

Assignment 2

by Joshua Beer

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Power and Machines

Investigation into Three-Phase Induction Motors

This is obviously the wrong title

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PSDE5027

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1. Research

1.1 Thyristors and their usage as controlled rectifiers

Thyristors are multi-layered semi-conductor devices and are use current flow to control the voltage.

(<https://www.electronics-tutorials.ws/power/thyristor.html>, 2018) States that “a thyristor is a four layer (P-N-P-N) semiconductor device that contains three PN junctions in series.” By using thyristors in a circuit they can be used to control phase, AC motors and lamps. This is because the thyristor consists of two P-N junctions back to back containing an anode, cathode and gate. The P-N junctions can be switched on and off at an extremely fast rate which is why the power to the load can be controlled. Figure 1 shows how the thyristor is made up.

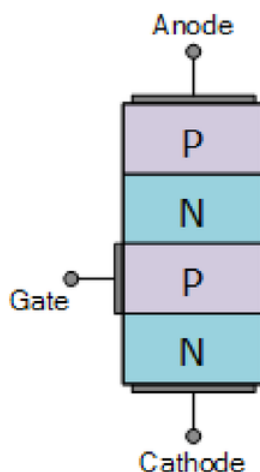


Figure 1 - Thyristor

(<https://www.electronics-tutorials.ws/power/thyristor.html>, 2018)

The gate detects small changes in current which allows it to switch on and off and therefore allows larger currents to flow from the anode to cathode, therefore controlling the flow. This will then keep flowing even if the smaller current at the gate is lost as it “latches” the signal as such to allow the larger current to continue to flow from anode to cathode. (Woodford, 2012)

Thyristors and transistors are very similar in their function apart from as mentioned above thyristors can latch the on/off signal whereas transistors cannot, also thyristors are able to deal with much larger voltages and current, typically hundreds of volts and 5-10 amps current. This enables them to act as electronic relays as such. *underestimate*

There are three states which thyristors can work in:

Forward blocking;

Where the gate is switched off and both the 1st and 3rd junctions are forward biased but the 2nd one is therefore reversed biased and will not let current flow through the junctions.

Reverse blocking;

By swapping the connections of the anode and cathode, the 1st and 3rd junctions are now reversed biased and therefore current will still not flow.

Forward conducting;

This allows current to flow through the thyristor when current is applied to the gate and is switched on, this happens because it now turns the first junction on which then activates the third junction and once both of the junctions are saturated (by activating over and over) then current can flow from the anode to cathode. This is how the latching happens until the circuit is turned off, this cannot be done using the gate though it has to be done by interrupting the main power to the current flowing through the transistor.

1.2 Half wave-controlled rectifier

A half-controlled rectifier works by having a thyristor in the circuit which means when the AC waveform is powering the circuit only half the wave will be let through and measured across RL. This is because when the positive AC wave is going through the thyristor it will be acting like a forward biased transistor and allowing the current to flow through, whereas when negative the transistor will act like a reversed biased transistor and will not let current flow. This is why only half the waveform is measured and creates a pulsing DC wave. (<http://www.circuitstoday.com/half-wave-rectifiers>, 2018)

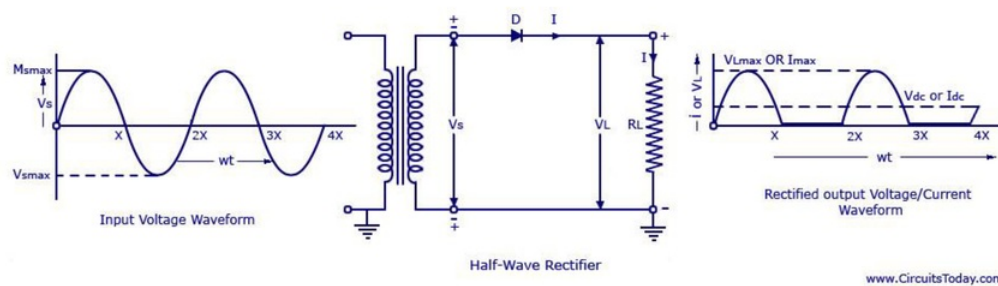


Figure 2 - Half Wave-Controlled Rectifier Circuit and Waveform

(<http://www.circuitstoday.com/half-wave-rectifiers>, 2018)

Figure 2 shows the AC input waveform which goes into the circuit as described above the half wave DC output is as shown on the right.

If a current is induced in the circuit then the gaps between pulses in the DC waveform will not be zero and therefore a current will always be supplied.

When controlled, changing the firing angle will delay the pulse and create a vertical increase in voltage from zero to where the voltage max would have been without the firing angle.

The formula for voltage average for half wave-controlled is:

$$V_{av} = \frac{V_{max} (1 + \cos \alpha)}{2\pi}$$

1.3 Full wave-controlled rectifier

In a full wave rectifier two diodes are now used in the circuit, as shown in figure 3. Which means that when the positive part of the AC waveform is applied, the first diode will allow the current to flow and the second diode will block the current flowing once the negative part of the AC waveform is applied the first diode will block the current flowing and the second diode will allow current to flow. Therefore the DC pulse output will be constant as shown in figure 3 also.

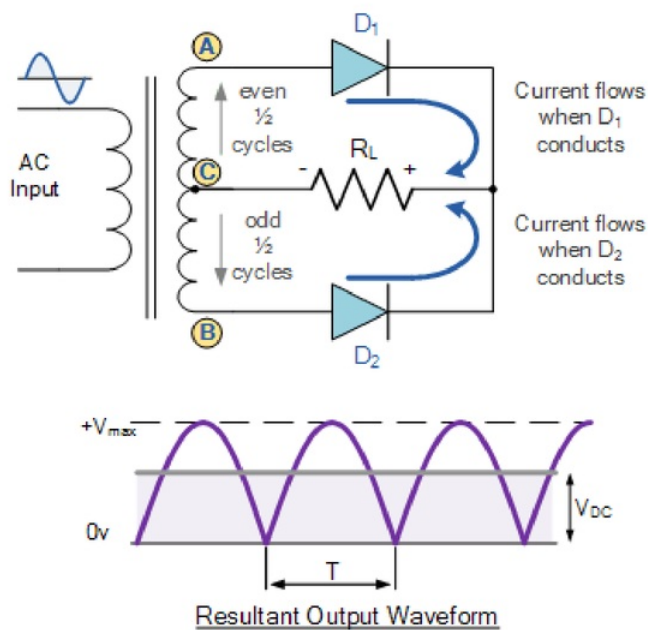


Figure 3 - Full Wave Rectifier Circuit and Waveform

(https://www.electronics-tutorials.ws/diode/diode_6.html, 2018)

This then leads to an average voltage for the DC pulse, the formula for this can be found below.

$$V_{av} = \frac{V_{max} (1 + \cos \alpha)}{\pi}$$

Another type of full wave rectifier circuit can be seen in figure 4 below.

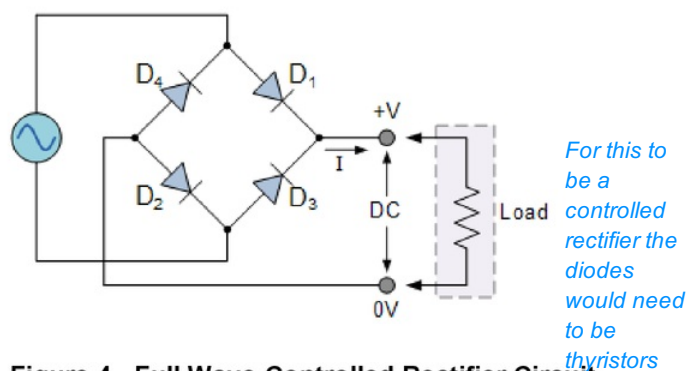


Figure 4 - Full Wave-Controlled Rectifier Circuit

Figure 4 contains 4 diodes wired in series with one another, this works just as the circuit explained above but this time the diodes work in pairs. Therefore D1 and D2 will allow current to flow while D3 and D4 block the current flow and visa versa. These diodes can be replaced by thyristors to allow the firing angle to be changed and therefore controlling the DC voltage output from the circuit by delaying the pulses. This waveform can be seen in figure 5.

