Enhancing Analog Laboratory Power Supplies Functionality Using Microcontroller

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Abstract — This paper explores the enhancement of analog laboratory power supplies through the integration of microcontroller-based technology to upgrade and expand their user interfaces. Analog power supplies traditionally offer basic functionality with limited user interaction capabilities. This approach focuses on improving user accessibility and functionality by introducing a microcontroller-driven interface. The study concludes with a discussion on the potential applications and benefits of integrating microcontroller technology into analog laboratory power supplies, paving the way for more sophisticated and adaptable laboratory equipment in research and educational environments.

Keywords — analog power supply, embedded PSU, PSU UI, power supply user interface, PSU microcontroller

I. INTRODUCTION

The upgraded user interface enables precise control of output parameters such as voltage and current, offering users greater flexibility and accuracy in laboratory PSU settings. Additionally, advanced features such as digital display of output values [1-3], programmable presets [4-6], and remote control capability [7-9] are implemented to enhance usability and convenience.

Key aspects of the design include the selection of suitable microcontroller hardware [10-12] and development of intuitive firmware [13-16]. Practical implementation and experimental results demonstrate improvements in user experience and operational efficiency compared to conventional soulutions.

The goal of the development is to develop a device suitable for converting an analog power supply into a digital one. The goal is that the factory power supply should undergo as few modifications as possible. The subject is now an OMSZÖV OE-712 three-channel DC stabilized analog power supply. The device presented in the thesis can of course be used for any type of instrument. The solution is facilitated by the fact that the original documentation of the instrument is available, which describes its operation in detail, and also includes the circuit diagram and the PCB design.

II. DESCRIPTION OF THE TARGET INSTRUMENT

The OMSZÖV OE-712 instrument can be set to the desired value with the four (P1, P2, P3, P4) potentiometers on the front panel (see on Fig.1.). Replacing them with two two-channel digital potentiometers, the value of which will be set by the microcontroller. This solution involves the fewest changes within the instrument, because it is enough to replace only these limited number of parts.

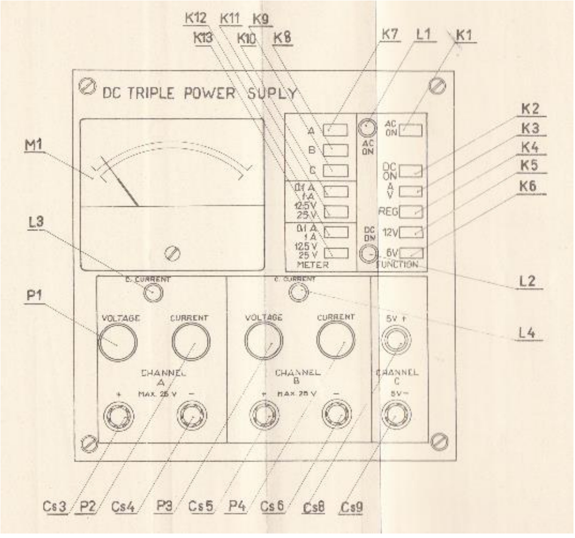

Figure 1: Drawing of the front panel of the laboratory power supply unit

In order to still be able to set the outputs manually, four rotary encoders are used. The digital potentiometers can be set based on their status. The principle of operation of the power supply unit (see on Fig. 2.) is that the filtered unstabilized direct voltage generated from the alternating voltage is regulated to the value of the set stable voltage by the pass-through transistor. The pass transistor is driven by operational amplifiers. The simplified diagram of the power supply is shown in Fig. 2. The mains voltage is connected to the mains transformer via a low-pass LC filter. The task of the input low-pass filter is to prevent high-frequency noise from the network to reach the output of the power supply. The mains transformer supplies the alternating voltage required for the device, after it is rectified, it also provides the voltage required for the output voltage and for powering the reference circuit and operational amplifiers.

Graetz rectifiers and capacitors produce a filtered, unstabilized direct voltage from the alternating voltages, from which the pass-through transistor produces a constant voltage and current with closed-loop control. The reference voltage required for comparison and generation of error signals is produced by a thermally compensated, high-stability IC. The heat-compensated Zener diode and operational amplifier included in the two integrated circuit cases provide the reference voltage.

