A NOVEL DIRECTION MEASUREMENT SIGNAL CONDITIONING CIRCUITRY

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Abstract

This paper presents an approach in signal conditioning circuitry design for direction measurement. The goal of this project is to achieve an accurate measurement of the direction using a photodiode as a transducer. A signal conditioning circuitry is used to transform the input signal from a sensor into a suitable output in terms of degree (°). The reflection of light is captured by a photodiode when the slotted disc rotated. The slotted disc has different depth at every corner. The signals captured at every depth and then transformed to the desired output.

Keywords

Signal conditioning circuitry, photodiode, reflection, and slotted disc.

1 Introduction

Wind is a phenomenon caused by large moving masses of air molecules. These molecules comprise the gaseous atmosphere that surrounds our planet. Moving air masses (wind) are most often quantified in terms of their relative direction and velocity. Because of the type of weather is closely linked to these moving air masses, a great deal of meteorological information can be gleaned from wind speed and wind direction measurements.

For instance, the passage of a weather front, which is cold or warm, is always followed by a change in the wind direction, temperature and barometric pressure. Wind speed can also be an excellent indicator of current and future weather conditions. In general, constant wind direction and low to moderate, which is not gusting wind velocity, indicate a stable air mass and thus fair weather. High wind velocity, gusting and variable wind direction indicates an unstable air mass and unsettled weather.

The two methods commonly used to measure wind direction are the potentiometer as a transducer and photodiode as a sensor. First method by direct wind direction readout or a potentiometer for remote readings attached to the rotating shaft of the wind vane [4]. For meteorological purposes, wind direction is universally expressed in terms of compass heading degrees which is 0° - 360° [7] but for this paper covered more on the wind direction for anemometer using light source and photodiode depends on the target which is depth of each corner at slotted disc.

2 Project overview

This paper introduces the concepts of reflection detection from light source to a photodiode to measure the direction by signal conditioning circuitry. The reflective concept is especially attractive for broad sensor use doe to accuracy, simplicity and potential low cost. The concept is shown in Figure 1 [1]. The light beam transmitted the light source from driver circuit to slotted disc rotation with the different depth as a target and then returned the light to the detector, which is photodiode. When a target breaks a reflected beam, the photodiode is detected and amplify the signal to a voltage output depend on the depth on slotted disc in every corner. The sensitivity of the detected light depends on how far the reflecting fiber is form the fiber optic probe [2], [3].

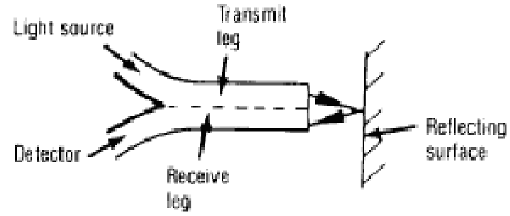

Figure 1 *Reflective concept of fiber optic*

Figure 2a shows the block diagram of the measuring instrument consist of the overall design of a simple direction measurement system. It has three part of circuit, which is transmitter, or driver circuit contains an ultra bright blue LED, which provides a very high intensity, and receiver circuit, which it contains of photodiode and signal conditioning circuitry while the slotted disc is mounting to the anemometer. The wind causes the slotted disc to rotate at the rate proportional to the wind direction. Optical fiber cables are capable to transmit the light signal from the light source through the slotted disc. Signal received from the photodiode will then be processed accordingly. This can be done in the signal conditioning circuitry. The block diagram of the signal conditioning circuit is shown in Figure 2b.

