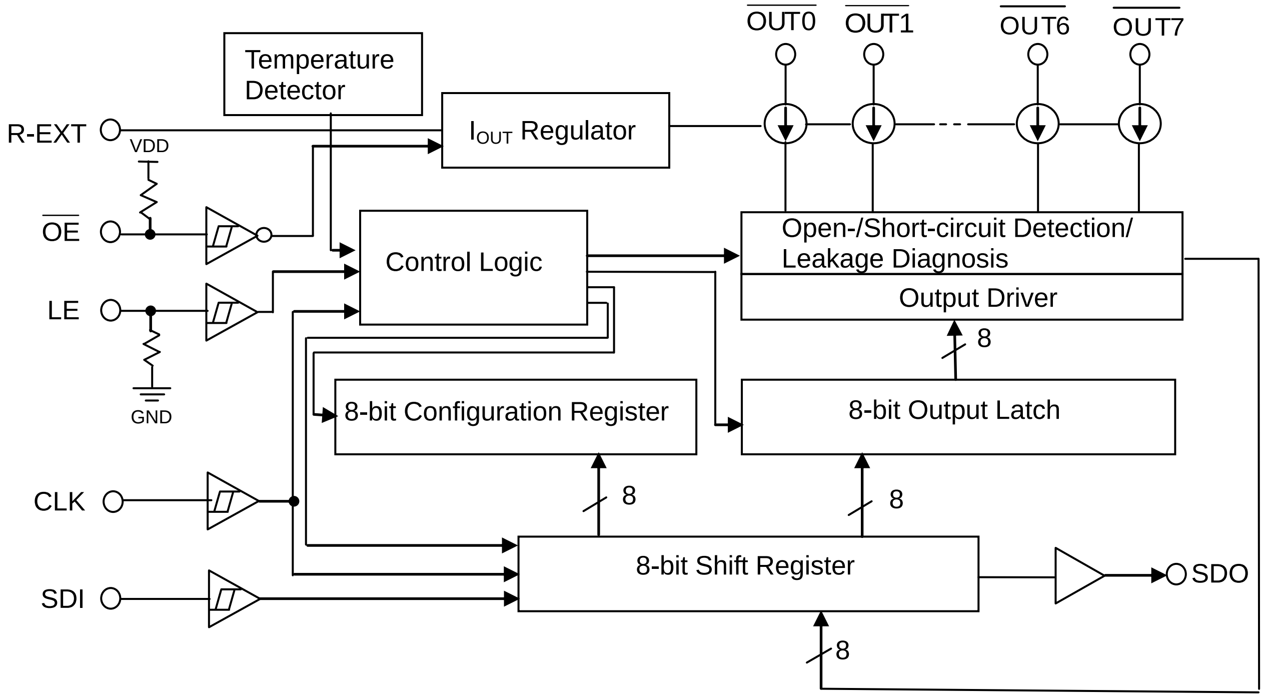


MBI5137GD/GP

Terminal Description

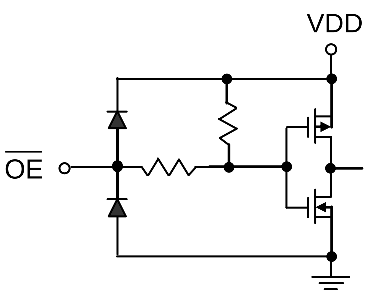
Pin Name	Function
GND	Ground terminal for control logic and current sinks
SDI	Serial-data input to the shift register
CLK	Clock input terminal used to shift data on rising edge and carries command information when LE is asserted.
LE	Data strobe terminal and control command with CLK for extended functions
$\overline{\text{OUT0}}$ ~ $\overline{\text{OUT7}}$	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

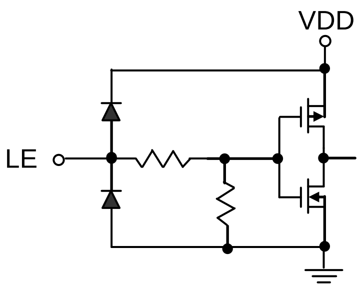


Equivalent Circuits of Inputs and Outputs

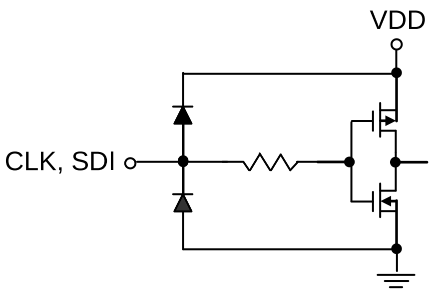
OE Terminal



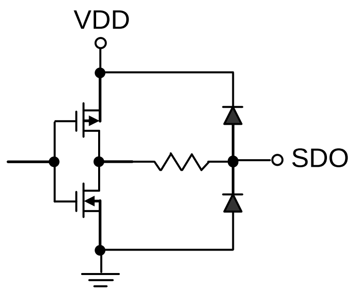
LE Terminal



CLK, SDI Terminal



SDO Terminal



Maximum Ratings

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	0~7.0	V
Sustaining Voltage at SDI, $\overline{OE}$, LE, CLK Pins		V_{IN}	-0.4 to VDD+0.4	V
Sustaining Voltage at CKO, SDO Pins		V_{OUT}	-0.4~V_{DD}+0.4	V
Sustaining Voltage at $\overline{OUTn}$ Pins		V_{DS}	-0.5~+17	V
Output Current ($\overline{OUT0}$ ~ $\overline{OUT7}$)		I_{OUT}	+90	mA
GND Terminal Current		I_{GND}	+720	mA
Power Dissipation (On 4 Layer PCB, Ta=25°C)*	GD Type	P_D	2.09	W
	GP Type		1.14	
Thermal Resistance (On 4 Layer PCB, Ta=25°C)*	GD Type	$R_{th(j-a)}$	59.83	°C/W
	GP Type		110	
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 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.

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

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

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}	$\overline{OUT0}$ ~ $\overline{OUT7}$	-	-	17.0	V
Output Current		I_{OUT}	Refer to “Test Circuit for Electrical Characteristics”	5	-	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
Open-Circuit 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, $\overline{OUT0}$ ~ $\overline{OUT7}$ =Off	-	2.2	3.0	mA
		I_{DD}(off) 2	R_{ext}=5.6KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =Off	-	5.4	7.0	mA
		I_{DD}(off) 3	R_{ext}=2.4KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =Off	-	7.0	8.2	mA
	“On”	I_{DD}(on) 1	R_{ext}=5.6KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =On	-	5.6	7.5	mA
		I_{DD}(on) 2	R_{ext}=2.4KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =On	-	7.5	8.5	mA
	Sleep mode	I_{DD}(sleep)	-	-	124	200	μA
	0-Power mode	I_{DD}(0-Power)	-	-	124	200	μA
Thermal Flag Temperature		T_{TF}	Junction Temperature	-	160	-	°C

*One channel on.

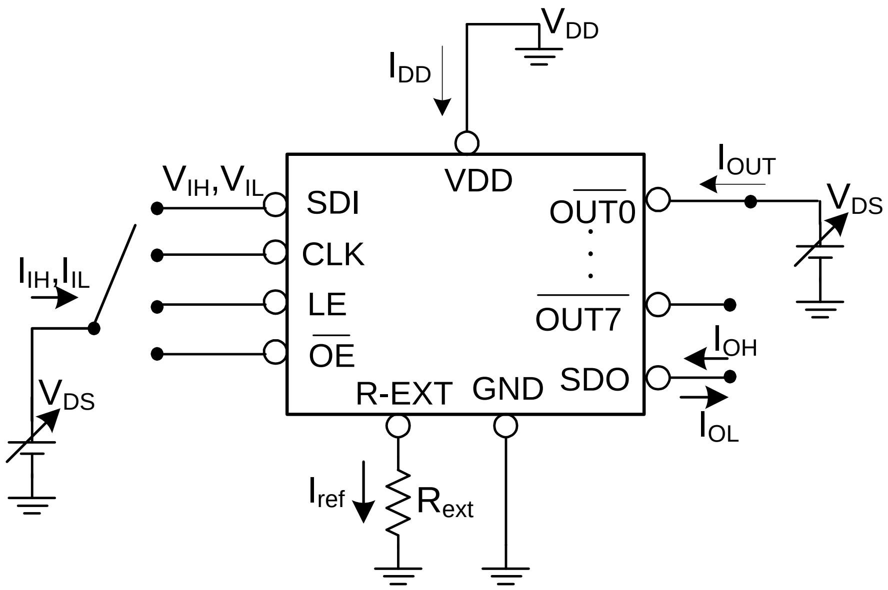
**LED short detection threshold voltage ($V_{SD,TH}$) and leakage diagnosis threshold voltage ($V_{LD,TH}$) are configurable voltages. Please see the “Definition of Configuration Register” for details.

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}	$\overline{OUT0}$ ~ $\overline{OUT7}$		-	-	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
Open-Circuit 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, $\overline{OUT0}$ ~ $\overline{OUT7}$ =Off		-	1.8	2.6	mA
		I_{DD}(off) 2	R_{ext}=5.6KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =Off		-	4.9	6.5	mA
		I_{DD}(off) 3	R_{ext}=2.4KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =Off		-	6.5	7.7	mA
	"On"	I_{DD}(on) 1	R_{ext}=5.6KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =On		-	5.1	7.0	mA
		I_{DD}(on) 2	R_{ext}=2.4KΩ, $\overline{OUT0}$ ~ $\overline{OUT7}$ =On		-	7.0	8.0	mA
	Sleep mode	I_{DD}(sleep)	-		-	42	100	μA
	0-Power mode	I_{DD}(0-Power)	-		-	42	100	μA
Thermal Flag Temperature		T_{TF}	Junction Temperature		-	-	160	-

*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	-	22	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pLH2}		-	20	-	ns
	CLK-SDO	t_{pLH3}		-	20	30	ns
	LE-SDO (Read Configuration)	t_{pLH4}		-	23	-	ns
	LE-SDO (Thermal Detection)	t_{pLH5}		-	40	-	ns
	$\overline{OE}$-SDO	t_{pLH6}		-	-	40	ns
Propagation Delay Time ("H" to "L")	LE-$\overline{OUT0}$	t_{pHL1}		-	24	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pHL2}		-	20	-	ns
	CLK-SDO	t_{pHL3}		-	20	30	ns
	LE-SDO (Read Configuration)	t_{pLH4}		-	23	-	ns
	LE-SDO (Thermal Detection)	t_{pLH5}		-	40	-	ns
	$\overline{OE}$- SDO	t_{pLH6}		-	-	40	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	14	-	ns
Output Fall Time of Output Ports		t_{of}		7	11	-	ns
Compulsory error detection operation time**		t_{ERR-C}		-	-	700	ns
$\overline{OE}$ with uniform output***		$t_{w(OE)}$		50	-	-	ns

