



**APPLICATION IDEAS: DRIVING LEDS USING L497X, L597X,
L692X DC-DC CONVERTERS FAMILIES**

This application note, describes the main applications and driving methods for LEDs. After this, several application ideas using ST DC-DC converters are shown.

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2 INTRODUCTION

LED (Light Emitting Diode) is a Light Emitted p-n junction Diode, under forward bias. If a forward bias is applied between the p-n layers, electrons and holes are meeting in the active layer, and recombine themselves, emitting photons. If a reverse bias is applied, they don't move in the active layer, and consequentially, no light is emitted. LEDs generate practically a monochromatic light, with a focused beam of a single wavelength. Therefore, there is not wasted energy, and no filters are required to obtain different colors. The emitted radiation wavelength depends on the dopants. Due to their construction technology, LEDs are not subjected to shock, vibrations and heat, and this makes their life very long, measured in order of years (Typically 100.000 hours with an operating temperature comprised between -40°C and +85°C). Thanks to all these characteristics, LEDs are widely used in particular color-specific, power-crucial and high reliability application:

- Mobile appliances
 - Mobile phone screen and keyboard backlight
 - PDAs, MP3 players and digital camera backlight
- Signs and displays
 - Advertising signs
 - Traffic variable messages signs
- Automotive applications
 - Interior application: lights for instrumental panel and dashboard
 - Exterior lighting stop/turn/tail lights
- Signals
 - Traffic signals
 - Arrows and pedestrian signals
- Illumination
 - Flashlights
 - Architectural and design lighting
 - Emergency lighting
 - Water features and pools

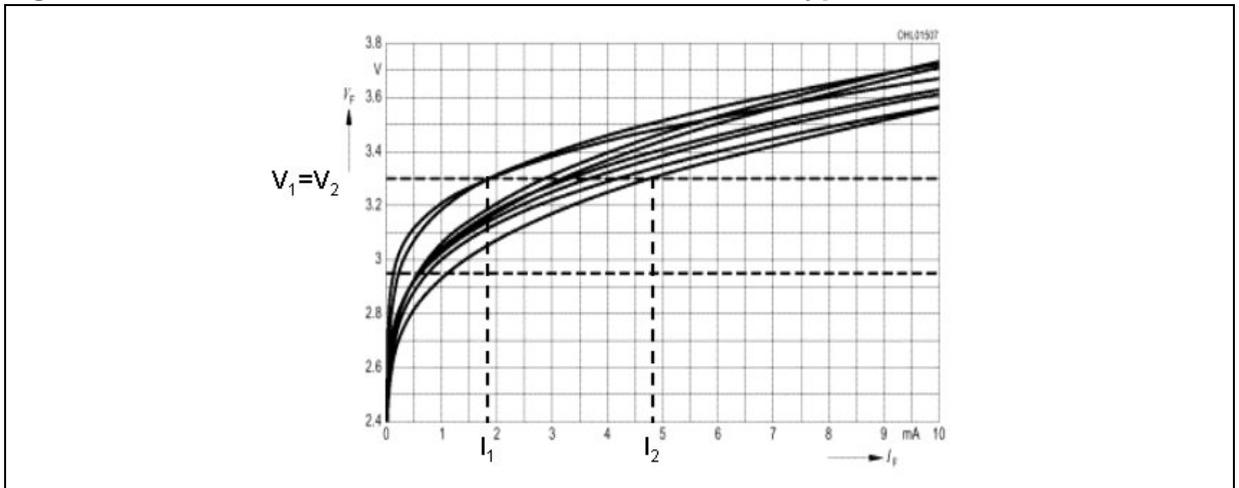
3 DRIVING LEADS

LEDs are devices where the light intensity (brightness), measured in millicandelas, or in Lumens, is proportional to the forward current flowing through them. There are two main categories of LEDs: the white-blue LEDs, with a typical voltage drop of 3-4V, and the green-red-yellow ones, with a typical voltage drop, which is about 2V. It is possible to make another distinction based on the forward current:

- Low current LEDs, from 15mA to 50mA, mainly used in the portable market for backlight and signaling applications.
- High current LEDs, with forward current between 350mA to 1000mA, typically used in lighting applications.

