

Introduction

The White Light-Emitting Diode (WLED) is becoming more and more popular for LCD back lighting in visual display electronics. Whether for lighting up LCDs in PDAs, cell phones or remote controls, the luminescence of the WLED makes the LCD displays bright and pleasant to the human eye. In order to make the WLEDs emit light, a forward voltage must be applied across the anode and the cathode of the WLEDs. The MIC2297 is an excellent WLED driver that can drive up to 10 WLEDs in series. In this applications note, how the MIC2297 is used to drive up to 60 WLEDs using a very simple current mirror technique is demonstrated (See Figure 1).

What is a White Light-Emitting Diode (WLED)?

The WLED is a type of semiconductor diode that emits light when a forward bias voltage is applied to the p-n junction that forms the diode. The positive (p+) of the LED is called the anode and the negative (n-) portion of the LED is called the cathode. Once a forward bias voltage is

applied, the LED will emit an electroluminescent light with a specific wavelength, depending upon what material was used to create it. The wavelength is what determines the color emitted by the diode. The WLED is a popular choice in electronic backlighting because it generates a colorless brightness that does not alter the original intended color from the LCD.

What is a WLED Driver?

It only takes around 3 volts to forward bias a WLED and to turn it on. To drive a series of 10 WLED, it would take 30V across all of them. A WLED driver, for example Micrel's MIC2297, is a boost regulator that can drive WLEDs in series. The boost regulator is a DC-to-DC converter that takes a low input voltage (2.5V to 10V) and converts it to a high output voltage (up to 40V). This high output voltage is then applied across a series of WLEDs. The MIC2297 can easily boost the output voltage to an appropriate level to forward bias all the WLEDs, as shown in Figure 2.

