

**REGENT UNIVERSITY COLLEGE OF SCIENCE AND
TECHNOLOGY**



**DESIGN AND CONSTRUCTION OF A DC TO AC AUTOMATIC
POWER INVERTER / CHARGER WITH A SIX CHANNEL RF BASED
REMOTE CONTROL LOAD MANAGEMENT SWITCH**

PRESENTED BY

MICHAEL KOFI ADU

ID NO: 01140112

**THESIS SUBMITTED TO THE SCHOOL OF INFORMATICS
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REQUIREDMENT FOR THE AWARD OF BACHELOR OF
ENGINEERING IN APPLIED ELECTRONICS AND
SYSTEMS ENGINEERING**

(INSTRUMENTATION OPTION)

DECLARATION

This dissertation has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree elsewhere.

The thesis is a result of my investigations, except where otherwise stated. All sources used in production of this thesis were acknowledged by appropriate citation and explicit references and were included in the bibliography that is appended.

I hereby declare that the preparation and presentation of this study were supervised in accordance with the guidelines and supervision laid down by Regent University College of Science and Technology.

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Students Signature

(Michael Kofi Adu)

This thesis is submitted for examination with the full knowledge and acceptance of my supervisor.

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Supervisor's Signature

(Dr. Paul Kwabena Obeng)

ABSTRACT

In the light of prevailing power cuts in the country, there is a sudden rise of a need to come up with backup power solutions. The most common backup supply systems available on the market are Automotive Generator Sets (convert mechanical energy to electrical energy by means of burning fossil fuel) and UPS (Uninterrupted power supply). Even though all these backup supply systems turn to perform their said functions to some extent, they turn to pose some challenges. Some of the limitations of using generator as alternative or additional source of electricity are mostly noisy during its operation, which causes disturbances in the neighborhood. The carbon mono-oxide and the black oil from the generator pose threats to the environment as air and soil or water pollutant making it non-environmentally friendly. The cost of maintenance turns to be expensive since they run on fuel, compared to an Inverter. This makes it quite unaffordable by people with low income. The 600VA DC-AC power inverter is designed to produce backup power that runs on 12V DC batteries which are ecofriendly to produce backup power for a longer period of time. This project would increase the knowledge on power inverter application by constructing a 12V DC to 220V AC with output power rating at 600VA with frequency varying between 49.95Hz, which is approximately 50 Hz. The traditional square wave derived from a stable multi-vibrator would be substituted for modified sine wave oscillator which would be designed by the combination of a timer and a flip-flop. The signal from the flip-flop is fed to a dual input Class AB pull-push amplifier to produce an alternating output with the same waveform but with a higher power enough to power up any equipment in the power rating of the system. The parallel state built by the RFP40N10 (N-Channel Mosfets) is to conduct large amount of power through the primary of the transformer to oscillate thereby generating an output at the secondary of the transformer.

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First and foremost, my sincere gratitude goes to God Almighty for His great protection upon my life from the beginning to the end of my study at Regent University College of Science and Technology.

DEDICATION

I dedicate this project to God Almighty for the travelling mercies granted to me throughout this program.

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CHAPTER ONE

INTRODUCTION

1.1 Background Of Study

The DC to AC Automatic Power Inverter/Charger With A Six Channel RF (Radio frequency) based Remote controlled switch is an electronics device that automatically turns on when the 230V AC mains voltage fails to supply electricity to electrical and electronics appliances during blackouts. Electricity is obtained by the use of a modified sine wave DC to AC power inverter which converts direct current (DC) stored in a 12V DC battery to alternating current (AC). Batteries have a fixed life and running power consuming equipment using the battery could be very expensive . Hence, rechargeable batteries can be used in this type of situation to reduce the cost. The converted AC can be at any required voltage and frequency through the use of appropriate transformers, oscillators, switching and control circuits. Inverters are commonly used to supply AC power from DC sources such as solar panels or rechargeable batteries. [1]

The use of semiconductor power devices such as bipolar transistors, for voltage amplification, particularly the MOSFET as the power switches, makes the inverter a better power supply. The inverter is less noisy, provides complete automatic switchover function, possess no environmental threats, less bulky and less expensive to maintain.

There are three basic types of inverters; square wave, modified sine wave and pure sine wave invertors.

A square wave inverter will run simple things like tools with universal motors without. Square wave inverters are seldom seen any more

The output of a modified sine wave inverter is similar to a square wave output except that the output goes to zero volts for a time before switching positive or negative. It is simple and low cost and is compatible with most electronic devices, except for sensitive or specialized equipment, for example certain laser printers. A pure sine wave inverter produces a nearly perfect sine wave output that is essentially the same as utility-supplied grid power. Thus it is compatible with all AC electronic devices. This is the type used in grid-tie inverters. Its design is more complex, and costs 5 or 10 times more per unit power. The electrical inverter is a high-power electronic oscillator. From the late nineteenth century through the middle of the twentieth century, DC-to-AC power inversion was accomplished using rotary converters or motor-generator sets (M-G sets)[1]. In the early twentieth century, vacuum tubes and gas filled tubes began to be used as switches in inverter circuits. [2] The most widely used type of tube was the thyatron.

The origins of electromechanical inverters give a good understanding of the term inverter. Early AC to DC converters used an induction or synchronous AC motor directly-connected to a generator also called dynamo so that the generator's commutator reverses its connections at exactly the right moments to produce DC. A later development is the synchronous converter, in which the motor and generator windings are combined into one armature, with slip rings at one end and a commutator at the other with only one field frame. The result with either arrangement was AC-in, DC-out. With an M-G set, the DC can be considered to be separately generated from the AC, while with a synchronous converter, it can be considered to be "mechanically rectified AC" in a certain sense. Given the right auxiliary and control equipment, an M-G set or rotary converter can be "run backwards", converting DC to AC. Hence an inverter may be considered as an inverted converter. [2]

Like the inverter, there are other forms of backup systems which includes the uninterrupted power supply and the generator set. An Uninterrupted Power Supply (UPS) system is an alternate or backup source of power with the electric utility company being the primary source. The UPS provides protection of load against line frequency variations, elimination of power line noise and voltage transients, voltage regulation, and uninterruptible power for critical loads during failures of normal utility source. A UPS can be considered a source of standby power or emergency power depending on the nature of the critical loads. The amount of power that the UPS must supply also depends on these specific needs. These needs can include emergency lighting for evacuation, emergency perimeter lighting for security, orderly shutdown of manufacturing or computer operations, continued operation of life support or critical medical equipment, safe operation of equipment during sags and brownouts, and a combination of the preceding needs.

The generator set is also another type of backup system which supplies power by burning fossil fuel. It converts mechanical energy to electrical energy. They are categorized in various forms depending on the capacity or power needed.

1.2 Statement of Problem

The most common backup supply systems available on the market are Automotive Generator Sets (convert mechanical energy to electrical energy by means of burning fossil fuel) and UPS (Uninterrupted power supply). Even though all these backup supply systems turn to perform their said functions, they turn to pose challenges.

Some of the limitations of using generator as alternative or additional source of electricity are:

Noisy: Most of the automotive power generators are noisy during its operation, which causes disturbances in the neighborhood.

Environmental threat: The carbon mono-oxide and the black oil from the generator pose threats to the environment as air and soil or water pollutant making it non-environmentally friendly.

Bulky: Most generators are big plant; therefore, generation of power at remote places is not too easy.

Expensive: Cost of maintenance turns to be expensive since they run on fuel, compared to an Inverter. This makes it quite unaffordable by people with low income.

The UPS is ecofriendly but is also designed to provide backup for a short period of time, which makes it not ideal for backup systems intended to run appliances for long periods of time.

It is to this effect that the 600VA DC-AC power inverter is designed to produce backup power that runs on 12V DC batteries which are ecofriendly to produce backup power for a longer period of time. Controlling load increase or decrease backup time when energy is saved on turning off devices which are not essential. End users usually feel lazy and reluctant to go round turning of lights and other gadgets when they are not in use. With this system the user can be at one location and control appliances with a touch of a bottom.

1.3 General Objectives

The main objective of this project is to design and construct a DC to AC automatic power inverter/charger with a six channel RF based remote controlled load management switch.

1.3.1 Specific Objective

It is the goal and objective of this project to:

- Design a modified sine wave inverter using a 555 timer as a pulse generator and TC 4013 flip-flop to drive a class B amplifier using two set of MOSFET array and a center-tapped transformer.
- Apply new technologies in the design of power inverters/charging systems which utilizes the same transformer for the inverting of 12V DC to 230V AC and converting 230V AC to 12V DC for the charging of the battery.
- Control the operation of the internal circuitry and the external loads with an RF based 6 channel wireless remote control module.

1.4 Significance of Study

The main problem in Ghana within the energy sector recently is the generation and distribution of electrical power. This situation has been attributed to a local word known as “dumso”- meaning excessive fluctuation of power.

The main significance of this project is to help solve this “dumso” problem in the country, by providing a prolonged backup system of electrical power.

Another problem this project will solve is the pollution of the environment by generator sets which burns fossil fuel and releases carbon monoxide into the environment, accompanied by noise.

This problem will be solved because the inverter does not depend of fossil fuel and does not produce excessive noise, making it environmentally friendly.

This inverter is accompanied by the following features making it very significant;

- The system has an RF remote control system that allows the end user to switch 'ON' or OFF from one point.
- Low cost modified sine wave inverter to upgrade on the square wave inverter without increasing cost of production.
- Force air cooling system which allows the machine to run continuously without overheating.
- Microsecond automatic load transfer and switching to avoid computer based systems from restarting.
- Low battery power consumption.

1.5 Scope of Study

A 200 meter remote control module is configured to serve as a toggle switch to control home appliances from a distance. The system applies the principle of full wave rectification, converts 220V mains AC to 12V DC from a 15volt step-down transformer. This is regulated using an adjustable mode voltage regulator and a charge controller circuit to protect the battery from overcharging. The charging mode is regulated by zener diodes which clips the voltage to specified voltage needed by the battery type by controlling the reference voltage. The DC is controlled with an array of logical arranged relays which forms an automatic switching control system. The automatic switching is made up of array of SPDT (Single Pole Double Throw) relay switch which is powered by the mains via a power supply unit. When the switch is powered, it is sent to a standby mode which keeps it there until the mains fail. Immediately the mains fail the switch is toggled to on position allowing current to flow through the closed circuit for the appliance to turn on automatically.

This project would increase the knowledge on power inverter application because; it is targeted at manufacturing a 12V DC to 220V AC with output power rating at 600VA with frequency varying between 60/50Hz. The traditional square wave derived from a stable multi-vibrator would be substituted for modified sine wave oscillator which would be designed by the combination of a timer and a flip-flop. The signal from the flip-flop is fed to a dual input Class AB pull-push amplifier to produce an alternating output with the same waveform but with a higher power enough to power up any equipment in the power rating of the system. The parallel state built by the RFP40N10 (N-Channel Mosfets) is to conduct large amount of power through the primary of the transformer to oscillate. Since the primary of the power transformer is center tapped, it joins the transistor arrangement to form a class AB power amplifier with less noise and time crossover distortion is eliminated.

1.6 Organization Of The Study

Chapter one gives a background of the study and introduces the subject matter of the project. It also explains the purpose and objectives of the present work.

Chapter Two explains the literature of the work and gives some of the information that already exist.

Chapter three is Methodology which elaborates the component used and the method of design and construction of the prototype.

Results and discussions is presented in chapter four.

The project ends with chapter five where a final conclusion on the entire project is made and recommendations for further work.

CHAPTER TWO

LITERATURE REVIEW

2.0. Introduction

An inverter is an electrical device that converts direct current (DC) to alternating current (AC) or signal. The converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. Solid-state inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. The inverter performs the opposite function of a rectifier. [3]

2.1. Types of Inverters

There are three basic types of dc-ac converters: square wave, modified sinewave, and pure sine wave (see the diagram below). The **square wave** is the simplest and cheapest type, but nowadays it is practically not used commercially because of low power quality. The **modified sine wave** topologies (which are actually modified square waves) provide square waves with some dead spots between positive and negative half-cycles. They are suitable for many electronic loads, although their THD (*total harmonic distortion*) is about 25%.

The quality of the inverter output waveform can be expressed by using the Fourier analysis data to calculate the total harmonic distortion (THD). The total harmonic distortion (THD) is the square root of the sum of the squares of the harmonic voltages divided by the fundamental voltage:

$$\text{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1}$$

Priced in the range of \$.05-\$.10 per watt, modified Sinewave models are the most popular low-cost inverters on the consumer market today, particularly among car and domestic inverters. If you are buying a model whose description does not state that it is a pure Sinewave type, then most likely it is a modified one. Note that output voltage waveform in conventional modified Sinewave DC-AC circuits has only two levels: zero or peak voltage of both polarities. By adding another voltage level, a designer can reduce THD typically from 25% to 6.5%.

Periodically connecting the output to a specific voltage level with proper timing can produce a multiple-level waveform which is closer to sinusoidal than conventional modified Sinewave. A Sinewave inverter produces output with low total harmonic distortion (normally below 3%). It is the most expensive type of AC power source, which is used when there is a need for clean sinusoidal output for some sensitive devices such as medical equipment, laser printers, stereos, etc. [4]

There are a number of topologies used in the inverter circuits. Cheap square wave circuits suitable primarily for hobbyist's projects may use just a push-pull converter with a step-up transformer. Most commercially manufactured models use a multi-stage concept. With such technique, first a Switching-Mode Power Supply (SMPS) steps up a voltage from an input source to another DC voltage corresponding to the peak value of the desired sinusoidal voltage. The output stage then generates an AC. This stage usually uses a full-bridge or half-bridge configuration. If a half-bridge is used, the DC-link voltage should be more than twice the peak of the generated output. Input to output galvanic isolation is provided by either a high-frequency transformer in the SMPS pre-regulator, or by a large low-frequency output transformer. If a low-frequency transformer is used, the sinusoidal voltage is generated on its primary side and transformed to the secondary side. The output can be controlled either in

square-wave mode or in pulse width-modulated (PWM) mode. Sine wave circuits use PWM mode, in which the output voltage and frequency are controlled by varying the duty cycle of the high frequency pulses. Chopped signal then passes through a low pass LC-filter to supply a clean sinusoidal output. Although such approach is more expensive, it is usually employed in the backup devices for home or business use, which require high quality of AC power. [5]

2.1.1 Basic Designs

In one simple inverter circuit, DC power is connected to a transformer through the center tap of the primary winding. A switch is rapidly switched back and forth to allow current to flow back to the DC source following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of current in the primary winding of the transformer produces alternating current (AC) in the secondary circuit.

