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Uninterruptible Power Supply System (UPS)

By

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A project report submitted in partial fulfillment of requirements for the degree of bachelor of applied electronics of electronics and physics department.

Supervised By
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ABSTRACT

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An *Uninterruptible Power Supply* (UPS) is an electrical device which convert the electrical current from alternative current into direct current to charge the batters until the Power is on, and when the power is off it start to covert the direct current continuously.

This project will introduce the basic requirement of *Uninterruptible Power Supply* design, and will show a single phase *Uninterruptible Power Supply* work that will be implemented.

ملخص المشروع

Uninterruptible Power Supply System
(UPS)

اعداد

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نظام التجهيز الكهربائي المستمر (UPS) هو جهاز كهربائي، يعمل على تحول التيار المتردد الى تيار مستمر، ليقوم بعملية شحن البطاريات أثناء وجود جهد من المصدر، وعندما ينقطع جهد المصدر يبدأ بتحويل التيار المستمر الى تيار متردد مرة أخرى لتزويد الحمل.

هذا المشروع سوف يستعرض الأشياء الأساسية لتصميم نظام التجهيز الكهربائي المستمر (UPS) وبعرضه ليكون جاهزا للعمل.

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Introduction

One of the most important variables in world is energy, which is used to drive every work, for example energy that will enable the electron to orbiting the nucleus and energy that will enable the human to do all of his body function (heart bombing, breathing, hearing, and thinking). This project will discuss the design of one of the electrical energy supply.

1.1 Why an *Uninterruptible Power Supply*?

In the 19th century a new way of energy is discovered, it's called the electrical energy, which gives a new way of life, it has many uses and applications, and it becomes the most useful energy in the world.

Examples of electrical energy applications are medical equipment, air and traffic control systems, electronic data processing systems, telecommunication equipment, and process plant instrumentation. An *Uninterruptible Power Supply* (UPS) operates in conjunction with the utility power supply to ensure a continuous supply of electric energy to critical loads [1]. The critical loads normally use the utility as their energy source. However, in the event of utility supply interruptions, the UPS provides the energy to those loads. Closely related to, but distinct from, the UPS is the *Standby Power Supply* (SPS). While the UPS ensures that the proper voltage is supplied to the load without break in the event of a power failure, the SPS permits a break during load transfer from the utility supply to the SPS.

1.2 The main problem

Most of people use a electrical device such as computer in their houses, works, on the other hand hospital use the medical devices to keep the patient healthy, and every body needs this electrical energy, but what happens if they had an un expectance problem causing the electrical power to be off.

To solve this problem engineers think of a source of electrical power that gives unbreakable electrical power in the time of the source stops supplying with the power. They first invented mechanical generator supply, with the certain electrical energy, but it have to be started after the source cut off, so the user will lose what he had in a computer, medical device, and that will cause the problem.

Until the idea come to the scientists, that to have a power source supply the user with power rather than the source power ON or OFF, so the user of the electrical power will not be able to lose any of his work, the project team chose the problem of loosing the power to put it in the uses technology, because this technology is not used in our society in it way, and to continue what the scientists start in this subject.

1.3 Previous Project

There was under graduated project in the Palestine Polytechnic University library [2], it was found very useful but it has different applications. It was a diploma project, and it's true to say that system has some bugs in its design.

The previous system was the UPS solar system, and was based on converting the sun shining energy to an electrical energy. The main concept of our project, and previous project, are similar, while the previous project was based on the sun light energy to be the main source of power, whereby the UPS system charges the batteries in the day, and in the night it supplies with the power from the battery. So without the

sunshine there won't be charging for the battery and the system must work in the supplying mode.

1.4 Project Features

This project is a *Uninterruptible Power Supply* system, based on the electrical power supply to be the main power supply, the system checks the statue of input power sequentially and take the state mode in case, to start the battery supply or leave the power supply as it is, so if the voltage supply decreased less than 180 AC volts, the system automatically start to supply from battery, on other hand if the voltage supply increased more than 250 AC volts the battery supply works too [3].

So the new features in this project could be summarized as follow:

- Using of the second step of the 250 AC volt that is given to the system and protect the load device to the UPS.
- Indicator displays the voltage which is stored in the battery to keep the user familiar with the state of the system.
- Alarm system tells the user the states of power supply and working duty of the battery.
- The protection of the circuit is solved by adding a component to separate each step from others, this is done to maintain the system and the load to UPS.

So this project will be well adapted and could be movable in any state. To have satiable load work and the UPS output waveform is closed to alternative AC signal as possible. The project product is compact and compatible with dedicated AC load.

1.5 Estimated Cost of the Project

This project will cost around $170 excluding the design cost. For more details see appendix A1.1.

1.6 Time Plan

The work had been divided into two semesters, first semester include the collecting of data, analysis, system specification, and design. In the second semester the implementation plan will be done. For more information see appendix A1.2.

1.7 Report Content

This report will cover the designing and implementation of the UPS system including the following topics:

Chapter two gives a theoretical background related to the main idea of the project and some information about special components. Chapter three gives a general idea about of the project, defining the objectives to be performed by the system, including block diagrams of project. Chapter four discusses the design option and justifies them for the project; in addition it shows some elements and description of parts. Chapter five shows the testing implementation, summary and conclusion. Finally chapter six shows the calculation of project

CHAPTER TWO

Theoretical Background

2.1 Types of UPS System

The majority of modern UPS systems is standby type, and has no moving parts. For these systems, electric energy is most commonly stored in batteries [3]. This project focuses on static UPS systems.

The main components of a typical static UPS are [3]:

1. Battery charger unit.
2. Battery unit.
3. Inverter unit.
4. Filter unit.

UPS system has either single- or three-phase outputs. UPS system with three phase output often provides a neutral conductor to enable the connecting of single phase loads to the UPS output [3].

In this case, the load on the three phase UPS could be unbalanced. As a result, the UPS output voltage will also be unbalanced. For different unbalance load case, UPS manufacturers specify limits on the amount of output voltage unbalance for their equipment.

The loads to UPS systems are often non-linear when supplied with a fundamental frequency sinusoidal voltage; they draw currents that contain harmonic frequency current components in addition to the fundamental frequency component. These harmonic current components also distort the UPS output voltage. Manufacturers

usually provide the limits on the harmonic voltage distortion that appears on the output voltage of their UPS systems [4].

Static UPS systems are categorized into two main types: double conversion and single conversion. This classification is based on the manner in which the UPS delivers power to the critical load.

These two basic UPS types are discussed below.

2.1.1 Double conversion UPS

In a double conversion UPS, the utility voltage is first converted to dc by the battery charger, the dc voltage is next converted to an ac sine wave by the combination of the inverter and the filter.

Figure 2.1 shows the block diagram of a basic double conversion UPS. The input supply to the UPS can be either single phase or three phases. Similarly, the output of the UPS can be either single phase or three phases.

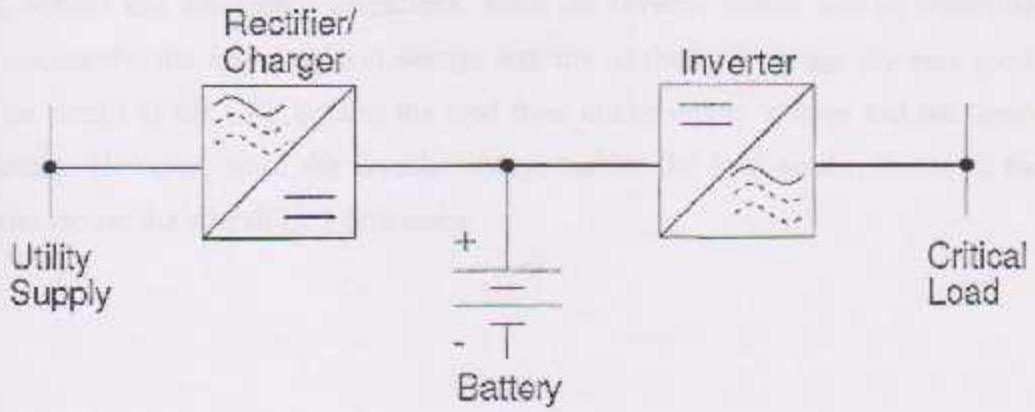


Figure 2.1 Double Conversions *UPS* Principle

The inverter of a double conversion UPS is in continuous operation, and supplies the load in both normal and emergency situations. Under normal operation, with the utility supply available, the dc circuit of the UPS is fed from the utility through the rectifier. If the utility voltage is interrupted, the inverter automatically draws load power from the battery, and the load experiences no break in its terminal voltage [4].

The duration of backup time, during which the critical load can be supplied from the battery, essentially depends on the battery capacity. For long duration utility voltage interruptions, an auxiliary power source, such as a diesel-generator set, can be started and brought on line to feed the load. The UPS is required to provide load power for the time it takes to bring the auxiliary power source on line.

The double conversion UPS configuration permits an auxiliary power source to be connected to its dc circuit. For example, the dc output of a rectifier is fed from a diesel-generator set can be connected in parallel to the battery. The battery can supply the load power without break until the diesel-generator set can be started. Before the battery backup time is exceeded, the set can start up and provide the load power through the UPS dc circuit.

Note that the UPS inverter essentially determines the critical load voltage in both, normal and emergency operations. Since the inverter output can be controlled very accurately, the frequency and voltage stability of the load voltage are very good. The dc circuit of the UPS isolates the load from utility supply voltage and frequency variations. However, since the inverter always carries the load power, losses in the inverter reduce the overall UPS efficiency.

2.1.2 Single conversion UPS

A single conversion UPS system does not have a separate charger for the battery. Rather, the inverter of a single conversion UPS has bi-directional power handling capability. When utility voltage is available, the inverter draws power from the utility to charge the battery, if needed. If the utility voltage is interrupted, the battery provides power to the load through the inverter. Figure 2.2 shows the block diagram of the basic single conversion UPS system.

Note that unlike double conversion UPS systems, single conversion systems do not carry the load power when the utility voltage is available. Because of this, single conversion systems typically have better efficiency than double conversion systems. However, the critical load on a single conversion system is more susceptible to utility supply voltage deviations than a load on a double conversion system.

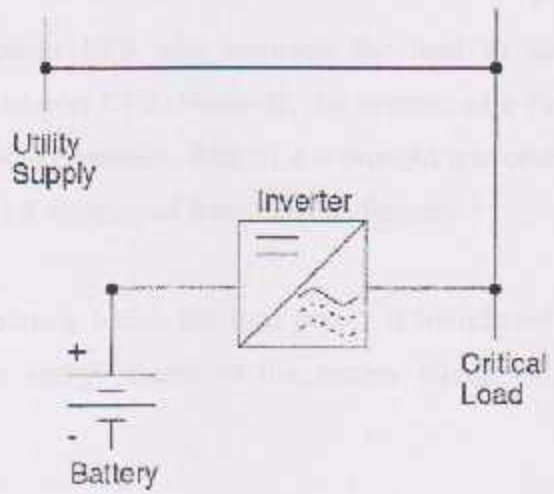


Figure 2.2 Single Conversion UPS Principle

The single conversion UPS system shown in Figure 2.2 is also often called a line interactive UPS. It is always connected to the load in parallel with the utility supply. In addition to feed the load without break in case of utility failure, it can also provide buck or boost functionality, so that the load voltage magnitude remains constant in the face of utility voltage magnitude variations.

Unlike the system of Figure 2.2, some versions of line interactive UPS system may introduce a short break in load power, as the load is transferred from the utility to the UPS, or vice versa. In such systems, a transfer switch affects the transfer of the load from the utility to the UPS, and back. Such systems are more appropriately termed as Standby Power Systems (SPS).

Two important variations of the line interactive UPS are the tri-port UPS, and the Ferro resonant UPS. In a tri-port UPS, the load, the utility and the UPS inverter are each respectively connected to one winding of a three-winding transformer. The UPS inverter operates continuously. The phase of the inverter output voltage is adjusted so that it supplies no power. It may even take battery charging power from the utility. When the utility voltage fails, the utility is disconnected from the three winding transformer, and the UPS inverter supplies the load through the transformer.

The Ferro resonant UPS also connects the load to the utility through a transformer, as does a tri-port UPS. However, the inverter of a Ferro resonant UPS is normally not in continuous operation. Rather, it is brought into operation only when the utility power fails and is disconnected from the transformer.

In the interval during which the load power is transferred to the inverter, the load is feed from the energy stored in the battery circuit of the Ferro resonant transformer [4].

The Ferro resonant transformer isolates the load from disturbances on the utility supply. It also provides good regulation of the load voltage magnitude, without having to switch on the inverter even if the utility voltage magnitude drops by about 10%. The inverter of a Ferro resonant UPS, when turned on, operates at line frequency. The transformer design provides a sinusoidal voltage to the load without the need for additional filters. Line frequency operation of the inverter, as opposed to pulse width

modulated (PWM) operation, implies that the inverter switching losses are low, and overall efficiency is high.

In this project the following topics will be discusses, first generality of the project will be shown (the uses of the project, types, and what is the project), then building the circuit of the project as a block diagram and analysis of project circuits will be showed, after that data sheet of the electrical component that is used in the project (for each piece), are attached. Then the working principles of the projects circuits will be show.

2.2 Power Electronic Inverters for UPS Systems

A modern UPS system interfaces its battery with the critical load by means of an inverter; this inverter is made up of semiconductor power switches. The inverter input voltage is DC, and its output voltage is single- or three-phase AC voltage.
The DC to AC conversion is achieved by appropriate control of the semiconductor switches of the inverter. Several families of semiconductor switches are available for general inverter applications. However, for UPS applications, the preferred switch is the Insulated Gate Bipolar Transistor (IGBT) [5].

Figure 2.3 shows the basic schematic diagram of an inverter with constant DC voltage and a single phase AC output. The inverter power circuit is made up with four semiconductor power switches [5].

Each switch consists of an IGBT and a diode, as shown in Figure 2.3. The terminal E is the emitter, C is the collector, and G is the gate. Usually, the diode and the IGBT are both internally connected in the same package. Only the terminals C, E and G are brought out of the package for external circuit connections.

Depending on the current carrying capacity of the switch, a package may contain different numbers of switches. For high current ratings, a package may contain only one switch consist of an IGBT and a diode. Medium current rated packages may contain two switches, for example switches 1 and 3 in figure 2.3, which form a phase leg which spans the DC bus of the inverter. For small current ratings, all the switches that build the inverter circuit (four for single phase inverters and six for three phase inverters) are included in one package.

The IGBT is turned on by applying a positive voltage at the gate relative to the emitter. In the absence of this voltage, the switch is off, and cannot conduct current from the collector to the emitter.

However, the diode ensures that current can always own in the opposite direction. All inverter circuits are essentially switching circuits, in that they synthesize the output ac voltage by appropriately turning their semiconductor switches on and off. This section describes single- and three-phase inverter circuits, and these aspects of their control concepts that are relevant to UPS applications, for further information on single phase and three phase inverter power circuits, and their control methods.

The inverter circuits described below are used with both, double and single conversion UPS systems. The inverters are capable of four quadrant operation, by which they can source or sink both active and reactive power. Their ability to function as bidirectional real power sources makes them suitable for use with single-conversion UPS systems [6].

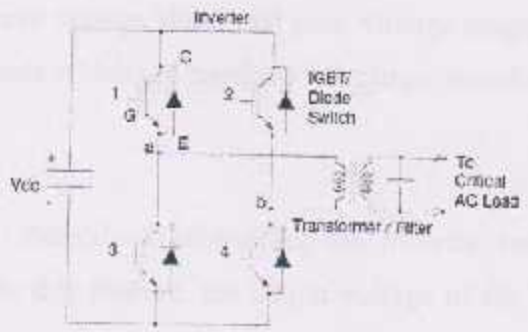


Figure 2.3 Single Phase Inverters

2.2.1 Single Phase Inverters

Figure 2.3 shows the schematic diagram of a single phase inverter. The battery forms the DC bus of the inverter. The inverter AC output terminals, a and b in Figure 2.3, are connected to a transformer.

The critical AC load is connected across the capacitor on the transformer secondary winding. The capacitor and the leakage inductance of the transformer, form a filter which provides sinusoidal ac voltage to the critical load.

The transformer at the inverter output Figure 2.3 serves to match the inverter fundamental output voltage magnitude with the voltage magnitude required by the load. The maximum value of the inverter fundamental output voltage magnitude is limited by the available battery DC voltage. The transformer boosts up the inverter output voltage to the required load voltage. In addition to voltage matching, the transformer also serves to isolate the load from the inverter.

In the simple switching strategy, the IGBT pair 1 and 4 is switched on and off in complement to the pair 2 and 3. This produces an alternating square wave at the inverter output, with amplitude equal to the dc battery voltage, and a frequency equal to the desired output frequency (50 Hz or 60 Hz). UPS systems which employ inverters that follow this square wave switching method are usually low cost, low power systems. Sometimes, the output filter is also omitted, and the square wave voltage is applied directly to the load. These UPS systems may be used with loads that can withstand a square wave voltage shape and poor voltage magnitude regulation, but in general, for critical loads which are sensitive to voltage waveform distortion, these are better avoided.

The preferred method of controlling the inverter switches is *Pulse Width Modulation* (PWM). In this method, the output voltage of the inverter is switched in

pulses of appropriate duration. The output filter acts on these pulses to produce a sinusoidal voltage at the critical load terminals.

With PWM, the width and position of each individual pulse of the inverter output voltage can be controlled so as to produce a load voltage of the desired magnitude and frequency. The ability to control the load voltage magnitude means that it can be kept within tight tolerances in the face of changing load current and utility voltage magnitude. The ability to control the frequency also means that the load voltage frequency can be kept within tight tolerances.

