racesim BUILD

KEY FEATURES

- Named "MRAP Seatmover" Made almost entirely from **M**DF, **R**ope **A**nd **P**ulleys
- Uses common materials and no special tools required
- 3rd DOF for traction loss easily added
- Electronics neatly housed inside the racesim
- Electronics neatly housed inside the racesim

DIY DESIGN NOTES FOR A 2/3DOF RACESIM USING MDF

"Everyone who builds a DIY project has their own set of goals and constraints which they work with."

"The rest is up to you to customize to your specific requirements."

"After reading through the vast amount of valuable information in the motion simulator forums and reviewing many designs, I have taken what I believe suits my requirements best…"

Craig Hoffmann

Aka RufusDufus

MANUAL VERSION 0.1

Contents

Introduction

I stumbled across the DIY motion simulator community by chance while searching the web for other unrelated information. I was fascinated with the quality and complexity of the designs and the support everyone gave each other. After finding the software was free for private use I was certain I wanted to give it a go myself.

This manual is my attempt at giving back to the community everything that I have learned from my time in the forums. Thanks to all those who answered questions and participated in the discussions.

While it is written more as a record of my own build in case I have to make any repairs later, I have tried as much as possible to include diagrams or photos to assist anyone that wants to use all or part of the design. Unless you use *all* the same materials you will need to make adjustments to suit. The rest is up to you to customize to your specific requirements.

I will point out that this is a reasonably heavy unit and not as small as many others in the forums. Personally I liked the idea of a solid professional looking unit and space wasn't an issue. You wouldn't want to be moving this racesim every time you have finished using it – it is large and heavy.

Design Goals

Everyone who builds a DIY project has their own set of goals and constraints which they work with. This is great for the person building the project however means that the design may not be ideal for someone else. This project is no exception, I have come up with a build that suits my needs without concern for other's requirements.

The design objectives and constraints for this build were:

- Car raceseat style simulator
- 2DOF movement of the racing seat only
- Ability to add 3rd DOF for traction loss at later stage
- Use materials that I have the tools and skill to work with
- Low cost is important but not the primary driver
- Look good enough (in my eyes) to be kept in the kids play room
- Robust and solid design that will last
- Ability to easily break down and transport in my car

Approach Adopted

After trolling through the vast amount of valuable information in the motion simulator forums and reviewing many designs, I have taken what I believe suits my requirements best and arrived at the following design. It is somewhat different to most in the forums but works on the same general principles.

- Made predominantly with MDF
- Use "Big" worm gear motors
- Use cable and pulleys to transfer movement from motors to seat
- Use Arduino controller and H-Bridges to drive motors

As such I have named it the "**MRAP Seatmover**". MRAP being short for MDF, Rope And Pulleys.

Bill Of Materials

All costs are in Australian dollars as of 2013
B nnnnn

Qty	Description	Cost	Notes
?	MDF Sheets 900 x 1200 x 16mm		Local hardware store (Bunnings) $25.94 per sheet
2	Worm Drive Motors	$240.45	Includes $22.45 delivery fee. http://www.motiondynamics.com.au/
2	BTS7960B 43A H-Bridges	$ 32.25	Ebay, search for "bts7960b"
1	12V 30A Switch Mode Power Supply	$ 38.82	Ebay, common 360W supply sold for LED lighting, search "360w led"
1	Arduino Duo R3	$ 16.90	Ebay
1	LED Volt/Current meter	$ 16.99	Ebay, optional
1	1/2in Drive Universal socket	$ 6.99	Super cheap auto (or hardware store)
1	Fixed Back Car Seat	$109.00	On special at soldsmart.com.au
1	4 point Seat belt	$ 36.00	Ebay, Optional
8	Small Hoist Pulleys	$ 21.48	Ebay, price is for 10 pcs, search "0.03 pulley"
2	5K Potentiometers	-	Already had them
6	Small Turnbuckles	$ 25.80	Local hardware store (Bunnings) $4.30ea
1	Rope Grunt Hi Viz Safety 180kg	$ 5.00	10m roll – only need about 2m Local hardware store (Bunnings)
1	Wire spade terminals	$ 3.60	10 in packet Local hardware store (Bunnings)
2	Terminal strips	$ 10.20	Local hardware store (Bunnings)
2	150mm x 12mm Bolt & Nuts	$	Used for the drive shaft
1m	Multi-colour Ribbon Cable	-	Already had some – for wiring Arduino

*** NEED TO COMPLETE THIS SECTION ***

Other items that will be needed include

- 12V high current hook up wire
- Solder and soldering iron
- Circular saw/Jigsaw or good hand saw
- Electric or hand drill
- Various nails and screws
- Wood glue
- Computer to run game and the motion simulator software
- Suitable TV, monitor, or projector
- Force feedback steering wheel and pedals
- Paint