The electromechanical version of the switching device includes two stationary contacts and a spring supported moving contact. The spring holds the movable contact against one of the stationary contacts and an electromagnet pulls the movable contact to the opposite stationary contact. The current in the electromagnet is interrupted by the action of the switch so that the switch continually switches rapidly back and forth. This type of electromechanical inverter switch, called a vibrator or buzzer, was once used in vacuum tube automobile radios. A similar mechanism has been used in door bells, buzzers and tattoo guns. [6]

As they became available with adequate power ratings, transistors and various other types of semiconductor switches have been incorporated into inverter circuit designs.

2.1.2. Advanced Designs

There are many different power circuit topologies and control strategies used in inverter designs. Different design approaches address various issues that may be more or less important depending on the way that the inverter is intended to be used. [8]

The issue of waveform quality can be addressed in many ways. Capacitors and inductors can be used to filter the waveform. If the design includes a transformer, filtering can be applied to the primary or the secondary side of the transformer or to both sides. Low-pass filters are applied to allow the fundamental component of the waveform to pass to the output while limiting the passage of the harmonic components. If the inverter is designed to provide power at a fixed frequency, a resonant filter can be used. For an adjustable frequency inverter, the filter must be tuned to a frequency that is above the maximum fundamental frequency.

2.2. Power Inverters and Waveforms

Inverters, besides coming in a wide variety of power capacities, are distinguished primarily by the shape of the alternating current wave they produce. The three major waveforms are square-wave, modified sine-wave and true sine-wave. Almost all inverters rely on push pull class B amplifier but the wave of the power output largely depends on the type of oscillator used in the design. For example if an astable multi-vibrator is used as the oscillator in an inverter, the wave form at the output would be square wave because the multi-vibrator is a square wave oscillator. [9]

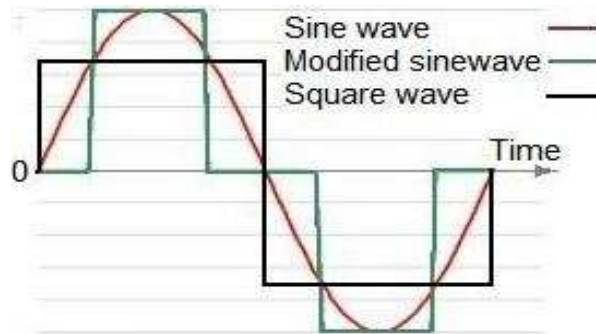


Figure 2.1. : Types of inverters' wave forms [9]

2.3. Square Wave Inverters

Square wave inverters are largely obsolete, as the waveform shape is not well suited for running most modern appliances. The oscillator as mentioned earlier determines the output wave form. Therefore emphases would be laid on the square wave oscillator. The most common type of square wave inverters is based on astable multi-vibrator.

2.3.1. Multi-vibrator

A multi-vibrator is basically an electronic circuit constituting two amplifier circuits arranged with regenerative feedback used to implement a variety of simple two-state systems such as oscillators, timers and flip-flops. One of the amplifiers is conducting while the other is cut off.

When an input signal to one amplifier is large enough, the transistor can be driven into cutoff, and its collector voltage will be almost V_{CC} . However, when the transistor is driven into saturation, its collector voltage will be about 0 volts. A circuit that is designed to go quickly from cutoff to saturation will produce a square or rectangular wave at its output. This principle is used in multivibrator. Multivibrators are classified according to the number of steady (stable) states of the circuit. A steady state exists when circuit operation is essentially

constant; that is, one transistor remains in conduction and the other remains cut off until an external signal is applied. [10]

The three types of multivibrators are the ASTABLE, MONOSTABLE, and BISTABLE.

- **Astable multi-vibrator:** The astable circuit has no stable state. With no external signal applied, the transistors alternately switch from cutoff to saturation at a frequency determined by the RC time constants of the coupling circuits. It continuously oscillates from one state to the other. Due to this, it does not require an input (Clock pulse or other).
- **Monostable multi-vibrator:** The monostable multi-vibrator has in one of the states is stable, but the other is not. The monostable circuit has one stable state; one transistor conducts while the other is cut off. A signal must be applied to change this condition. After a period of time, determined by the internal RC components, the circuit will return to its original condition where it remains until the next signal arrives. This circuit is also known as a one shot multivibrator.
- **Bistable multi-vibrator:** The bistable multivibrator has two stable states. It remains in one of the stable states until a trigger is applied. It then FLIPS to the other stable condition and remains there until another trigger is applied. The multivibrator then changes back (FLOPS) to its first stable state. Such a circuit is important as the fundamental building block of a register or memory device. This circuit is also known as a latch or a flip-flop.[11]

In its simplest form the multi-vibrator circuit consists of two cross-coupled transistors. Using resistor-capacitor networks within the circuit to define the time periods of the unstable states, the various types may be implemented. Multi-vibrators find applications in a variety of

systems where square waves or timed intervals are required. Simple circuits tend to be inaccurate since many factors affect their timing, so they are rarely used where very high precision is required.

Before the advent of low-cost integrated circuits, chains of multi-vibrator found use as frequency dividers. A free-running multi-vibrator with a frequency of one-half to one-tenth of the reference frequency would accurately lock to the reference frequency. This technique was used in early electronic organs, to keep notes of different octaves accurately in tune. Other applications included early television systems, where the various line and frame frequencies were kept synchronized by pulses included in the video signal.

2.3.2. Astable Multi-vibrator Circuits

An astable multi-vibrator is also known as a free-running multi-vibrator. It is called free-running because it alternates between two different output voltage levels during the time it is on. The output remains at each voltage level for a definite period of time. If you looked at this output on an oscilloscope, you would see continuous square or rectangular waveforms. The astable multi-vibrator has two outputs, but no inputs. [12]

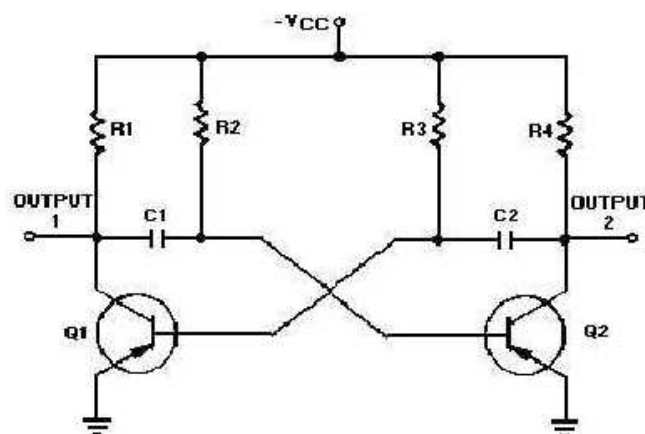


Figure 2.2.: Astable Multi-vibrator [12]

The astable multi-vibrator is said to oscillate. To understand why the astable multi-vibrator oscillates, assume that transistor Q1 saturates and transistor Q2 cuts off when the circuit is energized. This situation is shown in figure 3. We assume Q1 saturates and Q2 is in cutoff because the circuit is symmetrical; that is, $R1 = R4$, $R2 = R3$, $C1 = C2$, and $Q1 = Q2$. It is impossible to tell which transistor will actually conduct when the circuit is energized. For this reason, either of the transistors may be assumed to conduct for circuit analysis purposes.

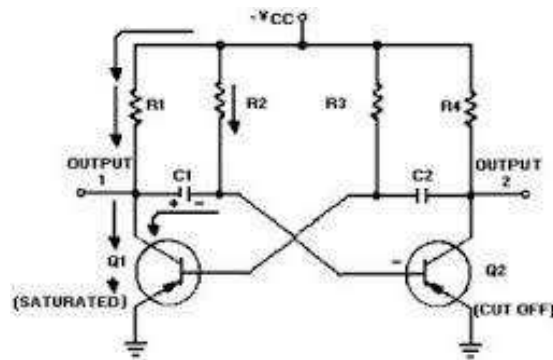


Figure 2.3. : Astable multi-vibrator (Q1 saturated) [14]

Essentially, all the current in the circuit flows through Q1; Q1 offers almost no resistance to current flow. Notice that capacitor C1 is charging. Since Q1 offers almost no resistance in its saturated state, the rate of charge of C1 depends only on the time constant of R2 and C1 (recall that $T_c = RC$). Notice that the right-hand side of capacitor C1 is connected to the base of transistor Q2, which is now at cutoff.

Analysis of what is happening is that, the right-hand side of capacitor C1 becomes increasingly negative. If the base of Q2 becomes sufficiently negative, Q2 will conduct. After a certain period of time, the base of Q2 will become sufficiently negative to cause Q2 to change states from cutoff to conduction. The time necessary for Q2 to become saturated is determined by the time constant $R2C1$.

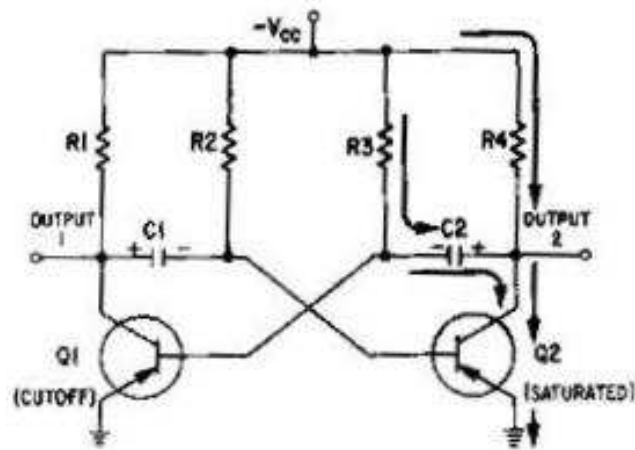


Figure 2.4. : Astable multi-vibrator (Q2 saturated)

The next state is shown in figure 2.4. The negative voltage accumulated on the right side on capacitor C1 has caused Q2 to conduct. Now the following sequence of events takes place almost instantaneously. Q2 starts conducting and quickly saturates, and the voltage at output 2 changes from approximately $-V_{CC}$ to approximately 0 volts. This change in voltage is coupled through C2 to the base of Q1, forcing Q1 to cutoff. Now Q1 is in cutoff and Q2 is in saturation. This is the circuit situation shown in figure 2.4.

Notice that figure 2.4 is the mirror image of figure 2.3. In figure 2.4 the left side of capacitor C2 becomes more negative at a rate determined by the time constant $R3C2$. As the left side of C2 becomes more negative, the base of Q1 also becomes more negative. When the base of Q1 becomes negative enough to allow Q1 to conduct, Q1 will again go into saturation. The resulting change in voltage at output 1 will cause Q2 to return to the cutoff state.

The output waveform from transistor Q2, as shown in figure 2.5. The waveform of the output voltage (from either output of the multi-vibrator) alternates from approximately zero volts to approximately $-V_{CC}$, remaining in each state for a definite period of time. The time may range from a microsecond to as much as a second or two. In some applications, the time period of higher voltage ($-V_{CC}$) and the time period of lower voltage (0 volts) will be equal. Other

applications require differing higher- and lower-voltage times. For example, timing and gating circuits often have different pulse widths as shown in figure 2.6. [6]

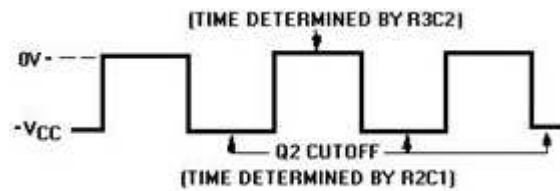


Figure 2.5. : Square wave output from Q2. [16]

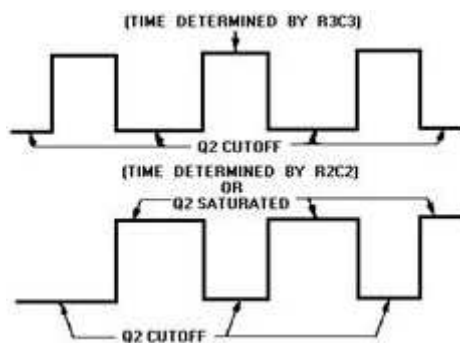


Figure 2.6. : Rectangular waves [16]

2.3.3. Astable Multivibrator using 555 Timer

An Astable Multivibrator is an oscillator circuit that continuously produces rectangular wave without the aid of external triggering. So Astable Multivibrators are known as free running oscillators. Astable Multivibrator using 555 Timer is very simple, easy to design, very stable and low cost. It can be used for timing from microseconds to hours. Due to these reasons 555 has a large number of applications. [17]

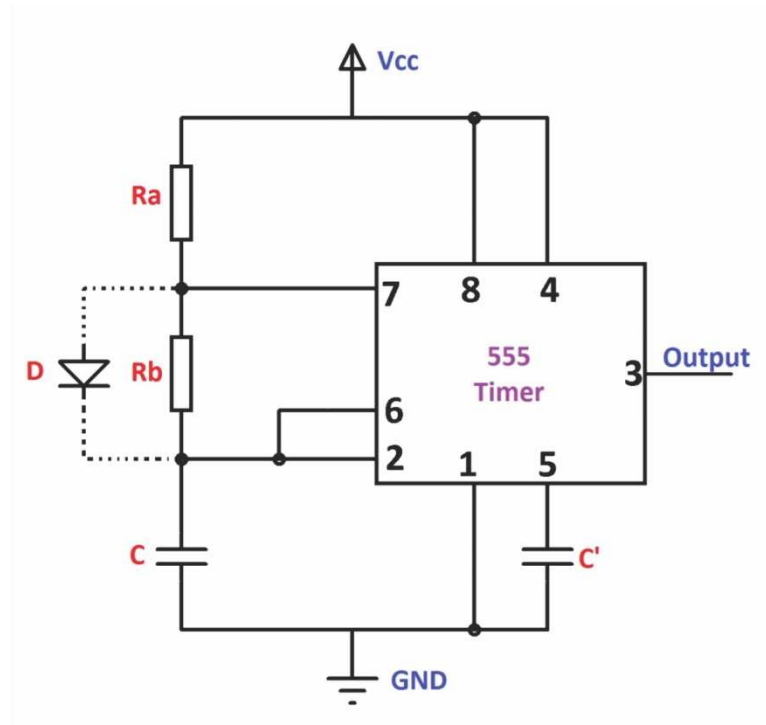


Figure 2.7. Astable Multivibrator using 555 Timer Circuit Diagram [17]

Figure 2.7 shows the circuit diagram of a 555 Timer wired in Astable Mode. 8th pin and 1st pin of the IC are used to give power, V_{cc} and GND respectively. The 4th pin is RESET pin which is active low and is connected to V_{cc} to avoid accidental resets. 5th pin is the Control Voltage pin which is not used. So to avoid high frequency noises it is connected to a capacitor C' whose other end is connected to ground. Usually $C' = 0.01\mu F$. The Trigger (pin 2) and Threshold (pin 6) inputs are connected to the capacitor which determines the output of the timer. Discharge pin (pin 7) is connected to the resistor R_b such that the capacitor can discharge through R_b . Diode D connected in parallel to R_b is only used when an output of duty cycle less than or equal to 50% is required. For the sake of explaining the working, Circuit Diagram with Internal Block diagram is shown in figure 2.8. Since the Control Voltage (pin 5) is not used the comparator reference voltages will be $2/3 V_{cc}$ and $1/3 V_{cc}$ respectively. So

the output of the 555 will set (goes high) when the capacitor voltage goes below $\frac{1}{3} V_{cc}$ and output will reset (goes low) when the capacitor voltage gets to $\frac{2}{3} V_{cc}$.

