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CONVERSION OF ORDINARY CRO TO STORAGE CRO AND THE USE OF THE LOW PERSISTENCE SCREEN CRO IN EXAMINING SLOW WAVEFORMS

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Abstract

In this article it is described how to convert an inexpensive ordinary cathode ray oscilloscope (CRO) to a storage CRO. The storage CRO is useful for examining slow and non-periodic waveforms. Examples of a slow sine waveform, a slow sawtooth waveform and a slow charging capacitor are given as illustrations.

Keywords: *Digitization, microcontroller, sampling, storage-CRO and successive-approximation.*

1. Introduction

A CRO with a low persistence screen contains low persistence phosphors in its screen. Persistence is the time for the light emitted by the phosphor to decay to 10% of its initial intensity. This type of screen makes it difficult to display very low frequency waveforms. The solution to the above problem is to use a digital storage oscilloscope.

Storage oscilloscopes are expensive for most people or educational institutions. The storage CRO is useful for examining slow waveforms, for example, electrocardio-graph (ECG) waveforms, magnetolluric currents, and it is useful for examining nonperiodic waveforms such as a one-shot impulse from an accelerometer. If we can digitize the waveform and store the results, then we can display the results on a CRO at a convenient time and with as many repetitions as desired.

Whereas an analog oscilloscope works by directly applying a voltage being measured to an electron beam across the oscilloscope screen, in contrast, a digital oscilloscope samples the waveform and uses a digital-to-analog converter (ADC) to convert the voltage being measured into digital information. It then uses this digital information to reconstruct the waveform on the screen. This way the low persistence nature of the CRO's screen can be eliminated.

For many applications either an analog or digital oscilloscope will do. However, each type possesses unique characteristics making it more or less suitable for specific tasks. Analog oscilloscopes may be preferred when it is important to display rapidly varying signals in “real time.” Digital oscilloscopes allow one to capture and view events that may happen only once. They can process the digital waveform data or send the data to a computer for processing. Also, they can store the digital waveform data for later viewing and printing.

The objectives of this work are to convert ordinary CRO to storage CRO and to demostrate how to examine slow wave Forms using a CRO with persistence screen.

2. Some Theoretical Background

2.1 Sampling theorem

The sampling theorem (Proakis and Salehi, 1994) is one of the most important results in the analysis of signals and has widespread applications in communications and signal processing. This theorem together with results from signal quantization techniques provides a bridge that connects the analog world to digital techniques. The theorem simply states that if a signal is bandlimited, say to a frequency F, then it can be sampled at multiples of some basic sampling interval T_S, where T_S 1/2f.

2.2 Analog-to-digital converter

There are many methods used in analog-to-digital conversion (Cook and White, 1995). For maximum speed, flash conversion is used. A good compromise on speed and accuracy is given by the successive approximation method (Green, 1999). The approximation is carried out by means of a software program in a microcontrolller. The technique works as follows: the most significant bit in a digital-to-analog converter (DAC) is set to one, and all the others are set to zero. If the comparator indicates that the analog signal is greater than the digital signal, then the highest bit is made zero, and the next lower bit is set to one and the test is repeated. This iterative process is repeated until all bits have been tested, starting with the most significant bit (MSB) and ending with the least significant bit (LSB). This analog-to-digital conversion is used in a program, which digitizes 256 points on a waveform and then stores the results.

2.3 Frequency measurement

We need a formula for calculating the frequency of a sinusoidal input waveform. If we sample N points using a sampling interval T_s, we sample NT_s cycles of the waveform. These are fitted into a time NT_D, where T_D is the display rate per point at the CRO, so that the apparent cycle or period of the displayed waveform is given by $=T_DT/T_s$, where T is the period of the input waveform. Thus the frequency f=1/T of the input waveform is given by

$$F=T/T_S f' \qquad (1)$$

where $f'=1/T'$, the frequency of the displayed wave (apparent wave).

