# DN06067/D

# Three LED 300 mA MR16 Driver

ON Semiconductor®

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## DESIGN NOTE

**Table 1. DEVICE DETAILS**

| Device | Application | Input Voltage | Output Power | Topology | I/O Isolation |
|---|---|---|---|---|---|
| CAT4201 | MR-16 LED Lamp | 12 Vac | 2.7 W | Step-down | None |

**Table 2. OTHER SPECIFICATIONS**

| | Output |
|---|---|
| Output Voltage | 9.1 V |
| Nominal Input Power | 3.4 W |
| Nominal Average Current | 300 mA |
| Max Average Current | 310 mA |
| Min Average Current | 295 mA |
| Typical Efficiency | 83% |

**Table 3. LED KEY SPECIFICATIONS**

| LED | Maximum Rating | Forward Voltage @ 350 mA | Typical Color | Typical Luminous Flux @ 350 mA |
|---|---|---|---|---|
| CREE Xlamp® XR-E | 1 A/3.7 W | 3.3 V | Cool White | 107 lm |

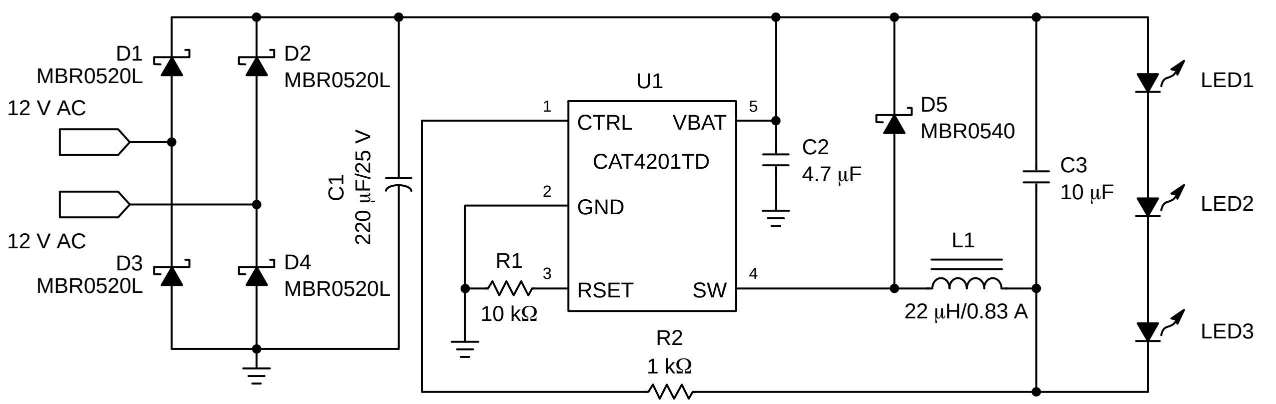



**Figure 1. Schematic**

**Circuit Description**

The CAT4201 is a step-down, easy-to-configure, dimmable LED driver. The package is a 5-pin SOT−23; with fewer than 10 discrete components (most of them surface mount), the whole PCB can be small enough to fit into the base of an MR16 bulb. The voltage ratings on pins VBAT, CTRL and SW are 40 V, so driving 12 LEDs is possible with adequate voltage. The RSET pin determines the output DC current; CTRL is for dimming signal input. SW is the output of internal MOSFET.

The CAT4201 driver is strongly recommended for its compact circuitry and high efficiency making it ideally suited for the replacement of filament-based bulb, in applications such as spot light.

