A PROJECT REPORT

ON

DESIGNS AND CONSTRUCTION

OF

A 6-WATTS FREQUENCY MODULATION (FM)

TRANSMITTER

WITH

AUTOMATIC FREQUENCY CONTROL (AFC)

INCORPORATED

OLADEJI F. O.

95/4578

DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

NIGER STATE, NIGERIA.

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (B. ENG.) ELECTRICAL/COMPUTER

DECEMBER, 2000

CERTIFICATION

This is to certify that I, (Oladeji, Francis Oladoye 95/4578) had successfully completed the project on Design and Construction of a 6 Watts Frequency Modulation (FM) Transmitter with Automatic Frequency Control (AFC) for the award of Bachelor of Engineering Degree, Department of Electrical and Computer Engineering, Federal University of Technology, Minna, Niger State, Nigeria.

____________________ ____________________

MR. USMAN, ABRAHAM U. SIGN/DATE

SUPERVISOR

____________________ ____________________

DR. (ENGR.)Y. A ADEDIRAN SIGN/DATE

HEAD OF DEPARTMENT

____________________ 17/1/2001

EXTERNAL EXAMINER SIGN/DATE

DECLARATION

I hereby declare that this thesis is my original work and has never been presented elsewhere for the award of any degree. Information derived from published and unpublished work of others has been duly acknowledged in the text.

OLADEJI, FRANCIS ____________ ____________

STUDENT'S NAME SIGNATURE DATE

DEDICATION

This work is dedicated to the honour of God, the Father of our Lord Jesus Christ, to my parents Mr. & Mrs. E. O. Oladeji, my sisters Grace and Rachel, and to my brothers Johnson, Solomon and Ebenezer.

You all mean a lot to me. This is to you.

ABSTRACT

This project is on the Design and Construction of a 6-Watts Frequency Modulated (F.M) transmitter with Automatic Frequency Control (AFC) Incorporated.

It is designed to operate between 88-108 MHz. A special integrated circuit (IC) used for voltage amplification met gain and phase matched channels requirements.

Also, the op-amp for low pass filter is overload protected on input and output with no latch-up when common mode range is exceeded.

External compensation capacitor is incorporated in the circuit for stability.

The use of integrated circuit (IC) in the design is responsible for the reduced size and weight of the system.

services, and are used mainly at very high frequencies for broadcasting purposes. Frequency Modulation provides greater signal-to-noise ratio than Amplitude Modulation for the same antenna input power. This is also an advantage in operating at very high frequencies, where noise is considerably less than at the lower or medium frequency bands.

1.2 AIMS AND OBJECTIVES

The aim of this project is to achieve a 6-watts Frequency Modulation (FM) transmitter with Automatic Frequency Control (AFC) incorporated which, to some extent, can transmit messages with some degree of accuracy as well as quality.

The power a transmitter delivers to the antenna may vary from a fraction of a watt to 1,000,000 watts. Lower powers are used mainly for portable or mobile services, while higher powers are required for broadcasting over large areas and in point-to-point communications.

There are various types of devices used in communication systems such as radio transmitter and receiver. Therefore, it is noteworthy that communication would not be completed if the transmitting end is neglected. Hence in this project, we shall look into the transmitter which is designed to translate audio frequency spectrum and to amplify the signal to the desired radiation power level.

However, frequency modulation can simply be defined as the process that occurs when the carrier frequency is made to vary about its unmodulated value in such a way that the instantaneous deviation is directly proportional to the instantaneous amplitude of the modulating signals and the rate at which the carrier frequencies varies is identical to the frequency information of the message.

As a result of this modulation process, the frequency band of the message signal is shifted to a suitable region within the spectrum so that transmission over a communication channel becomes feasible.

1.3 METHODOLOGY

There are two types of transmitters: The high level transmitter and the low level transmitter. Low level transmitter is the one in which at the output of the oscillator, the power of

1.5 PROJECT OUTLINE

The design and construction of a 6-watts FM radio transmitter with Automatic Frequency Control (AFC) is meant to transmit signals up to 300 meters distance and is a way of exposing students to the practical knowledge of their profession. It prepares students to be competent in their disciplines.

This project cover four chapters in which Chapter One briefly and carefully introduces the project topic, the aims and objects, the method used in the design of an FM transmitter, and some relevant history about the work of great scientists and engineers in the field of communications.