- When the circuit is switched ON, the capacitor (C) voltage will be less than $\frac{1}{3} V_{cc}$. So the output of the lower comparator will be HIGH and of the higher comparator will be LOW. This SETs the output of the SR Flip-flop.
- Thus the discharging transistor will be OFF and the capacitor C starts charging from V_{cc} through resistor R_a & R_b .
- When the capacitor voltage becomes greater than $\frac{1}{3} V_{cc}$ (less than $\frac{2}{3} V_{cc}$), the output of both comparators will be LOW and the output of SR Flip-flop will be same as the previous condition. Thus the capacitor continuous to charge. Capacitor voltage goes above $\frac{2}{3} V_{cc}$. [7]

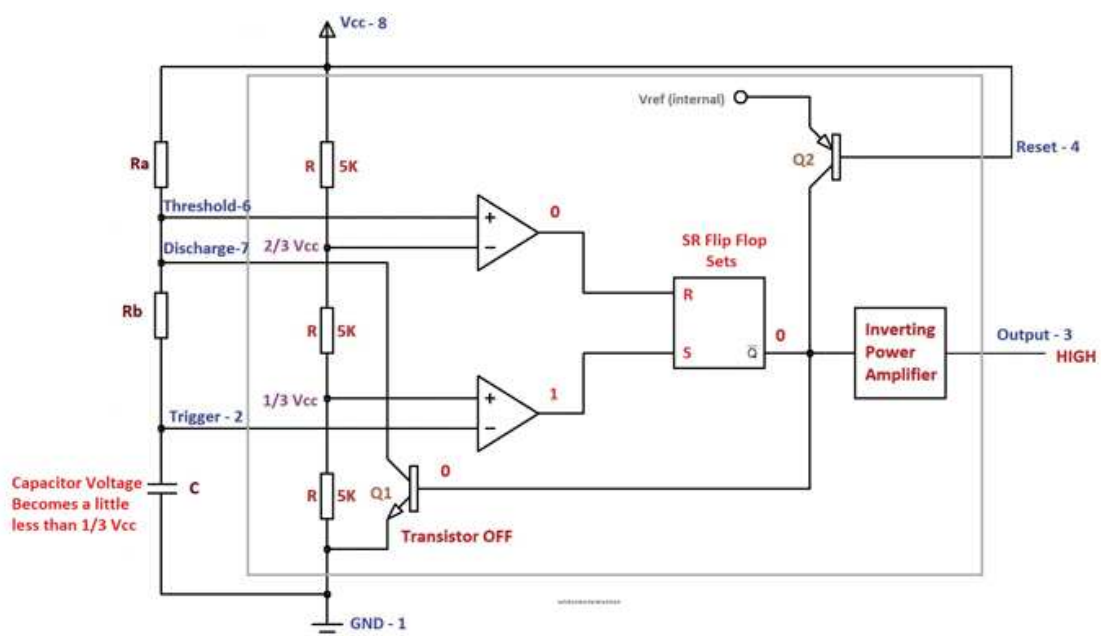


Figure 2.8. Astable Multivibrator using 555 Timer Working [18]

- When the capacitor voltage will becomes slightly greater than $\frac{2}{3} V_{cc}$ the output of the higher comparator will be HIGH and of lower comparator will be LOW. This resets the SR Flip-flop.
- Thus the discharging transistor turns ON and the capacitor starts discharging through resistor R_b .
- Soon the capacitor voltage will be less than $\frac{2}{3} V_{cc}$ and output of both comparators will be LOW. So the output of the SR Flip-flop will be the previous state.
- So the discharging of capacitor continuous.
- When the capacitor voltage will become less than $\frac{1}{3} V_{cc}$, the output SETs since the output of lower comparator is HIGH and of higher comparator is LOW and the capacitor starts charging again.
- This process continuous and a rectangular wave will be obtained at the output. [18]

Capacitor Charges through R_a and R_b .

$$T_{high} = 0.693(R_a + R_b)C$$

Capacitor Discharges through R_b

$$T_{low} = 0.693R_bC$$

$$\text{Duty Cycle} = T_{high}/(T_{high} + T_{low})$$

Where T_{high} and T_{low} are the time period of HIGH and LOW of the output of 555.

From this we can find that Duty Cycle less than or equal to 50% cannot be obtained. There are two ways to obtain this.

- Inverting the output
- Using a Diode Parallel to resistor Rb

Inverting the Output

In this method, just compliment the output. Thus the Duty Cycle = $T_{low}/(T_{low} + T_{high})$.

Where T_{low} and T_{high} are the time period of LOW and HIGH of output of 555. In this method the duty cycle of the output of 555 will be greater than 50% and that of inverter will be less than 50%.

Duty Cycle of 555 = $1 - \text{Duty Cycle of Inverter}$

Using a Diode Parallel to resistor Rb

In this method we will connect a diode parallel to resistor Rb as shown dotted in the first circuit diagram above. Thus the charging current of capacitor will bypass the resistor Rb.

Thus $T_{high} = 0.693R_aC$ [18]

Thus a Duty Cycle less than or equal to 50% can easily obtained.

2.3.4. Constraints of Square Wave Inverters

Even though the square wave is highly economical due its affordability in terms of cost of production, it has some clampdown such as:

- High audio noise which turns to be very visible when it is being used to operate an audio system.

- ii. Incompatibility with certain communication gadgets such as fax machine, modems, routers and other equipments which run on motors such as fan, printers, photo copiers etc.
- iii. Low surge power

It is to this fact that new system like the modified sine wave which is built on the foundations of modified square wave is being introduced.

2.4.1. Pure Sine Wave

Pure or True Sine Wave inverters provide electrical power similar to the utility power you receive from the outlets in your home or office, which is highly reliable and does not produce electrical noise interference associated with the other types of inverters. With its "perfect" sine wave output, the power produced by the inverter fully assures that your sensitive loads will be correctly powered, with no interference. Some appliances which are likely to require Pure Sine Wave include computers, digital clocks, battery chargers, light dimmers, variable speed motors, and audio/visual equipment. If your application is an important video presentation at work, opera on your expensive sound system, surveillance video, a telecommunications application, any calibrated measuring equipment, or any other sensitive load, you must use a Pure Sine Wave inverter. [19]

2.4.2. Modified Square/Sine Wave Inverter

An inverter allows the use of 230V electrical appliances from a battery or a solar battery. It must therefore supply a voltage that corresponds to an RMS of 230 Volts sine-wave like household main supply or similar. Sine-wave voltages are not easy to generate. The advantage of sine-wave voltages is the soft temporal rise of voltage and the absence of harmonic oscillations, which cause unwanted counter forces on engines, interferences on

radio equipment and surge currents on condensers. On the other hand, square wave voltages can be generated very simply by switches, e.g. electronic valves like MOSFET transistors. In former times electromagnetically switches, which operated like a door bell were used for this task. They were called "chopper cartridge" and mastered frequencies up to 200 cycles per second. The efficiency of a modified square wave inverter is higher than the appropriate sine wave inverter, due to its simplicity. With the help of a transformer the generated modified square wave voltage can be transformed to a value of 230 Volts or even higher (radio transmitters). [20]

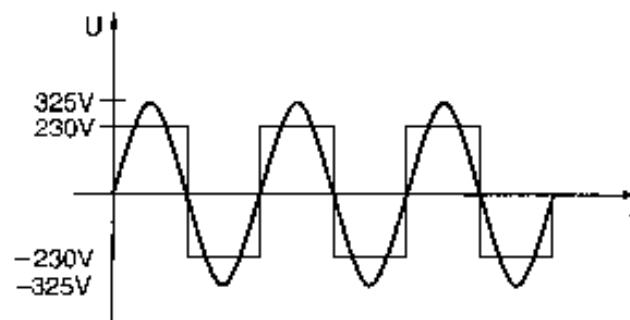


Figure 2.9. : Sine-wave voltage and conventional square wave voltage with both 230 Volt R.M.S [20]

Figure 2.9 above shows a sine-wave as well as a square wave voltage with in each case an rms of 230 Volts. In both cases an electric lamp would light with the same intensity. This is, as we know, the definition of rms. As we recognize in Figure 2.7. However the peak value of the sine-wave voltage is 325 Volts, i.e. factor $\sqrt{2}$ more than rms. For electric lamps this is insignificant and electric engines are appropriate for it. Electronic devices were even designed for the peak voltage of sine-wave voltage, because internally they generate DC voltage from the AC supply voltage. A condenser will be loaded on exactly the peak value of the sine-wave voltage. Electronic devices thereby usually cannot be operated on 230 Volts

square waves. The industry nevertheless manufactured modified square wave inverters according to this principle in former times.

The inverter works with a trick, to obtain the same results from square wave voltage as for modified sine-wave voltage.

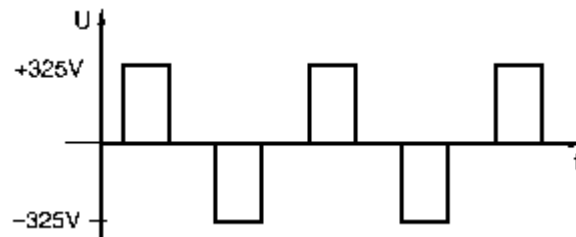


Figure 2.10. : Voltage with duty cycle 25% for 230 Volts r.m.s ("*Modified sine*") [20]

Square wave voltage in figure develops the same peak value as sine-wave voltage of 230 Volts, i.e. $230 \text{ Volt} * \sqrt{2} = 325 \text{ Volts}$ and nevertheless thereby obtains the demanded r.m.s of 230 V. Square wave voltage as shown in the previous figure (full half wave) with peak value of the corresponding sine-wave voltage would cause double amount of electrical power on electric consumers. The trick is, to switch the output power only for one half of every conducting cycle, thus resulting on a duty cycle of 25% on behalf of the complete oscillation period. If the calculated double amount of electric power will be generated only half the time effective power remains the same. Industry called this cam shape "*modified sine*", in order to be able to differentiate the devices from conventional square wave inverters. [20]

The inverter may feed nearly all electrical appliances, designed for 230 Volts, with exception of rotary field engines that use condensers for generation of an auxiliary phase (condenser engines). Engines of this type are used in most refrigerators, washing machines, dishwashers and some few machine tools. Fluorescent lamps with a series inductivity to limit the operating current won't work correctly on our inverter not necessary problem with the output

waveform but in terms of power rating and specific function the inverter is designed for. This problem can be solved by increasing the duty cycle on more than 25% while decreasing the peak voltage to 275 Volts. Instead fluorescent lamps with electronics (energy saving lamps) will work very well on the inverter. There may also be problems with some small plug power supplies. An increased magnetizing current results on square wave voltages, while there would be a predominantly inductive load ($\cos \phi \ll 1$). Duty cycle 25% and $\cos \phi = 0$ will result in load currents up to factor $\sqrt{2}$ (approx. factor 1.5).

This project (600VA inverter) is suitable for:

- electric drills, fret saws, circular saws, electric chain saws, grinders
- Vacuum cleaners, coffee machines, irons, dryers, mixers, sewing machines, electric razors, etc.
- lamps, energy-savings lamps
- Electronic devices, e.g. music amplifiers, battery chargers
- Computers and accessories
- Televisions and radios
- Radio transmitters, high voltage generators, among other things.

2.4.3 Modifying Sine Wave Using Discrete Square Waves

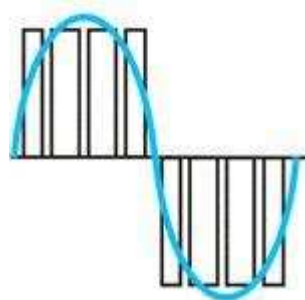


Figure 2.11.: Modified sine wave [21]

Figure 2.11 provide an interesting design of a single modified sine wave cycle made by chopping a few square waves. Here, each positive and negative half cycle contain 3 discrete individual narrow square waves, each block is separated by a notch, the center two “pillars” are identical but are twice in magnitude than the extreme ones.

The average value of this special arrangement of discrete square waves effectively imitates a sinusoidal wave. This configuration is as good as a pure sine AC waveform and thus will be suitable to operate almost all appliances safely.

