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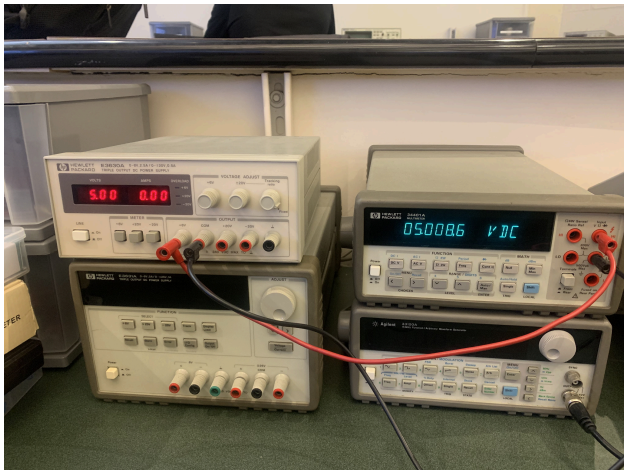
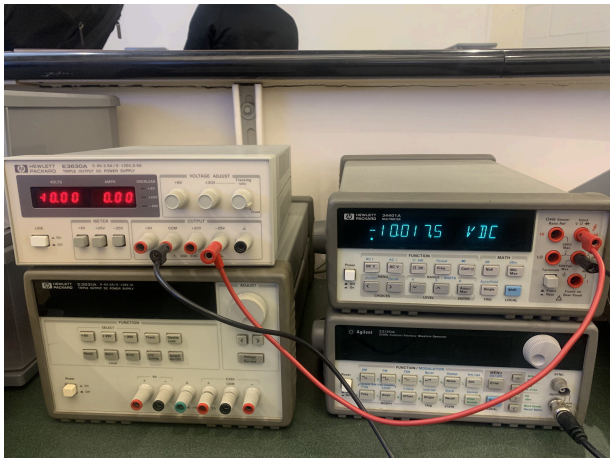
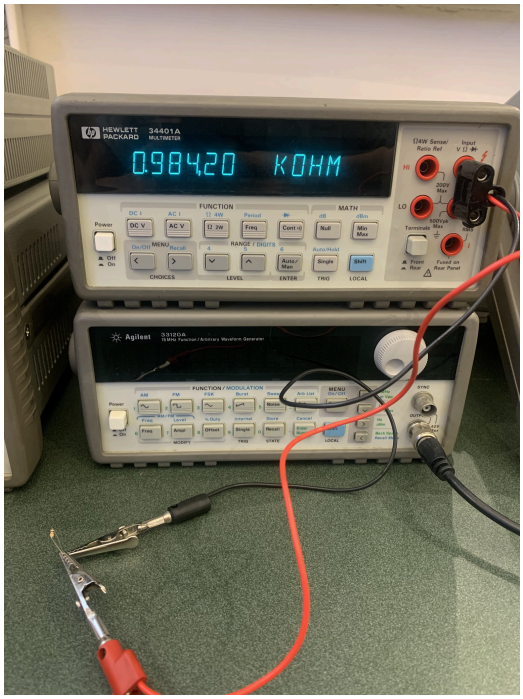
ECSE-2050 - Introduction to Electronics
Lab 1: Linear circuits
2024-01-10

