IDP: Pulsed Infra-Red Beacon/Sensor

The Beacon

This contains a Siemens SF485 infra-red emitter, radiating light of approximately 880nm wavelength. Its radiation characteristic is shown below. When activated, the beacon emits a number of IR pulses, each of 100ms duration, spaced by 100ms. The number of pulses emitted is determined by the rotary switch mounted on the top of the beacon: for position 0, 0 pulse is emitted, for positon 1, 1 pulse and so on until position 9 which emits 9 pulses.
For the current with which it is driven, the device emits on axis approximately 6.4mW/steradian.

The Receiver

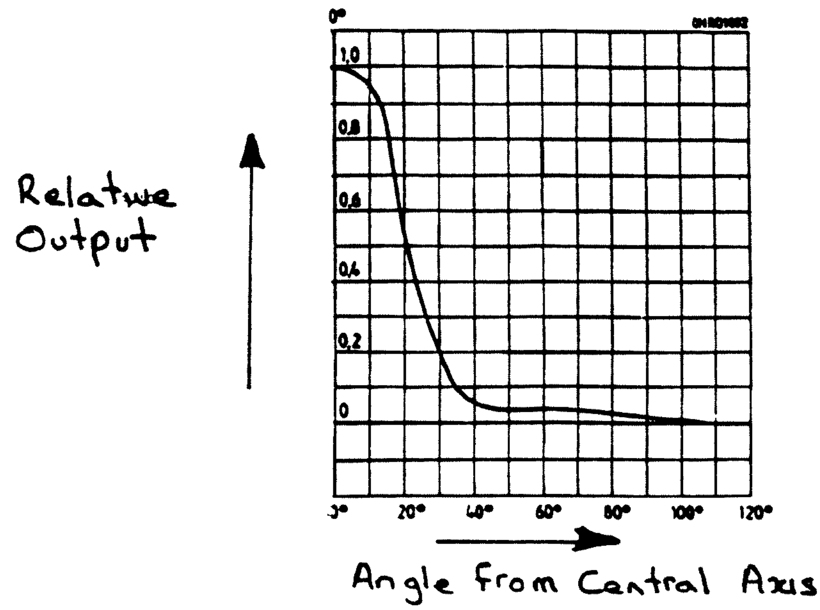
In the project you may be required to design a receiver for the above beacon. You will be supplied with a Siemens SFH313 phototransistor, which is spectrally matched to the SF485 described above. Graphical data on the SFH313 dark and photocurrents, and its directional characteristics are given over. Its area, sensitive to light radiation, is $0.55mm^2$.

From the information given you should be able to estimate the on-axis phototransistor current at a given distance from the emitter, and 10^o off axis. From this calculation you should be able to design a simple circuit, similar to that of the infra-red reflective sensor, to enable the receiver to detect the light pulses, and produce output pulses compatible with 74HC logic. Confirm experimentally that the circuit works, and adjust component values if necessary.

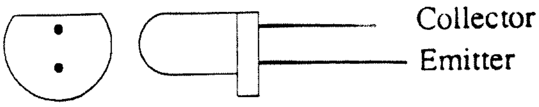
A Counting Circuit

As described above, the beacon will emit between one and ten (inclusive) pulses. You will need to design a circuit, using the 74HC logic supplied, to count these pulses. You will need to consider how the count is communicated to your microcontroller, and how the counter will be cleared.

SFH 485–Radiation characteristic
$I_{REL} = f(\varphi)$



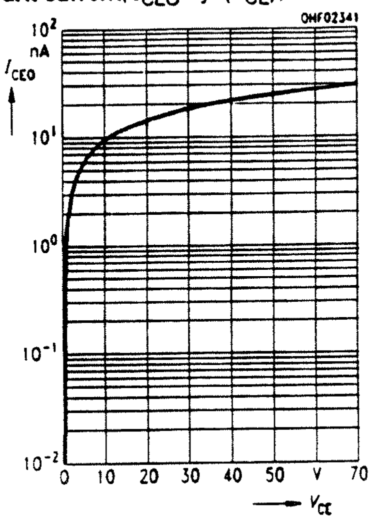
SFH 313



Maximum ratings:

