

Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 - Circuits and Electronics

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Lab Equipment Handout

(Handout F04-009)

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This handout is intended to provide a brief technical overview of the lab instruments which we will be using in 6.002: the oscilloscope, multimeter, function generator, and the protoboard. It incorporates much of the material found in the individual instrument manuals, while including some background information as to how each of the instruments work. The goal of this handout is to serve as a reference of common lab procedures and terminology, while trying to build technical intuition about each instrument's functionality and familiarizing students with their use. Students with previous lab experience might find it helpful to simply skim over the handout and focus only on unfamiliar sections and terminology.

THE OSCILLOSCOPE

The oscilloscope is an electronic instrument based on the cathode ray tube (CRT) – not unlike the picture tube of a television set – which is capable of generating a graph of an input signal versus a second variable. In most applications the vertical (Y) axis represents voltage and the horizontal (X) axis represents time (although other configurations are possible). Essentially, the oscilloscope consists of four main parts: an electron gun, a time-base generator (that serves as a clock), two sets of deflection plates used to steer the electron beam, and a phosphorescent screen which lights up when struck by electrons. The electron gun, deflection plates, and the phosphorescent screen are all enclosed by a glass envelope which has been sealed and evacuated.

The visible part of the CRT tube, the "screen", is the outside of the glass wall on whose inner surface lies the phosphorescent film. The screen is inscribed with a set of axes enclosed by a grid. As

the oscilloscope operates, the electron beam traces a graph of the input voltage versus time on the phosphorescent film behind these axes. The horizontal axis is the time axis, and the vertical axis is the voltage axis.

PRINCIPLES OF OPERATION

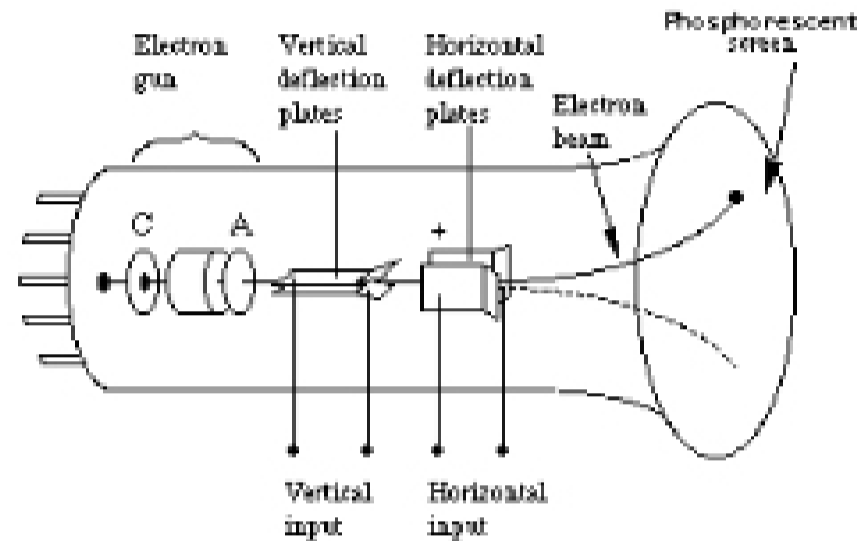


Figure 1 The internal parts of an oscilloscope

The main component of an oscilloscope is an electron gun which ejects a constant beam of electrons into the surrounding vacuum (see Figure 1). As the beam emerges from the gun, it passes through a set of parallel plates (the **Vertical deflection plates**) oriented horizontally. The voltage to be displayed is amplified and applied across these plates producing an electric field which deflects the path of the electrons vertically. The polarity of the signal of interest determines whether the deflections will be up or down and the magnitude of the signal determines the amount of vertical displacement of the electrons.

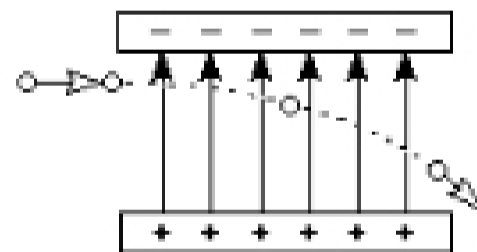


Figure 2 Deflection of an electron in a uniform electric field

After the beam has passed through the **Vertical deflection plates**, it passes through a second set of similar plates that are oriented vertically. A potential difference applied to these plates produces an electric field which deflects the electrons left or right. Under most configurations (one common exception is XY mode to be discussed later), these **Horizontal deflection plates** make the

beam move sideways at a constant speed. By adjusting this speed with the Sweep knob, the resulting trace on the screen can be spread out or compressed.

If the two deflecting voltages were held constant, the electron beam would strike a fixed point on the phosphorescent film and a stationary point would be visible on the screen. However, most voltages of interest are time-varying and so the voltage applied to the **Horizontal deflection plates** is varied with time in such a way that the spot moves from left to right on the screen as time passes. Since the phosphorescent material has the property of emitting light for several milliseconds after the electrons have passed, the total effect is for the electrons to leave behind a visible trail – a time-varying waveform.

The horizontal deflection voltage (or "sweep" voltage) is also varied in such a way that when the beam reaches the right-hand edge of the screen, it starts over at the left-hand side. If the signal to be displayed varies periodically in time, it is possible to synchronize the sweep voltage with the signal so that the curve appears motionless on the screen. This is done with the **Trigger Level** control which sets the oscilloscope to begin a trace when the voltage it measures reaches a certain value. The (+) or (-) button lets you choose whether you want the oscilloscope to trigger on a positive or negative voltage. A trace that is running across the screen can usually be stabilized by adjusting the trigger level (as long as the waveform is periodic!).

USING THE SCOPE

Now that we have acquired a basic understanding of how the oscilloscope works, we can proceed to explore some of the most common tasks which can be accomplished with it. The oscilloscope which we will be using in 6.002 is the Tektronix 2445 - a four channel (input) scope. Since the oscilloscope has four channels, we could simultaneously graph four distinct input voltages on the CRT (although we won't get that complicated in 6.002!). Aside from the display itself, the oscilloscope consists of various control panels which give the user complete control of how the scope processes and displays its inputs. In the section that follows we will describe each of the control panels and outline the functionality of each of the settings found therein.

THE DISPLAY