The Octapus Project

Chapter Contents

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Project Provider

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Abstract

The EESW Project Challenge opportunity was presented to Team A from Coleg Menai, together with the opportunity to collaborate with the Photonics Academy of Wales @ Bangor (PAWB). The decision was arrived at to design and create a novel Musical Tone generating device, which incorporated the Photonics concept of utilizing the characteristics of a Laser Beam, whose beam intensity could be varied to eight different Light receiving intensities, with each of the eight Light intensity values being responsible for activating each of one of the eight Notes of a Musical Scale.

Laboratory Observations, and various Investigations, were carried out to consider how the initial Laser Beam Intensity could be varied. The final solution was to utilize the Linear Polarization characteristic of a Laser Diode, together with an additional Linear Polarizing Filter (the Polarizer), and to pass the light through a second Linear Polarizing Filter (the Analyser) capable of being rotated through 90^0, and then to detect the varying emergent Laser Beam Intensity with a Photodiode Sensor and appropriate processing Optoelectronic circuitry. Through this procedure, which effectively utilizes Malus Law, the Laser Beam Intensity could be varied from a zero value (when the Polarizer and Analyser have their Linear Polarization direction crossed) up through a range of increasing intensity values up to a maximum (when the Polarizer and Analyser have their Linear Polarization direction parallel). The mechanical link to produce the angular rotation of the Analyser Filter was produced by the linear movement of what effectively became the eight keys to produce the eight note Octave.

The various Optoelectronic circuits, the Polarizing Filters and the Laser were all mounted on a Display Project Board, and after the initial testing, calibration, alignment, and final tuning had been completed, a fully functional and highly innovative, 8 Musical Note Octave Instrument has been achieved. The bonus quality outcome from this Project is that this Musical Instrument could be utilized by a physically handicapped person without any finger availability or movement, for the fingers of a hand are not necessary to produce the Musical Tones.

Acknowledgements

It is important to remember that the project was worked on by a team and the people mentioned in the different sections of the report were only the main people in charge of the specific tasks. The whole team (Bryn, Robyn and Stephanie) performed together for most parts of the project, and we all assisted each other when we needed each other, in this report the three of us have talked about different aspects of the project, but the work throughout the project has been divided evenly and we have worked well as a team and helped each other out when necessary. An individual which we must greatly thank is Mr. Ray Davies, without Ray's knowledge and experience we would have been clueless in this project, he's often busy with university students and attending meetings and seminars across the country, but we have been visiting the PAWB workshop on most Thursdays throughout the year (our day off from college). He has not only taught us about something completely new (photonics), and helped us with our work all year, but has also kindly lent us the equipment and resources to build the project, which would have cost us hundreds of pounds (£198.60). Ray deserves a lot of the credit for the help he has given us, and we are all very grateful. Another individual which we are very grateful to is Mr. Iolo Williams, Iolo has helped us keep on track all year with this project, volunteering and meeting us every Monday morning in college for an hour meeting even though his lectures did not begin until the late afternoon, he has helped us stay motivated all year round and has given us endless advice on the way we go about things with this project and the report, a lot of the credit from our project must also go to Iolo. As a team, we would also like to thank the following individuals for their assistance during our project;

- Katie Howard – For giving her advice and using her experience to help us in aspects of our project, while she was working on her own project as a university student. She also lent us materials for our project for which we are grateful
- Neil Parry – Our course tutor, for introducing us to Mr. Iolo Williams and the EESW project
- Mohammad Mogaddamia Imanpour – For additional materials linked to Photonics
- Sharon Wyn Hughes & Gwyn Bennett-Williams from AVA – For assistance with printing the final versions of our report.

1 Project Brief

Purpose of the Project

The purpose of our Project was to create a prototype device that used various aspects of the new and innovative 21st Century enabling Technology of Photonics, to aid, or in some way provide a beneficial outcome for, a person who has a some kind of disability, such as missing limbs, a reduced physical mobility condition, or even simply someone temporarily recovering from a serious accident.

Decision concerning the selection of the Specific Project

After completing several Observations of Photonics based concepts, made available to the Project Group in the PAWB Photonics Laboratory of Bangor University, it was decided to utilize the optical characteristics associated with the utilization of a Laser Diode passing through two Polarizing Filters as the basic starting point. The Group had been introduced to the change in Laser Beam Intensity which could be engineered by the relative rotation of one of the two Polarizing Filters. It was pointed out to the Project Group that the PAWB approach to any Project is always first to select the “solution” concept which appeals to the Project designers, and then imaginatively let the Group’s thinking initiatives devise a challenge in which that “solution” might be incorporated.

The task for the Project Group then was to consider how such twin Polarizing Filters might be utilized in an outcome which might be of benefit to a handicapped person. The Project Group came up with the idea of designing a new type of Musical Instrument, which utilized a Laser Diode, whose beam intensity could be controlled by the relative rotation of two Polarizing Filters, with this range of the different Laser Beam Intensities being the origin and source of the different Musical Tones for this Instrument.

Project Brief

The design required the creation of an investigative developed system, in which the body movement of the paralysed operator might be confined only to simple body movements, in the absence of any more normal finger movement input. These simple body, and perhaps even Head, movements will enable a Low Powered Laser Diode signal to be directed towards an optical sensing system which, in turn, can activate the different Musical Tone Notes of the Instrument device – with the anticipated potential that a paralysed person can still create some personal input towards creating Musical sounds.

2 Introduction

Coleg Menai

Coleg Menai is a further education college located in Bangor, Gwynedd, North Wales. The college also has Campus locations in Parc Menai, Llangefni, Caernarfon and Holyhead.

The college provides a range of academic and vocational courses including as well as some Higher Education courses in conjunction with Bangor University, Glyndŵr University and the University of South Wales.

On April 2, 2012, Coleg Menai and Coleg Llandrillo Cymru (which included Coleg Meirion-Dwyfor) merged to create Grwp Llandrillo Menai, the largest college group in Wales. Coleg Menai itself was formed in 1994 when Gwynedd Technical College was merged with Coleg Pencraig in Llangefni. The Engineering Department has been based in the same block at the college since it first opened in 1957, when it was known as Caernarvonshire Technical College. An interesting fact is that the engineering block was designed to resemble a ship (the main block) with a following wake (the workshops).

All three members of our team (Stephanie Harris, Bryn Jones and Robyn Vaughan-Williams) are based in the Engineering Block in Coleg Menai on Bangor's main site, and this current Course features as the first year of the Level 3 Extended Diploma in Mechanical Engineering. The current Coleg Menai Project coordinator for the EESW Project is Mr Iolo Williams. We have a large number of facilities available for use in creating any prototype involvements, such as workshops, lathes, millers and a variety of materials.

The Photonics Academy of Wales @ Bangor (PAWB)

The Photonics Academy of Wales @ Bangor (PAWB) is located within the Bangor University School of Electronic Engineering, and the

Director of PAWB is Mr Ray Davies. PAWB has a long standing history of working with student groups involved with the design and construction of working Prototype outcomes which utilize Photonics Concepts in highly original achievements.

Photonics is the science of the harnessing light, and Photonics has been identified as THE enabling Technology of the 21st Century. PAWB has pioneered the development of a huge range of prototype devices, all designed and created by students involved with opportunities for practical hands-on Laboratory Observations and Investigations. From such opportunities, students utilize their own individual imagination, insight, and ingenuity to create entirely original and innovative new applications of Photonics concepts.

3 Student Profiles

Name:	Robyn Vaughan-Williams
Age:	17
From:	Prenteg, Porthmadog
Interests:	Engineering, Science, Music, and Literature

Name:	Bryn Saunders Jones
Age:	18
From:	Llanerchymedd, Anglesey
Interests:	Cars, Energy Production, Building PC's, Rugby and Golf

Name:	Stephanie Celine Harris
Age:	19
From:	Tŷ Croes, Anglesey
Interests:	Music, Science

4 Analysis

Upon discovering that our project was going to be based on Photonics, we set out to find some information about it, as this was a completely new topic for all of us. We did our initial research on the internet so we could get a basic idea of what Photonics is, to prepare ourselves for whatever may be ahead. We were also given numerous copies of Photonics magazines by our college Electronic and Electrical Principles tutor, Mohammad Imanpour, to further aid our research.

After considering the Project Brief we were set, it was decided to go and see Ray Davies, to find out about the potential of Photonics in his laboratory in Bangor, and to discuss with him our ideas. The brief states that we had to do something that would help a person with disabilities. We all started thinking about the problems that a person with impaired mobility might experience.

