4-DOF ACRYLIC ROBOTIC ARM LEARNING & ASSEMBLY MANUAL

A Complete Step-by-Step Guide for Mechanical Assembly, Hardware Connections, and Electronic Control via Arduino and Dual Joystick Handle

Controller Board: UNO R3 + V5 Expansion Shield
Actuators: MG90S Metal Gear Servos

1. Product Overview & Kit Contents

The is a classic 4 Degrees of Freedom (4-DOF) desktop robotic arm designed for educational purposes, STEM learning, and maker spaces. Inspired by industrial multi-axis robotic manipulators, this kit offers an affordable, structurally robust, and user-friendly gateway into the world of robotics engineering and micro-controller automation.

Movement Control Method:

The robotic arm is controlled intuitively via a dual-axis PlayStation 2 (PS2) style joystick interface. The two joysticks translate physical user hand movements into real-time angle parameters, driving four high-torque MG90S micro servos that manipulate the base rotation, shoulder pivot, elbow joint, and mechanical claw gripper simultaneously.

Target Audience Guidelines:

- Highly Recommended: College/University engineering students, technical vocational classes, and adult DIY hobbyists.
- Suitable: High school students (grades 9–12) with basic engineering curiosity.
- Caution advised: Middle school students should work strictly under parental or instructor guidance.
- Not Recommended: Primary school children, due to small screw fittings and delicate mechanical alignments.

1.1 Complete Hardware Parts List

Please unpack your storage box and verify that all the following components are present before starting compilation:

Item No.	Component Description	Quantity
1	Premium Laser-Cut Acrylic Structural Plates Section (Protected by paper film)	1 Set
2	Arduino UNO R3 Compatible Microcontroller Development Board	1 Unit
3	V5 Sensor Expansion Shield for clean servo/joystick pin distribution	1 Unit
4	High-Torque MG90S Metal Gear Micro Servos (with horn sets & screws)	4 Units
5	5V 2A Regulated External DC Power Adapter (Wall Charger Pin)	1 Unit
6	DC Barrel Jack Terminal Converter Adapter Block (Screw Terminal)	1 Unit
7	150mm (15cm) Servo Extension Jumper Lead Wire	1 Piece
8	Dual-Axis Analog PS2 Joystick Breakout Board Modules	2 Units
9	Laser-Cut Acrylic Remote Control Handle Base Plate & Spacer Standoffs	1 Set
10	50cm Female-to-Female DuPont Jumper Ribbon Connection Wires	10 Pieces
11	Flexible Spiral Cable Sleeve / Winding Heat Shrink Tube (5cm length)	1 Piece
12	Hardware Fasteners Packet (Assorted M2 / M3 Screws, Nuts, and Washers)	1 Packet

2. Critical Installation Precautions

CRITICAL MANDATORY WARNING — PLEASE READ BEFORE UNSCREWING ANY COMPONENT:

DO NOT assemble the acrylic structural frame first! You must connect all electrical boards, wire the joysticks, plug in the 4 servos, upload the test firmware, and power on the system to calibrate and center all servos before fastening them into the acrylic brackets.

Why this is vital: Servos ship from the factory at random internal gear positions. If you assemble the rigid acrylic joints around an uncalibrated servo horn, the arm might immediately lock up, bind, strip its gears, or draw excessive current and burn out when powered on. Centering the servos to exactly 90 degrees electronically assures that the arm moves symmetrically within its structural ranges without hitting mechanical limits.

3. Assembly of the Dual-Joystick Remote Handle

The control desk for the is composed of two thumb joysticks mounted on a designated ergonomic acrylic holding handle. Follow these structural instructions to construct it:

- Step 3.1: Locate the flat acrylic handle base plate and peel off the brown protective masking paper on both sides to expose the crystal-clear or colored polished finish.
- Step 3.2: Align the first PS2 joystick breakout board module over the left side mounting holes. Insert small M2 screws from the top face down through the board holes.
- Step 3.3: Thread corresponding M2 nuts on the reverse side of the plate and tighten them evenly with a small cross-head screwdriver. Do not overtighten, as excessive pressure can crack the acrylic base.
- Step 3.4: Repeat the same installation step for the second joystick board module on the right side of the handle plate.
- Step 3.5: Take the two plastic moulded thumb rocker caps and press them firmly downwards onto the metallic rectangular shafts of both joysticks until they click in and pivot smoothly.

