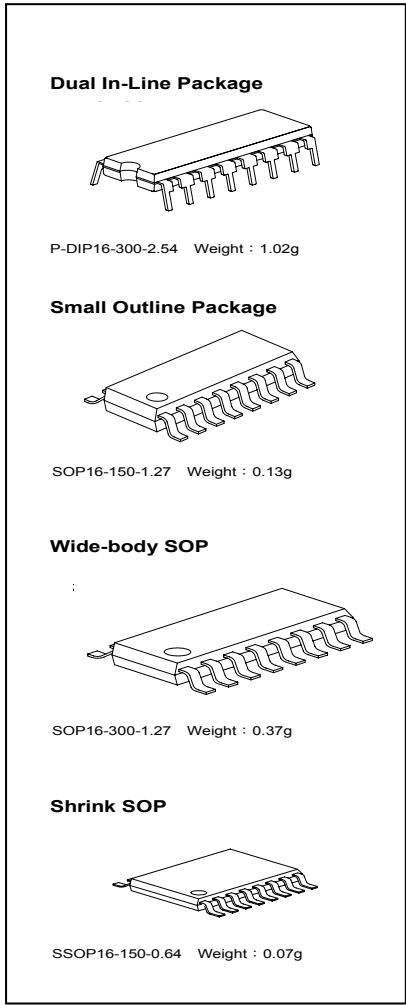




8-Bit Constant Current LED Sink Driver with Open/Short Circuit Detection

Features

- Compatible with MBI5168 in package and electrical characteristics
- Exploit **Share-I-O™** technique to provide two operation modes: Normal Mode with the same functionality as MB5168, Open-/Short-Circuit Detection mode to detect individual LED errors
- 8 constant-current output channels
- Constant output current invariant to load voltage change
- Excellent output current accuracy, between channels: <math>< \pm 3\% \text{ (max.)}</math>, and between ICs: <math>< \pm 6\% \text{ (max.)}</math>
- Output current adjusted through an external resistor
- Constant output current range: 5 -120 mA
- Fast response of output current, \overline{OE} (min.): 200 ns @ $I_{out} < 60\text{mA}$
 \overline{OE} (min.): 400 ns @ $I_{out} = 60\sim 100\text{mA}$
- 25MHz clock frequency
- Schmitt trigger input
- 3.3V~ 5V supply voltage
- Optional for "Pb-free & Green" Package



Current Accuracy		Conditions
Between Channels	Between ICs	
<math>< \pm 3\%</math>	<math>< \pm 6\%</math>	$I_{OUT} = 10 \sim 100 \text{ mA},$ $V_{DS} = 0.8\text{V}, V_{DD} = 5.0\text{V}$

Product Description

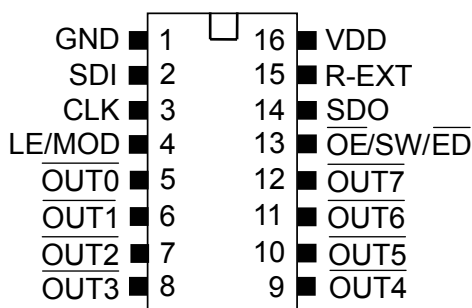
MBI5169 succeeds MBI5168 and also exploits **PrecisionDrive™** technology to enhance its output characteristics. Furthermore, MBI5169 uses the idea of **Share-I-O™** technology to make MBI5169 backward compatible with MBI5168 in both package and electrical characteristics and extend its functionality for LED load Open-/Short-circuit Detection in LED display systems, especially LED traffic sign applications.

MBI5169 contains an 8-bit Shift Register and an 8-bit Output Latch, which convert serial input data into parallel output format. At MBI5169 output stages, eight regulated current ports are designed to provide uniform and constant current sinks with small skew between ports for driving LED's within a wide range of forward voltage (Vf) variations. Users may adjust the output current from 5 mA to 120 mA with an external resistor R_{ext} , which gives users flexibility in controlling the light intensity of LED's. MBI5169 guarantees to endure maximum 17V at the output ports. Besides, the high clock frequency up to 25 MHz also satisfies the system requirements of high volume data transmission.

By means of the **Share-I-O™** technique, MBI5169 adds new functionality on pins SDO, LE, and \overline{OE} of MBI5168 to provide an additionally effective function, Open-/Short-circuit Detection, without any extra pins. Thus, MBI5169 could be a drop-in replacement of MBI5168. The printed circuit board originally designed for MBI5168 may be also applied to MBI5169. In MBI5169 there are two operation modes and three phases: Normal Mode phase, Mode Switching transition phase, and Open-/Short-circuit Detection mode phase. The signal on the multiple function pin $\overline{OE}/\overline{SW}/\overline{ED}$ would be monitored. Once an one-clock-wide short pulse appears on the pin $\overline{OE}/\overline{SW}/\overline{ED}$, MBI5169 would enter the Mode Switching phase. At this moment, the voltage level on the pin LE/MOD is used for determining the next mode to which MBI5169 is going to switch.

In the Open-/Short-circuit Detection mode phase, the low-voltage-level signal $\overline{OE}/\overline{SW}/\overline{ED}$ can enable output channels and detect the status of the output current to tell if the driving current level is enough or not. The detected error status would be loaded into the 8-bit Shift Register and be shifted out via the pin SDO along with the signal CLK. Then system controller could read the error status and know whether the LED's are properly lit or not. In the Normal Mode phase, MBI5169 performs as MBI5168. Users can get detailed ideas about how MBI5169 works in the section **Operation Principle**.

Pin Assignment



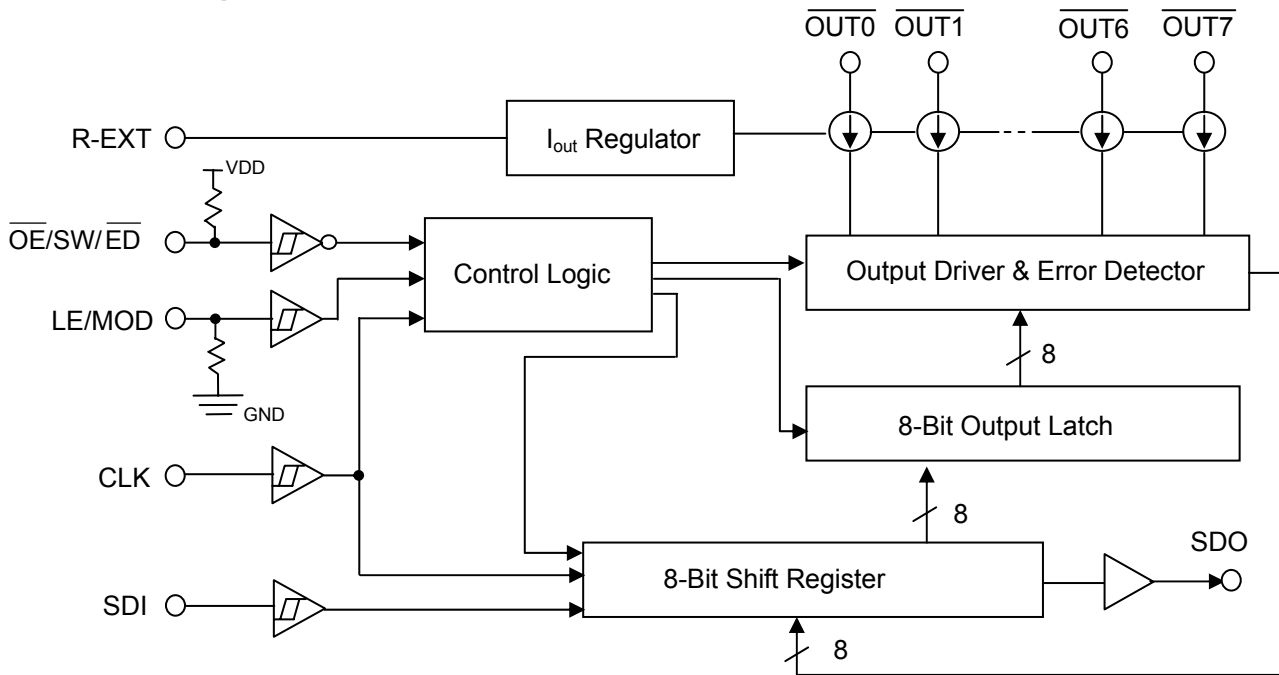
Terminal Description

Pin No.	Pin Name	Function
1	GND	Ground terminal for control logic and current sinks
2	SDI	Serial-data input to the Shift Register
3	CLK	Clock input terminal for data shift at the rising edge
4	LE/MOD	<p>Data strobe input terminal: except in the Mode Switching phase, serial data is transferred to the respective Output Latch when LE/MOD is high; the data is latched inside the Output Latch when LE/MOD goes low. If the data in the Output Latch is “1” (High), the respective output channel will be enabled after $\overline{OE}/\overline{SW}/\overline{ED}$ is pulled down to low.</p> <p>Mode selection input terminal: in the Mode Switching phase, LE/MOD couldn't strobe serial data but its level is used for determining the next mode to which MBI5169 is going to switch. When LE/MOD is high, the next mode is the Open-/Short-circuit Detection mode; when low, the next mode is the Normal Mode. (See Operation Principle)</p>
5-12	$\overline{OUT0} \sim \overline{OUT7}$	Constant current output terminals
13	$\overline{OE}/\overline{SW}/\overline{ED}$	<p>Output enable terminal: no matter in what phase MBI5169 operates, the signal $\overline{OE}/\overline{SW}/\overline{ED}$ can always enable output drivers to sink current. When its level is (active) low, the output drivers are enabled; when high, all output drivers are turned OFF (blanked).</p> <p>Mode switching trigger terminal: a one-clock-wide short signal pulse of $\overline{OE}/\overline{SW}/\overline{ED}$ could put MBI5169 into the Mode Switching phase.</p> <p>Error detection enable terminal: in the Open-/Short-circuit Detection mode, the active low signal $\overline{OE}/\overline{SW}/\overline{ED}$ can make MBI5169 not just enable output drivers but detect LED load error status. The detected error status would be stored into the Shift Register. (See Operation Principle)</p>
14	SDO	Serial-data output to the following SDI of next driver IC
15	R-EXT	Input terminal used for connecting an external resistor in order to set up the current level of all output ports
16	VDD	Supply voltage terminal

In MBI5169, the relationship between the functions of pin 4 and 13 and the operation phases is listed below:

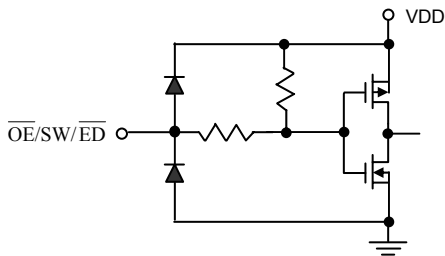
Pin No.	Pin Name	Function	Normal Mode	Mode Switching	Open-/Short-circuit Detection Mode
4	LE/MOD	LE: latching serial data into the Output Latch	Yes	No	Yes
		MOD: mode selection	No	Yes	No
13	$\overline{OE}/\overline{SW}/\overline{ED}$	\overline{OE} : enabling the current output drivers	Yes	Yes	Yes
		\overline{SW} : entering the Mode Switching phase	Yes	Yes	Yes
		\overline{ED} : enabling error detection and storing results into the Shift Register	No	No	Yes

