DESIGN AND CONSTRUCTION OF A FREQUENCY CONVERTER

BY

AGBONIFO ETINOSA CYNTHIA

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A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF ENGINEERING [B.ENG] DEGREE.

IN

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING,
SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA.

DECEMBER 2000

DECLARATI ON

I Sincerely declare that the design and construction of this project and all information poduced in this report was solely done by me and that it has been produced before.

E. C. AGBONIFO

CERTIFICATION

This is to certify that te project was designed, constructed and reported by Miss Agbonifo, E. C. and supervised in the department of Electrical/Computer Engineering, Federal University of Technology, Minna.

MR. PAUL ATTAH

....

SUPERVISOR SIGNATURE & DATE

DR. Y. A. ADEDIRAN

....

HEAD OF DEPARTMENT SIGNATURE & DATE

....

EXTERNAL EXAMINER SIGNATURE & DATE

DEDICATION

This project is dedicated to God Almighty who has kept me alive to do this project and also to have kept my family and friends alive to rejoice with me.

I dedicate this project to my wonderful mother, my example of courage and strength in a woman full of virtue.

ACKNOWLEDGEMENT

Glory and honour be to God for giving me the grace to complete my degree Programme despite the hurdles along my path, I am forever spelling.

My sincere gratitude goes to my beloved parents, Engr. & Mrs. S. A. O. Agbonifo, for their parental supports morally, spiritually, financially and otherwise. And to my brothers and sisters for their love and support. Rosemary, Sandra, Michael, Richard, and most of all Maxwell.

I will like to thank to thank those who stood by my side during this period, Deacon and Mrs. Lanre Olusola, Uncle Jackson, my beloved friends Elisha Chelsea, Solomon Baba and Ruth Baba, Kemi, Blessing, John Onimisi, Hellen Aliyu and special thanks to my supervisor, Mr. Paul Attah of the Department of Electrical/Computer Engineering, FUT, Minna for your support, encouragement and advice brought relief and gave me added courage and assurance of success.

And most of all I am very grateful to my dearest friend John Jiya Musa for your love and

comfort and encouragement when I almost gave up. May God Bless you. Amen.

ABSTRACT

This project is concerned with the design, construction and testing of a frequency converter which is a device that convert the main frequency signals of 50 Hertz to a frequency signal of 400 Hertz, used to operate aviation equipments, powered via a.c. source.

The major features of this project is the frequency multiplier from a phase lock loop (PLL) design comprising of a phase comparitor, filter circuit, a voltage control regulator which are compact in a 4046 digital IC. A frequency counter which multiplies the frequency by a factor of 8 from 50 to 400Hz.

Also a wave shaping circuit is designed where the square wave produced by the frequency multiplier is shaped back to sine wave which is the suitable form used to power aviation equipment.

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4.1. CONCLUSION

4.2. RECOMMENDATION

REFERENCES.

CHAPTER ONE
GENERAL INTRODUCTION

1.1. INTRODUCTION

The frequency of a periodic waveform is the number of oscilliations per unit time. One of the basic properties of a waveform which could be triangular sinusoidial pulse or stair case signals. But in this project a square wave and sine wave was used.

Different devices operate at different frequencies, (depending on the devices.) Considering the Aviation equipment which operates at frequencies higher than that provided by the mains supply which is at frequency of 50 Hertz. There is a need to convert the frequency signals from the mains to a higher signal of exactly 400 Hertz for signals needed to operate aviation equipment. Thus, frequency converter can be used for this purpose.

The frequency converter is an instrument that can be used to convert the 50Hz from the main supply to 400Hz needed to operate aviation devices. It is a very useful device in laboratory for engineers, technicians and students as well, especially those in aviation engineering department.

In this project, the phase lock loop circuit for frequency multiplication is adopted to get the harmonics of the mains frequency to realize 400Hz in building the frequency converter.

1.2. LITERATURE REVIEW

At the beginning of the 19th Century, Spencer produced frequency generator by the connection of analog components to generate a multiple frequency of the input frequency .

And since the invention of transistors, by J.k. Louis, L. J. Maxwell, and F.B. Spencer in 1950 made possible the invention of 4046 integrated circuit.

