# Machining Science and Technology Task 1

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SC20B062

# Raw Materials



- Polycarbonate blanks of sizes

1. 300 x 300 x 65 mm^3 – Housing top part base
2. 300 x 300 x 20 mm^3 – Housing top part lid
3. 300 x 300 x 30 mm^3 – Housing bottom part

Overall size of Housing – 300 x 300 x 115 mm^3

# Mechanical Properties of Polycarbonate



| Mechanical Property | Value |
|---|---|
| Young's Modulus | 2 – 2.4 GPa |
| Tensile Strength | 55 – 75 MPa |
| Elongation at fracture | 80-150 % |
| Compressive Strength | >80 MPa |
| Poisson's Ratio | 0.37 |
| Rockwell Hardness | M70 |
| Izod Impact Strength | 600 – 850 J/m |
| Notch Test | 20–35 $kJ/m^2$ |
| Abrasive resistance ASTM D1044 | 10-15 mg/1000 cycles |

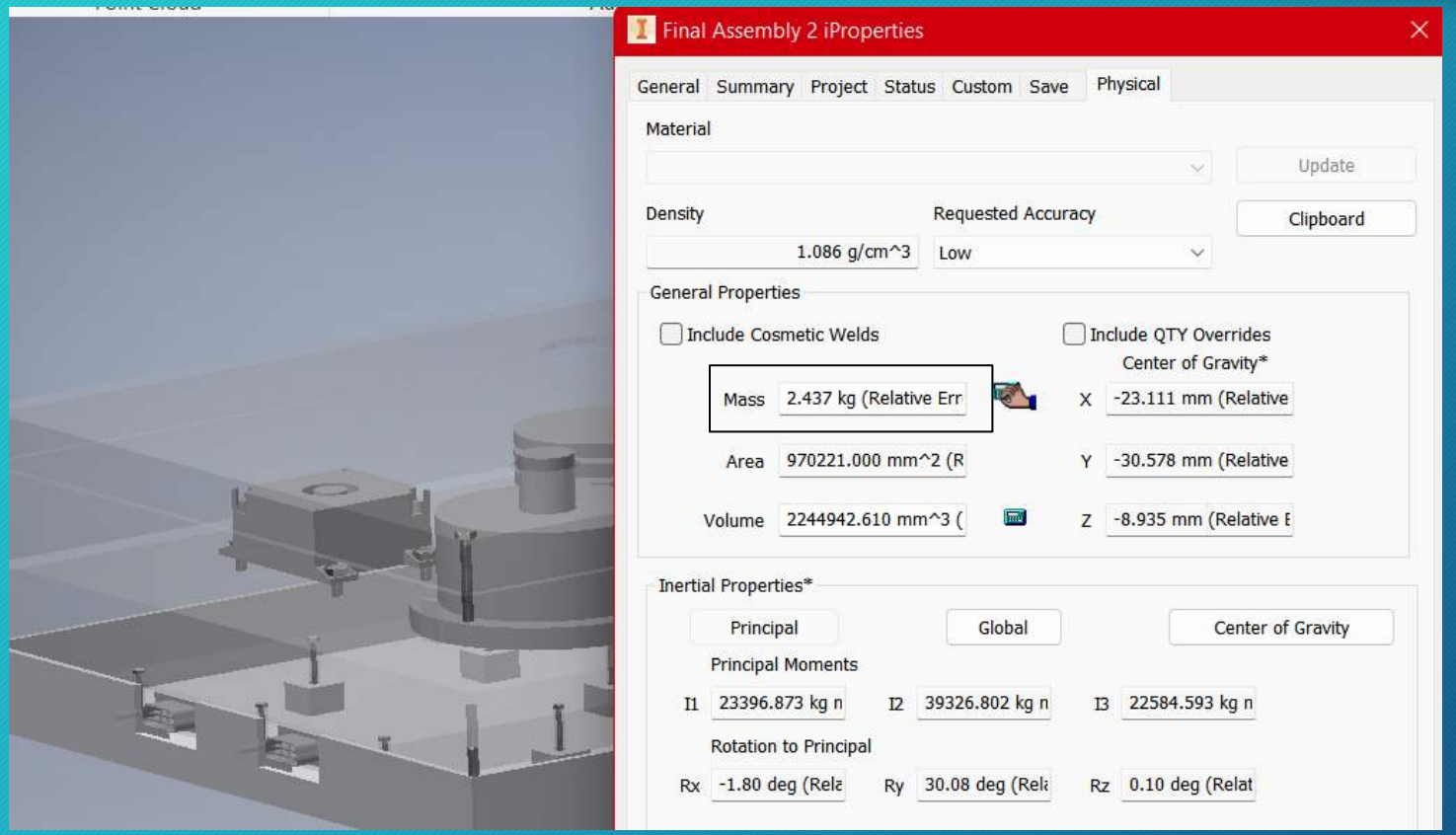
# Design Considerations



- The mentioned sensors had to be exposed outside the housing. Holes/Slots were made accordingly. The antenna of Sensor 4 is exposed out. Holes were made to expose the top parts of Sensor 1 and 3. D-pins are exposed through slots.
- Clearance was required for the electronic board. Bottom housing was made such that the clearance is well met.
- Weight had to be less than 3kg. Thickness has manipulated to accommodate it. Material chosen has good strength properties.
- It was decided to use bolts to join three parts of the housing. (Lid, Base and Bottom).

