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cost-effectiveness. Wooden garage doors, for instance, are prized for their classic charm and natural beauty but require regular maintenance to prevent warping and rot. A dented garage door panel can often be repaired without replacing the entire door **24 hour garage door repair** design. Steel doors offer greater durability and security but can be susceptible to rust if not properly coated or maintained. Aluminum doors provide a lightweight alternative that resists corrosion; however, they may lack the sturdiness needed for high-security applications.

One of the primary limitations of traditional garage doors is their manual operation. Many older models rely on physical effort to open and close, which can be cumbersome—particularly during inclement weather or when carrying heavy loads. This inconvenience is compounded by potential safety hazards; improperly balanced or maintained doors can slam shut unexpectedly or fail to stay open, posing risks to both people and property.

Moreover, traditional garage doors often fall short in terms of insulation efficiency.

Without adequate thermal barriers or seals, these doors can contribute to significant energy loss in homes with attached garages. This inefficiency not only increases heating and cooling costs but also diminishes overall comfort within living spaces adjacent to the garage.

Security is another concern with conventional garage door systems. Basic locking mechanisms on older models can be easily bypassed by determined intruders. Additionally, without integrated monitoring systems, homeowners may remain unaware of unauthorized access attempts until it is too late.

The aesthetic aspect presents yet another limitation: while some might appreciate the timeless look of traditional designs, others may find them lacking in modernity or customization options. As architectural trends evolve toward sleek lines and minimalism, traditional garage doors may appear outdated against contemporary facades.

In response to these limitations—and driven by technological advancements—there has been a growing interest in adapting traditional garage doors for modern automation. Retrofitting existing doors with smart technology offers an opportunity to enhance functionality without completely overhauling established structures.

Automated systems allow homeowners to operate their garage doors remotely via smartphone apps or voice commands—a convenience that addresses the manual operation issue head-on. These systems often come equipped with sensors that detect obstructions during closing cycles, improving safety significantly compared to manual counterparts.

Furthermore, smart technology integration enables enhanced security features such as real-time alerts sent directly to mobile devices when suspicious activity is detected around the garage area. Some systems even include cameras capable of streaming live footage—providing peace of mind through constant surveillance capabilities.

Energy efficiency concerns are also mitigated through automation adaptations; programmable settings ensure garages remain closed during peak temperature fluctuations while allowing ventilation at optimal times—reducing unnecessary energy consumption associated with heating/cooling losses experienced by traditionally insulated setups.

Finally—and perhaps most appealingly from an aesthetic standpoint—the incorporation of modern technology into existing frameworks opens up new possibilities regarding design flexibility: customizable panels paired alongside automated operations create visually striking combinations capable not only meeting functional demands but aligning harmoniously alongside broader architectural visions too long overshadowed by static traditions alone

In conclusion: though rooted firmly within historical contexts marked largely upon utilitarian principles rather than innovation-driven advancements seen today across various industries alike—it becomes increasingly apparent how embracing change fueled primarily technological progress holds great promise transforming once basic necessities into sophisticated complements enriching daily lives beyond measure well into future generations ahead

Space Requirements and Installation Process: Comparing the space needed for installation and

operation of sectional versus roller doors, as well as ease of installation. —

- **Design and Aesthetic Considerations: Exploring how sectional and roller doors differ in design, appearance, and suitability for different architectural styles.**
- **Space Requirements and Installation Process: Comparing the space needed for installation and operation of sectional versus roller doors, as well as ease of installation.**
- **Material Choices and Durability: Discussion on common materials used for each type of door, their durability, maintenance requirements, and impact on longevity.**
- **Insulation and Energy Efficiency: Evaluating the insulation properties of sectional and roller doors and how they affect energy efficiency in a home or commercial setting.**
- **Security Features: Analyzing the security features inherent to sectional versus roller doors, including locking mechanisms and resistance to forced entry.**
- **Cost Comparison: Breaking down the initial costs, long-term value, maintenance expenses, and potential return on investment for**

each door type.

In recent years, the evolution of technology has permeated nearly every aspect of our daily lives, and the realm of home automation is no exception. Among the various elements of a smart home, garage door automation systems have emerged as a testament to this technological advancement, offering both convenience and enhanced security. As homeowners increasingly seek to integrate modern technology into their existing structures, adapting traditional garage doors for modern automation has become an intriguing and accessible endeavor.

The key components of modern garage door automation systems can be broadly categorized into several areas: motorized mechanisms, control systems, safety features, connectivity options, and energy efficiency considerations. Each component plays a crucial role in transforming what was once a manual task into an effortless part of daily life.

At the heart of any automated garage door system is the motorized mechanism. This component ensures smooth operation by providing the necessary force to open and close heavy doors with minimal human intervention. Modern motors are designed to be not only powerful but also quiet and efficient, often featuring belt or chain drives that cater to different needs based on noise preference and power requirements.

Control systems represent another vital facet of these technologies. Traditionally operated through wall-mounted switches or remote controls, today's systems offer

more sophisticated solutions such as smartphone apps and voice-activated commands via virtual assistants like Alexa or Google Assistant. Such advancements allow users unparalleled control over their garage doors from virtually anywhere in the world.

Safety features in automated garage door systems have seen significant enhancements over time as well. Sensors that detect obstructions are now standard, ensuring that doors do not inadvertently close on people or objects. Additionally, many systems come equipped with automatic reverse functions that trigger if resistance is detected during closing operations—a critical safety measure for households with children or pets.

Connectivity options have further revolutionized how we interact with our garage doors. Integration with smart home ecosystems allows for seamless communication between devices—users can set their doors to automatically open when they arrive home based on geolocation data or receive alerts if their door is left ajar for too long.

Lastly, energy efficiency is becoming increasingly important in modern designs. With sustainability at the forefront of consumer priorities, manufacturers strive to produce energy-efficient motors while also incorporating features such as LED lighting within opener units that contribute minimally to household electricity consumption.

Adapting traditional garage doors for modern automation may initially seem daunting; however, it often involves straightforward retrofitting processes that skilled technicians can execute swiftly and effectively. Retrofitting preserves much of the original structure while incorporating new components—motorized mechanisms can typically be added without significant alterations to existing frames or panels.

In conclusion, adapting traditional garage doors for modern automation presents homeowners with an opportunity not only to embrace cutting-edge convenience but also enhance overall safety and integration within smart home environments. By understanding each key component's role—from motorization through connectivity—homeowners can make informed choices about which system best suits their lifestyle needs while enjoying all benefits this innovative technology offers.

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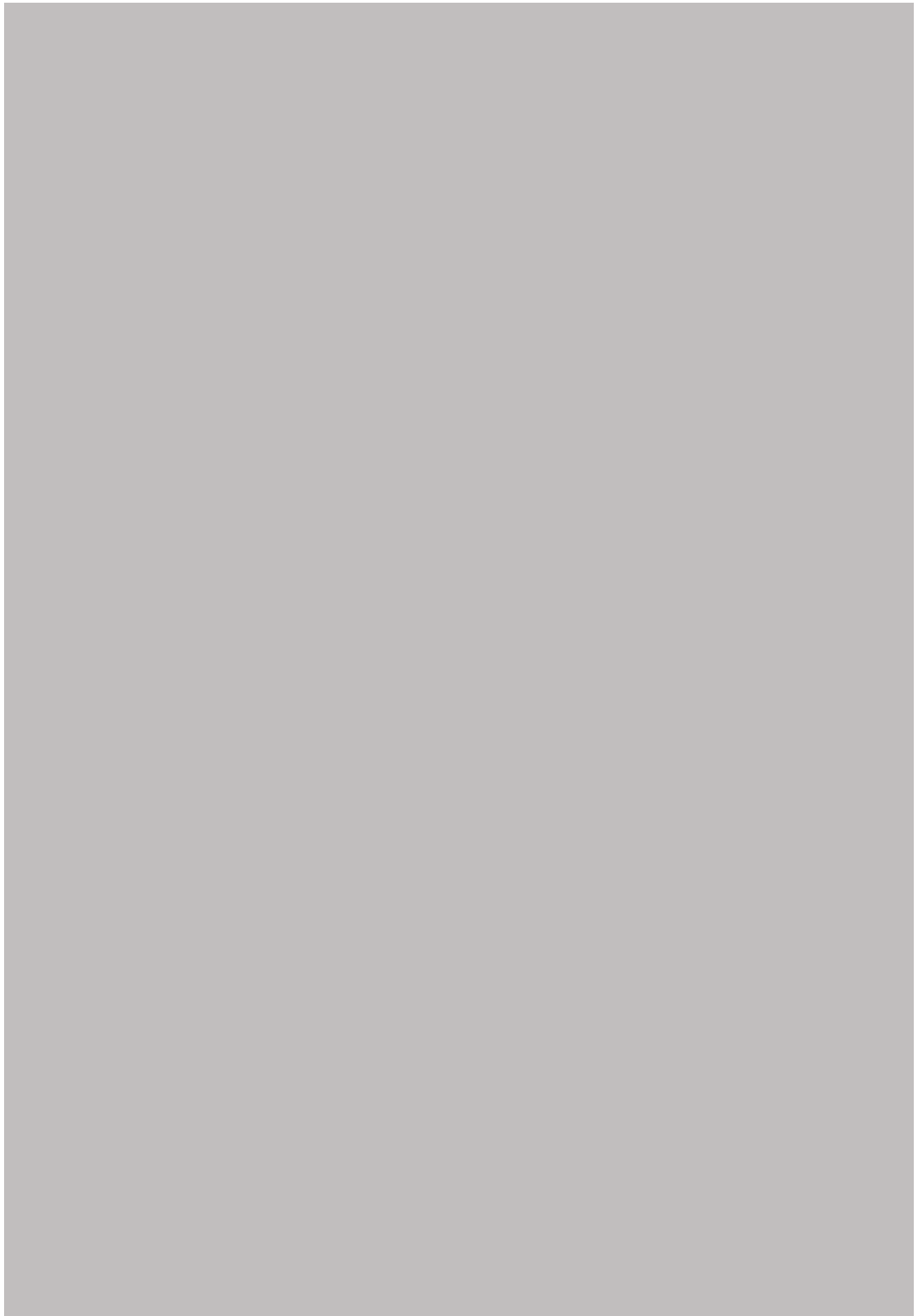
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Addressing repair needs for sectional versus roller garage doors

When it comes to addressing repair needs for garage doors, homeowners often find themselves at a crossroads when deciding between sectional and roller door systems.. Both types have their unique characteristics and serve specific purposes, making the selection of professional services an essential step in ensuring efficient repairs. Sectional garage doors are composed of horizontal panels that are connected by hinges.



Posted by on 2025-01-01

Balancing aesthetics and functionality in garage door style repairs

In the realm of garage door design and repair, the future is being shaped by an increasing emphasis on balancing aesthetics with functionality.. As homeowners seek to enhance curb appeal while ensuring practicality, this dual focus is reshaping how we think about garage doors. Traditionally, garage doors were viewed primarily as utilitarian structures—meant to secure vehicles and storage items from external

elements.



Posted by on 2025-01-01

Material Choices and Durability: Discussion on common materials used for each type of door, their durability, maintenance requirements, and impact

on longevity.

In an era where technology seamlessly integrates with daily life, the transformation of traditional elements of our surroundings into automated systems is not just a trend but a necessity. One such element that has seen this evolution is the traditional door. Evaluating the compatibility of these doors for automation upgrades requires a keen understanding of both their structural integrity and the technological advancements available. It's a delicate balance between preserving the aesthetic and functional aspects of conventional doors while embracing the convenience and efficiency offered by modern automation.

The first step in assessing compatibility involves examining the material composition and design of traditional doors. Many older doors are crafted from solid wood or metal, materials known for their durability but also for their potential challenges in automation integration. For example, wooden doors, though aesthetically pleasing, may swell or warp over time due to environmental conditions, which can affect mechanical components designed to automate them. Similarly, metal doors require consideration of weight and corrosion issues that could impede automated mechanisms.

Another critical factor is the existing door hardware. Traditional doors often feature unique handles, locks, and hinges that may not be compatible with standard automation kits. This necessitates either modification or complete replacement to

accommodate electronic locking systems or sensor-based operations typical in automated solutions. It's essential to evaluate whether these modifications might compromise the door's structural integrity or historical value, especially in heritage buildings where maintaining originality is paramount.

