Memorandum

Subject

To: Prof. Kyle Winfree EE476C

From: Ali Muqeem, Ali Alfadhli, Salman Alajmi, Ahmad Alfaresi

Date: 5/3/2020

Re: Group Design Review 4

Dear Dr. Winfree,

Attached below is the Group Design Review 4 assignment. In this assignment, the main objective is to show our work and what is the final status of the project. Our main idea is to show our work and explain the details of our project. This document will also guide the user on how to work with all of the components.

Respectfully,

Electric Drives Team

Electric Drives

<u>Group Design Review 4.</u>

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Table of Contents

List of Figures.

1.0 Introduction.

The idea of our project is to create a low cost platform for electric drives experimentations. Our client Dr. Yaramasu is currently teaching an electric drives course and in this course they use an expensive platform called ‘dSPACE’ to perform lab experiments and these hardware labs are quite expensive which cost around $4000. Our objective is to get familiar with these experiments and learn about them and convert these experiments using a cheaper alternative, so students can access these labs everywhere and whenever they want. The Arduino board is a great alternative and we will use it to implement the dSPACE experiment into the board with the help of MATLAB Simulink software. Simulink software is the main design program for this project and we will convert the provided dSPACE blocks into a design that works with the Arduino, installing the Arduino support package will help us for this process. The final model will have the complete setup using the PCB on which all the boards will connect together in a single chip and the Arduino will link with the PCB where the current and voltage controllers will present as well.

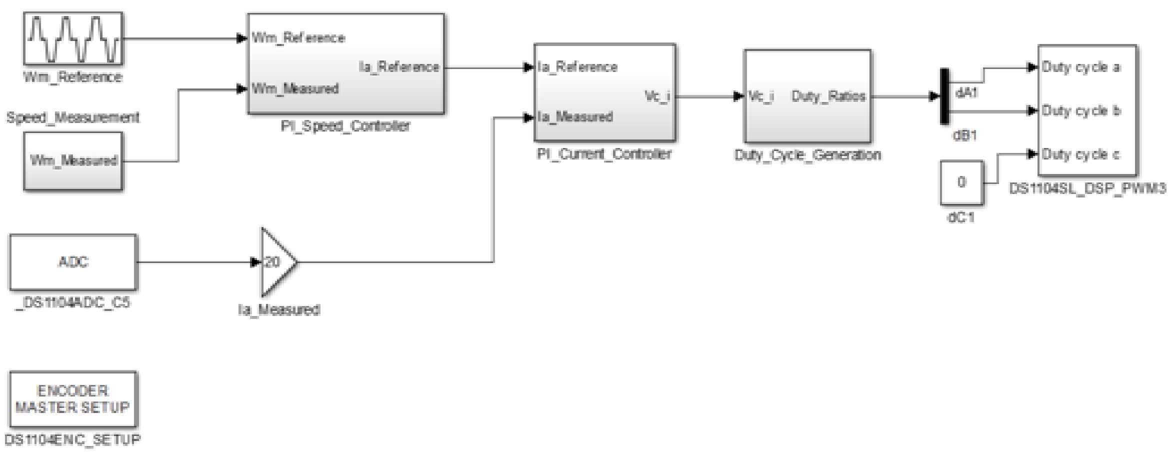

Figure 1:dSPACE Experiment in MATLAB Simulink

2.0 Status of planned features.

Work Breakdown Structure

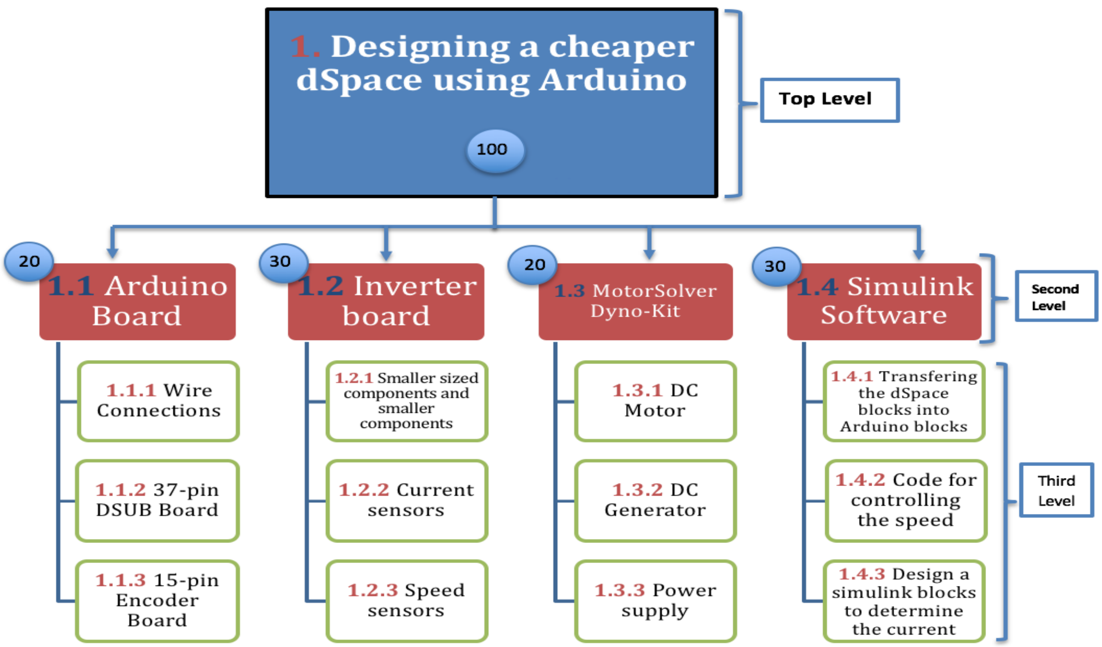

Figure 2: Work Breakdown Structure.

