

assignment 2

by Joseff Jones

FILE	2874_JOSEFF_JONES_ASSIGNMENT_2_157716_1866247897.DOCX		
TIME SUBMITTED	18-APR-2018 06:52PM (UTC+0100)	WORD COUNT	4237
SUBMISSION ID	86806613	CHARACTER COUNT	25480

HND Electrical and Electronic Engineering

PSDE5027 – Power & Machines
Assignment 2 – Investigation into Single
Quadrant DC Motor Drive

Joseff Jones

Date of Submission: 18/4/18

Word count: 4202

Table of Contents

1. Research.....	4
1.1 - Thyristors and their usage as controlled rectifiers	4
1.2 - Full-wave, half-controlled rectifier circuit and typical waveforms produced when connected to a DC motor together with a suitable formula for calculating average armature voltage	10
1.3 - Typical low-power DC drive such as the Parker 512C.....	12
1.4 - Applications of DC drives in industry	14
2. Simulation of a Half-Controlled Rectifier Circuit.....	15
3. Practical Investigation into a Single Quadrant DC Drive	17
4. Conclusions and Recommendations	26
5. Citation List	27

Table of Figures

Figure 1 - Thyristor on Schematic	4
Figure 2 - Layered Structure of an SCR	4
Figure 3 - SCR I-V Curve from electronicspost.com	5
Figure 4 - Symbol of TRIAC.....	6
Figure 5 - TRIAC I-V Curve from circuitstoday.com	6
Figure 6 - GTO Symbol	7
Figure 7 - GTO I-V Curve from electronicshub.org.....	7
Figure 8 - MCT Symbols from www.elprocus.com	8
Figure 9 - SCR AC Phase-Control from www.allaboutcircuits.com	9
Figure 10 - Full-Wave Full-Controlled Rectifier from www.efxkits.us	10
Figure 11 - Full-Wave Half-Controlled Rectifier from www.efxkits.us.....	10
Figure 12 - Full-Wave Half-Controlled Waveform	11
Figure 13 - Parker 512C Component Identification from parker.com	13
Figure 14 - Simulated Circuit.....	15
Figure 15 - 120V Simulated – T2	15
Figure 16 - 120V Simulated - T1	16
Figure 17 - 60V Simulated - T1.....	16
Figure 18 - Practical Build Setup	17
Figure 19 - Practical DC Drive Connections.....	17
Figure 20 - Picoscope Measurement @ 567RPM - T2	18
Figure 21 - Picoscope Measurement @567RPM - T1	18
Figure 22 - Picoscope Measurement at 1178RPM - T2.....	19
Figure 23 - Picoscope Measurement at 1178RPM - T1.....	19
Figure 24 - Picoscope Measurement at 1977RPM - T2.....	20
Figure 25 - Picoscope Measurement @577RPM @.2NM.....	21
Figure 26 - Picoscope Measurement @577RPM @.4NM.....	21
Figure 27 - Picoscope Measurement @577RPM @.6NM.....	22

1. Research

1.1 - Thyristors and their usage as controlled rectifiers

Thyristors are semiconductor switches that typically have three terminals – an anode, cathode and gate; the gate is in control of the flow of current between the anode and cathode. Thyristors also have four layers i.e. three PN junctions in series (P-N-P-N). Figure 1 shows the schematic symbol for a generic thyristor.

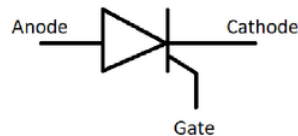


Figure 1 - Thyristor on Schematic

There are several types of thyristor, the most common of which and the ones described in detail in this report are – the SCR, the TRIAC, the GTO and the MCT.

SCRs

The SCR, or the silicon-controlled rectifier, is the most fundamental thyristor and is often what is being described when basic thyristor theory is discussed – this is because SCR is just a trade name of General Electric for the thyristor according to the (Silicon Controlled Rectifier (SCR), 2018) article. The function of the SCR is to block electrical signals going between the anode and cathode; when a small current is applied to the gate, the SCR will then turn on and allow current flow from the anode to the cathode and then latch, effectively becoming a latching diode. The SCR will latch like that until the current flowing from the anode to the cathode falls below a certain latching threshold, and it will then block current in both directions once more. According to (Hughes, 2013), the turn-off time for a thyristor is typically 100-200μs. The SCR can also turn on if the forward breakover voltage is exceeded, but it's not designed to be turned on in this way as it can damage the device. The figure below shows the layered structure of the SCR, where J1 and J3 are forward-biased P-N junctions and J2 is a reverse-biased P-N junction.

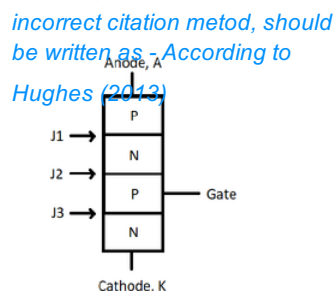


Figure 2 - Layered Structure of an SCR

The layered structure of the SCR (shown in figure 2) shows how the SCR functions – J1 and J3 are forward-biased, only allowing flow of electrons from anode to cathode, but J2 is reverse-biased, only allowing flow of electrons from cathode to anode. When a small current is applied to the gate, J2's depletion region is broken down and the SCR allows the flow of electrons from anode to cathode.

The I-V curve for the SCR can be seen in the figure below.

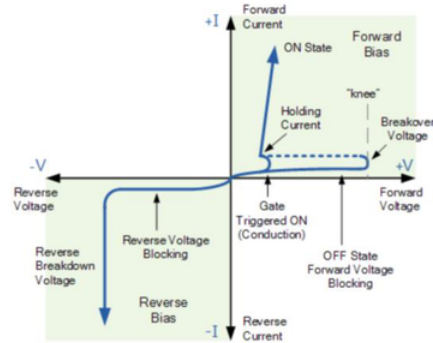


Figure 3 - SCR I-V Curve from electronicspost.com

The I-V curve for the SCR shows how the current and voltage behave through the device. The I-V curve of the SCR is similar to a normal diode, but the SCR has a forward-blocking region, which can be turned off either by the gate being triggered, or by the breakover voltage being met.

SCRs are used in several applications for their power switching capabilities – they are better than mechanical switches because they are solid-state (meaning they only use electronic components and aren't prone to the same wear that mechanical switches are) and are often more appropriate than transistors because they can handle much larger power and are generally cheaper. SCRs are not very suitable for high-frequency switching, as they are slower at switching than alternatives like MOSFETs. SCRs can also be used as controlled rectifiers for AC phase-control, which is a form of controlling the amount of voltage going into a device or system, one method of doing this is single-pulse rectification.

TRIACs

TRIACs are three-terminal devices that have similar properties to SCRs and are in effect two SCRs back-to-back, therefore the gate of the TRIAC involves using a little more current to activate compared to the SCR. TRIACs can conduct in either direction when triggered, unlike the SCR which only conducts from the anode to the cathode. Below is the symbol for a TRIAC.

