Design of a 1-D Sonic Anemometer
MDR Presentation

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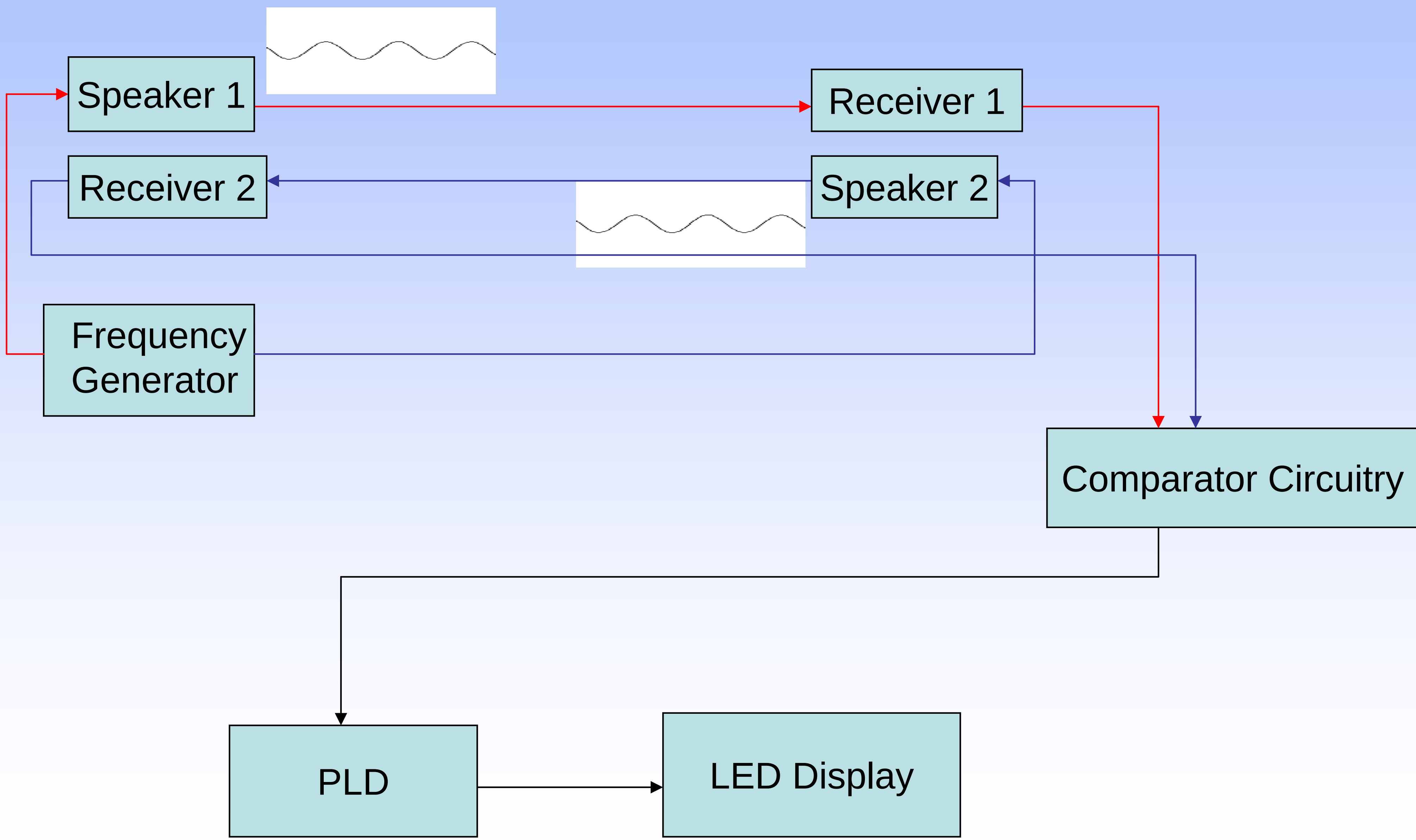
Background

- What is a Sonic Anemometer?
  - Device that measures wind speed
- What is unique about our anemometer?
  - Will measure small wind speeds
  - Will be utilized by the Geoscience Department for weather research

Background (Cont’d)

- Anemometer uses transducers to send and receive ultrasonic signals through air
- Used two transmitters and two receivers
- Absolute time will vary with wind speed
- Sine wave sent from function generator to both transmitters

Block Diagram



Initial Calculations

- Found how absolute time was affected by a change of 1mm/s in velocity
  - Began with simple equations for velocity that relate distance, time, and temperature to speed of signal

$$v_{signal} = \frac{d}{t} \qquad v_{signal} = 331.45\left(\sqrt{1 + (T/273)}\right)$$

  - Assumed room temperature, so that the velocity of sound in air was 343.37 m/s
  - Looked at the change in absolute time that resulted from a change of 1mm/s in wind speed over a distance of 1.06 m

$$v_1 = 343.378 m/s = \frac{1.06m}{t_1} \quad , \quad v_2 = 343.376 m/s = \frac{1.06m}{t_2}$$

Initial Calculations (Cont'd)

