Comprehensive Protection Relay for Refrigerator

Project Report

P-223

Submitted in partial fulfilment of the requirements
for the award of the Degree of
Bachelor of Engineering
in Electrical and Electronics Engineering
of the Bharathiar University, Coimbatore-641 046.

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Certificate

This is to Certify that the Project Report entitled

Comprehensive Protection Relay for Refrigerator

has been submitted by

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In partial fulfilment for the award of

Bachelor of Engineering in Electrical and Electronics Engineering

Branch of Bharathiar University, Coimbatore-641 046

during the academic year 1995-'96.

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PROFESSOR & HEAD
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Head of the Department
PROFESSOR & HEAD
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Certified that the candidate was examined by us in the project work Viva-Voce Examination

held on ______________ and the University Register Number was ______________

Internal Examiner

External Examiner

ACKNOWLEDGMENT

We express our heartful gratitude and indebtedness to our guide **Dr.K.A.PALANISWAMY**, BE,MSc(Engg).,Ph.D,FIE,C.Eng(I),MISTE, Professor and Head, Electrical and Electronics Engineering Department, for his guidance and encouragement throughout the Project Work.

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We are also grateful to **Prof.N.A.GNANAM** of Government College of Technology, Coimbatore for suggesting this project and helping us with the fabrication.

We also thank all the staff members of the Electrical and Electronics Engineering Department for their help and encouragement.

SYNOPSIS

This project outlines the design, fabrication and testing of a basic form of a low cost protective scheme for the domestic refrigerator. Due to the fluctuation in the power supply, severe damages are caused in refrigerators. Since cost of repairs of these damages are very high a reliable protective scheme at an affordable price is needed.

Our comprehensive protection scheme comprises of an under voltage relay, an over voltage relay, an over current relay and a timer with time delay on "power on", thus providing a complete protection to the compressor motor of the domestic refrigerators.

CONTENTS

CHAPTER 1

Introduction

1. INTRODUCTION

Refrigerators are the most commonly used appliances in many houses. With recent technological advances the design of refrigerators have been perfected and breakdown of the present day refrigerators due to manufacturing defects are very rare and some of the manufacturers even give a warranty of as much as seven years. But still, the breakdown of refrigerators due to burning of their compressor motors do occur often and the cost of repairs are quite high running to a few thousands of rupees. These breakdowns are mostly attributed to very wide fluctuations in the power supply.

1.1 CAUSES OF FAILURE:

The compressors of the modern day refrigerators and the electric motor driving them are integrated and hermetically sealed. In case of any breakdown the sealed unit has to be cut open and then only repairs can be carried out on the motor. The compressor used in refrigerators are of the positive displacement type and when the primemover (motor) stops, the pressure difference between the suction and the delivery sides does not equalise immediately .It takes some time since the compressed refrigerant has to flow in a closed circuit through a thin capillary tube. If the power supply is resumed immediately before the pressure difference decreases, the motor has to start with almost full load torque. But the motors normally used in the refrigerators are of single phase, split phase fractional horse power motors (usually 0.2 to 0.5 HP) of a very compact and light weight design, with a very low starting torque. So the motor will stall and have a large current and the burnout of the motor coils will have to be prevented by the action of the over load(thermal type) relay incorporated in the starting relay of the split phase motor. The thermal type overload relays have a larger operating time and if the power supply is frequently interrupted and re-sumed either due to some loose connections in the wiring or by inadvertently turning off the appliance and immediately turning on may cause costly burnout of the compressor motor.

In our country the domestic power supply voltage is 230 V nominal and as per the Electricity Act can have a maximum variation of ± 10 % of this nominal value, which means the power supply company has to ensure that the supply voltage will be within 207 V to 253 V. Yet very poor power supply conditions are often encountered in many households. The voltage during peak load periods dips well below 170 V at tail ends and during light loads may be higher than 270 V. The designers of the compressor motor have taken this fact in to consideration and the motors are designed to operate over a wide range of supply voltage from 180 V to 260 V. But if the motors are operated for a long time beyond these limits, it results in their burnouts.

The motors are of the single phase induction type which has a fairly constant speed torque characteristics and hence if the motor is operated with a very low supply voltage, it will try to draw increase load current to keep the power constant. This will cause increased ohmic losses in the machine and may cause the windings to the damaged.

If the motor is to operate at voltages much higher than the rated voltage, the iron losses in the motor will be high since

