Name/NetID: Teammate:

Points: ____/8

Module: The Oscilloscope's XY Mode

Module Outline

In this module you will use the oscilloscope in a different mode. This mode can be used to trace out the transfer characteristics of many different devices (called IV curves in lecture). For this experiment, you will need to cooperate with a neighboring team to share their function generator.

When the oscilloscope was used in previous experiments, a time-varying signal was input to channel 1 and/or channel 2. The oscilloscope displayed the signal voltage along the vertical axis vs. time along the horizontal axis. Sometimes it is useful to replace time on the horizontal axis with a "control" signal from an external source. This can be done using the xy *mode*.

Consider, for instance, if we wanted to display the current/voltage (IV) characteristics of a diode. The scope could be used to measure the voltage across the diode, V_D, and plot that vs. time. Suppose we also measure (using Ch. 2 of the scope), the voltage across a series resistor, V_R. By Ohm's Law, V_R is proportional to the current flowing through the diode, so an oscilloscope plot with V_R on the vertical axis and V_D on the horizontal axis would provide a (scaled) view of how the current through and voltage across a diode are related to each other.

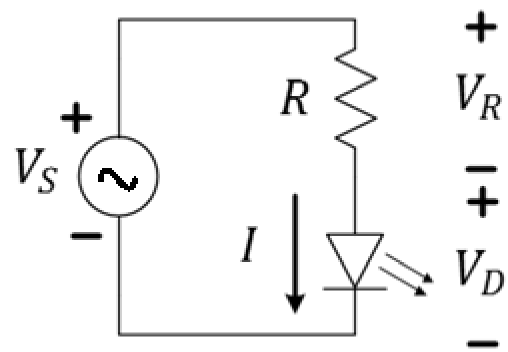

Figure 1: A useful application of the oscilloscope's xy-mode would be to plot V_R vs. V_D for this diode circuit and scale the result to represent I vs. V_D.

A fun way to experiment with this mode is by generating **Lissajous figures** – these are figures created by connecting channel 1 to a function generator outputting a sine wave and channel 2 to a different sinusoid - hence the need for sharing functions generators. By letting channel 1 drive the horizontal and channel 2 the vertical, a shape will be traced out on the scope's display.

In this mode, the variations in x *and* y are time-varying. For example: consider the two equations $x(t) = \sin(t)$ and $y(t) = \cos(t)$. The resulting shape is described by a single equation, $x^2(t) + y^2(t) = 1$, which is the equation of a circle. The set of equations, where the variables, in this case *x* and *y*, are written in terms of another variable, in this case *t*, are called *parametric equations*. Often, it is not simple to find an equation for the shape of the resulting curve. In such cases, we may take a graphical approach to understand the resulting figure.

