DESIGN AND CONSTRUCTION OF A CAR BATTERY STATE INDICATOR

BY

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ELECTRICAL AND COMPUTER ENGINEERING

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A PROJECT REPORT SUBMITTED IN PARTIAL

FULFILMENT OF THE REQUIREMENT FOR THE

DEGREE OF BACHELOR OF ENGINEERING [B. ENG.]

AT

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

NIGER STATE, NIGERIA.

NOVEMBER, 2004.

CERTIFICATION

This is to certify that this project was carried out by **ALLI MARIAM** of the Department of Electrical and computer Engineering of the Federal University of Technology Minna under the Supervision of Dr. Y. A. Adediran for the award of Bacholor of Engineering (B. ENG.).

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EXTERNAL EXAMINER

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DATE

DECLARATION

I hereby declare that this project report is an original work of mine and has never been presented in any form for the award of a Bachelor degree or Diploma Certificate. All information derived from published and unpublished works have been duly acknowledged.

.... ALLI MARIAM 98/6876EE

.... DATE

DEDICATION

"A friend may well be reckoned the master piece of nature"

I couldn't agree more with Ralph Waldo Emerson.

My friend....

"She who truly knows me
Sometimes completely unworthy
I feel of this Angel
Who always guards me
Even in the subtlest of ways
If ever I find myself an ingrate
That it seemed that I had nothing to
Glorify Him, my Maker for
Then reason enough is she
To give thanks
With my every breath
Until the last".

Pras mangha "Oh pat!", this one's for you.

ACKNOWLEDGEMENT

Bismillahi - Rahmani - Raheem,

Praise be to Allah, the Exalted, Lord of the worlds, the Ever Living, the One who sustains and protects all that exists.

I am eternally grateful to my parents, Alh. And Mrs. J.M Alli for their love, care and most of all their understanding. Thanks mum and dad, you are the best. Tale, thanks love, for your support and for putting up with me when I was unbearable, which was pretty often. Mihru, for the laughter that never fails to bring out the sun on cloudy days, I thank you. Thank you N.A.S. for going with me on the search for the almost elusive BF 496.

To Engr. Onyejiuwa A. A, NAMA HQ my profound gratitude for helping to track down BF 496.

My appreciation, to my supervisor, Dr. Y. A. Adediran, H.O.D., Engr. M.D. Abdullahi, Lecturers and the department knows no bounds.

Papi, my dearest, thank you. Not only for holding me when I cried but for allowing me cry.

Amina, Mora, Musa Bawa, Adamu M. Z. (Engr), Lehmullah, Tope, Bobo, Dede J., O. Z., Abdumaru, Sade and Myra. Friends indeed you all are. Thank you for being there in my time of need.

ABSTRACT

The car battery state indicator is designed to show the state of the car battery from when the car ignition is turned ON all through driving.

This project is preset to show four voltages: 11.5V, 12.5V, 13.5V and 15.2V. These voltage levels indicate low battery, not charging, insufficient charging and over charging state respectively of the car battery.

The circuit uses an integrated circuit, a quad comparator, which compares the battery voltage with a fixed reference voltage. Each comparator works independently and its corresponding LED (Light Emitting Diode) comes on when the battery voltage connected to its input exceeds a certain value.

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CHAPTER ONE

1.0. INTRODUCTION

Our contribution to the society is sometimes fuelled by personal experience, complemented by the knowledge of a particular field of study.

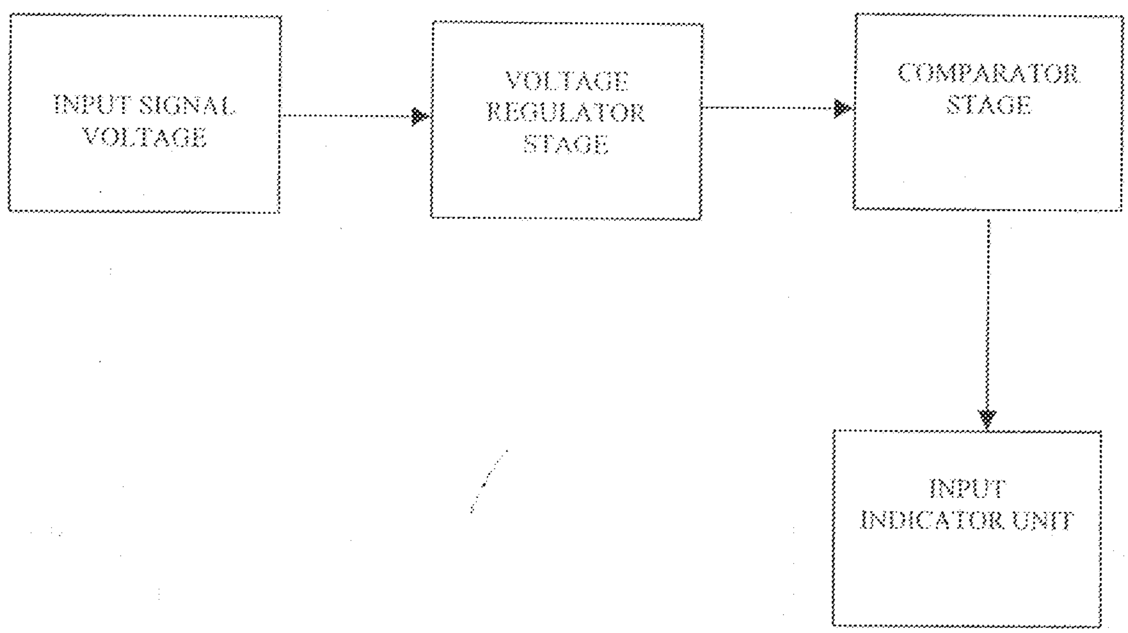
Observing most cars today, provision is not made to observe the state of the car battery without which the car is useless. All one can tell about one's battery from the dash board indicator is that the battery is weak.

This project is designed to show four voltage levels which indicate low, not charging, insufficient charging and over charging states of the battery respectively. It basically involves comparing the battery voltage with the reference voltage.

The main IC used is a quad-comparator which has four comparators integrated in it. Each comparator works independently and its corresponding LED (light emitting diode) comes on when the battery voltage connected to its input exceeds a certain value. The reference signal is a fixed voltage achieved by variable resistor at the negative input of the comparator.

This project therefore enables one to know the condition of the car battery from when one turns on the ignition all through driving. It helps to pin point the problem with the car battery or the car battery charging circuit. It is easier and comforting to actually know the state of one's car battery as one drives. This project can be implemented in all vehicles.

1.1. GENERAL BLOCK DIAGRAM



The input signal is the voltage from the battery, this voltage is regulated at this stage. This stage provides the reference voltage. The voltage regulator stage consists of zener diode, transistors, resistors, capacitor and a variable resistor.

The regulated voltage is fed to the four comparator (A,B,C,D) which make up the comparator stage. Of these, comparator A is used for low battery indication, B for not charging, C for insufficient charging and D for over charging.

Each comparator compares the battery voltage fed into it with the reference voltage. When the battery voltage is low, the comparator's output also goes low and lights the corresponding LED which comprises of the indicator unit.