There was a need for aviation equipment to be serviced on ground which led to the discovery of the frequency multiplier used in this project to improve or sustain present as the case may be.

1.3. PROJECT OBJECTIVE AND MOTIVATION

The objective of the frequency converter are very important in the sequence of design 'S and electronic components were used and during actual construction students get familiar th such components as resistors, transistors, capacitors, etc.

During the design sequence and construction, students learn the ability to practically put use the knowledge acquired in electrical department by the various ideas and principles ght by the lecturers; the fundamental ideas during analog electronics and secretary courses ertaken by the student in the department. The ability to analyse and solve problems omplete expression. Do embelish this !

T... ...tive of this project is also to provide a frequency converter instrument

1.4. PROJECT OUTLINE

The frequency converter is an important instrument used to convert the main frequency signals from its 50Hz to higher frequency. This thesis highlights the design procedure involved in the design construction, and testing of digital testing converter.

Chapter One enumerates the general introduction into the project as a whole by introducing a device giving the literature review and the objectives of the frequency converter.

Chapter two explains the steps involved in the system design, the operating principle of the frequency converter, the consideration involved in choosing the Hertz and component used. The different system blocks that makes up the frequency converter.

Chapter three covers the details of construction, testing and trouble shooting and the results obtained at the end of the project along with how various components were shouldered on a veroboard and how the device was tested.

Finally, Chapter four discusses the conclusion reached and the recommendation given

CHAPTER TWO

SYSTEM DESIGN AND ANALYSIS

2.1 OPERATING PRINCIPLE OF THE FREQUENCY CONVERTER

This chapter involves investigation of the device, principle of operation as well as the design analysis in terms of the operational stages, if the frequency converter. A stage by-stage analysis is made for the circuit. The operational stages comprising of a wave clipper, 4046 Integrated Circuit. The operational stages comprising of a wave clipper, 4046 Integrated Circuit, 4040 Integrated Circuit and the sine wave generator stages. This is illustrated in Figure 2.1

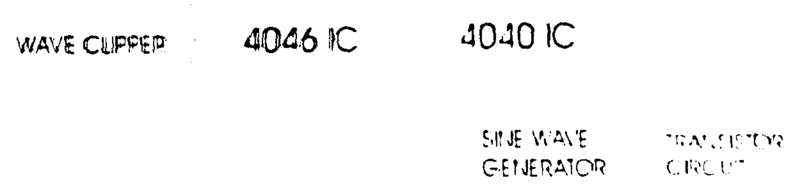


Fig.2.1 Schematic Block Diagram of a Frequency Converter.

The operating principle is that when the switch is ON, the LED at the power supply unit indicates the presence of power in the device. The a.c signal from the centre tap is ground How does a.c sipil flow in it ? Correct this tap of the transformer is passed to ground. A zener diode connected in the clipping circuit help to achieve this. The square wave now getting to the phase lock loop frequency multiplies which comprises of the 4046 integrated circuit and 4040 integrated circuit. The PLL (Phase Lock Loop) uses feedback to produce a replica of an input frequency. Just like an op amp circuit, thé difference between the input voltages is the frequency or phase difference. The 4046 integrated circuit is responsible for comparing the input signals whilè the 4040 does the frequency multiplication.

The multiplied signal frequency is passed to the sine wave generator which is responsible for the conversion of the square wave to a sine wave suitable for aviation equipment.

2.2 POWER SUPPLY MODULE.

The Power Supply Unit provides the d.c operating voltage and current required by the frequency converter. This is due to the ability to convert from a.c to d.c power, by the process of rectification.

In this project a regulated power supply of 12 volts was designed with its output remaining almost constant within the bounds of the current drawn from it.
The Power Supply is made up of a 12 volts rated transformer to step-down the mains voltage from 240 volts to 12 volts followed by a full wave rectifier to rectify the voltage waveform and then a filter used in smoothening the rectified waveform which has ripples. thereafter, a regulator is used to obtain an almost perfect dc. The block diagram is shown in fig. 2.2.