- Calculated t_1 and t_2

$$t_2 = .00308699s \qquad t_1 = .00308697s$$

- Found change in absolute time

$$\Delta t = t_2 - t_1 = 17.9801ns$$

- Found the frequency of the counter we will need

$$f = \frac{1}{T} = \frac{1}{\Delta t} = \frac{1}{16.962ns} = 58.95MHz$$

  - Chose a counter frequency higher than 58.95MHz
  - Solved for the number of bits in the counter register

$$2^x = 2f$$

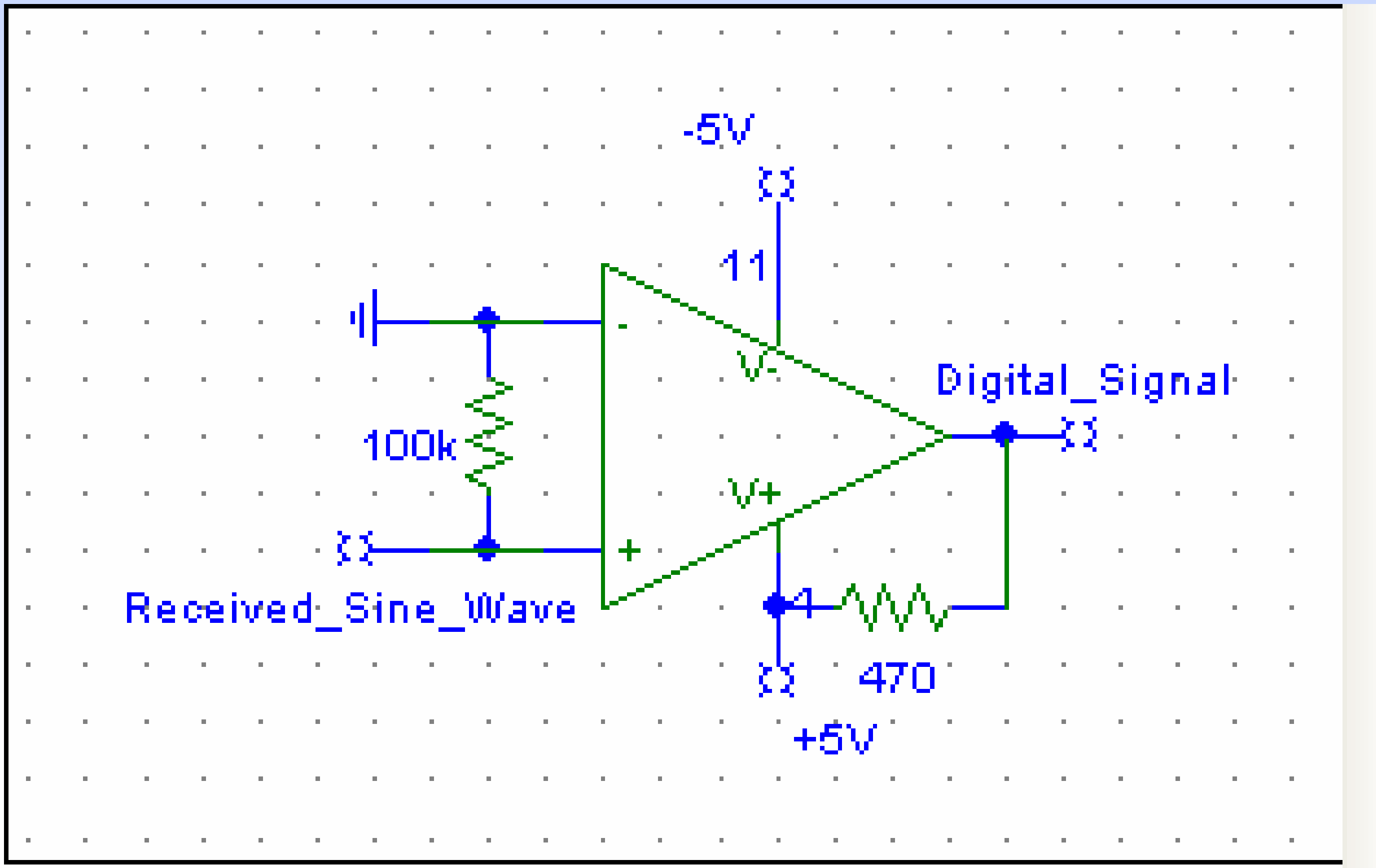
$$x = 27bits$$

Zero Crossing Detector

- Chose to convert sine waves to digital signals using LM339 Comparator
- Digital signal is high only when amplitude of the sine wave is greater than zero
- Distance between zero crossings stays the same width
- Must use zero crossings because of amplitude variations caused by side winds
- Phase difference of two received waves is the difference in zero crossing locations

