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Dedication

This project is dedicated to my parents for their unrelenting effort to see me attain the best education can offer despite the challenges they have constantly faced.
Acknowledgement

I am and forever will be grateful to The Almighty Father for His unconditional love and provision during the course of not only this project but most importantly my life.

Secondly, I am grateful to my supervisor Dr. G. Kamucha for his guidance, positive criticism and motivation that he gave me throughout this project.

I would also like to thank my friends and colleagues especially Patrick Otuoma and Melvin Oguta for their academic, moral and material support.

Lastly, I must acknowledge the moral and financial support that my parents have accorded me during the course of my study, it would have been impossible to manage everything without you.

MAY THE UNDESERVED FAVOUR OF THE ALMIGHTY FATHER FOLLOW ALL OF YOU ALWAYS FOR YOUR BURNING DESIRE TO HELP YOUR NEIGHBOURS.
# Table of Contents

Dedication..................................................................................................................... i  
Acknowledgement ........................................................................................................ ii  
Table of Contents ......................................................................................................... iii  
ABSTRACT .................................................................................................................... v  

1 CHAPTER ONE: INTRODUCTION .............................................................................. 1  
1.1 OBJECTIVE; ........................................................................................................ 1  
1.2 SCOPE; .................................................................................................................. 1  
1.3 OVERVIEW OF THE LIGHT SWITCHING CONTROL UNIT; ............................... 3  
1.4 Advanced lighting CONTROL; .............................................................................. 5  

2 CHAPTER TWO: OCCUPANCY SENSING ................................................................. 6  
2.1 Introduction: motion detection; ............................................................................ 6  
2.2 Principle of operation .......................................................................................... 9  
   2.2.1 Photovoltaic mode ......................................................................................... 9  
   2.2.2 Photoconductive mode ................................................................................. 9  
   2.2.3 Other modes of operation ........................................................................... 10  
2.3 MATERIALS ......................................................................................................... 10  
   2.3.1 Features; ....................................................................................................... 12  
2.4 Materials and Emission Wavelengths ................................................................. 13  
2.5 Device Structures; .............................................................................................. 15  
   □ Surface-emitting LEDs ...................................................................................... 15  
   □ Edge-emitting LEDs ......................................................................................... 15  
2.6 Emission Properties ............................................................................................ 16  
2.7 Efficiency ............................................................................................................. 16  
2.8 Electrical Characteristics ................................................................................... 16
2.9 Applications of Light-emitting Diodes .................................................................17
2.10 Methods of motion Sensing..................................................................................17
  2.10.1 Pyroelectric sensors; ......................................................................................17
  2.10.2 Fresnel Lens; ..................................................................................................21
  2.10.3 Infrared emission and sensing; ......................................................................24
  2.10.4 Modulated infrared beam ..............................................................................27
3 CHAPTER THREE: ENTRY AND EXIT PROCESSING; ........................................30
  3.1 Door sensing method ..........................................................................................30
  3.2 Entry exit processing ..........................................................................................31
  3.3 Principle of operation of the entry exit processing circuit; ................................34
4 CHAPTER FOUR: COUNTING AND LIGHT DEPENDENT RESISTOR CONTROL;...35
  4.1 Counting mechanisms employed.......................................................................35
    4.1 Mechanism of operation of the counter .........................................................36
    4.2 Output processing ............................................................................................36
    4.3 Light Dependent Resistor Control ..................................................................37
5 CHAPTER FIVE: ........................................................................................................38
  5.1 Recommendations and future work; .................................................................38
  5.2 Conclusion; ........................................................................................................38
6 REFERENCES ........................................................................................................39
ABSTRACT

The objective of this project- Light Switching Control Unit is to develop a mechanism for automatically switching ON lights in a room only when they are needed. That is to say the lights should only be ON only when the room is occupied and that illumination levels in the room warrant that the lights be switched ON.

The need to conserve energy at this time and age cannot be over emphasized. Its not enough to say that we are conserving energy by using low power consuming 'energy saving' bulbs when we actually leave them ON when we are not using them, worse still we switch them ON when natural illumination from the sun provides sufficient illumination levels in the room!