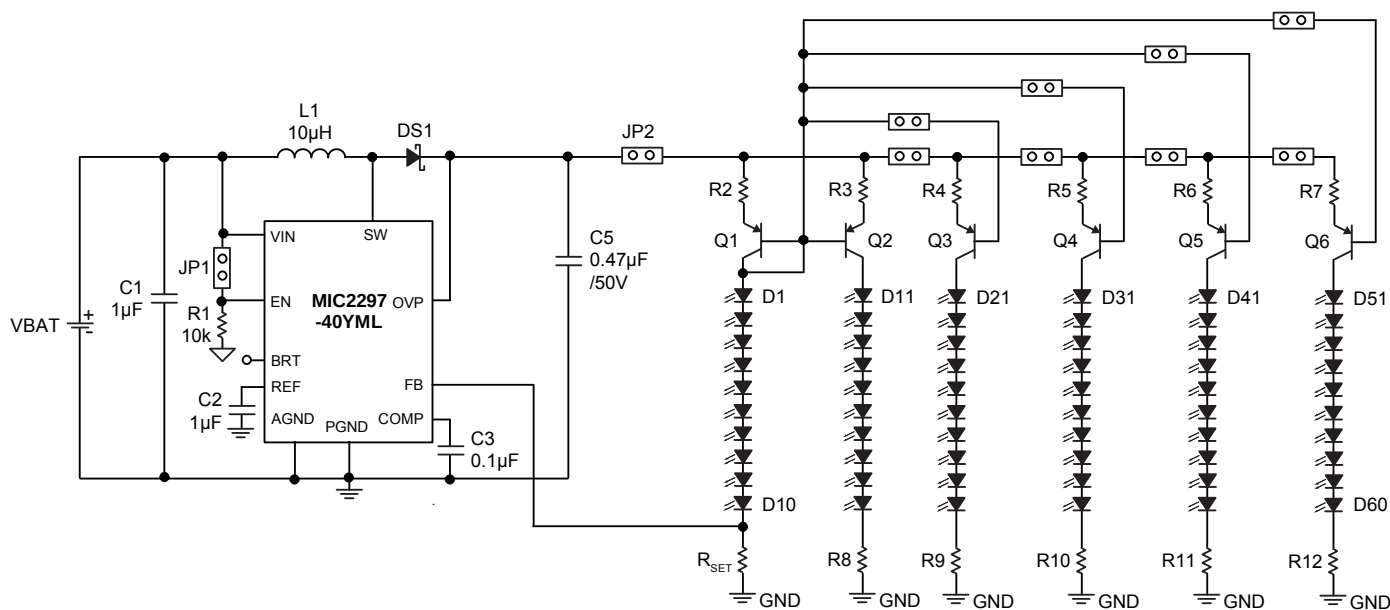


Figure 1. MIC2297 60WLED Driver Circuit

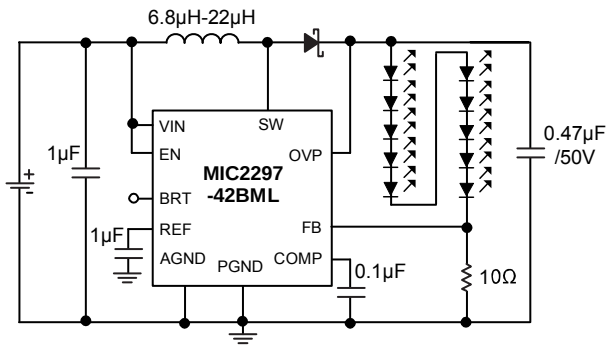


Figure 2. Typical MIC2297 10 WLED Driver Circuit

How does the MIC2297 WLED Driver work?

As long as a device can forward bias a WLED, it will light up. There are many methods of driving WLEDs, either in parallel or in series. The MIC2297 is a boost regulator designed to drive a string WLEDs in series. It has a switch current limit of 1.2A. The total input power of a boost regulator can be calculated by:

$$P_{IN} = V_{IN} * I_{LIMIT} \quad (1)$$

Where P_{IN} is the total input power, V_{IN} is the input voltage and I_{LIMIT} is the switch current limit. Due to losses in power conversion, the maximum output power the MIC2297 can deliver is around 80% of the total input power (this is an estimate). The total output power required by a WLED application will depend upon the output voltage and the WLED current and can be calculated by:

$$P_{OUT} = V_{OUT} * I_{LED} \quad (2)$$

Where P_{OUT} is the amount of power required by the application, V_{OUT} is the output voltage needed to forward bias the WLEDs and I_{LED} is the current through the WLEDs.

A typical application with 10 WLED ($V_{OUT} = 30V$) with a WLED current of 20mA will only require 0.6W of output power. Using equation (1), if the input voltage is 3.6V, the MIC2297 will have a total input power of around 4.3W. Assuming 80% efficiency, it can easily handle the 0.6W requirement of a 10 WLED application.

Is there Dimming Control?

The MIC2297 can be dimmed using two methods. DCV control and PWM control. See the DCV and PWM Brightness Control subsection for detailed information.

DCV Brightness Control

The brightness level can be set by applying a DC voltage (BRT) to the BRT pin. When a DC voltage is applied to the BRT pin, the feedback voltage is changed from the default value of 200mV to:

$$V_{FB} = BRT / 5 \quad (3)$$

Assuming BRT equals 1V, then V_{FB} will be 200mV and I_{LED} may be calculated by:

$$I_{LED} = V_{FB} / R_{SET}$$

$$I_{LED} = 200mV / 10\Omega$$

$$I_{LED} = 20mA$$

Similarly, if BRT equals 2V, then V_{FB} will be 400mV and the I_{LED} may be calculated by:

$$I_{LED} = V_{FB} / R_{SET}$$

$$I_{LED} = 400mV / 10\Omega$$

$$I_{LED} = 40mA$$

The feedback voltage can be changed using the BRT pin. Changing the feedback voltage changes the WLED current, which will change the WLED brightness. If the BRT pin is open, then the default V_{FB} will be 200mV.

