DEVELOPMENT OF ELECTRODYNAMICS TRANSDUCER FOR SOLID PARTICLE MEASUREMENT

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical (Hons.) (Electronics)

Faculty of Electrical & Electronics Engineering

University Malaysia Pahang

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Signature :________________________________

Author : NORHASLINDA MOHD ROSLI

Date : 21 JUNE 2012

"I declare that I have checked this project and I think this project has achieve the scope and objective .This project has also achieve the requirement for award of the degree of Bachelor of Electrical Engineering (Electronics)."

Signature : ________________________________

Name of Supervisor : MOHD RIDUWAN GHAZALI

Position :Lecturer

Date : 21 JUNE 2012

Specially dedicated with deepest love to:

My beloved family especially my parents for their support, guidance and love, and also my beloved friends for support during to complete my final project.

ACKNOWLEDGMENT

First of all, Alhamdulillah, the highest thanks and praise to Allah S.W.T the Almighty and Merciful for His Willingness and guidance for giving me strength in finishing this valuable thesis.

With this opportunity, I would like to acknowledge and extend my gratitude to my dedicated supervisor, Mr. Mohd Riduwan b.Ghazali who guided me through in this project with clarity and that priceless gift of getting things done by sharing his valuable ideas as well as his knowledge. It would have been difficult to complete this project without enthusiastic support, insight and advice given by her.

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I have gained a lot of help and support from friends and staffs in the Faculty of Electrical & Electronics Engineering. The great cooperation, kindheartedness and readiness to share worth experiences that have been shown by them will be always appreciated and treasured by me

ABSTRACT

The electrostatic sensor was used in process industry because low cost and robust. Electrostatic charge can be detected using sensing device or called as electrode sensor and convert into voltage using associated electronic or known as electrodynamics transducer.The sensing device or electrode sensor consists of a conductor, insulated from the pipeline which may take a variety of different shapes and sizes. The associated electronics is a circuit for signal conditioning to invert the voltage. In the pipeline system, non-intrusive electrode sensor was assembled or implemented. Movement of solid particles which is sand will generate electrostatic charges and can be detect using sensing device or electrode and convert into voltage by electrodynamics transducer or associated electronic. The pipeline system will develop for solid particle flow and the electrodynamics transducer for signal conditioning circuit. The three outputs are amplified voltage, rectified voltage and average voltage will captured and analysis by oscilloscope.

ABSTRAK

Pengesan elektrostatik telah digunakan dalam proses industry kerana kos rendah dan tidak berubah-ubah. Cas electrostatik boleh dikesan menggunakan peranti pengesan atau dipanggil sebagai elektrod pengesan dan ditukar kepada voltan oleh gabungan elektronik atau dikenali sebagai electrodinamika transduser. Peranti pengesan mengandungi konduktor, yang tidak bersambung dengan saluran paip yang mana terdapat dalam pelbagai saiz dan bentuk. Manakala, gabungan elektronik terdapat litar untuk isyarat keadaan. Di dalam saluran paip, elektrod pengesan yang tidak mengganggu dipasang. Pergerakan zarah pepejal akan menghasilkan cas-cas elektrostatik yang mana akan dikesan oleh peranti pengesan atau elektrod dan ditukar kepada voltan menggunakan electrodinmika transduser atau gabungan elektronik. Saluran paip direka untuk laluan zarah pepejal dan litar electrodinamika transduser direka utntuk litar isyarat keadaan. Tiga keputusan yang diperolehi adalah voltan penguat, voltan pembetul, dan voltan purata dan disahkan dan dianalisis dengan osiloskop.

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LIST OF ABBREVIATIONS

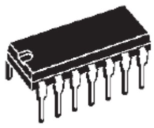
D	Diode
GND	Ground
AC	Alternate current

APPENDIX B

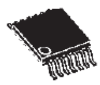
TL084
TL084A - TL084B

GENERAL PURPOSEJ-FET QUAD OPERATIONAL AMPLIFIERS

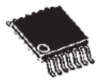
- WIDE COMMON-MODE (UP TO V_{CC}^{+}) AND DIFFERENTIAL VOLTAGE RANGE
- LOW INPUT BIAS AND OFFSET CURRENT
- OUTPUT SHORT-CIRCUIT PROTECTION
- HIGH INPUT IMPEDANCE J–FET INPUT STAGE
- INTERNAL FREQUENCY COMPENSATION
- LATCH UP FREE OPERATION
- HIGH SLEW RATE : 16V/µs (typ)



N
DIP14
(Plastic Package)



D
SO14
(Plastic Micropackage)



P
TSSOP14
(Thin Shrink Small Outline Package)

DESCRIPTION

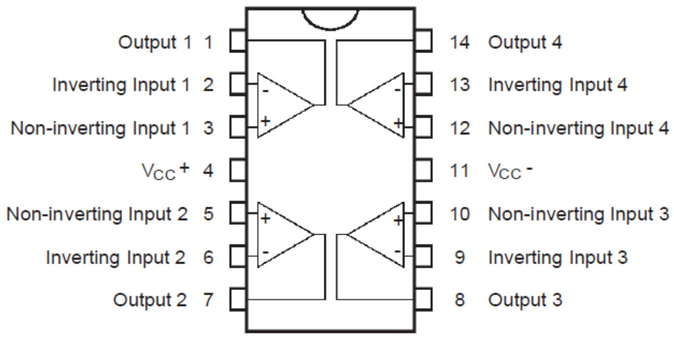
The TL084, TL084A and TL084B are high speed J–FET input quad operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit.

The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

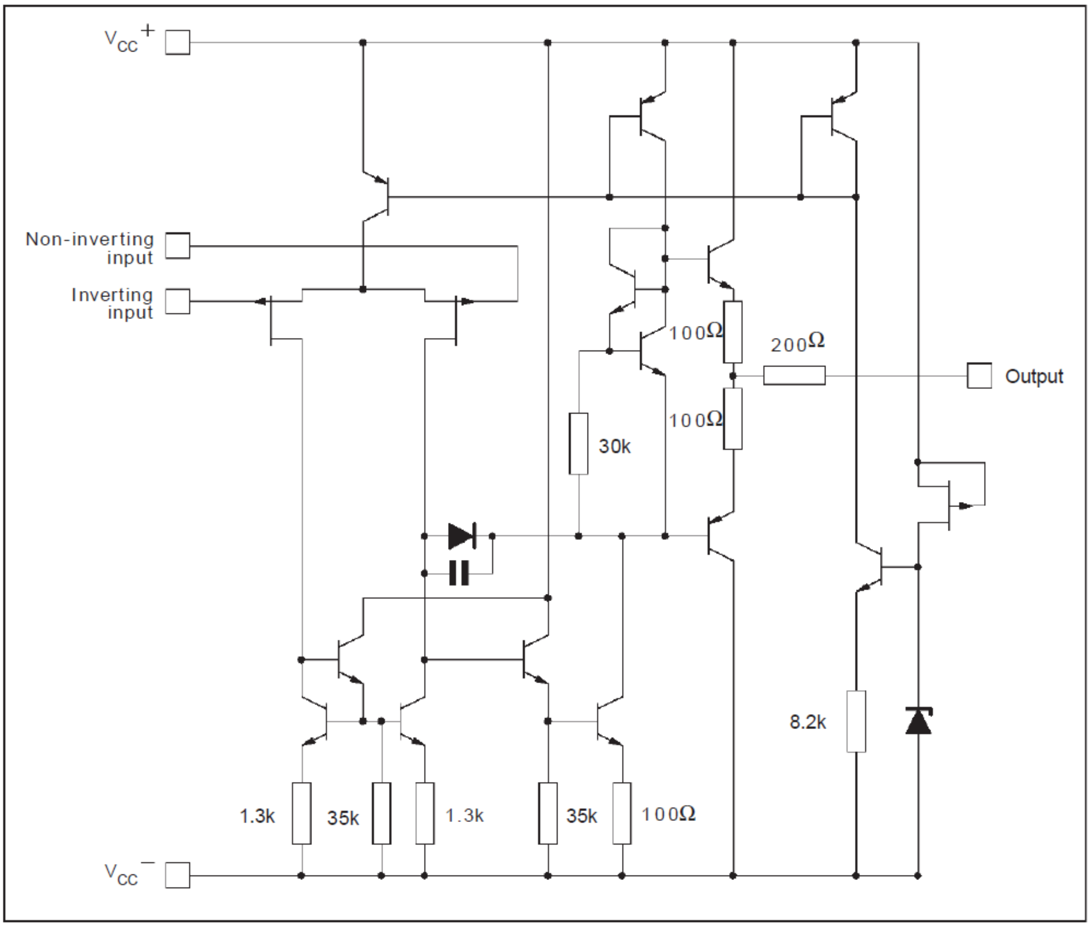
ORDER CODES

Part Number	Temperature Range	Package		
		N	D	P
TL084M/AM/BM	–55°C, +125°C	•	•	•
TL084I/AI/BI	–40°C, +105°C	•	•	•
TL084C/AC/BC	0°C, +70°C	•	•	•
Examples : TL084CN, TL084CD				

PIN CONNECTIONS (top view)



SCHEMATIC DIAGRAM (each amplifier)



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter		Value	Unit
V_{CC}	Supply Voltage - (note 1)		±18	V
V_i	Input Voltage - (note 3)		±15	V
V_{id}	Differential Input Voltage - (note 2)		±30	V
P_{tot}	Power Dissipation		680	mW
	Output Short-circuit Duration - (note 4)		Infinite	
T_{oper}	Operating Free Air Temperature Range	TL084C,AC,BC TL084I,AI,BI TL084M,AM,BM	0 to 70 –40 to 105 –55 to 125	°C
T_{stg}	Storage Temperature Range		–65 to 150	°C

Notes :
1. All voltage values, except differential voltage, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V_{CC}^{+} and V_{CC}^{-}.
2. Differential voltages are at the non-inverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and /or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

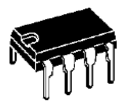
APPENDIX C

SGS-THOMSON MICROELECTRONICS

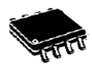
LF151 LF251 - LF351

WIDE BANDWIDTH SINGLE J-FET OPERATIONAL AMPLIFIER

- INTERNALLY ADJUSTABLE INPUT OFFSET VOLTAGE
- LOW POWER CONSUMPTION
- WIDE COMMON-MODE (UP TO V_{CC}^+) AND DIFFERENTIAL VOLTAGE RANGE
- LOW INPUT BIAS AND OFFSET CURRENT
- OUTPUT SHORT-CIRCUIT PROTECTION
- HIGH INPUT IMPEDANCE J–FET INPUT STAGE
- INTERNAL FREQUENCY COMPENSATION
- LATCH UP FREE OPERATION
- HIGH SLEW RATE : 16V/µs (typ)



N
DIP8
(Plastic Package)



D
SO8
(Plastic Micropackage)

DESCRIPTION

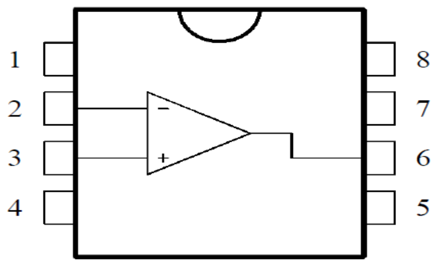
These circuits are high speed J–FET input single operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit.

