DESIGN AND DEVELOPMENT OF EQUIPMENT PROTECTOR FROM MAINS POWER INTERRUPTIONS

By

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CERTIFICATION OF APPROVAL

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Approved:

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UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

kgabo Marcus Rapelego

ABSTRACT

The objective of this project was to design and develop a protection device that would protect electrical equipment from main power disturbances. Most of industrial and household equipment require a supply of electricity for their operation. It is therefore important to take measures to prevent power quality disturbances and interruptions that may affect the operation of any equipment. Mains power disturbances may cause inefficient operation of electrical equipment and damage to them. The methodology of this project includes literature survey, design, construction of prototype model, performance parameters measurements and documentation of development progress. Literature survey was done to learn different types of electrical disturbances, their consequences, as well as the existing protection devices used in preventing the effects of these disturbances on electrical equipment. The designed device is to be used specifically for the protection of household electrical equipment from under and over voltage as well as frequent mains power interruptions. This protection device will disconnect household electrical equipment from mains power during the occurrence of under and over voltage, as well as frequent mains power interruptions. This device was put to test under different electrical conditions such as changes in voltage, frequency, load etc. The device shows that it can operate satisfactory under the parameters tested.

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LIST OF ABBREVIATIONS AND SYMBOLS

UPS	Uninterrupted power supply
N	Number of turns of a transformer
DC	Direct current
AC	Alternating current
f	Frequency
Φ	Magnetic flux
S	Complex power
V	voltage
V_{IN}	Input voltage
I	current
E_{sec}	Induced secondary voltage
$V_{r(pp)}$	Peak-to-peak ripple voltage
$V_{p(rect)}$	Peak output voltage of the rectifier
R_L	Load resistor of the rectifier
$\frac{d\Phi}{dt}$	Rate of change of flux
T_W	Time width of monostable multivibrator pulse
TTL	Transistor-transistor logic
IC	Integrated circuits
UTP	Upper trip point
LTP	Lower trip point
UV	Under voltage
OV	Over voltage
RV	Variable resistor

CHAPTER 1
INTRODUCTION

1.1 Background of Study

In this project, an electrical protection device capable of isolating the load from mains power in the event of under and over voltage was designed. This device will also handle frequent mains interruptions some times experienced in domestic use. Existing domestically protection devices were studied critically to understand their limitations and this information was utilized in the project design to overcome them. The limitations found in the existing devices include their inability to restore operation by themselves and to isolate the load whenever the mains voltage exceeds the required level.

The protection device designed in this project continuously monitors the state of the mains power; isolate the load from the mains power in the event of under and over voltage as well as frequent mains power interruptions. The device also restores power automatically to the load upon the clearance of electrical interruptions and disturbance mentioned above. The feature that enables the device to prevent the effect of frequent mains power interruptions is the incorporation of retriggerable monostable multivibrator. This monostable introduces a time delay during the abnormal condition which continues until normal conditions are restored.

1.2 Problem Statement

Protection of electrical equipment from under and over voltage as well as frequent mains interruption is of high importance. This is necessary to prevent damage and inefficient operation of industrial and household equipment. It is required that the electrical equipment be operated at their rated voltage, power etc. Over voltage may result in over current, which may lead to over heating capable of burning electrical circuits. Frequent occurrence of mains power interruption may degrade the operational life of electrical equipment.

1.3 Objectives and Scope of Study

The objective of this project is to design a protection device to prevent damage from mains power interruptions. The scope of the project was defined so as to ensure that the project is feasible and can be completed within the given time frame. The project focused on frequent mains interruption, under and over voltage protection. This device will disconnect the precious household equipment in the event of abnormal electrical conditions and will automatically restore the connection upon the clearance of abnormalities. The report also gives literature review, design process, Electronic workbench (EWB) simulation, construction of prototype and test results of device performance under different conditions.

CHAPTER 2
LITERATURE REVIEW

Literature survey was done to obtain insight knowledge on different types of mains interruptions, their causes, and consequences and how electrical equipment are protected from them. Different types of protection devices were studied, including their advantages, disadvantages and limitations. Knowledge of the above-mentioned was necessary for the successful completion of this project. There are nine most common mains power related disturbances [11]. These include: power failure, power sag, under-voltage, switching transient, over-voltage, power surge, voltage spike, frequency variations, electrical line noise and harmonic distortion.

Power failure, which is defined as total loss of power is caused due to events like lightening strike, power over demands, accidents, natural disasters etc. Power failure may cause loss of production in industries and inconveniencies to home users.

Power sag is a short-term low voltage caused by the startup of large loads, utility switching, power services that are too small for the demand, i.e. under-supply etc. Power sag can cause system crashes and damage to hardware.

Under-voltage is a reduction in mains voltage for extended period of time. This can be caused by an intentional utility voltage reduction to conserve power and also due to heavy loads being switched. **Switching transient** is an instantaneous under-voltage in the range of nanoseconds. Under voltage can cause inefficient operation of electrical equipment by causing them to operate below their voltage.
Over-voltage is an increase in mains voltage for extended periods. Over-voltages can be triggered by a rapid reduction in power loads, heavy equipment being turned off or

by utility switching. The result is a potentially damage to the hardware.

Power surge is a short-term high voltage above 110 per cent of nominal voltage. It can be caused by a lightning strike and this can cause line voltages to reach 6,000 volts. Power surge is almost similar to **voltage spike**. Both always result in data loss and hardware damage.

There are different types of electrical protection devices used in protecting industrial and household equipment. These include automatic voltage regulators, earth leakage circuit breakers, fuses etc.

Automatic voltage regulators have the ability to stabilize the voltage to the required level. They step up or step down the voltage in the event of under and over voltage respectively. When the voltage drops sharply, they are unable to step up the voltage to the required level. Hence they subject the load to under voltage situation. They are also unable to disconnect the load from mains power during these events. In case of frequent power interruptions, voltage regulators fail to disconnect the load from mains. This results in damage to equipment.

Fuses are used for the protection of electrical equipment from over current [4]. They are non-restorable and must be replaced once blown. Again if they are used in a distribution board without an indicator, it will require massive search to locate the blown fuse. Fuses are not suitable for the protection of three-phase supply since only one blown fuse may expose the load to high phase-to-phase voltage. From this phase voltage motors may get damaged due to over heating of the windings.

Earth leakage circuit breakers are used for the protection of household electrical equipment. They require human intervention to put them back in operation once tripped [4]. The importance of self-restoring devices can be pointed out by using the following example. During the occurrence of over current, which is associated with under voltage, fuses of fridges would blow and there would be no cooling even when the mains power is restored. This means that the food stuff will be rotted. The fridge would remain out of power until the availability of house owner. With resettable over current circuit breaker, the power would be restored even if the fridge was unattended.

Load-separation is also one of the methods used in preventing mains power disturbances [13]. This method is used when heavy loads and light loads are to be used at the same time. Heavy loads are connected to separate supply to prevent light loads from switching transient caused by heavy loads like motors.

There are different types of uninterrupted power supplies (UPS), namely offline-standby, online double conversion and line interactive [16]. An uninterruptible power supply (UPS) can eliminate costly downtime caused by power disturbances. When the power goes out, the UPS will instantaneously switch over to battery mode, enabling one to shut down equipment in an orderly fashion without data loss. Under normal operation, in offline-standby UPS, the power flows straight through the unit and hence only RFI filtering is usually provided. When the input voltage fails or fluctuates outside the pre-set tolerance window, the UPS detects this and a relay will close, allowing the UPS to start feeding battery power via the inverter. But UPS have a poor output voltage regulation. Fluctuations such as sags and surges are still passed straight to the load. A line-interactive UPS operates in a very similar fashion to an offline UPS, except with the advantage of better filtering and output voltage. Whilst not eliminating mains-borne interference. Line-interactive technologies reduce the impact of spikes, surges and sags by 'clipping' the peaks and valleys, boosting power or switching to battery back-up. Line interactive UPS are costly due to better filtering and voltage boosting features.

A UPS using true online double conversion technology provides the highest level of power protection available. The UPS converts the 230V input AC mains supply to DC power, which is then used to charge the battery. The DC current flow is then fed through an inverter stage, which reconstructs the 230V AC mains output. Because the AC output is completely regenerated, it will be completely free from any mains-borne interference such as spikes and voltage variations. The output voltage and frequency is controlled precisely, thus ensuring a clean and stable sine wave power output. Online UPS are able to withstand large fluctuations on the input voltage before transferring to battery power, thus eliminating unnecessary battery discharges. There is no break unlike other UPS when the load supply is switched to batteries. Due to the high technology used in these UPS, they are the most costly UPS than any other UPS and are only used in big industries.

Relevant theories were understood during the literature survey and they were considered in carrying out the project and its analysis. The voltage of an ac power source with fixed active and reactive power drops when it is overloaded so as to compensate for the high current drawn by the load [2]. The flux density is proportional to the voltage induced in the windings of the transformer. The core of a transformer is rated at certain flux density and therefore saturation of the transformer core will occur if the transformer is operated at high flux density. Once the core is saturated then the induced voltage in the secondary remains constant [1, 7]. The design of the transformer does not impose any practical upper limit of how much supply frequency can exceed the rated transformer frequency, but supply frequency lower than the rated transformer frequency has the same effect as an over-voltage [12]. Only transformers of same rated input voltages can be connected in parallel or else the current will circulate in the closed loop and cause the transformer to overheat [14]. The mains voltage is directly proportional to the supply frequency due to the formula $V_{mains} = V_P \text{Sin} 2\pi f t$, where V_P is the maximum mains peak voltage. The induced voltage in the secondary winding of the transformer is given by the equations

$$E_{sec} = N\frac{d\Phi}{dt} \qquad (1)$$

$$E_{sec} = 4.44 f N\Phi \qquad (2)$$

Where N is number of turns, f is frequency and Φ is magnetic flux. If the winding resistance and inductance are ignored, the secondary voltage at the terminal of the transformer is $V_{sec} = E_{sec}$ [2]. The application of supply voltage higher than the rated input voltage of the transformer will eventually cause noticeable saturation effect and overheating in the transformer [12]. When the applied input voltage to the transformer is less that that of the transformer's rated input voltage, the complex power of the transformer is reduced by the same percentage as the voltage is reduced [14].

CHAPTER 3
METHODOLOGY

3.1 Procedure Used to Carry Out the Project.

The following four steps were followed to carry out the project:

- Literature review
- Design and construction of prototype model
- Measurements of device performance
- Documentation of development progress

3.1.1 Literature Survey

Literature survey was done to understand electrical protection in general, why is electrical protection necessary and to obtain design ideas. Existing protection devices related to the project where also studied to point out their limitations and disadvantages. Details on the studied existing protection devices are already presented in chapter 2.

3.1.2 Design and Construction of Prototype Model

The designed protection device is consisting of four main circuits which are

- Unregulated power supply
- Dual polarity power supply
- Decision-making circuit consisting of
    - Two comparators and
    - Retriggerable monostable multivibrator
- Switching elements

- Transistor and
- Relay

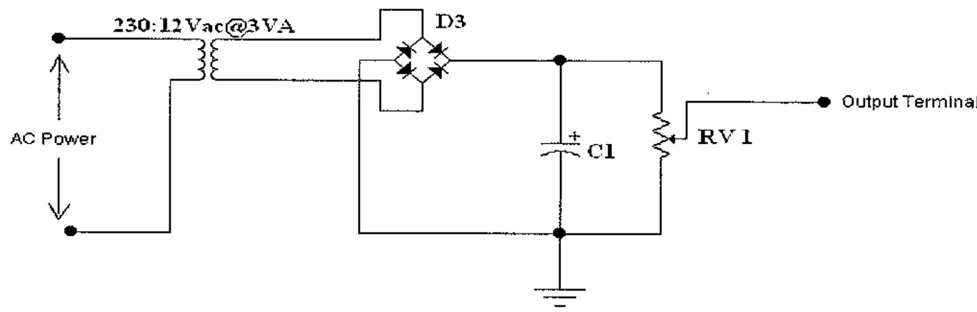


Figure 3.1: Unregulated power supply

3.1.2.1 Unregulated Power Supply

The unregulated power supply shown in figure (3.1), rectifies the stepped down mains voltage into dc. This provides the sample that is monitored by the decision-making circuit. The output dc voltage of the unregulated power supply is proportional to the applied mains voltage. In this circuit, a step down transformer with voltage ratio of 230:12V and rated power of 3VA is used. The centre tap of the transformer (6V-0-6V) is used to provide the sample. The maximum current that the transformer can deliver is calculated using equation

$$S = VI \qquad (3)$$

$$I = \frac{S}{V} = \frac{3VA}{12V} \approx 250mA$$

A bridge rectifier is used to rectify the transformers output voltage into dc voltage. For the safety, the diode with peak inverse voltage (PIV) of at least two times the transformers secondary voltage was used (1N4001). The capacitor C1 is used to filter out the ripple in the rectified ac voltage. The residual amount of the ripple voltage is determined by the value of the capacitor. The larger the value of the capacitor the smaller the ripple. In order to calculate the value of the capacitor a minimum ripple voltage was assumed. The output voltage of the rectifier without a filtering capacitor was measured and the following equation was used to calculate the capacitance.

$$V_{r(pp)} = \frac{V_{P(rect)}}{f_{FWR} R_L C} \qquad (4)$$

R_L = RV1 = 10K ohm

$V_{p(rect)}$ = 19.97 V, measured value.

$V_{r(pp)}$ assumed to be 0.009

Hence C = 2218.9μF

2218.9μF was standardized to a capacitor value of 2200μF. The capacitor voltage rating is required to be greater than the peak output voltage of the rectifier. The peak output voltage of the rectifier at 240V ac, which is the maximum input voltage of the transformer, was measured to be 20.86 V. Therefore a 2200μF capacitor with voltage rating of 50V was used.

3.1.2.2 Dual Polarity Power Supply

Dual polarity power supply, figure (3.2), is used to supply dc power to the active components of the designed circuit. This dual polarity power supply uses a full wave rectifier coupled with a center-taped transformer. The transformer is rated at 36 VA with maximum rated voltage ratio of 230:24Vac. Since the rectifier is connected through the 12V-0-12V transformer, the maximum current delivered by the supply is 1.5A, calculated using equation (3). A filtering capacitor of 2200μF rated at 50V is again used for filtering the ripple voltages of the rectifier. For the two regulators to work, their input voltage should fall within the range $19V \leq V_{IN} \leq 40V$ and $-35V \leq V_{IN} \leq -19V$ and always higher than the output voltage of the regulator by at least 3V. The power is dissipated by the regulators as heat by mounting them to heat sinks. The unregulated input to the positive and negative voltage regulators is 24.55 volt and -24.55 volt respectively.

