

MB39C605

ASSP

TRIAC Dimmable PSR LED Driver IC for LED Lighting

Data Sheet (Full Production)



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1. Description

MB39C605 is a PSR (Primary Side Regulation) LED driver IC for LED lighting. Using the information of the primary peak current and the transformer-energy-zero time, it is able to deliver a well regulated current to the secondary side without using an opto-coupler in an isolated flyback topology. Using critical conduction mode, it is able to allow the use of small transformer. In addition, MB39C605 has a Phase dimmable circuit built-in and can constitute the lighting system corresponding to the TRIAC dimming.

It is most suitable for the general lighting applications, for example replacement of commercial and residential incandescent lamp and so on.

2. Features

- PSR topology in an isolated flyback circuit
- High efficiency (>80% : Not dimming) and low EMI by detecting transformer zero energy
- TRIAC Dimmable LED lighting
- High-reliable protective function
 - Under voltage lock out (UVLO)
 - Output over voltage protection (OVP)
 - Transformer over current protection (OCP)
 - Output short circuit protection (SCP)
 - Over temperature protection (OTP)
- Switching frequency setting : 30kHz to 133kHz
- Input voltage range VDD : 9V to 20V
- Input voltage range for LED lighting applications : AC110V_{RMS}, AC230V_{RMS}
- Output power range for LED lighting applications : 5W to 10W
- Small Package : SOP-8 (3.9mm × 5.05mm × 1.75mm[Max])

3. Applications

- Leading edge/Trailing edge dimmable LED lighting



Online Design Simulation Easy DesignSim

This product supports the web-based design simulation tool.
It can easily select external components and can display useful information.
Please access from the following URL.

<http://www.spansion.com/easydesignsim/>

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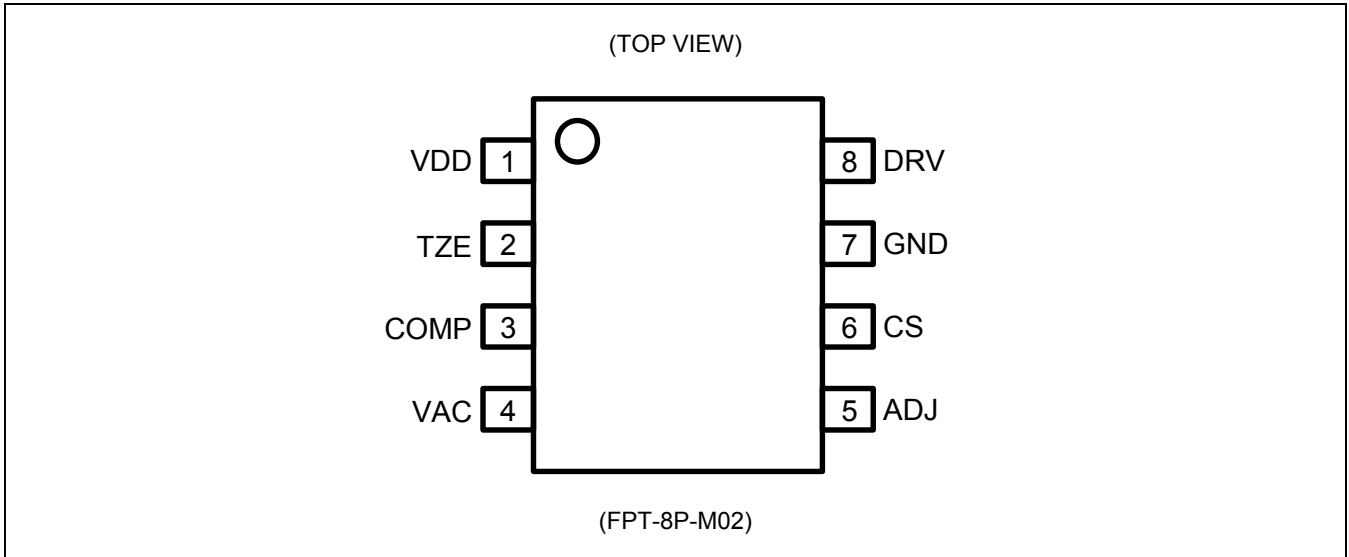
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4. Pin Assignment