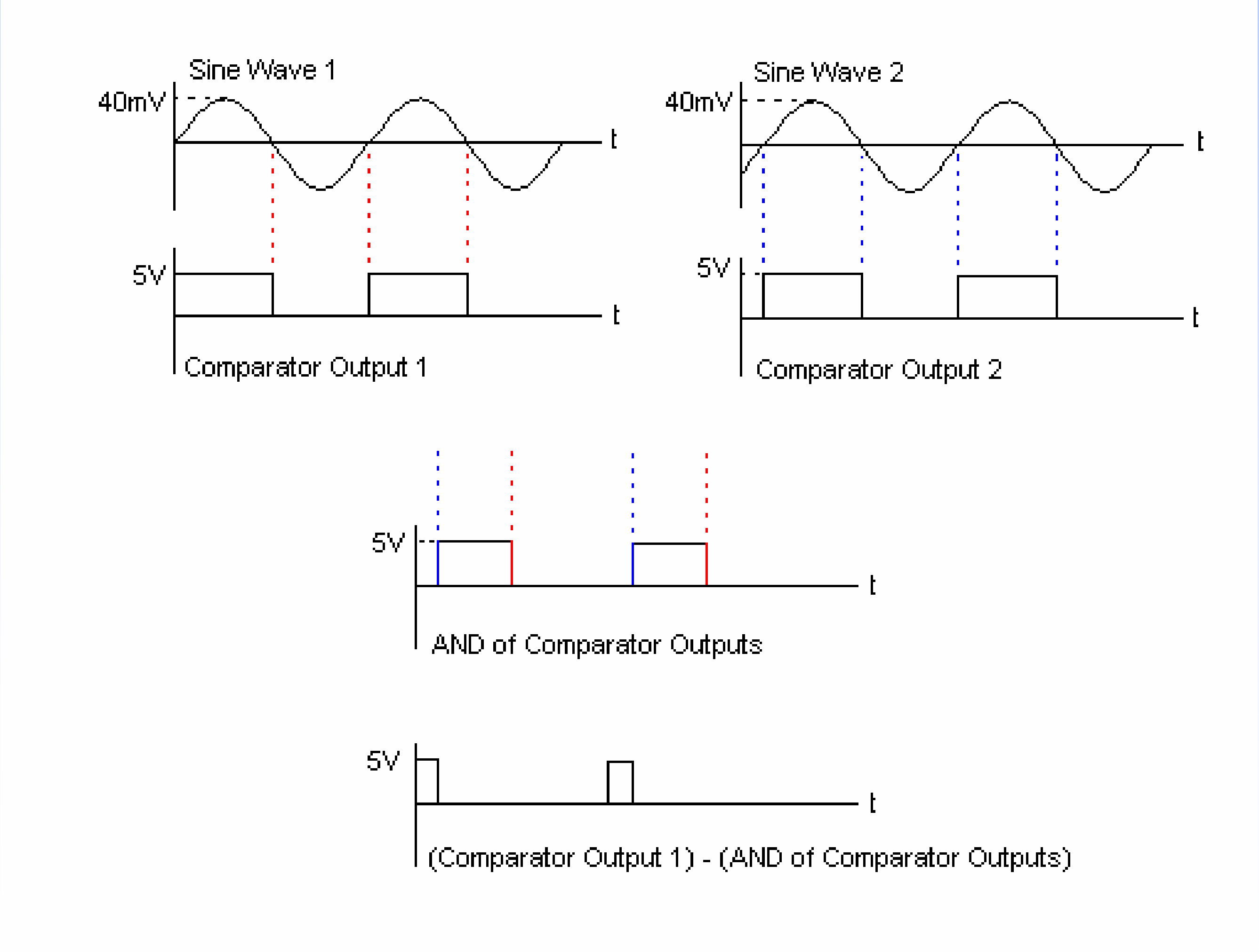
Comparator

- Used LM339 because operates at higher frequencies and has less delay time
- Comparator circuitry:



Comparator (Cont’d)

- Input and output waveforms of comparator circuitry



Comparator Theory

$$v_1 = v_{signal} + v_{wind} = \frac{d}{t - \Delta t}$$

$$v_2 = v_{signal} - v_{wind} = \frac{d}{t + \Delta t}$$

$$2 \cdot v_{wind} = v_1 - v_2 = \frac{d}{t - \Delta t} - \frac{d}{t + \Delta t}$$

$$2 \cdot v_{wind} = d \cdot \left(\frac{1}{t - \Delta t} - \frac{1}{t + \Delta t} \right)$$

fact: if $x << 1$, then

$$\frac{1}{\text{1-x}} \approx 1 + x$$

$$2 \cdot v_{wind} = \frac{d}{t}\left[1 + \frac{\Delta t}{t} - \left(1 + \frac{-\Delta t}{t} \right) \right]$$

$$2 \cdot v_{wind} = \frac{d}{t}\left(\frac{2\Delta t}{t} \right)$$

$$v_{wind} = \frac{d}{t}\left(\frac{\Delta t}{t} \right) = \frac{{v_{signal}}^2}{d}\Delta t$$

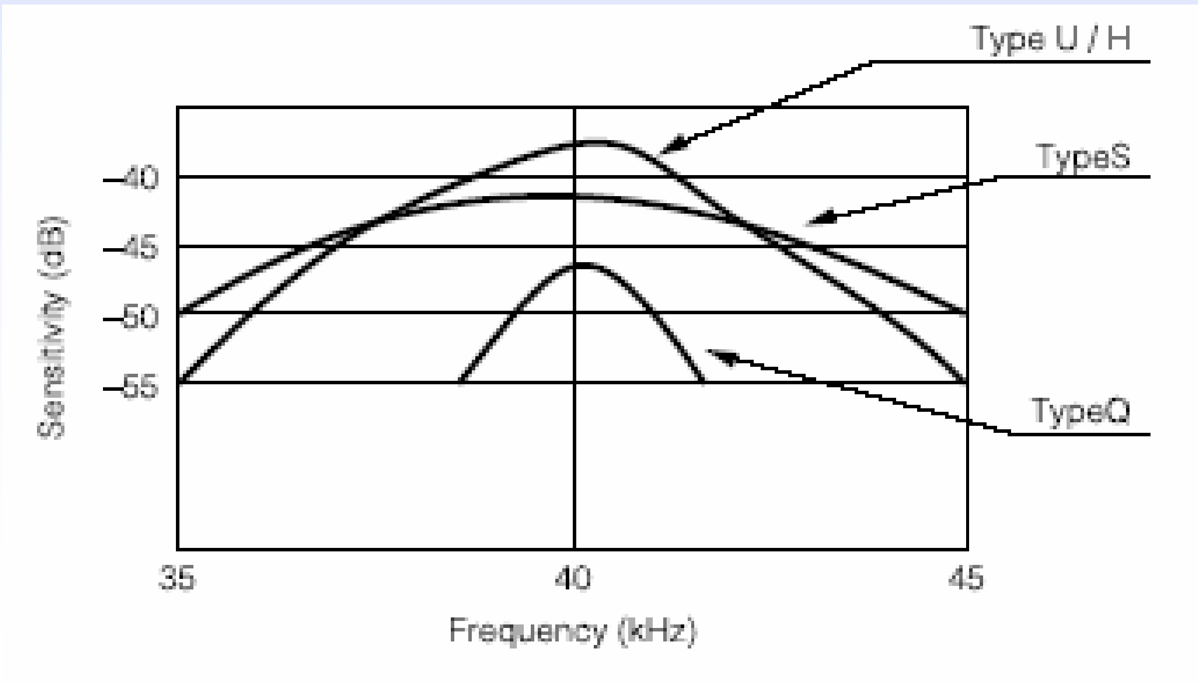
$$v_{wind} = \frac{{v_{signal}}^2}{d}\Delta t$$

and v_{signal} depends only on temperature

This shows that we only need to find the change in time between the two waves.