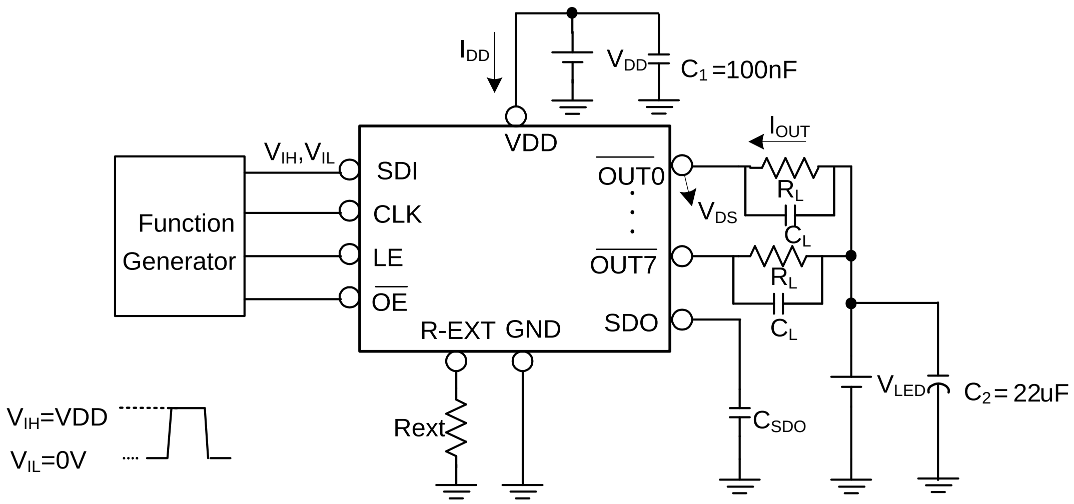
*If t_r or t_f is large, it may be critical to achieve the timing required for data transfer between two cascaded drivers.
**Users have to leave more time than the maximum error detection time for the error detection.
***With uniform output current of all output ports.
Note: Please refer to the following paragraph of "Timing Waveform" for the detailed timing sequence.

Switching Characteristics (V_{DD}=3.3V)

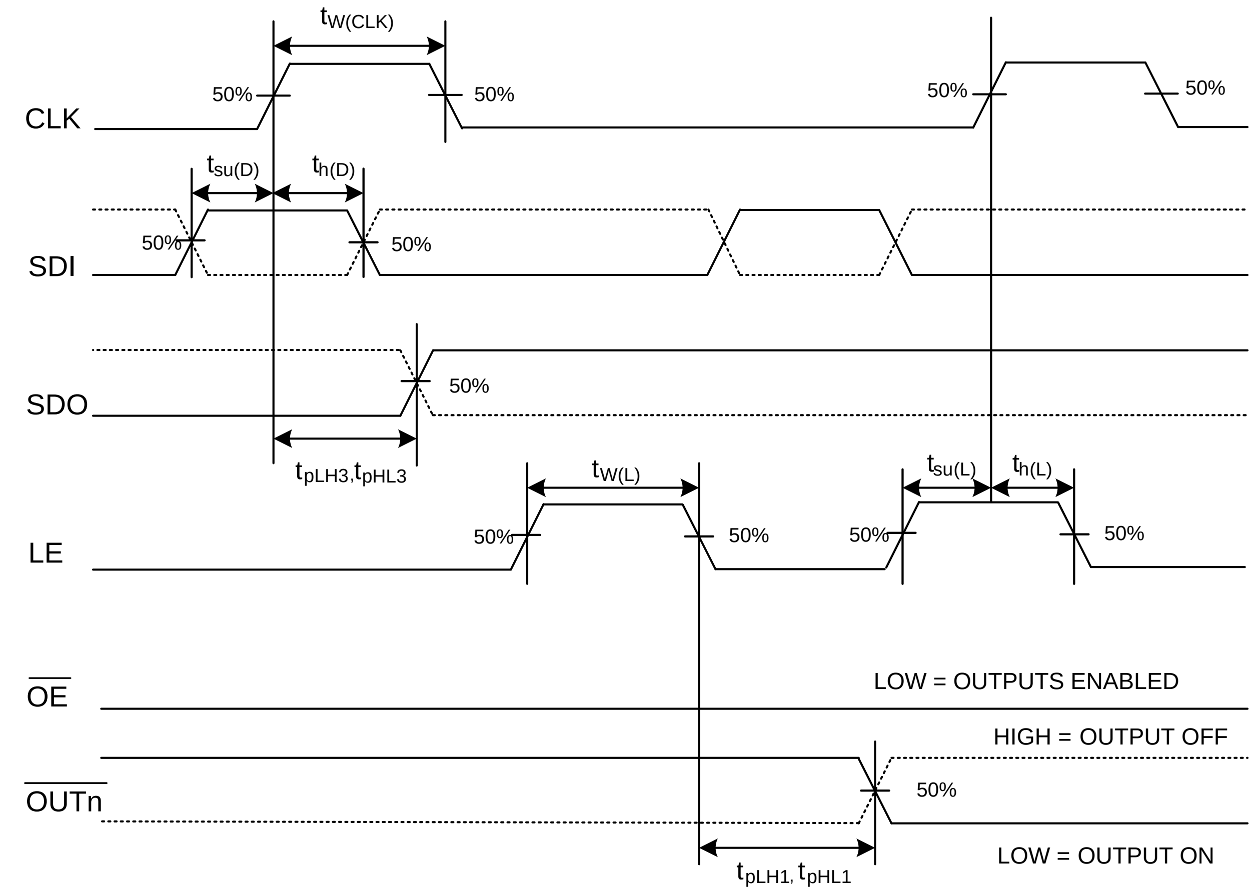
Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time (“L” to “H”)	LE-$\overline{OUT0}$	t_{pLH1}	V_{DD}=3.3V V_{DS}=1.0V V_{IH}=V_{DD} V_{IL}=GND R_{ext}=7.5KΩ I_{OUT}=20mA V_{LED}=4V R_L=150Ω C_L=10pF C1=100nF C2=22uF C_{SDO}=10pF	-	30	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pLH2}			23	-	ns
	CLK-SDO	t_{pLH3}		-	30	40	ns
	LE-SDO (Read Configuration)	t_{pLH4}		-	32	-	ns
	LE-SDO (Thermal Detection)	t_{pLH5}		-	55	-	ns
	$\overline{OE}$-SDO	t_{pLH6}		-	-	55	ns
Propagation Delay Time (“H” to “L”)	LE-$\overline{OUT0}$	t_{pHL1}		-	35	-	ns
	$\overline{OE}$-$\overline{OUT0}$	t_{pHL2}		-	29	-	ns
	CLK-SDO	t_{pHL3}		-	30	40	ns
	LE-SDO (Read Configuration)	t_{pHL4}		-	32	-	ns
	LE-SDO (Thermal Detection)	t_{pHL5}		-	55	-	ns
	$\overline{OE}$-SDO	t_{pHL6}		-	-	55	ns
Stagger delay	$\overline{OUTn}$-$\overline{OUTn+1}$	t_{stag}		-	3.5	5	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}		16	20	-	ns
Output Fall Time of Output Ports		t_{of}		16	20	-	ns
Compulsory error detection operation time**		t_{ERR-C}		-	-	700	ns
$\overline{OE}$ with uniform output***		$t_{w(OE)}$		50	-	-	ns

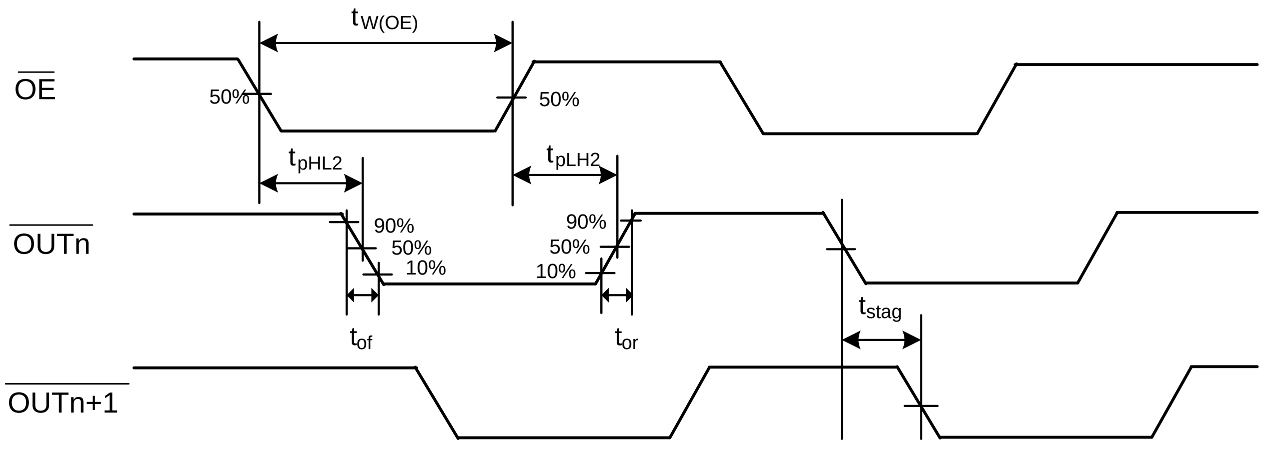
*If t_r or t_f is large, it may be critical to achieve the timing required for data transfer between two cascaded drivers.
**Users have to leave more time than the maximum error detection time for the error detection.
***With uniform output current of all output ports.
Note: Please refer to the following paragraph of “Timing Waveform” for the detailed timing sequence.

