Bicycle lighting

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Headlight mounted on the handle bar of bicycle

Bicycle lighting is illumination attached to bicycles whose purpose above all is, along with reflectors, to improve the visibility of the bicycle and its rider to other road users under circumstances of poor ambient illumination. A secondary purpose is to illuminate reflective materials such as cat's eyes and traffic signs. A third purpose may be to illuminate the roadway so that the rider can see the way ahead. Serving the latter purposes require much more luminous flux and thus more power.

Many jurisdictions require one or more bicycle lights to be fitted to bicycles ridden at night — generally a white light in the front and a red light at the back.

Early bicycle lighting: candle lamps, oil lamps and carbide lamps

Early bicycle lamps and two early bottle dynamos (1935)

Contents

History


A carbide lamp

The earliest bicycle lamps were oil-powered and started to be manufactured in 1876 for the Ordinary (High-Bicycle) and solid tyred tricycles. From 1896 acetylene gas lighting for bicycles started to be introduced and later in 1899 acetylene gas lamps for the motor-car became popular. Their carbide lamps were powered by acetylene gas, produced by combining calcium carbide with water. The light given was very bright but the lamps required regular maintenance.[1]

From as early as 1888 electric-powered bicycle lamps were manufactured but did not become a viable proposition until 1898. They comprised an incandescent bulb and either a lead-acid battery or a dynamo. Lead-acid batteries were replaced by dry cells and later by alkaline batteries. Dynamos improved in efficiency and reliability, recently being incorporated into the wheel hub, for example. Moulding techniques for plastics also improved, allowing lens optics to be improved and cost reduced. Incandescent bulbs were replaced first by sealed-unit halogen lamps and later by high-output light emitting diodes.

In Germany, it was illegal to use bicycles without a dynamo-based lighting system except on "racing bicycles" below 11 kg.[2] This stimulated the market in Germany for high quality dynamos. Since 5 July 2013, a change in the law allows use of battery-powered lights.

Lighting system

Electrical system

Batteries, either rechargeable or disposable, are often used to power electric bicycle lights. Where batteries are unwanted a magneto is used. In cycling circles the device is called a "dynamo" even though the device does not have a commutator. See section Dynamo systems for details.

Voltages

3 volt: Often supplied by 2 AA or C/D cell batteries.

6 volt: Sometimes 4 AA batteries are used; also supplied from bottle-shaped battery or hub dynamos, and lead-acid batteries

9 volt: Sometimes supplied by a PP3 battery

12 volt: Mostly supplied by sealed lead-acid batteries. The main advantage with this voltage is versatility of the electric system, such as the ability to charge a cell phone battery with a cigar lighter receptacle as cell phones are now becoming more and more needed for users, though 5 volt USB is also used for that purpose too. It also allows electric air compressors to fix flat tires. Some 12 volt dynamos are available too, though their watt rating is underpowered for medium to high watt applications.

Light sources

The simplest bicycle headlights use a tungsten filament incandescent lamp or a halogen incandescent lamp. LEDs and high intensity discharge lights are also used.

Legal requirements

A group of amateur cyclists during a night ride in Chișinău. The great majority of the participants have their front light devices enabled, but only the most powerful ones are visible on the asphalt. The street lights provide a sufficiently bright light, thus reducing the lighting equipment role to being observable in traffic.

Under the International Vienna Convention on Road Traffic (1968) of the United Nations, a bicycle is a vehicle. Article 44 of the Convention stipulates that: "Cycles without an engine in international traffic shall: (c) Be equipped with a red reflecting device at the rear and with devices such that the cycle can show a white or selective-yellow light to the front and a red light to the rear." In some countries, for example France, it may be an offence even to sell a bicycle not fitted with legally compliant lighting system. Germany requires that all bikes over 11 kg be fitted with compliant dynamo lighting systems, but even lightweight bikes are required to be fitted with lights (battery powered lights allowed) except when racing.[3] However, not all countries impose this requirement on cyclists.

