DESIGN AND CONSTRUCTION OF A VARIABLE FREQUENCY AUDIO SIGNAL GENERATOR

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NIGER STATE, NIGERIA

AUGUST, 2003

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THIS IS SUBMITTED TO THE DEPARTMENT OF

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ENGINEERING AND ENGINEERING TECHNOLOGY,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

NIGER STATE, NIGERIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF

BACHELOR OF ENGINEERING DEGREE (B.Eng.) IN ELECTRICAL AND

COMPUTER ENGINEERING.

AUGUST, 2003

CERTIFICATION

I certify that this work was carried out by me MOUMOUNI AZIA.Y. of the Department of Electrical and Computer Engineering, Federal university of Technology Minna.

....

Engr.KOLO J.G. Date

(Project Supervisor)

.... 6/4/58

Engr. M.N.NWOHU Date

(Head of Department)

....

External Examiner Date

DECLARATION

I hereby declare that the project work is an original concept wholly carried out by MOUMOUNI AZIA Y., under the supervision of KOLO J.G of the Department of Electrical and Computer Engineering, Federal University of Technology, Minna.

MOUMOUNI AZIA YAYE

23rd August 2003

Date

DEDICATION

I dedicate this work to my father MOUMOUNI AZIA, my mother, my Uncle AZIA AMADOU and all my brothers and sisters specially HABIBATA Moumouni Azia.

ACKNOWLEDGMENT

My most profound thanks and gratitude go to Almighty ALLAH for His mercy over me and who granted me the full heart during this study. My heart feet appreciation to goes to my supervisor KOLO I. G. whose effort has been to bring the best out of me. I appreciate the effort made by my departmental Lecturers in seeing that I arrive at this stage. I m sincerely indebted to my fellow mates for their cooperation in class. I also owe Hamma Sooley (Djoumassi), Mayaou Hachimou, for their support

This acknowledgement will not be complete if I fail to appreciate the love and moral support of Atta Abba Tchiari. I thank all the entire people of Nigeria who have shown me the legendary Hospitality of Africans.

May ALLAH bless us.

ABSTRACT

Signal generator is a piece of electronic test equipment that delivers a waveform Output(s) of accurately calibrated frequency. The frequency may be anywhere from audio to microwave, depending upon the intended use of the instrument.

THE VARIABLE FREQUENCY AUDIO SIGNAL GENERATOR design for in this project covers the frequency range of 10HZ-75KHZ. The principle of operation of the project is based on generation of one wave from and making conversion to other required waveforms. The main problem posed was the sustenance of the oscillations in such a wide range of frequency. The project finds a wide use in electronic laboratories and other electronic repair centers in the area of radar, communication receivers repairs, frequency note generator, computers, scanning/ timing circuits, etc.. Because of the indispensable nature of the equipment, it is envisaged that the effort be encouraged or developed considering its importance and comparatives cost advantage it offers.

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CHAPTER ONE

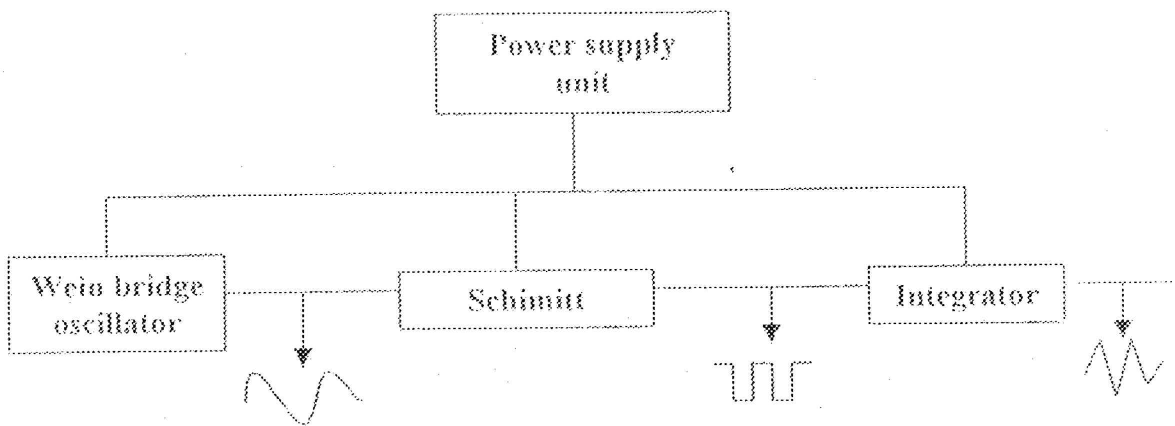
1.1 INTRODUCTION

A signal generator is basically an electronic oscillator which produces time dependent signals of prescribed characteristics such a frequency, amplitude, shapes and or duty cycle. It is a piece of electronic test equipment that delivers an output of accurately calibrated frequency. The frequency may be anywhere from audio to microwave, depending upon the intended use of the instrument. The frequency and the amplitude are adjustable over a wide range.The signal generator is an important application of oscillators. The oscillators must have excellent frequency stability and its amplitude must remain content over the tuning range. The need for this generation of time-dependent signal of prescribed characteristics is often related to the technological advancement being recorded in the fields of communications, radar system and computers. Signal generators are used in radar equipment, audio frequency note generator, FM, RF Generation, digital electronics as in computers, in scanning circuits, timing circuits and also in synchronization of pulses. The Nigerian Armed force, especially the navy, finds a wide use of this testing equipment, especially in the repairs of her radar systems and various transceivers on board naval fleet.

1.2 LITERATURE REVIEW

In modern instruments, sine, square and triangular wave output are produced by a wave form generator which could be of integrated circuit (IC) from or active component that can generate wave forms like collpits or Wien bridge oscillators. The electronic oscillator converts DC energy to AC energy at high frequency. It is described as an electronic source of an alternating current or voltage. It generates an AC output signal without requiring any externally applied input signal and repeats two opposite actions at a regular rate. The oscillators can however be sinusoidal or non-sinusoidal.

The principle of operation of the project design is based on generation of one waveform and making conversion to the others reacquired waveforms. Fig 1.3 (a) below shows the block diagram of signal generator that produces a sine wave, a square wave, and a triangular wave. A wien Bridge oscillator produces the sine wave. This sine wave is one of the outputs. Then the sine wave also drives a Schmidt trigger/zero crossing detector to produce a square wave. This square wave is a second output. Finally the square wave drives an integrator to produce a triangular waveform.



For audio circuit test, square waves are used and the response of an oscilloscope is used to deduce important information about the amplifier performance. Most audio frequency generators contain attenuator to reduce the output voltage by fixed steps or continuously where necessary. This is termed " Amplitude control". This is achieved by passing the source signal (usually sine waves) via a unity gain amplifier a varying the gain below unity. The three most common types of signal generators are:

i) A.M-R.F Signal Generator.

This generator supplies R F signals at any one frequency in it is range. The RF output is available with or without modulation by an internal audio signal.

ii) F.M-R.F signal Generator

A signal Generator of this type is generally called a sweep generator because its frequency modulated output sweeps through a range of radio frequency

It is used for alignment of receivers with an oscilloscope in the output to obtain a visual response curve for tuned amplifier

iii) Audio signal Generator

The audio signal Generator provides any frequency in the range from 20HZ, at the low end, usually to more than 100KHZ at the high end

1.3 OBJECTIVE OF THE PROJECT

The purpose of this work is to produce a design for an audio signal generator that:

1) Produces sine, square and triangular output waveforms

2) The audio frequency to cover the range of 10HZ to 75KHZ

3) The amplitude covers 12 V peak to peak.

4) has highly stabilized amplitude and voltage amplification.

5) has good frequency stability.

CHAPTER TWO

2.0 POWER SUPPLIES

A power supply converts the AC input of the 50 HZ. Power line to DC output voltage. The basic function of a power supply is illustrated by the block diagram shown in fig 2.0.a below

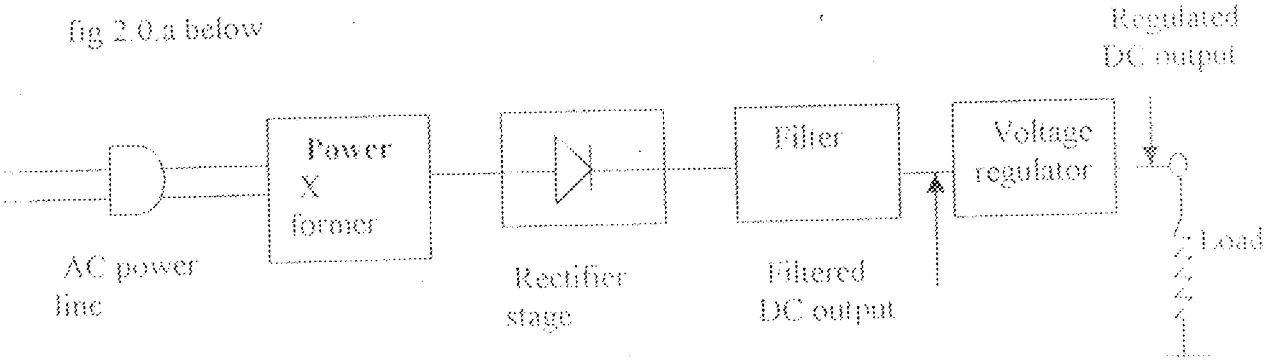


Fig 2.0.(a)

Basically, a rectifier unit is needed to change the AC input to DC output. Filter capacitors are also used however to remove the pulsating variations from the DC output. A DC voltage has a polarity but it can still have changes in values. In addition a power transformer is often used to step up or step down the AC input voltage of the rectifier. The 120 V of the AC power line can be increased or decreased according to the turns ratio of the power transformer. Finally a voltage regulator may be used for the DC output. A Regulator keeps the DC output constant when the DC load current changes. Otherwise DC voltage will tend to decrease as the load current increases

2.1 TRANSFORMER: WORKING PRINCIPLES

A transformer is a static or stationary piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit. It can raise or lower the voltage in a circuit but with a corresponding decrease or increase in current. The physical basis of a transformer is mutual induction between two circuits linked by a flux. In its simplest from, it consists of two inductive coils, which are electrically separated but magnetically linked through a path of loss reluctance. The two coils possess high mutual inductance. If one coil is connected to a source of alternating voltage, an alternating flux is setup in the laminated core, most of which is linked with other coil in which it produces mutually induced EMF. According to Faraday's laws of electro-magnetic induction, $e = \mu \frac{dI}{dt}$

If the second coil circuit is closed, a current flows in it and so electric energy is transferred (entirely magnetically) from the first coil to the second coil (i.e primary winding to secondary winding).

