

P151664 PED Assign 2

by Derek Lockhart

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Inverters

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1. Introduction

This lab exercise shall investigate three-phase inverters their uses. Three phase inverters produce a three phase a.c. signal powered from a d.c. source where each phase is separated by 120° [1]. Three phase inverters are used in both high and low powered applications, they provide Variable Voltage Variable Frequency (VVVF) power adaptable for the specific needs of the load[2], with ac motors a VVVF allows the supply to regulate the speed and torques of the motor[3][4]. Du discusses the development position of three phase inverters using Pulse Width Modulation (PWM), as of 2003, were such that in their largest implementation, Insulated Gate Bipolar Transistors (IGBTs) were capable of supporting industrial and national scale High Voltage Direct Current (HVDC) instead of the traditional thyristor method[5]. In this exercise, PWM shall be used to convert a DC power source into the three phase AC output using three half bridges constructed using enhancement mode Metal Oxide Semiconductor Field Effect Transistors (MOSFETs). The PWM drive signal for the MOSFETs is stored in microcontroller memory[6], the rate at which the memory is addressed determines the rate of change of the PWM signal and therefore the frequency of the AC waveform produced[7].

2. Method

2.1 Three Phase Inverter

The LJ Create Digiac Experiment platform 300-02 [8] in conjunction with the AC Power study module 305-17 [9] is used to analyse the properties of a single phase of the three PWM inverter. The circuit to be used is shown in Figure 1.

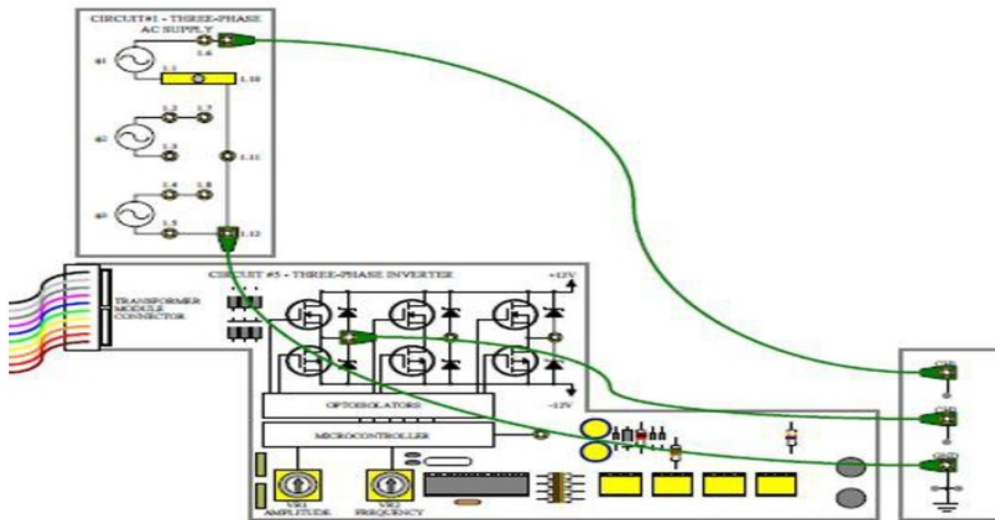


Figure 1 Pulse Width Modulation Inverter Circuit

As seen in Figure 1, VR1 and VR2 provide control over the supply amplitude and switching frequency driving the MOSFETs, with the resulting a.c. waveform and its precursor PWM signal, available respectively, on channels 1 & 2 of a virtual oscilloscope

To investigate over current protection the circuit was reconfigured in accordance with Figure 4, as such the output of the a.c. supply will feed a single arm of a star connected load.



A short was placed across the load by connecting sockets 2.2 and 2.3 and the effect of this noted, followed by the effects of removal of the link.

2.3 Fault Finding

The circuit was reconfigured to that shown in Figure 7.

