

1602836 Assignment 2 DI

by Daniel Ince

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1. Executive Summary

This assignment contains an investigation into different induction motor drives, namely the quasi-square inverter and pulse-width modulation techniques. Research was conducted into methods of speed control, commercial AC drives and filtering requirements of modern power converters. This theory allowed simulations to be carried out of the two variable speed control drives and the results analysed.

Whilst being earlier technology, the quasi-square drive is still a useful drive when it comes to specific low power applications. The PWM output producing a more sinusoidal waveform and thus a smoother motor torque and superior performance.

Also investigated were buck and boost switch mode power supplies, with ideal component values calculated for a specific output. These values were input into a simulation to evaluate the performance against the theory. Both supplies were effective at stepping up or stepping down the voltage and the boost converter was able to maintain continuous current with the minimum inductor value determined through calculations.

2. Research

Methods of speed control

The setup of induction motors is one that initially does not allow for variable speed control like DC motors. Now more widespread, these motors have been developed with a multitude of methods to control the speed. According to Augustine, et al. (2015), a commonly used method is varying the voltage and frequency, keeping the ratio constant. This is due to the torque being directly proportional to the stator magnetic field. The stator voltage to frequency ratio can be varied by the same amount to keep the torque constant while changing the speed shown in figure 1.

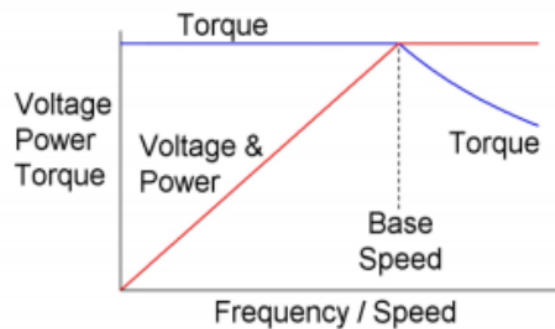


Figure 1: Voltage against frequency (Augustine, et al., 2015)

Augustine states that "At base speed, the voltage and frequency reach at the rated values." (2015, p. 166) As the voltage is now at rated value, it cannot be increased further and so the frequency must be increased further to achieve a higher speed at the cost of torque. This is because the ratio is no longer equal. PWM is used to alter the amplitude of a sine wave through the intersection of a triangular

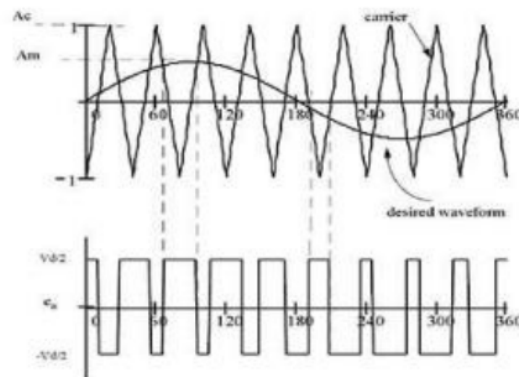
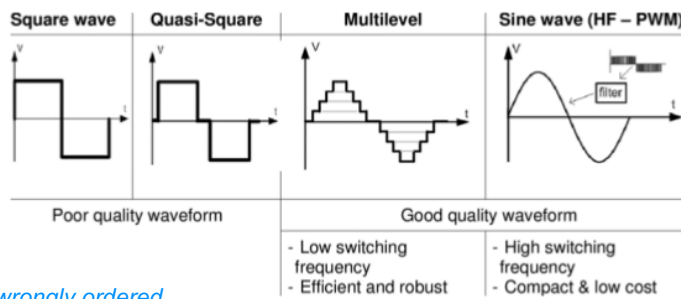


Figure 2: Sinusoidal PWM (Augustine, et al., 2015)

carrier wave. Figure 2 shows how the intersecting points of the carrier on the sine wave are responsible for determining the pulse width as the wave is essentially aliasing, determining the switching for the rectifier. A comparator is used to compare the carrier and reference waveforms to switch high when the reference is above the carrier wave and vice-versa. This method has fewer low

order harmonics from the switching compared to other control methods. However, voltage saturation can occur as stated by M. Arivalagan *last name only* “with decrease in frequency, flux will increase and this change in value of flux causes saturation of rotor and stator cores which will further cause increase in no load current of the motor.” (2015) To counter this field weakening methods are required to be used. The motor currents on PWM are much smoother and closely mimic a sinusoidal trend compared to other methods.



Figures are wrongly ordered

Figure 4: Inverter topology table (Le, 2015)

Quasi-square inverting can also be performed through use of a three-phase rectifier where each transistor is switched on for 180°. The overlap of transistors across the three phases creates a stepped current waveform through use of a DC link. The benefit of quasi-square inverters is highlighted by Guynes, “No heavy filters or complex timing circuits are necessary; therefore, the resulting inverter is smaller, lighter weight, and simpler, implying greater reliability and lower cost.” (1977)

Rectification is the opposite process, turning AC into DC

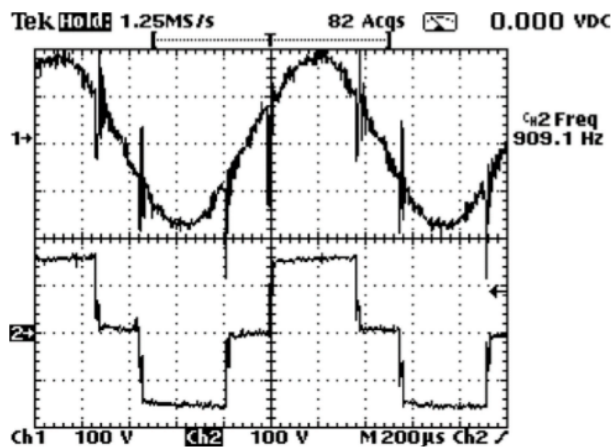


Figure 3: AC signal versus output current waveform (Poddar, 2009)

This figure is not appropriate for quasi square inversion

Figure 4 shows the initial sinewave with sharp peaks and current waveforms that are not smooth either. This is down to the harmonics that are produced developing the quasi-square waveform, these become more apparent at lower speeds and can result in motor pulsating. The space flight industry have used quasi-square wave motor control in the past because of the high reliability of the systems, as explained by Guynes et al., “Even though the tested Q-S wave inverter-motor system has a slightly

lower efficiency than a sine wave motor system when operating a high PF (greater than 0.7) motor, the Q-S system is much simpler and more reliable with fewer parts.” (1977, p. 19) Concluding that this is the superior system for space flight applications. The low frequency harmonics generated during low speeds create pulsating torque and motor instability as they interfere with the frequency. Quasi square is typically used for low power applications. As stated by The Inverter Store, “Many appliances get their timing from the peak of the line power – basically, the modified sine has a flat top rather than a peak – this may cause the occasional double trigger.” (2017)

Before explain flux vector, you should have explained the PWM method in more detail and compared with the quasi-square.

A modern method is using flux vector control within the variable frequency drive, this uses either sensorless open or closed loop feedback to modulate magnetising current vectors. Transdrive (2020) explain, the open loop design is suitable for most applications but is less accurate than closed loop.

The closed loop system requires an encoder which can be costly, but is more accurate, especially at lower speed and torque control. Closed loop is optimal for applying field weakening, as stated by M.

Mengoni states that “.....

Mengoni, “best results are obtained using closed-loop controllers based on the principle of reducing the flux reference as soon as the voltage request becomes greater than the available voltage.” (2008) Pole changing speed control is also commonly used in squirrel cage induction motors.

Is this the right place to mention this very basic method?

Multilevel inverters (figure 5), are installed in high power and voltage applications, particularly in the energy sector. As explained by Don Gruenbacher et al., (2014) there are many advantages of this type of inverter over conventional two-level inverters as they are less demanding on semiconductors and produce less harmonic distortion. This is down to the number of levels within the inverter, the higher levels produce an output waveform that becomes closer to a true sine wave with the correct switching angles. Harmonics can also be further reduced by superimposing PWM, however the high frequency PWM can result in more switching loss and thus a compromise must be found.