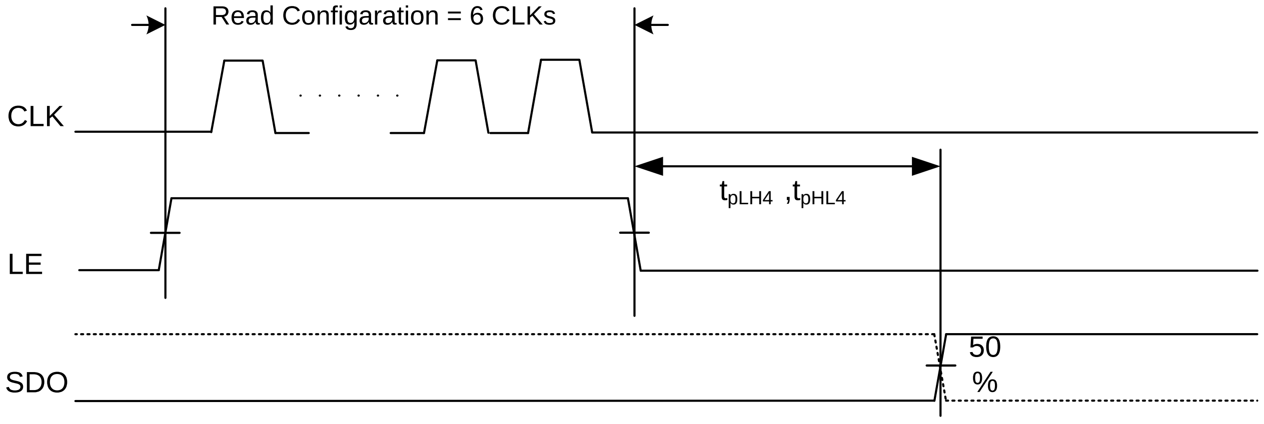
Test Circuit for Switching Characteristics

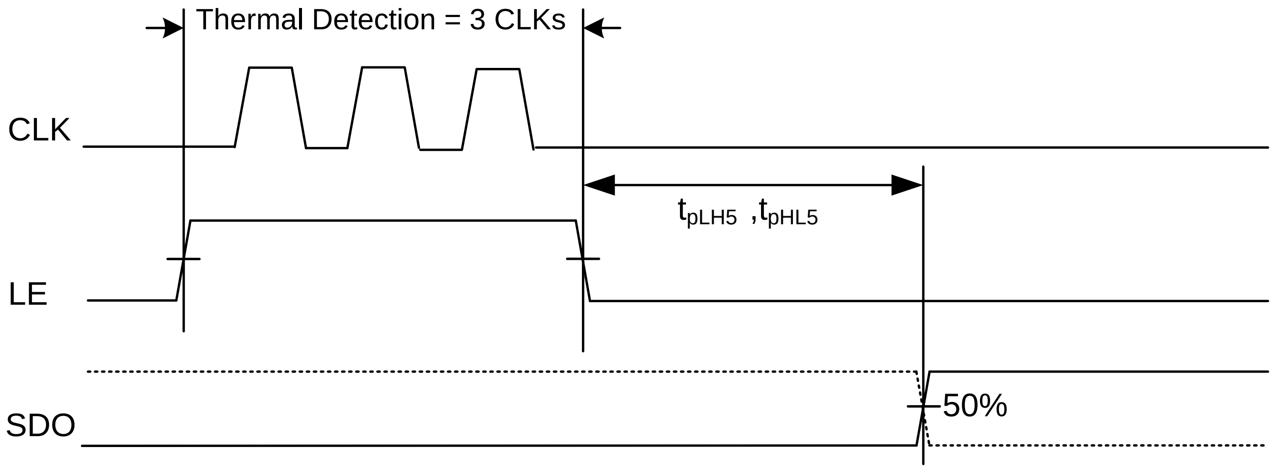


Timing Waveform

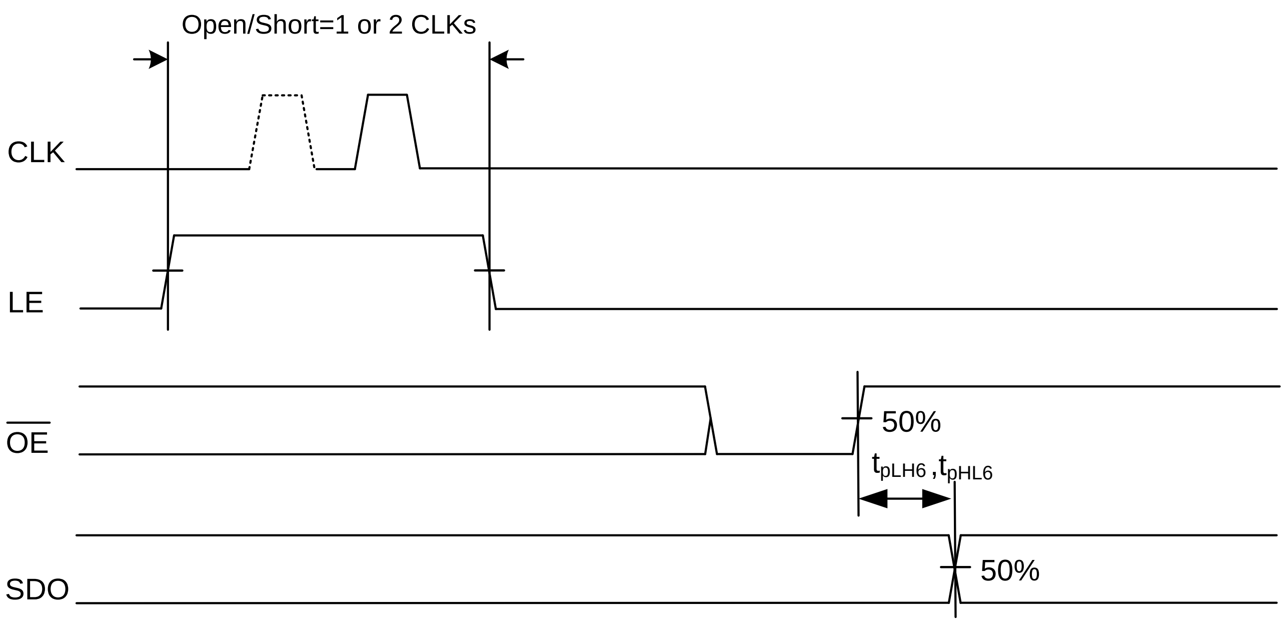








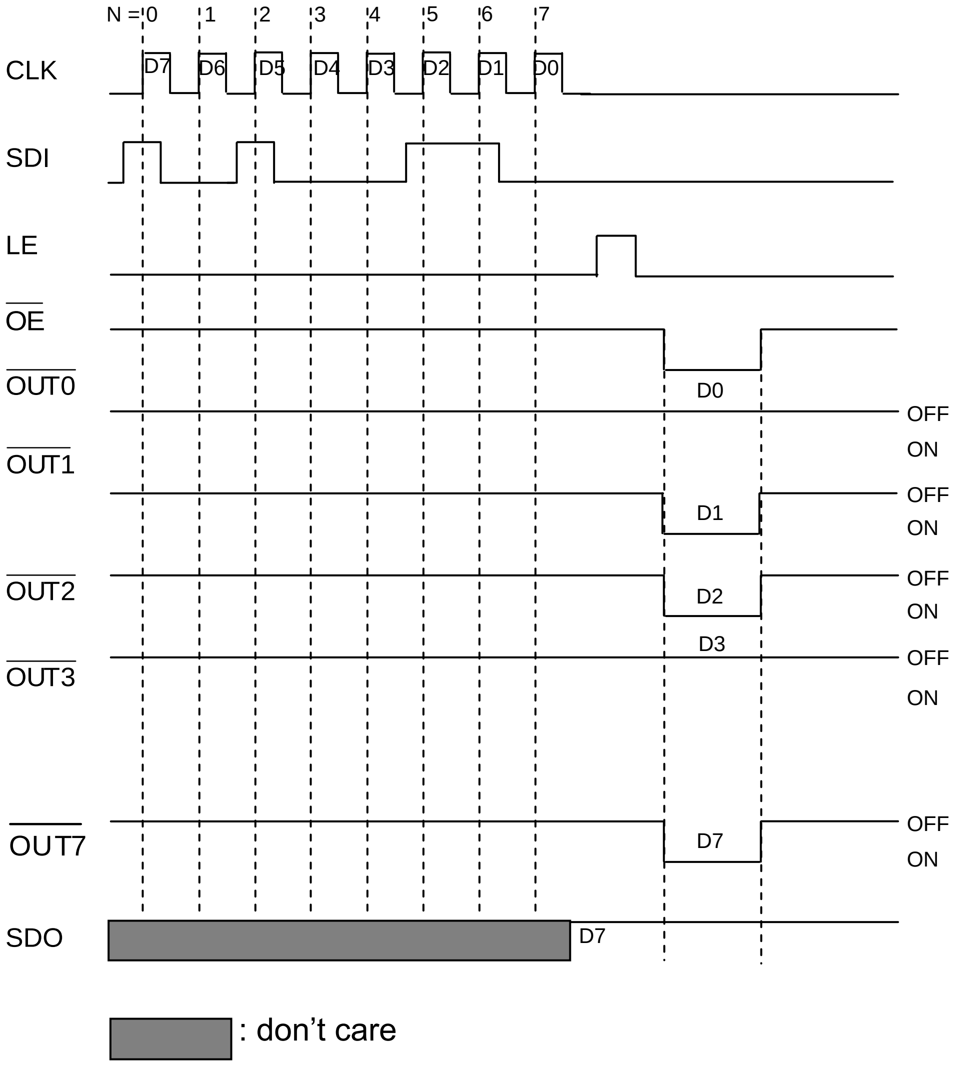
Error Detection Time Decided by $\overline{\text{OE}}$



Control the Output Ports

The data are shifted from the SDI to the 8-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

7	6	5	4	3	2	1	0

e.g. Default Value

7	6	5	4	3	2	1	0
1	1	0	0	1	0	0	0

Bit	Definition	Value	Function
7	Threshold voltage for short-circuit detection ($V_{SD,TH}$) or leakage diagnosis ($V_{LD,TH}$)	00	0.4 x V_{DD}
		01	0.5 x V_{DD}
6		10	0.6 x V_{DD}
		11(Default)	0.7 x V_{DD}
5	0-Power mode	0 (Default)	Disable 0-power mode
		1	Enable 0-power mode
4	Sleep mode	0 (Default)	Disable sleep mode
		1	Enable sleep mode
3	Detection current for compulsory open/short	00	Reserved
		01	Reserved
2		10(Default)	Default small current for error detection current
		11	Detection current=I_{OUT}=($V_{R\text{-}EXT}$/R_{ext})x120, $V_{R\text{-}EXT}$=1.23Volt
1	Compulsory open/short-circuit detection time	0 (Default)	The error detection is close to 700ns. Users have to leave more than 700ns for error detection.
		1	The detection operation time is determined by the falling edge of LE to the rising edge of $\overline{OE}$. This setting is for short-circuit and open-circuit detections only.
0	Reserved	0 (Default)	Reserved

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
Open-circuit detection	High	1	Start open-circuit error detection
Short-circuit detection	High	2	Start short-circuit error detection
Thermal detection	High	3	Start IC thermal detection
Write configuration	High	4	Serial data are latched to the “configuration register”
Leakage diagnosis	High	5	Start leakage diagnosis
Read configuration	High	6	Read out the setting of the configuration register
Wake-up	High	7	Wake up from sleep mode or 0-power mode
Enable “write configuration”	High	8	Enable to write the configuration register Sent before “write configuration” command
Sleep mode	High	9	Enter sleep mode if bit “C” of the configuration register is “1”.

Note: Number of CLK $\geqq$10: no action.
For detailed timing diagrams, please refer to the section of “Principle of Operation”.