It is the task of the inverter control circuit to generate the PWM pattern which controls the switching on and off of the inverter switches. The control circuit does this such that the PWM voltage pattern at the output has the desired fundamental component amplitude and frequency.

A common way to generate the PWM switching pattern at the inverter AC terminals is the sine triangle comparison method. In this method, the control circuit compares a reference sine wave having the desired output frequency with a higher frequency triangle wave, as shown in figure 2.4. If the value of the sine signal is greater than that of the triangle signal, the switches 1 and 4 are turned on.

Otherwise, switches 2 and 3 are turned on. This strategy to control the switches results in the pulse pattern shown in figure 2.4, this pattern appears across the inverter ac output terminals a and b Figure 2.3.

The frequency of the triangle wave determines the inverter switching frequency, which is the frequency at which the inverter switches operate. The filter formed by the transformer leakage inductance and the capacitor, serves to ensure that only the sinusoidal fundamental component of the pulse pattern at the inverter output is applied to the load.

The amplitude of the triangle wave is fixed, and the amplitude of the reference sine wave can be changed by the controller. As the amplitude of the reference sine wave is increased up from zero, the amplitude of the fundamental component of the pulse pattern appearing at the inverter output increases proportionately. This proportionality is maintained until the amplitudes of the sine wave and the triangle wave are equal. As the sine wave amplitude is increased beyond the triangle wave amplitude, the amplitude of the fundamental of the inverter output pulse pattern is no longer proportional to the reference sin wave amplitude.

In addition to controlling the output voltage amplitude, the UPS controller also needs to control the frequency and phase of the output voltage. Often, control of frequency and phase may be more critical than control of the amplitude. For example, errors in the frequency and phase of the inverter output voltage may result in loss of synchronization between the filtered inverter output voltage and an alternate bypass source. In this situation, it may not be possible to affect a no-break transfer of the load from the UPS to the bypass source, and vice versa.

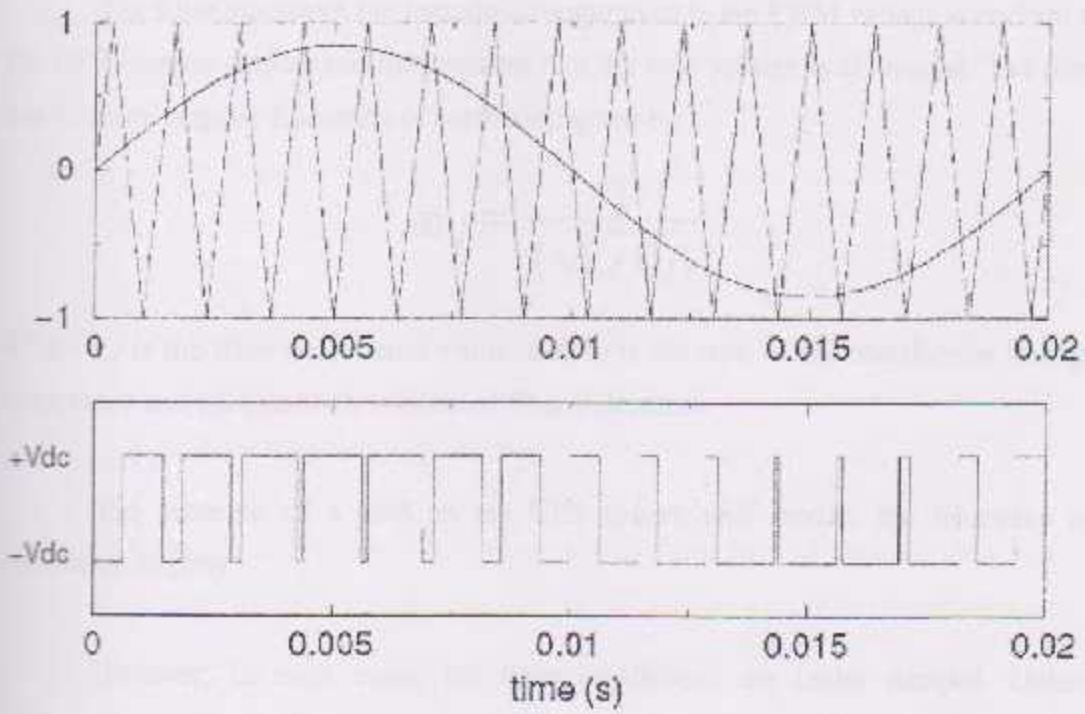


Figure 2.4: Output Signal of Inverter

By using the IC CD4047 as a pulse width modulation to supply the MOSFET with the suitable wave form of AC signal.

2.2.2 Three phase inverter:

UPS systems with a three phase output voltage incorporate a three phase inverter. The most commonly three phase inverter power circuit is used an extension of the single phase inverter. Most of three phase circuit has one more leg of IGBT switches than the single phase inverter. The inverter output is usually given to a three phase filter to produce a balanced sinusoidal voltage supply for the critical load. For more information about three phase inverter see appendix A1.3.

2.3 Damping of Output Filter Oscillations

The filter attenuates the harmonic components in the PWM voltage waveform at the UPS inverter output, and thus ensures that the load voltage is sinusoidal. The filter has a natural angular frequency of oscillation given by:

$$\omega_f = \frac{1}{(\sqrt{L_f C_f})}$$

Where C_f is the filter capacitance value, and L_f is the sum of the transformer leakage inductance and the externally connected filter inductance.

The presence of a load on the UPS system will modify the frequency of oscillation slightly.

However, in most cases, the filter oscillations are under damped. Unless actively damped by the inverter controller, these oscillations would be superimposed on the desired sinusoidal output voltage.

Filter oscillation damping is achieved by appropriately modifying the references that the controller provides to the pulse width modulator. Often, this modification takes the form of adding a damping signal to the original sinusoidal signal before providing it to the pulse width modulator. A common method to generate the damping signal is to make it proportional to the time-derivative of the voltage across the filter capacitor. It can be shown that this practice is effective in damping the filter oscillations.

Since the filter capacitor current is proportional to the time-derivative of the voltage, many practical implementations use capacitor current measurement and feedback to achieve filter oscillation damping.

The output signal is not approximately sinusoidal signal, so that filter is used to improving the signal to be as sinusoidal signal form.

2.4 Batteries for UPS systems

Battery designs are usually tailored for the needs of particular applications. UPS applications are characterized by the following features:

1. UPS applications are usually stationary.
2. UPS batteries rapidly discharge and charge frequently.

Because of these features, batteries for UPS applications are of two main types:

(1) Lead-acid batteries.

(2) Nickel-cadmium batteries.

Lead-acid batteries find more widespread use than nickel-cadmium batteries. Lead-acid batteries are cheaper than equivalent nickel-cadmium batteries. Further, lead-acid batteries are available in larger capacities than nickel-cadmium batteries.

Batteries meant for use with UPS systems are designed for short duration use, with high discharge rates. A typical figure for the UPS backup time is 15 min, after which either an alternate source is used to supply the critical load, or the load is shut down in a pre-determined manner.

As a battery discharges its stored energy into the load its terminal voltage decreases. In UPS applications, the battery is allowed to discharge down to a specified end-of-discharge voltage. The energy storage capacity of a battery is given in ampere-hours, and is specified by the battery manufacturer for a given discharge rate, electrolyte temperature, specific gravity, and end-of-discharge voltage.

When the utility supply is available, the UPS battery does not supply the load. Instead, the charger keeps the battery in float service by keeping the battery terminal voltage slightly higher than the normal battery voltage. This compensates for battery internal losses, and keeps the battery fully charged.

The battery needs to be recharged after a temporary utility supply failure. The charger may apply the normal at service voltage to the battery terminals to recharge the battery. The recharging process can be speeded up by applying at the battery terminals, a boost voltage that is higher than the float voltage. UPS manufacturers using boost recharging in their equipment need to ensure that the boost voltage is always less than the maximum voltage specified by the battery manufacturer, and also less than the maximum DC voltage specified for the equipment connected to the battery terminals. Excessive boost charging may shorten battery life. Some battery types, for example, valve regulated lead-acid batteries, do not permit boost charging.

UPS manufacturers also need to design their equipment so that battery discharging and charging cycles are minimized during normal operation. In a double conversion *UPS* system, the battery may be discharged by a load change which may be beyond the rectifier rating. A drop in the utility supply voltage magnitude may also

cause load power to be drawn from the battery, for more information see appendix A1.4.

The type of battery used for this project is lead-acid battery because it more widespread, cheaper, have large capacities then other types of batteries.

2.5 Control methods for *UPS* systems

Pulse width modulation control of the *UPS* inverter, is at the lower control level, and directly controls the turning on and off of the inverter semiconductor switches. The reference signals to the pulse width modulator are provided from higher control levels. These control levels essentially determine the instantaneous amplitude and frequency of the reference sin waves, and provide these as references to the pulse width modulator.

Modern *UPS* control systems are implemented digitally, using hardware controller with digital processors implementation, here the comparator circuit are used.

The *UPS* control produces the reference signals for the modulator to achieve various tasks. The basic tasks include:

1. Load voltage magnitude and frequency regulation.
2. Damping of output filter oscillations.
3. Maintaining a sinusoidal voltage waveform at the load.
4. Maintaining phase voltage balance (for three Phase *UPS*.)
5. Ensuring power sharing (for parallel redundant *UPS* systems.)

Apart from these basic tasks, the *UPS* control system should also provide for battery functions charging and float operations. At a higher level, the controller also often provides features for battery monitoring, during normal operation and during battery discharge and charge. Interfacing between the *UPS* and the protected equipment

permits the graceful shutdown of the equipment in case the battery voltage falls below the specified minimum value during long duration utility failures.

These control system requirements are common to both *UPS* types double- and single-conversion.

CHAPTER THREE

Design Concepts

3.1 Project objectives

Building the project in order to solve many problems that had a relation to the project is considered, so this project aims to the following aspects:

- To supply the user of the electrical energy with an additional emergency power supply when the power is off.

- To give the user of electrical energy protection against the over range voltage (over 250 volts) or the under range voltage (below 180 volts), where the device worked in range between 180 to 250 volts.

- This system provides a protection to the information of electrical power work user, such as computer user, provide user to keep his work on computer is protected from vanish.

3.2 UPS Block Diagram

Figure 3.1 shows the general block diagram of the UPS system. It contains three main stages, (a) Rectification stage that is used to charge the batteries, it consists of transformer, bridge, filter, and a two parallel voltage regulator, (b) The inversion stage that is used to convert the DC voltage to AC voltage, it's built up from MOSFET bridge, filter circuit, and transformer. (c) Control circuit is used to switch the voltage source (battery or local) contain a comparator and Triac. For more information see chapter 4.

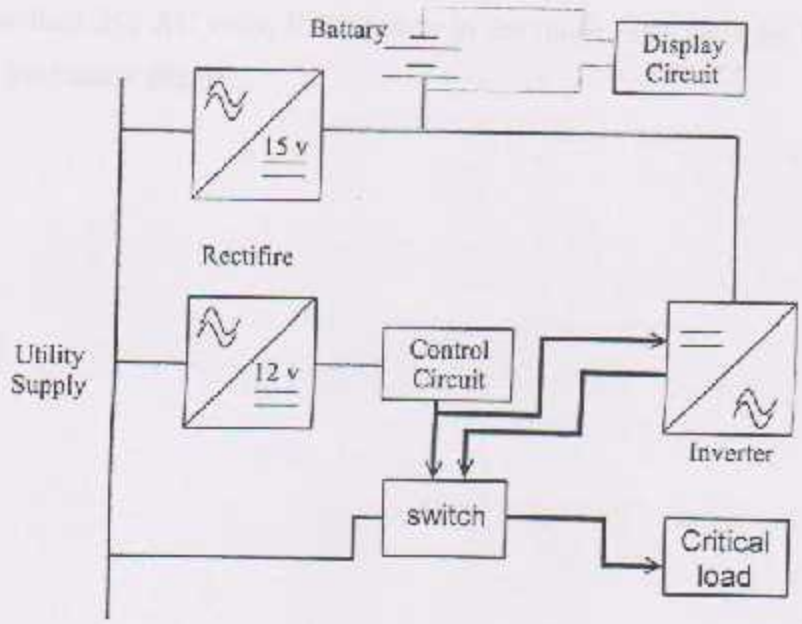


Figure 3.1 Block Diagram of the System

3.3 System work principle

This section discusses how every stage of the system works, and shows the general idea about the system:

- The Rectification circuit will provide the battery suitable DC power to be charged.

- The battery is still charging until the control circuit turned on the UPS system the battery will supply the inverter circuit with a DC voltage. This DC voltage will transform to AC signal using IC CD4047.

- This AC signal will enter to the inverter transformer to supply load with 220 AC volts suitable to the device connected with the UPS.

- This control circuit works only if the AC power is less than 180 AC volts, or more than 250 AC volts, if the power in the range (180-250) the UPS still off and the battery charge.

CHAPTER FOUR

Hardware system Design

The block diagram in chapter three showed the system, this system is built in many stages, which made a complete system, what are the component of each stage and how it work? This question will be answered in this chapter.

4.1 Rectifier Circuit

The rectifier circuit supplies with a DC voltage from an AC voltage. Figure 4.1 shows the circuit of the rectifier circuit, it consists of three stages, the transforming stage, bridge stage, and filtering stage, each stage is expect to fix DC signal in the terminal of the battery.

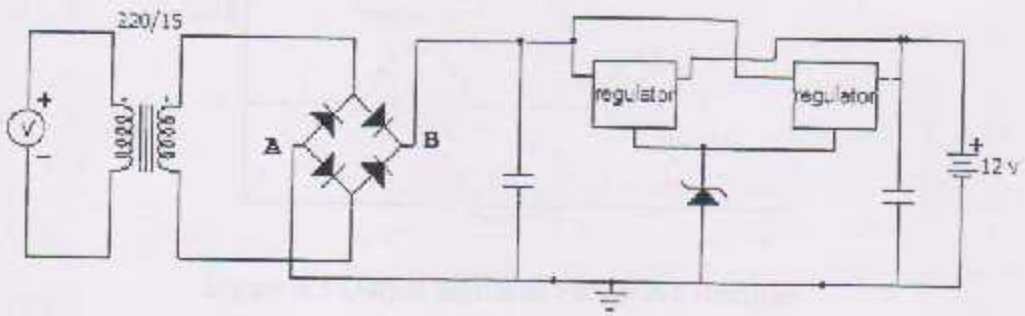


Figure 4.1 Rectifier Circuit

The circuit input is 220 AC volts (from the net), this value had to be transformed to be 15 volt (suitable to the battery), so the transformer output is 15 AC volts, and we should use rectifier to charge the battery.

Step two the bridge convert the signal from the AC to DC, on alternate half-cycle point A (or B) is "grounded" through D1 (or D2) while A (or B) is connected to the load through D3 (or D4). (see Figure 4.2).

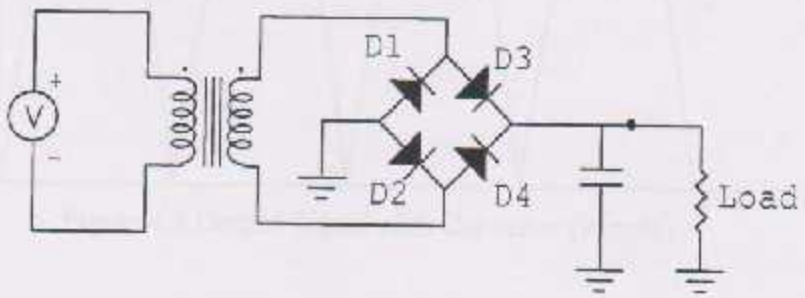


Figure 4.2 Full Wave Rectifiers with Capacitor

The voltage is vary (alternative signal) so the diode will work each tow together, in negative part of sin wave and in positive part of the sine wave.

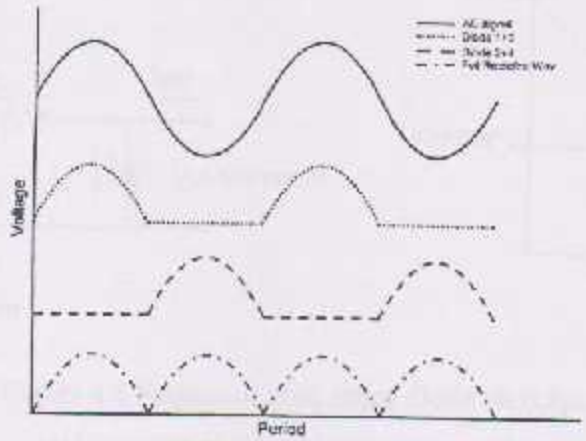


Figure 4.3 Output Signal of Full Wave Rectifier

The above full wave rectifier circuit still does a poor job of delivering a DC voltage. The cusps or valleys can be smoothed out by attaching a capacitor to ground. The capacitor acts as a charge reservoir that can supply current to the load over the course of the "valley."