Many jurisdictions require bicycles to be fitted with reflectors at point of sale. In the United States this is regulated by the Consumer Product Safety Commission. CPSC compliant reflectors (also commonly fitted in other markets) have three retro-reflective panels positioned at 30° angles. The standard requires a forward-facing white reflector on the front of the bicycle, sideways-facing white reflectors on each wheel, a red reflector mounted on the rear, and yellow reflectors mounted on the front and back of each pedal. Some interpret this as an endorsement of reflector-only night cycling.

Many jurisdictions require the use of a headlight and a rear light or reflector after dark. Most European countries and some US states require front and rear lights at night, while others allow reflectors only at the rear. Some jurisdictions impose requirements on light output and the size of lamp and reflector lenses; some require compliance with standards defined by third parties; some simply stipulate a minimum distance from which any lighting device should be visible. In some jurisdictions such as Germany and the Netherlands, flashing red tail lights are illegal, in others they are allowed.

In the UK, the regulations governing bicycle lights are set out in the Road Vehicles Lighting Regulations 1989[4] and their subsequent amendments, summarized in the Highway Code.[5] The regulations require a white front light, a red rear light, a red rear reflector, and amber/yellow pedal reflectors on the front and rear of both pedals. Reflectors must conform to BS 6102/2 or an equivalent European standard. The situation for lights is more complicated:

- a light with a steady mode is considered approved only if it conforms to BS 6102/3 or an equivalent European standard;
- a light without a steady mode is considered approved only if it flashes at a constant rate of between 60 and 240 flashes per minute and has a luminous intensity of at least 4 candela;

The majority of LED lights available are not approved for UK use since they have steady modes that do not conform to BS 6102/3. It is, however, legal to fit additional lights providing that they are of the correct colour, they do not dazzle other road users and that if they flash, they do so at a constant rate of between 60 and 240 flashes per minute.

National cyclists' organisations such as LAB (US) or CTC (UK)[6] are a source of lighting information.

Safety

The use of lights for night riding is generally recommended or required by authorities as a basic safety precaution, even in a well-lit urban context. Studies show a correlation between collisions and failure to use lights[7] even during daytime.[8]

It has been estimated that 75% of bicycles used in the United States at night do not meet the legal requirements for lighting. In countries where bicycles are used widely for commuting and short trips, such as the Netherlands and Scandinavia, bicycle head- and tail lighting regulation is heavily enforced by the authorities.[9] However, a study from 2013[10] shows that different lighting regulations seem to have little influence on bicycle accident rates, and points out a lack of studies into the safety benefits of bicycle lighting.

Front lighting

LEDs

An LED headlight

Red or yellow LEDs suitable for use as rear lights have been available for many years. Recently, white LEDs which satisfy the requirements for a front light have come on the market, and some jurisdictions have made or are considering making these legally acceptable. Very high-power LEDs are sensitive to overheating and over-driving, if the enclosure or driving electronics are poorly designed. Both of these conditions significantly shorten the LED's lifespan, causing them to dim or completely burn out, and LEDs are expensive to replace. Most LEDs have a higher luminous efficacy than halogen lights, but poorly designed driving electronics can negate the advantage. Electronics are needed for battery-powered LEDs to keep light high while battery voltage declines, and to provide flashing and dimming.

Low-power LEDs are sufficient for riding on well-lit streets, but do not generally project a very bright beam as it is difficult to collimate the output from multiple LEDs into a single usable beam. This can be overcome by using a few very high-power LEDs - each with their own optics. It is now possible to buy LED equivalents for halogen rechargeable systems (including drop-in replacement bulbs), and LED lights for dynamos. On a dynamo, LEDs produce more light than halogen lights at very low speeds (down to 3 km/h according to one manufacturer).

High-power LED systems often include an option to dim the LEDs. This done not by reducing the current but by flashing the LED, reducing the time current flows. By contrast, halving the brightness of a halogen bulb only slightly increases battery life.

Advantages

- High luminous efficacy leading to long battery life for a given brightness
- Lifetime around 50000 hours of operation if current and temperature is managed
- Can be dimmed via current chopping
- Instantaneous turn on/off and blinking

Disadvantages

- Limited light output per single LED - overcome by multi LED lights
- High power LEDs require a constant current source making them more expensive to manufacture but as a result do not dim through use

Low power LED lights are mainly for "being seen", or as an emergency backup, and are the dominant choice for rear lights.