3.0 Section 1- Overview:

Electric motor drives are applied in various applications such as wind power generation, and in hybrid vehicles [1], [2]. There are various components which are used in the DSP-Based electric drives. Some of these components include the motor coupling system, the power electronic drive board, DSP based DSI1104, MATLAB Simulink, and a control desk center [1]. Each of these components works in such a manner that there is coordination between each of the components in order to complete the task in consideration. Our project is about creating a low cost platform for electric drive experimentations. Some platforms, such as dSPACE cost a lot of money and it is a great platform for electric drives experiments; however, there is another way to implement these experiments and it is by using an Arduino board, which is way cheaper than dSPACE platform. The final product is to have an inverter board that can be connected with the Arduino and the DC motor to implement dSPACE experiments. MATLAB Simulink is the solution for designing a system that can control the motor.

Our client is Dr. Venkata Yaramasu, assistant professor at Northern Arizona University. Dr. Yaramasu has many research interests, such as wind power energy, electric vehicles, high power converters, model predictive control and he teaches electric drives course. The main task that Dr. Yaramasu assigned for us during last semester is to finish the dSPACE labs, understand all of them and implement them on an Arduino board. This semester, our task is to continue to work on the Arduino experiments using MATLAB Simulink and design an inverter board that is smaller than the one that we currently have at the labs and fit the Arduino board under it to test our designs with it.

4.0 Section 2.

Electrical Drives are most commonly used for controlling multiple devices together through a single board. Most of the time electrical drives are used for controlling the motor. Electrical derives mostly communicate through the system using the MATLAB Simulink modules which provide a complete control and feedback system control to accurately operate the devices. Electric motor drives are applied in various applications such as wind power generation, and in hybrid vehicles [3]. There are various components which are used in the DSP-Based electric drives. Some of these components include the motor coupling system, the power electronic drive board, DSP based DSI1104, MATLAB Simulink, and a control desk center. Each of these components works in such a manner that there is coordination between each of the components in order to complete the task in consideration [4]. For example, the motor coupling system comprises of several components but the main component of these components is the motor to be controlled and any other component coupled with it. The other motor to be coupled can be of any type, that is, AC or DC. In addition, an encoder is used in order to monitor the speed of the motor which is controlled. The speed of an electric motor drive systems requires to be controlled. There are a number of ways on how an electric motor can be controlled, hardware and/or software based. For example, the most common electric motor drive includes dSPACE, MATLAB and Simulink controllers. But there is a possibility of utilizing the Arduino controller in controlling motor speed [4]. Thus, in this case, a consideration is made to design an Arduino based Board controller which can be used in electric motor drives teaching because of its relatively low cost.

4.1 DSP based electric drives systems:

DSP based electric drives systems comprises of the four major components, the motor coupling system, the power electronic drive board, DSP based DSI1104, MATLAB Simulink, and a control desk center [4]. All the components work in unison with one another in that there is a simultaneous coordination of the activities in all components. All the components work in coordination with each other so as to complete the task. For example, the motor coupling system comprises of several components but the main component of these components is the motor to be controlled and any other component coupled with it. The other motor to be coupled can be of any type, that is, AC or DC. In addition, an encoder is used in order to monitor the speed of the motor which is controlled.

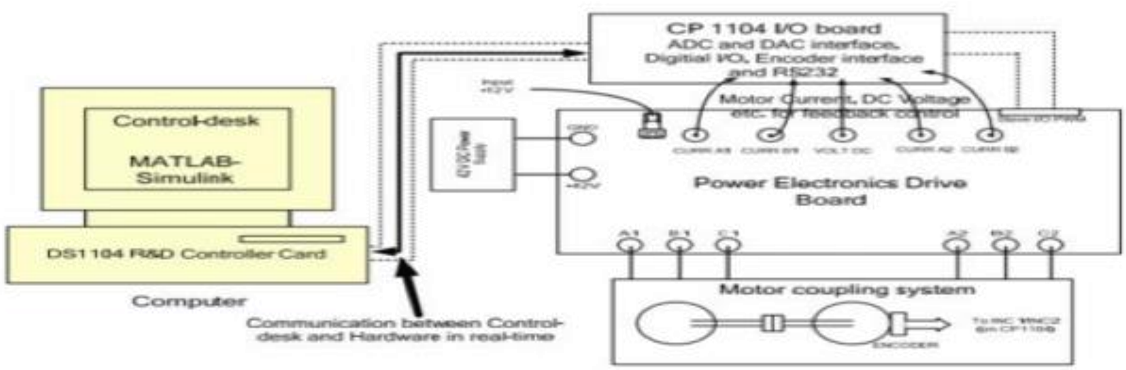

Figure 1.1: DSP-based electric-drives laboratory system

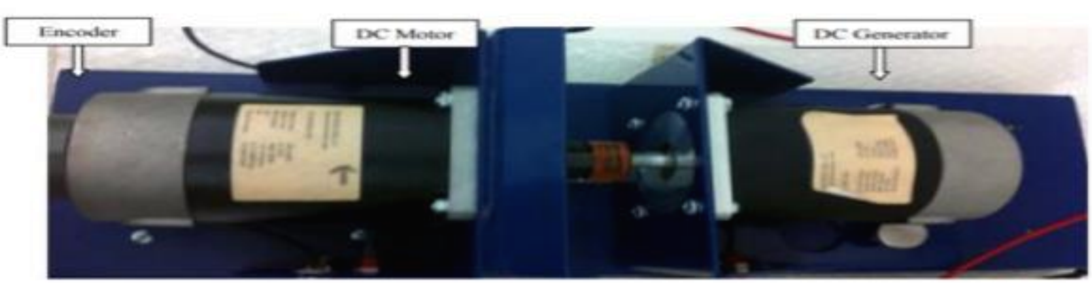

Figure 3: DSP-Based Coupling System [3]

The power electronic Drive board gives the machines the current which is at the right voltage levels for the operations of the machines. Also, it should be noted that in order for the system to provide a pulse width modulated voltage signal, it needs control signals so that it can give the appropriate signal. Thus, figure 2 below is the image of the drawing of the electronic power controller circuit.

