GOCE DELCEV UNIVERSITY - STIP
FACULTY OF COMPUTER SCIENCE

ISSN 2545-4803 on line

BALKAN JOURNAL OF APPLIED MATHEMATICS AND INFORMATICS (BJAMI)

YEAR 2020

VOLUME III, Number 2

GOCE DELCEV UNIVERSITY - STIP, REPUBLIC OF NORTH MACEDONIA
FACULTY OF COMPUTER SCIENCE

ISSN 2545-4803 on line

BALKAN JOURNAL OF APPLIED MATHEMATICS AND INFORMATICS

(BJAMI)

YEAR 2020 VOLUME III, Number 2

AIMS AND SCOPE:
BJAMI publishes original research articles in the areas of applied mathematics and informatics.

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Republic of North Macedonia

BALKAN JOURNAL
OF APPLIED MATHEMATICS AND INFORMATICS (BJAMI), Vol 3

ISSN 2545-4803 on line
Vol. 3, No. 2, Year 2020

EDITORIAL BOARD

CONTENT

UDC: 621.373.12.049.77:621.314.6.016.2

SINE INVERTER SYSTEM BASED ON SPECIAL CIRCUIT

GOCE STEFANOV, VASILIJA SARAC, MAJA KUKUSEVA PANEVA

Abstract. In this paper, based on a specific example of an ASIC (Application Specific Integrated Circuit) type of an integrated circuit, the impact of the development of microelectronics in the application of these circuits in power electronics is considered. By applying this type of an integrated circuit, and by simply connecting its input pins to low or high potential, the operating mode of the circuit is defined, and thus the operating mode of the power converter. This paper first describes the characteristics of the circuit, and then the experimentally obtained results from the test- prototype inverter in which this integrated circuit is built are given.

1. Introduction

The power electronics contribute to the fast and reliable design of power converters designed to regulate the speed of both DC and AC motors [1]. The development of power electronics is based on the development of microelectronics circuits [2]. There are mainly two directions for the development of integrated circuits that are used in power electronics. On one side are microcomputers [3], [4], [5], and on the other side are typical integrated circuits designed for special purposes [6], [7]. Microcomputers are the intelligent electronic component that has many advantages over discrete electronic components. Their main advantage is the packing density of the chip itself. It is the result of the development of microelectronics and it enables over one million discrete electronic elements to be embedded on a surface of 1 cm^2. Their second advantage, which distinguishes them from discrete electronic components, is their application flexibility [3], [4], [5]. The latter implies the ability to run different applications with the same network hardware, and with software changes. But, on the other hand, the design of electronic circuits with a microcomputer requires knowledge of appropriate software and in the development of the product converter, it is necessary to include more specialists who know the hardware, software, and have knowledge related to the topology of converters.

Unlike the design of the converters based on a microcomputer, the design based on special circuits requires reduced knowledge of hardware and software, and only a good knowledge of converter topology is enough to make a successful converter product [6], [7]. The chosen approach to designing a converter depends on its nominal power. But, for small and medium power up to 5kW, it can be said that the design of a converter with special circuits is more economically justified.

Therefore, in this paper, the authors proposed and verified the possibility of using an inverter system based on a special circuit that can operate in a mode of constant and variable frequency and amplitude conditions to gain more optimal results compared to

Keywords: inverter, integrated circuit, sine output voltage

other inverter systems. The system represented in this paper uses a low-cost microcontroller. The purpose of using this system is to evaluate the degree of precision that can be achieved by using this newly proposed integrated solution.

2. SPWM Technique

Guided by the main goal of the paper, the implementation of the special integrated circuit in generating SPWM (sine pulse wave modulation) signals and converter with power and interconnection of these parts will be explained.

In Figure 1, a block diagram of a 1-phase motor controlled by a special integrated circuit is shown.

