MBI1816

Macroblock

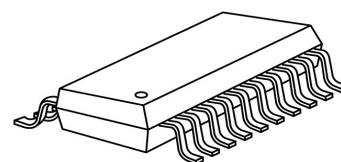## All-Ways-On™ Constant-Current LED Driver

Features

- 16 constant-current output channels
- Constant output current invariant to load voltage change
- Excellent output current accuracy:
  between channels: <±3% (max.), and
  between ICs: <±6% (max.)
- Output current adjusted through an external resistor
- Constant output current range per channel: 5-60 mA
- Schmitt trigger input
- 5V supply voltage
- Package Type: "Pb-free & Green" package with thermal pad

Thin Shrink SOP

GT: TSSOP20-173-0.65

Current Accuracy		Conditions
Between Channels	Between ICs	
< ±3%	< ±6%	I_{OUT} = 5 ~ 60 mA

Product Description

MBI1816 is an instant On/Off LED driver for lighting applications and exploits PrecisionDrive™ technology to enhance its output characteristics. At MBI1816 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.

MBI1816 provides users 16-channel constant current ports to match LEDs with equal current. Users may adjust the output current from 5 mA to 60 mA through an external resistor, R_{ext}, which gives users flexibility in controlling the light intensity of LEDs. In addition, users can precisely adjust LED brightness from 0% to 100% via output enable ($\overline{OE}$) with Pulse Width Modulation.

Additionally, to ensure the system reliability, MBI1816 is built with Thermal Protection (TP) function and thermal pad. The TP function protects IC from over temperature (150°C). Also, the thermal pad enhances the power dissipation. As a result, a large amount of current can be handled safely in one package.

Applications

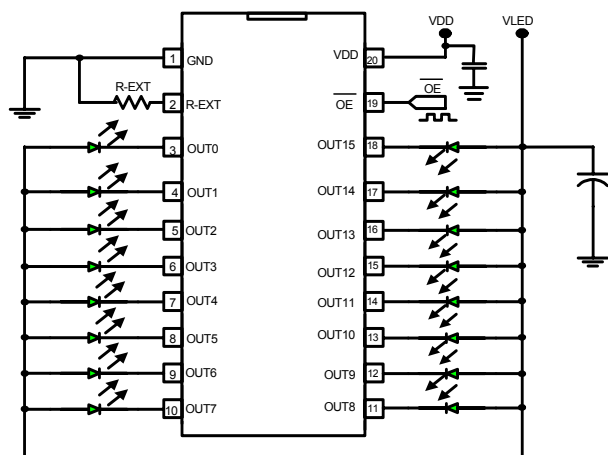- Automotive interior lighting
- Channel letter
- Decoration lighting