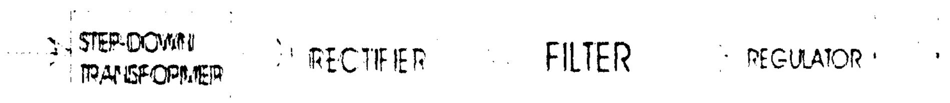


Fig. 2.2. BLOCK DIAGRAM OF THE POWER SUPPLY MODULE

2.3 THE TRANSFORMER.

The transformer stage precede this device since the amplitude of the a.c voltage required is different from that of the mains voltage and electrical isolation is required for safety purposes, so a step-down transformer rated 12 volts was used for this project. The transformer consisting of two coils wound on the same iron-core uses the principle of electromagnetic induction in which the changing flux developed in one coil links the other as shown in fig. 2.3 (a)

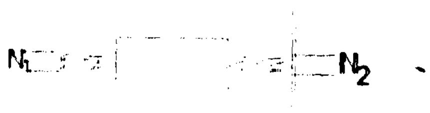


Fig. 2.2 (a)

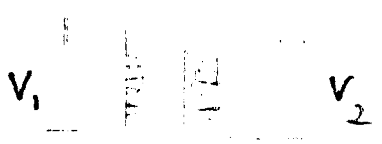


Fig. 2.3 (b)

Thus a transformer consist of a primary winding which is part of the main supply and a secondary winding which is part of the secondary circuit.
The voltage induced in the primary winding is V!secondary winding is V2 and the number of turns of primary and secondary are n1, and n2 respectively. They are related as shown below.

The transformer diagram is shown on fig. 2.3(b).

2.4 RECTIFICATION

This is a circuit, which employs one or more diodes to convert a.c voltage into pulsating d.c voltage. This project made use of a centre-tapped transformer circuit using two diodes as shown in fig 2.4(a). For full wave rectification, the centre-tap is usually taken as the ground or zero voltage reference point.

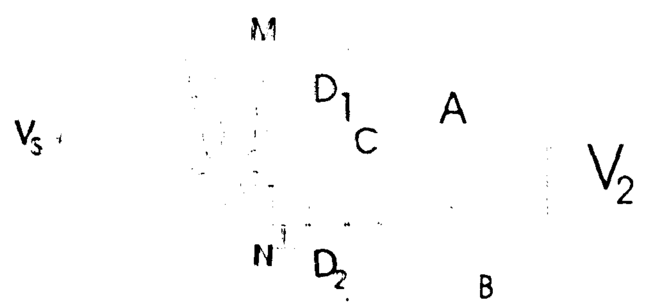


Fig. 2.4(a) RECTIFICATION CIRCUIT.

When input a.c supply is switched on, the ends M and N of the transformer secondary become positive and negative alternatively.
During the positive half-cycle M is at positive potential G is at zero potential while at N is negative potential. Diode D1 being forward-based and diode D2 being reverse biased therefore conducts while diode D2 is open circuited. MD1 allows current to flow through. In that circuit or loop.
During the negative half-cycle D1 is reverse-biased and D2 conducts because is forward biased that is when terminal N becomes positive and M becomes negative then current flows through ND2CABG. Figure 2.4b shows the rectified waveform.

Figure 2.4b shows the rectified waveform.

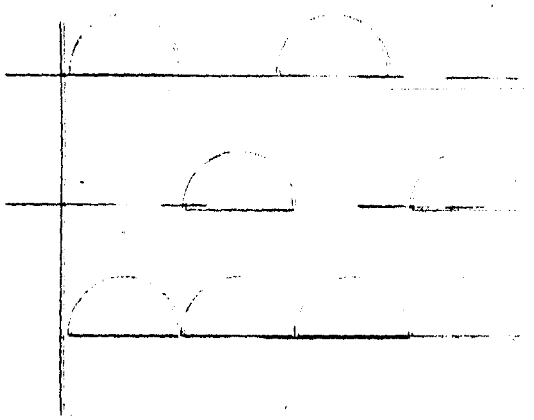


Fig. 2.4(b)

As shown in WAVEFORM 2.4(b). It means both half cycles have been utilized. The rectified output voltage frequency is twice the supply frequency.

2.5 SMOOTHENING (FILTER) CIRCUIT

The pulsating voltage from the rectifier is passed through a capacitor filter or smoothening circuit to get a well filtered d.c voltage required to power the integrated circuits used for this project. This smoothening is done by filtering away the ripple in the output voltage. The ripple refers to the undulation of pulsating d.c. voltage about the average d.c. voltage reference level.