1.2. DESIGN SPECIFICATIONS

Input voltage: 11.5V, 12.5V, 13.5V and 15.V

Supply voltage: 12V (D.C)

Regulated Voltage: 8V (D.C)

Display Board: 100 X 100mm LED BOARD

CHAPTER TWO

2.0. LITERATURE REVIEW

The voltage across the terminals of a battery that requires recharging should not be allowed to drop below a certain minimum voltage. The moment that happens, the battery should be put on charge. It would be impractical to install a meter and keep watching the battery voltage. Electronic circuit have been developed that can keep a continuous watch on the battery voltage and either give an audio / visual alarm, or switch off the load on battery, or switch on the charger as soon as the battery voltage drops below a predetermined voltage. These circuits are called monitoring circuits. The primary requisite of all monitoring circuit is that they themselves should not draw excessive power from the battery and drain it off.

On August 16, 2003. Domie James a free lance circuit engineering designer, who has designed and constructed a lot of functional electronic circuits, deigned a low battery indicator whereby he employed the use of LM741 Op-Amp, 3 Resistor (2 of which were IKΩ and the third 100Ω), Zener diode 5.1V and LED. Once battery voltage drops below a certain value the LED is illuminated.

Dallas Semiconductor Company, America on February3, 2003 designed a low battery indicator that uses a low powered CMOS integrated circuit, an inexpensive comparator with shutdown capability in a 6 - pin SC70 package. It remains in shutdown while the battery voltage is at normal operative levels, but asserts low battery out put when battery voltage falls below a preset threshold; to provide a LED visual indication of a low battery condition without excessive battery current drain. This achieved by pulsing the LED at a low frequency and low duty circle and conserving battery current in the off cycle by placing comparator in shutdown.

This project does not differ much in that it is also a voltage monitoring circuit. But it specifically monitors the voltage levels of a car battery. The car battery state indicator is preset to show four voltages: 11.5V, 12.5V, 13.5V, and 15.2V these voltage levels respectively indicate low battery, not charging, insufficient charging and over charging states respectively of the car's battery. The circuit uses an integrated circuit LM339 which has four comparators in one package. Each comparator works independently and its corresponding LED comes on when the battery voltage connected to its input exceeds a certain voltage. The voltage values are preset by independent potentiometers. A common source of voltage reference is used for all comparators.

2.1 COMPONENTS REVIEW

Comparator:

A comparator is a circuit that compares an input voltage with a reference voltage. The output of the comparator then indicates whether the input signal is either above or below the reference voltage.

Operational amplifiers (Op-Amp) and comparators look similar. They even have very similar schematic symbol, the comparator uses open loop voltage gain to control it. It has a differential analogue input and a digital out put. The comparator has no feedback. Fig. 2.1 is the top view schematic of LM339 IC.

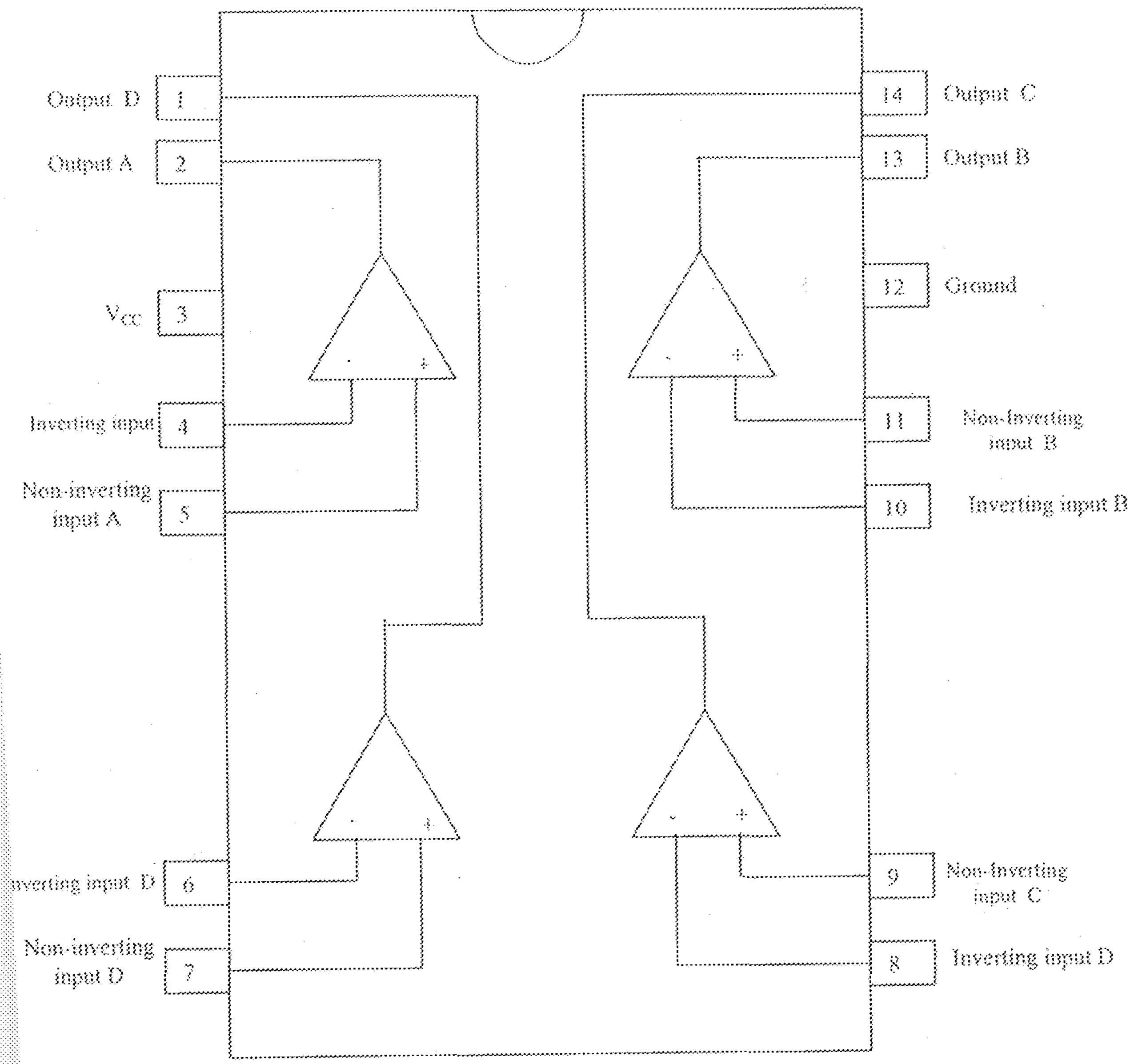


Fig. 2.1: *Front view schematic of LM339.*

2.2. OPERATIONAL AMPLIFIER (OP-AMP)

An operational amplifier IC is a solid state integrated circuit that uses external feed back to control its function. It is one of the most versatile device in all electronics. The term "Op-Amp" was originally used to describe a chain of high performance D.C amplifiers that was used as a basis for analogue type of computers long ago. The very high gain Op-Amp IC's of our days uses external feedback network to control responses. The Op-Amp without any external devices is called "Open loop" mode referring actually to the so-called "Ideal" operational amplifiers with infinite open loop gain, input resistance, band with and a zero output resistance. However, in practice no Op-Amp can meet these ideal characteristics.