The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

ORDER CODES

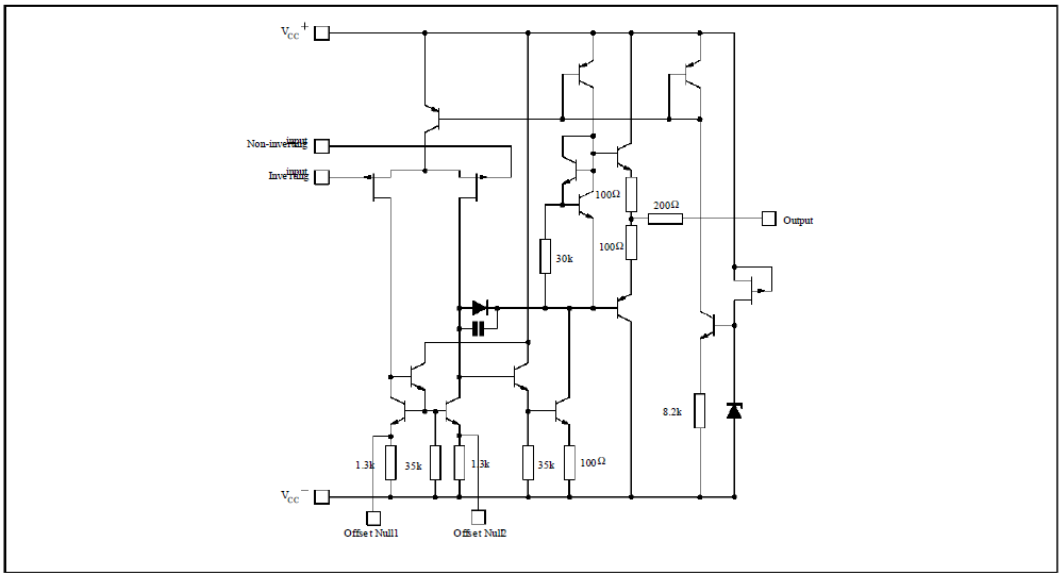
Part Number	Temperature	Package	
		N	D
LF351	0°C, +70°C	•	•
LF251	–40°C, +105°C	•	•
LF151	–55°C, +125°C	•	•

PIN CONNECTIONS (top view)

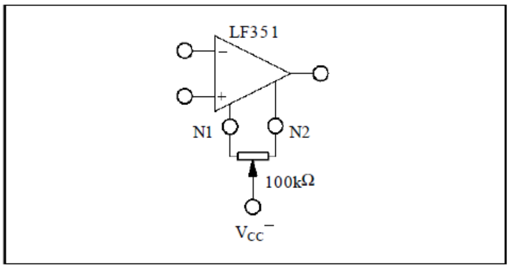


1 - Offset Null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^-
5 - Offset Null 2
6 - Output
7 - V_{CC}^+
8 - N.C.

SCHEMATIC DIAGRAM



INPUT OFFSET VOLTAGE NULL CIRCUITS



ABSOLUTE MAXIMUM RATINGS

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P_{tot}	Power Dissipation		680	mW
	Output Short-circuit Duration - (note 4)		Infinite	
T_{oper}	Operating Free Air Temperature Range	LF351 LF251 LF151	0 to 70 –40 to 105 –55 to 125	°C
T_{stg}	Storage Temperature Range		–65 to 150	°C

Notes :
1. All voltage values, except differential voltage, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V_{CC}^+ and V_{CC}^-.
2. Differential voltages are at the non-inverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and /or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.0 Background of Project

The development of this project is to design an electrodynamics transducer for solid particle measurement. Electrodynamics transducer or called as associated electronic consists of circuit for signal conditioning and the electrodes or sensing device consists of a conductor, insulated from the pipeline which may take a variety of different shapes and sizes[4,7]. Movement of solid particles in pipeline generates an electrostatic charge which is can be detected by using electrode or sensing device and converted into voltage by the electrodynamics transducer or associated electronics. Many processes in industries require continuous,smooth and consistent delivery of solids particle.In order to achieve those requirement, a proper measurement need to be install. Electrodynamics transducer offers the most inexpensive and simplest means of measuring solids flows in pipe. Besides that, electrodynamics transducer are widely used in industries because robust and low cost implementation in measurement. Application that applicable are process tomography, particle size processing and soil properties determination. But, some problem might occur such as poor throughput excessive power consumption , blockages caking and product degradation.

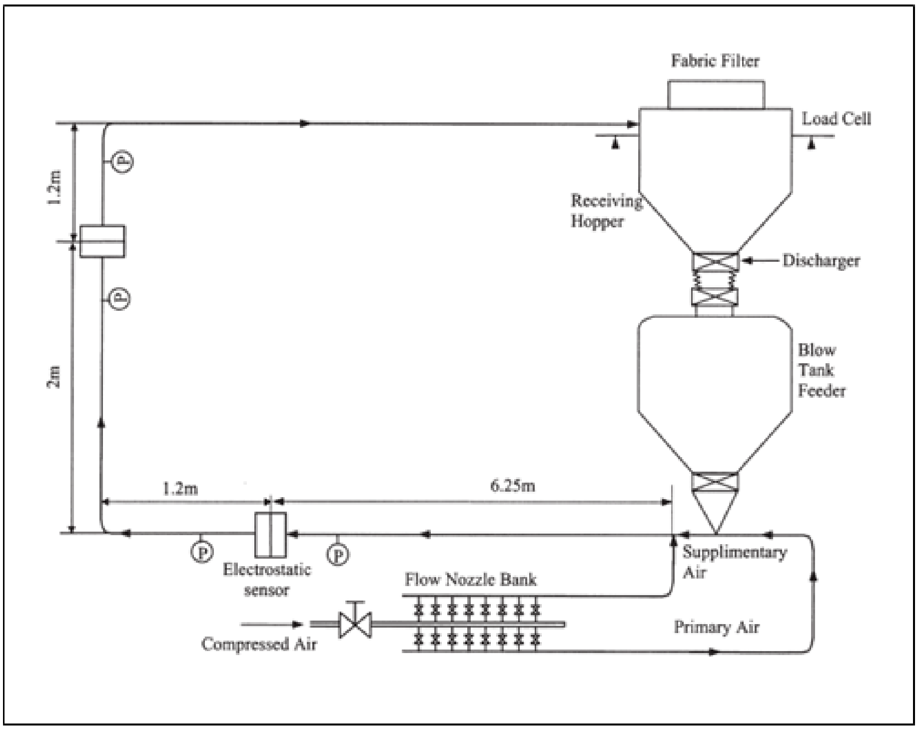


Figure 1.1: Process in industry

Solid particles flowing in a pipeline is a common mode of transport in industries. This is because pipeline transportation can avoid waste through spillage and minimizes the risk of handling of hazardous materials. Pharmaceutical industries, food stuff manufacturing industries, cement, and chemical industries are a few industries to exploit this transportation technique. For such industries, monitoring and controlling material flow through the pipe is an essential element to ensure efficiency and safety of the system. The purpose of this paper is to present electrical charge tomography, which is one of the most efficient, robust, cost-effective, and non-invasive tomography methods of monitoring solid particles flow in a pipeline. The figure 1.2 the assemble of electrode sensor in industry. There are three type of electrode sensor which are, ring shape, pin shape and quarter ring shape. The ring shape is widely used but it needs a lot of cost and hard to implement. The figure 1.3 was the process test rig which is for two types of coal: Colombian Coal(CC) and South Africa coal (SA), Biomass additions of 0%, 5%, 10%, 15%, and 20% were tested by premixing with the SA before milling [2]. The biomass fuel was dried sawdust pellets from the furniture manufacturing industry.

The coal samples were stored in open air prior to the tests and hence had high moisture content due to rainfall.

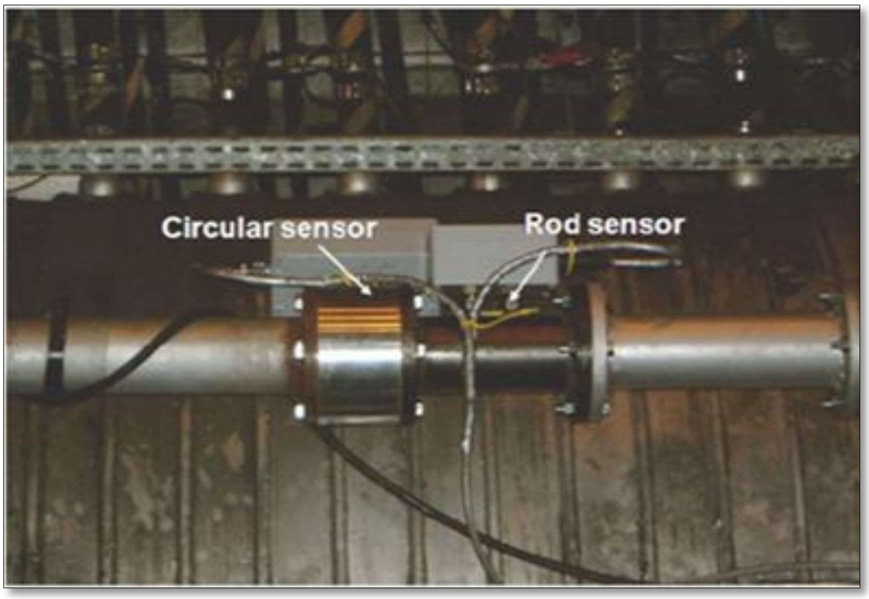


Figure 1.2: Installation of electrostatic sensor

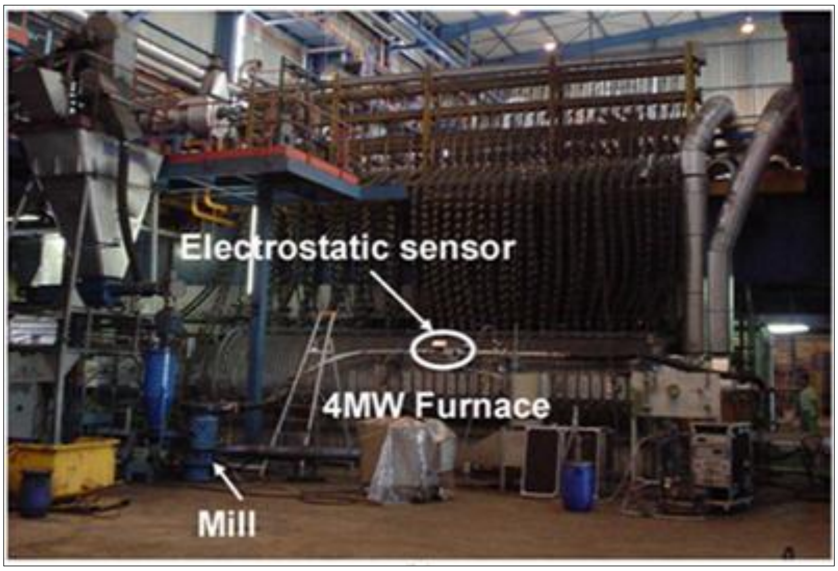


Figure 1.3: Overview the combustion test rig

The key design of this method is electrostatic transducer and solid particle. Sand was used as solid particle because the particles in sand were much closed and they cannot move but vibrate in fixed position. The block diagrams of a sensing system as shown in figure 1.The other term which refer to electrodynmic are electrostatic and triboelectric. ‘Electrodyamic’ refers to the fact that the change arose from the movement of particles. ‘Triboelectric’ emphasized that the particles are charged due to the friction or direct contact between the particles and the electrode. ‘Electrostatic’ implies the electrosatic nature of the sensing principle of the sensor.