August 2005, V1.02

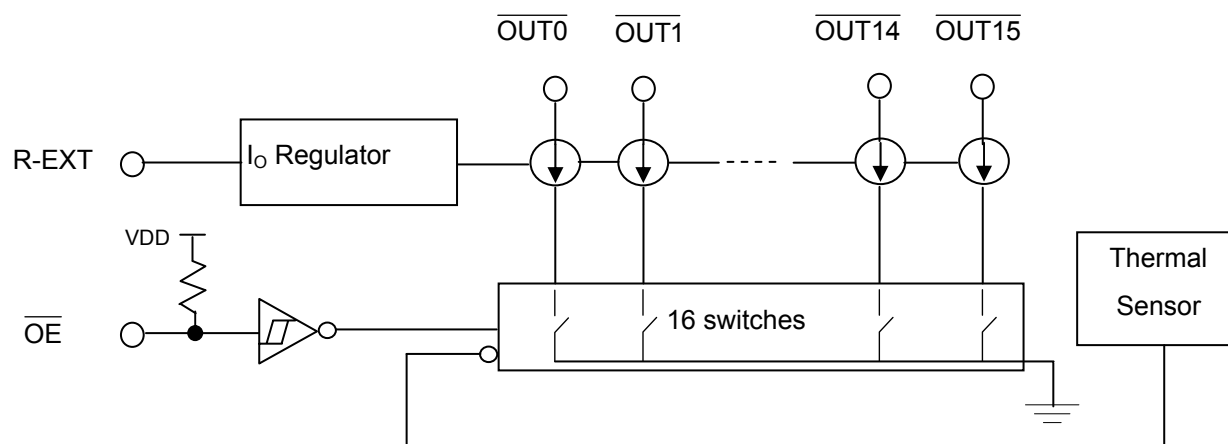## Typical Application Circuit

Figure 1

Functional Diagram

Pin Configuration

```
GND   █ 1        20 █ VDD
R-EXT █ 2        19 █ OE‾
OUT0‾ █ 3        18 █ OUT15‾
OUT1‾ █ 4        17 █ OUT14‾
OUT2‾ █ 5        16 █ OUT13‾
OUT3‾ █ 6        15 █ OUT12‾
OUT4‾ █ 7        14 █ OUT11‾
OUT5‾ █ 8        13 █ OUT10‾
OUT6‾ █ 9        12 █ OUT9‾
OUT7‾ █ 10       11 █ OUT8‾
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MBI1816GT

Pin Description

Pin Name	Function
GND	Ground terminal for control logic and current sink
$\overline{OUT0} \sim \overline{OUT15}$	Constant current output terminals
$\overline{OE}$	Output enable terminal When $\overline{OE}$ is active (low), the output pins are enabled; when $\overline{OE}$ is inactive (high), all output pins are turned OFF (blanked).
R-EXT	Terminal used to connect an external resistor (R_{ext}) for setting up output current for all output channels
VDD	5V supply voltage terminal
Thermal Pad	Power dissipation terminals connected to GND*

*To eliminate the noise influence, the thermal pad is suggested to be connected to GND on PCB.

In addition, desired thermal conductivity will be improved, if a heat-conducting copper foil on PCB is soldered with thermal pad.

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}	90	mA
Sustaining Voltage		V_{DS}	-0.5~$+17.0$	V
GND Terminal Current		I_{GND}	1000	mA
Power Dissipation* (On PCB, Ta=25°C)	TSSOP20	P_D	0.85	W