Transformer is thus a device that:

i) transfers electric power from one circuit to the other

ii) it does so without the change of frequency

iii) it accomplishes this by electromagnetic induction

iv) where the two electric circuits are in mutual inductive influence of each other

2.2 RECTIFIER DIODES

Silicon diodes are generally used for power supply rectification. Their maximum current rating ranges from 500 mA for small units, to more than 10A . The advantage they offer is very low internal voltage drop of approximately one volt. Diode current flows only when the AC input provides forward voltage. The direction of hole current consists of positive charges, while electron flow is in the opposite direction. The three popular types of rectifier circuits include:

i) <u>Half wave Rectifier</u>

Only one Diode is needed to conduct on one alternation of every cycle of the AC input.

ii) <u>Full wave Rectifier</u>

Two diodes are used to conduct on opposite half cycles. Each diode supplies one half of DC load current.

iii) <u>Full wave Bridge rectifier:</u>

This circuit uses four Diodes in two pairs.

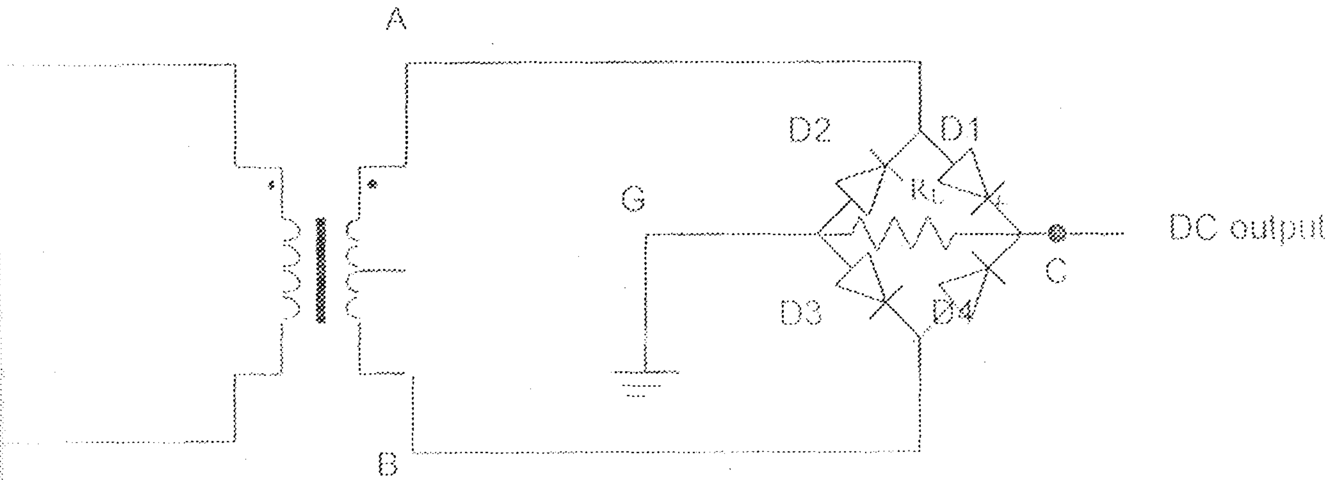


Fig. 2.2 (a)

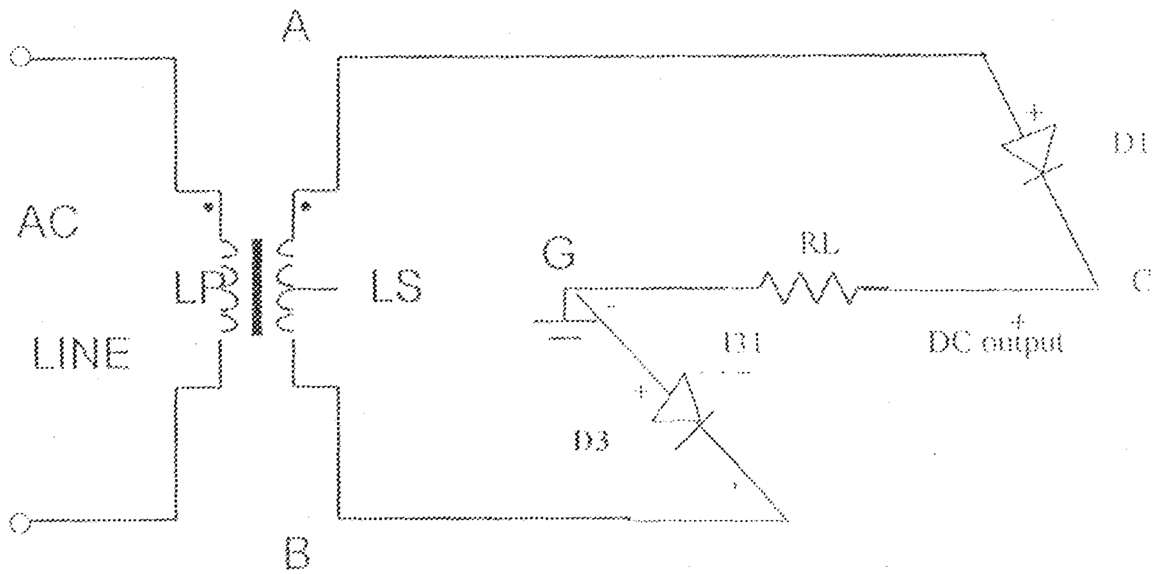


Fig.2.2 (b)

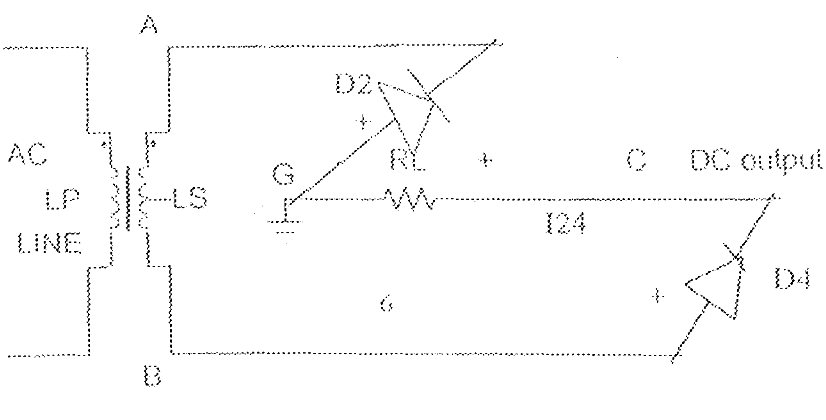


Fig 2.2 (c)

The four leads correspond to terminal A,B,C and G. Two leads are for the AC input and two for the DC output. The details of conduction by the four diodes are shown in figure 2.2 b and 2.2. c above.

2.3 POWER SUPPLY FILTERING

The preceding rectified waveforms are not good for much as they stand. They are DC only in the sense that they do not change polarity. But they still have lots of "ripple" which are periodic variations in voltage about the steady value that has to be smoothed out in order to generate genuine DC

A filter capacitor smooths the output voltage because capacitor opposes any change in voltage. The filter capacitor must be connected in parallel with positive voltage Other wise, a series capacitor will block the DC output. A filter choke smooths the output current because inductor opposes any variations in current. The coil is connected in series so that the DC output current must flow through it.

A filter capacitor is the main factor in reducing ripple. Capacitor charges through the low internal resistance of the conducting rectifier. The capacitor charges fast, however, the discharge path through the higher resistance of the load has a much longer RC time constant. Therefore the capacitor discharges slowly. The slow discharge prevents the capacitor voltage from decreasing much before the capacitor is charged again by the rectifier. The net result is that the DC output voltage across the capacitor has a relatively constant level. The capacitor value is chosen so that $R_{load}C >> 1/f$ where f is the ripple frequency, a 120HZ,

May be chosen to ensure small ripple.

Percentage of Ripple:

The ripple factor is a measure of how effective the filter is in reducing the AC ripple in the DC output voltage.

$$\text{Ripple factor \%} = \frac{V_{ripple}}{V_{dc}} * 100$$

2. 4 VOLTAGE REGULATORS

The DC output voltage of the power supply tends to decrease when the load current increases. Also the RMS-AC input level may vary up or down. Regulation in a power supply is used to keep the DC voltage output constant in spite of variation in either the DC load current or the AC input voltage. Voltage regulation also improves the filtering.

Regulation factor, the ability of power supply to maintain a constant DC output voltage with variation in the load is specified as load regulation factor %

$$\text{Regulation factor} = \frac{V_N - V_L}{V_N} X100$$

Where V_N is the open circuit output with no load

V_L is the full load output.

It should be noted that the lower the percentage the better the voltage regulation. A lower value means less difference between the load and no load voltages. For the purpose of the audio signal generator construction the following circuit diagram in the fig 2 4 a below is employed to provide + 15V/-15V power supply for the construction.

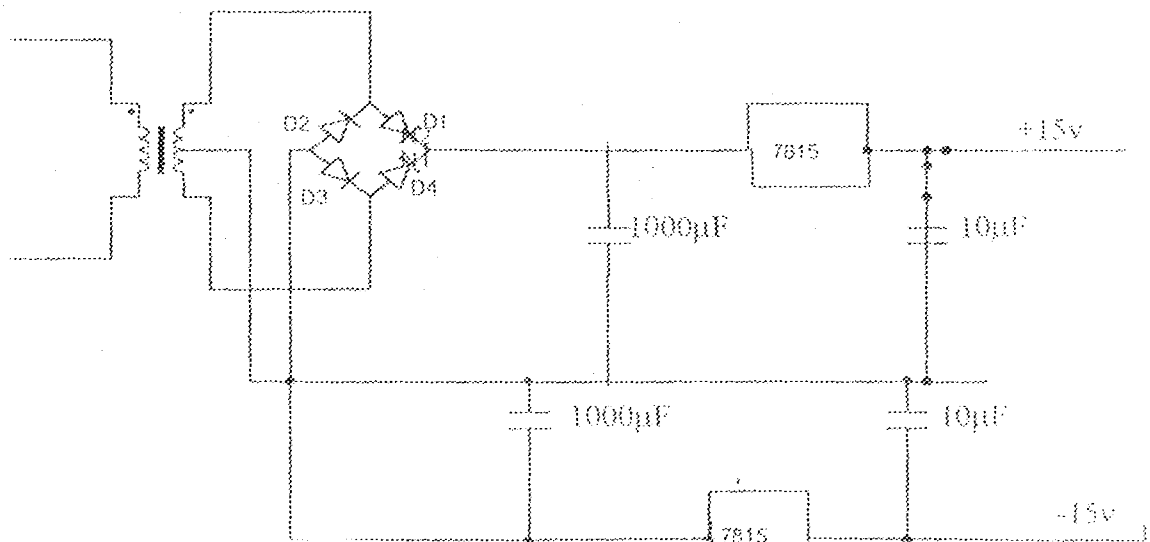


Fig.2.3. (a)

CHAPTER THREE

3.0 DESIGN CONSIDERATIONS

3.1 THE WIEN BRIDGE OSCILLATOR

Principle; Generation of sine wave form from wien Bridge oscillator and conversion to other wave form afterwards.