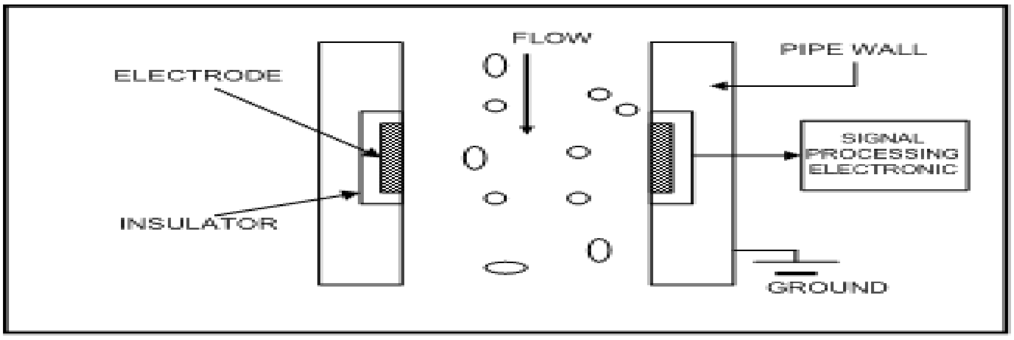


Figure 1.4: The Block Diagram of an Electrostatic Sensing System

This project can be used in food manufacturing industry by implemented the electrostatic sensor. Once the food cross the electrode sensor, the system automatically can count, and identify the size of packaging. It is also can be applied in electronic component.

1.2 Objectives of project

The main objective of this project is to develop electrodynamics transducer for solid particular measurement. The specific objectives of this project are listed below:

i. Develop non-intrusive pipeline system for solid particle measurement

ii. Design of circuit electrodynamics transducer.

iii. Analysis the three signal waveform which are amplified voltage, rectifier voltage and average voltage.

1.3 Scope of Project

The scopes of project based on the development of electrodynamics transducer are:

i. Design the pipeline system consist three different sizes of electrodes which are 8mm, 13mm, and 14mm.

ii. Design electrodynamics transducer circuit to detect electrostatic charge and convert into voltage.

iii. Capture the three signal outputs which are amplified voltage, rectified voltage and averaged voltage.

1.4 Thesis Overview

This thesis consists of five chapters and each chapter will in details about this project including introduction, literature review, methodology, result and analysis, and conclusion.

The first chapter, it is discuss about the basic idea of this project which is based on electrodynamics transducer. The main concept is about to develop non intrusive pipeline and design the electrodynamics transducer circuit.

Literature review chapter consists of the explanation about the movement particle in pipeline and how its generate charge, about the circuit conditioning and the method use to get the voltage signal.

Furthermore, detail explanation in methodology about the design will be presented. Each step will be explains more detail in order to get the desired output. But, the important things, the charge detect by the electrode sensor and convert into voltage.

In addition, result and analysis in this project will shown in chapter 4 either achieved the goal or not.

Last but not least, is on conclusion and recommendation of this project. This chapter, will summarize about the whole step had be done and give better recommendation for better performance and result.

CHAPTER 2

LITERATURE REVIEW

2.1 Electrostatic

Electrostatics involves the buildup of charge on the surface of objects due to contact with other surfaces. Although charge exchange happens whenever any two surfaces contact and separate, the effects of charge exchange are usually only noticed when at least one of the surfaces has a high resistance to electrical flow. This is because the charges that transfer to or from the highly resistive surface are more or less trapped there for a long enough time for their effects to be observed. These charges then remain on the object until they either bleed off to ground or are quickly neutralized by a discharge: e.g., the familiar phenomenon of a static 'shock' is caused by the neutralization of charge built up in the body from contact with nonconductive surfaces[15]. Example of the electrostatic phenomena is the attraction of the plastic wrap to your hand after removes it from package.

An electric charge near a metal object cause the mobile charges in the metal to separate. If the external charge is positive as shown in figure 2.1, negative charge are attracted and move to the surface object. Electrostatic field line cannot penetrate conductive object; they always end of induced charges o surface[15].

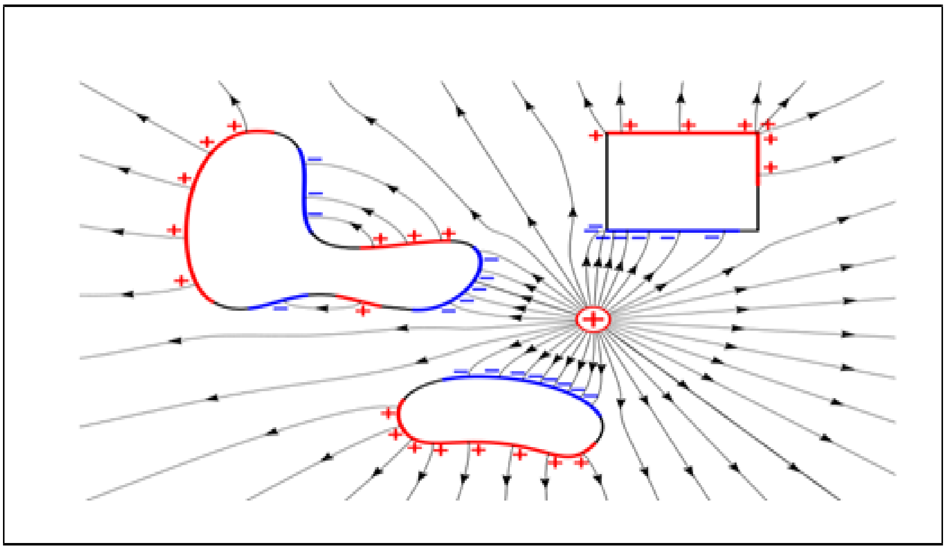


Figure 2.1: Diagram of charge induced in conductive object.

From this definition and Coulomb's law, it follows that the magnitude of the electric field *E* created by a single point charge *Q* is:

$$E = \frac{Q}{4\pi r^2 \varepsilon_0}$$

Where E is the electric field, ε_0 is the permittivity of free space (8.854×10^{-12} F/m), and R is the distance between the charged particle and a particular point.

2.2 Electrode Sensor

A number of different shapes of electrode e have been used as sensing elements for the flow measurement stud (pin) electrode, quarter ring electrode, and ring electrode [9]. Figure 2.2 show the type of electrode. Ring electrode is widely used process industry but it is no longer applicable, because it is difficult to install, costly and often impractical for large pipeline in inconvenient locations. Besides that, this ring shape is most sensitive to particulate near the pipeline wall. However, pin electrodes which consist of circular and rectangular shapes had been thoroughly investigated. In this project, circular electrode sensor was used. Figure 2.3 show the shape of pin electrode.

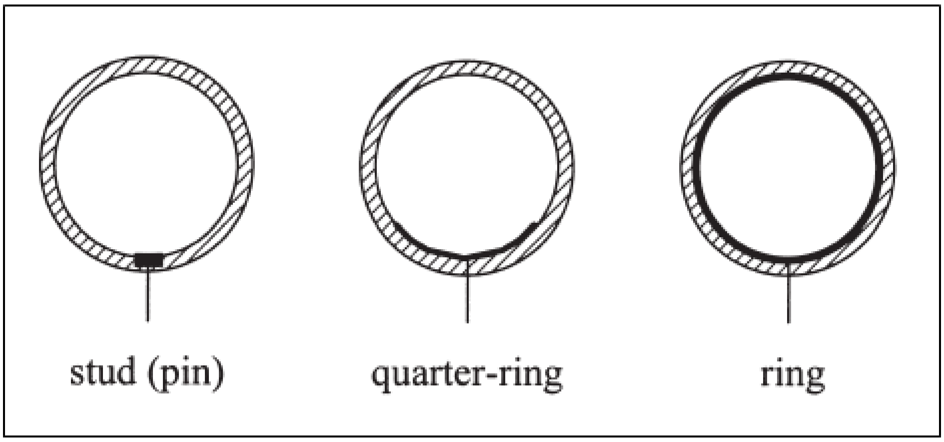


Figure 2.2: Electrodes used in electrode sensor

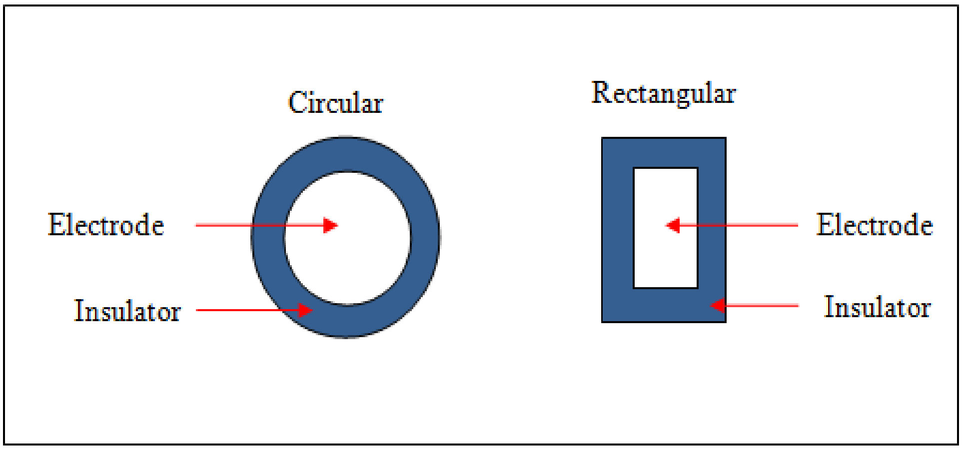


Figure 2.3: Pin electrode

There are two ways how to implement the electrode sensor in pipeline which are called intrusive electrode or non-intrusive electrode. Since, the intrusive electrode extends into the particle flow, it can “sample” the flow conditions along the cross section, particularly if several such electrodes are positioned around the perimeter of the pipeline. Intrusive electrodes will cause a disturbance to the particle itself. In addition, it may be of concern that particles striking the upstream electrode will lose some of their velocity, affecting the sensor measurement [2]. However, in striking the upstream electrode, the particle will release its charge; no signal will be induced on the downstream electrode.

Non-intrusive electrode was used in this project to detect the electrostatic charges; means the electrode sensor was implemented align with the pipe wall. Thus, only the surface of electrode was exposed to the solid particle and will not disturb the flow it. Figure 2.4 show, the way to implement the sensor electrode.

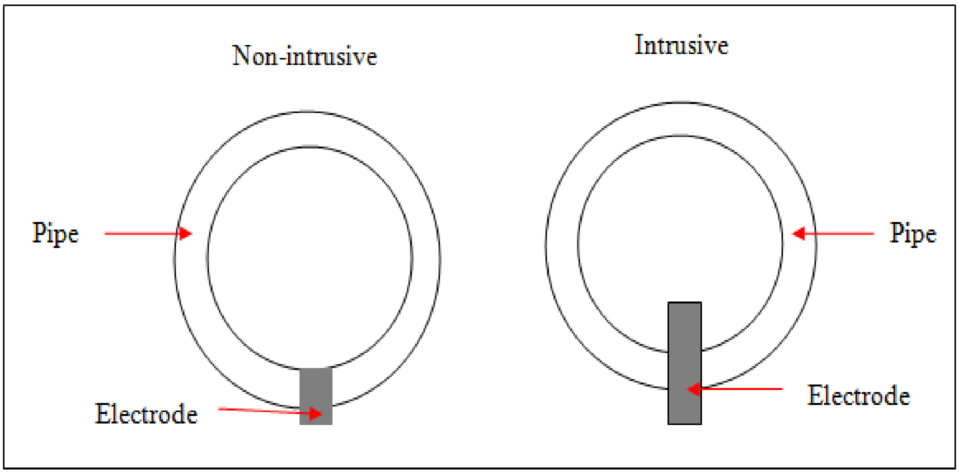


Figure 2.4: Implemented of electrode sensor

Moreover, the pipe wall was isolated from the sensor electrode by putting the insulator which is rubber. If the electrode is exposed directly to solid particle, direct change transfer due to the contact between the particle and the electrode can take place. However, if the axial dimension of an exposed electrode is small compared to the pipe diameter, electrostatic induction will be the dominant interaction [9].

