MERENJE FREKVENCIJE TROFAZNOG GENERATORA PRIMENOM PIC MIKROKONTROLERA

MEASUREMENT OF THREE-PHASE GENERATOR FREQUENCY BY USING THE PIC MICROCONTROLLER

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U radu je prikazan uređaj za merenje frekvencije trofaznog AC generatora iz opsega 1-100 Hz. Uređaj kao ulazni signal koristi medjufazni AC napon, a na svom izlazu daje DC signal iz opsega 0-5V koji je proporcionalan frekvenciji 1-100 Hz. Merač frekvencije se sastoji iz modula za napajanje, modula za galvansku izolaciju i modula za merenje frekvencije. U modulu za galvansku izolaciju ulazni AC signal se pretvara u impulsni signal koji je galvanski izolovan od ulaznog signala. Tako formiran impulsni signal se dalje obrađuje u modulu za merenje frekvencije. Frekvencija ulaznog signala se određuje merenjem trajanja njegove periode, brojanjem impulsa poznate frekvencije. Mikrokontroler PIC 16F877A je iskorišćen da izvrši preračunavanje izmerenog broja impusa u broj koji je proporcionalan frekvenciji ulaznog signala. Sračunata vrednost se iz mikrokontrolera šalje kao binarni 10-bitni broj na D/A konvertor R-2R tipa. Nakon konverzije u analogni signal i kondicioniranja, na izlazu uređaja dobija se DC napon iz opsega 0-5 V proporcionalan ulaznoj frekvenciji. Uređaj opisan u radu može da se koristi za merenje frekvencije trofaznog vetrogeneratora.

Ključne reči: *merenje; frekvencija; mikrokontroler; vetrogenerator*

This paper presents a device for measuring the frequency of a three-phase AC generator in the range 1-100 Hz. Device uses the inter-phase AC voltage as an input, and at its output it produces a DC signal in the range 0-5V. The frequency meter consists of a power supply module, a galvanic isolation module and a frequency measurement module. In the galvanic isolation module, the input AC signal is converted into a pulse signal which is galvanically isolated from the input. Such pulse signal is further processed in the frequency measurement module. The frequency is determined by measuring the number of pulses of the known frequency. The PIC 16F877A microcontroller calculates the number of pulses as a binary 10-bit number and sends it to the D/A converter (R-2R type). After conditioning, a DC voltage signal (0-5 V) proportional to the input signal frequency is obtained at the output of the device. The device described here can be used to measure the frequency of the three-phase wind turbine.

Key words: *measurement; frequency; microcontroller; wind generator*

1 Introduction

Wind turbines, as sources of electricity in modern distribution systems, have experienced remarkable technological and technical progress in the last ten years, as a reaction to global environmental and energy problems, with a rapid trend of increasing installed capacity in the world [1]. The basic problem that occurs when converting the kinetic energy of the wind into electrical energy is to ensure the reliable and efficient operation of the generator under the conditions of variable wind power. Under the conditions of a large variation of the wind speed, the problem of satisfying all technical criteria regarding the transfer of electrical energy occurs. For this reason it is necessary to

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monitor and control these parameters (voltage variations, harmonic level, frequency, etc.) in real time.

Frequency is an important parameter used in science and engineering to specify the rate of oscillatory and vibratory phenomena, such as mechanical vibrations, audio signals (sound), radio waves [2]. Frequency is the number of occurrences of a repeating event per unit of time [3]. The period is the duration of time of one cycle in a repeating event, so the period is the reciprocal of the frequency.

In this paper, a device for measuring the frequency of a three-phase AC generator in the range 1-100 Hz is described. This device uses the inter-phase AC voltage as an input, and at its output, it produces a DC signal in the range 0-5V, that is proportional to the frequency in the range 1-100 Hz. Such a device can be used to measure the frequency of the three-phase wind turbine.

