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MB39C601

ASSP
TRIAC Dimmable LED Driver IC for LED Lighting

Data Sheet (Full Production)

Publication Number MB39C601_DS405-00008 Revision 2.1 Issue Date January 31, 2014

MB39C601

ASSP
TRIAC Dimmable LED Driver IC for LED Lighting

Data Sheet (Full Production)

■ DESCRIPTION

MB39C601 is a flyback type switching regulator contorller IC. The LED current is regulated by controlling the switching on-time or controlling the switching frequency, depending on the LED load.
It is most suitable for the general lighting applications, for example stocks of commercial and residential light bulbs and so on.

■ FEATURES

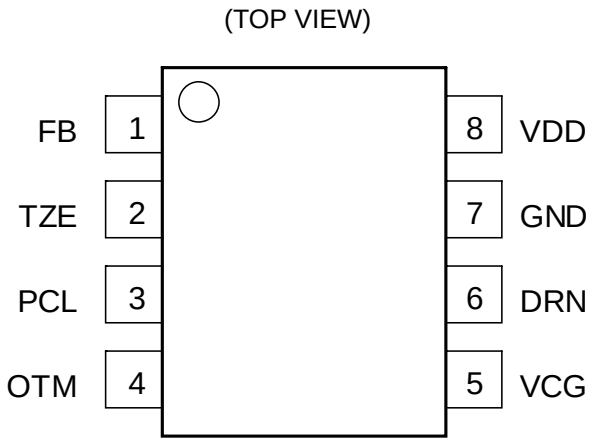
- High power factor in single conversion
- High efficiency at the light load, at Low Power Mode (LPM) Burst Operation in switching frequency control
- Frequency setting depend on the FB pin current : 30 kHz to 130 kHz
- Control of the current of Primary Winding without the external sense resistor
- TRIAC Dimmable LED lighting
- Helps to achieve high efficiency and low EMI by detecting transformer zero energy
- Built-in under voltage lock out function
- Built-in over load protection function
- Built-in output over voltage protection function
- Built-in over temperature protection function
- LED load :25W (Max)
- Input voltage range VDD : 9V to 20V
- Input voltage range for LED lighting applications : $AC110V_{RMS}$, $AC230V_{RMS}$
- Package : SOP-8 (3.9mm × 5.05mm × 1.75mm [Max])

■ APPLICATIONS

- LED lighting
- TRIAC dimmable LED lighting etc.

Publication Number MB39C601_DS405-00008 Revision 2.1 Issue Date January 31, 2014

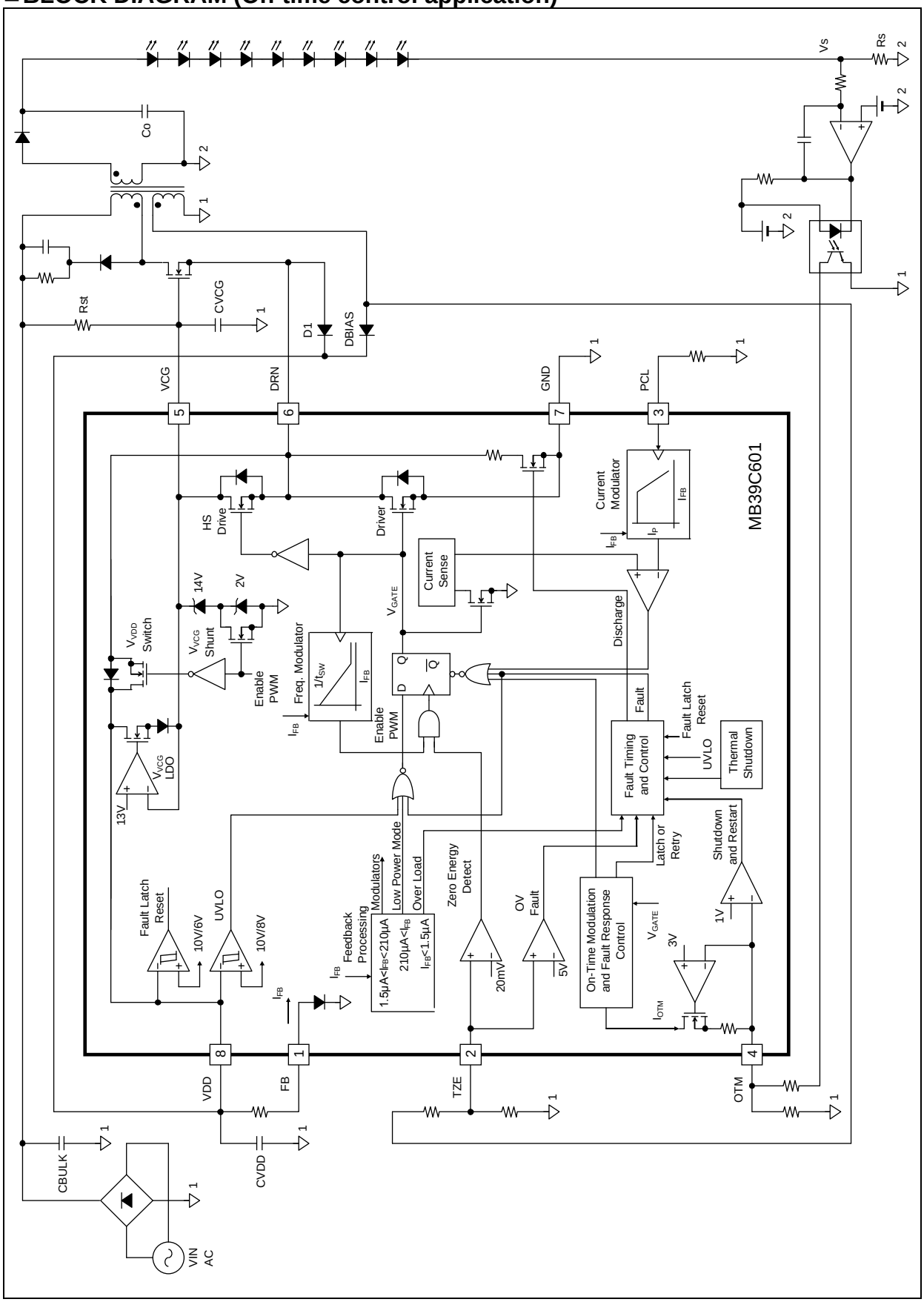
■ PIN ASSIGNMENT



■ PIN DESCRIPTIONS

Pin No.	Pin Name	I/O	Description
1	FB	I	Switching frequency setting pin.
2	TZE	I	Transformer auxiliary winding zero energy detecting pin.
3	PCL	I	Pin for controlling peak current of transformer primary winding.
4	OTM	I	On-time setting pin.
5	VCG	-	External MOSFET gate bias pin.
6	DRN	O	External MOSFET source connection pin.
7	GND	-	Ground pin.
8	VDD	-	Power supply pin.

■BLOCK DIAGRAM (On-time control application)



■ ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Condition	Rating		Unit
			Min	Max	
Power supply voltage	V_{VDD}	VDD pin	-0.3	+25.0	V
Input voltage	V_{DRN}	DRN pin	-	+20.0	V
	V_{VCG}	VCG pin	-0.3	+16.0	V
	V_{TZE}	TZE pin	-0.3	+6.0	V
	V_{OTM}	OTM pin	-0.3	+6.0	V
	V_{PCL}	PCL pin	-0.3	+6.0	V
	V_{FB}	FB pin	-0.3	+2.0	V
Input current	I_{VCG}	VCG pin	-	10	mA
	I_{OTM}	OTM pin	-1	0	mA
	I_{PCL}	PCL pin	-1	0	mA
	I_{FB}	FB pin	0	1	mA
Output current	I_{DRN}	DRN pin	-	800	mA
	I_{DRN}	DRN pin, Pulsed 400ns, 2% duty cycle	-1.5	+6.0	A
Power dissipation	P_D	Ta ≤ +25°C	-	800*	mW
Storage temperature	T_{STG}		-55	+125	°C

*: The value when using two layers PCB.
Reference: θja (wind speed 0m/s): 125°C/W

WARNING: 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.

■ RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Condition	Value			Unit
			Min	Typ	Max	
VDD pin input voltage	VDD	VDD pin	9	-	20	V
VCG pin input voltage	VCG	VCG pin (from low-impedance source)	9	-	13	V
VCG pin input current	I_{VCG}	VCG pin (from high-impedance source)	10	-	2000	µA
OTM pin ground resistance	R_{OTM}	OTM pin Shutdown/retry mode	10	-	100	kΩ
		OTM pin Latch-off mode	150	-	750	kΩ
PCL pin ground resistance	R_{PCL}	PCL pin	24.3	-	200.0	kΩ
TZE pin connection resistance	R_{TZE1}	TZE pin Auxiliary winding connection resistor	50	-	200	kΩ
VCG pin grounded capacity	C_{VCG}	VCG pin	33	-	200	nF
VDD pin bypass capacity	C_{BP}	Ceramic capacitor value to set between VDD and GND pin	0.1	-	1.0	µF
Operating ambient temperature	Ta	-	-40	+25	+85	°C

WARNING: 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.
Any use of semiconductor devices will be under their recommended operating condition.
Operation under any conditions other than these conditions may adversely affect reliability of device and could result in device failure.
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.

■ELECTRICAL CHARACTERISTICS

(Ta = +25°C, V_{VDD} = 12V)

Parameter		Symbol	Pin No.	Condition	Value			Unit
					Min	Typ	Max	
VDD and VCG SUPPLY	VCG voltage (Operating)	$VCG_{(OPERATING)}$	5	V_{VDD}=14V, I_{VCG}=2.0mA	13	14	15	V
	VCG voltage (Disable)	$VCG_{(DISABLED)}$	5	V_{VDD}=12V, I_{VCG}=26µA, I_{FB}=350µA	15	16	17	V
	VCG voltage difference	ΔVCG	5	$VCG_{(DISABLED)}$- $VCG_{(OPERATING)}$	1.75	2.00	2.15	V
	VCG Shunt input current	$I_{VCG(SREG)}$	5	V_{VCG}=$VCG_{(DISABLED)}$- 100mV, V_{VDD}=12V	-	12	26	µA
	VCG Shunt Load Regulation	$ΔVCG_{(SREG)}$	5	26µA<I_{VCG} ≤ 5mA, I_{FB}=350µA	-	125	200	mV
	VCG LDO regulation voltage	$VCG_{(LREG)}$	5	V_{VDD}=20V, I_{VCG}=-2mA	-	13	-	V
	VCG LDO Dropout voltage	$VCG_{(LREG, DO)}$	-	VDD-VCG, V_{VDD}=11V, I_{VCG}=-2mA	-	2.0	2.8	V
	UVLO Turn-on threshold voltage	$VDD_{(ON)}$	8	-	9.7	10.2	10.7	V
	UVLO Turn-off threshold voltage	$VDD_{(OFF)}$	8	-	7.55	8.00	8.50	V
	UVLO hysteresis	$ΔVDD_{(UVLO)}$	8	$VDD_{(ON)}$ - $VDD_{(OFF)}$	1.9	2.2	2.5	V
	VDD switch on-resistance	$R_{DS, ON (VDD)}$	6,8	V_{VCG}=12V, V_{VDD}=7V, I_{DRN}=50mA	-	4*	10*	Ω
	Fault Latch Reset VDD voltage	$VDD_{(FAULT RESET)}$	8	-	5.6	6.0	6.4	V