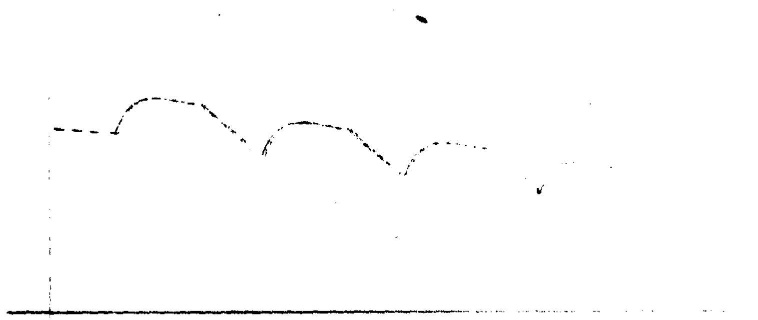


Fig. 2.3 Diagram Illustrating The Filtering Action Of The Shunt Capacitor.

The capacitor-filter circuit is adopted for this power supply, the capacitor is connected across the load and acts to filter.

When the rectifier is conducting, the capacitor charges rapidly to about the peak voltage of the input voltage, between the pulsations of the waves, the voltage from the rectifier drops, the capacitor then discharges to the load. Fig 2.5 shows the associated waveform illustrating the action of the capacitor filter.

2.6 CLIPPING CIRCUIT

These are diodes wave shaping circuits i.e circuits meant to control the shape of the voltage and current waveforms to suit desired purposes.
The output of a clipping circuit appears as if a portion of the input signal were clipped off. At the rectifier stage an idea diode was connected to the positive terminal as shown in fig 2.6 (a) in order to clip off the negative half cycle.

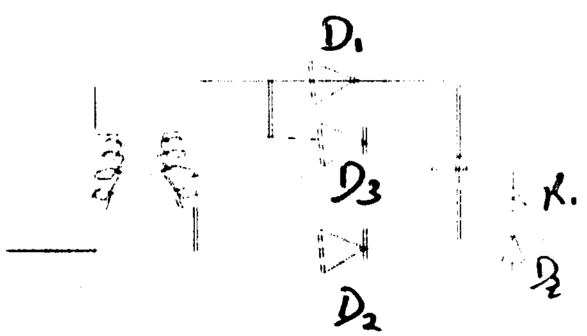


Fig 2.6 (a) Diagram of the wave clipper

On getting tot he input of the frequency multiplier the zener diode act use functions as a wave at the input of the frequency multiplier by clipping the positive half cycles at 12 volts act clipper.

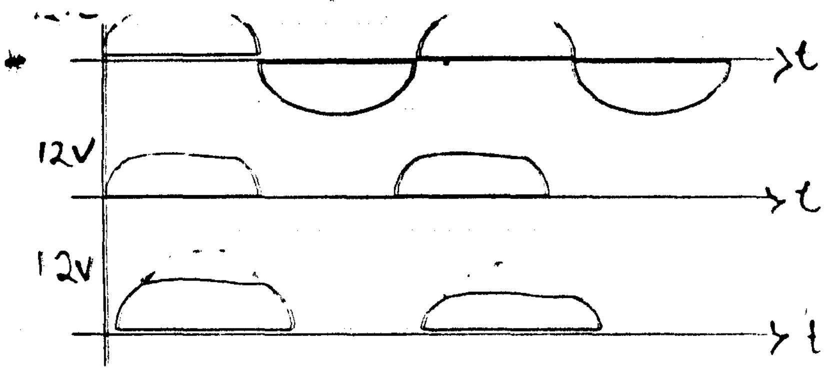


Fig 2.6 (b) Diagram Of The Clipped Waveform

2.7 CALCULATION OF DUTY RATIO OF THE CLIPPING CIRCUIT.

Vdd = 12vd.c

CMOS recognises any voltage below 30% Vdd as low and above 66% as high. When D3 rectifies Ac to do by using Vm sinwt.

Then the voltage at cathode of D3 becomes

12 2 Sin wt ....

As long as it is positive for duty ratio.