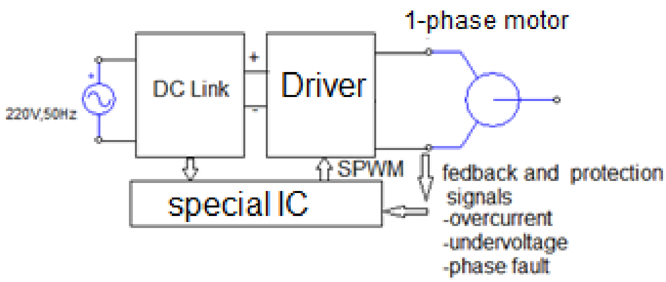


Figure 1. *Block diagram of 1-phase motor controlled by a microcontroller*

2.1. **SPWM signal**

In this concept, a SPWM signal is a width modulated signal with certain values in such a way that the output signal has as close as possible sine wave shape. Using this on MOSFET or IGBT transistors results in a sine wave inverter.

It is generally known that the PWM signal is a pulse width modulation. That means the width can be modulated with a square signal and with this, the power can be controlled. But, in the case of usual PWM, the signal width always has the same value. In the case of SPWM or sinusoidal pulse width modulation, the width of the signal is increasing and decreasing, and the results in the simulation of the sine-wave curve. For a small width pulse, the output will increase a little bit and that represents the zone after "0" crosses the sine wave. Then, with the increasing of the signal widths, the output signal is getting bigger and bigger and then the widths start to get lower, just as in a sine wave. Using two switching transistors, both the positive and negative sides of the sine wave are obtained as shown in Figure 2.

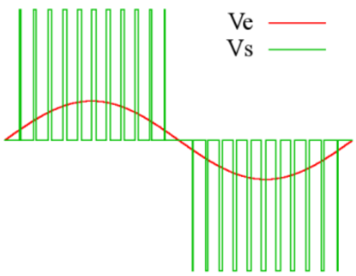


Figure 2. *Construction of SPWM signal*

Figure 3 shows how the width of the SPWM can create a good sinusoidal shape at the output. Integral Circuit is used to generate this SPWM signal that is applied to the power driver connected to the motor. In Figure 3, the SPWM signal, current and voltage waveforms of the motor are shown.

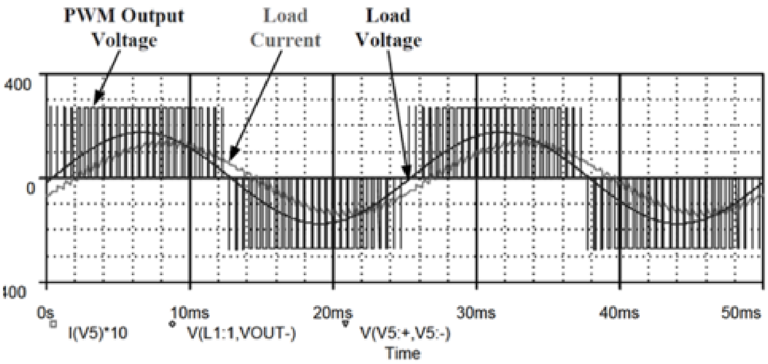


Figure 3. *SPWM signal, current and voltage waveforms of the motor*

2.2. **SPWM Integral Circuit**

As said, this paper is based on the implementation of the circuit on which the regulation is performed. One of the main components of this circuit is the EGS002 driver board (Figure 4). It is characterized by a control chip and two driver chips. The driver board can be used to provide protection against voltage, current, and temperature, as these functions are integrated into the driver due to the architecture of the card. The AC 50/60 Hz configuration is also available, as are the soft start and dead time modes. Finally, it is possible to connect this device to an LCD screen that allows visualization of the most important parameters such as voltage, current frequency, and temperature.

