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Ultrasonic Distance Measurement Technique in Chair of Cripple Application

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ABSTRACT

The present paper illustrates a type of distance measurement by use an ultrasonic sensor for distance from the foundation of selected points to a frontal object. The sensor was based on the measurement time of travel to an ultrasonic pulse-echo, that was reflected by the object. A controlled technique was use to obtain reflected pulses that were able to detectable by means of a threshold comparator. Such a technique, which takes the frequency response of the ultrasonic transducers into account, allows received pulse detection to be obtained. Experiments performed with a 40 kHz piezoelectric-transducer based sensor, showed a standard stability in laboratory experiment and the sensor still works at motion state by bond the sensor with chair of cripple system. The experimental standard deviation of the linearity with respect to the distance has been found 0.005%. The sensor is composed of only low cost components, thus being equipment in many cases, and is able to adapt to different conditions in order to give the best results.

Keywords: Ultrasonic sensor, Controlled technique, Chair of cripple system.

تقنية قياس المسافة بواسطة الموجات فوق الصوتية في تطبيقات كراسي المعوقين

لخلاصة:

البحث الحالي يوضح نوع لمقياس المسافةِ باستعمال المتحسّسَ فوق الصّوتيَ للمسافةِ مِنْ أرضية النقاطِ المختارةِ إلى جسم أمامي. إنّ المتحسّسَ مستند على قياس وقتِ انتقال نبضِة الموجة فوق الصّوتية، الذي ينعكسُ من الجسم . استعمال هذي التقنيةُ للحُصُول على النبضاتِ المنعكسةِ الممكن اكتِشافها عن طريق المقارنة عند العتبة .ان مثل هذه التقنية والتي تاخذ استجابة الترددات للمتحسسات الفوق الصوتية بالحساب والتي تسمح بالكشف عن الموجات المستلمة التي يمكن الحصول عليها . التجارب انجزت على متحسس محول piezoelectric ضمن تردد 40kHz مبيناً الاستقرارية القياسية للتجارب المختبرية ، لوحظ استقرار القياس في تجربةِ المختبر لمتحسّس يعمل في حالةِ الحركةِ والثبات، عند ربط المتحسس بنظام كرسي المعاق. الانحراف المعياري التجريبي للخطيةِ فيما يتعلق بالمسافة وُجِدتْ ٠.٠٠٥ %. إنّ المتحسّسَ متكوّن من مكوّناتِ منخفضة الكلفةِ ، وهكذا يمكن تطبيقه في العديد مِنْ الحالاتِ، وقادر على التكيُّف لشروطِ مختلفةِ لكي تعطي أفضل النتائج.

كلمات رئيسية: متحسس فوق صوتي ،تقنيات السيطرة ، تطبيقات كراسي المعوقين

Nomenclature

LATIN SYMBOLS		
Symbol	**Description**	**Unit**
D	distance between the reflecting object and the transducer position	m
ToT	The time of travel of an ultrasonic pulse	s
V_s	sound velocity	m/s
V_o	sound velocity at $0C^0$	m/s
T	temperature in	C^0
TTL	transistor – transistor logic	

1. Introduction

Ultrasonic sensor is frequently used for various applications from object identification up to process monitoring and robot control. The measurement method is based on pulse-echo techniques, where the distance information is retrieved from a time-of-flight measurement, that is, the time an ultrasonic wave needs to travel from the transmitter to the receiver after being reflected by an object as (Cai1993).

Different techniques can be used to generate ultrasonic waves. Among them, continuous wave and pulse-echo techniques are widely known. More complex methods involving the modulation of either continuous or pulse waves have been reported, in continuous wave methods, the transmitter generates a continuous output, whose echo is detected by a separate receiver. Accuracy depends on the measurement of phase shift between the transmitted and reflected wave. Although better performances than with pulse-echo measurements can be obtained, complex hardware is required to measure phase and, in most cases, different frequencies need to be used in order to determine the number of integer wavelengths in the phase shift as (Marioli1992).

The pulse-echo method is based on the estimation of the time delay between the moment of emission and the arrival of the reflected wave.

The ultrasonic signal is affected by the propagating medium, the attenuation of which increases with the frequency. Moreover, the signal-to-noise ratio (SNR) is altered by the absorption of the target, external vibrations, and air turbulence as (Gueuning1996).

