

# A Cost Effective Compact Oscilloscope using Laptop and Arduino

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## Abstract

Oscilloscope is an essential test instrument that enables one to see and analyse the graphs of electronic circuits very quickly and conveniently. This tool is more expensive than the other measuring instruments. General oscilloscope has complexity in terms of size, cost and storage memory. This paper reports the drawing and development of oscilloscope which can display the waveforms and determines the voltage levels, frequency, time period, Amplitude etc. Arduino software (IDE) is open software source to construct a cost effective Arduino oscilloscope, with sampling frequency rate of 12KSa/s, capable of performing the same task as some of the cheap oscilloscopes. The major parts in this project are the data converter and the data plotter. An Analog-to-digital converter (ADC) is used to convert the Analog data to a digital signal. Node MCU CP2102 consists of CP2102 microcontroller which has an Analog to digital converter. The waveforms are displayed on the screen by reading the values per time. This oscilloscope requires very few components, portable, less power and generates low internal noise.

## I. INTRODUCTION

In engineer's lab oscilloscope is an essential tool which allows to see how the electrical signal varies over time. Oscilloscopes are basically classified into two types namely analog and digital. Analog oscilloscopes are earliest and easily understandable. Continuously variable voltages are used in analog oscilloscope and it works by applying a direct voltage obtained by measuring an electron beam moving across the screen. In a digital oscilloscope an additional step is required before the signal is shown on the screen. The discrete binary numbers used in digital oscilloscope for representing the sample voltages. The waveform is sampled by digital oscilloscope and uses an analog to digital converter. Oscilloscopes are used by automotive technicians to diagnose electric problems in cars, integrity of their signals are tested by cell phone manufacturers. Special oscilloscopes are used for compliance testing such as USB and CAN protocols.

Different types of oscilloscopes are available in the market. As an example, the price of Falcon digital oscilloscope is around 20,000 rupees. By using Field Programmable Gate Arrays (FPGA), digital oscilloscopes can be made. Such oscilloscopes have microprocessor embedded together with input and output peripherals and programmable gate arrays. This being a standalone meets the practical need of the end user. FPGA being programmed works well without a computer but the major limitation is the cost of the board is very high. So it is proposed to design a cost effective oscilloscope to meet the needs of the lab courses using Arduino and laptop.

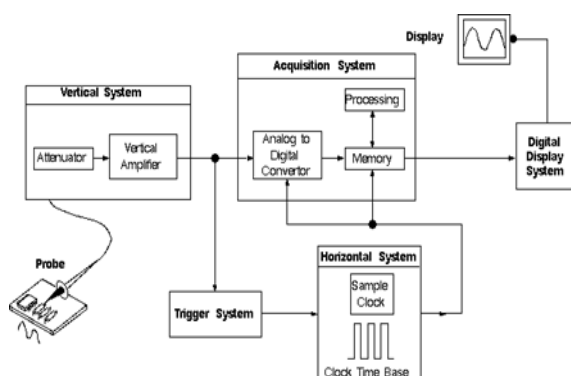
## II. LITERATURE SURVEY

Data acquisition is done by using Atmel microcontroller and a wave is displayed on GLCD screen by reading finite number of samples. Microcontroller stops sampling when the memory is full. These digital oscilloscopes are triggered

externally but the firmware was already integrated with the triggering function [1]. Digital oscilloscopes have more impedance and used for analysis of both analog and digital circuits with high accuracy. A data acquisition system is designed for knowing exactly multichannel analog inputs and converting them into digital format before transferring them into pc. The data is stored in the PC memory and then displayed on the screen. The circuitry is complex and it is currently used for the instructional purpose in laboratory [2]. PC based oscilloscopes can display signals at a time and used to capture signal up to 5 kHz. A PC is embedded with specialized hardware to link it to the devices to measure and control. Addition and subtraction of the inputs signals are done easily and comparisons can be done with the stored data in the memory [4]. Multi channel of the ADC are utilized to obtain the multichannel performance. To manage the acquisition and to represent the signals, software has been developed. Handheld digital oscilloscopes are applicable for only low frequency measurement applications like basic electronic circuits[5].