As such, when an automated switching mechanism that takes into consideration the room occupancy and illumination levels is used to replace wall switches, then a big stride will have been taken when it comes to saving lighting energy that accounts for slightly more than 40% of our total energy consumption. What's more, costs that go into making such notices as 'HAVE YOU SWITCHED OFF THE LIGHTS? PLEASE SWITCH OFF THE LIGHTS TO CONSERVE ENERGY,' that are more often than not ignored, will be eliminated as they would be rendered irrelevant by this automatic switching mechanism!
CHAPTER ONE: INTRODUCTION

1.1 OBJECTIVE;

The objective of this project is to design, build and test a switching mechanism that automatically switches ON room lights only when the room is occupied and that illumination within the room is not sufficient therefore warranting the need for artificial lighting.

1.2 SCOPE;

The project took into consideration the cheapest methods to arrive at what has otherwise been an expensive implementation by designers. It incorporated a cheap yet effective occupancy sensing method by the use of infrared emission and sensing. Here, use was made of the infrared emitter diodes and infrared photo detectors such as the infrared photodiode and the infrared phototransistor. Theory concerning these devices has been thoroughly analyzed by the author of this report in chapter two.

Chapter two also goes ahead to explain the various signal conditioning methods that are used when these devices are used as motion sensors. This chapter ends by explaining the methods chosen for the design of the motion sensors and why they were chosen.

In chapter three, signal processing is done so as to determine whether we have an entry or exit depending on the information obtained from the sensing section. The element of memory that is so required for this project is realized with the use of flip-flops, the data (D) flip-flop is especially relevant in this regard. At the end of this chapter it becomes clear why the method of having the sensors at the door as opposed to inside the room was preferred.

Counting is done in chapter four with the design of the modulus 100 counting mechanism using 74192 up and down decade counters with their outputs conditioned to switch ON or OFF an IRF 130 or an equivalent switching MOSFET. The output of this MOSFET feeds the input of the next section-The Light Dependent Resistor (LDR) control.
Chapter four also covers the use of the Light Dependent Resistor (ORP 12) and transistor (the BC547 BJT) switches to switch ON or OFF a relay which is the interface to mains used in lighting.

Chapter five contains the recommendations for future work on and concludes the report.

References used to obtain some of the material used in this report are recorded in the reference section and may be useful for further reading.
1.3 OVERVIEW OF THE LIGHT SWITCHING CONTROL UNIT;

Light switching systems have at least one or more of the following:

- Occupancy sensing unit(s)
- Motion sensing unit(s)
- Dimming and brightening controls
- Illumination levels detector(s)
- Light switching mechanisms
- Computer hardware and software for processing units
- Automatic corridor lights controllers

Generally, light switching control units have one objective; to conserve lighting energy. Depending on other modifications that users may desire, a system that allows for easy modification and expansion is the next big thing in light switching control.

Such features as counting entry and exit can be enhanced to know how many people are in the room at any given time, their age and gender too can be known with just a slight modification of the door sensing method for the case of The Light Switching Control Unit.

More on these interesting realizations is thoroughly covered in chapter nine of this report. This chapter titled, Future Research Work and Recommendations, also looks at the advantages of this project and compares it to what has been done out there. Important points such as cost of coming up with this project is given the major consideration in the chapter.
Fig. 1.1 The light switching control unit flow chart

START

IS THE ROOM OCCUPIED?

IS ILLUMINATION SUFFICIENT?

SWITCH ON THE ROOM LIGHTS.

YES

NO

YES

STOP

NO
1.4 Advanced lighting CONTROL;

Lighting control systems use automated intelligence to deliver the required illumination level, where you want it, when you want it. Luminaires can automatically turn on, off or dim at set times or under set conditions. Users have control over their own illumination levels to provide an optimal working environment while preventing energy waste from over-illumination.

Lighting control systems include some or all of the following:

- on/off and dimming controls
- occupancy sensors to detect whether rooms are occupied
- photo sensors to detect the current illumination levels provided by natural and/or artificial light
- scheduling that turns on, off, and dims luminaires at preset times
- a centralized control system interface (such as a wall panel or computer software) to manage all of the above
- a method of communication between the lighting equipment and control system
- a method of measuring, displaying, and responding to lighting energy usage

Lighting control systems vary widely according to the technologies used to complete these tasks, as well as their degree of difficulty and cost. Historically though, the more system-wide controls and advanced strategies that are used, the greater the complexity, which often makes these solutions difficult or even impossible to implement across large-scale environments.
CHAPTER TWO: OCCUPANCY SENSING

1.5 Introduction: motion detection;

Motion can be detected by measuring change in speed or vector of an object or objects in the field of view. This can be achieved either by mechanical devices that physically interact with the field or by electronic devices that quantify and measure changes in the given environment.

