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DESIGN AND CONSTRUCTION OF AN ADVANCED 40WATTS WIRELESS PUBLIC ADDRESS SYSTEM

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ABSTRACT

This paper details the design, development, and implementation of an advanced wireless public address (PA) system, highlighting its components and functionalities. The system integrates several crucial circuits: a power supply unit, an FM transmitter unit, a frequency modulation (FM) receiver unit, and both preamplifier and amplifier stages. The process begins with an audio signal, which is captured and converted into an electrical signal by the microphone. This signal is then wirelessly transmitted via the FM transmitter. Upon reception, the signal undergoes demodulation by the FM receiver, followed by initial amplification in the preamplifier stage to prepare it for further processing. Subsequent amplification in the power amplifier stage delivers a robust 40-watt output to an 8-ohm loudspeaker, ensuring clear and powerful audio delivery. To enhance the system's capabilities, an additional FM transmitter operating at a frequency of 87.5 MHz was incorporated, allowing for expanded functionality and improved performance. This system offers a sophisticated solution for modern wireless public address needs, providing efficient audio transmission and high-quality sound reproduction.

Keywords: Frequency modulator (FM), Receiver, Wireless public address, Microphone, Transmitted

1.0 INTRODUCTION

As time goes, people realize the importance of going to school, and for this reason, the university admits larger number of students. The problem of talking to this large crowd of students arises. Although many people have developed several public address systems but they are not able to eliminate this problem completely (Augarten, 2021). A public address system is an electronic sound amplification and distribution system with a microphone, amplifier and loudspeakers, used to allow a person to address a large public, for example for announcements of movements at large and noisy air and rail terminals or at a sports stadium (Boylestad and Nashelsky, 2020). The term is also used for systems which may additionally have a mixing console, amplifiers and loudspeakers suitable for music as well as speech, used to reinforce a sound source, such as recorded music or a person giving a speech or distributing the sound throughout a venue or building (John, 2018; Edeh et al, 2021).

A public address system allows easy broadcast of information to a large group of individuals. The information could be speech, recorded program or announcement. Public address systems typically consist of input sources, preamplifiers, control and monitoring equipment, and loudspeakers. Input sources could be microphones that provide a sound input for the system or audio/music sources. These input sources are fed into the preamplifiers. The pre amplified signals are then passed into the audio power amplifiers (Horowitz & Hill, 2019). In general, the purpose of an amplifier is to increase the amplitude of a weak signal to a stronger signal. Amplifiers find application in all kinds of electronic devices designed to perform number of functions. There are many different types of amplifiers, each with a specific purpose (Kondoh, 2018). This project is specified on audio amplifier. Audio power amplifiers are amplifiers designed to drive loudspeakers with specified impedance. These amplifiers amplify the audio signals to an adequate speaker line level. In other words, one can opine that the public address system is an electronic amplification system used for communication in areas requiring higher voice amplitude. Microphone is a device that converts sound waves into electrical waves (Kumar, 2020). It is an acoustic-to-electric transducer or sensor that converts sound into an electrical signal. Microphones are used in many applications such as telephones, hearing aids, live and recorded audio engineering, in radio and television broadcasting and in computers for recording voice, and for non-acoustic purposes such as ultrasonic checking. The sensitive transducer element of a microphone is called its element (Leach, 2020, Edeh et al, 2020). Since a wireless microphone is used in this project; a wireless microphone is one in which communication is not limited by a cable. The wireless microphone consists of the transmitter and the receiver. In this project, an advanced 40watts wireless public address system is constructed.

2. METHODOLOGY

So many processes were involved before the completion of this project. Taking them one after the other as shown below, one will have a clear-cut understanding of the research methodology principle of operation, description and elucidated explanation, of the discrete electronics components used towards the successful accomplishment of this project- Design and Construction of an advanced Wireless public Address System.

The following steps were taken before this project was successfully completed

i. Sourcing for circuit diagram

ii. Modification of the existing circuit diagram

iii. Sourcing for required components, by using data book/data sheet, to determine the manufacture voltage, current specification.

iv. Proteus/simulation

v. Circuit construction / testing/result.

