LED Drivers

Features and Benefits

- Supply voltage, V_{BB}, 450 V maximum, 25 to 400 V recommended; Note: lowest voltage can vary depending on LED loads
- Output current I_O(max) options:
  - 0.5 A, LC5205D
  - 1.0 A, LC5210D
- Constant current control circuit:
  - Fixed off-time PWM constant current control, off-time adjustable by external components
  - Externally adjustable output current by input voltage to REF pin
- Output current dimming by external PWM signal; low signal to TOFF pin shuts off output current, and PWM signal input to that pin enables dimming
- Undervoltage lockout protection (UVLO)
- Overcurrent protection (OCP); latched in response to the short-to-GND condition
- Thermal Shutdown protection (TSD); protects IC from damage due to excess temperature, auto-restart when temperature drops below threshold

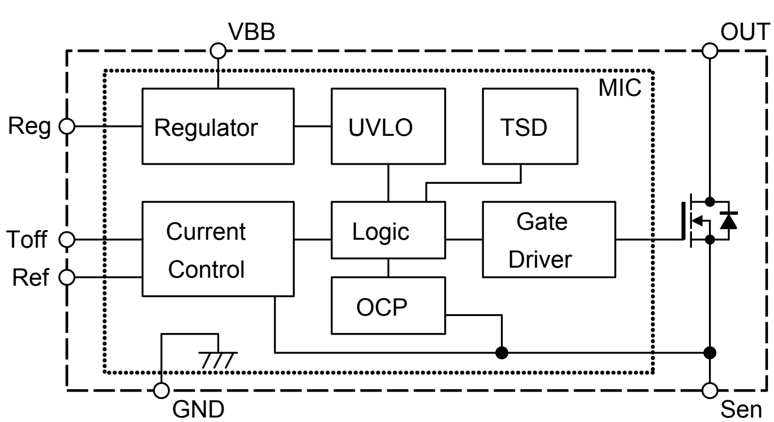
Package: 7-pin DIP

Not to scale

Description

LC5200 series is an off-line LED driver IC which includes both a main controller integrated circuit (MIC) and a power MOSFET. Its high voltage capability allows direct connection to a wide range of supply voltages ranging from 25 to 400 V (recommended). The LC5200 uses constant current mode to drive LEDs. The package is a standard 8-pin DIP, with pin 7 removed for greater creepage distance from the supply pin.

Functional Block Diagram



Selection Guide

Part Number	Output Current, $I_O(max)$ (A)
LC5205D	0.5
LC5210D	1.0

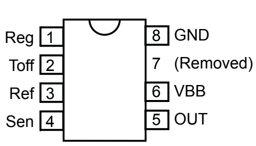
Absolute Maximum Ratings at T_A = 25°C

Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{BB}		450	V
Output Breakdown Voltage	V_O		450	V
Output Current	I_O	LC5205D, $t_w \geq 1$ µs	0.5	A
		LC5210D, $t_w \geq 1$ µs	1.0	A
REF Pin Input Voltage	V_{REF}		–0.3 to V_{REG} + 0.3	V
SENSE Pin Voltage	V_{RS}	$t_w \geq 1$ µs	±2	V
Allowable Power Dissipation	P_D	On Sanken evaluation PCB; affected by application PCB layout	1.73	W
Junction Temperature	T_J		150	ºC
Operating Ambient Temperature	T_A		–40 to 105	ºC
Storage Temperature	T_{stg}		–40 to 150	ºC

Recommended Operating Conditions

Characteristic	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{BB}	Lowest voltage can vary depending on LED loads	25	–	400	V
Average Output Current	I_O	LC5205D	–	–	0.4	A
		LC5210D	–	–	0.8	A
REF Input Voltage	V_{REF}	In normal operation	–	–	0.5	V
Case Temperature	T_C	Measured at center of case, T_J < 150°C	–	–	105	°C

Pin-out Diagram



Terminal List Table

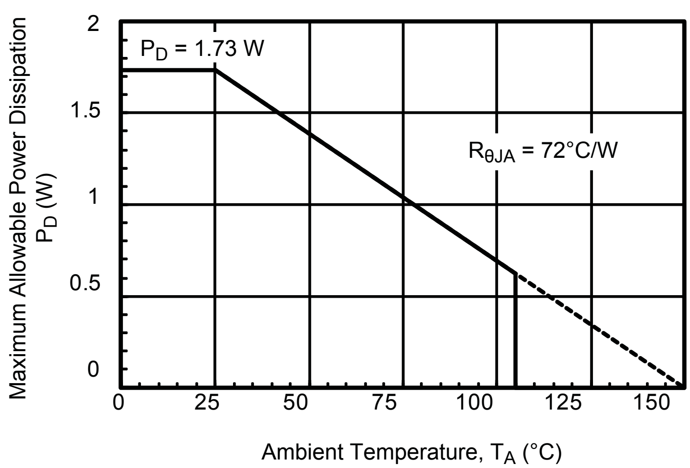
Name	Number	Function
Reg	1	Regulator output pin for powering external components. Connect 0.1 µF bypass capacitor between this pin and GND.
Toff	2	For self-oscillation operation, connect external capacitor and resistor to set off-time. For externally-controlled PWM operation, input PWM adjustment signal.
Ref	3	Reference voltage input pin, for output peak current.
Sen	4	Connect external resistor for PWM peak current control and OCP.
OUT	5	Internally connected to the MOSFET drain, output connection to LED load.
VBB	6	Supply voltage pin; internally connected to the voltage regulator to power the internal circuits.
–	7	No connection; pin removed to increase creepage distance from VBB pin.
GND	8	Device ground pin.

All performance characteristics given are typical values for circuit or system baseline design only and are at the nominal operating voltage and an ambient temperature of 25°C, unless otherwise stated.