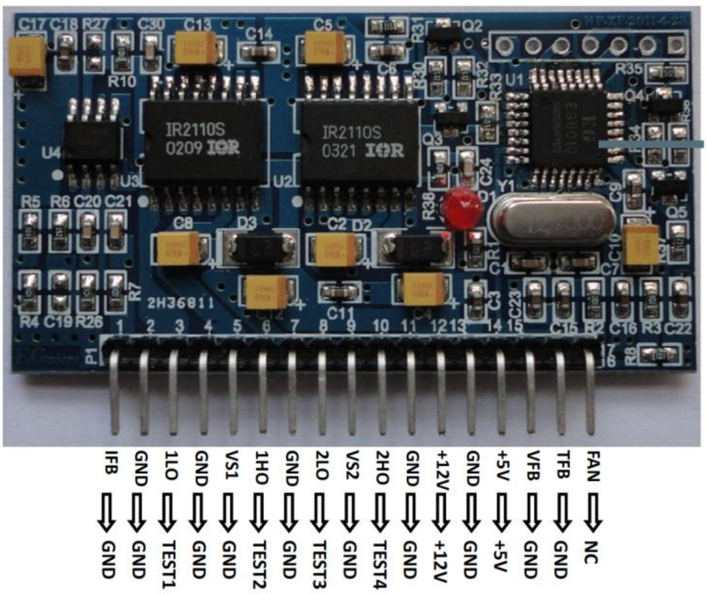


Figure 4. *EGS002 driver board*

The heart of this card is the installed ASIC EG8010 (Application Specific Integrated Circuit) chip. This circuit supports the operation of the inverter in variable voltage modes and constant frequency and variable voltage and variable frequency modes. EG8010 is a digital chip, very well-functioning with its own dead-time control of pure sine wave inverter generator chip, used in a two-stage DC-DC-AC power conversion structure or a single-stage DC-AC power frequency transformers. With boost architecture and an external 12MHz crystal oscillator, high precision is achieved, and harmonic distortions are very small. The chip uses CMOS technology, the internal integration of SPWM sine generator, dead-time control circuit, multiplier factor range, soft start circuit, protection circuit, RS232 serial communication interface, and a serial LCD driver. Some of the features of the chip are: 5V single power supply, 50Hz pure sine wave of the fixed frequency of 60Hz pure sine wave of fixed, unipolar and bipolar modulation, pin 4 dead times (300ns dead time 500ns dead time 1.0µs dead time 1.5µs dead time), PWM carrier frequency 23.4KHz, voltage, current, real-time temperature feedback, overvoltage, under-voltage, overcurrent and overheating protection, etc. The ASIC EG8010 chip is used in various applications such as single-phase pure sine-wave inverters, PV Inverters, wind power inverters, Uninterruptible Power Supply UPS systems, digital generator systems, IF power, single-phase motor speed controllers, single-phase inverters, sine-wave dimmers sine-wave regulator, and sine-wave generator.

The first mode is used for AC voltage consumers and the second for AC motor speed regulation. Therefore, it is appropriate to elaborate on the specifications of this chip. Figure 5 shows the electrical circuit of the board EGS002 with a built IC EG8010 and IRF2110 driver.

2.2.1 Characteristics of EG 8010 Special Integral Circuit

As already mentioned, ASIC EG8010 represents the heart of the EGS002 board. This Integral Circuit on the output provides pure sine waves at 50/60 Hz with high precision and low harmonic distortion. The external 12MHz crystal oscillator allows the adjustment of the system clock. Lastly, there is a sinusoidal SPWM generator. In Figure 6, the block diagram of this circuit is shown. This circuit can operate in unipolar and bipolar modes. With a unipolar modulation operation, only one of the two bridges (SPWMOUT3 and SPWMOUT4) will be used for the output modulation in SPWM; the other bridge (SPWMOUT1, SPWMOUT2) will be used for the fundamental output. From the circuit point of view, there will be an inductor and a capacitor, to create an LC filter, connected to the output port of the SPWM and there will also be a voltage feedback circuit connected to the output of the inductor.