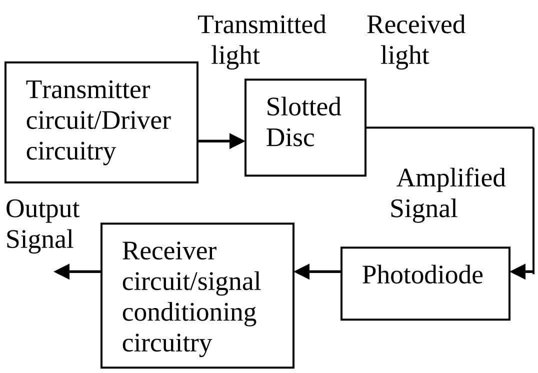

Figure 2a Block *diagram of measuring instrument*

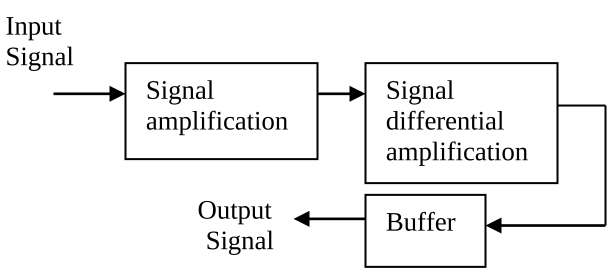

Figure 2b *Block diagram of the signal conditioning circuitry.*

2.1 Circuit design

Figure 3a shows a transmitter or driver circuit with a Vcc = 5V, R1 = 1kΩ, R2 = 100kΩ and an ultra bright LED. The LED can produce a very bright blue light so that the photodiode can easily detect it. The amplifier (UA741) amplifies the signal from the 5VDC supply and Figure 3b shows pin configuration of UA741. Figure 4a shows the signal conditioning circuits, which include 3 stages, which is signal amplification, signal differential amplification and buffer circuitry and Figure 4b shows the pin configuration of CA3140 [8].

Signal amplification circuit consists of a current-to-voltage converter, which also acts as the first stage of amplification. CA3140E is used to convert current signal to voltage signal. Since the current level of the photodiode is almost zero, a large value of resistor R_1 and R_2.

A differential amplifier produces an output voltage signal equal to product of the differential voltage gain and the difference between the potentials applied to the –IN and output signal from first stage [6]. A buffer is required to avoid the second amplification circuit from affecting the circuit before it. The differential output from buffer will be used to send signal to the Digital Voltmeter (DVM).

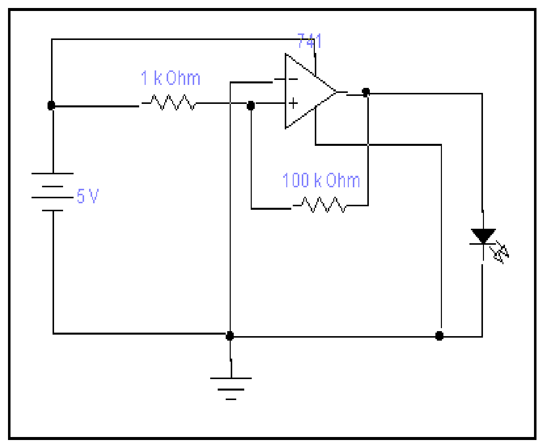

Figure 3a *Transmitter circuitry*

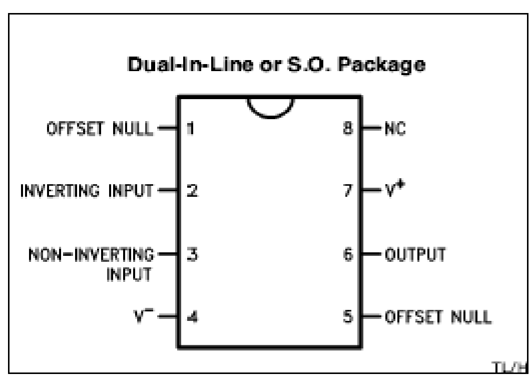

Figure 3b *Pin configuration of UA741.*

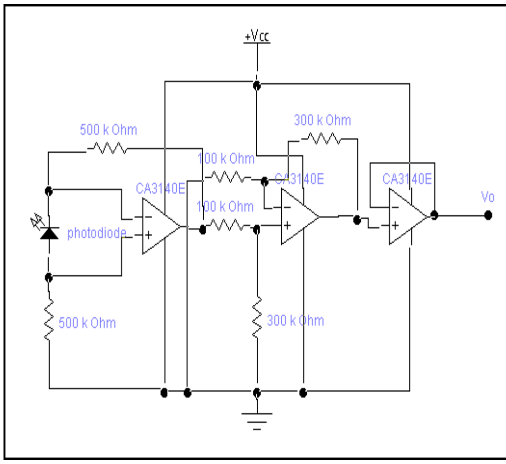

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Figure 4a *Signal conditioning circuitry/receiver circuitry*

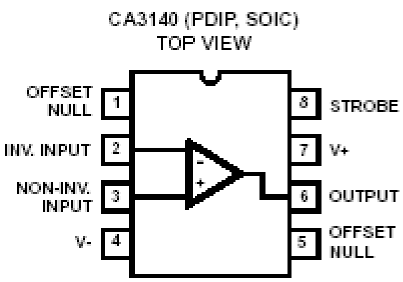

Figure 4b *Pin configuration of CA3140*

3 Methodology

Many step we can do to get the desired output of wind direction. Figure 5 shows the summarize of designing and testing the signal conditioning circuit of wind direction.

