THE FEASIBILITY OF BITSCOPE RASPBERRY PI FOR MONITORING VOLTAGE AND CAPTURING DATA

FAISAL ABDULKAREM HASAN BA-BTAIN

A project report submitted in partial
fulfillment of the requirement for the award of the
Degree of Master of Electrical Engineering with Honors

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

FEBRUARY 2022

For my beloved mother and father, Thank you for the support and sacrifices.

Thank you for your encouragement for this research as well as for futureundertakings.

For my friends, thank you for the support and suggestion

ACKNOWLEDGEMENT

Firstly, I wish to express deep gratitude to all people and firms that contributed to the work presented in this project. Particularly, I thank my advisor, Ir. Dr. Rahisham bin Abd Rahman for his numerous discussions and unwavering support and guidance, and enlightening technical observations and suggestions.

Secondly, I would like to thank my family. I would not be who I am today without the love, support, encouragement, and trust of my parents. Despite being continents apart throughout my master's degree, I have always felt that they are near me all the time because of their love and support. I am also thankful to my grandparents, uncles, and aunts in my homeland, where the memories still live with me here.

I would also like to thank all my colleagues, friends, and seniors at the faculty of electrical and electronic engineering for providing moral support and a pleasant atmosphere. Special thanks to my brother Hasan and my best friends Ahmed Helmi, Dr. Ali Salim, and Munirah for making my time unforgettable.

Finally, I would like also to give special thanks to all the staff of University Tun Hussein Onn Malaysia (UTHM), especially the staff of the faculty of Electrical and Electronic Engineering (FKEE) as they provided me with adequate facilities in pursuing my project.

ABSTRACT

A Raspberry Pi seems like a small open-circuit board in today's world, when computers are increasing more effective and advanced, it was created to provide a low-cost computer to every learner. Bitscope is a gadget with a high sampling rate and a high resolution, and the analog signal was converted to digital using a high-speed ADC. An oscilloscope is an electronic test instrument also an oscilloscope shows waveforms on some form of display. The oscilloscope has no storage memory, only shows the analyzed signal in real-time, the users capture the waveform manually, and it must store in a suitable place because of its size and weight. The method used in this project is to propose software that is fully user programmable -based oscilloscopes. To determine the Bitscope functionality a basic ohm's law circuit is constructed to test the voltage output waveform and the output voltage waveform can be obtained on the Bitscope DSO. The results demonstrated proved that the prototype of the proposed measurement tool called (Digital Storage Oscilloscope) DSO which can display cursors performs and reports waveform measurements and adjusts voltage scale the vertical size of the waveform and that is fully user programmable -based oscilloscopes. These two portable devices allow users to be design software architecture, monitor and analyze voltage waveforms and capture data.

ABSTRAK

Raspberry Pi kelihatan seperti papan litar terbuka kecil di dunia hari ini, apabila komputer semakin berkesan dan maju, ia dicipta untuk menyediakan komputer kos rendah kepada setiap pelajar. Bitscope ialah alat dengan kadar pensampelan yang tinggi dan resolusi tinggi, dan isyarat analog telah ditukar kepada digital menggunakan ADC berkelajuan tinggi. Osiloskop ialah instrumen ujian elektronik juga osiloskop menunjukkan bentuk gelombang pada beberapa bentuk paparan. Osiloskop tidak mempunyai memori storan, hanya menunjukkan isyarat yang dianalisis dalam masa nyata, pengguna menangkap bentuk gelombang secara manual, dan ia mesti menyimpan di tempat yang sesuai kerana saiz dan beratnya. Kaedah yang digunakan dalam projek ini adalah untuk mencadangkan perisian yang sepenuhnya menggunakan osiloskop berasaskan boleh atur cara. Untuk menentukan kefungsian Bitscope litar undang-undang asas ohm dibina untuk menguji bentuk gelombang keluaran voltan dan bentuk gelombang voltan keluaran boleh diperolehi pada Bitscope DSO. Keputusan yang ditunjukkan membuktikan bahawa prototaip alat ukuran yang dicadangkan dipanggil (Digital Storage Oscilloscope) DSO yang boleh memaparkan kursor melaksanakan dan melaporkan ukuran bentuk gelombang dan melaraskan skala voltan saiz menegak bentuk gelombang dan itu adalah osiloskop berasaskan boleh atur cara sepenuhnya oleh pengguna.