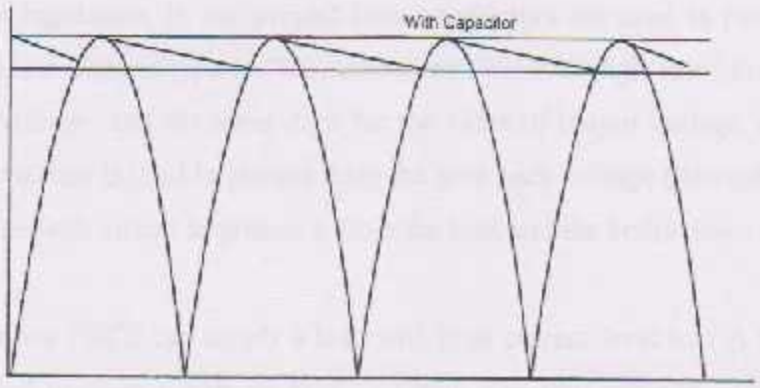


Figure 4.4 Output Signal with Capacitor (Ripple)

The regulation and ripple of the full wave rectifier and power supply capacitor can be improved by adding a Zener diode "shunt" across the output.

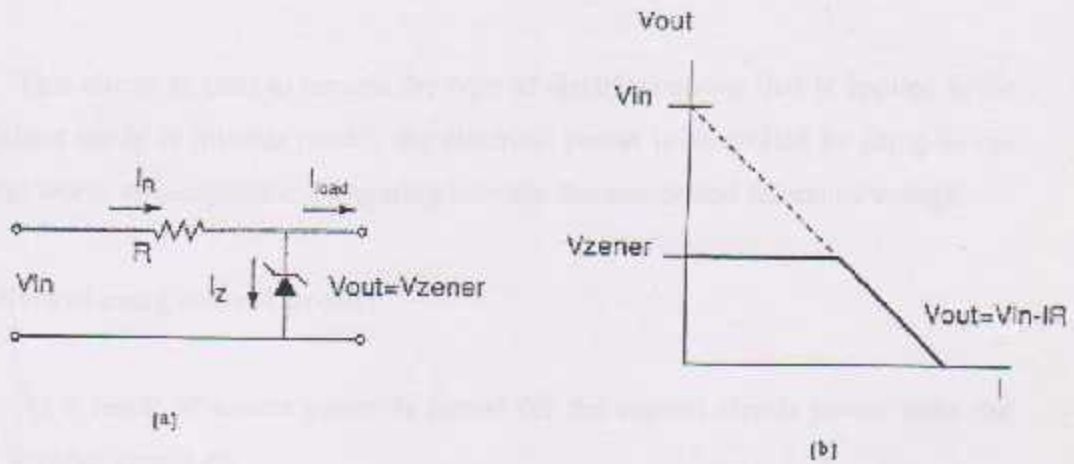


Figure 4.5 Regulator with zener diode on output

(a) Connection of zener (b) output voltage scheme

The Zener draws current in the reverse direction to keep V out at V zener, (typically at least a few mA must flow through the zener to ensure accurate regulation) the resistor limits the current through the zener diode in case the load is removed. This protects the zener from excessive current flow.

Step three are regulators, step is used to have a direct signal from the output of regulator, the output voltage must be constant level of magnitude and direction, there is

many kind of regulators, in our project linear regulators are used to provide constant voltage, the most famous type is 78xx where the first two digit from the right for the value of the voltage, and the other digit for the value of output voltage, as seen in the circuit, the capacitor is used to protect from the feed back voltage (always the regulator designed inside with circuit to protect it from the heat and the brake down current).

The series 78XX can supply a load with high current level to 1 A if it used with a heat sink, and you can supply another load with a current using regulator as 78LXX with range 100mA, 78MXX with range 500mA and 78TXX with range goes to 3A [3].

4.2 Control circuit

This circuit is used to control the type of electrical power that is applied to the load (direct mode or inverter mode), the electrical power is controlled by using an op-amp that works as comparator, comparing between the source and reference voltage.

Objectives of using control circuit:

- As a result of source power is turned off the control circuit power turns the inverter circuit on.
- When the input voltage is decreased less than 180 volts, the control circuits turn the inverter on.
- In addition, the input voltage is increased over of 250 volts the control circuits turns the inverter circuit on.
- When the source input range of (180-250) volt the output of control circuit is zero volt, that make the inverter circuit to be turned off (output of not gate is 1), this signal effect on the triac unit , to choice the input source of the load.

As shown in the figure 4.2 , using transformer to transform 220 VAC to 12 VDC suitable for control circuit, then the signal enter to a bridge and take the form of the 12 volt DC voltage

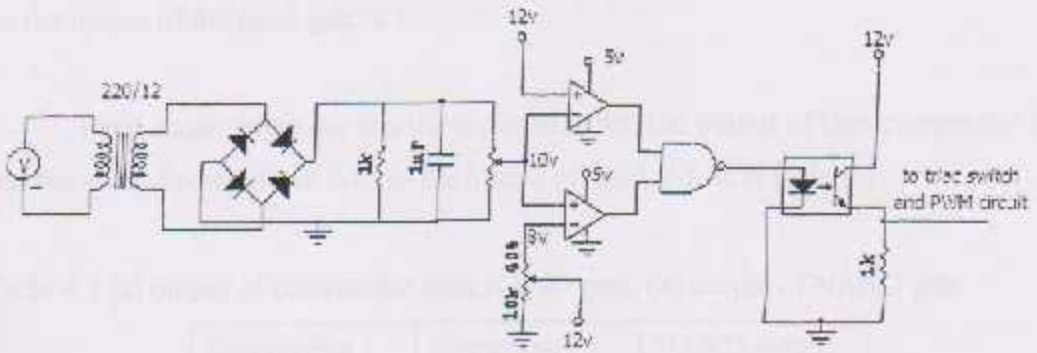


Figure 4.6 Control Circuit

After the transforming to the 12 DC volts signal is compared with the reference voltage, as seen in Figure 4.6 to the two comparator in opposite direction, when the value of the input voltage is applied in the input of the comparator, the comparator chose the perfect situation, the comparator perform that as follow:

Stage 1: Input voltage 200 volt, the first comparator have 250 volt on positive terminal and 200 volt on negative, so the output of the comparing is equal 1, for the second comparator the positive terminal have 200 volt and negative terminal have 180 volt, so the output voltage is 1, this two values from two comparator enter to nand gate, so the output of the nand gate is zero, see table 4.1.

Stage 2: Input voltage 260 volt, the first comparator have 250 volt on positive terminal and 260 volt on negative, so the output of the comparing is equal 0, for the second comparator the positive terminal have 260 volt and negative terminal have 180 volt, so the output voltage is 1, this two values from two comparator inter to nand gate, so the output of the nand gate is 1.

Stage 3: Input voltage 100 volt, the first comparator have 250 volt on positive terminal and 100 volt on negative, so the output of the comparing is equal 1, for the second comparator the positive terminal have 100 volt and negative terminal have 180 volt, so the output voltage is 0, this two values from two comparator inter to nand gate, so the output of the nand gate is 1.

Final stage: when the electrical power is off, the output of first comparator is 1, and the second comparator is 0, so the output of nand is 1 as in table 4.1.

Table 4.1 (a) output of comparator with NAND gate, (b) output of NAND gate

Comparator 1	Comparator 2	NAND output
0	0	1
0	1	1
1	0	1
1	1	0

V_{upper}	V_{lower}	V_{in}	V_{out}
250 v	180 v	200 v	0
250 v	180 v	260 v	1
250 v	180 v	100 v	1
250 v	180 v	0 v	1

As seen in the figure 4.6 we use the opto-coupler as isolation element to isolate each part of the other to not have any reverse current.

4.3 Triac circuit

Figure 4.7 show a Triac circuit that is used as an electronic switch, work to choose the perfect and safety situation for system work.

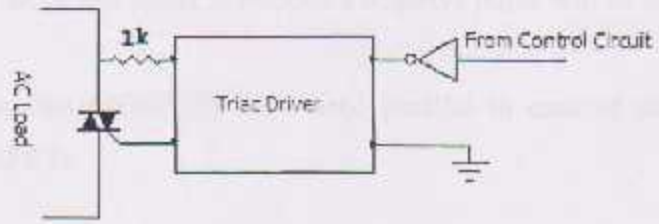


Figure 4.7 Triac Electronic Switch Circuit

4.4 Inverter circuit

As showed in the figure, the inverter circuit is built up from a half bridge of E-MOSFET semiconductor switches, tow diodes, transformer, and the DC source (battery), the operation of this circuit is to counter a suitable an AC power from the input DC power to the load.

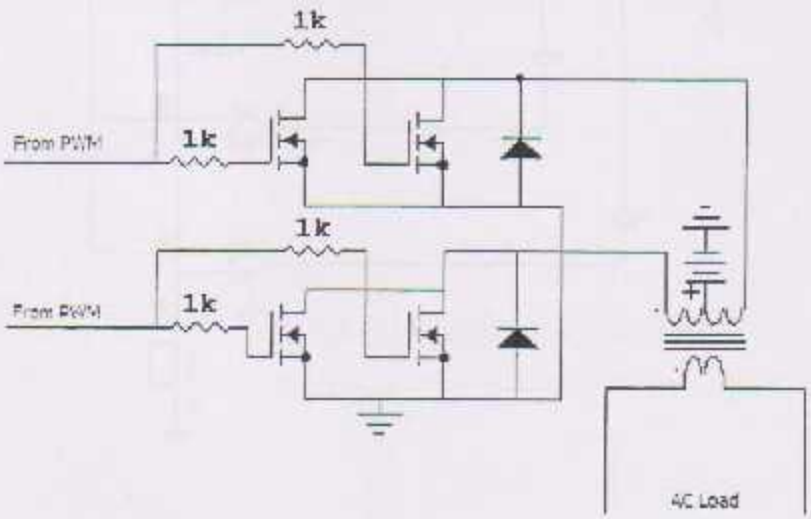


Figure 4.8 Inverter Circuit

when the output pulse of the control circuit trigger the inverters, then its trigger the PWM IC which provided with two form of pulses (negative and positive) ,then it's go to the four MOSFET where the positive pulse turned on the upper MOSFET, and the negative turned on the lower MOSFET consequently.

As the MOSFET work, the upper MOSFET gives a positive pulse, and when the lower MOSFET work and upper is stopped a negative pulse will be obtained.

Note: the two MOSFETs were used parallel in case of decrease the current entering to MOSFETs.

4.5 Display Circuit

This circuit simply used four comparator to compare the voltage of the battery with the input voltage of the comparator as seen in the Figure 4.9

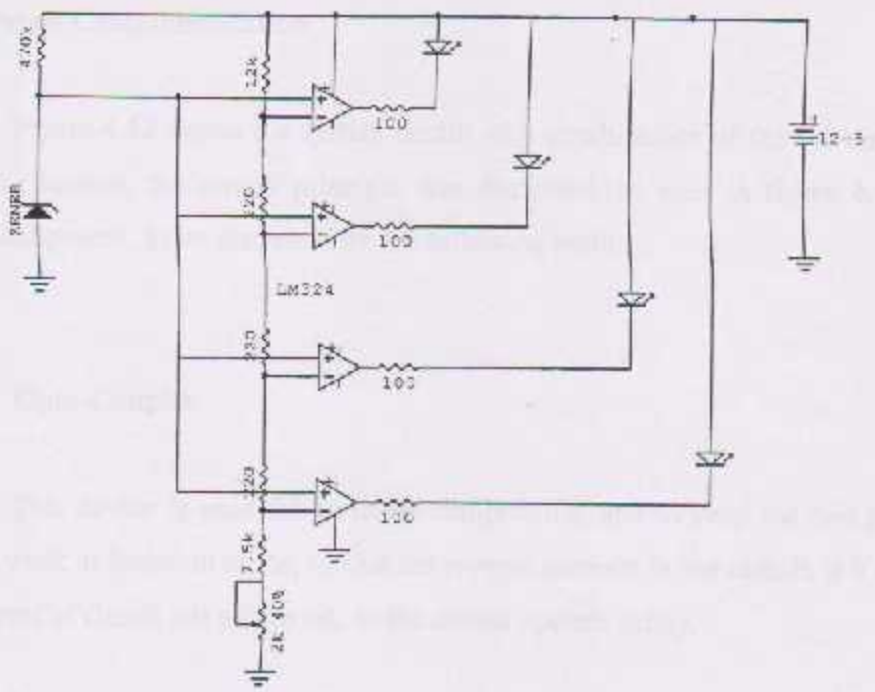


Figure 4.9: Display Circuit

4.6 Alarm Circuit

This circuit simply uses a 555 timer to supply a buzzer with suitable voltage pulses when the inversion station work, see figure 4.10 [7].

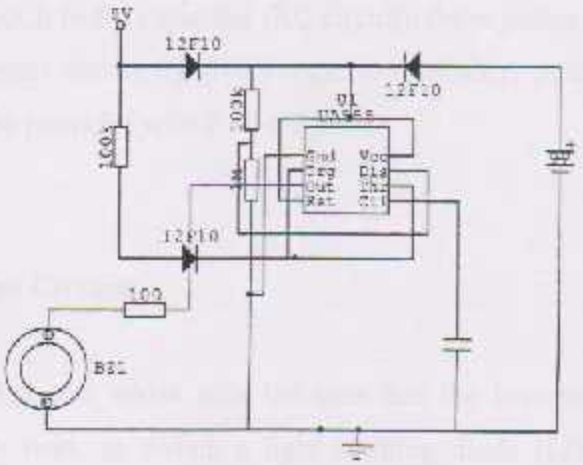


Figure 4.10: Alarm Circuit

4.7 System Complementation

Figure 4.12 shows the system circuit with combination of the sub circuit, in the previous section, the circuit principle was discussed, as seen in figure 4.12 there is some component, to be discussed by the following section.

4.7.1 Opto-Coupler

This device is used for isolation components, and to keep the two parts of the circuit work in isolation mode, so that the reverse currents in the circuit, if it exists, will affect part of circuit not all circuit, so the circuit operate safely.

4.7.2 CD 4047 Oscillator

The IC CD 4047 is an pulse generator (oscillator), it could be controlled the frequency of the pulse which come out from this IC by changing the value of the varied resistance and connect it to the capacitor (RC circuit), these pulses are used to drive the MOSFET in the inverter circuit, by give a negative or positive pulse in successive way, the MOSFETs will be provided with PWM signals.

4.7.3 System Statue Circuits

Now the alarm part which tells the user that the inverter is work, it simply contain an transistor work as switch a light emitting diode (LED) when the signal comes from the control circuit to inverter, it turns the transistor on to make the current flow from collector to emitter grater than zero.

4.7.4 Filtering Circuit

This circuit will make the signal smoother, the signal from the inverter, the output signal have some distortion in it, so this circuit will make it smooth as possible, figure 4.11 show the circuit.