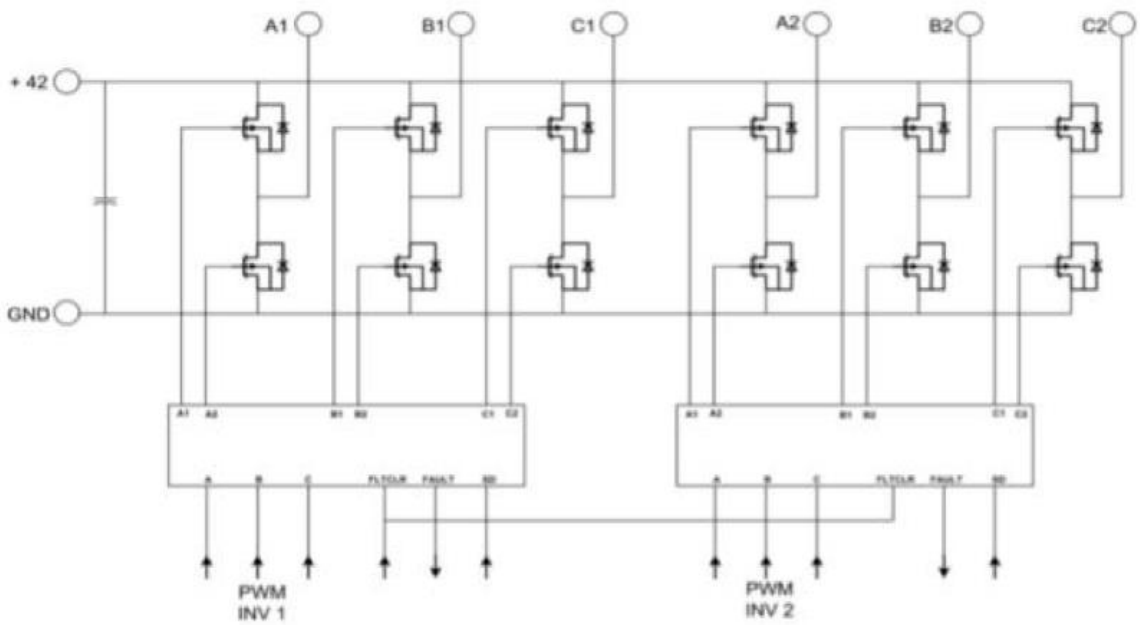

Figure 4: Electronic Power Drive Control Board Circuit Diagram [3]

DS1104 R&D controller board and the CP 1104 input/output board takes the instructions given to it in order to control the various variables of the electric drive system. This input/output system takes signals in discrete-time-step for processing. After the signal is processed, a feedback is given in order to control the system. MATLAB Simulink is used in modelling of the system to be controlled. Based on the instruction given to the control system, Simulink provides a basis on which the simulation of the modelled system can be implemented [3]. Some of the parameters which can be controlled by the controller in this case include the speed, torque, and the gain [3].

3.2 Torque, Speed, and Voltage Control of a DC Motor

In order to control the speed of DSP-Based electric motor, the current and the signal encoder provides feedback signal which is used to control the motor speed. Figure 3 below is drawing of complete motor speed control.

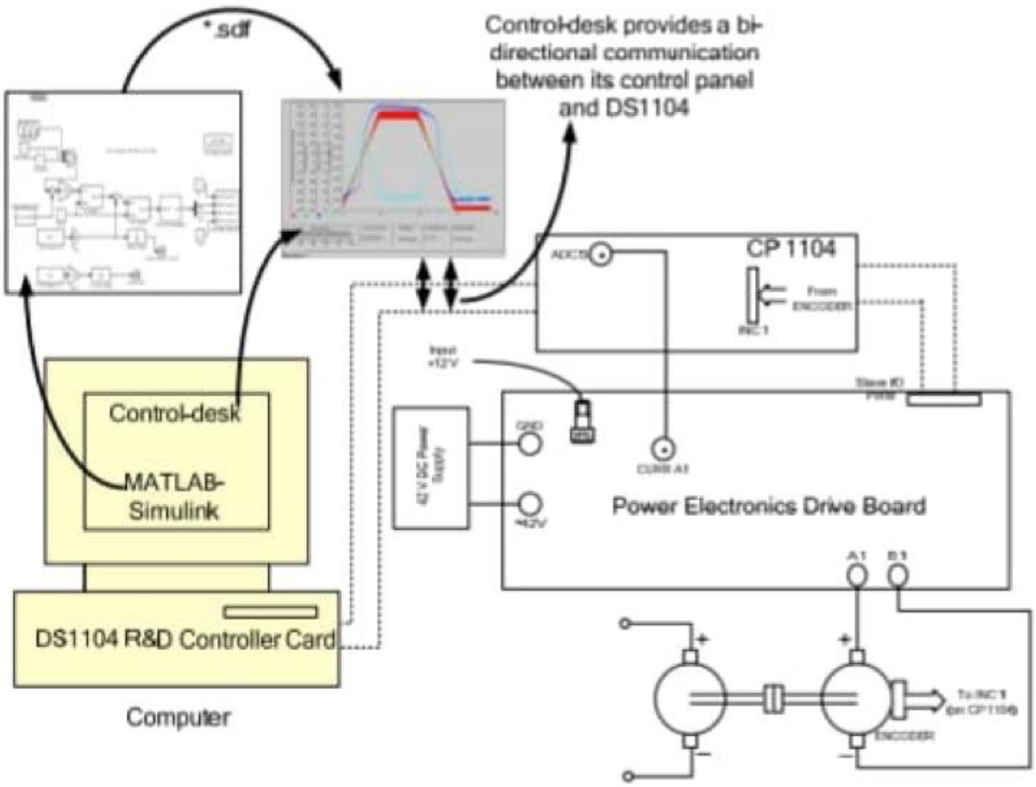

Figure 5: Motor Speed Control Diagram

Voltage regulation is an important parameter in any working circuit. Thus, utilizing switch mode DC switch converter will make it easier to control voltage in a system. In order to use this approach in controlling the voltage, the input voltage is controlled within a certain value like between 0 and input voltage.