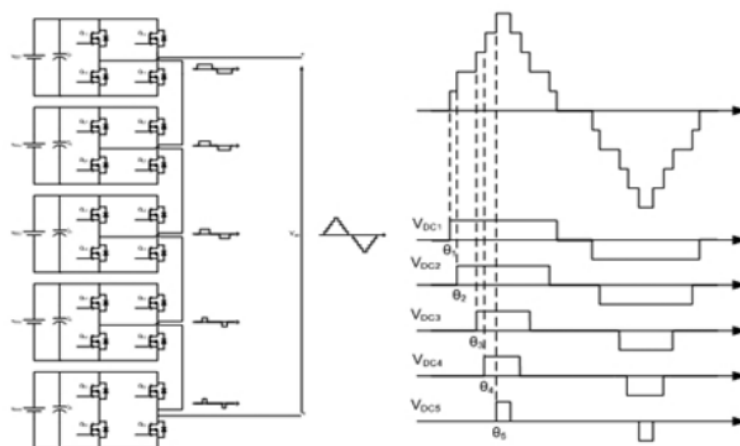


Figure 5: Multilevel inverter (Electrical Equipment, 2020)

Commercial AC motor drives

One type of AC motor drive is the variable frequency drive, this can regulate voltage and frequency to the motor especially during start up to prevent large amounts of current being drawn. Anaheim Automation state, "This allows the AC motor to generate up to 150% of its rated torque, which could potentially be generated from the beginning, all the way up to full speed, without wasting energy." (2020) This type of drive is low maintenance and provides better protection for the motor by limiting current during normal use and so increases the lifespan of the motor being used.



Figure 6: Variable frequency drives (Anaheim Automation, 2020)

The configurations of these drives vary; however the typical configuration is AC to DC converter, DC link and Inverter to provide the varied frequency AC signal to the motor.

The control can be performed through use of a current or voltage source inverter drive. Thyristors are used to modulate the pulse width and regulate the voltage/frequency ratio. The current source variant requires large internal inductors to regulate the current ripple within the DC link and so parts can be expensive. This drive also has regenerative functionality but is dependent on a larger motor load and requires a lot of input and output filters due to the PWM harmonics.

The voltage source inverter uses a bridge rectifier for the DC link and capacitors to smooth the voltage ripple and is not load dependant. Both these variants result in poor motor performance such as pulsating when at low speeds/frequencies and generate a lot of harmonic back into the power source.

One of the most widely used and efficient drives is the Pulse Width Modulation (PWM) drive. The current output to the motor is very similar to a sine wave and is smoother than with other drive types. High power semiconductors such as IGBTs are used in the inverter section with the switching controlled by some form of microprocessor. This allows the wave period and voltage pulse width to be varied at the same time to create a smooth average current to the motor. Switching frequencies from 4KHz to 16KHz can be used, the higher frequencies offer a smoother waveform.

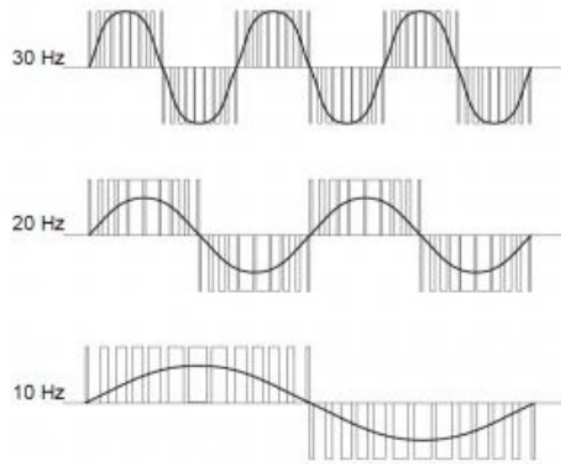


Figure 7: Varied frequency and pulse width (Glampe, 2017)

Figure 7 displays the combination of varied voltage pulse and wave period from the drive. Mike Glampe states, "Motor speeds can be optimized for the application to achieve higher system efficiency (i.e. fan control)." (2017) This means that the drive can be set up so the motor does not experience pulsating at low speeds and can run at high efficiency. An advantage stated by Anaheim Automation (2020) is that these drives can be used in applications requiring more than one motor, whilst also having a low initial cost.



SINAMICS S120 blocksize, booksize, and chassis formats

Figure 8: (Siemens, 2020)

A popular commercial drive is Siemens S120 drive, this is commonly used for industrial and process control applications. As stated by Siemens, "It offers AC/AC single drives and coordinated DC/AC drives for multi-axis applications." (2020) This drive is a modular drive as shown in figure 8 and includes smart modules and filters as seen in figure 9.

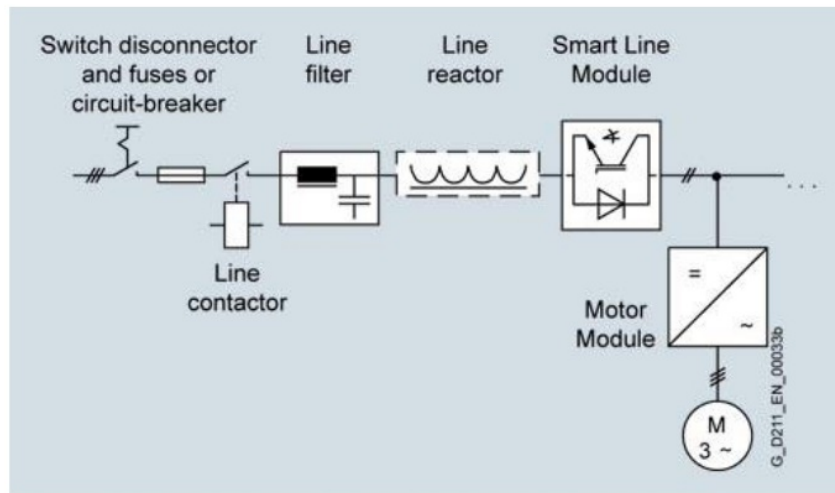


Figure 9: S120 block diagram

What are the main features of this drive?

You were also asked to consider Commercial AC induction motor drives available with consideration given to cost, power range, business, customer and user needs, the wider engineering context, aesthetics, operation, maintenance and reliability.

Filtering requirements of modern power converters

Modern power converters require filtering to process the input and provide protection for the device and supply, figure 8 displays a typical filter configuration for a power converter.

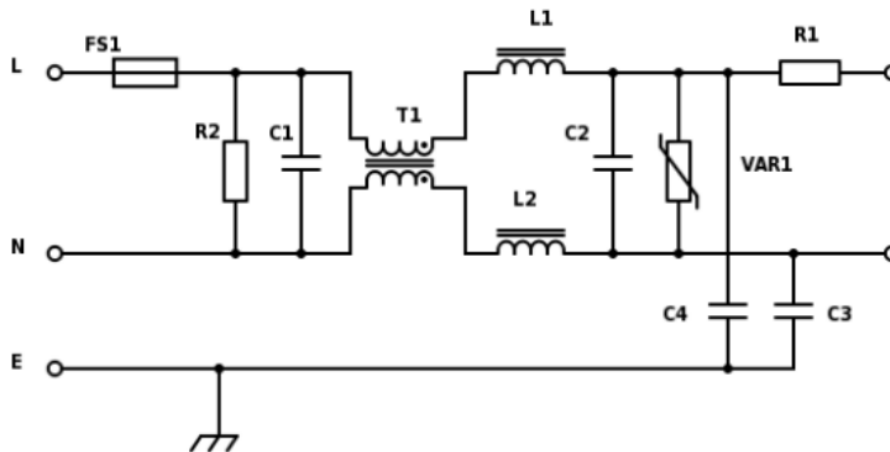


Figure 10: An example of an input filter (Chidley, 2017)

[According to Chidley \(2017\), ...](#)

Adam Chidley (2017) explains how this typical filter achieves many functions. The capacitors C1, C2 and inductors reduce differential mode noise. Common mode noise is quietened by the transformer along with capacitors

C3 and C4. Extra resistance R1 is added to reduce overcurrent on the output and the variable resistor connected across the output provides transient/surge attenuation. The input resistor R2 is used to slowly discharge the capacitors when the device is powered down and a fast blowing fuse is also added for protection.

A lot of the requirements and specifications for these components are set by international standards. Chidley also states *"A high-power converter or inverter is likely to feature all of these components but open up a modern mobile phone adapter and you will see very little obvious input filtering. This illustrates the fact that meeting the standards depends heavily on the converter design and particularly the power level."* (2017) [page number?](#)

[According to Texas Instruments \(2011\), ...](#)

Texas Instruments (2011) explain that the two main functions of an input filter for switch mode power supplies are; to reduce electromagnetic interference such as harmonics generated from the switching, and to prevent the supply from outputting high frequency voltage.

