

1809800

by Iwan CostelloDowns

A WELL WRITTEN REPORT WITH GOOD USE OF THE
WORD COUNT. RESEARCH WAS APPROPRIATE AND CITATIONS
CONSISTENT. GOOD KNOWLEDGE WAS EVIDENT AND THE
CONCLUSIONS SHOWED SOME CRITICAL ANALYSIS.

MARK AGREED

FILE	12714_IWAN_COSTELLODOWNS_1809800_179200_2015613018.DOCX (19.75M)		
TIME SUBMITTED	06-MAY-2021 11:02PM (UTC+0100)	WORD COUNT	4086
SUBMISSION ID	152052646	CHARACTER COUNT	23396

Course: HND Electrical and Electronic Engineering
Module: SGEE5006 Power and Machines
Assignment: DC Motors and Drives, and AC
Transmission lines
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University number: 1809800
Date submitted: 06/05/2021
Word count: 3000

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1. Executive Summary

The main ethos of this assignment was the investigation of DC motors and drives, specifically their rectification and applicational techniques as well as simulation of DC drive operation and transmission line behaviour.

First research was carried out into the applications and methods of DC machines specifically in heavy industry and the various design nuances, eventually the research concluded upon the design an applicability of H bridge drives with complementary PWM control which was the design looked in the practical tasks, specifically the Parker 512C. A simulation of the drive type seen in the research was done within the second task observing the effect of no load behaviour and load behaviour, the same was done in a practical sense on a real motor and Parker drive unit, both task involved calculations and solid conclusion were made upon those results in relation to the practical and simulated results. Finally an investigation was done into an AC transmission line, using some data the whole system was calculate out and a simulated circuit was proposed, again the results of both were compared and concluded upon. An overall conclusion was done on the actions and results found in the report and review of the performance and results of the assignment were discussed and evaluated.

2. Research

Industrial DC Machine Applications

DC machines are widely used for their flexibility and versatility within the realm of control, making them a substantial option within industry despite their initial high cost when it comes to control. However in the present day most energy is produced in AC format and the decline Dc machines, specifically DC generators means that they are only really used in supplying excitation of small and medium range alternators, in fact only about 25% of the motors currently manufactured are DC. (EEEGuide, 2014)

Word/s missing

Due to revolutions in power electronic conversion techniques DC generation has waned in favour SCR rectifiers and various other more efficient techniques that are not as susceptible to noise, have a greater power factor, better braking and are relatively more compact and cost efficient. (EEEGuide, 2014)

However there is still use for DC generators in dynamometers, welding techniques, cross field generation within closed loop controls systems, tachogenerators and separately excited generators are still in systems with wide output voltage control such as the War-Leonard system of speed control. (EEEGuide, 2014)

Correctly cited

There are three main types of DC motors, Series, Shunt and Compound, their relative usefulness in industry will now be examined.

Shunt DC motors are motors in which the shunt field winding is only parallel to the armature winding and not the series field winding, this mean that these motors are excellent for speed regulation as the shunt field can be excited separately form the armature windings. They are most commonly found within systems where constant speed is a necessity and the starting conditions are not too extreme, therefore are found in lathes, centrifugal pumps, fans, lifts, and conveyors. (Circuit Globe, 2021)

Correctly cited

Series DC motors are usually not used for variable speed drive applications as within this type of the entire armature current flows through the field winding, meaning a substantial amount of starting torque is generated and running without a load can harm the machine. Because of this this type of motor is usually found in hight torque requirement environments such as traction systems, cranes, compressors, and vacuum systems. (Linquip , 2020)

Correctly cited

The most common is separately excited due to the connection to DC drives
Consider permanent magnet motors

Compound motors possess both series and shunt field windings, they can be connected either cumulatively and differentially, cumulative being a series field to shunt field connection providing good starting torque without great speed regulation, differential has average speed regulation and operates at a nominal constant speed. These motors can be found in presses, shears, elevators, rolling mills and heavy planners. Small motors of this type in fractional kilowatt operating areas are mainly used in control systems such as within techno generators for speed sensing and in servo motors for tracking and positioning. (Circuit Globe, 2021)

Correctly cited

Methods of control of DC machines from an AC supply

H Bridge Control

A simple H bridge is one of the most common methods to regulate DC control via AC, Fig.1 show the simplified circuit diagram of the H bridge.

This requires a DC supply

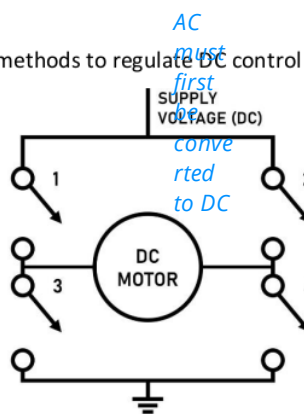


Fig.1 – H Bridge Circuit - (Cavallo, 2021)

Spelling

Using two sets of controlled and paired switches, (1 & 4, 2 & 3), witch when one pair is closed powers the motor, using certain switch configurations a 4-quadrant motor can be made while changing the polarity will affect the motor differently, in effect switching the leads of the of DC motor reversing the rotational direction at whim. Using transistors, the process can be scaled down to micro processor size. These systems can also be used in speed control, if directional control is desired then the H bridge simply acts as a non-regenerative DC drive, to further control the motor a system of regenerative DC driving can be made, Fig.2 illustrates this. (buildelectroniccircuits, 2018)

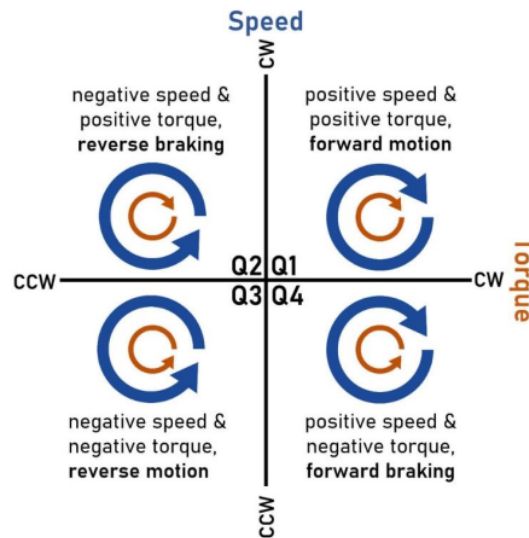


Fig.2 – H Bridge Graph - (Cavallo, 2021)

As seen from the graph, braking capabilities have been added to the system, meaning that instead of cutting power switching polarities as the motor is running will have a deceleration effect on the speed. Quadrants 1 and 3 are the motoring quadrants in which purely acceleration is provide in either direction whereas quadrants 2 and 4 are the braking quadrants where the motor will decelerate. When the speed is opposing the torque then the motor will act as a generator and will feed current back into the power supply, this not only breaks the motor but also increases efficiency. Fig.3 shows how the motor acts as a load and as a generator, when decelerating the voltage E_a which is the voltage produced by the motor will cause a flow of current back into the source V_a . (Cavallo, 2021)

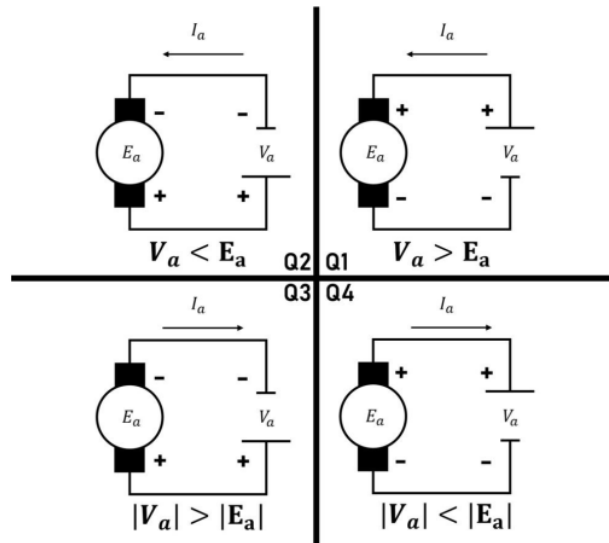


Fig.3 – H Bridge Quadrant Loading - (Cavallo, 2021)

Speed Control Using Pulse Width Modulation (PWM)

PWM speed control can be used for DC machines as well as AC machines, using high/low coded voltage spikes the speed of the motor can be controlled via voltage modulation. When an adjustable speed drive sends the pulses to the motor the smoothing effect caused by the coil inductance has the effect of the motor act as if it is being powered by a lower/higher voltage. PWM is an inexpensive method of speed control with the functionality that any duty cycle can be implemented allowing for continuous motor control. When paired with h bridges the motor behaviour can be controlled in the speed, direction, and braking realms. (Electronics Tutorials, 2020)

Armature Control via Variable resistance

This is an old outdated method

Furthermore, another method of control is the variable resistance method, in altering the resistance of the field or coil the current is manipulated. As speed is proportional to the strength of the armatures magnetic field which itself is proportional to current the speed of the shaft can be managed. Dubbed rheostats, these variable resistors in series with the coil can manipulate the current and thus the speed. By resistance alteration, an increase in resistance within the armature coil will induce a decreased speed. An increase in the stator resistance will induce a speed increase. The PWM and h bridge method are preferable as this method has a significant drawback of inefficient energy use due to resistance losses. (Electrical4u, 2020)

To conclude, from the research it can be state that in comparison to other options of variable speed control such as the variable resistance method, a H bridge design offers a large range of behavioural states such as the ability to brake the system as well as direction, paired with PWM and the benefits of speed control make DC machine control one of the best options available for engineers in need of precision motor performance.

It was expected that you would also consider thyristor controlled rectifiers in this section to support the practical in the tests of the assignment

Construction and Operation of a Typical Single Quadrant DC Drive Such as The Parker 512C

Repetition

Being a single quadrant DC drive the drive and referring to the research earlier, it can be expected to only run in the forward motion, and it cannot brake or reverse its motion, as seen earlier this mean the drive is non-regenerative. This means reverse kinetic energy or friction will be needed to stop the inertia of the rotation. From the data sheet as seen below in Fig.4 it can be observe that the motor is of low power rating across different phase wirings and uses thyristors for its rectification and speed control. Appendix 1 shows the data sheet schematic of the drive unit from which the terminal connections can be seen as well as the parameter setting potentiometers and feedback LEDS. (Inverter Drive Supermarket, 2020)

Never include a datasheet in a report. Read it and quote from it. Then cite it as your source.

Parker SSD Drives 512C 32A Single Quadrant DC Thyristor (thyristor) Drive for 400V, 230V or 110V single/two phase supply.

Typical Motor Output from 400V AC supply: 8.2kW (11HP) at 320V DC for speed and torque control.

Typical Motor Output from 230V AC supply: 4.6kW (6.2HP) at 180V DC.

Typical Motor Output from 110V AC supply: 2.3kW (3.1HP) at 90V DC.

Simple to set-up in analogue, fully-isolated form and ready to run from its default settings.

Dimensions: 160mm Wide x 130mm Deep x 240mm High.

Mounting: Panel mount with screw fixings on 253 x 120mm centres.

Terminals include:-

2 x Analogue Setpoint Inputs with Current Limit Input.

Tacho input (or internal AVF) Feedback.

4 x Analogue Outputs for Ramp, Total Setpoint, Actual Speed and Current.