Chapter Two deals with the design and calculation in which components used and how their respective values were arrived at through calculation and in some cases preferred value used.

Chapter Three is designed to cover testing, method of troubleshooting and reliability of the project.

Lastly, Chapter Four of the project deals with Conclusion, Recommendation and Reference of the books consulted for the purpose of the project.

2.3 MICROPHONE

A microphone is typically a transducer, which converts acoustic signals i.e sound waves, into electric signals. Different types of microphones exist for different types of applications which range from telephone handset transmitter, public address system, recording, broadcasting to scientific measurements. Factors to be considered before choosing a suitable type of microphone include amongst others cost, robustness, frequency response, size, sensitivity, etc.

In this project, a crystal microphone was used which operates on the principle of piezo electric effect. Its frequency response depends largely upon its dimensions. The microphone is converted to commonly use one (carbon microphone) as shown in figure 2.3.

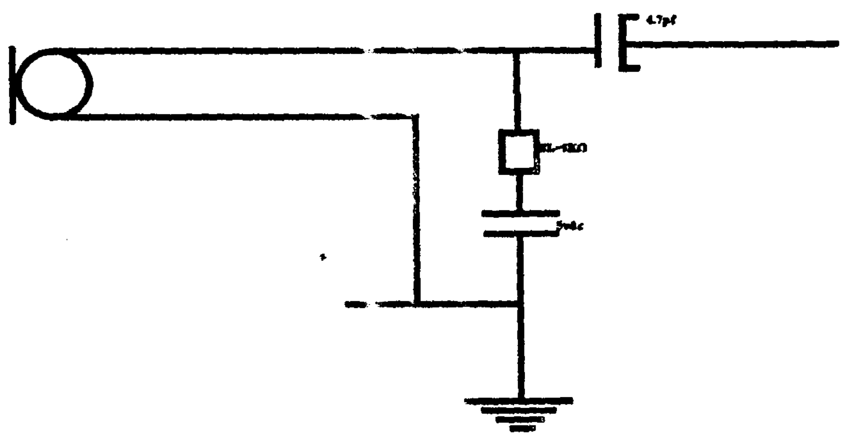


Fig 2.3 Carbon microphone circuit diagram

2.4 PRE-AMPLIFICATION STAGE

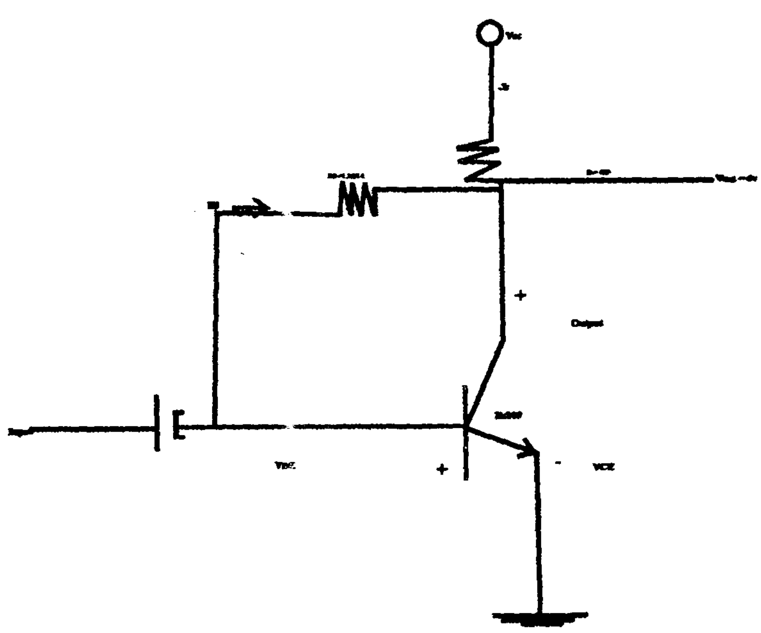


Fig.2.4 Pre-amplification circuit diagram

Therefore, the current I_B used to bias the transistor is 3.33μA

To calculate RB:

From equation 2.2

$$V_{CE} = I_B R_B + V_{BE}$$

But V_{BE} for silicon transistor is 0.7volts

$$\begin{aligned}
&\therefore V_{CE} = I_B R_B + 0.7 \\
&I_B R_B = V_{CE} - 0.7 \\
&R_B = \frac{V_{CE} - 0.7}{I_B} \\
&= (6 - 0.7)/3.33x10^{-6} \\
&R_B = 1.56M\Omega
\end{aligned}$$

Vout = $V_{CC} - I_C R_C$

$$\begin{aligned}
&12 - 1x10^{-3} x6x10^{3} = 12 - 6 = 6v \\
&\therefore Vout = 6v
\end{aligned}$$

2.5 VOLTAGE AMPLIFICATION STAGE

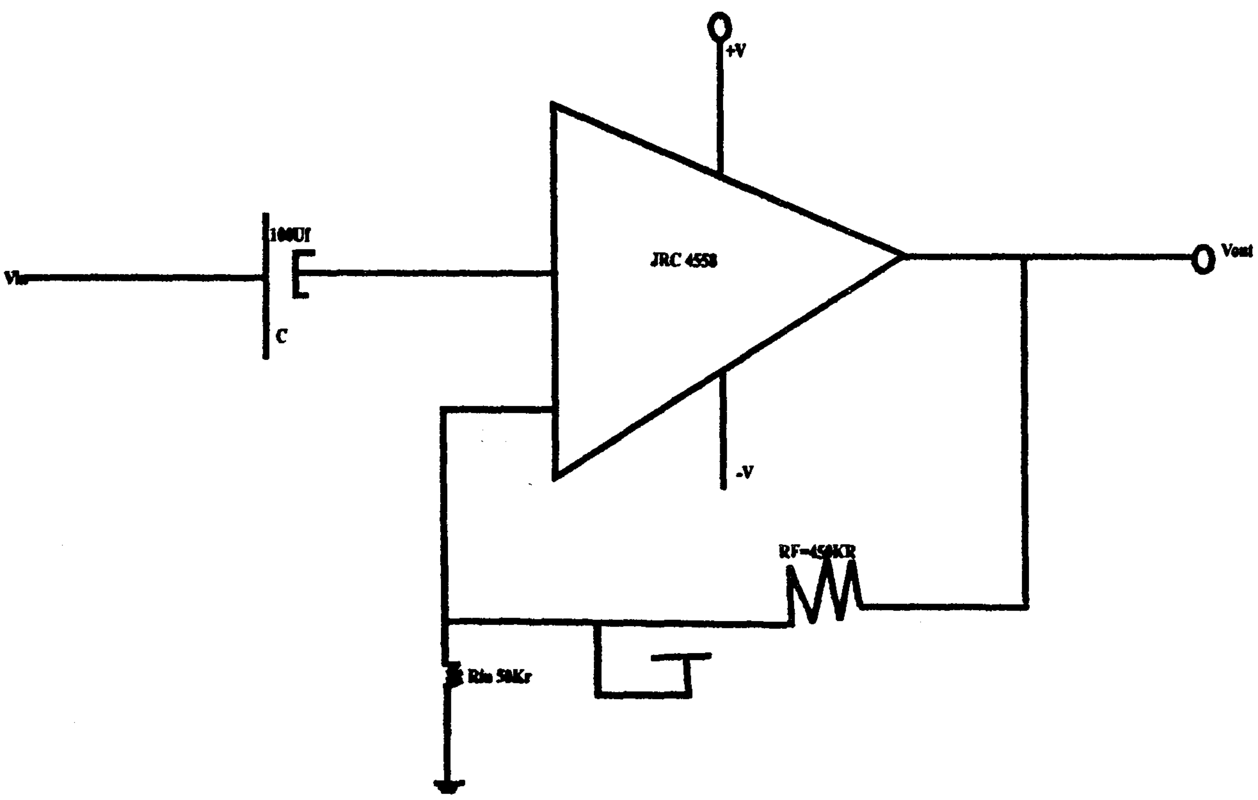


Fig 2.5 JRC 4558 Op-Amp Circuit for voltage amplification.

