

# Portable Oscilloscope using Programmable System on Chip and Nokia 5110 Graphics LCD

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## ABSTRACT

This paper aims to showcase the development of a ‘Portable oscilloscope’ which would provide the basic functionality of a CRO, using Programmable System on Chip development board and a Nokia graphics LCD. The basic aim for the development of this project was the necessity of a student friendly oscilloscope which could be used for educational purposes.

## General Terms

Portable devices, Oscilloscopes.

## Keywords

Oscilloscope, portability, PSoC, troubleshooting.

## 1. INTRODUCTION

The basic aim of this project was to make a reliable and portable oscilloscope which could be used to display waveforms of different types and up to a few KHz range. Features like voltage/div scaling, DC offset adjustment, etc. were later incorporated in the model developed as a part of improvement to the basic design.

The oscilloscope is implemented using a PSoC4 board and displayed on a Nokia 5110 LCD screen. The waveform to be observed or any waveform generating source’s output is given as input to the PSoC4 board which is programmed to send the required data for the waveform to be interpreted and displayed by the LCD screen.

## 2. IMPLEMENTATION

### 2.1 Block Diagram

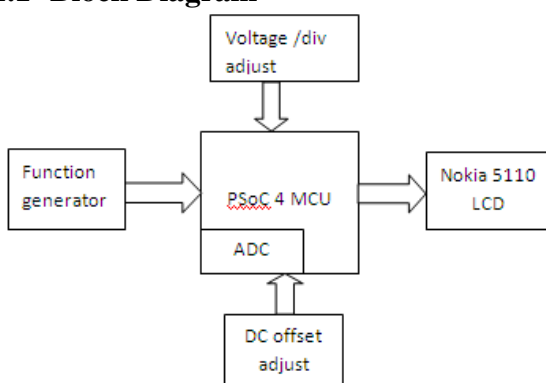


Fig 1: Block diagram for portable Oscilloscope

The input to the PSoC4 board comes from a function generator or any other frequency generating source. The ADC<sup>[3]</sup> in the PSoC4 accepts this input and converts it into a digital o/p which is manipulated using the MCU to display a Pixel on the screen for a particular voltage level of the incoming voltage.

For DC offset adjustment, a potentiometer is used to provide an additional bias at the input to the ADC of the board. For

enabling volts/div adjustment another potentiometer with its variable terminal connected to the second channel of ADC is used. The digital output corresponding to the second channel of the ADC is then used for scaling the output of the ADC for the first channel after suitable manipulation

## 2.2 Component Details

### 2.2.1 Programmable System on Chip4 Board

PSoC4<sup>[1]</sup> was introduced by Cypress semiconductors in 2002. It is basically an ARM-based PSoC, featuring the low-power Cortex-M0 processor. The board is programmed using PSoC Creator. It is an Integrated Design Environment (IDE) which allows to develop applications for PSoC platform.

The main component used for implementing the oscilloscope is the ADC in PSoC4, which is of SAR type. The ADC is configured to operate with 12 bit resolution and a sampling rate of 166666 samples per sec. The configuration is single ended with 2 channels.

### 2.2.2 Nokia 5110 Graphics LCD



Fig 2: Nokia 5110 graphics LCD screen

It is a 48 x 84 LCD. It was originally intended for as a cell phone screen. Built into this LCD is a Philips PCD8544 display controller, which converts the massive parallel interface of the raw LCD to a more convenient serial one.

The LCD has a display data RAM where the values for displaying data are written. The DDRAM is actually a matrix of 48 rows and 84 columns with each cell of the matrix representing a pixel. When a certain number of pixels are ON in a certain pattern a character gets displayed. The 48 rows of the DDRAM are divided into six banks containing 8 rows each, hence effectively we have 6 rows. The 8 rows correspond to the 8 bits of a byte, the byte representing the binary value of the pattern. The lowermost bit of a bank represents the MSB and uppermost bit the LSB. The column address ranges from 0 to 83 (Y) and row address from 0 to 5 (X). There are two modes of addressing available- vertical and horizontal.

Here we use vertical addressing mode where printing takes place column wise. Also we have left banks 0 and 5 for printing the values of time/div and volts/div.

