

E11: Autonomous Vehicles

Lab 3: Machining

In this lab, you'll use Harvey Mudd's machine shops to make the sensor tower and sensor bracket. You will make these parts from technical drawings using a mill and sheet metal tools.

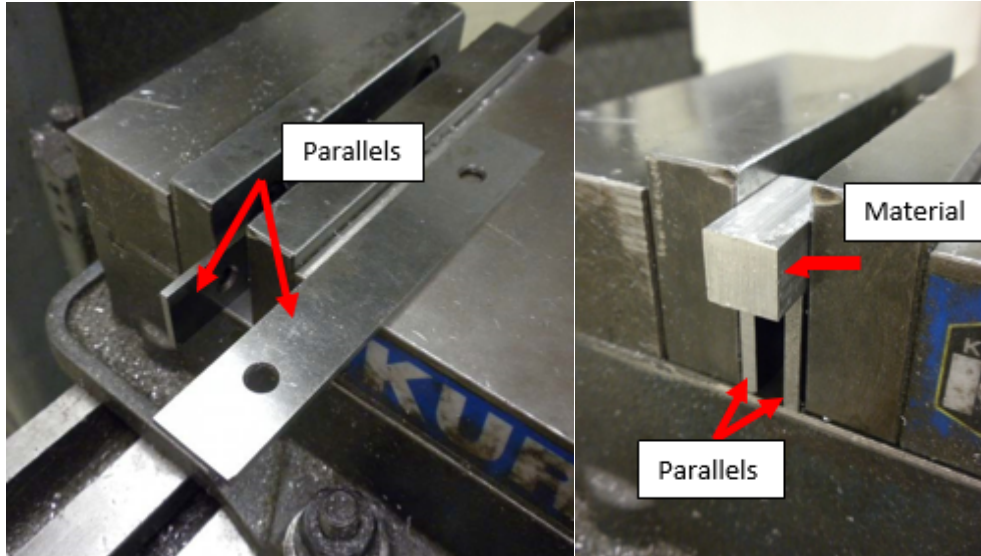
The challenge of this lab is to get everyone through the mill work in a timely fashion, and this is most efficient if you can watch somebody ahead of you and learn the tricks. Plan to divide into groups of 2-3 with each mill to build your sensor tower. Watch what the other members of your group are doing on the mill so your work will go faster. If you are the third person in the group or have already finished your mill work, move on to the sheet metal work to build your bracket.

Sensor Tower

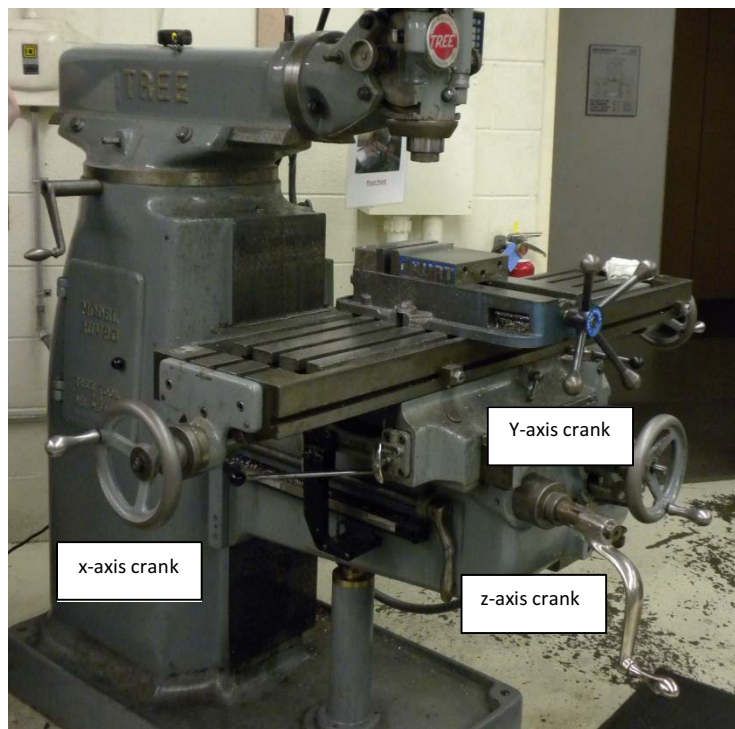
The sensor tower is built using the metal rod (with square cross section) in your lab kit. You can assume the cross section of the rod is 0.5"X0.5"; you do not need to face these edges. However, the length of your piece is nonstandard and you will need to face both ends to length.

