DESIGN CONSTRUCTION AND TESTING OF A RAPID LIGHT CHANGE PROXIMITY DETECTOR SWITCH

BY

OBOTEE STEPHEN OJEMROAYAKIE
MATRIC NO 93/3925EE

OF

DEPARTMENT OF ELECTRICAL COMPUTER ENGINEERING.
SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA. NIGER STATE

SUBMITTED TO THE DEPARTMENT OF ELECTRICAL
AND COMPUTER ENGINEERING
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF A BACHELOR DEGREE
IN ELECTRICAL COMPUTER ENGINEERING

DECEMBER, 2000.

CERTIFICATION

I hereby certify that this project work was carried out by Mr Obotee Stephen of the Department of Electrical/Computer Engineering, Federal University of Technology, Minna, Niger State, Nigeria.

H.O.D'S ...s signature Date

Supervisor's signature Date

External Examiner's sign 17/1/2001 Date

DEDICATION

This project work is dedicated to the lord Almighty, my brother Mr. S. Obotee and my beloved Sister Mrs. Juliet Okitiakpe.

ACKNOWLEDGEMENT

First and foremost, I acknowledge the special work of the lord for the guidance and protection which he has been giving to me. For if not for the lord's sake, I wouldn't have lived to see and construct this project.

Secondly, special thanks goes to my project supervisors Engr. Kenneth Pinne, Engr. A Shehu and our Head of Department Dr. Engr. Y.A. Adediran for the untiring efforts which they have made during the project building, testing and in the writing of the associated report.

My greatest gratitude goes to my brother Mr. Samuel Obotee and sister Mrs. Juliet Okitiakpe, for the financial backing which they have been giving to me.

Also, I owe my colleagues in struggle Mr Emegere Sylvester, Mr. Elisha, Mr. Egbejuma William, Mr Dim Simon and Mr. Kingsley Abiala, a series of thanks for their individual contribution to make this project work a success.

Those that contributed to this project, whose names are not mentioned here, due to space, time or the human short memory, should forgive me. The lord almighty should reward them all Amen.

TABLE OF CONTENT

CONTENT		PAGE
Title page		i
Certification		ii
Dedication		iii
Acknowledgement		iv
Table of content		v
Abstract,.		vi
CHAPTER ONE		
1.1	Introduction	1
1.2	Method of operation	2
1.3	Literature review	2
CHAPTER TWO		
2.1	Design Analysis	4
2.2	Design Calculation for the sensor	4
2.3	Design Calculation for the comparator circuit	5
2.4	The pin layout of µA741	6
2.5	The internal Architecture of µA741	6
2.6	Design calculation of the alarm circuit	7
2.7	The internal architecture of 4011B	9
CHAPTER THREE		
3.1	Construction and testing	10
3.2	System circuit diagram	
3.3 and 3.4	Systems schematic diagram	
3.5	Suggestions on how to improve on this project	16
3.6	Mechanical construction diagram.	17
CHAPTER FOUR		
4.1	Conclusion	18
4.2	Recommendation	18
	Reference	19
	Appendix	20

ABSTRACT

This project work concentrates on the design, construction and testing of a rapid light change proximity detector switch.

The switch uses a photocell as its sensor. The sensed signal is sent to an amplifier. The resultant signal from this circuit is rectified. The rectified version of this signal is used to bias a transistor. This causes a relay contact to make. Hence triggering the appropriate circuit into conduction.

The circuit could be used in intruder alarm systems or in certain other application where proximity detection is required.

CHAPTER ONE

1.1 INTRODUCTION

The rapid light change proximity detector switch is better described than defined. It is a kind of circuit that is used to trigger another circuit. The circuit uses a photocell as its sensor. It is not a light operated switch of the type which responds to some particular ambient light level. It differs from the common proximity switches in that while it uses a photocell as its sensing element, the common proximity detectors uses infrared rays. It will for example trigger if a torch is shone on or near the photocell or if someone passing in front of the Unit casts a shadow onto the photocell the unit on the other hand is unaffected by natural slow changes in light level.

In its simplest form it is a light change detector which uses a photoresistor. The photoresistor (photocell) is a component whose resistance increase when light falls on it. And hence creating a low resistance path for the flow of current. But when darkness falls, the behaviour is reversed. This property of the photoresistor enables it to control the flow of current into another circuit.

This simple switch can be employed in any circuit where proximity detection is the watch word. It has a wide range of safety/security applications. In the area of safety for example, the switch could be used to design a circuit that will issue a warning signal to anybody that gets close to a dangerous area. This is achieved by making the switch to operate a tape recorder or computer in which a warning signal has formerly been recorded or programmed.

In the industry it could be used to trigger a counting circuit in a bid to counting the number of items produced by a particular machine. In the area of security it could be used to trigger an alarm circuit which will serve as a warning to soldiers on guard that the enemies are close. And in residential usage it could be employed to trigger an alarm circuit which will draw the attention of the inhabitants of the house.

In the project work, the simple circuit to be triggered is the alarm ciruit.

1.1 METHOD OF OPERATION

When the shadow of someone passing in fronts of the photocell falls on the cell or when a torch light is shown on the photocell, there is a decrease on resistance of the photoresistor which causes a rapid change in the output voltage from the photocell circuit. This change in voltage will be passed to the input of the amplifier and will appear at the output. The output from the operational amplifier is coupled with a capacitor to a rectifying and smoothening circuit consisting of diodes and capacitor respectively.

