HALIOS The perfect interface technology

Electronic Concept fulfils optical sensor dream

The following article explains how a new optic-electronic concept can bring about contact-free, invisible detection even under adverse ambient conditions, by using the new HALIOS technology. This system will, in the future, be able to simplify considerably the interface between man and machine (MMI) in many products which are used on a day-to-day basis.

By Dr. Frank Rottmann and Dr. Egbert Spiegel

Optical measuring systems used for detecting either movements or the proximity of an object have been around for some time now. For example, in industrial automation, millions of reflex light barriers function day after day without breaking down because they are bound to a fixed and suitable installation place. However, for general applications, for example contact-free optical switches in cars or even for detecting simple human gestures or movements, these optical systems have hardly been viable because ambient light and the ageing phenomenon have prevented them from functioning properly.

Principles of the new system

HALIOS stands for High Ambient Light Independent Optical System. This is a combination of optical transmission and reception elements (LEDs and photo diodes) together with a new electrical signal-evaluation system for detecting movement or the presence of objects through a closed infrared-translucent surface.

This new technology is self-adjusting and compensates for environmental disturbances such as changes in ambient light, ageing of optical components, surface impurities and scratches as well as parasitic reflection effects over the whole optical path. This works by capturing the light from two independent, opposing optical transmitters with a photo diode and regulating this in such a way that, under all conditions, a static zero sum signal is received. It is therefore only the transient regulating processes that contain the desired information, which can be accurately captured and evaluated by post-connection hardware and software.

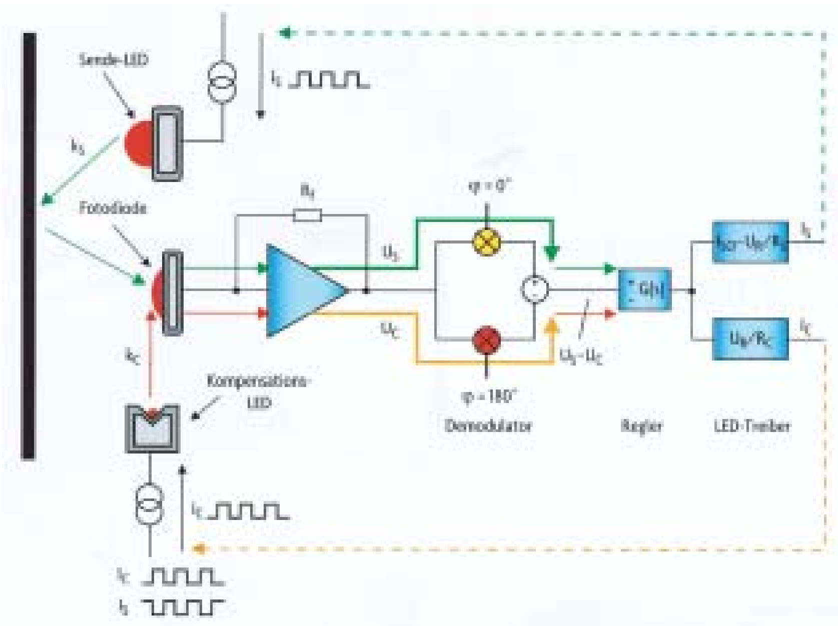

Figure 1: Block diagram and signal flow of HALIOS

By using suitable evaluation electronics, touching or wiping movements over an input surface, or the near touch of a finger can be accurately recognised without actual contact and converted into electric switching signals even with considerable changes in the ambient light. Since three-dimensional movement over a surface can be recorded, it is also possible for HALIOS to be used for one, two and three-dimensional optical-input devices. Moreover, the technology works without any mechanical parts whatsoever and is therefore wear free. Optical elements arranged behind a translucent, printable input surface are therefore able to form switches, keys, control panels and regulators.

$k_{S,opt}$	=	transmission factor of the optical sending path
$k_{C,opt}$	=	transmission factor of the optical sending compensation
R_f	=	transimpedance (effective)
U_S	=	output voltage sending diode part
U_C	=	output voltage compensation diode part
$I_{P,S}$	=	photo current sending diode part
$I_{P,C}$	=	photo current compensation diode part
I_S	=	sending current of the LED
I_C	=	compensation current of the LED

Table 1: Explanation and definition of the derivation HALIOS equations

Derivations of the HALIOS equations

The optical components of a HALIOS system for proximity and switch applications consist of a transmissions LED for the optical wanted signal and a compensation signal which produces a reference signal. Light from the compensation LED is directed only onto the photo diode so that interaction with the actual object does not take place. Both signals are captured by the same photo diode. The LEDs are driven alternatingly with 180 degree phase-shifted signals. Both signals from the photo diode are then converted into a voltage and amplified, after which they are then separated with a synchronous demodulator and subtracted from one another.