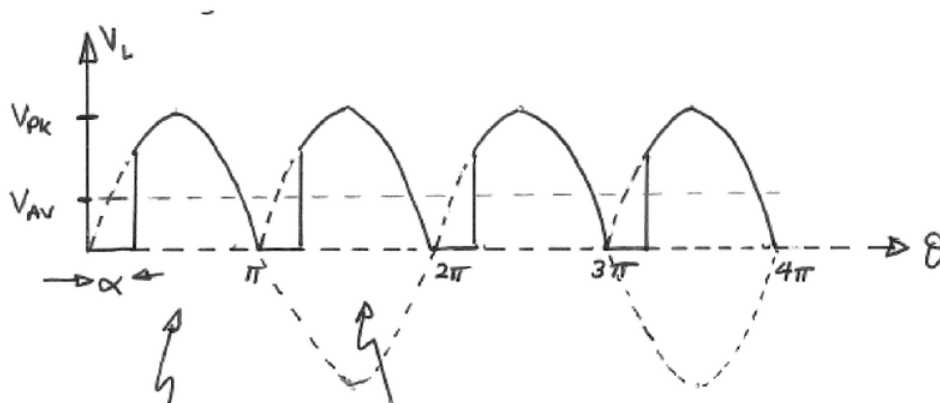


Figure 5 - Full Wave-Controlled Rectifier Waveform

Figure 5 shows the waveform of a fully rectified waveform and firing angle (delay) shown by alpha.

1.4 Low Power DC Drive (Parker 512 C)

According to (Parker, 2018) The 512C converter is intended for use in an Industrial Environment, it should be mounted within an enclosure which provides protection to the converter and the user. The converter should be permanently earthed at the terminals provided. The 512C converter is suitable for the control of Permanent Magnet and Shunt Wound DC Motors. The converters are designed to operate from a single phase ac mains supply in the range of 110Vac to 415Vac at 50 or 60Hz. A simple transformer tap arrangement allows the converter to be programmed to suit the applied voltage. The Speed of the DC Motor is controlled using a linear closed loop system with a feedback signal from either tachogenerator or armature voltage, the feedback source being switch selectable. A current loop within the speed loop always ensures that controlled levels of current are applied to the motor, actual levels being scaleable via programmable switches."

this is one big quote and show poor evidence of understanding

These are specifications and details of how the Parker 512 C DC drive should be installed and used within industrial environments. It also describes how a low power DC drive works.

1.5 Applications of DC drives in industry

DC motors are suitable for many applications in industry, these include conveyors, turntables and others for which adjustable speed and constant or low-speed torque are required.

should be cited as Processingmagazine state that "
According to (Processingmagazine, 2016) "They also work well in dynamic braking and reversing applications, which are common in many industrial machines."

This is because they can very easily accelerate up to speed as there is constant linear torque and power supplied. This also allows the applications to stop and reverse direction of power very quickly. It makes DC motors a popular choice in many new designs, particularly for fractional hp applications.

2. Simulation of a Half-Controlled Rectifier Circuit

For this part of the assignment is asks to design a circuit and use a suitable simulation program (Multisim) to analyse the performance of a single-phase, full-wave, half-controlled rectifier connected to a DC motor armature modelled as a load containing an inductance, a resistance and a battery (for the back EMF).

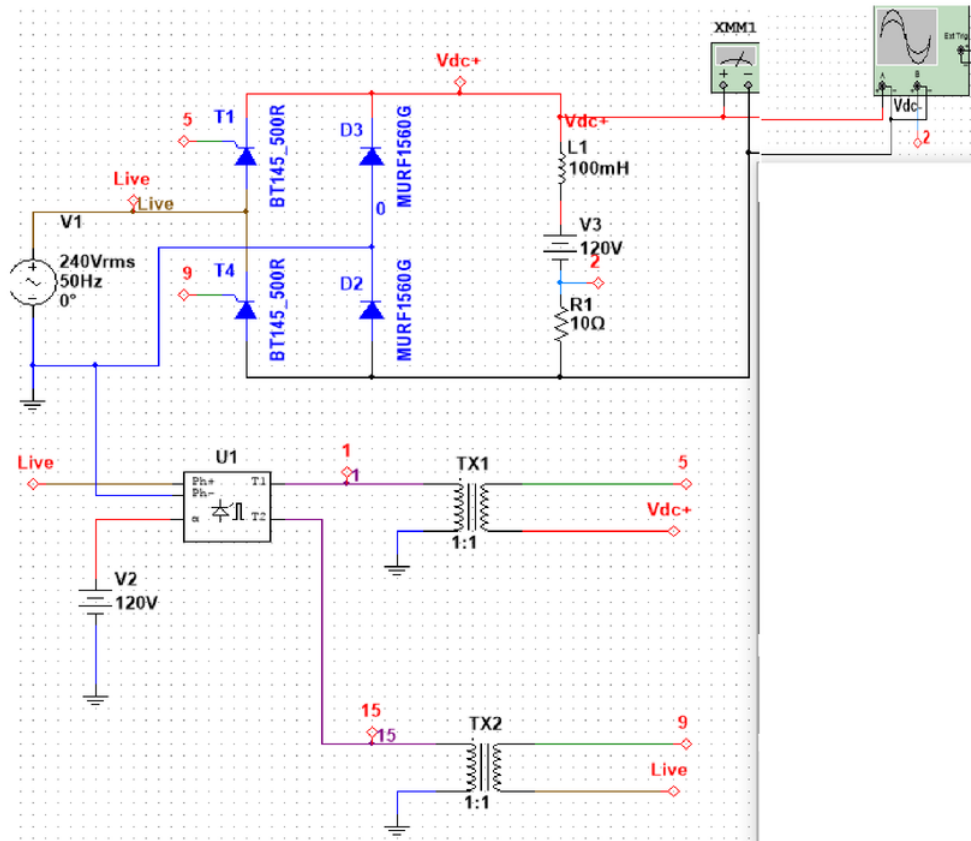


Figure 6 – Half-Controlled Rectifier Simulation Circuit

Figure 6 shows the circuit used to simulated the half-controlled rectifier simulation circuit. It includes a load containing inductance (L1) a resistance (R1) and a battery (V3).

2.1 Firing Angle Results 1

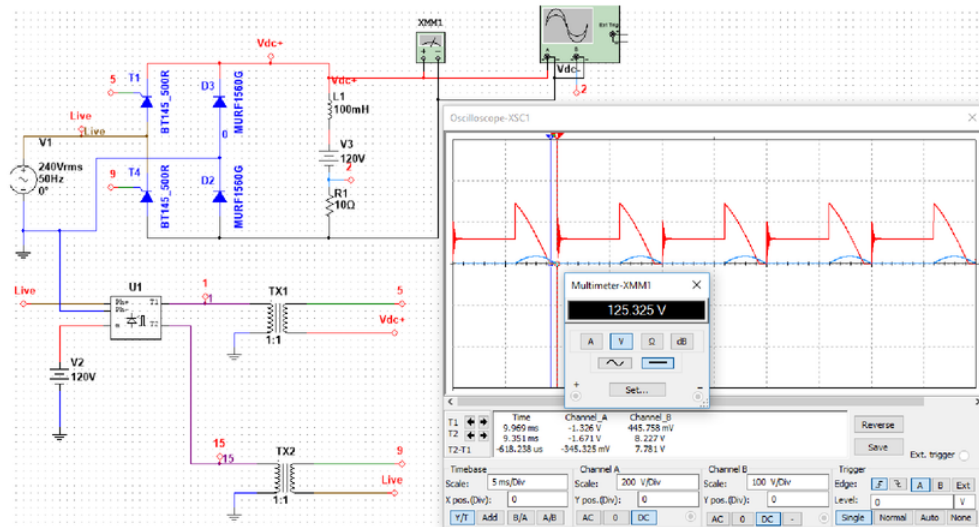


Figure 7 - Firing Angle 1 Circuit (120 Degrees) (1)

By setting the back EMF to 120 V and the firing angle to 120 V (shown by V2 in figure 7) the oscilloscope shows the half-controlled rectified waveform and the multimeter shows the voltage average for the armature to be 125.325 V.

