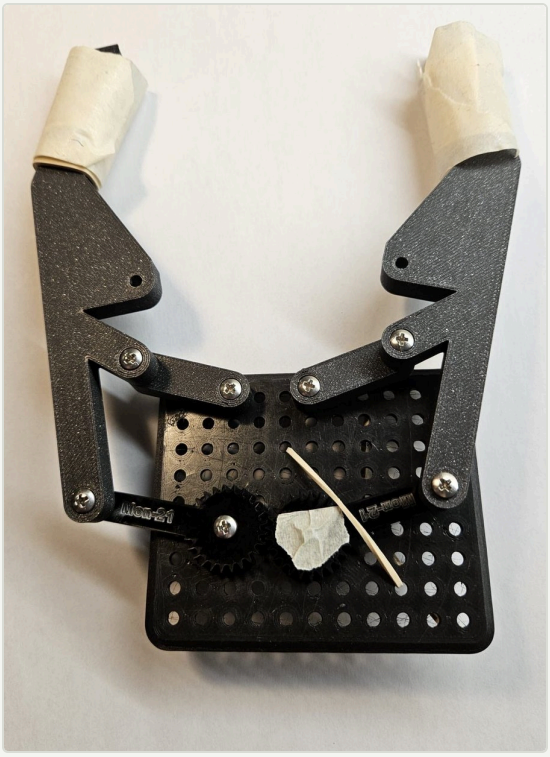
FIRST-YEAR ENGINEERING DESIGN PROJECT · TEAM OF FIVE

Q-Arm Warehouse Gripper

An end effector that lets a robotic arm pick customer orders in a mock warehouse. Our team designed, 3D printed and programmed a gear-synchronised claw. I was the project manager and designed the gears, the friction pads and the final jaw shape.

MY ROLE	TEAM	DURATION	BUILT WITH
Project manager, mechanical design	**Five engineers**	**9 weeks**	**CAD, 3D printing, Q-Arm**



The final build: two printed jaws with padded fingertips, driven by a meshing gear pair on a perforated platform.

THE BRIEF

The goal was an end effector for warehouse operations: a mechanism mounted on the Q-Arm that grabs items, identifies them and places them in a basket to fill a customer's order. It brought three phases together into one working system: design, build and code.

PROBLEM	Grab and identify a variety of objects with maximum efficiency, while minimising material waste and physical strain.
OBJECTIVE	A claw that is lightweight and mobile, yet sturdy enough to lift objects of different weights, running alongside fully working code.
CONSTRAINTS	Minimise material waste and environmental impact. Keep cost and productivity efficient. Keep the workspace safe for every team member. Work quickly.
FUNCTION	Pick a set number of items, different in shape, size and mass, and move them to a basket to fulfil the order.

MY CONTRIBUTIONS AT A GLANCE

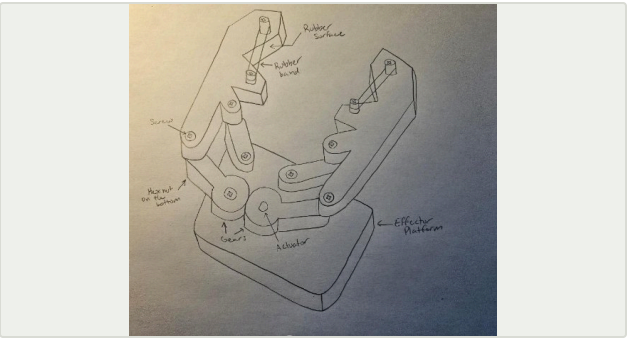
LEADERSHIP
Project manager: weekly meetings outside Design Studio, realistic weekly goals, kept five people moving together.

MECHANICAL
Designed the meshing gear arms, added the fingertip friction pads, and set the final jaw shape.

SOFTWARE
Wrote the function that summarises the customer's order, integrated into the team's main program.

Design process

We sketched individual concepts, merged the strongest features into one claw, then took it through CAD to printed hardware.