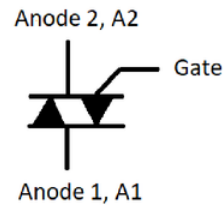


Figure 4 - Symbol of TRIAC

As can be seen from the symbol, there are two anodes (sometimes called main terminals denoted as MT) and a gate; because there are two anodes, the component is not polarised and can be connected in either orientation. The TRIAC has an advantage to the SCR for AC phase-control because it can control the entire AC wave whereas the SCR can only control half of it; the TRIAC achieves this because of its design involving two SCRs - one SCR allows the positive half of the waveform through and the other SCR allows the negative half of the waveform through. It's possible to exclusively allow one half of the waveform through for specific applications by firing the gate at specific intervals using phase-control.

The I-V curve for the TRIAC can be seen in the figure below.

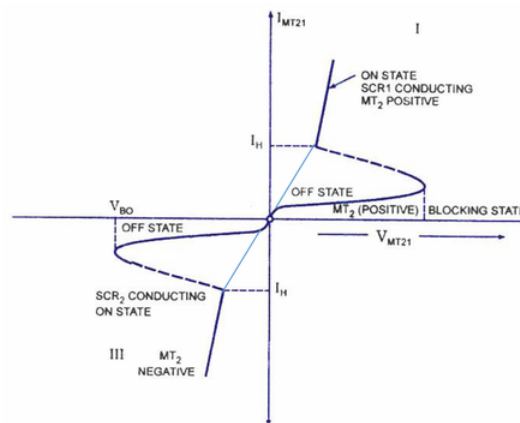


Figure 5 - TRIAC I-V Curve from circuitstoday.com

The I-V curve for the TRIAC is similar to the SCR's I-V curve, except the TRIAC can turn on in the reverse-blocking region as well as forward, either by passing the breakover voltage or by firing the gate. The TRIAC is similar to the SCR in that it will latch for as long as the current passing through the anode is above the designated latching/holding current for that particular TRIAC.

Because TRIACs can allow negative currents through as well as positive currents, they can be more useful than SCRs if the drive needs negative currents e.g. if a motor needed to turn in both directions.

GTO

The GTO (gate turn-off thyristor) is essentially an SCR in that it only conducts in one direction after a sufficient positive gate current has been injected; the difference is that the GTO can also be turned off using a negative current at the gate. The GTO has a much higher voltage drop than the SCR when it is on, but the GTO can switch much faster than the SCR. Below is the symbol for a GTO.

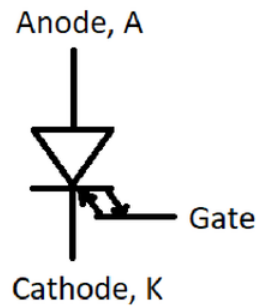


Figure 6 - GTO Symbol

The voltage and current characteristics of the GTO are similar to the SCR, but the latching current is much greater for the GTO, a higher gate current is required to turn the GTO on, and the gate pulse needs to be held longer for the GTO. Also, the “overall switching speed of GTO is faster than thyristor (SCR) but voltage drop of GTO is larger” according to (A Review on Power Semiconductor Devices, 2018). GTOs also can’t typically handle currents and voltages as great as the SCR handles.

The I-V curve for the GTO can be seen in the figure below.

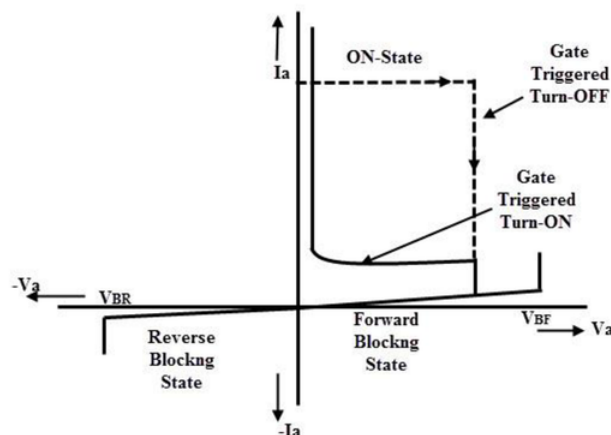


Figure 7 - GTO I-V Curve from electronics-hub.org

From the I-V curve it can be seen that the GTO can be turned off with a negative current, it can also be seen that when the gate is triggered to be turned off, the GTO blocks a positive forward voltage momentarily.

MCT

MCTs (MOS-controlled thyristors) are power switches that can turn both off and on via the gate, like the GTO. With regards to design, MCTs are effectively SCRs with two MOSFETs (metal-oxide-semiconductor field-effect transistors) attached to the gate, one for turning on and the other for turning off. There are two types of MCT – the P-MCT and the N-MCT, the symbols of which are shown below.

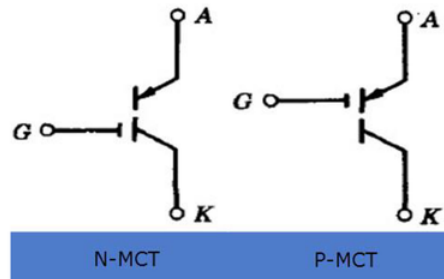


Figure 8 - MCT Symbols from www.elprocus.com

Of all the thyristors mentioned in the report, the MCT can handle the highest frequency of switching with very low switching losses; the MCT also has a relatively low forward-conduction volt-drop, much lower than the GTO's. The biggest drawback of the MCT is that it can't handle currents as large as the SCR/TRIAC or GTO can. The I-V curve for the MCT is similar to that of the GTO, as both function in a similar manner with different characteristics.

MCTs can be used in a number of applications such as circuit breakers and AC phase-control.

good explanations

Usage as Controlled Rectifiers

The thyristors mentioned above can be used as controlled rectifiers in a number of rectification circuits, a common usage of controlled rectifiers is in circuits with passive loads.

Controlled Rectification in Passive Load Circuits

Mentioned earlier in the report was single-pulse rectification (also known as half-wave rectification); the figure below shows a circuit where single-pulse rectification is exemplified on a passive circuit. The thyristor being used in the figure is a basic SCR.

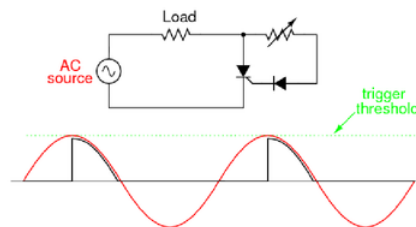


Figure 9 - SCR AC Phase-Control from www.allaboutcircuits.com

The circuit contains an AC source, a load, a potentiometer, a diode, and the thyristor; the circuit contains no active loads as “by definition, a passive load is one that contains no inherent source of energy. The simplest passive load is a resistor” - (2014, p. 516). The SCR is there to be used as both a rectifier and a switch – as the AC goes through the gate of the SCR, the SCR latches when the current is large enough and positive, and unlatches when the current going through the anode is below the latching current (the current will be positive and negative at the same time at both the anode and gate because the circuit is purely resistive). The potentiometer is what controls the switch functionality of the SCR and enables phase-control; this is because increasing the resistance will mean a greater current will reach the gate, turning the latch on sooner, and decreasing the resistance will mean less current will reach the gate, turning the latch on later – with the right potentiometer value, it’s possible to make it so that the SCR only latches when the AC is at its peak positive current value, producing the waveform seen in figure 4 and therefore reducing the amount of current going through the system – AC phase-control. The diode is there to prevent negative currents going into the SCR, as this can cause issues. This circuit gives only one peak, which is why it’s called single-pulse rectification. This type of circuit is only useful if steady DC is not required by the motor being driven which is uncommon.