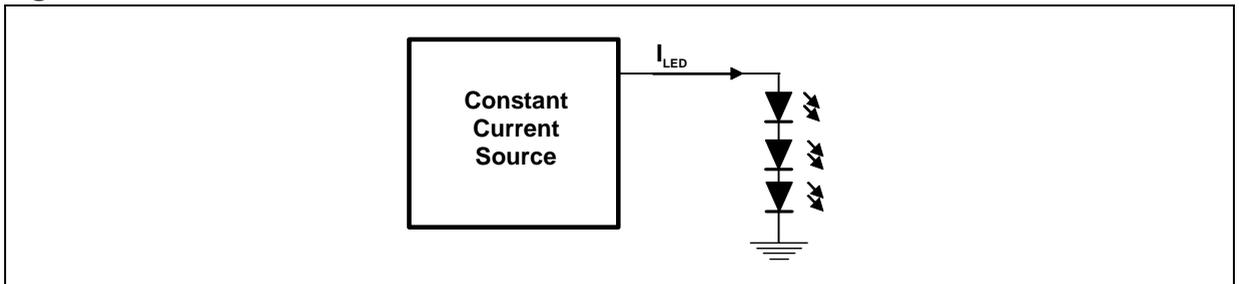
Moreover, applying the same forward voltage to different LEDs of the same type, the current flowing through them can change significantly. This can be seen in Figure 1, showing the V-I characteristic of different LEDs of the same type.

Figure 1. V-I characteristic of 8 white LEDs of the same type



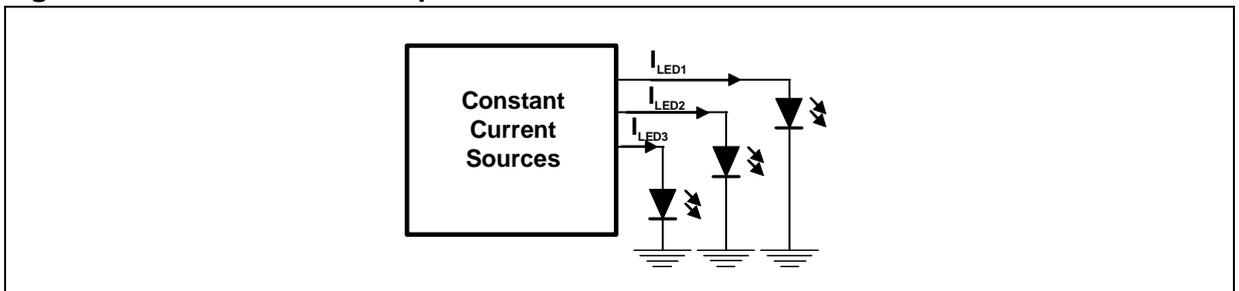
This is why, in order to have a brightness matching between different LEDs, they must be driven by matched constant current sources. Based on these considerations, it is clear that, in principle, the easiest and cheapest way to drive LEDs is to connect them in series as shown in Figure 2. However, this implies that the LED driver must provide an output voltage that is the sum of the LEDs forward voltage.

Figure 2. Basic schematic of series driven LEDs



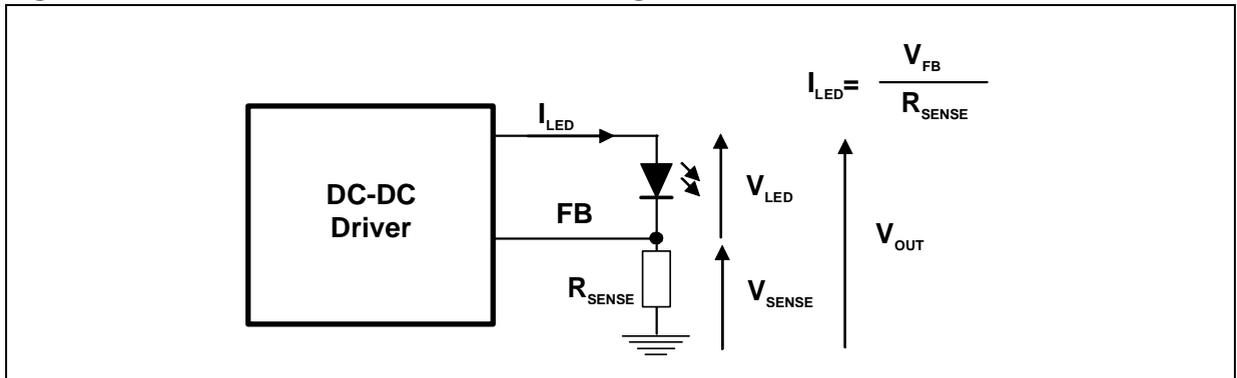
So, in other cases, the preferred solution is to drive LEDs in parallel, matching the different current sources, as shown in Figure 3.

