

PSDE6016 - Assignment 1

Kristian Payne

by Kristian Payne

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Prifysgol Cymru
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University of Wales
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BSc (Hons) Electrical and Electronic Engineering
PSDE6016: Power Electronics and Drives
Assignment: Investigation into DC Drives and Control
Methods

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1. RESEARCH

Ward Leonard system

The ward Leonard system was one of the earliest types of VSD (Variable speed drive). It is supplied by a 3 phase AC supply that is directly connected to a 3 Phase AC induction motor. The motor directly drives a separately excited DC generator which provides a variable voltage to a shunt wound DC motor which in-turn drives a machine. The output voltage of the generator controls the speed of the DC motor. This type of VSD system is not commonly found in industry *any more* due to high maintenance costs and high start-up costs. It was frequently used for applications that required good torque control due to its speed and torque properties. (Barnes 2003)

Modern DC drives

One of the biggest differences from the Ward Leonard system to a modern DC drive is related to the technique in which the variable voltage is generated from a 3 phase AC Supply. In modern DC drives AC is converted to DC using controlled rectification, achieved by a thyristor bridge circuit (commonly a 12-pulse bridge to reduce harmonics in the AC supply). The average value of the rectified voltage can be varied by adjusting the firing angle of the thyristors.

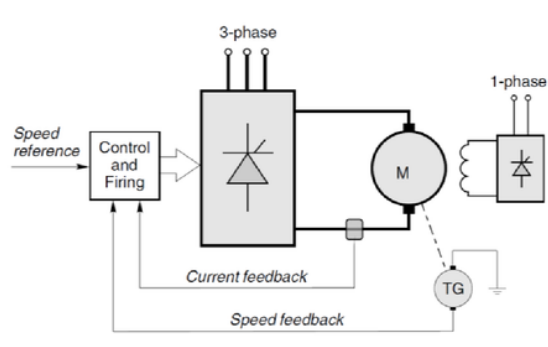


Figure 1: Block Diagram of a modern DC drive (Hughes, 2006, Elsevier).

Analog DC Drives

When using an analog DC drive, the required motor velocity is input into the drive as a speed reference, which is normally a voltage of $\pm 10\text{V}$ (Powerflex Digital DC Drive, 2017). This voltage is normally controlled by a potentiometer. In most examples this can make it quite simple to tune and adjust an individual Analog DC drive, but when this method must be used for several drives that all require the same tuning parameters or adjustments it can take a substantial amount of time. (control, 2004)

Digital DC Drives

Tuning and adjustment on a digital DC drive can also be achieved by using a potentiometer to control the speed reference voltage between $\pm 10\text{V}$. This method still has the same disadvantages as an analog drive. Two common methods of controlling digital drives are: using the drives keypad or using a PLC. Many digital drives can be fitted with a keypad. A Parker DC590+ drive can be fitted with a 6901 keypad that monitors and provides local control of the drive. Diagnostic information can be viewed, parameters can be changed, and the motor can be started or stopped just by using the 6901 keypad. The Keypad can be mounted to the front of the drive or can be remotely mounted. This is a very simple and cost-effective method of controlling the drive due to not needing any other equipment (Parker Hannifin Manufacturing, 2016)

A PLC can output an analog voltage to control the speed reference, but the superior use of a plc would be to connect it to the drive using a communications interface protocol such as fieldbus. Fieldbus is a group of industrial network protocols which are used for real time control (Hittanagi et al., 2017). Multiple devices can be connected to a fieldbus network and can all be controlled from one station. An engineer could tune and adjust multiple drives at a

time over the fieldbus network and fault find and diagnose problems on multiple drives at a time that could be in different parts of a factory.

Analog vs digital DC Drives

Analog drives commonly have a lower price and have great performance when using tach feedback. Digital drives are costlier, but: are easier to set up, can be adjusted quickly with parameters copied to multiple units, are more flexible, have better diagnostic capabilities and can dynamically tune compared to analog drives. (Drive technologies - Engineering Reference, 2005)

Single and three Phase DC Drives

Generally, single phase power is suitable for running a motor below 5 horsepower. Anything above that then three phase power is typically used. Single phase motors draw significantly more power than a similar three phase motor. This makes a three-phase motor a more efficient choice for many applications. When selecting a DC drive for an application it is important to analyse each available option. During analysis, the performance parameters of a circuit are very important. The performance parameters that are normally inspected are:

Rectifier efficiency, motor efficiency, ripple factor, form factor.

Firing angle(deg)	0	30	45	60	90
Rectifier efficiency(%)	80.02	76.67	71.21	67.60	57.21
Form factor	1.125	1.157	1.219	1.277	1.555
Ripple factor	0.615	0.682	0.699	0.793	1.184
Motor efficiency(%)	82.34	81.07	78.66	76.14	64.83
Voltage THD	0.35	0.36	0.37	0.43	0.54
Current THD	0.148	0.152	0.142	0.127	0.197

Figure 2: Performance parameters of a single-Phase full wave-controlled rectifier (Tariq et al., 2012,).

Firing angle(deg)	0	30	45	60	90
Rectifier efficiency	99.62	95.25	89.62	79.56	17.23
Form factor	1.001	1.017	1.048	1.135	4.960
Ripple factor	0.0421	0.1840	0.3129	0.5362	4.858
Motor efficiency	97.36	96.93	96.09	94.46	57.35
Voltage THD	0.994	0.887	0.797	0.778	0.750
Current THD	0.164	0.183	0.212	0.285	0.262

Figure 3: Performance parameters of a three-Phase full wave-controlled rectifier (Tariq et al., 2012,).

A conference paper on the analysis of a thyristor-controlled DC Drive (Tariq et al., 2012), compares the performance parameters of a single-Phase and three-phase full wave-controlled rectifier fed DC motor (see Figure 2 and 3). On comparing the data from Figure 2 and 3, the three-phase full wave-controlled rectifier Fed DC motor has superior rectifier efficiency, form factor, ripple factor and motor efficiency when having a firing angle of 60 degrees or less, with the single phase having better performance parameters at a firing angle of 90 degrees. This shows that the three-phase full wave-controlled rectifier circuit would have a higher ratio of power converted from AC to DC, would have a higher quality output power and the motor would have a greater ability to convert electrical energy into mechanical energy when the circuit has a firing angle of 60 degrees or less.

In conclusion, the research has shown that a Three Phase full wave digital DC drive would be highly superior in multiple industrial applications.

