

# IMPLEMENTATION OF ARM-7 BASED DIGITAL CRO

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**Abstract:** CRO[1] is used to measure the frequency, amplitude and display the waveforms. But the cost of the analog CRO is high and it occupies more space, it is not portable. The PC based CRO reduces the cost and it useful for another system software like MATLAB. ARM-7 processor connected through RS-232 UART[3] serial port, which is used to interface between user and the processor. We can add some features in real mode and storage mode also. We are generating the sine waves in channel1 to 4 simultaneously and display it on the screen at different frequencies.

**Keywords:** Analog CRO, waveforms, ARM-7 processor, RS-232 UART serial port.

## I.INTRODUCTION

Measurement defined as the process of determining the amount or capacity by comparison with accepted standards of the systems units being used. The major parts of electrical experimentation is signal generation and measurement. CRO used for signal measurement and function generator used for signal generation. There are different types of function generators and CROs available in the market. CRO s used in any field where a parameter can be converted into a proportional voltage for observation example meteorology biology and medicine. They are Dual beam CRO, Dual trace CRO, Analog & Digital Storage Oscilloscopes[2], VLF Sampling Oscilloscope, and Digital readout oscilloscope. Depending upon the application we use various CROs. Function generators produce different waveforms of adjustable frequency. The common output waveforms are sine square, triangular and sawtooth waves. The frequency may be from a fraction of Hertz to several hundred kHz.

The main drawback with the signal generators and CRO is cost, compatibility and portability. The main purpose is reduce the hardware cost to minimum and portability. ARM7 based LPC2148 (flash version), is a high-performance FLASH micro controller provide highest design flexibility. It has 512 Kbytes of FLASH program memory, 2Kbytes of data memory and 368 bytes of RAM.

## II. ANALOG TO DIGITAL CONVERSION

The analog signal is converted into digital signal by using analog to Digital converter. The conversion involves quantization , small error will encounter. An ADC[4] performs the conversions periodically. An ADC may also provide an isolated measurement such as an electronic device that converts an input analog voltage or current to a digital number, which is proportional to input voltage or current. The digital output uses different coding techniques. It is a two's complement binary number that is proportional to the input, but there are other possibilities. Applications of ADC is music recorder and Digital Signal processing. ADC[5] implementing methods are flash ADC, Successive approximation ADC, Ramp compare ADC, Wilkinson ADC, Integrating ADC, Data encoded ADC[6], A pipeline ADC, Sigma delta ADC etc. The successive approximation ADC is more popular. Sampling can be done for varying in space, time, or any other dimensions. Functions that vary with time, i.e. continuous time can be sampled using sampling . Thus, the sampled function is  $s(nT)$ , for integer values of n.The sampling frequency is defined as the no. of samples per sec. i.e.  $f_s = 1/T$ .

Interpolation algorithm is used to reconstruct the continuous function. When the time interval between adjacent samples is a constant (T), the sequence of delta functions are known as Dirac comb. Sampled signals are not reconstructed and stored. Nyquist frequency of the sampler,  $s(t)$  frequency components must higher than  $f_s/2$  Hz. Without an anti-aliasing filter i.e. low pass filter, frequencies higher than the Nyquist frequency i.e.  $f_s > 2f_m$  will influence the samples in a way that is misinterpreted by the interpolation process. The guard band between the samples must be appropriate otherwise over sampling and under sampling done. There are different noises like jitter noise, quantization noise, thermal sensor noise, analog circuit noise, etc.

### III. IMPLEMENTATION

The LPC2148 also supports low voltage self-programming. The in-circuit debugging allows to “emulate” the LPC2148 without an in-circuit emulator.