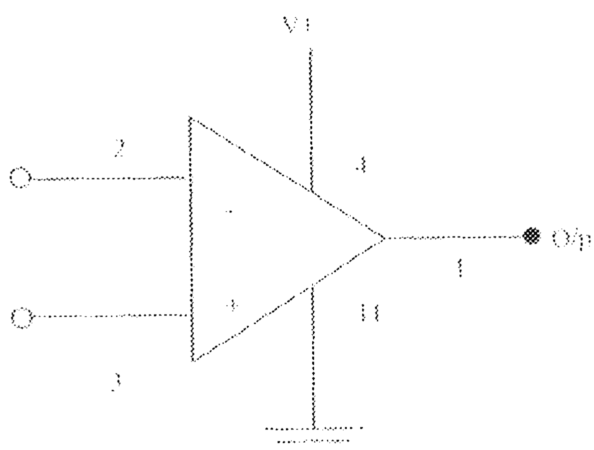


Fig. 2.2: *Schematic representation of Operational Amplifier*

2.3. TRANSISTOR

Transistors are active component used basically as amplifiers and switches. The two main types of transistor are the bipolar function transistor (BJT) where operations depends on the flow of both minority and majority carriers and the unipolar or field effect transistor (FET) in which current is due to majority carriers only (either electrons or holes).

The transistor as a switch operates in class A mode in this mode of bias, the circuit is designed in such a way that current flows without any signal present. The value of bias current is either increased or decreased about its mean value by the input signal (if operated as an amplifier) or ON and OFF by the input signal if operated as a switch.

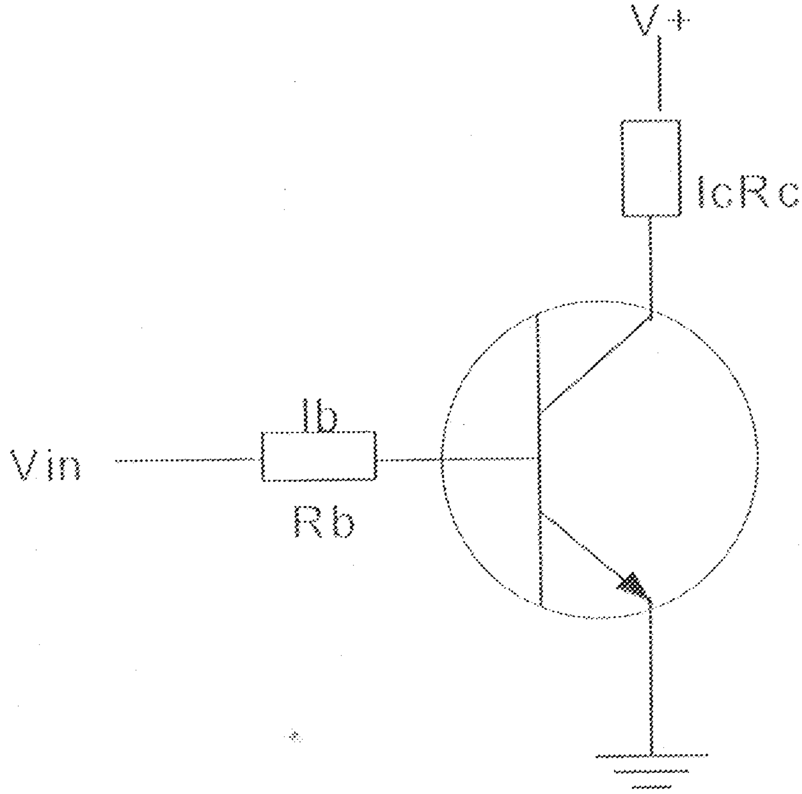


Fig. 2.3

For the transistor configuration, since the transistor is biased to saturation .

Vce = 0 when the transistor is on which implies that

UF = $I_C R_C$ + Uce

Vin = $I_B R_B$ + VBE

Ic/Ib = hfE

$$R_b = \frac{V_{in} - U_{BE}}{I_b}$$

Where,

I_C = Collector current

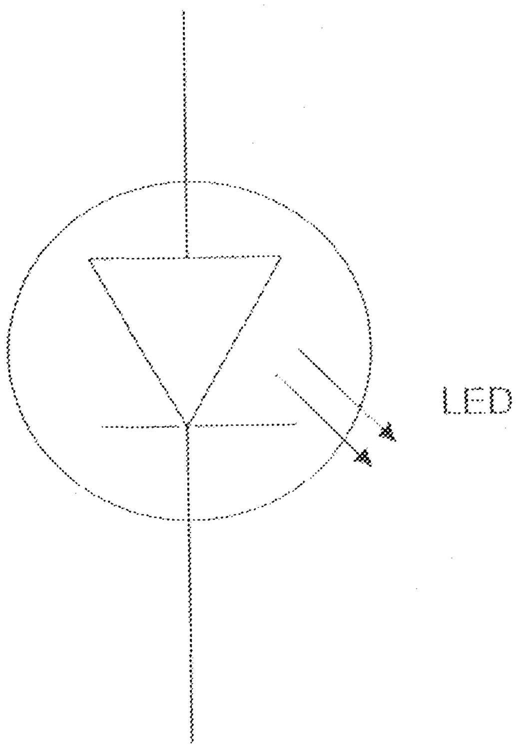
I_b = base current

V_{in} = Input voltage

V_+ = Supply voltage

H_{fe} = current gain

2.4. LIGHT EMITTING DIODE (LED)



The LED is a pn function device that emits light when based in a forward direction. They are frequently used, as pilot light in electronic appliances to indicate whether the circuit is closed or not. The light emitted can either be invisible (Infra-red) or can be in the visible spectrum. The flat side of the bulb or the shortage of the two wires extending from the LED is the negative end and should be connected to the negative side of the battery. LED's operate relatively at low voltages between 1 to 5 volts and draws current of about 10 to 50 milli-amps. Voltages and currents substantially above this values can melt a LED chip. The LED has two region separated by a junction. The P region is dominated by the positive changes and the n region by negative charge. When the voltage is applied the current start to flow, electron in n-region has sufficient energy to move across into the P-region. Once in the P-region the electrons are immediately attracted to the charges due to the mutual Coulomb force of attraction between opposite electric charges. Each time an electron recombine with a positive charge, electric potential energy is converted into electromagnetic energy. A quantum of electromagnetic energy is emitted in the form of photon of light. Different coloured LED's emit light predominantly of a single colour.

2.5. OTHER PASSIVE COMPONENT

Passive components are components, which cannot amplify power and require an external power source to operate. They include resistors, indicators, transformers, capacitors etc. Their application range from potential dividers to current control (an in resistors), filtration of ripple voltages and unwanted a.c. voltages (as in capacitors). They form the elements of the network circuit oscillator stage and are also used generally for signal conduction in circuit. Their schematics are shown below in fig. 2.5