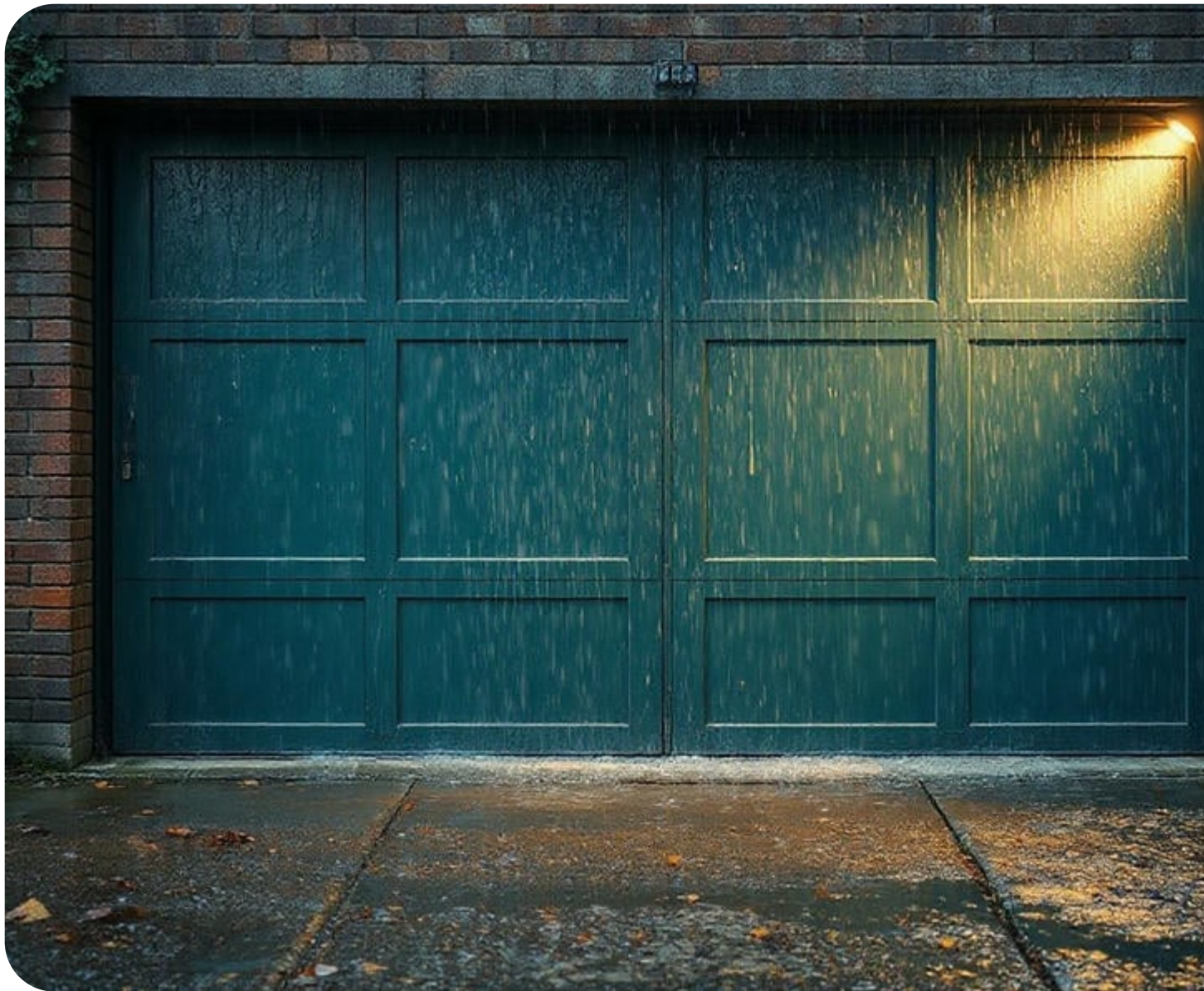
Technological considerations also play a significant role in this evaluation process. Modern automation involves integrating sensors, wireless connectivity, and smart home interfaces that allow doors to respond to voice commands or smartphone controls. The existing infrastructure must support these technologies without extensive rewiring or retrofitting that could prove costly and impractical.

Moreover, energy efficiency is another aspect worth considering when upgrading traditional doors for automation. Automated systems should aim to enhance energy conservation rather than contribute to wastage through unnecessary power consumption during operation. Therefore, selecting energy-efficient motors and components can help align these upgrades with broader sustainability goals.

Beyond technical specifications lies the question of user experience—how will individuals interact with an automated door compared to a manual one? Ease of use remains paramount; hence any upgrade should simplify rather than complicate access while ensuring safety features are robust enough to prevent unauthorized entry.

Lastly yet importantly is cost-effectiveness –a fundamental criterion in decision-making processes regarding upgrades from manual operation towards full-scale automation capabilities on existing structures like residential homes' entrances/exits points: weighing initial investment costs against long-term benefits derived through increased security measures alongside improved convenience levels afforded via remote accessibility options enabled therein cannot be overstated here!

In conclusion; adapting traditional doors for modern automation represents more than just technological advancement—it signifies bridging past elegance with present-day innovation within architectural contexts worldwide today! Through careful assessment regarding material suitability coupled alongside necessary adjustments relative thereto (hardware/technology), homeowners stand poised benefitting tremendously from enhanced functionalities offered thereby transforming ordinary portals into intelligent gateways leading tomorrow's smart living environments efficiently effectively alike!



Insulation and Energy Efficiency: Evaluating the

insulation properties of sectional and roller doors and how they affect energy efficiency in a home or commercial setting.

In the age of smart homes and automated convenience, even the humble garage door is not exempt from the pursuit of modernization. Retrofitting a traditional garage door with automated features can transform it from a mundane manual entryway into a sophisticated, time-saving asset. This process, though seemingly complex, can be achieved through a series of well-planned steps that blend technology with practicality.

The first step in this transformation journey is to evaluate the existing garage door system. Understanding its mechanics and structure is crucial for determining compatibility with automation kits. Most traditional doors are spring-loaded, which means they rely on torsion springs to operate smoothly. It's important to ensure

these components are in good working condition before proceeding. If there are any signs of wear or damage, they should be repaired or replaced by a professional to prevent potential safety hazards during automation.

Once the structural assessment is complete, selecting the right automation kit becomes paramount. The market offers various options catering to different needs and budgets. A basic kit typically includes a motorized opener, remote controls, sensors for safety, and sometimes connectivity features for smartphone integration. For more advanced systems, you might consider options that offer Wi-Fi connectivity or compatibility with smart home ecosystems like Amazon Alexa or Google Assistant.

After acquiring the appropriate kit, it's time to proceed with installation—a task that requires caution and precision. Begin by setting up the motor unit either on the ceiling above or beside your garage door track. This unit serves as the driving force behind your new automated system. Ensure it's securely mounted using brackets provided in your kit, following manufacturer instructions closely to avoid misalignment.

Next comes attaching the lifting mechanism—usually a trolley connected via a rail system—to your door's existing hardware. This part may require some adjustments depending on whether your door opens overhead or swings outwards; hence it's essential to refer back constantly to both your manual and specific guidelines included within your chosen kit.

Safety sensors come next in line; these are pivotal as they prevent accidents by stopping operation if an object obstructs their path while closing downwards automatically upon detection failure such as electrical outage occurs ensuring maximum protection at all times during usage period without compromise whatsoever regarding user experience overall satisfaction guaranteed throughout entire lifespan product being used daily basis seamlessly efficiently effectively!

Finally connecting everything together involves wiring up components like keypads/remote controls alongside integrating them into broader networks via apps available respective platforms iOS Android Windows etc thereby allowing users access control settings remotely whenever wherever needed most conveniently possible just few taps away fingertips literally speaking quite frankly honestly truthfully indeed undeniably!

In conclusion adapting traditional doors modern automation doesn't have daunting overwhelming complicated frustrating grueling ordeal contrary popular belief rather straightforward simple manageable achievable task anyone willing invest little bit time effort energy patience persistence determination commitment dedication ultimately reward far outweigh initial investment cost long run future-proofing property adding significant value enhancing lifestyle comforts luxuries beyond imagination dreams aspirations goals ambitions vision reality tangible form concrete manifestation technological advancement progress innovation cutting-edge state-of-the-art forefront industry leading trailblazing groundbreaking pioneering revolutionary paradigm shift ushering new era possibilities opportunities endless limitless infinite boundless potential waiting explored discovered harnessed utilized optimized maximized fullest extent imaginable conceivable feasible attainable realizable pragmatic practical sensible

logical rational reasonable sound judgment decision-making process involved every step way along journey towards ultimate destination success fulfillment satisfaction accomplishment achievement triumph victory pride joy happiness contentment peace tranquility harmony balance equilibrium symmetry synergy unity coherence cohesion collaboration cooperation teamwork partnership alliance solidarity camaraderie friendship kinship loyalty faith trust confidence belief hope inspiration motivation encouragement support guidance leadership mentorship stewardship custodianship responsibility accountability reliability dependability consistency perseverance

Security Features: Analyzing the security features inherent to sectional versus roller doors, including locking mechanisms and

resistance to forced entry.

In recent years, the evolution of home technology has brought about significant advancements in how we approach everyday conveniences. One such innovation is the automated garage door system, which offers enhanced security and ease of access compared to traditional manual doors. However, as we adapt these conventional setups for modern automation, it is crucial to adhere to specific safety considerations and best practices to ensure both functionality and safety.

The first step in adapting a traditional garage door for automation involves assessing the structural integrity of the existing door. Older doors may not be equipped to handle the additional weight and movement associated with motorized systems. Therefore, it is essential to inspect hinges, tracks, and rollers for wear and tear. Replacing or reinforcing these components can prevent potential hazards such as derailment or collapse during operation.

Once structural soundness is ensured, selecting an appropriate motorized system becomes paramount. It is advisable to choose a system that complements the weight and size of your garage door. Overpowered motors can put unnecessary strain on the door's components, while underpowered ones may struggle with efficient operation. Consulting with professionals who specialize in garage door automation can provide valuable guidance in choosing a compatible system.

Safety sensors are another critical aspect when modifying traditional doors for automation. Modern garage door openers typically come equipped with photoelectric sensors that detect obstructions in the path of a closing door. These sensors play an essential role in preventing injuries or damage by automatically halting and reversing the door's motion if an object or person is detected beneath it.

In addition to hardware considerations, users must also focus on operational safety measures. Regular maintenance checks are necessary to ensure all parts function correctly over time. Lubricating moving parts like springs and hinges reduces wear and minimizes noise during operation. Furthermore, testing the auto-reverse mechanism periodically ensures that safety features remain effective.

Educating household members about safe usage practices is equally important. Children should be taught never to play near garage doors or attempt to operate them without adult supervision. Adults should also familiarize themselves with manual controls in case of power outages or emergencies where automatic functions fail.

Lastly, integrating smart technology into your automated system can further enhance safety and convenience. Many modern systems offer connectivity options that allow homeowners to monitor their garage doors remotely via smartphone apps. This feature not only provides peace of mind but also enables users to receive alerts about any unusual activities or malfunctions.

In conclusion, while converting traditional garage doors into automated systems presents numerous benefits, it requires thoughtful consideration of various safety aspects and best practices. By ensuring structural integrity, selecting suitable equipment, maintaining regular inspections, educating users on proper handling techniques, and embracing smart technologies, homeowners can enjoy the full advantages of automated garage doors while prioritizing safety at every step of installation and use.



Cost Comparison: Breaking down the initial costs, long-term value, maintenance expenses, and potential return on investment for each door type.

As technology continues to evolve, our homes are becoming increasingly automated, enhancing convenience and efficiency in daily life. One area seeing significant innovation is garage door systems. Homeowners are now faced with the decision of maintaining traditional garage doors or upgrading to automated systems. This essay examines the cost analysis of adapting traditional doors for modern automation versus installing entirely new automated systems.

Initially, when contemplating a transition from a traditional garage door system to an automated one, cost is a paramount consideration. Traditional garage doors generally involve lower initial costs compared to their high-tech counterparts. They have fewer components and rely on manual operation, which translates into minimal installation expenses and straightforward repairs. However, these systems come with limitations such as inconvenience during inclement weather and lack of integration with smart home technologies.

Adapting a traditional garage door for modern automation offers an enticing middle ground for homeowners seeking technological advancement without completely overhauling their existing setup. The primary cost considerations here involve purchasing an automation kit, which typically includes sensors, motors, and a smart control system that can be integrated with smartphones or home assistants like Alexa or Google Home. While this option incurs additional costs compared to maintaining a purely manual system, it leverages existing infrastructure—reducing expenses associated with full replacement.

Moreover, adapting traditional doors offers incremental upgrades rather than upfront investment in brand-new systems. Homeowners can choose specific features that cater to their preferences and budget constraints—be it remote access capabilities or enhanced security features like motion detectors and automatic locking mechanisms.

On the other hand, investing in a completely new automated garage door system presents its own set of advantages despite higher initial costs. These systems come

equipped with advanced safety features such as rolling code technology for secure entry and obstruction detection to prevent accidents. Furthermore, they often include energy-efficient operations that reduce long-term utility expenses—a factor worth considering in today's environmentally conscious world.

New installations also offer seamless integration with comprehensive smart home ecosystems—allowing users not only remote access but also synchronized functionalities alongside lighting controls or climate settings within the house itself.

When evaluating maintenance costs between these options over time; while both require occasional servicing due to wear-and-tear on mechanical parts—the complexity level differs significantly between them which might affect service charges accordingly (i.e., diagnosing issues within highly sophisticated electronics typically demands specialized skill sets).

Ultimately deciding whether one should adapt existing structures versus opting entirely new hinges upon individual circumstances: current condition/age of their present setup; personal preference toward cutting-edge technology; available financial resources etc.. It's essential each homeowner carefully assesses what aligns best given unique needs before making informed decisions concerning their property investments!