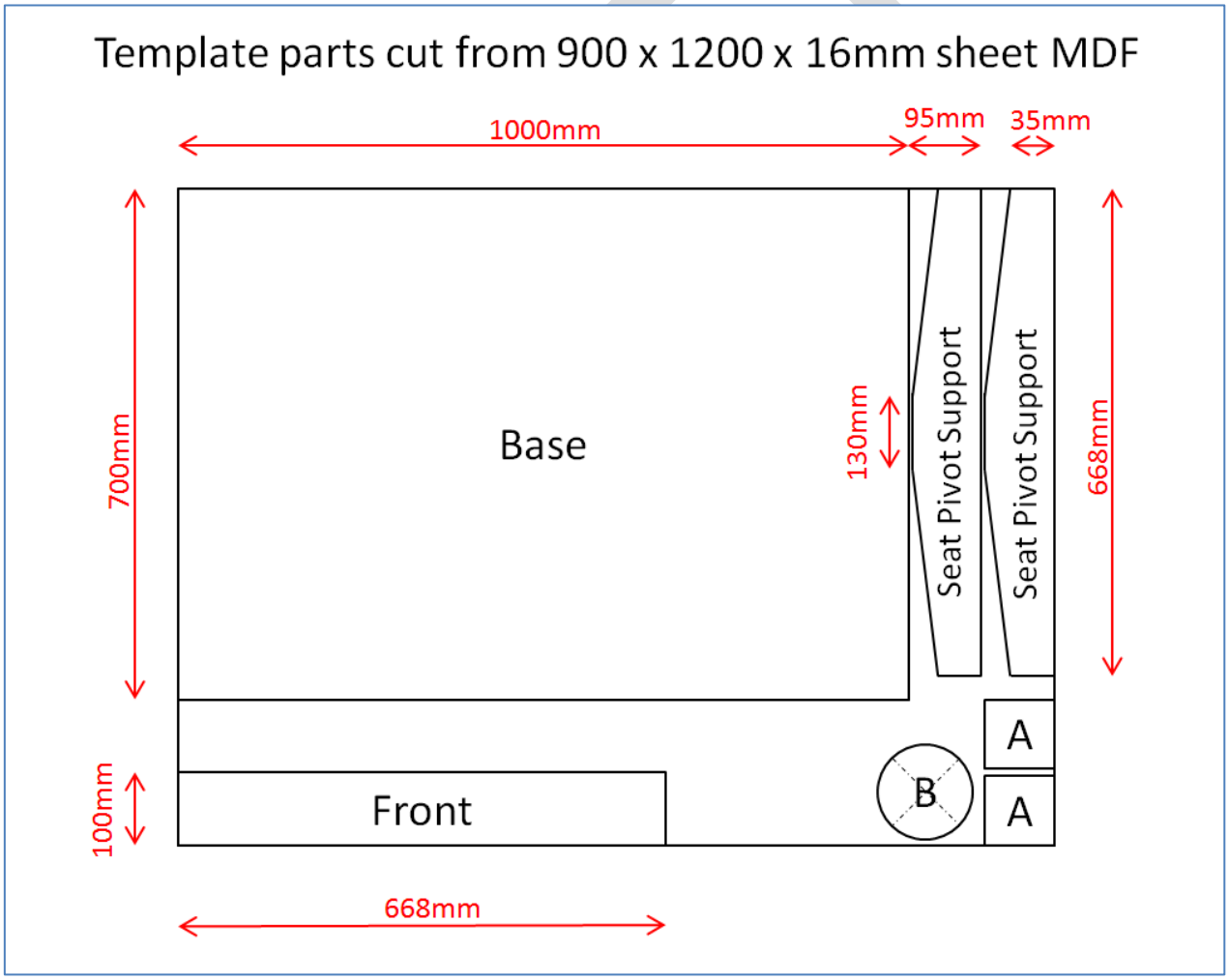
- Spare time

MDF Part Templates

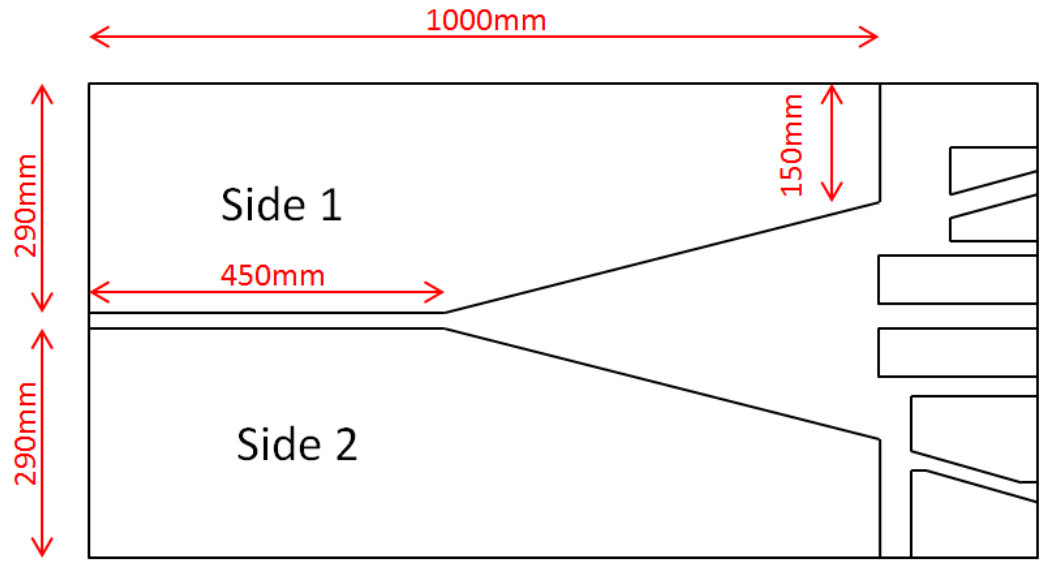
The MDF parts were cut from 2 sheets 900 x 1200 x 16mm. Part dimensions are shown in the figures below. If you use an MDF sheet thickness other than 16mm you will need to make adjustments to the dimensions. I would not recommend using sheets thinner than 16mm though.

It is important to note that you may need to adjust some of the dimensions to suit your own requirements and available materials. I have tried to detail where you may need to do this throughout the build instructions.

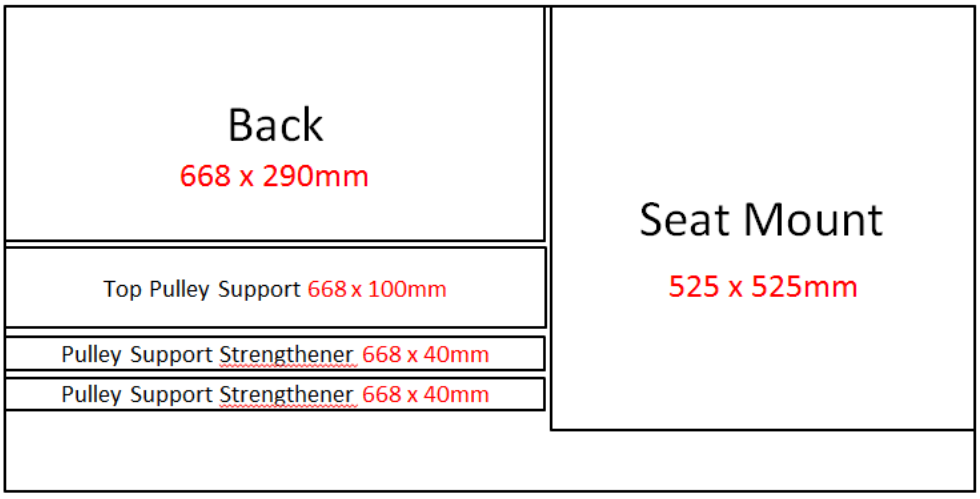
Take your time measuring and cutting the parts. The more accurate you are here the easier and neater it will be when fitting everything together.