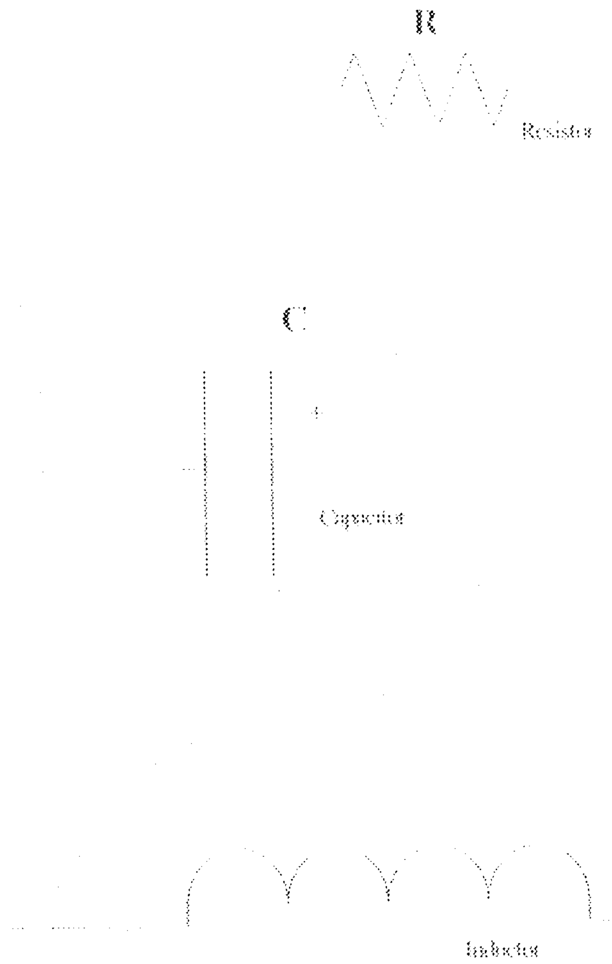
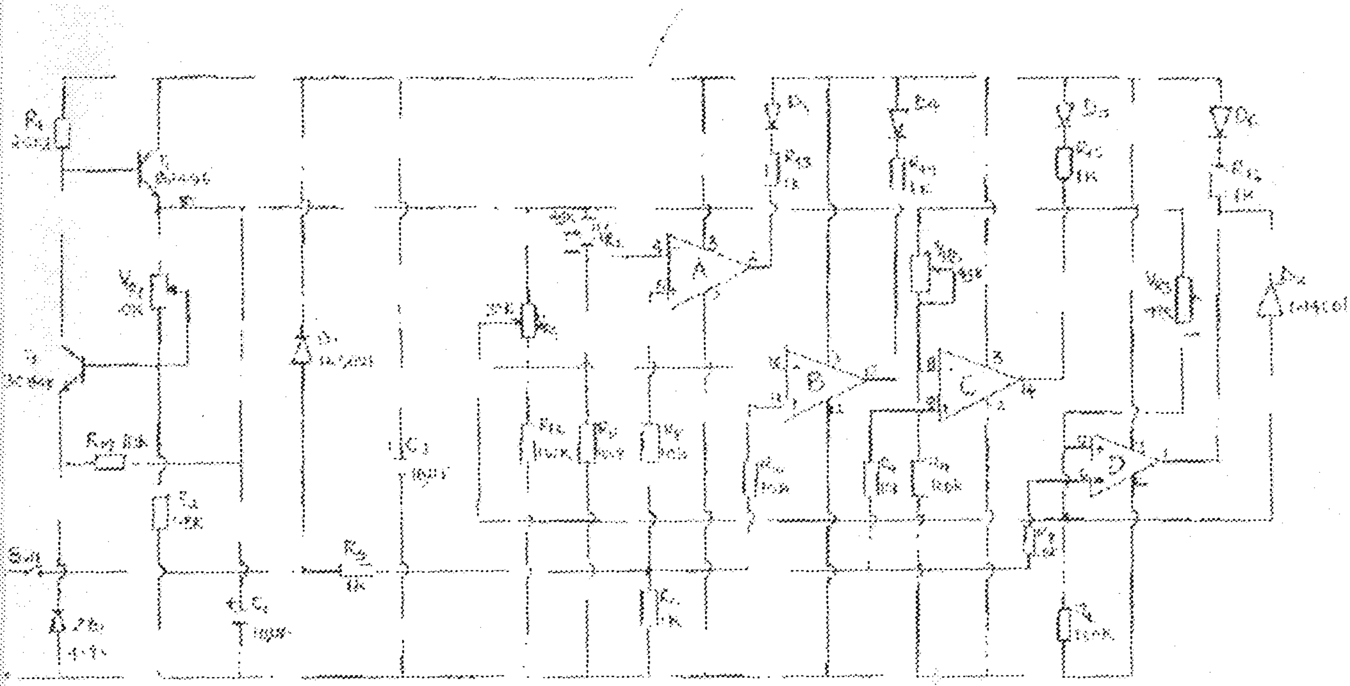


Fig 2.5: Schematic representation of some passive components.

CHAPTER THREE

3.0. PRINCIPLE OF OPERATION



The car battery state indicator is preset to show four voltages: 11.5V, 12.5V., 13.5V and 15.2V. These voltage levels indicates low battery, not charging, inefficient charging and over charging state respectively of the car battery.

The circuit uses an integrated circuit LM339 which has four comparators in one package. Each comparator works independently and its corresponding LED comes on when the battery voltage connected to its input exceeds a certain value. The voltage values are preset by independent potentiometers. A common source of voltage reference is used for all comparators. Zener diode ZD_1, transistors T_1 and T_2, Resistors R_1,R_2, and R_{10}. Capacitor C_1 and preset potentiometer VR_1 form the voltage regulator circuit which provides a contents current to the Zener diode for conduction as well as maintains a steady output voltage at the emitter of T_1. The value of the voltage is adjusted by VR_1. In this case it is set to give 8 volts. Diode D_1 supplies the operating power to the IC directly from the battery. It also protects IC from accidental reverse connections of the battery.

The regulated voltage is fed to the four comparators A,B,C and D in IC. Of these comparator A is use for low battery indication, B is for not charging, C is for insufficient charging and D for over charging. The corresponding indicting LED's are D_3, D_4, D_5, D_6.

The battery voltage is divided by voltage divider R_3 and R_4 and is applied to input pins of the comparators via R_7, R_8, R_9, R_{10}. This voltage is fed to be the non-inverting input of the comparators. As long as the input voltage at the comparators non-inverting (+) input terminal remains higher than the reference voltage, the corresponding LED remains extinguished. When the battery is low, the comparators out put also goes low and lights the corresponding LED.

In the case of comparators D. The connection to its input pins 6 and 7 are reversed ie. The reference voltage is applied to the non-inverting (+) input while the battery voltage is applied to the inverting (-) input terminal therefore when the battery voltage exceed the reference voltage the associated LED glows. This condition is coursed by a fault in the charging system.

3.1. COMPARATOR STAGE

Comparator D:

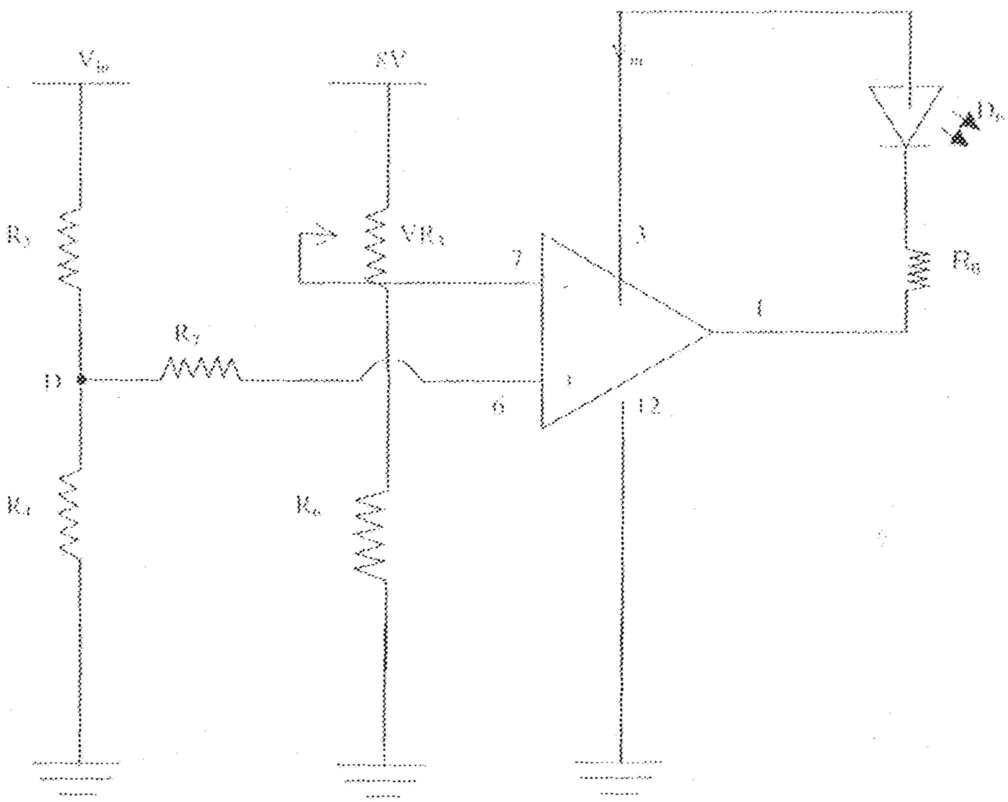


Fig. 3.0

For V_{R3} = 10K, R_6 = 100K

Voltage at pin 7, ie. the non-inverting pin

$$V_7 = \frac{R_6 \times 8}{R_6 + V_{R3}} = \frac{100K \times 8}{100K + 10K}$$

$$= \frac{800K}{110K}$$

$$= 7.3V$$

The difference voltage of comparator D is 7.3V since comparator D is for overcharging state for $R_7 // R_4$

$$R_{T1} = \frac{R_7 R_4}{R_7 + R_4} = \frac{1K \times 10K}{1K + 10} = \frac{10M}{11K}$$

$$= 909.1\Omega$$

$$R_{T1} = 1K$$

$$V_D = \frac{V_{in} \times R_{C1}}{R_{T1} \times R_3} = \frac{15.2 \times 1K}{1K + 1K} = \frac{15.2K}{2K}$$

$$= 7.6V$$

V_6 = Voltage in the inverting input 6.

$$= \frac{R_7 \times V_D}{R_7 + R_3} = \frac{10K \times 7.6K}{10K + 1K} = \frac{76K}{11K}$$

$$= 6.91V$$

$$V_6 = 6.91V$$

But reference voltage was calculated to be 7.3V.

i.e. $7.3 - 6.91V = 0.39V \approx 0V$.

The battery voltage exceeds the reference voltage hence the corresponding LED comes ON.

Also $V_D = V_{in} - V_{R15} = 15.2 - I_f \times R_{15}$.

I_f = Forward current of the diode ≈ 10mA

$$\Rightarrow R_{16} = \frac{V_{in} - V_D}{I_f} = \frac{15.2 - 1.7}{10 \times 10^{-3}}$$

$$= 1.35 \times 10^3 = 1.4K\Omega$$

Preferred value of 1K was used for R_{16}.

3.2 Comparator A

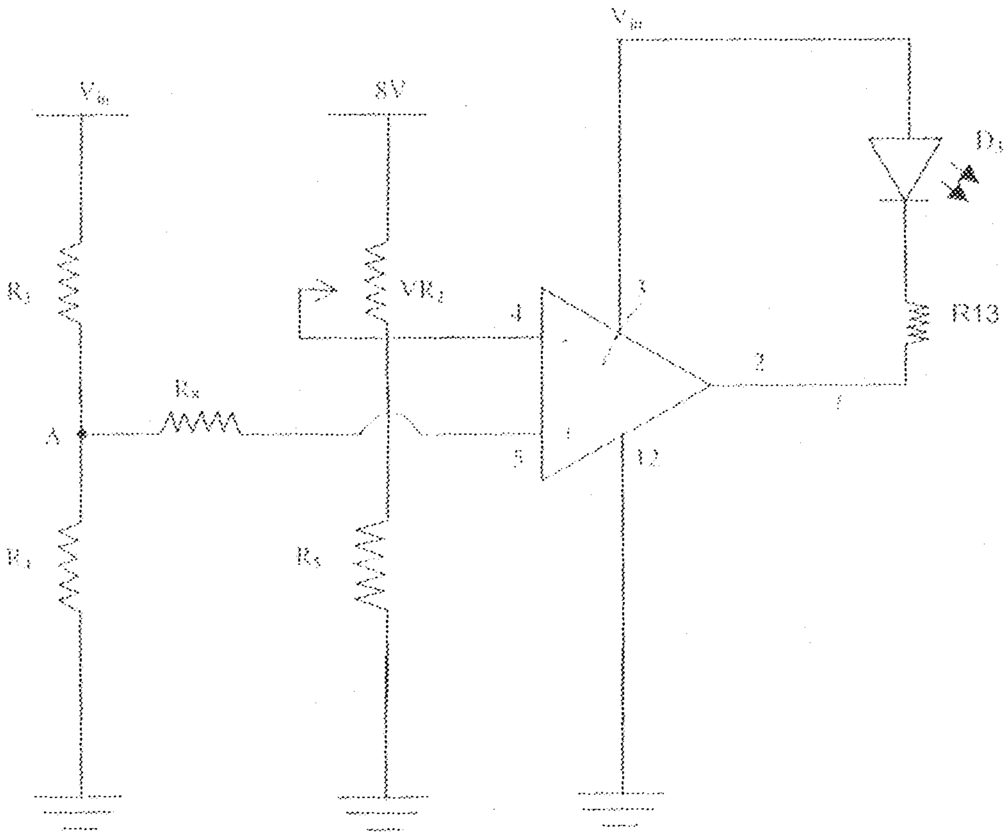


Fig. 3.1

For V_{R2} = 47K, R_5 = 100K

Voltage at the inverting input (pin 4) is

$$V_4 = \frac{R_5 \times 8}{R_5 + V_{R2}} = \frac{100K \times 8}{100K + 47K}$$

$$= 5.44V$$

i.e the reference voltage of comparator A is 5.44.

Since comparator A is used for low battery state, i.e when car

battery is at 11.5V

for $R_8 // R_4$ = R_{T2}

$$R_{T2} = \frac{R_8 \times R_4}{R_8 + R_4} = \frac{1K \times 10K}{1K + 10} = \frac{10M}{11K}$$

$$= 909.1\Omega$$

$$R_{T2} \approx 1K\Omega$$

$$V_A = \frac{V_{B} \times R_{T2}}{R_{T2} \times R_3} = \frac{11.5 \times 1K}{1K + 1K}$$

$$= 5.75V$$

V_5 = Voltage in the non-inverting input 5.

$$= \frac{R_8 \times V_A}{R_8 + R_3} = \frac{10K \times 7.75K}{10K + 1K} = \frac{57.5K}{11K}$$

$$V_5 = 5.23V$$

Reference voltage i.e. voltage at the inverting input was calculated to be 5.44V.

Therefore, 5.23 – 5.44V = -0.21V ; which implies low output. Hence, as compared with the V_{in}, the LED comes ON.

Also $V_D = V_{in} - V_{R14} = 11.5 - I_f \times R_{14}$

But I_f = forward current of the diode ≈ 10mA

$$\Rightarrow R_{14} = \frac{V_{in} - V_D}{I_f} = \frac{11.5 - 1.7}{10 \times 10^{-3}}$$

$$= \frac{28 \times 10^3}{10}$$

$$= 0.98 \times 10^3 \approx 1K\Omega$$

Preferred value of 1KΩ was used for R_{13}.

