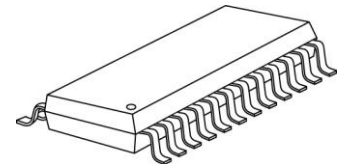
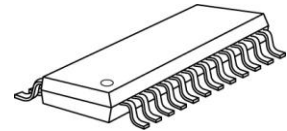


**16-Channel Constant Current LED Sink Driver
with Low Knee Voltage****Features**

- 16 constant-current output channels
- Constant output current invariant to load voltage change:
Constant output current range:
3-40mA@ $V_{DD}=5V$;
3-30mA@ $V_{DD}=3.3V$
- Excellent output current accuracy:
-between channels: $\pm 3\%$ (typ.) and $\pm 5\%$ (max.)
-between ICs: $\pm 3\%$ (typ.) and $\pm 6\%$ (max.)
- Low Knee Voltage:
 $I_{OUT}=20mA @ V_{DS}=0.2V; V_{DD}=3.3V$
 $I_{OUT}=20mA @ V_{DS}=0.2V; V_{DD}=5.0V$
- Output current adjusted through an external resistor
- Fast response of output current, \overline{OE} (min.): 70ns with good uniformity between output channels
- Staggered delay of output
- 25MHz clock frequency
- Schmitt trigger input
- 3.3V/ 5V supply voltage
- "Pb-free & Green" Package

Small Outline Package

GF: SOP24-300-1.00

Shrink SOP

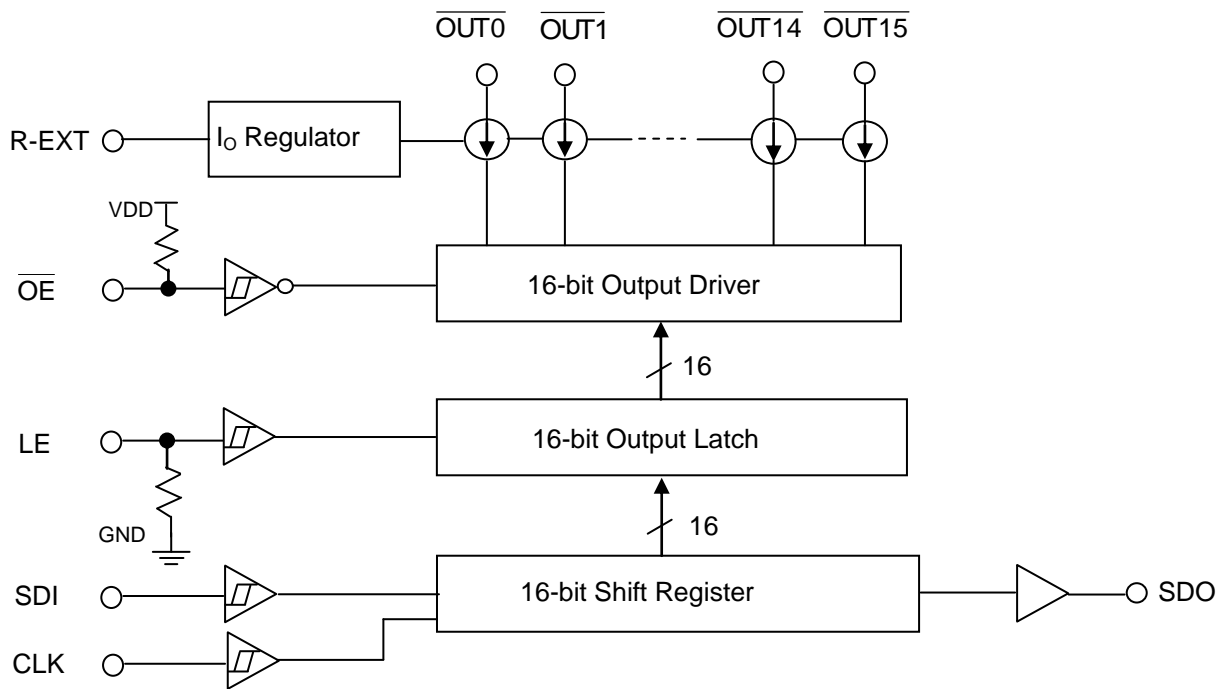
GP: SSOP24L-150-0.64

Product Description

MBI5035 is a 16-channel constant current LED driver with $V_{DS}=0.2V @ I_{OUT}=20mA$, which is excellent compared to the conventional design. MBI5035 is especially designed for low power consumption LED display applications. The low knee voltage (LKV) design makes MBI5035 work at a constant output current with low V_{DS} and still guarantees PrecisionDrive™ feature. With PrecisionDrive™, MBI5035 is designed for LED displays which require to operate at low current and match the luminous intensity of each channel. MBI5035 contains a serial buffer and data latches which convert serial input data into parallel output format. At MBI5035 output stage, sixteen regulated current ports are designed to provide uniform and constant current sinks for driving LEDs within a large range of V_F variations.

MBI5035 provides users with great flexibility and device performance in their low power system design for LED display applications. It accepts an input voltage range from 3.3V to 5.0V and maintains constant current up from 3mA to 40mA determined by an external resistor, R_{ext} , which gives users flexibility in controlling the light intensity of LEDs. MBI5035 guarantees to endure maximum 17V at the output port. The high clock frequency, 25 MHz, also satisfies the system requirements of high volume data transmission.

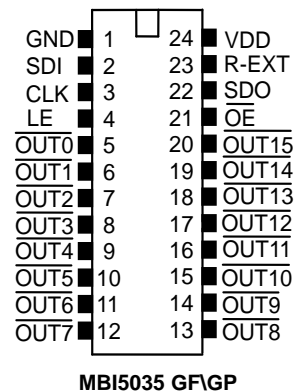
Block Diagram



Terminal Description

Pin No.	Pin Name	Function
1	GND	Ground terminal for control logic and current sink
2	SDI	Serial-data input to the shift register
3	CLK	Clock input terminal for data shift on rising edge
4	LE	Data strobe input terminal Serial data is transferred to the output latch when LE is high. The data will be latched when LE goes low.
5~20	$\overline{\text{OUT0}} \sim \overline{\text{OUT15}}$	Constant current output terminals
21	$\overline{\text{OE}}$	Output enable terminal When $\overline{\text{OE}}$ is (active) low, the output drivers are enabled; when $\overline{\text{OE}}$ is high, all output drivers are turned OFF (blanked).
22	SDO	Serial-data output to the following SDI of next driver IC. SDO signal changes on rising edge of CLK.
23	R-EXT	Input terminal used to connect an external resistor for setting up output current for all output channels
24	VDD	3.3V/5V supply voltage terminal

