UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN ELECTRICAL AND COMPUTER ENGINEERING

ECE-118(218): INTRODUCTION TO MECHATRONICS

LAB 2 – MECHANICAL PROTOTYPING

OVERVIEW:

In this lab, you will learn to use (and be trained on) the LaserCutter, build a prototype robot chassis out of MDF and foamcore, and solder your beacon detector onto perf board. The purpose of this lab is to give you a working understanding of Solidworks and prototyping for mechanical design. For your robot chassis, you will first cut your platform and wheels out on the laser cutter. You will then design your motor mounts in SolidWorks and cut out a tower and sensor platform from foamcore to understand the advantages and disadvantages of both types of prototyping. You will print the motor mounts, cut the base, build the tower, and glue everything together.

You will also redesign and solder your beacon detector down on perfboard with a regulator and power connector. This will be tested against the competition beacons to ensure each team has at least one working beacon detector at the start of the project.

COMMENTS:

This is a very different lab than the previous two. You will be working with your hands and SolidWorks to create something you design on the computer and actually build it. You will be working with sharp knives and hot glue: be careful (especially when you are tired).

Typically there are people in the class who are very experienced with SolidWorks. If you partner with one of these people, make sure that the less experienced teammate handles the mouse and keyboard on the computer (the experienced partner can talk, point, and explain, but should not be driving the computer—we call this “meat servo”).

Soldering up your circuit will take longer than you expect. Test everything as you go along; it will not work if you just solder the whole thing up and plug it in.

We will be around to help, but again: the more you have prepared, the easier it will be.

PRELAB:

Choose a partner to do the lab with, and join a group together in the “Lab 2 # XXX” category on CANVAS. For instructions on how to do this, see the ECE118_LabSubmission document on the website. If you have not chosen a partner by Monday, we will randomly assign one to you (most likely on Tuesday). Note that Piazza is an excellent way to find partners.

Each part of the lab has prelab exercises. Complete these by yourself (you are welcome to collaborate with your teammate, but the work should be your own) and submit them using the assignment submission on the CANVAS website. The requirements for the prelab deliverables are detailed in each section, make sure you read the lab carefully and answer them all.

Note that you need to electronically submit your prelab and lab report files in a very specific format. See the ECE118_LabSubmission document on the class website for instructions on how to submit your files and how to verify that you have done so.

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PART 0 – SOLIDWORKS BASICS

OVERVIEW:

This is background material that you need to read very carefully. This is background on how to get SolidWorks working, and some settings you need to make it all work. You will be using SolidWorks to design your parts and cut them out on the laser cutter.

REFERENCE MATERIAL:

- SolidWorks Introduction: 3D Design Overview (watch first two videos)
- SolidWorks Lesson One: Parts (all parts)
- SolidWorks Lesson Two: Assemblies (watch first two parts)
- SolidWorks Lesson Three: Drawings (watch first three parts)

PRELAB:

Complete the tutorials in the Reference Material above. Take clear screen shots of your finished assemblies for the prelab. Turn in a dimensioned drawing of the created parts and assemblies.

BACKGROUND:

SolidWorks is an amazing and useful tool, well used in industry, but a complex one. In this class we use it primarily to design 2D shapes to make 3D structures so many of the tool sets will not be germane. SolidWorks is very well documented so any confusion can be resolved with the help tutorials included in the package. This section will introduce you to the tools you need in SolidWorks and understanding the very concepts of SolidWorks.

SolidWorks is, in essence, a series of building blocks. You use sketches to create features, features to make parts, and parts come together with mates to form an assembly. Drawings allow you to specify the relevant aspects of these assemblies. In this class, we will be using the drawings to print the parts out on the laser cutter.

Sketch: this is where you design the shape of your piece in 2D. SolidWorks has an entire toolkit devoted to lines, squares, arcs, Bezier curves, and others to produce your sketch. Lines are used to create features in your sketch. Alternately, lines and shapes labelled “for construction” are used to help set up the geometry as required. Construction lines show up as dotted lines on your sketch. It helps to label all sketches appropriately (i.e.: main body, slot for Wall B, etc.).

