MICROCONTROLLER SYSTEM OF HYDROGEN PULSE INJECTION ON STELLARATOR URAGAN-3M

S.P. Gubarev, V.B. Korovin, V.M. Listopad, A.V. Lozin, Yu.K. Mironov, G.P. Opaleva, V.S. Romanov, V.S. Taran, N.V. Zamanov, M.I. Zolototrubova

Institute of Plasma Physics of the NSC KIPT, Kharkov, Ukraine

E-mail: gubarev@kipt.kharkov.ua

This paper describes a renewed system of pulse injection of working gas into the vacuum vessel of the stellarator Uragan -3M. The system was designed and fabricated in the Institute of Plasma Physics of NSC "Kharkov Institute of Physics and Technology" and is intended for providing of the fast-acting dosed injection of hydrogen by the given algorithm. A distinctive feature of the developed system is the use of designed microprocessor-based controller to control the operation of the piezoelectric valve.

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INTRODUCTION

In the experiments on magnetic plasma confinement important is the control for the dosed injection of working gas into the vessel volume of the device. As a rule, the gas has to be injected according to the preliminary formulated program. Recently in the Institute of Plasma Physics of NSC Kharkov Institute of Physics and Technology, to satisfy requirements of a working plan for U-3M experiments, a system of working gas pulsed injection was developed and fabricated. It has several advantages compared to the previously described construction [1].

1. EXPERIMENT DEVICE

This system uses a piezoelectric valve model PEV-1 produced by the American firm Key High Vacuum Products.

The features of the valve:

- Level of injection 0…500 [sccm] – (standard cubic ccentimeters per min);
- Level of loss at closing < $1 \cdot 10^{-9}$sccm / (1 atm He at the input);
- Time of response (reacting) – 2 ms;
- Max entrance pressure – 50 psi;
- Requirements for the control signals - U=0…100 V, I≤10 mkA;
- Max operation voltage – 100 VDC;
- Range of working temperatures of +10 to +60 °C.

The valve is disposed outside of the vacuum chamber, and into the chamber the gas is fed by means of 2 m stainless tube with 18 mm inner diameter. Gas injection is located near the frame type antenna used for RF plasma produce (RF generator Kascad-1).

A distinctive feature of the developed system is the use of designed microprocessor-based controller to control the operation of the piezoelectric valve. Its photo is shown in Fig. 1.

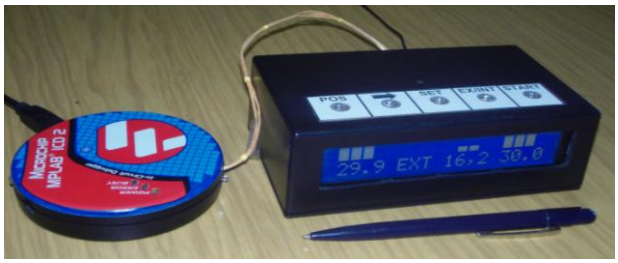

Fig. 1. Appearance of microcontroller system of hydrogen pulse injection

It is implemented on the basis of microcontroller series PIC18FK manufactured by Microchip Technology Inc. [2]. The controller provides the function of operational settings of the working gas injection , the operation mode selection, synchronization with other systems of the experimental installation and visualization of injection process as a graphical mnemonic scheme. The block diagram of the developed microprocessor controller is shown in Fig. 2.

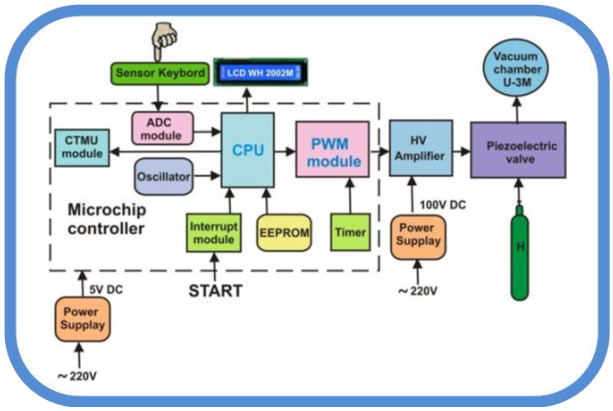

Fig. 2. Block diagram of microcontroller system pulsed hydrogen injection

The system uses the following hardware modules (see Fig. 2):

- Charge Time Measurement Unit (CTMU) works in conjunction with the A/D Converter;

- 12-bit Analog-to-Digital (A/D) Converter module;
- Capture/ Compare/ Pulse-Width Modulation (PWM) module;
- Timer 0, Timer 1 and Timer 2 modules;
- EEPROM.

