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Design and Implementation of an Improved Wind Speed Meter (Anemometer)

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Abstract: *This wind speed meter design is based on the working principle of two major components namely; a tiny motor savaged from a computer hard disk and the frequency-to-voltage converter IC (LM2917), whose voltage output is linear with frequency input. This paper presents how the varying frequency output from the hard disk motor was passed through a frequency-to-voltage converter(LM2917). The output voltage of the IC is then read off as wind speed after the calibration process. This wind speed meter measures wind speed from 10km/hrs to 25km/hrs due to the mechanical properties of the hard disk motor bearing used.*
Keywords: *Anemometer, Calibration, frequency, galvanometer, speed,*

I. Introduction

The Anemometer is also known as a wind vane. A cup anemometer measures wind velocity or speed; an instrument with three or four small hollow metal hemispheres set so that they catch the wind and revolve about a vertical rod. An electrical device records the revolutions of the cups and calculates the wind velocity. The word anemometer comes from the Greek word for wind, "anemos."

In 1450, the Italian art architect Leon Battista Alberti invented the first mechanical anemometer. This instrument consisted of a disk placed perpendicular to the wind. It would rotate by the force of the wind, and by the angle of inclination of the disk the wind force momentary showed itself. The same type of anemometer was later re-invented by Englishman Robert Hooke who is often mistakenly considered the inventor of the first anemometer. The Mayans were also building wind towers (anemometers) at the same time as Hooke. [1]

1.1 Types Of Anemometer

1.1.1 Hemispherical Cup Anemometer

The hemispherical cup anemometer (still in used today) was invented in 1846 by Irish researcher, John Thomas Romney Robinson and consisted of four hemispherical cups. The cups rotated horizontally with the wind and a combination of wheels recorded the number of revolutions in a given time.

The most common and least expensive method incorporates a series of cups on small arms that can rotate freely (fig.1). Aerodynamic forcing by the wind causes the cup to rotate at a speed roughly proportional to the wind speed. A magnet on the rotating cup assembly and a Hall Effect sensor on the fixed base produce an electrical pulse each time the cup assembly completes one revolution. The wind speed measurement is made by counting the number of rotations in a certain time span (typically one second or less). Wind direction is determined by a separate vane that is free to rotate and is shaped in a manner that causes it to turn into the prevailing wind. A potentiometer attached to the vane produces an electrical output that varies with the direction the vane is pointing [1].

Figure 1: Cup Vane System (RM Young Wind sentry)

1.1.2 Sonic Anemometer

A sonic anemometer determines instantaneous wind speed and direction (turbulence) by measuring how much sound waves traveling between a pair of transducers are sped up or slowed down by the effect of the wind. Geologist Dr. Andreas Pflitsch invented the sonic anemometer in 1994.

Sonic anemometers are generally considered preferable to traditional cup and vane systems because they lack moving parts that are susceptible to damage in the field. As a result, sonics are less likely to experience data inaccuracy, such as drift in measurements, or data loss due to the wearing out of mechanical components such as bearings. In light winds (<1-2 m/sec) cup and vane systems are often unresponsive because the wind does not provide enough force to overcome the turning resistance of the bearings. (See fig. 2 for an example of this). The main drawbacks of sonic systems are cost, although these have come down significantly in recent years. Cup and vane instrument combinations are available for as little as $260. The least expensive sonic anemometer found was a 2D model by Met One with a list price of $1,350[1]

Figure 2: Sonic Anemometer (Viasala 425)

This paper was inspired by the need to improve on the existing anemometer. It is critical to be able to measure wind speed accurately. The main objective of the work was to build a cheap anemometer with locally available materials (i.e., the motor was sourced from a dead computer hard disk drive at no cost at all)

