DESIGN AND CONSTRUCTION OF A COMPUTER INTERFACED SEISMIC SENSOR

BY

MUSTAFA SHEHU SALIHU
96/5316EE

A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ELECTRICAL AND COMPUTER ENGINEERING.

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

NIGER STATE.

FEBRUARY 2002

DECLARATION

I, MUSTAFA SHEHU S. hereby declare that this project presented for the degree of Bachelor of Engineering, is an original work of mine, and has never been presented either wholly or partly for the award of diploma or degree certificate in any other institution.

The information derived from published or unpublished work of others had been acknowledged.

------------------------------ 28/02/2002

Signature. Date

CERTIFICATION

This is to certify that MUSTAFA SHEHU S. carried out this project work, under the supervision of ENGR. M. D ABDULLAHI and submitted to the electrical and computer engineering department of the Federal University of technology Minna, in partial fulfillment of the requirements for the award of a bachelor of Engineering (**B.Eng**.) degree in electrical and computer Engineering.

------------------------------ 05/03/2002

Engr. M.D Abdullahi — Date

Project Supervisor

------------------------------ 5/3/02

DR. Y.A Adediran — Date

Head of Department

------------------------------ ------------------------

DR. T.A. Akinbulire — Date

External Supervisor

DEDICATION

This project work is dedicated to Almighty ALLAH (S.W.T), to whom all thanks must be given, to my parents whose guidance, care and support, contributed to the successful completion of my academic studies.

ACKNOWLEDGEMENT

My acknowledgement goes to those who had in one way or the other contributed to the success of this project. In this regard, I am mostly indebted to my supervisor, in the person of ENGR. M.D ABDULLAHI under whose guidance, advice and constructive criticism, I was able to achieve this work. To him, I am indeed most grateful. My appreciation also goes to the head of electrical and computer engineering department, DR. Y. A ADEDIRAN, and to all the academic and technical staff of the department.

On the family side, I am mostly grateful to those who have always shown some concern for my progress in pursuit of academic excellence and to those who ensured that I got this stage. In this regard I am very much grateful to my father, PROF. S. MUSTAFA, for his fatherly assistance, support and encouragement during the hard times. My sincere appreciation also goes to my mother, MRS. F. MUSTAFA for her motherly advice and contribution, which made an enormous impact into my life. My appreciation also goes to my sister HALIMA, my brothers SULEIMAN and ABDULSALAM, for their encouragement in one way or the other. I am also very appreciative of the contributions of other members of the MUSTAFA'S family, too numerous to mention here.

Also, I will like to express my appreciation to all the colleagues of mine, which in one way or the other contributed to the successful pursuit of my degree program. Let me not forget especially my very good friend Lateef, and others like Tambawwal, Umar, Ahmed, Aromnde, Zangina, Fidelis, Emir, Aminu, Yusuf, Bala, Jimada and all others who had also contributed to my success.

And above all, I am most grateful to almighty ALLAH (S.W.T) for his infinite mercy, blessing and guidance in seeing me through.

ABSTRACT

This project work presents the development of a computer interfaced seismic sensor. The seismic sensor is capable of detecting seismic signals and vibrations, on solid ground from the earth's surface. The seismic sensor provides significant flexibility to the user as it can be easily interfaced to a personal computer.

The user needs only to read seismic signals by viewing the results as waveforms on a graphical environment known as a seismogram. The seismogram is the software-based program, with digital signal processing facilities to perform the analysis.

To read a seismic signal, the signal must be converted to a digital form before it can be viewed on the interactive graphical environment.

The project integrates both hardware and software concepts with both working in unison through interfacing

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CHAPTER ONE

1.1 INTRODUCTION

The use of a Computer dramatically extends the engineers ability to acquire and process a chunk of real world data. Though theoretically all forms of data can be analyzed manually with powerful algorithms and complex mathematics. However as the acquired data increases in bulk and complexity, the probability of error make large scale analytic solutions very difficult and impractical. The Computer removes this limitations due to the high speed of computation and accuracy of its microprocessor.

The computer interfaced seismic sensor brings about the definition of the term seismic. Seismic are vibrations from the earth's surface produced by earthquakes, tremors, or heavy moving vehicles such as trains and trucks. Nuclear tests carried out underground are also another source of seismic signals. These vibrations could be a few meters to thousands of kilometers away from the main source. Naturally the human sensory organs cannot sense most of these vibrations. The use of the computer in data gathering, analysis and interpretation of the results is where it plays its most important role. The engineer would be interested in interpreting the intensity and type of seismic signals produced from the earth's surface. This type of information would be a very valuable piece of data for other scientists and engineers.

Suppose we attach a data acquisition device such as the seismic sensor to the Computer and use it to acquire a substantial amount of real world data. We are now introduced to the concept of interfacing. In the context of microprocessor-based systems, the term interfacing refers to the physical connections between the systems involved and the way in which data is to be exchanged. The systems involved are typically a microprocessor and an external device. Many of the pieces of equipment to which a microprocessor might be connected, are however analogue in nature. The two systems combined together form a transmitter and receiver unit. The microprocessor-based system, which receives data from the external device, is the receiver while the other is the transmitter. However it is not normally possible to connect directly such devices to a microprocessor bus system due to lack of compatibility. A circuit known as an interface is used between the external device and the microprocessor.

There are numerous types of techniques of processing data for the Engineer. One of the most prominent is Digital Signal Processing (**DSP**). This is one of the most powerful technologies that will shape science and engineering in the twenty-first century. Revolutionary changes have been made in a broad range of fields: communications, medical imaging, radar and sonar, high fidelity music reproduction and oil prospecting, to name just a few. **DSP** is the mathematics, the algorithms and the techniques used in manipulate these signals after they have been converted into a digital form. The unique type of data it uses distinguishes **DSP** from other areas in computer science: signals. To the electrical engineer these signals originate as sensory data from the real world. They could be seismic vibrations, visual images or sound waves. Today in the modern field of electrical engineering **DSP** is accomplished with software. The software aids the engineer to process the data with sophisticated algorithms. With **DSP** digital filters can be designed with software that are highly accurate and reliable over their analogue counterparts. Digital filters can achieve thousands of times better performance than analog filters.

1.2 LITERATURE REVIEW

The roots of interfacing were began in the 1960s and 1970s when digital Computers first became available. Computers were expensive during this era and interfacing was limited to only a few critical applications. Pioneering efforts were made in four key areas. Radar and sonar, were national security was at risk; oil exploration, were large amounts of money could be made; space exploration where the data are irreplaceable; and medical imaging where lives could be made. The Personal Computer revolution of the 1980s and 1990s brought the emergence of **DSP**. Rather than being motivated by military and government needs, **DSP** was suddenly driven by the commercial and engineering sectors. In the early 1980s **DSP** was taught as a graduate level course in electrical engineering. A decade later, **DSP** had become a standard part of the undergraduate curriculum. Today, **DSP** can be compared to a previous technological revolution; electronics, while still the realm of electrical engineering, nearly every scientist and engineer has some background in basic circuit design. Without it they would be lost in the technological world.

As early as the 1920s, geophysicists discovered that the structure of the earth's crust could be probed with sound and vibration. Prospectors could set off an explosion and record the echoes from boundary layers more than ten kilometers below the surface. These echo seismograms were interpreted by the raw eye to map the subsurface structure. The reflection seismic method rapidly became the primary method for locating petroleum and mineral deposits, and remains so today. The same could be said for geologists. They could study vibrations in the earth and detect earthquakes with the use of an instrument called a seismometer. They could record and interpret the raw data collected on a seismogram. The procedure was, a sound pulse boundary sent into the ground, produced a single echo for each boundary layer the pulse passes through. Unfortunately, the situation is not usually this simple. Each echo returning to the surface must pass through all the other boundary layers above where it originated. This resulted in the echo bouncing between layers, giving rise to echoes of echoes being detected at the surface. The secondary echoes made the detected signal very complicated and difficult to interpret. Digital signal processing has being widely used since the 1960s to isolate the primary from the secondary echoes in reflection seismograms. This was achieved with the use of digital filters that could be easily implemented with software. The early geophysicists managed without **DSP** by looking in easy places where multiple reflections were minimized. **DSP** allowed the exploration for oil in difficult locations such as under the sea.

A software tool that is available for most computers is an integrated development environment. This means that everything needed to program and test **DSP** algorithms are combined into one smoothly functioning package. A Company based in the United States called Analog Devices (**AD**) provided an integrated development environment in a software product called **VisualDSP** that could run under Windows 95/98 and Windows NT. This software had a graphical user interface environment with an editor specialized for creating **DSP** programs. This software was very good for fast program development. But its major drawback was that specialized hardware was needed for testing and running the programs. This resulted in increased cost and incompatibility with most computers.

1.3 PROJECT OBJECTIVES AND MOTIVATIONS

The main objective of the project work was to be able to detect seismic signals from the environment, with a seismic sensor interfaced with a computer and to process the signals with **DSP** techniques using software on a graphical user interface environment. The program is expected to output useful data after it has processed the seismic signals fed in by the sensor to the computer. However the processing of seismic signals with the aid of a computer may be desired for the following reasons, which are briefly discussed below.

Before the engineer or scientist explores for oil, mineral resources or investigates for tremors and earthquakes in the earth it may be necessary to take seismic readings from the surface. The raw data gathered can be analyzed and interpreted with the aid of a computer. Most existing sensor devices are mechanical in nature and therefore are inaccurate and less sensitive to vibrations. The advancement in computer technology with new **DSP** techniques greatly enhances the performance of the sensor as its sensitivity is highly improved. This enables it to detect vibrations at very low frequencies. Very often investigating the activity of an area is of paramount importance to the scientist. Data gathering and analysis with obsolete equipment and complex mathematics is often very unreliable, boring, inefficient and time consuming. Interpreted results are usually based on approximations. The computer removes these limitations by effecting a desirable change.

