**3D**POV : Technical Manual

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**Date** : April 17, 2015

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| **Rev. no.** | **Date Issue** | **Author(s)** | **Brief Description of Changes** |
| 0x010 | Feb. 10, 2015 | PDG, AEJ, LJM, RSO | Initial Draft, Project Overview started |
| 0x011 | Feb. 12, 2015 | PDG, AEJ, LJM, RSO | Project Overview updated |
| 0x012 | Feb. 17, 2015 | PDG, AEJ, LJM, RSO | Functional, Technical requirements started |
| 0x013 | Apr. 09, 2015 | AEJ | Hall Effect sensor information updated |
| 0x014 | Apr. 10, 2015 | AEJ,LJM | Various edits, added use scenarios |
| 0x015 | Apr. 17, 2015 | AEJ | Various small edits |
| 0x016 |  |  |  |
| 0x017 |  |  |  |
| 0x018 |  |  |  |
| 0x019 |  |  |  |
| 0x01A |  |  |  |
| 0x01B |  |  |  |
| 0x01C |  |  |  |
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| 0x01E |  |  |  |
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# 3DPOV - Project Overview

## Purpose of the Product

The three dimensional persistence of vision display, 3DPOV display for short, is a product which can display a 3D image through the use of optical illusions and precision engineering. The 3DPOV display is sponsored by the College of Engineering and Computer Science and the design team consists of two electrical engineers and two computer engineers.

When we first thought of the idea, we had a vision of how hobbyists, specifically people into 3D printing and the makerspace have a need that is currently unsatisfied. If you think of how 3D printing works, in order to be able to get an actual feel for the sizes and dimensions of a 3D model, you would have to spend hours setting up the 3D printer and physically printing the object. Additionally, you have to invest in that 3D model because of the cost of the filament used to form the 3D printed object.

The 3DPOV display intends to solve this issue by allowing the user to get a real size representation of the 3D model by simply uploading it to the device and instantly having a tangible 3D object to observe and manipulate, thus saving time and money for the user. The 3DPOV display would cost about as much as a low-mid range 3D printer, an investment that the hobbyist would be willing to make, and the investment would quickly return to the buyer in savings from 3D printer filament materials alone.

The 3DPOV display could also be targeted towards tech-savvy homeowners as well, as the 3DPOV display would make for a really cool display piece to show off in the home.

Our design goal with the 3DPOV display is to prove the abilities of a 3D display without focusing in on the more complex interactions of the final product to be developed in a later development iteration of the product. In other words, for this design phase, we will be able to produce 3D images and animations with the 3DPOV display without incorporating the full-on user interaction and complex data management required for our envisioned end product.

## Users

The main user base for the 3DPOV display would be technology proficient individuals primarily, however the user interface for the 3DPOV display would still be simple enough to use for most people.

In more detail, since our main user base is hobbyists and 3d printing aficionados, it assumed that they are comfortable with 3D modeling software and are able to parse a more technical document. We would expect that users would also make their own modifications and tweaks to the system to suit their uses as is common in the 3D printing community. From this, it is a goal of ours to build a strong community around the 3DPOV display that is rich with ideas and knowledge.

## Relevant Facts and Assumptions

For the purposes of this technical document, we will assume that you are familiar with basic electronics and hardware. Additionally, we will assume a basic understanding of various electrical, mechanical, and computer concepts.

## Similar Product Information

The 3DPOV display is intended to be used as a standalone product for increased productivity and cost reduction for the 3D printing/makerspace community. The 3DPOV display would be a powerful tool in a tinkerer’s arsenal of tools to get a product from concept to a printed reality because of the sheer time and money that can be saved by being able to see the 3D object immediately.

The idea for a persistence of vision display is not a new idea, however it has only ever been made as a personal project. The 3DPOV display is the first of its kind to target the 3D printing market (or any market) and will revolutionize the 3D printing process.

# Use-Case Scenarios

## Scenario A – “Jän”

Jän, A 3D printing aficionado, is a very active member in doing steam-punk inspired 3D printed costumes inspired by movies. In his normal workflow, he drafts his ideas using 3D modeling software. Many times, however, he wants to be able to see how a certain piece looks to scale or fitted into the project he is working on. He can use the 3DPOV display to get to-scale organic representations of any piece he can think up. In the process of doing this, he now can process other pieces and save time and materials.