One Photonics concept we thought was particularly interesting was the utilization of polarized light and how you could change its intensity using a polarizing filter. After a group discussion, we decided that we could use this for our project. We realised that we could use the varying light intensities to give us more than one output, which would prove to be very useful.

After considering the photonics concepts, we have decided to name the project, the OCTAPUS, which is an Acronym for **O**ptical **C**oncept **T**rialling **A**ctivation **P**olarization **U**tilization **S**onics. This Acronym indicates the Prototype nature of the Project, and includes information as to how it operates - i.e. the utilization of the Polarization characteristics of a Laser Diode to produce different sound frequencies.

5 Procedure

Forming a team

In the month of October, 2015, during one of our Lecture sessions, we were approached by the Project coordinator Iolo Williams about the amazing opportunity to be members of our college's EESW team.

We had our first meeting at 11 a.m. on Monday 30th November in room A8 on the ground floor Engineering Block in Coleg Menai, where we discussed what the Project would entail, our plans to collaborate with PAWB and thus our project engineer Ray Davies. We discussed our backgrounds in Engineering and what skills we could bring to the team.

We ended the meeting with plans to go to the PAWB laboratory to begin discussing and planning out our project.

Sessions at PAWB

After our first meeting, we received an E-mail from Iolo confirming that we would be spending Monday the 14th & Tuesday 15th of December at the PAWB laboratory.

When we arrived in the PAWB laboratory, we introduced ourselves to Ray, and he explained that he felt it would be good if our project involved Photonics, as it was one of his areas of expertise. He began to show us various projects that he has worked on, explaining how and why they work, and we started thinking of different ideas we could make a reality.

We spent our first day and a half at PAWB exploring the various facets of Photonics, from the Laser optical speckle effect, to how Polarizing Filters operate

In the afternoon of our second day at the PAWB laboratory, we discussed with Ray our various ideas, and how we would implement them in the real world.

Following our two days spent at PAWB, our decision was made to create the OCTAPUS, a Photonics focused idea to design and construct a Musical Tone generating Instrument which generated the various Notes of one octave by detecting eight different Laser Beam Intensities, with these eight different intensities being achieved by the relative rotational positions of the two Polarizing Filters. Our project engineer, Ray Davies assisted our Project Group by indicating a list of the various Optoelectronic circuits we would need to create, and a flow diagram of the order in which these circuits, and the entire Project, all connected together.

In our next session at PAWB, we began building the eight Astable Multivibrator circuits, which became the circuits that actually generated the eight different frequency Musical Tones. The type of Integrated Circuits (IC) we used for these circuits was an IC 555, which is an extremely useful chip, as it can be used for various applications, such a Timer, and Pulse Generator. When putting the IC 555 chip onto a breadboard, it was essential that we wore a grounding wristband connected to the oscilloscope Ground, so as to make sure the operator is connected to a zero voltage level, since all IC components are extremely electrical static sensitive. We had to ensure this 0 V connection because the chip is only designed to handle 5 V, and as anybody is likely to carry a natural voltage of up to 3,000 volts, handling the IC without being properly grounded can destroy any IC operational capabilities.

During this session, we were able to make six tone generators and test them all to make sure they all worked as they were expected to perform. They were tested by connecting them to an oscilloscope, a power supply and a speaker. The first thing we did before checking if the circuits actually generated a tone was to check if the IC was in proper working order. We did this by ensuring that the IC did not get hot, did not produce smoke, and did not produce a burning smell once there was a power supply connected to the circuit. After doing this crucial check, we were able to connect a speaker to the Tone Generator, to ascertain if a tone was generated. All six circuits performed their Tone generation correctly; the last two tone generators were built and tested during another session. The reason we need eight is because each individual circuit will only produce a single note, therefore we need eight in order to get a whole eight note octave.

During our February half term, we made a start on building the voltage comparator circuits. Just as we did with the tone generators, we needed 8 voltage comparator circuits as this is what triggers each individual note being played. The idea is that each individual note will respond when there is a particular voltage being fed through the circuit; in this case, the higher the note, the higher the voltage. The components that determine how much voltage gets through the circuits are the variable resistors; we are able to set these to meet our specific voltage requirements. Unlike the tone generators, the voltage comparators are using an IC 339.

Next on the list to build were the buffer voltage followers. We needed a total of 16 of these. This is because a buffer will be connected to the input and output of the voltage comparators; therefore we need double the amount. These circuits require an IC 348. Thankfully for us, the buffer voltage follower circuits did not take too long to build, which meant that we had the rest of the session to test all the circuits we'd built so far. Whilst doing this, we discovered a fault in one of the tone generator circuits. Once we referred back to the circuit diagram we realised there was a fault in the wiring, which was swiftly corrected.

Something that also happened in this session, Robyn was set the task of designing and building a logic control circuit. During this session he managed to finish the design.

In our next session at PAWB, Robyn built the logic control circuit necessary to activate each tone generator circuit individually. Whilst Robyn was doing this, Bryn was building the circuit for an operational amplifier to provide a boost in voltage in the circuit where needed; and Steph was setting up 8 LEDs to connect to each individual tone generator, so you can visually see which tone generator is being activated and therefore you would know which note you are playing.

After all the new circuits were tested, we mounted everything on to a large piece of acrylic. Once all the circuits were properly stuck down, we connected all the circuits together through power and ground. Once we had done this, we tested the circuit to make sure they were all connected through power and ground correctly.

The next step after this was to wire everything up. Although a seemingly straight forward task, we ran into some problems at this stage. A few things weren't working as they should've been which meant we had to begin the lengthy process of fault finding; this proved to be extra challenging due to our inexperience doing this type of thing. In the end, we discovered that these problems were being caused by faults in the wiring, which was then corrected.

Once everything was wired up correctly, including the batteries and speakers, the next thing we had to do was to set the voltage comparators correctly. We did this by connecting them to an oscilloscope and setting their voltage individually. After that, we were able to tune the tone generators properly, again, done by connecting them to the oscilloscope and tuning them individually by setting them at the correct frequencies. The reason that this step was done last is because different wiring, even different speakers will affect the amount of voltage getting through to the tone generators, which would cause them to go out of tune.

Next to all the circuitry is the mechanical part of the project. We acquired all the parts necessary to build this from the PAWB laboratory. The mechanical arm is simply made out of a draw slide, as this allows easy movement. There are also metal fixtures in order to hold the laser, Polarizing Filter, steering lens and analysing filter in place. Ray ensured that these were aligned properly as this is essential for the project to work. We also had to learn how to align the laser properly as this is a valuable skill; if we are unable to align the laser, the project will cease to work. We also added a fibre optic cable. The laser points directly into one end of the fibre optic while the other end of the fibre optic points straight at a photodiode. Basically, the function of the fibre optic cable is to enable us to bend the laser beam so it ends up pointing in the direction we need it to go.

Even after we thought that we had finished building the Project, we realised that there were a few adjustments that could be done to improve it. The tone generating circuits have been modified slightly, by replacing all the high value variable resistance potentiometers with a fixed high resistance in series with a much lower value variable resistance potentiometer. This means that the task of tuning the instrument is now much more accurate, and far more sensitive for the actual tuning. The 8 Tone Generators (the Astable Multivibrators) have been retuned, and the whole Project is now working really well in its new configuration. This slight change in resistors was straightforward to achieve - one of the wires we had inserted in the circuit was removed, and replaced by a fixed resistor, and a lower variable resistance Potentiometer replaced the original one we had used. The increased sensitivity, and reliability, for maintaining the tuning of the circuits has been very much improved by doing this.

