1-D Sonic Anemometer

Preliminary Design Review

ECE 415: Senior Design Project
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Abstract

This paper discusses a proposed design for a 1-D sonic anemometer. It will describe the background of the project and will examine the criteria and specifications that this design should achieve. It will provide a technical description of the proposed design, and will provide in detail the goals of this project.

Introduction

For our senior design project, we are working for the University of Massachusetts Amherst Geoscience Department to design a 1-D sonic anemometer. This device, as suggested to us by Professor Jackson of the Electrical and Computer Engineering Department and Professor Voss of the Geoscience Department, measures small wind speeds by sending ultrasonic signals through the air between transducers. Once fully functional, the Geoscience department will be able to use the instrument for their research.

Technical Description

Our design consists of two transducers, a frequency generator, a counter, and a PIC microprocessor, along with other amplification and switching circuitry.

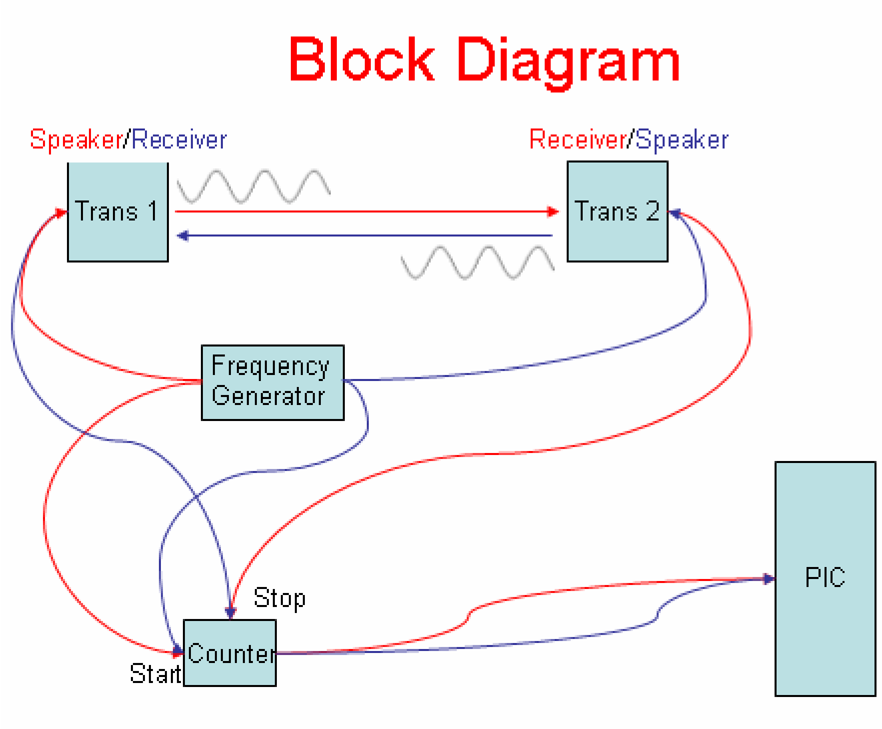
The frequency generator is the first part of the design. It sends out a continuous sine wave to each of the two transducers. Initially we have chosen to use a frequency generator in the lab for testing, but we plan on building our own frequency generator, possibly by using a 555 timer setup.

The two transducers have the ability to act as both transmitters and receivers, and we are able to implement a change between the operations through some switching circuitry. Initially, the transducers act as transmitters, sending the continuous sine waves from the frequency generator out through space towards the opposite transducer. Once the signal has been transmitted, the switching circuitry changes the function of the transducers, and they act as receivers. The transducers receive the wave sent from the opposite transducer, and the counter is able to take the data from the two signals to find the phase difference between the two waves.

The output of the two transducers in receive mode will be converted into a digital signal using an op-amp comparator chip, the LM339. The output of these two comparators will be multiplied together to produce a signal that is a digital high between the zero crossing of the first wave until the zero crossing of the second wave.

The counter will start on the rising edge of the pulse and will stop at the end of the high pulse. This will determine the phase difference between the two continuous sine waves, and the information will be sent to the PIC microprocessor so that calculations can be done to determine the wind speed at that time.

We have currently been experimenting with two receivers and two transmitters. These are the Panasonic P9894-ND (receiver) and the Panasonic P9895-ND (transmitter). We have been able to send the sine waves successfully and display the output on an oscilloscope. Each transducer costs $9.20, and was purchased by the Geoscience Department to be used for further experimentation in this project. Our plan is to ultimately purchase the two multi-use transducers for both transmitting and receiving, which will cost approximately $60 each. We are currently considering the 270-1000-ND or 270-1001-ND from Digikey.



Initial Calculations

Initially, we wanted to find an average absolute time for one point on the wave to get from one transducer to the other. We also wanted to find the absolute time difference when the wind was traveling 1mm/s.

$$\text{Assume: } v_{wind} = 1\text{mm/s},\ d = 1\text{m}$$

Calculate the absolute time when there is no wind speed:

$$v = d/t$$

$$330m/s = 1m/t_1$$

$$t_1 = 3.030303 \text{ [ms]}$$

$$330.002m/s = 1m/t_2$$

$$t2 = 3.030284665 \text{ [ms]}$$

$$\Delta t = t_1 - t_2 = 1.8365e\text{-}8 \text{ [s]}$$

This information led us to believe that there would be enough time to implement the switching circuitry, because the absolute time for the wave to travel from one transducer to the other was around 0.003s.

We can also calculate the necessary frquency of the counter, which would be $1/\Delta t$ = 54.45MHz. With this counter, we would need a 26 bit register as well. We have determined that a possible part that would work well with our project is the 8-bit Bidirectional Binary Counter, the 74F269. This part has a high clock frequency of 100MHZ, which will work well with our initial calculated necessary clock frequency.

Design Specifications

The main goals we have set for this design are as follows:

- Design a 1-D anemometer that will measure small wind speeds
- Minimize weight, power, and cost
- Implement counters along with other circuitry to calculate zero crossings of sine waves in space
- Send and receive ultrasonic signals across transducers that are not affected by noise
- Multiply our two sent signals to generate a pulse whose width determines the phase offset, thus allowing us to calculate wind speed

Design Issues and Considerations

There are several complications that we have studied that could affect this design. The first is the transducer angular offset. We have determined that using this method of only one pair of transducers, the offset will not affect the system, it will only provide a slightly longer path for the wave to travel. Because we are measuring the difference between the zero crossings of these two waves, the frequency and wavelength of the sine waves are the most important factors. Having a slightly longer path will not affect these two factors.

The next important consideration is the chip delay. Each function in the system has a certain amount of delay, and the delays may not always be consistent. Our solution to this problem is to take several hundred measurements each second and average them.

Conclusions

If successful, our device will be able to measure small wind speeds accurately. The design can be utilized in the Geoscience Department for continued weather research. Our instrument will work seamlessly with the other components they are currently using for their research.