GT5304

1.5A, Constant Current LED Driver

Advanced

1. Features

- High Efficiency: Up to 98%
- Up to 1.5A Output Current
- Integrated 1A MOSFET Switch
- 5V to 40V Input Voltage Range
- No External Compensation Required
- Separate PWM Dimming and Low Power Shutdown
- Brightness Control Using DC Voltage
- Thermal Compensation
- Supports All-ceramic Output Capacitors and Capacitor-less Outputs
- Over Temperature Shutdown
- Cycle-by-Cycle Current Limit
- Operating Temperature: -40℃ to +125℃
- 8-Pin SOP Package and HSOP Package

2. General Description

The GT5304 device is a high efficiency monolithic step-down switching regulator designed to deliver constant currents to drive single or multiple series connected high power LEDs. The GT5304 is ideal for automotive, industrial, and general lighting applications. This device operates from an input supply between 5V and 40V and provides an external adjustable output current of up to 1A with a current limit of 1.5A. It integrates a high-side, N-channel MOSFET switch. The constant on-time architecture and an external resistor allow the regulator output voltage and switching frequency to adjust as needed to deliver a constant current to series and series-parallel connected LED arrays of varying number and type. Output current can be adjusted above, or below the set value by applying an external DC voltage or PWM signal to the DIM pin.

The fault condition protections such as broken/open LED connections, low power shutdown and over temperature hysteretic shutdown are implemented. Additional feature also includes cycle-by-cycle current limit.

The GT5304 is available in an 8-Pin SOP package and thermal enhanced HSOP package.

3. Applications

- LED Driver
- Constant Current Source
- Automotive Lighting
- General Illumination
- Industrial Lighting