Features: Once you are satisfied with your sketch (press the check mark), you turn it into a feature. In this class, features typically—due to the limitations of the laser cutter—will either be an extrusion (to make a positive spaced object) or a cut (to make a negative space) on your part. A part can have multiple features in different planes but in this class you will primarily have all your sketches/features in the same plane, since you are designing flat pieces (again, because we are cutting them on a laser cutter).

Part: is a single file which contains a solid single 3D piece. It could be a wall, a gear, or even a motor. Each part contains its own set of local variables and can import variables from the assemblies it belongs to. The parts that you cut out on the laser cutter will need to be 100% accurate, as they dictate where the laser cuts. The parts you do not cut out also need to be accurate if their dimensions are relevant to your assembly. For example, in modeling an old roller skate wheel such as those used on the roaches, you will likely model it as simply a disc with a centered hole. You will need the interior diameter, exterior diameter, and thickness accurate but you do not need to have the curvature or the details of the spokes.

Assembly: is a file that consists of parts or even other assemblies. In it you will build your full model from your collection of parts and determine the relations (Mates) of each part to the other. Assemblies also hold the global variables and equations of all the parts, including the material thickness. Assemblies can also be vehicles for creating new cuts in parts that correspond to the features of other parts. Building your assembly and mates well will allow you to make little changes (like adjusting the material thickness, or moving a board two inches to the left) and have the entire model update automatically.

Mates: are the defined relations between parts in an assembly. They can be simple ones such as concentricity (two circular parts sharing the same center) or alignment (two parts sharing the same plane). They can be complex ones: width mate (a part's width is centered between two other parts planes) or even a gear mate (where the gears teeth are properly meshed together).

Drawings: is typically where you show off the dimensions of assemblies and parts so that someone might build your assembly and parts without extra help. In this class you will use the drawings primarily as print sheets of your parts for the laser cutter. You will layout all your parts on a 20x30" sheet and the laser cutter will cut the lines on the drawing.

SETTINGS:

Even if you are an experienced SolidWorks user (and especially if you are new to the program), review these set up rules and follow through on these tutorials.

DON'T LEAVE SOLIDWORKS OPEN and idle on your desktop. We only have 60 licenses off the FlexLM server in the whole school. Feel free to close someone's SolidWorks (save their documents and leave a note) if you see someone leave it idling for more than 30 minutes.

TURN OFF ANTI_ALIASING every time you log into SolidWorks. SolidWorks is designed for top line GPUs, GPUs that are not installed in most workstation computers, nor for that matter, most laptops. Anti-aliasing looks cool but makes your program run slow when you start having complex assemblies.

Click Options or Tools->Options and choose: Display/Selection. Under the anti-aliasing section, choose: None.

ENSURE ENGLISH DIMENSIONS every time you log into SolidWorks: American industry runs in English (SAE) dimensions and you will need SolidWorks to do so too. We don't want half your rocket robot designed in metric and the other half in imperial units.

Click Options or Tools->Options. Click the Document

OUTLINE:

Complete the tutorials in the Reference Material above. Take clear screen shots of your finished assemblies for the prelab. Turn in a dimensioned drawing of the created parts and assemblies.

For the lab report, there is nothing to include, since this is turned in with the prelab.

PART 1 – A SIMPLE GEARBOX

OVERVIEW:

This lab assignment is to use Solidworks to create a virtual gearbox assembly. You will learn how to use global and local equations as well as a wide variety of mates in order to ensure your assembly can easily be cut from both foamcore and MDF (although you will not do any cutting for this part of the lab).

REFERENCE MATERIAL:

- Gearbox starter files from the class website
- Tab and Slot video†
- Relations Outside a Part video†
- Toolbox video†
- Gearbox Demo video†
- Material Variables in SolidWorks handout
- ECE-118 SolidWorks to LaserCutter handout

†These videos were made with a previous version of SolidWorks, and while not an exact match to the current version, should be close enough to demonstrate what we are trying to show you.

PRELAB:

Nothing on the prelab for this part.

BUMPS AND ROAD HAZARDS:

Don't leave SolidWorks open and idle on your desktop. We only have 60 licenses off the FlexLM server in the whole school. Feel free to close someone's SolidWorks (save their documents and leave a note) if you see someone leave it idling for more than 30 minutes.

The videos we have posted are for an older version of SolidWorks (which changes substantially between updates). If you discover something in the videos that does not work in the current version, please make a piazza post about it and we will announce it to the class.

