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Design of Fire Siren System Based on Power Line Carrier

Francis Ekor and Adabara Ibrahim

Department of Electrical and Telecommunications Engineering, School of Engineering & Applied Sciences, Kampala International University, Uganda.

ABSTRACT

The Design of Fire Siren System based Power Line Carrier (PLC) is a prototype that enables to transmit signal from located sensor using existing power distribution line cable to give warning for possible fire hazards to local residents. This project describes the system in detail based on conceptual idea. It is designed to warn residents in case of fire in the vicinity. The sensor will provide signal if there is any extreme temperature increase. Then the signal is transmitted over power distribution line using specific circuit and equipment to each resident house and finally the signal is used to activate the siren system installed in local resident house. The concept of this project is to build a new system to control alarm system in house. The various blocks constituting the whole system was successfully implemented.

Keywords: Fire Siren System, Power Line Carrier, and transmitter

INTRODUCTION

During recent year of Information Technology, the present focus is on the creation and also dispersion of information. In purpose to reach the end-users for the provision of information, the popular technologies currently being used include telephone wires, Ethernet cabling, fiber optic, wireless and satellite technologies. However each has its limitations of cost and availability to reach the maximum number of users [1]. Every building and home is already equipped with the power line and connected to the power grid, by using this electric power line as the data transmission medium it provide advantage in term of wiring cost [2]. The power line carrier (PLC) communication systems use the existing AC electrical wiring as the network medium to provide high speed network access points almost anywhere there is an AC outlet [3]. In most cases, building a home network using the existing AC electrical wiring is easier than trying to run wires, more secure and more reliable than radio wireless systems like 802.11b, and relatively inexpensive as well. For most small office home office (SOHO) applications, this is an excellent solution to the networking problems [4].

The communication system for low bandwidth analog and digital information over residential, commercial and high voltage power lines have been built. Power line has been considered for the transmission of electricity in the past [5,6,7]. However, recently have several companies turned serious attention to communicating over power lines for the purpose of data communication networking? The power line potentially to become as a powerful medium to be able to deliver not only electricity or control signals, but even full duplex high- speed data and multimedia content, and now it is still being explore. Since the developments of power line networking is still considering new, the information is mostly dispersed. There is a lack of collective reference material that summarizes the existing technologies, available solutions and technology trends in the power line carrier communications [8,9,10].

METHODOLOGY

To feed the signal from sensor into power distribution line, a suitable modulation technique will be used. The modulator function to convert signal from the sensor in the form of suitable signal before transmitted through power distribution line. At the receiving system the transmitted signal will be demodulated and connected to the buzzer or siren unit to warn residents.

In this project, the focus will be on ways to sending or transmitting signal over AC power line. To make this transmission possible, some equipment or circuit need to be defined such as transmitter and receiver circuit. Modulation is also important thing that need to be known to make this transmission reliable. Suitable modulation technique needs to be chosen as well as the modulator circuit. One more important thing that must be concentrating is the method for injecting the signal into AC power line. The overall flow of this project can be shown in flow chart below:

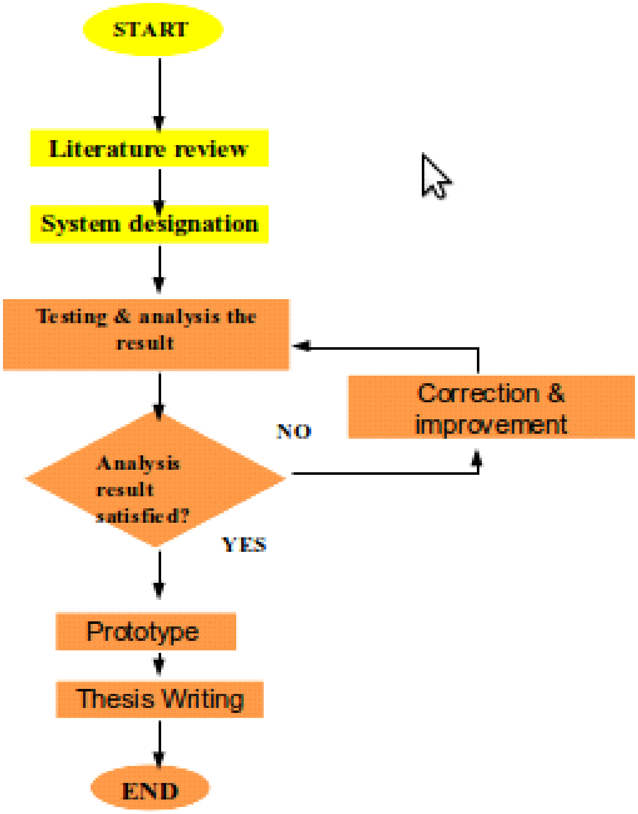

Chart 1.1:Flow Chart of Overall System Designation Procedure

Designing Procedure

This project started with literature review on PLC (Power Line Carrier). Gather the knowledge and understanding the concept of PLC. In the same time, reviews on example of PLC system are continuously to get better understanding.

Next for the system designation procedure, by all information had been gathered as reference, a suitable modulation technique would be chosen for this system. The required system for transmitting and receiving signal from the sensor would be obtained as well. The system possibly consists of several important circuits to ensure signal can be transmit and receive efficiently. This transmitting and receiving system could be consists of modulator circuit, filter circuit, amplifier circuit, and coupler circuit.

After the system designation available, the design will be tested. The system will be tested based on the design and characterization. Analysis on the performance and characteristics also would be conducted. The results are important to determine the optimum configuration. If the results obtained do not satisfy, the modification is needed to improve the earlier design for obtaining the best design. This modification procedure will be performs continuously until the perfect design had been obtained.

Finally after the final design obtained, the design will be prototype as a model for the overall system. And the project writing could be performed as the final procedure needed for completing this project. Chart 3.2 and Chart 1.2 and 1.2 below shows the weekly planning for FYP 1 and FYP 2.

