Laser Navigation Eye Safety Classification for Optical Mouse Sensor

White Paper

Introduction

The nature of light emitting sources used in products mandates compliance to Optical Radiation Regulations worldwide. The light emitting sources in the products that this document addresses emit sufficiently low levels of optical radiation in a selected wavelength range, only eyes may be at risk; thus, we shall refer to "eye safety" rather than optical radiation safety. The laser used as a light source in an optical mouse must meet eye safety regulations, and correctly classified, to safeguard user safety and prevent any untoward incidents that can seriously harm the user. A product that is incorrectly classified to be safe, and emits radiation accessible to a viewer above the Class 1 level can cause irreversible damage to the viewer's retina.

This white paper will discuss in detail eye safety standards classification, precautions that can be taken, and where Avago Technologies LaserStream optical sensors are Class 1 Eye Safe. Any devices that are above Class 1 are considered hazardous for users.

The International Electrotechnical Commission (IEC) is an international standards organization that oversees, in part, the standards procedures for eye safety regulations. The IEC document that this application note will refer to is IEC 60825-1, Edition 1.2. The European standardization organization has published an identical document that is referred to as EN 60825-1. All European member countries are obliged to publish this European standard as the identical national standard. The IEC standard is also adopted by practically all nations who publish a laser safety standard, including Australia, Japan and Canada.

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The Retinal Hazard Region

The eye is the most sensitive end organ and is generally the most vulnerable to injury because of its imaging characteristics. This is true for all spectral regions, but most particularly in the visible and near infrared parts (or wavelengths) of the spectrum. Together, they are termed as the retinal hazard region. The retinal hazard region wavelength ranges from 400 nm to 1400 nm. Only electromagnetic radiation in this region can present a hazard to the retina. The energy absorbed in the retinas or other parts of the eye can bring about physical and chemical changes; namely thermal damage and photochemical damage.

When we see, energy is absorbed into the retina where most of it is converted into heat. The heat will flow relatively slowly and if the peak temperature is high enough, it can cause disruption of the organic tissue; and a burn or lesion is produced. This is called thermal damage hazard. Thermal damage hazard is the only damage mechanism of concern for Lasers at wavelengths longer than 600 nm. Over the range 400nm to 600nm, for exposure times greater than 10s, there is an additional mechanism; photochemical damage. At wavelengths shorter than 600 nm, photons of high enough energy can break chemical bonds. The resulting will form a new molecule. Usually the molecules formed are not the same as the ones existed before the bonds were broken. Thus, photoreceptor molecules are destroyed. This is called photochemical damage. Thermal damage and photochemical damage are the only hazards of concern when dealing with Blue LEDs.

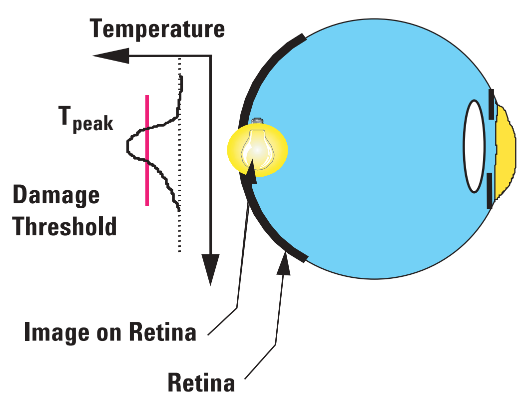


Figure 1. Seeing means energy is absorbed in the retina. This generates heat. Heat flows relatively slowly. If the peak temperature is high enough, a burn or lesion is produced. This may heal, or produce a scar. Scarring means vision loss.

IEC Eye Safety Classification

There are 5 major product classes in the IEC standard with another 2 sub classes. The major product classes are Class 1, 2, 3R, 3B and 4. The sub classes are Class 1M and 2M.

