Baumer
Passion for Sensors

White Paper

Ambient light as interference source for optical sensors – Challenges and solutions

Object detection commonly deploys optical sensors. They provide precise non-contact detection at short response times. Furthermore, these sensors master both short and long distances and fit where space is a constraint. However, there is one drawback with light barriers and photoelectric sensors. They operate on visible light of the same spectral range as artificial light or sunlight. Consequently, such light may cause detection errors in light barriers and photoelectric sensors. Most tricky is the fact that in virtually no place lighting conditions will be the same. An optical sensor proving error-free detection at the manufacturer's may struggle with different lighting conditions at the customer's. This white paper will inform you why ambient light has such a significant influence on optical sensors. And, you will be provided with the solution: Reliable detection by optical sensors in any lighting condition - including LED and bright sunlight. The Baumer sensor toolbox offering the next generation of optical sensors provides users with all the benefits of unrivalled ambient light immunity and hence will eliminate many error sources in production.

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1 Introduction

Do you know the lighting conditions that are present at your production lines? May the lighting situation change soon due to lack of energy? Do you know how the deployed optical sensors will react to any change in lighting? Optical sensors may be very sensitive to changing light conditions, which may result into detection errors or even total failure. But why? Let's take a closer look at how optical sensors work and at the interfering factors by ambient light to answer the question. The example below uses a photoelectric sensor based on triangulation.

The signal striking the PDA comprises the diffusely reflected light beam generated by light source Q together with the present ambient light. Ambient light includes a content of both DC (constant frequency) and AC (alternating frequency). A very high DC content means direct solar radiation. The AC content may refer to artificial lighting. More and more common LED operate on a similar or larger frequency spectrum than optical sensors. This may cause detection errors. In the event of a detection error, the optical sensor is not in a position to identify whether the signal received is emitted by the sensor light or an interfering source.

2 Sensors very prone to ambient light

A common and conventional principle for optical distance measurement and object detection is triangulation. The principle is quite simple: the longer the distance to the object, the acuter the angle of the reflected sensor light. The sensor determines this angle based on the position at which the reflected light strikes the receiver, the Photo Diode Array (PDA). Figure 1 is a function diagram of a triangulation-based optical sensor. Light source Q generates a light beam focused by lens L1 on optical axis A1. The diffuse object-reflected light at position x1 is refocused by lens L2 and strikes the PDA. Distance x1 is calculated by position y1 and the light distribution in the beam striking the PDA, in relation to focal length f, basic distance b and the resulting angle $\alpha 1$. The light beam striking pixel no. 3 will result in position y2 and angle $\alpha 2$ out of which the new distance x2 is calculated.

3 Ambient light as interfering factor

LED lamps are the most challenging sources of ambient light, since their AC content ranges from 30 kHz to 150 kHz. Optics, electronics and algorithms are applied to remedy such unwanted interference by ambient light. Known measures are optical and analog filters as well as pulsed operation of light source Q. However, this would not suffice if for example a sensor with 25 kHz sampling rate is exposed to interfering light of 100 kHz, as shown in figure 2. The sensor's considerably lower sampling rate would entail undersampling, the so-called aliasing effect. Mapping of the LED spectral content is in the low frequency range, which may cause measuring errors. The following describes the interfering factors of various light sources with high AC content, particularly LED lamps, as well as noise compensation in undersampling.