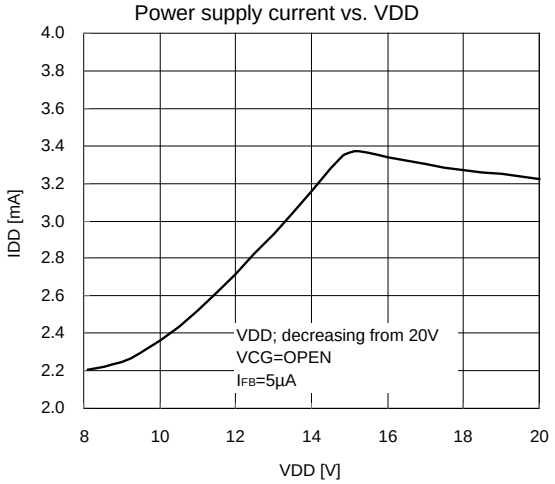
Parameter		Symbol	Pin No.	Condition	Value			Unit
					Min	Typ	Max	
MODULATION	Minimum switching period	$t_{SW(HF)}$	6	FM mode I_{FB}=5µA	7.215	7.760	8.305	µs
	Maximum switching period	$t_{SW(LF)}$	6	$I_{FB}=I_{FB, CNR3}$ -20µA	31.5	35.0	38.5	µs
	DRN peak current	$I_{DRN(peak)}$	6	I_{FB}=5µA, I_{PCL}=100µA	-	3*	-	A
			6	I_{FB}=5µA, I_{PCL}=30µA	-	1*	-	A
	Minimum peak current for R_{PCL} open	$I_{DRN (peak, absmin)}$	6	R_{PCL} =OPEN	-	0.45*	-	A
	ILIM blanking time	$t_{BLANK (ILIM)}$	6	I_{FB}=5µA, R_{PCL}=100kΩ, 1.2A pull-up on DRN	-	400*	-	ns
	PCL voltage	V_{PCL}	3	I_{FB}=5µA	2.94	3.00	3.06	V
			3	I_{FB}=230µA	0.95	1.00	1.05	V
	I_{FB} range for FM mode	$I_{FB, CNR1}$	1	$t_S=t_{S(LF)}$, $I_{DRN}=I_{DRN(peak, max)}$	145	165	195	µA
	I_{FB} range for AM mode	$I_{FB,CNR2}$- $I_{FB,CNR1}$	1	$t_S=t_{S(LF)}$, $I_{DRN(peak)}$ variation range= $I_{DRN(peak, max)}$ to $I_{DRN(peak, min)}$	35	45	65	µA
	I_{FB} range for LPM	$I_{FB,CNR3}$- $I_{FB,CNR2}$	1	-	50	70	90	µA
	I_{FB} hysteresis for LPM	$I_{FB, LPM-HYST}$	1	-	10	25	40	µA
	FB voltage	V_{FB}	1	I_{FB}=10µA	0.34	0.70	0.84	V
DRIVER	Driver on-resistance	$R_{DS(on)(DRN)}$	6,7	I_{DRN}=4.0A	-	200*	400*	mΩ
	Driver off leakage current	$I_{DRN(OFF)}$	6,7	V_{DRN}=12V	-	1.5	20.0	µA
	High-side driver on-resistance	$R_{DS(on)(HSDRV)}$	5,6	High-side Driver current=50mA	-	6*	11*	Ω
	DRN discharge current	I_{DIS}	6,7	VDD=OPEN, DRN=12V, Fault latch set	2.38	3.40	4.42	mA
TRANSFORMER ZERO ENERGY DETECTION	TZE zero energy threshold voltage	$V_{TZE(TH)}$	2	-	5*	20*	50*	mV
	TZE clamp voltage	$V_{TZE(CLAMP)}$	2	I_{TZE}= -10µA	-200	-160	-100	mV
	Start timer operation threshold voltage	$V_{TZE(START)}$	2	-	0.10	0.15	0.20	V
	Driver turn-on Delay time	$t_{DRY(TZE)}$	6	150Ω pull-up 12V on DRN	-	150	-	ns
	Wait time for zero energy detection	$t_{WAIT(TZE)}$	6	-	2.0	2.4	2.8	µs
	Start timer period	t_{ST}	6	V_{TZE}=0V	150	240	300	µs

Parameter		Symbol	Pin No.	Condition	Value			Unit
					Min	Typ	Max	
OVERVOLTAGE FAULT	OVP threshold voltage	$V_{TZE(OVP)}$	2	-	4.85	5.00	5.15	V
	OVP blanking time	$t_{BLANK, OVP}$	6	-	0.6	1.0	1.7	µs
	Input bias current	$I_{TZE(bias)}$	2	V_{TZE}=5V	-0.1	0	+0.1	µA
OVERLOAD FAULT	Over Load detection current	$I_{FB(OL)}$	1	-	0*	1.5*	3.0*	µA
	Over Load delay time	t_{OL}	6	I_{FB}=0A	200	250	300	ms
	Retry time after Over Load	t_{RETRY}	6	R_{OTM}=76kΩ	-	750	-	ms
	Over Load detection boundary resistance	$R_{OTM(TH)}$	4	-	100	120	150	kΩ
SHUTDOWN THRESHOLD	Shutdown Threshold voltage	$V_{OTM(Vth)}$	4	OTM= 	0.7	1.0	1.3	V
	Shutdown OTM current	$I_{OTM, PU}$	4	V_{OTM} = $V_{OTM(vth)}$	-600	-450	-300	µA
MAXIMUM ON TIME	ON-Time	t_{OTM}	6	R_{OTM}=383kΩ	3.74	4.17	4.60	µs
			6	R_{OTM}=76kΩ	3.4	3.8	4.2	µs
	OTM voltage	V_{OTM}	4	-	2.7	3.0	3.3	V
OTP	Protection temperature	T_{SD}	-	Tj, temperature rising	-	+150*	-	°C
	Protection temperature hysteresis	T_{SD_HYS}	-	Tj, temperature falling, degrees below T_{SD}	-	25*	-	°C
POWER SUPPLY CURRENT	Power supply current	I_{VDD} (STATIC)	8	V_{VDD}=20V, V_{TZE}=1V	1.36	1.80	2.34	mA
		I_{VDD} (OPERATING)	8	V_{VDD}=20V	-	3.0*	3.7*	mA
	Power supply current for LPM	$I_{VDD(LPM)}$	8	I_{FB}=350µA	-	550	900	µA
	Power supply current for UVLO	$I_{VDD(UVLO)}$	8	V_{VDD}= $VDD_{(ON)}$ - 100mV	-	285	500	µA