## Scenario B – “R2-D2”

R2-D2, the lovable astromech droid, needs to deliver a critical message to Obi-Wan Kenobi for Princess Leia, who is in grave danger. In a dramatic turn of events, R2-D2’s hologram projection system is in a state where it is too expensive to fix, but the message needs to be heard. Luke Sykwalker then realizes he can attach R2-D2 to the 3DPOV display to get a crisp 3D image. R2-D2 then is finally able to send out the message and help save the galaxy thanks to the 3DPOV display.

## Scenario C – “Dr. McMech”

Dr. McMech has his PhD in mechanical engineering and he specializes in highly complex fluid and thermal dynamics. He wants a way to be able to see a real 3D representation of his fluid and thermal simulations he builds for his research. He uses the 3DPOV display to be able to observe and analyze the simulations in an organic 3D representations.

## Scenario D – “Dr. Transform”

Dr. Transform has his PhD in electrical engineering, specializing in the optics and signal processing. For a complex problem he is working on, he needs to do two-dimensional Fourier transforms. Dr. Transform utilizes the graphics abilities of the 3DPOV display in order to view the complex 3D diagrams that result from his Fourier analysis.

## Scenario E – “DJ 3D”

DJ 3D is a local artist who loves to mix his music to cool music visualizations. He always loved how WINAMP had so many cool visual plugins. DJ 3D also happens to be a hobbyist and so he writes code to do a 3D visualization to his music. He then uses the 3DPOV display to view the 3D music visualizations in a real 3D space and he brought to his gigs as his own unique style.

# Functional Requirements

The 3DPOV display has four main functional requirements: a quality display, a quiet system, a safe system, and a professional enclosure. These are all very important requirements to the system in their own ways. Additionally, the display has some stringent data communication requirements as well as user interface requirements as well.

## Specific High Level Functions

### Quality Display

The 3DPOV must have a high quality display to ensure an enjoyable experience for the end user. In order to ensure this, it is subsequently important for the 3DPOV display to have low image jitter and low noise to minimize interference with the graphics display. Additionally, it is necessary to have a smooth, consistent rotation which is triggered every rotation and has accurate speed control over the system to help ensure the display remains in one location and isn’t noisy.

### Quiet System

The 3DPOV display must also be a quiet system to ensure an enjoyable experience for the end user. Our quietness benchmark would be relative to 3D printers and we will ensure that the display is not louder than the standard 3D printer. Subsequently, it is important to minimize motor and mechanical noises from the system in order to make the system quitter.

### Safe System

It is imperative that the 3DPOV display is a very safe system because customer safety is always a priority for us. In order ensure the safety of the system, the 3DPOV display must come with a clear enclosure to isolate the rotating parts from the user. It is also important to make sure that there are kill systems in place in the event that something does go wrong, as well as having a system to ensure that 3DPOV display runs cool.

### Professional Enclosure

Finally, it is important that the 3DPOV display has a professional enclosure that really looks nice and presentable. The enclosure would tie together the safety aspects with the user interface aspects of the system and should sit firmly on a flat surface.

## Specific Low Level Functions

### SPI Bus

The first low level functional requirement revolves around getting a 3D image displayed. The hardware used communicates over SPI, therefore it is important to have a structured, well maintained and organized SPI bus in order to avoid data corruption and improper operation. Both the memory chips and the LED drivers are on the SPI bus.

### Hall Effect Interrupt Handling

Another requirement for displaying a 3D image is to have proper interrupt handlers for the signal coming from the Hall Effect sensor. With a properly set up interrupt handler, we are able to display a 3D image which is synced and stationary, thus reducing image jitter.

### Transfers Power up to the Rotating Assembly

In order for the system to run, it needs to have power. This is a technical difficulty due to the fact that we can’t simply hook up a power cable to the PCBs which are spinning at 1800 rpm. In order to power the system, there needs to be a system which sends the DC power and ground up to the boards.

### Smooth, Consistent 1800 rpm rotations

In order to achieve a low noise, low jitter 3D display, the 3DPOV display need to maintain smooth rotations at a constant 1800 rpm. This is facilitated by the electronic speed controller and sensors.

### Minimal mechanical noise and vibrations

The 3DPOV display need to have minimal mechanical noise and low vibrations in order to deliver a quality visual experience and a safe system. Mechanical tunings are being done constantly to maintain solidarity.