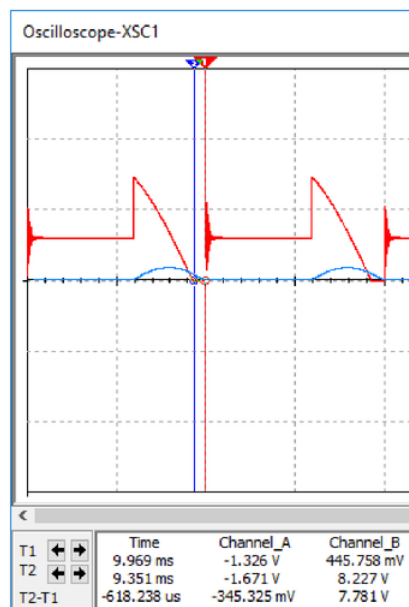


Figure 8 - Firing Angle 1 Oscilloscope (1)

By looking at the values on figure 8, T1 can be seen to be 618.238 us.

Therefore $618.238 \text{ us} / 10 \text{ ms} * \pi = 0.194 \text{ rads} = \text{beta}$. This is the firing angle in radians, this will be used in the formula to check the Vav.

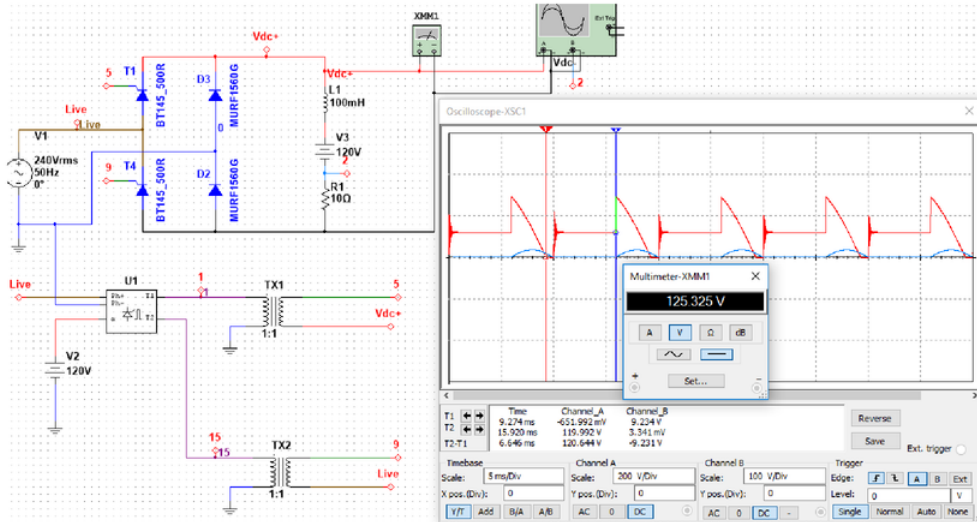


Figure 9 - Firing Angle 1 Circuit (120 Degrees) (2)

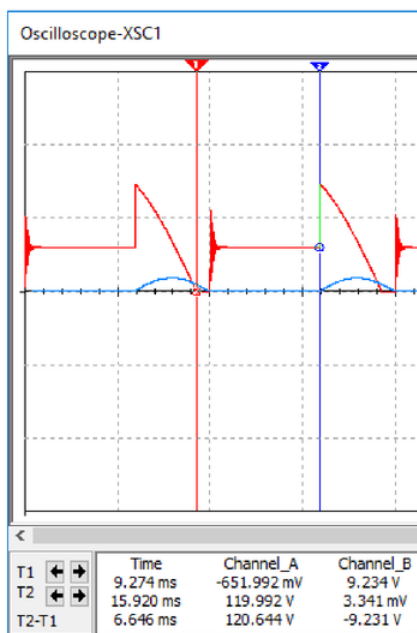


Figure 10 - Firing Angle 1 Oscilloscope (2)

As the time (T2) above is a fraction of 10 ms, the distance between the two points for T2 can be checked with the equation;

$T2 = 6.646 \text{ ms} / 10\text{ms} * \pi = 2.0879 \text{ rads} = \text{alpha firing angle (close to actual angle of 120 as 120 degrees is 2.09 radians)}$ and EMF is shown as 119.992 on the image above. This proves the results as the firing angle was set to 120 V, so taking into account minor discrepancies the equation gives the same result.

Again the alpha angle is used in the formula to check the Vav.

Vrms = 240 V for the equations below.

$$V_{max} = \sqrt{2} \times V_{rms}$$

$$V_{max} = \sqrt{2} \times 240 = 339V$$

Good formula but this was supposed to be found from the research

$$V_{av} = \frac{E(\text{Alpha} - \text{Beta}) + V_{max} (1 + \cos \text{Alpha})}{\pi}$$

$$V_{av} = \frac{120(2.0879 - 0.194) + 339 (1 + \cos(2.0879))}{\pi} = 126.9032796 \text{ V}$$

This result is very close to the measured armature voltage of 125.325 V, this means the simulation was very close to the theory and the measurements of the cursors must have been very accurate to get the right values.

2.2 Firing Angle Results 1

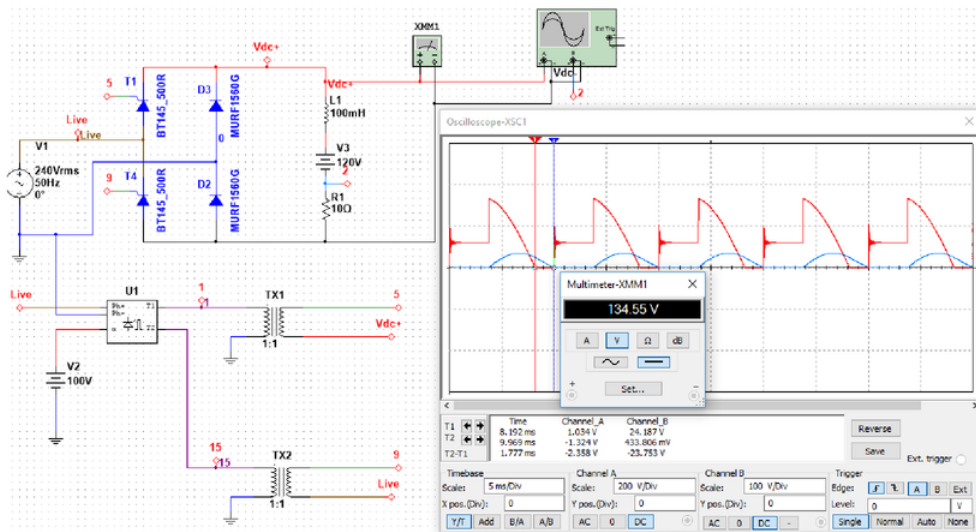


Figure 11 - Firing Angle 2 Circuit (100 Degrees) (1)

By setting the back EMF to 120 V and the firing angle to 100 V (shown by V2 in figure 11) the oscilloscope shows the half-controlled rectified waveform and the multimeter shows the voltage average for the armature to be 134.55 V.

