

Introduction

The illustration below shows a typical light barrier application. The transmitter emits a modulated light signal to the detector. If there is no obstacle between the transmitter and the detector, the modulated transmitter light can be received by the detector. If an obstacle blocks the light path, no transmitter signal can be received. The change between received signal and no signal can be used to control a machine, an automatic door, or also to count objects. It is the intention of this document to describe the relevant aspects of such and as-called through-beam light barrier.

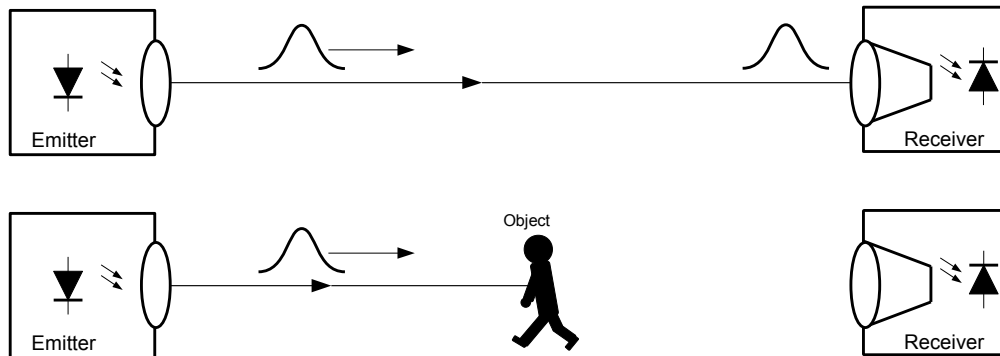


Figure 1: Working principle of a through beam light barrier

Emitter - Working with modulated light

Light, which is seen by the receiver in a light barrier, does not only stem from the transmitter. During the day, natural daylight by the sun generates a heavy light flux which can be several orders of magnitude higher than the light from the transmitter. On earth, the sunlight can be as heavy as 1 kW/m^2 . If we have a Receiver lens with a diameter of 20mm, a receiving area of 3.14 cm^2 receives sunlight. The total power of the sunlight appearing on the photo receiver is then 314mW. If the photo diode has a quantum efficiency of 90% and is reverse biased with a voltage of 5V, a photo current of 56mA is generated (no daylight filter in use). On the other hand, if we just analyze the photo current generated by the LED of the transmitter, it can be as small as 30nA or even less. Thus, the 'disturbing' sunlight in this example is 1.86 million times stronger (125 dB) than the useful signal from the LED. Typically, a daylight filter is placed in front of the receiver. Such a filter blocks approx. 95% of the ambient light. However, the DC photo current generated by full sunlight in the example above is still 2.8mA.

However, the good part of the message is that sunlight is DC light which generates a DC current in the photo diode. If we use AC light with our transmitter, the receiver sees a modulated light by the superposition of the environment light and the LED. Thus, a simple demodulation in the receiver can separate the two parts. At the end, only the photo current generated by the LED of the light barrier will be used. It is to note, that most of the light sources used for illumination purposes generate DC light or have at least a weak AC part.

Generating AC modulated light with an LED can be done in various forms. The modulation function can be, i.e., sinusoidal, rectangular, pulsed, pulse-coded, etc. It is ideal to use a modulation scheme which has a very low duty cycle with short pulses emitting high pulse energy and long delays to the next pulse or pulse train. Since LEDs can be modulated with very high frequencies (up to tens of MHz), the overall current consumption will be low because of a short on-time and a long off-time of the LED. Figure 2 shows the concept. The LED current is controlled by the resistor R_1 and the voltage across. Typical values are 1A peak for $5\mu\text{s}$ and a delay of $100\mu\text{s}$. The resulting duty cycle is 1:20 and thus the average LED current 50mA.

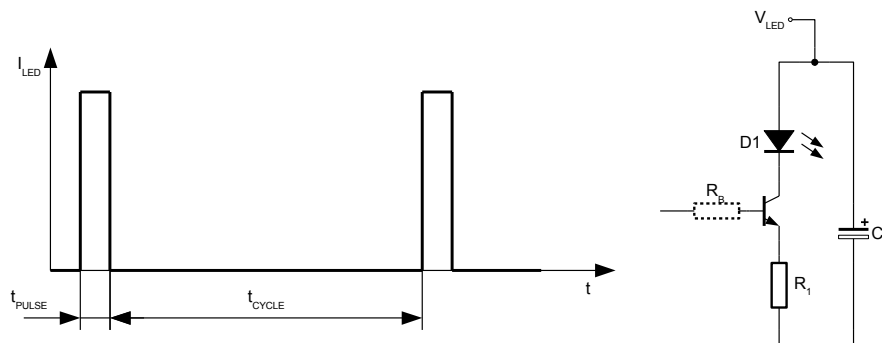


Figure 2: Pulse-modulated LED current

Photo receiver

Typically, the photo receiver consists of a photo diode, an AC amplifier, filter, signal shaping circuitry and a comparator. All these blocks (and many more) are integrated into epc's photo receiver chips like the epc10x or 13x family. These chips have a very high AC photo-current sensitivity and allow high DC photo currents at the same time without being saturated. The photo diodes from the epc3xx family are a perfect match for these chips. Figure 3 shows a sample receiver circuit. Please refer also to the data sheets of the products mentioned in this application note.