2 The principle of operation

The frequency of the generator is determined by measuring the duration of its periods. Figure 1 shows the principle of operation of the frequency measurement device. The sinusoidal signal of the positive half-period of the generator is first transformed into the rectangular shape. The pulse signal is galvanically isolated from the input signal and is introduced into the frequency measurement part of the device. The duration of input signal period is determined by counting the pulses of the known frequency (in this case 32768 Hz) by using the 16-bit counter. At the end of the input signal period, the downward edge of the impulse stops charging the counter and initiates the generation of two successive monostable pulses (I2 and I3), each with duration of 1ms.

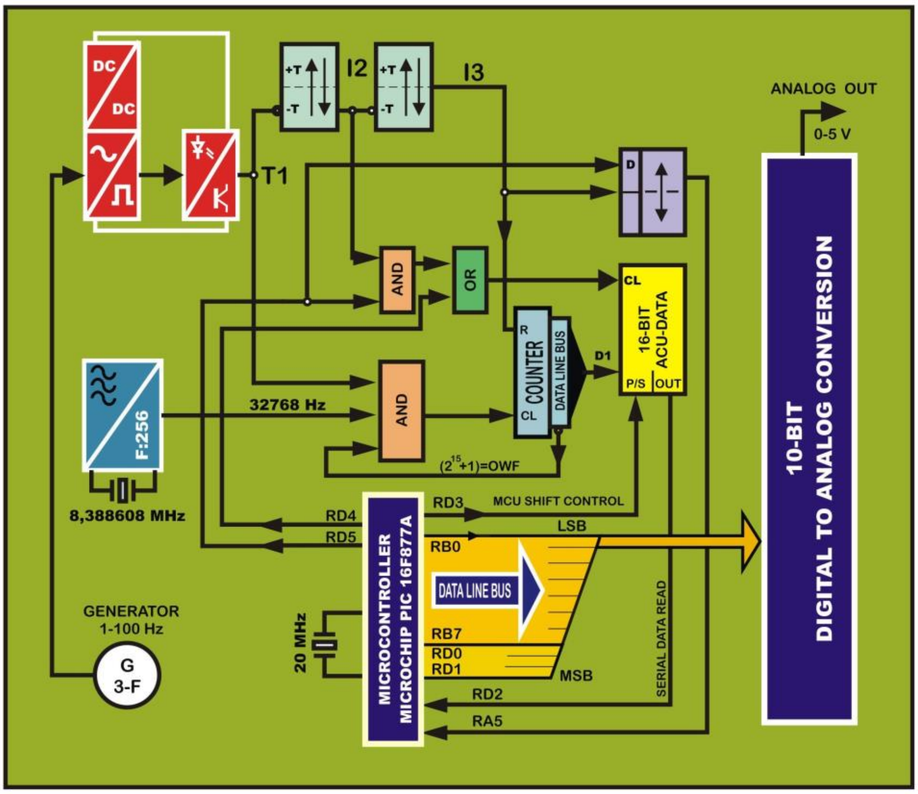

Fig. 1. The principle of operation of the frequency measurement device

The rising edge of the pulse I2 provides a clock for moving the content of the counter into the two 8-bit shift registers (16-bit accumulator). The I3 pulse resets the counter preparing it for the new counting cycle. By setting the RA5 to high, the microcontroller PIC 16F877A [4] (MCU) is informed that the pulse counting period has been started. The MCU responds to high level at RA5 by placing the signals RD5 and RD3 to low. By setting the RA5 to low, the MCU is informed that the pulse counting period has been completed. After that, the MCU generates 16 clock pulses at RD4 line, allowing serial entry from the shift registers into the MCU memory via RD2 line. After loading the contents of the counter, the MCU sets RD5 and RD3 to high and starts calculating the frequency. As soon as the MCU finishes with the frequency calculation, the result is displayed as a 10-bit number on the MCU ports RB0-RB7 and RD0-RD1. These ports are connected to the inputs of the R-2R D/A converter, so that, a DC voltage proportional to the frequency of the input signal is obtained.