T1 angle of 100 degrees and armature voltage of 134.55 Volts

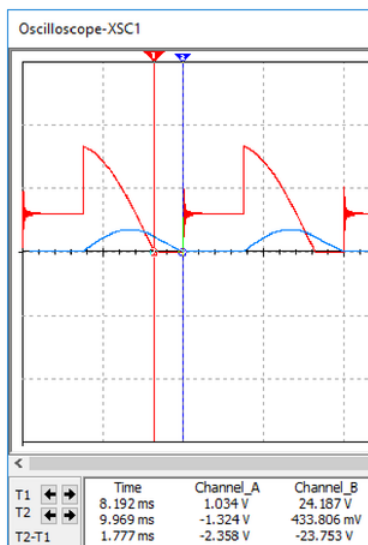


Figure 12 - Firing Angle 2 Oscilloscope (1)

By looking at the values on figure 12, T1 can be seen to be 1.777 ms.

Therefore $1.777 \text{ ms} / 10 \text{ ms} * \pi = 0.558 \text{ rads} = \text{beta}$. This is the firing angle in radians, this will be used in the formula to check the Vav.

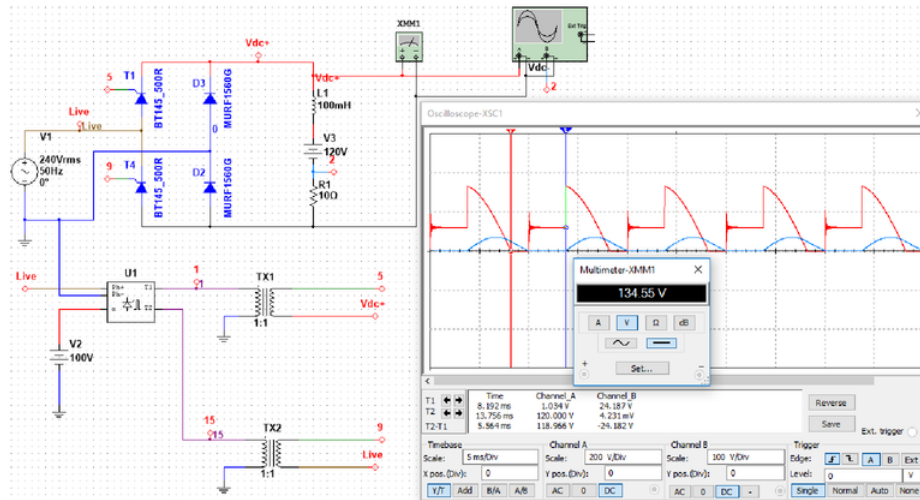


Figure 13 - Firing Angle 2 Circuit (100 Degrees) (2)

T2 angle of 100 degrees

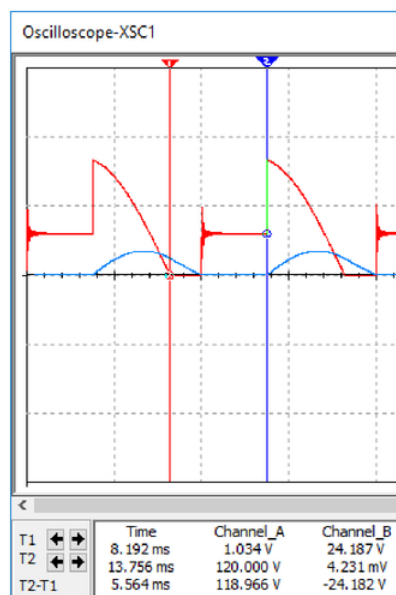


Figure 14 - Firing Angle 2 Oscilloscope (2)

As the time (T2) above is a fraction of 10 ms, the distance between the two points for T2 can be checked with the equation;

$T2 = 5.564 \text{ ms} / 10 \text{ ms} * 3.141 = 1.748 \text{ rads}$ (close to 100 degrees as 1.745 radians is 100 degrees) = alpha firing angle (close to actual angle of 100) and EMF is shown as 120 v on the image above. This proves the results as the firing angle was set to 100 V, so taking into account minor discrepancies the equation gives the same result.

Again the alpha angle is used in the formula to check the Vav.

Vrms = 240 V for the equations below.

$$V_{max} = \sqrt{2} \times V_{rms}$$

$$V_{max} = \sqrt{2} \times 240 = 339V$$

$$V_{av} = \frac{E(\text{Alpha} - \text{Beta}) + V_{max} (1 + \cos \text{Alpha})}{\pi}$$

$$V_{av} = \frac{100(1.748-0.558)+339 (1+\cos(1.748))}{\pi} = 126.7643179 \text{ V}$$

This result is not as close to the measured armature voltage of 134.55 V, this means the simulation was very close to the theory as the firing angle was checked to be the same using the measurements but the cursors measurements must have not been as accurate as the firing angle tests part 1, this is why there is roughly an 8 V discrepancy to the right value.

2.3 Mechanical Loading and Armature Inductance

The next part of this task is to simulate the effects of differing mechanical loads on the armature inductance for the same firing angle. This will be done by changing the back EMF to create results where there is continuous current in one set and non-continuous current in the other set.

The firing angle will be kept at 50 degrees and the back EMF changed from 120 to 150 V. When there is continuous current there will be no visible back EMF in the results, this can be shown in the figures below (15 and 16). The continuous current is shown on the oscilloscope as the blue line which never reaches zero, therefore no back EMF is present.

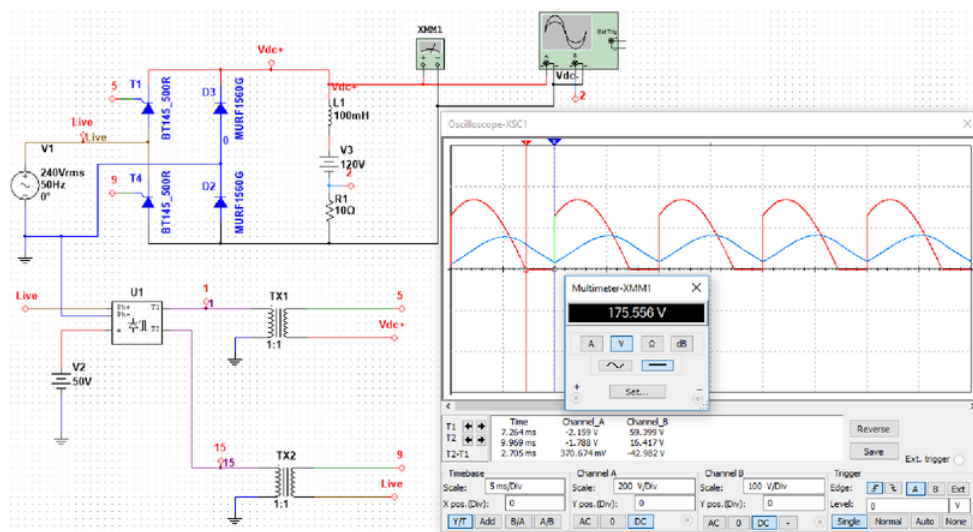


Figure 15 - Mechanical Load, Continuous Current (1)

EMF of 120 V and an angle of 50 degrees creates a continuous current and therefore no T1, there is no back EMF.

Figure 15 also shows an armature voltage of 175.56 V.

