Microcontroller Controlled Inverter Application

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Abstract: - The limited use of fossil fuels has increased the interest in renewable energy sources. Renewable energy sources are generally direct current (DC) production. The popularity of inverters converting from DC to AC is increasing due to the generation of the generated DC signal and the current grid being alternating current (AC). In this study, a computer-controlled inverter was designed with the 16F877 microcontroller chosen as the model, and frequency and amplitude controls were realized with the serial communication system of this structure. A digital-analog converter (DAC) circuit is formed by connecting the R-2R ladder type resistor to the relevant ports of the microprocessor. With the codes written to the microprocessor, the signal response was taken from the DAC circuit, and the signal response at the ports was combined with the inverter and collector operational amplifier (op-amp) circuits, and the inverter design was completed.

Key-Words: Inverter, PC control, Serial communication, Microcontroller

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1 Introduction

An inverter is an electrical power converter that converts direct current (DC) to alternating current (AC). AC power generated at the inverter output; It can be at any voltage and frequency depending on the transformers used, the switching and control circuits. In other words, they convert 12, 24 or 48 V DC battery voltage to 230 V AC 50 Hz voltage. They work in minimum and maximum ranges.

If it is necessary to summarize the application areas; such as mobile vehicles, renewable energy applications such as wind and solar energy, remote areas where grid electricity is not available, communication applications including GSM, battery backup energy applications against power cuts.

PC-controlled applications have become widespread due to their different advantages. Speed control of asynchronous motors, which occupy a lot of space in the application area, can be done by frequency change. In this respect, the speed control of asynchronous motors can be easily achieved in the system created. Since the system is PC-controlled, it allows control over the internet and thus from remote points.

2 Literature Reviews

Mallalieu, Arieatas, So'Brien have developed a low-cost PC-controlled measurement laboratory. It has the possibility to control and command 8 different channels in its works [1]. Tolbert and Habetler proposed a multistage carrier-based inverter. The inverter they propose is implemented with a 6-stage diode to operate at 10 kW power [2]. Levi, Vukosavic, Martin Jones A single-phase multi-motor system has been realized. A voltage source inverter with a controlled drive system has been realized by utilizing a single source. They used multiple driver circuits for variable speed controls [3]. Noguchi, Yamamoto and Kondo; Torque controlled application was carried out with inverter. By reducing the fluctuations in the stator flux, they reduced the fluctuations in torque by 30%. In their system, they applied a PWM signal to the stator using a switching element [4].

Yen-Shin Lai suggested NSVM technique instead of classical SVM for motor control with PWM. They observed that the common mode voltage decreased by 50% with the proposed method. They used PC with INTELQ80586 CPU processor to drive IGBTs to their systems [5]. Ye, Jain, C.Sen, for alternating current high frequency and high voltage low current applications; They proposed a current sharing loop and a voltage feedback control loop. By using the proposed system, 500 kHz, 100 W inverter modules were connected in parallel and an inverter with 500 kHz 28 V effective value was realized [6]. Lai and Chen; They proposed direct torque control for induction motor drives. The method they recommend; They have shown that it can be used even in the 1 cycle/minute region [7]. Peng proposed an inverter topology that compensates for the voltage itself. In the proposed structure, MOSFETs are switched, allowing the application of inverters and converters at different levels [8].

In this study, the input signal to the microprocessor is realized with the relevant codes written in the Micro-Code Studio program. A digital-analog converter (DAC) circuit is formed by connecting the R-2R ladder type resistor at the microprocessor output to the PORTB and PORTC outputs of the microprocessor. The signal at the PORTB output is given to the inverting op-amp circuit, and the input signal is output with a 180° phase difference and given to the collector op-amp circuit with the input signal coming from PORTC. Thus, the two input signals have formed the positive (+) and negative (-) alternans of the sinusoidal signal at the collector op-amp circuit output. A 10 µF C filter is used to get rid of the output harmonics.