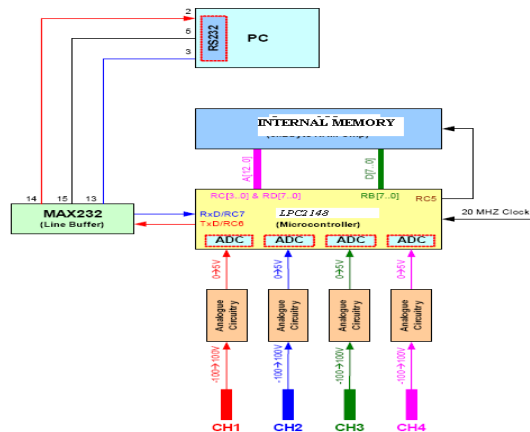


Fig. 1 Block Diagram

Four ADC pins are used for data acquisition, a Max-232 is used to convert the TTL serial logic to the correct RS232 format. An analog circuit is required to make sure the input voltage to the ARM7 based LPC2148 ADC falls between 0 to 5V, i.e. Bipolar. Two 741 op-amps, and a couple of diodes are used for protection as the ADC cannot handle voltages outside its range. A 5V voltage regulator is used to power supply i.e. 7 to 20 V DC to the circuit; there is a large DC input range of 7 to 20V.

### i).COMMUNICATION PROTOCOL DEVELOPMENT

There are two main communication protocols: real-time and storage. To control the LPC2148, RS232 UART has separate transmit and receive lines so there is no chance of collision with the real-time data and storage data. It must be setup in the LPC2148 to control message waiting to read.

**1)Real-Time Mode:** At high sample frequencies, the problem with the waiting time to read the read the transmit and receive signals and one solution is that to software offset the waveforms to compensate for the time delays. If we use four LPC2148s, sampling can occur simultaneously. A master/slave communication protocol synchronize the all LPC2148s. LPC2148 microcontrollers cost is less so multiple LPC2148s in designs are widely used. The microprocessor design will control everything (e.g. PC), although there are four channels in the real-time mode. Each Channel is sampled 1000-times like channel 1 sampled 1000 times, then channel 2 is sampled 1000-times, and so on and the process repeats forever. There are two types of mode controls

1. Chop mode
2. Alternate mode

In chop mode each channel must share the RS232 throughput. If one channel is enabled, maximum sample rate is 4KHz. If two channels enabled, maximum sample rate of 2KHz each. If four channels enabled, maximum sample rate of 1KHz each.

The disadvantage of alternate mode is timing information between different channel, then information is lost. It is corrected by the software. LPC2148s real-time timers, known that how much time as elapsed between the sampling of channels. The PC program draws the waveforms with the correct time gap between the channels. Another disadvantage is that continuous monitoring is impossible. Alternate mode is only useful for periodical waveforms, else chop mode is preferable.

**2)Storage Mode:** Read the finite number of samples and store into the external RAM. Then these readings are transferred to the PC in one large block, to remove the bottleneck on RS232 and provide faster sample rates.

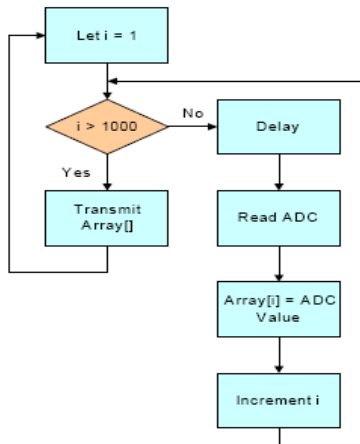


Fig. 2 Illustration of storage mode with one channel

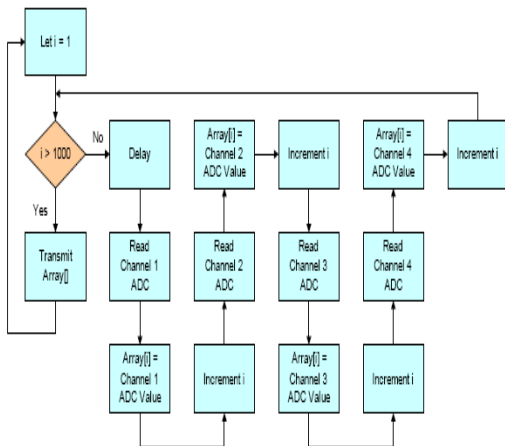


Fig. 3 Illustration of storage mode with four channels (chop mode)

Alternate sampling can be applied to storage mode. The main reason is that the alternate sampling mode maximize the sample rate of each channel in the real-time mode. It removes the bottleneck on RS232, but LPC2148 ADC, hence alternate mode cannot increase channel sample rates. There are two mode controls i.e. alternate mode and chop mode. But the alternate sampling is no real advantage over chop mode. In the alternate mode, it maximize the sample rate of each channel in the real-time mode. It is no longer applies as storage mode removes the RS232 bottleneck, and the speed of the LPC2148 ADC is decreased, hence alternate mode cannot increase channel sample rates.