2.3 Electrodynamics Transducer

The circuit diagram of the electrodynamics transducer is shown in figure 2.6. the transducer consist of plain metal rod , termed the electrode which capacitance to the earth and connected to the signal conditioning circuit. A resistor is connected in parallel to the capacitor to provide charge or discharge path. The charged particles in the pipe flow past the electrode including charge into it in the process [5]. The flow of current will provide a varying voltage. This voltage will buffer by non-inverting amplifier whose output will be input circuitry and is amplified and conditioned by further circuitry.

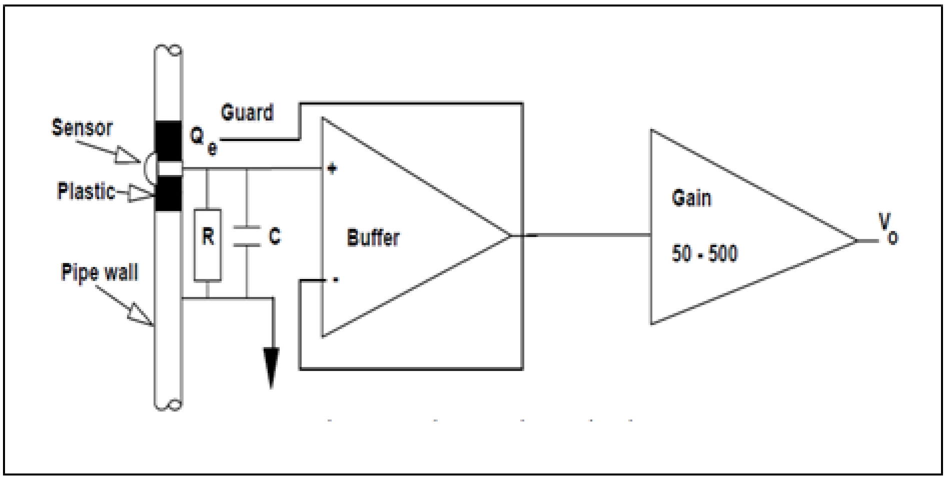


Figure 2.5: Transducer circuit.

Figure 2.6 show the block diagram of electrostatic transducer circuit [13]. The AC generate voltage will be the input for the non inverting voltage follower. Then, the output of this stage is used as guard voltage for input circuitry and is AC coupled to the input of the non-inverting voltage amplifier. The output 1 was AC amplified voltage, output 2 AC rectifier voltage and output 3 average voltage.

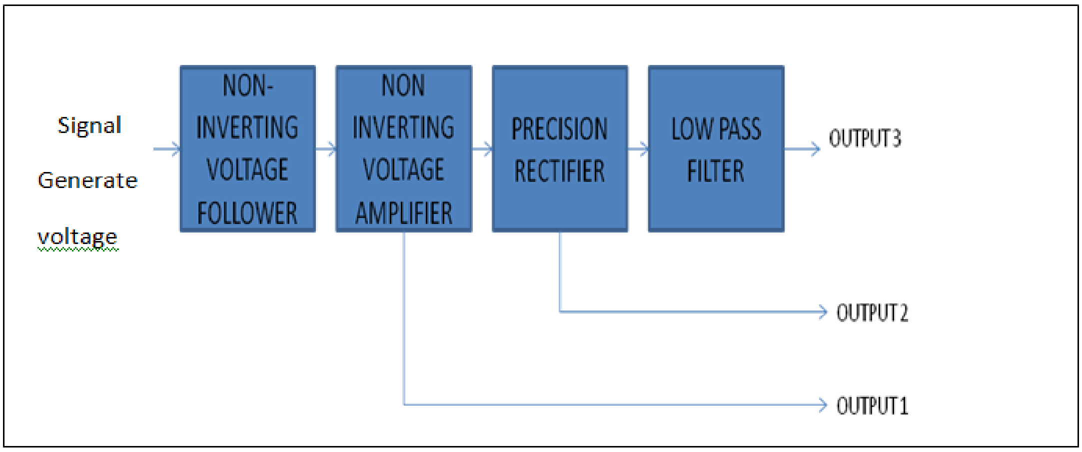


Figure 2.6: Block diagram of electrodynamics transducer circuit

The configuration of non-inverting voltage amplifier, the input voltage signal, (Vin) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes positive in value in contrast to the "Inverting Amplifier" circuit. The result of this is that the output signal is "in-phase" with the input signal. Then, rectifier circuits are used in the design circuits. In such applications, the voltage being rectified usually much greater than the diode voltage drop. Only the positive-going portions of the output waveform, which correspond to the negative-going portions of the input signal, actually reach the output. The direct feedback diode shunts any negative-going output back to the “-“ input directly, preventing it from being reproduced.

2.4 Pipeline System

In order to get the accurate charge without distortion, make sure no corrosion happen in the pipeline. If the electrode embedded inside the pipeline so that there is o direct contact between the particle and the electrode [9] In contrast, if the electrode is exposed directly to the particles and the electrode can take place. The figure 2.7: show the overall of design pipeline: hardware.

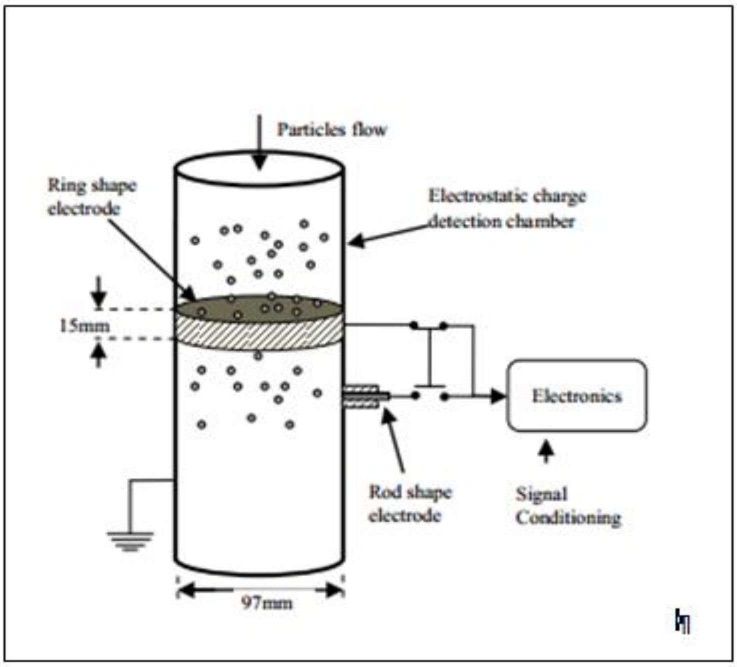


Figure 2.7: design of pipeline system

Figure 2.8 shows a picture of applied test rig; it is consist of a particles bunker in the top, rotary feeder to control mass flow rate in the pipe and a vacuum loader which refill the bunker [14]. Plastic bead was used as solid particle. The plastic bead will flow through the pipeline system and the flow rate of plastic was control by the rotary feeder. The measurement system begin when electrical charge detected by electrostatic sensor. Electrostatic sensor converts the detected signal to an AC voltage and then this signal is sampled by 1 kHz sampling frequency using an A-to-D signal converter. And converted signal is applied in computer software to extract mass flow rate and concentration profile. The pump will suck plastic bead, from the vacuum load automatically and the process will continuously.

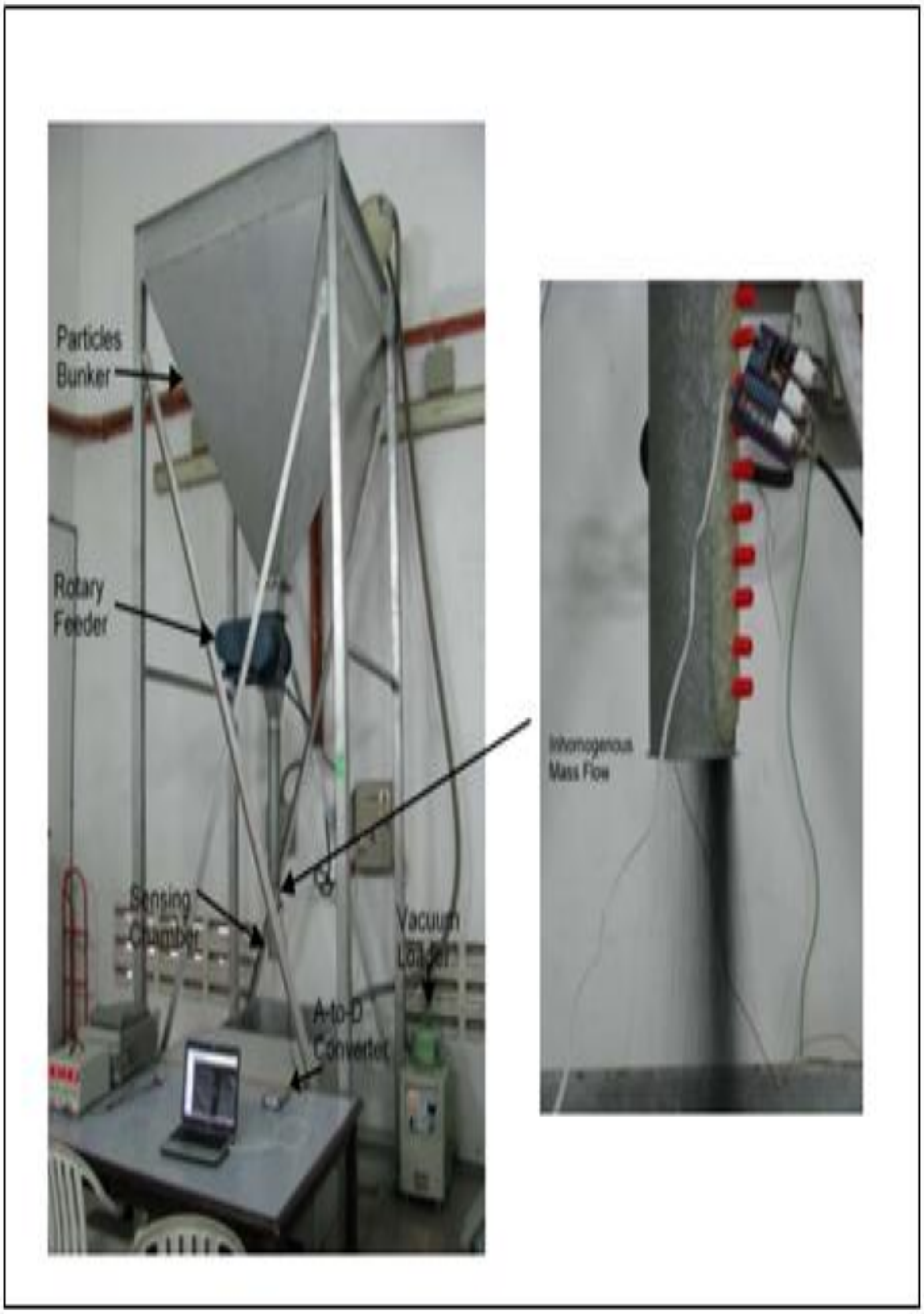


Figure 2.9: Test rig process

In this project, the solid will used is sand and the system is not run automatically which is, the solid particle flow manually.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project focused on development of electrodynamics transducer for solid particle measurement. So, the project has been proposed by using circular electrode and the overall project show in figure 3.1. First at all, design the pipeline system which consists of three holes to implement the different sizes of electrode sensor. The sizes of the electrode sensor are 8mm, 13mm and 14mm. Then, design the electrodynamics transducer circuit for convert the charge into voltage. In order to support the pipeline design, some mathematical model was applied. Lastly, validate the three output voltage signal using oscilloscope for further analysis.

