

Preliminary Datasheet

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
 - 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, OE (min.): 50ns (V_{DD}=5V, I_{OUT}=20mA)
- Staggered delay of output, preventing from current surge
- 30MHz clock frequency
- Schmitt trigger input

Applications

- LED traffic signs
- LED message signs



Shrink SOP



GP: SSOP24L-150-0.64

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

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**TM technology to enhance its output characteristics. Furthermore, MBI5037 uses the concept of **Share-I-O**TM 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. With the **Share-I-O**TM technique, the printed circuit board originally designed for MBI5026 may be also applicable to MBI5037, if the \overline{OE} is controllable. In addition, MBI5037 features two power saving modes: sleep mode and 0-Power mode to increase the power efficiency. Therefore, MBI5037 is especially suitable for LED traffic sign and message sign applications.

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 small current. The image will not be impacted since the turn-on duration and current are so small. MBI5037 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, 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. Both modes reduce the supply current of MBI5037 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, MBI5037 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.

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 (VF) 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.

OE

LE

MBI5037

Neumüller Elektronik GmbH info@neumueller.com 16-Channel Constant Current LED Driver with Silent LED Error Detection and Power Saving Modes **Block Diagram OUTO** OUT 1 OUT14 OUT15 Temperature Detector R-EXT O IOUT Regulator Open-/Short-circuit Detection/ Leakage Diagnosis **Control Logic** 16-bit Output Driver 16 16-bit Output Latch 16-bit Configuration Register 16 16 CLK (16-bit Shift Register SDO SDI (16

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

Pin Configuration

GND	1•	24	VDD
SDI	2	23	R-EXT
CLK	3	22	SDO
LE	4	21	OE
OUT0	5	20	OUT15
OUT1	6	19	OUT14
OUT2	7	18	OUT13
OUT3	8	17	OUT12
OUT4	9	16	OUT11
OUT5	10	15	OUT10
OUT6	11	14	OUT9
OUT7	12	13	OUT8

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
OUT0 ~ OUT15	Constant current output ports
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



Silent LED Error Detection and Power Saving Modes

Equivalent Circuits of Inputs and Outputs



16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

Maximum Ratings

Character	istic	Symbol	Rating	Unit
Supply Voltage		Vdd	0~7.0	V
Sustaining Voltage at SDI, OE	, LE, CLK Pins	V _{IN}	-0.4 ~ V _{DD} +0.4	V
Sustaining Voltage at CKO, SD	O Pins	Vout	-0.4~V _{DD} +0.4	V
Sustaining Voltage at OUTn F	Pins	V _{DS}	-0.5~17	V
Output Current (OUT0 ~ OUT1	5)	Ι _{ουτ}	+90	mA
GND Terminal Current			1440	mA
Power Dissipation (On 4 Layer PCB, Ta=25°C)*	GF Type GD Type GP Type	Po	2.55 2.82 2.08	W
Thermal Resistance (On 4 Layer PCB, Ta=25°C)*	GF Type GD Type GP Type	R _{th(j-a)}	49.04 44.34 60.07	°C/W
Junction Temperature		Tj,max	150**	°C
Operating Ambient Temperatu	e	T _{opr}	-40 ~ +85	°C
Storage Temperature		T _{stg}	-55 ~ +150	°C
	Human Body Mode (MIL-STD-883G Method 3015.7)	НВМ	Class 3B (8000V)	-
ESD Rating	Machine Mode (JEDEC EIA/JESD22-A115,)	ММ	Class C (≧400V)	-

*The PCB size is 76.2mm*114.3mm in simulation. Please refer to JEDEC JESD51.

** Operation at the maximum rating for extended periods may reduce the device reliability; therefore, the suggested operation 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.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes **Electrical Characteristics (V**_{DD}=5.0V; Ta=25°C)

