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Bootloader for Sci-Trace

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Anotation:
This paper describes a realization of Bootloader for microcontrollers AVR and investigates a design for its implementation into the Sci-Trace device. Electronics in Sci-Trace consists of control board, patch board and secondary modules. Patch board only function is to connect the control board and secondary modules. Secondary modules have several functions, such as lighting regulation, step motors control, etc. Information display is connected to control board and it is used to show the temperature inside the device, supply voltage and bus utilization. Electronical parts are located in standard rack system. Special firmware was designed for control board and secondary modules microcontrollers. Also software for simple firmware upgrade into the microcontrollers was developed.

Anotace:
Tato práce popisuje realizaci Bootloaderu pro mikrokontroléry AVR a zabývá se návrhem a samotnou implementací do zařízení Sci-Trace. Elektronika v zařízení Sci-Trace je složena z řídící jednotky, propojovací desky a sekundárních modulů. Propojovací deska je zapojena mezi řídící jednotkou a sekundárními moduly. Sekundární moduly jsou navrhnuty pro konkrétní využítí, jako například regulace osvětlení, ovládání krokových motorů apod. Informační displej je připojen k řídící jednotce a je využit k zobrazení, teploty uvnitř elektroniky, napájecích napětích a napětí na lince. Elektronické části jsou umístěny ve standardním 19 palcovém racku. Firmware pro Řídící jednotku a sekundární moduly je navrhnut pro dané řešení, stejně tak je vytvořen software pro jednoduché nahrávání firmwaru do mikrokontroléru.

INTRODUCTION

A realization of a Bootloader [1] for AVR microcontrollers is investigated and a proposal for implementation of the Bootloader into a device called Sci-Trace (see in Fig. 1) is made in this work. The Sci-Trace device is used for elemental analysis of samples in the Laboratory of Laser Spectroscopy at the Brno University of Technology. Experiments are performed using LIBS (laser-induced breakdown spectroscopy) technique.

Fig. 1: Photography Sci-Trace device.

The device contains a laser power supply, a PC, control electronics, pressure system and other devices. There is an optical breadboard on the top of the device. An interaction chamber [2], in which the experiments are performed, is mounted on the breadboard. Inside of interaction chamber is sample holder, where can be placed sample with defined dimension or pellets with standard diameters. Thanks to the control and analyses software, the Sci-Trace device is used for elemental mapping of the sample surface [3] [4].

CONCEPT OF BOOTLOADER

The concept of a Bootloader can be found in a variety of microcontrollers, or more complex processors. Concept of the Bootloader for Atmel microcontrollers [5] is based on the FLASH memory separated into two parts – application and Bootloader part. One part of the memory is able to reprogram the other part. Every page of the memory needs to be erased before it can be written into. The Bootloader waits for a flag and writes data into special page buffer, which has a size of one page. Size of one page is independent on the size of FLASH memory in Microcontrollers. Some of chips have only application part without Bootloader part, on the other hand few chip have only Bootloader part without application part, but it is only small percentage of Atmel Corporation production.
The last step is "calling a macro" which loads the content of the page buffer into the page. Then, fuse bits for the microcontroller have to be set to make it start from the Bootloader address instead of zero

address. In the factory state fuse bits for Bootloader are not programmed and Bootloader part behaves like application part.
Another important part is interrupt in the AVR chip and his addressing. When Bootloader part is inactive, vector table starts from zero address. In a case we want to use interrupt in a Bootloader part, we must move vector table on start of Bootloader address by two specifics bits in a MCUCR register.

MECHANICAL AND ELECTRICAL CONSTRUCTION

A control electronics is necessary to control the device. It is divided into a base patch board, secondary modules and a control board. The patch board is used to connect the secondary modules to the control board. The control board secures communication between a user and the secondary modules. Some of the modules are: three axis manipulator placed inside the interaction chamber, and pressure system module, which enables under- or overpressure inside the chamber. Drawback of current control electronics is a patch board, because individual modules cannot be swapped from one slot to another without changes in the internal cable connections.
Another drawback of the current configuration is impossibility to upgrade the firmware of the control board and the secondary modules without external serial programmer.
This problem is resolved by implementation Bootloader system into the AVR chips in control board and secondary modules. In modification (see in Fig. 2) on control board is connected data pin from FTDI chip [6] to the reset pin. On secondary module is reset pin connected over patch board to output pin on control board. This change allows user to reset module and then reprogram it easily without external programmer.

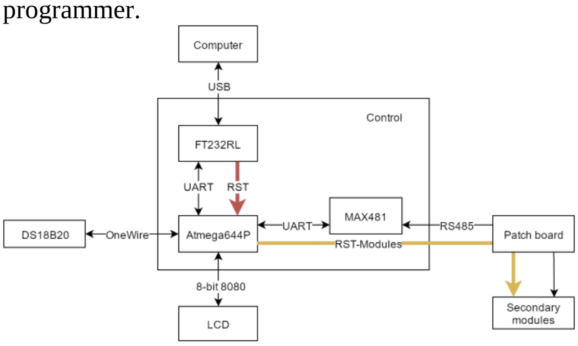

Fig. 2: Block diagram electronics.

The control electronics is designed to fit into a 19" rack system. The patch board (see model in Fig. 3) is designed in compliance to ČSN standard [7] and enables unlimited number of patch boards to be connected to each other in a chain. The patch board itself serves only for distribution of power supply and data among all the modules. For this reason, connectors were moved from the backside of the patch board to the foreside of each individual module.

