A Study on Low Cost Microcontrollers for Converter Applications

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Abstract – *In this project, the development of a control system based on single phase inverter in hardware and simulation have been conducted to study the use of low-cost microcontroller for converter application. Therefore, this project aims to develop a voltage control system that can be designed in Raspberry Pi and Arduino to understand the effectiveness of the microcontrollers. The inverter voltage is being controlled using Pulse Width Modulation (PWM) that is modelled using a feedback control using the MATLAB Simulink as a code generation. At the meantime, the Proportional (P) control has been used for the inverter output control in order the output voltage to follow the target reference value. This study has been divided into two stages where the MATLAB simulation has been developed for determined the control response for the single-phase inverter when using the Raspberry PI and Arduino as the source generation. After it has been successfully designing deed, the hardware has been set up to see the operation of the inverter with the voltage control that has been built in the MATLAB, by connecting to a resistive load as to represent any household applications such as a fluorescent lamp. The results show that, by using these low-cost microcontrollers, the controller is more accessible to be developed in the MATLAB and able to respond well to the hardware.*

Keywords: *single-phase inverter, Proportional- voltage control, MATLAB, Raspberry PI, Arduino*

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I. Introduction

One of the most popular household applications nowadays is a fluorescent lamp which is also can be represented as a resistive load [1]. It is widely used in residential, commercial or industry because it is simple, reliable, efficient and gives comfortable toward the consumer. The resistive load can be defined as the conversion of electrical energy (current) into heat using power resistor [2]. The resistive load is a load, which consumes electrical energy in a sinusoidal manner. This means the current flow is directly proportional to the voltage [3]. Therefore, it is a load that contains no inductance or capacitance elements but only a pure resistance. However, when the resistive load is energized, the current rises instantly to its steady-state value without first rising to higher value [4].

As for these issues, a control system is needed, and it is better to be included for controlling the losses at the resistive load. Therefore, this project has taken an initiative to study on the application of voltage control in using low-cost microcontroller to control the voltage. In the meantime, the voltage control should significantly enhance the performance of systems through compensation [5] by using the Proportional (P) controller for this project. Therefore, it requires a mathematical model control blocks which represent the input and the output and later can be downloaded to the specific microcontroller.

An inverter is a power electronic device that uses Pulse Width Modulation (PWM) switching technique to modify the DC input voltage [6] based on the modulation index. As stated in [7], Raspberry Pi microcontroller is most suitable to be applied for resistive load control because its fast respond in time, more efficiency and simple structure. Raspberry Pi is also easier to be interfaced with MATLAB Simulink software by using the support library package that is available in MATLAB. Several tests set system has been setup given in [8]-[9] where it shows that the low-cost microcontrollers are suitable to be applied for power converter operation because of its ability to collect the feedback response from the sensors and generates the desired PWM signal using the Simulink block. So, by using this low-cost microcontroller where it is considerably cheap and also easy to develop the control performance [10] which is the primary configuration system for this project.

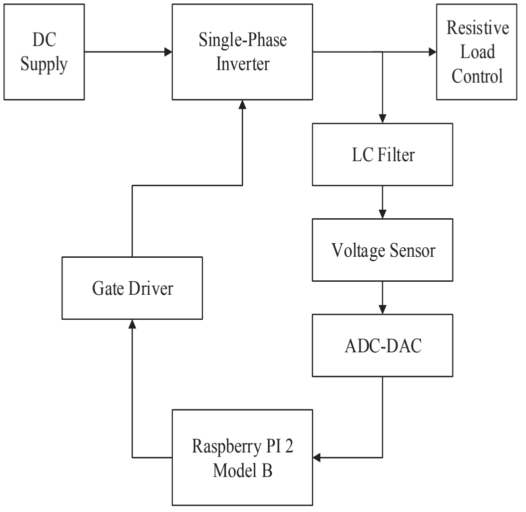

Fig. 1. Block diagram of this project

Fig. 1 shows the block diagram of this project. This project consists of several main parts which are DC supply, single-phase inverter, resistive load and microcontrollers. The resistive load control will operate based on P-voltage control inside the microcontroller. The voltage sensor is known as a voltage divider which is also used to step down the output voltage for the Raspberry Pi process which requires only 5V input. The voltage sensor aid is to make the feedback condition, and it is one part of the main control circuit for generating PWM signal to the gate driver.

II. System Development

In this section, the system development will be explained regarding simulation and hardware environments. Before the hardware can be set up and run, the simulation system should be done to see the response of the P- voltage control to the inverter. Fig. 2 shows the simulation system with the voltage P control system.

