DESIGN AND CONSTRUCTION OF A MICROCONTROLLER BASED VOLTAGE CONTROLLED OSCILLATOR

BY

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DEDICATION

This project is dedicated to my beloved family, the Mohoro's family, for their immense contribution and support through out my academic pursuit. Thank you for being there.

Declaration

I Nuhu Bello Kontagora, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the federal university of technology, Minna.

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Oh! Mummy and Daddy, yours is special, as your contributions are well felt and appreciated.

To my beloved friends: Iliyasu, B/K, House coach, Jimmy, Yakubu, Ajee, Adam, Alh. Yunusa, Abdullahi, M. Bello, and my colleagues Ma'aruf, Mohammed Nasir, and the rest, you guys are wonderful, the memories of your contributions cannot be lost forever, thank you all

ABSTRACT

The project is all about frequency generation and control, it comprises of four units namely, the power supply unit, the control unit, the display unit, and the oscillation unit.

These units are linked together to function as the microcontroller based voltage controlled oscillator.

The project generates four distinct frequencies of 114KHZ, 151KHZ, 189KHZ, and 227KHZ. If any of these frequencies are required, it can be selected using a button that is provided.

A display is also provided to help in the selection of the value required

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 MEANING OF OSCILLATOR.

Oscillator is an electronic device with positive feedback. In other words it is a non rotating device that generates an alternating signal at a desired frequency when energised with a direct current (DC) power, [1]

Most electronic instruments we know today are driven by a signal either from an oscillator or any signal generator of some sort; this makes signal generation important phenomena in electronics trouble shooting and development.

More so, in any instrument that processes input to produce output or any equipment that performs periodic function, oscillators are necessary.

1.2THE NEED FOR MICROCONTROLLER BASED VOLTAGE CONTROLLED OSCILLATOR.

The preference of oscillators in communication system is ubiquitous. Basically, the goal of a communication link is to exchange information between two separate points. This exchange of information is mostly done using some kind of modulated carrier signal. The modulating signal is a low power base band signal with distinct frequency which is provided by an oscillator. [2]

After modulation, the carrier signal is further amplified until it has adequate power for transmission. Some systems e.g. the global positioning systems (GPS), uses only a single carrier signal for the information exchange.

However, most systems use multiple carrier frequencies within a certain frequency band, to be able to transmit or receive on these frequencies (called channel), multiple oscillation frequencies have to be available in the transmitting and receiving devices. To accomplish this without the need for multiple oscillators, an oscillator with variable frequency and high level of control is needed; Oscillators of which the oscillation frequency can be tuned by changing the voltage of a specific node of the oscillator's circuitry via a microcontroller is called a microcontroller based voltage controlled oscillator.

1.3METHODOLOGY.

A bottom-up approach was employed in the realization of this project; it ranges from the understanding of basic electronic principles that govern the operation of all electronic circuits to the complete construction of the final circuit.

Microcontroller based voltage controlled oscillator is based on the ability of a microcontroller to source and sink current which can be used to on a switch, that completes the circuit through a variable resistor to the voltage controlled oscillator which generates the output waveforms.

1.4 AIMS AND OBJECTIVES.

The aims and objectives of this project are:

- To design a microcontroller based voltage controlled oscillator.
- To construct a microcontroller based voltage controlled oscillator.
- Frequency generation.
- To construct a motor's drive speed controller.
- FM and AM detection in radio engineering.
- A reliable VCO for PLL implementation.

1.5 SCOPE.

Although this project is primarily concerned with the relationship between a microcontroller and a voltage controlled oscillator, many of the principles, techniques and approaches discussed are of basic importance, and they find application in satellite transmission, data communication, telephone switching, digital computer operations and more.

1.6 LIMITATIONS.

The microcontroller based voltage controlled oscillator of this project is concerned with the control of the output frequency of the VCO, by eliminating the effect of frequency pushing (change in output frequency due to variation in supply voltage), not minding the pulling factor on the VCO which determines its susceptibility to output load variations.

Again it is restricted to four (4) different but fixed frequencies of 114KHZ, 151KHZ, 189KHZ and 227KHZ.

1.7 PROJECT OUTLINE.

Chapter one is the general introduction, it contains information on oscillators, the need for microcontroller based voltage controlled oscillator, methodology, aims and objectives, scope, limitations, and project outline.

Chapter two is the literature review, it contains theoretical background, other signal sources, and microcontroller based VCO,

Chapter three is the design and implementation; it contains information on the design of all the units that made up the system and its principle of operation.

Chapter four is the test and result section.

Chapter five is the general conclusion section, it comprises of the summary, conclusion, recommendation and references.

CHAPTER TWO

LITERATURE REVIEW

2.1 THEORETICAL BACKGROUND

Voltage controlled oscillators are well known and widely used in the electronic industry today. Within the digital communication field, VCOs are used in variety of application such as frequency synthesizers, signal generation (e.g. signal transmission) e.t.c.

VCOs are typically designed to perform within a given set of boundary condition and perform according to a specified standard. Typical conditions include for example, performance over operating temperature ranges, sensitivity to vibrations, output sensitivity to interference and the like. Typical performance standards include; output signal frequency stability, output signal programmability e.t.c. [5]

A typical VCO circuit generates an oscillating output signal having a specified frequency. The signal can have several different waveforms, (e.g. square, saw tooth, triangular e.t.c). The frequency of the output is tuneable and is a function of an input voltage, an external resistance and capacitance or the like. The type of applications in which the VCO circuit is used dictates its operating conditions and performance requirements.