Thermal Resistance (By simulation)		$R_{th(j-a)}$	31.99	°C/W
Empirical Thermal Resistance* (On PCB, Ta=25°C)			117	
Operating Junction Temperature		$T_{j,max}$	125	°C
Operating Temperature		T_{opr}	-40~$+85$	°C
Storage Temperature		T_{stg}	-55~$+150$	°C

*Users must notice that the power dissipation (almost equaling to I_{OUT} x V_{DS}) should be within the Safe Operation Area shown in Figure 6.

All-Ways-On[TM] High-Power LED Driver

Electrical Characteristics

Characteristic		Symbol	Condition		Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-		4.5	5.0	5.5	V
Sustaining Voltage at $\overline{OUT}$ pin		V_{DS}	$\overline{OUT0}$ ~ $\overline{OUT15}$		-	-	17.0	V
Output Current		I_{OUT}	DC Test Circuit		5	-	60*	mA
Input Voltage	"H" level	V_{IH}	T_a= -40~85ºC		$0.7 \times V_{DD}$	-	V_{DD}	V
	"L" level	V_{IL}	T_a= -40~85ºC		GND	-	$0.3 \times V_{DD}$	V
Output Leakage Current		I_{OH}	V_{OH}= 17.0V		-	-	0.5	µA
Output Current 1		I_{OUT1}	V_{DS}= 0.6V	R_{ext}= 2.4kΩ	-	30.5	-	mA
Current Skew 1		dI_{OUT1}	I_{OL}= 30.5mA V_{DS}= 0.6V	R_{ext}= 2.4kΩ	-	±1	±3	%
Output Current 2		I_{OUT2}	V_{DS}= 0.8V	R_{ext}= 1.3kΩ	-	56	-	mA
Current Skew 2		dI_{OUT2}	I_{OL}= 56mA V_{DS}= 0.8V	R_{ext}= 1.3kΩ	-	±1	±3	%
Regulation of Output Current vs. Sustaining Voltage		$\%/dV_{DS}$	V_{DS} within 1.0V and 3.0V		-	±0.1	-	% / V
Regulation of Output Current vs. Supply Voltage		$\%/dV_{DD}$	V_{DD} within 4.5V and 5.5V		-	±1	-	% / V
Pull-up Resistor		$R_{IN}(up)$	$\overline{OE}$		250	500	800	KΩ