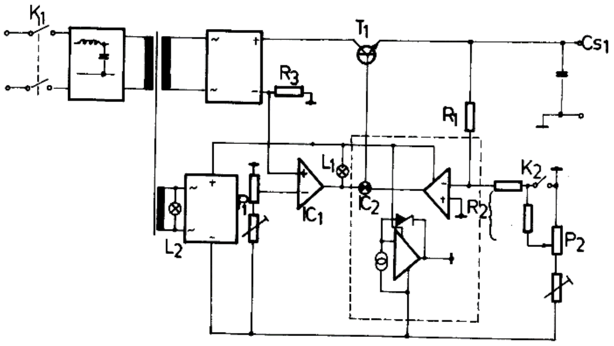

Figure 2: Block diagram of one channel of the laboratory power supply unit

III. REALIZATION

The goal is to make a PCB Shield (a circuit that can be easily attached to an open source board built around a microcontroller), which will contain the additional electronics and the connectors with which it is connected to the inside of the lab power supply and to the peripherals (LCD display, encoders, current measuring sensor). Thus ensuring the modular structure of the microcontroller base board, the additional Shield as a target PCB and the analog lab power supply system.

A. *Digital potentiometer*

The design started with the selection of digital potentiometers. From the technical documentation and circuit diagram of the laboratory power supply unit, it can be seen that the values of the voltage regulating potentiometers P7 and P15 are 4,7 KΩ, and the values of the current limit setting potentiometers P1 and P9 are 1 KΩ. The maximum output voltage is 25 V and the maximum output current is 1 A.

In addition to the above, the requirements imposed on the IC are the following. If the aim is to regulate the voltage with an accuracy of 0.1 V, it is necessary to be able to set the potentiometer in 25/0.1=250 steps, this requires the installation of an 8-bit resolution device (8 bits = 256 states). It is advisable to approximate the original 4,7KΩ values with the resistance values of the potentiometers.

The digital potentiometer should have a serial communication interface that is supported by the used microcontroller in terms of hardware and firmware, and should have THT housing to facilitate testability and development. Based on the conditions, the choice of components fell on the MCP4261 502E/P IC.

B. *Current measurement*

An ACS712 Hall cell current meter was installed for the current measurement. It operates on a 5V power supply, which is provided by a microcontroller panel with a 5V voltage regulator. As an output, it gives a voltage value, which is half of the supply voltage in the case of a current of 0 Ampere, and in the case of a change in the current strength of 1 Ampere, a voltage change of 0.185 V can be measured at the output. The output of the current meter can be read using the internal 12 bit analog/digital converter of the microcontroller. I_{max} = 5 Amps, which is sufficient, even with a modified programmable ADC gain amplifier

The output of the power supply is fed back to one of the analog inputs of the microcontroller via a suitably sized voltage divider. The maximum output voltage of the lab power supply is 25 V, this must be distributed in such a way that the part that falls into the input of the microcontroller (in the case of Arduino Due, on board pins A10 and A11) is in no way greater than 3.3 V, since this is the connectable maximum voltage. In addition, the goal was to use high-value resistors so that the output would not be significantly loaded.

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25V/3.3V = 7.57 is the ratio of the voltage divider resistors, a high value available resistor is 150 KΩ, and 150 KΩ /7.57 = 19,82 KΩ ≈ 20 KΩ, which will be the other member of the resistor divider . In order for the measurement to be accurate, the exact values of the resistances must be known. Four-wire resistance measurements with a multimeter show the following: R9 = 19,6 KΩ, R10 = 143,6 KΩ, R11 = 18,8 KΩ, R12 = 136,2 KΩ.

The voltage of points A10 and A11 calculated from the above must be below 3.3 V at a voltage of 25 V, if this is not met, the values of the resistors must be modified. These results play an important role in writing the program and calibrating the system.