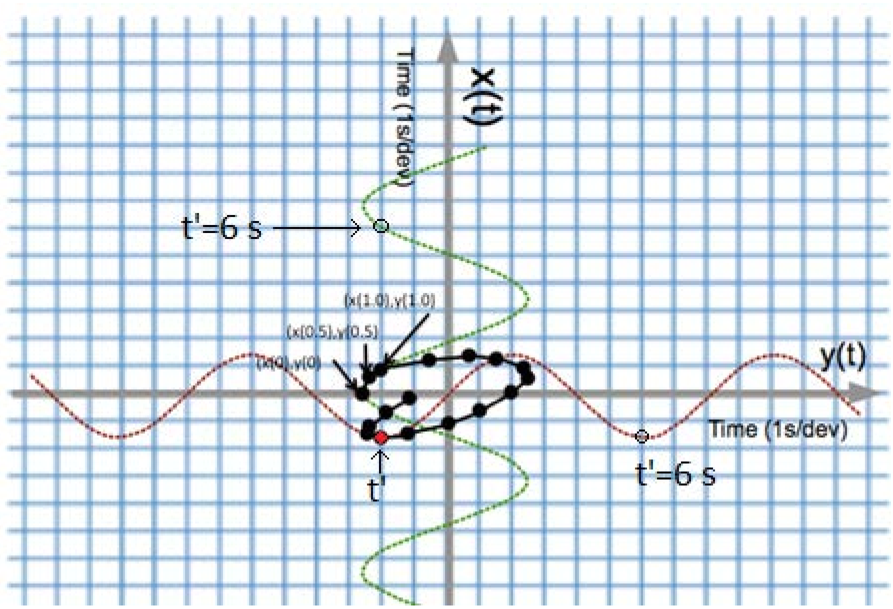

Figure 2: Graphical description of the xy mode. At each point in time, t' ($t' = 6\ s$ in the example above), the amplitude of $y(t')$ and the amplitude of $x(t')$ provide a data point to be plotted on the oscilloscope. NOTE. The time-varying voltage signals $x(t)$ vs. t and $y(t)$ vs. t (shown in red and green above) are never actually plotted on the oscilloscope unless taken out of xy mode.

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By plotting $x(t)$ along the vertical axis and $y(t)$ along the horizontal axis the resulting curve can be drawn by plotting $(x(0), y(0))$, $(x(0.5), y(0.5))$, $(x(1), y(1))$, … For the frequencies of the sine waveforms depicted in the graph above, it will take many cycles before the curve begins to repeat itself. Only the time interval $t = 0 - 8\ s$ has been plotted.

Wikipedia and YouTube have a wealth of information about these curves. It is probably the most fun you can have with an oscilloscope (unless it secretly plays Tetris as did our old scopes). Laser light shows often use complex parametric equations to draw interesting figures with light.

To understand some of the questions in this module, think about the following set of parametric equations and the shape of the figure that would result from each:

1. Identical sine waves
   - $x(t) = \sin(2000\pi t)$
   - $y(t) = \sin(2000\pi t)$
2. Sine waves with the same frequency but out of phase by $\frac{\pi}{2}\ rad$ (that is, $90°$)
   - $x(t) = \sin(2000\pi t)$
   - $y(t) = \sin(2000\pi t + \pi/2)$
3. Sine waves with the same frequency with a phase difference that varies with time
   - $x(t) = \sin(2000\pi t)$
   - $y(t) = \sin(2000\pi t + \phi(t))$

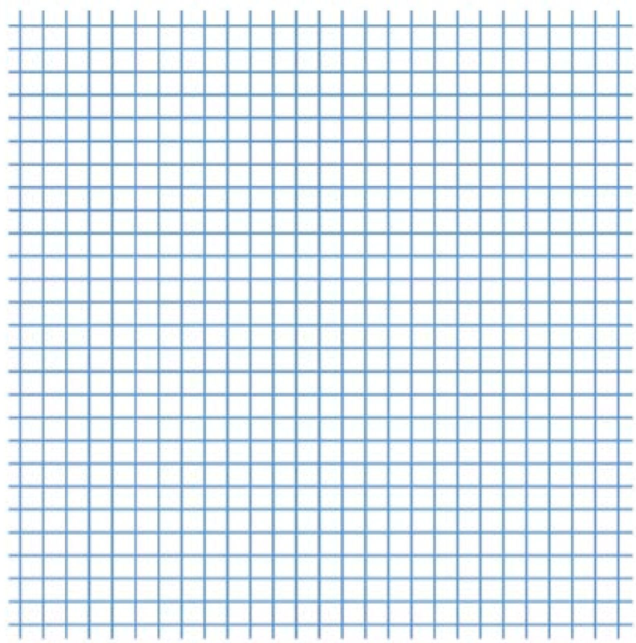
Notes:

Procedures

Using the output from 2 function generators, generate Lissajous figures.

- ✓ Connect the output of your function generator to channel 1 of the oscilloscope. Have the function generator output a sine wave with a peak-to-peak amplitude of 2V, a frequency of 1kHz, and a 0V offset.
- ✓ Connect the output of your neighbor's function generator to channel 2. Have the function generator output a sine wave with a peak-to-peak amplitude of 2V, a frequency of 1kHz, and a 0V offset. You can use the function generator at the same time as your neighbors if you use a special connector – a T connector – that allows 2 BNC connectors to connect to the output of the function generator. Please see your TA if you do not have one.
- ✓ At this point you should see two sine waves on the display of the oscilloscope. Push the ***Menu/Zoom*** button on the oscilloscope in the set of buttons controlling the horizontal sweep and put the display in XY mode. The oscilloscope is now displaying the same information except now one of the sine waves is driving the x-axis deviations and the other the y-axis.