vi. Building the casing

vii. General check / trouble shooting

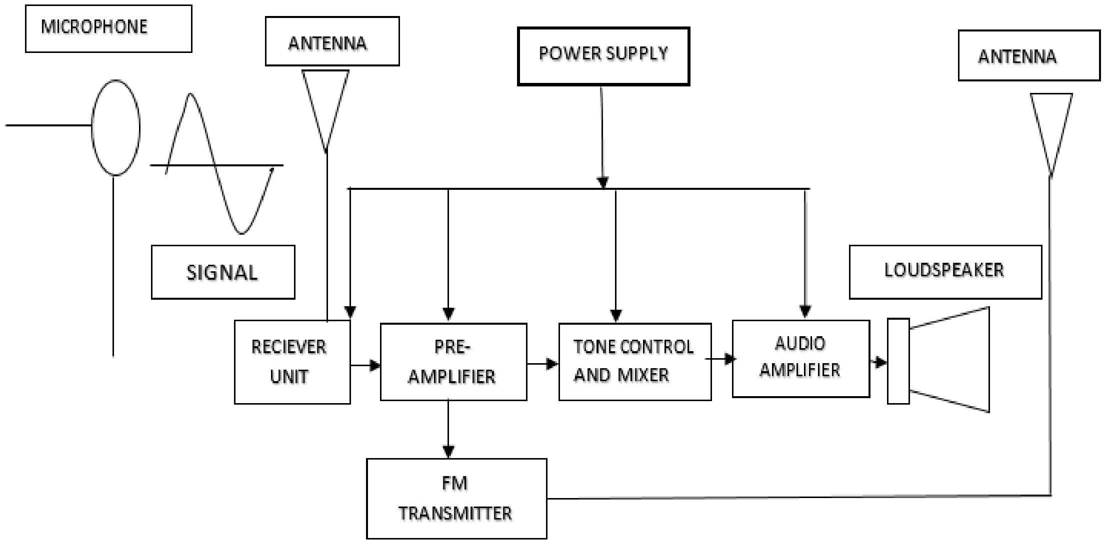

Figure 1: Block Diagram of the system

2.1 BLOCK DIAGRAM DESCRIPTION

The signal is fed into the system through the microphone. The microphone serves as the transducer that converts the sound wave into an electrical signal. This signal is being sent to the antenna through the FM transmitter. With the help of the receiver antenna, the FM receiver receives the signal transmitted by the microphone transmitter. The signal received by the FM receiver is small and cannot be amplified to a desired output with pre-amplification. Therefore, the signal is passed to a pre-amplifier and the output of the pre-amplifier is fed into the tone control unit (where we can adjust the bass and the treble). After this stage, the control signal is fed into the audio amplifier which delivers the output power to the load (loudspeaker) is used in this circuit.The signal from the receiver needs to be transmitted to another nearby FM receiver. Because of this the pre-amplifier signal is now sent to the FM transmitter which transmits at a frequency 87.50 MHz to any nearby radio receiver by the help of the antenna.The block diagram of Fig 1, made use of three different antennas; one is to transmit and the other two is to receive the microphone signals

2.2 AMPLIFIER CIRCUIT DESIGN

Taking a preamplifier with a voltage gain of 50, quiescent collector current of 1mA and a Vcc of +25V, for signals from 20Hz to 20kHz. Rc is chosen to set Vc at 0.5Vcc for the largest possible symmetrical swing without clipping. with Vc at 24V and Vc at 11V, Rc is determined from (Otasowie, 2019):

$$Vc = V_{cc} - I_c R \qquad (1)$$

$$Rc = \frac{(Vcc - Vc)}{Ic} \qquad (2)$$

$$Rc = \frac{24-11}{0.01}\Omega \qquad (3)$$

$$Rc = 13000\Omega = 13K \qquad (4)$$

Re is selected to set a voltage gain of 50 therefore,

$Av = \frac{-Rc}{Re}$ (5)

$50 = \frac{-13000}{Re}$ (6)

Re =260Ω

Note that; Re = R_{E1}+re (7)

Where re is the transistor base-emitter resistance.

R_{E1} is the bypass emitter resistor 1

And re = $\frac{25}{Ic}$mA = 25Ω (8)

Thus R_E 1 = 260 -25 =235Ω but nearest preferred value is 260 Ω

The problem with a Class A transistor amplifier is that emitter voltage varies significantly as the base emitter drop varies with temperature since the base I held at constant voltage by R1 and R2. To solve this, a bypassed emitter RE is added to ensure temperature stability. If the value is too small the emitter voltage will be much smaller than the base emitter drop leading to the temperature instability (usually with a value about 0.1Rc i.e. 1.3k Ω).

The emitter bypass capacitor was chosen so its impedance was small compared with Re at the lowest signal frequency of interest (650Hz for human voice)(Malik, 2020; Zhao et al, 2022):

$X_c = \frac{1}{1/2\pi FC} < R_c$ (9)

let C be 10μF = $\frac{1}{2\pi\ X650\ X10^{-6}}$= 244 Ω and this is far lesser than 260Ω

R1 and R2 is made stiff enough to set V_b on the criterion that R1//R2 is much less than the dc impedance looking into the base. A ratio 10:1 is ideal.

R2 is made to be equal to 1/10th $h_{fe}R_e$

Therefore R2 = $\frac{1}{10\ X\ 100X260}$ = 2.6kΩ

$VB = \frac{VccR2}{(R1+R2)}$ (10)

VB = VBE +VE (11)

VB=0.7 +2.6 =3.3V

Therefore, substituting the value of VB, R2 and VCC into equation (10)

$3.3V = \frac{24(2.6K)}{(R1+2.6K)}$

Solving for R1 we get 16.3KΩ

The nearest preferred value for R1 is 17K.

Thus, the Parallel combination of R1 and R2 i.e (17K//2.6K) gives 2.3K which is <<hfeRe (26K) thereby fulfilling the criterion.