ELECTRICAL CHARACTERISTICS Valid at T_A = 25°C and V_{BB} = 140 V, unless otherwise noted

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Supply Voltage Input Current	I_{BB}	Normal operation	–	2	–	mA
	I_{BBS}	At output off	–	0.6	1	mA
MOSFET Breakdown Voltage	V_{DSS}	I_D = 1 mA	450	–	–	V
MOSFET On-Voltage	$V_{DS(on)}$	I_D = 0.5 A, LC5205	–	3	–	V
		I_D = 1.0 A, LC5210	–	2.5	–	V
MOSFET Diode Forward Voltage	V_F	I_D = 0.5 A, LC5205	–	0.85	–	V
		I_D = 1.0 A, LC5210	–	0.9	–	V
REG Pin Output Voltage	V_{REG}	I_{REG} = 0 mA	11.5	12	12.5	V
REG Pin Maximum Output Current	I_{REG}	V_{REG} = 11.5 V	–	–	2	mA
Maximum PWM Operating Frequency	f_{clk}	PWM frequency	–	–	200	kHz
REF Pin Input Voltage	V_{REF}		0	–	1	V
REF Pin Input Current	I_{REF}		–	±10	–	μA
SENSE Pin Voltage	V_{RS}		V_{REF} – 0.03	V_{REF}	V_{REF} + 0.03	V
SENSE Pin Current	I_{RS}		–	±10	–	μA
OCP Threshold Voltage	V_{OCP}	Measured at SENSE pin	–	3	–	V
PWM Off-Time	T_{POFF}	R_{TOFF} = 560 kΩ, C_{TOFF} = 220 pF	–	21	–	μs
UVLO On Threshold Voltage	$V_{UVLO(on)}$	For V_{BB}	–	13	–	V
UVLO Off Threshold Voltage	$V_{UVLO(off)}$	For V_{BB}	–	14	–	V
TSD Threshold Temperature	T_{TSD}	Main controller IC (MIC) temperature	–	150	–	°C
TSD Hysteresis Temperature	T_{TSDhys}		–	55	–	°C
Switching Time	t_r	I_D = 0.4 A	–	20	–	ns
	t_f	I_D = 0.4 A	–	50	–	ns

Power Dissipation versus Ambient Temperature



Functional Description

Regulator

The LC5200 series provides 12 V output voltage, generated from the supply voltage on the VBB pin, which is used to power internal circuits and external components. When the gate capacitance charging of the MOSFET occurs, it generates a current surge, which results in ripple voltage. This could affect operation, therefore, connect a 0.1 µF ceramic capacitor at the REG pin to stabilize operation.

Current Control

Current control is done by a fixed off-time PWM topology. The output current level can be set by the input voltage on the REF pin, and voltage across the current sense resistor at the SENSE pin. In addition, the fixed off-time can be adjusted by the values selected for the external capacitor and resistor at the TOFF pin.

UVLO (Undervoltage Lock Out)

This prevents the device from malfunctioning by shutting down the output circuit when the internal supply voltage becomes lower than the ULVO threshold voltage, V_{UVLO}. In addition, the UVLO circuit is used for the power-on reset function of overcurrent protection (OCP).

TSD (Thermal Shutdown)

When the main control chip (MIC) temperature exceeds the TSD threshold temperature, T_{TSD}, the device shuts off the output (system logic continues to operate), in order to avoid abnormal temperature increase. When the temperature drops by the hysteresis amount, T_{TSDhys}, or if the supply voltage is recycled, the device returns to normal operation. Note: The primary source of heating is the MOSFET, and there is a delay while the heat spreads to the MIC and is sensed. Therefore, a rapid temperature increase of the MOSFET may damage the device.

OCP (Overcurrent Protection)

When the SENSE pin input voltage reaches the OCP threshold, V_{OCP}, it shuts off the output and shifts into latch mode. In order to release from latch mode, cycle the device power supply.

Note: OCP is for protecting the device from excess current. OCP may not work at an LED-short condition because the coil may suppress current increase.

Internal Switching Logic

The device turns the MOSFET gate driver circuit on or off based on the status of the current control sensing circuit and the protection circuits.

Gate-Driver Operation

This comprises the MOSFET gate driver circuit.

The two device versions in the LC5200 series are distinguished from each other by the MOSFET current rating. Select the current rating that best matches the application circuit.

Application Information

Typical Application Example

A typical application circuit is shown in figure 1. The values of the external components are shown in the adjacent table.

Component Value Setting

LED LED current should not exceed the LC5200 device current ratings. Set the total voltage drop across the LED string to be less than V_{BB}; otherwise, the LED string turns off. As a general design rule, the PWM off-time should be longer if there is a small drop in voltage across the LED string, and it should be shorter if there is a high drop in voltage across the LED string. For the LC5205D, a 9 to 30 V drop across the LED string is recommended for proper operation.