Wien oscillator:

There are many oscillators configuration that can provide a good quality sine wave signal, but the wien oscillator is adopted here because of its simplicity and can provide very good result provided oscillation is properly regulated. Type basic circuit diagram for a wien oscillator using an integrated circuit is shown in fig 3.0.a below

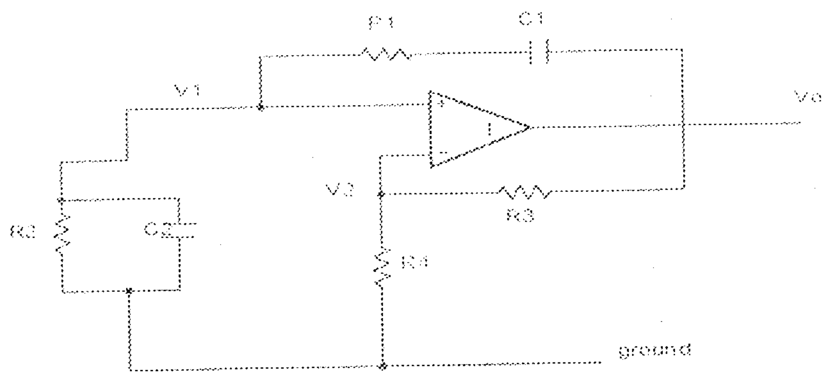


Fig.3.0 (a)

An oscillator circuit in which a balanced Bridge is used as the feed back network is the wien bridge oscillator shown in fig 3.0(a) above.

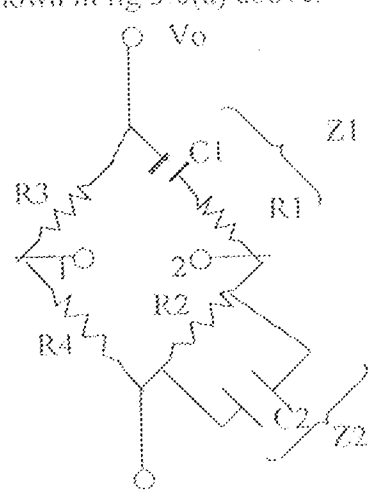


Fig 3.0 (b)

The "bridge " is clearly indicated in fig 3.0 (b) above. The four arms of the bridge are Z_1, Z_2, R_3 and R_4. The input to the bridge is the output V_0 of the op. Amp. and the output of the bridge between nodes 1 and 2 supplies the differential input to the op. amp. There are two feed back paths: Positive feedback through $Z_1$and Z_2, whose components determine the frequency of oscillation, and negation through R_3 and R_4, whose elements affect the amplitude of oscillation.

Now using the basic circuit diagram for a wien oscillator with an integrated circuit as shown in fig3.0(a)

$$\frac{V_0 - V_1}{Z_1} = \frac{V_1 - 0}{Z_2} \quad \ldots\ldots\ldots\ldots(1)$$

$$V_2 = V_0 \frac{R_4}{R_3 + R_4} \quad \ldots\ldots\ldots(2)$$

Re-writing equations (1) & (2) we have

$$\frac{V_0}{Z_1} - \frac{V_1}{Z_1} - \frac{V_1}{Z_2} = 0 \ldots\ldots\ldots\ldots\ldots(1)$$

$$V_2 = \frac{V_0}{1+(R_3/R_4)} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

$$\frac{V_0}{Z_1} - V_1[1/Z_1 + 1/Z_2] = 0$$

Then for an ideal op amp $V_1 \approx V_2$

$$V_1 \approx V_2 = \frac{V_0}{1+(R_3/R_4)} \quad \ldots\ldots\ldots\ldots\ldots(3)$$

using (3) in (1)

$$\frac{V_0}{Z_1} - \left(\frac{V_0}{1+(R_3/R_4)}\right)[1/Z_1 + 1/Z_2] = 0$$

$$\frac{1}{Z_1} - \left(\frac{1}{1+(R_3/R_4)}\right)[1/Z_1 + 1/Z_2] = 0$$

$$1 - \left(\frac{1}{1+(R_3/R_4)}\right)[1 + Z_1/Z_2] = 0$$

$$\left(\frac{1}{1+(R_3/R_4)}\right)[1 + Z_1/Z_2] = 1$$

$1 + Z_1/Z_2 = 1 + R_3 / R_4$

$Z_1 = R_1 + 1/ j\omega c_1$ and $1/Z_2 = 1/R_2 + j\omega c_2$

$\therefore 1 + Z_1/Z_2 = 1 + R_3 /R_4$

$Z_1/Z_2 = R_3 /R_4$

$(R_1 + 1/j\omega C_1) * (1/R_2 + j\omega C_2) = R_3/R_4$

$R_1/R_2 + j\omega R_1C_2 + 1/j\omega C_1R_2 + C_2/C_1 = R_3/R_4$

$R_1/R_2 + C_2/C_1 + j(\omega R_1C_2 - 1/ \omega C_1R_2) = R_3/R_4$

Combing the real values

$R_1/R_2 + C_2/ C_1 = R_3 / R_4$

Also combing the imaginary .

$\omega R_1C_2 - 1/\omega c_1R_2 = 0$

$\omega^2 R_1R_2C_1C_2 - 1 = 0$

$\omega^2 R_1R_2C_1C_2 = 1$

$\omega^2 = 1/ R_1R_2C_1C_2$

When $R_1 = R_2 = R$: $C_1 = C_2 = C$

$\omega^2 = 1/ R^2C^2$

$\omega = \sqrt{[1/R^2C^2]} = 1/RC$

$\therefore F = 1/ 2\pi RC$

In the analysis, the positive feedback network is investigated.

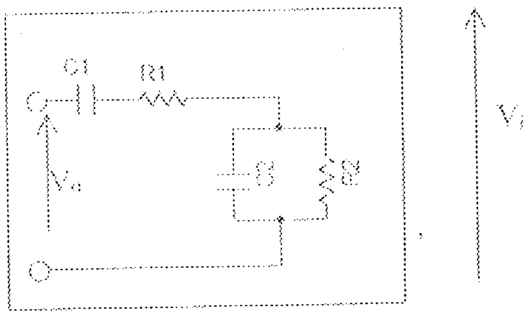


Fig. 3.1

When circuit figure 3 above is treated as a series of parallel potential divider network,

$$V_1 = \frac{V_0 \ X \ \dfrac{R_2 / j\omega C_2}{R_2 + (1/j\omega C_2)}}{R_1 + 1/j\omega C_1 + \dfrac{R_2/j\omega C_2}{R_2 + 1/ j\omega C_2}} \quad \ldots\ \ldots\ \ldots\ldots(4)$$

Multiplying numerator and denominator by ($R_2 + 1/j\omega C_2$)

$$V_1 = \frac{V_0 X \ \dfrac{R_2}{j\omega C_2}}{R_2R_1 + R_1/j\omega C_2 + R_2/ j\omega C_1 + 1/(j\omega)^2 C_1C_2 + R_2 /j\omega C_2} \quad \ldots(4)$$

$$V_1 = \frac{V_0 X j\omega/R_1C_2}{(j\omega)^2 + j\omega\ (1/ R_2 C_2 + 1/ R_1C_1 + 1/ R_1C_2) + 1/C_1C_2R_1R_2}$$

Since $j^2 = -1$ then

$$V_1 = \frac{V_0 \times j\omega / R_1 C_2}{-\omega^2 + j\omega\,(1/R_2C_2 + 1/R_1C_1 + 1/R_1C_2) + 1/C_1C_2R_1R_2}$$

As seen from equation (4) above the necessary angle condition for the expression can only be satisfied if the denominator is also imaginary since the numerator is also imaginary. This will occur at any frequency when the real parts of the denominator become zero.

Therefore ,

$$-\omega^2 + \frac{1}{C_1C_2R_1R_2} = 0$$

$$\omega^2 = \frac{1}{C_1C_2R_1R_2}$$

$$\omega = 1/\sqrt{[C_1C_2R_1R_2]} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Also from equation (4) , voltage ratio at this frequency is given by

$$V_0/V_1 = \frac{j\omega\,(1/R_1C_1 + 1/R_2C_2 + 1/R_1C_2)}{j\omega/R_1C_2}$$

when $j\omega$ cancels and multiplying through by $R_1R_2C_1C_2$

$$V_0/V_1 = \frac{R_1C_1 + R_2C_2 + R_2C_1}{R_2C_1}$$

$$V_0/V_1 = \frac{R_1/R_2 + C_2/C_1 + 1}{1} = R_1/R_2 + C_2/C_1 + 1 \quad \ldots\ldots\ldots 6$$

For practical applications $R_1 = R_2 = R$ and $C_1 = C_2 = C$

Equation (5) and (6) then become

$\omega = 1/CR$ and $V_0/V_1 = 3$

The above results can all be applied to the bridge circuit shown in figure 3.0. V_0 in this case only be in phase with V_1 at the frequency given by equation (5). The amplitude V_0 with now depend on the the ratio R_3/R_4.

In General

$$V_1 = V_0\left(\frac{R_2C_1}{R_1C_1 + R_2C_2 + R_2C_1} - R_3 / R_3 + R_4\right)$$

Equation (6) shows no phase change for V_0/V_1 at the specified frequency. Thus the circuit will be completed by a non-inverting amplifier ($0 + \phi = 0$) having a gain that is reciprocal of the network gain.

Taking the practical case of equal capacitors and resistors, the requisite gain is + 3

3.2 GAIN

Provided the voltage gain of the operational amplifier is at a little higher than the losses through the wien circuit, the circuit will oscilate the zero-phase shift frequency. In order to sustain oscillation, the voltage gain of the amplifier needs to be at least three times. The closed loop voltage gain of the amplifier is set by resistors R_3 and R_4, which form a conventional negation feed back circuit, the voltage gain is equal to:

$$\frac{(R_4 + R_3)}{R_4} = 1 + R_3/R_4$$

In practice, it is not good enough to merely set the voltage gain of the amplifier to over thee times. This would provide oscillation, but the circuit will oscillate too strongly that the output will become severely clipped. This will give an output wave of more like a low quality square wave than a pure sine wave signal. Even if the gain was carefully adjusted to just the right level. It would only require a small change in the loading on the output of the amplifier to either quench oscillation, or to allow it to run out of control.