In fact the present design is much more efficient than the usual circuits used in many inverters. From this circuit it’s possible to get an efficiency of almost 90%, because here the output devices are either turned fully on or fully off.

2.5. RF Based Wireless Remote Control System

It is often required to switch electrical appliances from a distance without being a direct line of sight between the transmitter and receiver. An RF based wireless remote control system (RF Transmitter & RF Receiver) can be used to control an output load from a remote place. RF transmitter, as the name suggests, uses radio frequency to send the signals at a particular frequency and a baud rate.[22]

The RF receiver can receive these signals only if it is configured for the pre-defined signal/data pattern. An ideal solution for this application is provided by compact transmitter and receiver modules, which operate at a frequency of 434 MHz and are available ready-made. Here, the radio frequency (RF) transmission system employs Amplitude Shift Keying (ASK) with transmitter (and receiver) operating at 434 MHz. The use of the ready-made RF

module simplifies the construction of a wireless remote control system and also makes it more reliable. [22]

2.5.1. RF Transmitter

This simple RF transmitter, consisting of a 434MHz license-exempt Transmitter module and an encoder IC, was designed to remotely switch simple appliances on and off. The RF part consists of a standard 434MHz transmitter module, which works at a frequency of 433.92 MHz and has a range of about 400m according to the manufacture. The transmitter module has four pins. Apart from “Data” and the “Vcc” pin, there is a common ground (GND) for data and supply. Last is the RF output (ANT) pin.

Note that, for the transmission of a unique signal, an encoder is crucial. For this, one renowned encoder is IC HT12E from Holtek. HT12E is capable of encoding information which consists of N address bits and 12N data bits. Each address/ data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF transmission medium upon receipt of a trigger signal. Solder bridges TJ1 and TJ2 are used to set the address and data bits. [21]



Figure 2.12. RF Based Wireless Remote Control System receiver module [21]

Table 2.1. Pin Assignment of the 434MHz Transmitter module

Pin	Function
1	GND

2	Data In
3	Vcc
4	ANT

The current consumption with a supply voltage of near 5.4V is about 10 mA. Since the current consumption is very little, the power can also be provided by standard button cells. Recommended antenna length is 17 cm for 433.92 MHz, and a stiff wire can be used as the antenna. Remember to mount the antenna (aerial) as close as possible to pin 4 (ANT) of the transmitter module.

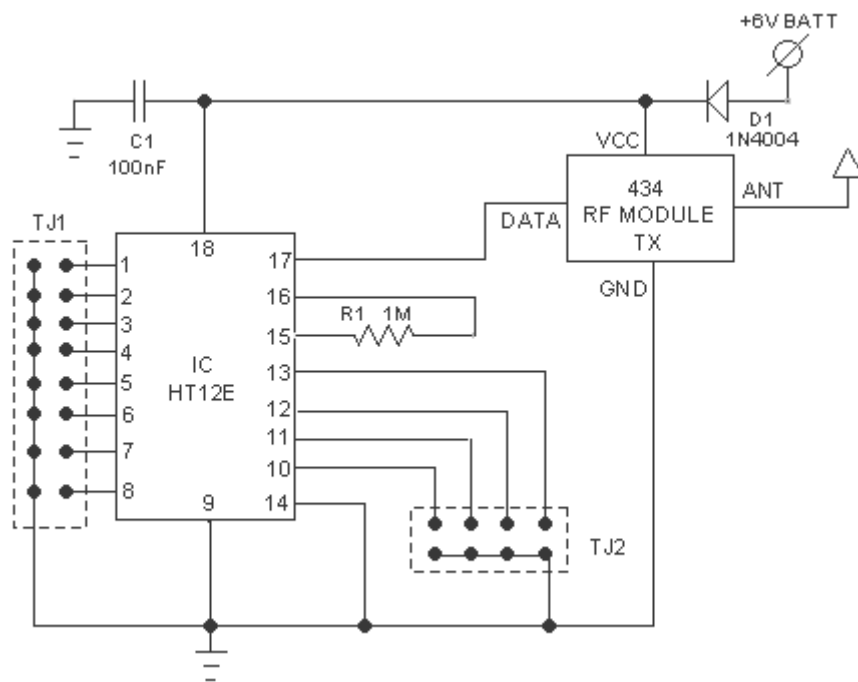


Figure 2.13. RF Transmitter Schematic Diagram [21]

2.5.2. RF Receiver

This circuit complements the RF transmitter built around the small 434MHz transmitter module. The receiver picks up the transmitted signals using the 434Mhz receiver module.

This integrated RF receiver module has been tuned to a frequency of 433.92MHz, exactly same as for the RF transmitter.

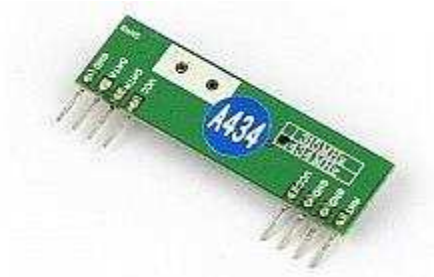


Figure 2.14. 434MHz receiver module [21]

The miniature 434MHz RF receiver module receives On-Off Keyed (OOK) modulation signal and demodulates it to digital signal for the next decoder stage. Local oscillator is made of Phase Locked Loop (PLL) structure. Technically, this is an Amplitude Shift Keying (ASK) receiver module based on a single-conversion, super-heterodyne receiver architecture and incorporates an entire Phase-Locked Loop (PLL) for precise local oscillator (LO) generation. It can use in OOK / HCS / PWM modulation signal and demodulate to digital signal. [21]

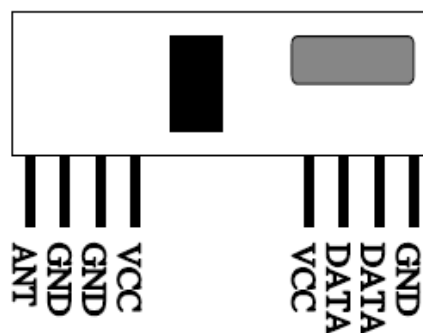


Figure 2.15. Pin Assignment of the 434MHz Receiver module [21]

- 1 Antenna
- 2 Ground

- 3 Ground
- 4 Vcc
- 5 Vcc
- 6 Linear Data (Normally NOT used)
- 7 Digital Data (Normally Used)
- 8 Ground

The receiver module has eight (4+4) pins. Apart from three “ground (GND)” and two “Vcc” pins, there are two pins (one for Digital Data & other for Linear Data) for data output. Last is the RF input (ANT) pin.

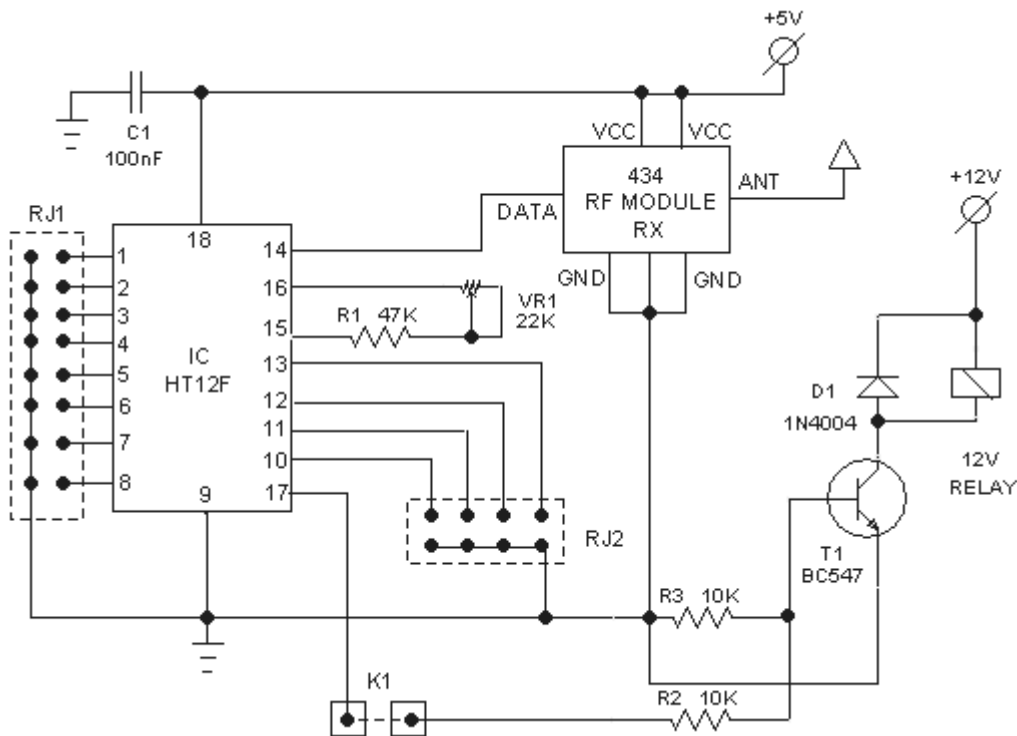


Figure 2.16. RF Receiver Schematic Diagram [21]

The “coded” signal transmitted by the transmitter is processed at the receiver side by the decoder IC HT12F from Holtek. VR1 and R1 are used to tweak the oscillator frequency of

the decoder to that of the transmitter. Any possible variations due to component tolerances and/or a different supply voltage can be compensated by this arrangement. HT12F is capable of decoding information's that consist of N bits of address and 12N bits of data. HT12F decoder IC receives serial addresses and data from the HT12E encoder that are transmitted by the RF transmitter module. HT12D compare the serial input data three times continuously with the local addresses.

If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The "Valid Transmission" (VT) pin also goes high to indicate a valid transmission.

For proper operation, a pair of HT12E/HT12F ICs with the same number of addresses and data format should be chosen. The data bits are set up using solder bridges RJ1 and RJ2. Output of the decoder is brought out on a pin header K1 , making the logical signal available to circuits that need it. This output is also fed to the relay driver transistor T1. The RF Receiver circuit can be powered from a standard 5VDC supply. Just as for the RF Transmitter, the aerial (17 cm for 433.92 MHz) has to be mounted as close as possible to the RF IN (ANT) pin of the 434MHz RF receiver module. [22]

Notes

- RF transmitter circuit can be safely powered from DC 4.5V to 6V power supply. Here, diode D1 is added to introduce a 0.65V drop, but this is not very crucial
- The 434 MHz RF module (TX &Rx) is available from many sources. Connection terminals are usually labeled on the PCB. In case of any doubt, refer datasheets of the RF modules

- In practice, the transmitter is usually powered by batteries. But you can power the receiver from an onboard /external dc supply too. In this case, make an optional “noise filter” arrangement , as shown here, to “clean” the 5V power rails of the 434MHz RF receiver module

CHAPTER THREE

METHODOLOGY, SYSTEM DESIGN AND IMPLEMENTATION

3.1 System Design

For smooth construction of this project the system was divided into three main sectors namely, AC to DC converter for the charging of the battery, DC to AC inversion for the converting of battery power (DC) to electricity (AC), and switching system for the co-ordination and synchronization of the system.

3.1.1 DC to AC Inverter

The circuit diagram for the astable multivibrator using IC 555 is shown in figure 3.1. The astable multivibrator generates a square wave, the period of which is determined by the circuit external to IC 555. The astable multivibrator does not require any external trigger to change the state of the output. Hence the name free running oscillator. The time during which the output is either high or low is determined by the two resistors and a capacitor which are externally connected to the 555 timer.

However as soon as the voltage across the capacitor equals $\frac{2}{3} V_{cc}$, comparator1 triggers the flip-flop and the output switches to low state. Now capacitor C discharges through RB and the transistor Q1. When voltage across C equals $\frac{1}{3} V_{cc}$, comparator 2's output triggers the flip-flop and the output goes high. Then the cycle repeats. The capacitor is periodically charged and discharged between $\frac{2}{3} V_{cc}$ and $\frac{1}{3} V_{cc}$ respectively. The time during which the capacitor charges from $\frac{1}{3} V_{cc}$ to $\frac{2}{3} V_{cc}$ is equal to the time the output remains high and is given by V_{cc} through RA and RB.

$$t_c = 0.693(R_A + R_B)C$$

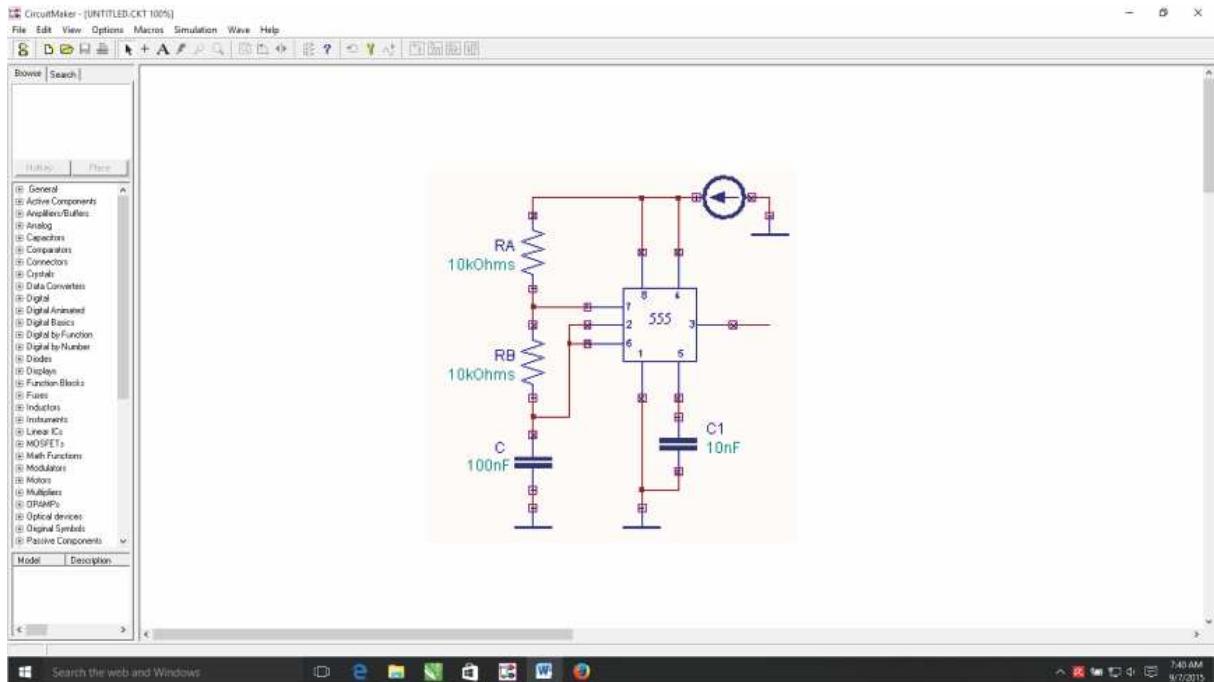


Figure 3.1. Simulation of the astable multivibrator

The above figure shows the 555 timer connected as an astable multivibrator. Initially when the output is high capacitor C starts charging towards.

where R_A and R_B are in ohms and C is in Farads. Similarly the time during which the capacitor discharges from $2/3 V_{cc}$ to $1/3 V_{cc}$ is equal to the

time the output is low and is given by

$$t_d = 0.693R_B C$$

Thus the total time period of the output waveform is

$$T = t_c + t_d = 0.693(R_A + 2R_B)C$$

Therefore the frequency of oscillation

$$f = \frac{1}{T} = \frac{1.45}{(R_A + 2R_B)C}$$

The output frequency, f is independent of the supply voltage V_{cc} .