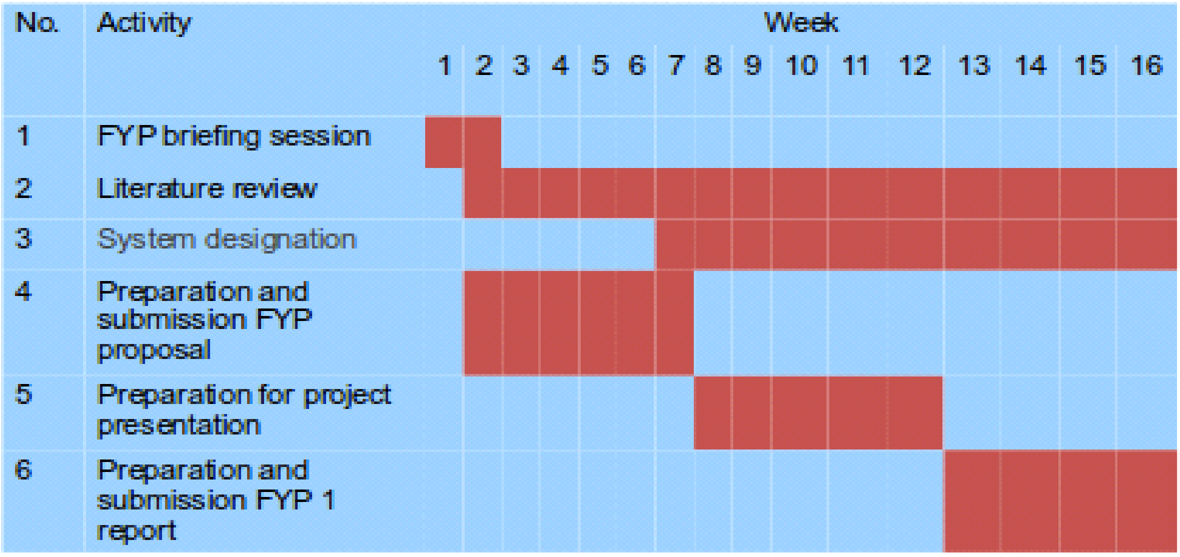

Chart 1.2 Gantt chart for FYP 1

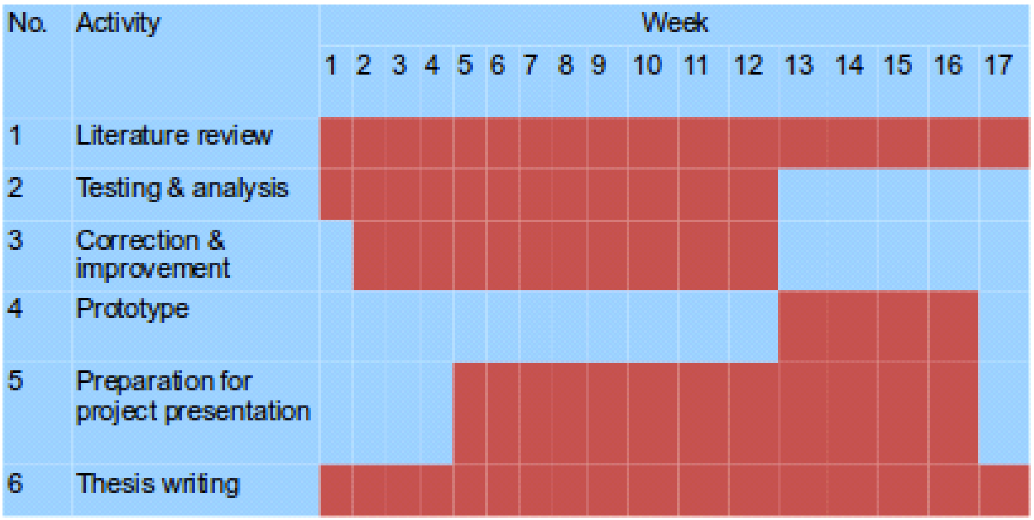

Chart 1.3 Gantt chart for FYP 2

Designing Method

To build the Design of Fire Siren System based on Power Line Carrier, all circuit will be design and simulate using Multism as the simulator software. After all circuit design has been simulated and functional properly, the simulated design will be used for the hardware implementation. All circuit design is based on literature review and optimization in purpose to obtain the best result. For the simulation design, each circuit will be design and simulate individually starting with designing the modulator circuit, amplifier circuit, filter circuit and finally coupler circuit. When all individual circuits have been designed and simulated can functional perfectly, all these design will compressed and combined each other to perform transmitter and receiver function of Power Line Carrier

Communication (PLCC). For the hardware design, all simulation design will be used for the fabrication of the hardware. All circuits will be arranged on portable board before it can be tested. In test procedure, commonly the function generator will be used to generate input and the oscilloscope to observe the output of the circuit. Finally, all circuits' components will be soldered together on the strip board (SB) and will be tested again for the functionality.

RESULT AND DISCUSSION

All information regarding Power Line Carrier Communication (PLCC) during literature review have been use to build this Design of Fire Siren System based on Power Line Carrier. This system actually new design of a fire siren system that will use existing power distribution line as the transmission medium to transmit audio signal that will be generated by Early Fire Siren system at transmitting part to the receiving part and finally the receiving signal will use to turn the warning system „ON". Early Fire Siren system is a detection system which consist the sensor, controller and oscillator circuits. In the Early Fire Siren system the oscillator circuits will generate two different signal which is modulating signal and carrier signal when the sensor sense any extreme changes in term of temperature. And then these two different signals will be pass through the modulator circuit for the transmission over power distribution line.

In this chapter the designing procedure and the details of each circuit in this system will be explained in details. This system will be divided into two main parts which are the transmitter circuit and receiver circuit. In the transmitter circuit it consists of modulator circuit, audio amplifier circuit and coupling circuit. And in the transmitter circuit it consists of coupling circuit, filter circuit and audio amplifier circuit. In designing procedure, Multisim ver.10 software will be used as the simulator. All circuit will be designed and test using this software. Figure below shows the block diagram of PLC system design that would be used for this fire siren system.

Figure 1: Block Diagram of PLC System Design.

When creating a system for transmitting a frequency modulated wave, a number of building blocks have to be considered, the diagram below gives a very broad impression of the transmitter, receiver and their individual parts.