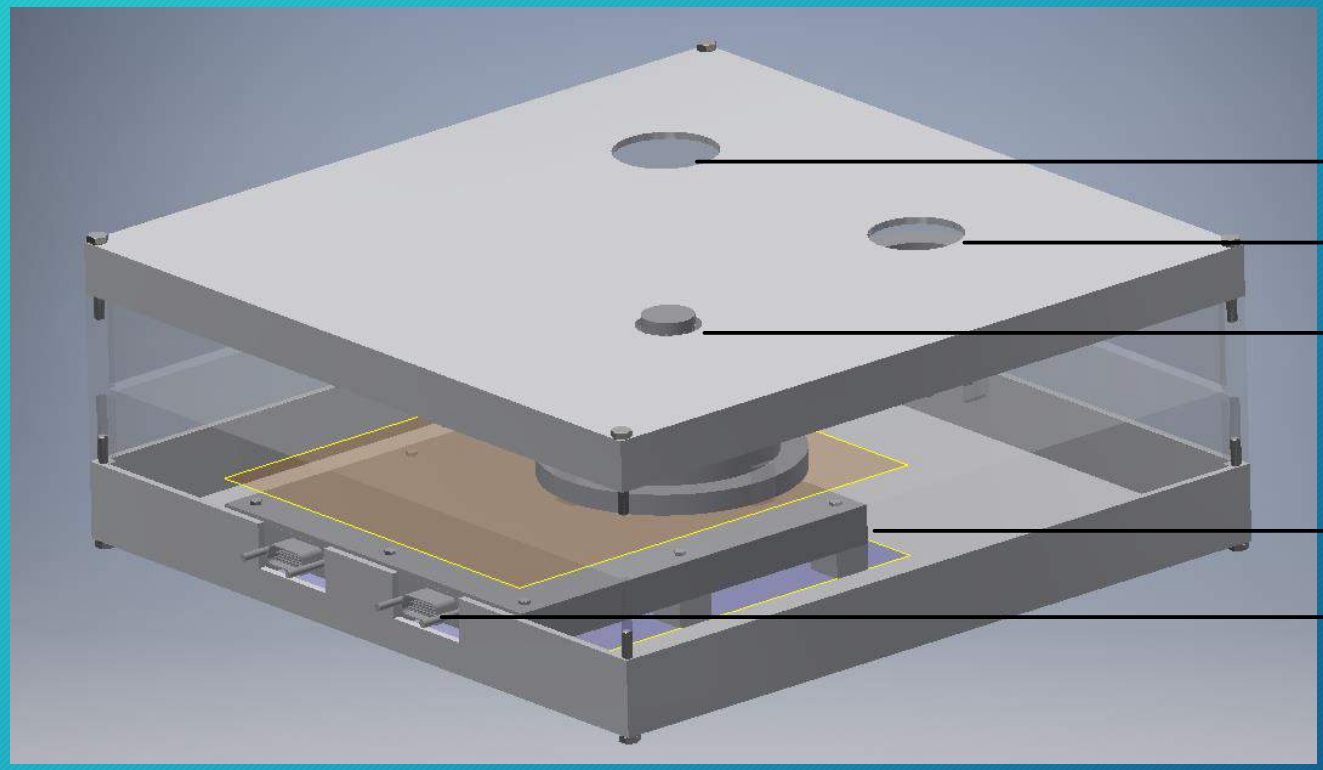
# Weight of Designed Model – 2.437 kg





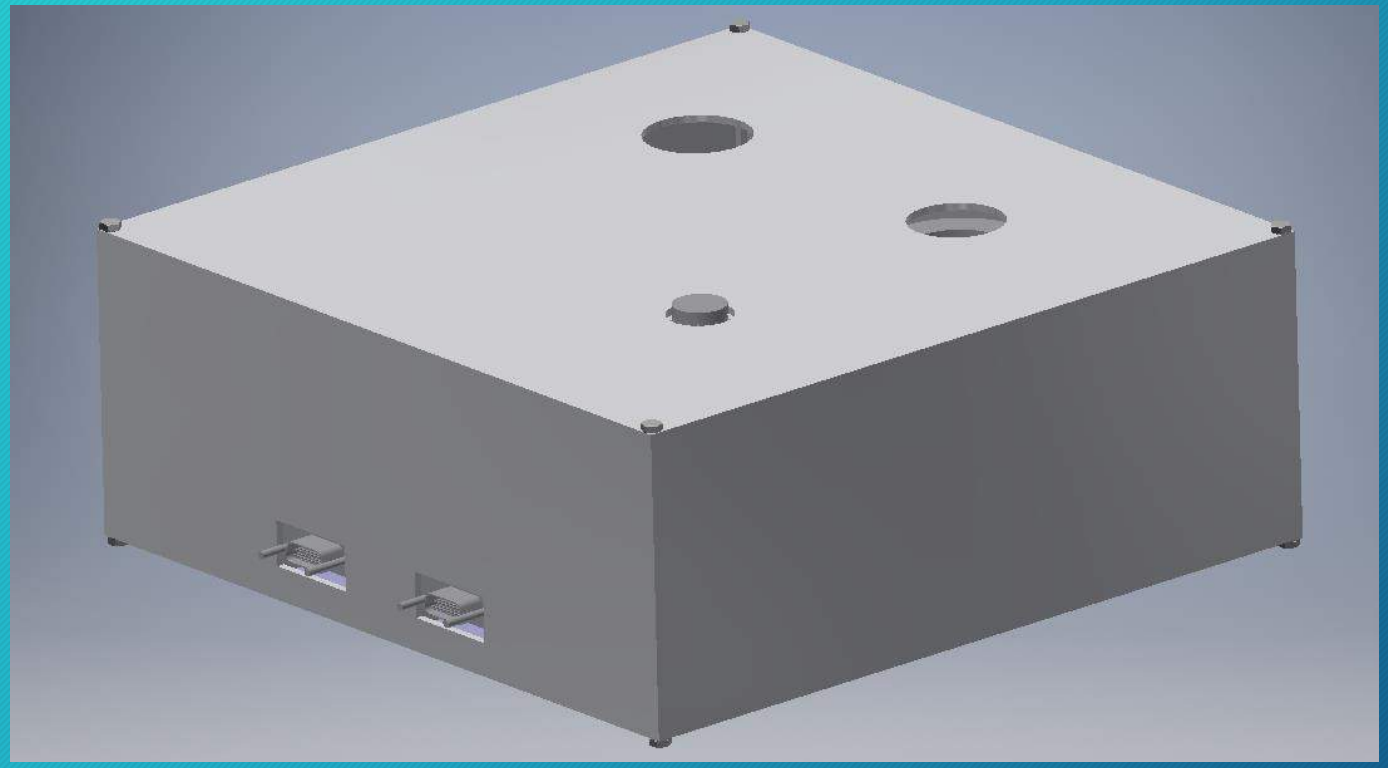
# Constraints in assembly met





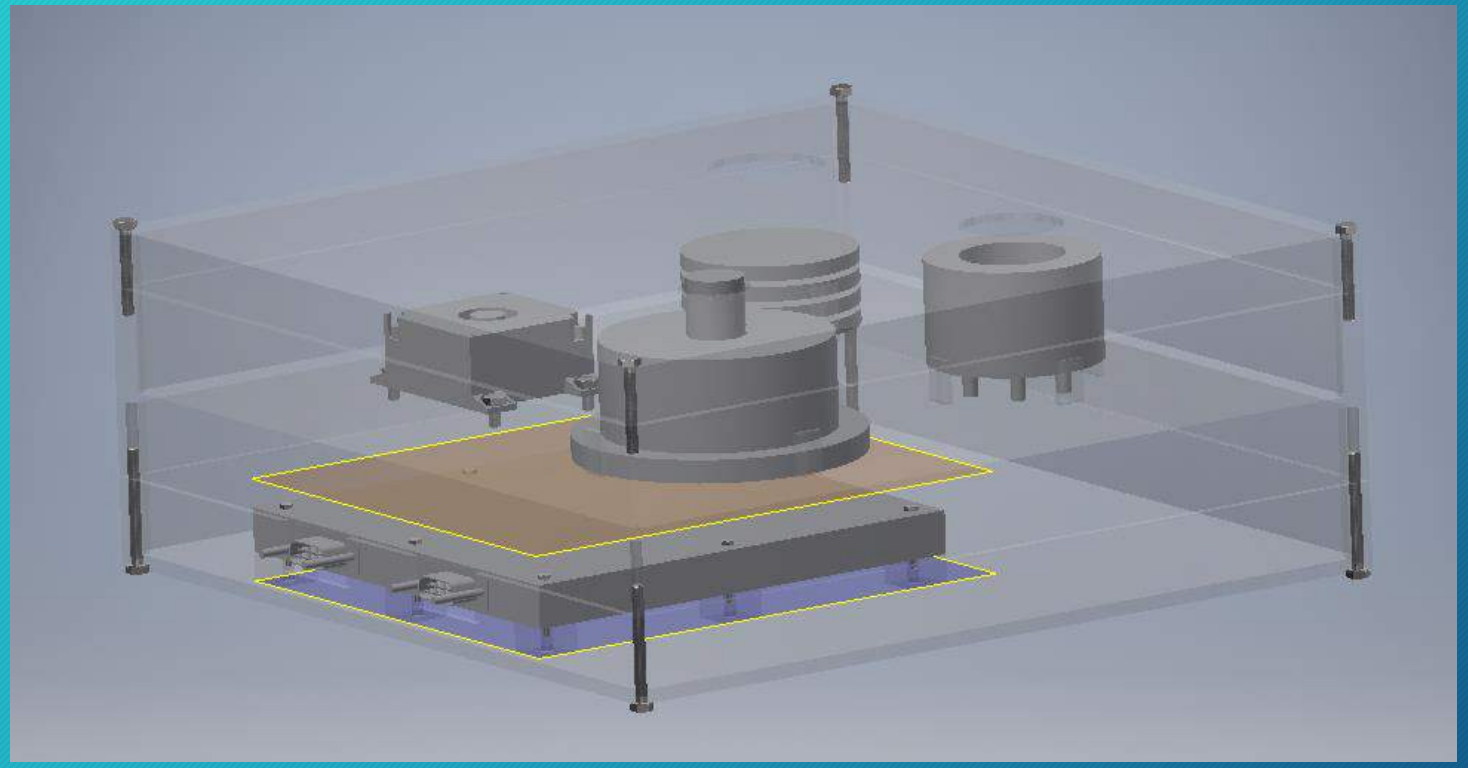
# 3D Model Images





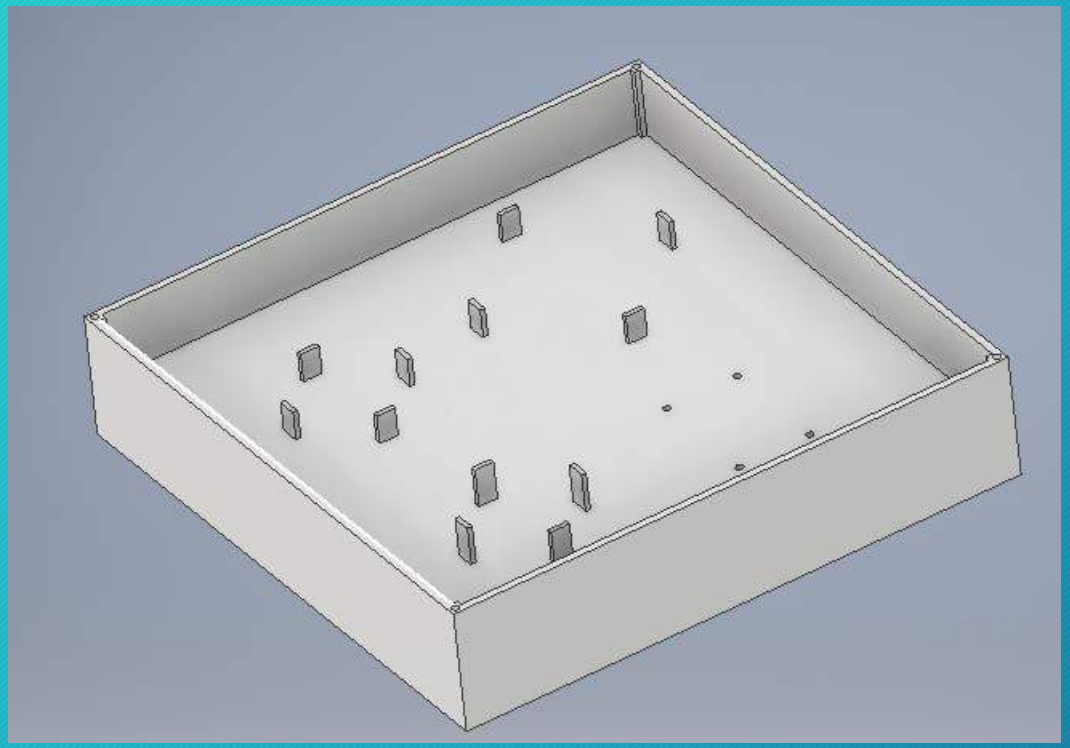
# Transparent view of 3D model

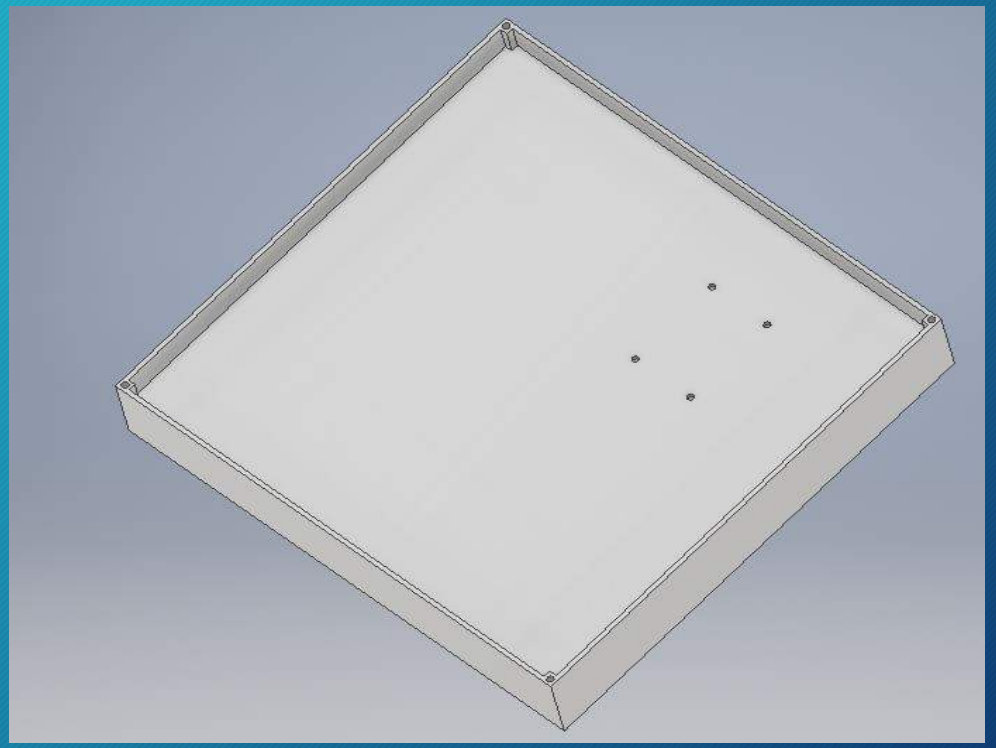




# Housing Top Part - Base

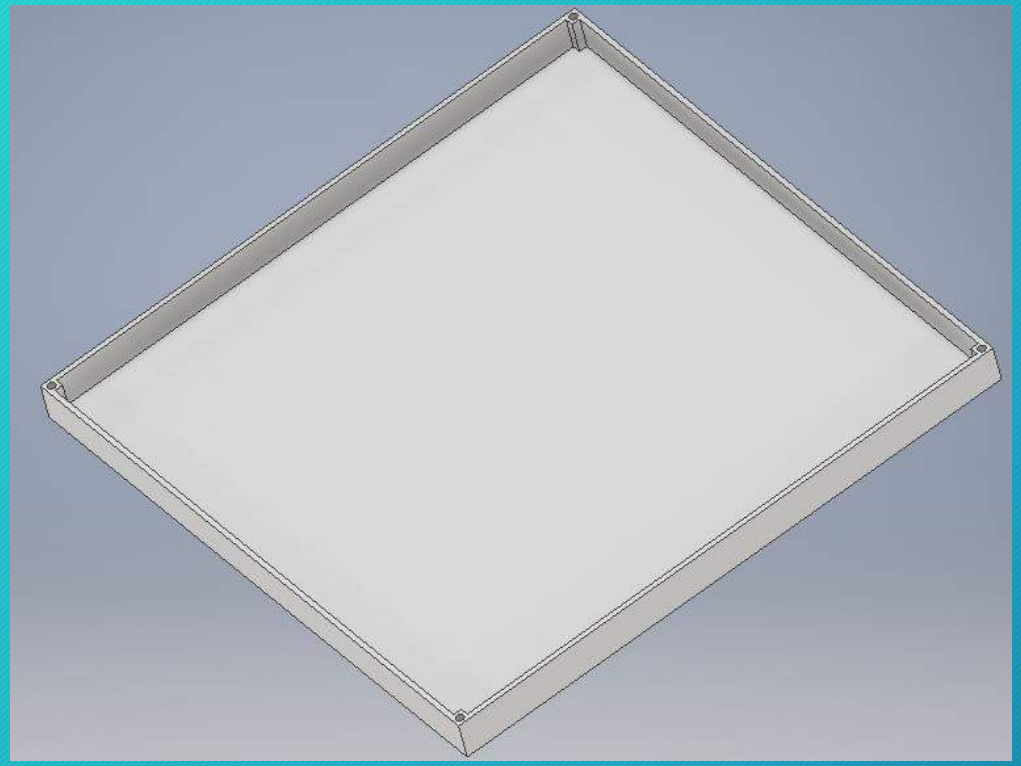