The Block Diagram of the wind speed meter is shown below

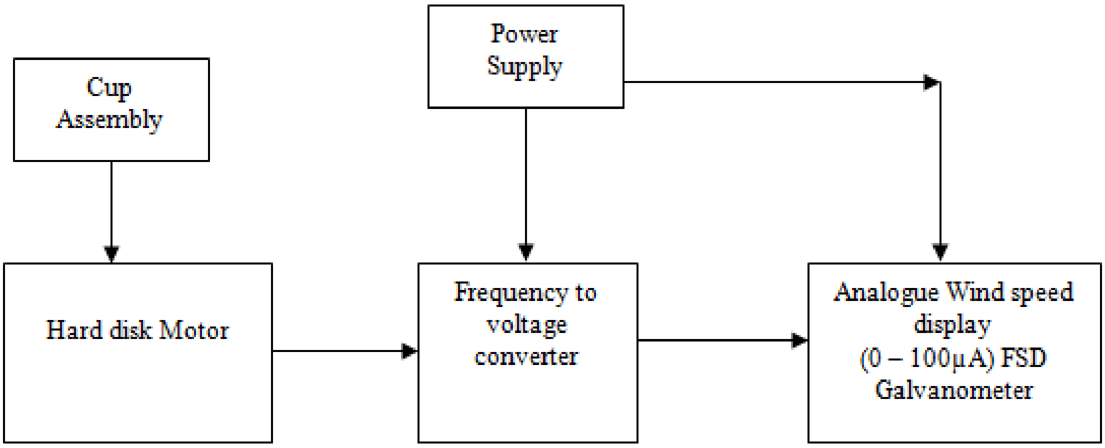

Figure 3: Block Diagram of the wind speed meter

II. Materials And Methods

The wind speed motor operates like a mini voltage generator when spun . When spun, the hard disk motor generates an output with varying frequency. If this output is connected straight to a galvanometer, it will give an output that will constitute a non-linear scale, which displays the generated voltage in terms of wind speed. Calibration records reveal that the output voltage is not linear with the wind speed. It becomes nonlinear, as wind speed gets higher. This work titled “Design and implementation of Wind Speed Meter”, however, seeks to address this anomaly by incorporating a better electronic circuit centered around an integrated circuit called the frequency-to-voltage converter, whose voltage output is linear with frequency input. As shown in figure 4 below