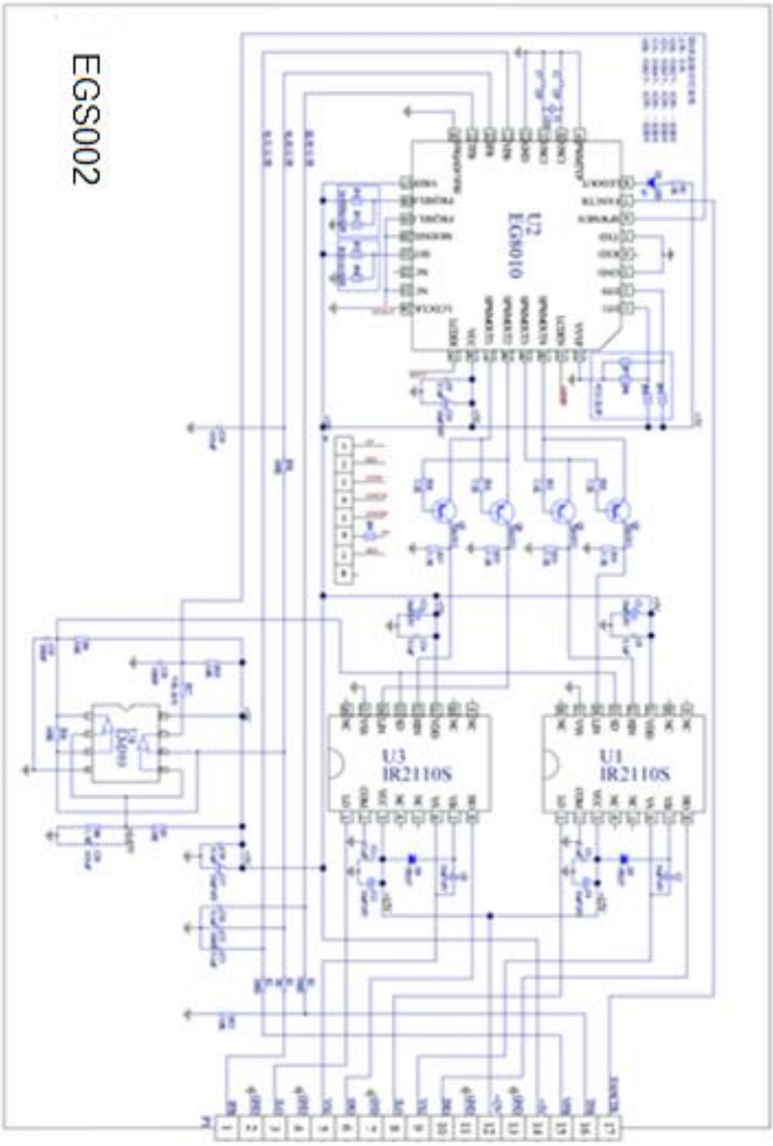


Figure 5. *The electrical circuit on the board EG002 with a built IC EG8010 and driver IRF2110*