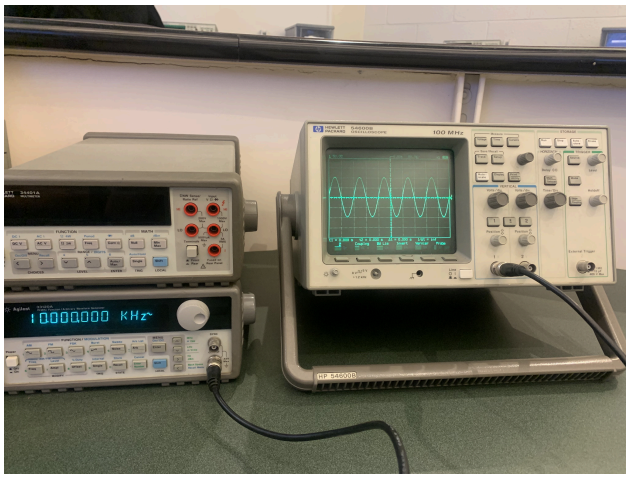
- Objective:
    - Learn to use the Lab Equipment
- Equipment:
    - HP E3630A Triple Output DC Power Supply
    - HP 34401A Multimeter
    - Agilent 33120A 15MHz Function/Arbitrary Waveform Generator
    - HP 54600B Oscilloscope
- Procedure:
    - Power Supply and Multimeter:
        - Output and measure +5V:
        - Power on both devices with power toggle button
        - Set Power Supply to display +6V with the +6V toggle button
        - Use banana-banana cables to connect Power Supply to Multimeter
            - Red goes +6V to input V, black goes COM to LO
        - Set Power Supply voltage to 5V with +6V dial
        - Set Multimeter Function to DC V with button
        - Set range to XX.XXX,X V or X.XXX,XX V by using the RANGE section
            - Either Auto or Manual with Up and Down
        - Make sure the multimeter reads the voltage you expect
        - Test again with -10V:
            - Swap red cable from +6V to -20V
            - Select -20V with toggle button
            - Set voltage to -10V with the -20V dial
            - Check for correct multimeter output
    - Multimeter
        - DC V has already been tested, just test resistance now
        - Replace banana-banana cables with banana-aligator
        - Connect 1k resistor to alligator clips
        - Set mode to resistance
        - Set range to X.XXX,XX kOHM, again with Auto or Manual up and down
        - Make sure output is correct
        - Power off both devices and return cables
    - Function Gen and Oscilloscope
        - Power on both devices
        - Connect output to channel 1 with BNC-BNC cable
        - Set function gen to desired settings

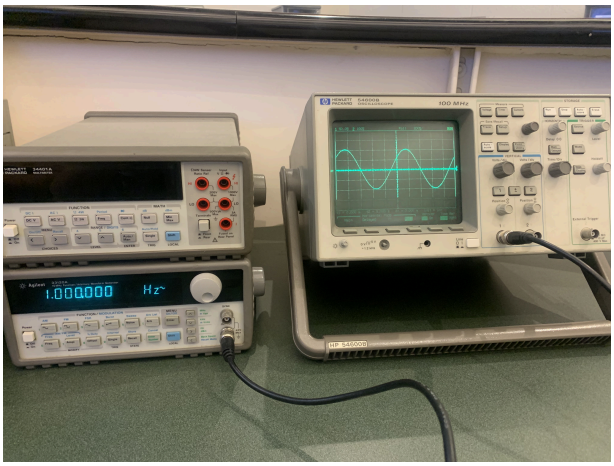
            - 10KHz, select frequency, use left and right buttons to select digit/unit, use dial to change it
            - Sine wave with corresponding button
            - 100mV, select Amplitude, change the same way as frequency
        - Tune Oscilloscope to read the signal
            - Run
            - Vertical volts/div until the whole wave amplitude can be seen on screen
            - Position should be 0
            - Horizontal time/div until a few periods are clearly visible
            - Trigger to 0V
        - Test other waveforms and frequencies
            - Set a low frequency (1Hz) and horizontal mode to roll for real time measurement
- Results:
    - All went according to plan, we completed our objective by learning how to use the equpment. Images below:


5.00 0.00
050086 VDC


+0.00 0.00
-100175 VDC


HEWLETT PACKARD 34401A MULTIMETER
098420 KOHM
Agilent 33120A


100 MHz
1.0000000 KHz


100 MHz
1.000000 Hz

Overall notes:
- This laboratory has one session allocated for completion
- All students are to deliver a lab report by the submission deadline

Answer the questions below

1. Consider the following: We apply a voltage and a current may result. Can we consider this as a cause-and-effect scenario? Can we consider this as a stimulus-and-response scenario? Can we consider this as an input-and-output scenario?
Yes, yes, and yes. Voltage can be considered a cause, stimulus, and input, while current can be seen as an effect, response, and output due to the voltage.

Resistor

2. What is the function of a resistor? Give the current-voltage characteristic of a resistor.
Resistors have many different use cases, but in general, they resist the flow of current by converting that energy to heat. They are ohmic, following V=IR. Plotting the IV graph, we have a line with constant slope 1/R.