Junction Temperature Threshold		T_x	When T_j approaches T_x and $\overline{OUT}$ is shut off.		-	150	-	°C
Supply Current	"OFF"	$I_{DD}(off)$ 1	R_{ext}= Open, $\overline{OUT0}$ ~ $\overline{OUT15}$ = Off		-	5	9	mA
		$I_{DD}(off)$ 2	R_{ext}= 2.4kΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ = Off		-	6	10	
		$I_{DD}(off)$ 3	R_{ext}= 1.3kΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ = Off		-	8	12	
	"ON"	$I_{DD}(on)$ 1	R_{ext}= 2.4kΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ = On		-	6	10	
		$I_{DD}(on)$ 2	R_{ext}= 1.3kΩ, $\overline{OUT0}$ ~ $\overline{OUT15}$ = On		-	7	10	

* Each output current, I_{OUT}, can be driven up to 90mA, but the total output current should be smaller than 1A.
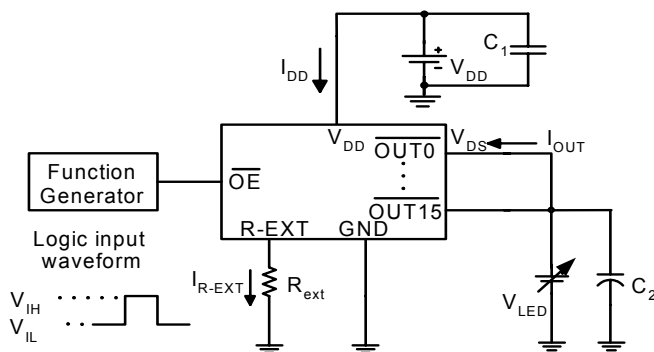
Test Circuit for Electrical Characteristics

Figure 2

Switching Characteristics

Characteristic		Symbol	Condition	Min.	Typ.	Max.	Unit
Propagation Delay Time ("L" to "H")	$\overline{OE}$ - $\overline{OUTn}$	t_{pLH}	V_{DD}= 5.0 V V_{DS}= 1.0V	0.1	0.3	0.5	µs
Propagation Delay Time ("H" to "L")	$\overline{OE}$ - $\overline{OUTn}$	t_{pHL}	V_{IH}= V_{DD} V_{IL}= GND	0.05	0.1	0.2	µs
Pulse Width	$\overline{OE}$	$t_{w(OE)}$	R_{ext}= 1229Ω (I_{OUTn}=60mA)	1	-	-	µs
Output Rise Time of $\overline{OUT}$ (turn off)		t_{or}	V_L= 4.0 V R_L= 44.62 Ω	0.1	0.3	0.5	ns
Output Fall Time of $\overline{OUT}$ (turn on)		t_{of}	C_L= 10 pF	0.1	0.3	0.5	ns

Test Circuit for Switching Characteristics

Figure 3

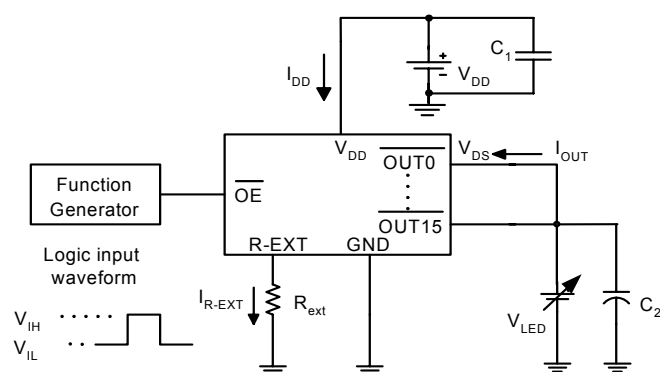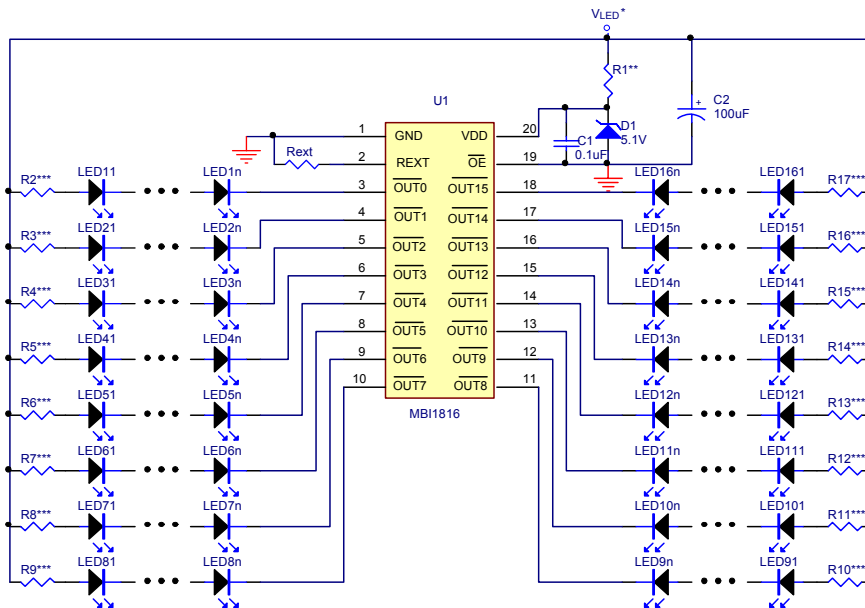# MBI1816 All-Ways-On^{TM} High-Power LED Driver