3 SIMULATION

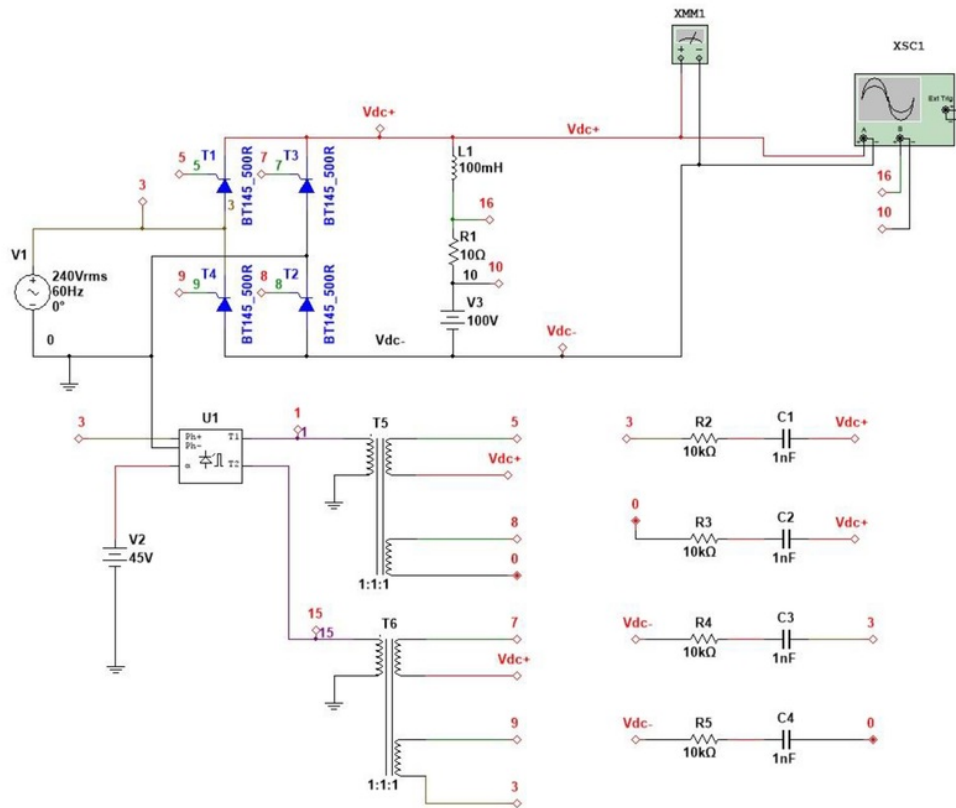
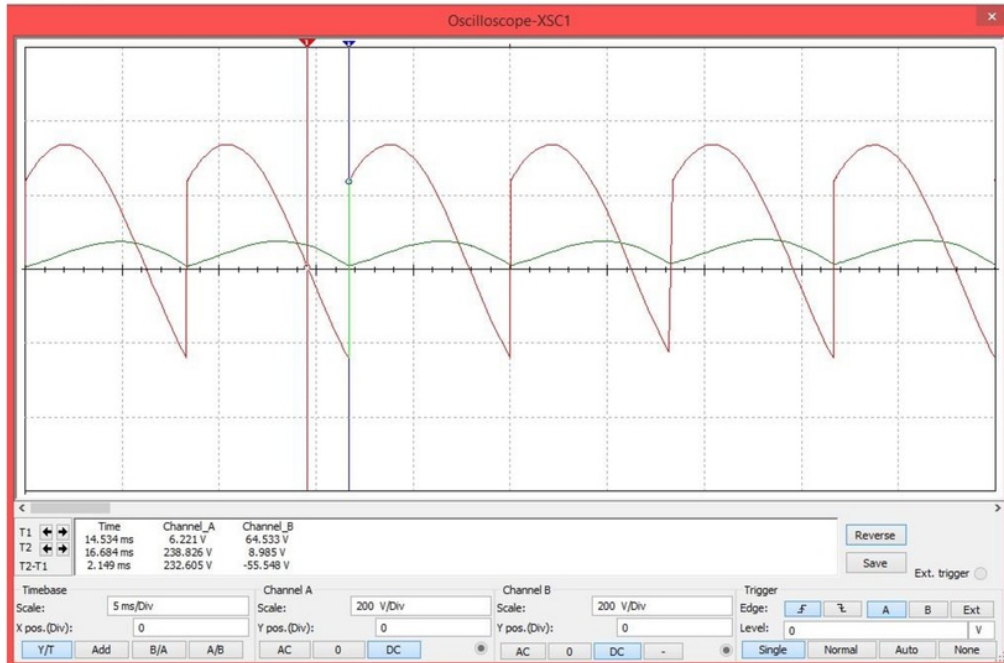


Figure 4: Multisim circuit

The circuit in figure 4 was built and simulated functioning on Multisim. It is a Single-Phase full wave fully-controlled rectification circuit with an inductive load and EMF to model the effects of a DC motor. Thyristors T1 and T2 are fired at an angle α and thyristors T3 and T4 are fired together at angle $\alpha + \pi$. The thyristors are fired by phase angle controller U1 with the firing angle being the same as the input voltage, the V_{mean} value is measured by multi-meter XMM1 and the output waveform is measure by oscilloscope XSC1.

Firing angle
339.411



(Lander, 1994)

4. PRACTICAL EXPERIMENTS



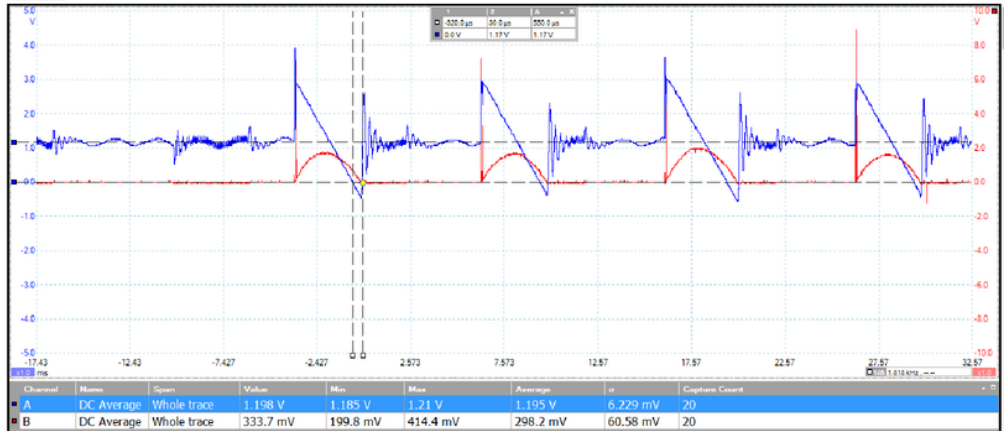
Voltage	Set Speed	Current
	2	-1A
	4	-1A
103V	5	-1A
69V	6	-3.3A
Unrecordable	10	-3.5A

Voltage	Load	Current
119V		0.26A-0.29A
126V	0.6NM	1.1A
129V	1NM	2A
131V	1.5NM	3A
118V	2NM	5A

