

PHILLIP ROWE ASSIGNMENT

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by Phillip Rowe

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Well structured

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1. Executive summary

This is a description of the contents not a summary of the report.

In this assignment, an investigation was made into inverter drives and switch mode power supplies. Methods used in order to control a three phase squirrel cage motor were researched and applications and efficient methods with given. Commercial AC induction drives were also looked at giving a wide range of characteristics such as cost, reliability and maintenance. Finally the filtering requirements of modern day drives were looked at. Multiple multisim circuits were then critically analysed and evaluated, in order to compare practical simulation to theoretical results.

2. Research

Methods of speed control

Variable frequency

what is this?

A variable frequency drive changes the capacity of the artificial lift system by varying the motor speed. (Wells, 2008). Variable frequency related directly to the speed of the motor, this means the faster the frequency the faster the motor RPM. The output of a variable frequency is called pulse width modulation(PWM). PWM controls the amplitude of the frequency wave in order to control how fast/slow the motor goes. Following below in figure 1 is an oscilloscope reading of PWM. By cycling the three phases on and off rapidly, by varying the width of duty cycle this regulates the voltage applied to the motor.

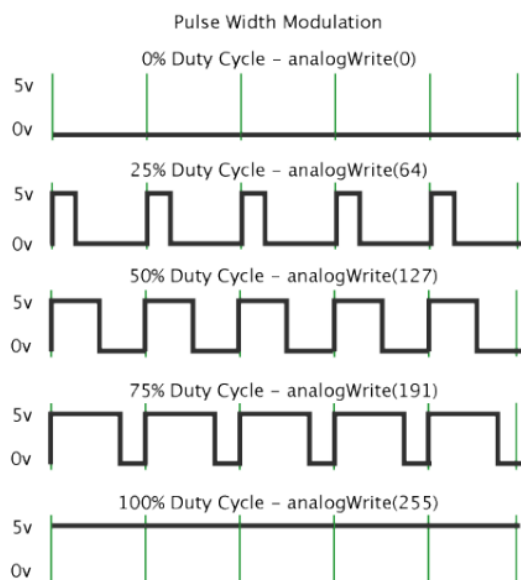


Figure 1- PWM (Hartel, 2015)

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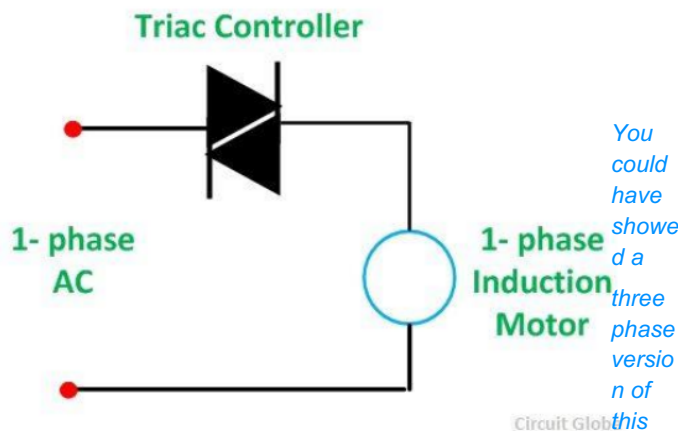
Variable-frequency drives are widely used to control the speed of conveyor systems, blower speeds, pump speeds and machine tool speeds. (Evans, 2019). The most efficient application for this method would be pump speeds. This is because a pump for most applications will not be required to run at full load all the time, so by tailoring the duty cycle to the speed demand of the pump this would save massive amounts of power. *Can you give quantitative data from a credible source for this?*

Voltage regulation

Correctly cited

Stator Voltage Control is a method used to control the speed of an Induction Motor. (Smith, 2018).

In order to control the speed of the motor the supply voltage can be varied in order to give a reduced or increased speed. This control method does not alter the synchronous speed of the motor. With this method, the voltage is varied until the torque which is required from the load is developed, this will give the desired speed. This method of speed control is performed by using a triac in most domestic applications. The firing angle to the triac is varied to change the speed, this is known as a solid state regulator. This is represented below in figure 2.



You could have showed a three phase version of this

Figure 2- Variable voltage (Smith, 2018)

These solid state relays are more compact and efficient compared to conventional variable regulators therefore they are more widely used. Typical applications for voltage control are large fan units. This is due to the reduced starting voltage which will then lower the starting current making high current motors use less power until they are at synchronous speed and their best efficiency rating.

Commercial AC motor drives

AC servo motor drive *This is only relevant if the drive is a flux vector drive and can be connected to a 3 phase induction motor*

A servo drive is designed in order to power and manage the performance of electric servomechanisms. The servo drive continuously monitors the feedback signals in order to continuously respond to any deviations which are seen in the closed loop control system. This will then be reflected in the response as the overall performance as the fast acceleration and precise speed/position control is near perfect. Servo control loops within the drive are used for controlling torque, velocity, or position (or a combination of the three). (Collins, 2018). Following below in figure 3 is a typical PID look for a servo motor control.

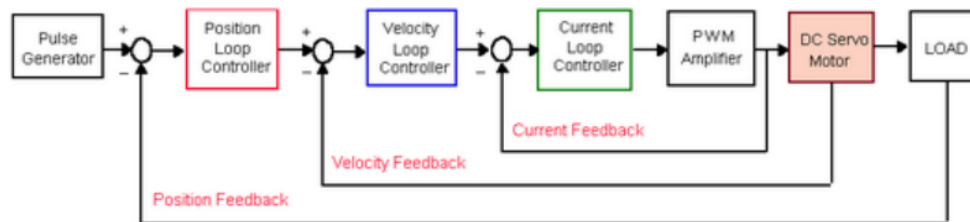


Figure 3- PID servo drive (Collins, 2018)

the author's surname needs to be outside the brackets
According (ATO, 2015) the typical servo drive can range from 100W up to around 7.5KW, with the cost starting at about \$300 and reach a top end of around \$2000. Since the power range doesn't span high enough, the servo drive is best suitable for customers with medium to small applications. Applications mainly involve in automation, robotics, CNC machinery, and other applications a high level of precision and needful versatility. (Williams, 2019). The aesthetics of this drive are perfect for taking up little space as the drives are very compact, this can be seen below in figure 4. These type of drives are basically maintenance free, with only small checks which need to be carried out which can be very quick visual checks. Since these drives are basically maintenance free, they are very reliable drives since there is very little which can go wrong.