3 Description of the frequency meter modules

The frequency meter consists of a power supply module, a galvanic isolation module and a frequency measurement module. The power supply module is realized as separate single-sided PCB, as shown in Figure 2. The galvanic isolation module and a frequency measurement module are located on the same single-sided PCB as shown in Figure 3.

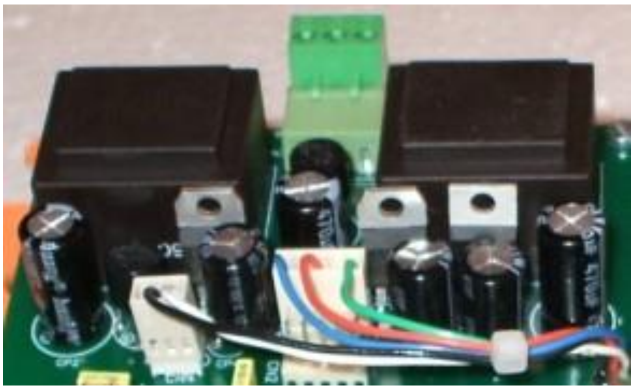

Fig. 2. Single-sided PCB of the power supply module with the components attached

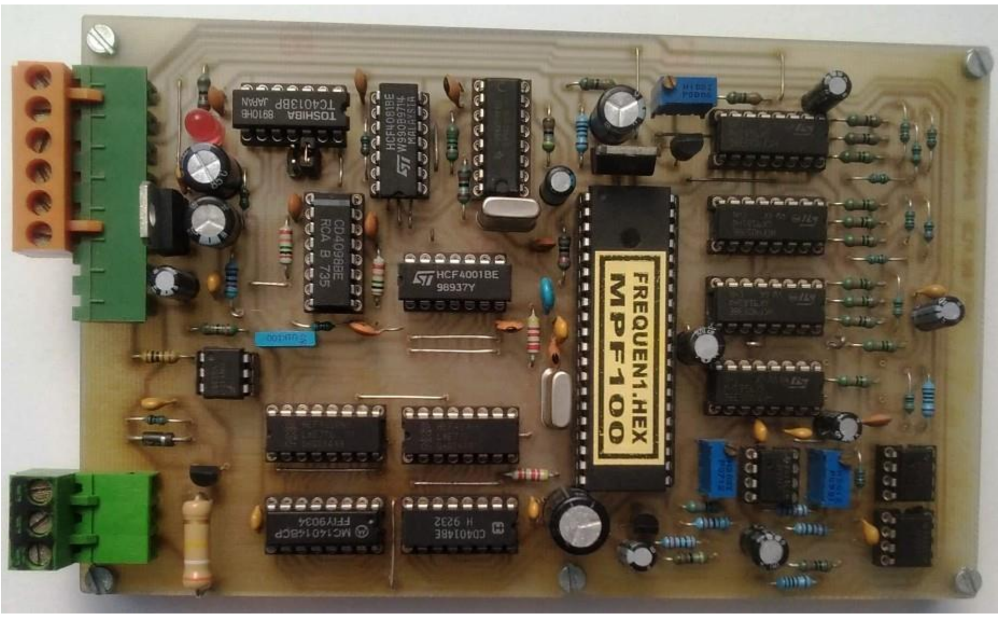

Fig. 3. Single-sided PCB of the frequency measurement device with the components attached

3.1 Power supply module

The power supply module supplies the other two modules of the device with ± 12 V DC. Each module is powered by a special rectifier unit containing Graetz bridge, positive and negative voltage regulators of type LM7812 and LM7912, as well as a group of capacitors for voltage filtering. These two rectifier units are, for safety reasons, implemented with the two separate network transformers, of which one is 220/15 Vac /1.8 VA and another one 220/ 2x15 Vac /1.8 VA, as shown in Figure 2.