Figure 4-1 Pin Assignment



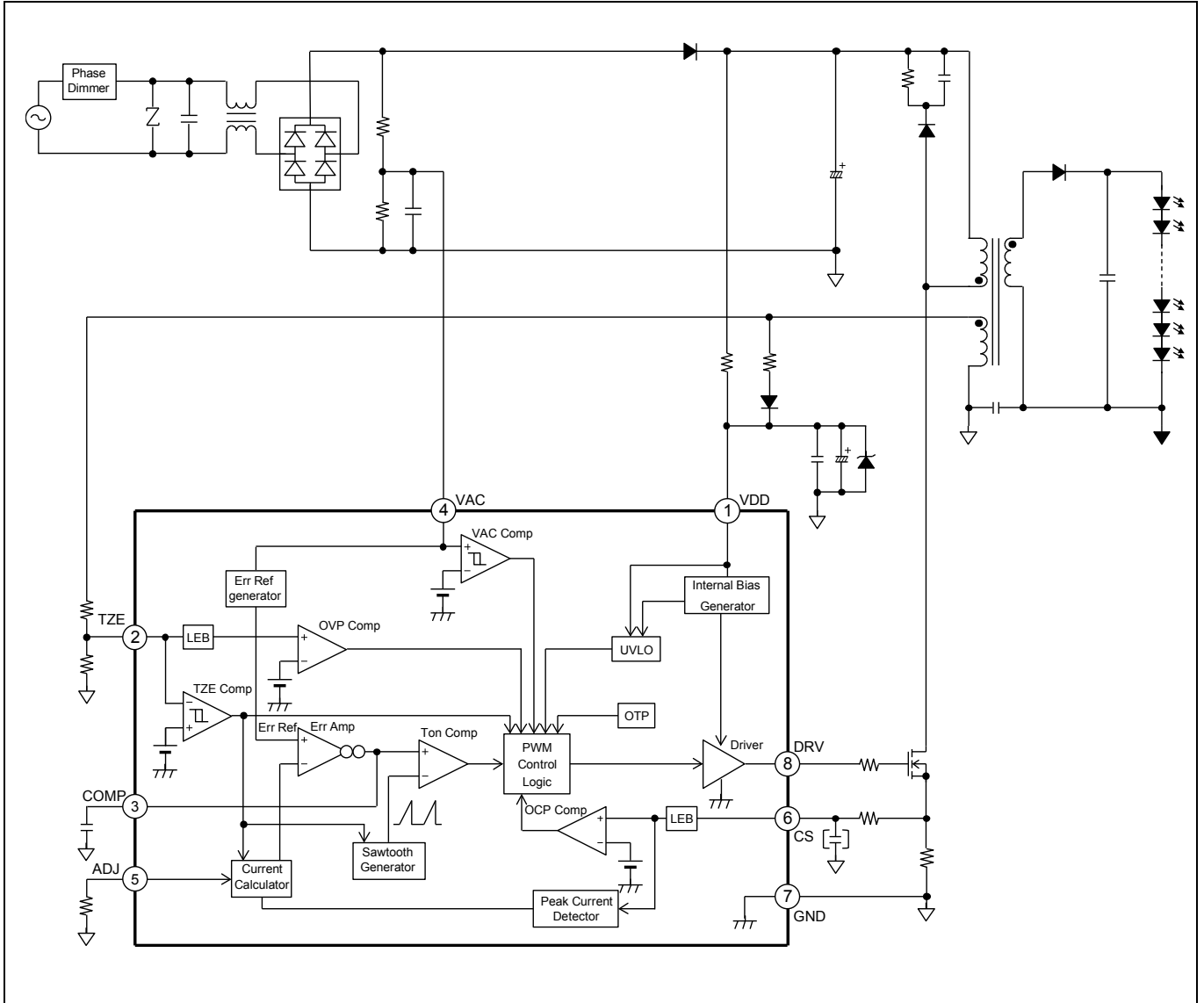
5. Pin Descriptions

Table 5-1 Pin Descriptions

Pin No.	Pin Name	I/O	Description
1	VDD	-	Power supply pin.
2	TZE	I	Transformer Zero Energy detecting pin.
3	COMP	O	External Capacitor connection pin for the compensation.
4	VAC	I	TRIAC dimming control pin.
5	ADJ	O	Pin for adjusting the switch-on timing.
6	CS	I	Pin for detecting peak current of transformer primary winding.
7	GND	-	Ground pin.
8	DRV	O	External MOSFET gate connection pin.

6. Block Diagram

Figure 6-1 Block Diagram (Isolated Flyback application)



7. Absolute Maximum Ratings

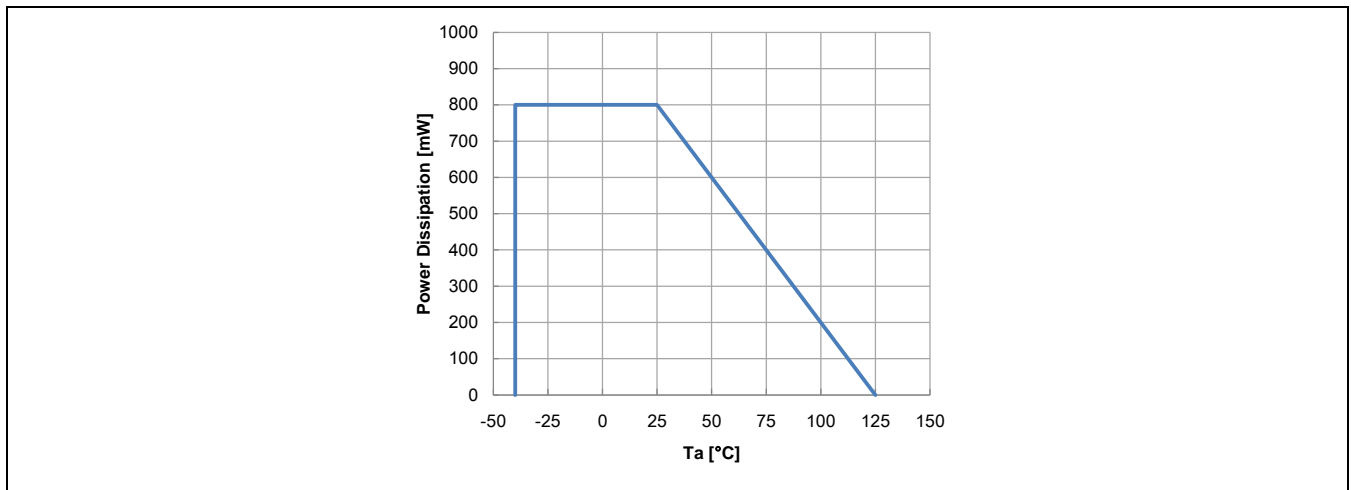
Table 7-1 Absolute Maximum Rating

Parameter	Symbol	Condition	Rating		Unit
			Min	Max	
Power Supply Voltage	V_{VDD}	VDD pin	-0.3	+25	V
Input Voltage	V_{CS}	CS pin	-0.3	+6.0	V
	V_{TZE}	TZE pin	-0.3	+6.0	V
	V_{VAC}	VAC pin	-0.3	+6.0	V
Output Voltage	V_{DRV}	DRV pin	-0.3	+25	V
Output Current	I_{ADJ}	ADJ pin	-1	-	mA
	I_{DRV}	DRV pin DC level	-50	+50	mA
Power Dissipation	P_D	$T_a \leq +25^\circ\text{C}$	-	800 (*1)	mW
Storage temperature	T_{STG}	-	-55	+125	$^\circ\text{C}$
ESD Voltage 1	V_{ESDH}	Human Body Model	-2000	+2000	V
ESD Voltage 2	V_{ESDM}	Machine Model	-200	+180	V
ESD Voltage 3	V_{ESDC}	Charged Device Model	-1000	+1000	V

*1: The value when using two layers PCB.

Reference: θ_{ja} (wind speed 0m/s): $+125^\circ\text{C/W}$

Figure 7-1 Power Dissipation



WARNING:

1. Semiconductor devices may be permanently damaged by application of stress (including, without limitation, voltage, current or temperature) in excess of absolute maximum ratings. Do not exceed any of these ratings.

8. Recommended Operating Conditions

Table 8-1 Recommended Operating Conditions

Parameter	Symbol	Condition	Value			Unit
			Min	Typ	Max	
VDD pin Input Voltage	VDD	VDD pin	9	-	20	V
VAC pin Input Voltage	V _{VAC}	VAC pin After UVLO release	0	-	5	V
VAC pin Input Current	I _{VAC}	VAC pin Before UVLO release	0	-	2.5	μA
TZE pin Resistance	R _{TZE}	TZE pin	50	-	200	kΩ
ADJ pin Resistance	R _{ADJ}	ADJ pin	9.3	-	185.5	kΩ
COMP pin Capacitance	C _{COMP}	COMP pin	-	0.01	-	μF
VDD pin Capacitance	C _{BP}	Set between VDD pin and GND pin	-	4.7	-	μF
Operating Junction Temperature	T _j	-	-40	-	+125	°C

WARNING:

1. The recommended operating conditions are required in order to ensure the normal operation of the semiconductor device. All of the device's electrical characteristics are warranted when the device is operated under these conditions.
2. Any use of semiconductor devices will be under their recommended operating condition.
3. Operation under any conditions other than these conditions may adversely affect reliability of device and could result in device failure.
4. No warranty is made with respect to any use, operating conditions or combinations not represented on this data sheet. If you are considering application under any conditions other than listed herein, please contact sales representatives beforehand.