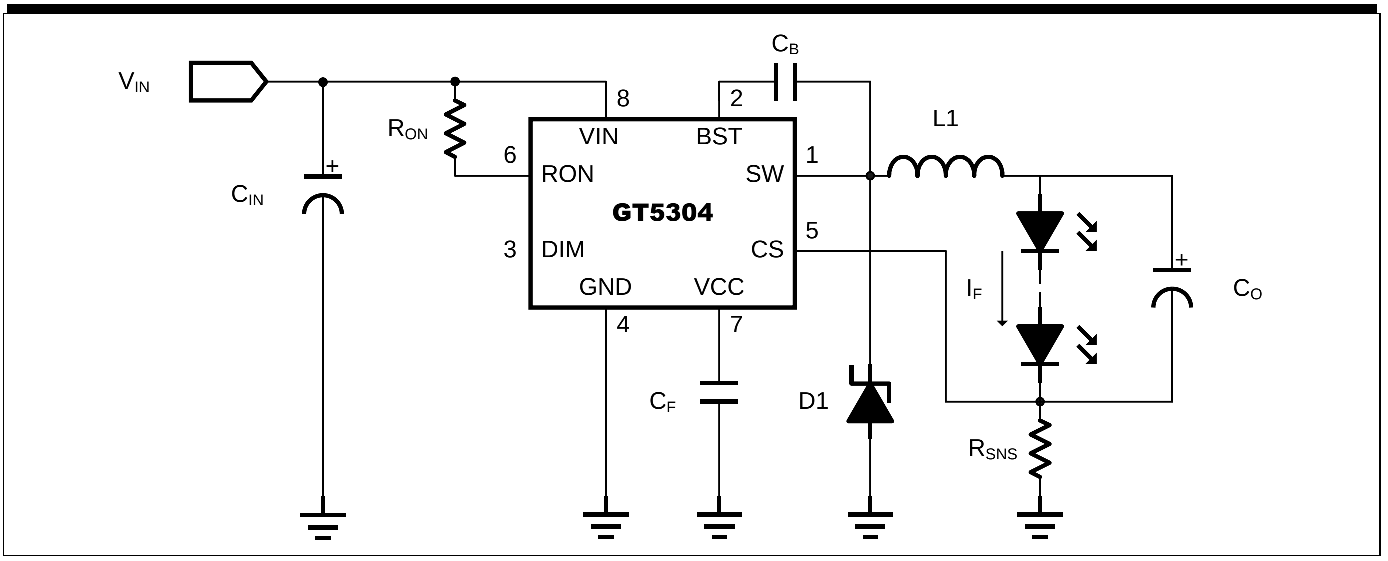


Figure 1. Typical Application Circuit

4. Functional Block Diagram

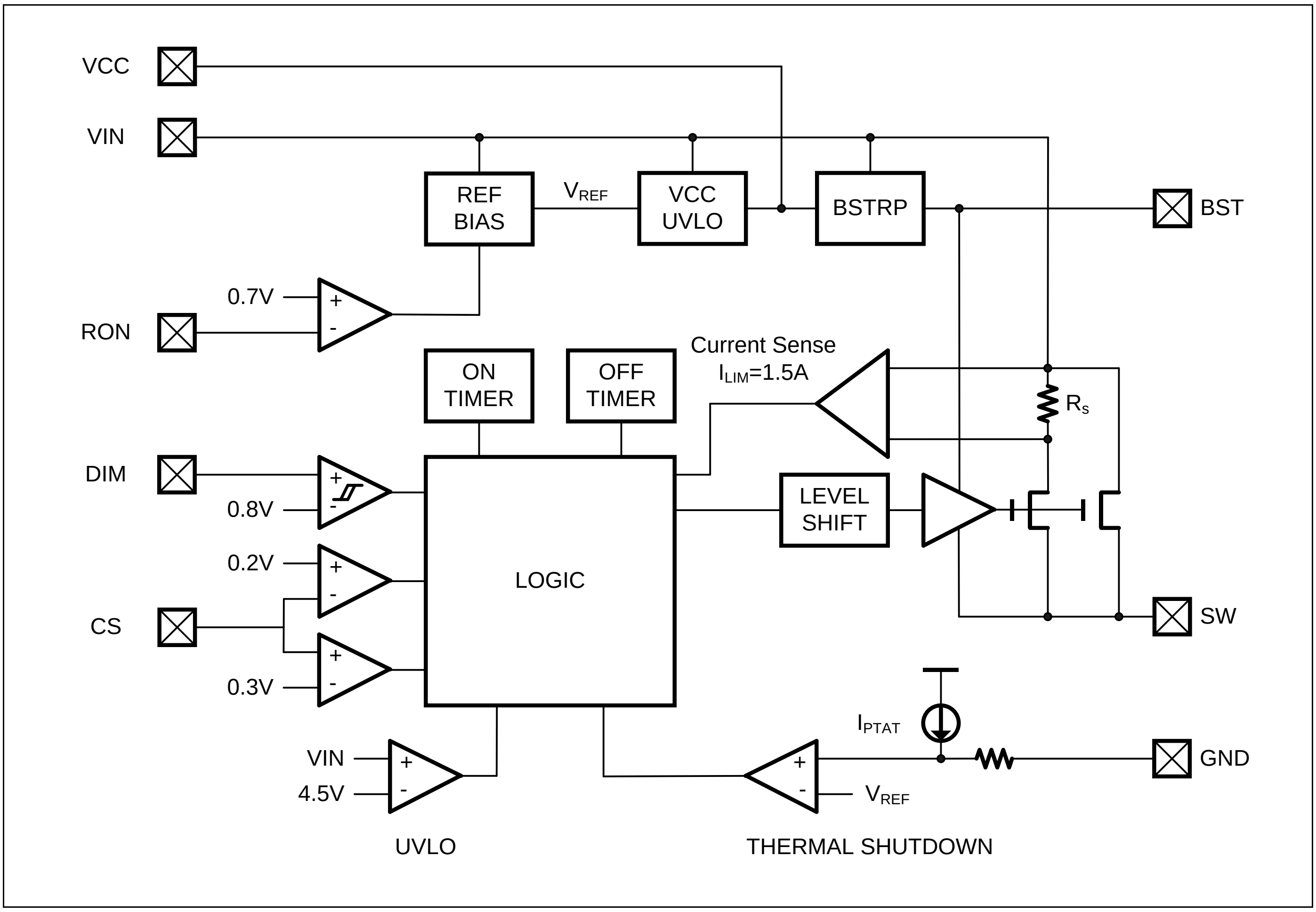


Figure 2. Constant On-Time LED Driver Block Diagram

5. Pin Configuration

5.1 SOP8 (Top View)

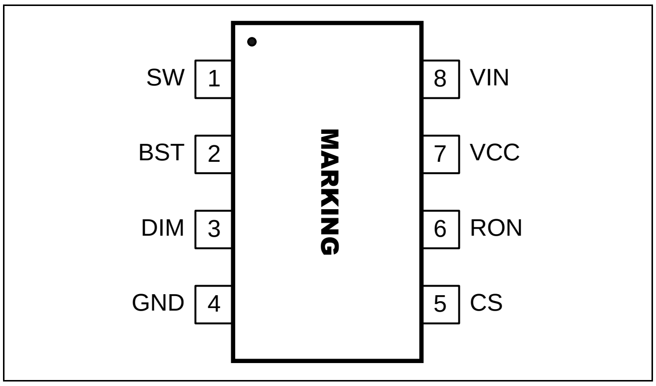


Figure 3. Pin Assignment Diagram (SOP8 Package)

5.2 HSOP8 (Top View)

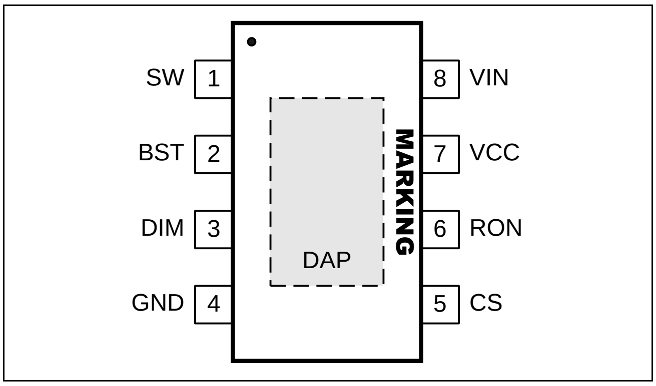


Figure 4. Pin Assignment Diagram (SOPP8 Package)

Note: Please see section “**Part Markings**” for detailed Marking Information.