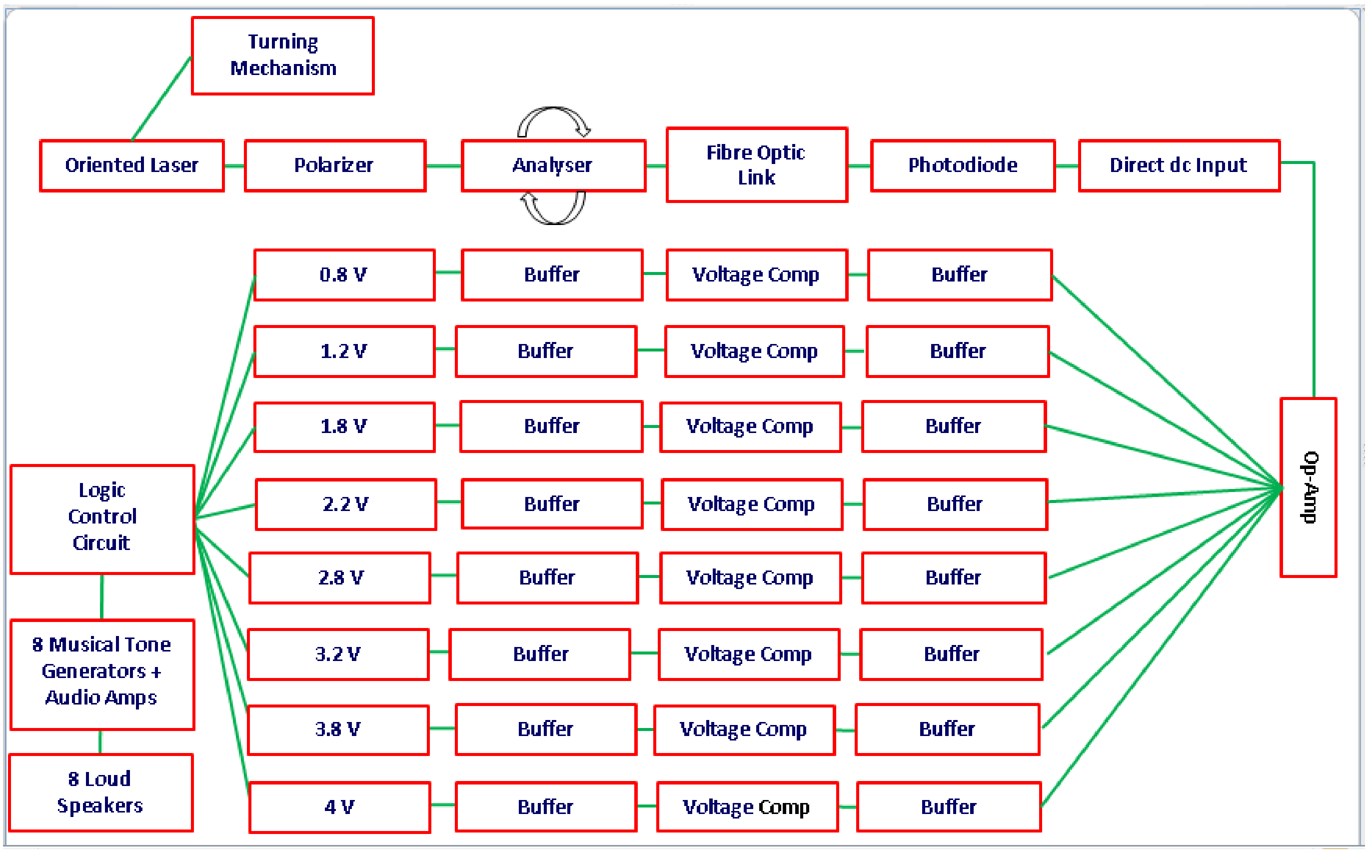
Ideas and final solution

When thinking about other ideas that fit the project brief, we came up with the following: A laser operated page turner, whereby the operator would be able to turn the pages of a book, by activating a page turning system, via a laser or photo diode. A musical instrument operated by the movement of a fibre optic cable that would enable the playing of musical notes. A laser operated mechanical hand that would allow for a person without a hand to pick up certain objects. Another idea was a bathroom aid that would inform a blind person when their bath has filled to the desired level, using a laser, and a photo diode on a float.

In the end we decided to create the OCTAPUS which is the acronym we adopted for this Project, with the letters representing Optical Concept Trailing Activation Polarization Utilization Sonics, a musical device, controlled the intensity of light that is incident on a laser beam detecting Photodiode, after passing through two Polarizing Filters, one of which can be rotated 90 degrees. This rotation controls the intensity of light passing through the rotating Polarizing Filter, when the Filter is turned to various fractions of 90 degrees, with the signal processing circuitry being capable of delivering the output of different musical notes.

6 Design

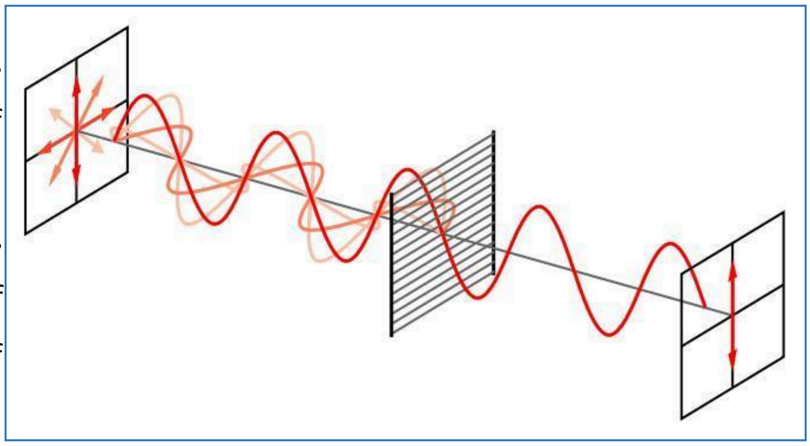
6.1 Flow Diagram Planning



Above is a flow Diagram of all the components in the OCTAPUS, displaying the order in which the components interface with each other.

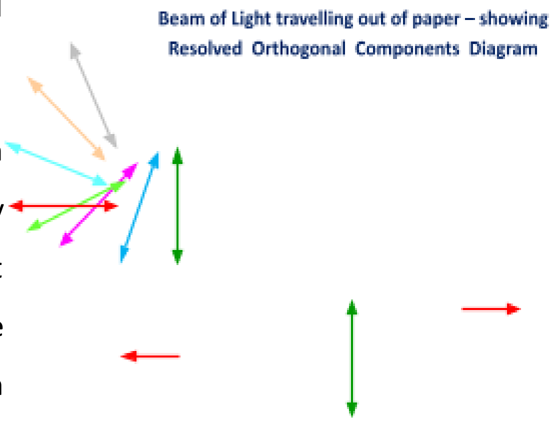
6.2 Polarization Concepts

A ray of light is known to consist of a transverse vibration of an electro-magnetic field. Light is made up of Photons, which are basically created whenever there is an oscillation of an electric field.

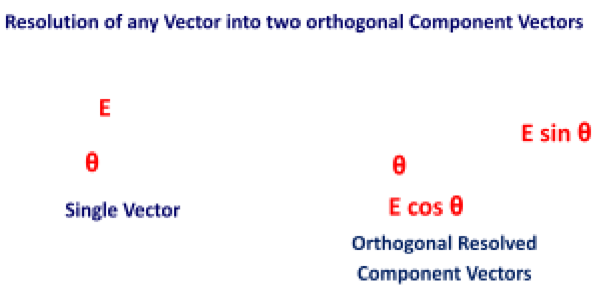


All Photons are Linearly Polarized, with a specified individual direction of vibration of their associated Electric Field (E). In a Beam of Light emerging from any source, each Photon will, in an unpolarised beam of Light, have a randomized direction of transverse vibration.

Therefore, as shown in the diagram below, a beam of unpolarised light travelling out of the page (the red dot), will have all the Photons vibrating in all directions.

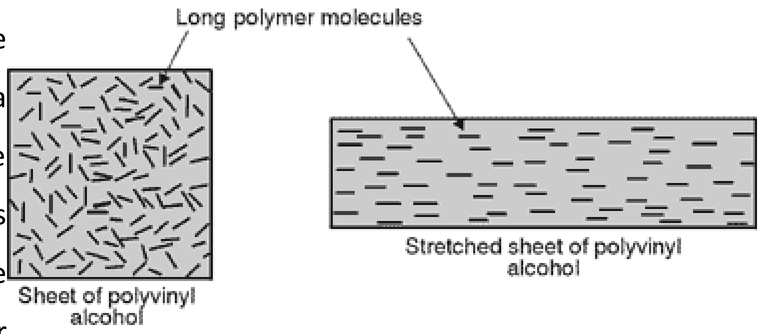


By resolving each of the individual Photon Electric Field (E) vibrations into two mutually orthogonal directions, the above opposite shows that the resultant two Electric Field Components can be achieved. This implies that any unpolarised Light Beam can be considered as consisting of just two orthogonally oriented Electric Field Component Vectors.