Error Code

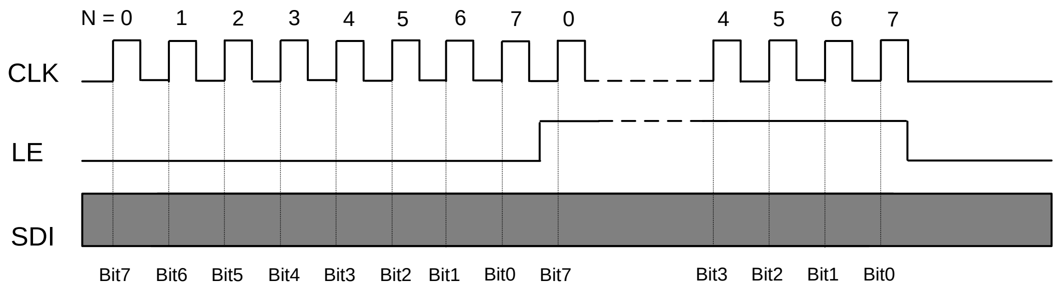
If the error detection is invalid, the error code remains "1". Please refer to section of "Principle of Operation" for the condition of valid error detection.

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

Writing Configuration Register

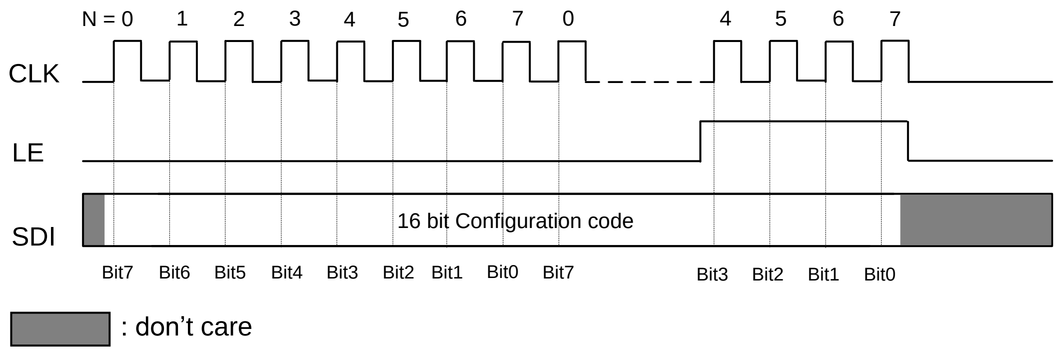
To write to configuration register, the controller must send an "enable write configuration" command firstly, i.e. LE contains 8 CLKs rising edge, as shown in the figure below.

Enable write configuration



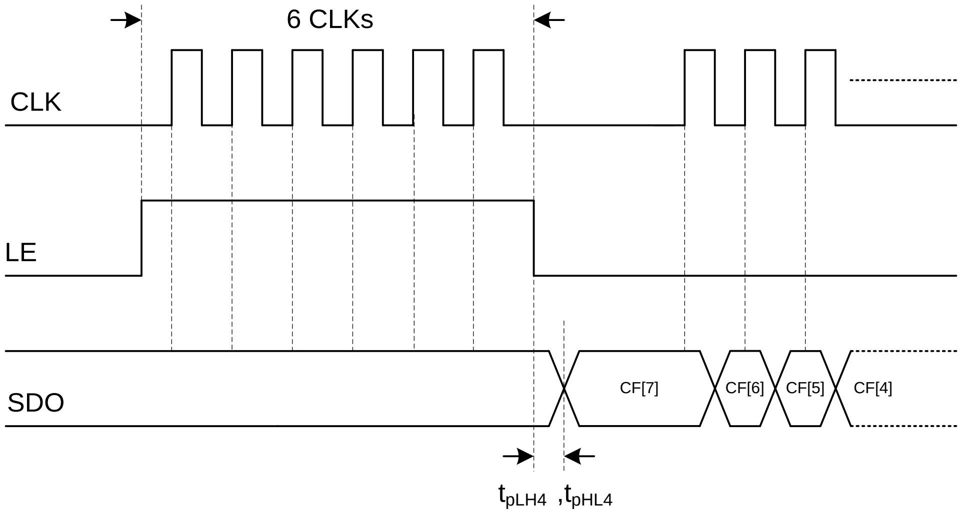
Secondly, the controller should send a "write configuration" command, i.e. LE contains 4 CLKs rising edge, as shown in the figure below. Then the MBI5137 will latch the shift-in data to the configuration register and update the configuration register.

Write configuration



Reading Configuration Register

If users want to know the current setting of the configuration register, users could send the “read configuration” command, i.e. LE contains 6 CLKs rising edge. The MSB (CF[7]) of the configuration register will be shifted out first.



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 “1” of the configuration register. If bit “1” is set to the default value “0”, the detection operation time will be 700ns (Figure 1). Otherwise, users may determine the detection operation time from the falling edge of LE to the rising edge of $\overline{OE}$ by setting bit “1” to the value “1” (Figure 2). The settings of detection operation time are only applicable for open-circuit and short-circuit detections.

The detection current is set by bit [3:2] of the configuration register. If bit [3:2] is set to the value “10” (default), the detection current is default small current. If bit [3:2] 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 “1” and bit [3:2], please refer to the section of “Definition of Configuration Register”.

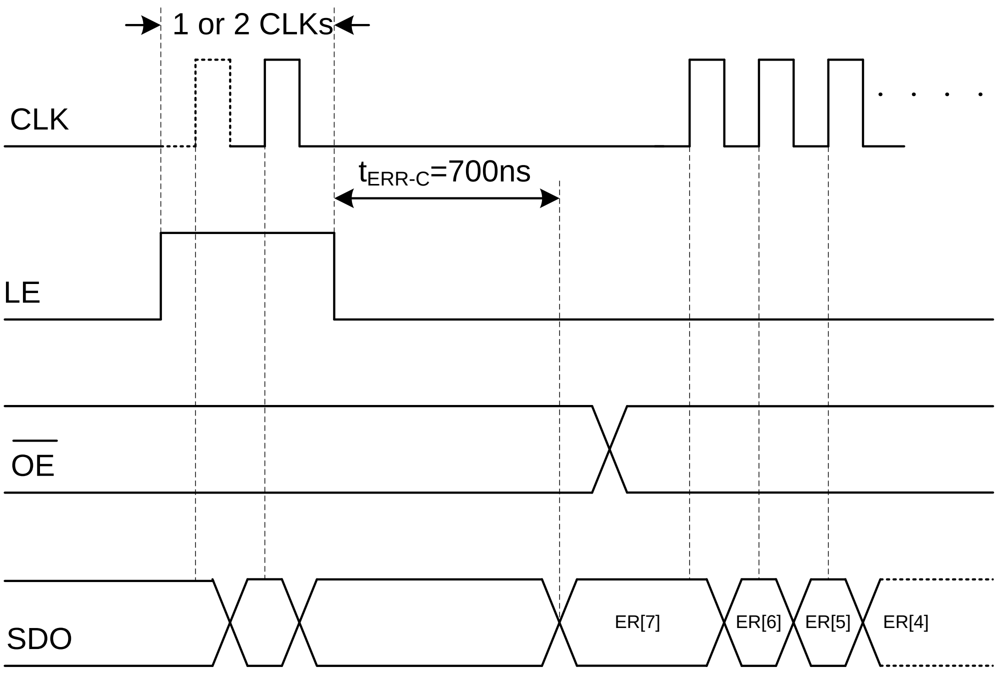


Figure 1

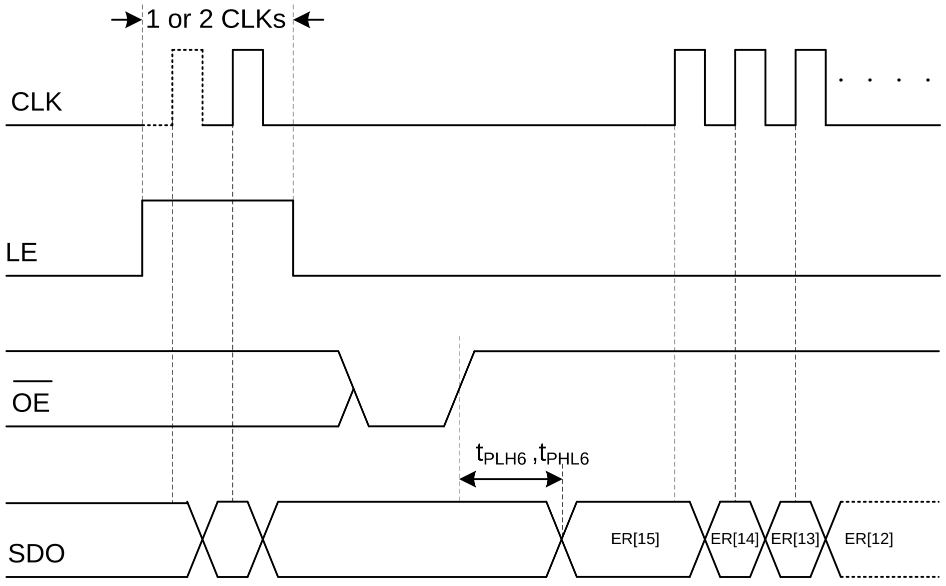


Figure 2

Silent Error Detection (Default)

The default setting of error detection time 700ns. This is also called "silent error detection" because MBI5137 runs the detection without LED flickers. No matter the data is 1 or 0, the output ports will be turned on small current 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 of compulsory open and short detection is designed for specific applications. When the output loading is heavy, e.g. the PCB trace is long, the default small current and detection time may not be enough for error detection. Users can set the detection time and current by setting different values on the configuration register.

By setting the configuration register bit [1] ="1", the detection operation time is determined by the falling edge of LE to the rising edge of $\overline{OE}$.

In addition to detecting with default small current, MBI5137 can also set the detection current by R_{ext}, i.e., the normal current in normal operation. In the configuration register, bit [3:2] are used to set the current for detection. If bits [3:2] is set to "11", the current for detection depend on R_{EXT} setting. The default setting of bits [3:2] is "10"; that is, the default current for detection is small current.

Compulsory Open-Circuit Detection

The principle of MBI5137 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 open-circuit detection threshold voltage ($V_{OD,TH}$ = 0.35V (typ.), please refer to the Electrical Characteristics.). Thus, after the command of "compulsory open-circuit detection", the output ports of MBI5137 will be turned on.