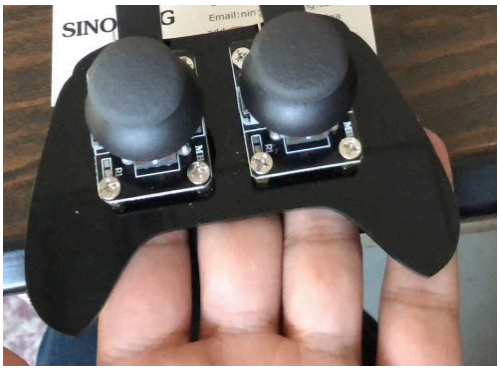


Figure Description: Top and angled view of the finished remote control handle, showcasing the twin joysticks securely screwed into place with thumb caps attached.

4. Electrical Connections & Detailed Wiring Specifications

To route signals cleanly from the joysticks and servos to the central micro-controller, the V5 Sensor Shield is stacked directly over the Arduino UNO R3 board. This aligns all pins into triplets of S (Signal - Orange/Yellow Row), V (VCC/Power - Red Row), and G (GND/Ground - Black/Blue Row).

4.1 DC Power Adapter & Supply Connection Terminal

Servos require high current impulses that the Arduino's built-in USB 5V rail cannot deliver alone. Running the arm solely on computer USB will cause the board to reset constantly or brown out.

- Take the external 5V 2A power supply adapter block and plug its male barrel lead into the female DC Screw Terminal block adapter provided.
- Locate the stripped terminal leads or separate red/black jumper feeds. Connect the positive terminal wire (RED) into the POSITIVE (+) slot of the screw converter, and screw it tight.
- Connect the negative terminal wire (BLACK) into the NEGATIVE (-) slot of the screw converter, and secure it.
- Wire the outputs directly into the dedicated power input terminal block block found on the edge of the V5 sensor shield. Double-check polarity so you don't instantly fry the expansion shield capacitors.

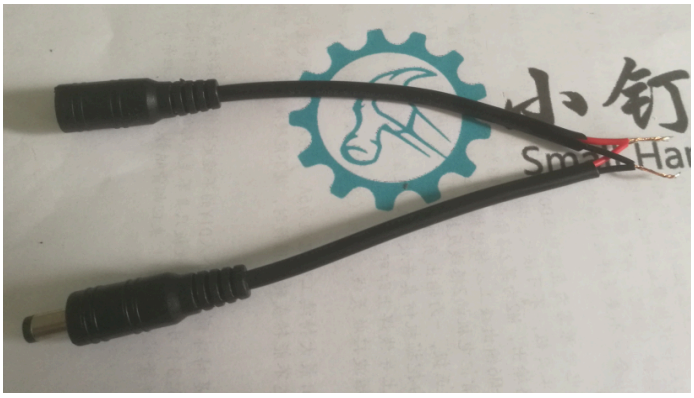
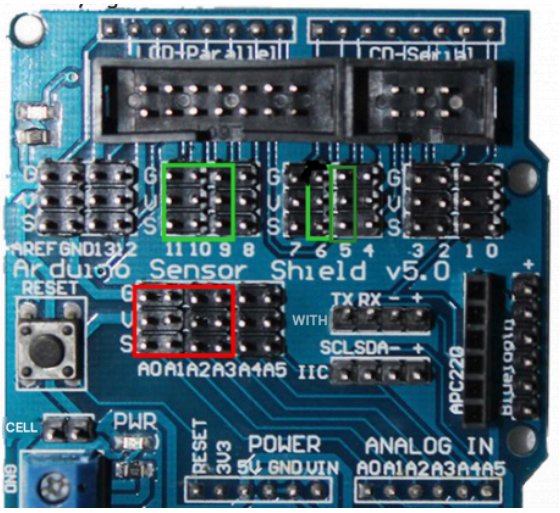


Figure Description: Detailed view of the DC barrel adapter conversion. Showing red wire matching '+' terminal and black wire matching '-' terminal leading safely to the V5 Shield power input.

