

Using Digital Oscilloscopes in Introductory Physics Labs

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Abstract:

We are in the process of converting various experiments from high quality but aging analog oscilloscopes containing a cathode ray tube (CRT) to modern digital oscilloscopes (Tektronix model TDS 210). These lovely instruments have a (remarkable) maximum sampling rate of 1 giga-sample/s and provide some automatic measurement features and convenient hardcopy printout. We will discuss the advantages and disadvantages of these new instruments, and the revisions in the instructional materials related to their introduction into our introductory physics laboratories.

What is an oscilloscope? Answer: A voltmeter which makes a graph of V vs. t

What are the key features of most digital scopes (DS)?

- * No CRT
- * Repeatedly "digitizes" the input voltage, i.e., measures and generates a digital value to represent the input voltage, and stores these values in a (digital) memory, similar to a computer's memory.
- * Displays these values as a graph of V vs. t on a display screen, which often is an LCD screen.

What is the fundamental difference between a digital scope and an ordinary "analog" (i.e., CRT-based) oscilloscope? Answer: An "analog" scope uses the CRT screen and the persistence of your eye to "store" the waveform, while a digital scope uses ordinary integrated circuits (IC's).

So what's the big deal about a digital scope? Stated alternatively, what are the advantages of a digital scope, over an "analog", CRT-based oscilloscope?

Answer(s): Consider the Tektronix model TDS210, the lowest cost Tektronix digital scope (DS).

- * **Press Autoset and the input signal will be displayed!** The DS automatically adjusts the trigger level, vertical scale, and horizontal time scale to values appropriate for displaying the input signal! While for connoisseurs like physics teachers, this feature is not perfect (I often tweak the controls to get exactly what I want), it is still quite **WONDERFUL!**
- * **A DS is in effect a "storage" scope, i.e., it can store a measured waveform indefinitely** (i.e., much like the more expensive type of CRT scope known as a storage scope). Thus, transient pulses can be "captured" and studied at leisure.
- * **Press Hardcopy and the screen display is printed**, along with lots of information about the scope's settings (such as the vertical and horizontal scales, trigger level, zero level, etc.).

- * **Automatic measurements of the waveform!** Press **Measure** and get more wonderful things. One can set the scope to measure and display with each waveform the:
 - * frequency, period & RMS value (of the first cycle displayed);
 - * mean and peak-to-peak value (of the entire displayed waveform or "record").
 With an optional module, the TDS210 can also:
 - * automatically measure rise time, fall time, and pulse widths;
 - * calculate, display and print a real-time FFT of the input signal.
 - * displays stock tips, tomorrow's winning lotto number, etc. (gotcha, didn't I?)
- * **Measure very fast events without putting your head (and the scope) in a bag!** For example, with a square-wave signal at the Channel 1 input, use a one meter length of cable to connect the signal also to the Channel 2 input. Then press **Autoset** and see clearly the time delay due to the one meter length of cable! While one can also do this on a comparable analog scope (i.e., one with a comparable bandwidth), typically the beam trace on the analog scope is very faint, and requires reduced lighting to be viewed.
- * **Reset all the controls at the touch of a button!** For example, select **Recall Factory (setup)** when you turn on the DS, and all controls are returned to a standard setting, regardless of how the controls were left by the previous user (or student)!!! This is wonderful in teaching laboratories; for example, we no longer hear, "we don't see anything" because the beam intensity is set too low.

There are other advantages as well. There also are some disadvantages, or said differently, applications where an analog scope performs better in some respects.

A tidbit: Tektronix no longer makes analog scopes.

Remarkable fact: The maximum sampling rate of the TDS210 is a remarkable 1 giga-sample per second, or one sample every ns!!!!

(However, this does not mean the instrument has a bandwidth of 500 megahertz; I think of the TDS210 as having a analog front end with a bandwidth of 60 MHz [5.8 ns risetime] followed by a digitizer that we can set to sample as a rate of up to 1 GHz. Selecting a time scale indirectly selects the digitizing rate.)

Disadvantages:

- * **The V vs. t display on a digital scope** is subject to **aliasing**, which results in a false or misleading display. This occurs if the sampling rate is too low, i.e., less than twice the highest frequency in the signal. If the properties of the waveform change when you change the time scale of the display, aliasing is present.
- * **The display produced in the X-Y mode of the TDS210 is of lower quality than that of comparable analog scopes**, principally because data is not collected continuously. In the case of Lissajous figures, this results in gaps in the figures. Actually, the figures are mostly gap, and not much figure! By adjusting a "persistence" control, the full figures can be displayed. However, comparable displays on analog scopes are much sharper, more pleasing, and less subject to misinterpretation.

Other slightly negative features peculiar to the TDS210 digital scope, and perhaps other digital scopes as well:

- * The vertical gain cannot be adjusted continuously.
- * The horizontal (time) scale cannot be adjusted continuously.
- * The least sensitive vertical scale (without using a probe) is 5 V/Div (as compared to 10 V/Div on the analog scope Tektronix 2213).

I will illustrate various features, etc, of the TDS210 with transparencies that (primarily) are copies of printouts from the DS for various waveforms and situations.

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