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Low Cost Raspberry Pi Oscilloscope

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***Abstract*—Oscilloscope is an electronic test instrument which helps in monitoring the constantly varying voltage signal, that is represented in a two dimensional plot as a function of time. Oscilloscope can be called as CRO or DSO. It also display any other form of signal by converting it into voltages. These types of oscilloscopes are costly and they are difficult to carry to different places. Cost of maintenance and repair is very high in these kind of oscilloscope. Hence, in this project portable and cost effective Oscilloscope has been developed with the help of Raspberry Pi boards. Raspberry Pi is a tiny and an affordable computer which gives best Graphical User Interface and Graphical Programming can be done with the help of Matplotlib. Matplotlib is a plotting library for the Python programming language and it is built upon Numpy. MCP3008 (ADC), a 10 bit analog to digital converter, sampling at the rate of 200ksps is also used. This helps in converting the external signals to digital signals. With the help of Raspberry Pi, the captured signals are plotted and can be viewed in the output screen. Wi-Fi module is interfaced with Raspberry Pi and by installing a RDP (remote desktop connection) android application in the mobile phone, output can be viewed on mobile phone using Wi-Fi. With the help of remote desktop connection, portability is achieved.**

***Index Terms*—Raspberry Pi, Oscilloscope, CRO, DSO**

I. Introduction

Oscilloscope, which is also called by different names like oscillography, CRO (Cathode-Ray Oscilloscope) or DSO (Digital Storage Oscilloscope) is an electronic test instrument which helps in monitoring the constantly varying voltage signal, that is represented in a two dimensional plot as a function of time. As mentioned in the previous statement, Oscilloscope are used to monitor the electrical signal that are varying with respect to time such that time and voltage provides a shape which can be continuously graphed against a calibrated scale. Properties like frequency, amplitude, rise time, distortion, time interval and others can be analyzed using the graph obtained. Now a days these properties are calculated and displayed directly in modern digital instruments whereas during previous times these value calculation requires manual measuring of waveforms from the scales displayed in the instrument screen. The fields in which the oscilloscopes are widely used are science, medicine, engineering, automotive and telecommunication. For laboratory work and equipment maintenance, the general purpose oscilloscopes are used. Special purpose oscilloscope are used in analyzing automotive ignition system and in electrocardiogram instrument to display the heartbeat of humans as a waveform. The DSO (Digital Storage Oscilloscope) is used in most of the industrial application and a minimal count of simple analog CROs are used by hobbyists. The usage of DSOs has increased because the electrostatic storage method in analog storage scopes like CROs are replaced with digital memory and it can store data for a long time without degradation and with uniform brightness. In addition to the above advantage, DSOs also allow complex processing of signals with the help of digital signal processing circuits that supports high speed.

II. Literature review

Reference [1] proposed Real Time ECG Acquisition system using Raspberry pi in June 2014. The main purpose is to display the ECG signals in real time manner. By using raspberry pi with MCP3008, ECG signals can be displayed. They used electrodes to receive the signal from heart and converted to digital ones with the help of ADC. Data collected from ADC is sent to raspberry pi and the values are plotted in real time.

Reference [2] proposed Raspberry Pi and Wi-Fi based Home automation System in May 2016. The proposed system provides remote operation of home appliances and physical intrusion security when host not available in home. They used PIR sensor to receive the data and to transmit them using wireless networks. It mainly emphasis that data can be transferred or sent in form wireless through Wi-Fi using raspberry Pi.

Reference [3] proposed The Design and Implementation of Handheld Multipurpose Scope Using Bluetooth IOIO Board in April 2015. The proposed system provides functions of oscilloscope like CRO and Logic Analysers, etc., and the output shall be viewed on an smart Phone or Tablet. The system was able to handle signals upto a range of 1 GHz

by using Bluetooth IOIO board. Bluetooth IOIO board. The proposed system is compact, high speed.

Reference [4] proposed A Virtual Instrument Oscilloscope for signal measurements in May 2015. The proposed system was a virtual instrument providing all the features of a real oscilloscope. Since, this system is a virtual system, front panels can be designed for great GUI experience. Also provides a path for updating the panels in the future.

Reference [5] proposed LabVIEW Based Digital CRO for Electronic Measurement Techniques in February 2013. The main purpose is to develop the CRO by using LabVIEW. In LabVIEW a user interface with set of tools and objects have been developed in this system. Digital CRO in LabVIEW operates like an original CRO. It mainly emphasizes that the signals are displayed with the help of graphical programming.