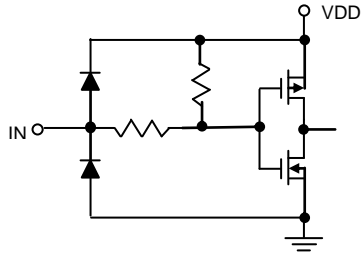
Pin Configuration



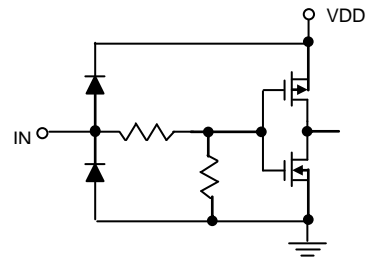
MBI5035 GF/GP

Equivalent Circuits of Inputs and Outputs

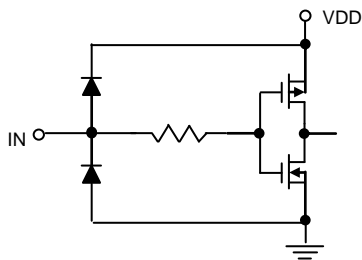
\overline{OE} terminal



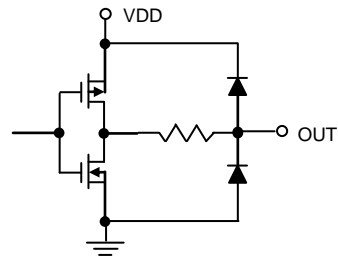
LE terminal



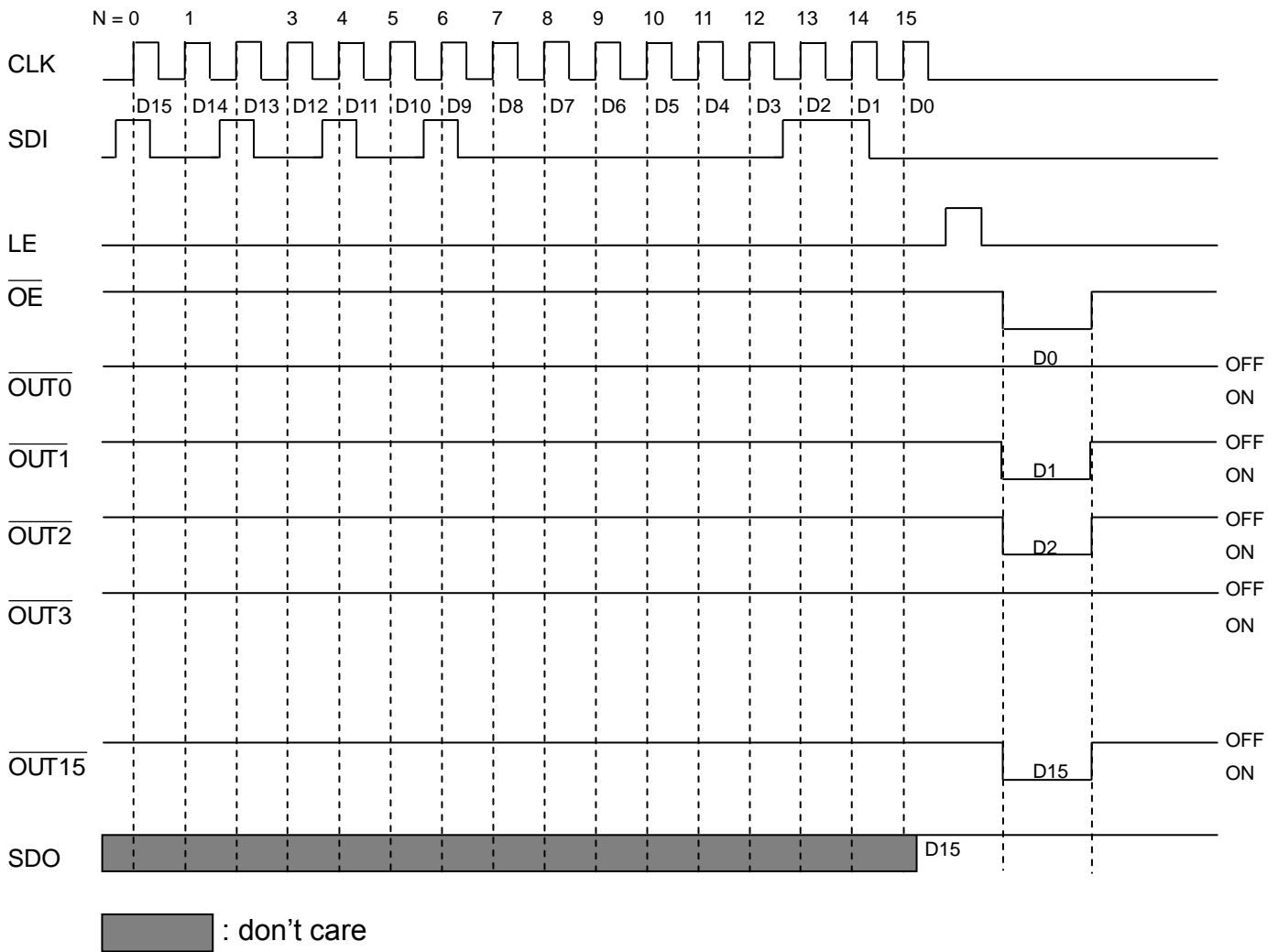
CLK, SDI terminal



SDO terminal



Timing Diagram



Truth Table

CLK	LE	OE	SDI	OUT0...OUT7...OUT15	SDO
	H	L	D_n	$\overline{D_n} \dots \overline{D_{n-7}} \dots \overline{D_{n-15}}$	D_{n-15}
	L	L	D_{n+1}	No Change	D_{n-14}
	H	L	D_{n+2}	$\overline{D_{n+2}} \dots \overline{D_{n-5}} \dots \overline{D_{n-13}}$	D_{n-13}
	X	L	D_{n+3}	$\overline{D_{n+2}} \dots \overline{D_{n-5}} \dots \overline{D_{n-13}}$	D_{n-13}
	X	H	D_{n+4}	Off	D_{n-13}

Maximum Ratings

Characteristic		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}	+50	mA
Sustaining Voltage at OUT Port		V_{DS}	-0.5~+17.0	V
GND Terminal Current		I_{GND}	+800	mA
Power Dissipation (On PCB, $T_a=25^{\circ}C$)	GF-type	P_D	2.35	W
	GP-type		1.76	
Thermal Resistance (On PCB, $T_a=25^{\circ}C$)	GF-type	$R_{th(j-a)}$	53.28	$^{\circ}C/W$
	GP-type		70.90	
Operating Temperature		T_{opr}	-40~+85	$^{\circ}C$
Storage Temperature		T_{stg}	-55~+150	$^{\circ}C$