C1 is chosen so that all frequencies of interest are passed by the high pass filter it forms in combination with the parallel resistance of the base biasing resistors (the impedance looking into the base itself will usually be much larger because of the way the base resistors are chosen and it can be ignored); that is,

$C1 = \frac{1}{2\pi F * Req}$ (12)

Where Req = R2//R3 =17k//2.6k= 2.25kΩ

$C_1 = \frac{1}{2\pi * 650 * Req}$ (13)

$C_1 = \frac{1}{2\pi * 650 * 2.25}$ (14)

C_1 =108.8ΩF ≈100μF

The input impedance is therefore the Thevenin equivalent resistance R_{Th} of the voltage divider in parallel with the dc impedance looking into the base, which satisfies the criterion of impedance matching

RTH = R1//R2 (15)

RTH= 17K//2.6K = 2.25K

The dc impedance looking into the base is $h_{fe}Re$

=100×260Ω =26K

Then Z_{IN} = 2.25K//26K = 2K

The signal processor comprises a simple Baxandall volume control/mixer realized with a passive filter into a wide bandwidth op-amp. It is implemented as shown in the circuit diagramwith volume control for input, as well as bass boost and treble gain control. The lower 3dB frequency is set at about 33.86Hz by C4 (1ΩF) with an upper roll off at about 20.4 kHz. This is meant to ensure that at higher frequencies unity gain is achieved, (Montoro & Schneider, 2018)

The voltage amplification stage is designed using the LM833N opa-mp with excellent audio qualities, high slew rate >5uv/s, wide bandwidth, and very linear output. Negative feedback is used to set the closed loop gain of the amplifier at 20dB. The input resistor R2 is made high enough to limit the effects of input bias currents and offset voltage.

$Av = 1 + \frac{Rf}{Ri}$ (16)

Rf=100kΩ, Ri= 10kΩ

Then, $\frac{Rf}{Ri} = \frac{100}{10} = 10$ (17)

Av= 1+10=11

$A_v(dB) = 20 \log 11 = 20.8dB$ (18)

$F_{OL} = \frac{1}{2\pi * R1 * C1}$ (19)

$F_{OL} = \frac{1}{2\pi * 100 * 10^3 * 100 * 10^{-9}} = 15.9Hz$

$F_{OH} = \frac{1}{2\pi * R1 * C2}$ (20)

$F_{OH} = \frac{1}{2\pi * 10000 * 1 * 10^{-9}} = 15.92$ KHz

Therefore, Effective Bandwidth = 15.8 KHz

The power supplied to the load by the amplifier is drawn from the power supply that provide the input or dc power. The amount of this input power can be calculated using

Pi(dc)=Vcc*Idc (21)

Where Vcc is 25V and Idc has an approximate value of 3A

Pi (dc) = 25V×3A=76W

For the output power,

$P_o(ac) = \frac{Vcc^2}{2Rl}$ (23)

Where Vcc = 25V and R_L = 8Ω

$Po\ (ac) = \frac{625}{16} = 39.06W$

For the efficiency

The efficiency of any amplifier can be calculated using the equation below:

$$\%\eta = \frac{Po(ac)}{Pi(dc)} \times 100\% \qquad (24)$$

$$\%\eta = \frac{VccIdc}{Vcc^2\ 2Rl} \text{ x } 100\%$$

$$\%\eta = 51.3\%$$

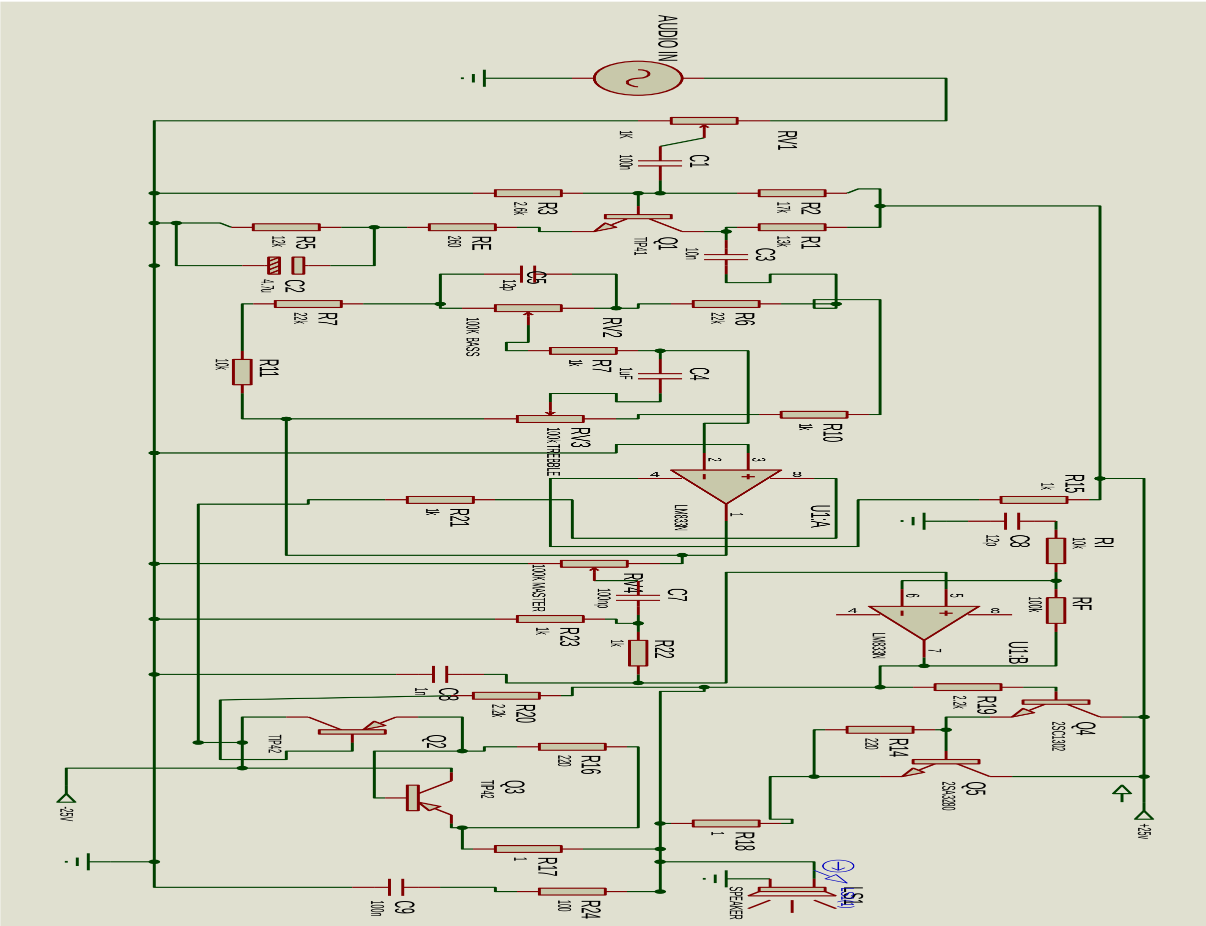

Figure 2: circuit diagram of an amplifier

From the circuit diagram above (figure2), the Audio signal is effectively coupled into the input stage. This is a transistor current source with a voltage divider bias. The TIP41 transistor is used and the base voltage VB provided by a stiff voltage divider. “Stiff” in the sense that the divider impedance R1//R2 is much less than the dc impedance looking into the base $h_{Fe}R_E$. Applying VB to the base with VB> 0.6V, ensures that the emitter is always conducting. This bias is adopted to obtain a combination of bias stability, linearity and large voltage gain because it is more or less independent of transistor current gain (beta value); beta is temperature sensitive and its actual value is usually not well defined. With average gain of 50 (34dB) the output is amplified and effectively non-inverted. The output of this first stage is capacitively coupled to a signal processor. The signal processor is a standard Baxandall feedback tone control, and gives an almost dead flat frequency response with the controls in the centre position (Russell, 2019). It is pertinent to note that it is inverting, which

complements the microphone preamplifier (also inverting) so the absolute signal polarity is maintained. The signal is then passed through a passive Band pass filter at the non-inverting input of the opamp U1:B. The -3dB cut-off frequency is set at about 15Hz and the upper roll-off frequency 115.7 kHz. This ensures a linear amplification of signals within the entire audio frequency range. A variable resistor is provided to adjust signals intensity (MASTER VOLUME) at the input of the Band pass filter. The signal is further amplified through the Voltage Amplifier Stage with a nominal closed loop gain of (20.4dB). By means of negative feedback, the overall gain is somewhat reduced and noise signal eliminated at this stage.
Finally, the signal passes through a high-current output stage, which drives the speaker load. The output stage is a trans-resistance power amplifier, translating the small-signal output current from the Voltage Amplifier stage to a highly amplified voltage signal at its output node. The selected topology utilizes a darlington pair in a push-pull Class AB arrangement. The Darlington pair consists of two complementary transistors connected as shown in circuit diagram above (figure 2). This structure doubles the beta value of the transistor, allowing low gain devices to be used for high gain applications. This is especially useful when considering the low noise transistors (TIP41, TIP42, 2SC1302 and 2SA3280) that are employed in this design. The entire unit derives the amplified power from a rectified, capacitor-filtered, unregulated power supply unit that is used to produce dual voltages of approximately +/-25 volts with low noise and minimal ripple. Safely measures are incorporated to prevent a potential lethal shock from filter capacitors during fabrication. Circuit protection is implemented at the power supply unit by means of a 3A slow-blow fuse. Additionally, circuitry such as the R-C Zobel network is provided to avoid damage to input/output devices and the speaker coils (Sessler & West, 2019).

2.3FM TRANSMITTER CIRCUIT DESIGN

The simple FM transmitter schematic is shown in figure 2 below. The audio input is AC-coupled to the base of NPN Q2 through capacitor C4. The 3nF capacitor C4, NPN Q2, and its 100Ω emitter resistor R5 comprise the pre-emphasis filter.