As mentioned before, the simulation model is developed in MATLAB software, where the voltage control has been developed based on P-Voltage control strategy. The reason why only the P control is used is that the overshoot response of the resistive voltage is not considered because the fluorescent lamp requires high voltage at the starting condition. At the same time, the PWM signal operation has been developed inside the Sinusoidal Voltage PWM (SVPWM) block which is the switching signal generation.

The P controller gain was set by inserting the value of *Kp* which is based on the try and error. As for the Raspberry Pi microcontroller, it has a limitation where the Raspberry Pi is not able to collect analogue signal from the analogue feedback signal. Therefore, this project is also used the Arduino to be an interfacing unit for the Raspberry Pi. It is where the Arduino will convert the analogue signal from the hardware system and then changes it to the digital signal that has been processed in the Raspberry Pi.

Then, Raspberry Pi will convert back the signal again to analogue with the mathematical model that has been developed within the P-voltage control system which is not explained in this paper. The Raspberry Pi system designed with the Matlab/Simulink is shown in Fig. 3. First, the model is developed in Matlab/Simulink with all the input and output configuration where it combines the P-Control structure. Then, all the model will be downloaded to the microcontroller before the performance of the controller can be observed.

Fig. 4 shows the overall hardware setup for this project. This project consists of several main parts which are DC supply, single-phase inverter, resistive load control and a voltage feedback sensor. The most important part of this project is the microcontroller.

However, the voltage sensor is used to divide the output voltage of the inverter to the suitable voltage requires by the microcontroller. This is because the microcontroller requires between the 0-5V signal to be a usable signal inside the microcontrollers. Therefore the digital to analogue converter has been developed inside the Matlab/Simulink system which will be represented by the actual reading from the output. At the same time, the voltage sensor is used for the voltage feedback operation, and it is one part of a control circuit that provides minimum voltage required to be supplied to the microcontroller.

III. Results and Analysis

This section will explain the findings of using these microcontrollers as a low-cost microcontroller system. The simulation test has been conducted when Fig. 2 is running in the closed loop to observe the inverter output signal with the P voltage control strategy combined with a resistive load that has been set as in Fig. 5.

Here, Fig. 5 shows that the voltage signal waveform of the inverter output is square before any *LC* filter is connected to the system. The configuration of the LC filter will not be explained here. This peak pulse signal shows that the voltage target reaches to 20V, where it is similar value with the voltage reference that has been set for the reference voltage at the control system. When the *LC* filter is applied, the output inverter is maintained to be at 20V as shown in Fig. 6. It indicates that the chosen value of the inductor and capacitor for the *LC* filter is suitable to change the square signal to a sinusoidal signal with small distortion at the signal.