9. Electrical Characteristics

Table 9-1 Electrical Characteristics

(Ta = +25°C, V_{VDD} = 12V)

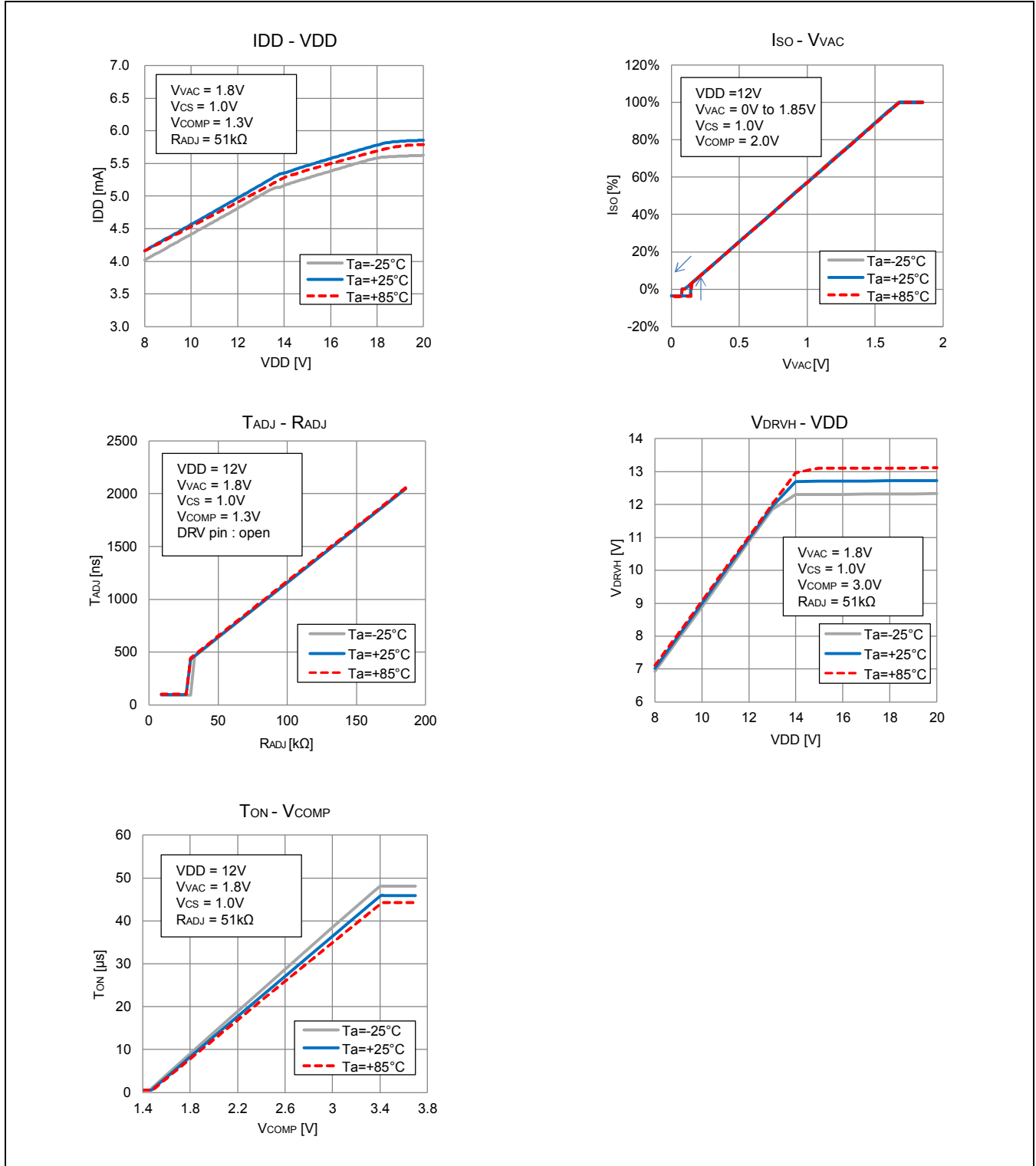
Parameter		Symbol	Pin	Condition	Value			Unit
					Min	Typ	Max	
POWER SUPPLY CURRENT	Power supply current	I _{VDD(STATIC)}	VDD	V _{VDD} =20V, V _{TZE} =1V	-	3	3.6	mA
		I _{VDD(OPERATING)}	VDD	V _{VDD} =20V, Q _g =20nC, f _{SW} =133kHz	-	5.6	-	mA
UVLO	UVLO Turn-on threshold voltage	V _{TH}	VDD	-	12.25	13	13.75	V
	UVLO Turn-off threshold voltage	V _{TL}	VDD	-	7.55	7.9	8.5	V
	Startup current	I _{START}	VDD	V _{VDD} =7V	-	65	160	μA
TRANSFORMER ZERO ENERGY DETECTION	Zero energy threshold voltage	V _{TZETL}	TZE	TZE="H" to "L"	-	20	-	mV
	Zero energy threshold voltage	V _{TZETH}	TZE	TZE="L" to "H"	0.6	0.7	0.8	V
	TZE clamp voltage	V _{TZECLAMP}	TZE	I _{TZE} =-10μA	-200	-160	-100	mV
	OVP threshold voltage	V _{TZEOVP}	TZE	-	4.15	4.3	4.45	V
	OVP blanking time	t _{OVPBLANK}	TZE	-	0.6	1	1.7	μs
	TZE input current	I _{TZE}	TZE	V _{TZE} =5V	-1	-	+1	μA
COMPENSATION	Source current	I _{SO}	COMP	V _{COMP} =2V, V _{CS} =0V V _{VAC} =1.85V	-	27	-	μA
	Trans conductance	gm	COMP	V _{COMP} =2.5V, V _{CS} =1V	-	96	-	μA/V
DIMMING	VAC input current	I _{VAC}	VAC	V _{VAC} =5V	-0.1	-	+0.1	μA
	VACCOMP threshold voltage	V _{VACCOMPVTH}	VAC	-	135	150	165	mV
	VACCOMP hysteresis	V _{VACCOMPVHYS}	VAC	-	-	70	-	mV
ADJUSTMENT	ADJ voltage	V _{ADJ}	ADJ	-	1.81	1.85	1.89	V
	ADJ source current	I _{ADJ}	ADJ	V _{ADJ} =0V	250	450	650	μA
	ADJ time	T _{ADJ}	TZE DRV	T _{ADJ} (R _{ADJ} =51kΩ) - T _{ADJ} (R _{ADJ} =9.1kΩ)	490	550	610	ns
	Minimum switching period	T _{SW}	TZE DRV	-	6.75	7.5	8.25	μs

(Ta = +25°C, V_{VDD} = 12V)

Parameter		Symbol	Pin	Condition	Value			Unit
					Min	Typ	Max	
CURRENT SENSE	OCP threshold voltage	V _{OCPH}	CS	-	1.9	2	2.1	V
	OCP delay time	t _{OCPDLY}	CS	-	-	400	500	ns
	CS input current	I _{CS}	CS	V _{CS} =5V	-1	-	+1	μA
DRV	DRV high voltage	V _{DRVH}	DRV	VDD=18V, I _{DRV} =-30mA	7.6	9.4	-	V
	DRV low voltage	V _{DRVL}	DRV	VDD=18V, I _{DRV} =30mA	-	130	260	mV
	Rise time	t _{RISE}	DRV	VDD=18V, CLOAD=1nF	-	94	-	ns
	Fall time	t _{FALL}	DRV	VDD=18V, CLOAD=1nF	-	16	-	ns
	Minimum on time	t _{ONMIN}	DRV	TZE trigger	300	500	700	ns
	Maximum on time	t _{ONMAX}	DRV	-	27	44	60	μs
	Minimum off time	t _{OFFMIN}	DRV	-	1	1.5	1.93	μs
	Maximum off time	t _{OFFMAX}	DRV	TZE=GND	270	320	370	μs
OTP	OTP threshold	T _{OTP}	-	T _j , temperature rising	-	+150	-	°C
	OTP hysteresis	T _{OTPHYS}	-	T _j , temperature falling, degrees below T _{OTP}	-	+25	-	°C