3.3 AMPLITUDE STABILIZATION

In order to obtain really good result, it is necessary to incorporate an automatic gain control (AGC) circuit. This automatically adjusts the gain of the amplifier so that the output level is maintained at a suitable level. There are various methods of amplitude stabilization as examples of automatic gain control. Use can be made of avalanche diodes (Zener diodes) for automatically controlling the gain of the oscillator and hence stabilizing the amplitude of the sinusoids. An active AGC loop may also be used with a field effect transistor (FET) as a voltage control transistor. The other method, which serves to stabilize the amplitude against variations due to fluctuations, accessioned by the aging of transistors, component etc. is the thermistor/ sensistor method.

3.4 THERMISTOR/ SENSISTOR METHOD OF STABILIZATION

The sensistor / thermistor method is probably the most popular, as it generally gives lower distortion, and it is a much more simple arrangement. Its only real draw back the special thermistors for this application are relatively expensive. One modification consists simply in replacing the resistor R_3 by a sensistor, which has a positive thermal coefficient.

3.5 THERMISTORS AND SENSISTORS

The conductivity of germanium and silicon is found to increase approximately 6-8% per degree increase in temperature. Such a large change in conductivity with temperature places a limitation upon the use of semi-conductor devices in some circuits. On the other hand, for some applications it is exactly this property of semi-conductors that is used to advantage. A semi-conductor used in this manner is called a thermistor. Silicon and germanium are however not used as thermistors their properties are too sensitive to impurities. Commercial tthermistors consist of sintered mixtures of such oscides as NiO and Mn_2O_3.

The exponential decrease in resistivity (reciprocal of conductivity) of a semi conductor should be contrasted with the small and almost linear increase in resistivity of a metal. An increase in the temperature of a metal result in greater thermal motion of the ions, and hence decrease slightly the mean free path of the free electrons. The result is decrease in the mobility, and hence in conductivity. For most metals the resistance increase about 0.4% per degree centigrade increase in temperature.

It should be noted that a thermistor has a negative coefficient of resistance, whereas that of a metal is positive and of much smaller magnitude. A heavily dope semi-conductor can exhibit a positive temperature coefficient of resistance, for under these circumstances the materials acquire metallic properties and the resistance increases because of the decrease in career mobility with temperature. Such a device is called a sensistor. It has a temperature coefficient of resistance +0.7% per degree centigrade.

3.6 PRINCIPLES OF SENSISTOR METHOD OF STABILIZATION

The two paths of positive feed back through $Z_1$and Z_2 whose components determine the frequency of oscillation, and negative feed back through R_3 and R_4 whose elements affect the amplitude of oscillation have a loop gain given by -βA where

$\beta = -Vf\,'/V_0 = -Z_2 / Z_1 + Z_2$ and $A = 1 + R_3/R_4$

The amplitude of oscillation is determined by the extent to which the loop gain -βA is greater than unity. If the output V_0 increases (for any reason), the current in R_4 increases and gain A decreases. The regulation mechanism introduced by the sensistor operates by automatically changing A to keep the gain more constant.

The temperature of R_4 is determined by the roost mean square (RMS) value of the current, which passes through it. If the RMS value of the current changes, then, because of the thermal lag of the sensistor, the temperature will be determined by the average value over a large number of cycles of the RMS value of the current. An important fact to keep in mind about the mechanism just described is that because of the thermal lag of the sensistor, the resistance of the sensistor during the course of a single cycle is very nearly absolutely constant.

Therefore, at any fixed amplitude of oscillation, the sensistor behaves entirely like an ordinary linear resistor. A thermistor which has a negative temperature coefficient can also be used but it must replace R_3 rather than R_4. Increased temperature gives reduced resistance but it is self-eating.

3.7 THE BARKHAUSEN CRITERION

It is of importance to now investigate the basic principles governing the sinusoidal generator.

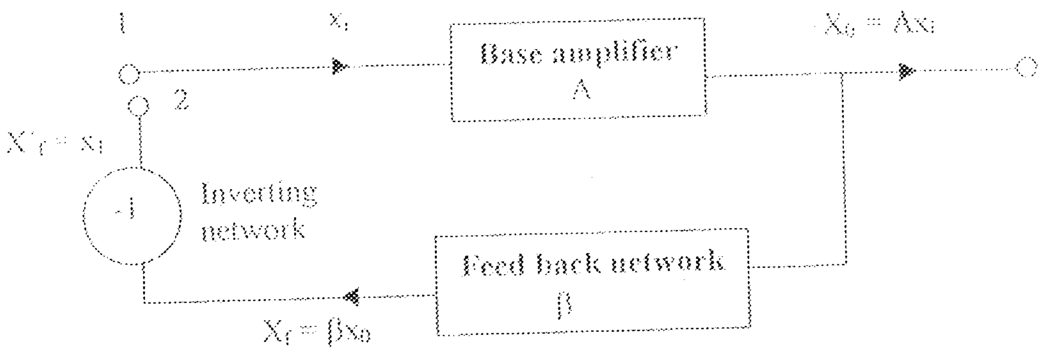


Fig.3.1 (a)

Fig 3.1.4 (a) above shows an amplifier, a feed back network, and an input mixing circuit not yet connected to form a close loop. The amplifier provides an input signal X_0 as a consequence of the signal X_i applied directly to the amplifier-input terminal. The output of the feed back network is $x_f = \beta x_0 = A\beta x_i$, and the output of the mixing circuit (which is simply an inverter) is

$$x'f = -xf = -A\beta x_i$$

From fig 3.1.4 (a) the loop gain is

$$\text{Loop gain} = x'f / x_i = -xf / x_i = -\beta A$$

Suppose it should happen that signals are adjusted in such a way that the signal $x'f$ is identically equal to the externally applied input signal x_i.

It should be noted that the statement $x'f = x_i$ means that the instantaneous values have $x'f$ and x_i are exactly equal at all times. The condition $x'f = x_i$ is equivalent to $-A\beta = 1$.

The loop gain must equal unity. For sinusoidal wave form the equation $x'f = x_i$ is equivalent to the condition that the amplitude, phase and frequency of x_i and $x'f$ must be identical. Hence, the following important principle:

The frequency at which a sinusoidal oscillator

Will operator is the frequency for which the total

Shift introduced; as a signal process form

The input terminals, through the amplifier and feed back network, and back again to the input is precisely zero (or of course, an integral multiple of 2π).

Stated more simply:

The frequency of a sinusoidal oscillator is determined by the condition that the loop gain phase shift is zero

The principle given above determines the frequency, provided that the circuit oscillates at all. Another condition which must

be met is that the magnitude of x_i and $x'f$ must be identical. This condition is then embodied in the following principle:

Oscillation will not be sustained if, at the oscillator

frequency, the magnitude of the product of the transfer

gain of the amplifier and the magnitude of the feedback factor of the feed back network (the magnitude of loop gain) is less than unity.

The condition of unity loop gain $-A\beta = 1$ is called: BACRKHAUSEN CRITERION.

This condition implies of course both the phase of $-A\beta$ in the above principles are consistent with the feedback formula

$A_f = A/1 + \beta A$ for if $-A\beta = 1$ then $A_f \rightarrow \infty$ which may be interpreted to mean that there exists an output voltage even in absence of an externally applied signal voltage.

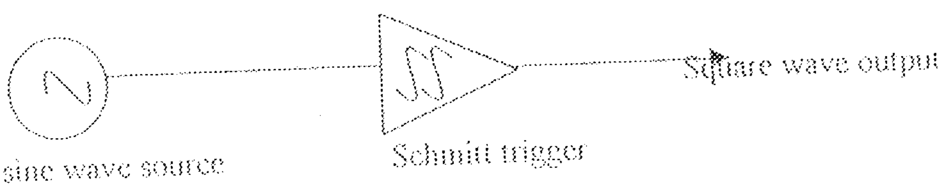
The Barkhausen criterion is used to determine how to cause the system to oscillate and to find the frequency of the sinusoid generated.

While the first two principles stated earlier must be satisfied on purely theoretical grounds, we may add a third general principle dictated by practical considerations

"In every practical oscillator the loop gain is slightly larger than unit, and the amplitude of the oscillations is limited by the onset of non-linearity".

3.8 COMPARATOR OPERATION (SCHIMITT TRIGGER)

The schimitt trigger circuit is one, which the output voltage can only take up either one of the two possible values. The schimitt trigger is employed to convert an input signal of sinusoidal wave shape into rectangular wave form.



Ideally, the schimitt trigger would switch to its high level output voltage as the input voltage wave form passed through its zero crossing from the negative to the positive voltage, and would switch back to its low level output as the input passed through its negative zero crossing. In practice, of course the schimitt trigger must have a finite hysteries range, so the switch takes place a little after each zero crossing.

3.9 OP.AMP SCHIMITT TRIGGER OPERATION

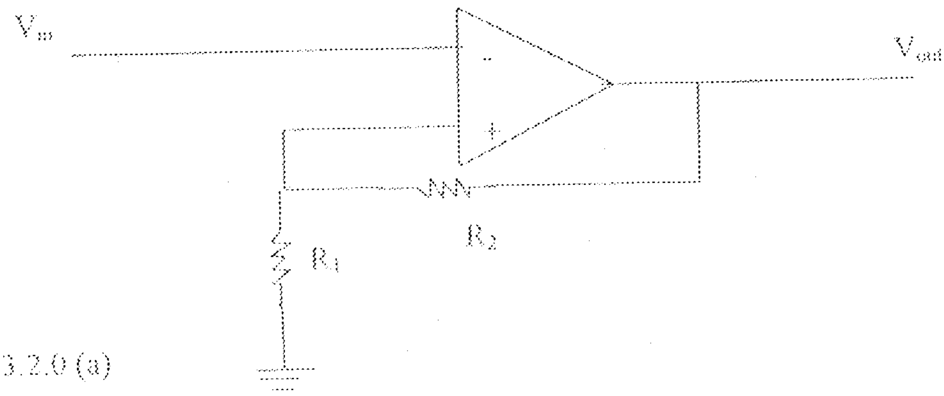


Fig 3.2.0 (a)

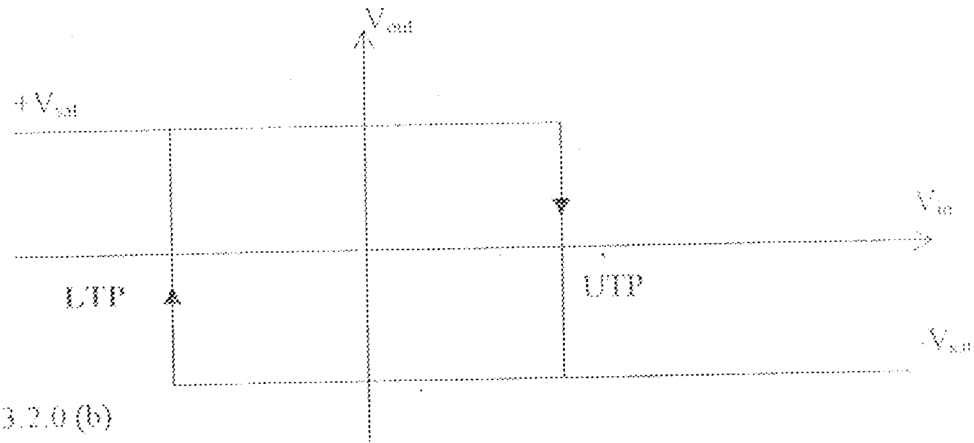


Fig.3.2.0 (b)

Fig 3.2.0(a) shows an op amp schimitt trigger, because the positive feedback to the non-inverting input, the output is saturated in either the positive or negative direction. Assuming the output is positively saturated. Then a positive voltage is feedback to the non-inverting input. This positive voltage is called the upper tripping (UTP). As long as the inverting remains positively saturated. This means the operation point is some where along the upper part of the graph in figure 3.2.0(b)

If we slowly increase the input, we eventually reach a point where it is slightly more positive than the UTP. When this happens, the error voltage changes polarity driving the Op Amp into negative saturation (fig.3. 2.0 (b)). With the output now negative the voltage divider feeds back a negative voltage to the inverting input. This negative voltage is referred to as the lower trip point (LTP). The output remains in negative saturation as long as the input voltage is more positive than the LTP. The only way to change is the output is to decrease the input voltage until it is slightly more negative than the LTP. Then the error voltage changes polarity and the output switches back to the positive saturation.