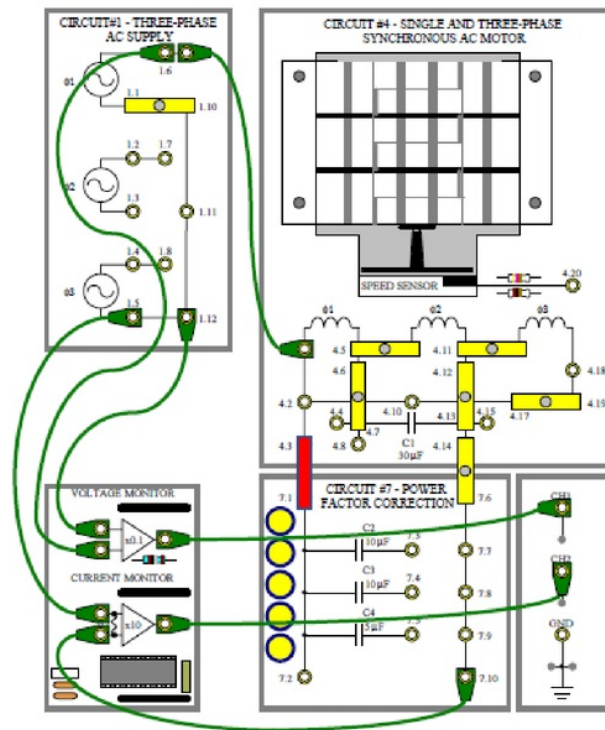


Figure 3 Fault Diagnosis Circuit

In this configuration a synchronous motor is driven by a single-phase supply, as discussed in previous exercises, synchronous motors create an inductive lag on the supply current.

The current lag needs correcting with capacitance which will be selected from C2-C4. The introduction of a link between 4.3 and 7.1 (in red) enables the selection of power factor correction capacitors. When this link is used the system fails and the fault must be diagnosed.

3. Results

3.1 Three phase Inverter

It can be seen in Figure 4 that the highest rate of change of the sine wave coincides with the highest rate of change of the PWM signal.

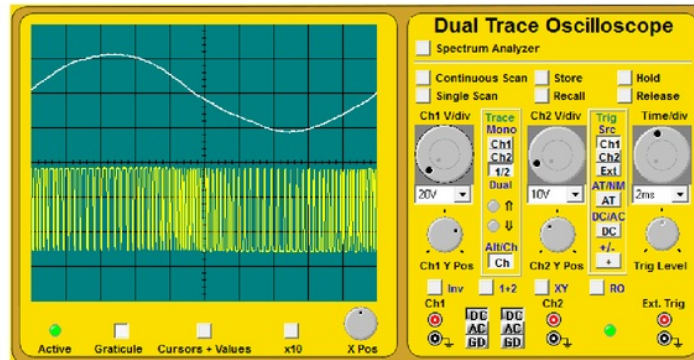


Figure 4 Virtual oscilloscope AC and PWM waveforms

When the signal is expanded to show only a half cycle, as shown in Figure 5, it can also be seen that, at the sinewave peak, the rate of change slows and the positive PWM pulses become broader. **(Q1a)** Conversely, the negative portion of the sinusoid would show a comparable train of negative PWM pulses becoming broader as the peak is approached.

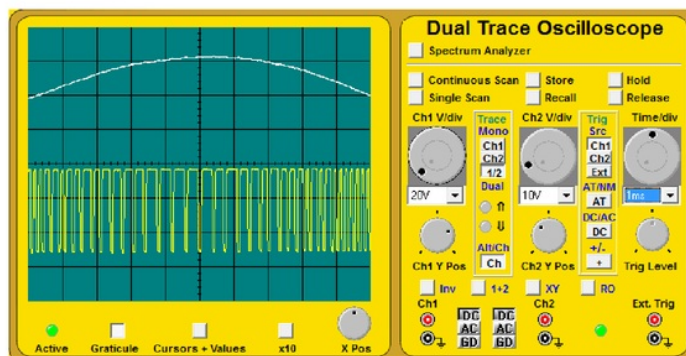


Figure 5 Virtual oscilloscope AC and PWM waveform positive cycles

On closer analysis, it can also be seen that approximately 40 microcontroller pulses are used per half-cycle (**Q1b**) and the sine wave also shows no apparent ripple beyond some, pixellation that is consistent with the limitations of the virtual oscilloscope (**Q1c**).