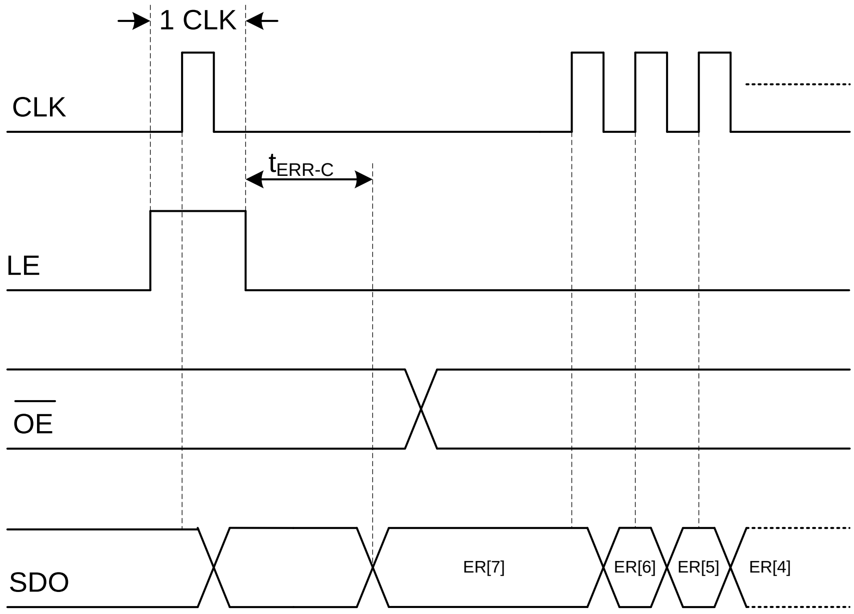


Figure 3

Note: Figure 3 is an example when the configuration register bit "1" is set to the default value "0". In such condition, the detection operation time is 700ns.

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 MBI5137 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 short-circuit detection ($V_{SD.TH}$ = 0.70xV_{DD}, default. Please refer to the Definition of Configuration Register for different setting.). For the selection of a suitable threshold voltage, please refer to the following paragraph of “Setting the Threshold Voltage for Short-Circuit Detection”. Thus, after the command of “compulsory short-circuit detection”, the output ports of MBI5137 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.

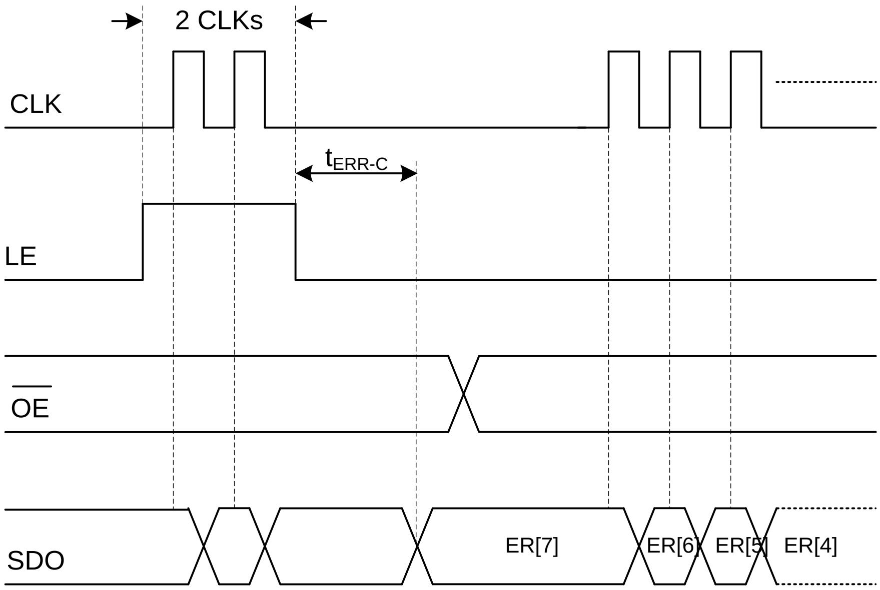


Figure 4

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 MBI5137 identifies the LED as short-circuit.

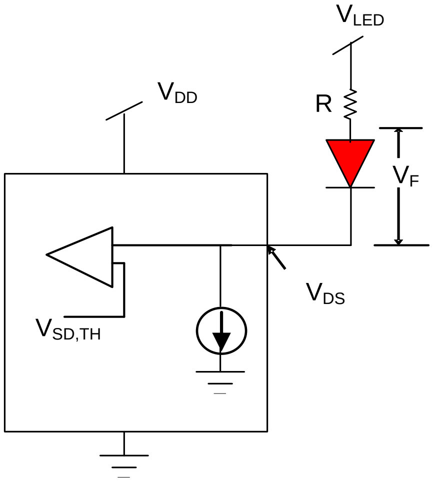


Figure 5

The MBI5137 provides settable $V_{SD,TH}$ for different LED configuration. For example, if each output port of MBI5137 drives one red LED, the $V_{SD,TH}$ shall be set smaller. If each output port of MBI5137 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, MBI5137 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, MBI5137 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 MBI5137.

** Threshold voltage of short-circuit 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. For the detailed setting of threshold voltage of leakage diagnosis, please refer to the Definition of Configuration Register.

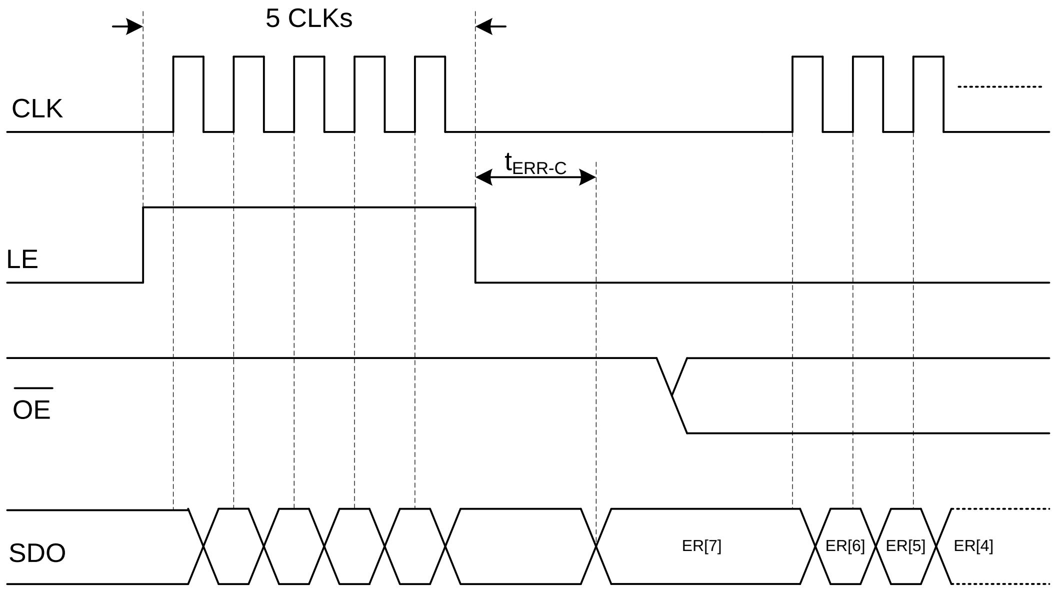


Figure 6

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}.
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 MBI5137≧T_{TF}	0 (SDO=7F(HEX))	Overheating
The junction temperature of MBI5137<T_{TF}	1 (SDO=FF)	Normal

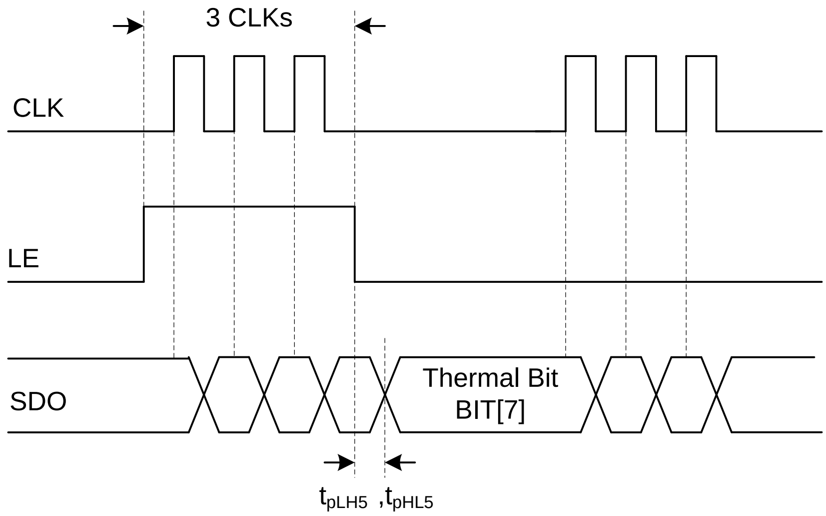


Figure 7

At the falling edge of LE, if MBI5137 is overheated, the code "7F(HEX)" is delivered to SDO; otherwise, the code "FF(HEX)" is latched to sift register.

Power Saving Modes

There are two power saving modes to reduce the I_{DD} current: sleep mode and 0-Power mode.

Power saving mode	Description	Application
Sleep mode	Force the MBI5137 to enter and leave the power saving mode by commands.	For LED displays that are occasionally turned on, but the power of the system is not turned off.
0-Power mode	MBI5137 enters or leaves the 0-Power mode automatically, if all the data are zero. Users may also force MBI5137 to leave the 0-Power mode by command. Bit "5" of the configuration register shall be set to 1 to enable this mode.	When partial LEDs on LED displays are usually turned off.

Sleep Mode

MBI5137 will enter the sleep mode when users issue the sleep mode command: LE contains 9 CLK. To escape the sleep mode, users have to send the wake-up command: LE contains 7 CLK. In the sleep mode, the I_{DD} of MBI5137 will be reduced to about 3% of the I_{DD} in the normal mode (see "Electrical Characteristics" for details).

To wake up from the sleep mode, MBI5137 takes about 1ms.

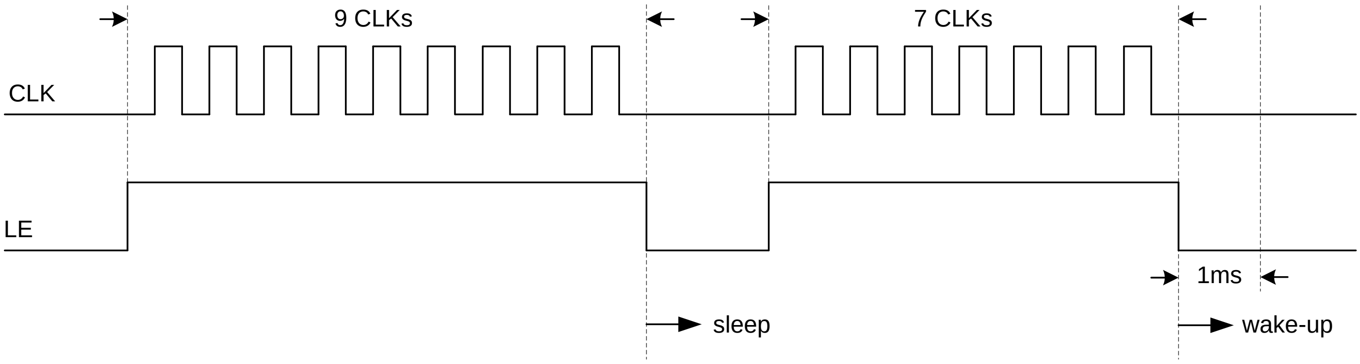


Figure 8

In the sleep mode, MBI5137 will not execute any other command except the wakeup command, but the shift register still keeps shifting data with the clock.