Reference [6] proposed Implementation of Image processing of Raspberry Pi in May 2015. The main purpose is to analyse the image signal in Real time without having much difficulties. Raspberry pi consists of a Camera slot to interface the CMOS camera. Low and Dark contrast images can be captured and analysed with Raspberry Pi. Matplotlib and numpy are the software that helps to analyse signal in real time. Matplotlib produces quality figures for publication in many interactive environments and variety of hardcopy formats by using the Python 2D plotting library.

III. Existing Methodology

A. Basic Oscilloscope

The four sections in a basic oscilloscope are the display, vertical, horizontal and trigger controls. A CRT or LCD panel is laid with horizontal and vertical reference lines often called as graticule acts as a display. Most of the display sections is equipped with three basic controls like intensity knob, focus knob and a beam finder button in addition to the display screen.

The vertical section contains a Volts per Division (Volts/Div) selector knob for controlling the displayed signal amplitude. This knob is an AC/DC/Ground selector switch and also acts as a primary (vertical) input for the instrument. It is also equipped with a vertical beam position knob.

The horizontal section contains a Seconds per Division (Sec/Div) selector switch which acts as a primary control for the instrument to control the sweep or time base. It acts as a horizontal plotting input for dual X-Y axis signal and a horizontal beam position knob is generally located in this section.

The start of event sweep is controlled by the trigger section and the restart of the trigger after each sweep can be done automatically or can be configured in such a way that is responds to event that occurs internally or externally. The primary controls like source and coupling selector switches are present in this section along with an external (EXT) trigger input and a level adjustment.

In addition to all these four section, oscilloscopes are also provided with probe which can connect inputs to the instruments and has ten times the oscilloscopes internal impedance. As a results of increased impedance, there is a -10X attenuation factor helping in isolating the capacitive load of the probe cable from the measured signal. Certain probes having a switch helps the operator in bypassing the appropriate resistor.

B. Size and Portability

Modern oscilloscopes are mostly portable instruments which are lightweight and compact in size such that it can be easily carried by a person. In addition to portability, there are a number of miniature battery powered instruments used in service field application available in the present market. Laboratory oscilloscopes, mostly the older units contains vacuum tubes which are benchtop devices mounted to dedicated carts. Rack mounted or permanently mounted special purpose oscilloscopes are used as custom housing instrument.

C. Inputs

The input connectors, usually a coaxial connector like BNC or UHF type, are used to feed the signal for measurement. For lower frequencies banana plugs or binding posts are used. In case the input signal source is having its own coaxial connector then the coaxial connector of the instrument can be simpler otherwise a specialized probe like scope probe can be used to supply the oscilloscope. An open wire test lead for connecting to the observed point is not accepted and a probe is necessary. The input impedance of the general purpose oscilloscope used in present days is of 1 M in parallel with a 20pF capacitance and allows the standard oscilloscope probe to be used. Scopes used for high frequency signals having an input of 50 must be connected directly to a 50 signal source or with Z_0 or active probes. More rarely used inputs are ones which are used for triggering the sweep, XY horizontal deflection for mode displays and brightening/darkening traces called Z_0-axis inputs.

The signal to be measured is fed to one of the input connectors, which is usually a coaxial connector such as a BNC or UHF type. Binding posts or banana plugs may be used for lower frequencies. If the signal source has its own coaxial connector, then a simple coaxial cable is used; otherwise, a specialised cable called a ”scope probe”, supplied with the oscilloscope, is used. In general, for routine use, an open wire test lead for connecting to the point being observed is not satisfactory, and a probe is generally necessary. General purpose oscilloscopes usually present has an input impedance of 1 MΩ in parallel with a small but known capacitance such as 20pF. This allows the use of standard oscilloscope probes. Scopes for use with very high frequencies may have 50Ω inputs, which must be either connected directly to a 50Ω signal source or used with Z_0 or active probes.Less-frequently-used inputs include one (or two) for triggering the sweep, horizontal deflection for X-Y mode displays, and trace brightening/darkening, sometimes called z′-axis inputs.