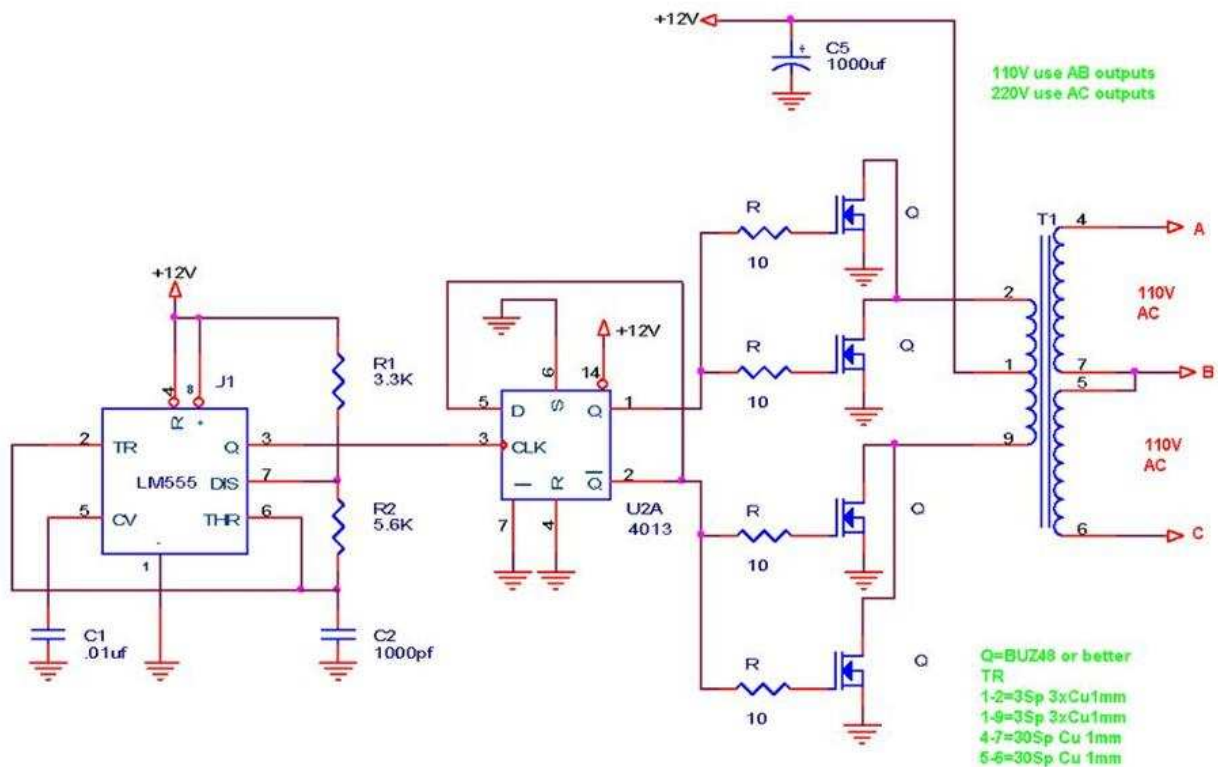


Figure 3.2. DC to AC Modified Sine Wave Inverter

The DC to AC inverter was sub divided into four stages namely Regulating, Oscillation, Decoding and Signal Amplification for a chronological construction. The inverter itself is only responsible for converting 12 Volt DC from battery into 220 Volt AC, 50 Hz, modified sine wave. This is made up of the oscillator, decoding, the regulator and the signal amplifier. Figure 3.1 shows the schematic circuit of the Oscillation and Signal Amplification Schematic part of the inverter.

A classic 555 timer chip, identified as IC1 LM555, is configured as an astable multivibrator at a frequency close to 100 Hz, which can be adjusted accurately by means of varying the resistance of R2. As the mark/space ratio (duty factor) of the 555 output is a long way from being 1:1 (50%), it is used to drive a D-type flip-flop produced using a CMOS type 4013 IC. This produces perfect complementary square-wave signals (i.e. in anti-phase) on its Q₁ and

Q_2 outputs suitable for driving the output power transistors. As the output current available from the CMOS 4013 is very small, mosfets power transistors are used to arrive at the necessary output current. In this design one has chosen IRF3710 from National Instruments [23] which are cheap and readily available, but any equivalent power mosfets could be used. These drive a 230 V to 2×12 V center-tapped transformer used ‘backwards’ to produce the 230 V output. The presence of the 230 VAC is indicated by an LED light, while a VDR (voltage dependent resistor) type S10K250 or S07K250 clips off the spikes and surges that may appear at the mosfets switching points. The output signal this circuit produces is approximately a modified square wave; only approximately, since it is somewhat distorted by passing through the transformer. Fortunately, it is suitable for the majority of electrical devices it is capable of supplying, whether they be light bulbs, small motors, or power supplies for electronic devices.

Even though the circuit is intended and designed to be powered by a car battery, i.e. from 12 V, the transformer is specified with a 12V primary. But at full power you need to allow for a voltage drop of around 3 V between the collector and emitter of the power transistors. The Darlington transistors should be fitted onto a finned anodized aluminum heat-sink using the standard insulating accessories of mica washers and shouldered washers, as their collectors are connected to the metal cans and would otherwise be short-circuited. An output power of 1000VA implies a current consumption of the order of 83.33 A from the 12 V battery at the ‘primary side’. So the wires connecting the collectors of the IRF3710 [22] T1 and T2 to the transformer primary, the source of T1 and T2 to the battery negative terminal, and the battery positive terminal to the transformer primary will need to have a minimum cross-sectional area of 2 mm^2 so as to minimize voltage drop.

The transformer used is a 230 V to 2×9 V type, with an E/I iron core, rated at around 1200 VA. Properly constructed on the board shown here, the circuit should work at once, the only adjustment being to set the output to a frequency of 50 Hz with P1. one should keep in mind that the frequency stability of the 555 is fairly poor by today's standards, so you shouldn't rely on it to drive your radio-alarm correctly – but is such a device very useful or indeed desirable to have on holiday anyway? Watch out too for the fact that the output voltage of this inverter is just as dangerous as the mains from your domestic power sockets.

3.1.2. Automatic Load transfer Switch

The automatic load transfer switch alternates the load between the mains supply and the inverted power from the battery. 24VDC powered single pole double throw (SPDT) relays as electromagnetic switches to control the operation of the inverter turn on and off immediately grid mains fail.

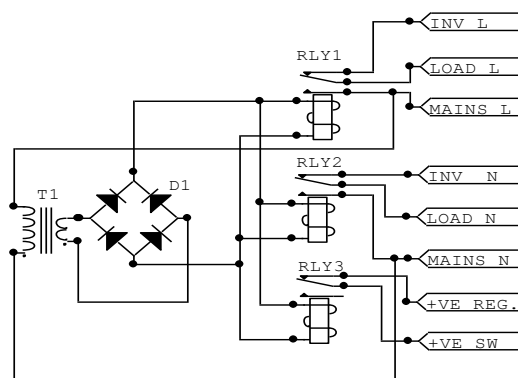


Figure 3.3. Automatic Switching circuit

When grid power is on, the transformer T1 is energized which triggers all the switches to “ON” mode. At this mode the loads automatically connects to the grid power and DC supply to the regulator is cut off to stop the inverters from operating.

When the grid power goes “OFF” the switches are released and the load automatically connects itself to the inverter and at the same time power is released to the regulator circuit which causes the inverter circuit to start operation. No capacitor is used to filter or smoothing the rectified power from the bridge diode because the introduction of a capacitor to a relay power supply increases the tendency for a delay in switching the relays to either “ON” or “OFF” mode.

3.1.3. Battery Charger and Control System

The system utilizes the same transformer for inverting and charging. This charge control system opens and closes circuit for mains to flow through the transformer for battery charging. From the circuit figure 3.4 it is seen that the Op-amp uA741 is in the heart of the circuit. This is connected as a comparator circuit. Usually the voltage at pin 3 will be equal to 6V with the Zener diode ZD1-6V. While the battery has a voltage charged in full. The output voltage at pin 6 to negative voltage across the Zener diode, goes to make the transistor C945-Q1 and the Relay-RY1 does not work as well. So the AC voltage input to the transformer-T1 will be cut off. The reduction of the battery voltage will make the voltage at pin 2 of IC1 lower than at pin 3. This makes the voltage at pin 6 of IC1 positive and if it is higher than 3.3V, it will result in the base current (I_b of Q1) entering biased to Q1 doing and the relay also work, so the contact of relay will connect the ACV to the transformer T1 so has the secondary coil ACV to a bridge circuit BD1 to DCV (12Vdc) and across drop at C1-1,000uF for filter signal full wave rectifier form, to the charging battery system again. Until the voltage battery full will make pin 2 of IC1 positive when compared with voltage at pin 3. This circuit will cut off the current that charges battery at once, and begin to renew charge again when voltage is lower than the setup.

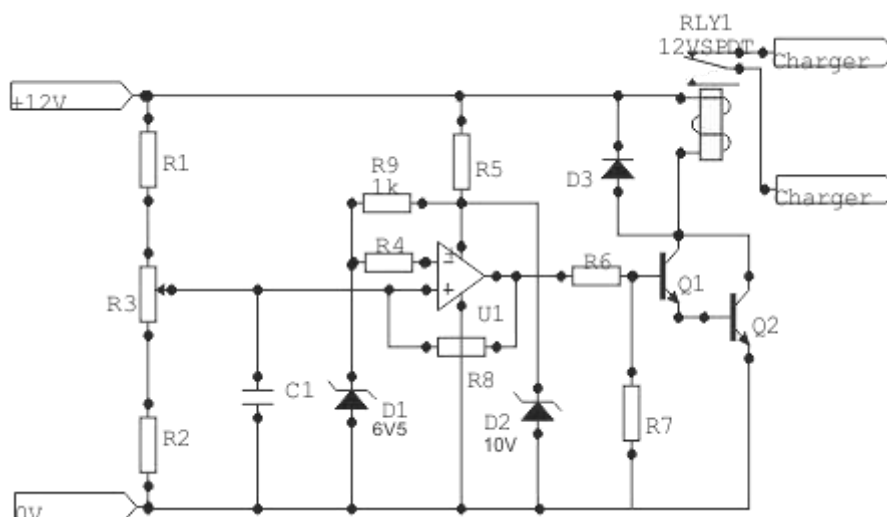


Figure 3.4. Charge Controller Circuit

3.1.4. Wireless Switch Module

Table 3.1. Technical Specifications

Operating voltage:	DC12V
Static current:	$\leq 300\text{mA}$
Load control:	alternating current/direct current
Output current:	$\leq 10\text{A}$
Operating frequency:	315MHz- 433MHz
Receiver sensibility:	-105dbm
Operating temperature:	-20- +70
Size:	68*48*18mm
Weight:	102g(including the remote controller)
Remote control distance:	200m (in wide-open area)



Figure 3.5. Picture of the front view of the 6 channel RF Wireless smart receiver controller

Description:

This 6-channel multifunction RF receiving controller is for sending open signal and close signal to 6 relays. It can be used to turn on/ off, connect/disconnect or implement other specific controlling program on the controlled devices or motor. Typical applications for relays include fields of electronically operated gate, windows, lifting appliance, switch, lifter, industrial control, security industry etc.

The RF controller has the advantages of high confidentiality, high stability, low power, and use expediently; no need for traditional connecting wire or dial fixing code switch, all you need to do is learn to match the code of the remote controller and the receiving controller.

Output mode:

APDC-6PCX has 5 output modes: self-lock, interlock, non-lock, 3 relays self-lock coexisting with 3 relays non-lock and 1 relay self-lock coexisting with 5 relays non-lock.

Self-lock ——press 1

Press key 1, the corresponding relay will be actuated and keeps closed. Press 1 again, the relay 1 is disconnected. Press 2, the corresponding relay is actuated and keeps closed, press 2 again, relay 2 is disconnected. 3, 4, 5 and 6 works in the same way.

Interlock —— press 2

Press 1, the corresponding relay will be actuated and keeps closed. When you press 2, relay 1 will be disconnected and relay 2 is actuated simultaneously and keeps closed. Relay 3, 4, 5 and 6 works by that analogy.

3. Non-lock ——press 4

Press 1, the corresponding relay is actuated and it is disconnected right after you release the key 1. Relay 2, 3, 4, 5 and 6 works in the same way.

4.3 relays self-lock coexisting with 3 relays non-lock ——press 3

Among the 6 relays corresponding to the remote control, relay 1/2/3/ are in self-lock mode, relay 4/5/6 are in non-lock mode.

