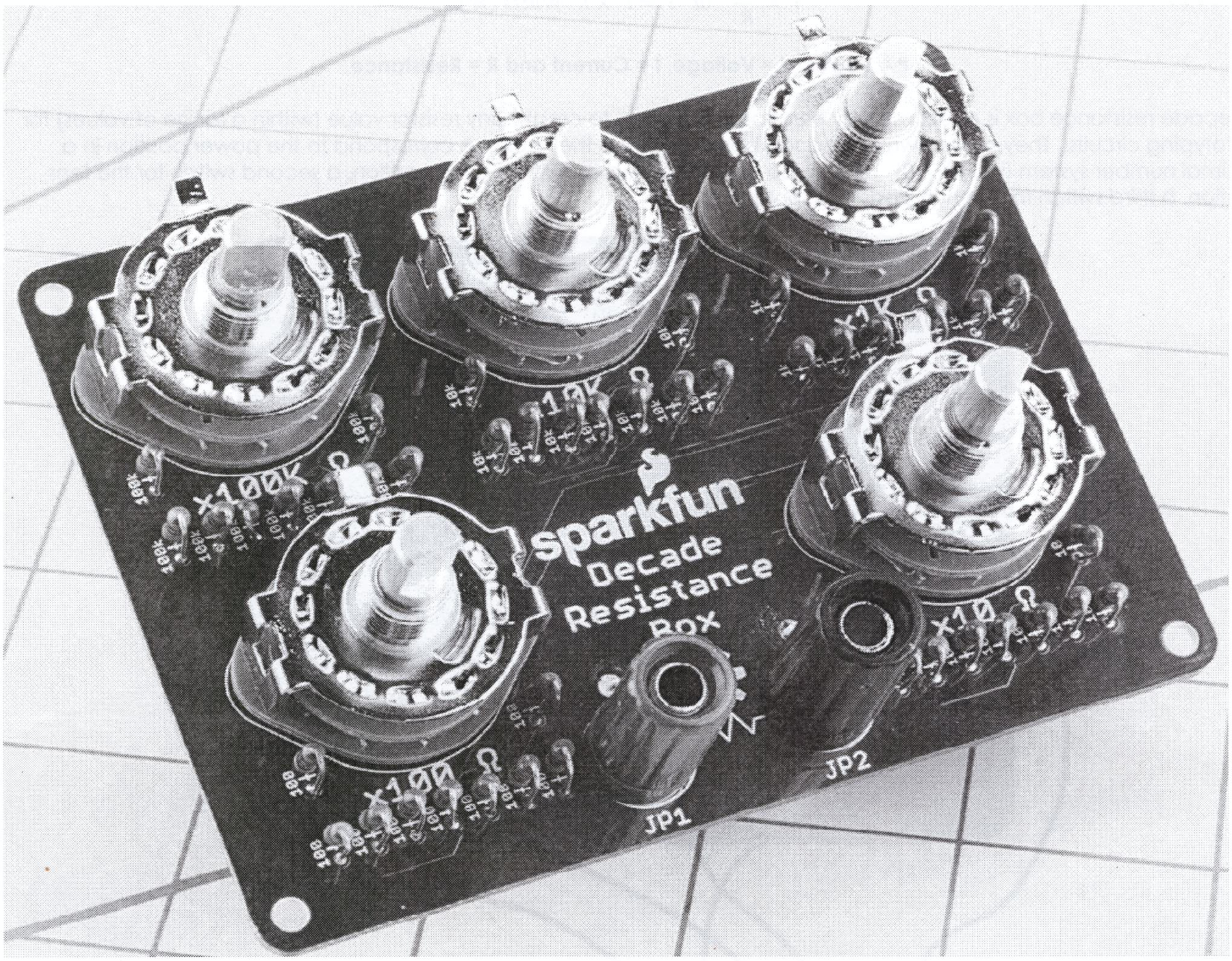
ECET 190 DECADE RESISTANCE BOX PROJECT



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html
lab site

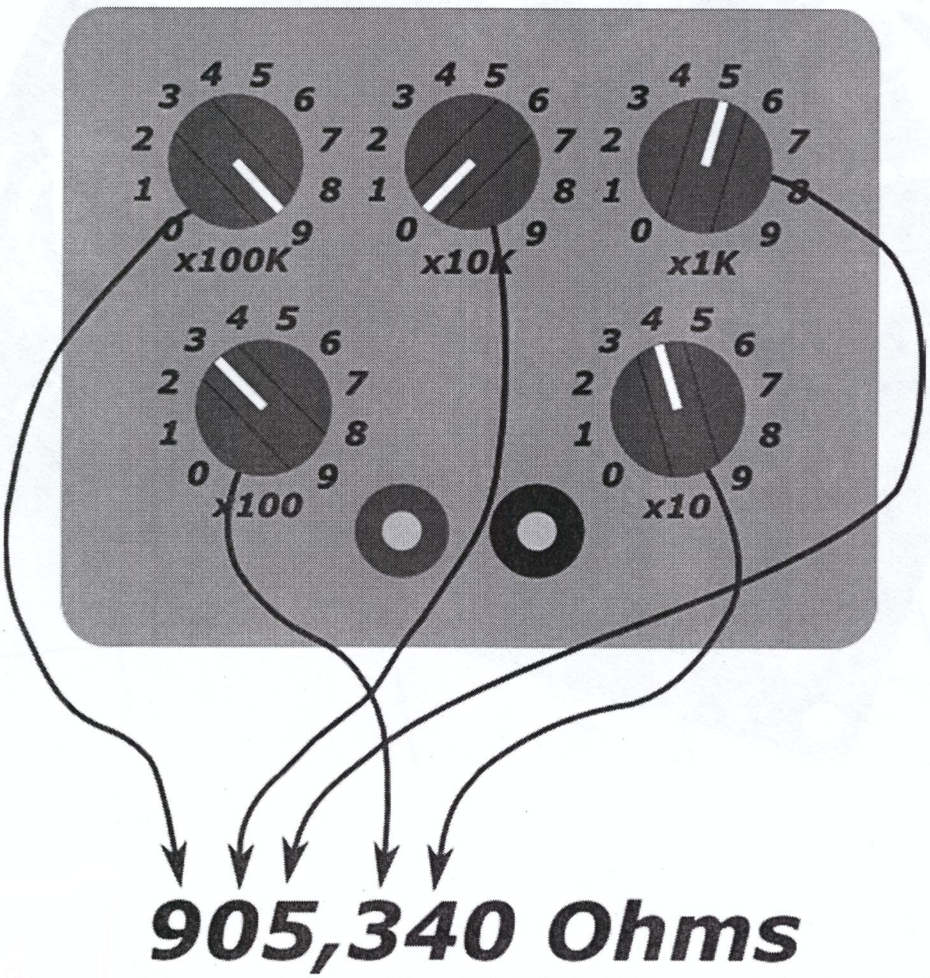
Introduction

Resistance is a unit used to indicate how much a circuit or device resists the flow of electricity. It is measured in units called Ohm's and it has been given the Greek symbol of Ω (Omega). We will use a digital multimeter to measure resistance. The resistors included in the kit are have a tolerance of 1% which means that if the stated value is 100Ω then the measured value is expected to be between 99Ω and 101Ω or 100Ω ± 1%. Resistors also have a power rating which is an indication of how much heat they can dissipate before breaking. The resistors in your kit are 1/4W (or 250 mW) which means you have to be careful and calculate the power used by the decade box before connecting it to a circuit. Power can be calculated a few different ways but the formulas you will need are:

$$P = \frac{V^2}{R} \quad or \quad P = i^2 \times R \quad Watts\ (W)$$

P = Power, V = Voltage, I = Current and R = Resistance

A decade resistance box is a tool used by electronic designers to create any resistor value (within a range of values) for prototyping circuits. They are known as *decade* boxes because their controls correspond to the power position in a decimal number system (i.e. 10^0, 10^1, 10^2 ...). So one switch represents the ones position, a second switch for the tens position, a third switch for the hundreds position and so on.