Work of the CPU is synchronized by clock generator. The required parameters of the signal control and opening valve are provided by PWM module (Fig. 3). Pulse width and pause entered by the operator via the touch panel and displayed on the LCD. It is possible to display information in two rows of twenty characters.

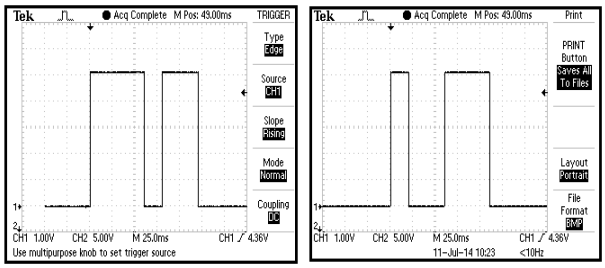

Fig. 3. Examples of waveforms of PWM

To perform the required functions of the microcontroller, the original software was designed. To provide successive operation of hardware modules, the software system consists of the main program and a set of routines:

- subroutine of configuration and control of charge time;
- measurement unit (CTMU);
- subroutine of ADC module configuration and control;
- subroutine of PWM settings and control;
- subroutine of timers 0, 1 and 2 configuration and control;
- subprogram for saving in a nonvolatile memory (NVRAM);
- EPROM.

The main program coordinates all program modules.

Subroutine of setting and control of the pulse width modulator (PWM) defines the mode of hardware module operation and the parameters of the output signal. Subroutine of control turns on the PWM in a requested time.

Subroutine for configuration and control of analog-to-digital converter (ADC) sets the speed of conversion, the destination data format, the active channel number, and triggers the process of data conversion. Thereafter, control subroutine reads the data of an active channel.

A distinctive feature of the developed controller design is the use of touch controls. It is connected with a sufficiently large number of required input parameters defined by buttons and switches. Taking into account small size of the controller enclosure (157 mm × 95 mm × 53 mm) and the expected expansion of the feature set of the controller in future (registration of plasma response to the injection of hydrogen), which would entail an increase in the number of controls the use of he touch panel can be considered as the best solution. Such design is inexpensive and allows to increase simply the number of sensor pads in the condition of limited space. For these purposes the company Microchip Technology Inc. produces a number of microcontrollers including an inexpensive 18-series. Required functions for the system are provided by microcontroller PIC18F25K80. The Charge Time Measurement Unit (CTMU) is integrated into microcontroller crystal, it can measure relative changes of capacitance in specific time delay. The CTMU works in conjunction with the A/D Converter to provide time or charge measurement .The CTMU is ideal for interfacing with capacitive-based sensors. The principle of operation of such module is to measure a changing of voltage level at the ADC input.

The signal at the input of the ADC has a sawtooth shape (Fig. 4). This is the result of changes of the voltage drop across the resistance of the input circuits of the ADC during charging input capacitance by fixed current (0.55…550 μA), produced by CTMU module for a fixed time (tens of microseconds). When one touches the touch pad, the total input capacitance, and hence the time of charging, are increased. The corresponding values of voltage difference will be deciphered by the loaded program as touching the touch pad.

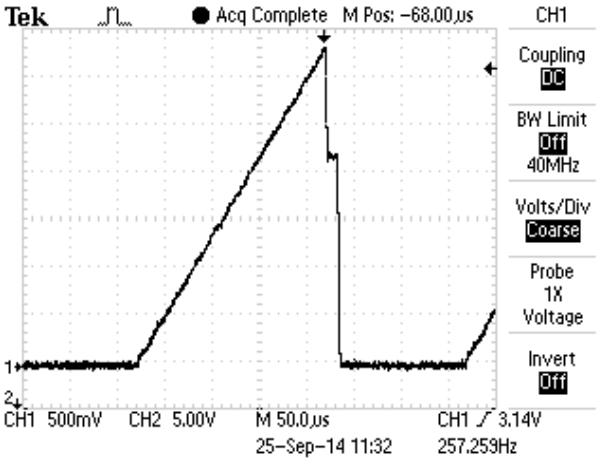

Fig. 4. CTMU

All three timers operate in interrupt mode. Setting subroutines of timers set modes and interrupt response time. Subroutine of control is carried out on / off timers and handles interrupts. Timer 0 sets the frequency of the survey, which checks whether the change in the charge of the capacitor occurred. Timer 1 is used for setting high-precision pulse parameters for switching on the valve of hydrogen injection. If special accuracy is not necessary, the Timer 2 is used; it configures signal shape and starts the PWM.

The program of the data saving in the non-volatile EEPROM memory writes the pulse parameters of switching on the hydrogen injection valve. All software modules were created in the development environment MPLAB IDE on a specialized high-level language C18, which was created for programming microcontrollers of 18 Series.