0-Power Mode

By setting bit "5" of the configuration register, the 0-Power mode of MBI5137 will be effective. When all the output data of the MBI5137 are "0", MBI5137 will enter the 0-Power mode automatically. When the non-zero data is latched, the MBI5137 will leave 0-Power mode automatically (Figure 9). User may also force MBI5137 to leave the 0-Power mode by command (Figure 10).

In the 0-Power mode, the I_{DD} of MBI5137 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 MBI5137 to turn on or turn off the cascaded LEDs in the group simultaneously. Therefore, the 0-Power mode of MBI5137 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 detections) will not be performed, but the other commands (write and read configurations) are still active. If the sleep mode command is issued, MBI5137 will leave the 0-Power mode and enter the sleep mode.

Automatically enter and leave the 0-Power mode

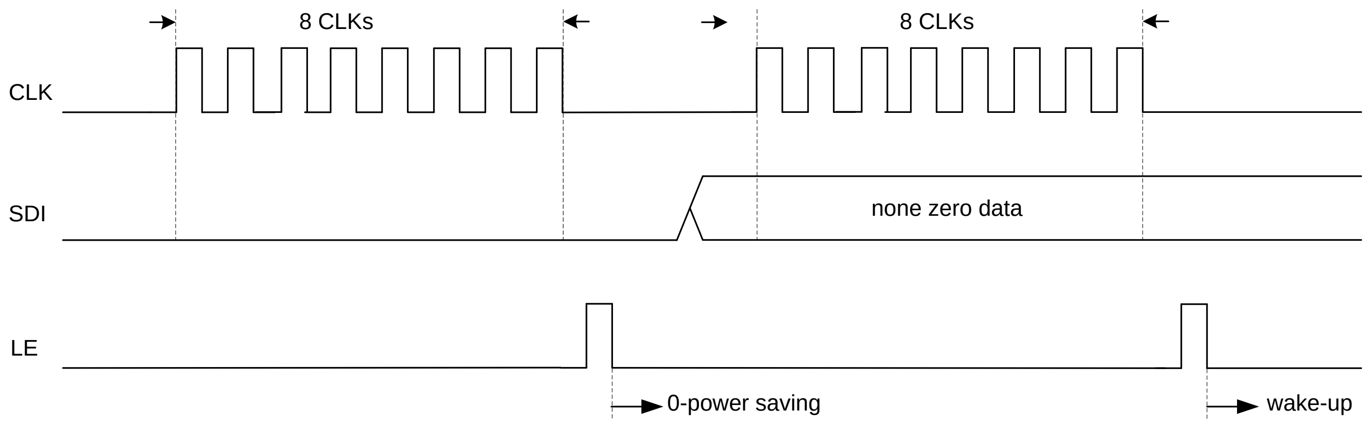


Figure 9

Enter the 0-Power mode automatically but leave by the command

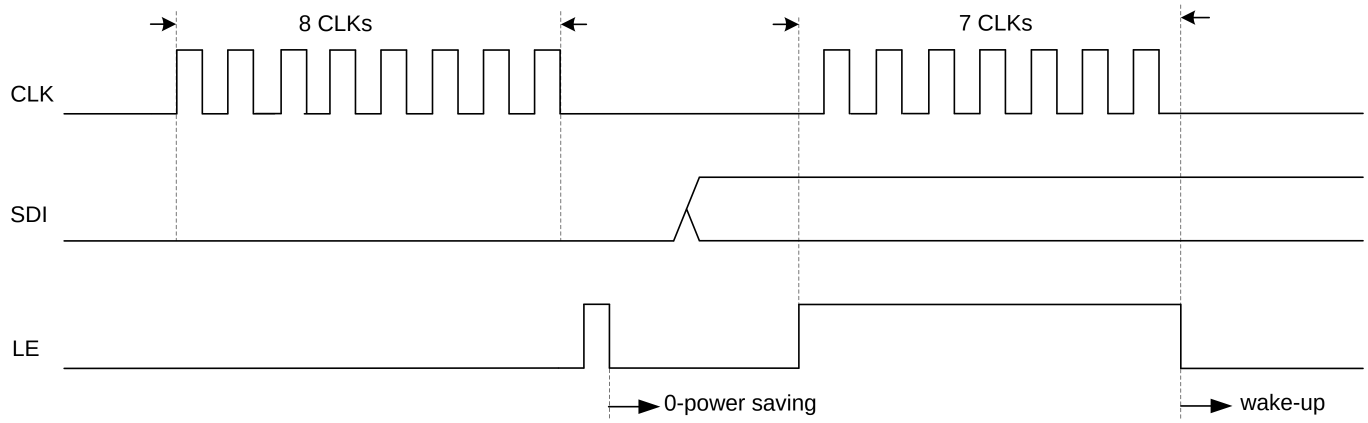


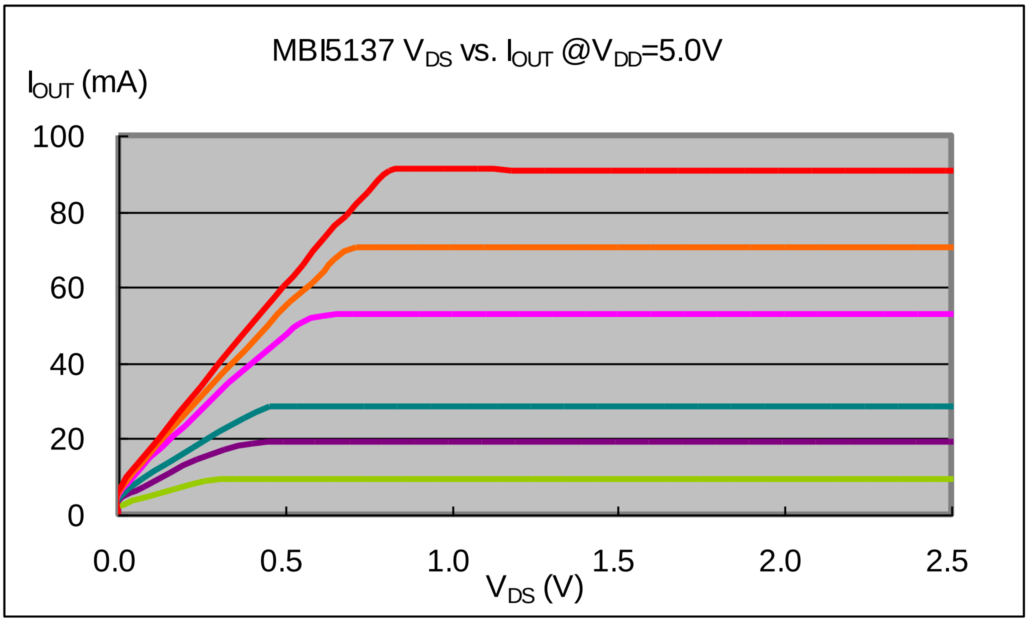
Figure 10

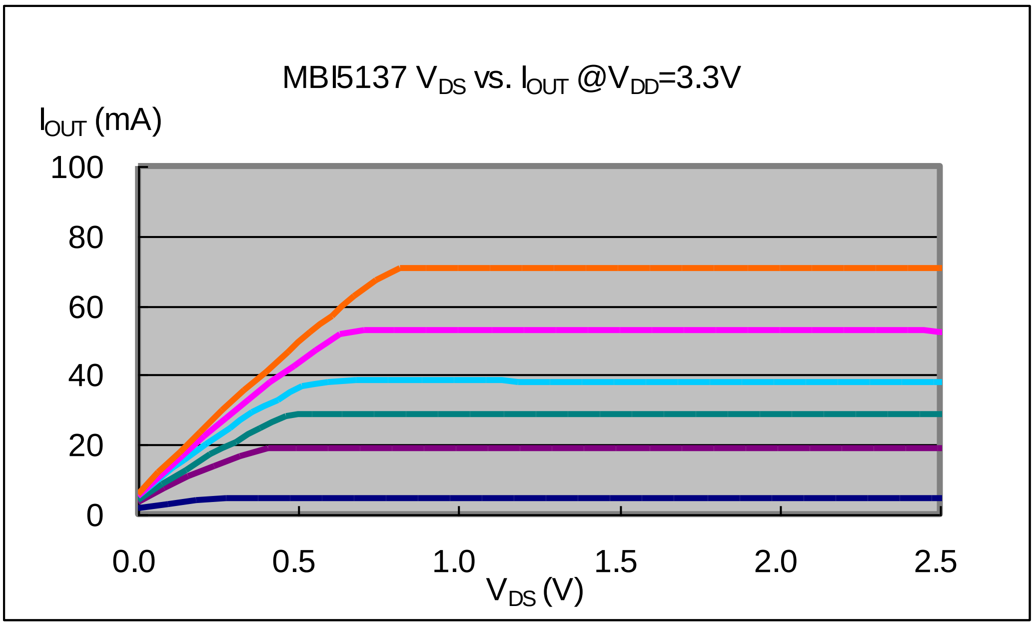
Constant Current

In LED display applications, MBI5137 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).