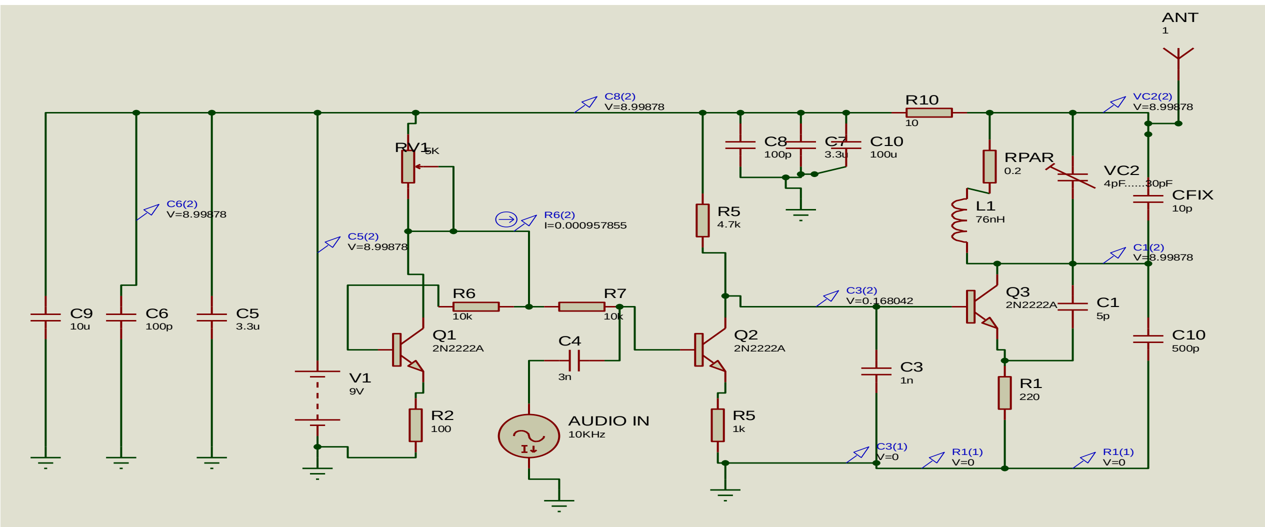

Figure 3: circuit diagram of an FM transmitter circuit

The input impedance looking into the base of Q2 is approximately,

$$R6 + R7 = \beta \times Re \qquad (25)$$

Which is 200*100 = 20kΩ.

The product of the series capacitance, C4, and the resistance to ground is set equal to the desired audio pre-emphasis of 75µs (1 / 13.3 kHz) giving a capacitance value of 3.75nF

The NPN transistors Q1 and Q2 form a current mirror. The resistor RV1 in the collector of Q1 sets the current through Q1. Since Q2 has the same base-emitter voltage as Q1, the same quiescent current will flow through Q2. As the value of resistance RGAIN increases from 0 to 5k, the voltage across the base-emitter junction of Q1 increases which in turn increases the collector current in Q1.

Since the trans-conductance of a BJT equals IC / VT where VT is the thermal voltage and the gain from base of Q2 to its collector is proportional to its trans-conductance, the gain of the stage is set by the resistor RV1. This is sufficient to cover a wide range of input signal voltage magnitudes. The audio signal, after being filtered, and amplified, is directly coupled to the base of transistor Q3, which is configured as a Colpitt's oscillator. Capacitor C3 shorts the base of Q3 to AC ground.

The inductor is hand-wound with an air core. Using the empirical formula,

$$L = \frac{an\ 2}{(9a+10b)} \qquad (26)$$

Where, a is the radius in inches, b the length in inches, and n the number of turns, the inductor's inductance value was calculated, 76nH. The variable capacitor CTUNE is used to tune the frequency. A series parasitic resistance RPAR of 0.2 was added to the schematic for more realistic simulation; the value was measured after the circuit was built. A parasitic capacitance of 500fF was added between the oscillator output and ground to account for board trace inductances. Transient simulation shows the oscillator starts and oscillates at 94MHz with a magnitude of 16.5Vpp; this does not exceed the specified breakdown voltage from collector to emitter of 75V.

For transmitted frequency, $F = \frac{1}{2\pi\sqrt{LC}}$ (27)

Where,

L = 76nH

C = 43.5pF

$$F = \frac{1}{2\pi\sqrt{76*10^{-9}*43.5*10^{-12}}} = 87.5MHz$$

2.4 POWER SUPPLY CIRCUIT DESIGN

The transformer primary voltage is 220V ac, which is directly from the mains supply. The rectifier circuit used in this project makes use of the bridge rectifier shown above which uses four rectifier diodes, the IN4148 (specifications shown in data sheet; appendix 3f). The rectified signal is then passed through a smoothening capacitor to remove the ripples which results to a steadier signal output. A voltage regulator IN4749 (24V zener) is connected at the output to give a constant value of 24V.