1.2 - Full-wave, half-controlled rectifier circuit and typical waveforms produced when connected to a DC motor together with a suitable formula for calculating average armature voltage

Full-wave half-controlled rectifiers are an alternative to full-wave full-controlled rectifiers – the half-controlled variants lack the ability to behave as inverters as they can “supply unidirectional current with both positive and negative voltage polarity” - (Module 2 - AC to DC Converters, 2018). The need for an alternative comes from the inefficiency of full-wave full-controlled rectifiers in terms of power factor, output voltage and form factor and also from the complexity and cost of full-wave full-controlled rectifiers, even though sometimes there’s no benefit from having a full-wave full-controlled rectifier over a full-wave half-controlled rectifier. The below circuit shows a full-wave full-controlled rectifier.

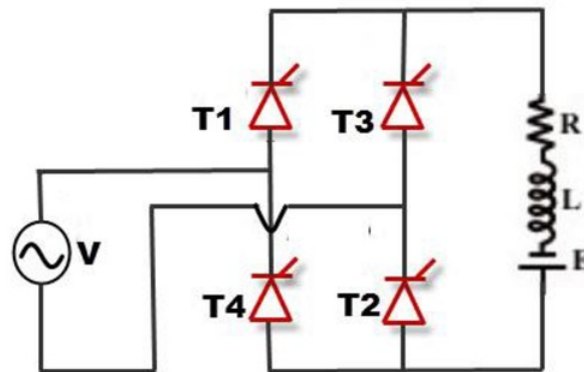


Figure 10 - Full-Wave Full-Controlled Rectifier from www.efxkits.us

In order to turn the full-wave full-controlled rectifier into the more efficient full-wave half-controlled rectifier, two of the thyristors (T4 and T2 on the diagram above) need to be replaced by diodes; seen in the figure below.

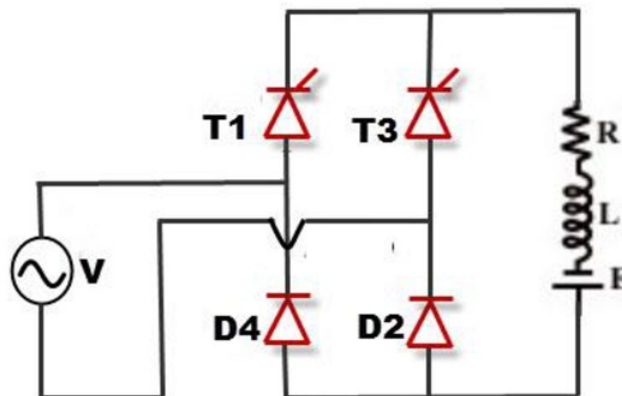
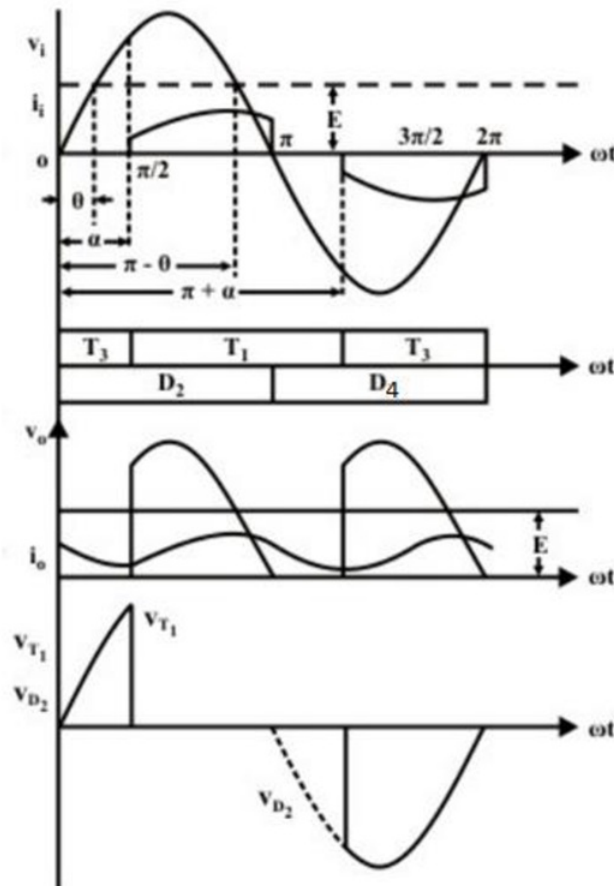


Figure 11 - Full-Wave Half-Controlled Rectifier from www.efxkits.us

good but this is not the correct configuration used in the Parker drive, T3 and D4 should be swapped to allow for a commutation path to exist to prevent load voltage from going negative.

In the half-controlled rectifier circuit, thyristor T1 and diode D2 conduct the positive half of the input voltage. By the time the supply voltage crosses from positive to negative, D4 begins conducting and commutates D2, clamping the load voltage to zero until T3 is triggered as the supply voltage goes to negative. T1 and T3 cannot be triggered at the same time, and neither can D4 or D2.

The resulting waveform for the circuit is shown below and was obtained from <http://www.nptel.ac.in>.



this waveform should also contain the back emf but since current is continuous it is correct but does not help in your explanation of the formula for average voltage where the back emf is present for discontinuous current.

Figure 12 - Full-Wave Half-Controlled Waveform

The waveforms above show the input voltage/current, when the thyristors/diodes conduct with regards to the input voltage, the output voltage and current, and the voltage in T1 and D2. What can be observed from the waveforms is that when T1D2 start conduction at $\omega t = \alpha$, the output voltage becomes equal to the input voltage. As the input voltage begins going negative, D4 begins conducting and T1 remains active as the load current commutates from D2 to D4, freewheeling through D2 into T1. The output voltage remains at zero until T3 is triggered. T3 and D4 remain on until the process repeats. From this, the output voltage can be concluded to be:

$$V_{oav} = \frac{1}{\pi} \int_0^{\pi} v_o d\omega t = \frac{1}{\pi} \int_{\alpha}^{\pi} \sqrt{2} V_i \sin \omega t d\omega t = \frac{\sqrt{2} V_i}{\pi} (1 + \cos \alpha)$$

only applies to continuous current

1.3 - Typical low-power DC drive such as the Parker 512C

Description

The practical investigation for this assignment involved the use of a Parker 512C DC drive. Low-power DC drives such as the Parker 512C are designed to be operated on single-phase mains voltage from 110-415V AC, while the Parker 512C specifically can work on either 50Hz or 60Hz. According to the product manual for the 512C (found at parker.com) the DC drive maintains the speed of the connected permanent magnet/shunt-wound DC motor using “linear closed-loop control with feedback signal from either armature voltage or tachogenerator, enabling the motor speed to be maintained under variable load conditions”. The DC drive has stall-protection that causes the controller to trip which removes all current from the connected motor after approximately 60 seconds, and fuses with overvoltage protection are installed to the field and control circuit.