3. Simulation of Inverter Drives

Quasi-square

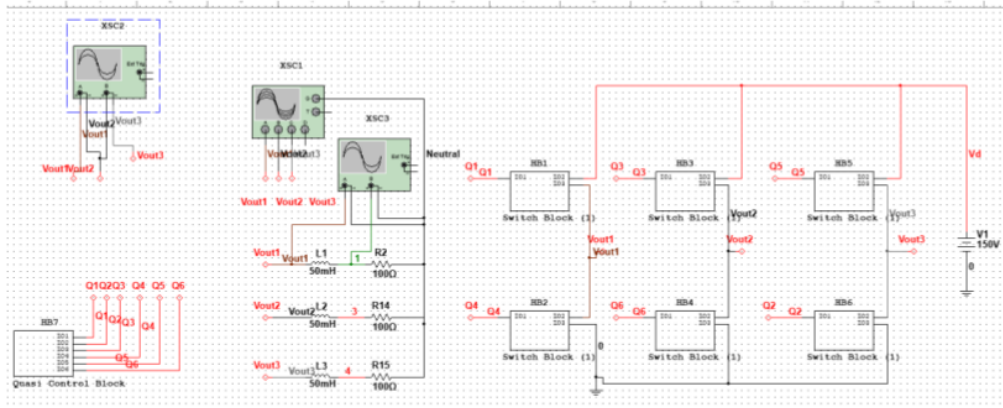
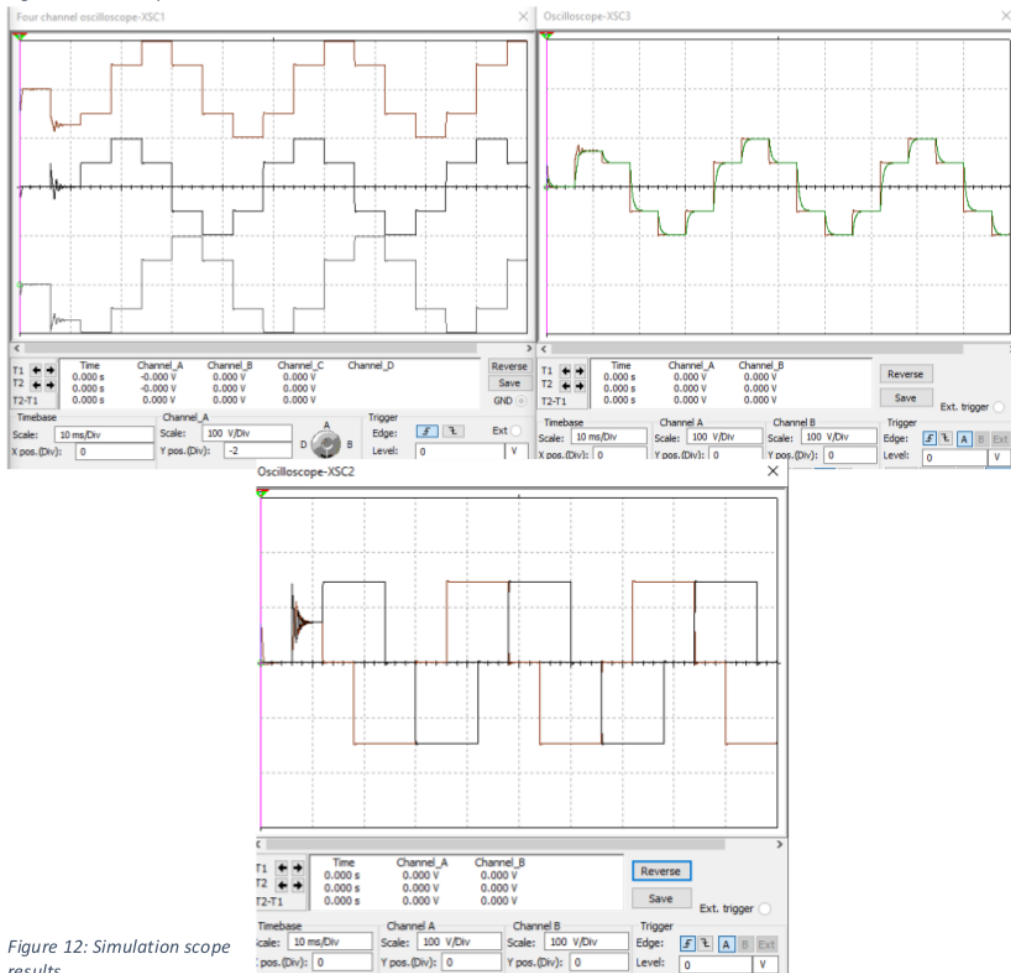


Figure 11: Quasi square simulation



The quasi-square drive was simulated, this method uses a variable DC source to maintain the appropriate voltage to frequency ratio. The quasi control-block is responsible for sending the variable voltage signal to the switch block for allowing the 150V DC link added onto the inverter circuit for varying the frequency. Pulses from the six generators are sent to control the switch block timing, this includes a transistor, a flywheel diode and a capacitor for suppression.

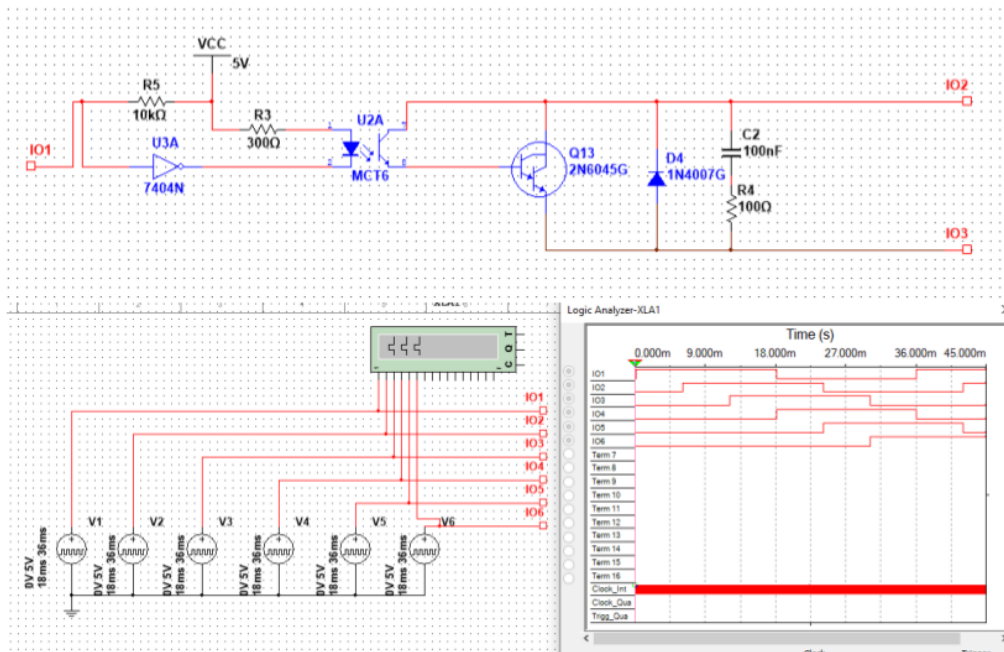


Figure 13: Quasi control block (bottom) and switch block (top)

The current output for the three phases on scope XSC1 in figure 11 is a typical modified sine wave wave with sharp jumps between the wave steps. Scope XSC3 displays the summation waveform before and after the inductor (simulated motor coil) This depends on the time constant for the RL values. As shown, channel B waveform is not as clear cut as before the coil due to the current having to build and discharge. These waveforms match the theory as they are not perfectly sinusoidal, with the current stepping sharply as each switch block is turned on. As the speed is reduced on the motor, the frequency will be reduced meaning these steps become more noticeable creating the pulsating torque and instability mentioned in the research.

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using

Scope XSC2 displays the voltage pulses across the phases oscillating between positive and negative and averaging out overall. The harmonics seen at the beginning of the scopes are caused during the initial switch on.