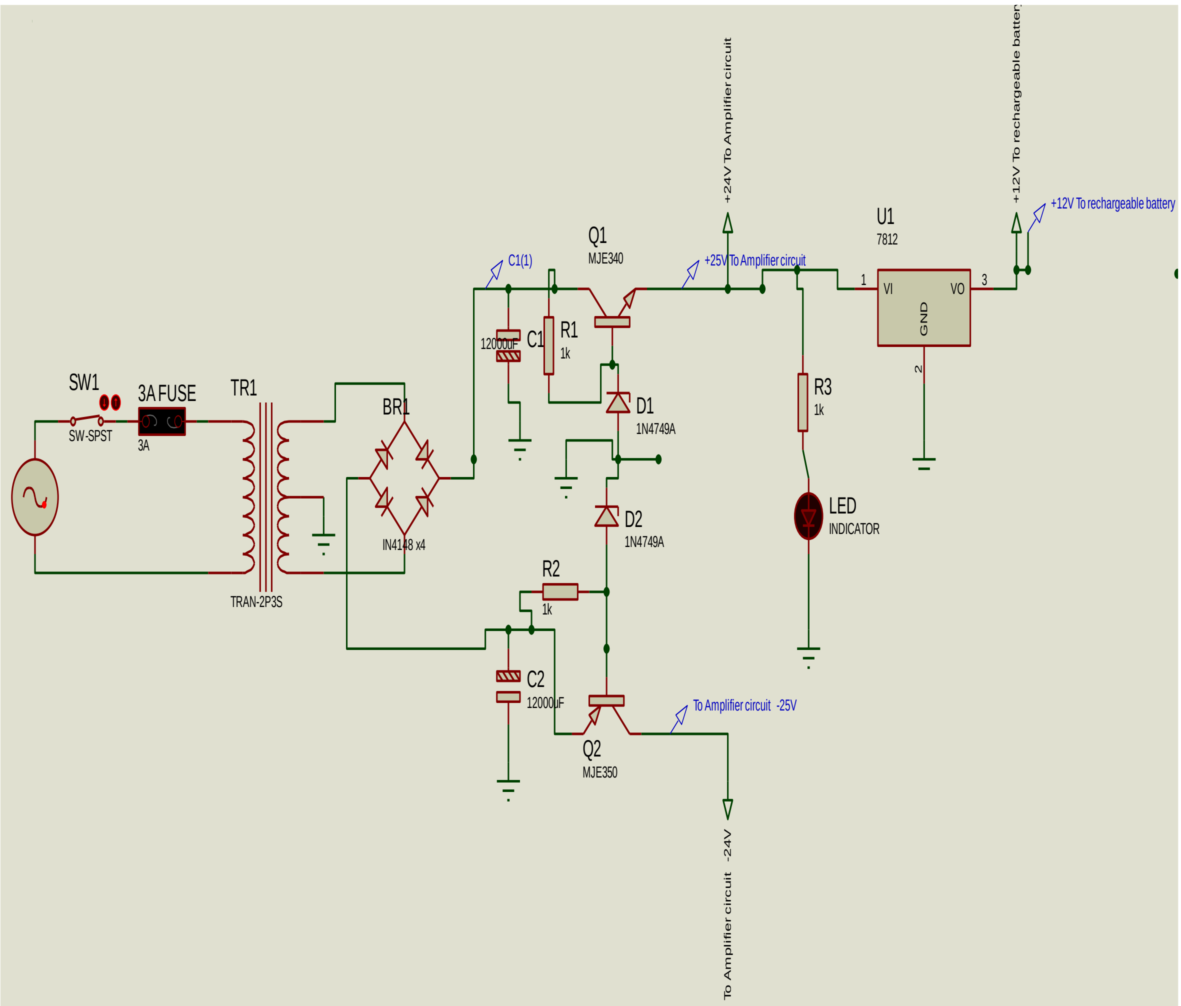

Figure 4: Power Supply Circuit

For the capacitor used for smoothening, a ripple factor of 0.1 was used. The formula is given below:

$$C = \frac{Iload}{F * Vpk-pk\ ripple} \tag{28}$$

$$C = \frac{3}{100 * 25 * 0.1} = \frac{3}{250} = 0.012F$$

C= 12,000μF

With a minimum voltage rating of $25 * \sqrt{2}$ = 35v +20% safety margin =40V

But we used a capacitor with a voltage rating of 50.

