1 Introduction

1.1 Project Purpose

In the week leading up to the summer school many tutorials were provided which contained information that was needed in order to complete a quality project; these stated that the overall purpose for any project completed at the OpTIC Summer School was to create a prototype design that would involve electronic circuits and may involve mechanical moving parts; e.g. motors.

In order to achieve any working project a basic overview of knowledge related to both electronics and optics was provided; this information was vital to learn from so that when the summer school commenced, each student would be at a stage near enough to undertake their own experiments in relation to a project that must be creatively designed. Creativity was as much a purpose of Summer School as any other aim; many of the tutorials were not academic in any normal sense, but were designed to help boost our knowledge of where to draw ideas from and how to start creating our own project. It was a combination of both knowledge of what light can achieve and the methods to pull creativity that would lead on to the creating of the prototype projects.

Never the less many of the more important tutorials were academically simple yet vital; it was almost certainly a purpose of our projects to grasp these concepts as it soon became obvious that school had failed to provide us with much of the information needed. One perfect example was the consideration of how important a ground connection was. A tutorial was sent to the students:

A question was asked:

" In Circuit 3, a Ground (Gnd) connection is made as shown – what happens to the LED when Switch S is closed ? Does the LED Light up, or not, and why ?"

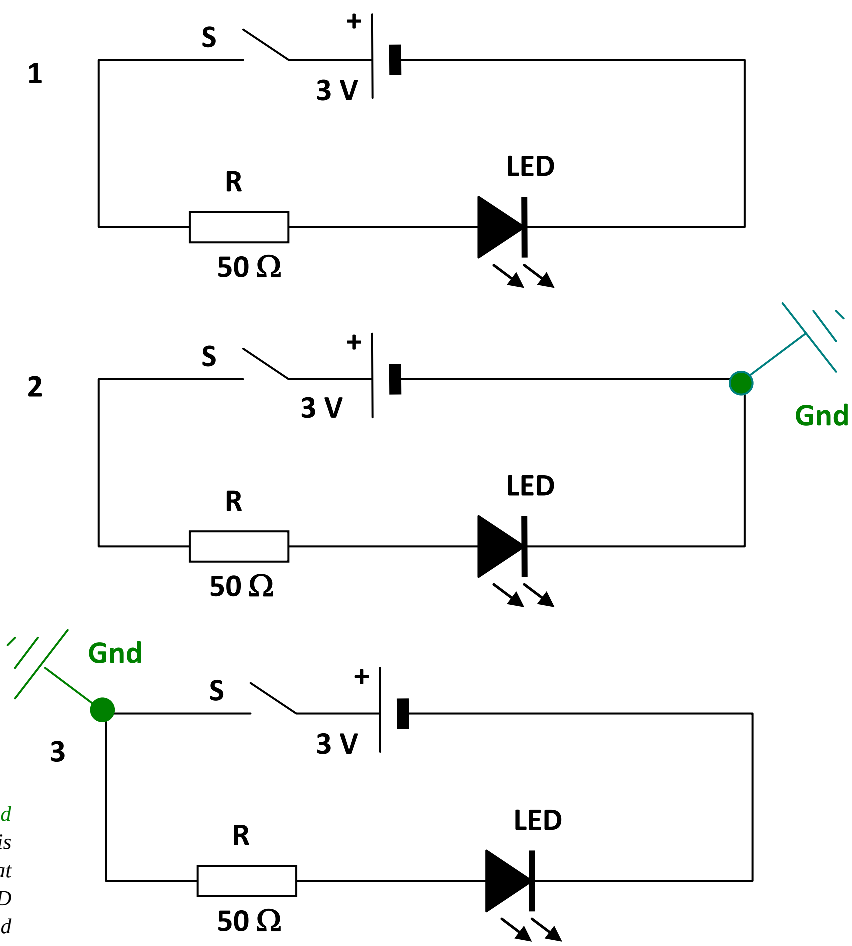


Figure 1 **Diagram provided in the Tutorials, aimed to help the students understand ground connection**

Figure 1 was provided so that the students would understand how the ground connection worked; this was important for one of the first tasks the students would complete at OpTIC would be to create a -5 V and +5 V connection using 1 or 2 power packs.

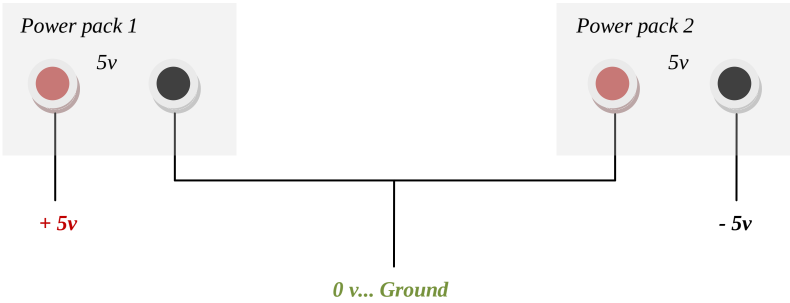


Figure 2 **+5,-5 and 0 V connections with 2 power packs**

Figure 2 shows this configuration and shows why knowledge of how a relative 0 V connection can be made is important. By simply connecting the negative and positive terminals of these two identical power packs; a relative 0V is formed, this setup would be needed in the creating of projects for many circuits that would require a 5V and -5V to work; this will be looked at in more detail in the theory section of this report.

The ground tutorial provided didn't just feed the students information on ground connections; it was hoped that through enough input the answer would be discovered; similar methods were used for most of information provided in other tutorials. All of this time prior to the Summer School had as much importance and purpose as what would follow on from what we learnt; and at first it was small steps of progress that were undertaken. Below is figure 3, it was what I achieved from my first reaction to the ground question, I looked for anywhere to confirm what would happen in the circuit and found a computer program that could interpret what would happen in a circuit. With confirmation of the LED lighting more questions could then be asked.

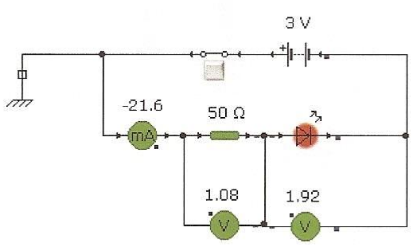


Figure 3 **LED Lit circuit, involving ground**

This was in fact one of the first times that any work I had completed in preparation for the Summer School had been linked to an **empirical outcome**. Empirical data is held very highly in regard and it was again part of the purpose of completing a project; that the students were to understand that whilst circuits and the behaviour of light can be proved mathematically; what happens in reality often varies. So in creating our projects it was more important to view observations; to watch a change; to see an outcome, than to prove one exists first. In later sections of this report I will explain the experiments that were undertaken throughout the projects.

The tutorials did not just contain information on ground connect; what we were provided with was varied; another example of what was required to be learnt before the Summer School began would be the electronic logic gates; I will examine these amongst other electronic equipment in the theory section of this report.

1.2 A Specific Project Purpose

Whilst I believe much of the purpose of undertaking a project was not to do with final outcome; the prototype I would be designing would still have an important purpose to fill. In the weeks leading up to when the summer school would commence my ideas followed little organisation, it took some time before ideas eventually came that I would even begin considering to undertake.

After several university open days in which I enquired and searched for ideas, and after the first direct input tutorials from the Summer School I had settled that my project should directly help people or a specific group of people. Throughout the previous year I had been completing a Graphics Products course in which the project was required to revolve around catering objects or environments for people with disabilities, and on one particular date the class took on the role of a blind person; we were required to navigate Chester Zoo whilst blindfolded as research. This in itself was a great opportunity for the graphics coursework but it also directly inspired the project I would work on for the Science Bursary. In no way can you truly replicate what it is like to be blinded but I immediately found out where the most difficulties occurred; and despite their somewhat obvious nature it was important to highlight and experience them first hand:

- Immobile and Silent obstacle at low lying height
- Uneven ground due to wearing or aesthetical effect
- Steps; particularly when worn or varying in depth
- Any sudden drop in height; similar to a step but with no forewarning from gradient or handheld rail bard

There were more factors that came into account but I found it important enough to focus on creating a project that would help a blind person navigate an environment with some or all of the above. I contacted the Summer School and informed them I had in mind a guide robot or a pair of proximity sensor gloves that would squeeze the appropriate finger for obstacles or drops in varying directions. The rough design of the gloves is figure 4, shown below.

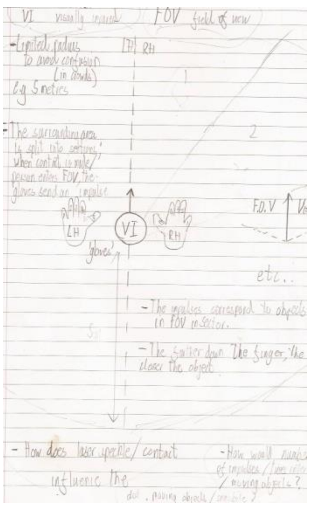


Figure 4 **Draft Proximity sensor glove design**

A guide robot had already been constructed that made use of several laser characteristics and improvements were already going to be made by another student. The proximity sensor gloves seemed the obvious route to take from there on; however due to the nature of the equipment provided and the difficulty of producing moving parts this idea eventually developed into a walking stick that would act as a proximity sensor.

The purpose of the project was now to investigate how this could be achieved using only light and electronics. The theory section of this project report compiles all the different components needed to produce the desires proximity sensor outcome, and the design specification describes how and why it has been designed using these components.

2 Theory

2.1 Light

Whilst I would have preferred to include a laser in my prototype project; there was in fact, no need. However, I had hoped to expand and develop my project in ways that might use a laser and the original designs for the project did involve the use of lasers until further development. This section of the project report will briefly cover the information provided through the tutorials and by further research that is relevant to what I used in my project. For details on how my project will work move onto the Design Specification section of the report.

2.1.1

A laser has 4 important characteristics which are all due to how they are formed in the resonant cavity and are as follows;

- A high intensity output beam
- A narrow cross-section
- A monochromatic output beam
- A coherent beam

When considering these four in relation to what the walking stick proximity sensor needs to achieve it begins to become clear why a laser it is not overall suitable. A laser beam can stay intact for kilometres because of its initial high intensity produced inside the laser resonant cavity, so why subject this over such short distanced; the blind or visually impaired person does not need to know about an obstacle one thousand metres from his current position. A laser can however be reduced in power by several methods; the most it relation to my project being polarization. The electronics could also be modified to pick up such changes in high voltage but the most part all photo sensors will have threshold limits, polarization and photo sensors will be explained in more detail further on in this section of the report. However, why start with such a high powered beam and then reduce its strength to suit your experiment when there could be a more adequately powered light source available.

The narrow cross section can only cover a very small area; if something were to move in front of the narrow beam; an empirical change in the amount of reflection could be picked up; but what if the object was simply just the left or right of where the beam passed; the electronics would decipher that no obstacle was in position and so the blind or visually impaired person would not be aware of any oncoming danger; this hints that a less convergent amount of light with a larger cross-section would be suitable.

The coherence of the beam related to some of my expansion ideas and to the mention polarization later on in this section of the report. On the following page is figure 5, a diagram effectively showing what the coherence of a laser means; all of the photons are in phase, causing spatial coherence, where photons are in line across the cross section of the beam, and temporal coherence, where photons are coherent along the beam.