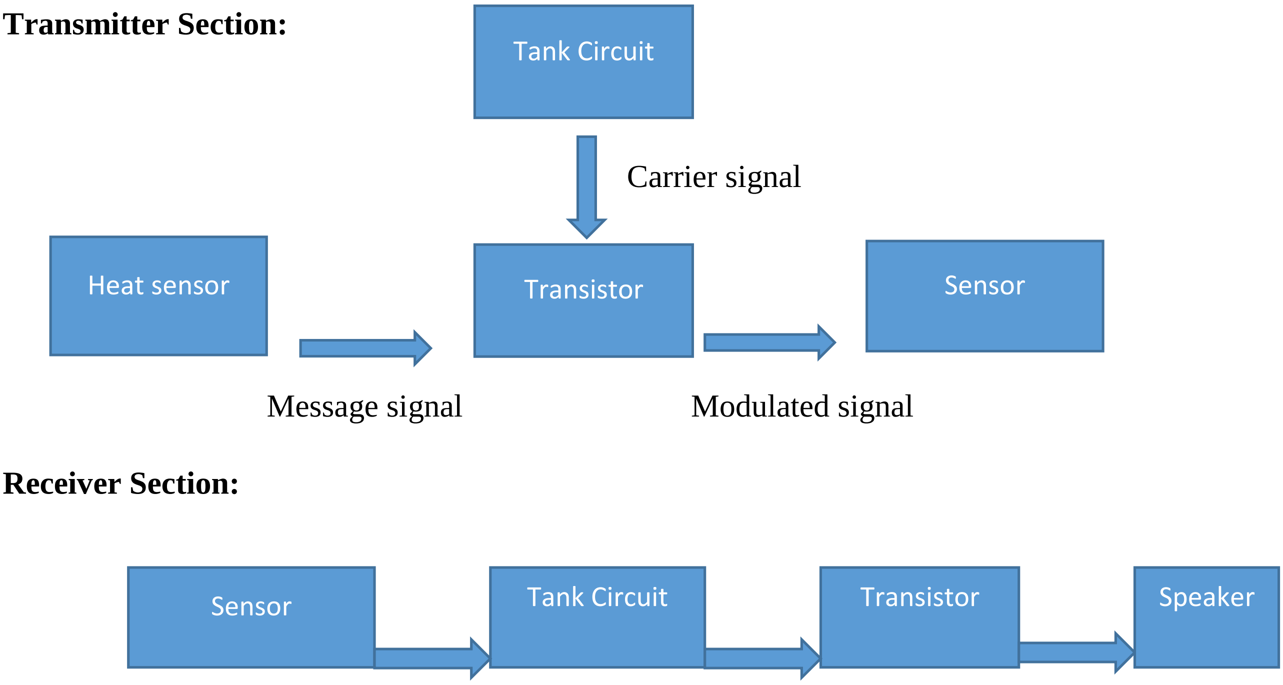

Figure 2: Fire Siren Block Diagram

From the block diagram, it is understood that the message signal or conversation signal is modulated with the carrier frequency which is generated by the tank circuit. The message signal and carrier signal is modulated by the transistor and transmit the modulated signal in the air through the antenna. The modulated signal is received by the receiver antenna and gives to the FM radio where the user can listen to the conversation. User should adjust the receiver frequency for receiving the signal from the transmitter. On the block diagram, the frequency is receive inform of electrical signal by the sensor and is modulated to the carrier signal and transmitted. There are different types of analogue modulation in which one type of modulation is amplitude modulation. Another type of modulation is angular modulation in which the frequency modulation and phase modulation will come. For this case FM modulation is used. In FM modulation, frequency of the carrier signal is varied in accordance to the instantaneous amplitude of the modulating signal. Normal Fire Siren will use this type of modulation to transmit signals; frequency modulation will give high throughput and efficiency when compared to amplitude modulation. MIC is placed in the room in which you want to listen to the conversation of the people and MIC will decode the conversation in to the signal which is given. The tank circuit will produce the carrier signal for the conversation or message signal a transistor will be used to amplify both the signals and send to air through the antenna.

The FM radio receiver will be adjusted to the assigned frequency for listening to the conversation.

FM Transmitter Circuit Design

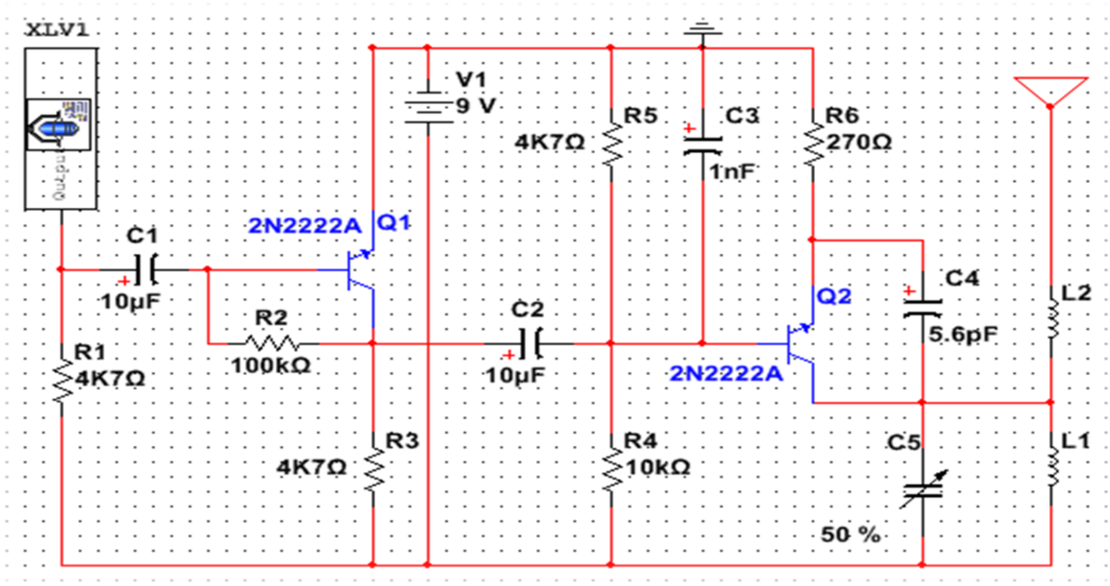

Figure 3: Transmitter Circuit Design

The Microphone is placed where you want to listen to the conversation of the people and it will decode the conversation in to the signal which is given to the capacitor C1, where C1 is used for removing the noise and turning the transistor Q1 in on mode to amplify the audio signal.

Audio signal from the microphone has very low level signal, of the order of millivolts. This extremely small voltage needs to be first amplified. A common emitter configuration of a bipolar transistor Q1 is biased to operate in class A region, produces an amplified inverted signal. The basic idea at work for amplifier used in the Fire Siren is that the 100kΩ resistor biases the transistor in a way that when the Audio input goes into the base pin of the 2n2222A it is multiplied to be many times larger by the time it hits the Collector point of the transistor.

Another important aspect of this circuit is the oscillator circuit. This is an LC oscillator where energy moves back and forth between the inductor and capacitor forming oscillations. It is mainly used for RF application.

When this oscillator is given a voltage input, the output signal is a mixture of the input signal and the oscillating output signal, producing a modulated signal. In other words, the frequency of the oscillator generated circuit varies with the application of an input signal, producing a frequency modulated signal. The tank circuit (capacitor C5 and L1, L2) which produce the carrier signal for the conversation or message signal, the transistor Q2 will amplify both the signals and send to air through the antenna.

The capacitor C5 is variable because it can be adjusted to produce a carrier signal. Remember carrier signal should be in range of 88 to 108 MHz so that FM radio receiver set can receive your transmitted signal.

The FM radio receiver set is adjusted to your frequency for listening to the conversation.

FM transmission is done by the process of audio amplification, modulation and then transmission. Here the same formula is adapted by first amplifying the audio signal with the NPN transistor, generating a carrier signal using an oscillator and then modulate the carrier signal with the amplified audio signal. The frequency is set at anywhere between the FM frequency range from 88MHz to 108MHz.

Selection of Vcc:

The NPN Bipolar Junction Transistor, 2N2222 is selected. Since V_{CEO} for this transistor is around 40V, a much lesser Vcc of about 9V is used.