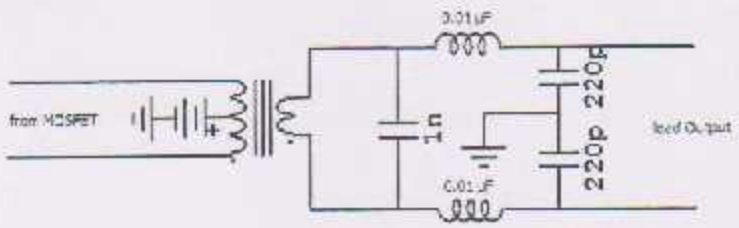


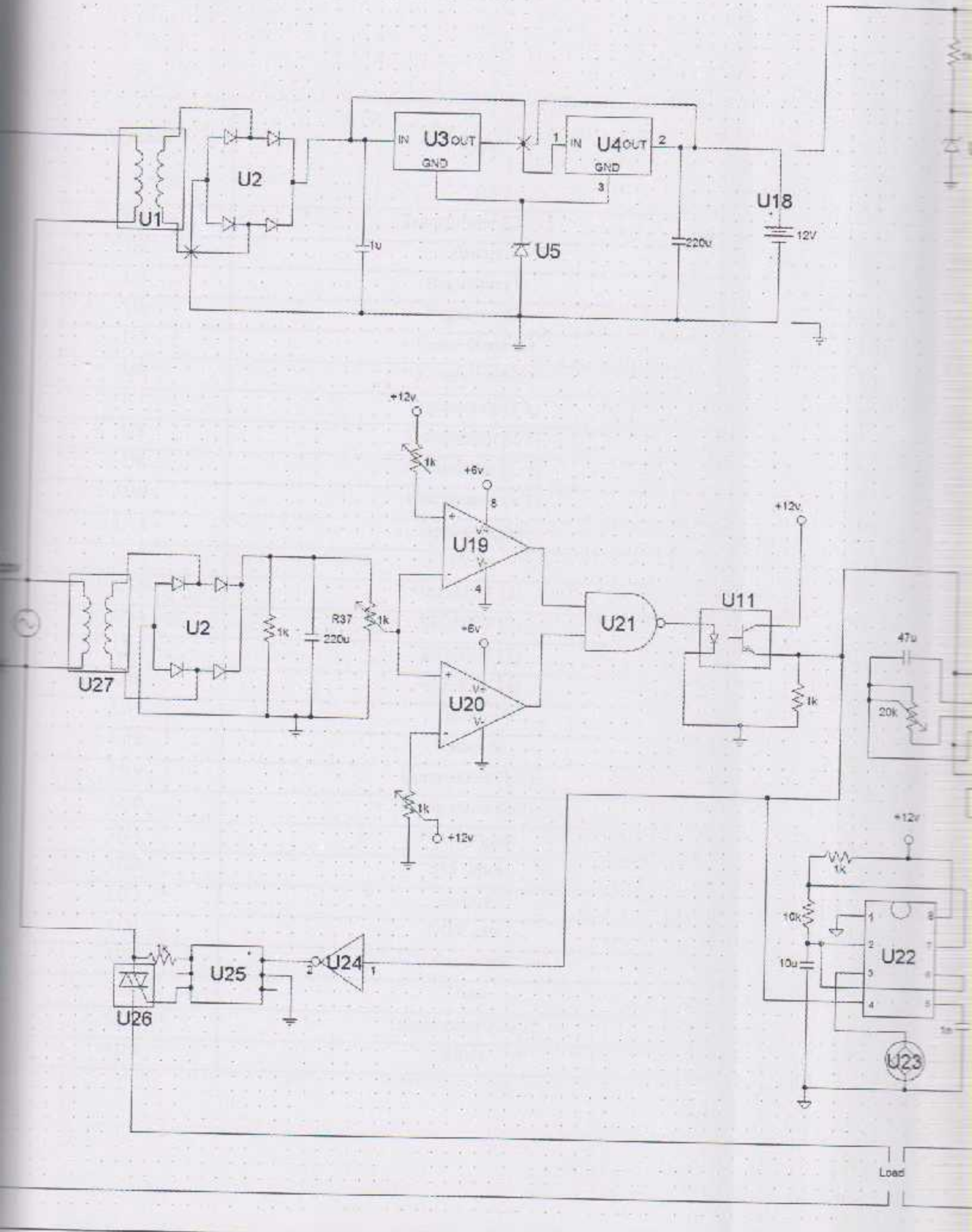
Figure 4.11 filtering circuit

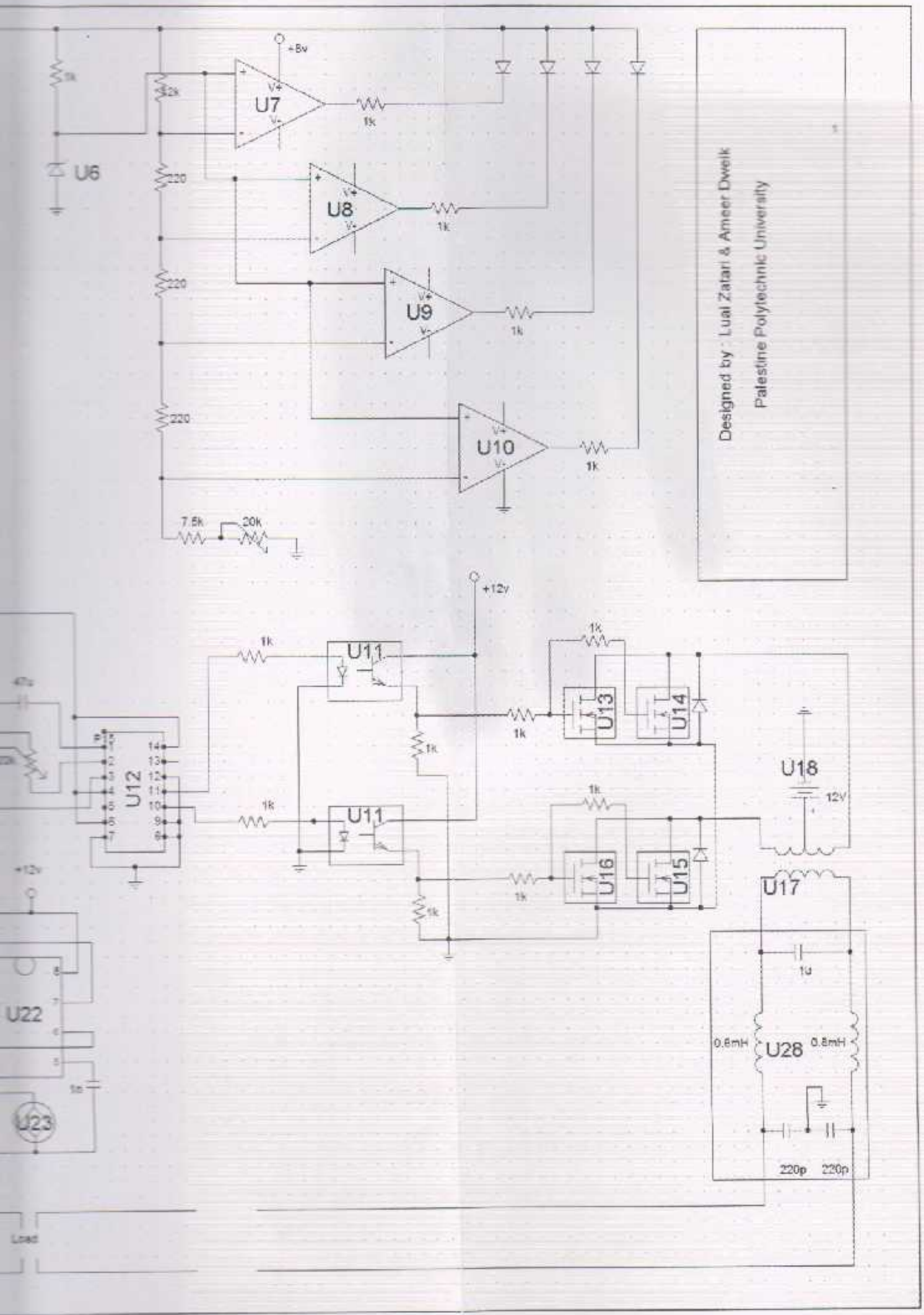
4.8 Transformers

This device is used to transform voltage from a high value to another low value, or from a low value to high value, or keep the voltage value as it (work as isolated device), and is used in other way to separation element to separate the voltage and current in primary from it in the secondary; here it's used as transforming element.

4.9 Batteries

In this system the type of battery used is lead-acid battery because it more widespread, cheaper, have large capacities then other types of batteries.


U1
U2
IN
U3
OUT
GND
1
IN
U4
OUT
GND
2
3
U18
12V
1u
U5
220u
+12v
1k
+6v
U19
U2
1k
R37
220u
1k
U21
U11
47u
U27
+6v
U20
20k
1k
1k
+12v
+12v
1k
10k
U22
10u
U25
U24
U26
U23
Load


+8v
U7
1k
U6
220
U8
1k
220
U9
1k
220
U10
1k
7.5k
20k
Designed by : Lual Zatari & Ameer Dweik
Palestine Polytechnic University
+12v
1k
U11
1k
U13
U14
1k
U18
12V
U12
U11
U16
U15
U17
1u
0.8mH
U28
0.8mH
220p
220p
U22
U23
Load

Symbol	*Type*
U1	Transformer 220/15
U2	Bridge
U3	Regulator (1)
U4	Regulator (2)
U5	Zener diode (1)
U6	Zener diode (2)
U7	Comparator (1/1)
U8	Comparator (2/1)
U9	Comparator (3 /1)
U10	Comparator (4/1)
U11	Opto-Coupler
U12	PWM
U13	MOSFET (1)
U14	MOSFET (2)
U15	MOSFET (3)
U16	MOSFET (4)
U17	Inverter
U18	Batteries
U19	Comparator (1/2)
U20	Comparator (2/2)
U21	NAND gate
U22	555 timer
U23	Buzzer
U24	NOT gate
U25	Triac driver
U26	Triac
U27	Transformer 220/12
U28	Filter

CHAPTER FIVE

Conclusion and Future Work

5.1 Conclusion

UPS systems play an important role in ensuring the proper functioning of critical electrical equipment.

Working together with the main utility power supply, these systems ensure that electric voltage with the appropriate specifications is available at all times to power the critical equipment. UPS systems protect their critical loads not only from utility power supply interruptions. But also from problems such as utility voltage sags and surges. It is often difficult for large power utilities, with their mix of loads having different power quality requirements, to meet the needs of individual critical loads economically. The use of UPS systems is often the most economical solution for providing high quality power to critical electrical loads.

5.2 Future Work

As a future looking for this project and system, the system can be used to help for more than one use so we can look to the following thing:

The UPS system could be connected with the source of the solar cells, so that alternating energy source will be yielded without additional costs.

UPS system could be used as a reference to the entire electrical device or system in order to solve the problem of losing work as power off.

The UPS system is designed to use for one device, in future, it's recommended to build a UPS for any building to keep the all systems are working as single unit.

CHAPTER SIX

Project Calculation

In order to identify the project parts specification, some design aspects should be followed. Soto determines the project equipment specification; the project team derived the project into stages in order to simplify the analyses, as shown in previous chapters.

6.1 Charging Stage

This stage is used to charge the battery, so that the output voltage should be grater than the battery voltage, the best value to charge the battery without casing any harm for it must be approximately 14 volts, because of the specification of the battery type in the standby mode see appendix B.1.

So in the charge stage the voltage across the battery terminal is in equation

$$V_{out} = V_{regulator} + V_{zener} = 8 + 5.1 = 13.1 \text{ DC volts}$$

And for the current

$$I_{terminal} = I_{regulator1} + I_{regulator2} + I_{zener} = 1+1+0.6 = 2.6 \text{ A}$$

6.1.1 Transformer

Choosing the transformer and the battery specification should be considered, in this project the battery that was used have 12 DC volts and 7 Ah work, where there are two batteries in parallel with equivalent work 3.5 Ah, so as seen in work there are the voltage across the battery should be grater than or equal 12 DC volts, that means the output voltage of transformer should be grate than or equal the battery voltage, and the same thing to the current, it must be equal or grater than the battery current, project used transformer [primary voltage to secondary voltage-220/15] volts and 5A battery.

6.1.2 Diode Bridge

Similarly the current and voltage must be in considered, but the bridge doesn't affect the voltage, so that the current has the most important consideration, it should be grater than 3.5A (the battery current), Project used bridge of rated 10A current.

6.1.3 Regulators

To make the battery charge better and to keep battery work for a long time, the charging voltage must be constant as can as possible (the voltage changes when the AC line voltage changes), so the regulator keeps the voltage constant at 8 volts see appendix B.2.

6.2 Control Circuit

The transformer is used to supply the control elements with the voltage station to the load, but the elements work in DC situation, so the transformer and rectifier elements should supply the elements with 10 DC volts (value of 220 AC volts to the

load), there is no high current losses, because the elements in this circuit have low power rating. Transformer in this circuit is 220/12 AC volts with 300mA current.

6.2.1 IC LM324 (comparator) and CD4011(NAND gate)

These parts accept TTL level that could be operate with 5 – 25 DC volts, similarly in the NAND gate element.

6.2.2 CD4047 (Pulse Width Modulator)

This part supply the project with a negative and positive pulses like AC signal, it should have frequency of 50Hz, it can be adjusted according to following equation:

$$\text{Time} = \frac{1}{\text{frequancy}}$$

$$\tau = \frac{1}{50\text{Hz}} = 0.02 \text{ second}$$

And

$$\tau = R \times C$$

Where $C = 0.47\ \mu f$, $t = 0.02$, so

$$R = \frac{\tau}{C} = \frac{0.02}{0.47\ \mu F} = 4.25\ k\Omega$$

6.3 Inverter and MOSFET

Inverter used in this project was 1KVA power rating, so the load current is characterized by the equation:

$$P = V \times I$$

So

$$I = \frac{P}{V} = \frac{1000\ VA}{220\ volts} = 4.5\ A\ (load\ current)$$

So that the maximum current in the MOSFET is 5A and voltage circuit is 50v.

6.4 ON-OFF Time

The time that the element takes to turn on the inverter and supply the load after the critical load cut off is given by following:

Each element takes 0.001 second (as range value) to operate, where the project have 5 elements in the control and inverter circuit, so that the ON-OFF time will be

$$T_{ON\text{-}OFF} = 0.001 \times 5 = 0.005\ second$$

Where the maximum ON-OFF time should be 0.02 second, so that the load will not affected with the change of the source.

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[3] - Thomas L. Floyd, *Electronics Devices*, fifth edition, prentice hall. International Inc, New Jersey, 1999.

[4] - http://www.itic.org.

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[6] - ITIC Technical Committee 3, *ITI (CBEMA) Curve Application Note*, Information Technology Industry Council (ITI, formerly known as the Computer & Business Equipment Manufacturer's Association), 1996.

[7] – Palestine Polytechnic University, Electronics Laboratory sheets, 2004.

[8] – http://www.datasheets4u.com.

APPENDIX A

APPENDIX A

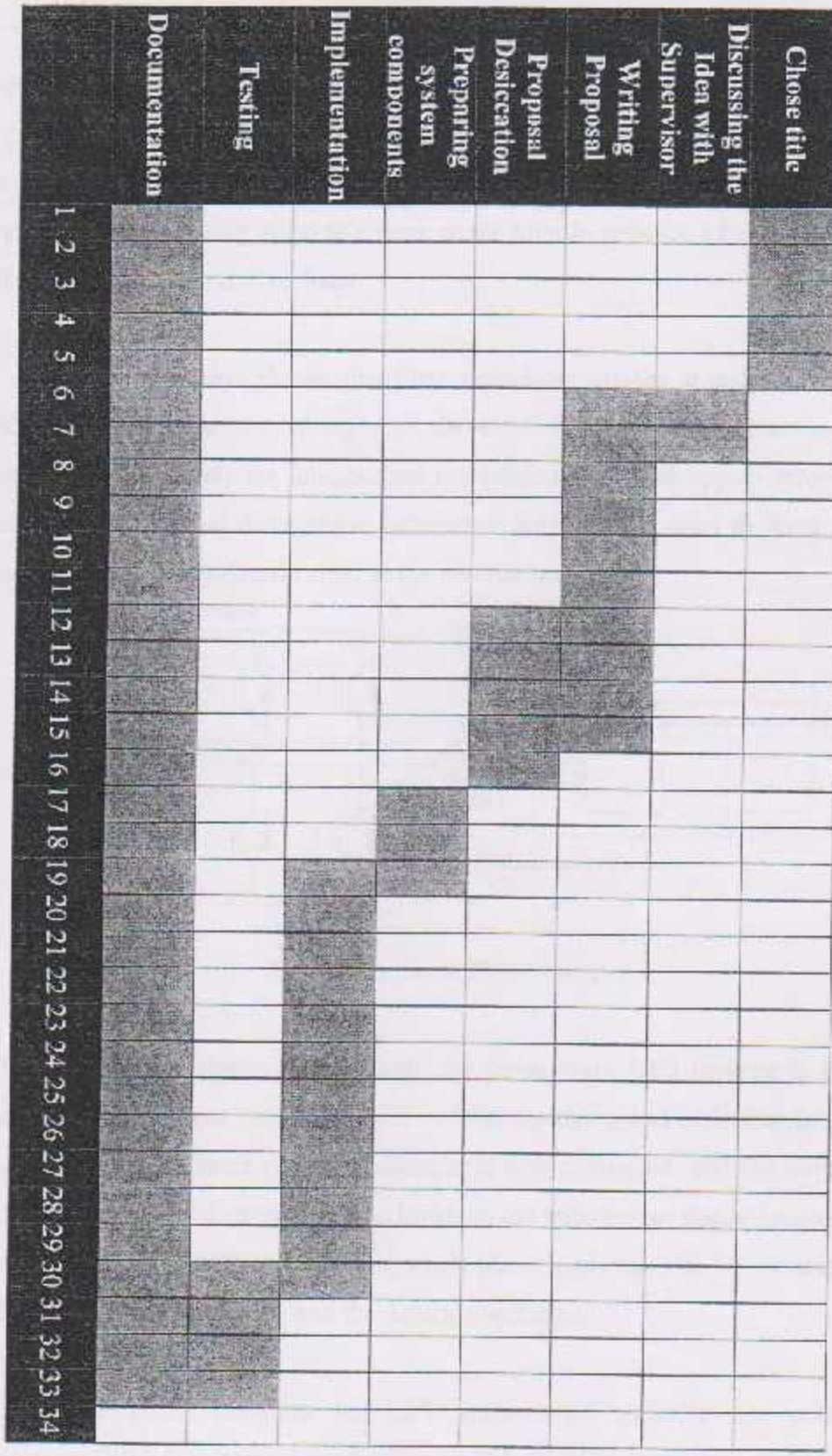
Appendix A.1

A1.1 Project Cost Table

Table A.1 Project Cost

Unit	Details	Number	Cost in $	Total cost in $
Inverter	_____	1	22	22
Bridge	_____	2	1	2
Capacitor	_____	6	0.25	1.5
Variable resistance	_____	6	0.25	1.5
Carbonic resistance	_____	10	---	1
Voltage regulator	+8VDC / 1A	2	1	2
Zener diode	5.1VAC	1	0.25	0.25
Batteries	12V / 7A / 20Ah	2	12	24
Diode (Si)	_____	3	0.25	0.75
IC LM324 (OpAmp)	_____	2	1	2
IC CD4047 (PWM)	_____	1	1	1
IC 4N25 (Opto-Coupler)	_____	3	1	3
IC CD 4011 (NAND)	_____	1	1	1
MOSFET transistor	100V / 40A / 75W	4	8	32
Triac	500...800V /16A	1	2.5	2.5
Buzzer	_____	1	2	2
IC 555 Timer	_____	1	1	1
Case	_____	---	15	15
Accessories	_____	---	55.5	55.5
Total cost of system	_____	---	---	170$

A1.2 Time Plane



TablcA.2 Scheduled Time Plane

A1.3 Three Phase Inverter

UPS systems with a three phase output voltage incorporate a three phase inverter. The most commonly used three phase inverter power circuit is an extension of the single phase inverter, and is shown in Figure A.1. This three phase circuit has one more leg of IGBT switches than the single phase inverter of Figure 2.3. The inverter output is usually given to a three phase filter to produce a balanced sinusoidal voltage supply for the critical load.

Figure A.1 also shows the filter capacitors on the transformer load side winding. These capacitors, along with the transformer leakage inductance, form a filter which allows only the fundamental component voltage to appear across the load terminals. An external three phase inductance may also be used to form the filter, especially if there is no transformer at the inverter output.

