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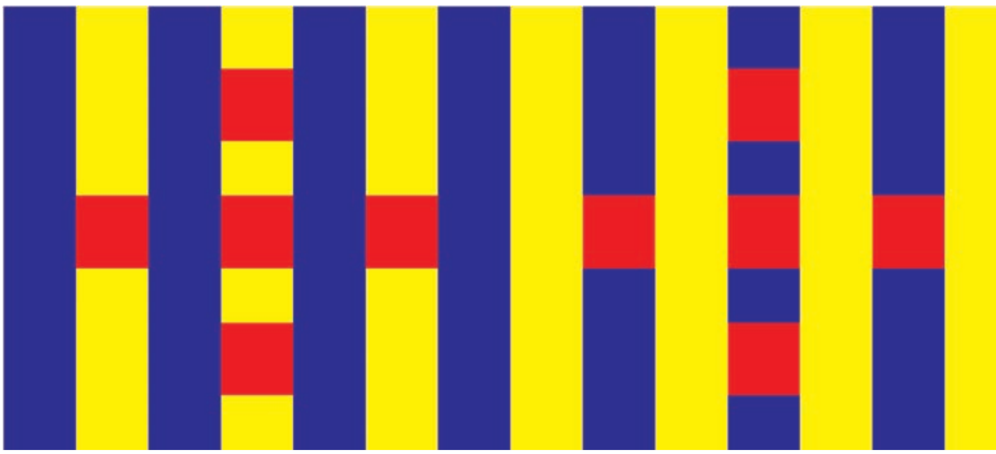
TECH REPORT

Lighting the Flight Deck



This illustration demonstrates the phenomenon called simultaneous contrast. The red squares on either side have identical values; however, our eyes perceive the squares on the left to be darker because of their surrounding color. Optical phenomena add complexity to lighting specifications and influence the design and development of human machine interfaces.

The flight deck is the ultimate human machine interface (HMI) application. It uses human senses of touch, hearing and sight in a safety critical situation. This article focuses on sight and its lowest common denominator—light—and the current lighting technology affecting the human element of flight deck instrumentation.

Access Intelligence

When selecting a light source for the flight deck, the type of light used is not the only consideration. It is also important to understand how humans perceive light and color under various conditions.

Light is a form of electromagnetic energy that travels in waves. The length of the wave (wavelength or amplitude) and its speed (frequency or hertz) determine the color of the light. The visible light frequencies, also called the spectral colors, are located on the electromagnetic spectrum between infrared and ultraviolet frequencies. Infrared frequencies are higher than visible light and ultraviolet frequencies are lower.

The color white is made up of all the spectral colors, which can be shown by shining a white light through a prism, reflecting a rainbow of all the visible colors. The colors we see are determined by how an object reflects or absorbs light waves that contact it. It is the reflected waves that give objects the color we see. If a surface absorbs all the light waves, we see the color black, which is the absence of all color. If an absorptive filter is used on a surface, the reflected color will change.

If a surface is smooth, the light will reflect at 90 degrees from its point of contact on the surface and the object will appear very glossy; if the surface is rough, the reflection will be diffused and the object will appear matte or flat.

Our perception of color can also be changed by how we illuminate a surface. For example, in white light, an apple appears red because it is absorbing all the light waves except the red waves, which it is reflecting.

But if a green light is used to illuminate a red apple, the apple will appear dark or black. This is because the green light does not have any red wavelengths for the apple to reflect, so it absorbs all the light, reflects none, and thus appears black.

Visible light is located on the electromagnetic spectrum between the infrared and ultraviolet frequencies.

We can use the primary colors of red, green and blue, in varying formulas, to create any color. This is called additive color mixing. We can also use the colors cyan, magenta and yellow to produce any color. This is called subtractive color mixing. If the additive colors are mixed equally, they create white; if the subtractive colors are mixed equally, they create black.

The light and colors we see are detected by rods and cones in our eyes. Rods do not detect color, but are able to detect very small amounts of light; cones detect color, but are not very sensitive to light. As light decreases, we are less likely to see color.

Lighting the Way Forward

Bright, colorful, tiny, reliable, rugged, adaptable, economical, and long-lived. These words describe attributes of a form of lighting that is receiving new respect and growing use in aerospace.

We're referring to light-emitting diodes (LEDs). Although LEDs have been commercially available since the 1960s, improved technology is giving them several advantages over other forms of lighting, such as incandescent and electroluminescent lighting (EL).

An example of LED lighting is the traffic light. Municipalities nationwide are replacing incandescent halogen bulbs, earlier hailed for their brightness and cost efficiency, with LEDs in their traffic lights. The LEDs are brilliantly visible, operate for thousands of hours longer and cost far, far less to operate than the bulbs they replace. LEDs are composed of a diode—which is a semiconductor device made of material that can conduct electrical current. When an electric current is applied to the diode, electrons in the material move about and emit particles of energy in the form of light (i.e., photons). The LED also has a bulb device that aims and reflects the emitted light to provide the best illumination.