Block Diagram

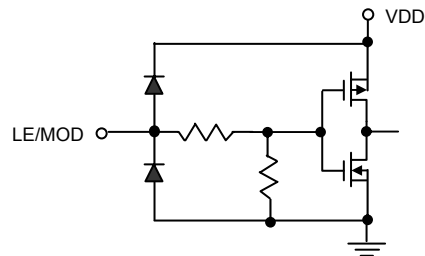


Equivalent Circuits of Inputs and Outputs

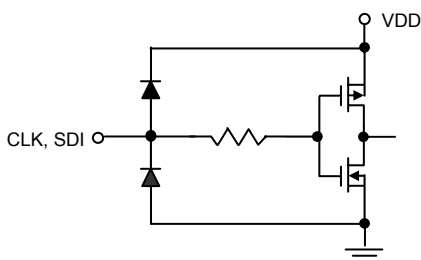
OE/SW/ED Terminal



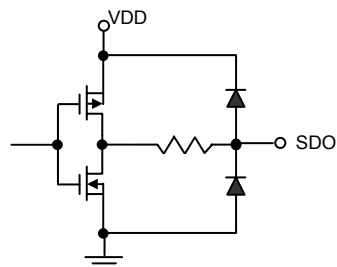
LE/MOD Terminal



CLK, SDI Terminal

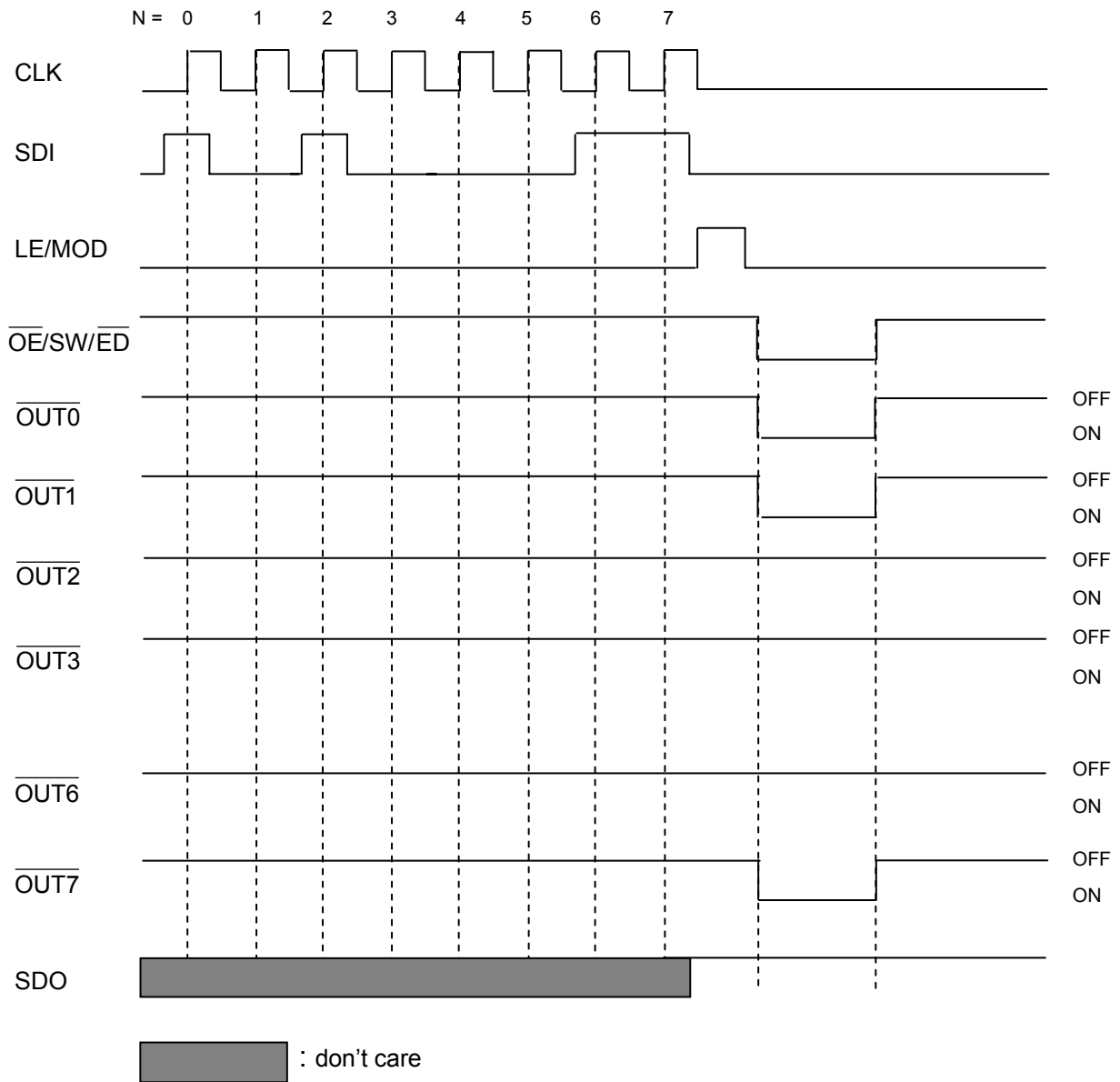


SDO Terminal



Timing Diagram

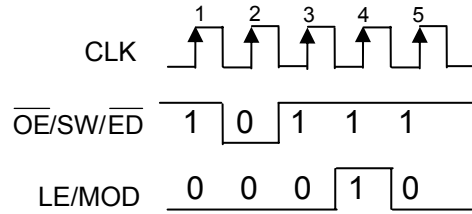
Normal Mode



Truth Table (In Normal Mode)

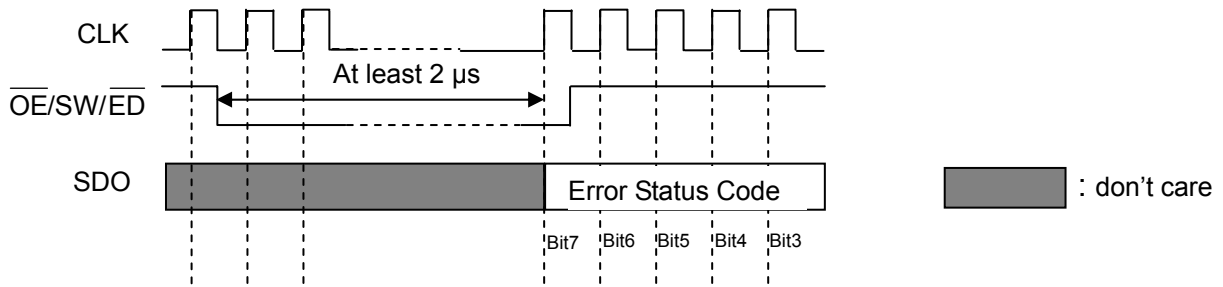
CLK	LE/MOD	OE/SW/ED	SDI	OUT0 ... OUT5 ... OUT7	SDO
	H	L	D_n	$\overline{D_{n+2}} \dots \overline{D_{n-3}} \dots \overline{D_{n-5}}$	D_{n-7}
	L	L	D_{n+1}	No Change	D_{n-6}
	H	L	D_{n+2}	$\overline{D_{n+2}} \dots \overline{D_{n-3}} \dots \overline{D_{n-5}}$	D_{n-5}
	X	L	D_{n+3}	$\overline{D_{n+2}} \dots \overline{D_{n-3}} \dots \overline{D_{n-5}}$	D_{n-5}
	X	H	D_{n+3}	Off	D_{n-5}

Switching to Open-/Short-Circuit Detection Mode



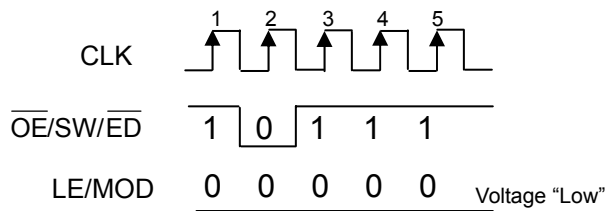
The above shows an example of the signal sequence that can set the next operation mode of MBI5169 to be the Open-/Short-circuit Detection mode. The LE/MOD active pulse here would not latch any serial data.

Reading Error Status Code (In Open-/Short-Circuit Detection Mode)



When MBI5169 is working in the Open-/Short-circuit Detection mode, the above signal sequence example can let a system controller read the Error Status codes via the pin SDO.

Switching to Normal Mode



The above signal sequence example can make MBI5169 resume to the Normal Mode.

Note:

If users want to know the detailed process, that is how to enter the Open-/Short-circuit Detection mode, detect the LED load error status, and go back to the Normal Mode, please refer to the contents in **Operation Principle**.

Maximum Ratings

Characteristics			Symbol	Rating		Unit
Supply Voltage			V_{DD}	0 ~ 7.0		V
Input Voltage			V_{IN}	-0.4 ~ $V_{DD} + 0.4$		V
Output Current			I_{OUT}	+120		mA
Output Voltage			V_{DS}	-0.5 ~ +20.0		V
Clock Frequency			F_{CLK}	25		MHz
GND Terminal Current			I_{GND}	1000		mA
Power Dissipation (On PCB, $T_a=25^\circ\text{C}$)	CN	GN	P_D	1.55	1.66	W
	CD	GD		1.17	1.43	
	CDW	GDW		1.62	1.46	
	CP	GP		1.05	1.25	
Thermal Resistance (On PCB, $T_a=25^\circ\text{C}$)	CN	GN	$R_{th(j-a)}$	64.35	60.20	$^\circ\text{C/W}$
	CD	GD		85.82	70.14	
	CDW	GDW		61.63	68.67	
	CP	GP		94.91	80.00	
Operating Temperature			T_{opr}	-40 ~ +85		$^\circ\text{C}$
Storage Temperature			T_{stg}	-55 ~ +150		$^\circ\text{C}$

Recommended Operating Conditions

Characteristics	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage	V_{DD}	-	4.5	5.0	5.5	V
Output Voltage	V_{DS}	$\overline{OUT0} \sim \overline{OUT7}$	-	-	17.0	V
Output Current	I_{OUT}	$\overline{OUT0} \sim \overline{OUT7}$	5	-	120	mA
	I_{OH}	SDO	-	-	-1.0	mA
	I_{OL}	SDO	-	-	1.0	mA
Input Voltage	V_{IH}	CLK, $\overline{OE/SW/ED}$, LE/MOD, and SDI	$0.7V_{DD}$	-	$V_{DD}+0.3$	V
	V_{IL}	CLK, $\overline{OE/SW/ED}$, LE/MOD, and SDI	-0.3	-	$0.3V_{DD}$	V
CLK Pulse Width	$t_{w(CLK)}$	-	20	-	-	ns
Setup Time for SDI	$t_{su(D)}$		5	-	-	ns
Hold Time for SDI	$t_{h(D)}$		10	-	-	ns
LE/MOD Pulse Width	$t_{w(L)}$		20	-	-	ns
Setup Time for LE/MOD	$t_{su(L)}$	For data strobe	5	-	-	ns
Hold Time for LE/MOD	$t_{h(L)}$		10	-	-	ns
Setup Time for LE/MOD	$t_{su(MOD)}$	In Mode Switching	5	-	-	ns
Hold Time for LE/MOD	$t_{h(MOD)}$		10	-	-	ns
$\overline{OE/SW/ED}$ Pulse Width	$t_{w(SW)}$	To trigger Mode Switching	20	-	-	ns
	$t_{w(OE)}$	$I_{out} < 60mA$	200	-	-	ns
	$t_{w(OE)}$	$I_{out} = 60\sim 100mA$	400	-	-	ns
	$t_{w(ED)}$	When detecting LED error status	2010	-	-	ns
Setup Time for Correctly-Generated Error Status Code *	$t_{su(ER)}$	When detecting LED error status	2000	-	-	ns
Setup Time for $\overline{OE/SW/ED}$	$t_{su(SW)}$	To trigger Mode Switching or when detecting LED error status	5	-	-	ns
Hold Time for $\overline{OE/SW/ED}$	$t_{h(SW)}$		10	-	-	ns
Clock Frequency	F_{CLK}	Cascade Operation ($V_{DD} = 5.0V$)	-	-	25	MHz

* In the Open-/Short-circuit Detection mode, when $\overline{OE/SW/ED}$ is pulled down to LOW for enabling output drivers and error detection, the output drivers must be enabled for at least 2us so that the error status code could be correctly generated. See **Operation Principle** and **Timing Waveform**.