The techniques described in this paper are part of an effort to develop a low-cost distance measurement by an ultrasonic pulse generated using a piezoelectric transmitter (T) transducer and the echo reflected by the object is received by another piezoelectric receiver (R) transducer, the two transducers are mounted close to each other to make up the measuring head, as shown in **Fig1**. The variety of reflected an objects and the object absorbance for ultrasound wave will not discuss in this research because the time of travel for ultrasonic pulse not affected by the variety of reflected an objects and the object absorbance (RICARDO 1998).

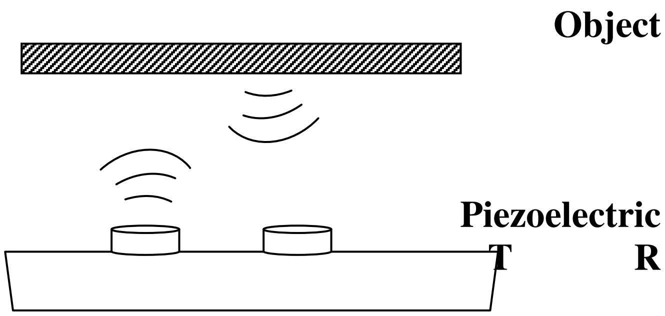

Fig.(1) Transmitting and receiving

The 8051 microcontroller, will describe in section 2.3, is programmed to assign the transmitted signal, adjust the gain-controlled amplifier, and wait to be interrupted by the digital volt to evaluate the time, after calculations, the values of the measured distance are displaced on the display module.

1.1 Distance Measuring Theory

The distance in air is often measured by using ultrasonic sensors. The main measuring principle is based on a pulse time of travel (ToT) estimation (pulse echo method). The distance between the reflecting object and the transducer position (typically, a pair of sensors acting as transmitter and receiver, respectively) is computed as (C.CAI 1993):

$$D = {(ToT \times V_S)}/{2} \tag{1}$$

The time of travel of an ultrasonic pulse ToT, i.e., the time taken for the ultrasonic pulse to travel the distance from the system to the subject and back to the system is accurately measured by the microcontroller

The velocity of sound in air, V_s depends on the temperature according to the approximated eq(2) (RICHARD 1995):

$$V_S = V_O \times \sqrt{1 + \frac{T}{273}} \tag{2}$$

The velocity-of-sound on air at 0 C is equal to 331.6m/s, the changes in the range of 330-360m/s have to, therefore, be expected for temperature changes in the range of 0-40 C^0 (C.CAI 1993) .Such an effect must be taken into account in the determination of the distance; hence a temperature sensor is required.

The ultrasonic pulse is generated using a piezoelectric transducer and the echo reflected by the object is received by other piezoelectric transducer. The two transducers are mounted close to each other to make up the measuring head.

2. Related work

In order to understand the motivation for an ultrasonic sensing system, we review a related work. (Dirk Bank 2002) present a novel ultrasonic sensing system for autonomous mobile systems. It describes how wide angled ultrasonic transducers can be used to obtain substantial information from the environment. This can be achieved by exploiting the overlapping of detection cones from neighbor sensors and by receiving cross echoes between them. The ultrasonic sensing system also allows the detection of multiple echoes from different echo paths for each sensor. In this way, a significantly higher number of echoes can be obtained in comparison to conventional ultrasonic sensing systems for mobile robots in order to benefit from the increased sensor information.

(Alexander 2006) present integrated optical distance measurement sensor works on the time-of-flight principle. The distance information is obtained from the correlation of received light and the transmitted signal. The bridge circuit concept ensures suppression of background light by equally charging and discharging the capacitor within one period, while integrating the wanted signal.

(Tomoaki2002) detecting and correcting a difference of coordinate system definition among a team of robot is mandatory when robots operates in the same environment. Utilizing ultrasonic range finder with a flat wall detection algorithm is possible to implement the proposed framework. The implementation constraints the presence of a flat wall as a part of the environment in order to calculate the difference of coordinate system, already defined among the robots. Then it automatically corrects the difference of the definition of coordinate systems.

(Meng-H Y 2003) present a highly accurate Binary Amplitude-Shift-Keyed (BASK) ultrasonic tremor measurement system for use in isothermal air is developed. In this work a simple but efficient algorithm based upon phase shifts generated by three ultrasonic waves of different frequencies. By the proposed method, it can conduct larger range measurement than the phase-shift method and also get higher accuracy compared with the time-of-flight (TOF) method. microcomputer - based system includes two important parts. One of which is BASK modulation signal generator. The other is a phase meter designed to record and compute the phase shifts of the three different frequencies and the result motion is then sent to either an LCD for display or a PC.