3.2 Galvanic isolation module

In the galvanic isolation module (shown in Figure 4 on the left), the input AC signal is converted into a pulse signal and galvanically isolated from the input circuit by using the opto-isolator IC0 (CNY17) [5]. A positive half period of the input sine wave voltage is converted to the rectangular pulse of approximately the same duration. The voltage level of the polarization of the silicon transistor T1.1 is approximately 0.65 V, which introduces a time shift of the rectangular pulse relative to the start of the positive half-wave of the input sine wave.

Such obtained pulse signal is further processed in the frequency measurement module. The problem of delay and the formation of the pulse of the same duration as the input signal period is solved by introducing the input pulse signal to D type flip-flop (IC-2.1:A). After passing throughout the flip-flop (Q out) the input pulse signal changes its polarity and its frequency is divided by 2. Therefore, at the Q out of D flip-flop, the obtained pulse signal is the same in duration as the period of the input sine wave.

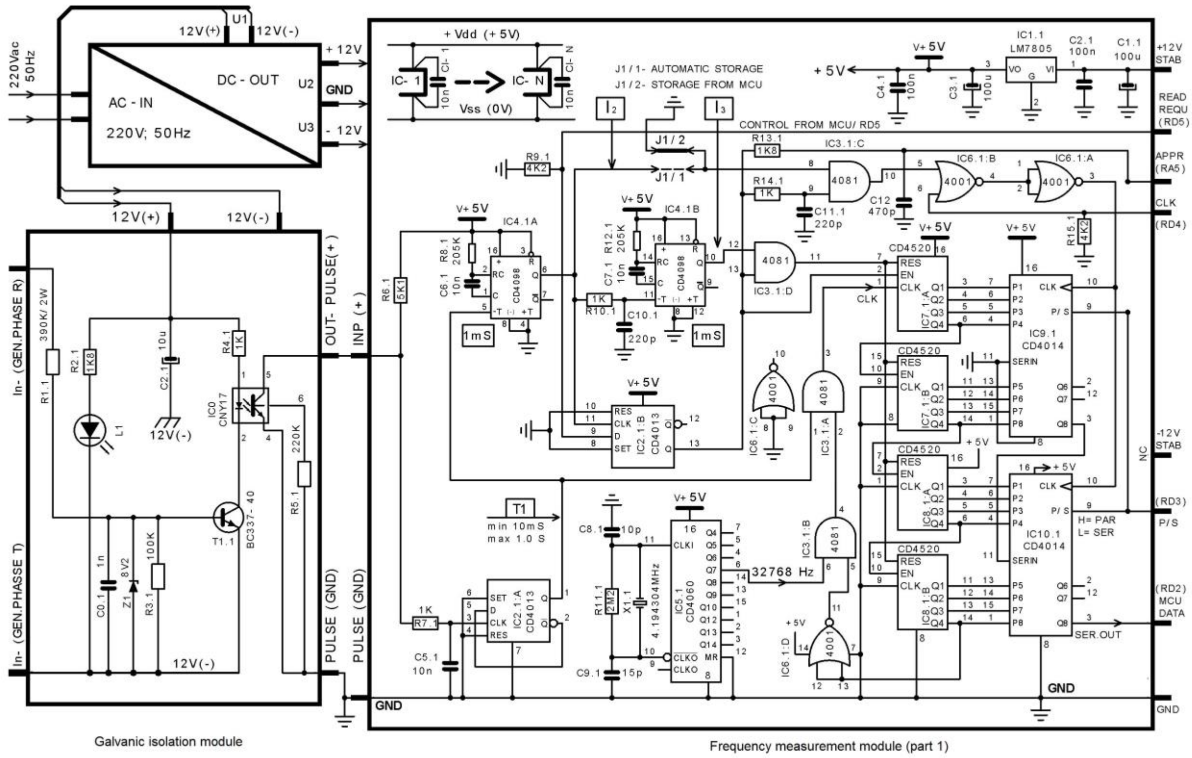

Fig. 4. Electrical scheme of the frequency measurement device (part 1)

3.3 Frequency measurement module

The frequency measurement module consists of two parts:

- The input signal period measurement part,
- The part for converting the measured period into the analog signal.