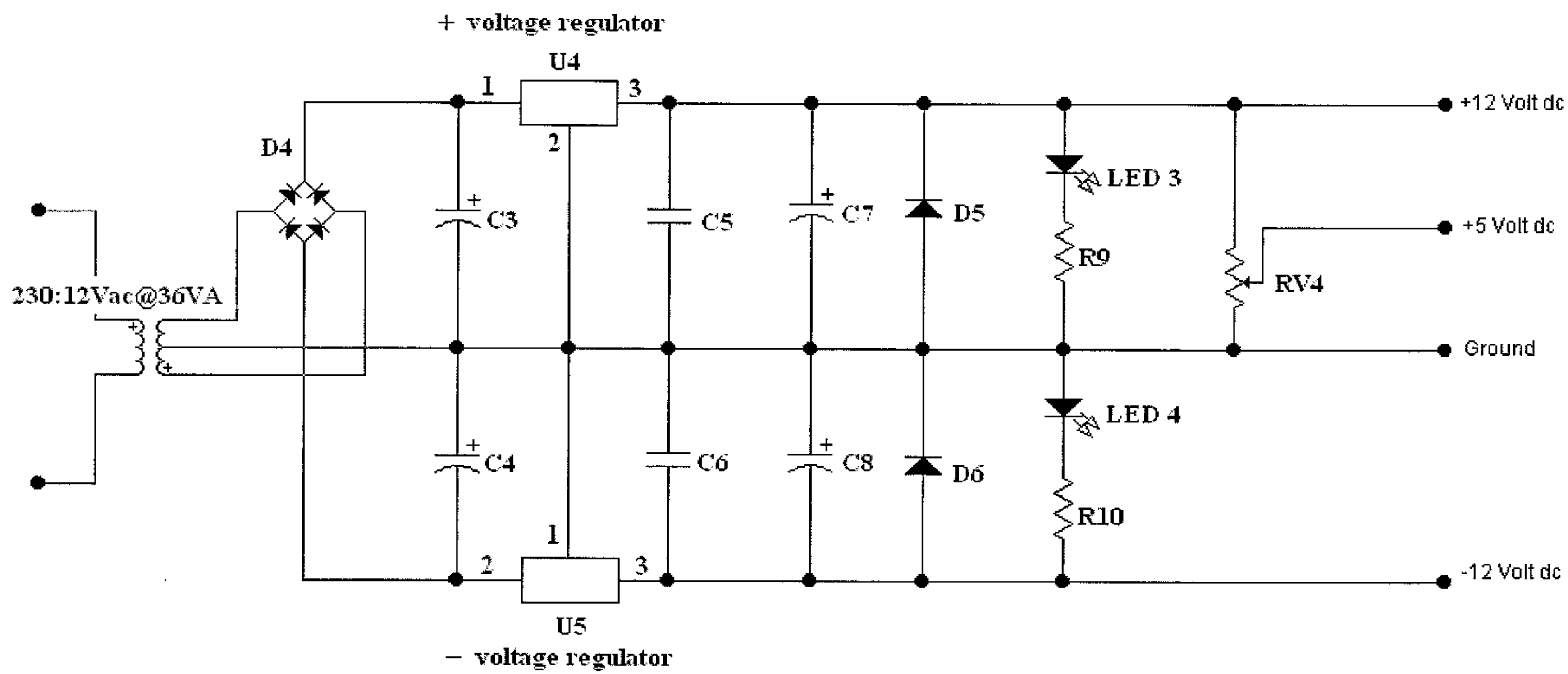


Figure 3.2: Dual polarity power supply

When the input voltage to the regulators exceeds the maximum input voltage, the excess energy is dissipated as heat. This energy can be calculated using the equation

$$S_d = \Delta V I_o \qquad (5)$$

ΔV is the difference between the input voltage and the output voltage of the regulator and I_o is the current drawn by the load. If this excess energy is not dissipated, the regulators would overheat and automatically turn off when temperature reaches 150 ^{O}C. Capacitors, C7 and C8 are used to improve the regulators ability to change to sudden changes in load current and to prevent uncontrollable oscillations. The diodes D5 and D6 are used to protect the regulator from back emf which may affect the power supply when it is connected to an inductive load. LED 3 and LED 4 are used as indicators to show that output regulated power is available and the resistors R9 and R10 are used as current limiting resistors for the LEDs.

3.1.2.3 Decision-Making Circuit

The decision-making circuit uses the reference voltages set at the comparators and the delay switching time set at the monostable multivibrator to make decisions (i.e. in deciding whether to connect or disconnect the load from the mains). The reference voltage set at the comparators act as the lower and the upper limits for the normal operation window of the device. The reference voltages are selected to be 9.29Vdc and 10.12Vdc which correspond to applied ac voltage of 220V ac and 240Vac respectively. RV2 set the lower limit of 9.29V dc at the non-inverting input of operational amplifier U1 while RV3 set the upper limit of 10.12V dc at the inverting input of U2. The resistor R5 and the capacitor C2 set the time duration of the monostable output pulse. This pulse width is calculated as

$$T_W = 0.45 * R5 * C2 \qquad (6)$$

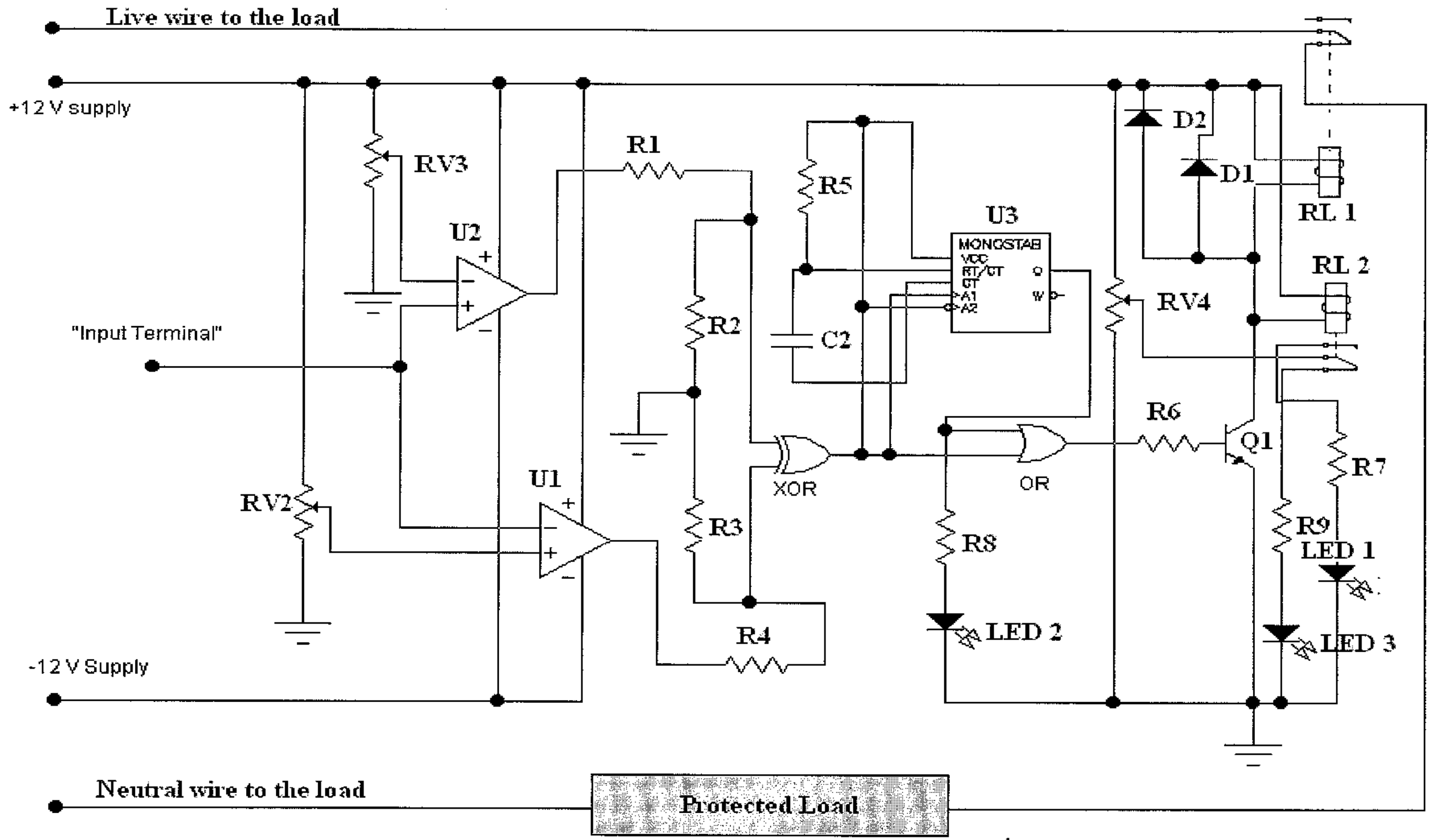


Figure 3.3: Decision-making circuit and switching elements

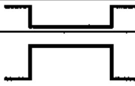
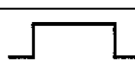
In this circuit, the pulse width T_W is chosen to be 4.5 seconds. The values of R5 and C2 were calculated to be 100K Ohm and 100μF using equation (6).

The resistor R6 set the amount of current flowing into the transistors base. The diodes D1 and D2 protect the transistor from back emf. R7, R8 and R9 are current limiting resistors for the LED 1, 2 and 3 respectively. RV4 steps down 12V dc to 5V dc to supply the LEDs and components that requires a +5V supply. LED 2 indicates when the monostable multivibrator output is high. LED 1 and LED 3 respectively indicate when the mains condition is normal and abnormal.

3.1.2.4 Operation of the Device

The operation of the circuit is summarized in table (3.1)

Table 3.1: Truth table summarizing the operation of the designed protection device

UV Comparator	OV Comparator	OR gate Inputs		OR gate output	Condition
		XOR gate output	Monostable output		
0	0	0		0	Normal
1	0	1		1	Under voltage
0	1	1		1	Over voltage

The mains voltage is applied across two dc power supplies connected in parallel (refer to figure (3.4)). The ac voltage is rectified to dc voltage by the two power supplies. The regulated power supply (i.e. figure 3.2) supplies power to the active components of the circuit with +12V,-12V and +5V. The unregulated power supply (i.e. figure (3.1)) output dc voltage that corresponds to the applied mains voltage. The output dc voltage of figure (3.1) is then applied to under and over voltage comparators via variable resistor, RV1 to be monitored.

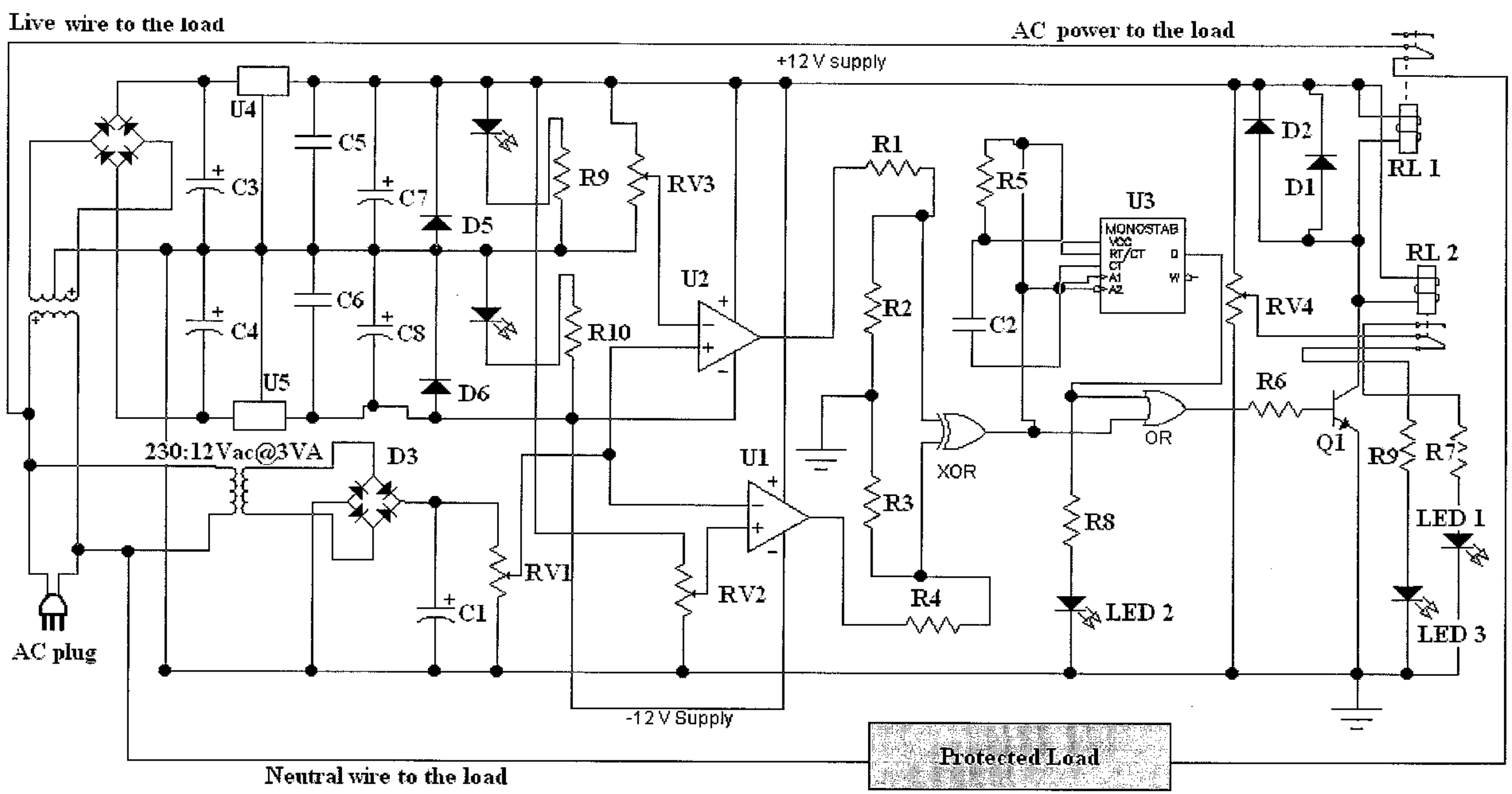


Figure 3.4: Complete circuit of the protection device

Under normal operation, i.e. at applied ac voltage ranging from 220V ac to 240V ac, the dc voltage applied at the inverting and non-inverting terminal of U1 and U2, respectively, is within 9.29V dc to 10.12V dc range. This minimum and maximum limit of operation window of the circuit is set at the comparators by RV2 and RV3 as shown in figure (3.4). When the output dc voltage is within 9.29V to 10.12Vdc voltage, both the operation amplifiers, U1 and U2 give -12 volt interpreted as 0 by the XOR gate since all voltages below 0.8V are equivalent to logic level 0 and all voltages above 2.0V are equivalent to logic 1 for TTL ICs. The output of the XOR gate remains at logic 0 [9]. This leaves monostable multivibrator, U3 not triggered and therefore its output, Q is also 0. Both the output of monostable and XOR gate, which are zeros, are then fed to the OR gate whose output also remain zero keeping the transistor, Q1 off. The relays, RL1 and RL2 are connected to the collector of Q1. The relays remain de-energized since Q1 is off preventing the flow of current to ground. The load connected to the protection device obtains ac supply via the normally-closed contracts of RL1.

Abnormal conditions occur when applied ac voltage goes outside the operation window (i.e. when ac voltage is below 220V ac or above 240V ac). When the ac voltage increases above 240V ac, the voltage at the non-inverting terminal of operational amplifier U2 increases above 10.12V dc. The output of U2 becomes +12V driving the XOR gate which in turn drives the OR gate and the monostable multivibrator U3. The OR gate drives the transistor Q1 allowing the flow of current through the relay to reach the ground and hence energizing RL1 and RL2. Consequently RL1 disconnects the ac supply and the load is turned off. Thus the load is protected against over-voltage.

When the applied ac voltage drops below 220V ac, under-voltage condition occurs. The dc voltage at the inverting terminal of operation amplifier U1, drops below 9.29. Thus the output of operational amplifier U1 becomes +12V dc, driving the XOR gate. The XOR gate drives the OR gate and the monostable multivibrator U3. The OR gate drives the transistor Q1 which in turn allows the flow of current through the relay to reach the ground and hence energizing RL1 and RL2. Consequently RL1 disconnects the ac supply and the load is turned off. Thus the load is protected against under-voltage.

When frequent mains interruption occurs, the monostable is frequently retriggered. This causes its pulse to remains at logic 1 causing the output of the OR gate to remain at logic 1. In turn the OR gate keeps the transistor on. The transistor then keeps RL1 energized. The relay in turn keeps the load disconnected from the mains power. Thus the load is protected from frequent mains interruptions.