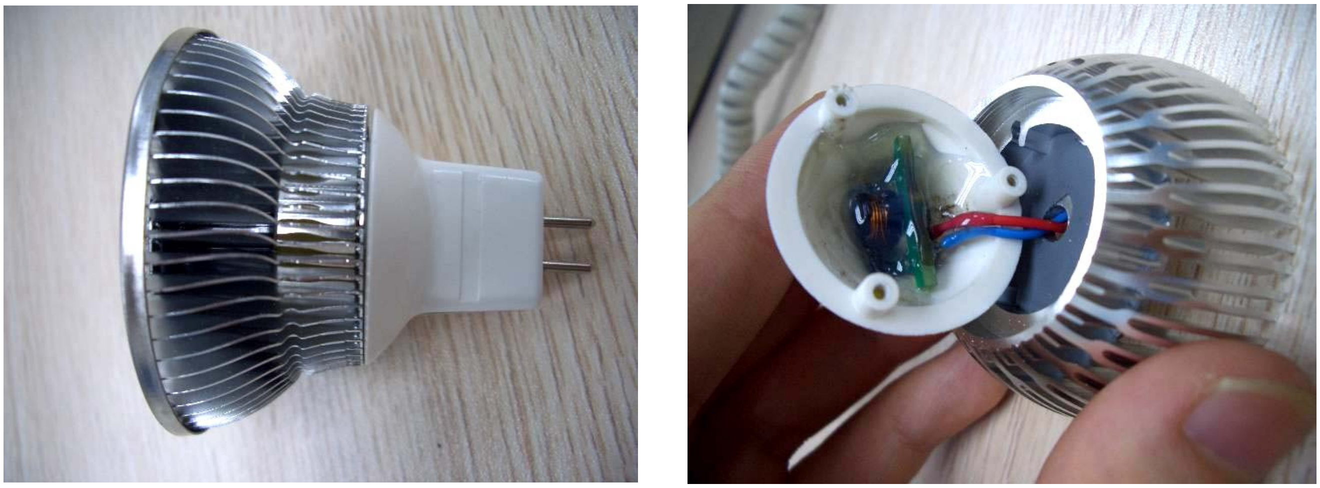


**Figure 2. MR-16 LED Cases. Miniature LED Driver Board can be Embedded into the Base**

### Theory of Operation

The application circuit is a simple buck converter. In the case of AC applications, the input is rectified through a bridge rectifier. VBAT and GND are directly connected to the two terminals of the bulk capacitor C1 which reduces the current ripple. During the first switching phase, the internal MOSFET will charge the inductor with linearly rising current until the switching-off of MOSFET; during the second phase, the MOSFET is cut off, and the current stored in the inductor will discharge through the Schottky diode (D5), and the current decays till next period of switching. The output capacitor is used to reduce the current ripple in the LED. RSET is voltage regulated at 1.2 V, thus resistor connected to RSET determines the RSET current. The RSET current is approximately proportional to the output constant current of CAT4201.

### Circuit Configuration

VBAT has a voltage rating of −0.3 to +40 V, therefore an input voltage up to 24 Vac at the bridge is safe. A large C1 is necessary to keep a higher level of input voltage. Large fluctuation of rectified AC current will pull the output current to zero at double line frequency, thus reducing the output current. 220 μF is adequate in this design. Voltage rating of C1 should be 25 V for 12 Vac input. MBR0520L was selected for the bridge rectifier because of its low forward voltage.

It is recommended to use at least 4.7 μF for C2 as output capacitor to reduce output ripple. Larger C2 will effectively suppress the output ripple, and raise the output current by several milliampers. However since its contribution to total efficiency is insignificant and that human eye cannot sense high frequency fluctuation, capacitance larger than 10 μF is not necessary. The value of L is recommended to be 22 μH in order to set a proper switching frequency about 150 kHz. The LED current range is 0~350 mA, so the rms current rating of inductor around 800 mA is adequate.

The total continuous current though the rectifiers are always below 400 mA even though 350 mA output current is supplied. Therefore a 0.5 A continuous current rating is enough for rectifiers. Careful observation of voltage across the freewheeling D5 diode shows that voltage spikes over 20 V can be found even with 12 Vac input. A higher input voltage (such as 15 V) further stresses the diode, increasing the risk of failure. So the voltage rating on D5 should be 30 V or 40 V. ON Semiconductor’s Schottky rectifier MBR0540 was selected for D5.

RSET pin configures the value of the output current. RSET voltage is regulated at 1.2 V. Adding a resistor between RSET and GND determines the RSET current, which has an approximately linear relationship with output constant voltage:

$$I_{LED} = 2500 \cdot I_{RSET} \qquad \text{(eq. 1)}$$

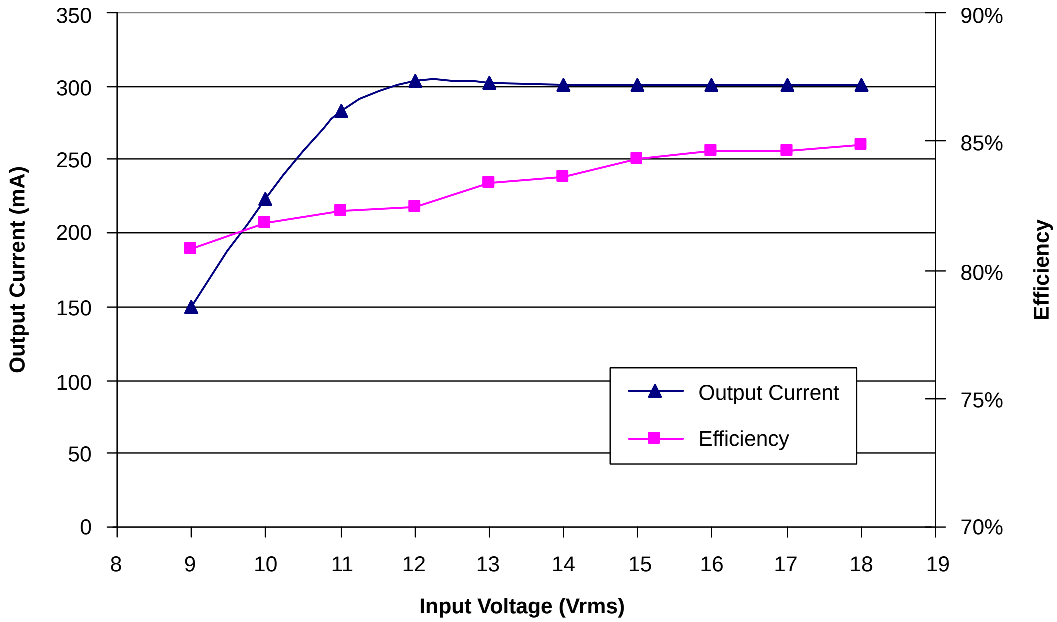
It can be calculated that for 300 mA output, $I_{RSET}$ = 0.12 mA. The RSET resistor value should be 10 kΩ.

A smaller RSET resistance will possibly increase the output current, but it is recommended to use at least 8.0 kΩ for stable operation. If the input voltage is high enough (e.g. 15 Vac), one can set RSET to be 8.2k, which guarantees at least 350 mA output.

CTRL derives voltage from the cathode of LED through R2. Value of R2 is not critical.

### Performance and Characteristics

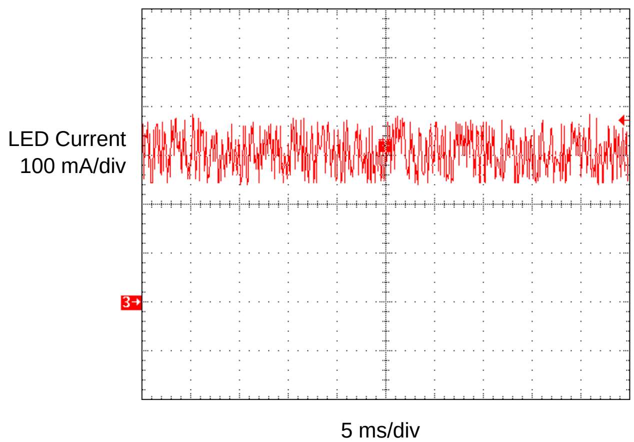
*1. Input Voltage − Output Current − Efficiency Relationship**

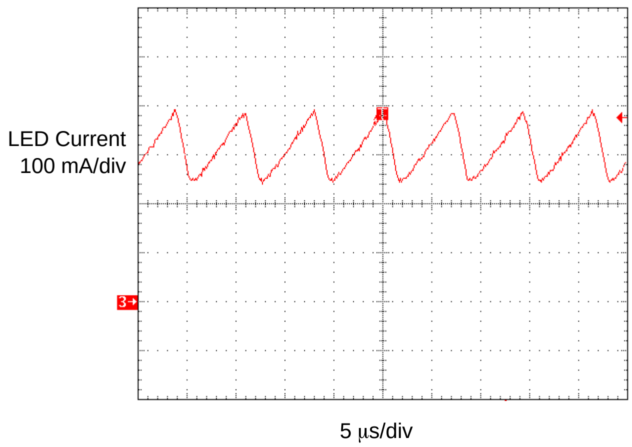



*Equipment: Global Specialties 1506 AC isolated variable AC line supply; Voltech PM1000 AC Power analyzer; Tektronix TDS754D digital phosphor oscilloscope; Tektronix TCP202 current probe; Agilent 34401A multimeter.

*2. LED Current Waveforms**

$V_{IN}$ = 12 Vac 50 Hz, circuit is configured according to the schematic in page 1 of this document.