Operation

The datasheet for the 512C DC drive proved invaluable when understanding the operation of the DC drive. Before operating the 512C, it's advised that the rotation of the motor is not obscured and that nobody else is using another part of the equipment. The equipment should be visually inspected for damage. To properly set-up the 512C it's advisable to first disconnect the load from the motor's shaft, rotate the rotor to ensure the tachogenerator is connected properly and shows a positive tacho feedback when it's rotated in the forward rotation and shows a negative tacho feedback when it's rotated in the negative rotation. The switches need to be checked to ensure they are in their correct states – the switches and what they control are:

SW1, SW2 – Speed range

SW3 – Tachogenerator

SW4 – Hold/run

SW5, SW6, SW7 – Current calibration

SW8 – Absolute/normalised armature current

It's also advisable to check the transformer's supply tap, check that the external set-points are all set to zero, and to check that external run contacts are open.

Once the preceding checks and preparations have been made, the DC drive can be turned on (the LED “Power On” should be illuminated). The first thing to check that the “STALL” LED isn't illuminated – if it is, the hold/run switch needs to be checked and then the stall reset needs to be triggered (switch 15). When the RUN contact is closed, the drive should be given a small speed demand of around 10% of full speed along with a small main current limit to in order to get the motor to rotate – if the motor rotates to more than 10% of full speed, the main current should be turned completely off. If this does happen and depending on the problem, the following actions should be made:

Problem	Action
Direction correct but speed is too great	Reverse tacho polarity
Direction incorrect and speed is too great	Reverse field polarity
Direction incorrect	Reverse tacho and field polarity

this is more of an instruction of how to use the drive rather than an explanation of how it works.

The next step is to increase the speed of the motor to maximum to ensure that the voltage of the armature does not exceed the motor's rating, this can be adjusted using P7 (shown on the component identification figure below). The minimum speed should then be set using P6. The potentiometer P3 should be set up to adjust the stability and improve the transient response. The armature current should be constantly monitored, ensuring steady state current does not exceed 100% of the controller rating.

Component Identification

The figure below shows the components such as switches and potentiometers for the Parker 512C – this proved useful when setting up the practical investigation.

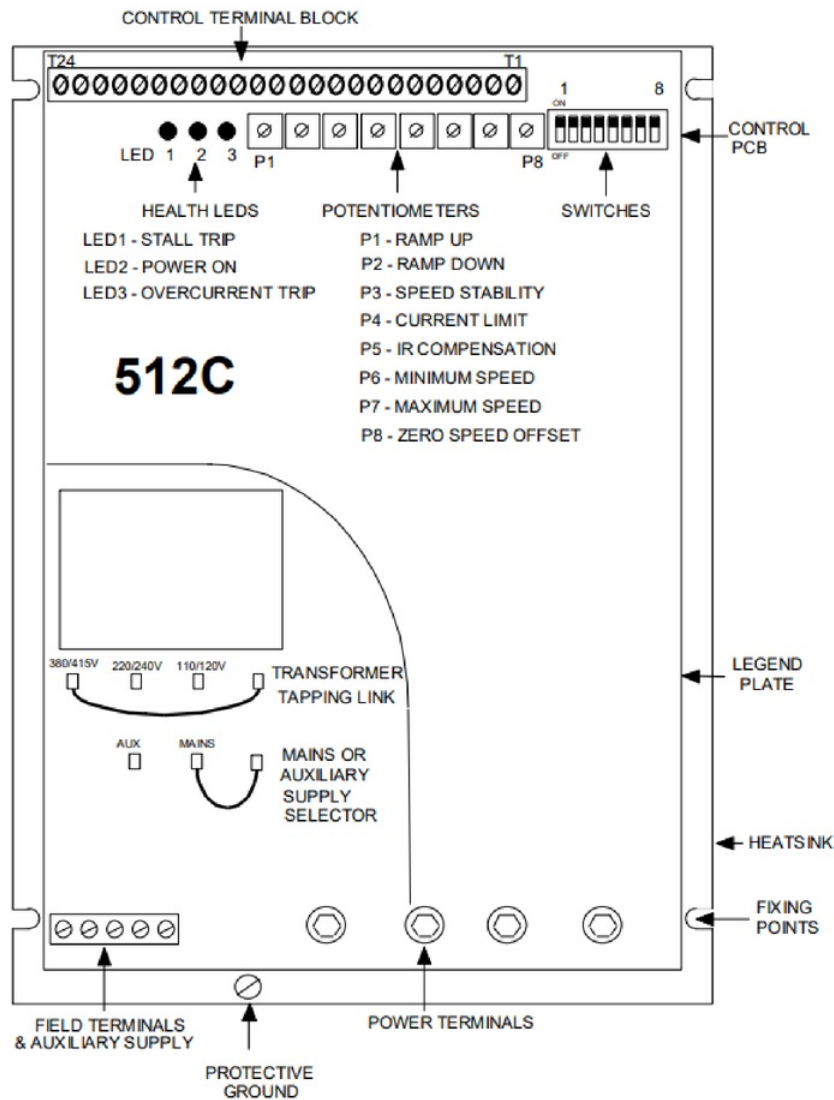


Figure 13 - Parker 512C Component Identification from parker.com

1.4 - Applications of DC drives in industry

DC drives have a very broad spectrum of uses in industry, such as synchronous motor thyristor exciters, lathes, milling machines, motor braking systems and roller tables in mills. Sprint-electric.com have a list of a large amount of applications for DC drives and where DC drives can be found in industry, some of the most common applications also included in the list are noted below.

Applications in Metal Industries

Rolling mill – requires DC drives that can handle up to 1000kW

Strip mill – requires DC drives that can handle up to 100kW

Tube mill – requires DC drives that can handle up to 300kW

Applications in the Chemical Industry

Mixers – requires DC drives that can handle up to 150kW

Extruders - requires DC drives that can handle up to 100kW

Applications involving Lifts, Hoists and Cranes

Lift & hoist – requires DC drives that can handle 3kW-60kW depending on size

Crane – requires DC drives that can handle 3kW-75kW depending on size

Applications in the Plastics Industry

Extruders – requires DC drives that can handle 5kW-400kW

Sheet Line Reeler – requires DC drives that can handle 1.5kW-15kW

2. Simulation of a Half-Controlled Rectifier Circuit

Multisim was used to simulate a half-controlled rectifier circuit that would be used to determine the behaviour of the circuit when being deployed for practical purposes. The built circuit is shown in the figure below.