1.4 APPLICATIONS

In the vast field of electrical engineering, this project work can be used for a wide variety of applications in other engineering fields and science disciplines that may include:

An aid to research projects: Scientists and engineers may use the seismic sensor alike in the gathering of raw data from the earth's surface such as the geophysicist investigating the activity of geological formations below the earth.

Applications for oil and mineral exploration: The device can be used in the field of seismology for locating petroleum and mineral deposits in the earth. This is applicable in the reflection seismic method where reflected echoes are recorded on a seismogram and interpreted by the raw eye to map the subsurface structure.

Security and military surveillance: It can be used in detecting intruders or moving objects such as cars and trains. The military could use it to detect underground nuclear tests conducted by hostile countries.

Earthquake and tremor detection: The geologist could use the device for detecting tremors in the earth's crust prior to warning of an impeding earthquake.

The intensity and duration of the earthquake could be easily recorded on a seismogram.

1.5 PROJECT LAYOUT

This project was organized in chapters and each chapter explained briefly the topic to be discussed. The overall chapters gave the relevant information necessary to reveal the electrical engineering and computer science technologies used in the realization of the project objectives.

Chapter one gives the general introduction to the whole project work, the literature review and the project objectives and motivations. The vast fields of electrical engineering and other science related disciplines that the project could be put to use were also enumerated.

Chapter two discussed briefly, the theory and design of the seismic sensor circuit and the program design methodologies

Chapter three also explained in brief and concise terms the actual circuit design, construction and the software development approach used. It also explained the way in which the program was organized and its mode of operation. The organization of the whole program body was also illustrated with a flowchart showing the various modules that constitute the software. Samples of data acquired and used during the testing phase of the program development with the results obtained were also discussed.

The concluding chapter four summarizes the contents of the project, examined and recommended any future development possibilities.

CHAPTER TWO

2.1 THEORY AND SYSTEM DESIGN

The design process for developing the Computer Interfaced Seismic Sensor (CISS) is made up of the following stages, which are outlined below.

The need: The design process begins with a need from the engineer.

Analysis of the problem: Before developing a design it is necessary to find out the true nature of the problem; i.e. to determine exactly what the end product is required to do. This is an important stage in that not defining the problem accurately can lead to waste on designs that will not meet the need.

Preparation of a specification: Following the analysis of the problem, a specification of the requirements can be prepared. All the functions required of the design, together with any desirable features, should be specified. Thus there might be a statement of dimensions, sensitivity required, input and output requirements, operating environment, relevant standards and codes of practice.

Generation of possible solutions: Outline solutions are prepared which are worked out in sufficient detail to indicate the means of solving the specified problem. It also means finding the specified problem. It also means finding out how similar problems were solved in the past.

Selection of a suitable solution: The various possible solutions are evaluated and the most suitable one selected.

Designing the hardware and software: The detail of the selected solution has now to be worked out. This might require the development of a detailed block diagram of the system, showing how the various elements are to be interconnected. With all the integrated circuit pin numbers identified, a decision is made as to whether a microprocessor is to be used, and which one from the chosen family will provide the required facilities. The development of a pseudocode program might be used to indicate the structure involved in the required program.

Building and testing the hardware: The hardware might be assembled on a prototype board where circuitry can be easily constructed and altered. The board consists of rows of solderless sockets of, which there are spring clips to grip any pins or connecting wires. In wiring up a board, a useful method is to first insert all integrated circuits into sockets, making sure all pins are straight, with the ICS laid out in essentially the same positions as on the circuit diagram. Color-coded wires can be used to make the interconnections. A systematic approach to the wiring is essential. First wire all Vcc and ground pins, then the data and address lines, using different colored wires for Vcc, ground, and data and address connections.

Writing and testing the software: The use of modular programming allows the programming task to be broken down into subtasks or modules so that programs can be written, tested and debugged for each module before the modules are assembled to give the complete program.

Testing the system: At the completion of all these tasks the completed system is tested to ensure that it satisfies the engineer's need.

2.2 SYSTEM DESIGN

The computer interfaced seismic sensor (CISS) is a peripheral hardware and data acquisition device that is connected to the parallel port of an IBM compatible Computer by means of interfacing. The Computer reads in the data and analyzes it. All these functions are controlled by software that is the device driver. A device driver is a special program, which allows a Computer to recognize and control an external hardware device. Thus the system can be said to be composed of hardware and software.

Its principle of operation is by the detection of seismic signals, which are vibrations from the earth. The seismic sensor converts the signal to an electrical signal. The signal is passed through a sample and hold circuit, where it is sampled and then passed through an anti-alias, low-pass filter to prevent aliasing and passage of the high frequency components. The filtered signal is then passed to an analogue to digital converter, which converts the analog signal to an 8-bit digital signal.

The final stage is the computer-based system where a software program reads and processes the digital data with digital processing techniques. The final result is then displayed on a graphical user interface program known as a seismograph.

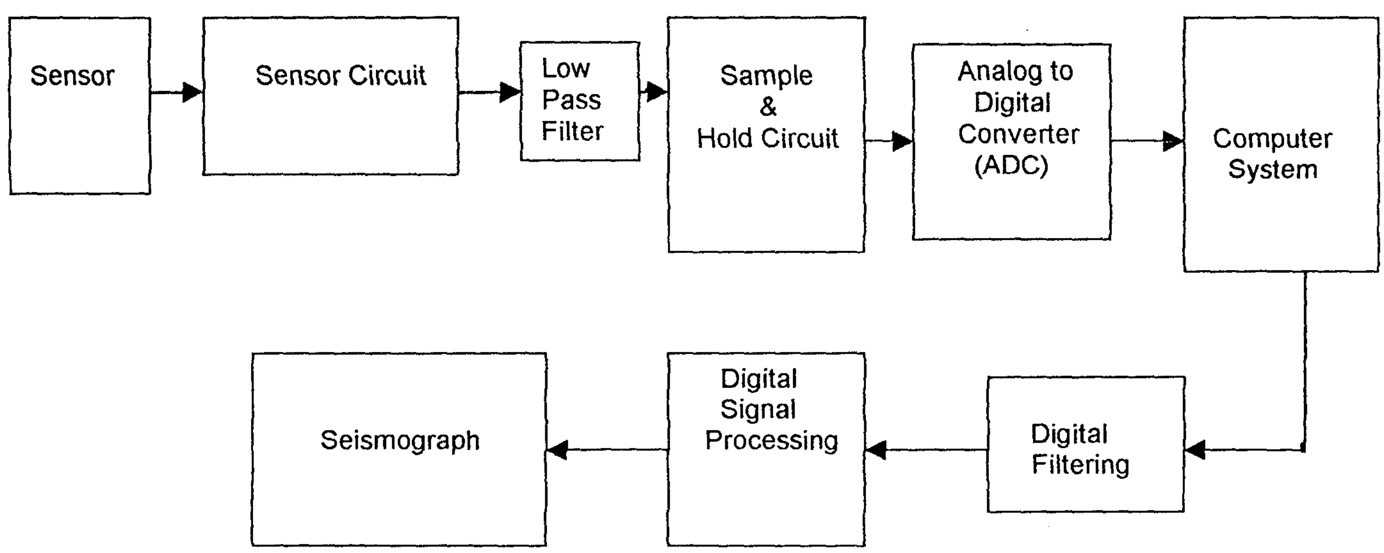


Fig 2.1 Block Diagram of The Computer Interfaced Seismic Sensor.

2.3 THE PARALLEL PORT

The parallel port on most computers is found in any of these two configurations.

- On a multi-input/output (i/o) card
- On the motherboard

Another name for the parallel port is the printer port. The parallel port is either unidirectional or bi-directional. This means that it can read only, or read and write data to it. The most modern Computers have their port configured as bi-directional. The **PC** accesses the various **I/O** ports by using a unique address code. Each device on board in the computer has an address that no other device in the **PC** shares with it. The parallel port on most **IBM** compatible computers starts with an address of 0378 base 16 in hexadecimal. The parallel port is made up of three ports. The data port, the status port and the control port. Internally the printer port may be regarded as just three, **TTL** compatible, 8-bit ports at consecutive i/o address as shown in fig 1.1. The starting address is used for the data port and the next address is used for the status port and then followed by the control port.

PORT	**ADDRESS (HEX)**	**PORT NAME**
Port A	0x378	Data Port
Port B	0x379	Status Port
Port C	0x37A	Control Port