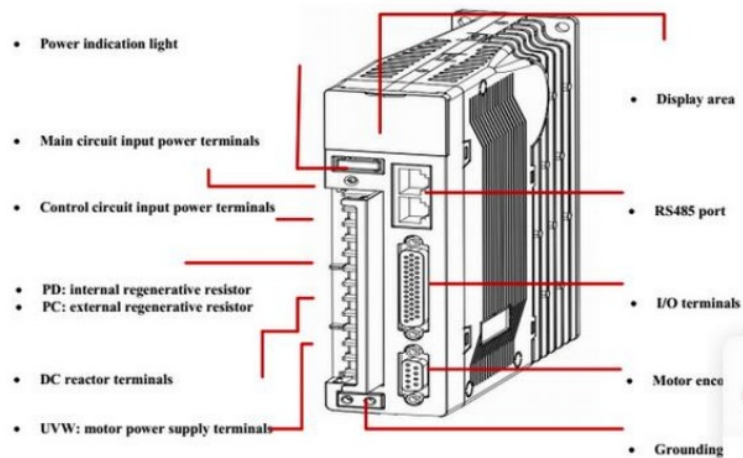


Figure 4- Servo drive

(Mechatronics, 2020)

Sensorless vector drives

The vector drive works by controlling the current and field orientation on an AC induction motor. This itself makes it one of the best drives available to customers. Sensor less vector control, also known as field-oriented control, outputs performance comparable to that of a motor drive using position/velocity feedback — in turn decreasing drive-system cost. (Eitel, 2011). The cost of these drives can range from around £500 anywhere up to £10000. Veichi AC70 is one of the classic general purpose vector control drive that it offers 380V, 660V and 1140V 0.75KW to 1100KW models. (Green, 2016). These type of drives would be used for heavy industrial applications due to their high torque/current performance with such efficient speed and position control. Following below in figure 5 is a typical PID control drawing for a sensorless vector drive.

servo drives
control a
different type of
ac motor not
field orientation
assignment

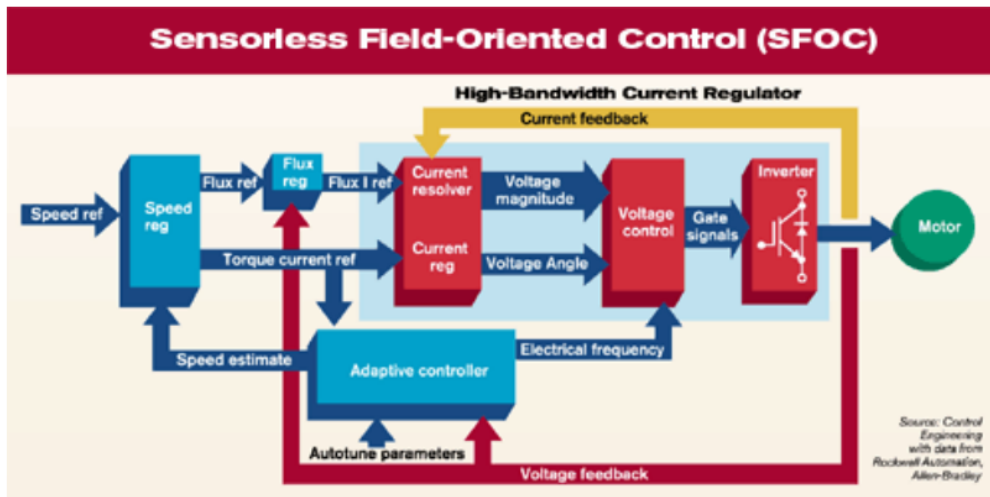


Figure 5- Sensorless vector drive PID (Frank J. Bartos, 2015)

This section is good

The customers would be steel works, automotive plants and paper mills, these all require either large current demand or excellent position control. The drive itself is very compact with no maintenance needed, obviously the size will depend on what KW drive is being used, however they are still very space consuming. There is no need for maintenance on these drives at all. Due to the sophisticated algorithms that this drive uses in order to predict the field orientation, this drive is a highly reliable drive since there is one unit in the drive which does these calculations.

You could have considered the VSI and CSI types of drive and said something about the Siemens S120 drive.
Filtering requirements

Some frequency-dependant components in electronic hardware can produce electric, magnetic or electromagnetic fields. If these fields are strong enough, they can interfere with other apparatus and cause undesired effects. (IDSM, 2019). The problem with AC inverters is that with EMI (electromagnetic interference) is produced by switching waveforms. Long cable lengths can also contribute to the affects of this, shielding motor cables is one type of solution however it is expensive and may not limit common mode emissions. There are international standards set in order to determine acceptable limits for EMI, this is EN55011. Audible noise can also be an issue, if the PWM switching frequency is in the audible range, below about 20kHz, and the inverter output is not filtered, stator lamination vibration can cause an annoying 'whine'. (Cooper, 2017) There are numerous filters which can be used, for heavy industry applications which demand high current and have long cable lengths a sine former filter can be used. Following below in figure 6 is a circuit diagram of a sineformer filter.

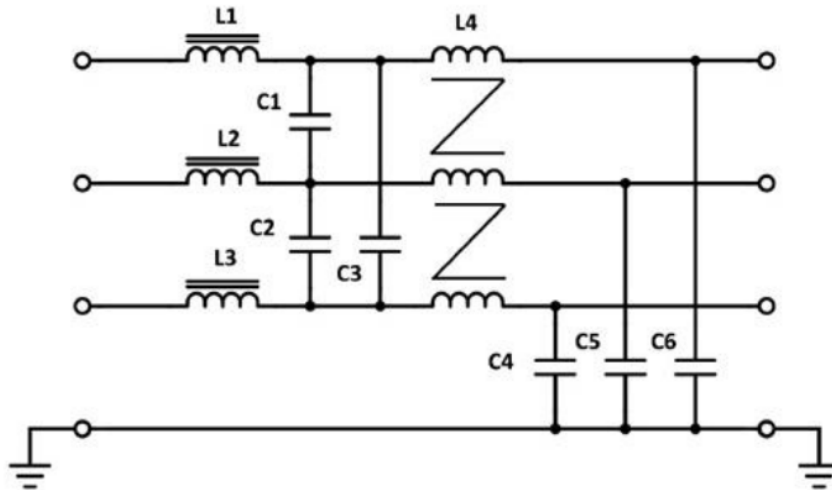


Figure 6- sineformer filter (Cooper, 2017)

This filter is capable of being used on drive up to around 320A/520VAC. The filter makes use of a common mode choke which can dramatically reduce common mode currents and differential noise. This filter also reduces dV/dt on waveforms which causes significant reduction in bearing currents and has the lowest possible EMI. This type of filter is maintenance free and can be retrofitted into any existing application. Whilst this type of filter can be expensive due to its partnership with shielded cable, calculations have been carried out and in the long term this filter is cheaper than the risk of failures, downtime and replacement of motors caused by noise/EMI.

3. Simulation of inverter drives

Quasi-square wave inverter

Following below in figure 7 is the quasi square multisim circuit. The circuit consists of a firing circuit, pulse circuit and also the end load (the motor). The pulse circuit determines when to send a pulse to the base of the transistor.

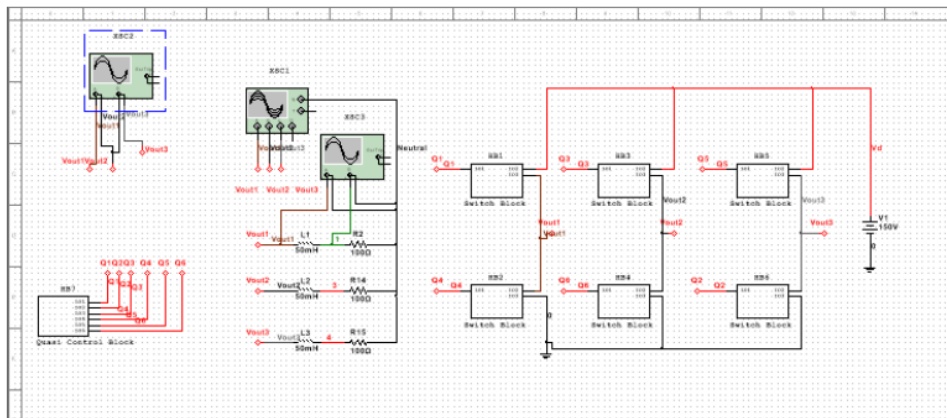


Figure 7 – Quasi square multisim circuit

Following below in figure 8 is the output waveform for the three phase voltage of the quasi square waveform.