10. Standard Characteristics

Figure 10-1 Standard Characteristics



11. Function Explanations

11.1 LED Current Control by PSR (Primary Side Regulation)

MB39C605 regulates the average LED current (I_{LED}) by feeding back the information based on Primary Winding peak current (I_{P_PEAK}) and Secondary Winding energy discharge time (T_{DIS}) and switching period. Figure 11-1 shows the operating waveform in a steady state. I_P is Primary Winding current and I_S is Secondary Winding current. I_{LED} as an average current of the Secondary Winding is expressed by the following calculation.

$$I_{LED} = \frac{1}{2} \times I_{S_PEAK} \times \frac{T_{DIS}}{T_{SW}}$$

Using Primary Winding peak current (I_{P_PEAK}) and the turns ratio (N_P/N_S) with Primary Winding turns (N_P) and Secondary Winding turns (N_S), Secondary Winding peak current (I_{S_PEAK}) is expressed by the following calculation.

$$I_{S_PEAK} = \frac{N_P}{N_S} \times I_{P_PEAK}$$

Therefore, I_{LED} is expressed by the following calculation.

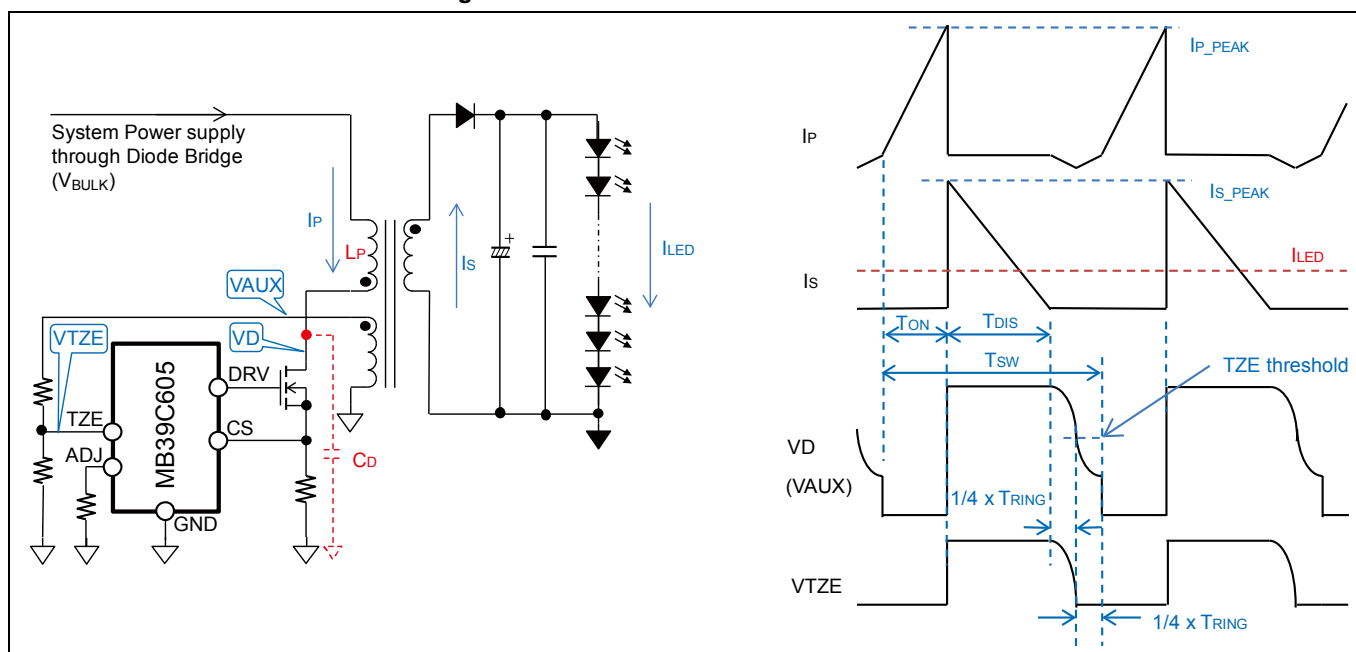
$$I_{LED} = \frac{1}{2} \times \frac{N_P}{N_S} \times I_{P_PEAK} \times \frac{T_{DIS}}{T_{SW}}$$

MB39C605 regulates I_{LED} , by detecting T_{DIS} and T_{SW} by TZE pin and detecting I_{P_PEAK} by CS pin. In addition, using Primary Winding inductance of transformer (L_P) and switching on time (T_{ON}), I_{P_PEAK} is expressed by the following calculation.

$$I_{P_PEAK} = \frac{V_{BULK}}{L_P} \times T_{ON}$$

Namely, MB39C605 regulates I_{P_PEAK} by controlling T_{ON} based on a detection result, and so regulates I_{LED} .

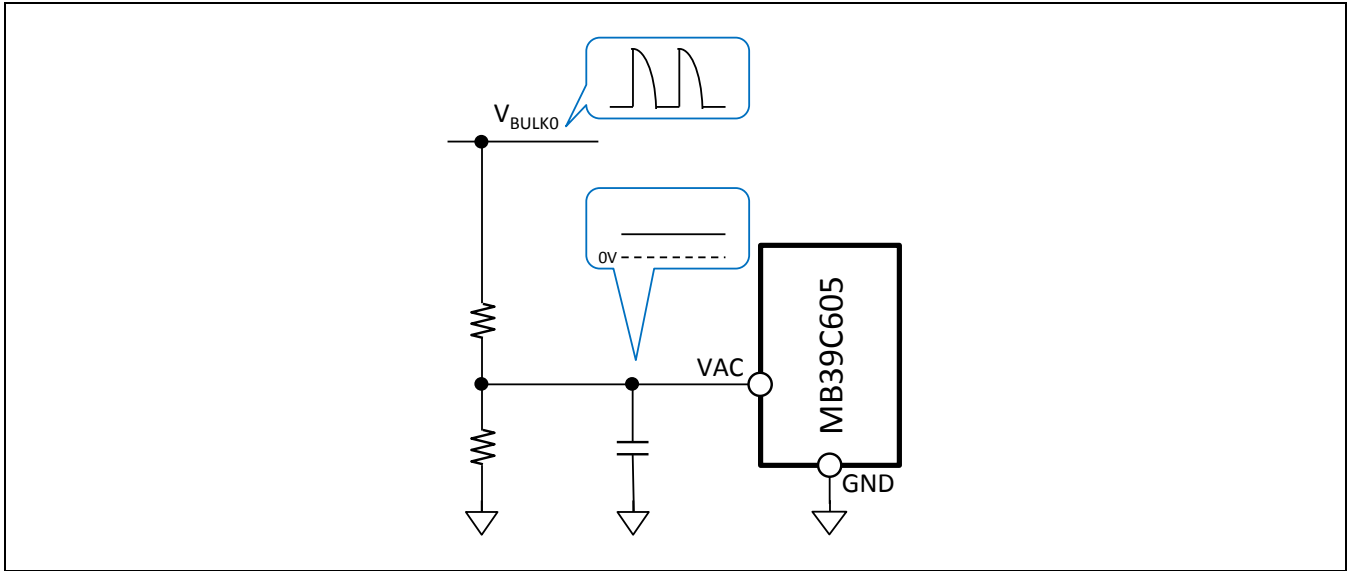
Figure 11-1 LED Current Control Waveform



11.2 Dimming Function

MB39C605 has the Phase dimmable circuit built-in and controls I_{LED} by changing a reference of ERRAMP of the PSR block based on the input dimming control level of VAC pin and realized dimming. Figure 11-2 shows the input configuration of VAC pin in TRIAC dimming. It is possible to configurate TRAIC dimmable system by inputting the level that smoothed V_{BULK0} signal into VAC pin.