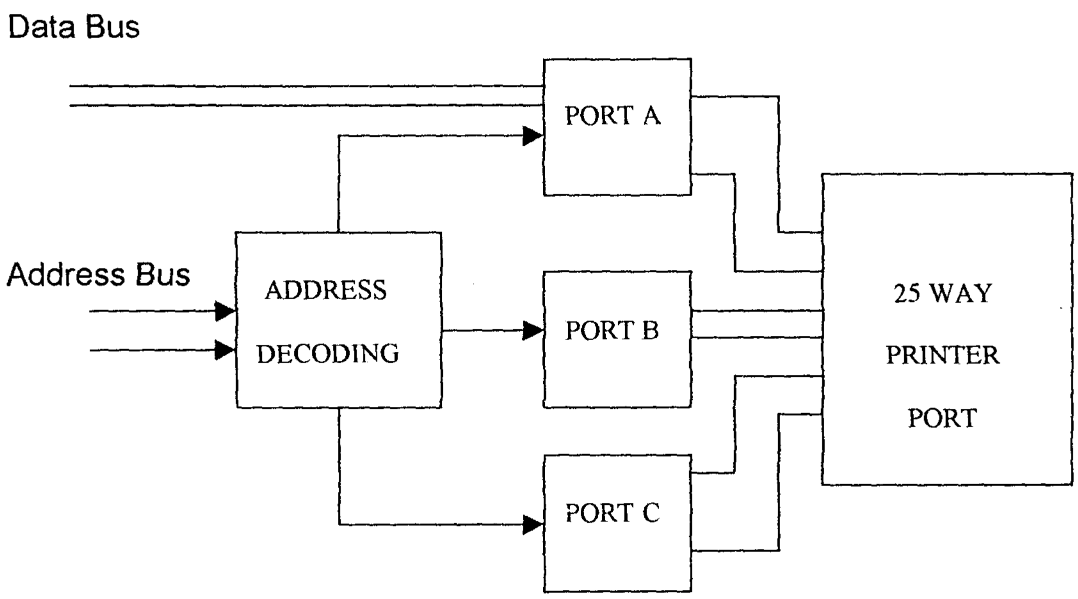


Fig 2.2 Organization of the parallel port

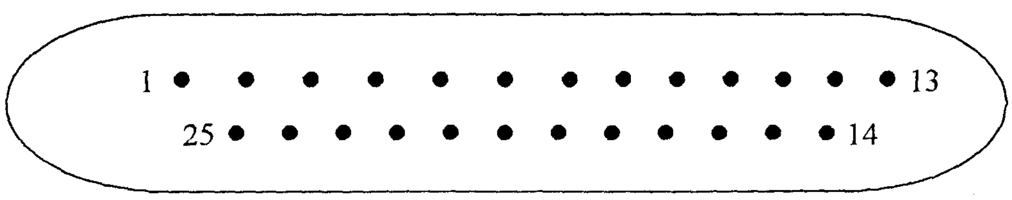


Fig 2.3 The parallel port pin outs

Table 2.1 The Parallel Port Pin Functions

Pin	I/O	Signal	Port
1	O	Data Strobe	port C bit 0
2	O	Data bit 0	port A bit 0
3	O	Data bit 1	port A bit 1
4	O	Data bit 2	port A bit 2
5	O	Data bit 3	port A bit 3
6	O	Data bit 4	port A bit 4
7	O	Data bit 5	port A bit 5
8	O	Data bit 6	port A bit 6
9	O	Data bit 7	port A bit 7
10	I	Data acknowledge	port B bit 6
11	I	Busy	port B bit 7
12	I	Out of paper	port B bit 5
13	I	Selected	port B bit 4
14	O	Auto line feed	port C bit 1
15	I	Error status	port B bit 3
16	O	Initialize	port C bit 2
17	-	Select	port C bit 3
18	-	0v	
19	-	0v	
20	-	0v	
21	-	0v	
22	-	0v	
23	-	0v	
24	-	0v	
25	-	0v	

2.4 THE SENSOR CIRCUIT

The sensor is the most important part of the system that is responsible for sensing the seismic signals. It is basically made up of a sensor and an operational amplifier. The sensor consists of a relay coil with a small piece of magnet suspended above it with a string. These two together behave as a current source. A displacement in the magnet's position results to a change in the current setup in the coil.

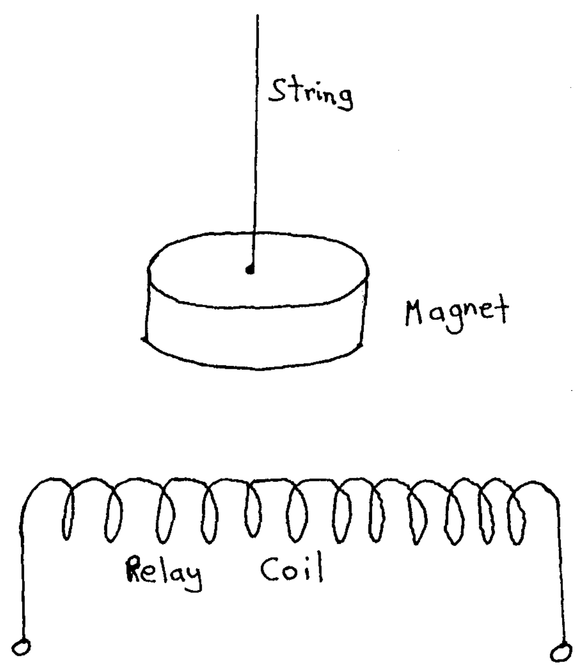


Fig 2.4 A magnet and coil setup

2.4.1 RELATIONSHIP BETWEEN MAGNETISM AND ELECTRICITY

It is a well-known fact that whenever an electric current flows through a conductor, a magnetic field is immediately brought in the space surrounding the conductor. It can be said that when electrons are in motion, they produce a magnetic field. The converse of this is also true. When a magnetic field embracing a conductor moves relative to the conductor, it produces a flow of electrons in the conductor. This phenomenon whereby an e.m.f and hence current is induced in any conductor which is cut across or is cut by a magnetic flux is known as electromagnetic induction.

The above facts are summed up into laws known as faraday's laws of electromagnetic induction.

First law: it states;

Whenever the magnetic flux linked with a circuit changes, an e.m.f is always induced in it. Whenever a conductor cuts the magnetic flux, an e.m.f is induced in that conductor.

Second law: it states;

The magnitude of the induced e.m.f is equal to the rate of change of flux linkages.

2.5 THE OPERATIONAL AMPLIFIER

An operational amplifier (op amp) amplifies the difference Vd = (V1 – V2) between two input signals exhibiting the open-loop voltage gain.

$$Aov = \frac{Vo}{Vd} \quad \text{.........................} \quad (1.)$$

In fig 2.4, terminal 1 is the inverting input (labeled with a minus sign on the actual amplifier). Signal v1 is amplified in magnitude and appears phase-inverted at the output. Terminal 2 is the noninverting input (labeled with a plus sign); output due to v2 is phase-preserved. In magnitude, the open-loop voltage gain in op amps ranges from 104 to 107. The maximum magnitude of the output voltage from an op amp is called its saturation voltage. This voltage is approximately 2V smaller than the power supply voltage. The amplifier is linear over the range

$$- \{ (Vcc - 2) < Vo < Vcc - 2 \} \text{ Volts}$$

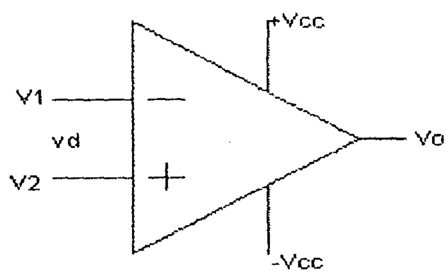


Fig 2.5 The operational amplifier

The ideal operational amplifier has the essential characteristics, which serve as standards for determining the goodness of a practical op amp:

1. The open – loop voltage gain Av is negatively infinite
2. The input impedance R2 between terminals 1 and 2 is infinitely large; thus the input current is zero.
3. The output impedance Ro is zero; consequently, the output voltage is independent of the load.

2.5.1 THE INVERTING AMPLIFIER

The inverting amplifier of fig 2.6 has its noninverting input connected to the ground or common. A signal is applied through input resistor R1, and negative current feedback is implemented through feedback resistor RF. Output Vo has polarity opposite that of input Vs.

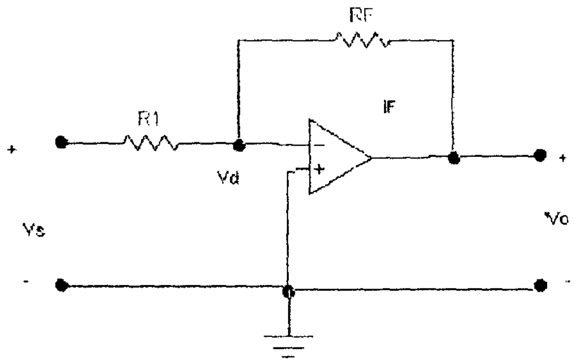


Fig 2.6 Circuit diagram of an inverting amplifier

By the method of node voltages at the inverting input, the current balance is

$$\frac{Vs - Vd}{R1} + \frac{Vo - Vd}{RF} = I_{in} = \frac{Vd}{Rd} \quad \text{.......................} \quad (2.)$$

Where Rd is the differential input resistance. By equation (1), Vd = Vo / Av which, when substituted into equation (3) gives

$$\frac{Vs - Vo / Av}{R1} + \frac{Vo - Vo / Av}{RF} = \frac{Vo / Rd}{Av} \quad \text{.......................} \quad (3.)$$

In the limit as Av $\rightarrow$ $-\infty$, equation (4) becomes

$$\frac{Vs}{R1} + \frac{Vo}{RF} = 0 \quad \text{So That} \quad Av = \frac{Vo}{Vs} = -\frac{RF}{R1} \quad \text{.......................} \quad (4.)$$

For this project an LM 358 op amp was used in designing the amplifier.

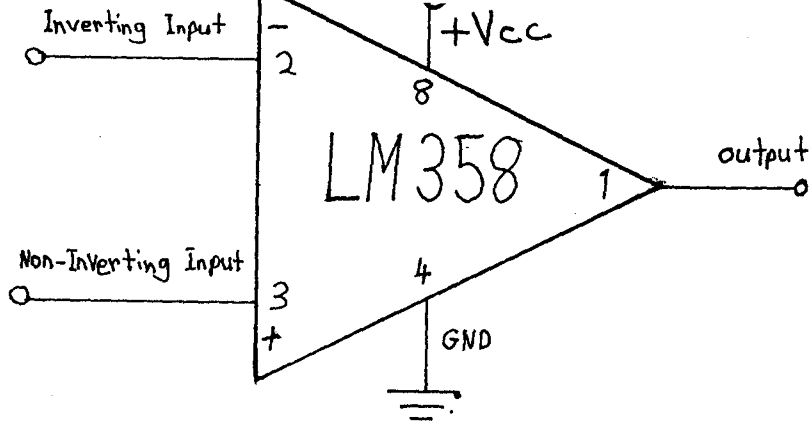


Fig 2.7 The LM358 operational amplifier

The LM358 is a low power single rail op amp, which makes it ideally suitable to be powered with 5 volts as it consumes less power

2.5.2 Calculation of the gain

The coil has a resistance of 100 ohms. The feedback resistor RF has a value of 10 Mega ohms. By placing these values into equation (1.):

$$Av = \frac{Vo}{Vs} = -\frac{RF}{R1}$$

$$Av = -\frac{10 \times 10^6}{100}$$

$$= -100000$$

$$Av = -100,000$$

The very large gain of the op amp indicates the exceptionally sensitive nature of the sensor.

