Final Project Report
E3390 Electronic Circuits Design Lab

Ultrasound Distance Measurement

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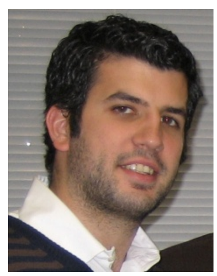

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1. Executive Summary

We are designing an Ultrasound Imaging System. Ultrasound is high frequency sound wave with frequencies of 20 kHz or higher. (Fig. 1) Ultrasound has many practical applications. It is often used in cameras to measure distance and used in ships to measure sea depth. However, more interesting applications of ultrasound are in the field of medicine. Using an array of piezoelectric transducers, ultrasound can be used to image the internal organs. It is often preferred to X-rays or CAT scans because it produces no harmful effects and is relatively cheap. We are designing s ultrasound system similar to ones used in prenatal care.

Our system takes a 25.3 kHz signal (operating frequency of the transducer) and performs amplitude modulation on it using a square wave with uneven duty cycle. The system then sends out this pulse using a transmitting transducer and measures the time elapsed for the pulse to bounce off an object and return to the receiving transducer. Knowing the duration of the travel and the velocity of sound in air, we can calculate the distance between the transducers and the object on the path of the sound wave.

In this configuration, this is an ultrasound distance measurement system. The system can be extended using multiple transmitter-receiver pairs (Fig 2.): If a 2D array of such pairs is used, each pair's output will be the distance to the nearest object on the path of the sound wave in the transducer direction. These individual measurements can be then regarded as grayscale pixel values and fed to a computer for a 3D plot. Thus, using multiple transducers, a simple distance measurement system can be converted into a 3D imaging system.

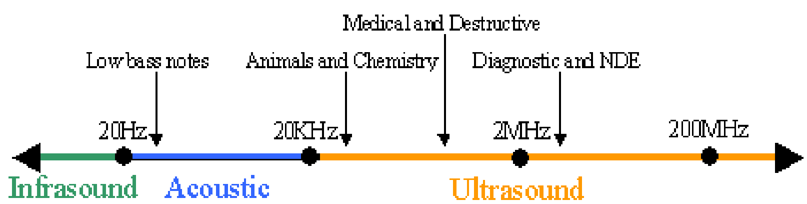


Figure 1: Spectrum of Acoustic waves.