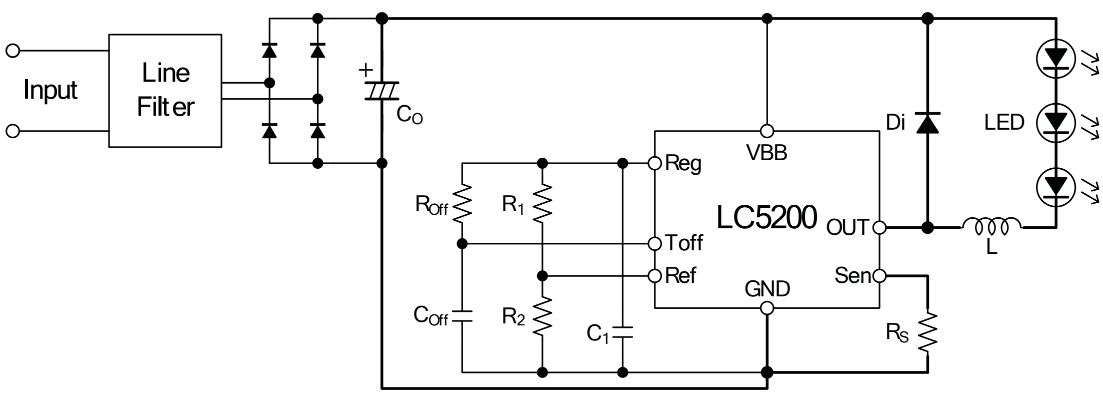


Figure 1. Typical application circuit

Referenced Typical Application Components

Symbol	Components	Values / Ratings	Descriptions
C_0	Electrolytic capacitor	≈100 µF / 450 V	Main supply source voltage rectifying capacitor Note: ≤ 1 µF can be used
C_1	Capacitor	0.1 µF / 25 V	The internal regulator output capacitor
C_{Off}	Capacitor	100 pF / 25 V	PWM off-time adjusting capacitor
Di	Diode	RL3A	High voltage, ultrafast rectifying, current recirculation diode
L	Coil	1 mH / 1 A	PWMing choke coil
LED	LEDs	———	LED load
R_1	Resistor	680 kΩ / $^1/_8$ W	Reference pin voltage setup resistor
R_2	Resistor	20 kΩ / $^1/_8$ W	Reference pin voltage setup resistor
R_{Off}	Resistor	620 kΩ / $^1/_8$ W	PWM off-time adjusting resistor
R_S	Resistor	1.0 Ω / 1 W	Output current sensing resistor

L This is the choke coil for constant-current PWM operation. The higher the inductance of this component, the less ripple amplitude the output current has. In general, 0.5 to 20 mH is recommended. Also ensure the coil does not saturate at the peak of the ripple current. Saturation causes high surge current and it could cause damage to the LEDs or the device.

Di This diode provides a path for recirculation current. If a diode with slow recovery characteristics is used, it will cause surge current when the MOSFET turns on, as well as noise increase and device malfunction may result. In addition, it causes efficiency drop. Therefore, the Sanken RL3A ultrafast recovery diode, or a diode of better or equal recovery characteristics (50 ns), is recommended.

C_O This is the main supply voltage rectifying capacitor. The greater the capacitance, the less ripple voltage occurs. In addition, because higher output power causes an increase of the ripple voltage, choose a proper value of capacitance for the output power. Even if the capacitance is low (like 1000 pF) and the ripple voltage becomes high, the device works. It also makes possible a non-electrolytic capacitor design, which results in lengthening unit life and reducing unit size and cost. However, if the bottom of the ripple voltage falls below the LC5200 UVLO threshold, or below the voltage drop of the LED string, the LEDs are turned off during that period.

C1 This capacitor is for stabilizing the internal regulator circuit operation. Connect a 0.1 µF capacitor as close to the device as possible in order to operate the MOSFET properly. Using a small capacitance value causes slow switching speed and malfunctioning, however, a large value of capacitance causes slow startup.

R1, R2, RS These determine the LED peak current, according to the following formula:

$$I_{PEAK} = V_{REG} \times R_2 / ([R_1 + R_2] \times R_S)$$

For example, if the target is an I_{PEAK} of 0.35 A, the formula becomes:

$$I_{PEAK} \approx 12\ (V) \times 20\ (k\Omega) / ([20\ (k\Omega) + 680\ (k\Omega)\ ] \times 1\ \Omega)$$

$$= 0.35\ A$$

Based on it, R_1 = 20 kΩ, R_2 = 680 kΩ, and R_S = 1 Ω can be determined.

Note that R_1 and R_2 cause power consumption by the internal regulator. Therefore, follow the formula below in order to minimize the power consumption:

$$(R_1 + R_2) > 500\ k\Omega$$

In actual design, the current peak tends to be higher than the estimated value, due to internal circuit delays. This becomes obvious at high di/dt conditions, which can result from high V_{BB} or from low coil inductance.

With regard to the resistor R_S, because output current runs through it, use a resistor rated for 2 to 3 times higher than the power dissipation.

R_{OFF}, C_{OFF} These decide PWM off-time, T_{POFF}. Figure 2 shows PWM off-time curves based on various values of C_{off} and R_{off}. PWM off-time is approximately 20 µs at the recommended values: R_{off} = 560 kΩ and C_{off} = 220 pF.

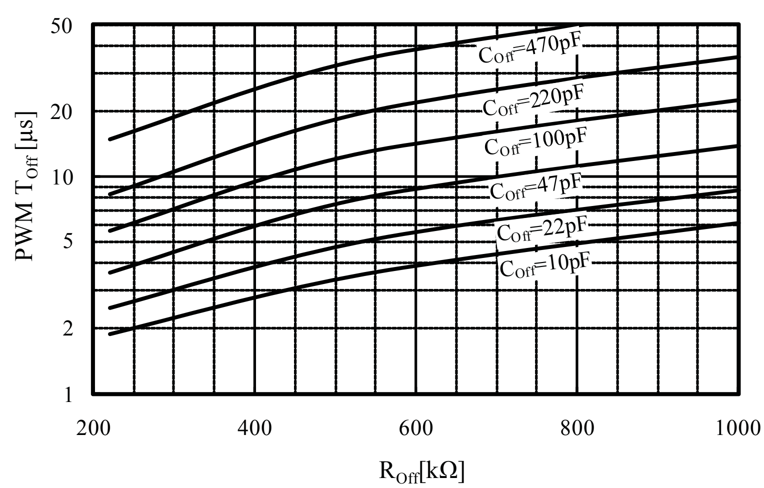


Figure 2. Affect of various values for capacitor C_{OFF} and resistor R_{OFF} on PWM off-time

Current Control

PWM current control works as shown in figure 3.

- **PWM On Period**. During MOSFET on-time, the current runs through the I_{ON} path (shown in red in figure 3, panel A).
- **MOSFET Turn Off**. During on-time, the current increases as the red waveform in panel B, and when it reaches the V_{SENSE} threshold voltage, the MOSFET turns off.
- **PWM Off Period**. During MOSFET off-time, the back EMF occurs on the coil and the energy which is charged on the coil during the on-time is deenergized by the current I_{OFF} running through the path in blue of panel A.
- **MOSFET Turn On**. After the fixed off-time, which is set by the external capacitor and resistor at the T_{off} pin, the MOSFET turns on again, and repeats the above operations.