In order to provide remote control of this design in a PC environment, a serial communication system has been implemented by using RS232 circuit and NI Labview program. This serial communication system provides a sensitive control opportunity by controlling the frequency and amplitude of the signal at the inverter output. While the output signal has no frequency limitation, its amplitude value is limited to 24 Volts (-12 / +12), which is the supply voltage of the collector op-amp circuit.

3 Material and Method

3.1. Digital-to-Analog Converters (DAC)

Circuits that convert a digital information signal into voltage or current proportional to its digital value are called digital-analog converters. This voltage or current is an analog signal that changes according to the values at the input. Figure 1 shows the block diagram of a 4-bit input DAC.

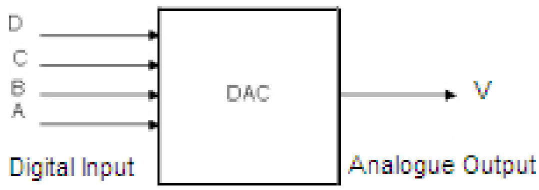

Figure 1. Block diagram of the DAC system

In D/A conversion processes, weight resistance DAC, R-2R ladder type DAC or PWM (Pulse Width Modulation) method is used.

3.2. Weight Resistive DAC Circuit

Figure 2 shows a simple circuit of the D/A converter. It is used as an op-amp collector in the circuit. The output voltage is equal to the sum of the weights of the D, C, B, a digital inputs.

Output voltage,

$$Vo = -\frac{Rf}{8R} Vref\,(A + 2B + 4C + 8D) \quad (1)$$

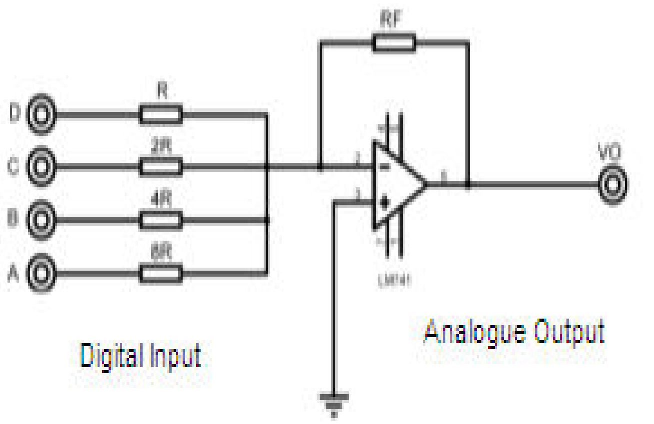

Figure 2. Weight resistive DAC circuit

3.3. R-2R Ladder Type DAC Circuit

It is the most used method for converting digital information to analog information. The R-2R ladder type circuit is shown in Figure 3. The output voltage is calculated as given in equation 2:

$$Vo = -\frac{Rf}{16R} Vref\,(A + 2B + 4C + 8D) \quad (2)$$

In this design, a DAC circuit is formed by connecting one string of R-2R ladder type resistor microprocessor to PORTB and the other string to PORTC. The expected signal response is obtained thanks to the inverter and collector op-amps used in the DAC circuit by writing the relevant codes to the microprocessor with the Micro Code Studio program.