Note that we are using SolidWorks 2018 x64. Once a part is opened in a newer version of SolidWorks, it cannot be used in an older version. Be careful with this if you work on your own machines with your own copy of SolidWorks.

OUTLINE:

You will be building up a virtual gearbox assembly in SolidWorks. Start by downloading the Gearbox starter files (which includes a PDF with the dimensioned drawing of the Gearbox). The dimensioned drawing is going to be the guide you use to make the gearbox in SolidWorks. All the information required to build the gearbox is contained within the dimensions of the drawing.

The videos above take you through the process of building the gearbox (and they are made using an older version of SolidWorks, so there might be some discrepancies). If you are familiar with SolidWorks, you don't need to follow the videos.

The important part is to have a Material Thickness variable, and to be able to change that value. You have been provided a motor part and a gear part (so you don't have to recreate a new one, which is difficult). You will create the gearbox using tab and slot construction.

Verify that your SolidWorks assembly is complete and has no undefined relations. You should be able to vary the Material Thickness variable by a factor of 2 in either direction and re-run the interference check and have it pass (and rebuild without errors).

Prepare a print sheet suitable for laser cutting your parts (only the lines that will be cut, at a 1:1 scale on a 20x30" page). This means you will be creating a second assembly document that has all of the parts laid out flat as per the SolidWorks to LaserCutter document. Demonstrate to the TA/tutors that you can change the Material Thickness variable and rebuild without interference for checkoff. Include a printout of the model from three perspectives and a pdf (not to scale) of your laser cutter print in the final report, along with a short paragraph describing the process of building the gearbox.

PART 2 – DESIGNING A MOTORIZED PLATFORM

OVERVIEW:

This assignment will have you create a small motorized platform (base of your robot) using multiple materials. The prototype will be modelled in SolidWorks, and will use both foamcore and MDF in different parts, requiring more sophistication in your equations.

REFERENCE MATERIAL:

- CKO Ch. 29
- ECE-118 Tips and Tricks document (Solidworks section)
- Fabulous Foamcore handout

PRELAB:

The sketch of your motorized platform, hand drawn (not SolidWorks).

BUMPS AND ROAD HAZARDS:

Don't leave SolidWorks open and idle on your desktop. We only have 60 licenses off the FlexLM server in the whole school. Feel free to close someone's SolidWorks (save their documents and leave a note) if you see someone leave it idling for more than 30 minutes.

Note that we are using SolidWorks 2017 x64. Once a part is opened in a newer version of SolidWorks, it cannot be used in an older version. Be careful with this if you work on your own machines with your own copy of SolidWorks.

OUTLINE:

You are going to design a basic motorized platform that could be a robot for this class (e.g.: the roach). The base plate, motor mounts, and wheels will be cut from MDF (in Part 3), and it will include a tower with a small square mounted to it made out of foamcore.

The design requirements for your motorized platform are as follows:

1. Platform base fits within an 11x11" rectangle (you don't have to go that big).
2. Platform base is made out of a single layer of MDF.
3. The motorized platform can move without tipping over and/or dragging parts on the ground (except for skids, spacers, or skegs).
4. The platform has two 76mm wheels cut from a single layer of MDF.
5. Motor mounts use tab in slot construction and are made to secure the drive motors against torque (dummy motors will be available in the labs for inspection, don't mount them).

6. Motor mounts are such that motors can be removed from structure without destroying the motor mounts or the motors themselves.
7. Platform has holes for mechanically mounting an H-bridge module (nominally 2.5” x 1.5”, however measure the one you are using) close to the motors.
8. The platform has a circular cylinder out of foamcore mounted to the center using tab in slot construction.
9. The foamcore cylinder is 6” in height, and 4.5” in diameter.
10. A square box mounts to the top of the circular cylinder, centered on the cylinder.
11. It is 1” deep, side length greater than 5” (up to you to specify exactly)
12. Box is open on top, no lid required.

Design the platform together with your teammate. Remember to think about where everything goes. Inspect the dummy motors (pick a pair that you will use for your design). Think about the motor mounts, and how things get assembled and disassembled. Include holes for screws to hold the H-bridge down. Give some thought to how the chassis will move when the motors turn the wheels; have you provided adequate support to the platform when accelerating or decelerating?