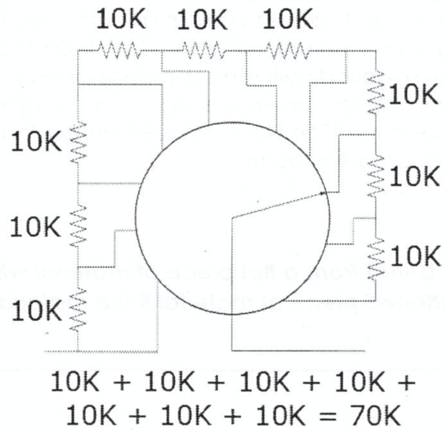
Your decade box will have a resistive range between 0Ω and 999,990Ω in 10Ω increments (no 'ones' switch). Once the switches are set the total resistor value will be a summation of five resistor values.

The decade box is the final project of the ECET 190 course and will use all the skills that you have learned.

Question 1: ***How many resistor value combinations are possible?***

Schematic

Here is the schematic of the 10kΩ switch:

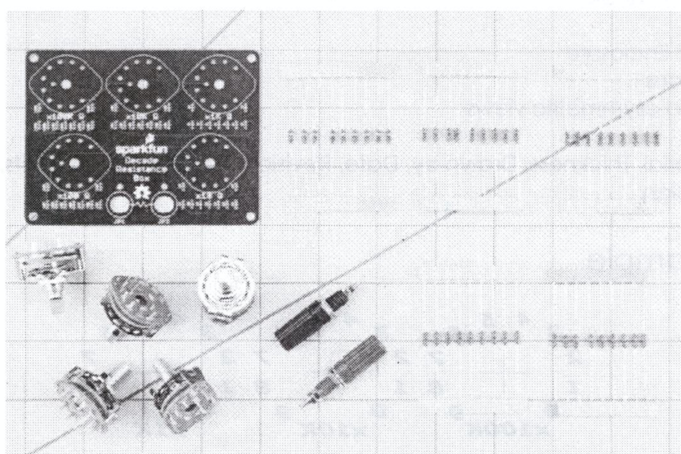


The other switches are the same except with different resistor values. The switches are wired in series which means that all the switches add together to create the total value of resistance of the decade box.

Tasks

Kit Check

Check that the kit contains all the parts below:



- One Decade Resistance Box PCB
- Nine 10 Ω Resistors (Brown - Black - Black - Gold - Brown)
- Nine 100 Ω Resistors (Brown - Black - Black - Black - Brown)
- Nine 1000 Ω Resistors (Brown - Black - Black - Brown - Brown)
- Nine 100K Ω Resistors (Brown - Black - Black - Orange - Brown)
- Nine 10K Ω Resistors (Brown - Black - Black - Red - Brown)
- One red banana jack
- One black banana jack
- Five 1-pole 10-position rotary switches, each with a dress washer and hex nut

If all parts are present and accounted for initial the Parts kit check box at the back of this document.

Working Drawing

In this task you will create a drawing of the enclosure that you want to enclose your decade box. To create this drawing will require that the center to center hole distance be known so that the clearance holes for the switch shafts can be drilled in the correct location. The drawing created must contain all parts used to create your enclosure. The drawings have to contain enough information that someone unfamiliar with the decade box could build the enclosure correctly. Therefore, nothing can be left to question so your drawing must include appropriate dimensions, material used and enough drawing views to represent the enclosure. Dimensioning your drawing means that the tolerance has to be reasonable. Please specify your tolerance in the 'Title Block' and remember that when your project is marked your tolerance will be verified against the fabricated enclosure.

Question 2:

If you want to create an 'L' shape (90^0 bend) from a flat piece of material with final outside dimensions of 1" by 1", what will be the dimensions of your flattened piece of material if the material is 1/16" thick?

