BEND IT LIKE EL LAMP!

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Electroluminescent (EL) lamps serve in ways no other lamp can. These lamps provide optimum light while using a minimum of space, and can bend to conform to the product's shape and even operate while being flexed

Electroluminescent (EL) lamps are solid-state, low-power, uniform-area light sources. Because of their thickness as small as 3 mm (0.012 inch) and the fact that these can be built into almost any size and shape, EL lamps are an ideal way to provide backlighting for LCDs, membrane keypads, and a variety of other applications.

EL lamps convert electrical energy into light. These lamps offer significant advantages over point-light sources (such as LEDs and incandescent and fluorescent lighting systems) and, therefore, are widely used. More and more wireless phone and pager manufacturers are using EL lighting systems in keypads and displays. EL lamps are very competitively priced. Even in applications where space and power are not issues, EL lamps cost less than other types of light sources.

The structure

A typical EL lamp consists of light-emitting phosphors sandwiched between two conductive electrodes. One of the electrodes is transparent, allowing light to escape. When an AC voltage is applied to the electrodes, the electrical field causes the phosphors to rapidly charge and discharge, resulting in the emission of light during each cycle. Since the number of light pulses depends on the magnitude of the applied voltage, the brightness of EL lamps can generally be controlled by varying the operating voltage.

Most of us have heard of the light-emitting diode (LED). In a similar vein, an EL lamp is basically a light-emitting capacitor (LEC). Like any capacitor, the LEC is made of a dielectric material sandwiched between two parallel conductors. However, an EL lamp stands apart from a normal capacitor in two ways: First, the dielectric is a phosphor that emits light when energised with an alternating electric field. Second, the top conductor is transparent, which allows illuminating phosphors to be visible. Of course, most capacitors are not as flexible as EL lamps. This flexibility of EL lamps provides the unique features of illuminating curved surfaces and withstanding stress when used over a membrane switch.

EL lamps are manufactured using the screen-printing method, where individual layers of the capacitor are deposited to yield the electronic device. Screen-printing yields low-cost displays for handset applications. It provides the dimensional control necessary to yield a device where the capacitance is controlled within the specified range to yield consistent illumination. There are no physical limitations to colours in EL lamps, although current phosphor colours are limited to blue, green, and orange.

The phosphor layer illuminates when the voltage applied to the two bus bars of the EL lamp changes the potential. Typical EL lamps require peak-to-peak voltages of 150-200V switching at a frequency of 200-450 Hz. Peak-to-peak voltage and frequency directly impact lamp brightness. The higher the voltage and the frequency, the brighter the EL lamp, although each lamp has the maximum specified voltage and frequency.

The phosphor layer is composed of multitude of tiny phosphor particles ranging in size from 5 to 35 microns. The phosphor used is typically ZnS. Over the course of lamp life, the illumination from ZnS phosphor particles degrades. This degradation occurs only when the EL lamp is powered on. Heat and humidity accelerate the degradation phenomena. Development efforts by the phosphor suppliers to microencapsulate individual phosphor particles have shown that EL lamps have an acceptable life for use in handsets, typically longer than 2500 hours of continuous use. This 2500-hour life is typically termed half-luminance, as the lamp life is the time it takes the lamp output (brightness) to decline to 50 per cent of its original (maximum) value.

Extech's big-digit stopwatch with EL backlighting

Benefits

EL lamps' unique construction allows them to serve in ways no other lamp can. These lamps provide optimum light while using a minimum of space, and can bend to conform to the product's shape and even operate while being

Power Consumption to Illuminate Handset Display and Keypad

Lighting system	Current drain	Assumptions
LEDs	112 mA	14 LEDs per handset with 8 mA per LED
Conventional EL	14 mA	(25 $cm^2 \times 0.9$ mA) + 10 mA for inverter losses
ELastolite	13 mA	(20 $cm^2 \times 0.9$ mA) + 10 mA for inverter losses

flexed. EL lamps are virtually shockproof and, unlike other lamps, are not subject to catastrophic failure.