Selection of Load Resistor R3:

The need to calculate the quiescent collector current is vital to get the value of a load resistor. Now, assuming this value to be about 1mA. The collector voltage needs to be about half of Vcc. This gives the value of load resistor, R3 as: Vc/Iq = 4.5KΩ. Now a 4.7KΩ resistor is selected for better operation.

Selection of Microphone Resistor R1:

The purpose of this resistor is to limit the current through the microphone, which should be less than the maximum current a microphone can handle. Assuming the current through microphone to be 0.4mA. This gives the value of R1 = (Vcc-Vb)/0.4

The voltage across the base, Vb is assumed to be 0.65V more than the emitter voltage Ve. Assume the emitter voltage to be 70% of Vcc, i.e. 6.3V. This gives Vb to be 7V.

R1= (9 - 7)/0.4= 5KΩ, here a 4.7kΩ resistor is selected.

Selection of Emitter Resistor R6:

The value of R6 is given by Ve/Ie, where Ie is the emitter current and is approximately equal to the collector current.

The bias current is approximated to be 10 times the base current. Now base current, Ib is equal to the collector current divided by the current gain. This gives the value of Ib to be 0.08mA. The bias current is thus 0.8mA.

This gives R6 = (Ve/Ie) = 200ohms but 270ohms is selected.

Selection of Voltage Divider Resistors R4 and R5:

To calculate the value of the voltage divider resistors, the bias current as well the voltage across the resistors are calculated.

Thus, R4 = V_b/I_{bias} = 8.7KΩ but 10KΩ resistor is selected.

R5= (Vcc-Vb/0.4mA) = 5KΩ but 4.7KΩ resistor is selected.

Selection of coupling Capacitor C1:

An electrolyte capacitor serves the purpose of modulating the current going through the transistor. A large value indicates low frequency (bass), whereas a lesser value increases treble (higher frequency) and also bypasses the DC signal. A value of 10uF is selected.

Selection of coupling Capacitor C2:

At this stage an electrolyte capacitor of about 10uF is selected as the coupling capacitor using the NI measurement tool.

Selection of Bypass Capacitor C3:

Here an electrolyte capacitor of 1nF, which bypasses the DC signal is selected.

Selection of Tank Capacitor C4:

This capacitor serves the purpose of keeping the tank circuit to vibrate. Since the transistor is NPN 2N2222A, the value of C4 is between 4 to 10 pF. A value of 5.6 pF capacitor is suitable.

Selection of tank circuit Components L and C5:

The resonant frequency of oscillations is given by the formulae;

$$f = \frac{\omega}{2\pi} = \frac{1}{(2\pi\sqrt{LC})}$$

Here the frequency required is between 88 MHz to 100 MHz. A value of 0.15μH is suitable for this inductor. This gives value of C5 to be around 18pF. Variable capacitor in the range of 5pF to 30pF also inductor in range of 0μH to 1μH are selected.

With L=0.15μH, C=18pF, and f = 97 MHz

FM Receiver Circuit Design

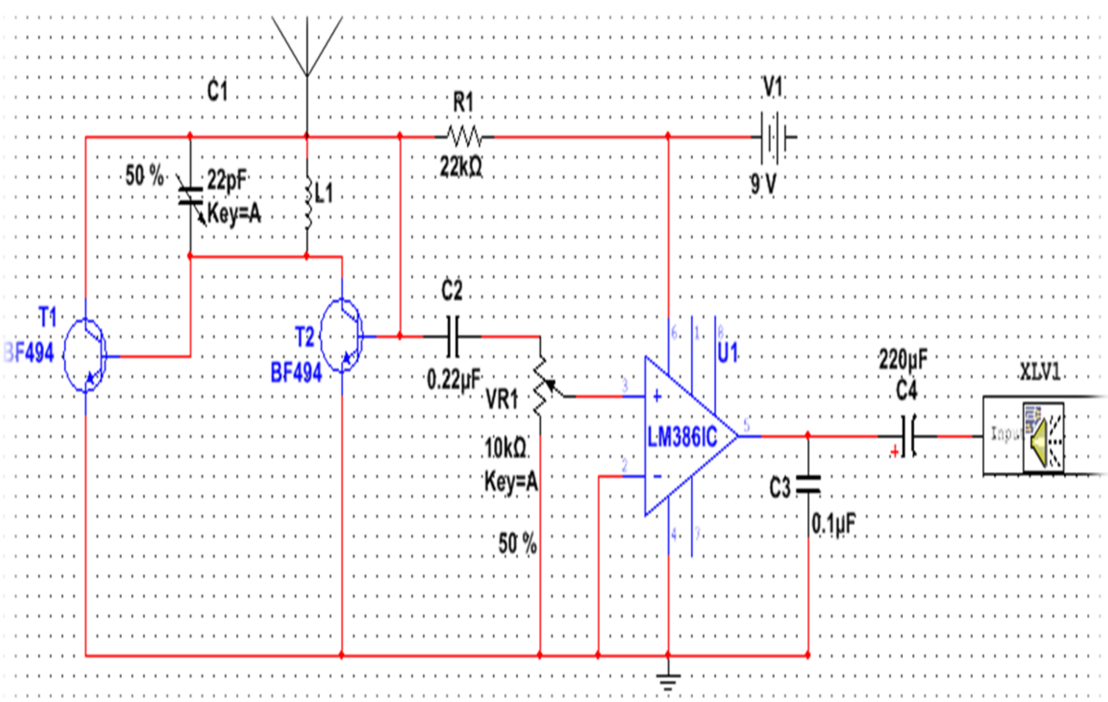

Figure 4: Fire Siren Receiver Circuit Design

Receiver is the reception of electromagnetic wave through air. The main principle of this circuit is to tune the circuit to the nearest frequency using the tank circuit. Data to be transmitted is frequency modulated at the transmission and is demodulated at the receiver side. Modulation is nothing but changing the property of the message signal with the respect to the carrier frequency. Frequency range of FM signal is 88MHz to 108MHz. The output can be heard using speaker or headphone, but will not be as loud.

The FM Radio circuit mainly consists of LM386 IC. This is a low voltage audio power amplifier. It has 8 pins. It operates at a supply voltage of 4-12 volts. It has an op-amp internally, which acts as an amplifier. The non-inverting pin is connected to the variable resistor of 10K Ohms. Inverting pin of the LM386 IC is connected to the ground. Sixth pin is connected to the VCC. Fourth pin is connected to the ground. Fifth pin is output and is connected to the capacitor which is connected to the speaker or microphone. Another capacitor is connected to ground pin. Sixth pin is the supply pin connected to the supply voltage. This amplifies the incoming frequency modulated signal.