PWM control simulation and analysis

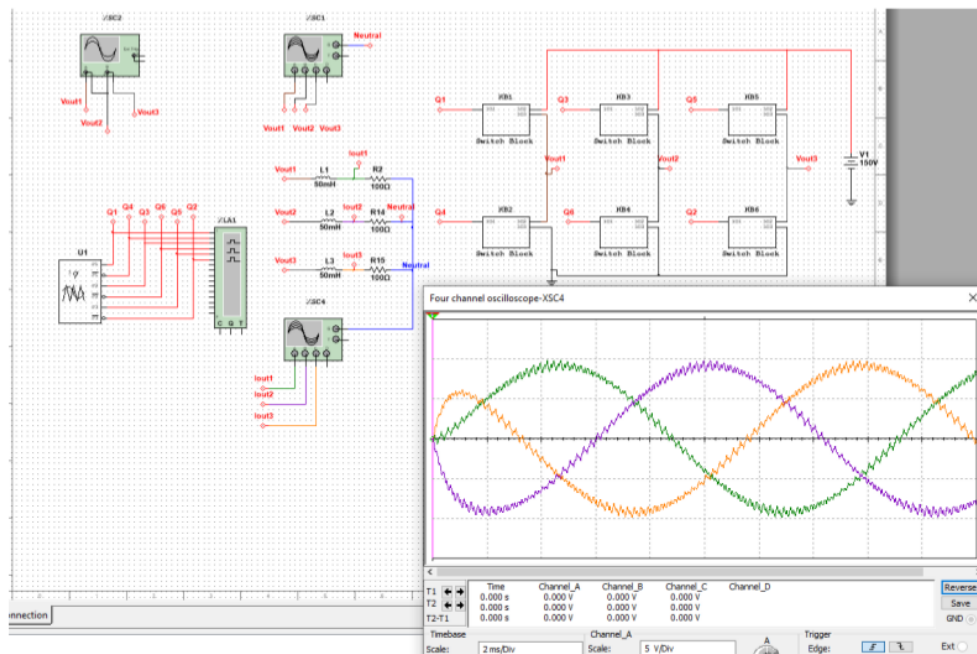


Figure 14: PWM resultant waveform

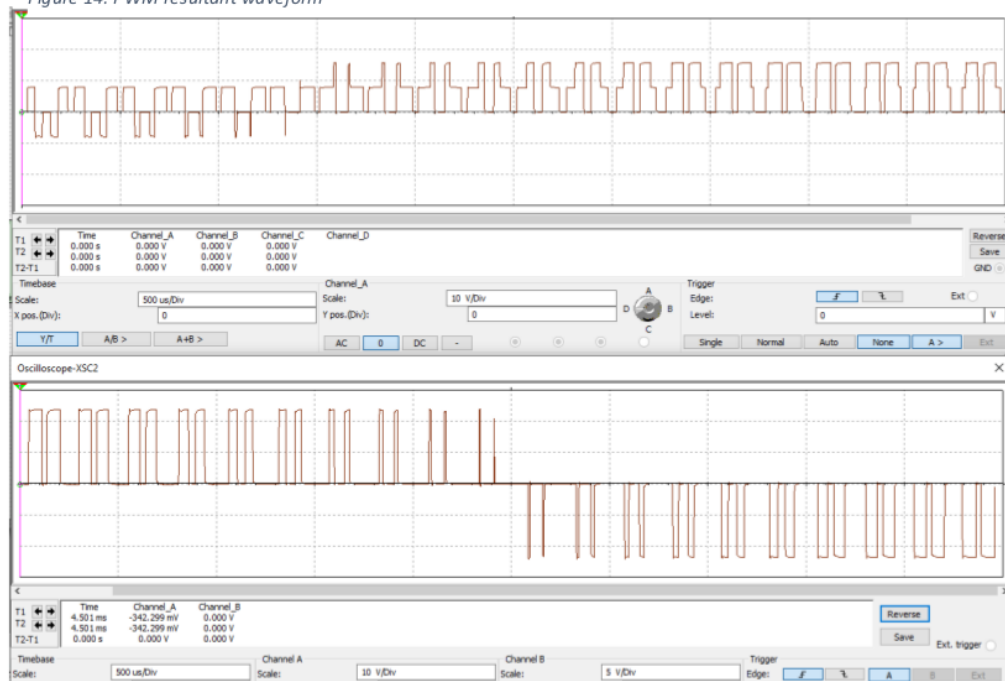


Figure 15: PWM pulses

The PWM drive was simulated, with a triangle/sine wave generator sending the control signals to the switch block for firing. Figure 14 shows the circuit simulation along with the three phase current outputs at the motor. These are closer to a sine wave and have no sudden stepping like the quasi-square drive and so have less harmonics. There is a small amount of ripple within the wave but this is negligible as the wave follows the sinusoidal trend closely. This ripple can be reduced by further increasing the frequency of the control signal. The current settings are a carrier wave of 4kHz and modulation frequency of 60Hz, these are much higher than that of the quasi-square drive.

Figure 15 and scope XSC1 display the voltage output for the phases against neutral as this is STAR connected. The pulses are seen to change in magnitude steps and width resulting in varying the average voltage to the motor. This provides an extra level of smoothness rather than just the one form. Scope XSC2 compares the voltage across the phases, here the resultant voltage cycles positive and negative whilst decreasing and increasing width to average out and provide a sinusoidal effect overall.

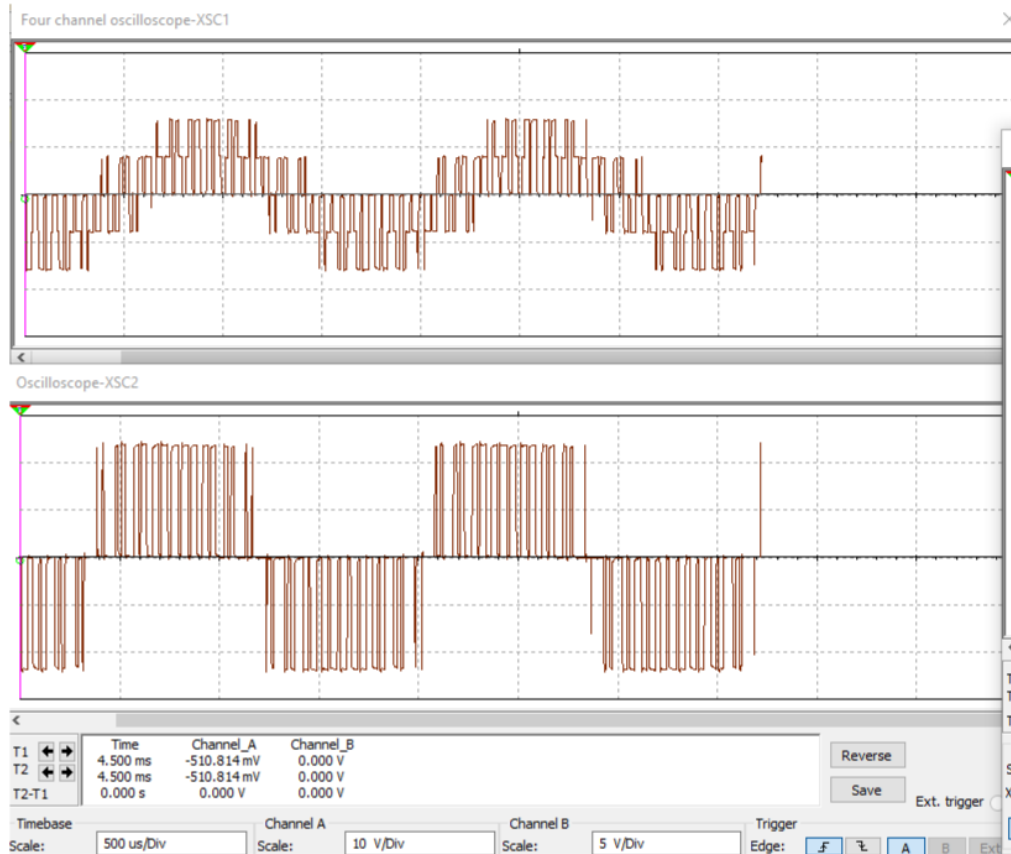


Figure 16: Increased carrier and modulation frequency

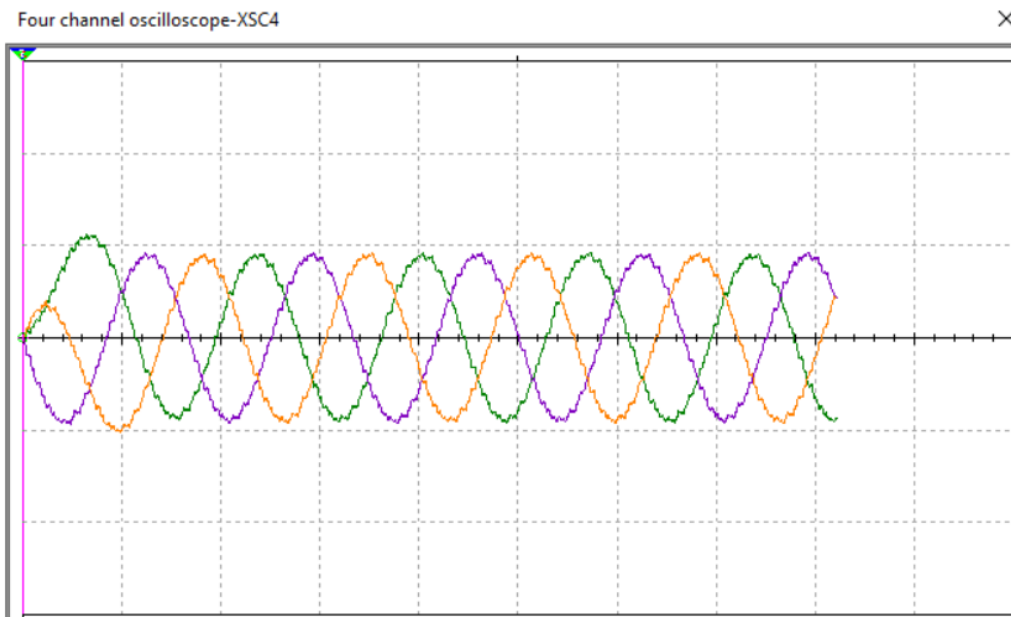


Figure 17: Increased carrier and modulation frequency current output

The carrier and modulation frequency was increased to 10kHz and 600Hz respectively, this is shown in figures 16 and 17. The result being that the output waveforms increased in frequency as the modulation was increased, whilst becoming closer to a true sine as the carrier frequency increased and so smoother motor torque.