Electroluminescence can be achieved at very low electric power. As a result, EL lamps consume much less power, which makes them an ideal choice when efficiency is a concern.

The light produced by EL lamps is as unique as their construction. Their soft, even light has no glare, so looking into the lamp doesn't strain the eyes unlike most other light sources.

As EL lamps operate at a low temperature, these are cooler than even fluorescent lamps and completely avoid the problems associated with heat build-up in other sources of light.

EL lamps are light-weight and thin, which provides for ultra-slim signs and displays. Provided bend radius is complied with, you can construct displays for a curved surface.

Operation

Fig. 1 shows the typical plug-'n'-play EL lamp system. Because EL lamps are a laminate, these exhibit a capacitance of the order of 0.39 nF to 0.54 nF per square centimetre (2.5 nF to 3.5 nF per square inch).

When a high voltage is applied across the electrodes, the resulting electric field excites the phosphor atoms to a higher energy state. When the electric field is removed, the atoms fall back to a lower energy state, emitting photons in the process. The wavelength of the emitted light is determined by the type of phosphor used and the frequency of the excitation voltage. With most phosphors, the spectrum of the emitted light tends to shift towards blue with an increase in excitation frequency.

The brightness of an EL lamp increases approximately with the square of applied voltage. Increasing the frequency increases the lamp brightness almost linearly but affects hue. (Most lamp manufacturers publish graphs depicting these relationships

EL used for glowing eyes sequence in an advertisement

for various types of lamps.) Excitation voltage usually ranges from 60 V_{p-p} to 200 V_{p-p} at 60 Hz to 1 kHz. Increasing the voltage and/or frequency, however, adversely affects lamp life—higher frequencies generally decrease lamp life more than the increased voltage.

For intermittent use, lamp life is seldom a concern. For example, if a lamp is used 20 minutes per day, over the course of ten years the lamp will be activated for a total of 1216 hours, well within the useful life of most EL lamps available. When designing a drive circuit, a balance needs to be struck between lamp brightness, hue, useful life, and supply current consumption.

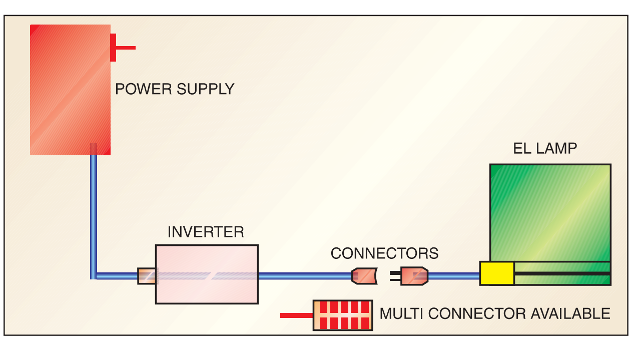

Fig. 1: Plug-'n'-play EL lamp system

Luminescent Systems' Aclar EL lamp

Construction

A typical electroluminescent lamp (Fig. 2) comprises a transparent conductive base. In general, a 175µm thick polyester film with indium-tin oxide (ITO) coating is used for this purpose. These ITO films are manufactured by vacuum sputtering, an expensive production technology. However, high material cost is the prime reason for the high pricing of these films. Screen-printing the conductive paste is another method.

In EL lamp constructions, where the luminescent areas (Fig. 4) are small compared to the total film surface, the contribution of the cost of ITO film to the total cost of the lamp is important. An economical alternative to ITO film will lower the lamp price.

When handling large film formats in screen-printing method, ITO film is easily damaged because the inorganic conductive coating is very brittle. A transparent, conductive polymer coating such as Orgacon on a polyester film can be stretched and folded. It can tolerate severe surface damage without influencing the surface conductivity. Orgacon EL film is ideal for industrial screen-printing. As Orgacon can be embossed and formed in any shape, it is more appropriate than ITO film for use as a transparent conductive base in EL lamps. A number of more environment-friendly and less expensive techniques are available to pattern the polymeric conductive layer.