BF494 is an NPN RF transistor. Initially it is open circuited. It starts conducting only when base gets the required cut off voltage. Base of the transistor T2 is connected to the base of the variable resistor through a capacitor of 0.22uF. Emitter pin is connected to the ground. Collector is connected to the tank circuit. Base of transistor T1 is connected to the tank circuit. Emitter pin is connected to the ground and collector is connected to the supply through a resistor of 22K ohms. The variable resistor controls the volume to the input amplifier. These transistors are used for detecting the frequency modulated signals.

Output of the IC is connected to the headphones or Mylar speaker through a capacitor of 220uf rated. The head phone or speaker will have two wires out. One is connected to the output of the capacitor and the other pin is connected to the ground pin.

Tank circuit consists of an inductor coil and a variable capacitor. This is connected to the antenna. This is the main part of the circuit as it tunes the radio to the required local frequency. In this tank circuit coil plays a main role. Coil is a copper wire wind into fixed number of turns.

The FM receiver section has two RF transistors T1 and T2 to detect the Frequency Modulated signals. Coil L1 and the variable capacitor form the tuned tank circuit to tune the receiver to the best FM station with strong signals. The signals are capacitor coupled through C2.

The balance of the inductor at the transmitter circuit of value 0.15μH is here considered to build the tank circuit of the receiver with the inductor requiring 4 turns of air core, 5mm diameter and 3.5mm length of the wire. These are then converted to get its real value to form a tank circuit at the receiver section with a capacitor substituted from the formulae.

$$\boldsymbol{f} = \frac{\mathbf{1}}{(\mathbf{2}\boldsymbol{\pi}\sqrt{\boldsymbol{LC}})}$$

Where; frequency used is in the range stated earlier used is 97MHz,

$$\mathbf{97MHz} = \frac{\mathbf{1}}{(\mathbf{2\pi}\sqrt{\mathbf{LC}})}$$

This value of variable capacitor is in the range of5pF to 30pF where the 22pF is selected for better output.

The inductor coil value will be between 0.1uH to 1uH where 0.12uH is selected. Forloudspeaker/headphone reproduction an amplifiers are used. Since in these amplifiers a battery with voltage bigger than 3 V is used. The R1 is counted from the formula.

$$R1 = \frac{Vcc - 3V}{0.167} K\Omega$$

Where Vcc is battery voltage, and 0.167mA is the current through R1, which supplies T1 and T2.

$R1 = \frac{9V-3V}{0.167} = 34K\Omega$, but $22K\Omega$ is used after manipulation.

Capacitors C1 and C2 combine together with R1, a pass-filter for very low frequencies, is used to separate the HF and LF parts of the receiver.

Why amplifier needed in this system? The reason is because in this power line carrier communication, the transmitted signal is in low level voltage in purpose to avoid this signal affected power line signal. Because of that purpose, the amplifier system is needed to amplify the low level signal especially at receiving system into certain higher level to ensure the signal can be used to activate the warning system. Audio amplifier system was decided to be used for amplifying low level AM signal in this system design. For this amplifier circuit design, IC LM741 operational amplifier (Op-Amp) was used. There are few reasons that cause the chosen of Op-Amp. Firstly by using this Op-Amp, simple design can be obtain but in same time it also can provide high gain. Others advantage is operational amplifier also low in term of cost, it easy to get in the market and easy to be design. In this system design, cascaded design has been used to achieve greater gain. Below is the figure of cascaded amplifier circuit design using operational amplifier.

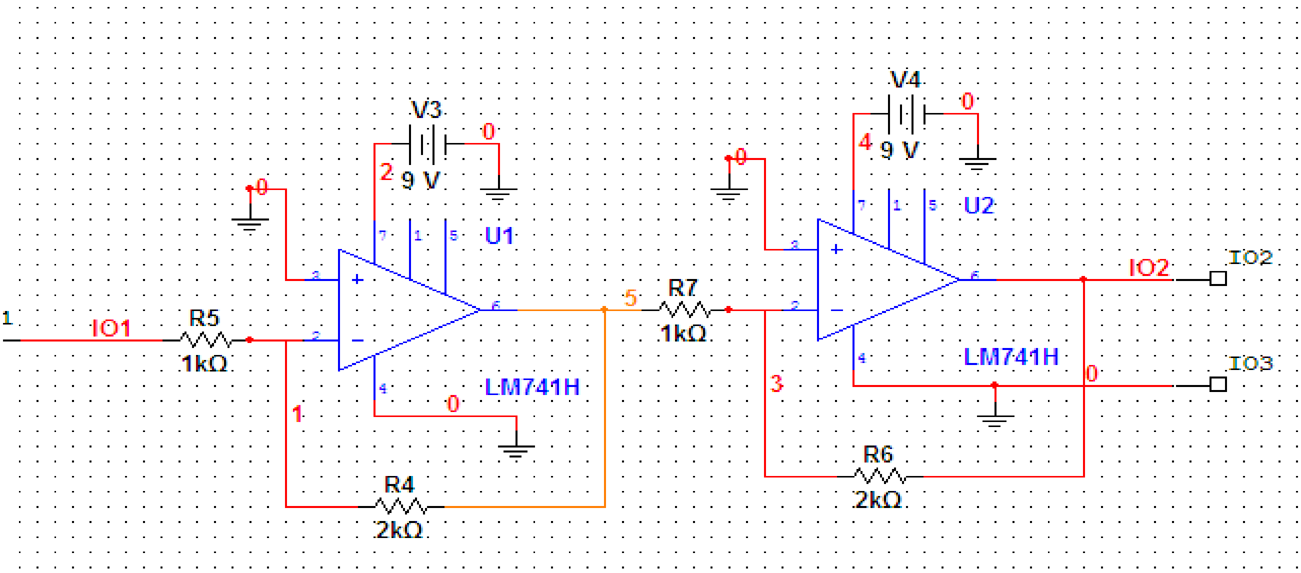

Figure 5: Amplifier Circuit.

From figure above, R5 and R7 is input resistor and R4 and R6 is reference resistor. The gain of this amplifier system can be increase easily by increasing the value of reference resistor R4 and R6. Below is the formula to calculate the overall gain for this amplifier circuit.

$A = (-Rf_1/Ri_1) \times (-Rf_2/Ri_2)$

Figure below shows AM output from the amplifier circuit. From the observation and comparison with the output of AM modulator circuit, it shows that this amplifier successfully provide sufficient gain to amplify the low amplitude of AM signal at its input to be higher amplitude at its output.