The UTP is provided by voltage divider resistors R_1 and R_2.

The upper trip point is:

$$UTP = [R_1/(R_1 + R_2)](+V_{sat})$$

where, $+V_{sat} = +V_{out}(max)$ of the comparator

The lower trip point is:

$$LTP = [R_1/(R_1 + R_2)](-V_{sat})$$

One way to generate the rectangular/square waves is to drive a schmitt trigger with a sine wave whose positive peak is greater than the UTP and whose negative peak is less than the LTP.

When equal resistor are used in the voltage divider,

$$UTP = R/2R(V_{sat}) = V_{sat}/2$$

similarly

$$LTP = -V_{sat}/2$$

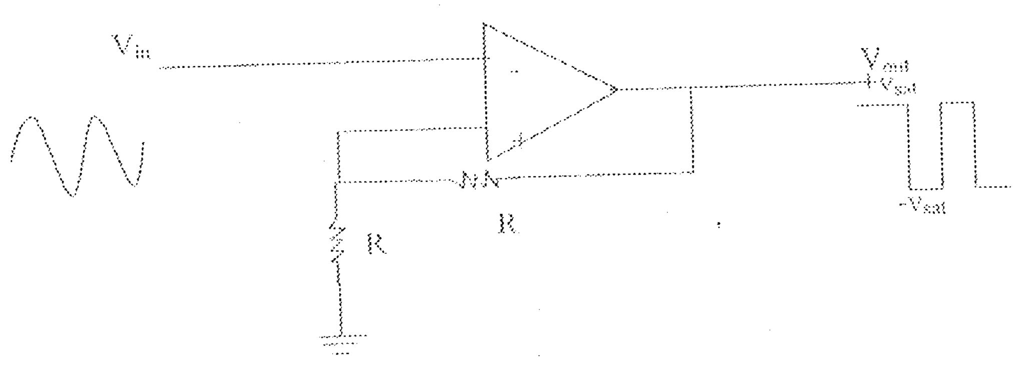


Fig. 3.2 (c)

3.10 OP AMP INTEGRATOR

The Op- Amp integrator employed in this case is used in generator of triangular waveforms the rectangular wave from produced by the schmitt trigger.

We think of integrator as determining the area under a curve. Since Op Amp integrator operates on a voltage over a period of time, we can think of its as proving a sum of voltage over time as illustrated in fig 3.3.0(a) and (b) below

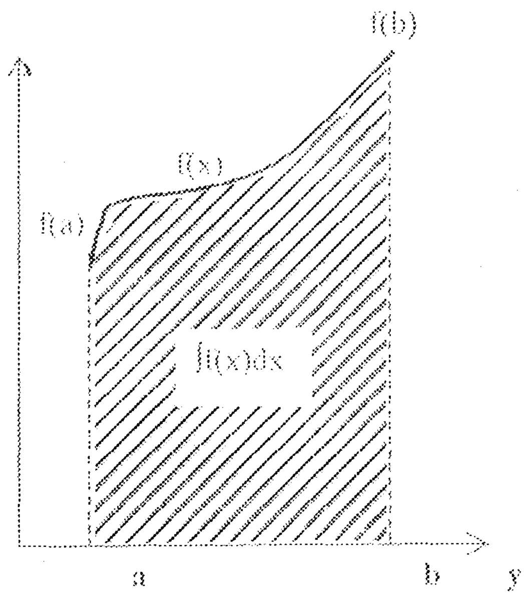


Fig 3.3 (a)

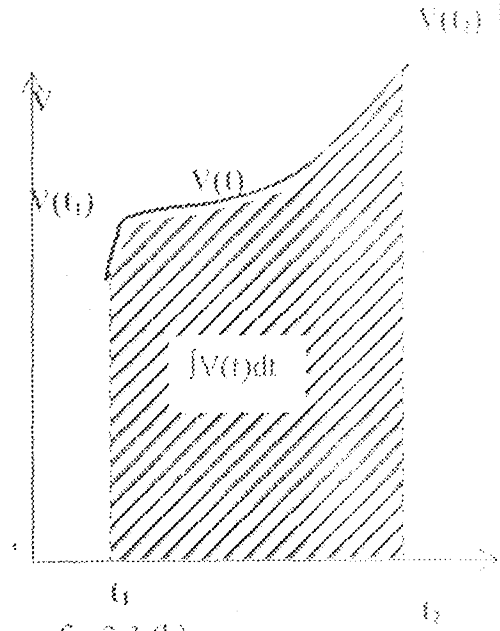
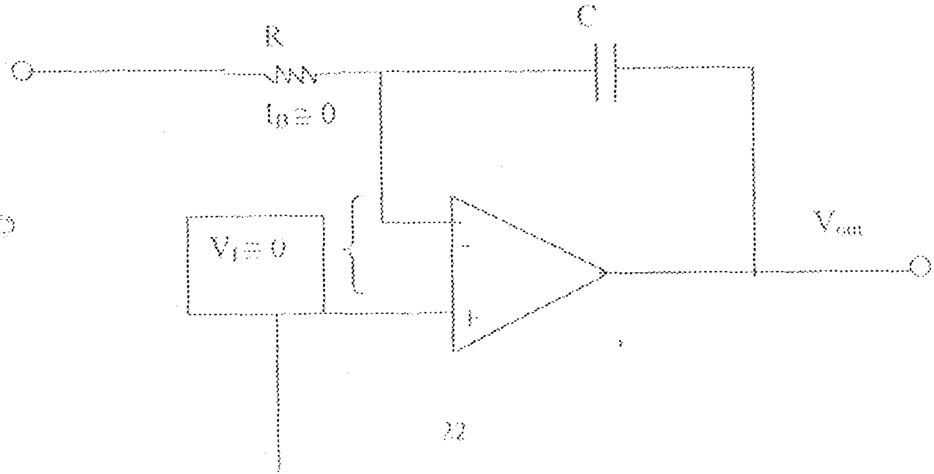


fig.3.3 (b)

Fig.3.3 0 ©



An Op amp integrator has a circuit configuration as shown in the fig 3.3.0(c) above.

To determine the integrating property of this circuit, we recall to determine the integrating property of this circuit, we recall some relations resulting from the definitions of capacitance.

Capacitance = Q/V where

Q = electric charge

V = voltage

We see that Q= CV

And a charge in charge /unit time, that is the capacitor current is given as:

$Ic = dq/dt = CdV/dt$ ... ... (1)

It the op amp is close to ideal $I_B \equiv 0$ and $Vi \equiv 0$ then

$I_R = ic$

$$V_{out} = -1/Rc\int_{t_2}^{t_1} V_1.dt$$

From the equation (1) we find that

$Ic = dq/dt = CdV_C/dt = i_R$

Since, Vi = o and $Vc = -V_{out}$

$Ic = -CdV_{out}/dt = V_1/R = iR$

Solving for dV_{out} we find:

$DV_{out} = -1/Rc(V_1dt)$

Integrating to obtain V_{out}

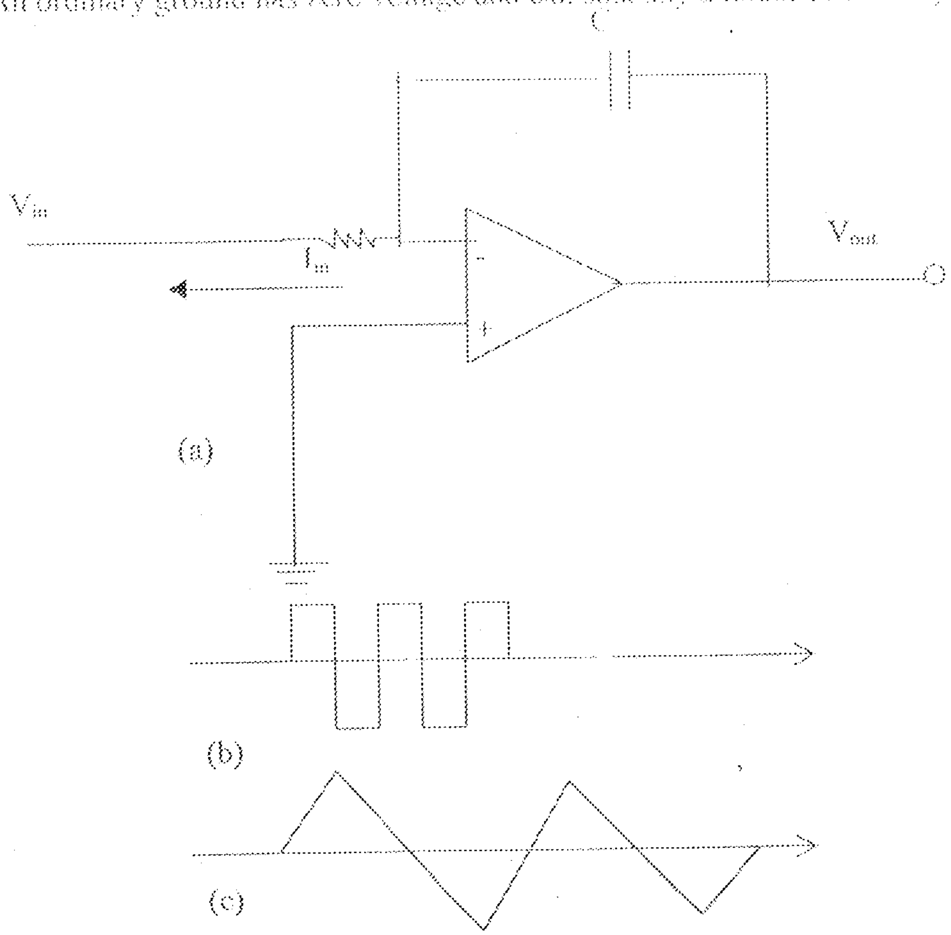
$$V_{out} = -1/Rc\int_{t_2}^{t_1} V_1.dt$$

3.11 PRINCIPLE OF OPERATION OF AN INTEGRATOR

The concept of virtual ground is first analyzed to understand how the integrator works

The operational amplifier has such a high voltage gain that the inverting input voltage approaches zero. Also because of high input impedance, the inverting input has approximately zero current. Since it has approximately zero voltage and current, the inverting input appears as virtual ground. This means it is a ground to voltage, but not to current.

