Vishay TSSP Sensor Kit

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The TSSP Sensor Kit is an evaluation board for proximity and presence sensing based on TSSP IR-receivers developed for sensor applications. The kit contains two IR-receivers, the TSSP53000 fix gain wide band receiver and the TSSP4P38, which is equipped with a special automatic gain control optimized for long distance proximity sensing. For signal transmission a VSLB3940 IR-emitter is driven by Arduino Nano output pins. Three different series resistors can be selected to adjust the emitter intensity for different detection distances. Respective forward currents and emitter intensities are displayed in table 1. Emitter and receiver are mounted in a TSSP-HA housing which contains an optical barrier to avoid crosstalk (Fig. 1). Several apertures are also included in the kit for testing in bright ambient or with different viewing angles.

TYPICAL VALUES FOR VSLB3940
FORWARD CURRENT AND INTENSITY AT DIFFERENT SERIES RESISTORS

	100 Ω	820 Ω	3.3 kΩ
Intensity I_e (mW/sr)	16	2.6	0.65
Forward current I_F (mA)	25	4	1

The TSSP sensor kit comprises three different approaches of reflective sensing: fast proximity (TSSP53000), long distance proximity (TSSP4P38), and presence sensing (TSSP53000). A short introduction to the three concepts will be given in the following. A more detailed technical explanation for long distance proximity is available under the following link: tssp-agcp-sensor. For basic technical information on presence sensing please click here: presence-sensor

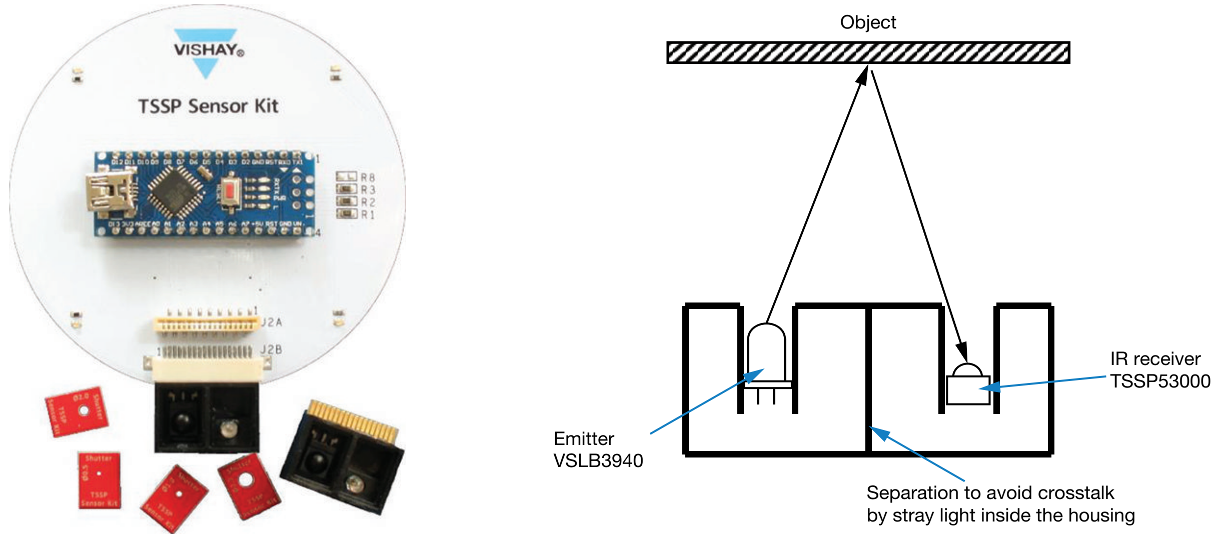

Fig. 1 - TSSP Sensor Kit

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PRESENCE SENSOR

In a presence sensing application the sensor simply detects if an obstacle is in front of the sensor or not corresponding to the two events “reflection yes” or “reflection no”. The application requires no further information, for example on the signal strength. The IR emitter transmits light which is reflected by the obstacle and then returns to the IR receiver, where a simple “active (Lo)” or “inactive (Hi)” signal is fed to the microcontroller (please see Fig. 1). If an obstacle is detected, the green LED in the operating panel lights up (please see Fig. 3).