2.6 THE SAMPLE AND HOLD CIRCUIT

The sample and hold circuit comes in handy when you want to convert analog signal to a stream of digital quantities. That is each analog level must be held steady while the conversion takes place. The sample and hold is required to keep the voltage entering the **ADC** constant while the conversion is taking place. The idea is to convert the voltage to numbers so that the computer can digest them.

The basic ingredients of a sample and hold circuit are two buffers, a capacitor and a **FET** switch. The input buffer generates a low-impedance copy of the input signal, forcing it across the capacitor **C**. To hold the analog level at any moment, the **FET** switch is simply opened. The high input impedance of the second buffer prevents loading of the capacitor so it holds its voltage until the **FET** switch is again closed. The **FET** passes the signal through during the sample and disconnects it during hold. Whatever signal was present when the **FET** is turned **OFF** is held on to capacitor **C**. The second high input buffer minimizes the capacitor current during hold. The value of **C** is a compromise. But the **FET's ON** resistance forms a low pass filter in combination with **C**, so **C** should be small if high-speed signals are to be followed accurately. **FETs** make very analog switches. Their combination of low **ON** resistance, extremely high **OFF** resistance, low leakage currents, and low capacitance makes them ideal as voltage – controlled switch elements for analog signals. An ideal analog switch behaves like a perfect mechanical switch. In the **ON** state it passes a signal through to a load without attenuation or nonlinearity. in the **OFF** state it is an open circuit.

Capacitors are not perfect. The most commonly appreciated shortcomings are leakage and nonzero temperature coefficient of capacitance. A more subtle problem is dielectric absorption. This can cause significant errors in integrators and other analog circuits that rely on the ideal characteristics of capacitors. In the case of a sample and hold followed by precision analog -to- digital conversion, the effect can be devastating. The best approach is to choose the capacitors carefully. Polystyrene type was chosen as their accuracy and leakage properties are excellent, and they have good temperature stability.

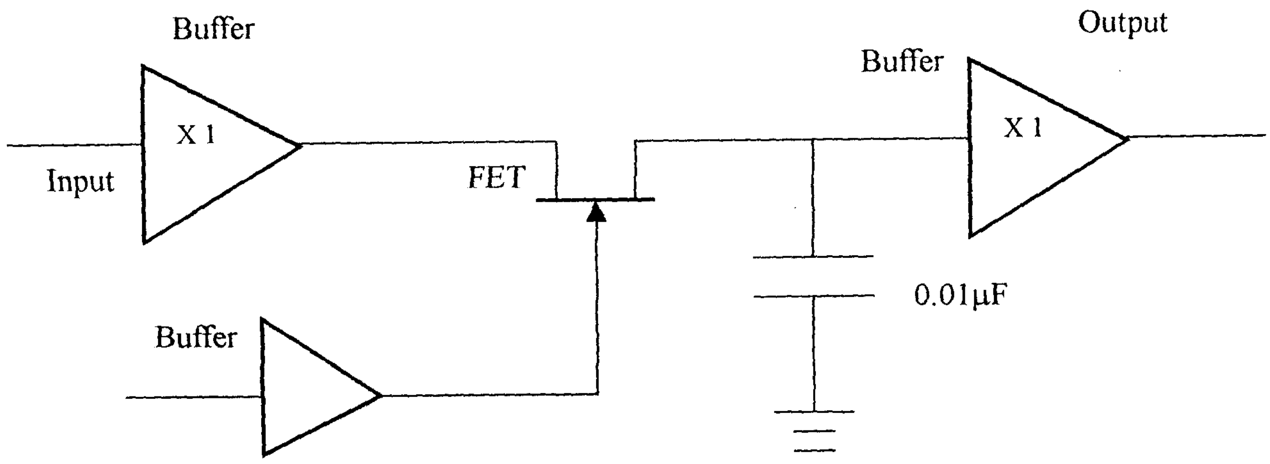


Fig 2.8 A sample and hold circuit

2.6.1 THE SAMPLING THEOREM

Supposing an analog signal is sampled. if the analog signal can be exactly reconstructed from the samples this is known as proper sampling. Even if the sampled data appears confusing or incomplete, the key information has been captured if the process is reversed. If the reconstructed signal does not match the original this is said to be improper sampling. As a result of this **Aliasing** occurs. **Aliasing** is a phenomenon where sinusoids change frequency during sampling. The sinusoid assumes another frequency different from its original frequency.

The sampling theorem states that a continuous signal can be properly sampled, only if it does not contain frequency components above one-half of the sampling rate, Ts. Ts is known as the sampling period.

Fs (i.e. $\frac{1}{Ts}$) is known as the sampling frequency

$$\frac{1}{Ts} > 2W \quad \text{------------(.5)}$$

2W is known as the **NYQUIST** frequency i.e. the maximum signal frequency. For proper sampling, the sampling frequency Fs, must exceed the maximum signal frequency, 2W.

2.7 THE LOW-PASS FILTER

A low-pass filter is an **RC** circuit, which only allows the low frequency components of a signal to pass through. High frequency components are blocked out.

The low-pass filter's output can be viewed as a signal source in its own right. When driven by a perfect **AC** voltage that has zero source impedance, the filter's output looks like **R** at low frequencies. The perfect signal source is replaced by a short circuit. It drops to zero impedance at high frequencies, where the capacitor dominates the output. The signal driving the filter sees a load of **R** plus the load resistance at low frequencies, dropping to **R** at high frequencies.

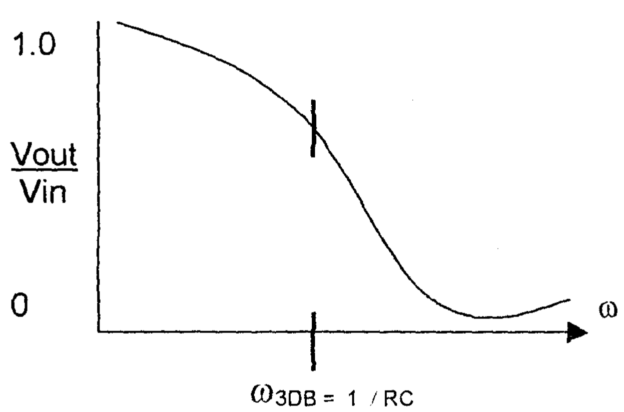


Fig 2.9 Freq response of a low- pass filter

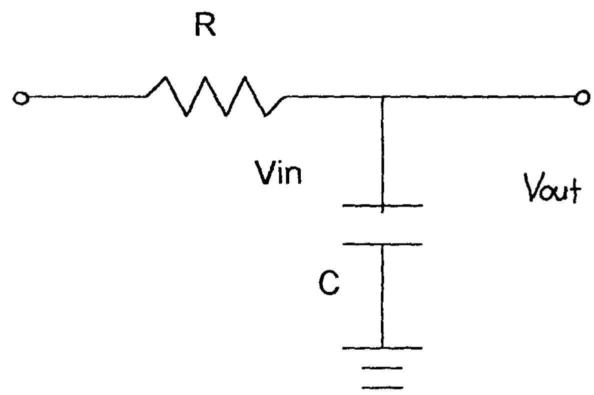


Fig 2.10 A low- pass filter

2.8 THE BESSEL FILTER

The Bessel filter (also called the Thompson filter) is an active filter that has excellent time – domain performance. It has a good step response. This parameter is used to evaluate how a filter responds when the input rapidly changes from one value to another. The Bessel filter minimizes waveform distortion, which are caused by overshoot and ringing. These are oscillations that slowly decrease in amplitude. A key property of the Bessel filter is that the rising and falling edges in the filter's output look similar. This is known as linear phase. These properties of the Bessel filter makes it ideal for use as an antialias filter.

2.8.1 THE ANTIALIAS FILTER

Before the seismic signal encounters the analog – to – digital converter, the input signal is processed with an analog low – pass filter known as an antialias filter. An antialias filter removes all frequencies above the Nyquist frequency to prevent aliasing during sampling, the selection of the antialias filter depends almost on one issue. How information is represented in the signals you intend to process. While there are many ways for information to be encoded in an analog waveform, only two methods are common. Time domain encoding and frequency domain encoding

In frequency domain encoding, the information is contained in sinusoidal waves that combine to form the signal. Audio signals are an excellent example of this. When a person hears speech or music, the perceived sound depends on the frequencies present, and not on the particular shape of the waveform.

Time domain encoding uses the shape of the waveform to store information. For seismic signals the shape of the waveform known as signatures provides the information being sought. Seismic signals are waveforms that vary over time. The Bessel filter is designed for just this problem. Its output closely resembles the original waveform.

Figure 2.11 shows a common building block for analog filter design, the modified sallen – key circuit. This is named after the authors of a 1950s paper describing the technique. The circuit is a two pole low – pass filter that can be configured to the design type.