In addition, the type of application also largely determines type of fabrication technology used to manufacture the VCO. A large number of modern digital integrated circuits are fabricated using well known and widely used CMOS technology, where the VCO circuit included in a CMOS IC. [5]

There is a problem, however, when the application in which the overall IC is used requires the VCO circuit to have an output with very low phase noise. For instance, where the IC is part of a high sped serial transmission system (e.g. high seed wireless transmission system). It is important that the output frequency of the VCO circuit be stable and jitters free, and be a consistent function of the control input (e.g. voltage, capacitance and the like) while the output frequency exhibit extremely low noise.

For example in the case where a VCO circuit is used in an application for clock recovery in a gigabit serial transmission system, it is important that the output frequency remains stable and jitter free, and the output waveform remains within specified limits, even at the output frequencies of 1GHz or more. The output frequency is used to sample data on a serial transmission line. Very little phase noise on the output signal can be tolerated. Distortion, defects, irregularities or variations in the VCO output frequency or the waveform can have a very detrimental effect on the reconstructed clock signal, and hence, could lead to sampling errors, lost data, decreased throughput, or other such problems.

Consequently, for these very high performance application, it is important that the VCO circuit provides a very stable, jitter free output signal at the specified frequency, and that the output, frequency exhibit as little phase noise as possible.

However, CMOS VCOs cannot reliably function at such high frequencies. It cannot reliably generate output signal having an acceptable waveform (e.g. free of phase noise) and having acceptable stability.

Thus, what is required is a circuit which produces a stable jitter free output signal with a waveform free of defects and irregularities. This project provides an advantageous solution to the above requirement.

2.2 OTHER SIGNAL SOURCES

Today in electronics, we have numerous signal sources, some of which are discussed below;

2.2.1 Harmonic oscillators

The harmonic oscillators generate a sinusoidal waveform. They consist of an amplifier that provides adequate gain and a resonant circuit that feeds back signal to the input. Oscillation occurs at the resonant frequency, where a positive gain arises around the loop. [6]

Some examples of harmonic oscillators are crystal oscillator and LC- tank oscillators

(Hartley and colpitts oscillators).

2.2.2 Relaxation oscillators

The relaxation oscillators can generate a saw tooth or triangular wave form. They are commonly used in monolithic integrated circuits. They can provide a wide range of operational frequencies with a minimal number of external components. Relaxation oscillator VCOs can have three topologies;

i. Grounded-capacitor VCOs

ii. Emitter- coupled VCOs

iii. Delay-based ring VCOs

The first two of these types operate similarly. The amount of time in each state depends on the time for a current to charge or discharge a capacitor. The delay based ring VCO operates somehow differently, however, for this type, the gain stages are connected in a ring.

The output frequency is then a function of the delay in each of the stages.

Harmonic oscillators have the following advantages over relaxation oscillators;

- Frequency stability with respect to temperature noise and power supply is much better for harmonic oscillators.
- They have good accuracy for frequency control since the frequency is controlled by a crystal or tank circuit.

Relaxation oscillators are however tuneable over a wider range of frequencies.

2.2.3 Sweep generators

The sweep generators also called time-based circuits produce linear voltage or current ranges versus time. This may be looked upon as integrators with constant amplitude input signal. They are widely used in applications such as cathode ray displays, digital voltmeters and televisions.

2.2.4. Pulse generators

Pulse generators produces a train of pulses whose width repetition rate, amplitude, polarity waveform may all be adjustable.

They also generate pulse pairs with suitable spacing and repetition rates or even coded pulse train. Most modern pulse generators are provided with logic level outputs for each connection to digital circuitry. They are used for timing and sampling.

2.2.5 Phase locked loop (PLL)

A phased locked loop is a closed loop feedback system in which a generated signal establishes a synchronization or "lock" with an input signal. [8] It consists of phase detector, a low pass filter, an amplifier and a voltage controlled oscillator (VCO). They are used in signal detection and processing applications.

2.3 MICROCONTROLLER BASED VOLTAGE CONTROLLED OSCILLATOR

This is the most flexible signal source of all. It is a vital element in many applications of electronics. It produces triangular and square wave over an enormous frequency range with excellent control.

The microcontroller based VCO in this project would find a great application in communication engineering, due to its degree of stability and jitter free nature.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