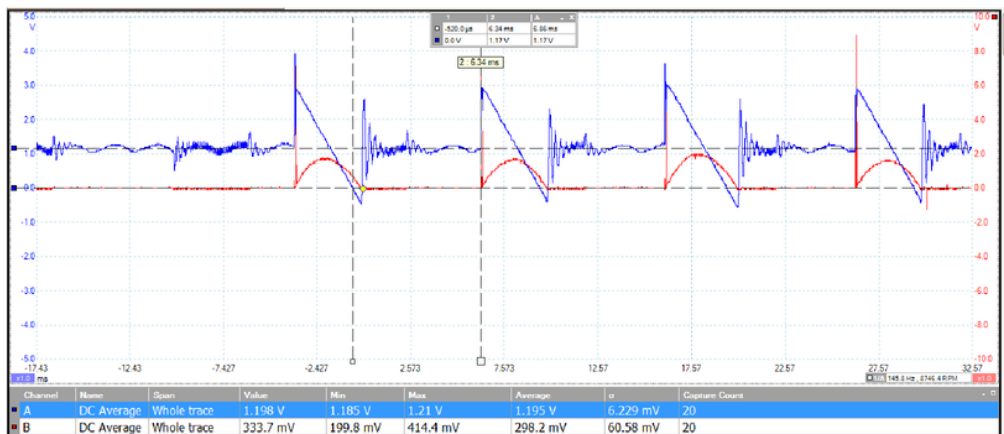
3.1 PART A –

Discontinuous Current in Forward Direction

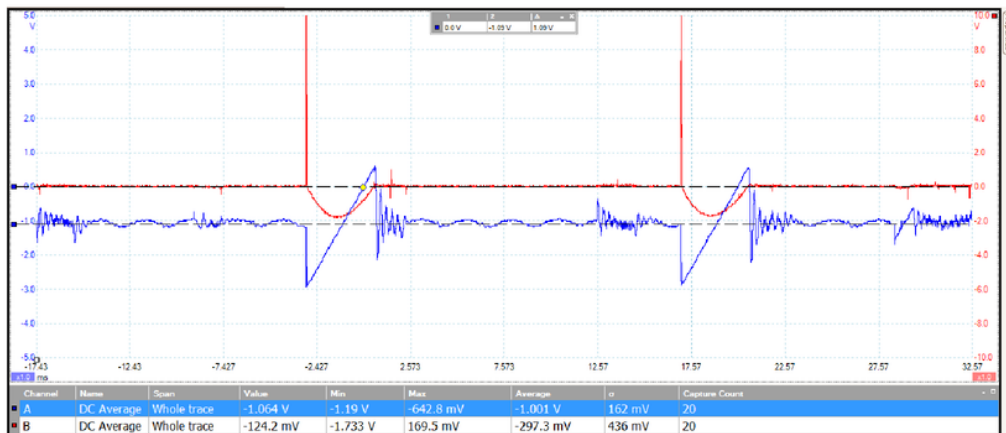
Beta



Alpha



Discontinuous Current in reverse Direction

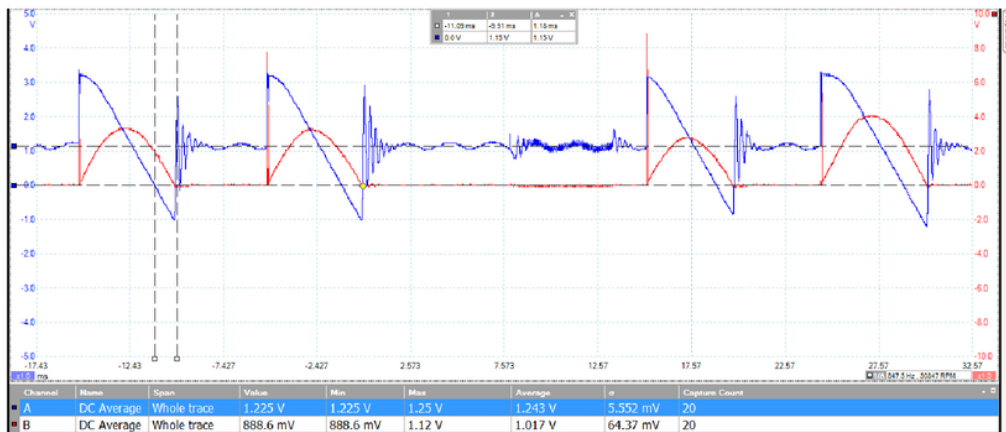


PART B –

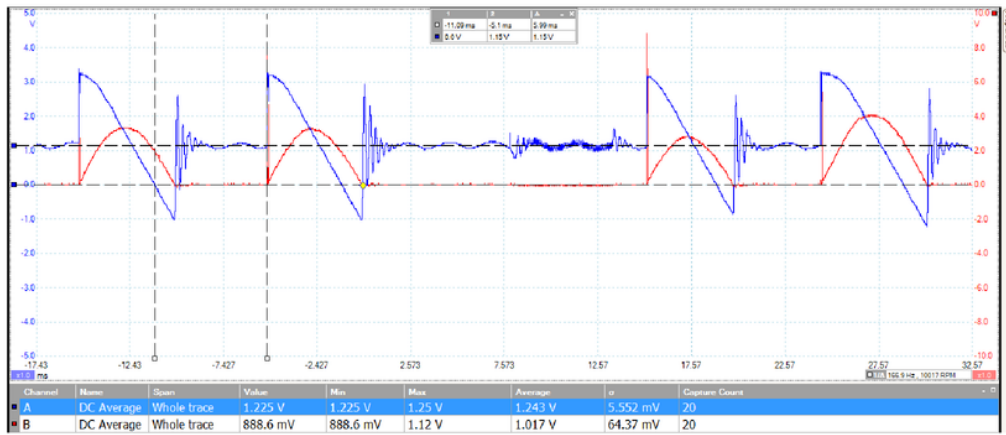
Applying 3 Different Loads to 1 Speed Setpoint