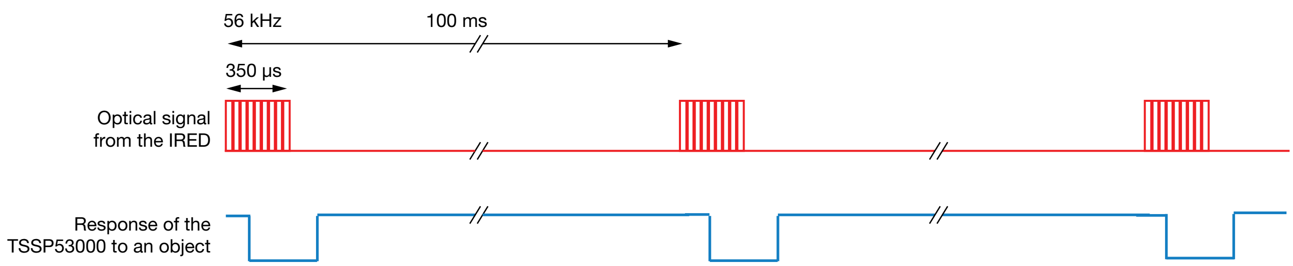

Fig. 2 - Pulsed Signal of the TSSP Presence Sensor Function in the Sensor Kit

Since an IR receiver provides only these two output states (Hi, Lo) such a kind of application can be easily facilitated with a pair of IR emitter and IR receiver, as shown in the presence sensor example program.

The TSSP fix gain receivers have no automatic gain control and can readily accept a continuous 38 kHz or 56 kHz square wave signal.

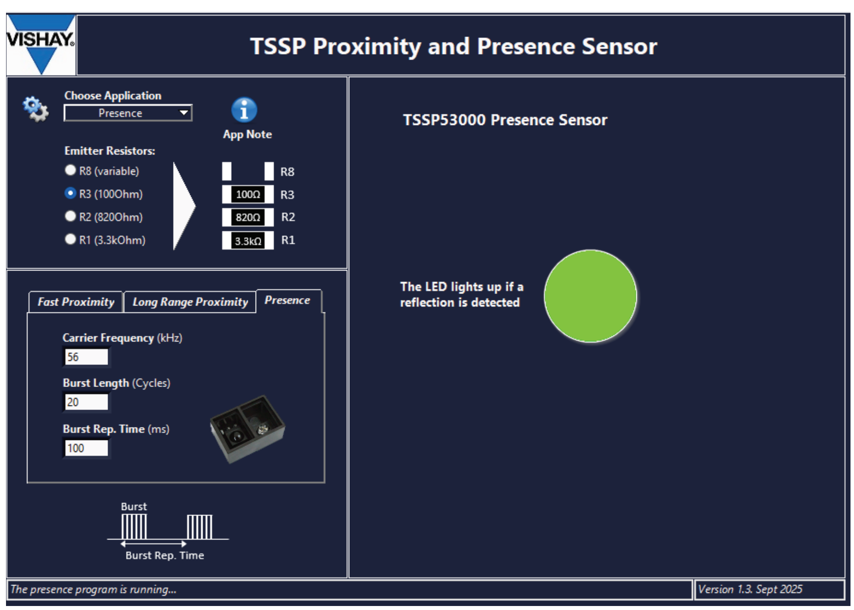

Fig. 3 - Operating Panel of the Presence Function in the TSSP Sensor Kit

Such a signal is recommended when fast reaction times are required. The receiver will respond after a short delay time of approximately 12 cycles of the modulation frequency (~ 214 µs at 56 kHz). The sensor kit shows how power saving can be implemented by using 350 µs bursts at 56 kHz with a moderate repetition time of 100 ms as shown in Fig. 2.

The burst length and repetition time can be tuned in the operating panel (Fig. 3), to achieve the best trade-off between reaction time and power saving. The emitter intensity can be modified by three different series resistors, which will control the detection range of the sensor. Since the receiver responsivity depends on the carrier frequency, the effective detection range can also be adjusted by changing the corresponding value in the operating panel.