Kedua-dua peranti mudah alih ini membolehkan pengguna mereka bentuk seni bina perisian, memantau dan menganalisis bentuk gelombang voltan dan menangkap data.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

A	–	Amper
V	–	Voltage
K	–	A unit of potential equal to a thousand
Ω	–	Ohm
DSO	–	Digital Storage oscilloscope
DDR	–	Digital Data Recorder
V/Div	–	Voltage per Division
DAQ	–	Data Acquisition
ADC	–	Analog to Digital Converter
DACs	–	Digital to Analog Converters
WSN	–	Wireless Sensor Network
VNC	–	Virtual Network Computing
SD	–	Secure Digital
Vpp	–	Voltage peak-peak
DC	–	Direct Current

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

An oscilloscope is an electronic test instrument. It graphically indicates changes in the signal voltage, typically as a two-dimensional plot of one or more signals as a function of time. So basically, an oscilloscope shows waveforms on some form of display. Sound or vibration signals - too can be deduced from the oscilloscope; however, this is done by converting them into voltage signals.

Oscilloscopes (also known as scopes) are devices that test and display voltage signals as waveforms, which are visual representations of voltage fluctuation over time. The signals are shown on a graph to demonstrate how they change over time. The voltage measurement is shown by the vertical (Y) axis, while time is represented by the horizontal (X) axis. For accurate measurements of microwave waveforms, modulated signals, and nonlinear processes, several current high-speed oscilloscopes are well suited [1].

A Raspberry Pi seems like a small open-circuit board in today's world, when computers are increasing more effective and advanced. It has been gaining popularity among students since its inception in the computer area. The Raspberry Pi was created to provide a low-cost computer to every learner. It connects to a keyboard, a TV, resulting in a low-cost computer. This low-cost computer can handle various functions, including word processing, gaming, programming, and so on. This single-board computer may be used to complete a variety of projects. For example, using the Raspberry Pi, a credit card-sized device with embedded software, can create hardware for signal measurement that meets the standard electronic size and test specifications. PCs are now being used in an increasing number of studies.

Furthermore, traditional acquisition processes are prohibitively costly. Computers are no longer a luxury but rather a requirement for everyone in today's world. The Raspberry Pi is a credit-card-sized device that aims to provide a computer to everyone on the planet. Raspberry Pi is designed to be a platform for kids to learn programming and for enthusiasts to do various forms of commercial programming [2]. The Raspberry Pi is an ARM processor-based embedded device that can be connected to any HDMI-compatible monitor or television (TV) and used with a standard (USB) keyboard and mouse. It's a little gadget that allows users of all levels and ages to improve their computer capabilities and features. It starts up from a (SD) memory card that is plugged in. It is the cheapest, simplest, and most user-friendly device for writing programmes in Scratch, Python, and Perl, among other programming languages. The Raspberry Pi is constructed using integrated chips. It has its own memory (RAM), processor, and graphics card (GPU). It features 40 GPIO (general-purpose input/output) pins that may be used to execute extra functions on input and output signals [3].

1.2 Problem statement

An oscilloscope is an instrument used to measure voltage waveform for time on the screen. It uses a probe to connect the test point with the oscilloscope. but the main problem in an oscilloscope is that it has no storage memory, only shows the analyzed signal in real-time, the users capture the waveform manually, and it has to store in a suitable place because of its size and weight [4].

