Affordable Raspberry Pi based oscilloscope

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Abstract—**This paper proposes affordable solution for oscilloscope readout integration in wider data (measurement) acquisition. While it is possible to buy the ready-made instrument on the market, they are often inaccessible due to their high cost (compared to their performance), or closed software backend.**

Manufacturers often ask for additional expenses in order to control the instrumentation sold by them, or the bundled software is too restrictive. This leads to many problems. In order to minimize the problems, simplified approach needs to be implemented, as well as low cost of physical circuitry.

The oscilloscope presented in the paper, has the same readout characteristics as the various market available products often two times it's price, while having open software backend and frontend.

This could lead to easier widespread adoption, and better understanding of the devices available for end customer.

(Abstract)

Keywords- Oscilloscope; Raspberry Pi; Industry 4.0; Virtual instrumentation; ADC; IoT; Data Acquisition; LabVIEW; PC; Web-based

I. Introduction

Oscilloscopes are necessary measurement equipment in electrical engineering education, biomedical engineering and various industrial application. The main purpose of digital oscilloscopes is analyzing analog and digital circuits. Advantage of today's digital oscilloscope is high input impedance. This makes measurements highly accurate [1]. Another advantage is high sampling rate, that implies highly precise measurements event on pulse signals. Digital oscilloscopes also have ability of connecting with PCs. This makes storing data and future analysis. Those features make price higher and not affordable for student laboratories, home and mass industry usage.

Above explained oscilloscopes are not used commonly in maximal possibilities and therefore low-cost simpler alternatives find their application.

Modern acquisition systems are oriented to virtual instrumentation. Virtual instrumentation implies usage of PC as processing and visualization unit and specialized hardware for acquisition. Virtual instrumentation is well known for its modularization and low-cost.

With Industry 4.0 revolution, the need for remote monitoring emerged. In industry application, there is need for constant signal monitoring. Therefore, desirable advantage of oscilloscope is possibility for remote monitoring.

The main purpose of this paper is to present an approach of implementation of low-cost Internet-of-Things digital oscilloscope.

II. Literature Review

In referent paper [2] simple conditioning hardware system is presented. Purpose of this system is ensuring that input signal of higher amplitude and DC value can be processed on Analog-to-Digital Converter. By development of integrated circuits, implementation can be improved by usage of better operational amplifier in field of frequency response.

Paper [1] exposes PC-based system for visualization of acquired signal. Since computation is not complex PC can be changed by single board computer such as Raspberry Pi.

Usage of Raspberry Pi single board computer as processing unit is presented in [3]. Raspberry Pi is better for this purpose then simple microcontroller because of its various capability for remote connecting. Raspberry Pi also allows the user to have visualization locally and remotely. Also, since the Pi is computer, it allows developing of both backend and frontend application for data visualization and functionalities such as signal scaling in terms of amplitude and time. When it comes to automatic measurements, Raspberry Pi has more computing power, so it can do even complex mathematics in real time.

In [4] and [5] different implementations of Web-based virtual oscilloscope are presented. Today's technology allows real-time representation of acquired signal rather than real-time video capturing. In [6] usage of LabVIEW tools for virtual instrumentation is exposed. Since LabVIEW is not open-source program, for our aim would be better if development of specialized backend and frontend application is possible.

