Ultrasonic Range Finder System

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ABSTRACT. This paper describes a distance-measuring system based on ultrasonic sound utilizing the MSP430F ultralow-power micro-controller. The system transmits a burst of ultrasonic sound waves towards the subject and then receives the corresponding echo. The MSP430 integrated analog comparator Comparator A is used to detect the arrival of the echo to the system. The time taken for the ultrasonic burst to travel the distance from the system to the subject and back to the system is accurately measured by the MSP430. Assuming the speed of sound in air at room temperature to be 1100 ft/s, the MSP430 computes the distance between the system and the subject. The minimum distance that this system can measure is 0 cm and is limited by the transmitter's transducer settling-time. The maximum distance that can be measured is 2.5 meters. The amplitude of the echo depends on the reflecting material, shape, and size. Sound-absorbing targets such as carpets and reflecting surfaces less than two square feet in area reflect poorly. The maximum measurable range is lower for such subjects. If the amplitude of the echo received by the system is so low that it is not detectable by the Comparator A, the system goes out of range.

1. Introduction

The Ultrasonic Range Finder offers precise ranging information from roughly 0 cm to 2.5 meters, figure 1.

This range, easy interfacing, and minimal power requirements make this an ideal ranger for robotics applications.

The module includes a solid state relay for direct drive applications ac or dc type output e.g. burglar alarms or automatic ring bell and garage doors opener.

The output RF interface 433Mhz is designed with a TX 433-LC chip and provides one way link 9600 (8N1) baud rate for future extensions of the module applications area.

There are implemented also, 4 warning levels user selectable and the module has the capability to measure the ambient temperature.

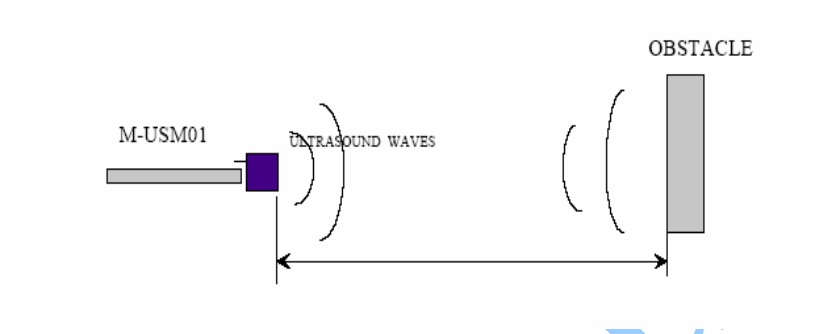

Figure 1

2. Theory of Operation

The ranger works by transmitting a pulse of sound outside the range of human hearing.

This pulse travels at the speed of sound (roughly 0.9 ft/msec) away from the ranger in a cone shape and the sound reflects back to the ranger from any object in the path of this sonic wave.

The ranger pauses for a brief interval after the sound is transmitted and then awaits the reflected sound in the form of an echo.

After the ranger has computed the distance the two values of temperature and distance are sent over the RF serial link (see the technical data for the RF chip in the next chapter) each one preceded by the corespondent ASCII identifier T respectively D.

The controller checks the state of the SW1 switches and compares the computed distance with the corresponding software preset value.

If the distance value is smaller, the SOLID State Relay will close the J3 contact thus the load connected there will be turned on.

The devices used to transmit and receive the ultrasonic sound waves in this application are 40-kHz ceramic ultrasonic transducers from Murata.

The MSP430 drives the transmitter transducer with a 12-cycle burst of 40-kHz square-wave signal derived from the crystal oscillator, and the receiver transducer receives the echo. The Timer A in the MSP430 is configured to count the 40-kHz crystal frequency such that the time

measurement resolution is 25 µs. The measurement time base is very stable as it is derived from a quartz-crystal oscillator. The echo received by the receiver transducer is amplified by an operational amplifier and the amplified output is fed to the Comparator A input.

The Comparator A senses the presence of the echo signal at its input and triggers a capture of Timer A count value to capture compare register CCR1.

The capture is done exactly at the instant the echo arrives at the system. The captured count is the measure of the time taken for the ultrasonic burst to travel the distance from the system to the subject and back to the system. The distance in inches from the system to the subject is computed by the MSP430 using this measured time.

Figure 2 shows the oscilloscope traces for one complete measurement cycle.

Trace 1 shows the 12-cycle, 40-kHz burst at the output of the transmitter transducer. Trace 2 shows the amplified receiver transducer output at pin 1 of the operational amplifier. The first burst-signal on the trace represents the signal directly received from the transmitter and is ignored by the MSP430. The next burst on the trace represents the echo reflected by the subject and is the signal used by the MSP430 for measurement. Trace 3 shows the width of the time interval measured by the MSP430. This width represents the time it takes for the burst to travel the distance from the measuring system to the subject and back, and it depends on the distance measured.

3. Connections

The ranger requires four connections to operate.

First are the power and ground lines. The ranger requires a 9V power supply capable of handling roughly 30mA of continuous output. The remaining two wires are the solid state relay output contacts.

The connections can be made by soldering wire leads to the board or header pins/sockets depending on your needs.