1.3 Aim and Objectives

This project aims to design and construct effective hardware and software needed for the functionality of the Raspberry Pi-based oscilloscope. Notably, the objectives that must be accomplished to produce the system (Raspberry Pi-based oscilloscope):

a) To establish a portable data acquisition and measurement device that is fully user programmable -based oscilloscopes.

b) To design software architecture and develop a prototype of the proposed measurement tool.
c) To obtain the output data captured in digital and analog signal forms using various values of inputs.

1.4 Scopes of study

The goal of this design is to create an oscilloscope using the software. The goal is to monitor the signal, which is accomplished by applying signal conditioning to the signal and then feeding it into a high-level sampling rate, high-resolve ADC. The data from it will be sent to the high-speed processor of the Raspberry Pi. The Raspberry Pi reads data from a serial port, then creates a GUI, and then processes it before displaying it on a display device. In this project, an oscilloscope based on Raspberry Pi will be built [5]. The scopes of this research are the following:

a) An extensive review of published research about the study was undertaken. General insights into the Raspberry Pi and the software that has been used.
b) Experimenting with the Bitscope device in oscilloscope applications such as data acquisition.
c) Use Bitscope, which is having a sensible resolution and a very high sampling rate. Bit Scope is using a high-speed Analog-Digital Converter, and the analog signal has been converted to digital. To be sure the digital data should not lose, it will store in the ARM Microcontroller's memory.
d) Construct a simple circuit using a function generator and resistor to calculate the voltage and current values.
e) Capturing the voltage values using the Bitscope and digital multimeter using variant values of voltage on short and long periods.

1.5 Outline of the report

In this thesis, Chapter 1 gives a general introduction to the project, problem statements, objectives, and project scope in this thesis. Subsequently, it details the project's goal in objectives, followed by its problem statement and the project's Scope. Chapter 2 covers the literature review that explained electrical measurement units, electrical supply, Data Acquisition (DAQ), and Raspberry Pi that show this project's relation. Chapter 3 presents the methodology of the project that will explain all methods to complete the project. It includes a flow chart and a detailed explanation. Chapter 4 presents the result and discussion of this project and the date Recorder. Finally, chapter 5 present the conclusion of this project and recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

A survey was carried out to investigate recent research related to the project. Important information was gathered and collected so that the data can be summarized. It gains further perspective and learns the project that it has studied. This section also explores the theory for the project. The theories obtained are based on research that was conducted previously by others. Also, this chapter electrical Measurement units, electrical supply, oscilloscopes such as type analog and digital. Then explain the Data Acquisition (DAQ) and Raspberry Pi3.

2.2 Electrical Measurement Units

The methods, devices, and calculations used to measure electrical values are known as electrical measurements. Physical qualities such as force, pressure, temperature, flow, and a variety of others can be turned into electrical signals using transducers, which can then be monitored and recorded easily [6]. Resistor, Voltage(V), and Ampere [A] are the standard units of electrical measurement used to express voltage, current, and resistance. When the amounts being measured are very big or very small, it is often essential to employ multiples or sub-multiples of these basic electrical measuring units in electrical or electronic circuits and systems [7]. A list of some of the standard electrical measurement units used in electrical calculations and component values can be provided in Table 2.1.

Table 2.1: list of some of the standard electrical measurement units.

Electrical parameter	Measuring unit	Symbol	Description
Voltage	Volt	V	Unit of Electrical Potential V = I × R
Current	Ampere	I	Unit of Electrical Potential I = V / R
Resistance	Ohm	R	Unit of DC Resistance R = V / I
Frequency	Herts	Hz	Unit of Frequency f = 1 / T
Capacitance	Farad	C	Unit of Capacitance C = Q / V

2.3 Electrical Supply

A voltage or current source, often known as an electrical supply, is a device that supplies electrical power to a circuit in the form of a voltage or current source. Alternating and direct power sources are two different kinds of power sources. A sinusoidally varying DC voltage and a sinusoidally varying AC voltage are both sinusoidally varying voltages. Depending on whether their value is influenced by a constant or time-varying voltage or current elsewhere in the circuit, electrical sources, whether current or voltage sources, may be classified as dependent or independent [8].