Motion can be detected by: sound (acoustic sensors), opacity (optical and infrared sensors and video image processors), geomagnetism (magnetic sensors, magnetometers), reflection of transmitted energy (infrared laser radar, ultrasonic sensors, and microwave radar sensors), electromagnetic induction (inductive-loop detectors), and vibration (triboelectric, seismic, and inertia-switch sensors). Acoustic sensors are based on: electret effect, inductive coupling, capacitive coupling, triboelectric effect, piezoelectric effect, and fiber optic transmission. Radar intrusion sensors have the lowest rate of false alarms.

The principal methods by which motion can be electronically identified are optical detection and acoustical detection. Infrared light or laser technology may be used for optical detection. Motion detection devices, such as motion detectors, have sensors that detect movement and send a signal to a sound device that produces an alarm or switch on an image recording device. There are motion detectors which employ cameras connected to a computer which stores and manages captured images to be viewed later or viewed over a computer network.

The chief applications for such detection are;

(a) Detection of unauthorized entry,

(b) Detection of cessation of occupancy of an area to extinguish lighting

(c) Detection of a moving object which triggers a camera to record subsequent events.
The motion detector is thus a linchpin of electronic security systems, but is also a valuable tool in preventing the illumination of unoccupied spaces

Motion sensors are often used in indoor spaces to control electric lighting. If no motion is detected, it is assumed that the space is empty, and thus does not need to be lit. Turning off the lights in such circumstances can save substantial amounts of energy. In lighting practice occupancy sensors are sometime also called "presence sensors" or "vacancy sensors"

Occupancy sensors for lighting control use infrared (IR) or acoustic technology, or a combination of the two. The field of view of the sensor must be carefully selected/adjusted so that it responds only to motion in the space served by the controlled lighting. For example, an occupancy sensor controlling lights in an office should not detect motion in the corridor outside the office. Sensors and their placement are never perfect, therefore most systems incorporate a delay time before switching. This delay time is often user-selectable, but a typical default value is 15 minutes. This means that the sensor must detect no motion for the entire delay time before the lights are switched. Most systems switch lights off at the end of the delay time, but more sophisticated systems with dimming technology reduce lighting slowly to a minimum level (or zero) over several minutes, to minimize the potential disruption in adjacent spaces. If lights are off and an occupant re-enters a space, most current systems switch lights back on when motion is detected. However, systems designed to switch lights off automatically with no occupancy, and that require the occupant to switch lights on when they re-enter are gaining in popularity due to their potential for increased energy savings. These savings accrue because in spaces with access to daylight the occupant may decide on their return that they no longer require supplemental electric light.
2.2 INFRARED DETECTION

2.2.1 Infrared radiation;

Infrared radiation exists in the electromagnetic spectrum at a wavelength that is longer than visible light. It cannot be seen but it can be detected. Objects that generate heat also generate infrared radiation and those objects include animals and the human body whose radiation is strongest at a wavelength of 9.4um. Infrared in this range will not pass through many types of material that pass visible light such as ordinary window glass and plastic. However it will pass through, with some attenuation, material that is opaque to visible light such as germanium and silicon. An unprocessed silicon wafer makes a good IR window in a weatherproof enclosure for outdoor use. It also provides additional filtering for light in the visible range. 9.4um infrared will also pass through polyethylene which is usually used to make Fresnel lenses to focus the infrared onto sensor elements.

Fig 2.1 The electromagnetic spectrum
2.2.2 Photodiodes;

A photodiode is a type of photo detector capable of converting light into either current or voltage, depending upon the mode of operation

1.6 Principle of operation

A photodiode is a PN junction or PIN structure. When a photon of sufficient energy strikes the diode, it excites an electron, thereby creating a free electron and a positively charged electron hole. This mechanism is also known as the photoelectric effect. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced. This photocurrent is the sum of both the dark current (without light) and the light current, so the dark current must be minimized to enhance the sensitivity of the device.