Figure 3. Basic schematic of parallel driven LEDs



A typical way to realize a constant current source to drive LEDs is to use a DC-DC converter, as shown in Figure 4. Since the voltage control loop of the device regulates the voltage at the FB pin, a constant current source can be obtained simply connecting a resistor between this pin and GND.

Figure 4. Basic schematic of a DC-DC driving LEDs



The efficiency of the system is given by the general formula:

$$\text{Eff} = \frac{P_{\text{out}}}{P_{\text{in}}} \quad \text{Eq 1}$$

In case of LEDs, the useful power (that is P_{OUT}), is the LEDs power, given by:

$$P_{\text{LED}} = \sum_{i=1}^n V_{\text{LED}i} \cdot I_{\text{LED}i} \quad \text{Eq 2}$$

So, the efficiency of the system is:

$$\text{Eff} = \frac{P_{\text{LED}}}{P_{\text{IN}}} \quad \text{Eq 3}$$

The power dissipated on the R_{SENSE} resistor is obviously not contributing to the output power and so it should be minimized. This implies that the FB pin voltage should be as low as possible.

4 APPLICATION IDEAS

The best device for a particular application can be selected based on its input voltage range, output current capability, output voltage range, as in standard DC-DC choice. However, some particularity of the application emphasizes the importance of other parameters. For example, a very low FB voltage, in order to minimize the power dissipation by the sense resistor, is very important. Beside this, the possibility to change the voltage across the sense resistor, in order to easily adjust the LEDs brightness, is often required. The following paragraphs show some LEDs driving solutions, distinguishing two main application classes:

- DC bus supplied applications
- Battery powered applications

4.1 DC BUS SUPPLY

Most of automotive and lighting applications belong to this category. The most common input voltages are 12V, 18V, 24V and 48V. For these applications L497xD, L597xD and the L6902D families of step-down monolithic DC-DC converters are suggested. Table 1, summarizes the devices characteristics (devices are grouped by family and sorted by output current):

Table 1. DC-DC converters with DC bus supply

Device	I _{out} (A)	V _{out} (V)	V _{in} (V)	F _{sw} (KHz)	Additional Features	Packages
L4976D	1	0.5 to 50	8 to 55	Up to 300	5.1V V _{ref}	Minidip/SO16W
L4971D	1.5	3.3 to 50	8 to 55	Up to 300		Minidip/SO16W
L4978D	2	3.3 to 50	8 to 55	Up to 300		Minidip/SO16W
L4973Dx3.3	3.5	0.5 to 50	8 to 55	Up to 300	5.1V V _{ref}	DIP18/SO20
L4973Dx5.1	3.5	5.1 to 50	8 to 55	Up to 300		DIP18/SO20
L6902D	1	0.5 to 35	8 to 36	250	Constant current control, 3.3V V _{ref}	SO8
L5970D	1	0.5 to 35	4.4 to 36	250	3.3V V _{ref}	SO8
L5972D	1.5	1.23 to 35	4.4 to 36	250		SO8
L5973AD	1.5	0.5 to 35	4.4 to 36	500	3.3V V _{ref}	HSOP8
L5973D	2	0.5 to 35	4.4 to 36	250	3.3V V _{ref}	HSOP8

4.1.1 L5970D APPLICATION IDEA

The L5970D is a monolithic step-down power switching regulator, capable to deliver up to 1A of continuous output current. The input voltage range is comprised between 4.4V to 36V. The feedback voltage is 1.23V, but with a resistor divider connected with the internal reference of 3.3V, is possible to reduce the sense resistor voltage. This helps in order to reduce the wasted power and to adjust the LEDs brightness.

