UNIVERSAL RASPBERRY PI BASED DATA LOGGER DEVELOPED FOR THE NCK GEOPHYSICAL OBSERVATORY – IAGA DIVISION 5. OBSERVATORY, INSTRUMENTS, SURVEYS AND ANALYSES

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A single-board computer (SBC) is a complete computer built on a single circuit board, with microprocessor(s), memory, input/output (I/O) and other features required of a functional computer. Although the first appearance of a SBC dates back to as early as 1976, they became widely used in the field of electrical engineering and automation only in the past few years thanks to the emerge of low cost, well-supported models such as the Raspberry Pi (Raspberry Pi Foundation UK, http://www.raspberrypi.org/, http://lemi.nck.ggki.hu, 2015-06-04).

This technological breakthrough opened the door also towards scientific applications especially in the field of continuous data acquisition. Due to their small size and low power consumption, SBCs are ideally suited for running most of the services that arise in a modern-age digital observatory: they can act as a time server, a data server, a web server or a data logger – just to mention a few. Another useful property of SBCs is that instead of a hard drive they boot from a SD memory card which makes it easy to create backup systems only by mirroring the content of the SD card. In other words, the same hardware is capable of booting two different systems – tailored to possibly two completely different objectives – only by switching SD cards. For these reasons, we made the strategic decision to gradually replace all of our conventional PCs with SBCs.

In a conventional setup, the measured analogue signal is amplified and then forwarded into an analogue-to-digital (A/D) converter which is connected (in our case mostly externally) to an ordinary PC which runs some software for data collection. This approach has many limitations. E.g. due to economic reasons, in some cases the same PC runs the data logging software of two different measurements, which increases the risk of obtaining an unnecessary gap in one of the recordings while we carry out maintenance on the other. Another drawback is that the data logging PCs oftentimes carry out (too many) additional tasks such as data conversion, processing or visualization which reduces the transparency of the system and makes it poorly scalable. With SBCs in mind, however, the number of PCs we can insert into the system is practically unlimited so we can dedicate a separate SBC to each objective. This led us to the idea of developing a custom, general-purpose data-logger by equipping an SBC with an A/D converter module and integrating them into a compact case.

Our first prototype uses a Raspberry Pi (RPi) as an SBC (http://geodata.ggki.hu/rpilogger, 2015-06-04). The RPi has USB and Ethernet interfaces and other low-level interfaces for communication with analog-to-digital converters (ADCs) like SPI, I2C, UART, etc. Its power consumption (3-5 W in total) is very adventurous compared to e.g. a notebook or a desktop computer (40-400 W approximately). It can be equipped with a full-fledged Linux operating system which makes the whole construction very reliable and configurable for individual tasks. The current design uses the ADS1115 chip from Analog Devices (http://www.ti.com/product/ads1115, 2015-06-04). This is a pseudo-differential ADC with 16 bits resolution (65536) and a programmable gain in 5 steps (as if the reference voltage could be selected by software to be one of 5 possibilities). It also contains a built-in multiplexer (4 channels single ended or 2 differential) and it is capable to sample a channel (either single ended or differential) up to 860 Hz. It has a high impedance pseudo differential input measuring in reference to a floating potential which is useful to avoid ground loops. The extensibility of the RPi makes is possible to insert more ADC instances, further increasing the number of channels that can be sampled. The resolution and maximal sampling rate also can be increased for instance by replacing the ADS1115 with a more expensive chip. In our current construction the

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input range is configured to +/- 10 V. Originally, the RPi is powered by 5 V via a micro USB interface. In the casing of our prototype we replaced this with a more robust USB-B connector and we also added POE (power over Ethernet support), which makes it possible to operate the device also far from a power supply.

Currently, 3 different means are offered for user interaction:

1) The data-logger is equipped with a 4x20 character LED display to show basic information (such as current date, IP address and disk usage) and a rotary switch for sample rate selection and basic user input.
2) The data-logger can be configured to act also as a web server, so we developed a web-based graphical configuration interface similar to what is shipped with most of the routers.
3) A further option is logging in into the device via secure shell (SSH). It is intended for power users with expertise in Linux system administration. This last option however gives total control over the device to the user due to the fact that we use only open source software.

The core of our data logging software is written in ANSI C. By default, the program starts automatically as a standard Linux system daemon which ensures continuous operation. The program outputs files which are already in the widely used and supperted netCDF binary format. The frequency of file output operations is quite high in order to minimize the possibility of a data loss due to unexpected events such as a power failure. These files are then concatenated into regular, 1 hour long pieces by a separate background process, so normally the end-user does not have to cope with small files stored in a chaotic structure. Besides that the data logging software also sends its data in real-time via websocket communication which is consumed by other applications such as our online data visualization tool.

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