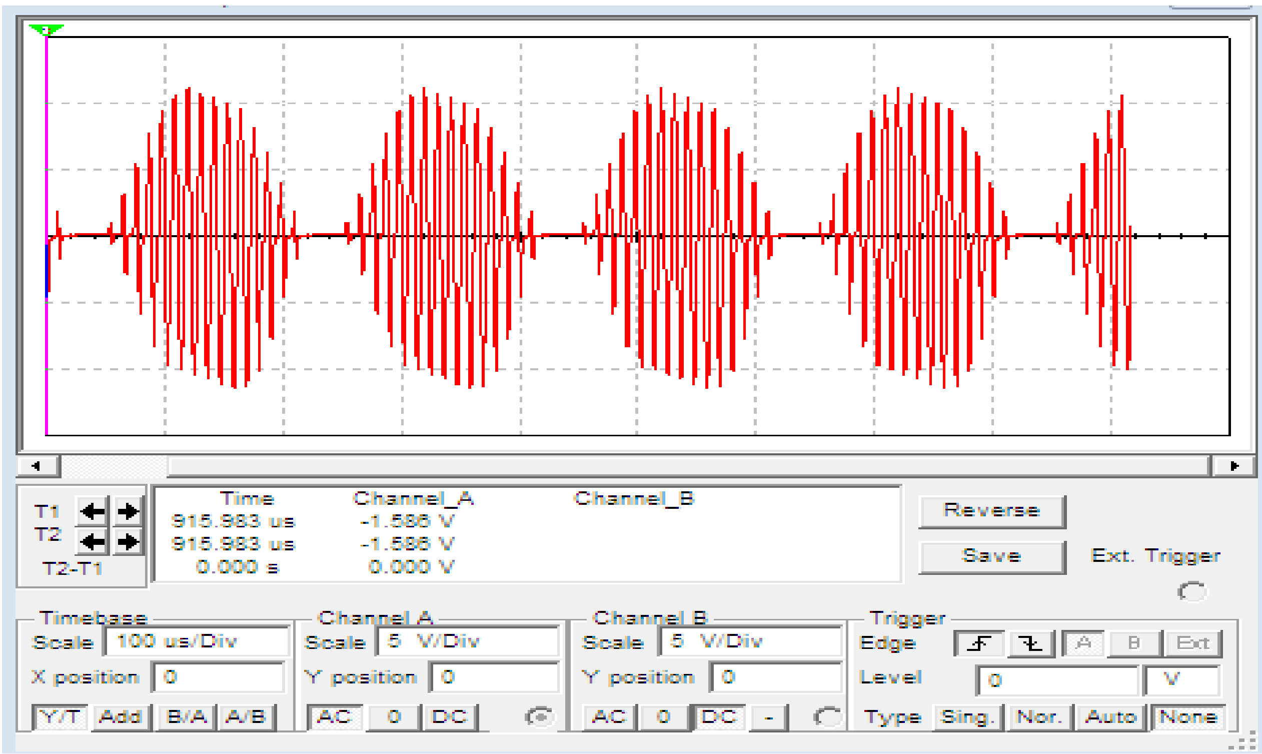

Figure 6: Output of Amplifier Circuit.

In power line carrier communication, filter is ones important circuit that will be needed. It functions to provide enough attenuation on its stop band in its frequency response to produce filtering function. In this system, filter is use to filter out 50 Hz power line signal and others unwanted signal except the transmitted AM signal. In this filter design, 0.5 dB chebyshev band-pass filter using L-C components has been used. Specific calculations are used to design or calculate each filter elements. The designing procedures for this band-pass filter begin with choosing the bandwidth (BW) for the system and number of element (N). Theoretically the larger number of element (N) will provide higher attenuation at stop band but it also will increase the complexity of the circuit.

After the bandwidth is chosen, then calculate $\Delta = f_2 - f_1 / f_0$ and obtain element values (g) from the table. And finally calculate the value of each components using specific formula. Below is the calculation on filter design for this power line carrier system:

Choose BW = 12kHz from 84 kHz until 96 kHz and N = 5

$\Delta =$ (96k – 84k) / 90k = 0.1333

From table g1 = g5 =1.7058, g2 = g4= 1.2296 and g3 = 2.5408

Calculate value for each filter components

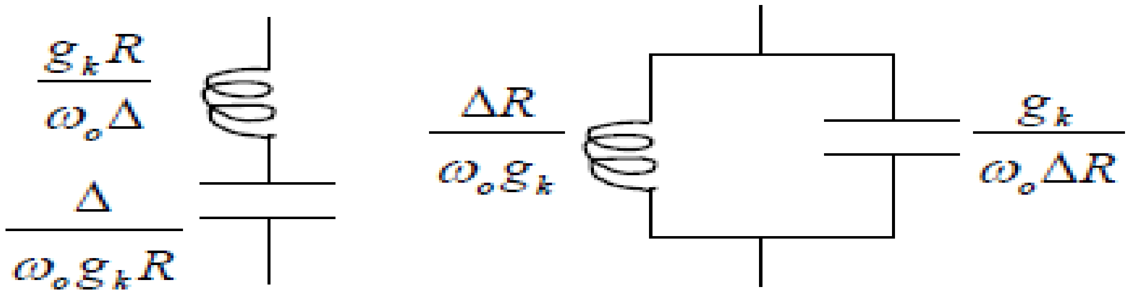

Figure 7: Band-Pass Filter Transformations.

L 1 = L 5 =
C 1 = C 5 =
0.1333
= 2.76nF ≈ 2.2nF
2π 90k (1.7058)(50)
L 2 = L 4 =
C 2 = C 4 =
1.7058(50)
= 1.13mH ≈ 1mH
2π 90k (0.1333)
0.1333(50)
= 9.56μH ≈ 10μH
2π 90k (1.2296)
1.2296
= 326nF ≈ 330nF
2π 90k (0.1333)(50)
L 3 = 2.5408(50)
= 1.68mH ≈ 1.5mH
2π 90k (0.1333)
C 3 = 0.1333
= 1.86nF ≈ 2nF
2π 90k (2.5408)(50)
1.7058(50)

In this filter design, calculation is done on various values of bandwidth (BW) and element number in purpose to obtain the components value that match with the standard value that available in the market. And finally, filter design with bandwidth equal to 12 kHz and element number equal to 5 was chosen as the final design because all calculation on components value that obtained using both this two parameters are available in the market. Figure below shows the circuit diagram for this filter design.

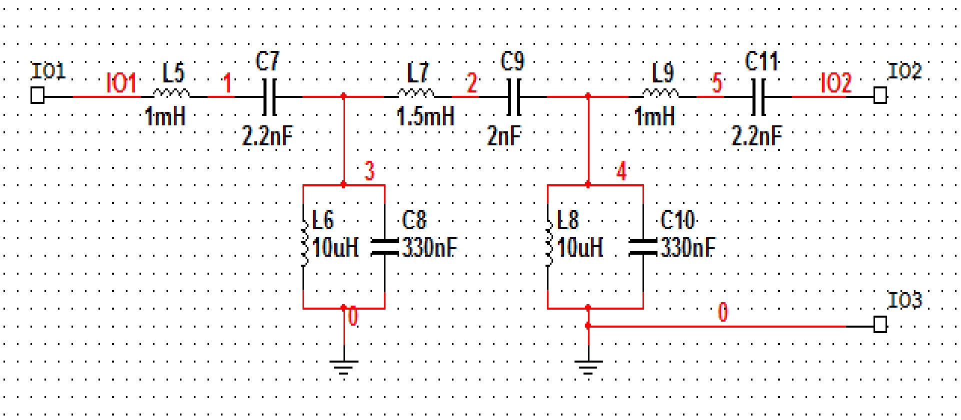

Figure 8: Band-Pass Filter Circuit.