5. Relay self-lock coexisting with 5 relays non-lock——press 5

Among the 6 relays corresponding to the remote control, relay 1 is in self-lock mode; relay 2/3/ 4/5/6 are in non-lock mode.

Learning method:

One will enter learning state after the led indicator of the receiver blinks in 2 seconds. Press any key on the controller; if the led indicator blinks once, it has received the signal, and the

learning is successful. Press the learned key; you can control the corresponding relay now. After the learning, the remote can work.

If a learned remote controller gets lost, you should clear the stored information in the receiver controller. Thus, the lost one cannot controller the receiver any more. A new one must be learned **Clear the code:**

Long press the learning key on the receiver for about 8 seconds, if the indicator light is off after 2 times of blink, the existing code is cleared. This receiver can store as much as 30 different remote control codes.

3.1.5 System Block Diagram

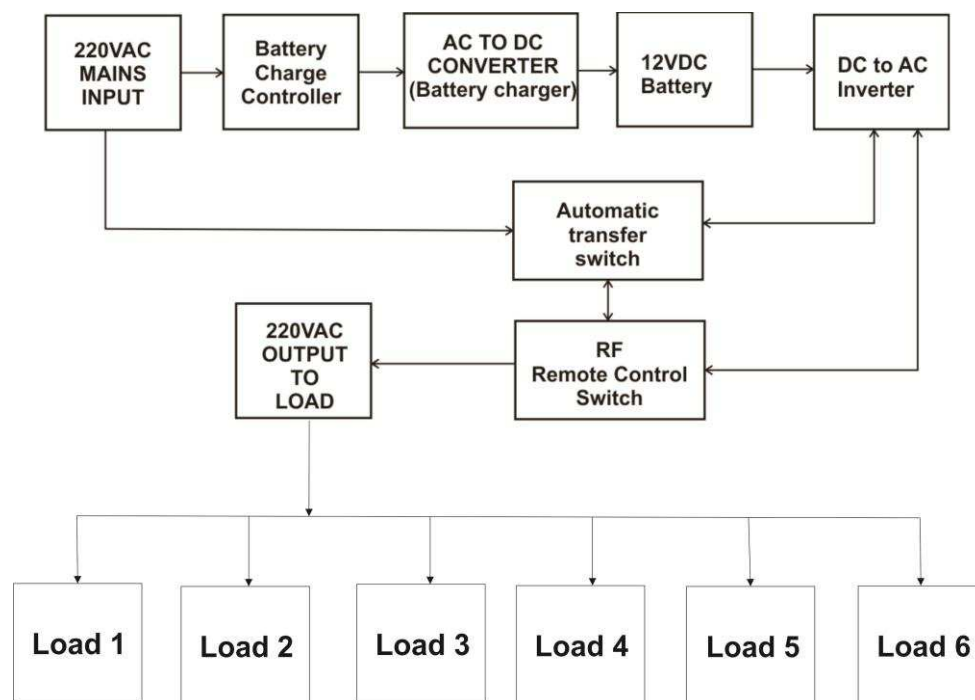


Figure 3.6. System block diagram

3.1.6. System Design Circuit

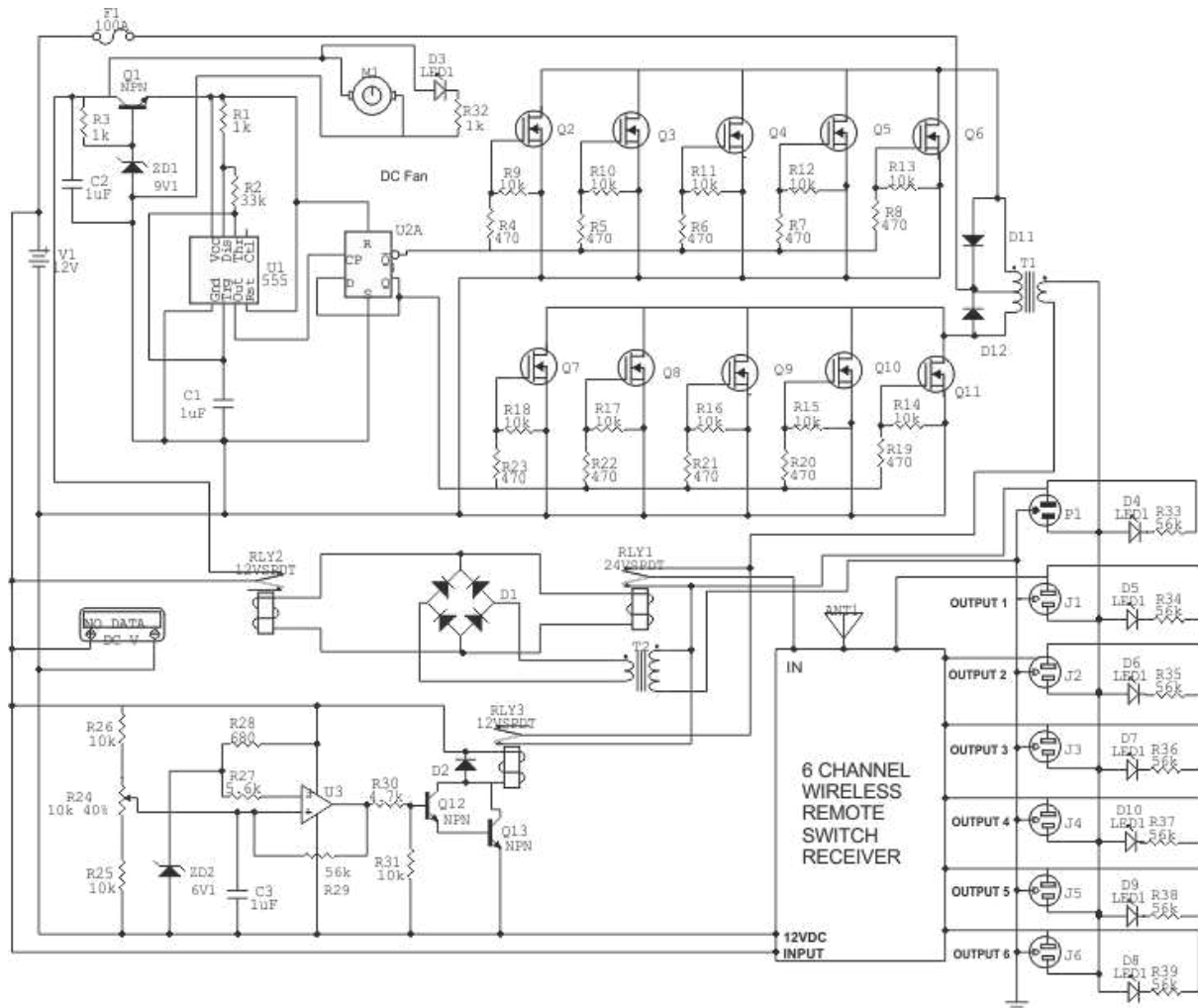


Figure 3.7 schematic circuits for the entire project

3.2. System Development

The construction of this system requires several tools and equipment either than the specific electrical and electronics components required for this system. Some of this tool involves testing and measuring, soldering and joining, tightening and loosening. Since electronics components like integrated circuits cannot be tested with any instrument quick miniature assembly in other to test these components.

3.2.1. Hand Tools

(a) Soldering iron

For electronics work the best type is one powered by mains electricity it should have a heatproof cable for safety. The iron's power rating should be 15 to 25W and it should be fitted with a small bit of 2 to 3mm diameter for heat sensitive components like ICs and small transistors and 60 to 100watts for thick cables and joints.



Figure 3.8. Soldering iron [23]

Low voltage soldering irons are available, but their extra safety is undermined if one have a mains lead to their power supply. Temperature controlled irons are excellent for frequent use, but not worth the extra expense if one are a beginner. Gas-powered irons are designed for use where no mains supply is available and are not suitable for everyday use. Pistol shaped solder guns are far too powerful and cumbersome for normal electronics use. [23]

(b) Soldering iron stand

One must have a safe place to put the iron when one are not holding it. The stand should include a sponge which can be dampened for cleaning the tip of the iron. [23]



Figure 3.9. Soldering iron stand [23]

(c) De-soldering pump (solder sucker)

A tool for removing solder when de-soldering a joint to correct a mistake or replace a component. [23]



Figure 3.10. De-soldering pump (solder sucker) [23]

(d) Reel of solder

The best size for electronics is 22swg (SWG = standard wire gauge). [23]



Figure 3.11. Reel of solder [23]

(e) Side cutter

For trimming component leads close to the circuit board. [24]



Figure 3.12. Side cutter [24]

(f) Wire stripper

Most designs include a cutter as well, but they are not suitable for trimming component leads.

[24]



Figure 3.13. Wire Stripper [24]

(h) Small pliers

Usually called 'snipe nose' pliers, these are for bending component leads etc. If one put a strong rubber band across the handles the pliers make a convenient holder for parts such as switches while one solder the contacts. [24]



Figure 3.14. Small plier [24]

(i) Small flat-blade screwdriver

For scraping away excess flux and dirt between tracks, as well as driving screws. [24]



Figure 3.15. Small flat-blade screwdriver [24]

(j) Heat sink

One can buy a special tool, but a standard crocodile clip works just as well and is cheaper.

[25]



Figure 3.16. Heat sink [25]

(k) PCB rubber

This is an abrasive rubber for cleaning PCBs. It can also be used to clean stripboard where the copper tracks have become dull and tarnished. [25]



Figure 3.17. PCB rubber [25]

(I) Small electric drill

Ideally this should be mounted in a drill stand. One will need a range of small drill bits, but for most holes a 1mm bit is suitable. Larger holes can be drilled with a hand drill but 1mm bits are too fragile to use reliably in a hand drill. [26]



Figure 3.18. Small battery powered electric drill [26]

3.2.2 Testing and Measuring Tools

These instruments are used to measure frequency, waveform, voltage, current and resistance.

(a) Oscilloscope

An oscilloscope's primary function is to provide a graph of a signal's voltage over time. This is useful for measuring such things as clock frequencies, duty cycles of pulse-width-modulated signals, propagation delay, or signal rise and fall times. It can also alert one to the presence of glitches in oner logic or bouncing switches. [27]

The **oscilloscope** (also known as a **scope**, **CRO**, **DSO** or, an **O-scope**) is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually as a two-dimensional graph of one or more electrical potential differences using the vertical or 'Y' axis, plotted as a function of time, (horizontal or 'x' axis). Although an oscilloscope displays voltage on its vertical axis, any other quantity that can be converted to a voltage can be displayed as well. In most instances, oscilloscopes show events that repeat with either no change, or change slowly.

Oscilloscopes are commonly used to observe the exact wave shape of an electrical signal. In addition to the amplitude of the signal, an oscilloscope can show distortion, the time between two events (such as pulse width, period, or rise time) and relative timing of two related signals.

One of the most frequent uses of scopes is troubleshooting malfunctioning electronic equipment. One of the advantages of a scope is that it can graphically show signals: where a voltmeter may show a totally unexpected voltage, a scope may reveal that the circuit is oscillating. In other cases the precise shape or timing of a pulse is important.

In a piece of electronic equipment, for example, the connections between stages (e.g. electronic mixers, electronic oscillators, amplifiers) may be 'probed' for the expected signal, using the scope as a simple signal tracer. If the expected signal is absent or incorrect, some preceding stage of the electronics is not operating correctly. Since most failures occur because of a single faulty component, each measurement can prove that half of the stages of a complex piece of equipment either work, or probably did not cause the fault. [27]

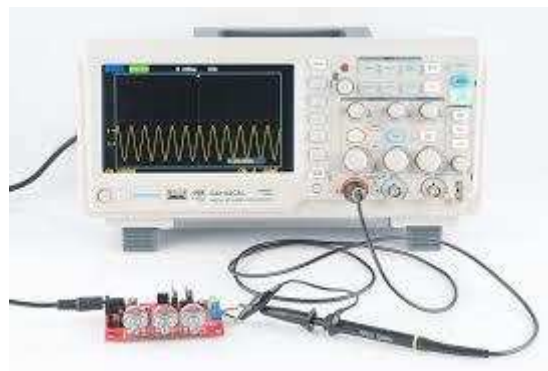


Figure 3.19. Oscilloscope [27]

The Basic Oscilloscope Controls

1. VERTICAL - Controls the vertical alignment of the traces as well as which traces are shown, their scale, which one is the selected one, etc. Note that only the currently selected trace will be affected by the controls in this group.
2. HORIZONTAL - Controls the time scale and position. Note that all traces are affected simultaneously by these controls.
3. TRIGGER - Controls the triggering. This is useful for horizontally aligning a repeating signal with itself.
4. ACQUIRE - Controls the method of acquiring samples. It also has the autose button that will cause the oscilloscope to automatically choose settings for all the other controls that it thinks will best display the current waveforms. This is a very useful button, but I have found it chooses good values about 80% of the time.

5. Miscellaneous - This section is the unlabeled set of controls that is at the top of the control panel. The controls in this section are mostly high level functions that are not specific to a given waveform. It is in this section that one find the "General Purpose Knob" referred to later.

6. Selector buttons along the right and bottom of the screen (not shown in picutre) - These are used to select from menus that appear on the bottom and right of the screen, just like one would do with an ATM machine at the bank.

(b) AVO meter

The **AVO meter** was a British brand of multimeter, latterly owned by Megger. The most widespread of the range was the Model 8, which was produced in various versions from the 1950s until 2008, the last version being the Mark 7.

It is often called simply an **AVO** and derives its name from the first letter of the words amperes, volts, and ohms. It was conceived by the Post Office engineer Donald Macadie in 1923. [28]

Technical Features

It was by far the best instrument of its kind in the UK from 1923 to at least the 1960s. Almost uniquely for a radio repairman's multimeter it measures alternating current up to 10 A as well as AC and DC voltages up to at least 1000 V. The Model 8 Mk. V included additional inputs to measure up to 3000 V. As an ohmmeter it measures from 0.1 Ω up to 200 k Ω in three ranges. The instrument has an accuracy of $\pm 1\%$ of FSD on DC ranges and $\pm 2\%$ on AC ranges. Its maximum current draw of 50 μA at full-scale deflection (corresponding to 20,000 ohms per volt) is sufficient in most cases to reduce voltage measurement error due to circuit loading by the meter to an acceptable level. A pair of rotary switches are used to select the range to be

measured, being arranged in such a way as to minimise the risk of damage to the instrument should the wrong range be selected. Further protection is provided by an overload cut-out and fuses.