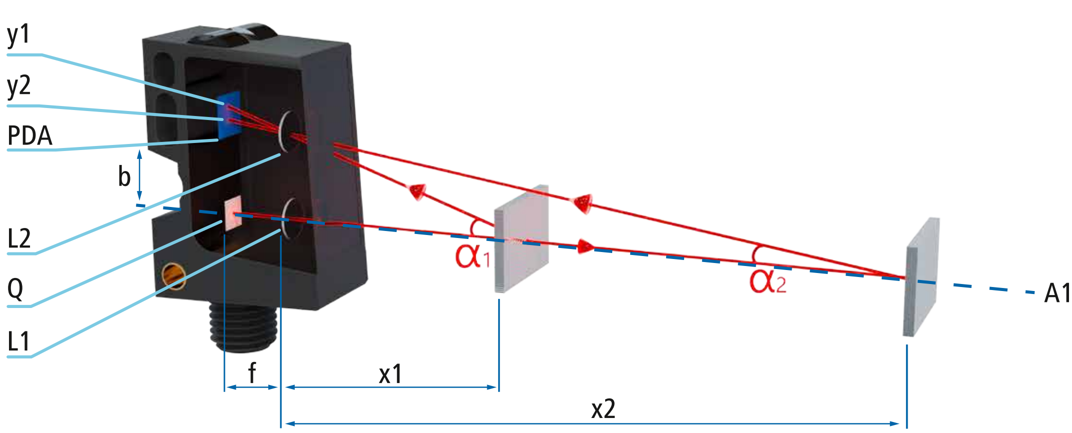

Figure 1: Optical sensor based on the triangulation method

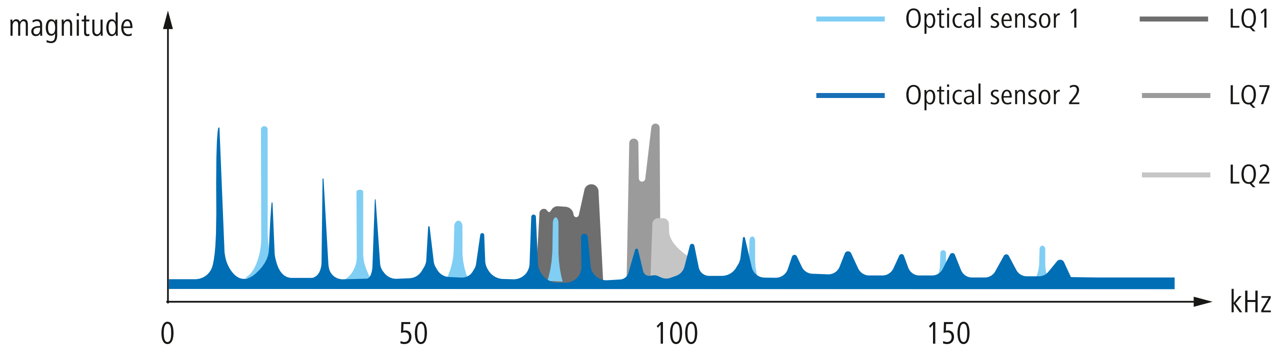

Figure 2: Superposition of frequency spectrum of different interfering light sources and optical sensors.

Table 1 shows different light sources LQ1 to LQ7 of varied manufacturers as well as artificial interference source LQ8 to simulate light properties; this way it serves for quantification of influencing factors. In a research project Baumer explored the influence of such light sources on sensor measurement results.
The frequency response classification in table 1 shows that any LED light provides an average frequency $f0$ which is within bandwidth Δf at modulation frequency fm. The shape of the modulation signal is also typical.

Center frequency $f0$ and frequency bandwidth Δf enable to determine the minimum and maximum spectral share of any light source. Light source LQ2 provides the maximum spectral share of 100 Hz, while light source LQ4 with 31 kHz has the lowest. Such extreme frequency changes in light intensity originate in high frequency- components in the light source power supply. Here, switching regulators do the voltage conversion and, thanks to their high frequency, enable maximum efficient voltage conversion at minimized electronics dimensions. The different light sources LQ1 to LQ7 present three modulation forms: sinusoidal, SALA and LASA. Sinusoidal is the conventional sine wave. SALA shows a steeply rising and slowly falling waveform. LASA is inverted to SALA i.e. slowly rising and steeply falling waveform. Figure 3 shows the SALA and LASA modulation waveforms at the example signal frequency fa of 100 Hz. The AC content of the light source as a percentage is determined by ripple W.

The low-frequency sine signal of light source LQ6 does not show any modulation behavior, which is due to the low modulation frequency. The LQ8 artificial interference light source developed by Baumer reproduces all relevant individual settings to simulate a large variety of interfering light which is emitted by conventional and other light sources.

	Light source	Average frequency f_0	Bandwidth Δf	Modulation frequency f_m	Shape: modulation signal	Ripple W
LQ_1	LEDs	76 kHz	15 kHz	100 kHz	SALA	13%
LQ_2	Fluorescent material	98 kHz	10 kHz	100 kHz	LASA	29%
LQ_3	LEDs	48 kHz	30 kHz	100 kHz	SALA	3%
LQ_4	LEDs	49 kHz	35 kHz	100 kHz	SALA	4%
LQ_5	LEDs	55 kHz	8 kHz	100 kHz	SALA	8%
LQ_6	LEDs	100 kHz	n.a.	n.a.	n.a.	40%
LQ_7	LEDs	91 kHz	12 kHz	100 kHz	Sinus	13%
LQ_8	Single LED	config.	config.	config.	config.	config.