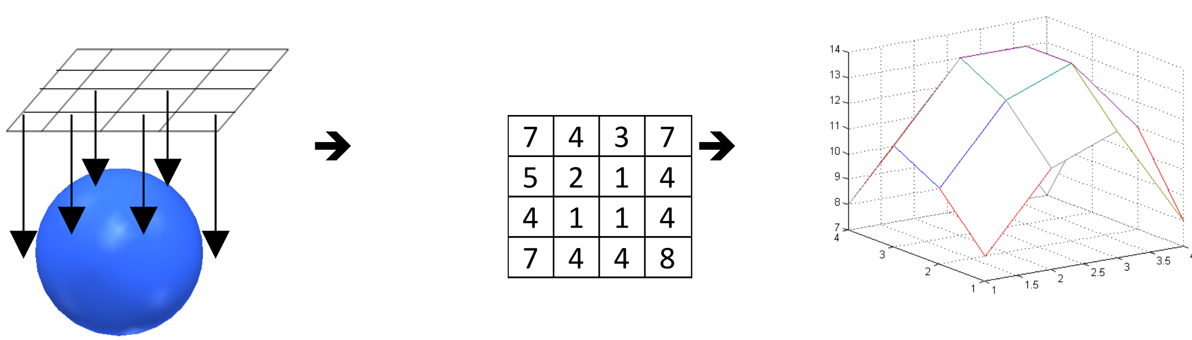
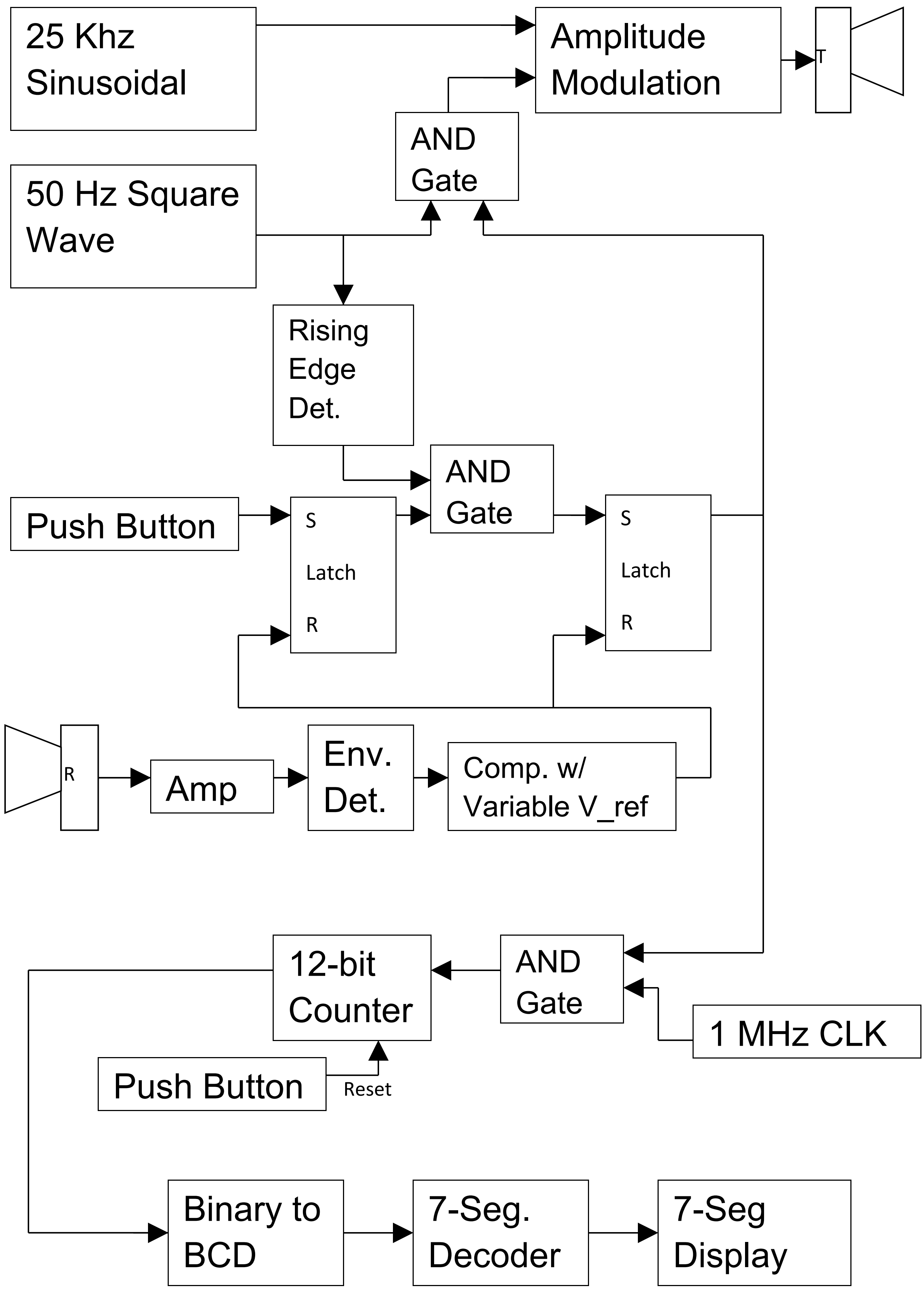


Figure 2: 3D imaging using multiple distance measurements

2. Block Diagram for Single Distance Measurement



Design Targets:

- To get a single distance measurement for every push at the button.
- Immunity to noise that can register an early hence faulty reading.