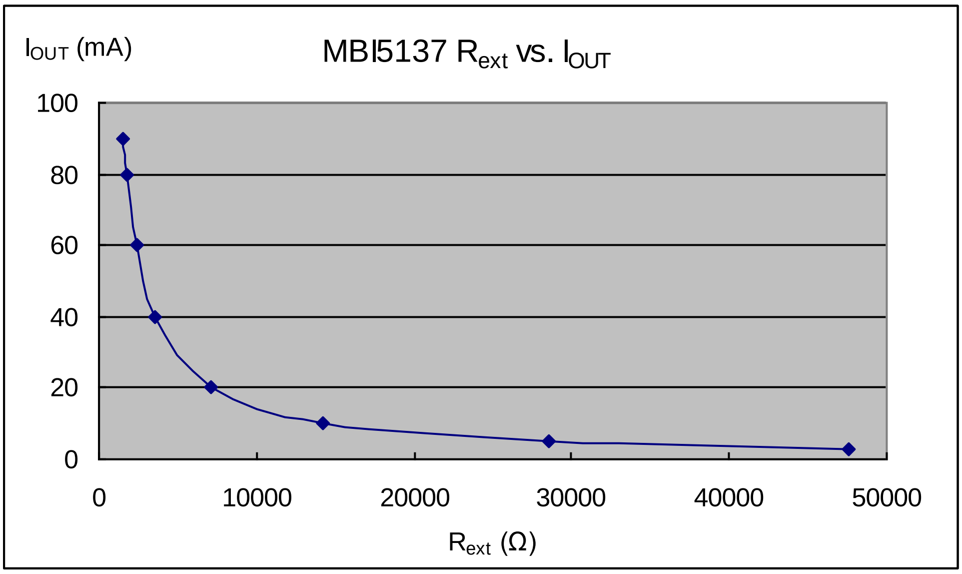
2) In addition, the characteristics curve of output stage in the saturation region is flat and users can refer to the figure as shown below. Thus, the output current can be kept constant regardless of the variations of LED forward voltages (Vf). The output current level in the saturation region is defined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





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 by the equation:

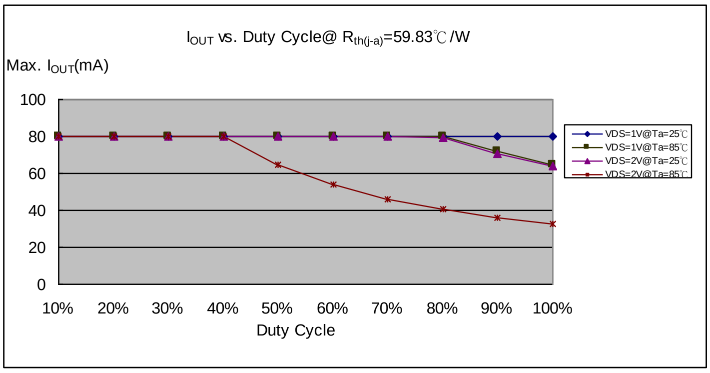
$V_{R\text{-}EXT}$=1.23Volt ; $I_{OUT}=(V_{R\text{-}EXT}/R_{ext})\times116$

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.

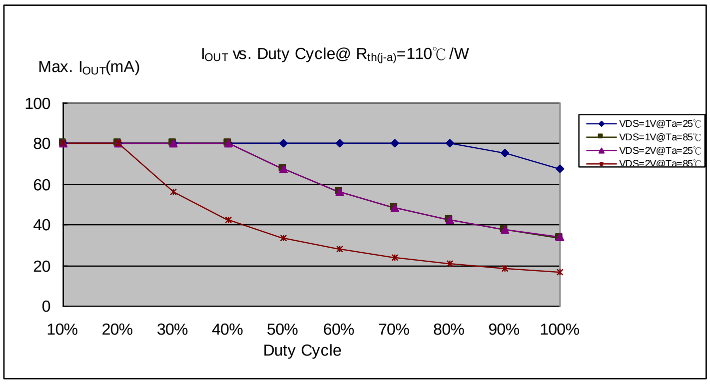
Package Power Dissipation (PD)

The maximum allowable package power dissipation is determined as $P_D(max)=(Tj–Ta)/R_{th(j-a)}$. When 8 output channels are turned on simultaneously, the actual package power dissipation is $P_D(act)=(I_{DD}xV_{DD})+(I_{OUT}xDutyxV_{DS}x8)$. Therefore, to keep $P_D(act)≤P_D(max)$, the allowable maximum output current as a function of duty cycle is:

$I_{OUT}=\{[(Tj–Ta)/R_{th(j-a)}]–(I_{DD}xV_{DD})\}/V_{DS}/Duty/8$, where Tj=150°C.



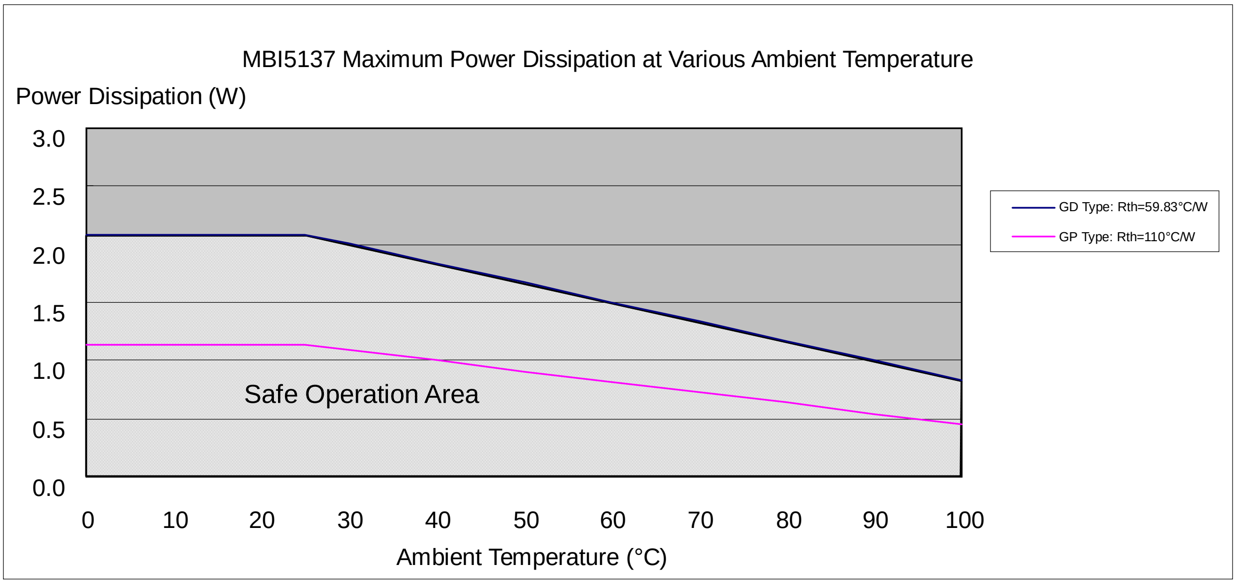
MBI5137GD



MBI5137GP

Condition: I_{OUT}=80mA, 16 output channels	
Device Type	$R_{th(j-a)}$ (°C/W)
GD	59.83
GP	110

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

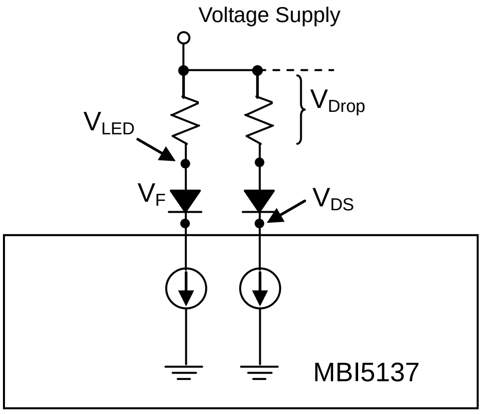


Load Supply Voltage (V_{LED})

MBI5137 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.

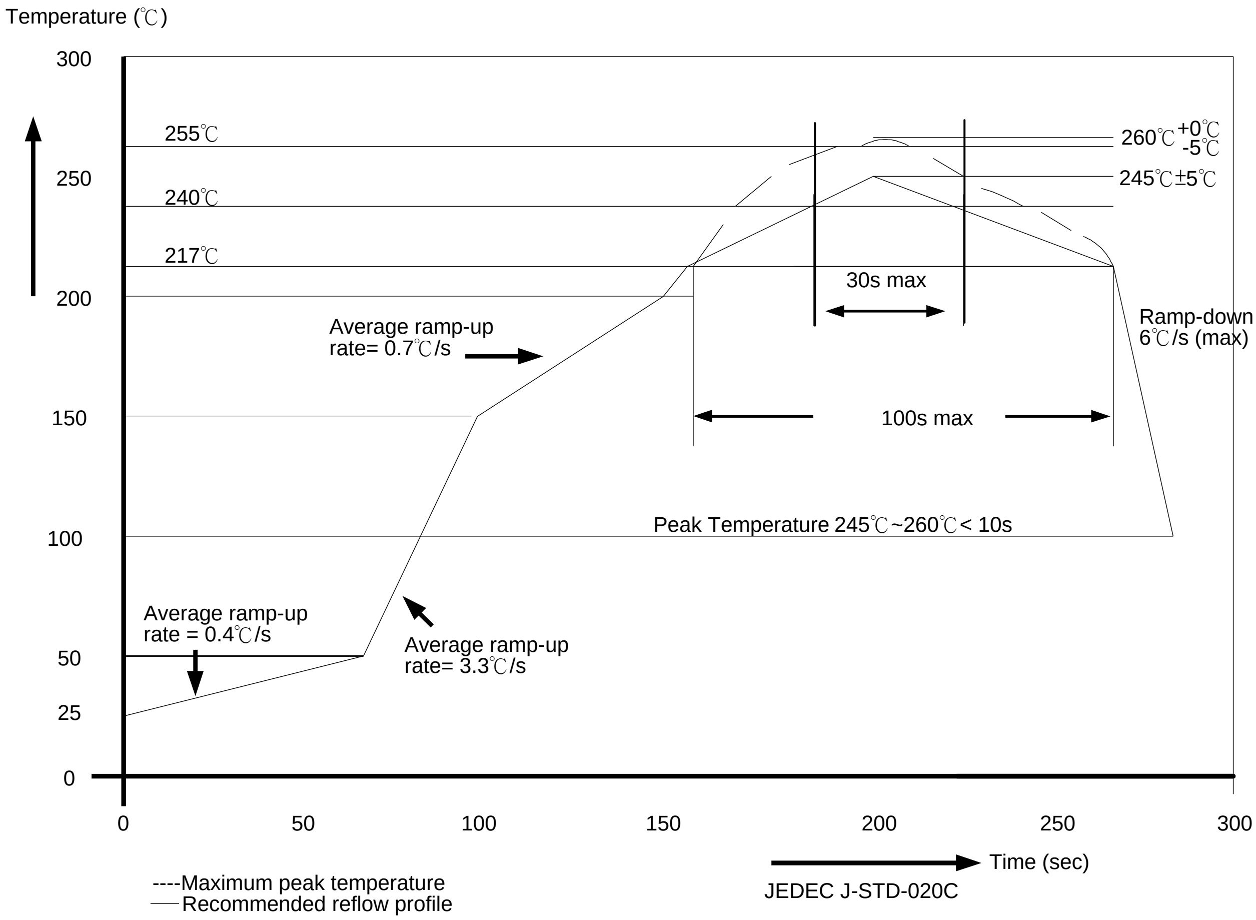


Switching Noise Reduction

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”.

