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Application of ultrasonic distance sensors for measuring height as a tool in unmanned aerial vehicles with a stabilized position in the vertical plane

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Abstract
The paper presents a review of ultrasonic sensors. Attention is focused on the possibility of using such sensors to keep an unmanned aerial vehicle at a constant altitude above the surface. Such a task requires filtered and unfiltered signals, so that the ground level can be distinguished even when obstacles are present. Three selected sensors were tested. The possibility of connecting these sensors to external devices was also studied. The potential of the individual sensors and of a set of sensors is discussed. The study showed that the best solution is to use a set of three ultrasonic sensors. Alternatively, a sensor with both unfiltered and filtered measurement was proved to be an adequate option.

Introduction and assumptions

The following review was conducted for the purpose of unmanned aerial vehicles designed for surveys of levees and other civil infrastructure. Such vehicles should maintain a constant altitude above the surveyed structure. To achieve this, altitude measurments must be taken continuously, with an accuracy of 1 millimeter. It is also expected that the sensor will be able to provide independent data about any other object in its range. Connectivity with external devices used for signal analysis, particularly PC and Raspberry Pi computers as well as Arduino and Netduino microcontrollers (Raspberry Pi, 2016; Netduino, 2016; Arduino, 2016), is also required.

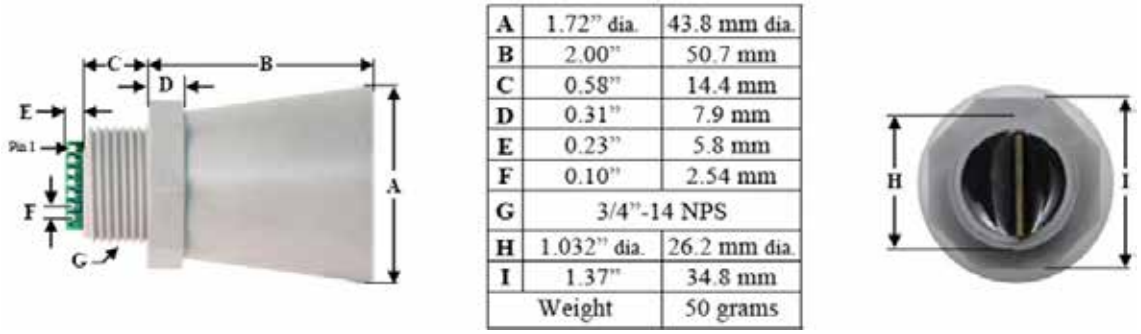
Selection of sensors for analysis

Many manufacturers offer ultrasonic sensors with a range of a few meters. Such solutions are presented in (Azis et al., 2004; Costa et al., 2012; Anthony et al., 2014). Among these sensors only MaxBotix Inc offers sensors equipped with a system that calculates the distance. The company offers a wide range of products, with the common name of XL-MaxSonar.

Because of the functional requirements, only three ultrasonic distance sensors have been selected for investigation and analysis: XL-MaxSonar-WR1 MB7062 – because it includes a stabilizing filter, XL-MaxSonar-WRL MB7066 – because it has a range of 10 meters, and XL-MaxSonar-WRL MB7076 – which also has a range of 10 meters but

Part Number	AN Voltage	Serial Data (0 to Vcc level)	Pulse Width	Analog Envelope	Stability Filter	Most Likely Filter	Refresh Rate	Other Packages Available	7 meter range	10 meter range
MB7052	Yes	RS232	Yes		Yes	Yes	6.6 Hz	Yes	Yes	
MB7060	Yes	RS232	Yes				10 Hz	Yes	Yes	
MB7062	Yes	RS232	Yes		Yes		10 Hz	Yes	Yes	
MB7066	Yes	RS232	Yes				10 Hz			Yes
MB7070	Yes	RS232		Yes			10 Hz	Yes	Yes	
MB7072	Yes	RS232		Yes	Yes		10 Hz	Yes	Yes	
MB7076	Yes	RS232		Yes			10 Hz			Yes
MB7092	Yes	RS232		Yes	Yes	Yes	10 Hz	Yes	Yes	

Figure 1. Comparison of the basic parameters of the XL-MaxSonar-WR family of sensors (MaxBotix, 2016)



A	1.72" dia.	43.8 mm dia.
B	2.00"	50.7 mm
C	0.58"	14.4 mm
D	0.31"	7.9 mm
E	0.23"	5.8 mm
F	0.10"	2.54 mm
G	3/4"-14 NPS	
H	1.032" dia.	26.2 mm dia.
I	1.37"	34.8 mm
	Weight	50 grams

Figure 2. Appearance and dimensions of the XL-MaxSonar-WR family of sensors (MaxBotix, 2016)

additionally has an analog output, the so-called Analog Envelope. All sensors are equipped with the "Full Horn" housing, which directs the signal more precisely than other types of enclosures.