5.3 Pin Descriptions

Pin No.	Name	I/O	Function
1	SW	O	Switching node for the converter. Connect inductor to this node.
2	BST	I	A 1~10nF ceramic capacitor is connected from this pin to the SW pin to drive the power switch’s gate above Bootstrap the power supply voltage.
3	DIM	I	Multi-function On/Off and brightness control pin: • Leave floating for normal operation • Drive to voltage below 0.8V to turn off output current • Drive with DC voltage (0.8V<VDIM<2.2V) to adjust output current from 65% to 100% of I_{OUTnom} • Connect a TTL-level PWM signal to enable/disable power MOSFET and reduce the average output current to the LED array.
4	GND	-	Connect this pin to system ground.
5	CS	I	Set the current through the LED array by connecting a resistor from this pin to ground
6	RON	I	Set the regulator controlled on-time by connecting this pin to VIN
7	VCC	O	Output of internal linear regulator. Bypass this pin with a 0.1μF ceramic capacitor
8	VIN	-	Supply. Connect this pin to a supply voltage from 5V to 40V
DAP	GND	Thermal Pad	Connect to ground, Place at least 4~6 vias from DAP to bottom layer ground plane

6. Functional Description

6.1 Operation

The GT5304 uses variable frequency, constant on-time step-down architecture with internal top power switch. The regulator on-time can be programmed through RON pin, which allows the optimum switching frequency selection for particular application and provides wide input/output range and fast enable/disable function. The architecture eliminates the need for small signal control loop compensation. When the regulator runs in continuous conduction mode (CCM) the controlled on-time maintains a constant. These features make the regulator ideal for use as a constant current source for LEDs with forward current as high as 1.2A. The regulator also provides fast transient response, PWM dimming, a low power shutdown mode, thermal protection, and output over voltage protection.

The operating description is referring to functional block diagram (***Figure 3***). During normal operation, A voltage signal V_{SNS} is created as the LED current flows through the current setting resistor R_{SNS} to ground. V_{SNS} is fed back to the CS pin, where it is compared against the internal generated 200mV reference V_{REF}. The comparator turns on the power MOSFET when V_{SNS} falls below V_{REF}. The power MOSFET conducts for a controlled on-time t_{ON}, set by an external resistor R_{ON}, and the input voltage V_{IN}. The on-time is determined by the following equation:

$$t_{ON} = 1.35 \times 10^{-10} \times \frac{R_{ON}}{V_{IN}}$$

At the end of t_{ON} the power MOSFET will turn off for a minimum off-time $t_{OFF-MIN}$ of 270ns. Once $t_{OFF-MIN}$ is completed the CS comparator compares V_{SNS} and V_{REF} again, waiting to begin the next cycle.

The GT5304 regulator should be operated in CCM, where the inductor current stays positive throughout the switching cycle. In steady state CCM operation, the regulator maintains a constant frequency that can be selected as below:

$$f_{SW} = \frac{V_O}{1.35 \times 10^{-10} \times R_{ON}}$$

$$V_O = n \times V_F + 200mV$$

Where V_F is the forward voltage of each LED, n is the number of LEDs in series.

6.2 Inductor Current

The steady state inductor current ripple is

$$\Delta i_L = \frac{V_{IN} - V_O}{L} t_{ON}$$

In constant on time architecture the regulator controls the valley of ΔV_{SNS}, the AC portion of V_{SNS}. The valley inductor current is

$$I_{L\,min} = \frac{0.2}{R_{SNS}} - \frac{V_O \times t_{SNS}}{L}$$

where t_{SNS} is the propagation delay of the sense comparator. The average inductor (LED) current is

$$I_L = I_F = I_{L\,min} + \frac{\Delta i_L}{2}$$

6.3 Maximum and Minimum Output Voltages

The maximum duty cycle of the regulator and the maximum output voltage are given by

$$D_{max} = \frac{t_{ON}}{t_{ON} + t_{OFF\,min}}$$

$$V_{O\,max} = D_{max} \times V_{IN}$$

The maximum number of LEDs, n_{max}, is given by

$$n_{max} = \frac{V_{O\,max} - 200mV}{V_{F\,max}}$$

where V_{Fmax} is the maximum forward voltage of the LEDs used. At low switching frequency the maximum duty cycle and output voltage are higher, allowing the regulators to regulate output voltages that are nearly equal to input voltage. The following equation relates switching frequency to maximum output voltage

$$V_{O\,max} = V_{IN} \times (1 - \frac{270ns}{T_{SW}})$$

Or

$$V_{O\,max} = V_{IN} \times (1 - 270ns \times f_{SW})$$

The minimum recommended on-time for the regulator is 270ns. This lower limit for t_{ON} determines the minimum duty cycle and output voltage that can be regulated based on input voltage and switching frequency.

$V_{O\,min} = V_{IN} \times 270ns \times f_{SW}$

6.4 Internal MOSFET and Driver

The GT5304 integrated a high side power MOSFET as well as a floating driver connected from the SW pin to BST pin. Both rise time and fall time are typically 20ns. An external C_{bst} capacitor from BST to SW is used by internal bootstrap circuit to provide the over drive voltage for the power MOSFET. A typical value of 10nF should be used for the bootstrap capacitor C_{bst}.