In seismic exploration and in engineering seismology, frequencies of interest range from 10 – 1000Hz. For the design of the low – pass filter, the cutoff frequency f_c was set at 1KHz

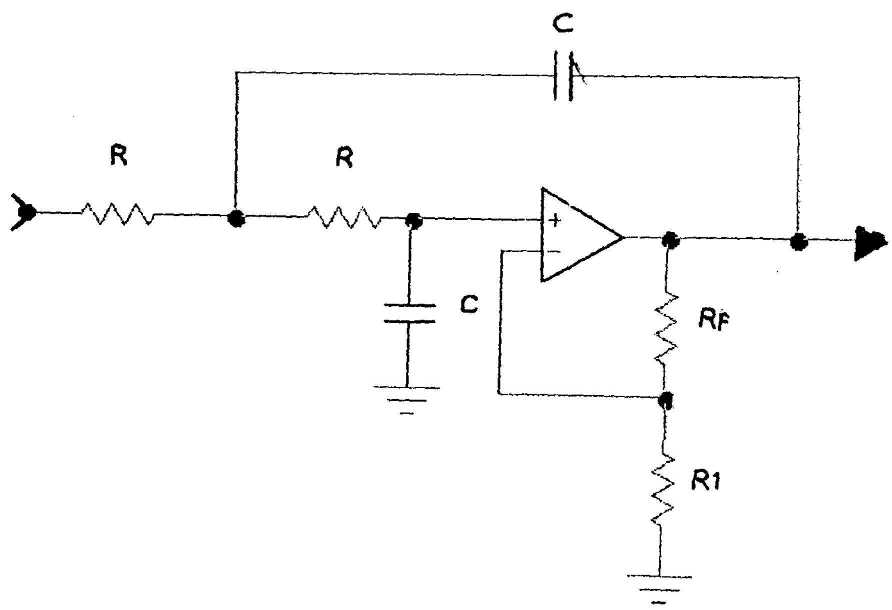


Fig 2.11 The Modified Sallen – Key Circuit

$$R = \frac{K1}{Cf_c} \qquad (6.)$$

$$R_f = R1K2 \qquad (7.)$$

To design a 1KHz 2 pole Bessel filter

Fc = 1KHz

K1 = 0.1251

K2 = 0.2680

Arbitrarily selecting R1 = 10k and C = 0.01μF (common values for op amp circuits)

Substituting the values into equation (6.)

$$R = \frac{0.1251}{0.01 \times 10^{-6} \times 1 \times 10^{3}}$$

$= 12510$

$=$ 12.5K to the nearest 1% standard resistor value

Substituting the values into equation (7.)

$R_f = 12.5k \times 0.2680$

$= 3350$

$= 3.3k$ to the nearest 1% standard resistor value

R = 12.5K

R1 = 10K

Rf = 3.3K

C = 0.01μF

2.9 THE ANALOG TO DIGITAL CONVERTER

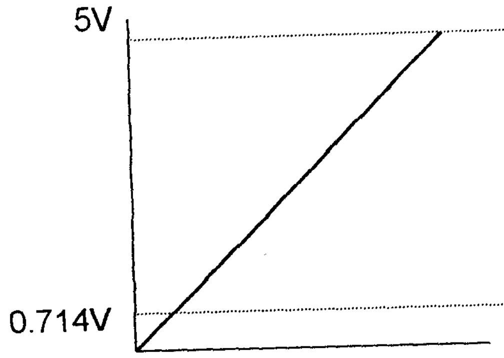
An **ADC** takes the instantaneous value of an analogue input signal and then produces as its output a coded digital word with a weight that corresponds to the digital word with a weight that corresponds to the level of the analogue signal. It is often necessary to convert an analog signal to an accurate digital number proportional to its amplitude and vice versa. This is essential in an application in which a Computer or processor is logging, controlling an experiment or data. To represent an analog signal into digital form we have to code them into bits. The more bits we use, the greater the accuracy. For example a voltage signal that rises from 0V to 5V at uniform rate is to be represented into 8-bit digital form. With eight different values for the digital signal, the original signal is split into seven steps. Each step in the digital signal represents a change of 5V / 7 = 0.7143V in the analogue signal. In other words the best accuracy we can achieve is 7.143%. More correctly we can achieve a resolution of 7.143% since accuracy does not depend solely on resolution. In general, resolution is given by

$$\text{Resolution} = \frac{\text{analogue range}}{2^n - 1} \qquad \text{where } n = \text{number of bits}$$

with more bits, greater resolution is possible

$$8 \text{ bit} = \frac{1}{2n - 1} \times 100 = 0.4\%$$

$$12 \text{ bit} = \frac{1}{2^{12} - 1} \times 100 = 0.02\%$$



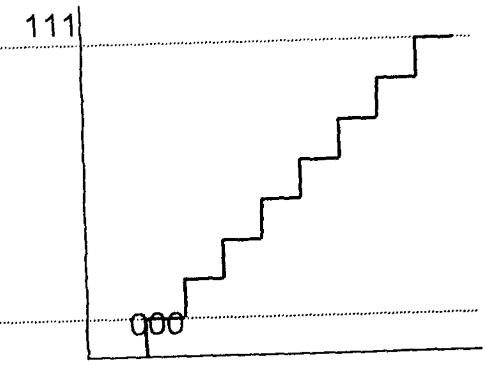


Fig 2.12 Analog signal **Fig 2.13 Nearest digital number**

2.9.1 MODE OF OPERATION

A wide variety of techniques are used in analogue to digital conversion. From the slow and inexpensive to the very fast types which are relatively costly. The common techniques are:

- voltage to frequency
- parallel or flash conversion
- single ramp and counter
- successive approximation

The technique used for this project is the successive approximation method. This is a popular method used in microprocessor systems as it is relatively fast, has good accuracy and can be controlled with software.

2.9.2 SUCCESSIVE APROXIMATION

This method operates by feeding various output codes into a **D/A** converter and comparing the result with the analog input via a comparator. The way it's usually done is to set all bits initially to 0. Then beginning with the most significant bit, each bit in turn is set provisionally to 1. If the **D/A** output does not exceed the input signal voltage, the bit is left as a 1, otherwise it is set back to 0. For an n-bit **A/D**, n such steps are required. This could be described as a binary search beginning at the middle. A successive – approximation **ADC** has a **START OF CONVERSION** input and an **END OF CONVERSION** output. The digital output is always provided in parallel format all bits at once, on n separate output lines. In some cases usually in serial format as well on n successive output bits with the **MSB** on a single output.

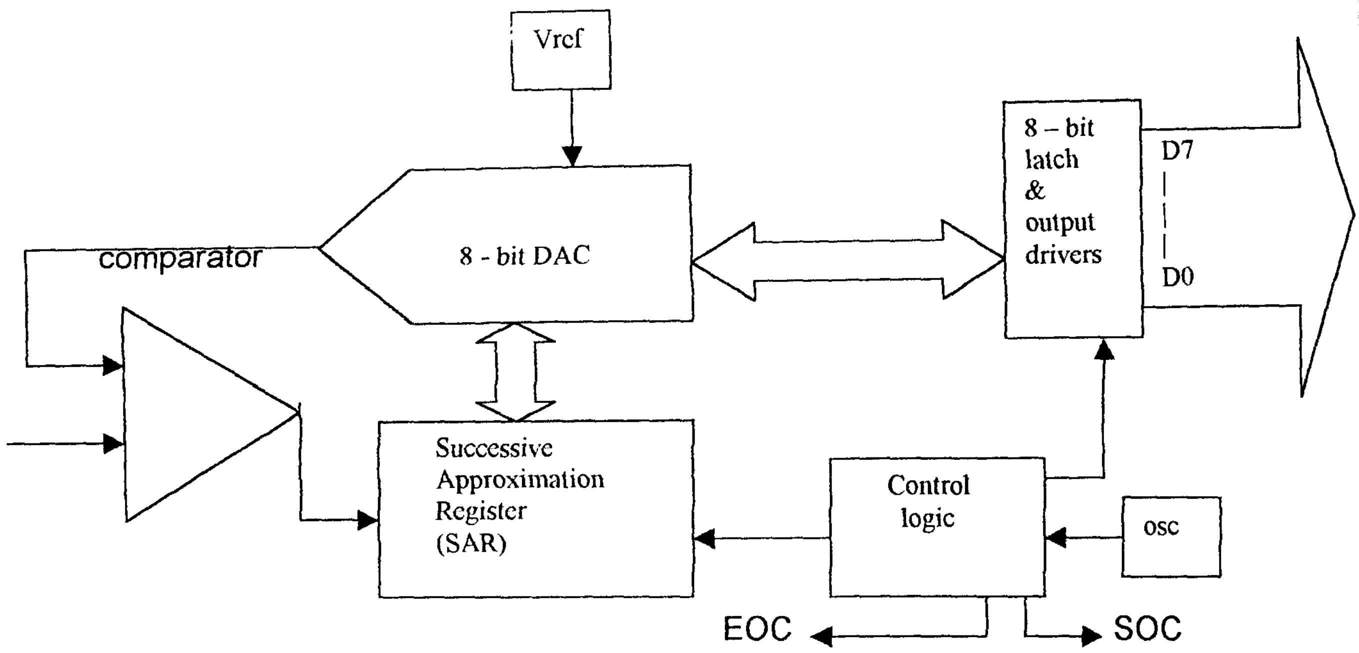


Fig 2.14 Successive- approximation ADC

2.10 THE ADC0808 WITH 8 – CHANNEL MULTIPLEXER

The **ADC0808** data acquisition component is a monolithic **CMOS** device with an 8 – bit analog – to – digital converter, 8 – channel multiplexer and microprocessor compatible control logic. The 8 – bit **A/D** converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8 – channel multiplexer can directly access any of 8 – single – ended analog signals. The device eliminates the need for external zero and full scale adjustments. East interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched **TTL TRI – STATE** outputs.

Incorporating the most desirable aspects of several A/D conversion techniques has optimized the design of the ADC0808. The **ADC0808** offers high speed, high accuracy, minimal temperature dependence, excellent long – term accuracy and repeatability, and consumes minimal power. These features made this device ideally suited for use in the project.