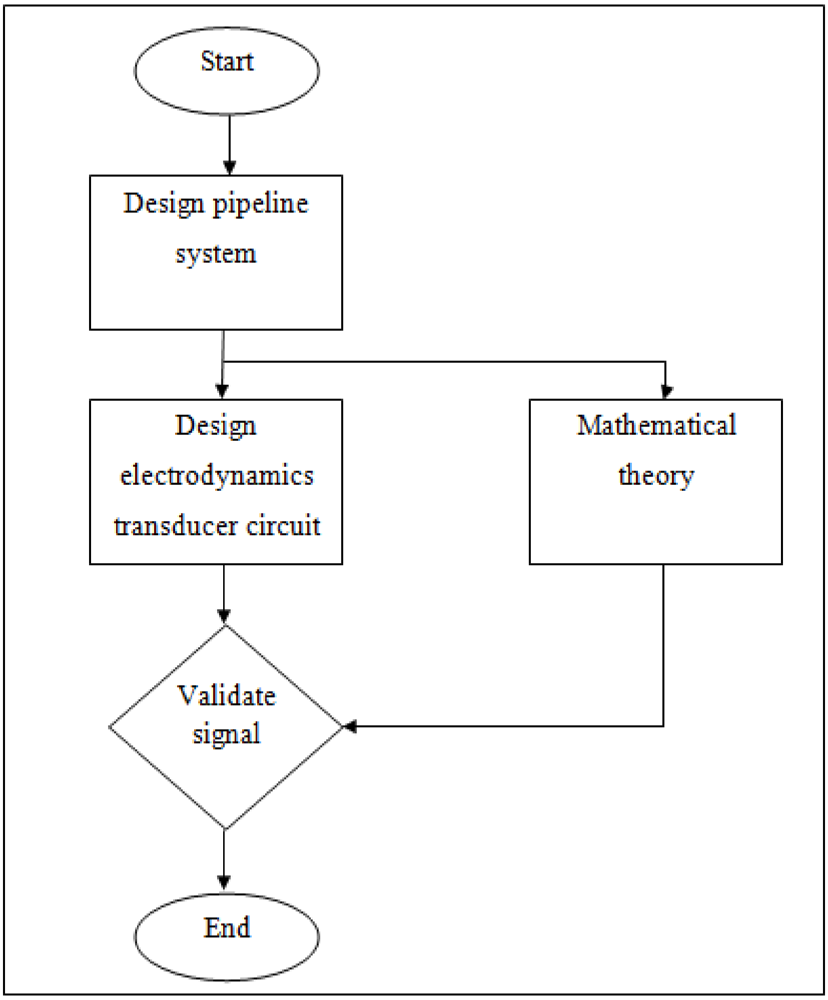


Figure 3.1: Flow chart of project

3.2 Hardware

The initial part for this project is to design non-intrusive pipeline system. But some problem might occur such as caking, blockages, and excessive power consumption. The pipeline system was design compute three different size of circular electrode was implemented. The length of pipeline is 49 cm and the diameter is 12 cm. In the pipeline, avoid the corrosion in order to get the accurate electrostatic charge. Figure 3.2 show the schematic pipeline system.

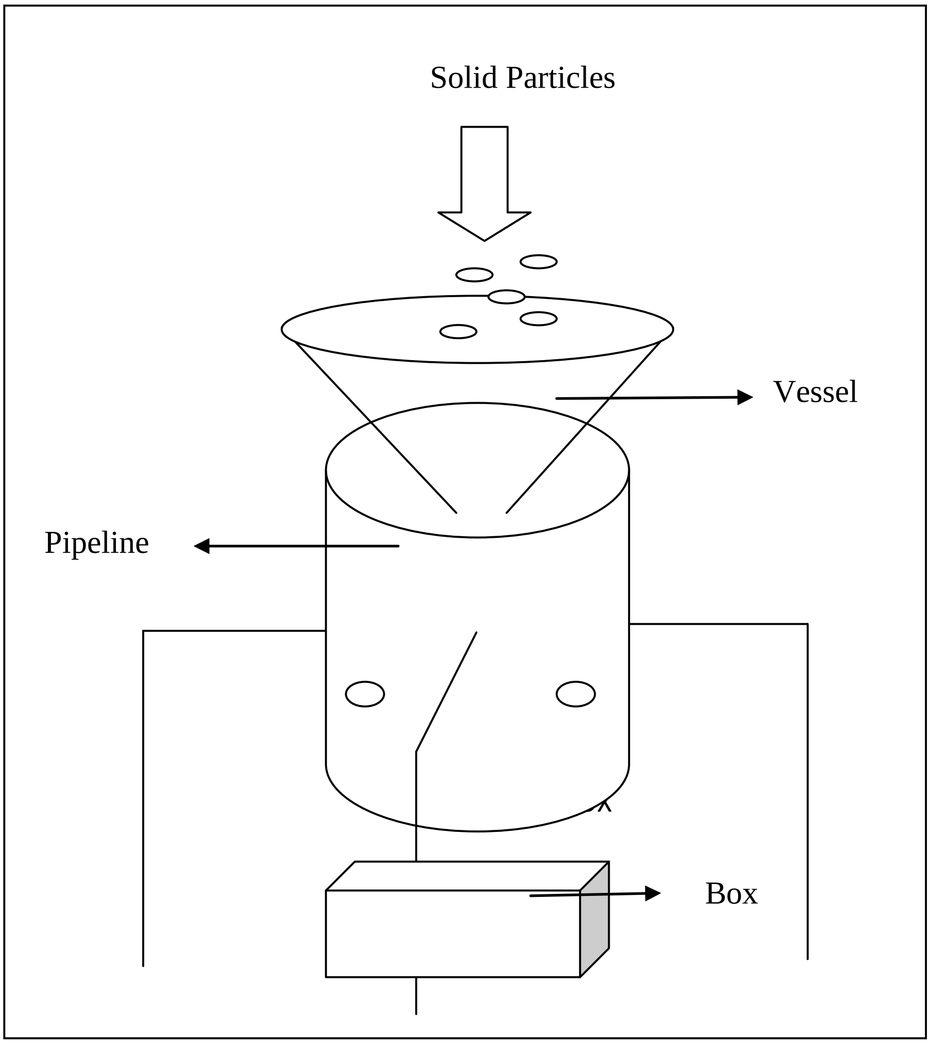


Figure 3.2: Design of schematic pipeline system

Electrode sensor can have number of different shape and size such as rectangular and circular. But, in this project, circular electrode was used which is in size 14mm, 13mm and 8mm. The advantage of using circular electrode is easy to install and low Figure 3.3 show the design of pipeline system.

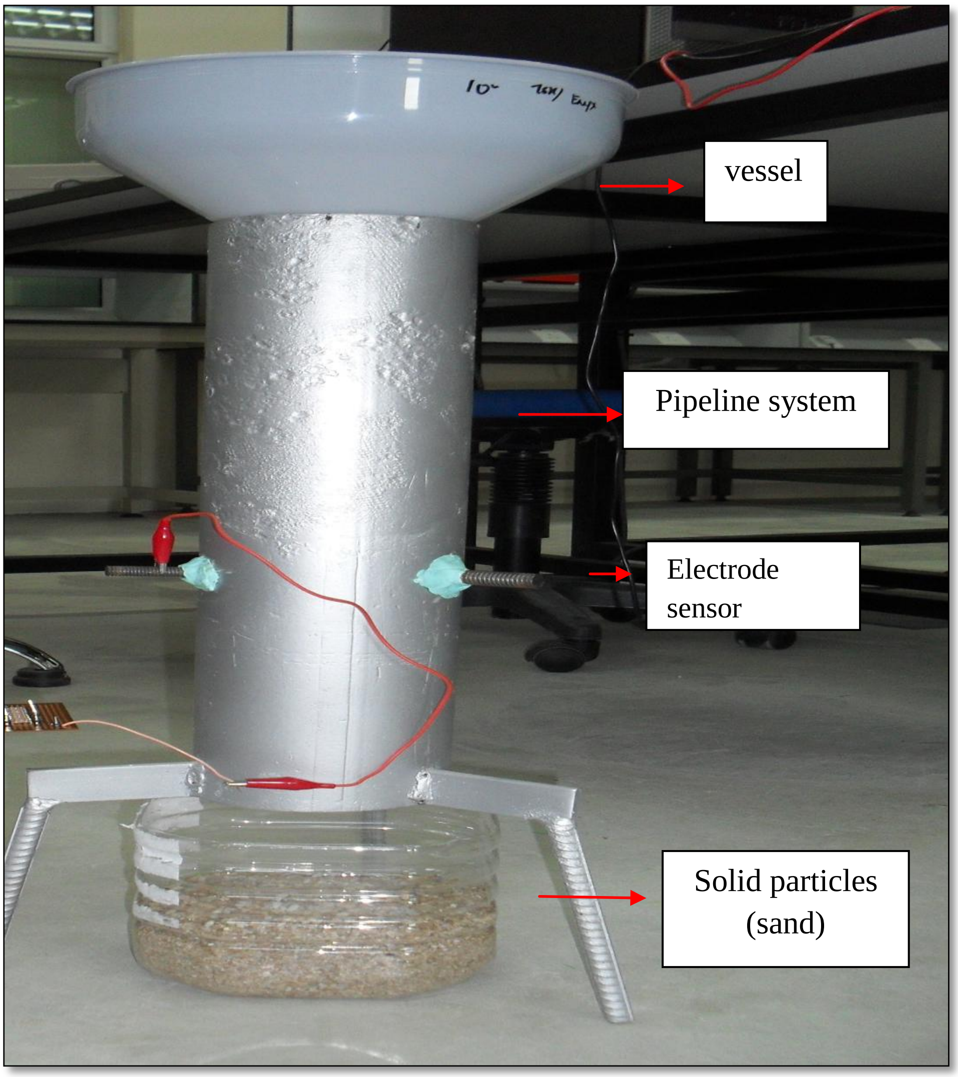


Figure 3.3: Pipeline system

The electrode sensor was implemented in the pipeline system. Between the pipeline and electrode they were insulator to avoid the connection between pipeline and electrode. If the connection occurs, the induction will not produce. The surface of electrode sensor will directly contact to the flow of solid particle. Thus, the sensor electrode will detect the charge. Figure 3.4 show how the sensor electrode was implemented in the pipeline system.

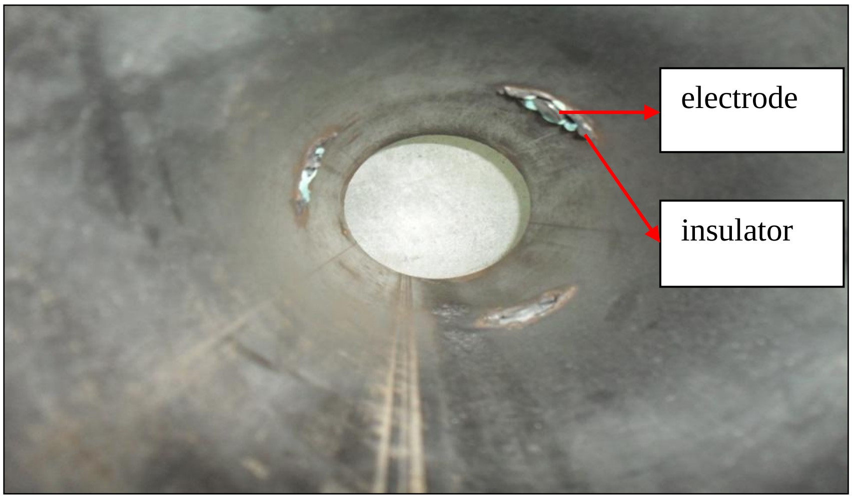


Figure 3.4: Implemented of electrode in pipeline

The sand was used is solid particle because the particle in sand are held in place strong electrostatic forces and densely packed together. Besides that, need to use in large quantity and sand easy to get. Flow rate of the solid particle need to be consider. Vessel was put on the top of pipeline system to minimize the flow rate of solid particle. In otherwise, because this project not automatically move the solid particles to get charged. Thus, the flowing of solid particles need to be control. Figure 3.5, show the solid particles was used in this project.