(Richard W.1995) autonomous vehicles are equipped with a variety of instrumentation and controls depending upon the mission of the target vehicle. One of the biggest challenges in developing low risk autonomous vehicles is keeping the cost down, ultrasonic sensors and a global positioning systems result in a low-cost autonomous vehicle that will navigate to a desired location with obstacle avoidance.

2.1 System controlled technique

The ultrasonic distance measurement system consists of two ultrasonic transducer (one of them is used to transmit the signal and the other is used to receive the reflected signal), the controller has a signal generator source system, an auto-gain-controlled amplifier system, and a acquisition signal system. A Intel micro-controller is used to administrate the operation of the entire calculation system as shown in the block diagram of **Fig. 2.**

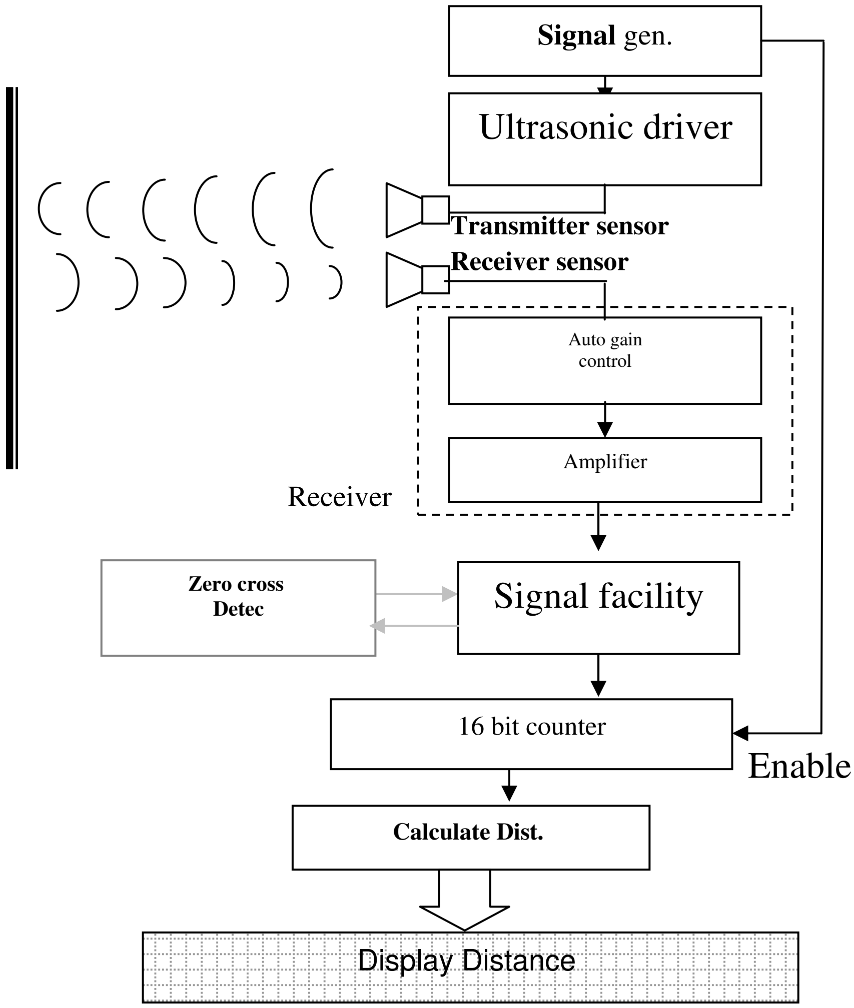

Fig.2. An ultrasonic distance measurement system.

The hardware of the system for distance measurement can be conveniently divided into five parts; the operation of each module is described as the follows.

2.2 Ultrasonic Signal Source

Ultrasonic signal generator source consist from integrated circuit for Triple five IC (555) to generate square signal in frequency (40 KHz), which is the ultrasonic frequency, and (5volts peak value) and switched on for a short time by an electronic switch to which a clock pulse is fed (single pulse packets are generated with a period of the signal generated is 25µs because it enough to transmit more than one pulse which corresponds to a wavelength of about 9mm, the signal is translated to logic inverter to transform the signals from (5 to 0) v and (0 to 5) v, the low voltage translated in the same time in two ways one of them going to the microcontroller to enable the counter, the other is translated with logically high level voltage to the ultrasonic driver which is a type of power-converter of the signals from (5 to +12) v and (0 to -12) therefore the output potential difference voltage on ultrasonic terminals becomes 24V at last the signal arrived to transducer (ultrasonic sensor) that generated the air ultrasonic signal.