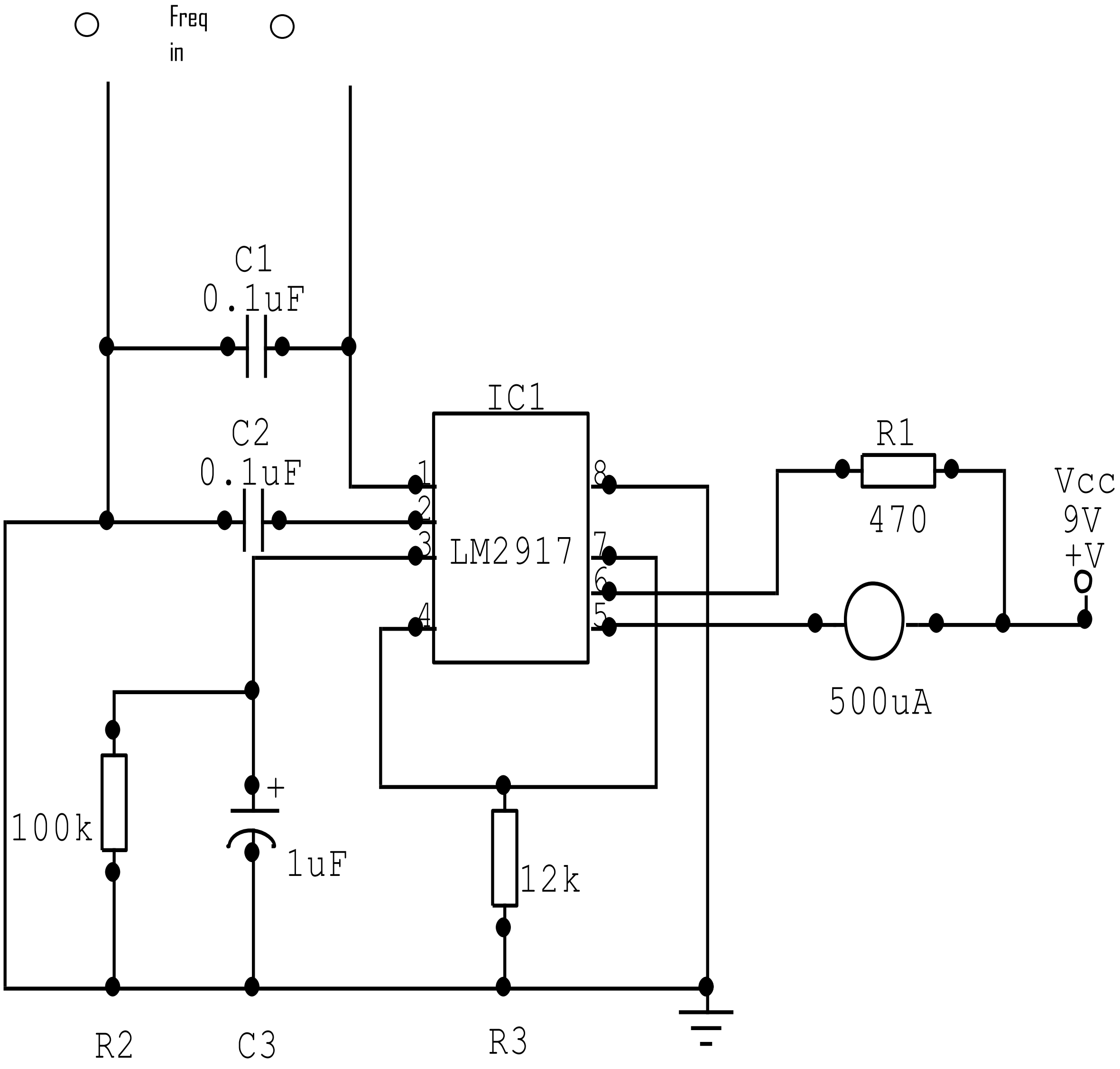

Figure 4 Circuit diagram for wind speed meter

The Frequency to Voltage Converter is the major electronic component of this work. Hence, we shall review its schematic diagram and applications. The Equivalent schematic diagram of LM2917 IC is shown in figure 5[2]