The differential signal controls a regulator which influences the amplitude of the current from the compensation diode and/or the transmissions diode, and regulates this to a value of zero. In an equalised state therefore, the signals received by the photo diode from the transmissions and compensation paths have the same value. In order to carry out various functions, the output signal from the regulator is further electronically analysed and evaluated. Figure 1 shows schematically a block diagram and signal flow for a switch with an additional proximity function where one can for example control one's own background lighting.

The following shows how the adjusted state is robust enough regarding the so-called ambient light effect, in other words, its immunity to changes in the ambient light level itself as well as to the photo diode sensitivity following strong illumination or temperature changes. Some initial explanations and definitions simplify the derivations of the basic HALIOS equations (Table 1).

Equations for HALIOS

$$I_{P,S} = k_{PD} \cdot k_{S,opt} \cdot I_S \qquad (1)$$

$$I_{P,C} = k_{PD} \cdot k_{C,opt} \cdot I_C \qquad (2)$$

$$U_S = R_f \cdot I_{P,S}$$
$$U_C = R_f \cdot I_{P,C} \qquad (3)$$

$$U_S - U_C = R_f \cdot k_{PD} (k_{S,opt} \cdot I_S - k_{C,opt} \cdot I_C) \qquad (4)$$

$$k_{s,opt}/k_{C,opt} = I_C/I_S \qquad (5)$$

$$U_S - I_C = R_f (k_{PD} \cdot k_{S,opt} \cdot I_S - I_C) \qquad (6)$$

$$I_C/I_S = k_{PD} \cdot k_{S,opt} \qquad (7)$$

The proportional part of the photo current caused by the transmission LED is calculated (equation 1 see formulae) from the optical transmissions factor $K_{S,opt}$ (containing the characteristics and the optics of the LED) and the transmissions factor of the photo diode K_{PD} (photo current in relation to optical power). The resultant value for the compensation path is shown at (2).

Both signal currents pass through the same amplifier and are, according to (3), converted into voltages. In the demodulator, both proportional signal parts are separated and, according to (4), subtracted from one another. The regulator ensures that the difference U_S-U_C is zero, by altering the current I_C and/or I_S.

Equation (4) further shows that, in order to fulfil this condition, the properties of the amplifier (summarised in R_f) and the properties of the photo diode K_{PD} are no longer relevant. This results in the basic equation for the adjusted state according to (5).

This steady state also remains unaffected by sudden changes in the transmissions factor of the photo diode (K_{PD}), caused for example, by a high incidence of light (ambient light effect). This means that there is no deviation activity which might cause the proximity threshold to be exceeded.

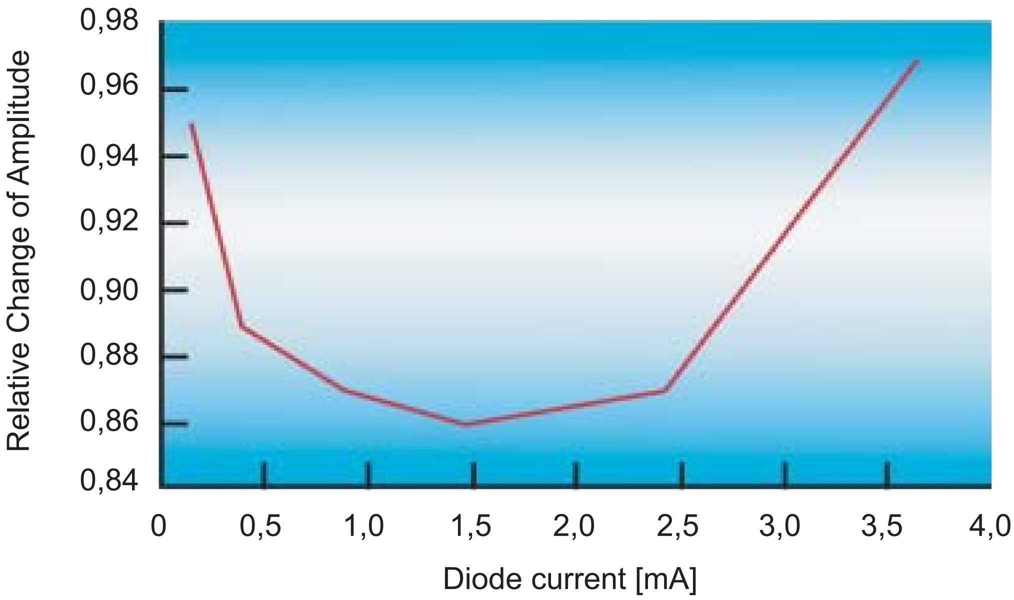

Figure 2: Relative amplitude changing of a 31.25kHz signal as a function of the photo diode current based by the illumination, measured at a SFH2400, by OSRAM