Fig.**3**. shows the generated signal of 40 kHz represented by storage oscilloscope.

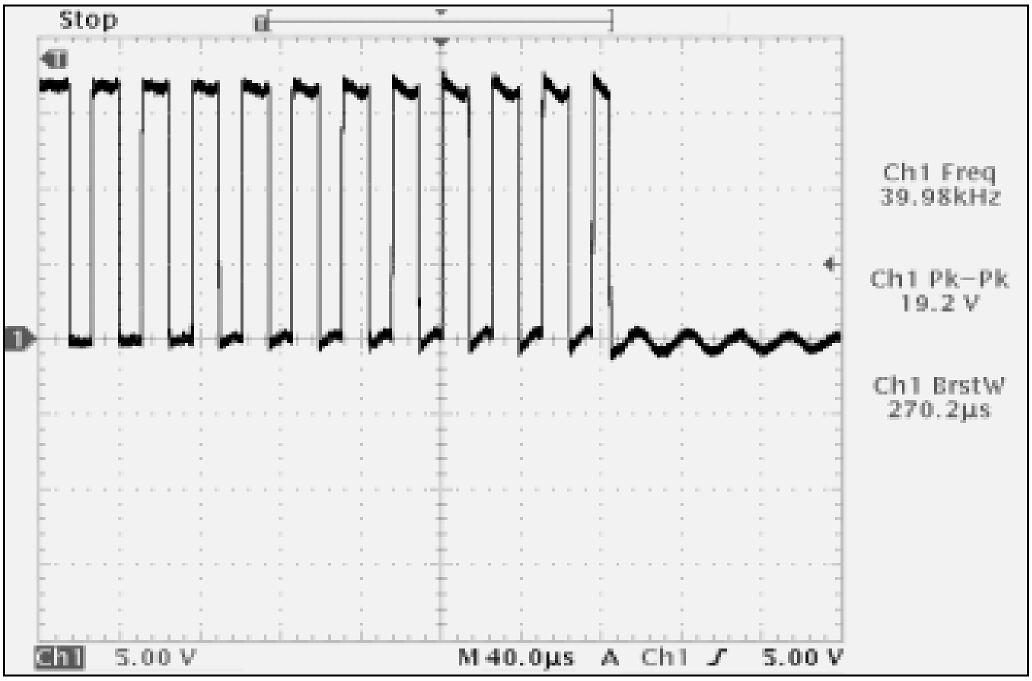

Fig. 3. Ultrasonic signal generator source.

2.3 Auto-gain-controlled (AGC) Amplifier

The ultrasonic signal is received by ultrasonic receiver but it's become weak because the loses in the energy of the signal by transmitted in the air. The ultrasonic signal to be received usually fluctuates in a voltage range from a few µV to *m*V, from experiments the acoustic attenuation effects are large when the distance between transmitter and receiver is over 10cm. to reduce the errors from acoustic attenuation, the gain of the amplifier must be adjusted automatically when acoustic attenuation occurs. Therefore, the error effects related to acoustic attenuation will be minimized in this AGC module by keeping the amplitude of the received signal dynamically constant.

Amplifier: The selective amplifier filters out the external sound with the help of other frequencies, i.e. only the information signal is passed on. This information signal is rectified and amplified, the gain of this amplifier is approach to 500times, after then signal translate to inverter and to thyristor to obtain a transistor – transistor logic (TTL) signal and then applied it at counter in microcontroller.

Microcontrollers: A typical microcontroller is a true computer on a chip. The design incorporates all of the features found in a micro-processor center processing unit CPU that has Arithmetic logic unit ALU, program counter PC, stack pointer SP and registers. It also able to add the other features needed to make a complete computer: read only memory ROM, read access memory RAM, parallel digital I/O, universal serial RS232, analog to digital ADC, and a digital to analog DAC as (Kennth2005). **Fig. 4**. shows the block diagram of a typical microcontroller.