2 x Digital outputs for Health and Zero Speed (selectable to Zero Setpoint) including + & - 10V power supply for Potentiometers.

Separate AC input to Field Bridge (allows flexibility for the Motor field Voltage).

Input Current: 48A.

Input Voltage: 110V/120V, 220V/240V, 380V/415V, or 460V/480V single phase/two phase +-10% at 50/60Hz.

Ambient: Rated at 40C.

Ventilation space above and below: 75mm.

Ventilation space at sides: 0mm.

Heat Loss: 75W at maximum output.

Part number: 512C-32-00-00-00, Exactly the same as SSD Drives, Rapier Drives, Eurotherm Drives and RS - 512C-32-01-00-00. Sometimes specified as 512C32000000.

Replaces SSD, Eurotherm, Rapier Drives and RS 510.

 Parker SSD 512C Manual (Issue 10) (1.2 MB)



Fig.4 – Parker 512C Specification - (Inverter Drive Supermarket, 2020)

3. Simulation of a Half-Controlled Rectifier Circuit

Rectifier Simulation and Analysis

Write in the past tense

Using Multisim as the stimulatory software, the performance of a single-phase full wave half-controlled rectifier ^{was} will be analysed when connected to a DC motor armature modelled as a load containing an inductance, a resistance, and a battery (for the back EMF). Three different firing angles ^{were} will be chosen, and the current and voltage waveforms ^{were} will be recorded and analysed in relation to calculated values, this ^{was} will also be done for discontinuous current in radians and the average armature voltage. All results ^{were} will be tabulated as per the specification and a conclusion upon accuracy will be drawn.

To conduct the experiment, an oscilloscope and voltmeter will be used to capture and record the response of the circuit. The circuit will be explained in full at the end of this task, but a brief summary is required to comprehend the experimental procedure. The DC supply V2 will set the phase angle, this will be altered 3 times to capture 3 different responses within the cycle. The aforementioned oscilloscope will be used to find the values for T1 and T2, this will show the thyristor firing points. Using these two values in a calculation that will be seen later the average voltage and phase angle can be found, the phase angle should match the DC supply value of V2, the closeness of this result will indicate if the procedure was carried out correctly.

Images and calculations should be in the appendix and a table of results for comparison and comment should be included in the main report

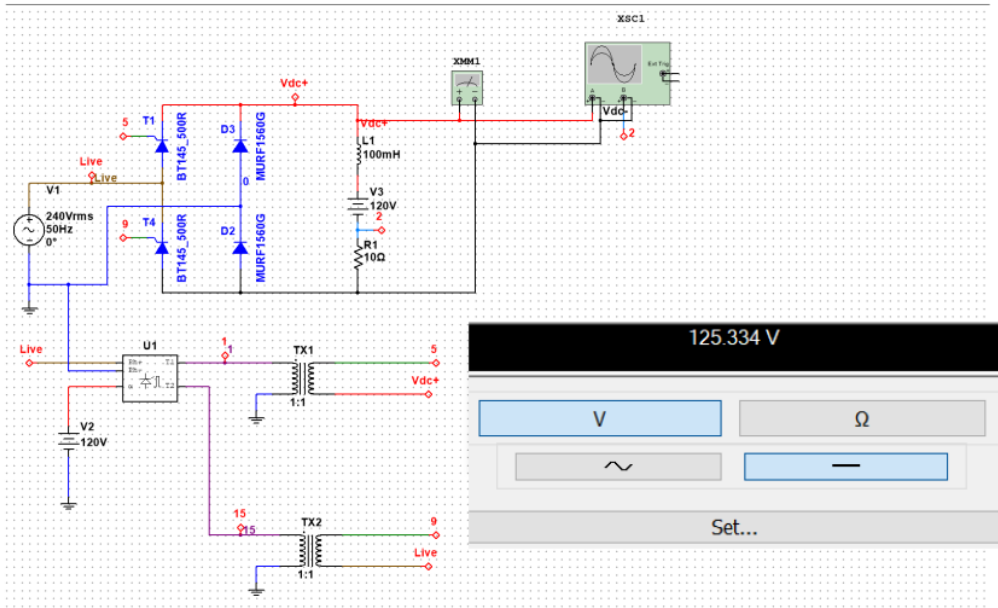


Fig.5 – 120° Phase Angle Circuit

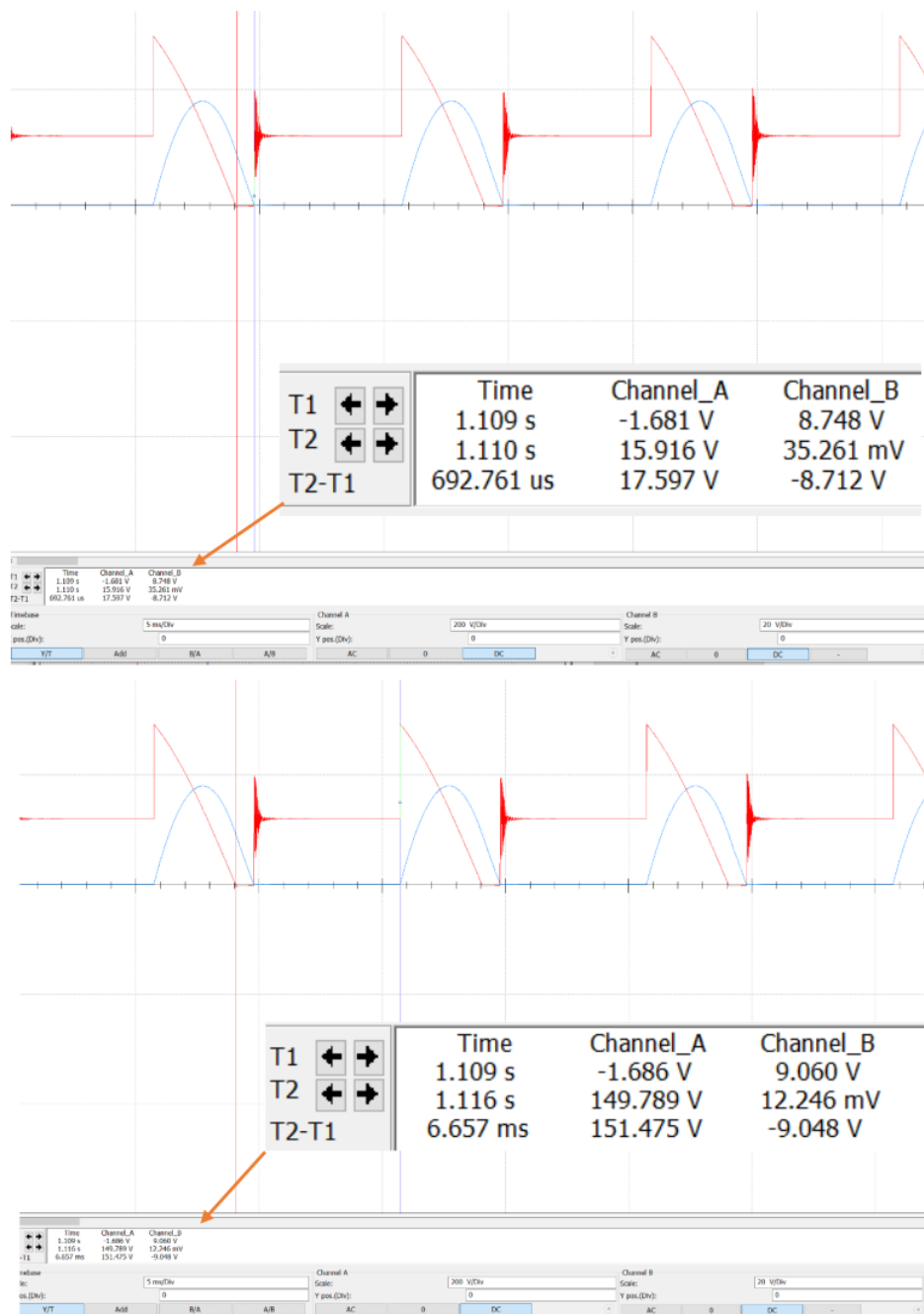


Fig.6 – 120° Phase Angle Response

At 120 degrees:

$$\text{Full period} = \frac{1}{f} = \frac{1}{50\text{Hz}} = 20\text{ms}$$

For a half period the length is 10ms which relates to π rad.

$$\beta = \frac{t_1}{10\text{ms}} \times \pi \text{ and } \alpha = \frac{t_2}{10\text{ms}} \times \pi$$

$$\beta = \frac{t_1}{10\text{ms}} \times \pi = \frac{0.692 \times 10^{-3}}{10} \times \pi = 0.2173 \text{ rads}$$

$$\alpha = \frac{t_2}{10\text{ms}} \times \pi = \frac{6.657 \times 10^{-3}}{10} \times \pi = 2.091 \text{ rads}$$

To calculate the average voltage with back EMF:

$$\text{Voltage average} = \frac{E}{\pi} (\alpha - \beta) + \frac{V_{pk}}{\pi} (1 + \cos(\alpha))$$

$$\text{Voltage average} = \frac{120}{\pi} (2.091 - 0.2173) + \frac{149.789}{\pi} (1 + \cos(2.091))$$

$$\text{Voltage average} = 71.57 + 46.68 = 118.25\text{v}$$

For phase angle:

$$t_2 \times 180^\circ = 0.657 \times 180^\circ = 118.26^\circ$$

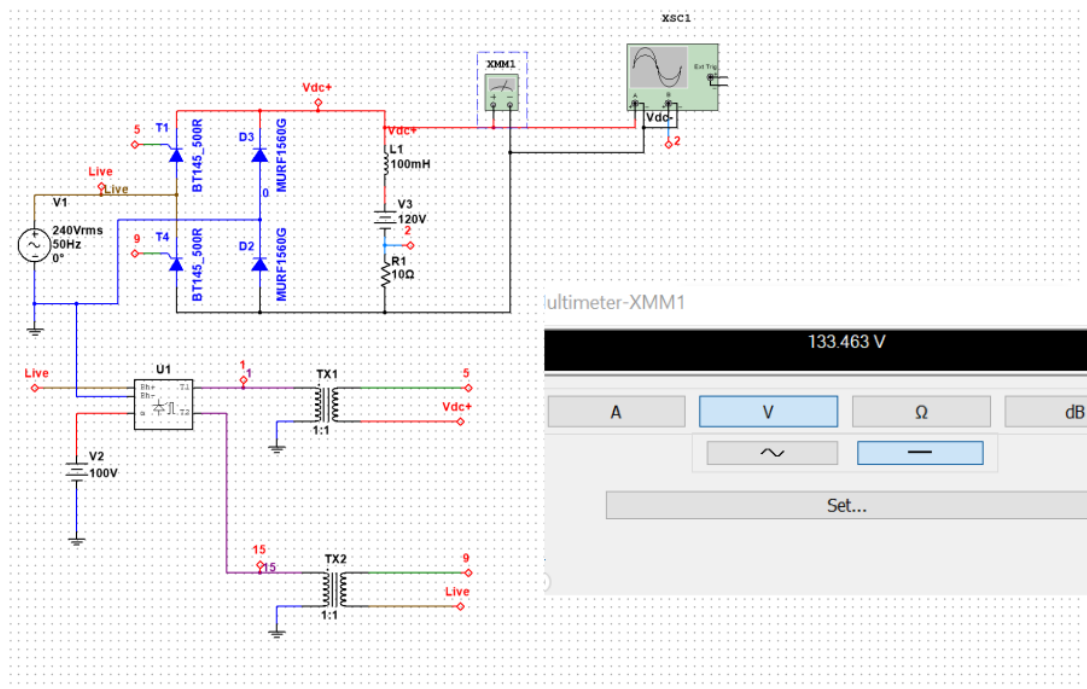


Fig.7 – 100° Phase Angle Circuit

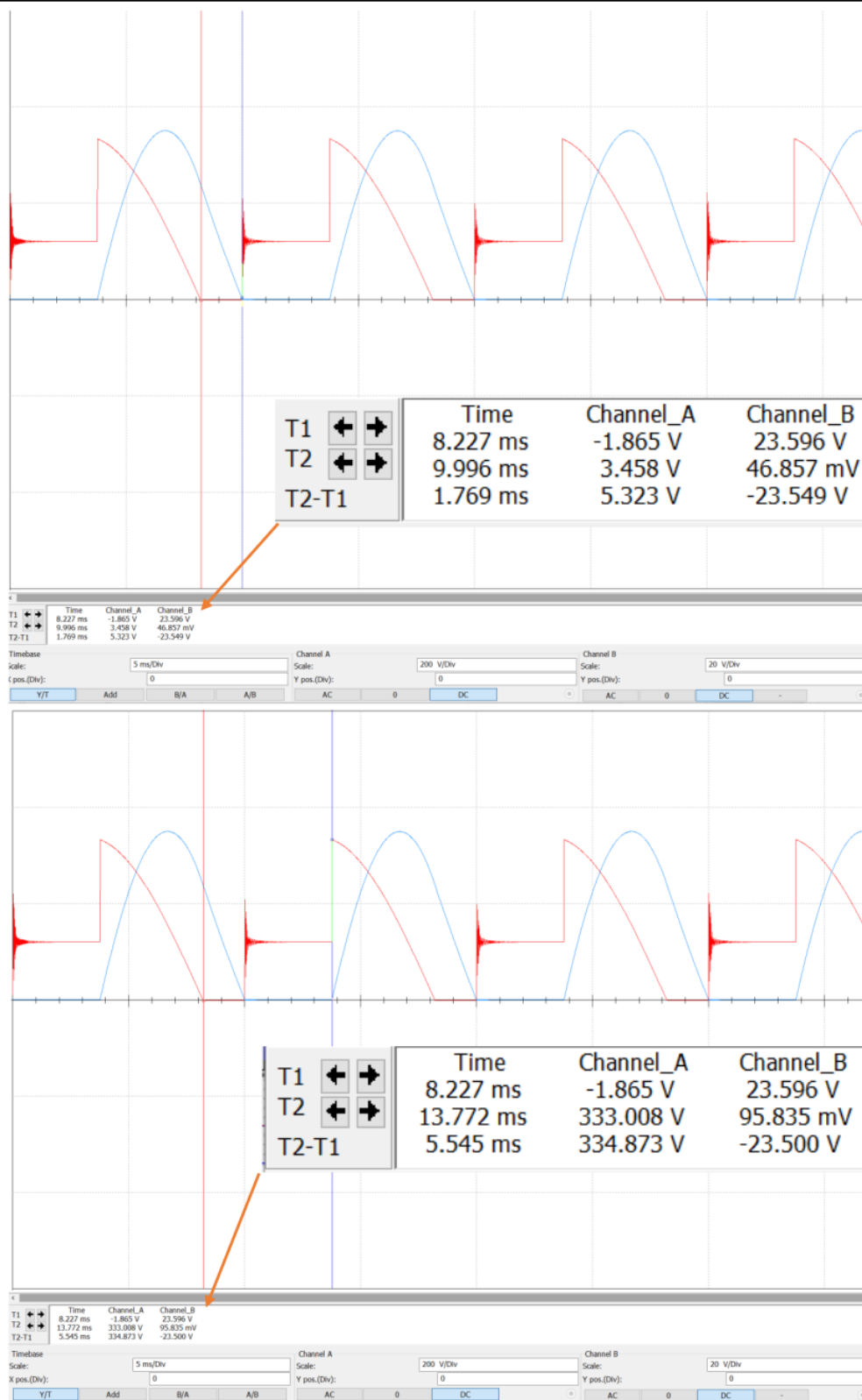


Fig.8 – 100° Phase Angle Response

Using the same 10ms half period:

$$\beta = \frac{t_1}{10ms} \times \pi \text{ and } \alpha = \frac{t_2}{10ms} \times \pi$$

$$\beta = \frac{t_1}{10ms} \times \pi = \frac{1.769 \times 10^{-3}}{10} \times \pi = 0.5557 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{5.545 \times 10^{-3}}{10} \times \pi = 1.742 \text{ rads}$$

To calculate the average voltage with back EMF:

$$\text{Voltage average} = \frac{E}{\pi} (\alpha - \beta) + \frac{V_{pk}}{\pi} (1 + \cos(\alpha))$$

$$\text{Voltage average} = \frac{120}{\pi} (1.742 - 0.5557) + \frac{333.008}{\pi} (1 + \cos(1.742))$$

$$\text{Voltage average} = 38.19 + 107.984 = 146.157 \text{ v}$$

For phase angle:

$$t_2 \times 180^\circ = 0.5557 \times 180^\circ = 100.026^\circ$$

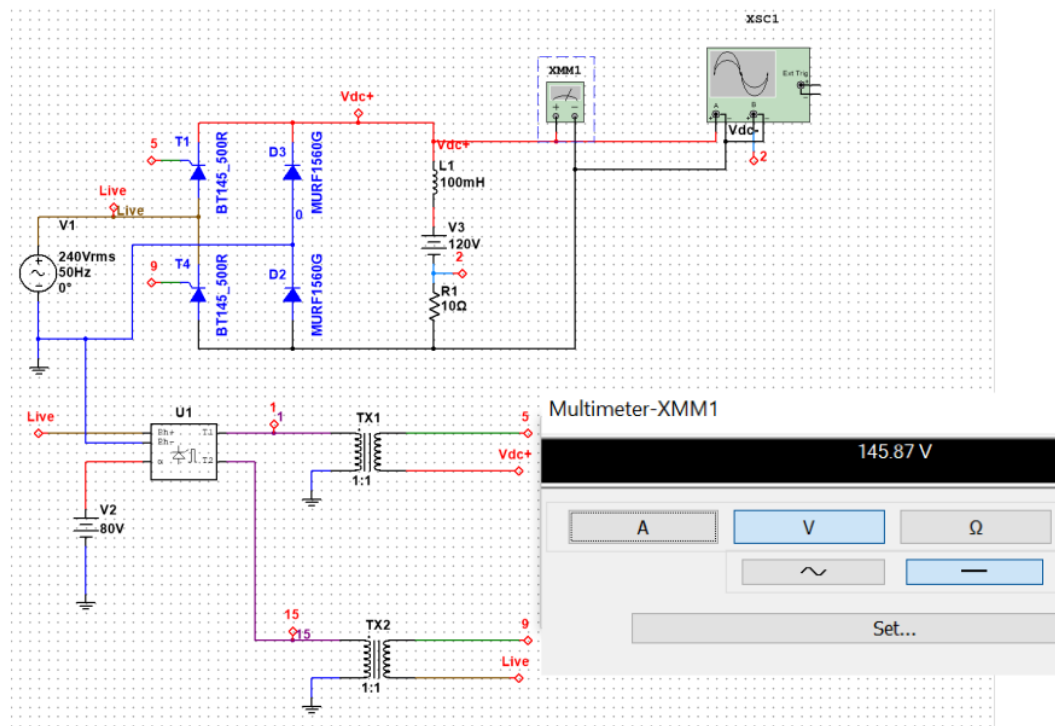


Fig.9 – 80° Phase Angle Circuit

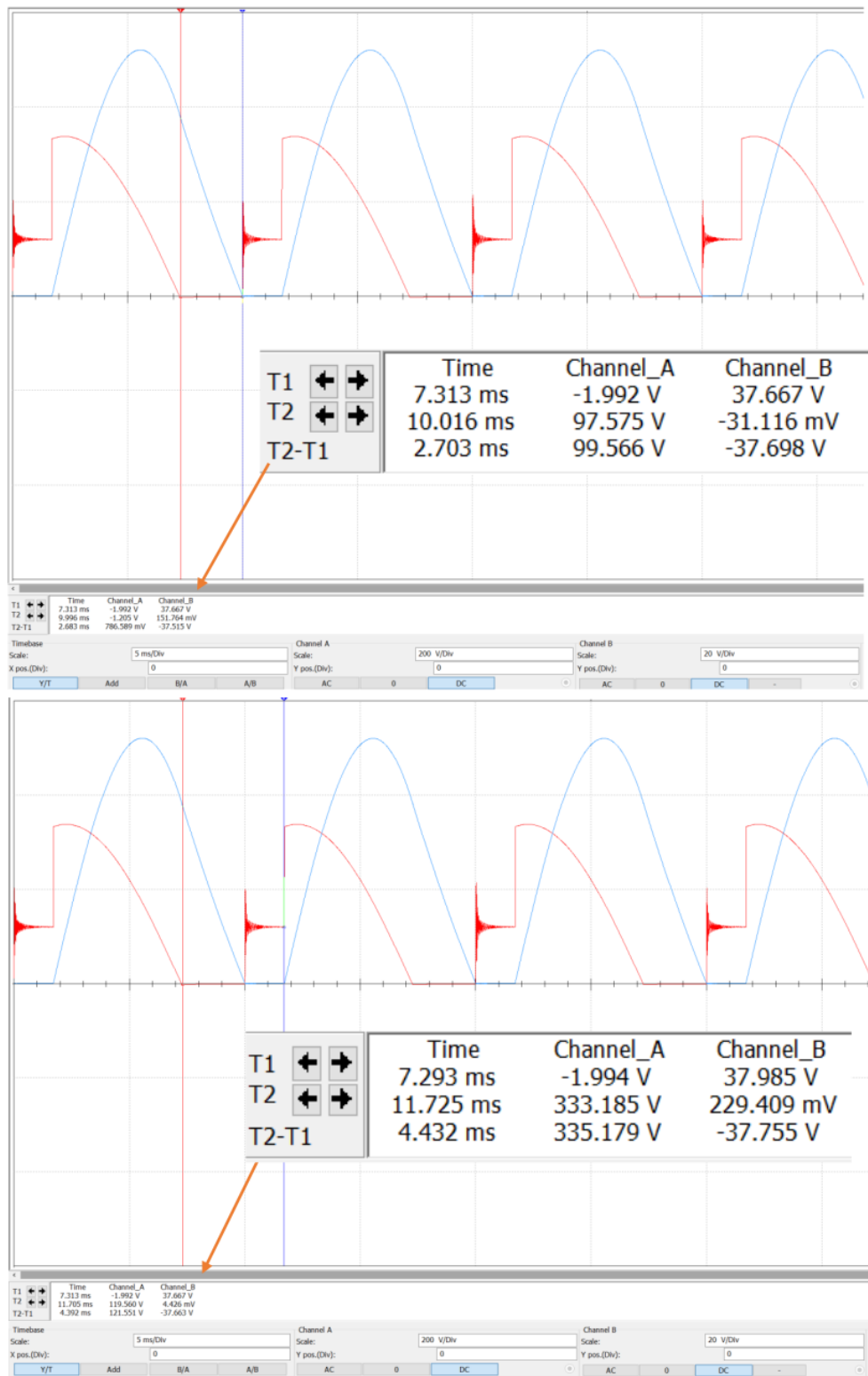


Fig.10 – 80° Phase Angle Response

Using the same 10ms half period:

$$\beta = \frac{t_1}{10ms} \times \pi \text{ and } \alpha = \frac{t_2}{10ms} \times \pi$$

$$\beta = \frac{t_1}{10ms} \times \pi = \frac{2.703 \times 10^{-3}}{10} \times \pi = 0.849 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{4.432 \times 10^{-3}}{10} \times \pi = 1.3599 \text{ rads}$$

To calculate the average voltage with back EMF:

$$\text{Voltage average} = \frac{E}{\pi} (\alpha - \beta) + \frac{V_{pk}}{\pi} (1 + \cos(\alpha))$$

$$\text{Voltage average} = \frac{120}{\pi} (1.3599 - 0.849) + \frac{333.185}{\pi} (1 + \cos(1.3599))$$

$$\text{Voltage average} = 38.19 + 106.05 = 144.24 \text{ v}$$

For phase angle:

$$t_2 \times 180^\circ = 4.432 \times 180^\circ = 797.76^\circ$$

From Figures 5 – 10 and the accompanying calculation the results are tabulated thusly for both the phase angle and voltage average simulation and calculations.