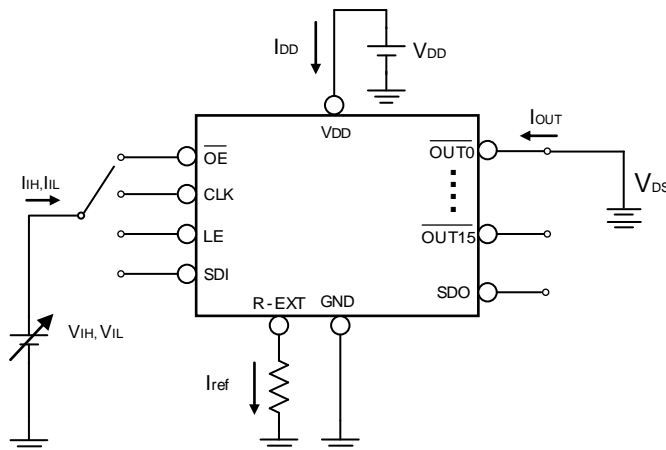
Electrical Characteristics (V_{DD} = 5.0V)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V _{DD}	-	4.5	5.0	5.5	V
Sustaining Voltage at OUT Ports		V _{DS}	$\overline{\text{OUT0}} \sim \overline{\text{OUT15}}$	-	-	17.0	V
Output Current		I _{OUT}	Refer to "Test Circuit for Electrical Characteristics"	3	-	40	mA
		I _{OH}	SDO	-	-	-1.0	mA
		I _{OL}	SDO	-	-	1.0	mA
Input Voltage	"H" level	V _{IH}	Ta = -40~85°C	0.7*V _{DD}	-	V _{DD}	V
	"L" level	V _{IL}	Ta = -40~85°C	GND	-	0.3*V _{DD}	V
Output Leakage Current		I _{OH}	V _{DS} =17.0V	-	-	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} =0.25V R _{ext} =930 Ω	-	20	-	mA
Current Skew (Channel)		dl _{OUT1}	I _{OUT} =20mA V _{DS} =0.25V R _{ext} =930Ω	-	±3.0	±5.0	%
Current Skew (IC)		dl _{OUT2}	I _{OUT} =20mA V _{DS} =0.25V R _{ext} =930Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation		%/dV _{DS}	V _{DS} within 0.25V and 1.5V	-	±0.2	±0.5	%/V
Output Current vs. Supply Voltage Regulation		%/dV _{DD}	V _{DD} within 4.5V and 5.5V	-	±1.0	±2.0	%/V
Low Knee Voltage		V _{DS}	I _{OUT} =20mA	-	0.2	0.25	V
Pull-up Resistor		R _{IN(up)}	$\overline{\text{OE}}$	250	500	800	KΩ
Pull-down Resistor		R _{IN(down)}	LE	250	500	800	KΩ
Supply Current	"OFF"	I _{DD(off) 1}	R _{ext} =Open, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{Off}$	-	2.5	4.5	mA
		I _{DD(off) 2}	R _{ext} =6000Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{Off}$	-	3.5	5.5	
		I _{DD(off) 3}	R _{ext} =930Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{Off}$	-	7.0	9.0	
	"ON"	I _{DD(on) 1}	R _{ext} =6000Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{On}$	-	3.5	5.5	
		I _{DD(on) 2}	R _{ext} =930Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{On}$	-	7.0	9.5	

Electrical Characteristics (V_{DD} = 3.3V)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V _{DD}	-	3.0	3.3	3.6	V
Sustaining Voltage at OUT Ports		V _{DS}	$\overline{\text{OUT0}} \sim \overline{\text{OUT15}}$	-	-	17.0	V
Output Current		I _{OUT}	Refer to "Test Circuit for Electrical Characteristics"	3	-	30	mA
		I _{OH}	SDO	-	-	-1.0	mA
		I _{OL}	SDO	-	-	1.0	mA
Input Voltage	"H" level	V _{IH}	T _a =-40~85°C	0.7*V _{DD}	-	V _{DD}	V
	"L" level	V _{IL}	T _a =-40~85°C	GND	-	0.3*V _{DD}	V
Output Leakage Current		I _{OH}	V _{DS} =17.0V	-	-	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} =0.25V R _{ext} =930 Ω	-	20	-	mA
Current Skew (Channel)		dI _{OUT1}	I _{OUT} =20mA V _{DS} =0.25V R _{ext} =930Ω	-	±3.0	±5.0	%
Current Skew (IC)		dI _{OUT2}	I _{OUT} =20mA V _{DS} =0.25V R _{ext} =930Ω	-	±3.0	±6.0	%
Output Current vs. Output Voltage Regulation		%/dV _{DS}	V _{DS} within 0.5V and 1.5V	-	±0.2	±0.5	%/V
Output Current vs. Supply Voltage Regulation		%/dV _{DD}	V _{DD} within 3.0V and 3.6V	-	±1.0	±2.0	%/V
Low Knee Voltage		V _{DS}	I _{OUT} =20mA	-	0.2	0.25	V
Pull-up Resistor		R _{IN(up)}	$\overline{\text{OE}}$	250	500	800	KΩ
Pull-down Resistor		R _{IN(down)}	LE	250	500	800	KΩ
Supply Current	"OFF"	I _{DD(off) 1}	R _{ext} =Open, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{Off}$	-	2.0	4.0	mA
		I _{DD(off) 2}	R _{ext} =6000Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{Off}$	-	3.0	5.0	
		I _{DD(off) 3}	R _{ext} =930Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{Off}$	-	6.5	8.5	
	"ON"	I _{DD(on) 1}	R _{ext} =6000Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{On}$	-	3.0	5.5	
		I _{DD(on) 2}	R _{ext} =930Ω, $\overline{\text{OUT0}} \sim \overline{\text{OUT15}} = \text{On}$	-	6.5	9.0	

Test Circuit for Electrical Characteristics



Switching Characteristics (V_{DD} = 5.0V)

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	CLK- $\overline{\text{OUT0}}$	t _{pLH1}	V _{IH} =V _{DD} V _{IL} =GND R _{ext} =930Ω R _L =150Ω C _L =10PF I _{OUT} =20mA C1=100nF C2=22 μ F C _{SDO} =10PF V _L =3.3V	-	55	65	ns
	LE- $\overline{\text{OUT0}}$	t _{pLH2}		-	55	65	ns
	$\overline{\text{OE}}$ - $\overline{\text{OUT0}}$	t _{pLH3}		-	55	65	ns
	CLK-SDO	t _{pLH}		-		40	ns
Propagation Delay Time ("H" to "L")	CLK- $\overline{\text{OUT0}}$	t _{pHL1}		-	35	45	ns
	LE- $\overline{\text{OUT0}}$	t _{pHL2}		-	35	45	ns
	$\overline{\text{OE}}$ - $\overline{\text{OUT0}}$	t _{pHL3}		-	35	45	ns
	CLK-SDO	t _{pHL}		-		40	ns
Staggered Delay of Output*	Output Group 1~ Output Group 2	t _{stag1}		-	5	10	ns
Pulse Width	CLK	t _{w(CLK)}		20	-	-	ns
	LE	t _{w(L)}		20	-	-	ns
Data Clock Frequency		F _{CLK}		-	-	25	MHz
Hold Time for LE		t _{h(L)}		10	-	-	ns
Setup Time for LE		t _{su(L)}		10	-	-	ns
Hold Time for SDI		t _{h(D)}		5	-	-	ns
Setup Time for SDI		t _{su(D)}		3	-	-	ns
Maximum CLK Rise Time		t _r		-	-	500	ns
Maximum CLK Fall Time		t _f		-	-	500	ns
SDO Rise Time		t _{r,SDO}		-	10	-	ns
SDO Fall Time		t _{f,SDO}		-	10	-	ns
Output Rise Time of Output Ports		t _{or}	30	35		ns	
Output Fall Time of Output Ports		t _{of}	30	35	-	ns	
$\overline{\text{OE}}$ Pulse Width		t _{w(OE)}	70	100	-	ns	
Output On-time Error		t _{ON_ERR}	On/off latch data=all "1", 70 ns $\overline{\text{OE}}$ low level one-shot pulse input	0	7	12	ns