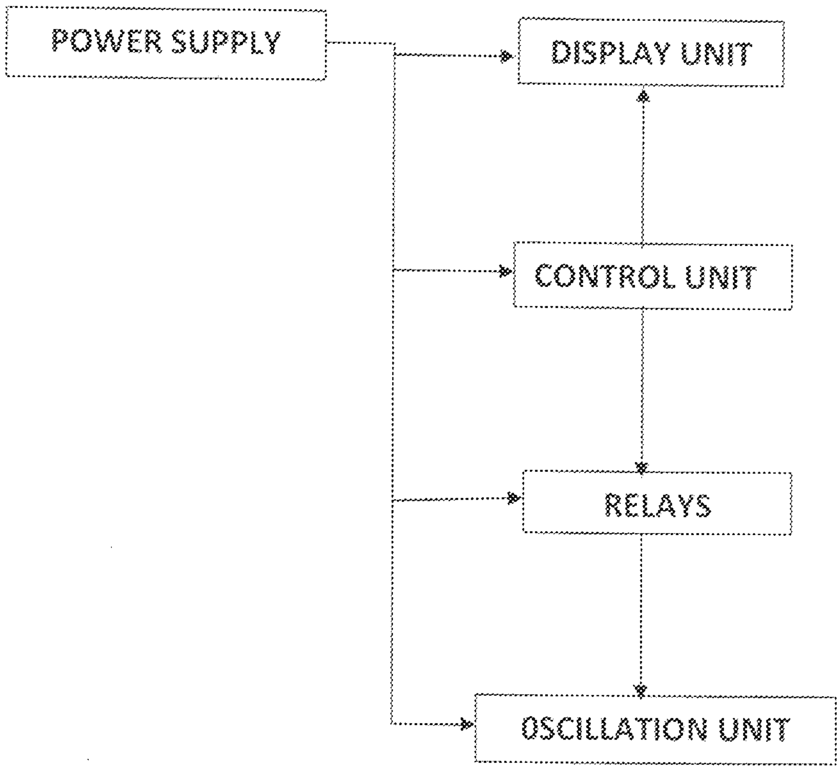

FIG: 3.1 SIMPLIFIED BLOCK DIAGRAM OF A MICROCONTROLLER BASED VOLTAGE CONTROLLED OSCILLATOR

The microcontroller based voltage controlled oscillator as can be seen in the block diagram, comprises of the following units:

1. Power supply unit

2. Control unit

3. Display unit

4. Oscillation unit

These units are incorporated to function together in the realization of this project.

3.1DESIGN OF THE POWER SUPPLY UNIT

Most electronic circuits requires DC voltage for their operation, the microcontroller based voltage controlled oscillator is not an exemption as it required a DC voltage of 5v and 12v which were provided through the process:

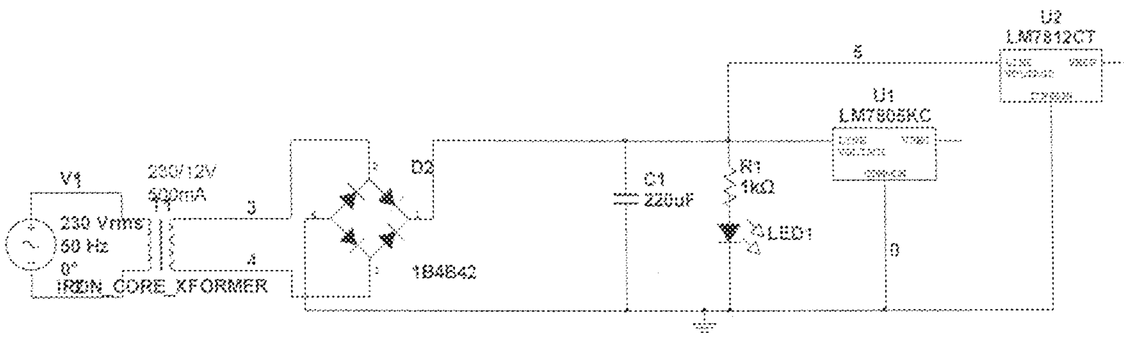

FIG3.2 CIRCUIT DIAGRAM OF THE POWER SUPPLY UNIT

From the local AC mains of 230V, a step down transformer with the rating 230/12V, 500mA, was used to step down the voltage to 12V AC. Then a full wave diode bridge rectifier was used to convert the 12V AC to direct current (DC) according to the calculation

$$Ed = \frac{2Em}{\pi} \tag{3.1}$$

Where Ed = average DC voltage value

$Em =$ Instantaneous or peak value

But $Em = E\sqrt{2}$ (3.2)

Where E= root mean square value

Therefore, $Em = 12\sqrt{2}$

$Em = 16.97V$

And $Ed = 2 \times \frac{16.97}{\pi}$

$Ed = 10.80V$

A direct current has now being provided but with some ripples that needs to be filtered. A capacitor of capacitance 2200µf, 25V was used to provide the filtering' the value of the capacitor was prompted by the calculation:

It takes the capacitor a period (T) to charge, which is half the total period. Thus for a frequency of 50HZ,

The time (T) $= \frac{1}{2F}$ (3.3)

T $= \frac{1}{2 \times 50}$

T$= \frac{1}{100}$

T=0.01sec

But a silicon diode takes 0.7V

For twin diodes we have 1.4V

$$Vpeak = 16.97 - 1.4$$

$$Vpeak = 15.5V$$

$$dv = Vpeak - Vmin \quad (3.4)$$

And $Vmin = Vreg.max + Head$ (3.5)

Let the head=1

Therefore, $Vmin = 12 + 1$

$$Vmin = 13V$$

And $dv = 15.5 - 13$

$$dv = 2.5V$$

The capacitor is a function of change in voltage (dv), as in the relationship

$$Q = Cdv \quad (3.6)$$

$$Q = It \quad (3.7)$$

$$Cdv = It \quad (3.8)$$

$$C = \frac{It}{dv} \quad (3.9)$$

Where $I = 500mA$ (Current rating of the transformer)

$$C = 0.01 \times \frac{0.5}{2.5}$$

$C = 0.002F$

$C \approx 2000\mu F$

But 2000μF is not in the market, so, 2200μF was adopted with the voltage rating of 25V, which is reasonably more than the 12V that enters through it from the transformer.

An LM7805 voltage regulator was used to provide a positive 5V that powers the microcontroller, the displays and the relays. Similarly an LM7812 voltage regulator was used to provide 12V that powers the LM566H voltage controlled oscillator (VCO), and was used to set the voltage values at the variable resistors.