"Alien Eye" home built mountain bike light using standard MR16 5 W 12V LED Lamp

Low-cost battery lights

Low-cost battery lights can be a good choice for occasional use, and usually meet legislative requirements. But the saving can often be negated by poor battery life. These lights are low-power but compensate this to some extent with good optics. Some newer models have LEDs instead of halogen lamps.

Advantages of low-cost battery lights

- Low cost
- Readily available (both lights and batteries)

Disadvantages

- Cost of batteries, unless they are rechargeable. This stops it being "low-cost" due to the amount of batteries used over time.
- Generally low power

Flashlights

There are some high-power flashlights with rechargeable lithium-ion batteries. Although not specifically designed for bicycle use, these are a viable alternative to rechargeable halogen lights, though they are still expensive. They can be fastened to the bicycle handlebars with various mounting devices such as a "lock-block". Although the optics of these flashlights are generally high quality they are still rotationally symmetrical (unlike motor vehicle lights).

Advantages of rechargeable flashlights

- Versatile - can also be used as a flashlight off the bike
- Portable, so theft resistant

Disadvantages

- Limited burn time
- Heavy (rechargeable systems generally separate the weight of the battery from the lamp); weight may be an issue for off-road riders due to vibration
- Optics not optimised for road use
- Sometimes difficult to mount on the bike, which also leads to a safety issue—if a light falls off its mount, it may fall into and block the front wheel and cause it to immediately stop, typically causing the bike to flip.

Halogen lights

Although these lights were primarily designed for off-road use, where they are almost universal, many commuters and transportational cyclists now choose to use high-power halogen front lights which operate from a NiMH, lead-acid, or Li-ion rechargeable battery pack.

A bicycle with a chrome-plated headlight as a styling cue reminiscent to chopper motorcycles.

The lights used by most halogen rechargeable systems are cheap, bright but fairly simple: they project a cone of light (wide and narrow beam options are available) which is good for off-road use but not ideal for road use as it can dazzle oncoming road users. This is why rechargeable halogen lights do not meet legal requirements in some jurisdictions.

Many systems use standard commercial prefocused optics, making a wide range of power and beam width combinations available. Most systems allow simultaneous connection of different lamps - for example, a wide and a narrow beam for off-road riding, or a high- and a low-power beam for road riding.

Advantages of rechargeable halogen systems

- High power output
- Readily available
- Reasonable battery capacity
- Very reliable
- Can usually be easily removed from the bicycle or to prevent theft
- Lamps are cheap and widely available.
- More suitable as an option for seeing ahead, instead of just "being seen".

Disadvantages

- Limited run-time between battery recharges
- Hassle of being certain to keep batteries charged
- Batteries have limited life, typically 500-1000 recharge cycles
- Power cycling reduces lamp life

HID lights

High-intensity discharge (HID) lights were the brightest lights available for bicycles until recently eclipsed by the advances in LED lights. They are very efficient, very bright, but expensive. They also tend to have high power consumption (although they use less power than halogens for higher output), so a relatively limited burn time. Otherwise they have the same advantages and disadvantages as rechargeable halogen systems, and like halogen systems they are designed primarily for off-road use, having rotationally symmetrical beams which cast as much light up as down. An additional disadvantage compared with halogen or LED lights is that the HID lamp does not tolerate repeated strikes, and in many cases does not relight immediately after shutting down. Likewise, should the battery level fall too low, the lamp will shut down rather than dimming. But the longer battery life than halogens tends to negate these problems, as many riders simply switch the light on and leave it running throughout the ride.


A homebrew HID light assembly consisting of a 10 watt HID light (right) and a 30 watt HID light (left) as well as three 1 watt Luxeon high power LEDs

Advantages of rechargeable HID systems

- Very high power output
- High luminous efficacy

Disadvantages

- Expensive
- Lamp requires warm up before reaching full output
- Inefficient on medium power settings
- Unable to run on very low power due to being unable to maintain the arc that generates the light

If using a HID lighting system on the road, lights should be adjusted to avoid dazzling oncoming traffic.

