Microcontrollable bipolar semiconductor power supply for CuBr laser

P.V. Vybornov and V.V. Tatur

Institute of Monitoring of Climatic and Ecological Systems, Siberian Branch of the Russian Academy of Sciences, Tomsk

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We describe a control circuit for a semiconductor power switch of a bipolar power supply of CuBr laser designed based on a novel microcontroller from Atmel Corporation.

Introduction

In the past decade microprocessor systems has been established to be the principal technical basis in control automation.[1,2] This is due to their flexibility and the possibility of their quick retuning even in the case of significant changes to control algorithms. Moreover, a microprocessor, being a system's central module, enables one to easily implement the principles of open systems, whose functional capabilities can be enhanced gradually, either when necessary or with the advent of new technologies. This allows one to achieve a long-term conformity of microprocessor-based control systems to the latest technical demands.

From the functional viewpoint, microcontrollers are the most widely used type of specialized microprocessors. These are microprocessor systems aimed at implementing the algorithms of digital control of different objects and processes. The specific feature of a microprocessor is the arrangement within one semiconductor crystal, in addition to CPU, of the internal memory and of a large set of peripheral tools. With such a microcontroller, it is possible to solve a wide range of problems in many different fields of science and technology.

Development of a bipolar power supply for a CuBr laser using state-of-the-art high-power transistors as switches (see Refs. 3–5) and application of high-end circuit solutions has favored transition to microcontrollable facilities, having thus widened the system's functional capabilities. Note that solution of all the problems stated for the microcontroller of this power supply is not just possible, but is most optimal with a single microcontroller.

Statement of the problem and microcontroller choice

The main function of a microcontroller is formation of four control signals *1* to *4* (see Fig. 1) with the help of semiconductor switches in two cascades of the charging and discharging circuits of a bipolar power supply of a CuBr laser.[5] To make the performance of the circuit more efficient, pulse lengths and inter-pulse periods must be set independently. Additional functions of the microcontroller-based device are: 1) control of the sensor that records null cycles in the first and the second cascades of the discharge loop and of the sensor that detects short circuits in the first and the second cascades of the charge circuit, and counter actions in case of sensor activation episodes; 2) counting and storage of the circuit operation time.

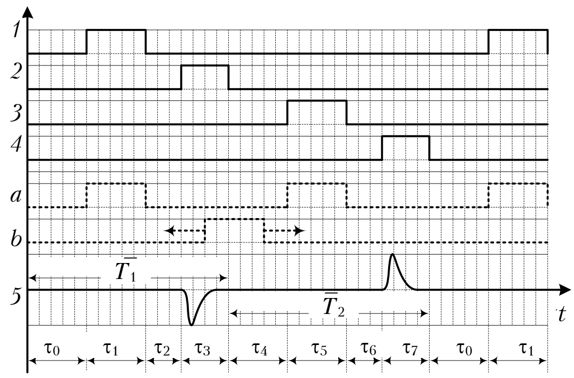

Fig. 1. Time sequence of the signals in the control circuit of a power supply.

The above tasks can be successfully completed if a microcontroller is chosen based on the following criteria:

– high efficiency;

– execution of most instructions within single clock cycle;

– minimum of nine I/O ports available;

– minimum of three I/O ports with external interrupt available;

– 8- and 16-bit timers;

– minimum 2 Kbytes of data memory space.

With the above selection criteria in mind and with the account of the customer parameters and performance characteristics, such as customizing options, proper software updates, and a reasonable price, an ATtiny2313-20PI microcontroller from Atmel Corporation seems to be a proper choice.

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Microcontroller operation algorithm

In the microcontroller operation circuit, two modes are distinguished. One of them fits the program that realizes the algorithm developed.

In the first (initial) mode, the microcontroller forms a sequence of control signals *2* and *4* (Fig. 1) with the help of high-power semiconductor switches of the first and the second cascades of discharge circuit, respectively. The status of the sensors and circuit operation time are not recorded.

The initial mode is essential, because the direct stabilized voltage formation circuit that feeds the two cascades of the discharge loop of the bipolar power supply of a CuBr laser, to avoid current rushes, provides for a smooth charging of a high-power capacitor battery what takes time.[5]

Switching to the second (main) mode occurs upon user initiative via injection of the control signal, where it is now the microcontroller that orders signals *1*, *2*, *3*, and *4*, which control the semiconductor power switches of both the first and the second cascades of the charge and discharge loops, respectively. Circuit operation time is recorded.

Because the charging and discharging cascades operate in sequence, the bipolar high-voltage signal *5* is formed at the output of the power supply (see Fig. 1).

If one of the sensors triggers in the main mode, the microcontroller stops operation of the power supply within two clock cycles by blocking two control signals, *1* and *3*, and registers the time length of the circuit operation. Detection of null cycles in the first and second cascades of the discharge loop (signal a, in Fig. 1) is possible only at time moments τ_1 and τ_5, while the detection of short circuits in the first and second cascades of the charge circuit (signal b, in Fig. 1) is possible at any time. False sensor action is impossible.

In case of no sensor signals, the circuit closes down after a user reenters the control signal. In this case, the microcontroller switches to the initial mode and records the duration of the circuit operation. Operation of power modules can be resumed only after disconnection of the supply and a reset.

Concluding remarks

The use of an ATtiny2313-20PI microcontroller manufactured by the Atmel Corporation in a unit controlling a bipolar semiconductor power supply of a CuBr laser, instead of microchips formerly used here has allowed us to:

– reduce the power consumption and dimensions of the control circuit;

– form a sequence of control pulses (τ_1, τ_3, τ_5, and τ_7) and interpulse intervals (τ_0, τ_2, τ_4, and τ_6), independently with the durations from 1 to 12 and from 1 to 50 μs, respectively, being multiple of 0.1 μs;

– generate a periodic $T_1/T_2 = 1$ (see Fig. 1) or aperiodic $T_1/T_2 \neq 1$ signal *5* at the source output when necessary;

– record and store the duration of circuit operation;

– use up to four independent sensors; in case of sensor action, system's response time being 0.1 μs.

The authors believe that the capabilities of new microcontrollers demonstrated in this work prove once more that their effect is not limited to improvement of technical and performance characteristics of the device they are used in. They can also give rise to extension of the scope of investigations.

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