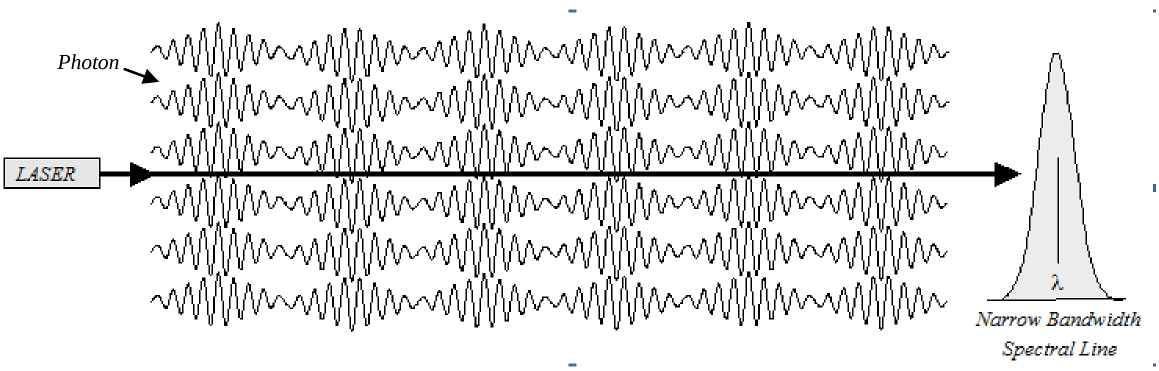


Figure 5 **The perfectly in sync photons representing both forms of coherence in a laser**

I have chosen the mention coherence because it can be used to measure if part of a laser has in fact travelled a longer distance through what is known as an interferometer; these will be explained later in this section.

Having two separate laser beams meet will always cause interference patterns; having two from the exact same source that have been split and come back together will form organised interference patters due to the varying phase difference between the two separate parts of the beam when they meet back together. This is commonly known as destructive and constructive interference; and is best represented in the crude yet understandable format shown below in figure 6 and 7. In figure 6 it is considered the two beams have come back together fully in phase; the photons are in exactly the same relative positions were before the beam was split, in figure 7 the opposite has happened and the photons have no cancelled their overall effect out. In between these two extremes are varying amounts of interference that cause a graded light intensity.

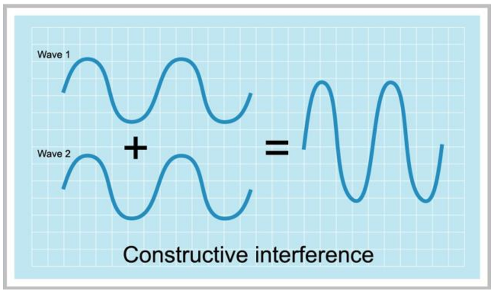


Figure 6 **Photons remain in sync - in phase**

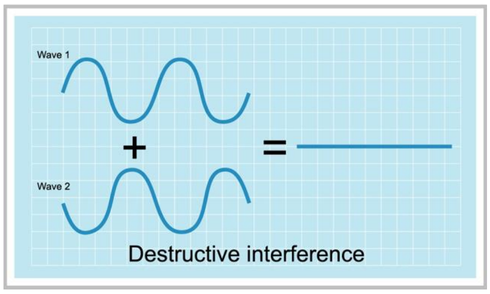


Figure 7 **Photons no longer in sync – out of phase**

2.1.2

An Interferometer splits a beam of light into two separate coherent beams and controls the lengths for which they are separate; changes in the interference patterns caused by these changes in distance can be measured.

When the interference is very strong and concentrated and does not blur the difference in lengths for two split beams must be close to a multiple of the wavelength, for the photons are now in phase. When this distance is not near the wavelength interference patterns will become less distinct. On the next page Figure 8 shows what an interferometer is achieving, figure 9 is a common interferometer setup.

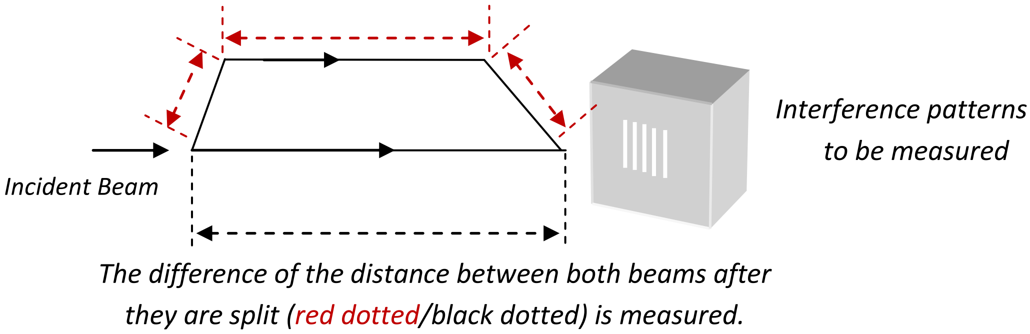


Figure 8 **Interferometer setup**

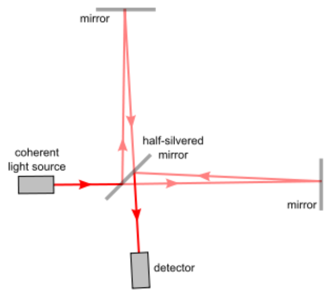


Figure 9 **Michelson interferometer.**

I am giving this brief overview of coherence and interferometers because the equipment at OpTIC Summer School can only measure the intensity of light; nothing more, more expensive equipment could directly detect a change in coherence; but the best effect that could be produced in a project would be to pick up the change in the light intensity coming from the interference pattern; which would only have changed if the distance one of the parts of beams had became longer/shorter. This explains why I might have used this in one of my expansion ideas shown in the design specification section of this report.

2.1.3

Polarisation is one of the four major encoding treatments that can be placed upon a laser; the other three forms of treatment being pulsing, placement and protraction; none of which relate to my project. Usually an optical component is contained within the resonant cavity of the laser which will then result in outward beam already being polarized; the electric field of the entire beam moving in one direction.

The polarisation of light could have provided my project with two separate design additions; the first of which relies on being able to reduce the output strength of any form of light. With a laser only one polarization plane is needed since the incident beam is already polarised; the strength of the output then can be reduced and re-increased by rotating the polarisation plane at varying angles.

When the polarization of a laser is at right angles to the polarising plane; none of the laser beam should be escaping through the gap. In the angles before and beyond a right angle the power of the beam emitted will a partial value dependant on the angle; the effect of which is that the polarization plane can be used as a power control. Any form of light can be manipulated and encoded to the same effect with two sheets of polaroid, one followed after the other. In terms of the proximity sensor the amount of light that is being scattered back into a photo sensor after hitting an object can be changed, so the user can have some control measure over what distances they decide are safe or dangerous. The electronics involved in this project can also produce the same effect, explained further in later sections of this report.

The other effect that could have been implemented into my project occurs when any form of light hits a surface; the light scattered from the surface becomes partially polarized in the direction of the plane of the surface. It is in this way that Polaroid can block out glare bouncing from a highly reflective surface. In the design specification section of this report the idea to expand the use of the walking stick relating to this effect is shown.

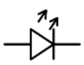
2.1.4

The wavelength of infra-red light spans between being longer than visible light; 400nm - 700nm, but shorter than terahertz radiation, 100 µm - 1 mm, in relation to this project this is only important because it is distinguishable from other forms of light by the electronics.

Infra-red light in this project would improve upon a laser in matters of safety as even a lower powered laser can directly damage the eyes cornea or retina; however infra-red light is still dangerous. The aesthetical value of Infra-red light is that it cannot be seen and would not look intrusive in any environment unlike a laser, but this is also the danger of infra-red light; since the retina has no awareness of the infra-red light; the eye could focus upon it and no pain receptors would inform the brain that the cornea or retina were being burned. There is no method by which the eye can distinguish how powerful the infra-red light is; and therefore the eye could effectively be staring into a very bright torch for an extended period of time. Due to the design of the light source of this project being near to the ground; this risks associated with the infra-red light are considerably reduced.

2.2 Electronics

This project consisted of a range of electronic circuits and components that would piece together and form a working prototype; the design specification and construction covers how the electronics form together to produce the desired outcome. The data sheets for the components described here can be found in Appendix B.

2.2.1 

The infrared L.E.D's available at the Summer School varied in one relative important aspect; the angle at which light would be emitted; Farnell, the UK electronics provider had infrared LED's that could emit from around 10 degrees to a full all direction emitter. All LED's used at the summer school would be run on a 5V supply, stepped down from a 9V battery pack.

- IR EMITTER, 5V
  - Wavelength, Typ:950nm
  - Power Dissipation:210mW
  - Forward Current:1A
  - Voltage, Vf Max:2.6V
  - Viewing Angle:17°
  - Case Style:T-1 3/4
  - Operating Temperature Range:-55°C to +100°C
  - LED Colour: Clear
  - Mounting Type: Through Hole

Figure 10 **VISHAY SILICONIX - TSAL7200 - IR EMITTER, 5V**

Above is figure 10, a small part of the information listed on the data sheet from the TSAL7200; the infra-red emitter used in this project. The 17 degree angle from which light is emitted is an advantage over the narrow cross section of a laser beam; more light is likely to reach a surface and scatter back into the photo sensor in the general direction stated, rather than a specific narrow line of sight. A more complete data sheet can be found in Appendix B.

A typical LED consists of a junction diode made from the semiconducting compound gallium arsenide phosphide; it will only emit light when in forward biased. The junction consist of two 'sides'; an 'n' side, with many free negative charge carries, and a 'p' side where electrons have been removed leaving many holes, hence it is positive. When this p n junction is forward biased electrons move across from the n side to p side, these electrons are attracted to the holes and reconnect with them near the junction; figure 11 below shows this effect. The holes can also act vice versa; moving and combining with the electrons.

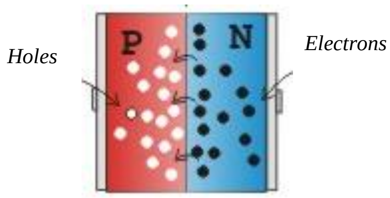
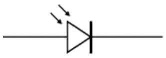


Figure 11 **p n Junction**

This recombination signals a change in energy levels for the electrons and energy is released because of these changes. In many semi conductors this energy would be mostly transmitted as heat but with gallium arsenide phosphide a portion of specific light is emitted. The p n junction is located very close to the surface of the L.E.D; and this light is soon focused by the inbuilt curved lenses that are found on most L.E.D's, this lens determines the divergence of the L.E.D.

2.2.2 

In order to pick up any infrared light off a scattered obstacle; an infrared photo diode is needed; the infrared photodiodes provided at OpTIC vary in sensitivity and speed, allocated to their appropriate TSL number; 260, 261 or 262. The infrared photodiode 261 has both a medium sensitivity and reaction speed to incident infra-red light, and is the photodiode that I used in this project despite the fact that this project did not need a faster speed and relied on sensing any scattered light off a surface.

In using the more sensitive photodiode the reaction speed is lowered and in gaining a faster reaction speed the sensitivity is reduced; the difference is caused by slight changes in the internal components of an infrared diode. The operating rise time of the mid sensitivity photodiode used in this project is 70µs, whilst the slow 260 has a rise time of 240 µs, the fastest and least sensitive 262 has the smallest rise time of 7 µs. The data sheet relative to the TSL 261 mid sensitivity photodiode is located in appendix B.

A photodiode operates in reverse bias; with more leakage current as increasing light energy breaks bonds in a crystal lattice structure of a semiconductor, creating electrons and holes. A choice of material can be made here that determines the band gap of a material; the band gap is what a photon's energy must overcome to produce and electron-hole pair. Once photons with high enough energy are detected electrons are excited onto a conduction band. The conduction band carries these electrons as a current because of the field that the p side/semiconductor and n side/semiconductor create. Figure 12 below shows the diagram of a photovoltaic cell; the photodiode contains a setup similar to this.