Features

- Easy interface to all microprocessors.
- Operates with **$5V_{DC}$** or analog span adjusted voltage reference.
- No zero or full scale adjust required logic.
- 8 – channel multiplexer with address logic.
- 0V to 5V input range with single 5V power supply.
- Outputs meet **TTL** voltage level specifications.
- 28 – pin molded chip carrier package.

Key specifications

- Resolution	8 bits
- Total unadjusted error	± 1 / 2 LSB and ± 1 LSB
- Single supply	$5V_{DC}$
- Low power	15mV
- Conversion Time	100μs

2.11 THE SOFTWARE

The software is the program, which controls the external hardware device. It reads in data from the **ADC** and then process it after conversion to digital form. The program also functions as a device driver. The software goes through the following steps, which are shown in figure 3.2.

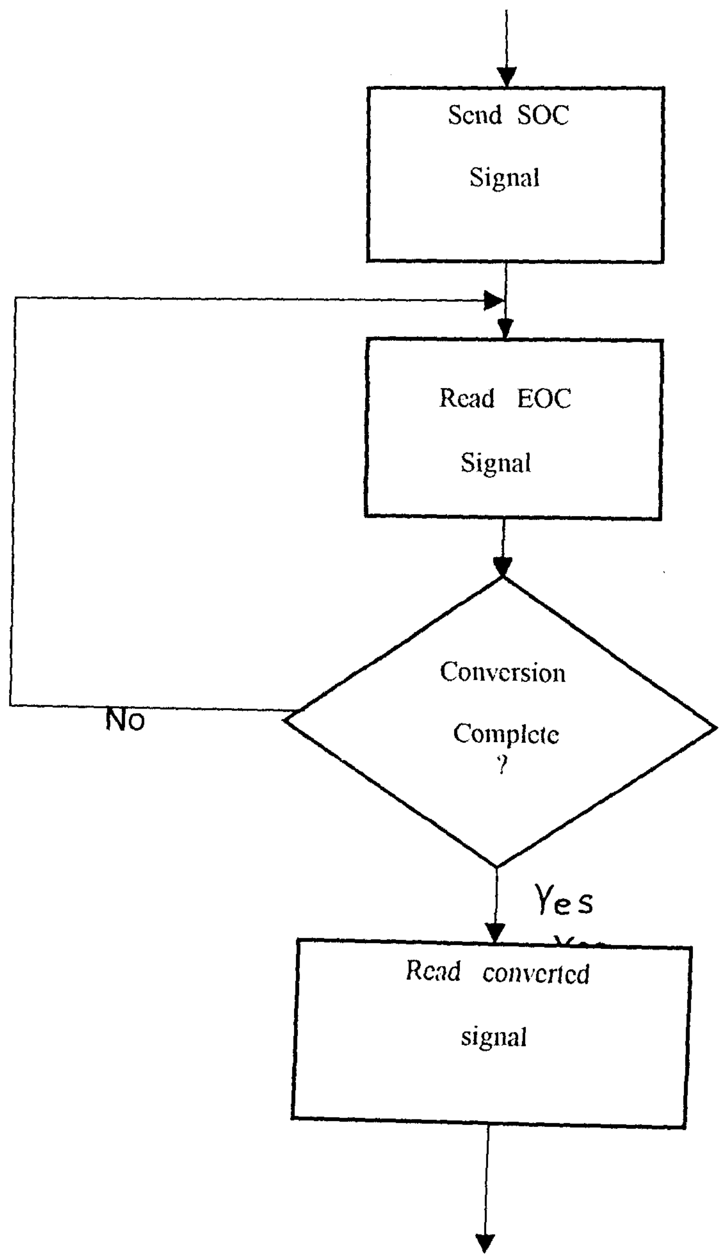


Fig 2.15 A flow chart of the software process

The software program was developed and written using the **C+ +** programming language. It is a high level language with a compiler for converting the source code to an object code, which is the executable file. It also has low level capability for assembly language programming. It is a structured programming language with object oriented programming features. The **C+ +** language was invented in 1980 by Bjorne Straustrop, at Bell Laboratory in Murray Hall, New Jersey in the United States. Then it was originally known as the **C** language. It was changed to **C+ +** in 1983 with the introduction of object oriented programming. Its last major revision was in 1990 and it was used in the development of operating systems, system software and hardware device drivers. It very good and portable due to its machine language compatibility.

2.11.1 THE SEISMOGRAPH

The graphical user interface program was developed and written with the **C + +** Builder compiler language. This software is used for writing application programs that incorporate graphics. It is a window-based language as written programs can be run on a Windows Operating System. The seismograph is used to view the seismic waveforms on the graphical environment. The program incorporates digital signal processing and digital

Filters for processing the data. Low level programming with assembly codes was also integrated in the main program. Low level programming allows the engineer to program the internal hardware of a computer. Direct access of the hardware enhances the speed of

the program. The program was written with user friendly features, and mouse support for

the user. The program source code is provided in the Appendix section.

2.12 THE POWER SUPPLY UNIT

The power supply was designed with a custom made 24V **DC** transformer and a voltage regulator. A 5 volts **IC** Regulator was used to power the seismic sensor as all components in the circuit required 5 volts.

An indicator in the form of a light emitting diode (**LED**) was provided to indicate the **ON** or **OFF** state of the power supply unit.

CHAPTER THREE

3.1 CONSTRUCTION PROCEDURE

On completion of the design, the components needed to build the circuit were bought according to the manufacturer data specification.

The construction began with the implementation of the design on a breadboard. this was done in modules by proceeding from one module to another after due testing.

1. The modules are as follows:
2. The power supply circuit
3. The sensor circuit
4. The sample and hold circuit
5. The filter circuit
6. The **ADC** circuit

The various aspects of the design were then modified to obtain a reliable working circuit before it was constructed permanently on a vero board.

3.1.1 PRECAUTIONS

1) Limiting the use of excess wires with adequate distance planned the veroboard layout. This was to avoid short circuit and reduce resistance.
2) **IC** sockets were used on the vero board instead of direct soldering of the **ICs** to avoid damage by excess heat.
3) **IC** components were placed in Antistatic foams and were only removed prior to use to avoid damage by static charges.
4) The body was grounded to discharge static charges.
5) A digital multimeter was used to check contact and continuity.
6) The power supply unit was separated from the main circuit.

7) When the software and hardware were ready after testing, trouble shooting and debugging they were finally interfaced and tested.

3.1.2 TOOLS USED

1. Breadboard
2. Veroboard
3. Soldering Iron
4. Cutters
5. Long Nosed Pliers
6. Jumper Wires
7. Solder Sucker
8. Digital Multimeter
9. Solder Lead
10. Antistatic Foam

3.2 TESTING

After the seismic sensor was constructed and finally soldered to the vero board, viewing the digital outputs on eight **LEDs** tested the seismic sensor. This was used to test the correctness of its binary outputs. The software program was tested and debugged for any errors by breaking the program into sub smaller tasks known as modules. The advantages of this technique are, errors that occur in a program can be easily traced to the module that controls a particular function in a program. Modules are independent of one another and they can be called several times in a program. This means that so many functions can access it at the same time.

The seismic sensor was interfaced to a computer by connecting it through the parallel port with a parallel port cable. It was then switched **ON**. The software program was run on the computer by clicking on its icon with a mouse on the computer screen.

The seismograph appeared on the screen and the **CLEAR** button on the program was clicked with the mouse to clear the contents of its memory.

3.3 RESULT

The seismograph displayed waveform patterns on its screen that varied with time. The waveforms were observed to exhibit some spikes with sharp edges that are known as signatures. Signatures are waveform patterns that are used to study the characteristics of seismic signals. They are used by seismologists in the field of seismology.

The waveform was read by clicking on the **HOLD** button with the mouse. To continue the waveform the **RELEASE** button was clicked.