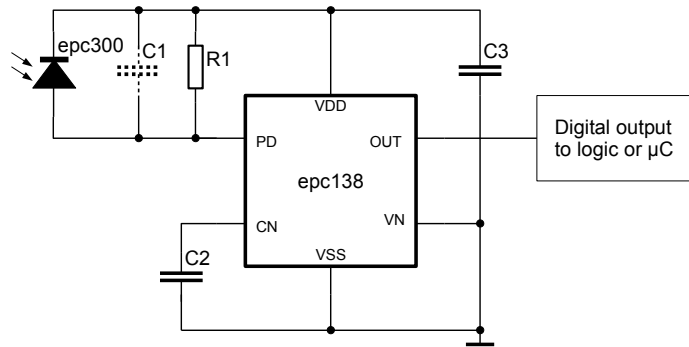


Figure 3: Sample photo receiver circuit using an epc300 photo diode and an epc138 photo receiver chip

What operating range can be achieved?

The crucial question in a light barrier is always which operating range can be achieved. As discussed before, an optimal emitter configuration and operation together with a sensitive receiver and a receiver lens as big as possible will achieve the longest operating range. The following parameters define the operating range:

- Emitter power (P_{Tx})
- Emitter aperture angle (cone) to calculate the illuminated area on the receiver side (A_{Tx})
- Receiver sensitivity (S_{Rx} , P_{Rx})
- Active area of the receiver (A_{Rx}). If a lens is placed in front of the receiver, the active area is equal to the lens area.
- Lens efficiency (η)

Figure 4 shows the setup for the power calculation in the receiver.

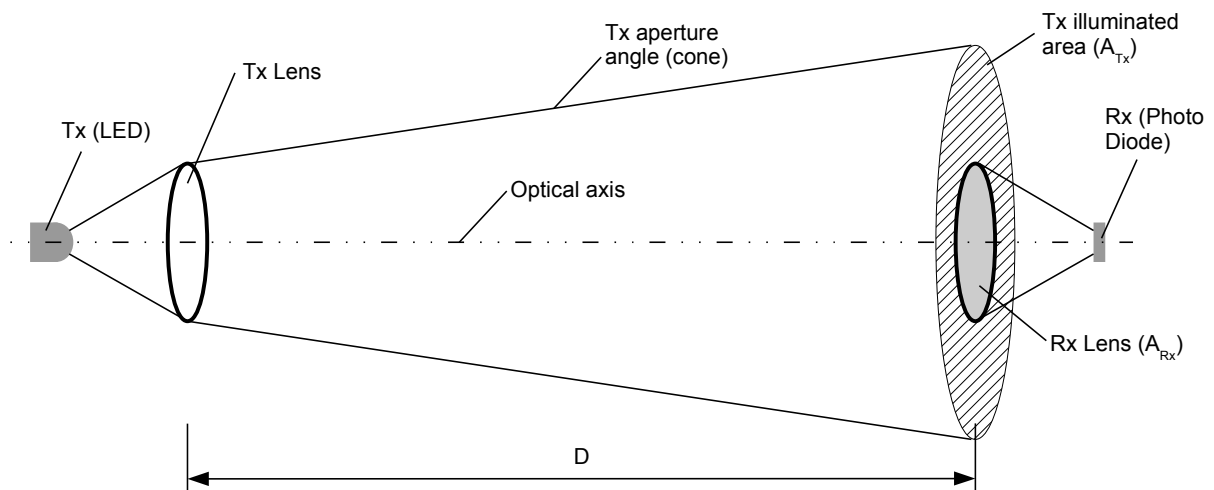


Figure 4: Power calculation layout

The formula to calculate the optical power received by the receiver photo diode is shown in (1):

$$P_{Rx} = \frac{P_{Tx} * A_{Rx} * \eta_{lens}}{A_{Tx}} \quad (1)$$

This formula is a good approximation when the receiver lens is in the middle (centered) of the area illuminated by the emitter. However, if the receiver lens is not on the optical axis of the emitter, less optical power will be received due to an inhomogeneous energy distribution of the light across the emitter aperture.

The formula to calculate the maximal possible range of a through beam light barrier is as shown in (2):

$$d = \frac{1}{\tan \alpha} * \sqrt{\frac{P_{Tx} * A_{Rx} * \eta_{lens} * S_{\lambda}}{P_{Rx} * \pi}} \quad (2)$$

Whereas:

Term	Description	Example	Comments
α	Emitter LED half angle	10°	(SFH4650)
P_{Tx}	Peak power of the emitter LED	50mW	@100mA forward current, (SFH4650)
A_{Rx}	Receiver lens area	80mm (ø10mm)	assume that the total light power is focused on the photo diode
η_{lens}	Lens efficiency	75%	plastic lens with daylight filter, no anti reflex coating
P_{Rx}	Light power to trigger the receiver threshold	80nA	typical value for epc138
S_{λ}	Spectral sensitivity of the photo diode	0.6A/W	@850nm, typical value for epc300

By using the actual values from the table above, the range limit is calculated by using (2):

$$d = \frac{1}{\tan 10^{\circ}} * \sqrt{\frac{50mW * 80mm^2 * 0.75 * 0.6}{80nW * \pi}} = 15.2m \quad (3)$$

In order to achieve a reliable operation, the trigger threshold should be exceeded by a minimum of 50% in the real application. This leads to an operating range of this particular setup of 12.4m.

Conclusion

This application note shows how simple a first approximation calculation for a light barrier layout can be. And by using epc photo diodes and signal ASICs, the realization of very robust industrial light barriers can be achieved with a minimal part count system that still delivers maximum performance in the final application.

DISCLAIMER: Information furnished by ESPROS Photonics AG is believed to be accurate and reliable. However, no responsibility is assumed for its use. ESPROS Photonics Corp. makes no representation, that the interconnection of its circuits as described herein will not infringe on existing patent rights.