Application Circuits

(a) MBI1816 application circuit, where V_{LED} and V_{DD} share a single voltage source.
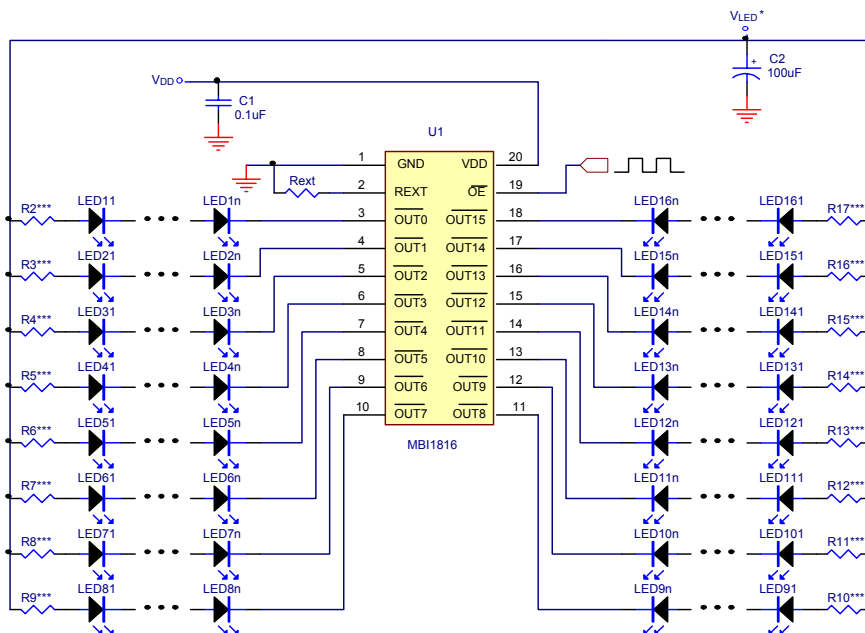

* $V_{LED} > V_{DS} + V_{F,LED} \times n$; $V_{F,LED}$: Forward voltage of LED; n: LED count
** $R1 = (V_{LED} - 5.1V) / I_{DD}$; refer to Electrical Characteristics for I_{DD}
*** $R2 \sim R17 = [V_{LED} - V_{DS} - (V_{F,LED} \times n)] / I_{LED}$

(b) MBI1816 application circuit with dimming control by PWM signal, where V_{LED} and V_{DD} use voltage sources separately.

* $V_{LED} = V_{DS} + V_{F,LED} \times n$; $V_{F,LED}$: Forward voltage of LED; n: LED count

Figure 4

Constant Current

In LED lighting applications, MBI1816 provides nearly no variation 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 ±3%, and that between ICs is less than ±6%.

2) In addition, the current characteristic of output stage is flat and users can refer to the figure as shown below. The output current can be kept constant regardless of the variations of LED forward voltages (V_F). This guarantees LED to be performed on the same brightness as user's specification.
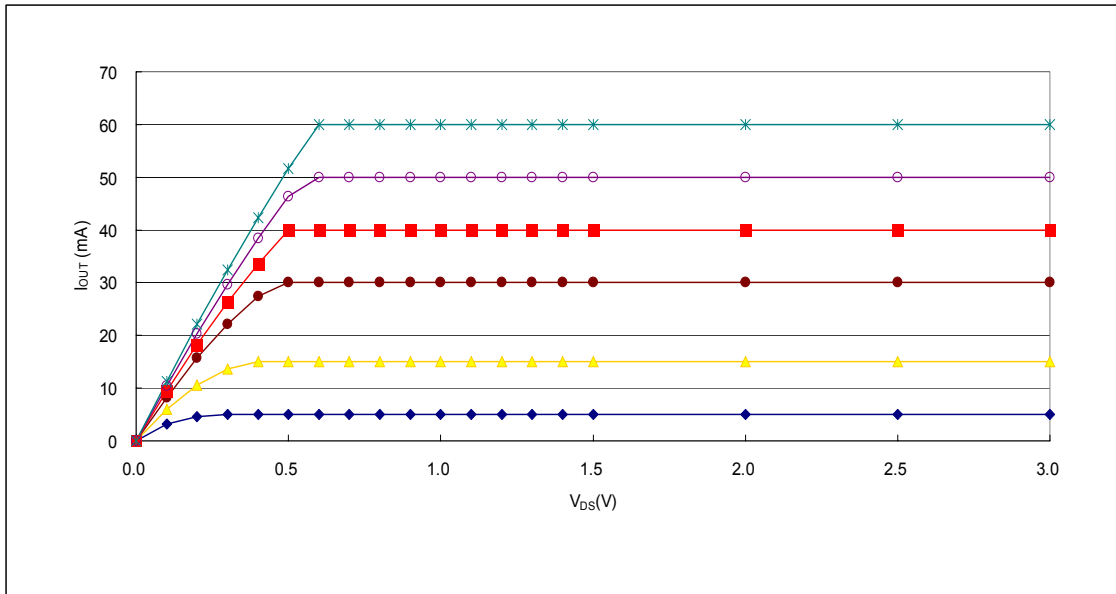

Figure 5

Setting Output Current

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.
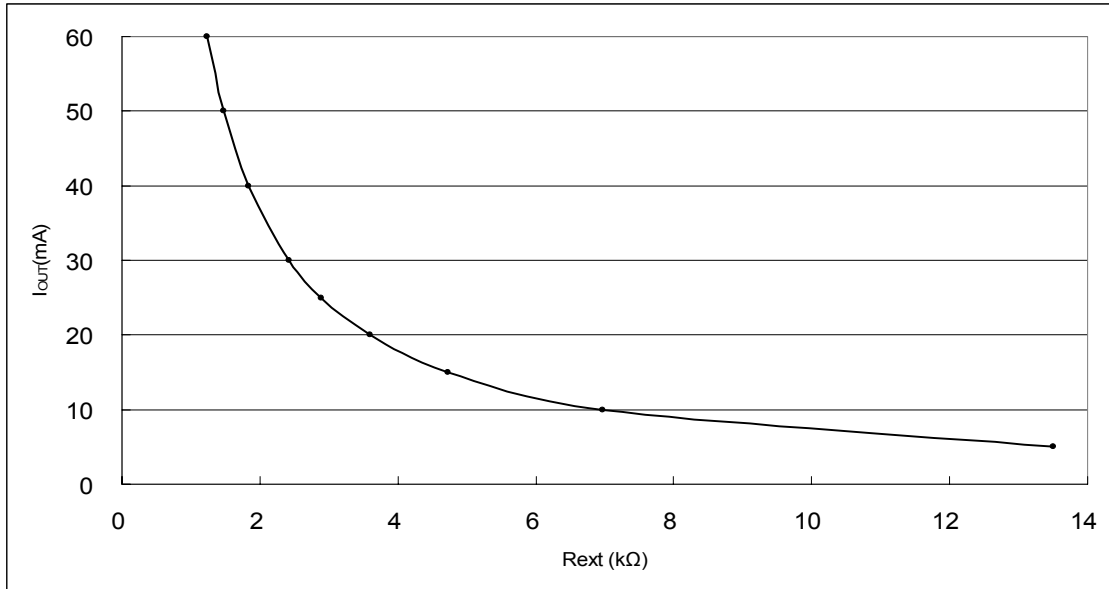

Figure 6

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

$V_{R\text{-}EXT}$ = 1.24V ;

R_{ext} = ($V_{R\text{-}EXT}$ / I_{OUT}) × 59 = (1.24V / I_{OUT}) × 59,