Template parts cut from 600 x 1200 x 16mm sheet MDF



Template parts cut from 600 x 1200 x 16mm sheet MDF

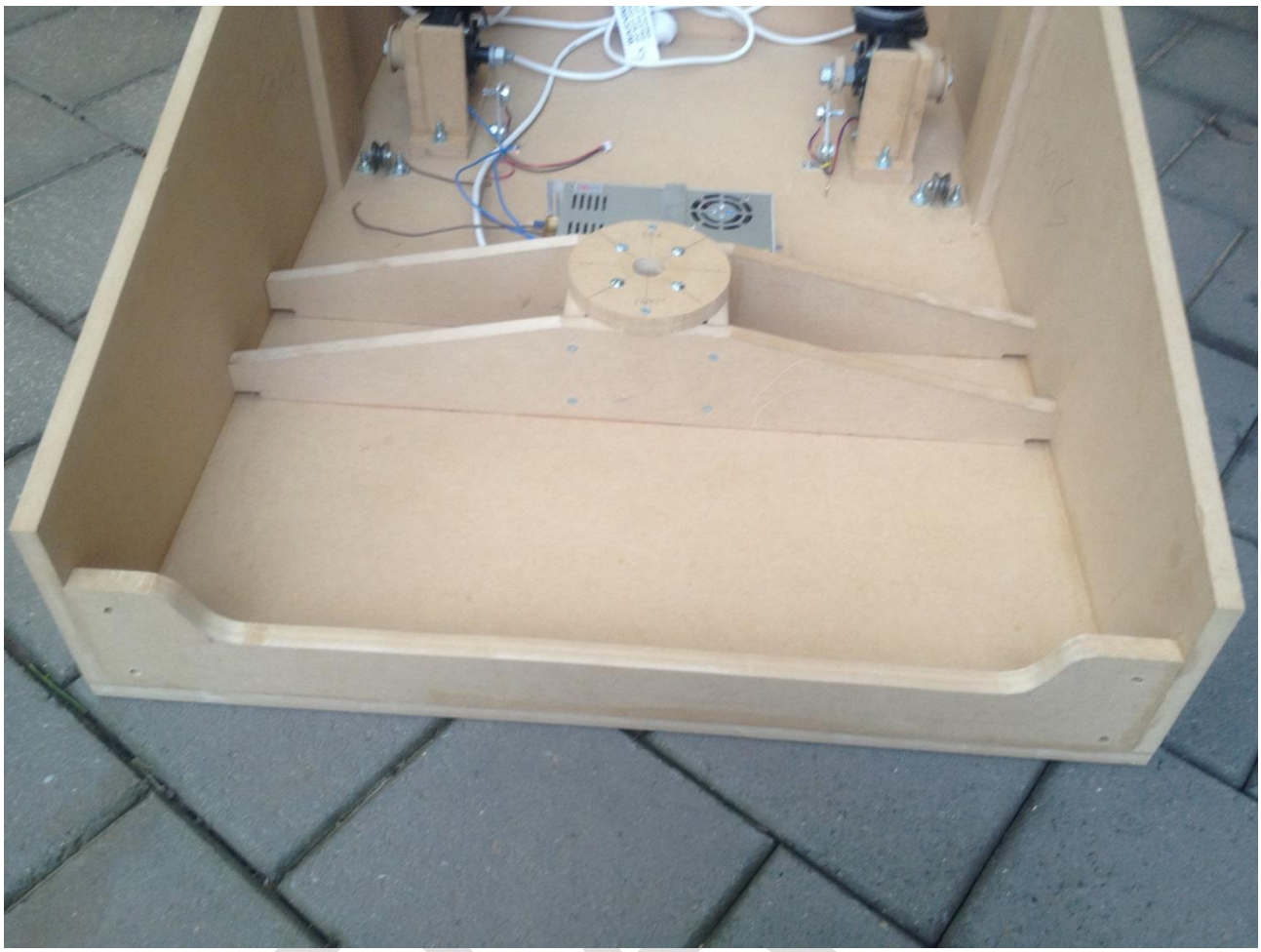


Assembling the Base

Next I added the seat supports.

I cut the corners out before mounting the assembly into the base unit. This was to allow the cabling to run from the front to the back. Unfortunately I didn't make them big enough for the connectors and ferrites on the cable so I had a difficult job of trying to enlarge them later. I would now suggest cutting out a 20mmx20mm square out of the corners of the support assembly – but check the cables/connectors being used.

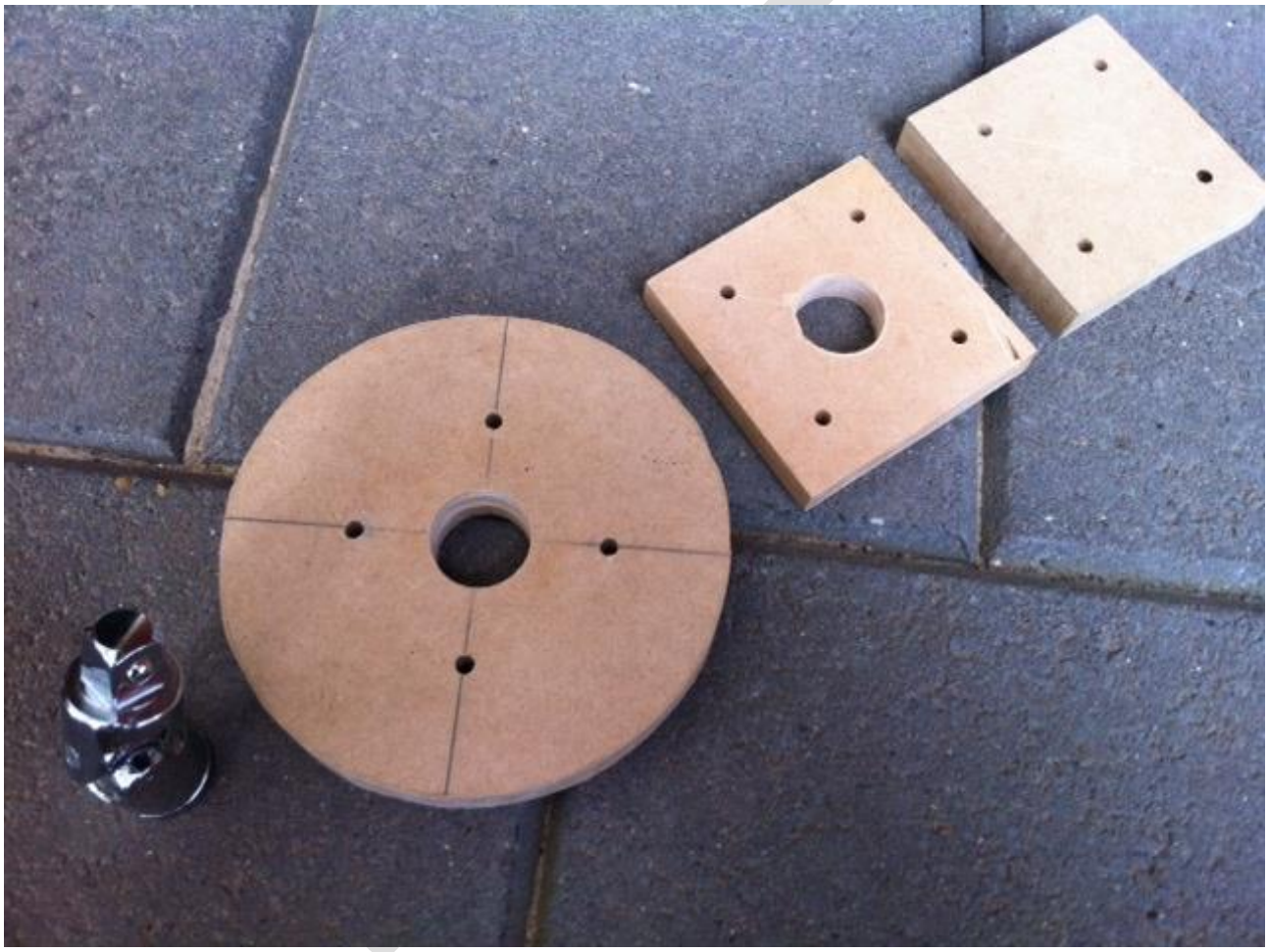
The assembled seat support then mounts inside the base unit, glued and screwed from the bottom to hold while the glue dries. This, together with the pivot used, sets the height of the seat so if you are planning to use something other than the 1/2in universal socket for the pivot you may need to make adjustments here. The goal is to have the seat platform central (in height) in the base unit so that it can move equal distance up and down.