4. Design and Simulation of Switch Mode Power Supplies

Buck converter calculated values

To allow comparison of theory and simulation, the following calculations were performed to determine various values for the buck power supply performance.

The load current (I_o) is determined through the output voltage and resistance; $I_o = \frac{V_o}{R_L} = \frac{16}{2} = 8A$

The duty cycle and on-off times are calculated by first working out the period;

$$t_1 + t_2 = \frac{1}{f} \rightarrow \frac{1}{200kHz} = 5\mu s \quad D = \frac{V_{out}}{E} \rightarrow \frac{16}{40} = 0.4$$

$$\text{As } \frac{t_1}{t_1+t_2} = \frac{V_o}{E} \text{ then; } t_1 = \frac{V_o}{E} \times (t_1 + t_2) \rightarrow 0.4 \times 5\mu s = 2\mu s$$

$$\therefore t_2 = 5\mu s - 2\mu s = 3\mu s$$

During the closed switch state, the inductor current (ii) rises at a rate of; $E - V_o = L \frac{di_L}{dt}$ as the rise and fall is linear.

$$\text{So, } \frac{di_L}{dt} = \frac{40-16}{L} \rightarrow \frac{24}{L} \text{ during closed state.}$$

When the switch opens, the inductor current falls at a rate of; $0 - V_o = L \frac{di_L}{dt}$

$$\therefore \frac{di_L}{dt} = \frac{-16}{L} \text{ during open state.}$$

The peak inductor current is worked out as $2 \times I_o = 16$, because $I_o = \frac{I_{max}}{2}$. To work out the inductor value, the gradient must be determined from the current rising waveform. Now as $\frac{di_L}{dt} = \frac{24}{L}$ with a peak current of 16 amps across an on time of $3\mu s$, the gradient is; $\frac{16}{3\mu s}$

$$\therefore \frac{24}{L} \times \frac{16}{3\mu s} \rightarrow L = 3\mu s \times \frac{24}{16} = 4.5\mu H$$

incorrect, L should be 3uH

The capacitor value for a ripple voltage of 100mV is calculated;

Since $I_o = i_L + i_c = 8A$, while the inductor current rises, the capacitor current must fall from 8A to negative 8A for the peak inductor current. It can be halved as the area to be calculated is within one half cycle, $\frac{t}{2} = 2.5\mu s$. Now using $\Delta q = \Delta i_c \times t$ and the area of a triangle $\rightarrow \Delta q = \frac{1}{2} \times 2.5\mu s \times 8 = 10\mu C$

$$\text{Therefore, using; } \Delta V_c = \frac{\Delta q}{C} \text{ to give } C = \frac{\Delta q}{\Delta V_c} \rightarrow \frac{10\mu C}{0.1} = 100\mu F.$$

Buck converter simulation and analysis

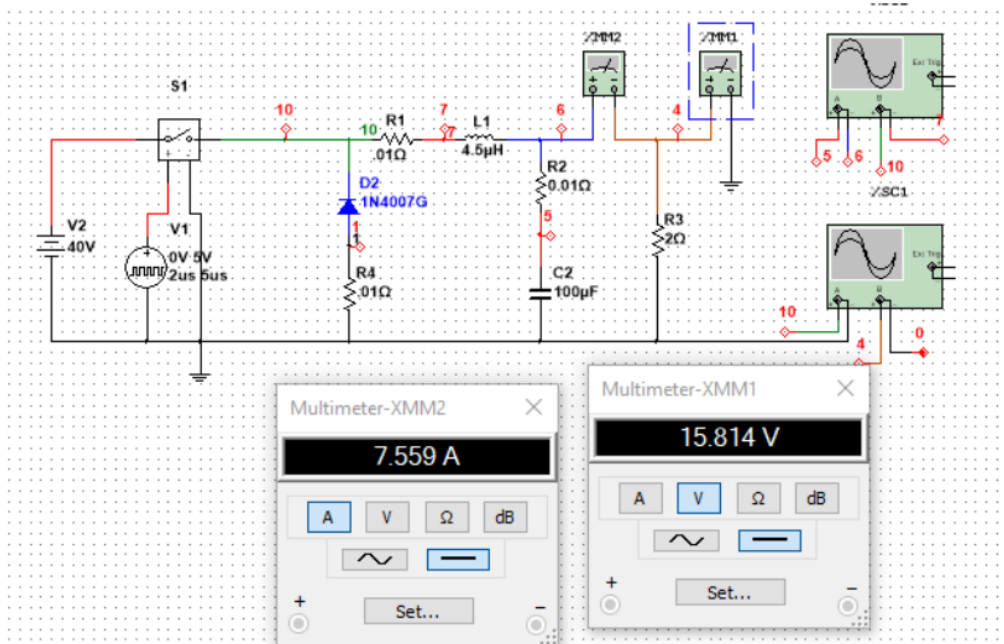


Figure 18: Buck converter simulation

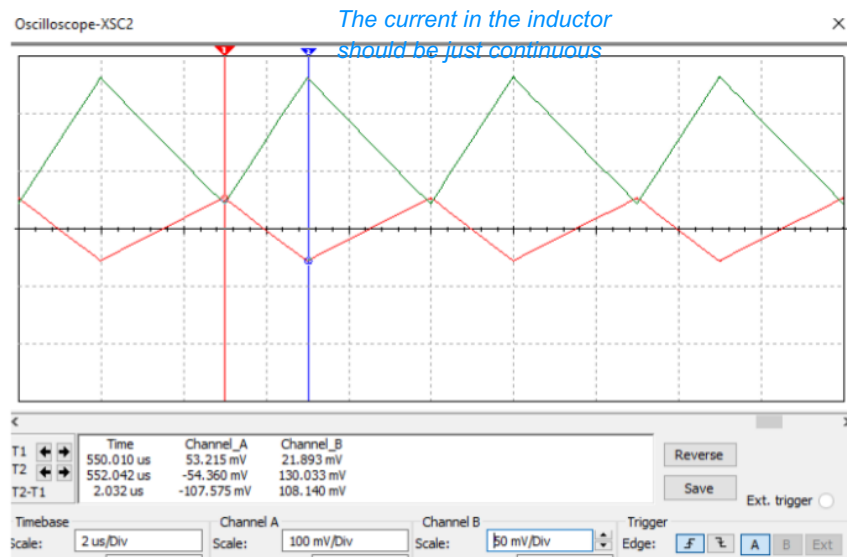


Figure 19: Capacitor and inductor current.

if you had calculated the value of the inductor correctly, the current would be just continuous

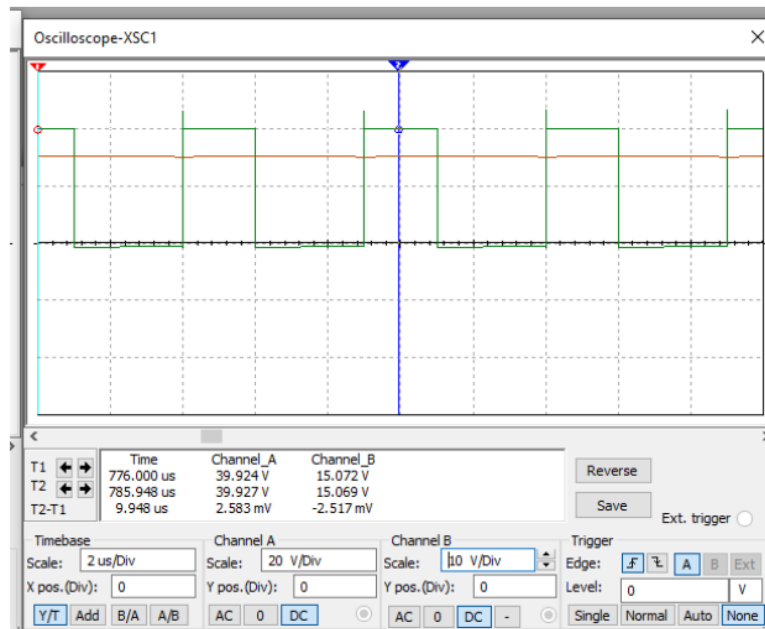


Figure 20: PWM versus average output.