C. *LCD display*

The voltage and current values are displayed on a 2x16 character LCD display as shown in the figure below (Fig. 3.). Its management is simple, several program libraries are available for it. The LCD module and the microcontroller communicate via an I^2C communication bus. We connect the dedicated I^2C pins (20 SDA and 21 SCL) to the corresponding pins of the display. The 5V supply voltage required for operation is provided by the microcontroller development panel.

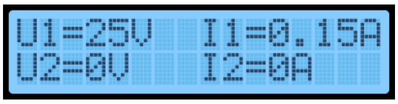
U1=25V I1=0.15A
U2=0V I2=0A

Figure 3: Extended user interface

D. *System description*

Fig. 4. shows the shield's final wiring diagram. For the sake of clarity, the externally placed connectors (pin rows) have a similar layout and have the same name as the socket to which they will be connected.

The most critical part of the PCB design is that the rows of pins with which the Shield is connected to the Arduino board are in exactly the same position as the socket where they fit. To ensure this, the CAD files on the official Arduino website provide guidance when designing the board.

The rows of pins with which it is connected to the Arduino will face downwards (bottom side), and those from which the Shield is connected to the inside of the power supply will face upward (top side).

It is also possible to supply power to the Shield through the connector labeled POWER. This connects directly to the VIN and GND pins of the Arduino. Wider (0.5 mm) conductor strips were created for the power cables. The diagram below (Fig. 5) shows the PCB plan, the upper copper foil is shown in red and the lower copper foil is shown in blue.

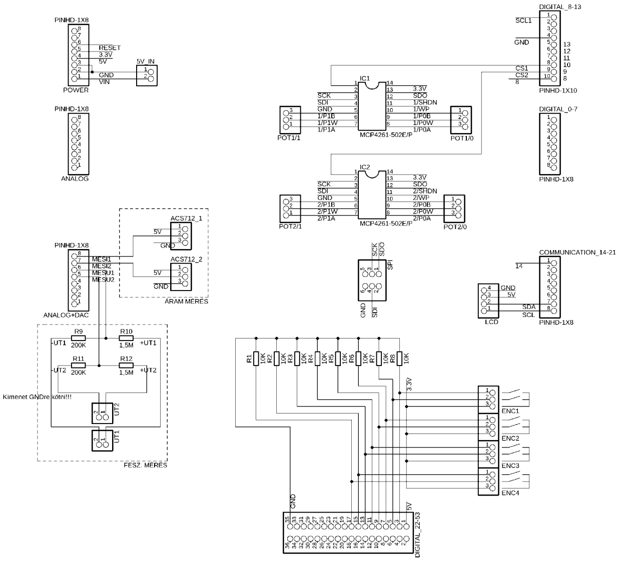

Figure 4: Circuit diagram of the auxiliary circuit

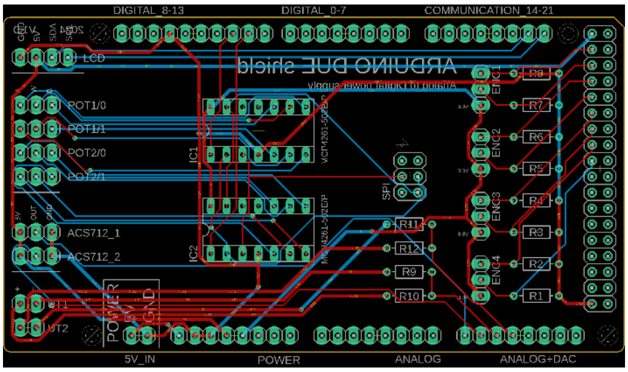

Figure 5: PCB plan of the auxiliary circuit

E. *Shield és a tápegység összekötése*

Instead of the factory potentiometers, the outputs of the digital potentiometers must be connected (POT1/0, POT1/1, POT2/0, POT2/1 connectors on the shield, see on Fig. 6.), which perform the following functions:

- POT1/0: CHA voltage adjustment,
- POT1/1: CHA current adjustment,
- POT2/0: CHB voltage adjustment,
- POT2/1: CHB current adjustment.