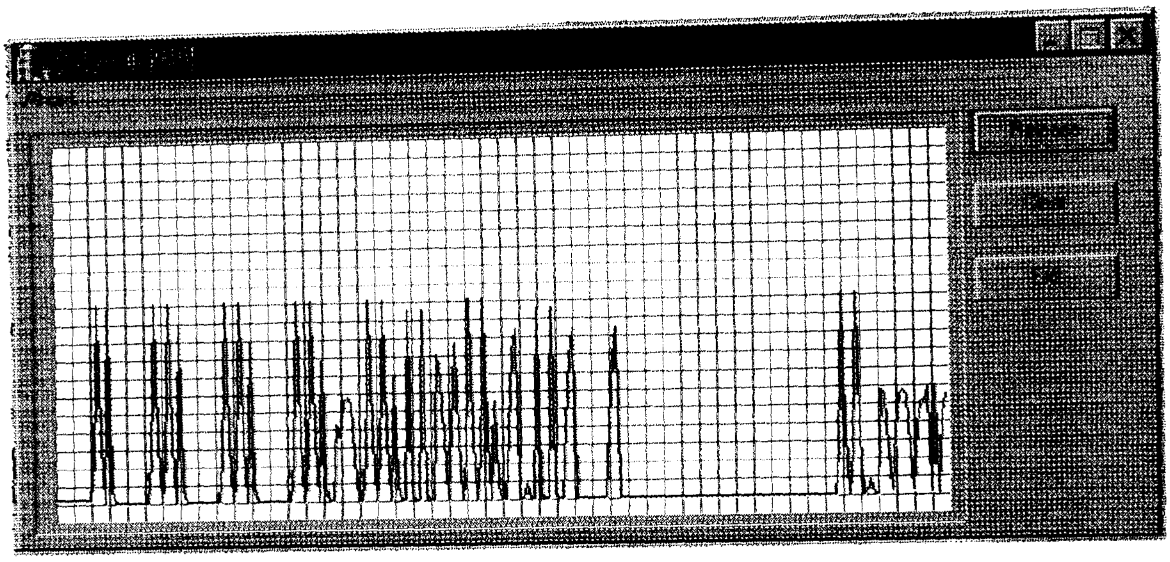


Fig 3·1 The Seismic Signals viewed on the Seismograph when active

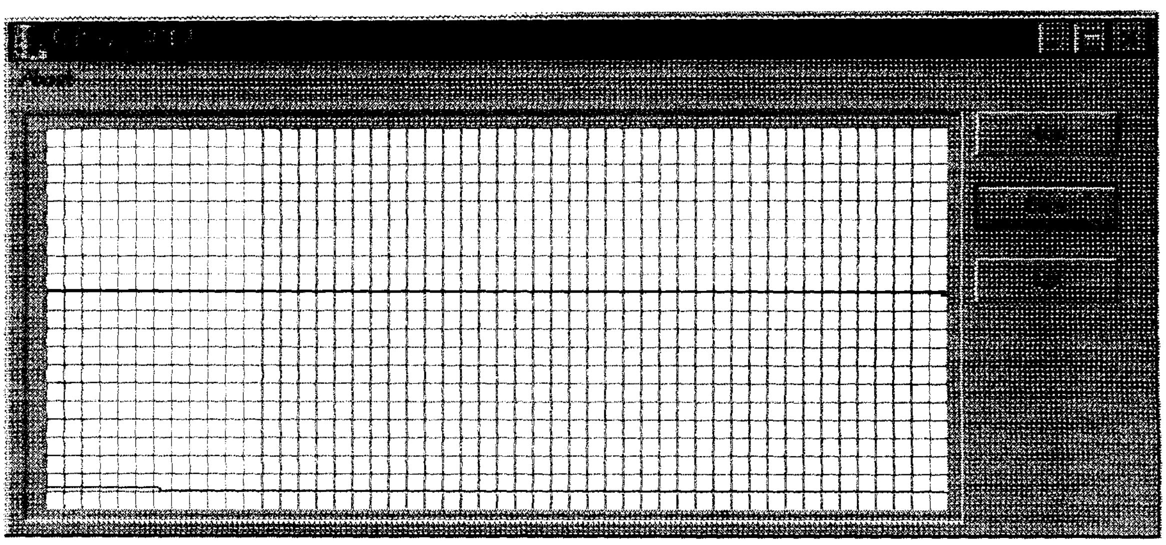


Fig 3·2 The Seismic Signals viewed on the Seismograph when inactive

3.4 DISCUSSION OF RESULT

From the results it was observed on the seismograph that the seismic signals displayed sinusoidal waveforms with sharp edges called spikes. These waveforms are called signatures. The waveforms varied with time as it shifted in phases from left to right. The digital signal processing of the waves was smooth, accurate and precise.

A seismic signal with a resonance factor of zero displayed a straight line. A resonance factor greater than one was characterized with sharp spiked edges.

The concept and operation of the computer interfaced seismic sensor, could be clearly understood from the results that it gave.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

The aim of this project work was achieved, thus the computer interfaced seismic sensor is capable of detecting virtually any seismic signal comprising of vibrations, tremors, earthquakes and other sources of seismic signals.

The development of the seismic sensor, however, required a greater understanding of the basic techniques used in electronics design hardware and software engineering. The ability of the engineer to be able to transform these series of steps into a complete realizable system is, however, a major part of the overall tasks required.

Expectedly, the seismic sensor was tested and it was able to detect seismic signals by displaying the signals as waveforms on a software graphical environment known as a seismograph. It was however noted that during the analysis of the signals the importance of the computer in digital signal processing could not be over emphasized. Signal processing was done within fractions of a second.

4.2 RECOMMENDATIONS

This project work was developed in a manner that will enhance its future improvement.

(i) Hence interested individuals wishing to improve on this project may consider the following recommendations enumerated below.

(ii) The development of a more sensitive seismic sensor that can detect seismic signals thousands of kilometers away.

(iii) The incorporation of an **ADC** with higher bits for greater resolution and higher accuracy of the digital data.

(iv) The incorporation of more sophisticated digital signal techniques for processing the data acquired by the seismic sensor.

(v) The addition of more flexibility to the software program especially in the task of data file generation for results of analysis.

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APPENDIX

PROGRAM SOURCE CODE LISTING

```
#include <dos.h>

#define DATAPORT 0X0378
#define STATUSPORT 0X0379
#define CTRLPORT 0X037A
#define SOC_MASK 0X01     // strobe(black)  to SOC
#define CLK_MASK 0X02     // Auto  feed(brown/white) to CLK
#define ALE_MASK 0X08     // select in (green/white) to ALE
#define EOC_MASK 0X20     // select   (light green) to EOC
                          // (blue/white) to GND




        // function that writes data to the parallel port



        void WritePort(unsigned int Port,unsigned char Data )
{
asm{
MOV AL,Data
MOV DX,Port
OUT DX,AL
}
}


                // funtion that reads data from the data port



                        unsigned char ReadPort(unsigned int Port)
                        {
                        unsigned char Data;
                        asm{
                        MOV DX,Port
                        IN AL,DX
                        MOV Data,AL
                        }
                        return Data;
                        }
```

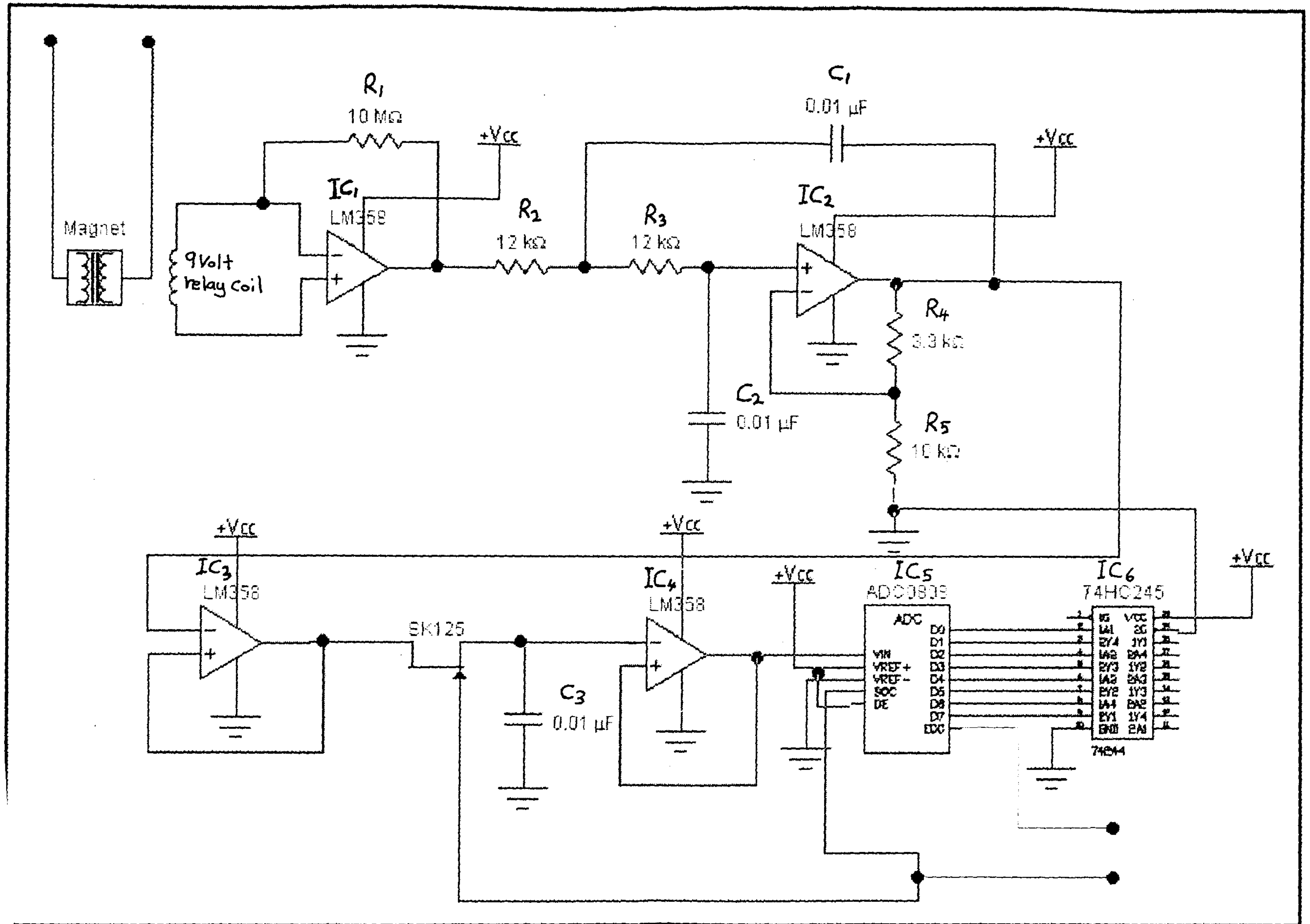
```
// function that sets all the ports to LOW


void InitInterface()
{
unsigned char InitData;
InitData= ReadPort(CTRLPORT);
InitData |= 0X0F;//All control line LOW
InitData |= 0X20; // Read mode
WritePort(CTRLPORT,InitData);
}


//


void Pulse( unsigned char Mask )
{
Mask &= 0x0F ;
unsigned char Temp;
Temp= ReadPort(CTRLPORT);
Temp &=(~Mask); //High Logic
WritePort(CTRLPORT,Temp);



Temp |= Mask;  //Low logic
WritePort(CTRLPORT,Temp)  ;
}


// function that sets the clock signal


void ClockCycle()
{
Pulse(CLK_MASK) ;
}


// function that sends the start of  conversion signal
```

```
void Start()
{
Pulse(SOC_MASK) ;
ClockCycle() ;
}


// function that enables the address latch


void AddressLatch()
{
Pulse(ALE_MASK) ;
}



int End()
{
unsigned char Data = ReadPort(STATUSPORT) ;
if( Data & EOC_MASK ) return 1 ;
return 0 ;
}


// function that sets the sampling rate


unsigned char Sample()
{
AddressLatch() ;
Start() ;

while(!End())  ClockCycle() ;

return ReadPort(DATAPORT) ;
}
```

```
// Test Driver that detects the hardware device

#include <stdio.h>
#include <conio.h>
#include <graphics.h>
//------------------------------------------------------------------------
#ifndef SciesmoGraphH
#define SciesmoGraphH

#include <vcl\graphics.hpp>


        class  SciesmoGraph{
                public :
                SciesmoGraph( TCanvas* ) ;
                ~SciesmoGraph() ;

                private :
                //Variables
                unsigned char      Buffer[250] ;
                TCanvas*           Canvas ;

                //Functions
                                   void
            WritePort(unsigned int Port,unsigned char Data);
                                   unsigned char
            ReadPort(unsigned int Port) ;
    void            Pulse(unsigned char ) ;
    void            ClockCycle() ;
    void            Start() ;
    void            AddressLatch() ;
```