This average output voltage can take any of the waveforms based on the arrangement of the output circuitry [3], [4]. The possible waveforms can be triangular, square or rectangular. Thus, the control voltage plays an important role in shaping the output voltage based on the duty ratio and the switching function. In order to determine the torque of the motor, a relationship between speed and torque and speed should be considered. In such case, a motor is run at a constant frequency at a proportional input voltage. Figure 4 below shows the Simulink diagram of a motor torque speed controller [3].

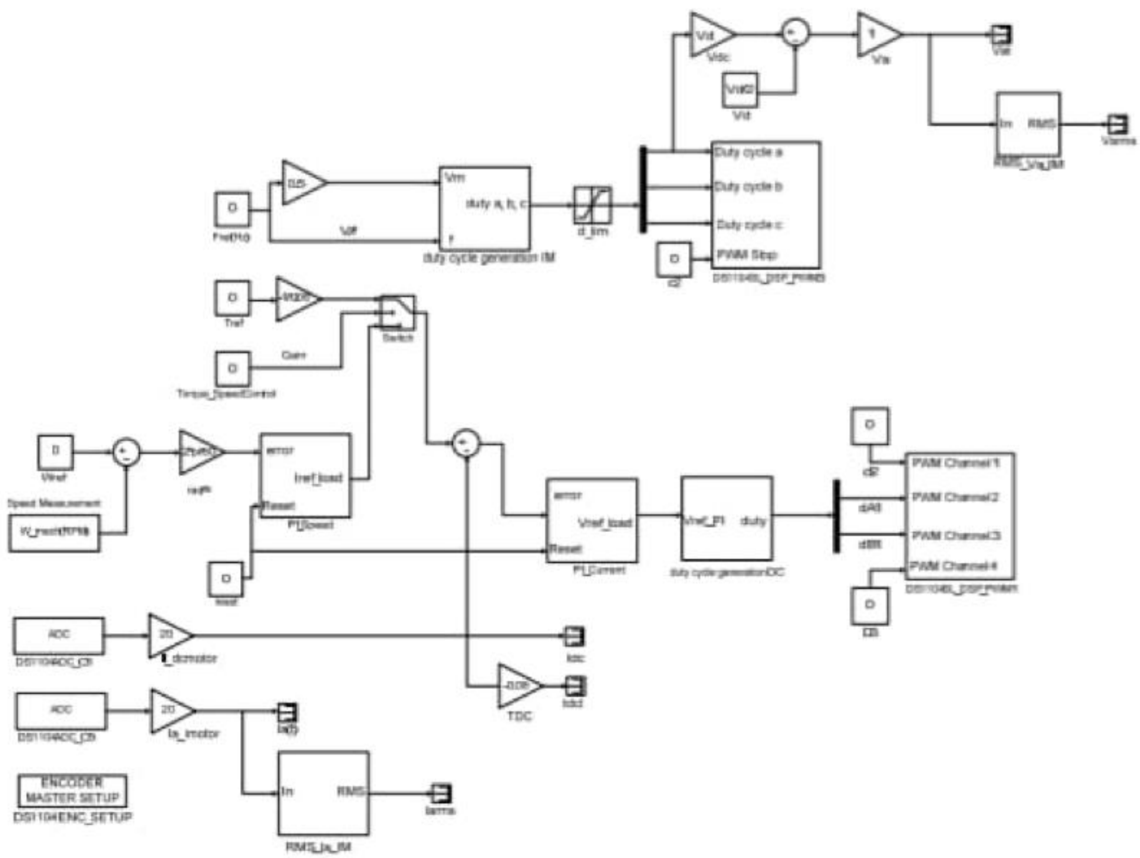

Figure 6: Simulink Torque-Speed Diagram

From figure 4, it is observed that the DC motor is coupled to a DC into DC motor which is run under either a torque or speed control.

Based on the discussion above about utilization of Arduino in implementing electric motor controllers is not an easy task but it needs a great number of tradeoffs in order to come up with the solution of implementing the controller [7]. Also, utilizing Arduino controllers will be a cheaper option to implement the controlling the speed of motors but with some limitations on the optimality levels of the performance of the application. Thus, maximum care should be taken when making a decision on how to use Arduino controllers in control electric drives. Electric Drives systems have been used for a long time and with the advancement in technology, electric drives have been contributing to control the devices and provide a mechanism to automate the structures [8]. It can conclude that Electric drives can efficiently control the motors, generators, relays, etc. Now people are trying to make energy-efficient controls that save energy and at the same time provide highly efficient work. From the sources, it can conclude that using of Thyristor Converter and the use of Squirrel Cage Induction motors provide an efficient energy system. From the sources, it can also conclude that multiple applications have developed for the use of Electric Drives these applications include, paper machines, traction applications, solid-state controls, etc. These applications have been now converting to automate processes because in automate process energy efficiency can achieve.

5.0 Section 3

Our project topic is “Low Cost Platform for Electric Drive Experimentation”, so our main problem that we are trying to solve is to come up with cheaper alternative platform. Therefore, the dSPACE hardware is quite expensive and it costs $4000 and the software upgrades cost $300.