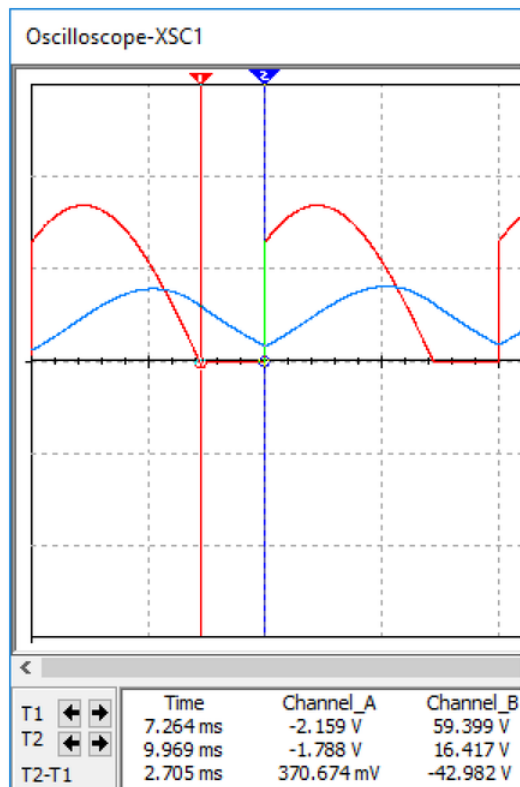


Figure 16 - Mechanical Load, Continuous Current Oscilloscope (1)

Figure 16 showing the current (blue line) never reaches zero and thus proving there's no back EMF.

By changing the EMF of the circuit to 150 V and keeping the firing angle the same (50 degrees) then non-continuous current will occur and will reach zero. This can be seen in figures 17 and 18.

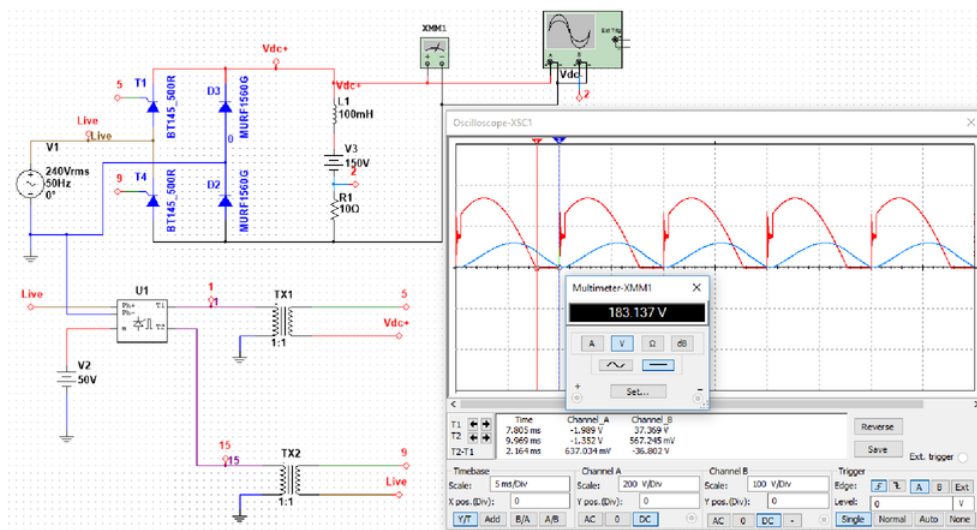


Figure 17 - Mechanical Load, Continuous Current (2)

EMF of 150 and 50 degrees phase angle

T1 is 2.164 ms and the armature voltage is 183.14 V

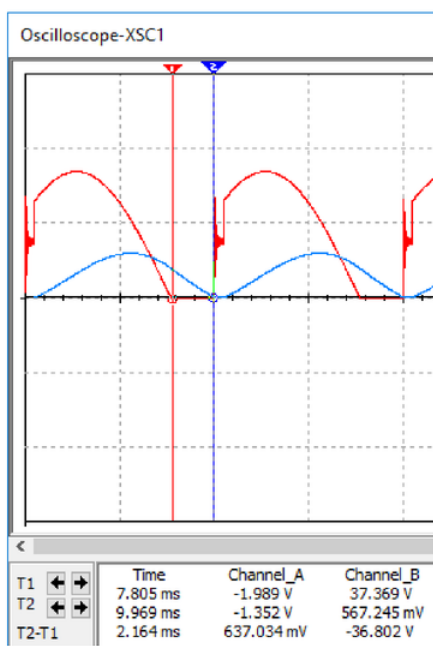


Figure 18 - Mechanical Load, Continuous Current Oscilloscope T1

Figure 18 shows that there is back EMF and this can be seen by the current (blue line) reaching zero on the oscilloscope.

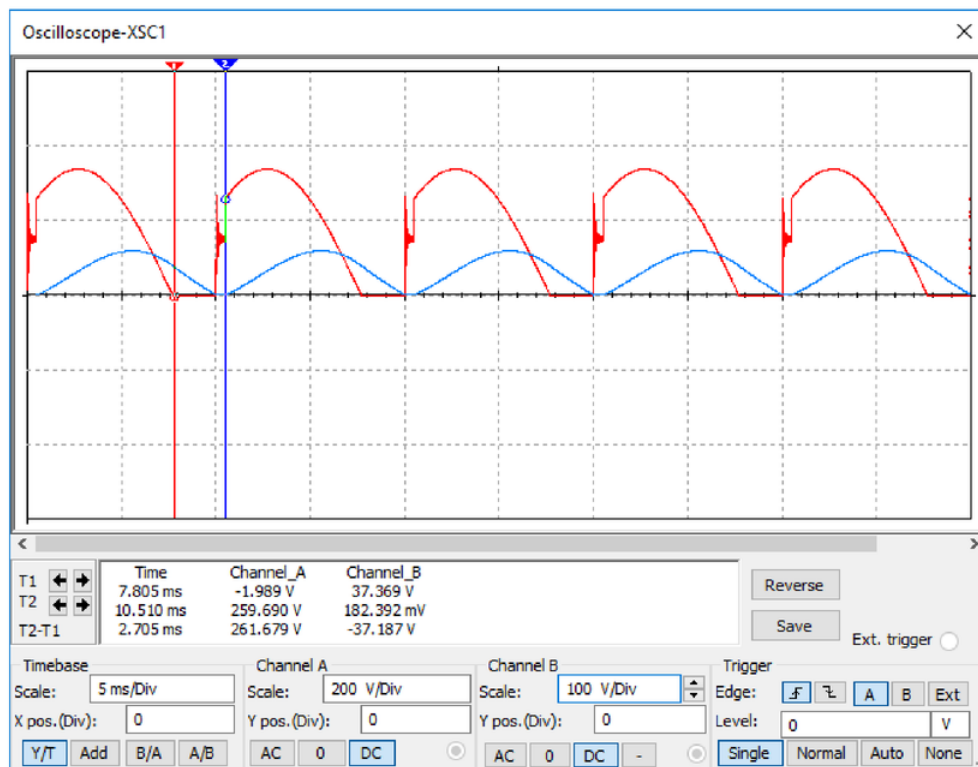


Figure 19 - Mechanical Load, Continuous Current Oscilloscope T2

Figure 19 shows T2 being measured at 2.705 ms.

table of results should be present for comparisons

3. Practical Investigation into a Single Quadrant DC Drive

This part of the assignment asked for an experiment to take place by working in a small team to practically analyse the performance of the Parker 512 C drive. A DC motor including the use of a prony brake, and a multi meter and laser sensor are to be used to measure certain variables including the voltage and RPM of the motor.

To achieve this, a group of 3 was formed and to undertake the results, health and safety precautions were taken to perform the experiment. These were that all participants should wear protective glasses and to be cautious when going near the drive to make alterations.

My role in the group was to take the results off the laptop which meant recording T1 and T2 values along with the speed in RPM of the drive. This was to be done for two experiments, one for armature voltage and current waveforms under no-load conditions and armature current waveforms under mechanical load conditions. These would each be set at 3 different speeds for the no-load with results taken by myself for each speed change and 3 different mechanical loads for the second experiment.