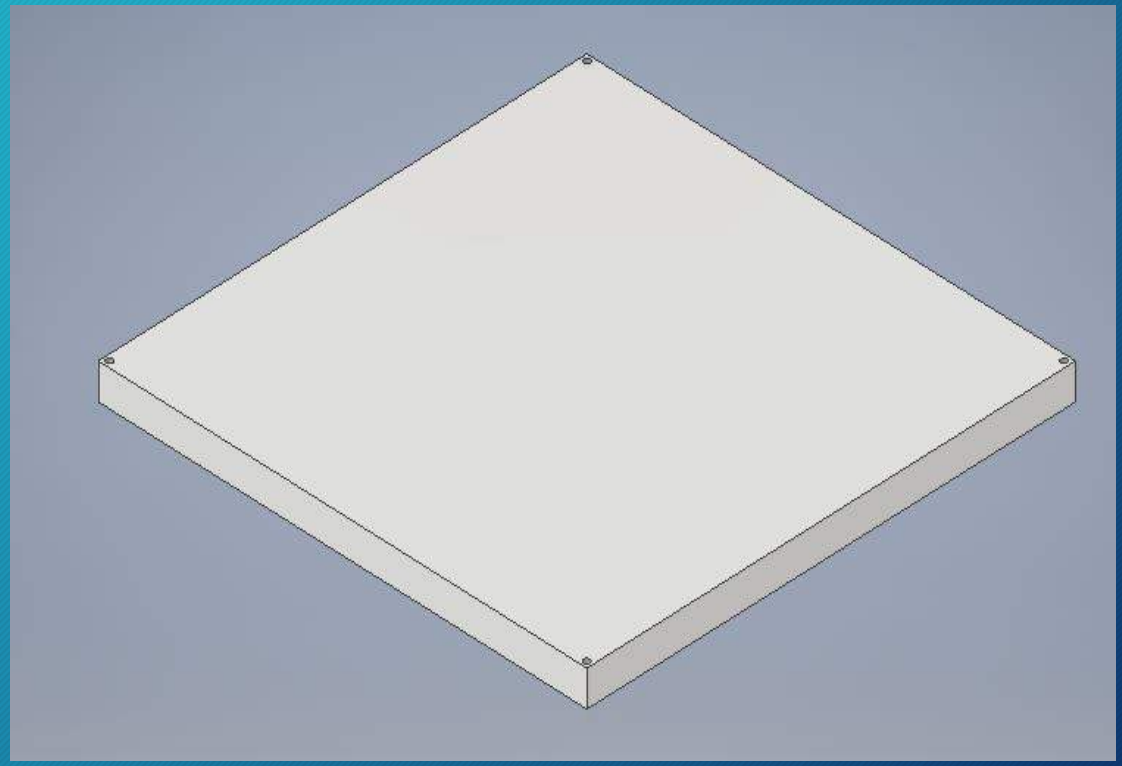




# Housing Top Part - Lid

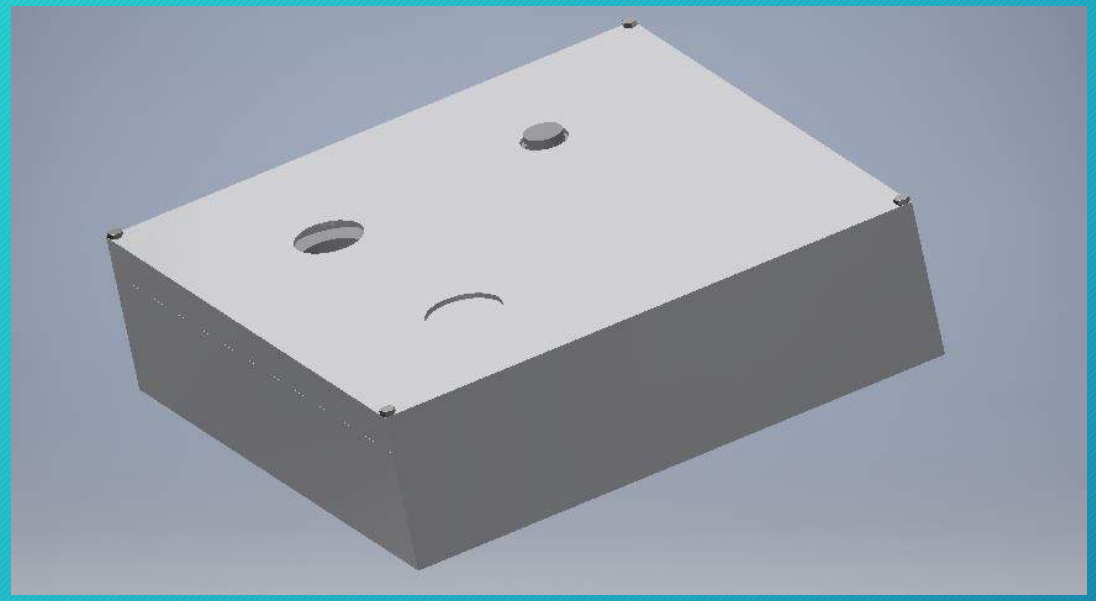


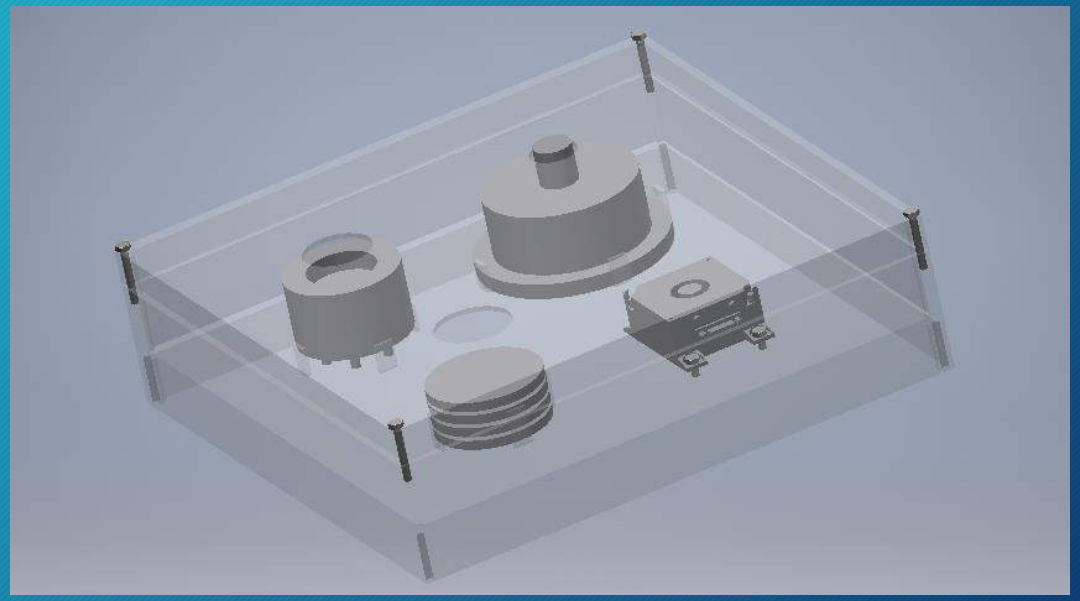




# Housing Top Part

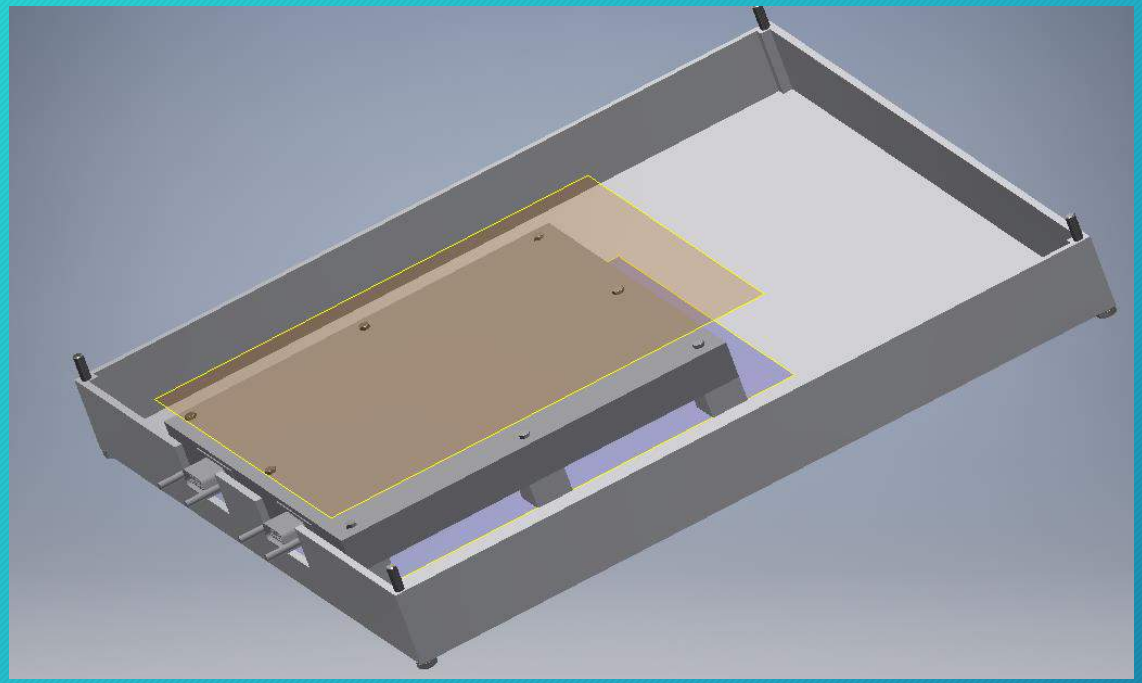


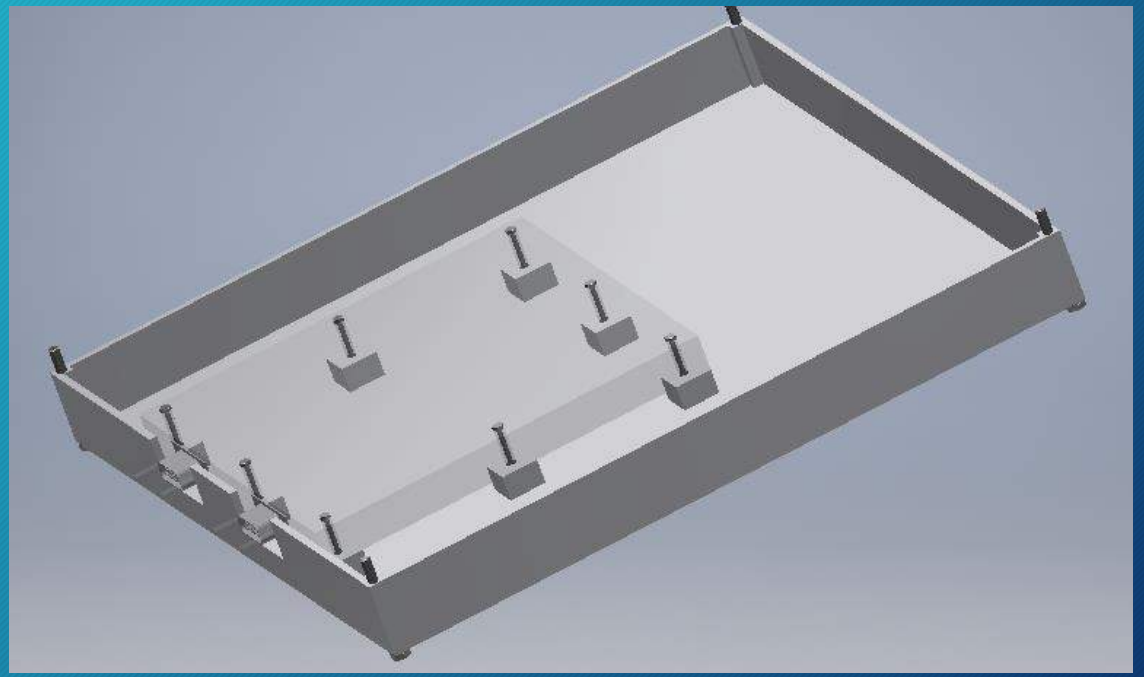




# Housing Bottom Part

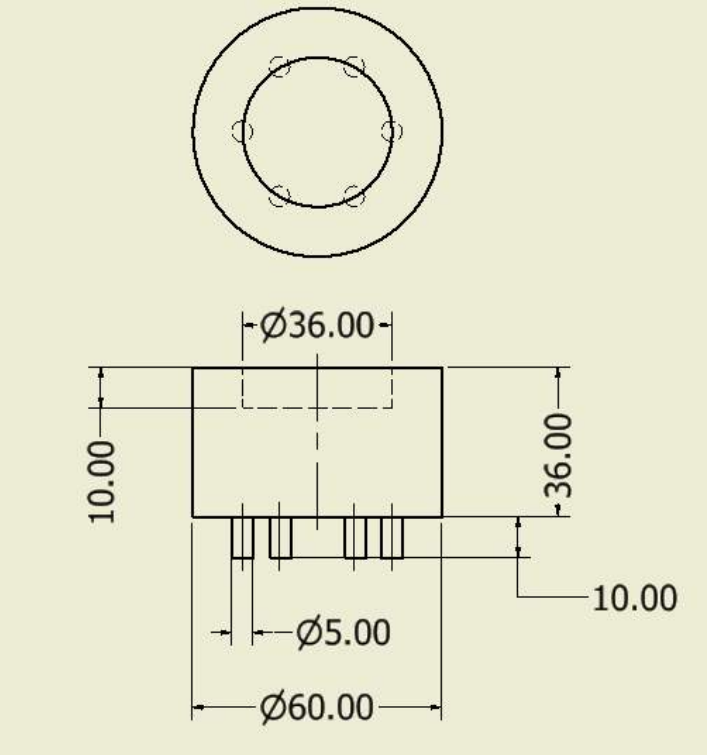


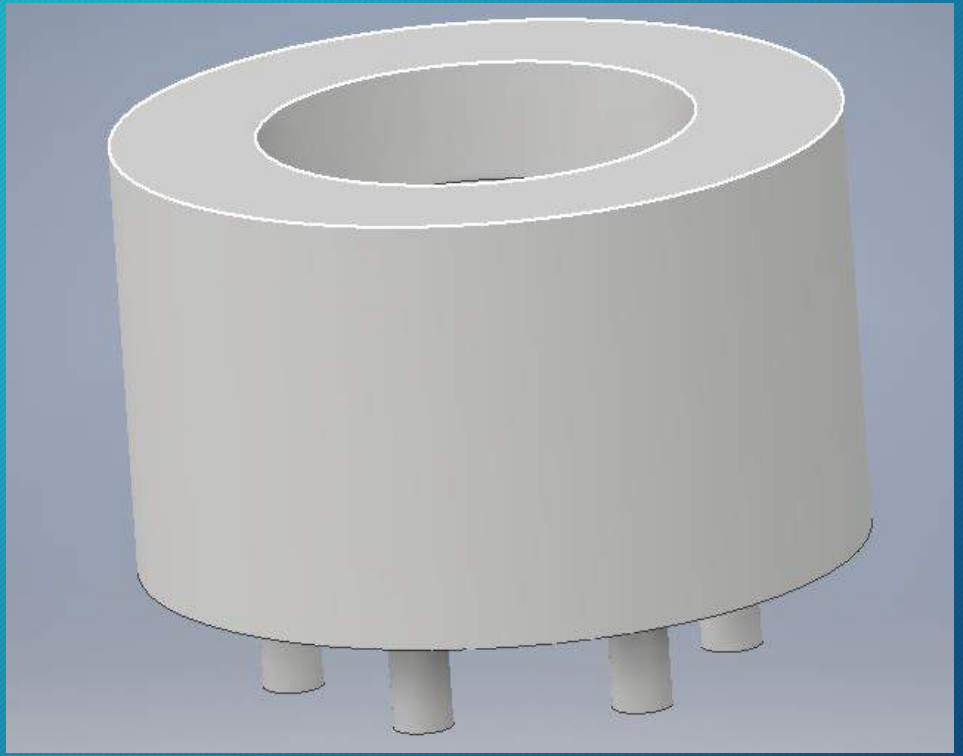