When the unit is activated, the positive bias produced across the smoothing capacitor is sufficient to bias the transistor into conduction so that it energises the relay coil of the circuit which is required to be activated. In this case the circuit to be triggered is an alarm circuit.

1.2 LITERATURE REVIEW

Proximity detection has been achieved at one time or the other in the past, in various ways. Differences lies in the various forms of detecting element (sensor) or circuit used. And also on the various circuits to be triggered. The first detector that comes to mind is that which uses infra-red radiation. This is a kind of line detector. An intruder could bypass the line, knowing that there is such a detector in place. This also has a disadvantage in the sense that infra-red radiations are being absorbed by alcohol vapour.

The other form of detector known is that which uses a photoresistor (photocell). This is a form of volume detector. This has the advantage of the fact that the intruder would have to pass through the volume occupied by the beam of light which used be interrupted for the circuit to be triggered. And it cannot be absorbed by alcohol vapour. The disadvantage of this form of detector lies in the fact that it responds to some particular ambient light level. Or it may respond to natural slow changes in light level.

Now, this project is aimed at designing a detector that does not respond to natural slow changes in light level, and does not respond to light of a particular ambient light level;.

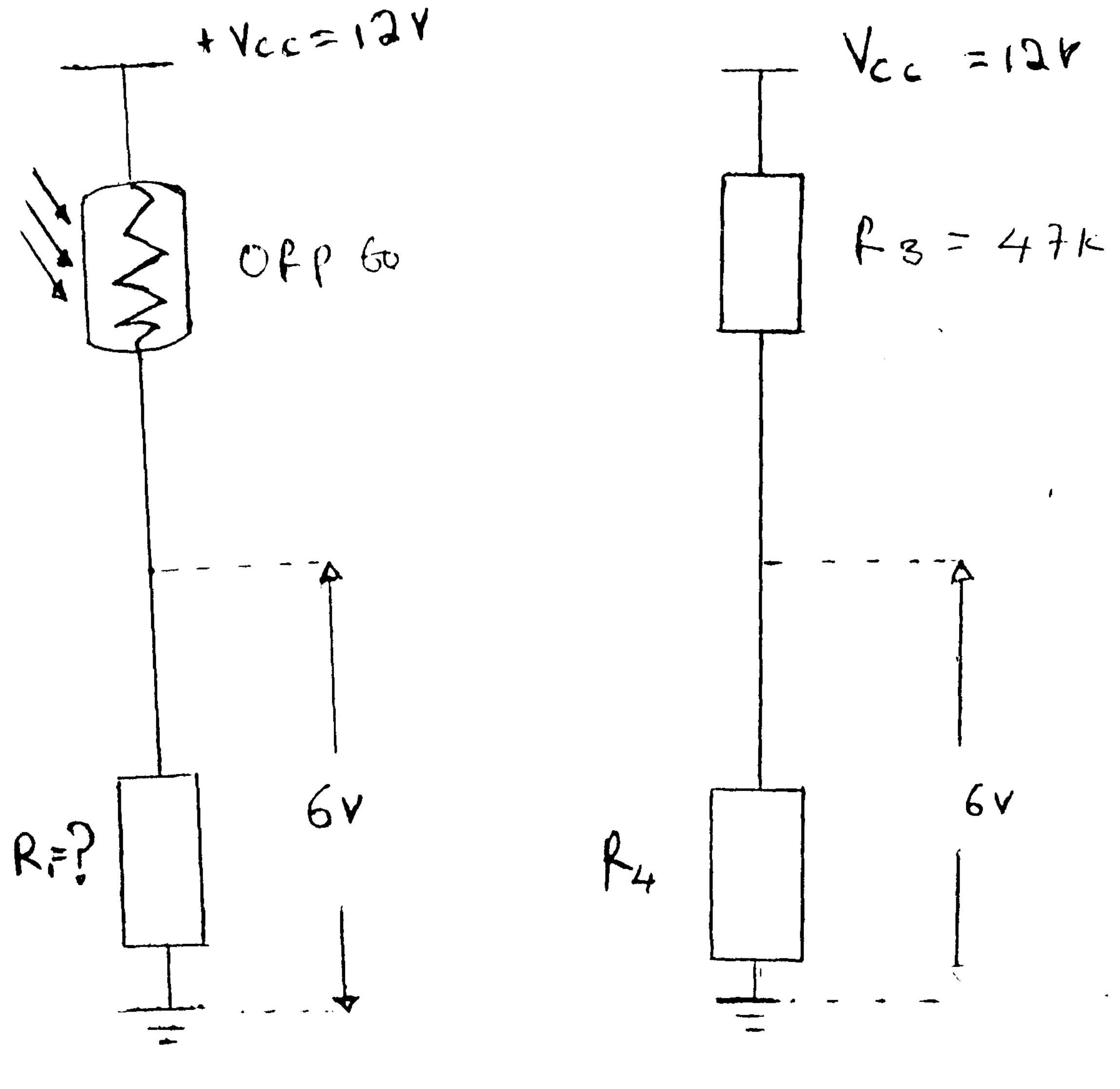


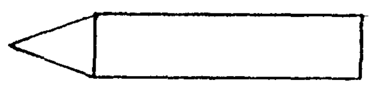
Fig 1. Photocell / potential divider circuit

CHAPTER TWO

2.0 DESIGN CALCULATION/CONSIDERATION

The art of designing is to select the most suitable solution on the basis of size, cost and performance (electronics digest, winter 1981).

2.1 DESIGN CALCULATION FOR THE PHOTOCELL (SENSOR)

Fig 1: 

photocell/potential divider Circuit.