3.2 DESIGN OF THE CONTROL UNIT

The main component of the control unit is the microcontroller, where AT89S51 an Atmel product was used. It has 40 pins, four (4) ports, (P0, P1, P2, and P3). Its reset pin is at pin9 where a 1μF capacitor was connected to Vcc and a 33KΩ resistor, this capacitor and a resistor team up to provide the reset circuitry. [4]

Also a crystal oscillator of 12MHZ was used at pins 18 and 19, to define the performance of the microcontroller. Pin 31 which is known as external access, was connected to the Vcc to enable it to access its internal code memory where the codes written to it are stored.

An interrupt button through which you make selection of the value of the control voltage that goes to the VCO, was connected to pin 21 of the microcontroller

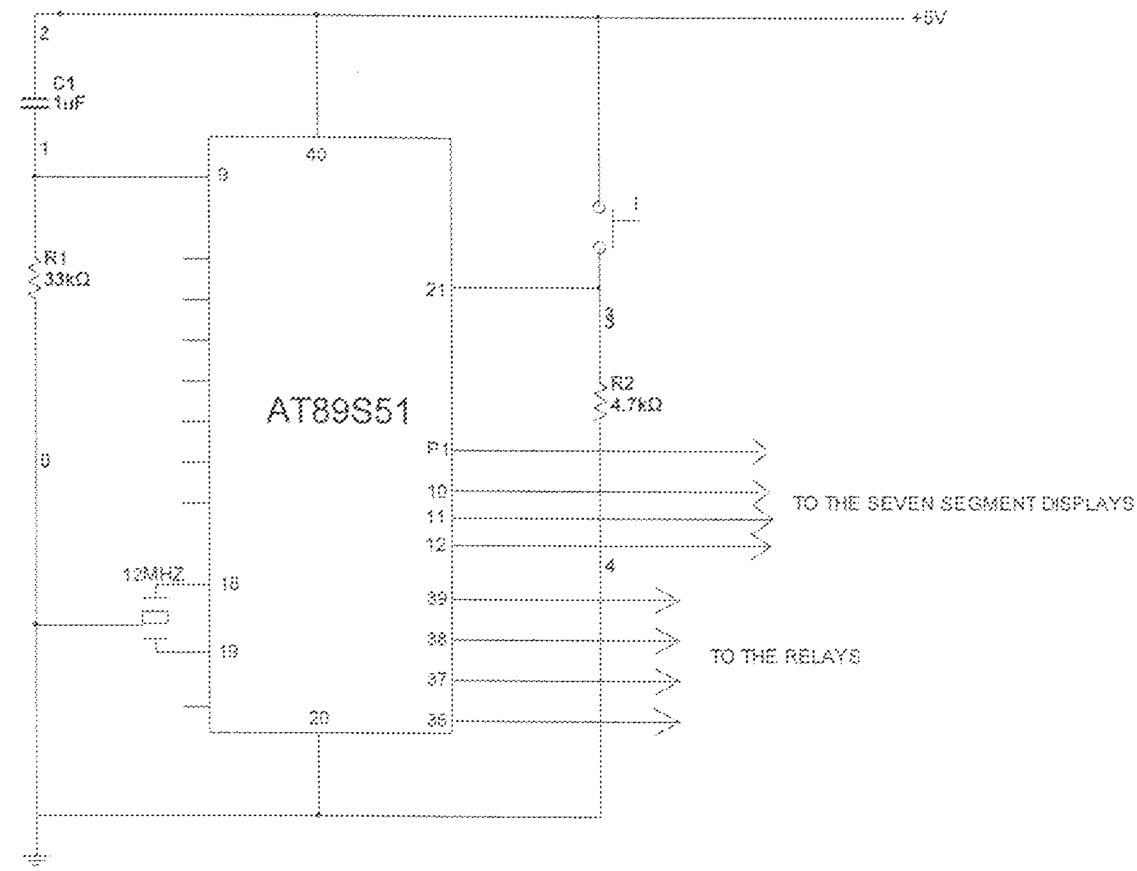

FIG3.3 CIRCUIT CONNECTIONS OF THE CONTROL UNIT

The button is connected to the ground via a 4.7KΩ resistor, the value of this resistor was chosen according to the calculation:

Since the maximum current that this microcontroller can sink is 7mA, then I have to make sure that what goes through it does not exceed 7mA.

$$V = IR \tag{3.10}$$

$$R = \frac{V}{I} \tag{3.11}$$

But V=5V

Let I=1mA

Then $R = \frac{5}{1e^{-3}}$

R=5KΩ.

4.7KΩ was adopted for this design.

The resistor does not only serve as a current limiter, but also acts as a load that consumes the 5V, so that it does not breach the circuit.

So that each time the button is pushed, we are generating frequency alternately within the four distinct values specified earlier.