I_{OUT} = ($V_{R\text{-}EXT}$ / R_{ex}) × 59 = (1.24V / R_{ext}) × 59 within ± 6% chip skew

where R_{ext} is the resistance of the external resistor connected to R-EXT terminal and $V_{R\text{-}EXT}$ is the voltage of R-EXT terminal. The magnitude of current (as a function of R_{ext}) is around 56mA at 1.2kΩ and 30.5mA at 2.4kΩ.

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 is backward compatible to standard 215ºC to 240ºC reflow processes which adopt tin/lead (SnPb) solder paste. However, in the whole Pb-free soldering processes and materials, 100% pure tin (Sn) will all require up to 260^{o}C for proper soldering on boards, referring to J-STD-020C as shown below.

Temperature (℃)

300 ─

255℃ ──────────────────────────── 260℃$^{+0℃}_{-5℃}$

250 ─

240℃ ──────────────────────────── 245℃±5℃

217℃

200 ─

Average ramp-up rate= 0.7℃/s →

30s max

Ramp-down 6℃/s (max)

150 ─

100s max

100 ─

Peak Temperature 245℃~260℃< 10s

Average ramp-up rate = 0.4℃/s

Average ramp-up rate= 3.3℃/s

50 ─

25 ─

0 ─

0   50   100   150   200   250   300

Time (sec)

----Maximum peak temperature
──Recommended reflow profile

Acc. J-STD-020C

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

Package Power Dissipation (P$_D$)

The maximum power dissipation, P$_D$(max) = (T$_{j,max}$ − T$_a$) / R$_{th(j-a)}$, decreases as the ambient temperature increases.

Max. Power Dissipation at Various Ambient Temperature

Type: TSSOP20(GT); Rth(j-a)=117(°C/W)*

Safe Operation Area