Various aspects

Voltage and frequency. The nominal voltage and frequency for EL lamps are 115 volts and 400 Hz, respectively. These values originated from the initial use of EL lamps in aircrafts and represent the standard voltage and frequency in aircrafts. However, EL lamp operation is not tied to these values and lamps can be tailored for

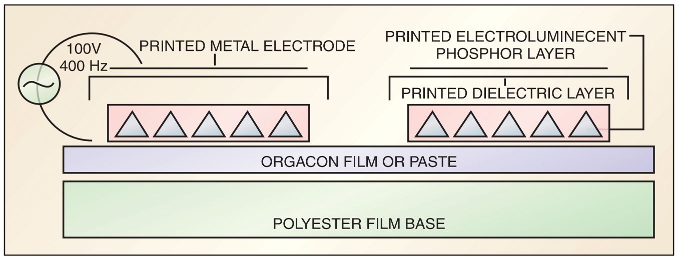

Fig. 2: EL lamp construction

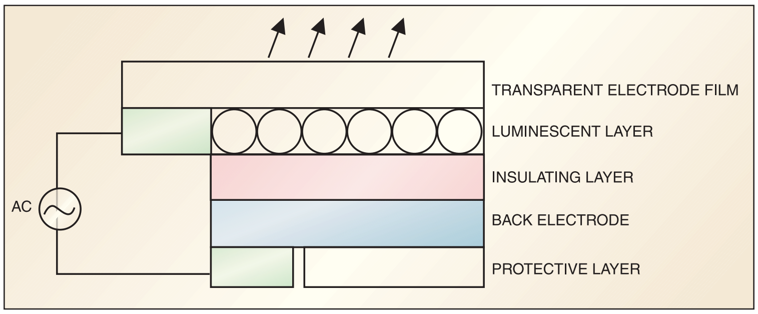

Fig. 3: EL lamp from Seiko Precision is made of a multi-layer material containing special fluorescent dyes, dispersed in a binder with a high electrical constant. When an AC is applied, the lamp (sheet) emits light

EL backlighting features

- Cold light source
- Low power consumption by EL lamp plus DC/AC inverter
- Excellent light uniformity
- Easy to replace lamps
- EL lamps and inverters available for LCD character modules and certain graphic modules
- Easy upgrade from reflective to EL backlighting
- Same mechanical/electrical specifications for reflective and EL types
- Automatic voltage compensation by DC/AC inverters as lamp life deteriorates
- Up to 14 colours possible
- Easy to cut to desired shape
- Vibration- and shock-resistant
- Different sections can be activated separately

operation at 40-220V AC, 50-5000 Hz.

Lifetime. The brightness of EL sheet decreases with time. Some of the factors that reduce lamp life are higher voltage, higher frequency, DC supply, high humidity, and high temperature.

Brightness can be increased by applying a higher voltage (Fig. 5) or a higher frequency. It is also determined by the voltage of the AC electricity provided. Voltage is determined by the inverter driver used. (An inverter driver is a small device that acts much like the ballast in a fluorescent light fixture.) The driver determines both the voltage and the frequency applied. A higher voltage slightly reduces the lifetime but it is preferred where a higher supply current can be accepted. A higher frequency considerably reduces the lifetime, yet it is preferred where a low supply current is essential and is the most suitable for short operating periods. The phosphor in an EL lamp degrades steadily during operation, depending on the level of AC voltage, driving frequency, and temperature. This inherent degradation of EL phosphors results in a decrease of brightness.