# Sensor 1

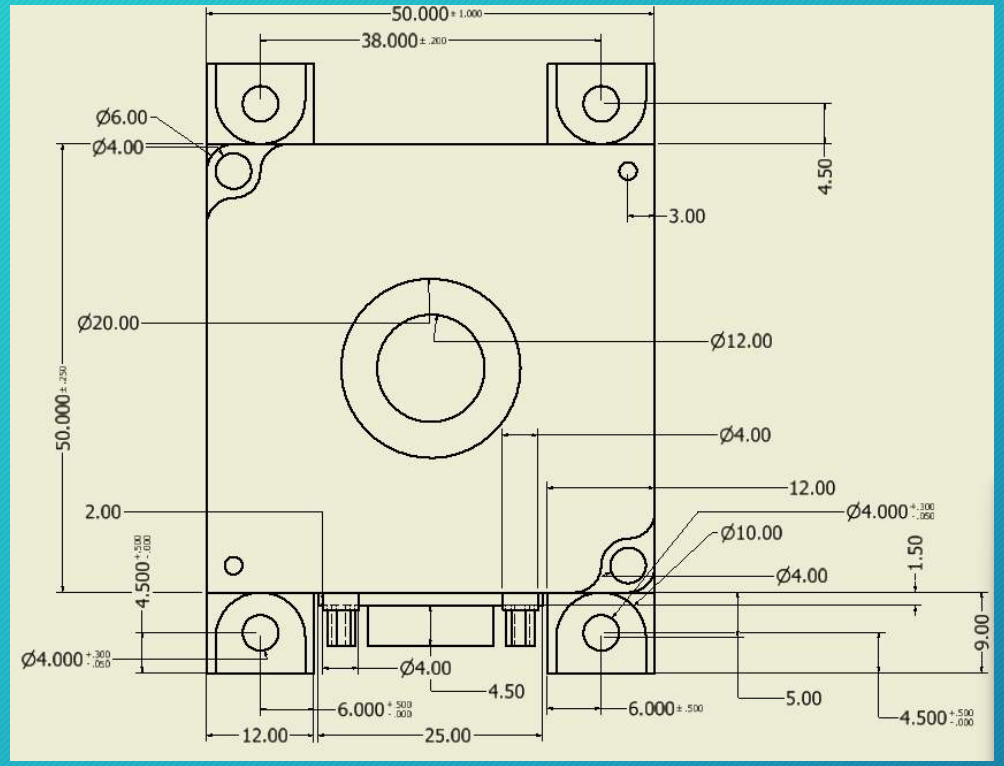




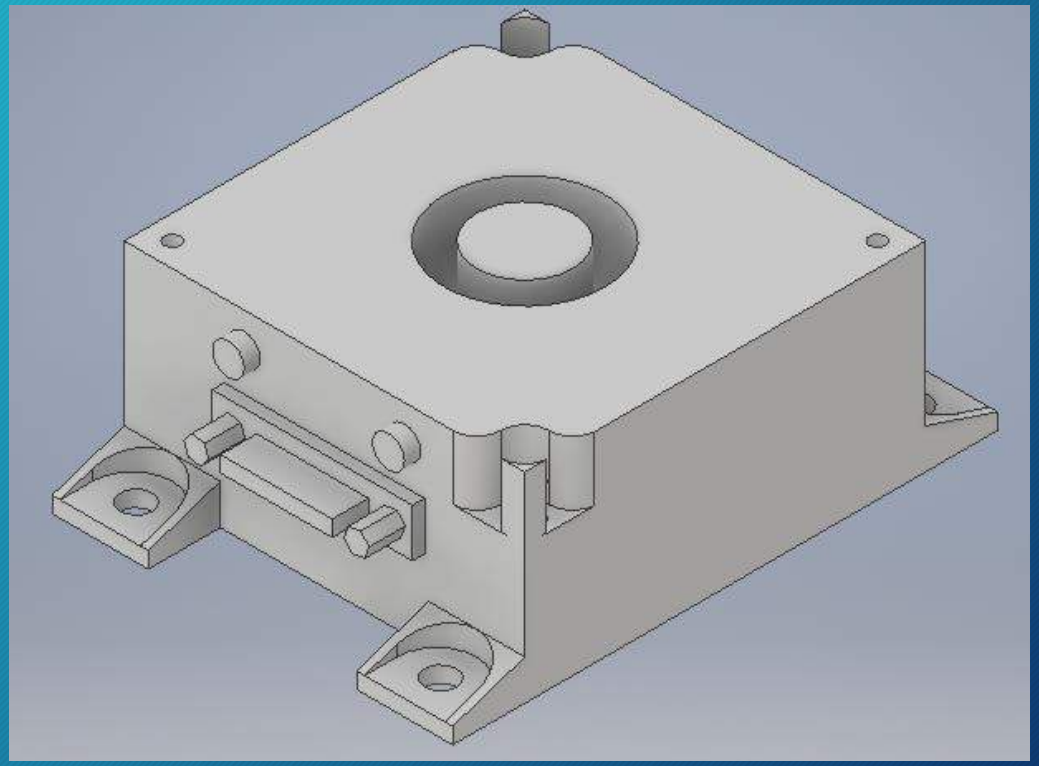



# Sensor 2



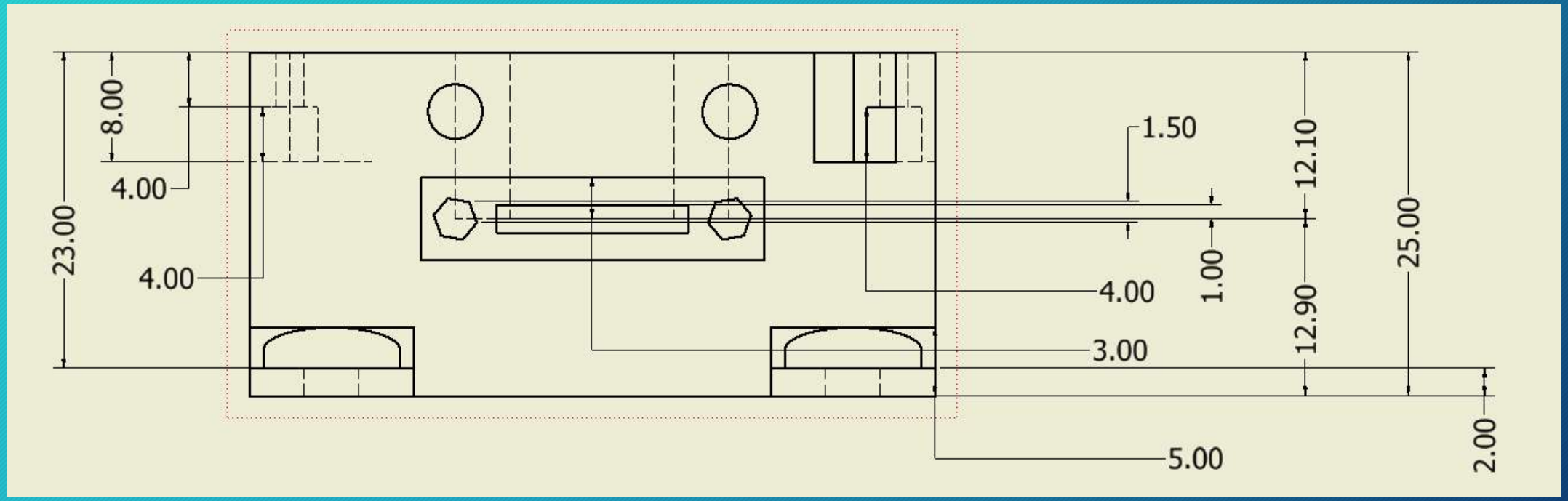



Top view



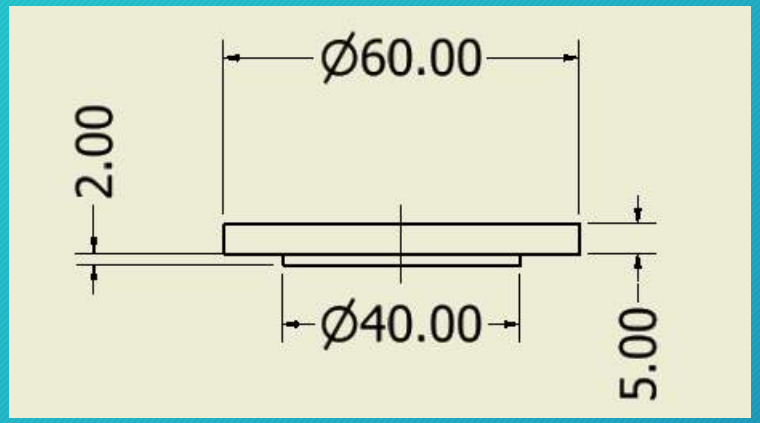
# Sensor 2 Front view



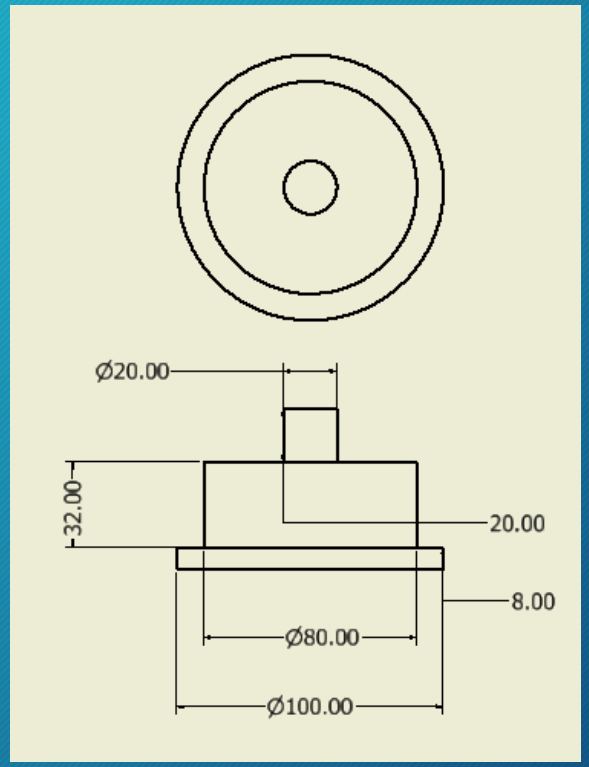


# Sensor 3 and 4





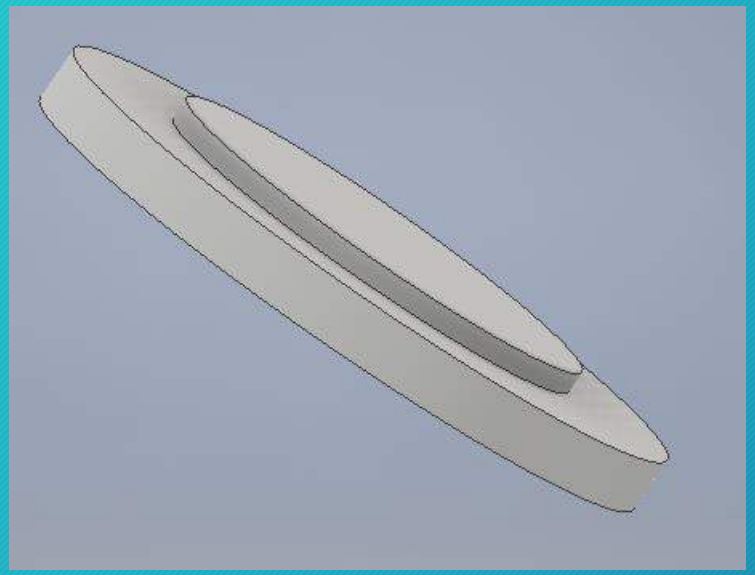

Sensor 3
Front view

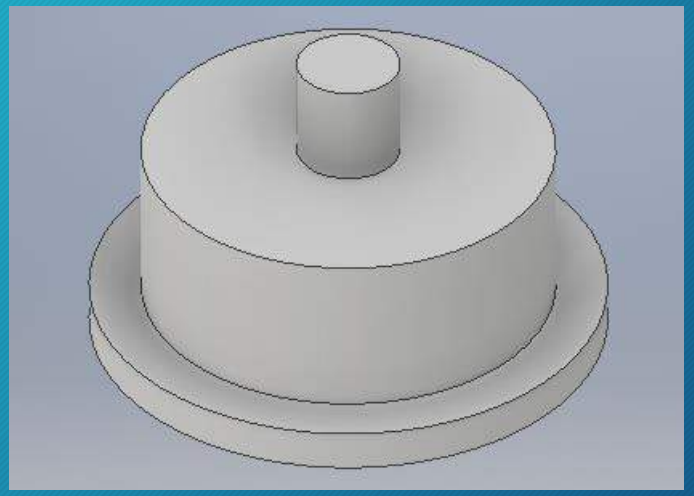



Sensor 4