D. Basic Operation

The basic function of an oscilloscope is to display Signal vs Time. This is generally done by applying a sawtooth signal

to the X-axis amplifier as shown in Fig. 1. The electron beam scans the screen during the rising edge of the sawtooth signal. The beam reaches the starting point when the sawtooth signals voltage drops to 0V. To get a stable signal on the CRO, the

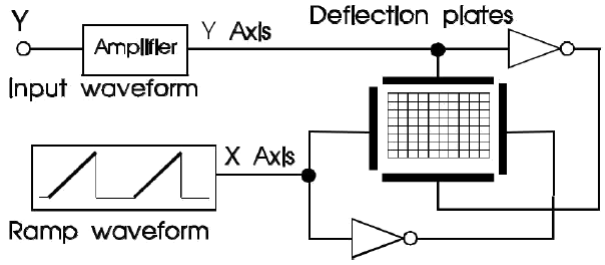

Fig. 1. A Ramp-driven X-Axis Input

sawtooth signal should be in phase with the signal to be observed. This is usually done with help of a triggering circuit. The triggering circuits plots the same waveform repeatedly, by identifying the same points in the input signal. The triggering

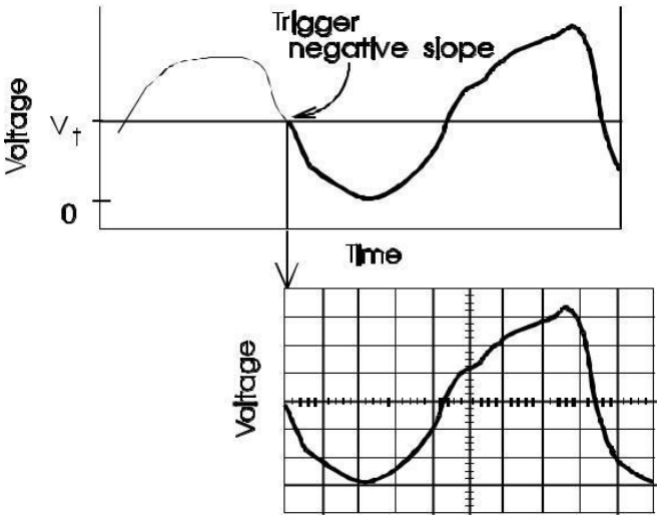

Fig. 2. A Trigerring Example

circuit provides the option of choosing positive or negative slope of the ramp signal to be compared with the input waveform. When the two singals are equal, the circuit emits a pulse. This pulse controls the ramp waveform generator to generate one full cycle of rising/falling edge ramp. once pulse is given to this circuit, it cannot be stopped midway while retriggering the generator circuit. This is illustrated in Fig. 2 for a single cycle and in Fig. 3 for multiple cycles. The triggering circuit is also connected with a timebase circuit. It provides a window for displaying the signal more informative. This is achieved by controlling the time the ramp signal reaches the maximum value. The width of the timebase can be changed to get subtle information about the signal. This is the working principle of an oscilloscope.

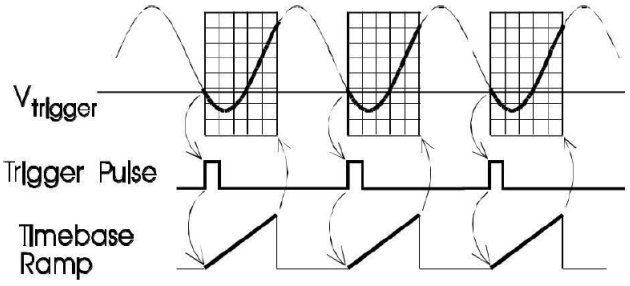

Fig. 3. Several Trigerring Cycles

E. Problems with existing system

Oscilloscopes are used in many applications but it has certain disadvantages.

- Oscilloscopes are costly and requires highly skilled technicians to replace the components
- Difficult to carry to all places
- Cannot be used by zoologists and hobbyists because of its size and weight
- Oscilloscopes can be over sensitive to interference coming from nearby circuits

IV. Proposed Methodology

This project aim is to develop a low cost oscilloscope that can be used to analyze signal and to display it. This project helps zoologists and hobbyists to view signals in easy way. Raspberry Pi oscilloscope is easily portable and available at low cost. For viewing the output signal, external screen or mobile phone can be used.

A. Block Diagram and Description

Fig. 4 shows the block diagram of this proposed system.