Some tips:

- Never place an endmill in a drill chuck!
 - Never turn on the mill when the endmill is already in contact with the metal – always back away from the material before turning it on.
 - Follow mill speed suggestions posted on the shop walls.
 - It's easier to take off a little more than to put some back.
 - Always stop the machine before making measurements with calipers.
 - Apply cutting oil to the endmill or drill bit before every cut.
1. Use a metal file to remove any burrs from the ends of your stock metal piece.
 2. Turn on the digital readout and press one of the **reset** buttons to activate the readout. Clean the work area of debris and oil using a shop rag
 3. Place your material **flat** on the **parallels** (sometimes referred to as spacers, try 1" parallels to start), with about one half of an inch protruding out of the **left side** of the vice.



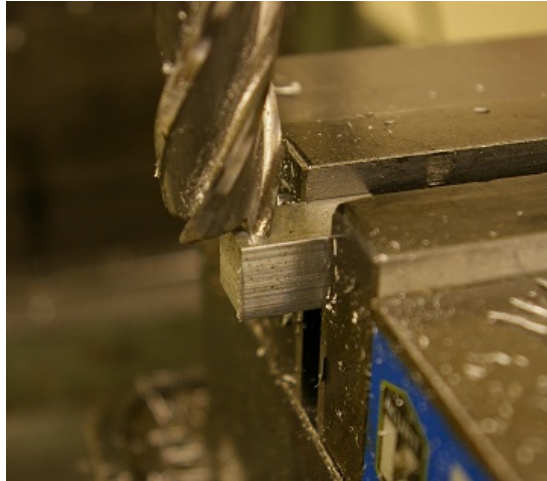
4. Ask the shop proctor for a **0.5-1" endmill and collet** to face the end of the material protruding from the vice. Face refers to the process of taking off a small amount of material in order to ensure an even and smooth end. Turn on the motor to set the speed, selecting 1300 rpm for a 1" endmill, 2000 rpm for a 0.5" endmill, and a linear change for sizes in between.
5. To insert the endmill into the mill, have a lab instructor or shop proctor assist you! After inserting the endmill, familiarize yourself with the axes of the mill, and which handles correspond to those axes.



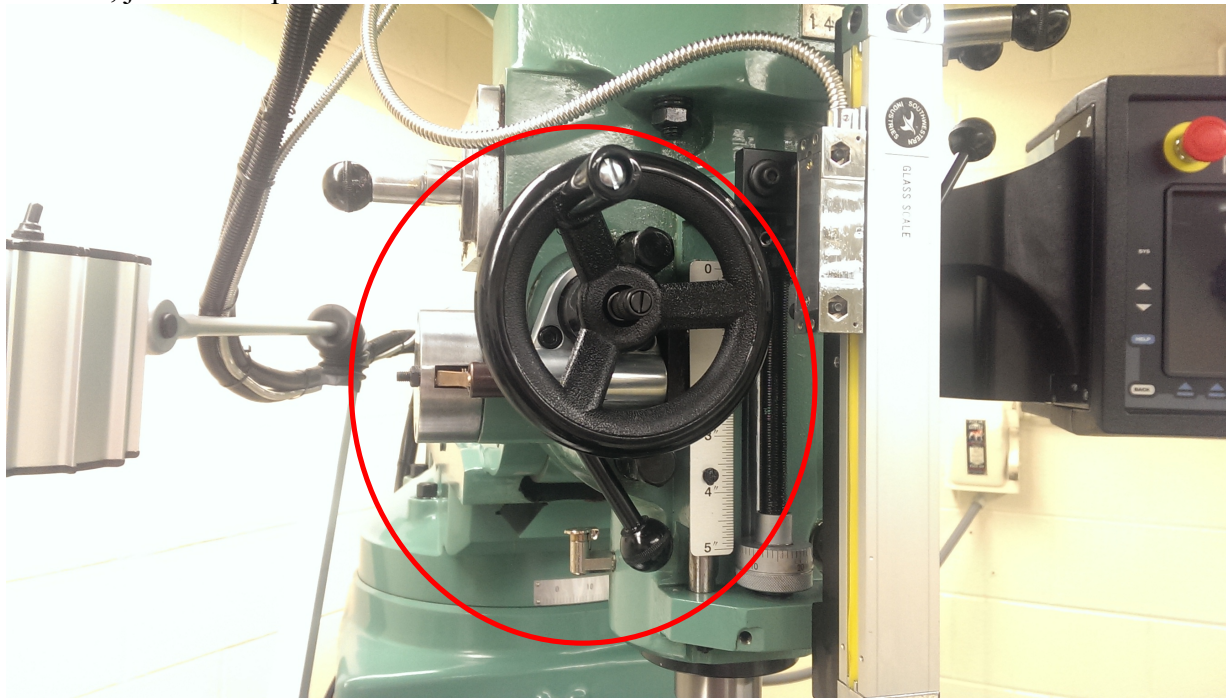
6. Start with the material in front of the endmill. Once the endmill is spinning, apply cutting oil with the brush and gradually move it forward (along the y-direction) to face the first end. The slower you move, the smoother the cut.