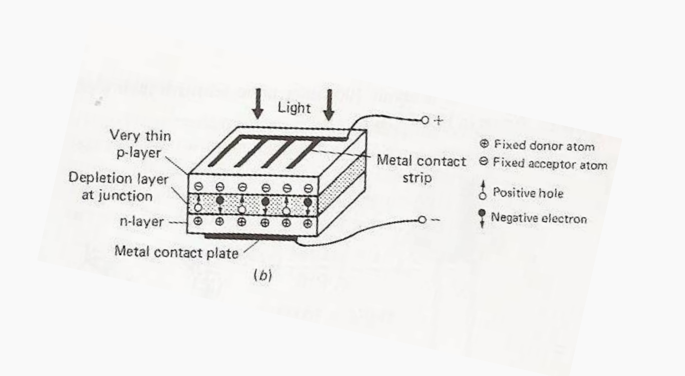


Figure 12 **Diagram of a Photovoltaic cell**

2.2.3

Over the next few pages the circuits involved with this project will be mentioned; all data sheets for the chips in relation to these circuits are in appendix B of this report. The circuits all show chip pin outs that inform the user where the power, ground, inputs and outputs are found; there are vital to be aware of; as they vary between different chips.

Operation Amplifiers and Buffers

Use

The operation amplifier shown to the right in figure 13 is designed to increase the current and amplify an input voltage to a larger value. It is useful to have the infrared photo diode output (which is a voltage since the photodiode contains its own smaller operational amplifier) lead directly into an operation amplifier so that the small voltages induced by scattered light falling on the photodiode are increased to values which other electronics circuits can recognise (Voltages below 0.5V are inappropriate as a voltage input; such small values can limit how well circuits such as voltage comparators compute the voltages and therefore unwanted outputs may be produced).

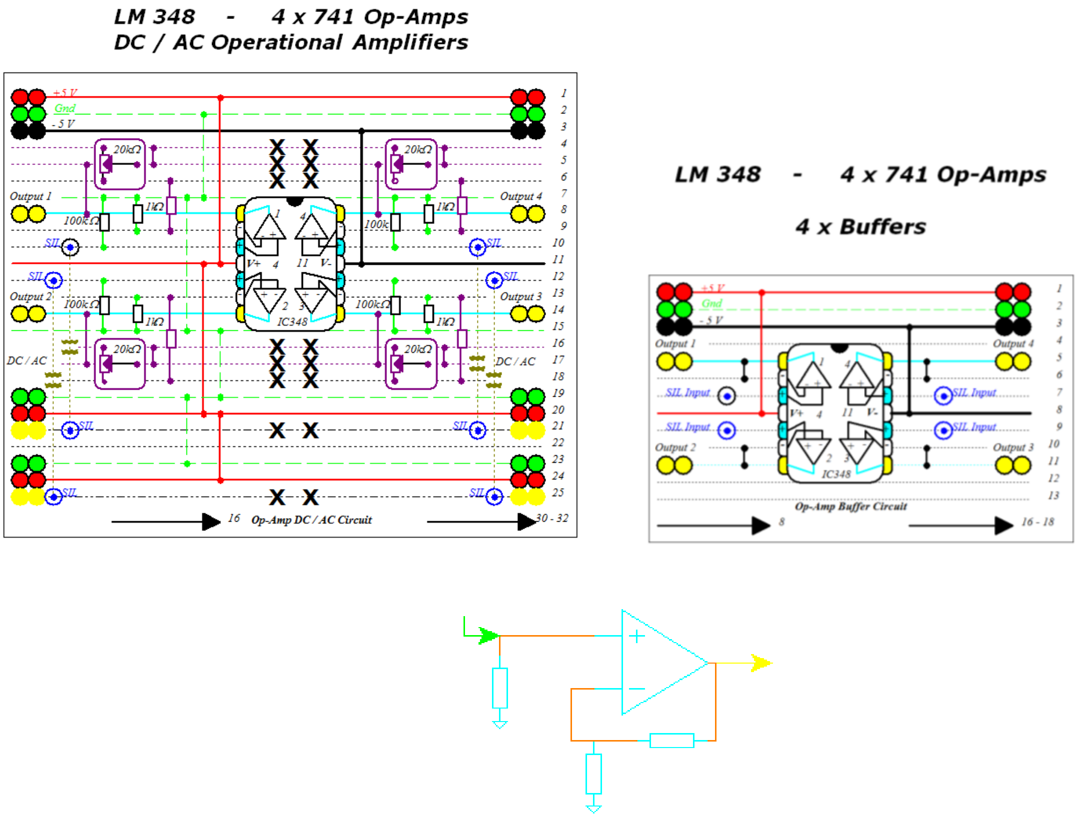


Figure 13 **741 circuits, Op-Amp and Buffers**

How it Works

An Operational Amplifier is effectively a negative feedback circuit, its output is reduced to a defined value by a varying part of the output being thread into an inversing input; figure 13 above is a representation of how most Op-Amps are constructed. The feedback and inversing input resistor's values determine the gain of the Operation amplifier. The following equation is used to calculate the gain;

Vout = Vin*((Rf/Ri)+1), (where Rf is feedback and Ri inverse input)

If both these resistors are the same the voltage will be doubled. ((1 + 1) * V in = V out); by increasing the reversing input resistance in comparison to the feedback this gain can be increased. It is up to the user to decide upon the gain of the Op Amp.

The Op Amp chip is designed to want to balance both of its inputs, if an output of 2 Volts is given from an input of 1V, and both resistors are equal (diagram bottom of figure 12) (gain of 2 – half of output voltage is fed back as inversed input); then the op amp is balanced and will not try to change anything. If at any time an output of 1.8 Volts is given with the same input 1V and equal resistors; (gain of 2 – half of output voltage is fed back as inversed input) the inversing input would now be 0.9. The Op Amp wants to make both inputs equal so it modifies the output it is producing until the inversing input equals the first input, in this case the Op Amp would increase its output to 2 Volt in order for the inverse feedback to become 1 Volt.

This is not direct process; in the space of a very short time the Op Amp acts like a spring, trying output values higher and lower in repetition until it reaches a balanced system. (In the example above the output might be increased to 2.2 and then back down to 1.9 and then back to 2.1, this would repeat until 2 Volts is reached.

The buffer uses the same chip as it is effectively utilising an operational amplifier with only a gain of one, to the right of figure 13, the circuit shows how the buffer has no resistors to split up the output voltage; instead the entire output becomes the inversing input. This means that the buffer can be used to re-increase current at any point in circuit without modifying the voltage.

The Op Amp and Buffers requires 5 volts and -5 volt rails.

Voltage Comparator

<u>Use</u>

Voltage comparators can take a varying input voltage and only produce a high output when this voltage meets or exceeds a predefined value. Voltage comparators are used to compute voltage amounts and can turn an alternating voltage into a direct voltage.

<u>How it works</u>

Figure 14 on the next page shows a voltage comparator strip board layout; this design is related to an operation amplifier because it works in a similar way. A comparator is effectively an Op amp operating without negative feedback; it will only activate when the positive non inverting input is greater than the negative inverting input. When this condition is met a high output is produced; similar to the power voltage that the Op Amp runs on.

By modifying the gain of the comparator the user use can set the value of the negative input; this is the voltage that the input of the non-inverting must provide before the circuit produces an output high.

Voltage comparators require a positive 5 volts.

IC 339 Quad Comparator Strip-board Layout

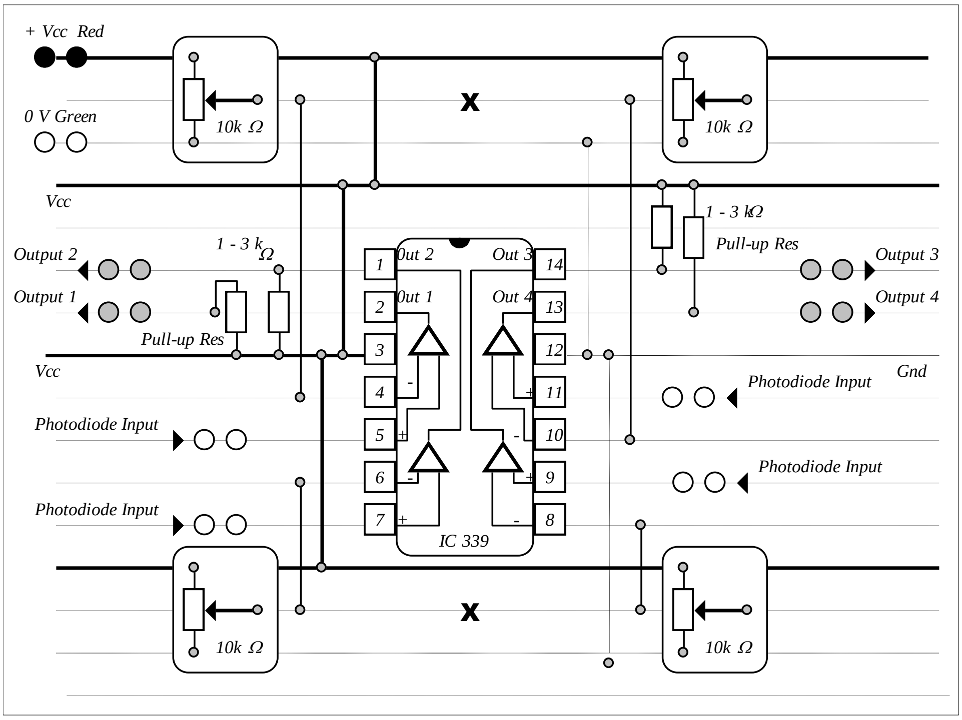


Figure 14 **IC 339 Quad Comparator pin out and circuit diagram**

Power Amplifiers

Use

The use of a Power Amp is to take a signal output from previous circuits and make that signal suitable to drive a speaker. This transformation is fundamentally an increase in the strength of the signal; if the modulating signal from another circuit was directly connected to a speaker the signal would be far too weak; and no distinct sound would be formed.

Power Amplifies require a positive 5 volts.

555 Astables

Use

A 555 chip is designed to produce an output that combines high signals and low signals; these signals are switched at certain frequencies to create a vibrating output; as long as the frequencies of these vibrations remain within logic gates reaction speeds; then this frequency can be sent through a prototypes logic brain. By changing capacitor and resistance values within the circuit a varying range of frequencies can be produced; for example a middle c could be replicated (261 Hz) or a low modulation of 1 Hz, depending on the values of the components.

By including astables in a prototype; the vibrating signals may affect other aspects of the circuits, this is explained later in project report.

Astables require a positive 5 volts.

Distribution Board

<u>Use</u>

In order to supply power for all the circuits involved in prototype project; a distribution circuit is needed; such a board should regulate and support many SIL's for the different voltages that circuits need.