Seat Platform & Pivot

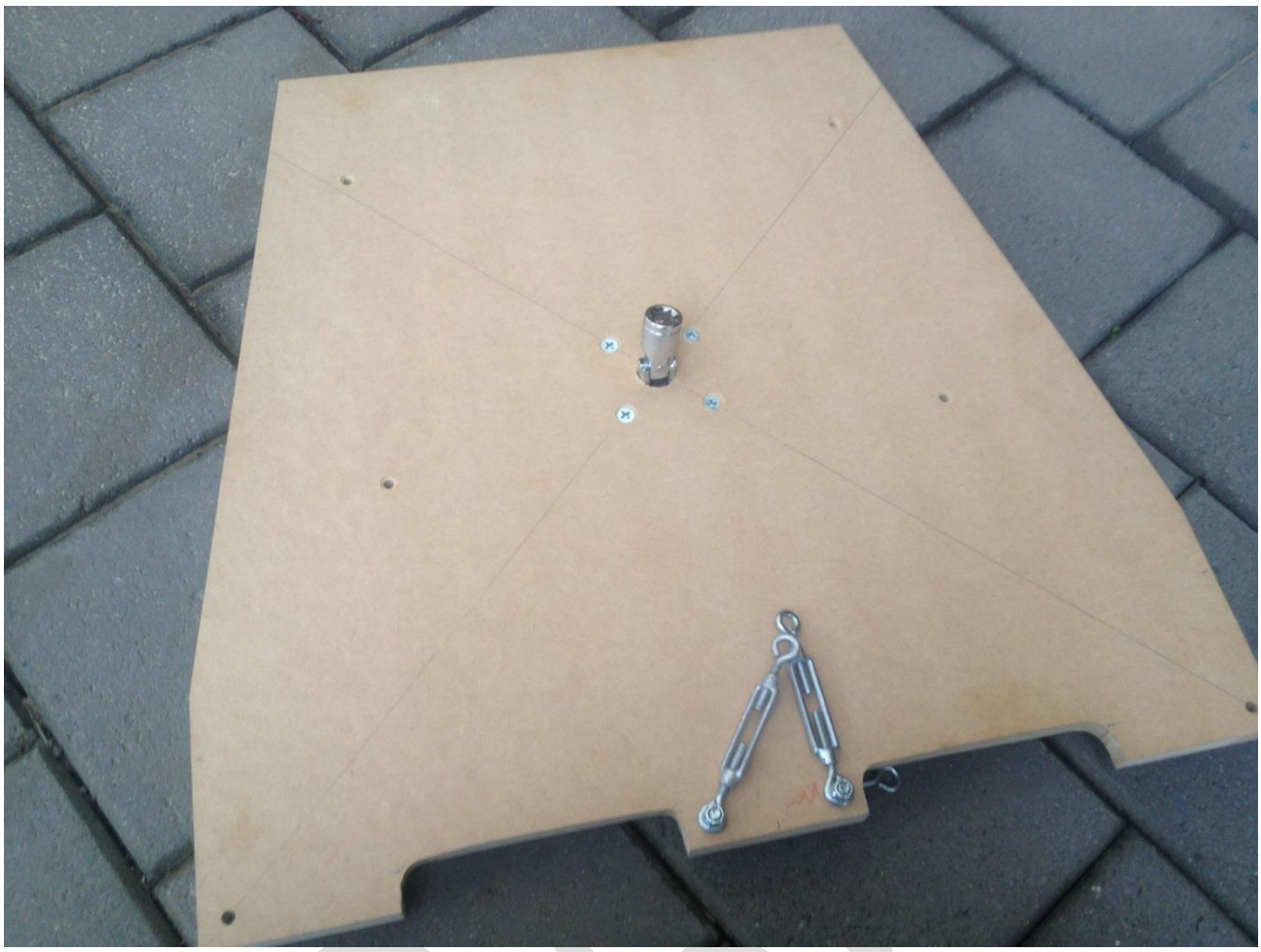
Once the seat support was in place I moved on to the pivot mount. Here I decided to use a 1/2in universal socket adaptor as it was only $6 from the local auto shop (or hardware store). Will it be strong enough in the long term? I'm not sure, but it seems to do the job well at the moment and is cheap and easily replaced if necessary.

The pivot point is centered on the seat platform however when mounting the seat on the platform it needs to be placed so as to best balance the seated driver.



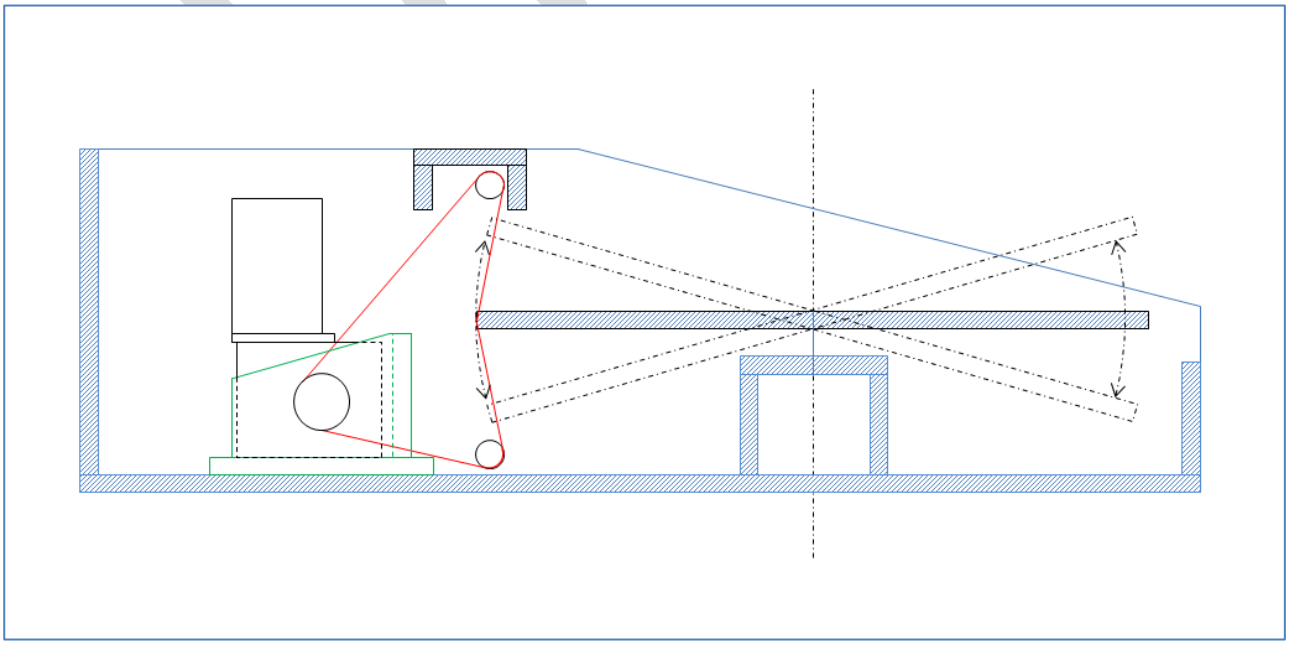
Try to make the fit of the 1/2in universal socket into the MDF as snug as possible to avoid any rattles when the simulator is in motion. This really relies on having the right size drills. I find spade drills are the best for this size hole in MDF. For the sockets I had, a 24mm spade drill produced the perfect fit – experiment in a scrap piece first. It would be better to have the hole slightly smaller to start with and take the time to slowly sand or file it out to fit rather than start with a hole that is too large.

At this stage I made the seat platform square (600mmx600mm), later once everything was assembled I trimmed it down to taper the sides to the front of the seat. The photo below shows after I have trimmed it down. Be sure to mark the center of the platform as this is where the pivot mounts. The seat is later positioned on the platform to produce the best balance.



Positioning the pulleys

****** Do a diagram of the pulley dimensions ******



The top and bottom pulleys are cheap metal ones I found on ebay. There were 5 in the pack and they were from China. Fairly rough but they seem good enough for the job. See below:

Next I modified 4 of the pulleys so that they could be mounted in a vertical position bolted directly to the base of the simulator. To do this I pulled the pulleys apart and bent the metal side plates outward and then reassembled them. See below:

A modification I will probably do at a later stage is replace the bold through the pulley wheel with a slightly larger one. They wheels tend to wobble around a bit – but at the moment I don't have the right size bolts and I want to keep on with the build.

The top pulleys are mounted to a piece of MDF U-channel. The U-channel is made of three straight lengths of MDF glued and screwed into a U-channel. This is done for strength so that it has minimal flex when the ropes are tensioned.

Constructing the Motor Drive Pulley

Continuing with my goal to make as much of the simulator as possible using readily available materials, I started to look for suitable pulleys for the motor drive. These seemed harder to come by so I decided to see how easy it would be to make my own. Since I was using MDF already it seemed like a good starting point. It turned out to be perfect for this application and was easy to make a drive pulley the size needed. I also later discovered the rope used seemed to grip to the MDF very well also eliminating any slip.