Individual Block Descriptions:

Signal Generation & Transmitter:

The piezoelectric transmitter is fed a signal of 25.3 kHz (the operating frequency of transmitter) sinosoid that is amplitude modified by a 50 Hz square wave with an uneven duty cycle. The signal then acts like a pulse of 25.3 kHz signals sent a bursts of 50 times per seconds.

When the push-button is pushed, it sets the first latch, whose output is connected to an AND gate. This allows the output of the Rising Edge Detection Circuit to pass through and reach a second latch, whose output is ANDed with the 50Hz square wave and the counter clock. This means that, after the push-button is pushed, at the first rising edge of the 50Hz signal, the transducer will send out the modulated chirp. Since that rising edge also initiates the counting by letting the clock pass through the AND gate, the result is that the counter starts counting at the same moment the transducer transmits the chirp.

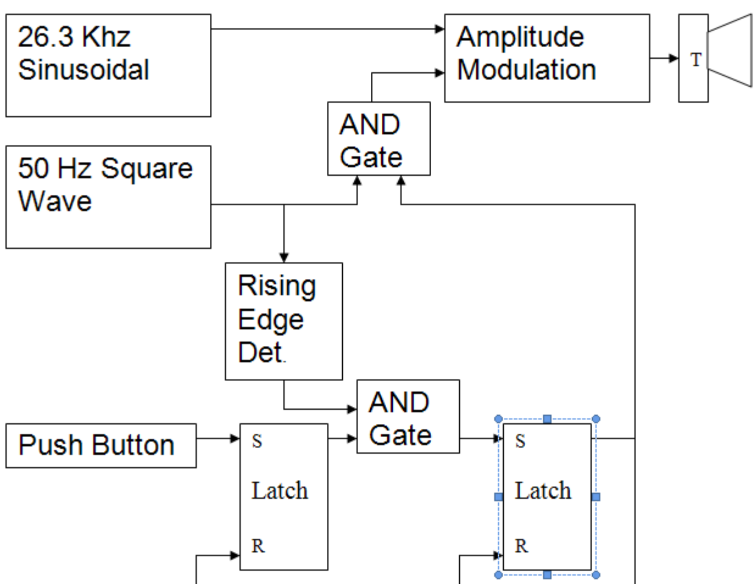


Figure 1: Block Diagram for Signal Generation & Transmission

Receiver & Detector:

There is no need for a bandpass filter to avoid noise at the output of the receiver, since the receiving transducer itself acts as a bandpass filter itself around 25.3KHz. We then amplify the signal because the received signal is usually in tenths of milivolts. The signal is then sent to an envelope detector because the received signal was a short burst of sinosoid at 25.3 kHz. However, we do not need to detect each sinosoid peak, we need to only detect the overall peak (detect the square wave, not the carrier frequency.) Afterwards the signal is sent to a comparator with a variable V_{Ref}. The calibration of this value proved to be crucial to the working of the circuit. If it is low, we have a more accurate reading since the percentage of the incoming signal that we ignore is lower. However, this causes the circuit to be too sensitive to noise, thus making consecutice readings less coherent. If it is high, we are ignoring a large part of the signal after it initially arrives at the receiver and therefore we get a reading that is higher than it is supposed to (the circuit perceives the distance to be longer.), but successive readings are coherent. We typically used a V_{Ref} of 3.75 volts. Our signal swing was from 0 V to 5 V. So 3.75V is the 75% point. This is on the high end of the calibration, meaning that we usually got readings that are 40% to 50% higher tham the actual distance, but successive readings differed negligibly. For the purpose of an imaging system, coherence is prefereable to accuracy, since if each transducer pair has the same average error, this will cancel out when we plot the received values without effecting the overall shape of the imaged item. However, if cohoerence is lost, each transducer will have a different error due to the random nature of noise, and the image will be distorted. When the comparator detects the signal, it then sends a logical one (5 V) to the latches as reset. This causes the latches to output a logic 0, which makes both the transmitting transducer stop transmitting until the next push button stop and more importantly, blocks the counter clock which causes the counting to stop. We now have a distance reading.