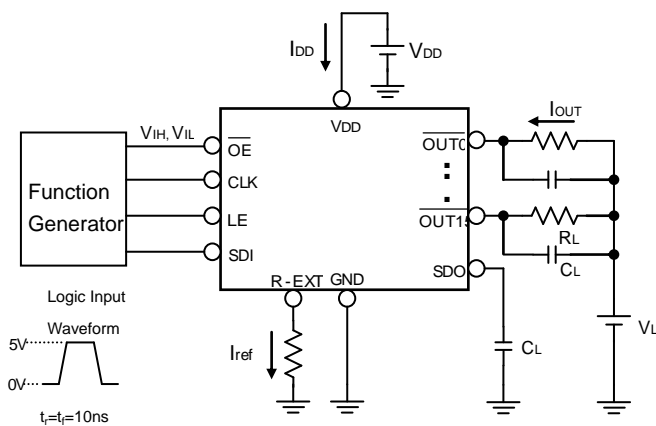
* MBI5035 has a built-in stagger circuit to perform delay mechanism. Among output ports exist a graduated 5ns delay time between $\overline{\text{OUT}2n}$ and $\overline{\text{OUT}2n+1}$, by which the output ports will be divided to two groups at a different time so that the instant current from the power line will be lowered.

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

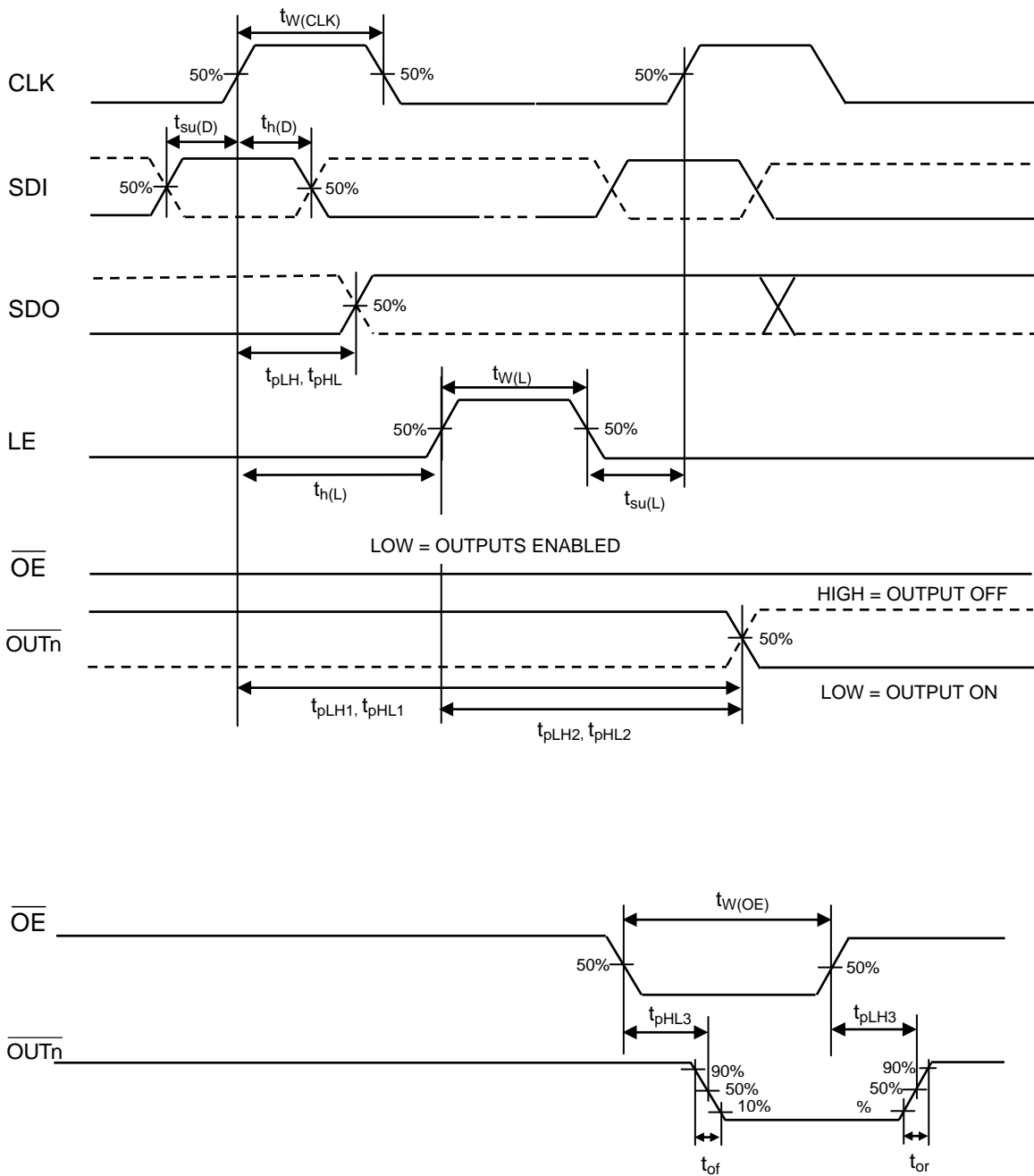
with Low Knee Voltage

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	CLK- $\overline{OUT0}$	t_{pLH1}	$V_{IH}=V_{DD}$ $V_{IL}=GND$ $R_{ext}=930\Omega$ $R_L=150\Omega$ $C_L=10PF$ $I_{OUT}=20mA$ $C1=100nF$ $C2=22\mu F$ $C_{SDO}=10PF$ $V_L=3.3V$	-	65	75	ns
	LE- $\overline{OUT0}$	t_{pLH2}		-	65	75	ns
	\overline{OE} - $\overline{OUT0}$	t_{pLH3}		-	65	75	ns
	CLK-SDO	t_{pLH}		-	-	50	ns
Propagation Delay Time ("H" to "L")	CLK- $\overline{OUT0}$	t_{pHL1}		-	40	50	ns
	LE- $\overline{OUT0}$	t_{pHL2}		-	40	50	ns
	\overline{OE} - $\overline{OUT0}$	t_{pHL3}		-	40	50	ns
	CLK-SDO	t_{pHL}		-	-	50	ns
Staggered Delay of Output	Output Group 1~ Output Group 2	t_{stag1}		-	7	15	ns
Pulse Width	CLK	$t_w(CLK)$		20	-	-	ns
	LE	$t_w(L)$		20	-	-	ns
Data Clock Frequency		F_{CLK}		-	-	20	MHz