Rear lighting

Filament lamps

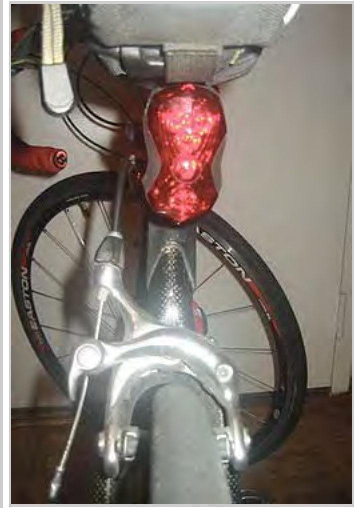
The only real advantage to these is that they are often omnidirectional, a quality useful in running lights which must be visible through a very wide arc. Newer LED lights have this feature, removing even this final advantage. Energizer once made a 2.4W halogen rear lamp, which was essentially a headlamp with a red lens, but most rear lights only need to be around 0.5W.

LEDs

Most LED lights will work in either flashing or steady modes. Some LED lights have multiple banks of LEDs allowing both flashing and steady light at once. This can also be achieved by having one flashing light and one steady one.

In many countries, LED flashers are the norm for rear lights. In others such as Germany and the Netherlands flashing lights are forbidden by law. In the UK flashing LEDs (front and rear) are legal from October 2005, provided that the lights conform to the requirements of the current Road Vehicles Lighting regulations.[11] Many vendors claim EU compliance, however this provides no consistent safety or legal value across the Union.

The most common power source for rear LEDs is a set of alkaline cells and rechargeable cells. In both cases the battery tends to fail quickly when it goes; it is widely considered good practice to have two rear lights in case a battery fails en route.



Rear LED light mounted on the seatpost of a road bicycle

Advantages of LED rear lights

- Compared with incandescent lamps, near-infinite service life
- Bright
- High luminous efficacy
- Cheap
- Usually a choice of flashing or steady

Xenon strobes

An innovation in bicycle lighting, though common in industrial applications, xenon strobes are brighter than LEDs and are used by some as rear lights.

Home built "Red Giant" tail light. 1/2 W LED mounted in a standard reflector

Advantages of xenon strobes

- Very bright

Disadvantages

- Relatively expensive
- High power consumption (short battery life)
- Lamps require fairly frequent replacement
- Intense light can be a serious irritation to other road users
- Brief flash followed by darkness, can interfere with night vision and make judgement of cyclist's position difficult.

Power supplies

Batteries

The introduction of the Low self-discharge NiMH battery (LSD-NiMH) in 2005 made rechargeable AA and AAA sized batteries more viable for powering LED bicycle lights. Previously, the self-discharge effect of NiCAD and NiMH batteries caused the battery to run down over a period of weeks or a few months, even when not in use. This was particularly a problem for low powered LED lights, and for users who only used their bicycle lights occasionally. The LSD-NiMH battery greatly reduced the self-discharge effect, allowing the battery to keep its charge for a year or more.

For higher-powered lights, an external battery pack of 12V VRLA battery is often required. These battery packs usually strap to the top tube of the frame, or come in the shape that fits in a water bottle cage, or can be placed in a basket. A cable connects the battery pack to the light. Another advantage with battery power (especially with 12 volt) is the ability to power other components outside of lighting, as well as all from one battery (as long as they run safe on 12 volts) though wire spaghetti from splicing can be a setback depending on how complicated the electric system is.

Alternatively, Li-ion and LiPo batteries have been becoming more popular with bicyclists due to their higher capacity and lighter weight compared with conventional batteries. More specifically, the 18650 battery, which has been popular with electric car manufacturers (for the same reasons) and are commonly found in laptops and flashlights.

Dynamo systems

Dynamo systems require no batteries and may be permanently fitted to the bike.

Bicycle "dynamos" are actually magnetos and produce alternating current.