7. Take the piece out of the vice, lightly file off any burrs, and rotate the part so that the other rough end is sticking out of the vice as you did in step #3, but keep just over half of the material in the vice and let the rest hang out. Face this end just like in step 6. After the cut, do not move the table in the x-direction!
8. Now you have to cut your piece so that it is the right length (1.000", note the drawing showed 0.81", this is the only difference). To do so, you need to know how much material to cut off. With calipers, measure your part while in the vice. In the digital readout, set the x-dimension to **negative** <YOUR PART LENGTH>. (Ask a shop proctor how to do this! The shop may have a few sets of calipers available, but you will likely have to share or bring in your own.)
9. With the x-dimension as your reference, continue making cuts using the same process as before (don't forget to add cutting oil before each cut!) You should take off about 0.05" at a time, or up to 0.1" if you go slowly.
10. Verify your final size with calipers while your part is in the vise. Are you within tolerance? If you cut too much, you may have to start over. ***Be sure to not remove your piece from the vice in order to maintain its current x-position relative to the endmill's cutting edge - this is essential for the next step.***
11. To create the cutout at the top of the sensor tower, you must reconfigure the digital readout values. We can take advantage of the endmill's current position to do this. The endmill is currently positioned to barely scrape the end of your piece. Your x-dimension should say -1.000". Let's change this to 0.000". This x-location is your zero point in x. Now, file the burrs on top of your part and move the endmill above the part by lowering the table or raising the head. Now move x to 0.29".
12. You can easily find a zero point in z by moving the endmill via the quill handle. Lower the endmill until it touches the surface of your work piece. You should feel a clutch engage as you press lightly against the surface. If in doubt, ask a shop proctor to confirm. You can then lock the quill and set z-dimension to 0".



13. Move the table in the y-direction so you are no longer above your part. Engage the fine adjust wheel and then unlock the quill. You can use this wheel to move the quill (and by extension the endmill) in the z-direction. Lower the endmill to $-0.050''$ in the z-direction (also known as “50 thou”, short for “50 thousandths” since one thousandth is $0.001''$). Make a cut by moving the y-direction through the material, just like step 6.



14. Continue making cuts by about $0.050''$ each until the second-to-last cut. Then, cut off only $0.040''$. For the final pass, you will remove $0.010''$ in both the z- and x-direction. To do so, lower the endmill $0.010''$ and move $0.010''$ in the x-direction so that the DRO should read Z: $-0.300''$ and X: $0.300''$. Then make your final pass.

15. Remove your part and file any sharp edges or burrs with a smooth-finish file. This is called deburring.

Allow your partners to complete their parts to this point before proceeding to the next step.

16. To drill the 0.2” phototransistor hole, you will need an accurate value for the x- and y-axes on the DRO. Insert your part following the figure below. Essentially you are about to configure the DRO to act as if a fixed coordinate frame exists on your part. You can accomplish this task with an edge finder. To use an edge finder, first remove the endmill from the mill and insert a drill chuck. You may have to change collet sizes. Ask a proctor to show this step. Now insert the edge finder into the drill chuck and tighten it with the chuck key. To ensure that the edge-finder behaves as expected, operate the mill at 1000 rpm.



17. Turn on the mill and bring your edge-finder to the bottom edge of your part (the side facing you). As you bring the edge finder closer, the spinning eccentricity will decrease. Keep bringing it closer until the eccentricity “stops,” and it spins smoothly. Finally keep bringing the edge finder a tiny bit closer until it “kicks.” When you see the kick, your edge finder is flush with the edge. Stop the spindle and do not move the table.