Transducers

- Part numbers P9895-ND and P9894-ND
- One for transmit and one for receive
- Lowest frequency for cost effectiveness and familiarization
- Nominal frequency 40.0 kHz
- Temperature range -40-100°C

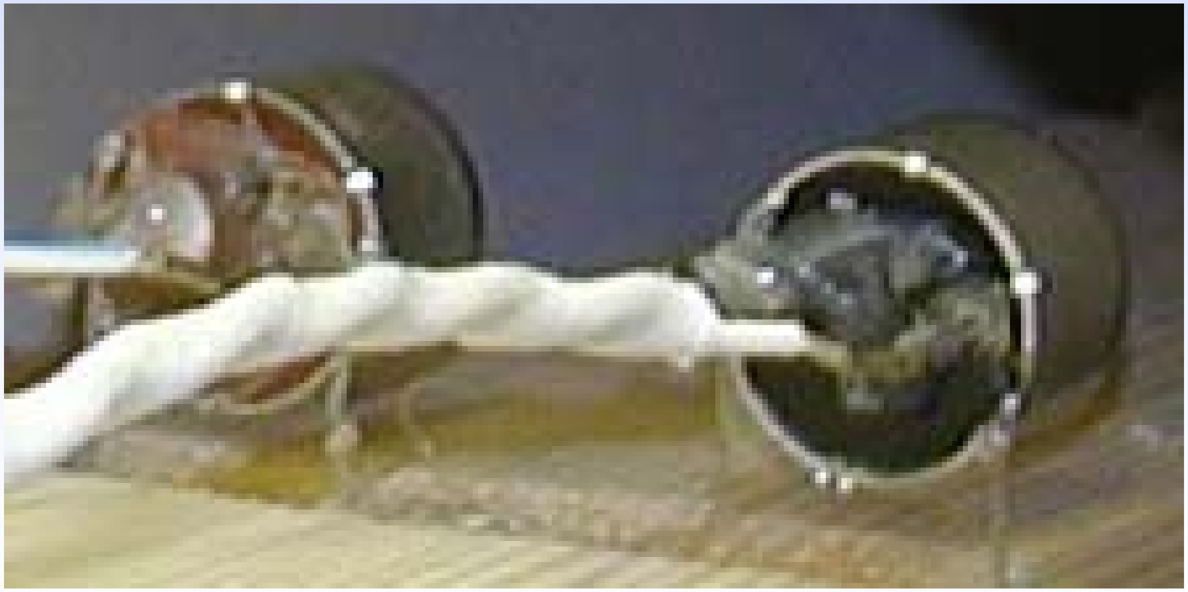


Sensitivity

$\frac{1V}{Pa}$ is 0dB

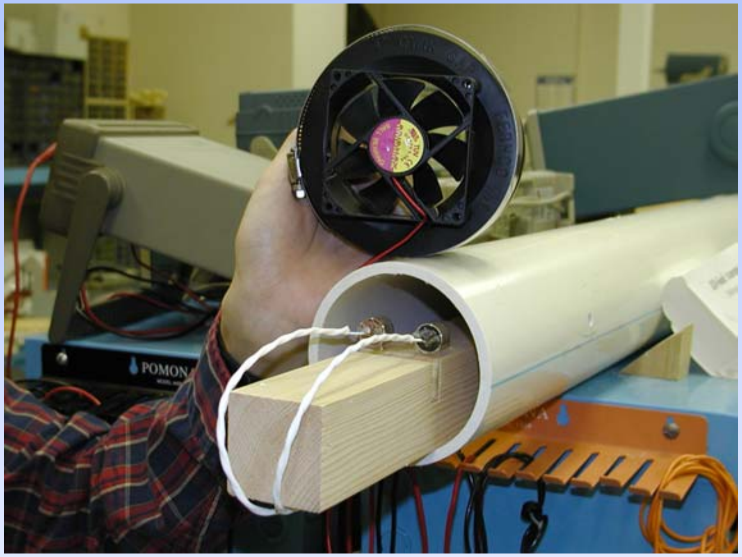
Transducers (Cont'd)

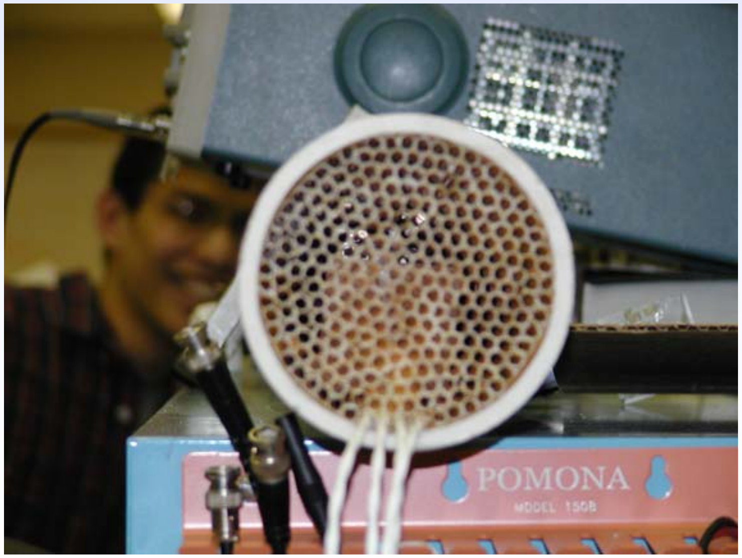
- Optimal measured frequency of 40.2 kHz
- Continuous sine input for optimal received signal