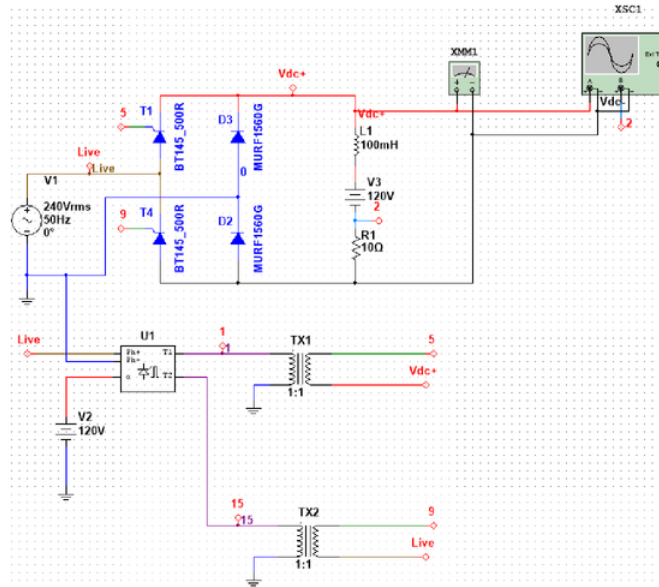


Figure 14 - Simulated Circuit

In order to simulate the circuit, the value of V3 (back-emf) was being used as a variable and an oscilloscope was used to measure T2 and T1. The first value of V3 that was measured was 120V.

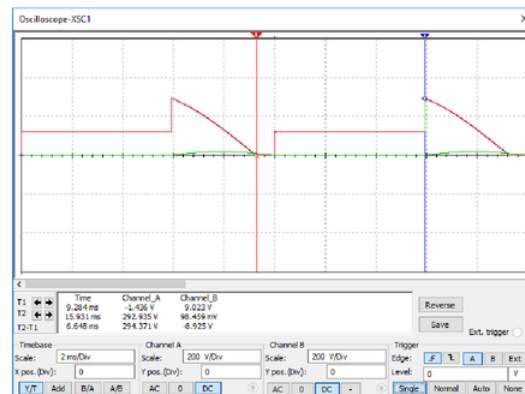


Figure 15 - 120V Simulated – T2

The value of T2 was measured by placing a cursor at the end of one pulse and the beginning of the second step up, T2 in this case was 6.648ms.

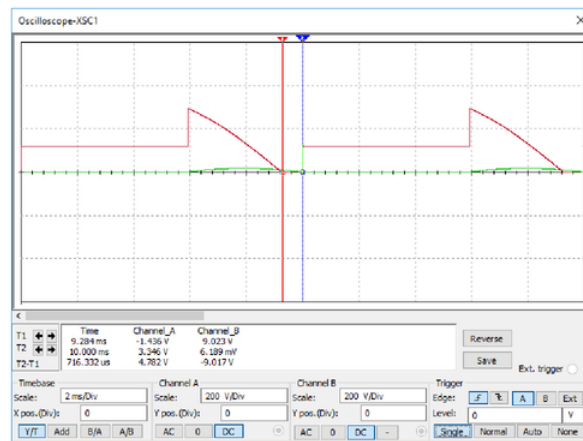


Figure 16 - 120V Simulated - T1

T1 was measured using cursors between the end of one pulse and the beginning of the next step up, T1 in this case was 716us.

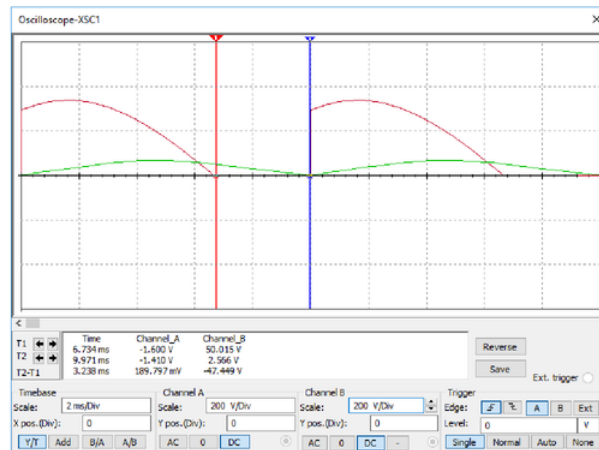


Figure 17 - 60V Simulated - T1

T2 was measured to be 3.238ms, there was no T1 in this case.

When attempting to change the firing angle of the thyristor by altering V2, Multisim would crash before anything happened. Every attempt at fixing the circuit failed, at multiple tested values.

where are your calculations of average voltage and comparisons with measured values?

3. Practical Investigation into a Single Quadrant DC Drive

For the practical investigation, two experiments were carried out – one experiment involved measuring the armature volts and determining t_1 , t_2 at no-load speed, and the next experiment involved doing the same but with a prony brake being used to apply a load. The figure below shows the setup for the overall practical.



Figure 18 - Practical Build Setup

The figure below shows the internal connections for the DC drive.



Figure 19 - Practical DC Drive Connections

While taking measurements from the motor being driven by the DC drive, Picoscope software was used to take measurements for the DC average as well as and also to produce waveforms which portrayed how the circuit was behaving. Screenshots of the Picoscope software are shown below.

No Load

At 40V, the speed of the motor was 567RPM. The figure below indicates that only 400mV was being used but that's only because the voltage was stepped down x100 before being put into the Picoscope software. T2 was measured to be 8.12ms.

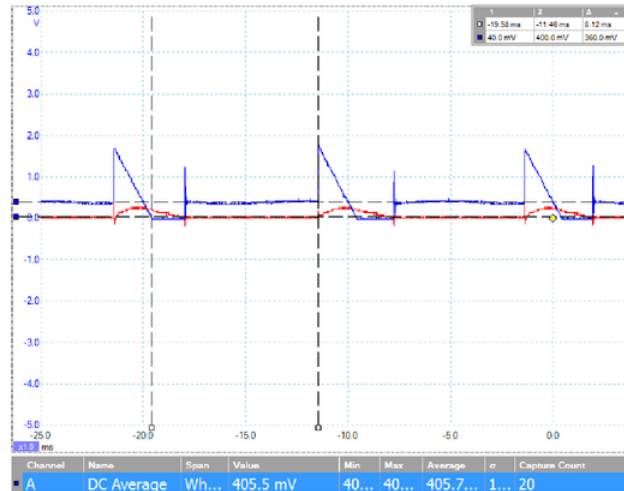


Figure 20 - Picoscope Measurement @ 567RPM - T2

T1 was measured to be 1.69ms at the same speed.