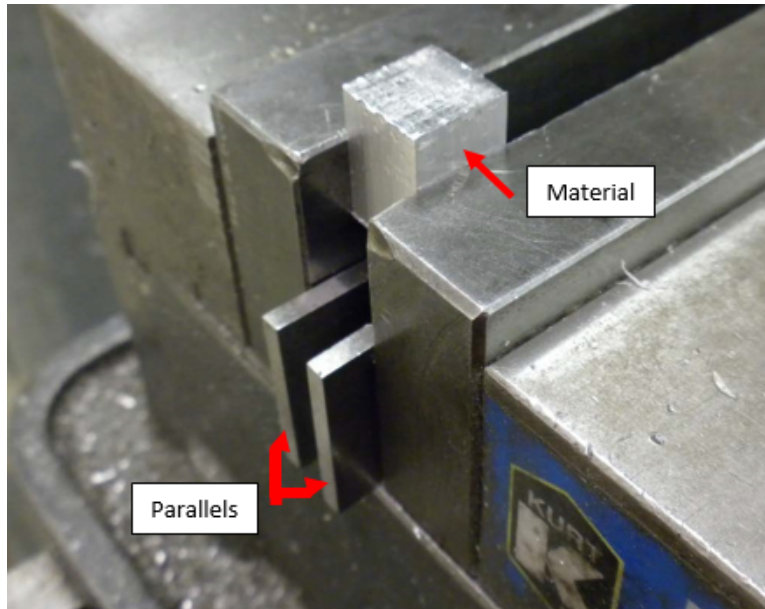
Since the edge finder has a part diameter of 0.2", you must configure the DRO to correspond to 0.1" below the edge of your piece. Program -0.1" into the y-dimension. By setting the DRO, you are, in a sense, superimposing a coordinate frame onto your part.

Repeat this process in the x-direction. The coordinate (0,0) should correspond to the top left of your part.

At this point, the origin should now correspond to the lower left corner of your piece (relative to you looking at it). Check to make sure your set coordinate makes sense with respect to your piece.



18. Replace the edge finder with a combination drill & countersink. Make sure the drill is set to 2000 rpm. Lubricate, touch down to your hole location, then pull up. Lubricate again, then go down until you form a straight hole with a funnel on top.
19. Select the proper sized drill bit and place it in the drill chuck. Drill through the piece, backing out to remove material frequently. Ease up on your downward pressure when you're about to break through. This will reduce any burrs that may occur.
20. To drill the threaded hole on the bottom for a machine screw, you may need some new parallels so that when you rotate the part, it won't stick up too far out of the vice. Mount the sensor tower in the vice, taking care to keep it vertical.



21. Use the edge finder again to set the coordinate system as you did in step 17. Place the origin at the lower left corner of your piece. You will then need to drill the hole, then tap it to create the threads. First use the combination drill & countersink again to start the hole as you did in step #18. Then refer to the tap & drill chart next to the shop proctor's desk for the proper drill size for the tapped hole. To set the depth follow the procedure in step #12. You may have to move the table so you can touch uncut material with the drill bit.
22. When tapping, make sure you use the correct size AND thread pitch. If you don't match both, your tower will not fit on your robot. Lubricate the tap and your hole with RapidTap tapping fluid before beginning. Using the spring loaded tap guide (ask the proctor for guidance on using this device) turn the tap until it seems solidly in place. From here on out, get in the pattern of going $\frac{1}{2}$ turn forward, followed by $\frac{1}{4}$ turn back. Keep track of your depth so that you don't go too deep or too shallow. An 8-32 tap has 32 threads (and therefore full rotations) for each inch of depth. If the tap gets unreasonably difficult to turn, STOP! Over turning is how you break taps. Back the tap out and look for debris in the hole or other obstructions.
23. Clean up your workspace. Vacuum around the mill and return the tools you have been using.
24. Deburr your part.