Table 1: Properties of the light sources

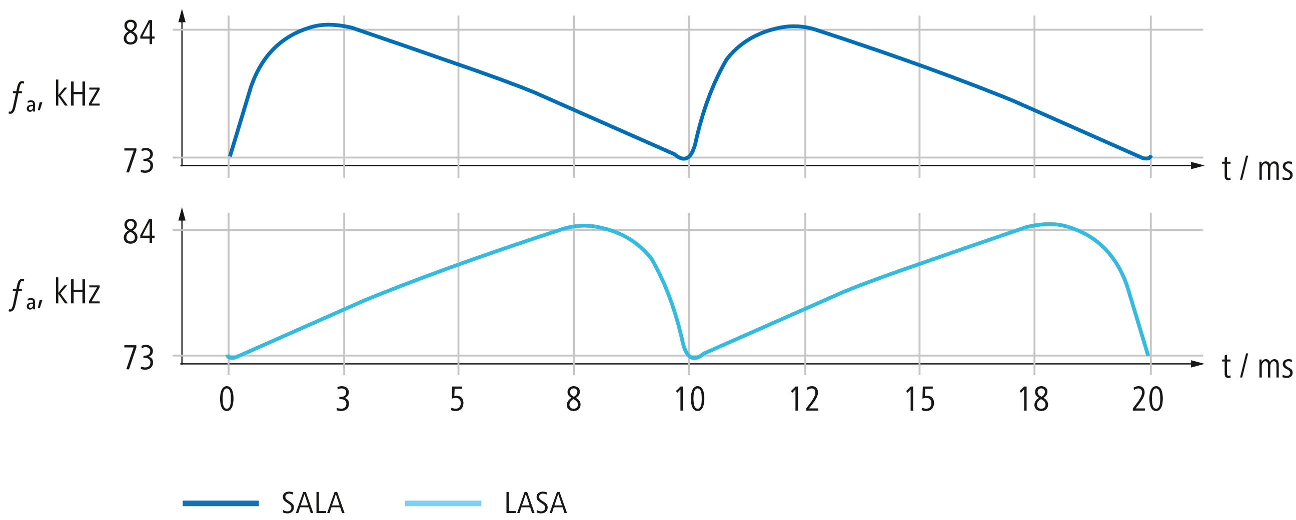

Figure 3: SALA and LASA modulation waveforms

4 Ambient light effects on processes

Thanks to their low power consumption, LED lamps experience an ever-increasing use in new or retrofit lighting installations. Consequently, ambient light conditions respectively interfering factors change. Most of the time, lighting conditions in the company lab, assembly and production floors are well known. But what are present-day lighting situations respectively what will they be like in the future? Who can say how optical sensors will react to changing ambient light conditions? Tests have proved optical sensors of different brands prone to interference by LED light of various frequencies. Yet, as long as the time-relevant switching behavior is maintained, troubleshooting is quite simple. But it's completely different with optical sensors that adapt their internal measuring cycles to the interference frequency, which results in increased response respectively cycle times. This in turn may entail process cycle times being no longer being adhered to, or system shutdown or, worst case, machine crash. Here, troubleshooting is extremely difficult since the root cause is not immediately evident, neither the malfunction can be remedied automatically.

5 Big effort in troubleshooting and counter actions

Searching the root cause throughout the entire optical sensor system and interfering light sources is complex and time-consuming. Switching errors in optical sensors are often due to object properties (material, geometry and surface), to process conditions (detection range, process speed), installation situation (angle dependencies and interfering objects) or incorrect parameterization/manipulation. Furthermore, lighting situations can change with daylight intensity. This is even worse with sensors featuring the mentioned adaptive response or switching cycle times. Once the cause and hence the interfering light source has been identified, corresponding counteractions can be taken. Depending on process speed and sensor parameterization options, additional filter settings may already remedy the problem. Aligning the sensor position would be another quite simple solution. Should these actions not be an option due to process conditions and installation situation, the situation gets expensive and time-consuming, since only alternatives may be cover or replace the sensor.