Figure 5. L5970D driving up to 6 high current white LEDs

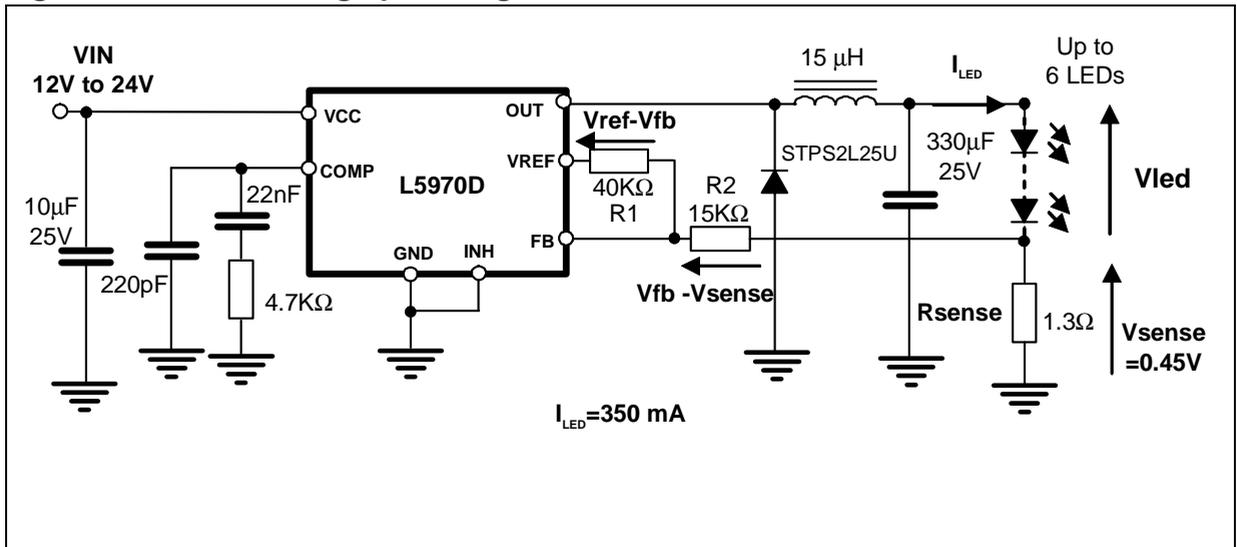


Figure 5 shows how to drive 6 LEDs in series.

The V_{SENSE} is reduced down to 0.45V, in order to minimize the wasted power. The formula used to reduce it is:

$$V_{SENSE} = V_{FB} - \left\{ \left[\frac{(V_{REF} - V_{FB})}{R_1} \right] \cdot R_2 \right\} \quad \text{Eq 4}$$

The table below shows the efficiency of the application.

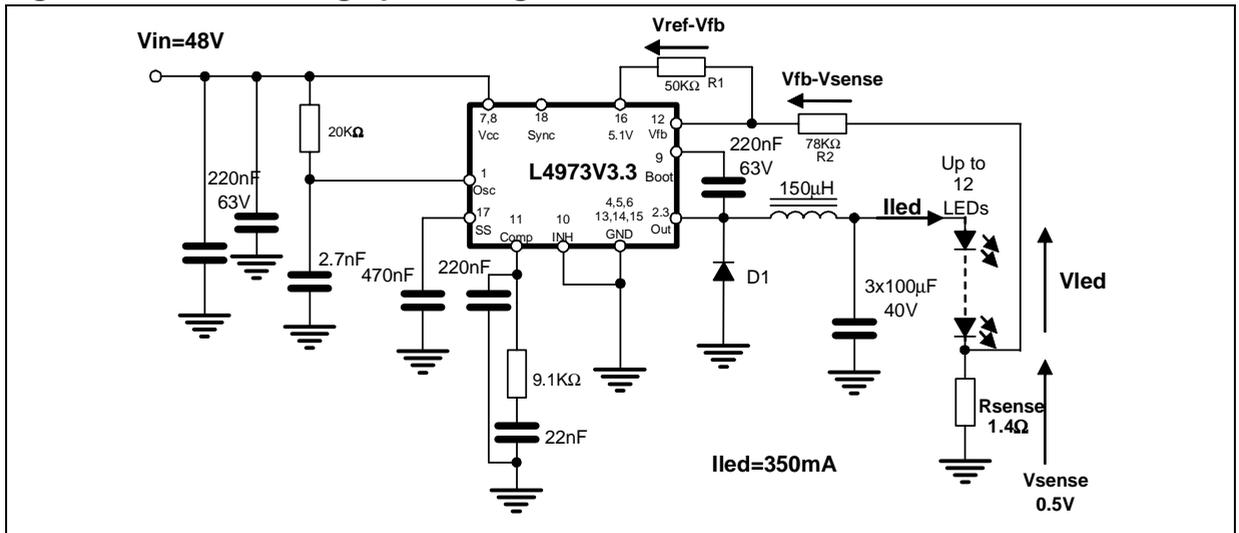
Table 2. Efficiency results of the L5970D driving series LEDs