PWM Brightness Control

The brightness level can also be set by applying a PWM signal to the BRT pin. To calculate the feedback voltage when a PWM signal is applied to the BRT pin, use the following formula:

$$V_{FB} = V_{PEAK} / 5 * D \quad (4)$$

V_{PEAK} is the peak of the PWM voltage and D is the duty cycle. If V_{PEAK} is 1V and the duty cycle is 1%, then V_{FB} can be calculated by:

$$V_{FB} = 1V / 5 * 0.01$$

$$V_{FB} = 2mV$$

The I_{LED} can then be calculated by:

$$I_{LED} = V_{FB} / R_3$$

$$I_{LED} = 2mV / 10\Omega$$

$$I_{LED} = 200\mu A$$

Similarly, if the V_{PEAK} is 1V and the duty cycle is 50%, then V_{FB} can be calculated by:

$$V_{FB} = 1V / 5 * 0.5$$

$$V_{FB} = 100mV$$

The I_{LED} can then be calculated by:

$$I_{LED} = V_{FB} / R_3$$

$$I_{LED} = 100mV / 10\Omega$$

$$I_{LED} = 10mA$$

With PWM brightness control, the MIC2297 has great versatility since brightness may be set anywhere from 0 to 100 percent.

Can more WLEDs be driven?

Since the MIC2297 can handle much more power than a meager 0.6W 10 WLED application, it should be able to drive more WLEDs. If one placed more WLEDs in series

with the string of 10 WLEDs, then the output voltage would become higher and higher. Micrel's MIC2297 can boost up to a maximum of 40V. This means one can only add about three more WLEDs in series for a total of only 13 WLEDs. Fortunately, more WLEDs can be driven in parallel! A simple current mirror circuit can copy a current string, shown in Figure 3.

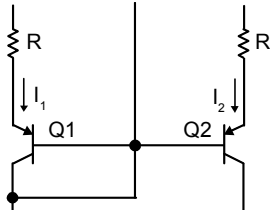


Figure 3. Simple Current Mirror

Assuming both transistors Q1 and Q2 match, the currents (I_1) and (I_2) will be equal. By copying the WLED current from the original WLED current, the amount of WLEDs driven can be doubled, tripled, and so on. The amount of output power will of course increase respectively. Since the MIC2297 can handle much more power, the current mirror can be modified to host additional strings (I_3 , I_4 , I_5 , I_6). This technique can be shown in Figure 1.

How can the MIC2297 drive 60 WLED?

The MIC2297 WLED driver will boost the input voltage from a low voltage to a higher output voltage. The high output voltage is needed to forward bias the WLED strings. Since there are 10 WLEDs in each string, the MIC2297 will boost the output voltage to around 30V. This 30V output voltage will be applied across all 6 strings of WLEDs and turn the WLEDs on. The current mirror will duplicate the WLED current across all 6 strings of WLEDs to maintain the same brightness across all WLEDs. Since there are 6 strings of WLEDs, the WLED current will be 6 times as much ($6 \times 20\text{mA} = 120\text{mA}$). The new output power requirement can be calculated using equation (2):

$$\begin{aligned} P_{\text{OUT}} &= V_{\text{OUT}} * 6 * I_{\text{LED}} \\ P_{\text{OUT}} &= 30\text{V} * 6 * 20\text{mA} \\ P_{\text{OUT}} &= 3.6\text{W} \end{aligned}$$

If one assumes 80% efficiency conversion from input to output by the MIC2297, then the input power can be calculated by the output power divided by the efficiency:

$$\begin{aligned} P_{\text{OUT}} / 80\% \\ P_{\text{IN}} &= 4.5\text{W} \end{aligned}$$

In order to support a demand of 3.6W from the output, the supply must be greater than 4.5W. With input voltage ranging from 2.5V to 10V and a current limit of 1.2A, the MIC2297 can handle a 3.6W demand on the output as long as the input voltage is greater than 4V (assuming 80% efficiency).

How well do the WLED currents match?