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FAST PROXIMITY

In proximity sensing the sensor detects not only the presence of an obstacle, but also provides the additional information if an obstacle is approaching the sensor or moving away from it. This requires additional information about the signal strength of the reflected emitter signal. An object moving towards the sensor will cause an increasing signal strength. The signal decreases when the object is leaving the detection area. Due to their design, IR receivers have only two output states, “inactive Hi” and active “low” and thus cannot provide an information on the signal strength. Nevertheless, one can think of several measurement techniques which provide access to this information. One approach is to reduce the duty cycle of the emitter signal.

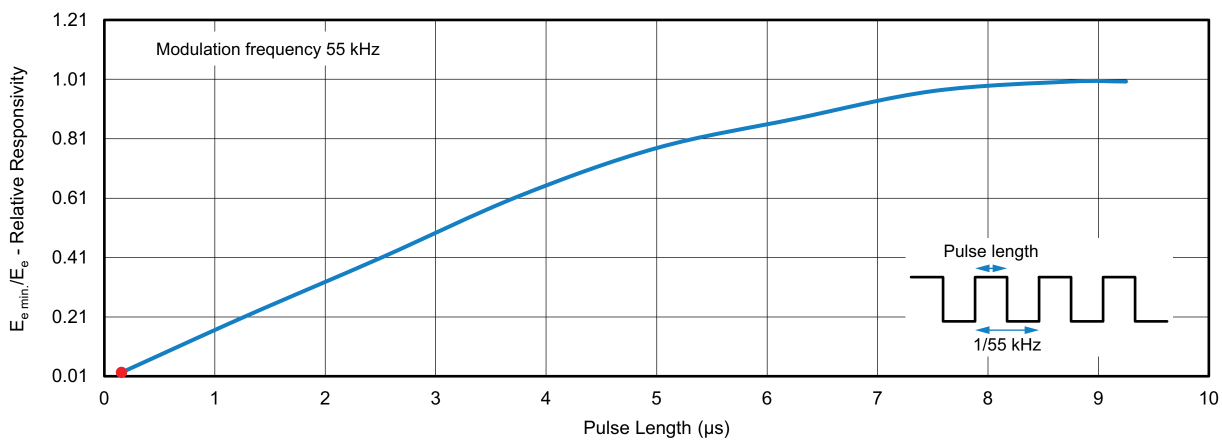

Fig. 4 - TSSP53000 Relative Responsivity vs. Pulse Length

A lower duty cycle decreases the average power transferred in the IR signal absorption process and leads to a lower responsivity of the receiver. The sensor kit varies the carrier pulse length, which is related to the duty cycle as indicated in the inset of Fig. 4. 50 % duty cycle correspond to 9.1 µs pulse length at 55 kHz. Fig. 4 shows also the relative responsivity of the TSSP53000 vs. pulse length. The relative responsivity can be decreased to 0.017 at the shortest pulse length of 125 ns indicated by the red dot (●). This is also the starting point of the frequency variation explained below.

Fig. 5 illustrates how the detection range of the TSSP sensor kit is affected by the pulse length, when the target is a standard Kodak gray card (25.4 cm x 20.3 cm) with 18 % reflectivity. For other targets the distance curve will change because the reflected signal strength depends on the size and reflectivity of the object, for a more detailed review please see presence-sensor.

In the sensor kit set up the shortest pulse length we can send with the Arduino is 125 ns, which is the limit of the 16 MHz on board clock (62.5 ns) in the phase correct PWM mode.