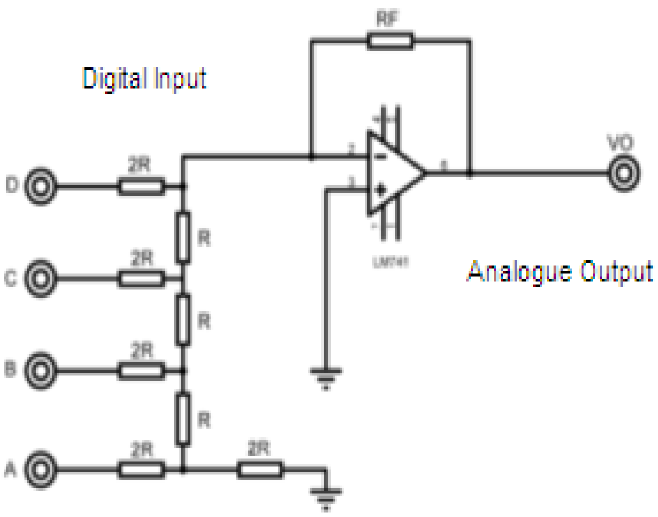

Figure 3. R-2R DAC circuit

3.4. Supply Layer

It is the floor used to provide the necessary energy of the inverter circuit. The supply stage has been designed to provide the +5 Volt (V) supply voltages required for the circuit to work. A 7805 voltage regulator is used to provide the +5 V voltage needed by the microcontroller. Thanks to the capacitors added to the circuit, it is tried to prevent unwanted interference. As a result, it is possible to operate the inverter circuit by using any external power source providing +9 V - +30 V DC voltages. The circuit diagram is shown in Figure 4.

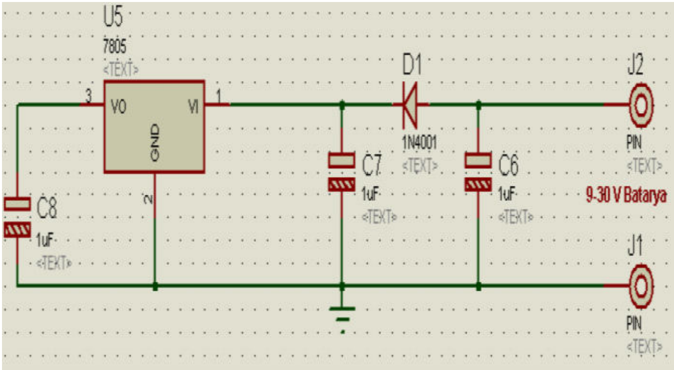

Figure 4. 7805 supply stage circuit diagram

The +12 V / -12 V DC supply required for the operation of the collector and inverting op-amp circuits was used, respectively, with 7812 and 7912 regulators. Since the microcontroller needs +5 V DC voltage, three regulator circuits can work with the same DC supply source. The diagram of 7812 and 7912 regulator circuits is shown in Figure 5.

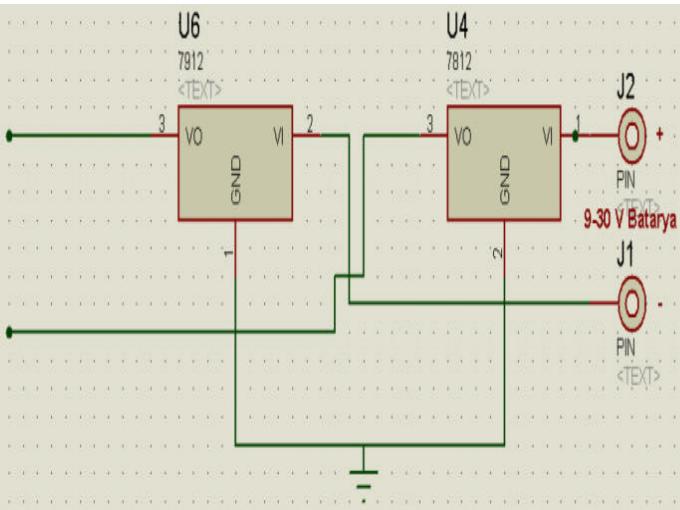

Figure 5. 7812 and 7912 supply stage circuit diagram

3.5. Microprocessor Layer

The microprocessor stage is designed to fulfill the function of the R-2R ladder type DAC circuit. 16F877, a powerful product of the PIC family, is used as a microprocessor. PIC (Peripheral Interface Controller) is the name given to the microcontrollers produced by Microchip. In PIC products, the command word size and the bus length can be different. Produced PIC microcontrollers are divided into different family names according to the data bus bit number and word size of the controller.

The reason for using the 16F877 microprocessor in this design is that there are 33 I/O ports. In this direction, the first block of the R-2R ladder type resistor scheme is connected to 8 bits of PORTB, and the next second block is connected to 8 bits of PORTC.