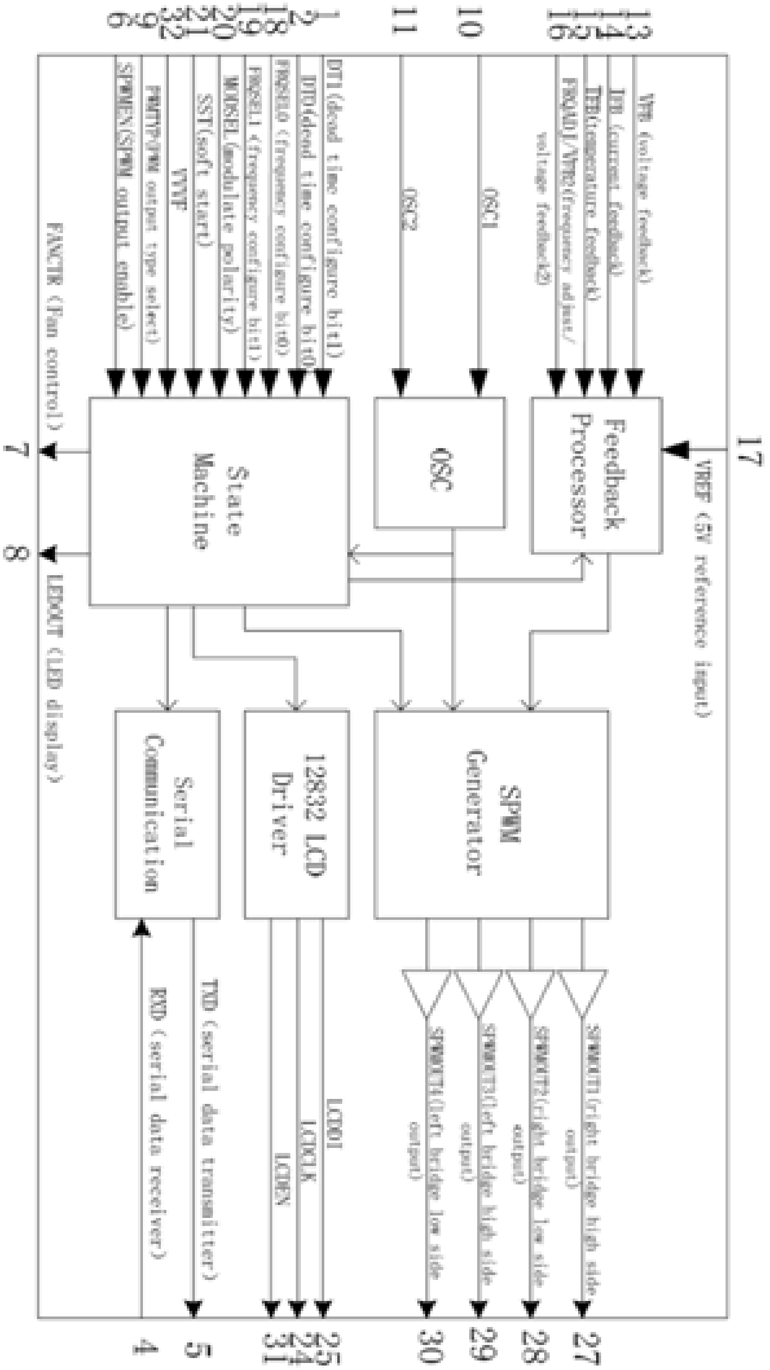


Figure 6. *Block diagram on EG 8010 circuit*

2.2.1.1 Feedback on AC Output Voltage

With this type of operation, the EG8010 chip can measure the AC output voltage of the inverter via the appropriate VFB pin (pin #13), through the feedback process itself. The feedback circuit on the AC output voltage is shown in Figure 7. With this type of modulation, therefore, it is possible to calculate the error between the measured peak voltage and the reference voltage (3V) and adjust the output voltage accordingly.

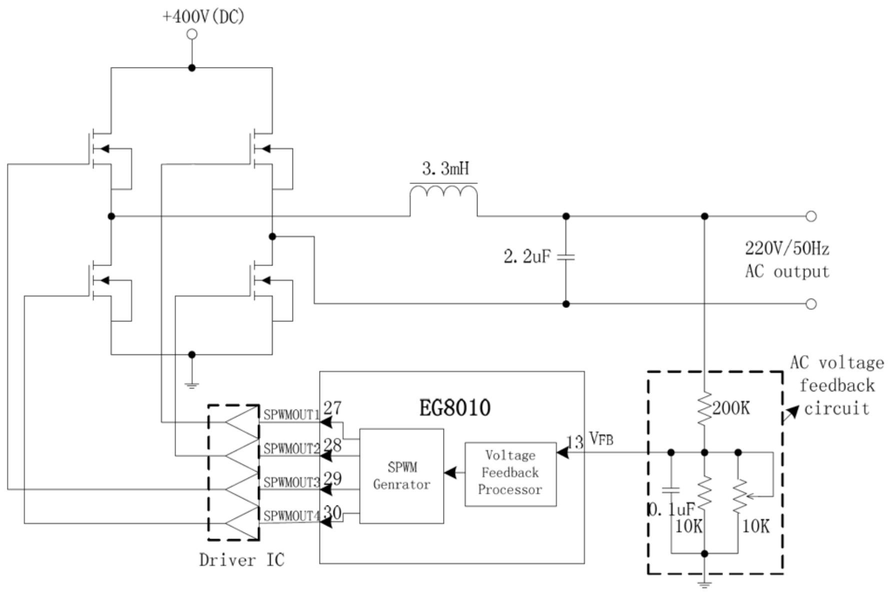


Figure 7. *Feedback circuit on AC output voltage*

Therefore, when the output voltage increases, the relative pin voltage will also increase. So, in order to achieve the stabilization of the voltage, the circuit will automatically perform the error calculation and adjust the division factor of the interval by decreasing the voltage to stabilize it. On the contrary, when the voltage on this pin decreases, the chip will increase the output voltage. This adjustment can be seen in Figure 8.