One current sensor had been connected in series with the output of channels A and B. They must be connected to the corresponding connector on the Shield (ACS712_1 and ACS712_2). The UT1 and UT2 connections are connected to channels A and B of the power supply in parallel.

The PCB was made in a PCB factory based on the plans, after it arrived it just had to be assembled and attached to the Arduino board, on which it fit perfectly (Fig. 7).

The wires can be distinguished from each other based on their color. A pinheader has been soldered to the end of each wire bundle, making it easy to connect them. Inside the power supply unit, the custom-made wire harness had to be soldered to the factory internal wires.

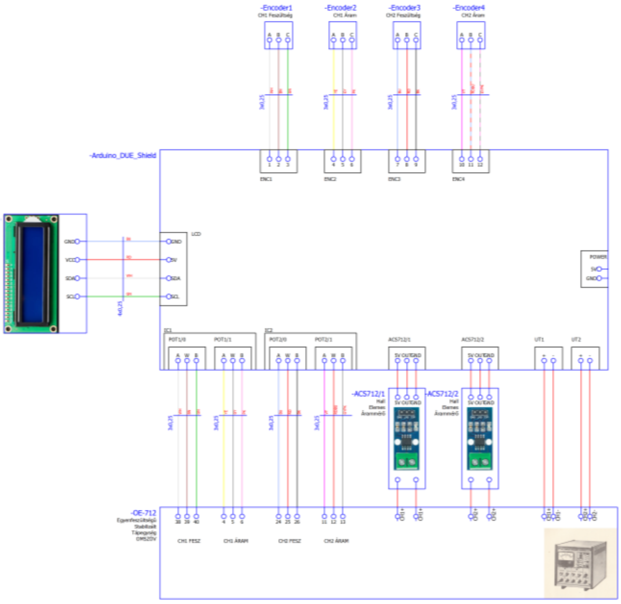

Figure 6: System architecture

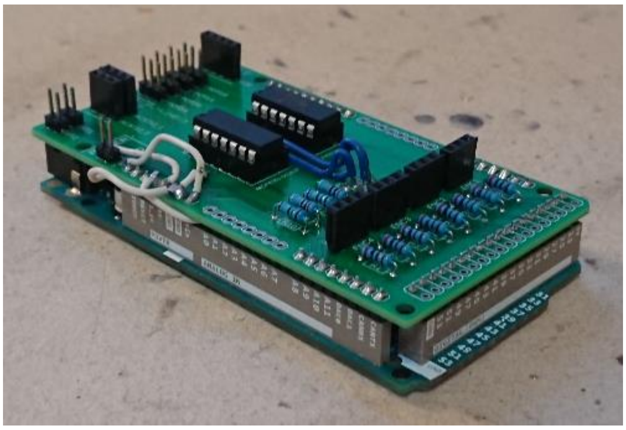

Figure 7: The developed shield

IV. FIRMWARE IMPLEMENTATION

A. *Calibration of the current meter*

The most important parts of the routines uploaded to the Arduino are presented below. The function performs the calibration of the current sensors (offset compensation operation) (Fig. 8). During the calibration, the program performs 50 samples on the two specified analog inputs (channel1 and channel2), arranges them in a row, discards the upper and the lower 10-10 values, and then calculates the average of the remaining 30 values (it is important that before calling it to 0 the output current of the power supply must be adjusted). It subtracts the value of the calculated average from the value 2048 (12-bit samples are taken → 4096/2 = 2048) and uses this value as an offset. The value of the current sensor corresponding to 0 amperes is calculated with the zeroAmpere variable, adding the offset.