The size of the motor drive pulley required was calculated as follows:

I wanted a max (no load) seat speed of 200mm/s *(MaxSeatSpeed)*
The motor wormgear output is 160 rpm *(MotorSpeed)*
Therefore:

$$\text{Pulley Diameter} = (\text{MaxSeatSpeed} * 60 / \text{MotorSpeed}) / \pi$$

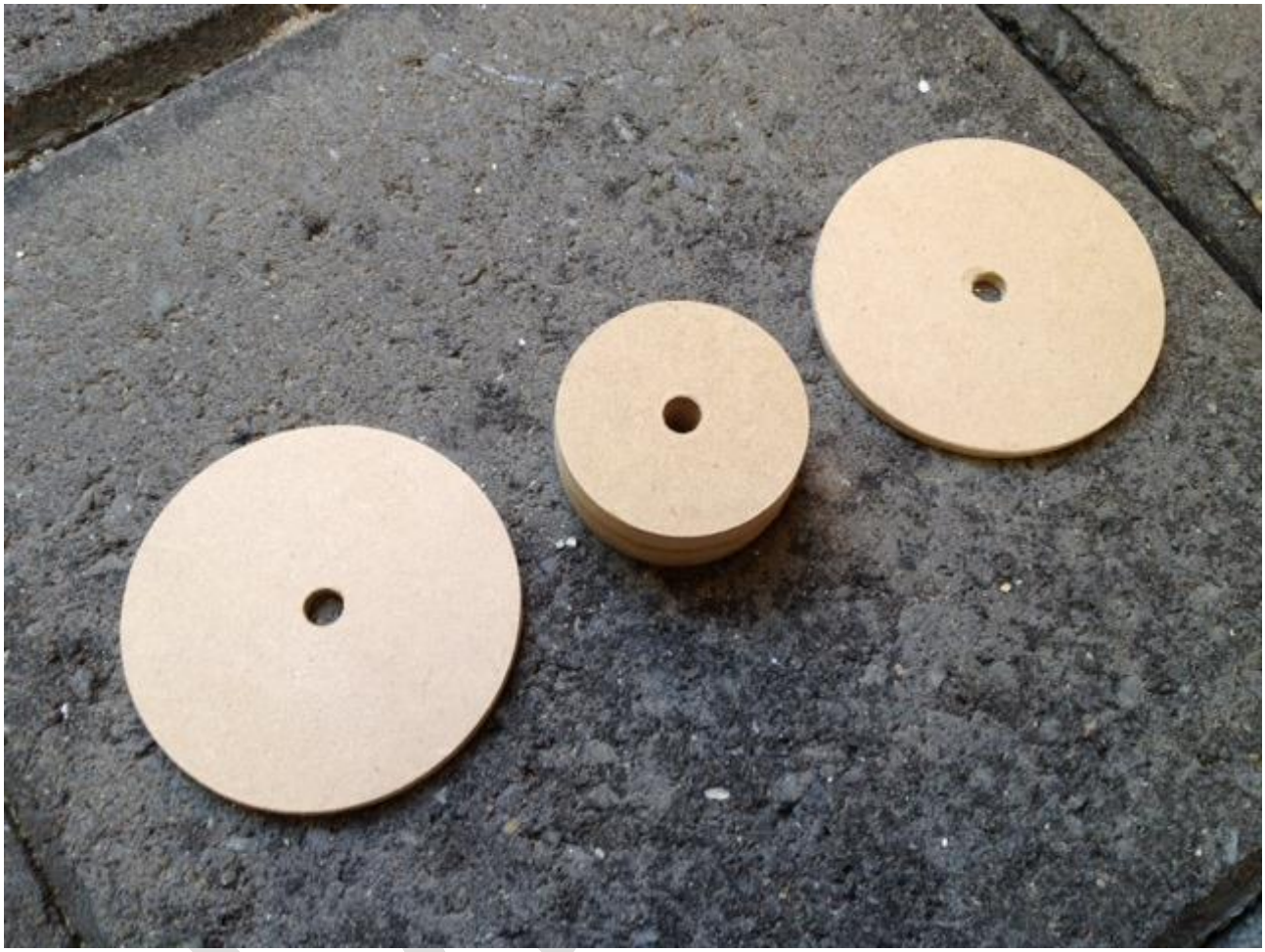
$$\text{Pulley Diameter} = (200 * 60 / 160) / 3.14159$$
$$= 24\text{mm (approx.)}$$

Note how small the diameter is which means the motor is placed under much less load compared to the traditional level arm/connecting rod style designs that typically have at least 50mm lever (equates to 100mm diameter). I don't have any to test but believe this design would suit wiper motors very well (you would increase the pulley diameter to 64mm for a 60rpm wiper motor which is still better than a 50mm lever).

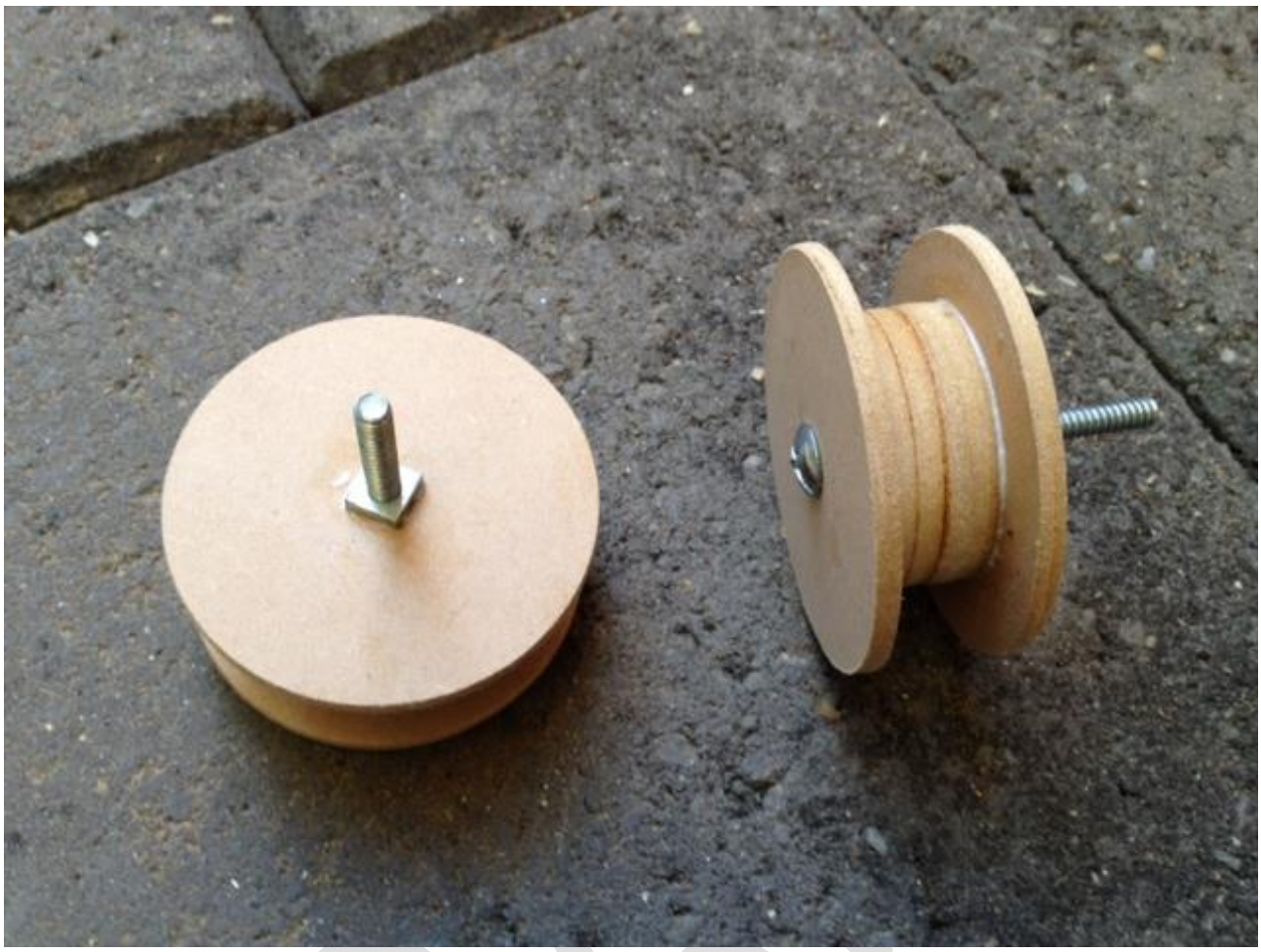
Actually I decided a 24mm pulley wheel was too small for my plans to make it out of MDF. I had a hole saw drill attachment that made 40mm discs so I went with that giving a speed of 335mm/s.