# Sensor 3 and 4

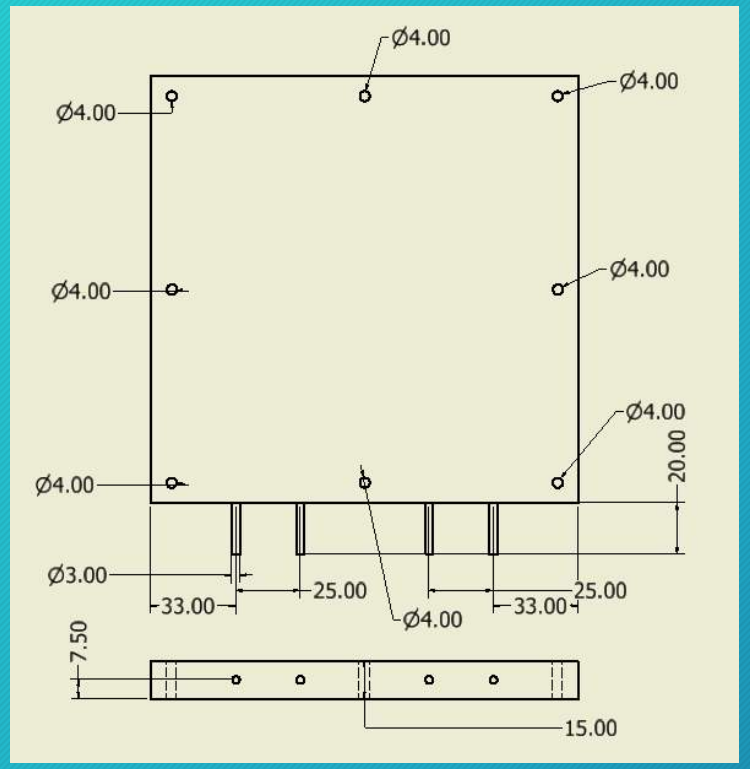


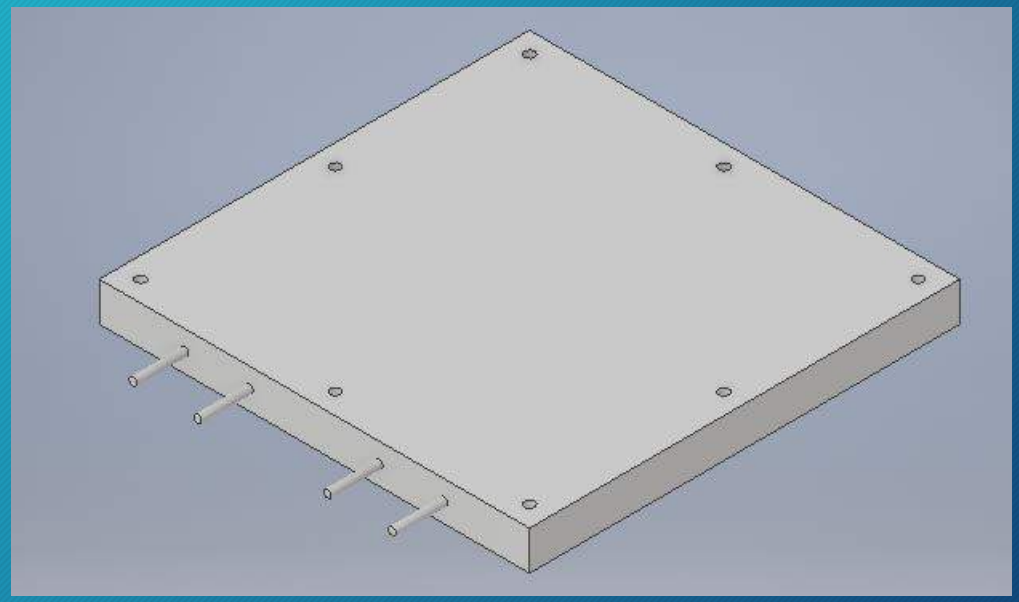




# Electronics Board

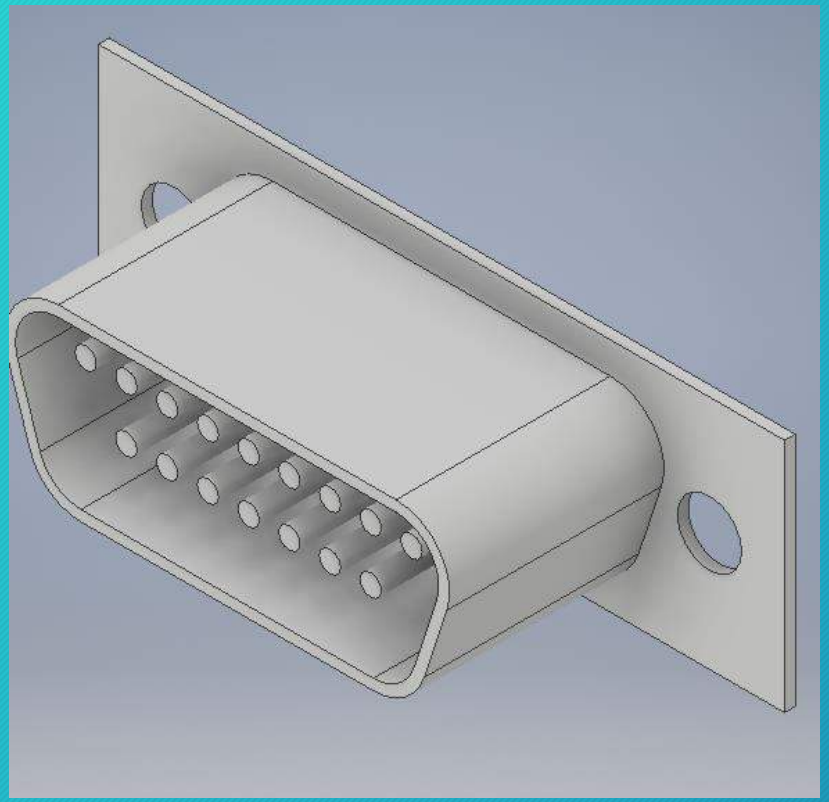


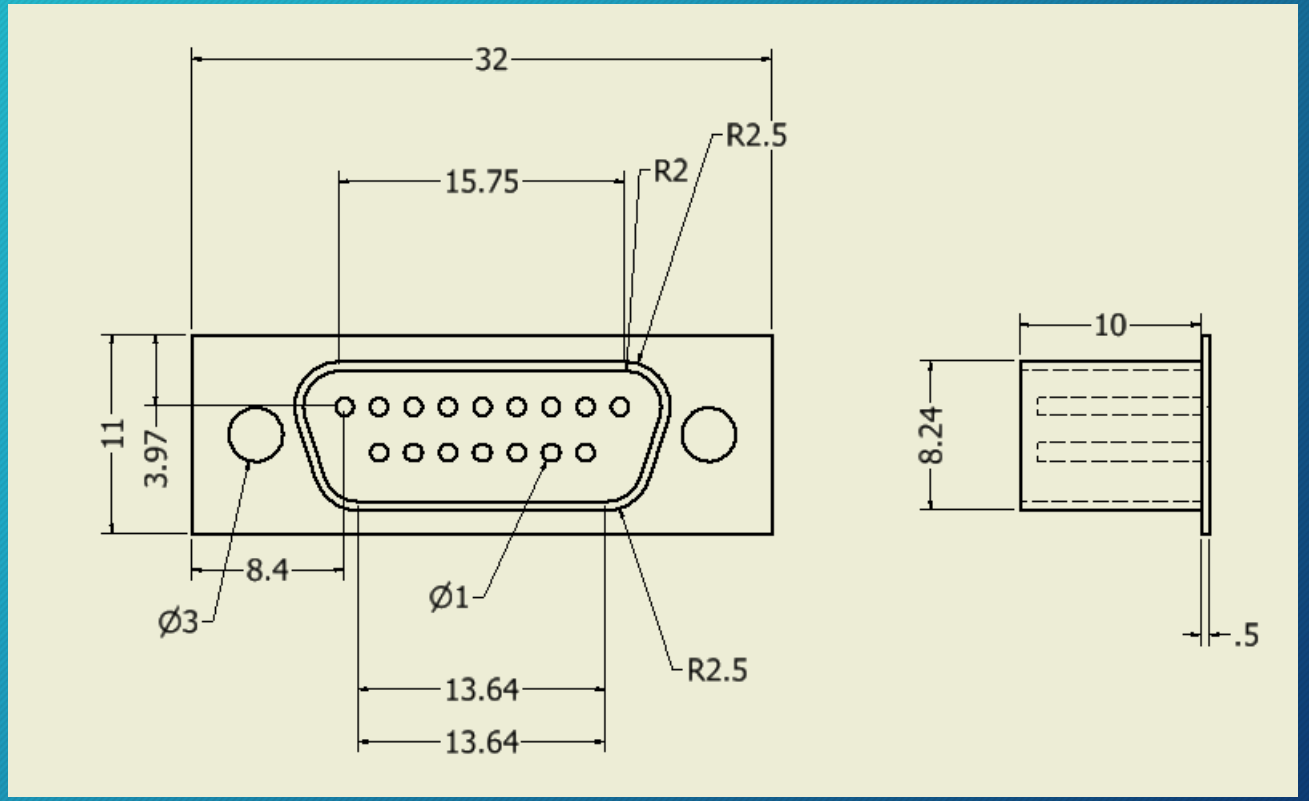


# D-pins







# Assembly of Housing

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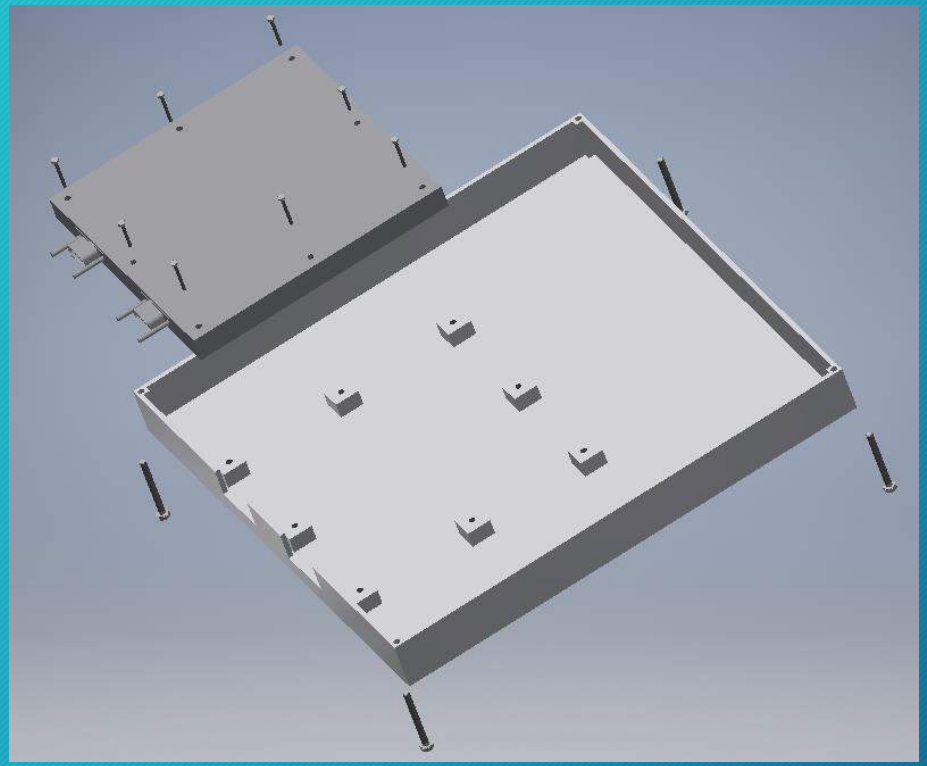
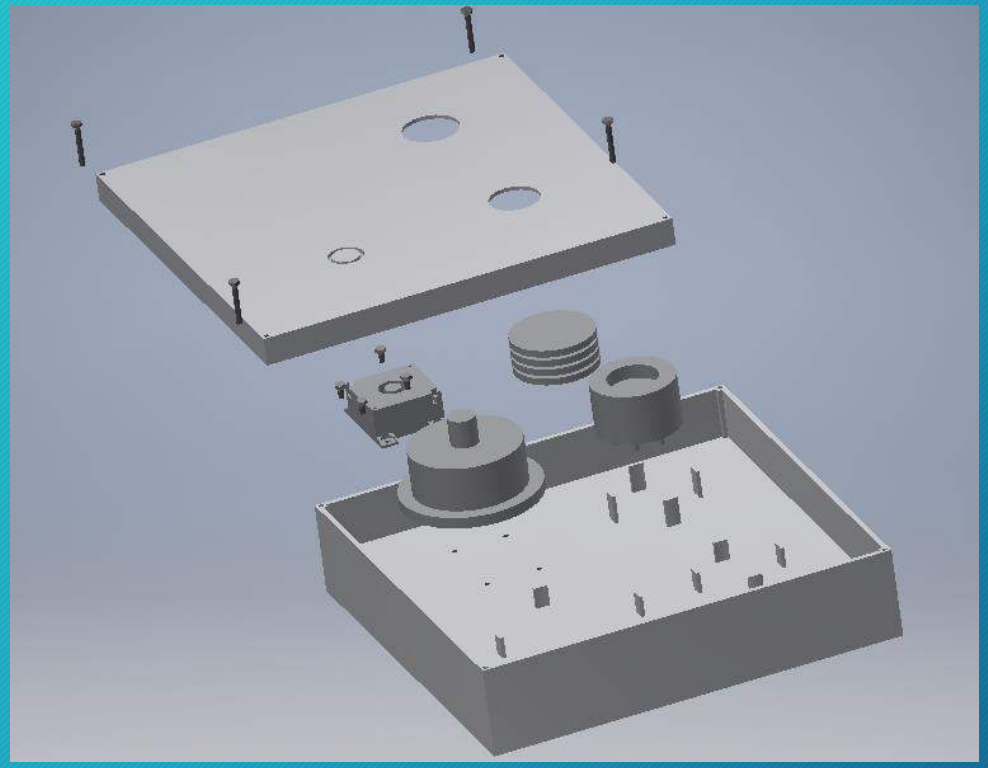
# Bottom housing assembly