In conclusion: balancing practicality against innovation remains key when evaluating whether convert conventional garages into tech-savvy spaces through either adaptation installation altogether anew!

In recent years, the realm of garage door technology has undergone a significant transformation, driven by the relentless march of innovation and the increasing demand for convenience and security. As we peer into the future, it's clear that adapting traditional garage doors for modern automation will be at the forefront of these technological advancements. This evolution is not just about incorporating sophisticated systems but also about reimagining how our garages interact with us and our smart homes.

The first wave of innovation in this space is likely to focus on integrating smart technologies that enhance user convenience. Traditional garage doors, once solely operated via remote controls or manual efforts, are now being equipped with internet-connected devices. These allow homeowners to control their garage doors remotely through smartphone apps or voice-activated assistants like Amazon's Alexa or Google Assistant. The ease of opening and closing a garage door from anywhere in the world not only adds a layer of convenience but also ensures peace of mind when it comes to home security.

Furthermore, as we adapt these traditional structures for modern needs, safety features are becoming increasingly sophisticated. The latest innovations include

sensors that can detect obstructions and stop a closing door automatically to prevent accidents. Future trends indicate an increase in machine learning algorithms that could predict malfunctions before they occur, alerting homeowners to necessary maintenance tasks before they become urgent repairs.

Energy efficiency is another critical area where garage door technology is poised for change. Modern automated systems will likely incorporate solar panels or other renewable energy sources to power their operations sustainably. Moreover, improved insulation materials and designs could help maintain optimal temperatures inside garages, reducing overall household energy consumption.

One potential innovation lies in the realm of biometric access control systems. Fingerprint scanners or facial recognition technology may soon replace traditional keypads or remotes entirely. Such advancements would provide unparalleled security by ensuring that only authorized individuals can operate the door while simultaneously keeping track of who enters and exits.

Additionally, as smart homes become more interconnected ecosystems, it's anticipated that future garage doors will seamlessly integrate with other home automation systems. For instance, your home's security system might automatically lock all entry points if your smart garage door senses you've left for work without manually activating any alarms.

Finally, augmented reality (AR) could revolutionize how we interact with our garages altogether. Imagine using an AR application on your smartphone to visualize where you should park based on available space within your garage optimizing storage solutions even further than before!

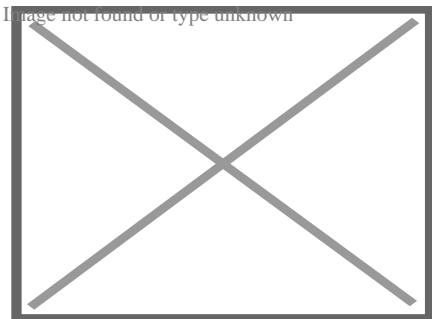
In conclusion, as we look ahead at future trends in garage door technology and potential innovations aimed at adapting traditional doors for modern automation purposes—there's no denying this industry holds tremendous promise! By embracing cutting-edge technologies like IoT devices combined with enhanced safety measures plus sustainable practices alongside seamless integration into broader smart-home networks—we stand ready today facing tomorrow's challenges head-on: transforming what was once merely functional into something truly extraordinary!

About light-emitting diode

This article is about the electronic device. For specific use in lighting, see LED lamp.

"LED" and "Led" redirect here. For other uses, see LED (disambiguation).

Light-emitting diode



Blue, green, and red LEDs in 5 mm diffused cases. There are many different variants of LEDs.

Working principle

Electroluminescence

Inventor

- H. J. Round (1907)[¹]
- Oleg Losev (1927)[²]
- James R. Biard (1961)[³]
- Nick Holonyak (1962)[⁴]

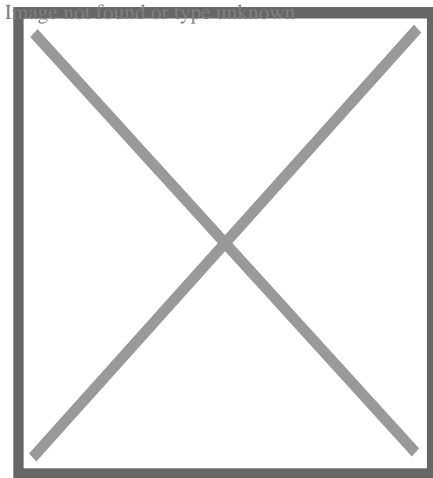
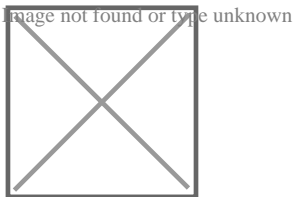
First production

October 1962; 62 years ago

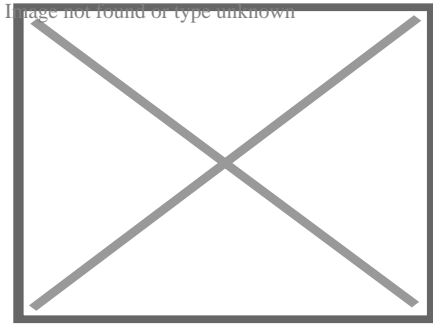
Pin names

Anode and cathode

Electronic symbol



Parts of a conventional LED. The flat bottom surfaces of the anvil and post embedded inside the epoxy act as anchors, to prevent the conductors from being forcefully pulled out via mechanical strain or vibration.



Close-up image of a surface-mount LED

Close-up of an LED with the voltage being increased and decreased to show a detailed view of its operation

Modern LED retrofit with E27 screw in base

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A bulb-shaped modern retrofit LED lamp with aluminum heat sink, a light diffusing dome and E27 screw base, using a built-in power supply working on mains voltage

A **light-emitting diode (LED)** is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor.^[5] White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.^[6]

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared (IR) light.^[7] Infrared LEDs are used in remote-

control circuits, such as those used with a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red.

Early LEDs were often used as indicator lamps, replacing small incandescent bulbs, and in seven-segment displays. Later developments produced LEDs available in visible, ultraviolet (UV), and infrared wavelengths with high, low, or intermediate light output, for instance, white LEDs suitable for room and outdoor lighting. LEDs have also given rise to new types of displays and sensors, while their high switching rates are useful in advanced communications technology with applications as diverse as aviation lighting, fairy lights, strip lights, automotive headlamps, advertising, general lighting, traffic signals, camera flashes, lighted wallpaper, horticultural grow lights, and medical devices.^[8]

LEDs have many advantages over incandescent light sources, including lower power consumption, a longer lifetime, improved physical robustness, smaller sizes, and faster switching. In exchange for these generally favorable attributes, disadvantages of LEDs include electrical limitations to low voltage and generally to DC (not AC) power, the inability to provide steady illumination from a pulsing DC or an AC electrical supply source, and a lesser maximum operating temperature and storage temperature.

LEDs are transducers of electricity into light. They operate in reverse of photodiodes, which convert light into electricity.

History

[edit]

Main article: History of LEDs

The first LED was created by Soviet inventor Oleg Losev^[9] in 1927, but electroluminescence was already known for 20 years, and relied on a diode made of silicon carbide.

Commercially viable LEDs only became available after Texas Instruments engineers patented efficient near-infrared emission from a diode based on GaAs in 1962.

From 1968, commercial LEDs were extremely costly and saw no practical use. Monsanto and Hewlett-Packard led the development of LEDs to the point where, in the 1970s, a unit cost less than five cents.^[10]

Physics of light production and emission

[edit]

Main article: Light-emitting diode physics

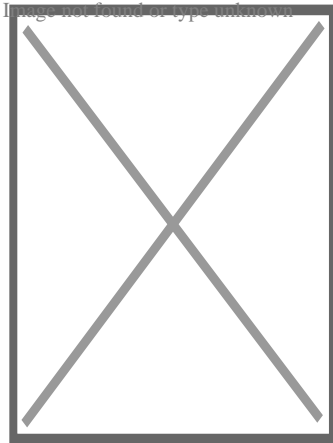
In a light-emitting diode, the recombination of electrons and electron holes in a semiconductor produces light (be it infrared, visible or UV), a process called "electroluminescence". The wavelength of the light depends on the energy band gap of the semiconductors used. Since these materials have a high index of refraction, design features of the devices such as special optical coatings and die shape are required to efficiently emit light.^[11]

Unlike a laser, the light emitted from an LED is neither spectrally coherent nor even highly monochromatic. Its spectrum is sufficiently narrow that it appears to the human eye as a pure (saturated) color.^[12]^[13] Also unlike

most lasers, its radiation is not spatially coherent, so it cannot approach the very high intensity characteristic of lasers.

Single-color LEDs

[edit]

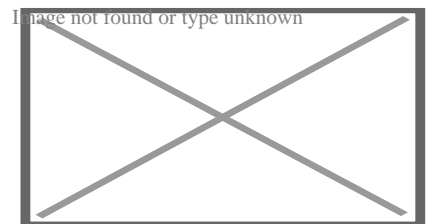


Blue LEDs

By selection of different semiconductor materials, single-color LEDs can be made that emit light in a narrow band of wavelengths from near-infrared through the visible spectrum and into the ultraviolet range. The required operating voltages of LEDs increase as the emitted wavelengths become shorter (higher energy, red to blue), because of their increasing semiconductor band gap.

Blue LEDs have an active region consisting of one or more InGaN quantum wells sandwiched between thicker layers of GaN, called cladding layers. By

External videos



"The Original Blue Video icon LED", Science History Institute

varying the relative In/Ga fraction in the InGaN quantum wells, the light emission can in theory be varied from violet to amber.

Aluminium gallium nitride (AlGaN) of varying Al/Ga fraction can be used to manufacture the cladding and quantum well layers for ultraviolet LEDs, but these devices have not yet reached the level of efficiency and technological maturity of InGaN/GaN blue/green devices. If unalloyed GaN is used in this case to form the active quantum well layers, the device emits near-ultraviolet light with a peak wavelength centred around 365 nm. Green LEDs manufactured from the InGaN/GaN system are far more efficient and brighter than green LEDs produced with non-nitride material systems, but practical devices still exhibit efficiency too low for high-brightness applications. ^[citation needed]

With AlGaN and AlGaN, even shorter wavelengths are achievable. Near-UV emitters at wavelengths around 360–395 nm are already cheap and often encountered, for example, as black light lamp replacements for inspection of anti-counterfeiting UV watermarks in documents and bank notes, and for UV curing. Substantially more expensive, shorter-wavelength diodes are commercially available for wavelengths down to 240 nm.^[14] As the photosensitivity of microorganisms approximately matches the absorption spectrum of DNA, with a peak at about 260 nm, UV LED emitting at 250–270 nm are expected in prospective disinfection and sterilization devices. Recent research has shown that commercially available UVA LEDs (365 nm) are already effective disinfection and sterilization devices.^[15] UV-C wavelengths were obtained in laboratories using aluminium nitride (210 nm),^[16] boron nitride (215 nm)^[17]^[18] and diamond (235 nm).^[19]

White LEDs

[edit]

There are two primary ways of producing white light-emitting diodes. One is to use individual LEDs that emit three primary colors—red, green and blue—and then mix all the colors to form white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, similar to a fluorescent lamp. The yellow phosphor is cerium-doped YAG crystals suspended in the package or coated on the LED. This YAG phosphor causes white LEDs to appear yellow when off, and the space between the crystals allow some blue light to pass through in LEDs with partial phosphor conversion. Alternatively, white LEDs may use other phosphors like manganese(IV)-doped potassium fluorosilicate (PFS) or other engineered phosphors. PFS assists in red light generation, and is used in conjunction with conventional Ce:YAG phosphor.

In LEDs with PFS phosphor, some blue light passes through the phosphors, the Ce:YAG phosphor converts blue light to green and red (yellow) light, and the PFS phosphor converts blue light to red light. The color, emission spectrum or color temperature of white phosphor converted and other phosphor converted LEDs can be controlled by changing the concentration of several phosphors that form a phosphor blend used in an LED package.^{[20][21][22][23]}

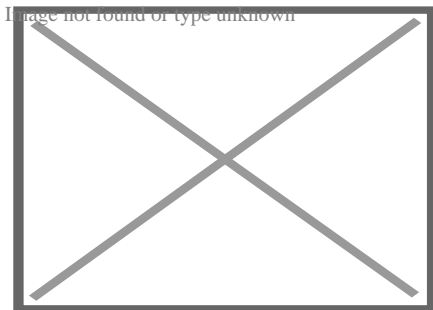
The 'whiteness' of the light produced is engineered to suit the human eye. Because of metamerism, it is possible to have quite different spectra that appear white. The appearance of objects illuminated by that light may vary

as the spectrum varies. This is the issue of color rendition, quite separate from color temperature. An orange or cyan object could appear with the wrong color and much darker as the LED or phosphor does not emit the wavelength it reflects. The best color rendition LEDs use a mix of phosphors, resulting in less efficiency and better color rendering.^[citation needed]

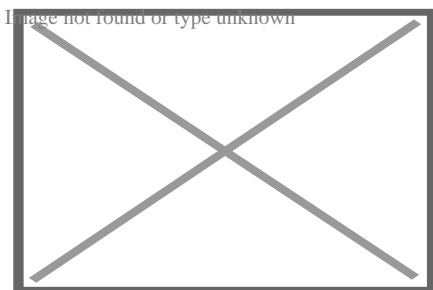
The first white light-emitting diodes (LEDs) were offered for sale in the autumn of 1996.^[24] Nichia made some of the first white LEDs which were based on blue LEDs with Ce:YAG phosphor.^[25] Ce:YAG is often grown using the Czochralski method.^[26]

RGB systems

[edit]



Combined spectral curves for blue, yellow-green, and high-brightness red solid-state semiconductor LEDs. FWHM spectral bandwidth is approximately 24–27 nm for all three colors.