Phase Angle	
Simulated Results	Calculated Results
120°	118.26°
100°	100.026°
80°	79.77°

Average Voltage (V)	
<i>There is something wrong with some of your results or there is a calculation error</i>	
Simulated Results (V)	Calculated Results (V)
125.334V	119.25V
133.463V	146.157V
145.87V	144.24V

From the tabulated results several observations can be made, first is that the results for the phase angle set are extremely close and therefore can be said to be correct and accurate. The average voltage results showed a greater variance but with the expected trend and fairly approximate values that the assumption can be made that the methods used to obtain these are correct given their relative similarity. Inaccuracies within the method may include the human error involved in reading and interfacing with the software, due to the nature of the calculations a slight inaccurate cursor placement or rounding error can produce a noticeable anomalous reading such as the second voltage average reading. Another hypothesis on the variation of data obtained is the possible fallibility of the simulation software in so much that the simulation does not accurately calculate the exact value in relation to the calculated set once discounting for rounding errors.

Simulating Mechanical Load on The Circuit

Within Multisim to simulate the effect a motor would have connected to the circuit the back Emf for three values were obtained at an 80° firing angle. To achieve this, as can be seen in Fig.11 the voltage power supply V3 could be altered to change the EMF, it was decided to run the simulation at 120V, 100V and 80V EMF values as can be observed in Figures 11 - 16. It is worth noting that Fig.16 shows that the current does not decrease to zero before the thyristor fires again whereas the other two simulations do.

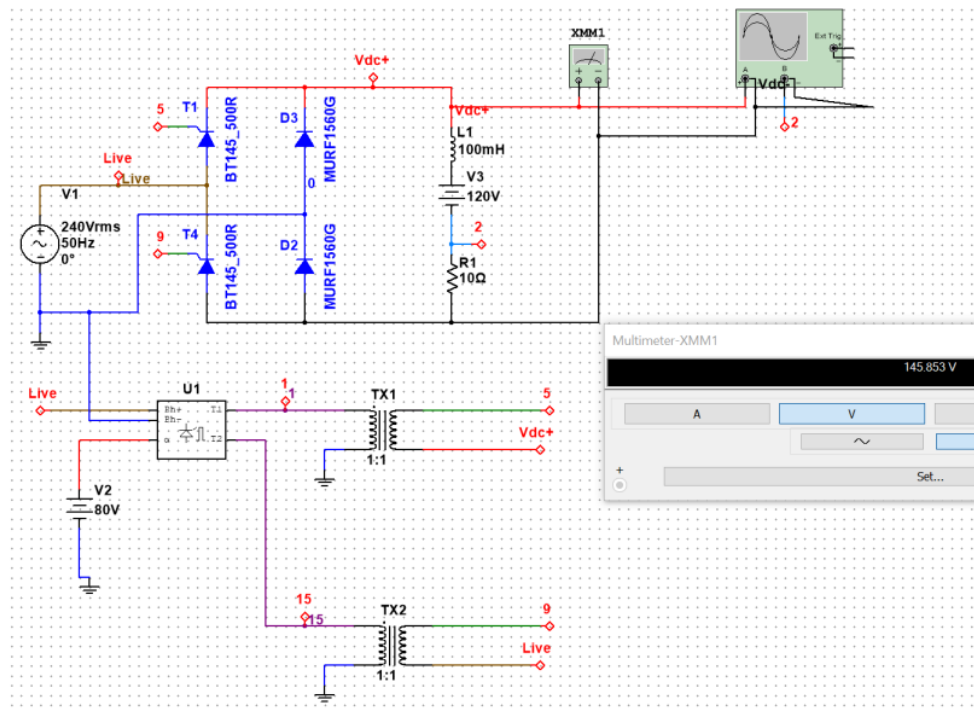


Fig.11 – 120 Back EMF and 80° Firing Angle

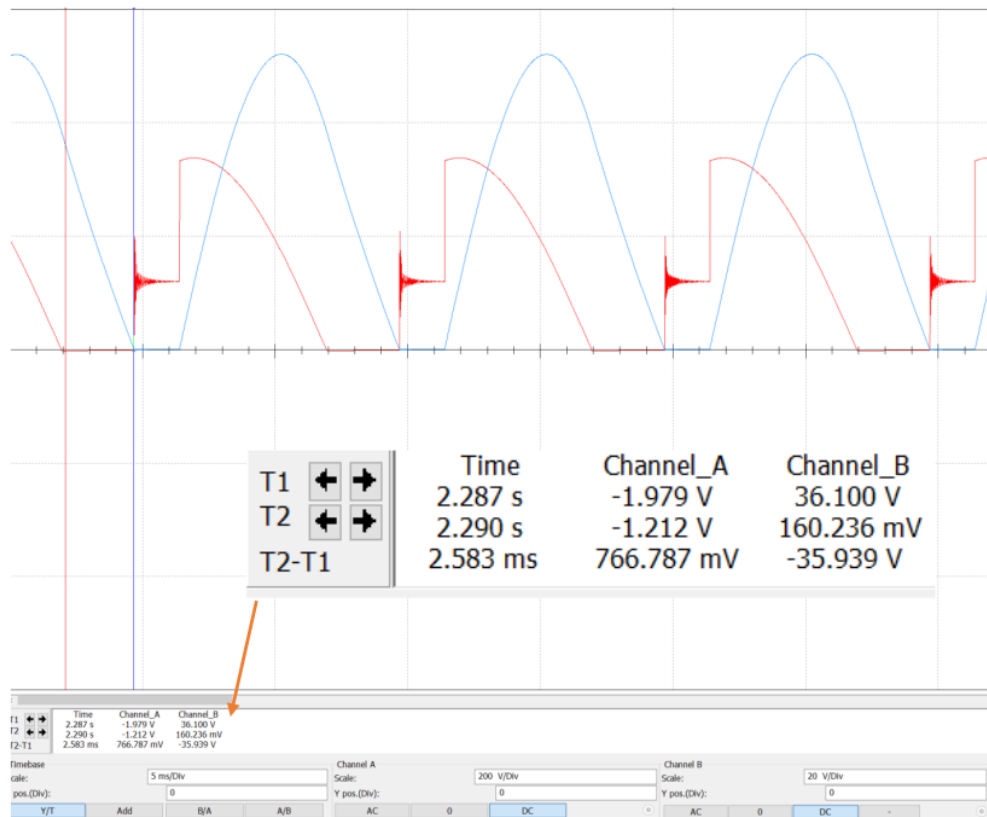


Fig.12 – 120 Back EMF and 80° Firing Angle Response

Using a 10ms Half cycle:

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{2.583 \times 10^{-3}}{10} \times \pi = 0.81147 \text{ rads}$$

For average voltage:

$$\text{Voltage average} = \frac{333.008}{\pi} \left(1 + \cos(0.81147) \right) = 179.009V$$

The peak voltage
337 not 333

For phase angle:

$$t_2 \times 180^\circ = 2.583 \times 10^{-3} \times 180^\circ = 46.494^\circ$$

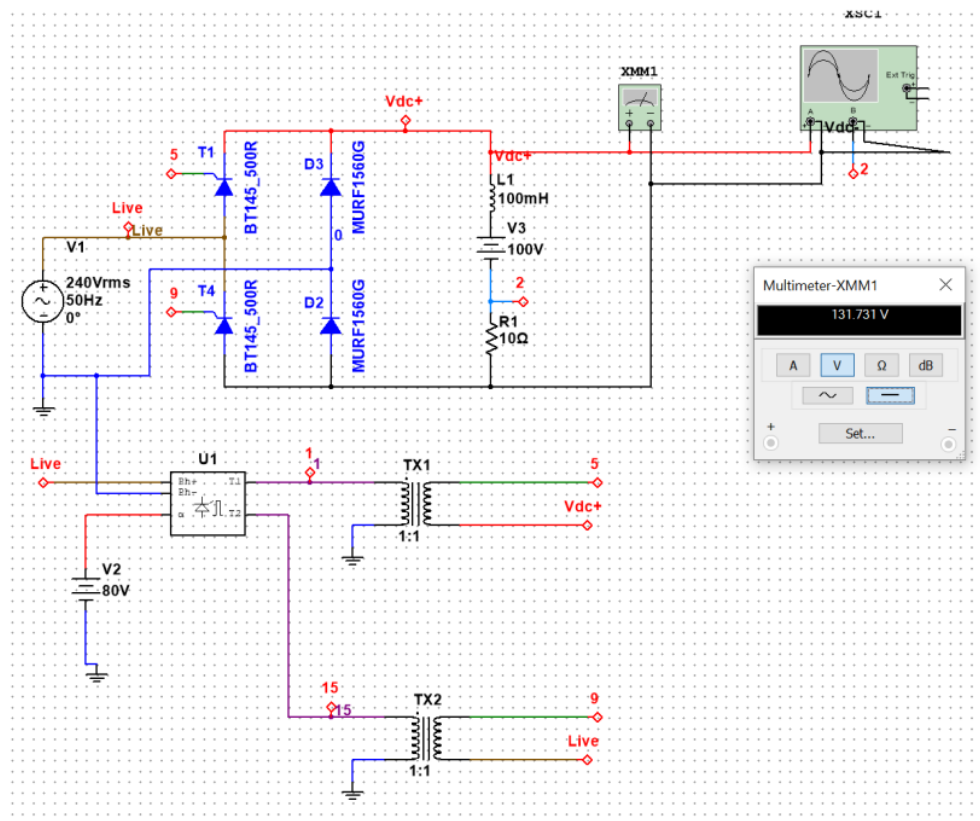


Fig.13 – 100 Back EMF and 80° Firing Angle

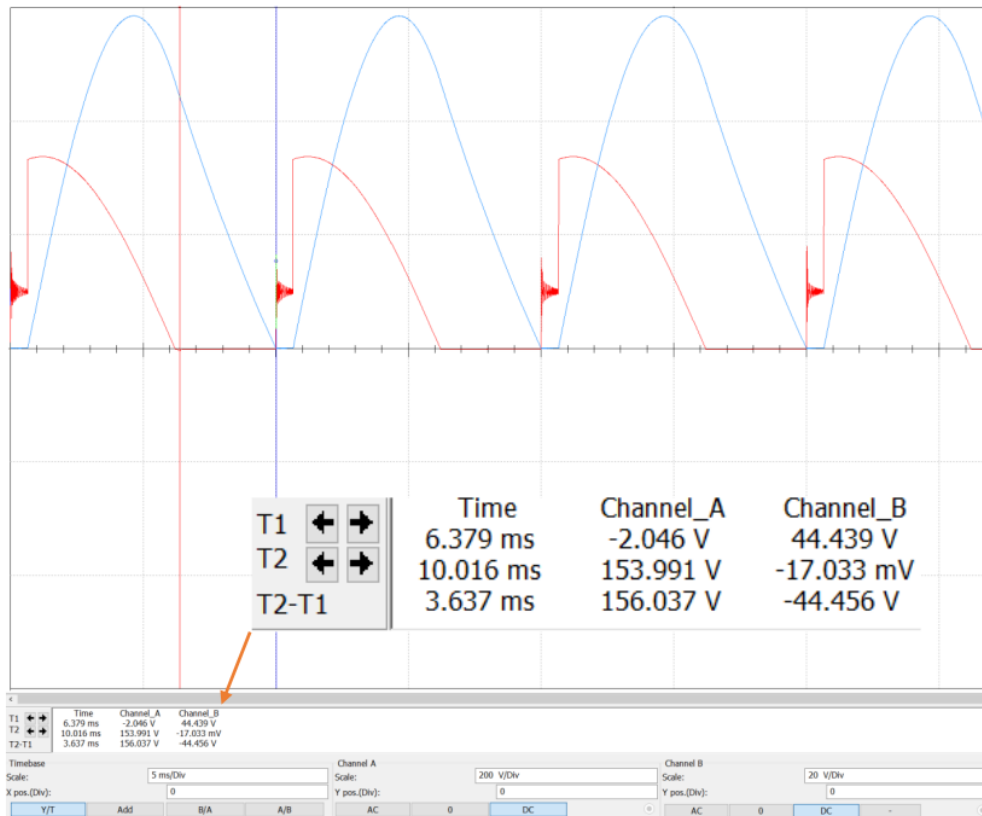


Fig.14 – 100 Back EMF and 80° Firing Angle Response

Using a 10ms Half cycle:

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{3.637 \times 10^{-3}}{10} \times \pi = 1.142 \text{rads}$$

For average voltage:

$$\text{Voltage average} = \frac{333.008}{\pi} (1 + \cos(1.142)) = 150.07V$$

The peak voltage should be around 337 not 333

For phase angle:

$$t_2 \times 180^\circ = 0.3637 \times 180^\circ = 65.466^\circ$$

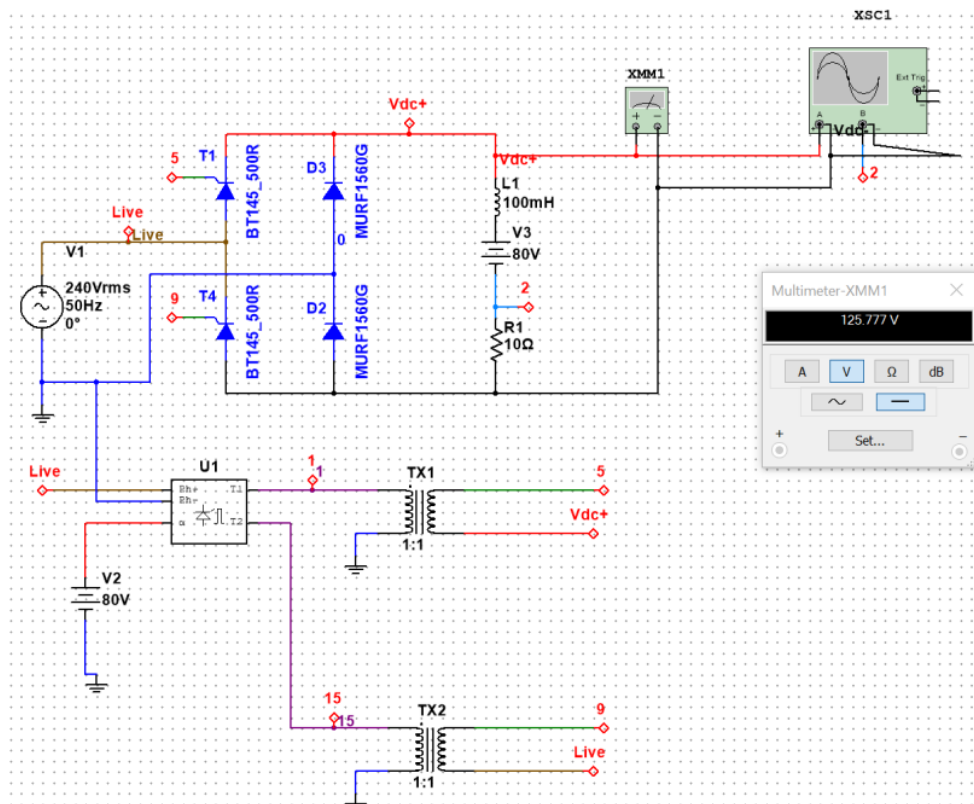


Fig.15 – 80 Back EMF and 80° Firing Angle

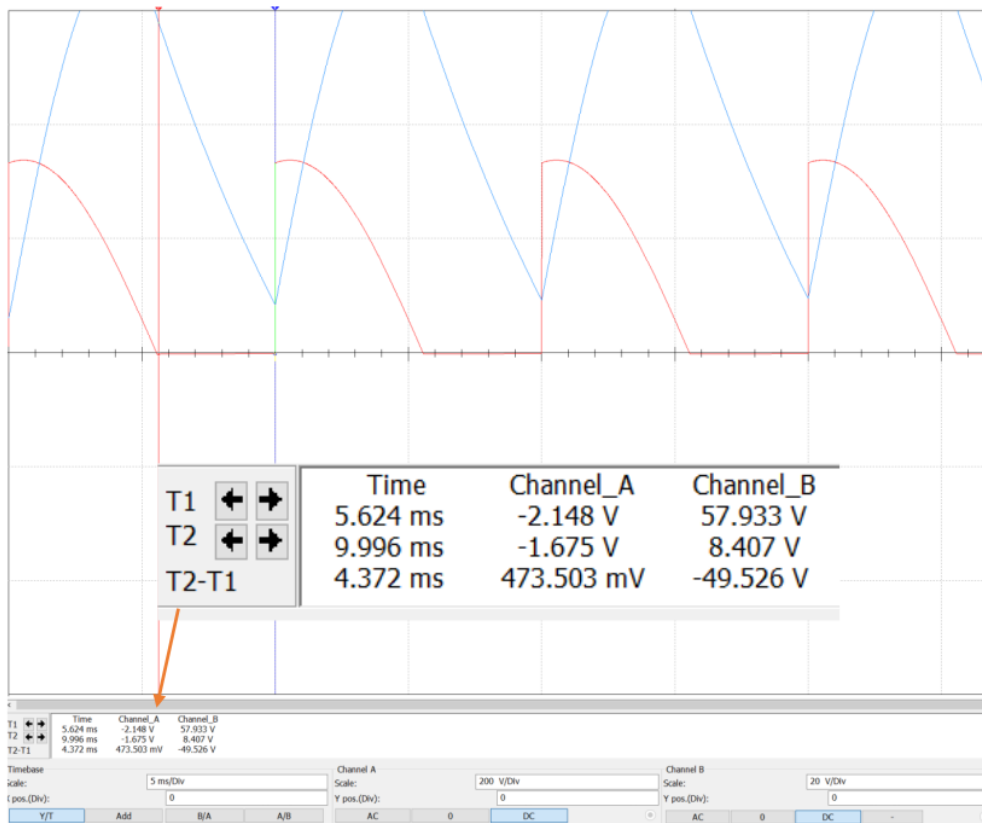


Fig.16 – 80 Back EMF and 80° Firing Angle Response

Using a 10ms Half cycle:

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{4.327 \times 10^{-3}}{10} \times \pi = 1.359 \text{ rads}$$

For average voltage:

$$\text{Voltage average} = \frac{333.008}{\pi} (1 + \cos(1.359)) = 126.450V$$

The peak voltage should be around 337 not 333

For phase angle:

$$t_2 \times 180^\circ = 0.4372 \times 180^\circ = 78.696^\circ$$

Phase Angle (Degrees)	
Simulated Results	Calculated Results
120	46.494°
100	65.466°
80	78.696°

You are using the wrong value for V_{peak} in your calculations which should always be 337. This explains why your calculations do not match your simulations

Average Voltage (V)		
Set Value (V)	Simulated Results (V)	Calculated Results (V)
120V	145.853V	179.009V
100V	133.733V	150.07V
80V	125.777V	126.450V

From the simulated and calculated results the tables above were collated, as stated earlier the output current is non continuous for 120V and 100V and thus the average voltage values are extremely differentiated from the simulated whereas the 80V result is very close and therefore can be said to be accurate. This phenomenon occurs when the current is continuous as only then will the firing angle matches the back EMF value.

Explanation of The Simulation Circuit

Fig.17 shows the full wave single phase half controlled rectifier, a facsimile of the Parker 512C discussed earlier and is therefore a single quadrant drive. Supplied, as is expected, with AC the thyristors T1 and T4 and the diodes D2 and D3 are where rectification occurs, the diodes and thyristors pass only positive voltage as T1 and D2 work in opposite to D3 and T4 over a full cycle. To simulate a motor within the simulation the conductor L1 and resistor R1 are placed in series with a DC supply V3 which acts as the back EMF of the motor. The DC supply V2 powers the phase angle controller and sends a pulse for each phase waveform. Transformers TX1 and TX2 are used as isolation transformers and bypass the supply at terminations Vdc+, 5 and 9 and live causing direct pulses into the motor circuit.