The strip board design for the distribution board circuit is located in appendix A; the design shows that by using two regulators an input of 9 volts and -9 volts can be modified into rows of SIL's for 9 Volts, 5 Volts and -5 Volt. The design also takes into account separate switches to disconnect the power supply from any other circuits apart from the distribution board,

Common switches that are used in prototypes include;

- Direct power connection from the battery pack
- Distribution Connection for +5 volts and -5 volts Rail
- Distribution Connection for +9 volts
- Separate + 5 volts connecting L.E.D's

Below is figure 15, part of the data sheets that refer to the regulators used in this prototype; more of the data sheet can be found in Appendix B of this project report

STMICROELECTRONICS - L7805CV - V REG +5.0V, 7805, TO-220-3

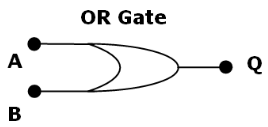
- V REG +5.0V, 7805, TO-220-3
- Voltage Regulator Type: Positive Fixed
- Voltage, Input Max:35V
- Voltage, Output Max:5V
- Max Output Current:1.5A
- Voltage, Dropout:2V
- No. of Outputs:1
- Voltage, Supply Min:8V
- Voltage, Supply Max:20V
- Termination Type: Through Hole
- Case Style:TO-220
- Max Operating Temperature:150°C
- Min Temperature Operating:0°C
- Base Number:7805
- Device Marking:L7805CV
- IC Generic Number:7805
- Operating Voltage Tolerance +:4%
- Voltage Regulator IC Case Style:TO-220
- Voltage, Input Min:7V
- Voltage, Output:5V
- Voltage:5V

Figure 15 **Voltage Regulator Circuit and Regulator data description**

2.2.4

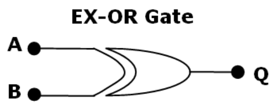
In order to utilise the outputs of all of the circuits considered over the previous pages; logic gates must be used. By combining multiple logic gates an effective brain of the prototype project is made. Each type of gate will produce a high signal ‘1’ or a low ‘0’ as an output depending on the combination of inputs; the way each gate interprets its inputs to produce an output is explained by its name. The three types of gate involved in my project are shown in figure 16 below.

To produce a high (‘1’):



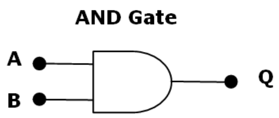
Input		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

Only one input needed.



Input		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

(Exclusive shortened to Ex)
Only one input
but not both.



Input		Output
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

Both Inputs needed.

Figure 16 **Truth Tables, OR, EX-OR- AND**

The symbols on the left are how these logic gates will be represented in the project brain diagram in the construction part of this project report. With only these three gates many varied outcomes that are linked to the previous circuits mentioned can be produced.

The chips provided at OpTIC were the 7400 series, which are fast enough to interpret the frequencies this project specified but require all first inputs to be grounded; in the construction of this project the logic gates were originally not producing the desired outcome because the initial inputs were not being taken to ground. These gates will run high if no input is specified. Below in figure 17 are the chip pin outs.

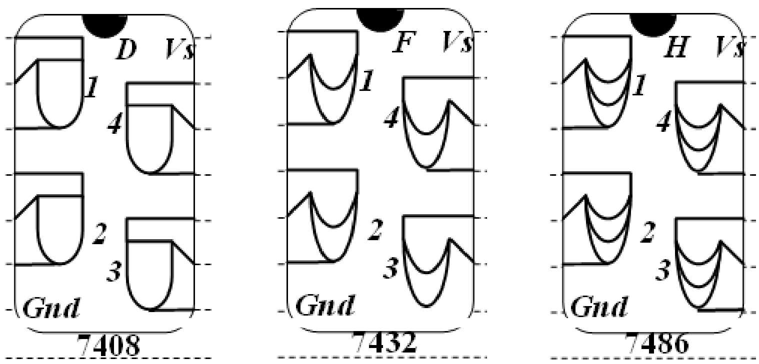


Figure 17 **Logic gate chip pin outs. And, Or, Ex-Or respectively from left to right**

- To avoid damaging any chip, the handler must be grounded to avoid static charges running through the chip.

- Temporary holders called Dual In Lines, or DIL's, are provided so that the chips legs do not have to be permanently soldered in place.

- Single In Lines, or SIL's, are used to hold the wires that will connect any two components or circuits together. SIL's are particularly useful for the distribution board or any temporary ground connection made in the construction process.

2.2.5

As mentioned in the introduction being able to create a ground at any time is particularly useful; it is needed to test any circuit that requires negative and positive input voltages, it is needed when handling chips in order to protect the chip from static and it is needed when producing a final prototype. All circuits in the prototype must be connected to a common ground; that ground can be produced by connecting groups of batteries in the way that figure 2 suggests.

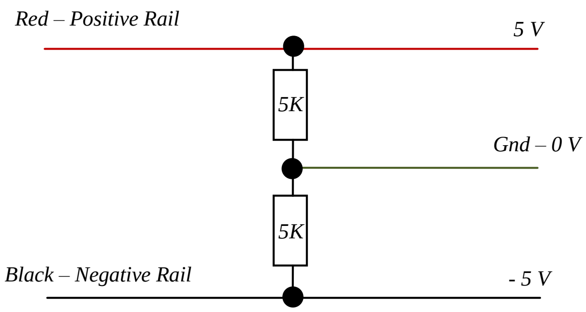


Figure 18 **Positive Negative and Ground connection with only one power pack.**

By using a simple voltage divider setup such as shown in figure 18 above; any student at the OpTIC Summer School could begin investigating with an operational amplifier. This is covered in the Initial Experimentation section of the report.

2.2.6

In the construction of a prototype project, the use of vibrating signals may be used; for example to produce a frequency of sound. When such frequencies are passing near and through many circuits and wires it can create instability in the power rails, and therefore stop many circuits from functioning fully, causing them to produce incorrect outputs, or no outputs at all. In order to stop this from happening capacitors can be placed across the power rails to stabilise their inputs; it may be necessary to place such capacitors on every circuit in order to make the effect of vibrating signals minimal.

3 Design Specification

The theory section of the report has covered information that is relevant to this project. Over the course of the Science Bursary it was the necessary to use this information and form a realistic design that could become a working prototype by the end of the four or five weeks. In this section the final design for the prototype proximity sensor walking stick is shown as well as alternative and expansion ideas that were never realised.

3.1 Project Overview

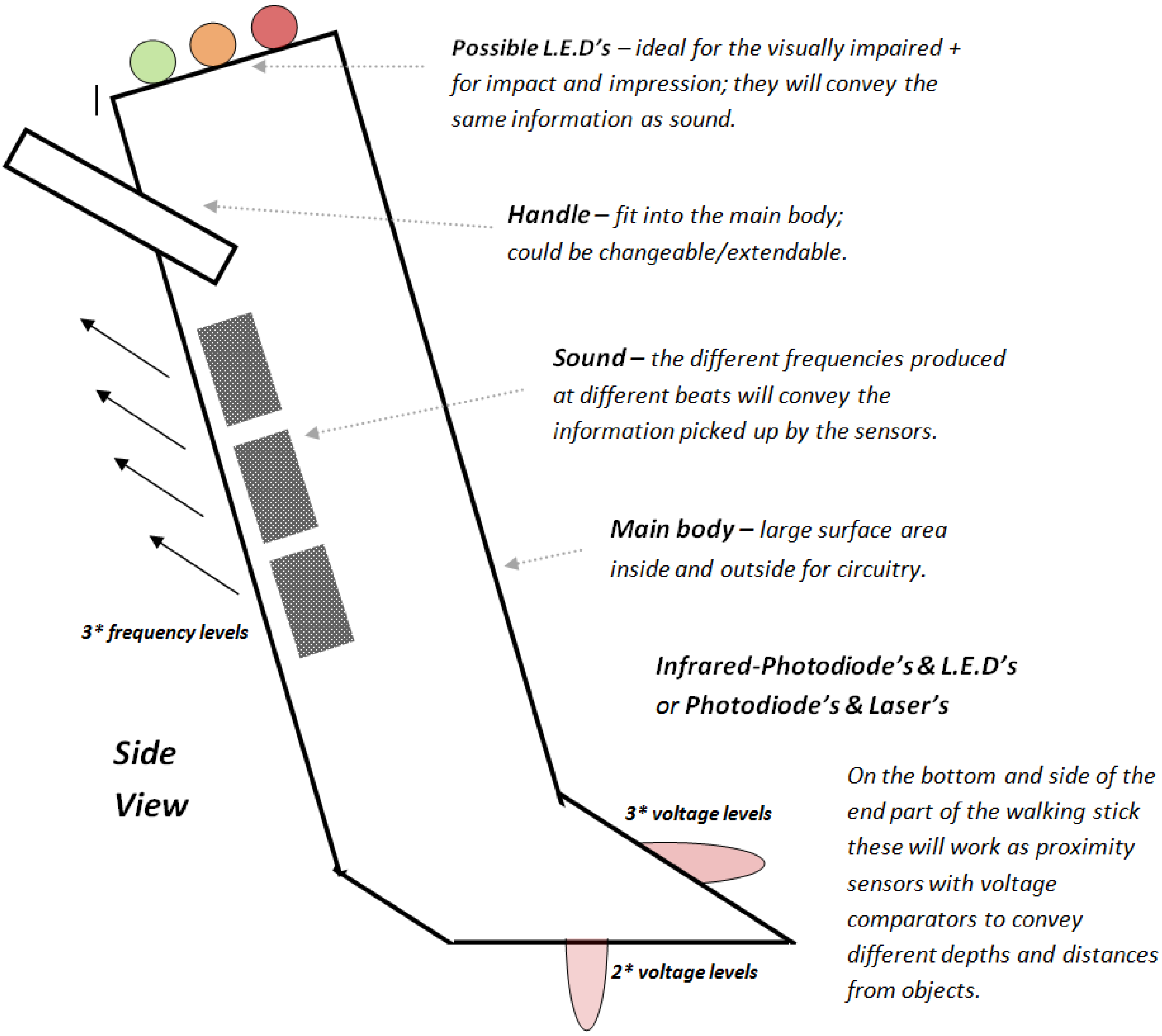


Figure 19 **Project Initial Design**

Figure 19 is the first impression of this project design, near the bottom of the image are the sensors that will eventually produce an output relative to which direction and how far away an obstacle is; which, in this diagram; is considered to be a sound. In relation to this design, many plausible ideas were stimulated; they are considered on the following page.

- In the first designs I considered that Polariser could be used to manipulate the range of when "FAR" and "NEAR" are defined, or perhaps the user could have direct access to part of the electronics that would also change these values.

- By using a chord, the user would be able to recognise more than one overlapping frequency and would not have to deal with harsh intrusive frequencies.

After deciding upon sound to primarily define the direction and distance many chords were sampled until a suitable sound that reflected a subtle warning was found. The three frequencies of sound with two different modulations to represented whether the object was close or far would be used. Being a prototype it was considered this was an acceptable warning, however in a real commercial product more complex sounds or even words could be used to inform the visually impaired person of their surroundings. Figure 20 below features the frequencies that were chosen for this project.

44	e′	E4	329.628
43	d♯′/e♭′	D♯4/E♭4	311.127
42	d′	D4	293.665
41	c♯′/d♭′	C♯4/D♭4	277.183

40	c′ (1-line 8ve)	C4 (Middle C)	261.626
39	b	B3	246.942
38	a♯/b♭	A♯3/B♭3	233.082
37	a	A3	220.000

Left: *a (220 HZ)* Centre: *Middle c (261.626 HZ)* Right: e *(329.628 HZ)*

Will sound at 1HZ when *FAR.* Will sound at 2 HZ when *NEAR.*

The bottom range will sound a constant overlapping noise when turned on as the proximity sensor in front is no longer the most important feature at this time.

Figure 20 **Frequencies to be Implemented**

After the sounds had been defined the design specification continued towards other specific ideas; shown on the next page, these helped form a physical image of what needed to be achieved through the optoelectronics and so started influence what circuitry would be needed.