3.3 Comparator C:

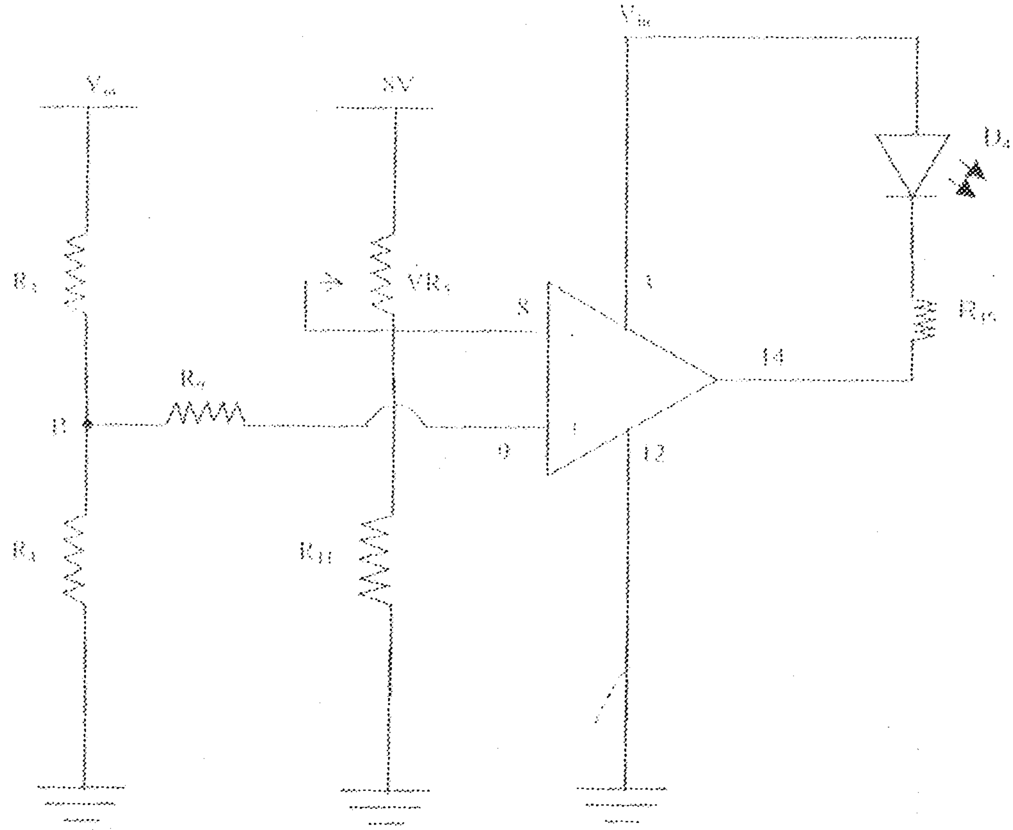


Fig. 3.2

For $V_{R5} = 47K$, $R_{11} = 100K$

Voltage at inverting input (pin 8) is

$$V_8 = \frac{R_{11} \times 8}{R_{11} + V_{R3}} = \frac{100K \times 8}{100K + 47K}$$

$$= \quad 5.44V$$

The reference voltage of comparator C is 5.44 since comparator C is for insufficient charging state; when the car battery is at 13.5V

for $R_9 // R_4 = R_{T3}$

$$R_{T3} = \frac{R_9 R_4}{R_9 + R_4} = \frac{1K \times 10K}{1K + 10} = \frac{10M}{11K}$$

$$= 909.1\Omega$$

$$R_{T3} = 1K$$

$$V_C = \frac{V_{in} \times R_{T3}}{R_{T3} + R_3} = \frac{13.5 \times 1K}{1K + 1K} = \frac{15.2K}{2K}$$

$$= 6.75V$$

V_9 = Voltage in the inverting input 9.

$$= \frac{R_9 \times V_C}{R_9 + R_3} = \frac{10K \times 6.75K}{10K + 1K} = \frac{67.5K}{11K}$$

$$= 6.14V$$

$$V_9 = 6.14V$$

But reference voltage was calculated to be 5.44.

i.e. $5.44 - 6.14V = -0.70V \approx 0V$.

The battery voltage exceeds the reference voltage hence the corresponding LED comes ON.

Also $V_C = V_{in} - V_{R15} = 13.5 - I_f \times R_{15.}$

I_f = Forward current of the diode $\approx$ 10mA

$$\Rightarrow R_{15} = \frac{V_{in} - V_C}{I_f} = \frac{13.5 - 1.7}{10 \times 10^{-3}}$$

$$= 1.2 \times 10^3 = 1.2K\Omega$$

Preferred value of 1K was used for R_{15}.

3.4 Comparator B

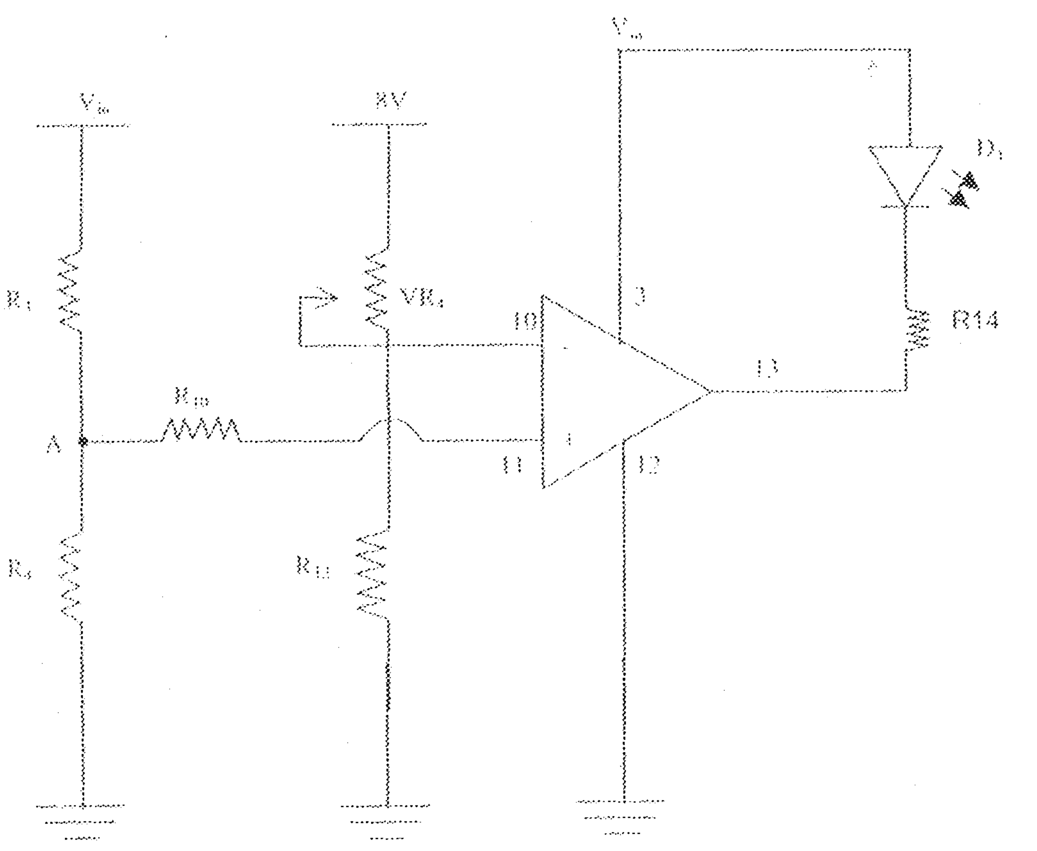


Fig. 3.1

For V_{R4} = 22K, R_{12} = 100K

Voltage at the inverting input (pin 10) is

$$V_{10} = \frac{R_{12} \times 8}{R_{12} + V_{R4}} = \frac{100K \times 8}{100K + 22K}$$

$$= 6.56V$$

i.e the reference voltage of comparator B is 6.56.