Electrical Characteristics (V_{DD} = 5.0V)

Characteristics		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V _{DD}	-		4.5	5.0	5.5	V
Output Voltage		V _{DS}	OUT0 ~ OUT7		-	-	17.0	V
Output Current		I _{OUT}	Test Circuit for Electrical Characteristics		5	-	120	mA
		I _{OH}	SDO		-	-	-1.0	mA
		I _{OL}	SDO		-	-	1.0	mA
Input Voltage	“H” level	V _{IH}	Ta = -40~85°C		0.7V _{DD}	-	V _{DD}	V
	“L” level	V _{IL}	Ta = -40~85°C		GND	-	0.3V _{DD}	V
Output Leakage Current			V _{DS} =17.0V and channel off		-	-	0.5	µA
Output Voltage	SDO	V _{OL}	I _{OL} =+1.0mA		-	-	0.4	V
		V _{OH}	I _{OH} =-1.0mA		4.6	-	-	V
Output Current 1		I _{OUT1}	V _{DS} =0.5V	R _{ext} =744 Ω	-	25.26	-	mA
Current Skew (between channels)		dI _{OUT1}	I _{OUT} =25.26mA V _{DS} ≥0.5V	R _{ext} =744 Ω	-	±1	±3	%
Output Current 2		I _{OUT2}	V _{DS} =0.6V	R _{ext} =372 Ω	-	50.52	-	mA
Current Skew (between channels)		dI _{OUT2}	I _{OUT} =50.52mA V _{DS} ≥0.6V	R _{ext} =372 Ω	-	±1	±3	%
Output Current 3		I _{OUT3}	V _{DS} =0.8V	R _{ext} =186 Ω	-	101.0	-	mA
Current Skew (between channels)		dI _{OUT3}	I _{OUT} =101.0mA V _{DS} ≥0.8V	R _{ext} =186 Ω	-	±1	±3	%
Output Current vs. Output Voltage Regulation		%/dV _{DS}	V _{DS} within 1.0V and 3.0V		-	±0.1	-	% / V
Output Current vs. Supply Voltage Regulation		%/dV _{DD}	V _{DD} within 4.5V and 5.5V		-	±1	-	% / V
Pull-up Resistance		R _{IN(up)}	OE/SW/ED		250	500	800	KΩ
Pull-down Resistance		R _{IN(down)}	LE/MOD		250	500	800	KΩ
Threshold Current for Error Detection**		I _{out, Th1}	R _{ext} =744 Ω, I _{out, target} = 25.26mA		-	-	25.2	mA
		I _{out, Th2}	R _{ext} =372 Ω, I _{out, target} = 50.52mA		-	-	40.3	mA
		I _{out, Th3}	R _{ext} =186 Ω, I _{out, target} = 101.0mA		-	-	70.6	mA
Supply Current	“OFF”	I _{DD(off) 0}	R _{ext} =Open, OUT0 ~ OUT7 =Off		-	2.85	3.65	mA
		I _{DD(off) 1}	R _{ext} =744 Ω, OUT0 ~ OUT7 =Off		-	5.9	7.9	
		I _{DD(off) 2}	R _{ext} =372 Ω, OUT0 ~ OUT7 =Off		-	8.7	10.7	
		I _{DD(off) 3}	R _{ext} =186 Ω, OUT0 ~ OUT7 =Off		-	14.4	16.4	
	“ON”	I _{DD(on) 1}	R _{ext} =744 Ω, OUT0 ~ OUT7 =On		-	5.8	7.8	
		I _{DD(on) 2}	R _{ext} =372 Ω, OUT0 ~ OUT7 =On		-	8.7	10.7	
I _{DD(on) 3}		R _{ext} =186 Ω, OUT0 ~ OUT7 =On		-	13.5	15.5		

** To effectively detect the load open-circuit error at the output ports, MBI5169 has a built-in current detection circuit. The current detection circuit will detect the effective current I_{out, effect} and compare it with the threshold current I_{out, Th}. If I_{out, effect} is less than the threshold current I_{out, Th}, an error flag (LOW) will be asserted and stored into the built-in Shift Register. Each external resistor R_{ext} would determine a target output current I_{out, target}, which has a corresponding threshold current I_{out, Th}. To bias LED operation point properly and detect LED errors, there is a minimum effective output current requirement for each R_{ext}, such as I_{out, Th1}, I_{out, Th2}, and I_{out, Th3}.

Electrical Characteristics ($V_{DD} = 3.3V$)

Characteristics		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-		3.0	3.3	3.6	V
Output Voltage		V_{DS}	$\overline{OUT0} \sim \overline{OUT7}$		-	-	17.0	V
Output Current		I_{OUT}	Test Circuit for Electrical Characteristics		5	-	120	mA
		I_{OH}	SDO		-	-	-1.0	mA
		I_{OL}	SDO		-	-	1.0	mA
Input Voltage	"H" level	V_{IH}	$T_a = -40 \sim 85^\circ C$		$0.7V_{DD}$	-	V_{DD}	V
	"L" level	V_{IL}	$T_a = -40 \sim 85^\circ C$		GND	-	$0.3V_{DD}$	V
Output Leakage Current			$V_{DS} = 17.0V$ and channel off		-	-	0.5	μA
Output Voltage	SDO	V_{OL}	$I_{OL} = +1.0mA$		-	-	0.4	V
		V_{OH}	$I_{OH} = -1.0mA$		2.9	-	-	V
Output Current 1		I_{OUT1}	$V_{DS} = 0.5V$	$R_{ext} = 744 \Omega$	-	25.26	-	mA
Current Skew (between channels)		dI_{OUT1}	$I_{OUT} = 25.26mA$ $V_{DS} \geq 0.5V$	$R_{ext} = 744 \Omega$	-	± 1	± 3	%
Output Current 2		I_{OUT2}	$V_{DS} = 0.6V$	$R_{ext} = 372 \Omega$	-	50.52	-	mA
Current Skew (between channels)		dI_{OUT2}	$I_{OUT} = 50.52mA$ $V_{DS} \geq 0.6V$	$R_{ext} = 372 \Omega$	-	± 1	± 3	%
Output Current vs. Output Voltage Regulation		$\%/dV_{DS}$	V_{DS} within 1.0V and 3.0V		-	± 0.1	-	% / V
Output Current vs. Supply Voltage Regulation		$\%/dV_{DD}$	V_{DD} within 3.2V and 3.6V		-	± 1	-	% / V
Pull-up Resistance		$R_{IN(up)}$	$\overline{OE}/\overline{SW}/\overline{ED}$		250	500	800	K Ω
Pull-down Resistance		$R_{IN(down)}$	LE/MOD		250	500	800	K Ω
Threshold Current for Error Detection		$I_{out, Th1}$	$R_{ext} = 744 \Omega$, $I_{out, target} = 25.26mA$		-	-	25.2	mA
		$I_{out, Th2}$	$R_{ext} = 372 \Omega$, $I_{out, target} = 50.52mA$		-	-	40.3	mA
Supply Current	"OFF"	$I_{DD(off) 0}$	$R_{ext} = \text{Open}$, $\overline{OUT0} \sim \overline{OUT7} = \text{Off}$		-	0.78	1.58	mA
		$I_{DD(off) 1}$	$R_{ext} = 744 \Omega$, $\overline{OUT0} \sim \overline{OUT7} = \text{Off}$		-	3.6	4.4	
		$I_{DD(off) 2}$	$R_{ext} = 372 \Omega$, $\overline{OUT0} \sim \overline{OUT7} = \text{Off}$		-	6.5	7.3	
	"ON"	$I_{DD(on) 1}$	$R_{ext} = 744 \Omega$, $\overline{OUT0} \sim \overline{OUT7} = \text{On}$		-	3.6	4.2	
		$I_{DD(on) 2}$	$R_{ext} = 372 \Omega$, $\overline{OUT0} \sim \overline{OUT7} = \text{On}$		-	6.4	7.2	

Switching Characteristics (V_{DD} = 5.0V)

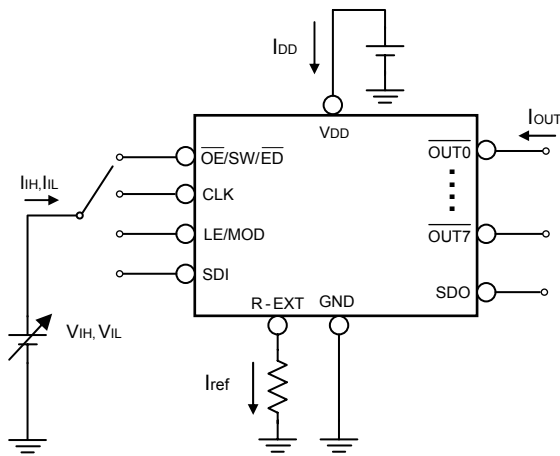
Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	CLK - $\overline{\text{OUTn}}$	t _{pLH1}	Test Circuit for Switching Characteristics V _{DD} =5.0 V V _{DS} =0.8 V V _{IH} =V _{DD} V _{IL} =GND R _{ext} =372 Ω V _L =4.0 V R _L =64 Ω C _L =10 pF	-	100	150	ns
	LE/MOD - $\overline{\text{OUTn}}$	t _{pLH2}		-	100	150	ns
	$\overline{\text{OE/SW/ED}}$ - $\overline{\text{OUTn}}$	t _{pLH3}		-	100	150	ns
	CLK - SDO	t _{pLH}		20	25	30	ns
Propagation Delay Time ("H" to "L")	CLK - $\overline{\text{OUTn}}$	t _{pHL1}		-	100	150	ns
	LE/MOD - $\overline{\text{OUTn}}$	t _{pHL2}		-	100	150	ns
	$\overline{\text{OE/SW/ED}}$ - $\overline{\text{OUTn}}$	t _{pHL3}		-	100	150	ns
	CLK - SDO	t _{pHL}		20	25	30	ns
Pulse Width	CLK	t _{w(CLK)}		20	-	-	ns
	LE/MOD	t _{w(L)}		20	-	-	ns
	$\overline{\text{OE/SW/ED}}$ (@ I _{out} < 60mA)	t _{w(OE)}		200	-	-	ns
Hold Time for LE/MOD		t _{h(L)}		10	-	-	ns
Setup Time for LE/MOD		t _{su(L)}		5	-	-	ns
Maximum CLK Rise Time		t _r ***	-	-	500	ns	
Maximum CLK Fall Time		t _f ***	-	-	500	ns	
Output Rise Time of Vout (turn off)		t _{or}	-	120	150	ns	
Output Fall Time of Vout (turn on)		t _{of}	-	200	250	ns	
Clock Frequency		F _{CLK}	Cascade Operation	-	-	25.0	MHz

*** If MBI5169 are connected in cascade and t_r or t_f is large, it may be critical to achieve the timing required for data transfer between two cascaded LED drivers MBI5169.