Figure 4 shows the current control circuit and figure 5 shows the timing diagram of that circuit. When the MOSFET turns on, both the load current and V_{Sen}, across the sensing resistor R_S, increase. Comp2 compares V_{Sen} and V_{Ref} and its output is inverted at $V_{Sen} > V_{Ref}$ (see point A in figure 5). This resets the latter R_S latch and it results in turning off the MOSFET after the signal goes through several logic circuits. At the same time, C_{off} at the T_{off} pin is discharged by the internal MOS switch, and when the Comp1 inverting input (linked to the T_{off} pin) voltage becomes lower than 2 V, Comp1 output is inverted and it sets the R_S latch. This turns off the MOS switch and initiates the charging process of C_{off} by R_{off}. C_{off} voltage (T_{off} pin) increases by it and when its voltage reaches 3 V, Comp1 output becomes high and it turns on the MOSFET (point B in figure 5). The Blank Pulse circuit creates periods that mask surge or ringing noise, from turn off edge to just after the turn on edge, for securing proper PWM operation.

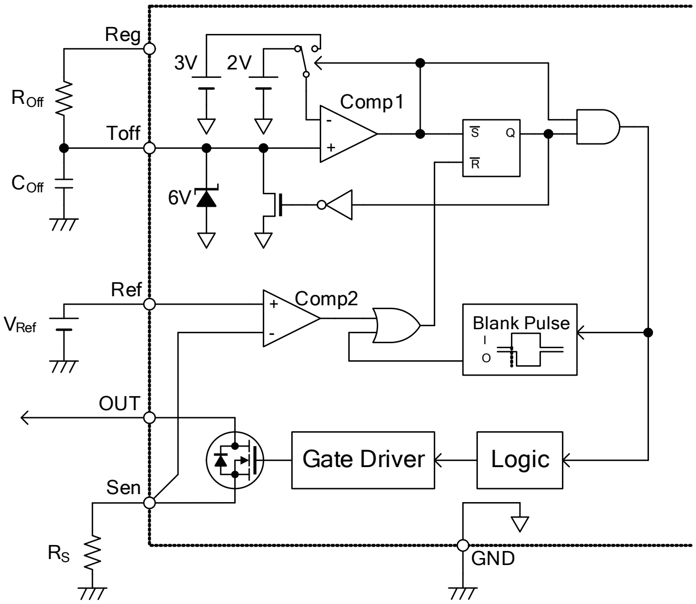


Figure 4. Current Control Circuit

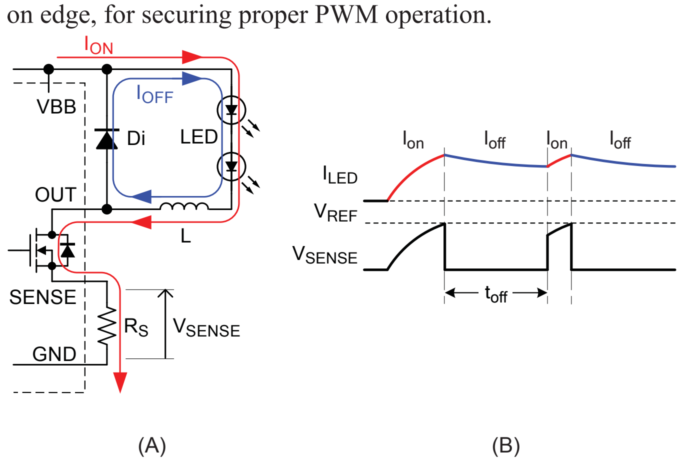


Figure 3. Output current control circuit

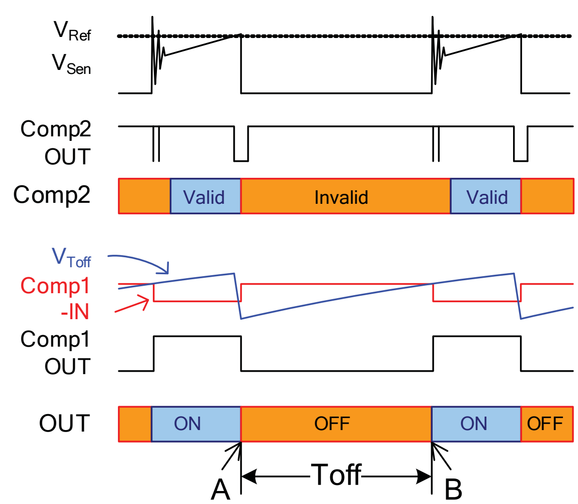


Figure 5. Current Control Circuit Timing Chart

LED Current Setting and Dimming

Output current level can be set using two alternative methods:

- **Internal PWM Control**. The LC5200 series provides fixed off-time PWM current control operation, allowing implementation of an LED constant-current control circuit with only a small quantity of external components.

  The output current is calculated by the formula below:

  $$I_O = V_{REF} / R_S$$

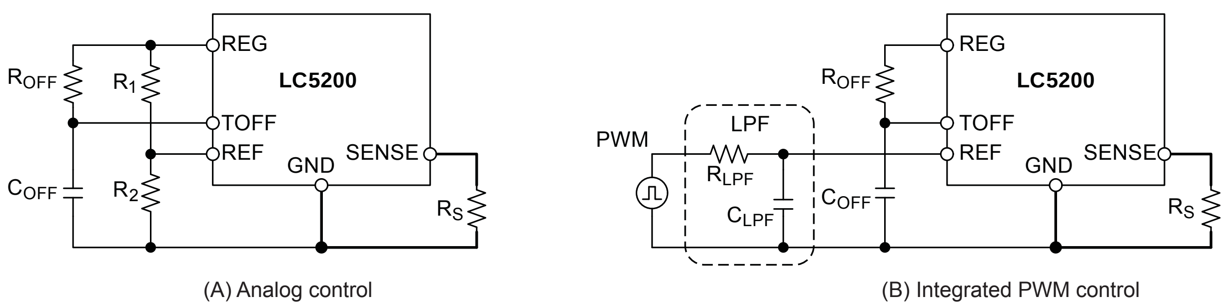
  Based on this formula, there are two methods of LED current control available:

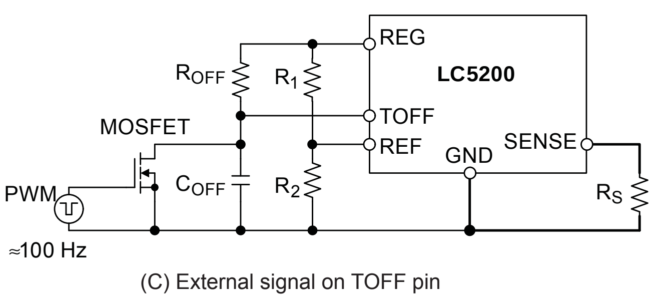
  ▫ Analog control, varying the REF pin voltage as shown in figure 6, panel A)

  ▫ PWM integrated control, inputting external PWM signal through a low pass filter (LPF) and connecting the output to the REF pin (figure 6, panel B)

  In either method, the TOFF pin voltage is used to turn the MOSFET on or off, therefore, the circuit in figure 6, panel C also works to adjust the output current by the external signal. In this application, when the external small signal MOSFET turns on, LC5200 stops an output pulse.

- **External PWM Control**. In this method of control, the LC5200 allows direct on/off control of the MOSFET, for synchronizing PWM operation among LED arrays or for other reasons. With this method, a pull-up shunt is connected from the REF pin to the regulator output as shown figure 7. The capacitor and resistor are removed from the TOFF pin, and instead the PWM signal is input to the TOFF pin. Note that for this method, the internal peak current control is disabled; therefore, it requires an external current control circuit for constant current operation. However, overcurrent protection is still in active to protect the LC5200 and LEDs from excessive current. The TOFF pin threshold has hysteresis characteristics: from < 2 V to MOSFET off, and from > 3 V to MOSFET on. Therefore, use 5 V CMOS compatible input for the control.

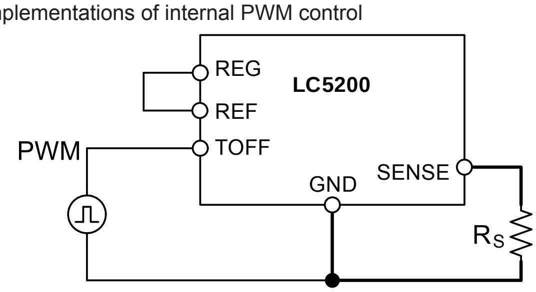




Internal PWM Truth Table

PWM	OUT
Low	Low (ON)
High	High (OFF)

Figure 6. Implementations of internal PWM control



External PWM Truth Table

TOFF	OUT
Low < 2 V	High (OFF)
High > 3 V	Low (ON)

Figure 7. Implementation of external PWM control

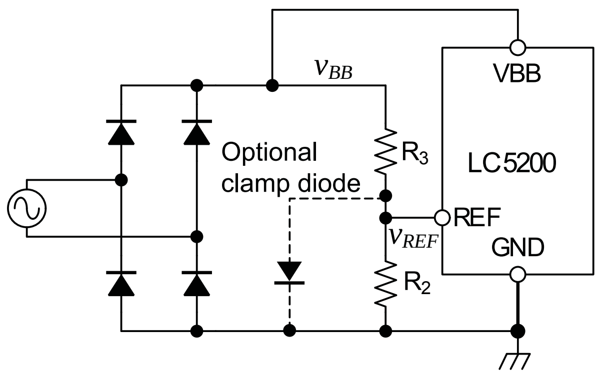
About TRIAC Dimming Control (Phase Control)

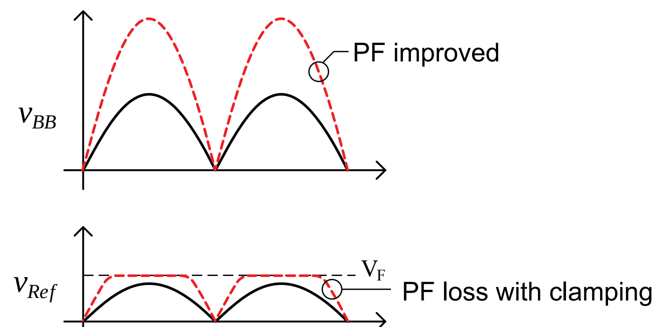
Commonly used TRIAC dimmers are designed for mainly resistive loads and they require TRIAC holding current for proper phase controls. LC5200 series does not respond to this type of dimmers because it does not have function to create the holding current during phase off period.

Power Factor Improvement

Making the LED current proportional to the AC input voltage improves the power factor, and it can be realized using LC5200 series REF pin function. Figure 8 shows the application circuit. There is no AC rectification capacitor, and R2 and R3 divide the AC voltage to create a proportional low voltage as the AC voltage for the REF pin. This way, LED current follows the AC voltage shape and improves the power factor. In case the REF voltage fluctuates widely, place a clamp diode in parallel with R2 to protect the REF pin. In that case, the REF voltage becomes distorted (lower waveform in figure 8) and could cause the power factor to decrease.