Sensor Bracket

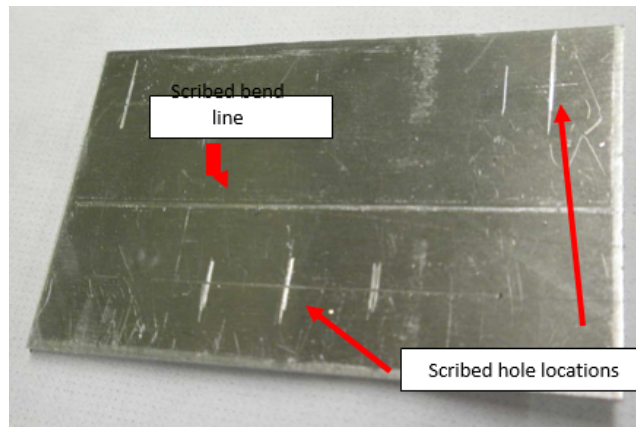
The sensor bracket requires use of the sheet metal shop. You will receive a piece of sheet metal that is 1.1 by 1.75 by .0625 inches. The bracket requires the use of

1. Calipers
2. the notcher
3. layout fluid
4. a hand punch
5. a hand drill

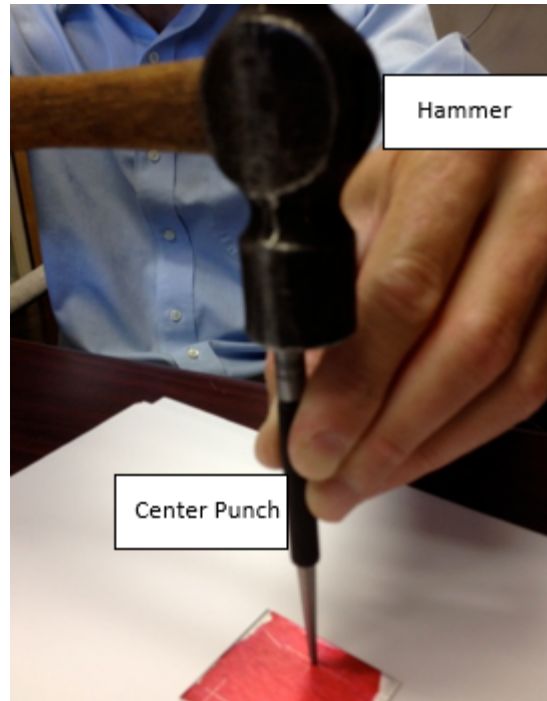
6. sheet metal bender (Pan & Box Brake)
7. hammer
8. pocket scribe

The calipers will be used to measure and mark the part for production. The notcher will chop the sheet metal down to 1.1 x 1.75". The hand punch will be used for the holes. The sheet metal bender will be used to bend the plate to form the proper shape. The hand drill will be used to expand existing holes on the mounting bracket.

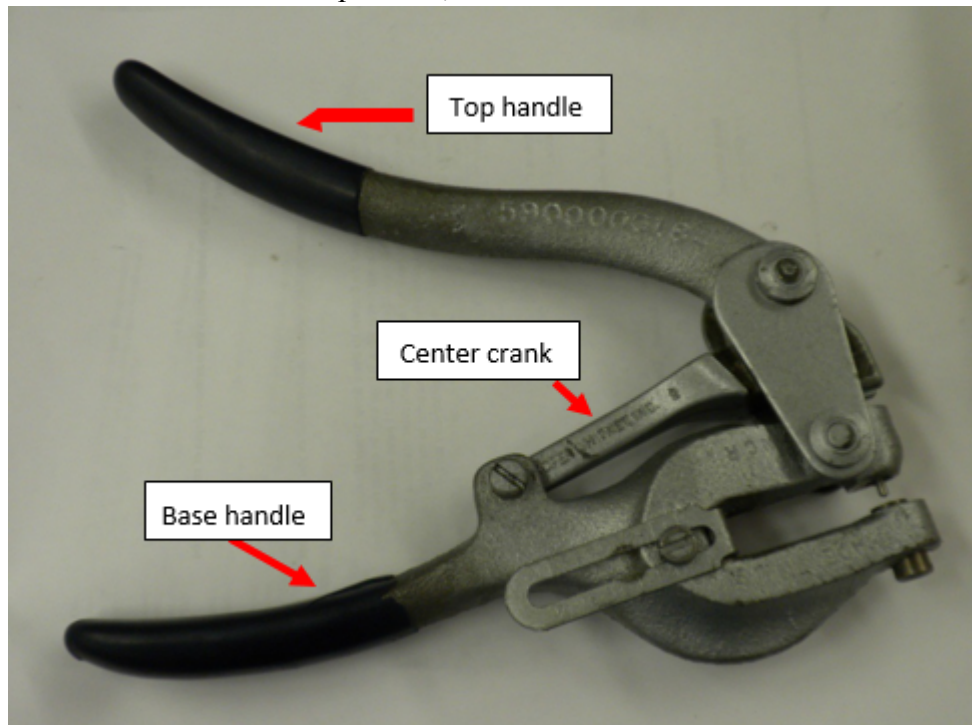
1. The first thing to do is understand the machine drawing for the part. The drawing has dimensions to show the size of the plate, where the holes are placed, how big the holes are, and a dotted line to show where the part should be bent.
2. After you understand the drawing, use the notcher to chop the plate down to width. If the jig is properly positioned, the cut will be square and of the right size. Note: it will take some effort to hold the metal piece in place while you perform the cut. Hold the piece tightly with one hand and take advantage of the long lever arm of the tool with your other arm to execute the cut. When you are done, leave the handle up so that no one impales themselves on it.
3. Coat the piece in a thin layer of layout fluid (could be clear or red in color) and dry it with compressed air.
4. Scribe intersecting lines on your part to mark where the holes should go. Also scribe a line where your bend will go.