The input signal period measuring part consists of an oscillator (IC5), a counter (IC7, IC8), a D flip-flop (IC2), a monostable multivibrator (IC4), shift registers (IC9, IC10), logic circuits for controlling the operation of the counters and registers (IC3, IC6), a positive voltage regulator (IC1), and the passive components (resistors, capacitors) as shown in Figure 4.

The part for converting the measured time into the analog signal consists of a microcontroller PIC 16F877A (IC1), a voltage regulator (IC2), analog switches (IC3-IC6), low-noise OP amplifiers (IC7-IC9), a precise voltage regulator (IC10), and passive components (resistors, capacitors) as shown in Figure 5.

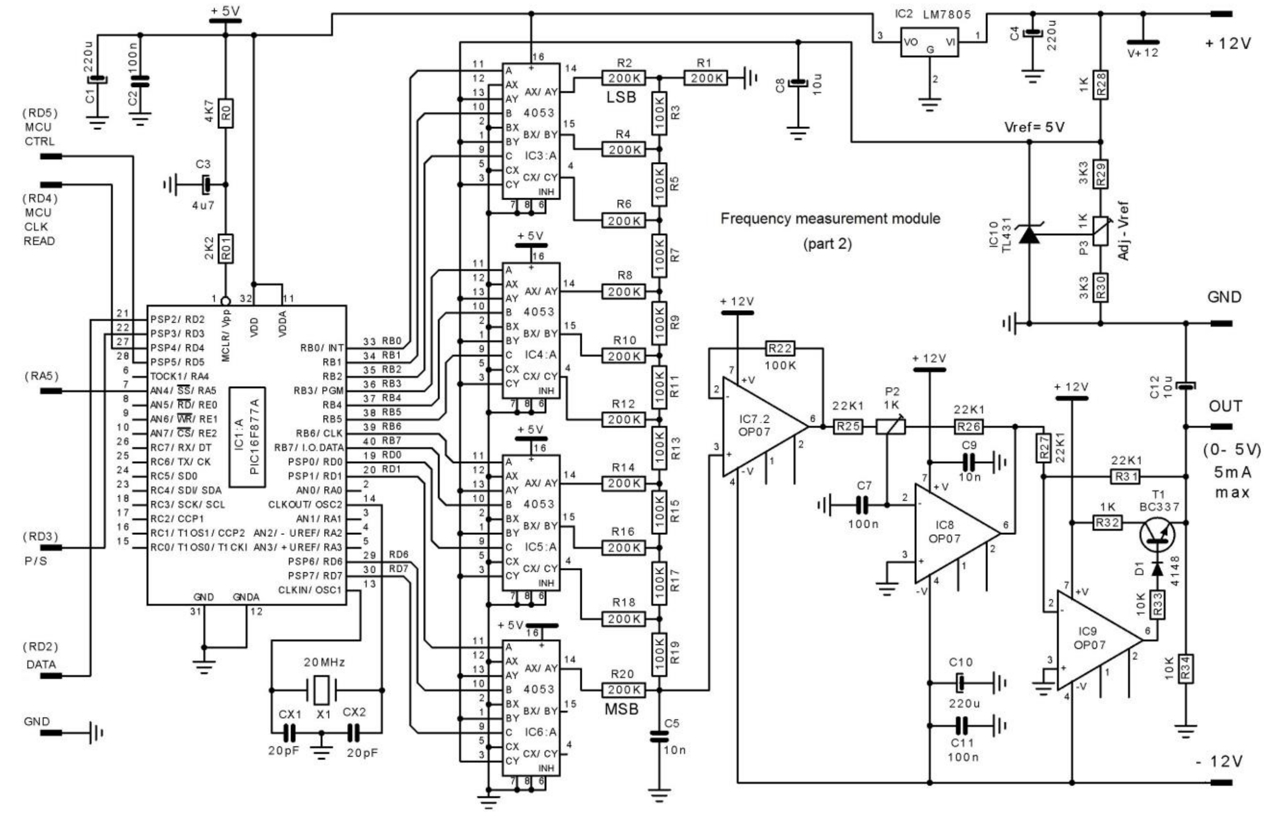

Fig. 5. Electrical scheme of the frequency measurement device (part 2)

The input signal frequency is determined by measuring the number of pulses of known frequency during the period of input signal. Initially, at the beginning of the measurement cycle, signals RD5 and RA5 are set to high (see Figure 4). This enables the operation of the counter (IC7.1:A) during the period of input signal (Q output of IC2.1:A is set to high). In that period of time, a high logic level is present at input (pin 1) of AND gate (IC3.1:A), which allows passing of the pulses from the oscillator (IC5) into the counter.

At the end of the input signal period, the downward edge of T1 pulse stops charging the counter and initiates formation of the two successive monostable pulses (I2 and I3), each with the duration of 1ms, as shown in Figure 4. The rising edge of the I2 pulse (Q output of IC4.1:A is set to high) sets the RA5 to low and provides a clock for moving the contents of the counter into two 8-bit shift registers. Impulse I3 resets the counter and prepares it for the new counting cycle.

The MCU responds to high level at RA5 by setting RD5 and RD3 to low. After that, the MCU generates 16 clock pulses at the RD4, allowing serial entry of data from the shift registers into the MCU memory via RD2 line. Afterwards, the MCU sets RD5 to high and starts the calculations. The MPC calculates the frequency as the number of oscillator pulses in one second, which is 32768. When the input frequency is 100 Hz, the counter contains 328 pulses. As soon as the MCU finishes with the frequency calculation, the result is displayed as a 10-bit number on the MCU ports RB0-RB7 and RD0-RD1. These ports are connected to the inputs of the R-2R D/A converter; hence, a DC voltage proportional to the frequency of the input signal is obtained.