Class 1 No risk to eyes including use of optical instrument. No risk to skin. Laser emitting devices are lasers that are safe under reasonably foreseeable conditions of operation, including the use of optical instruments for intrabeam viewing. Class 1 denotes lasers that do not pose a hazard under normal or single fault conditions.

Class 1M Denotes devices that are safe to view if magnifying viewing aids are not used.

Class 2 No risk to eyes for short time exposure including use of optical instruments. No risk to skin. Lasers emitting visible radiation (400nm to700 nm) where eye protection is normally provided by an aversion response, such as the blink reflex. This means that the low power light is not intended for direct viewing.

Class 2M Equivalent to Class 2 if magnifying viewing aids are not used.

Class 3R Direct intrabeam viewing is potentially hazardous, label must be used.

Class 3B Denotes lasers that can pose a hazard when viewed directly whether magnifying viewing aids are used or not.

Class 4 Devices produce hazards from both direct viewing and reflections. These lasers also pose hazards for skin and can cause fire.

Each Avago Technologies laser product's Light Output Power (LOP) is calibrated individually, to ensure the lasing power meets the Class 1 eye safety limits. This has to be guardbanded to overtemperature value, which is guaranteed in the product datasheet. The mouse with calibrated LOP has to be certified by a recognized 3rd party laboratory in order to declare its meeting Class 1, Certification house such as TUV in Germany and JQA in Japan are some examples of recognize bodies for providing eye safety certification service.

After designing and manufacturing mice, following the recommended circuits and printed circuit board guidelines in Avago Technologies provided documents, 100% production calibration and verification should be performed. Avago Technologies does 100% testings on their packaged Vertical Cavity Surface Emitting Lasers (VCSELs) at 27+/-2ºC to re-ensure that the target optical power of 450uW can be achieved.

IEC Product Classification Labels

Each laser product may carry label(s) to notify users of the laser class; Classes 1 and 1M products may carry such labels, while higher-class products must carry them. The labels shall be permanently fixed, legible and clearly visible during operation of the optical mouse. The labels shall be positioned so that it can be read without exposing the user to potential laser radiation in excess of the AEL for Class 1. The labels' text borders and symbols shall be black on a yellow background except for Class 1 where this color combination need not be used. If the size of the design of the product makes labeling impractical, the label should be included with the user information or on the package or even both.

Class 1 laser products shall each have an affixed and explanatory label bearing the words:

CLASS 1 LASER PRODUCT

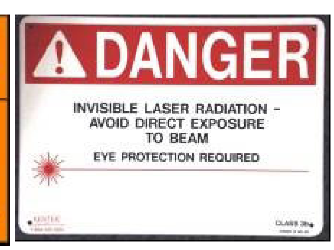
Class 3B (or Class 3R) laser products shall each have an affixed warning label and an explanatory label bearing the words:

LASER RADIATION
AVOID EXPOSURE TO BEAM
CLASS 3B (or CLASS 3R) LASER PRODUCT

Each Class 3R, Class 3B and Class 4 laser product shall have an affixed label close to each aperture through which laser radiation in excess of AEL for Class 1 or Class 2 is emitted. The label (s) shall bear the words:

LASER APERTURE
or
AVOID EXPOSURE – LASER RADIATION
IS EMITTED FROM THIS APERTURE

Each laser product, except those of Class 1 and Class 1M, shall be described on the explanatory label by a statement of the maximum output of laser radiation, the pulse duration (if appropriate) and emitted wavelength(s). The name and publication date of the standard to which the product was classified shall be included on the explanatory label or elsewhere in close proximity on the product. For Class 1 and Class 1M, instead of the labels on the product, the information may be contained in the user information.



Required Information which Affects Eye-Safety Classifications

It is the manufacturer's responsibility to provide the correct classification of a laser product, which shall be based on the following parameters :

Wavelength

In the range from 400 nm to 1400 nm, the minimum value should be used since it yields the most restrictive limit for AEL calculations. This allows for the wavelength spread in the overall VCSEL distribution.