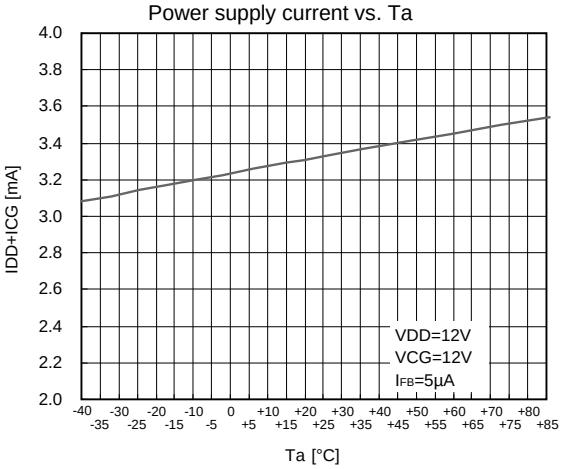
*: Standard design value

■ TYPICAL CHARACTERISTICS

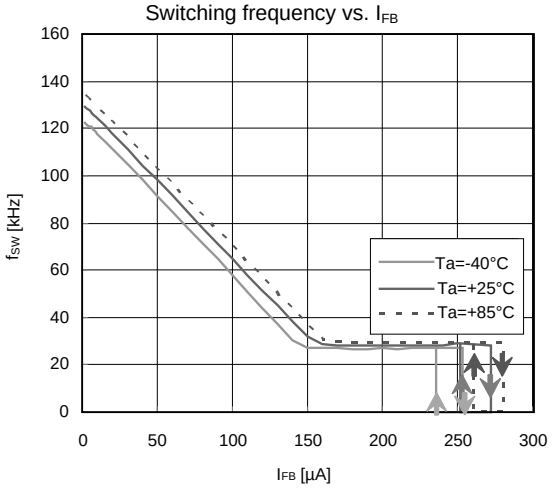
Power supply current vs. VDD



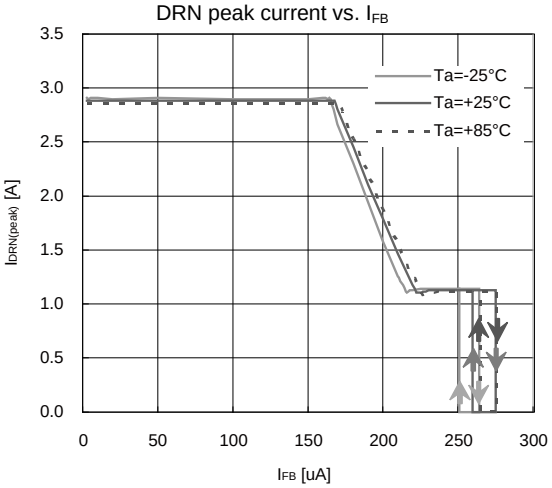
Power supply current vs. Ta



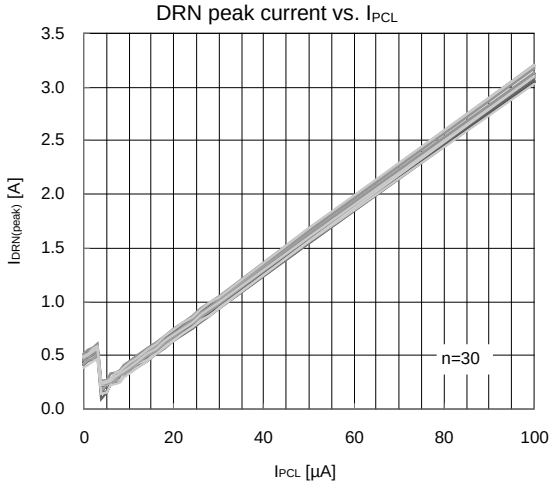
Switching frequency vs. I_{FB}



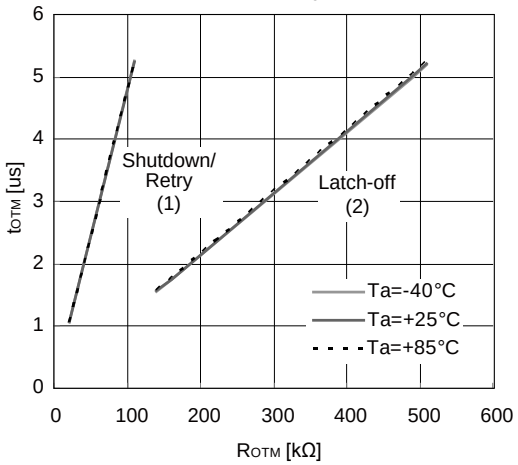
DRN peak current vs. I_{FB}



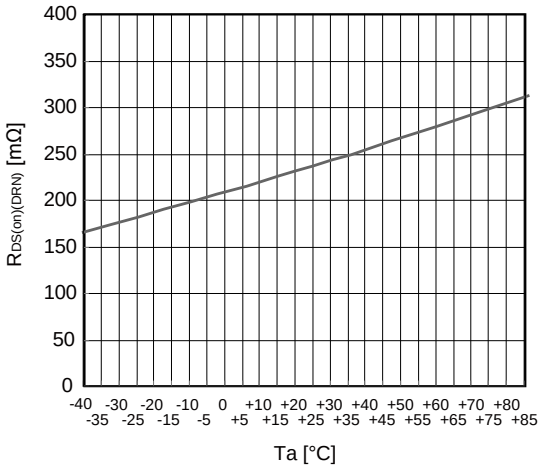
DRN peak current vs. I_{PCL}



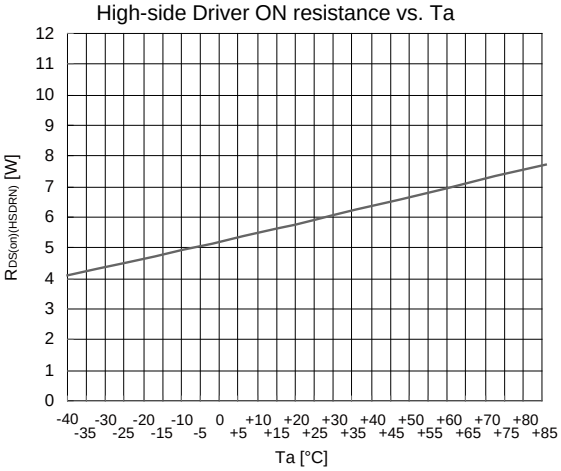
ON time vs. R_{OTM}



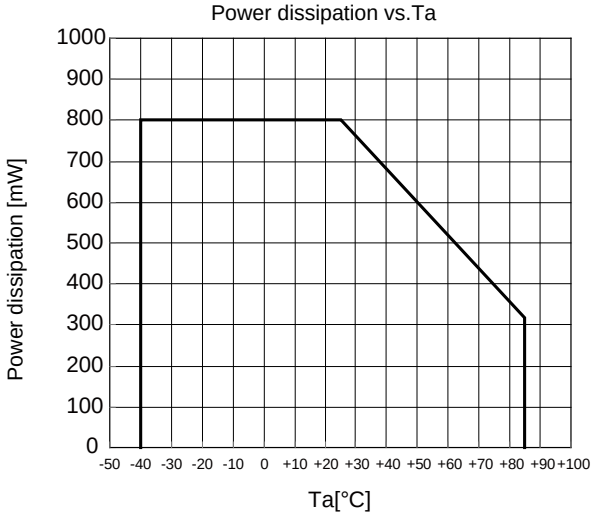
Driver ON resistance vs. Ta



High-side Driver ON resistance vs. Ta



Power dissipation vs.Ta



■ FUNCTION EXPLANATION

(1) LED Current Control Function

MB39C601 is a flyback type switching regulator controller. The LED current is regulated by controlling the switching on-time or controlling the switching frequency depending on the LED load.
The LED current is converted into detecting voltage (Vs) by sense resistor (Rs) connected in series with LED. Vs is compared by an external error amplifier (Err AMP).When Vs falls below a reference voltage, Err AMP output rises and the current that flows into the Opto-Coupler is decreased.

The OTM pin current is controlled via the Opto-Coupler in the on-time control block. In on-time control, it controls on-time at OTM pin current. So, on-time increases when the current of the OTM pin decreases. And the average current supplied to LED is regulated, because on-time is regulated at the constant switching frequency.

The FB pin current is controlled via the Opto-Coupler in the switching frequency control block. In switching frequency control, it controls switching frequency at FB pin current. So, switching frequency becomes high when the current of the FB pin decreases. And the average current supplied to LED is regulated, because switching frequency is regulated at the constant on-time.

(2) Cascode Switching

The switch in Primary Winding is a cascode connection.The gate of external MOSFET is connected with the VCG pin, and the source is connected with the drain of internal Driver MOSFET.
When the swich is on-state, internal Driver MOSFET is turned on, HS Driver MOSFET is turned off, and the source voltage of external MOSFET goes down to GND. For this period the DC bias is supplied to the gate of external MOSFET from the VCG pin. Therefore external MOSFET is turned on.

When the switch is off-state, internal Driver MOSFET is turned off, HS Driver MOSFET is turned on, and the source voltage of external MOSFET goes up to VCG voltage. For this period the DC bias is supplied to the gate of external MOSFET from VCG pin. Therefore external MOSFET is turned off.
Moreover, the current flowing into internal Driver MOSFET is equal to the current of Primary Winding. Therefore, the peak current into Primary Winding can be detected without the sense resistor.

(3) Natural PFC (Power Factor Correction) Function

In the AC voltage input, when the input current waveform is brought close to the sine-wave, and the phase difference is brought close to Zero, Power Factor is improved.
In the flyback method operating in discontinuous conduction mode, when the input capacitance is set small, the input current almost becomes equal with peak current of Primary Winding.

$$I_{PEAK} = \left(\frac{V_{BULK} \times t_{ON}}{L_{MP}} \right) = \left(\frac{V_{BULK}}{\left(\frac{L_{MP}}{t_{ON}} \right)} \right)$$

V_{BULK} : Supply voltage of Primary Winding
L_{MP} : Inductance of Primary Winding
t_{ON} : On-time

In on-time control, if loop response of Error Amp. is set to lower than the AC frequency (below 1/10 of the AC frequency), on-time can be constant. Therefore, input current is proportional to input voltage, so Power Factor is regulated.

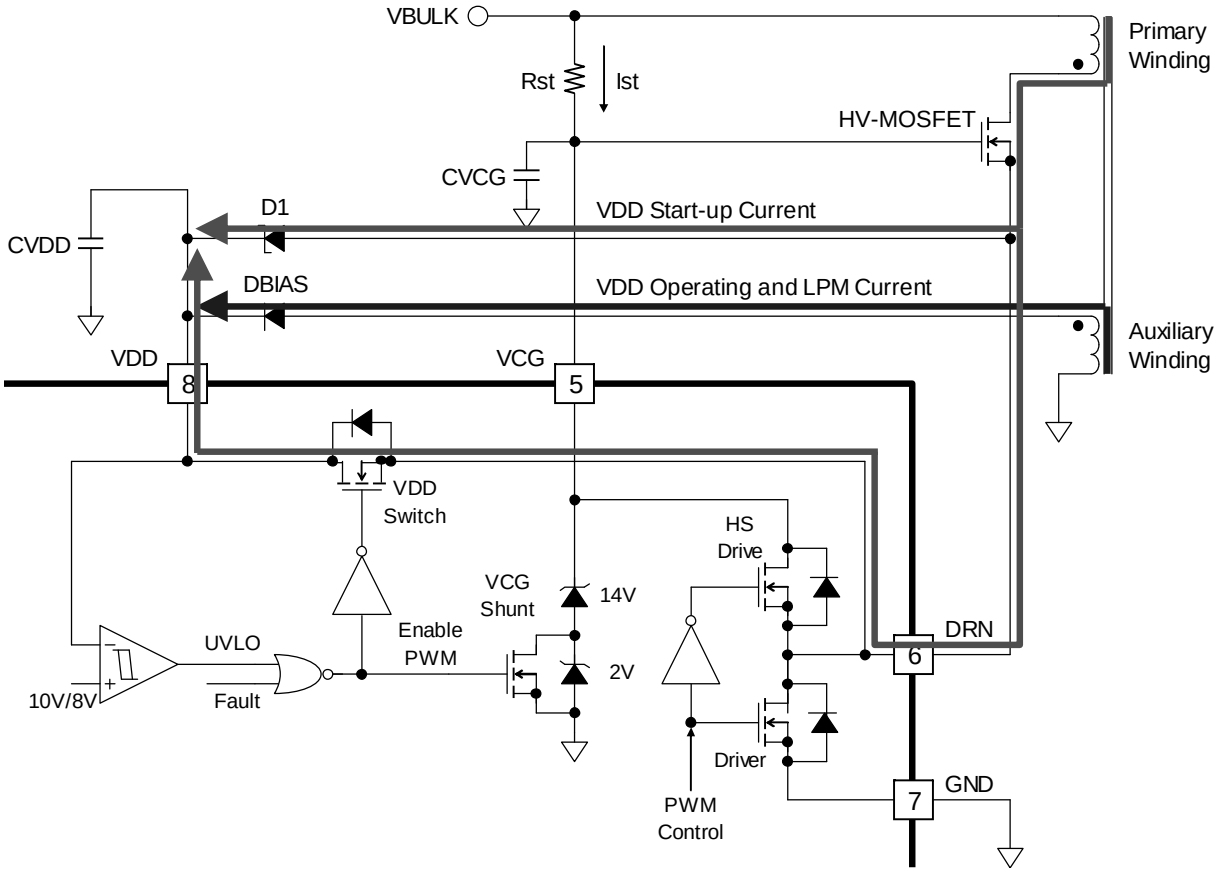
(4) Power-Up Sequencing

When the voltage is input to VBULK, the electric charge is charged to capacitance of the VCG pin (CVCG) through starting resistor (Rst). So, the voltage of the VCG pin rises. The voltage of the DRN pin rises by source follower when the voltage of the VCG pin reaches the threshold voltage of the external HVMOSFET. The DRN pin is connected with the VDD pin through the internal VDD Switch, and VDD capacitor (CVDD) is charged from the DRN pin. When the voltage at the VDD pin reaches the threshold voltage of UVLO, the VDD Switch is turned off, and the internal Bias circuit operates, and the switching is started.