### III. SYSTEM REQUIREMENTS

The research about designing oscilloscope is in this section, the data of the entire system and the tools required for implementing the subsystems of the oscilloscope is reported. Along with that the significance of operation of each of the subsystem is reported. The detailed discussion of the principle of operation from the first stage to the last stage is reported..



**Fig. 1 Block diagram of oscilloscope**

The complete system is divided into four parts

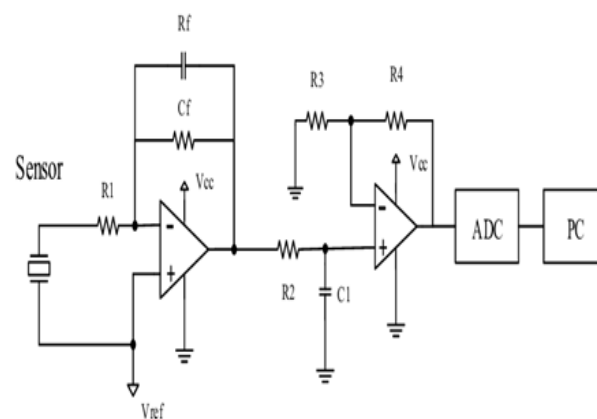
1. Power supply
2. Analog signal conditioning unit
3. Analog to Digital Converter
4. Process and output unit

#### 1. Power Supply

The power supply to the Arduino is provided through DC power jack (7-12V), the USB connector (5V), or the VIN pin of the board (7-12V). The ac power supply is given through the transformer. The power supply is varied or limited by connecting a potentiometer to the transformer. A small protection circuit is used to protect when the voltage exceeds more than 5V.

#### 2. Analog signal conditioning unit

Similar unit used in [3] has been used here. The voltage to be given to the arduino at the input should



**Fig.2 Diagram of the Analog signal conditioning unit.**

all in the range of 0V to 5V. The OPAMP 741 is fed with an input of 2.5V at the inverting terminal that is constant. For voltages less than zero it acts as DC offset. It replicates that the maximum voltage ranges from 0V to 5V for a maximum voltage of  $\pm 100$  V AC. The second OPAMP is designed in the circuit to act as negative amplifier to synch with the input wave and to invert the output of the first amplifier. During this process, high voltages that might result may cause the microcontroller ADC to

damage resulting the entire circuit to malfunction. To avoid this two zener diodes are used regulate the voltage produced. Observations are made for a sine wave input of -50V to +50V and the same wave is observed at the output. The phases of both the waves are found to be identical.

### 3. Analog to Digital Converter

The mode of operation of ADC in Atmega328 from [9] is considered. The contribution from the Analog signal conditioning unit has been straightforwardly associated with the Analog IN 3 pin in the Arduino UNO. A solitary divert oscilloscope is made in this task. Numerous channels are included later by associating Analog Signal Condition Units with Analog IN pins that are unused. Arduino has six Analog-to-digital converter channels. Among these channels any one of the channel is used as input channel. A limit of 2 channels is wanted to stay away from complexity nature.

### 4. Processing and Display unit

Triggering hardware is not required. So the entire function for triggering is coded completely in the firmware. The system Captures the Analog to Digital samples until a full amount completes the reading method is sustained. The centre value of the wave is calculated. Once more it starts reading the new samples and comparing the older samples. If the present sample is larger compared to the older sample the microcontroller reads the preceding sample and compares it with the mid value which is previously computed. If the present sample is below the previous sample then microcontroller again starts recording newer samples and compares with the older samples. The microcontroller checks whether or not of future recored sample is more than the center value computed. If it is larger, the start of the wave is seen.. The microcontroller begins taking future samples in to the integral RAM. The microcontroller then prints on the screen these samples.

### Auto Calibration and Display

In order to fix the wave shape on to the screen (laptop in this case) a function called auto calibration is introduced. The threshold voltage level of ATMEL AOC is 1 to 1024 with a voltage of 0 to 5VDC. To fix into the display area the calibration function scales the original level of the signal down by 16 times. In this project, laptop is used for displaying purpose.