4.2 System Wiring Matrix Table

Use the 50cm female-to-female DuPont jumper wires to map out the connections according to this absolute pinning index table:

Source Component	Breakout Pin Label	V5 Shield Destination Pin	Shield Row Layer Target
Left Control Joystick	GND	GND Pin Bank	G (Ground Row)
Left Control Joystick	+5V / VCC	5V Pin Bank	V (VCC / Power Row)
Left Control Joystick	VRx (Horizontal X Axis)	Analog Input Pin A0	S (Signal Row Line)
Left Control Joystick	VRy (Vertical Y Axis)	Analog Input Pin A1	S (Signal Row Line)
Left Control Joystick	SW (Click Switch Button)	Digital I/O Pin D2	S (Signal Row Line)
Right Control Joystick	GND	GND Pin Bank	G (Ground Row)
Right Control Joystick	+5V / VCC	5V Pin Bank	V (VCC / Power Row)
Right Control Joystick	VRx (Horizontal X Axis)	Analog Input Pin A2	S (Signal Row Line)
Right Control Joystick	VRy (Vertical Y Axis)	Analog Input Pin A3	S (Signal Row Line)
Right Control Joystick	SW (Click Switch Button)	Digital I/O Pin D4	S (Signal Row Line)
Servo 1: Base Axis	3-Pin Connector (Brn/Red/Org)	Digital PWM Pin D9	Match Colors: G=Brown, V=Red, S=Orange
Servo 2: Left Arm Shoulder	3-Pin Connector (Brn/Red/Org)	Digital PWM Pin D10	Match Colors: G=Brown, V=Red, S=Orange
Servo 3: Right Arm Elbow	3-Pin Connector (Brn/Red/Org)	Digital PWM Pin D11	Match Colors: G=Brown, V=Red, S=Orange
Servo 4: Claw Gripper	3-Pin Connector (via Ext. Wire)	Digital PWM Pin D12	Match Colors: G=Brown, V=Red, S=Orange



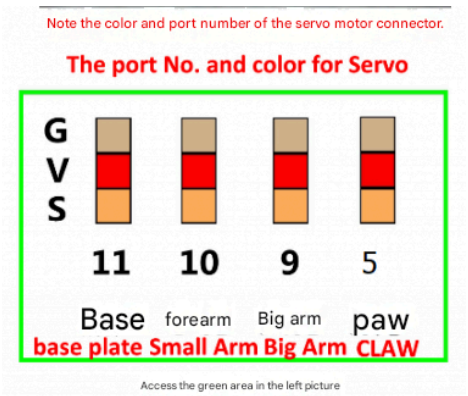


Figure Description: Full overview diagram representing the V5 expansion shield mounted over the Uno board, with all 10 joystick lines and 4 colour-coded servo plugs connected exactly according to the wiring matrix.

5. Pre-Assembly Servo Power-On Testing & Calibration

Once the structural electronics loop is completely mapped out, perform this functional validation protocol before touching the mechanical arm plates:

- Step 5.1: Attach your Uno board to a computer or laptop via a standard USB Type A-to-B blue communication cable.
- Step 5.2: Open the Arduino IDE software on the PC, load the system sketch code listed in Section 7 of this manual, verify the code compilation, and press 'Upload'.
- Step 5.3: Once the status bar indicates 'Done Uploading', remove the USB cord. Now connect your 5V 2A high-amperage external wall adapter supply to the DC barrel head linked to the V5 shield.
- Step 5.4: Turn on the shield's hardware slide switch. You should immediately observe the internal LEDs illumination on the microcontroller and the expansion shield.
- Step 5.5: Push and wiggle both joysticks around. Observe if all 4 individual detached servos twitch, rotate, and follow the analogue coordinates symmetrically.
- Step 5.6: Release the joystick thumbs entirely to allow them to sit dead centre. The program will automatically default and drive all 4 servo shafts to their calibration zero-datum index (exactly 90 degrees mid-point angle).
- Step 5.7: Do not turn or torque the servo splines by hand after this step. Disconnect the power block line. The servos are now properly centred and safe to embed into the plastic brackets!