3.3 DESIGN OF THE DISPLAY UNIT.

The main component of the display unit is the seven segment display, common anode type. Each has 8 pins of which one of the pins is the common where all the anodes

Are connected

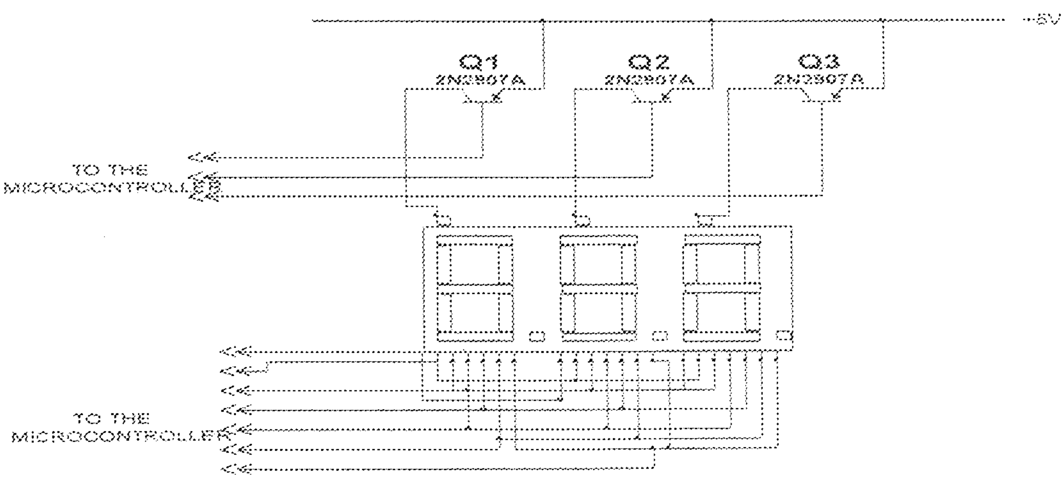

FIG3.4 CIRCUIT DIAGRAM OF THE DISPLAY UNIT

3.4 DESIGN OF THE OSCILLATION UNIT.

LM566H voltage controlled oscillator, is the main component of this unit, the pin configuration is shown in figure 3.3.1 below.

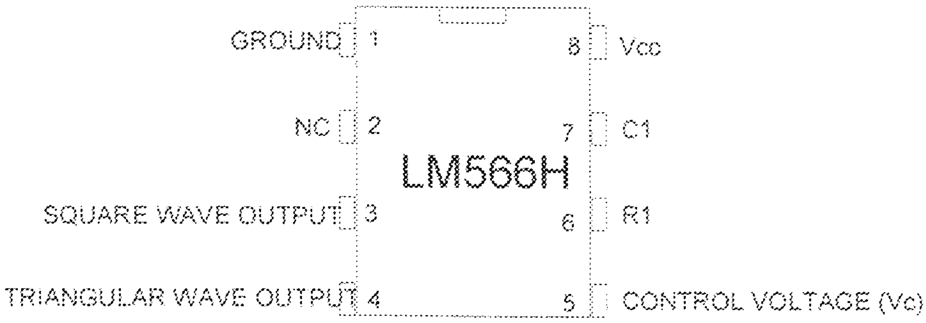

Figure3.5 pins configuration of LM566H (VCO)

This VCO is capable of generating both square and triangular wave forms. Whose frequency is set by an external resistor and a capacitor, and can vary by varying the control voltage applied to its pin5 [8]. It has a free running frequency given by:

$$Fo = \frac{2}{R1C1} \times \frac{Vcc - Vc}{Vcc} \qquad (3.12)$$

With the following restrictions:

- $2K\Omega \leq R1 \geq 20K\Omega$
- $\left(\frac{3}{4}\right)Vcc \leq Vc \geq Vcc$
- $10V \leq Vcc \geq 24V$
- $Fo < 1MHZ$

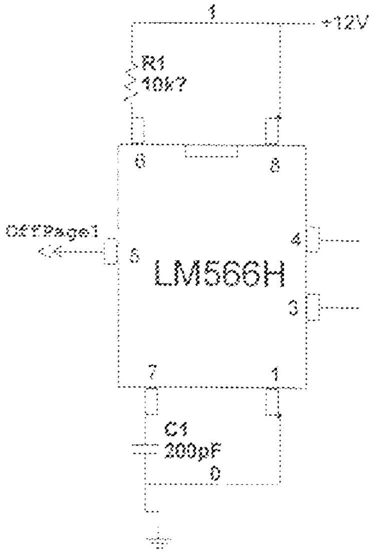

FIG3.3.2A CIRCUIT CONNECTION OF LM566H (VCO)

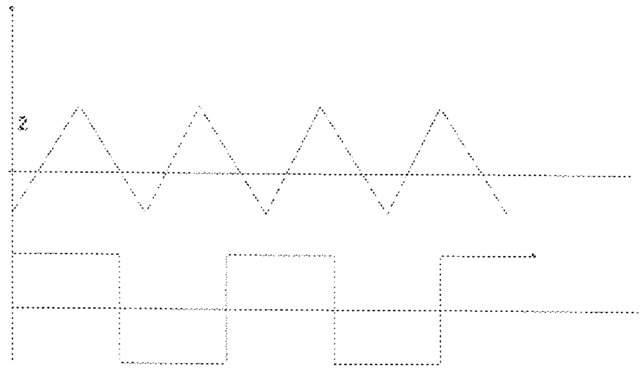

FIG3.3.2B OUTPUT WAVEFORMS OF PINS 3 AND 4

10kΩ was chosen to be the value of the resistor R1, since it is within the range, and 220pF was used for the capacitor C1.

R1 and C1 constitute the frequency determining network, which is one of the requirements for oscillation

The project is designed to generate four (4) distinct values of frequency in accordance with the calculations:

As the control voltage (Vc), changes the value of the output frequency also changes since it is a function of the control voltage. Thus:

When Vc=9V.

$$Fo = \frac{2}{10000 \times 220e^{-12}} \times \frac{(12-9)}{12}$$

Fo=114KHZ.