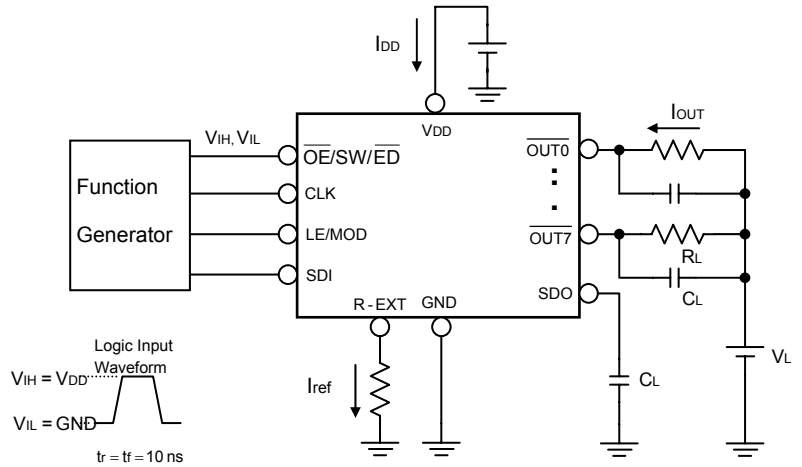
Switching Characteristics ($V_{DD} = 3.3V$)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	CLK - \overline{OUTn}	t_{pLH1}	Test Circuit for Switching Characteristics $V_{DD}=3.3V$ $V_{DS}=0.8V$ $V_{IH}=V_{DD}$ $V_{IL}=GND$ $R_{ext}=372\Omega$ $V_L=4.0V$ $R_L=64\Omega$ $C_L=10pF$	-	100	150	ns
	LE/MOD - \overline{OUTn}	t_{pLH2}		-	100	150	ns
	$\overline{OE/SW/ED}$ - \overline{OUTn}	t_{pLH3}		-	100	150	ns
	CLK - SDO	t_{pLH}		45	55	65	ns
Propagation Delay Time ("H" to "L")	CLK - \overline{OUTn}	t_{pHL1}		-	130	200	ns
	LE/MOD - \overline{OUTn}	t_{pHL2}		-	130	200	ns
	$\overline{OE/SW/ED}$ - \overline{OUTn}	t_{pHL3}		-	130	200	ns
	CLK - SDO	t_{pHL}		45	55	65	ns
Pulse Width	CLK	$t_w(CLK)$		20	-	-	ns
	LE/MOD	$t_w(L)$		20	-	-	ns
	$\overline{OE/SW/ED}$ (@ $I_{out} < 60mA$)	$t_w(OE)$		200	-	-	ns
Hold Time for LE/MOD		$t_h(L)$		10	-	-	ns
Setup Time for LE/MOD		$t_{su}(L)$		5	-	-	ns
Maximum CLK Rise Time		t_r	-	-	500	ns	
Maximum CLK Fall Time		t_f	-	-	500	ns	
Output Rise Time of Vout (turn off)		t_{or}	-	120	150	ns	
Output Fall Time of Vout (turn on)		t_{of}	-	200	400	ns	
Clock Frequency		F_{CLK}	Cascade Operation	-	-	12.0	MHz

Test Circuit for Electrical Characteristics

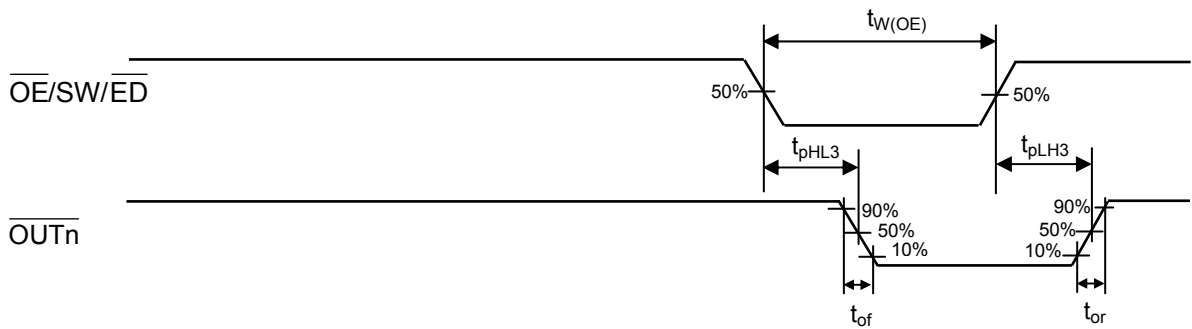
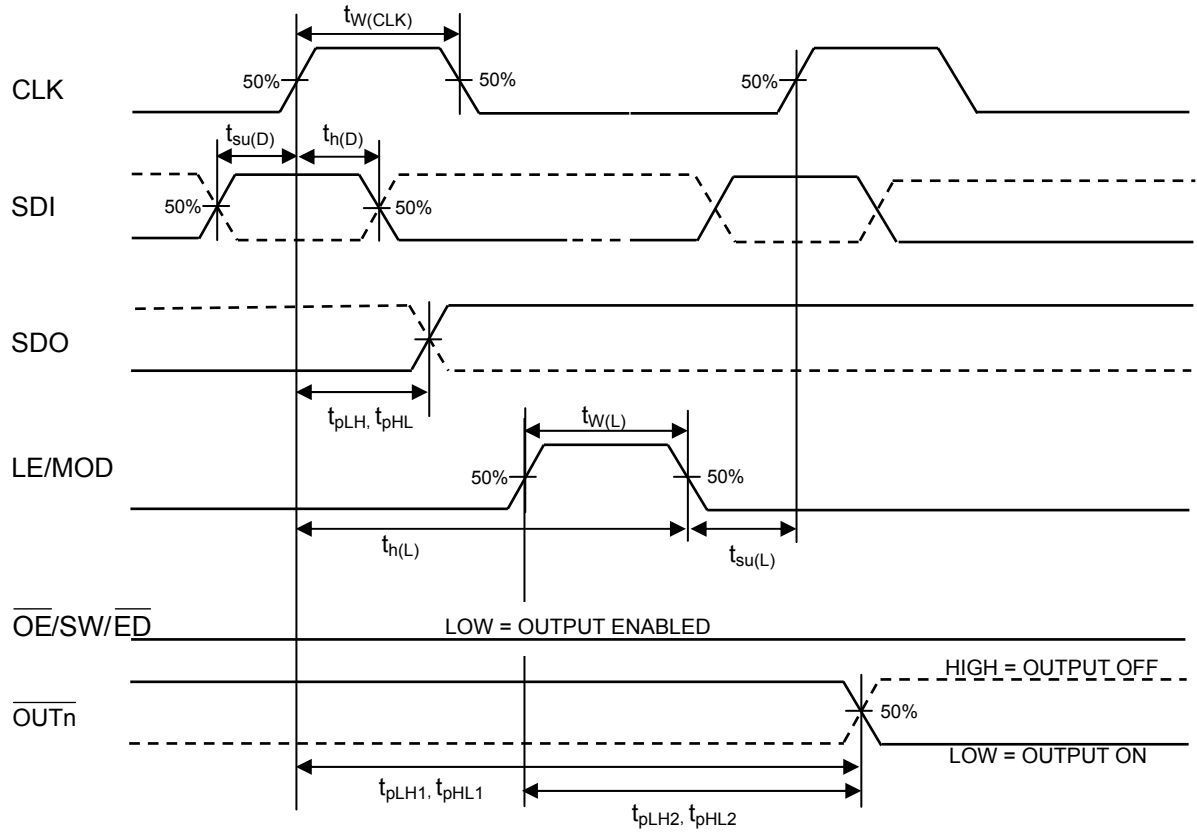