Characteristics		Symbol	Condition	Min.	Тур.	Max.	Unit
Supply Voltage		Vdd	That assures the IC works properly	4.5	5.0	5.5	V
Sustaining OUT Ports	Voltage at	V _{DS}	OUT0 ~ OUT15	-	-	17.0	V
		lout	Refer to "Test Circuit for Electrical Characteristics"	5	-	80	mA
Output Cu	rrent	Іон	SDO, V _{OH} =4.6V	-	-	-1.0	mA
		Iol	SDO, Vol=0.4V	-	-	1.0	mA
Input	"H" level	VIH	Ta=-40~85ºC	$0.7 \mathrm{xV}_{\mathrm{DD}}$	-	Vdd	V
Voltage	"L" level	VIL	Ta=-40~85ºC	GND		$0.3 x V_{DD}$	V
Output Lea Current	akage	Іон	V _{DS} =17.0V and all channels off		-	0.2	μΑ
Output	SD0	V _{OL}	I _{OL} =+1.0mA	V_{DD} -0.4	-	0.4	V
Voltage	300	V _{OH}	I _{OH} =-1.0mA	4.6	-	-	V
Current Sk (Channel)	œw	dlout1/lout	Iout=20mA V _{DS} =1.0V Rext=7.5KΩ	-	±1.5	±3.0	%
Current Skew (IC)		dlout2/lout	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} =7500 Ω @20mA	-	±0.1	±0.3	% / V
Output Cu Supply Vo Regulation	rrent vs. Itage 1*	%/dV _{DD}	V_{DD} within 4.5V and 5.5V	-	±1.0	±2.0	% / V
Open-Circ Threshold	uit Detection Voltage**	Vod,th		-	0.35	0.40	V
Pull-down	Resistor	Rın(down)	LE	250	500	800	KΩ
Pull-up Re	sistor	Rın(up)	OE	250	500	800	KΩ
		I _{DD} (off) 1	R _{ext} =Open, OUT0 ~ OUT15 =Off	-	2.2	3.0	mA
	"Off"	Idd(off) 2	R _{ext} =5.6KΩ, OUT0 ~ OUT15 =Off	-	5.4	7.0	mA
		IDD(off) 3	$R_{ext}=2.4K\Omega, \overline{OUTO} \sim \overline{OUT15} = Off$	-	7.0	8.2	mA
Supply	"On"	I _{DD} (on) 1	$R_{ext}=5.6K\Omega, \overline{OUTO} \sim \overline{OUT15} = On$	-	5.6	7.5	mA
Current	OI	IDD(on) 2	$R_{ext}=2.4K\Omega, \overline{OUTO} \sim \overline{OUT15} = On$	-	7.5	8.5	mA
	Sleep mode	IDD(sleep)	-	-	124	200	μA
	0-Power mode	I _{DD} (0-Power)	-	-	124	200	μA
Thermal F Temperatu	lag ıre	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.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

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

Characteristics		Symbol	Cond	Min.	Тур.	Max.	Unit	
Supply Voltag	ge	V _{DD}	That assures the I	3.0	3.3	3.6	V	
Sustaining Vo OUT Ports	oltage at	V _{DS}	$\overline{OUT0} \sim \overline{OUT15}$		-	-	17.0	V
		Ιουτ	Refer to "Test Circ Characteristics"	uit for Electrical	3	-	60	mA
Output Curre	nt	I _{OH}	SDO, V _{OH} =2.9V		-	-	-1.0	mA
		I _{OL}	SDO, V _{OL} =0.4V		-	·	1.0	mA
Input	"H" level	Vін	Ta=-40~85⁰C		0.7xV _{DD}	- /	Vdd	V
Voltage	"L" level	VIL	Ta=-40~85⁰C		GND	-	0.3xV _{DD}	V
Output Leaka	age Current	Іон	V _{DS} =17.0V and all	channels off	-	-	0.2	μA
Output	800	Vol	I _{OL} =+1.0mA		V _{DD} -0.4	-	0.4	V
Voltage	300	V _{OH}	I _{ОН} =-1.0mA		2.9	-	-	V
Current Skev	v (Channel)	dlout1/lout	I _{OUT} =20mA V _{DS} =1.0V	R _{ext} =7.5KΩ	-	±1.5	±3.0	%
Current Skew (IC)		dlout2/lout	Iout=20mA V _{DS} =1.0V Rext=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 Curre Supply Voltag Regulation*	nt vs. ge	%/dVdd	V_{DD} within 3.0V and 3.6V		-	±1.0	±2.0	% / V
Open-Circuit Threshold Vo	Detection ltage**	V _{OD,TH}			-	0.35	0.40	V
Pull-down Re	esistor	Rin(down)	LE		250	500	800	KΩ
Pull-up Resis	stor	R _{IN} (up)	OE		250	500	800	KΩ
		I _{DD} (off) 1	R _{ext} =Open, OUTO	~ ~ OUT15 =Off	-	1.8	2.6	mA
	"Off"	IDD(Off) 2	$R_{ext}=5.6K\Omega, \overline{OUTO}$	~ OUT15 =Off	-	4.9	6.5	mA
		IDD(off) 3	$R_{ext}=2.4K\Omega, \overline{OUTO}$	~ OUT15 =Off	-	6.5	7.7	mA
Supply	"On"	I _{DD} (on) 1	$R_{ext}=5.6K\Omega, \overline{OUTO}$	~ OUT15 =On	-	5.1	7.0	mA
Current		IDD(on) 2	$R_{ext}=2.4K\Omega, \overline{OUTO}$	~ OUT15 =On	-	7.0	8.0	mA
	Sleep mode	Sleep mode I _{DD} (sleep) -		-	42	100	μA	
	0-Power mode	I _{DD} (0-Power)	-			42	100	μA
Thermal Flag Temperature		T _{TF}	Junction Temperat	ure	-	-	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.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