Since comparator B is used for not charging state, i.e when car battery is at 12.5V

for R_{10} // R_4 = R_{T4}

$$R_{T4} = \frac{R_{10} \times R_4}{R_{10} + R_4} = \frac{1K \times 10K}{1K + 10} = \frac{10M}{11K}$$

$$= 909.1\Omega$$

$$R_{T4} \approx 1K\Omega$$

$$V_B = \frac{V_{in} \times R_{T4}}{R_{T4} + R_3} = \frac{12.5 \times 1K}{1K + 1K}$$

$$= 6.25V$$

V_{11} = Voltage in the non-inverting input 11.

$$= \frac{R_{10} \times V_B}{R_{10} + R_3} = \frac{10K \times 6.25K}{10K + 1K} = \frac{62.5K}{11K}$$

$$V_5 = 5.68V$$

Reference voltage i.e. voltage at the inverting input was calculated to be 6.56V.

Therefore, 6.25 – 6.56V = -0.31V ; which implies low output. Hence, as compared with the V_{in}, the LED comes ON.

$$\text{Also } V_{in} = V_D + V_{R13} = V_D + I_f \times R_{13}.$$

$$\text{But } I_f = \text{forward current of the diode} \approx 10mA$$

$$\Rightarrow R_{14} = \frac{V_{in} - V_D}{I_f} = \frac{12.5 - 1.7}{10 \times 10^{-3}}$$

$$= 1.08K\Omega \approx 1K\Omega$$

Preferred value of 1KΩ was used for R_{14}.

CHAPTER FOUR

TESTING AND CONSTRUCTION

4.0. TESTING

The physical realization of project is very vital. The designed on paper and analysis were carried out; the project was therefore implemented and tested to ensure its working ability and was finally constructed to meet desired specification. The process of testing and implementation involved the use of some equipment stated below.

i. **Bench Power Supply:** This was made to supply voltage to various stages of the circuit during the breadboard test before battery power supply in the circuit. Also during the soldering of the project, the power supply was still used until the project was finaly installed.

ii. **Oscilloscope:** The oscilloscope can be used to observe in the ripples in the power supply wave form and to ensure that all wave form are correct and their frequencies are accurate. The waveform of the comparator output was checked to see if there were any hysterisis signals.

iii. **Digital multi-meter:** The digital multi-meter basically measures voltage, resistance, continuity, current, frequency, temperature and transistor h_{fe}. The process implementation of the design and the board required the measurement of parameters like voltage, continuity, resistance and in some cases frequency measurement. The digital multi-meter was used to check the various voltage drop at all stages in the project and most importantly the output of each of the comparators as well as to check the reference voltage in each of the comparators circuit. Also the multi meters was used to trouble short during soldering and coupling.

3.1. IMPLEMENTATION

The implementation of this project was done on the bread board. The power supply was just derived from a bench power supply in the university electronics laboratory. To confirm the workability of the circuit before the battery power supply was installed.

Stage by stage testing was done according to the block representation, on the breadboard before soldering of components commenced on vero-board. The various circuit and stage were soldered to meet desired workability of the project. For proper understanding of how the circuit operates, the pin configuration of the IC LM339 is shown in fig 2.1.

4.2. CONSTRUCTION

The construction of the project was done in the different stages; the soldering of the circuit components and the casing.

The comparator circuit was first soldered before the display (LEDs) and the voltage regulator circuit. The soldering was done on a vero board. The layout of components is shown in fig 4.1

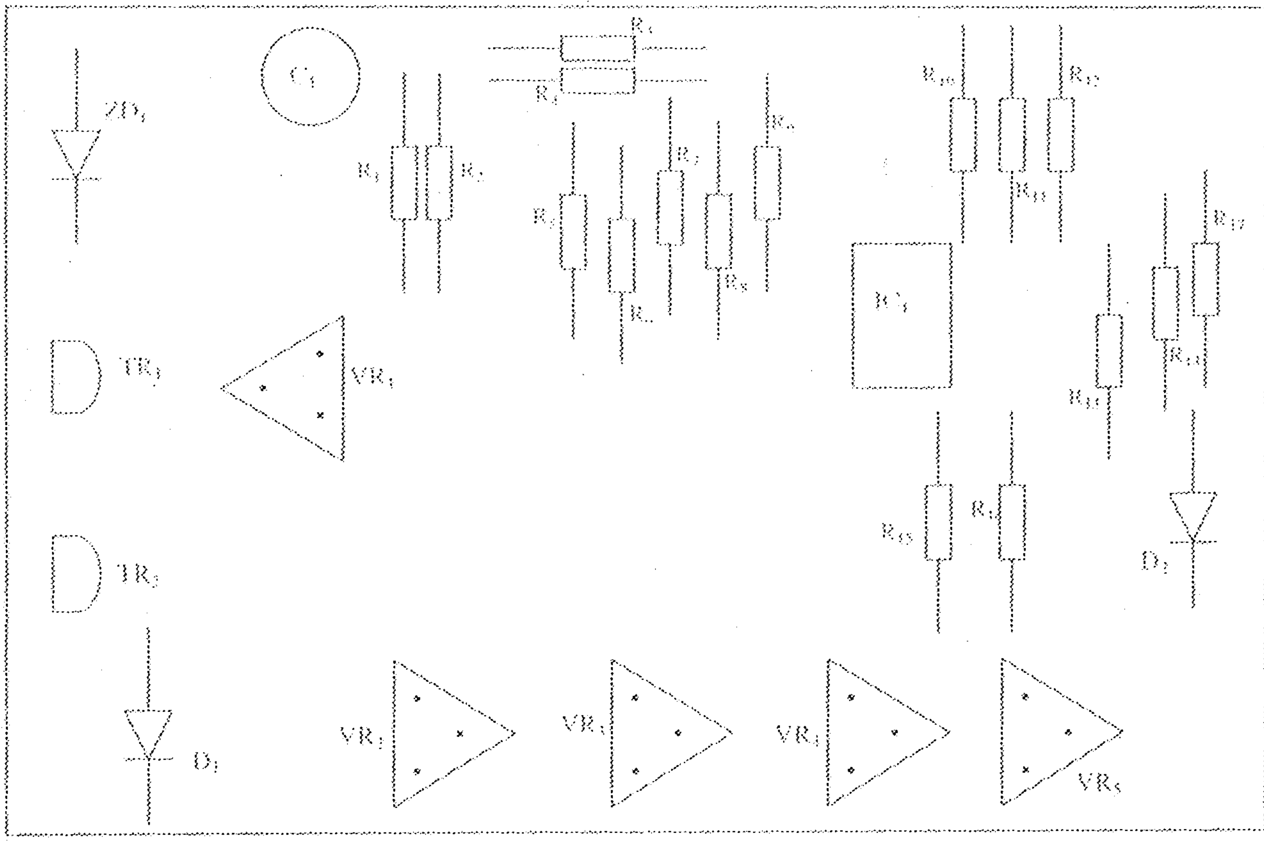


Fig. 4.1: *Components layout on vero-board*

IC_1	LM 339
ZD_1	Zener diode (4.7V)
TR_2	BC 548
TR_1	BF 496
D_1, D_2	IN 4001
VR_1 VR_3	10KΩ

VR_5	22KΩ
C_1, C_2	10μF
R_1	10KΩ
R_2	1.5KΩ
R_3, R_4, R_{13}, R_{15}, R_{16}, R_{17}	1KΩ
R_5, R_6, R_{11}, R_{12},	100KΩ
R_7, R_8, R_9, R_{10},	10KΩ

The second phase of the project construction is the casing. This project was coupled to a metal casing. The casing material being stainless steel designed with special perforation and vents to ensure that the system does not over heat.