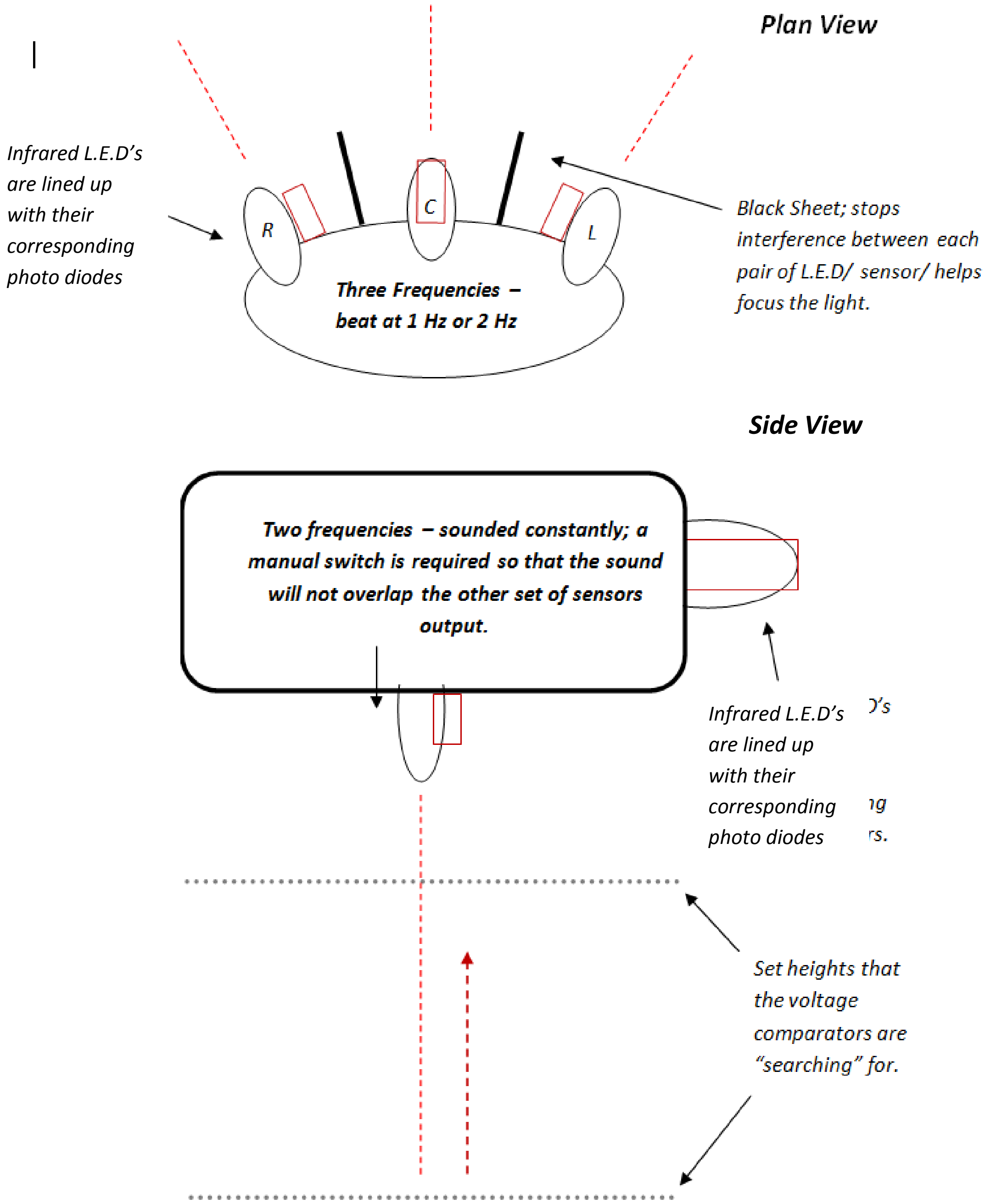


Figure 21 **Setup for L.E.D's and Photodiodes**

A varying output will be sent from voltage comparators depending on what direction and how high the incident voltage from the scattered light is. This incident voltage is produced by infrared photodiodes that will have picked up the scattered infrared light if it has reflected off an obstacle, this is voltage is then modified by the Operational Amplifier to suitable amounts depending on how far away the user considers and obstacle to become dangerous. These setting will differ for the bottom step sensor and the three forward facing directions sensors.

Figure 21 above shows how this is represented; the black dotted lines are settings that have been chosen through using the electronic circuits. It is at this point in the project that investigation into how long the range of such setups can averagely reach is vital, it forms part of the initial experimentation section of this report.

3.2 Additional Designs

Throughout the completion of the project many additional designs that could have been possible were recorded.

In my current design when the user is measuring the height of steps a constant sound is produced, this is due to the need for this sound to be distinct; the visually impaired person must recognise exactly what the sound is expressing in order to understand their environment. However having an overlapping noise means that whilst the user is measuring whether the height of a step is suitable to traverse, he or she can no longer recognise an obstacle in front of them as the modulating sound has been overridden. A suitable solution to this problem may have been a vibrating handle; this handle would simply contain a motor that spins at different speeds depending on how far an obstacle was in front of the user. With the vibrating handle the visually impaired person can no longer decipher between directions; but would at least be aware of any obstacles in the near vicinity. Figure 22 below shows three further additional ideas that I never fully investigated but could have been appropriately useful.

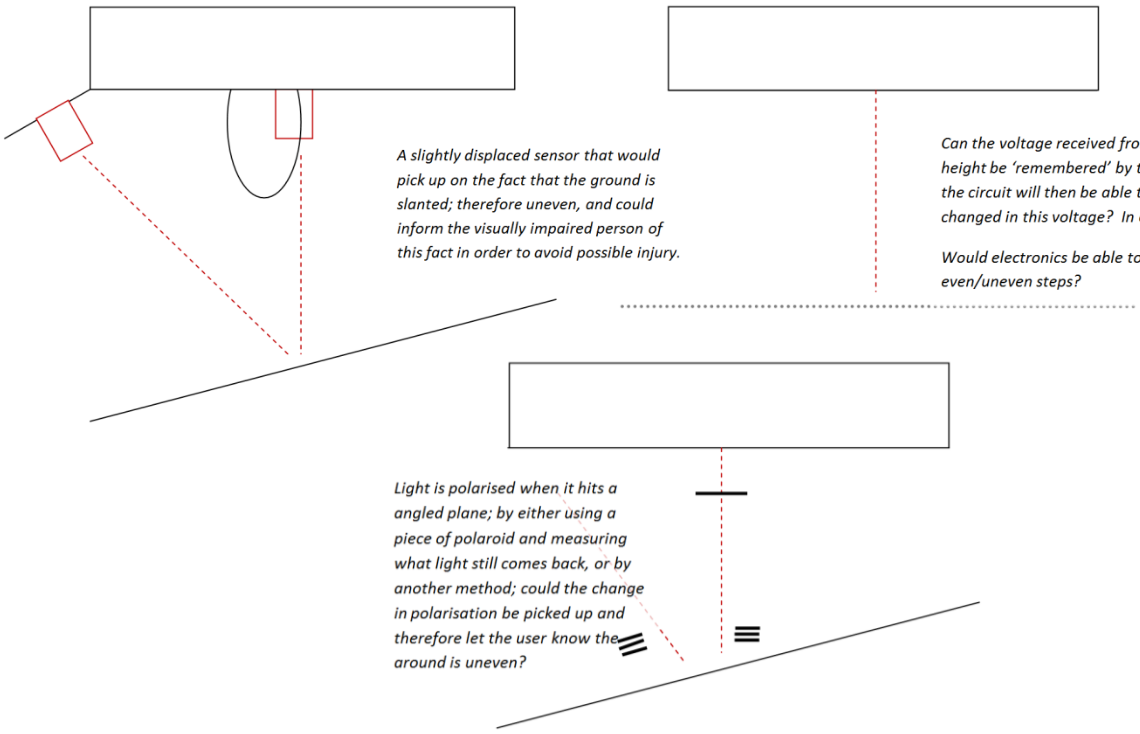


Figure 22 **Three Additional Ideas**

All of the above ideas reflect somewhat on research taken whilst students were blindfolded for a day and whilst they queered disabled people; including the visually impaired. The research clearly stated that uneven ground and steps were very dangerous and uncomfortable for the visually impaired, which is why each of the three ideas above would have attempted to solve the problem of being unaware of uneven or worn steps and ground.

There was another additional idea which will mention in a further section of this project report.

4 Initial Experimentation

Whilst developing ideas and transforming them into a plausible design was a goal to be completed in the first weeks of the Summer School at OpTIC, vital experimentation was also taking place. This experimentation was both a supplement to inspire the development of ideas and an examination of ideas to see if the outcome expected through designing would match what was actually produced by circuits and optoelectronics equipment.

4.1 Operation Amplifier

4.1.1

The first circuit that anybody at OpTIC produced was an operational amplifier, from which an input from a photodiode produced an output readable voltage that could be picked up on an oscilloscope. In the very first experiments an L.E.D was used as an output, it would light when the photodiode was directly exposed to light. Figure 23 below is an image of the operational amplifier that was built on the second and third day of the Summer School. This operational amplifier contained a 1K ohm inverse input resistor and a variable resistor that could contain anything from 1K – 1M ohm resistance for the feedback.

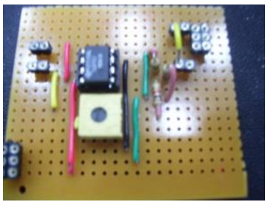


Figure 23 **Operational Amplifier**

After the initial introduction to the Operational Amplifier the effect of adding a capacitor was shown; a brief flash output could now be produced. The experimentation continued as shown in figure 24 below, with the occasional introduction of new components such as infra-red L.E.D's, Lasers or pieces of polaroid at regular intervals. After gaining knowledge of how to setup such circuits and how to use the oscilloscope, the experimenting was left to the discretion of the student.

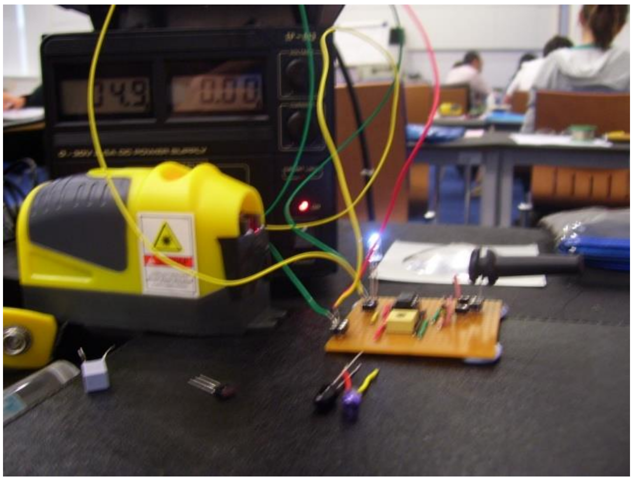


Figure 24 **Initial Experiments**

The photodiodes that are used are in fact sensors that produce an output voltage in their own right; each photodiode has its own operational amplifier inside it that creates this output voltage.

4.1.2

It was through the cycling of components that it was decided to use L.E.D's rather than the lasers; the latter of which had been more difficult to align and often exceeded the threshold voltages of the photodiodes at inappropriate distances. When infrared light emitting diodes were tested using only white card as a 'obstacle', the flexibility in both divergence and distance of infrared soon became clear; light was scattering back into the photodiode and producing a recognisable voltages for distances between 30cm and 50cm depending on what value the feedback resistance was, and normal room light was not interfering with the investigation.