6. Detailed Mechanical Assembly of the Acrylic Arm Structure

With the internal gears perfectly calibrated to the neutral position, proceed with the physical layout. Please peel off the matte protective masking sheets from all acrylic plates to uncover the clean glossy surface underneath.

6.1 Section A: Heavy Base Foundation & Rotation Platter

- 1. Unpack the wide rectangular acrylic stabilizing bottom plate. Fit four rubber cushion feet or support pillars onto its four outer corner holes using short bolts.
- 2. Seat the 'Servo 1' (Base Rotation Axis) directly into the recessed square center cutout. Pass two slim long M2 bolts through the servo structural ears down through the base plate, securing them firmly with nuts.
- 3. Take the flat circular rotating platter gear wheel. Place it flush over the protruding brass/plastic gear output spline of Servo 1. Secure a single metal arm horn to this platter from underneath using small self-tapping screws, then slide it onto the servo spindle. Fasten it via the central shaft lock screw.

6.2 Section B: Main Vertical Shoulder Tower Support

- 1. Slot the vertical left side structural tower strut and right side strut upright into the corresponding locking sockets built on top of the round base platter disk.
- 2. Take Servo 2 (Shoulder Pivot Axis) and slide it sideways into its bracket frame on the left support leg wall. Secure its casing using long bolts and corresponding nuts.
- 3. Mount Servo 3 (Elbow Pivot Axis) symmetrically onto the matching right support leg frame slot and bolt it into position.
- 4. Ensure both servo wire exits route smoothly towards the rear of the platform without being crushed between the perpendicular acrylic joints.

6.3 Section C: Double Parallel Linkage Arm Setup

The uses an intricate parallel structure which acts like an industrial parallelogram linkage. This ensures that the upper mechanical claw stays automatically level with the horizon while moving vertically.

- 1. Fasten the main long primary lifting bone arm piece onto the servo horn of the Left Shoulder Servo (Servo 2).
- 2. Mount the complementary secondary passive slave push-rod arm linkage onto the opposite right side bracket. Connect the trailing end via an M3 screw passing loose through an internal plastic washer separator.
- 3. CRITICAL ADJUSTMENT: When assembling structural link joints with M3 screws and nuts, DO NOT tighten them fully down! These joints are rotational pivot points. If you tighten them fully, the acrylic sections will lock up, the motor will stall, draw peak current, and fail. Ensure there is roughly a 0.5mm tiny clearance gap so the linkage arms toggle effortlessly under their own weight.

6.4 Section D: Mechanical Gripper Assembly (Claw module)

- 1. Locate the micro mechanical claw gripper framework plates. Mount the final Servo 4 (Claw Actuator Axis) directly into the miniature rectangular plate slot.
- 2. Fit the driving gear finger plate over the servo splined shaft. Next, index the secondary interlocking passive finger gear plate onto its adjacent static pivot spacer post.
- 3. Interleave the gear tooth profiles perfectly together: Position the servo arm so that when it sweeps, the two curved fingers open wide and mesh flush without slipping or binding teeth. Clamp them down using the servo horn retaining self-tapping center screw.
- 4. Mount the finished claw gripper sub-assembly onto the terminal forward mounting plate of the forearm links using dual small screws.

6.5 Section E: Wire Management & Cable Dressing

- 1. The claw gripper servo wire is too short to reach back to the controller base shield when the arm fully extends. Take the 15mm (15cm) servo extension jumper cable wire and attach it inline to the claw servo plug. Wrap a short length of heat shrink wrap or electrical tape over the union joint to prevent it pulling apart.

- 2. Gather the loose wires from all 4 servos together, pass them cleanly through the center clearance cavities of the lower structural base links, and slide the flexible plastic spiral winding sleeve wrap over them to create a single neat bundle.
- 3. Plug the grouped wiring ends back into pins D9, D10, D11, and D12 on the V5 shield, checking that wire colours match the 'G V S' rows perfectly.