STEP 1: Get information of wind direction in library and internet in terms of objective of this project paper.

STEP 2: Develop the signal conditioning circuit which is electrical signal and do the simulation using pspice. Buy the component and construct the circuit.

STEP 3: Develop the signal conditioning circuit which is light signal in terms of intensity sensor. Buy the component and construct the circuit

Do the Laboratory Works

1. Electrical Test

- Construct the 5V and 10V voltage regulator
- Test the signal conditioning circuit at breadboard.
- Vary the potentiometer as a transducer and get the desired output related the input voltage.
- Transfer that circuit to the vera board.
- Do the calibration and get the data from testing

2. Light Testing

- Test the signal conditioning circuit at bread board.
- Test the photodiode without the fibre optic and take the value.
- Test the photodiode with the fiber optic.

Figure 6

4 Results

Several experiments were required to test the capability of the circuit. The circuit design was gone through two experiments. These experiments were to test the electrical signal circuitry and the light intensity signal circuitry as shown below:

4.1 Calibration and testing the electrical signal circuit.

The first experiment was to test the electrical signal circuit. A 12-volt power supply was connected to the 5V and 10V voltage regulator circuit. Then the output of 5V voltage regulator connected to the input of potentiometer while the 10V voltage regulator gives the supply of amplifier. The potentiometer was varied and the output was observed from the Digital Voltmeter. Table 1 shows the calibration of the output signal by varying the potentiometer.

Range (%)	Input Potentiometer (kΩ)	Output Voltage (V)	Wind Direction (°)
0	0	0	0
25	5	1.25	90
50	10	2.5	180
75	15	3.75	270
100	20	5	360

Table 1a Calibration result

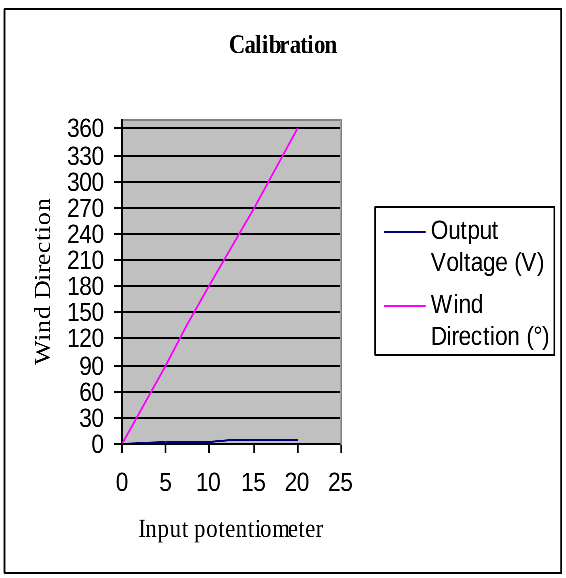

Figure 7a *Linearity relationships with the calibration.*

Input potentiometer (kΩ)	Output Voltage (V)	Wind Direction (°)
0.410	0.053840	3.8765
0.490	0.075450	5.4324
0.510	0.086310	6.2143
0.530	0.095290	6.8609
0.780	0.150000	10.8000
1.050	0.240000	17.2800
1.260	0.310000	22.3200
1.780	0.450000	32.4000
2.070	0.540000	38.8800
2.380	0.640000	46.0800
2.620	0.710000	51.1200
3.150	0.870000	62.6400
3.490	0.950000	68.4000
3.650	1.010000	72.7200
3.730	1.030000	74.1600
4.060	1.130000	81.3600
4.380	1.230000	88.5600
4.760	1.340000	96.4800
5.100	1.440000	103.6800
5.400	1.520000	109.4400
5.730	1.620000	116.6400
6.060	1.720000	123.8400
6.310	1.810000	130.3200
6.760	1.930000	138.9600
6.980	2.010000	144.7200
7.300	2.100000	151.2000
7.780	2.240000	161.2800
8.210	2.360000	169.9200
8.480	2.450000	176.4000
8.830	2.550000	183.6000
9.160	2.640000	190.0800
9.470	2.740000	197.2800
9.840	2.850000	205.2000
10.16	2.940000	211.6800
10.43	3.030000	218.1600
10.87	3.160000	227.5200
11.08	3.230000	232.5600
11.45	3.330000	239.7600
11.70	3.400000	244.8000
12.21	3.560000	256.3200
12.50	3.650000	262.8000
12.88	3.760000	270.7200
13.08	3.820000	275.0400
13.41	3.930000	282.9600
13.78	4.020000	289.4400