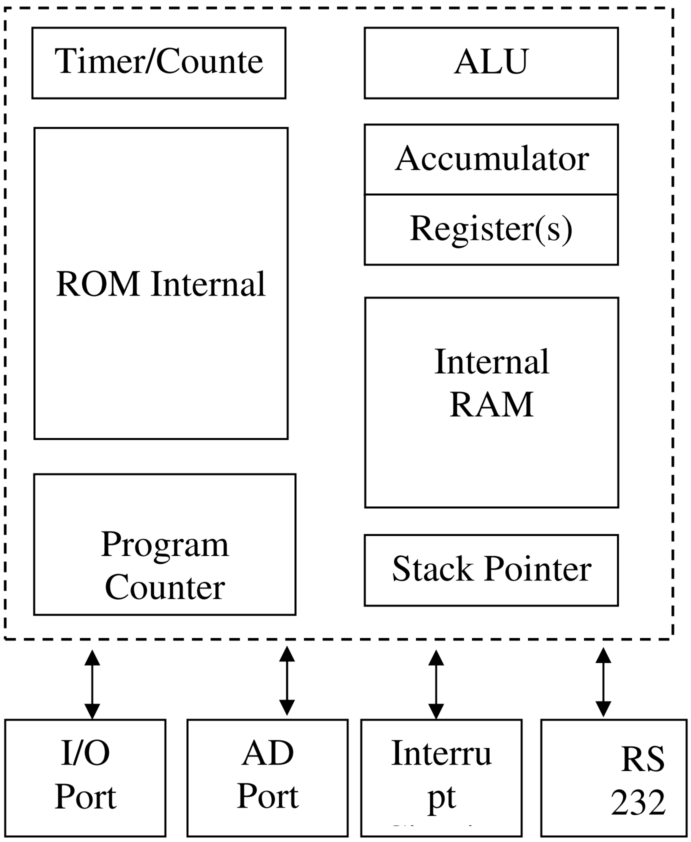

Fig.4. A typical microcontroller (89F51)

Like the microcomputer, a microcontroller 89F51 is a general- purpose device, but one that is meant to read data, perform limited calculations on that data, and control its environment based on those calculation. The prime use of a microcontroller is to control the operation of a machine using a fixed program that is stored in ROM and that does not change over the lifetime of the system. The microcontroller counter is used for application of calculate the pulse time-of- travel (ToT), and compute relative distance in decimal to load to 7-Sigments display.

Timer Counter Interrupts: Many microcontroller applications require the counting of external even such as the frequency of a pulse train, or the generation of precise internal time delays between computer actions. Both of these tasks can be accomplished using software techniques, but software loops for counting or timing keep the processor occupied so that other perhaps more important, functions are interrupt timer. To relieve the processor on this manner, two 16-bit up counters, named T0 and T1, are provided for the general use of the programmer. Each counter may be programmed to count internal clock pulses, acting as a timer, or programmed to count external pulses as counter, therefore it used to count pulse time-of-travel (ToT) and begin it's work when it's received enable from inverter for speed 1µs for one bit, the theoretical Eq(1) and laboratory experiments gives the development for relation between number of count in micro-seconds and displacement in mm that load to display screen.

3. Experimental

3.1 Experimentally work

The sensor has been initially calibrated and tested in laboratory for distances in the range of 0.1 – 2 m and for temperatures in the range of 25 – 40 ^{o}C. The experiments are handled 3 times at every distance. The table(1) is the error distance values with the actual distance. The error increase with distance because of the effect of unstudied parameters on ultrasonic wave like humidity, atmospheric pressure, and air dust percentage.

Table 1. Actual distance and error.

Actual Distance (Cm)	Error Distance (Cm)
10	0
30	0.2
50	0.35
70	0.53
90	0.708
110	0.88
130	1.058
150	1.23
170	1.408
190	1.5

The error data in the error plots is shown in Fig. 5. The standard error value is the arage results of the repeating test for each condition.