Shimano Nexus hub dynamo

Types

There are three main types:

- *Hub dynamos* are built into the front or rear wheel hub. These are generally the most reliable and most efficient of the three types.
- *Bottle dynamos* (or *sidewall dynamos*) attach to the seatstay or fork and are rotated by a small wheel in contact with the tire sidewall. These are easier to retrofit than hub dynamos, but are prone to slipping, especially in wet conditions.
- *Bottom-bracket dynamos* are attached between the chainstays behind the bottom bracket and are powered by a roller against the tire. These are easy to fit and do not wear the tire sidewall.

Other types of dynamos exist, but are less common. For example, there are dynamos that are attached to the fork and driven by the wheel's spokes.

Output and optics

Dynamos are generally limited to about 3 W of output power, although the best 12 V hub dynamos can produce 6 W at speed[12] A bottle dynamo is likely to slip if run at twice the nominal power, a hub dynamo does not have this problem.

At speed a dynamo can overpower the lamp, causing it to fail. Historically this was a nuisance, but modern lamps and dynamos often incorporate Zener diodes to prevent overvoltage, and dynamos can be designed to "saturate" beyond a certain voltage to protect the lamp.

Good dynamos can achieve efficiencies of up to 70% (i.e., under 5 W of the rider's output is diverted to produce 3 W of electricity) and provide good light output at low speeds.

To produce light when the bike is stationary, some dynamo lights have a *stand light* facility, usually a single blue-white (front light) or red (rear light) LED powered by a capacitor, which runs for around five minutes.

Advantages of dynamo lighting

- Usage time not limited by battery life
- No recharging or change of batteries necessary
- More environmentally friendly and inexpensive to run than battery-powered lights

- Typically do not have to be removed when the bicycle is parked

Disadvantages

- Provide no lighting when the bicycle is moving very slowly or is stopped, unless the system is equipped with capacitors or back-up batteries
- Maximum power output obtainable is lower than with batteries
- Difficult to remove by the owner if this is necessary to thwart theft or vandalism, or to use them on more than one bicycle
- Retrofitting a bicycle is more difficult because mounting is more difficult (due to lamp and power source being separate)
- Cheap or poorly aligned dynamos produce noticeable drag
- Old dynamos and lamps did not limit their output voltage, leading to early failure of the incandescent light bulbs in the lamps. Modern lamps and dynamos contain voltage limiters to solve this problem.[13]
- Not suitable for high-power applications outside of lighting, unless designed to recharge an on-board battery.
- Bottle dynamos may be noisy, can be difficult to adjust, can slip under wet conditions, and may wear the sidewall of the tire

Magnetic lights

Lights can be powered through electromagnetic induction. A Danish producer is well known for this and many Danish bikes feature it. The lights are mounted on the bike wheels, eliminating the need for batteries. The advantages are pretty much the same as with dynamo lighting while incurring less resistance to the rider than traditional dynamos and eliminating the noise and wear of the tire.

Supplementary lighting and visibility.

Headtorches

Headtorches are a useful adjunct to bicycle lights. They can be pointed without steering the bike, giving useful "fill-in" lighting especially on poor or very dark roads. They have the added safety benefit of positioning the light higher on the cyclist for increased visibility. They also allow the wearer to read road and directional signs placed on high signposts. However, due to the high position of the light the glare may dazzle oncoming traffic.[14]

Some rechargeable systems offer a head torch option powered from the main battery pack.

Reflective and high-visibility materials

Retro-reflective materials, in the form of fixed reflectors, reflective tape, and reflective clothing, are useful in making a cyclist visible to other road users. Reflective materials can be applied to bike, rider, or luggage; also, tyres are available with reflective sidewalls. Reflectives are visible only when in the beam of a headlight, and even then only within a narrow locus. Importantly, they *do nothing to light up the road*. Reflectors are *not* a substitute for lights, but are an important supplement to portable lighting.