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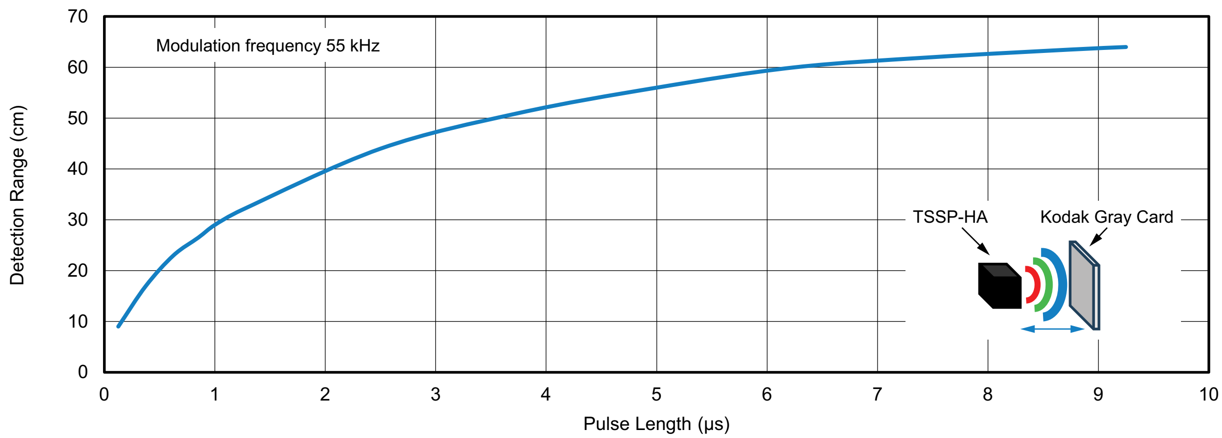

Fig. 5 - Detection Range of the TSSP Sensor Kit (R = 100 Ω) at Various Pulse Length, Kodak Gray Card 18 %

Under these measurement conditions the lower detection range limit at 125 ns is reached at approximately 9 cm distance to the gray card. Moving the gray card closer to the sensor will not change the pulse length anymore. For moving the detection field closer to the sensor, the series resistor can be increased which reduces the emitter power and thus the detection range, but this will also shorten the maximum detection distance.

For a wider detection field, the responsivity of the receiver must be further reduced. This can be achieved by exploiting the band pass filter characteristics of the IR receiver. Detuning the modulation frequency of the emitter signal away from 55 kHz causes the receiver to be less responsive to the signal. The result is shown in Fig. 6, where the responsivity of the TSSP53000 is shown at various modulation frequencies for the minimum pulse length of 0.125 µs.

The low responsivity of max. 1.7 % at 55 kHz is a consequence of the short pulse length of 0.125 µs. This point (●) is the continuation of the lower responsivity limit in Fig. 4, where we varied the pulse length.

Below 44 kHz, the TSSP53000 frequency characteristics is not monotonically decreasing anymore, which causes an irritation of the sensor kit algorithm and leads to uncontrolled jumps of the frequency control.

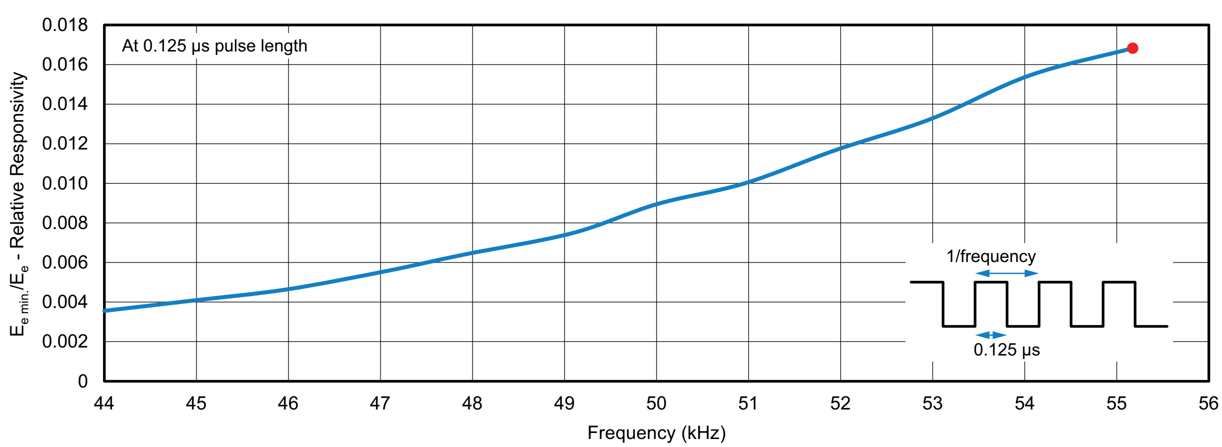

Fig. 6 - Relative Responsivity of the TSSP53000 at Various Modulation Frequencies

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This behavior is also found in standard TSSP fix gain receivers like the TSSP4056, but the non-monotonic region is reached earlier. For this reason, it is recommended to use only the pulse length variation (duty cycle) with the standard TSSP-fix gain receivers.

