

LAB 1

Introduction to Equipment and Circuits

The basics of Thévenin's theorem and AC circuits are covered in Physics 234 or Physics 231. You may wish to review that material before starting these labs.

Reading: Malvino: Ch. 1., Ch. 16, sections 9, 10, 11,16, 17,18, 19, 20

Hayes and Horowitz: Class 1, Worked Examples and Lab 1.
Especially "*A preliminary note on procedure*."

Hayes and Horowitz: Class 2, Worked Examples and Lab 2.
Read "*A Note on Reading Capacitor values*", p51, H&H

Hayes and Horowitz: Class 2, p 44 , Class 3, sections A and B, Lab 3, section 3-1

Horowitz and Hill: section 1.22

1. Oscilloscope and function generator

These are a few warm-up exercises in using the Hewlett-Packard function generator and Tektronix Digital Oscilloscope.

a) Show two signals on the oscilloscope display

Adjust the function generator to produce a sine wave set the AMPLITUDE to 2 V_{pp}. Apply the sine wave signal from the function generator to Channel 1 of the oscilloscope. Simultaneously apply the SYNCH output signal of the function generator to Channel 2. Press, in sequence, the oscilloscope's AUTOSET, CLEAR MENU and CH 1 buttons. AUTOSET should configure the scope to measure the signals coming into the inputs. The CLEAR MENU and CH 1 buttons ensure that the display is clean and your next operations will affect the CH 1 display. The green light next to CH 1 should be lit. You should see a 2 V_{pp} signal displayed on the CH 1 trace and a square wave displayed on the CH 2 trace. What is the peak-to-peak voltage of the square wave?

Hint: The function generator's output voltage display depends on the Z_{out} setting of the function generator. Z_{out} can be set to either 50 Ω or infinity. If the setting is 50 Ω then the displayed output voltage will be 1/2 the voltage produced by the function generator, because it assumes it is driving a 50 Ω load and the output voltage is split evenly between its 50 Ω output impedance and a 50 Ω load. If Z_{out} is infinity then the display will be the full voltage produced by the function generator, which is the voltage applied

to a very high impedance load. For this course the Z_{out} setting should be infinity. The Z_{out} setting does not affect the actual output of the function generator, it only changes the numerical display.

b) Change the scale and position of the waveforms

Turn the SCALE knob under VERTICAL. Notice how the display changes. The V/DIV legend beneath the display reflects the scale changes. Adjust the CH 1 scale to 1 V/div. Press CH 2 and investigate the VERTICAL SCALE adjustment as before and leave CH 2 on 1 V/div. Press CH 1. Play with the VERTICAL POSITION knob.

Turn the HORIZONTAL SCALE knob and note how the displayed waveform changes. The legend beneath the display reflects the change in sweep rate. Move the trace left and right with the HORIZONTAL POSITION control.

After you have changed a few settings you should be able to return to the original configuration by pressing AUTOSET. The result of AUTOSET depends on the signals which input to the oscilloscope, so if you have changed the function generator output in any way AUTOSET will result in a different configuration. Furthermore, not all of the oscilloscope's function settings are reconfigured by AUTOSET. It is possible to save all settings of particular configuration for later recall from the oscilloscope's internal memory. See the User's Manual for how to do this.

c) Investigate the difference between AC, DC, and GND input coupling.

Press VERTICAL MENU. Observe the signals when you choose AC, DC and GND on the menu. Normally you use DC, even when you are measuring AC signals. The purpose of the AC coupled input is to subtract a DC offset from a signal so that you can magnify the alternating component. Add a DC offset to the signal by pulling the OFFSET button on the function generator. You should notice that AC coupling subtracts the offset from the displayed waveform.

Avoid AC coupling unless you need to subtract an offset — at low frequencies AC coupling can distort the signal's display. AC coupling puts a high-pass filter on the input to remove the DC offset. So see this, put the coupling on AC and decrease the function generator's frequency until the signal starts to appear smaller in amplitude. After you finish put the frequency back to its original value.

d) Learn the operation of the scope's sweep and trigger controls.

Press TRIGGER MENU. Make sure trigger source is CH1. Vary the level control to observe the effect of changing the trigger level. There is a floating T on the screen to show you

where the triggered position of the input signal is displayed. There is also an arrow on the right-hand side of the screen to indicate the trigger voltage level. If either of these indicators are not visible they may have been turned off. Consult the user's manual or an instructor to find out how to turn them on again.

Change the trigger source to CH 2, which displays the SYNCH signal. What effect does changing the trigger level have now?