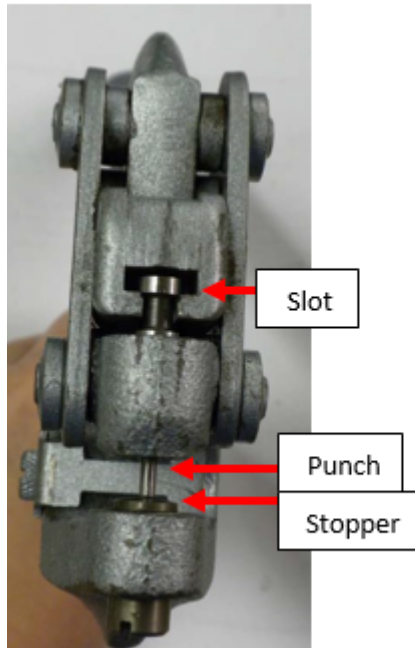


5. Use a hammer and center punch to create a small divot at each desired hole location. This will be used to properly position the hole punch.

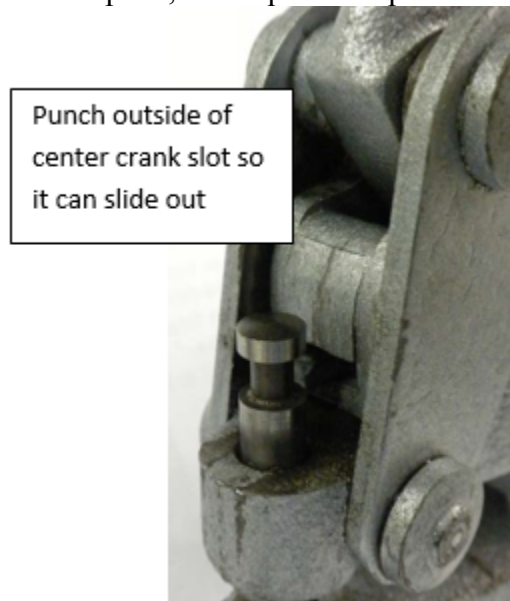
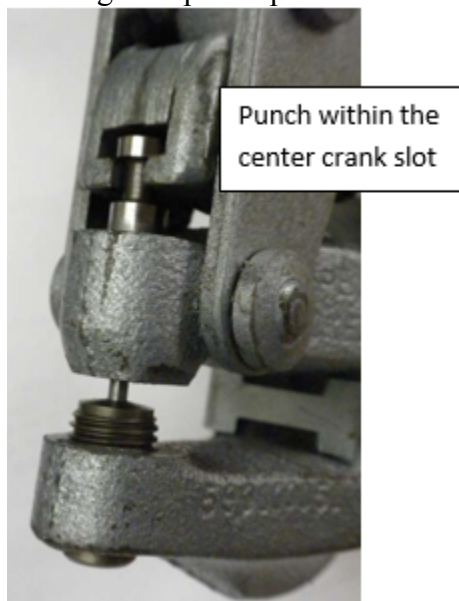


- Slide in the proper punch for the hole you wish to make. If you have any trouble, consult a lab instructor or shop proctor! To remove and insert punches, first remove the screw on the handle.