The circuit of the TSSP53000 was designed to accept a wider range of modulation frequencies than the standard TSSP parts. For example, when using this part at 50 % duty cycle, the frequency range can be extended down to ~ 34 kHz. In the sensor kit it facilitates the operation with pulse length and frequency variation.

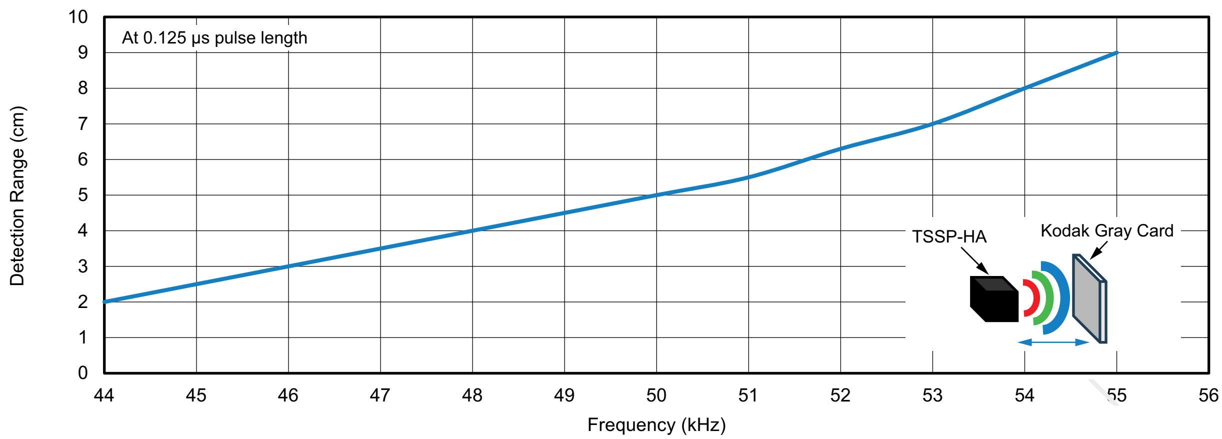

Fig. 7 - Detection Range of the TSSP Sensor Kit (R = 100 Ω) at Various Frequencies With a Kodak Gray Card 18 %

Fig. 7 illustrates how the receiving range of the TSSP sensor kit changes with the modulation frequency at the shortest pulse length of 125 ns. The receiving distance decreases monotonically from 55 kHz to 44 kHz.

The combination of pulse length and frequency variation allows a detection field between 2 cm to 63 cm with a Kodak Gray Card target.

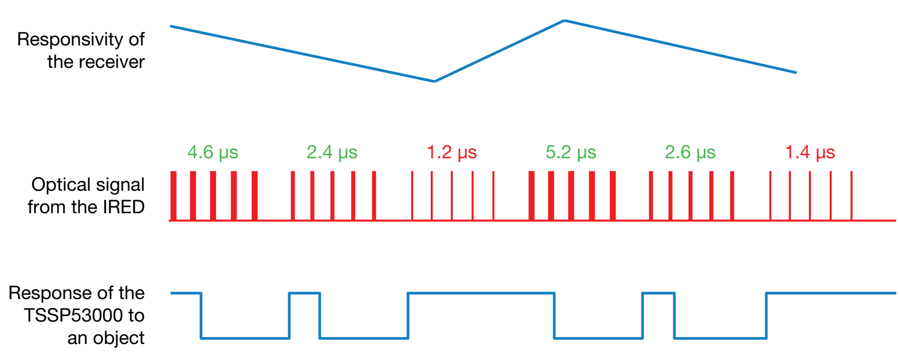

Fig. 8 - Simplified Sketch of the Pulse Length Iteration Applied in the Fast Proximity Program

During the fast proximity measurement, the pulse length is decreased step by step as long as an object is detected by the receiver. This iterative process lowers the responsivity of the receiver until the object cannot be detected anymore. In this situation when the receiver shows no output signal anymore, the pulse length is increased again which keeps the receiver responsivity permanently close to the threshold of object detection, please see Fig. 8. If the object is out of reach, the pulse length is tuned near 50 % carrier duty cycle or 9.2 µs pulse length at 55 kHz, corresponding to the highest sensitivity of the receiver. During the pulse length measurement, the frequency is held constantly at 55 kHz.