Because the motor is under less load it will typically run closer to max no load speed as well. If you really want to get technical you can calculate the optimal diameter to get max speed from the motor given the load – I couldn't be bothered with this.

To make the pulley wheel cut 1 disc out of the 16mm MDF with the diameter calculated above. Then cut two more discs out of some 3mm MDF with a diameter about 10-20mm larger than the first disc. Refer to images below:



Once you have the three discs, glue them together.



The construction of the pulley does not need to be extremely precise. If you don't have a hole saw, cut them as close to shape with any saw and then file or sand into a disc. Alternatively attach to an electric drill and sand it to shape while spinning it in the drill.

Constructing the Position Feedback Pulley

Since I was onto a winner with the MDF drive pulley, it made sense to use the same technique for the position feedback pulley.

The size of the position feedback pulley required was calculated as follows:

The pots used turned a max of just over 270 degs *(MaxPotTurn)*
I wanted a maximum movement in the seat of 150mm *(MaxSeatMovement)*
Therefore:

Pulley Diameter = (MaxSeatMovement * 360 / MaxPotTurn) / π

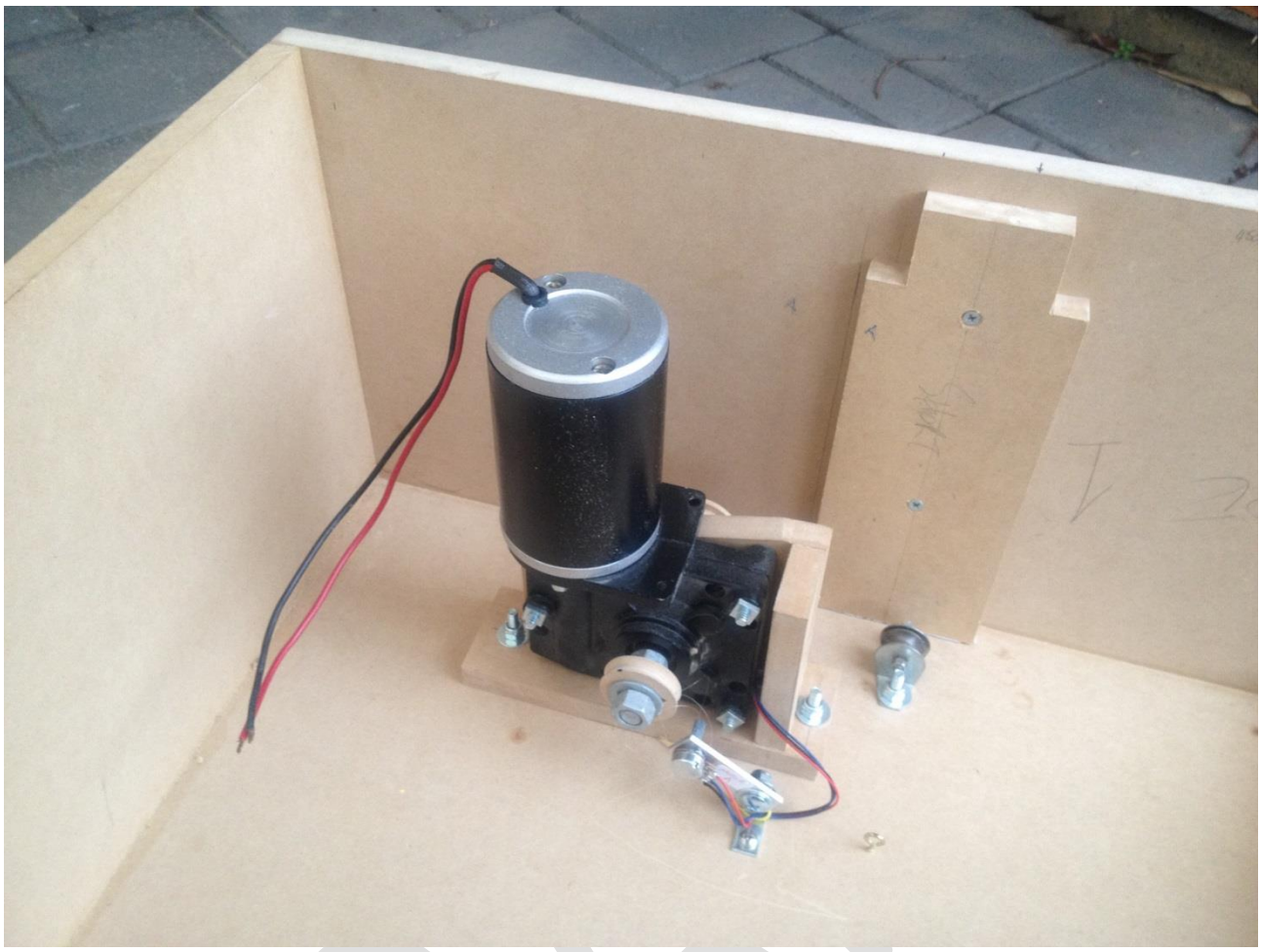
Pulley Diameter = (150 * 360 / 270) / 3.14159
= 64mm (approx.)

This calculation assumes that the position feedback pulley is driven off the same size pulley as the drive pulley.

Mounting the Motors

To make assembly easy I made a couple of motor mounts. The motors bolt to the mounts and then the complete assembly is bolted to the base of the racesim.

Don't forget to make one left and one right motor mount.