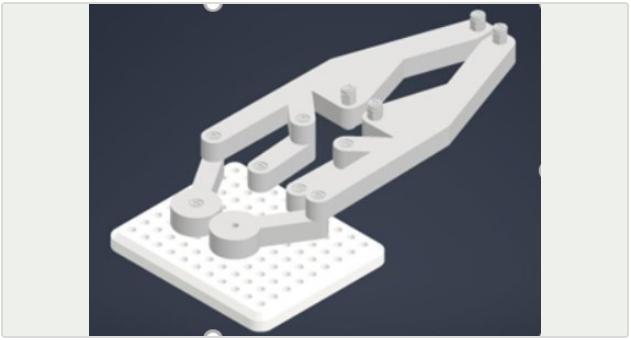


STAGE 1

Combining our concepts

Each of us brought a design. The merged sketch has two jaws driven through a gear pair by one actuator, on an effector platform, with a rubber surface and band at each fingertip.

> **Decision:** one actuator drives both jaws, so the claw always closes symmetrically.



STAGE 2

Full assembly in CAD

We modelled every part, checked that the linkage moved freely, and prepared files for 3D printing and laser cutting. The perforated platform keeps the part light and gives a grid of mounting points.

> **Built for:** low material use, so only load-carrying parts are solid.

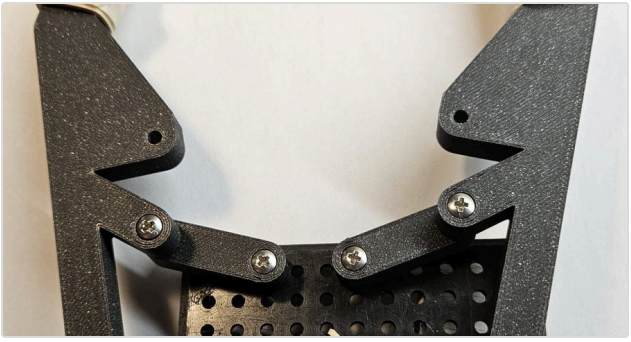


STAGE 3 · MY DESIGN

The gear arms

Each gear is a spur gear with its crank arm built into the same part, so nothing can slip between gear and arm. The two mesh directly: when the actuator turns one, the other turns the opposite way by the same amount.

> **Result:** the jaws mirror each other and centre the object as they close.



STAGE 4

Printed, assembled, padded

Printed parts are joined with screws and nuts at every pivot. I added friction at the fingertips with rubber bands and padding, and shaped the final notched jaw profile.

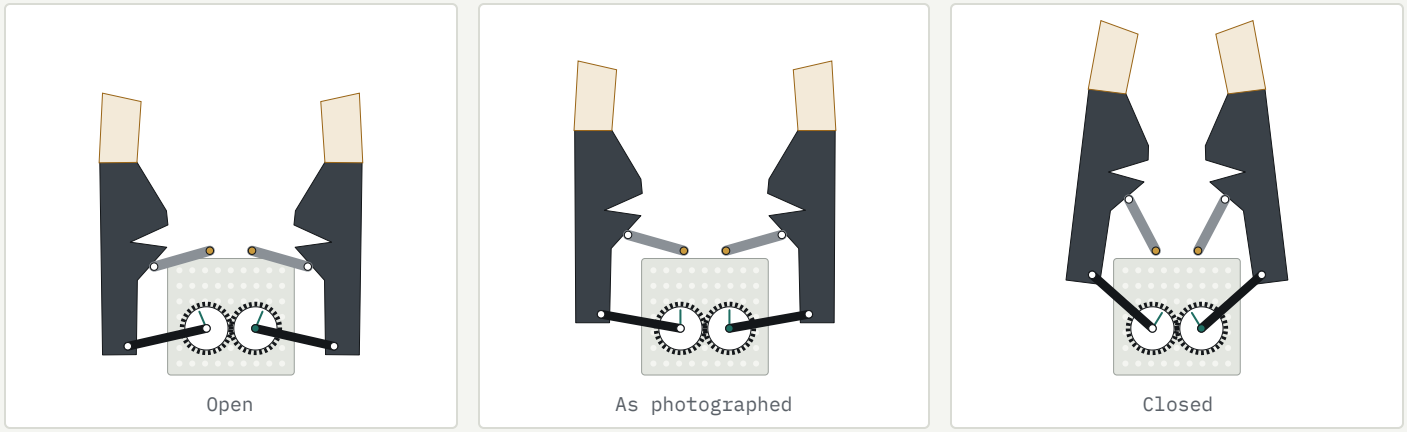
> **My addition:** the friction pads. Page 3 shows why they mattered.