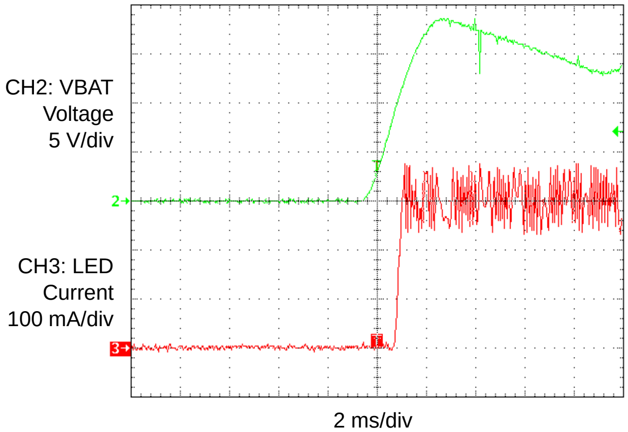



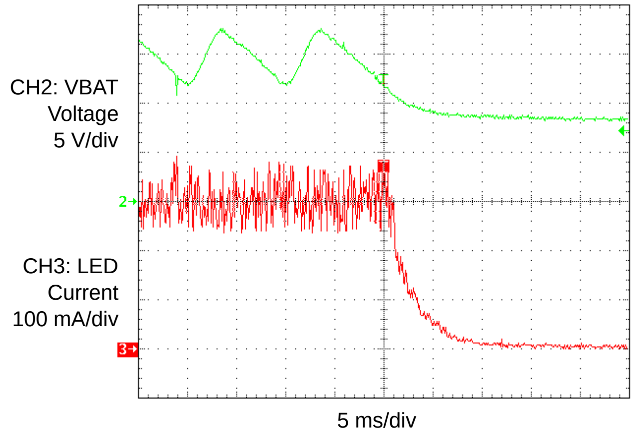

The LED current has got very slight low frequency (at twice the AC frequency, 2 × 50 Hz here) fluctuation due to the AC line input.

Using larger C1 or higher $V_{IN}$ will further flatten the AC related ripple current.

*3. Startup and Power Down Transient**

$V_{IN}$ = 12 Vac 50 Hz, circuit is configured according to the schematic in page 1 of this document.




*Equipment: Global Specialties 1506 AC isolated variable AC line supply; Voltech PM1000 AC Power analyzer; Tektronix TDS754D digital phosphor oscilloscope; Tektronix TCP202 current probe.

**Conclusion**

The information presented in this design note covers the various factors required about designing a three-LED MR−16 lamp using the CAT4201. The CAT4201 allows smaller footprint, fewer components for a MR−16 compatible adapter.

Reducing capacitor and inductor values, or removing the CTRL resistor is possible for further reduction of the cost and PCB size. Using a small bulk capacitor will lead to large drop of average output current, which is not recommended, but suitable for applications with less brightness (200~250 mA). Selecting high-quality LEDs with smaller forward voltage is very important in this design to achieve a higher output current.

**References**

[1] Data Sheet CAT4201: 350 mA High Efficiency Step Down LED Driver
[2] Data Sheet MBR0520L: 0.5 A, 20 V Schottky Rectifier
[3] Data Sheet MBR0540: 0.5 A, 40 V Schottky Rectifier

**Table 4. BILL OF MATERIALS**

| Part | Specifications and Ratings | Manufacturer |
|---|---|---|
| CAT4201TD | SOT−23, 40 V, 350 mA | ON Semiconductor |
| MBR0520L | 0.5 A, 20 V SMT Schottky Rectifier, $V_f$ = 0.38 V | ON Semiconductor |
| MBR0540 | 0.5 A, 40 V SMT Schottky Rectifier, $V_f$ = 0.51 V | ON Semiconductor |
| LEDs | CREE Xlamp 7090 XR−E, Cool White, Group Q5 | Cree |
| L1 | 22 μH, 0.9 A, 0.83 A (Isat.) Shielded 4 × 4 × 1.8 mm (LPS4018−223) | Coilcraft |
| C1 | 220 μF, 25 V | Panasonic |
| C2 | 4.7 μF, 25 V 1206 Ceramic | TDK |
| C3 | 10 μF, 16 V Ceramic | TDK |
| R1 | 10 kΩ 1/8 W SMT−0805, 1% | − |
| R2 | 1 kΩ 1/8 W SMT−0805, 5% | − |

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