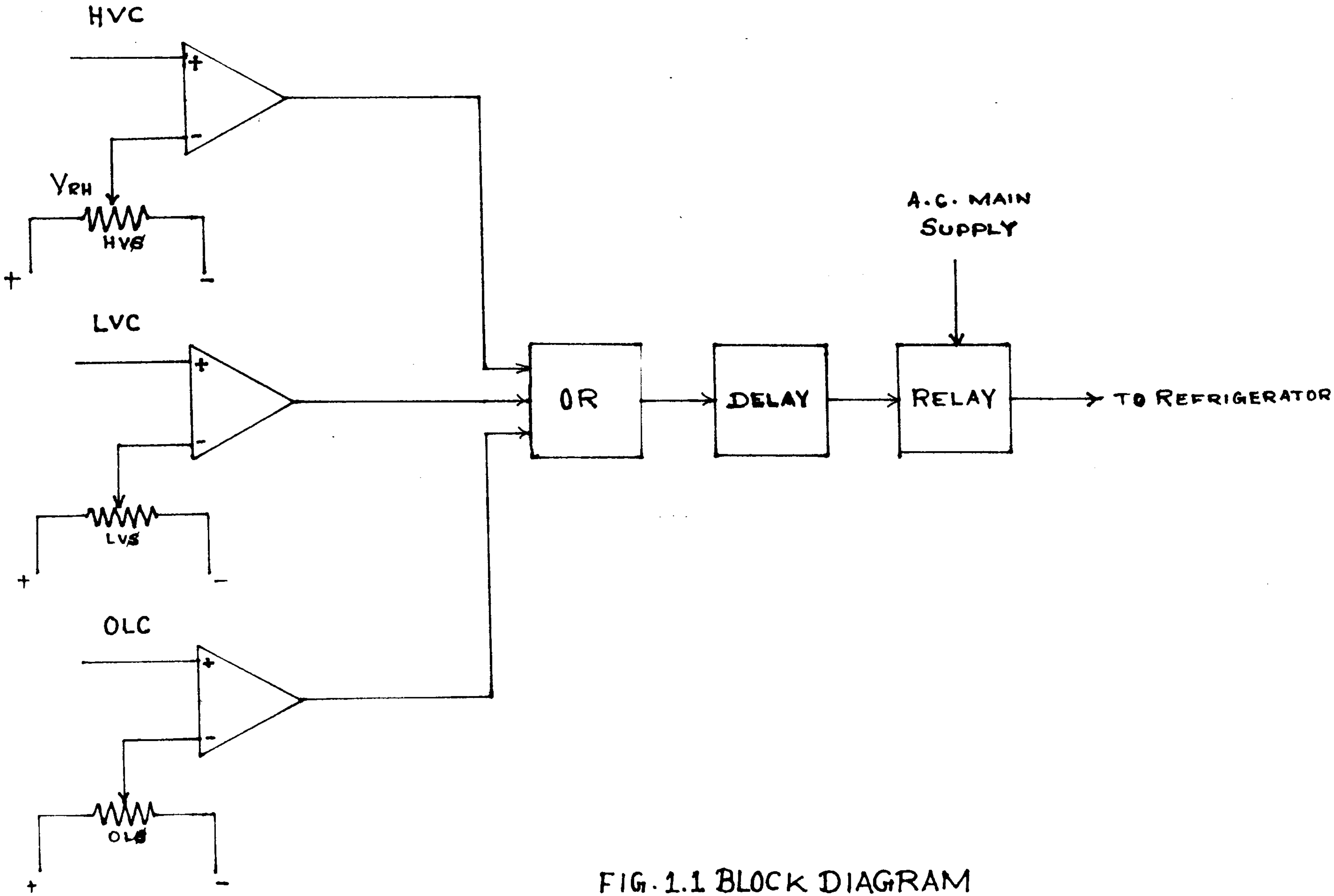

FIG. 1.1 BLOCK DIAGRAM

CHAPTER 2

Design of Protection Scheme

2. DESIGN OF PROTECTION SCHEME

2.1 INTRODUCTION:

The protection scheme for the refrigerators consist of under-voltage relay, over-voltage relay, over-current relay and a time delay relay. All these relays are designed by using integrated circuits so that the circuitry will be compact and highly reliable. The popular LM741 operational amplifier is used for under-voltage, over-voltage and over-current relays. The Timer cum relay driver is based on NE555 timer I.C.. The entire circuitry is designed for operation with a +12 V single supply. The circuit diagram of the low voltage d.c. supply is shown in Fig 2.1 and the complete circuit diagram of the comprehensive protection scheme is shown in Fig 2.2

2.2 POWER SUPPLY:

The low voltage (+12 V) d.c.power supply for the relay is designed with "7812" three terminal fixed voltage regulator I.C. The unregulated input required for "7812" must be at least 2 V higher than the output voltage of 12 V at the lowest expected power supply voltage. To ensure that the minimum input voltage of 14 V to the voltage regulator I.C., the peak value of the A.C voltage to the bridge rectifier must be at least 17 V (12 V RMS) taking into consideration the forward voltage drop (2*0.7 V) of the rectifier diodes and a 10% voltage regulation for the step down transformer. This voltage must be available at the secondary terminals of the step down transformer T1 at an input supply voltage of about 160 V. Hence a step down transformer 230 V/18 V at 1 Ampere is used for the low voltage d.c. supply. A 1000 microfarad/50 V capacitor is used as a filter capacitor. A small ceramic disc capacitor of 0.22 microfarad/63 V is provided close to the output terminal of the regulator to improve its transient response. An LED is also provided to indicate the "power on" condition.