Hold Time for LE		$t_h(L)$		10	-	-	ns
Setup Time for LE		$t_{su}(L)$		10	-	-	ns
Hold Time for SDI		$t_h(D)$		5	-	-	ns
Setup Time for SDI		$t_{su}(D)$		3	-	-	ns
Maximum CLK Rise Time		t_r		-	-	500	ns
Maximum CLK Fall Time		t_f		-	-	500	ns
SDO Rise Time		$t_{r,SDO}$		-	10	-	ns
SDO Fall Time		$t_{f,SDO}$		-	10	-	ns
Output Rise Time of Output Ports		t_{or}	35	40	-	ns	
Output Fall Time of Output Ports		t_{of}	35	40	-	ns	
\overline{OE} Pulse Width		$t_w(OE)$	100	130	-	ns	
Output On-time Error		t_{ON_ERR}	0	10	16	ns	

Test Circuit for Switching Characteristics



Timing Waveform

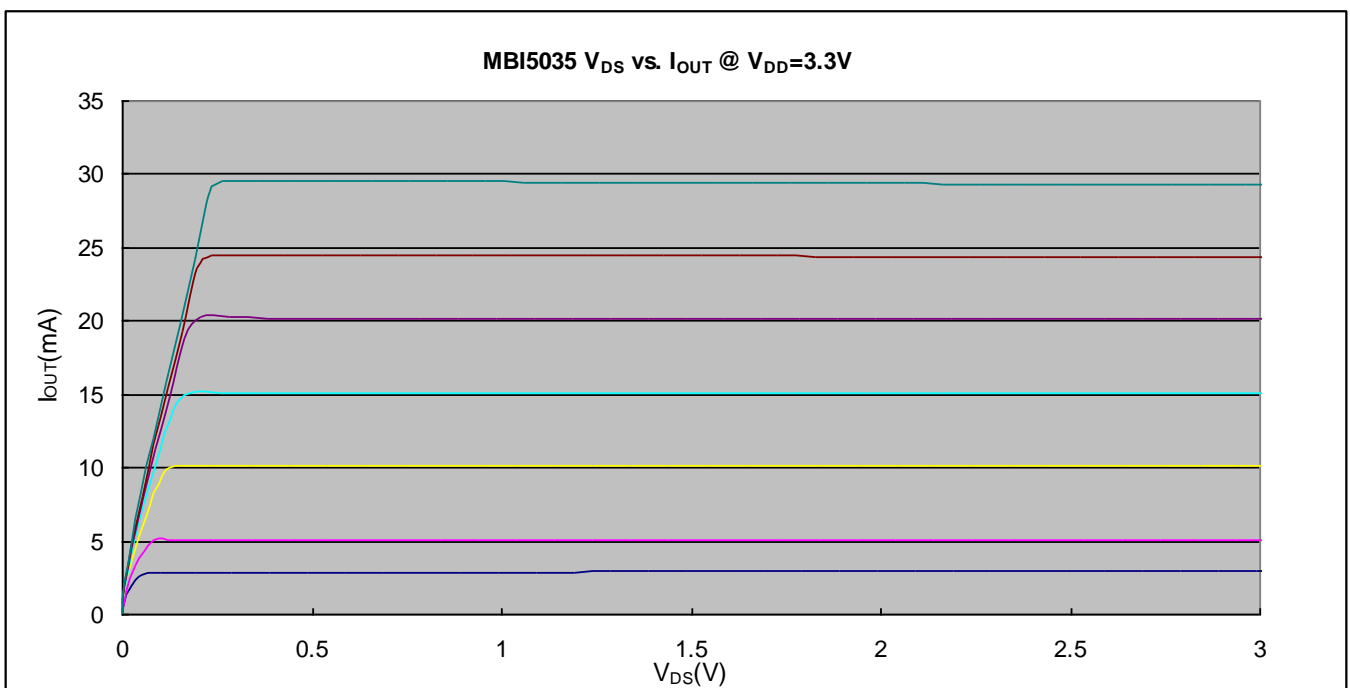
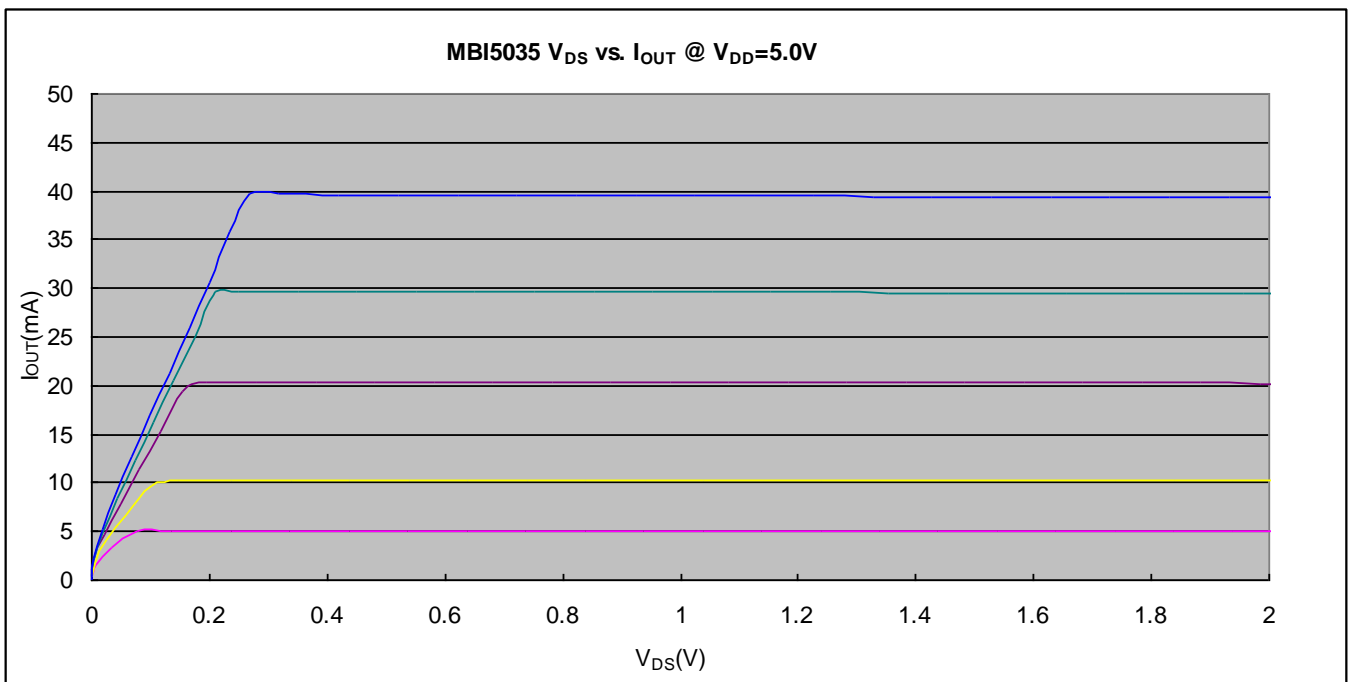


Application Information

Constant Current

To design LED displays, MBI5035 provides nearly no variations in current from channel to channel and from IC to IC. This can be achieved by:

- 1) The maximum current variation between channels is less than $\pm 3\%$, and that between ICs is less than $\pm 6\%$.
- 2) In addition, the current characteristic of output stage is flat and users can refer to the below figure. The output current can be kept constant regardless of the variations of LED forward voltages(V_F). This performs as a perfect static load regulation.