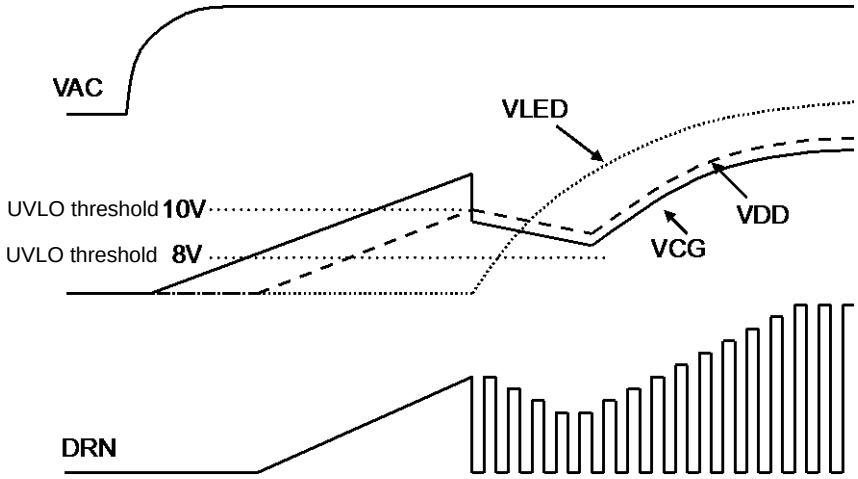
After the switching begins, the voltage at the VDD pin is supplied from Auxiliary Winding through the external diode (DBIAS). The voltage of an Auxiliary Winding is decided by rolling number ratio of Auxiliary Winding and Secondary Winding, and the voltage of Secondary Winding. Therefore, the voltage at the VDD pin is not supplied, until the voltage of Auxiliary Winding rises more than the voltage at the 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.

The external Schottky diode (D1) is required between the DRN pin and VDD pin. This diode is used to prevent the current that flows through the body diode of the VDD Switch.

- Current Passing When Starting



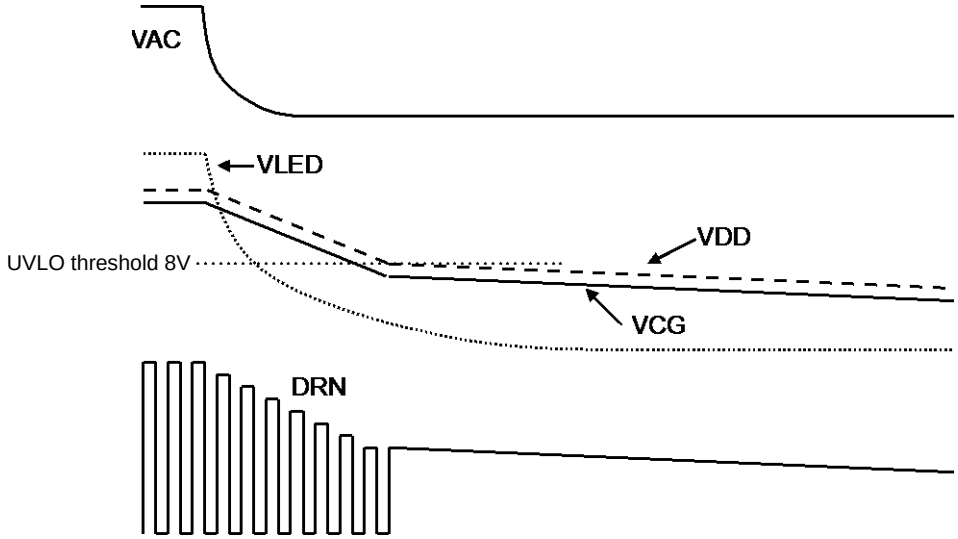
- Power-Up Sequencing



(5) Power Down Sequencing

When AC power is removed from the AC line, the current does not flow to Secondary Winding even if HV MOSFET is switching. The LED current is supplied from the output capacitance and decreases gradually. Similarly, the voltage at the VDD pin decreases because the current does not flow into Auxiliary Winding. The switching stops and MB39C601 becomes shutdown when the voltage at the VDD pin falls below the threshold voltage of UVLO.

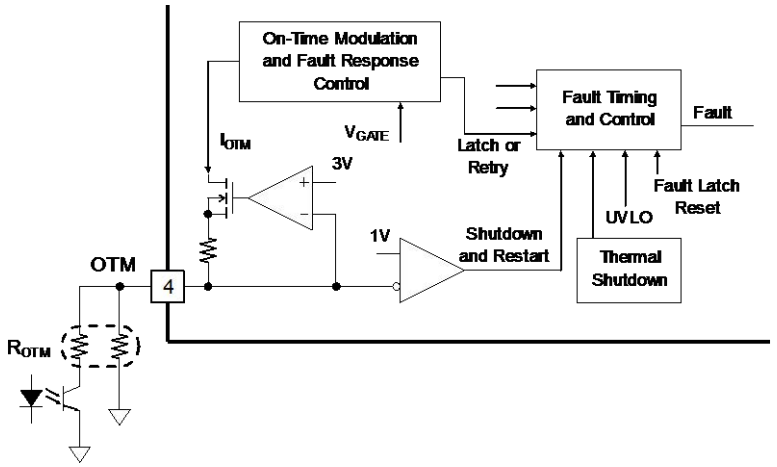
- Power Down Sequencing



(6) OTM Part

It is set on-time by connecting resistor (R_{OTM}) with the OTM pin. As shown in following figure, the on-time can be controlled by connecting the collector of the Opto-Coupler through resistor from OTM.

- OTM pin Control

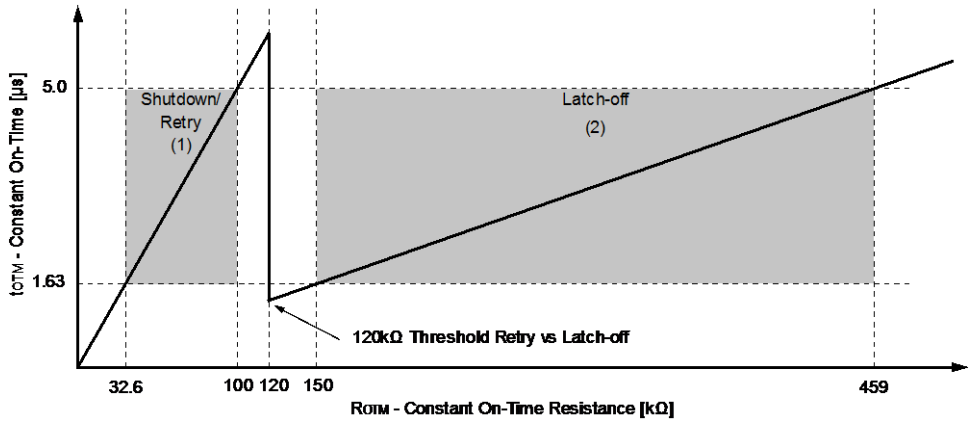


The following figure shows how the on-time is programmed over the range of between 1.5µs and 5.0µs for either range of programming resistors. The resistor range determines the controller response to a sustained overload fault (to either latch-off or to shutdown/retry). See the item of the overload protection about details of "latch-off" and "shutdown/retry". On-time is related to the programmed resistor based on the following equations.

(1) $R_{OTM} = t_{OTM} \times (2 \times 10^{10} \left[\frac{\Omega}{s} \right])$

(2) $R_{OTM} = t_{OTM} \times (0.918 \times 10^{11} \left[\frac{\Omega}{s} \right])$

- On-time Setting Range



Moreover, it can be shutted down by making the voltage of the OTM pin below "$V_{OTM\ (Vth)}$ (typ 1V)".

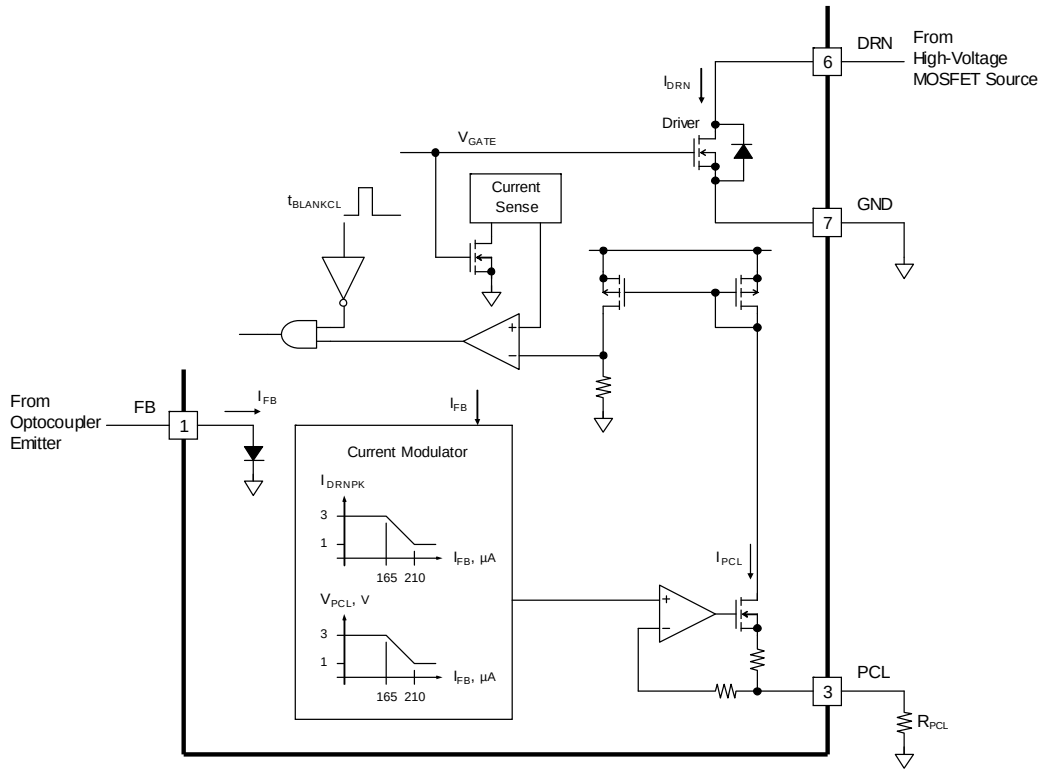
(7) PCL Part

It is set the peak current of Primary Winding by connecting resistor with the PCL pin.
The maximum peak current of Primary Side is set by connecting resistor (R_{PCL}) between the PCL pin and GND.

$$I_{DRN(pk)} = \left(\frac{100kV}{R_{PCL}} \right)$$

An about 400ns blanking time of the beginning of switching cycle is masking the spike noise. As a result, it prevents the sense of current from malfunctioning (See the figure below.).

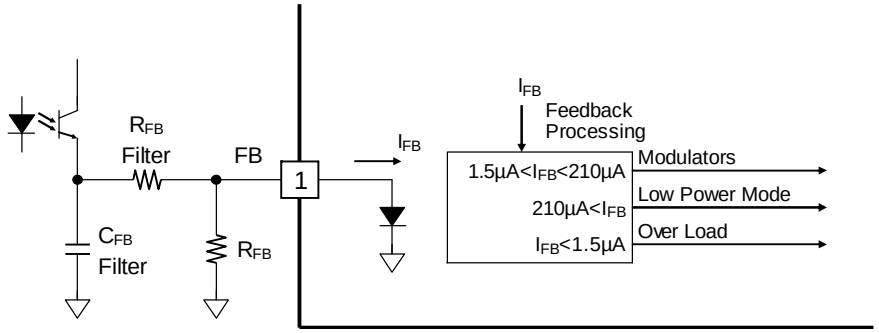
- Peak Current Control with PCL pin



(8) FB Part

The switching frequency is controlled by setting the current of the FB pin. In on-time control, the switching frequency is set by pulling up the FB pin to VDD. Moreover, as shown in following figure, it is possible to control the switching frequency by connecting the emitter of the Opto-Coupler from the FB pin through resistor. Resistor (R_{FB}) is connected to bleed off the dark current of Opto-Coupler.