3.1.3 Testing of Device Performance

The designed device was subjected to different electrical conditions, namely

- Applied mains voltage variation
- Supply frequency variation
- Load variation

3.1.3.1 Investigation of the Effect of Applied Mains Voltage changes

The designed protection device was subjected to changes in applied ac voltage. The main objectives of this experiment were:

- To see if the sample output dc voltage of the unregulated power supply changes linearly with the changes in mains voltage. It was desired that the output dc voltage changes proportionally with changes in mains voltage.

- To simulate the normal and abnormal conditions by applying the changes in applied mains voltage. This should not cause changes in lower-trip point (LTP) and upper-trip point (UTP). Lower and upper trip point voltages are the minimum and the maximum voltage limits of the device's normal operation window. According to the design, the LTP and UTP are desired not to change with changes in mains applied voltage or else the device would not serve it purpose efficiently.

The following steps were followed in carrying out this experiment:

- The device was connected to a variable ac power supply and the voltage was varied from 180 to 300.
- The dc voltage at the respective non-inverting terminal and inverting terminal of the comparators, U1 and U2 were measured together with the dc output voltage of the Unregulated power supply.
- The expected operation of the device was also observed.

3.1.3.2 Investigating the Effects of Frequency Changes on Device Operation

In order for the device to be globally used, it should operate efficiently under different frequencies. This is because different countries use different supply frequency. This consideration brought up the necessity to monitor the effect of frequency changes on the device operation. It is desired that the LTP, the UTP and the output dc sample voltage of Unregulated power supply to remain constant as the frequency is changed at fixed supply voltage. The steps followed in carrying out this experiment are as described below.

- The device was connected to ac power supply, the supplied voltage was fixed to each ac trip point and the frequency was varied from 45Hz to 100Hz.
- The dc voltage at the respective non-inverting terminal and inverting terminal of the comparators, U1 and U2 were measured together with the dc output voltage of the Unregulated power supply.

3.1.3.3 Investigating the Effect of Load Changes on Device Operation

The main objectives of this experiment were:

- To investigate effects of load changes on lower and the upper trip points of the protection device
- To investigate effects of load changes on the output voltage of Unregulated power supply.

In this experiment, it was desired that the lower and the upper trip point and output sample voltages of the Unregulated power supply remain unchanged as the load changes. This experiment was conducted following the steps below

- The device was connected to variable ac power supply and the supply voltage was set to 220Vac.
- Four bulbs of different power ratings were connected each at a time through the protection device. The used bulbs were rated at 40W, 60W, 80W and 100W
- The lower and the upper trip point voltages and the output of the unregulated power supply were measured for each load.
- The supply voltage was adjusted to 240V ac and step 2 and 3 were repeated.

3.1.4 Documentation of Development Progress

The results obtained in each phase of the project methodology were recorded in the weekly logbooks and progress reports.

3.2 Tools and Equipments Used

- Ac power source (with variable output ac voltage and frequency)
- Multimeter
- Oscilloscope

- Soldering and desoldering tools
- Three phase ac source with variable voltage
- Wattmeter

3.3 Circuit Components

3.3.1 Components for Unregulated power supply and Decision-making circuit

• TX 1	230:12 V ac @ 3VA Step down transformer	x 2
• D1, D2, D3	1N4001(Bridge rectifier)	x 4
• C1	22μF 50V, electrolytic capacitor	x 1
• RV1, RV4	10k Ohms	x 2
• RV3, RV2	500 Ohms	x 2
• R1, R4, R6	1k Ohms	x 2
• R2, R3	1.5k Ohms	x 3
• XOR	Exclusive-OR gate	x 1
• OR	OR gate	x 1
• R5	100k Ohms	x 1
• C2	100μF, electrolytic capacitor	x 1
• R7	200 Ohms	x 1
• R8	100 Ohms	x 1
• LED1, LED 2	Green LEDS	x 2
• Q1	2N3904	x 1
• U1, U2	LM741	x 2
• U3	74LS123	x 1
• RL 1, RL 2	Double throw single pole relays (DTSP)	x 2

3.3.2 Components for Dual Polarity Supply

• TX2	230:24Vac @36VA step down transformer	x 1
• D5	1N4007, Bridge rectifier	x 4
• C3, C4	2200µF, 35V, Electrolytic Capacitors	x 2
• C5, C6	100nF, Ceramic capacitors	x 2
• C7, C8	10µF, 25V, electrolytic capacitor	x 2
• D3, D4	1N4001	x 2
• LED 3, LED 4	Green LEDS	x 2
• R9, R10	470 Ohms	x 2
• RV4	500 Ohms	x 1
• U4	LM7812	x 1
• U5	LM7912	x 1

CHAPTER 4
RESULTS AND DISCUSSION

In order to monitor the effect of load, supply frequency and voltage changes, the output dc voltage of the Unregulated power supply, figure (3.1) and dual polarity power supply, figure (3.2) were measured. The output voltage of dual polarity supply is used to supply power to the active components of the circuit and also used in setting the reference voltage (i.e. minimum and maximum limit voltage of normal operation window of the device). This voltage should remain the same, if it changes with changes in load, supply frequency and voltage, then the circuit would operate undesirable because the normal operation window of the device will vary. Due to the use of voltage regulators LM7812 and LM7912 the output dc voltage of dual polarity power supply remained constant when the mains supply voltage were varied. This happens as long as the input voltages to the regulators satisfy the criteria, $19V \leq V_{IN} \leq 40V$ and $-35V \leq V_{IN} \leq -19V$ for LM7812 and LM7912, respectively.

The output dc voltage of Unregulated power supply was also measured to investigate how it is affected by changes in load, supply frequency and voltage. The output dc voltage of this supply is desired to vary linearly with changes in mains voltage only so as to reflect real time changes of mains voltage. The results are as shown and discussed in section 4.1 through 4.3

4.1 Response of the Unregulated Power Supply to Changes in Applied Voltage

Table 4.1: Measured output dc voltage of unregulated power supply

Applied primary ac voltage at 50Hz. (Volts)	Measured secondary ac voltage. (Volts)	Measured output dc voltage. (Volts)
180	11.44	7.6
190	12.06	8.01
200	12.68	8.43
210	13.29	8.86
220	13.90	9.29
230	14.49	9.7
240	15.06	10.12
250	15.59	10.54
260	16.08	10.97
270	16.52	11.39

The output dc voltage of figure (3.1) was measured at different applied ac voltages and tabulated in table (4.1). A graph of applied mains voltage versus output dc voltage was then drawn as shown in figure (4.1). Figure (4.1) shows a straight-line graph meaning that the output dc voltage changes linearly with the input ac voltage. The lower and upper limit voltages of the device operation window (i.e. 220V and 240V ac) correspond to 9.29V dc and 10.12V dc as expected. The normal operation window of the device, which define the voltages considered suitable for the electrical equipment is as shaded in figure (4.1). Any voltage that falls outside the shaded area is considered abnormal and therefore the protection device will isolate the load from the mains power.

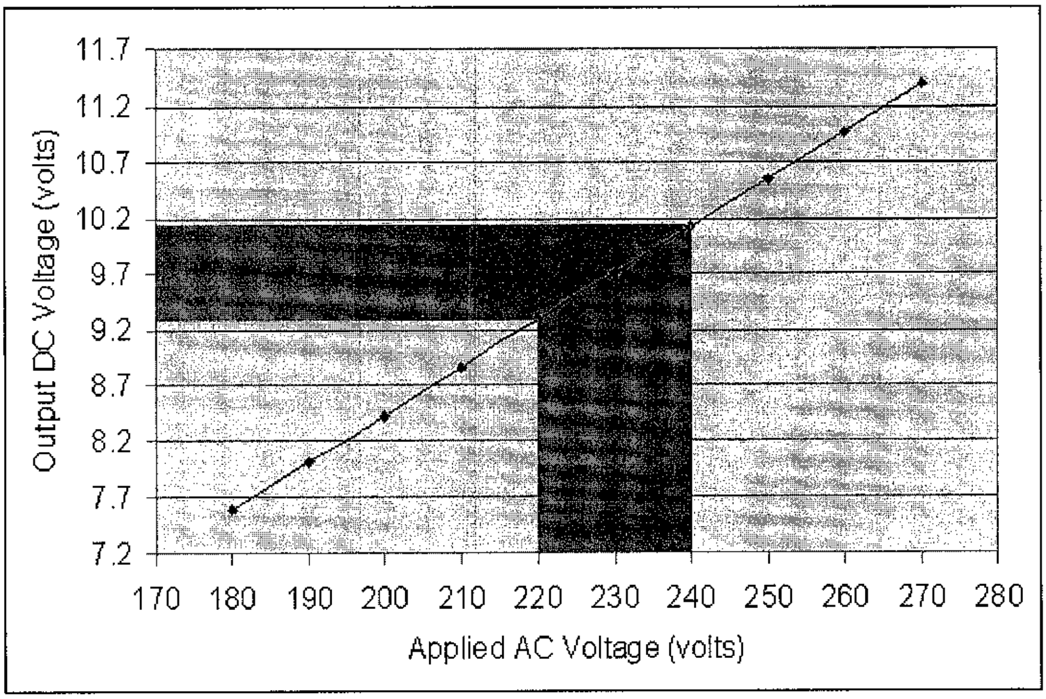


Figure 4.1: Output dc voltage versus applied ac voltage

4.2 Response of Unregulated Power Supply to Changes in Supply Frequency

The experiment to investigate the effect of frequency on the circuit operation has shown that as the frequency increases in steps of 10Hz, the output dc voltage of the rectifier increases in steps of 0.01V. The measured output dc voltages at varying frequency and fixed ac voltages are as tabulated and graphically represented in table (4.2), table (4.3) and figure (4.2) and figure (4.3) respectively.

Table 4.2: Measured output dc voltage at varying frequency and **220**Vac

Frequency (Hz)	Measured rectified voltage (Dc)
45	9.28
50	9.29
60	9.31
70	9.32
80	9.33
90	9.33
100	9.33

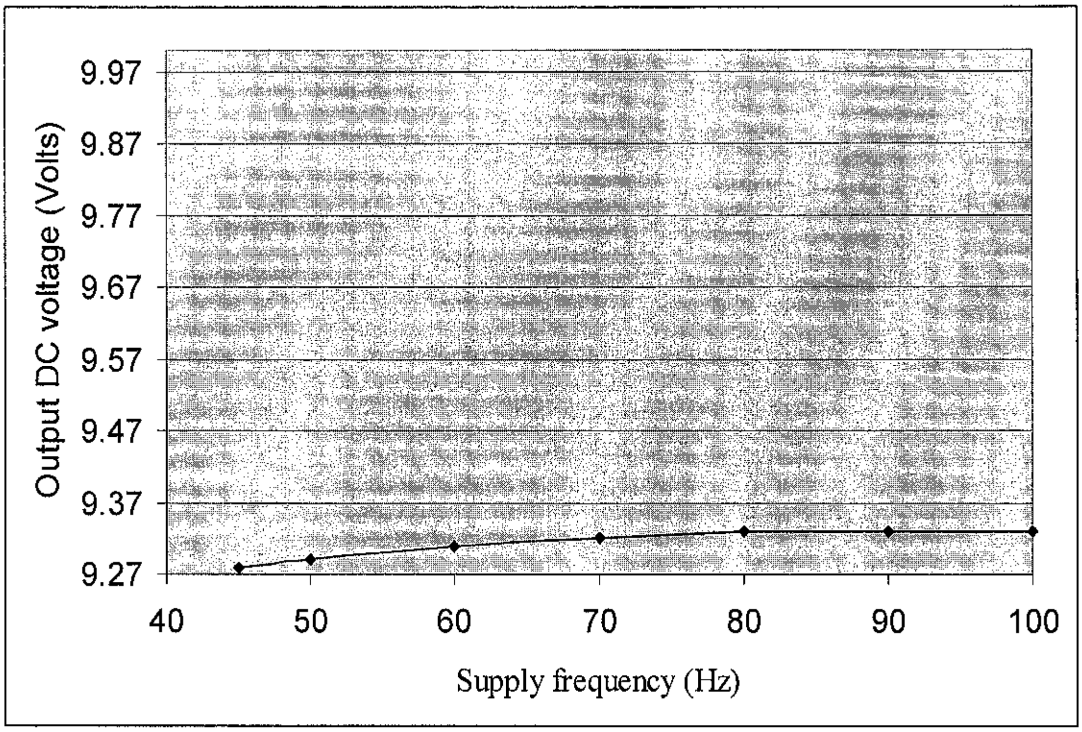


Figure 4.2: Output dc sample voltage versus supply frequency at **220V** ac supply

Table 4.3: Measured output dc voltage at varying frequency and **240**Vac

Frequency (Hz)	Measured rectified voltage (Volts)
45	10.11
50	10.12
60	10.15
70	10.16
80	10.17
90	10.17
100	10.17

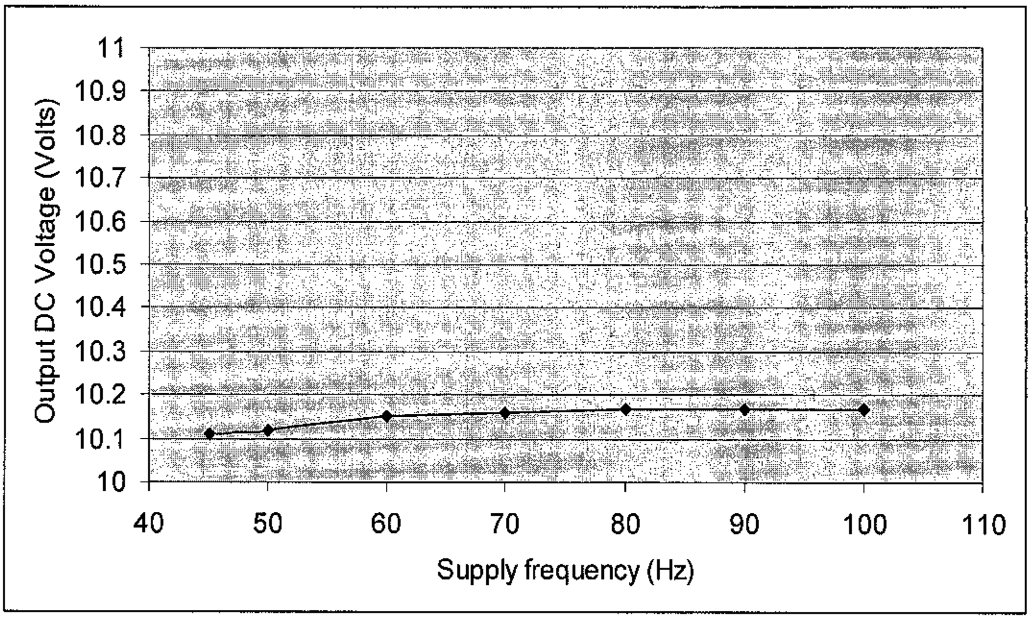


Figure 4.3: Output dc sample voltage versus supply frequency at **240V** ac supply

Table (4.2) and figure (4.2) shows tabulated and graphical representation of the measured output dc sample voltage of the Unregulated power supply at different supply frequencies at fixed 220V ac. While Table (4.3) and figure (4.3) shows tabulated and graphical representation of the measured output dc sample voltage of the Unregulated power supply at different supply frequencies at fixed 240V ac.

Theoretically induced voltage is directly proportional to the rate of change of current and this changing current induces flux in the core of the transformer, which in turn induces voltage in the secondary winding. As the frequency increases, the rate of flux increases and results in increase in induced voltage in the secondary winding as predicted by equation (1) and (2). But the core of the transformer is rated at certain magnetic flux density, as the flux reaches the maximum flux density of the core, the core is saturated. This saturation causes no further increase in induced voltage. Since the secondary voltage remains constant, the output dc voltage also remains constant as shown in figure (4.2) and (4.3).The increase in voltage with frequency is very small and insignificant to cause noticeable effect on the device operation. In both the experiments it is realized that the maximum deviation of the output dc voltage to the expected one is 0.05V and this is still insignificant to affect the device operation.