You can be creative with your designs, but keep them relatively small. **Absolutely no etching** is allowed on the laser cutter, so you will be doing simple cuts. Intricate shapes take longer to cut as the time it takes to cut anything on the laser cutter is proportional to the length of the total cuts in the design. Make sure you think about your design. Turn in your sketches (not SolidWorks) as part of the prelab. Rough dimensions and a few views should be sufficient to indicate that you have thought this through.

You will design your complete motorized platform in SolidWorks. There are at least two materials used, foamcore (nominally 3/16” thick) and MDF (nominally ¼” thick)[†]. This should include the motor mounts and wheels, the base, the tower, and the box on top of the tower. Think about the fact that the H-bridge requires wires to your motors to power them. Have you left yourself a way to get the wires to the motors?

Demonstrate your SolidWorks designs to the TA/tutors for checkoff. Again, they will be manipulating your material thicknesses and the entire design should rebuild without errors. Include a full set of three views and perspective of your motorized platform in the lab report, along with a description of your design, and why you chose to implement it in this particular way.

PART 3 – PROTOTYPING THE MOTORIZED PLATFORM

OVERVIEW:

In this assignment, you will use the laser cutter to cut your base, wheels, and motor mounts out of MDF, and hand cut out the tower and box out of foamcore. After doing a trial fit, you will glue everything together using hot glue.

REFERENCE MATERIAL:

- CKO Ch. 29
- ECE-118 Tips and Tricks document (Solidworks section)
- ECE-118 SolidWorks to LaserCutter handout
- Fabulous Foamcore handout

[†] It should go without saying that you should obviously never trust the material thickness given, but measure it yourself.

PRELAB:

Ensure that all of your safety training is complete. You cannot use the laser cutter unless you have completed the LHAT training.

BUMPS AND ROAD HAZARDS:

The laser cutter is a very easy to use machine, and is very safe to use. However, it is using a 130W laser to burn through material and mishandling the settings can start a fire. Remember that fire requires three things to go: fuel (the material being cut), oxygen (air), and heat (the laser). Removing any of the three will stop the fire. This will be part of your safety training, and we will go over what to do and how in the case of a fire.

The knives you use for cutting foamcore are very sharp. Always cut in a way such that if the knife slips that no parts of you are going to get cut. The knives get dull quickly when cutting foamcore; dull knives are dangerous as you have to pull harder. Hot glue guns get hot (as does the glue). Be careful not to burn yourself when assembling parts.

OUTLINE:

You are going to be using the laser cutter to cut out the MDF platform you designed in Part 2, and will be hand cutting the foamcore tower and box on top. This will familiarize you with basic prototyping techniques.

After you have been checked off for Part 2 above, lay out the base, motor mounts, and wheels onto a 20x20” sheet, and export it as a .DXF file as per the SolidWorks to LaserCutter document. Before proceeding you need to have this layout checked off by a TA/tutor.

You will first need to receive laser cutter training. Training takes about 90 minutes, and only one team at a time will get trained. The TAs will circulate a queue sheet—sign up, and be ready when your time comes. If you are absent/unprepared, you’ll get booted to the back of the line. Bring the .DXF file on a thumbdrive.

Under the direction of the TAs, you will cut out your parts from a 2x2’ piece of MDF. After the parts are cut out, you will remove them and the scrap from the laser cutter. You will take the scrap with you to store in your own location or throw away in the dumpsters outside of Baskin. **DO NOT LEAVE SCRAP** in BE-138.

Test fit all of the MDF parts and make sure things fit together nicely. Don’t glue anything together yet until you have made the foamcore parts.

Use your construction skills and the fabulous foamcore handout to create the box and the cylinder (Remember both the tabs and slots to have something to fit together). You will be hand cutting these with the razor blade knives.

Build the box first that will sit atop the cylinder, using the knives, rulers, and patience. Use lap joints at the edges; the final box should have exposed foam only on the top plane and be neat and straight. Next build the cylinder that goes between the box and the base. The cylinder must have **AT LEAST 16 SIDES** to approach a circular cross section. Again, remember tabs and slots, and close the cylinder using a lap joint.

Test fit the column and box into the base. Do not glue them just yet, but make sure everything goes where it needs to and fits together. It is easier to fix something before it is glued down. Show the test fit parts to the TA/tutors for an OK to glue everything together.