An RGB LED projecting red, green, and blue onto a surface

Mixing red, green, and blue sources to produce white light needs electronic circuits to control the blending of the colors. Since LEDs have slightly different emission patterns, the color balance may change depending on the angle of view, even if the RGB sources are in a single package, so RGB diodes are seldom used to produce white lighting. Nonetheless, this method has many applications because of the flexibility of mixing different colors,^[27] and in principle, this mechanism also has higher quantum efficiency in producing white light.^[28]

There are several types of multicolor white LEDs: di-, tri-, and tetrachromatic white LEDs. Several key factors that play among these different methods include color stability, color rendering capability, and luminous efficacy. Often, higher efficiency means lower color rendering, presenting a trade-off between the luminous efficacy and color rendering. For example, the dichromatic white LEDs have the best luminous efficacy (120 lm/W), but the lowest color rendering capability. Although tetrachromatic white LEDs have excellent color rendering capability, they often have poor luminous efficacy. Trichromatic white LEDs are in between, having both good luminous efficacy (>70 lm/W) and fair color rendering capability.^[29]

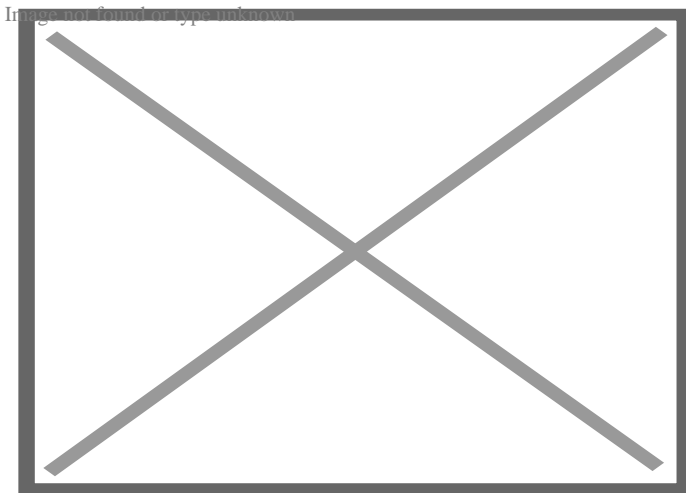
One of the challenges is the development of more efficient green LEDs. The theoretical maximum for green LEDs is 683 lumens per watt but as of 2010 few green LEDs exceed even 100 lumens per watt. The blue and red LEDs approach their theoretical limits. *[citation needed]*

Multicolor LEDs offer a means to form light of different colors. Most perceivable colors can be formed by mixing different amounts of three primary colors. This allows precise dynamic color control. Their emission power decays exponentially with rising temperature,^[30] resulting in a substantial change in color stability. Such problems inhibit industrial use. Multicolor LEDs without phosphors cannot provide good color rendering because each LED is a narrowband source. LEDs without phosphor, while a poorer solution for general lighting, are the best solution for displays, either backlight of LCD, or direct LED based pixels.

Dimming a multicolor LED source to match the characteristics of incandescent lamps is difficult because manufacturing variations, age, and temperature change the actual color value output. To emulate the appearance of dimming incandescent lamps may require a feedback system with color sensor to actively monitor and control the color.^[31]

Phosphor-based LEDs

[edit]



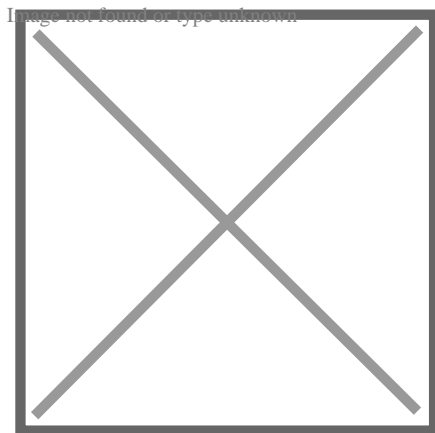
Spectrum of a white LED showing blue light directly emitted by the GaN-based LED (peak at about 465 nm) and the more broadband Stokes-shifted light emitted by the Ce^{3+} :YAG phosphor, which emits at roughly 500–700 nm

This method involves coating LEDs of one color (mostly blue LEDs made of InGaN) with phosphors of different colors to form white light; the resultant LEDs are called phosphor-based or phosphor-converted white LEDs (pcLEDs).^[32] A fraction of the blue light undergoes the Stokes shift, which transforms it from shorter wavelengths to longer. Depending on the original LED's color, various color phosphors are used. Using several phosphor layers of distinct colors broadens the emitted spectrum, effectively raising the color rendering index (CRI).^[33]

Phosphor-based LEDs have efficiency losses due to heat loss from the Stokes shift and also other phosphor-related issues. Their luminous efficacies compared to normal LEDs depend on the spectral distribution of the resultant light output and the original wavelength of the LED itself. For example, the luminous efficacy of a typical YAG yellow phosphor based white LED ranges from 3 to 5 times the luminous efficacy of the original blue LED because of the human eye's greater sensitivity to yellow than to blue (as modeled in the luminosity function).

Due to the simplicity of manufacturing, the phosphor method is still the most popular method for making high-intensity white LEDs. The design and production of a light source or light fixture using a monochrome emitter with phosphor conversion is simpler and cheaper than a complex RGB system, and the majority of high-intensity white LEDs presently on the market are

manufactured using phosphor light conversion. [citation needed]



1 watt 9 volt three chips SMD phosphor based white LED

Among the challenges being faced to improve the efficiency of LED-based white light sources is the development of more efficient phosphors. As of 2010, the most efficient yellow phosphor is still the YAG phosphor, with less than 10% Stokes shift loss. Losses attributable to internal optical losses due to re-absorption in the LED chip and in the LED packaging itself account typically for another 10% to 30% of efficiency loss. Currently, in the area of phosphor LED development, much effort is being spent on optimizing these devices to higher light output and higher operation temperatures. For instance, the efficiency can be raised by adapting better package design or by using a more suitable type of phosphor. Conformal coating process is frequently used to address the issue of varying phosphor thickness. [citation needed]

Some phosphor-based white LEDs encapsulate InGaN blue LEDs inside phosphor-coated epoxy. Alternatively, the LED might be paired with a remote phosphor, a preformed polycarbonate piece coated with the phosphor material. Remote phosphors provide more diffuse light, which is desirable for many applications. Remote phosphor designs are also more tolerant of

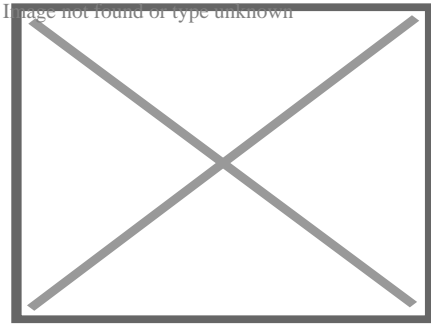
variations in the LED emissions spectrum. A common yellow phosphor material is cerium-doped yttrium aluminium garnet ($\text{Ce}^{3+}:\text{YAG}$).^[citation needed]

White LEDs can also be made by coating near-ultraviolet (NUV) LEDs with a mixture of high-efficiency europium-based phosphors that emit red and blue, plus copper and aluminium-doped zinc sulfide ($\text{ZnS}:\text{Cu, Al}$) that emits green. This is a method analogous to the way fluorescent lamps work. This method is less efficient than blue LEDs with YAG:Ce phosphor, as the Stokes shift is larger, so more energy is converted to heat, but yields light with better spectral characteristics, which render color better. Due to the higher radiative output of the ultraviolet LEDs than of the blue ones, both methods offer comparable brightness. A concern is that UV light may leak from a malfunctioning light source and cause harm to human eyes or skin.^[citation needed]

A new style of wafers composed of gallium-nitride-on-silicon (GaN-on-Si) is being used to produce white LEDs using 200-mm silicon wafers. This avoids the typical costly sapphire substrate in relatively small 100- or 150-mm wafer sizes.^[34] The sapphire apparatus must be coupled with a mirror-like collector to reflect light that would otherwise be wasted. It was predicted that since 2020, 40% of all GaN LEDs are made with GaN-on-Si. Manufacturing large sapphire material is difficult, while large silicon material is cheaper and more abundant. LED companies shifting from using sapphire to silicon should be a minimal investment.^[35]

Mixed white LEDs

[edit]



Tunable white LED array in a floodlight

There are RGBW LEDs that combine RGB units with a phosphor white LED on the market. Doing so retains the extremely tunable color of RGB LED, but allows color rendering and efficiency to be optimized when a color close to white is selected.^[36]

Some phosphor white LED units are "tunable white", blending two extremes of color temperatures (commonly 2700K and 6500K) to produce intermediate values. This feature allows users to change the lighting to suit the current use of a multifunction room.^[37] As illustrated by a straight line on the chromaticity diagram, simple two-white blends will have a pink bias, becoming most severe in the middle. A small amount of green light, provided by another LED, could correct the problem.^[38] Some products are RGBWW, i.e. RGBW with tunable white.^[39]

A final class of white LED with mixed light is dim-to-warm. These are ordinary 2700K white LED bulbs with a small red LED that turns on when the bulb is dimmed. Doing so makes the color warmer, emulating an incandescent light bulb.^[39]

Other white LEDs

[edit]

Another method used to produce experimental white light LEDs used no phosphors at all and was based on homoepitaxially grown zinc selenide (ZnSe) on a ZnSe substrate that simultaneously emitted blue light from its active region and yellow light from the substrate.^[40]

Organic light-emitting diodes (OLEDs)

[edit]

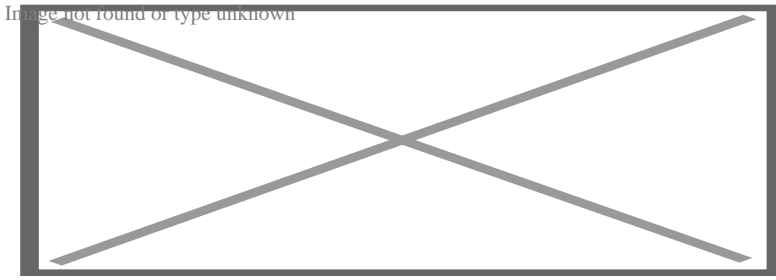
Main article: OLED

In an organic light-emitting diode (OLED), the electroluminescent material composing the emissive layer of the diode is an organic compound. The organic material is electrically conductive due to the delocalization of pi electrons caused by conjugation over all or part of the molecule, and the material therefore functions as an organic semiconductor.^[41] The organic materials can be small organic molecules in a crystalline phase, or polymers.^[42]

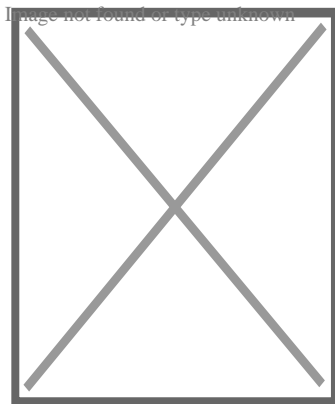
The potential advantages of OLEDs include thin, low-cost displays with a low driving voltage, wide viewing angle, and high contrast and color gamut.^[43] Polymer LEDs have the added benefit of printable and flexible displays.^[44]^[45] ^[46] OLEDs have been used to make visual displays for portable electronic devices such as cellphones, digital cameras, lighting and televisions.^[42]^[43]

Types

[edit]



LEDs are produced in a variety of shapes and sizes. The color of the plastic lens is often the same as the actual color of light emitted, but not always. For instance, purple plastic is often used for infrared LEDs, and most blue devices have colorless housings. Modern high-power LEDs such as those used for lighting and backlighting are generally found in surface-mount technology (SMT) packages (not shown).



A variety of different diffused 5 mm THT-LEDs

- Red, 650 – 625nm
- Orange, 600 – 610nm
- Yellow, 587 – 591nm
- Green, 570 – 575nm
- Blue, 465 – 467nm
- Purple, 395 – 400nm

LEDs are made in different packages for different applications. A single or a few LED junctions may be packed in one miniature device for use as an indicator or pilot lamp. An LED array may include controlling circuits within the same package, which may range from a simple resistor, blinking or color changing control, or an addressable controller for RGB devices. Higher-powered white-emitting devices will be mounted on heat sinks and will be used for illumination. Alphanumeric displays in dot matrix or bar formats are widely available. Special packages permit connection of LEDs to optical fibers for high-speed data communication links.