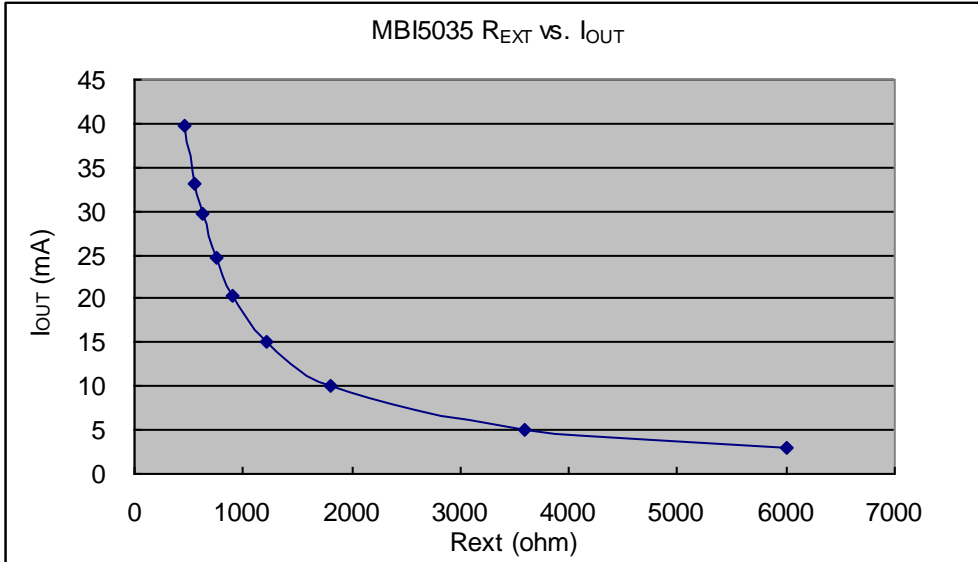
Adjusting Output Current

with Low Knee Voltage

The output current of each channel (I_{OUT}) is set by an external resistor, R_{EXT} . The relationship between I_{OUT} and R_{EXT} is shown in the following figure.

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

$$V_{R-EXT}=1.24V ; I_{OUT}=V_{R-EXT} \cdot (1/R_{EXT}) \times 15; R_{EXT}=(V_{R-EXT}/I_{OUT}) \times 15$$



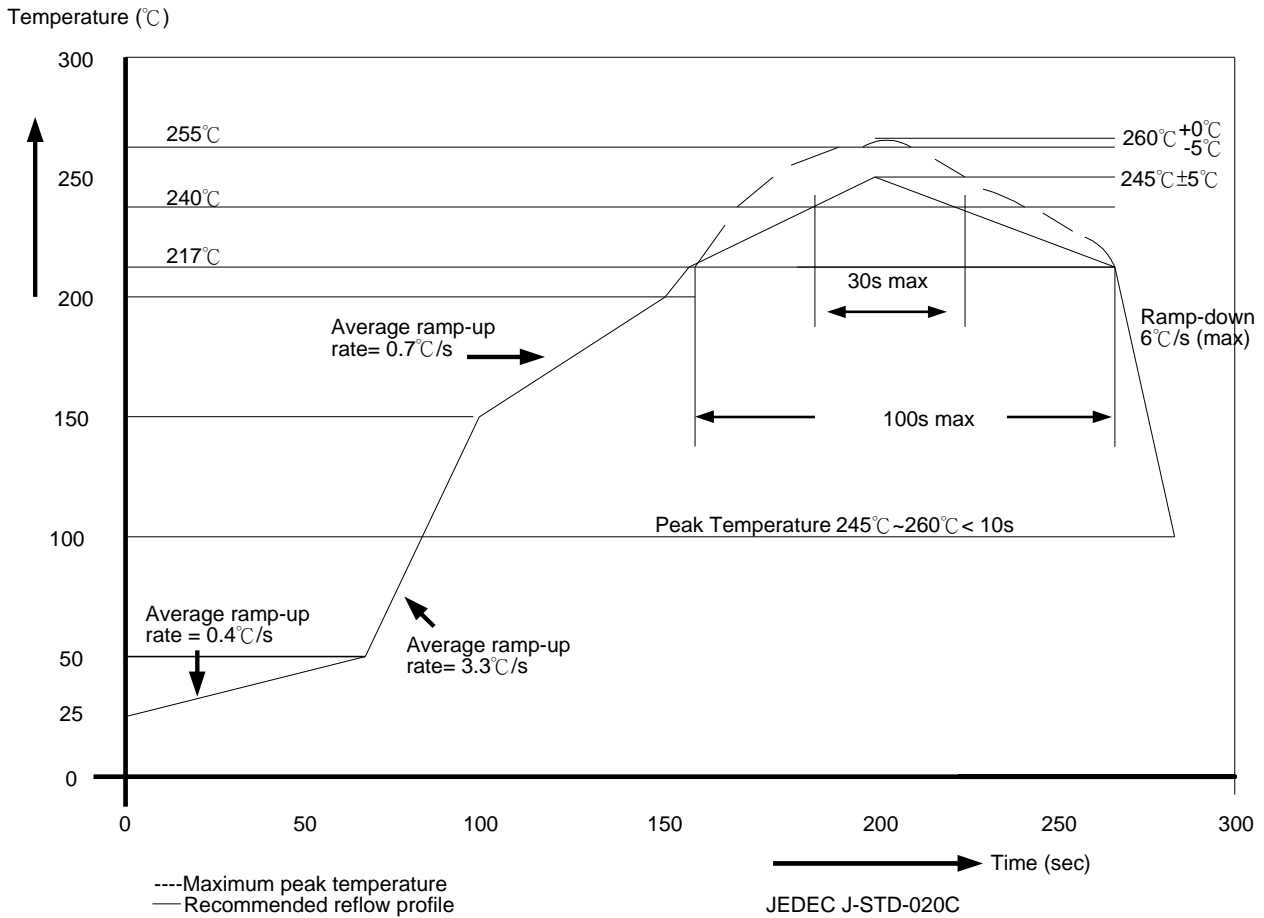
Where R_{EXT} is the resistance of the external resistor connected to R-EXT terminal and V_{R-EXT} is the voltage of R-EXT terminal. The magnitude of current (as a function of R_{EXT}) is around 20mA at 930Ω and 10mA at 1860Ω.