The information signal from PORTB constitutes the negative alternan of the output signal, and the information signal from PORTC constitutes the positive alternan of the output signal. In order for the waveform formed in PORT B to turn into negative, the PORTB output is input into the inverting op-amp circuit. When the PORTC output collector op-amp circuit is given with the obtained waveform, the desired sinus signal is obtained.

3.6. MAX-232 Communication Layer

The voltage levels in the serial port, which is one of the communication units opening from the computer to the outside world, vary between +15 V -15 V. These levels are incompatible with circuits that communicate at TTL level (0 V–5 V), the serial port of the computer can be communicated with circuits at TTL (transistor to transistor logic) level through the integrated circuit called MAX-232 serial port buffer.

The MAX-232 communication layer communicates with the NI Labview program in serial communication standard. PIC 16F877 microcontroller uses TX-transmitter, RX-receiver pins of MAX-232 for serial communication. The circuit ISIS diagram is given in Figure 6.

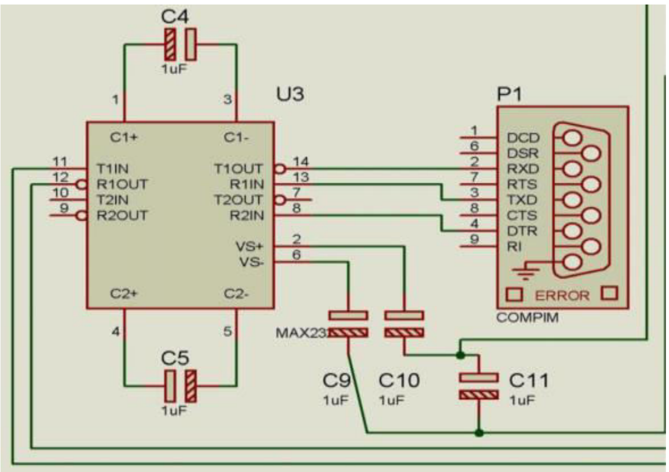

Figure 6. MAX-232 communication layer schematic

3.7. DAC Application

The block structure of the implemented system is given in Figure 7.

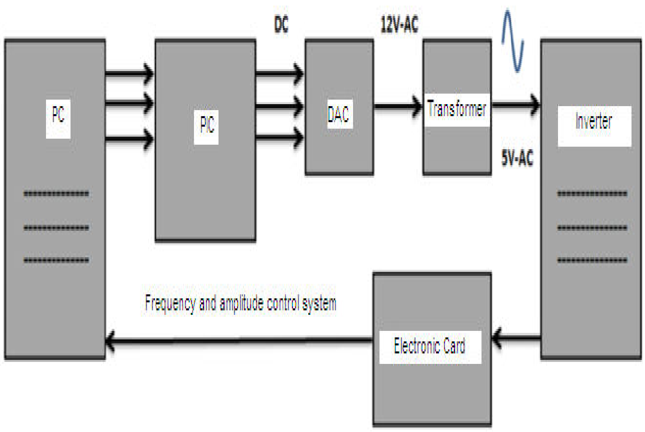

Figure 7. PC-controlled inverter block structure

When a symmetrical 9-30 V DC supply is made from the J1 and J2 pins in the circuit shown in Figure 8., the +12V -12V supply voltage needed by the op-amp will be obtained thanks to the 7812 and 7912 regulator circuits. With the 7805 regulator circuit, the microprocessor is supplied with +5V.