2.6.3 **LOW- PASS FILTER DESIGN CONSIDERATION.**

1. Obtain data for low pass filters normalised for wc=1rad/s using butterworth table.

2. Based on 1, it is easier to obtain a normalised active filter circuit first as follows:

(a) Select at least one capacitance as C = 1f

(b) Other capacitance should be a lower or high multiple of 1f

(c) Capacitance Value of capacitor in (b) must be selected in such a way that calculation under the radical of G_2 yield a positive number

3. Conductance is the reciprocal of the resistance (symbol G), the unit of conductance is siemens.

Calculate conductance G_1 G_2 and G_3 using the following formulae

$b_0 = G_2\, G_3/C_1$-----------------------------------2.6

$b_1 = G_1 + G_2+G_3$-----------------------------------2.7

$K = R_2/R_1 = G_1/G_2$ -----------------------------------2.8

4. Carry out the Denormalization process

(a) Denormalization is carried out by dividing the capacitor – normalised values by impedance scaling factor (1sf) and by multiplying Resistor normalised values by impedance scaling factor.

(b) Denormalised value (Practical Value) of the capacitor C_p is given as

$$C_P = \frac{C_n}{\mu(isf)} where\, \mu = \frac{w_C}{w_n}$$

C_p = practical capacitor value

C_n = Normalised capacitor value

μ = Frequency normalizing factor

Isf = impedance scaling factor

$W_c = 2\pi f_c$, the desired cut off frequency expressed in radian/second

$W_c = 2\pi f_n$, the normalised cut off frequency expressed as Iradian/second.

(c) Denormalised resistor Value (practical Value) Rp is given as

R_p = Rn (Isf)

Based on design consideration;

To find the low pass filter normalised value for Wo = rad/s

Using Butterworth table;

Selecting $C_2 = 1f$

Form the table $b_o = 1$, $b_1 = 1.41421$

Also the constant K of the active filter circuit, which represent the circuit gain is set to be 10 while the cut of frequency fc = 3.4kHZ been the maximum frequency of the audio voice signal.

Then, selecting a lesser multiple of C_2

i.e $C_1 = 0.001 = 1mf$

Recall equation 6,7 and 8

$$bo = G_1G_3/C_1$$

Hence

$$G_3 = \frac{b_0C_1}{G_2} \text{------------------(a)}$$

$$b_1 = G_1 + G_2 + G_3 \text{----------(b)}$$

$$K = \frac{R_2}{R_1} = \frac{G_1}{G_2}$$

Hence

$$G_1 = KG_2 \text{-----------------(c)}$$

Putting (a) and (c) in (b), and solve for G_2 results in therefore,

$$b_1 = KG_2 + G_2 + b_0C_1/G_2$$

Also

$$b_1G_2 = KG_2^2 + G_2^2 + b_0C_1$$

$$\therefore G^2_2 (K+1) - b_1G_2 + b_0C_1 = 0$$

Hence

$$G_2 = \frac{b_1 \pm \sqrt{b_1^2 - 4(K+1)boC_1}}{2(4+1)}$$

$$\frac{1.41421 \pm \sqrt{(1.4142)^2 - 4(11)0.001}}{2(11)}$$

$$= \left(1.4142 \pm \sqrt{1.9559899}\right)/22$$

$$\left(1.4142 + 1.398567088\right)/22$$

$$2.812777 / 22 = 0.1279$$

$$G_2 = 0.1279 \ mho$$

But ,

$$G_3 = C_1 bo / G2$$

$$\frac{\left(1 \times 10^{-3}\right)(1)}{0.1279} = 0.0078$$

$$G_3 = 0.0078$$

Also from equation (c)

$$G_1 = KG_2 = 10x0.1279 = 1.279$$

Hence

$$G_1 = 1.279$$

$$G_2 = 0.1279$$

$$G_3 = 0.0078$$

To find the practical value

Scaling factor Isf = $\frac{f_c}{20\pi}$

Where fc = 3.4×10^3

$$R_1 = \frac{1}{G_1} \times Isf = \frac{1}{1.279} \times 3.4 \times 10^3 / 20\pi$$

But k =10 common factor

$$\therefore R_1 = 42.309 \times 10$$

$$= 423\Omega$$

$$R_2 = \frac{1}{G_2} \times Isf$$

$$= \frac{1}{0.279} \times \frac{170}{\pi}$$

$$= 193.952$$

Also K = 10 = common factor

$$R_2 = 193.952 \times 10$$
$$= 1939.52$$
$$\therefore R_2 = 1.940 K\Omega$$
Also
$$R_3 = \frac{1}{G_3} \times Isf$$
$$= \frac{1}{0.0078} \times \frac{170}{\pi}$$
$$= 6921.012$$