In this project, we came up with many different solutions to the problems that we explained. Our solution for the cost problems is to use cheaper platform, which is using Arduino control board instead of dSPACE. Also, in our project we verified that we can implement the Arduino platform to the dSPACE based experiments. In addition, to solve the hardware problems, we can use the PCBs to connect all the components together which can be more reliable, cheaper, and easy to fix. Furthermore, we are going to use less space and lower the cost of our project by using smaller and cheaper components in our circuit boards

Our project is based on three main subsystems which they are Arduino, MATLAB/Simulink, and PCB. Using the Arduino platform is to control the output signals from the circuit boards (PCB) to operate the DC motor, which can be an alternative for the dSPACE hardware. In addition, we use the MATLAB/Simulink platform is the software part of our project, and we use it to control the speed of the DC motor and measure the current. Also, we use the printed circuit boards (PCBs) to connect all the components together. We do this by connecting the inverter board to the Arduino board and DC motor, and from the Arduino board to the Simulink to operate the DC motor.

5.1 Explaining the usage:

In this project, we are trying to make the platform easy to use and reachable by students and instructors. In addition, we used more common and cheaper subsystems to make it easier for students to get access for these experiments at home. We tested the Arduino platform and we compared it with the dSPACE experimentations, and we got the same functionality as the dSPACE. Therefore, this can be a good learning experience and accessible by everyone whenever they want.

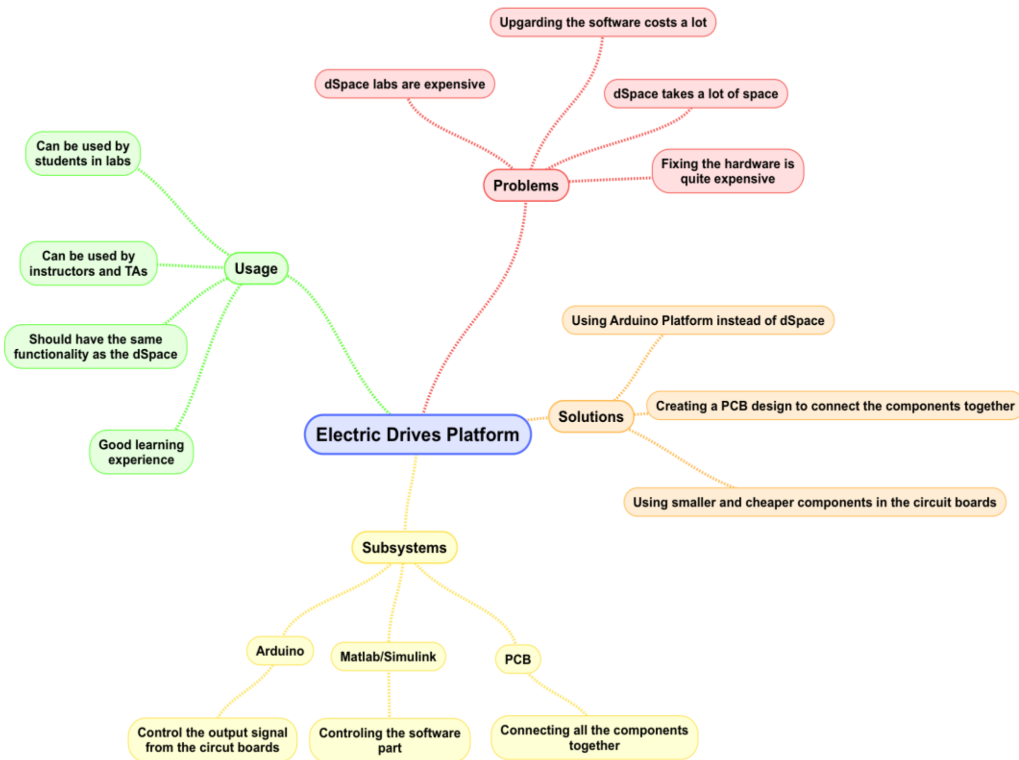

Figure 7: Usage

6.0 Section 4.

The project is to develop a low-cost platform that works for Electric Drives. Currently, the Electric Drives are using the dSPACE DS1104 hardware along with the MATLAB-Simulink based software control which is quite costly and in the project, we need to develop the same platform which can perform all the tasks in the Electric Drives but the platform will build using the Arduino board which will cost quite less. Our prototype includes using three major parts that are going to be useful for our final product. We will address our three prototypes that our team demonstrated. The three prototypes that are used for our project are: Arduino, Inverter board, and MATLAB Simulink, these prototypes we chose are the most important parts in our project that will form the final demonstration for the project. The group demonstrated for the TA and explained how these prototypes will be used in the final product build. By choosing these three prototypes the team considered a lot of aspects to cover for the final result of the project. We will explain how we worked to fit these porotypes into the final demonstration, and our successes and failures during that process. Also, we will mention our results and what did we learn from this project.

The team chose these three prototypes because it is going to be important for the final result of our project. The reason for using Arduino is that it is user friendly and the Arduino board provide a vast range of components attached to it directly which can directly access by simply using the Arduino programming. Also, motors have chosen because it is an essential part of a platform to work with the electric drive. Moreover, the inverter is the main part of converting analog to digital currency and it is also the essential part of an electric drive platform that's why these prototypes have been chosen. Combining our prototypes to fit the bigger picture, we will have all these three prototypes working together to operate our final product. The Arduino is going to be a huge part to implement the dSPACE experiments, we are going to use the Arduino to convert dSPACE labs into Arduino with the usage of MATLAB Simulink to operate the system. The main idea is to find a cheaper method to make these dSPACE experiments work and to understand the way of how they work, so we can make improvements and develop our prototypes. By using the Arduino, we can convert the experiments by connecting the DR37-M2 with the Arduino and with that part we can connect the 37 pin d sub from the inverter to the Arduino. The inverter board is a great part that can be a link between the Arduino and the motor. We are going to use the DC motor in our experiments to run the DSPACE experiments and the Arduino implementation of dSPACE. By using the inverter we can run the motor and compare both Arduino and dSPACE results by using a converter on the board that can show us both results. MATLAB Simulink is important for our project because we can program everything through it. By using MATLAB Simulink, we can give commands for speed measurement, set PWM pin, use Arduino packages to convert dSPACE experiments. The group expected to have some challenges through our experiments and simulations, and we put a lot of effort to solve it and find a way to complete the tasks. The most challenging task is to learn how to convert the dSPACE experiments using the Arduino and changing the Simulink files using the Arduino packages and this challenge was expected because it takes some time to get all the ideas together in order to get a result We had some aspects of unknown in our project such as that we don't know yet if the Arduino board is as functional as the dSPACE. Therefore, we will do some experiments to compare between Arduino board and dSPACE to see the values differences between them. In addition, the team from last capstone project were using the MEGA Arduino board for their project and they did a good job working with the codes and the inverter board. Therefore, our plan was to continue the progress from where they stopped and do some improvements to make the project more reliable. However, we noticed that the MEGA Arduino board can cause some issues in simulation.