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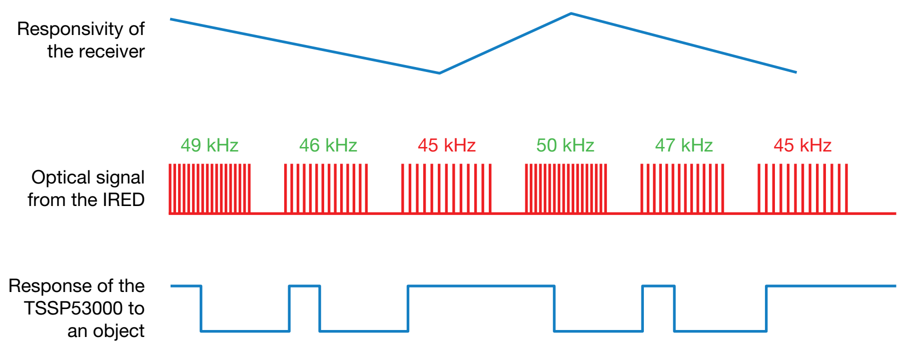

Fig. 9 - Simplified Sketch of the Frequency Iteration in the Fast Proximity Program

The frequency measurement becomes active only when the pulse length limit at 125 ns is reached and the object can still be detected. It uses the same iteration process as the pulse length method. The modulation frequency is decreased step by step to the threshold of object detection as shown in Fig. 9. The selection of pulse length and the frequency parameter are then a measure of the relative distance to the target.

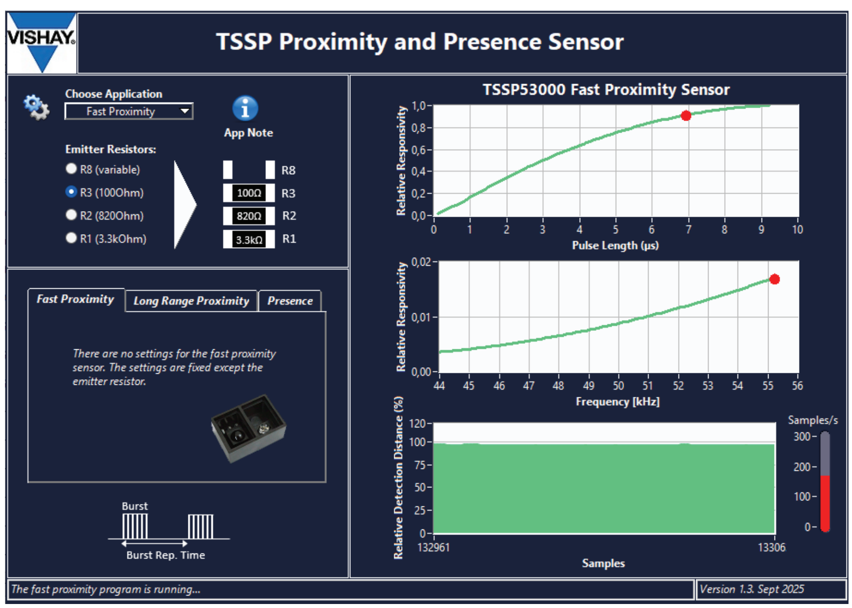

Fig. 10 - Operating Panel of the TSSP4056 Fast Proximity Function in the TSSP Sensor Kit

The graphical user interface of the fast proximity measurement is displayed in Fig. 10. It contains charts for the relative responsivity vs. pulse length and vs. frequency and a relative detection distance chart which displays the square root of the responsivity data. This is an oversimplification, since a square root behavior is only expected for large targets and (or) short distances and could fail to provide accurate data in other cases. This chart shall only provide a rough indication for the relative target distance when R = 100 Ω is selected.