> **Design choices against the constraints.** Material waste: a perforated platform and slim printed links, with only the load-carrying parts solid. Speed: one actuator closes both jaws at once, so every grip is a single motion. Grip: friction pads instead of a bigger actuator (page 3).

How it works, and why it grips

Two mirrored four-bar linkages tied together by one gear pair, and friction pads sized by a simple force balance.

LINKAGE MODEL, MEASURED FROM THE REAL GRIPPER



actuator gear fixed pivots rubber pads

Pivot positions are taken from the photo of the real gripper; the motion is solved as two mirrored four-bar linkages.

FOUR-BAR LINKAGE

Each side: crank on the gear, the jaw itself, and a short link to a fixed pivot. The jaw rotates and moves inward as it closes.

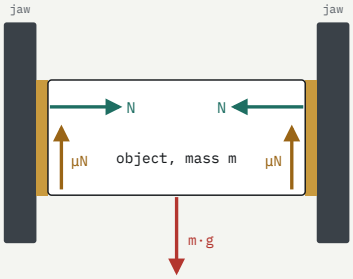
MESHING GEARS

Equal spur gears turn in opposite directions at the same speed, so one actuator drives both linkages.

WHY SYMMETRIC

If one jaw led, it would shove the object sideways. Mirrored jaws meet it from both sides at once and centre it.

GRIP CHECK: WHY THE FRICTION PADS MATTERED



The claw holds an object by friction. Each jaw squeezes with a normal force N, and the friction at both contacts must carry the weight with margin:

$$2 \cdot \mu \cdot N \geq SF \cdot m \cdot g \quad \rightarrow \quad N = SF \cdot m \cdot g / (2\mu), \quad SF = 2$$

OBJECT MASS	BARE PRINT, μ ≈ 0.3	RUBBER PAD, μ ≈ 0.7
100 g	3.3 N	1.4 N
250 g	8.2 N	3.5 N
500 g	16.4 N	7.0 N

Squeeze needed per jaw. μ values are typical textbook figures for hard plastic and rubber, used to show the trend, not measured on our parts.

Takeaway. Rubber pads cut the clamping force needed for the same object by 57%. That means less load on the actuator, the gear teeth and every printed pivot, which is why a strip of rubber was worth more than a stronger motor.

Software, team and leadership

Each of us wrote part of the program, and I kept five people working as one team.

INDIVIDUAL FUNCTIONS, ONE MAIN PROGRAM

Each team member drew a flowchart and wrote functions for part of the Q-Arm's autonomous movement. We then combined them into a single main function that runs a whole order from start to finish. Mine produces the summary of the customer's order once picking is done.

1	2	3	4	5	6
Take the order	**Identify the item**	**Move to pick**	**Grip**	**Place in basket**	**Order summary**
Which items, how many	Find the next object	Arm positions the claw	Actuator closes the claw	Release, repeat	My function

Simplified program flow. Step 6 is the function I wrote.

WHO DID WHAT

THE TEAM

What we did together

- Brainstormed individually, then merged our designs into one claw
- Built the CAD model and prepared parts for 3D printing and laser cutting
- Wrote flowcharts and functions for the Q-Arm's autonomous moves, then joined them into one main function
- Ran test cases, collected data, and refined the mechanical and software parts after each round

ME

What I owned

- **Project management:** weekly meetings outside Design Studio, realistic weekly goals
- **Gears:** the meshing gear arms that synchronise the jaws
- **Grip:** the friction pads at the fingertips
- **Jaw shape:** the final claw profile
- **Code:** the order-summary function
- **Support:** helped across CAD, build, testing and code wherever needed

LEADING THROUGH TWO SETBACKS

The laser cutting fell through.