The Buck switched mode power supply was built on multisim and ran with the calculated component. The PWM switch is controlling the unfiltered DC input of 40V and regulating it down to the desired current and voltage output. As shown in figure 18, the output current is 7.559A, this is close to the calculated value of 8A. The slight difference being down to the initial start up of Multisim. The voltage is 15.814V, very similar to the output voltage set within the calculations. Differences between the measured and calculated may be affected by small rounding errors during calculations and also switching harmonics within the simulation, not accounted for in the calculations.

The output voltage shown on the oscilloscope in figure 19 follows the traditional output of a buck converter. The ripple between peak and trough is seen at approximately 100mV, this has been achieved through determining the correct capacitor for this magnitude of ripple. Figure 20 displays input and output voltage, these can be seen as 39.924V and 15.072V respectively. The pulses peak at 40V with some harmonics at the beginning, the smooth output is steady at approximately 15V.

Figure 19 displays the inductor and capacitor current together. As per theory, the capacitor current must fall as the inductor current rises in order to average out at a constant value. This can be seen here as the gradients are reversed for each current, ultimately with the sum of the two equalling a smoother value above zero as they are not equal.

A simple error earlier on has caused the predicted values and the simulated one to be different. You should have gone back over your calculations and checked them.

Boost converter calculated values

To calculate the duty cycle, the zero average voltage across the inductor for one complete cycle equation is used;

$V_s t_{on} - (V_o - V_s) t_{off} = 0$ combined with $t_1 = DT$ and $t_2 = T(1 - D)$ to produce;

$$V_s DT = (V_o - V_s)(1 - D)T \text{ and } \frac{V_o}{V_s} = \frac{1}{1-D}$$

D is the switch duty cycle and T is the switching period.

$$\text{So, } D = 1 - \frac{V_o}{V_s} \rightarrow 1 - \frac{12}{20} = 0.4$$

The peak-to-peak ripple current for the inductor is found by first looking at the current increase during the on-time, using;

$$\Delta i_L = \frac{V_s t_{on}}{L} = \frac{V_s DT}{L} \text{ as T is worked out to be } T = \frac{1}{20 \text{ kHz}} = 50 \mu s$$

$$\text{Therefore; } \Delta i_L = \frac{12 \times 0.4 \times 50 \mu s}{150 \mu H} = 1.6 A$$

$$\text{The peak inductor current is found as } I_{L(Peak)} = I_{L(Av)} + \frac{\Delta i_L}{2}$$

Neglecting losses, Input power = Output power and so $V_s I_L = V_o I_o$

$$\text{Now, } I_{L(Av)} = \frac{V_o}{V_s} \times I_o \rightarrow \frac{20}{12} \times 1.5 = 2.5 A \text{ and therefore, using the previous equation;}$$

$$I_{L(Peak)} = 2.5 + \frac{1.6}{2} = 3.3 A$$

The minimum inductor value whilst still producing continuous current is to be determined. Neglecting losses, $V_s I_{L(Av)} = V_o I_o$ and so; $I_o = \frac{V_o}{R} = I_{L(Av)} \frac{V_s}{V_o} = I_{L(Av)}(1 - D)$

The boundary condition between continuous and discontinuous inductor current is found as;

$$I_{L(Av)} = \frac{\Delta i_L}{2} \text{ and so using the previous equation and } \Delta i_L = \frac{V_s t_{on}}{L} = \frac{V_s DT}{L}$$

$$\frac{V_o}{R} = \frac{\Delta i_L}{2} (1 - D) = \frac{V_s}{2L} DT(1 - D) \text{ and using } \frac{V_o}{V_s} = \frac{1}{1-D} \text{ to produce the equation for the minimum inductor value: } L = \frac{1}{2} RTD(1 - D)^2 \rightarrow L = \frac{1}{2} \times \frac{20}{1.5} \times 50 \mu s \times 0.4(1 - 0.4)^2 = 48 \mu H$$

Boost converter simulation and analysis

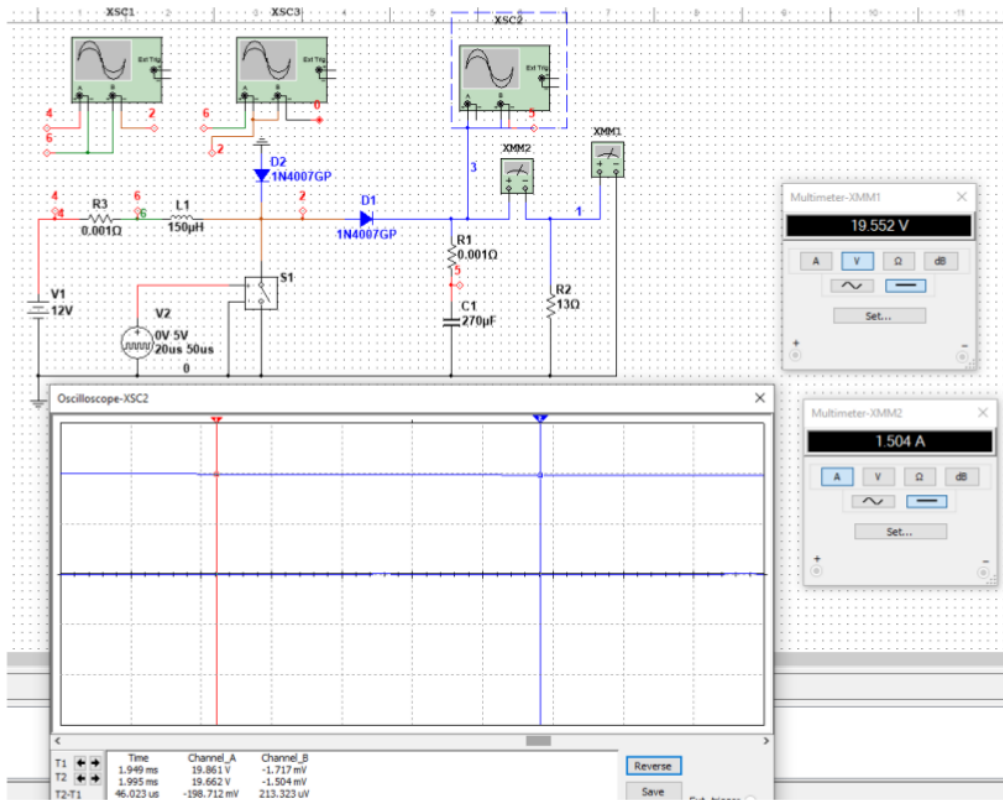


Figure 21: Boost converter simulation

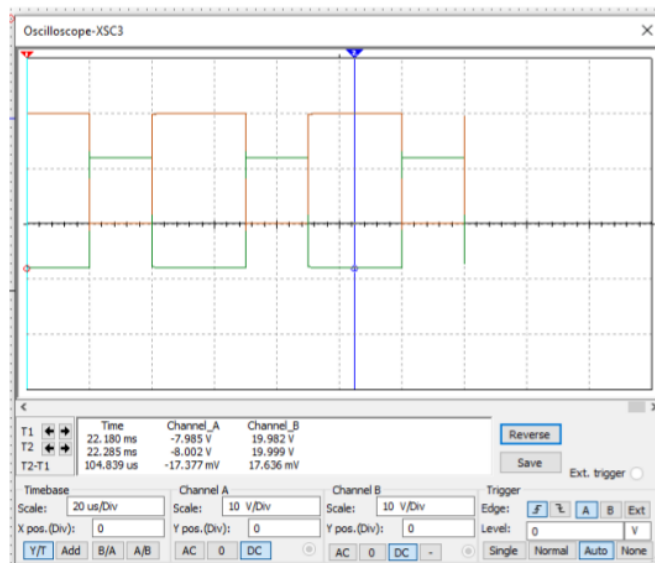


Figure 22: Switch voltage (orange) versus Inductor voltage (green)

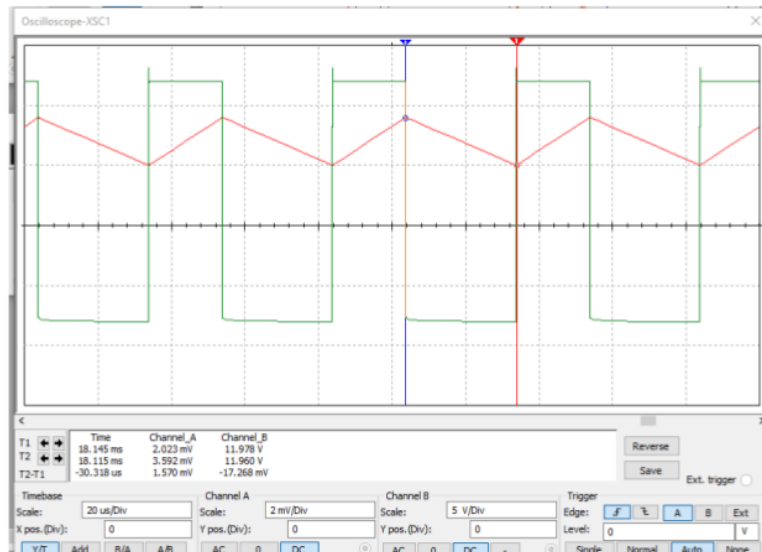


Figure 23: Inductor current (red) versus PWM pulses

The boost converter was simulated and the calculated ideal values for continuous current were implemented, as seen in the figure, the converter is outputting Approximately 20V and 1.5A. Scope XSC2 in figures 21 and 24 shows a very stable voltage and a variance in current as the capacitor charges and discharges. Scope XSC3 shows the voltage across before and after the inductor and switch. In figure 23 the pulses and continuous current can be seen with a ripple of approximately 1.6A as per