Efficiency	1 LED	2 LEDs	3 LEDs	4 LEDs	5LEDs	6LEDs
Vin=12V						
Iout=350mA	76%	89%	93.5%			
Vin=18V						
Iout=350mA		83.5%	90%	95%	90%	
Vin=24V						
Iout=350mA			86.5%	90%	94.5%	97.5%

4.1.2 L4973D APPLICATION IDEA

This application is really closed to the previous one. The substantial different is in the input voltage, up to 55V. The device can deliver up to 3.5A of continuous output current. Thus, it is possible to drive more white LEDs connected in series. Figure 6 shown the schematic circuit of L4973D supplied with a 48V bus. It is driving up to 12 high current white LEDs. Even in this case, the voltage drop across the sense resistor is minimized for efficiency reasons, by the same trick used for the L5970D.

Figure 6. L4973D driving up to 12 high current white LEDs



The efficiency of this application is given by the following table.

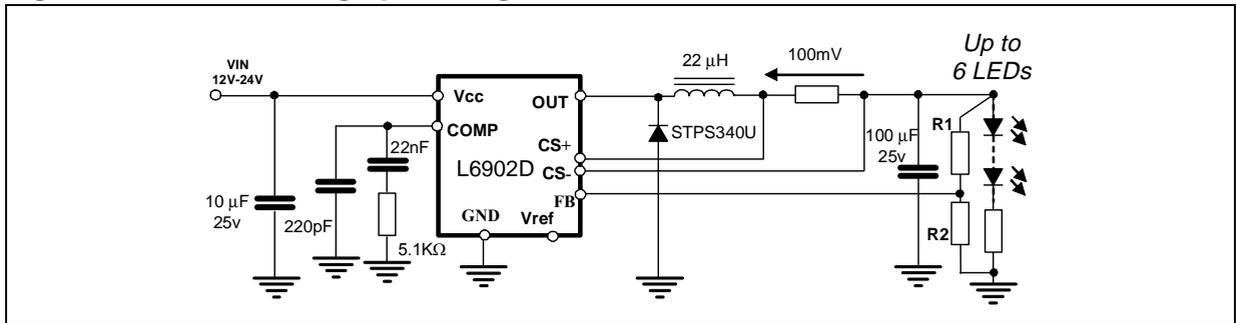
Table 3. Efficiency of L4973D driving up to 12 LEDs

Efficiency	8 LEDs	10 LEDs	12 LEDs
Vin=48V			
Iout=350mA	95%	96%	98%

4.1.3 L6902D APPLICATION IDEA

The L6902D is a simple and complete step down switching regulator, with adjustable current limit. This device is a good solution for LEDs lighting applications, thanks to its inner current loop that allows regulating a constant current at the output with a minimum voltage drop across the external sense resistor (100mV). Figure 7 shows a schematic application of L6902D, driving up to 6 high current white LEDs. The device works in current limit mode, set to 350mA; each LED current is 350mA. The losses on RSENSE are only 70mW.

Figure 7. L6902D driving up to 6 high current white LEDs



The additional benefit of this device is that its voltage loop can be used to perform an over voltage protection as indicated in figure 7.

The table 4 indicates the efficiency values of this application.

Table 4. Efficiency of L6902D driving up to 6 LEDs

Efficiency	1 LED	2 LEDs	3 LEDS	4 LEDs	5LEDS	6LEDs
Vin=12V						
Iout=350mA	75%	89%				
Vin=18V						
Iout=350mA		86%	89%	96.5%		
Vin=24V						
Iout=350mA		84%	88%	90%	94%	97.5%

4.2 BATTERY POWERED APPLICATION

Battery powered applications are characterized by lower input voltages compared to the applications shown in the previous pages. In these applications, the input voltage changes with the battery discharge profile. The battery types for this kind of applications are:

- Li-Ion cell, with the voltage range comprised between 4.2V and 2.7V or less;
- Ni-MH cell, with the voltage range between 1.5V to 0.9V.