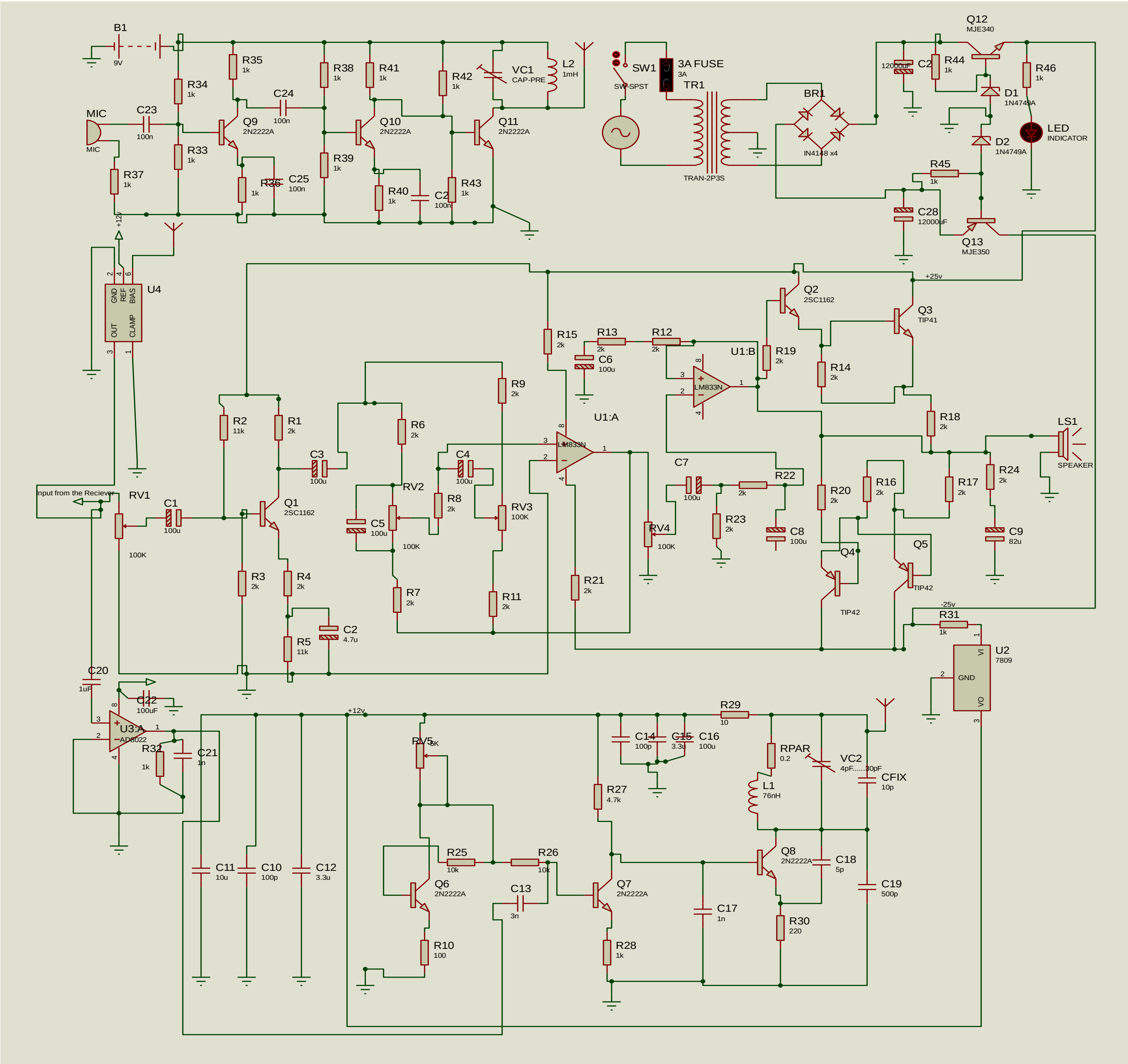

Fig 5: Circuit diagram of an advanced wireless public address system

3.0 RESULTS AND DISCUSSION

3.1 Simulation Results

The implementation of the design work was achieved with the help of proteus design suit. Proteus design suit is an electronic design automation tool, a window application for schematic capture, simulation and PCB layout design. The overall circuit was first designed and simulated using proteus design suit. The PCB layout and the 3D visualizer of this window application aided to ease the construction of the circuitry optimizing space and materials.

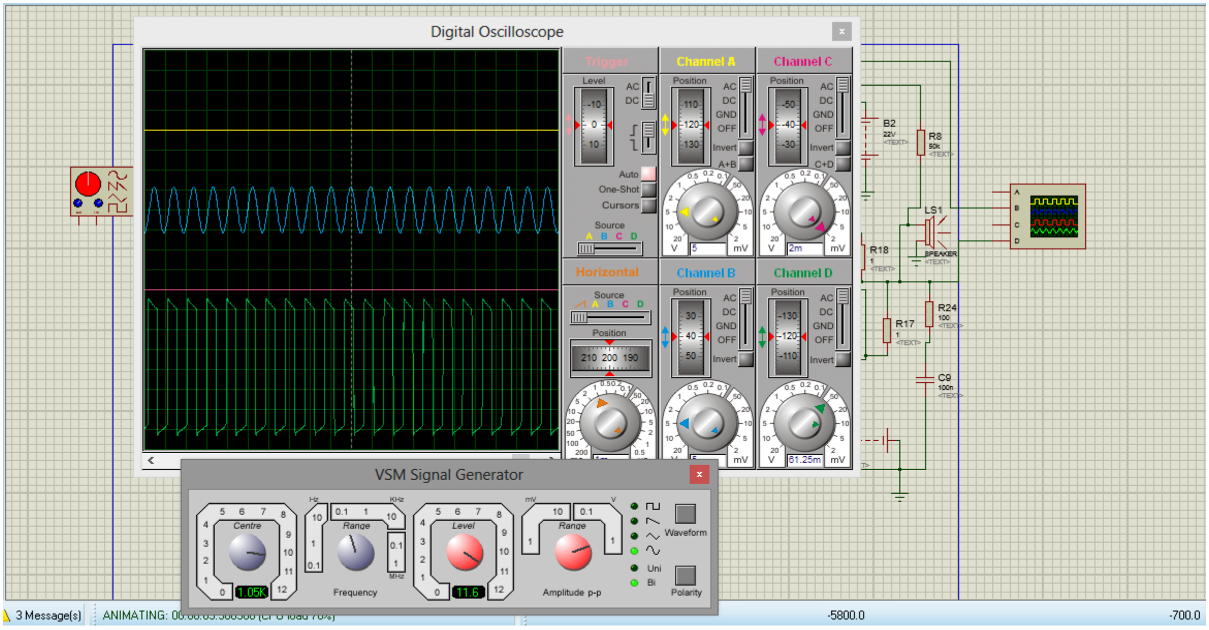

Fig.6: amplifier circuit output waveform using proteus

From Fig.6**,** the waveform in the upper channel shows the input signal to the amplifier while the waveform in the lower channel shows the amplified output waveform at level 11.6V which is approximately 12V (Peak output Voltage).