2.3 OVER VOLTAGE RELAY:

The over-voltage relay is designed with "741" operational amplifier A1 functioning as an inverting level detector. A constant reference voltage of 6 V derived from the potential divider action of R9 and R10 and filtered by a 10 microfarad/25 V capacitor is applied to the non-inverting input of the "741 operational amplifier. The voltage sensing circuit (common to both over-voltage and under-voltage relay) comprises of a 230 V/12 V/0.5 A step down transformer T2 whose secondary output rectified and filtered by D6, C3, R2 and C4 and provides a d.c voltage proportional to the A.C.supply voltage. The nominal value of the d.c. output of the above circuit will be about 18 V. This voltage is applied to a potential divider circuit consist of R7, R8 and a 10k POT. The output of this potentiometer setting of POT1 (over-voltage setting) is adjusted such that when the A.C. supply voltage just exceeds 270 V the output of A1 will change from a high level of 12 V to ground level, which will be indicated by LED, D8 being turned "on" to indicate an over-voltage condition. The occurrence of an over-voltage condition or a under-voltage condition or an over load condition sensed by A1, A2 and A3 respectively is used to actuate a timer cum relay driver (NE555, used as a monostable circuit whose time delay, T is equal to 1.1*R*C) by connecting the output of A1, A2 and A3 through an "OR" gate formed by diodes D9, D11 and D12 to the Trigger and Threshold input pins. When an over-voltage condition occurs the output of A1 will go to "low" level. With the "trigger" input of NE555 at low level will cause the output of NE555 to change to "high" level thus turning off the 12 V electromagnetic relay whose contacts are connected in series with the refrigerator to be protected. The relay will turn off the power supply as long as the "trigger" input is held at low level by the occurrence of an over-voltage or under-voltage or over-current condition. When the power supply voltage returns to normal (allowable value), the electromagnetic relay will be energised with a time delay of 120 seconds, determined by the 1mega Ohm resistor and the 100 microfarad capacitor, thus providing the necessary time delay on "power on" to allow for the pressure equalisation in the compressor.

2.4 UNDER VOLTAGE RELAY:

The under-voltage relay is also designed with "741" operational amplifier A2 functioning as a non-inverting level detector with the reference voltage given to the inverting input and output of voltage sensor circuit given to the non-inverting input through a potential divider formed by R15, R16 and POT2. The potential divider setting is adjusted such that when the input A.C. supply falls below 160 V the output of under-voltage relay (output of A2) change from +12 V to ground level thus tripping the electromagnetic relay in a way similar to the occurance of an over-voltage condition. This will be indicated by the LED, D10 at the output of A2 , that an under-voltage condition is existing.

2.5 OVER-CURRENT RELAY:

The compressor of all the refrigerators are provided with a thermal type over load relay and a starting relay mounted on the compressor housing. The over-load relay provided in this scheme is only back-up protection to the already existing relay and will be operating only under abnormal conditions. The over-current transformer T3 with a burden of 10 ohms 15 watt resistor is connected across the secondary. The primary of current transformer is connected in series with the refrigerator. The a.c voltage across the burden R4 is rectified and filtered by D7, C5, R5 and C6 to provide a d.c. voltage proportional to the load current. This voltage is applied with a small "offset" voltage of about 1 volt derived from 12 V supply through R23 and R24 applied to the inverting input of A3. The non-inverting input of A3 is connected to a potential divider circuit at the output of A3 consisting of R18, R20 and POT3. The operational amplifier A3 is designed here as an inverting level detector with a hysteresis. The setting of the potentiometer P3 can be adjusted such that the output of A3 will change from "high" level to "low" level when the load current exceeds the safe limit. Since the operational amplifier A3 unlike A1 and A2 is provided with a hysteresis in its operation as a level detector, the output will be latched to "low" level and has to be manually reset by pushing the reset button. The 0.1 microfarad/63v capacitor in the reset circuit will ensure that the over-current relay will not latchup on "power on" and the output of A3 will be at "high" level.

2.6 TIMER CUM RELAY DRIVER:

A NE555 timer I.C. is used in a monostable circuit configuration. The time delay is provided by R14 and C11. The time delay is about 120 seconds. The timer I.C. mounted on a suitable heat sink is capable of sourcing or sinking a load current of 200 milli amperes. Hence it is used to drive the 12 V electromagnetic relay whose coil current is about 50 milliamperes. A pre-wheeling diode D13 is provided across the relay coil to protect the NE555 from damage due to over-voltage while interrupting the relay coil current, an LED indication is provided in the over-current relay circuit also by D14. A small ceramic capacitor of 0.1 microfarad/63 V is provided at the V_{CC} terminals of all I.C.s to suppress any tendency to oscillate. The current transformer used in the circuit is constructed with the core of a 230 V/6 V/0.5 A small transformer wound with a primary of 12 turns of 16 SWG enameled copper wire and a secondary of 120 turns of 24 SWG enameled copper wire. The entire circuitry is assembled on a single sided PCB designed and fabricated to accommodate all the components other than the transformer and the electromagnetic relay.