Multiply by common factor =10

$$\therefore R_3 = 69210.12$$
$$R_3 = 69.21 k\Omega$$

To find the capacitance of the capacitors

Frequency normalized factor "μ" is given as

$$\mu = \frac{w_c}{w_n} = \frac{2\pi fc}{2\pi fn}$$
$$but\ 2\pi fn = 1$$
$$= \frac{2\pi \times 3.4 \times 10^3}{1} = 6.8\pi \times 10^3$$
$$\therefore \mu = 21.36283 \times 10^3$$

Applying the formular

$$C_p = C_n / (\mu \times Isf)$$

For $C_n = C_2$ = 1f (as selected before)

$$C_p \frac{1}{(21.36283 x 10^3) \times \frac{170}{\pi}}$$
$$= 865.05 x 10^{-9}$$
Also
$$C_p = C_2 = \frac{865.05}{10} = 86.5 \times 10^{-9}$$
Hence,
$$C_2 = 86.5 nf$$

To calculate the values of inductor used in the oscillating tank;

$$F = \frac{1}{2\pi\sqrt{LC_t}}$$
$$\frac{1}{2x3.142\sqrt{LC_t}}$$
$$\sqrt{L} = \frac{1}{2\times3.142\times108\times10^6\times\sqrt{111.73x10^{-12}}}$$
$$\sqrt{L} = 1.393951\times10^{-4}$$
$$L = 1.18065\times10^{-2}$$
$$Hence$$
$$L = 11.8065mH$$

Dynamic Resistance r^s of the oscillator when there is resonance:

Q = $2\pi fo/r^s$, where Q of the transistor used is 1M and fo is the maximum frequency of transmission.

$$Q = 2\pi foL / r^s$$
$$1x10^6 = \left(2\times3.142\times108\times10^6\times11.8065\times10^{-3}\right)/r^s$$
$$r^s = \left(2\times3.142\times108x10^6\times11.80657\right)/1\times10^6$$
$$r^s = 8011788.475/1\times10^6$$

$$= 8.011788475$$

But the prefered used:

$$r^s = 10.735199\Omega$$

To calculate R_B;

$R_B = [(V_{CC} - V_{BE})2BR_C]/V_{CE}$

But $R_C = r^s$

$$R_B = \left[(12-0.7)\times2\times300\times10.735\right]/12$$
$$= (11.03\times2\times300\times10.735)/12$$
$$= 71045.54757/12$$
$$= 5920.462297$$
$$R_B \approx 6k\Omega$$

2.8.2 **ANTENNA DESIGN.**

For this project the small radiator ($L \leq \lambda$) is used which is for frequencies in the range 10kHZ-IGHZ. This category includes single dipole and slot radiators, strip and micro strip antennas; loop antennas and frequency-independent radiators. Knowing the frequency of the transmission to be 100MHz, the length or the antenna is calculated by the relation $\lambda = V/F$

Where:

V= velocity of sound in air = 3x108 ms^{-1}

F = Frequency at which the signal is to be radiated

λ = wave length of the signal

$\therefore \lambda = 3 \times 10^8 \, ms^{-1} / 100 \times 10Hz = 3m$

Hence,

$\lambda = 3m$

Since 3m single- dipole and slot radiators antenna was not available in market, a strip of copper wire which length –equals 3m was wound round a ferrite-rod.

To obtain better efficiency, the antenna must be able to radiate large fraction of the supplied power hence, there is a need for the antenna length to approach a quarter wavelength of working frequency.

$$\therefore length = \frac{\lambda}{4} = 3/4 = 0.75m$$

To convert the unit to cm

Length = 0.75m x 100 = 75cm.

Hence, at the frequency of operation, the antenna required will be of length 75cm.