Equivalent Schematic Diagram

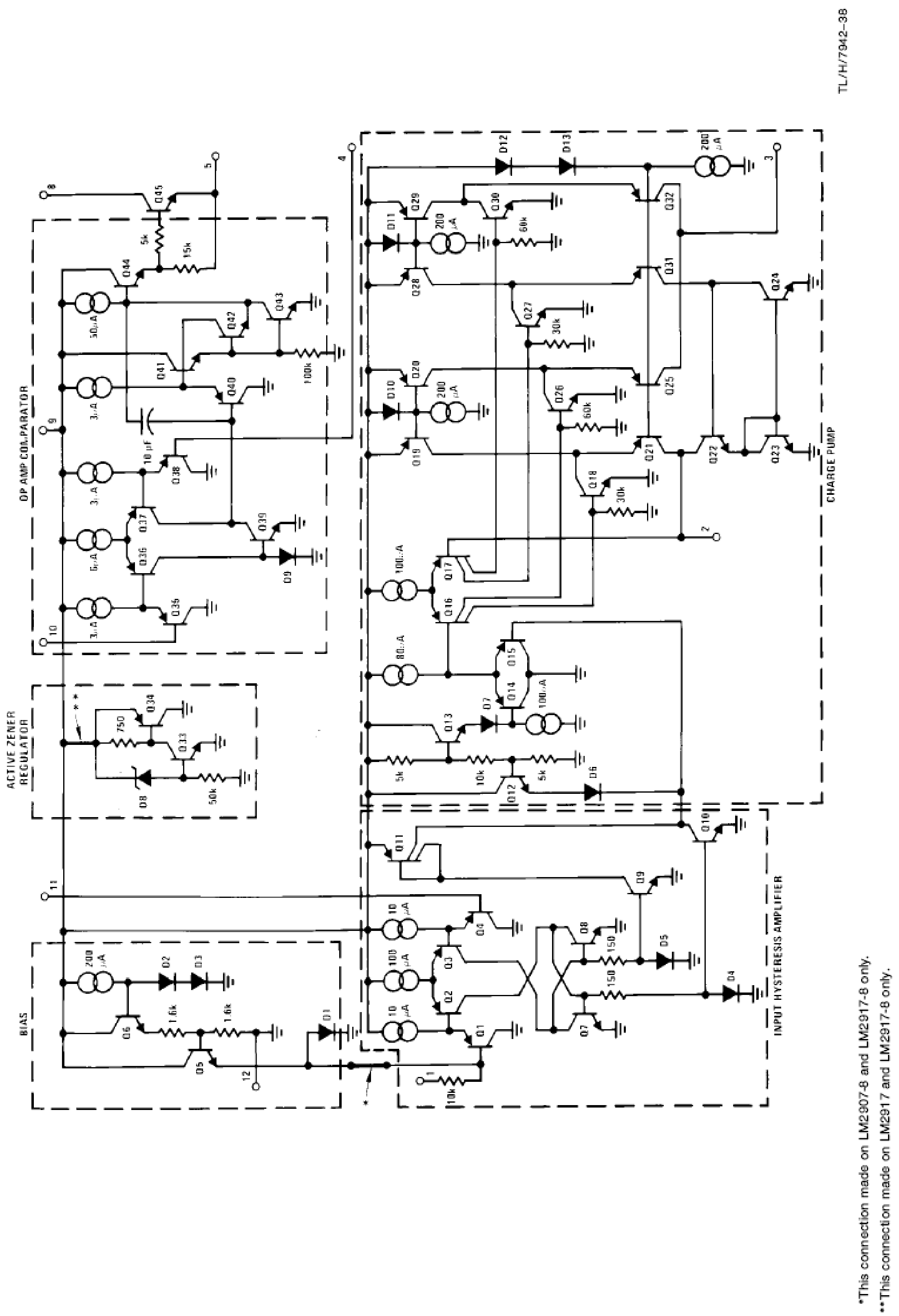

Figure 5: Equivalent circuit of the frequency-to-voltage IC

2.1 The Frequency-To-Voltage Converter

The LM2907, LM2917 series are monolithic frequency to voltage converters with a high gain op amp/comparator designed to operate a relay, lamp, or other load when the input frequency reaches or exceeds a selected rate. The tachometer uses a charge pump technique and offers frequency doubling for low ripple, full input protection in two versions (LM2907-8, LM2917-8) and its output swings to ground for a zero frequency input. .[2]

The LM2917 IC has numerous advantages namely: Output swings to ground for zero frequency input, the chip is easy to use and there is no ambiguity in determining its output ($V_{OUT} = f_{IN}$ x V_{CC} x R1 x C1), only one RC network provides frequency doubling, Zener regulator on chip allows accurate and stable frequency to voltage or current conversion (LM2917).[2]

Several features of this unique IC are:Ground referenced tachometer input interfaces directly with variable reluctance magnetic pickups, Op amp/comparator has floating transistor output, 50 mA sink or source to operate relays, solenoids, meters, or LEDs, Frequency doubling for low ripple, Tachometer has built-in hysteresis with either differential input or ground referenced input, Built-in zener on LM2917, 90.3% linearity, typical ground referenced tachometer is fully protected from damage due to swings above V_{CC} and below ground.[2]

2.2 Applications of the LM2917 IC

The LM2917 IC has a wide range of applications in :

- Voltage driven meter indicating Engine RPM,
- A capacitance meter
- A remote speed switch,
- A variable reluctance magnetic pickup buffer circuit
- A finger touch or contact switch circuit
- An over speed indicator circuit [2]

