MASSACHVSETTS INSTITVTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.002x – Circuits and Electronics
20 February 2004

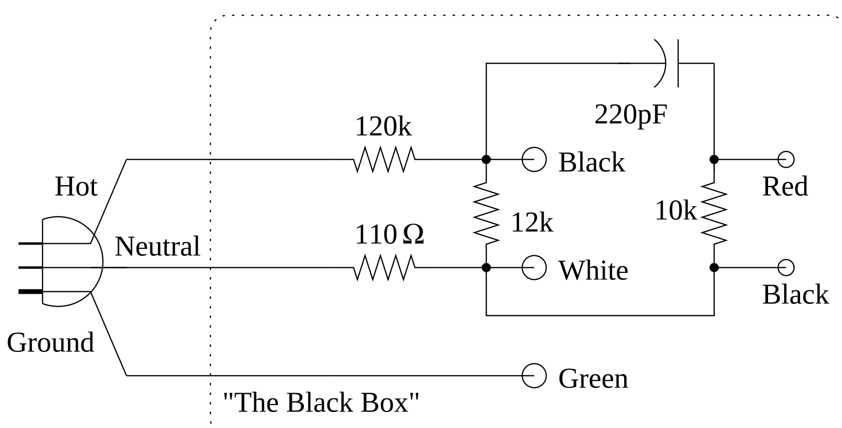
Laboratory 1: Measuring X-10 signals

This laboratory is focussed on electrical measurement of X-10 signals in power circuits. We will learn about the use of instruments, such as the digital multimeter (DMM) and the oscilloscope. We will learn about safety: how to safely examine the signals on the power line. We will observe the superposition of the X-10 signals on the 60 Hz power waveform, and we will see why we need a filter to separate the X-10 signal from the power. We will not understand the filter now, but we will by the end of the term.

In order to safely examine the waveforms on the power line we must

- reduce the voltage that appears across exposed terminals (why?)
- limit the current available at exposed terminals (why?)

We have prepared a "black box" that plugs into the power line and presents safe terminals for you to measure. The box has the following stuff in it:



The large circles represent the colored terminals on the box. You may attach the probes of instruments to these terminals to observe the 60Hz waveform. Each terminal is labeled with the color of the plastic ring around that terminal on the actual box.

The small circles represent the smaller terminals on the box. These are the outputs of the filter that will allow us to see the small 120 kHz X-10 signal superimposed on the 60 Hz power waveform, by suppressing the 60 Hz component.

Before coming to lab

Write one or two short sentences, answering the following questions:

- What is the maximum voltage that can appear between the exposed terminals of the black box?
- What is the maximum current that can be drawn from the black box, if you short any two terminals? (Assume that the capacitor is an open circuit for 60 Hz.)
- Why is it essential that the plug that connects to the power line be properly polarized here? How could it be deadly if it were not correctly connected?

In the lab

Becoming familiar with the lab equipment

The best way to become acquainted with the lab equipment is to use it. In our lab we will be dealing with three types of equipment: The oscilloscope, the digital multimeter and the function generator.