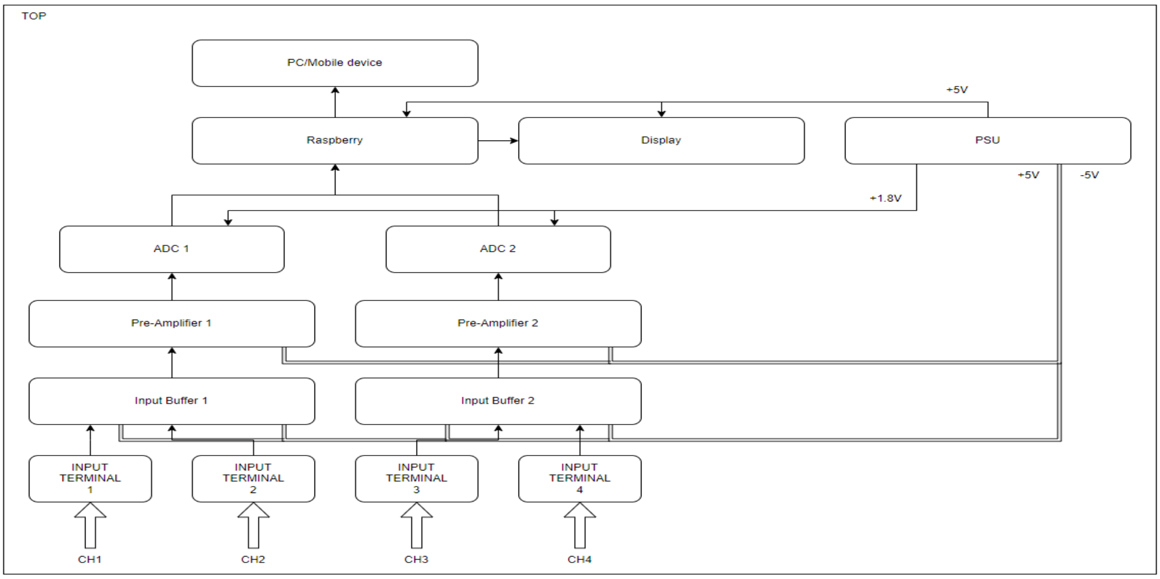

Fig 1: Block diagram of Internet-of-Things digital oscilloscope

The main idea of this paper is to expose implementation of low-cost, accurate and precise four channel oscilloscope. Developed oscilloscope should have ability of visualization locally and remotely. Visualization tools, such as amplitude and time scaling and measurements, should be initialized from local and remote.

III. HARDWARE ARCHITECTURE

In Fig. 1 block diagram of entire system is presented. Observed signal can be acquired by any of four input channels. Input buffers are circuits that has purpose of reducing the power

of input signal, so it cannot damage rest of oscilloscope design. The role of pre-amplifier is reducing amplitude of input signal in order to proper work of analog-to-digital converters. Authors recommend usage of ADC3224 analog-to-digital converter, due to its relatively low cost and high performance. It is integrated circuit with 2 converters, each with 2 inputs. PSU refers to power-supply unit that should ensure a stable power supply to entire circuit. Captured signal should be presented locally on display module and remotely in PC or mobile phone application.

Block diagram of power supply circuit is presented in Fig. 2. It consists of transformer that has a role in reducing the amplitude of grid supply, fuse, switch and stabilization unit, for example LT7805 and LT7905. The purpose of stabilization unit is getting of ideal DC voltage of intensity that is convenient for supply of Raspberry Pi and operational amplifiers.

Input buffer circuit presented in Fig. 3 consists of DC Coupling, Voltage divider and protection, frequency compensation unit and input buffer. DC Coupling buffer is