Figure 3.20 AVO meter [28]

3.2.3. Electrical and electronics Components

(a) Resistors

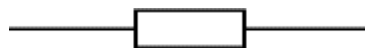


Figure 3.21. Resistor [29]

Resistors restrict the flow of electric current, for example a resistor is placed in series with a light-emitting diode (LED) to limit the current passing through the LED. Resistors may be connected either way round. They are not damaged by heat when soldering. Electrical energy is converted to heat when current flows through a resistor. Usually the effect is negligible, but if the resistance is low (or the voltage across the resistor high) a large current may pass making the resistor become noticeably warm. The resistor must be able to withstand the heating effect and resistors have power ratings to show this. [29]

Power ratings of resistors are rarely quoted in parts lists because for most circuits the standard power ratings of 0.25W or 0.5W are suitable. For the rare cases where a higher power is required it should be clearly specified in the parts list, these will be circuits using **low value resistors** (less than about 300 Ω) or **high voltages** (more than 15V).

The power, P, developed in a resistor is given by:

P = I² × R where: P = power developed in the resistor in watts (W)

or I = current through the resistor in amps (A)

P = V² / R R = resistance of the resistor in ohms (Ω)

V = voltage across the resistor in volts (V)

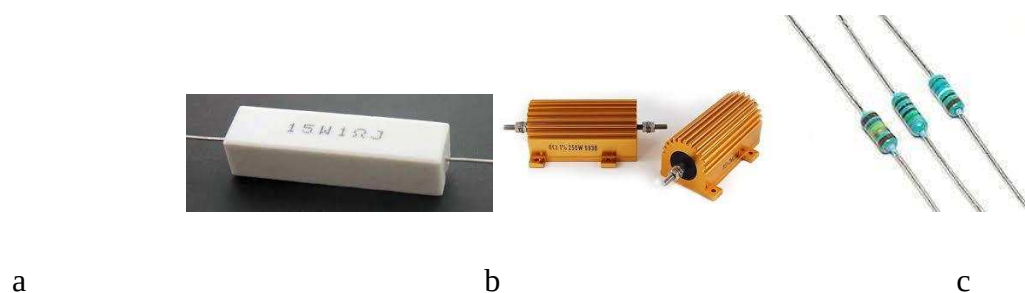


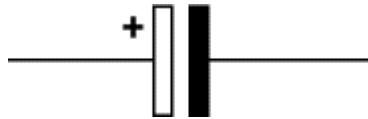
Figure 3.22.High and low wattage resistors [29]

(b) Capacitors

Capacitors store electric charge. They are used with resistors in timing circuits because it takes time for a capacitor to fill with charge. They are used to smooth varying DC supplies by acting as a reservoir of charge. They are also used in filter circuits because capacitors easily pass AC (changing) signals but they block DC (constant) signals. [29]



Examples: physical component a. Cylindrical shape



b. Circuit symbol.

Figure 3.23. Polarized capacitors [29]

Electrolytic capacitors are polarized and they must be connected the correct way round, at least one of their leads will be marked + or -. They are not damaged by heat when soldering. There are two designs of electrolytic capacitors; axial where the leads are attached to each end (220 μ F in picture) and radial where both leads are at the same end (10 μ F in picture). Radial capacitors tend to be a little smaller and they stand upright on the circuit board.

It is easy to find the value of electrolytic capacitors because they are clearly printed with their capacitance and voltage rating. The voltage rating can be quite low (6V for example) and it should always be checked when selecting an electrolytic capacitor. If the project parts list does not specify a voltage, choose a capacitor with a rating which is greater than the project's power supply voltage. 25V is a sensible minimum for most battery circuits. [29]

Unpolarised capacitors (small values, up to 1 μ F)



Examples: a. axial and cylindrical

b. Circuit symbol

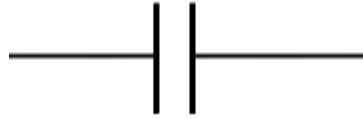


Figure 3.24.Unpolarized capacitor [29]

Small value capacitors are unpolarised and may be connected either way round. They are not damaged by heat when soldering, except for one unusual type (polystyrene). They have high voltage ratings of at least 50V, usually 250V or so. It can be difficult to find the values of these small capacitors because there are many types of them and several different labelling systems!

Many small value capacitors have their value printed but without a multiplier, so one need to use experience to work out what the multiplier should be!

For example **0.1** means $0.1\mu\text{F} = 100\text{nF}$.

Sometimes **.** is used in place of the decimal point

For example: **4n7** means 4.7nF .

Capacitor Number Code

A number code is often used on small capacitors where printing is difficult:

- the 1st number is the 1st digit,
- the 2nd number is the 2nd digit,
- the 3rd number is the number of zeros to give the capacitance in pF.
- Ignore any letters - they just indicate tolerance and voltage rating.

(c) Diodes

Diodes allow electricity to flow in only one direction. The arrow of the circuit symbol shows the direction in which the current can flow. Diodes are the electrical version of a valve and early diodes were actually called valves. Electricity uses up a little energy pushing its way through the diode, rather like a person pushing through a door with a spring. This means that there is a small voltage across a conducting diode, it is called the forward voltage drop and is about 0.7V for all normal diodes which are made from silicon. The forward voltage drop of a diode is almost constant whatever the current passing through the diode so they have a very steep characteristic (current-voltage graph). When a reverse voltage is applied a perfect diode does not conduct, but all real diodes leak a very tiny current of a few μA or less. This can be ignored in most circuits because it will be very much smaller than the current flowing in the forward direction. However, all diodes have a **maximum reverse voltage** (usually 50V or more) and if this is exceeded the diode will fail and pass a large current in the reverse direction, this is called breakdown. [29]

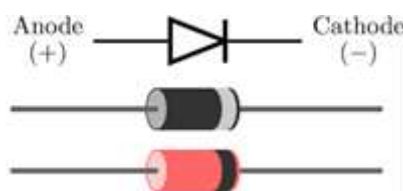


Figure 3.25. Anode and cathode of diode [29]

Diodes must be connected the correct way round, the diagram may be labelled **A** or + for anode and **K** or - for cathode (yes, it really is k, not c, for cathode!). The cathode is marked by a line painted on the body. Diodes are labelled with their code in small print, one may need a magnifying glass to read this on small signal diodes!

Small signal diodes can be damaged by heat when soldering, but the risk is small unless one are using a germanium diode (codes beginning OA...) in which case one should use a heat sink clipped to the lead between the joint and the diode body. A standard crocodile clip can be used as a heat sink. Rectifier diodes are quite robust and no special precautions are needed for soldering them. [29]

(d) Transistors

Transistors amplify current, for example they can be used to amplify the small output current from a logic IC so that it can operate a lamp, relay or other high current device. In many circuits a resistor is used to convert the changing current to a changing voltage, so the transistor is being used to amplify voltage.

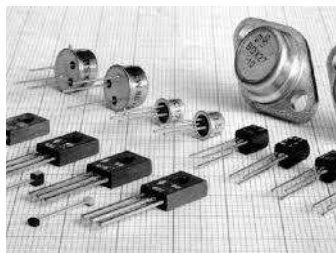


Figure 3.26. Plastic and metal cap transistor [29]

A transistor may be used as a switch (either fully on with maximum current, or fully off with no current) and as an amplifier (always partly on). The amount of current amplification is called the **current gain**, symbol h_{FE}

There are two types of standard transistors, **NPN** and **PNP**, with different circuit symbols. The letters refer to the layers of semiconductor material used to make the transistor. Most transistors used today are NPN because this is the easiest type to make from silicon. If one are new to electronics it is best to start by learning how to use NPN transistors.

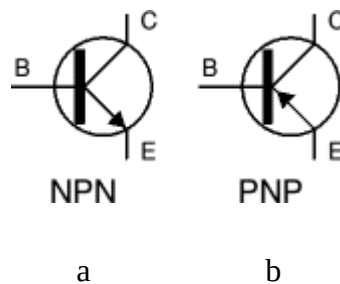


Figure 3.27. Transistor Symbols [29]

The leads are labeled **base** (B), **collector** (C) and **emitter** (E).

These terms refer to the internal operation of a transistor but they are not much help in understanding how a transistor is used, so just treat them as labels!

A Darlington pair is two transistors connected together to give a very high current gain.

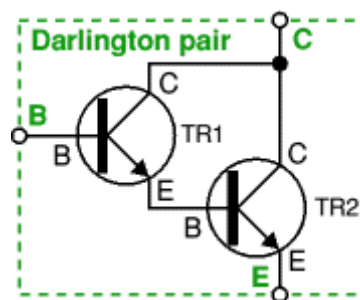


Figure 3.28. Darlington pair Transistor [29]

Transistors have three leads which must be connected the correct way round. Please take care with this because a wrongly connected transistor may be damaged instantly when one switch on.

If one are lucky the orientation of the transistor will be clear from the PCB or strip board laonet diagram, otherwise one will need to refer to a supplier's catalogue to identify the leads.

The drawings on the right show the leads for some of the most common case styles. ^[15]

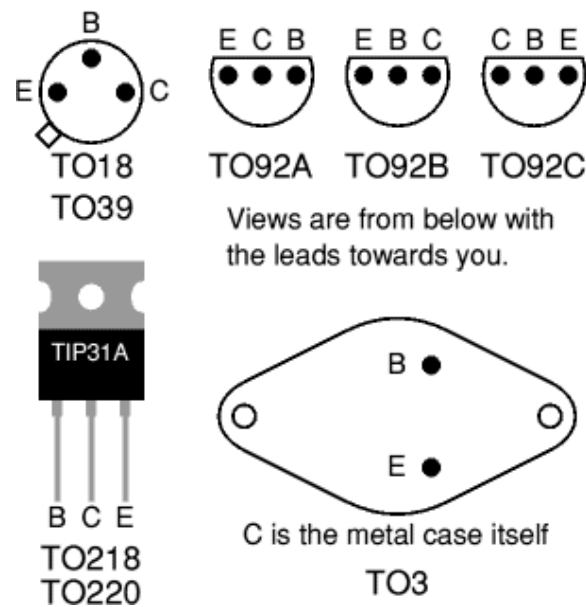


Figure 3.29. Transistor leads [29]

(e) Power Transformers

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors—the transformer's coils. A varying current in the first or *primary* winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the *secondary* winding. This varying magnetic field induces a varying electromotive force (EMF), or "voltage", in the secondary winding. This effect is called mutual induction. If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. In an ideal transformer, the induced voltage in the secondary winding (V_s) is in proportion to the primary voltage (V_p), and is given by the ratio of the number of turns in the secondary (N_s) to the number of turns in the primary (N_p) as follows:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

By appropriate selection of the ratio of turns, a transformer thus allows an alternating current (AC) voltage to be "stepped up" by making N_s greater than N_p , or "stepped down" by making N_s less than N_p .

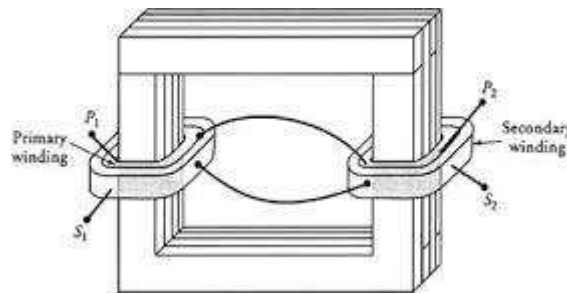


Figure 3.30. Transformer (core type) [30]

(f) Varistors

A varistor is an electronic component with a "diode-like" nonlinear current–voltage characteristic. The name is a portmanteau of variable resistor. Varistors are often used to protect circuits against excessive transient voltages by incorporating them into the circuit in such a way that, when triggered, they will shunt the current created by the high voltage away from sensitive components. A varistor is also known as Voltage Dependent Resistor or VDR. [31]

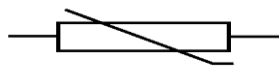


Figure 3.31. Varistor symbol [31]

A varistor's function is to conduct significantly increased current when voltage is excessive.

Only non-ohmic variable resistors are usually called varistors. Other, ohmic types of variable resistor include the potentiometer and the rheostat.



Figure 3.32. S14K385 Varistor [31]

(h) Integrated Circuits (NE555N)

The 8-pin 555 timer must be one of the most useful ICs ever made and it is used in many projects. With just a few external components it can be used to build many circuits, not all of them involve timing. A popular version is the NE555 and this is suitable in most cases where a '555 timer' is specified. The 556 is a dual version of the 555 housed in a 14-pin package, the two timers (A and B) share the same power supply pins. The circuit diagrams on this page show a 555, but they could all be adapted to use one half of a 556.

Low power versions of the 555 are made, such as the ICM7555, but these should only be used when specified (to increase battery life) because their maximum output current of about 20mA (with a 9V supply) is too low for many standard 555 circuits. The ICM7555 has the same pin arrangement as a standard 555. [20] The circuit symbol for a 555 (and 556) is a box with the pins arranged to suit the circuit diagram: for example 555 pin 8 at the top for the +Vs supply, 555 pin 3 output on the right. Usually just the pin numbers are used and they are not labelled with their function.

The 555 and 556 can be used with a supply voltage (V_s) in the range 4.5 to 15V (18V absolute maximum). Standard 555 and 556 ICs create a significant 'glitch' on the supply when their output changes state. This is rarely a problem in simple circuits with no other ICs, but in more complex circuits a **smoothing capacitor** (eg 100 μ F) should be connected across the + V_s and 0V supply near the 555 or 556.