4.3 Response of Unregulated Power Supply to Changes in Load

Table 4.4: Measured output dc voltage at varying load and supply voltage at 237V ac

Loads (Watts)	Output Dc Voltage (Volts)
40	10.03
60	10.03
80	10.03
100	10.03

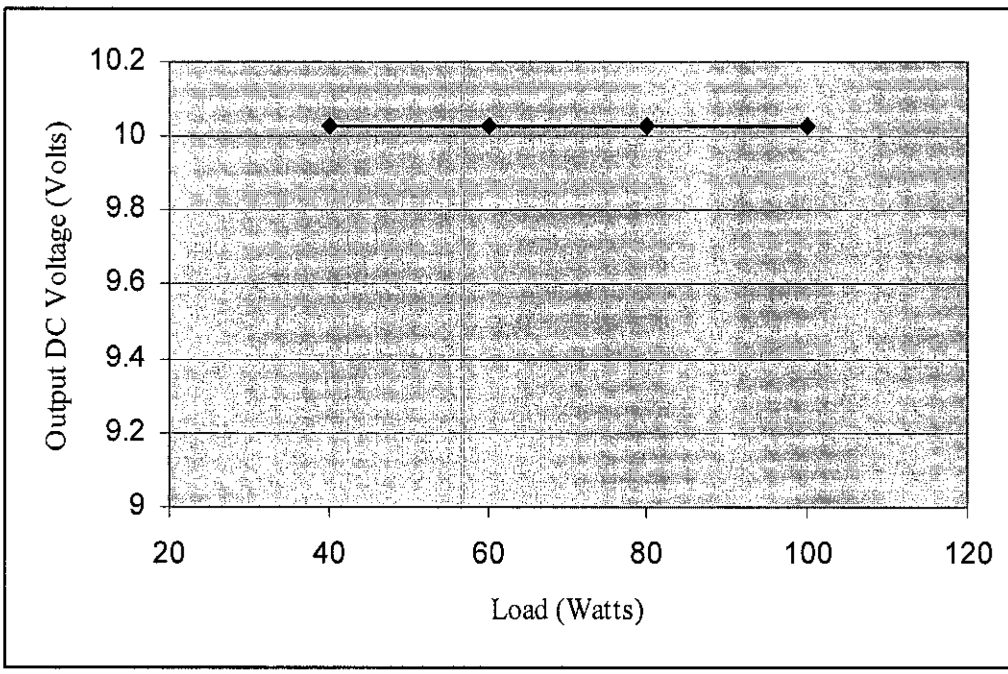


Figure 4.4: Output dc voltage versus load graph

The measured output dc voltage of the unregulated power supply remained 10.03V as the load changes from 40W to 100W. This indicates that the load has no effect on the output voltage of the unregulated power supply provided that the output current of the supply source is sufficient to drive both the load and the protection device.

CHAPTER 5

CONCLUSION AND RECOMMENDTIONS

5.1 Conclusion

The main objectives of the project were to design an equipment protector from mains power disturbances for domestic use. This device was designed to disconnect the load from mains power in the event of frequent mains interruptions, under and over voltage without being affected by other electrical parameters. The device was tested under varying supply mains voltages, frequency and load. It was found that the frequency has no significant effect to the device operation. The device gave normal operation as expected when mains supply voltage deviated from the device's normal operation window. The value and types of loads also have no effect to the operation of the device provided that the mains current is sufficient to power both the protection device and the load it operate satisfactorily. With these results it can be concluded that the major objectives of the project are met by the device.

5.2 Recommendations

- It has been realized that the device fails to prevent data loss in computers when the disturbances occur. Although it may cause temporary data loss but will prevent corruption of computer hardware and software. This is because frequent interruptions would have caused more damage. Therefore it is recommended that a low cost UPS with small back up time be incorporated with the device.
- Voltage stabilizers and boosters may be incorporated for low-level disturbances. But in the event of frequent mains interruption, this device is the savior of precious equipments.

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APPENDIX A

SNAP SHOTS OF PROTOTYPE MODEL

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SNAP SHOTS OF PROTOTYPE MODEL

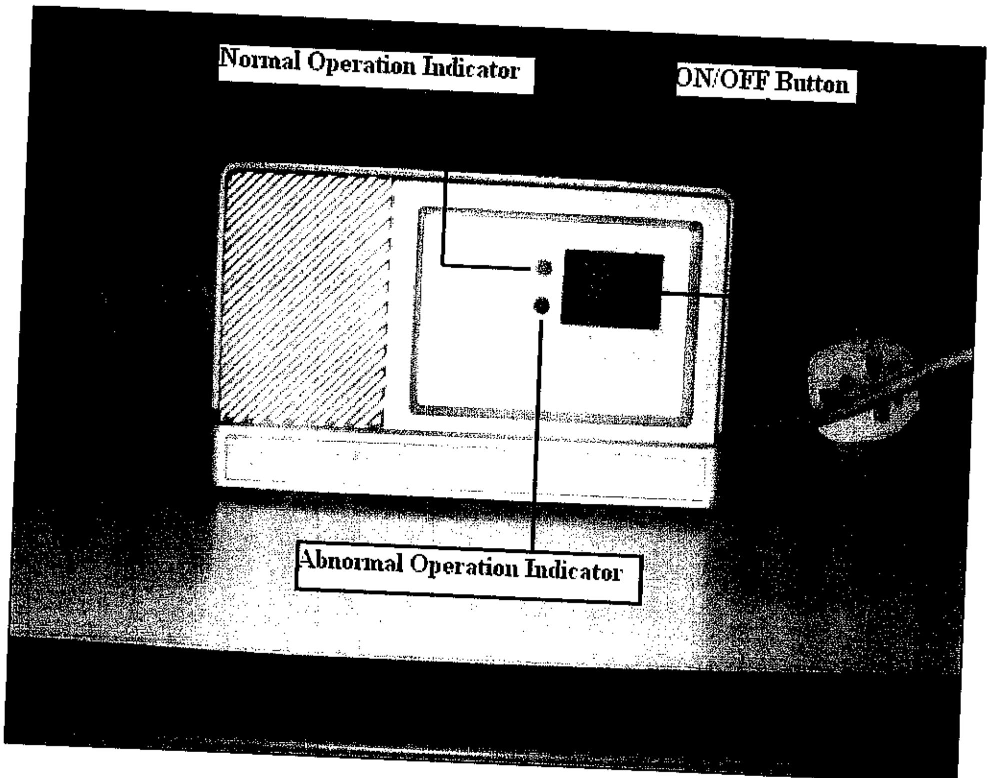


Figure A-1: Front view of prototype model

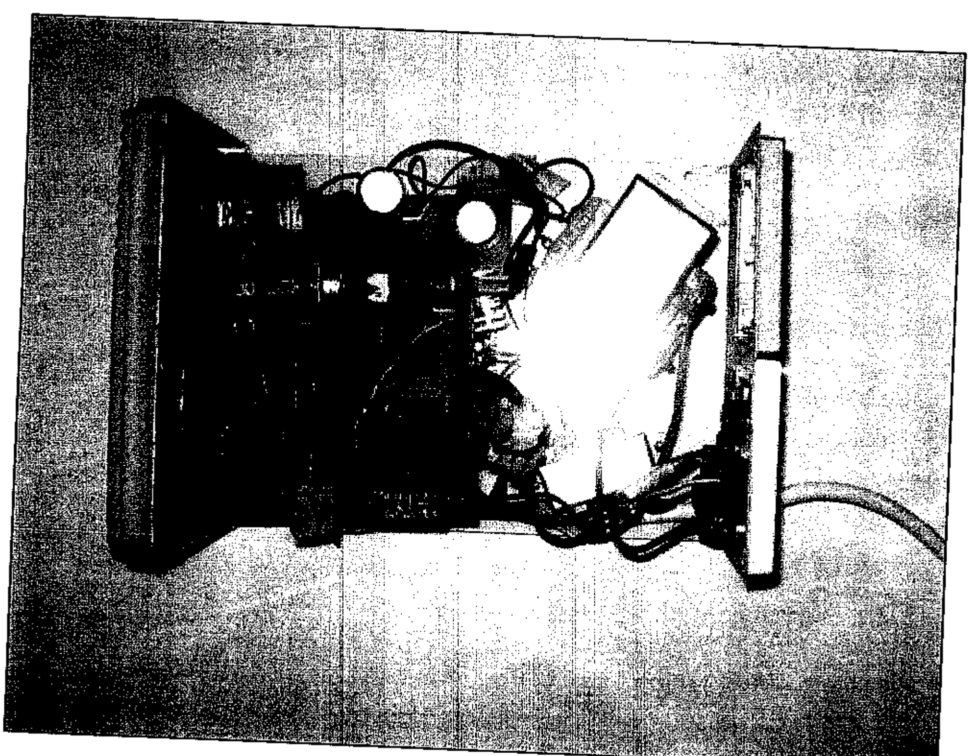


Figure A-2: Top view of prototype model

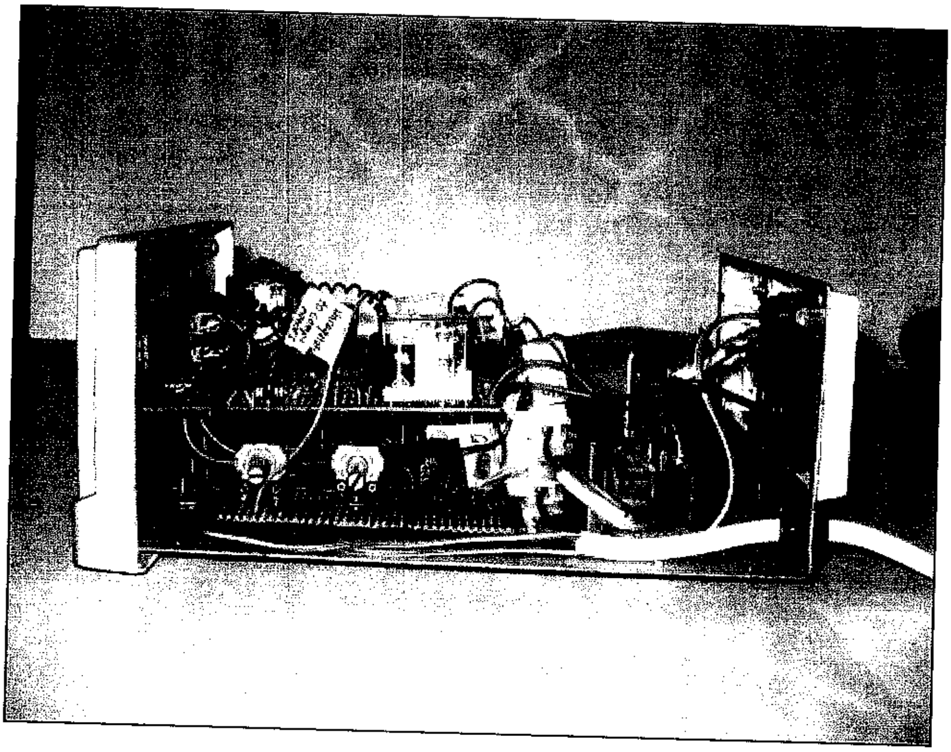


Figure A-3: Left view of prototype model

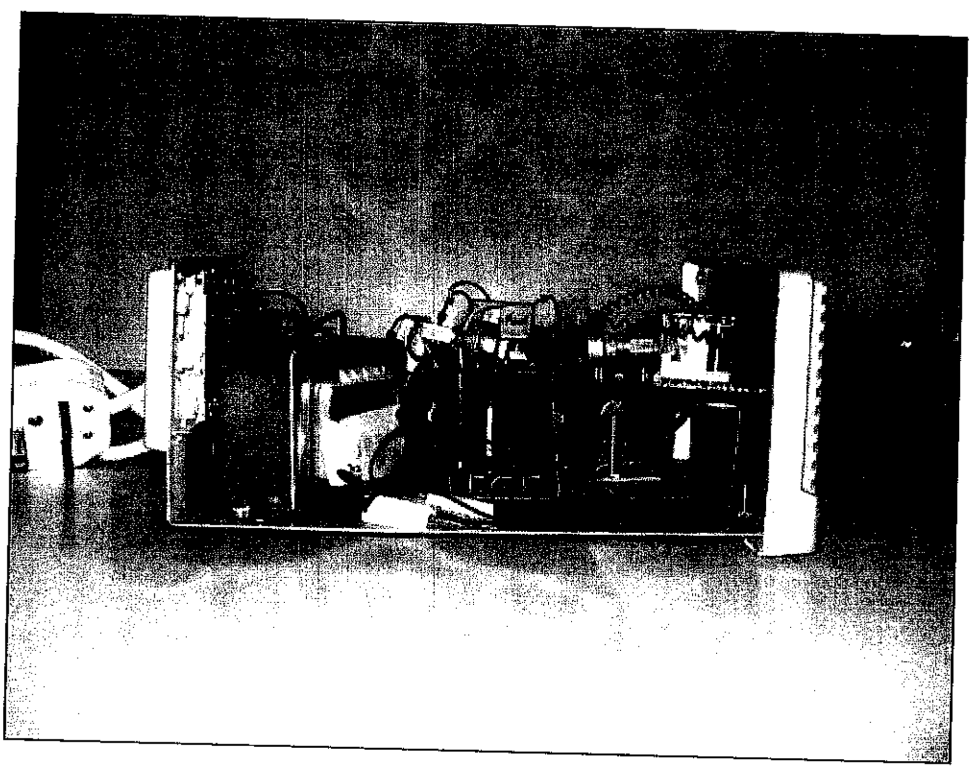


Figure A- 4: Right view of prototype model

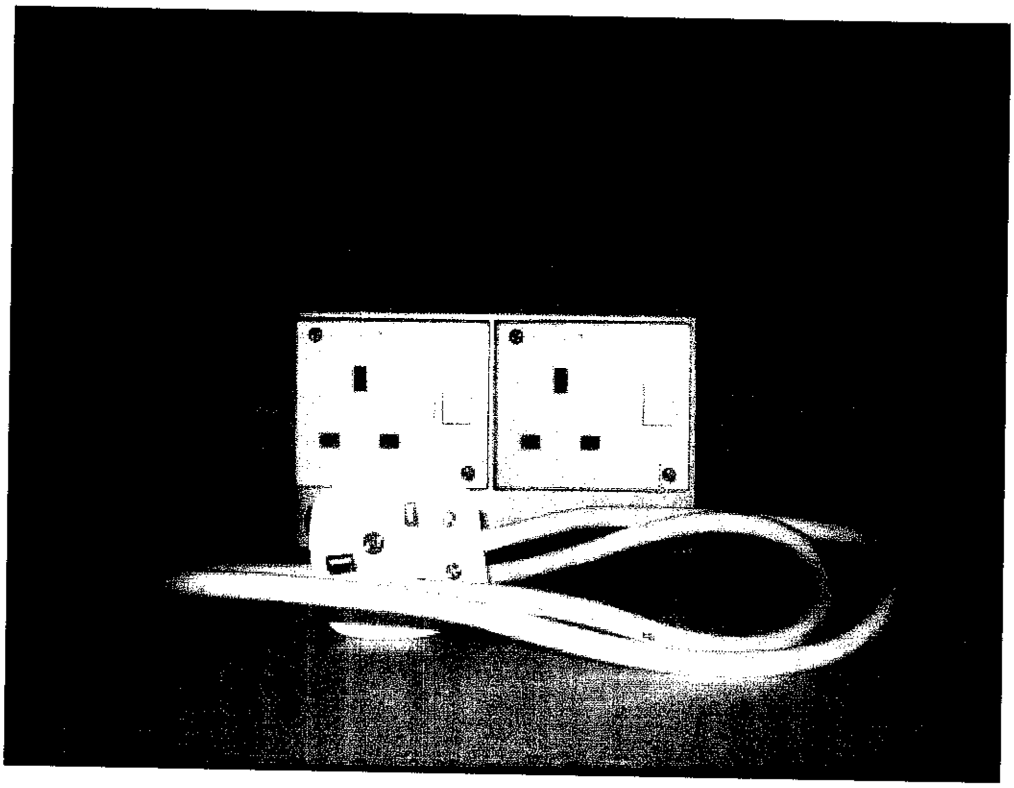


Figure A- 5: Back view of prototype model

APPENDIX B

ADDITIONAL RESULTS AND ANALYSIS OF THE RESPONSE OF THE DEVICE TO CHANGES IN LOAD

APPENDIX B

ADDITIONAL RESULTS AND ANALYSIS OF THE RESPONSE OF THE DEVICE TO CHANGES IN LOAD

Table B-1: Measured voltage supplied to resistive load via the device at 230.2V_{mains}

Resistive load (Watts)	Ac Voltage supplied to the load through the device (Volts)
60	230.2
120	229.6
240	228
480	224.6
900	222.9

Figure (B-1) shows a graphical representation of the measured ac voltage supplied to resistive loads of different wattage. The supplied voltage decreases as the load wattage increases. This is because the resistive load with high wattage draws more current. The output power of the source supply used is fixed, therefore as the load draws more current from the load, the output voltage decreases to compensate the increase in current drawn by the load. This is justified by the equation

$$V = \frac{P_O}{I_O} \qquad (7)$$

From equation (7), when the output power, P_O of the supply is fixed and the current, I_O drawn by the load increases, the voltage V will decrease. By doing so the supply maintains its output power fixed. The supplied voltage to the load dropped to below 220V ac for resistive loads greater than 900 watts. Therefore the device isolated the load from mains voltage as designed. From these results it may be concluded that the device will be capable of driving any resistive load as long as the output voltage of the source does not change with changes in current drawn by the load. This then implies that the source supply will have to be a Slack type in order for the device to be able to protect resistive load of any rated power. Slack type power source is a power source whose voltage and phase angle are fixed and its complex power adjustable [2].