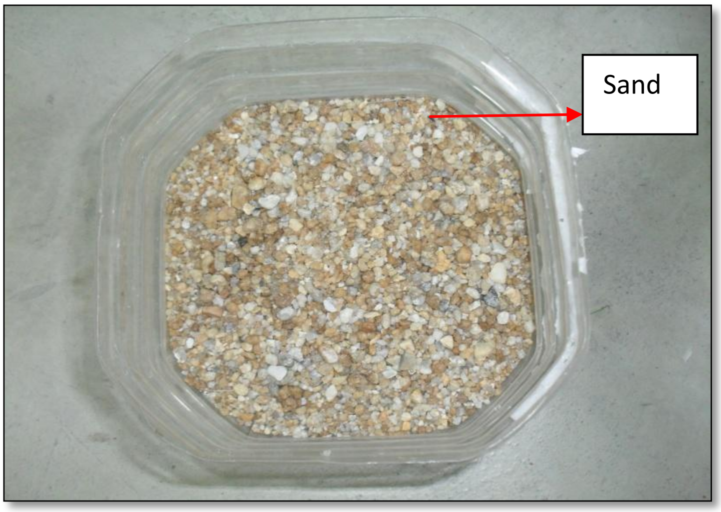


Figure 3.5: Solid particles (sand)

3.3 Design of Electrodynamics Transducer Circuit

The solid particle charge flow perpendicular with the pipeline. The induced charge will generate at the electrode sensor. The resistor which connected to the electrode sensor and parallel with the capacitor will convert the electrostatic charge into the voltage. The capacitor will function as charge/discharge. Based on theory, Zener diode IN4733 is a special two terminal diode use to regulate voltage in a circuit. Unlike regulate diode, the Zener diode will allow reverse current flow if the reverse voltage across it reaches a high enough level. Op-amp TL084 will generate sinusoidal voltage because circular electrode was used. Figure 3.6 show the circuit to convert electrostatic charge into voltage.

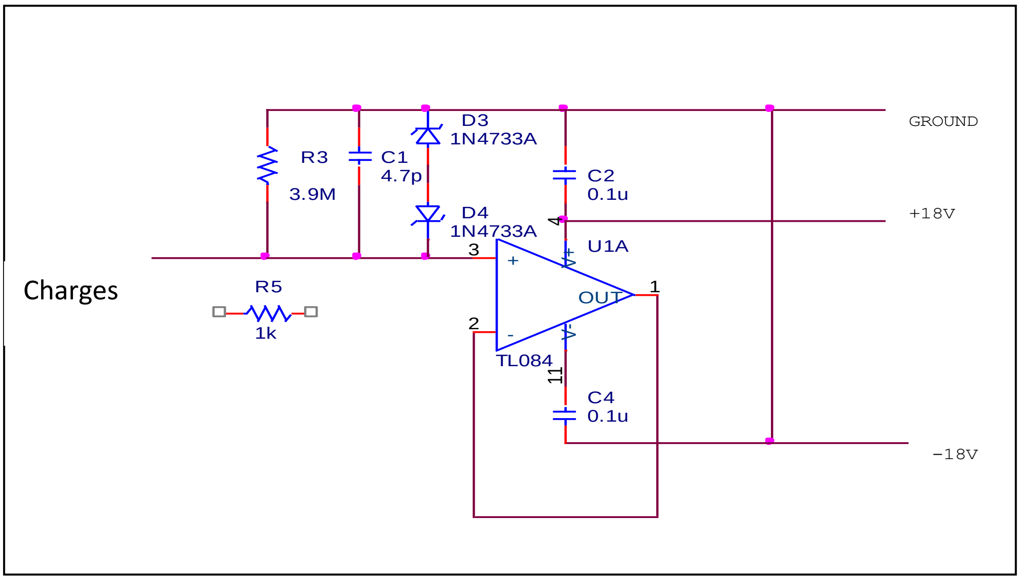


Figure 3.6: Circuit to convert charge into voltage

In order to get the amplified AC voltage, non inverting amplifier was used as show in figure 3.7. A signal applied keeps its polarity at the output. A positive input remains a positive output.

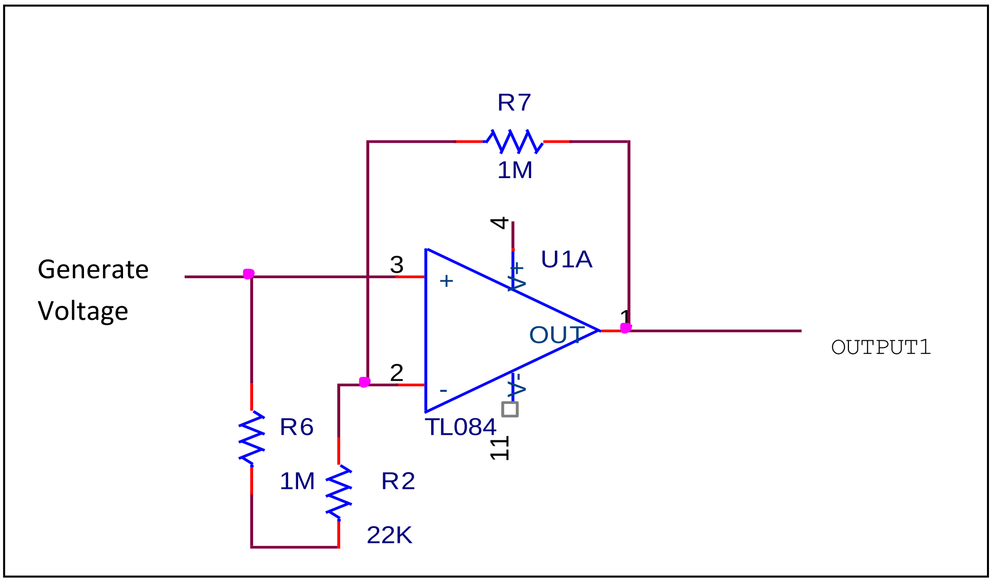


Figure 3.7: Circuit of output 1(amplified voltage)

The output 1, then will be the input for circuit 2 which inverting voltage amplifier. It is use as guard voltage for the input circuit. The diode 1N914 was used because it is electronic device that will allow current to pass through in one direction, while blocking current through it in the other direction. Sometimes are called rectifier detector depends on how it used in circuit. Below, figure 3.8 circuit of output 2. For the output 3, it is derive from the circuit output 1 combine with circuit with output 2 which get the average voltage for output 3.

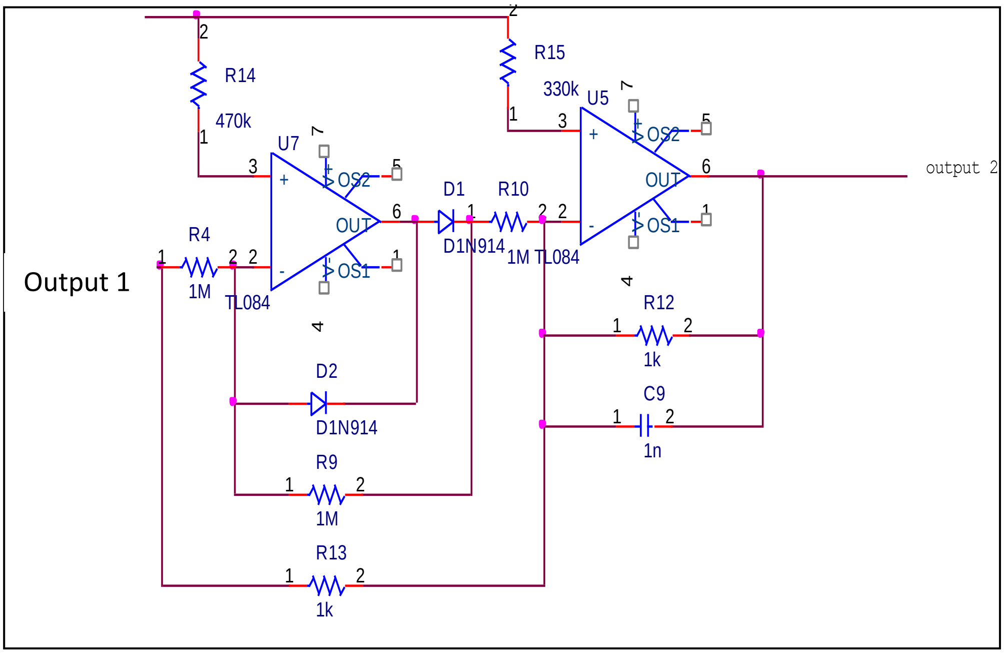


Figure 3.8: Circuit of output 2 (rectified voltage)

Figure 3.9 show the circuit for electrodynamics transducer which consists the operational amplifier to get the voltage output.

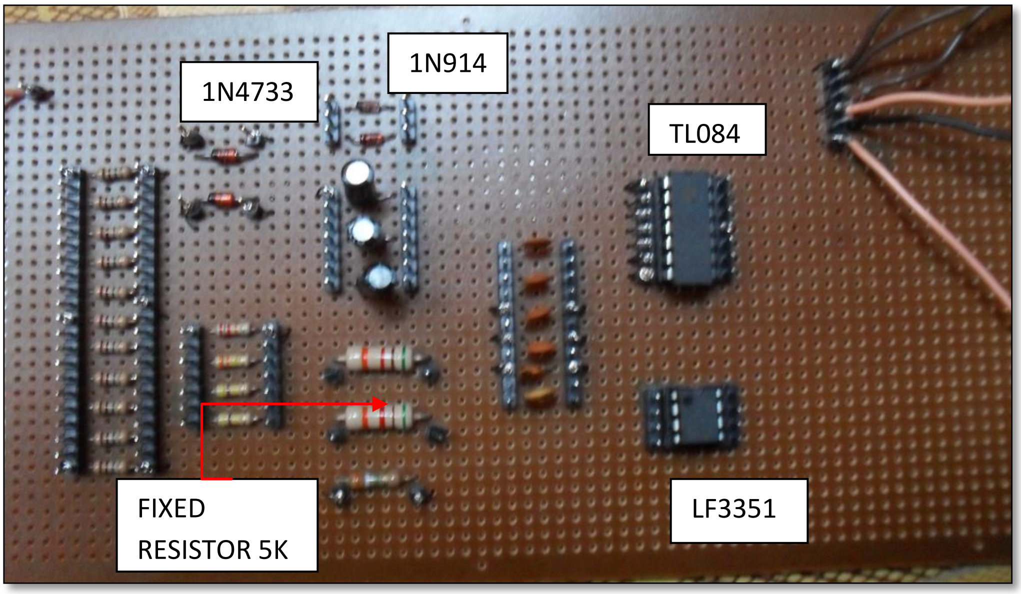


Figure 3.9: Electrodynamics transducer circuit.