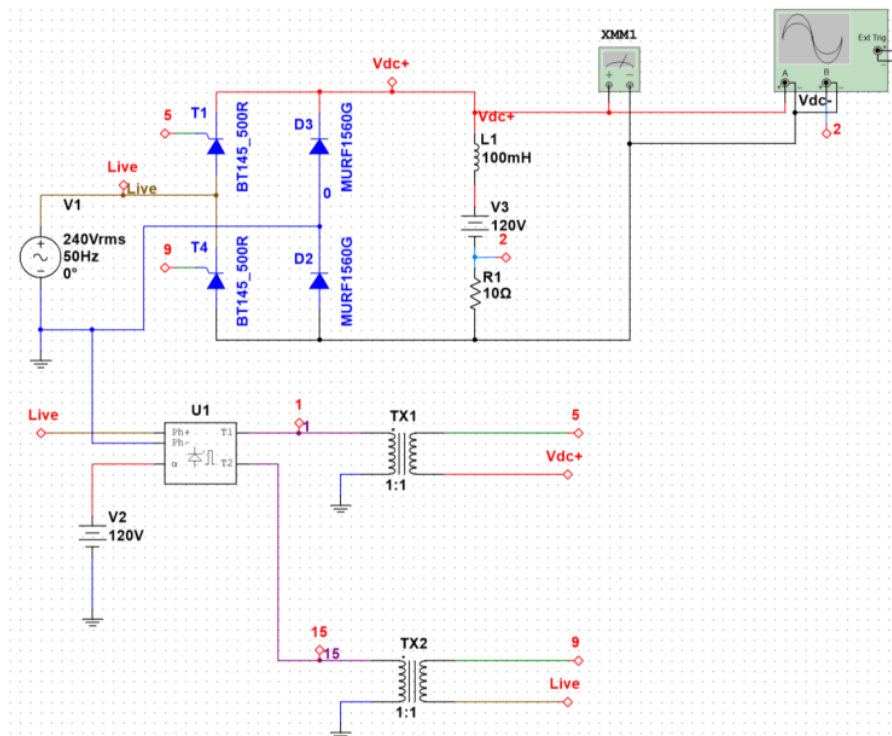


Fig.17 – Single Phase, Full Wave Half Controlled Rectifier Circuit

4. Practical Investigation into a Single Quadrant DC Drive

This experiment involved running a DC motor connected to the aforementioned Parker 512C drive unit, using a Picoscope waveform analyser attached to the motor, running the software on a laptop the waveforms in Fig.18 – 23 were captured. Two tests were conducted one where the motor was run under no load and an increasing load test. The setup of the experiment can be observed in appendix 2.

No Load Test

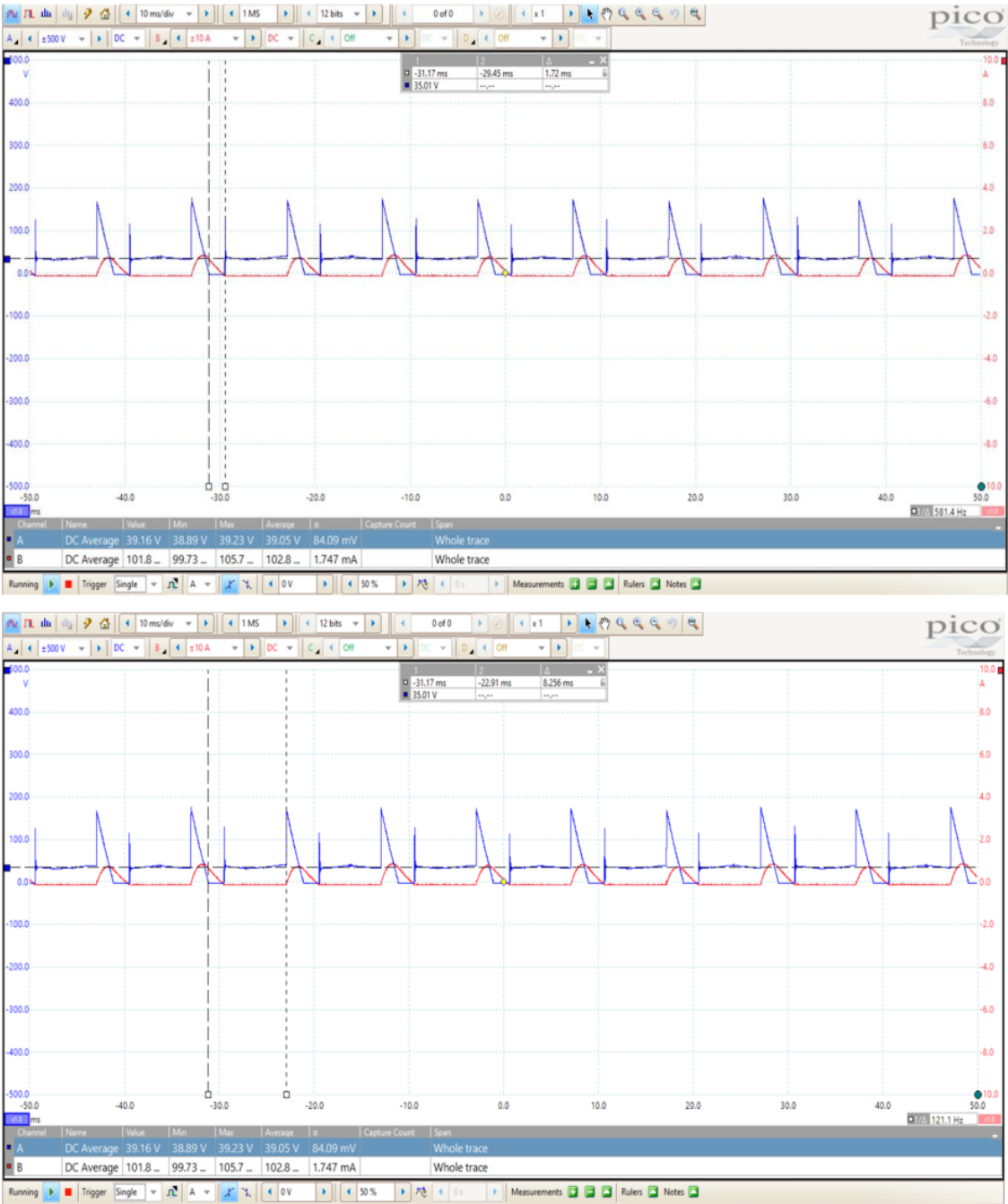


Fig.18 – Waveform at 554 RPM

$$\beta = \frac{t_1}{10ms} \times \pi = \frac{1.72 \times 10^{-3}}{10} \times \pi = 0.54 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{8.256 \times 10^{-3}}{10} \times \pi = 2.594 \text{ rads}$$

Recorded average armature voltage: 39.05V

Calculated average armature voltage:

$$Voltage\ average = \frac{E}{\pi}(\alpha - \beta) + \frac{V_{pk}}{\pi}(1 + \cos(\alpha))$$

$$Voltage\ average = \frac{35.01}{\pi}(2.594 - 0.54) + \frac{337.230}{\pi}(1 + \cos(2.594))$$

$$Voltage\ average = 38.577v$$

$$\beta = \frac{t_1}{10ms} \times \pi = \frac{756.8 \times 10^{-6}}{10} \times \pi = 0.238 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{7.706 \times 10^{-3}}{10} \times \pi = 2.421 \text{ rads}$$

Recorded average armature voltage: 72.1V

Calculated average armature voltage:

$$\text{Voltage average} = \frac{E}{\pi}(\alpha - \beta) + \frac{V_{pk}}{\pi}(1 + \cos(\alpha))$$

$$\text{Voltage average} = \frac{69.12}{\pi}(2.421 - 0.238) + \frac{337.230}{\pi}(1 + \cos(2.421))$$

$$\text{Voltage average} = 74.69V$$

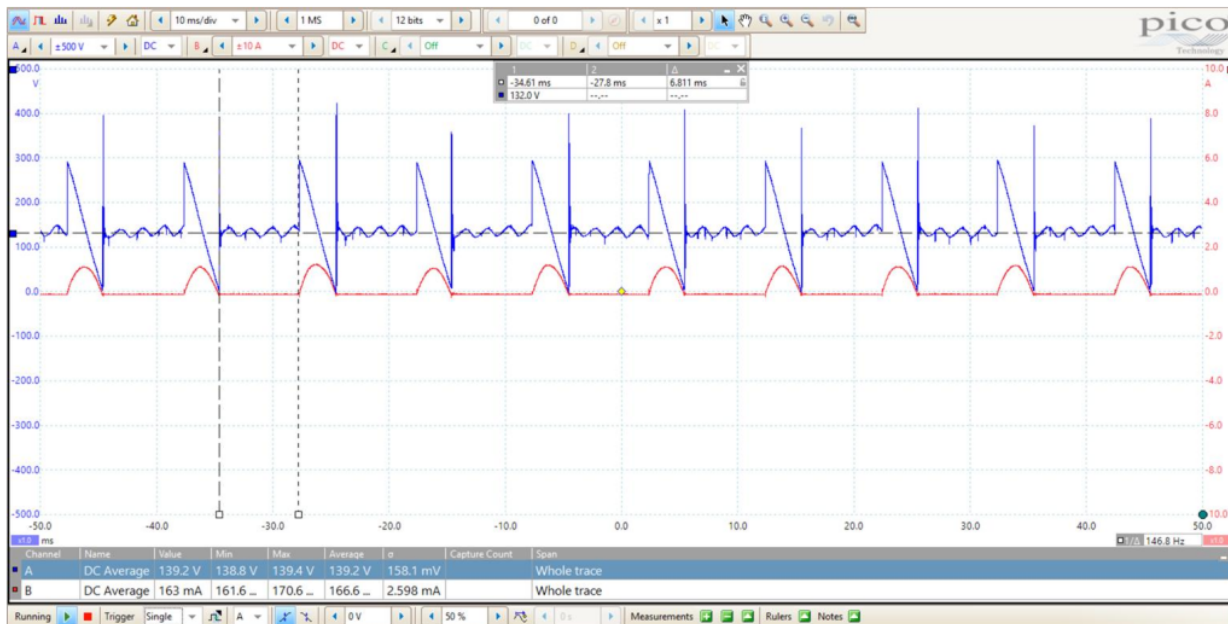


Fig.20 – Waveform at 2020 RPM

For this task unfortunately T1 was not recorder and only T2 could be taken.

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{6.811 \times 10^{-3}}{10} \times \pi = 2.14 \text{ rads}$$