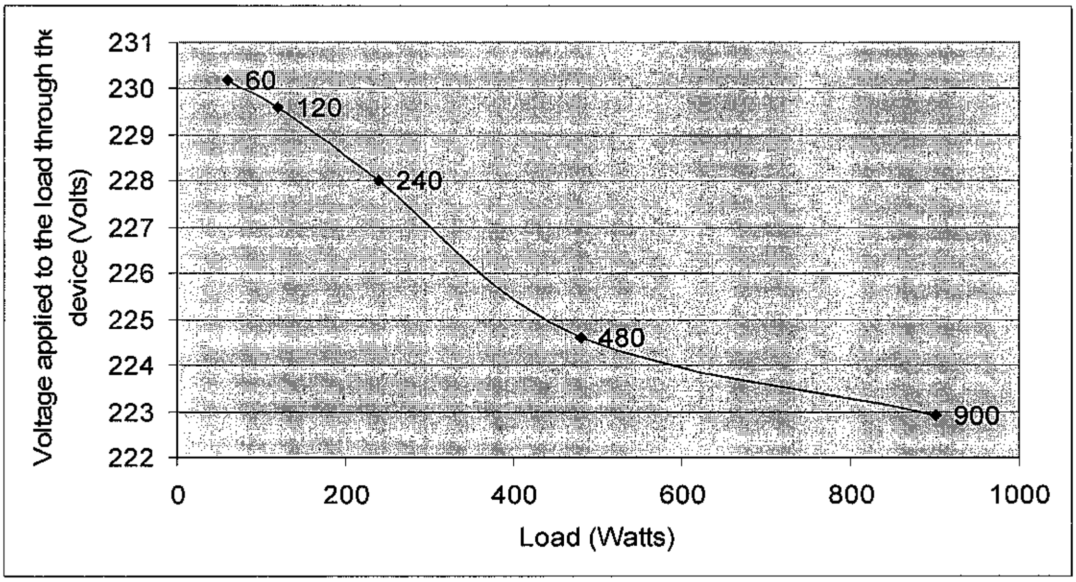


Figure B-1: Respond of device to resistive load

Table B-2: Measured voltage supplied to capacitive load via the device at $230.2V_{mains}$

Capacitive load (VAR)	Ac Voltage supplied to the load through the device (Volts)
60	231.2
120	231.2
240	231.2
480	231.5
1140	231.6

Table (B-2) and figure (B-2) tabulates and graphical represents the measured voltage across the capacitive load respectively. In capacitive load the current leads the voltage by 90^o, i.e. the current reaches the peak before the voltage. The instantaneous power at the terminals of the capacitive load is continuously exchanged between the capacitive load and the source supply driving the inductive load [8]. In other words the reactive power is stored in the capacitive load during the positive cycle and later dissipated back to the load during the negative cycle. As this happens the voltage across the capacitive load varies accordingly as represented by figure (B-2)

From the equation of a power factor for capacitive load

$$pf = \cos\theta = 2\pi fCR \qquad (8)$$

As the capacitance increases the power factor increases. Increase in power factor means a decrease in power factor angle θ. The equation

$$V = \frac{Q}{I\sin\theta} \qquad (9)$$

shows the relation between reactive power and voltage across a capacitive load. The reactive factor, sine θ decreases with decrease in power factor angle (decrease in power factor angle indirectly means increase in power factor). Therefore the voltage across the capacitive load increases with increase in capacitive load since this reactive factor is inversely proportional to the voltage, as illustrated by equation (9).

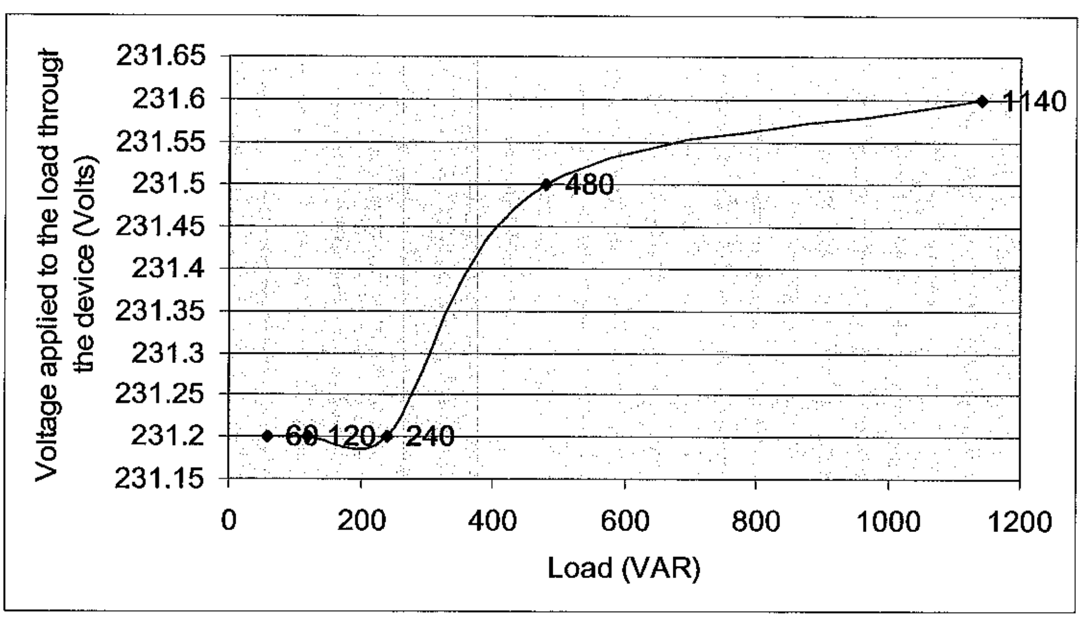


Figure B-2: Respond of device to capacitive load

The results obtained for the inductive load are as tabulated in table (B-3) and graphically represented in figure (B-3).

Table B-2: Measured voltage supplied to capacitive load via the device at $230.2V_{mains}$

Inductive load (VAR)	Ac Voltage supplied to the load through the device (Volts)
60	230.1
120	231
240	230.9
480	230.4
1140	229.1

In inductive load the current lags the voltage by 90°, i.e. the voltage reaches the peak before the current. Similarly as in the capacitive load, the instantaneous power at the terminals of the inductive load is continuously exchanged between the inductive load and the source supply driving the inductive load [8]. In other words the reactive power is stored in the inductive load during the positive cycle and later dissipated back to the load during the negative cycle. As this happens the voltage across the inductive load varies accordingly as represented by figure (B-3)

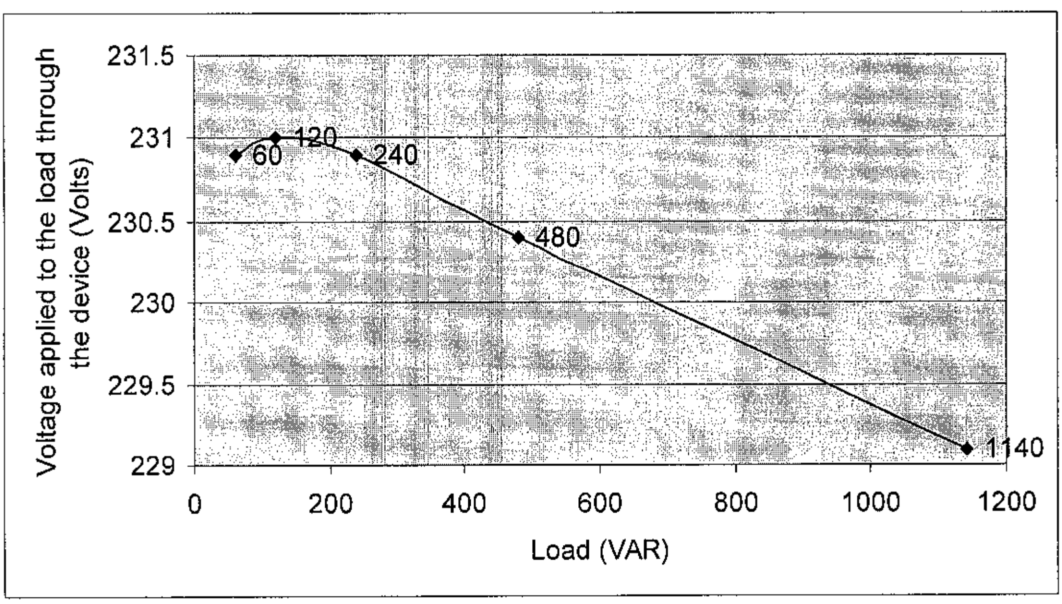


Figure B-3: Respond of device to inductive load

APPENDIX C

DATASHEETS OF ACTIVE COMPONENTS USED

FAIRCHILD
SEMICONDUCTOR®

1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.

DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

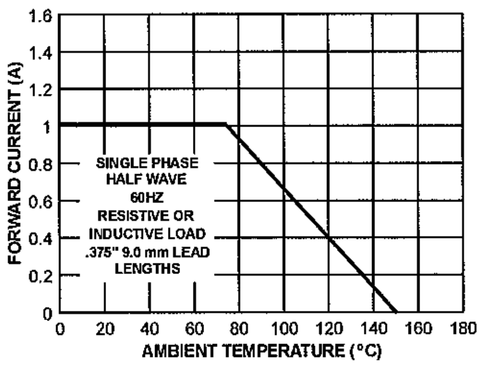
Electrical Characteristics

T_A = 25°C unless otherwise noted

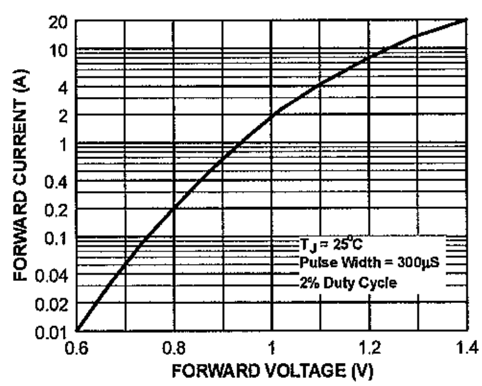
Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

Typical Characteristics

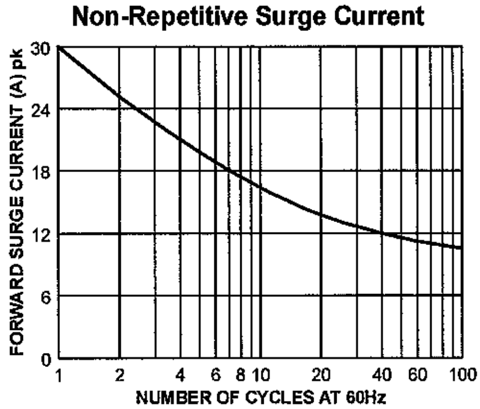
Forward Current Derating Curve



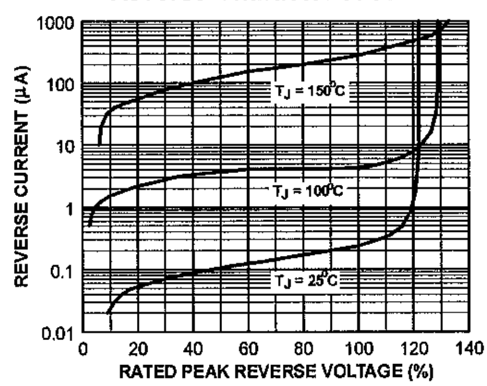
Forward Characteristics



Non-Repetitive Surge Current



Reverse Characteristics



FAIRCHILD
SEMICONDUCTOR®

www.fairchildsemi.com

MC79XX/MC79XXA/LM79XX

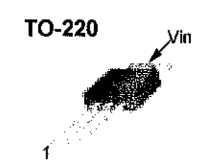
3-Terminal 1A Negative Voltage Regulator

Features

- Output Current in Excess of 1A
- Output Voltages of -5, -6, -8 , -9, -10, -12, -15, -18 and -24V
- Internal Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Compensation

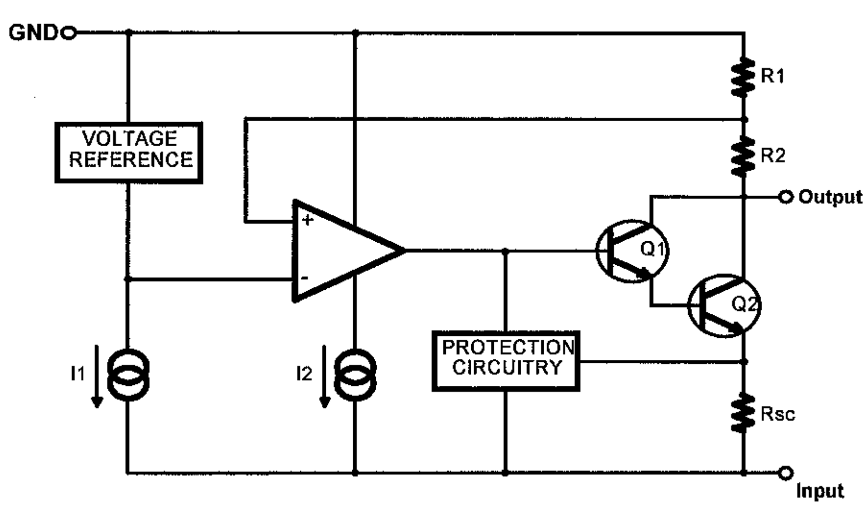
Description

The MC79XX / MC79XXA/ LM79XX series of three terminal negative regulators are available in TO-220 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.