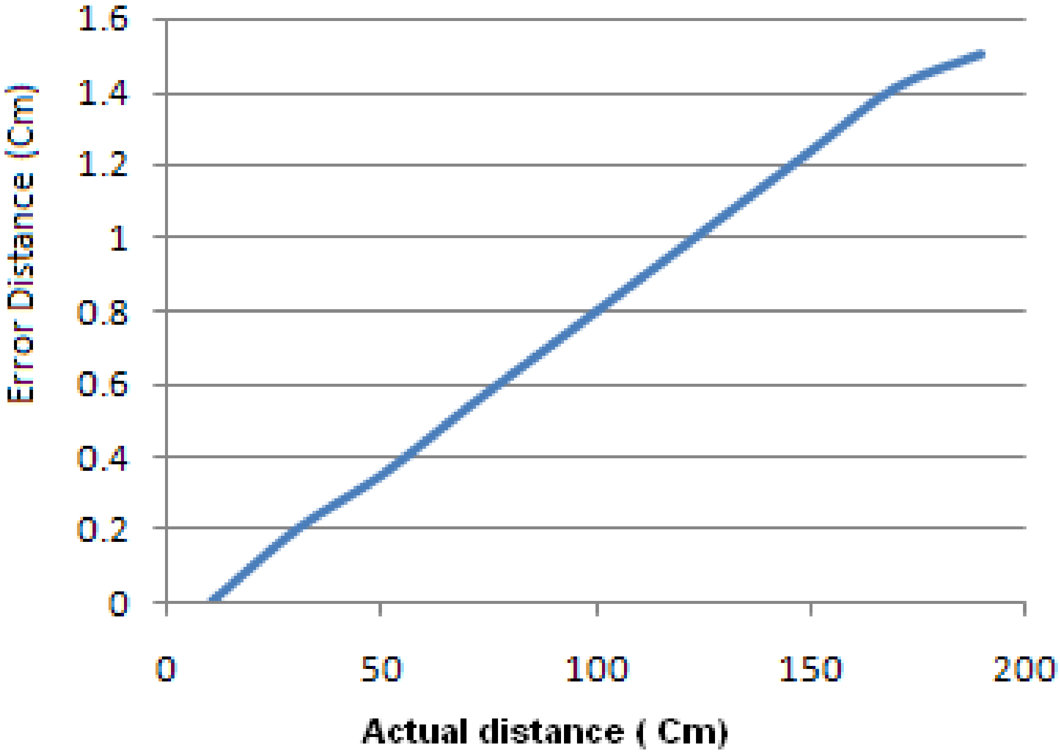

Fig.5. Error in measuring distance

The average of the standard error is about 0.98 mm from the obtained data in our experiments. The experimental standard deviation of the linearity has been found to be of 1cm, while the temperature effect produces a standard deviation of less than 1cm when the distance is measured from a flat surface. The experimental standard deviation of the linearity with respect to the distance has been found 0.005% if compare with reference (ALESSIO 2001) the experimental standard deviation of the linearity with respect to the distance has been found to be 0.012% (ALESSIO 2001).

3.2 Field Experiments

The measuring head has been mounted onto the cripple chair, which has been equipped with frontal ultrasonic sensors to measure the front distance during the crippler movement, that will prevent chair from trapping and accidents. **Fig.6**. shows the wheelchair .

Fig.6. The cripple wheelchair

The electronic controller is used to operate the power chair. It consists of joystick, the joystick controls the direction and speed of the wheelchair. When the joystick moves from the neutral (center) position, the electromagnetic brakes release and allow the wheelchair to move. When the joystick release and it allow returning to the neutral position, the electromagnetic brakes will engage, the joystick is consist from four coils in quadrilateral and has four terminal wires, two of them are input which are (vcc and Gnd), and the other give different voltage in each Direction about the neutral position. The chair controller circuit is consisting of central digital signal process controller with additional integral circuit and motor driver which control the two dc motors via the joystick, as shown in **fig.7**. Appendix (A) Shows main circuit board that used for measuring distance. The task is to alarm start in the chair when it be too close from an obstacle. The ultrasonic distance measurement that attached to the front of the chair will give a signal indicate that the chair is become close from The mission is to stop the chair when it be too close from an obstacle. The ultrasonic distance measurement that attached to the front of the chair will give a signal indicate that the chair is become close from an obstacle. In this case we will test the signal coming from the joystick if it refer to that the chair wanted to going toward the obstacle the signal is stopped and give the voltage referred to the neutral position of joystick chair controller. If the signal do not refer to that the chair wanted to going toward the obstacle, the signal will follow to the chair controller.