Adding the Pulley Cables

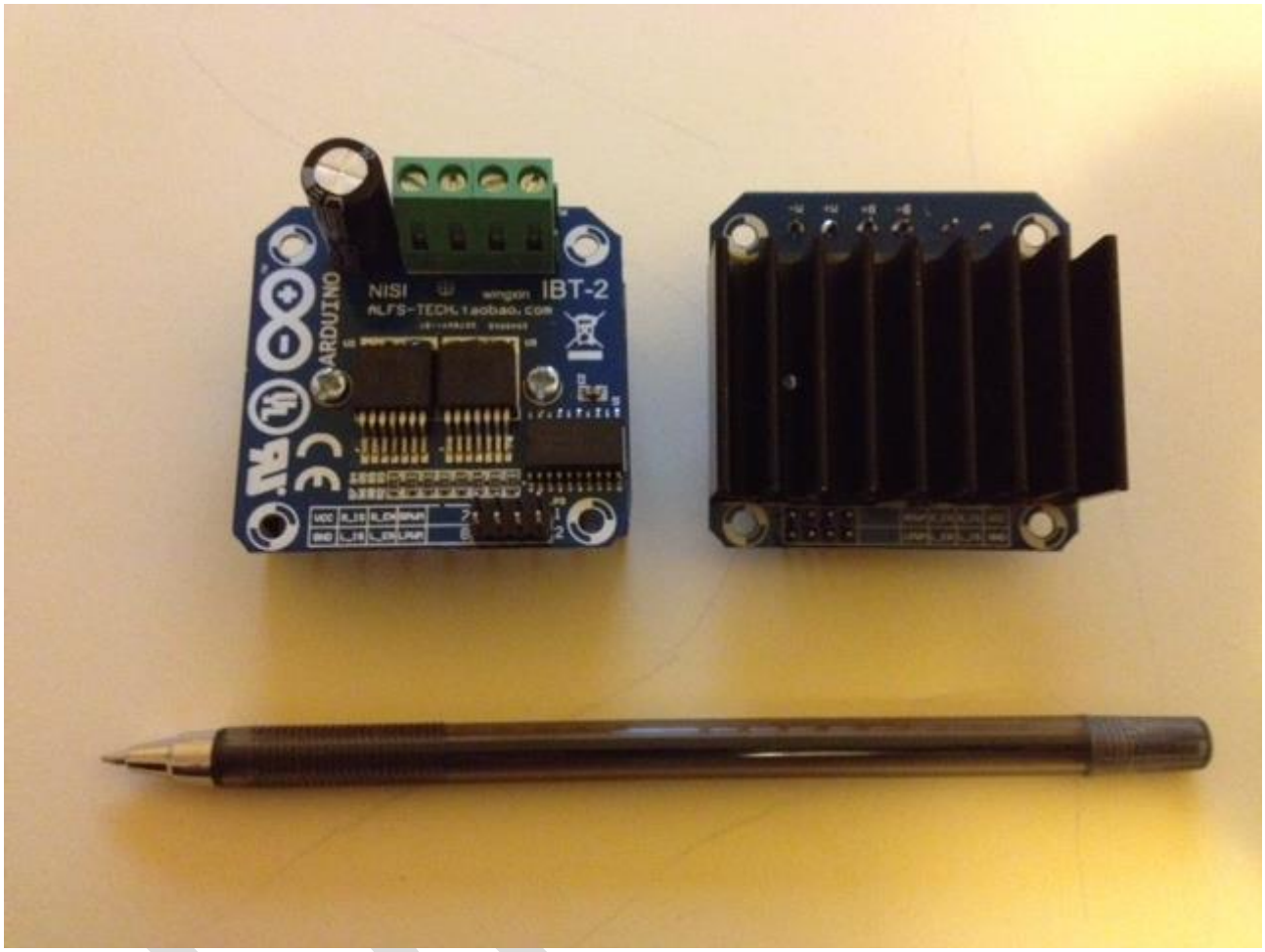
While working on the design I was quite unsure if rope and pulleys would work for this application. I was even thinking I may require stainless steel cable.

However after a visit to the hardware store I found some cheap "Grunt Hi Viz Safety Rope" with a rated breaking strength of 180kg. It was a woven rope with 4mm diameter and appeared to have no stretch at all which seemed ideal. So I decided to use this for the initial tests. It worked well and is still being used.

Given how cheap it is even if it eventually breaks I have plenty to do numerous repairs – although I am hoping it won't come to this!

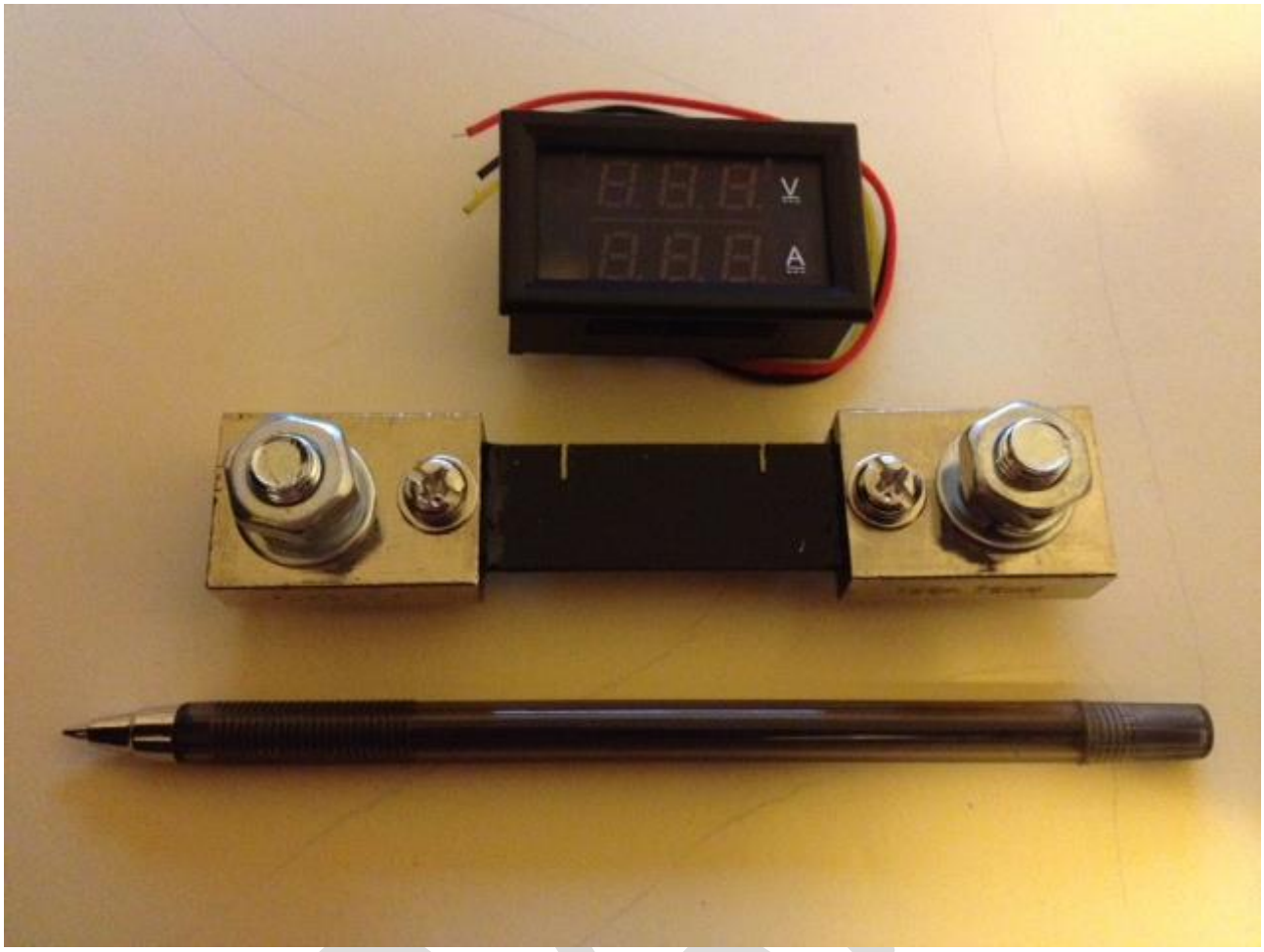
Wiring the Motors and Controllers

I chose to use the Arduino Open source X-PID software together with an Arduino Duo R3. The H-Bridges were found on ebay – I believe IBT-2 is the model and is often referred to as a BTS7960B 43A Motor Driver.