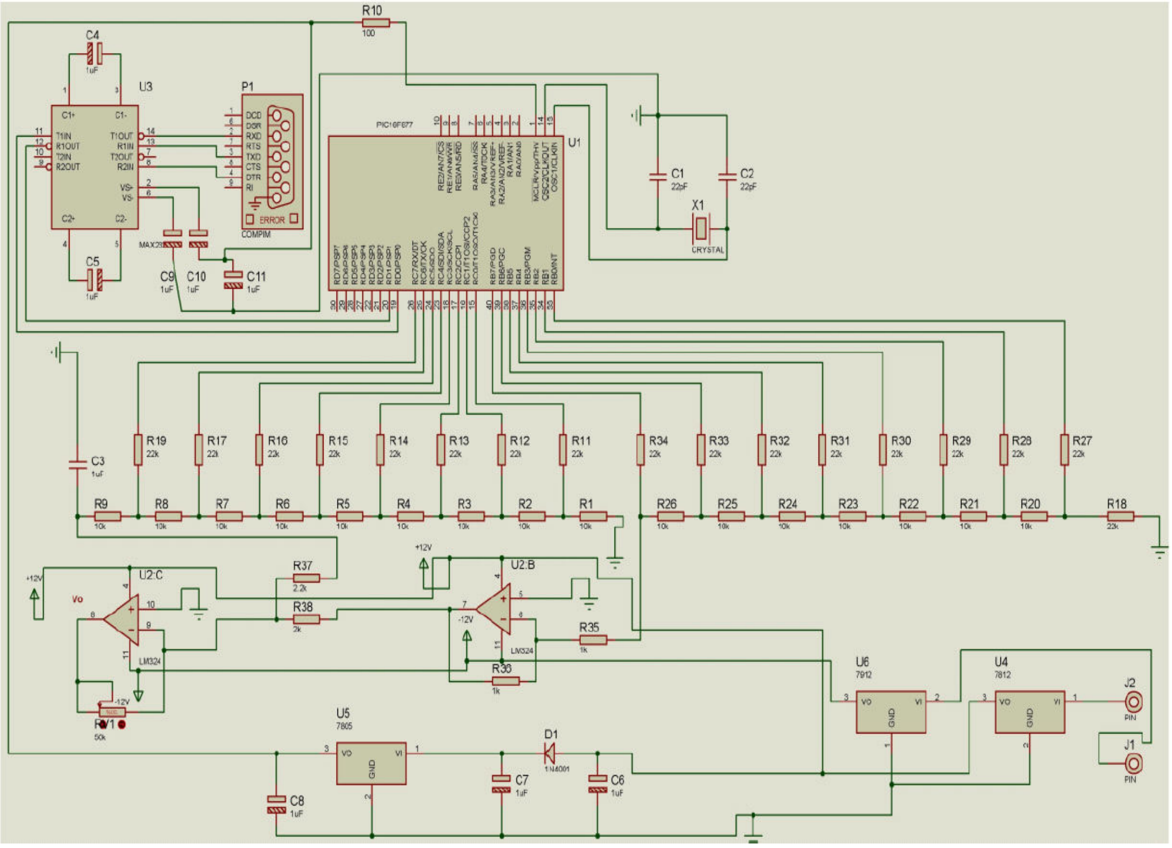

Figure 8. Inverter circuit schematic with 16-bit bus

For the circuit whose schematic circuit is shown in Figure 8, a printed circuit design has been made and the circuit shown in Figure 9 has been drawn. Figure 10 shows its realization.

For the circuit whose schematic circuit is shown in Figure 8, a printed circuit design has been made and the circuit shown in Figure 9 has been drawn. Figure 10 shows its realization.