Miniature

[edit]

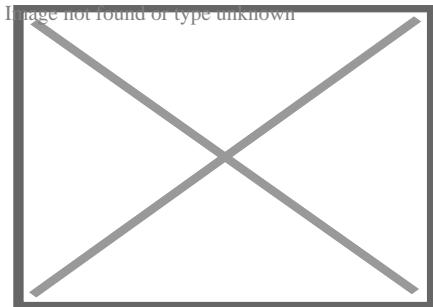
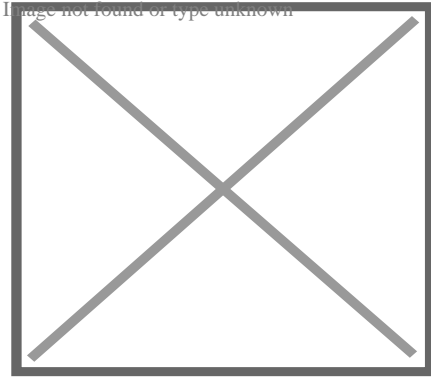


Image of miniature surface mount LEDs in most common sizes. They can be much smaller than a traditional 5 mm lamp type LED, shown on the upper left corner.



Very small (1.6×1.6×0.35 mm) red, green, and blue surface mount miniature LED package with gold wire bonding details

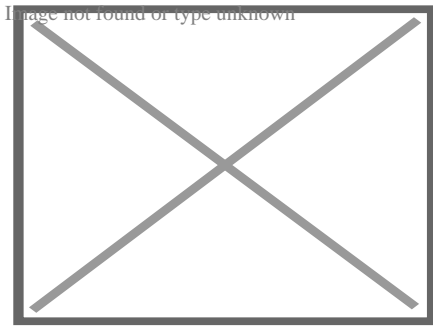
These are mostly single-die LEDs used as indicators, and they come in various sizes from 1.8 mm to 10 mm, through-hole and surface mount packages.^[47] Typical current ratings range from around 1 mA to above 20 mA. LED's can be soldered to a flexible PCB strip to form LED tape popularly used for decoration.

Common package shapes include round, with a domed or flat top, rectangular with a flat top (as used in bar-graph displays), and triangular or square with a flat top. The encapsulation may also be clear or tinted to improve contrast and viewing angle. Infrared devices may have a black tint to block visible light while passing infrared radiation, such as the Osram SFH 4546.^[48]

5 V and 12 V LEDs are ordinary miniature LEDs that have a series resistor for direct connection to a 5 V or 12 V supply.^[49]

High-power

[edit]



High-power light-emitting diodes attached to an LED star base
(Luxeon, Lumileds)

See also: Solid-state lighting, LED lamp, and Thermal management of high-power LEDs

High-power LEDs (HP-LEDs) or high-output LEDs (HO-LEDs) can be driven at currents from hundreds of mA to more than an ampere, compared with the tens of mA for other LEDs. Some can emit over a thousand lumens.^[50]^[51] LED power densities up to 300 W/cm^2 have been achieved. Since overheating is destructive, the HP-LEDs must be mounted on a heat sink to allow for heat dissipation. If the heat from an HP-LED is not removed, the device fails in seconds. One HP-LED can often replace an incandescent bulb in a flashlight, or be set in an array to form a powerful LED lamp.

Some HP-LEDs in this category are the Nichia 19 series, Lumileds Rebel Led, Osram Opto Semiconductors Golden Dragon, and Cree X-lamp. As of September 2009, some HP-LEDs manufactured by Cree exceed 105 lm/W .^[52]

Examples for Haitz's law—which predicts an exponential rise in light output and efficacy of LEDs over time—are the CREE XP-G series LED, which achieved 105 lm/W in 2009^[52] and the Nichia 19 series with a typical efficacy of 140 lm/W , released in 2010.^[53]

AC-driven

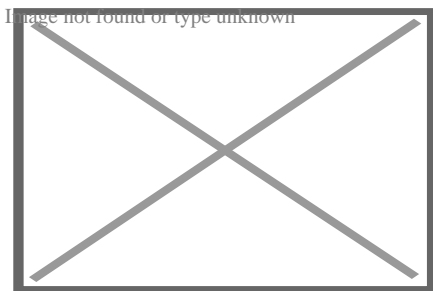
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LEDs developed by Seoul Semiconductor can operate on AC power without a DC converter. For each half-cycle, part of the LED emits light and part is dark, and this is reversed during the next half-cycle. The efficiency of this type of HP-LED is typically 40 lm/W.^[54] A large number of LED elements in series may be able to operate directly from line voltage. In 2009, Seoul Semiconductor released a high DC voltage LED, named 'Acrich MJT', capable of being driven from AC power with a simple controlling circuit. The low-power dissipation of these LEDs affords them more flexibility than the original AC LED design.^[55]

Strip

[edit]

This section is an excerpt from LED strip light.[edit]



Several LED spots being reflected as continuous lighting strip

An LED strip, tape, or ribbon light is a flexible circuit board populated by surface-mount light-emitting diodes (SMD LEDs) and other components that usually comes with an adhesive backing. Traditionally, strip lights had been used solely in accent lighting, backlighting, task lighting, and decorative

lighting applications, such as cove lighting.

LED strip lights originated in the early 2000s. Since then, increased luminous efficacy and higher-power SMDs have allowed them to be used in applications such as high brightness task lighting, fluorescent and halogen lighting fixture replacements, indirect lighting applications, ultraviolet inspection during manufacturing processes, set and costume design, and growing plants.

Application-specific

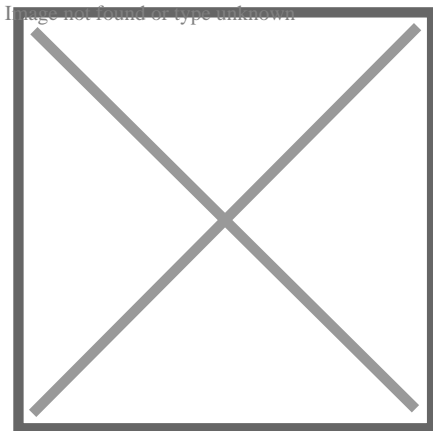
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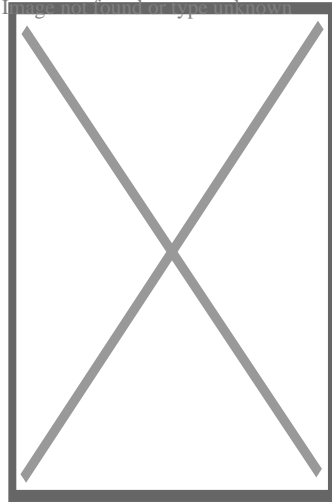


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RGB-SMD-LED



Composite image of an 11 × 44 LED matrix lapel name tag display using 1608/0603-type SMD LEDs. Top: A little over half of the 21 × 86 mm display. Center: Close-up of LEDs in ambient light. Bottom: LEDs in their own red light.

Flashing

Flashing LEDs are used as attention seeking indicators without requiring external electronics. Flashing LEDs resemble standard LEDs but they contain an integrated voltage regulator and a multivibrator circuit that causes the LED to flash with a typical period of one second. In diffused lens LEDs, this circuit is visible as a small black dot. Most flashing LEDs emit light of one color, but more sophisticated devices can flash between multiple colors and even fade through a color sequence using RGB color mixing. Flashing SMD LEDs in the 0805 and other size formats have been available since early 2019.

Flickering

Integrated electronics Simple electronic circuits integrated into the LED package have been around since at least 2011 which produce a random LED intensity pattern reminiscent of a flickering candle.^[56] Reverse engineering in 2024 has suggested that some flickering LEDs with

automatic sleep and wake modes might be using an integrated 8-bit microcontroller for such functionality.^[57]

Bi-color

Bi-color LEDs contain two different LED emitters in one case. There are two types of these. One type consists of two dies connected to the same two leads antiparallel to each other. Current flow in one direction emits one color, and current in the opposite direction emits the other color. The other type consists of two dies with separate leads for both dies and another lead for common anode or cathode so that they can be controlled independently. The most common bi-color combination is red/traditional green. Others include amber/traditional green, red/pure green, red/blue, and blue/pure green.

RGB tri-color

Tri-color LEDs contain three different LED emitters in one case. Each emitter is connected to a separate lead so they can be controlled independently. A four-lead arrangement is typical with one common lead (anode or cathode) and an additional lead for each color. Others have only two leads (positive and negative) and have a built-in electronic controller. RGB LEDs consist of one red, one green, and one blue LED.^[58] By independently adjusting each of the three, RGB LEDs are capable of producing a wide color gamut. Unlike dedicated-color LEDs, these do not produce pure wavelengths. Modules may not be optimized for smooth color mixing.

Decorative-multicolor

Decorative-multicolor LEDs incorporate several emitters of different colors supplied by only two lead-out wires. Colors are switched internally by varying the supply voltage.

Alphanumeric

Alphanumeric LEDs are available in seven-segment, starburst, and dot-matrix format. Seven-segment displays handle all numbers and a limited set of letters. Starburst displays can display all letters. Dot-matrix displays typically use 5×7 pixels per character. Seven-segment LED displays were in widespread use in the 1970s and 1980s, but rising use of liquid crystal displays, with their lower power needs and greater display flexibility, has reduced the popularity of numeric and alphanumeric LED displays.

Digital RGB

Digital RGB addressable LEDs contain their own "smart" control electronics. In addition to power and ground, these provide connections for data-in, data-out, clock and sometimes a strobe signal. These are connected in a daisy chain, which allows individual LEDs in a long LED strip light to be easily controlled by a microcontroller. Data sent to the first LED of the chain can control the brightness and color of each LED independently of the others. They are used where a combination of maximum control and minimum visible electronics are needed such as strings for Christmas and LED matrices. Some even have refresh rates in the kHz range, allowing for basic video applications. These devices are known by their part number (WS2812 being common) or a brand name such as NeoPixel.

Filament

An LED filament consists of multiple LED chips connected in series on a common longitudinal substrate that forms a thin rod reminiscent of a traditional incandescent filament.^[59] These are being used as a low-cost decorative alternative for traditional light bulbs that are being

phased out in many countries. The filaments use a rather high voltage, allowing them to work efficiently with mains voltages. Often a simple rectifier and capacitive current limiting are employed to create a low-cost replacement for a traditional light bulb without the complexity of the low voltage, high current converter that single die LEDs need.^[60] Usually, they are packaged in bulb similar to the lamps they were designed to replace, and filled with inert gas at slightly lower than ambient pressure to remove heat efficiently and prevent corrosion.

Chip-on-board arrays

Surface-mounted LEDs are frequently produced in chip on board (COB) arrays, allowing better heat dissipation than with a single LED of comparable luminous output.^[61] The LEDs can be arranged around a cylinder, and are called "corn cob lights" because of the rows of yellow LEDs.^[62]

Considerations for use

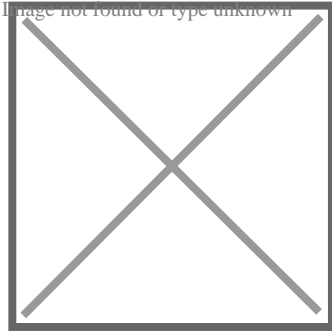
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- Efficiency: LEDs emit more lumens per watt than incandescent light bulbs.^[63] The efficiency of LED lighting fixtures is not affected by shape and size, unlike fluorescent light bulbs or tubes.
- Size: LEDs can be very small (smaller than 2 mm²^[64]) and are easily attached to printed circuit boards.

Power sources

[edit]

Main article: LED power sources



Simple LED circuit with resistor for current limiting

The current in an LED or other diodes rises exponentially with the applied voltage (see Shockley diode equation), so a small change in voltage can cause a large change in current. Current through the LED must be regulated by an external circuit such as a constant current source to prevent damage. Since most common power supplies are (nearly) constant-voltage sources, LED fixtures must include a power converter, or at least a current-limiting resistor. In some applications, the internal resistance of small batteries is sufficient to keep current within the LED rating.^[*citation needed*]

LEDs are sensitive to voltage. They must be supplied with a voltage above their threshold voltage and a current below their rating. Current and lifetime change greatly with a small change in applied voltage. They thus require a current-regulated supply (usually just a series resistor for indicator LEDs).^[⁶⁵]

Efficiency droop: The efficiency of LEDs decreases as the electric current increases. Heating also increases with higher currents, which compromises LED lifetime. These effects put practical limits on the current through an LED in high power applications.^[⁶⁶]

Electrical polarity

[edit]

Main article: Electrical polarity of LEDs

Unlike a traditional incandescent lamp, an LED will light only when voltage is applied in the forward direction of the diode. No current flows and no light is emitted if voltage is applied in the reverse direction. If the reverse voltage exceeds the breakdown voltage, which is typically about five volts, a large current flows and the LED will be damaged. If the reverse current is sufficiently limited to avoid damage, the reverse-conducting LED is a useful noise diode.^{[citation}

By definition, the energy band gap of any diode is higher when reverse-biased than when forward-biased. Because the band gap energy determines the wavelength of the light emitted, the color cannot be the same when reverse-biased. The reverse breakdown voltage is sufficiently high that the emitted wavelength cannot be similar enough to still be visible. Though dual-LED packages exist that contain a different color LED in each direction, it is not expected that any single LED element can emit visible light when reverse-biased.^[citation needed]

It is not known if any zener diode could exist that emits light only in reverse-bias mode. Uniquely, this type of LED would conduct when connected backwards.