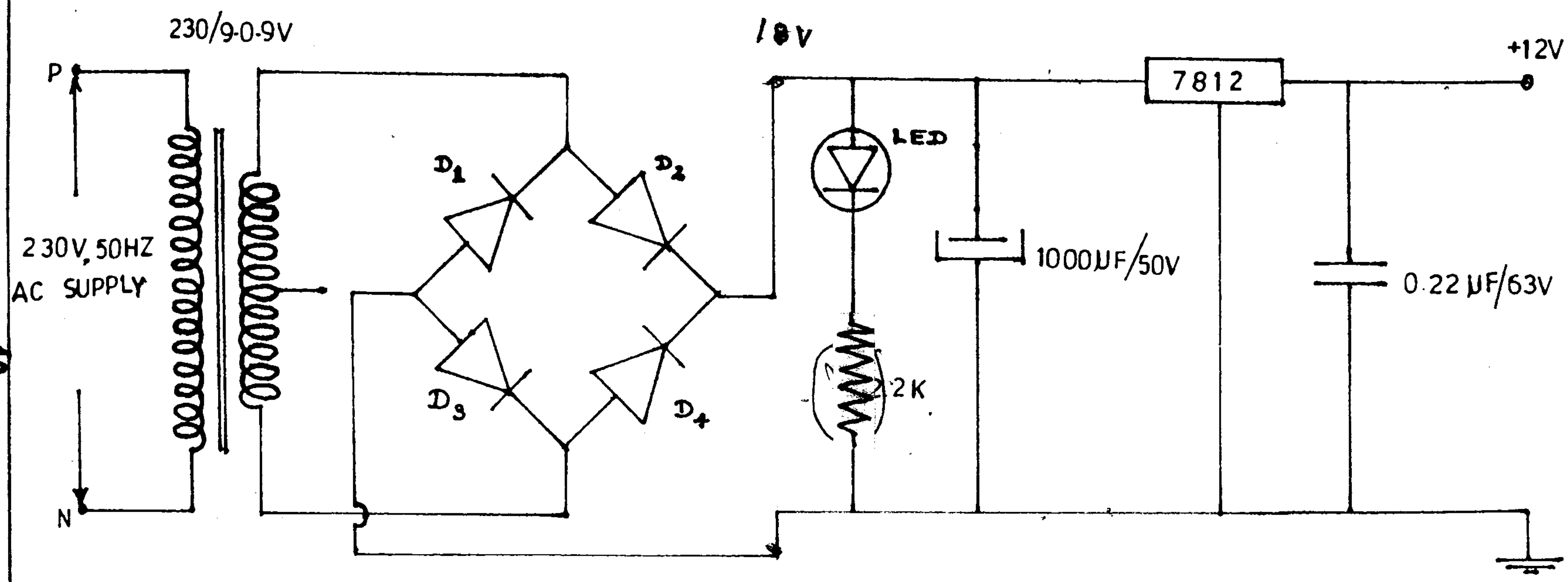

FIG. 2.1 POWER SUPPLY FOR I.C.S

3. TESTING AND CALIBRATION.

3.1 TESTING OF POWER SUPPLY:

The complete circuit of the protection scheme is assembled on the printed circuit board. For testing the +12 V power supply the I.C.s ("741" and "555") are removed from their bases and a 230 V, 50 Hz supply is given to the primary of the power supply transformer, T1. The output of the "7812" I.C. is checked with a multimeter and it was found to be 11.8 V, which is within the specifications of the I.C. (i.e. 11.4 V to 12.6 V).

3.2 TESTING AND CALIBRATION OF OVER AND UNDER VOLTAGE RELAYS:

The "741" and "555" I.C.s are inserted in their bases and a 0 to 270 V, 50 Hz variable A.C voltage from an auto transformer is applied to the primaries of the power supply and voltage sensing circuit transformers T1 and T2. With the input adjusted to 160 V, the 10k potentiometer POT2 is adjusted until the under-voltage indicator LED D10 just lights up. A slight increase in input A.C. voltage should turn off this LED.

Then the input voltage is increased to 270 V and the potentiometer POT1 is adjusted until the over-voltage indication LED, D8 just lights up. A slight decrease in the input A.C should turn off this LED.

3.3 TESTING AND CALIBRATION OF OVER-CURRENT RELAY:

The primary of the current transformer is connected in series with a nominal 230 V, 50Hz supply given to the primary of the transformers T1 and T2 and to the above series circuit. The load current is adjusted to about 3Amperes. The over-current relay setting POT3 is adjusted until the LED indication for over load just lights up. Since the relay circuit has a hysteresis in its characteristics, a reduction in load current will not turn off the LED. The pressing of the manual RESET switch with the load current reduces below the set value of 3 Amperes and turns the LED "off".

3.4 TESTING OF TIMER SECTION:

With a nominal input voltage of 230 V and a load current of less than 3 Amperes, the time interval between the instant of "power on" and the instant at which the electromagnetic relay pick-up is measured with a stop watch. It is found to be about 120 seconds.

Then the protection relay is tested with a domestic refrigerator and it is found to isolate the appliance on occurrence of under-voltage and over-voltage conditions (simulated with an auto-transformer) and is found to reconnect it with a time delay of 120 seconds after the voltage returns to normal value.

4. CONCLUSION

The protective relay scheme outlined in the previous chapter, was designed, constructed and tested. The relay unit was found to work well as per the design specifications. The cost of the prototype unit was about Rs 1200/=. The cost can be cut down to half the above figure, if it is produced on a large scale. The cost and size could be reduced further by eliminating the transformer T2 in the voltage sensing circuit and connecting this circuit to the unregulated d.c. voltage output of the power supply.

Though the scheme is suggested for the protection of compressors of the refrigerators, the same could be used for the protection of the compressors in the single phase window type Air-conditioners also. The current transformer of the scheme (5 A/0.5 A)has to be replaced with a current transformer of higher rating. The electromagnetic relay (with contacts rated at 10 A) has to be replaced with a power relay with suitable contact ratings. The Air-conditioners consist of a motor driven fan and a compressor. The protection scheme is required only for the compressor alone.