When Vc=9.5V,

$$Fo = \frac{2}{10000 \times 220e^{-12}} \times \frac{12 - 9.5}{12}$$

$Fo = 151$ KHZ.

When Vc=10V,

$$Fo = \frac{2}{10000 \times 220e^{-12}} \times \frac{12 - 10}{12}$$

$Fo = 189KHZ$.

When Vc=10.5V,

$$Fo = \frac{2}{10000 \times 220e^{-12}} \times \frac{12 - 10.5}{12}$$

$Fo = 227KHZ$

TABLE3.1 THEORITICAL FREQUENCY OUTPUTS EXPECTED

VALUE OF THE CONTROL VOLTAGE (Vc).	FREQUENCY GENERATED
9V	227KHZ
9.5V	189KHZ
10V	151KHZ
10.5V	114KHZ

3.5 PRINCIPLES OF OPERATION

The operation of microcontroller based voltage controlled oscillator is a master-slave relationship, with the microcontroller been the master that determines and control the output frequency of the VCO.

The microcontroller sources current and based on the codes written on it, determines the value of the control voltage (Vc) that goes to the pin 5 of the voltage controlled oscillator's circuit, through a variable resistor and a relay.

To select out of the four frequency values, just make your selection via an interrupt button provided. Every selection automatically switches ON the corresponding relay, which in turn selects the value of Vc on a variable resistor that goes to the 5^{th} pin of the oscillator.

The frequency value is displayed on the 3-seven segment displays cascaded together, whatever is displayed is what you shall get as the output of the VCO in KHZ.

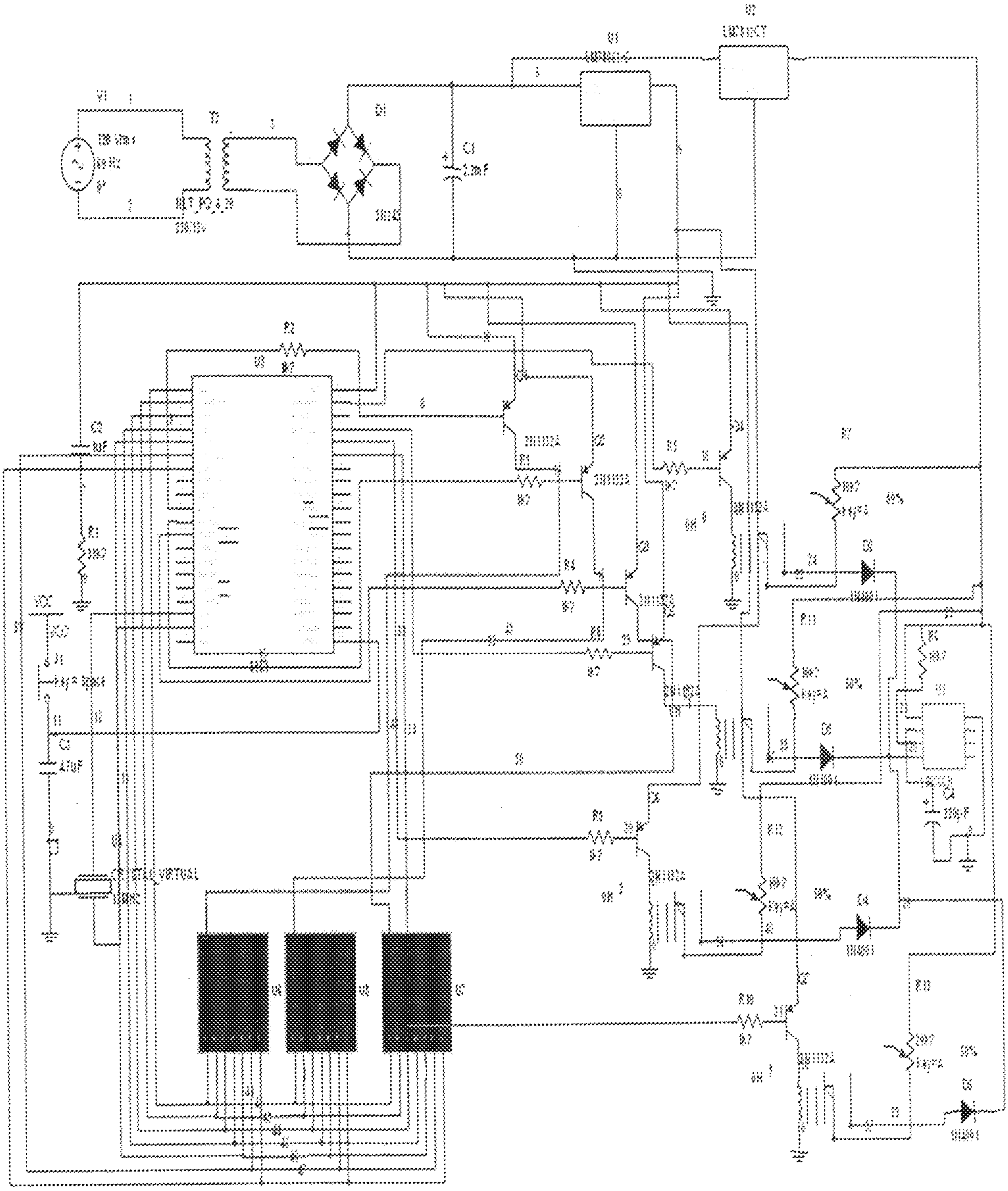

FIG3.6 COMPLETE CIRCUIT DIAGRAM OF MICROCONTROLLER BASED VOLTAGE CONTROLLED OSCILLATOR.