3.4 Identify the Component

The list of components need in this project:

NO	COMPONENT	QUANTITY
1	Op-amp TL084	1
2	Op-amp LF351	1
3	Diode 1N4733A	2
4	Diode 1N914	2
5	Resistor 3.9M	1
6	Resistor 330K	1
7	Resistor 22K	1
8	Resistor 470K	2
9	Resistor 1M	11
10	Variable resistor 5K	2
11	Capacitor 4.7p	1
12	Capacitor 5p	1
13	Capacitor 1u	3
14	Capacitor 0.1u	4

Table 1: List of component

CHAPTER 4

RESULT AND DISCUSION

4.1 Introduction

Movements of solid particle in pipeline systems, generate electrostatic charge. The amount of charge on solid particle depends on many factors, including physical and chemical properties of the particles (particle size and shape, velocity, volume resistivity) and environment in the pipeline [9]. The electrode sensor will detect the charged and convert into voltage by electrodynamics transducer circuit. The voltage signal was measured using oscilloscope. Figure 4.1 show the development of electrodynamics transducer for solid particle measurement.

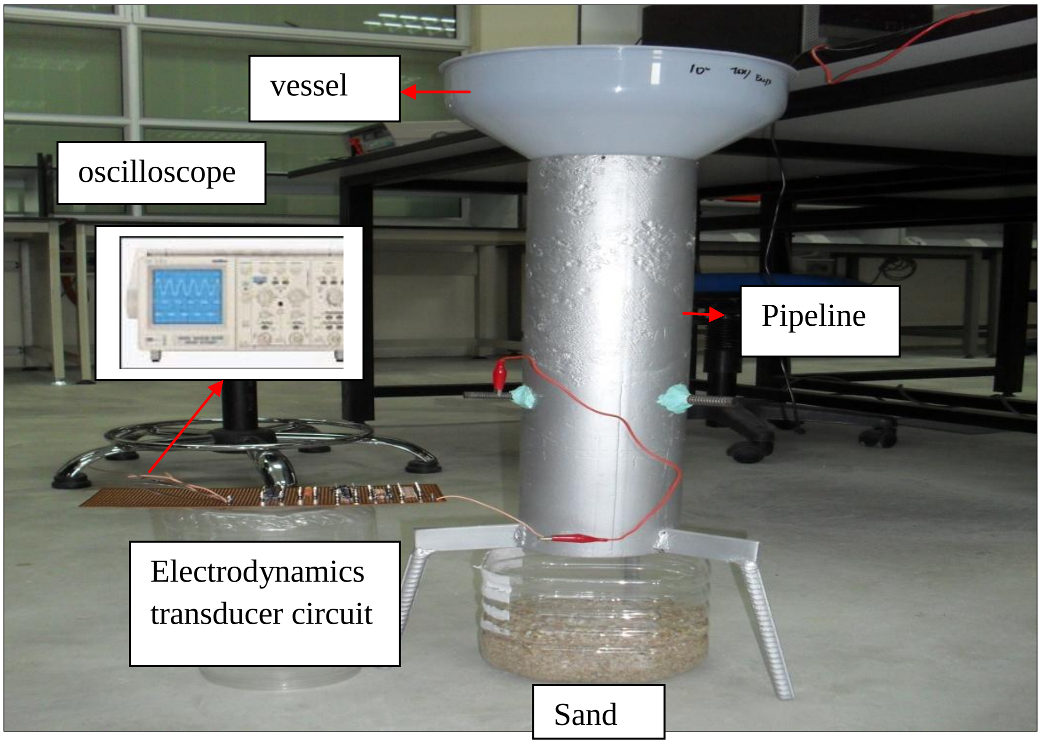
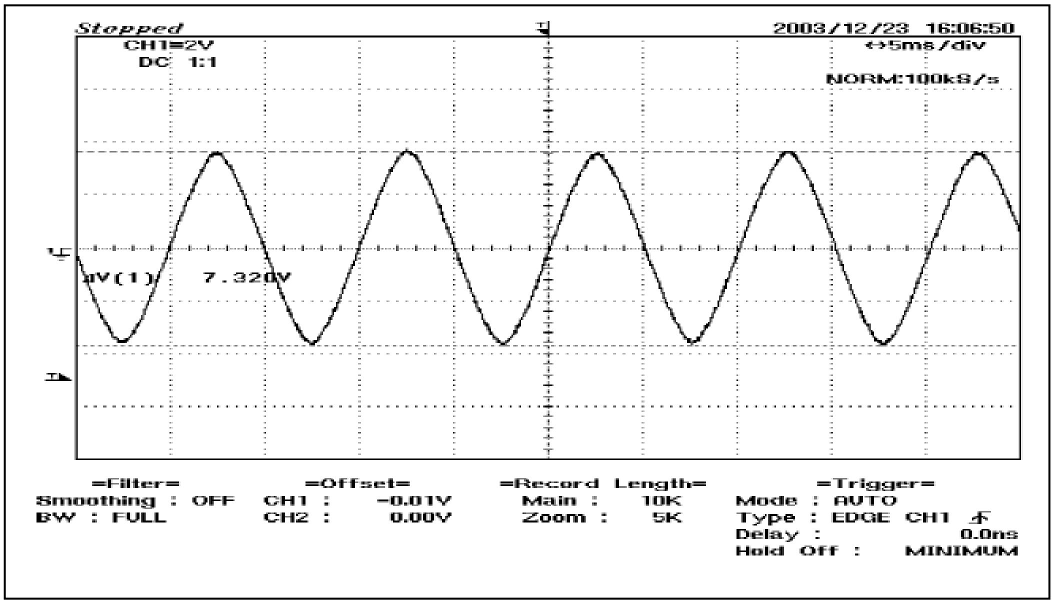


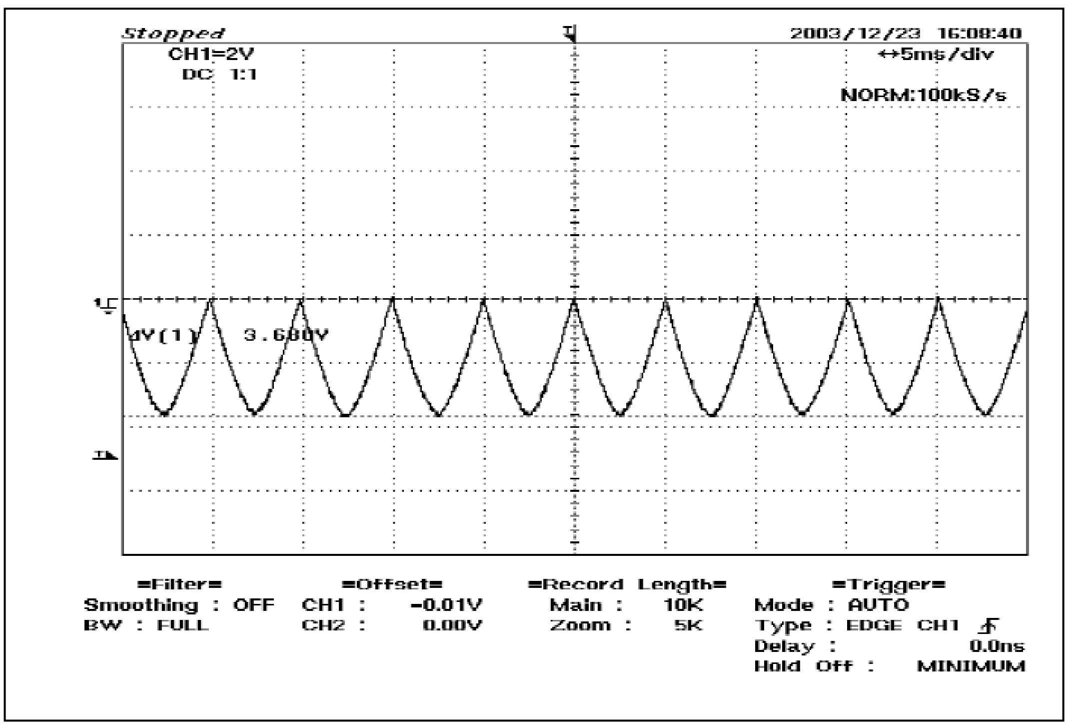
Figure 4.1: Pipeline system and circuit (from the side view)

4.2 Design of electrodynamics transducer circuit

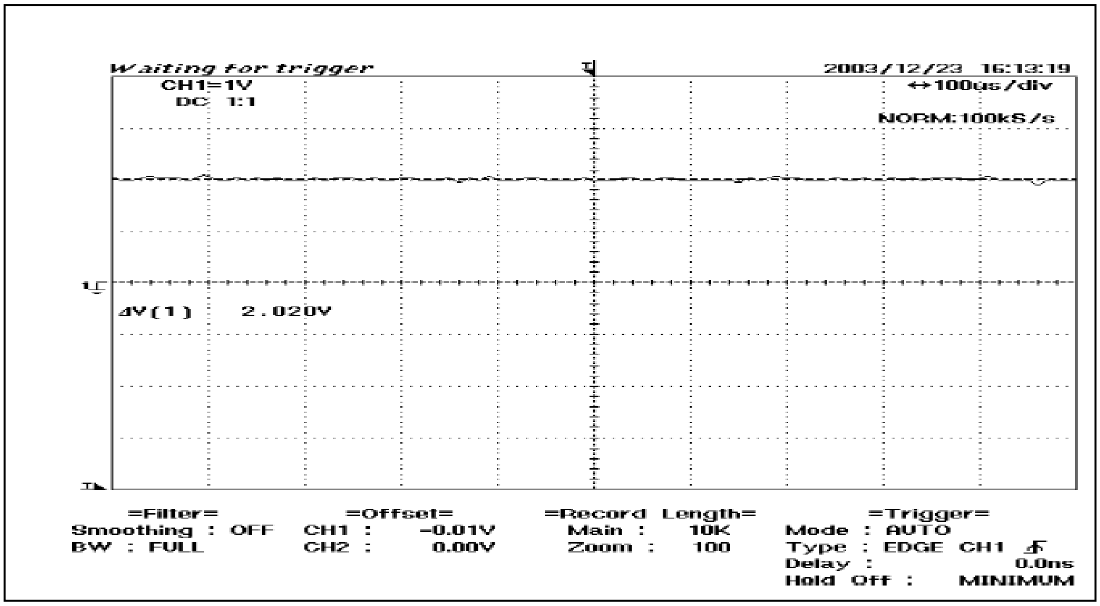
From the previous research M.fuad and Y.W.Lee (2004), the electrostatic sensor measurement for output I is amplified voltage, output 2 rectified voltage and output 3 was average voltage [13]. There was no obvious signal distortion. The circuit has function as predict from the previous research.