- FB pin Control



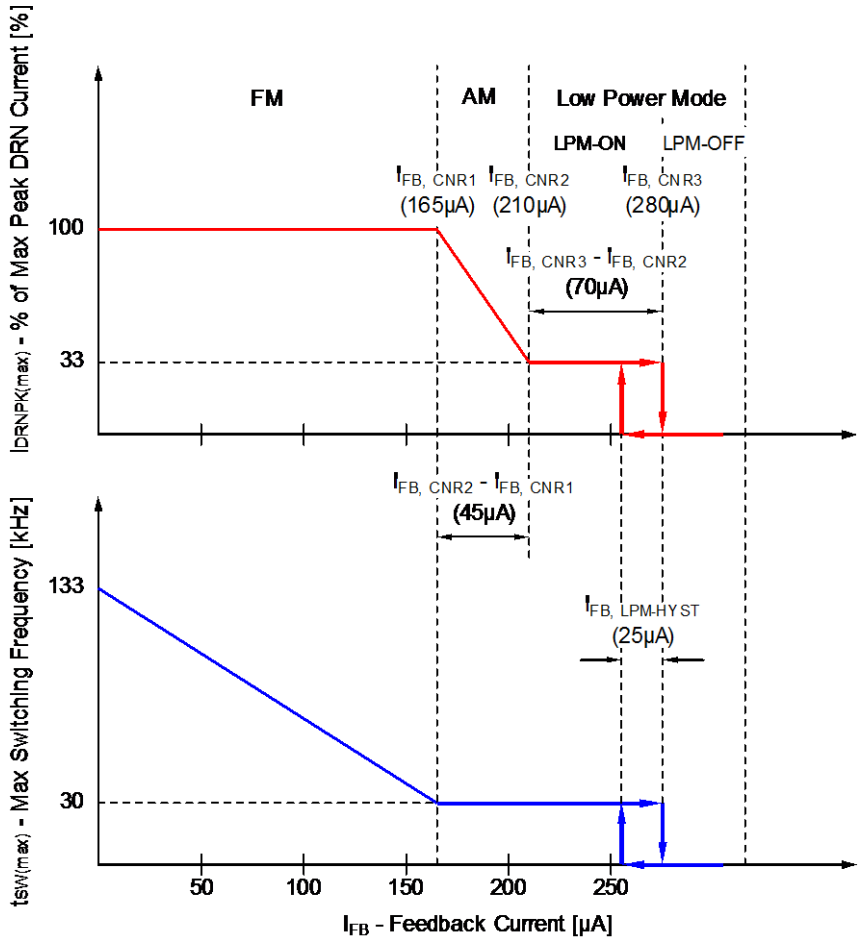
MB39C601 becomes the following three modes by FB current (I_{FB}).

1. Frequency Modulation Mode (FM)
   The peak current of HV-MOSFET is set to the maximum, and the LED current is regulated by adjusting the switching frequency with I_{FB}.The range of the switching frequency is from 30 kHz to 130 kHz. Maximum peak current $I_{DRN\ (peak,\ max)}$ of HV-MOSFET is set by the resistance of the PCL pin.

2. Amplitude Modulation Mode (AM)
   The LED current is regulated by adjusting the peak current of HV-MOSFET with I_{FB}.The switching frequency is about 30 kHz. And the range of HV-MOSFET of the peak current is from 33% to 100% of the maximum. Maximum peak current $I_{DRN\ (peak,\ max)}$ of HV-MOSFET is set by the resistance of the PCL pin.

3. Low Power Mode (LPM)
   MB39C601 becomes two states of LPM-ON and LPM-OFF at a light load. In the LPM-ON mode, it is operated at 30 kHz switching frequency. And the current is supplied to LED. At this time, the feedback current from the Opto-Coupler increases, and it changes to the LPM-OFF mode. In the LPM-OFF mode, it is not operated. And the current is supplied to LED from Co. When the feedback current from the Opto-Coupler decreases, it changes to the LPM-ON mode. LED is lit by the power saving repeating these two states.
   Three modes of the FM, AM, and LPM change depending on the load of LED. At the light load, three modes change from FM to AM to LPM.

- Switching Frequency and Peak Current Control Operation Based On FB pin

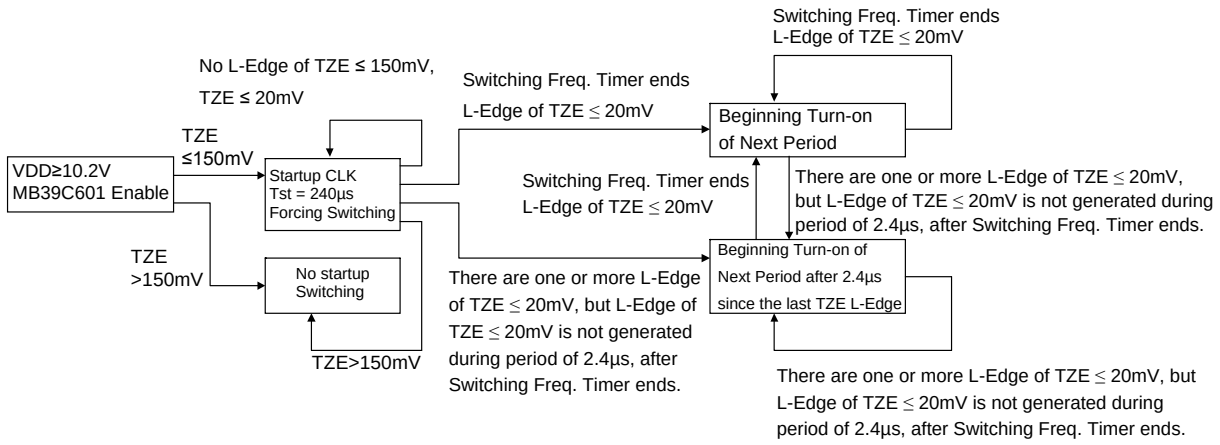


(9) TZE Part

MB39C601 requires all of the following three conditions in order to start the next switching cycle.

1. The time since the last turn-on edge must be equal to or longer than the switching time set by I_{FB}.
2. The time since the last turn-on edge must be longer than the minimum switching period set by MB39C601 (nominally 7.5µs which equals 133 kHz).
3. Immediately after zero energy detection at the TZE pin. Or, the time since the last zero energy detection must be longer than $t_{WAIT, (TZE)}$ (2.4µs or less).

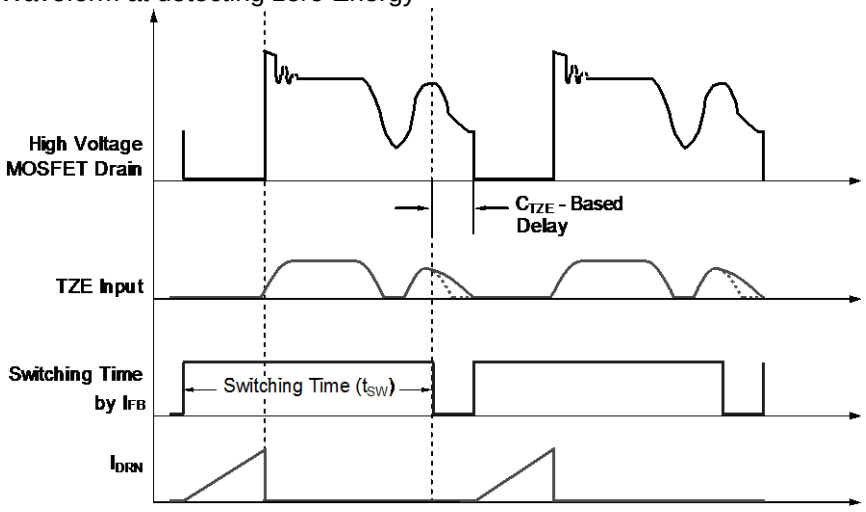
- Starting switching cycle diagram



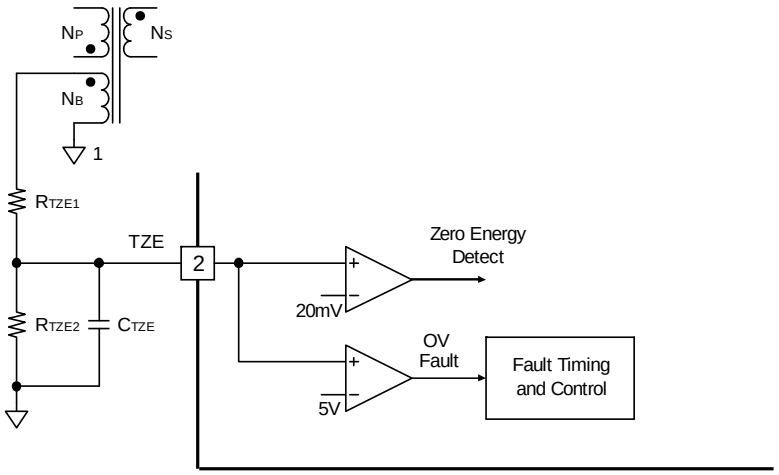
The TZE pin is connected with Auxiliary Winding of the transformer through the resistance division, and detects zero energy as shown "• TZE pin Connection".

A delay, 50ns to 200ns, can be added with C_{TZE} to adjust the turn-on of the primary switch with the resonant bottom of Primarty Winding waveform.

- Switching Waveform at detecting zero Energy



- TZE pin Connection



■ VARIOUS PROTECTION CIRCUITS

- 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 output HS DRIVER is turned off and output DRIVER is turned off, and the switching is stopped.The system returns if the VDD pin becomes more than the threshold voltage of the UVLO circuit.

- Over voltage Proteciton (OVP)

  When LED is in the state of open and the output voltage rises too much, the voltage of Auxiliary Winding and the voltage of the TZE pin rise. The over voltage is detected by sampling this voltage of the TZE pin. When TZE pin voltage rises more than the threshold voltage of OVP, the over voltage is detected. Output HS DRIVER is turned off, and output DRIVER is turned off, and the switching is stopped. (latch-off)

  If the VDD pin becomes below the voltage of Fault Latch Reset, OVP is released.