These prototypes will be used for our final projects result, which is the big picture and the team tried to cover many points to make it work. The inverter board will be smaller and we will make the Arduino fit under the board and Simulink will be used for programing. The group is expected to learn the whole concept of how to use these prototypes and make them work in order to create the final product. The plan was to work with Arduino MEGA, but our client, Dr. Yaramasu felt that the change was necessary because we needed more powerful Arduino board. As a result, we searched for better options and we saw that DUE Arduino can be a great alternative, because of its performance and functionality. The approaches that were used for completion is brainstorming of which prototype that is going to fit our big picture and these were the most valuable ones we could find. The whole team worked on the prototypes and managed to get a pass on the demonstration. The prototype demonstration was a success when we tested it. We made a successful attempt to connect all these three prototypes in order to control the speed of the dc motor using the Arduino instead of dSPACE. The major challenge was making the Simulink block diagrams work because it takes some time to learn the whole concept and how to make the Arduino packages work. Also, our second major challenge was changing the Arduino board from MEGA to DUE since they have different specifications and connections. The MEGA Arduino operated at 5v and DUE Arduino operate at 3.3v, so we tried to find a way around this challenge to solve it. Therefore, we managed to use the converter to operate the DUE Arduino at 3.3v instead of MEGA board. If the prototype wasn't functional, I think the problem would be with the wire connections in the inverter board or with the coding in Simulink. In other words, the wire connections or coding are two possible things that errors may happen with them. If we would do it again, we would have learned about MATLAB Simulink better because it will be easier to do all the experiments and converting them into Arduino. In addition, we would use better Arduino board for better performance, and we will try to use smaller components in the inverter board. The prototype took some time because we were learning the concept of converting DSPACE to Arduino experiments, so we had to do two experiments and get the results and we expected it to take some time. However, we were keeping up with the schedule that Dr. Yaramasu gave us to complete the tasks. Also, this schedule gave us an opportunity to work on the project from scratch, step by step, which allowed us to understand more about our project aspects. The perception of the projects is going to be great because we spent a lot of time learning the difficult material and once we learn everything we will do great in the future. Our concern with the prototype that might negatively impact on the project plan is MATLAB Simulink errors other than that there are no concerns.

In conclusion, the three prototypes are: Arduino, Inverter board, and MATLAB Simulink. These prototypes will help us to get the most results out of our project. Our main question we kept asking ourselves is what are the most valuable things that will be a great fit for the future of the project. We put a lot of effort in this project to achieve and make these prototypes functional and more reliable. During our meeting we were discussing about including the DC motor in our prototype but, we agreed that MATLAB Simulink would be the better option because Simulink is related to the DC motor and it has more options. We learned a lot from our experiments by researching about what is best for our project, and how to work on Arduino board and Simulink to control the DC motor. The team did a great job putting thoughts together and coming up with these three prototypes. We will continue keeping up with schedule and work on our prototypes until we achieve the perfect condition of our project.