1. GND 2. Input 3. Output

Internal Block Digram



Rev. 1.0.1

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage	V_I	-35	V
Thermal Resistance Junction-Case (Note1)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (Note1, 2)	$R_{\theta JA}$	65	
Operating Temperature Range	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Note:

1. Thermal resistance test board
   Size: 76.2mm * 114.3mm * 1.6mm(1S0P)
   JEDEC standard: JESD51-3, JESD51-7
2. Assume no ambient airflow

Electrical Characteristics (MC7905/LM7905)

(V_I = -10V, I_O = 500mA, 0°C ≤T_J≤ +125°C, C_I =2.2μF, C_O =1μF, unless otherwise specified.)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J = +25°C		-4.8	-5.0	-5.2	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I = -7V to -20V		-4.75	-5.0	-5.25	
Line Regulation (Note3)	ΔV_O	T_J = +25°C	V_I = -7V to -25V	-	35	100	mV
			V_I = -8V to -12V	-	8	50	
Load Regulation (Note3)	ΔV_O	T_J = +25°C I_O = 5mA to 1.5A		-	10	100	mV
		T_J =+25°C I_O = 250mA to 750mA		-	3	50	
Quiescent Current	I_Q	T_J =+25°C		-	3	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	0.05	0.5	mA
		V_I = -8V to -25V		-	0.1	0.8	
Temperature Coefficient of V_D	$\Delta V_O/\Delta T$	I_O = 5mA		-	- 0.4	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100kHz T_A =+25°C		-	40	-	μV
Ripple Rejection	RR	f = 120Hz ΔV_I = 10V		54	60	-	dB
Dropout Voltage	V_D	T_J = +25°C I_O = 1A		-	2	-	V
Short Circuit Current	I_{SC}	T_J =+25°C, V_I = -35V		-	300	-	mA
Peak Current	I_{PK}	T_J =+25°C		-	2.2	-	A

Note

3. 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.

Electrical Characteristics (MC7912) (Continued)

(V_I = -19V, I_O = 500mA, 0°C ≤T_J ≤ +125°C, C_I =2.2µF, C_O =1µF, unless otherwise specified.)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J = +25°C		-11.5	-12	-12.5	V
		I_O = 5mA to 1A, P_O ≤ 15W V_I = -15.5V to -27V		-11.4	-12	-12.6	
Line Regulation (Note1)	ΔV_O	T_J = +25°C	V_I = -14.5V to -30V	-	12	240	mV
			V_I = -16V to -22V	-	6	120	
Load Regulation (Note1)	ΔV_O	T_J = +25°C I_O = 5mA to 1.5A		-	12	240	mV
		T_J = +25°C I_O = 250mA to 750mA		-	4	120	
Quiescent Current	I_Q	T_J = +25°C		-	3	6	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		-	0.05	0.5	mA
		V_I = -14.5V to -30V		-	0.1	1	
Temperature Coefficient of V_D	$\Delta V_O/\Delta T$	I_O = 5mA		-	-0.8	-	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100kHz T_A = +25°C		-	200	-	µV
Ripple Rejection	RR	f = 120Hz ΔV_I = 10V		54	60	-	dB
Dropout Voltage	V_D	T_J = +25°C I_O = 1A		-	2	-	V
Short Circuit Current	I_{SC}	T_J = +25°C, V_I = -35V		-	300	-	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.

Typical Perfomance Characteristics

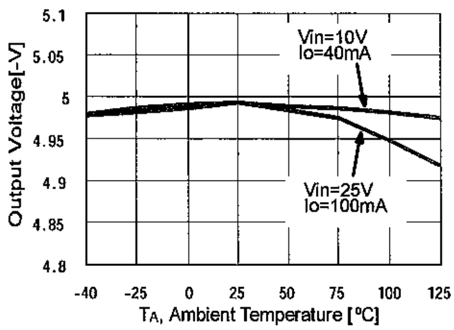


Figure 1. Output Voltage

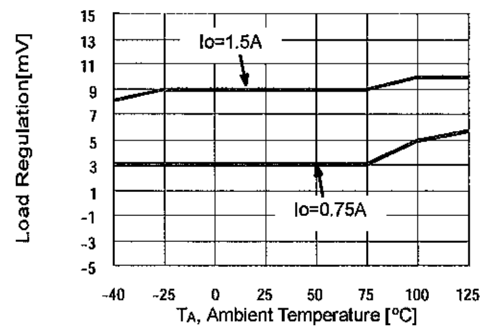


Figure 2. Load Regulation

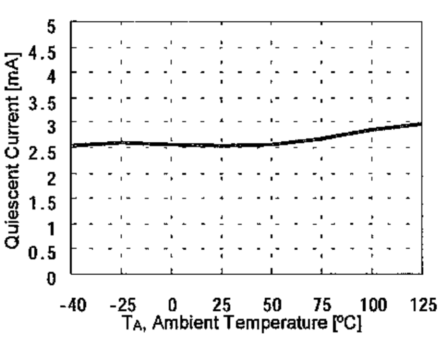


Figure 3. Quiescent Current

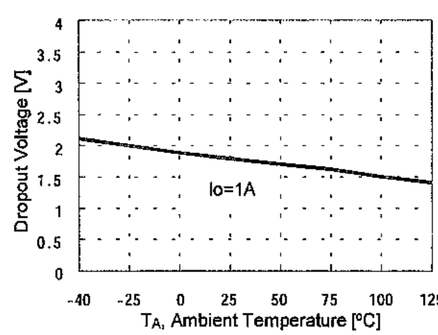


Figure 4. Dropout Voltage

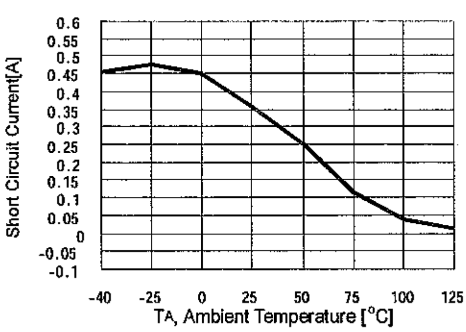


Figure 5. Short Circuit Current

Typical Applications

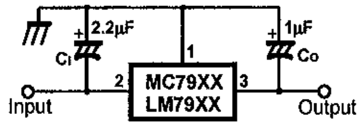


Figure 6. Negative Fixed output regulator

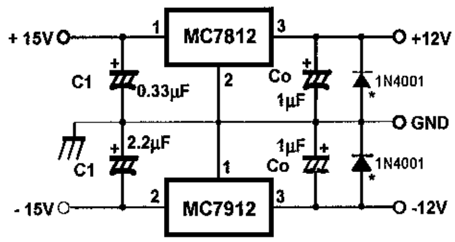


Figure 7. Split power supply (± 12V/1A)

Notes:

(1) To specify an output voltage, substitute voltage value for "XX "

(2) Required for stability. For value given, capacitor must be solid tantalum. If aluminium electronics are used, at least ten times value shown should be selected. C_I is required if regulator is located an appreciable distance from power supply filter.

(3) To improve transient response. If large capacitors are used, a high current diode from input to output (1N400I or similar) should be introduced to protect the device from momentary input short circuit.

National Semiconductor

May 2000

LM78XX
Series Voltage Regulators

General Description

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expanded to make the LM78XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features

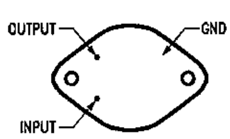
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range

LM7805C	5V
LM7812C	12V
LM7815C	15V

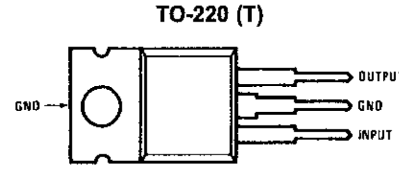
Connection Diagrams

Metal Can Package
TO-3 (K)
Aluminum



Bottom View
Order Number LM7805CK, LM7812CK or LM7815CK
See NS Package Number KC02A

Plastic Package
TO-220 (T)



Top View
Order Number LM7805CT, LM7812CT or LM7815CT
See NS Package Number T03B

 DS007746

Absolute Maximum Ratings (Note 3)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Voltage	
(V_O = 5V, 12V and 15V)	35V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range (T_A)	0°C to +70°C
Maximum Junction Temperature	
(K Package)	150°C
(T Package)	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	
TO-3 Package K	300°C
TO-220 Package T	230°C

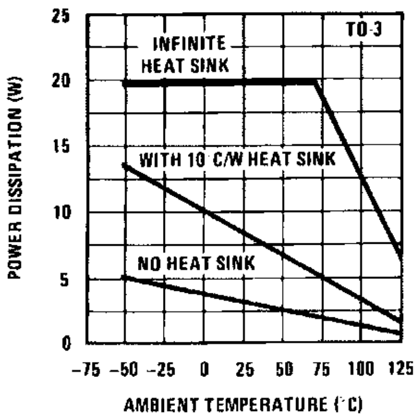
Electrical Characteristics LM78XXC (Note 2)

)°C ≤ T_J ≤ 125°C unless otherwise noted.

Output Voltage				5V			12V			15V			Units
Input Voltage (unless otherwise noted)				10V			19V			23V			
'mbol	Parameter	Conditions		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
ɔ	Output Voltage	Tj = 25°C, 5 mA ≤ I_O ≤ 1A		4.8	5	5.2	11.5	12	12.5	14.4	15	15.6	V
		P_D ≤ 15W, 5 mA ≤ I_O ≤ 1A		4.75		5.25	11.4		12.6	14.25		15.75	V
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(7.5 ≤ V_{IN} ≤ 20)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)		V
V_O	Line Regulation	I_O = 500 mA	Tj = 25°C		3	50		4	120		4	150	mV
			ΔV_{IN}		(7 ≤ V_{IN} ≤ 25)			14.5 ≤ V_{IN} ≤ 30)			(17.5 ≤ V_{IN} ≤ 30)		V
			0°C ≤ Tj ≤ +125°C			50			120			150	mV
			ΔV_{IN}		(8 ≤ V_{IN} ≤ 20)			(15 ≤ V_{IN} ≤ 27)			(18.5 ≤ V_{IN} ≤ 30)		V
		I_O ≤ 1A	Tj = 25°C			50			120			150	mV
			ΔV_{IN}		(7.5 ≤ V_{IN} ≤ 20)			(14.6 ≤ V_{IN} ≤ 27)			(17.7 ≤ V_{IN} ≤ 30)		V
			0°C ≤ Tj ≤ +125°C			25			60			75	mV
			ΔV_{IN}		(8 ≤ V_{IN} ≤ 12)			(16 ≤ V_{IN} ≤ 22)			(20 ≤ V_{IN} ≤ 26)		V
V_O	Load Regulation	Tj = 25°C	5 mA ≤ I_O ≤ 1.5A		10	50		12	120		12	150	mV
			250 mA ≤ I_O ≤ 750 mA			25			60			75	mV
		5 mA ≤ I_O ≤ 1A, 0°C ≤ Tj ≤ +125°C				50			120			150	mV
ɩ	Quiescent Current	I_O ≤ 1A	Tj = 25°C			8			8			8	mA
			0°C ≤ Tj ≤ +125°C			8.5			8.5			8.5	mA
I_Q	Quiescent Current Change	5 mA ≤ I_O ≤ 1A				0.5			0.5			0.5	mA
		Tj = 25°C, I_O ≤ 1A				1.0			1.0			1.0	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(7.5 ≤ V_{IN} ≤ 20)			(14.8 ≤ V_{IN}≤ 27)			(17.9 ≤ V_{IN} ≤ 30)		V
		I_O ≤ 500 mA, 0°C ≤ Tj ≤ +125°C				1.0			1.0			1.0	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(7 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN}≤ 30)			(17.5 ≤ V_{IN} ≤ 30)		V
N	Output Noise Voltage	T_A =25°C, 10 Hz ≤ f ≤ 100 kHz			40			75			90		μV
ΔV_{IN} / ΔV_{OUT}	Ripple Rejection	f = 120 Hz	I_O ≤ 1A, Tj = 25°C or	62	80		55	72		54	70		dB
			I_O ≤ 500 mA 0°C ≤ Tj ≤ +125°C	62			55			54			dB
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}			(8 ≤ V_{IN} ≤ 18)			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)		V
o	Dropout Voltage	Tj = 25°C, I_{OUT} = 1A			2.0			2.0			2.0		V
	Output Resistance	f = 1 kHz			8			18			19		mΩ

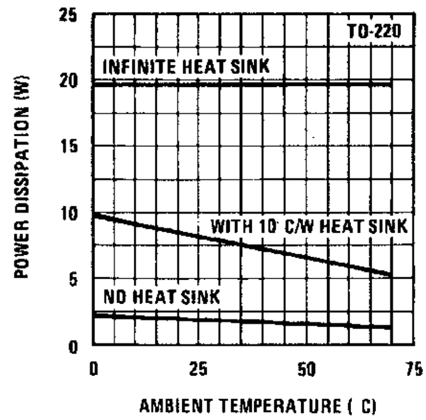
Typical Performance Characteristics

Maximum Average Power Dissipation



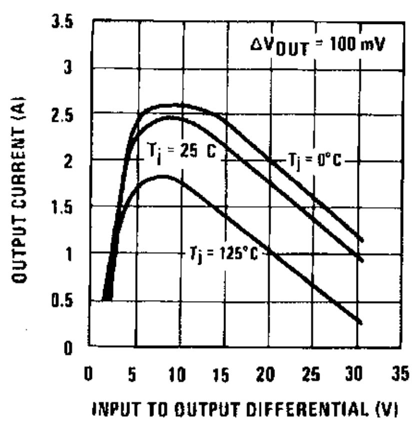
DS007746-5

Maximum Average Power Dissipation



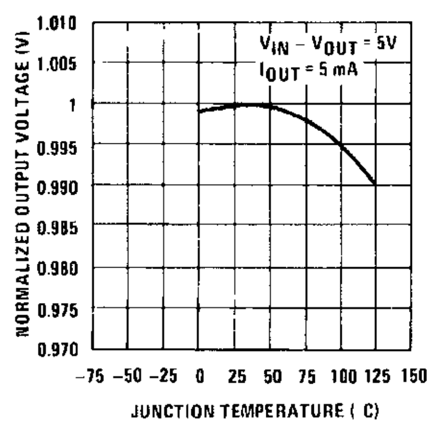
DS007746-6

Peak Output Current



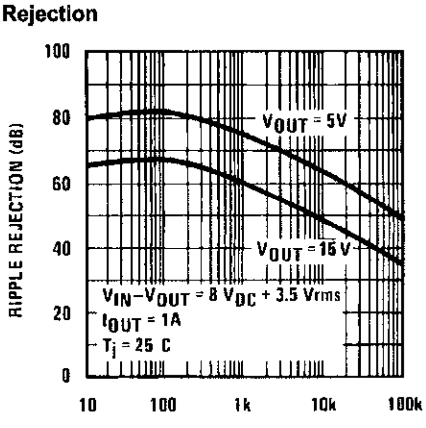
DS007746-7

Output Voltage (Normalized to 1V at T_J = 25°C)