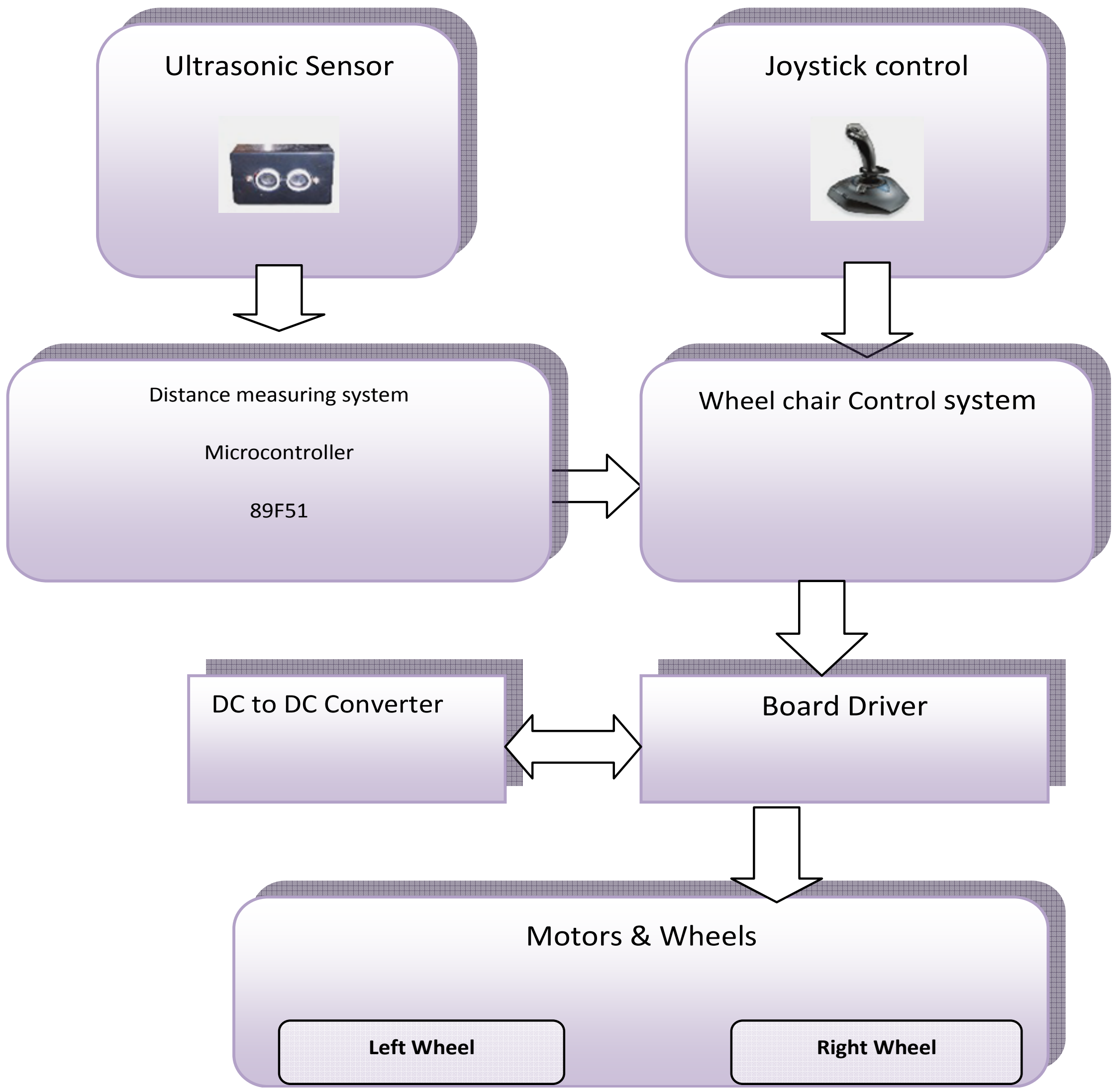

Fig.7. Control architecture of wheelchair

The collected objectives regarding the task completion times, and ability to reach the goal location. After task was completed, the distance from the start position to the goal position was measured. During trial one, the task completed by joystick control only, an average time of approximately 2 minutes 18 seconds, the task of joystick with ultrasonic sensing, an average of approximately 1 minutes 39 seconds. During trial two, the completed of the joystick control an average time of 2 minutes 6 seconds, the task of joystick with ultrasonic sensing, an average of 1 minute 35 seconds.

Table 2. Completion times for task.

Type of control	Trial 1	Trial 2	Trial 3
Joystick only	2.18	2.06	2
Joystick with Sensor	1.39	1.35	1.30

Table. 2 Show a completion times for task**.** During trial three, the completed of the joystick control with an average time of 2 minutes, the task of joystick with ultrasonic sensing, an average of 1 minute 30 seconds.