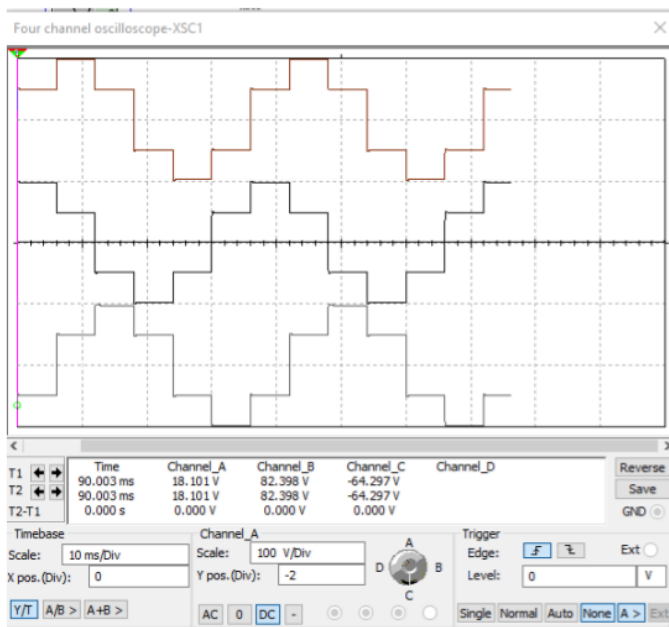


Figure 8

As seen in figure 9 is the output RMS voltage and current which is being applied to the star connected load. This is also known as the modified outputwave. Comparing this waveform to theoretical waves, they are identical and are as expected to be.

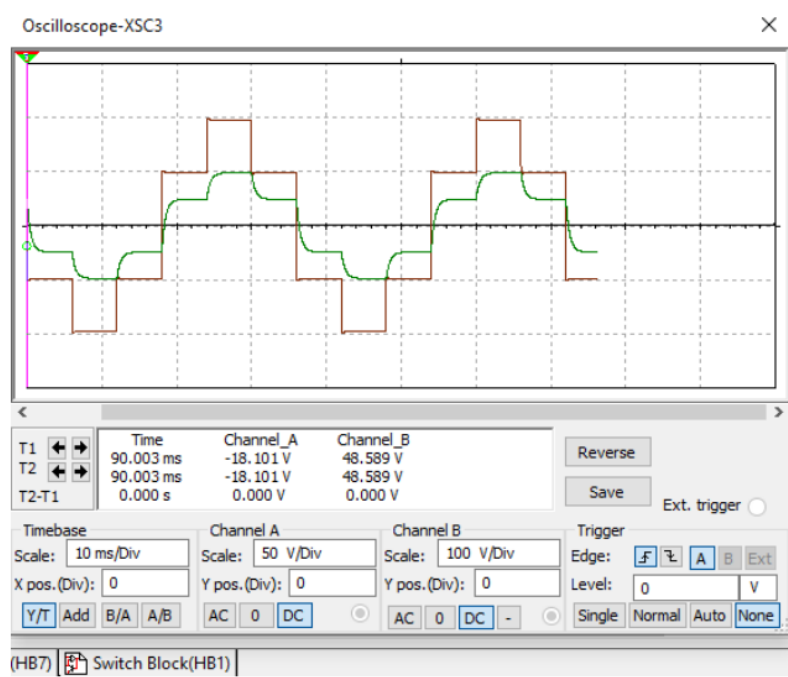


Figure 9 – RMS

Voltage and current

In order to change the RMS voltage applied to the load the width of the output quasi square wave needs to be either made longer or shorter. In figure 10 this is illustrated, the pulse time has been halved compared to the waveform in figure 9. This will mean that the wave form is smaller, so the transistors will conduct for less time meaning the effect on the motor torque will lower as the current will be lower.

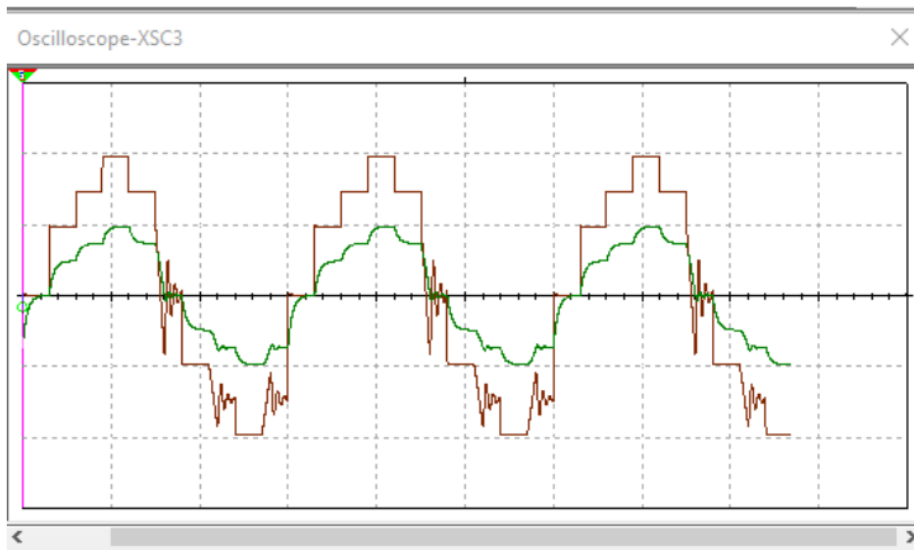


Figure 10

PWM Inverter

Following below in figure 11 is the multisim circuit for the PWM inverter simulation. It is made up of the output load (a motor) made up of inductance and resistance, a firing circuit, a pulse firing circuit and oscilloscopes for analysis.

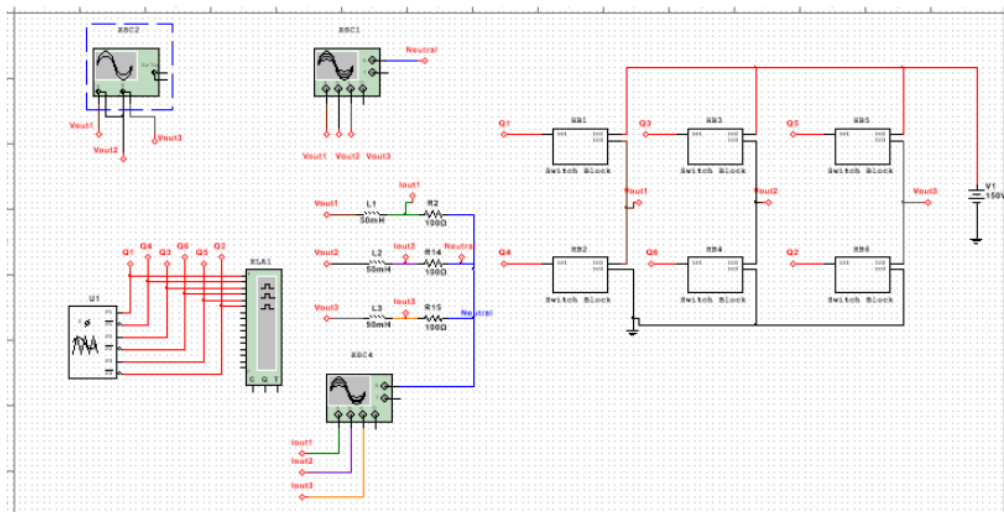


Figure 11- PWM inverter overview

Below in figure 12 is a simulations of the PWM inverter, the image shows the pulses and the output wave form known as notching.