Load 1 = 0.6Nm

Beta

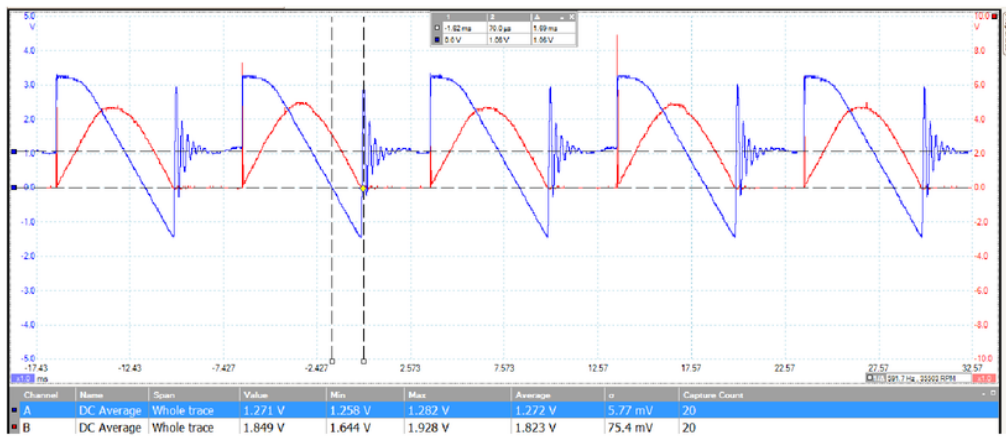


Alpha

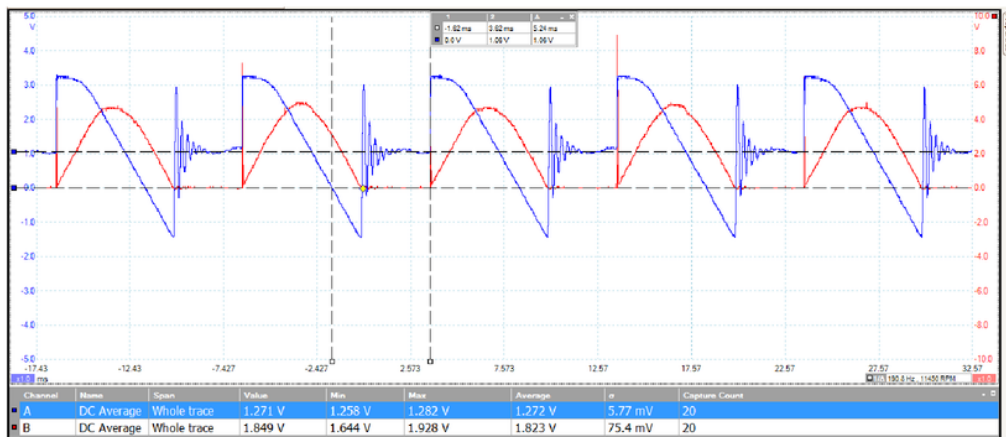


Load 2 = 1Nm

Beta

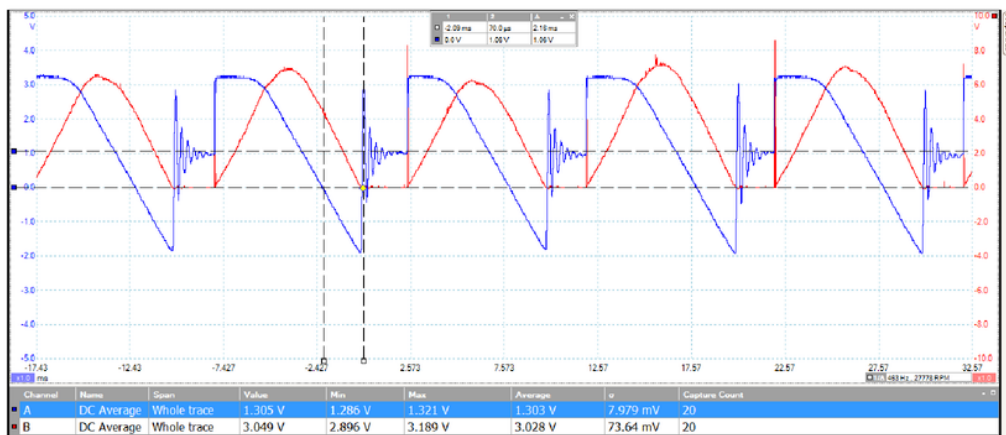


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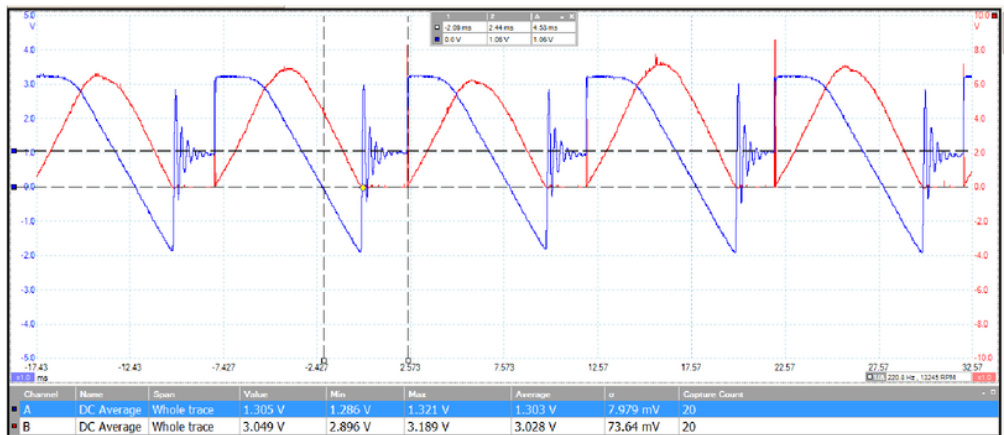