3. Material and Method

3.1 The storage oscilloscope program

Figure 1 shows a flowchart diagram of the storage oscilloscope program. The program, which is run in a microcontroller, consists of two major parts, the digitization part and the display part. A brief description follows: First the desired trigger level is chosen and stored. Scanning begins only when the analog signal is greater than the trigger level. The sampling rate and the scan time are determined by

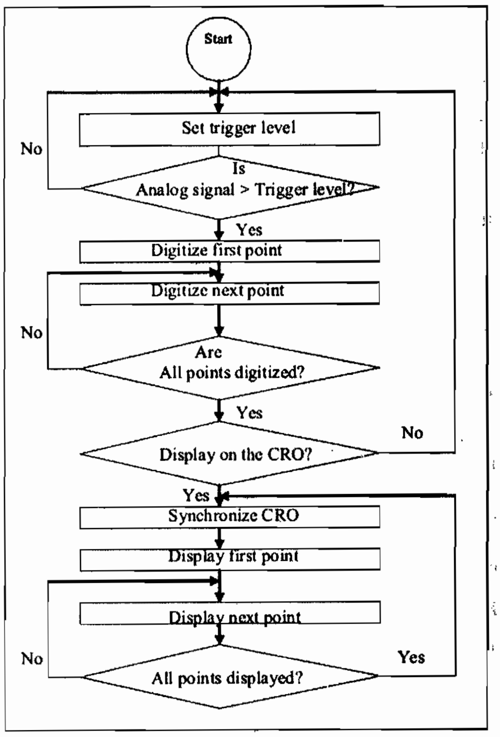

Fig. 1: Flowchart of the storage oscilloscope program.

software. We scan 256 points so that a microcontroller capable of storing 32 bytes can be used. After all the 256 points have been digitized and stored, a sync signal is generated before the display begins. The sync signal is generated by toggling an output pin of one of the ports of the microcontroller.

3.2 The circuit

Figure 2 shows the circuit used. The microcontroller used was the PIC™ microcontroller PIC16C76 (Microchip, 2003) from Microchip Technology Inc., USA. It outputs the scanned values on port C via a digital-to-analog converter AD558, here connected for an output range of 0-10V. Display on the CRO is enabled by a digital 1 on pin #22 (Display) of the microcontroller, otherwise digitization is repeated.

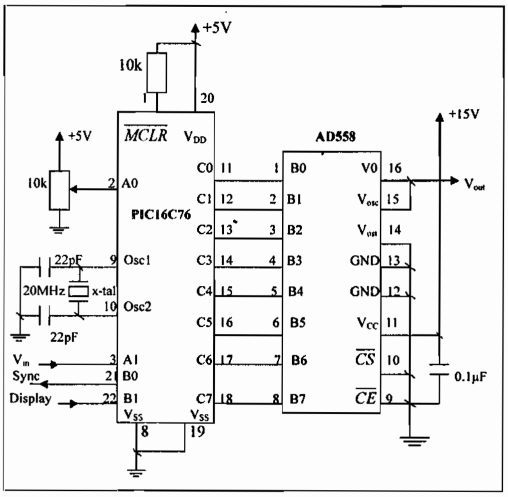

Fig. 2: Circuit diagram for the storage oscilloscope.

4. Analysis, Results and Discussion

4.1 Sampling rate

The sampling rate is software determined. A sampling interval of about 16.1 ms (or 62 Hz) was used, so that a sampling time of 256x16.1 ms or about 4.1 s is required to sample 256 points on the scan. Hence according to the sampling theorem (Proakis and Saleh, 1994) the signal to be digitized has to have a frequency of at most 62/2=31 Hz.

4.2 Display rate

The display was done by reading out points to the oscilloscope at a rate of 6 µs per point. This rate is software determined and it can be chosen to give a steady display. At this rate it takes 256x6 µs or 1.536 ms to display 256 points of the scan. This display rate gave good results.