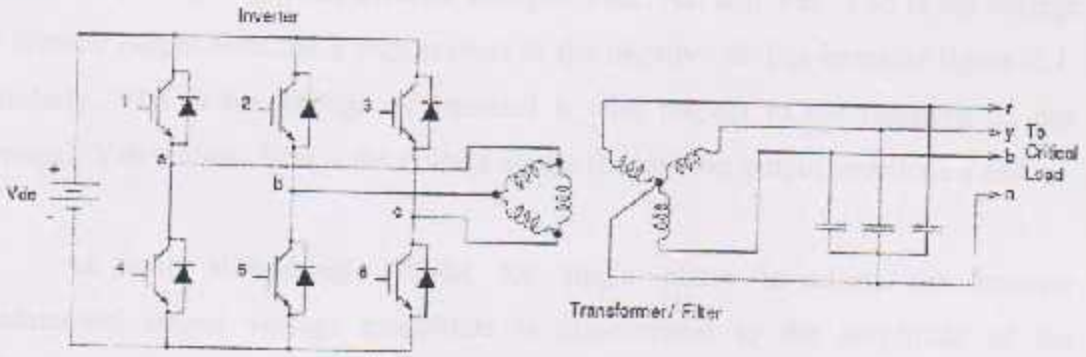


Figure A.1 Three Phase Inverter

As with the single phase circuit, the three phase UPS inverter is also often connected to an output transformer for voltage matching and isolation. In this case, the load side of the three phase transformer is way-connected, and the output to the load is a three phase, four-wire output in which the transformer star point provides the neutral conductor. In this arrangement, single phase loads can also be connected to the UPS output, between a phase and the neutral conductor.

Three phase inverters for UPS applications typically use pulse width modulation (PWM) to control the turning on and off of their semiconductor switches. A common method to generate the PWM pattern is the sine-triangle comparison

method, similar to the method described in the previous section for single phase inverter control.

The sine-triangle comparison method for three phase inverters uses three reference sine waves and one higher frequency triangle wave. The reference sine waves form a balanced set, having the same amplitude, and a relative phase shift of 120 degrees between each other. However, the UPS controller may cause deliberate unbalances in the three phase reference in order to compensate for unbalanced load on the UPS output.

Figure A.2 shows the sine-triangle comparison method for controlling three phase inverters. The uppermost section of Figure A.2 shows the three phase reference sine waves and the triangle wave. The reference sine waves are marked as a, b and c. The lower sections show the inverter voltages Van, Vbn and Vab. Van is the voltage of inverter output terminal a with respect to the negative dc bus terminal figure A.1. Similarly, Vbn is the voltage of terminal b with respect to the negative dc bus terminal. Vab = Van - Vbn is the voltage across the inverter output terminals a and b.

As with sine-triangle PWM for single phase inverters, the inverter fundamental output voltage magnitude is proportional to the amplitude of the reference signals, as long as the reference amplitude is less than the triangle amplitude. For larger reference amplitudes, proportionality is lost.

The sine-triangle comparison method described here for single- and three-phase inverters is one of several methods in use to control the switching of the inverter switches in UPS applications. There are numerous variations of the basic sine-triangle comparison method described here. In addition, there are many PWM methods that do not make use of sine-triangle comparisons at all.

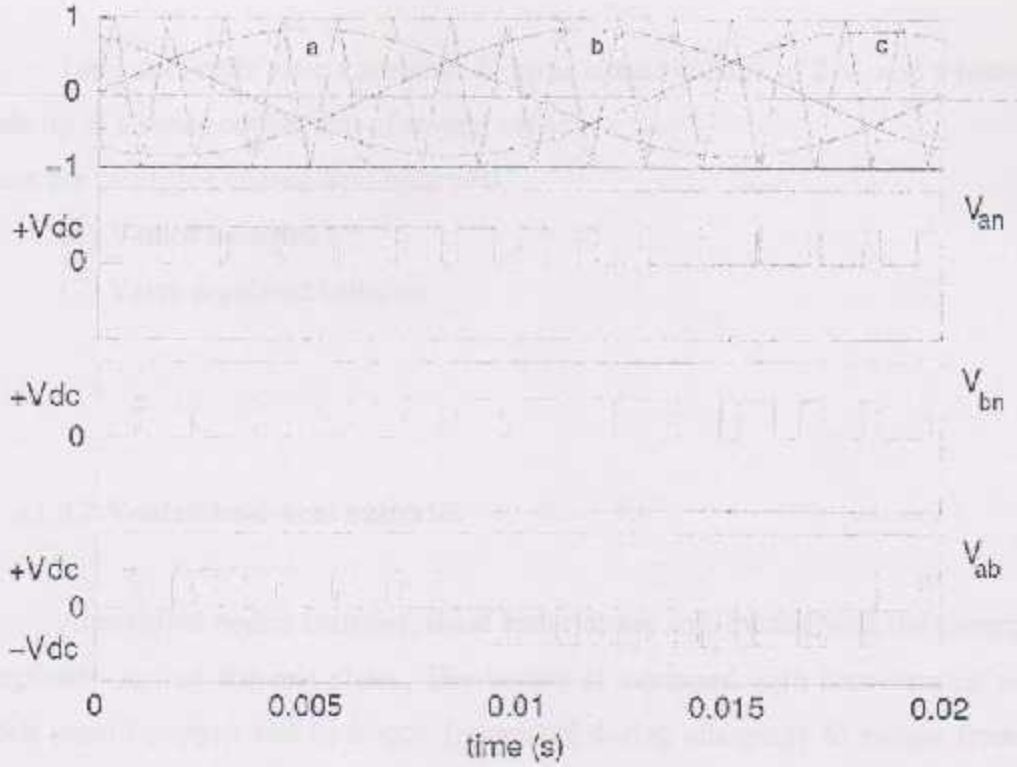


Figure A.2: Wave form of three phase inverter

A1.4 Batteries used in UPS system

A1.4.1 Lead-acid batteries

Lead-acid batteries use a solution of sulfuric acid and water as the electrolyte, lead dioxide for the positive plate, and lead for the negative plate. When the battery is under discharge, sulfate ions in the electrolyte are used up, and lead sulfate is formed at both electrodes. Water is also generated in the process. When the battery is recharged, lead sulfate is converted to lead dioxide at the positive plate and lead at the negative plate, and oxygen and hydrogen are released.

In a lead-acid cell, the specific gravity of the electrolyte is an indicator of the ratio of sulfuric acid to water. Batteries meant to be operated in high ambient temperature environments (about 30 C) usually have lower figures of specific gravity. Higher specific gravity figures result in cells with higher storage capacity. However, battery life is reduced, and internal losses are higher. A higher oat service voltage is needed to compensate for the higher losses.

Lead-acid cells have a nominal dc open circuit voltage of 2 V, and a battery is made up of a series connection of several cells.

There are two types of lead-acid batteries:

(1) Vented batteries.

(2) Valve regulated batteries.

A1.4.2 Vented lead-acid batteries

Also called ooded batteries, these batteries are constructed with the electrolyte completely ooding the cell plates. The battery is equipped with ame-arrestor vents, which permit oxygen and hydrogen {generated during charging} to escape from the battery. Regular maintenance of vented lead-acid batteries includes monitoring the level and specific gravity of the electrolyte.

These batteries have low internal resistance, and can provide high currents to the load during discharge. These batteries are often used in large stationary battery banks with high storage capacity.

A1.4.3 Valve regulated lead-acid batteries

In a valve regulated lead-acid (VRLA) battery, the electrolyte is immobilized. The bat battery is sealed, except for a vent that releases internal gases periodically to regulate internal pressure.

The generation of gases during charging is limited by a recombination process. Oxygen, which is generated at the anode during charging, is directed to the cathode instead of being vented out. This results in a reaction that essentially limits the loss of water from the battery. Since the battery needs no addition of water, it is often called a maintenance-free battery.

However, improper usage of a VRLA battery will result in a loss of water. The sealed construction of the battery does not permit the water to be replaced, and the battery dries out and becomes unusable. This can happen when the battery is overcharged, or charged at a higher voltage than recommended. Boost charging is usually not recommended for VRLA batteries.

A1.4.4 Nickel-cadmium batteries

Unlike the lead-acid battery, the nickel-cadmium battery uses an alkaline electrolyte, potassium hydroxide, which does not participate in the reaction. Nickel hydroxide at the anode, and cadmium hydroxide at the cathode, forms the active reagents.

A nickel-cadmium cell has an open circuit voltage of about 1.3 V, and batteries are made up of several series connected cells. Batteries can operate over wide temperature ranges, and can tolerate deep discharges better than lead-acid batteries. However, nickel-cadmium batteries are costlier than equivalent lead-acid batteries.

The most common constructions for nickel-cadmium batteries use a vented design, although sealed batteries are also available with limited capacity. Nickel-cadmium batteries can sustain high charging rates without damage, and can also be boost charged after a discharge cycle.

Nickel cadmium batteries consist of an active material be:

1. $Ni(OH)_4$ for positive plate of the battery.
2. Mixture of cadmium or cadmium oxide, with an iron mass.
3. acid consist form 21% of potassium hydrate with little of lithium hydrate for increasing the battery discharge time, where the number of positive plate is more than the negative.

Comical mutations of the nickel cadmium happened when the acid divided into positive ions (K^+) and negative ions (OH^-) so the comical reaction happened in the battery plates, on discharge process

$Ni(OH)_4 + 2K \rightarrow Ni(OH)_2 + 2HOH$ (anode reaction)

$Cd + 2OH \rightarrow Cd(OH)_2$ (cathode reaction)

For the charging

$Ni(OH)_2 + 2O \rightarrow Ni(OH)_4$ (anode reaction)

$Cd(OH)_2 + 2K \rightarrow Cd + 2KOH$ (cathode reaction)

APPENDIX B

DATA SHEET

TEXAS INSTRUMENTS

Data sheet acquired from Harris Semiconductor
SCHS044

CD4047B Types

CMOS Low-Power Monostable/Astable Multivibrator

High Voltage Types (20-Volt Rating)

■ CD4047B consists of a gatable astable multivibrator with logic techniques incorporated to permit positive or negative edge-triggered monostable multivibrator action with retriggering and external counting options.

Inputs include +TRIGGER, −TRIGGER, ASTABLE, $\overline{\text{ASTABLE}}$, RETRIGGER, and EXTERNAL RESET. Buffered outputs are $\overline{Q}$, Q, and OSCILLATOR. In all modes of operation, and external capacitor must be connected between C-Timing and RC-Common terminals, and an external resistor must be connected between the R-Timing and RC-Common terminals.

Astable operation is enabled by a high level on the ASTABLE input or a low level on the $\overline{\text{ASTABLE}}$ input, or both. The period of the square wave at the Q and $\overline{Q}$ outputs in this mode of operation is a function of the external components employed. "True" input pulses on the ASTABLE input or "Complement" pulses on the $\overline{\text{ASTABLE}}$ input allow the circuit to be used as a gatable multivibrator. The OSCILLATOR output period will be half of the Q terminal output in the astable mode. However, a 50% duty cycle is not guaranteed at this output.

The CD4047B triggers in the monostable mode when a positive-going edge occurs on the +TRIGGER-input while the -TRIGGER is held low. Input pulses may be of any duration relative to the output pulse.

If retrigger capability is desired, the RETRIGGER input is pulsed. The retriggerable mode of operation is limited to positive-going edge. The CD4047B will retrigger as long as the RETRIGGER-input is high, with or without transitions (See Fig. 34).

An external countdown option can be implemented by coupling "Q" to an external "N" counter and resetting the counter with the trigger pulse. The counter output pulse is fed back to the $\overline{\text{ASTABLE}}$ input and has a duration equal to N times the period of the multivibrator.

A high level on the EXTERNAL RESET input assures no output pulse during an "ON" power condition. This input can also be activated to terminate the output pulse at any time. For monostable operation, whenever V_{DD} is applied, an internal power-on reset circuit will clock the Q output low within one output period (I_M).

The CD4047B-Series types are supplied in 14-lead hermetic dual-in-line ceramic packages (D and F suffixes), 14-lead dual-in-line plastic packages (E suffix), and in chip form (H suffix).

Features:

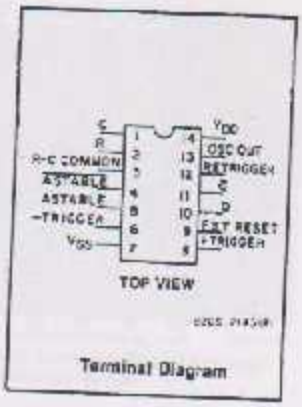
- *Low power consumption: special CMOS oscillator configuration*
- *Monostable (one-shot) or astable (free-running) operation*
- *True and complemented buffered outputs*
- *Only one external R and C required*
- *Buffered inputs*
- *100% tested for quiescent current at 20 V*
- *Standardized, symmetrical output characteristics*
- *5-V, 10-V, and 15-V parametric ratings*
- *Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"*

Monostable Multivibrator Features:

- *Positive- or negative-edge trigger*
- *Output pulse width independent of trigger pulse duration*
- *Retriggerable option for pulse width expansion*
- *Internal power-on reset circuit*
- *Long pulse widths possible using small RC components by means of external counter provision*
- *Fast recovery time essentially independent of pulse width*
- *Pulse-width accuracy maintained at duty cycles approaching 100%*

Astable Multivibrator Features:

- *Free-running or gatable operating modes*
- *50% duty cycle*



Terminal Diagram

- *Oscillator output available*
- *Good astable frequency stability:*
  Frequency deviation:
  = ±2% + 0.03%/°C @ 100 kHz
  = ±0.5% + 0.015%/°C @ 10 kHz
  (circuits "trimmed" to frequency V_{DD} = 10 V ± 10%)

Applications:

Digital equipment where low-power dissipation and/or high noise immunity are primary design requirements:

- *Envelope detection*
- *Frequency multiplication*
- *Frequency division*
- *Frequency discriminators*
- *Timing circuits*
- *Time-delay applications*

RECOMMENDED OPERATING CONDITIONS

For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	LIMITS MIN.	LIMITS MAX.	UNITS
Supply-Voltage Range (For T_A = Full Package-Temperature Range)	3	18	V
NOTE: IF AT 15 V OPERATION A 10 MΩ RESISTOR IS USED THE OPERATING TEMPERATURE SHOULD BE BETWEEN −25°C and 100°C			

MAXIMUM RATINGS, *Absolute-Maximum Values:*

DC SUPPLY-VOLTAGE RANGE, (V_{DD})
Voltages referenced to V_{SS} Terminal) ..... −0.5V to +20V
INPUT VOLTAGE RANGE, ALL INPUTS ..... −0.5V to V_{DD} +0.5V
DC INPUT CURRENT, ANY ONE INPUT ..... ±10mA
POWER DISSIPATION PER PACKAGE (P_D):
For T_A = −55°C to +100°C 500mW
For T_A = +100°C to +125°C ..... Derate Linearly at 12mW/°C to 200mW
DEVICE DISSIPATION PER OUTPUT TRANSISTOR:
FOR T_A = FULL PACKAGE-TEMPERATURE RANGE (All Package Types) 100mW
OPERATING-TEMPERATURE RANGE (T_A) ..... −55°C to +125°C
STORAGE TEMPERATURE RANGE (T_{stg}) ..... −65°C to +150°C
LEAD TEMPERATURE (DURING SOLDERING):
At distance 1/16 ± 1/32 inch (1.59 ± 0.79mm) from case for 10s max ..... +265°C

STATIC ELECTRICAL CHARACTERISTICS (CONTINUED)

CHARACTERISTICS	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)							UNITS
	V_O (V)	V_{IN} (V)	V_{DD} (V)	−55	−40	+85	+125	+25 Min.	+25 Typ.	+25 Max.	
Output Voltage: High-Level, V_{OH} Min.	—	0.5	5		4.95			4.95	5	—	V
	—	0,10	10		9.95			9.95	10	—	
	—	0,15	15		14.95			14.95	15	—	
Input Low Voltage, V_{IL} Max.	0.5,4.5	—	5		1.5			—	—	1.5	V
	1,9	—	10		3			—	—	3	
	1.5,13.5	—	15		4			—	—	4	
Input High Voltage, V_{IH} Min.	0.5,4.5	—	5		3.5			3.5	—	—	
	1.9	—	10		7			7	—	—	
	1.5,13.5	—	15		11			11	—	—	
Input Current I_{IN} Max.	—	0,18	18	±0.1	±0.1	±1	±1	—	$\pm 10^5$	±0.1	μA

DYNAMIC ELECTRICAL CHARACTERISTICS at $T_A = 25°C$; Input $t_r, t_f = 20$ ns, $C_L = 50$ pF, $R_L = 200$ kΩ

CHARACTERISTIC	V_{DD} (V)	LIMITS Min.	LIMITS TYP.	LIMITS MAX.	UNITS
Propagation Delay Time t_{PHL}, t_{PLH}					
Astable, $\overline{\text{Astable}}$ to Osc. Out	5	—	200	400	ns
	10	—	100	200	
	15	—	80	160	
Astable, $\overline{\text{Astable}}$ to Q, $\overline{Q}$	5	—	350	700	
	10	—	175	350	
	15	—	125	250	
+ or − Trigger to Q, $\overline{Q}$	5	—	500	1000	
	10	—	225	450	
	15	—	150	300	
Retrigger to Q, $\overline{Q}$	5	—	300	600	
	10	—	150	300	
	15	—	100	200	
External Reset to Q, $\overline{Q}$	5	—	250	500	
	10	—	100	200	
	15	—	70	140	
Transition Time, t_{THL}, t_{TLH} Osc. Out, Q, $\overline{Q}$	5	—	100	200	
	10	—	50	100	
	15	—	40	80	
Minimum Input Pulse Width, t_w	5	—	200	400	
+ Trigger, − Trigger	10	—	80	160	
	15	—	50	100	
Reset	5	—	100	200	
	10	—	50	100	
	15	—	30	60	
Retrigger	5	—	300	600	
	10	—	115	230	
	15	—	75	150	
Input Rise and Fall Time, t_r, t_f All Trigger Inputs					
For + Trigger: t_r	5	—	270	—	μs
t_r only is unlimited	10	—	18	—	
	15	—	9	—	
For − Trigger: t_f	5	—	325	—	
t_f only is unlimited	10	—	9	—	
	15	—	4	—	
Q or $\overline{Q}$ Deviation from 50% Duty Factor	5	—	±0.5	±1	%
	10	—	±0.5	±1	
	15	—	±0.1	±0.5	
Input Capacitance, C_{IN}	Any Input	—	5	7.5	pF

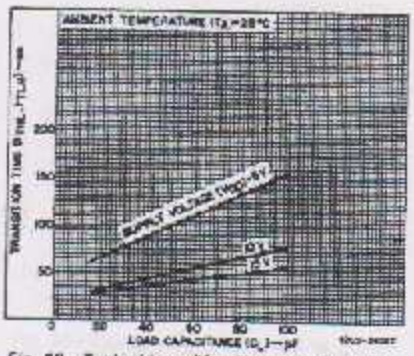


Fig. 10—Typical transition time as a function of load capacitance.