1.6.1 Photovoltaic mode

When used in zero bias or photovoltaic mode, the flow of photocurrent out of the device is restricted and a voltage builds up. This mode exploits the photovoltaic effect, which is the basis for solar cells in fact; a traditional solar cell is just a large area photodiode.

1.6.2 Photoconductive mode

In this mode the diode is often reverse biased, dramatically reducing the response time at the expense of increased noise. This increases the width of the depletion layer, which decreases the junction's capacitance resulting in faster response times. The reverse bias induces only a small amount of current (known as saturation or back current) along its direction while the photocurrent remains virtually the same. For a given spectral distribution, the photocurrent is linearly proportional to the luminance (and to the irradiance) Although this mode is faster, the photoconductive mode tends to exhibit more electronic noise. The leakage current of a good PIN diode is so low (< 1nA) that the Johnson-Nyquist noise of the load resistance in a typical circuit often dominates.
1.6.3 Other modes of operation

Avalanche photodiodes have a similar structure to regular photodiodes, but they are operated with much higher reverse bias. This allows each photo-generated carrier to be multiplied by avalanche breakdown, resulting in internal gain within the photodiode, which increases the effective responsivity of the device.

Phototransistors also consist of a photodiode with internal gain. A phototransistor is in essence nothing more than a bipolar transistor that is encased in a transparent case so that light can reach the base-collector junction. The electrons that are generated by photons in the base-collector junction are injected into the base, and this photodiode current is amplified by the transistor's current gain $\beta$ (or $h_{fe}$). Note that while phototransistors have a higher responsivity for light they are not able to detect low levels of light any better than photodiodes. Phototransistors also have significantly longer response times.

1.7 MATERIALS

The material used to make a photodiode is critical to defining its properties, because only photons with sufficient energy to excite electrons across the material's band gap will produce significant photocurrents.

Materials commonly used to produce photodiodes include;
Table 2.1 materials commonly used to make photodiodes

<table>
<thead>
<tr>
<th>Material</th>
<th>Electromagnetic spectrum wavelength range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>190 – 1100</td>
</tr>
<tr>
<td>Germanium</td>
<td>400 – 1700</td>
</tr>
<tr>
<td>Indium gallium arsenide</td>
<td>800 – 2600</td>
</tr>
<tr>
<td>Lead(II) sulfide</td>
<td>&lt;1000 – 3500</td>
</tr>
</tbody>
</table>

Because of their greater band gap, silicon-based photodiodes generate less noise than germanium-based photodiodes, but germanium photodiodes must be used for wavelengths longer than approximately 1 μm.

Fig 2.2 Response of a silicon photodiode wavelength of the incident light
1.7.1 **Features**;

Critical performance parameters of a photodiode include:

- **Responsivity**

  The ratio of generated photocurrent to incident light power, typically expressed in A/W when used in photoconductive mode. The responsivity may also be expressed as a Quantum efficiency, or the ratio of the number of photo generated carriers to incident photons and thus a unit less quantity.

- **Dark current**

  The current through the photodiode in the absence of light, when it is operated in photoconductive mode. The dark current includes photocurrent generated by background radiation and the saturation current of the semiconductor junction. Dark current must be accounted for by calibration if a photodiode is used to make an accurate optical power measurement, and it is also a source of noise when a photodiode is used in an optical communication system.

- **Noise-equivalent power (NEP)**

  The minimum input optical power to generate photocurrent, equal to the rms noise current in a 1 hertz bandwidth. The related characteristic detectivity (D) is the inverse of NEP, 1/NEP; and the specific detectivity (D*) is the detectivity normalized to the area (A) of the photodetector, $D^* = D \sqrt{A}$. The NEP is roughly the minimum detectable input power of a photodiode.
2.3.2 Light emitting diodes (LEDs)

A light-emitting diode (LED) is an optoelectronic device which generates light via electroluminescence. It contains a p–n junction, through which an electric current is sent. In the heterojunction, the current generates electrons and holes, which release their energy portions as photons when they recombine.

![LEDs](image)

Figure 2.3: Two light-emitting diodes, emitting white and red light

1.8 Materials and Emission Wavelengths

The center wavelength and thus the emission color of an LED are largely determined by the band gap energy of the semiconductor material used. Essentially the whole visible wavelength region can be covered with LEDs, although the achievable power output and efficiency is not equally high for all wavelengths.