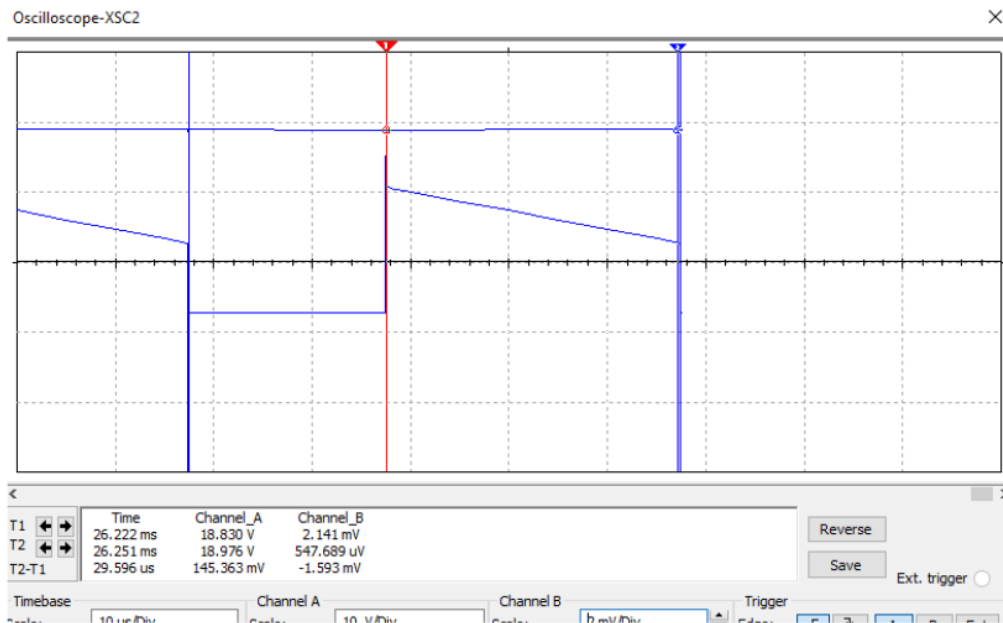


Figure 24: Output voltage and current

the calculations. The maximum and minimum currents are slightly different at 3.992A and 2.023A respectively, slightly higher than those calculated, however the overall current remains continuous.