As a consequence, the Buck topology is not the commonest one. Boost or Buck-Boost topologies are often required. We will focus our application examples on L692xD family, including a step-up converter (L6920D) and step-down converters (L6925D-L6926D) that can be used in both Boost and in Buck-Boost topology. Some application ideas are show below, in order to explain how to use these devices in LEDs applications, using external references and dimming.

Table 5. DC-DC converters for battery powered applications

Device	Iout (A)	Vout (V)	Vin (V)	Fsw (KHz)	Vfb (V)	Additional Features	Packages
L6920D	1	2 to 5.2	0.6 to 5.5	Not fixed	1.23		TSSOP8
L6925D	0.8	0.6 to Vin	2.7 to 5.5	Up to1400	0.6		MSOP8
L6926D	0.8	0.6 to Vin	2 to 5.5	Up to 1400	0.6		MSOP8

4.2.1 L6920D APPLICATION IDEA

The L6920D is a high efficiency Step-up converter. The start up is guaranteed at 1V, but the operating input voltage can goes down to 0.6V. With a maximum voltage of 5.5V the device

can be supplied with many battery types: from 1 Li-Ion cell, or 1 to 3 Ni-MH-Alkaline cells. In figure 8 is shown the typical application schematic of the device. The voltage Feedback is 1.23V. With the resistor divider, connected to the external reference, it is possible to reduce the sense voltage down to 0.4V, or less, in order to maximize the efficiency. In table 6 are reported the efficiency result of this application.