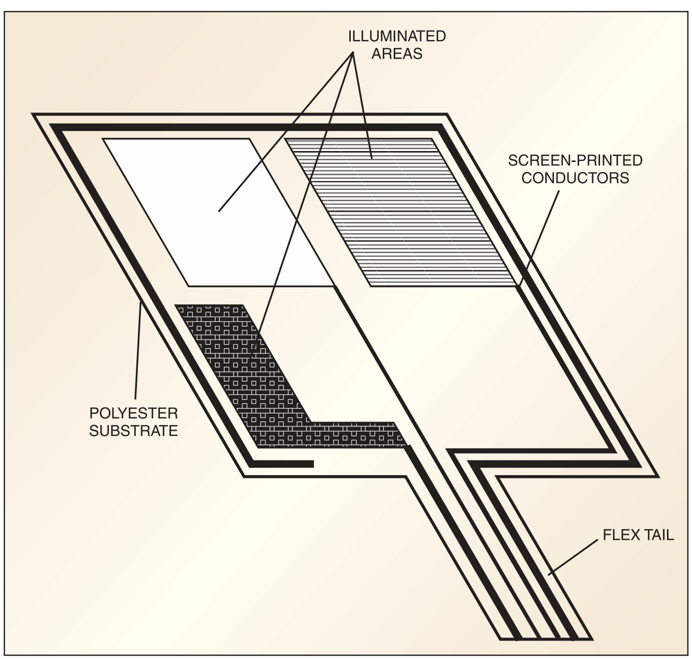

Fig. 4: In EL lamps illuminated areas are small compared to the total film surface

Unlike filament or fluorescent lamps, EL lamps don't catastrophically or abruptly fail. Instead, the lamp brightness gradually decreases over long periods of use. Humidity is the strongest contributor to shortened lamp life, unless special manufacturing processes are employed. Even in the absence of humidity, the phosphor itself gradually loses its efficiency over time and the lamp brightness gradually decreases.

Unfortunately, quantifying the lamp life is difficult because of variations in use, environment, and operating conditions.

Colour. EL lamp colour is usually specified in terms of CIE colour coordinates or apparent colour temperature. The primary lamp colour is determined by the phosphor type. Typical standard phosphor colours are blue, blue-green, and green. A colour different from the available primary phosphor colours can be obtained by blending multiple phosphors, adding fluorescent dyes to the phosphor layer, or by attaching a colour filter to the lamp.

Phosphor blending is the least preferred method, as not all phosphor types have the same brightness, lifetime, and operating characteristics. Therefore if multiple phosphor types are mixed, the colour could be unstable and subject to change over time.

Power source. Since EL lamps generally require drive voltages and frequencies not available from batteries or AC line voltage, a conversion is needed to obtain optimum colour and brightness. For battery operation, a DC-to-AC voltage frequency inverter is needed.

Weight and thickness. The weight of a typical Lumitek EL lamp is a mere 0.1 $gm.cm^2$ and the nominal thickness is 0.5 mm (0.02 inch). For certain specialised applications, the weight and thickness can be reduced by about 60 per cent.

Applications

EL lamps are used in a multitude of applications. These include LCD backlighting,

EL wire display for automobiles

instrument panels, measurement equipment, advertising signs, security equipment, mobile phones, automotive displays, watches/clocks, PDAs, cell phones, portable computers, safety clothing, electronic games and toys, and calculators.

EL cables

EL cables are similar to coaxial cables. The outside electrode is composed of two thin copper wires twisted in a spiral configuration around a semiconductive phosphor. The actual light is emitted due to the properties of the semiconductive phosphor between the copper-wire electrodes. Flexible electroluminescent cable comes in eight bright colours: deep-sea blue, bright red, lightning green, neon purple, fluorescent yellow green, gleaming white, electric yellow, and ice blue.