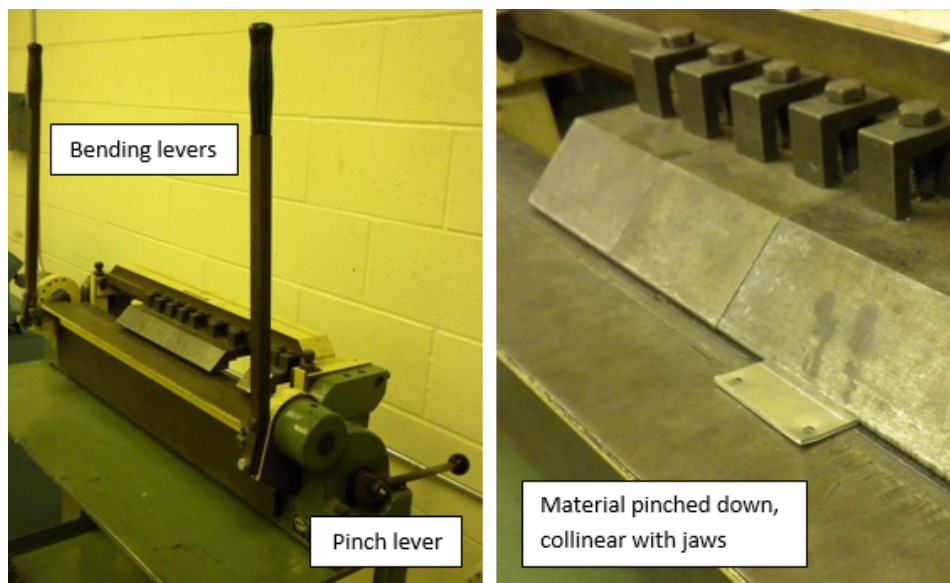


7. If you are removing the punch, hold the handle and center crank and pull upwards. Repeat this climbing motion until the slot in the center crank releases from the punch. The punch should now slide out. Unscrew the complimentary stopper opposite of the punch.
8. If you are inserting the punch, first screw in the complimentary stopper with the threaded end first. It should go through the threaded hole and sit slightly above the lip so that your bracket can rest on it. Position the handle and center crank such that it is behind the punch hole, then slide the punch in. Now using a similar climbing motion as removing the punch, align the slot on the center crank over and onto the punch. Align the threaded hole for the handle screw with the main body, and reapply the screw (it only goes in one direction with a ring traced around the hole).
9. Align the punch point with the divot on the plate, then squeeze to punch.



10. Repeat for other holes.

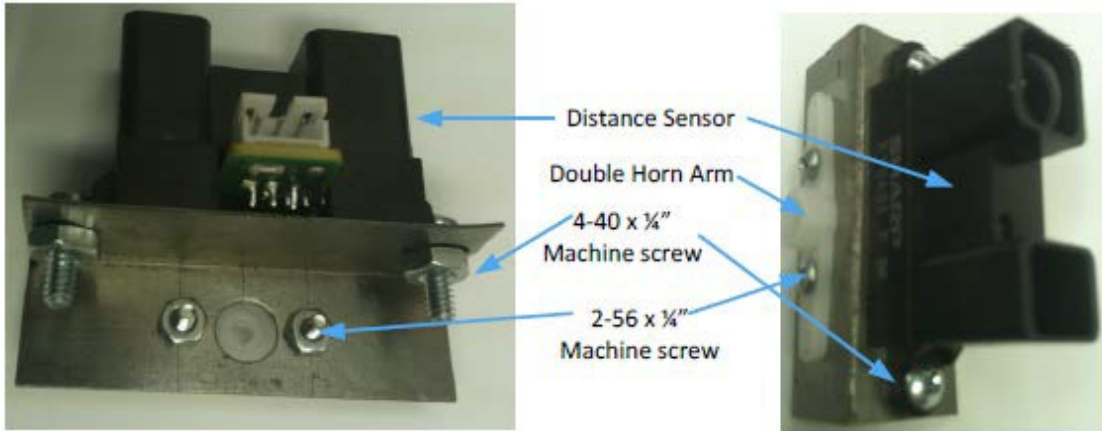
11. Once all of the holes are finished the bracket is ready to be bent. The part should be placed flat on the sheet metal bender's surface underneath the fingers. A small lever on the side is used to lower the fingers so it holds the part flat. See figure below.
12. Locate the bending line so it is collinear with the jaws edge. Lock the fingers into place with the back lever, and bend the brake arm up with the other lever. This will bend the part at the tip of the fingers.
13. Move the lever up until the plate is bent at 90 degrees. Lower the table and open the fingers. The bracket is now finished!
14. You will need to use the hole punch to widen two holes in the servo double horn arm to mate with the bracket. Find the double horn arm in your servo bag. Identify the two



screws aligned with the 0.090" holes in the bracket (second hole from the large center hole). Now, with the same 0.090" punch used for the sensor bracket, punch matching holes in the double horn arm.

