

Instructional Materials for Using Digital Oscilloscopes in Introductory Physics Labs

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Abstract: We are in the process of converting various laboratory activities from use of high quality but aging analog oscilloscopes containing a cathode ray tube (CRT) to use of modern digital oscilloscopes (Tektronix model TDS 210). We discussed the advantages and disadvantages of these new digital instruments previously (AAPT Announcer, Vol. 30, #4, page 99, paper DB01; notes available at <http://www.public.iastate.edu/~fcp>). In this presentation we will discuss the revisions in the instructional materials related to the introduction and use of the digital instruments.

Overview of our experience with converting to the TDS210 digital oscilloscope:

- * **We are very pleased with the outcome of our decision to purchase and use these instruments.**
- * **We have had no significant problems**, either in adapting the existing experiments to this new technology, or in the student's ability to use the instruments. In general, things have gone smoothly.
- * **Students produce much more complete documentation** of their lab experience, in a very natural way.
- * Some of the experiments required extensive revision, one very little.
- * **We have been able to replace some obsolete techniques** with modern methods based upon the digital scopes.

Features of the TDS210 digital oscilloscope which are heavily used in our revised experiments:

1. **Printed copies of the scope display:**
 - * These are automatically well documented, with information about the scale settings, ground level, and trigger (but unfortunately not date and time!). I find the printouts extremely useful when I am making measurements for my own use; the printouts improve my own efficiency in lab dramatically. Our students should experience this advantage also!
2. **Autoset** and related features:
 - * By having students press a few buttons, all controls of the scope are returned to a set of standard settings.
 - * Students routinely use **AUTOSET** to find the signal, and then make scale adjustments to taste.
3. **The Measure feature:**
 - * Professionals routinely use this feature, and our students should become familiar with it as well.
 - * This feature has reduced the tedious nature of a number of types of measurements, giving students time to do more interesting and instructive things.
 - * This feature has facilitated some measurements which are difficult to make efficiently any other way.

Other features of the TDS210 digital oscilloscope which our students use occasionally:

4. **The ability to see very fast signals clearly:**
 - * Students use this capability to measure time delays of several nanoseconds duration, and indirectly the speed of propagation of electrical signals.
5. **Signal averaging:** One can average up to 128 waveforms, reducing random noise in repetitive signals.

Characteristics peculiar to digital scopes that must be discussed:

1. **Aliasing!**

Things that we have de-emphasized since adopting the digital scopes:

1. **The XY display mode:** We no longer include activities based on the XY mode. If I were to include such in the future, I would use an analog scope. Digital scopes do not take data continuously; this causes gaps in Lissajous patterns, for example.

Observations for which we continue to use analog scopes:

1. Using a slow sweep to observe the shape of the amplitude modulation of an AM radio signal (while listening to same station!). While this can be done with a digital scope, the display is of higher quality on an analog scope.

Overview of our "oscilloscope" labs: The first three of the experiments listed below make heavy use of the digital oscilloscope. The fourth one makes heavy use of computer data acquisition (ULI) with less emphasis on the digital scope. We have not yet converted the fifth lab below from analog to digital scopes; here the scope serves primarily as qualitative amplitude detector as students search for the maximum response near various resonant frequencies.

Experiments in our calculus-based introductory physics sequence that use oscilloscopes:

| Experiment Name | Key instrumentation and devices | Degree of revision required |
|-----------------------------------|--|--|
| Time-dependent Electrical Signals | Digital oscilloscope, function generator, RC circuit, multimeters, DC power supply | extensive |
| Magnetic Induction | Digital oscilloscope, function generator with integral frequency meter, solenoids and pick-up coils, digital multimeter | intermediate; one obsolete instrument replaced |
| Electrical Oscillations | RF tank circuit with adj. C and L, digital oscilloscope, function generator, frequency meter, capacitor box, audio amplifier and speakers, antenna | intermediate; some measurements much nicer with digital scopes; AM modulated signals best viewed with an analog scope! |
| Vibrations of a Wire | PC, Vernier ULI, computer pre-amp, Data Logger software, digital oscilloscope, guitar pickup, audio amplifier and headphones, frequency meter, piano wire on wood bench, weights | little; we use the ULI for much data-taking, and its FFT for analysis. |
| Standing Waves in a Column of Air | Glass tube with microphone on a coaxial rod, speaker, analog oscilloscope, function generator with integral frequency meter | none; we continue to use our analog scopes |

I will show now printouts of various scope displays that illustrate measurements that are or can be made in these experiments.