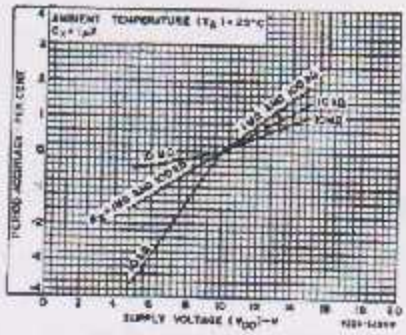


Fig. 11—Typical astable oscillator or Q, $\overline{Q}$ period accuracy vs. supply voltage.

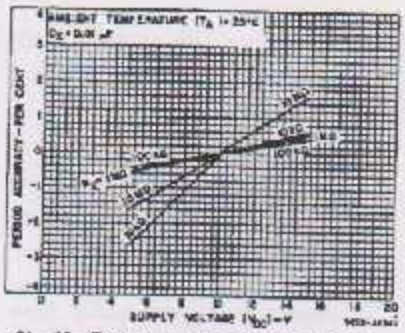


Fig. 12—Typical astable oscillator or Q, $\overline{Q}$ period accuracy vs. supply voltage.

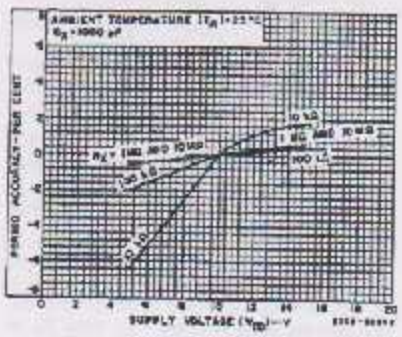


Fig. 13—Typical astable oscillator or Q, $\overline{Q}$ period accuracy vs. supply voltage.

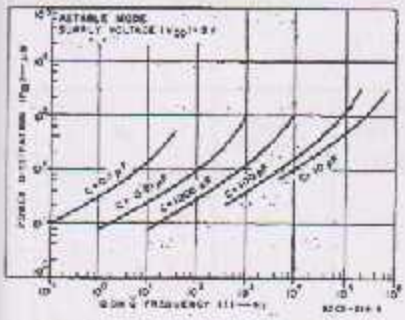


Fig. 26—Typical power dissipation vs. output frequency (V_{DD} = 5 V).

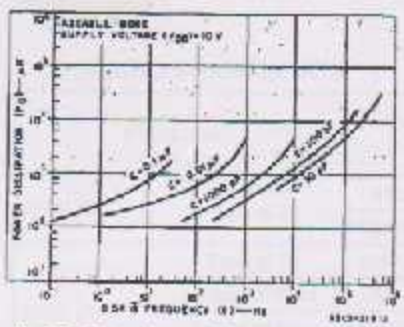


Fig. 27—Typical power dissipation vs. output frequency (V_{DD} = 10 V).

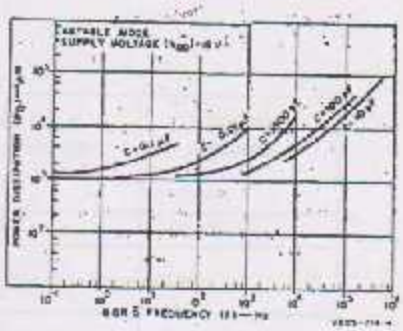


Fig. 28—Typical power dissipation vs. output frequency (V_{DD} = 15 V).

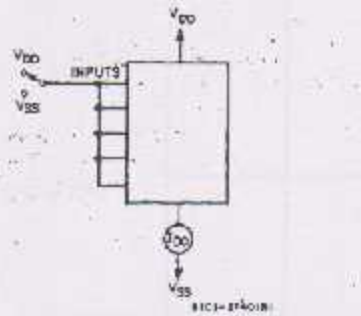


Fig. 29—Quiescent device current test circuit.

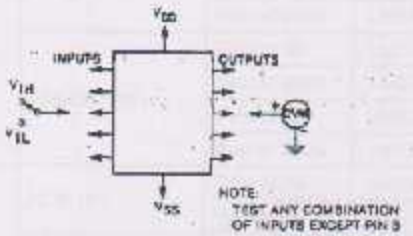


Fig. 30—Input-voltage test circuit.

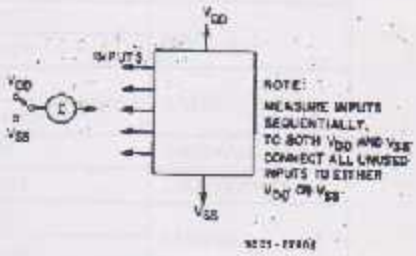


Fig. 31—Input-leakage-current test circuit.

1. Astable Mode Design Information

A. Unit-to-Unit Transfer-Voltage Variations — The following analysis presents variations from unit to unit as a function of transfer-voltage (V_{TR}) shift (33% — 67% V_{DD}) for free-running (astable) operation.

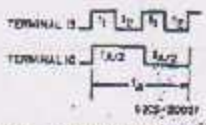


Fig. 32—Astable mode waveforms.

$$t_1 = -RC \ln \frac{V_{TR}}{V_{DD} + V_{TR}}$$

typically, $t_1 = 1.1\ RC$

$$t_2 = -RC \ln \frac{V_{DD} - V_{TR}}{2V_{DD} - V_{TR}};$$

typically, $t_2 = 1.1\ RC$

$$t_A = 2(t_1 + t_2)$$

$$= -2\ RC \ln \frac{(V_{TR})(V_{DD} - V_{TR})}{(V_{DD} + V_{TR})(2V_{DD} - V_{TR})}$$

Typ: $V_{TR} = 0.5\ V_{DD}$ $t_A = 4.40\ RC$
Min: $V_{TR} = 0.33\ V_{DD}$ $t_A = 4.62\ RC$
Max: $V_{TR} = 0.67\ V_{DD}$ $t_A = 4.62\ RC$

thus if $t_A = 4.40\ RC$ is used, the variation will be +5%, −0% due to variations in transfer voltage.

B. Variations Due to V_{DD} and Temperature Changes — In addition to variations from unit to unit, the astable period varies with V_{DD} and temperature. Typical variations are presented in graphical form in Figs. 11 to 18 with 10 V as reference for voltage variations curves and 25°C as reference for temperature variations curves.

II. Monostable Mode Design Information

The following analysis presents variations from unit to unit as a function of transfer-voltage (V_{TR}) shift (33% — 67% V_{DD}) for one-shot (monostable) operation.

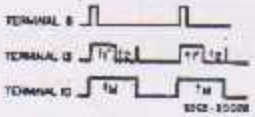


Fig. 33—Monostable waveforms.

$$t_1' = -RC \ln \frac{V_{TR}}{2V_{DD}}$$

typically, $t_1' = 1.38\ RC$

$$t_M = (t_1' + t_2)$$

$$t_M = -RC \ln \frac{(V_{TR})(V_{DD} - V_{TR})}{(2V_{DD} - V_{TR})(2V_{DD})}$$

where t_M = Monostable mode pulse width. Values for t_M are as follows:

Typ: $V_{TR} = 0.5\ V_{DD}$ $t_M = 2.48\ RC$
Min: $V_{TR} = 0.33\ V_{DD}$ $t_M = 2.71\ RC$
Max: $V_{TR} = 0.67\ V_{DD}$ $t_M = 2.48\ RC$

thus if $t_M = 2.48\ RC$ is used, the variation will be +9.3%, −0% due to variations in transfer voltage.

Note:

In the astable mode, the first positive half cycle has a duration of t_M; succeeding durations are $t_A/2$.

In addition to variations from unit to unit, the monostable pulse width varies with V_{DD} and temperature. These variations are presented in graphical form in Fig. 19 to 26 with 10 V as reference for voltage-variation curves and 25°C as reference for temperature-variation curves.

description/ordering information (continued)

ORDERING INFORMATION

T_A	V_{IO}max AT 25°C	MAX TESTED V_{CC}	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	7 mV	30 V	PDIP (N)	Tube of 25	LM324N	LM324N
					LM324KN	LM324KN
			SOIC (D)	Tube of 50	LM324D	LM324
				Reel of 2500	LM324DR	
				Tube of 50	LM324KD	LM324K
				Reel of 2500	LM324KDR	
			SOP (NS)	Reel of 2000	LM324NSR	LM324
				Tube of 50	LM324KNS	LM324K
				Reel of 2000	LM324KNSR	
			TSSOP (PW)	Tube of 90	LM324PW	L324
				Reel of 2000	LM324PWR	
				Tube of 90	LM324KPW	L324K
				Reel of 2000	LM324KPWR	
	3 mV	30 V	PDIP (N)	Tube of 25	LM324AN	LM324AN
				Tube of 25	LM324KAN	LM324KAN
			SOIC (D)	Tube of 50	LM324AD	LM324A
				Reel of 2500	LM324ADR	
				Tube of 50	LM324KAD	LM324KA
				Reel of 2500	LM324KADR	
			SOP (NS)	Reel of 2000	LM324ANSR	LM324A
				Tube of 50	LM324KANS	LM324KA
				Reel of 2000	LM324KANSR	
			SSOP (DB)	Reel of 2000	LM324ADBR	LM324A
			TSSOP (PW)	Tube of 90	LM324APW	L324A
				Reel of 2000	LM324APWR	
				Tube of 90	LM324KAPW	L324KA
				Reel of 2000	LM324KAPWR	
−25°C to 85°C	5 mV	30 V	PDIP (N)	Tube of 25	LM224N	LM224N
					LM224KN	LM224KN
			SOIC (D)	Tube of 50	LM224D	LM224
				Reel of 2500	LM224DR	
				Tube of 50	LM224KD	LM224K
				Reel of 2500	LM224KDR	
	3 mV	30 V	PDIP (N)	Tube of 25	LM224AN	LM224AN
				Tube of 25	LM224KAN	LM224KAN
			SOIC (D)	Tube of 50	LM224AD	LM224A
				Reel of 2500	LM224ADR	
				Tube of 50	LM224KAD	LM224KA
				Reel of 2500	LM224KADR	

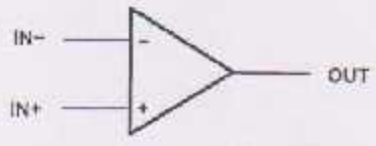
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

ORDERING INFORMATION (CONTINUED)

T_A	V_{IO}max AT 25°C	MAX TESTED V_{CC}	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−40°C to 125°C	7 mV	26 V	PDIP (N)	Tube of 25	LM2902N	LM2902N
				Tube of 25	LM2902KN	LM2902KN
			SOIC (D)	Tube of 50	LM2902D	LM2902
				Reel of 2500	LM2902DR	
				Tube of 50	LM2902KD	LM2902K
				Reel of 2500	LM2902KDR	
			SOP (NS)	Reel of 2000	LM2902NSR	LM2902
				Tube of 50	LM2902KNS	LM2902K
				Reel of 2000	LM2902KNSR	
			SSOP (DB)	Tube of 80	LM2902KDB	L2902K
				Reel of 2000	LM2902KDBR	
			TSSOP (PW)	Tube of 90	LM2902PW	L2902
				Reel of 2000	LM2902PWR	
				Tube of 90	LM2902KPW	L2902K
				Reel of 2000	LM2902KPWR	
		32 V	SOIC (D)	Reel of 2500	LM2902KVQDR	L2902KV
			TSSOP (PW)	Reel of 2000	LM2902KVQPWR	L2902KV
	2 mV	32 V	SOIC (D)	Reel of 2500	LM2902KAVQDR	L2902KA
			TSSOP (PW)	Reel of 2000	LM2902KAVQPWR	L2902KA
−55°C to 125°C	5 mV	30 V	CDIP (J)	Tube of 25	LM124J	LM124J
			CFP (W)	Tube of 25	LM124W	LM124W
			LCCC (FK)	Tube of 55	LM124FK	LM124FK
			SOIC (D)	Tube of 50	LM124D	LM124
				Reel of 2500	LM124DR	
	2 mV	30 V	CDIP (J)	Tube of 25	LM124AJ	LM124AJ
			LCCC (FK)	Tube of 55	LM124AFK	LM124AFK

†Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

symbol (each amplifier)



operating conditions, V_{CC} = ±15 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
SR	Slew rate at unity gain	R_L = 1 MΩ, C_L = 30 pF, V_I = ±10 V (see Figure 1)	0.5	V/μs
B_1	Unity-gain bandwidth	R_L = 1 MΩ, C_L = 20 pF (see Figure 1)	1.2	MHz
V_n	Equivalent input noise voltage	R_S = 100 Ω, V_I = 0 V, f = 1 kHz (see Figure 2)	35	nV/√Hz

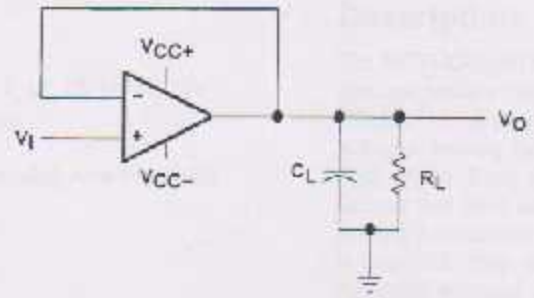


Figure 1. Unity-Gain Amplifier

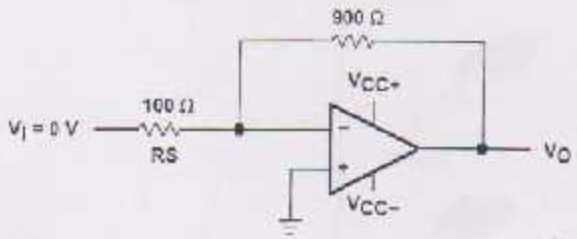


Figure 2. Noise-Test Circuit

FAIRCHILD
SEMICONDUCTOR®

www.fairchildsemi.com

MC78XX/LM78XX/MC78XXA

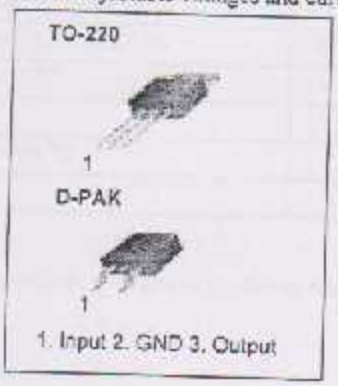
3-Terminal 1A Positive Voltage Regulator

Features

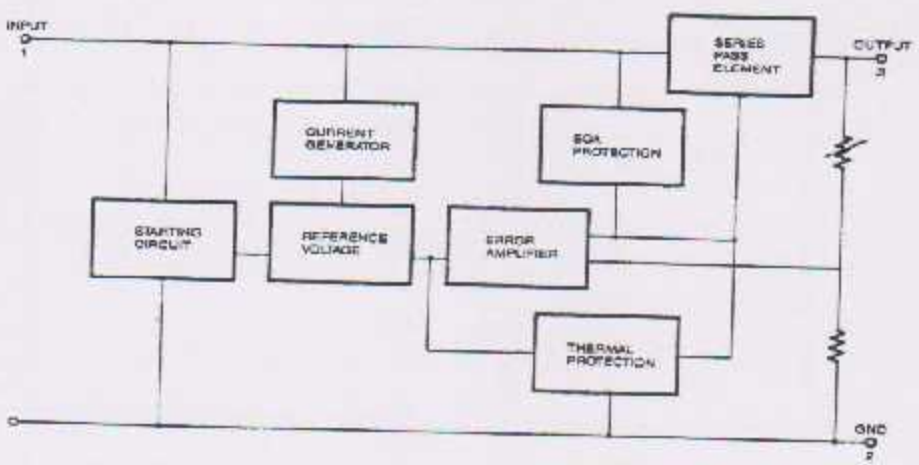
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The MC78XX/LM78XX/MC78XXA series of three terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



Internal Block Digram



Electrical Characteristics (MC7808)

(Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I =14V, C_I= 0.33μF, C_O= 0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7808			Unit
				Min.	Typ.	Max.	
Output Voltage	V_O	T_J =+25 °C		7.7	8.0	8.3	V
		5.0mA ≤ I_O ≤ 1.0A, P_O ≤ 15W V_I = 10.5V to 23V		7.6	8.0	8.4	
Line Regulation (Note1)	Regline	T_J =+25 °C	V_I = 10.5V to 25V	-	5.0	160	mV
			V_I = 11.5V to 17V	-	2.0	80	
Load Regulation (Note1)	Regload	T_J =+25 °C	I_O = 5.0mA to 1.5A	-	10	160	mV
			I_O= 250mA to 750mA	-	5.0	80	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.05	0.5	mA
		V_I = 10.5A to 25V		-	0.5	1.0	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25 °C		-	52	-	μV/Vo
Ripple Rejection	RR	f = 120Hz, V_I= 11.5V to 21.5V		56	73	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J=+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1 Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
by MOC3041/D

GlobalOptoisolator™

VDE | UL | CSA | SETI | SEMKO | DEMKO | NEMKO | BABT

# MOC3041
[IFT = 15 mA Max]
# MOC3042
[IFT = 10 mA Max]
# MOC3043*
[IFT = 5 mA Max]

*Motorola Preferred Device

6-Pin DIP Zero-Cross Optoisolators Triac Driver Output
(400 Volts Peak)

The MOC3041, MOC3042 and MOC3043 devices consist of gallium arsenide infrared emitting diodes optically coupled to a monolithic silicon detector performing the function of a Zero Voltage Crossing bilateral triac driver.