(An ordinary ground has zero voltage and can sink any amount of current).



Because inverting input acts like a virtual ground, the input current of fig 3.3.1(a) is

$i_{in} = V_{in}/R$

Since no current enters the inverting input, all of the input current must go to the capacitor.

$i_{out} = i_{in} = V_{in}/R$

When a capacitor has constant charging current its voltage is a ramp (linear change), because capacitance is defined as

$C = Q/V$

Which is re-arranged as $V = Q/C$

When the current is constant, Q increases linearly. Since V is directly proportional to Q, it increases linearly too. In other words, a constant charging current produces a ramp of voltage across the capacitor

When a square wave as in fig 3.3.1(b) drives the op amp integrator, the output gives a triangular wave as in 3.3.1 (c). A mathematical analysis shows the peak to peak output voltage:

$$V_{out}(p\text{-}p) = \frac{V_{in}(p\text{-}p)}{4fRC}$$

3.12 PRACTICAL INTEGRATOR CONSIDERATIONS

Because a capacitor appears open at zero frequency, the input offset in fig.3.3.1(a) may saturate the op Amp. To avoid this, a resistor is shunted across the capacitor as shown in fig 3.3.2 (a) below. The resistance R_2 is typically 5 - 10 times the input resistance R_1. The shunt resistance has virtually no effect on the output, provided the input frequency is much greater than.

$F = 1/2\pi R_2C$

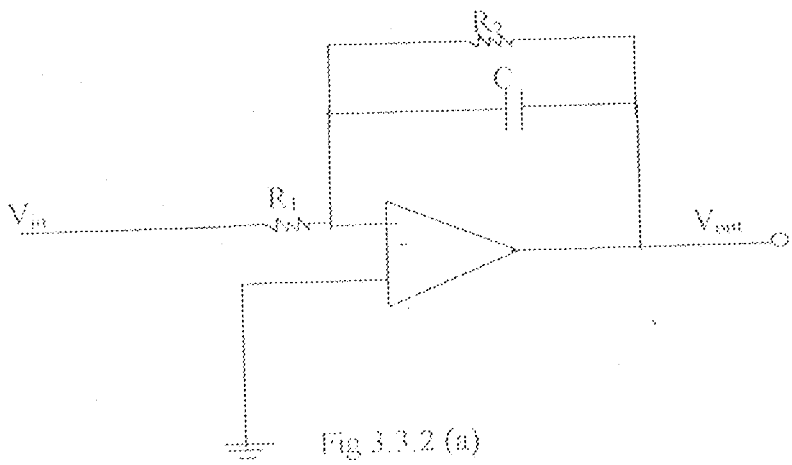


Fig 3.3.2 (a)

Shunt resistor across capacitor to minimize effect of input.

3.13 INTEGRATOR FREQUENCY RESPONSE

The frequency response of an integrator, using a fully compensated op am is shown below in fig 3.3.3.(a). It can be seen that for an open loop integrator, the integrating range is form its first break frequency to some what beyond the integrator crossing frequency. The first break frequency of the integrator is $1/2\pi RA_{OL}C$, with the Miller effect causing open loop gain A_{OL} to appear in the equation. Accuracy improves to about 5% at about three times this frequency through the crossing frequency for a very good op Amp. The crossing frequency of the integrator is $1/2\pi RC$.

When R_2 is added for low frequency stability, it can be seen from fig 3.3.2(a) below that the first break frequency is raised. This is due to Miller effect reduction caused by the low frequency gain reduction from A_{OL} to R_2/R_1. The first break frequency of the compensated integrator is $fx = 1/2\pi R1(R_2/R_1)C = 1/2\pi R_2C$

The integrating range is reduced to between $1/2\pi R_2C$ and a little above $1/2\pi R_1C$.

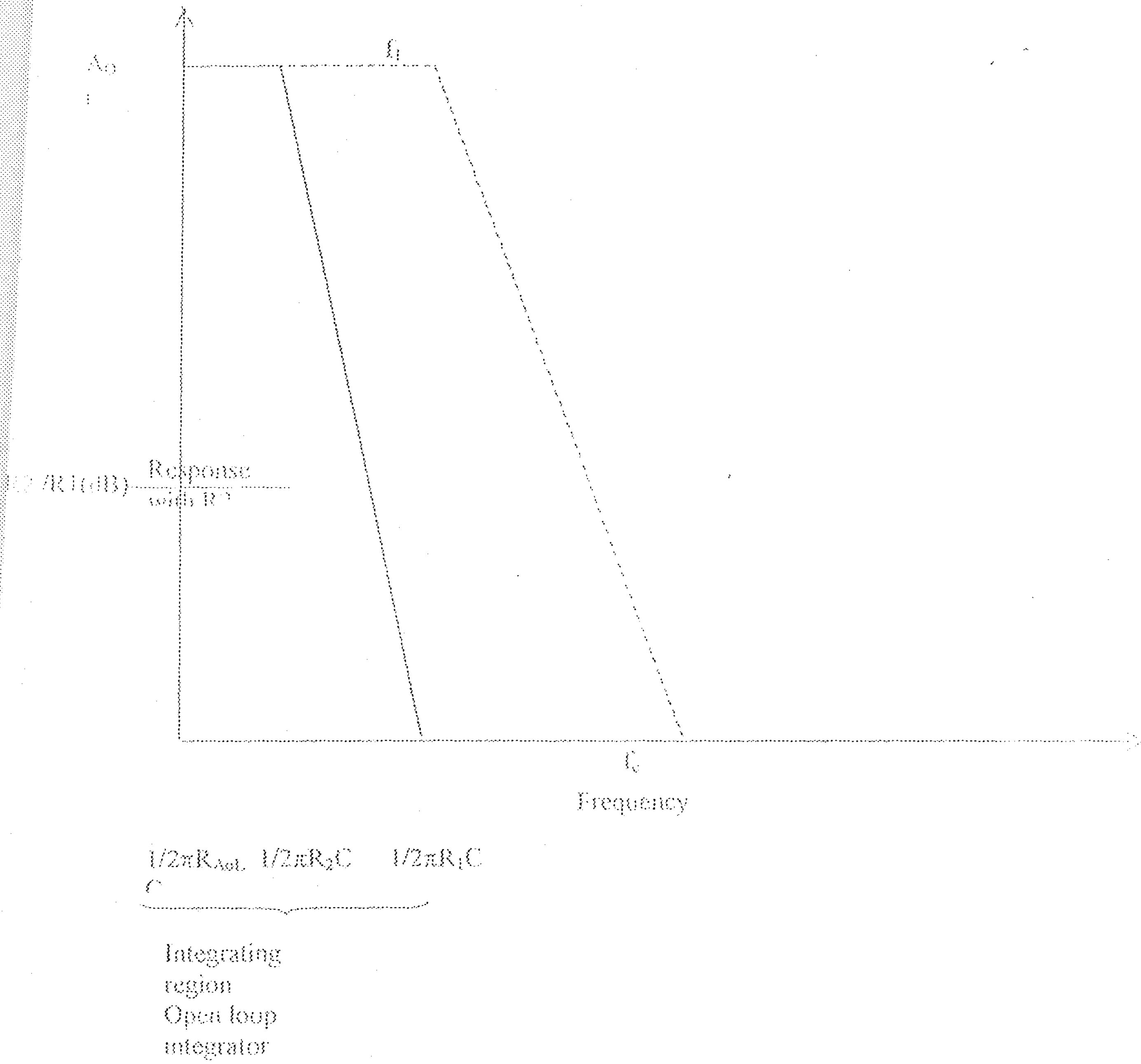

A0
f1
/R1(dB)
Response
with R
fc
Frequency
1/2πRAol 1/2πR2C 1/2πR1C
C
Integrating
region
Open loop
integrator

Fig. 3.3.3 (a)

CHAPTER FOUR

4.0 DESIGN/ WAVE FORMS ANALYSIS AND CONSTRUCTION

4.1 DESIGN ANALYSIS FOR THE POWER SUPPLY CIRCUIT

The aim of it is to design a circuit to supply +/-15V to the waveform generating circuit

Linear IC voltage regulators 7815, to supply +15V and 7915 to supply -15V.

The input voltage range into the 7815 is between 14 to 35 V while that for the 7915 is between -14.5 to 35 V.

a) A.C design procedure

In choosing a filter capacitor, about 8% ripple will be needed. The voltage out of the the capacitor and the voltage regulator =22V=Em

Em=22V=Em

Em= Em/ √2 = 22/√2 ≈ 15V

The rms value of the ripple voltage = (%ripple)V_{dcmL} = 8*15/100 =1.2

Peak to peak ac ripple voltage = 3.5 Vrms = 35*1.2 = 4.2V

Capacitor rating is given by

$C= I/200*V_0$

Assuming I_i = 0.5 A

Therefore C = 0.5 / 200*4.2 = 5952 µF

Choosing a capacitor of 1000µF

Also capacitor is given by WVDC = V_{dcmL} + 20% V_{dcmL} =22 + 4.4 =26.4 V

Thus the one with 30V assumed.

b) the design procedure for determining the transformer and diode values is as follows

V_{dcml} =22V, Erms = 15 V

Therefore a 240 V / 15 V transformer with a current rating of 0.5 a will be needed.