A supply voltage, such as from a battery or generator, creates a potential difference voltage between the two-terminal circuits, which allows current to flow. Voltage occurs even when there is no current. The most common voltage source for a circuit is the terminal voltage, which is the voltage that occurs at the positive and negative terminals of a battery [9].

A current source is a circuit component that monitors current flow directly without consideration to the voltage generated between its terminals, which is dictated by other circuit components. An perfect constant current source delivers a constant amount of current regardless of the impedance it is driving, and as a result, an independent current supply could potentially provide an infinite amount of energy [10].

2.4 Oscilloscope

Modern electronic signals are becoming increasingly complex, with a larger range of frequency and a signal that tends to be more immediate and unstable. As a result, signal detection has become more complex, and the detection equipment has been subjected to increasingly stringent standards. The digital storage oscilloscope, as a typical time-domain test instrument, has been widely used in circuit design and system debugging to detect sporadic, transient abnormal signals, as well as to analyze and solve circuit faults.[11]

The purpose of an oscilloscope is to be able to display waveforms on a screen. Time is displayed along the X-axis (horizontal axis) and amplitude is displayed along the Y-axis in the standard mode of operation (vertical axis). An oscilloscope can be used to visualize an electronic waveform in this manner. When a stone is placed into a pond, the waveform is similar to the ripples that travel along the surface. It is feasible to study the operation of the circuit and determine why any difficulties may occur by looking at a waveform in this manner.[12].

2.5 Type of Oscilloscope

An oscilloscope displays a graphic of a live signal captured from a test circuit on a screen. The voltage of the signal as it fluctuates over time is the most common depiction. Oscilloscopes are a sort of vital equipment used in electronics laboratories. They come in a variety of shapes and sizes.[13].

2.5.1 Analog Oscilloscope

The signal picked up by a probe is shown and traced on the screen using an analog oscilloscope. Because of the waveform's storage capacity, it can be displayed for longer periods rather than decaying instantly. When it comes to dealing with analog signals and transitory effects, analog oscilloscopes shine. In comparison to digital oscilloscopes, analog oscilloscopes have a greater dynamic range. These don't have aliasing issues, which can lead to inaccurate readings.[14]

Analog oscilloscopes are less expensive than digital oscilloscopes, making them an excellent choice for novices and enthusiasts. Audio and analog video applications benefit greatly from analog oscilloscopes that can also handle low-speed digital signals. there are advantages of Analog Oscilloscope which provides accurate performances for laboratory exercises also is cheaper than digital ones, and for measurement, Analog oscilloscopes do not need (Microprocessor), ADC, or acquisition memory.[15].

2.5.2 Digital Oscilloscope

The digital storage oscilloscope detects abnormal signals by signal capture, aberrant signal detection, storage, and display. As a consequence, the oscilloscope abnormal signal detection capacity is determined by indicators such as signal acquisition speed, accuracy, and real-time performance of abnormal signal identification, length and amount of abnormal signals recorded, location accuracy, and flexible display. Digital oscilloscopes feature powerful Digital Signal Processing algorithms and are thus appropriate for evaluating high-frequency transients. Digital oscilloscopes also have the greatest qualities of real-time signal accuracy and large storage capacity. [16].

2.6 Data acquisition (DAQ)

Data acquisition (DAQ) acquires or collects signal samples to measure physical occurrences and converts the information to a computer programme, according to National Instruments. It is the technique of using a computer to measure an electrical or physical event like voltage, current, temperature, pressure, or sound. PC-based DAQ systems take use of industry-standard PCs' processing power, productivity, display, and communication capabilities to provide a more powerful, versatile, and cost-effective measuring solution than conventional measurement systems.