III. Hardware Design

From figure 4 above, the design of this wind speed meter is centered on the voltage-to-frequency converter. In this case, it is acting as a frequency-to-current converter. The galvanometer is shunted with a 470Ω resistor. The galvanometer has an internal resistance of 1100 ohms with a full-scale deflection – FSD of 100µA. [3]

The output voltage of the frequency-to-voltage converter is represented by the formula:

$V_{OUT} = f_{IN}$ x V_{CC} x R1 x C1 (1)

Where,

V_{out}	=	Output voltage
f_{in}	=	Input frequency
V_{cc}	=	Supply voltage
R1	=	Galvanometer shunt resistor
C1	=	Input filter capacitor

V_{out} = f_{in} x 9 x 470 x 0.1 x 10^{-6}

3.1 Choosing R1 And C1

There are some limitations on the choice of R1 and C1, which should be considered for optimum performance. The timing capacitor also provides internal compensation for the charge pump and should be kept larger than 500 pF for very accurate operation. Smaller values can cause an error current on R1, especially at low temperatures. Several considerations must be met when choosing R1. The output current at pin 3 is internally fixed and therefore VO/R1 must be less than or equal to this value. If R1 is too large, it can become a significant fraction of the output impedance at pin 3, which degrades linearity. Also output ripple voltage must be considered and the size of C2 is affected by R1. An expression that describes the ripple content on pin 3 for a single R1C2 combination is:

$$V_{RIPPLE} = \frac{V_{CC}}{2} \times \frac{C1}{C2} \times \left(1 - \frac{V_{CC} \times f_{IN} \times C1}{I_2}\right) \text{pk-pk} \quad (2)$$

It appears R1 can be chosen independent of ripple, however response time, or the time it takes VOUT to stabilize at a new voltage increases as the size of C2 increases, so a compromise between ripple, response time, and linearity must be chosen carefully. As a final consideration, the maximum attainable input frequency is determined by V_{CC}, C1 and I_2: [3]

$$f_{MAX} = \frac{I_2}{C1 \times V_{CC}} \tag{3}$$

3.2 The design of the Rotating Cup Assembly

The rotating cup assembly consists of the three hemispherical table tennis eggs, computer hard disk motor and compact disk as shown in figure 7 below. The compact disc is made of plastic and that is why it was chosen for this work. This will greatly reduce the inertia force required to cause rotation of the assembly

Figure 7. Component of the rotating assembly

To design the cup carrier, the compact disc is constructed as follows :

- Scrape of the coating off the topside with smooth sand paper.
- Draw lines to divide the compact disc into four equal segments
- Draw another circle of diameter 65mm inside the main circle itself.

Construct on the compact disc as show in the figure 8 below.

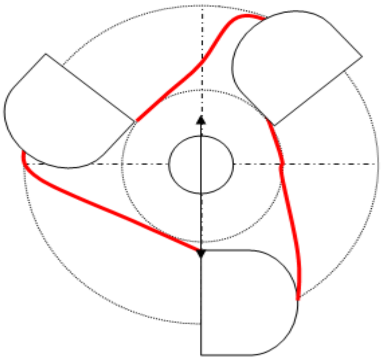

Figure 8: The compact disc carrier design

Cut out the shape indicated by the red line and glue the hemispherical table tennis eggs as shown in figure 8.. The resulting shape will be as show in figure 9 below.