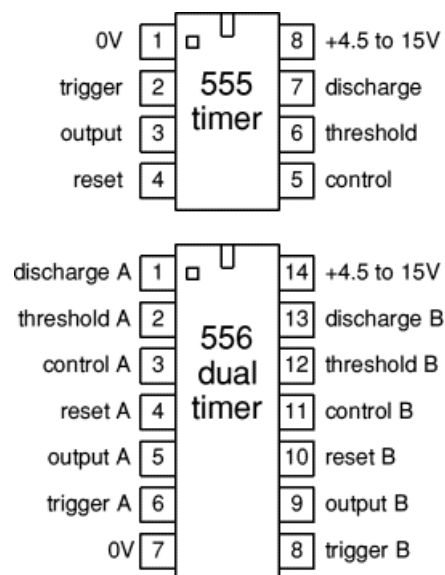


Figure 3.33 Pin configuration for NE555(top) and NE556 Timer (down) [20]

Inputs of 555/556

Trigger input: when $< \frac{1}{3} V_s$ ('active low') this makes the output high (+ V_s). It monitors the discharging of the timing capacitor in an astable circuit. It has a high input impedance $> 2M\Omega$.

Threshold input: when $> \frac{2}{3} V_s$ ('active high') this makes the output low (0V)*. It monitors the charging of the timing capacitor in astable and monostable circuits. It has a high input impedance $> 10M\Omega$.

* providing the trigger input is $> \frac{1}{3} V_s$, otherwise the trigger input will override the threshold input and hold the output high (+ V_s).

Reset input: when less than about 0.7V ('active low') this makes the output low (0V), overriding other inputs. When not required it should be connected to +Vs. It has an input impedance of about 10k Ω .

Control input: this can be used to adjust the threshold voltage which is set internally to be $\frac{2}{3}$ Vs. Usually this function is not required and the control input is connected to 0V with a 0.01 μ F capacitor to eliminate electrical noise. It can be left unconnected if noise is not a problem. The **discharge pin** is not an input, but it is listed here for convenience. It is connected to 0V when the timer output is low and is used to discharge the timing capacitor in astable and monostable circuits.

Output of 555/556

The output of a standard 555 or 556 can sink and source up to 200mA. This is more than most ICs and it is sufficient to supply many output transducers directly, including LEDs (with a resistor in series), low current lamps, piezo transducers, loudspeakers (with a capacitor in series), relay coils (with diode protection) and some motors (with diode protection). The output voltage does not quite reach 0V and +Vs, especially if a large current is flowing.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Results

The various parts of the inverter system were tested individually before assembly. The voltage at the output of the voltage regulator was checked to ensure that we get 18V peak to peak at the output of the flip-flop. The waveform and the frequency was tested using the oscilloscope and the signal generator. The turns ratio was of the transformer was varied and adjusted to ensure that output voltage did not exceed 240volts. The DC brushless fan was strategically positioned to pull out hot air emitted by the heatsink. The system was rated based on the amount of load it could operate freely without over heating within the theoretical rating. The filament bulb were the preferred load used for testing because they give a true reflection of R.M.S value.

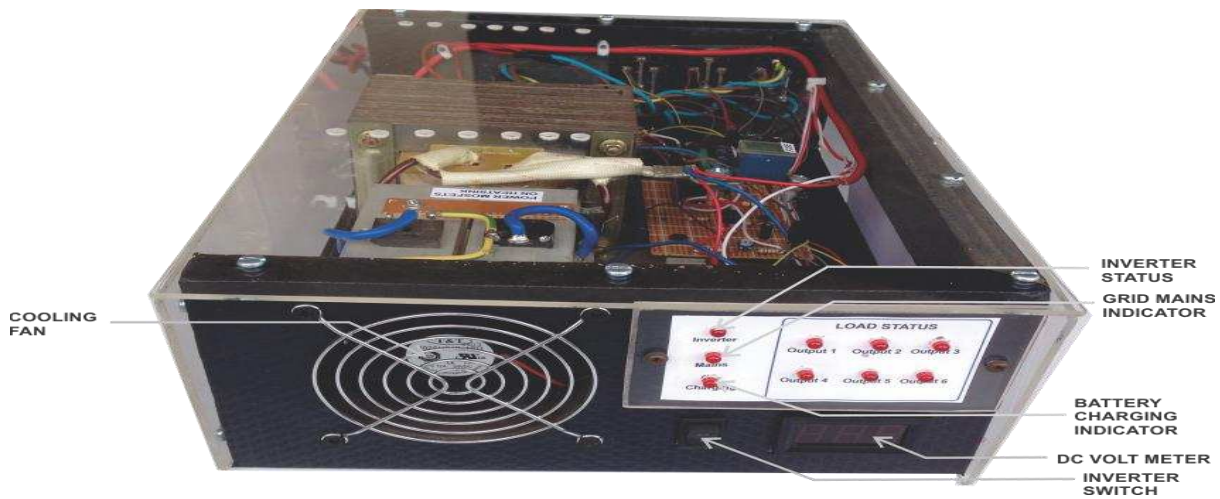


Figure 4.1. Front view of the prototype

The power consumption of the system was invariably reasonable as compared to DC to AC power inverters on the Ghanaian market. The charging system performed relatively slow as compared to the standard transformer battery charger but only lagged by about an hour when

being compared with the same operating conditions, rating and characteristics. The automatic load transfer performed very well beating most existing inverters with its microsecond switching respond. A computer was used to test the system and during to various load transfers, the computer did not restart the wireless remote controlled the switching of loads up to a distance of 200 meter.

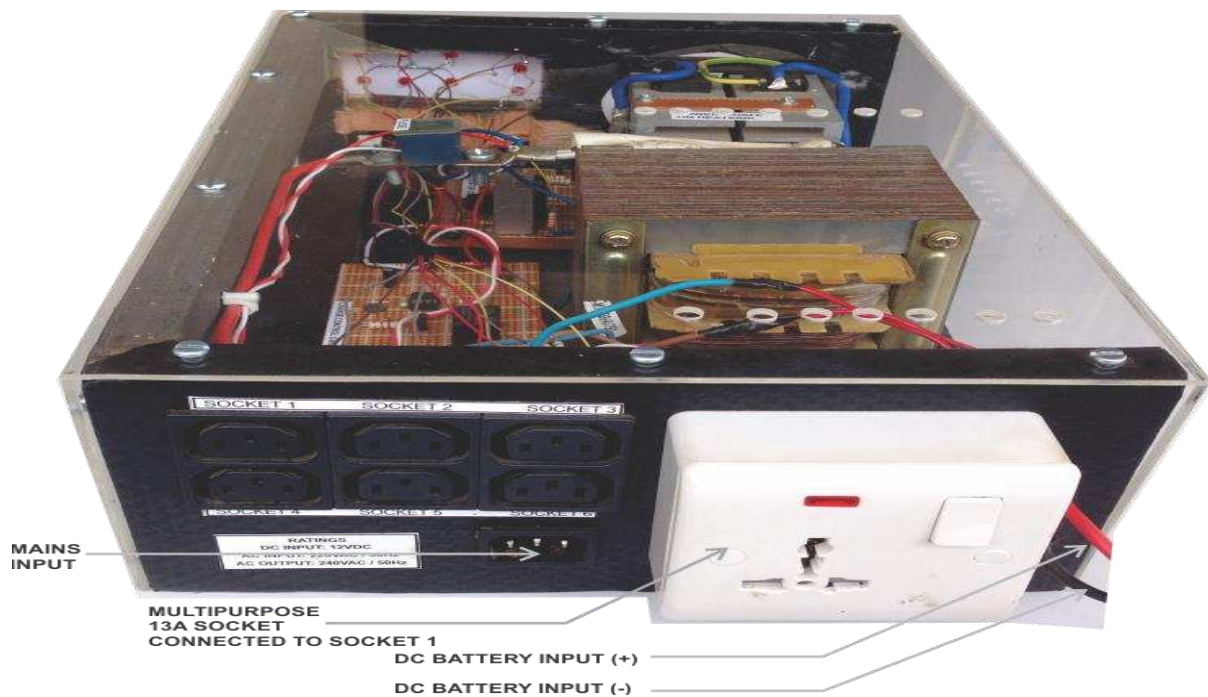


Figure 4.2. Back view of the prototype



Figure 4.3. Picture of the prototype under test

4.2 Cost Benefits Analysis

- The cost of the system would have been lower if the components were purchased on a high quantity.
- The system was designed based on the electronics components available in the country.

4.2.1 Material List

Table 4.1 Material List

ITEM NO	PARTS DESCRIPTION	QUANTITY	UNIT COST (GH¢)	TOTAL AMOUNT (GH¢)
------------	-------------------	----------	-----------------------	--------------------------

1	SPBT 24V Relay	3	10.00	30.00
2	50V/47uf	4	0.50	2.00
3	25V/220uf	2	0.50	1.00
4	103pf	1	1.00	8.00
5	104pf	3	0.50	1.50
6	50k Ω Potentiometer	1	3.50	3.50
7	470 Ω	10	0.50	5.00
8	2.2k Ω	6	0.30	1.80
9	10k Ω	20	0.50	10.00
10	56k Ω	10	0.50	5.00
11	22k Ω	2	0.30	0.60
12	10 Ω	4	0.30	1.20
13	5.6k Ω	2	0.50	2.00
14	680 Ω	4	0.50	2.00
15	0.22 Ω	4	0.30	1.20
16	C945 NPN Silicon Drive Transistor	4	0.20	0.80
17	TIP41	2	1.00	2.00
18	IRF3710	10	5.00	50.00
19	C2580	1	5.00	5.00
20	100A Fuse	1	2.00	2.00
21	Vero Board	2	1.20	2.40
22	Power Cable	1	2.00	2.00
23	220V/9-0-9Centre-Tapped Transformer	1	45.00	45.00
24	uA741 Op-Amp	1	0.50	0.50
25	Bridge Diode (GBU8M)	1	2.00	2.00
26	IC 4x4pins	1	2.00	2.00

27	13 Amps mains socket	1	3.00	3.00
28	10mm Auto flex cable	1	5.00	5.00
29	LED	3	0.20	0.60
30	Casing	1	20.00	20.00
31	NE555N	1	5.00	5.00
32	CD4013	1	7.50	7.50
33	6 Channel wireless remote switch module	1	250.00	250.00
	Sub Total			GHC 479.60

4.2.2 Labour Cost

$$\begin{aligned}
 \text{Total man hours} &= 20.00 \\
 \text{Rate Per Hour} &= \text{GhC } 2.50 \\
 \text{Labour Cost} &= \text{Rate Per Hour} \times \text{Total Man Hours} \\
 &= 20.00 \times 2.50 \\
 &= \text{GhC } 50.00
 \end{aligned}$$

4.2.3 Overheads

$$\begin{aligned}
 \text{Overhead} &= 10\% \text{ of the Labour Cost per Material Cost} \\
 &= (10/100) \times (50+479.60) = 52.96
 \end{aligned}$$

4.3.4 Total Cost

$$\begin{aligned}
 \text{Total cost GhC} &= \text{Material Cost} + \text{Labour Cost} + \text{Overheads} \\
 &= 479.60 + 50.00 + 52.96 \\
 &= 582.56
 \end{aligned}$$

4.3. Discussions

4.3.1. Modified Sine Wave Electricity Effect on loads.

Different appliances were affected to greater and lesser degrees by the different forms of AC. Resistive and universal motor loads were by the unaffected waveform. Resistive loads such as incandescent light bulbs and heat producing appliances such as kettles, jugs, irons, radiators and stoves overloaded the system during testing. Universal motors with brushes and commutators which are found in most hand tools and many kitchen appliances such as food processors, blenders and centrifugal type juice extractors operated well with the modified sine wave inverter.

Inductive loads ran with a little noise and got warmer. Inductive loads with voltage transformers and motors like those often found in refrigerators, freezers and washing machines. Induction motors also need a comparatively high surge current to start up and as such could not run with the system due to the capacity. For a 'modified sine wave inverter to handle an inductive load well, it needs to have a good surge capacity, but it also needs to have a feature referred to as 'dead-space clamp'. Some appliances run better with modified sinewave which noticeably would operate less well on square and stepped wave AC inverters. Those affected include:

- Some of the latest sewing machines
- Some programmable timers
- Microwave ovens (which operate more slowly)
- Some battery chargers
- Some cordless appliances

- Some dimmer switches
- Some digital clocks
- Some variable speed devices such as fans
- Some hi-fi and other sound equipment
- Some TVs and video equipment
- Some Fax's and Laser Printers
- Iron ballasted fluorescent lights.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- Electricity was generated from 12vdc maintenance free lead acid battery using the NE555 timer and a CD4013 flip-flop to generate modified sine wave pulses which were further amplified to a higher power capable of powering appliances with ratings up to 600VA.
- It is now established that power inverter is a DC to AC inverter device that is capable of turning DC power, like the power found in batteries or the kind collected from 12vdc battery, into AC power that is used to run everyday things in the home such as household appliances other electronic gadgets.
- The power inverter was able to transfer electrical and electronics loads from grid mains to the inverted power in a micro second without restarting.
- The 6 channel wireless remote switch installed in the inverter system allowed the systems and its loads to be controlled via radio in a distance of about 300meters without being blocked by any obstacle as would occur in infrared communication.

5.2 Recommendations

For future development of this device the following may be considered:

- The input supply from the battery which is 12 volts may be upgraded to 24 volts to increase the output power rating.
- The remote control system may be upgraded to a GSM based control system hereby eliminating the control range in terms of distance and direction.

- The system could be further improved to pure sine wave by employing technologies like microcontroller based H-bridge inverter system which by.
- By the use of microcontrollers and an LCD screen may be used to display the operating parameters like battery level, load percentage, input and output voltage level and the temperature of the system.

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GLOSSARY

(AC)	Alternating current usually follows a sinusoidal curve.
(A)	An abbreviation of the term ampere.
C	Capacitor, a device that stores electrical energy.
dB	A measure of voltage, current, or power gain equal to 0.1 Bel.
DC	Direct Current
E	A large conducting body with no electrical potential also called earth.
F	Frequency
G	Grounding
H	Hertz
I	Current
K	Kilo
L	Load
O	Ohms(Ω)
P	Power
P_{Max}	Maximum Power
Q	Transistor
R	Resistor
R_g	Ground Resistor
S	Switch
T	Transformer
V	Voltage
W	Watts
Z	Impedance

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