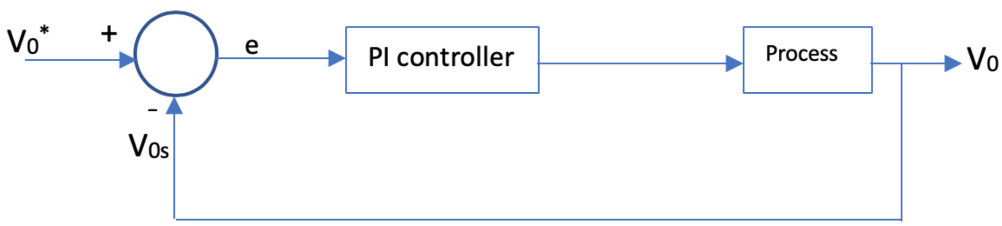


Figure 8. *PI controller on feedback circuit at EG8010*

It also uses a type of sampling at the peak point. This way, if the output voltage should deviate, for example, due to load or input voltage variation, the EG8010 can recover to the expected output voltage in a short period between one and three cycles of the generated alternate voltage.

2.2.1.2 Feedback on AC Output Current

Figure 9 shows the feedback circuit on the AC Output current. As for the voltage and current feedback, to be able to evaluate the overcurrent phenomena that could destroy the MOSFET, there will be a pin of the dedicated chip EG8010. In fact, in the presence of overcurrent, the pin IFB (pin #14) compares the voltage value of the circuit with the reference voltage value of 0.5V at overcurrent detection time equal to 600ms. If the current is higher than the inverter current, the EG8010 chip will set the SPWMOUT pins so that the MOSFET is switched off, in order to reduce the voltage to “0” depending on the settings of pin #9.

This way it is possible to protect both the MOSFET and the load. The overvoltage detection system has activation and deactivation cycles if the disturbance that led to the shutdown of the system for the first time is still present. The timing is different; in fact, 16s after deactivating the MOSFET, the chip will turn it on again for 100ms to determine the load current. If the problem persists, the MOSFET will be deactivated again, repeating this procedure for a maximum of 5 cycles, beyond which the SPWM output will be deactivated. To make the system work correctly, a forced restart will be necessary. If the starting current is too high, the periods of testing the starting current could be lengthened since it will be necessary to connect the IFB pin to the ground. On the other hand, if the chip detects the correct operation for at least an entire minute, then it will reset the counter.