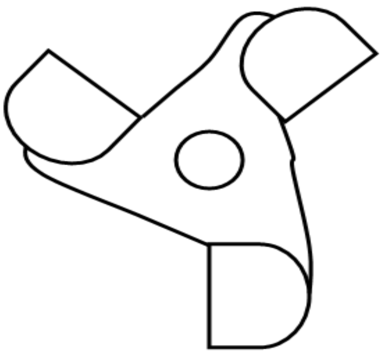

Figure 9: The cup-carrier assembly

IV. Construction Methodology

The following Materials/ Components are required for the construction of the wind speed meter : 6" length of 2" diameter PVC pipe,1pc Compact disc,1pc 100µA galvanometer,1pc of Computer hard disk motor,3pcs plastic table tennis eggs, Adhesive glue,1pc 9volts battery,1pc LM 2917 8 pin IC,2pcs 0.1pF capacitor,1pc 1µF capacitor, 5meter Length of conductor wire,1pc Vero board and Solder.

The tools used for the constructions are stated below: Soldering iron, Digital multimeter, Screw drivers, Lead sucker ,Mini hacksaw, Flat file, Cello tape, Electronic bread board, Long nose cutter and a vehicle with good speedometer for calibration

The circuit housing is simply a 2" PVC pipe cut to a length of 15cm as shown in figure 10.

Figure 10: The circuit housing

The circuit board consists of the Vero board upon which the components are mounted as shown in figure 11 below.

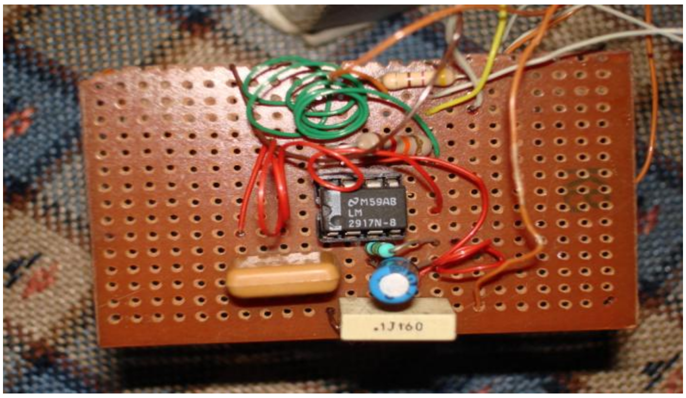

Figure 11: The circuit board

The complete wind speed meter is shown in the figure below.

Figure 12: The complete work

4.1 Calibration

After completing the construction of this project, it will be useless with out calibrating it against a standard. This is actually the most exciting part of the work. The calibration was done against a vehicle's speedometer. Someone other than the driver holds out the wind speed meter and reads off and marks out the corresponding vehicle speed on the galvanometer scale. The vehicle is accelerated to different speeds and the galvanometer scale is marked accordingly until full scale deflection is reached on the galvanometer. See calibration table below.

Table 1: Calibration table

S/N	VEHCILE SPEED (KM)	NUMBER OF DIVISIONS ON GALVANOMETER
1	10	0
2	11/11.5	5
3	12/12.5	10
4	17	15
5	18/19	20
6	21	25
7	25	30

From the table analysis, 1km/hr wind speed = 2 divisions on the galvanometer scale

V. Conclusion

The aim of this work which is to improve upon an existing design of a wind speed meter was indeed achieved. The output of this Integrated circuit is a linear one. The IC's internal voltage reference circuitry ensures accuracy does not degrade even as the battery discharges. It will run until power is too low, and then stop completely. However, this design is limited to measure wind speeds from 10km/hr to 25km/hr due to the type of motor used. This could be improved upon by the use of a motor with softer bearing.

In spite of the achievement of this project, there is still room for improvement. We therefore recommend further improvement as follows;

- The capability of this design could be expanded to measure low wind speeds by use of a different kind of motor with light weight bearing to enable easy rotation.
- A redesign could see the display of speed in digital form. This means that the galvanometer could be replaced with a seven segment digital display. However, more research would have to go into the design of the digital display driver circuit.
- A multi-range selector switch could be incorporated to enable the wind speed meter measure wind speed at various ranges. This project is limited to (10 to 25km/hr) wind speed range.
- we used a vehicle with an analogue speedometer for calibration. we would recommend that a vehicle with digital speedometer be used in future calibration in order to minimize or eliminate parallax error.

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