6.5 Fast Shutdown for PWM Dimming

When DIM pin is open circuit a typical 20µA pull-up current ensures that the GT5304 is in normal operation. When the DIM pin voltage goes below 0.8V, the internal switch driver is disabled, the switch of the GT5304 is turned off, all the bias remain active, inductor current will go to zero. When the DIM pin voltage goes higher than 0.85V, the IC goes back to normal operation. When the DIM pin is driven with a low frequency PWM signal, with a high level voltage (higher than 2.2V) and a low level voltage (below 0.8V), the output current of the IC will be switched on and off at the PWM frequency, resulting in a average output current I_{OUTavg} proportional to the PWM duty cycle. Dimming frequency and duty cycle are limited by the LED current rise time and fall time and the delay from activation of the DIM pin to the response of the internal power switch. In general, the dim frequency should be at least one order of magnitude lower than the switching frequency.

6.6 Brightness Control

The nominal average output current in the LED(s) is determined by the value of the external resistor connected between VCS and GND pins. The DIM pin can be driven by an external DC voltage to adjust the output current to a value below the nominal value defined by the resistor at VCS pin.

6.7 Peak Current Limit

When the power MOSFET current exceeds 1.5A (typical), the current limit comparator will turn off the power MOSFET, the power MOSFET will stay off for approximately 75x the steady state on time of the IC. At the end of this turn off time the system restarts. If the current limit condition persists, this process will continue, creating a low power hiccup mode, minimizing thermal stress on the IC and the external circuit components.

6.8 Over-voltage and Over-current Protection

When CS pin voltage exceeds 300mV, the internal over-voltage/over-current comparator will disable the power MOSFET. This threshold provides a hard limit for the output current. The output current overshoot is limited to 300mV/R_{SNS} .

The OVP/OCP comparator can also be used to prevent the output voltage from rising to V_{Omax} in the event of an output open-circuit. This is the most common failure mode for LED(s), due to breaking of the bond wires. Figure 4 shows a method using a zener diode, Z_1, and zener limiting resistor, R_Z, to limit the output voltage to the reverse breakdown voltage of Z_1 plus 200mV. The zener diode reverse breakdown voltage must be greater than the maximum combined forward voltage of all LED(s) in the array. The maximum recommended value for R_Z is 1kΩ.

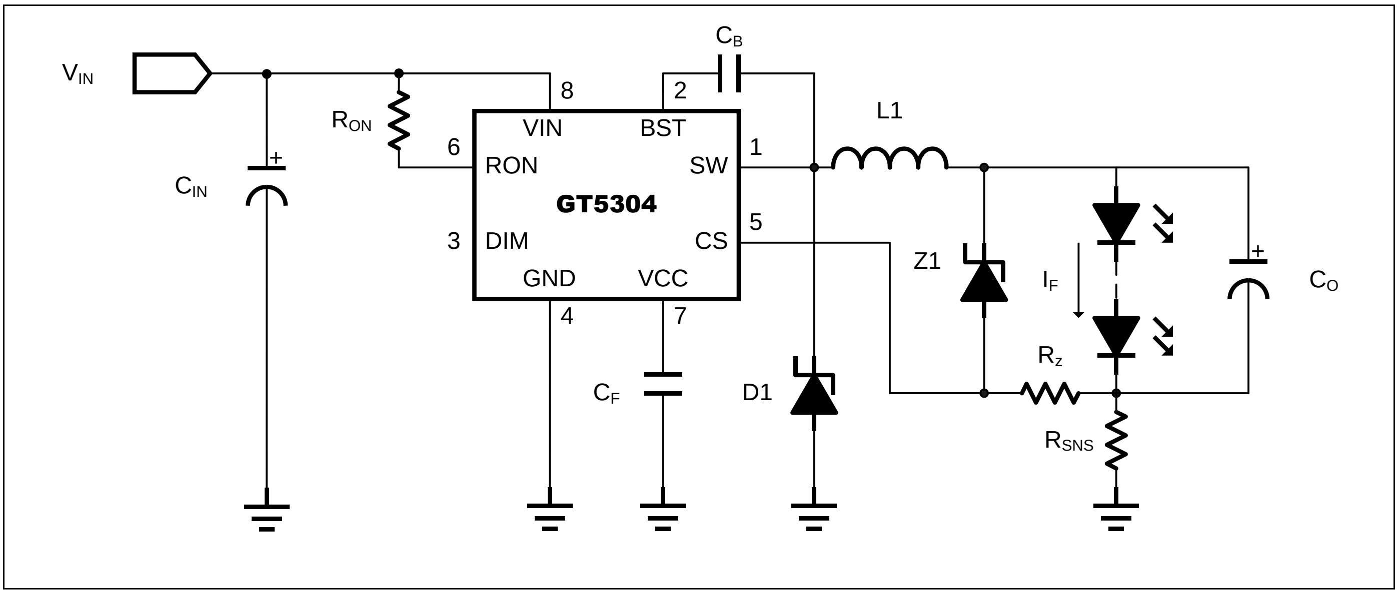


Figure 5. Output Open Circuit Protection

6.9 Low Power Shutdown

The GT5304 can be placed into a low power shutdown state (I_{IN}=20µA at V_{IN}=24V) by grounding the RON pin with a signal-level MOSFET as shown in ***Figure 5***.