(a) Output 1 of the electrostatic sensor



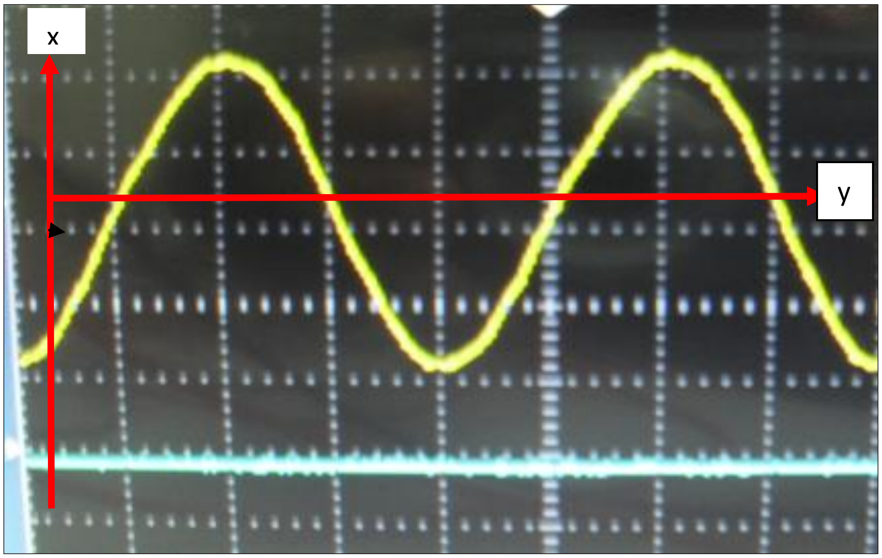
(b) Output 2 of the electrostatic sensor



(c) Output 3 of electrostatic sensor

Figure 4.2: Real testing results

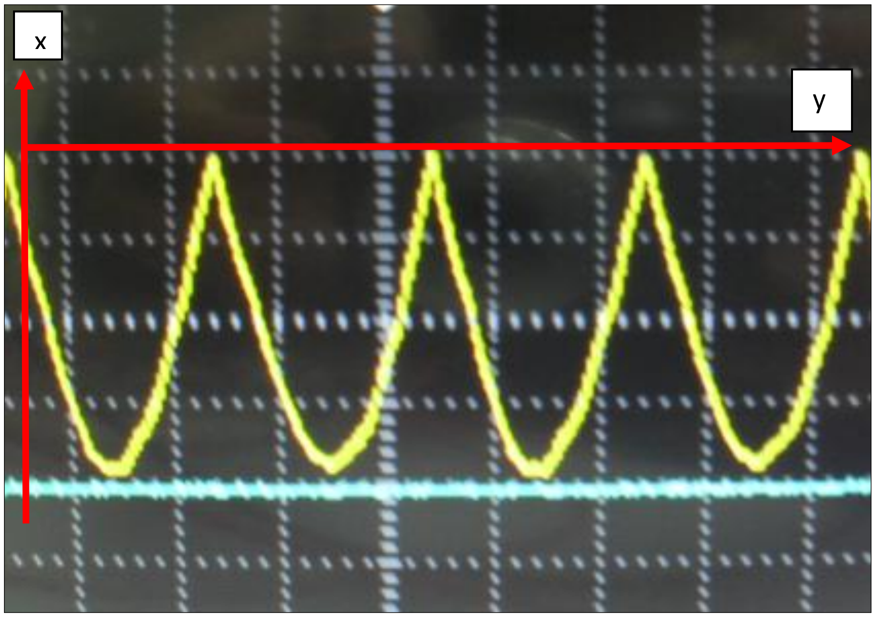
The power supply used to supply the operational amplifier, TL084. The output result was obtained from the op-amp which connected to circular electrode. There was no obvious distortion in the voltage signal. Output 1 was amplified AC voltage get from the non inverting circuit. Output 2 was rectified voltage signal and the last one, output 3 was average voltage. The circuit functioned as desired. However, there are some factors that can affect the magnitude of electrostatic charge. For examples, condition of the surfaces, state of electrostatic charge prior to contact, particle size and shape, force of contact, and environmental conditions such as pressure, atmospheric composition, and humidity [8]. Figure 4.3 show the testing result for development of solid particle measurement.



(a) Output 1, amplified voltage

In theoretical, the input voltage signal, (Vin) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes positive in value in contrast to the Inverting Amplifier circuit. The result of this is the output signal is in-phase with the input signal.

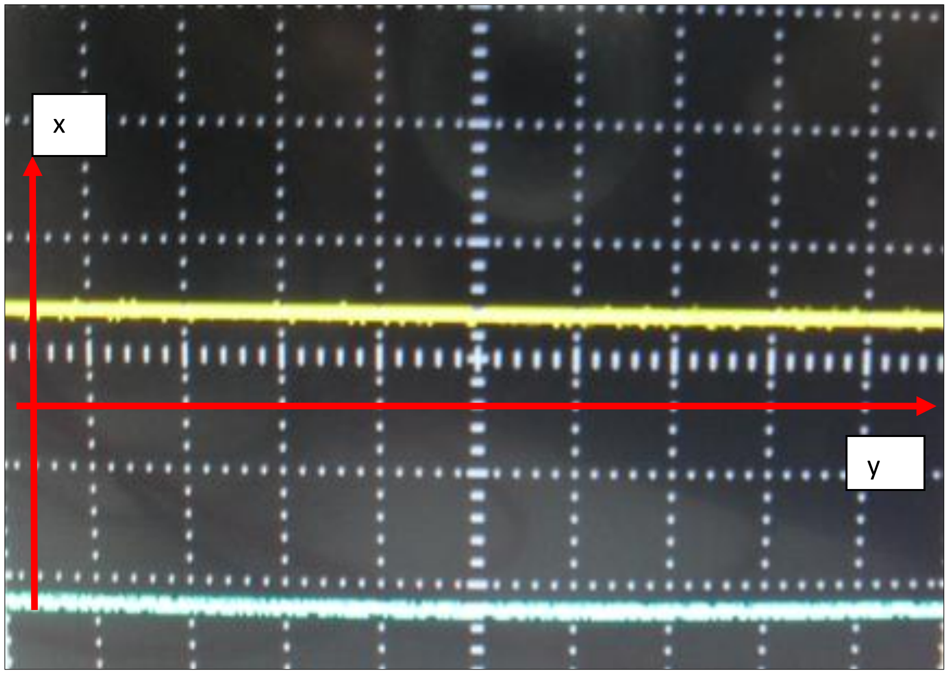
The output 1 for the circuit was amplifier voltage which is first order high pass filter. The simple first-order electronic high-pass filter shown in is implemented by placing an input voltage across the series combination of a capacitor and a resistor and using the voltage across the resistor as an output. At this stage, V_{amp} was 14.3V, V_{low} was -8.19v, V_{high} was 6.4V. The frequency of this output was 49.75 Hz.



(b) Output 2, rectified voltage

There are many applications for precision rectifiers, and most are suitable for use in audio circuits. A half wave precision rectifier is implemented using an op amp, and includes the diode in the feedback loop. This effectively cancels the forward voltage drop of the diode, so very low level signals well below the diode's forward voltage can still be rectified with minimal error.

The output 2, was the rectified voltage because the circuit use is the inverting amplifier. The output will invert from positive to negative. This is the full wave rectifier. The full-wave center-tapped rectifier polarity at the load may be reversed by changing the direction of the diodes. Furthermore, the reversed diodes can be paralleled with an existing positive-output rectifier. The result is dual-polarity full-wave center-tapped rectifier . At this stage, V_{amp} was 14.3V, V_{low} was -16.3V, V_{high} was 2V. The frequency of this output was 93.74 Hz.



(c) Output 3, average voltage

The output 3 was average voltage. The diode bridge will convert the sinus wave into one sided half wave. Then, by using the 5pf the resulting of DC voltage approximation of averages AC voltage.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project is considered success as the project has achieved the goal of the objective which is to develop non-intrusive pipeline and design the electrodynamics transducer. The desired output for further analysis also achieved which are output AC amplified voltage signal, rectified voltage signal and average voltage signal

The development of this project is to design electrodynamics transducer for solid particular measurement. In order to get the electrostatic charge, a non intrusive pipeline which is for solid particle flow past in is design and the circular electrode sensor connect to the circuit of electrodynamics transducer to convert the electrostatic charge into voltage signal. The circular electrodes are widely used in process industry because it is more applicable and appropriate to be applied. Further analysis can be investigate such as by using different size of solid particle, flow rate of solid particle and using the different shape of electrode.

5.2 Recommendations

Although all the goals are achieved, there are still some enhancement should be introduce to improve its quality. Some suggestions for improvement are as below:

i. Using another metal which hard to rusty but can produce magnetic flux.

ii. Using the continuously flow to flow the solid particle not manually.

iii. Add the device which can control the flow rate of solid particle.

iv. Further analysis can be done by measure the flow rate, different shape of electrode and size particle

LIST OF FIGURES

LIST OF SYMBOLS

+	Plus sign
-	Minus sign
n	Nano sign
pF	Piko Farad Sign
μ	Mikro Sign
M	Mega sign
K	Kilo sign
E	Electric field sign
Q	Charge Sign
ε_0	Permitivity of free space sign

REFERENCES

[1] Jian Q. Z., Y. Yan,(2003) “On-line Continuous Measurement of Particle Size Using Electrostatic Sensors”, *Powder Technology*. 135-136(2003) 164-168.

[2] Jiaqing Shao, J. Krabicka, Y. Yan “Velocity Measurement of Pneumatically Conveyed Particles Using Intrusive Electrostatic Sensors”, Transactions on Instrumentation and Measurement, Vol. 59, No.5, May 2010.

[3] Y. Yan, Lijun Xu, Peter Lee, “Mass Flow Measurement of Particles in a Pneumatic Suspension Using Electrostatic Sensing and Neural Network Techniques”, Transactions on Instrumentation and Measurement, Vol. 55, No.6, December 2006.

[4] M.R. Ghazali, W.I. Ibrahim, M.F Rahmat, “Electrostatic Sensor in Circular and Rectangular Shape Electrode for Solid Dry Pneumatic Conveyer System”, International Conference on Circuits, System and Simulation, Vol.7 2011.

[5] M.F. Rahmat, N.S. Kamaruddin, “An Electrodynamic Sensor for Electrostatic Charge Measurement”, Department of Control and Instrumentation Engineering, International Journal on Smart Sensing and Intelligent Systems, Vol.2 No.2 June 2009

.

[6] M.F. Rahmat, Y. Wee Lee, “Electrostatic Sensor for Real- Time Mass Flow Rate Measurement of Particle Conveying in Pneumatic Pipeline”, jurnal teknologi, 41(D) Dis. 2004: 91-104.

[7] F. Abdullah, M.F. Rahmat, “Measurement of Particle Size Using Electrostatic Sensor”, International Conference on Electrical, Control and Computer Engineering Pahang, Malaysia, June 21-22, 2011.

[8] Guardiola, J. V. Rojo, and G. Ramos. 1996. "Influence of Particle Size, Fluidization Velocity, and Relative Humidity on Fluidized Bed Electrostatics". *Journal of Electrostatics.* 37: 1-20.

[9] J. Ma and J. Yan (1999). "Design and Evaluation Electrostatic Sensors for the Measurement of Velocity of Pneumatically Conveyed Solids". Flow Measurement and Instrumentation 11 (2000) 195-204

[11] S R Woodhead, J C Denham and D I Armour-Chelu, "Electrostatic Sensors Applied to the Measurement of Electric Charge Transfer in Gas-Solids Pipelines", Journal of Physics: Conference Series 15 (2005) 108-112.

[12] Lihui Peng, Yan Zhang and Yong Yan, "Characteristizatio Of Electrostatic Sensor for Flow Measurement of Particulate Solids in Square- Shaped Pneumatic Conveying Pipelines", Sensors and Actuators A 141 (2008) 59-67.

[13] Mohd Fua'ad Hj Rahmat and Y. Wee Lee, "Electrostatic Sensor for Real Time Mass Flow Rate Measurement of Particle Conveying in Pneumatic Pipeline", Control & Instrumentation Department, Jurnal Teknologi, 41 (D) Dis.2004: 91-104.

[14] Mohd Fua'ad Rahmat and Teimour Tajdari, "Particle Mass Flow Rate and Concentration Measurement Using Electrode Sensor", International Journal on Sensing and Intelligent Systems Vol 4,No.2, June 2011.

[15] Meaning of Electrostatic, Website: http://en.wikipedia.org/wiki/Electrostatics, accessed on 21 May 2012.