Test Setup

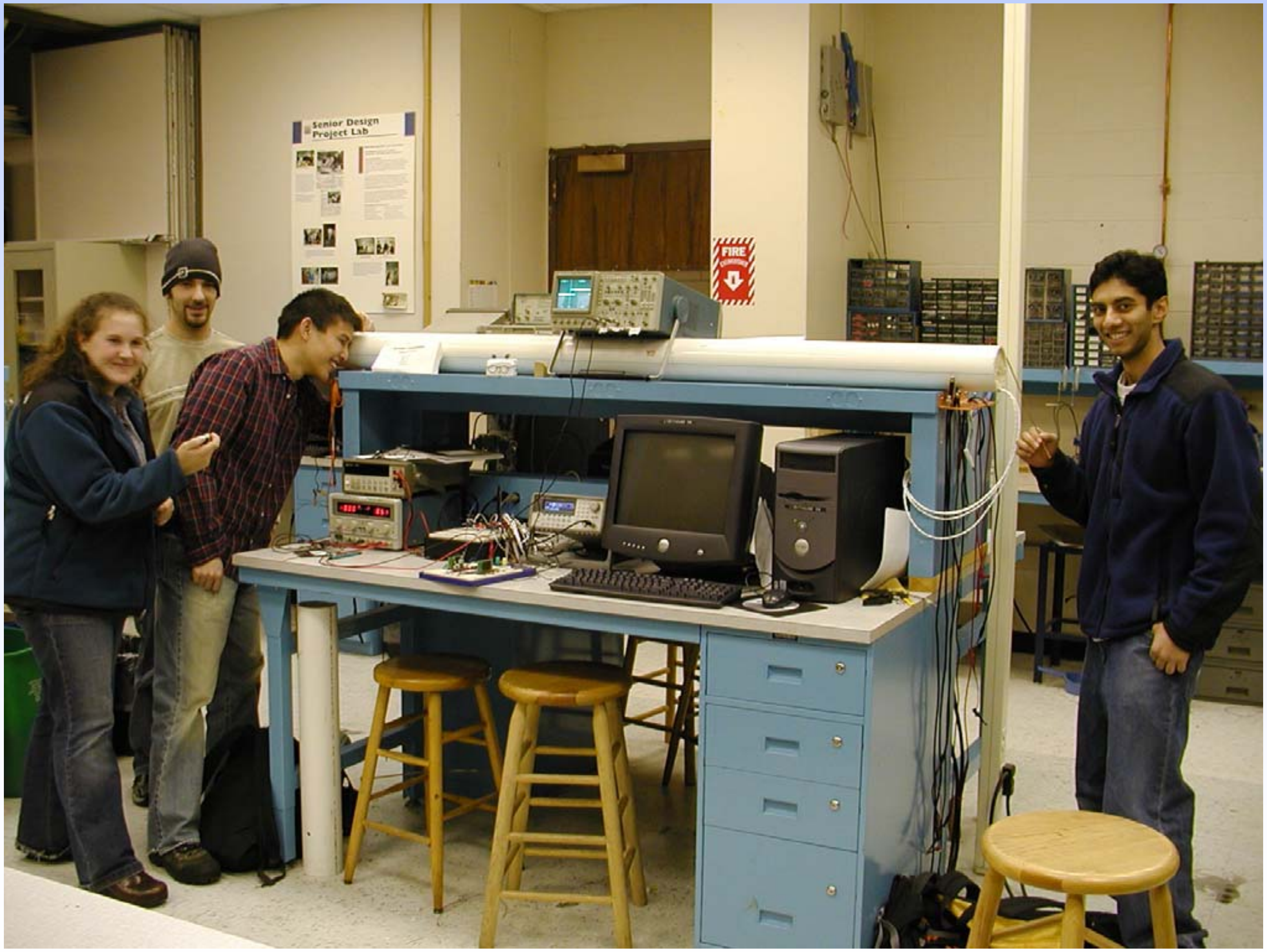
- DC fan
- 4”x84” PVC drain pipe
- Quick-cap (end cap)
- 6’x2”x2” pine board with slots separated 5”
- CD case for mounts
- Wendy’s™ straws
- Twisted pair insulated wire