They are designed for use with a triac in the interface of logic systems to equipment powered from 115 Vac lines, such as solid–state relays, industrial controls, motors, solenoids and consumer appliances, etc.

- Simplifies Logic Control of 115 Vac Power
- Zero Voltage Crossing
- dv/dt of 2000 V/µs Typical, 1000 V/µs Guaranteed
- ***To order devices that are tested and marked per VDE 0884 requirements, the suffix "V" must be included at end of part number. VDE 0884 is a test option.***

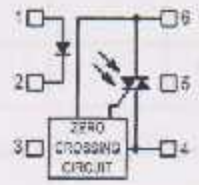
Recommended for 115/240 Vac(rms) Applications:

- Solenoid/Valve Controls
- Lighting Controls
- Static Power Switches
- AC Motor Drives
- Temperature Controls
- E.M. Contactors
- AC Motor Starters
- Solid State Relays

STYLE 6 PLASTIC

STANDARD THRU HOLE
CASE 730A–04

COUPLER SCHEMATIC



1. ANODE
2. CATHODE
3. NC
4. MAIN TERMINAL
5. SUBSTRATE
   DO NOT CONNECT
6. MAIN TERMINAL

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
INFRARED EMITTING DIODE			
Reverse Voltage	V_R	6	Volts
Forward Current — Continuous	I_F	60	mA
Total Power Dissipation @ T_A = 25°C Negligible Power in Output Driver Derate above 25°C	P_D	120 1.41	mW mW/°C
OUTPUT DRIVER			
Off–State Output Terminal Voltage	V_{DRM}	400	Volts
Peak Repetitive Surge Current (PW = 100 µs, 120 pps)	I_{TSM}	1	A
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 1.76	mW mW/°C
TOTAL DEVICE			
Isolation Surge Voltage(1) (Peak ac Voltage, 60 Hz, 1 Second Duration)	V_{ISO}	7500	Vac(pk)
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	250 2.94	mW mW/°C
Junction Temperature Range	T_J	−40 to +100	°C
Ambient Operating Temperature Range(2)	T_A	−40 to +85	°C
Storage Temperature Range(2)	T_{stg}	−40 to +150	°C
Soldering Temperature (10 s)	T_L	260	°C

1. Isolation surge voltage, V_{ISO}, is an internal device dielectric breakdown rating.
   For this test, Pins 1 and 2 are common, and Pins 4, 5 and 6 are common.
2. Refer to Quality and Reliability Section in Opto Data Book for information on test conditions.

Preferred devices are Motorola recommended choices for future use and best overall value.

GlobalOptoisolator is a trademark of Motorola, Inc.

(Replaces MOC3040/D)

MOTOROLA

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
INPUT LED					
Reverse Leakage Current (V_R = 6 V)	I_R	—	0.05	100	μA
Forward Voltage (I_F = 30 mA)	V_F	—	1.3	1.5	Volts
OUTPUT DETECTOR (I_F = 0 unless otherwise noted)					
Leakage with LED Off, Either Direction (Rated V_{DRM}(1))	I_{DRM1}	—	2	100	nA
Peak On-State Voltage, Either Direction (I_{TM} = 100 mA Peak)	V_{TM}	—	1.8	3	Volts
Critical Rate of Rise of Off-State Voltage(3)	dv/dt	1000	2000	—	V/μs
COUPLED					
LED Trigger Current, Current Required to Latch Output (Main Terminal Voltage = 3 V(2)) MOC3041 / MOC3042 / MOC3043	I_{FT}	— — —	— — —	15 10 5	mA
Holding Current, Either Direction	I_H	—	250	—	μA
Isolation Voltage (f = 60 Hz, t = 1 sec)	V_{ISO}	7500	—	—	Vac(pk)
ZERO CROSSING					
Inhibit Voltage (I_F = Rated I_{FT}, MT1–MT2 Voltage above which device will not trigger.)	V_{IH}	—	5	20	Volts
Leakage in Inhibited State (I_F = Rated I_{FT}, Rated V_{DRM}, Off State)	I_{DRM2}	—	—	500	μA

1. Test voltage must be applied within dv/dt rating.
2. All devices are guaranteed to trigger at an I_F value less than or equal to max I_{FT}. Therefore, recommended operating I_F lies between I_{FT} (15 mA for MOC3041, 10 mA for MOC3042, 5 mA for MOC3043) and absolute max I_F (60 mA).
3. This is static dv/dt. See Figure 7 for test circuit. Commutating dv/dt is a function of the load-driving thyristor(s) only.

TYPICAL ELECTRICAL CHARACTERISTICS

T_A = 25°C

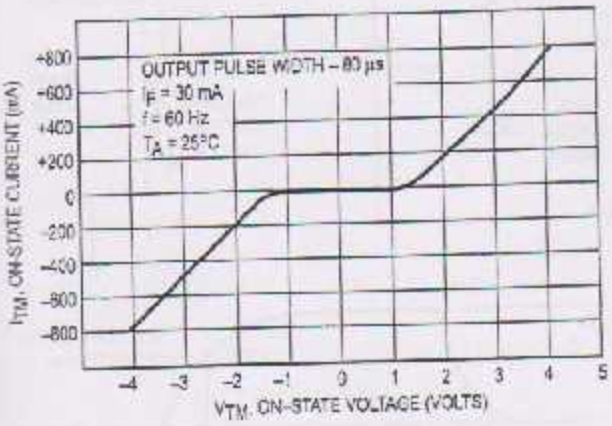


Figure 1. On-State Characteristics

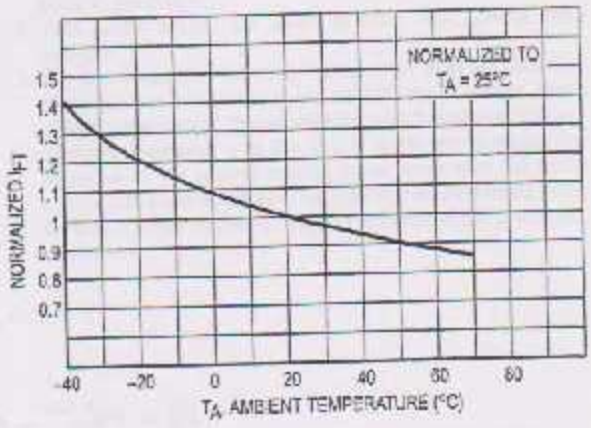


Figure 2. Trigger Current versus Temperature

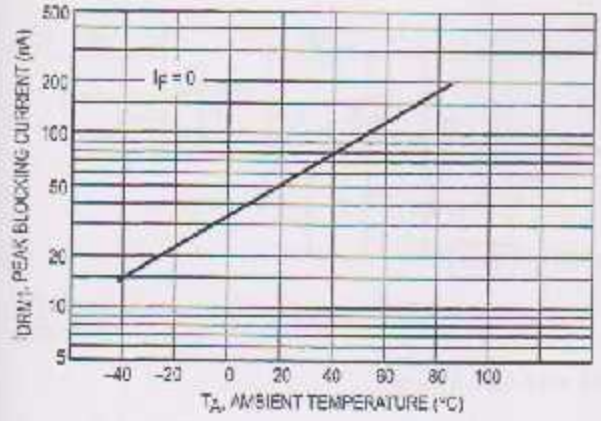


Figure 3. I_{DRM1}, Peak Blocking Current versus Temperature

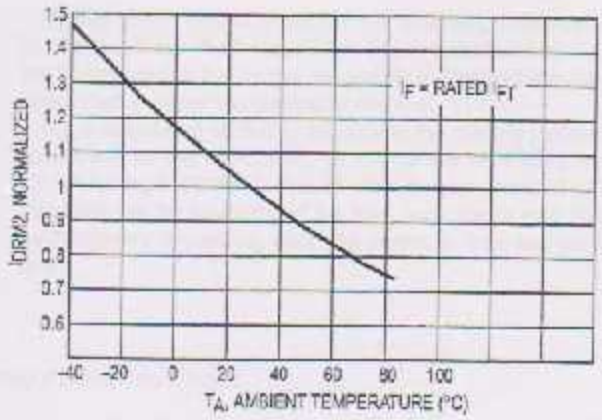


Figure 4. I_{DRM2}, Leakage in Inhibit State versus Temperature

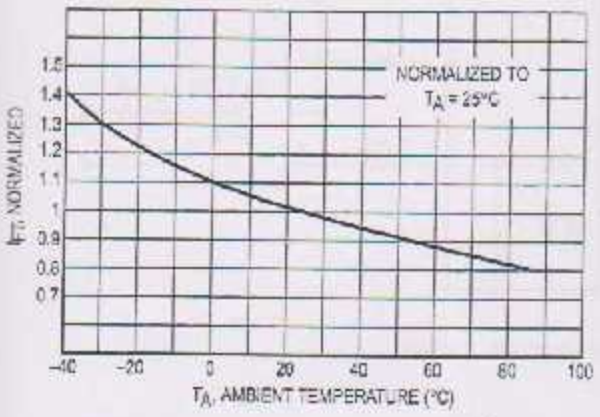


Figure 5. Trigger Current versus Temperature

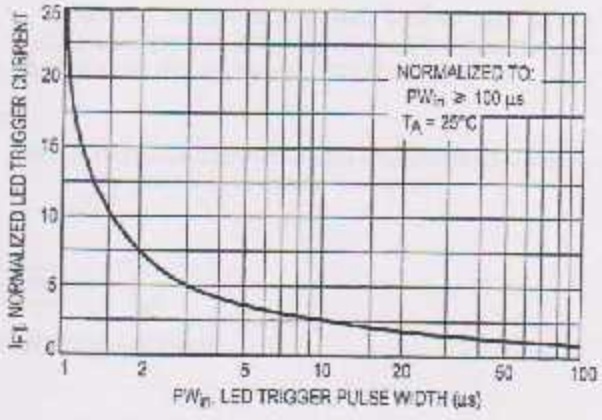
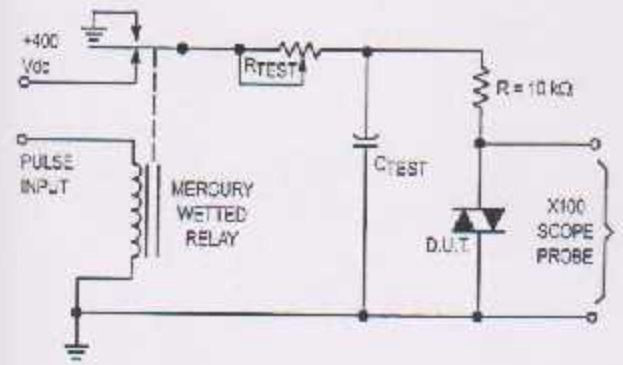


Figure 6. LED Current Required to Trigger versus LED Pulse Width



1. The mercury wetted relay provides a high speed repeated pulse to the D.U.T.
2. 100x scope probes are used, to allow high speeds and voltages.
3. The worst-case condition for static dv/dt is established by triggering the D.U.T. with a normal LED input current, then removing the current. The variable R_{TEST} allows the dv/dt to be gradually increased until the D.U.T. continues to trigger in response to the applied voltage pulse, even after the LED current has been removed. The dv/dt is then decreased until the D.U.T. stops triggering. t_{RC} is measured at this point and recorded.

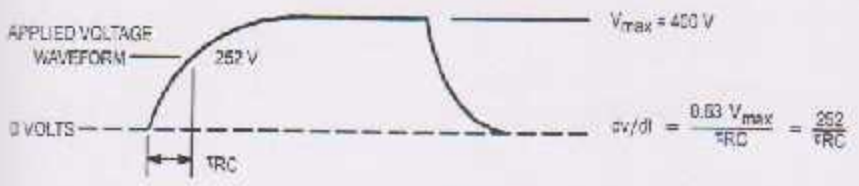
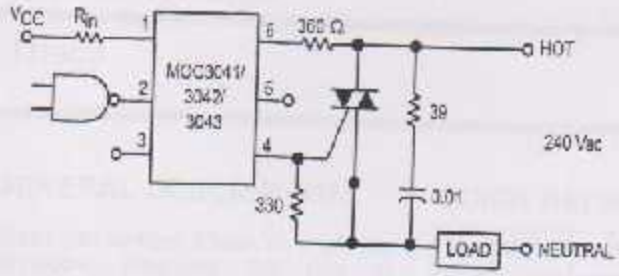


Figure 7. Static dv/dt Test Circuit

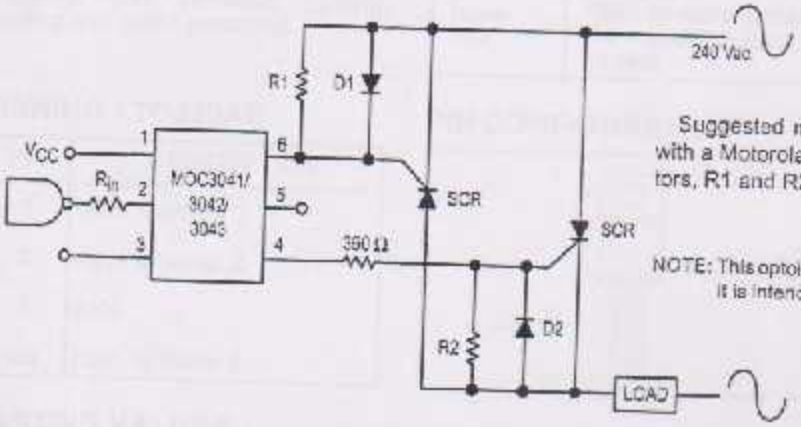


*For highly inductive loads (power factor < 0.5), change this value to 360 ohms.

Typical circuit for use when hot line switching is required. In this circuit the "hot" side of the line is switched and the load connected to the cold or neutral side. The load may be connected to either the neutral or hot line.

R_{in} is calculated so that I_F is equal to the rated I_{FT} of the part, 5 mA for the MOC3043, 10 mA for the MOC3042, or 15 mA for the MOC3041. The 39 ohm resistor and 0.01 µF capacitor are for snubbing of the triac and may or may not be necessary depending upon the particular triac and load used.

Figure 8. Hot–Line Switching Application Circuit



Suggested method of firing two, back–to–back SCR's, with a Motorola triac driver. Diodes can be 1N4001; resistors, R1 and R2, are optional 330 ohms.

NOTE: This optoisolator should not be used to drive a load directly. It is intended to be a trigger device only.

Figure 9. Inverse–Parallel SCR Driver Circuit

GENERAL DESCRIPTION

Glass passivated triacs in a plastic envelope, intended for use in applications requiring high bidirectional transient and blocking voltage capability and high thermal cycling performance. Typical applications include motor control, industrial and domestic lighting, heating and static switching.

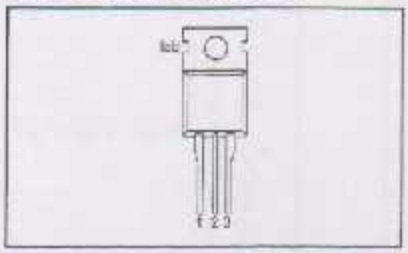
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	MAX.	MAX.	UNIT
	BT139-	500	600	800	
	BT139-	500F	600F	800F	
	BT139-	500G	600G	800G	
V_{DRM}	Repetitive peak off-state voltages	500	600	800	V
$I_{T(RMS)}$	RMS on-state current	16	16	16	A
I_{TSM}	Non-repetitive peak on-state current	140	140	140	A

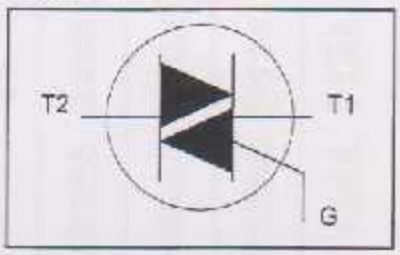
PINNING - TO220AB

PIN	DESCRIPTION
1	main terminal 1
2	main terminal 2
3	gate
tab	main terminal 2

PIN CONFIGURATION



SYMBOL



LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.			UNIT
				-500	-600	-800	
V_{DRM}	Repetitive peak off-state voltages		-	500[1]	600[1]	800	V
$I_{T(RMS)}$	RMS on-state current	full sine wave; $T_{mb} \leq 99$ °C	-		16		A
I_{TSM}	Non-repetitive peak on-state current	full sine wave; $T_j = 25$ °C prior to surge					
		t = 20 ms	-		140		A
		t = 16.7 ms	-		150		A
I^2t	I^2t for fusing	t = 10 ms	-		98		A^2s
dI_T/dt	Repetitive rate of rise of on-state current after triggering	$I_{TM} = 20$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/µs					
		T2+ G+	-		50		A/µs
		T2+ G-	-		50		A/µs
		T2- G-	-		50		A/µs
		T2- G+	-		10		A/µs
I_{GM}	Peak gate current		-		2		A
V_{GM}	Peak gate voltage		-		5		V
P_{GM}	Peak gate power		-		5		W
$P_{G(AV)}$	Average gate power	over any 20 ms period	-		0.5		W
T_{stg}	Storage temperature		-40		150		°C
T_j	Operating junction temperature		-		125		°C

1 Although not recommended, off-state voltages up to 800V may be applied without damage, but the triac may switch to the on-state. The rate of rise of current should not exceed 15 A/µs.