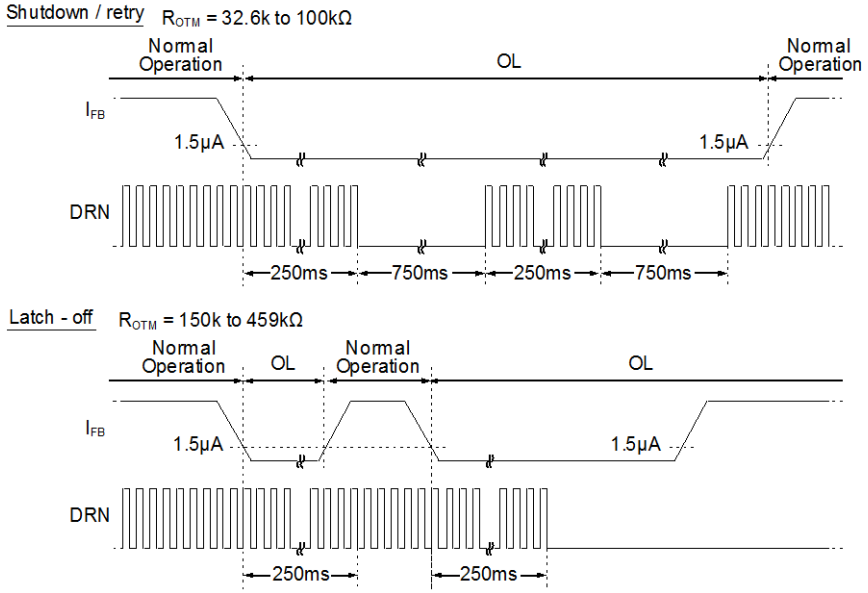
- Over load protection (OL)

  When the cathode or the anode of LED is short to GND and it becomes an overloaded status at switching frequency control, the current does not flow into Rs and there is no current feedback to IFB. The current of the FB pin detects the overload with 1.5µA or less. OL state is decided to latch-off or shutdown/retry by R_{OTM}.

  Shutdown/retry … MB39C601 becomes two states of switching on for 250ms and switching off for 750ms. These states are repeated. If it is not OL status, it returns.

  Latch-off … The switching is continued for 250ms. If it does not return from OL states for this period, output HS DRIVER is turned off, and output DRIVER is turned off, and the switching is stopped. If it returns from OL states after this time and the switching is still stopped (latch-off) and the VDD pin becomes below the voltage of Fault Latch Reset, Latch is released.

- Over Load Protection Sequencing

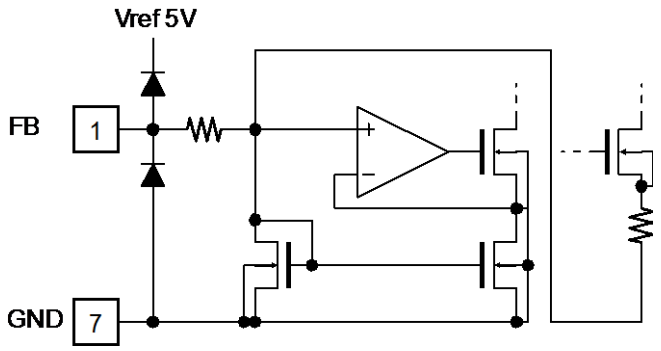
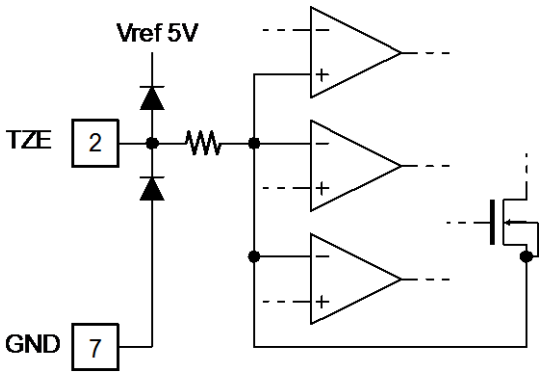
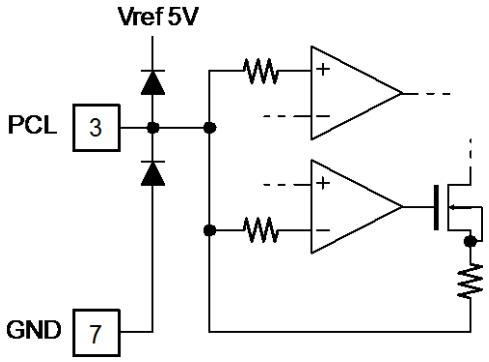
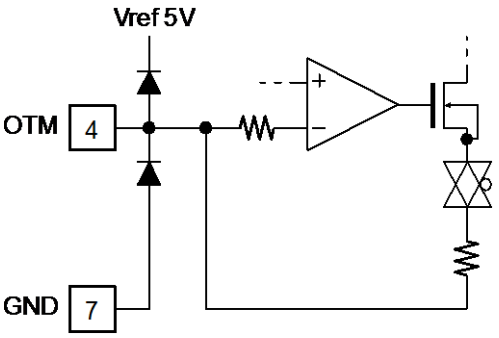


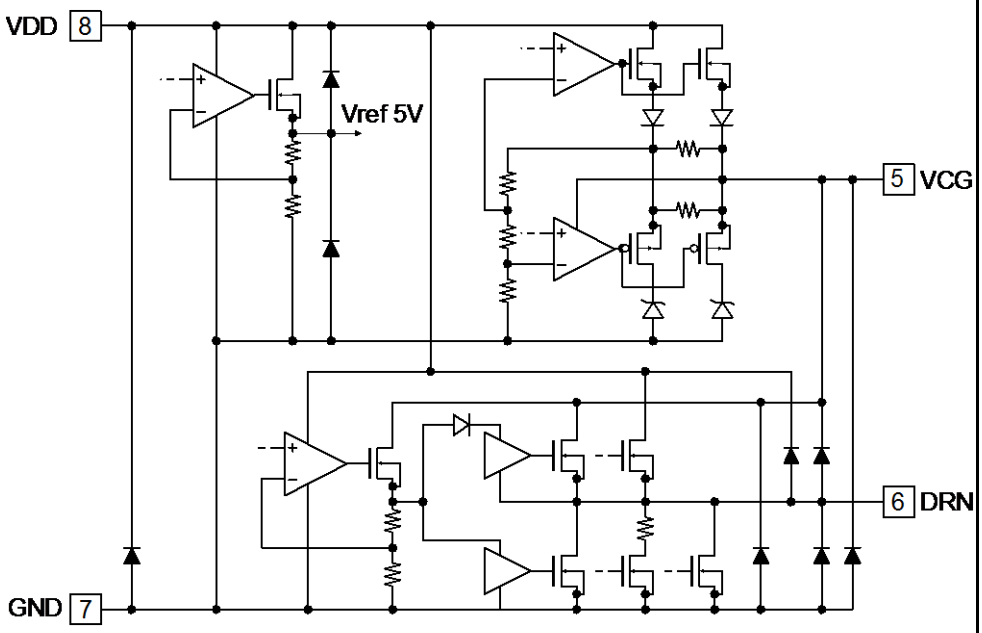
- Over temperature protection (OTP)
  The over temperature protection (OTP) is a function to protect IC from the thermal destruction.When the junction temperature reaches +150°C,output HS DRIVER is turn off, and output DRIVER is turned off, and the switching is stopped.It returns again when the junction temperature falls to +125°C (automatic recovery).

■ VARIOUS FUNCTION TABLES

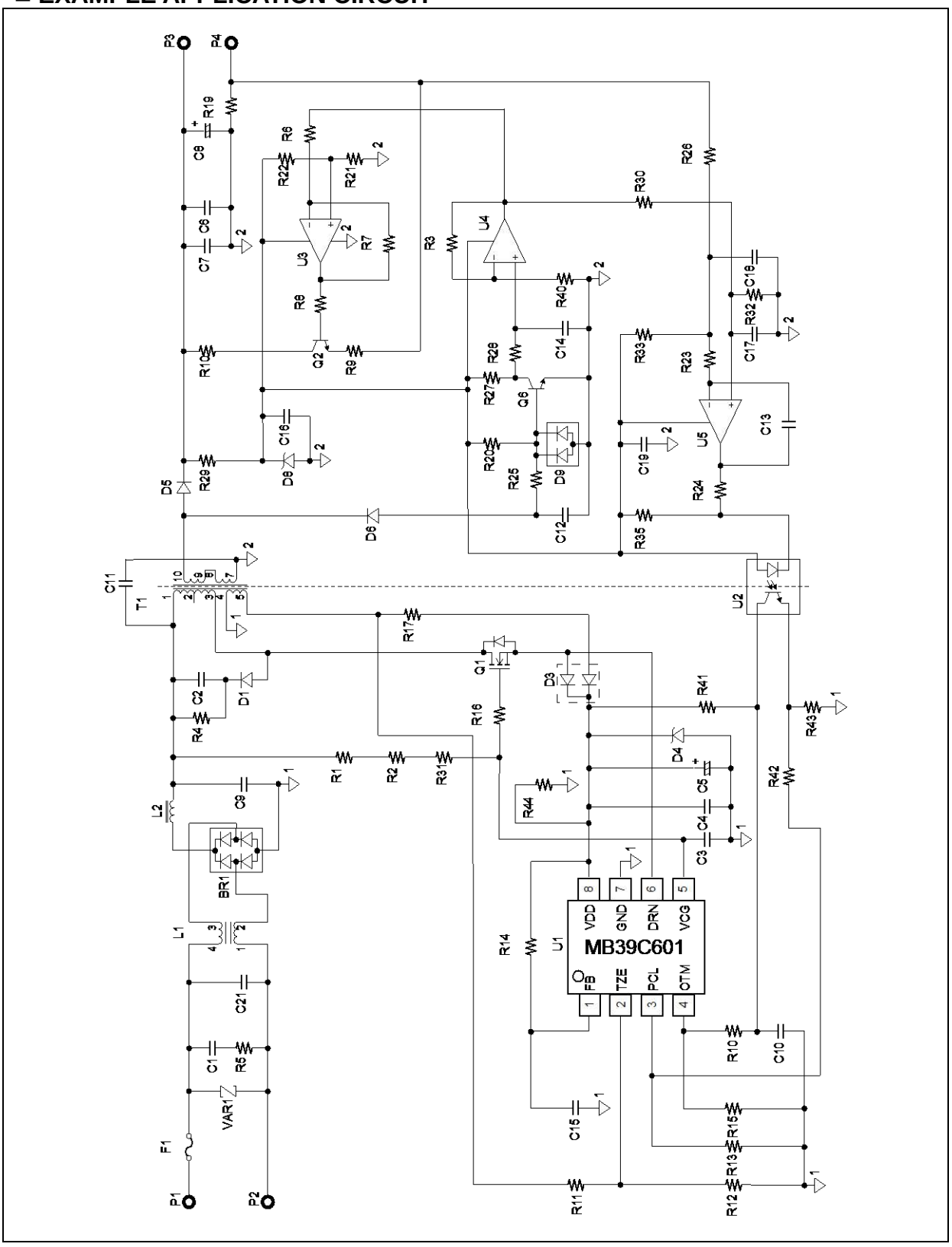
Function		DRN				Detection Condition at Protected Operation	Return Condition	Remarks
		LS_DRV	HS_DRV	VDD SW	Discharge SW			
Normal Operation				OFF	OFF	-	-	-
Under Voltage Lockout Protection (UVLO)		OFF	OFF	ON	OFF	VDD < 8.0V	VDD > 10.2V	Standby
OTM Shutdown		OFF	OFF	ON	OFF	OTM = GND	OTM > 1V	Standby
Over Voltage Protection (OVP)		OFF	OFF	ON	ON	TZE > 5V	VDD < 6V → VDD > 10.2V	Latch-off
Over Load Protection (OL)	Shutdown/ Retry Mode			OFF	OFF	I_{FB} < 1.5µA 32.6k < R_{OTM} < 100kΩ	I_{FB} > 1.5µA	Shutdown Retry OL Timer (250ms)
		OFF	OFF	ON	OFF			Shutdown Retry Fault (750ms)
	Latch-Off Mode	OFF	OFF	ON	ON	I_{FB} < 1.5µA 150k < R_{OTM} < 459kΩ	VDD < 6V → VDD > 10.2V	Latch-off
Stopped state of Low Power Mode		OFF	OFF	ON	OFF	I_{FB} > 280µA	I_{FB} < 255µA	-
Over Temperature Protection (OTP)		OFF	OFF	ON	OFF	Tj > +150°C	Tj < +125°C	-