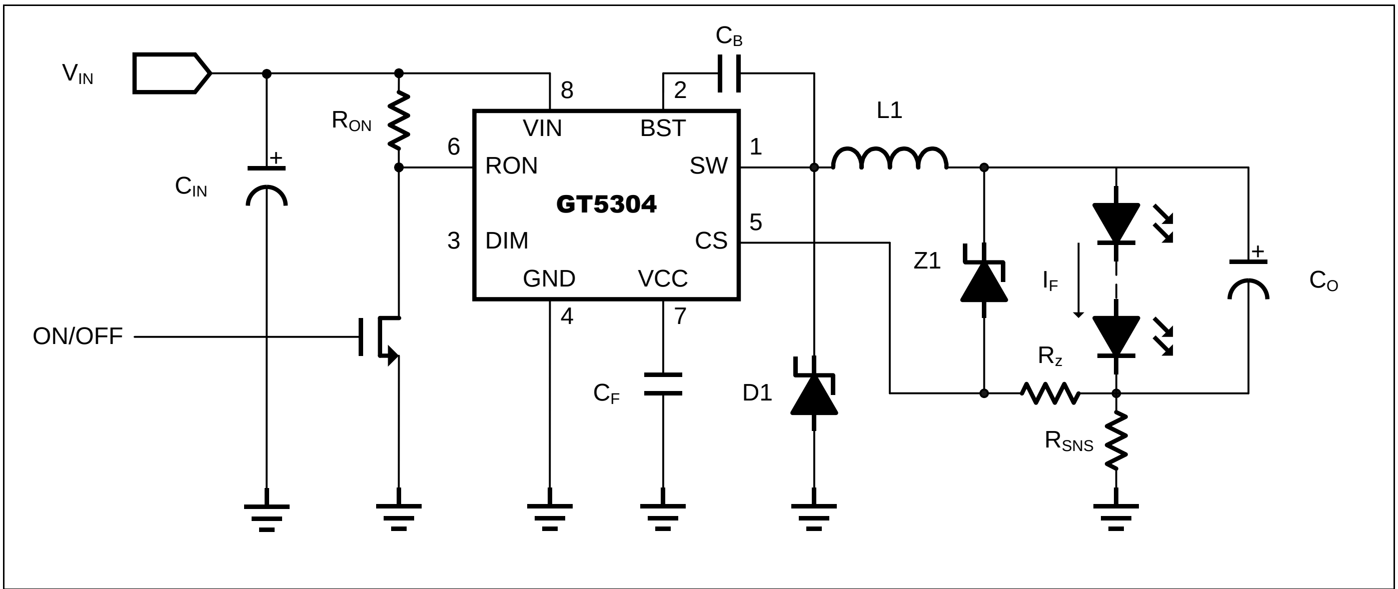


Figure 6. Low Power Shut Down

6.10 Thermal Compensation

High luminance LEDs often need to be supplied with a temperature compensated current in order to maintain reliable operation. The LEDs are usually mounted remotely from the device. If output current compensation is required, an external temperature sensing network – resistor divider with normal resistor and Negative Temperature Coefficient (NTC) thermistor, mounted very close to LEDs. The output of resistor divider can be used to drive DIM pin. In ***Figure***

6, R_2 is NTC thermistor and R_1 is normal resistor. ***Figure 7*** shows the relationship of output current with temperature.