3.2 Overcurrent Protection

The immediate effect of shorting out the load is to draw an excess amount of current from the supply, this was observed by an **OL** (Overload) indication on the virtual ammeter.

As the short circuit remains in place, the Digiac over current protection takes effect and causes the supply voltage to fall to **0V**.

This drop in the supply voltage allows the load current to reduce to a safer level, as it remains in place for further amount of time the protection circuits of the system further alter the microcontroller pulses to keep the load current to a safe level this can be seen in Figures 6 & 7.

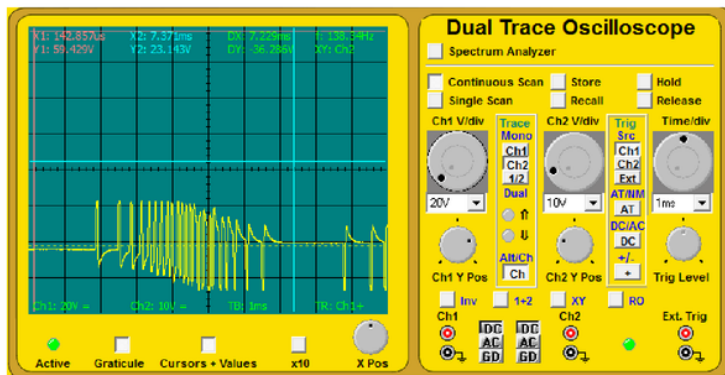


Figure 6 Altered PWM Signals

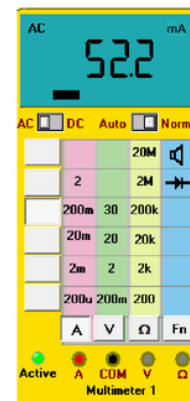


Figure 7 Supply current

With the short circuit removed the voltage and current do not return to normal, this is due to the excess heating that occurred during the over current condition. The situation does not change when the powered is cycled and the system requires sufficient down-time to cool before normal operation can be resumed. After a few minutes the power was restored, and normal operation is observed once more.

3.3 Fault Finding

In this configuration a synchronous motor is driven by a single-phase supply, as found in previous exercises, synchronous motors create an inductive lag on the current

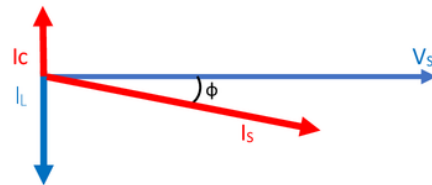


Figure 1 Current lag caused by motor inductance

This current lag angle requires reducing to reduce the electrical cost, due to the standard practice of using apparent power for electricity charging, an inductive load angle is reduced by capacitance. To enable this capacitance to be added a shorting link was added between 4.3 and 7.1 as indicated by the red link in Figure 7. This creates a circuit that is emulated in Figure 9.

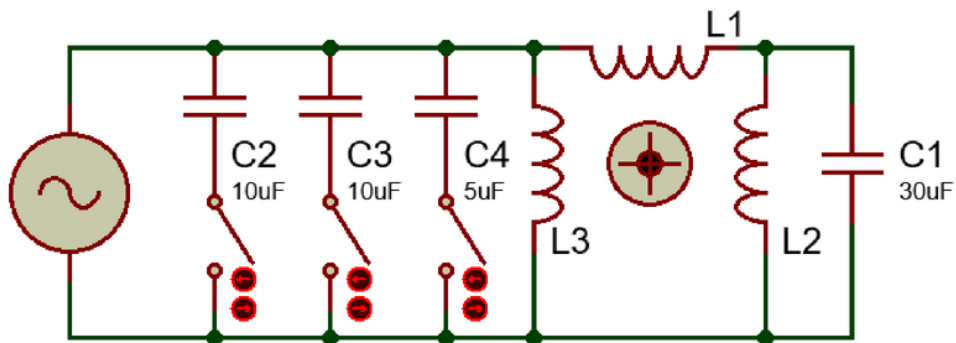


Figure 2 Motor circuit

It was noted that on addition of this link the system failed, this indicates a fault in the power factor correction circuits. After removing the power, a multimeter was used to isolate the fault, assisted by removal of extraneous links, down to an effective short between connections 7.6 and 7.1. This fault has the effect of shorting out L3 and the power supply.