Let the resistance of the photoresistor (photocell) = 30k

Let the reference voltage be 6V

Now with a supply voltage of 12V,

We have that from voltage divider principle (equation 3):

$$\frac{R_1}{R_1 + 30}.x12 = 6$$
$$12R_1 = 6R_1 + 180$$
$$6R_1 = 180$$
$$R_1 = 30K$$

But for reason of availability of component 27K was selected.

Also, from the diagram above;

Let R_3 = 47K

Vcc = 12V

Vref = 6V, R4 = ?

The from voltage divider principle,

$$\frac{R_4}{R_4 + 47}.x2 = 6$$
$$12R_4 = 6R_4 + 6\times 47$$
$$6R_4 = 6\times 47$$
$$R_4 = 47K$$

2.2 DESIGN CALCULATION FOR THE COMPARATOR CIRCUIT

Now for high sensibility a high gain is needed let the gain required for this design = 60dB.

Let the input resistance 'R_1' = 10k

Now from the gain relation for the operational amplifier, we have that the gain is in voltage $Av = \frac{RF}{R_1}$.

Where R_f if the feedback resistor value.

Now, from the decibel story;

XdB = 20log (gain ratio)....................[v]

Where X = gain in decibel. = 60 in this case,

gain ratio $= \frac{V_2}{V_1} = \frac{RF}{R_1}$

By substituting into equation [v],

We have that.

$$60dB = 20 \log_{10}\left[\frac{RF}{10^3}\right]$$

$$3 = \log_{10}\left[\frac{RF}{10^3}\right]$$

$$10^3 = \frac{RF}{10^3}$$

$$RF = 10^3 \times 10^3 = 10^3 = 1M\Omega$$

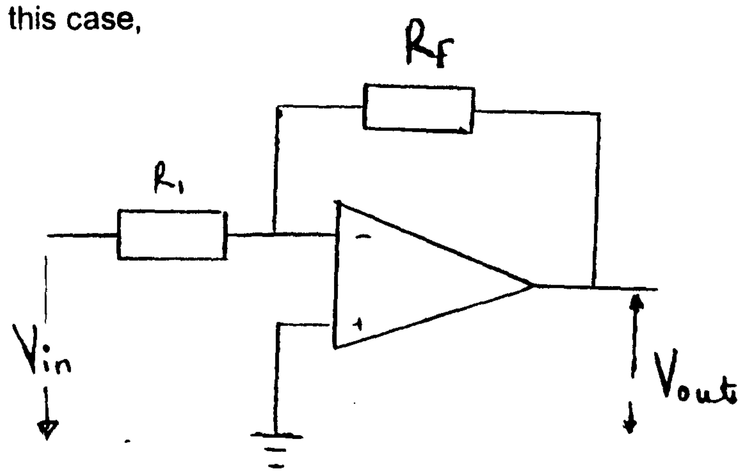


Fig 2. Operational amplifier with inverting input.

Hence the feedback resistor required to obtain this gain was chosen as 1MΩ.

The slew rate of the op-amp μA741 = 0.5

gain bandwidth = 1 to 1.5 MHZ

Noise Voltage At 1 KHZ = 20 to 50 not usually specified on data books.

Maximum current = 1.5 μA.

2.3 THE PIN LAYOUT OF μA741

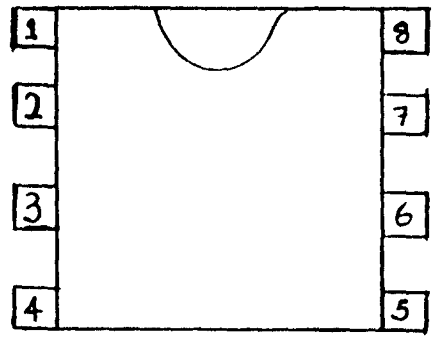


Fig 3 PIN LAYOUT of μA741

2.4 THE INTERNAL ARCHITECTURE OF μA741 IS AS SHOWN BELOW (SIMPLIFIED VERSION):

fig 4 Internal architecture of μA741

Shown above, is the simplified schematic diagram of the 741. This circuit is equivalent to the 741 and many later generation opamps. The input stage is a differential amp. Using pnp transistors (Q_1 and Q_2). To get a high CMRR, a current mirror (Q_{13} and Q_{14}) sources tail current to the different amp. Also to get a high a voltage gain possible for the diff. amp a current mirror load is used (Q_1 and Q_4). The output of the diff. amp (collector of Q_2) drives an emitter follower Q_5. This stage steps up the impedance level to avoid loading down the diff. amp. The signal output of Q_5 goes to Q_6, which is a class B driver, incidentally, the plus sign on the collector of Q_5 means that it is connected to the +Vcc supply. Similarly the minus sign on the bottoms of R_2 and R_3 mean that these are connected to earth supply.

DESIGN CALCULATION AND CONSIDERATION FOR THE AMPLIFIER CIRCUIT

Now the output signal from the rectifier circuit taken across capacitor C_6 is a positive going signal and hence it requires a transistor which uses a positive signal for forward biasing its base a emmitter junction. The appropriate transistor to use here is an NPN transistor, In this position the BC109C (an NPN transistor) was found to be appropriate. It has:

1. A VCEO (max) V of 20V
2. A VCBO (max) of 30V
3. A VEBO (max) OF 5V
4. Maximum collector current Ic max = 100mA
5. P_{TOT} max of 300mw
6. HFE (β) (520) 2mA

It is a low noise high gain amplifier.