4.3 Measured frequency

In the first two examples used, values of T_s=16.1 ms and T_D=6 µs were used in the formula in eqn. (1), which gave approximately f=f'/2683.The 1-Hz waveforms gave approximately f'=2.63 kHz, which gives F≅0.98Hz which is in good agreement with the theoretical value marked on the scale of the signal generator used.

Figures 3 and 4 show photographs of the results obtained by converting two 1-Hz waveforms to digital levels and then displaying them on an oscilloscope using the storage oscilloscope program. Figure 5 shows the charging of a capacitor using a time constant of approximately 1.0 s. A sweep rate of 0.1 ms cm^{-1} was used for all the displays.

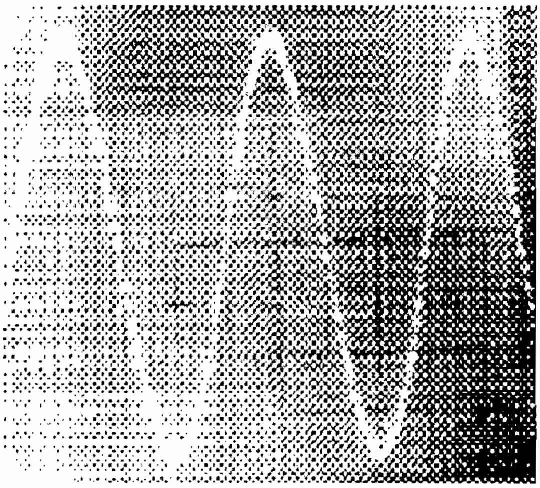

Fig. 3: Storage oscilloscope reconstruction of a 1-Hz sine waveform.

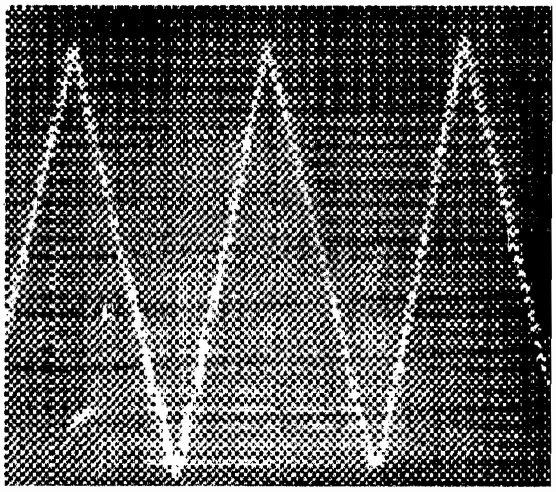

Fig. 4: Storage oscilloscope reconstruction of a 1-Hz sawtooth waveform.

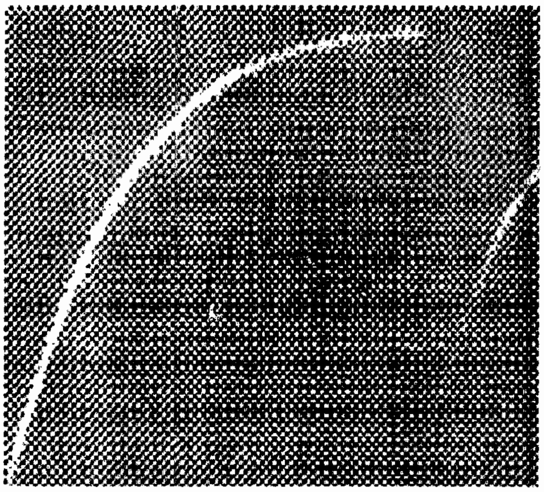

Fig. 5: Storage oscilloscope reconstruction of a charging capacitor using a Time constant of approx. 1.0 s

5. Conclusion

It has been demonstrated how to observe very slow waveforms on the CRO. We have also derived a formula for determining the frequency of an oscillating input waveform.

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