Research

Research Sensor XL-MaxSonar-WR1 MB7062

The XL-MaxSonar-WR1 MB7062 sensor has a range of 7 meters and two stabilizing filter measurement outputs: serial (RS232) and analog (pulse width modulation). The sensor may operate in two modes: continuous and forced.

This sensor indicates the distance to the first encountered object. The stabilizing measurement filter compares the last three measurements, if the difference between any two of these is below 10 cm the last measured distance is transferred to the sensor's output, otherwise the (old) previously measured distance is indicated. If no object has been detected within 60 minutes, the sensor returns the value 0.

Measurement Results

a) Measurement configuration: Power Supply – Sensor – PC, in a RS232 mode (Figures 3 and 4).

Figure 3. The measuring system in RS-232 mode

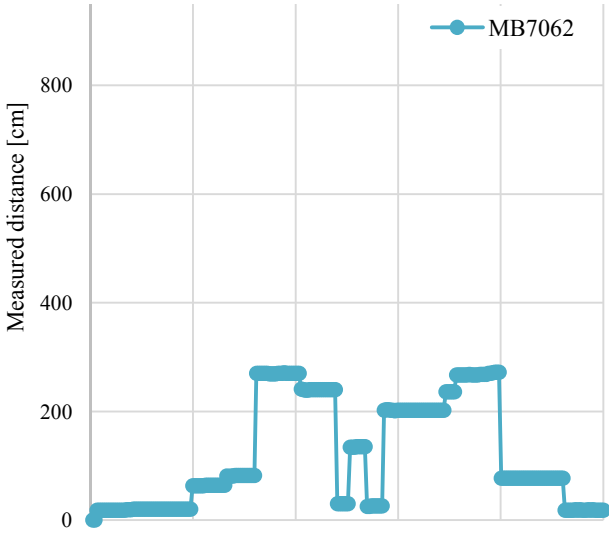


Figure 4. Distance measurements during rotation MB 7062 (around an axis OY), in the room

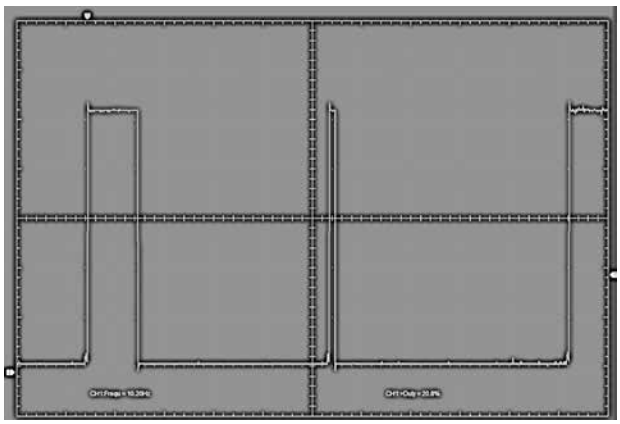


Figure 5. Screenshot of the oscilloscope screen when measuring distance, sensor MB7062 – temporarily overridden

b) Measurement configuration: Power Supply – Sensor – Oscilloscope, PWM mode (Pulse Width Modulation) (Figure 5).

Conclusion

A sensor in the RS232 mode detects the closest object, if the distance does not change by more than 10 cm within 200 ms. In PWM mode, the sensor does not use the distance filter and always provides the value of the distance to the nearest object.

Research Sensor XL-MaxSonar-WR1 MB7066

The sensor XL-MaxSonar-WR1 MB7066 has a range of 10 meters and two outputs, serial (RS232) and analog (pulse width modulation). The sensor has two modes: continuous and stimulated.