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1. NATIONAL SEMICONDCTOR CORPORATION, LINEAR DATABOOK 1 & 2.

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3. C.P.ARORA, "REFRIGERATION AND AIR CONDITIONING", TATA McGRAW-HILL PUBLISHING Co. NEW DELHI, 1981.

4. ANDREW D.ALTHOUSE, CARL H.TURNQUIST AND ALFRED F.BRACCIANO, "MODERN REFRIGERATION AND AIR CONDITIONING", GOODHEART WILLCOX Co., INC., USA 1968.

5. SHRIRAM COMPRESSORS, TECHNICAL HANDBOOK.

ANNEXURE

I.C. PIN CONNECTIONS AND ELECTRICAL CHARACTERISTICS

1. LM 741 OPERATIONAL AMPLIFIER.
2. LM 7812 VOLTAGE REGULATOR.
3. LM 555/NE 555 TIMER.

National Semiconductor Corporation

LM741/LM741A/LM741C/LM741E Operational Amplifier

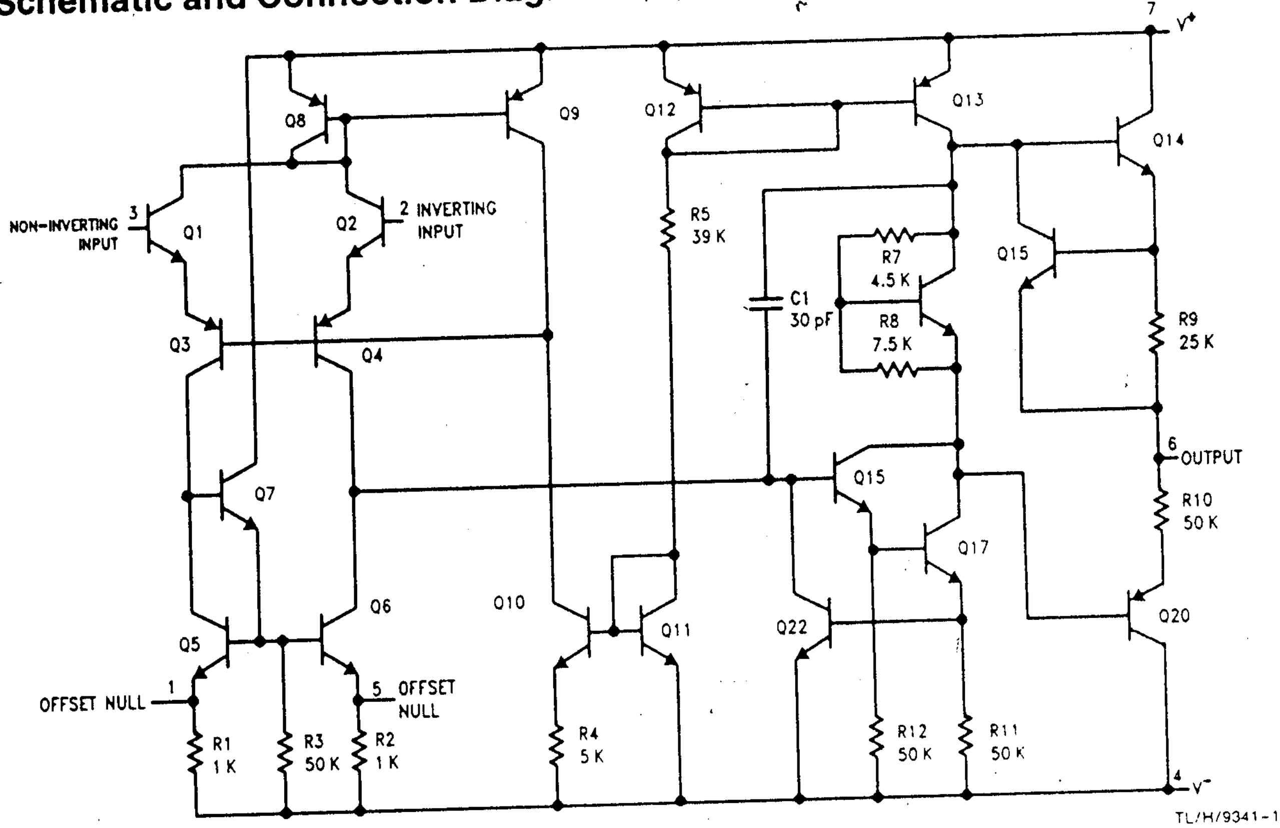
General Description

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.