Modulated signal resulting from varying carrier amplitudes based on the amplitude of information signal need to be injected into the power line for transmission. This responsibility is taken by the coupler circuit. The coupler circuit makes information signal transmission through the power line reliable. The coupler circuit is needed both at transmitting part and receiving part. There are several components needed in coupler circuit which commonly a combination of L- C components that provide impedance matching for the system. Below is the figure of coupler circuit for this system.

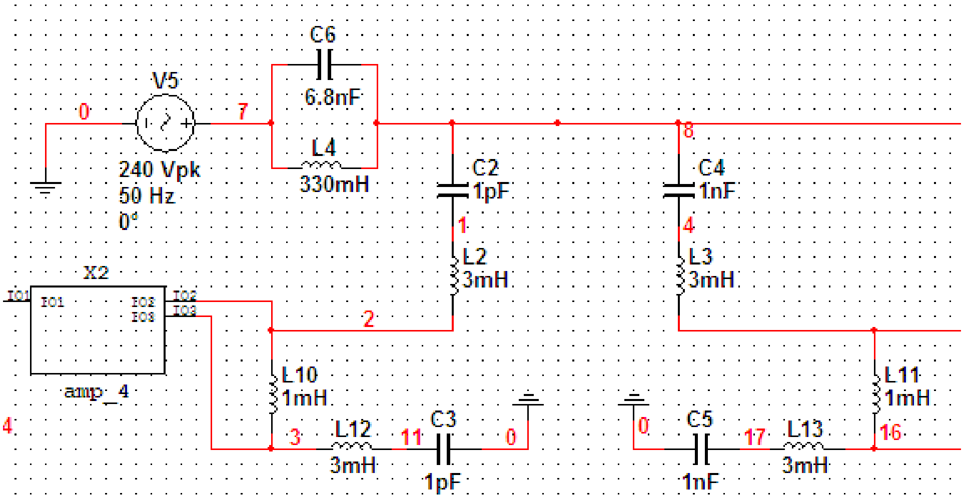

Figure 9: Coupler Circuits for Transmitting and Receiving Part.

From figure above, it can be seen that coupler circuit for transmitting and receiving part is same only few different at the components value. The coupler circuit consists of coupling capacitor, line tuner and line trap. C2 and C4 are the coupling capacitor for transmitting and receiving part. While parallel L-C component L4 and C6 is line trap circuit and the remaining components is the line tuner. The coupling capacitor functions as low pass filter to block high voltage power line signal from entering and damaging transmitter or receiver circuit. Line tuner components must be tuned to the carrier signal to ensure the signal can be transmit through power line. And Line Trap circuit function to direct carrier energy toward remote line terminal and to isolate the signal from bus impedance variation which can avoid carrier signal from to be attenuated by power line signal. The combination of these three circuits will provide necessary equipment in purpose for injecting AM signal into power line. Figure below shows the spectrum after coupling at transmitter and receiver. From the figure it can be shown the power line signal and AM signal exists in frequency spectrum which the AM signal is at center frequency 90 kHz. And at the output of receiver coupler circuit, it can be shown that only AM signal exists at the frequency spectrum. These two figure shows that this coupler circuit is properly and successfully work.

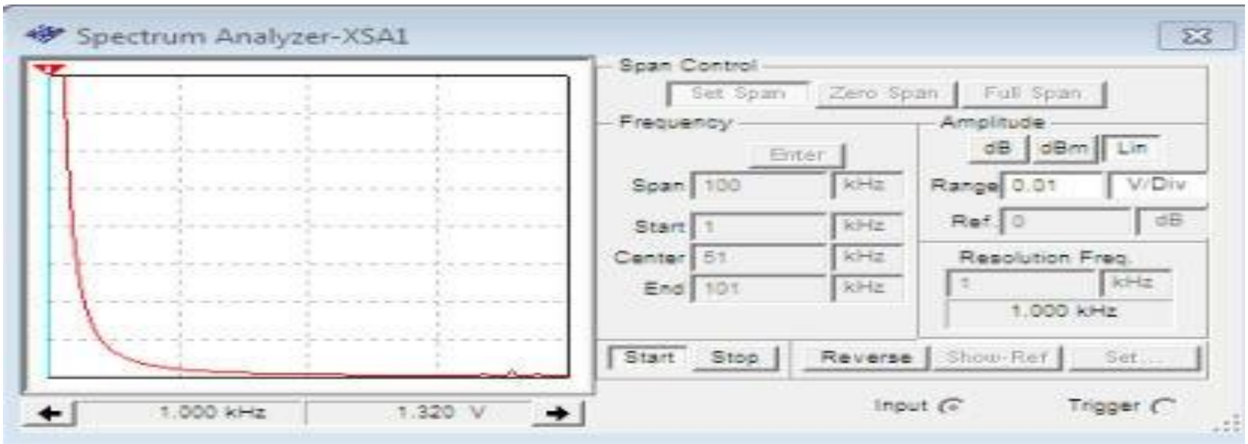

Figure 10: Frequency Spectrum of coupling signal in power line.

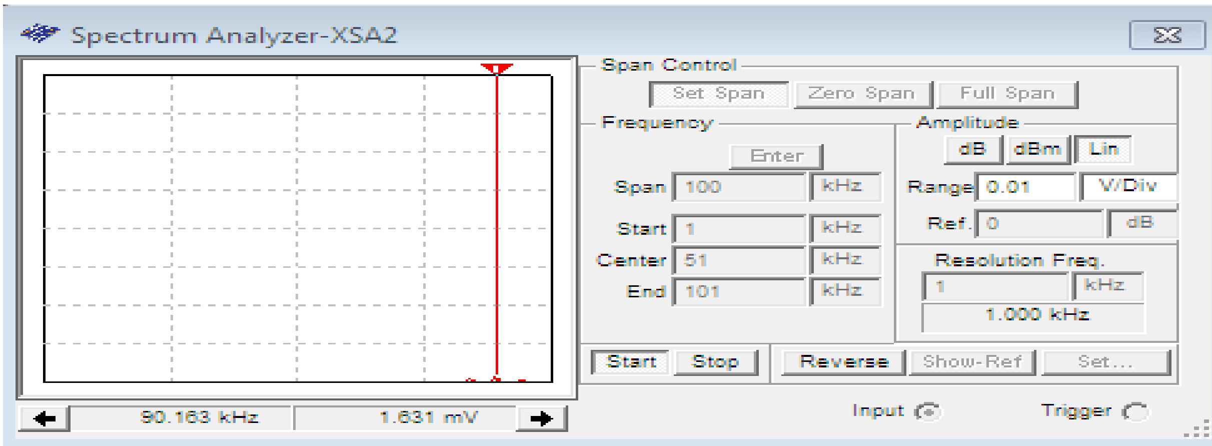

Figure 11: Output Spectrum of Receiver Coupler Circuit.