## II. Control Protocol

The LPC2148 checks the UART buffer regularly. If a control message received or detected, then it leaves the main program and checks (CRC check) that the message is valid or not, if not; return to the main program. If it is valid, it decode and implement the message.

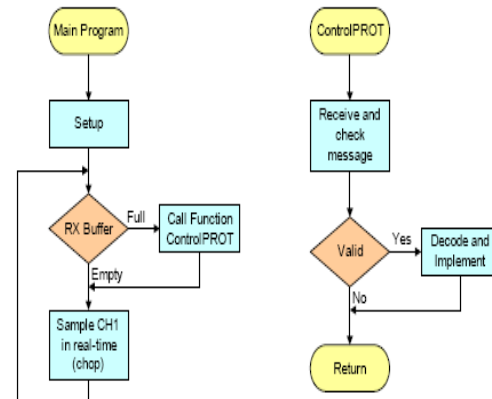


Fig.4 Illustration of the control protocol

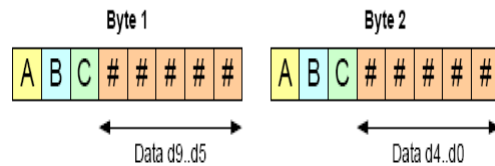


Fig. 5 Frame structure: Real Time.

If A = 0, byte 1; contains data d9...d5 (Upper 5-bits of ADC reading).

If A = 1, byte 2; contains data d4...d0 (Lower 5-bits of ADC reading).

B & C BITS are specify what channel the data is for.

For Ex.10 data bits, 16 bits in total, hence efficiency =  $10/16 \times 100 = 62.5\%$ . Synchronization between the PC and the LPC2148. The main problem with this is that if a byte is lost. It would be extremely difficult to recover another problem that the PC request for each and every reading (Master/Slave). So the delay in sending the request to the LPC2148 and to the processor. So it is slow in reality.

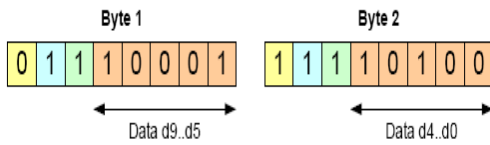


Fig. 6 Real-time frame structure with example

To maximize the data throughput, there is no check sum or CRC[8]. The frame structure is designed in such a way that some errors can be detected. The maximum sampling frequency of LPC2148 microcontroller ADC is higher than can be transmitted over RS232. Two bits are reserved for start and stop bits and 20-bits are sent per reading. If we use UART hardware, it gives the accurate values. LPC2148 can sample the next reading while the UART is transmitting the last reading. In the alternating sampling, sample rate will not decrease with the number of channels. Alternate mode is only useful for periodical waveforms, else we use chop mode. The LPC2148 has an 10-bit ADC, if speed is important the resolution could be reduced to 8-bits. For example four channels are always transmitted along with sync frame, 5-bytes for 4 channels, 80% efficient. For faster sample rates, storage mode must be used. For ex. the ARM7 samples a waveform at 20 KHz storing each reading into an array. Once a certain number of samples have been taken the ARM7 stops sampling and sends the readings to the PC in one large block (including CRC[7] or check sum), once ACK (Acknowledgment) is received from the PC the ARM7 starts sampling again and the process repeats forever. We can use a different transport medium i.e. USB / Parallel which would allow for faster real-time sample rates. The real-time communication protocol does not rely on the transport medium. If the transport medium is changed the real-time protocol should be OK. The 'data' field uses the same frames as specified for the real-time frame structure. The code reusable is the advantage.

We will check the frame by 2 ways

- Cal. CRC for the received frame and compare with the received CRC.
- Send the entire frame to the CRC function (including received CRC) and if the calculated CRC is zero then the frame is correct.

Theoretically the LPC2148s ADC can sample at  $(1/19.72\mu\text{S})$  50.7 KHz. After completion of conversion, TAD delay must complete before acquisition. During this time, the holding capacitor is not connected to the selected A/D input channel. For correct A/D conversions, the A/D conversion clock (TAD) time must be min. of  $1.6\mu\text{s}$ . RS 232 serial port is used to receive the data in real time mode. The real-time mode communications were first tested using the LPC2148 simulator program, where sine waves, square waves and random waves at variable frequencies and amplitudes were successfully sent to the scope program which correctly displayed the waveforms. Once the program was working on the simulator it was tested using a LPC2148 sampling waveforms, the program successfully displays the waveforms correctly.