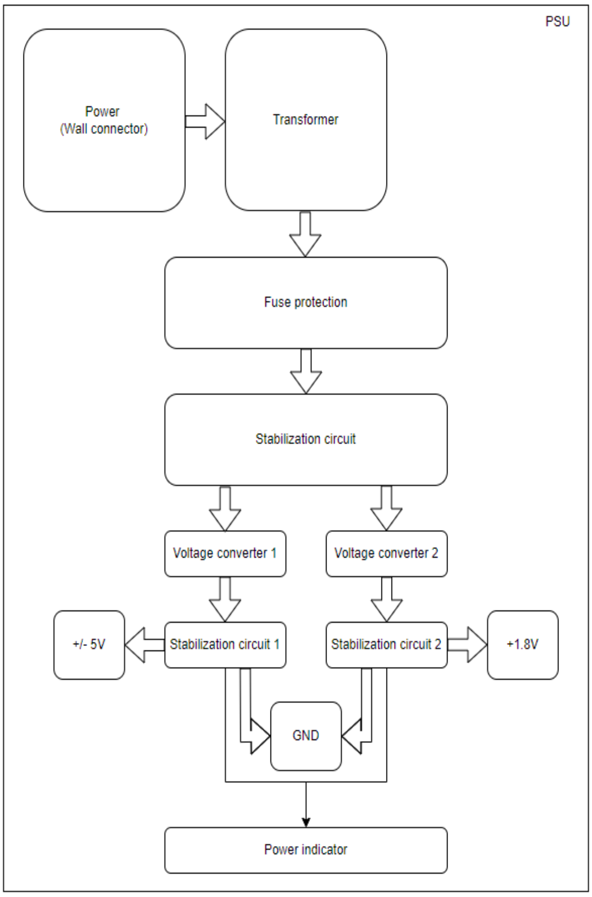

Fig. 2: Power supply unit

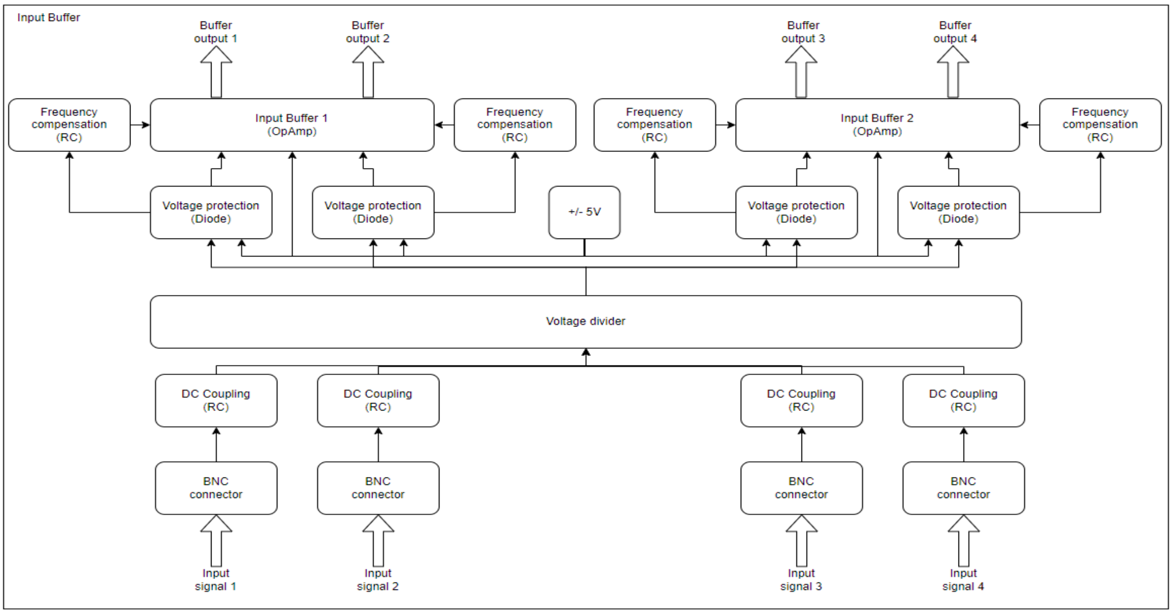

Fig. 3: Block diagram of input buffer circuit

standard RC circuit which should remove DC component from signal if it has DC component, if it is necessary to do so before signal acquisition. Voltage divider should reduce amplitude of input signal if it is higher than power supply. Voltage divider can be controlled form software by switching on and off FET for resistor choosing. Frequency compensation circuit should reduce RC (filter) influence of voltage divider. Input buffers are operational amplifiers that should reduce power of signal with respect of its voltage amplitude. Suggested operational amplifiers should be rail-to-rail input-output, for example OPA2320. Same operational amplifier can be used in pre-amplifier, too.