DAQ hardware serves as the link between a computer and signals. Its principal function is to digitise incoming analogue signals so that they may be interpreted by a computer. Other functionalities for automating measurement systems and processes are provided in many DAQ devices. Digital-to-analog converters (DACs), for

example, generate. analog signals, while digital I/O lines input and output digital signals, and counters/timers count and generate digital pulses.[17].

2.6.1 NI USB 6361: X Series DAQ

Figure 2.1 shows NI X Series multifunction DAQ devices for USB provide a new level of performance with NI-STC3 timing and synchronization technology, NI. Signal Streaming for high performance over USB, a wholly redesigned mechanical enclosure, and multicore-optimized driver and application software.[18]

There are a few specifications of NI-USB 6361 that are listed below:

1. OEM, BNC, and mass termination connectivity options are available
2. 16 analog inputs (8 on BNC variant), 2 MS/s 1-channel, 1 MS/s multichannel, 16-bit resolution, ±10V
3. analog outputs, 2.86 MS/s, 16-bit resolution, ±10V
4. 24 digital I/O lines (8 hardware-timed up to 1MHz)
5. Four 32-bit counter/timers for PWM, encoder, frequency, event counting, and more
6. Advanced timing and triggering with NI-STC3 timing and synchronization technology.

Figure 2.1: Data Acquisition card of NI-USB 6361.

2.7 Raspberry Pi

Raspberry Pi, at first glance, looks like a delicious fruit pie, but the fact is that this name symbolizes the most important innovations of 2012. The smallest and cheapest computer in the world, making the word "raspberry" Pi hesitates according to technical experts in the world's countries. Figure 2.2 shows the Raspberry Pi is an integrated computer and has made one electronic chip containing computer components, the traditional data processor CPU 700MHZ processor, GPU 250MHZ. It can play high-quality video HD,3D gaming with RAM reaching 512MB [19] as digital control outputs that can control electronic and electrical parts such as microcontrollers, all these possibilities on a microchip are what is known (SYSTEM ON SHIP). This system on Raspberry Pi runs on systems LINUX open source. Can use Raspberry Pi as any computer to surf the internet, email and edit files and documents via the LibreOffice package, or even convert any TV into a home entertainment system connected to the internet and can-do electronic control projects.