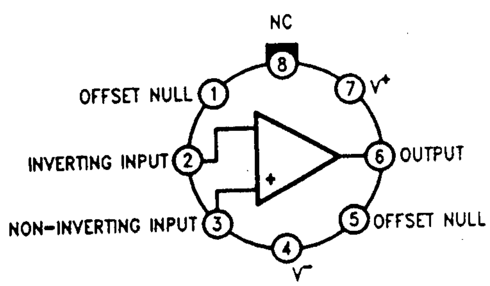
The LM741C/LM741E are identical to the LM741/LM741A except that the LM741C/LM741E have their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Schematic and Connection Diagrams (Top Views)



TL/H/9341-1

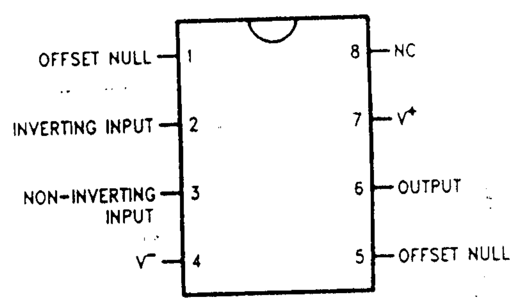
Metal Can Package



TL/H/9341-2

Order Number LM741H, LM741AH, LM741CH or LM741EH
See NS Package Number H08C

Dual-In-Line or S.O. Package

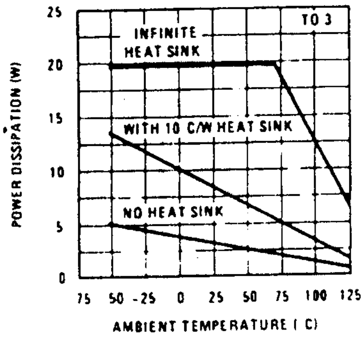


TL/H/9341-3

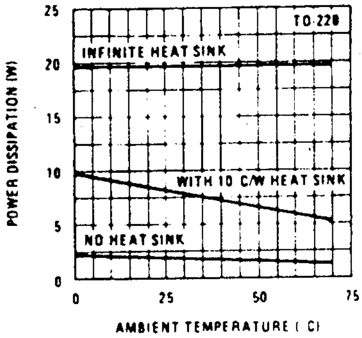
Order Number LM741CJ, LM741CM, LM741CN or LM741EN
See NS Package Number J08A, M08A or N08E

Typical Performance Characteristics

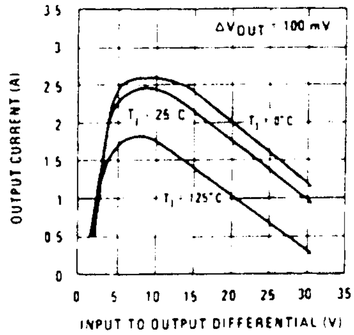
Maximum Average Power Dissipation



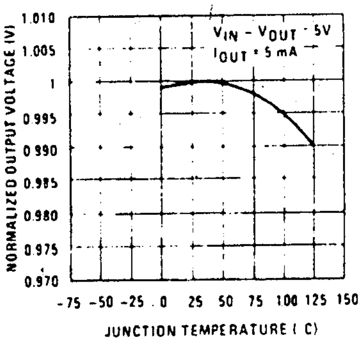
Maximum Average Power Dissipation



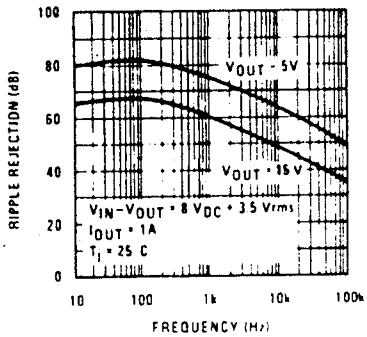
Peak Output Current



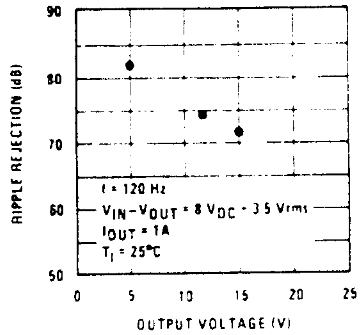
Output Voltage (Normalized to 1V at Tj = 25°C)



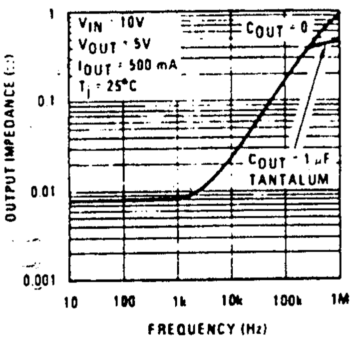
Ripple Rejection



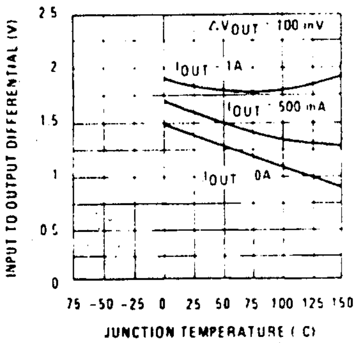
Ripple Rejection



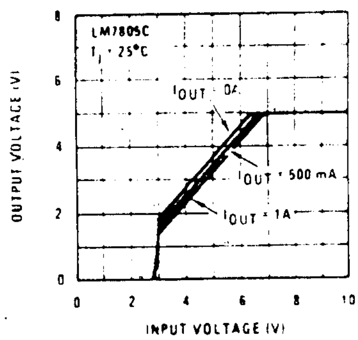
Output Impedance



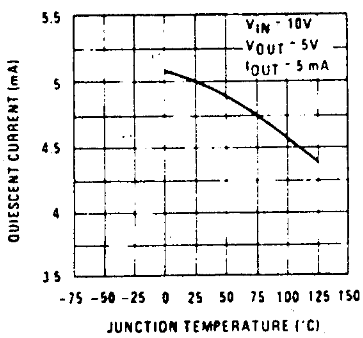
Dropout Voltage



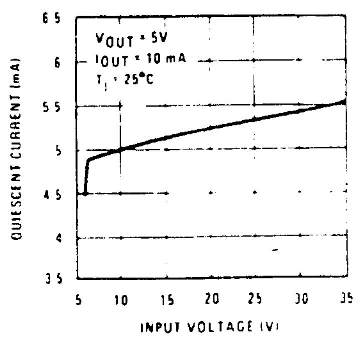
Dropout Characteristics



Quiescent Current



Quiescent Current



TL/H/7746-4

National Semiconductor Corporation

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 mininize 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.