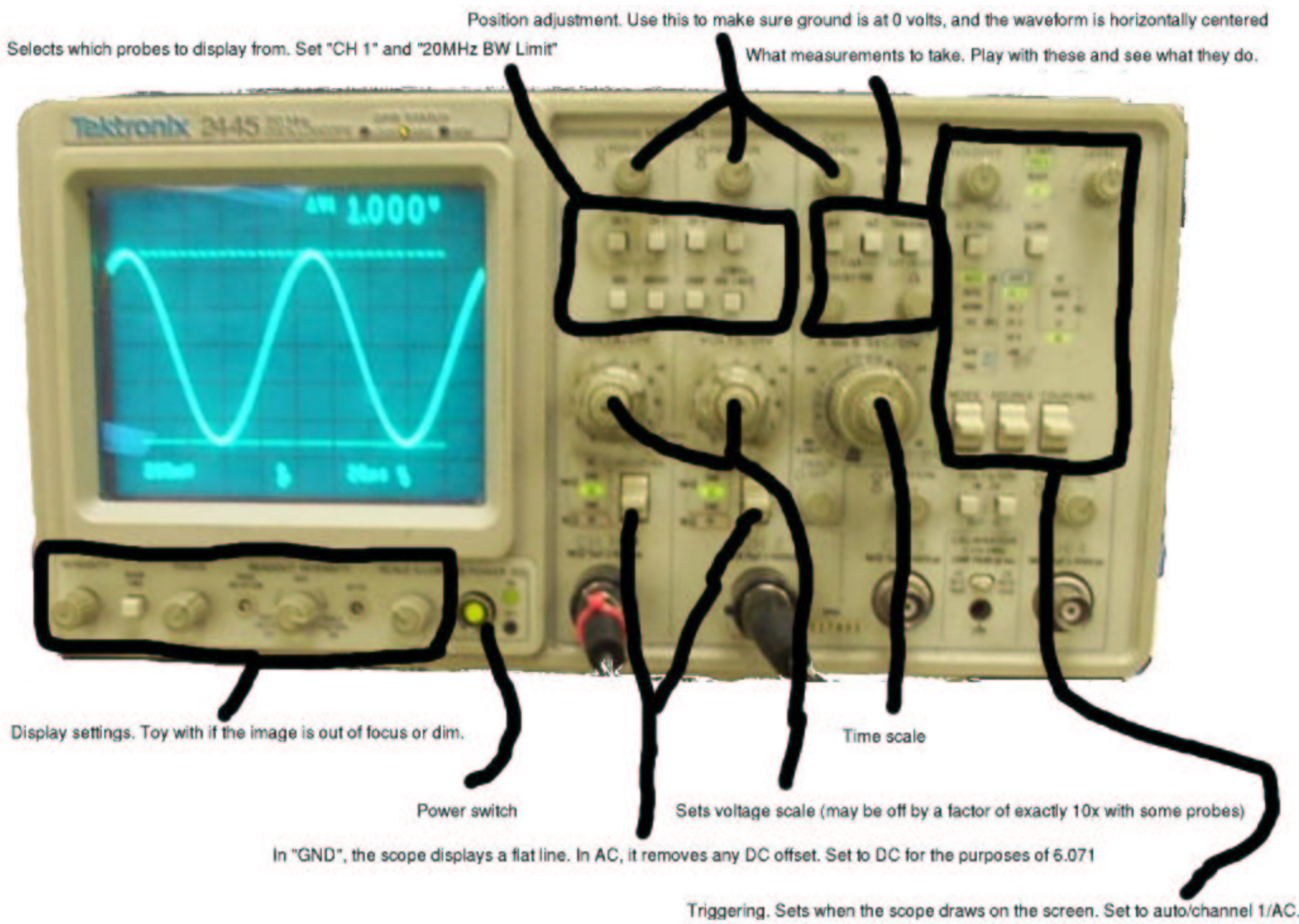
First turn on your scope and function generator. Connect the output of the signal generator into the scope. Fiddle with the knobs until you see a trace showing a signal. The proper scope configuration is shown in the figure. If you can't get this to work pretty quickly (5 minutes of active fiddling), ask for help.

Next we will calibrate the scope. Fiddle with the vertical position knob for the channel you are using (at the top of the scope, labeled "position"), and see how it moves the signal up and down. Set channel one coupling to "Ground" mode. This ties the input to ground instead of taking it from the probe, so you'll see a horizontal line. Turn the offset knob until the line is across the center of the screen. Switch the coupling back into "DC" mode.

Set the function generator to output a 1 kHz sine wave at 5 Volts. Measure the amplitude of the output on the scope (peak to peak) and the digital multimeter (AC setting, so RMS voltage).

Looking at 60 Hz waveforms

1. Plug the "black box" into your bench power strip.
2. Use the DMM to measure the RMS voltage between the Black and White terminals. Is this consistent with the resistor values and the nominal line voltage?
3. Use channel 1 of the oscilloscope to visualize the waveform between the Black and White terminals. You should think about the following questions and write a one sentence answer:
   (a) Which terminal must be attached to the ground of the probe?
   (b) How do you enable the trace for that channel?



(c) How must you set the input coupling for the channel?

(d) How do you set the channel gain to obtain a waveform that displays well on the 'scope? Are you in calibrated mode?

(e) How must you adjust the timebase?

(f) How must you adjust the trigger?

(g) What is the amplitude of the sinusoid you see? How do you compute it from what you see and the settings you have made? How does it relate to the RMS voltage you measured before?

(h) What is the frequency of the sinusoid that you see? How do you compute it from what you see and the settings you made?

You will note that the actual 60 Hz waveform is not a very nice sinusoid. The power plant puts out a much nicer waveform. Speculate about the reason for this observation. How might the characteristics of the load affect the waveform? Consider the fluorescent lights.

Looking at X-10 waveforms

4. Plug in the X-10 control box into the bench power strip. Again, write one sentence answers to each of the following questions.

5. Without changing the settings for channel 1, can you see any change to the waveform on channel 1 when you push the buttons on the control box?

6. Without changing the settings for channel 1, attach the channel 2 probe to the filter outputs. Make sure that you attach the probe ground for channel 2 to the correct output.

7. Adjust the channel 2 coupling and gain so that you see the X-10 signal on the channel 2 trace, when pushing a button on the control box. (How do you know which is the channel 2 trace?) What is the amplitude of the X-10 signals that you see?

8. Where in the 60 Hz waveform cycle does the X-10 signal appear? Sketch the X-10 waveform, showing its relationship to the 60 Hz waveform.

9. Demo: Instructors will use a storage 'scope to capture the X-10 signal for some particular command. Can you decode the command?