To display a point in the waveform we have to set a particular bit of a bank and column according to the amplitude of the

waveform. For example to display the starting point of a wave starting from negative cycle we have to set the lowermost pixel of bank 4 i.e. MSB of bank 4 column 0. Hence we write '1000000' i.e. 80H at position X=0 and Y=4. Similarly other voltage values are mapped according to their amplitudes by deciding the banks and then shifting '1'.

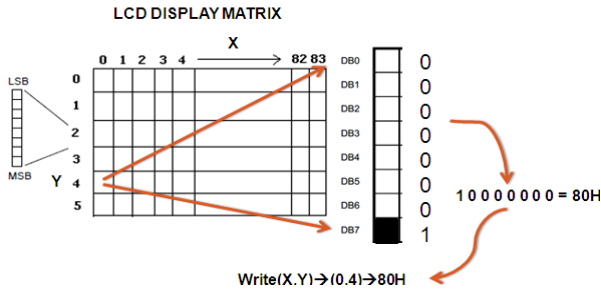


Fig 3: Setting a pixel of the LCD screen

The screen is then interfaced with the corresponding pins of the PSoC4 board. To display commands the appropriate values at appropriate positions on the LCD, the PSoC library for using Nokia 5110 graphics LCD was used as given by [2].

### 2.2.3 Potentiometers

Two 470K potentiometers are used for adjusting DC offset and volts/div. They are connected at the analog pins giving input to the 2 channels of ADC of PSoC4.

## 2.3 Displaying on LCD

Please use a 9-point Times Roman font, or other Roman font. The output of the ADC is 12 bit which needs to be scaled down and mapped to fit into the screen of the LCD. Hence the ADC output is shifted by 7 bits to the right, effectively reducing the resolution to 5 bits corresponding to 32 levels. The significant MSB changes are preserved in this way by removing the LSB bits by right shifting. As mentioned before in the description of LCD screen, the first and last banks are not used for waveform display.

The bank value is decided according to the digital output level from ADC after reduction in resolution as follows:

t=ADC output of 5 bits then-

Table 1. Bank selection condition

Range of t	Bank Number Selected
$t < 8$	4
$16 > t \geq 8$	3
$24 > t \geq 16$	2
$32 > t \geq 24$	1

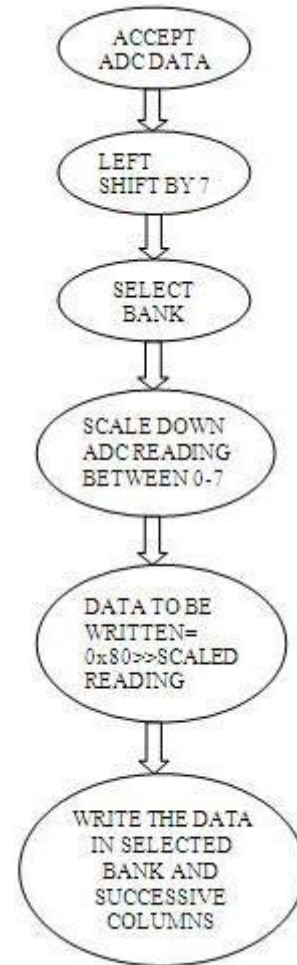
At the selected bank then, the voltage levels are mapped to the corresponding pixel by the formula:

$$\text{Value} = \text{old reading} - 8x \text{ (4-bank value of reading)} \dots (1)$$

The value 80H is then shifted value times for setting the respective pixel for the corresponding voltage amplitude.

This procedure is repeated for every 84 readings to write to the 84 columns of the LCD. The values of pixel to be set and their banks are then stored in 2 arrays then displayed at a time.