Test Circuit for Switching Characteristics

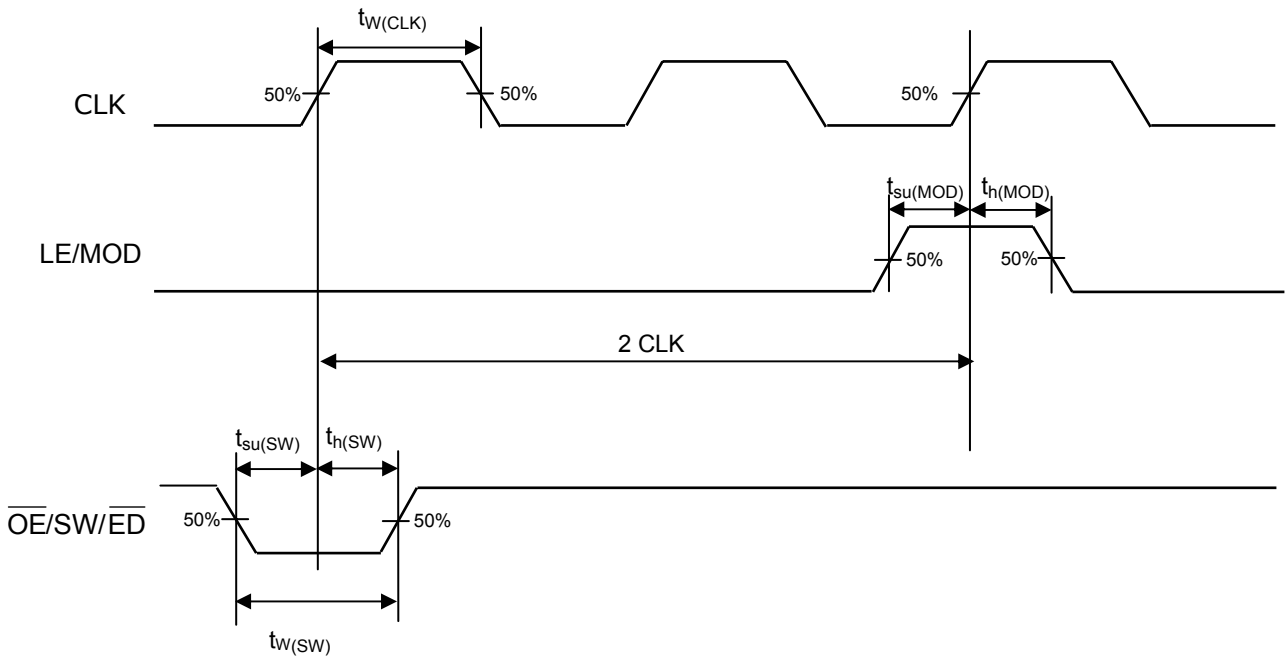


Timing Waveform

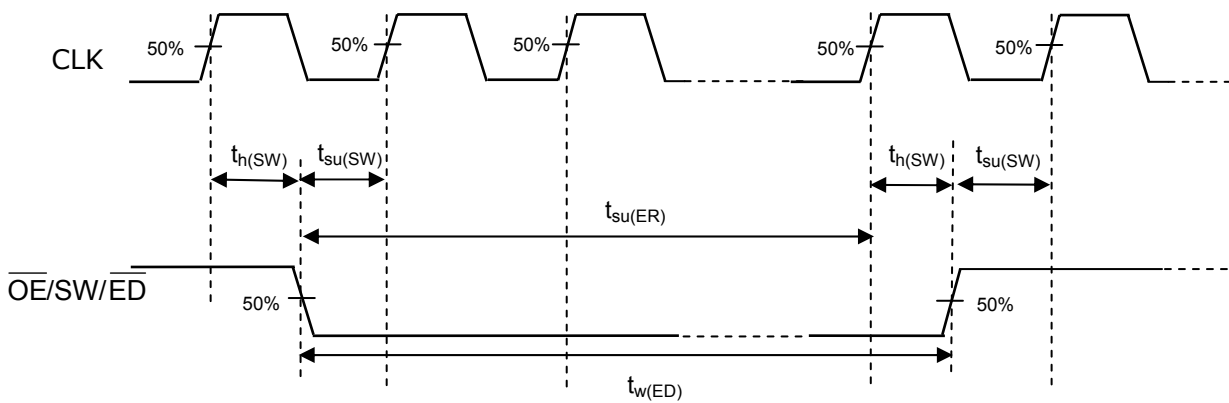
Normal Mode



Switching to Open-/Short-Circuit Detection Mode



Reading Error Status Code

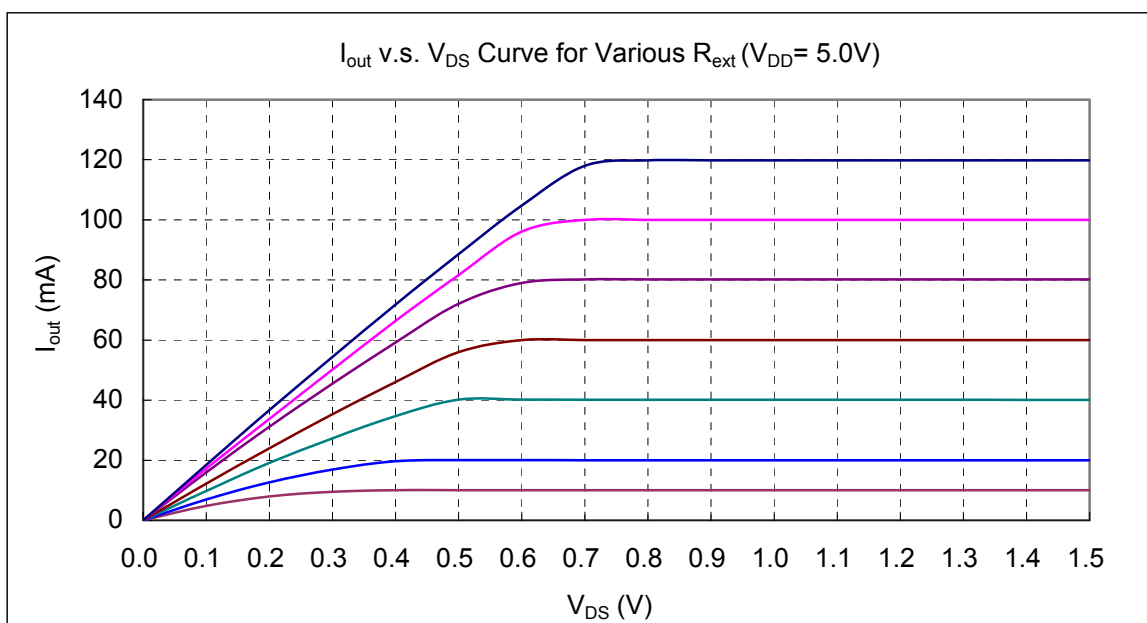


Operation Principle

Constant Current

In LED display applications, MBI5169 provides nearly no current variations from channel to channel and from IC to IC. This can be achieved by:

- 1) While $I_{OUT} \leq 100\text{mA}$, the maximum current skew between channels is less than $\pm 3\%$ and that between ICs is less than $\pm 6\%$.
- 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 (V_f).



Adjusting Output Current

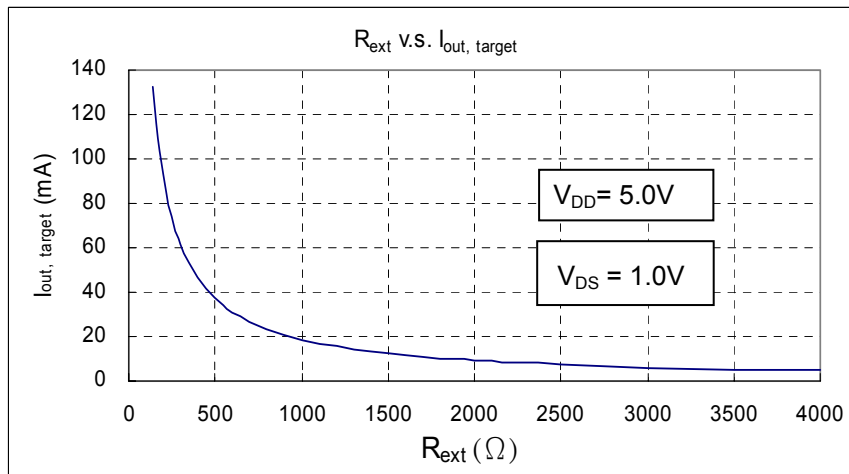
MBI5169 scales up the reference current I_{ref} set by the external resistor R_{ext} to sink a current I_{out} at each output port. As shown in the output characteristics figure, the output current in the saturation region is so flat that we define it as target current $I_{out, target}$. Following the below formulas, users can calculate the target output current $I_{out, target}$:

$$V_{R-EXT} = 1.253V$$

$$I_{ref} = V_{R-EXT} / R_{ext} \quad \text{if another end of the external resistor } R_{ext} \text{ is connected to ground.}$$

$$I_{out, target} = I_{ref} \times 15 = (1.253\text{Volt} / R_{ext}) \times 15$$

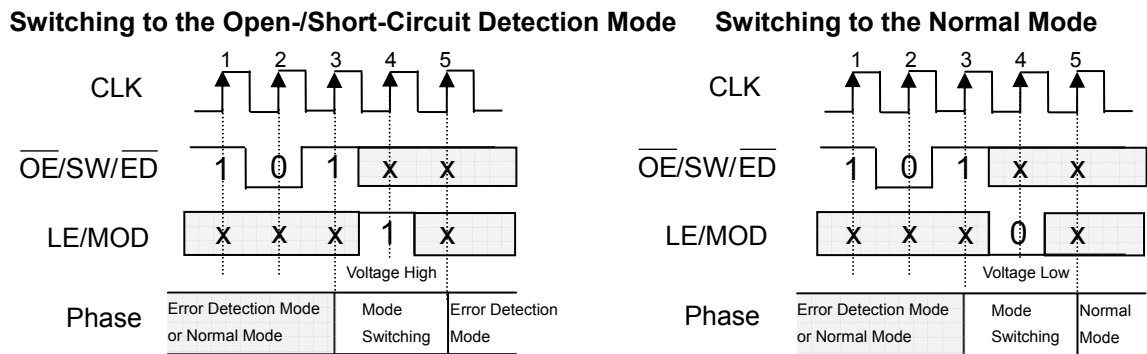
Where R_{ext} is the resistance of the external resistor connected to the R-EXT terminal and V_{R-EXT} is the voltage of the R-EXT terminal. The magnitude of current (as a function of R_{ext}) is around 50.52mA at 372Ω and 25.26mA at 744Ω. The following plot shows the relationship curve between the target output current of each channel ($I_{out, target}$) and the corresponding external resistor R_{ext} .



Operation Phases

MBI5169 exploits the **Share-I-O™** technique to extend the functionality of pins in MBI5168 in order to provide LED load error detection in Open-/Short-circuit Detection mode phase as well as the original function of MBI5168 in the Normal Mode phase. In order to switch between the two modes, MBI5169 monitors the signal $\overline{OE}/\overline{SW}/\overline{ED}$. Once a one-clock-wide pulse of $\overline{OE}/\overline{SW}/\overline{ED}$ appears, MBI5169 would enter the two-clock-period transition phase---the Mode Switching phase. After power-on, the default operation mode is the Normal Mode.

Operation Mode Switching



As shown in the above figures, once a one-clock-wide short pulse “101” of $\overline{OE/SW/ED}$ appears, MBI5169 would enter the mode switching phase. At the 4th rising edge of CLK, if LE/MOD is sampled as “Voltage High”, MBI5169 would switch to the Open-/Short-circuit Detection mode; otherwise, it would switch to the Normal Mode. Worthwhile noticing, the signal LE/MOD between the 3rd and the 5th rising edges of CLK can not latch any data. Its level is just used for determining which mode to switch. However, the short pulse of $\overline{OE/SW/ED}$ can still enable the output ports. During the mode switching, the serial data can still be transferred through the pin SDI and shifted out from the pin SDO.

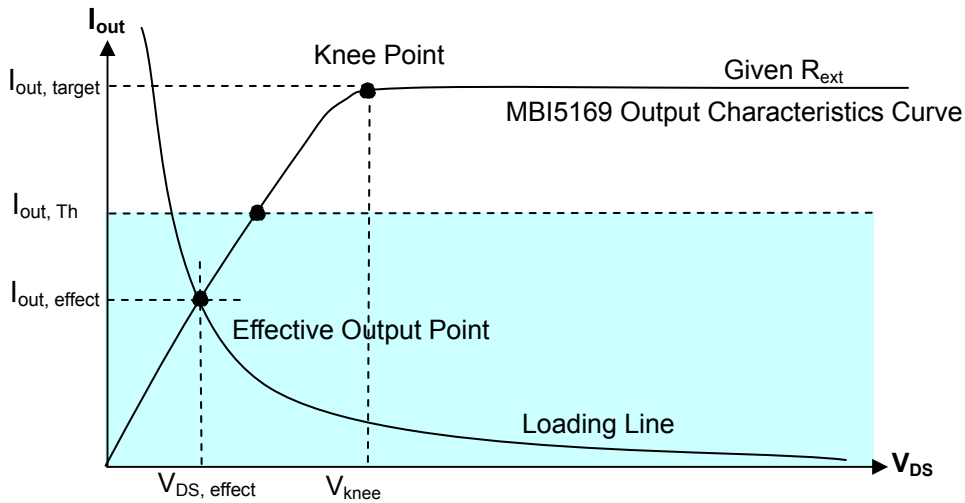
Note:

1. The signal sequence for the mode switching could be frequently used for making sure under which mode MBI5169 is working.
2. The aforementioned “1” and “0” are sampled at the rising edge of CLK. The “X” means its level would not affect the result of mode switching mechanism.

Normal Mode Phase

MBI5169 in the Normal Mode phase has similar functionality to MBI5168. The serial data could be transferred into MBI5169 via the pin SDI, shifted in the Shift Register, and go out via the pin SDO. The LE/MOD can latch the serial data in the Shift Register to the Output Latch. $\overline{OE/SW/ED}$ would enable the output drivers to sink current. The only difference is mentioned in the last paragraph about monitoring short pulse $\overline{OE/SW/ED}$. The short pulse would trigger MBI5169 to switch the operation mode. However, as long as the signal LE/MOD is not Voltage High in the Mode Switching phase, MBI5169 would still remain in the Normal Mode as if no mode switching occurs.

Open-Circuit Detection Principle



The principle of MBI5169 LED Open-Circuit Detection is based on the comparison between the effective current level $I_{out, effect}$ of each output port and the threshold current $I_{out, Th}$ corresponding to $I_{out, target}$. The cross point between the **Loading Line** and **MBI5169 Output Characteristics Curve** is called as effective output point ($V_{DS, effect}$, $I_{out, effect}$). If LED fails, for instance, due to open circuit, the **Loading Line** and the effective output point would change. Then, MBI5169 would catch the error status. But if the port is disabled, the output current would be absolutely 0mA and MBI5169 could not distinguish the change of the **Loading Line**. Thus, to detect the status of LED correctly, the output ports must be enabled. The relationship between the detected Error Status code and the position of the effective output point is shown in the following table.