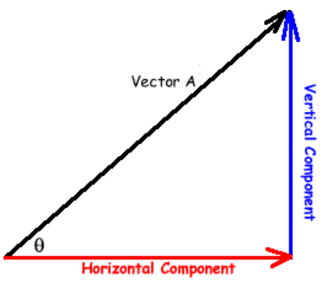


A Polarizing Filter is an optical Filter which simply absorbs ONE of these two Electric Field Components, but transmits the other orthogonal Electric Field Component, resulting in Linearly Polarized travelling through the Filter. Linearly polarized Light has all the individual Photon Electric Field vibrations confined to just ONE direction, which is, of course, transverse to the direction in which the Light is travelling.

A Polarizing Filter is made out of a polymer material. To start off with, the long chain molecules in the polymer all point in random directions. The polymer is then stretched, which causes a change in its structural format. This change takes the form of all the long chain molecules being aligned in the same direction as the stretching direction. The polymer material then has iodine added to these now aligned long chain molecules. Then, when Photons of Light enter this polymer material, the orbital electrons in the iodine absorb the components of the Photon Vibrations in the direction of the iodine coated long chain molecules, leaving the Photon vibrations at right angles to the iodine coated long chain molecule free to pass thought the material. This creates a Polarizing Filter, allowing only those Photon vibrations to pass through the Filter, with the transverse vibrations of all the emergent Photons being entirely at right angles to the direct in which the polymer material had been stretched.

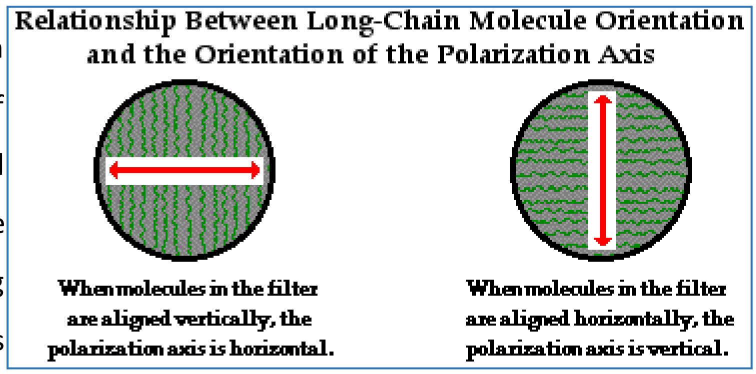


In a beam of Light, each of the travelling Photons vibrates in a specified linear direction, yet a polarizing filter only lets through light that is vibrating in one direction only. So how does it work?

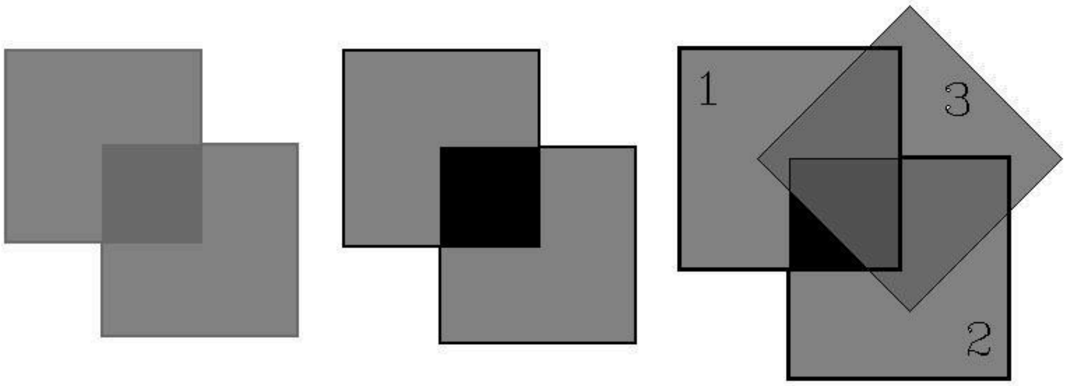


All photons possess individual oscillating Electric Field vectors. However, as indicated above, this can be simplified using a mathematical model. Even though all the different Photons in a Beam of Light vibrate (transversely to the travel direction of the Light) in all possible directions, any beam of light can be thought of (Mathematically and Empirically) as if all the Photons are vibrating in two mutually perpendicular directions. This is because vectors can be resolved to find a horizontal and a vertical components.

The photons that vibrate in a direction which is parallel to the long chain molecules of the polymer interact with the iodine coating and are absorbed by the electrons in the iodine. The photons that vibrate perpendicularly to the long chain molecules in the polymer are able to pass through the polarising filter.



The maximum amount of light that can pass through a polarising filter is 50% of normal light intensity. As explained above, this happens when molecules in the filter are aligned vertically and the direction of polarisation is horizontal or vice versa. A polarising filter can also completely stop polarised light from passing through them. This is achieved when the molecules in the filter are parallel to the direction of polarisation.



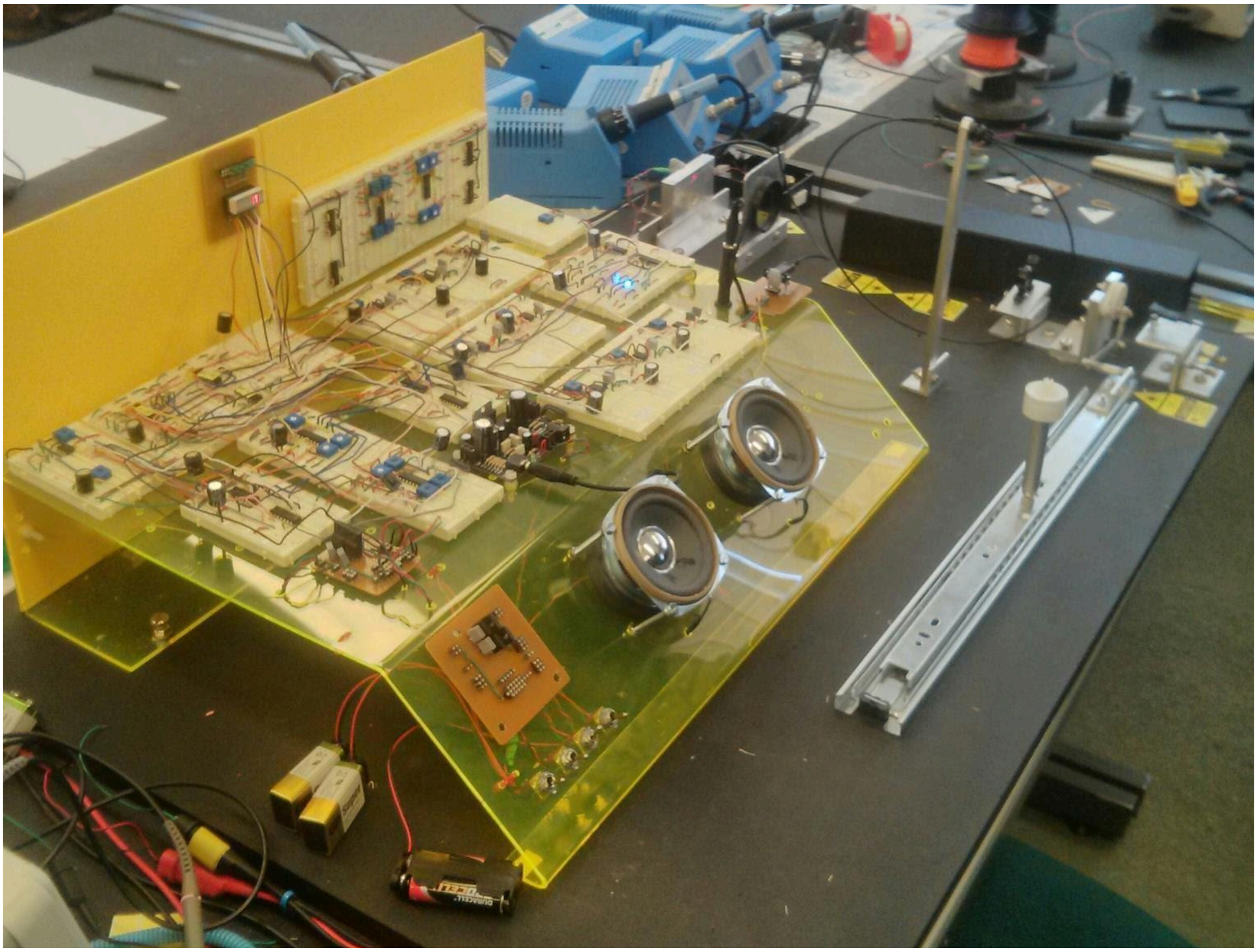
Parallel axes. Crossed axes. Polarizer (3) between two crossed polarizers (1) and (2).