■I/O PIN EQUIVALENT CIRCUIT DIAGRAM

Pin No.	Pin Name	Equivalent Circuit Diagram
1	FB	
2	TZE	
3	PCL	
4	OTM	

Pin No.	Pin Name	Equivalent Circuit Diagram
5	VCG	
6	DRN	

■ EXAMPLE APPLICATION CIRCUIT



- Part list
  - Vac 90V to 145V 50Hz/60Hz (Typ110V) Iout 390mA

No.	Component	Description	Part No.	Vendor
1	U1	IC PWM CTRLR CASCODE 8-SOIC	MB39C601	Spansion
2	U2	OPTO ISOLATOR TRANSISTOR OUTPUT	PS2561L-1-A	CEL
3	U3, U4, U5	IC OPAMP GP R-R 1MHZ SGL SOT23-5	LMV321IDBVR	TI
4	VR1	SUR ABSORBER 7MM 430V 1250A ZNR	ERZ-V07D431	Panasonic
5	BR1	IC RECT BRIDGE 0.5A 600V 4SOIC	MB6S	Fairchild
6	T1*	TRANSFORMER FLYBACK EE20/10/6 430µH RATIO Np/Ns=2.91/1 Np/Na=5.33/1	750811148	Wurth
7	F1	FUSE PICO FAST 2.5A 250V AXIAL	026302.5WRT1L	Littelfuse
8	L1	IND COMMON MODE CHOKE 40MH	750311650	Wurth
9	L2	JUMPER (RES 0.0Ω 1206)	RK73Z2B	KOA
10	Q1	MOSFET N-CH 650V 7.3A TO-220FP	SPA07N60C3	Infineon
11	Q2	TRANSISTOR NPN 100V 1A SOT-89	FCX493TA	Diodes
12	Q6	TRANSISTOR NPN GP 40V SOT23	MMBT3904-TP	Micro Commercial
13	C1*	CAP .47UF/400VDC METAL POLY	ECQ-E4474KF	Panasonic
14	C2	CAP CER 15000PF 250V X7R 1206	GRM31BR72E153KW01L	muRata
15	C3	CAP CER 10000PF 50V X7R 0603	GRM188R71H103KA01D	muRata
16	C4	CAP CER .1UF 25V X7R 10% 0603	GRM188R71E104KA01D	muRata
17	C5	CAP 100UF 25V ELECT RADIAL 2.5MM	EEU-FC1E101S	Panasonic
18	C6,C7	CAP CER 2.2UF 100V X7R 1210	GRM32ER72A225KA35	muRata
19	C8	CAP 560UF 50V ELECT HE RADIAL	UPW1H561MHD	Nichicon
20	C9	CAP .056UF/630VDC METAL POLY	ECQ-E10223KF	Panasonic
21	C10, C15, C17, C18, C19	CAP CER 10000PF 50V X7R 0603	GRM188R71H103KA01D	muRata
22	C11	CAP CER 2.2NF X1/Y1 RADIAL	DE1E3KX222MA4BL01	muRata
23	C12	CAP CER 220PF 630VDC U2J 1206	GRM31A7U2J221JW31D	muRata
24	C13	CAP CER 0.33UF 16V X7R 0603	GRM188R71C334KA01	muRata
25	C14	CAP CER 1UF 16V X7R 0805	GRM21BR71C105KA01#	muRata
26	C16	CAP CER .1UF 25V 0805	GRM21BR71E104KA01#	muRata
27	C21	CAP .022UF/305VAC X2 METAL POLYPRO	B32921C3223M	Epcos
28	D1	DIODE ULTRA FAST 800V 1A SMA	RS1K-13-F	Diodes
29	D3	DIODE ULTRA FAST 200V SOT-23	MMBD1404	Fairchild
30	D4	DIODE ZENER 18V 225MW SOT-23	BZX84C18LT1	On Semi
31	D5	DIODE GPP FAST 1A 600V DO-41	UF4005	Fairchild
32	D6	DIODE GPP FAST 1A 600V SMA	RS1J	Fairchild
33	D8	SHUNT REGULATOR 5.0V SOT-23	LM4040C50IDBZT	TI
34	D9	DIODE, SWITCHING 70V SC-70	BAW56WT1	On Semi
35	R1, R2, R31	RES 560kΩ 1/4W 1% 0805 SMD	RK73H2ATTD5603F	KOA
36	R3, R6, R15	RES 100kΩ 1/10W 1% 0603 SMD	ERJ-3EKF1003V	Panasonic
37	R4	RES 75.0kΩ 1/4W 5% 1206 SMD	RK73B2BTTD753J	KOA
38	R5	RES 510Ω METAL FILM 2W 5%	ERG-2SJ511A	Panasonic
39	R7	RES 464kΩ 1/10W 1% 0603 SMD	ERJ-3EKF4643V	Panasonic
40	R8	RES 4.42kΩ 1/10W 1% 0603 SMD	ERJ-3EKF4421V	Panasonic
41	R9	RES 39.2Ω 1/8W 5% 0805 SMD	RK73B2ATTD390J	KOA
42	R10	RES 1.0kΩ METAL FILM 2W 5%	ERG-2SJ102A	Panasonic
43	R11	RES 110kΩ 1/8W 5% 0805 SMD	RK73B2ATTD114J	KOA

No.	Component	Description	Part No.	Vendor
44	R12	RES 33.2kΩ 1/10W 1% 0603 SMD	ERJ-3EKF3322V	Panasonic
45	R13	RES 40.2kΩ 1/10W 1% 0603 SMD	ERJ-3EKF4022V	Panasonic
46	R14	RES 634kΩ1/10W 1% 0603 SMD	ERJ-3EKF6343V	Panasonic
47	R16	RES 5.1Ω 1/10W 1% 0603 SMD	RK73H1JTTD5R10F	KOA
48	R17	RES 3.00Ω 1/8W 1% 0805 SMD	RK73H2ATTD3R00F	KOA
49	R18	RES 10.0kΩ 1/10W 1% 0603 SMD	ERJ-3EKF1002V	Panasonic
50	R19	RES .33Ω 1/4W 1% 1206 SMD	ERJ-8RQFR33V	Panasonic
51	R20	RES 301kΩ 1/10W 1% 0603 SMD	ERJ-3EKF3013V	Panasonic
52	R21	RES 71.5kΩ 1/10W 1% 0603 SMD	ERJ-3EKF7152V	Panasonic
53	R22	RES 200kΩ 1/10W 1% 0603 SMD	ERJ-3EKF2003V	Panasonic
54	R24, R35	RES 3.01kΩ 1/10W 1% 0603 SMD	ERJ-3EKF3011V	Panasonic
55	R25, R33	RES 1.00MΩ 1/10W 1% 0603 SMD	ERJ-3EKF1004V	Panasonic
56	R26	RES 2.00kΩ 1/10W 1% 0603 SMD	ERJ-3EKF2001V	Panasonic
57	R27	RES 511kΩ 1/10W 1% 0603 SMD	ERJ-3EKF5113V	Panasonic
58	R23, R28	RES 20.0kΩ 1/10W 1% 0603 SMD	ERJ-3EKF2002V	Panasonic
59	R29	RES 12.7kΩ 1/8W 1% 0805 SMD	RK73H2ATTD1272F	KOA
60	R30	RES 604kΩ 1/10W 1% 0603 SMD	ERJ-3EKF6043V	Panasonic
61	R32	RES 17.4kΩ 1/10W 1% 0603 SMD	ERJ-3EKF1742V	Panasonic
62	R40	RES 16.5kΩ 1/10W 1% 0603 SMD	ERJ-3EKF1652V	Panasonic
63	R41			
64	R42			
65	R43	RES 0.0Ω 1/20W 5% 0603 SMD	RK73Z1J	KOA
66	R44	RES 1.0kΩ 1/10W 1% 0603 SMD	ERJ-3EKF1001V	Panasonic

*: Vac 180V to 265V 50Hz/60Hz (Typ 230V) Iout 390mA

Spansion : Spansion Inc.
Wurth : Adolf Wurth GmbH & Co. KG
Infineon : Infineon Technologies AG
CEL : California Eastern Laboratories, Inc
Fairchild : Fairchild Semiconductor International, lnc.
Diodes : Diodes, Inc
On Semi : ON Semiconductor
Panasonic : Panasonic Corporation
muRata : Murata Manufacturing Co., Ltd.
Epcos : EPCOS AG
KOA : KOA Corporation
TI : Texas Instruments Incorporated
Micro Commercial : Micro Commercial Components Corp.
Nichicon : NICHICON CORPORATION
Littelfuse : Littelfuse, Inc.

No.	Component	Description	Part No.	Vendor
6	C1	CAP .22UF/400VDC METAL POLY	ECQ-E4224KF	Panasonic
13	T1	TRANSFORMER FLYBACK EE20/10/6 1.2mH RATIO Np/Ns=4.42/1 Np/Na=8.15/1	750811145	Wurth

Panasonic : Panasonic Corporation
Wurth : Adolf Wurth GmbH & Co. KG

■ USAGE PRECAUTION

1. **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.

2. **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.

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

4. **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.

5. **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.