Test Circuit for Electrical Characteristics



16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes Switching Characteristics (V_{PD}=5.0V; Ta=25°C)

Characte	Symbol	Condition	Min.	Тур.	Max.	Unit	
	LE-OUTO	t _{pLH1}		-	22	-	ns
		t _{pLH2}		-	20		ns
Dran a nation Dalay Time	CLK-SDO	t _{pLH3}		-	20	30	ns
("L" to "H")	LE-SDO (Read Configuration)	t _{pLH4}		-	23	-	ns
	LE-SDO (Thermal Detection)	t _{pLH5}		-	40	•	ns
	OE -SDO	t _{pLH6}		-	-	40	ns
	LE-OUTO	t _{pHL1}		-	24	-	ns
	OE - OUTO	t _{pHL2}		-	20	-	ns
Propagation Delay Time	CLK-SDO	t _{pHL3}		-	20	30	ns
("H" to "L")	LE-SDO (Read Configuration)	t _{pLH4}	V _{DD} =5.0V V _{DS} =1.0V	-	23	-	ns
	LE-SDO (Thermal Detection)	t _{pLH5}	V _{IH} =V _{DD}	-	40	-	ns
	OE - SDO	t _{pLH6}	$R_{ext}=7.5K\Omega$	-	-	40	ns
Stagger delay	OUTn - OUTn + 1	t _{stag}	$I_{OUT}=20mA$	-	2	3	ns
Dulaa Width	CLK	t _{w(CLK)}	$R_{L}=150\Omega$	16.5	-	-	ns
	LE	t _{w(L)}	C∟=10pF	20	-	-	ns
Hold Time for LE		t _{h(L)}	C1=100hF C2=22uF	10	-	-	ns
Setup Time for LE		t _{su(L)}	C _{SDO} =10pF	10	-	-	ns
Hold Time for SDI		t _{h(D)}		5	-	-	ns
Setup Time for SDI		t _{su(D)}		3	-	-	ns
Maximum CLK Rise Time	*	tr		-	-	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 Outp	t _{or}		10	14	-	ns	
Output Fall Time of Outpu	ut Ports	t _{of}		7	11	-	ns
Compulsory error detection	on operation time**	terr-c		700	-	-	ns
OE with uniform output***	•	t _{w(OE)}		50	-	-	ns

*If tr or tf 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.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes Switching Characteristics (V_{PD}=3.3V; Ta=25°C)

Charact	teristics	Symbol	Condition	Min.	Тур.	Max.	Unit
	LE-OUTO	t _{pLH1}		-	30	-	ns
		t _{pLH2}			23	-	ns
	CLK-SDO	t _{pLH3}		-	30	40	ns
Propagation Delay Time ("L" to "H")	LE-SDO (Read Configuration)	t _{pLH4}		-	32	-	ns
	LE-SDO (Thermal Detection)	t _{pLH5}		-	55		ns
	OE -SDO	t _{pLH6}		-		55	ns
	LE-OUTO	t _{pHL1}			35	-	ns
	OE - OUTO	t _{pHL2}			29	-	ns
Propagation Delay	CLK-SDO	t _{pHL3}		-	30	40	ns
Time ("H" to "L")	LE-SDO (Read Configuration)	t _{pHL4}	V _{DD} =3.3V V _{DS} =1.0V	-	32	-	ns
	LE-SDO (Thermal Detection)	t _{pHL5}	VIH=VDD VIL=GND	-	55	-	ns
	OE -SDO	t _{pHL6}	R _{ext} =7.5KΩ I _{OUT} =20mA	-	-	55	ns
Stagger delay	OUTn - OUTn + 1	t _{stag}	V _{LED} =4V	-	3.5	5	ns
Dulaa Width	CLK	t _{w(CLK)}	RL=150Ω CL=10pF	20	-	-	ns
	LE	t _{w(L)}	C1=100nF	20	-	-	ns
Hold Time for LE		th(L)	C2=22UF C _{SDO} =10pF	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 Tir	tr		-	-	500	ns	
Maximum CLK Fall Tim	t _f		-	-	500	ns	
SDO Rise Time	t _{r,SDO}		-	8	-	ns	
SDO Fall Time	t _{f,SDO}		-	8	-	ns	
Output Rise Time of Ou	t _{or}		16	20	-	ns	
Output Fall Time of Out	t _{of}		16	20	-	ns	
Compulsory error detect	ction operation time**	t _{ERR-C}		700	-	-	ns
OE with uniform output	***	t _{w(OE)}		50	-	-	ns