The peak-inverse-voltage (piv) = V + acL + 20%V_{achL} = 22V + 4.4 = 26.4 V

Thus choosing one with Piv = 30 V

V_{dc} supplied by full wave rectifier is given as V_{dc} = 0.636 (Em-2V_t) or V_t = 0.6 for silicon diodes

V_{dc} = 0.636 (22-2*0.6) ≈ 13.23 V

Specifications:

Design values	selected values
Transformer: 240/15 V at 0.5 a →	240/15 V at 0.5 a
capacitor: 595.2 µF WVDC = 26.4 V →	1000µF, 30V
- diode Piv : 26.4 V →	0.5 a, 30 V
- regulator output voltage = +/-15V →	output volt +/-15V

4.2 WIEN OSCILLATOR DESIGN ANALYSIS

As deduced earlier the frequency of the wien oscillator the practical application is given by:

$f = 1/2\pi CR$

since the frequency range specification for the project is between 10HZ to 75 KHZ With the highest frequency specified to be equal to 75KHZ

R_1 is set to be equal R_2 and assumed to be 10KΩ

$\therefore R_1 = R_2 = 10$ KΩ; f = 75 KHZ

$\therefore C = 1/ 2\pi fR = 1/ 2\pi * 75 * 10^3 * 10 * 10^3 = 212.2$ Pf

Therefore the perferred value of 220 Pf chosen

Design values $C_1 = C_2 = 220$ Pf

$R_1 = R_2 = 10$ KΩ

4.3 CALCULATING FREQUENCY LIMITS FOR WIEN OSCILLATOR -

When frequency (highest) f = 75 KHZ

$R_1 = R_2 = 10$ KΩ $C_1 = C_2 = 220$ pf then frequency f = 75 KHz

$\therefore R = 1 / 2\pi fc = 1/ 2\pi * 75 * 10^3 * 220 * 10^{-12} = 99.52$ KΩ

Since 99. 52 KΩ exceeds the variable resistor (10 KΩ) that is designed to be used as frequency control, an alternative parameter variation is necessary.

This makes variation of capacitance C inevitable. Hence selector switches will be used to select capacitor values for different ranges. The capacitor values are therefore selected to give frequency limits within minimum and maximum range. To allow for even frequency range selection four switch selecting point is used to cover the audio frequency range specified for the design of the signal generator.

a) for frequency $f \leq 25$ KHz

$f = 1/2\pi RC$

$C = 1/2\pi fR = 1/ 1/2\pi * 10*10^3 * 25*10^3 = 1.5$ ηf

b) for frequency of between 25 - 50 KHz

$C = 1/2\pi fR = 1/ 2\pi * 10*10^3 * 50 * 10^3 = 318$ Pf

[preferred value of 330 Pf used]

c) for frequency of between 50 – 75 KHz

$C = 1/2\pi Rf = 1/ 2\pi * 10*10^3 * 75 * 10^3 = 212.2$ Pf

[preferred value of 220 Pf used]

Now the 10KΩ variable resistor now saves as the frequency control.

$f_{max} / f_{min} = R_{max} / R_{min}$

Since the frequency range is between 10 Hz – 75Khz

The resistance is in the ratio 100Ω: 9.9 KΩ.

4.4 GAIN/ ESTIMATION OF THE VALUES OF R_3 AND R_4

The closed loop voltage gain of the operational amplifier wien oscillator is set by resistors R_3 and R_4 (fig 3.0) which form a conventional negation feedback circuit.

The voltage gain is given by

$$\frac{R_4 + R_3}{R_4} = 1 + R_3 / R_4$$

As deduced earlier the gain of the oscillator is 3.

The circuit oscillates at zero phase shift amplifier is at least a little higher then losses through the wien circuit. Therefore when feedback amplifier gain is assumed higher by a factor 2.5.

∴ 2.5 X feed back amplifier gain = wien oscillator gain. 2.5 X amplifier gain = 3

amplifier gain = 3/2.5 = 1.2

But amplifier gain = $1 + R_3/R_4$ then $R_3 / R_4 = 0.2$

If R is assumed to be 1kΩ, then

$1000/R_4 = 0.2 \Rightarrow R_4 = 1000/0.2 = 5000\Omega$

$R_4 = 5k\Omega$ (variable resistor)

4.5 SCHIMITT TRIGGER/ZERO CROSSING DETECTOR ANALYSIS

As earlier explained in the previous chapter, the schimitt trigger converts input signal of sine wave shape into a rectangular wave form. It switches to its high level output voltage as the input voltage wave form passed through its zero crossing form negative to positive voltage and vice versa when vin is less then upper trip point (UTP) V_{out} is high. The UTP is provided by voltage divider resistors $R_1$and R_2. UTP = $R_1/(R_1 + R_2)$ (+ V_{sat}).

And V_{sat} = + V_{out} (max) of the comparator (about 1V Less than + V)

UTP = R_1 / (R_1 + R_2) (- V_{sat}).

Calculating the schimitt trigger components the hysterics is set to 2 V, + V = 15 V, - V = - 15 V, + V_{sat} = 14 V and - V_{sat} = -14 V

Now since the hysterics is 2 V and [UTP = (LTP)] for the circuit.

UTP = 1 V and LTP = - 1V

Let assume $IR_1 = IR_2$ = 0.1 mA. The bias current is neglected since $IR_1 >> I_B$

$$R_2 = \frac{(V_{sat}) - UTP}{IR_1} = \frac{14V - 1V}{0.1\ mA} = 130\ k\Omega$$

R_2 = UTP /I R_2 = 1 V/ 0.1 mA = 10 kΩ

It should be noted that the two diodes (IN 916) connected back in the design is purely for protection of the circuit. They do not affect the output of the design in any way

4.6 INTEGRATOR ANALYSIS

It was earlier postulated that f = 1 /2πRC

To allow for the frequency range selection, three switch selecting point is used in the op-amp integrator two as used in the wien oscillator to cover the frequency range specified.

The capacitor used with respect to their frequency ranges are given below :

frequency 25 KMz ≤ f ≥ 10 Hz C = 1.5 nf

frequency 50 KHz ≤ f ≥ 25 KHZ C = 330 pf

frequency 75 KHz ≤ f ≥ 50 KHz C = 220 pf

The value of the resistance R = 10 KΩ.

A mathematical analysis shows the peak to peak output voltage is :

$$V_{out}\ (p\text{-}p) = \frac{V_{in}(P\text{-}P)}{4fRC}$$

when f = 75KHz C = 220 pf R = 10 KΩ

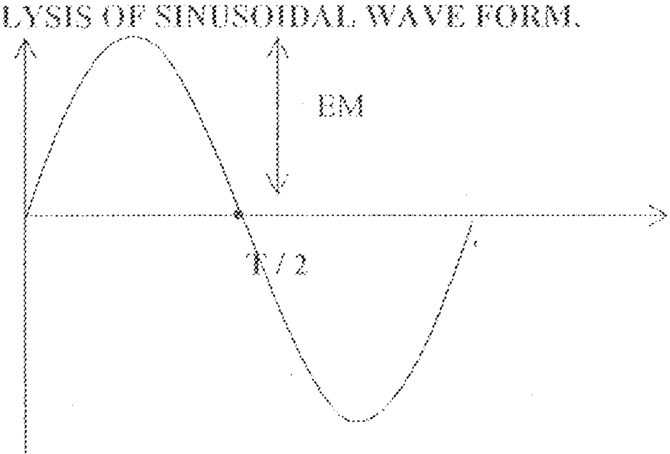
$$V_{om}(p\text{-}p) = \frac{15}{4 \times 75 \times 10^{3} \times 10 \times 10^{3} \times 220 \times 10^{-12}}$$

4.7 WAVE FORM ANALYSIS

The pictorial representation of the wave obtained form the designed signal generator can be observed on the oscilloscope. The three possible wave forms observable on the screen are the sinusoidal wave form, the rectangular wave form and the triangular wave form. It is possible to represent any periodic sine wave form mathematically as a Fourier series of sine and cosine terms at harmonic frequencies. Any non-sinusoidal wave is composed of a constant or a dc term, plus a series of harmonic terms in which the frequencies are integral multiples of the fundamental frequency.

In this analysis, a Fourier analysis of the wave forms being generated by the signal generator is obtained as function of time where Em is the maximum value of the wave and T is the period.

4.8 FOURIER ANALYSIS OF SINUSOIDAL WAVE FORM.



$f(t) = Em \sin \omega t \quad 0 < t \leq T$

since it is an odd function

$A_0 = an = 0$

$$b_n = 2/T \int_0^T (E_m \sin \omega t \sin n\omega t)\,dt$$

$$= 2/T\ E_m \int_0^T (\sin \omega t \sin n\omega t)\,dt$$

$$= (2E_m/T)\,1/2 \int_0^T [\cos(\omega - n\omega)t - \cos(\omega - n\omega)t]\,dt$$

If $\omega \neq n\omega$, $b_n = 0$

If $\omega = n\omega$, then $b_n = 2E_m/T \int_0^T \sin^2 \omega t\,dt$

using the identity

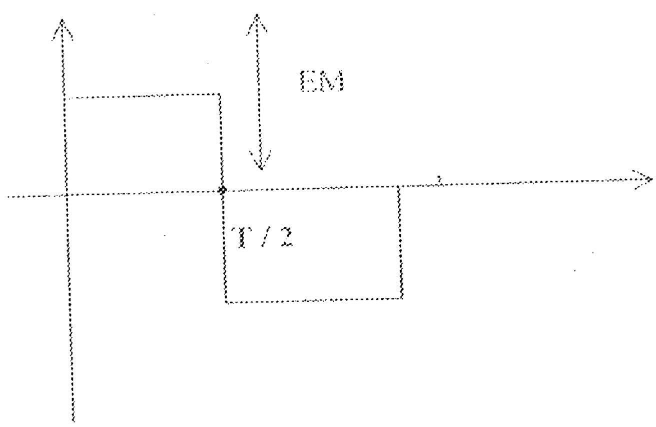
$\sin^2 \omega t = ½(1 - \cos 2\omega t)$

and integrating with respect to t, we will have

$$b_n = 2E_m/T\ \{T/2\} = E_m$$

$\therefore f(t) = E_m \sin(2\pi t/T)$

4.9 FOURIER ANALYSIS OF SQUARE WAVE FORM



$$\begin{cases} Em \quad 0 \le t \le T/2 \\ Em \quad T/2 \le t \le t \end{cases}$$

$$f(t) = A_0 + \sum_{n=1}^{\infty} an \cos n\omega t + bn \sin n\omega t$$

$$A_0 = 1/T \int_0^T f(t)dt$$

$$a_0 = 2/T \int_0^T f(t)\cos n\omega t dt$$

$$b_n = 2/T \int_0^T f(t) \sin n\omega t dt$$

Since it is an odd function

$A_0 = a_0 = 0$

$$bn = 2/T \int_0^{T/2} Em \sin n\omega t dt + \int_0^T -Em \sin n\omega t dt$$

$$= 2Em / n\omega t \, [- \cos n\omega t]_0^{T/2} + [\cos n\omega t]_{T/2}^{T}$$

$$= 2Em / n\omega t \, [\cos n\omega T - 2\cos n\omega T/2 + 1]$$

But $\omega T = 2\pi$

$$bn = Em / n\pi \, [1 + \cos n\omega T - 2\cos n\omega T/2]$$

$$= Em / n\pi \, [2 - 2\cos n\pi]$$

$$= 2Em / n\pi \, [1 - \cos n\pi]$$

$= 2Em / n\pi [1 - (-1)^n]$

bn= 0 for n = 0, 2,4…….. ……..