State of Output Port	Condition of Effective Output Point	Detected Open-Circuit Error Status Code	Meaning
OFF	$I_{out, effect} = 0mA \ll I_{out, Th}$	"0"	-
ON	$I_{out, effect} < I_{out, Th}$	"0"	Open Circuit
	$I_{out, effect} \geq I_{out, Th}$	"1"	Normal

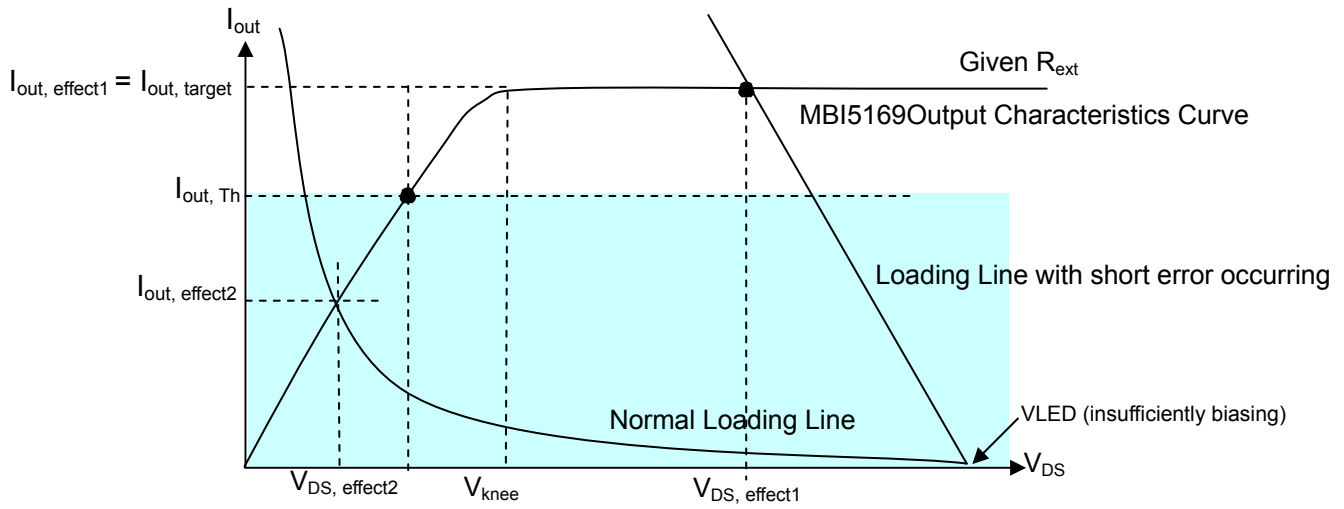
Note : As $I_{out, target} \geq 25mA$, the threshold current $I_{out, Th} = I_{out, target} \times 0.6 + 10mA$

As $I_{out, target} < 25mA$, the threshold current $I_{out, Th} = I_{out, target}$

Because the target current $I_{out, target}$ in the saturation region set by the external resistor R_{ext} is a little bigger than the corresponding threshold current $I_{out, Th}$ for error detection, system design engineers had better place the effective output point of normal LED load in the saturation region near the knee point, for instance, if they want to detect the LED open error. Then while LED is open, the effective output point would move to the origin, where $I_{out} = 0mA$. So, MBI5169 can distinguish and detect it and report an error status codes "0".

In fact, if LED's are normal, the enabled ports would report error status codes "1" and the disabled would report "0". The error status codes are the same as the content in the Output Latch.

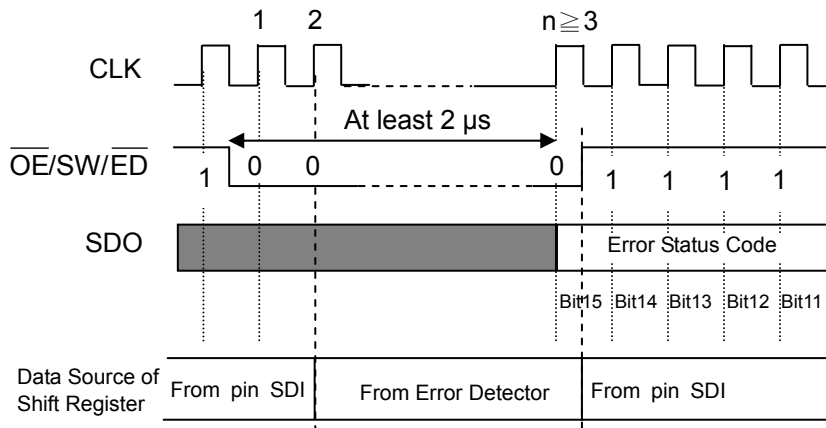
Short-Circuit Detection Principle



When LED is damaged, a short-circuit error may occur. To effectively detect the short-circuit error, LEDs need insufficiently biasing. The principle of MBI5169 LED Short Circuit Detection is based on the fact that the LED loading status is judged by comparing the effective current value ($I_{out, effect}$) of each output port with the threshold current ($I_{out, Th}$). When normal LED is insufficiently biased, its effective output point would be located at the segment $I_{out, effect} < I_{out, Th}$ of **MBI5169 Output Characteristics Curve**, compared with LED with a short error falling within the segment $I_{out, effect} > I_{out, Th}$. The relationship between the Error Status code and the effective output point is shown below:

State of Output Port	Condition of Effective Output Point	Detected Short-Circuit Error Status Code	Meaning
OFF	$I_{out, effect} = 0$	"0"	-
ON	$I_{out, effect} < I_{out, Th}$	"0"	Normal
	$I_{out, effect} \geq I_{out, Th}$	"1"	Short Circuit

Open-/Short-Circuit Detection Mode Phase and Reading Error Status Code



In the Open-/Short-circuit Detection mode, as long as $\overline{OE/SW/ED}$ is not at the Voltage Low, the serial data can still be shifted to the Shift Register via the pin SDI and shifted out via the SDO pin, and the positive pulse of LE/MOD can also make the data in the Shift Register latched to 8-bit Output Latch, as in the Normal Mode.

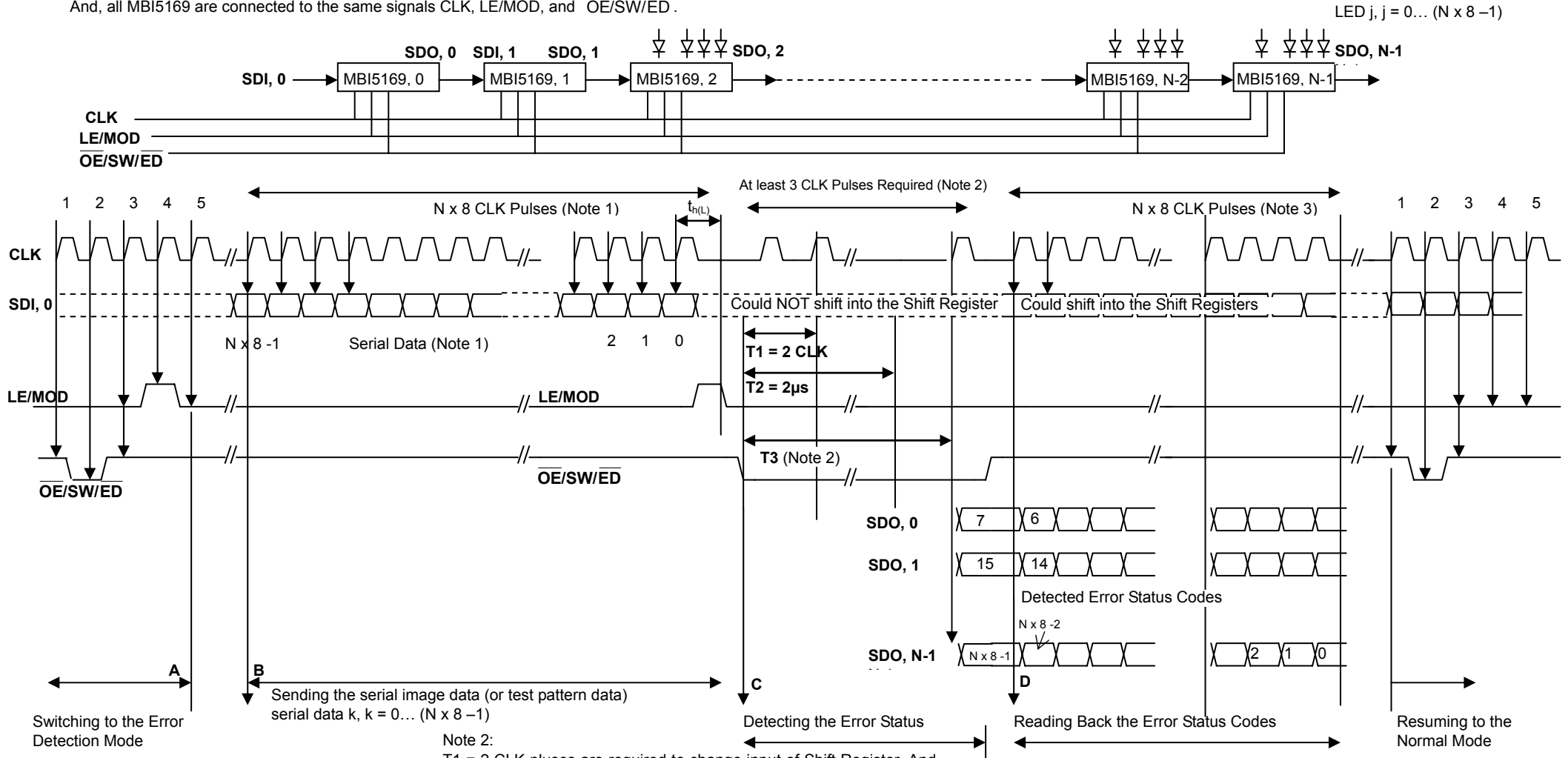
The difference between the Open-/Short-circuit Detection mode from the Normal Mode is that when the state of $\overline{OE/SW/ED}$ is pulled down to Voltage Low, MBI5169 in the Open-/Short-circuit Detection mode would execute error detection and load error status codes into the Shift Register, as well as enabling output ports to sink current. The above figure shows the timing sequence for error detection. The shown “0” and “1” are sampled at the rising edge of each CLK. At least three “0” must be sampled at the Voltage Low signal $\overline{OE/SW/ED}$. Just after the 2nd “0” is sampled, the data input source of the Shift Register would come from 8-bit parallel error status codes out of the circuit Error Detector, instead of serial data out of the pin SDI. Normally, the error status codes will be correctly generated at least 2 μ s after the falling edge of $\overline{OE/SW/ED}$. The occurrence of the 3rd or later “0” results in the event that MBI5169 saves the detected error status codes into the Shift Register. Thus, when $\overline{OE/SW/ED}$ is at the Voltage Low state, the serial data cannot be shifted into MBI5169 via the pin SDI. But when the state of $\overline{OE/SW/ED}$ is pulled up to Voltage High from Voltage Low, the data input source of the Shift Register would again come from the pin SDI. At the same time, the output ports are disabled and the error detection is completed. Then, the error status codes saved in the Shift Register could be shifted out via the pin SDO bit by bit along with CLK, as well as the new serial data can be shifted into MBI5169 via the pin SDI.

To sum up, MBI5169 in the Open-/Short-circuit Detection mode could transfer and latch new serial image data and show them to the output ports, as well as detecting LED load error status. The limitation is that in the Open-/Short-circuit Detection mode, it couldn't be allowed to **simultaneously** transfer serial data and detect LED load error status.

Timing Chart for Open-/Short- Circuit Detection Mode (An Example)

N of MBI5169 are connected in cascade, ie, SDO, k --> SDI, k+1.

And, all MBI5169 are connected to the same signals CLK, LE/MOD, and $\overline{OE}/\overline{SW}/\overline{ED}$.



Note 1:
N x 8 CLK pulses are required to shift the serial image data N x 8 bits needed by N of MBI5169.