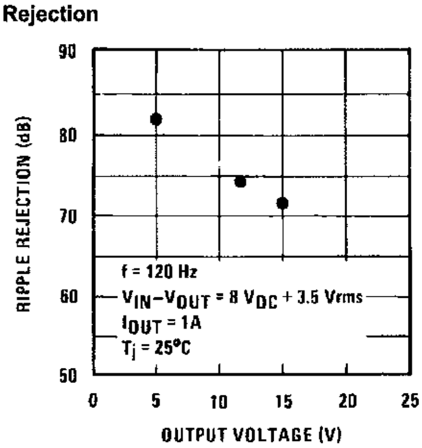
DS007746-8

Ripple Rejection



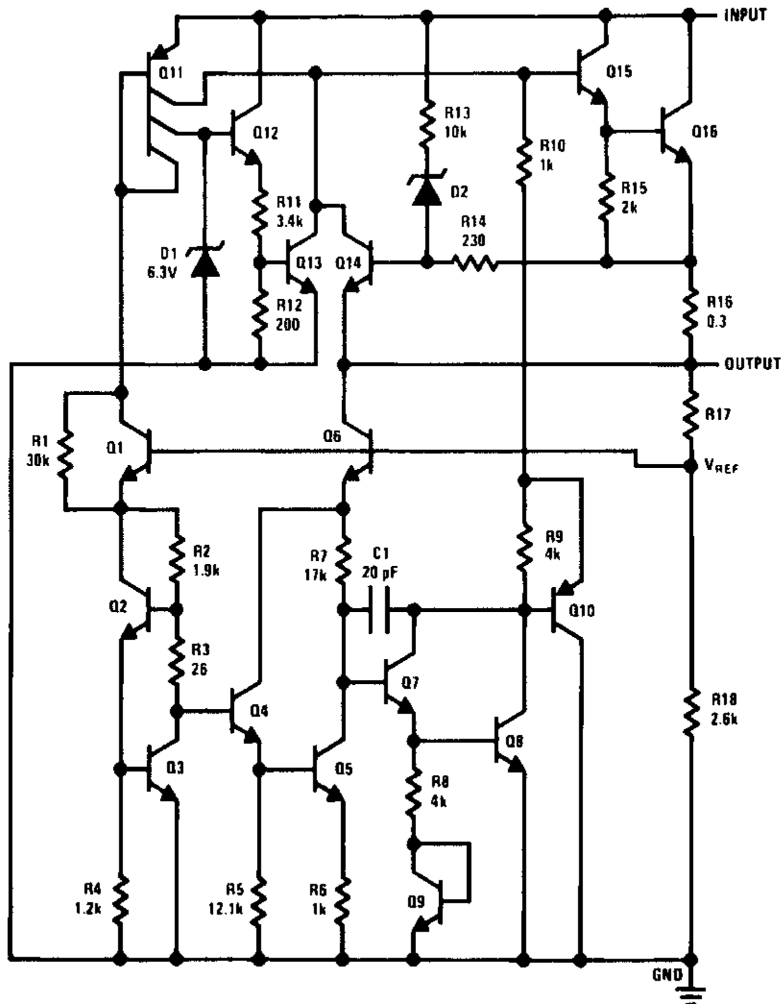
DS007746-9

Ripple Rejection



DS007746-10

Schematic



DS007746-1

Electrical Characteristics LM78XXC (Note 2) (Continued)

0°C ≤ T_J ≤ 125°C unless otherwise noted.

Output Voltage			5V			12V			15V			Units
Input Voltage (unless otherwise noted)			10V			19V			23V			
Symbol	Parameter	Conditions	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
	Short-Circuit Current	Tj = 25°C		2.1			1.5			1.2		A
	Peak Output Current	Tj = 25°C		2.4			2.4			2.4		A
	Average TC of V_{OUT}	0°C ≤ Tj ≤ +125°C, I_O = 5 mA		0.6			1.5			1.8		mV/°C
V_{IN}	Input Voltage Required to Maintain Line Regulation	Tj = 25°C, I_O ≤ 1A		7.5		14.6			17.7			V

Note 1: Thermal resistance of the TO-3 package (K, KC) is typically 4°C/W junction to case and 35°C/W case to ambient. Thermal resistance of the TO-220 package (T) is typically 4°C/W junction to case and 50°C/W case to ambient.

Note 2: All characteristics are measured with capacitor across the input of 0.22 µF, and a capacitor across the output of 0.1µF. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

Note 3: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. For guaranteed specifications and the test conditions, see Electrical Characteristics.

National Semiconductor

November 1994

LM741 Operational Amplifier

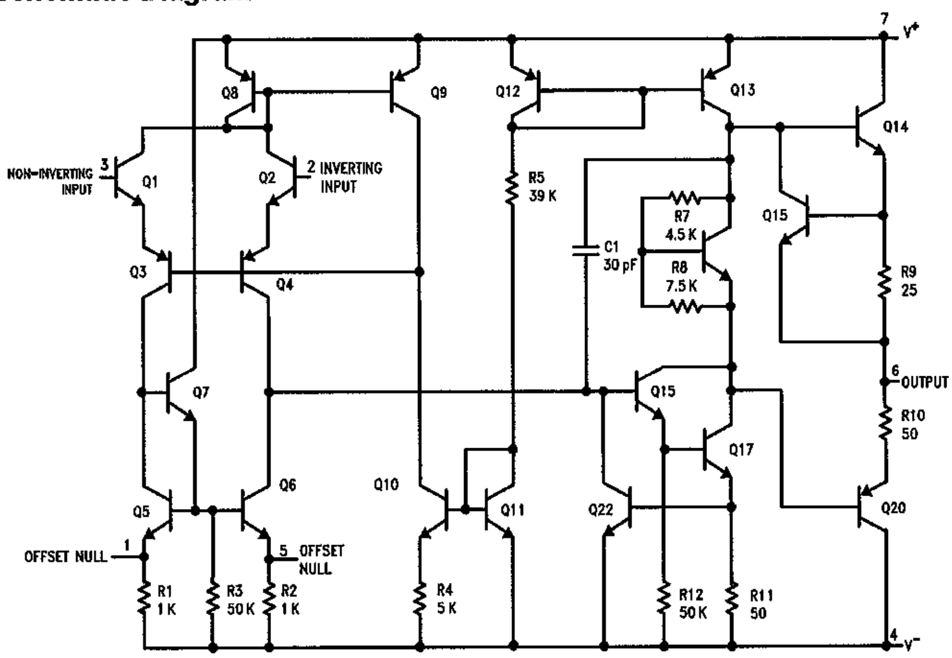
General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

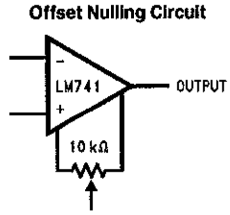
The LM741C/LM741E are identical to the LM741/LM741A except that the LM741C/LM741E have their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Schematic Diagram



TL/H/9341–1

Offset Nulling Circuit



TL/H/9341–7

RRD-B30M115/Printed in U. S. A.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 5)

	LM741A	LM741E	LM741	LM741C
Supply Voltage	±22V	±22V	±22V	±18V
Power Dissipation (Note 1)	500 mW	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V	±30V
Input Voltage (Note 2)	±15V	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	0°C to +70°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	100°C	150°C	100°C
Soldering Information				
N-Package (10 seconds)	260°C	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C	300°C
M-Package				
Vapor Phase (60 seconds)	215°C	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

	LM741A	LM741E	LM741	LM741C
ESD Tolerance (Note 6)	400V	400V	400V	400V

Electrical Characteristics (Note 3)

Parameter	Conditions	LM741A/LM741E			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							µV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	µA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$, $V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $R_L \geq 2\ k\Omega$, $V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV

Electrical Characteristics (Note 3) (Continued)

Parameter	Conditions	LM741A/LM741E			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25°C$	10	25	35		25			25		mA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50\Omega$, $V_{CM} = \pm 12V$	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 4)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/μs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741E	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			150							mW
	$T_A = T_{AMAX}$			150							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 1: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100°C/W	100°C/W	170°C/W	195°C/W
θ_{jC} (Junction to Case)	N/A	N/A	25°C/W	N/A

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Unless otherwise specified, these specifications apply for $V_S = \pm 15V$, $-55°C \leq T_A \leq +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \leq T_A \leq +70°C$.

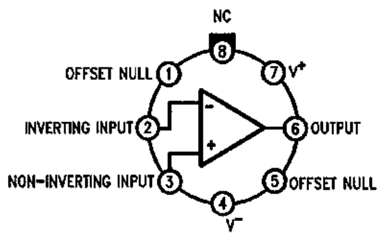
Note 4: Calculated value from: BW (MHz) = 0.35/Rise Time(μs).

Note 5: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 6: Human body model, 1.5 kΩ in series with 100 pF.

Connection Diagrams

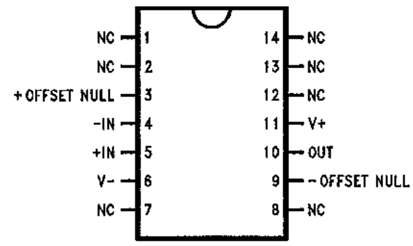
Metal Can Package



TL/H/9341–2

Order Number LM741H, LM741H/883*,
LM741AH/883 or LM741CH
See NS Package Number H08C

Ceramic Dual-In-Line Package



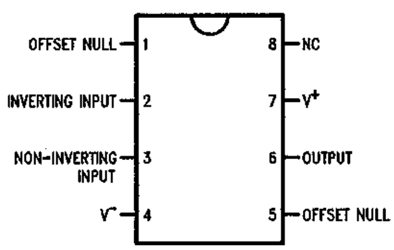
TL/H/9341–5

Order Number LM741J-14/883*, LM741AJ-14/883**
See NS Package Number J14A

*also available per JM38510/10101

**also available per JM38510/10102

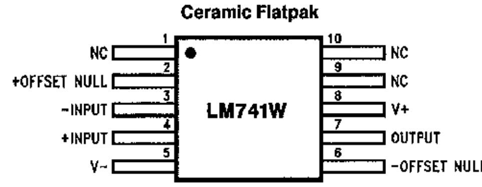
Dual-In-Line or S.O. Package



TL/H/9341–3

Order Number LM741J, LM741J/883,
LM741CM, LM741CN or LM741EN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak



TL/H/9341–6

Order Number LM741W/883
See NS Package Number W10A

*LM741H is available per JM38510/10101

National Semiconductor

June 1989

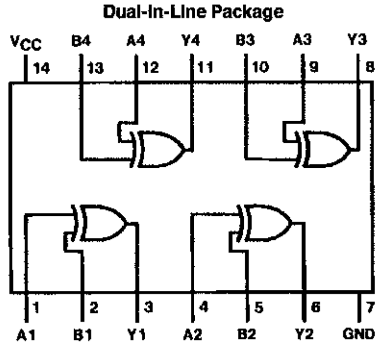
DM54LS86/DM74LS86
Quad 2-Input Exclusive-OR Gates

General Description

This device contains four independent gates each of which performs the logic exclusive-OR function.

Connection Diagram

Dual-In-Line Package



TL/F/6380–1

Order Number DM54LS86J, DM54LS86W, DM74LS86M or DM74LS86N
See NS Package Number J14A, M14A, N14A or W14B

Function Table

$Y = A \oplus B = \overline{A}B + A\overline{B}$

Inputs		Output
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	L

H = High Logic Level
L = Low Logic Level

 RRD-B30M105/Printed in U. S. A.

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	
DM54LS	−55°C to +125°C
DM74LS	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note: *The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.*

Recommended Operating Conditions

Symbol	Parameter	DM54LS86			DM74LS86			Units
		Min	Nom	Max	Min	Nom	Max	
V_{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High Level Input Voltage	2			2			V
V_{IL}	Low Level Input Voltage			0.7			0.8	V
I_{OH}	High Level Output Current			−0.4			−0.4	mA
I_{OL}	Low Level Output Current			4			8	mA
T_A	Free Air Operating Temperature	−55		125	0		70	°C

Electrical Characteristics over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 1)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA				−1.5	V
V_{OH}	High Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IL} = Max, V_{IH} = Min	DM54	2.5	3.4		V
			DM74	2.7	3.4		
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IL} = Max, V_{IH} = Min	DM54		0.25	0.4	V
			DM74		0.35	0.5	
		I_{OL} = 4 mA, V_{CC} = Min	DM74		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V				0.2	mA
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.7V				40	μA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V				−0.6	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 2)	DM54	−20		−100	mA
			DM74	−20		−100	
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max (Note 3)			6.1	10	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max (Note 4)			9	15	mA

Note 1: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 2: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Note 3: I_{CCH} is measured with all outputs open, one input at each gate at 4.5V, and the other inputs grounded.

Note 4: I_{CCL} is measured with all outputs open and all inputs grounded.

National Semiconductor

March 1991

DM74LS123 Dual Retriggerable One-Shot with Clear and Complementary Outputs

General Description

The DM74LS123 is a dual retriggerable monostable multivibrator capable of generating output pulses from a few nanoseconds to extremely long duration up to 100% duty cycle. Each device has three inputs permitting the choice of either leading edge or trailing edge triggering. Pin (A) is an active-low transition trigger input and pin (B) is an active-high transition trigger input. The clear (CLR) input terminates the output pulse at a predetermined time independent of the timing components. The clear input also serves as a trigger input when it is pulsed with a low level pulse transition (⊓⊔⊓). To obtain the best trouble free operation from this device please read the operating rules as well as the NSC one-shot application notes carefully and observe recommendations.

Features

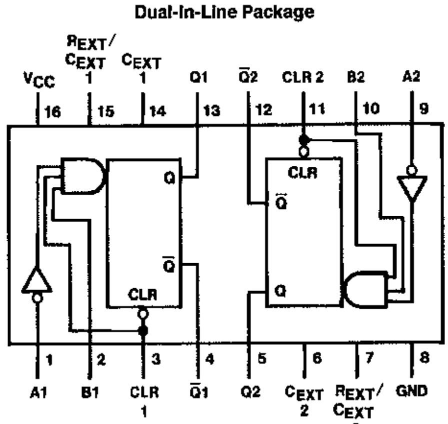
- DC triggered from active-high transition or active-low transition inputs
- Retriggerable to 100% duty cycle
- Compensated for V_{CC} and temperature variations
- Triggerable from CLEAR input
- DTL, TTL compatible
- Input clamp diodes

Functional Description

The basic output pulse width is determined by selection of an external resistor (R_X) and capacitor (C_X). Once triggered, the basic pulse width may be extended by retriggering the gated active-low transition or active-high transition inputs or be reduced by use of the active-low or CLEAR input. Retriggering to 100% duty cycle is possible by application of an input pulse train whose cycle time is shorter than the output cycle time such that a continuous "HIGH" logic state is maintained at the "Q" output.

Connection Diagram

Dual-In-Line Package



TL/F/6386–1

Order Number DM74LS123M or DM74LS123N
See NS Package Number M16A or N16E

Function Table

Inputs			Outputs	
CLEAR	A	B	Q	$\overline{Q}$
L	X	X	L	H
X	H	X	L	H
X	X	L	L	H
H	L	↑	⎍	⊔
H	↓	H	⎍	⊔
↑	L	H	⎍	⊔

H = High Logic Level
L = Low Logic Level
X = Can Be Either Low or High
↑ = Positive Going Transition
↓ = Negative Going Transition
⎍ = A Positive Pulse
⊔ = A Negative Pulse

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature	−65°C to +150°C

Note: *The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.*

Recommended Operating Conditions

Symbol	Parameter		Min	Nom	Max	Units
V_{CC}	Supply Voltage		4.75	5	5.25	V
V_{IH}	High Level Input Voltage		2			V
V_{IL}	Low Level Input Voltage				0.8	V
I_{OH}	High Level Output Current				−0.4	mA
I_{OL}	Low Level Output Current				8	mA
t_W	Pulse Width (Note 6)	A or B High	40			ns
		A or B Low	40			
		Clear Low	40			
R_{EXT}	External Timing Resistor		5		260	kΩ
C_{EXT}	External Timing Capacitance		No Restriction			μF
C_{WIRE}	Wiring Capacitance at R_{EXT}/C_{EXT} Terminal				50	pF
T_A	Free Air Operating Temperature		0		70	°C

Electrical Characteristics over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ (Note 1)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA			−1.5	V
V_{OH}	High Level Output Voltage	V_{CC} = Min, I_{OH} = Max V_{IL} = Max, V_{IH} = Min	2.7	3.4		V
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max V_{IL} = Max, V_{IH} = Min		0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V			0.1	mA
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.7V			20	μA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V			−0.4	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 2)	−20		−100	mA
I_{CC}	Supply Current	V_{CC} = Max (Notes 3,4 and 5)		12	20	mA

Note 1: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 2: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Note 3: Quiescent I_{CC} is measured (after clearing) with 2.4V applied to all clear and A inputs, B inputs grounded, all outputs open, C_{EXT} = 0.02 μF, and R_{EXT} = 25 kΩ.