CHAPTER FOUR

CONSTRUCTION, TEST AND RESULTS

4.1 CONSTRUCTION.

The project was constructed on a Vero board, according to the circuit diagram and specification.

The materials used for the construction includes:

- ✓ Soldering iron.
- ✓ Multimeter.
- ✓ Sucker.
- ✓ Jumpers.
- ✓ Lead
- ✓ Vero board.

The components used whose specifications are on the circuit diagram include:

- ✓ Transformer.
- ✓ Voltage regulators.
- ✓ Microcontroller.
- ✓ Relays.

- ✓ Transistors.
- ✓ Capacitors.
- ✓ Resistors.
- ✓ Diodes
- ✓ Voltage controlled oscillators.
- ✓ Variable resistors.
- ✓ Pushing button.

Beside this, a portable casing was used to house the entire project.

4.2TEST.

The testing of the project was carried out in the laboratory using an oscilloscope. The following steps were followed in setting the oscilloscope for the testing.

- The oscilloscope was powered.
- The negative of the oscilloscope was connected to the negative of the microcontroller based VCO.
- The positive terminal of the oscilloscope was connected to the first positive of the microcontroller based VCO.
- The type of wave form generated was observed.

- The positive of the oscilloscope was changed to the second positive terminal of the microcontroller based VCO.
- Also the waveform generated was observed.
- The time base of the oscilloscope was set at 10µs per division
- The division for a period of the generated signal was read and recorded.
- By pressing the interrupt button, the divisions are continuously read and are recorded.

4.3RESULTS.

Based on the settings of the oscilloscope, the time division was at 10µs/division.

For the first signal generated, the division for a period of the wave was read to be 8.5cm,

But the period (T) = base division × the division for a period.

$T = 8.5 \times 10e^{-6}$

T=8.5µS.

But

$$F = \frac{1}{T} \tag{3.14}$$

$$F = \frac{1}{8.5e^{-6}}$$

$F = 117KHZ$,

For the other three outputs the same procedure was carried to get the frequency value generated.

The results obtained are tabulated below:

TABLE4.1 FREQUENCY OUTPUTS OBTAINED

Value of control voltage (Vc).	Number of divisions for one period	Frequency expected from theory	Frequency obtained
10.5V	8.5cm	114KHZ	117KHZ
10V	6.6cm	151KHZ	152KHZ
9.5V	5.2cm	189KHZ	192KHZ
9V	4.4cm	227KHZ	228KHZ

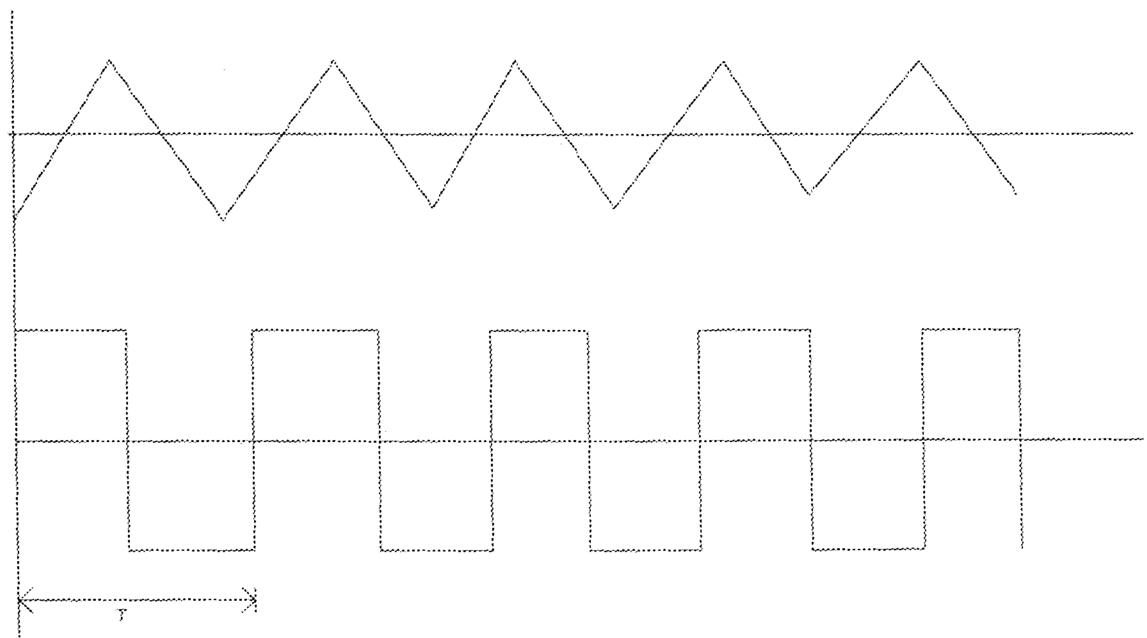

FIG4.1 OUTPUT WAVEFORMS GENERATED AS VIEWED FROM THE OSCILLOSCOPE.

4.4 DISCUSSION OF RESULTS.

As shown in table 4.1, the frequency generated, deviated from the frequency obtainable according to the theoretical calculations. This is true because in reality no system is devoid of irregularities. And for this project the variation may be as a result of variation in supply voltage or components under function, but never the less the deviations are within acceptable range.