Completion time for joystick with sensor is fastest and the completion time for joystick without sensor is slowest across all tasks during both trials. All task completion times decreased across the trials. The Completion time for joystick with sensor was the shortest across all tasks. One reason for this was that the addition circuit provided the fastest processing. As shown in **Fig.8.**

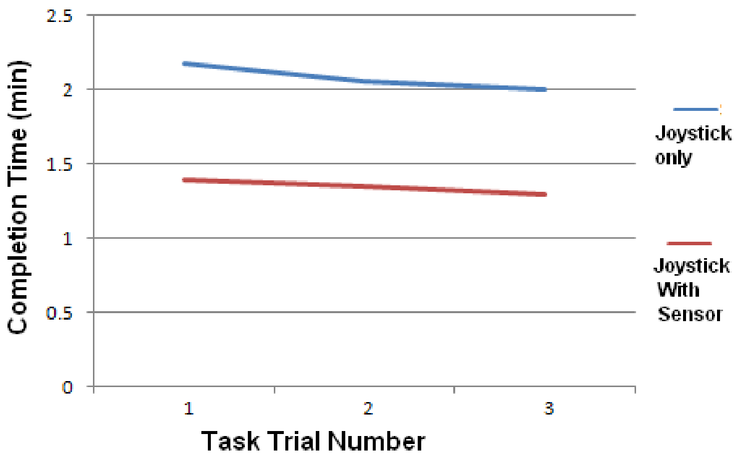

Fig.8. Joystick control with and without sensor

4. Conclusions

A low-cost distance sensor is described in this paper that is able to adapt to the environmental conditions. The sensor contains a measurement system and a driver of the signal that is used to drive the transmitter, that producing best accuracy under different conditions.

Tests have been performed in real lab conditions and have shown a regular behavior of the sensor under all typical driving of motion condition. The sensor features a simple and easy analog processing of the signal with employing microprocessors. Even with that, it's simple, the sensor allows resolutions good to be obtained in quiet conditions. The sensor output is display direct to screen and an additional digital output allows an easy implementation of smoothing motion techniques by means of the wheelchair object avoidances. The obtained measurements are accurate enough for many application as compare with other paper like (ALESSIO 2001) , as well as for giving an important information to active systems.

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Appendix A

Circuit board that used for measuring distance.

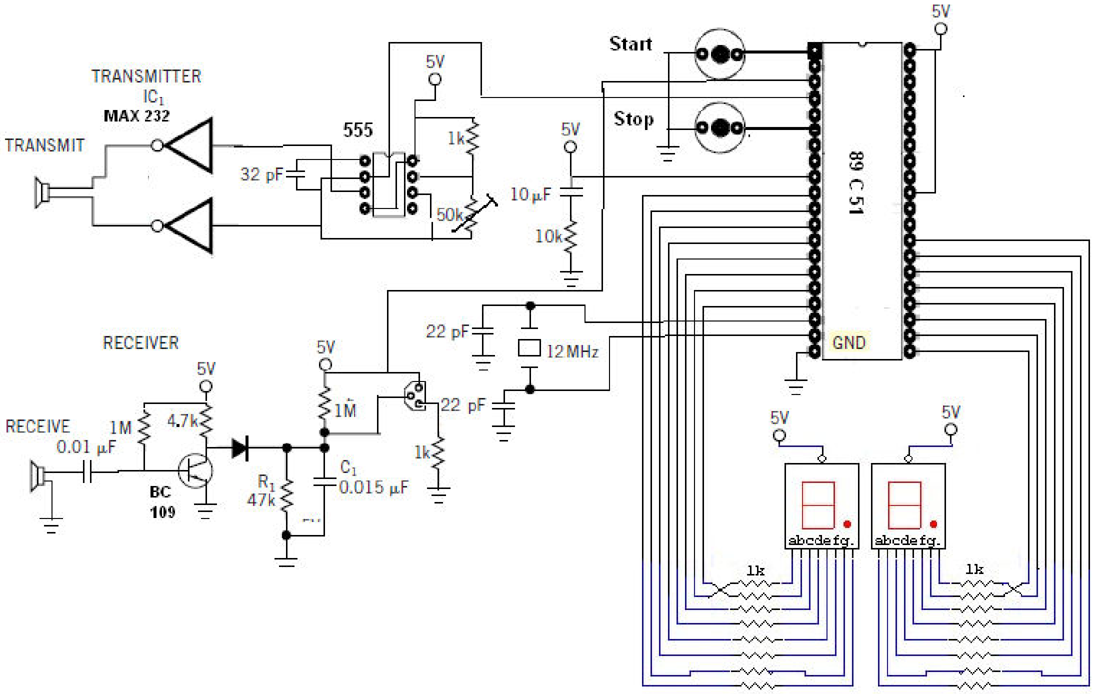

Fig. 9. Circuit diagram for ultrasonic measurements