In the overall system design for this power line carrier communication, all designed circuit which are modulator, amplifier, filter and coupler circuit combined together. Combination of all this circuit will ensure the signal transmission through power line is possible and the project Design of Fire Siren System based on Power Line Carrier will successfully work. Below is the figure of overall system design.

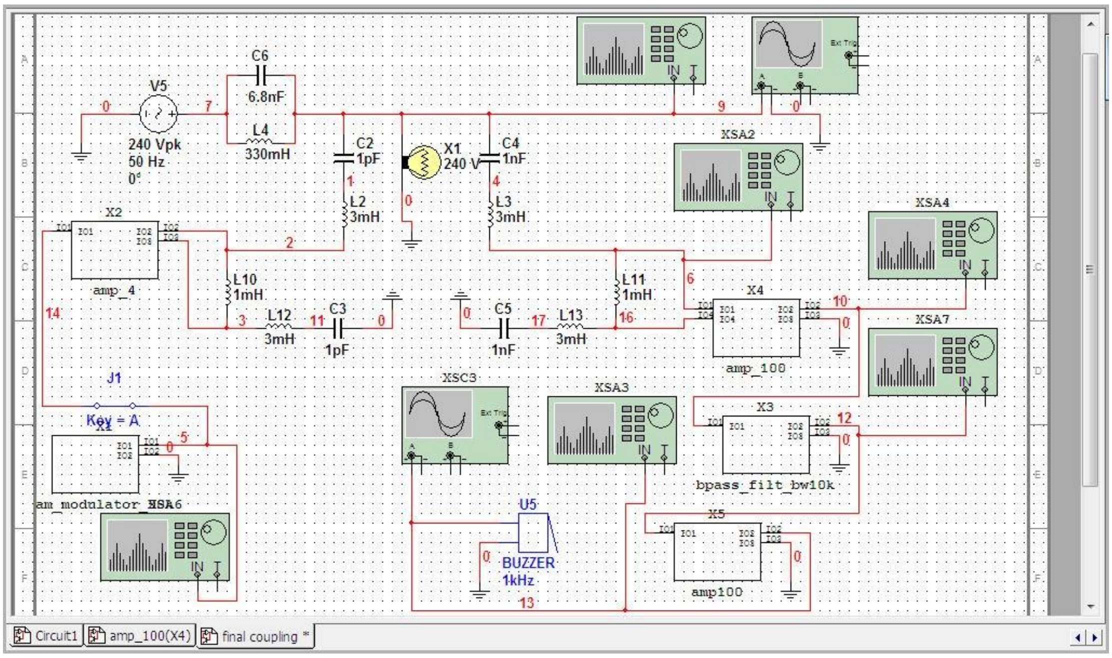

Figure 12: Overall System Design.

From the AM modulator, AM signal will be generated. Then amplifier will provide some amplification on AM signal before the coupler circuit injects the AM signal into power line. And at the receiving part, the coupler circuit will separate power line signal and AM signal and only allow AM signal pass through receiving part. Then received AM signal which extremely at low voltage will be amplify by amplifier circuit before the received signal will pass through filter circuit to filter out any unwanted signal except the AM signal. And finally filtered AM signal will feed into one more amplifier system to amplify the signal at appropriate signal before it can be used to turning alarm system „ON" or buzzer. Figure below shows the final output of AM signal that will be used to activate warning system or buzzer. The AM signal is at average peak of 6V which suitable with the buzzer specification.

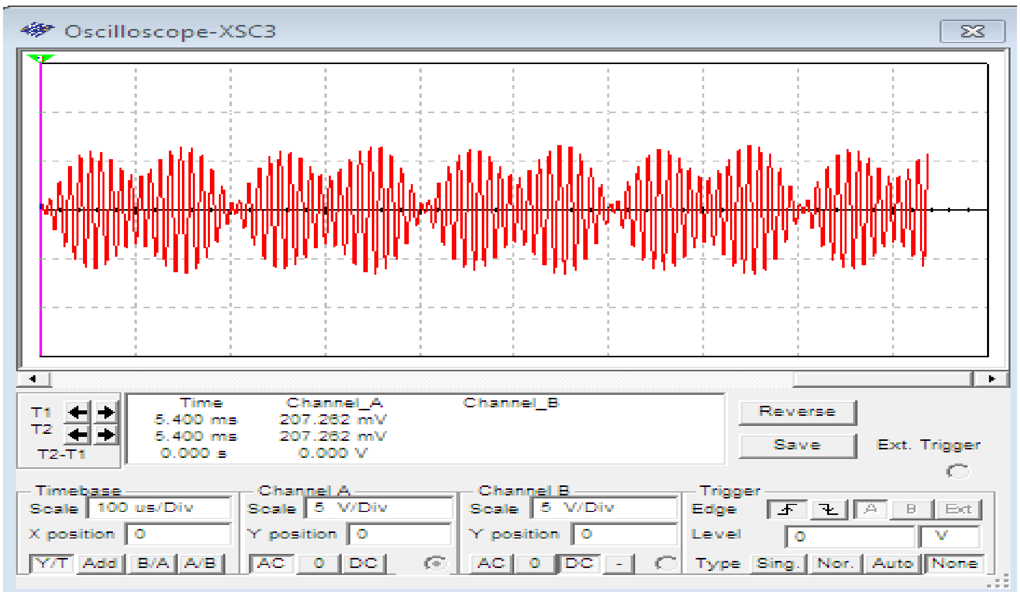

Figure 13: Final Output of AM Signal.

CONCLUSION AND RECOMMENDATION

The Design of Fire Siren System based on Power Line Carrier was completed for the simulation and hardware implementation. Basically, the scope of this project is more on how to transmit audio signal by using the concept of Power Line Carrier Communication (PLCC). This concept will provide some benefit especially in term of cost which the wiring installation cost could be reduced by taking advantage using existing power distribution line in home power line wiring as the wiring for this alarm system. The final design for this project Design of Fire Siren System based on Power Line Carrier consists of transmitter and receiver PLCC module which in transmitter part system it have modulator, amplifier and coupler circuit while in receiver system it consists of coupler circuit, band-pass filter, amplifier and buzzer to provide warning alert. Early Fire Siren that function to detect heat and generate the audio signal that need to be transmit through PLCC system must be connected at the input of modulator circuit at transmitter module.

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