The above diagrams, effectively demonstrate the fundamental principle of this Project, namely the utilization of Malus Law, which states that the Intensity of the Light (I_θ) emerging from an Analysing Polarizing Filter when the axis of the Analyser Filter has been rotated through an angle θ, compared with the Intensity emerging (I_{max}) when the Polarizer and the Analyser have parallel Polarization axes, is given by the equation

$$I_\theta = I_{max} \cos^2 \theta$$

The source of light travelling through the Polarizing Filter that we utilized in our project was a Laser Diode. Laser diodes produce Photons that are already linearly polarized in a particular direction; this definitely works in our favour as we need polarised light for our project to work. This analysis utilizes the reality that the Photons are quantised packets of Electro-magnetic Energy, with individual specified directional properties to the Electric Field vibrations. We were able to see the direction of Linear Polarisation of the Laser Diode Beam, for when the Laser Beam is expanded from its normal dot configuration, it was observed that the laser beam we used in this Project is not shaped like a dot, but rather like a rectangle, with the Laser Beam Linear Polarization direction being across the narrow side of the rectangle, as shown in the Diagram opposite.

In our project we used a Polarizer and an Analyser Filter. The Analyser was the second Filter that is used to analyse and control the intensity of the light coming through the first Polarizing Filter. The analyser is rotated by our rotating mechanism, adjusting the intensity of the laser. In front of the analyser there is one end of a fibre optic cable.



The other end of the fibre optic leads to a photodiode. The function of the photodiode is to respond to fluctuations in the emergent optical signal being transmitted by the Analyser. When the Photodiode detects these fluctuations, all the Optoelectronics circuits process this information, eventually producing the eight Musical Tone octave Notes.

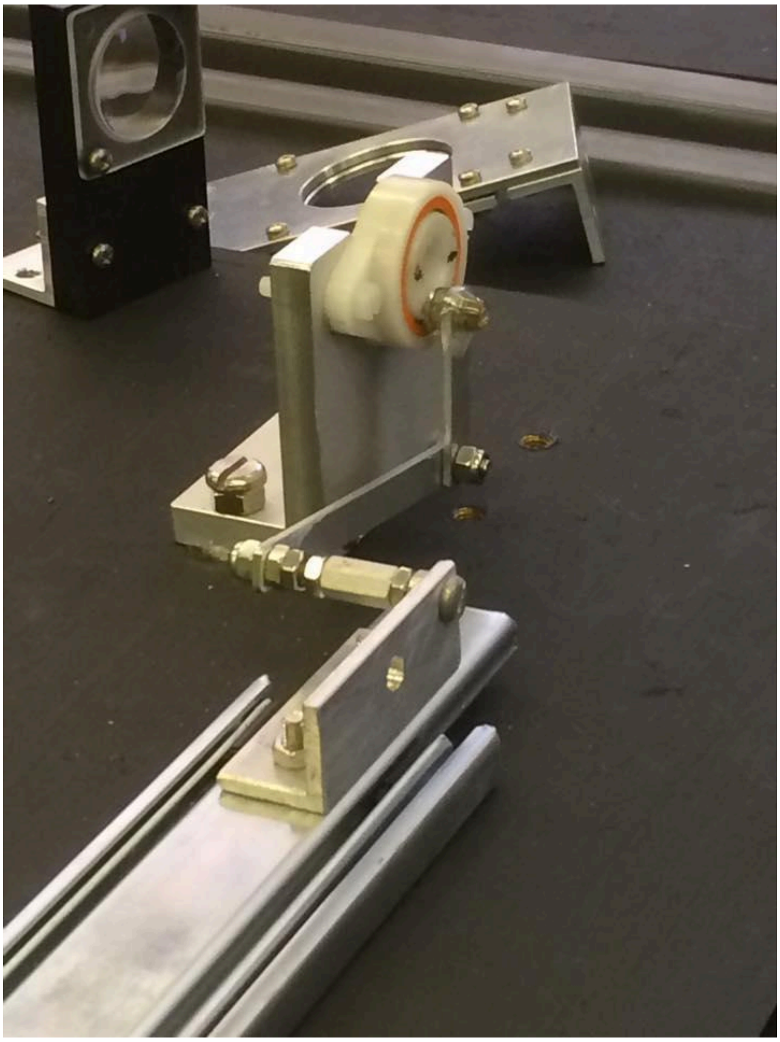
6.3 Laser alignment and mounting

'Tweak-ability' is one of the most important words in photonics. The work in photonics has to be accurate; therefore it is important to leave some slack in the construction of the systems which directly interact with the laser beam, such as the polarizing filter, to have the ability in future to recalibrate if necessary. When it came to the alignment of the laser to the fibre optic cable, Ray Davies showed us in a previous example of a university student's work, that the whole project did not work because they had set the alignment of their laser up incorrectly, and the project had been screwed into place, therefore they couldn't change the alignment, and the project subsequently never worked correctly. This is why Ray told us to leave some spare capacity to do this in our project. Firstly, the laser is held in a thick (20mm) block of aluminium. This is to keep the laser cool, as if it was held in a thin sheet of metal, it would get hot and would shorten its lifespan, or even worse break due to overheating. The laser beam then hits a polarizing filter, and then goes through a steering lens, which is used for greater accuracy to hit the fibre optic cable. It then hits a second polarized filter which is called the analyser, which is connected to the rotating mechanism. After which it then hits the fibre optic cable, which takes the laser beam to the photodiode in a closed environment to reduce room light interference. The steering lens and laser beam are respectively connected to a mount, using two bolts to push against the block of metal which grips it in to place; it is not bolted directly on to the mount, which is where the word tweak-ability comes in. One important note is that the fibre optic cable must not be bent too much, as sharp corners in fibre optics can reduce the light coming out the other side, in other words, as opposed to using a mechanical arm, the user could play with and bend the fibre optic cable, however there wouldn't be anywhere near as much accuracy as we have using the mechanical arm.

6.4 Ambient Light

We discovered while we were testing out our project that the room light was affecting the laser diode, which meant that there were errors as the correct note was not being played sometimes as the intensity of light was not what we wanted. To sort out the problem we could either use the project with no lighting from outside coming in, and all lights in the room off, or as we have done to use a cover to shield the photo diode and the laser beam's path. By doing so, no ambient lighting can affect the photo diode, and the work is much more accurate, as we could now control the intensity of light completely and no other factors would affect the results (room light, outdoor light).

6.5 Rotating Mechanism



Above is a photograph of the rotating mechanism, it housed a polaroid filter that it could rotate over 90 degrees, it is attached to a slide, in a way that converts lateral motion, to linear motion, creating the human interaction component of the device, to create this, we reused materials developed from a previous PAWB collaboration.

6.6 Additional Features

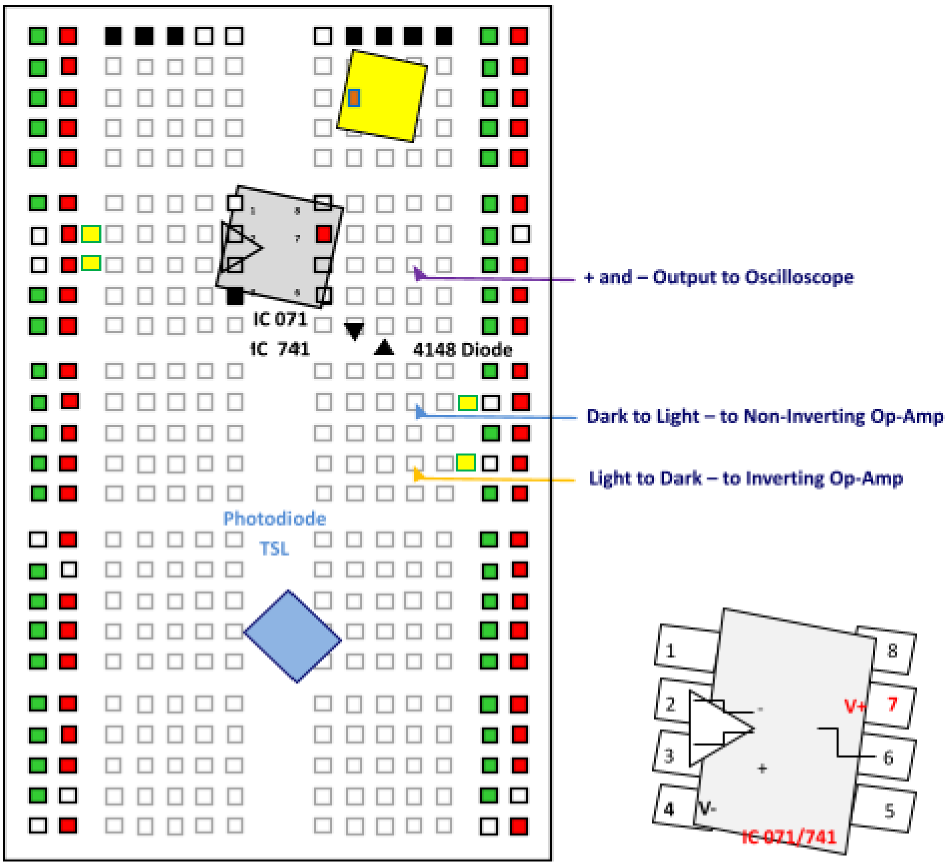
Something extra that has been introduced to this Project is an optional feature (controlled by an additional switch, and some additional wiring into the Project of a Light Dependent Resistor). The function of this feature is to enable the Notes either to sound normally, or, by flicking a switch, you can add a vibrato effect, which can be made to sound quite effective. The vibrato effect, which utilizes just one Light Dependent Resistor, means that the vibrato effect is produced optically, by changing the Light intensity falling on to the Light Dependent Resistor.