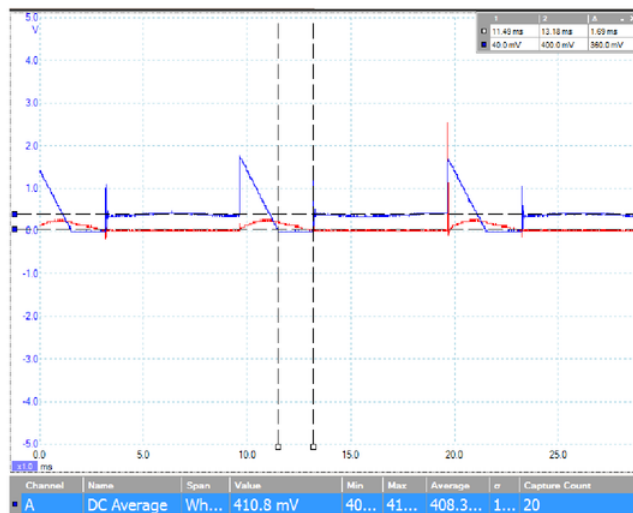


Figure 21 - Picoscope Measurement @567RPM - T1

At 80V, the speed of the motor was 1178rpm. The T2 value was measured to be 7.57ms.

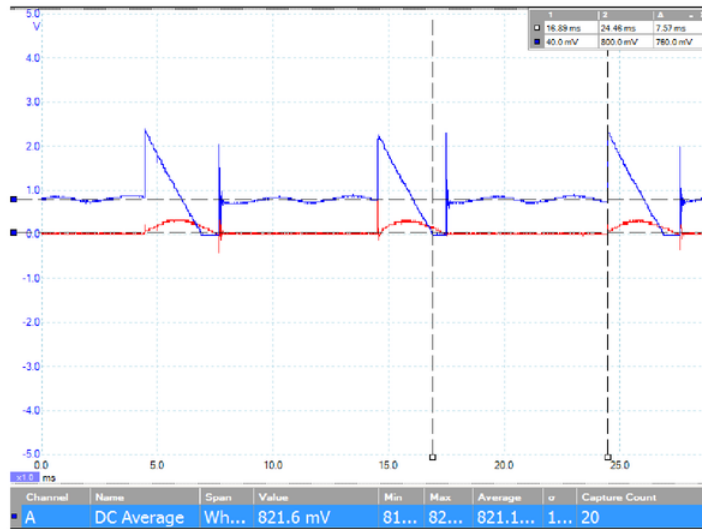


Figure 22 - Picoscope Measurement at 1178RPM - T2

The T1 value was measured to be 590us.

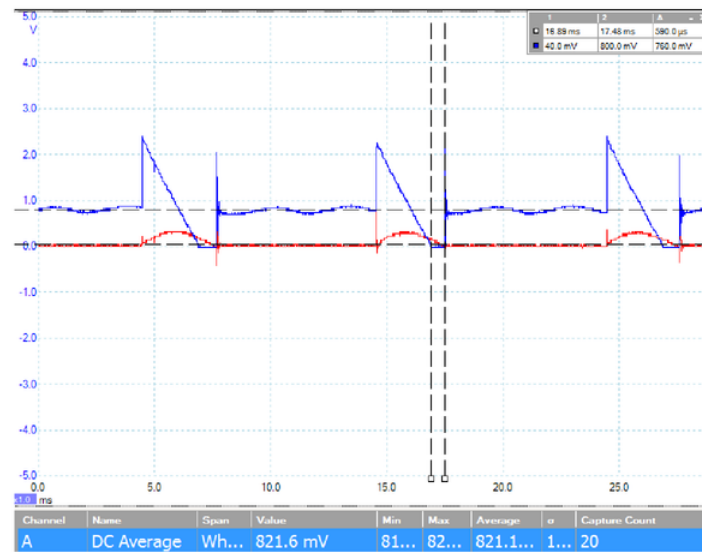


Figure 23 - Picoscope Measurement at 1178RPM - T1

At 132V, the motor was measured to be at 1977RPM. The value of T2 was 6.86ms.

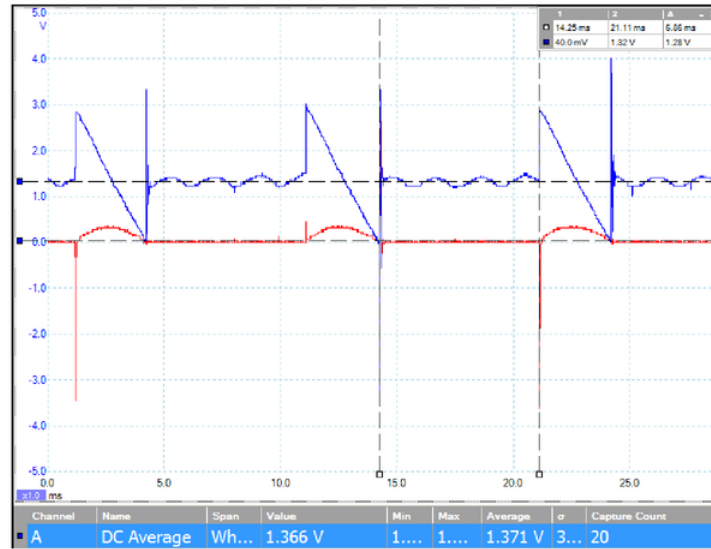


Figure 24 - Picoscope Measurement at 1977RPM - T2

T1 could not be measured.