The D/A converter is designed as a 10-bit device. It uses a known R-2R resistor network [6] in combination with analogue switches CD4053 (IC3 to IC6) [7]. The reference voltage for the resistor network generates adjustable and precise voltage reference TL431[8]. A potentiometer P3 is used to fine-tune the reference voltage (5V +/- 0.25V DC), as shown in Figure 5. The analog signal from D/A converter is supplied to the non-inverting OP amplifier (IC7), which has a very high input impedance. Its role is to eliminate the error due to the impact of the additional current load of the resistor network. Due to very low values of the offset voltage, (OP07), no additional trimers are needed to correct the output voltage values. The gain of inverting OP IC8 can be fine-tuned using the potentiometer P2. The setting range is defined by selecting the values of components P2, R25 and R26. Initially, potentiometer P2 should be set in the middle position.

The transistor T1 is connected to the output of inverting OP (IC9), to provide greater current availability of the output. At the output of the frequency measurement module, a DC signal in the range 0-5 V, that corresponds to input signal frequency in the range 1-100 Hz, is obtained.

4 Conclusion

To ensure the reliable and efficient operation of the wind turbine under the conditions of variable wind power it is necessary to monitor the key parameters of its operation in real time. In the paper, a device for measuring the frequency of a three-phase AC generator in the range 1-100 Hz is presented. As an input, this device uses the inter-phase AC voltage, and at its output, it produces a DC signal in the range 0-5V, which is galvanically separated from the input signal. Such output signal is suitable for further processing in the distributed control systems. Hence, the device described in the paper can be used for measuring the frequency of the three-phase wind turbine.

Acknowledgements

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5 References

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