Recorded average armature voltage: 139.2V

*where is your summary
of results table?*

Under Load Test



Fig.21 – Waveform of 0.4Nm at 1049rpm

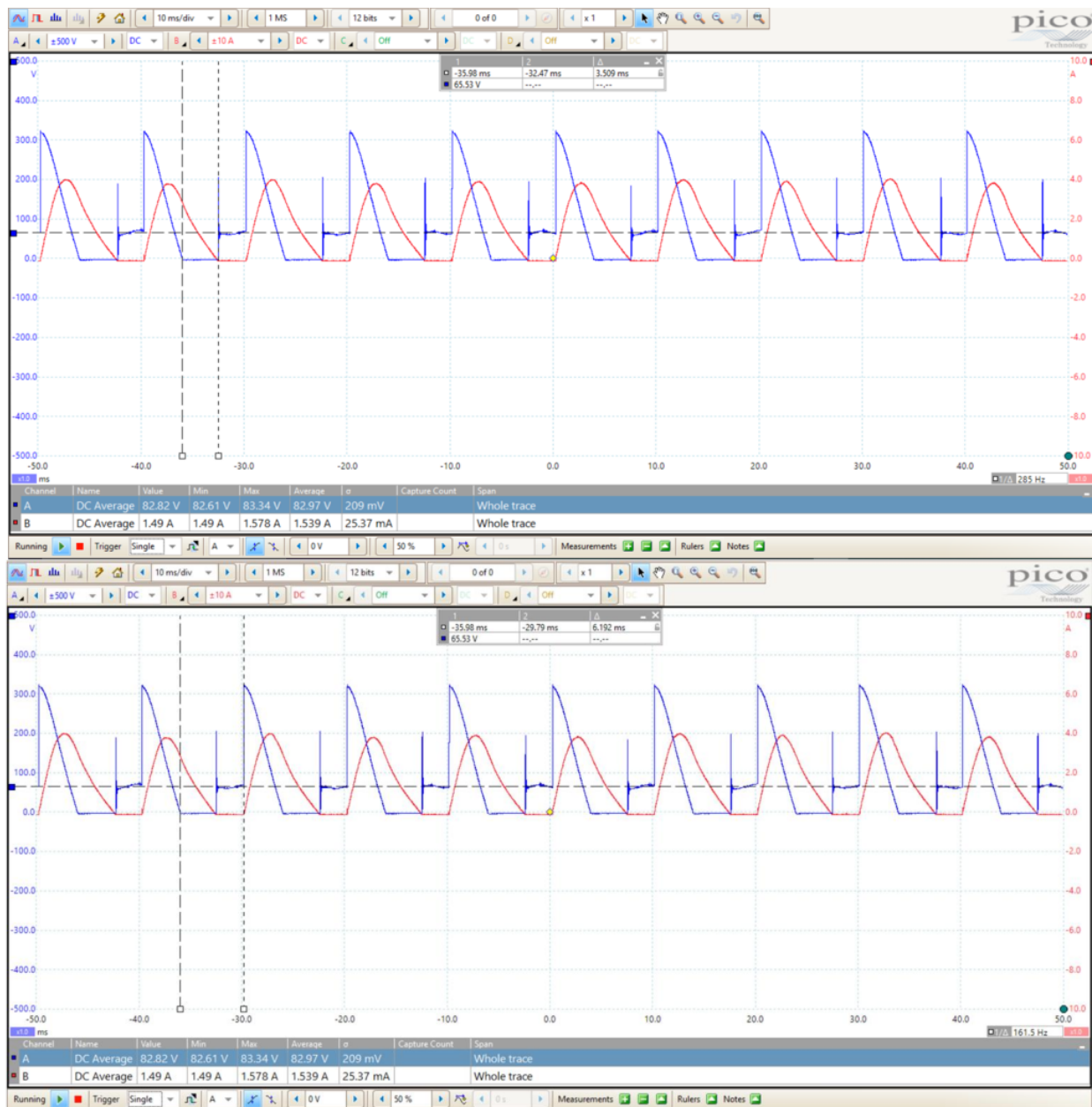


Fig.22 – Waveform of 0.8Nm at 1049rpm

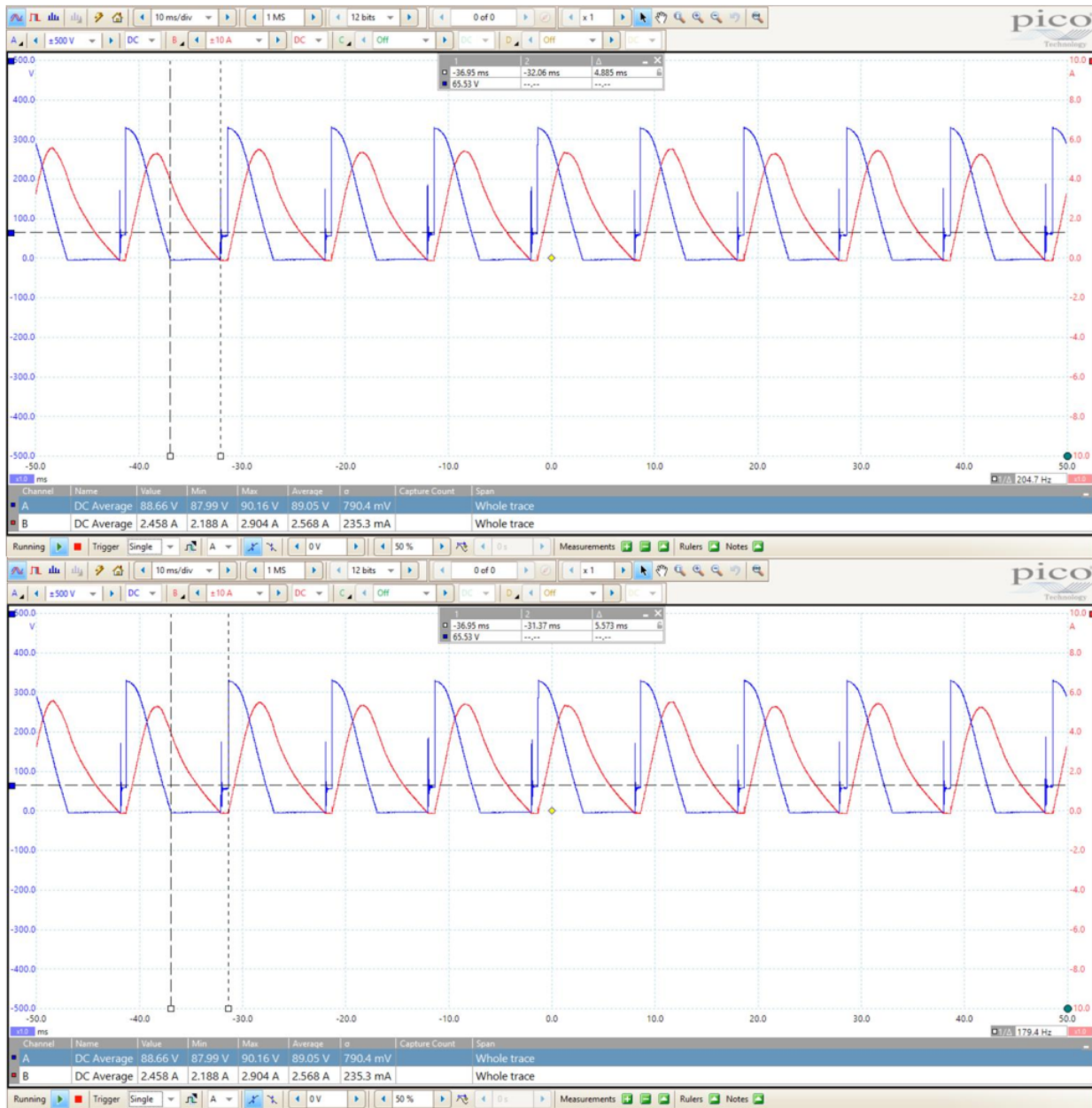


Fig.23 – Waveform of 0.8Nm at 1049rpm

From Figures 21 to 23 the trend that we can observe that as the load is increased in increments of Nm from 0.4 to 0.8 to 1.2Nm of frictional force is that the period of the duty cycle shortens, in other words the time between each voltage drop and thyristor firing point shortens, the ultimate consequence being continuous current. Furthermore the voltage and current also increase in proportion to friction which is expected as a basic understanding of load and power use in motor units.

5. Simulation of a Medium Length Transmission Line

A single-phase transmission lines has the following component constants:

- 21Ω Resistance
- 177mH Inductance
- $1.4\mu\text{F}$ Capacitance

A schematic drawing from Multisim of the nominal- π equivalent circuit can be seen below in Fig.24 with a load impedance of $250 + j130\Omega$ at Z1.

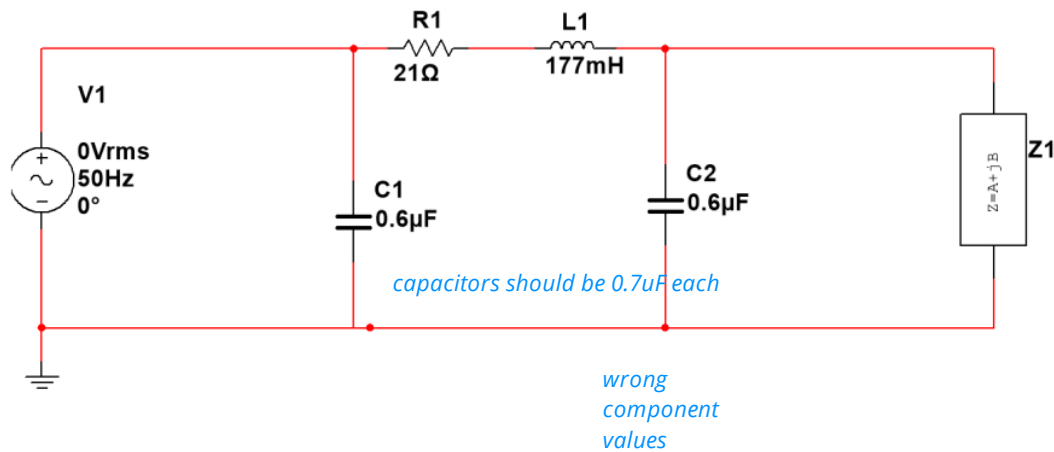


Fig.24 – Medium Length Transmission Line Sketch

Due to the length and the fact that the calculation are rather laborious they have been placed into the appendix section. Using the calculated values from Appendix 3 the series impedance and shunt admittance were found as well as the sending end voltage current and power factor when the load at the receiving end is 293.124A at 82.596KV with a power factor of 0.88722 lagging. To validate the accuracy of the calculated values a Multisim simulation can be run, the configuration of which can be seen in Fig.25.



To calculate overall powerline efficiency:

Sending:

$$274.873 \times 95327.65 \times 0.8851 = 23.19MW$$

Receiving:

$$293.124 \times 82.596 \times 10^3 \times 0.88722 = 21.48MW$$

$$Efficiency = \frac{21.48 \times 10^6}{23.19 \times 10^6} \times 100 = 92.98\%$$

Measurement	Simulated Values	Calculated Values
Sending Power Factor	0.87627 ⁰	0.8851 ⁰
Receiving Power Factor	0.88661 ⁰	0.88722 ⁰
Sending Power	23.091MW	23.19MW
Receiving Power	21.378MW	21.48MW

*They would have been closer if you
have chosen the correct components*

The calculated set of results are almost identical to the simulated results; therefore it can be surmised the calculations are correct and the simulation accurately simulate the behaviour of the circuit.

6. Overall Conclusions and Recommendations

In conclusion it can be stated that overall a good understanding of DC drive and AC supply methods of behaviour have been analysed and discussed. The research element mainly focused on the efficiency and use of H bridge drives in relation to DC speed control and while a good review of them is given in relation to other methods of control such as rheostats, perhaps other control methods could have been explored, regardless a good understating of the operation of H bridges is laid down and evaluated. Perhaps more research could have been done into specific uses of the Parker 512C so that the relative efficacy of these machines could be examined in real industrial settings. However, it is a fair assessment to say that all the sources used are relevant and are credible within the realm of their authorship.

The practical elements of the assignment are perhaps more detailed than the research element. The investigation into the performance of a single-phase full wave half-controlled rectifier was well conducted, the simulation element effectively correlated and proved the calculated theoretical predictive models laid out in the calculations. The second part in particular was interesting as it allowed the examination of a hypothetical motor and drive behaviour entirely within a simulated environment under load, demonstrating plainly the use that simulation software has in the modern engineering environment. The practical examination of the drive and motor behaviour was also an interesting in so much as it allowed the use of a new Picoscope analyser as well as a practical look at how the load effects the voltage and current trend, eventually leading to continuous current. The final task involving the transmission lines was also well executed and the results were nicely tabulated and once again used simulation resources to prove mathematical models, which in this task was extremely accurate. A recommendation for further analysis would be to examine the practical capabilities of motor braking and regenerative drives if given the chance.

As for the format of the report, all elements of the report meet a certain set standard, such as the use of correct figure numbering, citation list and the use of an appendix for ancillary information, furthermore the text follows the same formatting throughout. The various design and simulation software used was easily accessible and intuitive to use in which there was no problems encountered.