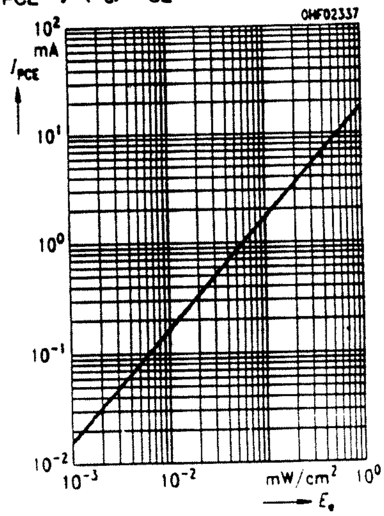
Collector-emitter voltage:	70V
Collector current:	50mA
Total power dissipation:	200mW

Dark current, $I_{CEO} = f\ (V_{CE}),\ E = 0$

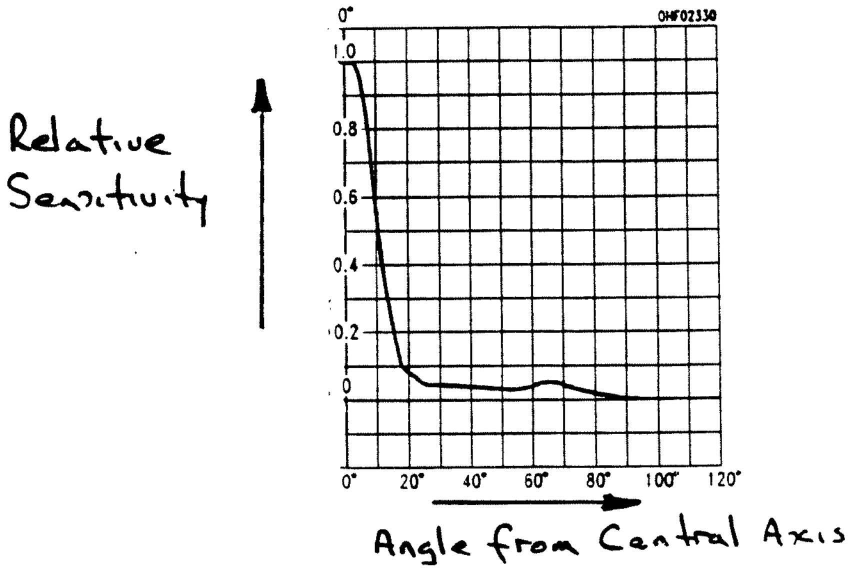


Photocurrent

$I_{PCE} = f\ (E_e),\ V_{CE} = 5\ V$



Directional characteristics $S_{rel} = f\ (\varphi)$



From Opto Electronics - Theory + Practice
Texas Instruments (1976)

3.1 Solid angle

The solid angle is a sterometric value. *Figure 3.1* shows a spherical sector of a sphere. The value of the solid angle Ω of a spherical sector (*Figure 3.2*) is determined by the ratio of the section of the spherical surface A to the square of the radial distance r. From this:

$$\Omega = \frac{A}{r^2} \cdot \Omega_0 \qquad (3.1)$$

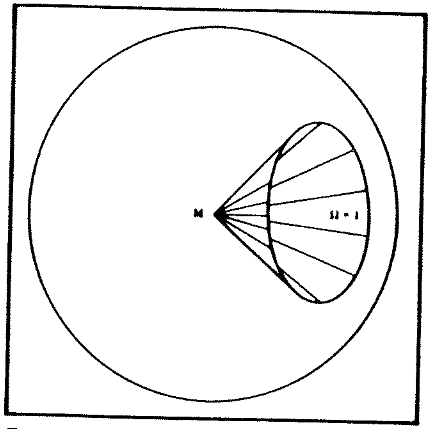


Figure 3.1
Sector of a sphere

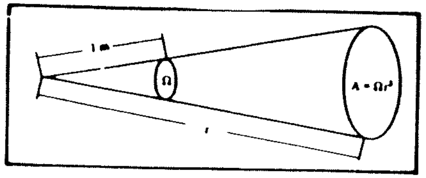


Figure 3.2
Calculation of the solid angle Ω of a spherical sector

The unit of the solid angle is the steradian, abbreviated to sr. The general dimension of the solid angle is, in accordance with equation (3.1), area per area. In radiation calculations, the possibilities arise, that either the unit sr is not converted with respect to m^2/m^2, or m^2/m^2 is not converted into sr. The correction factor $\Omega_0 = 1$ sr, which is inserted, prevents such calculation errors (see equation (2.19) and section 10.1).