*If tr or tr 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.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes **Test Circuit for Switching Characteristics**



16-Channel Constant Current LED Driver with Silent LED Error Detection and Power Saving Modes **Timing Waveform** t_{W(CLK)} 50% 50% 50% 50% CLK _ t_{su(D)} t_{h(D)} 50% 50% SDI 50% SDO t_{h(L} tpLH3,tpHL3 su(L t_{W(L} 50% 50% 50% LE LOW = OUTPUTS ENABLED ŌE HIGH = OUTPUT OFF 50% OUTn LOW = OUTPUT ON tpLH1, tpHL1 t_{W(OE)} ŌĒ 50% 50% t_{pHL2} t_{pLH2} 90% 90% OUTn 50% 50% 10% 10% t_{stag} t_{of} tor OUTn+1



16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

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.



16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

Definition of Configuration Register

MSB															LSB
F	Е	D	С	В	Α	9	8	7	6	5	4	3	2	1	0
e.g. D	efault	Value													
F	E	D	С	В	Α	9	8	7	6	5	4	3	2	1	0
	11	0	0	1	0				10)'b00 0	000 000	00			

Bit	Definition	Value	Function
E	Threshold voltage	00	0.4 x V _{DD}
Г	for short-circuit	01	0.5 x V _{DD}
	detection (V _{SD,TH}) or	10	0.6 x V _{DD}
E	leakage diagnosis (V _{LD,TH})	11(Default)	0.7 x V _{DD}
Р	0 Dower mode	0 (Default)	Disable 0-power mode
0	0-Power mode	1	Enable 0-power mode
<u> </u>	C Sleep mode	0 (Default)	Disable sleep mode
C		1	Enable sleep mode
D	Detection current	00	Reserved
Б	for compulsory	01	Reserved
٨	open/short-circuit	10(Default)	Default small current for error detection current
A	detection	11	Detection current=I _{OUT} =(V _{R-EXT} /R _{ext})x120, V _{R-EXT} =1.23Volt
		0 (Default)	The error detection is close to 700ns.
	Compulsory		Users have to leave more than 700ns for error detection.
9	open/short-circuit		The detection operation time is determined by the falling edge of LE to
	detection time	1	the rising edge of \overline{OE} .
			This setting is for short-circuit and open-circuit detections only.
8:0	Reserved	000000000 (Default)	Reserved

Control Command

	Signal	s Combination	Description		
Command Name	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 \geq 10: no action.

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

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

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 MBI5037 will latch the shift-in data to the configuration register and update the configuration register.

Write configuration





16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

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[15]) of the configuration register will be shifted out first.

→ 6 CLKs	←
LE	
SDO	CF[15] CF[14] CF[13] CF[12]
	→ t _{pLH4} ,t _{pHL4}

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

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 configuration register bit "9". If the configuration register bit "9" 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 configuration register bit "9" 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 configuration register bit [B:A] of the configuration register. If configuration register bit [B:A] is set to the value "10" (default), the detection current is default small current. If configuration register bits [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 configuration register bit "9", bit "A", and bit "B", please refer to the section of "Definition of Configuration Register".



Figure 1

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



Figure 2

Silent Error Detection (Default)

The default setting of error detection time 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 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 [9] ="1", the detection operation time is determined by the falling edge of LE to the rising edge of \overline{OE} .