Figure 11-2 VAC Pin Input Circuit



11.3 Power-On Sequence

When the AC line voltage is supplied, the voltage is supplied to V_{BULK} through a diode bridge and diode(D1) by charging the capacitor(C_{BULK}). And the current is supplied to VDD pin through start-up resistance(R_{st}). When VDD pin is charged and the voltage of VDD pin becomes more than the UVLO threshold voltage, the internal Bias circuit starts operating, and starts the dimming control. The hi-charging starts after UVLO release, and switching starts. In addition, MB39C605 becomes the forced switching mode at that time. ($T_{ON}=1.5\mu s$, $T_{OFF}=78\mu s$ to $320\mu s$) When the voltage of TZE pin becomes more than the threshold voltage ($V_{TZETH}=0.7V$), MB39C605 becomes the normal operation mode.

After the switching begins, the voltage of VDD pin is supplied through the external diode from Auxiliary Winding. In addition, the voltage of Auxiliary Winding is decided by the turns ratio with Auxiliary Winding turns and Secondary Winding turns, and the voltage of Secondary Winding. Therefore, the voltage of VDD pin is not supplied from Auxiliary Winding, until the voltage of Auxiliary Winding becomes more than the voltage of VDD pin. In this period, it is necessary to set the capacitor of the VDD pin to prevent the voltage of the VDD pin from falling below the threshold voltage of UVLO.

Figure 11-3 VDD Supply Path at Power-On

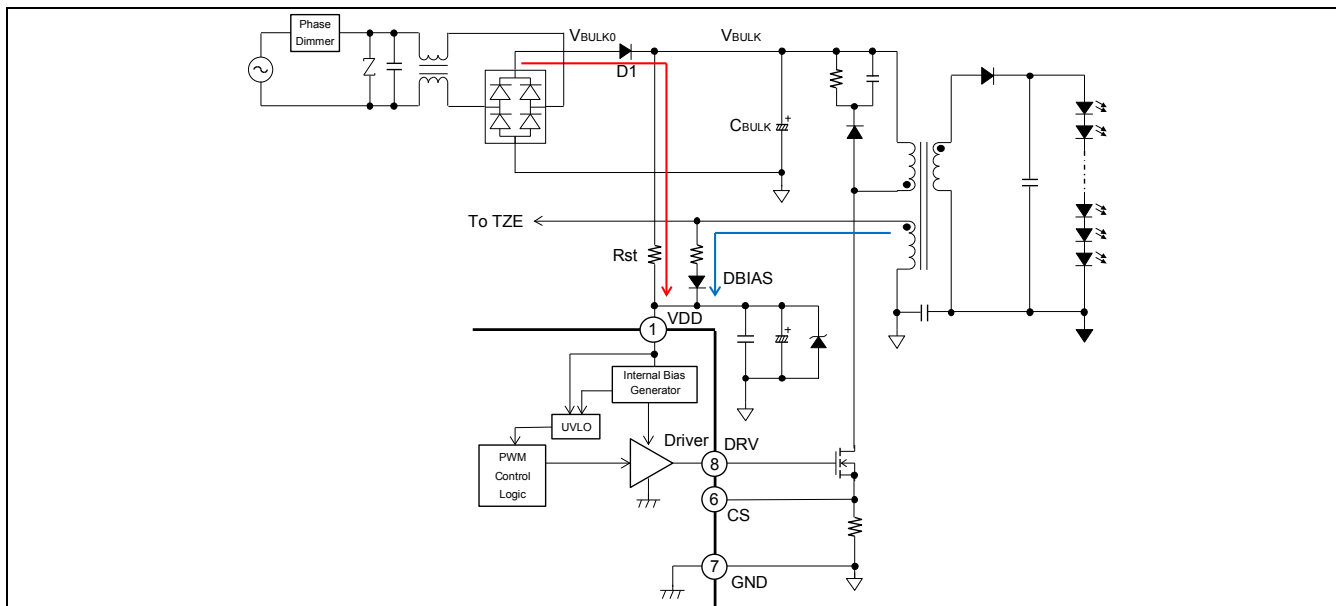
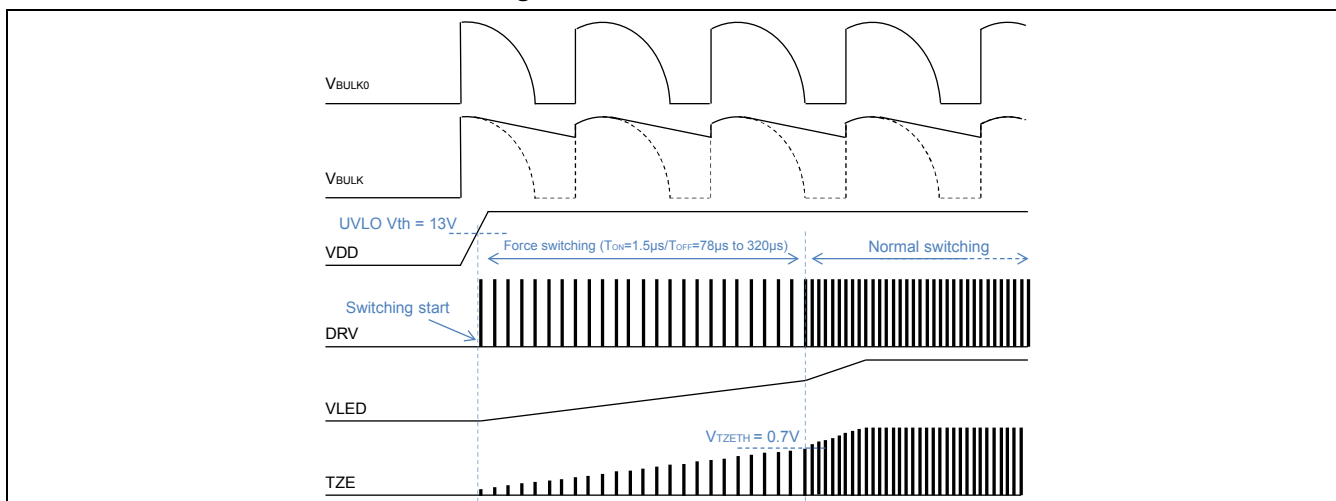