14.07	4.120000	296.6400
14.40	4.210000	303.1200
14.87	4.350000	313.2000
15.26	4.470000	321.8400
15.58	4.560000	328.3200
16.02	4.630000	333.3600
16.21	4.740000	341.2800
16.82	4.970000	357.8400
17.07	5.050000	363.6000

Table 1b *Testing with variation of potentiometer*

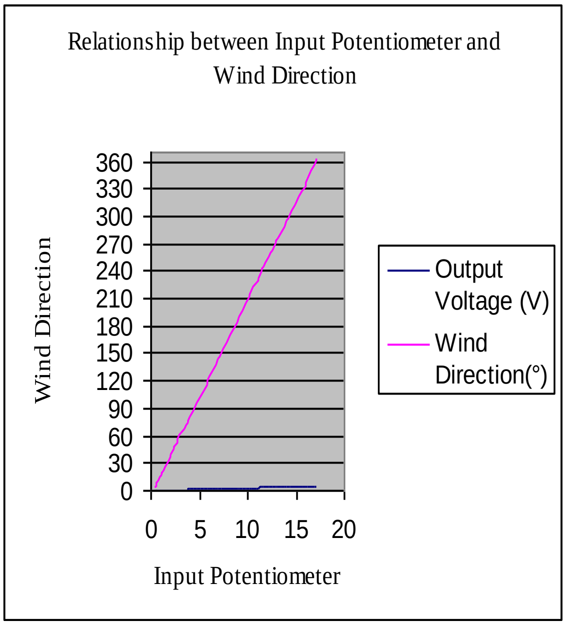

Figure 7b *Linearity relationship exists between the input potentiometer and output voltage wind direction*

From the Table 1a and 1b, we can conclude that the characteristic between the input potentiometer, desired input potentiometer and output of wind direction is linear. So, the wind direction can be measured by rotating vane from the variation of wiper potentiometer.

4.2 Testing the light intensity signal

The second experiment was to test the light intensity signal circuit. From Figure 1, the light source is from ultra bright LED in transmitter circuit as shown in Figure 3a, transmit the signal through the fibre optic to the reflection space which is slotted disc with a different depth and then the signal receive to the photodiode. The signal can be measured by signal conditioning circuitry as shown in Figure 4.From the experiment we observed that the depth is proportional with output voltage and the signal can be amplified to the desired output voltage between 0 to 5 volts which was applicable for the voltage standard. Table 2a shows the relationship between light intensity and distance.

Depth (mm)	Distance+ Length (mm)	Output Voltage (V)	Wind Direction (°)
8	10	0.521	46.89
7	9	0.93	83.7
6	8	1.4	126
5	7	2.013	181.17
4	6	2.851	256.59
3	5	3.911	351.99
2	4	4.015	361.35

Table 2a M*easurement 1*

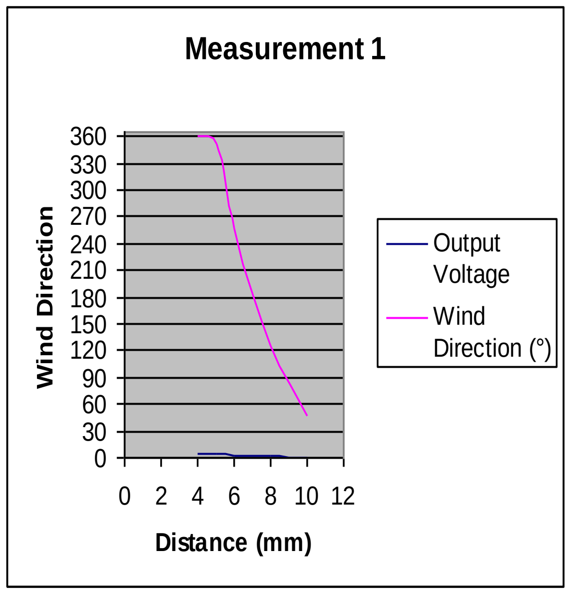

Figure 8a *Relationship between wind direction from intensity of light and distance*

Depth (mm)	Distance+ Length (mm)	Output Voltage (V)	Wind Direction (°)
8	10	0.432	38.88
7	9	1.258	113.22
6	8	1.901	171.09
5	7	2.314	208.26
4	6	2.991	269.19
3	5	3.925	353.25
2	4	4.015	361.35