*You should always provide a table
comparing theoretical and simulated
values*

Boost converter minimum inductor value simulation

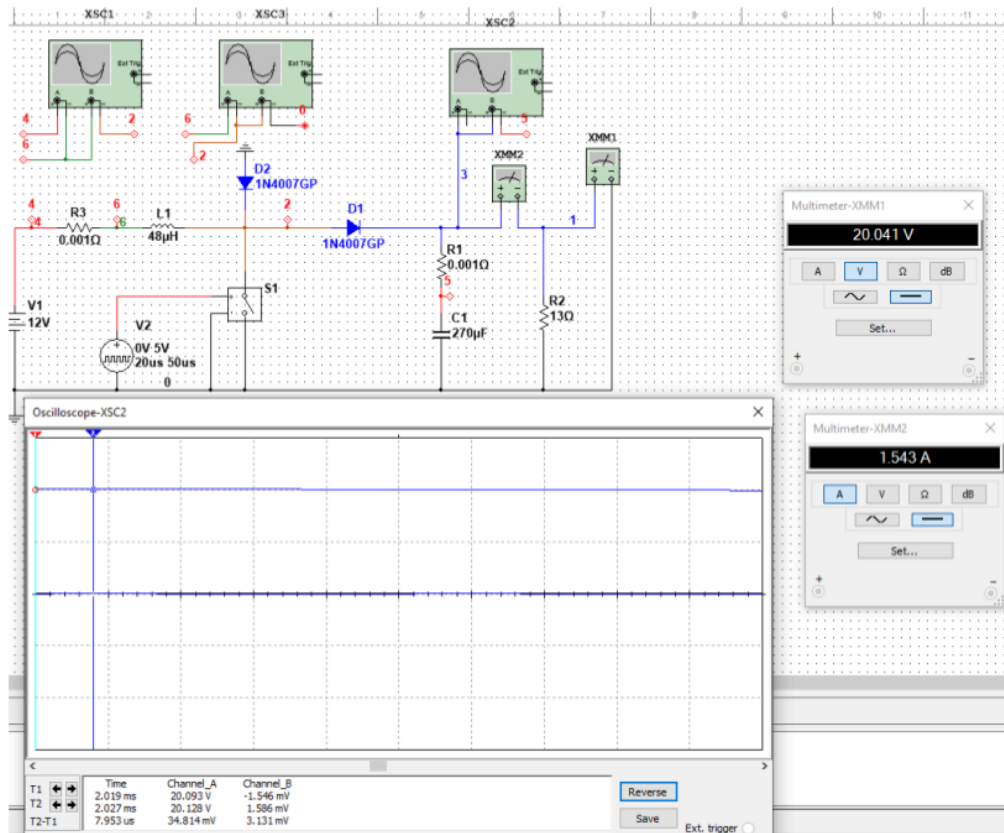


Figure 25: Minimum inductor value simulation

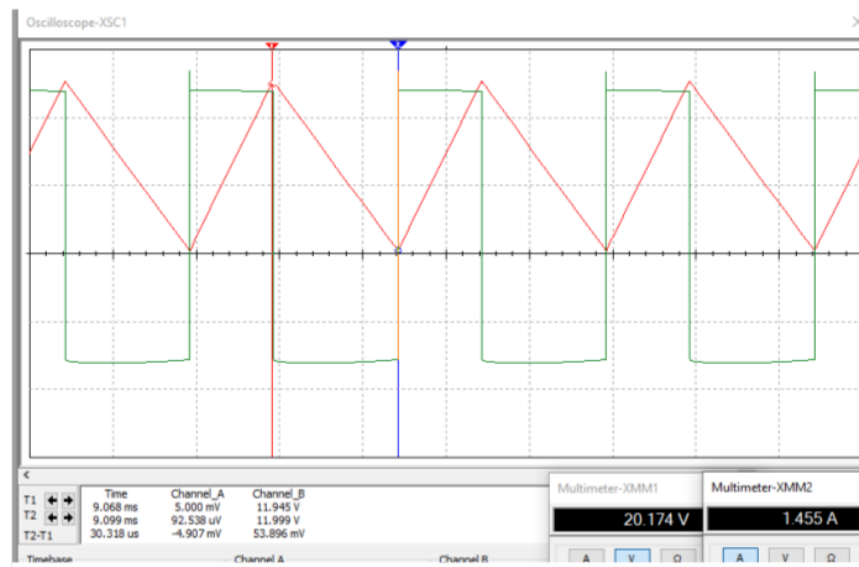


Figure 26: Pulse and inductor continuous current

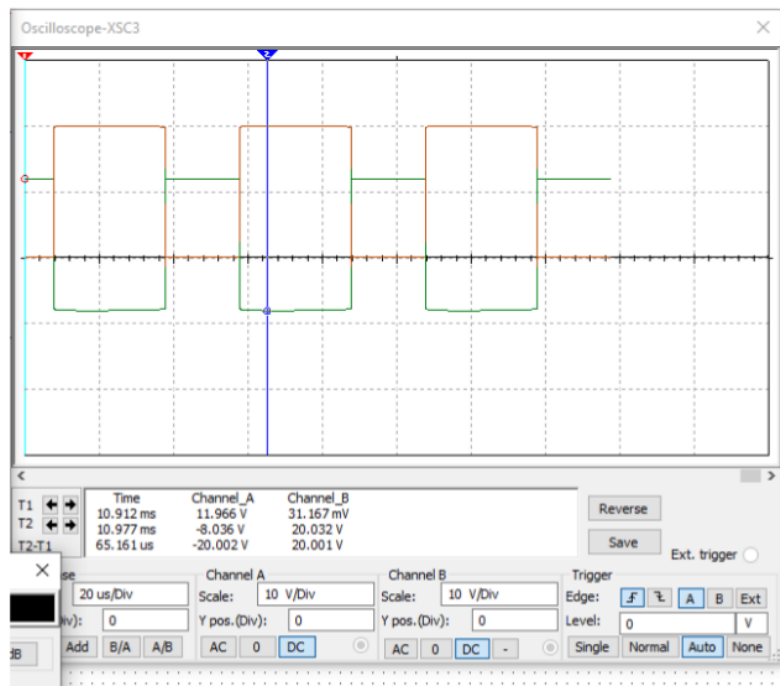


Figure 27: Switch and Inductor voltage

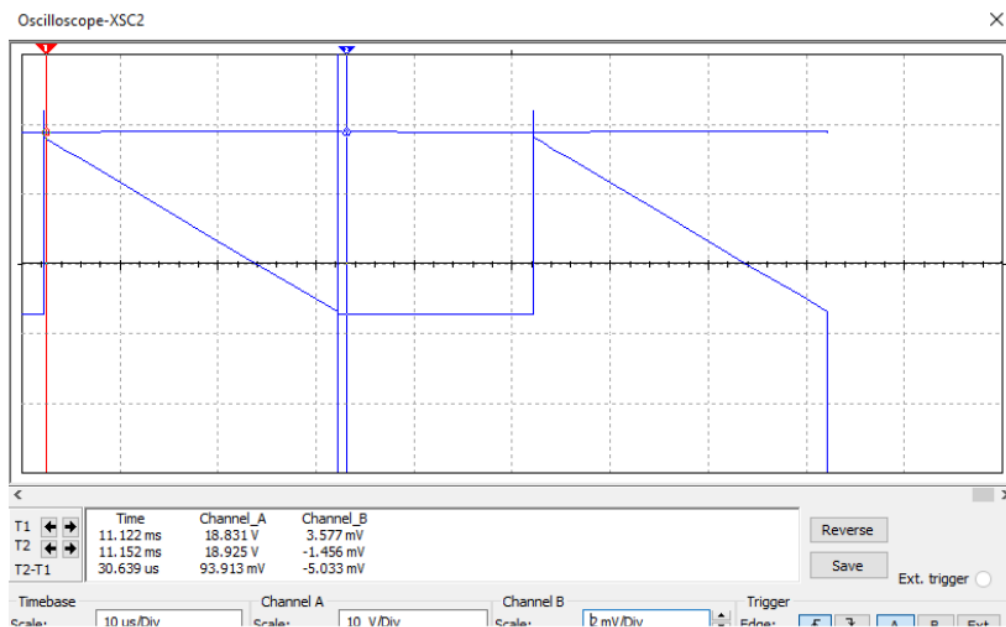


Figure 28: Output voltage and capacitor current

The minimum inductor value whilst still achieving continuous current was taken from the earlier calculations and implemented into the simulation, shown in figure 24. Dropping the value to $48\mu\text{H}$ maintained the average current value and greatly increased the ripple whilst remaining continuous as shown figure 26. This current output is a lot less smooth as the smaller inductor builds a smaller magnetic field, this allows a faster current build and fall due to the magnetic field requiring less energy to create and retain before dissipation.

5. Conclusions and Recommendations

The quasi-square drive allows a variable *this drive does not produce a sine wave current* to be generated for the three-phase motor supply. As this was an early form of control, the current waveform contains large steps between quasi-square levels and suffers from a lot of switching harmonics. This drive requires a variable voltage DC source to achieve a constant v/f ratio, as both change together based on the voltage, this varies the average current to the motor. As found through research, these drives suffer from low speed instability caused by harmonics. The motor torque can pulsate and is not recommended for high power applications, with a frequency limited to around 5Hz. Evidence of this is shown through the waveforms produced during the simulation. The modified sinewave can also cause timing issues due to the flat profile of the waveform with no peaks. Quasi-square inverters are also usually expensive due to a separate controlled rectifier being needed for the DC link and large components needed within.

smoother
PWM control provides the motor with a much more stable current supply with a wave that is more sinusoidal than that of quasi-square. This means that the motor produces smoother torque and is more stable. Less low order harmonics are produced in this drive as the voltage can be controlled through the switch timing and pulse width. The simulation results show a much smoother sine wave and how a higher frequency can be used to tailor the wave.

The buck converter simulation results successfully stepped down the voltage and matched the expectations of theory apart from a very small difference, potentially caused by switching harmonics not accounted for in calculations. *Not quite true, as the current was not 'just continuous'*

The boost converter results proved how the inductor size relates to ripple and determines if the current is continuous or not. The simulation waveforms tied in with calculation results aside from very small errors possibly due to parallax *?* error when measuring points on the scope. The capacitor and inductor filters used within these simulations smoothed the outputs as per the research conducted. These could be improved by incorporating a set point controller and utilising feedback. *good conclusion*

Overall, the research, calculations and theory conducted allowed the differences to be highlighted between different motor control methods and power supply converters. The more modern PWM drive being a more efficient and cheaper system to use in a broader range of applications.

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7. Appendix

1602836 Assignment 2 DI

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

70/100

Instructor

PAGE 1

PAGE 2

QM

Good Structure

Report is structured exactly as stated in the assignment brief.

PAGE 3

PAGE 4

PAGE 5

PAGE 6

Text Comment. last name only

QM

Punctuation Error

Punctuation error

Text Comment. Rectification is the opposite process, turning AC into DC

Text Comment. Figures are wrongly ordered

Text Comment. This figure is not appropriate for quasi square inversion

PAGE 7

Text Comment. This sources is out dated at 1977

Text Comment. What is double trigger?

Text Comment. Before explain flux vector, you should have explained the PWM method in more detail and compared with the quasi-square.

Text Comment. last name only

Text Comment. Mengoni states that "....."

Text Comment. Is this the right place to mention this very basic method?

Text Comment. according to

PAGE 8

Text Comment. This would have to be for a short duration to avoid overheating the motor

QM

Citation Needed

Cite Source:

Please use the link below to find links to information regarding specific citation styles:

http://www.plagiarism.org/plag_article_citation_styles.html

QM

Citation Needed

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Citation Needed

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PAGE 9

Text Comment. last name only is needed for a citation

Text Comment. according to

Text Comment. if stated, it must be a direct quotation

Text Comment. Siemens states that "....."

PAGE 10

Text Comment. What are the main features of this drive?

Text Comment. You were also asked to consider Commercial AC induction motor drives available with consideration given to cost, power range, business, customer and user needs, the wider engineering context, aesthetics, operation, maintenance and reliability.

PAGE 11

Text Comment. According to Chidley (2017), ...

Text Comment. page number?

Text Comment. According to Texas Instruments (2011), ...

PAGE 12

PAGE 13

Text Comment. good conclusion

PAGE 14

PAGE 15

PAGE 16

PAGE 17

Text Comment. incorrect, you should have divided by the on time of 2us not the off time of 3us

Text Comment. incorrect, L should be 3uH

PAGE 18

Text Comment. The current in the inductor should be just continuous

Text Comment. if you had calculated the value of the inductor correctly, the current would be just continuous

PAGE 19

Text Comment. A simple error earlier on has caused the predicted values and the simulated one to be different. You should have gone back over your calculations and checked them.

PAGE 20

PAGE 21

PAGE 22

PAGE 23

Text Comment. You should always provide a table comparing theoretical and simulated values

PAGE 24

PAGE 25

PAGE 26

PAGE 27

Text Comment. this drive does not produce a sinewave current

Text Comment. smoother

Text Comment. Not quite true, as the current was not 'just continuous'

Text Comment. ?

Text Comment. good conclusion

PAGE 28

PAGE 29

PAGE 30

PAGE 31

GRADING FORM: NEW CSG-RUBRIC

DANIEL
INCE

70

1. ENGAGEMENT WITH LITERATURE

 There is good evidence of reading from a wide range of mostly credible sources but Harvard method is not always consistently applied. You are still, in the main, ignoring the advice given on the correct method of citation but your method of listing is correct. You have not answered all parts of the research question. 12/20

12

2. KNOWLEDGE AND UNDERSTANDING

 There is evidence of understanding in many parts of the assignment. However, research material is presented in an unordered and almost random way with little thought to progression of ideas. Simulations have been explained very well showing a clear understanding of their operation. 13/20

13

3. COGNITIVE AND INTELLECTUAL

 Good evidence of analysis, most calculations are correct. However, you should always summarise results in a table of comparison. 14/20

14

4. PRACTICAL APPLICATION

 Excellent use of Multisim software for simulation of circuits with well presented graphs. 17/20

17

5. TRANSFERABLE SKILLS



Report is well structured and readable with a good presentation style. A reasonable executive summary.

14/20

14