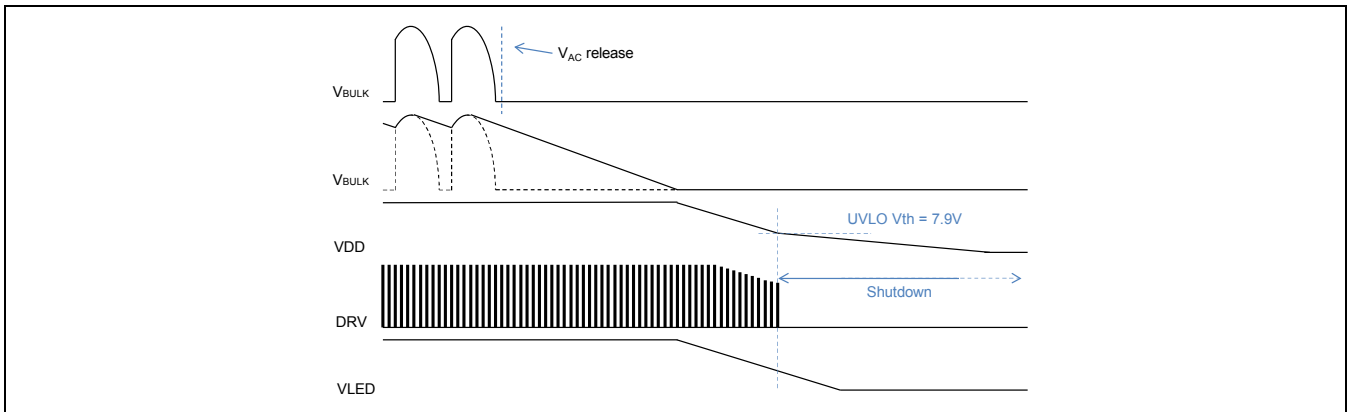
Figure 11-4 Power-On Waveform



11.4 Power-Off Sequence

When the AC line voltage is released, V_{BULK} is discharged by switching operation. At that time, I_{LED} is supplied from the output capacitor only and decreases gradually, because the current is not supplied to Secondary Winding. The voltage of VDD pin decreases, because the current supply to VDD pin becomes without Auxiliary Winding, both Rst. When the voltage of VDD pin becomes less than the UVLO threshold voltage, MB39C605 becomes shutdown.

Figure 11-5 Power-Off Waveform



11.5 I_{P_PEAK} Detection Function

This function detects Primary Winding peak current (I_{P_PEAK}) of Transformer. I_{LED} is set by connecting resistance (R_{CS}) to CS pin between GND pin. Maximum I_{P_PEAK} ($I_{P_PEAKMAX}$) at the time of the Over Current Protection (OCP) is set at the same time, too.

Using the turns ratio (N_P/N_S) with Primary Winding turns (N_P) and Secondary Winding turns (N_S), and I_{LED} , R_{CS} is expressed by the following calculation.

$$R_{CS} = \frac{N_P}{N_S} \times \frac{0.14}{I_{LED}}$$

In addition, using the OCP threshold voltage (V_{OCPTH}) and the sense resistance (R_{CS}), $I_{P_PEAKMAX}$ is expressed by the following calculation.

$$I_{P_PEAKMAX} = \frac{V_{OCPTH}}{R_{CS}}$$

11.6 Zero Voltage Switching Function

MB39C605 has zero voltage switching function built-in to minimize a switching loss of the external switching MOSFET. The following functions are necessary to realize zero voltage switching.

- (1) Detect that the energy of the transformer becomes zero
- (2) Let a driver turn on at the lowest point of the energy ringing of transformer

(1) is possible to detect by TZE pin through resistance connected Auxiliary Winding of transformer.

(2) is possible to realize by adjustment on on-timing of switching MOSFET and adjustment on detection of the Secondary side current-releasing time. Adjustment time (t_{ADJ}) is set by connecting resistance (R_{ADJ}) to ADJ pin between GND pin. Using Primary Winding inductance (L_P), and the parasitic capacitor of switching MOSFET drain (C_D), t_{ADJ} is expressed by the following calculation.

$$t_{ADJ} = \frac{\pi \sqrt{L_P \times C_D}}{2}$$

Using t_{ADJ} , R_{ADJ} is expressed by the following calculation.

$$R_{DLY} [k\Omega] = 0.092 \times t_{ADJ} [ns] - 3.85$$

11.7 Various Protection Functions

Under Voltage Lockout Protection (UVLO)

The under voltage lockout protection (UVLO) protects IC from malfunction and protects the system from destruction/deterioration during the transient state and momentary drop due to start up for the power supply pin voltage (VDD). The voltage decrease of the VDD pin is detected with comparator, and the voltage of DRV pin is turned to "L", and the switching is stopped. The system automatically returns to the normal operation mode when the voltage of VDD pin becomes more than the UVLO threshold voltage.

Over Voltage Protection (OVP)

The over voltage protection (OVP) protects parts of Secondary side from an excessive stress voltage by the rising of the output voltage, when the LED dropout. The output overvoltage is detected by TZE pin. When current of Secondary side is supplied, output voltage appears to TZE pin that is the voltage division of Auxiliary Winding. When the voltage of TZE pin rise more than the threshold of the over voltage detecting circuit and the period passes more than three switching cycles, the voltage of DRV pin is turned to "L", and the switching is stopped (latch off). A latch is removed, when the voltage of VDD pin becomes less than the UVLO threshold voltage.

Over Current Protection (OCP)

The over current protection (OCP) protects IC from the saturation of the inductor and the transformer. The drain current of the external switching MOSFET is limited by using OCP. When the voltage of CS pin becomes more than the OCP threshold voltage, the voltage of DRV pin is turned to "L", and the switching is stopped. When TZE pin detects Zero energy again, DRV pin is turned to "H" and the next switching cycle begin.

Short Circuit Protection (SCP)

The short circuit protection (SCP) protects the transformer and the diode of Secondary side from an excessive current stress. When the Output voltage decreases by a short circuit of the LED and the voltage of TZE pin does not become more than the SCP threshold voltage, the voltage of COMP pin is discharged to 1.5V and the switching cycle shifts to a low frequency mode ($T_{ON}=1.5\mu s/T_{OFF}=78\mu s$ to $320\mu s$).

Over Temperature Protection (OTP)

The over temperature protection (OTP) protects IC from the thermal destruction. When the junction temperature reaches $+150^{\circ}C$, DRV pin voltage is turned to "L", and the switching is stopped. It automatically returns to the normal operation mode when the junction temperature becomes below $+125^{\circ}C$.

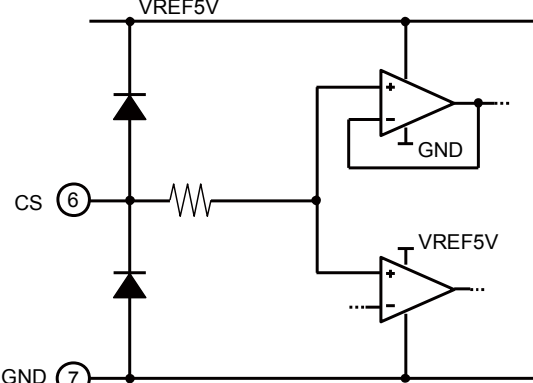
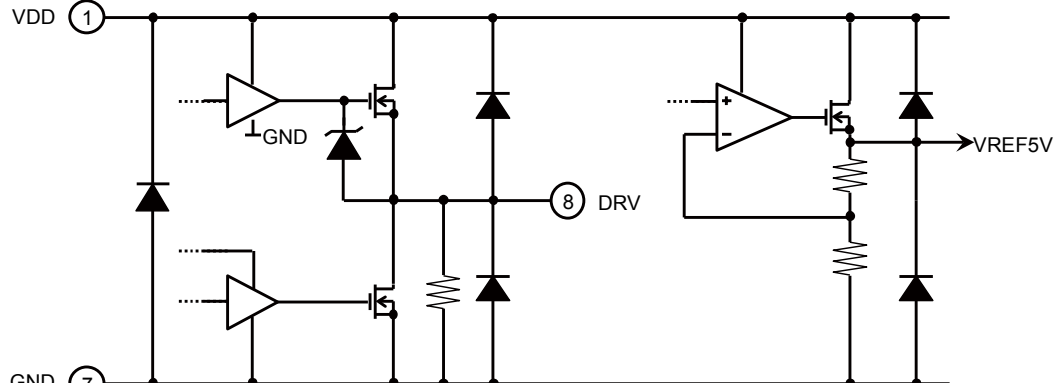
Table 11-1 Various Protection Functions Table