Figure 8. L6920D with external reference

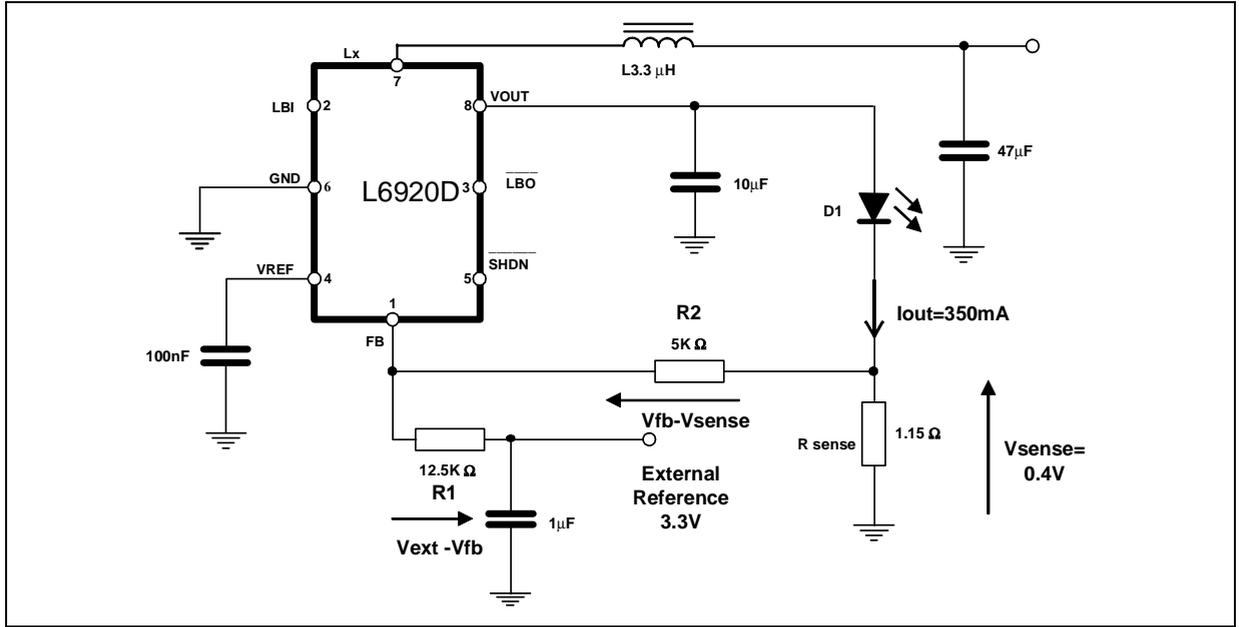


Table 6. Efficiency of L6920D driving a 350mA LED

Vin (V)	2	2.5	3	3.5	3.7
Eff (%)	88	88	90	86	84

4.2.2 L6926D BOOST TOPOLOGY APPLICATION IDEA

The L6926D is a high efficiency monolithic synchronous Step-down regulator, with an operating input voltage range comprised between 2V to 5.5V. The feedback voltage is equal to 0.6V; this allows low losses on the sense resistor. The device can be used in different topologies. In particular when the input voltage is lower than the typical LED voltage drop, a Boost topology can be implemented, as shown in Figure 9. This topology is possible only because the supply is a battery, not referred to Ground. As typical in Boost topology, this configuration doesn't have an effective short circuit protection. A battery discharge can be generated, when the device is turned off. The brightness control can be done by using a PWM signal. Varying the duty cycle of the signal is possible to change the medium current value, in order to adjust the brightness. In this case, the maximum intensity is achieved when the duty cycle of the PWM signal is equal to 0%. The minimum intensity is when the duty cycle reaches the 100%.

Figure 9. L6926D in boost topology with digital adjustable brightness control

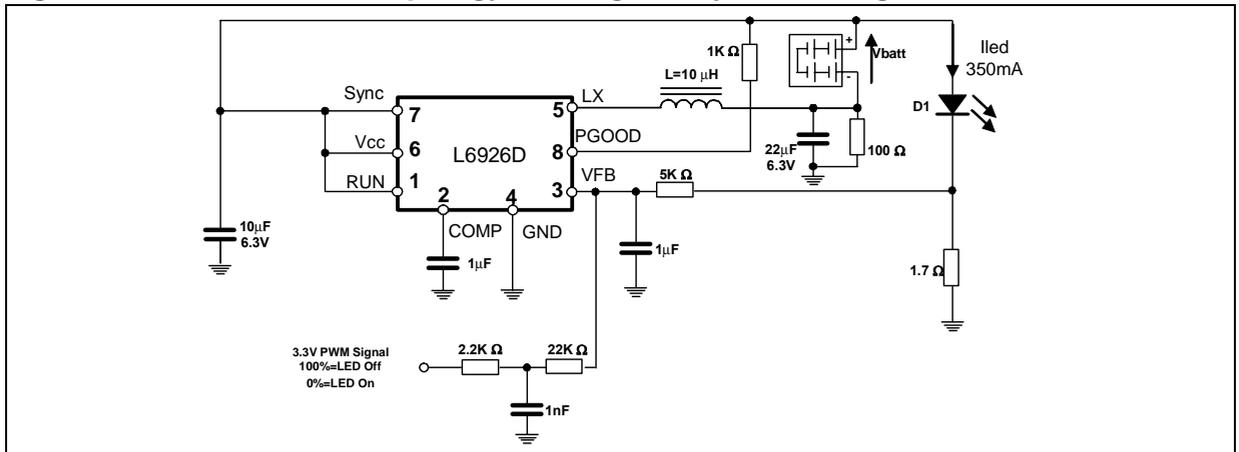


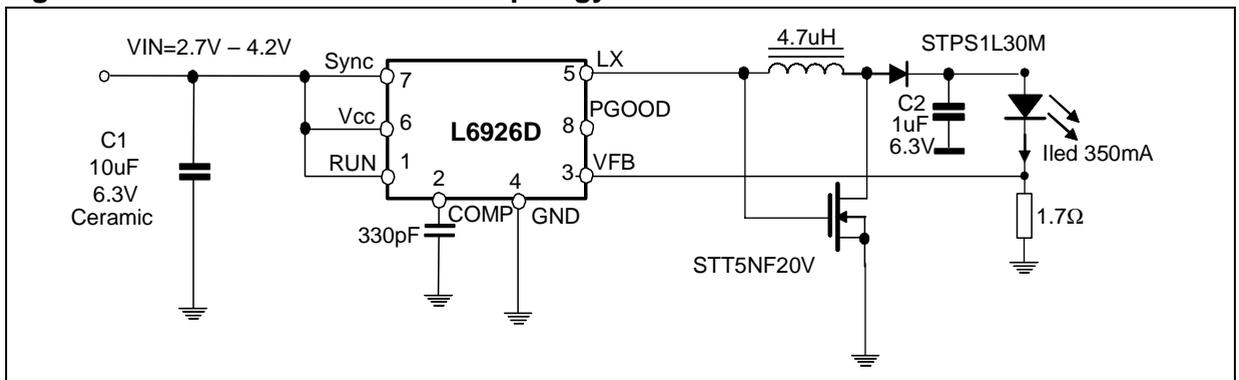
Table 7. L6926D in boost topology with digital adjustable brightness control