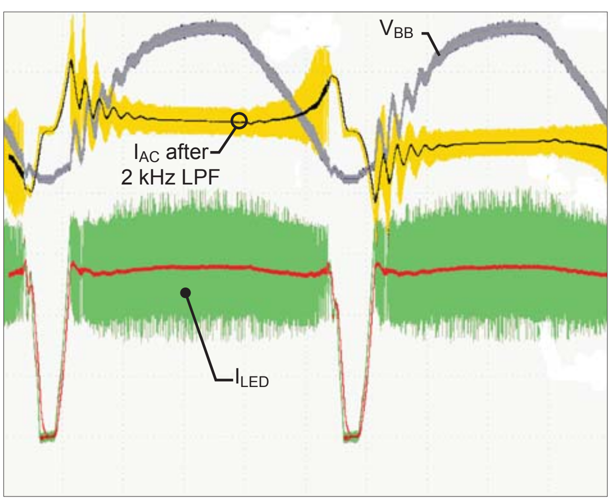
Figure 9 shows actual waveforms of the operation. Panel A shows operation with fixed REF pin voltage, and panel B shows operation with AC proportional REF pin voltage. For both operations, there is no AC rectification capacitor used. The yellow waveform is the AC input current, and the black waveform is a 2 kHz low pass filtered waveform. In panel B, the current forms a sine waveform, which means the power factor is improved.



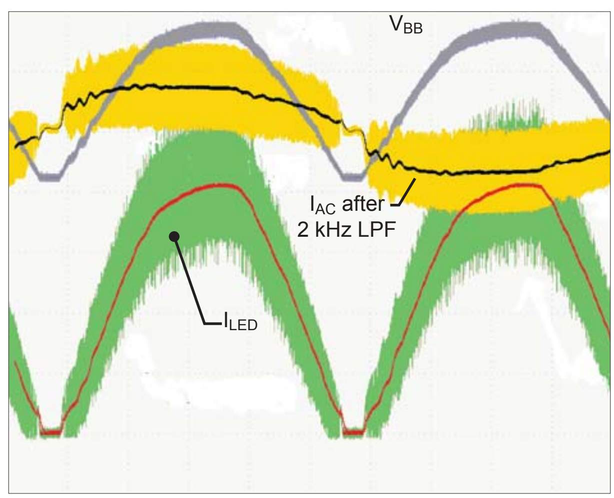


$$v_{Ref} = \frac{R_2}{R_2 + R_3} v_{BB}$$

Figure 8. Power factor improvement circuit



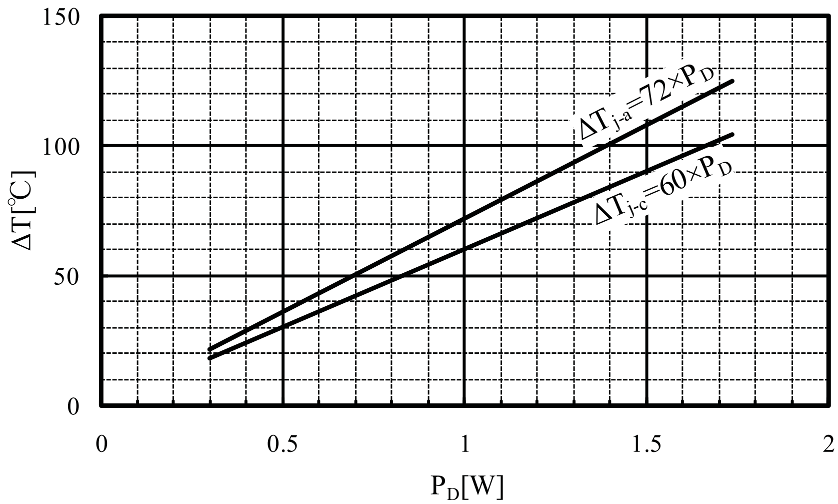
Fixed V_{REF}, PF = 49.1%



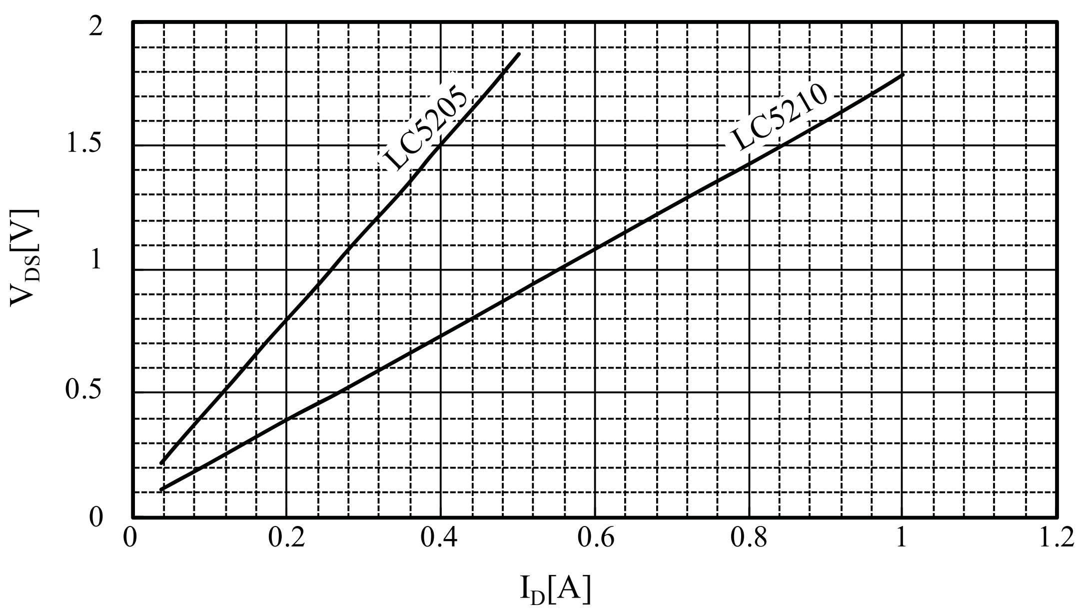
AC proportional voltage, PF = 82.9%

Figure 9. Power factor improvement operating waveforms: 100 VAC, 5 white LEDs in series, average LED current 0.5 A; black trace: AC input current I_{AC} after 2 kHz low pass filter = 500 mA/ div.; red trace: I_{AC} after 2 kHz low pass filter = 200 mA/ div.