With Brake

At 577RPM, t2 was 7.49ms @ .2NM

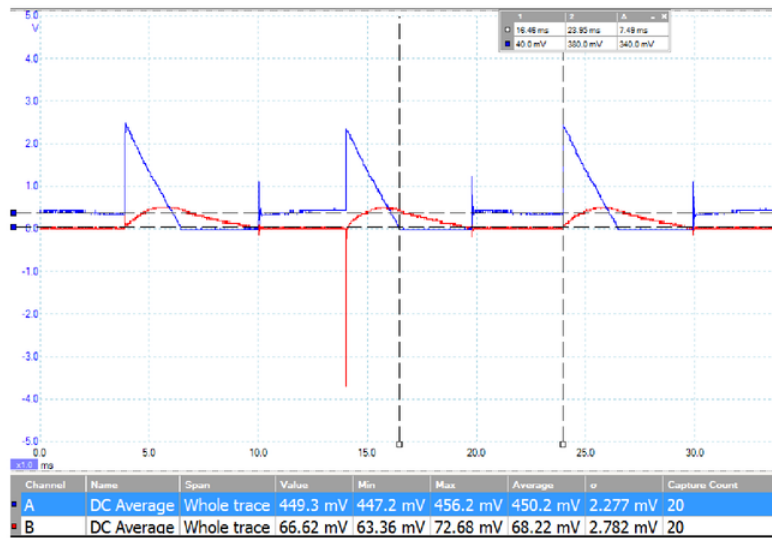


Figure 25 - Picoscope Measurement @577RPM @.2NM

At 577 RPM, t2 was 7.29ms @ .4NM

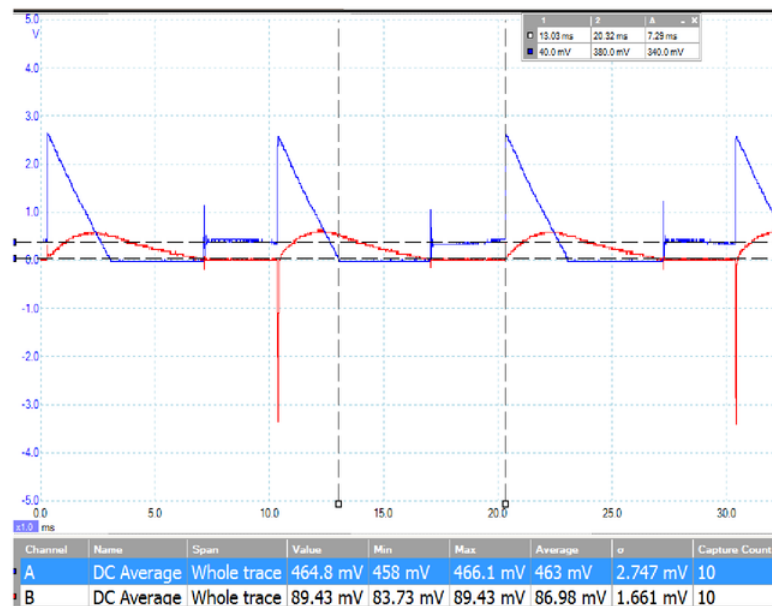


Figure 26 - Picoscope Measurement @577RPM @.4NM

@577.4 RPM, t2 was 6.9ms @ .6NM

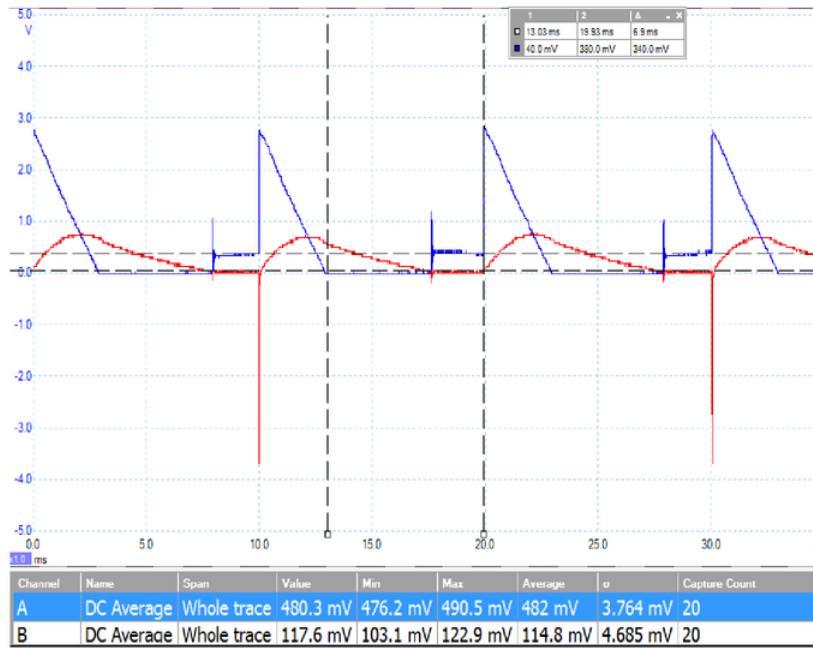


Figure 27 - Picoscope Measurement @577RPM @.6NM

Calculations were carried out using the values that were measured during the practical investigation to compare with the simulated results obtained from the Multisim circuits; the calculated results for the motor with no load are shown below.

No Load @ 567rpm

$$\text{Measured } V_{\text{mean}} = 40.6V$$

$$V_{\text{max}} = 337V$$

$$E = 40V$$

$$t_1 = 1.69ms$$

$$t_2 = 8.12ms$$

$$\beta = \frac{t_1}{10} \times \pi = \frac{1.69}{10} \times \pi = 0.531rad$$

$$\alpha = \frac{t_2}{10} \times \pi = \frac{8.12}{10} \times \pi = 2.551rad$$

$$\text{Calculated } V_{\text{mean}} = \frac{E(\alpha - \beta) + V_{\text{max}}[1 + \cos \alpha]}{\pi} = \frac{40(2.551 - 0.531) + 337[1 + \cos 2.551]}{\pi} = 44.276V$$

No Load @ 1179rpm

$$\text{Measured } V_{\text{mean}} = 82V$$

$$V_{\text{max}} = 337V$$

$$E = 80V$$

$$t_1 = 0.59ms$$

$$t_2 = 7.57ms$$

$$\beta = \frac{t_1}{10} \times \pi = \frac{0.59}{10} \times \pi = 0.185rad$$

$$\alpha = \frac{t_2}{10} \times \pi = \frac{7.57}{10} \times \pi = 2.378rad$$

$$\text{Calculated } V_{\text{mean}} = \frac{E(\alpha - \beta) + V_{\text{max}}[1 + \cos \alpha]}{\pi} = \frac{80(2.378 - 0.185) + 337[1 + \cos 2.378]}{\pi} = 85.6V$$

No Load @ 1977rpm

$$\text{Measured } V_{\text{mean}} = 137V$$

$$V_{\text{max}} = 337V$$

$$E = 132V$$

$$t_1 = 0ms$$

$$t_2 = 6.86ms$$

$$\beta = \frac{t_1}{10} \times \pi = \frac{0}{10} \times \pi = 0rad$$

$$\alpha = \frac{t_2}{10} \times \pi = \frac{6.86}{10} \times \pi = 2.155rad$$

$$\text{Calculated } V_{\text{mean}} = \frac{E(\alpha - \beta) + V_{\text{max}}[1 + \cos \alpha]}{\pi} = \frac{132(2.155 - 0) + 337[1 + \cos 2.155]}{\pi} = 138.65V$$

good work, good correlation between results

A brake was added to the motor to understand how the DC drive reacts to an added load, the measured values and their corresponding calculations are shown below.

With Brake Load @ 0.2Nm

$$\text{Measured } V_{\text{mean}} = 45V$$

$$V_{\text{max}} = 337V$$

$$E = 38V$$

$$t_1 = 0ms \quad \text{error, } t_1 \text{ had a value which you have not measured, look again at the Picoscope screen}$$

$$t_2 = 7.49ms$$

$$\beta = \frac{t_1}{10} \times \pi = \frac{0}{10} \times \pi = 0rad$$

$$\alpha = \frac{t_2}{10} \times \pi = \frac{7.49}{10} \times \pi = 2.35rad$$

$$\text{Calculated } V_{\text{mean}} = \frac{E(\alpha - \beta) + V_{\text{max}}[1 + \cos \alpha]}{\pi} = \frac{38(2.35 - 0) + 337[1 + \cos 2.35]}{\pi} = 60.31V$$