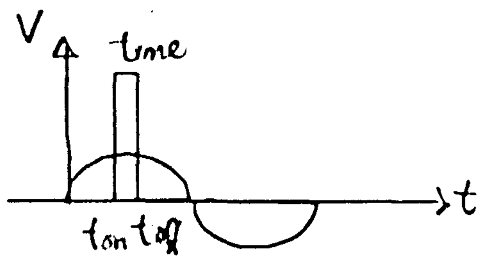
Ton starts when

12 2 Sin wt = 30% Vdd. w = 2 F

12 2 Sin 100 = 30/100 x 12 f = 50Hz.

100/30 2 S n 100t = 1

Ton = Sin - 1 (30/100/2)



100

= 680.4mSec

Toff:

The clipping is symmetric thus -

Here 180 is

Thus 2 is symbolic to T i.e Ton x Toff

0on = wton - wII x 50ton = 100 ton

=680.4 x 10 x100

=0.213 radians.

II - Oon - Ooff - 2.928 radians

toff = Ooff / 100 = 9.322 mSec

$$\text{Duty Ratio} = \frac{O_{off}\ O_{on}}{2\Pi} = \frac{t_{off} - t_{on}}{TS}$$

$$= \frac{8.6416 \times 10}{\text{Period}} = \frac{8.6416}{} \times 10$$

0.43208 i.e 43.208%
It is close to 50%

The duty ratio of the wave clipper determines the working ability of the circuit.

2.8 FREQUENCY MULTIPLIER

The frequency multiplier used in this project is a model of the Phase Lock Loop (PLL) which uses feedback to produce a replica of an input frequency. Just like an op-amp circuit. The difference is that it amplifies not the voltage difference between the inputs. But the frequency or phase difference.

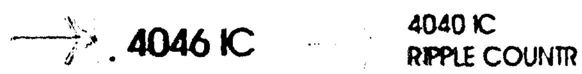


Fig. 2.8 BLOCK DIAGRAM OF THE FREQUENCY MULTIPLIER
See previous comment on title of Fig. 2.5

2.8 1 4046 INTEGRATED CIRCUIT.

The 4046 integrated circuit contains:

(i) Phase Detector type I
(ii) Phase Detector type II
(iii) Voltage Controlled Oscillator (VCO)
(iv) Lock Indicator

The CMOS 4046 phase detector is an IC that generates correction signals during the time when one square wave is rising edge leads the other. When the frequencies match (or lock), the remaining error is only a phase difference.
The phase error signal is been applied to the VCO in a way, which tends to diminish the phase error to zero. At this time the filter capacitor holds its voltage (like sample and hold) not as a filter at all.

2.8.2 4040B INTEGRATED CIRCUIT (RIPPLE COUNTER)

Due to this integrated circuit the frequency multiplier can generate a multiple of replica of

The input frequency. The 4040B integrated circuit is a multiplication factor.

Doing conical algebra

Fo = 400Hz (output frequency)
Fr = 50hz (input frequency)
Fo = 400 = 8 = 2 x 2 x 2 =2
Fr = 50

i.e output frequency is a multiple of the input frequency by a factor of 8.

A ripple counter 4040B is chosen here which can divide frequency from ½ to ½ 12 (i.e it's a 12 stage ripple counter). For this case stage 3 is chosen (i.e 2 = 8) which is found in pin 7 of the pack.

The efficiency of phase lock loop depends on duty ratio as calculated earlier in section 2.6 of signal. 50% is the ideal ratio the smaller the duty ratio, the narrower for the PLL to keep locked.

VCO (PLL) output frequency is directly proportional to input voltage (at pin 9)

VCO (PLL) output frequency is also inversely proportional to Rt and Ct.

Phase lock loop maximum locking frequency is proportional to Vdd.

For any circuit Rt, Ct and Vdd are kept constant.

Typical values that work for frequencies of 400Hz are chosen with reference to circuit ideas.

Damping time is allowed to be high since the circuit is not designed for fast changing frequencies.

This also help avoid over shoot in voltage controlled oscillator input line.