Appearance

[edit]

- Color: LEDs can emit light of an intended color without using any color filters as traditional lighting methods need. This is more efficient and can lower initial costs.

- Cool light: In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.
- Color rendition: Most cool-white LEDs have spectra that differ significantly from a black body radiator like the sun or an incandescent light. The spike at 460 nm and dip at 500 nm can make the color of objects appear differently under cool-white LED illumination than sunlight or incandescent sources, due to metamerism,^[67] red surfaces being rendered particularly poorly by typical phosphor-based cool-white LEDs. The same is true with green surfaces. The quality of color rendition of an LED is measured by the Color Rendering Index (CRI).
- Dimming: LEDs can be dimmed either by pulse-width modulation or lowering the forward current.^[68] This pulse-width modulation is why LED lights, particularly headlights on cars, when viewed on camera or by some people, seem to flash or flicker. This is a type of stroboscopic effect.

Light properties

[edit]

- Switch on time: LEDs light up extremely quickly. A typical red indicator LED achieves full brightness in under a microsecond.^[69] LEDs used in communications devices can have even faster response times.
- Focus: The solid package of the LED can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner. For larger LED packages total internal reflection (TIR) lenses are often used to the same effect. When large quantities of light are needed, many light sources such as LED chips are usually deployed, which are difficult to focus or collimate

on the same target.

- Area light source: Single LEDs do not approximate a point source of light giving a spherical light distribution, but rather a Lambertian distribution. So, LEDs are difficult to apply to uses needing a spherical light field. Different fields of light can be manipulated by the application of different optics or "lenses". LEDs cannot provide divergence below a few degrees.^[70]

Reliability

[edit]

- Shock resistance: LEDs, being solid-state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs, which are fragile.^[71]
- Thermal runaway: Parallel strings of LEDs will not share current evenly due to the manufacturing tolerances in their forward voltage. Running two or more strings from a single current source may result in LED failure as the devices warm up. If forward voltage binning is not possible, a circuit is required to ensure even distribution of current between parallel strands.^[72]
- Slow failure: LEDs mainly fail by dimming over time, rather than the abrupt failure of incandescent bulbs.^[73]
- Lifetime: LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be shorter or longer.^[74] Fluorescent tubes typically are rated at about 10,000 to 25,000 hours, depending partly on the conditions of use, and incandescent light bulbs at 1,000 to 2,000 hours. Several DOE demonstrations have shown that reduced maintenance costs from this

extended lifetime, rather than energy savings, is the primary factor in determining the payback period for an LED product.[⁷⁵]

- Cycling: LEDs are ideal for uses subject to frequent on-off cycling, unlike incandescent and fluorescent lamps that fail faster when cycled often, or high-intensity discharge lamps (HID lamps) that require a long time to warm up to full output and to cool down before they can be lighted again if they are being restarted.
- Temperature dependence: LED performance largely depends on the ambient temperature of the operating environment – or thermal management properties. Overdriving an LED in high ambient temperatures may result in overheating the LED package, eventually leading to device failure. An adequate heat sink is needed to maintain long life. This is especially important in automotive, medical, and military uses where devices must operate over a wide range of temperatures, and require low failure rates.

Manufacturing

[edit]

LED manufacturing involves multiple steps, including epitaxy, chip processing, chip separation, and packaging.[⁷⁶]

In a typical LED manufacturing process, encapsulation is performed after probing, dicing, die transfer from wafer to package, and wire bonding or flip chip mounting,[⁷⁷] perhaps using indium tin oxide, a transparent electrical conductor. In this case, the bond wire(s) are attached to the ITO film that has been deposited in the LEDs.

Flip chip circuit on board (COB) is a technique that can be used to manufacture LEDs.^[78]

Colors and materials

[edit]

Conventional LEDs are made from a variety of inorganic semiconductor materials. The following table shows the available colors with wavelength range, voltage drop and material:

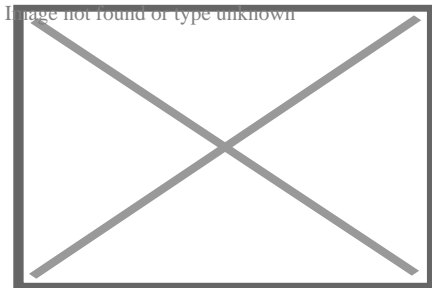
Color	Wavelength (nm)	Voltage (V)	Semiconductor material
Infrared	$\lambda > 760$	$V < 1.9$	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)
Red	$610 < \lambda < 760$	$1.63 < V < 2.03$	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Orange	$590 < \lambda < 610$	$2.03 < V < 2.10$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)

Yellow	570 < λ < 590	2.10 < E _g < 2.18	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Green	500 < λ < 570	1.9 ^[79] < E _g < 4.0	Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN) Gallium(III) phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
Blue	450 < λ < 500	2.48 < E _g < 3.7	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate – (under development)
Violet	400 < λ < 450	2.76 < E _g < 4.0	Indium gallium nitride (InGaN)
Purple	multiple types	2.48 < E _g < 3.7	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic

Ultraviolet	$\lambda < 400$	$3.1 < n < 4.4$	Diamond (235 nm) ^[80] Boron nitride (215 nm) ^[81] ^[82] Aluminium nitride (AlN) (210 nm) ^[16] Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN) – (down to 210 nm) ^[83]
White	Broad spectrum	$2.7 < n < 3.5$	Blue diode with yellow phosphor or violet/UV diode with multi-color phosphor

Applications

[edit]



Daytime running light LEDs of an automobile

LED uses fall into five major categories:

- Visual signals where light goes more or less directly from the source to the human eye, to convey a message or meaning
- Illumination where light is reflected from objects to give visual response of these objects
- Measuring and interacting with processes involving no human vision^[84]

- Narrow band light sensors where LEDs operate in a reverse-bias mode and respond to incident light, instead of emitting light^{[85][86][87][88]}
- Indoor cultivation, including cannabis.^[89]

The application of LEDs in horticulture has revolutionized plant cultivation by providing energy-efficient, customizable lighting solutions that optimize plant growth and development.^[90] LEDs offer precise control over light spectra, intensity, and photoperiods, enabling growers to tailor lighting conditions to the specific needs of different plant species and growth stages. This technology enhances photosynthesis, improves crop yields, and reduces energy costs compared to traditional lighting systems. Additionally, LEDs generate less heat, allowing closer placement to plants without risking thermal damage, and contribute to sustainable farming practices by lowering carbon footprints and extending growing seasons in controlled environments.^[91] Light spectrum affects growth, metabolite profile, and resistance against fungal phytopathogens of *Solanum lycopersicum* seedlings.^[92] LEDs can also be used in micropropagation.^[93]

Indicators and signs

[edit]

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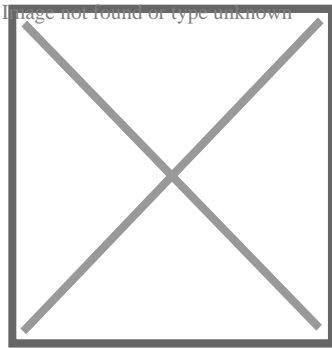


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The low energy consumption, low maintenance and small size of LEDs has led to uses as status indicators and displays on a variety of equipment and

installations. Large-area LED displays are used as stadium displays, dynamic decorative displays, and dynamic message signs on freeways. Thin, lightweight message displays are used at airports and railway stations, and as destination displays for trains, buses, trams, and ferries.



Red and green LED traffic signals

One-color light is well suited for traffic lights and signals, exit signs, emergency vehicle lighting, ships' navigation lights, and LED-based Christmas lights

Because of their long life, fast switching times, and visibility in broad daylight due to their high output and focus, LEDs have been used in automotive brake lights and turn signals. The use in brakes improves safety, due to a great reduction in the time needed to light fully, or faster rise time, about 0.1 second faster^[citation needed] than an incandescent bulb. This gives drivers behind more time to react. In a dual intensity circuit (rear markers and brakes) if the LEDs are not pulsed at a fast enough frequency, they can create a phantom array, where ghost images of the LED appear if the eyes quickly scan across the array. White LED headlamps are beginning to appear. Using LEDs has styling advantages because LEDs can form much thinner lights than incandescent lamps with parabolic reflectors.

Due to the relative cheapness of low output LEDs, they are also used in many temporary uses such as glowsticks and throwies. Artists have also used LEDs for LED art.

Lighting

[edit]

Main article: LED lamp

With the development of high-efficiency and high-power LEDs, it has become possible to use LEDs in lighting and illumination. To encourage the shift to LED lamps and other high-efficiency lighting, in 2008 the US Department of Energy created the L Prize competition. The Philips Lighting North America LED bulb won the first competition on August 3, 2011, after successfully completing 18 months of intensive field, lab, and product testing.^[94]

Efficient lighting is needed for sustainable architecture. As of 2011, some LED bulbs provide up to 150 lm/W and even inexpensive low-end models typically exceed 50 lm/W, so that a 6-watt LED could achieve the same results as a standard 40-watt incandescent bulb. The lower heat output of LEDs also reduces demand on air conditioning systems. Worldwide, LEDs are rapidly adopted to displace less effective sources such as incandescent lamps and CFLs and reduce electrical energy consumption and its associated emissions. Solar powered LEDs are used as street lights and in architectural lighting.

The mechanical robustness and long lifetime are used in automotive lighting on cars, motorcycles, and bicycle lights. LED street lights are employed on poles and in parking garages. In 2007, the Italian village of Torraca was the

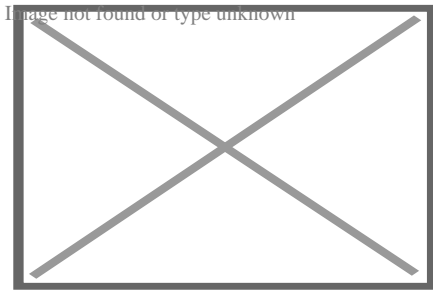
first place to convert its street lighting to LEDs.[⁹⁵]

Cabin lighting on recent [*when?*] Airbus and Boeing jetliners uses LED lighting. LEDs are also being used in airport and heliport lighting. LED airport fixtures currently include medium-intensity runway lights, runway centerline lights, taxiway centerline and edge lights, guidance signs, and obstruction lighting.

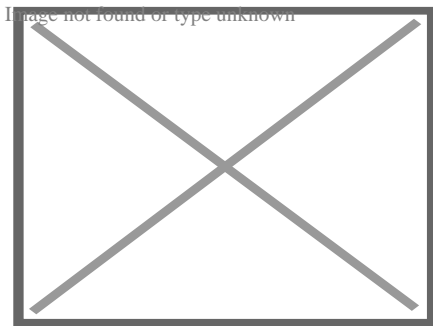
LEDs are also used as a light source for DLP projectors, and to backlight newer LCD television (referred to as LED TV), computer monitor (including laptop) and handheld device LCDs, succeeding older CCFL-backlit LCDs although being superseded by OLED screens. RGB LEDs raise the color gamut by as much as 45%. Screens for TV and computer displays can be made thinner using LEDs for backlighting.[⁹⁶]

LEDs are small, durable and need little power, so they are used in handheld devices such as flashlights. LED strobe lights or camera flashes operate at a safe, low voltage, instead of the 250+ volts commonly found in xenon flashlamp-based lighting. This is especially useful in cameras on mobile phones, where space is at a premium and bulky voltage-raising circuitry is undesirable.

LEDs are used for infrared illumination in night vision uses including security cameras. A ring of LEDs around a video camera, aimed forward into a retroreflective background, allows chroma keying in video productions.



LED for miners, to increase visibility inside mines



Los Angeles Vincent Thomas Bridge illuminated with blue LEDs

LEDs are used in mining operations, as cap lamps to provide light for miners. Research has been done to improve LEDs for mining, to reduce glare and to increase illumination, reducing risk of injury to the miners.^[97]

LEDs are increasingly finding uses in medical and educational applications, for example as mood enhancement.^[98] NASA has even sponsored research for the use of LEDs to promote health for astronauts.^[99]

Data communication and other signalling

[edit]

See also: Li-Fi, fibre optics, Visible light communication, and Optical disc

Light can be used to transmit data and analog signals. For example, lighting white LEDs can be used in systems assisting people to navigate in closed spaces while searching necessary rooms or objects.^[100]

Assistive listening devices in many theaters and similar spaces use arrays of infrared LEDs to send sound to listeners' receivers. Light-emitting diodes (as well as semiconductor lasers) are used to send data over many types of fiber optic cable, from digital audio over TOSLINK cables to the very high bandwidth fiber links that form the Internet backbone. For some time, computers were commonly equipped with IrDA interfaces, which allowed them to send and receive data to nearby machines via infrared.

Because LEDs can cycle on and off millions of times per second, very high data bandwidth can be achieved.^[101] For that reason, visible light communication (VLC) has been proposed as an alternative to the increasingly competitive radio bandwidth.^[102] VLC operates in the visible part of the electromagnetic spectrum, so data can be transmitted without occupying the frequencies of radio communications.