Most LED chips are made of inorganic semiconductor materials. For deep red emission, aluminum gallium arsenide (AlGaAs) can be used, which is otherwise common for near-infrared laser diodes. Shorter wavelengths in the red spectral region are achieved with gallium arsenide phosphide (GaAsP) and aluminum indium gallium phosphide (AlInGaP). Indium gallium nitride (InGaN) is very suitable for blue and violet LEDs. Despite high defect densities in these materials, internal quantum efficiencies of 70% and higher are achieved. Longer wavelengths (green and yellow) are obtained by increasing the indium (In) content, but the efficiency drops sharply as the wavelength is increased.
The technologically most difficult spectral region (in the visible range) is that of green–yellow–orange light.

<table>
<thead>
<tr>
<th>Material</th>
<th>Typical emission wavelengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>InGaN / GaN, ZnS</td>
<td>450–530 nm</td>
</tr>
<tr>
<td>GaP:N</td>
<td>565 nm</td>
</tr>
<tr>
<td>AlInGaP</td>
<td>590–620 nm</td>
</tr>
<tr>
<td>GaAsP, GaAsP:N</td>
<td>610–650 nm</td>
</tr>
<tr>
<td>InGaP</td>
<td>660–680 nm</td>
</tr>
<tr>
<td>AlGaAs, GaAs</td>
<td>680–860 nm</td>
</tr>
<tr>
<td>InGaAsP</td>
<td>1000–1700 nm</td>
</tr>
</tbody>
</table>

Table 2.2: Typical semiconductor materials and emission wavelengths of light-emitting diodes.

The near-infrared LEDs are based on AlGaAs.
1.9 Device Structures;

LEDs can be made as surface-emitting or edge-emitting devices.

- Surface-emitting LEDs

![Diagram of a flat-diode LED]

Figure 2.4 Structure of a flat-diode LED. The active area (shown in red) is slightly below the emitting surface.

Surface-emitting LEDs (SLEDs) have a thin active layer parallel to the surface from which the light extracted. In a simple flat-diode configuration (Figure 3), the active layer is just below the emitting surface, and the current is applied with a ring electrode. The light emitted in the 'wrong' direction is absorbed by the substrate. There are also devices where the substrate is made transparent, and the back electrode reflects back that light, so that at least some part of it can be used.

- Edge-emitting LEDs

Edge-emitting LEDs have a structure similar to that of edge-emitting semiconductor lasers: they are emitting from the edge of a cleaved wafer, where the active region meets the cleaved surface.
1.10 Emission Properties

Light emitted by LEDs has a low spatial coherence. It is originally emitted in all directions. Even though many LED devices emit light preferentially in one direction often via built-in reflecting structures, the focusability (beam quality) is very low, compared with, e.g., that of laser diodes.

The emission bandwidth is typically some tens of nanometers (e.g. 40 nm) or even > 100 nm, i.e., much broader than for laser diodes, and comparable to that of super luminescent diodes. This means that the temporal coherence is much lower than that of a laser, although it is much higher than for, e.g., an incandescent bulb.

1.11 Efficiency

The internal process of generating light in an LED, as described above, can have a very high quantum efficiency and power efficiency, at least in the blue–violet and in the red spectral region. Nevertheless, the device efficiency of early light-emitting diodes was relatively poor. The reason is that it is not possible to extract the internally generated light efficiently; most of the generated light was absorbed inside the device. A key challenge is total internal reflection at the surface of the semiconductor material: due to the high refractive index, light can escape only for relatively small angles of incidence, and even then there is substantial Fresnel reflection. In some LEDs, there is also a problem with reabsorption of light in the substrate.

1.12 Electrical Characteristics

As with any other semiconductor diode, a current can flow through an LED only from the p-doped part to the n-doped part (conventional current direction). A reverse voltage of a more than a few volts can destroy an LED.

In the forward direction, the current remains very small for low voltages and then rises very quickly (exponentially) with increasing voltage. Therefore, LEDs normally cannot be operated with a constant voltage; the current needs to be stabilized, e.g. by operation with a current source, or by using a simple series resistance for connecting to a constant voltage supply. The optical power is proportional to the operation current, except if the induced increase of
temperature decreases the quantum efficiency. The operation voltage is largely determined by
the bandgap energy of the material, and thus by the emission wavelength; red LEDs may be
operated with less than 2 V, while blue ones require of the order of 4 V.