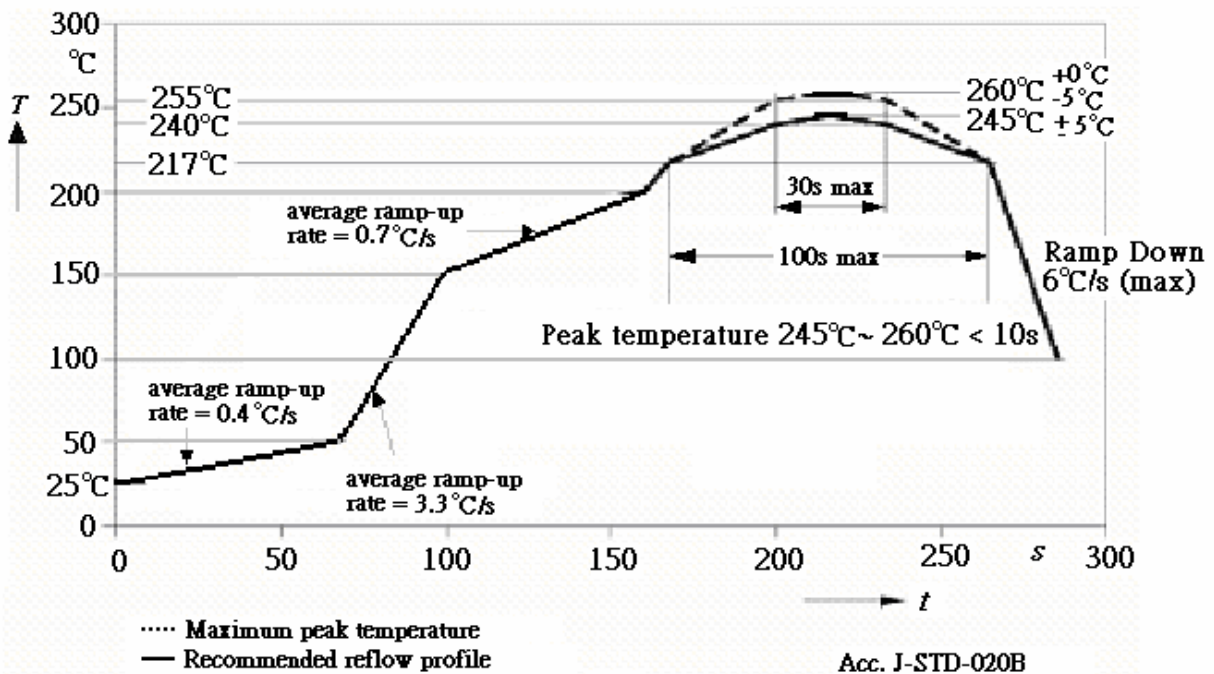
Note 2:
T1 = 2 CLK pluses are required to change input of Shift Register. And, when Short-Circuit Detection is executed, LEDs should be insufficiently biased during this period.
T2 = 2 μs is required to obtain the stable error status result.
T3 = the third CLK pulses is required before $\overline{OE}/\overline{SW}/\overline{ED}$ goes Voltage High. The rising edge of CLK writes the error status codes back to the MBI5169 built-in Shift Register.

Note 3:
The rising edge of CLK after the rising edge of $\overline{OE}/\overline{SW}/\overline{ED}$ would shift the new serial image data and error codes. An LED error will be represented by a "0", to overwrite the original image data "1". Image Data k, k = 0... (N x 8 - 1), = all "1" is suggested. N x 8 CLK pulses shift all N x 8 error results (Error Status Code) via Node SDO, N-1.

Application Information

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

Macroblock has defines "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 is backward compatible to standard 215°C to 240°C 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 up to 260°C for proper soldering on boards, referring to J-STD-020B as shown below.



*Note1: For details, please refer to Macroblock’s “Policy on Pb-free & Green Package”.

Package Power Dissipation (P_D)

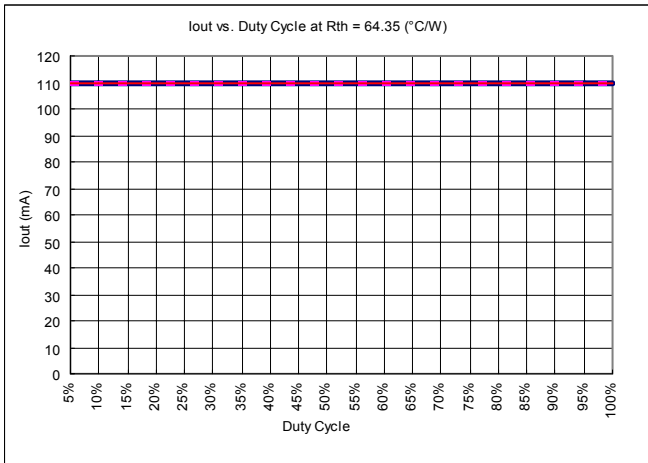
The maximum allowable package power dissipation is determined as $P_{D(max)} = (T_j - T_a) / R_{th(j-a)}$. When 8 output channels are turned on simultaneously, the actual package power dissipation is

$$P_{D(act)} = (I_{DD} \times V_{DD}) + (I_{OUT} \times Duty \times V_{DS} \times 8)$$

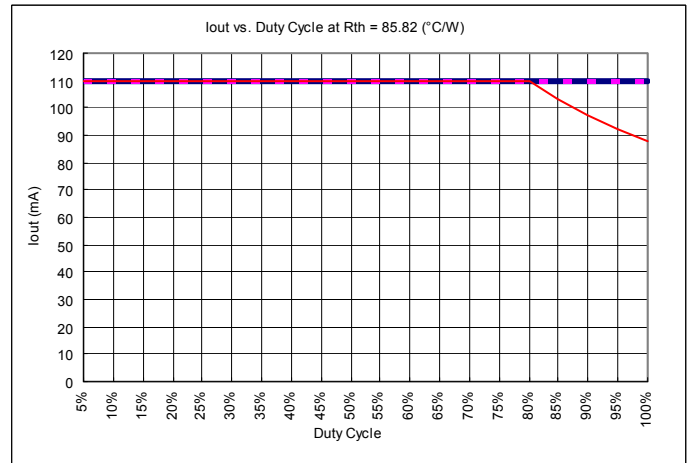
Therefore, to keep $P_{D(act)} \leq P_{D(max)}$, the allowable maximum output current as a function of duty cycle is

$$I_{OUT} = \{ [(T_j - T_a) / R_{th(j-a)}] - (I_{DD} \times V_{DD}) \} / V_{DS} / Duty / 8$$

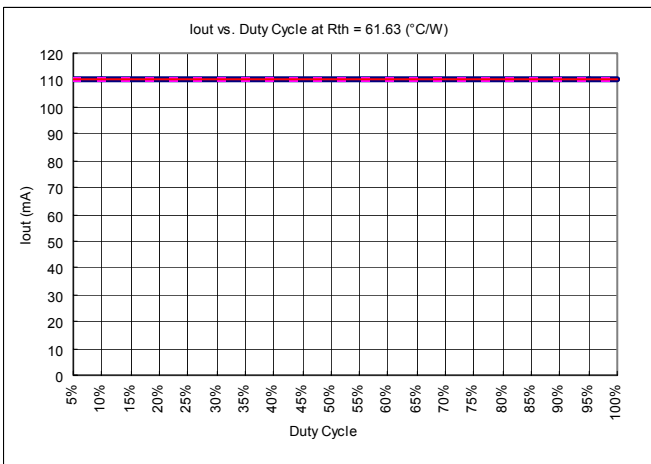
where $T_j = 150^\circ\text{C}$.



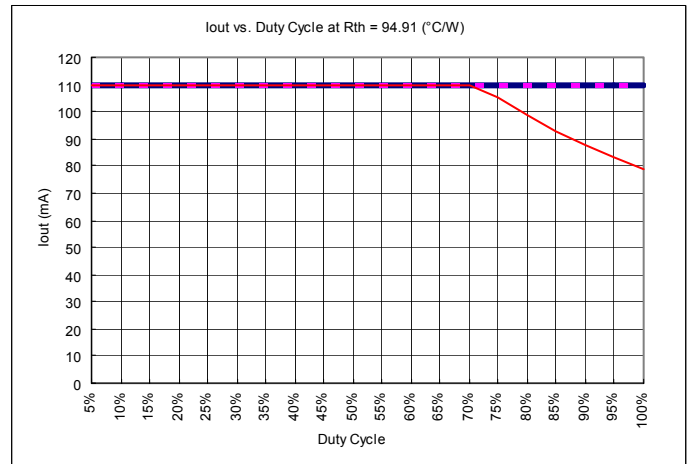
CN\GN Device Type



CD\GD Device Type



CDW\GDW Device



CP\GP Device Type

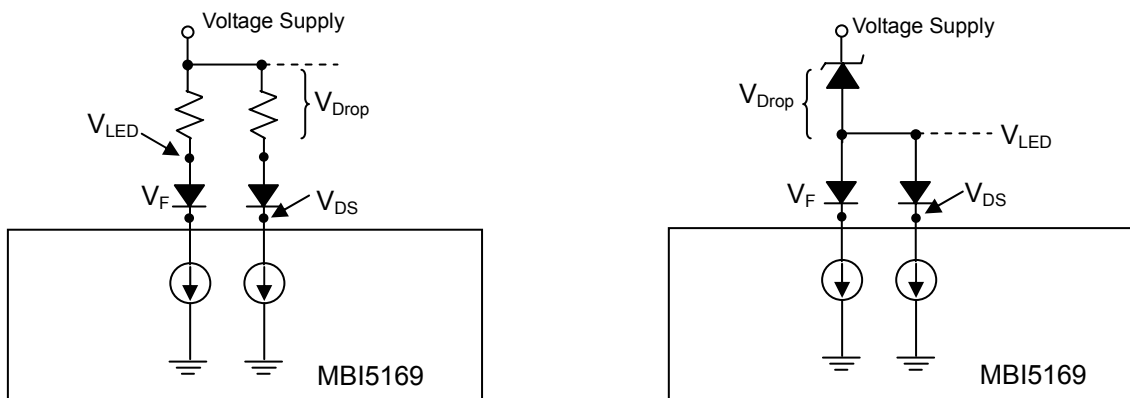
Condition : $V_{DS} = 1.0\text{V}$, $V_{DD} = 5.0\text{V}$, 8 output channels active, T_a is listed in the legend below.

Device Type		$R_{th(j-a)}$ (°C/W)		Note
CN	GN	64.35	60.20	
CD	GD	85.82	70.14	
CDW	GDW	61.63	68.67	
CP	GP	94.91	80.00	

— 25°C
 - - - 55°C
 — 85°C

Load Supply Voltage (V_{LED})

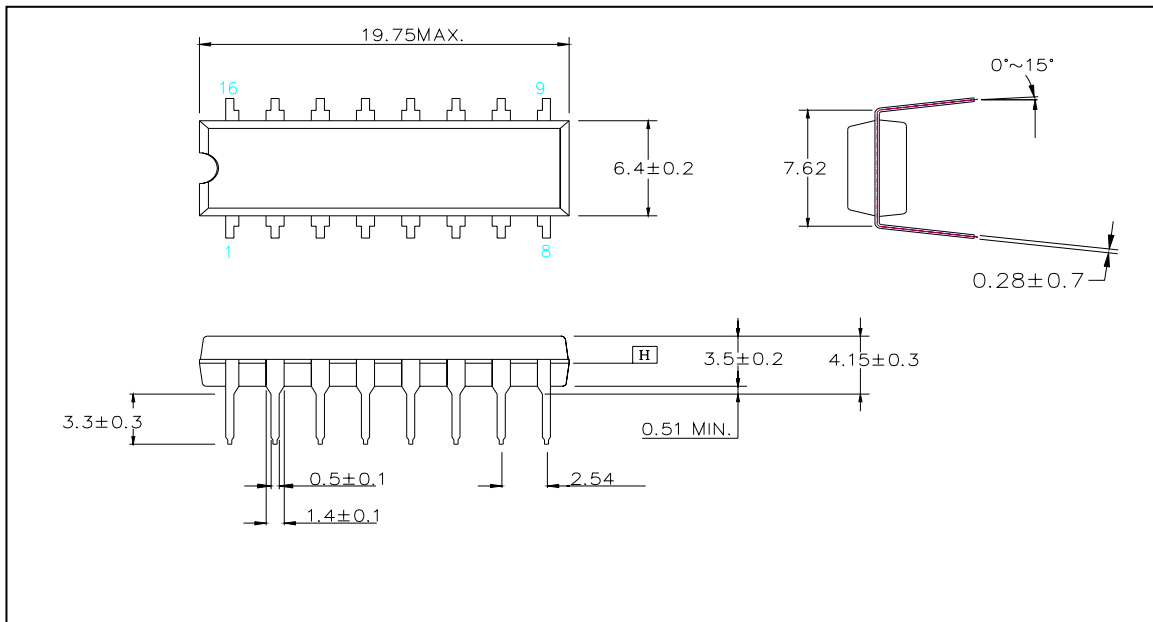
Considering the package power dissipating limits, users had better operate MBI5169 within $V_{DS} = 0.4V \sim 1.0V$. If V_{LED} is higher, for instance, than 5V, V_{DS} may be so high that $P_{D(Act)} > P_{D(max)}$, where $V_{DS} = V_{LED} - V_F$. In this case, it is recommended to use as low supply voltage as possible or to arrange a voltage reducer, V_{DROP} . The voltage reducer lets $V_{DS} = (V_{LED} - V_F) - V_{DROP}$. Resistors or Zener diodes can be used as the reducers in the applications as shown in the following figures.