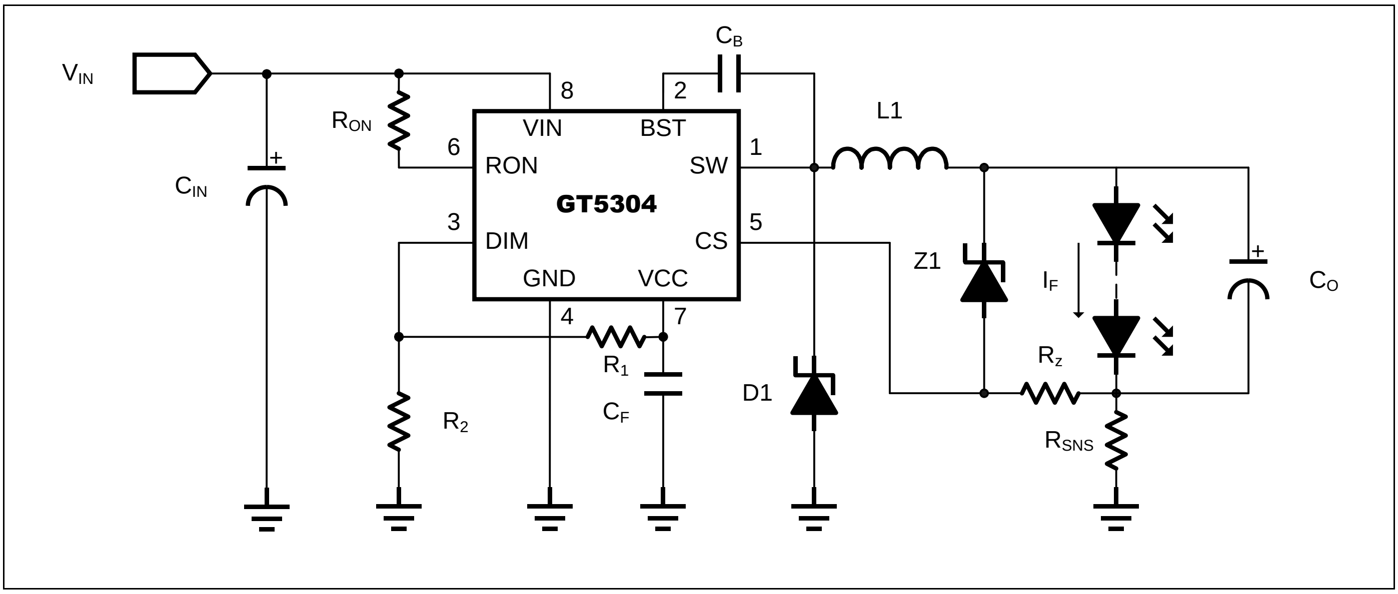


Figure 7. Temperature Compensation

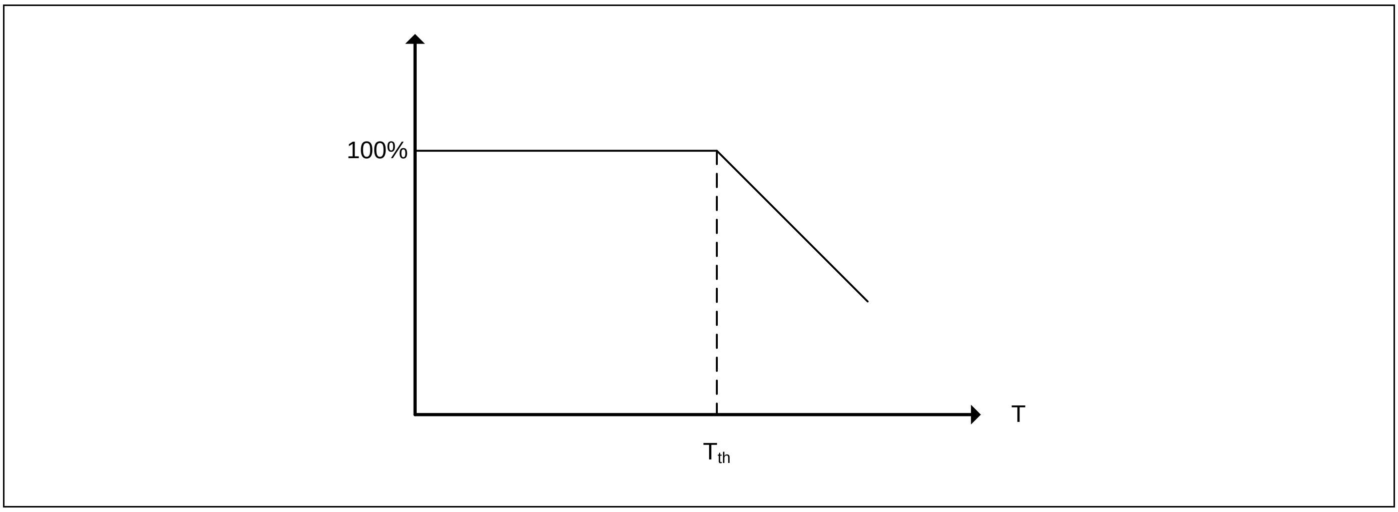


Figure 8. LED Output Current with Temperature

6.11 Thermal Shutdown

Internal thermal shutdown circuitry is provided to protect the IC in the event that the maximum junction temperature is exceeded. The shutdown temperature is set to 160℃ with a 30℃ hysteresis. During thermal shutdown the power MOSFET and the internal driver circuit are disabled.

6.12 Switching Frequency

Switching frequency is selected based on the trade-offs between efficiency, solution size/cost, and the range of output voltage that can be regulated. The low frequency provides better efficiency and wider output voltage range, but it requires bigger inductor thus higher cost. Many applications place limits on switching frequency due to EMI sensitivity. The on-time of the regulator can be programmed for switching frequency range from the 10's of kHz to over 1MHz. The maximum switching frequency is limited only by the minimum on-time and minimum off-time requirements.

6.13 LED Ripple Current

LED manufactures generally recommend values for Δi_F ranging from ±5% to ±20% of I_F. Higher LED current ripple current allows the use of smaller inductors, smaller output capacitors, or no output capacitors at all. The advantages of higher ripple current are reduction in the solution size and cost. Lower ripple current requires more output inductance, higher switching frequency, or additional output capacitance. The advantages of lower ripple current are a reduction in heating in the LED itself and greater tolerance in the average LED current before the current limit of the LED or the driving circuitry is reached.