Signal from output of input buffer is connected to amplification regulation circuit shown on figure 4. Amplification regulation circuit is operational amplifier in amplification connection. It's purpose is reducing amplitude of inout signal to range that can be processed on Analog-to-digital converter (ADC). For proposed ADC maximal input signal is 1.8V. Possible ranges are calculated from Raspberry Pi unit and can be set up by amplification switches (FET transistors).

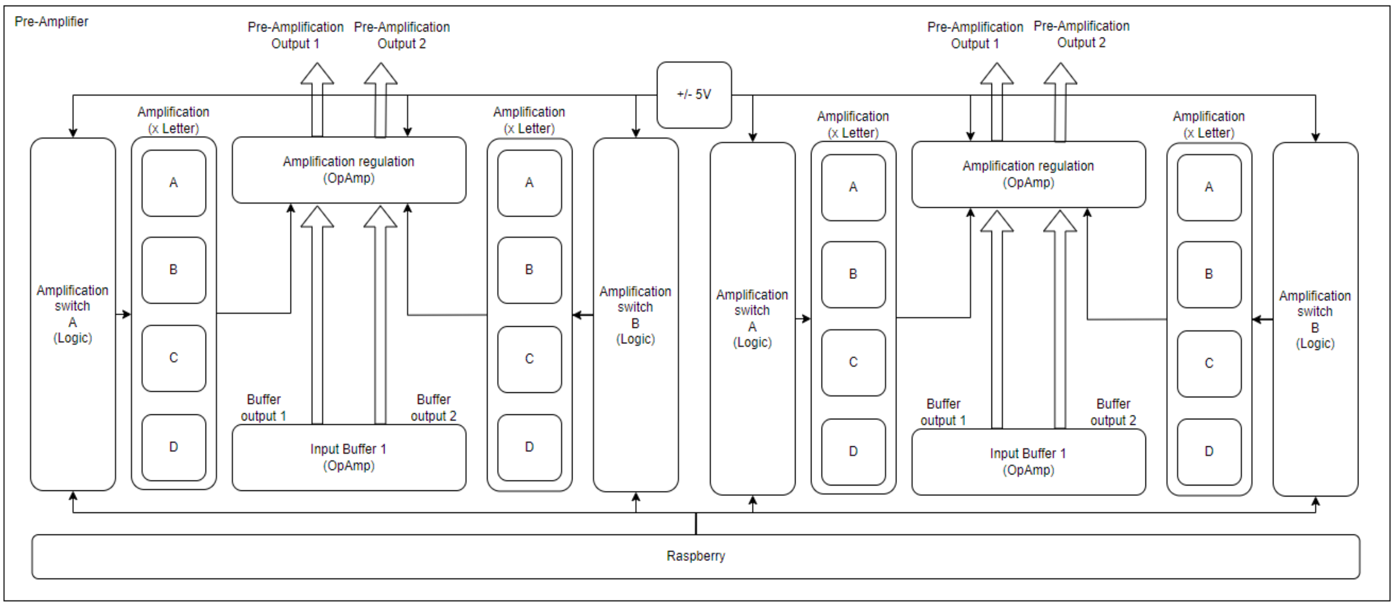

Fig. 4: Block diagram of pre-amplifier

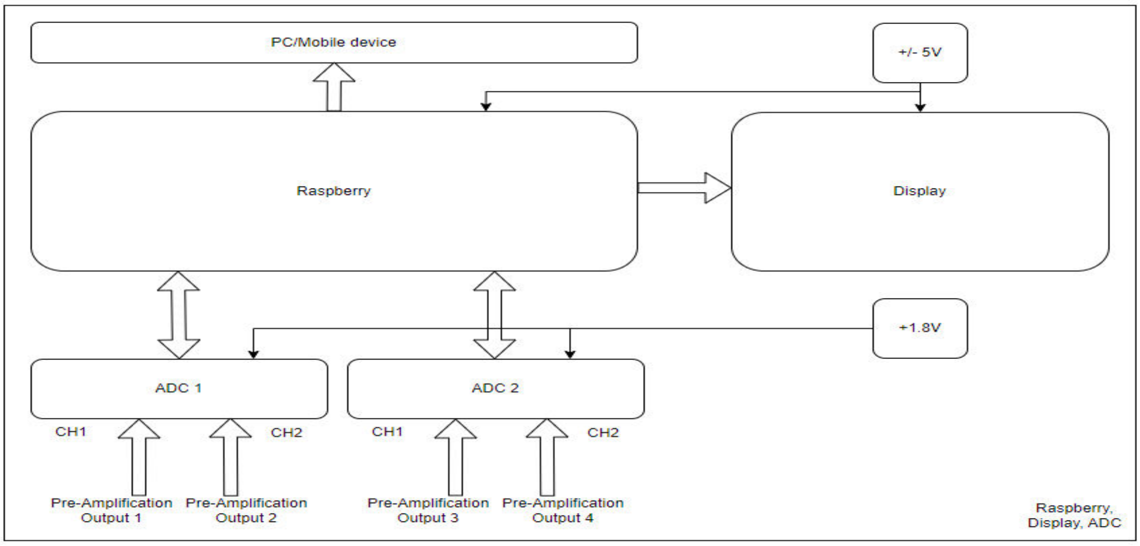

Fig. 5: Block diagram of ADC, Raspberry Pi and Displaying units

Signal from output of amplification regulation operational amplifiers is distributed to ADC. ADC makes computer-readable data from continual real-world data. Raspberry Pi computer reads data from operational amplifiers through SPI protocol. When data arrives, time stamp of data arriving is associated to signal value. Graphical user interface created in python programming language is application that presents data in local. Possibilities of scaling signal by its amplitude and period is possible. Computation of fine measurements are implemented. Possible measurements are average value, minimal and maximal value of, period and frequency of presented signal, but also, by applying simple data manipulation on array of readouts, it is possible to show Peak-to-Peak, root mean square and other similar values. On Raspberry Pi are implemented HTML Web page for remote access to data. Web page is accessible for remote user through Wi-Fi and TCP protocol. Possibilities of scaling and measuring are allowed from remote, too. Remote user can access to Web page from PC and mobile phone.

Proposed implementation achieves portability which can be useful in industrial, as well as, scholar applications.

IV. Conclusion