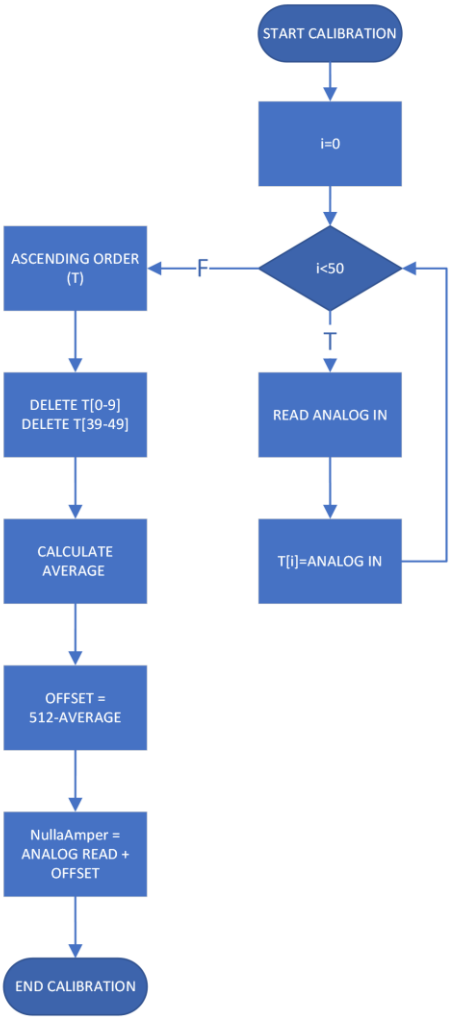

Figure 8: Current sensor calibration

B. *MCP4261 setting functions*

These functions describe the commands that control the MCP4261 digital potentiometers using SPI communication. The desired IC is selected with the CS (Chip Select) pin, and then the desired command to increase or decrease the resistance values is sent using the SPI.transfer function. First, it is necessary to pull the Select input of the IC to be set to logic low, then issue the increment or decrement command.

C. *void loop()*

The setup function runs once after switching on. The outputs and inputs are set here, followed by the main program.

Zero voltage1 and zero voltage2 calculate the zero point of the current sensors. The output value of the current sensors is converted into voltage values by compensating the offset and multiplying by the appropriate scale factor (using a reference voltage of 3.3 V). This voltage is saved in the zerovoltage1 and zerovoltage2 variables.

ActualVoltage1 and actualVoltage2 calculate the current voltage from the current sensors (Fig. 9). For this, the output value of the current sensor is added to the offset-compensated value, and then also multiplied by the scale factor, it is converted into a voltage value.

Current1 and current2 calculate the current value from the current sensors (Fig. 9). The current voltage subtracted from the zero point is divided by the current constant (0.185 A/V) to calculate the current.

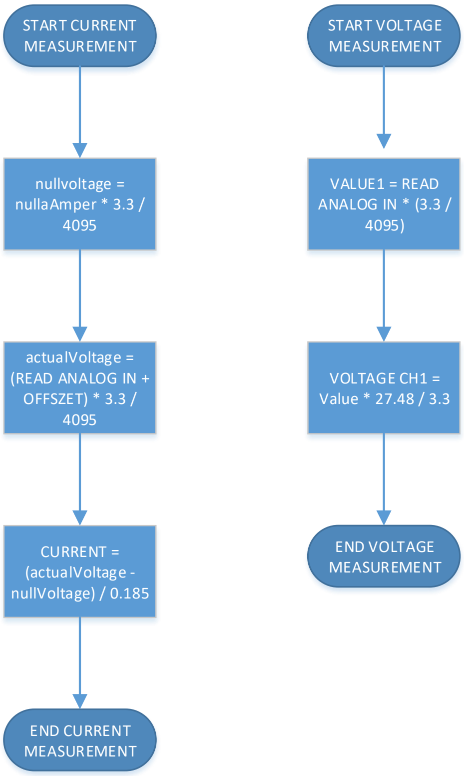

Figure 9: Current and voltage measure

This part is responsible for calculating voltage values. In the code fragment, it reads the values from two analog inputs (A10 and A11) and then represents them as voltage values.

Value1 and value2 normalize the values read from the analog inputs with the factor (3.3/4095.0) to obtain the voltage values from the analog values measured in the range 0-4095. CH_Voltage will be the currently measured voltage.

After this, there is the function that writes out the data, which will not be detailed now. After that, the program monitors the different states of the encoders (outputA and outputB) and then decides to increase or decrease the state of the potentiometers based on these (Fig. 10). To increase or decrease the potentiometers, use the functions increment0, increment1, decrement0, decrement1, which control the MCP4261 IC.