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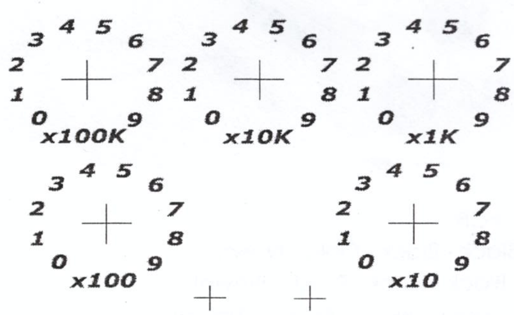
The working drawing must be signed off by your instructor before continuing. The instructor's signature does not guarantee that your enclosure is correctly designed but that you have spent enough time thinking through and documenting your design.

Your overall enclosure cannot exceed an envelope of 5"x4"x2". Smaller is perfectly acceptable. There must be at least 2 rivet holes (4 max) for joining the top and bottom halves of the enclosure together. The banana jacks can be mounted to the top or side of the enclosure. You can apply your own creativity to the design and add things like a sloping face plate or even, if you dare, go for a stealth look with side with angles less than 90^0. Marks will be added for increased difficulty; *however, poor execution of all designs will result in lost marks.*

The working drawing needs to include:

- Flattened Drawing of Enclosure
- Appropriate Dimensions
- Top, bottom, side and asymmetric views
- List of Fasteners used
- Title Block (Title, Material, Thickness, Drawn by, Date, Revision, Revision History, units, tolerance and scale)
- Face Plate Label Design

Face Plate Sticker Example



Cardboard Prototype

Once the drawing is approved you will need to create a full scale cardboard prototype of the enclosure including all holes. This will allow you to verify that your drawing is correct while working with a more forgiving material.

The prototype will be created from old file folders and both halves of the enclosure must be done. The prototype must be signed off by the instructor

Soldering the Components

Now that you have established all the important measurements from the PCB you can begin soldering on the components. As a 'rule of thumb' it is important to start with the lowest profile component. The reason for this is because if you soldering on a taller component it will make it harder to keep a shorter component flush with the board while soldering. For the decade box start soldering all the resistors and then the switches.

You will be marked based on you lead forming and quality of soldering (convex solder joints). Since the resistors are mounted in a vertical configuration it is important to make sure that there is a 2-4 mm gap between the resistor body and PCB. It is also important to maintain a consistent lead form for the top part of the resistor with another 2-4 mm spacing before the start of the bend. All the resistors must be oriented the same way with the resistor tolerance band towards the PCB.

Once the soldering is complete the boards need to be cleaned with alcohol. It is imperative that the flux and alcohol residue not make its way into the switch body or the switch will not function correctly. Once all the resistors are soldered clean off the flux residue and then solder the switches. Once the switches are soldered, clean the residue around the switch pins with alcohol being careful not to let the alcohol or flux residue fall through the hole in the PCB and thereby, getting into the switches.

Once the board has been cleaned bring it to the instructor to get marked. Now it is time to test the Decade Resistor Box.

Testing

Testing the decade box is very important as it will allow you to confidently use it in the future and it will have the added benefit of allowing you prove your Excel skills while tabulating and graphing the data.

You are required to measure, record and calculate the percentage error for each position of all five switches plus the minimum, maximum and 10 random values. This will be a minimum of 57 values. The percentage error is calculated as follows:

$$\%Error = \frac{R_{Measured} - R_{Set\ Value}}{R_{Set\ Value}} \times 100\%$$

The % Error has to be calculated in Excel using a formula you create. Pre-fill all the cells in the spreadsheet with the expected values so that once you have entered your data the % error is automatically calculated. ***Leave the zero value as zero and do not graph its error.***

To acquire the data turn all the switches fully counter clockwise so they are at their 0Ω setting. Then turn on your multimeter, select resistance and then place your probes on the two points shown in the picture. The orientation of your probes to the holes does not matter.

Once your probes are placed the display on the multimeter should indicate a value close to 0Ω.

Question 3: ***Why doesn't the multimeter read exactly 0Ω?***

Once you have answered the above question then you are ready to start collecting data. Start with the lowest resistance switch (10Ω increments) and switch it clockwise through the other 9 positions recording each value in your spreadsheet (the % error should automatically calculate). Return the switch to its 0Ω position and move onto the next higher resistance value switch. Once you have collected all 57 values you are ready to graph the results.