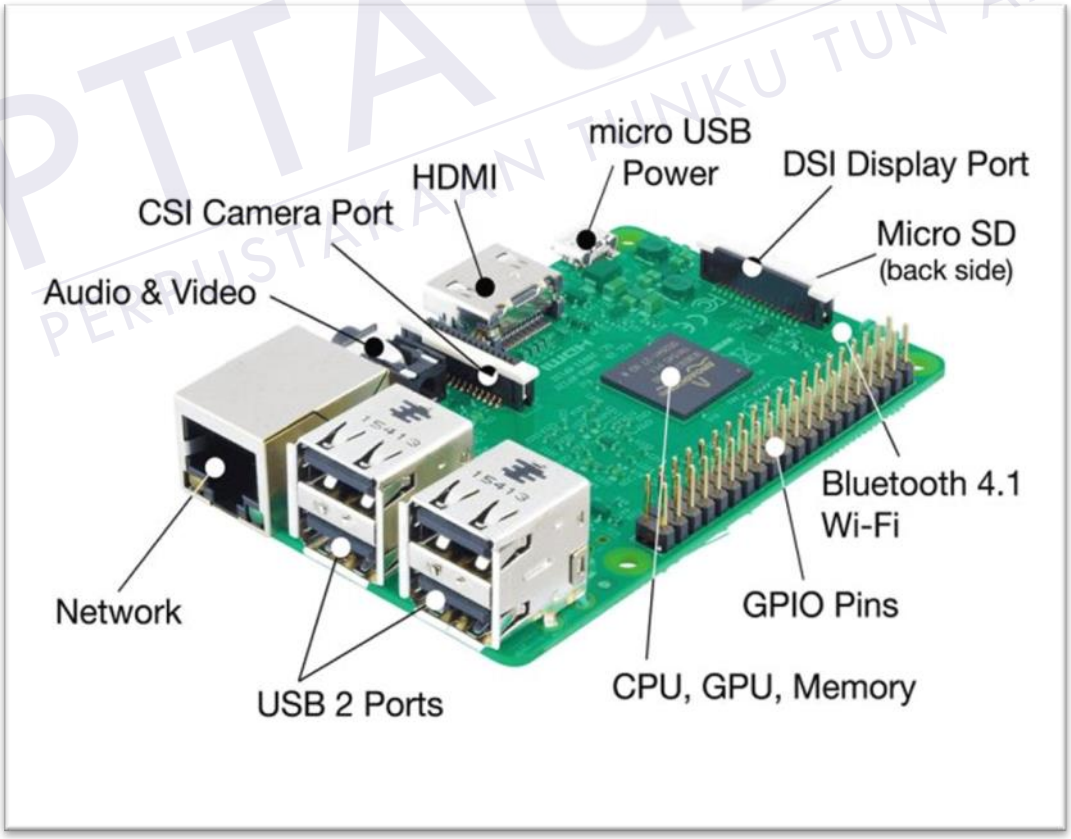

Figure 2.2: Raspberry Pi 3 Module B+.

2.8 Previous research summary

Wi-Fi client-server communication and ZigBee client-server communication are two examples of client-server communication. Client-server communication inside localhost for remote file sharing was also investigated in this research. Using the Raspberry Pi to Investigate IoT Applications In this project, the Raspberry Pi serves as a server, with many laptops serving as clients on the same network, as shown in Figure 2.4. The router establishes a wireless network between the devices. A wireless adapter and router are used to build a remote file-sharing environment. There are two XBee S1 series ZigBee communication devices in use. Windows users may now join the Raspberry Pi network after setting the Raspberry server site. Users must first login before accessing the file since it has been setup on the server side. It is vital to protect the data integrity and privacy of the file by preventing unauthorised access. The Raspberry Pi network login authentication is shown in Figure 2.3 [21]. The Raspberry Pi is perfect for developing tiny applications. It may be used to build intelligent applications by combining diverse components like as LED lights, sensors, speakers, cameras, and wireless networking devices. In this project, for example, two ZigBee modules connect with two distinct devices (laptop and Raspberry Pi). Sensors may be utilised to develop intelligent applications such as intelligent alarm systems, customer walk-in and walk-out demographics, temperature warning systems, and so on after a successful communication implementation. This project also demonstrates how to transfer files between a Raspberry Pi and a Windows computer [22]. The preceding study is summarised in Table 2.4.

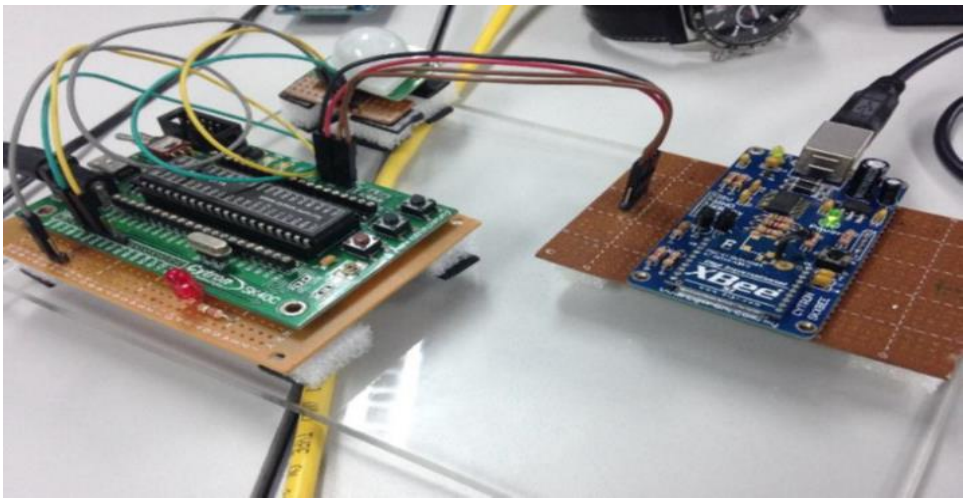

Figure 2.3: Wireless sensor connected.