CHAPTER FIVE

GENERAL CONCLUSION

5.1 CONCLUSION.

It can be concluded that the aims and objectives of the project has been achieved since frequencies have been generated. And the project as a whole can serve for what it was designed to, that is frequency generation with control

5.2 SUMMARY.

In summary the project is all about frequency generation and control, it comprises of four units namely, the power supply unit, the control unit, the display unit, and the oscillation unit.

These units are linked together to function as the microcontroller based voltage controlled oscillator.

The project generates four distinct frequencies of 114KHZ, 151KHZ, 189KHZ, and 227KHZ. If any of these frequencies are required, it can be selected using a button that is provided, a display is provided to help in the selection of the value required.

5.3 RECOMMENDATION.

I recommend that for future improvements on this project, a more flexible voltage controlled oscillator unit e.g. micronetics be used; which was not available as at the time of construction of this project.

I also recommend that, the department should encourage students to go into embedded system designs, as there is great need for them in the society today.

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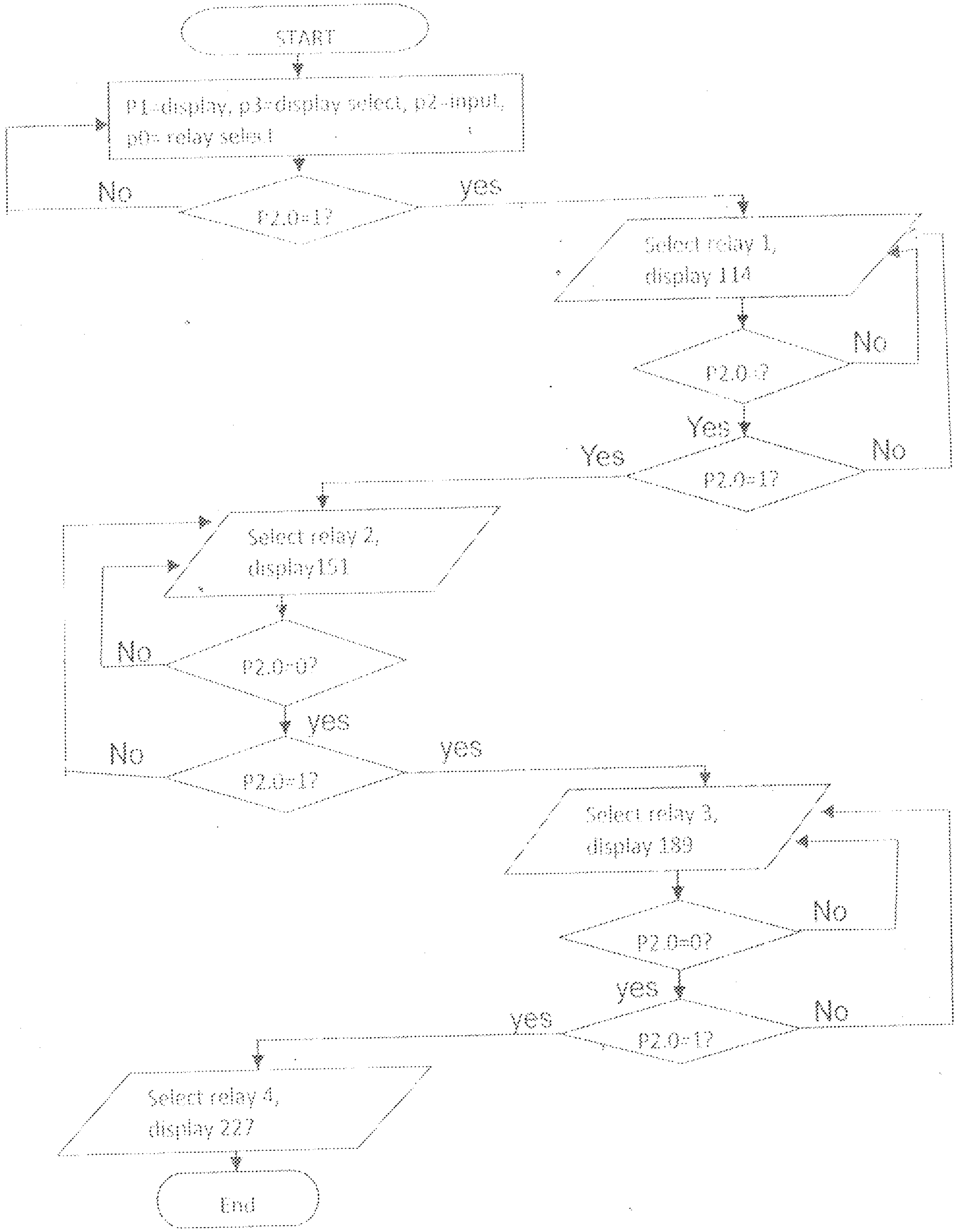
APPENDIX A


START
P1=display, p3=display select, p2=input, p0= relay select
P2.0=1?
No
yes
Select relay 1, display 114
P2.0=?
No
Yes
P2.0=1?
Yes
No
Select relay 2, display151
P2.0=0?
No
yes
P2.0=1?
No
yes
Select relay 3, display 189
P2.0=0?
No
yes
P2.0=1?
yes
No
Select relay 4, display 227
End

APPENDIX B

DEFINATION OF SOME AVEREBIATIONS USED

VCO ⟶ Voltage controlled oscillator

GPS ⟶ Global positioning system

KHZ ⟶ Kilohertz

CMOS ⟶ Complementary metal oxide semi conductor

IC ⟶ Integrated circuit

DC ⟶ Direct current

AC ⟶ Alternating current

GHZ ⟶ Gigahertz