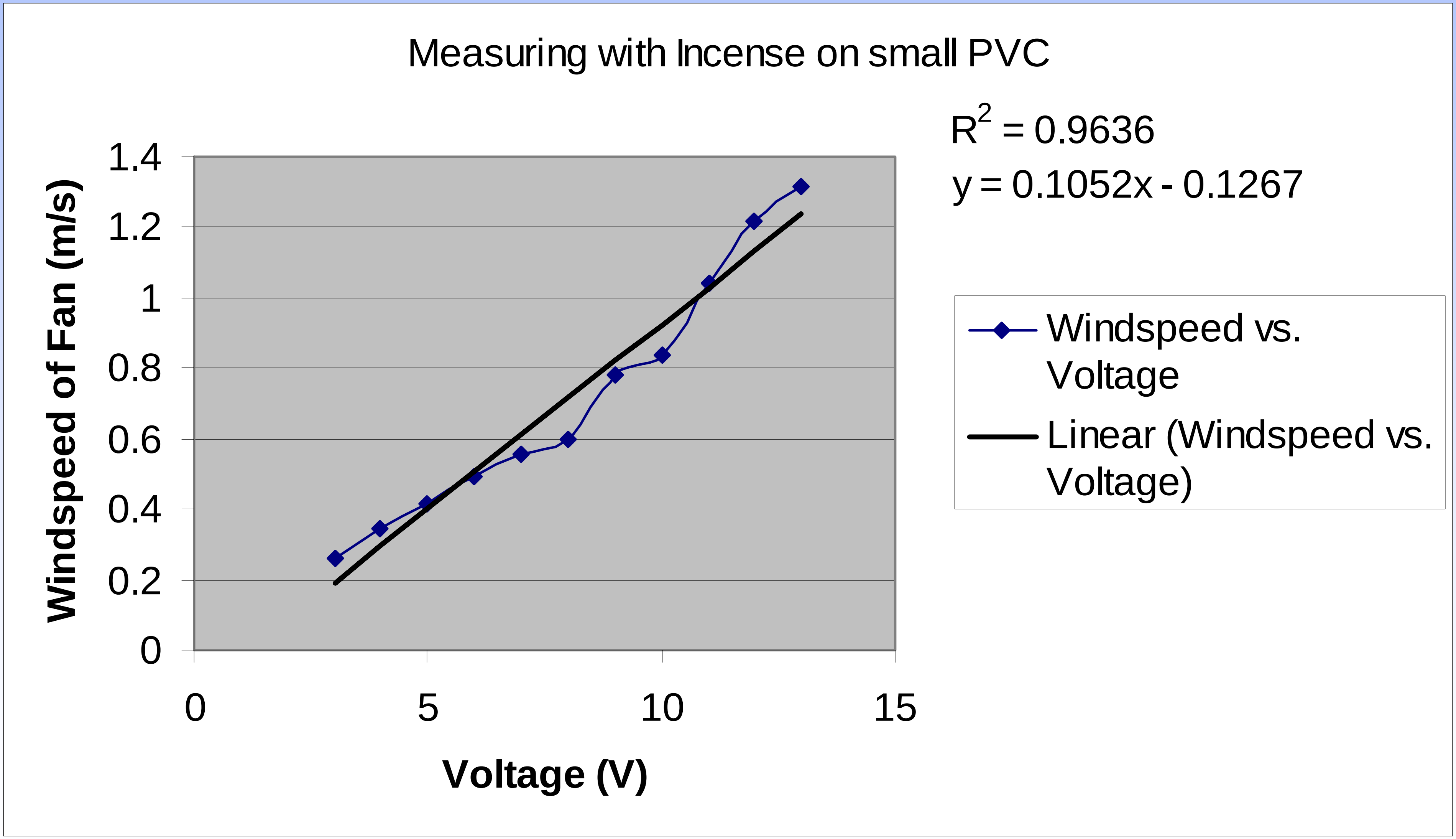


Wind Flow Testing

- Developed method to test wind speed generated by fan

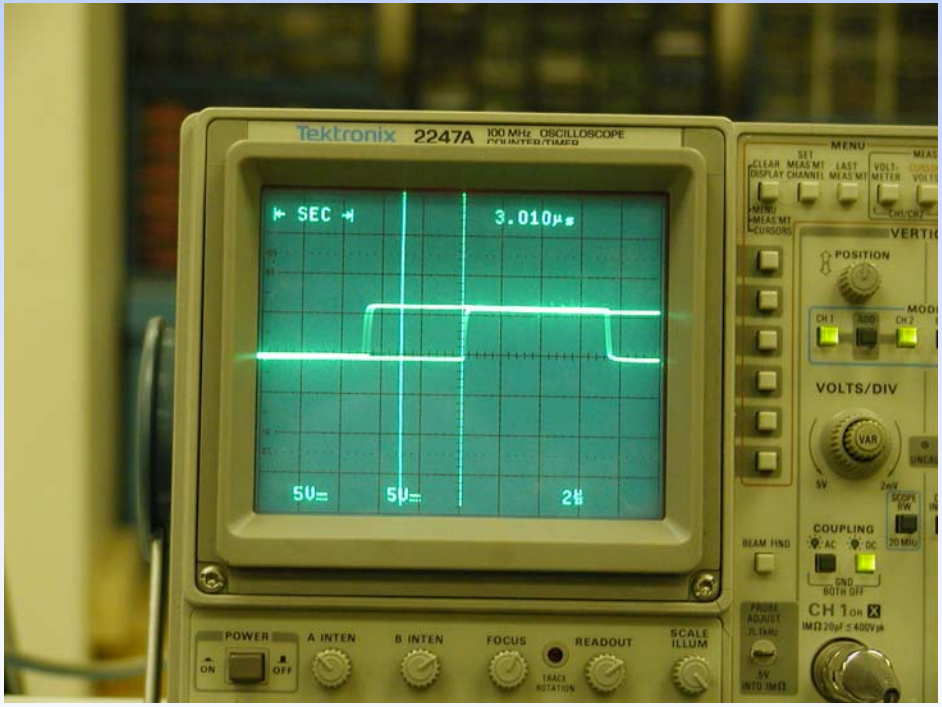


Wind Flow Testing (Cont'd)