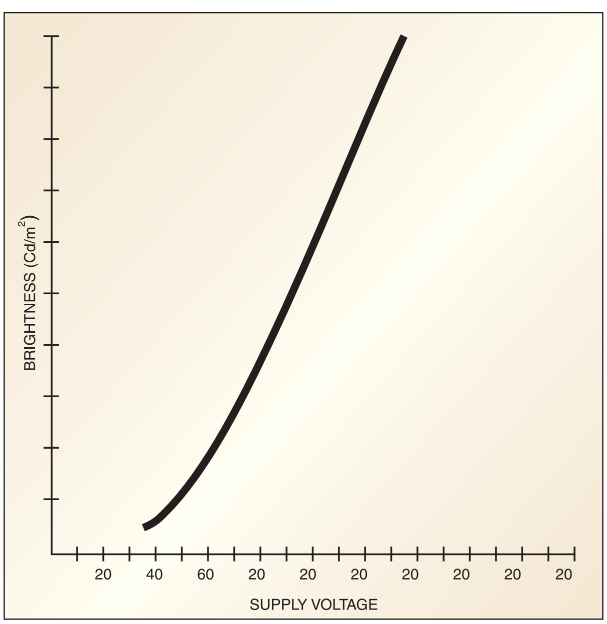

Fig. 5: Brightness versus supply voltage

EL cables glow evenly and look much like neon. Unlike conventional neon lighting, flexible electroluminescent cable can be cut and spliced to any length, needs no special tools for installation, costs much less, and is energy-efficient, weatherproof, cool to touch, and environment-friendly.

EL cable is bright enough to be seen from up to 122 metres (400 feet) at night and can be supported by common alkaline cell batteries or the automotive battery in your car depending on the application. You can use it to backlight or accent objects such as signs and licence plates to achieve a very appealing neon glow. If you double the cable, the neon glow is even stronger. White paint (semi-gloss or gloss) or reflective material can be applied to act as a reflective surface, which helps to increase the glow.

You can wrap an electroluminescent cable, with 8mm bending radius, around a pencil without damaging the electroluminescent core. The EL cable is coated with a durable layer of inert polyvinyl.

Comparison with LEDs

Power consumption. LEDs have been widely used to illuminate electronic equipment for over 20 years. These displays are reliable, low-cost point-light sources but consume significant power. In a typical wireless handset there are 14 LEDs to illuminate the keypad and display. As each LED consumes about 8 mA, the total current drain is over 100 mA. Assuming the user accesses the handset 60 times during a battery cycle and the lighting system is 'on' for an average of 30 seconds per use, the lighting system consumes 50 mA-hours during a battery cycle in a typical single-function phone handset.

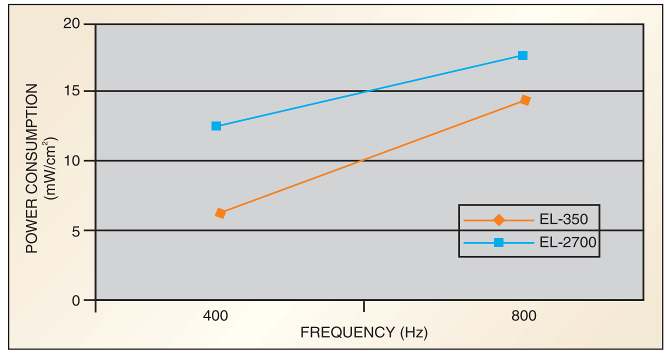

Fig. 6: Power consumption by EL lamps at 130V with Orgacon film, white phoshhor, and silver back electrode

LEDs are point-light sources and hence limited in illuminating an area uniformly. Lightpipes and lightguides are required to diffuse and spread the LED illumination across the entire keypad and display areas of the wireless handset. Design, test, and tool processes for these added components lengthen the handset design cycle. Lightguides or lightpipes add cost to the handset and consume precious space in the handset, and still result in a relatively non-uniform illumination of the keypad and display. To reduce battery drain from LEDs, handset manufacturers are beginning to install conventional EL lamps to light up displays and, in some models, keypads as well. EL reduces current drain by 75 per cent and provides uniform illumination of displays.

Noise. LEDs generate no audible or EMI/RFI noise. On the other hand, conventional EL lamps:

1. Resonate audible noise created by the EL driver circuits used to convert the voltage to >100V AC and frequency to 200-400 Hz.

2. Generate audible noise due to the field effect.

In the handsets using conventional EL lamps, there is audible noise whenever the EL lighting system is powered on. State-of-the-art EL drivers can operate at audible noise levels as low as 26 dB—a significant improvement over current drivers in the market but the noise is still audible to the handset user.

Size. LEDs require PC board space and routing for logic and power. Typically, EL lamps have a thickness of 0.125 to 0.250 mm. Current EL driver circuits used to convert DC into AC require a 12.5x12.5x 2.5mm (=390 mm^3) footprint. ❑

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