REFERENCES

[1] L. Wang, C. Chen, L. Ma, and J. Shen, “Development of multi-functional virtual oscilloscope based on the soundcard,” Proc. - 3rd Int. Conf. Meas. Technol. Mechatronics Autom. ICMTMA 2011, vol. 1, pp. 1056–1059, 2011, doi: 10.1109/ICMTMA.2011.264.

[2] "Buy a Raspberry Pi 3 Model B – Raspberry Pi," raspberrypi.org, Accessed: May 11, 2021. [Online]. Available: https://www.raspberrypi.org/.

[3] "Raspberry Pi Technology Intro, specifications, Seminar Abstract, Technical Report."https://www.collegelib.com/t-raspberry-pi-technology-intro specifications - seminar - abstract - technical - report. html (accessed May 11, 2021).

[4] P. Taklaja, J. Niitsoo, and I. Palu, "Wet tests on naturally polluted glass and composite insulators," PQ 2012 8th Int. Conf. - 2012 Electr. Power Qual. Supply Reliab. Conf. Proc., pp. 261–266, 2012, doi: 10.1109/PQ.2012.6256236.

[5] S. Kakade, "Oscilloscope Using Raspberry Pi Processor," pp. 156–158, 2016, doi: 10.17148/IJIREEICE.2016.4930.

[6] IEEE standard for synchrophasor measurements for power systems, IEEE Standard C37.118.1, 2011.

[7] I. Budovsky, “Measurement of phase angle errors of precision current shunts in the frequency range from 40 Hz to 200 kHz,” IEEE Trans. Instrum. Meas., vol. 56, no. 2, pp. 284 – 288, April 2007.

[8] T. H. Ortrneyer et al., “The effects of power system harmonics on power system equipment and loads,” IEEE Trans. Power App. Syst., vol. PAS-104. pp. 2555-2563, Sept. 1985

[9] I. Budovsky, “Standard of electrical power at frequencies up to 200 kHz,” IEEE Trans. Instrum. Meas., vol. 58, no. 4, pp. 1010–1016, Apr. 2009,

[10] HU Yu-feng, YIN Xiang-gen, CHEN De-shu,et al. Digital simulation of protective relaying based on TCSC[J].Automation of Electric Power Systems, 2002.

[11] T. S. Clement, P. D. Hale, D. F. Williams, C. M. Wang, A. Dienstfrey, and D. A. Keenan, “Calibration of sampling oscilloscopes with highspeed photodiodes, ” IEEE Trans. Microw. Theory Tech., Vol. 54, pp. 3173-3181, Aug. 2006

[12] P. D. Hale, C. M. Wang, D. F. Willaims, K. A. Remley, and J. Wepman, “Compensation of random and systematic timing errors in sampling oscilloscopes,” IEEE Trans. Instrum. Meas., Vol. 55, pp. 2146-2154, Dec. 2006

[13] Williams, P. Hale, K. A. Remley, “The sampling oscilloscope as a microwave instrument,” IEEE Microwave Magazine, vol. 8, no. 4, pp. 59-68, Aug. 2007.

[14] C. M. Wang, P. D. Hale, and D. F. Williams, “Uncertainty of time base corrections,” IEEE Trans. Instrum. Meas., vol. 58, no. 10, pp. 3468-3472, Oct. 2009.

[15] C. M. Wang, P. D. Hale, J. A. Jargon, D. F. Williams, and K. A. Remley, “Sequential estimation of time base corrections for an arbitrarily long waveform,” IEEE Trans. Instrum. Meas., vol. 61, no. 10, pp. 2689-2694, Oct. 2012.