6.14 ΔVSNS Requirement

A minimum ripple voltage of 25mV is recommended at the sense comparator to provide good signal to noise ratio. If no output capacitor

$$\Delta V_{SNS} = \Delta i_L \times R_{SNS} = \Delta i_F \times R_{SNS}$$

If output capacitor with ESR is used

$$\Delta V_{SNS} = \Delta i_F \times R_{SNS}$$

$$\Delta i_F = \frac{\Delta i_L}{1 + \frac{r_D}{Z_C}}$$

where

$$Z_C = ESR + \frac{1}{2\pi \times f_{SW} \times C_O}$$

r_D is the LED dynamic resistance, it is not always specified on the manufacture's datasheet, but it can be calculated as the inverse slope of n LED's V_F vs. I_F curve. Total dynamic resistance for a string of n LEDs connected in series can be calculated as the r_D of one device multiply by n. Small values of C_O that do not significantly reduce Δi_F can also be used to control EMI generated by switching action of the regulator.

6.15 Output Capacitors

Peak to peak ripple current in the LED(s) can be reduced by shunting a capacitor across the LED(s). With this topology the output inductance can be lowered, making the inductors smaller and less expensive. Alternately, the circuit could be run at lower frequency but keep the same inductor value, improving the efficiency and expanding the range of output voltage that can be regulated. Capacitors ranged from 0.5μF to 1μF are normally used. Small values of output capacitor can also be used to control the EMI generated by the switching action of the IC. EMI reduction becomes more important as the length of the connections between the LED and the rest of the circuit increase.

6.16 Input Capacitors

A low ESR capacitor should be used for input power supply decoupling. This capacitor has to supply the high peak current to inductor and smooth the current ripple on the input supply. A minimum value of 4.7μF is acceptable; the capacitor should be placed as close as possible to the VIN pin of the IC. But the higher values will improve performance at lower input voltages, especially when the source impedance is high. For maximum stability over temperature and voltage, capacitors with X7R, X5R, or better dielectric are recommended. Capacitors with Y5V dielectric are not suitable for decoupling in this application and should not be used.

6.17 Schottky Diode

A Schottky diode is used to get good efficiency due to its low forward biasing voltage and short reverse recovery time. The diode must be rated to handle the maximum input voltage plus any stitching ringing when the MOSFET is on. The diode is also selected to handle the average current $I_D=(1-D)I_F$, its peak current rating should be higher than the inductor peak current.

7. Electrical Characteristics

7.1 Absolute Maximum Ratings

Condition	Min	Max
Supply Voltage (V_{IN})	-0.3V	45V
Switch Voltage (V_{SW})	-1.0V	V_{IN}+1V
Bootstrap Voltage (V_{BST})	V_{SW}-0.3V	Vsw+6V
CS Voltage (V_{CS})	-0.3V	6V
RON Voltage (V_{RON})	-0.3V	6V
VCC Voltage (V_{VCC})	-0.3V	6V
DIM Voltage (V_{DIM})	-0.3V	6V
Operating Junction Temperature	-40℃	150℃
Storage Temperature	-55℃	150℃
Lead Temperature	-	300℃

Note: Stress greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions outside those indicated in the operational sections of this specification are not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

7.2 Operating Ratings

V_{IN}	5V to 40V
Junction Temperature Range	-40℃ to 125℃
Thermal Resistance θ_{JA} SOP8 Package	150℃/W
Thermal Resistance θ_{JA} HSOP8 Package	90℃/W

7.3 Electrical Characteristics

V_{IN}=24V unless otherwise specified, Typical values apply for T_A=25℃ unless otherwise specified, Min. / Max. values apply over full operating temperature range.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
On-time 1	T_{ON-1}	V_{IN}=10V, R_{ON}=200kΩ	2.1	2.75	3.4	µs
On-time 2	T_{ON-2}	V_{IN}=40V, R_{ON}=200kΩ	515	675	835	µs
Minimum off-time	T_{OFFMIN}	V_{CS}=0V	-	270	-	ns
Input Voltage Range	V_{IN}		5	-	40	V
Regulation and Over-voltage Comparators						
CS Regulation Threshold	V_{CS}	CS Decreasing, SW turns on	194	200	206	mV
CS Bias Current	I_{CS}	V_{CS}=0V	-	0.1	-	µA
Shutdown						
Shutdown Threshold	V_{SDTH}	RON/SD Increasing	0.3	0.7	1.05	V
Shutdown Hysteresis	V_{SDHYS}	RON/SD Decreasing	-	40	-	mV
Internal Regulator And Current Limit						
V_{CC} Regulated Voltage	V_{CC}		4	5	6	V
V_{CC} UVLO Threshold	V_{CCUVLO}	V_{CC} Increasing	-	4	-	V
V_{CC} UVLO Hysteresis	V_{CCUVH}	V_{CC} Decreasing	-	120	-	mV
Supply Quiescent Current	I_Q	No switching, V_{CS}=0.5V	-	608	900	µA
Supply Shutdown Current	I_{SHDN}	$V_{RON/SD}$=0V	-	20	50	µA
Current Limit Threshold	I_{LIM}		1.2	1.5	1.8	A
Dim Comparator						
Comparator Logic High	V_{IH}	DIM Increasing	2.2	-	-	V
Comparator Logic Low	V_{IL}	DIM Decreasing	-	-	0.8	V
MOSFET and Driver						
HS Switch On Resistance	R_{ON}	I_{SW}=200mA, V_{BST}-V_{SW}=5V	-	0.25	0.5	Ω
Thermal Shutdown Threshold	T_{SD}		-	160	-	℃
Thermal Shutdown Hysteresis	T_{SDHYS}		-	30	-	℃