Staggered Delay of Output

MBI5035 has a built-in staggered circuit to perform delay mechanism. Among output ports exist a graduated 5ns delay time between \overline{OUT}_{2n} and \overline{OUT}_{2n+1} , by which the output ports will be divided to two groups at a different time so that the instant current from the power line will be lowered.

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 the 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
≥2.5mm	250 +0 °C	245 +0 °C	245 +0 °C

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

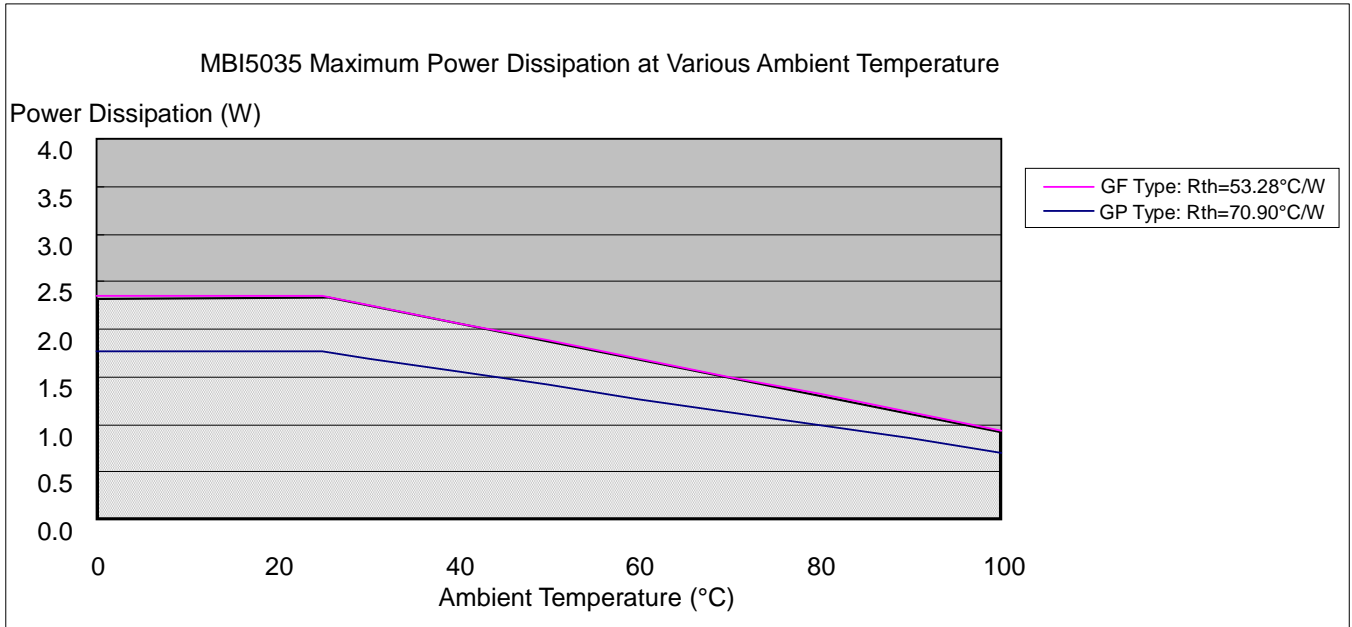
Package Power Dissipation (PD)

with Low Knee Voltage

The maximum allowable package power dissipation is determined as $P_D(max)=(T_j-T_a)/R_{th(j-a)}$. When 16 output channels are turned on simultaneously, the actual package power dissipation is

$P_D(act)=(I_{DD} \times V_{DD})+(I_{OUT} \times Duty \times V_{DS} \times 16)$. Therefore, to keep $P_D(act) \leq P_D(max)$, the allowable maximum output current as a function of duty cycle is:

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



Condition: $I_{OUT}=50\text{mA}$, 16 output channels	
Device Type	$R_{th(j-a)}$ (°C/W)
GF	53.28
GP	70.90

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

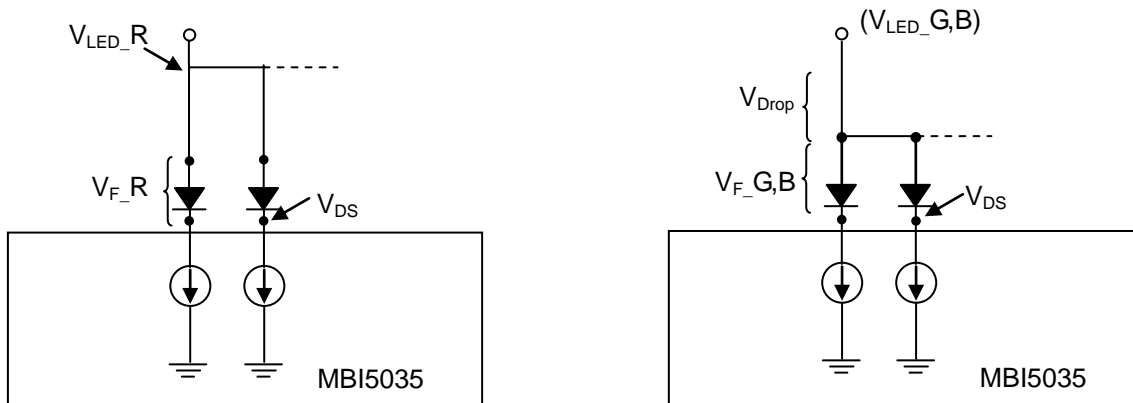
Load Supply Voltage (V_{LED})

with Low Knee Voltage

MBI5035 are designed to operate with V_{DS} ranging from 0.2V to 0.6V (depending on $I_{OUT}=3\sim 40mA$) to lower the heat dissipation and reduce the temperature on the package. In this case, it is recommended to use the lowest possible supply voltage V_{LED} . Because the V_F of red LED differs from green and blue LED, we suggest to separate V_{LED_R} from $V_{LED_G,B}$.