The implemented prototype circuit, shown in Fig. 11., is a microcontroller-driven system developed and successfully deployed during the research. This system precisely controls the operation of the power supply, allowing for fine-tuning of output voltage and current through digital adjustments. The analog components integrated within the circuit provide a stable, low-noise output, while the microcontroller control offers flexibility and programmability, enabling the user to select various setting profiles and automatic voltage regulation options. The device is suitable for laboratory measurement and testing tasks, where precise voltage and current values are critical, and it is particularly valuable for educational purposes, as it effectively demonstrates the operating principles of programmable power supplies and the advantages of analog-to-digital interface applications.

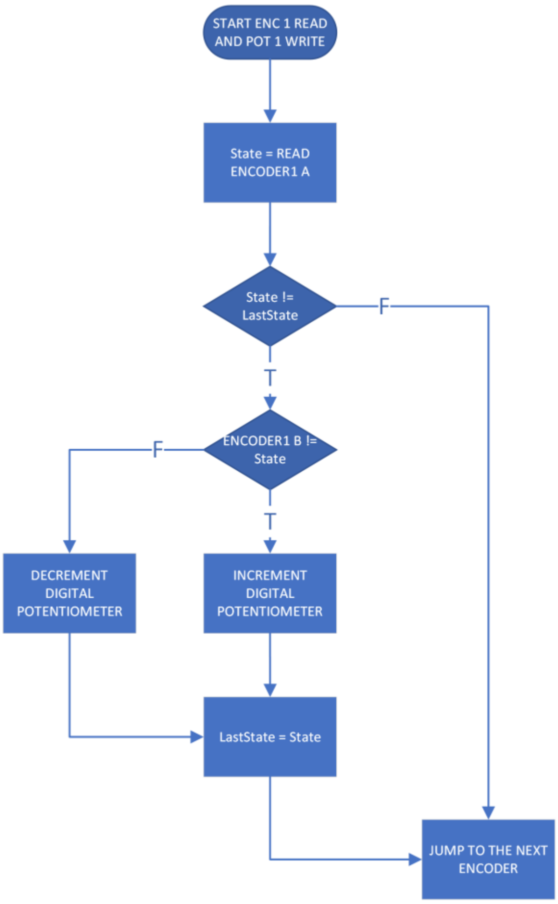

Figure 10: Encoders and digital potentiometers setup function

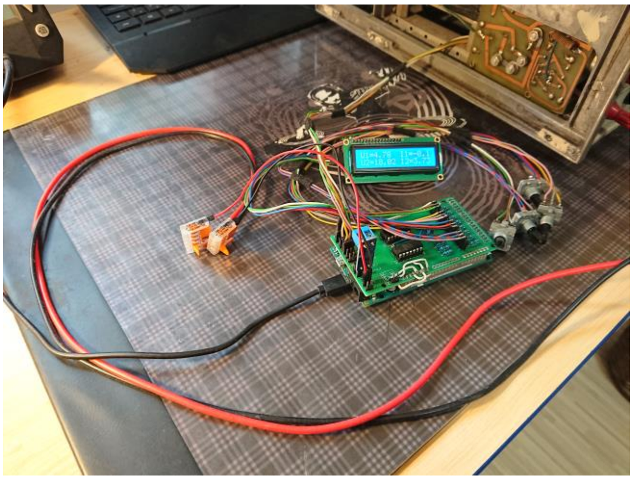

Figure 11: The assembled prototype of the device

CONCLUSION

In conclusion, the integration of microcontroller technology into analog laboratory power supplies significantly enhances their user interfaces and overall functionality. By upgrading the user interface, it is introduced precise control over output electrical parameters, digital displays, programmable presets, and remote control capabilities, thereby transforming traditional analog power supplies into more versatile and user-friendly devices. The practical implementation and experimental results confirm that these enhancements lead to improved user experience and operational efficiency. The microcontroller-based upgrades provide greater flexibility, accuracy, and convenience, making the power supplies more suitable for a variety of applications in research and educational settings.

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