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$R_{th\ j-mb}$	Thermal resistance junction to mounting base	full cycle	-	-	1.2	K/W
		half cycle	-	-	1.7	K/W
$R_{th\ j-a}$	Thermal resistance junction to ambient	in free air	-	60	-	K/W

STATIC CHARACTERISTICS

T_j = 25 °C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.			UNIT
		BT139-			...	...F	...G	
I_{GT}	Gate trigger current	V_D = 12 V; I_T = 0.1 A						
		T2+ G+	-	5	35	25	50	mA
		T2+ G-	-	8	35	25	50	mA
		T2- G-	-	10	35	25	50	mA
		T2- G+	-	22	70	70	100	mA
I_L	Latching current	V_D = 12 V; I_{GT} = 0.1 A						
		T2+ G+	-	7	40	40	60	mA
		T2+ G-	-	20	60	60	90	mA
		T2- G-	-	6	40	40	60	mA
		T2- G+	-	10	60	60	90	mA
I_H	Holding current	V_D = 12 V; I_{GT} = 0.1 A	-	6	30	30	60	mA
V_T	On-state voltage	I_T = 20 A	-	1.2		1.6		V
V_{GT}	Gate trigger voltage	V_D = 12 V; I_T = 0.1 A	-	0.7		1.5		V
		V_D = 400 V; I_T = 0.1 A; T_j = 125 °C	0.25	0.4		-		V
I_D	Off-state leakage current	V_D = $V_{DRM(max)}$; T_j = 125 °C	-	0.1		0.5		mA

DYNAMIC CHARACTERISTICS

T_j = 25 °C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.			TYP.	MAX.	UNIT
		BT139-	...	...F	...G			
dV_D/dt	Critical rate of rise of off-state voltage	V_{DM} = 67% $V_{DRM(max)}$; T_j = 125 °C; exponential waveform; gate open circuit	100	50	200	250	-	V/µs
dV_{com}/dt	Critical rate of change of commutating voltage	V_{DM} = 400 V; T_j = 95 °C; $I_{T(RMS)}$ = 16 A; dI_{com}/dt = 7.2 A/ms; gate open circuit	-	-	10	20	-	V/µs
t_{gt}	Gate controlled turn-on time	I_{TM} = 20 A; V_D = $V_{DRM(max)}$; I_G = 0.1 A; dI_G/dt = 5 A/µs	-	-	-	2	-	µs

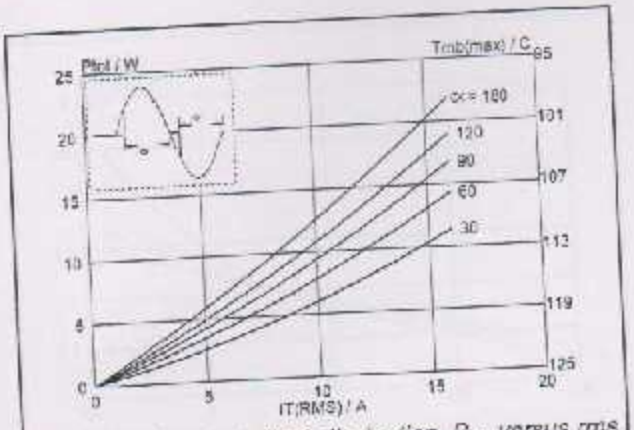


Fig.1. Maximum on-state dissipation, P_{tot}, versus rms on-state current, $I_{T(RMS)}$, where α = conduction angle.

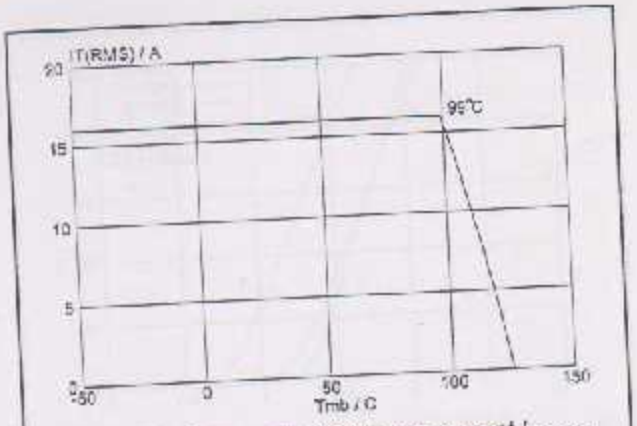


Fig.4. Maximum permissible rms current $I_{T(RMS)}$, versus mounting base temperature T_{mb}.

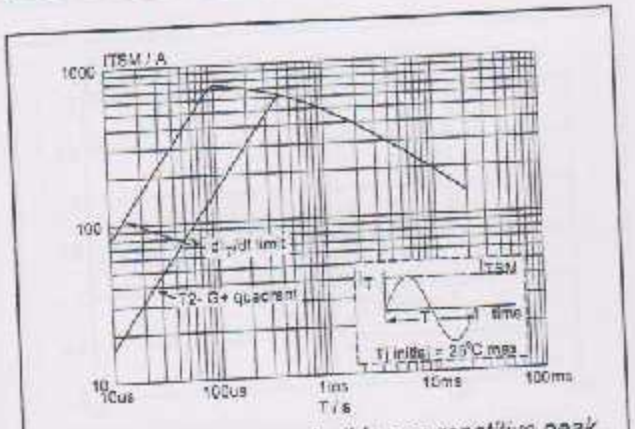


Fig.2. Maximum permissible non-repetitive peak on-state current I_{TSM}, versus pulse width t_p, for sinusoidal currents, $t_p \leq 20ms$.

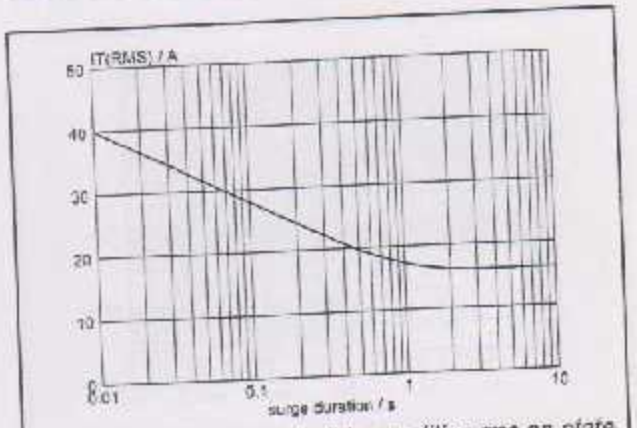


Fig.5. Maximum permissible repetitive rms on-state current $I_{T(RMS)}$, versus surge duration, for sinusoidal currents, $f = 50$ Hz; $T_{mb} \leq 99°C$.

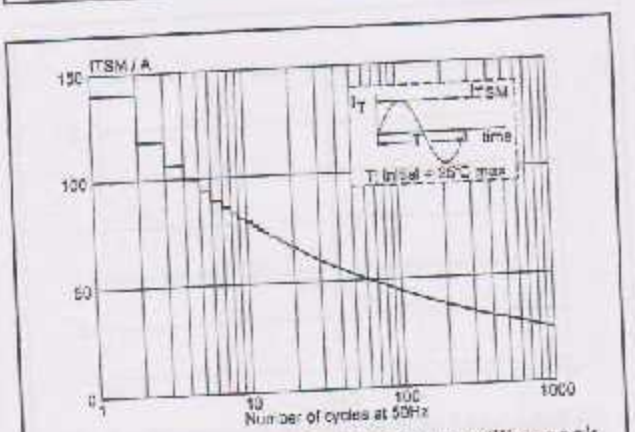


Fig.3. Maximum permissible non-repetitive peak on-state current I_{TSM}, versus number of cycles, for sinusoidel currents, $f = 50$ Hz.

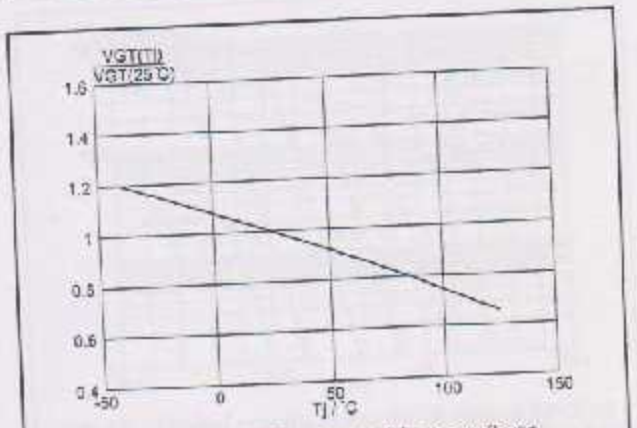


Fig.6. Normalised gate trigger voltage $V_{GT}(T_j)/ V_{GT}(25°C)$, versus junction temperature T_j.

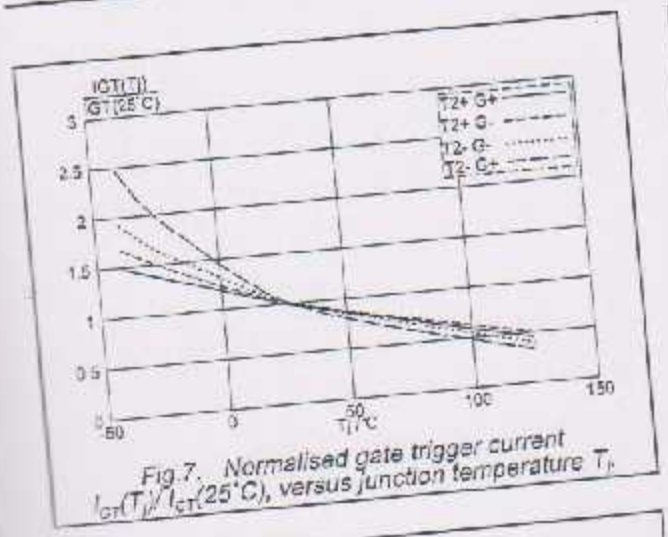


Fig.7. Normalised gate trigger current $I_{GT}(T_j)/I_{GT}(25°C)$, versus junction temperature T_j.

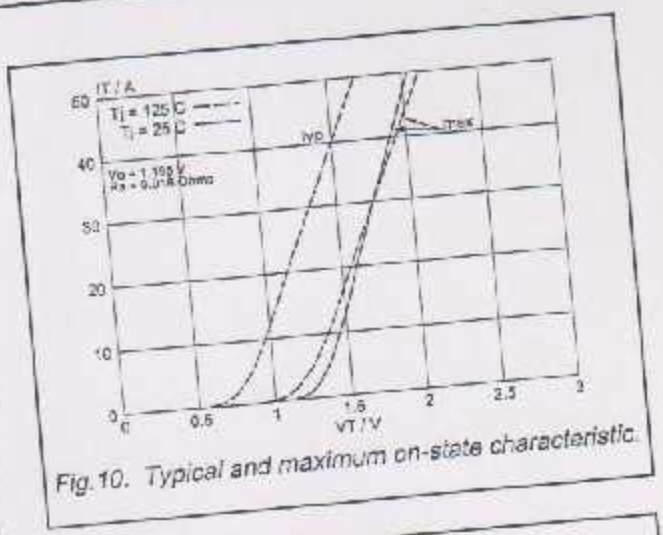


Fig.10. Typical and maximum on-state characteristic.

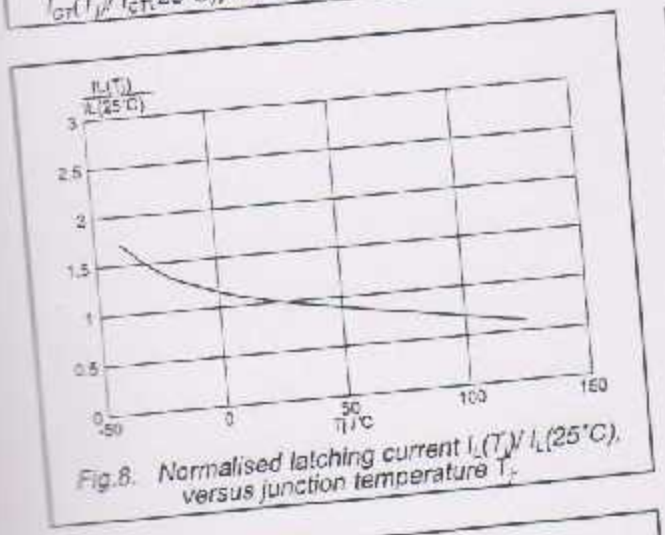


Fig.8. Normalised latching current $I_L(T_j)/I_L(25°C)$, versus junction temperature T_j.

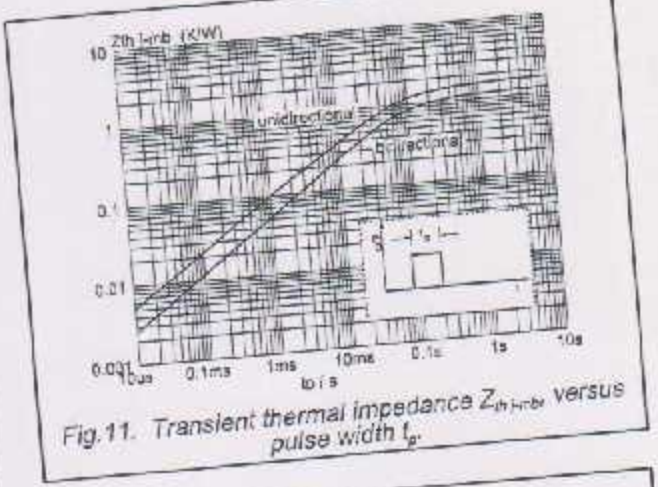


Fig.11. Transient thermal impedance $Z_{th\ j\text{-}mb}$ versus pulse width t_p.

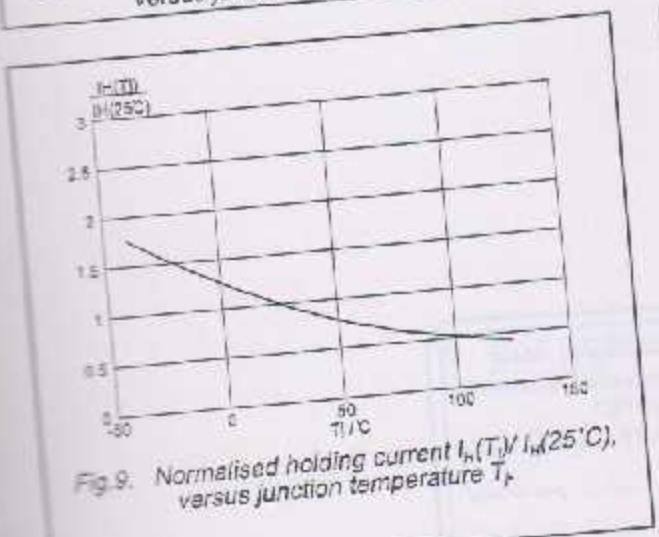


Fig.9. Normalised holding current $I_H(T_j)/I_H(25°C)$, versus junction temperature T_j.

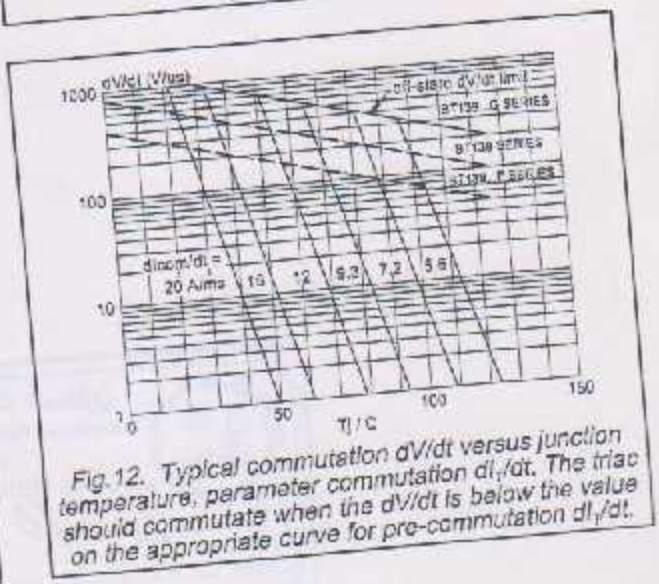


Fig.12. Typical commutation dV/dt versus junction temperature, parameter commutation dI_T/dt. The triac should commutate when the dV/dt is below the value on the appropriate curve for pre-commutation dI_T/dt.