The maximum mismatch of the WLED current is $\pm 4.5\%$. The mismatch in WLED can be caused by multiple factors in the circuit. The brightness of the WLEDs depends upon the current through them. The WLED current (I_{LED}) is set by the feedback voltage ($V_{\text{FB}} = 200\text{mV}$) of the MIC2297 divided by the set resistor R_{SET} .

$$I_{\text{LED}} = V_{\text{FB}} / R_{\text{SET}}$$

If a 10Ω resistor is used for R_{SET} , then the I_{LED} will be 20mA. Assuming we use the same resistance for all 6 strings of WLEDs, then the WLED current for all the WLEDs will be 20mA. Since there are differences between the WLED's forward voltage, the WLEDs will not all be exactly the same brightness. A typical WLED, such as the ones used in this circuit, has a $\pm 3\%$ mismatch on the forward voltage. Since the anode of each string is maintained relatively constant by the MIC2297 boost regulator, this will cause the voltage at the cathode of each string to be different by around 3%. This creates a mismatch in the WLED current. Another factor that could cause mismatch in the WLEDs is the mismatch of the R_{SET} resistors. In this 60 WLED circuit, 1% resistors are used, so the WLED current can be off by an additional 1% due to variation in the R_{SET} resistor. The mismatch in the current mirror transistors (Q1, Q2, etc.) will also cause the current to be different from string to string, so over-all the mismatch can add up to $\pm 4.5\%$. A difference of $\pm 4.5\%$ in WLED current mismatch is hard to detect by human eyes, and when the WLEDs are placed behind filter screens to brighten an LCD display, it is difficult for the user to notice the difference in brightness around the screen caused by the mismatch between WLED strings. That is why when the software programs change the brightness on an LCD screen, the brightness change is substantially lower or higher so that the end user can see the difference between each step.

MIC2297 WLED Efficiency

Figure 4 shows the efficiency for driving different number of WLEDs using MIC2297 at various input voltage levels.

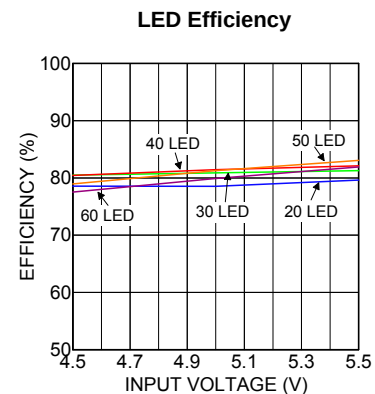
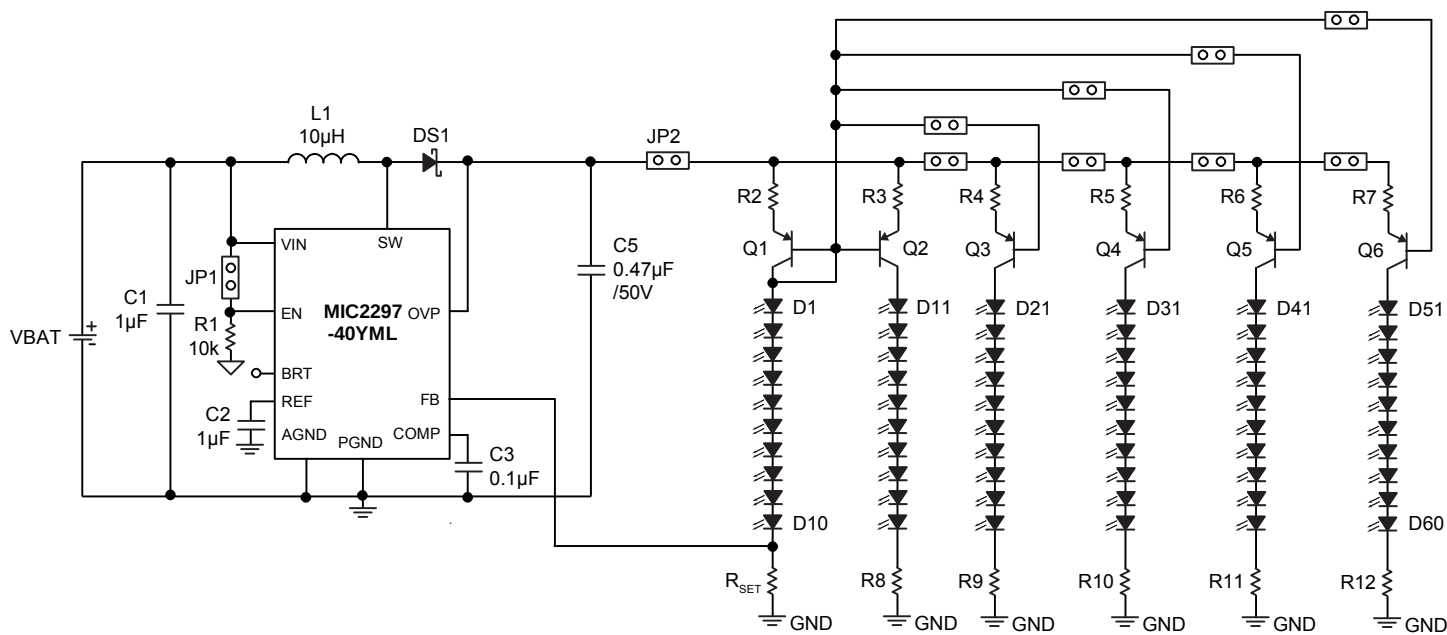