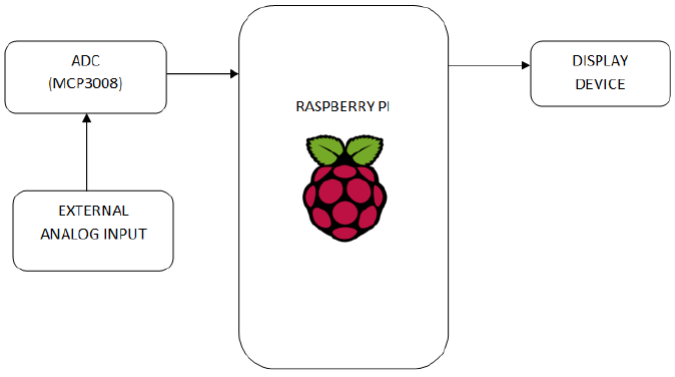

Fig. 4. Block Diagram of proposed System

1) Converting Analog Inputs: All the external world signals are analog signals. To convert the signals into digital signals, an ADC is required. In this project MCP3008, a 10bit ADC from microchip semiconductor with the sampling rate of 200ksps is used. This ADC helps in converting the analog signals into digital one with the sampling rate of 200ksps.

2) Processing the Digital Signals: For processing the digital signal, Raspberry pi - a mini computer is used.Raspberry Pi is a tiny and an affordable computer which gives best Graphical user interface. Graphical Programming can be done with the help of this Raspberry Pi. In this project, Raspberry Pi2 model B is used. Raspberry Pi supports better graphical user interface and graphical programming.

For graphical programming, Matplotlib is used. Matplotlib is a Python plotting library. IPython shell, Python scripts, web application servers and four graphical user interface toolkits are the various places where Matplotlib is used. The received digital signals are fed as an input to Raspberry Pi. By using Matplotlib, graphical programming is done for plotting the digital signal. Entire graphical programming is done with the help of python.

3) Displaying the Signal: For viewing the output, output monitor can be used. The output monitor can be an external display, touch screen or a pc monitor. Mostly the outputs are displayed in the pc monitor but in this project, a Wi-Fi module is interfaced with Raspberry Pi. Ardp, a software package exclusively for connecting with Raspberry Pi is installed in the mobile phone. By using hotspot, both Raspberry Pi and mobile phone is connected and the output can be viewed in the phone itself. In this project, mobile phone is used as a output screen.

4) MCP3008 Connection With Raspberry Pi: Fig. 5 shows how the Raspberry Pi is connected with MCP3008. Serial transmission is enabled in Raspberry Pi. In MCP3008 VDD and VREF given to +5v supply, AGND and DGND are connected to ground. Then Serial data and Serial clock are connected to appropriate pins in Raspberry Pi.

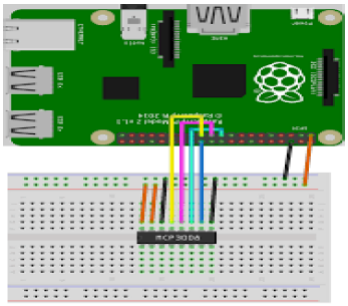

Fig. 5. MCP3008 Connection with Raspberry Pi

5) LEOXSYS Wi-Fi Module: As Raspberry Pi 2 does not have inbuilt Wi-Fi module, external Wi-Fi module has been used for aRDP remote desktop connection. Leoxsys Wi-Fi module is connected in Raspberry Pi and by using mobile phone hotspot connection has been established.

B. Software Description

The Raspberry Pi personal computer was launched in February 2012 created a world storm by selling out 10,000 units immediately. It is a credit card sized inexpensive circuit board which is exposed and a PC running with the free open source Linux OS that is fully programmable. The Pi board can be connected to Internet and also be plugged into a TV. The main intention behind the invention of this board is to kindle the interest of school children into computers and also drove the attention of educators, entrepreneurs and hobbyist worldwide. Raspberry Pi is usually programmed using python.

1) Programming with Python: Python gained its popularity by its simple structures and providing coding ability for all by using simple english keywords. It is a block structured language and the indentation is necessary to create a block. Thus the indentation also helps in make the code to look neat and structured.

Executing Python Files From The Command Line: To use command line environment for executing python programs, first use standard editors like Nano, Vi or Leafpad. After entering the python code in the file, save the file and use the command line to run the file. for example, to run a file named hello.py, type “python hello.py.”

2) Matplotlib: Matplotlib produces quality figures for publication in many interactive environments and variety of hardcopy formats across different platforms by using the Python 2D plotting library. It can be used in Python, IPython shell, Python scripts, web application servers, jupyter notebook and four graphical user interface toolkits. It makes difficult things possible and easy things easier. It also helps in generating histogram, plots, power spectra, error charts, bar charts, scatter plots, etc., by minimal code lines. Refer to the screenshots, thumbnail gallery and example directory for sampling.