8. Ordering Information

GT XX XX - XX X X

Temperature Range

Bank Commercial: 0℃~70℃

I Industrial: -40℃~125℃

Pb Status

G GREEN

Package Type:

G SOP

H HS0P

Part Number

Production Family

53 Power Management Product; LED Driver

Giantec Prefix

GT Giantec

Order Number	Package Description	Package Option
GT5304-GGI	5.1 x 4 mm SOP8	Tape and Reel 4000
GT5304-HGI	5.1 x 4 mm HSOP8	Tape and Reel 4000

9. Part Markings

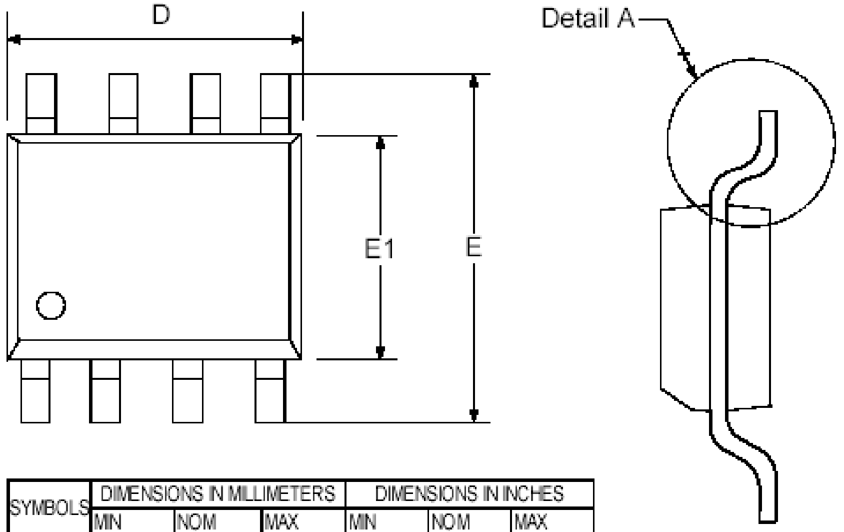
9.1 GT5304-GGI (Top View)

G	T	5	3	0	4	G	G	I
__	__	__	__	Lot Number	__	__	__	__
●		Y	Y	W	W	S	V	

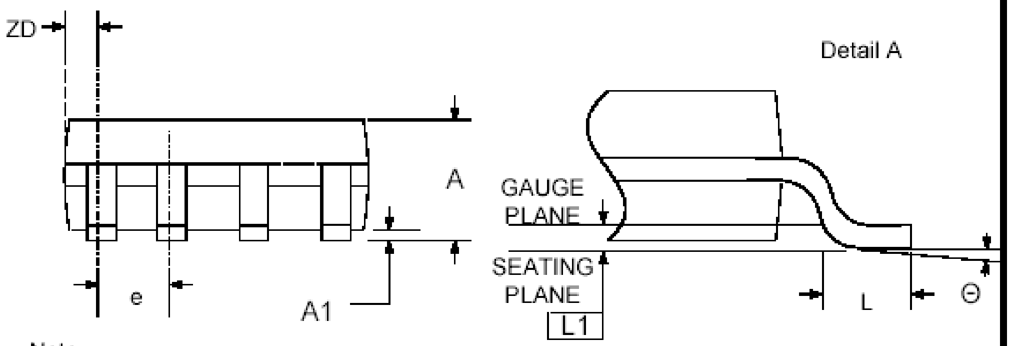
GT5304GGI	
Lot Number	States the last 9 characters of the wafer lot information
●	Pin 1 Indicator
YY	Seal Year
	00 = 2000
	01 = 2001
	99 = 2099
WW	Seal Week
	01 = Week 1
	02 = Week 2
	.
	.
	.
	51 = Week 51
	52 = Week 52
S	Subcon Code
	J = ASESH
	L = ASEKS
V	Die Version

10. Package Information

10.1 SOP8



SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.35	--	1.75	0.053	--	0.069
A1	0.10	--	0.25	0.004	--	0.010
b	0.33	--	0.51	0.013	--	0.020
D	4.80	--	5.00	0.189	--	0.197
E	5.80	--	6.20	0.228	--	0.244
E1	3.80	--	4.00	0.150	--	0.157
e	1.27 BSC.			0.050 BSC.		
L	0.38	--	1.27	0.015		0.050
L1	0.25 BSC.			0.010 BSC.		
ZD	0.545 REF.			0.021 REF.		
Θ	0	--	8°	0	--	8°



Note:

1. Controlling Dimension:MM
2. Dimension D and E1 do not include Mold protrusion
3. Dimension b does not include dambar protrusion/intrusion.
4. Refer to Jedec standard MS-012
5. Drawing is not to scale

TITLE	8L 150mil SOP Package Outline	Rev.	A	DATE	01/13/2010

11. Revision History

Revision	Date	Descriptions
A0	Jan., 2011	Initial Version