2.9 THE SINE WAVE SHAPER

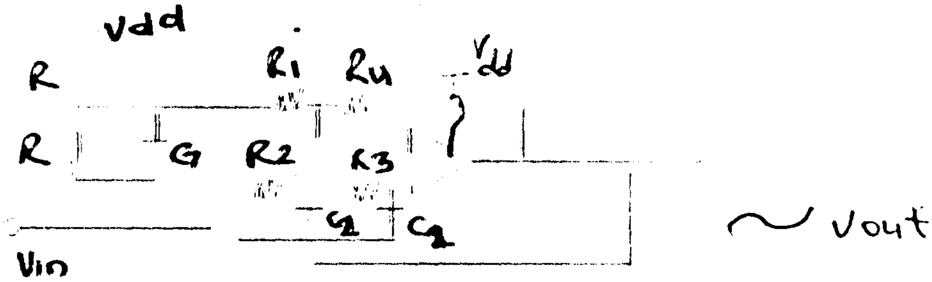
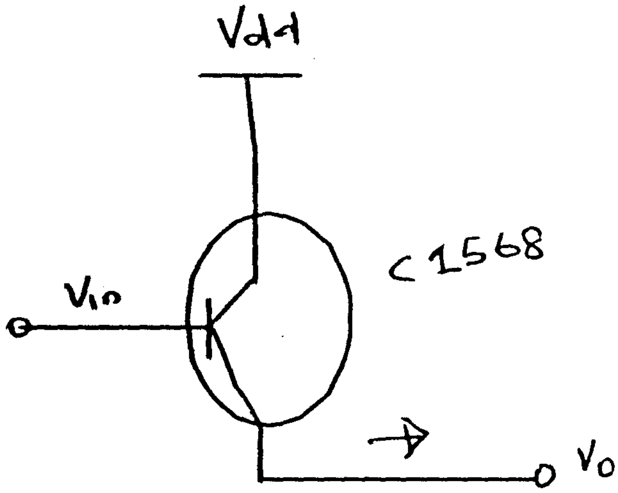


Fig 2.9 Schematic Diagram of a Sine Wave Shaper.
As shown in fig 2.9 the voltage gain is transformed by Ri and Riv.

$$1 + \frac{Rt}{RI} = \text{Av Voltage gain}$$

R2, R3 and C1, C2 on filter components
And they are standard values.

2.10 COMMON COLLECTOR MODE (CIRCUIT AMPLIFIER)



Vo = Vin 0.6v
The coefficient of Vin is unity

$$\frac{Io}{Iin} = AI - \frac{If}{IB} = \frac{(B + I)}{IB} IB$$

AI = B

Fig 2.10 Schematic Diagram of the amplifier.

25mA supplied by 741 is boosted to 2500mA.
This is more than sufficient current for powering the load.

CHAPTER THREE

CONSTRUCTION, TESTING AND RESULTS.

3.1. CONSTRUCTION TOOLS

Some electronic tools and equipments were used in the implementation of the circuit of the frequency converter , the tools are briefly discussed below:

= SOLDERING IRON:

A soldering iron with a 25 to 30 watt testing element was used for this project. High voltage can result in damage of element/electronics components.

= SOLDERING STAND:

This is made up of metal and its used for keeping the soldering iron in a state of upright position.

= SOLDER:

The lead actually used for the solding/soldering element. Resin of flux-core.

= SPONGE:

This is used for cleaning the tip of the soldering iron for every few uses.

= WIRE CUTTER [CLIPPERS] STRIPPERS:

Instrument which connects all parts of the cct together.

3.2. CONSTRUCTION DETAILS:

The overall cct layout was made so as to conform to the orderly schemistic diagram of the circuit where all Integrated Circuits used for the project were pointed in the same direction for logical signal flow and this also make tracking of the numbers easier.

3.3. CONSTRUCTION OF THE POWER SUPPLY MODULE:

The primary side of the 240 volt to 12 volts step-down transformer was connected to the mains supply while the secondary wire was connected to the vero board by soldered connection.

The following connections were done by soldering the components on the vero board

3.4. LAYOUT OF THE CLIPPING CIRCUIT:

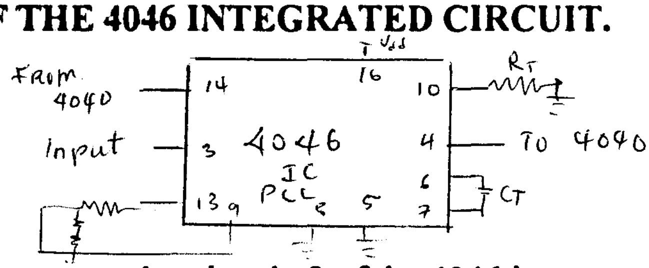
The following connections were made by soldering the necessary components on the circuit board as show Fig 3.4 CLIPPING CIRCUIT.