1.13 Applications of Light-emitting Diodes

Small LEDs are very widely used as small signal lights. Operated with a current of e.g. $5\times\text{mA}$, such devices produce enough light to be seen in normal ambient light conditions, and
different colors can be used, e.g. to signal different states of a device.

As LEDs can be quickly modulated, they are suitable for optical fiber communications over short
distances. While the poor directionality of their emission requires the use of multimode fibers
and thus restricts the transmission distances, the cost is significantly lower than for a system with
single-mode fibers and laser diode transmitters. Moderately fast power modulation is also useful,
e.g., for application in light barriers, as the modulated LED light is easily distinguished from the
ambient light, and for remote controls.

1.14 Methods of motion Sensing

1.14.1 Pyroelectric sensors;

The pyroelectric sensor is made of a crystalline material that generates a surface electric charge
when exposed to heat in the form of infrared radiation. When the amount of radiation striking the
crystal changes, the amount of charge also changes and can then be measured with a sensitive
FET device built into the sensor. The sensor elements are sensitive to radiation over a wide range
so a filter window is added to the TO5 package to limit detectable radiation to the 8 to 14mm
range which is most sensitive to human body radiation.

Typically, the FET source terminal pin 2 connects through a pull down resistor of about 100 K to
ground and feeds into a two stage amplifier having signal conditioning circuits. The amplifier is
typically bandwidth limited to below 10Hz to reject high frequency noise and is followed by a
window comparator that responds to both the positive and negative transitions of the sensor
output signal. A well filtered power source of from 3 to 15 volts should be connected to the FET
drain terminal pin 1
Fig 2.5 The PIR 325 pyroelectric sensor

The PIR325 sensor has two sensing elements connected in a voltage bucking configuration. This arrangement cancels signals caused by vibration, temperature changes and sunlight. A body passing in front of the sensor will activate first one and then the other element whereas other sources will affect both elements simultaneously and be cancelled. The radiation source must pass across the sensor in a horizontal direction when sensor pins 1 and 2 are on a horizontal plane so that the elements are sequentially exposed to the IR source. A focusing device is usually used in front of the sensor.
Fig 2.6 Motion sensing using the PIR325 pyroelectric sensor

The figure on the next page shows the PIR325, its electrical specifications and layout in its TO5 package. It has a wide viewing angle without an external lens.
Fig 2.7 PIR325 electrical specifications and layout
Fig 2.8 Motion detector circuit using the PIR325

1.14.2 Fresnel Lens;

A Fresnel lens is a Plano Convex lens that has been collapsed on itself to form a flat lens that retains its optical characteristics but is much smaller in thickness and therefore has less absorption losses.
The Fresnel lens is made of an infrared transmitting material that has an IR transmission range of 8 to 14um which is most sensitive to human body radiation. It is designed to have its grooves facing the IR sensing element so that a smooth surface is presented to the subject side of the lens which is usually the outside of an enclosure that houses the sensor.

The lens element is round with a diameter of 1 inch and has a flange that is 1.5 inches square. This flange is used for mounting the lens in a suitable frame or enclosure. Mounting can best and most easily be done with strips of Scotch tape. Silicone rubber can also be used if it overlaps the edges to form a captive mount.

The FL65 has a focal length of 0.65 inches from the lens to the sensing element. It has been determined by experiment to have a field of view of approximately 10 degrees when used with a PIR325 Pyroelectric sensor.
Fig 2.10 Fresnel lens beam focusing

- Focal length: 0.65"
- IR beam enters Fresnel lens
- Install lens with grooves facing PIR

- Mounting border: 1.5"
- Active area: 1.1"
- Thickness: 0.015"

Optimum transmittance in the 8 to 14 um region
1.14.3 Infrared emission and sensing;

For emitting infrared radiation, an infrared diode \text{IRD} is connected in series with a current limiting resistor $R_1$ as shown below;

![Infrared emission circuit](image)

**Fig 2.11 Infrared emission circuit**

The strength of the beam emitted from the diode depends on the current that flows through it. In order to yield a strong beam, the following parameters have to be considered;

- Maximum forward voltage, $V_F$
- Maximum forward current, $I_F$

The typical values of these are $V_F = 0.7\text{volts}$ and $I_F = 100\text{mA}$. The current limiting resistor can therefore be calculated using the formula below
Another important parameter is the beam or viewing angle, \( \vartheta_v \).