Figure 2 shows a measurement (carried out using simple laboratory techniques) of photo diode sensitivity in relation to illumination. The curve shows the relative change of photo diode sensitivity depending on the photo current, caused by illumination (relative change of K_{PD}).

One could omit the compensation LED and instead feed a corresponding compensation current I_C directly into the amplifier input (i.e. electronic compensation). This modification would result in a value as shown at (6). The adjusted state (U_S - U_C = 0) results from (7).

It can be seen that the behaviour of the photo diode with electronic compensation for ambient light variance, temperature changes and ageing, directly influence system behaviour. However, using the additional compensation LED precludes these disturbing factors effectively.

Another alternative would be to regulate amplitude of the amplifier's output to a constant value. The result here is similar to that shown in equation (7) - but in this case, the properties of the amplifier influence system behaviour as well. (When using integrated components, R_f is dependent on temperature and afflicted with larger tolerances).

As opposed to conventional light barrier systems that have been used until now, this new system no longer uses the amplitude values of the photo receiver but instead uses the control value "current through the compensation LED" as the actual measured indicator. To summarise, the

HALIOS has the following distinct advantages over conventional methods:
The signal received at the output of the amplifier path is a real zero signal. Because of this, any influences on the reception path are fully compensated for. In particular, non-linearities from the photo diode and fluctuations in the amplifying factor do not affect the desired signal.

In that a zero signal is at the reception amplifier output, the sensitivity of the desired signal is much higher.

This higher sensitivity means that it is possible to work with smaller signal amplitudes, and therefore reduce the amount of power consumed by the transmission LEDs. This is particularly useful for battery powered and/or rechargeable devices.

The ambient light factor is no longer relevant since the feature of the reception path does not influence the wanted signal.

During operation, system function is constantly monitored for integrity since, in the case of a component fault in the closed-loop control circuit, the output signal immediately adopts an extreme value.

Neither temperature fluctuations nor component ageing in the detector matter since the reception path and its photo diode do not affect the measuring signal.

Advantages and applications possibilities

The schematic at Figure 3 shows the simplest application of all i.e. the optical switch or key. Here, under an infrared-translucent surface, both transmission LEDs and the photo diode are positioned so that the reflection of the light from the wanted signal LED is detected on an approaching finger above the surface. The post-connected signal evaluation now detects the switching process fault-free so that it evaluates the reflection signal of the finger which approaches the surface at a certain speed and then stops abruptly by coming into contact with the surface. In order to obtain a definitive evaluation, it makes sense for the finger to remain on the translucent surface for a defined period of time.

The parameters "proximity speed" and "length of time on the surface" can be adapted to widely varying requirements and can be integrated into the electronic evaluation. What is important here is that it is not just the absolute temporary value that is evaluated but it is the definite reflectivity modification (1. derived from the temporary value) that is also evaluated to activate the switch. In this way, a temporal modifications profile can be electronically registered.

Should the profile be modified so that the finger after having touched the surface, then has to retreat again without remaining there, then a wiping movement triggers the activation