Thermal Design



MOSFET On Voltage versus Drain Current



WARNING — These devices are designed to be operated at lethal voltages and energy levels. Circuit designs that embody these components must conform with applicable safety requirements. Precautions must be taken to prevent accidental contact with power-line potentials. Do not connect grounded test equipment.

The use of an isolation transformer is recommended during circuit development and breadboarding.

Because reliability can be affected adversely by improper storage environments and handling methods, please observe the following cautions.

Cautions for Storage

- Ensure that storage conditions comply with the standard temperature (5°C to 35°C) and the standard relative humidity (around 40 to 75%); avoid storage locations that experience extreme changes in temperature or humidity.
- Avoid locations where dust or harmful gases are present and avoid direct sunlight.
- Reinspect for rust on leads and solderability of products that have been stored for a long time.

Cautions for Testing and Handling

When tests are carried out during inspection testing and other standard test periods, protect the products from power surges from the testing device, shorts between adjacent products, and shorts to the heatsink.

Remarks About Using Silicone Grease with a Heatsink

- When silicone grease is used in mounting this product on a heatsink, it shall be applied evenly and thinly. If more silicone grease than required is applied, it may produce stress.
- Coat the back surface of the product and both surfaces of the insulating plate to improve heat transfer between the product and the heatsink.
- Volatile-type silicone greases may permeate the product and produce cracks after long periods of time, resulting in reduced heat radiation effect, and possibly shortening the lifetime of the product.
- Our recommended silicone greases for heat radiation purposes, which will not cause any adverse effect on the product life, are indicated below:

Type	Suppliers
G746	Shin-Etsu Chemical Co., Ltd.
YG6260	Momentive Performance Materials
SC102	Dow Corning Toray Silicone Co., Ltd.

Heatsink Mounting Method

- Torque When Tightening Mounting Screws. Thermal resistance increases when tightening torque is low, and radiation effects are decreased. When the torque is too high, the screw can strip, the heatsink can be deformed, and distortion can arise in the product frame. To avoid these problems, observe the recommended tightening torques for this product package type, TO-3P (MT-100): 0.686 to 0.882 N•m (7 to 9 kgf•cm).
- Diameter of Heatsink Hole: < 4 mm. The deflection of the press mold when making the hole may cause the case material to crack at the joint with the heatsink. Please pay special attention for this effect.

Soldering

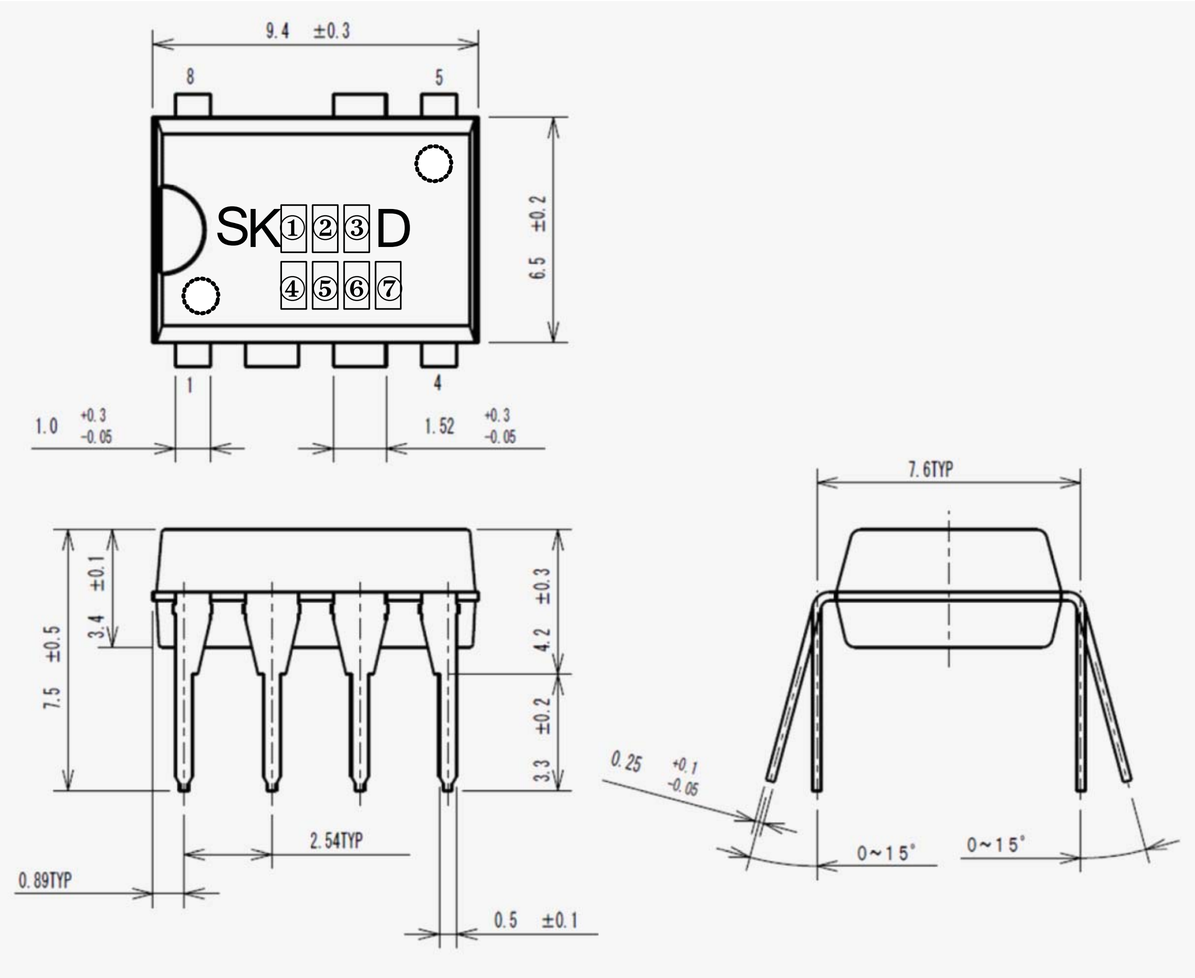
- When soldering the products, please be sure to minimize the working time, within the following limits:

  260±5°C 10 s

  350±5°C 3 s
- Soldering iron should be at a distance of at least 1.5 mm from the body of the products

Electrostatic Discharge

- When handling the products, operator must be grounded. Grounded wrist straps worn should have at least 1 MΩ of resistance to ground to prevent shock hazard.
- Workbenches where the products are handled should be grounded and be provided with conductive table and floor mats.
- When using measuring equipment such as a curve tracer, the equipment should be grounded.
- When soldering the products, the head of soldering irons or the solder bath must be grounded in other to prevent leak voltages generated by them from being applied to the products.
- The products should always be stored and transported in our shipping containers or conductive containers, or be wrapped in aluminum foil.