A 20k feedback pot was producing fairly limiting distances and would quite often fall below 0.5 V output after 20 cm. using a 50k pot in the operation amplifier produced adequate ranges of distance that would still produce voltage from scattered light up to 50cm away. The pot was never set to the maximum of 50000 ohms, where the operation amplifier would begin to produce an output even when the infrared photodiode was not in range of any obstacles. For the distances that were considered averagely dangerous for an obstacle; 40000 ohms was used.

Using **Vout = Vin*((Rf/Ri)+1),** a voltage output of 4.51 V was calculated when a input voltage of 0.11V from the photodiode was provided.

0.11*((40000/1000)+1) = 4.51

This input occurred when the obstacle (white card) was 18cm away from the photo diode; any closer and the output voltage will then reach saturation at the 5V threshold. As the obstacle is moved further away this output voltage slowly declines until becoming indeterminable when the obstacle is beyond 50cm distance from the photodiode.

From this point in the investigations the circuits that were going to be needed in the prototype were becoming clearer; from the output of the operational amplifier that was now known to be produced at sensible distances, voltage comparators would interpret the outputs and produce inputs when the voltages were only high enough to be considered a dangerous distance. The construction part of this report continues to describe how these circuits come together now that I knew I could produce distinctive inputs.

4.2 Further Experimentation

4.2.1

Whilst knowledge that the correct inputs could be successfully collected from the scattering of light was enough to start constructing a prototype; further investigation into the amount of infra-red light scattered off different materials with different colours is needed. With the current prototype design a user might mistake a bright white coloured object to be closer than its real position; this is because the white material could be reflecting (scattering) more light than an average dull coloured object. The opposite could occur when considering a much darker and rougher object. This might add considerable danger if the height of steps is misinterpreted.

It is this that leads to a final expansion idea which involves a project that is already working from a previous OpTIC set of students; a colour reader that could roughly interpret the colour of the floor. Aside from the obvious direct implication of attempting to solve another form of visual impairment this may also have improved the proximity sensor. By being able to determine the colour; amplifiers could have modified the voltages by preset values relative to each colour.

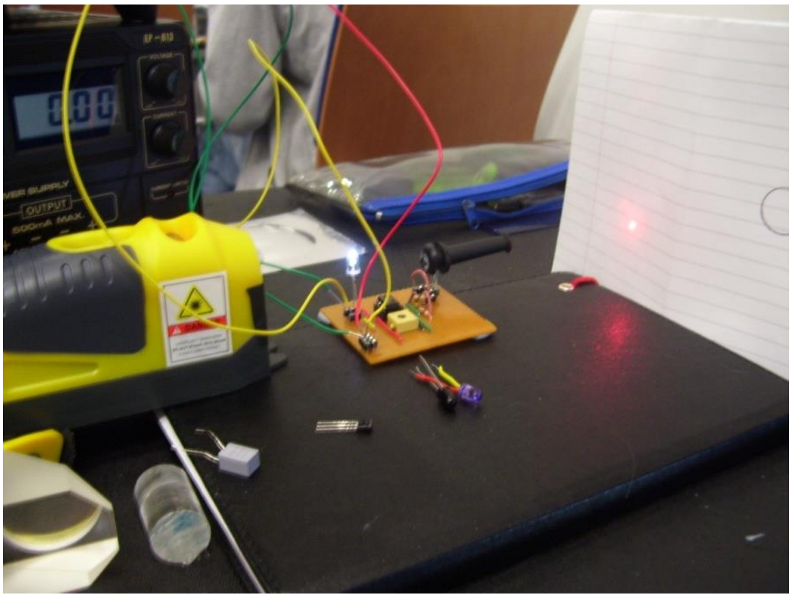


Figure 25 **Detecting Obstacles**

Figure 25 shows one of the many quick experiments that were taking place. Here an operational amplifier is detecting an obstacle (L.E.D is lit) in the near vicinity; this setup was used to investigate a laser; as can be seen working, and later by the infra-red L.E.D and photodiode lying in the foreground. This project functions because of scattered light that can be seen on the paper.

4.2.2

Other smaller experiments that were used to form a fully functioning design specification included traversing different heights of steps until the distances became inappropriate and dangerous, and the sampling of several chords to find sounds that would be recognisable, comfortable to experience and easy to produce with crude astables.

For this project a suitable drop for a step was decided to be limited at 22 cm with anything above 25 cm being considered a dangerous distance that would actuate the appropriate sound.

For each frequency that was chosen the wave length was calculated; which could then be used to program the astables by use of the oscilloscopes representation of a waveform. For the three frequencies in this project the following measurements had to be implemented:

- A 220 Hz 1/220.0 = 4.55 x 10^{-3} cm
- C 261.6 Hz 1/261.6 = 3.82 x 10^{-3} cm
- E 329.6 Hz 1/329.6 = 3.03 x 10^{-3} cm

By tweaking the 555 astable settings slowly and measuring the oscilloscope waveform, a fairly accurate frequency could eventually be formed.

5 Project Construction

With the ongoing input of experiments and design ideas the circuits that would be required in order to construct a fully working prototype were defined. The circuits are as follows;

Please refer to the theory section of this report for the uses of each circuit.

- A Distribution board with rails to provide multiple ground (0), +5, -5, and +9 voltage SIL's.
- An operational amplifier to take a direct output from the photodiode and send an modified voltage output onto voltage comparators. (Four, one for each direction)
- Eight Voltage comparators to interpret the input voltage and only send an output if these exceed certain preset values. (Far and Close values for all four direction)
- Astables to produce five frequencies; the three notes, A, C and E, and the two modulations of these notes, 1 Hz and 2 Hz.
- A circuit in which to mount L.E.D's into; with suitable resistors.
- Buffers to increase the current between certain stages of the overall design.
- A power amplifier in order to make the final output signal produced by a speaker.

However all these circuits need a system by which to control them in order to achieve the right outcome when given certain inputs; this is where a control brain that utilises logic gates is required.

Please refer to the theory section of this report for the truth tables and brief explanation of Logic Gates

5.1 Brain Design

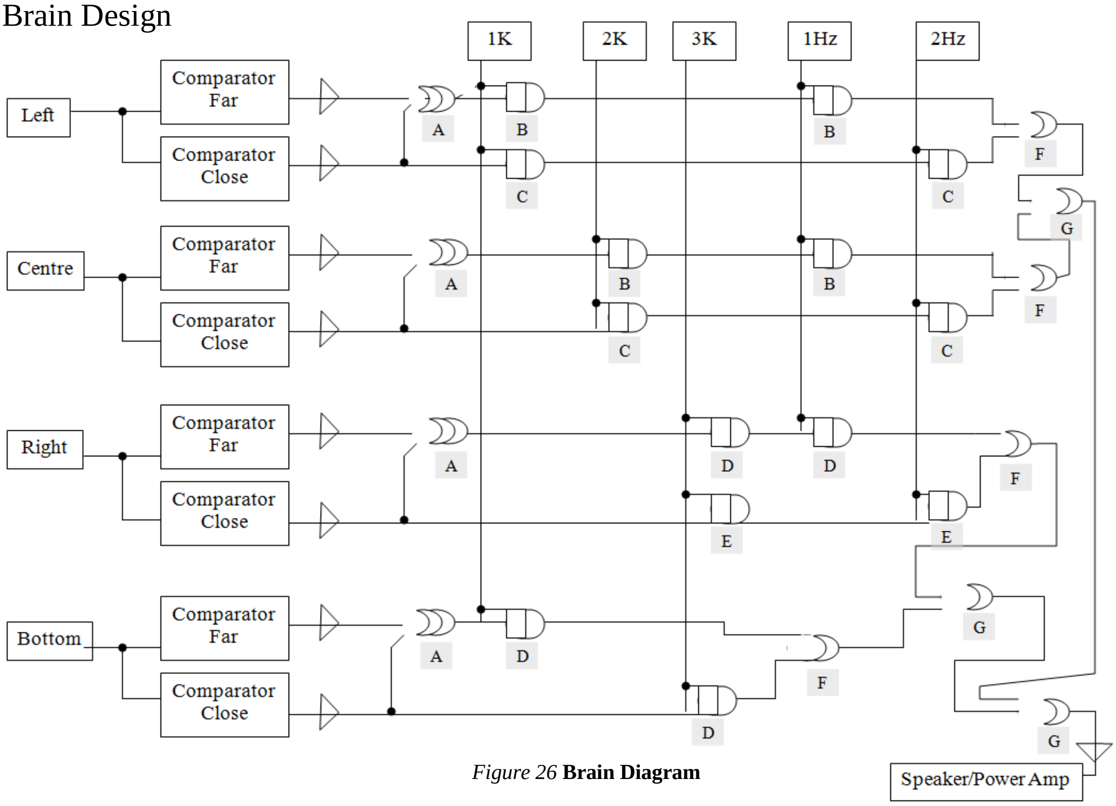


Figure 26 **Brain Diagram**

The brain design shows an overview of how starting with the four inputs and finishing with a speaker output can be achieved; it may be useful to have the truth tables from page 15 at hand when following this circuit through.

The 1K, 2K and 3K shown are actually placeholders for the final chord frequency; A, C, E. When designing this brain these frequencies had not yet been finalised. All the logic gates have been labelled with a letter; this letter has no link to any frequencies but refers to its position on a brain design that is shown on the following page; figure 28.

<u>Example Outcome(s):</u>

To show possible outcomes from figure 26 first consider a combination of inputs and move from left to right across the brain diagram.

An object is found on the right; it is far away, (see comparator far) following this path a EX-OR Gate/Chip A is reached, the truth tables show an EX-OR gate will produce a high output when one input is high, so follow the path further along as the signal has not been terminated. Next an AND Gate/Chip D is reached, the truth tables show an AND gate will produce a high output when both inputs are high. (The frequencies are constantly switching between high and low) So over a period of time this AND gate will switch on and off relative to the chosen frequency (E), continuing on to the right, another AND Gate/Chip D is met; this now modulates the already vibrating signal by 1 Hz; the frequency is now an E note modulating every 1 second. Following on a OR Gate/Chip F is met, OR gates will produce a high output when either or both inputs are high, so the modulated signal continues on; it will now pass several more OR gates until reaching a buffer and power amp in preparation for it to produce the sound it is programmed to produce.

Now that object moves closer and has activated right comparator close, following right from comparator close the signal splits up, one goes directly to the EX-OR Gate/Chip A. (In order for comparator close to have been activated comparator far will have activated first, and stayed active) The EX-OR gate will no longer produce a high output as it now has two high inputs, this terminated the effect of what occurred in the paragraph above. Instead now follow the other half of the split signal across, it will pass AND gates that provide it with the appropriate frequencies and will pass through all the OR gates ready to enter the buffer/power amp/speaker.

This set up will produce the correct sound for every situation; a faster modulation if an object is close, and a constant none modulated sound when measuring the step height. A switch is missing that would allow the user to turn on and off the effect of the bottom sensor, but was later included after the lower down OR Gate/F Chip.

This design was ready to be transferred onto a strip board design and become a working circuit, below is figure 27, the draft hand drawn copy. On the next page is figure 28 the final design.