Question 1: Draw the figure on the graph below.



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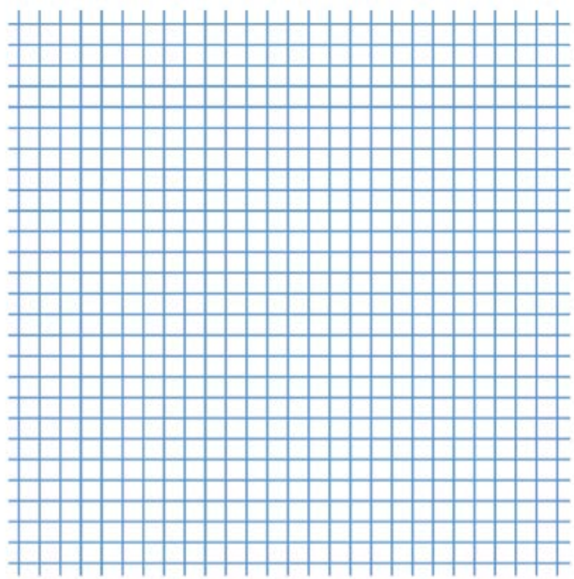
Question 2: Consider that the outputs of the both signal generators are sine waves of identical amplitudes and frequencies. Is the resulting figure what you expected? Explain.

Question 3: Is the figure time-varying? Describe how the figure is changing.

Question 4: Change the frequency of one of the function generators to 2kHz. Draw the resulting figure on the graph below.



Question 5: The following chart shows you some of the possible curves you can draw by varying the frequency and phase of the sinusoidal functions. Unfortunately, the phase of the signal generator outputs is fixed, though it often drifts slowly with time. Play with all sorts of different frequency combinations and see how many you can create. If you have a camera, take snapshots of your favorite (if not, sketch them on the right)!

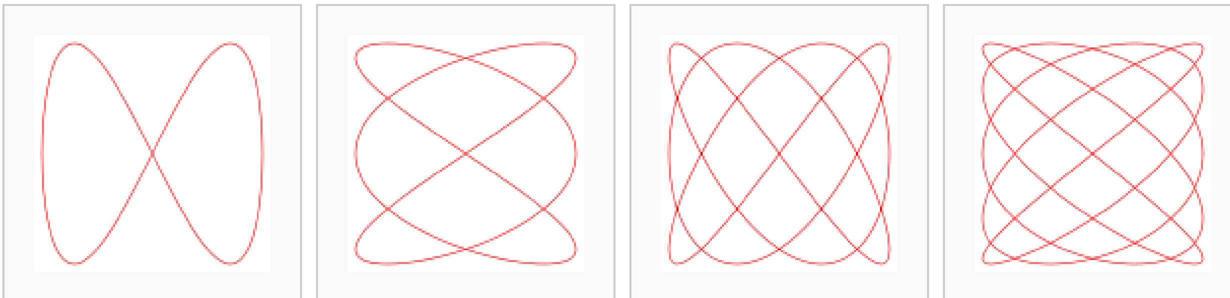


Figure 3: Typical Lissajous shapes. Source: http://en.wikipedia.org/wiki/Lissajous_curve. CC BY-SA 3.0.

Having fun? Try some other stuff…

- ✓ Because the important parameter is the *proportional values* of the frequencies of the two signals you can *watch* the figure being drawn. Reduce the frequencies of the signals to 10Hz and 20Hz. You should see a dot tracing out the figure you got in question 4.
- ✓ There are more functions that you can try – the signal generator can provide a sine wave, a square wave, a triangle wave, a sawtooth wave, a cardiac signal, a signal that sweeps frequencies, and many, many more. Play around with the function generators to see what patterns you can generate.
- ✓ Build the diode circuit of Figure 1 and plot the IV characteristic of a diode.

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