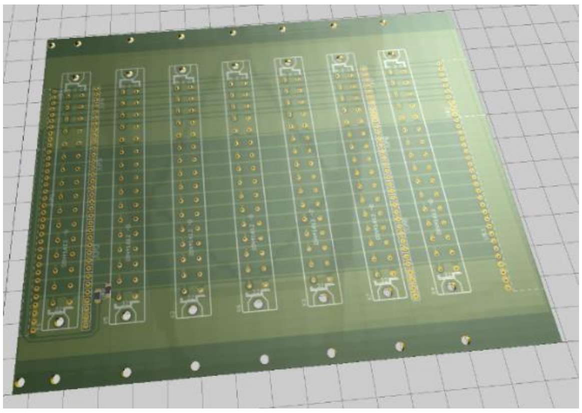

Fig. 3: Patch board.

The control board (see model in Fig. 4) was moved to the backside of the patch board to save space. Thanks to this the modules can be inserted into the patch board in any order which makes the system modular.

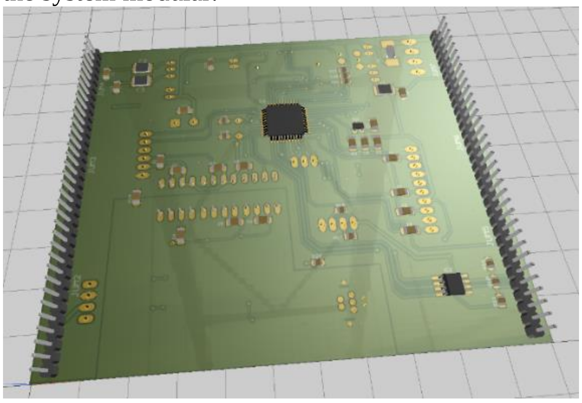

Fig. 4: Control board.

Using the Bootloader for the AVR microcontroller, the firmware of the control board and the modules can be updated. Another part of the system is an information display, which enables to check supply voltage, RS485 bus state [8], state of the USB connection, and temperature of the switch-mode power supply.
Next part of this work deals with creating of the Bootloader part state machine (see in Fig. 5) in the master memory. After hardware reset of the microcontroller, a 'P' command must be received from the PC to activate Bootloader mode. In the next stage program awaits input data from PC via UART. Some of the commands implemented in the state machine are: erase all FLASH memory, erase EEPROM memory, write data into FLASH memory by page on specific address, write data into EEPROM memory by page on specific address, verify memory for check of the data loaded into FLASH or EEPROM memory, etc.
Another part of the work is focused on creating the Bootloader part state machine in the slave memory of the secondary modules. The RS485 bus implements Trinamic protocol, which enables changing

the communication speed by a specific commands. There is a command in the application part of the Master microcontroller to reset all secondary modules. The Trinamic protocol contains address of target module, so only the required module enters Bootloader mode. State machine for Slave is very similar to the Master´s one. A freeware terminal can be used to write into application memory of Master or Slave, but this is a very complex process. For resolving this problem program called HexLoader was created [9].

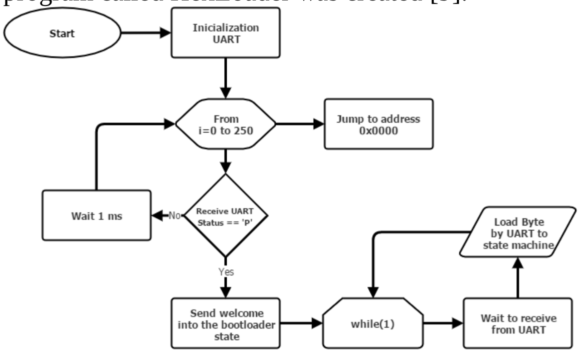

Fig. 5: State machine diagram.

The last part of the work was assembling all components of the system, e.g. patch board, control board, information display and switching power supply, into a 19" rack. The system was tested and debugged. Visualization the assembly of the control electronics can be seen on Fig. 6.

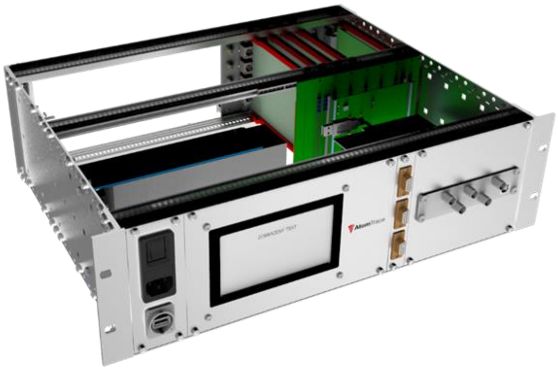

Fig. 6: Control electronics.

CONCLUSIONS

This paper describes the design of printed circuit board for the Sci-Trace device. In the first part is described the function of the Sci-Trace device, its basic components and measurement examples. Next step describes concept of the Bootloader, which is able to reprogram firmware of electronics without external programming device. Main electronical part of the device is the control board, connected to secondary modules using patch board. Computer then can control secondary modules by control board. Information display connected to control board shows RS485 condition, temperature inside rack and voltage supply for fast check of the electronics state.

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