In addition to the default small current as the detection current, MBI5037 can also set the detection current by R_{ext}, i.e., the normal current in normal operation. Configuration register bits [B:A] are used to set the current for detection. If configuration register bits [B:A] is set to "11", the current for detection depends on R_{ext} setting. The default setting of configuration register bits [B:A] is "10"; that is, the default current for detection is small current.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes 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 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 MBI5037 will be turned on.



Figure 3

Note: Figure 3 is an example when the configuration register bit "9" 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 terr.c.

4. If CLK is toggled during terr-c, the data in the shift register will be overwritten at terr-c.

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

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

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 short-circuit detection ($V_{SD.TH} = 0.70 \times V_{DD}$, 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 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.



Note: Figure 4 is an example when the configuration register bit "9" is set to the default value "0". In such condition, the detection operation time is 700ns.

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}.

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

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.





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:

 $V_{\text{LED}}-V_{\text{F}}=V_{\text{DS}}$

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.

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

Detection	Condition	Code	Result
Short-Circuit Detection	Vds>Vsd,th	0	Short-circuit
(Detect while turn-on)*	Vds <vsd,th< td=""><td>1</td><td>Normal</td></vsd,th<>	1	Normal
Leakage Diagnosis	V_{DS} > $V_{LD,TH}$ **	1	Normal
(Detect while turn-off)*	V_{DS}	0	Leakage

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

** 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.



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 $t_{\mbox{\scriptsize ERR-C}}$ duration.

5. If the OE is toggled during t_{ERR-C} , the error codes remain "1".

6. If CLK is toggled during $t_{\text{ERR-C}}$, the data in the shift register will be overwritten at $t_{\text{ERR-C}}$.

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

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 \ge T _{TF}	0 (SDO=7FFF(HEX))	Overheating
The junction temperature of MBI5037 <t<sub>TF</t<sub>	1 (SDO=FFFF)	Normal



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.

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

Power Saving Modes

There are two power saving modes to reduce the IDD current: sleep mode and 0-Power mode.

Power saving mode	Description	Application
Sleep mode	Force the MBI5037 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	MBI5037 enters or leaves the 0-Power mode automatically, if all the data are zero. Users may also force MBI5037 to leave the 0-Power mode by command. Bit "D" 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

MBI5037 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 MBI5037 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, MBI5037 takes about 1ms.



In the sleep mode, MBI5037 will not execute any other command except the wakeup command, but the shift register still keeps shifting data with the clock.

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

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 (Figure 9). User may also force MBI5037 to leave the 0-Power mode by command (Figure 10).

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.

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, MBI5037 will leave the 0-Power mode and enter the sleep mode.

LE Figure 9

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

Automatically enter and leave the 0-Power mode



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

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 $I_{OUT} \leq 80$ mA, 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 l_{out,target}.





16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

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-EXT}=1.23Volt ; I_{OUT}=(V_{R-EXT}/R_{ext})x116

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

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

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:

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

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



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

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.



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".

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

Soldering Process of "Pb-free & Green" Package Plating*

Macroblock has defined "Pb-Free & Green" to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free processes. Pure tin is widely accepted by customers and suppliers of electronic devices in Europe, Asia and the US as the lead-free surface finish of choice to replace tin-lead. Also, it adopts tin/lead (SnPb) solder paste, and please refer to the JEDEC J-STD-020C for the temperature of solder bath. However, in the whole Pb-free soldering processes and materials, 100% pure tin (Sn) will all require from 245 °C to 260°C for proper soldering on boards, referring to JEDEC J-STD-020C as shown below.



Package Thickness	Volume mm ³ <350	Volume mm ³ 350-2000	Volume mm ³ ≥ 2000
<1.6mm	260 +0 °C	260 +0 °C	260 +0 °C
1.6mm – 2.5mm	260 +0 °C	250 +0 °C	245 +0 °C
≧ 2.5 mm	250 +0 °C	245 +0 °C	245 +0 °C

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

16-Channel Constant Current LED Driver with

Silent LED Error Detection and Power Saving Modes

Package Outline



MBI5037GF Outline Drawing



MBI5037GD Outline Drawing

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



MBI5037GP Outline Drawing

Note: The unit for the outline drawing is mm.



Datasheet version	Device version code	
V1.00	A	
V2.00	В	
V3.00	С	
V3.01	С	
V3.02	C	
V3.03	С	

Product Ordering Information

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

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

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

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