Soldering Process of "Pb-free" Package Plating*

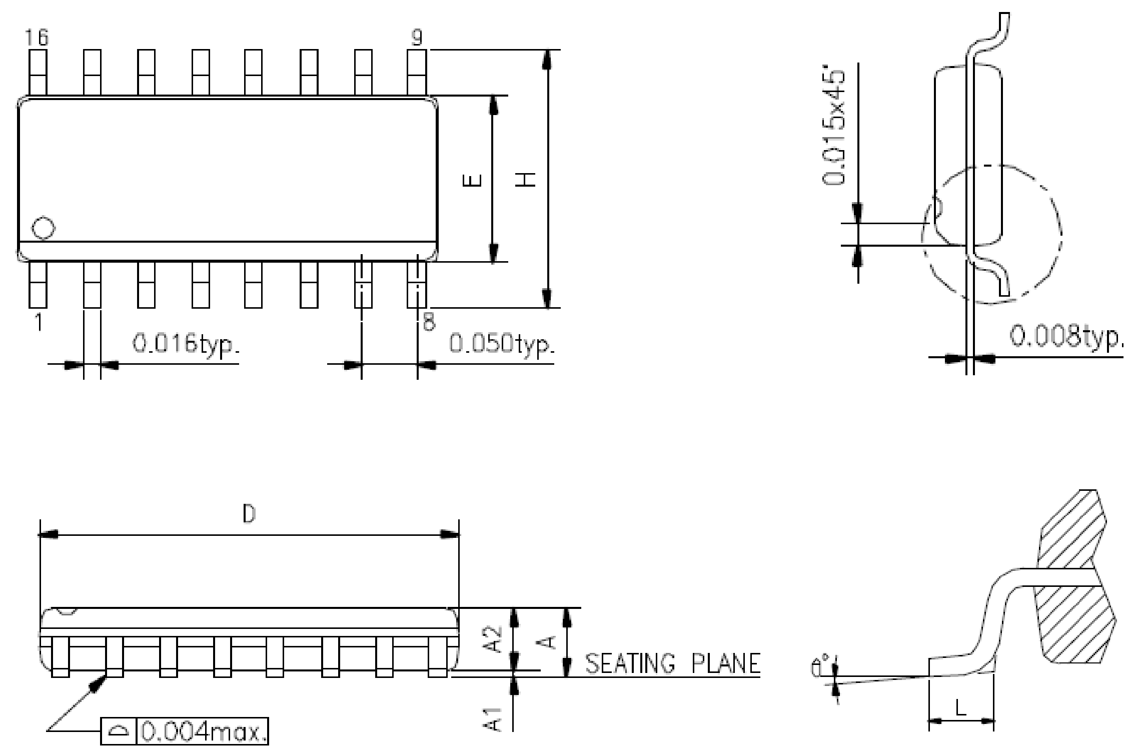
Macroblock has defined "Pb-Free" to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free processes. Pure tin is widely accepted by customers and suppliers of electronic devices in Europe, Asia and the US as the lead-free surface finish of choice to replace tin-lead. Also, it is backward compatible to standard 215ºC to 240ºC reflow processes which adopt tin/lead (SnPb) solder paste. 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 mm³ <350	Volume mm³ 350-2000	Volume mm³ ≧2000
<1.6mm	260 +0 °C	260 +0 °C	260 +0 °C
1.6mm – 2.5mm	260 +0 °C	250 +0 °C	245 +0 °C
≧2.5mm	250 +0 °C	245 +0 °C	245 +0 °C

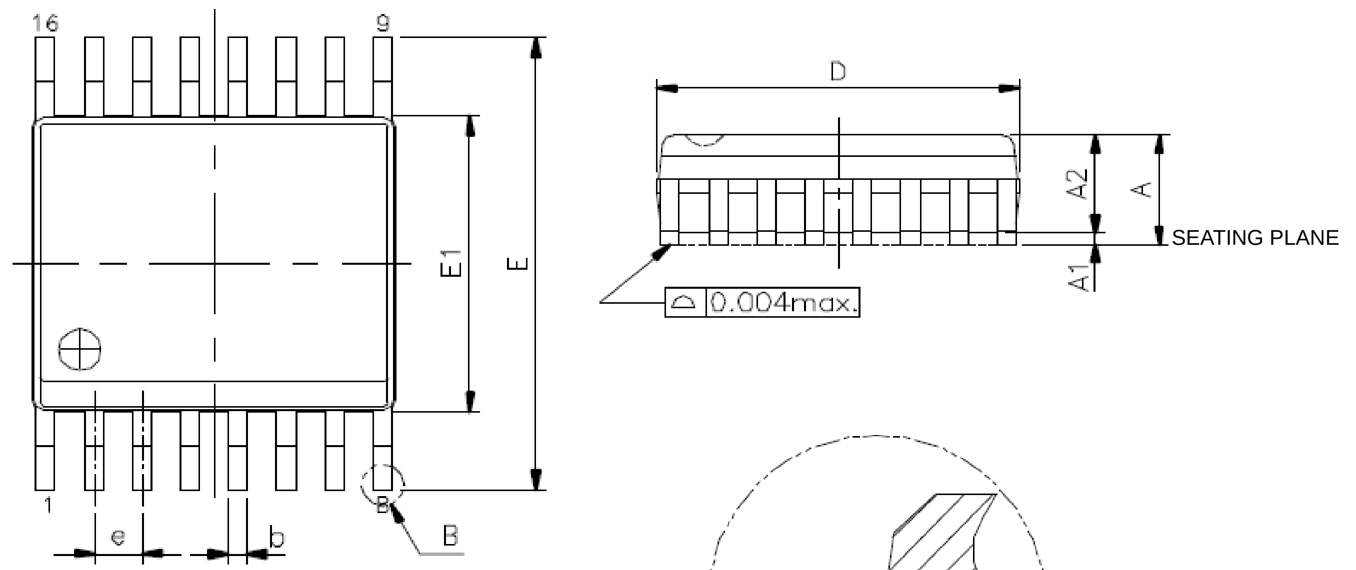
*Note: For details, please refer to Macroblock's "Policy on Pb-free & Green Package".

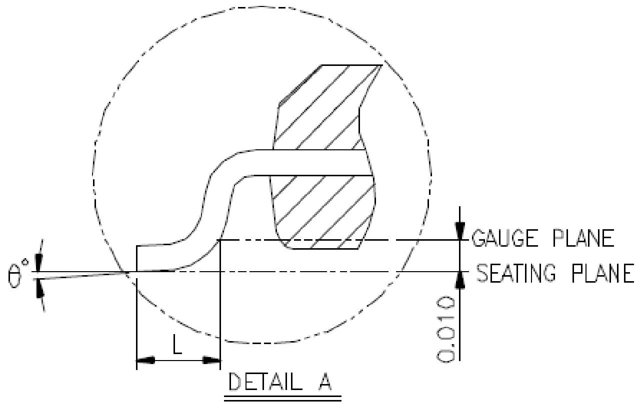
Package Outline

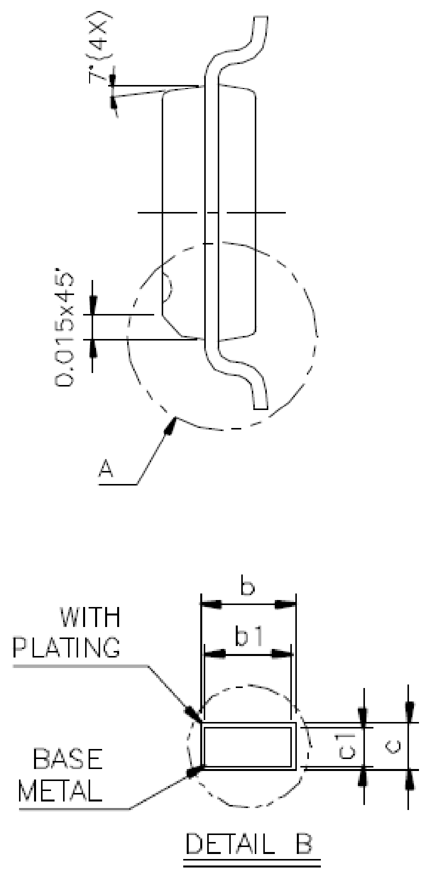


SYMBOLS	Dimensions shown in inchs		Dimensions shown in millimeters	
	MIN.	MAX.	MIN.	MAX.
A	0.053	0.069	1.346	1.753
A1	0.004	0.010	0.102	0.254
A2	0.049	0.065	1.245	1.651
D	0.386	0.394	9.804	10.008
E	0.150	0.157	3.810	3.988
H	0.228	0.244	5.791	6.198
L	0.016	0.050	0.406	1.270
θ ˚	0	8	0	8

MBI5137GD Outline Drawing



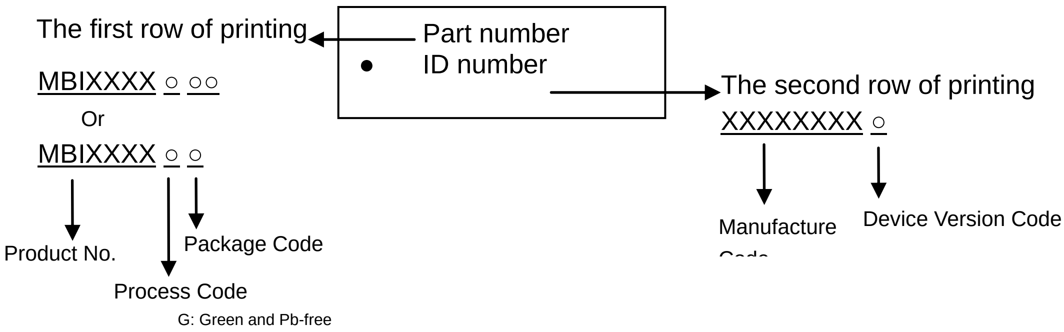




SYMBOLS	Dimensions shown in inchs			Dimensions shown in millimeters		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.053	—	0.069	1.346	—	1.753
A1	0.004	—	0.010	0.102	—	0.254
A2	0.049	—	0.059	1.245	—	1.499
b	0.008	—	0.012	0.203	—	0.305
b1	0.008	0.010	0.011	0.203	0.254	0.279
c	0.007	—	0.010	0.178	—	0.254
c1	0.007	0.008	0.009	0.178	0.203	0.229
D	0.189	0.193	0.197	4.801	4.902	5.004
E1	0.150	0.154	0.157	3.810	3.912	3.988
E	0.228	0.236	0.244	5.791	5.994	6.198
L	0.016	—	0.050	0.406	—	1.270
e	0.025 BASIC			0.635 BASIC		
θ°	0	—	8	0	—	8

MBI5137GP Outline Drawing

Product Top-mark Information



Product Revision History

Product Ordering Information

Part Number	RoHS Compliant Package Type	Weight (g)
MBI5137GD	SOP16-150-1.27	0.16
MBI5137GP	SSOP16-150-0.64	0.09

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