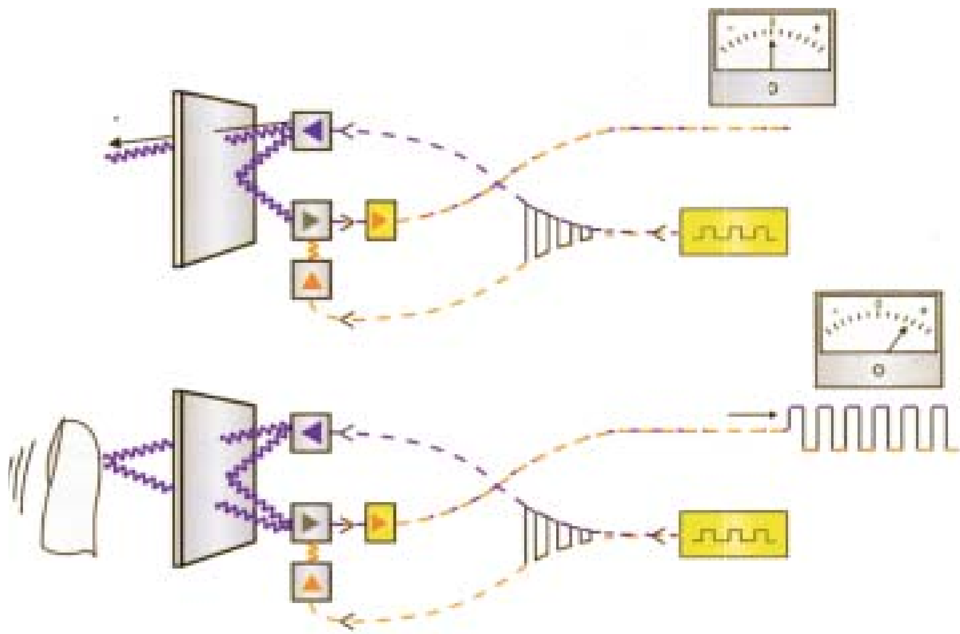

Figure 3: Schematical description of a mechanicless optical switch with additinal proximity function

Advantages and applications possibilities

(Figure 4). As both algorithms have completely different modification profiles, they can be combined independently from one another: switching on just by touching, or switching off just by wiping.

In addition, if the temporary values of the reflected signals are evaluated appropriately, the electronics can recognise an object approaching the active surface. This distance control means that in addition, a light switch for example can be activated before the actual switching process has taken place in order to locate the exact position of the switch in the dark. The concept of placing contact-free switches behind glass or other translucent surfaces also opens up countless design possibilities.

Adaptations to the optical elements and evaluation electronics can combine to form a distance sensor that is independent of ambient light. For example, the distance between a person's head and a telephone receiver can be detected through an infrared-translucent plastic casing. This can be used to adjust the volume of the phone loudspeaker. Where the distance increases beyond a certain point, the volume is increased. If however this distance decreases, then the volume is regulated to normal. Such a device fitted to a telephone would make the current on/off button for the loudspeaker redundant.

Depending on the respective type of optical elements, maximum measuring distances of considerably <10cm are possible , whereby through this new system, all the previously mentioned ambient influencing factors at the switch are eliminated. Keys and switches use only one active detection point. This new system can also be utilised in all three dimensions.

For instance, if the number of optical elements is doubled, the position of an object on a surface can be detected. This provides an efficient alternative to the familiar capacitive and resistive fields which are widely used in computers. A big advantage over resistive input fields is the mechanical insensitivity of the system since there is no direct contact between the mechanical input medium (finger, pen etc) and the optic-electronic position detection. As well as having an analogue position detection, it is possible to create a multi-function key board display which contains all the above-mentioned advantages by dividing up the surface in a fixed way. In particular, by simply placing this behind or underneath a surface which only has to be optically transparent, means that it is possible to have a whole range of new mechanic-free input media which are protected against pressure, water and other mechanical damage.

Another considerable advantage over capacitive surfaces is the possibility of being able to reduce the optical field drastically. For example, an optical micromouse with the new sensor under a plastic surface has been developed which is only as big as a fingertip. If a finger is now moved backwards and forwards over this surface (diameter between 10 and 20 mm) the sensor can recognise exactly the minute changes in the direction of the fingertip. This makes it possible to integrate very small and user-friendly micromice with high resolution into small devices as well. The evaluation algorithms can be formed arbitrarily by software, and the reliable position detection takes place according to the principle with all the coresopnding advantages. According to the form used, three or four LEDs and one or two photo diodes are necessary for these two-dimensional applications.

0-dimensional	1-dimensional	2-dimensional	3-dimensional
Optical switch / optical push-button with tip-or wipe-function	Optical slider	Optical mousepad (micromouse)	Micromouse with special function in in z-direction, e.g. mikro-mouse with zoom-function
Optical proximity-sensor	Separate switch arrays	Switch array	Gamepad
		Optical rotary potentiometer	Touchpad with zoomfunction