Now, the maximum base current of BC109C $= I\beta = \frac{Ic}{\beta} = \frac{100}{520} = 0.1923mA$.

Now, the maximum current that could be supplied by the selected op Amp is 1.5μA . So the NPN transistor selected is in line. The RLA 4088 requires a current of 10MA a voltage range of (6-12) volts. It has a pair of contacts, normally open and normally closed. In circuit, one of the normally open contacts is connected in such a way for it to maintain supply across the relay coil when triggered.

2.5 DESIGN CALCULATION OF THE ALARM CIRCUIT

The popular 4011Ic package used in this project work actually consists of (MOS logic gates. The complementary metal oxide semiconductor logic gates are very useful in implementing simple multivibrator circuits. A multivibrator may be monostable, Bistable or Astable. It is monostable when it has only pne stable state. It is bistable when it has two stable states. And it is said to be Astable, when it is not stable in any of its states. In the Astable state it does not require an external trigger pulses for it to be change from one states to the other.

This 4011 package consists of four CMOS NAND gates.

The circuit of the alarm shown consist of a timing circuit (RC circuit). The value of the frequency determining component are obtained as follows:

Let the frequency of operation = 600HZ (chosen within the audio freq range of 20KHZ – 16000KHZ)

Let R_3 = 100k

C_2 = ?

:. From the relation:

$$F = \frac{1}{2t_1} = \frac{1}{2.2\tau} - (W)$$

where T = RxCx

$$\therefore F = \frac{1}{2.2Rxcx}$$

by substitution,

$$600 = \frac{1}{2.2 \times 100 \times 10^3 \times Cx}$$

$$Cx = \frac{1}{600 \times 2.2 \times 100 \times 10^3}$$
$$\approx 8n$$

so for the fast astable, Cx was chosen to be 10n

for the slow astable.

Let R_5 = 6.8MΩ

C_3 = ?

