Application Note

Light Emitting Diode (IRED) Power Output Specifications

A method of specifying power output is to measure the power radiated into a cone whose apex is at the IRED. This cone is the solid angle over which the power output is measured. "Steradian" is the unit of measurement of the solid angle. The IRED output using this method is specified in terms of radiant intensity (I_E) with units of watts per steradian (W/sr.) and is usually measured with the solid angle centered about the IRED mechanical axis.

To understand the solid angle measurement of steradian, draw a circle on the surface of a sphere. The angle of the cone formed from the center of the sphere to each edge of the circle may be measured in steradians. It can also be said that the circle subtends a number of steradians. The number of steradians subtended is defined as the area of the sphere contained within the circle divided by the radius of the sphere squared.

Thus:

$$Sr = \frac{A}{R^2}$$

Where:

Sr = Steradian

A = Area of the sphere within the circle

R = Radius of sphere

This is being the definition of a steradian, the number of steradians in a sphere may be determined as follows:

Area of Sphere = 4π R^2

$$\frac{A}{R^2} = \frac{4\pi R^2}{R^2} = 4\pi$$

Therefore a sphere subtends 4π steradians. For small areas on the sphere or areas defined by small circles, the number of steradians can be approximated by using the area of the circle. This is expressed as:

$$Sr = \frac{A \text{ (of circle)}}{R^2} = \frac{\pi r^2}{R^2}$$

Where r = radius of the circle

A spherical radiator light source radiates equal power in all directions. For such a radiator the power output measured in W/sr would allow the prediction of the amount of power at a surface any distance from the radiator. However, IREDs are not spherical radiators and they are usually mounted in packages which alter the radiation pattern. An IRED in a lensed package will produce a typical beam pattern that is narrow around the mechanical axis of the device. This also indicates that if a detector with a very small area were placed at 0° (directly on the mechanical axis) and then moved to a position off the mechanical axis, the power measured by the detector will decrease. Also, if a large area detector is placed in front of the IRED the light striking the detector will not be of constant intensity over the surface of the detector. Therefore, if a measurement was made with a detector which subtends a 20 degree angle, and a measurement was made with a detector which subtends a 40 degree angle, it should be noted, the larger detector will not measure twice as much power. In order to specify the on axis power output in watts/unit area, a very small portion of the beam about the mechanical axis must be sampled. This will permit a more reliable point to point measurement. To illustrate this, the Honeywell SEP8505 is tested using a 0.081" aperture 0.400" from the lens surface. The light output is specified in terms of irradiance with units of W/cm^2. The output power is measured with a solar cell behind an aperture. The radiant intensity in W/sr can be calculated by using the 0.4" distance as the radius of a sphere and the 0.081" aperture as a circle on the surface of the sphere. The solid angle can be calculated as follows:

$$\text{Area of circle} = \left(\frac{0.081}{2}\right)^2 \pi = 5.15 \times 10^{-3} \text{ sq. in.}$$

Radius of sphere = 0.4 inches

$$Sr = \frac{A}{R} = \frac{5.15 \times 10^{-3}}{(.4)^2} = 3.22 \times 10^{-2} = 0.0322 \text{ sr}$$

If the power is measured by a detector behind the 0.081" aperture, this value can be divided by 0.0322 sr to determine the on axis radiant intensity in W/sr. If the angle subtended by the aperture is made larger, the measurement will no longer hold true. Therefore this measurement will yield accurate results when an aperture which subtends a smaller angle is used.

Caution must be exercised in using the various IRED parameters. If the output power is 2 mW/sr and the beam angle is typically 50 degrees total angle, these two parameters cannot be combined to interpret the radiant intensity power as 2 mW/sr over a 50 degree angle. The 50 degree angle is defined as the angle where the power is half of the power measured directly on axis. Therefore, this device could not possibly emit 2 mW/sr evenly over a 50 degree angle.

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The SEP8505-002 IRED irradiance for a drive current (I_F) of 20 mA is specified as 1.0 mW/cm^2 to 4.0 mW/cm^2 into a 0.081" diameter aperture placed 0.400" from the lens surface. As previously noted, this geometry will subtend 0.0322 sr.

To determine the power in watts at the aperture with the power specified in W/cm^2, it is necessary to determine the area of the aperture in cm^2. To convert from inches to centimeters (cm) it is necessary to multiply the inch dimension by 2.54 cm/in.

Therefore:

0.081 in. x 2.54 cm/in. = (0.081)(2.54) = 0.2057 cm

The area determined by:

$$A = \pi r^2 \text{ or } A = \frac{\pi d^2}{4}$$

Where:

A = Area

r = Aperture radius

d = Aperture diameter

Therefore:

$$A = \frac{(.2057)^2}{4} \pi = 0.0332 \text{ cm}$$

The total power (P_A) available at the aperture for both values (1.0 mW/cm^2 and 4.0 mW/cm^2) can be determined.

Since:

1.0 mW/cm^2 = 1.0 x 10^{-3} W/cm^2

P_A = 1.0 x 10^{-3} W/cm^2 x 0.0332 cm^2
= (1.0)(0.0332) x 10^{-3} W

P_A = 3.32 x 10^{-5} W

or,

P_A = 33.2 µW for the 1.0 mW/cm^2 value

And since:

4.0 mW/cm^2 = 4.0 x 10^{-3} W/cm^2

P_A = 4.0 x 10^{-3} W/cm^2 x 0.0322 cm^2
= (4.0)(0.0332) x 10^{-3} W

P_A = 13.28 x 10^{-5} W

or,

P_A = 132.8 µW for the 4.0 mW/cm^2 value

Since the aperture subtends 0.0322 sr, the radiant intensity expressed in W/sr can be determined by:

$$\frac{33.2 \times 10^{-6} \text{ W}}{0.0322 \text{ sr}} = 1.03 \times 10^{-3} \text{ W/sr or } 1.03 \text{mW/sr}$$

and

$$\frac{132.8 \times 10^{-6} \text{ W}}{0.0322 \text{ sr}} = 4.12 \times 10^{-3} \text{ W/sr or } 4.12 \text{ mW/sr}$$

The radiant intensity (I_E) of the SEP8505-002 may be specified as:

I_E = 1.03 mW/sr to 4.12 W/sr for I_F= 20 mA

when measured over 0.0322 sr (or less).

For most applications, this type of measurement is more useful than a total power output measurement. There are a few applications, such as in remote controls, where the total power emitted from the device is a more useful measurement.

Honeywell