3.1 Experiment 1, No-Load Conditions

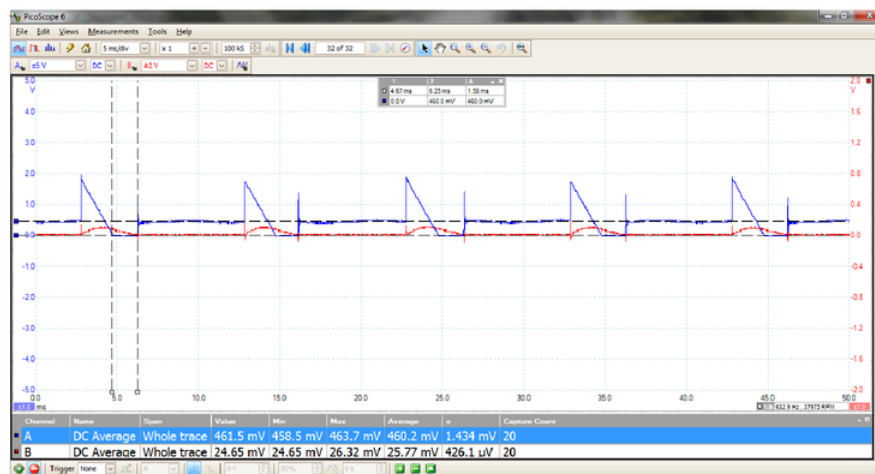


Figure 20 - Experiment 1 Current (1)

Speed = 651 RPM

1.58 ms = T1 and $V_{av} = 460.2\text{mV}$

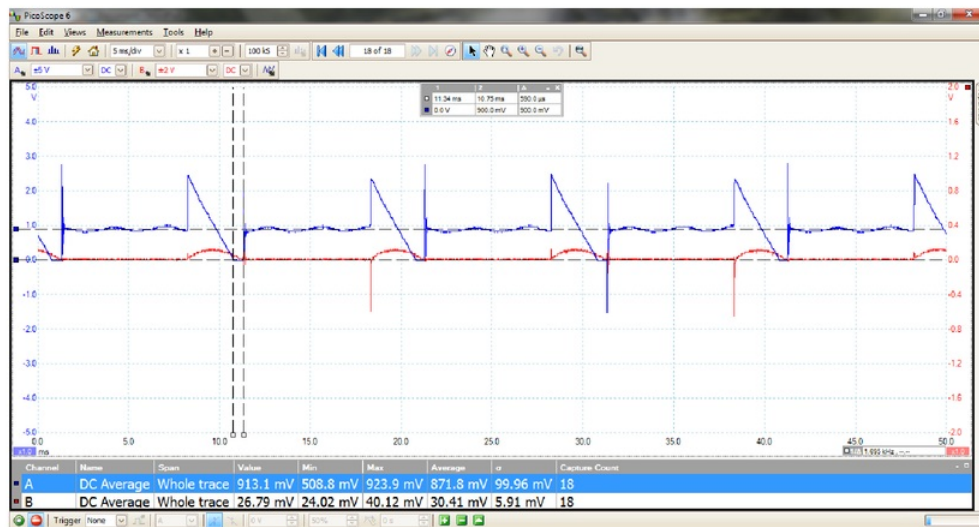


Figure 21 – Experiment 1 Current (2)

Speed = 1319 RPM

T1 = 59 micro s and Vav = 871.8 mV

Test 3 had no T1 value and therefore meant that there was no back EMF present and therefore as stated no value for T1 was obtained.

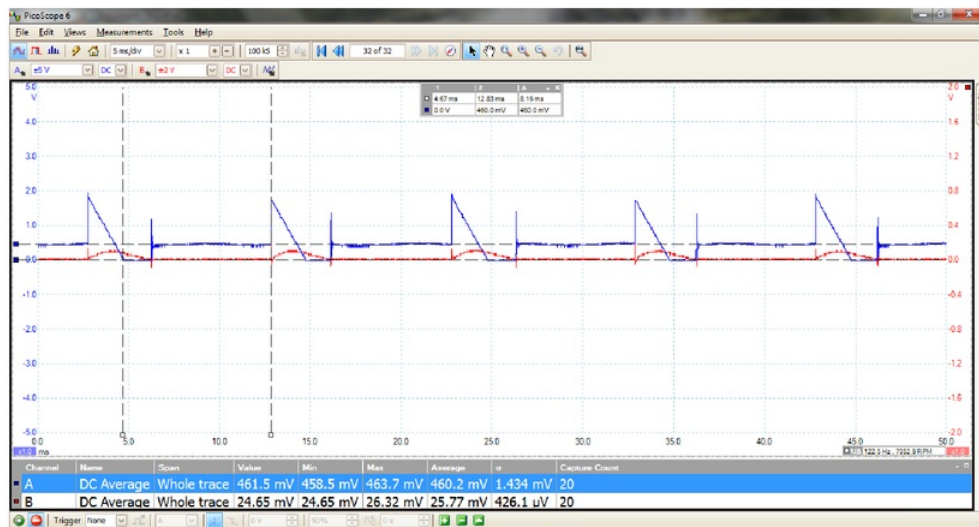


Figure 22 - Experiment 1 Voltage (1)

Speed = 651 RPM

T2 = 8.16 ms and Vav again is 460.2 mV

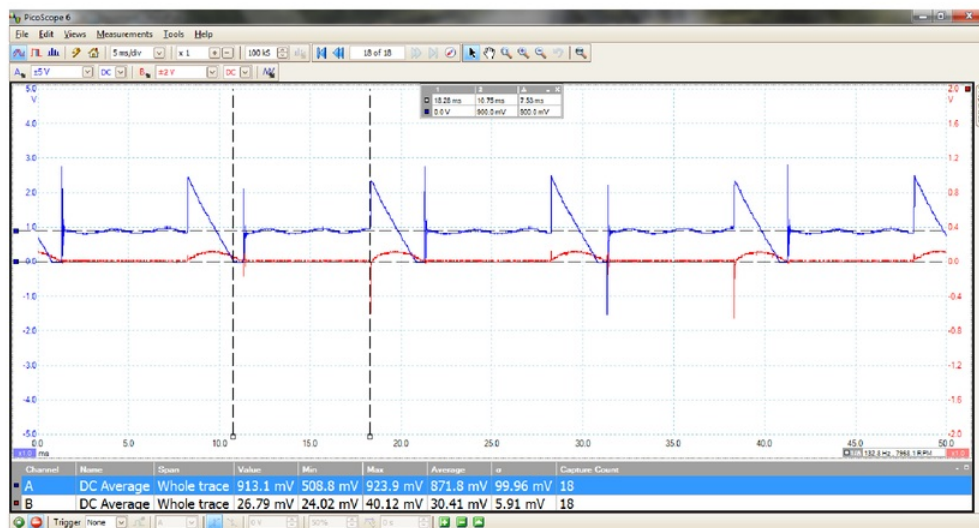


Figure 23 - Experiment 1 Voltage (2)

Speed = 1319 RPM

T2 = 7.53 ms and Vav again is 871.8 mV

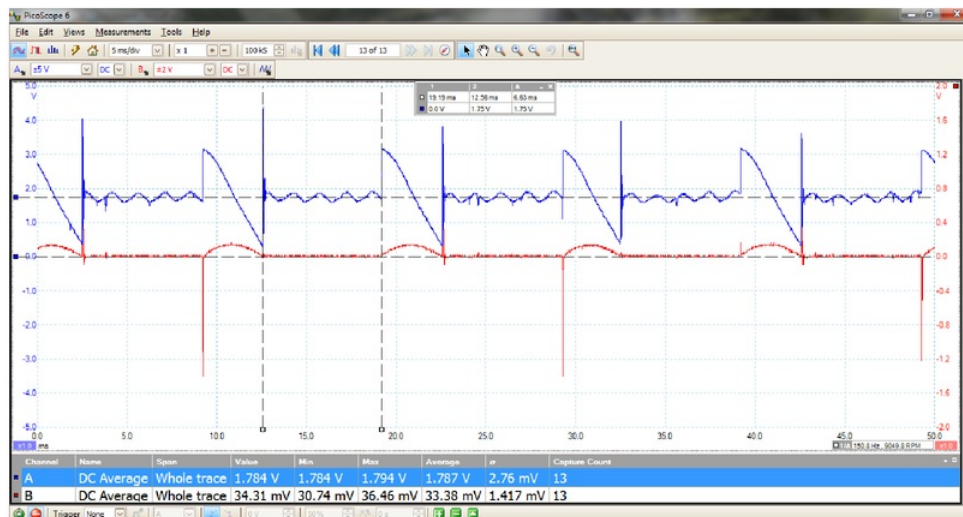


Figure 24 - Experiment 1 Voltage (3)