If the waveform is too high or low, then waveform on the screen will display as the top/bottom of the waveform will be cut off. If we drag it, it changes its position.

If the waveform is too high or low, then waveform on the screen will display as the top/bottom of the waveform will be cut off. If we drag it, it changes its position. If the waveform is offset to the right, see the data before the waveform triggered. It is mainly useful in frequency calculation. We have many options, level triggering and edge triggering.

There are many options like trigger off for different channels, "IND." independent triggering, where each channel has its unique trigger point. It increases the program flexibility and it allows for four unrelated waveforms to be monitored simultaneously on the same scope display. The tab of the controls dialog can enable/disable channels, change scope time-base and channel voltage scales. A quick way of moving channel offsets. It sets the sample rate, mode, and input range of the scope. The sample rate is selected for the calculation of the time base else the time-base is incorrect. Input range is selected for adjust the gain of the op-amps. Allow it is important that the correct input range is selected as this changes the binary representation of voltage. Sampling mode is selected here: Real-time scroll mode that the waveform is sampled, and stored onto the internal channel arrays in such a way that the waveform appears to scroll across the screen. Real-time buffered mode that data is buffered before copying to the internal channels arrays and is triggered so that the waveform appears to be stable

on the display. The grid configuration consisting horizontal squares and vertical squares.. Each square has 10 points; The default grid resolution is 10 x 8 (100 x 80), but 20 x 16 (200 x 160) is probably better suited for quad channel operation. The refresh rate specifies the time between screen refreshes. For ex. 200 ms is the default, that's a refresh rate of  $1/0.2 = 5$  Hz. It is too low.

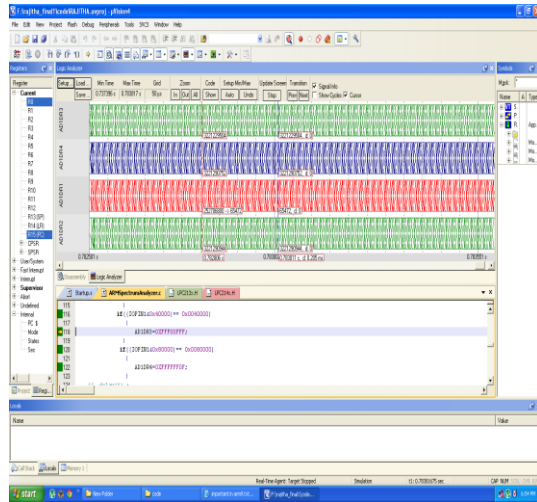


Fig. 7 Sine waveforms at 4 different channels

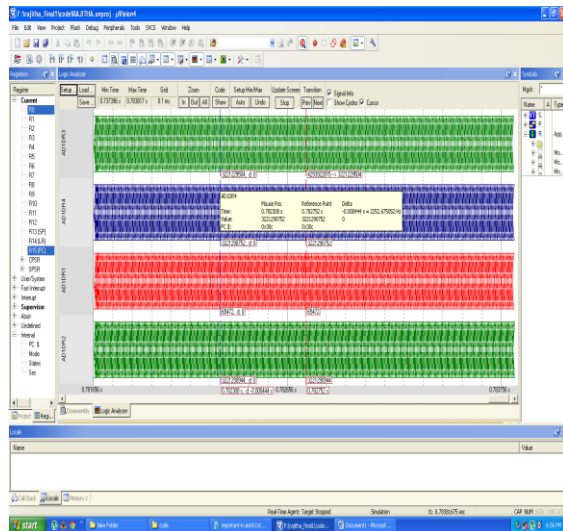


Fig.8 . Sine waveforms with different frequencies and amplitudes.

#### IV. CONCLUSION

RS-232 is used to receive the data in the real time mode, then it was tested using LPC2148 simulator, ex. Sine waves, square waves having different frequencies and amplitudes at four different channels. The program successfully displayed the sine waveforms correctly at various frequencies and amplitudes for test results.

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