Figure 4. Efficiency Curve



MIC2297 60 WLED Driver Circuit

Bill of Materials

Item	Part Number	Manufacturer	Description	Qty
C1, C2	C1608X5R1A105K	TDK ⁽¹⁾	1µF Ceramic Capacitor, 10V, X5R, Size 0603	2
C3	VJ0603Y104KXXAT	Vishay ⁽²⁾	0.1µF Ceramic Capacitor, 25V, X7R, Size 0603	1
C5	C2012X7R1H474M	TDK ⁽¹⁾	0.47µF Ceramic Capacitor, 50V, X7R, Size 0805	1
DS1	DFLS160-7	Diodes Inc ⁽³⁾	1A, 60V, Schottky Diode	1
L1	LTF5022T-100M1R4	TDK ⁽¹⁾	10µH, 1.4A I _{SAT.} , 160mΩ, (L5.2mm × 5.0mm × 2.2mm)	1
R1	CRCW06031002FRT1	Vishay ⁽²⁾	10KΩ, 1%, 1/16W, Size 0603	1
R2 – R7	CRCW060310R0FRT1	Vishay ⁽²⁾	10Ω, 1%, 1/16W, Size 0603	6
R _{SET}	CRCW060310R0FRT1	Vishay ⁽²⁾	10Ω, 1%, 1/16W, Size 0603	1
R8-R12	CRCW06030R0FRT1	Vishay ⁽²⁾	0Ω, 1%, 1/16W, Size 0603	5
Q1-Q6	MMBT3906FSCT-ND	Fairchild ⁽⁴⁾	2N3906, SOT-23 BJT (PNP)	6
D1-D60	SWTS907-Z1J1e	Seoul Semi ⁽⁵⁾	I _F (20mA), V _F (3V – 3.1V) WLED	60
U1	MIC2297-42YML	Micrel ⁽⁶⁾	600kHz 40V PWM White LED Driver	1

Notes

1. TDK: www.tdk.com
2. Vishay-Dale: www.vishay.com
3. Diodes Inc: www.diodes.com
4. Fairchild Semiconductor: www.fairchildsemi.com
5. Seoul Semiconductor: www.seousemicon.com
6. Micrel, Inc: www.micrel.com

MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA
TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB <http://www.micrel.com>

The information furnished by Micrel in this data sheet is believed to be accurate and reliable. However, no responsibility is assumed by Micrel for its use. Micrel reserves the right to change circuitry and specifications at any time without notification to the customer.

Micrel Products are not designed or authorized for use as components in life support appliances, devices or systems where malfunction of a product can reasonably be expected to result in personal injury. Life support devices or systems are devices or systems that (a) are intended for surgical implant into the body or (b) support or sustain life, and whose failure to perform can be reasonably expected to result in a significant injury to the user. A Purchaser's use or sale of Micrel Products for use in life support appliances, devices or systems is a Purchaser's own risk and Purchaser agrees to fully indemnify Micrel for any damages resulting from such use or sale.

© 2008 Micrel, Incorporated.