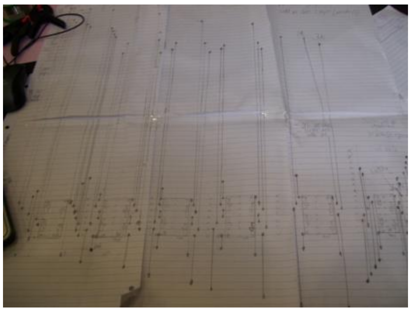


Figure 27 **Brain Circuit**

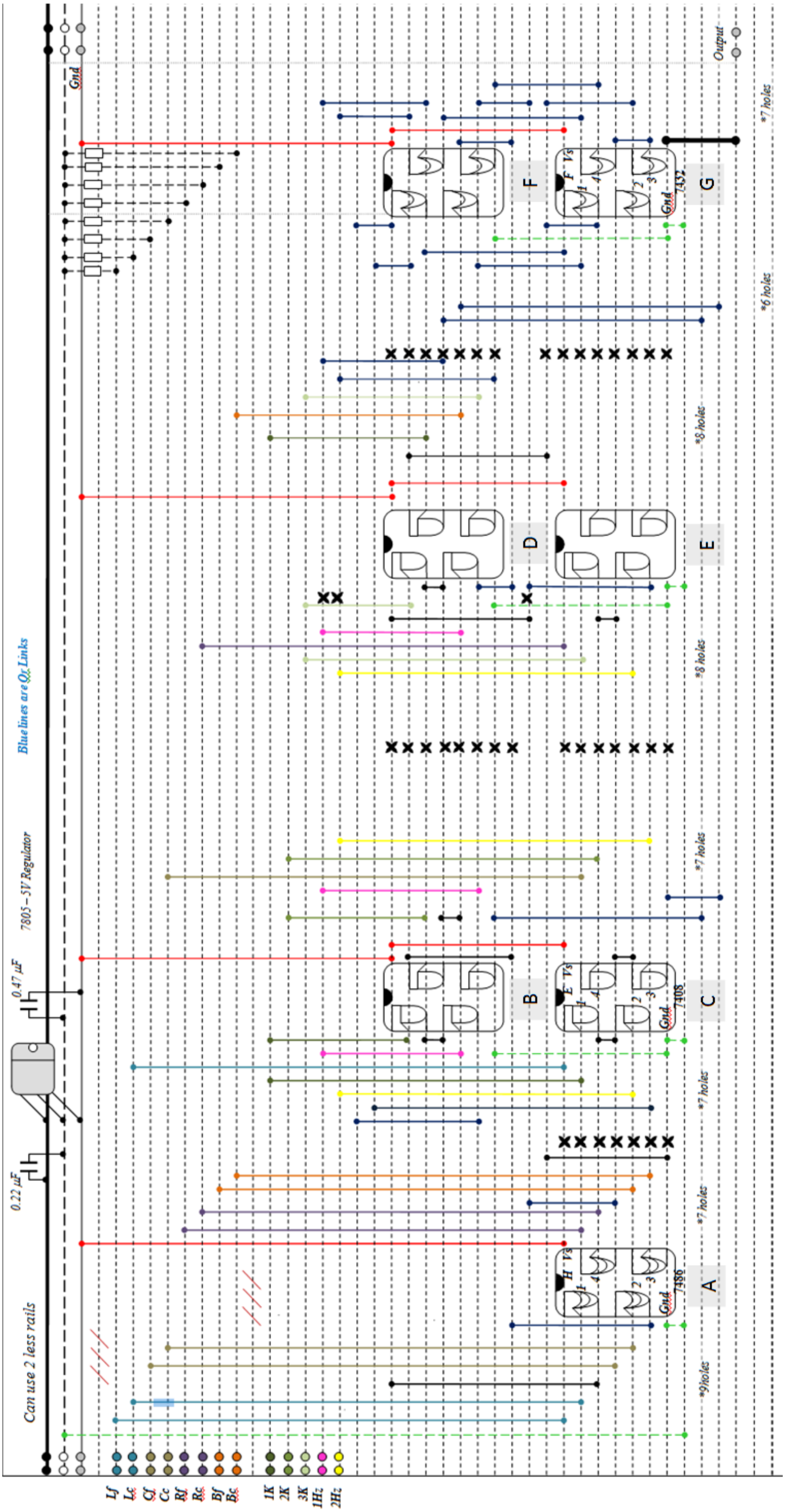


Figure 28 **Brain Circuit Final**

5.2 Circuit Construction Processes

5.2.1

A large part of the work that took place at OpTIC was simply the construction of all circuits needed; and the preparation and manufacture of an object to mount these circuits on. Figure 28 was the largest and most complex piece of circuitry in this project; throughout the soldering and testing processes many precautions had to be taken.

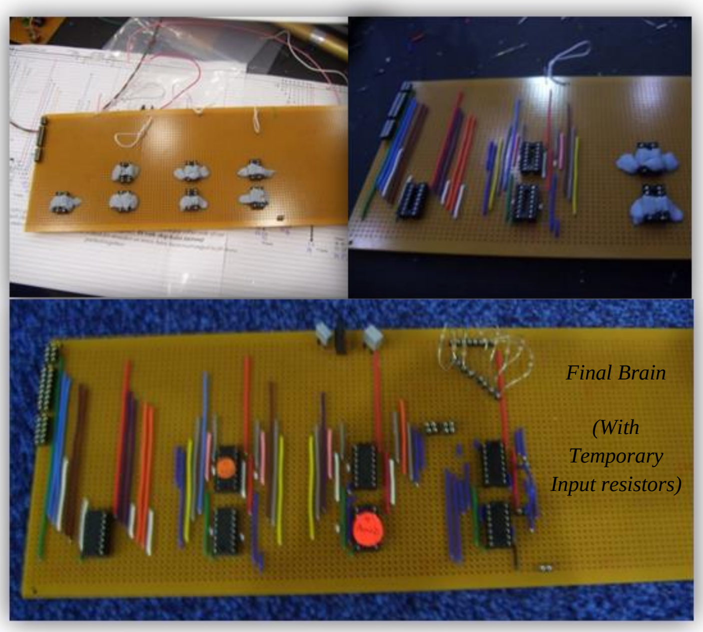
- Track cutting was to be used as the template for the rest of the design; between the track cuttings underneath the chips the number of rows available must be constantly monitored, extra tracks are often needed for temporary resistors or design modification; mistakes may occur that have to be worked around with further space. Below, figure 29 shows how the brain develops in completion over time.

- All first inputs must be grounded since any chip will run high without specified inputs.

- All tracks must be tested for unwanted connections before and after using a drill or file, loose bits of conducting metal can sometime lodge in place between tracks; this will consequently cause the whole circuit to fail.

- Each chip must be tested step by step; each power and ground checked for the right values with no modulation due to frequencies within the circuits. Each output should be tested for all possible combinations of inputs.

Spacing and Layout



Construction – Left to Right

Figure 29 **Brain Construction Developments**

Whilst the brain required much effort and thought all other circuits were just as important, and before construction of any mounting could commence, all circuits should be tested and working. The same precautions should be carried out when soldering and testing each circuit.

5.2.2

All circuits and components were either recycled or soldered and implemented on a new piece of circuit board. In order to produce a presentable prototype all of these circuits could have their rough edges removed and their corners curved, it was also required that as least wire as possible should be showing but as few components as possible should be permanently soldered; this would allow them to be easily replaced, removed or recycled in the future. Once all circuits were prepared and tested separately they were all roughly connected up and tested as a whole, this is shown in figure 30 below; the testing was now to find out if the overall correct outputs were produced when different combinations of inputs were induced; the infra-red photodiodes and L.E.D's were not connected up but tested separately, they would first needed to be mounted and sufficiently aligned in order to form proper outputs that could actuate the other circuits.

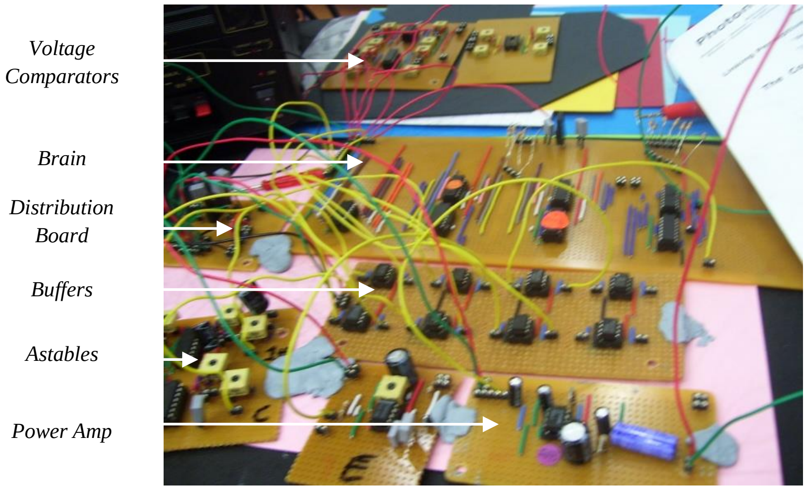


Figure 30 **Initial Complete Circuit Test**

At this stage the prototype was functioning as it should be; however the testing process would have to be repeated twice more; one when the project was mounted, and then finally once when wired in an organised and presentable way.

5.3 Mounting Construction Processes

This project was constructed totally out of acrylic, each piece being;

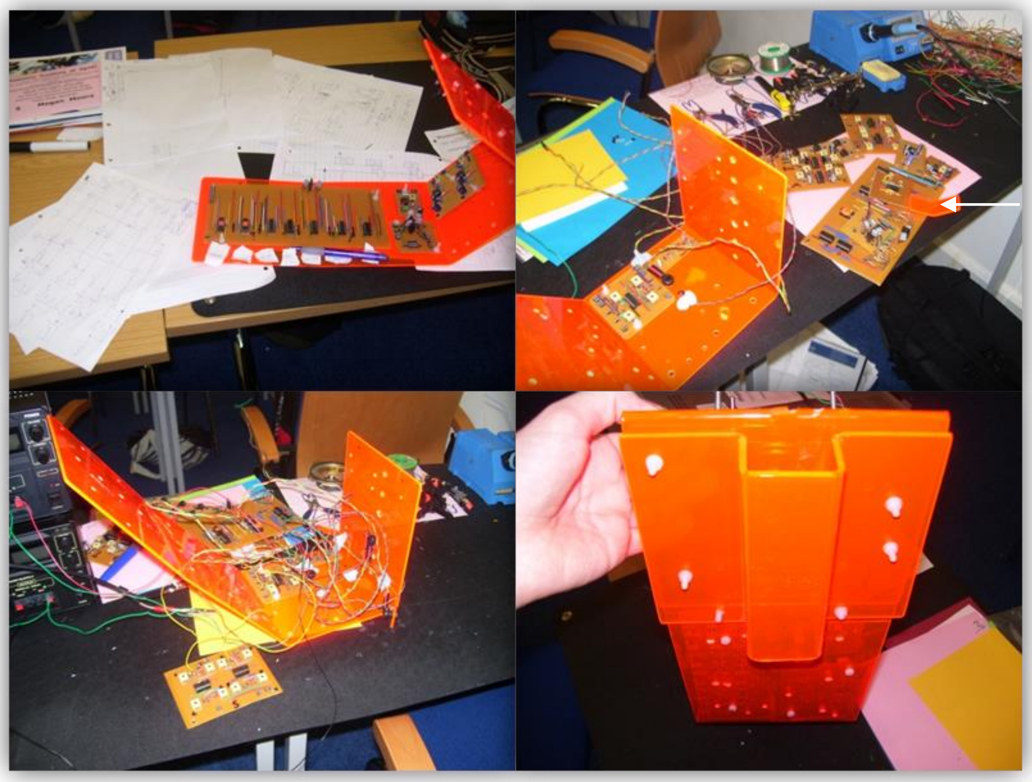
- Measured to fit the desired components and circuits, with enough space for all mounting holes, wire threading holes and switch placement holes.
- Cut out on a using a Band Saw
- Shaped used a line bender to specific angles.
- Drilled using Hand Drill/Pillar Drill/Power Drill (4 mm – Mounts | 5 mm – L.E.D | 8mm – Photodiode)
- Smoothen using varied numbers of Wet and Dry and finished with Aluminium Oxide - Brasso

On this page figure 31 shows the progression of the mounting progress; starting with a scrap piece of acrylic recycled last year and finishing with the final shape with circuits already mounted. The most difficult part of this process was the alignment and positioning of the infrared photodiodes and L.E.D's, and the correct positioning of the handle box.