Specifications

Voltage …….7.5-16[V] d.c.
Current …….20Typ. 30 Max[mA]
Frequency ……40[KHz]
Range……Min 0 --Max 2.5[m]

Sensitivity…… Detect a 3cm diameter object at 1.5m

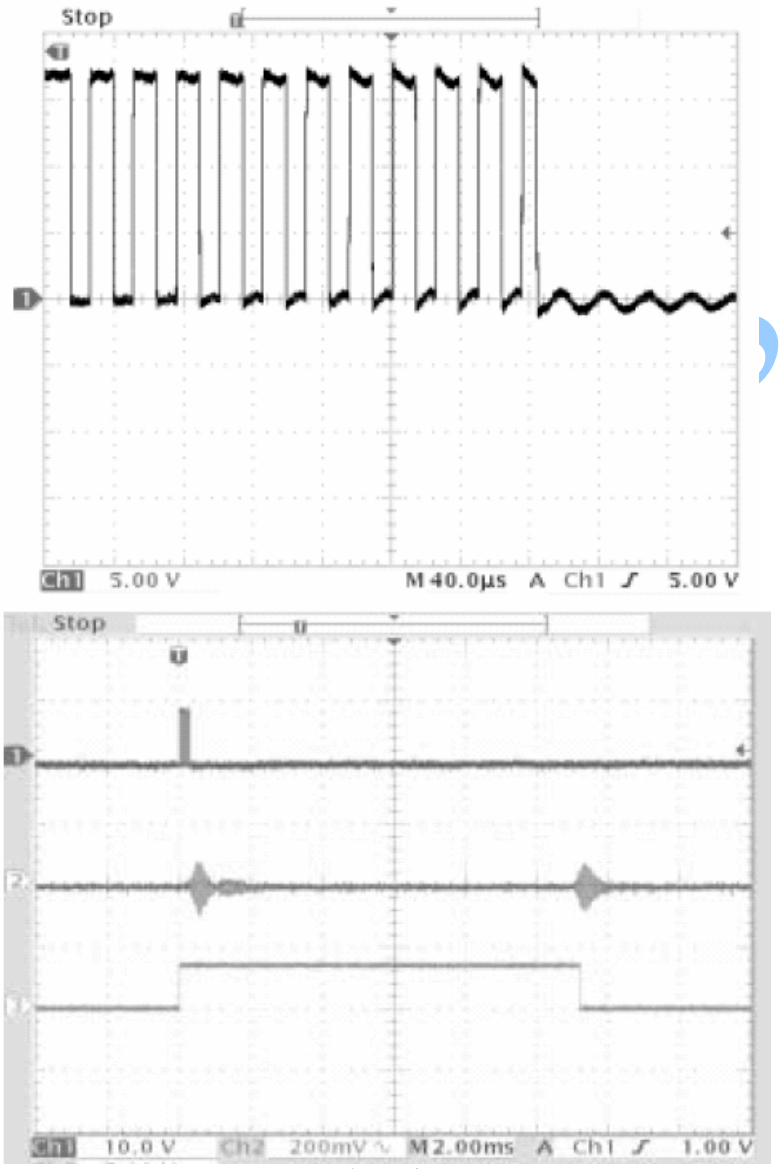

Figure 2

Output: Solid State Relay contact N.O.; 433MHz RF one way link; WIRED /9600/8N1/serial link
Input: warning level preset switch /four combinations.

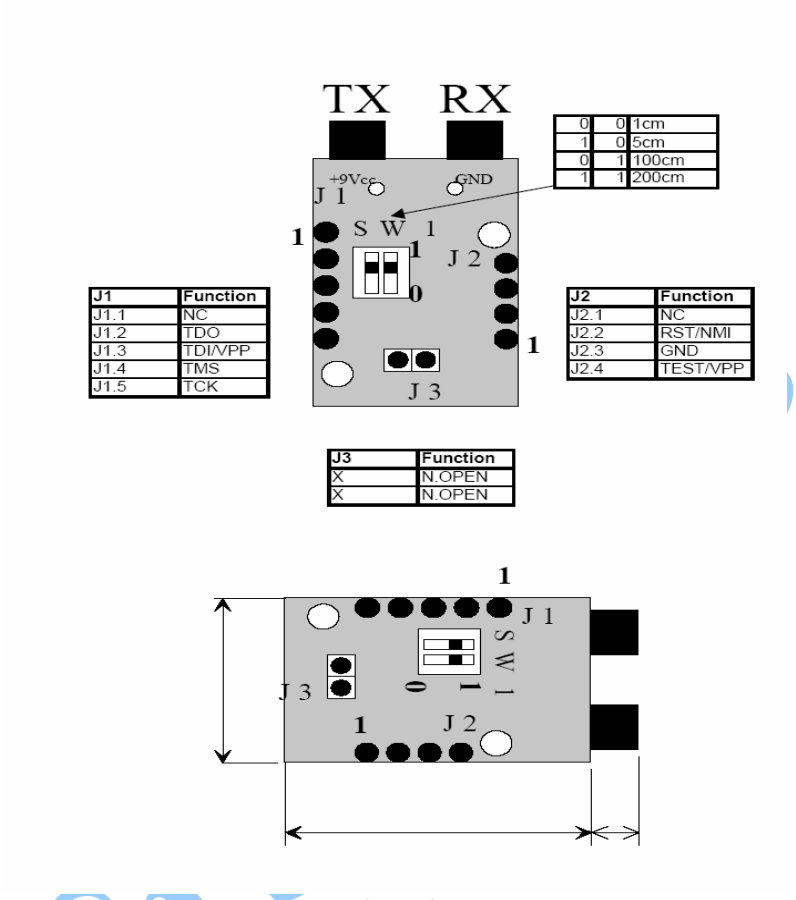

Figure 3

References

[***1] ***, *MSP430x41x Mixed Signal Microcontroller data sheet.*

[***2] ***, *MSP430x4xx Family User's Guide.*

[***3] ***, *MSP430 Family Mixed-Signal Microcontrollers,* application report.

[***4] ***, *TPS770xx Ultra Low-Power LDO Linear Regulators,* data sheet.

[***5] ***, *CD4049UB, CMOS Hex Inverting Buffer/Converter,* data sheet.