Machine vision systems

[edit]

Main article: Machine vision

Machine vision systems often require bright and homogeneous illumination, so features of interest are easier to process. LEDs are often used.

Barcode scanners are the most common example of machine vision applications, and many of those scanners use red LEDs instead of lasers. Optical computer mice use LEDs as a light source for the miniature camera within the mouse.

LEDs are useful for machine vision because they provide a compact, reliable source of light. LED lamps can be turned on and off to suit the needs of the vision system, and the shape of the beam produced can be tailored to match the system's requirements.

Biological detection

[edit]

The discovery of radiative recombination in aluminum gallium nitride (AlGaN) alloys by U.S. Army Research Laboratory (ARL) led to the conceptualization of UV light-emitting diodes (LEDs) to be incorporated in light-induced fluorescence sensors used for biological agent detection.^[103]^[104]^[105] In 2004, the Edgewood Chemical Biological Center (ECBC) initiated the effort to create a biological detector named TAC-BIO. The program capitalized on semiconductor UV optical sources (SUVOS) developed by the Defense Advanced Research Projects Agency (DARPA).^[105]

UV-induced fluorescence is one of the most robust techniques used for rapid real-time detection of biological aerosols.^[105] The first UV sensors were lasers lacking in-field-use practicality. In order to address this, DARPA incorporated SUVOS technology to create a low-cost, small, lightweight, low-power device. The TAC-BIO detector's response time was one minute from when it sensed a biological agent. It was also demonstrated that the detector could be operated unattended indoors and outdoors for weeks at a time.^[105]

Aerosolized biological particles fluoresce and scatter light under a UV light beam. Observed fluorescence is dependent on the applied wavelength and

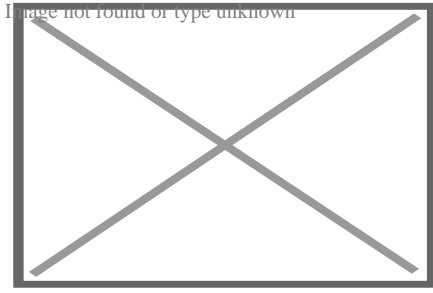
the biochemical fluorophores within the biological agent. UV induced fluorescence offers a rapid, accurate, efficient and logistically practical way for biological agent detection. This is because the use of UV fluorescence is reagentless, or a process that does not require an added chemical to produce a reaction, with no consumables, or produces no chemical byproducts.^[105]

Additionally, TAC-BIO can reliably discriminate between threat and non-threat aerosols. It was claimed to be sensitive enough to detect low concentrations, but not so sensitive that it would cause false positives. The particle-counting algorithm used in the device converted raw data into information by counting the photon pulses per unit of time from the fluorescence and scattering detectors, and comparing the value to a set threshold.^[106]

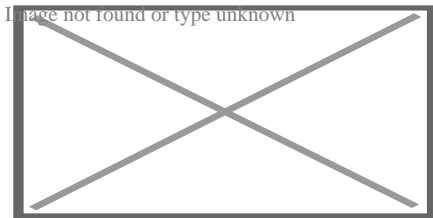
The original TAC-BIO was introduced in 2010, while the second-generation TAC-BIO GEN II, was designed in 2015 to be more cost-efficient, as plastic parts were used. Its small, light-weight design allows it to be mounted to vehicles, robots, and unmanned aerial vehicles. The second-generation device could also be utilized as an environmental detector to monitor air quality in hospitals, airplanes, or even in households to detect fungus and mold.^[107]^[108]

Other applications

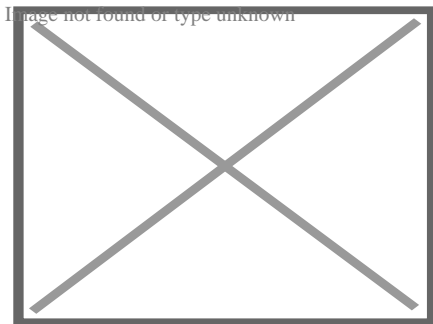
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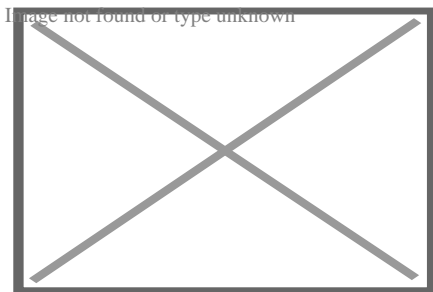
LED costume for stage performers



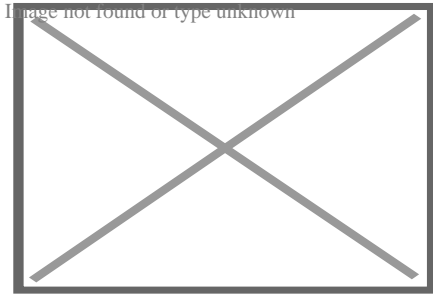
LED wallpaper by Meystyle



A large LED display behind a disc jockey



Seven-segment display that can display four digits and points



LED panel light source used in an early experiment on potato growth during Shuttle mission STS-73 to investigate the potential for growing food on future long duration missions

The light from LEDs can be modulated very quickly so they are used extensively in optical fiber and free space optics communications. This includes remote controls, such as for television sets, where infrared LEDs are often used. Opto-isolators use an LED combined with a photodiode or phototransistor to provide a signal path with electrical isolation between two circuits. This is especially useful in medical equipment where the signals from a low-voltage sensor circuit (usually battery-powered) in contact with a living organism must be electrically isolated from any possible electrical failure in a recording or monitoring device operating at potentially dangerous voltages. An optoisolator also lets information be transferred between circuits that do not share a common ground potential.

Many sensor systems rely on light as the signal source. LEDs are often ideal as a light source due to the requirements of the sensors. The Nintendo Wii's sensor bar uses infrared LEDs. Pulse oximeters use them for measuring oxygen saturation. Some flatbed scanners use arrays of RGB LEDs rather than the typical cold-cathode fluorescent lamp as the light source. Having independent control of three illuminated colors allows the scanner to calibrate itself for more accurate color balance, and there is no need for

warm-up. Further, its sensors only need be monochromatic, since at any one time the page being scanned is only lit by one color of light.

Since LEDs can also be used as photodiodes, they can be used for both photo emission and detection. This could be used, for example, in a touchscreen that registers reflected light from a finger or stylus.^[109] Many materials and biological systems are sensitive to, or dependent on, light. Grow lights use LEDs to increase photosynthesis in plants,^[110] and bacteria and viruses can be removed from water and other substances using UV LEDs for sterilization.^[15] LEDs of certain wavelengths have also been used for light therapy treatment of neonatal jaundice and acne.^[111]

UV LEDs, with spectra range of 220 nm to 395 nm, have other applications, such as water/air purification, surface disinfection, glue curing, free-space non-line-of-sight communication, high performance liquid chromatography, UV curing dye printing, phototherapy (295nm Vitamin D, 308nm Excimer lamp or laser replacement), medical/ analytical instrumentation, and DNA absorption.^{[104][112]}

LEDs have also been used as a medium-quality voltage reference in electronic circuits. The forward voltage drop (about 1.7 V for a red LED or 1.2V for an infrared) can be used instead of a Zener diode in low-voltage regulators. Red LEDs have the flattest I/V curve above the knee. Nitride-based LEDs have a fairly steep I/V curve and are useless for this purpose. Although LED forward voltage is far more current-dependent than a Zener diode, Zener diodes with breakdown voltages below 3 V are not widely available.

The progressive miniaturization of low-voltage lighting technology, such as LEDs and OLEDs, suitable to incorporate into low-thickness materials has fostered experimentation in combining light sources and wall covering surfaces for interior walls in the form of LED wallpaper.

Research and development

[edit]

Key challenges

[edit]

LEDs require optimized efficiency to hinge on ongoing improvements such as phosphor materials and quantum dots.^[113]

The process of down-conversion (the method by which materials convert more-energetic photons to different, less energetic colors) also needs improvement. For example, the red phosphors that are used today are thermally sensitive and need to be improved in that aspect so that they do not color shift and experience efficiency drop-off with temperature. Red phosphors could also benefit from a narrower spectral width to emit more lumens and becoming more efficient at converting photons.^[114]

In addition, work remains to be done in the realms of current efficiency droop, color shift, system reliability, light distribution, dimming, thermal management, and power supply performance.^[113]

Early suspicions were that the LED droop was caused by elevated temperatures. Scientists showed that temperature was not the root cause of

efficiency droop.^[115] The mechanism causing efficiency droop was identified in 2007 as Auger recombination, which was taken with mixed reaction.^[66] A 2013 study conclusively identified Auger recombination as the cause.^[116]

Potential technology

[edit]

A new family of LEDs are based on the semiconductors called perovskites. In 2018, less than four years after their discovery, the ability of perovskite LEDs (PLEDs) to produce light from electrons already rivaled those of the best performing OLEDs.^[117] They have a potential for cost-effectiveness as they can be processed from solution, a low-cost and low-tech method, which might allow perovskite-based devices that have large areas to be made with extremely low cost. Their efficiency is superior by eliminating non-radiative losses, in other words, elimination of recombination pathways that do not produce photons; or by solving outcoupling problem (prevalent for thin-film LEDs) or balancing charge carrier injection to increase the EQE (external quantum efficiency). The most up-to-date PLED devices have broken the performance barrier by shooting the EQE above 20%.^[118]

In 2018, Cao et al. and Lin et al. independently published two papers on developing perovskite LEDs with EQE greater than 20%, which made these two papers a mile-stone in PLED development. Their device have similar planar structure, i.e. the active layer (perovskite) is sandwiched between two electrodes. To achieve a high EQE, they not only reduced non-radiative recombination, but also utilized their own, subtly different methods to improve the EQE.^[118]

In the work of Cao *et al.*,^[119] researchers targeted the outcoupling problem, which is that the optical physics of thin-film LEDs causes the majority of light generated by the semiconductor to be trapped in the device.^[120] To achieve this goal, they demonstrated that solution-processed perovskites can spontaneously form submicrometre-scale crystal platelets, which can efficiently extract light from the device. These perovskites are formed via the introduction of amino acid additives into the perovskite precursor solutions. In addition, their method is able to passivate perovskite surface defects and reduce nonradiative recombination. Therefore, by improving the light outcoupling and reducing nonradiative losses, Cao and his colleagues successfully achieved PLED with EQE up to 20.7%.^[119]

Lin and his colleague used a different approach to generate high EQE. Instead of modifying the microstructure of perovskite layer, they chose to adopt a new strategy for managing the compositional distribution in the device—an approach that simultaneously provides high luminescence and balanced charge injection. In other words, they still used flat emissive layer, but tried to optimize the balance of electrons and holes injected into the perovskite, so as to make the most efficient use of the charge carriers. Moreover, in the perovskite layer, the crystals are perfectly enclosed by MABr additive (where MA is CH_3NH_3). The MABr shell passivates the nonradiative defects that would otherwise be present perovskite crystals, resulting in reduction of the nonradiative recombination. Therefore, by balancing charge injection and decreasing nonradiative losses, Lin and his colleagues developed PLED with EQE up to 20.3%.^[121]

Health and safety

[edit]

Certain blue LEDs and cool-white LEDs can exceed safe limits of the so-called blue-light hazard as defined in eye safety specifications such as "ANSI/IESNA RP-27.1-05: Recommended Practice for Photobiological Safety for Lamp and Lamp Systems".^[122] One study showed no evidence of a risk in normal use at domestic illuminance,^[123] and that caution is only needed for particular occupational situations or for specific populations.^[124] In 2006, the International Electrotechnical Commission published *IEC 62471 Photobiological safety of lamps and lamp systems*, replacing the application of early laser-oriented standards for classification of LED sources.^[125]

While LEDs have the advantage over fluorescent lamps, in that they do not contain mercury, they may contain other hazardous metals such as lead and arsenic.^[126]

In 2016 the American Medical Association (AMA) issued a statement concerning the possible adverse influence of blueish street lighting on the sleep-wake cycle of city-dwellers. Critics in the industry claim exposure levels are not high enough to have a noticeable effect.^[127]

Environmental issues

[edit]



- Light pollution: Because white LEDs emit more short wavelength light than sources such as high-pressure sodium vapor lamps, the increased blue and green sensitivity of scotopic vision means that white LEDs used in

outdoor lighting cause substantially more sky glow.^[55]

- Impact on wildlife: LEDs are much more attractive to insects than sodium-vapor lights, so much so that there has been speculative concern about the possibility of disruption to food webs.^[128]^[129] LED lighting near beaches, particularly intense blue and white colors, can disorient turtle hatchlings and make them wander inland instead.^[130] The use of "turtle-safe lighting" LEDs that emit only at narrow portions of the visible spectrum is encouraged by conservancy groups in order to reduce harm.^[131]
- Use in winter conditions: Since they do not give off much heat in comparison to incandescent lights, LED lights used for traffic control can have snow obscuring them, leading to accidents.^[132]^[133]