Function	DRV	COMP	ADJ	Detection Condition at Protected Operation	Return Condition	Remarks
Normal Operation	Active	Active	Active	-	-	-
Under Voltage Lockout Protection (UVLO)	L	L	L	VDD < 7.9V	VDD > 13V	Auto Restart
Over Voltage Protection (OVP)	L	1.5V fixation	Active	TZE > 4.2V	VDD < 7.9V → VDD > 13V	Latch off
Over Current Protection (OCP)	L	Active	Active	CS > 2V	Cycle by cycle	Auto Restart
Short Circuit Protection (SCP)	Active	1.5V fixation	Active	TZE (peak) < 0.7V	TZE (peak) > 0.7V	Auto Restart
Over Temperature Protection (OTP)	L	1.5V fixation	Active	Tj > $+150^{\circ}C$	Tj < $+125^{\circ}C$	Auto Restart

12. I/O Pin Equivalent Circuit Diagram

Figure 12-1 I/O Pin Equivalent Circuit Diagram

Pin No.	Pin Name	Equivalent Circuit Diagram
2	TZE	
3	COMP	
4	VAC	
5	ADJ	

Pin No.	Pin Name	Equivalent Circuit Diagram
6	CS	
8	DRV	

13. Usage Precautions

Do not configure the IC over the maximum ratings.

If the IC is used over the maximum ratings, the LSI may be permanently damaged.

It is preferable for the device to normally operate within the recommended usage conditions. Usage outside of these conditions can have an adverse effect on the reliability of the LSI.

Use the device within the recommended operating conditions.

The recommended values guarantee the normal LSI operation under the recommended operating conditions.

The electrical ratings are guaranteed when the device is used within the recommended operating conditions and under the conditions stated for each item.

Printed circuit board ground lines should be set up with consideration for common impedance.

Take appropriate measures against static electricity.

- Containers for semiconductor materials should have anti-static protection or be made of conductive material.
- After mounting, printed circuit boards should be stored and shipped in conductive bags or containers.
- Work platforms, tools, and instruments should be properly grounded.
- Working personnel should be grounded with resistance of 250 kΩ to 1 MΩ in serial between body and ground.

Do not apply negative voltages.

The use of negative voltages below - 0.3 V may make the parasitic transistor activated to the LSI, and can cause malfunctions.

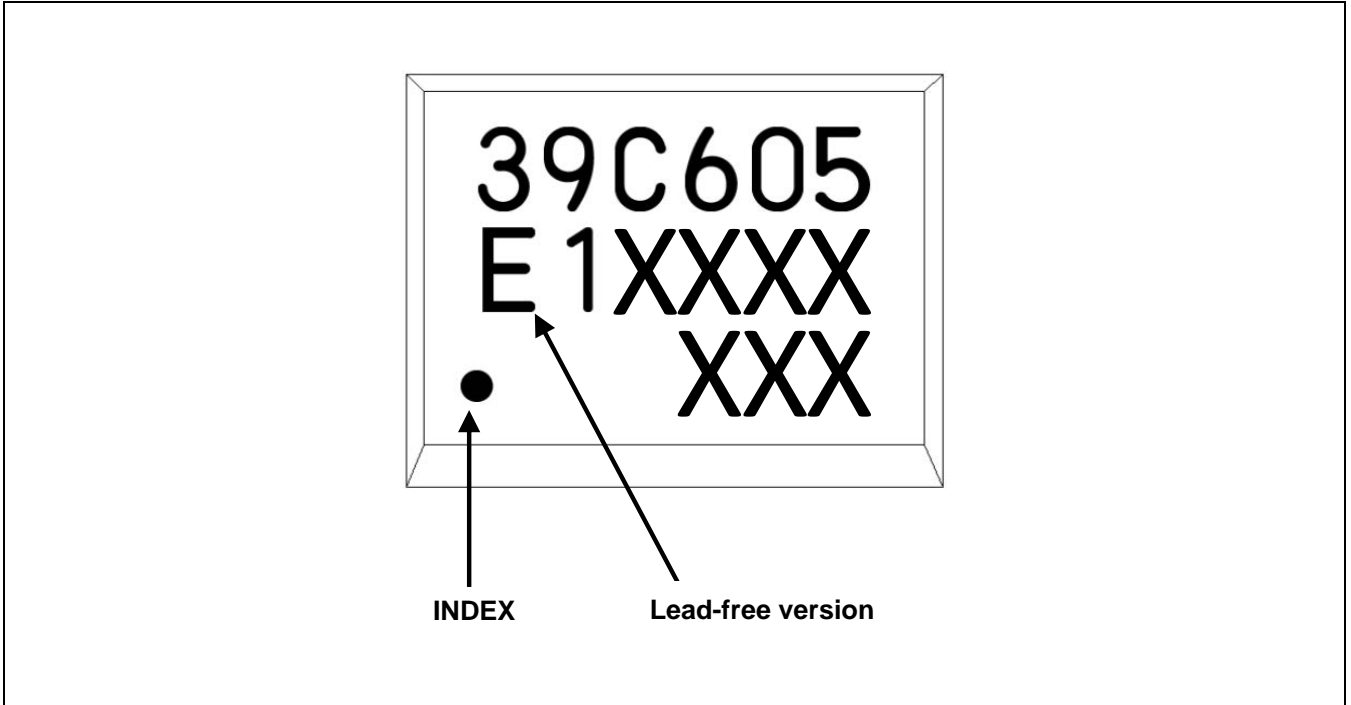
14. Ordering Information

Table 14-1 Ordering Information

Part Number	Package
MB39C605PNF	8-pin plastic SOP (FPT-8P-M02)

15. Marking Format

Figure 15-1 Marking Format



16. Labeling Sample

Figure 16-1 Labeling Sample

Lead-free mark

JEITA logo

JEDEC logo

MB123456P - 789 - GE1
 (3N) 1MB123456P-789-GE1 1000

QC PASS

1,000 PCS

MB123456P - 789 - GE1

2006/03/01

ASSEMBLED IN JAPAN

MB123456P - 789 - GE1
 1561190005

1/1

0605 - Z01A 1000

“ASSEMBLED IN CHINA” is printed on the label of a product assembled in China.

The part number of a lead-free product has The trailing characters “E1”.