Dimensions in MM
Terminal treatment: Ni plating and solder plating (Pb-free)

Marking

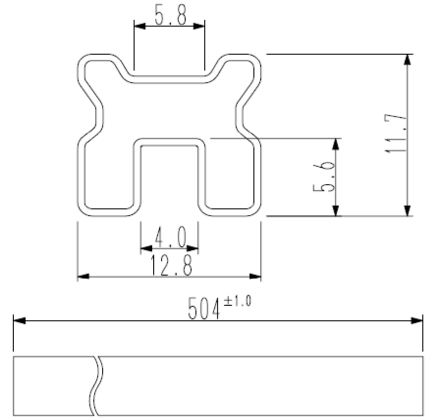
Position	Contents	Indication
①	The last digit of the year	0 to 9
②	The Month	1 to 9,O,N,D
③	The Week	1 to 3
④	Sanken Registration Number	alphanumeric characters
⑤		
⑥		
⑦		

Appearance: The body shall be clean and shall not bear any stain, rust or flaw.
Marking: The type number and lot number shall be clearly marked by laser so that cannot be erased easily.

Packing Specifications

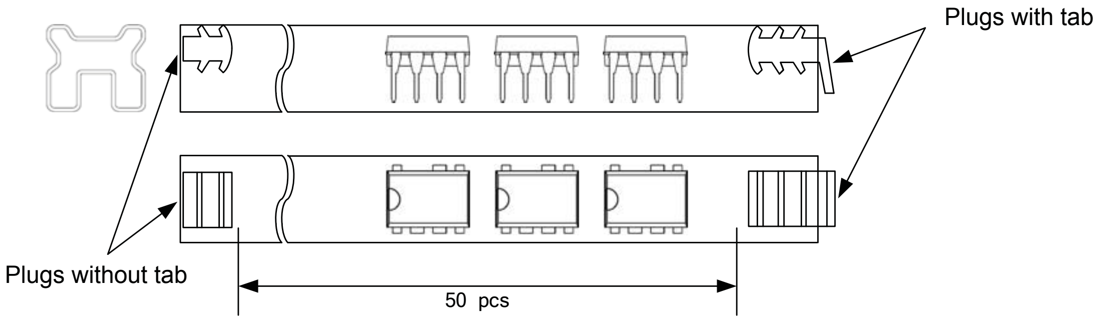
Minimum type of packing: Stick

Capacity:50pcs per stick



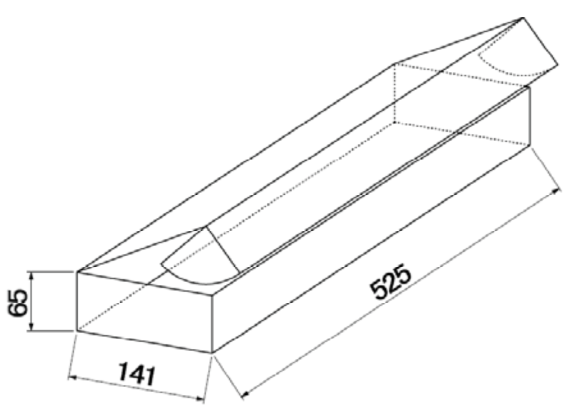
Dimensions in millimeters

Direction of parts insertion



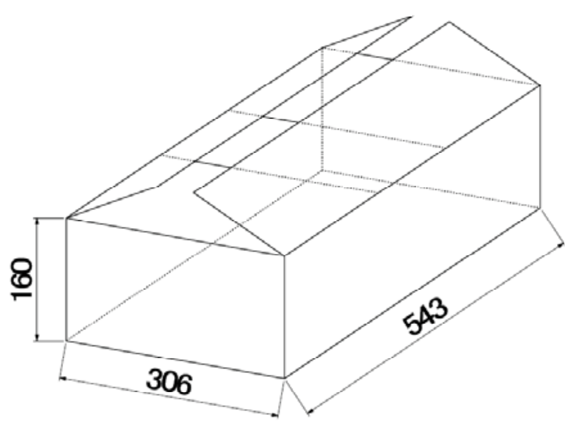
Packing style

Stick Packing 1 (Inner box)
Capacity:50 Sticks per box



Dimensions in millimeters

Stick Packing 2 (Outer Box)
Capacity:4 inner boxes per outer box
(Maximum quantity of Products:10,000 pcs.)



Dimensions in millimeters

Cautions and Warnings

Terminal connection

To avoid malfunction, terminals of this IC should not be left open.

Operation of the protection circuit

(OCP,TSD)
This product has two protection circuits (OCP and TSD). These protection circuits work by detecting excessive applied to the driver. Therefore, these function are not able to protect if the power exceeds the tolerance of the driver.

Handling

When static electricity is a problem, care should be taken to properly control the room humidity, especially in the winter when static electricity is most troublesome.

IC

Care should be taken with device leads and with assembly sequence to avoid applying static charges to IC leads. PC board pins should be shorted together to keep them at the same potential to avoid this kind of trouble.

Cautions for Storage

Ensure that storage conditions comply with the standard temperature (5°C to 35°C) and the standard relative humidity (approximately 40% to 75%) and avoid storage locations that experience extreme changes in temperature or humidity.

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