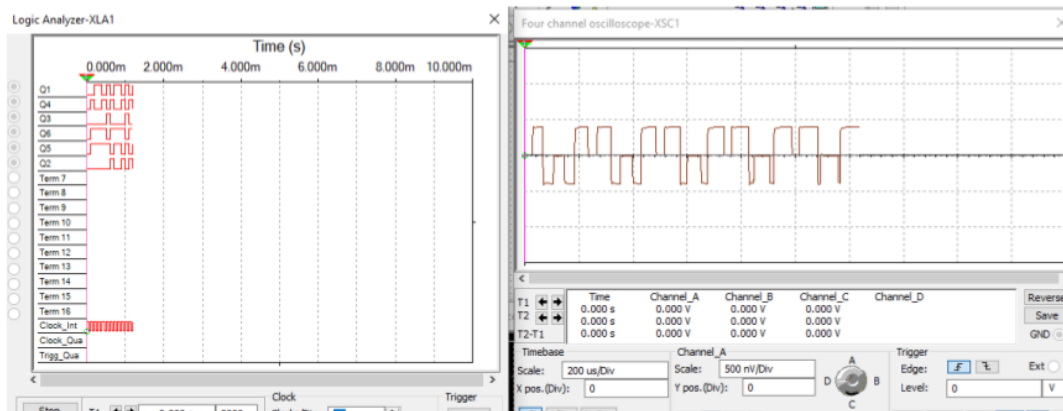


Figure 12- PWM notching

Now by changing the reference signal frequency, the pulses will be faster which will then increase the amount of PWM waves seen. As shown in figure 13 the reference signal has been changed to 6khz from 4khz.

PWM_SINUSOIDAL_3PHASE

Label	Display	Value	Fault	Pins	Variant
Reference signal frequency:		6k			Hz
Modulation frequency:		60			Hz
Amplitude modulation ratio:		800m			
Output voltage amplitude:		5			V
Output rise/fall time:		1n			s
☒ Adjust time step during crossings					

Figure 13- PWM reference

As seen in figure 14 is the resulting change of the reference frequency being increased, the result on the motor will be that it will be going slower as the PWM is smaller and the pulse isn't on for as long.

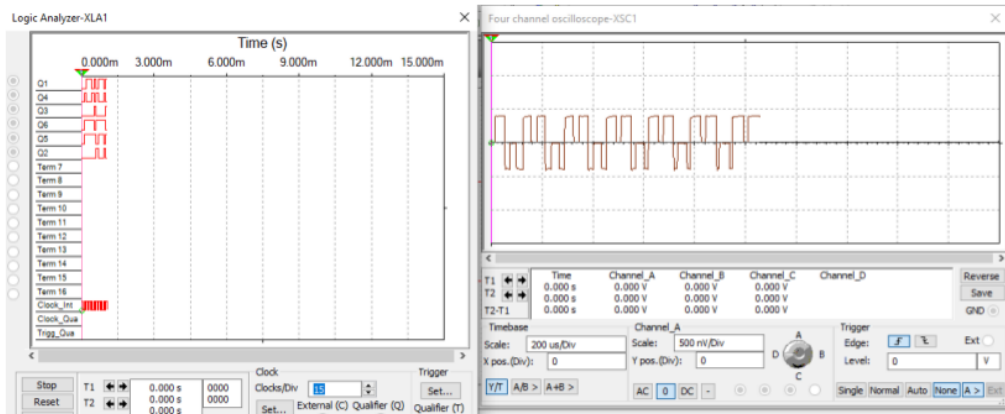


Figure 14- PWM

Shown in figure 15 is the output PWM which is applied to the motor. It can clearly be seen that there are short, small pulses which mean the full frequency is not being applied to the motor.

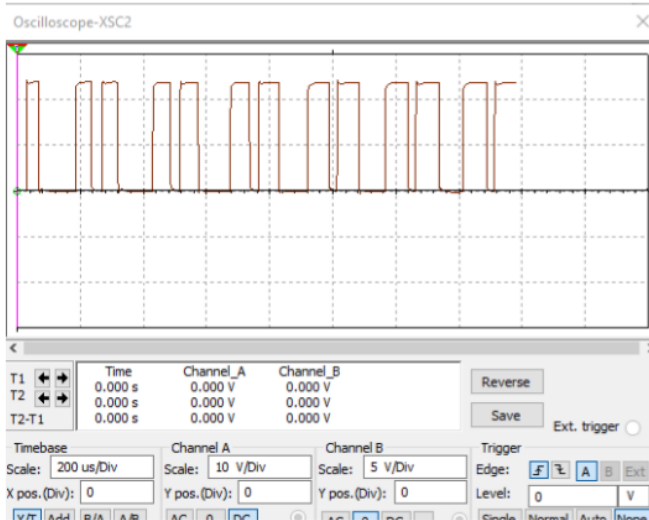


Figure 15

Now to demonstrate the effect of lowering the reference signal frequency, figure 16 shows this. It can be clearly seen that now the reference signal frequency has been lowered, the PWM waves are longer, therefore more of the sinewave is being applied to the motor meaning more volts and a faster RPM.

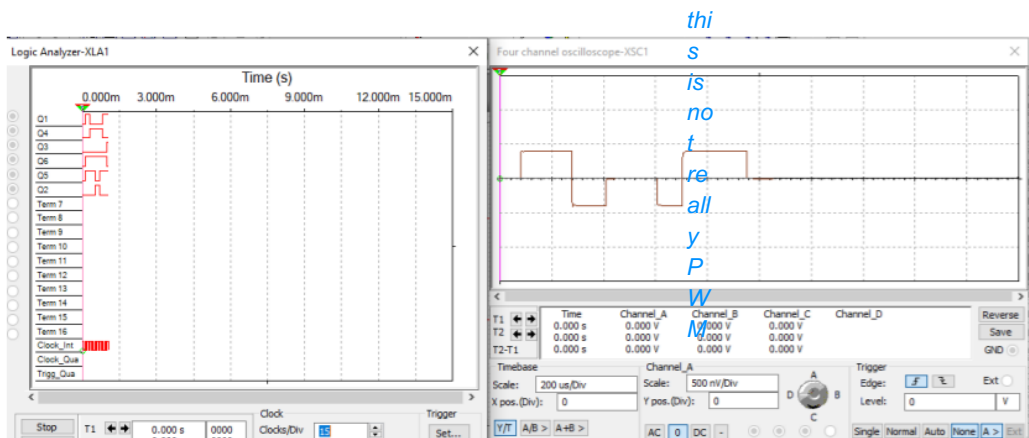


Figure 16- PWM faster

Shown below in figure 17 is the output PWM being applied to the motor, more of the wave is being applied meaning the frequency is higher which will increase the motor RPM.