3.5. CONSTRUCTION OF THE FREQUENCY MULTIPLIER.

The following connections were made.

3.5.1. LAYOUT OF THE 4046 INTEGRATED CIRCUIT.

Fig. 3.52 4040 IC

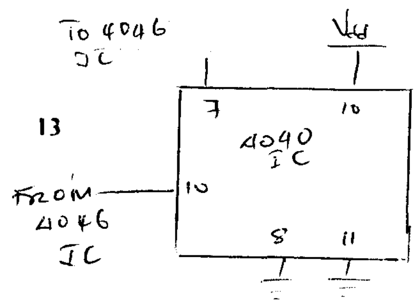


The input was connected to the pin 3 of the 4046 integrated circuit.
Pin 16 was connected to the dc voltage.
Pin 10 connected to a Resistor connected to ground.
Pin 5 and 8 are connected to ground.
Pin 14 is an input from the 4040 integrated circuit.
Pin 13 is connected to a damper circuit.
Pin 6 and 7 connected to CT in parallel.
Pin 4 is the output line to 4040 IC and to sine wave generator.

3.5.2. LAYOUT OF THE 4040 INTEGRATED CIRCUIT.

This is a frequency divider which has its pins 9 and 11 connected to ground.
Pin 10 to input from 4046.

13



Pin 7 connected as feedback to the 4046 integrated circuit.
Pin 16 is connected to dc input.

3.6. LAYOUT OF THE SINE WAVE GENERATOR:

The connection of the circuit is made as shown in Fig. 3.6 the diagram below:

Fig 3.6 A SINE WAVE GENERATOR

3.7. LAYOUT OF THE CIRCUIT AMPLIFIER:

A C1568 transistor of current gain B=100 was connected in a common collector mode on the circuit board as shown in figure 3.7.

THE CIRCUIT AMPLIFIER

3.8.CONSTRUCTION OF THE PROJECT CASING:

The construction of the system casing involves the use of a 1/4 plywood sawn into various dimensions .

A 15 mm. X 5mm and 16mm x 5mm cut was made on the front view for the on off switch, holes of diametre 2mm were drilled at the upper half of the 2 sides elevations. To permit air circulation into the box to keep the system at room temperature. The veroboard was screwed to the wooden bottom elevation.

However, before the mounting, the following electrical connections were made:

i. The ac power cord is connected to the primary of the fuse. Transformer via a 3A.

ii.The on off switch is connected to the circuit board by 2 cables red to the positive and back to the ground cables respectively

3.9. TESTING:

Since the frequency converter was designed to meet the requirement of the aviation workshop bench in that it has to be tested to ascertain whether it multiplied the main frequency by the use of an oscilloscopic which displays the waveform when the prob was placed at the point of connection to the transformer and also the prob was placed at the output terminals of the frequency converter. This was done after powering the system. A digital multimeter was used to measure the output voltage and the current and then the reading was noted. Also the frequency multipliered as expected which was also indicated by the Digital multimeter.

3.10. RESULTS AND DISCUSSIONS OF RESULT:

i. Input voltage 12 volts.
ii Output voltage 12 volts.
iii Frequency of input 50Hz.
iv Output frequency 400Hz.

The results obtained is consistent with the expected performance.
The ouput voltage of the device was maintained at 12 volts being that most aviation equipments operate at that/this voltage.

This is acceptable to most aviation equipment e.g track detector.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATION:

4.1. CONCLUSION

Finally the digital frequency converter projects being successfully done will be useful to Engineers, Technicians, and students in the aviation workshop or laboratory. The objectives and aims of this project were achieved.

4.2. RECOMMENDATION:

In order to obtain frequency signals of higher frequency, for example 800Hz, 1000Hz, etc. It is advised that further circuit be connected or constructed with analog components in order to expand the scope of this project.

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