Question 4: ***What is the maximum % Error do you expect to calculate and why?***

Graphing

Graph the data in Excel as % Error vs log(Expected Resistance) using a scatter plot with straight lines. The graph needs to have a title, legend with meaningful names, all axes labelled and correct range for both the x and y axes. The instructor needs to check off your data before you can continue to crafting the enclosure.

Graphing Example

This is a minimum example of what the graph needs to look like:

Enclosure Fabrication

It is finally time to start fabricating your enclosure. At this point you know what your enclosure will look like, that your measurements are correct and that your decade box electronics are fully functional. It is important that you commit from the start to creating an excellent enclosure as you will encounter a few problems even if everything goes well.

The first step is to shear two pieces of aluminum sized to the outside dimensions shown in your flattened drawing of your top and bottom parts. Once the parts are cut the edges must be deburred before you scribe the outline of your enclosure onto the aluminum. At the corner of your bends you need to drill a 1/8" hole (or slightly smaller) so that as the corner forms the material does not jam up on itself. Drill all the switch, jack and rivet holes before notching the corners as this will make it much easier (don't forget to center punch all holes before drilling). Once the two halves have been cut, deburred, drilled, notched and folded have them checked off by the instructor before assembling and/or applying the sticker to the front face plate. You are allowed to paint or otherwise finish your enclosure however you desire but you have to provide all materials and facility to do this at home as the school is not equipped with painting facilities nor will we provide you with paint.

Once your top and bottom halves have been approved you can move onto the final assembly. The first thing to do is complete the final finish then apply the face plate sticker, then mount the banana jacks and then solder tinned wires from jacks to the PCB. You may find it easier to solder the wires to the jacks and PCB before they are mounted in the case. The choice is yours. Once the jacks have been soldered mount the PCB onto the face plate. Once all this is done have the assembly checked off by the instructor before riveting the top and bottom halves together.

Rivet the two halves together after the pre-assembly is checked off by the instructor. Once the two are fastened it is time to add the knobs and do a final test of the decade box before handing it in with your report. Makes sure that you verify at least 5 measurements with the previous data collected. They should be nearly identical.

Report

To complete your project the following documentation must be handed in:

- Place your Excel spreadsheet with the data, graph and calculations in the D2L drop box specified by your instructor
- Create a Microsoft Word report that includes:
  - A cover page with a graphic of your completed decade box as well as your name, course instructor and date
  - A table of contents generated by Word
  - Introduction
  - Summary of steps completed
  - Summary of all issues that you encountered
  - Summary of what you learned
  - The answer to all the question contained in this document
  - A table that compares your finished project dimension with your drawings designed dimensions.
  - A conclusion that includes:
    - state if your finished project is within tolerance
    - what you liked about the project
    - what you would change in your design if you did it again
    - what you would change about how the project course (feedback for future students)
  - An appendix with your drawings and a printout of your Excel data table and %error plot
  - Correct use of 'Styles' is critical
  - The report must include a footer with page numbers and the 'file name'. The file name must be a Word 'Field' that can be updated in the document if the file name changes
  - The header must include the course number and name as well as your name
  - The header cannot appear on the cover page but must appear on all other pages

Task List

Please reference this list so that you don't fall behind in your project. The instructor will initial this table and their own book. This table will act as a backup completed task list in case there is any discrepancy. Do not throw out and do keep it up to date.

TASK	DUE DATE	DONE	INITIALS
Kit Check	November 16	☐	
Enclosure and Face Plate Drawing Design	November 16	☐	
Full Scale Cardboard Prototype	November 18	☐	
Soldering Components to PCB and Cleaned	November 23	☐	
Testing PCB with Excel Data and Graph	November 25	☐	
Test data spreadsheet submitted in D2L	November 30	☐	
Flattened Enclosure Top and Bottom	December 2	☐	
Folded Enclosure with PCB and Jacks Mounted with face plate sticker. Top and bottom not joined	December 7	☐	
Completed Enclosure fully assembled	December 9	☐	
Report	December 9	☐	