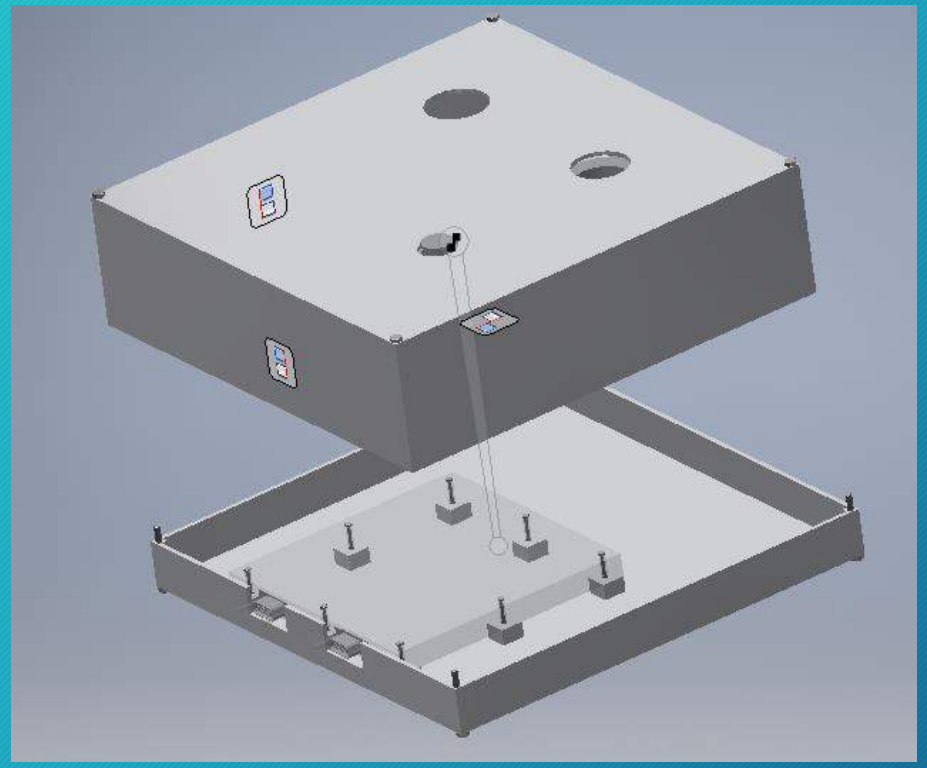
# Top housing assembly





# Full assembly





# Machining Operations

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# Machining of Polycarbonate



- Specialized jigs and fixtures required to prevent cracking under high tensile loads.
- PC can be machined using simple lathe or mill.
- For milling and lathe, high rpm (typically 15000) with high feed (typically 3 times that of Al) is used.
- For drilling, to accommodate the poor heat dissipation of the polymer, it is done with low drilling speed and high passes and feed.
- After each machining operation, annealing/stress relieving is required.
- Chatter reduces finish and tool life. The workpiece has to properly be fixed to the work bench.

# Lid Machining Sequence



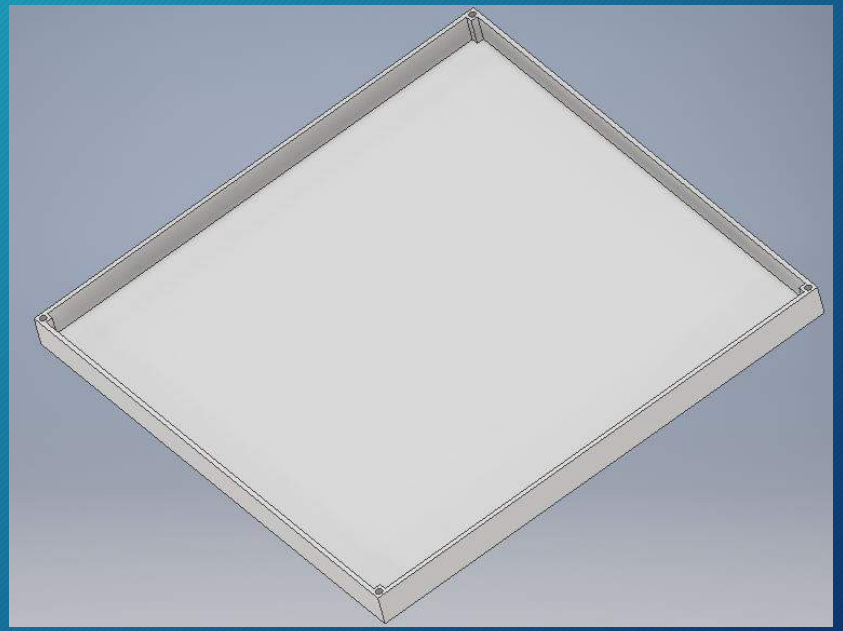
Slab milling

Drilling (holes)

# Lid of Top Housing



- Slab Milling
- Depth of cut – 17.3 mm
- Through holes drilled on four corners.



# Base Machining Sequence

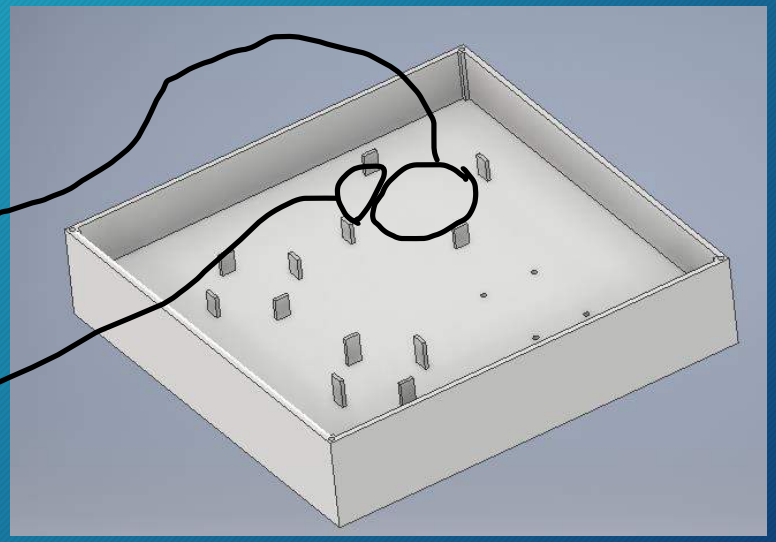


Slab milling (till the top of the supports) → End milling (making the supports) → Drilling (holes)

# Base of Top Housing



- Slab milling of the initial blank in initial pass.
- The supports for the sensors are made using end milling. Mill the inner diameter circles of the supports. Then mill the in-between material of supports
- Drilling of holes (on 4 corners – top and bottom).



# Bottom Housing Machining Sequence



Slab milling (till the board's supports)

Slab milling (to obtain the rectangular extrudes)

Drilling (holes)

# Bottom Housing



- The whole part can be slab milled from initial bottom housing blank.
- The stands for the board (square cross-sectional extrudes with holes) can then be drilled.
- 4 corners can be drilled.
- The opening for D-pins is slab milled.

# Machine Tools and Cutting Tools

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# Cutting Tool



- Need to have sharp cutting edge. This minimizes deformation.
- Contrary to tool selection in steel where we take slightly blunter tool to increase tool life.
- Blunt tool in PC will push the chip away instead of cutting it off.
- As a result, heat will be high (chip has the highest heat % of the heat balance) and the workpiece will have plastic distortions.
- Small grain size required in cutting edge
- HSS (High speed steel) good for this. Carbide tools without coatings are also good.

# Required cutting and machine tools



- Milling – Vertical Milling machine

1. End mill
2. Slab mill

- Drilling – Drilling machine

1. Drill bit

- Threading – Tapping

1. Taps

# End and Face mill



- More flutes in end mill to accommodate high feed.
- Burr formation is common in milling operations.
- Use secondary material at the edges so that the tool continues into the secondary material.
- High speed steel.

# Drill bit and Tap



- Drills with twist angles of 12°-18° and with large flute areas help remove chips and heat from the drilling hole.
- High speed steel
- Remove drill from holes frequently to allow cooling of workpiece and prevent chip accumulation.
- Don’t use a used drill bit. It will be dull and can impact the workpiece.
- 3000 rpm is required for 4mm diameter holes.
- Two flute taps with enlarged flutes will help remove chips and keep the taps clear.

# Coolant



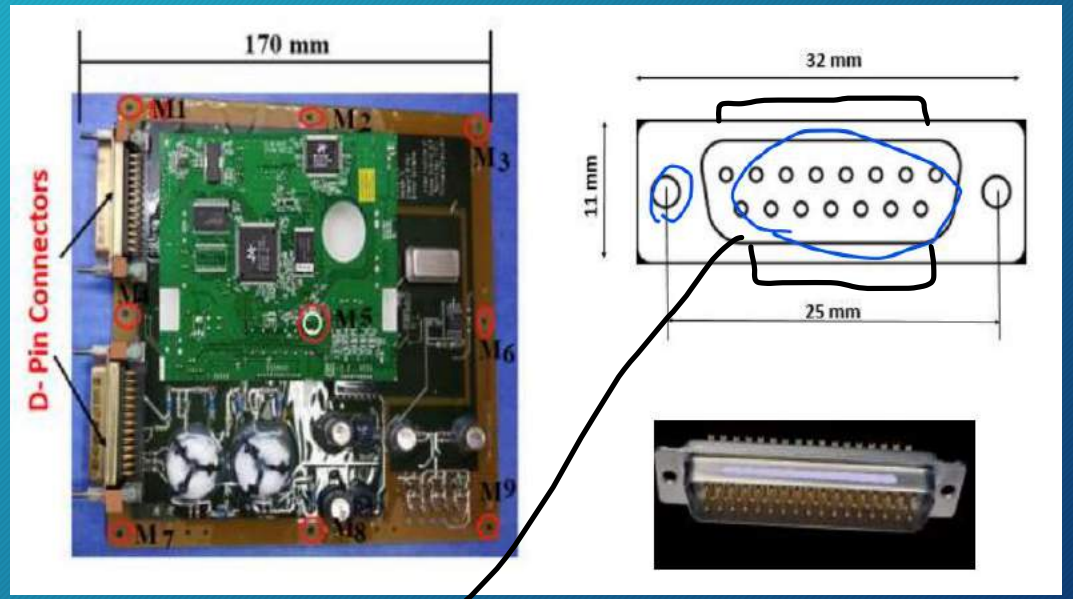
- PC can melt and chips can get welded to surface without coolant.
- Non aromatic, water soluble coolants give good surface finishes and close tolerances. Ex Spray mists.
- High pressure air current is a good choice as they blow away the chips too.
- For deep grooves, soap water can be used.
- Flood coolants - Trim 9106CS, Polycut.

# Assumptions

# Electronic board



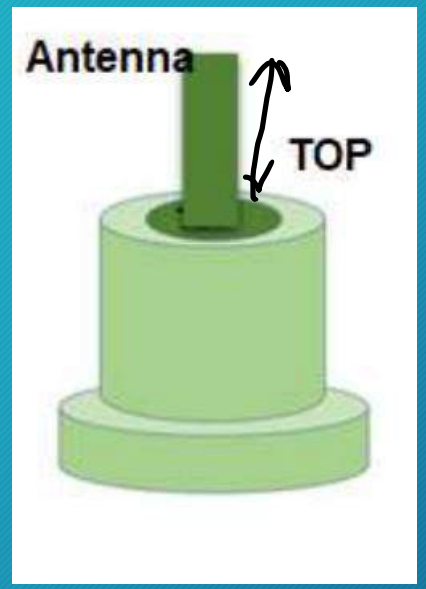
- Len from M1 to M3 given but length from edge to edge is assumed
- In the D-pin, the circles dimensions are assumed (radius of two larger holes and protrusion along with pins).
- Dimensions of covering of small pins are assumed.

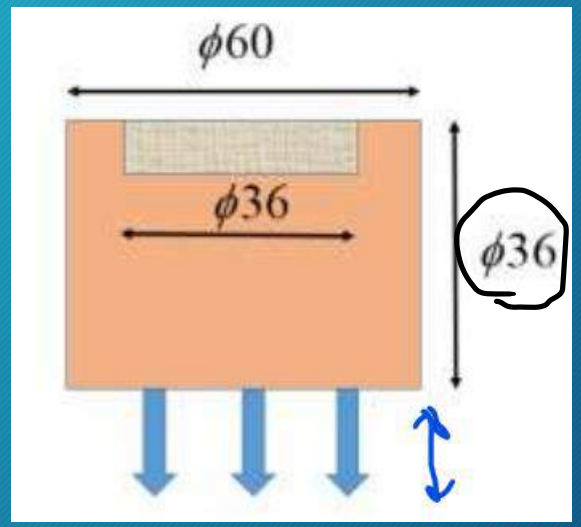


# Sensor 1 and 4



- Length of antenna is assumed in sensor 4
- Length dimension marked as diameter assumed as length.
- Length of pins assumed.