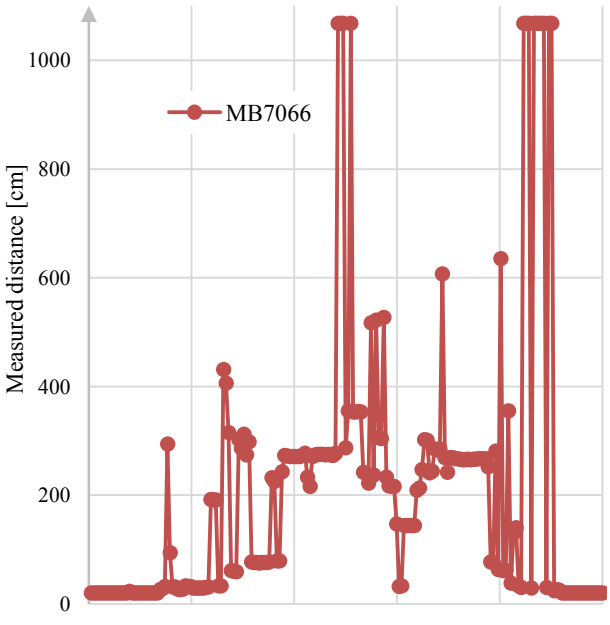


Figure 6. Distance measurements during rotation MB 7066 (around an axis OY) in the room

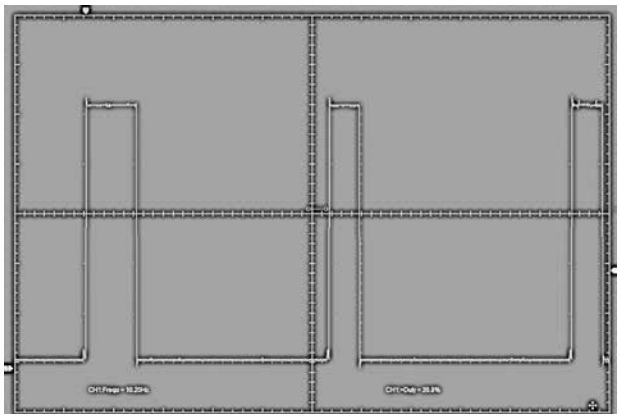


Figure 7. Screenshot of the oscilloscope when measuring distances, sensor MB7066 – changing the distance to closer object

Measurement Results

a) Measurement configuration: Power Supply – Sensor – PC, in a RS232 mode (Figure 6).
b) Measurement configuration: Power Supply – Sensor – Oscilloscope, PWM mode (Pulse Width Modulation) (Figure 7).

Conclusion

A sensor in the RS232 mode, as in the case of PWM mode, detects the most distant object within 10 m. The sensor is not resistant to multiple signal reflections from objects and indicates a greater distance than the largest one measured in the experimental room.

Research Sensor XL-MaxSonar-WR1 MB7076

The XL-MaxSonar-WR1 MB7076 sensore has a range of 10 meters and two outputs: serial (RS232) and analog (Analog Envelope). The analog output allows tracing the entire echo returning to the sensor, making the equipment unique and potentially the most useful among the surveyed devices.

Measurement Results

a) Measurement configuration: Power Supply – Sensor – PC, in a RS232 mode (Figure 8).
b) Measurement configuration: Power Supply – Sensor – Oscilloscope, Analog Envelope mode (Figures 9, 10 and 11).

Conclusion

A sensor in the RS232and PWM modes detects objects at a maximum distance of 10 m. The sensor is not resistant to multiple signal reflections from objects and indicates a greater distance than the largest one measured in the experimental room.

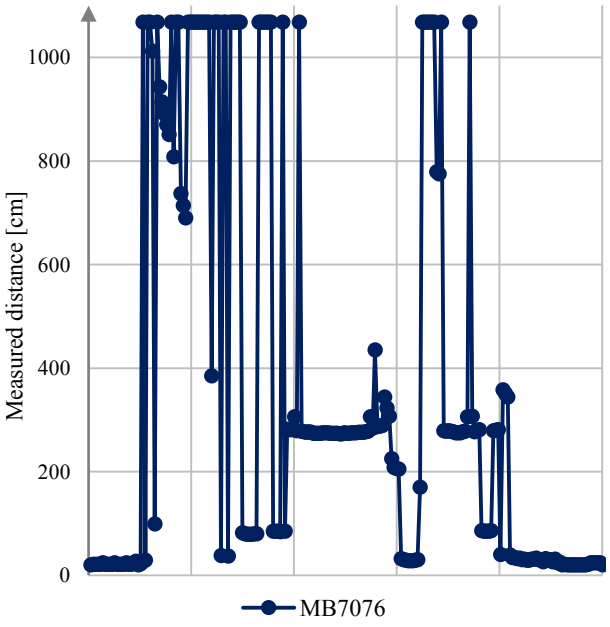


Figure 8. Distance measurements during rotation MB 7076 (around an axis OY) in the room