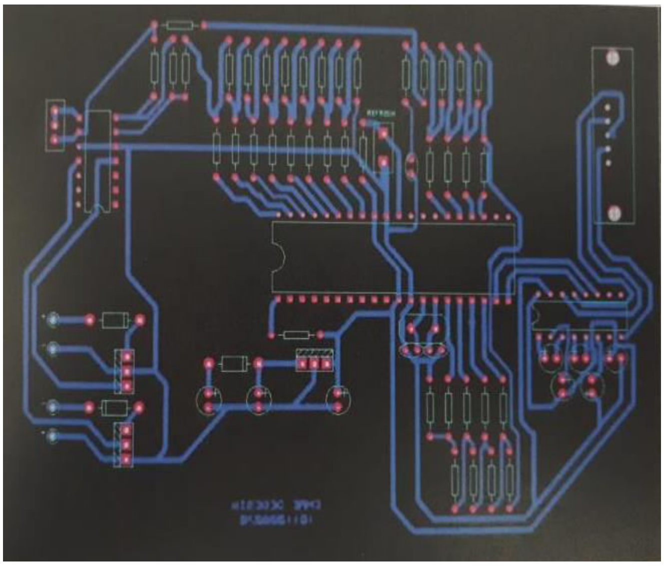

Figure 9. Inverter printed circuit drawing

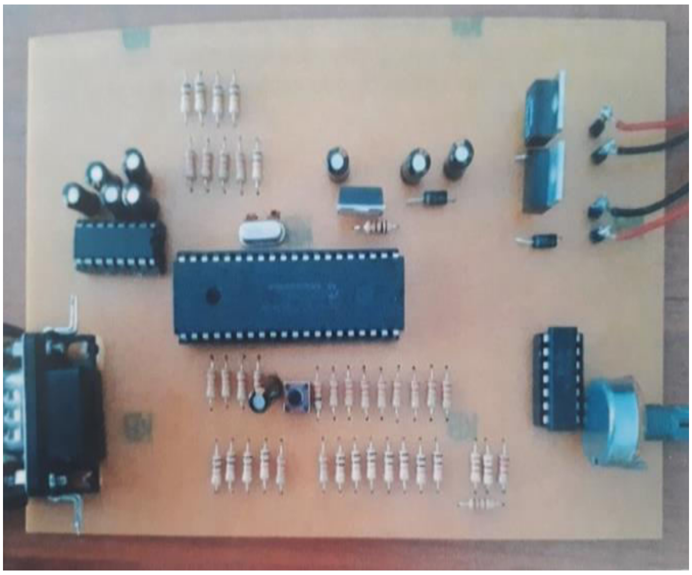

Figure 10. Realized inverter circuit

Despite the voltage and frequency values entered from the NI Labview communication interface program, the sinus code written to the microprocessor changes at that rate. In this way, the desired signal response is obtained from the op-amp output with the DAC assembly connected to the ports of the microprocessors.

While performing serial communication, a key character is needed in order for the microcontroller to receive correct data from the data coming from the PC. In practice; As seen in Figure 12 and Figure 13, V for voltage value and T for frequency is selected as the key.

4 Conclusions and Discussion

The signal at the output of PORTB (yellow sine indicated in Figure 11) is given to the inverting op-amp circuit, and the input signal is output with 180° phase difference (pink colored sinus indicated in Figure 11), with the input signal coming from PORTC (Figure 11'). The blue colored sine) collector is given to the op-amp circuit. Thus, the two input signals have formed the positive (+) and negative (-) alternans of the sinusoidal signal at the collector op-amp circuit output (green colored sinus in Figure 11).

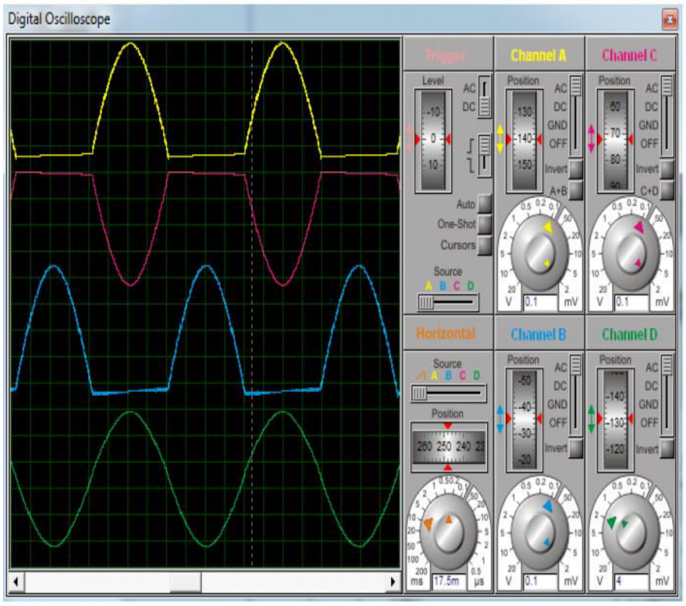

Figure 11. PORTB, PORTC, invert and collect op-amp output waveforms

Ready serial communication interface of NI Labview software is used for controlling the inverter from PC. The frequency of the sine waveform to be created with the interface used can be easily adjusted by the user.