Apparent source size and apparent source angular subtense

These terms refer to how large the source appears to be in linear dimension (size) and subtended angle when viewed from a standard distance of 100 mm. A semiconductor laser such as a VCSEL has a small emitting size (on the order of a few or few 10's of micrometers) and is considered to be a "small source". Thus the minimum angular subtense of 1.5 milliradians is used.

Divergence

The nature of laser beam is collimated, thus the divergence angle is taken as zero; distance is not a factor.

Pulsed vs. Continuous Wave

Pulsed operation has special criteria beyond meeting the average power limit. Short duration, high energy pulses can cause localized damage because the heat generated by the absorption in the retina does not have time to dissipate. Also, there is no significant eye movement to spread heat over a larger area.

Accessible Emission Limit (AEL)

AEL is the maximum accessible emission level permitted within a particular class. AEL values are dependent upon:

1. The wavelength of the LED.
2. The exposure time.
3. The apparent source size of the LED.

The maximum allowed emitted power or energy output is measured in Watts or Joules. This is an emission limit placed on a product, such as the mouse. It allows for a range of viewing conditions such as accommodation distance, use of optical aids, duration of exposure, and the wavelength dependent nature of the injury (chemical or thermal). The equation is in the form:

AEL = constant * wavelength factor * time factor * source size factor

Maximum Permissible Exposure (MPE)

This is the basis for the AELs. The MPE for a set of laser parameters is based on experimentally determined, minimum damage exposure level. This level is decreased to allow for variation in human eye damage susceptibility and experimental error, to which is added a safety margin. Thus, the MPE is the maximum safety exposure for a human. It is specified in energy density units W/m2 or J/m2. It is related to AEL, for example, an AEL Class 1 device is "safe" when viewed under the stated viewing conditions, where "safe" is defined as an exposure below the MPE for that condition. MPE is more useful for setting exposure limits under known viewing conditions. Whereas AEL is useful to specify the emission of a product independent of exact viewing conditions.

What is Single Fault?

Definition

From the IEC specification section 9.1:

The above tests shall be made under each and every reasonably foreseeable single-fault condition; however, faults which result in the emission of radiation in excess of the AEL for a limited period only, and for which it is not reasonably foreseeable that human access to the radiation will occur before the product is taken out of service, need not be considered.

A product is classified not only under a range of operating conditions, but also under reasonably foreseeable single fault conditions. A possible fault may be shown unreasonable if it requires tampering, or is of extremely low probability.

Foreseeable faults must be considered, and those that are not reasonable to occur or would not result in an increased hazard are dropped from consideration. Any remaining faults must be made to be unreasonable (e.g., by redesign, change in manufacturing process), or added to the list of conditions for AEL compliance testing.

Potential Faults

Reasonably foreseeable is not well defined in the standard; judgment must be used to determine which faults qualify. Here is a list of some single fault examples that must be considered:

- Any package pin shorted to GND or VDD
- Any package pin with resistive short to GND or VDD
- Any package pin being exposed to ESD
- Short between adjacent pins
- Loss of laser control due to ESD or other electrical disturbance that could be considered
- Likely or intentional misuse
- Internal circuit failure not caused by an external event
- Multiple failures related to a single event

Design and Additional Precautions

Avago Technologies optical navigation sensor is designed with built-in protection circuitry to cut off power to the VCSEL when there's a short circuit. It is able to detect a short circuit or fault condition at its XY_LASER pin, which could lead to excessive laser power output. A path to ground on this pin will trigger the fault detection circuit, which will turn off the laser drive current source and set the LASER_NEN output high. When used in combination with external components as shown in the block diagram below, the system will prevent excess laser power for a resistive path to ground at XY_LASER by shutting off the laser. In addition to the ground path fault detection described above, the fault detection circuit is continuously checked for proper operation by internally generating a path to ground with the laser turned off via LASER_NEN. If the XY_LASER pin is shorted to VDD3, this test will fail and will be reported as a fault. See Figure 2.