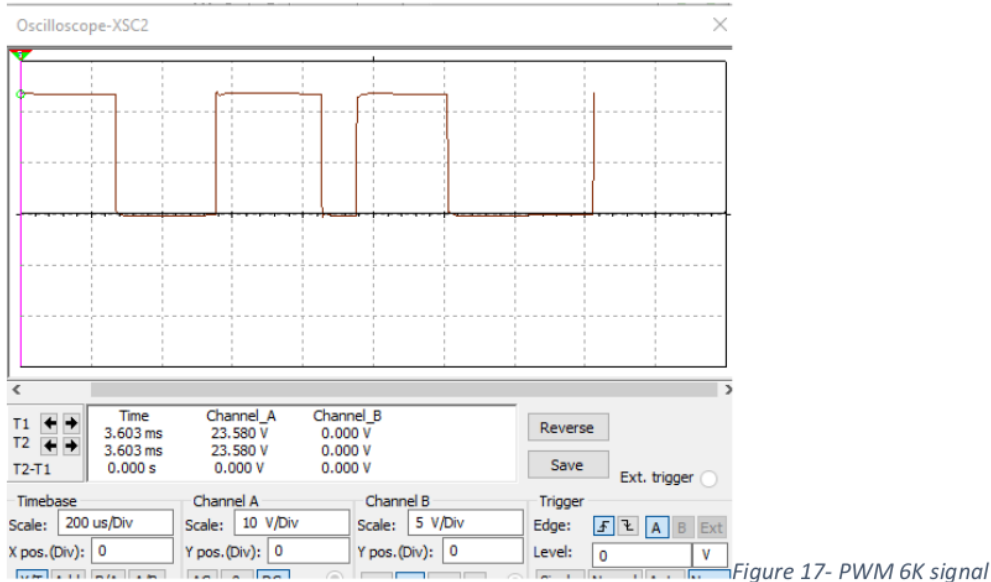


Figure 17- PWM 6K signal reference

Following below in figure 18 is the switching circuit used to supply voltage to the motor. The bipolar transistor receives a pulse to the base in order to switch it on and allow it to conduct. There is also a flywheel diode in the circuit which allows current to be dissipated when the transistor is turned off. The capacitor and inductor are used in order to try and suppress noise which could affect the motor.

You could have shown that the current waveforms from the PWM drive are much smoother and sinewave like that the quasi-square wave type

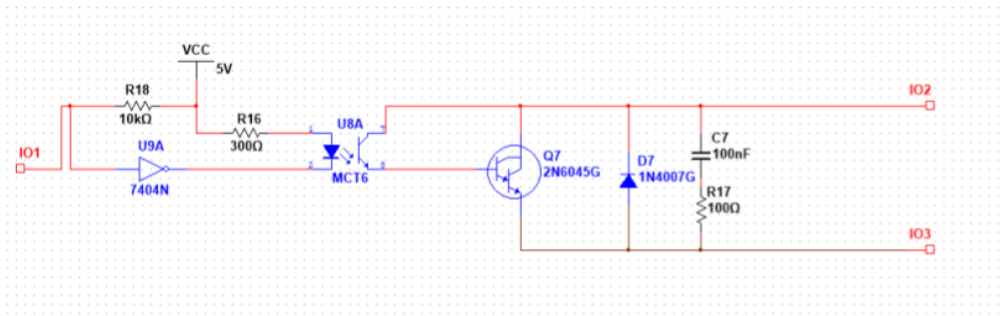


Figure 18 - Firing circuit

Comparing the wave forms analysed with theoretical waveforms, the circuit is reacting and performing as it should do. There is a correlation between how often there is a pulse to the base of a set of transistors and how often there is an output of PWM. The longer the PWM wave, the greater the line voltage.

4. Design and simulation of switch mode power supplies

Buck converter

Following below in figure 19 is the buck converter circuit that will be analysed.

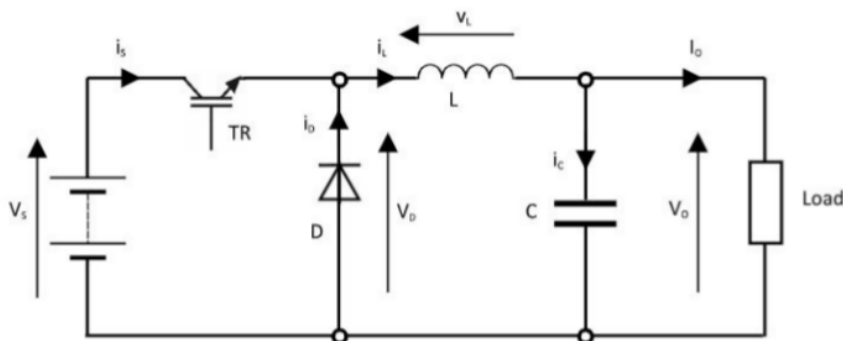


Figure 19-

Buck converter

$$\text{Load current} = I_o = V/R = 16/2 = 8\text{A}$$

Firstly calculate $t_1 + t_2$

$$t_1 + t_2 = \frac{1}{f} = \frac{1}{200 \times 10^3} = 5\mu\text{s}$$

$$D = 16/40 = 0.4$$

$$\frac{t1}{t1 + t2} = \frac{Vo}{E}$$

$$t1 = \frac{Vo}{E} x (t1 + t2)$$

$$t1 = \frac{16}{40} x (5 + 10^{-6}) = 2\mu s$$

$$t2 = 5 - 2 = 3\mu s$$

When the switch is closed, the rise will equal the value that is applicable for the equation.

$$\frac{diL}{dt} = \frac{40 - 16}{L} = \frac{24}{L}$$

When the switch is opened, iL will fall flat at a rate which is suitable for the equation.

$$0 - Vo = L \frac{diL}{dt}$$

$$\frac{diL}{dt} = \frac{-16}{L}$$

$$I_l \text{ will rise to } 2xI_o = 16A$$

Since $I_o = iL + iC = 8A$, since iL rises, iC must fall from $8A$ to $-8A$

The inductor current is given by $iL = iS + iD$ with only one flowing at a time

$iL = iS$ when ON

$iL = iD$ when OFF

When the switch is closed, inductor satisfies equation

$$40 - 16 = L \frac{diL}{dt}$$

$$\frac{diL}{dt} = \frac{24}{L}$$

$$\text{But gradient} = \frac{16}{3 \times 10^{-6}}$$

why use 3us, you should have used 2us

$$\frac{24}{L} = \frac{16}{3 \times 10^{-6}}$$

$$L = 3 \times 10^{-6} x \frac{24}{16} = 4.5\mu H$$

incorrect

$$\Delta q = \frac{1}{2} 2.5 \times 10^{-6} \times 8 = 10 \mu C$$

$$\Delta VC = \frac{\Delta q}{c}$$

$$C = \frac{\Delta q}{\Delta VC} = \frac{10 \times 10^{-6}}{0.1} = 100 \mu f$$

The average voltage across the inductor over one full cycle is zero

$$V_s \tan - (V_o - V_s) \text{toff} = 0$$

$$\text{Therefore: } V_s DT = (V_o - V_s)(1 - D)T$$

$$\frac{V_o}{V_s} = \frac{1}{1 - D}$$

Following below in figure 20 is the final multisim circuit for the buck converter.