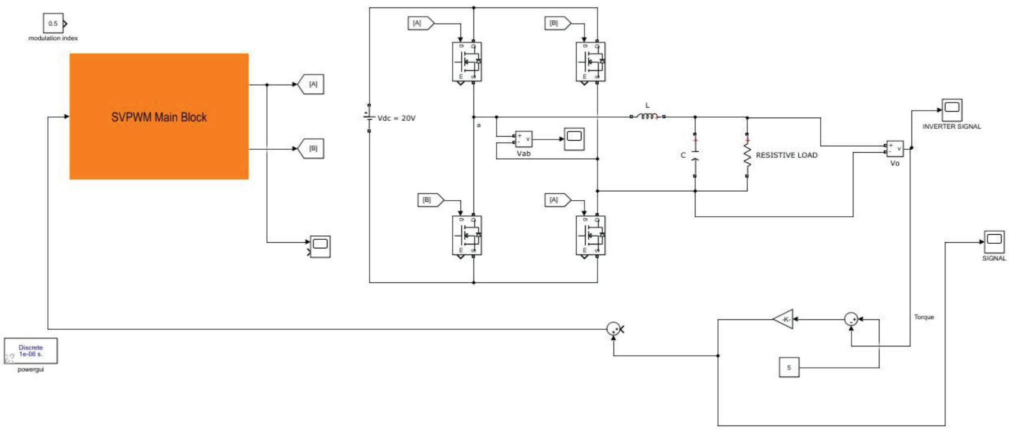

Fig. 2. Simulation setup circuit

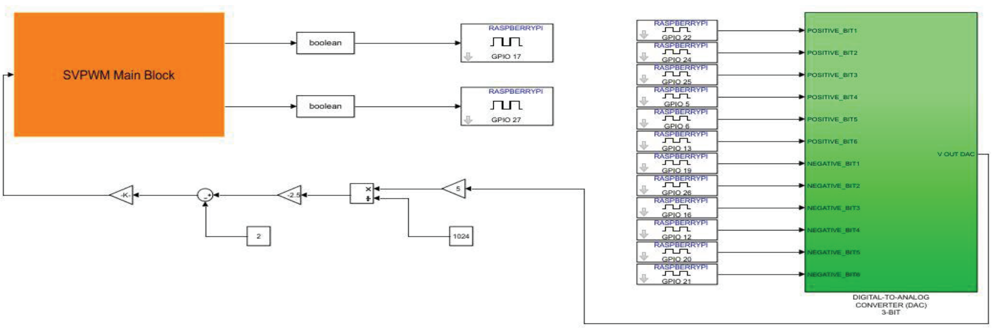

Fig. 3. System downloaded to the Raspberry Pi

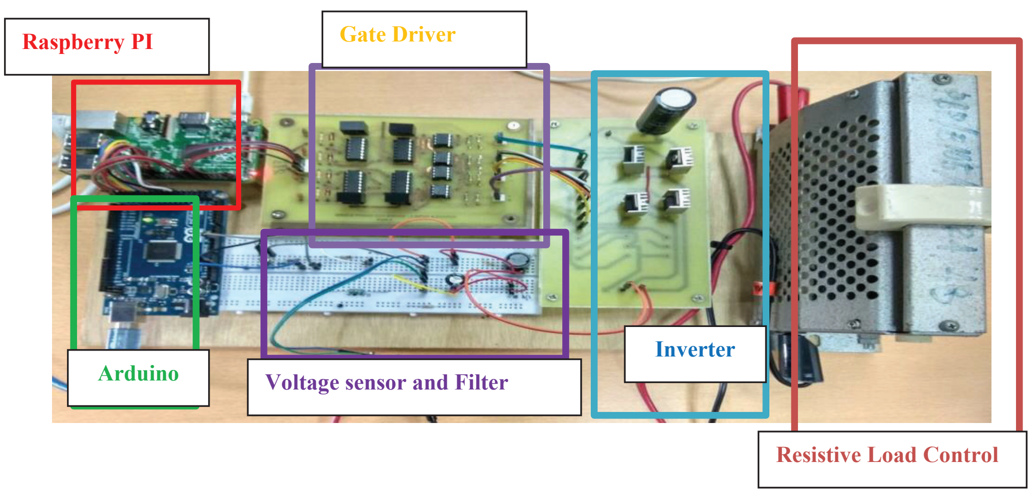

Fig. 4. Overall Hardware Setup Circuit

Fig. 6 shows the inverter voltage at the resistive load which is now in the sinusoidal waveform. This signal voltage follows the target voltage at 20V. The maximum value of the voltage at the resistive load was obtained in a range of 20V. That value of voltage is required as a control which follows the reference target.

Meanwhile, Fig.7 shows the voltage signal waveform that has been measured at the inverter output before the *LC* filter circuit when the reference target is reduced to 10V. This signal shows the target voltage obtained is 10V, which follows the voltage reference.

Fig. 8 shows the inverter voltage at the resistive load. This signal is at the same control voltage target which is almost to 9V. That value of voltage is required as a control purpose and still following the target reference voltage.

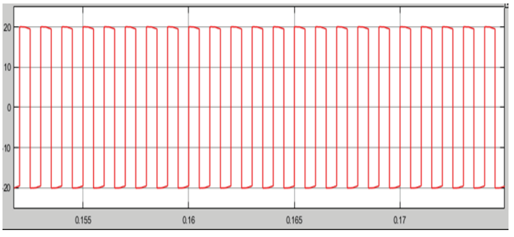

Fig. 5. The result of the voltage signal waveform before LC Filter at voltage reference 20Vdc

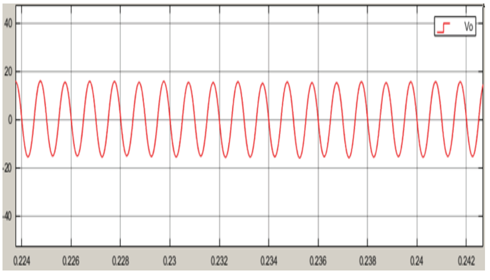

Fig. 6. The result of the voltage signal waveform at the resistive load at voltage reference 20Vdc