Table 2b *Measurement 2*

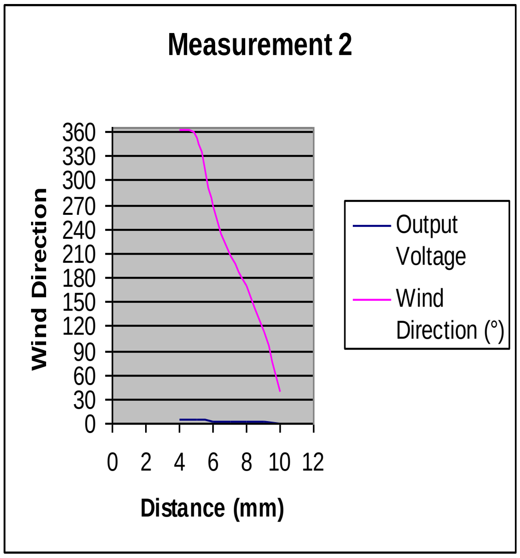

Figure 8b *Relationship between wind direction from intensity of light and distance*

From Figure 8a and Figure 8b shows the relationship between wind direction from intensity of light and distance. The intensity of light decreases the farther away a light of a given intensity is. The relationship between the distance of a source of light and its apparent intensity is governed by the inverse square law [5] approximately because of the mechanical part such as slotted disc and mounting part of light source to the photodiode. It only appears to do so as a result of being sensed at a different distance; the farther away it is sensed, the larger the area the photons are spread over and the fewer are sensed.

4.3 Discussions and Conclusions

A simple direction measurement for anemometer is an instrument designed to measure the wind direction besides the wind speed. Basically, the input signal, which is a light signal, is captured by a photodiode and being process in the signal conditioning circuit before it being transformed into the desired output signal that is in terms of degree.

Generally this project consists of 3 stages; driver circuitry/transmitter circuitry, photodiode and signal conditioning/receiver circuitry. The primary function of the driver circuitry is to transmit a continuous light signal in terms of intensity from ultra bright LED to the slotted disc through the fiber optic and then reflected the signal to the photodiode. The photodiode sense the light signal from the reflection concept through the slotted disc from the fiber optic and transform it into electrical signal. This signal is being process and modified in the signal conditioning circuit before it being transform in to desired output signal that is in terms of voltage. Signal conditioning consists of signal amplification, signal differential amplification and buffering. Several experiments had been carried out to test the system. The data was taken from the digital voltmeter (DVM). In order to test the circuit the slotted disc was mounted to the rotating rod.

However, the metal of slotted disc is not reflective space and then it not gives accurate and consistent readings. Thus, for a proper presentation, the slotted should be a special reflector and mounted on the anemometer. The PIN photodiode had been choosing because of light intensity is very high thus can provide very bright signal. Signal conditioning circuit provides a better signal after testing with the fiber optic.

A stable output signal can be observed by both methods. However, there were losses in the output signal result from the components used in light signal method. Otherwise, the output cannot give the maximum 5V and from testing we loss 1V. To overcome this problem, better components in terms of its specification and characteristic should be used. From the experiments, the overall output signal of the circuits provide a linear relationship between the input signal. The circuits were very sensitive to the input signal affected by the sensitivity of the photodiode. The result however was not accurate because of the mechanical design problem of the slotted disc. To overcome this, more slots need to be applied on the disc and metal of slotted have a good reflector. For conclusions, we assume the signal conditioning circuitry has an improvement pulses signal for stable wind. The circuitry also can measure a variation of light intensity signal depend on distance and the output signal was measured and observed. This signal however could be improved to be more accurate by creating more slots on the disc good reflector.

For the electrical signal circuit, the signal has more stable and the reading given a precise result. Thus for both method it can be conclude that the stable and improved signal could be measured from this project.

6 Future Developments

A few researches can be made to make some development on this project. Some modification on the system design of this project can be made to improve its accuracy and sensitivity. This can be done by design an optical fiber with a dome to converge the light and the slotted disc, so that there is more light immersion into the photodiode. By adding an interfacing to the output signal, the value of the measurement can be display on the computer. Doing some programming such as PIC, Visual Basic, can do this. Besides that, this project can expanse to detect not only the direction of the wind but also its speed, solar to measure the temperature, etc. However, more modification on the mechanical design of the anemometer is going to be done and the circuitry of the signal conditioning also needs to be design properly.

7 References

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