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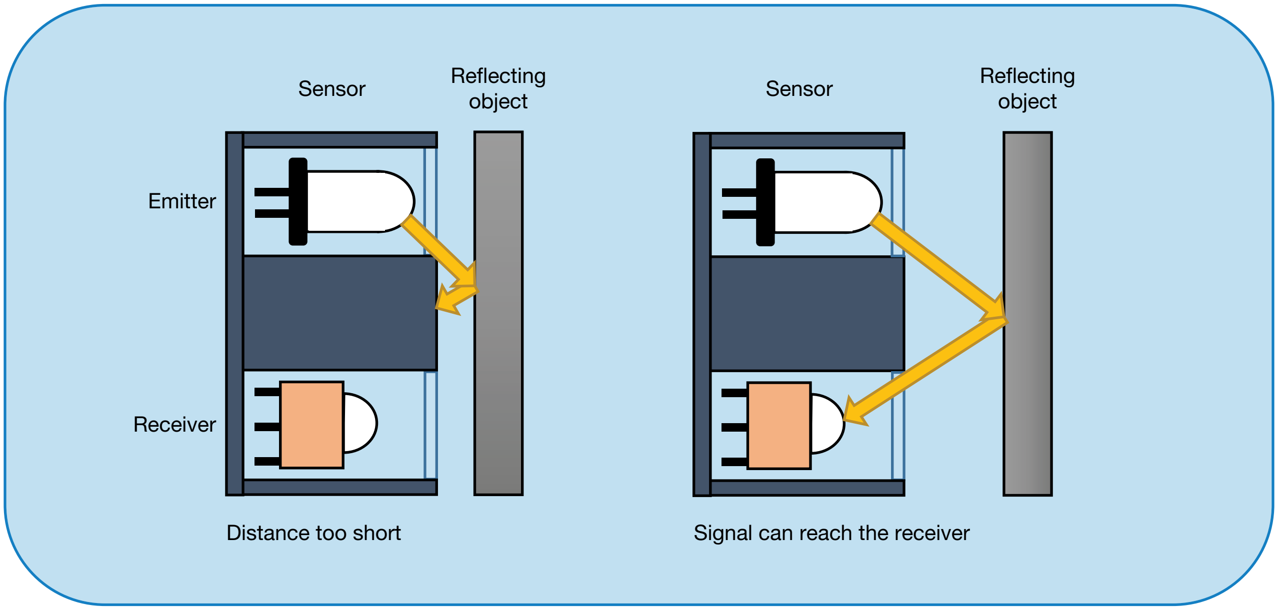

Fig. 11 - Limitation of the Sensor Resolution at Short Distance Due to Geometrical Constraints

At higher emitter series resistors, the detection range becomes shorter, and the sensor resolution might be limited by geometrical constraints of the TSSP-HA package.

As shown in Fig. 11, the emitter signal cannot reach the IR receiver anymore, when the TSSP-HA housing blocks the direct light path. This situation occurs only when the object gets in very close proximity to the sensor and might cause a decrease of the signal strength although an increase is expected.

There is an additional indicator for the measurement rate near the relative detection distance chart. The current program applies eight iterations of pulse length variation and the same number for the frequency approximation. If only the pulse length measurement is active the data rate is near 170 samples/s. If both measurements are active the measurement rate decreases to about 85 samples/s. The measurement speed can be further enhanced to approximately 200 samples/s by using shorter burst length. However, this will also reduce slightly the detection range. For this reason the current program uses 25 cycles burst length for enhanced sensitivity.

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LONG DISTANCE PROXIMITY

A second approach to measure the strength of an incoming optical signal evaluates the control speed of the receiver's automatic gain control (AGC). More precisely, the AGC logic examines the burst length and the gap times of the optical signal, to distinguish between data signal and noise. If the burst length exceeds a certain value, the AGC identifies a noise signal and starts to decrease the sensitivity.