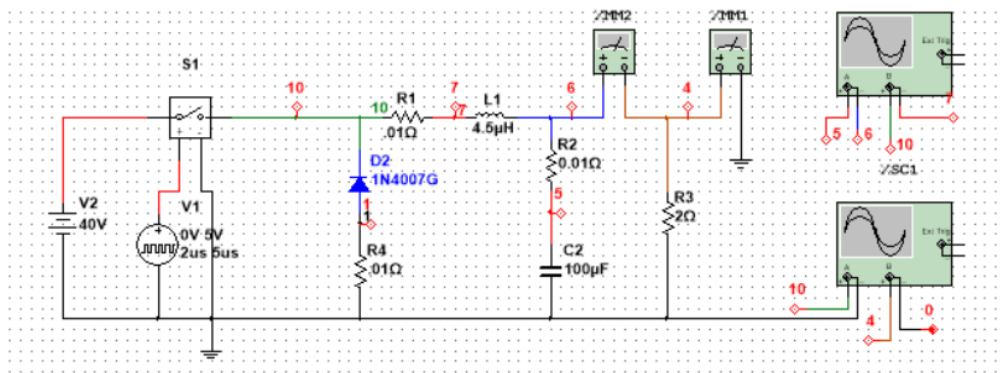


Figure 20 Buck converter multisim

As seen below in figure 21 is the constant output voltage (V_o) for the buck converter. The red line also represents V_D which is the voltage across the diode.

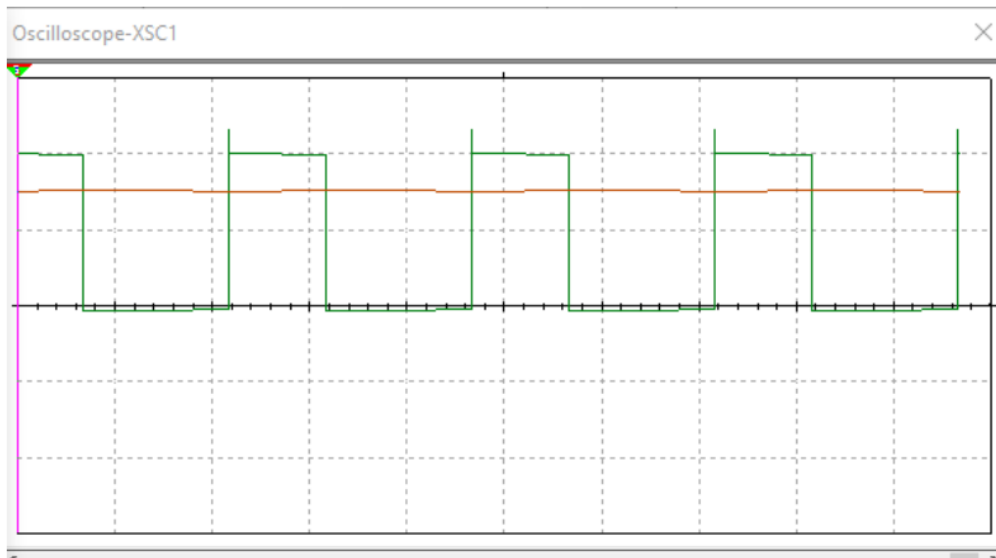


Figure 21 - Output waveform from buck converter

Below in figure 22 is the output continuous current for the buck converter. The green line represents the continuous current whilst the red line represents the charging and discharging of the capacitor.

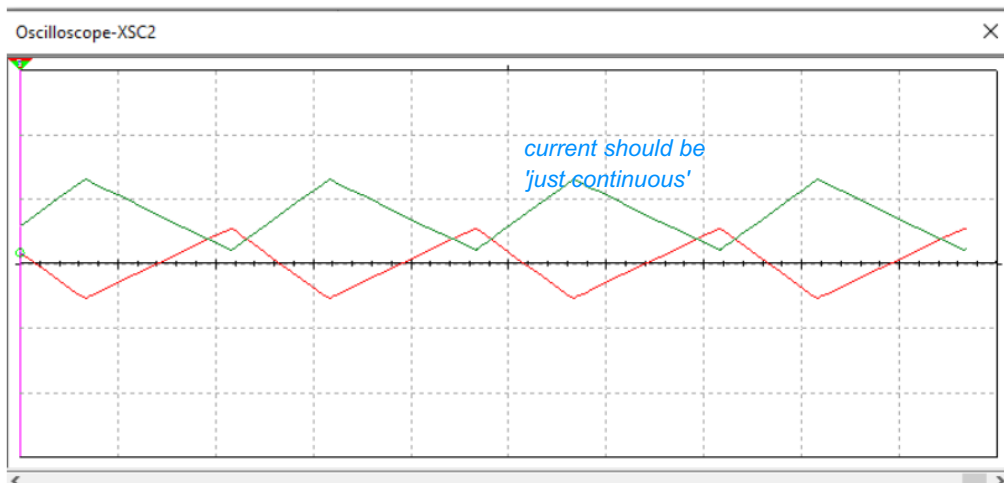


Figure 22 - Buck converter current

Looking at the results from the simulation the output waveforms do correlate with the theory as expected. With a purely resistive load the output voltage waveform should look like PWM blocks with a constant voltage line running through the waveforms also. The charging and discharging of the capacitor should mimic the current in the inductor, meaning when the current is rising in the capacitor, it should be discharging in the inductor and when the capacitor is discharging the current in the inductor should be rising.

You could have measured the average dc voltage and current to compare with the question.

Boost converter

Following below in figure 23 is the circuit of the boost converter. Firstly the calculations will be done in order to find out the duty cycle, Peak-peak ripple current of the inductor, the peak current of the inductor and the minimum inductor value for continuous inductor current.

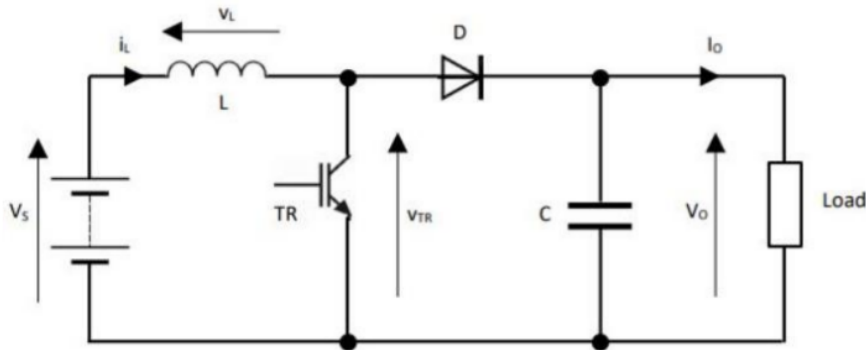


Figure 23 -

Boost converter circuit

The average voltage across the inductor over one full cycle is zero

$$V_s \text{ton} - (V_o - V_s) \text{toff} = 0$$

Therefore: $V_s DT = (V_o - V_s)(1 - D)T$

$$\frac{V_o}{V_s} = \frac{1}{1 - D}$$

Where D is the duty cycle and T is the switching period

$$D = 1 - \frac{V_s}{V_o} = 1 - \frac{12}{20} = 0.4$$

$$\Delta i_L = \frac{V_s \text{ton}}{L} = \frac{V_s DT}{L} = \frac{12 \times 0.4 \times 50 \times 10^{-6}}{150 \times 10^{-6}} = 1.6 \text{A}$$

$$V_s I_L(\text{av}) = V_o I_o$$

$$I_L(\text{av}) = \frac{V_o}{V_s} \times I_o = \frac{20}{12} \times 1.5 = 2.5 \text{A}$$

$$i_L(\text{peak}) = I_L(\text{av}) + \frac{\Delta i_L}{2} = 2.5 + 0.8 = 3.3 \text{A}$$

$$V_s I_L(\text{av}) = V_o I_o \text{ and So}$$

$$I_o = \frac{V_o}{R} = I_L(\text{av}) \frac{V_s}{V_o} = I_L(\text{av})(1 - D)$$

$$I_L(\text{av}) = \frac{\Delta I_L}{2}$$

$$\frac{V_o}{R} = \frac{\Delta i_L}{2} (1 - D) = \frac{V_s}{2L} DT(1 - D)$$

$$L = \frac{1}{2} = \frac{RTD(1 - D)^2}{2}$$

$$L = \frac{1}{2} \times \frac{20}{1.5} \times 50 \times 10^{-6} (1 - 0.4)^2 = 48 \mu H$$

$$D = 20 \mu s$$

$$RO = \frac{20}{1.5} = 13.33$$

Following below in figure 24 is the final circuit which has been built on multisim.