On the bike

Reflectors and reflective tape provide additional visibility (especially when applied to moving parts of the bicycle) and are mandatory in many jurisdictions. Pedal reflectors in particular are very visible to following traffic as they move up and down;[15] unfortunately they are not compatible with most clipless pedal systems, although adaptors are available for some, mainly older SPD models, and a few single-sided designs are available with built-in reflectors. In the UK, where front and rear pedal reflectors are compulsory after dark, most cyclists with clipless pedals are therefore riding illegally. The law is rarely if ever enforced, but could potentially be used in court to reduce financial compensation if the cyclist were to be hit by another vehicle. The CTC have suggested that the requirement should be waived if the cyclist fits an additional rear reflector or lighting, but this was not changed in the last revision of the UK vehicle lighting laws (which permitted flashing LEDs). Riders of recumbent bicycles have pointed out that the pedal reflector requirement is nonsensical for them, since the reflectors point straight up and down in use, and are invisible from other vehicles. As of 2008, California law allows white or yellow shoe reflectors (front and back), or reflective ankle bands, in lieu of pedal reflectors.

Clothing

On dark roads, retroreflective materials such as 3M's Scotchlite will show up boldly in car headlights.

The colour of lighting should be checked in the rider's surroundings. A single solid colour can disappear under artificial light, particularly yellow sodium vapour lighting, and colour blindness is common; red/green colourblindness can make yellow fluorescent vanish against a green background (hedges or grass), although people with red/green colourblindness dispute this. Vests with both yellow and orange fluorescent areas plus wide strips of reflective may be the best solution.

In recent times electroluminescent clothing has become available to add to the existing array of LED-illuminated armbands and helmet blinkies.

An illuminated bicycle jacket made out of clear vinyl, fiber optics, LEDs, and Christmas Lights that improves rider visibility

Measures of light output

Four units are commonly used to describe the light output of commercially available lighting devices:

- electric power, in watts, but this is a poor measure since it reports the consumption rather than the actual light output;
- luminous intensity of the beam in a given direction, in candelas, is a better measure of the output of light in a focused beam;
- total luminous flux emitted in all directions, in lumens is a better measure of the light output of non-directional light;
- illuminance provided to the road at a given distance is a measure of how much the light illuminates the road.

Electric power consumption in watts

The watt (W) is the unit of power, and is usually quoted for the electrical power input, not the light power output. Electrical power is the product of voltage and current (watts = volts × amperes). Input power is only useful when comparing lights of similar technologies. A 3 W halogen dynamo headlight will light the road up about the same as a rechargeable light of around 7–10 W, but the rechargeable usually outputs much more light to the sides, which is useful on trails (although wide and narrow beam versions are available). A 3 W LED is somewhat brighter than a halogen lamp but generally less well focused. HID lights put out large amounts of light and are often quoted in terms like "80 W halogen equivalent".

Luminous intensity in a given direction in candelas

The candela (cd) is the SI unit of luminous intensity, that is power per unit solid angle in a given direction, weighted according to the sensitivity of the human eye to various colours of light. A typical candle produces light with about 1 candela of luminous intensity in all directions. A lamp can produce higher luminous intensity either by producing more light, or by focusing it tighter. The luminous intensity of a light depends on many factors, including the colour of the light and the eye's sensitivity to that colour, the optics involved, reflector and lens. Despite its complexity, it is a more useful measure than watts, because it defines how much usable light is shed in a given place: a dynamo headlight designed for road use and focused for seeing the road makes more efficient use of the power of the lamp than lights using rotationally symmetrical optics.

Total luminous flux in lumens

The lumen (lm) is the SI unit for luminous flux, the total amount of light emitted by a source, weighted according to the sensitivity of the human eye to various colours of light. Lumens per watt is a common measure of the efficacy of a light source. The luminous flux is of less value for bicycle lighting due to the importance of directionality. Luminous intensity is much more useful, but lumens per watt is a handy way to compare the output of otherwise similar lights.

Illuminance at a given distance in lux

The lux (lx) is this SI unit for illuminance, that is the amount of light that illuminates a surface (the road, in the case of a bike light) per unit area at a given point, weighted according to the sensitivity of the human eye to various colours of light. Some manufacturers indicate the illuminance their front lights provide to the road at a point located a standard distance right in front of the bicycle.

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External links

- Bike Current FAQ page (http://www.purl.org/bicycling/FAQ/bikecurrent-FAQ/)

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