Load 3 = 1.5Nm

Beta

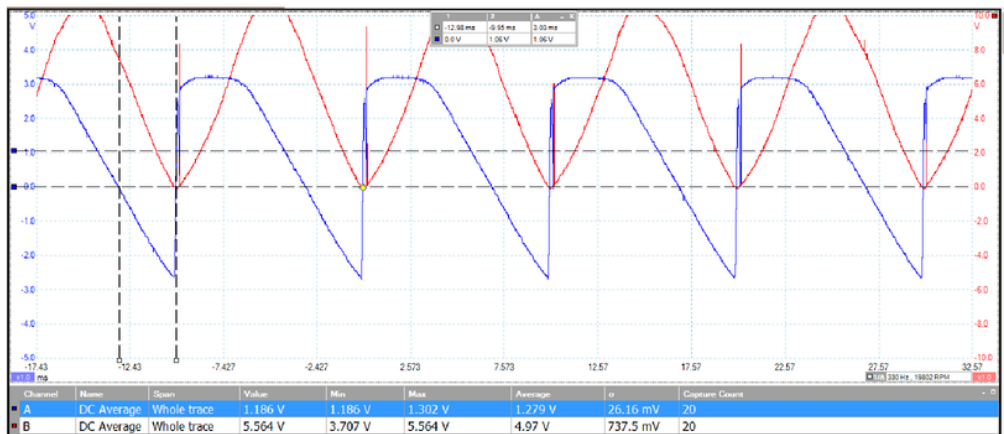


Alpha



Load = 2Nm

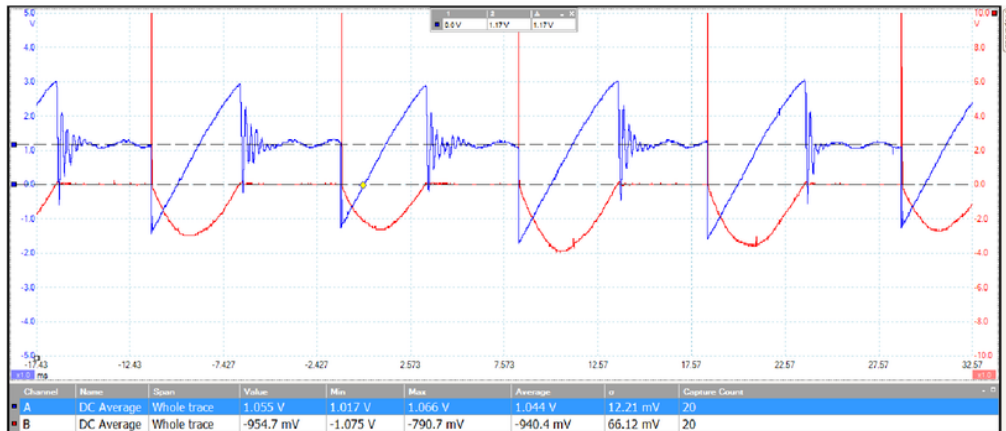
Alpha



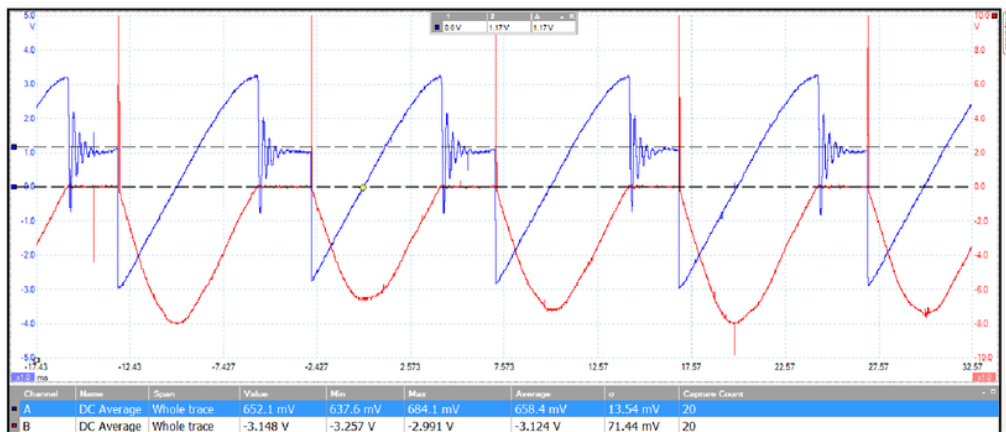
PART C –

Switching on the Feedback VSD Drive

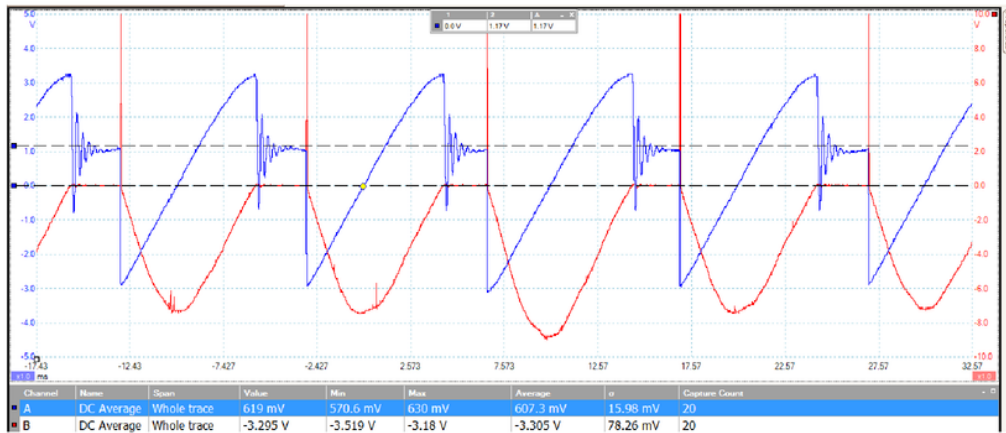
VSD Speed Setting = 5



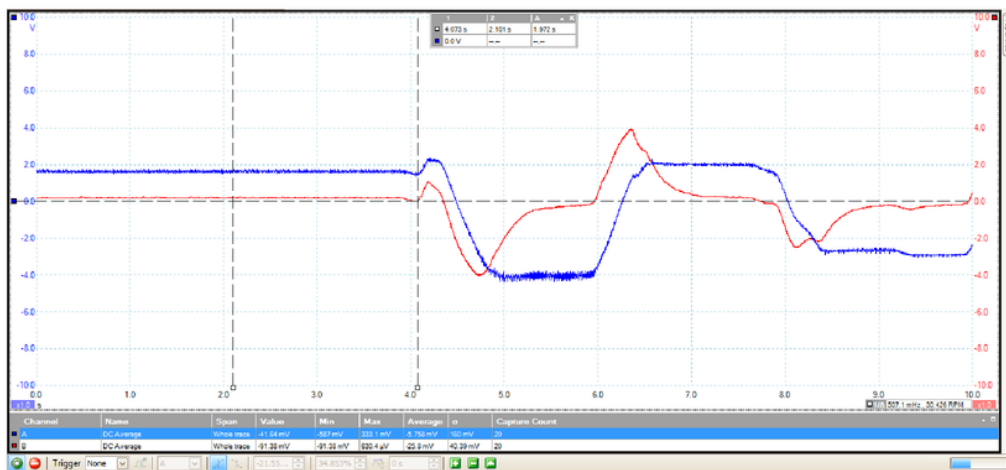
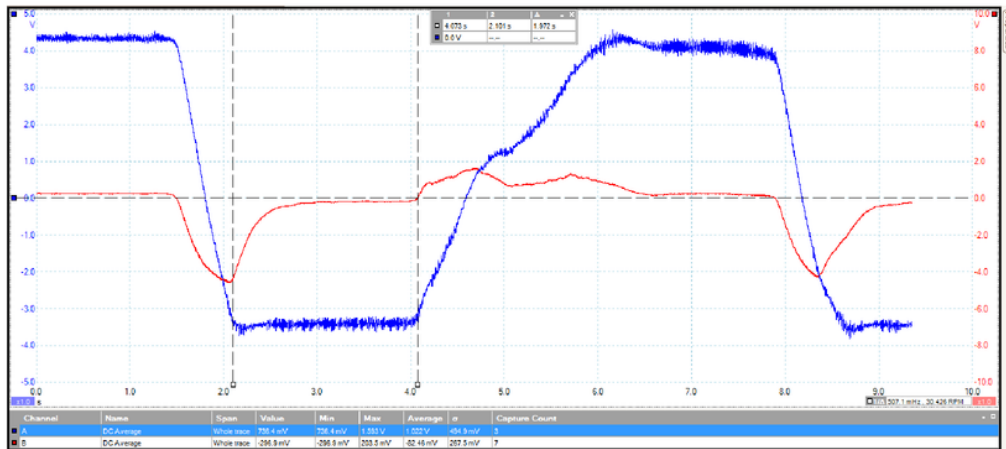
VSD Speed Setting = 6