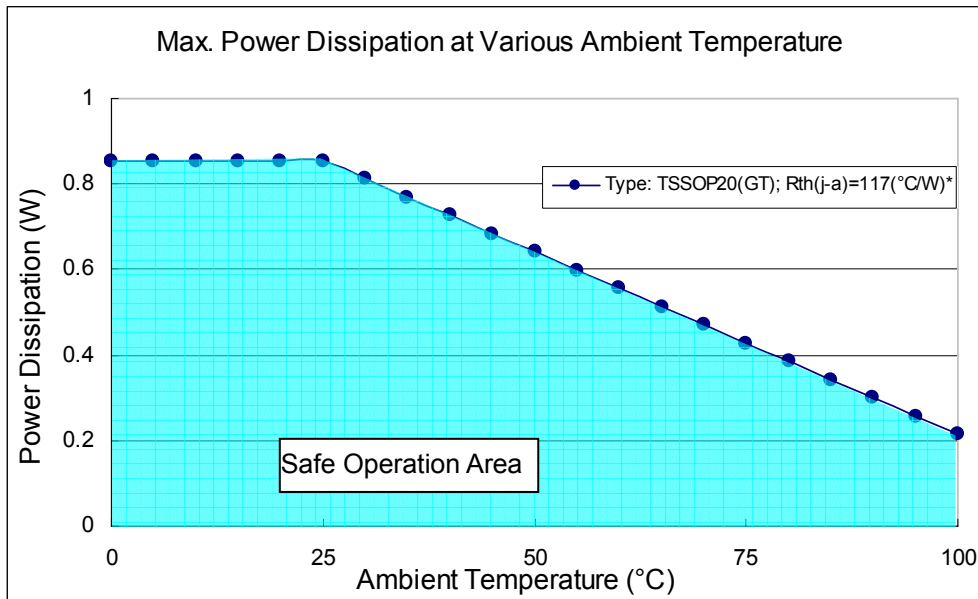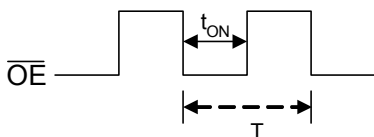Power Dissipation (W)

Ambient Temperature (°C)

Figure 7

The maximum allowable package power dissipation is determined as P$_D$(max) = (T$_{j,max}$ − T$_a$) / R$_{th(j-a)}$. When 16 output channels are turned on simultaneously, the actual package power dissipation is P$_D$(act) = (I$_{DD}$ x V$_{DD}$) + (I$_{OUT}$ x Duty x V$_{DS}$ x 16). Therefore, to keep P$_D$(act) ≤ P$_D$(max), the allowable maximum output current as a function of duty cycle is:

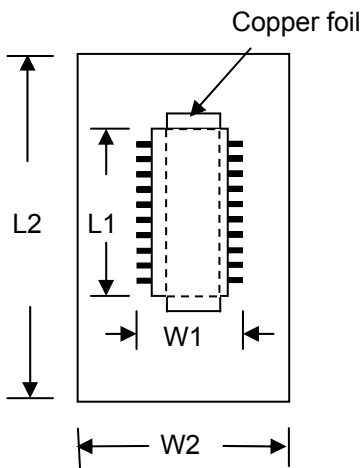I$_{OUT}$ = { [(T$_j$ − T$_a$) / R$_{th(j-a)}$] − (I$_{DD}$ x V$_{DD}$) } / V$_{DS}$ / Duty / 16,

where T$_j$ = 125°C;

Duty= t$_{ON}$ / T;

t$_{ON}$: the time of LEDs turning on; T: $\overline{OE}$ signal period

*Note: The empirical thermal resistor R$_{th(j-a)}$ =117 °C/W; it is based on the following structure.

Copper foil

The PCB area L2xW2 is 4 times of the IC's area L1xW1.
The thickness of the PCB is 1.6 mm, copper foil 1 Oz. The thermal pad on the IC's bottom has to be mounted on the copper foil.

TP Function (Thermal Protection)

When the junction temperature exceeds the threshold, T_X (150~~65~~°C), TP function turns off the output current. As soon as the temperature is below 150~~65~~°C, the output current will be turned on again. The on-state and off-state switch at a high frequency; thus, the blinking is imperceptible. However, the average output current is limited, and therefore, the driver is protected from being overheated.