### Data Communication between layers

Finally, in order for the 3DPOV display to work, their needs to be data communication between each PCB. The main signal that needs to travel between layers is the interrupt coming from the Hall Effect sensor on the lowest layer that synchronizes all the layers rotations.

## Interface Requirements

The 3DPOV display has many different layers of interface requirements, however, for the first phase of development there will be less emphasis on user interfaces to reduce complexity. Later design phases of the 3DPOV will build off of what we’ve done to create a more complete user interaction with the system.

### Graphical User Interface

There is no GUI planned for this phase of the design in order to minimize system complexity. Further refinements of the system will incorporate a well-made GUI that will allow the user to interact with 3D modeling software and the display in a seamless fashion.

### Hardware Interfaces

The main user interaction for the 3DPOV display (in this phase of the design) comes in the form of a speed control module. The speed control module consists of an Aluminum chassis containing the necessary hardware components to interface with the controller for the motor. This motor interaction is accomplished via a potentiometer with a nice, large, easy-to-use knob installed on the top. The speed control box has a barrel jack on the back for powering as well as an on/off switch.

Additionally, the microcontrollers located on each LED wing communicate to the memory and LED drivers through a four wire SPI system. The microcontroller serves as the master to the various slave nodes (the memory and LED drivers) and controls the operation of the specific layer. The Hall Effect sensor located on the lowest layer interfaces with all the microcontrollers in order to synchronize the display once per rotation.

### Communications Interfaces

For this phase of the design, there is no plan for a communication interface, however future iterations would have to facilitate a wireless communication channel between the user interface and the LED display utilizing either Bluetooth or Wi-Fi so that changes to the data being displayed can be changed remotely.

# Technical Requirements

The Three Dimensional Persistence of Vision Display (3DPOV Display) is a 3D display that creates a three dimensional image by rotating LEDs at approximately 1800 rpm (30 Hz) and pulsing the LEDs on and off at a rate which the eye can’t perceive. Since the eye stores an image in “memory” for approximately 1/16 of a second, when we spin an object quicker than 16 Hz it is perceived as a solid object (think of helicopter wings and fan blades). When we layer multiple blades vertically, this creates a 3D image to the human eye. The mechanical and electrical components sit on an 18 in2, ½ inch thick wooden base. Additionally, there is a two-output power supply, separate of the base, for powering the motor and the rotating electrical components.

The 3DPOV display has five main components:

1. The motor assembly, a 750 KV (KV = rpm/volt) Turnigy d2836/11 DC brushless motor, a Turnigy 30 (or 40) Amp Electronic Speed Controller (ESC), a 12V line capable of at least 3A, and an Arduino with a custom enclosure to control the ESC
2. The timing belt assembly, a 2.7:1 timing belt configuration consisting of a 2 flange, 4mm bore, T5 5mm pitch, 10mm belt width, 10 tooth aluminum alloy timing belt pulley, a 2 flange, 3/8 inch bore, T5 5mm pitch, 10 mm belt width, 27 tooth aluminum alloy timing belt pulley, and a single sided, 61 tooth, 10 mm polyurethane steel tensile timing belt
3. The mechanical assembly, the main rotating assembly consisting of a 5/16 inch diameter, 5.1625 inch long steel rod, two 7/8” outer diameter, 5/16” inner diameter steel ball bearings, a modified DC motor steel alloy shell, and 3/16” mounting bolts to affix the mechanical assembly to the platform.
4. The power electronics assembly, a machined down 2” diameter, 1” thick super-conductive copper ring w/ a 7/16” diameter bore, a 1/16” thick, 5/16” inner diameter plastic shield between the copper ring and the steel shaft, two carbon brushes from the DC motor, and one 5V, 18A supply line.
5. The main LED assembly, eight custom PCBs containing 32 white 3mm through-hole LEDs, two Maxim 6971 16 output constant current LED driver ICs, a 5V 16 MHz Arduino pro mini, a Melexis MLX92212LSE-ABA-000-RE three pin unipolar hall effect switch, and four Microchip 23LC1024 1 Mbit SPI nvSRAM chips.

## Specific Functions Accomplished

### Quality Display [3.1.1]

In order to achieve a high quality display, many of the systems have to work in tandem to produce the final results. The mechanical systems are fine-tuned and well balanced which reduces image jitter. The Hall Effect sensor synchronizes all the PCB layers and ensures that the image stays relative to the same fixed point where the magnet is (it doesn’t move around unwantedly). The 3mm white LEDs give the 3DPOV display a nice fine resolution, in factor our total resolution is: .