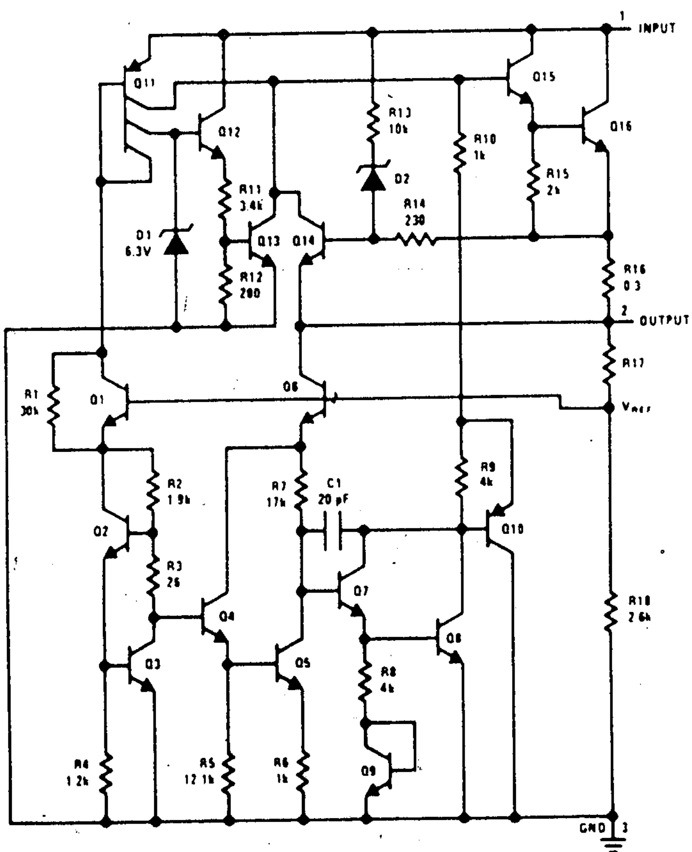
Features

- 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

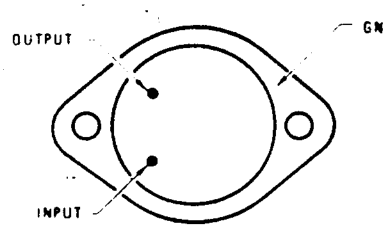
LM7805C	5V
LM7812C	12V
LM7815C	15V

Schematic and Connection Diagrams



TL/H/7746-1

Metal Can Package
TO-3 (K)
Aluminum

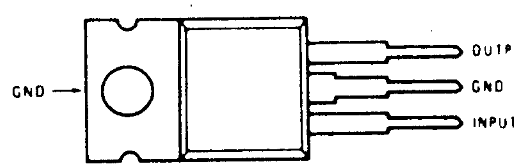


TL/H/7746-2

Bottom View

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

Plastic Package
TO-220 (T)



TL/H/7746-3

Top View

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

National Semiconductor Corporation

LM555/LM555C Timer

General Description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 mA or drive TTL circuits.