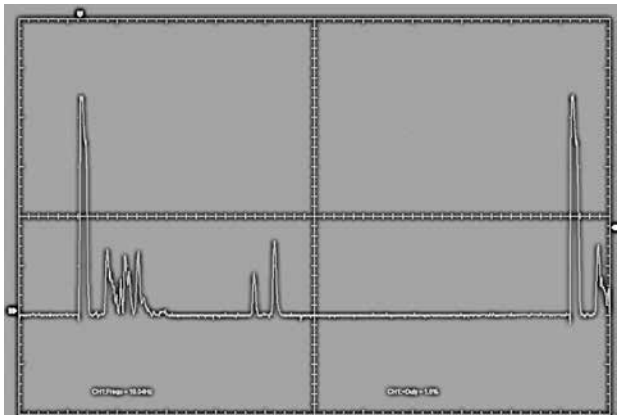


Figure 9. Screenshot of the oscilloscope when measuring distances, sensor MB7076 – large object (wall) at a distance of about 4 m

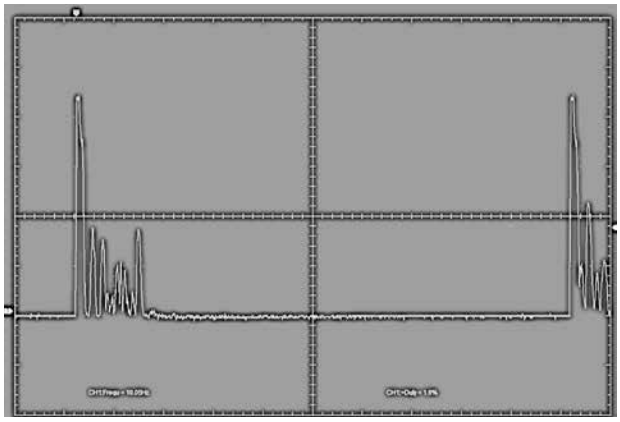


Figure 10. Screenshot of the oscilloscope when measuring distances, sensor MB7076 – sensor covered

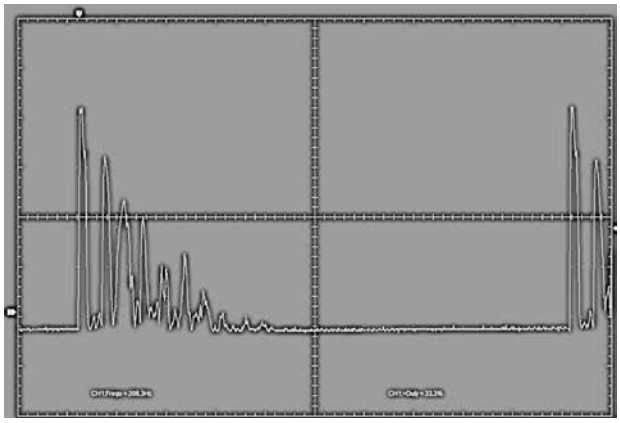


Figure 11. Screenshot of the oscilloscope when measuring distances, sensor MB7076 – several objects of different sizes at different distances

In Analog Envelope mode, smaller and larger objects can be detected; the signal is not modified by the sensor and can be processed in the following step.

Communication

The available outputs of the sensors are:

- Serial RS232 – suitable for connection to devices with a serial port, such as computers (including PC and Raspberry Pi) and microcontrollers (e.g. Netduino and Arduino);
- Analog – PWM – suitable for connection to devices that can read the state of the voltage input (typical digital value), microcontrollers (e.g. Netduino and Arduino), computers equipped with digital inputs (e.g. Raspberry Pi), or PC computers with a A/D converter;
- Analog – analog envelope – for connection to devices that have analog inputs, microcontrollers (e.g. Netduino and Arduino), or computer equipment with the analog-to-digital converter (Analog, 2016).

Summary and conclusions

After conducting the study, it was found that the MB7062 sensor does not meet the expected requirements, since it only gives the distance to the nearest object; however, it could work as an additional sensor to detect obstacles in the field. On the other hand, it is not advisable to use a MB7066 sensor, since it detects false objects due to multiple reflections of the acoustic signal.

For the planned use on unmanned aerial vehicles, the MB7076 sensor (with RS232 output) was chosen as the optimal solution. It gives the initially measured distance in the rs232 mode and filtered results

in the Analog Envelope. This output will detect and dismiss false results due to multiple reflections. Using this sensor, objects other than the ground can be found. This is an extremely important function: comparison of these two outputs allows rejection of the measurements obtained due to multi reflection.

The group of three sensors can be used in order to ensure redundancy of the most important measurements: two MB7076 sensors and one MB7062 (or similar) as a secondary sensor. The latter should be applied cyclically, activating the next sensor system for effective cooperation with the group. It ensures the continuous work of the sensors and eliminates their mutual interference.

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