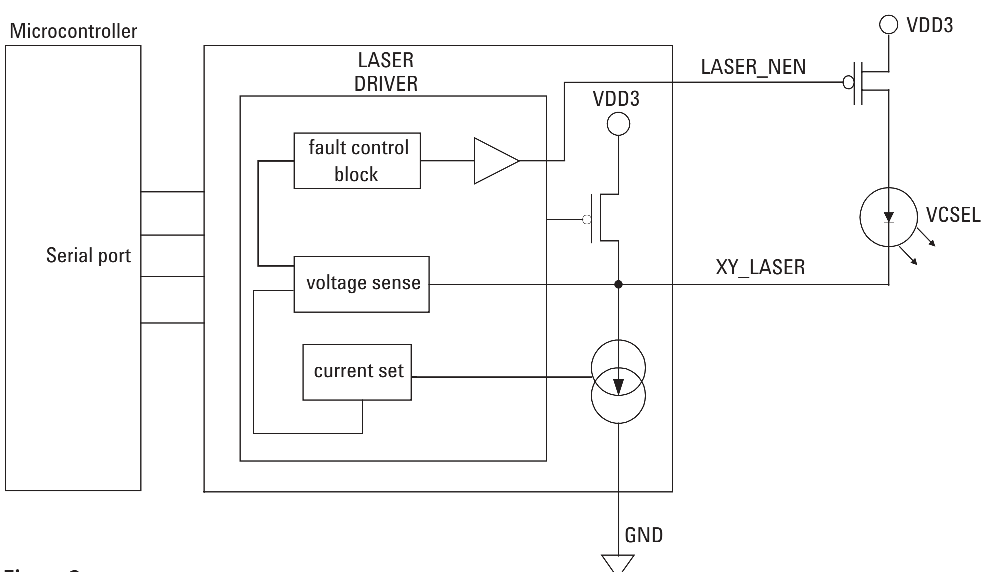


Figure 2.

What Are Potential Hazards for Exposure to a Non-Class 1 Laser Product?

In the wavelength range from 400 nm to 1400 nm (the retinal hazard region), electromagnetic radiation (EM) is transmitted through the various layers of the eye to the retina, where the visual image is formed. Only EM radiation in this range can present a hazard to the retina. Not only is the retinal region very sensitive, but the lens' focuses the incoming EM radiation to small, sharp images on the retina. Local intensity can be very high.

The cornea, lens and vitreous fluid are transparent to electromagnetic radiation in this wavelength range. Damage to the retinal tissue occurs by absorption of light and its conversion to heat by the melanin granules in the pigmented epithelium or by photochemical action to the photoreceptor. The focusing effects of the cornea and lens will increase the irradiance on the retina by up to 100,000 times.

The thermal damage mechanism is similar to cooking an egg and has a temperature threshold. While in the photochemical damage mechanism, each photon has the capability of breaking a chemical bond in a photoreceptor. In the near infrared region where these products emit, the only hazard is the thermal one.

A product that emits radiation accessible to a viewer above the Class 1 level may cause irreversible damage to the viewer's retina. In addition, a product incorrectly classified to be safe can present an unexpected hazard to the use.

Other References Materials for Eye Safe

a. IEC 60825-1 Ed. 1.2 2001-08 (basic standard) (includes 1996 and 2000 amendments)

b. Similar CENELEC documents, IEC prefix changed to EN (EN 60825-1)

c. Individual country documents, often using the IEC standard number but having country-specific prefixes (BS EN 60825-1 for Great Britain)

d. US CFR 21 Parts 1040.11 & 1040.11

Conclusion

It is highly recommended for a laser optical mouse to meet Class 1 eye safety standards and is correctly classified. This will ensure that the end product can be sold in any market worldwide and the users are not subjected to risks when using the laser optical mouse. Afterall, a product that emits radiation beyond the Class 1 level may cause irreversible damage to the viewer's retina.

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For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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