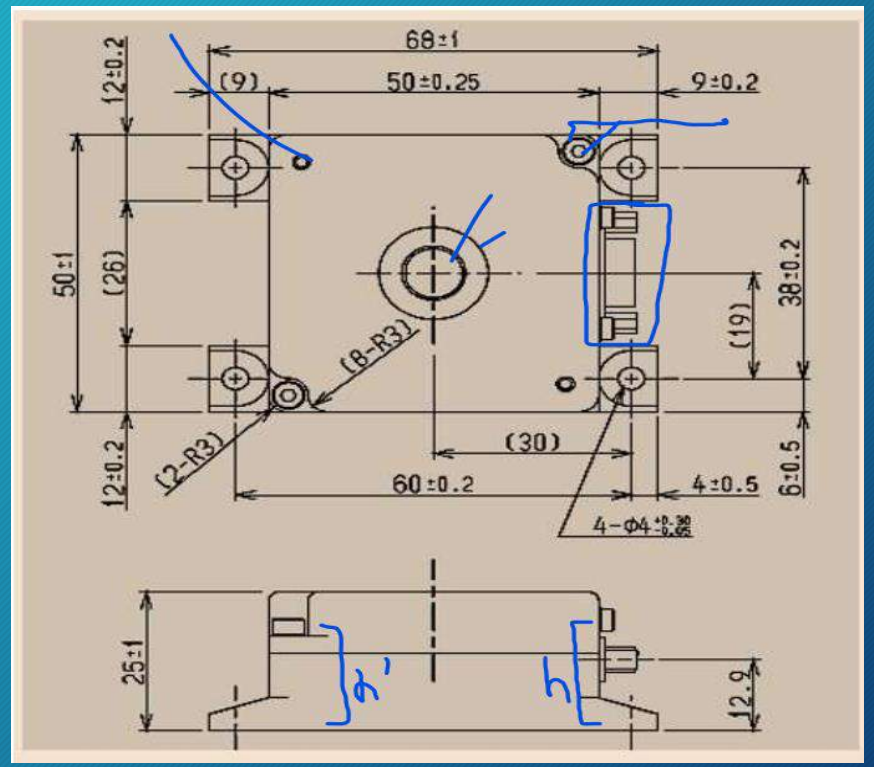


# Sensor 3



- Radius of the marked holes assumed. (Top view)
- Heights marked in front view assumed.
- The dimensions of the control knob marked by a rectangle in blue are assumed.
- Radius of the diagonally opposite knobs assumed (Top view).
- Central circles radii assumed (Top view).