Something else that we also thought would be very useful was additional lights, so you can visually see when things are switched on. LEDs have been added, so that when the Power switches are activated, two different LEDs indicate that the Circuits are "live", and the Laser Diode is "live" – this also improves the aesthetics of the Project.

7 Optoelectronic Circuits

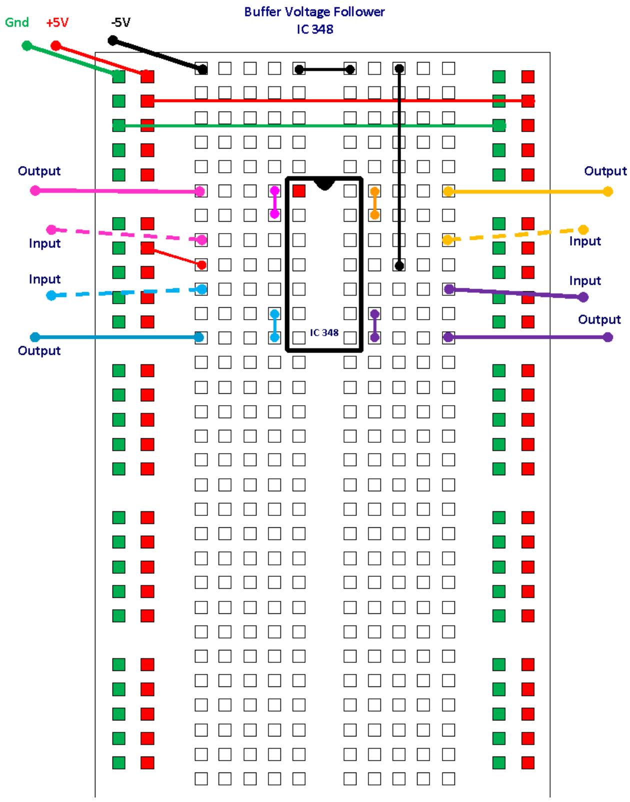
All of our circuits were built on breadboards in order to maximise the ease of construction and speed of prototyping.

7.1 Operational Amplifier and Photodiode



The above circuit diagram shows a variable Gain Voltage Amplifier. The purpose of this circuit is to provide an increase in the voltage available to any required value for the other processing Optoelectronic Circuits, depending on the intensity of the beam of light incident on the photodiode. The photodiode we used was a TSL 250 series, and this circuit's output connects to all the eight inputs of the first sequence Buffer Circuit. The variable Resistor 20 kΩ provided the variable Gain characteristics – clockwise rotation increases the Gain, and anti-clockwise rotation decreases the gain.

7.2 Buffer Voltage Follower

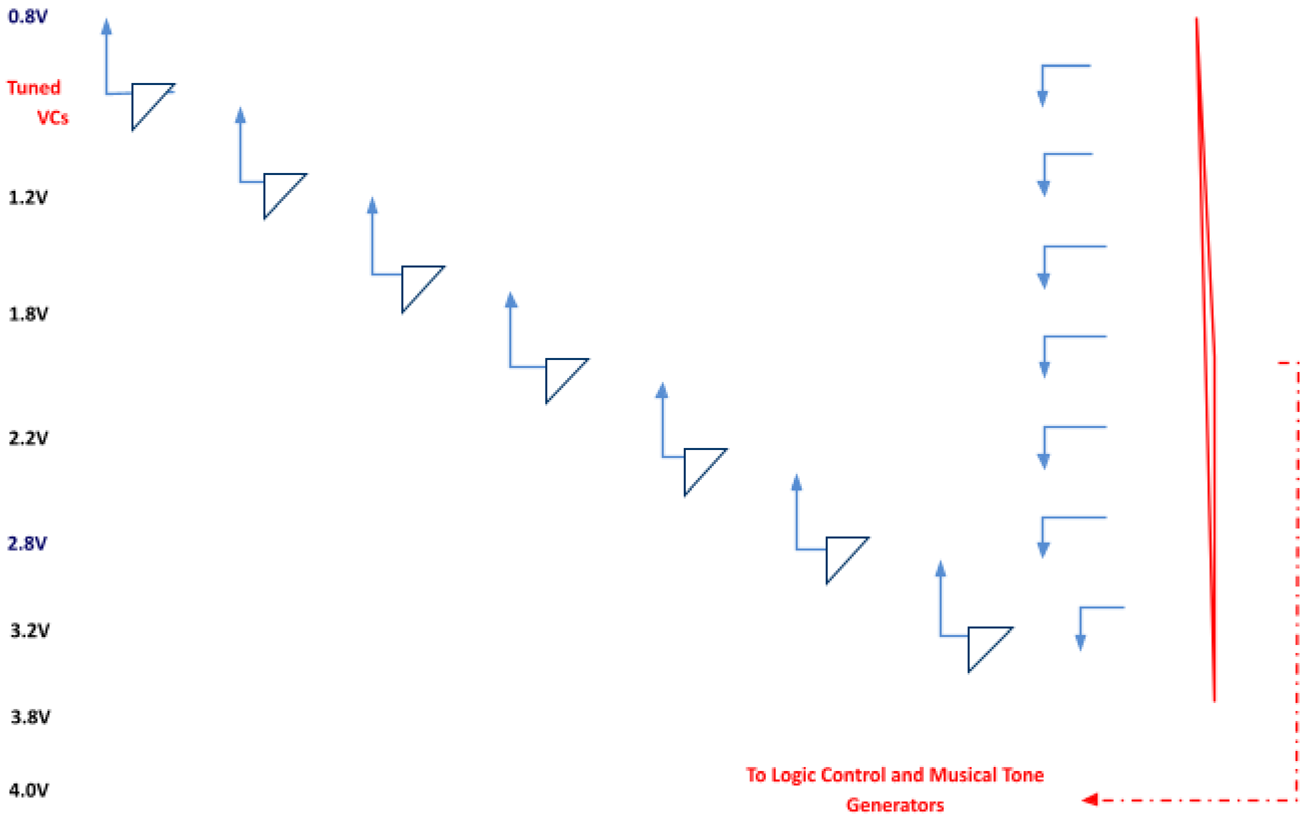


The above circuit diagram shows a Buffer Voltage Follower. The purpose of this circuit is to amplify the current in the circuit, and is an impedance matching necessity for the Voltage Comparator Circuit Hence, this circuit is used twice; it takes the input from the OP-AMP and outputs to the Voltage Comparator, and it takes the output from the Voltage Comparator, and inputs the signal to the Logic Control Circuits.