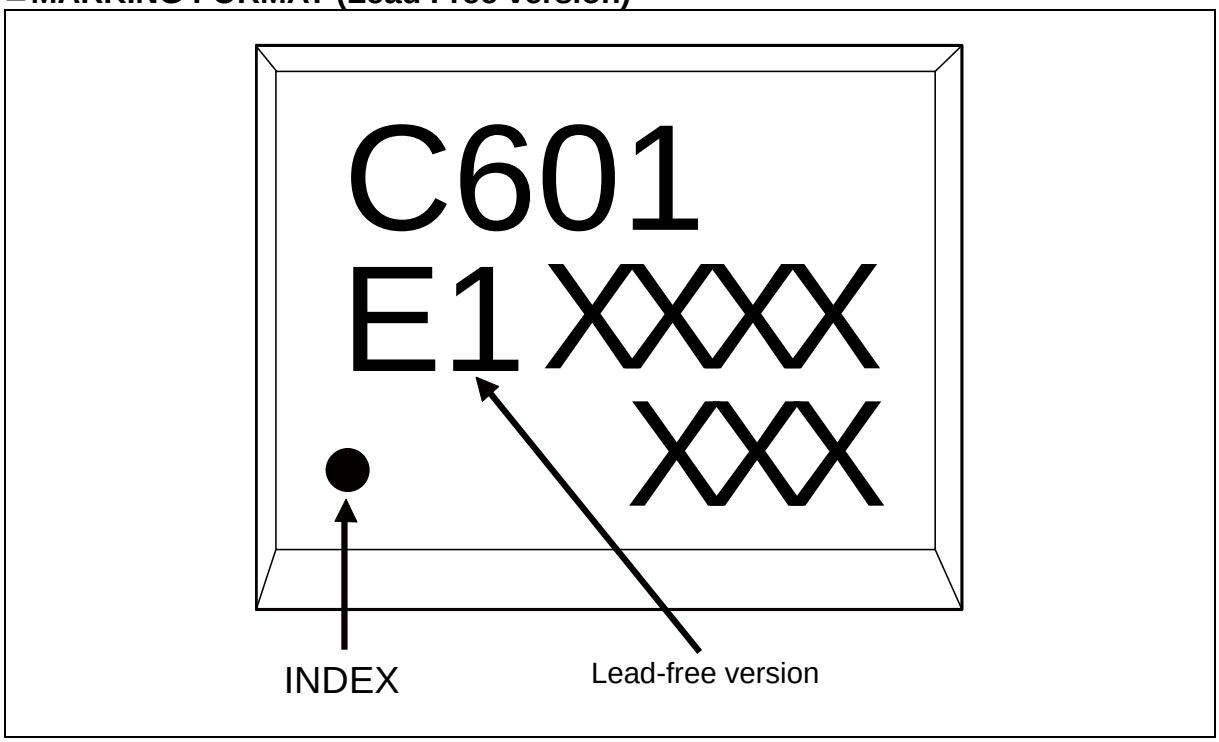
■ ORDERING INFORMATION

Part number	Package	Remarks
MB39C601PNF	8-pin plastic SOP (FPT-8P-M02)	

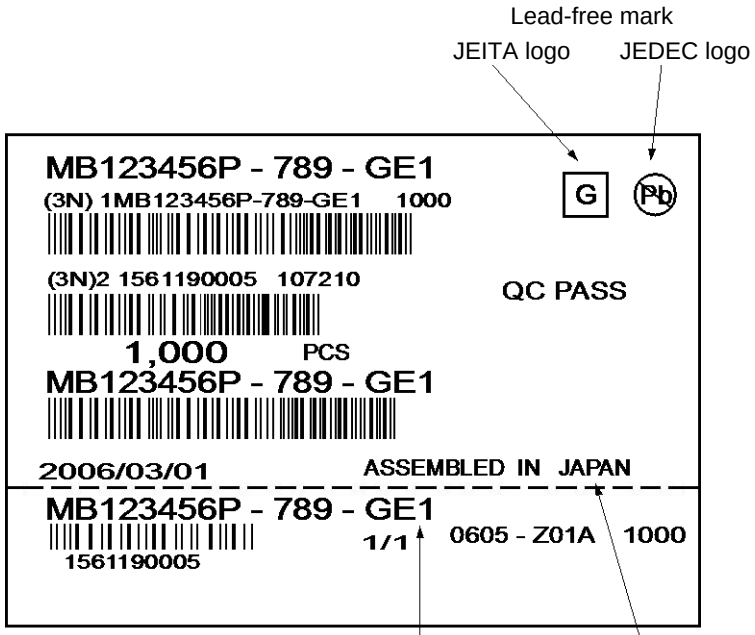
■ RoHS COMPLIANCE INFORMATION OF LEAD (Pb) FREE VERSION

The LSI products of Spansion with “E1” are compliant with RoHS Directive, and has observed the standard of lead, cadmium, mercury, Hexavalent chromium, polybrominated biphenyls (PBB), and polybrominated diphenyl ethers (PBDE). A product whose part number has trailing characters “E1” is RoHS compliant.

■ MARKING FORMAT (Lead Free version)



■ LABELING SAMPLE (Lead free version)



The part number of a lead-free product has the trailing characters "E1".

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

■ MB39C601PNF RECOMMENDED CONDITIONS OF MOISTURE SENSITIVITY LEVEL

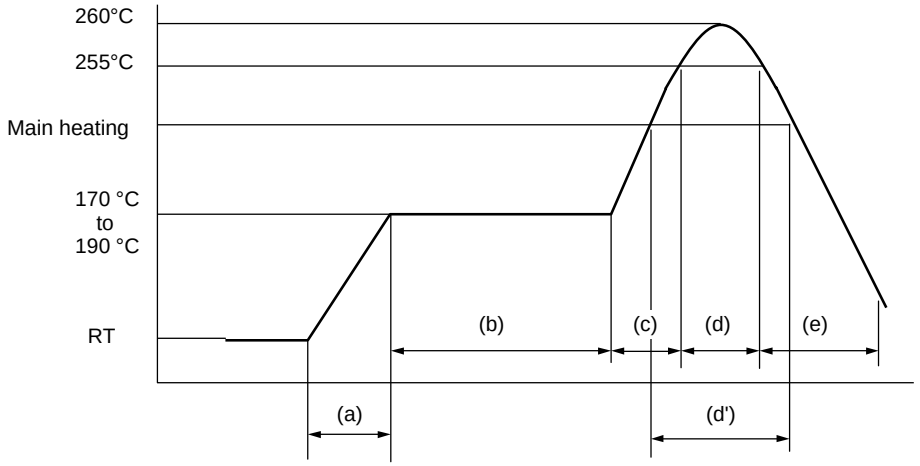
[Spansion Recommended Mounting Conditions]

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 two 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 two times.
Storage conditions	5°C to 30°C, 70% RH or less (the lowest possible humidity)	

[Mounting Conditions]

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

Note: Temperature : the top of the package bod

(2) JEDEC Condition: Moisture Sensitivity Level 3 (IPC/JEDEC J-STD-020D)

(3) Recommended manual soldering (partial heating method)

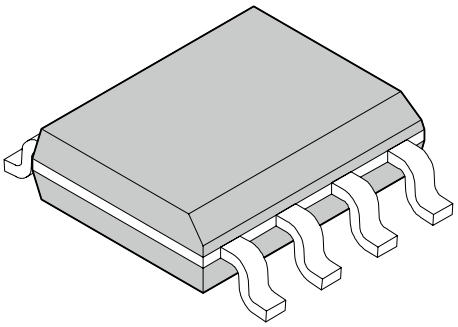
Item	Condition	
Storage period	Before opening	Within two years after manufacture
	Between opening and mounting	Within two years after manufacture (No need to control moisture during the storage period because of the partial heating method.)
Storage conditions	5°C to 30°C, 70% RH or less (the lowest possible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

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

(4) Recommended dip soldering

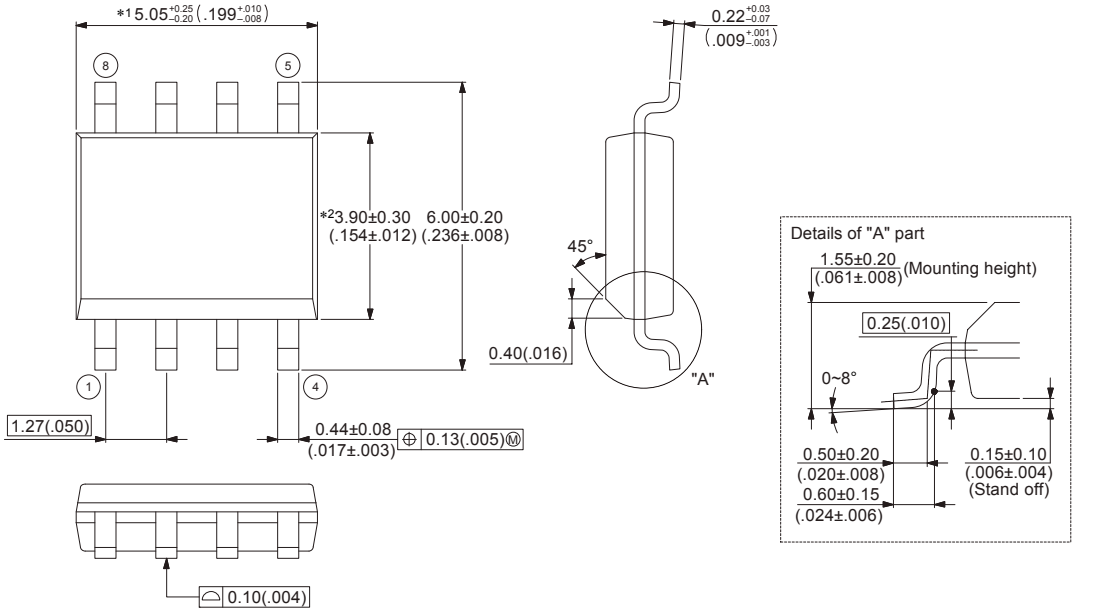
Item	Condition	
Mounting times	1 time	
Storage period	Before opening	Please use it within two years after manufacture.
	From opening and mounting	Less than 14 days
	When the storage period after opening was exceeded	Please process within 14 days after baking (125°C ±3°C, 24H+ 2H/─0H) . Baking can be performed up to two times.
Storage conditions	5°C to 30°C, 70% RH or less (the lowest possible humidity)	
Mounting condition	Temperature at soldering tub: 260°C Max Time: Five seconds or below	

■ PACKAGE DIMENSIONS

8-pin plastic SOP		
	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
(FPT-8P-M02)		

8-pin plastic SOP
(FPT-8P-M02)

Note 1) *1 : These dimensions include resin protrusion.
Note 2) *2 : These dimensions do not include resin protrusion.
Note 3) Pins width and pins thickness include plating thickness.
Note 4) Pins width do not include tie bar cutting remainder.



Dimensions in mm (inches).
Note: The values in parentheses are reference values.

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

■ MAJOR CHANGES

Page	Section	Change Results
Revision 0.1 [August, 2012]		
-	-	Initial release
Revision 1.0 [December, 2012]		
Revision 2.0 [July, 2013]		
Revision 2.1 [January 31, 2014]		
-	-	Company name and layout design change

Colophon

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