Original Recycled Acrylic

Alignment Testing – Marking holes for the drill

L.E.D +Diode Mount



Mounting Checked; Alignments Confirmed

Handle Box – Stick will extend from this section

Fully Mounted – Top section added for more surface area – Not Wired

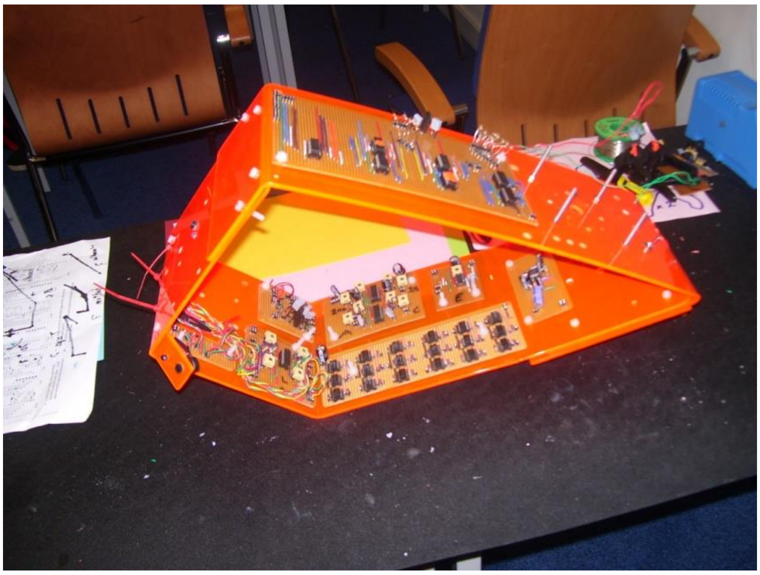


Figure 31 **Initial Complete Circuit Test**

6 Project Performance and Results

6.1 Final Testing – Solving of Problems

As previously stated the circuits are required to be tested several times; most importantly after a major design change in the mounting has occurred. Once this project was fully mounted and wired, as shown in figure 32; a final test of each input and output of every component, chip and power rail was required; this was carried with a combination of three power packs and an oscilloscope. The prototype now fully relied on the outputs from the infra-red photodiodes to actuate the rest of the circuit.

Switch for bottom sensor now implemented.

No handle yet constructed.

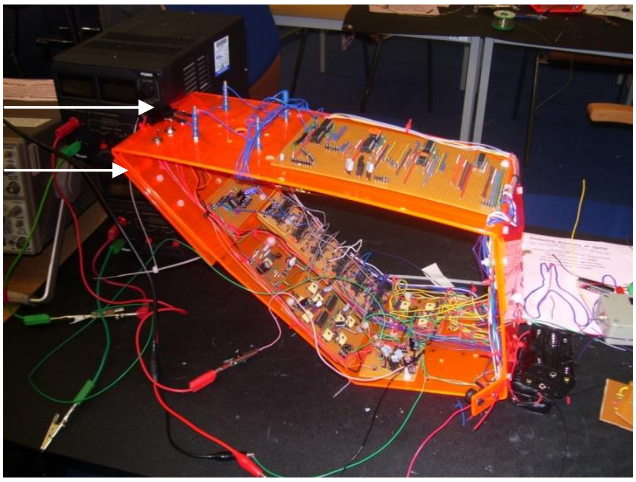


Figure 32 **Wired Final Test *(no batteries)***

6.1.1

On my first initial scan of all circuits a problem quickly came to light; when I switched the power to my distribution board, power rails were fluctuating and no longer had a stable 9V or –9V input, this of course meant that the step down 5V and -5V were also highly unstable. At first this problem seemed difficult to identify, but after realising that disconnecting some of the circuits; (more specifically; the astables) this fluctuation ceased. I rechecked my circuits and discovered two stabilising capacitors had become loose and disconnected; causing my power lines to be effected by many of the frequencies travelling around my circuits. Once the capacitors legs were re-cut to a more appropriate length, straightened and then connected back into the circuit; my distribution board began to function normally.

6.1.2

After this initial problem, every output and input was combed through and no further problems seemed to occur, however; when the circuits were all fully switched on, despite the confidence I had in every part working, the prototype did not function properly and the sound the speaker was producing was unidentifiable. Disconnecting the speaker, every input and output was tested again until eventually two faulty buffers at the bottom of one circuit were identified , they had worked before the mounting process but were no longer producing an output; by replacing the chips the buffers now worked. The prototype was switched on and the speaker reconnected.

6.1.3

The prototype still did not function properly and a final run through of all inputs and outputs ending in the last chip of the brain was undertaken. The second to last input of the OR chip G, the last chip in this entire prototype project, was running high constantly. In the construction and testing of the switch to enable the bottom sensor no ground connection had been added to the switching input, when the switch was broken the chip was receiving no input at all; and the 7 series gate chips run high when no input is specified. A wire and resistor taking this input to ground were added and all the circuits were switched on and the speaker was connected. The project worked.

6.2 Working Performance

The problems defined above and on the previous page are all problems that were solved on the last day of the Summer School at Optic leaving only limited time to test the projects capabilities. Only a few minutes of time were available to re-tweak the operational amplifiers gain and the voltage comparators settings that had been knocked in the mounting of the project. Tweaking each setting separately and testing every sound output in turn the project was now nearing a rough conclusion, and when guests arrived on the last day the project was in a working condition.

By placing objects in front of the prototype the sounds produced would exactly match what was intended of the project, a moderately harmonious modulating chord sounded when three objects were all placed at the same distance; when one or two of these objects were moved close the modulation would sound a fast modulating chord with the slow modulation of the further distance still audible every other modulation. The outcomes were ultimately distinct enough to tell apart and so the prototype succeeded in its general aim.

The prototype however, was not a walking stick; no mobile battery pack had yet been attached in place, and no ‘handle’ had been constructed, the project was very much still reliant on the desk bound power packs. The prototype was effectively a shell of what might be the base of a very oddly shaped and heavy walking stick, and because of its unwieldy nature; it was near impossible to lift the project in the air and then proceed to configure and show what the bottom step sensor could achieve. One final problem was an obvious variance in how the infrared photodiodes picked up a different amount of scattered light between different extremes in colour; an example being black and white. This was fortunately less of a problem as had been first expected through experiments; the danger distances did not tend to vary by a large distance, however, there was only a limited amount of time for this to be tested on the final day of the OpTIC Summer School.

7 Conclusions

7.1 Design Specification Achievements

In considering the production of designs and ideas involved in developing the prototype project I felt very successful. The base idea of a proximity sensor made from infra-red L.E.D's scattering off surfaces and being interpreted by infra-red photodiodes was undoubtedly simple in some contexts, but it was a both plausible and challenging project to take on over my five week OpTIC Summer School bursary, and I enjoyed every minute of it.

The process of developing these ideas plucked the strings of creativity and the understanding of theory, and whilst time was limited It was very easy to spend hours at a time simple scribbling down drafts of an idea; only to realise it won't work for some reason that never would have occurred for you to understand if not for pursuing the idea in the first place. It is in that was that I gained both a little knowledge and an ability to be creative as both these inevitably supported each other throughout the Bursary.

The designing of the overall base ideas for the project wasn't the only engaging task; I particularly enjoyed designing a brain for my project and then converting that into a real circuit on a strip board that physically interprets inputs I define and provides me with outputs that hope for. Aside from the completion of the overall prototype it was the designing of the brain that felt like the most important and self satisfying achievement. Whilst I am happy with these achievements I would, in retrospect; have liked to attempt a design specification that was slightly more complex and involved more of the wonderful components and optical phenomenon that had been presented to us at OpTIC alongside the first few weeks of work. Never the Less following this project from start to completion, and the producing everything that eventually pieced together to make it fully function is an achievement I am proud of.

7.2 Project Result Achievements

Despite the project not completely reflecting the geometric design specification or possessing the ergonomic and anthropometric disposition to suit a visually impaired user as a walking stick; the prototype successfully acts as a proximity sensor actuated by infra-red photodiodes. It is this success, which was only achieved in the last few hours on the last day of the OpTIC Summer School that is the true project result; and provides me with the biggest sense of achievement.

I would have liked to create something that I could in fact truly feel comfortable in calling a walking stick to aid the blind; but my prototype, although working; did not reflect what I first imagined when designing a walking stick. In the end is was merely a case that contained a working proximity sensor, with fully working circuits and components and an overall circuit design that has succeeded in turning infra-red light into what I believe a successful prototype science bursary project.

The use of empirical data has never really been specified to me before this Summer School; but now that I know what it is and now that I have used it through one way or another in completing this prototype I feel confident in utilising it. I am engaged by the way in which this project has developed through the empirical data gained by completing small but signification experiments, which I would have liked the chance to completed more of. Each of these experiments helps direct the way in which designs have been formed.

In order to have built this project I have learnt many different theories retaining to light and electronics that I have never come across before and have had to tackle a workload that I have never experienced before. These project results are produced by not only creativity but also by an extra amount of knowledge, organisational ability, enthusiasm and determination I have gained over the weeks leading up to and the weeks leading through the Science Bursary.

Overall although my project did not have all four sensors tweaked to a fine detail, and although the finished physical shape and mass of the object do not help to promote what the project is supposed to represent; I am content with what I have achieved and produced on the Summer School Science Bursary at OpTIC.

7.3 Project Implications, Further Development and Investigative Potential.

Over 2 million people in the UK suffer from severe visual impairment which makes the ability to improve these visually impaired peoples quality of life an important and worthwhile endeavour. I did not pursue designing this prototype proximity sensor walking stick because of statistics; if there was only one blind person in the whole world the project would still be worthwhile; but the statistics undeniable prove that by trying to design something that can make the visually impaired more aware of their environment, you could end up helping to improve many people’s lives.

In reality this project is rather crude; one of my disappointments with what I achieved in my Science Bursary was not producing many other ideas I had to improve the walking stick, but relatively that means that a lot is left open for further development. Like some of the diagrams located in the Design Specification section of this project report suggest; maybe this project can be developed to become a colour reader or inform the user if the ground is uneven or rough in front of them. There is certainly a lot in the way of detail to be improved upon; with the right investigations completed; better designs to produce many more distance values in more directions could be produced. With more detailed experiments taking place including different materials and colours for the obstacles, the walking stick could be programmed to measure such objects proximity more accurately.

I hope that something similar to S.T.E.P A.I.D is eventually produced; even if it works in a totally different way. I hope that in the future there might be a hand held proximity sensor that can interpret varying colours and materials or can sense dangerously uneven gradients; for it would achieve an important goal by improving the lives of the visually impaired.

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9 Appendix A Additional Circuit Diagrams

Split Voltage Regulator ± 9 V to ± 5 V with Distribution Board / Switches