As the paper shows, with a little know how in area of circuit design, and some knowledge of the new IoT technologies and protocols, it is possible to make useful instrumentation cost affordable.

First it is very important to take notes of the industry standard designs, and implement them properly in the signal acquisition and conditioning circuits. All the instrument operation usually done trough interaction with buttons, can be done virtually as well, if the necessary adjustments are made. Example of those would be usage of switching circuitry, activated trough simple handling of GPIO pins of Raspberry Pi.

It should be noted, as well, that proper signal throughput is assured by using reliable power supply, and amplifiers that will decrease possibility of signal interference and introduction of the noise that impacts the data acquisition negatively.

Being mindful of previous recommendations data acquisition afterward becomes the matter of choosing adequate A/D converter, and the one proposed in the paper is chosen for its good cast to performance ratio. Communication method between Raspberry Pi and ADC is dictated by the communication interface implemented on the chip of A/D converter, and in the case of this paper it is SPI communication, which is easy to understand, and well documented.

Usage of Raspberry Pi enables the whole system to operate on a higher level compared to the solution with MCU that would be a bit cheaper, but far more limited. Having entire computer as the heart of the whole system enables it to have multiple proper communication paths with other devices, either through the wireless or wired communication.

The end product would be able to display data properly on the Web page, and given the flexibility of the whole system, accessed and controlled remotely. All of this could lead to widespread adoption, especially in the usage case of student teaching which would be main target userbase for the whole system.

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