Mounting the Distance Sensor

1. Verify the positions of the holes in your bracket by connecting it to the distance sensor as shown below. Find the 2-56 x 1/4" and 4-40 x 1/4" machine screws and nuts in your toolkit (look for the smallest ones). The 2-56 x 1/4" screws and nuts is the smallest silver pair, and the 4-40 x 1/4" is the second smallest silver pair.



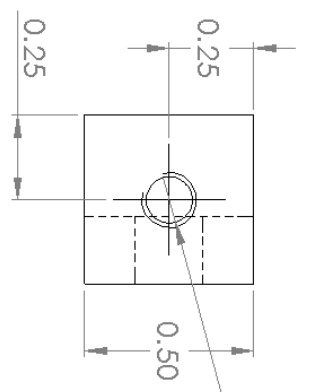
2. Use the pair of 2-56 x 1/4" machine screws and nuts to attach the double horn arm to your bracket with the arm underneath the bracket and the nuts on top of the bracket.
3. Use the pair of 4-40 x 1/4" machine screws and nuts to attach the distance sensor to the bracket.
4. If you have difficulties, your holes are located outside of their tolerances. Repunch the hole as necessary for the components to fit.

Checkoff

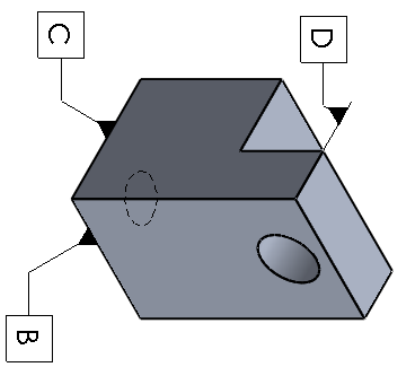
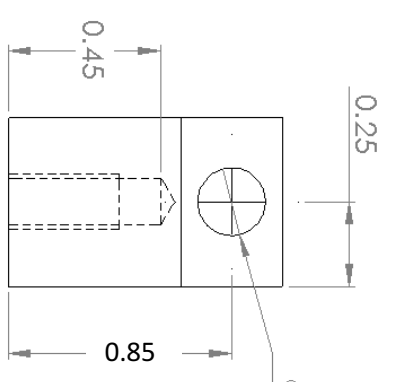
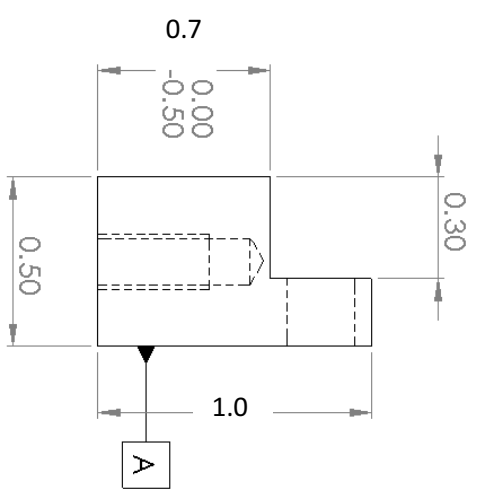
Your parts should now be complete. See your lab instructor to check off your parts for being in spe

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UNLESS OTHERWISE SPECIFIED:		DRAWN	NAME	DATE
DIMENSIONS ARE IN INCHES		CHECKED		
TOLERANCES:		ENG. APPR.		
FRACTIONAL \pm		MFG. APPR.		
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INTERPRET GEOMETRIC FINISH		MATERIAL		
DO NOT SCALE DRAWING		ALUMINUM		
APPLICATION		NEXT ASSY		
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SIZE DWG. NO. REV
A sensorTower
SCALE: 2:1 WEIGHT: SHEET 1 OF 1

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