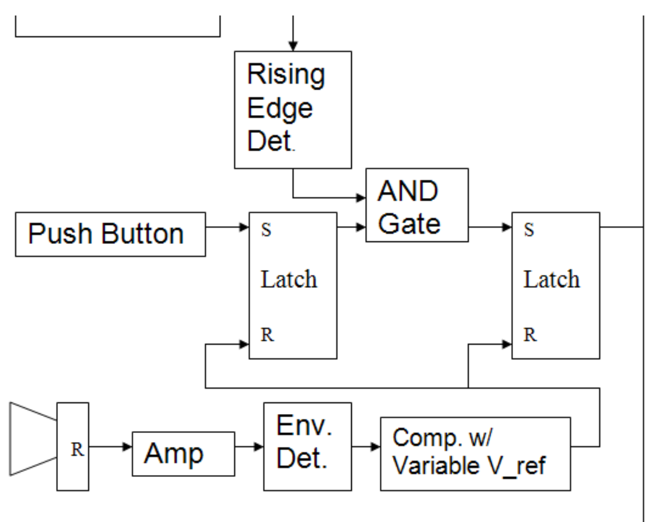


Figure 2: Block Diagram for Signal Reciver

Distance Calculations:

The counter starts counting when the initial signal was sent through the transmitter and stops counting when the receiver detects the signal. The result is then sent to the Binary to BCD decoder, which is then fed into a 7 segment decoder which decodes the signal for the seven segement display. The push button is used to reset the counter after each reading.

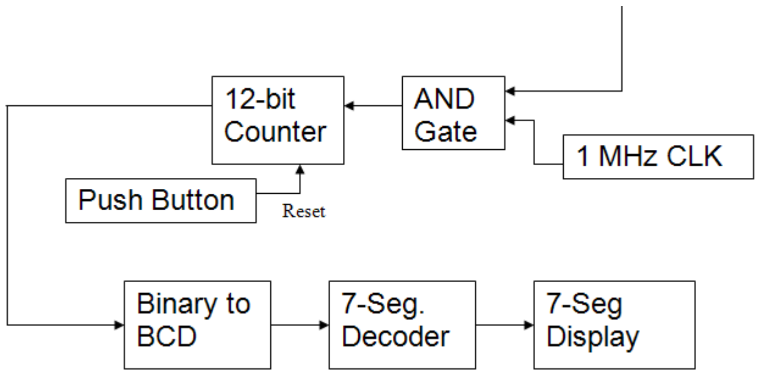


Figure 3: Block Diagram for Counter & Display

4. Bill of Materials:

We did not purchase any parts for our project. However we have included a breakdown for what this system should cost:

Part	Cost
Transducers:	$5-10
Resistors	$1
Capacitors	$1
Breadboard	$3
Op-Amps (LM741 & LF311)	20 x $0.25 = $5
AND Gates	7 x $0.25 = 1.75
Pushbuttons & wires	$1
Total:	**$23**

5. Health, Safety, & Environmental Issues:

Ultrasound has no known safety issues regarding to human health. It is simply sound waves at a frequency higher than human hearing range. The energy of the signal is also very low. Therefore it should not cause any damage to hearing or to human tissues. Certain animal can hear in the Ultrasound range. However our circuit operates for a very short duration for each distance calculation (1/50th of a second). Therefore, animals should not even notice that our circuit is operating.

The low amplitude and short duration of our ultrasound also does not interfere with any devices nearby.

6. Final Gantt Chart:

Category	February				March				April				May			
Clock/counter																
Transducer Interface																
Distance Calculation																
Display																
Debugging																

7. Criticism of This Course

As mentioned during presentations, this class would be more fruitful if a whole semester is allocated to development of ideas and various designs and a second semester of implementations. As the development of the design takes the first third or the first half of the semester, we neither have time to come up with more complicated designs nor to build the full extent of the circuit. In our case, were this a two-semester course, the building of the actual imaging system would have been possible.