7.0 WBS and Gantt Overview:

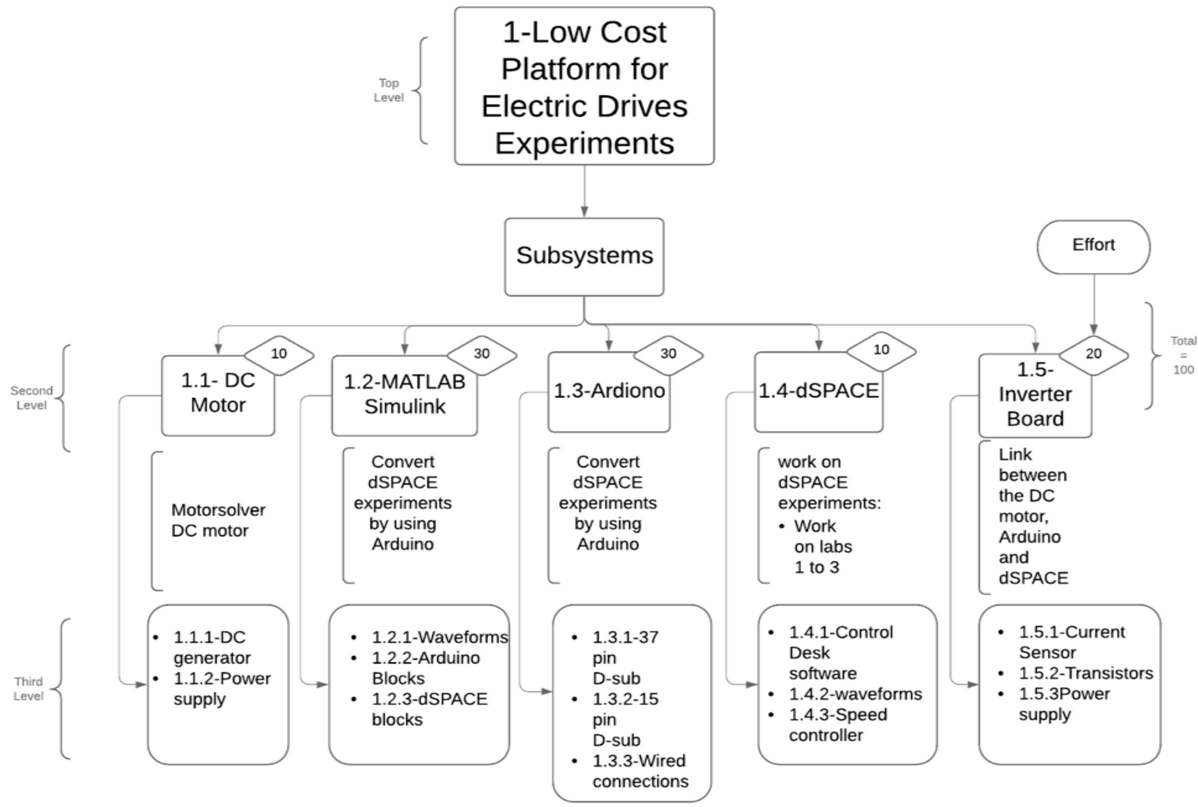

Figure 8: WBS System

8.0 Sub Systems.

The prototypes that we chose for our project were: Arduino, inverter board, and MATLAB Simulink. The prototype demonstration was a success, we demonstrated these three major part of our project and everything went well. Our major successes for this project is that we were able to make the dSPACE labs work and also for some of the Arduino implementation labs. The failures that we had was with some of Simulink blocks errors. Some for some labs these errors can take some time to fix because there are many things to consider if the result is a failure.

8.1 Top Level:

The top level chosen is the low cost platform for Electric Drives experiments. The main idea is about using an alternative version that is cheaper to implement dSPACE experiments on a low cost platform, which is the Arduino board.

8.2 Second Level:

Our main subsystem for this project is the Arduino board. The Arduino board is important for our project because it is the low cost option. We are going to make a smaller version of the inverter board and the Arduino will be the main subsystem.

8.3 Third Level:

Our second level of our WBS includes the DC motor, MATLAB Simulink, Arduino, dSPACE, and inverter board. The DC motor is one of the parts of our main project and it includes the DC generator. The generator in the motor plays a big part because it generates electricity in order for the motor to run. The power supplies for the DC motor are also included and we can use the 15 pin D-sub encoder to connect the motor with dSPACE or Arduino.

MATLAB Simulink is a great tool that can provide so much for our project. We can use this software to show the waveforms for both dSPACE labs and Arduino labs. The Arduino can be set up using Simulink blocks that are specified for Arduino by downloading the support package for it. The dSPACE blocks are provided with Simulink and we can run the labs by using these blocks.

The Arduino Board is very important because we can use it to implement dSPACE experimentations. The Arduino is connected to two main parts which are: 37 pin D-sub encoder and 15 pin D-sub encoder. These two parts are connected with the Arduino by checking the data sheets for each encoder, so we can make the connections with the Arduino and connect both the motor and the inverter.

The dSPACE labs had to be completed in order to convert these labs into Arduino. For dSPACE labs we can use Control Desk software to view waveforms. The Control Desk can also be used for many things such as, measure current, control speed of the motor, and measure speed.

Using an Inverter board is really important for our project because it can be used as a link for the Arduino/dSPACE and the DC motor. The inverter board has many components such as, current sensors, transistors, and it can be connected with the DC power supply to set up the voltage. The motor also has LEDs that could show us if there is a failure or not.

Memorandum

	A	B	C	D	E	F
1	Sub-System Planning	Duration	Start	Finish	Comments	% Complete
2	dSPACE Lab 1	4d	09/25/19	09/30/19	Completing lab 1 using dSPACE control desk.	100%
3	dSPACE Lab 2	4d	10/02/19	10/07/19	Completing lab 2 using dSPACE control desk.	100%
4	dSPACE Lab 3	4d	10/09/19	10/14/19	Completing lab 3 using dSPACE control desk.	100%
5	Arduino Mega Based Labs 1-3	9d	10/16/19	10/28/19	Complete Labs 1 to 3 using Arduino Mage to develop new ideas for a new Arduino Board.	70%
6	New Arduino Due Testing	4d	10/30/19	11/04/19	Learning about Arduino Due, search for datasheets and test the new Arduino.	100%
7	D-sub Double Solder	4d	11/06/19	11/11/19	Double soldering on the 15 pin D-sub encoder, used converter on the inverter board to work on Arduino and dSPACE at the same time.	100%
8	Arduino Due Labs	9d	11/13/19	11/25/19	Complete previous labs using Arduino Due.	65%
9	Arduino Mega Labs 4-7	6d	12/02/19	12/09/19	Complete Labs 4 to 7 using Arduino Mage.	60%
10	Arduino Mega Labs 8-9	6d	12/04/19	12/11/19	Complete Labs 8 and 9 using Arduino Mage.	0%

Electric Drives Gantt Chart

Period Highlight: 1

ACTIVITY	PLAN START (Month)	PLAN DURATION (Days)	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Lab1 in dSpace	9	7	9	7	100%
Lab 2-3 in dSpace	10	7	10	7	100%
Lab 1 in old Arduino	10	7	10	7	100%
Lab 2-3 old Arduino	10	7	10	7	100%
Lab 4-7 old Arduino	11	2	11	7	100%
Lab 8-9 old Arduino	11	7	11	7	75%
Finalizing new Arduino	11	7	11	7	100%
Soldering new Arduino	11	7	11	7	75%
Testing new Arduino	12	7	12	7	50%
Lab1 in new Arduino	1	7	..	..	0%
Redo Lab1 in new Arduino	1	7	..	..	0%
Lab 2-3 new Arduino	1	7	..	..	0%
Lab 4-7 new Arduino	2	7	..	..	0%
Lab 8-9 new Arduino	2	7	..	..	0%
Identify problems with new Arduino	2	7	..	..	0%
2nd revision of new Arduino	2	7	..	..	0%
Soldering 2nd revision	3	7	..	..	0%
Lab1 in 2nd Arduino	3	7	..	..	0%
Lab2-3 2nd Arduino	3	7	..	..	0%
Lab 4-7 2nd revision	3	7	..	..	0%
Lab 8-9 2nd revision	3	7	..	..	0%
Lab 1 manual	4	7	..	..	0%
Lab 2-3 manual	4	7	..	..	0%
Lab 4-7 manual	4	7	..	..	0%
Lab 8-9 manual	4	7	..	..	0%
Dissemination of project	5	1	..	..	0%