## IV. SOFTWARE USED

Here we have a tendency to used Arduino software system (IDE) version 1.7.0 that is free Arduino software system is well on the market within the Arduino web site and it's of freed from value and doesn't require any licenses or permissions. With the assistance of this software system we will simply transfer the program to the computer user with the assistance of a constitutional boot loader. During this project for hardware interfacing we have a tendency to use a compiler named "Processing". Process could be an artificial language, development surroundings and on-line community.

### PC Scope

PCSCOPE Software Application is described in[4].PCSCOPE Software Application is constructed initially by using programming language C and later a windows based application is created for user to interface the device with a well-designed Graphic User Interface. By changing the scaling parameters and graphic parameters, users are permitted to modify the input signal to a wanted output waveform. This framework is initially simulated by utilizing Programming language C. A signal is tested by connecting to PC by using parallel port connection, through the system hardware prototype. Recreation results show that the application can get signal from 0.1 Hz to 1 KHz. The signal is displayed continuously, with short of what 0.1 to 1 KHz. The examining time is around 20  $\mu$ s and the transformation time is roughly 100 $\mu$ s. So the sampling frequency will be around 50 KHz.

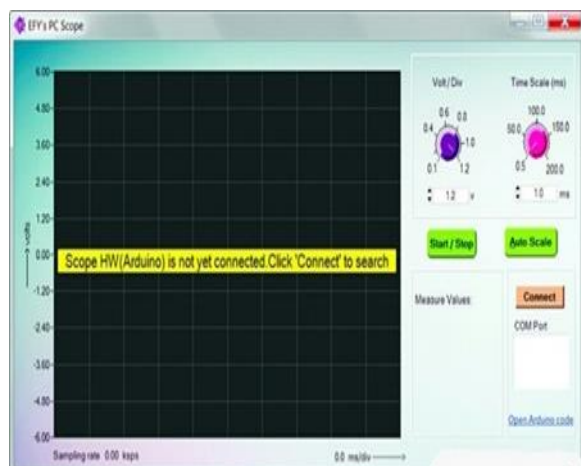


Fig.3 shows PC Scope software screen on laptop

## V. HARDWARE IMPLEMENTATION

Hardware connections are made by connecting the input of the Arduino UNO to the Analog signal conditioning unit and the output of the Arduino is connected to the laptop. Due to the built-in calibration function there is no need of addition of adjustment unit to the system. It is prudent that a small circuit is added to act as a shield to avoid the input voltage to exceed above 5V, and thereby limit the negative voltage. A less-power, quick exchanging diode like 1N4148 is utilized to ensure the information pin. Associate a 10-kilo-ohm resistor in arrangement with the information. It will function as a present limiter on if the input increases more than 5V. Extra voltage dividers are utilized in the event that one has to measure voltages higher than 5V. Hence, the hardware is easy to use. In the undertaking, a pin A0 is used to catch the info signal. The caught information signal is nourished to UART by means of UART-USB converter in the Arduino to the PC. A virtual COM port is made by Windows at whatever points the Arduino interfaces with the laptop. A Windows-based application is created utilizing NI Lab Windows which opens up the virtual COM port and starts plotting signals outwardly utilizing Graph libraries. Arduinocode is developed to read ADC values. The Arduino sketch is coded to peruse the ADC utilizing ISR, and the UART baud rate is arranged at 115200, which sends information at 85 $\mu$ s intervals. This gives a

successful sampling rate of 12kSa/s.