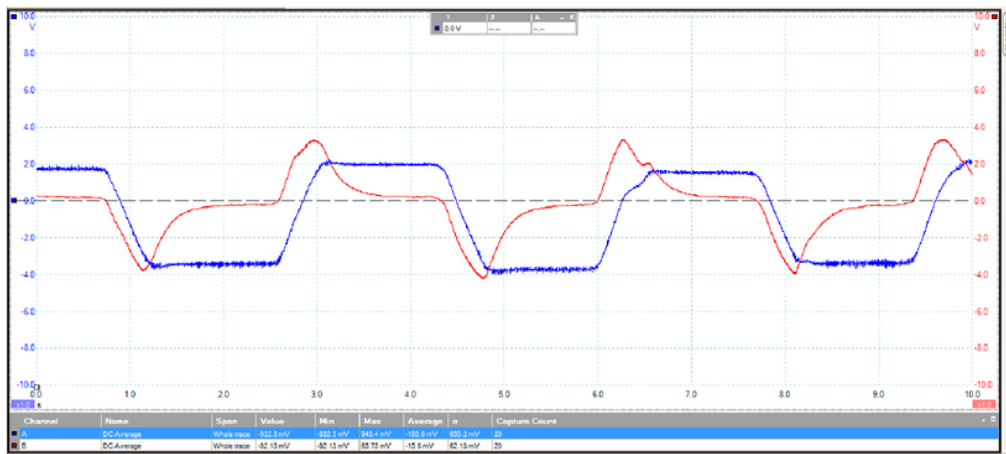
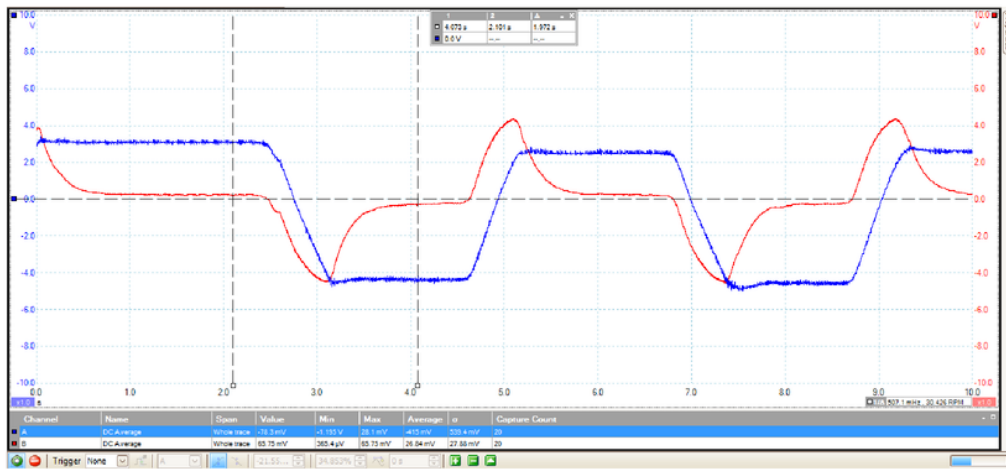