Table2: Some examples for a MMI-solution based on the HALIOS-principle

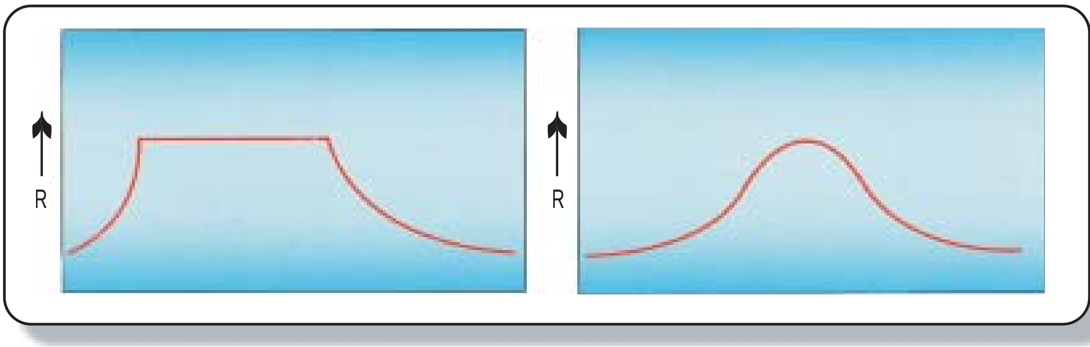

Figure 4: Reflection signal of a swicht actuation 'tip' (left) or 'wipe' (right)

If the new distance control is used as well then the third dimension is also viable. As a result, there is a three-dimensional input field where in addition to the x and y co-ordinates, a z co-ordinate can be used for the entering command at the respective position (which substitutes the familiar mouse click).

Electro-optical measuring system integrated into hardware

It makes sense to incorporate the electronic part of HALIOS in an integrated circuit. This IC contains the analogue and digital control and evaluation circuits as well as a defined applications interface according to customer specifications where the wanted signal is made available to the user. As well as the basic components for the functions "switch, slider" and micromouse" there is also a corresponding demonstrator. HALIOS ICs are designed and produced exclusively by ELMOS; in addition, it is possible to design reasonably-priced customer specific solutions as an exclusive ASIC, for individual applications. For this ELMOS has the benefit of many years' experience in customer and application-specific devices in the semi-conductor field for highly-integrated analogue/mixed signal ASICs which have been especially developed and optimised for the high requirements of the automotive industry.

More information about this new HALIOS-based concept was presented at the Convergence Trade Fair, Detroit in October 2002 and is currently being presented at the Electronica Trade Fair in Münich.

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graduated in Electrical Engineering from the University of Dortmund in 1984 and went on to do his PhD in the field of High Frequency Engineering/Integrated Optics. From 1988 to 1992 he worked in a medium-sized company as the product manager responsible for the development and sale of components used in micro-systems engineering. In 1992, he switched to ELMOS as a sales engineer and since 1997, he has been responsible for the Sales Division.

Dr. Egbert Spiegel
studied Electrical Engineering at the University of Dortmund. From 1990 to 1996 he carried out scientific research at the Fraunhofer Institute for Micro-electronic Circuits and Systems in Duisburg. After acquiring his Phd, he switched to the Nokia Research Centre in Bochum. He has been with ELMOS since 1998 and is in charge of the IC Design of the HALIOS systems in Dortmund.

HALIOS

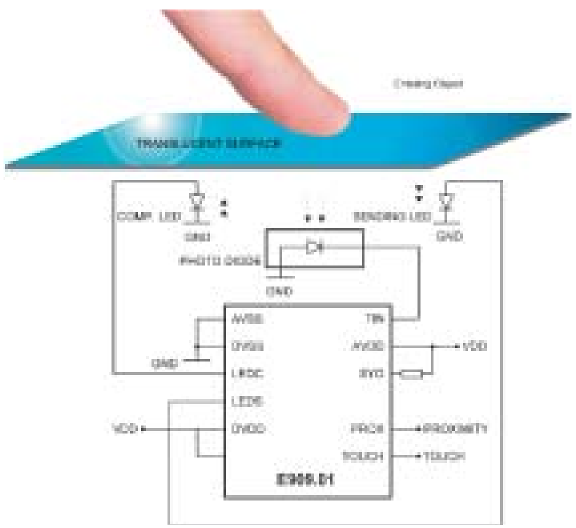
The perfect interface technology

Think About

Optical Switch IC

ELMOS Semiconductor AG

The HALIOS (High Ambient Light Independent Optical System) IC allows contact-free detection of any movement through a translucent surface even under adverse ambient light conditions.



H A L I O S

E909.01 Features

- Supply voltage range VDD: 3 V to 5.5 V
- Operational up to ≤ 200 klux ambient light
- Proximity, touch and switch function
- Parameter adjustment and functional data read back via SPI interface
- Status output for switch and proximity function
- -40˚C to 85˚C operating temperature
- SO16 package

Applications

- Waterproof switches
- Mechanic-less key pad array
- Motion switch and proximity sensing
- New styling opportunities

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