OPTICAL DESIGN OF AMBIENT LIGHT SENSOR

AN-32

Application Engineer
Bruce Ferguson

Microsemi™®

Microsemi
Integrated Products
11861 Western Avenue, Garden Grove, CA. 92841, 714-898-8121, Fax: 714-893-2570

TABLE OF CONTENTS

Microsemi
Integrated Products
11861 Western Avenue, Garden Grove, CA. 92841, 714-898-8121, Fax: 714-893-2570

INTRODUCTION

Microsemi Integrated Products offers a series of light sensors with a spectral response that resembles the human vision system. Some of these sensors or detectors such as the LX1970 and LX1972 respond linearly to changes in ambient light, others such as the LX1971 are extra sensitive to light at low levels providing a wider dynamic range. In either case when designing a closed loop lighting system it is often necessary to sense ambient light at the surface of the product of appliance.

Ambient light often comes from numerous light sources and from reflections off walls and objects in the room. Ambient lighting can be best thought of as a wide angle measurement as opposed to a measurement of what is directly in front of the light sensor.

APPLICATIONS

- PDA
- Notebook PC
- LCD TV
- Tablet PC
- Cell phones

PART SPECIFIC INFORMATION

Part Number	Product	T_A°C	Package Type
LX1970IDU	Visible Light Sensor	-40 to 85°C	**DU** Plastic MSOP 8-Pin
LX1971IDU	Wide Range Visible Light Sensor		**DU** Plastic MSOP 8-Pin
LX1972IBC	Ambient Light Detector		**BC** Plastic 1206 2-Pin

TABLE 1 – PART INFORMATION

Microsemi
Integrated Products
11861 Western Avenue, Garden Grove, CA. 92841, 714-898-8121, Fax: 714-893-2570

LUX METER

The lighting industry senses ambient light using a lux meter. The optics of a lux meter consists of a white translucent domed diffuser cover over the top of the "human eye" corrected light sensor. The Microsemi LX1970 is a good choice for the ambient light sensor because it resembles a human eye (or photopic) response and it has a wide viewing angle. The diffuser blends the edges of images to eliminate "hot spots" that can provide wide shifts in meter output with subtle shifts in position of the appliance. The dome shape helps eliminate the cosine effect which affects the meter reading relative to the angle of the light source. Figure 1 illustrates the cosine effect showing how without the dome, the beam from an off axis light source is weaker since it is spread out over a wider surface area and how adding the dome allows the light to illuminate approximately the same surface area of the dome producing an equivalent level of intensity inside the dome. The dome diffuser has the same radius of curvature on both sides.

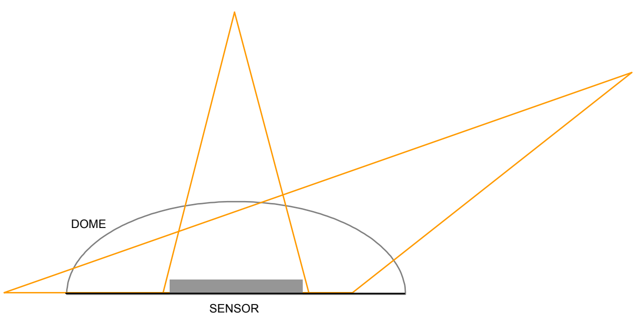


Figure 1 – Ambient Light Sensor (Lux Meter)

LIGHT WINDOW

In many cases, the light sensor can't be mounted directly under a domed diffuser cover. Sometimes it's necessary to route light from the surface of an appliance down into the interior to a light sensor mounted on a circuit board underneath. A simple way to do this is to provide a window from the light sensor to the surface. The window has a flat top surface, a flat bottom surface and the thickness that is the distance from the surface to the sensor. The stack up of this arrangement is shown in figure 2.

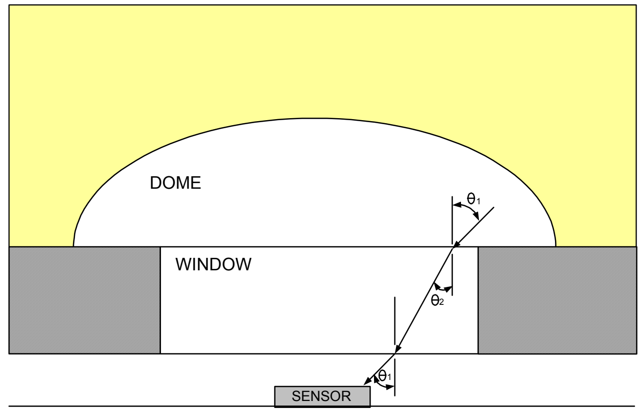


Figure 2 – Providing a Window From the Surface to an Internal Light Sensor

The refracting properties of glass or plastic changes the direction of the incident light rays and in doing so bends the light towards the bottom surface of the window. In the picture below, the relationship between θ1 and θ2 is determined by Snell's law:

Where η = 1.5 for glass or plastic relative to air.

For example if η = 1.5, θ1= 45°then θ2= 28°.

When the light ray exits the window, the angle becomes equal to θ1 again. Minimizing the gap is important, because the angled ray coming out of the window bottom can totally miss the light sensor that is mounted too far away from the bottom of the light pipe.

To design the window, the first step is to determine how wide the sensor viewing angle should be; this determines the largest incident angle, θ1. The internal angle can then be calculated using Snell's law. Next, determine the actual location of the light sensor relative to the center of the light pipe and the dimensional tolerance for this location. Also determine the worst case gap. Then starting at the light sensor, work from the bottom to the top geometrically and determine the width that the top of the window needs to be in order to direct the widest angle light rays down to the worst case location of the sensor given the mechanical tolerances.