The greatest possible solid angle is formed by the sphere. If the radial distance is related to r = 1, e.g., r = 1 m, then the solid angle is:

$$\Omega = \frac{4\pi m^2}{1 m^2} \cdot \Omega_0 = 4\pi \cdot \Omega_0 = 4\pi \text{ sr} \qquad (3.2)$$

Semi-infinite space, or a hemisphere with unit radius r = 1 m, has the solid angle:

$$\Omega = \frac{2\pi m^2}{1 m^2} \cdot \Omega_0 = 2\pi \cdot \Omega_0 = 2\pi\text{sr} \cdot \text{sr} \qquad (3.3)$$

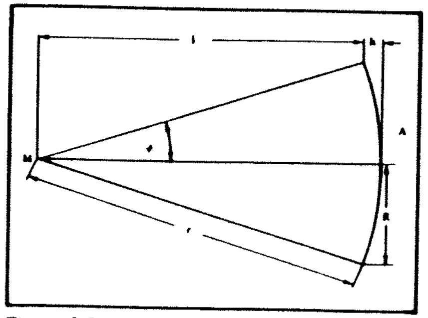


Figure 3.3
Two-dimensional representation of a spherical sector. A = Area cut out of the spherical surface by the spherical sector (spherical cap), h = height of the section, R = radius of the circumscribing circle, φ = half aperture angle, r = radial distance (from the centre to the surface of the sphere) = 1, l = r − h.

Figure 3.3 shows a two-dimensional representation of a spherical sector. Thus the solid angle Ω can be calculated with the half aperture angle φ.

$$\Omega = \frac{A}{r^2} \cdot \Omega_0 = \frac{2r \cdot \pi \cdot h}{r^2} \cdot \Omega_0$$

$$= \frac{2r^2 \cdot \pi (1-\cos\varphi)}{r^2} \cdot \Omega_0$$

$$= 2\pi (1-\cos\varphi) \cdot \Omega_0 \qquad (3.4)$$

With the values R and l, the solid angle can also be calculated:

$$\Omega = \frac{A}{r^2} \cdot \Omega_0 = \frac{2\pi r (r-l)}{r^2} \cdot \Omega_0$$

$$= 2\pi \left(1 - \frac{1}{\sqrt{R^2 + l^2}}\right) \Omega_0$$

$$= 2\pi \left(1 - \frac{1}{\sqrt{\frac{R^2}{l^2} + 1}}\right) \cdot \Omega_0 \qquad (3.5)$$

To clarify this, *Figure 3.4* shows the relationship between the solid angle Ω and the half aperture angle φ. For example:

1 sr = φ = 32·72°

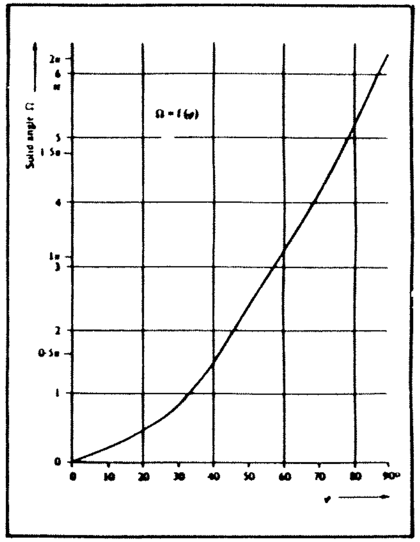


Figure 3.4
Dependence of the solid angle Ω on the half aperture angle φ of a spherical sector