Speed = 2597 RPM

T2 = 6.63 ms with Vav 1.787 V

3.2 Experiment 2, Mechanical Load Conditions

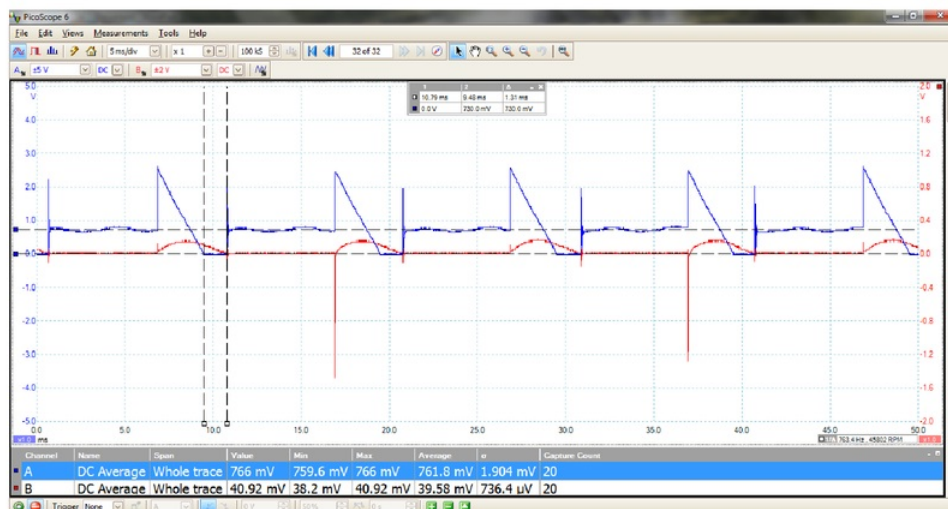


Figure 25 - Experiment 2 Current (1)

Speed = 1067 RPM

T1 = 1.31 ms and Vav 761.8 mV

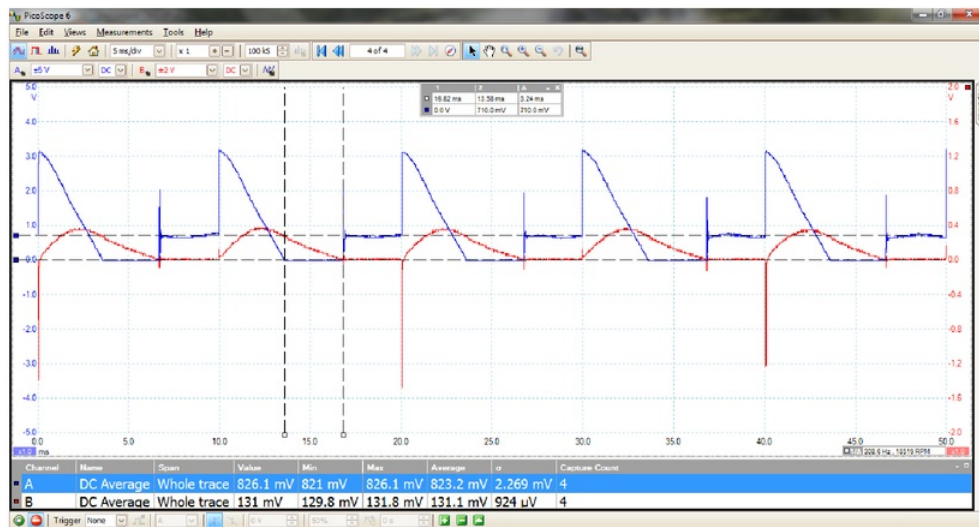


Figure 26 - Experiment 2 Current (2)

Speed = 1051 RPM

T1 = 3.24 and Vav 823.3 mV

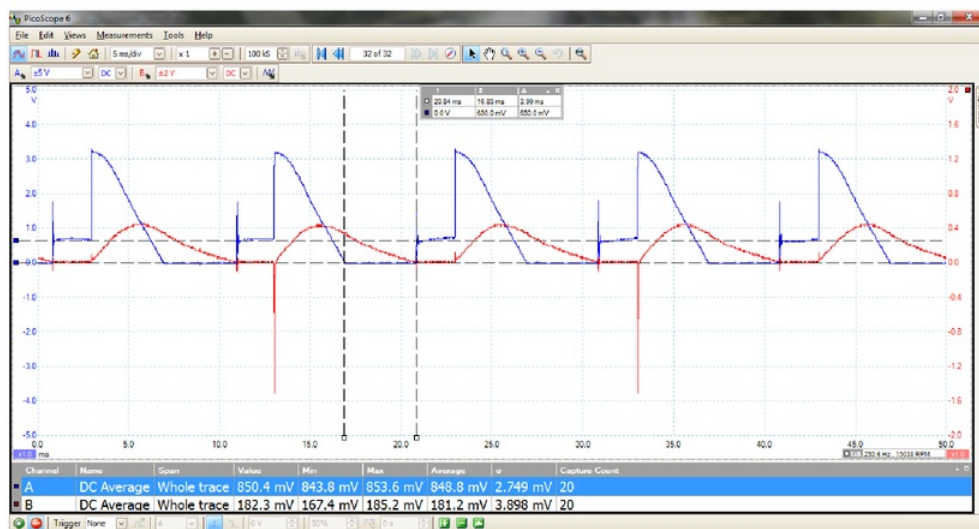


Figure 27 - Experiment 2 Current (3)

Speed = 1069 RPM

T1 = 3.99 ms and Vav 848.8 mV

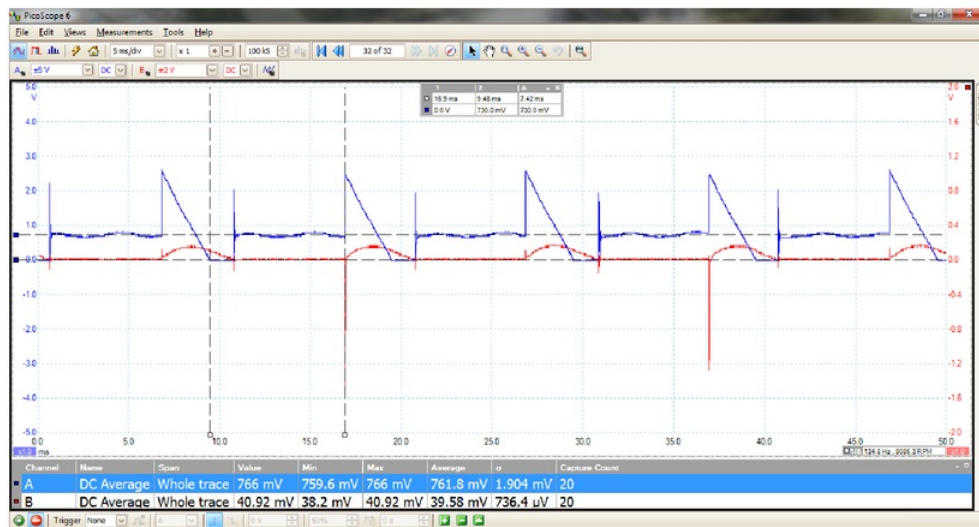


Figure 28 - Experiment 2 Voltage (1)