Our laser-cutting request wasn't approved until it was far too late to use. Instead of panicking, I pushed the team to stay calm and focus on our next best action with what we could still make. When plans change suddenly, a clear head finds the fix faster.

Deadlines started to slip.

Some delegated tasks fell behind because we weren't communicating clearly. I set weekly goals, realistic deadlines and regular check-ins so everyone knew what was due and when.

Reflection

My first engineering project, and the one that taught me the most about working in a team.

> **For a team to succeed as one, it has to work together as one, and the foundation of that is healthy communication.**
>
> WHAT I TOOK AWAY

LESSONS I CARRY FORWARD

- **Communication matters as much as technical skill.** Clear goals and deadlines kept five people pulling the same way.
- **Stay calm under sudden change.** Look for the next best action instead of the lost plan.
- **Be open-minded.** Our final claw came from combining everyone's ideas, not from picking one.

WHAT I'D DO DIFFERENTLY

- **Integrate early.** We combined everyone's functions in the final days, leaving little time to debug. Next time, integrate early and often.
- **Test more.** More time on testing would let decisions rest on measured results rather than theory, for example measuring grip force instead of estimating it.

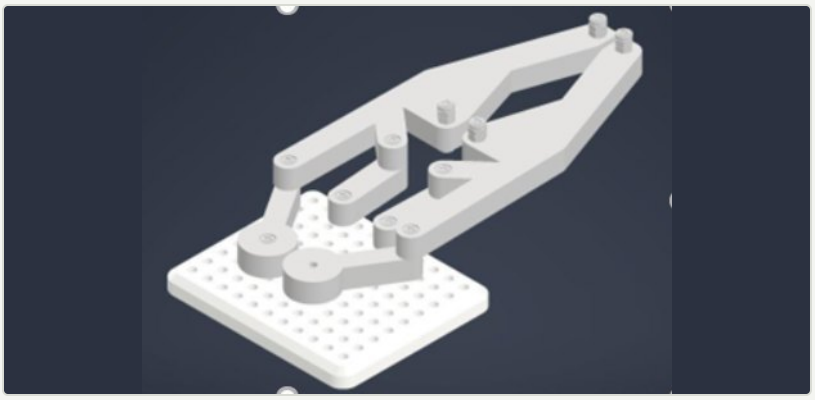
A QUESTION I STILL THINK ABOUT

How would more, or less, time have changed our result? With more pressure, would our meetings have been sharper, or would we have fallen behind? With more time, would we have spent it testing and improving? It made me realise that a team's pace shapes its outcome as much as its ideas do.

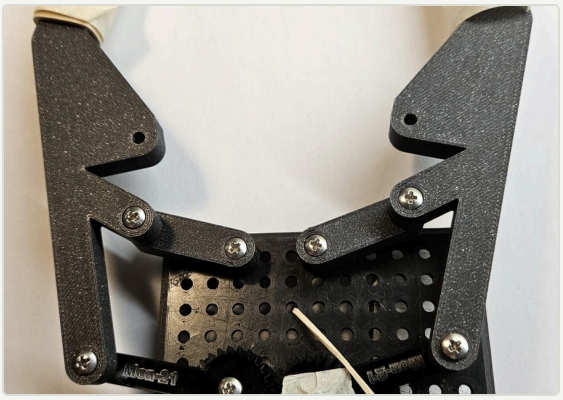
SKILLS THIS PROJECT USED

`Project management` `Linkage and gear design` `CAD` `3D printing` `Laser-cut part prep` `Friction and force analysis` `Flowcharting` `Programming` `Testing and iteration` `Team communication`

FROM CAD TO HARDWARE



CAD assembly on the perforated effector platform.



The printed and assembled gripper.

Next project. In my next design project, SWING-A-BOX, I was project manager again and also led the design, from my own concept sketch to 3D-printed prototype.