VSD Speed Setting = 7



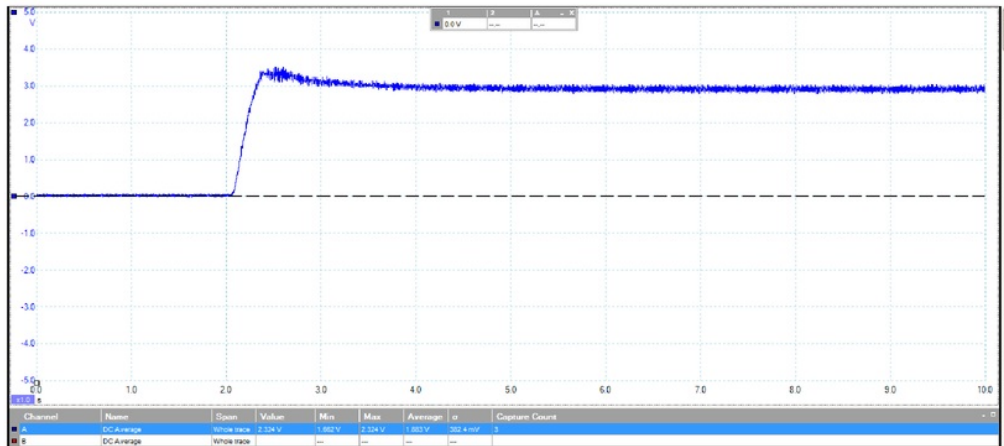
PART D -



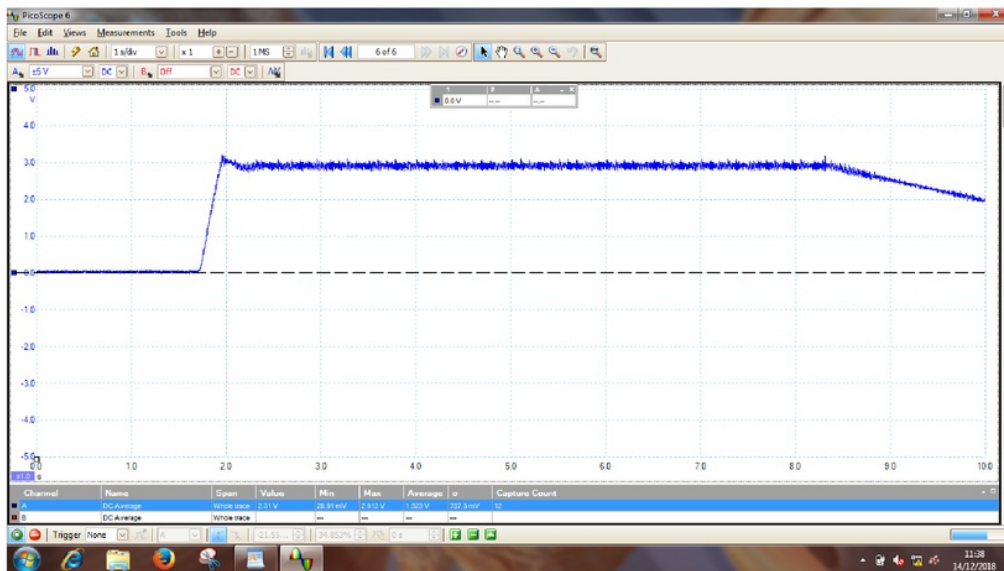


PART E

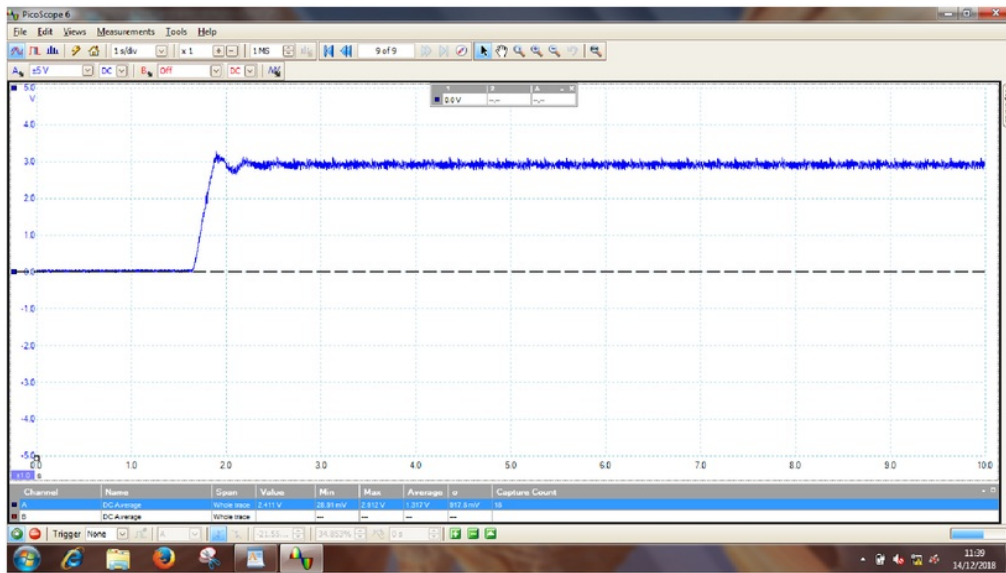
Speed $K_p K_i = 0$



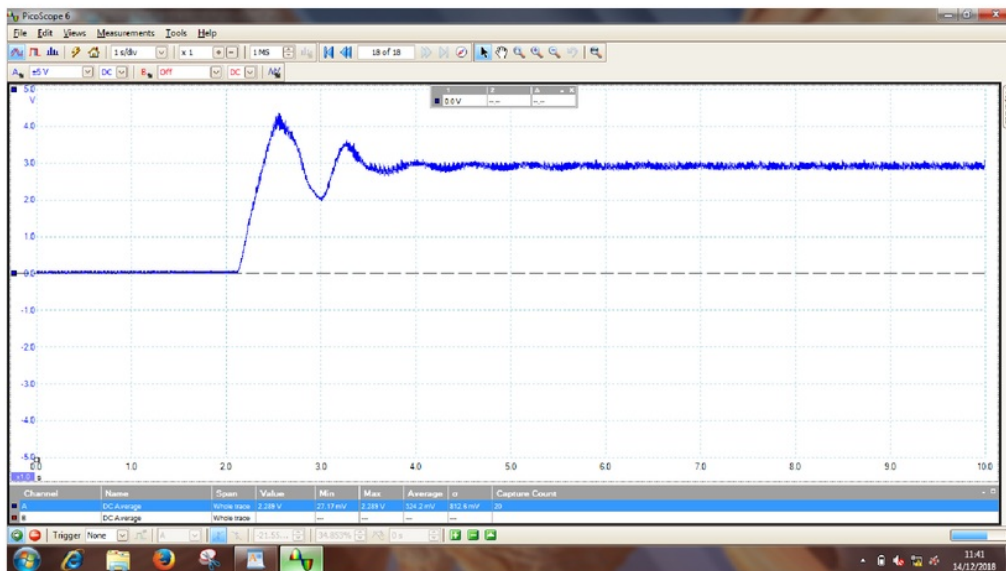
$K_p = \max$ $K_i = 0$



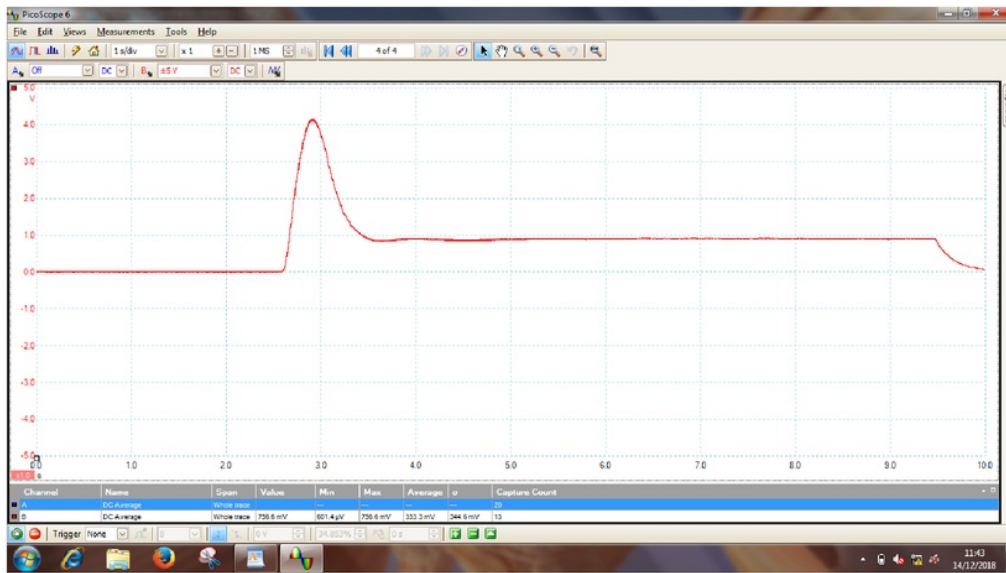
$K_p = \max$ $K_i = \max$



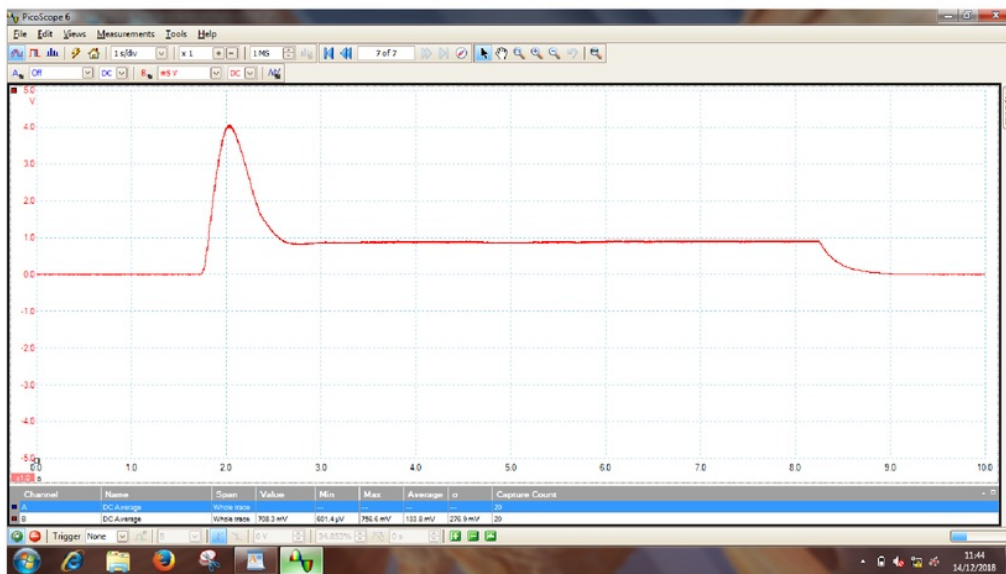
$k_p=0$ $k_i=\max$



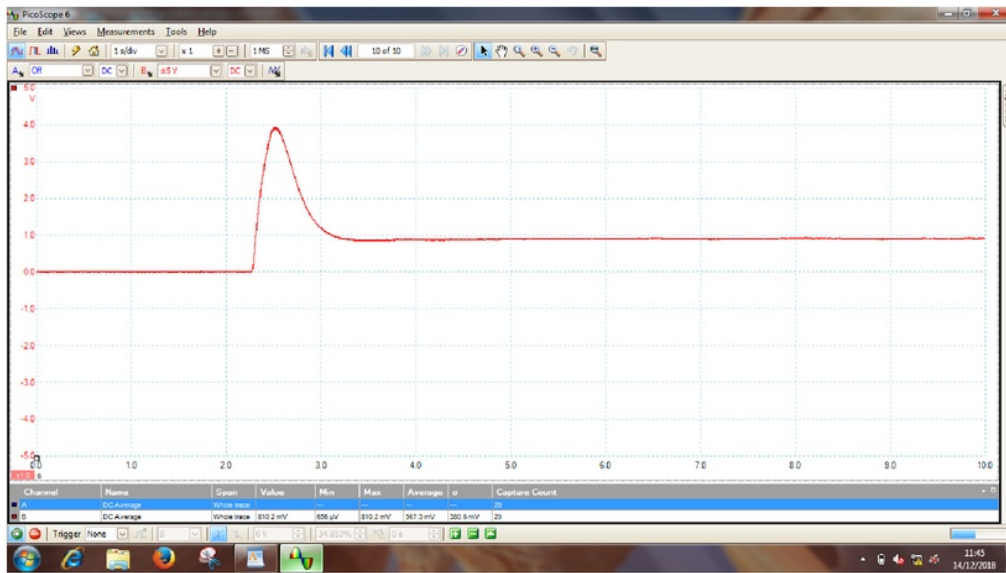
Current $k_i+k_p=0$



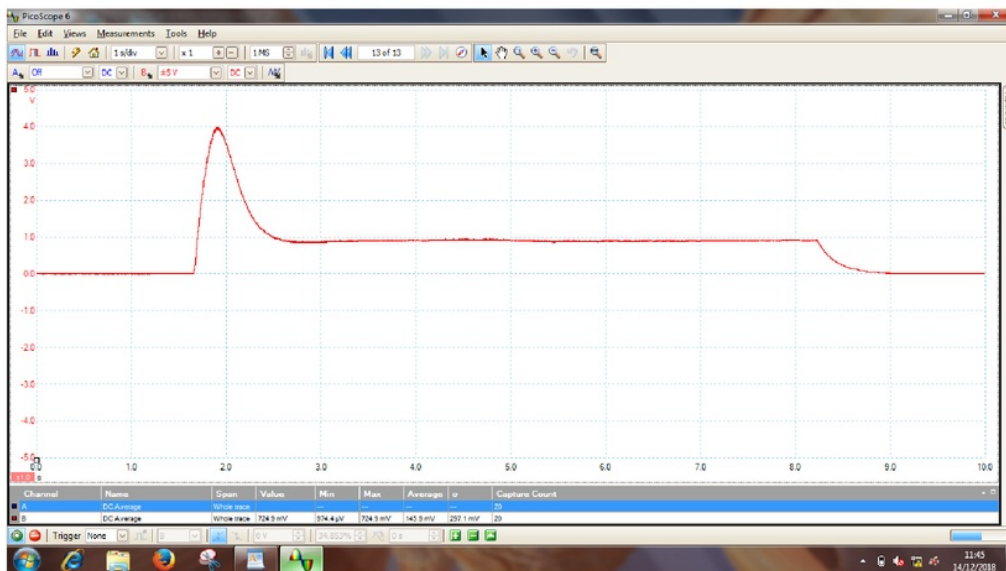
$k_p = \max$ $k_i = 0$



$k_p = \max$ $k_i = \max$



$k_p=0$ $k_i=\max$



5. TEAM WORKING

An important role was taken during the practical experiment which involved reading and recording the data measured by the ammeter and voltmeter. These readings were taken after the break load increased, and again when the set speed increased on the variable speed drive. Ensuring the data was read and recorded accurately was important as it could have affected the overall results of the practical experiment, especially due to the dependent variable (current and voltage) and independent variable (break load) being important aspects of the experiment. However, during many of the set points in which the data was taken, the voltmeter was fluctuating in its readings, and so in order to maintain accuracy of the readings, the run was repeated until a reliable reading could be taken.

Another crucial role in the team was to recognize any immediate errors in the readings to prevent them affecting the findings of the experiment. For example, if there was a notable difference between two data readings it would suggest that either the test was run wrong, or the equipment may have been incorrectly set up. Thus, identifying these errors early in the experiment helps to prevent later problems. Fortunately, there were no errors identified in the practical experiment.

6. CITATION LIST

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PSDE6016 - Assignment 1 Kristian Payne

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: NEW CSG-RUBRIC