Executable program for control of pulsed gas injection system was loaded into the memory of the microcontroller. Loading and reprogramming the microcontroller is performed by means of in-circuit debugger ICD 2 of Microchip Technology.

Tests of hydrogen pulse injection were carried out under various pressure values in the U-3M chamber and with different levels of pressure at the valve input.

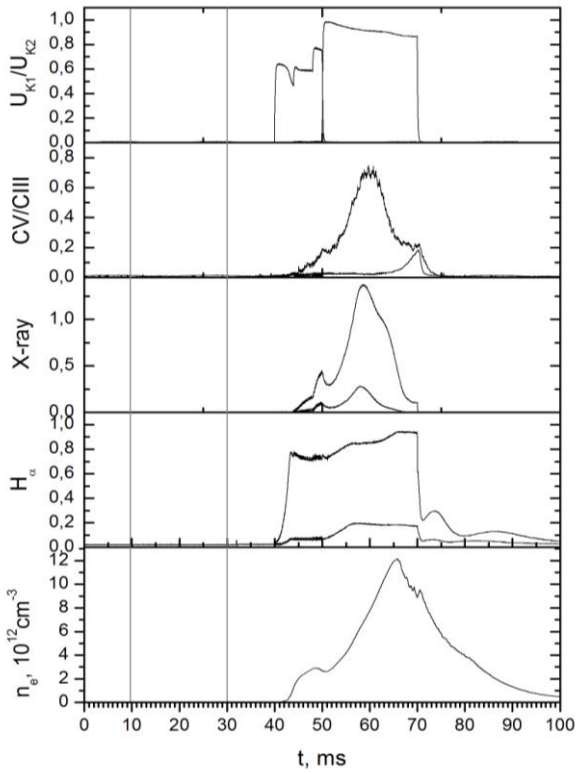

Fig. 5. The signals of some plasma diagnostics with hydrogen injection

Special tests were provided to determine the minimum pulse width of valve control sufficient for its sustainable operations. As a result of these tests the response time of gas injection system was found, equals to 20…40 ms under various conditions. Such quite a long response time is caused by the length of pipelines and the valve construction. Due to this, when operating at pressures 10^{-4}…10^{-5} Torr, it is necessary to increase the closing force of the valve, what, naturally, increases the inertia of the entire system. Since without additional control the level of leakage through the normally closed valve was high (above than in the passport) and changed the total pressure in the chamber, it was also determined the optimum pressure at the valve injection $P_h = 0.65$ atm and the minimum width of control pulse $\tau = 20$ ms.

The signals of some U-3M plasma diagnostics of the discharge number 117 during hydrogen injection using a piezoceramic valve are shown in Fig. 5.

CONCLUSIONS

Application of microcontroller allowed to create a compact and easy to use device for precise control system of pulse hydrogen injection for stellarator Uragan-3M. The details of the work of some units of the microcontroller are described, what can be useful for specialists engaged in developing instrumentation for scientific purposes.

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МИКРОКОНТРОЛЛЁРНАЯ СИСТЕМА ИМПУЛЬСНОГО НАПУСКА ВОДОРОДА НА СТЕЛЛАРАТОРЕ УРАГАН-3М

С.П. Губарев, В.Б. Коровин, В.М. Листопад, А.В. Лозин, Ю.К. Миронов, Г.П. Опалева, В.С. Романов, В.С. Таран, Н.В. Заманов, М.И. Золототрубова

Описана разработанная в Институте физики плазмы ННЦ ХФТИ обновленная система импульсного напуска рабочего газа на установке Ураган-3М. Система предназначена для обеспечения быстродействующего дозированного напуска водорода по заранее заданной программе. Отличительной особенностью системы является использование разработанного микропроцессорного контроллёра для управления работой пьезоэлектрического клапана.

МІКРОКОНТРОЛЕРНА СИСТЕМА ІМПУЛЬСНОГО НАПУСКУ ВОДНЮ НА СТЕЛАРАТОРІ УРАГАН-3М

С.П. Губарєв, В.Б. Коровін, М.М. Козуля, В.М. Листопад, А.В. Лозін, Ю.К. Міронов, Г.П. Опалєва, Р.О. Павліченко, В.С. Романов, В.С. Таран, Н.В. Заманов, М.І. Золототрубова

Описана розроблена в Інституті фізики плазми ННЦ ХФТІ оновлена система імпульсного напуску робочого газу на установці Ураган-3М. Система призначена для забезпечення швидкодіючого дозованого напуску водню за заздалегідь заданою програмою. Відмінною особливістю системи є використання розробленого мікропроцесорного контролера для управління роботою п'єзоелектричного клапана.