# Manufacturing Drawings

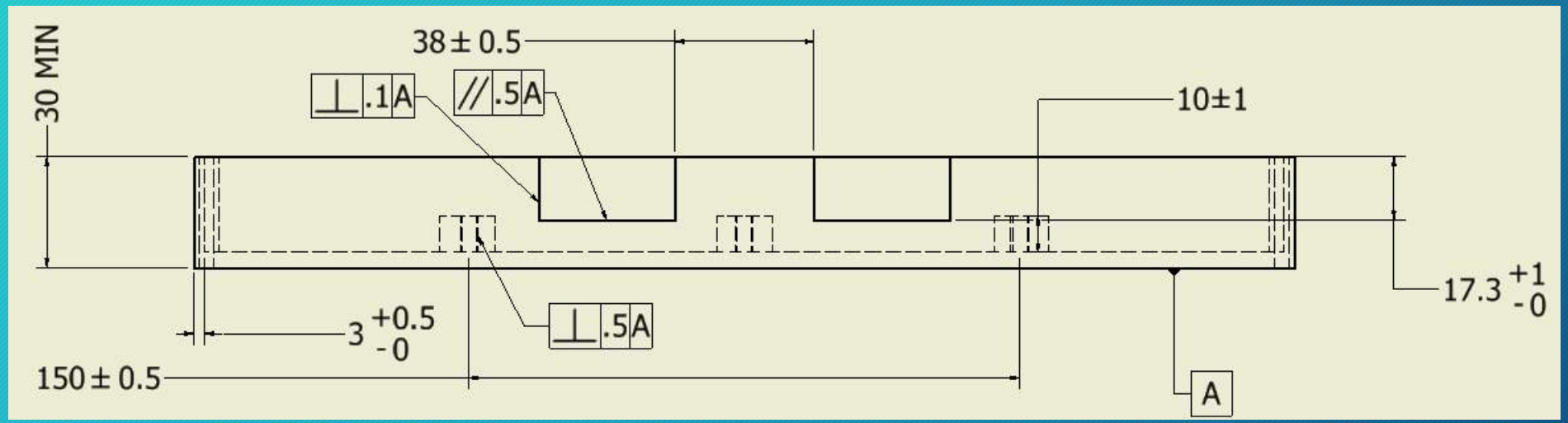


Metrology Evaluation

Please see uploaded pdfs

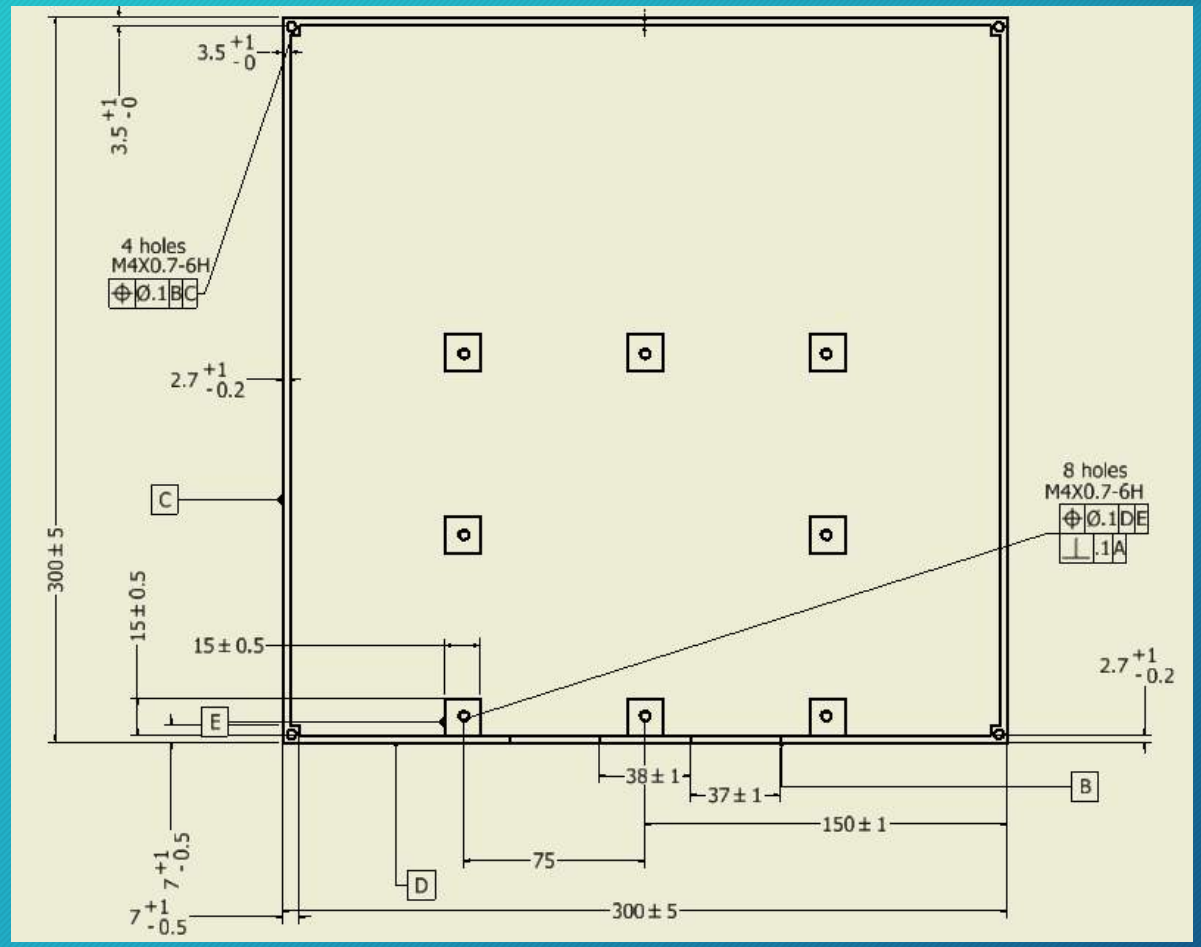
# Bottom Housing FV





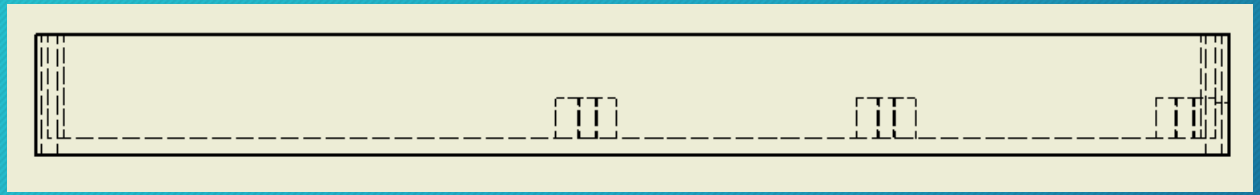
# Bottom Housing TV





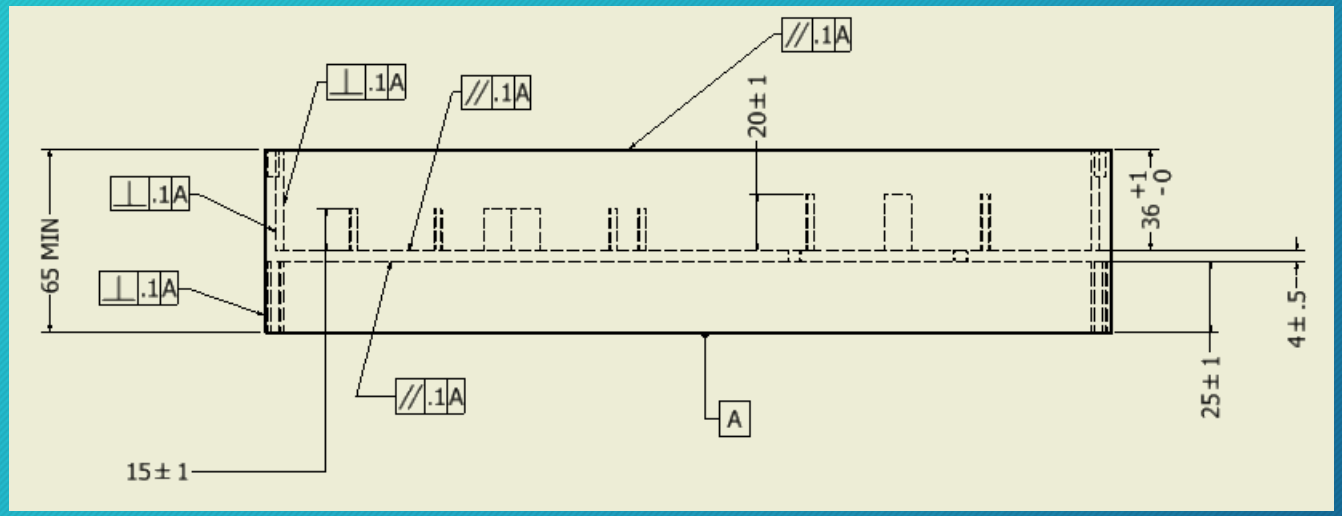
# Bottom Housing RSV





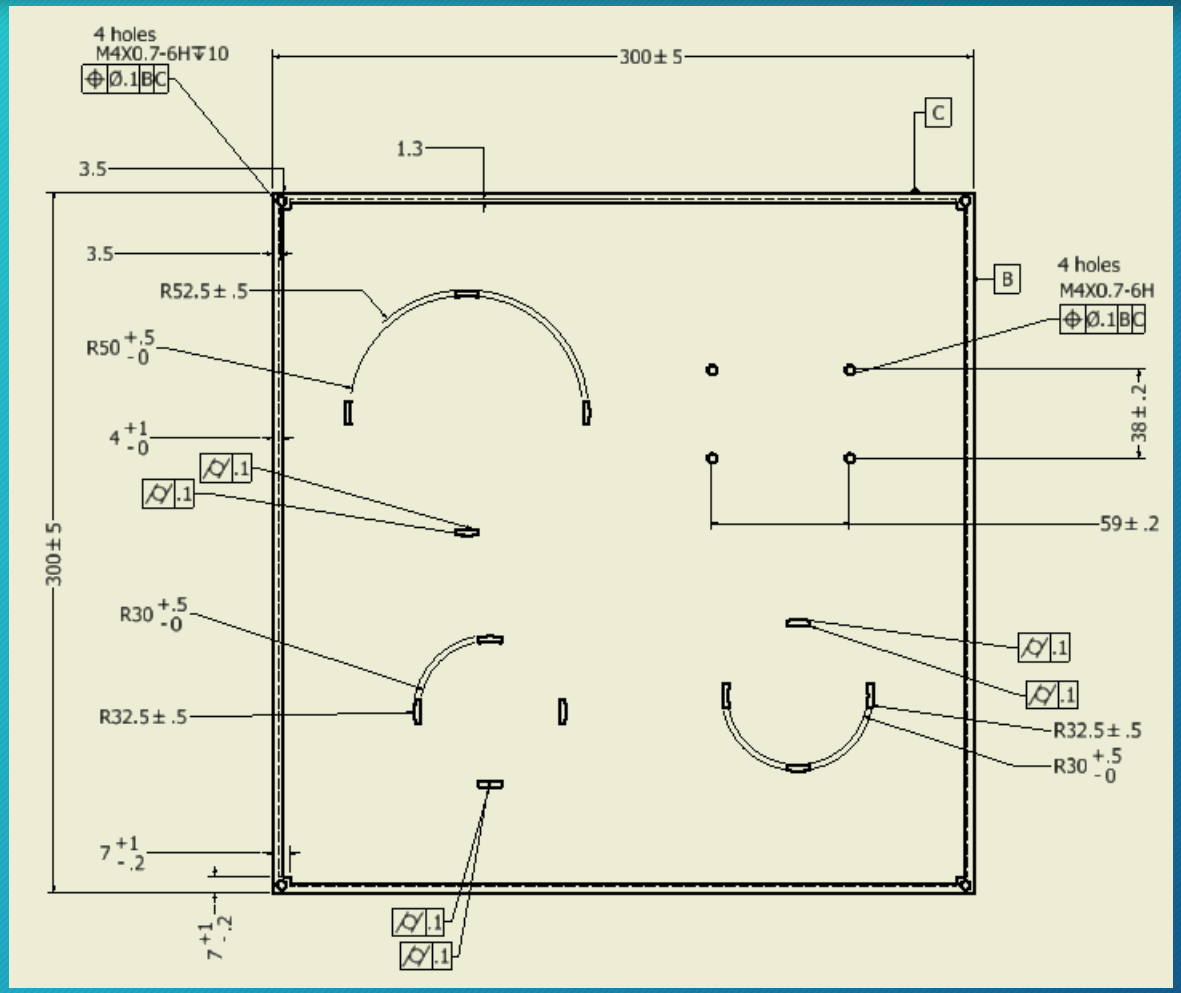
# Top Housing Base FV





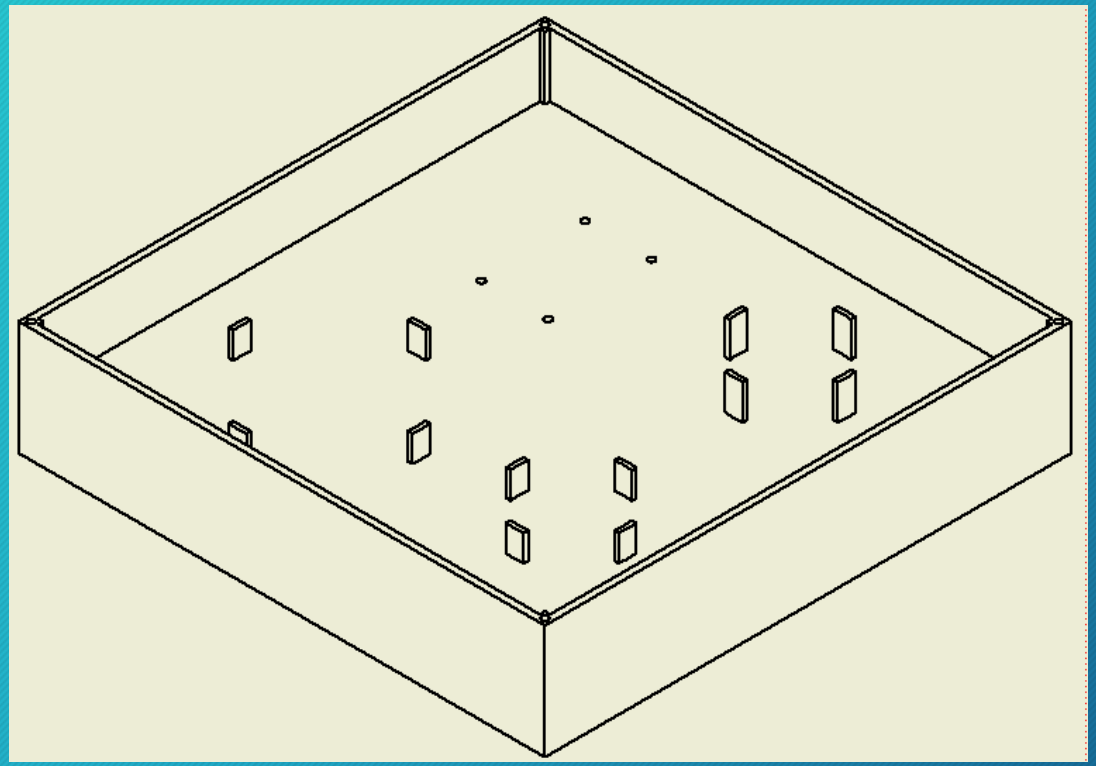
# Top Housing Base TV





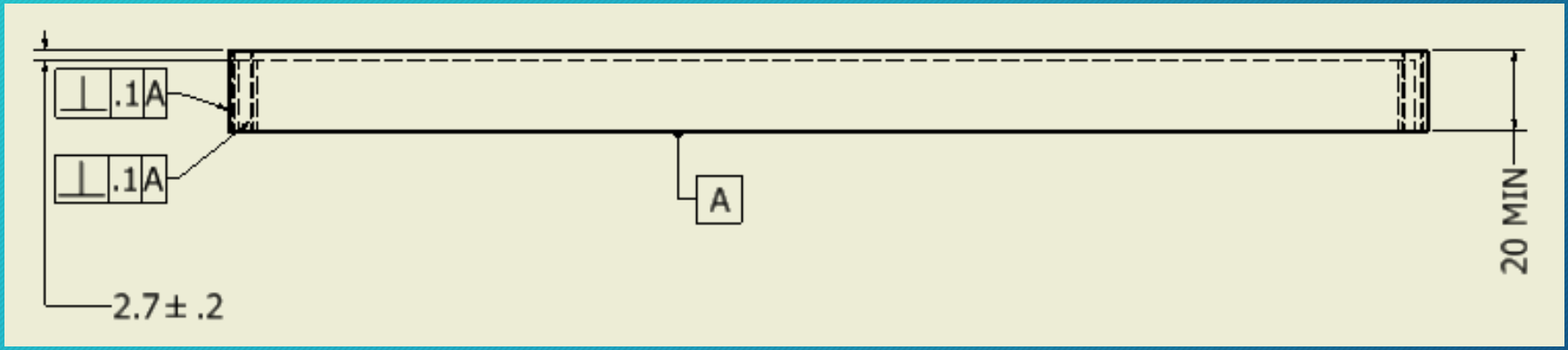
# Top Housing Base Isometric view





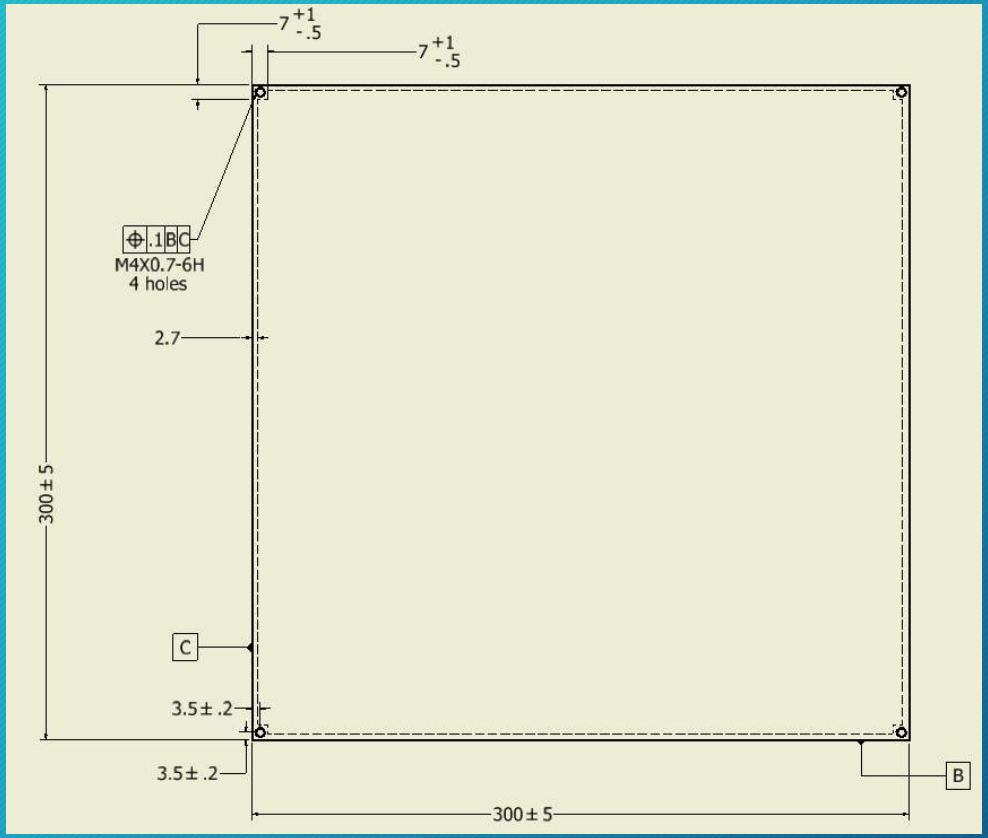
# Top Housing Lid FV





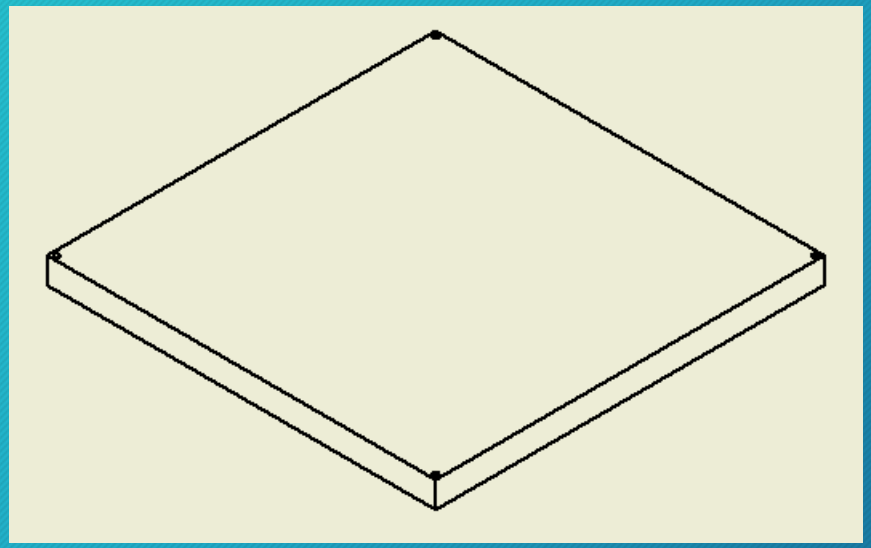
# Top Housing Lid TV





# Top Housing Lid Isometric View





# Measuring methods and Instruments



Metrology Evaluation

# Parallelism



- 2D – height gauge – This electronic device has a probe which when run on the surface measures parallelism wrt datum. The probe senses pressure variations when run along the surface. Internal working is similar to that of dial indicator.
- Dial indicator – The workpiece is divided into grids. The indicator is run over the workpiece. The starting points of each horizontal line is taken as 0(reference). Deflections for each grid point are taken. Then the parallelism is calculated for the whole surface wrt datum.
- Autocollimator – Light rays are captured by the autocollimator from the reflector as it moves along the surface. Based on the angle between the two initial parallel rays after reflection, the autocollimator calculates the parallelism.
- Coordinate measuring machine

# Perpendicularity



- 2D-Height gauge – when the probe is run along the surface perpendicular to datum, perpendicularity is outputted. The gauge is locked at 90 degree to datum.
- A crude method is to use a square ruler and feeler gauge. The perpendicular part of the ruler is placed touching the surface. Using a feeler gauge the gap between ruler and surface is measured. This is the perpendicularity.
- Coordinate measuring machine – Each point of the workpiece is a unique point in the coordinate system of the machine. Perpendicularity, parallelism, cylindricity are thus measured.

# Position Error And Cylindricity



- Coordinate measuring machine - Set the reference plane and put the stylus on the measurement point on the target. The measurement result is instantly displayed on the screen.

# Measurement of Lengths, Diameters and Threads



- 2D Height gauge – Lengths and diameters
- Vernier calliper – Lengths and depths
- Screw gauge – Lengths
- 3-pin micro-meter – Diameters
- Go-No go gauges – for diameter inspection
- Plug gauges – thread inspection

# References




- https://en.wikipedia.org/wiki/Polycarbonate#Properties_and_processing
- https://aipprecision.com/machining-polycarbonate-pc-a-plastics-guide/#:~:text=Polycarbonate%20rod%20and%20plate%20are,pressurized%20air%20and%20spray%20mists.
- https://www.emcoplastics.com/polycarbonate-machining-and-fabrication/
- https://www.fictiv.com/materials/cnc-machining-polycarbonate
- https://augustafreepress.com/everything-you-need-to-know-about-polycarbonate-machining/

- https://cdn.thomasnet.com/ccp/00399914/221437.pdf
- https://www.linkedin.com/pulse/5-tips-polycarbonate-milling-nicole-he
- https://fractory.com/milling-cutters-and-tools/
- https://brlcad.org/design/drafting/Drafting_Manual_DimensioningAndTolerancingSymbols_6-1.pdf
- https://www.keyence.com/ss/products/measure-sys/gd-and-t/orientation-tolerance/perpendicularity.jsp
- https://encyclopedia.pub/entry/1314#:~:text=An%20interferometer%20is%20a%20geometric,perpendicularity%2C%20parallelism%2C%20and%20angle.
- https://www.keyence.com/ss/products/measure-sys/gd-and-t/location-tolerance/position.jsp