The light emitted from an LED is a form of electroluminescence, because it is created when an electric current is applied to the diode. (EL lighting is also a form of electroluminescence, and its light is created by sending an electric current through atoms of phosphor.)

Electroluminescence of the type that LEDs emit was first seen in 1907 by Briton Henry Joseph Round, who was working for the Marconi Co. He was experimenting with a piece of silicon carbide, and when he passed current through it, a dull yellow light was emitted. The light was too dim for practical applications, but the findings piqued the interest of other scientists.

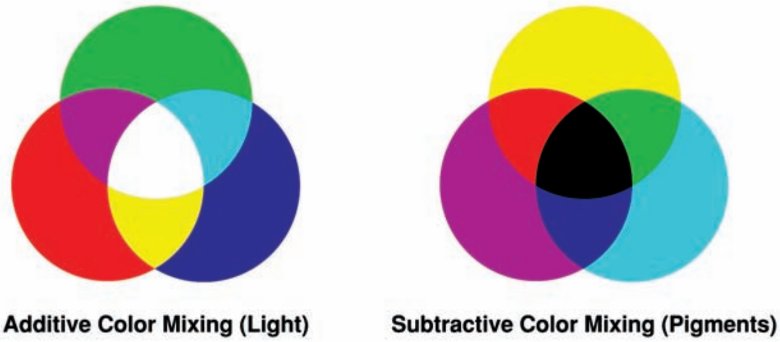
Experimenting with many different materials, scientists worldwide built upon Round's discovery. They found that the purest materials didn't always produce the brightest light because they were poor conductors of electricity. So scientists added impurities—called "doping"—and were able to produce brighter light emissions.

In 1955 scientist Rubin Braunstein of RCA reported the first infrared emission from a diode using gallium arsenide (GaAs), which came to be the best material to use. Scientists developed the first commercial LEDs in the 1960s; these only produced infrared light and were used as photosensors. More research also discovered that by adding different materials, different kinds of light—including the many colors of visible light—could be produced; the emitted light was even brighter than before.

In recent years, LED technology surmounted the last barrier to large-scale market success. Scientists perfected the technique to produce brilliant LED lighting in blue and white colors. As a result, LEDs became capable of producing any color light with all the hue, saturation and brightness (i.e., chromaticity) desired.

This success won over the high-volume automotive and communications markets. Manufacturers began to demand LED products, helping drive down production costs and thus open the door for LEDs in aviation.

Today LEDs emit colors spanning the light spectrum from infrared to visible to ultraviolet—we can't perceive infrared and ultraviolet light, but it is there and can be seen with



Combining light (additive colors) and combining pigments (subtractive colors) create different effects. If the additive colors are mixed equally, they create white, as illustrated, above left; if the subtractive colors are mixed equally, they create black, as shown above right.

special equipment. LED applications have grown from infrared sensors to monochrome digital watches. The push-button or touchscreen switches on most appliances use LEDs; the taillights in automobiles use LEDs; even flashlights use them.

Flight Deck Applications

LEDs are found today throughout modern airplanes. In aircraft development programs, the technology has become the preferred method of lighting for nearly every need except avionics displays. However, this is changing, too, as LED backlights are being developed to replace liquid crystal displays (LCDs) seen in "glass cockpit" integrated avionics suites. Deployment of LED technology on the flight deck is beginning with instrument panels and illumination lighting for the pilots. The cabin interior and exterior lighting of the aircraft also are adopting this reliable, low-power technology at a rapid pace.

Like all forms of light, LED lighting has three main attributes: saturation, hue, and brightness. Saturation refers to a color's intensity, with the most saturated color being one that has no white. Hue refers to the dominant wavelength of the color; a color's hue remains constant, but the color may appear lighter or darker depending on its saturation level. Brightness is related to a color's reflectivity and its luminance—that is, how many lumens it emits.

Today's LED technology takes advantage of all three attributes, plus additive or subtractive filtering to produce a full range of colors. LED lighting is also very visible under all kinds of ambient light, including bright sunlight.

Advantages of LEDs

LEDs outperform incandescent and EL lighting in many ways. Three big advantages are in power consumption, service life, and size/weight. Another benefit on the flight deck is reduced touch temperature and heat emissions for added comfort.

"Compared to LEDs, incandescent lights are power hogs and EL lighting is not much better," says Don Casto, a Lead Engineer for Lighting on IDD's Technical Staff. "In an application where incandescent lights would require 5.4 watts to operate, EL lighting will require 1 watt, but LEDs will only require 0.4 watts. This low-power advantage also translates into more uniform and brighter lighting when using LEDs, compared to incandescent or EL lighting, because you can use more LEDs without sacrificing power."

Regarding power requirements, LEDs are as flexible as other forms of lighting. Voltages available in IDD products are 4.5V, 5.0V, 12.0V, 27.5V, 28.0V and 115.0V.