![Diagram of a light emitting diode with cathode and anode, showing the beam angle.]

**Fig 2.12 The beam angle of a light emitting diode**

The beam angle finds relevance depending on the method of sensing used as will be seen in the next chapter.

The above design emits a beam that cannot be easily distinguished from emissions by other infrared sources. As such modulation of the infrared beam and creating a sensor that only perceives the modulated radiation is the method that is commonly used in infrared emission and sensing.

In this design the infrared beam is modulated by a rectangular pulse at a selected frequency \( f_o \). The receiver is a phototransistor that detects the emitted radiation and any other that is within its line of sight. In order that the modulated beam be distinguished from the others a band pass filter with a center frequency near \( f_o \) is included at its output.
The figures shown on the next page depict that scenario

**Fig 2.13** Infrared detector circuit using a photo transistor and an op amp comparator

The above design detects interruption of the incident beam and produces a logic pulse at its output. The non inverting op amp comparator has a reference voltage determined by the voltage divider bias of resistors R1 and R2. When light (infrared) is focused on the photo transistor, it is driven to saturation levels and becomes ON pulling the collector to near ground levels. This means that the voltage at non inverting input at R4 falls well below the reference set by the comparator hence the output at sensor\_out saturates at near $V_{EE} = 0V$.

When incident radiation is interrupted, the transistor is driven to cut off and is hence OFF. The collector voltage is driven to near $V_{cc} = 12V$ that is well above the reference set by the
comparator. The output will therefore saturate near or at \(V_{cc}\). The voltage divider serves to limit the output to near a logic HIGH level when the transistor is OFF.

Because this design was intended to be used with high frequency switching circuits, the comparator used had a hysteresis level of 0.06V to avoid false switching as result of switching noise.

The challenge with this design as was realized in its implementation is that while it is able to theoretically detect movement, practically that was impossible because other infrared sources caused the transistor to remain ON.

### 1.14.4 Modulated infrared beam

In order to make the sensor insensitive to other infrared light sources, the beam is modulated using a rectangular pulse wave of frequency \(f_o\). This was done using a 555 timer in the astable configuration as shown in the diagram below;

![Modulation of the infrared beam using a 555timer](image)

**Fig 2.14** Modulation of the infrared beam using a 555timer
The two infrared diodes were used to increase the strength of the emitted beam. The frequency of the emitted radiation is the frequency of the pulse train generated from the timer and is given by the formula shown below

\[
0 = \frac{1.443}{1 + \frac{3}{2}} \cdot \frac{2}{1}
\]

A high Q active band pass filter whose centre frequency is at \( f_0 \) hertz is shown below

![An active band pass filter](image)

**Fig 2.15 An active band pass filter**

The centre frequency \( f_0 \) hertz of the band pass filter can be shown to be calculated using the formula below.
The full implementation of the detector is as shown below;

Fig 2.16  Infrared detector with a band pass filter

The op amp buffer circuit is used to invert the output from the band pass filter.

For the above sensor the output is always a high but goes low when the modulated light fails to reach the photo transistor.
CHAPTER THREE: ENTRY AND EXIT PROCESSING;

1.1 Door sensing method

Entry and exit processing methods depended on the kind of motion sensing mechanism employed and area of application. This project was limited to a room with a single door that served both for entry and exit. This is illustrated in the diagram below.

The following facts are true about the single door method of detecting entry and exit:

- Persons get in or out one at time because of door space limitations, door spacing is approximately 1.5 meters.

Fig 3.1 Infrared door sensing mechanism employed in this project
The average height of persons who use the room is taken at a minimum of one meter
The average speed of walking into or out of the room is approximately 2 meters per second

Emitters used to generate the infrared beam were chosen with the following parameters being very important;

- High power emitters
- Narrower beam angles approximately \( 8^0 \)

These factors were important in ensuring that optimum beam strength reached the sensors

From figure 3.1 above it can be seen that sensor 1 and emitter 1 are positioned immediately before the door while sensor 2 and emitter 2 are just immediately before entering the room. Hence for an Entry one must interrupt line of sight 1 first then line of sight 2. The reverse will be interpreted as an Exit.