Glue the parts together and demonstrate it to the TA/tutors for checkoff. Do NOT glue the motors in, and make sure that your motor mounts allow the motors to be removed without destroying the motors or the motor mounts. After you have been checked off, return the motors to the benches. In your lab report, include pictures of your finished platform, and a detailed description of the construction methods and difficulties that you encountered. Include insights into improving your design.

PART 4 – BEACON DETECTOR ON PERFBOARD

OVERVIEW:

This assignment is to solder up a prototype beacon detector (that will hopefully be the one you will use in the final project). For the final project in this class, an infrared emitter is going to be used as a beacon to let you know when a target is active. The emitter is driven by a microcontroller and generates a 50% duty-cycle on/off wave at a frequency of 2 kHz. There are several sources of noise and interference, including daylight, monitors, wall current, and many others. Your design must detect the signal of interest at a range of 1-6ft., and reject the others.

This will be tested against a beacon which changes its frequency from 1.5 to 2 to 2.5 kHz.

REFERENCE MATERIAL:

- CKO Chapters 14, 15
- H & H Chapters 5-5.09
- Analog Filtering
- Your notes and prototype from Lab 1

PRELAB:

Review your lab notebook (and protoboard circuits) from the Lab 1 filter design. Given a new lab partner, you should have two independent designs. Choose the better one, combine the best parts of each one, or ask your classmates whose filter worked particularly well.

Your prelab should also include a full schematic of the circuit you intend to build to do the actual filtering to detect the beacon. Your prelab should also include the design layout on the perfboard (where the chips go, power, ground, etc.). This should be done neatly on graph paper or with a computer design tool.

Spend lots of time of this! An extra hour here will save you a huge amount of time in the lab.

BUMPS AND ROAD HAZARDS:

Polarized capacitors must be plugged in correctly. If you reverse polarity them, they will be damaged (and pop like a firecracker). Reversing polarity on any IC will usually destroy it (letting out the magic smoke). You want to operate your OpAmps in single-ended mode (0-3.3V power).

Regulators need filtering caps; if you forget them they will behave in odd ways. If you find yourself frustrated and tired, take a break. Walk away and get some nourishment. Take that time to rest and allow yourself to reset. Be smart about trying to do things when you are tired.

OUTLINE:

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This will be tested against a beacon which changes its frequency from 1.5 to 2 to 2.5 kHz.

You have already built and tested a protoboard design in the last lab. In this section of the lab, you will solder up the beacon detector and demonstrate that it works to the required specifications. These specifications are:

1. Must have a regulator (3.3V or 5V depending on your circuit) and be reverse polarity protected using a diode (should be able to operate from 6-12V on the power input).
2. Must be able to detect the 2KHz beacon from 1-6ft.
3. Must indicate the presence/absence of the beacon with an LED as well as a signal line out (3.3V-0V), polarity of signal is not specified.
4. Must reject the beacon at 1.5KHz and 2.5KHz at a range of 1ft.
5. Must be soldered to a single perfboard with a standard power connector.

Debug your breadboard circuit. Take the best of your designs and ensure that it is robust. If you are redesigning your filter, build it fully on the breadboard and maintain it there as a reference (don't remove parts to build).

Design your layout on the perf board. You will want it to be easily readable for you and your future teammates. You will also want to easily see the power and ground lines (convention is red wire for power, black for ground). It is often easier to use the same layout on your perf board that you use on your protoboard. Make a neat, detailed drawing in your lab notebook and reference it often. You can also use software (such as Eagle or Cadence) to design a layout.

Remember that you will most likely be soldering on the bottom of the perfboard, with the chips and components on the top. This can easily get confusing, so be sure to make a "looking at the bottom" drawing in your notebook that you can refer to often.

DO NOT dissemble your working filter off of your protoboard, instead, replicate the design on the perf board, and solder or wirewrap the parts together. Plan your soldering route ahead of time. Start with power and ground from the regulator. Give yourself rails or at the very least power each chip.

Set up each module one at a time. Test your circuit iteratively and make sure it works at each stage. If not, debug. Again, incremental development here; build a little, test a little, build a little more, test a little more, until the whole thing functions reliably. Test front to back and back to front in stages. Again, ensure there is an indicator LED that helps to debug the circuit.