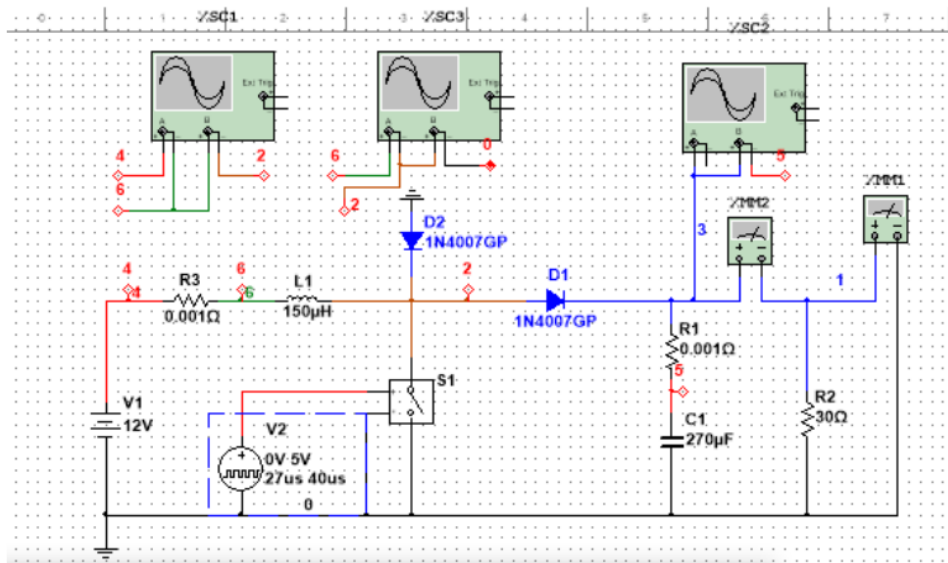


Figure 24- Boost converter multisim

Now the simulation has been built, it was run in order to show continuous current through the inductor. This is shown below in figure 25.

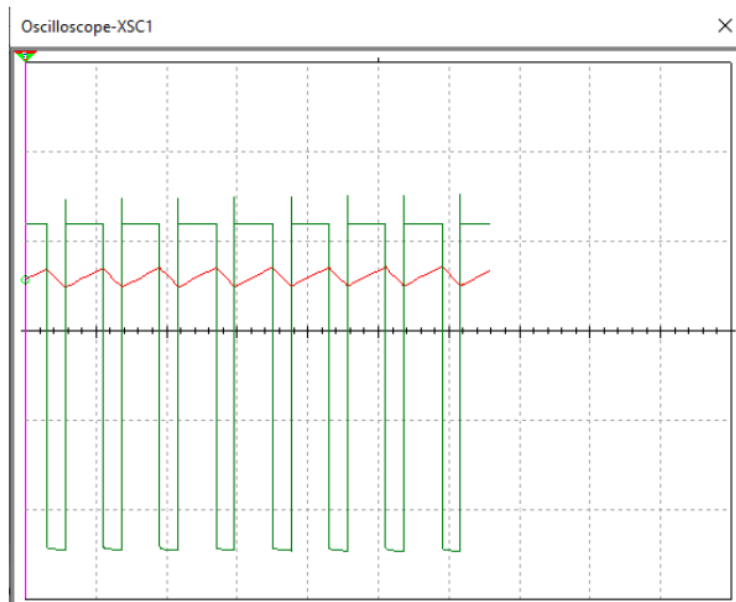


Figure 25 - Boost

converter continuous current

Following below in figure 26 is the modified multisim with the minimum inductor value for continuous current. This is as expected and correlates with the theory. The calculated minimum value for continuous current is correct as in figure 27 when the inductor value is decreased to 47uH the current goes discontinuous.

You should have measure the average voltage and current to compare with the design criteria of the question

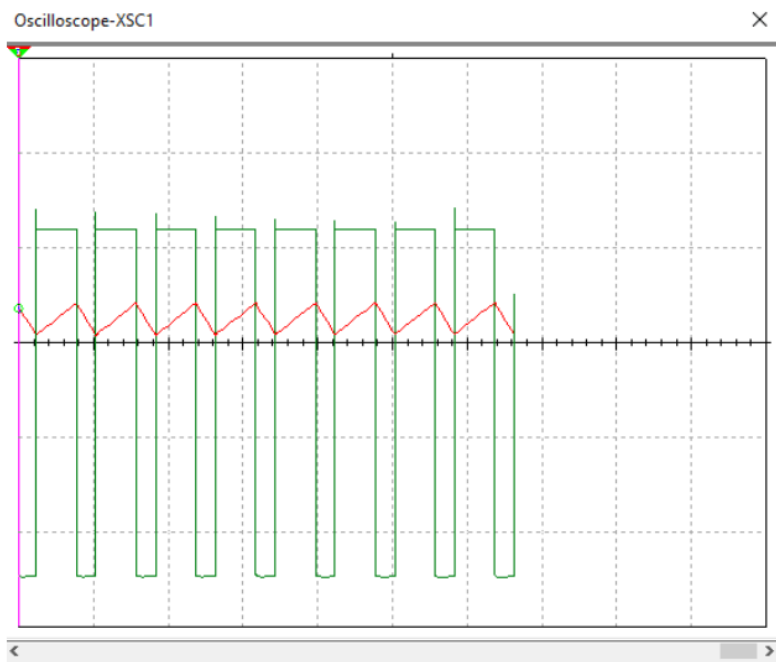


Figure 26- Minimum

inductor value for continuous current

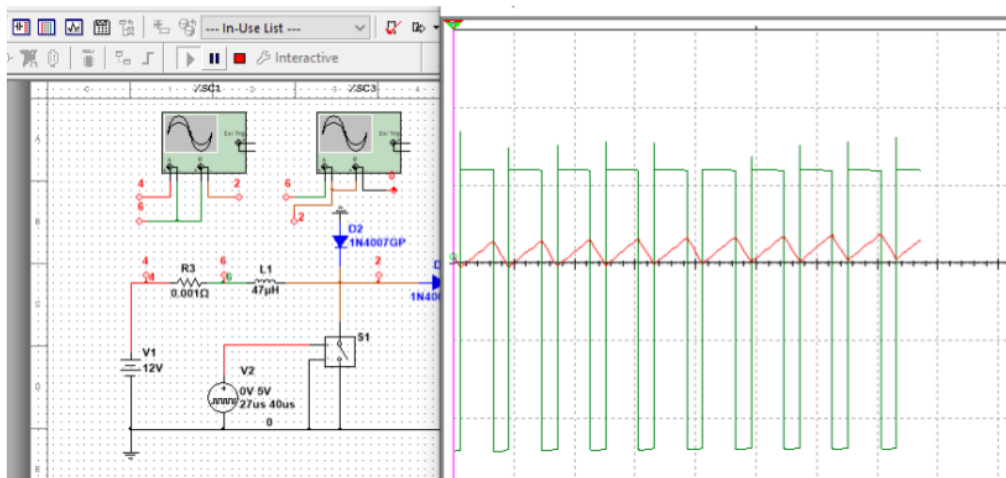


Figure 27 - Discontinuous current

this current is 'just continuous'