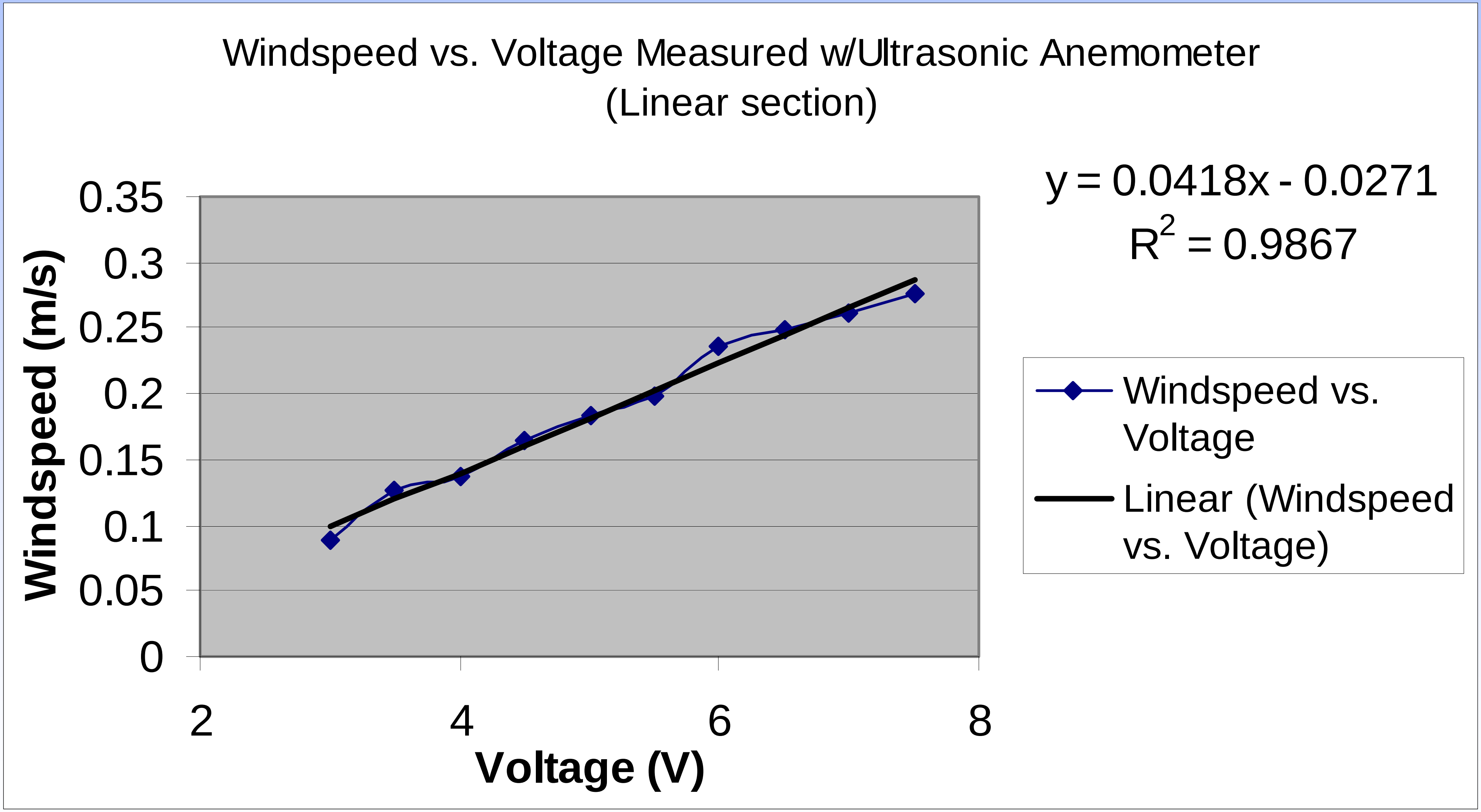


Wind Flow Testing (Cont'd)

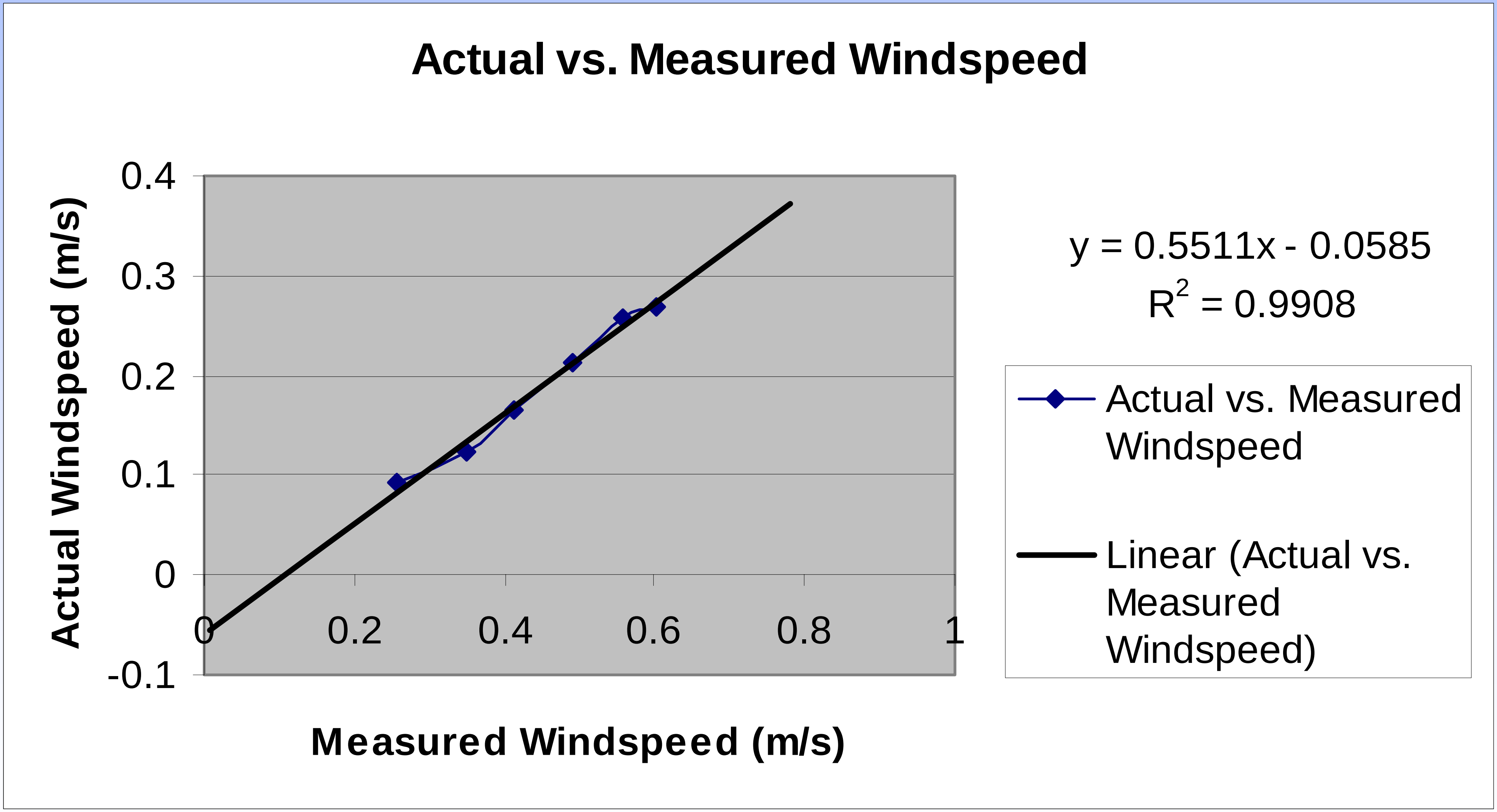
- Read phase difference from oscilloscope
- Compared generated wind speed to wind speed observed by system
- Found observed wind speed to be relatively close to actual wind speed