Vin (V)	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4
Eff (%)	76	79	80	82	83	85	86	86	87	88	89	89	90	91

4.2.3 L6926D BUCK-BOOST TOPOLOGY APPLICATION IDEA

If a single Li-Ion cell is used to supply the device, the Buck-Boost topology is usually required. In fact, the voltage drop across a white LED is comparable with the Li-Ion cell voltage. The advantage of this application is that the input voltage range can be higher or lower than the output ones and so the battery can be used over the full load range. Moreover, when the device is turned off, there isn't current flowing from the input to the output. An actual shutdown and short circuit protection are allowed. The typical application schematic is shown in figure 10.

Figure 10. L6926D in Buck-Boost topology



The efficiency of this system is reported in the table below:

Table 8. Efficiency of L6926D driving a 350mA LED in Buck-Boost topology

Vin (V)	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
Eff (%)	58	59	60	61	61	62	62	63	63	64	64	64	64	65

4.2.4 L6926D BUCK TOPOLOGY APPLICATION IDEA

An USB port gives a voltage range between 4.75V to 5.25V, and provides a maximum current of 500mA. This is a good solution to drive a single high current white LED, in Buck topology. Infact, the USB voltage is always higher than the output voltage required driving the LED. The output voltage is given by the sum of the LED drop and the feedback voltage. The Figure 11 shows the application schematic while the Table 9 reports the efficiency results.

Figure 11. L6926D supplied by USB port

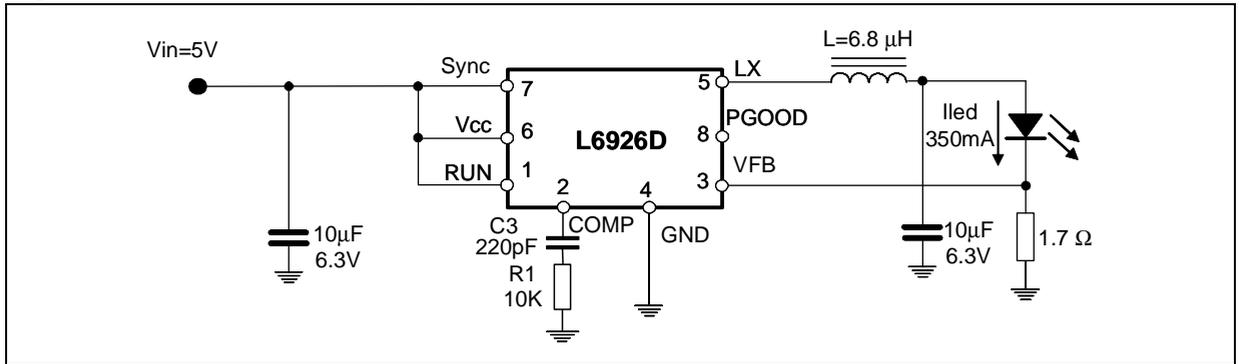


Table 9. Efficiency of L6926D driving a 350mA LED in Buck topology

Vin (V)	5	5.5	5.96
Eff (%)	85	84	84

All the battery powered application ideas shown in this paper, are performed with a white LED, which has a voltage drop of approximately 3.3V, and a forward current of 350mA.

5 CONCLUSION

The aim of this paper is to show how monolithic DC-DC converters can be used to drive LEDs. The right choice between all the ICs belonging to L497xD, L597xD and L692xD families depends on the final application requirements (power source, number of LEDs, additional functions etc...).

This paper shows only few application ideas about LEDs driving: it is possible to find much more details on the specific ICs in the dedicated Datasheet and Application Notes available on ST web site.

Table 10. Revision History

Date	Revision	Description of Changes
March 2004	1	First Issue
June 2004	2	Add. summary, changed any textes, changed style look.

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