FIBER OPTIC LIGHT PIPE

In certain circumstances, the light sensor can not be located directly under the sensing port in the cover. Often times to design appealing aesthetics for the appliance the port might have to conform to a certain size or shape. These mechanical constraints may force the designer to use a more sophisticated "light pipe" design to route the surface light to the sensor. A light pipe is a transparent material such as plastic or glass that acts as a light conduit. The sides of the light pipe are polished so the light trapped inside can reflect off the sides rather than leaking out. Only light rays inside the light pipe that strike the side at an angle greater than the critical angle meet the criterion for "total internal reflection" and propagate through the pipe. If the light pipe has bends or corners, they must be gradual or most of the light will leak out before it reaches the end of the light pipe. The critical angle can be calculated using Snell's law and is arcsine ($1/\eta$) where η is the index of refraction of the translucent material and air is the material surrounding it. For glass or plastic, with $\eta = 1.5$, the critical angle is 41.8 degrees. In some cases it may be possible to coat the outside of the light pipe with a reflective coating such as silver, to reduce the need to adhere to the critical angle criterion.

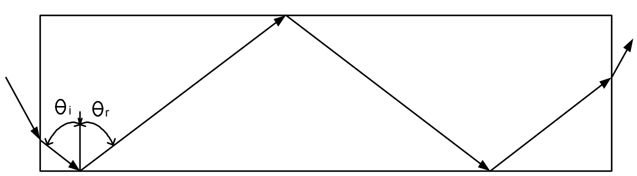
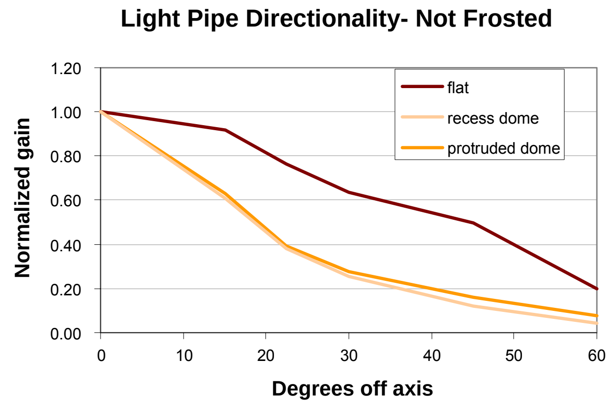


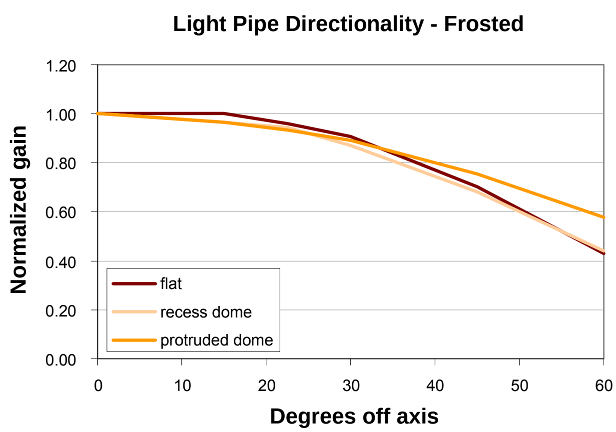
Figure 3 – Light Ray Propagation Through a Light Pipe.

DIRECTIONALITY OF LIGHT PIPE

Directionality is a problem if the sensor only sees light directly in front of the lens; if this is the case, a slightly off-axis light source may not be detected. There is some debate as to whether or not it helps reduce directionality to apply a domed surface to the top of the light pipe. The plot below shows that a flat surface is better (if the top surface is not diffused). This plot compares a flat lens to a domed lens that in one case is recessed and in the other case is protruding. The flat lens surface is probably better since it doesn't create a pocket for dirt. A protruding lens may be something that would break off.



Test showed that diffusing the top layer of the light pipe greatly improved the directional response. In these cases all three previous cases were greatly improved by frosting the top surface of the lens. For these tests a piece of masking tape was placed across the lens, but similar results can be obtained by frosting the lens or scuffing the top surface. Hazing the top surface is more esthetically appealing because it restricts view of the light sensor at the bottom of the light pipe.



The drawback to adding a diffuser on top of the light pipe is it reduces the amount of light that gets into the light pipe since some light is reflected off the top surface and some light is scattered out the sides of the light pipe due to the refracted angle. With a sensor such as the Microsemi LX197X it is easy to increase the sensor sensitivity by increasing the value of the scaling resistor.

LIGHT PIPE MECHANICAL CAUTIONS

When designing a light pipe it is important to make the light pipe wide enough to cover the sensitive area of the photo-detector; this can be a challenge given the stack up of mechanical tolerances of the light sensor and PCB mounting. Also the gap between the light sensor and light pipe should be small so off axis lighting doesn't pass over the top of the sensor undetected. If the light pipe and mounting bracket is a single molded plastic piece, the mounting brackets may inadvertently provide exit ports for light reflecting off the conduit sides. When light escapes, it can result in dead spots in the field of view of the ambient light sensor corresponding to wave patterns in the light pipe. The sides of the light pipe should be polished and smooth if possible so they reflect the light rather than allow it to escape out the side.

Microsemi
Integrated Products
11861 Western Avenue, Garden Grove, CA. 92841, 714-898-8121, Fax: 714-893-2570