5. Conclusion and recommendations

To draw a conclusion on this assignment, there are many different methods of speed control which have different advantages for different applications. Applications which need high starting current would not use soft start speed control/triacs as it will limit their starting voltage and current. The most effective basic speed controller would be a variable frequency drive as it can vary the frequency efficiently to the demand of the application. Commercial AC motor drives can provide effective speed and position control. There are numerous factors that can be taken into account when choosing the best type of drive. If cost is not an issue then a sensor less field orientated control drive should be used as it produces excellent speed, torque and position control. If cost is an issue then a smaller servo drive can be used with still amazing performance. The filtering for any AC drive should be as good possible, as if harmonics/EMI cause motor failures or drive failures then the cost of downtime and replacement would be more than the initial cost of putting in a good filtering circuit. The quasi square wave inverter performed as expected, the average voltage follows previous voltage spectrums analysed. It was proven in the simulation by varying the pulses to the transistors this can alter the period of how long the transistors conduct for hence varying how much voltage goes to the load. The PWM circuit performed like a typical PWM inverter, the blocky pulses put shape a normal sine wave for the output voltage. Then when varying the reference signal frequency in the firing block alters the width of the PWM blocks meaning the transistor staying on for either less or more time, varying the time the voltage is applied to the end load. The buck converter wave forms follow the theory, showing the correlation between the current in the inductor and the current in the capacitor. The output voltage mimics normal waveforms for the buck converter which looks like PWM however has a V_o constant voltage for the output voltage. Finally the boost converter acted as expected from the theory, the voltage in the inductor peaks when the switch is closed and drops off when the switch is opened. This also applies to the current as when the voltage drops so does the current in a saw tooth manner. Overall all of the practical circuits simulated correlate with the theoretical results/waveforms analysed.

6. Havard references

ATO, 2015. *ATO*. [Online]

Available at: <https://www.ato.com/ac-servo-motor-price-list>

[Accessed 20th April 2020].

Collins, D., 2018. *motioncontroltips*. [Online]

Available at: <https://www.motioncontroltips.com/selecting-a-servo-drive-9-things-you-need-to-know/>

[Accessed 20th April 2020].

Cooper, L., 2017. *electronicspecifier*. [Online]

Available at: <https://www.electronicspecifier.com/products/power/keeping-the-noise-down-converter-and-inverter-output-filtering>

[Accessed 20th April 2020].

Eitel, E., 2011. *machinedesign*. [Online]

Available at: <https://www.machinedesign.com/automation-iiot/sensors/article/21832900/sensorless-vector-control>

[Accessed 20th April 2020].

Evans, M., 2019. *industrial electronics*. [Online]

Available at: <http://www.industrial-electronics.com/index.html>

[Accessed 20th April 2020].

Frank J. Bartos, 2015. CONTROL ENGINEERING. *Sensorless AC Drives Fill Price/Performance Niche*, 1(1), p. All.

Green, K., 2016. *eeweb*. [Online]

Available at: <https://www.eeweb.com/profile/kate-green/articles/sensorless-vector-control-and-torque-control-vfd>

[Accessed 20th April 2020].

Hirzel, T., 2015. *arduino*. [Online]

Available at: <https://www.arduino.cc/en/tutorial/PWM>

[Accessed 18th April 2020].

IDSM, 2019. *inverterdrive*. [Online]

Available at: <https://inverterdrive.com/howto/EMC-Information-Application-1st-2nd-environment/>

[Accessed 20th April 2020].

Mechatronics, J., 2020. *Jinsanshi Mechatronics*. [Online]

Available at: <http://www.jss-motor.com/product/Servo-motor-driver-EPS-B1.html>

[Accessed 20th April 2020].

Smith, J., 2018. *circuitglobe*. [Online]

Available at: <https://circuitglobe.com/stator-voltage-control-of-an-induction-motor.html>

[Accessed 20th April 2020].

Wells, M. R., 2008. *Gas Well Deliquification*. 2nd ed. New York: Gulf Professional Publishing.

Williams, D., 2019. *watelectrical*. [Online]

Available at: <https://www.watelectrical.com/servo-motor-types-and-working-principle/>

[Accessed 20th April 2020].

PHILLIP ROWE ASSIGNMENT 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

PAGE 1

PAGE 2

Text Comment. Well structured

PAGE 3

PAGE 4

Text Comment. This is a description of the contents not a summary of the report.

Text Comment. what is this?

Text Comment. you could have explained quasi-square wave types also.

Text Comment. This is a bit too simplistic for this level

Text Comment. What would the motor voltage waveforms look like?

PAGE 5

Text Comment. Can you give quantitative data from a credible source for this?

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

Text Comment. You could have showed a three phase version of this

PAGE 6

Text Comment. This is only relevant if the drive is a flux vector drive and can be connected to a 3 phase induction motor.

Text Comment. the author's surname needs to be outside the brackets

PAGE 7

Text Comment. servo drives control a different type of ac motor not relevant to this assignment

PAGE 8

Text Comment. This section is good

Text Comment. You could have considered the VSI and CSI types of drive and said something about the Siemens S120 drive.

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

Text Comment. this is not really PWM

PAGE 16

Text Comment. You could have shown that the current waveforms from the PWM drive are much smoother and sinewave like that the quasi-square wave type

PAGE 17

Text Comment. why use 3us, you should have used 2us

Text Comment. incorrect

PAGE 18

Text Comment. current should be 'just continuous'

Text Comment. You could have measured the average dc voltage and current to compare with the question.

Text Comment. You should have measure the average voltage and current to compare with the design criteria of the question

Text Comment. this current is 'just continuous'

GRADING FORM: NEW CSG-RUBRIC

PHILLIP ROWE

63

1. ENGAGEMENT WITH LITERATURE



There is good evidence of reading from a wide range of credible sources. However, the inclusion of servo drives is not relevant and other opportunities for research have been missed. Method of citing is

13

mostly correct and citation list does conform to the Harvard method. 13/20

2. KNOWLEDGE AND UNDERSTANDING



Knowledge and understanding is generally good as seen in the research (though servo systems were not required). Introductions and explanation of simulation tasks are briefly given. 13/20

13

3. COGNITIVE AND INTELLECTUAL



There is some evidence of analysis the calculations and results. However, improvements could have been made to check the voltage and current of the switch mode supplies for comparison with the design criteria to verify success. Useful conclusions are offered. 12/20

12

4. PRACTICAL APPLICATION



Good use of Multisim for most parts except the PWM inverter where waveforms do not clear show operation. Simulated average voltage and current could also have been measured for the buck and boost converters to verify operation. 11/20

11

5. TRANSFERABLE SKILLS



Good structure, well presented, written within the word count. 14/20

14