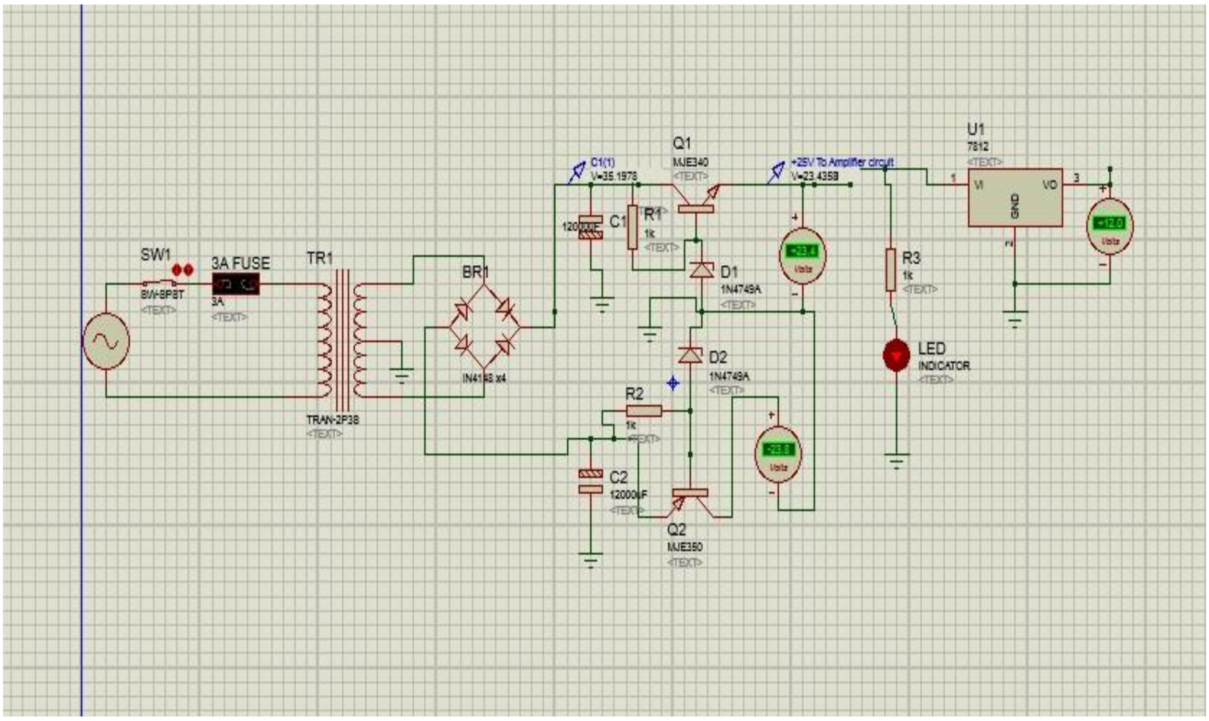

Fig.7: power supply circuit output voltages displayed on proteus.

Fig.7 shows the simulation results of the supply at +/-23.8volts, which is approximately 24V. The output of the 7812 IC (12V) regulator gave an output of 12.0V.

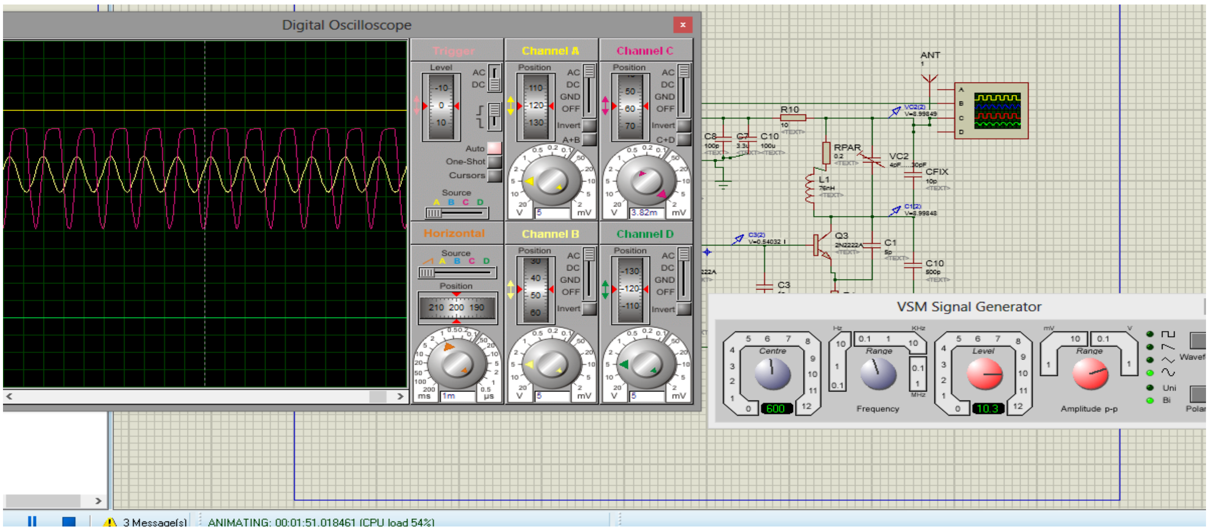

Fig.8: Output waveform of the transmitter circuit using proteus.

3.2 DISCUSSION

Advanced wireless public address system is capable of transmitting as well as receiving at the same time. The combination of the hardware components gives the final design. The PROTEUS provides the platform for simulating the various circuit diagrams on the hardware already designed and troubleshooting of the whole design. The major circuits used in the design include the amplifier, microphone/FM Transmitter, the FM receiver and the power supply. The microphone transmitter accepts the sound wave as its input and converts the sound wave into an electrical signal. The signal is being received by the FM microphone receiver, which is being passed through the pre-amplifier for pre-amplification. The pre-amplified signal is now sent to the main amplifier which performs the function of class AB. The output power (40W) of the amplifier is now sent to the loudspeaker (8Ω). Also from the pre-amplifier, the pre-amplified signal is sent to the FM transmitter (transmitting on 87.5MHz) for broadcasting. For the power supply, the main 220 ac voltage source is connected to the transformer which steps down the 220v to 30ac volts. But a DC voltage is required to power the circuit, hence, a bridge diode is used for rectification.

4.0 CONCLUSION

The aim of the advanced wireless public address system was achieved by transmitting, receiving and broadcasting of audio signals after construction. A great deal of design knowledge and modern hardware integration expertise has been impacted by carrying out this cutting-edge project. This project is recommended for schools, churches and places where there is need to broadcast to a higher number of people. solar charging system should be incorporated in this project so that it can operate even at environments where there is no power supply. It is also recommended that the research should continue towards studying the performance and improvement of an advanced wireless public address system

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