$V_{DS}=V_{LED}-V_F$, with V_{DS} ranging from 0.2V to 0.6V

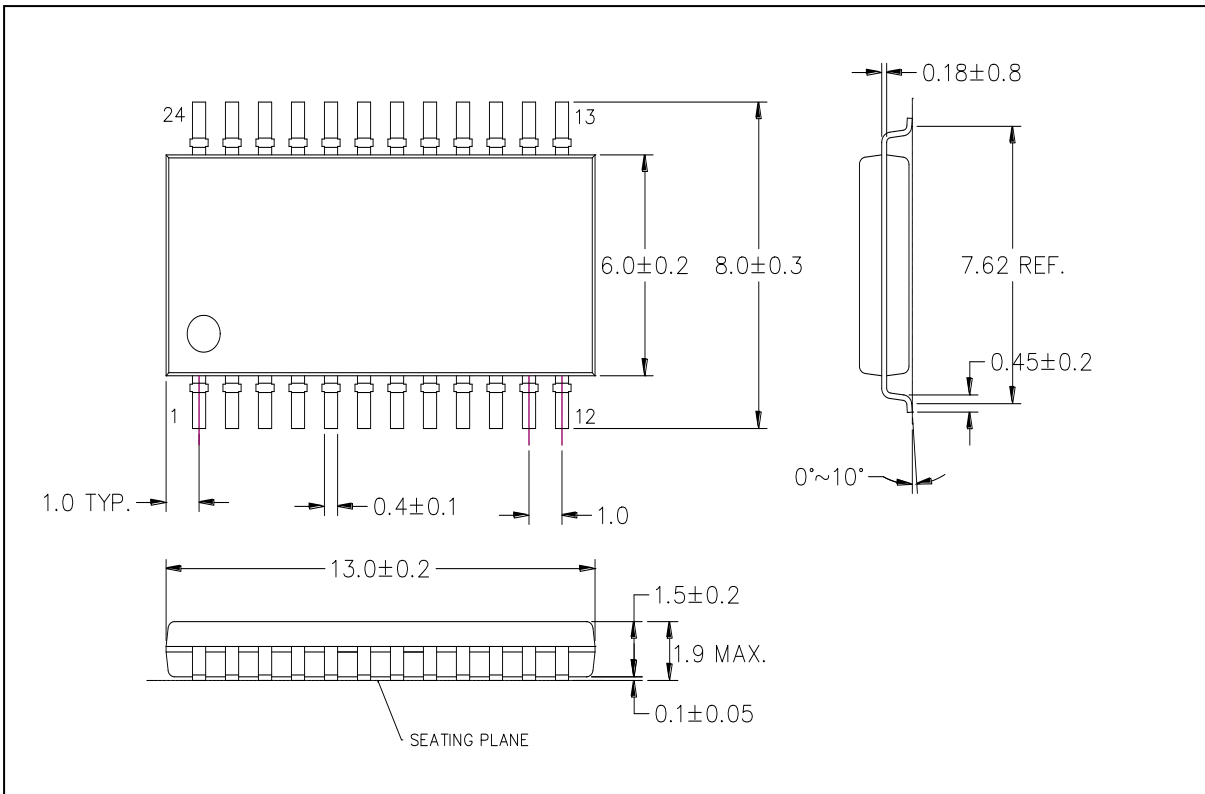
The applications are shown in the following figures.



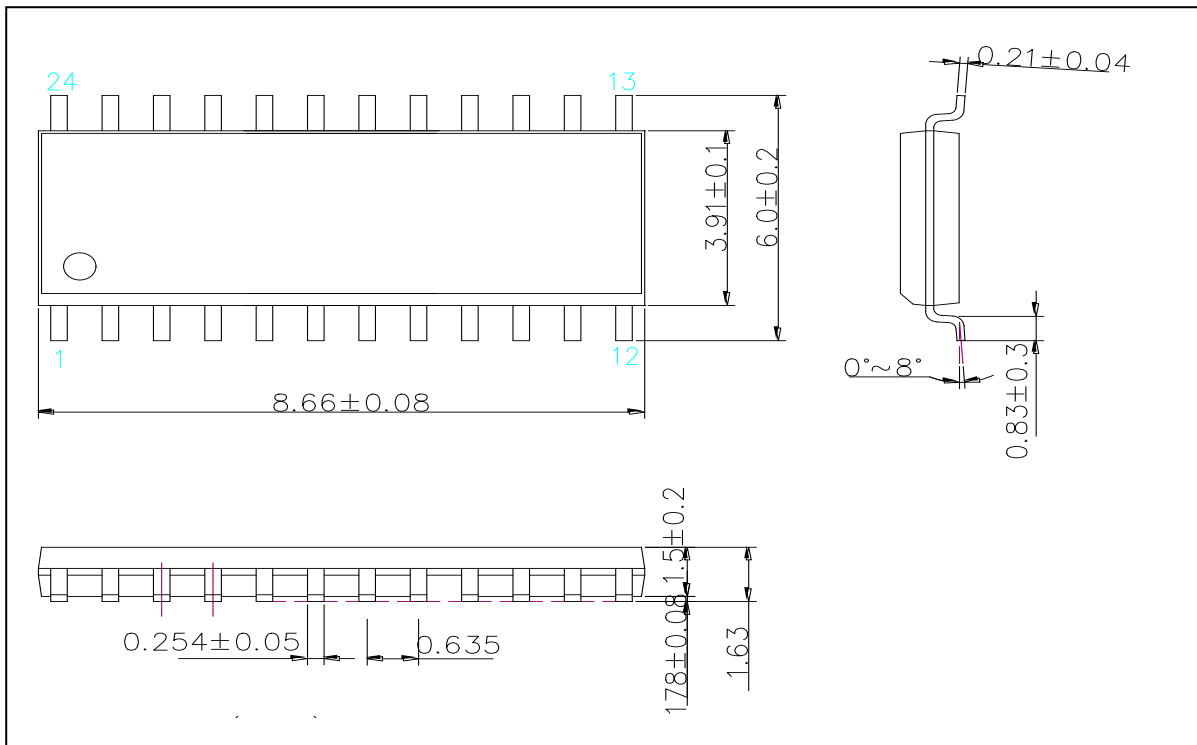
Switching Noise Reduction

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

Package Outline



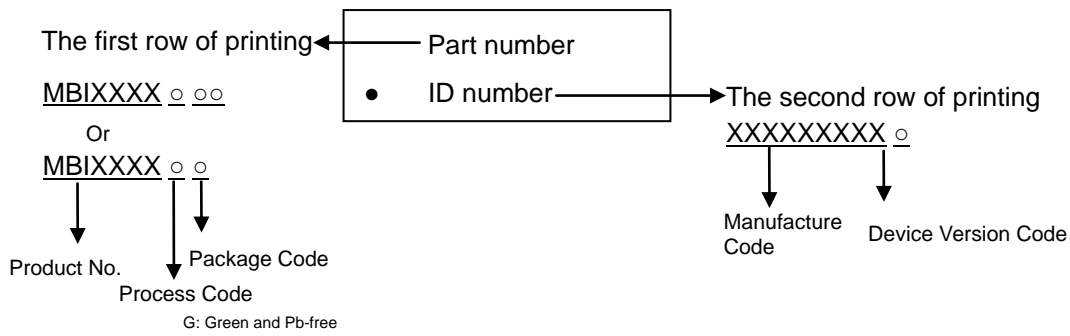
MBI5035GF Outline Drawing



MBI5035GP Outline Drawing

Note: The unit for the outline drawing is mm.

Product Top-mark Information



Product Revision History

Datasheet version	Device version code
V1.00	A

Product Ordering Information

Part Number	“Pb-free & Green” Package Type	Weight (g)
MBI5035GF	SOP24L-300-1.00	0.28
MBI5035GP	SSOP24L-150-0.64	0.11

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