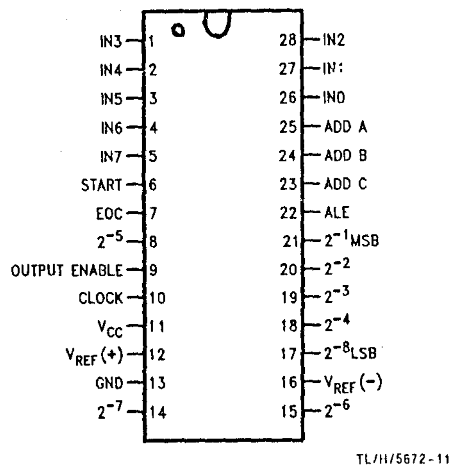
```
int                         End() ;

void                Refresh( TColor ) ;

public:
//Variables
bool                Hold ;
//Functions
void                        InitInterface() ;
void                Sample() ;
void                Refresh() ;
void                Clear() ;

            };
//------------------------------------------------------------------------------
#endif
```

Circuit Diagram of the Seismic Sensor



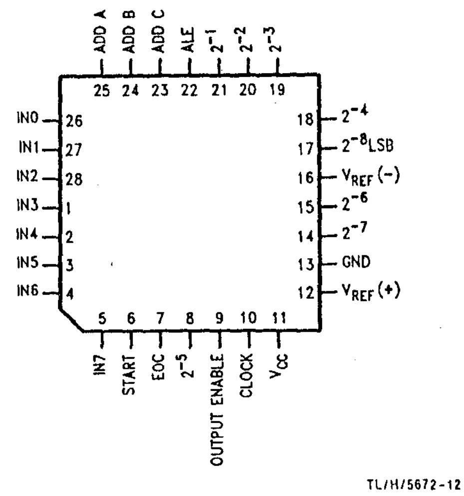
Connection Diagrams

Dual-In-Line Package



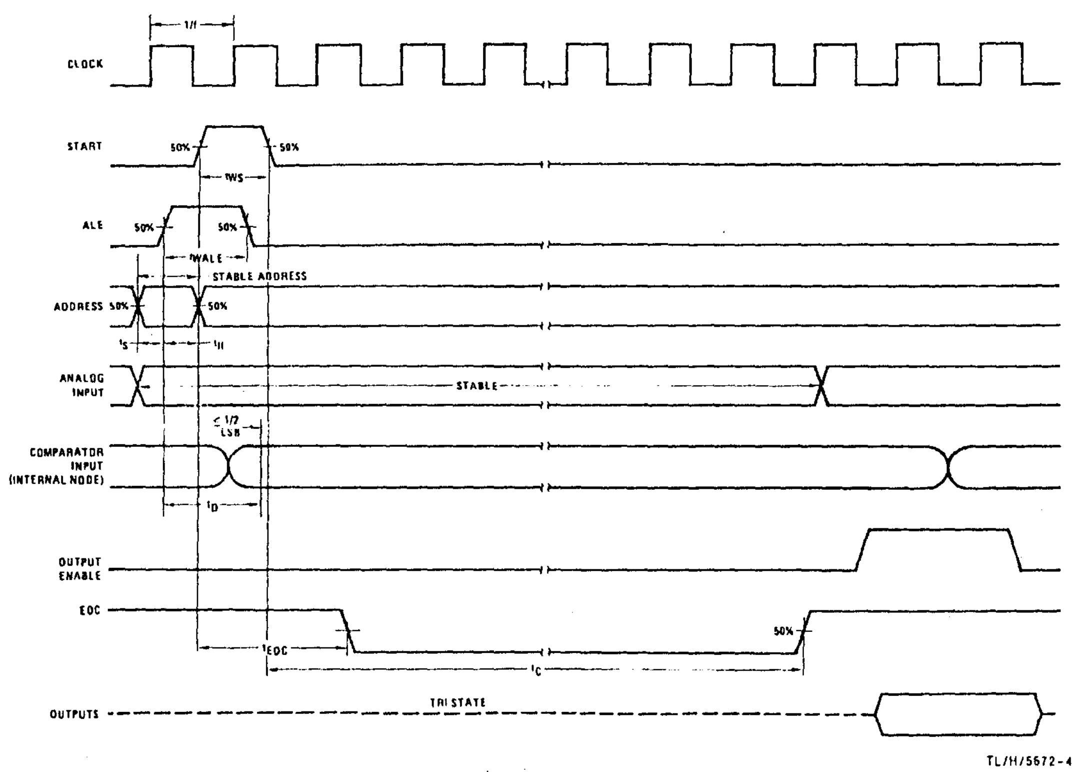
Order Number ADC0808CCN, ADC0809CCN, ADC0808CCJ or ADC0808CJ
See NS Package J28A or N28A

Molded Chip Carrier Package



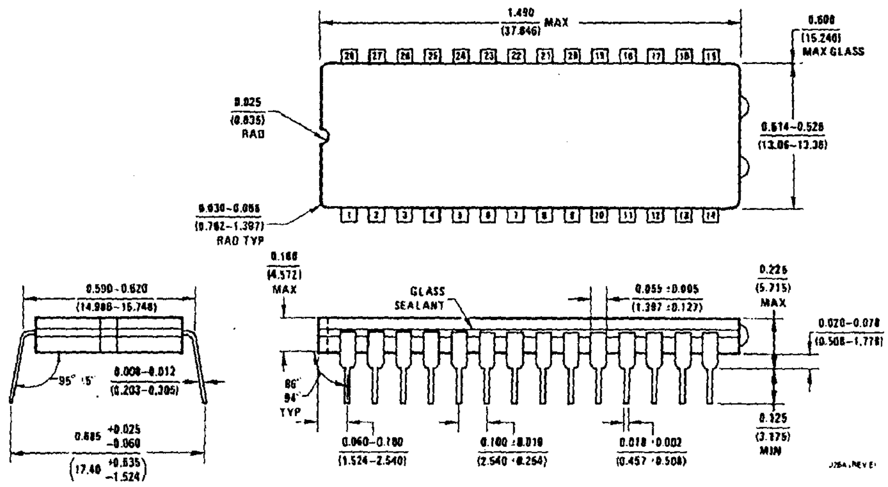
Order Number ADC0808CCV or ADC0809CCV
See NS Package V28A

Timing Diagram

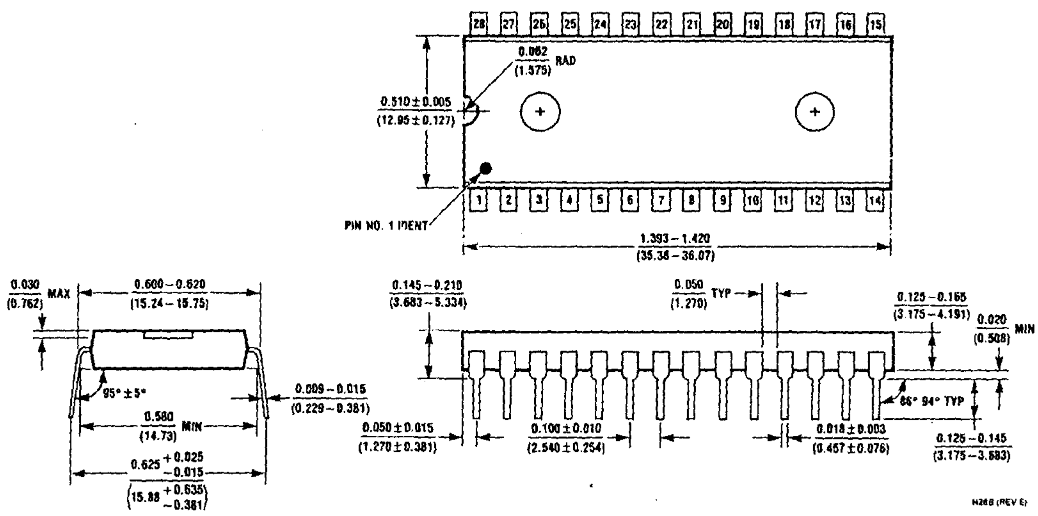


Pinout and Timing Diagram of the ADC0808

Physical Dimensions inches (millimeters)



Ceramic Dual-In-Line Package (J)
Order Number ADC0808CCJ or ADC0808CJ
NS Package Number J28A



Molded Dual-In-Line Package (N)
Order Number ADC0808CCN or ADC0809CCN
NS Package Number N28B

Physical Dimensions of the ADC0808