Sample results for the interface used are given in Figure 12 and Figure 13. The 'V1T50' command written to the user interface shows that the voltage value of the Inverter output signal remains constant and the transition time of the R-2R ladder assembly in PORTB and PORTC is determined as 50µS. Thus, Vpp=10.6 V, f=11.42 Hz was obtained. Signal response observed from the inverter output is as shown in Figure 12.

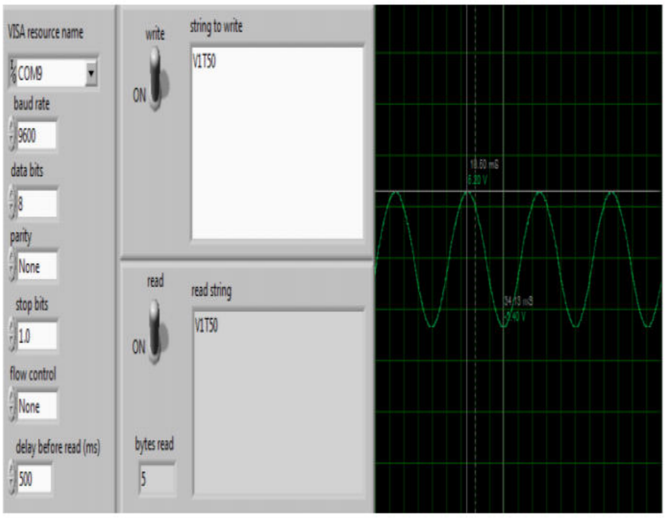

Figure 12. Inverter output waveform (Volt/Div: 2V Time/Div: 17.5Ms)

The 'V2T500' command written to the serial communication system shows that the voltage value of the inverter output signal is doubled and the transition time of the R-2R ladder assembly in PORTB and PORTC is determined as 500 µS. Thus, Vpp=20.5 V, f=7.14 Hz was obtained. Signal response observed from the inverter output is as shown in Figure 13.

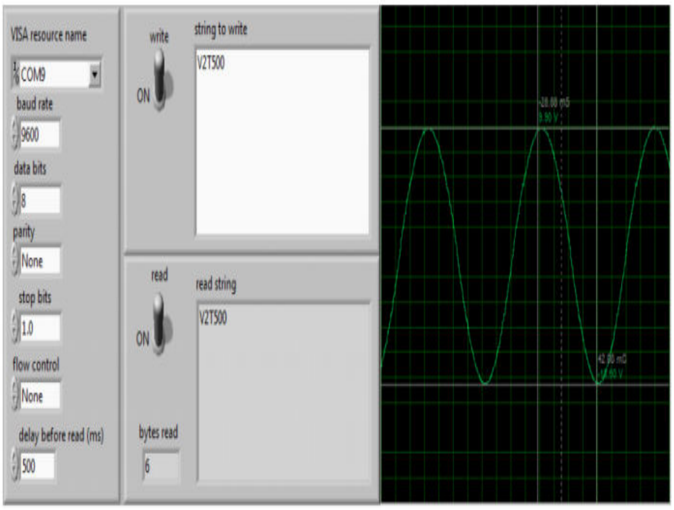

Figure 13. Inverter output waveform (Volt/Div: 2V Time/Div: 17.5Ms)

Inverter design is realized with PIC controlled weight resistive R-2R ladder type (DAC) circuit. With the addition of RS232 serial communication integration to this structure, the inverter output has become PC controlled with an interface program from a second channel. Thus, the inverter circuit has become controllable from the internet environment, that is, from remote points. Thanks to the interface used, the output voltage and frequency of the designed inverter can be adjusted simply by the user.

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