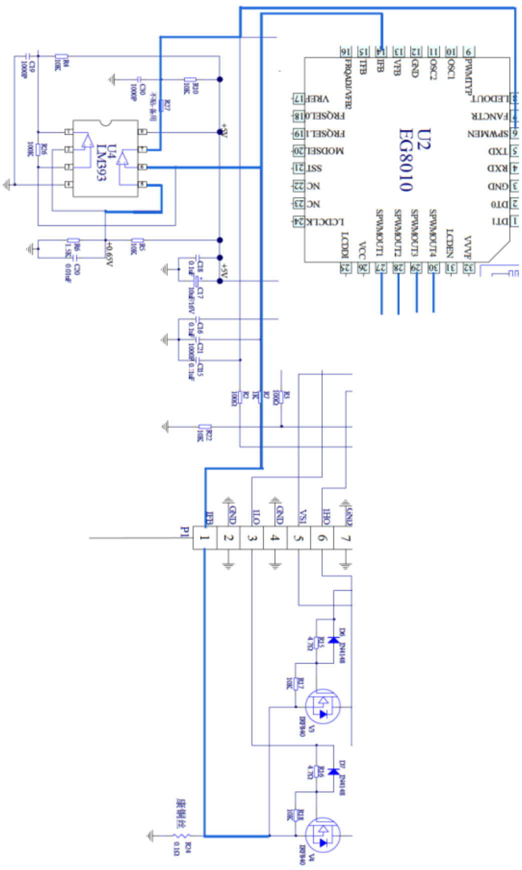


Figure 9. *Feedback circuit on AC Output current*

2.2.1.3 Settings of PWM output

The connection permit EG8010 and driver circuit IR2110 are given in Figure 10.

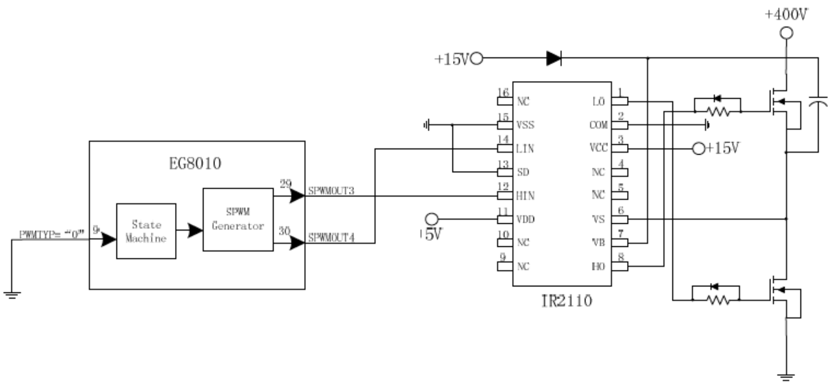
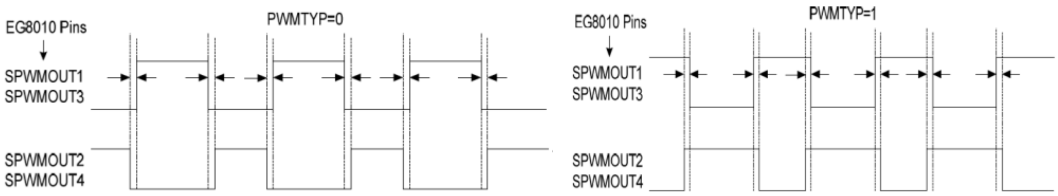


Figure 10. *Connection permit EG 8010 and driver circuit IR2110*

The setting is guaranteed by the PWMTYP pin which allows selecting the type of output. If the pin is set to "0", the positive PWM output is applied to the field where the dead level is low, like the IR2110 driver. This is shown in the diagrams in Figure 11a. Otherwise, if the PWMTYP is set to "1", the PWM output is negative and it is applied to the field where the dead level is high (Figure 11b).



a) b)

Figure 11. *PWM signals:* a) *Positive PWM output as input PWMTYP is set to logical 0, b) Negative PWM output as input PWMTYP is set to logical 1*

3. Experimental results

The operation of the EG8010 circuit is experimentally illustrated in the mode of variable voltage and constant frequency. For this purpose, the corresponding pins of the EG 8010 are set as follows: 50Hz (FRQSEL1, FRQSEL0=00), pins FRQADJ/V FB2, and VVVF do not affect. AC output voltage is adjusted by the feedback resistor R23. This application is used as a dimmer and voltage regulator.

The diagram in Figure 12 shows the pins of the board and the related external circuit to which the load is connected.