From the same relation

$$f = \frac{1}{2.2T}$$

$$T = RxCx = period$$

$$600 = \frac{1}{2.2RxCx}$$

$$= \frac{1}{2.2 \times 68 \times 10^{6} \times C_3}$$

$$C_3 = \frac{1}{2.2 \times 6.8 \times 10^{6} \times 600}$$

$$= 110n$$

for the reason of availability of component,

C_3 = 100nF

2.7 THE INTERNAL ARCHITECTURE OF 4011B

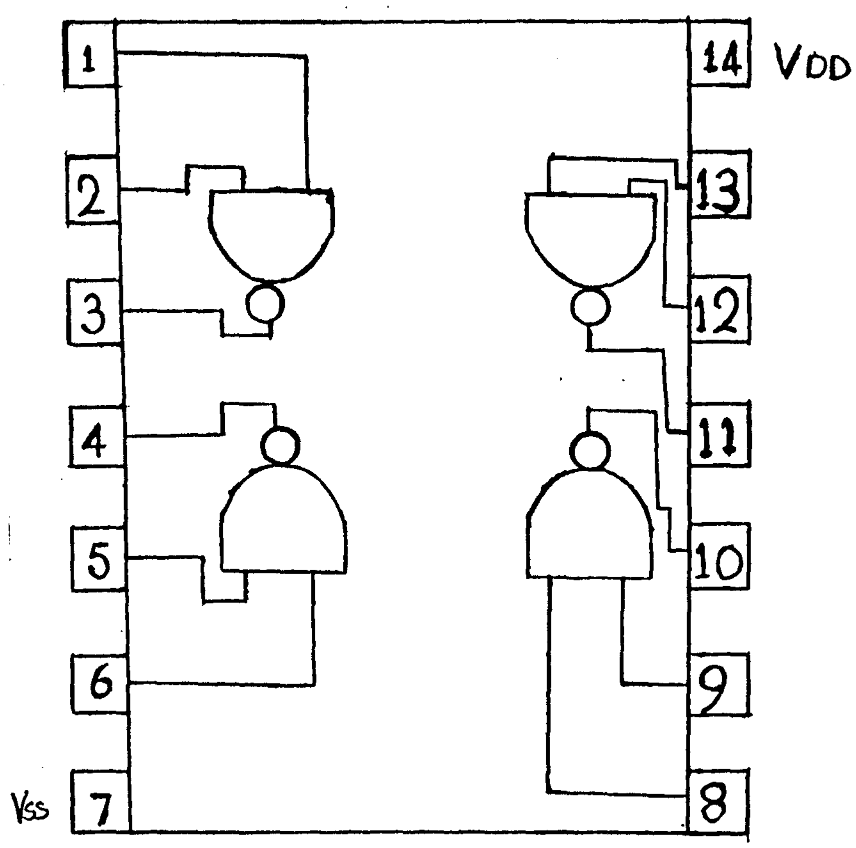


Fig 5 Internal architecture of 4011B

Propagation delay at 5v = 125ns

Propagation delay at 10v = 50ns

Propagation delay at 15v = 40ns

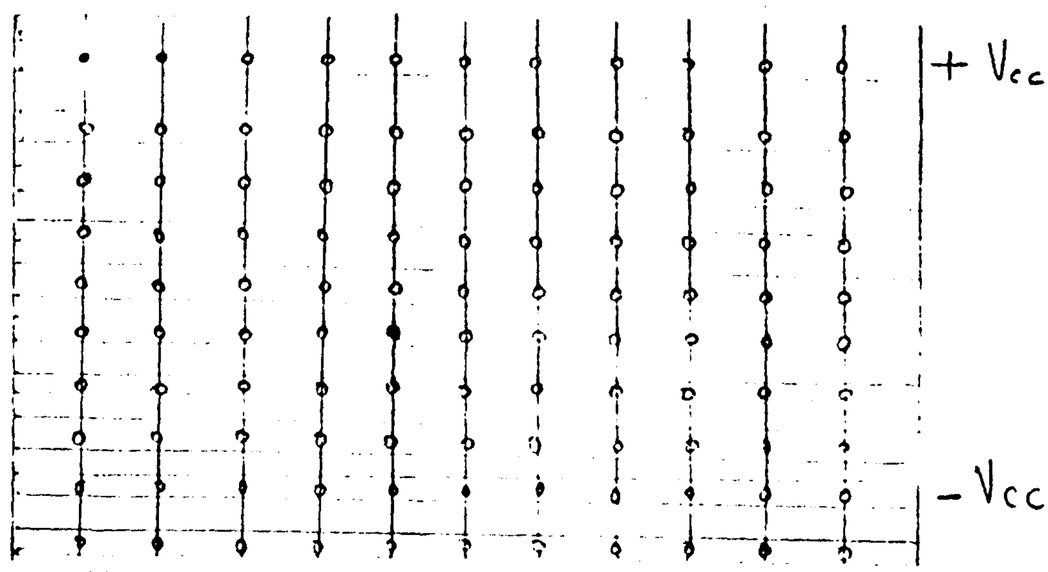
CHAPTER THREE

3.0 CONSTRUCTION AND TESTING

The project components were mounted on a veroboard. The size of the board to be used was arrived at after a careful consideration of the number of components to be used and the amount of space which they might likely occupy.

First the components themselves were examined and cross checked against their individual specifications. The terminals of the transistor were Identified. The identification of the transistor and capacitor's terminals were done with extra care. This is because if a transistor is connected with the wrong terminal in circuit it burns immediately (It become hot and finally burns out -).

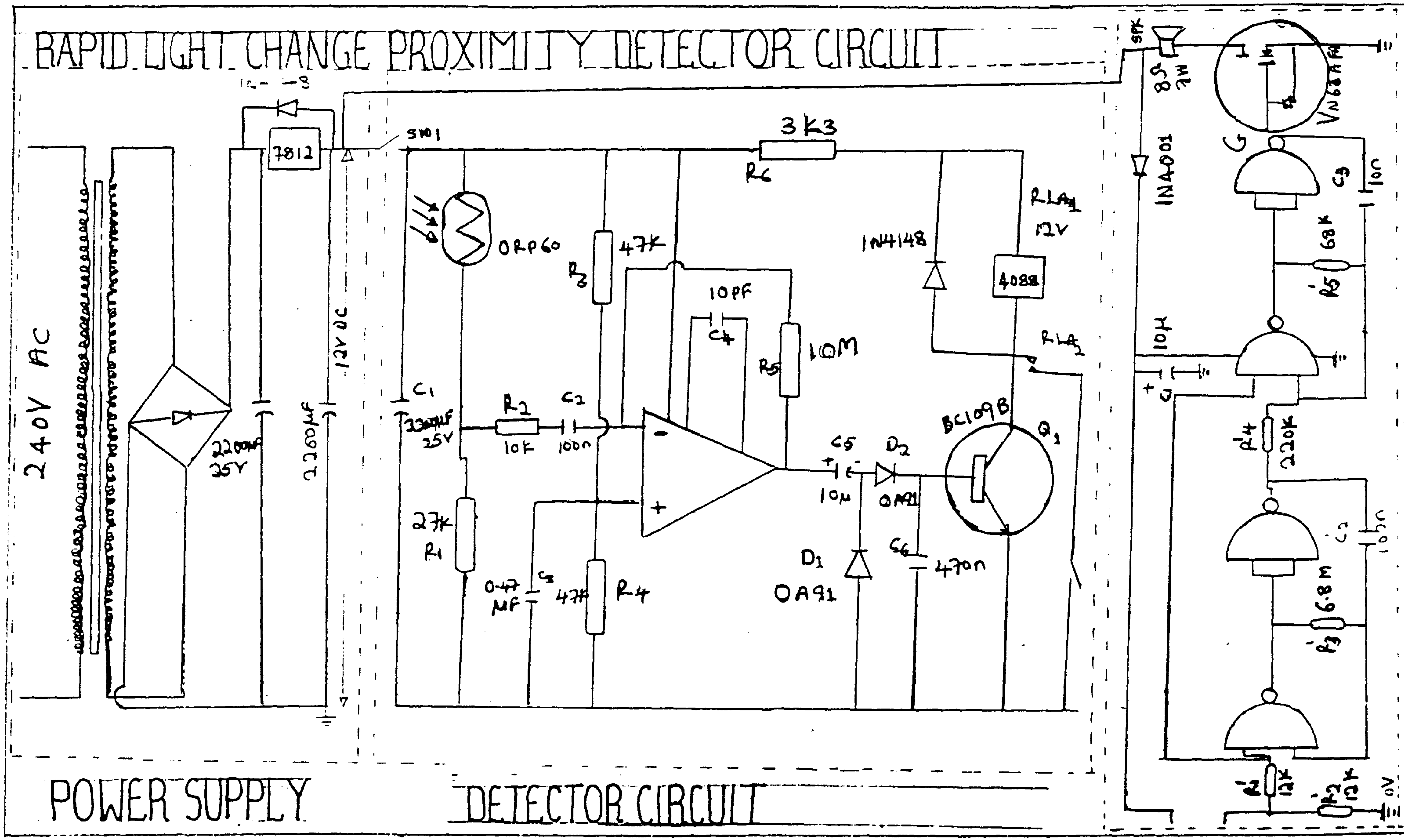
In the second place, the position to be occupied by each components on the veroboard were marked one with the aid of a pencil. The positive the and negative potential to be used on the veroboard was marked as shown on the sketch below:



The marking was done for it to serve as a guide during connection. The terminals of the components which have been installed, were trimed to avoid a short circuit.