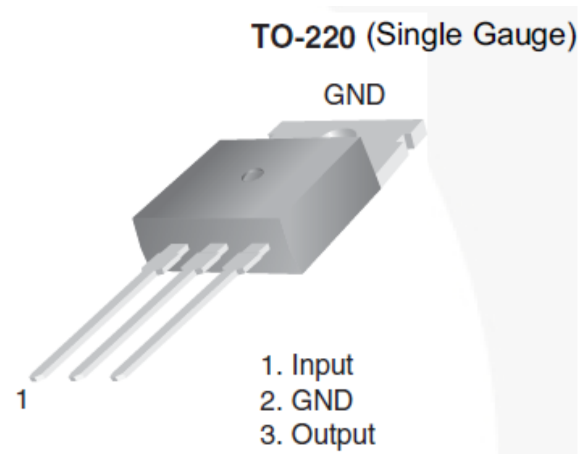
Incremental development here will save you hours/days (we are not kidding). Needless to say, the continuity function of the multimeters is quite useful here.

Demonstrate your soldered beacon detector to the TA/tutors for checkoff. It should meet all the specifications. Update your schematic to the final working design. Note: we only require one circuit per each partnership for this lab. However if you have a good circuit, we highly recommend making two to save yourself the grief (and time) of building another one during the project.

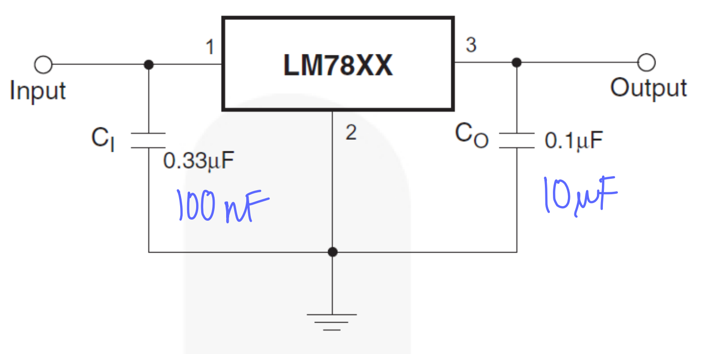
Include pictures of the final soldered beacon detector (top and bottom) in your report. Include the full updated schematic as well as a block by block explanation of how your beacon detector works. Include a short write-up about the process of prototyping the circuit.

Appendix A: LDO Regulators

The basic regulator used in most circuits is a fixed output LDO (low drop-out). This is a three terminal device with an input, ground, and output. The input is the supply voltage, which must be above the output voltage by the dropout voltage. As long as the voltage on the input is above the output + dropout voltage, the output will remain stable at the fixed voltage. Typically a diode is added inline to the input to ensure that if you reverse polarity on the input and ground, no current will flow (reverse polarity protection). See below for the pinouts for the TO-220 package of the 7805 regulator.



The regulators in your kits are 7805 (Fixed output at 5V) and can supply up to 1A of current. Note that they have a power rating, and will heat up approximately 70°C for every watt you pull through (they have an over current and thermal shutdown built in). If you are drawing a lot of current through, you will need to add a heatsink.



For stability, the regulator requires both an input filtering capacitor as well as an output filtering capacitor. Typically a 0.22uF cap on the input and a 0.1uF cap on the output will ensure that the regulated voltage stays good even with changes in the load.

Adding a regulator and reverse polarity protection to your circuit makes your circuit robust to variable inputs, and errors in hooking up power and ground. Use regulators with reverse polarity protection in every circuit module you make.

Checkoff and Time Tracking

Student Name:____ CruzID________________@ucsc.edu

Time Spent out of Lab	Time Spent in Lab	Lab Part - Description
		Part 0 – SolidWorks Basics
		Part 1 – A Simple Gearbox
		Part 2 – Designing a Motorized Platform
		Part 3 – Prototyping the Motorized Platform
		Part 4 – Beacon Detector on Perfboard

Checkoff: TA/Tutor Initials	Lab Part - Description
	Part 1 – A Simple Gearbox
	Part 2 – Designing a Motorized Platform
	Part 3 – Prototyping the Motorized Platform
	Part 4 – Beacon Detector on Perfboard