Another advantage concerns heat, an enemy of all electronic equipment. LED operating temperatures are 30 percent cooler than incandescent lights, which have a surface temperature of 110 degrees F (43°C), compared with 78 degrees F (26°C) for LEDs. LEDs add less heat to the flight deck and are cooler to the touch than incandescent lights.

"LEDs are also shockproof and environmentally rugged," Casto continues. "They have no moving parts, giving them a ruggedness not possessed by incandescent bulbs, which have filaments subject to vibration and fatigue failure."

These attributes mean that LEDs have useful lives of 500,000 hours, compared with 100,000 hours for incandescent lighting, and only 8,000 hours for EL lighting. LED mean-time-between-failure [MTBF] rates are even more impressive, at more than 300,000 hours (when operating at full power), compared with only 23,000 hours for incandescent and 8,000 hours for EL. EL lighting is short-lived because it fades over time.

LED lighting is compatible with night vision systems, meeting or exceeding NVIS Green panel Class A or B performance requirements for MIL-L-85762A or MIL-STD-3009, Casto adds. To achieve the night vision criteria, subtractive filters are used to remove any infrared lightwaves, which compromise or reduce night vision capabilities.

These factors mean reduced maintenance and service costs for instrument panels incorporating LEDs, compared with previous generations of technology. As to LED affordability, high market demand, spurred by the huge automotive and communications industries, and automated fabrication have resulted in lower production and acquisition costs. Additionally, LEDs are surface-mountable, which enables automated assembly in some applications.

IDD Expertise

Mass production advantages add challenges for aircraft flight deck applications, however, and require solutions from aviation lighting providers. As commercial users continue to drive LEDs brighter, for example, slight color shifts can result. At the same time the aerospace industry requires tightly specified products that ensure consistency year after year over the life of the aircraft. This means that aerospace manufacturers must adapt their designs and processes to accommodate changes in the materials while avoiding variation in the fielded product.

IDD's designs and processes address these "improvements" in technology in order to maintain its products within aerospace tolerances. A leading company in the field of flight deck instrument panels and controllers, IDD Aerospace has deployed hundreds of LED parts on new flight deck developments such as the Airbus A380, Boeing 787, Bombardier Challenger 300, Embraer 170/175 and 190/195, and many other recent programs. As a leading supplier to the industry, IDD has an intimate knowledge of the shift to LEDs. The company uses more than 15,000 LEDs per month to produce several types of illuminated panels for flight decks.

"Our products include lightplate panels, illuminated keyboards and bezels, integrated switch panels, control panel assemblies, and integrated control panels, all generally custom-designed to meet the various industry human machine interface and lighting specifications," explains Ray Nicoli, Director of Engineering, IDD Aerospace.

Pilots control the brightness of the instrument panels through central controllers that simultaneously dim or brighten the instrument panels, based on night or day flight or the amount of ambient light from the displays. LEDs can also be dimmed in the cockpit. In cockpits that use a mixture of incandescent and LED lighting, uniform dimming of lighting with disparate technology is a challenge. This is because incandescent lighting dims "slower," as filaments cool from white hot to red hot to dark cool, while LED lighting dims down a uniform straight line until the lighting is off. The incandescent phenomenon is known as the "lighting curve."

However, this is not a problem in today's modern flight decks. Companies like IDD have created electronics that coordinate the flight deck's dimming in a way that matches the incandescent curve. IDD offers four methods to control LED brightness: via an analog dimming control voltage, via a custom integrated circuit, via a digital communications interface, or via an external PWM (pulse width modulation) dimming control unit/signal.

IDD produces 40,000 lightplates each year, as well as illuminated integrated switch panels, bezels and control panel assemblies for aircraft such as the Boeing 787, Airbus A380, Embraer 170/190 family and military platforms such as the U.S. Presidential Helicopter and the F-35.

A Look to the Future

Researchers worldwide are busily perfecting the next evolution in LED technology: organic and polymer LEDs. These LEDs, which are also solid state semiconductors, are constructed of a substrate, a transparent anode, layers of organic molecules or larger polymer molecules, a conducting layer, an emissive layer and a cathode. When an electric current passes through the semiconductor, the OLED/PLED can emit light in all the colors that today's LEDs do. Light is created through electrophosphorescence.

OLEDs/PLEDs are also only a few hundred nanometers thick, or about 200 times smaller than one human hair. Scientists envision using this technology to create fantastic new products. One thought: large-screen, high-definition televisions that are only a quarter-inch thick and can even be rolled up when not used.

Already mass production techniques have been perfected, using inkjet technology to precisely create the molecular layers on OLED/PLED substrates. OLEDs are being used in screens for digital cameras, PDAs and cell phones. Their miniscule size is reducing weight, power and space constraints to bring new features to market for the products that host them.

The advantages for the flight deck are reduced weight, volume and power, in addition to rapid production and development. The challenges facing deployment of OLEDs in the flight deck include color shift, degradation and variation, some of the same issues that the current LED technology faced when initially proposed for the cockpit.