6 Challenges

Light barriers/ photoelectric sensors are the most common optical sensors. Consequently, these sensors are deployed in large quantities which entails a certain sensitivity to price. Furthermore, miniaturization is increasing by the ever-growing demand for more compact sensors to fit confined space. Specific processes pose high demands on sensor cycle times or switching frequencies, which makes things even more complex. This results in a very limited choice of electronic components, which reflects for example in the limited processing capacity of microcontrollers. For this reason, more than 30 years ago Baumer decided to develop own ASICs (Application Specific Integrated Circuit) for certain

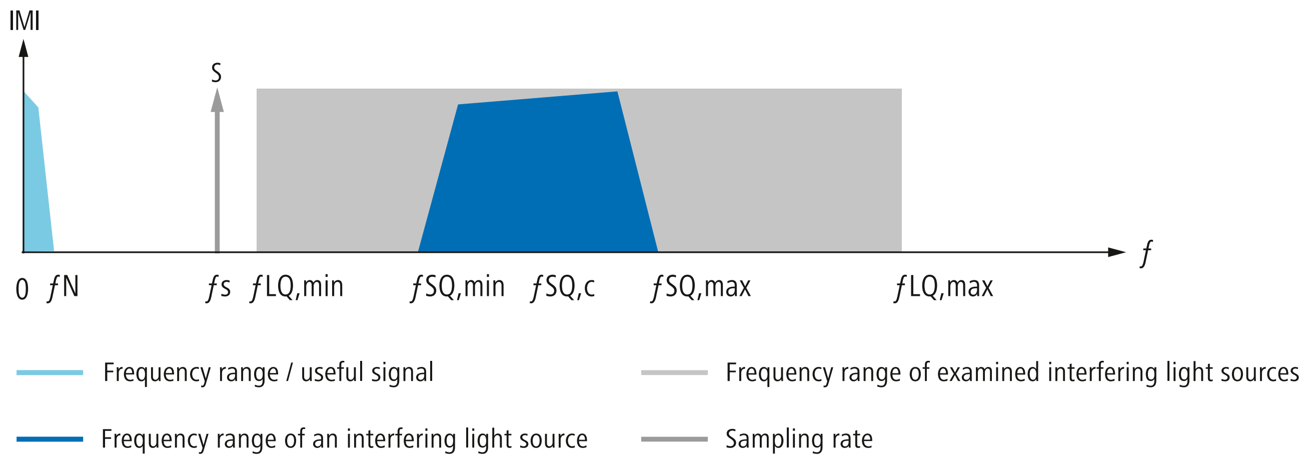

Figure 4: Sampling process to separate the useful signal from the interference.

key components. The challenge was exploiting the properties of interfering light and sampling with limited microcontroller processing capacity to extract unwanted interference from the desired signals (see figure 4).

7 Solution

Interfering light is compensated by identifying the properties such as intensity and position on the Photo Diode Array (PDA), as well as the current frequency.
The Baumer light barriers and photoelectric sensors excel by Aline®, a CMOS sensor (Complementary Metal-Oxide Semiconductor) developed by Baumer. It interacts with optical and analog filters, with a specially designed digital filter, a controller concept and ambient light algorithms. By measuring brightness and the measuring light pulse of the sensor's light source, interference is extracted from the measuring respectively desired sensor signals. The sophisticated filter and control system together with ambient light algorithms will suppress interference frequencies and interfering jumps.

The development effort pays off. Baumer light barriers/photoelectric sensors provide unrivalled ambient light immunity and thus help eliminate many error sources in production right from the start. This ensures maximum process safety even under changing light conditions and is prerequisite for safe 24/7 operation at maximum system uptime.

8 Conclusion

Optical sensors prone to interference by ambient light may impair process reliability by switching errors. Most of the time, the root cause is not obvious which entails much and expensive effort in troubleshooting. Shutdown of the entire installation is often the consequence. At Baumer, we explored the weak points of optical sensors in extensive research studies and developed reliable solutions.

With the latest generation of optical sensors Baumer provides users with all the benefits of unrivalled ambient light immunity. Right from the start, the Baumer light barriers and photoelectric sensors eliminate many error sources in production. This results in maximum process safety for 24/7 operation.

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