Note 4: I_{CC} is measured in the triggered state with 2.4V applied to all clear and B inputs, A inputs grounded, all outputs open, C_{EXT} = 0.02 μF, and R_{EXT} = 25 kΩ.

Note 5: With all outputs open and 4.5V applied to all data and clear inputs, I_{CC} is measured after a momentary ground, then 4.5V is applied to the clock.

Note 6: T_A = 25°C and V_{CC} = 5V.

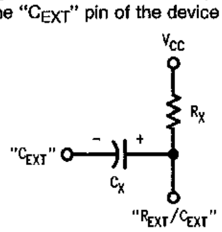
Switching Characteristics at V_{CC} = 5V and T_A = 25°C

Symbol	Parameters	From (Input) To (Output)	R_L = 2 kΩ				Units
			C_L = 15pF C_{EXT} = 0 pF, R_{EXT} = 5 kΩ		C_L = 15pF C_{EXT} = 1000 pF, R_{EXT} = 10 KΩ		
			Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time Low to High Level Output	A to Q		33			ns
t_{PLH}	Propagation Delay Time Low to High Level Output	B to Q		44			ns
t_{PHL}	Propagation Delay Time High to Low Level Output	A to $\overline{Q}$		45			ns
t_{PHL}	Propagation Delay Time High to Low Level Output	B to $\overline{Q}$		56			ns
t_{PLH}	Propagation Delay Time Low to High Level Output	Clear to $\overline{Q}$		45			ns
t_{PHL}	Propagation Delay Time High to Low Level Output	Clear to Q		27			ns
$t_{WQ(Min)}$	Minimum Width of Pulse at Output Q	A or B to Q		200			ns
$t_{W(out)}$	Output Pulse Width	A or B to Q			4	5	μs

Operating Rules

1. An external resistor (R_X) and an external capacitor (C_X) are required for proper operation. The value of C_X may vary from 0 to any necessary value. For small time constants high-grade mica, glass, polypropylene, polycarbonate, or polystyrene material capacitors may be used. For large time constants use tantalum or special aluminum capacitors. If the timing capacitors have leakages approaching 100 nA or if stray capacitance from either terminal to ground is greater than 50 pF the timing equations may not represent the pulse width the device generates.
2. When an electrolytic capacitor is used for C_X a switching diode is often required for standard TTL one-shots to prevent high inverse leakage current. This switching diode is not needed for the 'LS123 one-shot and should not be used. In general the use of the switching diode is not recommended with retriggerable operation.

Furthermore, if a polarized timing capacitor is used on the 'LS123 the negative terminal of the capacitor should be connected to the "C_{EXT}" pin of the device *(Figure 1)*.



('LS123)

TL/F/6386-8

FIGURE 1

3. For $C_X >> 1000$ pF the output pulse width (T_W) is defined as follows:

   $T_W = KR_X C_X$

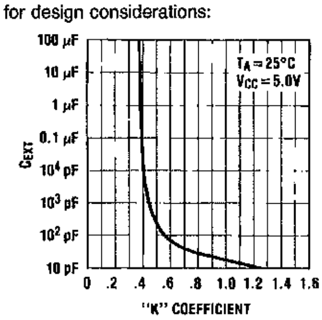
   where [R_X is in kΩ]

   [C_X is in pF]

   [T_W is in ns]

   $K \approx 0.37$

4. The multiplicative factor K is plotted as a function of C_X below for design considerations:

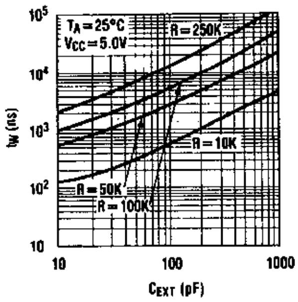


TL/F/6386-2

FIGURE 2

Operating Rules (Continued)

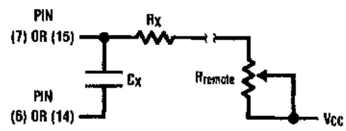
5. For C_X < 1000 pF see *Figure 3* for T_W vs C_X family curves with R_X as a parameter:



TL/F/6386-3

FIGURE 3

6. To obtain variable pulse widths by remote trimming, the following circuit is recommended:



TL/F/6386-4

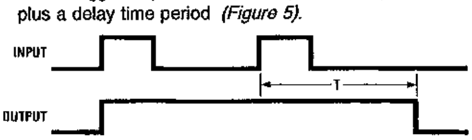
FIGURE 4

Note: "R_{remote}" should be as close to the device pin as possible.

7. The retriggerable pulse width is calculated as shown below:

$$T = T_W + t_{PLH} = K \times R_X \times C_X + t_{PLH}$$

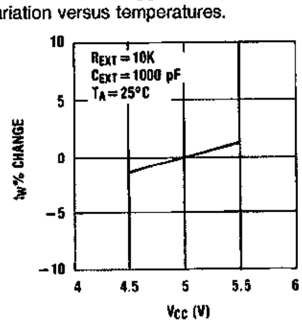
The retriggered pulse width is equal to the pulse width plus a delay time period *(Figure 5)*.



TL/F/6386-5

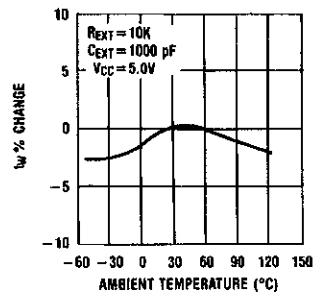
FIGURE 5

8. Output pulse width variation versus V_{CC} and temperatures: *Figure 6* depicts the relationship between pulse width variation versus V_{CC}, and *Figure 7* depicts pulse width variation versus temperatures.



TL/F/6386-6

FIGURE 6



TL/F/6386-7

FIGURE 7

9. Under any operating condition C_X and R_X must be kept as close to the one-shot device pins as possible to minimize stray capacitance, to reduce noise pick-up, and to reduce I-R and Ldi/dt voltage developed along their connecting paths. If the lead length from C_X to pins (6) and (7) or pins (14) and (15) is greater than 3 cm, for example, the output pulse width might be quite different from values predicted from the appropriate equations. A non-inductive and low capacitive path is necessary to ensure complete discharge of C_X in each cycle of its operation so that the output pulse width will be accurate.

10. The C_{EXT} pins of this device are internally connected to the internal ground. For optimum system performance they should be hard wired to the system's return ground plane.

11. V_{CC} and ground wiring should conform to good high-frequency standards and practices so that switching transients on the V_{CC} and ground return leads do not cause interaction between one-shots. A 0.01 μF to 0.10 μF bypass capacitor (disk ceramic or monolithic type) from V_{CC} to ground is necessary on each device. Furthermore, the bypass capacitor should be located as close to the V_{CC}-pin as space permits.

For further detailed device characteristics and output performance please refer to the NSC one-shot application note AN-372.

National Semiconductor

May 1989

54LS32/DM54LS32/DM74LS32 Quad 2-Input OR Gates

General Description

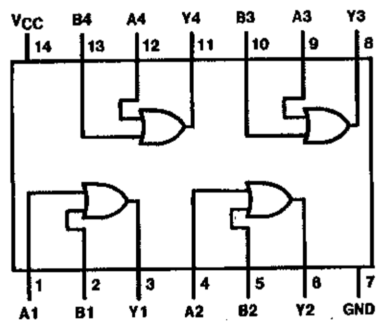
This device contains four independent gates each of which performs the logic OR function.

Features

- Alternate Military/Aerospace device (54LS32) is available. Contact a National Semiconductor Sales Office/Distributor for specifications.

Connection Diagram

Dual-In-Line Package



TL/F/6381–1

Order Number 54LS32DMQB, 54LS32FMQB, 54LS32LMQB, DM54LS32J, DM54LS32W, DM74LS32M or DM74LS32N
See NS Package Number E20A, J14A, M14A, N14A or W14B

Function Table

Y = A + B

Inputs		Output
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	H

H = High Logic Level
L = Low Logic Level

54LS32/DM54LS32/DM74LS32 Quad 2-Input OR Gates

RRD-B30M105/Printed in U. S. A.

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	
DM54LS and 54LS	−55°C to +125°C
DM74LS	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Note: *The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.*

Recommended Operating Conditions

Symbol	Parameter	DM54LS32			DM74LS32			Units
		Min	Nom	Max	Min	Nom	Max	
V_{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High Level Input Voltage	2			2			V
V_{IL}	Low Level Input Voltage			0.7			0.8	V
I_{OH}	High Level Output Current			−0.4			−0.4	mA
I_{OL}	Low Level Output Current			4			8	mA
T_A	Free Air Operating Temperature	−55		125	0		70	°C

Electrical Characteristics over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 1)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA				−1.5	V
V_{OH}	High Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IH} = Min	DM54	2.5	3.4		V
			DM74	2.7	3.4		
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IL} = Max	DM54		0.25	0.4	V
			DM74		0.35	0.5	
		I_{OL} = 4 mA, V_{CC} = Min	DM74		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V				0.1	mA
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.7V				20	μA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V				−0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 2)	DM54	−20		−100	mA
			DM74	−20		−100	
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max			3.1	6.2	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max			4.9	9.8	mA

Switching Characteristics at V_{CC} = 5V and T_A = 25°C (See Section 1 for Test Waveforms and Output Load)

Symbol	Parameter	R_L = 2 kΩ				Units
		C_L = 15 pF		C_L = 50 pF		
		Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time Low to High Level Output	3	11	4	15	ns
t_{PHL}	Propagation Delay Time High to Low Level Output	3	11	4	15	ns

Note 1: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 2: Not more than one output should be shorted at a time, and the duration should not exceed one second.

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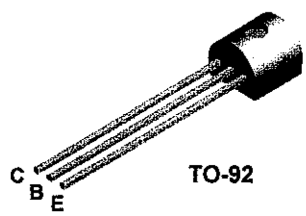
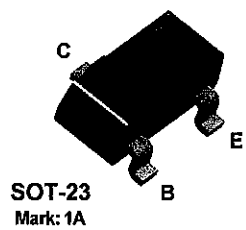
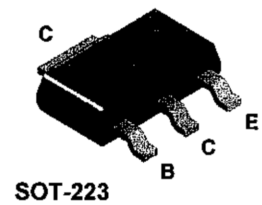
2N3904 MMBT3904 PZT3904







NPN General Purpose Amplifier

This device is designed as a general purpose amplifier and switch. The useful dynamic range extends to 100 mA as a switch and to 100 MHz as an amplifier.

Absolute Maximum Ratings* T_A = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	60	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current - Continuous	200	mA
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics T_A = 25°C unless otherwise noted

Symbol	Characteristic	Max			Units
		2N3904	*MMBT3904	**PZT3904	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	1,000 8.0	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3			°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	125	°C/W

*Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

**Device mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm; mounting pad for the collector lead min. 6 cm^2.

NPN General Purpose Amplifier
(continued)

Electrical Characteristics
T_A = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 1.0 mA, I_B = 0	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 10 μA, I_E = 0	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 10 μA, I_C = 0	6.0		V
I_{BL}	Base Cutoff Current	V_{CE} = 30 V, V_{EB} = 3V		50	nA
I_{CEX}	Collector Cutoff Current	V_{CE} = 30 V, V_{EB} = 3V		50	nA
ON CHARACTERISTICS*					
h_{FE}	DC Current Gain	I_C = 0.1 mA, V_{CE} = 1.0 V I_C = 1.0 mA, V_{CE} = 1.0 V I_C = 10 mA, V_{CE} = 1.0 V I_C = 50 mA, V_{CE} = 1.0 V I_C = 100 mA, V_{CE} = 1.0 V	40 70 100 60 30	 300 	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 10 mA, I_B = 1.0 mA I_C = 50 mA, I_B = 5.0 mA		0.2 0.3	V V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 10 mA, I_B = 1.0 mA I_C = 50 mA, I_B = 5.0 mA	0.65	0.85 0.95	V V
SMALL SIGNAL CHARACTERISTICS					
f_T	Current Gain - Bandwidth Product	I_C = 10 mA, V_{CE} = 20 V, f = 100 MHz	300		MHz
C_{obo}	Output Capacitance	V_{CB} = 5.0 V, I_E = 0, f = 1.0 MHz		4.0	pF
C_{ibo}	Input Capacitance	V_{EB} = 0.5 V, I_C = 0, f = 1.0 MHz		8.0	pF
NF	Noise Figure	I_C = 100 μA, V_{CE} = 5.0 V, R_S =1.0kΩ,f=10 Hz to 15.7kHz		5.0	dB
SWITCHING CHARACTERISTICS					
t_d	Delay Time	V_{CC} = 3.0 V, V_{BE} = 0.5 V,		35	ns
t_r	Rise Time	I_C = 10 mA, I_{B1} = 1.0 mA		35	ns
t_s	Storage Time	V_{CC} = 3.0 V, I_C = 10mA		200	ns
t_f	Fall Time	I_{B1} = I_{B2} = 1.0 mA		50	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

Spice Model

NPN (Is=6.734f Xti=3 Eg=1.11 Vaf=74.03 Bf=416.4 Ne=1.259 Ise=6.734 Ikf=66.78m Xtb=1.5 Br=.7371 Nc=2 Isc=0 Ikr=0 Rc=1 Cjc=3.638p Mjc=.3085 Vjc=.75 Fc=.5 Cje=4.493p Mje=.2593 Vje=.75 Tr=239.5n Tf=301.2p Itf=.4 Vtf=4 Xtf=2 Rb=10)

Test Circuits

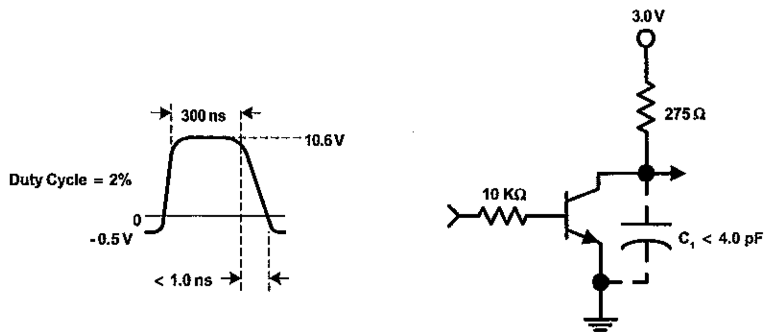


FIGURE 1: Delay and Rise Time Equivalent Test Circuit

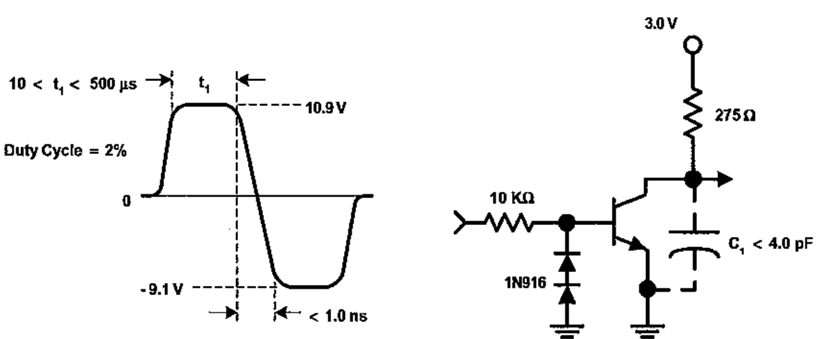


FIGURE 2: Storage and Fall Time Equivalent Test Circuit