Speed = 1067 RPM

T2 = 7.42 ms Vav again is 761.8 mV

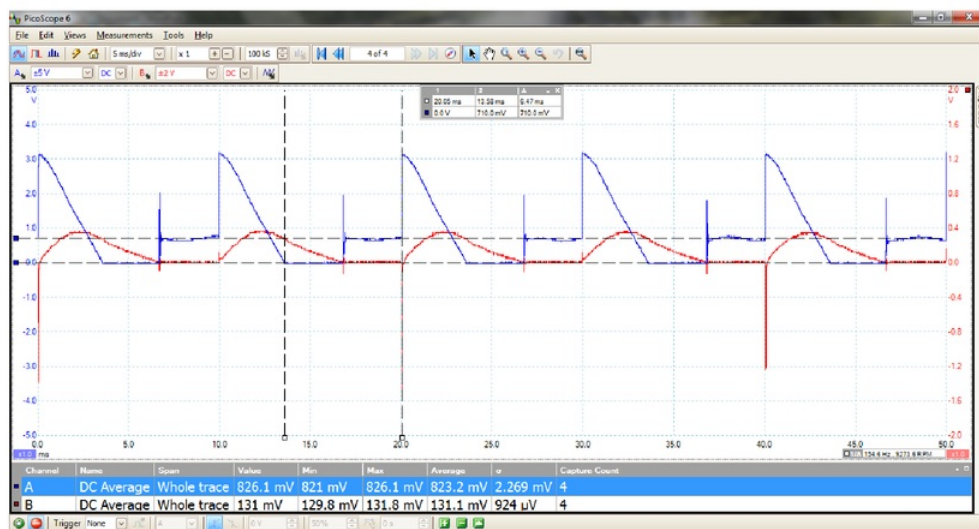


Figure 29 - Experiment 2 Voltage (2)

Speed = 1051 RPM

T2 = 6.47 Vav again is 823.2 mV

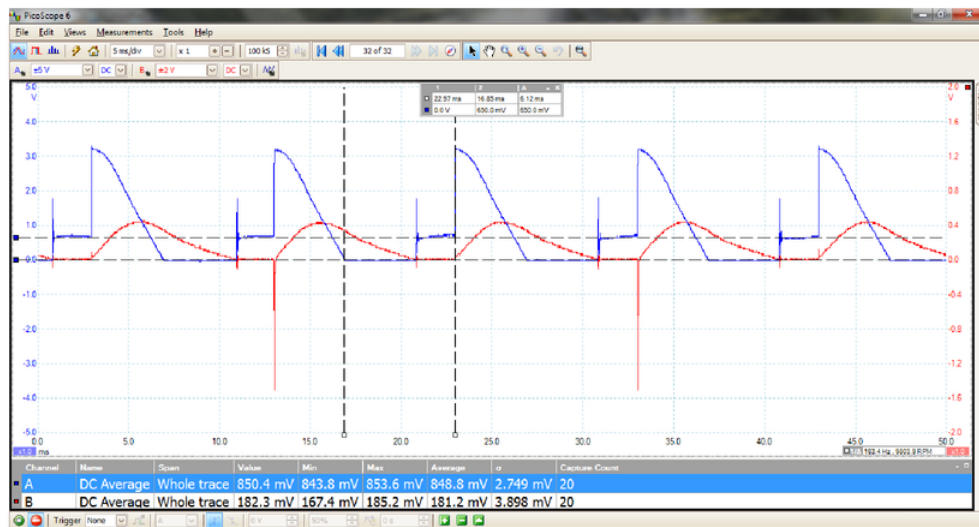


Figure 30 - Experiment 2 Voltage (3)

Speed = 1069 RPM

T2 = 6.12 ms Vav again is 848.8 mV

Experiment 1 is showing the speed increase of the motor under no-load conditions and the effect of the current and voltage for the DC output drive and the motor is working harder to increase the speed therefore increasing Vav.

Experiment 2 is showing the speed decrease by applying the prony brake to the motor and therefore the results showing the change in current and voltage for the DC output drive and the motor is working harder to keep the same speed therefore increasing Vav.

4. Conclusions and Recommendations

In conclusion the research part of the assignment has helped my understanding of the working of thyristors and DC drives in industry and how they work together by changing AC motors to DC controlled drives.

this is confusing as AC motors are not part of this assignment

This knowledge was then applied to be able to make simulations of half-controlled waveforms and full-controlled waveforms and these results were analysed and calculations were used to find out if the simulations were comparable to theory which they were and any anomalies were explained and justified. This part of my learning was successful. *but what exactly did you learn?*

The research and simulation knowledge was then transferred to the practical experiments and allowed similar results to be taken, parts of the practical results have been missed out and therefore have been more unsuccessful in learning how to compare the simulated results and practical results.

The simulated results and practical results are comparable with the simulator doing a very good job of simulating the AC motor to DC drive and how this can be controlled.

no AC motors were used in this assignment!!!!!!

Overall I have learnt what I have done in my research and have applied this knowledge practically and simulations to create results which I have understood.

Recommendations if the assignment was to be done again would be to do the simulations first then the practical as a better understanding would've been gained by doing it in this order.

5. Citation List

Works Cited

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Available at: <http://www.explainthatstuff.com/how-thyristors-work.html>

6. Appendices

Assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

52/100

PAGE 1

Text Comment. This is obviously the wrong title

PAGE 2

PAGE 3

PAGE 4

Text Comment. WHAT ABOUT DC MOTORS

PAGE 5

Text Comment. underestimate

PAGE 6

PAGE 7

Text Comment. For this to be a controlled rectifier the diodes would need to be thyristors

PAGE 8

Text Comment. The research task was to investigate full-wave, half controlled rectifier and the formula research or derived was meant to enable you to calculate the average dc voltage in the simulation and practical tasks.

Text Comment. Should be cited as Parker states that "....." (2016, page ?)

Text Comment. this is one big quote and show poor evidence of understanding

PAGE 9

Text Comment. should be cited as Processingmagazine state that "....." (2016, page ?)

PAGE 10

PAGE 11

PAGE 12

PAGE 13

Text Comment. Good formula but this was supposed to be found from the research

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

Text Comment. table of results should be present for comparisons

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

Text Comment. this is confusing as AC motors are not part of this assignment

Text Comment. but what exactly did you learn?

Text Comment. no AC motors were used in this assignment!!!!!!!

GRADING FORM: CSG-RUBIC

JOSHUA BEER**52****RESEARCH-INFORMED LITERATURE**

Section 1: Your research - Some good descriptions of thyristors given. However, this task was to investigate full-wave, half controlled rectifier and the formula research or derived was meant to enable you to calculate the average dc voltage in the simulation and practical tasks. The section on the dc drive is mainly one big quotation. (7/15) Section 5: Your use of Harvard for citing and listing - A range of sources cited and listed but not done correctly according to Harvard method. (2/5)

9**KNOWLEDGE AND UNDERSTANDING**

Section 2: Explanation of simulation circuit - Brief explanation given with good diagrams. (5/10)
Section 3: Explanation of practical circuit. Briefly described but no supporting photos or circuit diagram. (5/10)

10**ANALYSIS**

Section 2: Analysis of results from simulation –

15

Generally good results and comparisons but no table of values presented. (6/10) Section 3: Analysis of results from practical experiment – Well presented results with some comparison with theory but no calculations and little analysis. (4/10) Section 4: Overall conclusions and recommendations – Some conclusions offered, with one recommendation, but you are clearly confused about the difference between an ac motor and a dc motor. (5/10)

PRACTICAL APPLICATION AND DEP.



Section 2: Simulation – Good use of simulation software. (7/10) Section 3: Practical experiment – Good use of equipment and Picoscope software. (6/10)

13

SKILLS FOR PROFESSIONAL PRAC.



All sections – Well presented and structured. (3/5) Section 4: Team role – Briefly explained in section 3. (2/5)

5