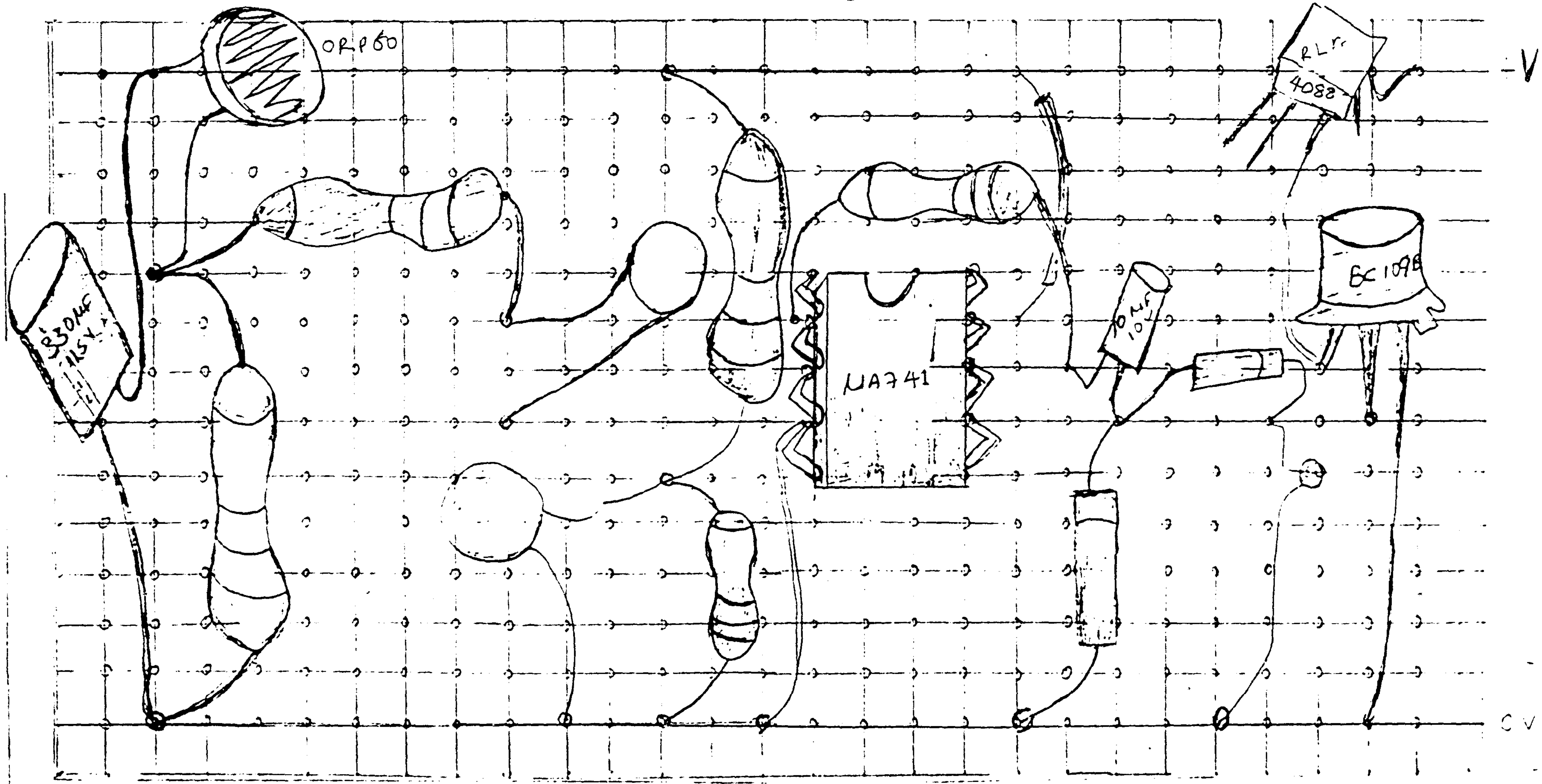
Lastly the component were soldered to the veroboard. Care was taken for not allowing heat to destroy some of the circuit components (heat from the hot soldering iron). The veroboard was cleaned first before the soldering procedure started. This was to avoid the formation of a cold joint.

The complete circuit diagram of the rapid light change proximity detector switch and the schematic diagram are as shown below:

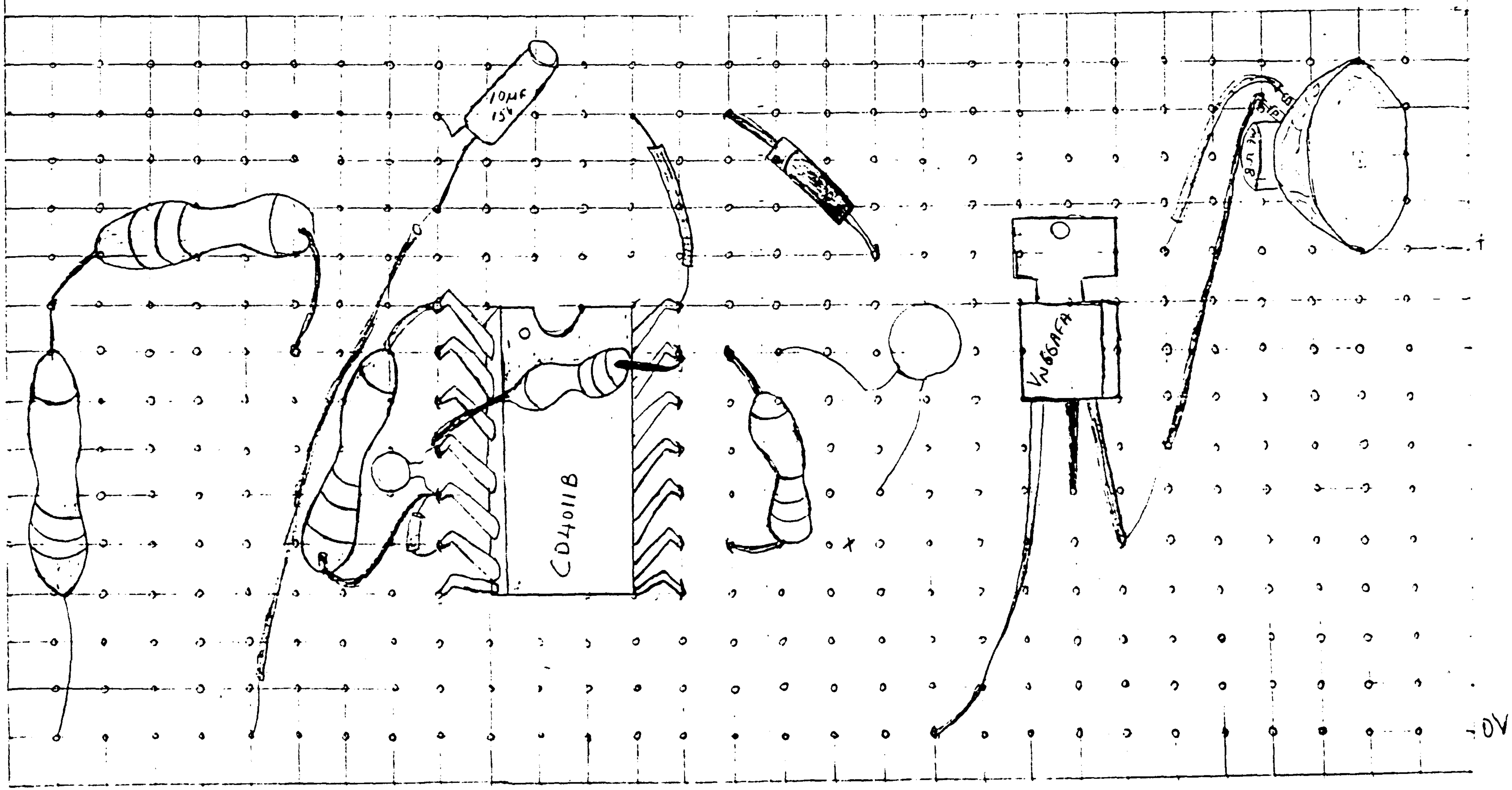


RAPID LIGHT CHANGE PROXIMITY DETECTOR CIRCUIT
240V AC
7812
12V DC
2200µF
SW1
3K3
R6
ORP60
47K
R3
10PF
C4
10M
R5
1N4148
RLA1
12V
4088
RLA2
C1
R2
10K
C2
100n
C5
10µ
D2
OA91
BC109B
Q1
27K
R1
0·47 MF
C3
47K
R4
D1
OA91
C6
470n
POWER SUPPLY
DETECTOR CIRCUIT
ALARM CIRCUIT
SPK
8Ω 3W
1N4001
VN66AF
68K
10n
10H
220K
6·8M
100n
12K
0V

SCHEMATIC DIAGRAM OF DETECTOR CIRCUIT



SCHEMATIC DIAGRAM OF THE ALARM CIRCUIT



3.4.1 COMPONENT SPECIFICATION AND COSTING

RESISTORS		
COMPONENT	SPECIFICATION	COST(₦)
Resistor R1	27KΩ	10.00
Resistor R2	10KΩ	10.00
Resistor R3	47KΩ	10.00
Resistor R4	47KΩ	10.00
Resistor R5	10KΩ	10.00
Resistor R6	3.3KΩ	10.00
Resistor $R^1 1$	12KΩ	10.00
Resistor $R^1 2$	12KΩ	10.00
Resistor $R^1 3$	6.8 KΩ	10.00
Resistor $R^1 4$	220K	10.00
Resistor $R^1 5$	180K (Variable)	10.00
		60.00

CAPACITORS		
COMPONENT	SPECIFICATION	COST(₦)
Capacitor C1	330μF (10v)	20.00
Capacitor C2	100n	20.00
Capacitor C3	220n	10.00
Capacitor C4	8.2p	10.00
Capacitor C5	10μF	15.00
Capacitor C6	470n	10.00
Capacitor $C_1^{\prime}$	10μF	15.00
Capacitor $C_2^{\prime}$	100n	10.00
Capacitor filter cap	2200μF	40.00

ASSORTED COMPONENT TYPES		
COMPONENT	SPECIFICATION	COST(₦)
Transistor	BC109B	30.00
MOSFET	VN66AF	250.00
ICI	CD4011B	70.00
OpAmp	μA741	40.00
LDR	-	150.00
LED	-4PCS	40.00
Transformer	220V/12V	150.00
Veroboard	-	100.00
Bread Board	-	450.00
Dissoibering Pump	-	100.00
Diode	1N400	50.00
Relay	12V	80.00
On/Off Switch		70.00
Speaker	8Ω, 7W	150.00
Wooden Casing		200.00
Connecting Wire		60.00
Soldering Lead		20.00
Typing Printing/Binding		1,500.00
Transportation		2,000.00
NET TOTAL:		**5,800.00**

This prices above are valid at the time of my design construction.