Load Supply Voltage (V_{LED})

MBI1816 is designed to operate with adequate V_{DS} to achieve constant current. V_{DS} together with I_{OUT} should not exceed the package power dissipation limit, $P_{D(max)}$.

As in Figure 8, $V_{DS} = V_{LED} - V_F$, and V_{LED} is the load supply voltage. $P_{D(act)}$ will be greater than $P_{D(max)}$, if V_{DS} drops too much voltage on the driver. 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 $V_{DS} = (V_{LED} - V_F) - V_{DROP}$.

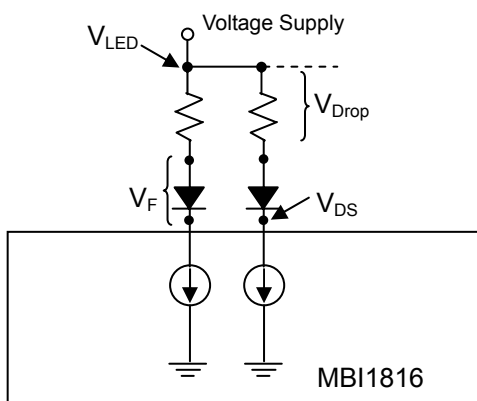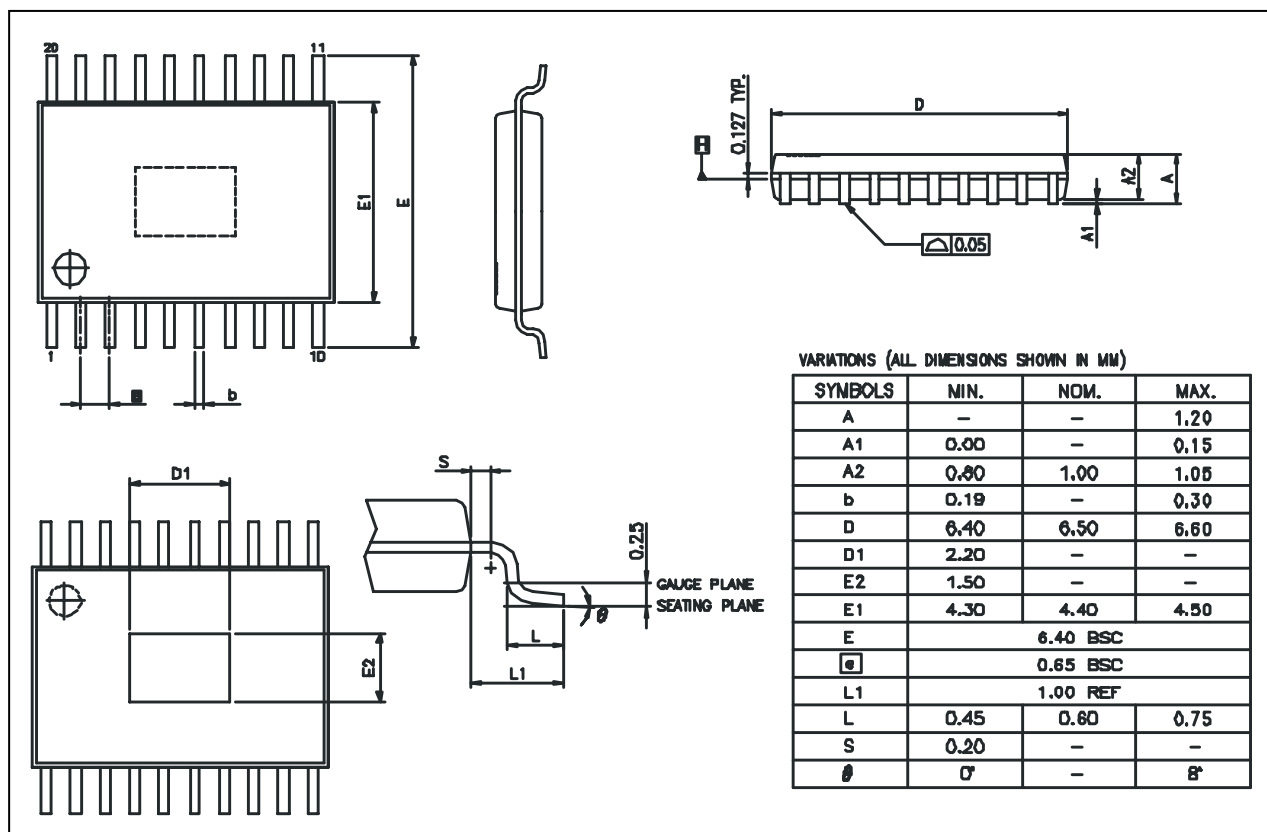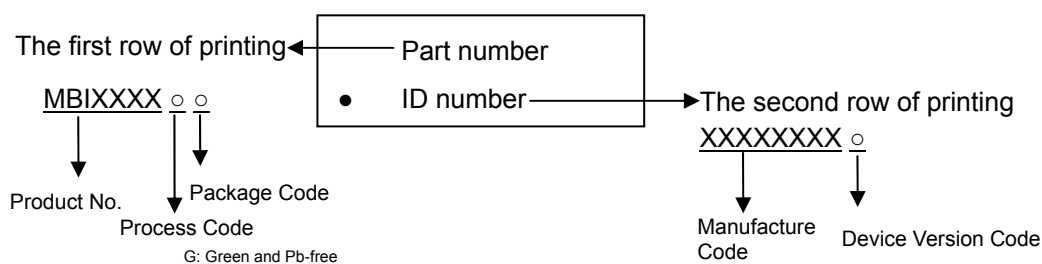Resistors can be used in the applications as shown in Figure 8.

Figure 8

Outline Drawing

Note: The unit for the outline drawing is mm.

VARIATIONS (ALL DIMENSIONS SHOWN IN MM)			
SYMBOLS	MIN.	NOM.	MAX.
A	–	–	1.20
A1	0.00	–	0.15
A2	0.80	1.00	1.05
b	0.19	–	0.30
D	6.40	6.50	6.60
D1	2.20	–	–
E2	1.50	–	–
E1	4.30	4.40	4.50
E	6.40 BSC		
e	0.65 BSC		
L1	1.00 REF		
L	0.45	0.60	0.75
S	0.20	–	–
θ	0°	–	8°

Product Top-mark Information

The first row of printing ◄——— Part number

MBIXXXX ○ ○
● ID number ———► The second row of printing

XXXXXXXX ○

Product No.   Package Code
    Process Code
    G: Green and Pb-free

Manufacture Code   Device Version Code

Product Revision History

Datasheet Version	Device Version Code
V1.00	*Not defined*
V1.01	A
V1.02	B

Product Ordering Information

Part Number	Package Type	Weight (g)
MBI1816GT	TSSOP-173-0.65	0.0065