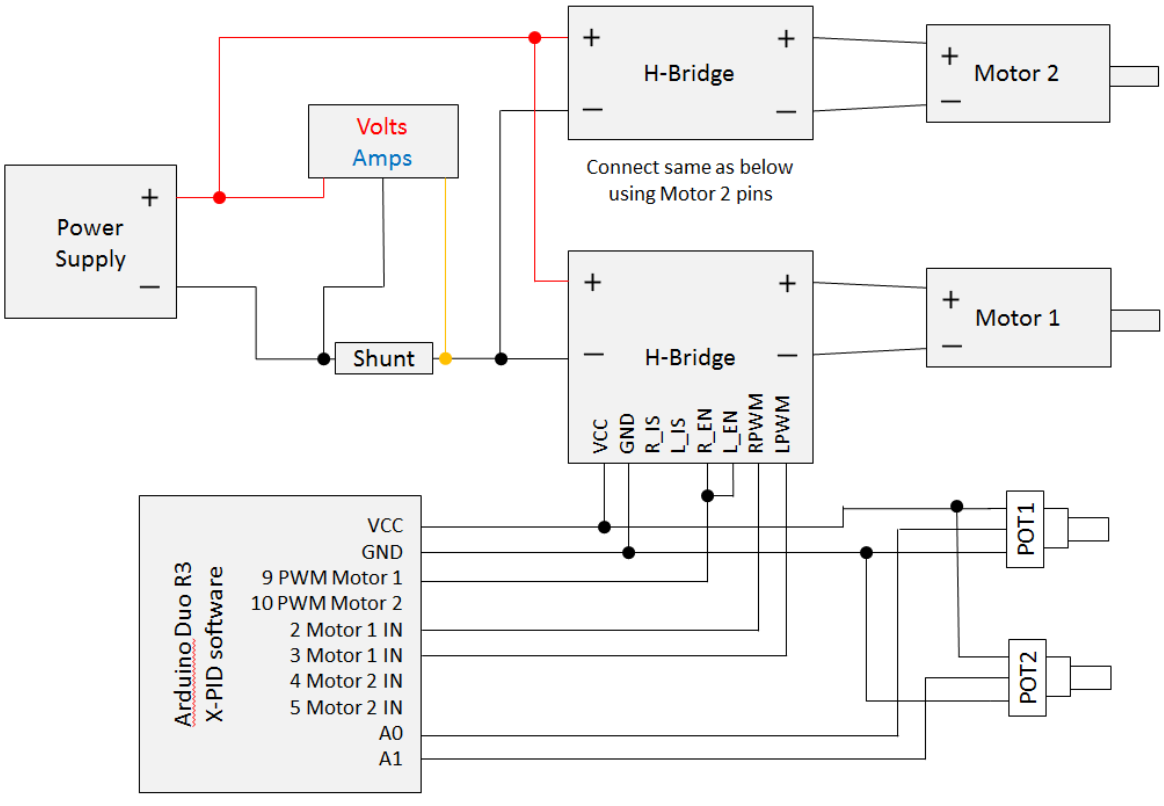


These H-Bridges have two sets of inputs for PWM, one for each direction. After a closer look at the circuit and BTS7960B datasheet I realized it was possible to use the inputs labeled R_PWM and L_PWM (which are actually the driver highside/lowside select inputs) for the motor direction inputs, and tie the R_EN and L_EN (the driver enable inputs) together and connect them to the Arduino PWM output. Refer to the wiring details.

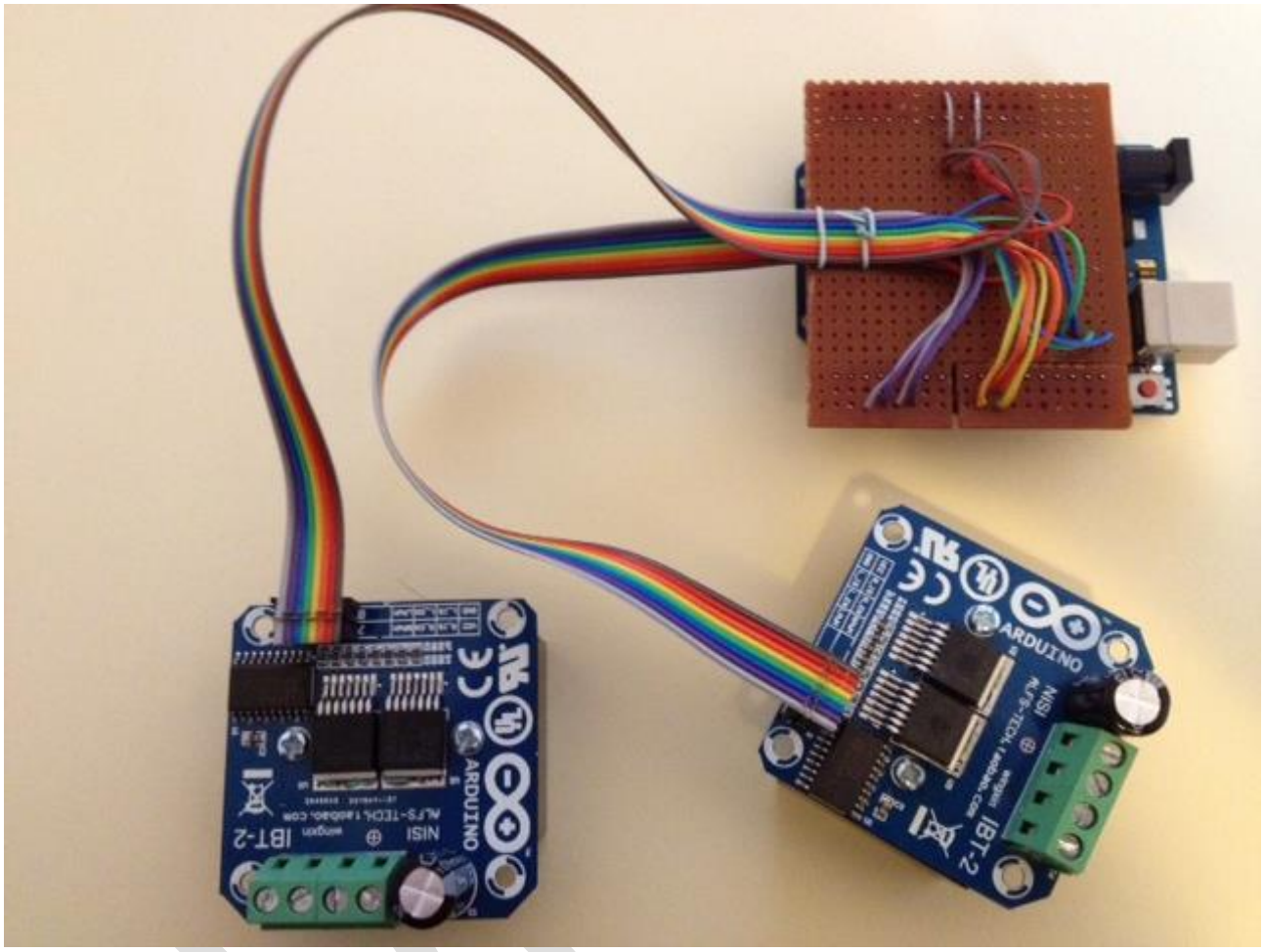
I found a combined Voltage and Current panel meter on ebay and decided to get one to wire into the motor power circuit to monitor the load. You could easily leave this out, I just thought it was a nice touch to the design.



Wiring Details



To make assembly and repairs/modifications as easy as possible I tried to use connectors as much as possible between the modules rather than solder directly to them. For the Arduino I used some prototype pcb to make a piggyback board that could be unplugged and all the wiring was connected to that. I have quite a stock of electronics at home so I didn't have to go and buy anything, but this does increase costs a bit.



**** INSERT PHOTO *****

Mounting the Motors and Controllers

Limit Switches

Not yet implemented… I like living on the edge!

Emergency Stop

Not yet implemented… Hopefully it doesn't end in flames!

Adding a Steering Wheel and Pedals

Using G27 Wheels and pedals. I have gathered info on the gearstick to steering wheel interface and looking into a plugin design that allows using an alternate gearshift and switch layout in parallel to the original.

Build Assessment

Now that the build is (semi) complete and tested I have the following comments:

- Overall the design was successful and met my requirements
- It was quite easy to make – especially if you have power tools
- The design is really solid and I would expect 12mm MDF would have been suitable reducing both cost and weight (I wouldn't go thinner, and I would stay with 16mm for the actual Seat Platform to prevent any flexing)
- I feel that the big motors I have used are actually overkill in this design as the whole approach aims to minimize the load on the motors.
- I would suspect this would be an ideal design for standard wiper motors with a few adjustments to the pulley dimensions (although I have never had or used such motors to confirm)