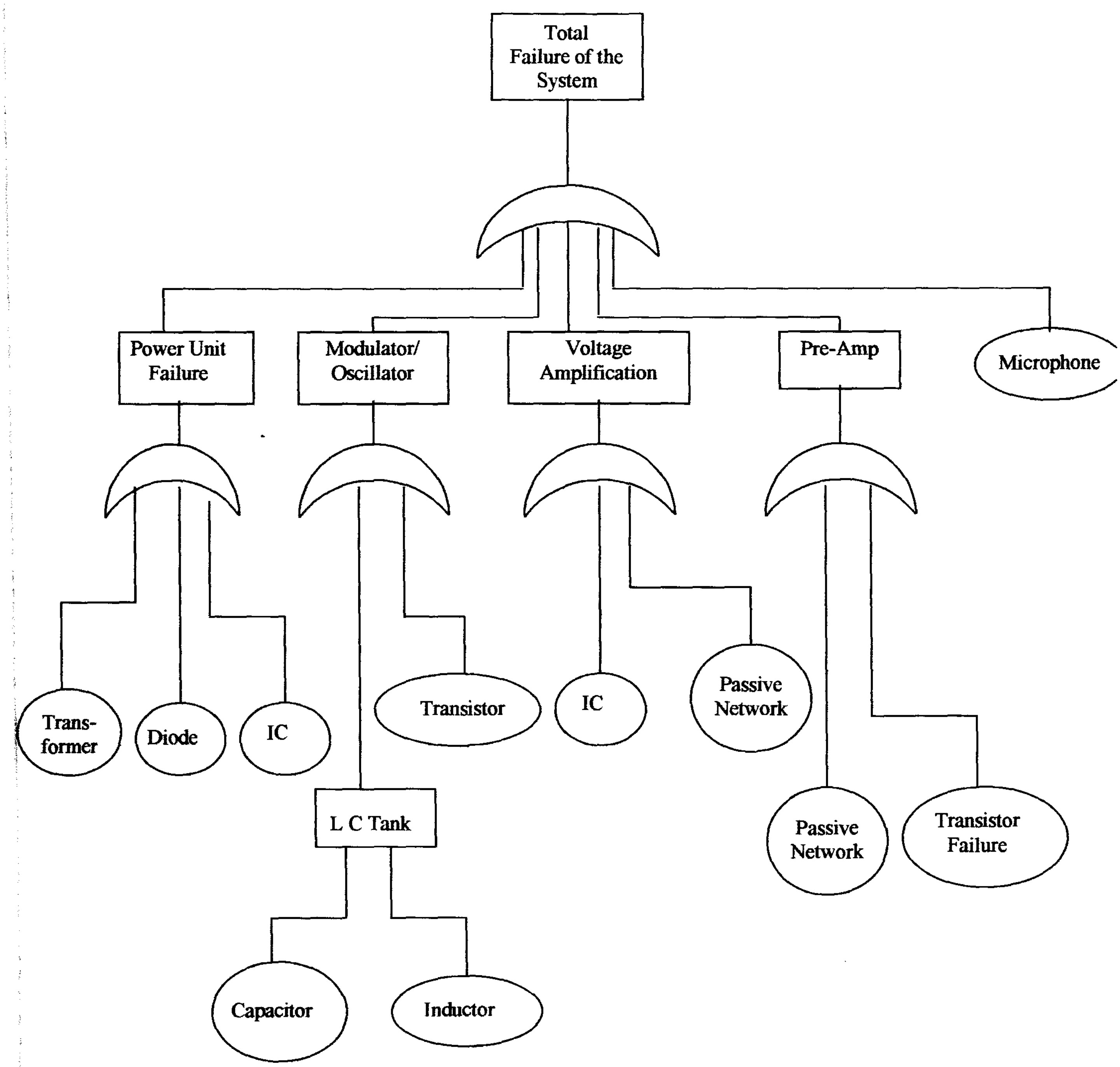
radio was taken farther away from the transmitter, then a clearer signal was obtained.

During soldering on veroboard, adequate care was taken to avoid problem of bridging.

3.4 RELIABILITY OF THE PROJECT

3.4.1 INTRODUCTION

The reliability of a 6-watts FM transmitter with automatic frequency control (AFC) can be calculated using method of faults tree analysis.