7. Team Working

The team that comprised the practical experiment were, the author, Richard Harrison, Mason Morgan, and Thomas Grennan. It is worth noting that all Covid 19 social distancing measures were adhered to during the team working process.

The team worked together by dividing the workload and tasks between individual members, the author, set up the experiment by making all terminated connections and mechanical connections. The Pico scope software was monitored by Richard Harrison who provided the screenshots from the experiment. Thomas Grennan and Mason Morgan altered the load on the motor during that specific test and recorded written results. Overall the team worked effectively to obtain all relevant data needed for experimental analysis and it can be deemed a successful endeavour.

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9. Appendix

Appendix 1 – Parker 512C Data Sheet Schematic - (Parker, 2016)

An Overview of the Converter 2-1

Chapter 2 AN OVERVIEW OF THE CONVERTER

Component Identification

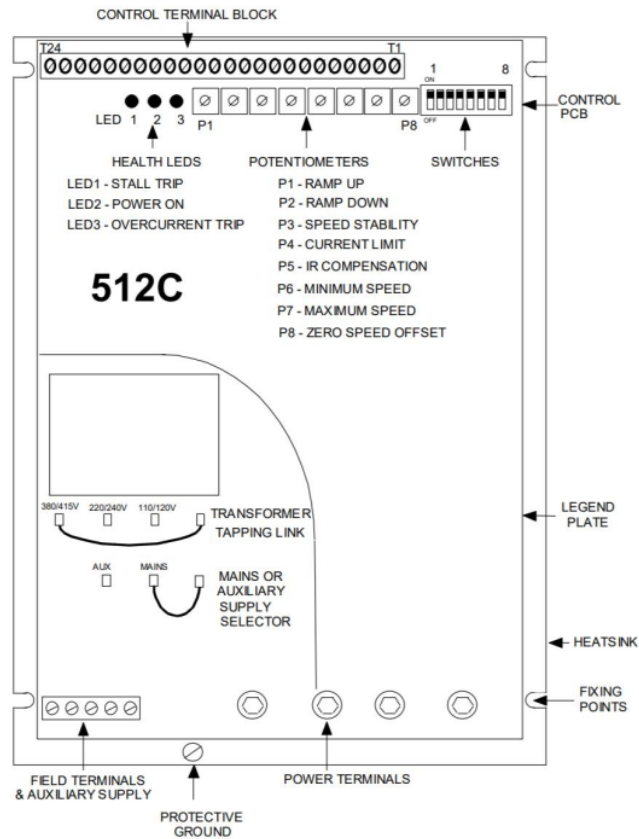


Figure 2-1 View of Component Parts

Appendix 2 – Practical Experiment Setup Pictures



Appendix 3 – Transmission Line Calculations

Impedance:

$$\begin{aligned}Z_s &= 21 + j\omega \times 177mH \\Z_s &= 21 + j \times 2\pi \times 50 \times 177 \times 10^{-3} \\Z_s &= 21 + j55.606\Omega\end{aligned}$$

To convert to polar form:

$$\begin{aligned}\sqrt{21^2 + 55.606^2} \angle \left(\frac{55.606}{21} \right) \\= 59.44 \angle 69.31^\circ\end{aligned}$$

Shunt admittance:

$$\begin{aligned}Y &= j \times 2 \times \pi \times 50 \times 1.4 \times 10^{-6} \quad C = 0.7\mu F \text{ not } 1.4\mu F \\Y &= j0.439 \times 10^{-3}\end{aligned}$$

Or

$$Y = j0.439 \times 10^{-3} \angle 90^\circ$$

Given that the receiving end load is 82.596KV(VRN) at 293.124A(IRN) with a 0.88722 lagging power factor:

$$\begin{aligned}\text{Receiving current} &= 293.124 \angle (0.88722) \\ \text{Receiving current} &= 293.124 \angle -27.47^\circ\end{aligned}$$

Using the nominal π circuit:

$$\begin{aligned}293.124 \angle -27.47^\circ + 82.596 \times 10^3 \angle 0^\circ \times \frac{0.439 \times 10^{-3}}{2} \angle 90^\circ \\= 293.124 \angle -27.47^\circ + 18.13 \angle 90^\circ\end{aligned}$$

Then into cartesian form:

$$\begin{aligned}293.124 \cos \cos (27.47) &= 260.075 \text{ and } 293.124 \sin \sin (27.47) = 135.213 \\260.075 \text{ and } 135.213 &= 260.075 - j135.213 \\ \text{adding the } 18.13 \angle 90^\circ \\260.075 - j135.213 + j18.13 \\&= 260.075 - j117.083A\end{aligned}$$

Then back to polar form:

$$\begin{aligned}\sqrt{260.075^2 + 117.083^2} \angle \left(\frac{117.083}{260.075} \right) \\= 285.215A \angle -24.24^\circ\end{aligned}$$

At Sending end:

$$\begin{aligned} \text{Sending voltage} &= 82.596 \times 10^3 \angle 0^\circ + 285.215 \angle -24.24^\circ \times 59.44 \angle 69.31^\circ \\ &= 82.596 \times 10^3 \angle 0^\circ + 16953.18 \angle 45.07^\circ \end{aligned}$$

Into cartesian:

$$\begin{aligned} 16953.18 \cos \cos (45.07) &= 11973.05 \\ 16953.18 \sin \sin (45.07) &= 12002.35 \end{aligned}$$

Therefore:

$$\begin{aligned} &11973.05 + j12002.35 \\ 82.596 \times 10^3 + 11973.05 + j12002.35 \\ &= 94569.05 + j12002.35 \end{aligned}$$

Back into polar:

$$\begin{aligned} \sqrt{94569.05^2 + 12002.35^2} &= 95327.65 \\ \left(\frac{12002.35}{94569.05} \right) &= 7.23^\circ \\ &= 95327.65V \angle 7.23^\circ \end{aligned}$$

At Sending end:

$$\begin{aligned} \text{Sending current} &= 260.075 - j117.083 + 95327.65 \angle 7.23^\circ \times \frac{0.439 \times 10^{-3}}{2} \angle 90^\circ \\ &= 260.075 - j117.083 + 20.924 \angle 97.23^\circ \end{aligned}$$

Into cartesian:

$$\begin{aligned} 20.924 \cos \cos (97.23) &= -2.633 \\ 20.924 \sin \sin (97.23) &= 20.758 \\ 260.075 - j117.083 - 2.633 + j20.758 \\ &= 257.442 - j96.325 \end{aligned}$$

Back into polar:

$$\begin{aligned} \sqrt{257.442^2 + 96.325^2} &= 274.873 \\ \left(\frac{96.325}{257.442} \right) &= 20.51^\circ \\ &= 274.873A \angle 20.51^\circ \end{aligned}$$

Sending current/voltage angle:

$$\text{Sending angle} = 7.23^\circ - (-20.51^\circ) = 27.74^\circ$$

Sending power factor:

$$\text{Sending power factor} = \cos (27.74^\circ) = 0.8851 \text{ Lagging}$$

1809800

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

56/100

PAGE 1

PAGE 2

PAGE 3

QM

Spelling

Spelling error

QM

Spelling

Spelling error

PAGE 4

QM

Word/s missing

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

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Correctly cited

Citation method conforms to Harvard standard, well done.

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Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 5

Text Comment. The most common is separately excited due to the connection to DC drives

Text Comment. You could also have consider permanent magnet motors

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

Text Comment. AC must first be converted to DC

Text Comment. This requires a DC supply

QM

Spelling

Spelling error

Text Comment. For larger motors, the power transistors will need to be large to cope with the heat

PAGE 6

PAGE 7

Text Comment. This is an old outdated method

Text Comment. It was expected that you would also consider thyristor controlled rectifiers in this section to support the practical in the tests of the assignment

PAGE 8

QM

Repetition

Already stated elsewhere, repeating information is considered boring by your reader

Text Comment. Never include a datasheet in a report. Read it and quote from it. Then cite it as your source.

PAGE 9

Text Comment. Write in the past tense

Text Comment. was

Text Comment. were

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PAGE 10

Text Comment. Images and calculations should be in the appendix and a table of results for comparison and comment should be included in the main report

PAGE 11

PAGE 12

Text Comment. The peak voltage should be around 337 not 149

PAGE 13

PAGE 14

PAGE 15

Text Comment. The peak voltage should be around 337 not 333

PAGE 16

PAGE 17

PAGE 18

Text Comment. The peak voltage should be around 337 not 333

PAGE 19

Text Comment. There is something wrong with some of your results or there is a calculation error

PAGE 20

PAGE 21

Text Comment. The peak voltage should be around 337 not 333

PAGE 22

PAGE 23

Text Comment. The peak voltage should be around 337 not 333

PAGE 24

PAGE 25

Text Comment. The peak voltage should be around 337 not 333

PAGE 26

Text Comment. You are using the wrong value for V_{peak} in your calculations which should always be 337. This explains why your calculations do not match your simulations

PAGE 27

PAGE 28

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PAGE 34

Text Comment. where is your summary of results table?

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

Text Comment. capacitors should be 0.7uF each

Text Comment. wrong component values

PAGE 40

Text Comment. Read the question again, the total capacitance was 1.4uF

PAGE 41

Text Comment. They would have been closer if you have chosen the correct components

PAGE 42

Text Comment. The focus should have been the control of a DC motor from an AC supply

Text Comment. The 514 would allow you to do that.

PAGE 43

PAGE 44

PAGE 45

PAGE 46

PAGE 47

Text Comment. C = 0.7uF not 1.4uF

PAGE 48

GRADING FORM: NEW CSG-RUBRIC

IWAN COSTELLODOWNS

56

1. ENGAGEMENT WITH LITERATURE



Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Very

11

good use of referencing, with no/very few inaccuracies or inconsistencies. However, if you read the research question more carefully, you will see that the focus was on the control of a DC motor from an AC supply suggesting a controlled rectifier rather than a H bridge chopper. (11/20)

2. KNOWLEDGE AND UNDERSTANDING



Knowledge is reasonably extensive. Exhibits very competent critical understanding of the well-established concepts and principles of the subject and the main methods of enquiry. Breadth and depth of knowledge. (12/20)

12

3. COGNITIVE AND INTELLECTUAL



Some critical evaluation and analysis of concepts and principles, though descriptive in parts. An emerging awareness the limits of their knowledge and ability to use evidence to support the argument though with some tendency to assert/state opinion rather than argue on the basis of reason and evidence. Mostly valid arguments and logical judgements. There are a few minor errors that have affected your results which should have tallied much closer to theory if you have chosen the correct values (10/20)

10

4. PRACTICAL APPLICATION



A very good application of a range of established methods, materials, tools and/or techniques. Very

13

good consideration of the context of the application, with perceptive insights. Consistent, accurate and logical application of theory to practice, making appropriate links between the two. Can identify problems and propose appropriate solutions outside the context in which they were first studied. Evidence of some creativity. (13/20)

5. TRANSFERABLE SKILLS



Can communicate effectively in a suitable medium for the audience, but may have minor errors. Mostly coherent, organised work, in a suitable structure and is for the most part clearly expressed. Can work effectively independently and/or as part of a team, with clear contribution to group activities. Demonstrates the skills for employment requiring the exercise of personal responsibility and decision-making, with some areas of strength and some of minor weakness. Word count exceeded and there are some awkward sentences. (10/20)

10