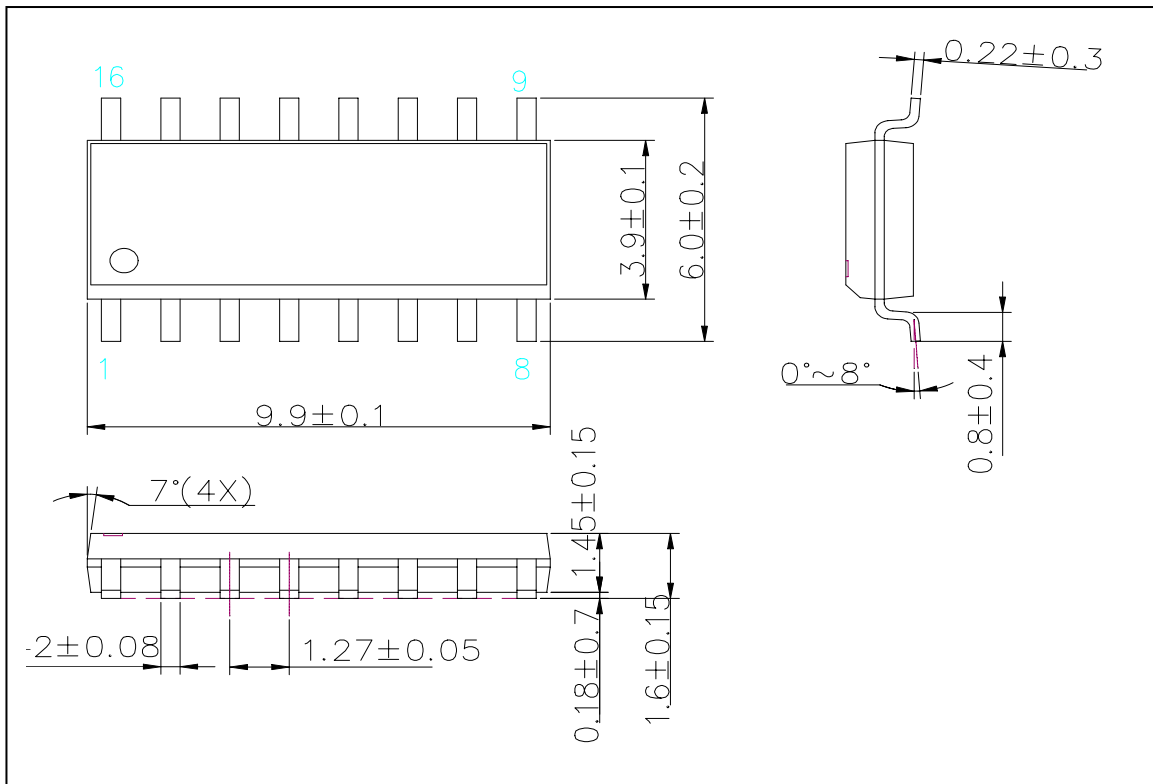
Switching Noise Reduction

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

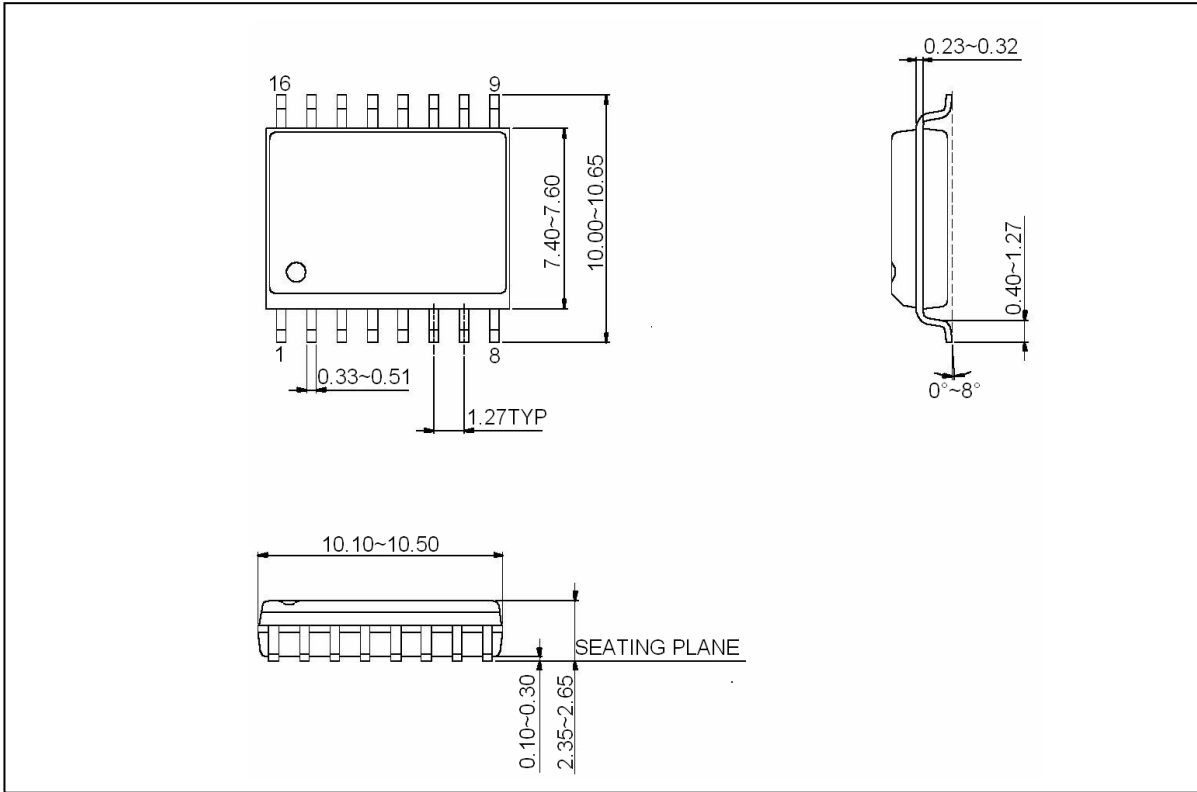
Outline Drawings



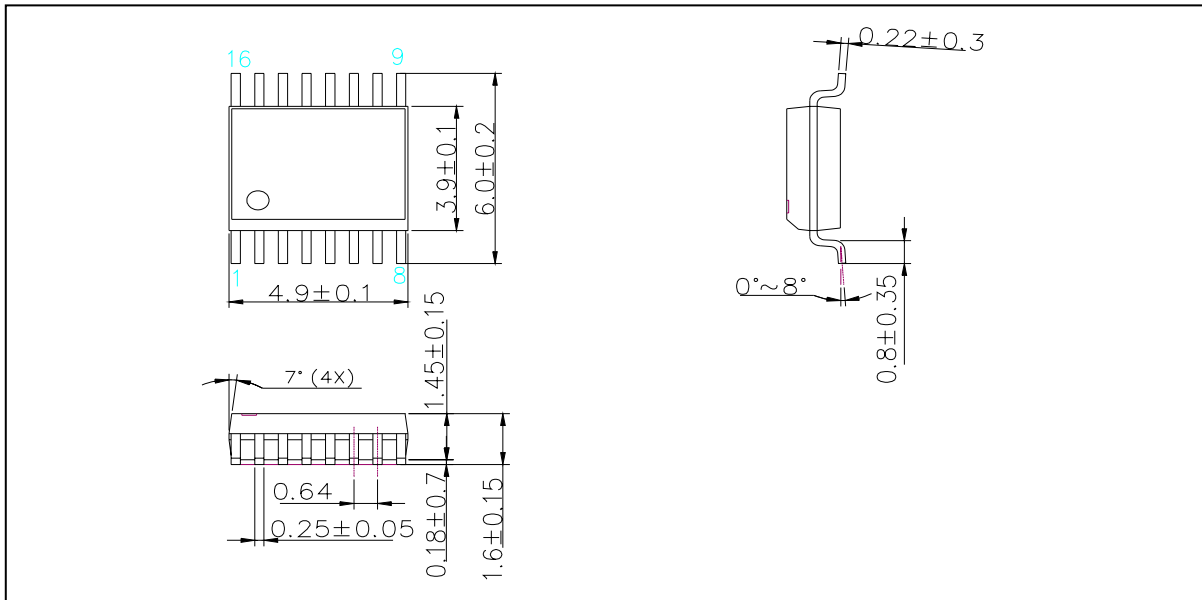
MBI5169CN\IGN Outline Drawing



MBI5169CD\GD Outline Drawing



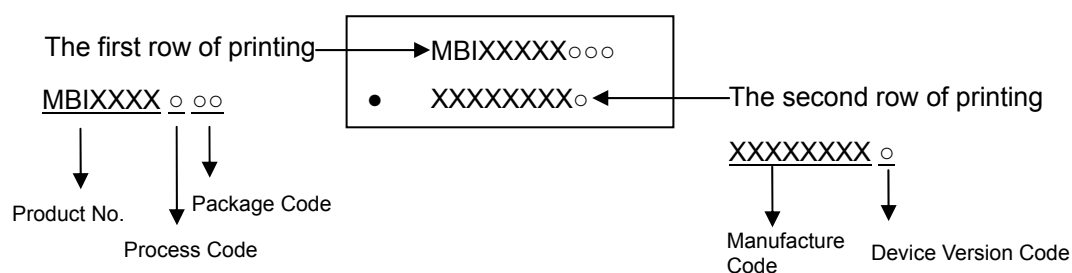
MBI5169CDW/GDW Outline Drawing



MBI5169CP/GP Outline Drawing

Note: The unit for the outline drawing is mm.

Product Top-mark Information



Product Revision History

Datasheet version	Device version code
VA.00	<i>Not defined</i>
VA.02	A

Product Ordering Information

Part Number	Package Type	Weight (g)
MBI5169CN	P-DIP16-300-2.54	1.02
MBI5169CD	SOP16-150-1.27	0.13
MBI5169CDW	SOP16-300-1.27	0.37
MBI5169CP	SSOP16-150-0.64	0.07

Part Number	“Pb-free & Green” Package Type	Weight (g)
MBI5169GN	P-DIP16-300-2.54	1.02
MBI5169GD	SOP16-150-1.27	0.13
MBI5169GDW	SOP16-300-1.27	0.37
MBI5169GP	SSOP16-150-0.64	0.07

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