## 2.4 Algorithm for Waveform Display



## 2.5 Volts/Div and DC Offset

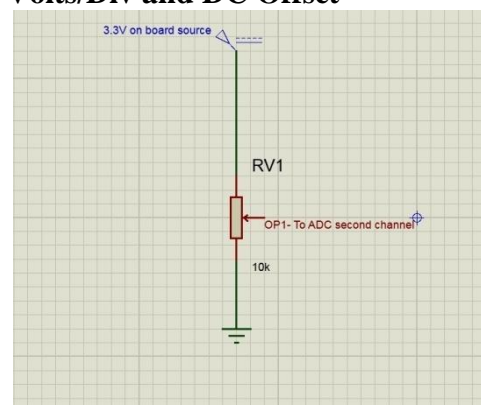
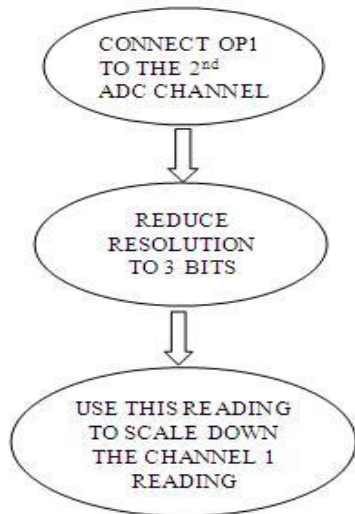


Fig 4: Arrangement for Volt/div and DC offset adjustment

The output of frequency generating source is given as input to the analog pin of ADC through a 470K potentiometer. On varying the shaft, the waveform could be adjusted as required.

For volts/div variation another channel of ADC is connected to a potentiometer whose extreme pins are given 3.3 V and ground respectively. The second channel output resolution is reduced to 3 bits. Then the output of first channel is divided by this second channel output thus scaling the voltage values.

## 2.6 Algorithm for Volts/Div scaling



## 2.7 To achieve DC offset Adjustment

To achieve DC –offset adjustment, an arrangement similar to Fig 3 was made and applied simultaneously with the analog i/p applied at the channel 1 of the ADC. Depending on the rotation of the potentiometric knob the DC offset voltage on the channel 2 of the ADC changes and the waveform shifts its position on the graphics LCD.

## 3. RESULTS

### 3.1 Testing

During testing phase the input given was DC voltage and the DC offset was variation was observed. Later the actual time varying voltage waveform was tested. It was found that the performance of the oscilloscope in terms of peak value displayed improved when we reduced the resolution to 6 bits instead of 5 bits.

With ADC input range of 0-5V the output achieved was satisfactory with maximum voltage of  $3V_{pp}$ . waveforms of different types like sine, triangular, sawtooth and square were observed. With increase in frequency above 6.6 KHz the waveform shape distorts and not very clear.

The results obtained can be tabulated as below:

**Table 2. Final results obtained**

Functions	Specifications
Waveform display	Max amplitude- $3V_{pp}$
High frequency wave display	Max freq-6.226 KHz
Volt/div adjustment	possible
DC offset adjustment	possible
Waveforms displayed	sine,triangular, sawtooth, square



**Fig 5: Sine wave of 1.5 Vp-p and frequency of 1 KHz**

## 4. APPLICATIONS

1. It can be used for low power trouble shooting purposes.
2. It can be used as a replacement to the bulky CRO's that we otherwise use for educational purposes.
3. It is portable and user friendly and thus can be used for on the spot troubleshooting.

## 5. CONCLUSION

Although the results obtained have limitations with respect to maximum voltage and frequency, for a low cost portable oscilloscope the results are satisfactory.

Adding improvements in the oscilloscope like push button and storing would enable it to perform functions like storing the waveform and printing it like a DSO.

## 4. REFERENCES

- [1] PSoC 4200 family datasheet-Cypress
- [2] PSoC 4 Pioneer Kit Community Project#061 – Nokia 5110 LCD Interface- Element-14
- [3] The SAR-ADC datasheet for PSoC4 by Cypress.
- [4] ARM CORTEX website: <http://www.arm.com/products/processors/cortex-m/cortex-m0.php>
- [5] Ameya Wagh<sup>1</sup>, Zalak Dave<sup>2</sup>, Gaurav Singh<sup>3</sup>, Varun Dange, Abhay Tamba<sup>4</sup> and Sachin Gengaje<sup>5</sup>. –A low cost portable oscilloscope for educational platforms based on programmable system on chip- [www.eduvance.in](http://www.eduvance.in).