7.3 Voltage Comparator

The above circuit diagram is known as a voltage comparator. This Circuit utilizes a Differential Op-Amp, with the Inverting Input pre-set to a specified Input, by a Variable Resistance Potentiometer. When the Input Signal to the Non-Inverting Input lies BELOW that earlier pre-set Voltage, then the Voltage Comparator Output is equal to Zero Voltage (Logic Low = Logic 0). As soon as the Input Voltage rises about the earlier pre-set Voltage, the Voltage Comparator Circuit suddenly rises to its maximum value of 5V (Logic High - \logic 1). By setting each of the eight Voltage Comparators to 8 different preset values, ranging from 0.8V up to around 4.0V, it was possible to trigger each of the 8 Voltage Comparators in sequence, and controlled by the rising or falling values obtained from the Photodiode Voltage, which changed, depending upon the amount of Light emerging from the rotation of the Analysing Polarizing Filter. Each circuit when assembled on a breadboard acts as 8 separate voltage comparators, with each voltage comparator outputting a Signal, through Buffers, to one of the eight inputs of the first logic control circuit.

7.4 Logic Control



The above diagram shows the first logic control circuit used, it consists of 7 AND Logic Gates, and 8 EX-OR Logic Gates, the function of this circuit is to control which Astable Tone generator is activated, by only allowing one output to be active at a time.

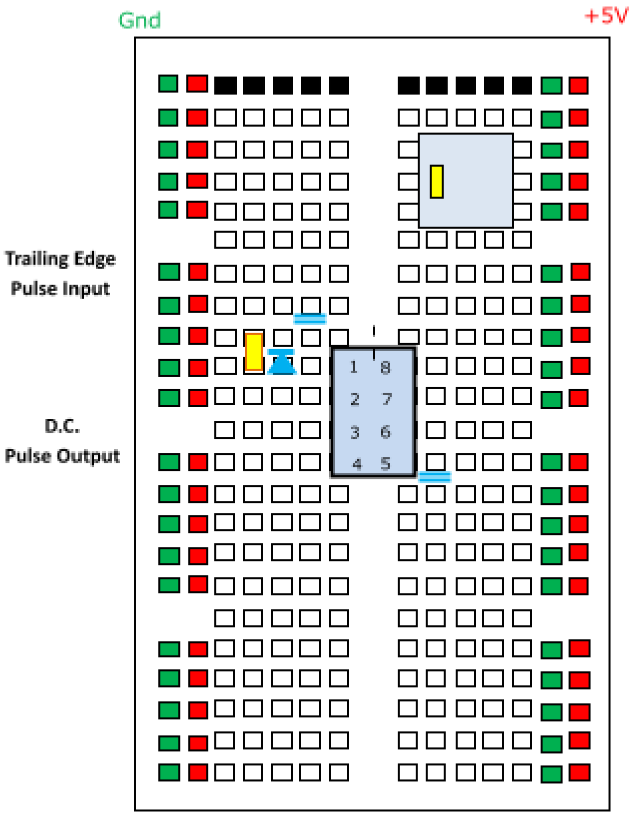
To begin with the circuit was assembled the system in a computer simulator, to ensure that the design worked so as to save on production cost, and then Robyn assembled the design in the real world, on a breadboard, with two IC 7408 chips which are composed of four AND logic gates, and two IC 7486 chips which are composed of four EX-OR logic gates. Each initial Input to the Logic Gates required a 1kΩ resistor pull-down, to ensure that the Input remained at Logic 0, when there was no Input, since the Inputs in these ICs tend to float High when there is no applied Input. 8 LED's were also added, to indicate which output was "live" at any instant, this also made fault finding easier at a later time. Robyn colour coded each of the distinct paths, to make it easier to check for faults. Robyn placed the two AND chips one above another on one breadboard, and the two EX-OR gates on another board. The boards then had the earth and live wires connected.

From each of 8
Tuned Signal Notes

To Audio Amplifier

The above diagram shows the second logic control circuit, it consists of 8 OR logic gates, the purpose of this circuit was to allow only one output signal to the speakers at any one time. Ray Davies helped design the circuit and Bryn built it, using two IC's on one board. The pattern on an op-amp is; input, input, output. A wire had to run from the output to the next input (top) eight consecutive times. Bryn used different coloured wires on each one for identification (thus easier to find faults), and also to easily follow the circuit.

7.5 Astable Multivibrator Tone Generator



The above diagram is for the Astable Multivibrator. The purpose of this circuit is to produce the signal that is then sent to the loud speakers. The note produced by this circuit can be controlled by changing the resistance of the variable resistor. This can be done by ear, or fine-tuned by connecting it to a Frequency Input oscilloscope.

8 Conclusion

In this project we set out to create something which would be in some way beneficial to somebody with a disability.

8.1 Analysis of Achievement

If light possesses intensity, it can be useful. We used to a polarizing filter to change the intensity of the Laser Beam to control eight different musical notes; effectively converting light information into sound. To successfully utilize these Photonics concepts, we had to consider three things; input, interface and interaction. The input is simply the Laser; the interface is the polarizing filter and the interaction is of course the production of sound. So basically we have an input going into the interface, and then the interface causes an interaction.

Despite running into several problems during the process of building the OCTAPUS prototype, through fault finding and lots of testing, we were eventually able to get the prototype to work as it should. Once we got everything to work as we wanted, the tuned the 8 Octave notes correctly, and adjusted the levels of Polarization of the Laser, as well as the output from the Op-Amp, which were crucial adjustments to achieve.

Due to the fact that the OCTAPUS is only able to produce one octave, we thought the most logical scale to tune the notes to was C-Major. We came to this decision because we wanted to keep it simple. The C-Major scale consists of the notes C, D, E, F, G, A and B; basically it has no sharps or flats. Also C-Major is one of the most common key signatures used in Western music. The lower C note of the OCTAPUS has been tuned to middle-C.

We set out to create something that would somehow help a disabled person and we believe we've definitely achieved this. Humans have always had a special connection with music as it can have profound effects on the mind. By playing notes in a particular order you can invoke ideas, memories and pure emotion, whether that's joy, sadness, longing and so on; the list goes on. Because the OCTAPUS is so easily operated by sliding a bar, even someone with limited, to no movement in their hands could operate it without a problem and create their own music. This could apply to someone who has severe arthritis in their hands; someone who has had their hand or arm amputated, they could even move the bar with their mouth or foot. The OCTAPUS can also be used by a deaf person. The LED lights connected to the OCTAPUS indicate which note it is that is being played, so if a deaf person has some knowledge of music theory, they can continue to make music. Even if they did not have any knowledge of music theory at all, the LED lights would turn this musical instrument into something that creates a visual experience for a deaf person also.

We truly believe that the OCTAPUS would greatly improve the quality of life experienced by somebody who had a disability, by giving them the ultimate tool that would allow them to express themselves creatively, both musically and visually. For this reason, we believe that our project has enormous potential to benefit mankind.

8.2 Further Developments

We have already been considering further developments for the OCTAPUS project. One thing we have considered is to make it so that we can isolate any given note, so you can jump between the notes rather than being limited to just going up and down the scale. If this was done, it would make it a much more versatile instrument. We can achieve this by building more logic control circuits. This is something we originally did intend to do, however we had to re-evaluate our project goals and take a more realistic view on the amount of time we had to work on the project. We realised that we did not have sufficient time to build the extra circuitry required for this and decided not to include it.