Wind Flow Testing (Cont'd)



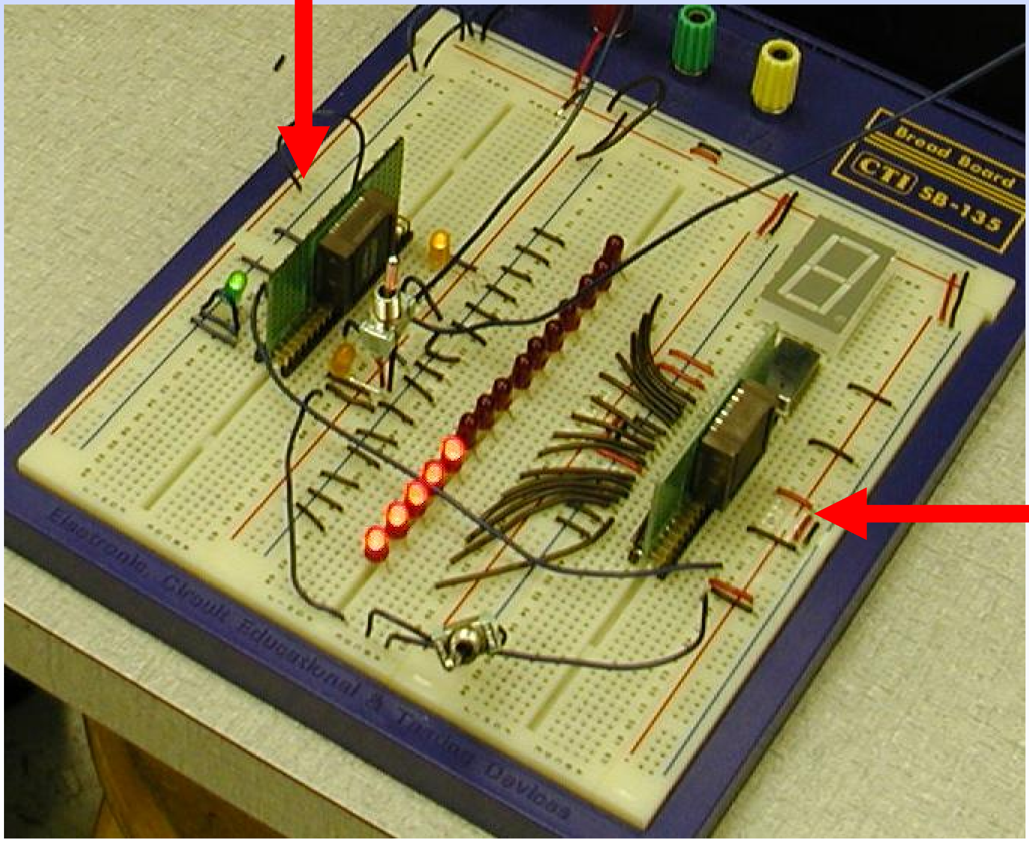
Wind Flow Testing (Cont'd)



PLD/Counter

• PLD Controller (Left)

- For direction and clock signal



•PLD Counter (Right)

- Temporary until counter is received

• 4 MHz clock (will use 125MHz)

Complications

- BiCMOS Comparator has offset base current, which affects the zero-crossing detection
- An LM741 is not capable of functioning properly with a 40kHz signal, which forced us to use the LM339 comparator
- Side winds affect the amplitude of the wave, which greatly affects the zero-crossing detection
- Noise in the system had to be minimized

Expenses

Balance	-500.00	Prof Voss Account	Remaining	-463.20		Voss	
Balance	-500.00	SDP Account	Remaining	-493.71			SDP
			Total Spent	$43.09			
			Total Remain	-956.91			
Item Type	**Description**	**Stock No.**	**Catalog**	**Price**	**Quantity**	**Price**	**Price**
Transducer	Reciever, 40kHz, -40ºC to 100ºC, 4kHz bandwidth	P9894-ND	DigiKey	$9.20	2	$18.40	$0.00
Transducer	Transmitter,40kHz, -40ºC to 100ºC, 4kHz bandwidth	P9895-ND	DigiKey	$9.20	2	$18.40	$0.00
Pipe	4" x 10' PVC Drain Pipe - Solid	4"x10' White	Cowls	$6.29	1	$0.00	$6.29
Samples	(used in design)						
Prof. Ciesielski		Altera Max7000 7032-12 PLD's and Mount			3		
Great Brook Lumber		6' Pine Board			1		

Conclusion

- We were able to remedy several of the complications
- Anemometer is capable of measuring a wind speed, and was tested on the oscilloscope
- Although there is an initial offset, shown by the graphs, the proper trend is followed
- From here, we will be able to use digital logic and display the wind speed on 15 LED’s, as well as display the direction