The pyplot module provides an interface which is MATLAB like and that combining with IPython can be used for simple plotting. By making use of an object oriented interface or a set of familiar functions, the MATLAB power user can have a full control of font properties, axes properties and line styles.

V. RESULTS AND DISCUSSION

A. Real Time Plot at Instance

Real Time Plot at Instance helps the user to see a predefined set of values as set by the user and the range can be varied easily. It helps to analyze the particular instance or particular range of values as required and helps of further analysis. Fig. 6 shows set of 100 values set by the user and its plot in Real Time Using the Matplotlib tool.

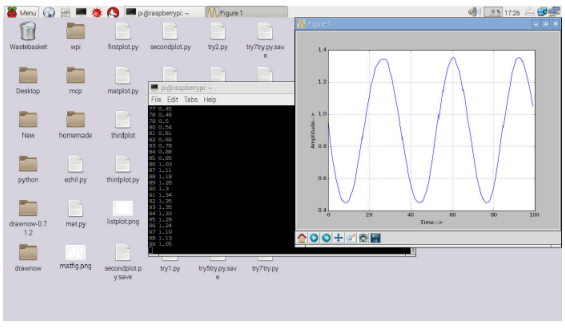

Fig. 6. Real Time Plot at Instance

B. Storing The Data and Plotting

Often we are required to store the real world signals for a prolonged duration, for example : in order to analyze the tone of a bird (or) to measure heart rate for a particular duration, we are in need to store the signals and this proposed project helps for further reference too. This can be done by storing the signals in form of data for required duration. Then the stored data are plotted for analyses purpose. Fig. 7 shows the plotting of signal from a file and a scroll box below helps to scroll between various time duration.

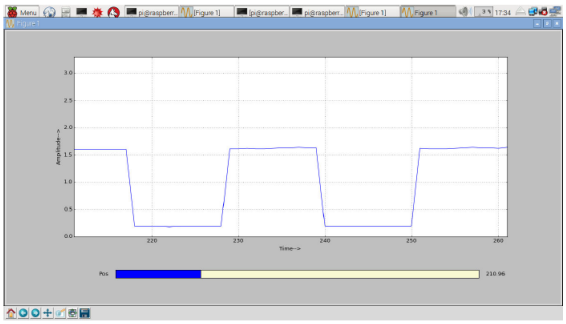

Fig. 7. Storing the Data and Plotting

C. Portability using Mobile Phone

Project objective is to make a low cost and portable oscilloscope. As mobile phones are carried by everyone, it is useful to integrate Raspberry Pi with mobile phone. It further reduces the cost by avoiding external display. Fig. 8 shows the integrated form of Raspberry Pi with mobile phone and its current plot in mobile phone.

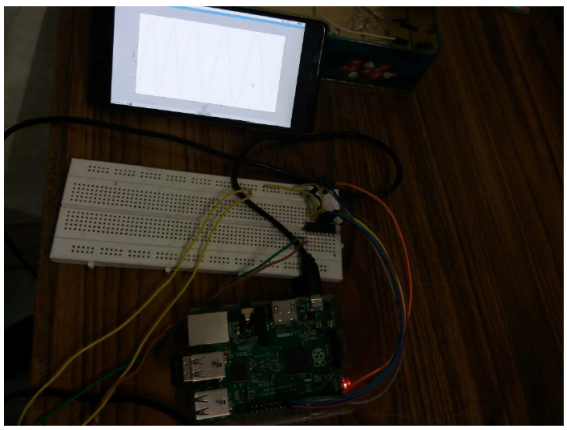

Fig. 8. Portability using Mobile Phone

VI. CONCLUSION AND FUTURE WORK

Raspberry Pi oscilloscope proved to be a low cost and portable one. It is very useful for hobbyists, zoologist, children and people who are interested to view and analyse the signals. As this is incorporated in mobile phones, it increases portability. This reduces the further cost of using external display device. Further, mobile phones provide excellent Graphical User Interface (GUI), which further helps to analyse the waveform easily. The extension of this project has been planned to do with high speed ADC. By using high speed ADC (ADS805), input frequency can be extended up to maximum range of about 10MHz. As ADS805 also has negative input range up to -3.3v, negative voltages can also be measured. Also by using FFT algorithm, manual calculation of frequency can be neglected and the frequency can be displayed in the output screen.

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