1.2 Entry exit processing

To process entry and exit with this form of sensing required the following:

- Two inputs \( S_1 \) and \( S_2 \) which are the outputs of sensors 1 and 2
- A storage mechanism (memory)
- A timed memory clearing mechanism

The circuit shown in figure 3.2 on the next page is the processing circuit that was developed. Here data flip flops were used as the storage elements. For the memory clearing a low frequency astable multivibrator was used. The frequency of clearing is largely determined by the average time for an entry or exit operation
Where;

- $f_c$ is the frequency of memory reset or clearing frequency
- $T$ is the average time for an entry or an exit operations

The average time for an entry or exit operation $T$ is determined by the speed at which somebody gets into or out of the room and the sensor spacing used.

For example if the sensor spacing is 15cm and the average speed of entry or exit is 2 meters per second, then $T$ will be given by

$$T = \frac{S_{sp}}{V} = \frac{0.15}{2} = 0.075 \text{ seconds}$$

Where;

- $S_{sp}$ is the sensor spacing in metres
- $V$ is the average speed of entry or exit in metres per second

The processing circuit will therefore have a clearing frequency at around 13hertz ie

$$f_c = \frac{1}{T} = \frac{1}{0.075} = 13 \text{ Hz}$$

After the clearing frequency has been calculated then an astable555 timer multivibrator can be designed to produce pulses that clear the memory cells at the appropriate times to avoid false entries and exits.
The free running 1 kHz clock and the clearing circuit were constructed using the 555 timer astable multivibrator.
1.3 **Principle of operation of the entry exit processing circuit;**

For an entry, sensor 1 is interrupted first followed by sensor 2. When S1 goes HIGH, a HIGH is stored in the top most flip flop which remains in that state unless the flip flop is cleared. With a high already stored in the top most flip flop, the input to the immediately lower flip flop will be a HIGH since they are directly connected.

In this state when sensor 2 is then interrupted, a HIGH is stored in the second flip flop and an ENTRY is registered. All this must happen within a time allowance before the memories are cleared.

The lower memory cells have their inputs reversed so that an EXIT will only be registered if sensor 2 is interrupted earlier than sensor 1 and this too must happen only within the allowed time duration.
CHAPTER FOUR: COUNTING AND LIGHT DEPENDENT RESISTOR CONTROL:

4.1 Counting mechanisms employed

The outputs of the entry exit processing circuit were connected through inverter gates then fed to a modulus 100 counter implementation using the 74192 up and down BCD decade counter. This is shown below;

![Modulus 100 counter implementation using the 74192 ICs](image-url)
1.4 Mechanism of operation of the counter

The counters are negatively edge triggered and this is the reason why inverter gates are used at their inputs. A pulse at either of the inputs causes the counter outputs to change either up or down depending on which input the pulse occurred. Pin 5 is the count clock pulse up while pin 4 is the count clock pulse down. The entry output of the processing unit is fed to pin 5 of the counter through an inverter while the exit is fed to pin 6 also through an inverter.

1.5 Output processing

The counter outputs are ORED together as shown below and the output used to control the Light Dependent Resistor unit.

![Fig 4.2 Output processing circuit](image-url)
1.6 Light Dependent Resistor Control

The light dependent resistor control unit is the final subsystem in this project design.

The function of the LDR is to check room illumination levels and switch on room lights when the room is occupied.

The Schmitt trigger configuration of Q1 and Q2 helps to give a sharper switching performance and therefore prevent gradual switching that is often accompanied by switching transients.

The function of diode D₁ is to protect transistor Q3 from the effects of back emf that is generated when the relay goes OFF.
CHAPTER FIVE:

2.1 Recommendations and future work;

The light switching control unit can be further expanded to perform among other functions recording the number of occupants of a room at any given time. This is made much easier to do now that the implementation used a BCD decade counter. The gender of the rooms occupants can also determined because all that has to be done is to modify the entry exit sensing methods. Further research is recommended to make these ideas tangible.

Another important idea is the use of LED lamps that require only 5V to switch on and consume very little power while at the same time providing sufficient illumination. When used together with the light switching control unit then a substantial amount of energy will be saved.

For much larger projects along this line, the use of microcontrollers and programmable logic devices is recommended as they make the overall implementation much smaller and less prone to error.

2.2 Conclusion;

From the research done and the implementation this project can be considered a success since it met its objectives.
REFERENCES


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