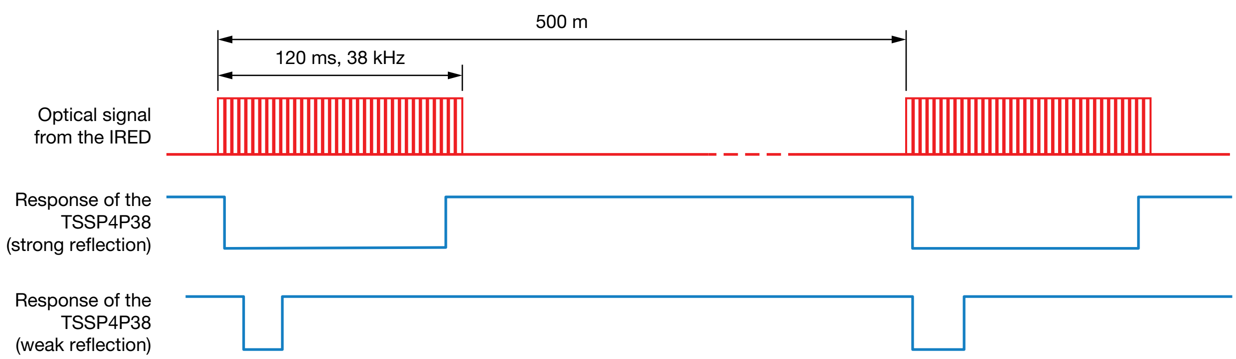

Fig. 12 - TSSP Sensor Kit Signal Pattern for Long Distance Proximity

The time required to suppress such a signal is long at a high irradiance and short at low irradiance, resulting in a pulse length corresponding to the distance of an object. This kind of analog information can be evaluated by a microcontroller. The signal pattern applied in the TSSP sensor kit is illustrated in Fig. 12. A burst length of 120 ms is long enough for the AGC to suppress the signal, either partly (strong signal) or almost completely (weak signal).

The output burst length is shown in the operating panel in Fig. 13. A long burst corresponds to a short object distance and vice versa. After such a long burst signal the receiver needs to recover to its maximum sensitivity again. A repetition time of 500 ms provides enough gap time for the receiver to reach full sensitivity and to start the next measurement. Burst length and repetition time can also be adjusted in the operating panel.

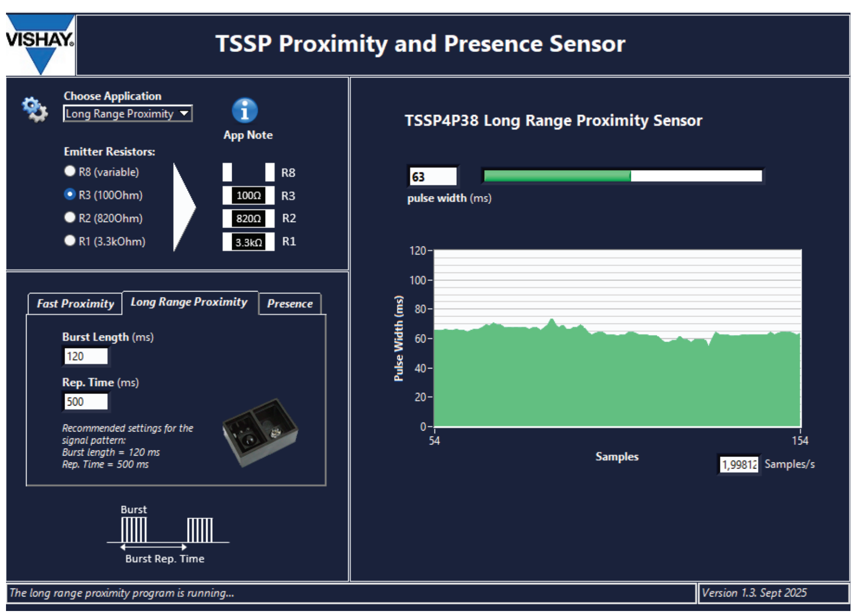

Fig. 13 - Operating Panel of the Long Distance Proximity Program in the TSSP Sensor Kit