See also

[edit]

-  [Electronics portal](#)
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-  [Energy portal](#)
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- LED tattoo
- High-CRI LED lighting
- List of light sources
- MicroLED
- Superluminescent diode
- Perovskite light-emitting diode

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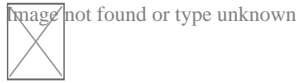
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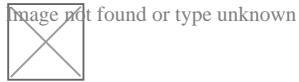
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Lighting

Concepts

- Accent lighting
- Color rendering index
- Color temperature
- Electric light
- Glare
- Light fixture
- Light pollution
 - Hawaii
 - Hong Kong
- Lightbulb socket
 - Bi-pin lamp base
 - Edison screw
- Luminous efficacy
- Task lighting

- Incandescent
 - Regular
 - Edison
 - Halogen
 - Nernst
 - Cathodoluminescent
 - Electron-stimulated
 - Chemiluminescent
 - Electrochemiluminescence
 - Electroluminescent
 - field-induced polymer
- Luminescent
 - Fluorescent
 - Fluorescent lamp (compact)
 - Fluorescent induction
 - Photoluminescent
 - Laser headlamp
 - Radioluminescence
 - Solid-state
 - LED lamp
 - Acetylene/Carbide
 - Argand
 - Campfire
 - Candle
 - Carcel
 - Diya
 - Flare
 - Gas
 - Kerosene
 - Petromax
 - Lantern

Stationary

- Reflector
 - Ellipsoidal reflector
 - Multifaceted reflector
 - Parabolic aluminized reflector (PAR)
- Aviation obstruction
- Balanced-arm lamp
- Chandelier
- Emergency light
- Gas lighting
- Gooseneck lamp
- Intelligent street lighting
- Light tube
- Nightlight
- Neon lighting
- Pendant light
- Recessed light
- Sconce
- Street light
 - in the US
- Torchère
- Track lighting
- Troffer

Portable

- Bicycle lighting
- Flashlight
 - Mechanically powered
 - Tactical
- Glow stick
- Headlamp
 - outdoor
- Lantern
- Laser pointer
- Navigation light
- Searchlight
- Solar lamp
- Automotive light bulb types
- Daytime running lamp
- Headlamp
 - hidden
 - high-intensity discharge
 - sealed beam

Automotive

- Rear position lights
- Reversing lights
- Safety reflector
 - retroreflector
- Stop lights
- Turn signals
 - trafficators

- Aroma lamp
 - Blacklight
 - Bubble light
 - Christmas lights
 - Crackle tube
 - DJ lighting
 - Electroluminescent wire
 - Lava lamp
 - Marquee
 - Plasma globe
 - Strobe light
 - Floodlight
 - Footlight
 - Gobo
 - Scoop
 - Spotlight
 - ellipsoidal reflector
 - Stage lighting instrument
 - Germicidal
 - Grow light
 - Infrared lamp
 - Stroboscope
 - Tanning
- **Display**
 - **Decorative**
 - **Theatrical**
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Related topics

- Battlefield illumination
- Bioluminescence
- Laser
- Light art
- Luminous gemstones
- Signal lamp
- Sources
 - Reflected

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Display technology

**Past
generation**

- Eidophor
- Cathode-ray tube (CRT)
- Jumbotron
- Electroluminescent display (ELD)
- Rear-projection display
- Plasma display panel (PDP)
 - ALiS
- Quantum dot display (QLED)
- Electronic paper
 - E Ink
 - Gyricon
- Light-emitting diode display (LED)
 - Organic light-emitting diode (OLED)
 - Active-Matrix Organic light-emitting diode (AMOLED)

**Current
generation**

- Liquid-crystal display (LCD)
 - TFT
 - TN
 - IPS

**Video
displays**

- LED-backlit
- Blue Phase
- Digital Light Processing (DLP)
- Liquid crystal on silicon (LCoS)
- microLED
- Electroluminescent Quantum Dots (ELQD/QD-LED)
- Organic light-emitting transistor (OLET)
- Surface-conduction electron-emitter display (SED)

- Electromechanical
 - Flip-dot
 - Split-flap
- Eggcrate
- Fiber-optic
- Nixie tube
- Vacuum fluorescent display (VFD)

Non-video

- Light-emitting electrochemical cell (LEC)
- Lightguide display
- Dot-matrix display
- Seven-segment display (SSD)
- Eight-segment display
- Nine-segment display
- Fourteen-segment display (FSD)
- Sixteen-segment display (SISD)
- Stereoscopic
- Autostereoscopic
- Multiscopic
- Hologram

3D display

- Holographic display
 - Computer-generated holography
- Volumetric
- Fog display

**Static
media**

- Monoscope
- Movie projector
- Neon sign
- Slide projector
- Transparency
- Laser beam
- EDID

**Display
capabilities**

- CEA-861
- DisplayID
- Always-on display
- See-through display
- Scan line
- History of display technology
- Large-screen television technology

**Related
articles**

- Optimum HDTV viewing distance
- High Dynamic Range (HDR)
- Color Light Output
- Flexible display
- Comparison of CRT, LCD, plasma, and OLED displays

Comparison of display technology

- v
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- e

Electronic components

**MOS
transistors**

- Transistor
- NMOS
- PMOS
- BiCMOS
- BioFET
- Chemical field-effect transistor (ChemFET)
- Complementary MOS (CMOS)
- Depletion-load NMOS
- Fin field-effect transistor (FinFET)
- Floating-gate MOSFET (FGMOS)
- Insulated-gate bipolar transistor (IGBT)
- ISFET
- LDMOS
- MOS field-effect transistor (MOSFET)
- Multi-gate field-effect transistor (MuGFET)
- Power MOSFET
- Thin-film transistor (TFT)
- VMOS
- UMOS
- Bipolar junction transistor (BJT)
- Darlington transistor
- Diffused junction transistor
- Field-effect transistor (FET)
 - Junction Gate FET (JFET)
 - Organic FET (OFET)

**Other
transistors**

- Light-emitting transistor (LET)
 - Organic LET (OLET)
- Pentode transistor
- Point-contact transistor

Voltage regulators

- Linear regulator
- Low-dropout regulator
- Switching regulator
- Buck
- Boost
- Buck-boost
- Split-pi
- Āâ€Āçâ,-Ā uk
- SEPIC
- Charge pump
- Switched capacitor
- Acorn tube
- Audion
- Beam tetrode
- Barretter
- Compactron
- Diode
- Fleming valve
- Neutron tube

Vacuum tubes

- Nonode
- Nuvistor
- Pentagrid (Hexode, Heptode, Octode)
- Pentode
- Photomultiplier
- Phototube
- Tetrode
- Triode

- Backward-wave oscillator (BWO)
- Cavity magnetron
- Crossed-field amplifier (CFA)
- Gyrotron

**Vacuum tubes
(RF)**

- Inductive output tube (IOT)
- Klystron
- Maser
- Sutton tube
- Traveling-wave tube (TWT)
- X-ray tube
- Beam deflection tube
- Charactron
- Iconoscope
- Magic eye tube

**Cathode-ray
tubes**

- Monoscope
- Selectron tube
- Storage tube
- Trochotron
- Video camera tube
- Williams tube

**Gas-filled
tubes**

- Cold cathode
- Crossatron
- Dekatron
- Ignitron
- Krytron
- Mercury-arc valve
- Neon lamp
- Nixie tube
- Thyatron
- Trigatron
- Voltage-regulator tube
- Potentiometer

Adjustable

- digital
- Variable capacitor
- Varicap

- Connector
 - audio and video
 - electrical power
 - RF
- Electrolytic detector
- Ferrite
- Antifuse
- Fuse
 - resettable
 - eFUSE
- Resistor
- Switch
- Thermistor
- Transformer
- Varistor
- Wire
 - Wollaston wire
- Capacitor
 - types
- Ceramic resonator
- Crystal oscillator

Passive

Reactive

- Inductor
- Parametron
- Relay
 - reed relay
 - mercury relay

○ Germany

○ Japan

○ Czech Republic

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About Overhead Door Company of Joliet

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Things To Do in Will County

Photo

Joliet Area Historical Museum

4.6 (679)

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Joliet Iron Works Park

4.6 (148)

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Route 66 Park

4.3 (435)

Photo

Gaylord Building Historic Site

4.8 (209)

Photo

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Isle A La Cache Museum Pavilion

5 (1)

Photo

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Dellwood Park

4.7 (1975)

Photo

Route 66 Experience Sign

3.7 (3)

Driving Directions in Will County

Driving Directions From Honorable Bennett Braun to Overhead Door Company of Joliet

Driving Directions From Pep Boys to Overhead Door Company of Joliet

Driving Directions From MainStay Suites Joliet I-80 to Overhead Door Company of Joliet

Driving Directions From Dollar General to Overhead Door Company of Joliet

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Driving Directions From Joliet Iron Works Historic Site to Overhead Door Company of Joliet

Driving Directions From Will County Historical Museum and Research Center to Overhead Door Company of Joliet

Driving Directions From Gemini Giant to Overhead Door Company of Joliet

Driving Directions From Knoch Knolls Nature Center to Overhead Door Company of Joliet

Driving Directions From Gemini Giant to Overhead Door Company of Joliet

Driving Directions From Illinois State Museum–Lockport Gallery to Overhead Door Company of Joliet

Driving Directions From Old Joliet Prison to Overhead Door Company of Joliet

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Reviews for Overhead Door Company of Joliet

Overhead Door Company of Joliet

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Andrea Nitsche

(4)

Scheduling was easy, job was done quickly. Little disappointed that they gave me a quote over email (which they confirmed was for labor and materials), but when they finished it was just over \$30 more. Not a huge deal, but when I asked why, I was told they gave me an approx cost and it depends on what is needed. I get that in general, however, they installed the door and I gave them my address and pics of the existing prior to getting a quote. I feel like they could have been more upfront with pricing. And just a heads up, it was pricey... Had them change the weather stripping,

from ringing my doorbell to pulling out my driveway when done was literally 20 mins, cost was just over \$260

Overhead Door Company of Joliet

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Kelley Jansa

(5)

We used Middleton Door to upgrade our garage door. We had three different companies come out to quote the job and across the board Middleton was better. They were professional, had plenty of different options and priced appropriately. The door we ordered came with a small dent and they handled getting a new panel ordered and reinstalled very quickly.

Overhead Door Company of Joliet

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Jim Chuporak

(5)

Received a notice the morning of telling me when to expect the men to come and put the door in. he was on time, answered all my questions, worked diligently in the cold. And did an absolutely awesome job. Everything was cleaned up, hauled away from the old door. I am extremely happy with the service I received from the first phone call I made through having the door put in. My wife and I are very, very happy with the door.

Overhead Door Company of Joliet

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Owen McCarthy

(5)

I called the office just by chance to see if there was an available opening for a service call to repair a busted spring. Unfortunately I didn't catch the name of the person who answered, but she couldn't have been more pleasant and polite. She was able to get a tech to my house in an hour. I believe

the tech's name was Mike and he too was amazing. He quickly resolved my issue and even corrected a couple of things that he saw that weren't quite right. I would recommend to anyone and will definitely call on Middleton for any future needs. Thank you all for your great service.

Overhead Door Company of Joliet

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Hector Melero

(5)

Had a really great experience with Middleton Overhead Doors. My door started to bow and after several attempts on me fixing it I just couldn't get it. I didn't want to pay on something I knew I could fix. Well, I gave up and they came out and made it look easy. I know what they are doing not to mention they called me before hand to confirm my appointment and they showed up at there scheduled appointment. I highly recommend Middleton Overhead Doors on any work that needs to be done

Adapting Traditional Doors for Modern Automation [View GBP](#)

Check our other pages :

- [Identifying Unique Aspects of Contemporary Designs](#)
- [Adapting Traditional Doors for Modern Automation](#)
- [Steps for Integrating Smartphone Access Controls](#)
- [Characteristics of Carriage House Style Garage Doors](#)

Frequently Asked Questions

What are the key components needed to automate a traditional garage door?

To automate a traditional garage door, you typically need an electric garage door opener, compatible smart home integration (such as Wi-Fi or Bluetooth-enabled devices), sensors for safety (like motion and obstruction detectors), and remote controls or smartphone apps for operation.

Can any traditional garage door be adapted for modern automation?

Most traditional garage doors can be adapted for modern automation; however, the condition of the door and its compatibility with available openers are crucial. Older or damaged doors may require reinforcement or replacement parts to ensure safe and effective operation.

How do I ensure safety when automating my garage door?

To ensure safety, install sensors that detect obstructions in the path of the closing door, regularly maintain mechanical components to avoid malfunctions, and secure your system with encrypted connections if its connected to a smart home network. Additionally, keep manual overrides accessible in case of power outages.

What are potential challenges when adapting a traditional garage door for automation?

Challenges may include compatibility issues between old hardware and new technology, potential structural adjustments needed for older doors, ensuring reliable connectivity if using smart features, and managing costs associated with upgrading components like springs or tracks.

Overhead Door Company of Joliet

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Google Business Profile

Company Website : **<https://overheaddoorjoliet.com/garage-door-repair-romeoville.aspx>**

Sitemap

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