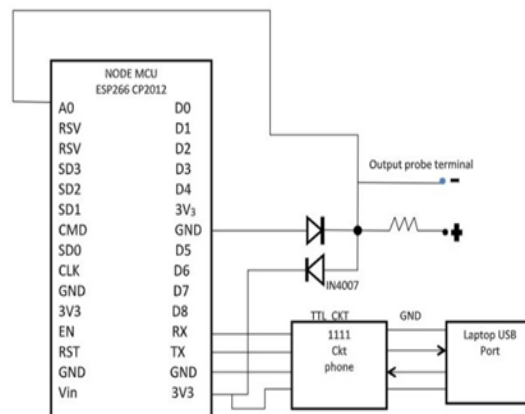


Fig .4 shows hardware schematic of oscilloscope

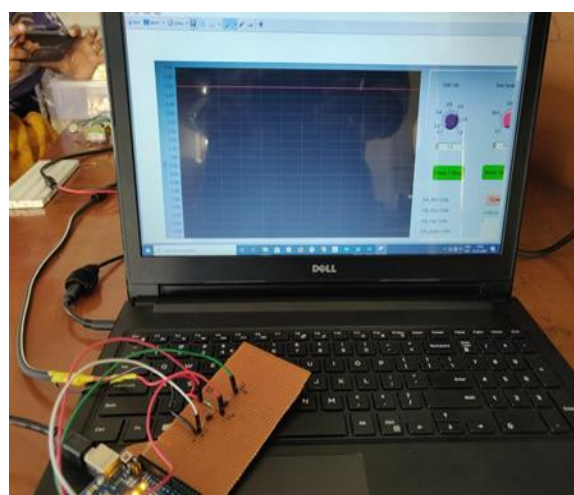
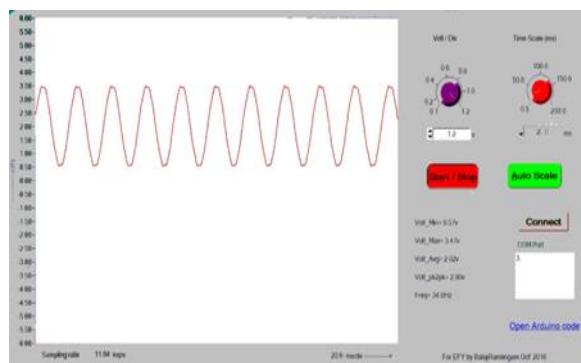


Fig.5 circuit diagram of the Arduino and laptop

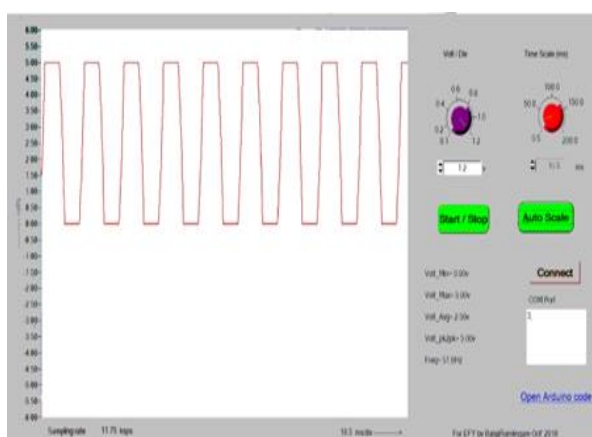
## VI. RESULT AND DISCUSSIONS

This project has been tested with different frequencies for different waveforms. It captures the frequencies up to 50 kHz with sampling rate of 12,000 samples/sec without any signal distortion. By analysing the results the approximate wave shapes are obtained which are used for research students at a very low cost. This oscilloscope can determine voltages only up to 5V; additional voltage dividers are used to measure voltages more than 5V.





**Fig.6 shows the output of the sine wave generator.**



**Fig.7 shows the square wave form**



**Fig.8 shows dc line when connected to 5V in the Arduino board**

## VII. CONCLUSION

Oscilloscopes are already available for high price in the market. To observe the variations in the electrical signal many different hardware circuits are being used. This paper describes an easy solution to design and analyse the oscilloscope at a very low

price so that it is easily affordable by the end-users. This oscilloscope is tested with different electrical circuits. It can measure the frequencies up to 50 KHz and provides a sampling rate of 12,000samples/sec. An auto scale is integrated in the pc scope, avoiding the need to adjust the waveforms like in the conventional oscilloscopes. Apart from this, the measurements are approximately equal to conventional oscilloscope measurement. It is used for demo purposes in laboratory courses. It is portable, requires less size and easily understandable to the users.

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