With Brake Load @ 0.4Nm

$$\text{Measured } V_{\text{mean}} = 46.3V$$

$$V_{\text{max}} = 337V$$

$$E = 38V$$

$$t_1 = 0ms \quad \text{error, } t_1 \text{ has a value}$$

$$t_2 = 7.29ms$$

$$\beta = \frac{t_1}{10} \times \pi = \frac{0}{10} \times \pi = 0rad$$

$$\alpha = \frac{t_2}{10} \times \pi = \frac{7.29}{10} \times \pi = 2.29rad$$

$$\text{Calculated } V_{\text{mean}} = \frac{E(\alpha - \beta) + V_{\text{max}}[1 + \cos \alpha]}{\pi} = \frac{38(2.29 - 0) + 337[1 + \cos 2.29]}{\pi} = 64.3V$$

With Brake Load @ 0.6Nm

$$\text{Measured } V_{\text{mean}} = 48.2V$$

$$V_{\text{max}} = 337V$$

$$E = 38V$$

$$t_1 = 0ms \quad \text{error, } t_1 \text{ has a vlaue}$$

$$t_2 = 6.9ms$$

$$\beta = \frac{t_1}{10} \times \pi = \frac{0}{10} \times \pi = 0rad$$

$$\alpha = \frac{t_2}{10} \times \pi = \frac{6.9}{10} \times \pi = 2.17rad$$

$$\text{Calculated } V_{\text{mean}} = \frac{E(\alpha - \beta) + V_{\text{max}}[1 + \cos \alpha]}{\pi} = \frac{38(2.17 - 0) + 337[1 + \cos 2.17]}{\pi} = 73V$$

if you had included a value for t1, results would be much closer

A comparison table was drawn up to compare calculated values with measured values, that table is shown below.

E (V)	t1 (ms)	t2 (ms)	α (rad)	β (rad)	Mean Voltage	
					Measured Value	Calculated Value
40	1.69	8.12	0.531	2.551	41	44.276
80	0.59	7.57	0.185	2.378	82	85.6
137	0	6.86	2.155	0	132	138.65
45	0	7.49	2.35	0	38	60.31
46.4	0	7.29	2.29	0	38	64.3
48.2	0	6.9	2.17	0	38	73

errors

The top three rows show the no-load results and the bottom three show the results with the prony brake load. T1 and T2 values were identical between calculation and measurement, and α and β values in the table were both calculated. The no-load results were very close between the calculated and measured values, but the load-speeds were different as the measured value didn't change but the calculated values did.

4. Conclusions and Recommendations

The research that was carried out at the beginning of the assignment proved useful when understanding controlled rectification and specifically full-wave, half-controlled rectification. Research into the Parker 512C DC drive proved very useful too because it gave an understanding into how the DC drive being used for the practical was set-up and how to operate it properly. The simulations carried out in Multisim were not as useful as were hoped as Multisim kept crashing when attempting to alter the firing angle; results for altering the back EMF were obtained however. The practical results were all able to be obtained and those results that were obtained corroborated with the calculated results – the only discrepancies were with the measured/calculated mean voltages from the motor, which could be due to the calculations not accounting for the load. The practical results were obtained as a team of three, where one member took screenshots of the Picoscope software, another wrote measured values and another took the frequency of the motor.

I have no recommendations, other than the distribution of student edition Multisim keys to allow students to access Multisim at home in order to have more time with figuring out problems that might occur.

5. Citation List

A Review on Power Semiconductor Devices. (2018, 3 28). Retrieved from allaboutcircuits.com:
<https://www.allaboutcircuits.com/technical-articles/a-review-on-power-semiconductor-devices/>

Hughes, A. (2013). *Electric Motors and Drives*. Oxford: Elsevier Ltd.

Module 2 - AC to DC Converters. (2018, April). Retrieved from <http://www.nptel.ac.in>:
[http://www.nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Power%20Electronics/PDF/L-11\(DK\)\(PE\)%20\(\(EE\)NPTEL\).pdf](http://www.nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Power%20Electronics/PDF/L-11(DK)(PE)%20((EE)NPTEL).pdf)

Parker 512C Product Manual. (2018). Retrieved from Parker.com:
<https://www.parker.com/literature/SSD%20Drives/DC%20Drives/HA389196.pdf>

Silicon Controlled Rectifier (SCR). (2018, March 28). Retrieved from electrical4u.com:
[https://www.electrical4u.com/silicon-controlled-rectifier-\(scr\)/](https://www.electrical4u.com/silicon-controlled-rectifier-(scr)/)

Where are DC drives used in industry? (2018). Retrieved from Sprint Electric: <https://www.sprint-electric.com/wp-content/uploads/2017/11/3119-SPR-WhereDrivesAreUsed-FIN.pdf>

Wildi, T. (2014). *Electrical Machines, Drives and Power Systems*. Essex: Pearson Education Limited.

assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

44/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

Text Comment. incorrect citation metod, should be written as - According to Hughes (2013)

PAGE 5

PAGE 6

Text Comment. good explanations

PAGE 7

PAGE 8

Text Comment. good explanations

PAGE 9

PAGE 10

Text Comment. good but this is not the correct configuration used in the Parker drive, T3 and D4 should be swapped to allow for a commutation path to exist to prevent load voltage from going negative.

PAGE 11

Text Comment. this waveform should also contain the back emf but since current is continuous it is correct but does not help in your explanation of the formula for average voltage where the back emf is present for discontinuous current.

Text Comment. only applies to continuous current

Text Comment. this is more of an instruction of how to use the drive rather than an explanation of how it works.

Text Comment. where are your calculations of average voltage and comparisons with measured values?

Text Comment. good work, good correlation between results

Text Comment. error, t1 had a value which you have not measured, look again at the Picoscope screen

Text Comment. if you had included a value for t1, results would be much closer

Text Comment. error, t1 has a value

Text Comment. error, t1 has a vlaue

Text Comment. errors

JOSEFF JONES**44****RESEARCH-INFORMED LITERATURE**

Section 1: Your research - a good section showing a wide range of research. However, the circuit is not quite correct and the formula is incomplete as it only applies to continuous current. (10/15) Section 5: Your use of Harvard for citing and listing - A range of source used but not always cited correct and not listed using the Harvard method. This option must be switched on within MS Word. (1/5)

11**KNOWLEDGE AND UNDERSTANDING**

Section 2: Explanation of simulation circuit - Briefly stated but little explanation given. (3/10) Section 3: Explanation of practical circuit. Briefly outlined with supporting photos (4/10)

7**ANALYSIS**

Section 2: Analysis of results from simulation – Some good results but no calculations and no comparisons made. (3/10) Section 3: Analysis of results from practical experiment – Good presentation of results and half calculated values are correct but half are not due to assumption that t_1 was zero which is not true. (5/10) Section 4:

12

Overall conclusions and recommendations – Some conclusions offered but should be more specific and less subjective. (4/10)

PRACTICAL APPLICATION AND DEP.



Section 2: Simulation – Good use of software but task is incomplete. (4/10) Section 3: Practical experiment – Good use of equipment and Picoscope software but not all values have been recorded. (5/10)

9

SKILLS FOR PROFESSIONAL PRAC.



All sections – Well structured and presented. (4/5)
Section 4: Team role –Brief mention made (1/5)

5