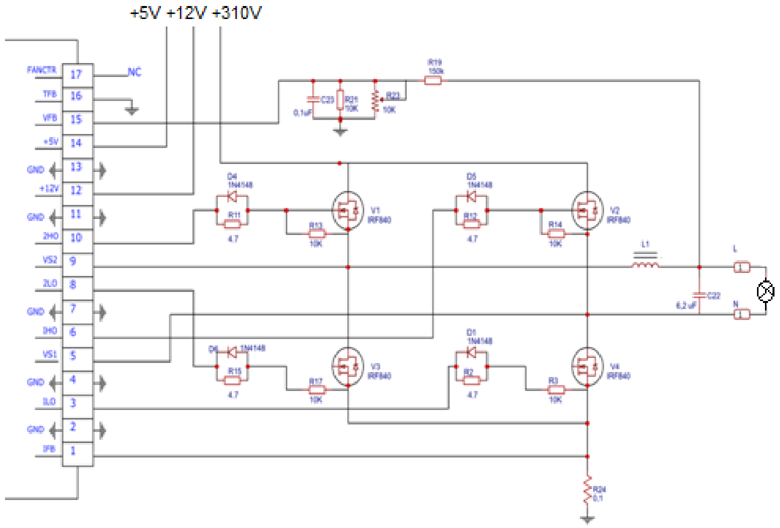
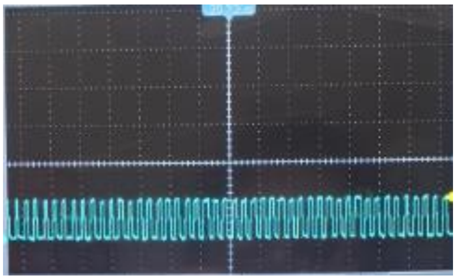


Figure 12. *The pins of the board and the related external circuit to which the load is connected*

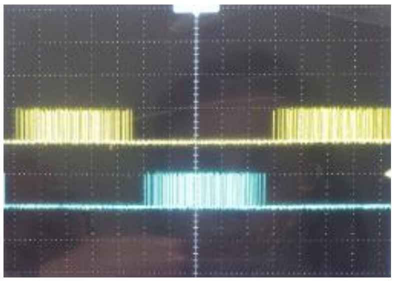
In Figure 13, the experimental test-prototype converter circuit which is based on the EG 8010 integral circuit in the mode of variable voltage and constant frequency is given.

Figure 13. *Experimental test-prototype converter circuit based on EG 8010 integral circuit in the mode of variable voltage and constant frequency*

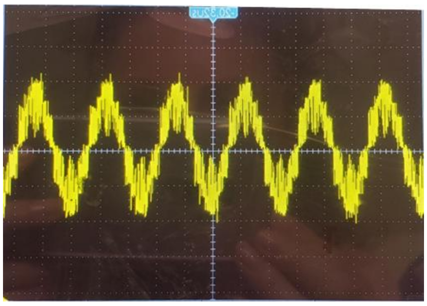
In Figures 14a and 14b, the PWM waveform of the output SPWMOUT3 signal, and both PWM waveforms together, one of the outputs SPWMOUT3 signal and the other of the SPWMOUT3 signal on EG 8010 are shown, respectively. Figure 14c presents the waveform of the output voltage on pin L and N on the inverter circuit.



a)



b)



c)

Figure 14. *The waveform of the pinout at EG 8010 in the mode of variable voltage and constant frequency: a) PWM waveform of the output SPWMOUT3 (horizontal 800 µs/div and vertical 5 V/div) b) PWM waveform of the output SPWMOUT3 (horizontal 4 ms/div and vertical 5 V/div) c) output voltage of pin L and N (horizontal 8 ms/div and vertical 200 V/div)*

From Figure 14a it can be seen that the pulse on the output SPWMOUT3 is PWM, while from Figure 14b it can be seen that the pulses on output SPWMOUT3 and SPWMOUT3 are phase-shifted by 180º. It provides orthogonal switching of MOSFET transistors in the one-half bridge. Figure 14c shows that the output voltage of the converter on pins L and N is sinusoidal with frequency 50 Hz and amplitude 350 V.

4. Conclusion

The paper analyzes the application of a special integrated circuit with a controlling inverter so that sine output voltage is generated. The characteristics of the circuit are given and the advantages of its application concerning the inverters controlled by microcomputer are emphasized. The circuit design and its experimental verification of the prototype of inverter control are also presented. The experimentally obtained results show that the output voltage of the inverter is sinusoidal.

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