3.4 SUGGESTION ON HOW TO IMPROVE ON THIS PROJECT

Inspite of the wide use to which the proximity detector switch could be put, there is still the need to improve on it so that.

1. It can cover a wider area of application

2. The circuit to he triggered on will switch of after some time.

3. The reset circuit should be authomized

For it to cover a wider area, the sensitivity should de increased. For the reset circuit to be automatic a triming circuit should be included. This will enable it to trigger off after some time.

3.5 MECHANICAL CONSTRUCTION DIAGRAM

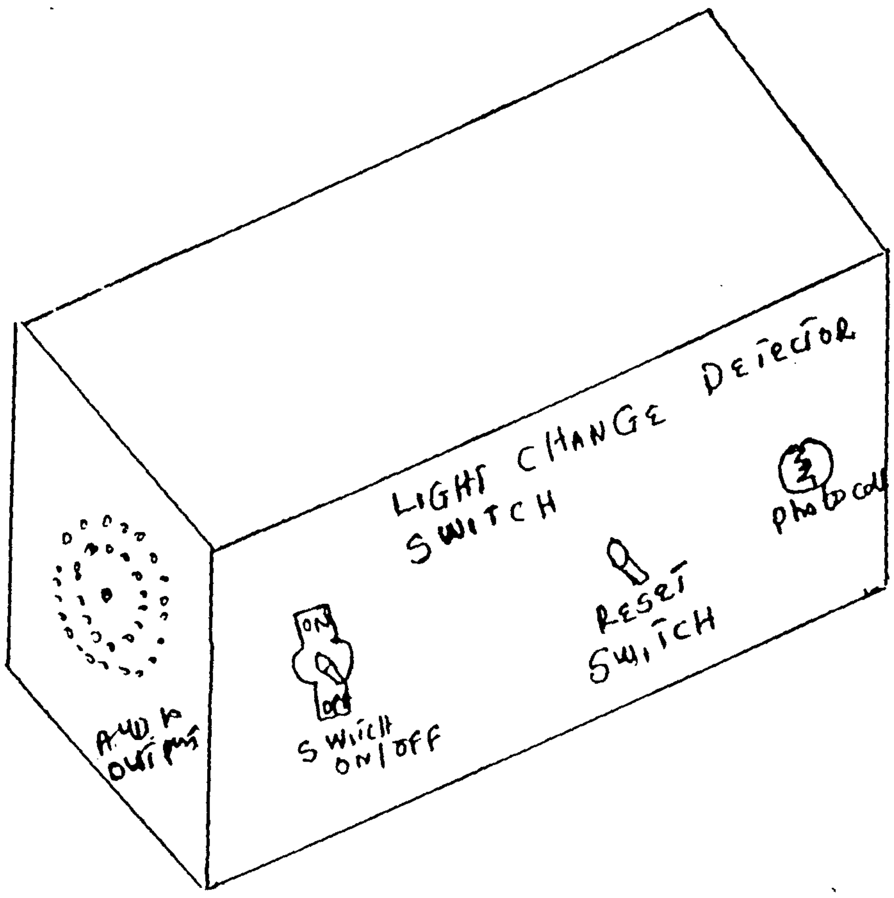


Fig 7 MECHANICAL CONSTRUCTION DIAGRAM

CHAPTER FOUR

4.1 CONCLUSION

The practical work was carried out exactly as designed. At the end of the practical construction. It was observed that the unit responded to light levels of all intensities. But what differs is the distance of the source from the sensor. When a touch light is shone on it or when the shadow of someone passing in front of the unit at a distance of about two to three feet from the sensor falls on it, a clicking sound is heared. And the alarm signal, which serves as the test circuit in the design of this project work, comes on.

In a sentence, the produced project work meets the design or proposed goal.

4.2 RECOMMENDATIONS

The project work which forms a part of the university education is of many benefits to the students. But it is not being encouraged by the school authorities for effective handling of the project work by students, I recommend that:

1. Components should be provided to the students. This will enable them to embark on the construction of Many projects. Thereby strengthening their hands. This will enable them to produce better projects.

REFERENCES

1. Analysis and design of digital IC by David A. Hodges and Horace G. Jackson. Pages 104 and (124)
2. Basic Electrical Engineering an instrumentation for Engineers by E.C Bell and R.W whitehead. (1981) (pages 79, 81, 98 and 102)
3. Electronics digest, Winter 1981 pages 82, 96 and 101
4. Transistor Circuit Techniques Discrete and intergrated by G.T Ritchie third Edition. Published by chapman & hall (1993) pages 4, 119, 26 and 46

APPENDIX A

R_f	=	Feedback Resistor
CMMR	=	Common mode rejection ratio
V_{CEO}	=	Max. collector emitter leakage current
V_{CBO}	=	Max. collector base leakage current
V_{CBO}	=	Max. base emitter leakage current
P_{TOT}	=	Max. Peak too peak power
$H_{Fa}\beta$	=	Common emitter current gain
RLA	=	Relay
CMOS	=	Complementary metal oxide semiconductor
N/C	=	Non connected
V_{ref}	=	Reference voltage