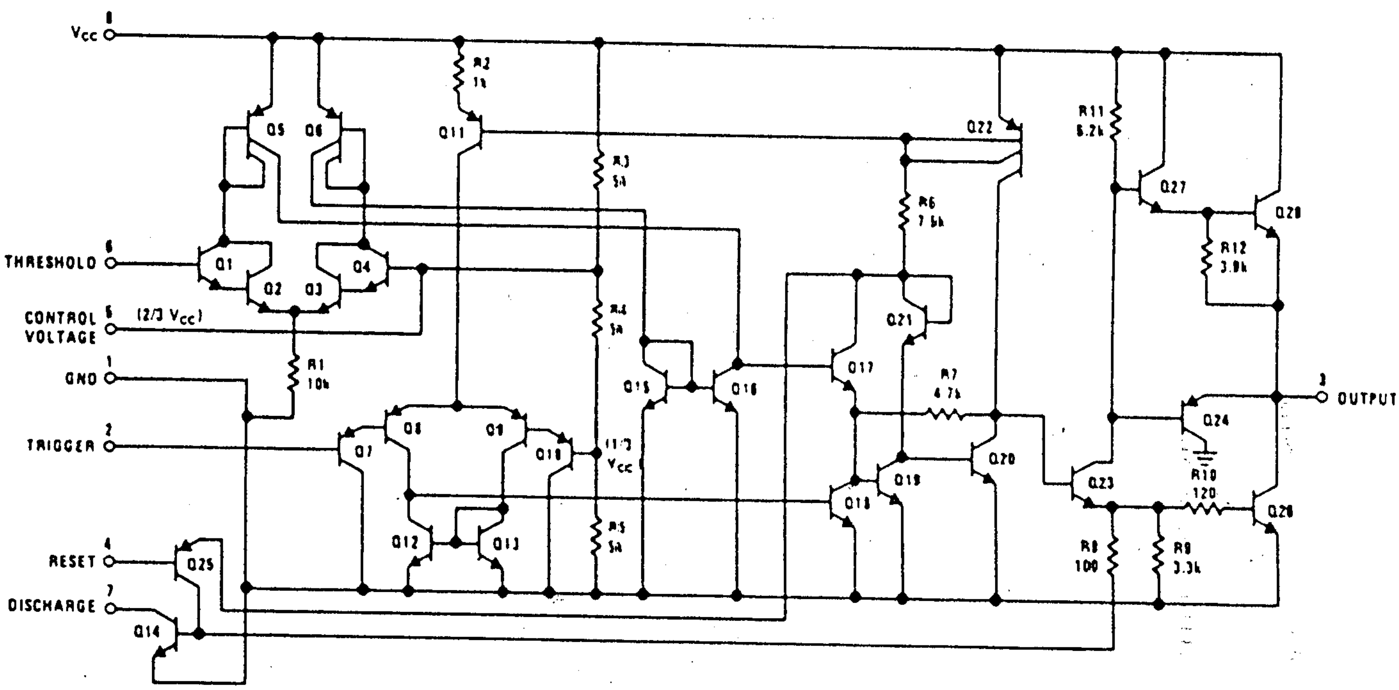
Features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output

Applications

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

Schematic Diagram

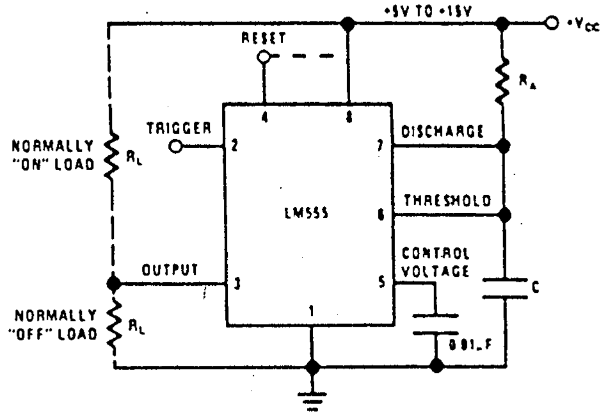


TL/H/7851-1

Application Information

MONOSTABLE OPERATION

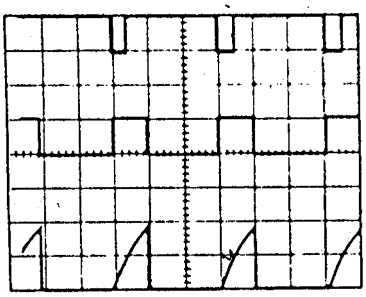
In this mode of operation, the timer functions as a one-shot (*Figure 1*). The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.



TL/H/7851-5

FIGURE 1. Monostable

The voltage across the capacitor then increases exponentially for a period of $t = 1.1\ R_A\ C$, at the end of which time the voltage equals 2/3 V_{CC}. The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state. *Figure 2* shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing internal is independent of supply.



TL/H/7851-6

V_{CC} = 5V	Top Trace: Input 5V/Div.
TIME = 0.1 ms/DIV.	Middle Trace: Output 5V/Div.
R_A = 9.1 kΩ	Bottom Trace: Capacitor Voltage 2V/Div.
C = 0.01 μF	

FIGURE 2. Monostable Waveforms

During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

NOTE: In monostable operation, the trigger should be driven high before the end of timing cycle.

ASTABLE OPERATION

If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a

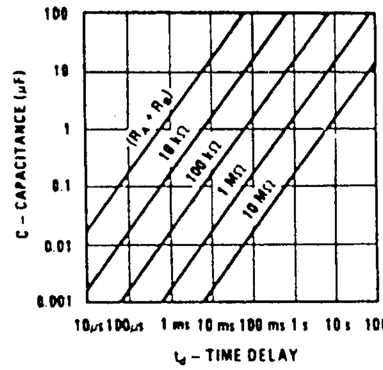


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FIGURE 3. Time Delay

multivibrator. The external capacitor charges through R_A + R_B and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.

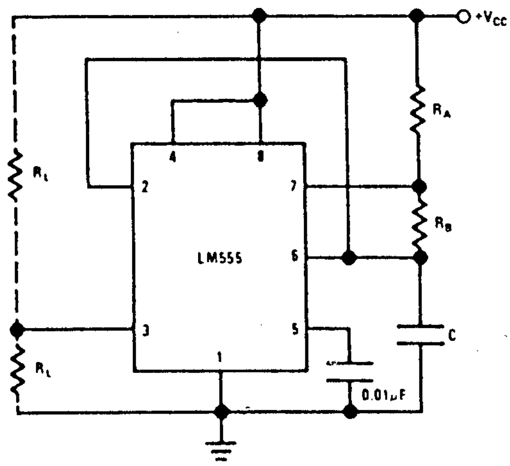

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FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.