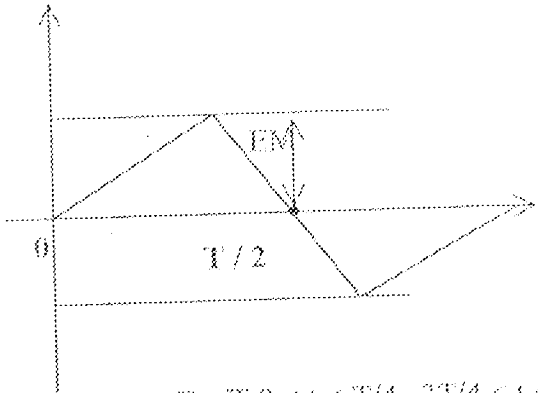
bn= 2Em /πn for n = 1,3 …….

Therefore

$$f(t) = 4Em / \pi \sum_{n=1}^{\infty} 1/n \sin n\omega t, \ \omega = 2\pi/T$$

$$f(t) = 4Em / \pi \sum_{n=1}^{\infty} 1/n \sin n\omega t/T$$

4.10 FOURIER ANALYSIS OF TRIANGULAR WAVE FORM



$$f(t) = \begin{cases} 4Em/T & 0 \le t \le T/4,\ 3T/4 < t < T \\ -4Em/T, & T/4 \le t \le T/2,\ T/2 \le t \le 3T/4 \end{cases}$$

$A_0 = a_n = 0$

$$bn = 2/T \int_0^T 4Em/T \sin \omega t$$

$$bn = 8Em/T^2 \int_{-\infty}^{\infty} t \sin n\omega t dt$$

$$bn = 8Em/T^2 \int_0^{T/4} t \sin n\omega t dt - \int_{T/4}^{T/2} t \sin n\omega t dt - \int_{T/2}^{3T/4} t \sin n\omega t dt + \int_{3T/4}^{T} t \sin n\omega t dt$$

Integrating by part gives

$$\int_{-\infty}^{\infty} t \sin n\omega t dt = [\, t(-\cos n\omega t/n\omega)]_{-\infty}^{\infty} + 1/n\omega \int_{-\infty}^{\infty} \cos n\omega t dt$$

$$\int_{-\infty}^{\infty} t \sin n\omega t dt = [\, t(-\cos n\omega t/n\omega)]_{-\infty}^{\infty} + 1/n\omega [\sin n\omega t/ n\omega]_{+\infty}^{-\infty}$$

using integrating over respective intervals and noting that $\omega t = 2\pi$

$bn = 8Em / T^2 \{ [\, T/ 4n\omega + 1/n\omega^2 \,] - [\, T/ 4n\omega + 1/n^2\omega^2 \,] - [\, - T/ 4n\omega + 1/n^2\omega^2 \,] + [\, T/ -$

$4n\omega + 1/n^2\omega^2 \,]$

$= 8Em / T^2[4/ n^2\omega] = 8Em / \pi^2 n^2$

Therefore

$$f(t) = 8Em / \pi^2 n^2 \sum_{n=1}^{\infty} 1/n^2 \sin(2\pi nt/T)$$

$$f(t) = 8Em / \pi^2 n^2 \sum_{n=1}^{\infty} (-1^{(n-1)/2})1/n^2 \sin(2\pi nt/T)$$

CHAPTER FIVE

5.0 TESTING, VALIDATION, RECOMMENDATION AND CONCLUSION

5.1 CONSTRUCTION AND VALIDATION

The essence of the project is to design a signal generator that:

a) produces sine, square and triangular wave forms

b) the audio frequency covers frequency range of 10Hz – 75 Kz

c) the amplitude is between 1V – 12 v variations

d) has highly stabilized amplitude and voltage amplification.

e) Generates exceedingly good wave outputs

f) Has good frequency stability

As earlier enumerated the construction is based on the principle that a wien bridge oscillator produces the sine wave. The sine wave also drives a schimitt trigger to produce a square wave. Finally, the square wave drives an integrator to produce a triangular wave.

The construction was connected on the bread board and the corresponding wave form outputs observed with some adjustments made. The construction work was made easy through the use of the bread board. Sine the whole unit can be divided into sub-units, each of the stages was mounted on the bread board to test its performance before moving to the next stage.

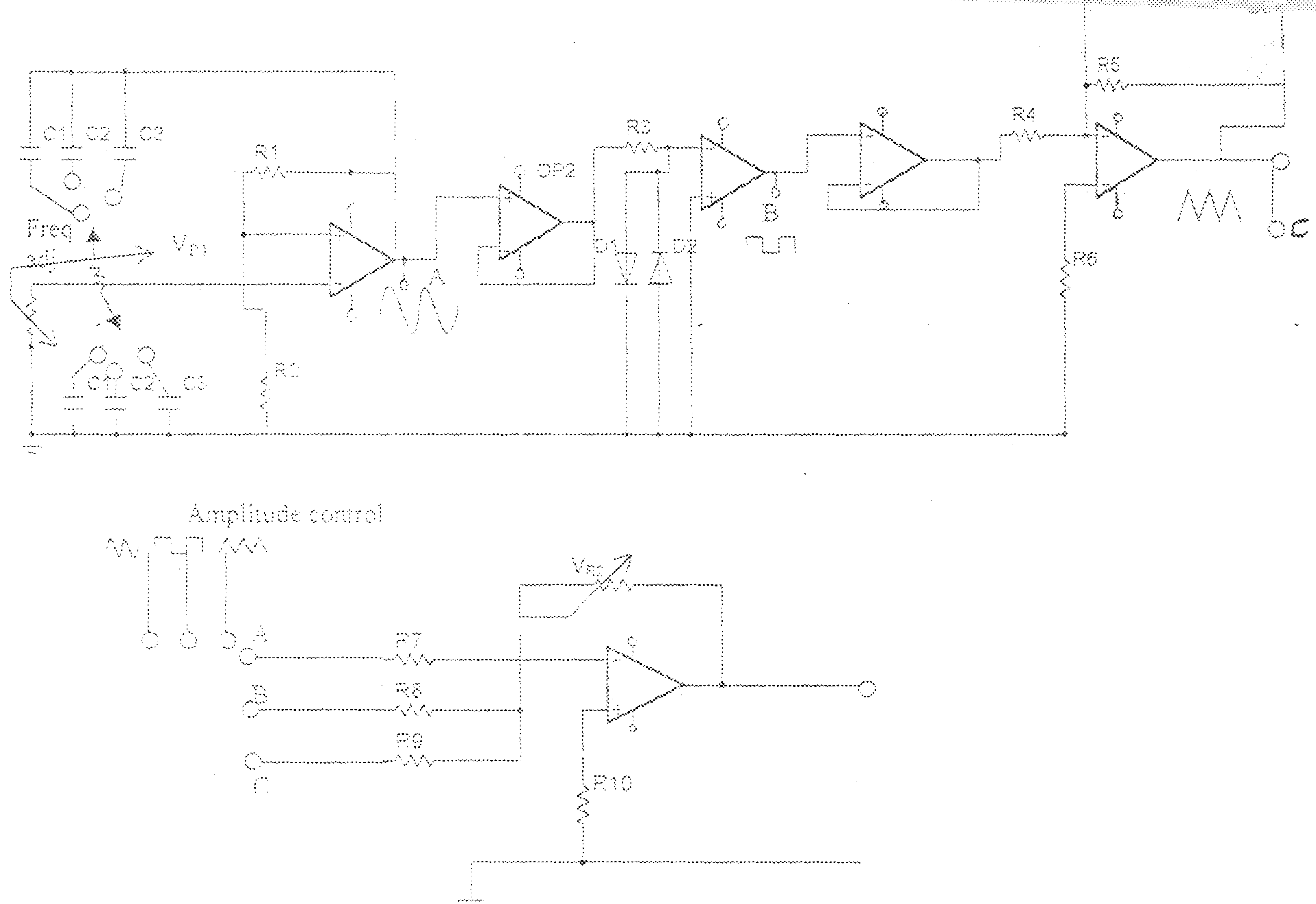
It was then followed with the transferring of the boarded project on the circuit board soldering. The soldering on this circuit board was also done in stages. As part of precautions observed, the compon-nt and the board were "thinned" , so as to avoid dry points and over heating of the board components correct polarities were also observed.

5.2 TESTING AND PERFORMANCE EVALUATION

Every electrically designed constructional project must be subjected to te[...] order to determine the performance of the desired functions of the project. The desi[...] signal generator was tested okay with the desired output waveforms taking note o[...] frequency variations in the audio range.

5.3 CIRCUIT MODEL

The complete circuit diagram of the designed audio signal generator is as sh[...] in fig 5.3.0 below- (next page)



Complete circuit diagram for the audio signal generator.

5.3 PROBLEMS AND SOURCES OF ERRORS

Because of the wide frequency range of coverage, sustaining oscillations at these frequencies was not a simple task. The provision for capacitors for varying range of frequencies for the wien circuit and integrator circuit was highly demanding

Use was also made of internally compensated integrated circuit (IC) while the operational voltage amplifiers were employed at the subsequent output wave forms to gater for the lost wave form amplitude

5.4 MAINTENANCE AND RELIABILITY

The design and construction of the audio signal generator is of much a grade of precision that its reliability is particularly commendable. The signal generator is suitable for use in any condition. The only maintenance is its proper handling of its use and possible replacement of a protective fuse in the power supply unit

The design is also characterized by the advantage that, when there is technical fault in the system, it is relatively easy to repair. The construction is in stages and each stage can be maintained separately to quickly find out where the fault is. It is, however advised that such be reported to the manufacturer or designer.

5.5 RECOMMENDATION

There are many other techniques of generating waveforms of this nature. But, the method adopted here was of simple operation and good reliability. There is a comparatively better output wave form results.

A signal generator of this nature is indispensable instrument/ equipment in any electronic laboratory and electronic repair centers. It is, therefore, recommended that this effort be encouraged considering its importance and comparative cost advantage it offers.

5.6 CONCLUSION

The construction of this audio signal generator was carried out according to the design specification and analysis discussed in chapter three. The analysis of the results obtained aided the construction within the limit of error

Effort has been made in this project to provide three major wave form signals for use in communication world. The device has been designed to complement or serve as an alternative to the conventional (usually expensive) signal generator

Signal generator.

Signal generators are used in radar, Audio frequency noisé generation, FM-RF generation, for digital electronics as in computers and also in synchronization of pulses , etc

The design of the device can be amended and changes made to increase the flexibility vis-a- vis to improve performance and minimize cost of production

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