KRISTIAN PAYNE

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1. ENGAGEMENT WITH LITERATURE



Engagement with a good range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing, with no inaccuracies or inconsistencies. Note however, that you have not addressed all the aspects of research required in the brief and the Bibliography should not contain all the sources from the Citation list. (7/15)

7

2. KNOWLEDGE AND UNDERSTANDING



Knowledge is reasonably detailed, accurate in some parts with a good systematic understanding of the field of study and to some extent, current research

6

and scholarship. Note however, that not all aspects of the research required have been considered and references to Ward Leonard was inappropriate as it does not represent current technologies. A brief explanation has been given of the one simulation circuit and no explanation given of practical setup. (6/20)

3. COGNITIVE AND INTELLECTUAL



No formulas have been derived and there are few results presented for simulation but no analysis. Practical experiment shows many resulting waveforms and tabulated values but no evidence of analysis and comparison with theory. No conclusions or recommendations presented. (7/30)

7

4. PRACTICAL APPLICATION



An adequate awareness and mostly appropriate application of well-established methods, materials, tools and/or techniques. Basic appreciation of the context of the application. Some theoretical knowledge and understanding applied in practice, but not always making logical links between the two. Little evidence of ability to identify problems and propose basic solutions in complex and unpredictable contexts without fully appreciating the complexity. (7/20)

7

5. TRANSFERABLE SKILLS

Can communicate in a suitable format, 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 required in graduate employment, with some areas of strength and some of minor weakness
Note that there is no executive summary. (7/15)

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