[16]] K. A. Remley, D. F. Williams, P. D. Hale, C. M. Wang, J. Jargon, and Y. Park, “Millimeter-Wave Modulated-Signal and Error-Vector Magnitude Measurement with Uncertainty,” IEEE Trans. Microw. Theory Techn., vol. 66, no. 5, pp.1710–1720, May 2015.

[17] "Data Acquisition (DAQ) - N.I." https://www.ni.com/en-my/shop/data-acquisition.html (accessed May 25, 2021).

[18] X. S. U. Manual, "DAQ X Series," Program, no. December 2010.

[19] "Help Videos - Raspberry Pi." https://www.raspberrypi.org/help/videos/ (accessed May 25, 2021).

[20] C. Wai Zhao, J. Jegatheesan, and S. Chee Loon, "Exploring IOT Application Using Raspberry Pi," Int. J. Comput. Networks Appl., vol. 2, no. 1, pp. 27–34, 2015, [Online]. Available: http://www.digi.com.

[21] M. Haghighi and D. Cliff, "Sensomax: An agent-based middleware for decentralized dynamic data-gathering in wireless sensor networks," Proc. 2013

Int. Conf. Collab. Technol. Syst. CTS 2013, pp. 107–114, 2013, doi: 10.1109/CTS.2013.6567214.

[22] M. Cagnetti, F. Leccese, and D. Trinca, "A New Remote and Automated Control System for the Vineyard Hail Protection Based on ZigBee Sensors, Raspberry-Pi Electronic Card and WiMAX," J. Agric. Sci. Technol., vol. 3, no. January 2013, pp. 853–864, 2013, [Online]. Available: http://search.proquest.com/openview/8

[23] M. Maksimović, V. Vujović, B. Perišić, and V. Milošević, "Developing a fuzzy logic-based system for monitoring and early detection of residential fire based on thermistor sensors," Comput. Sci. Inf. Syst., vol. 12, no. 1, pp. 63–89, 2015,

[24] V. Vujović and M. Maksimović, "Raspberry Pi as a Wireless Sensor node: Performances and constraints," 2014 37th Int. Conv. Inf. Commun. Technol. Electron. Microelectron. MIPRO 2014 - Proc., no. May, pp. 1013–1018, 2014,

[25] G. D. Zhou and T. H. Yi, "Recent developments on wireless sensor networks technology for bridge health monitoring," Math. Probl. Eng., vol. 2013, 2013,

[26] M. Maksimović, V. Vujović, N. Davidović, V. Milošević, and B. Perišić, "Raspberry Pi as the Internet of Things hardware : Performances and Constraints," Des. Issues, vol. 3, no. JUNE, p. 8, 2014.

[27] "RS232 Specifications and standard - Lammert Bies." https://www.lammertbies.nl/comm/info/rs-232-specs (accessed May 25, 2021).

[28] R. World, accurate word instrumentation with Python.

[29] R. Alee, "Reading Data from a Digital Multimeter Using a Raspberry Pi," Turku Univ. Appl. Sci. Publ., pp. 1–36, 2013.

[30] "GPIO Raspberry Pi Documentation." https://www.raspberrypi.org/documentation/usage/gpio/ (accessed May 28, 2021).

[31] R. Pi, "Raspberry Pi gets customized OS called Raspbian," PhysOrg, no. July, pp. 1–3, 2016, [Online]. Available: http://phys.org/news/2012-07-raspberry-pi-customized-os-raspbian.html.

[32] "Operating system images – Raspberry Pi." https://www.raspberrypi.org/software/operating-systems/ (accessed May 28, 2021).

[33] “BitScope DSO User Guide.” https://docs.bitscope.com/KLTUKBXN/#cwtc5863qtge (accessed May 28, 2021).

[34] "Installing operating system images - Raspberry Pi Documentation." https://www.raspberrypi.org/documentation/installation/installing-images/ (accessed Jun. 17, 2021).