17. Recommended Conditions of Moisture Sensitivity Level

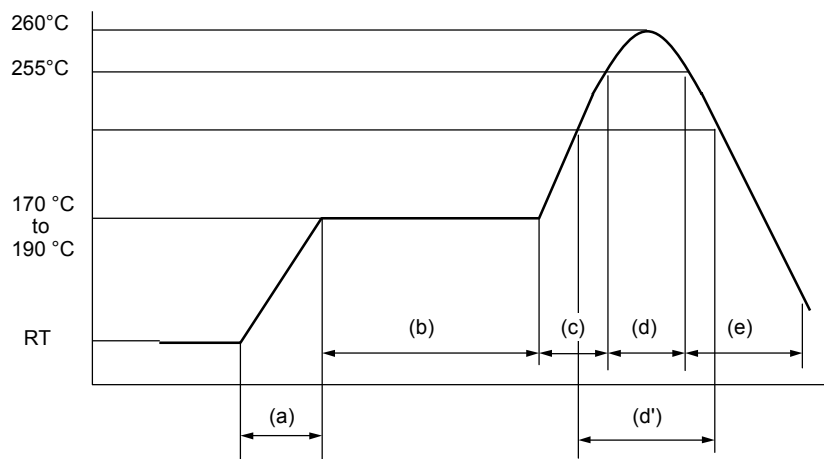
17.1 Recommended Reflow Condition

Table 17-1 Recommended Reflow Condition

Item	Condition	
Mounting Method	IR (infrared reflow), warm air reflow	
Mounting times	2 times	
Storage period	Before opening	Please use it within 2 years after manufacture.
	From opening to the 2nd reflow	Less than 8 days
	When the storage period after opening was exceeded	Please process within 8 days after baking (125°C±3°C, 24H+2H/-0H) Baking can be performed up to 2 times.
Storage conditions	5°C to 30°C, 70% RH or less (the lowest possible humidity)	

17.2 Reflow Profile

Figure 17-1 Reflow Profile



H rank : 260°C Max

- (a) Temperature Increase gradient : Average 1°C/s to 4°C/s
- (b) Preliminary Heating : Temperature 170°C to 190°C, 60s to 180s
- (c) Temperature Increase gradient : Average 1°C/s to 4°C/s
- (d) Peak Temperature : Temperature 260°C Max.
255°C or more, 10s or less
- (d') Main Heating : Temperature 230°C or more, 40s or less
or
Temperature 225°C or more, 60s or less
or
Temperature 220°C or more, 80s or less
- (e) Cooling : Natural cooling or forced cooling

Note : Temperature : the top of the package body

17.3 JEDEC Condition

Moisture Sensitivity Level3 (IPC/JEDEC J-STD-020D)

17.4 Recommended manual soldering (partial heating method)

Table 17-2 Recommended manual soldering

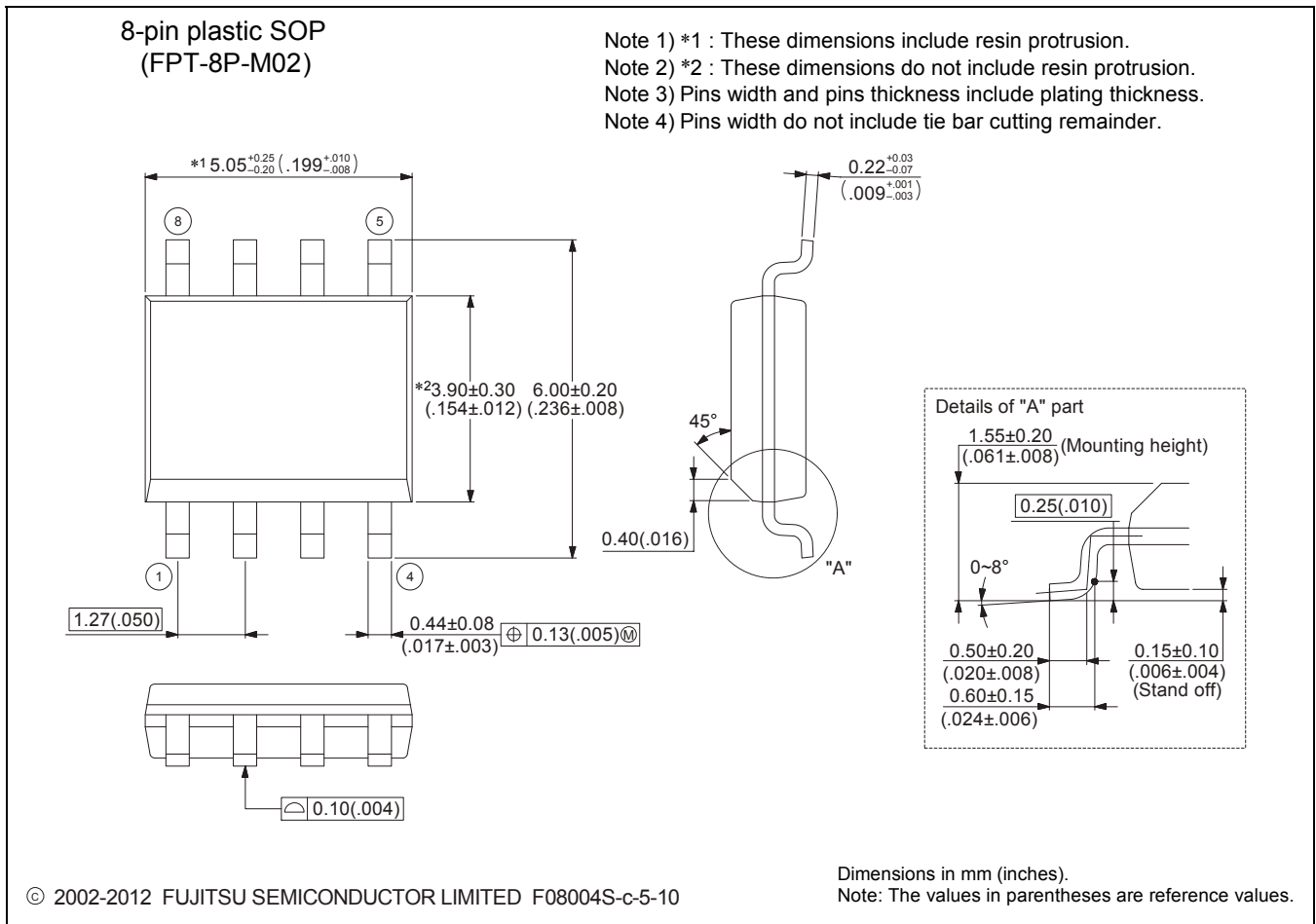
Item	Condition	
Storage period	Before opening	Within 2 years after manufacture
	Between opening and mounting	Within 2 years after manufacture (No need to control moisture during the storage period because of the partial heating method.)
Storage conditions	5°C to 30°C, 70%RH or less (the lowest possible humidity)	
Mounting conditions	Temperature at the tip of a soldering iron : 400°C Max. Time : 5 seconds or below per pin (*1)	

*1: Make sure that the tip of a soldering iron does not come in contact with the package body.

18. Package Dimensions

Figure 18-1 Package Dimensions

<p>8-pin plastic SOP</p> <p>(FPT-8P-M02)</p>	Lead pitch	1.27 mm
	Package width × package length	3.9 mm × 5.05 mm
	Lead shape	Gullwing
	Sealing method	Plastic mold
	Mounting height	1.75 mm MAX
	Weight	0.06 g



Please check the latest package dimension at the following URL.
<http://edevice.fujitsu.com/package/jp-search/>

19. Major Changes

Page	Section	Change Results
Revision 1.0		
-	-	Initial release

Colophon

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