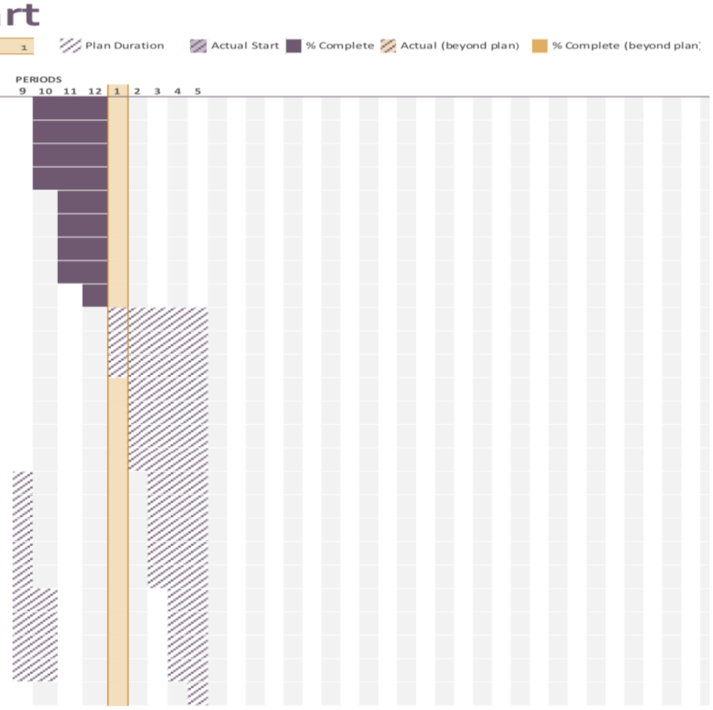

Figure 9: Work plan.

9.0 closing summary:

In this assignment, we explained each provided section by introducing our project aspects that we have been working on. There are many sections that we had to cover in order to show all of our work. The beginning of this assignment describes an overview about our project and our client

9.1 Brief

Since the last semester when the team started to work on the project, we did some research to learn more about the dSPACE platform and Arduino control board. We learned a lot about our project platforms, and we explored some new ideas to implement it on our project. Therefore, last semester we focused specifically on working with dSPACE labs to learn more about this platform. We did three labs in dSPACE, and we registered the values we got from dSPACE labs. Also, every team member has an important role working in this project with different prototypes. My role was working in Simulink software to implement dSPACE labs with an Arduino control board.

The team worked on converting the labs from dSPACE into Arduino using MATLAB Simulink software. There were many things that were out of consideration in our project, we had so many errors because we are building the Simulink block design from scratch. Details such as the soldered wires, signals from the motor, PWM generators and library files must be focused on precisely in order to have a lab that works properly. The team faces so many problems with MATLAB Simulink because of these details. The first problem that we had with the speed measurement, the team worked on the blocks that were supposed to give you the speed measurement, but it wouldn't read because we thought that there was a power shortage with our soldered wire, so we talked to our client about this problem and he told us to try another block for speed measurement and it worked fine. The previous block was created to read the speed from the encoder using the A,B,Z functions and the Z function did not work, so we had to use the WM_measured block multiplied by gain to have the correct readings. The next problem was about building the S-functions. The team uses two computers to run dSPACE in mirror with Arduino for direct comparisons, we used to work on only one computer and all of our files and Arduino lab progress are there, so when we used the new computer for the comparison, an error shows up because of the missing file paths. The error was fixed by moving all of our files into the other computer and the S-function was built successfully. Currently the team is working on sending 5V PWM signals from pins using the oscilloscope. We made the design and everything for this task, but the signal from the oscilloscope has too much noise and we are trying to fix it.

9.2 Challenges.

The main challenge is that we had to create Simulink design from scratch and MATLAB Simulink is really challenging because most classes do not teach students about Simulink and the idea of creating a design from scratch with this software is really challenging.

The team plan was to select the final design in the first semester of the capstone project and then develop the prototypes for different components, and in the second semester develop the inverter board and then manufacture the complete project.

9.3 Status Report.

The classes are changed to online because of the COVID 19 situation, so there are a lot of plans that had to be changed. Dr. Yaramasu provided us with some tasks that we had to work on and it is about doing researches on some useful articles and gather as much information as we possibly can and we finished these tasks. The labs were closed, so there is nothing that we could do to fully finish everything related to our project. Our Simulink designs are saved on the AMPERE labs computer and the only thing that we needed to work on is to modify our designs to make the Arduino labs work perfectly and then proceed to the PCB design as advised by our client Dr. Yaramasu. The team spent $133.73 out of $500 for the project and the remaining amount is $366.27.

9.4 Conclusion:

The team worked on the Arduino labs and we will try to do our best to complete as many labs as possible. The main idea of this project is almost done by showing that it is possible to use a cheaper platform for electric drives experimentations. MATLAB Simulink is the software that we worked on to run all the labs along with the control desk for dSPACE. The most important thing with this cheaper alternative is that the students can have access to these labs everywhere even at home. We understood how the dSPACE works and we researched about how to use the Arduino control board. Now, we are working on Arduino labs and we will continue the progress to finish the tasks we have in our schedule. A powerful Arduino is not hard to get compared to dSPACE because this platform is really expensive and not everyone can pay 4000$ for this platform. We are doing our best to get everything done. The Arduino labs had some errors that needed to be fixed. Our project is mainly depending on the labs assigned to us by our client Dr. Venkata Yaramasu and we are almost getting these errors fixed. We will test these labs and check that they are all working as needed then compare it with the high cost dSPACE and that will conclude our project.

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