### Quiet System [3.1.2]

We use rubber dampeners throughout the system to both reduce mechanical vibrations and to help make the system quitter overall. The main source of noise is from the DC brushless motor so we sound isolated it from the outside environment. Additionally, the enclosure and Plexiglas shield work in tandem to make the system quieter.

### Safe System [3.1.3]

There are multiple safety systems incorporated into the 3DPOV display. The primary line of defense from possible projectiles is the 1/8 inch thick clear acrylic (Plexiglas) shield that sits over the top of the rotating system to block projectiles from leaving the enclosed area and potentially injuring the user. Additionally, there is a kill switch system implemented in the case that something does go wrong, you just have to hit the large kill button. Finally, the DC brushless motor inherently has safety features due to the fact that it will stop rotating if it incurs too much torque applied instantaneously. This means that if a hand were to collide with the wings, the motor would be stopped by the torque from the collision and wouldn’t continue to run.

### Professional Enclosure [3.1.4]

We fabricated our professional enclosure out of nice wood materials and gave it a solid base coat of paint. The clear acrylic enclosure still allows complete vision from any of the useful angles. The controller for the ESC sits in a professional aluminum enclosure, fitted with a sleek, large knob for fine tuning the speed of the system.

### SPI Bus [3.2.1]

The SPI bus is shared by the LED drivers, the memory chips, and the Arduino Pro Mini. The Pro mini acts as the Master and the LED drivers and memory chips are slaves. The memory chips get chip selected with an active low signal when being used and can be suspended mid transmission (a very useful feature). The LED drivers don’t have a chip select, but they do have enables for certain latches on the device. The latches, LE and ~OE, are shared between the two LED drivers. We communicate with the devices at a bus clock rate of 8 MHz (1/2 the clock of the Pro Mini) and we operate in SPI Mode 0 (active high clock that is sampled on the rising edge of the SPI clock). Bits are streamed MSB first to all devices on the bus.

### Hall Effect Interrupt Handing [3.2.2]

We handle the signal from the Hall Effect sensor by sending it to pin 2 on each of the Arduino Pro Minis. The Arduino has built in functionality for an interrupt, called attachInterrupt(), for pins 2 and 3, and the pin 2 interrupt is in fact the highest priority interrupt that the ATMEGA328p addresses other than the RESET interrupt. An interrupt is generated up a falling edge of the signal from the Hall Effect sensor (the Hall Effect sensor sits at 5V and drops down to 0V when it passes over the magnet).

### Transfers Power up to the Rotating Assembly [3.2.3]

We transfer power to the PCBs of the rotating assembly via a carbon graphite brush system. Basically, we have a super conductive copper ring that is isolated from the shaft via a plastic spacer inserted inside the ring. We have a carbon graphite brush with power attached to it that will conduct the power into the copper and then we can attach a wire to the copper ring to get +5V up the PCBs. The ground connection is sent up through the shaft and each PCB individually pull the ground connection off the shaft. The +5V signal has to be connected between the layers along with other important communications signals.

### Smooth, Consistent 1800 rpm rotations [3.2.4]

The Brushless ESC for our DC Brushless motor facilitates the main speed control for us. The great part about DC brushless motors is that they have built in sensors that do speed control already, so the speed is very stable without us doing anything. We control the ESC with an Arduino Pro Mini that has a potentiometer hooked up to it. The Arduino pretends to be an RC controller like you would have for an RC car or a quad copter and sends over servo signals based on the position of the potentiometer. The brushless ESC then converts the received servo signal and the provided DC power into the appropriate 3 phase signal to power the DC brushless motor.

### Minimal Mechanical Noise and Vibrations [3.2.5]

As was mentioned earlier, we incorporated rubber dampening into the majority of the mechanical components to help reduce vibrations and noise. Additionally, we carefully balanced and fine-tuned the system to ensure it was stable. Finally, we made sure the shaft was securely bolted to the enclosure through a system with multiple bearings and large bolts. Through the help of the machine shop, we machined a high precision coupling and shaft insert for the third bearing. We needed this third bearing in order to reduce the play in the shaft that is resultant of the lower shaft not being perfectly straight.

### Data Communications between Layers [3.2.6]

Between each layer, the Hall Effect sensor output signal and two I2C lines are passed up. The Hall Effect sensor ensures the systems are all synchronized and the I2C lines are for back up communication.