Name:

DESIGN FOR MANUFACTURING

Design for Manufacturing (DFM) is a crucial process that ensures a product can be efficiently and cost-effectively produced while maintaining quality and functionality. Without DFM, products may be difficult or expensive to manufacture, leading to production delays, material waste, or assembly issues. For example, a design with overly complex features might require specialized tooling, increasing costs, while a part that doesn't account for standard material sizes could lead to excessive scrap. Another key consideration is ensuring that parts fit together correctly for their intended function. If tolerances are too tight, parts may be difficult or impossible to assemble, while overly loose tolerances can cause instability or failure in the final product.

Several key DFM principles help optimize the manufacturing process. One of the most important is **design simplification**, which minimizes unnecessary features and reduces the number of components, making assembly easier. **Material selection** also plays a critical role, ensuring that parts are made from cost-effective and manufacturable materials without compromising strength or durability.

A key aspect of DFM involves G-coding to rapid prototype with 3D printers and CNC machines. **G-code** is the programming language that directs CNC (Computer Numerical Control) machines on how to move, cut, and shape materials to produce a design accurately. This ensures that parts are manufactured with precision and consistency, which is essential for proper fit and function. Meanwhile, **rapid prototyping** allows engineers to quickly produce physical models using technologies like 3D printing or CNC machining, enabling faster design validation and iteration. By combining these tools with DFM principles, manufacturers can reduce production errors, optimize material use, and improve overall product quality.

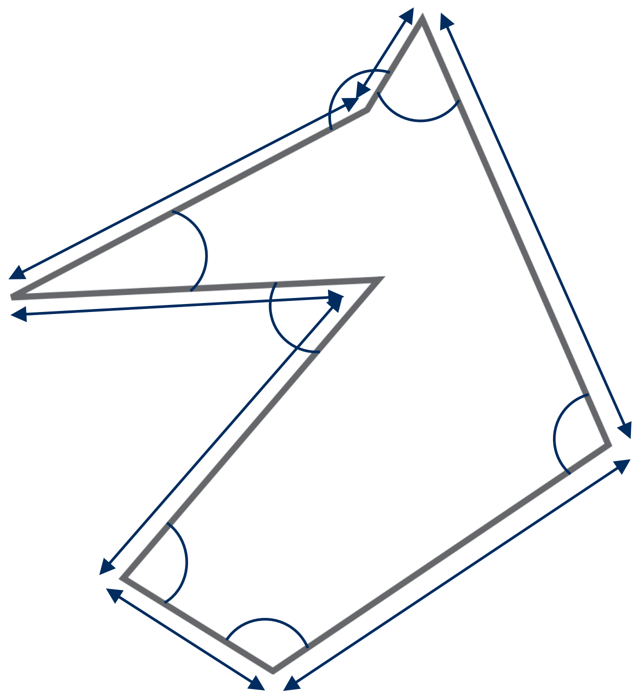
In this hands-on activity, you will apply DFM concepts to design and manufacture a custom part. You will determine the design measurements and code a 3D printer to rapidly produce a prototype. Through this process, you will gain a deeper understanding of how design decisions impact manufacturability and how integrating DFM principles early on leads to better, more cost-effective products.

❓ *Quick Start: How does rapid prototyping help during the design process?*

PART 1: MEASUREMENTS AND SCHEMATIC

We need to design a custom piece to fit into a new part with a unique hole design. Use the provided measurement tools to create a schematic of the needed part. Keep in mind that the part will be created with a 3D printer that uses a 1.75mm filament.

1. Collect the length measurements of each side of the part and the angle measurements for each corner. Record those on the unscaled part below.



❓ *Consider how much wiggle room will needed between the 3D printed part (your design) and the provided unique hole. Should the design have the exact measurements as the hole?*

2. Look at the provided designs to determine which design should be used by the 3D printer. Take some measurements and compare them to your schematic to help you choose. Circle your selection below.

1 2 3 4

PART 2: G-CODE AND RAPID PROTOTYPING

To print the design, the 3D printer needs a set of directions in the form of g-code. Write the program needed to print the design you chose. Example commands are on page four.

Record the g-code for your design below.

3D pen information

- Use PLA which extrudes between 190-230°C
- Ideal feed rates are about 3600-9000 mm/min
- Ideal extrusion amounts are the length of the distance traveled
  - Challenge:

$$Extrusion = \frac{distance\ traveled\ (mm) \times layer\ height\ (0.3\ mm) \times line\ width\ (0.75\ mm)}{2.41\ mm^3}$$

1 ____

2 ____

3 ____

4 ____

5 ____

6 ____

7 ____

8 ____

9 ____

10 ____

11 ____

12 ____

13 ____

14 ____

15 ____

COMMON G-CODE COMMANDS

Commands	*Description*	*Examples*

G28	*Homing Routine*
	
	Most of your print files will begin with this command so that the printer starts from a known location.
		`G28 ; home all axes (X, Y, and Z)`
		
		`G28 X Y ; home X and Y axes`
		
		`G28 Z ; home Z axis only`

G90	*Absolute Positioning Mode*
	
	Absolute positioning means that you will be telling your 3D printer to move an exact XYZ coordinate.
		`G90 ; use absolute positioning for the XYZ axe`
		
		`G1 X10 F3600 ; move to the X=10mm position on the bed at a speed of 3600 mm/min`
		
		`G1 X20 F3600 ; move to X=20mm at a speed of 3600 mm/min`

G91	*Relative Positioning Mode*
	
	Relative positioning is used when you want to tell the printer how far it should move from the current location.
		`G91 ; use relative positioning for the XYZ axes`
		
		`G1 X10 F3600 ; move 10mm to the right of the current location at a speed of 3600 mm/min`
		
		`G1 X10 F3600 ; move another 10mm to the right at a speed of 3600 mm/min`

M104 and M109	*Extruder Heating Commands*
	
	The M104 command starts heating the extruder, but then allows you to run other commands immediately afterwards.
	
	The M109 command will actually wait until the desired temperature is reached before allowing any other commands to run.
		`M104 S190 ; start heating nozzle to 190 degrees Celsius`
		
		`G28 X0 ; home the X axis while the extruder is still heating`
		
		`M109 S190; wait for nozzle to reach 190 degrees before continuing with any other commands`

G1	*Linear Movement*
	
	The G1 command tells your printer to move in a straight line to the location that you specify. You can use this to move just a single axis, or multiple axes at once. Keep in mind that your extruder is controlled just like any other axis, so you can also use this command to extrude or retract filament from the nozzle.
		`G1 X0 Y0 F2400 ; move to the X=0 Y=0 position on the bed at a speed of 2400 mm/min`
		
		`G1 Z10 F1200 ; move the Z-axis to Z=10mm at a slower speed of 1200 mm/min`
		
		`G1 X30 E10 F1800 ; push 10mm of filament into the nozzle while moving to the X=30 position at the same time`