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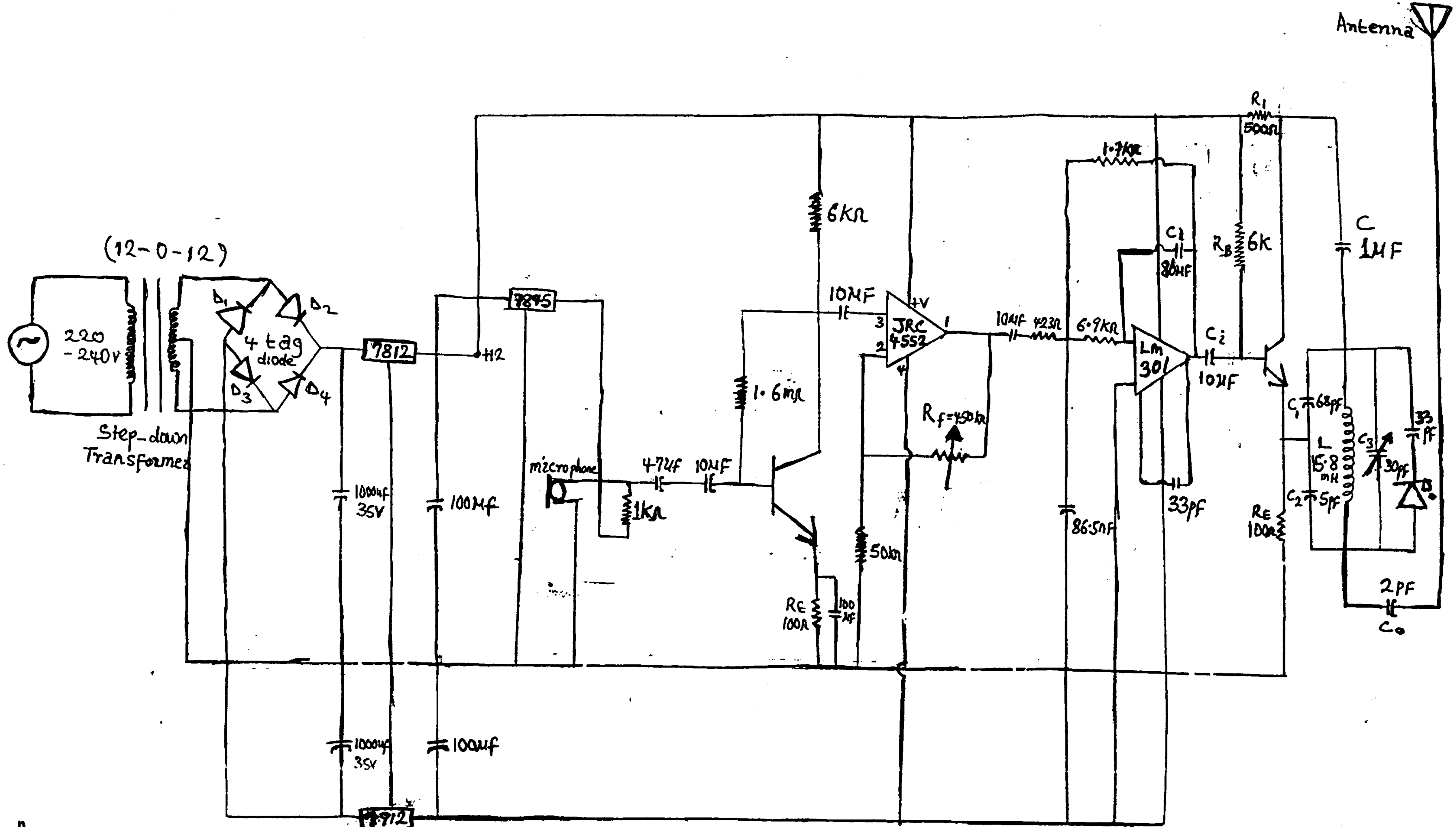
Antenna
(12-0-12)
220
-240V
Step-down
Transformer
D1
D2
D3
D4
4 tag
diode
7812
7845
+12
7912
1000uf
35V
100Mf
100uf
microphone
1kΩ
47uf
10MF
1.6mΩ
6KΩ
RE
100Ω
100
uf
50kΩ
10MF
JRC
4552
+V
Rf=450kΩ
10uF
423Ω
6.9kΩ
1.7kΩ
LM
301
C2
86MF
33pF
Ci
10uF
86.5nF
R1
500Ω
RB
6K
C
1MF
C1
68pF
L
15.8
mH
C3
30pF
33
pF
C2
5pF
RE
100Ω
2PF
Co

A SCHEMATI