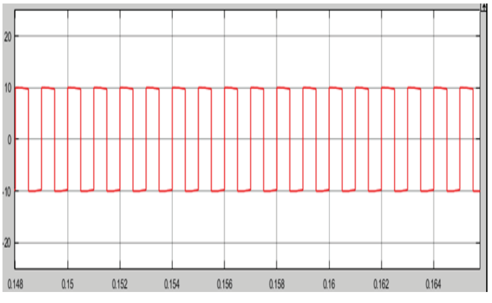

Fig. 7. The result of the voltage signal waveform before *LC* Filter at voltage reference 10Vdc

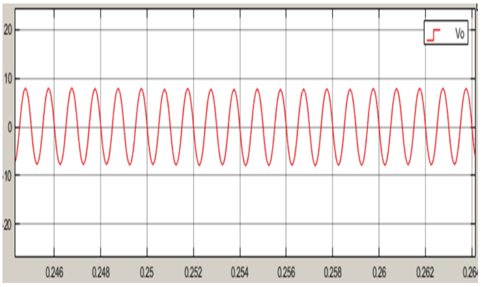

Fig. 8. The result of the voltage signal waveform at the resistive load at voltage reference 10Vdc

In the next several figures, the results have been collected when the system is running in the hardware operation. Fig. 9 shows the inverter output after the *LC* filter is included in the circuit. The waveform of the sinusoidal waveform is due to the filter been used. This filter is used to obtain the sinusoidal waveform before it is connected to the voltage divider. It can be seen that the output of the voltage value is much higher than the reference target voltage which is $V_{out} = 9.2$V while the peak to peak voltage $V_{in} = 18.4$V. Therefore, the higher the value of voltage obtained, the higher the efficiency of this inverter.

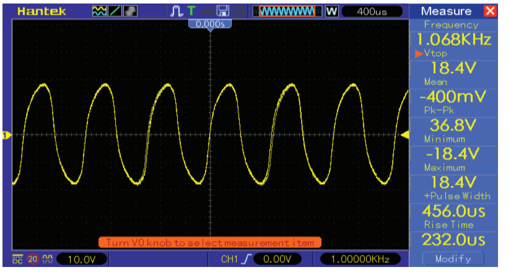

Fig. 9. Output waveform of *LC* Filter circuit

During this condition, the voltage sensor is also monitored. It is to make sure the signal from the sensor is responded well when the target control voltage is changing. For this part, the voltage sensor circuit has been tested, and the result obtained shows that a shift up sinusoidal waveform as shown in Fig. 10.

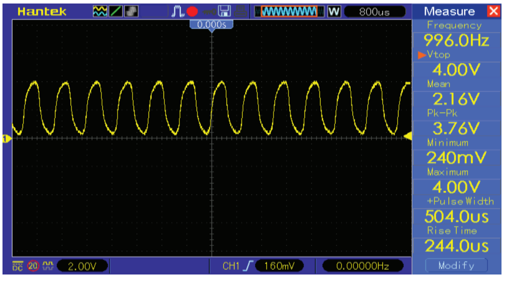

Fig. 10. Output waveform of the voltage sensor circuit

For the closed-loop test on the hardware circuit, the result is monitored before the LC filter. The result is in the square waveform as shown in Fig. 11. The square waveform is obtained after the connection is made with the resistive loop. This voltage inverter output is set at the reference voltage at 20Vdc. The increasing of the resistive load will also increase the voltage.

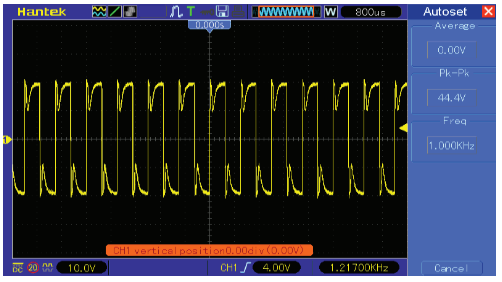

Fig. 11. The output waveform of the closed circuit on the inverter at voltage reference 20Vdc

IV. Conclusion

Based on results obtained in the project, the low-cost microcontrollers can be a simple process which allows the authors to download any control model and test to the inverter converter system. Meanwhile, in a closed loop system, the feedback that comes from the voltage sensor can be a source of input to the microcontroller. As from the result of the simulation in a closed loop when the references voltage are set to 10V and 20V, the P-Control can trace this reference signal by generating a suitable PWM signal at the inverter. As for the hardware, the reference voltage is also set to 20V in the closed loop, and the inverter output obtained is $44V_{pp}$. For an accurate output signal, a good *LC* filter design is necessary. It can be concluded that this paper has proven that, low cost microcontrollers can be a good platform to understand the operation of power converters, control development and signal processing techniques for project which can be conducted by the undergraduate student.

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