.3. PROBLEMS ENCOUNTERED

Several problems were encountered during this project. The problem range from design problems to implementation problem and also construction problems. The major problems are as follows:

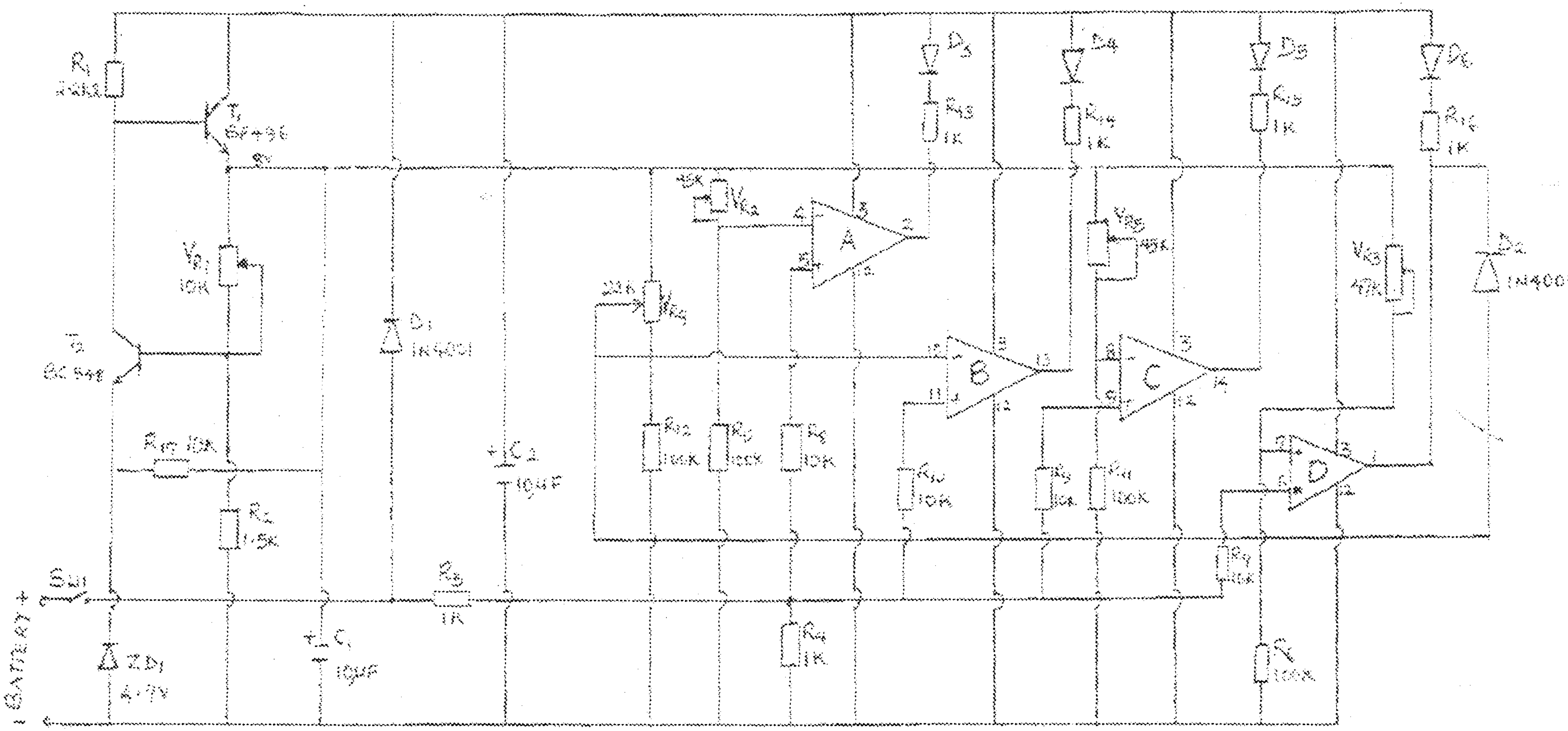
i. Two LEDs came on when the battery was first connected. This was the first design challenge the project posed. This was solved by adjusting the variable resistors especially VR1.

ii. The output from the first comparator was high which ought to be low, this was due to a broken variable resistor which was replaced thereby resolving the problem.

iii. Calculated values for components were replaced with preferred values, which were used though this caused drift in output of the comparators but these drifts were negligible since they were within range and did not affect the indicators.

iv. Taking serious care in construction of the project solved soldering and measurement error.

4.4: COMPREHENSIVE CIRCUIT DIAGRAM



4.5 COMPONENTS LIST

IC_1	LM 339 (Quad comparator)
ZD_1	Zener diode (4.7V)
TR_2	BC 548
TR_1	BF 496
D_1, D_2	IN 4001 (Diode)
VR_1 VR_3	10KΩ (Variable resistor)
VR_2, VR_4	47KΩ (Variable resistor)
VR_5	22KΩ (Variable resistor)
C_1, C_2	10μF (Capacitor)
R_1	2.2KΩ (Resistor)
R_2	1.5.KΩ (Resistor)
R_3, R_4, R_{13}, R_{15}, R_{16}, R_{17}	1KΩ (Resistor)
R_5, R_6, R_{11}, R_{12},	100KΩ (Resistor)
R_7, R_8, R_9, R_{10},	10KΩ (Resistor)
D_3, D_4, D_5, D_6	Light Emitting Diode (LED)

CHAPTER FIVE

CONCLUSION RECOMMENDATION

5.0. CONCLUSION

This project which is the design and construction of a car battery state indicator was designed considering some factors such as economy, availability of components and research materials efficiency, compatibility and portability also durability.

The performance of this project after testing met design specification. The general operating of the project and performance is dependent on the presence of the battery and also the stage of the battery. The operation is also dependent on how well the soldering is also done and the positioning of the components on the vero-board. The IC and the variable resistors were soldered away from the battery position to prevent heat radiation which, might occur and affect the performance of the entire system.

The construction was done in such a way that it makes maintenance and repairs an easy and affordable task for the user should there be any breakdown. All components were soldered on one vero-board, which makes troubleshooting easy.

This project provided exposure to digital electronics and practical electronics in general. The design of the car battery state indicator involves research in both digital and analogue electronic. Intensive work was done on comparators, batteries and cells.

I wish to thank the department, my supervisor(s) and project co-ordinator for giving me the opportunity to carry out this project. However, like every aspect of engineering there is still room for improvement and further research in the project as suggested in the recommendation below.

5.1. RECOMMENDATIONS

Areas of recommendation for further research are as follows.

i. A digital display could be designed and incorporated within the circuit to show values of the voltage states.

ii. Software of the design would enable further research and improvement of the system.

iii. The car battery state indicator could be made with audio facilities to enable the state of the car battery be heard to avoid distraction during driving.

iv. The department should acquire more books to aid research in the departmental library.

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