3. Consider applying a voltage and we consider the voltage to be a cause and the resulting current to be the effect. Cause = 0 ⇒ Effect = 0? Is the effect proportional to the cause? Is a resistor a linear circuit element?
Yes, the effect is proportional to the cause, and resistors are a linear circuit element.

Capacitor

4. What is the function of a capacitor? Write the equation giving the impedance of a capacitor. Give the current-voltage characteristic of a capacitor.
The function of a capacitor is to resist change in voltage. $Z=1/(wC)$ (high impedance for low frequencies). $I=C\ dV/dt$ (change in voltage causes current flow)

5. Consider applying a voltage and we consider the voltage to be a cause and the resulting current to be the effect. Cause = 0 ⇒ Effect = 0? Is the effect proportional to the cause? Is a capacitor a linear circuit element?
No, 0V does not mean 0A, as voltage can momentarily be at 0 while increasing or decreasing, meaning current will be flowing. The correct variables to look at would be rate of change of voltage, and current. These give a proportional relationship, making a capacitor a linear circuit element.

Inductor

6. What is the function of an inductor? Write the equation giving the impedance of an inductor. Give the current-voltage characteristic of an inductor.
The function of an inductor is to resist change in current. $Z=wL$ (high impedance for high frequencies). $V=L\ dI/dt$ (change in current causes voltage)

7. Consider applying a voltage and we consider the voltage to be a cause and the resulting current to be the effect. Cause = 0 ⇒ Effect = 0? Is the effect proportional to the cause? Is an inductor a linear circuit element?
No, 0V does not mean 0A, as voltage can be non zero while current is passing zero while increasing or decreasing, there will be voltage with no current. The correct variables to look at

would be rate of change of current, and voltage. These give a proportional relationship, making an inductor a linear circuit element.

Power sources
8. Is a voltage source a linear circuit element?
Yes (ideally)
9. Is a current source a linear circuit element?
Yes (ideally)
10. Conversion of DC power sources: Can we transform any voltage source into a current source? Can we transform any current source into a voltage source?
Yes, if we have a Voltage source, we move the internal resistance to be parallel rather than series and turn it into a current source of I=V/R. To convert a current source to a voltage source, we move the internal resistance to series and turn it into a voltage source of V=IR.

Superposition principle
11. What is it?
A principle of linear systems with multiple sources.
12. When can we apply it?
When we have a linear system (RLC) with multiple voltage and/or current sources.
13. How do we apply it?
Given a linear system with multiple sources, we can ignore all sources but 1 at a time (shorting voltage sources and opening current sources), and find all currents and voltages. Do this for each source, sum together the results of each individual source, and you'll have the results of all the combined sources thanks to the systems being linear.

Forward-looking questions
14. What is a diode? What is the IV characteristic of a diode?
Essentially, a non linear resistor. There is little (ideally no) current flow until the voltage reaches a turn on voltage (often 0.7V or 0.3V), where above that it has an (ideally) constant voltage drop, that realistically increases slowly due to internal resistance. Ideally there is also no back current when a negative voltage is applied, but in reality there is, and at some larger negative voltage (often -50V to -100V) the diode will break down and allow significant current flow.
15. What is the turn-on voltage (also called threshold or knee voltage) of a Si diode? Is a diode a linear circuit element? What is the mathematical function of a diode's IV characteristic?
The turn on voltage of an Si diode is 0.7V (Ge is 0.3). Diodes are non linear because the IV relationship is non linear. The function of an ideal diode with internal resistance would be
$I=f(V)=\begin{cases} V<0.7 & 0 \\ V\geq 0.7 & (V-0.7)/R \end{cases}$
Though realistically, there's breakdown voltage, and the curve is more smoothed than a piecewise of linear functions.
16. Can you experimentally verify any of your statements?

Yes, you simply connect a diode to a power supply and measure current as you vary voltage. A current limiting resistor may help. (by the wording of this question I assume actually doing this isn't necessary)

17. Can you confirm any of your statements by simulation (Spice)?

Yes, again, you simply measure current as you vary voltage. (Diode profiles in LTspice are a pain, I'm just using the default)