Change the trigger slope from positive to negative. Note the difference.

There's a button labelled "Set Level to 50%" which is handy to quickly stabilize a signal on the screen when you don't know where the trigger level should be set.

Reconnect the SYNCH signal from the function generator to EXT TRIG. Select EXT TRIG for the trigger source. This frees CH 2 for observing another signal while still allowing the trigger signal to come from SYNCH of the function generator.

e) Learn to measure frequency, assuming that the horizontal time base is accurately calibrated. Centre the displayed waveform about a horizontal line. Measure the period from zero crossing to zero crossing and calculate the frequency. Compare with the value obtained using the MEASURE menu and from the function generator readout.

f) Generate Lissajous figures by applying two signals of different frequencies to CH 1 and CH 2 (Use the transformer for one signal.) Choose the DISPLAY menu and switch to the XY display instead of the YT display. If the HORIZONTAL SCALE setting is vastly inappropriate for the signal being displayed, the Lissajous figure may be incomplete. To see this, try varying HORIZ SCALE when displaying a Lissajous figure to make sure at least one full cycle is being displayed.

g) Invert a signal using the VERTICAL menu and add, subtract, multiply and divide two signals applied to the two channels using the MATH functions. Use the function generator for one signal, and the PROB COMP signal for another.

h) Printing

There is a program which allows downloading the oscilloscope display to a computer attached to the oscilloscope through the IEEE-488 interface. One can save the scope display in a file or print it on the class printer. Ask your instructor if it is available and how to use it.

2. Cascaded Filters

a) Investigate the frequency response of a low-pass filter made by cascading two identical RC filters. How does the 3dB point of the combination compare to that of the individual filter? Is the attenuation larger than 6dB/octave at frequencies well above the 3dB frequency?

b) Build a band pass filter by cascading a high pass and a low pass filter. To avoid each filter seriously affecting the other, use the following design criterion: the output impedance of the first filter should be about $1/10$ the input impedance of the second filter where only resistive impedances are considered. (The resistor values should be 1:10.) Measure its frequency response.

3. Fourier Analysis using a Parallel LC Circuit

Construct the parallel resonant circuit of Fig. 2.1. The parallel LC circuit is often called a “tank.” Pick values of L and C to give a resonant frequency of around 10 kHz. Measure the internal resistance of L . What is the Q value you expect from the resonant circuit. If the value of L the inductor is not well established, use the circuit to determine L .

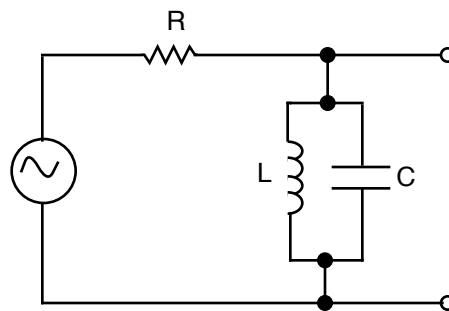


Fig 2.1
The Parallel LC Resonant circuit

Note: The parallel LRC circuit is analogous to the series LRC circuit. Whereas the series circuit is drive with an alternating voltage source, the parallel circuit is driven by a current source. The calculations in both cases correspond with each other if, in the parallel case, one uses admittances (complex conductance) to calculate currents instead of using impedances to calculate voltages. The function generator is a voltage source, but you can make an approximate current source by placing a relatively large resistor in series with its output. (The signal generator behaves as a current source if R is much larger than the magnitude of the impedance of the parallel LC circuit.)

Drive the circuit of Fig. 2.1 with a sine wave and carefully observe the frequency response of the output voltage. Set up the function generator to sweep a range of frequencies and display the response on the oscilloscope.

Next drive it with a square wave sweep. You will get peaks in the output sine wave response at the circuit’s resonant frequency and at certain lower frequencies that have harmonics at the resonant frequency. This is a sort of backward Fourier analysis. The first few terms of the Fourier expansion of a square wave should be roughly related to the peak frequencies and amplitudes.

Homework

1. Design the band pass filter for part 2b. Make the lower 3dB point 100 Hz and the upper 3dB point 10 kHz. Use a 1 k resistor and a 10 k resistor.
2. Make a spreadsheet to calculate the component values for the parallel LC circuit of part 1. Include a calculation for the Q of the circuit using the series resistance of L . Recall that one can model the series resistance as a parallel resistance for purposes of analysing the parallel LC circuit.
3. The purpose of the R in fig. 2.1 is to make the function generator appear to act like a current source. How effective is this and how might the limitations of this ruse affect the agreement between theory and experiment?