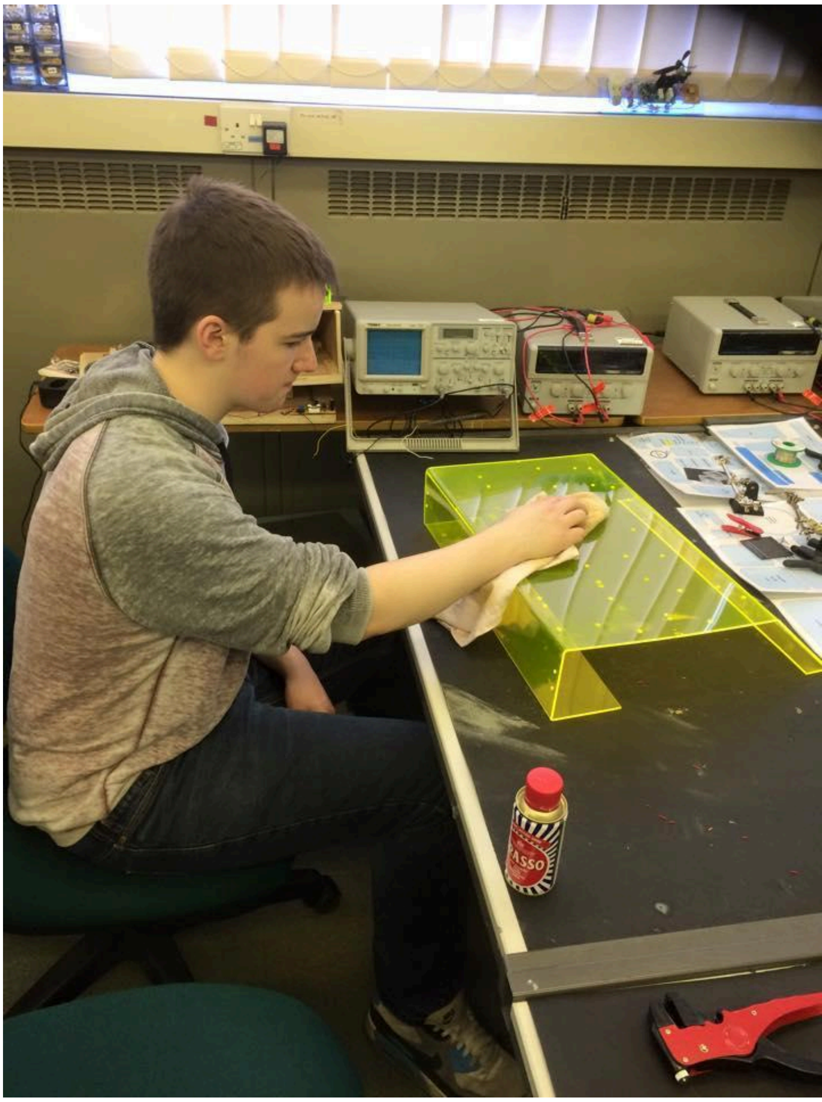
Another development to this project could be to improve its sound. At the moment, the type of sound it produces is a square wave, which gives us a metallic, electronic sort of noise. By building more circuitry we can improve this by making the instrument produce sinewaves instead, which would give us a smoother, less harsh sound. Again, we did not have the time to build the extra circuitry.

As this is only a prototype, the next stage in developments would be to commercialise it. The total cost of everything used to build the prototype came to about £200, however, all the circuitry we built could be reduced and all put on just one IC, which would only cost roughly £20. We as a team are seriously considering commercialising this, as we truly believe (as mentioned earlier) in its benefit to mankind.

8.3 Additional Applications

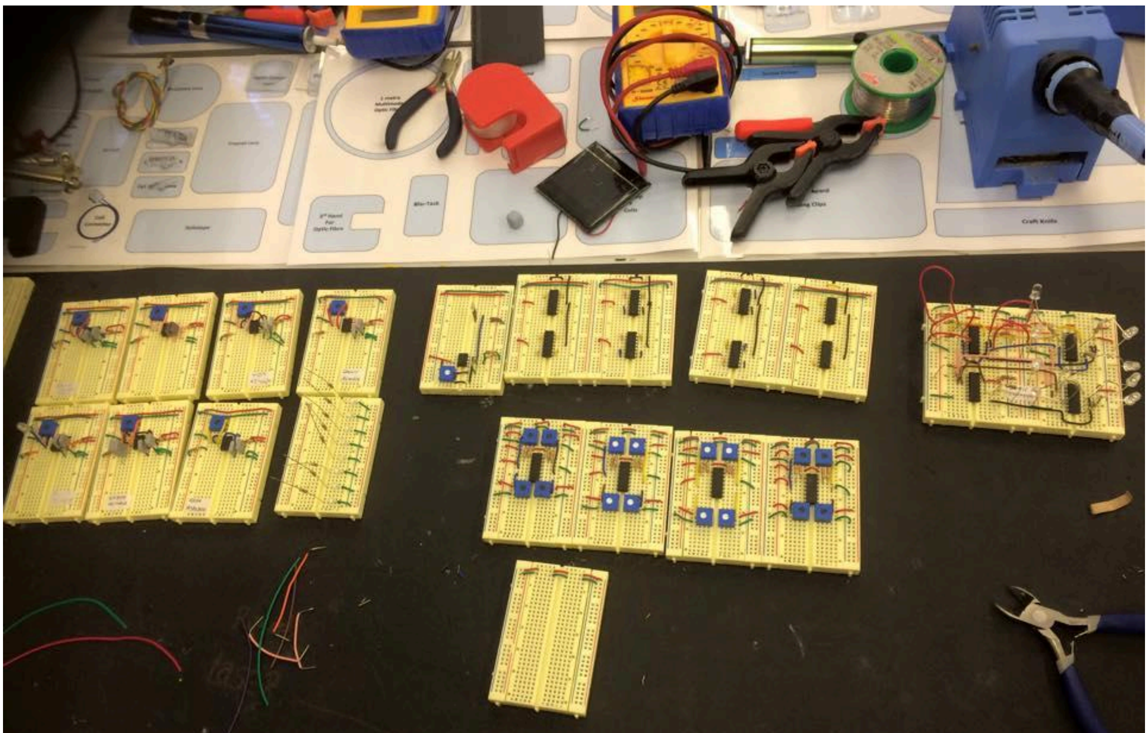
The same concepts could be used for many different applications due to the fact that it has eight different outputs. Examples of these could be a dimmer switch; a control system for a motor, possibly controlling a flood gate; it can measure the degrees of rotation of a mechanical wrist, or the bend of a finger; or even a modular control system.

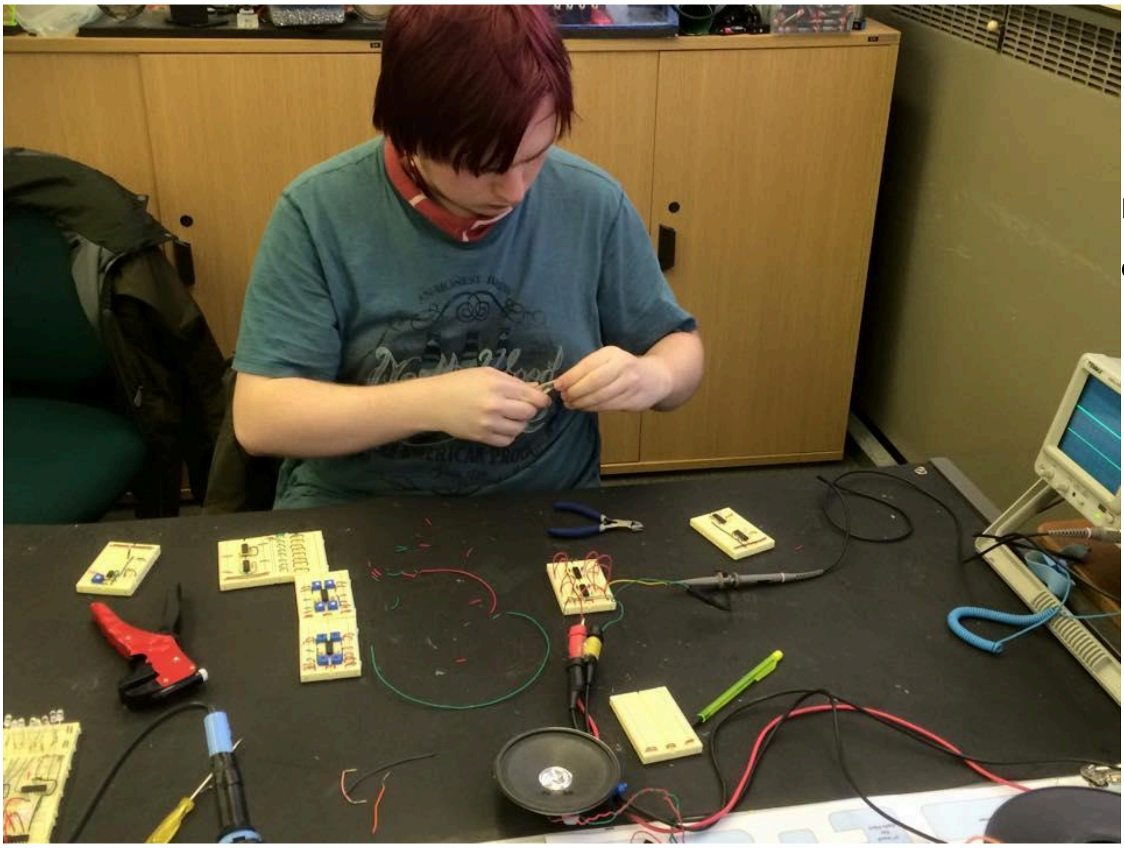
9 Appendices



Bryn polishing the acrylic, before mounting the electronic circuits.

Electronic circuitry.





Robyn building circuits.

Mounted circuits.