4. Discussion

4.1 Three-Phase Inverter

A three-phase inverter provides a variable voltage variable frequency (VVVF) supply that can be adapted to the needs of the load. This is evidenced by the adjustment of VR1 and VR2. This adjusts the voltage supplied to the MOSFET circuit and the rate at which the PWM waveform is accessed from EPROM memory in the microcontroller. The rate of change of the a.c. output is in direct response to the width of the PWM pulses as previously discussed and seen in Figure 4.

4.2 Overcurrent Protection

The overload current found on application of the load short is entirely predictable and in line with Ohm's Law, $I = V \div R$. The overcurrent protection reducing the voltage to reduce the current is equally predictable.

With the short circuit removed the voltage and current do not return to normal. This is due to the excess heating that occurred during the over current condition. The situation further does not change when the powered is cycled as the system requires sufficient time for the "Thermal Fuse" to cool before normal operation can be resumed. After a few minutes the power was restored, and normal operation was observed once more. This may be a misdescription of a thermal fuse and is more likely to be a thermal switch as

thermal fuses are single use devices and a thermal switch is able to recover from an overheat condition[10].

4.3 Fault Finding

As previously described, the introduction of the power factor correction circuit induces the fault symptoms such that the motor shuts down. Isolation of the power factor correction circuit by removal of links enabled the fault to be isolated to a short between 7.6 and 7.1 (or similar) by use of a multimeter, this has the effect of shorting out inductor L3 and the faulted power supply circuit is shown in Figure 10. In all likelihood, this would, if left to continue, result in a further thermal protection circuit activation.

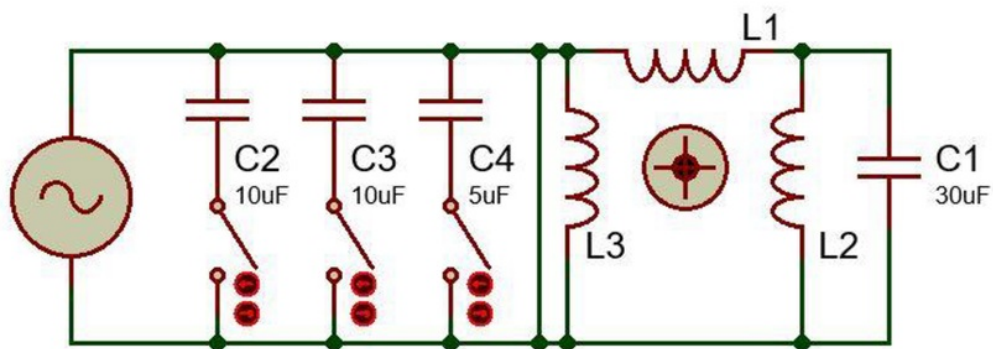


Figure 3 Motor circuit in fault condition

5. Conclusion

This exercise has investigated three phase inverters, overcurrent protection and the effects of an example fault scenario. It has been shown that an inverter is a device to convert d.c. in a.c. and can use PWM to create a variable voltage variable frequency supply. The PWM signal was generated by a microcontroller is stored in EEPROM and the rate at which the EEPROM is addressed will vary the frequency of the three-phase signal. The generation of three-phase supplies by PWM is such that a broader PWM pulse will give a lower frequency of output. The purpose of over current protection is to prevent damage to the power supply and further damage to the load during a fault condition.

6. References

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Excellent range of high quality sources used, although some omissions present.

4

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



You have shown an excellent knowledge and understanding of the concepts and applications of 3 phase generation using PWM.

21.3

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Thoroughly logical work, supported by evaluated evidence. High quality analysis. Strong, persuasive, conclusions.

21

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An advanced application of a range of methods and techniques. The context of the application is well considered, with use of relevant examples.

21

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate with an exceptionally high level of professionalism. Work is exceptionally coherent, very fluent and is presented professionally.

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