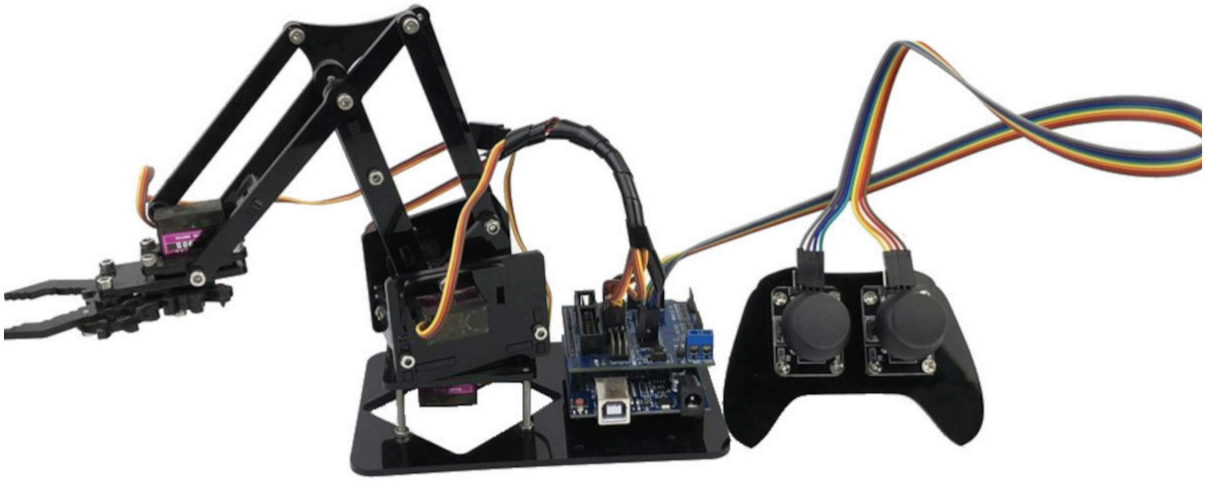


Figure Description: Complete side and perspective rendering of the fully integrated SNAM2000 4-DOF acrylic robotic arm, showing all linked joints correctly bolted, claw attached, and wired bundle routed cleanly to the controller chassis.

7. Software Program & Code Deployment Setup

The following professional Arduino C/C++ script is designed to run on the UNO R3 controller board. It incorporates real-time analog joystick sampling, low-pass deadzone filtering to avoid servo chatter/vibration when hands are off, and safety angle sweep constraints to ensure your arm joints never over-extend and smash into the acrylic walls.

```
#include <Servo.h>

// Define Servo Objects for the 4 Axis Links
Servo baseServo;     // Connected to Digital PWM D9
Servo shoulderServo; // Connected to Digital PWM D10
Servo elbowServo;    // Connected to Digital PWM D11
Servo clawServo;     // Connected to Digital PWM D12

// Define Joystick Analog Pin Map Assignments
const int LeftJoyX  = A0; // Controls Base Rotation Axis
const int LeftJoyY  = A1; // Controls Lower Shoulder Joint
const int LeftJoySW = 2;  // Left Joystick Click button pin

const int RightJoyX = A2; // Controls Upper Elbow Joint
const int RightJoyY = A3; // Controls Claw Gripper 開/合
const int RightJoySW = 4; // Right Joystick Click button pin

// Real-time Dynamic Axis Positioning Variables
float baseAngle     = 90.0;
float shoulderAngle = 90.0;
float elbowAngle    = 90.0;
float clawAngle     = 90.0;

// Dynamic Speed Adjust Factors for precision movement control
const float speedFactor = 0.15;
const int joystickDeadzone = 40; // Filter out resting analog noise/vibrations

void setup() {
  // Pin assignments linked directly to V5 Sensor Shield channels
  baseServo.attach(9);
  shoulderServo.attach(10);
  elbowServo.attach(11);
  clawServo.attach(12);

  // Initialize all joints to perfectly centered safe mid-points
  baseServo.write((int)baseAngle);
  shoulderServo.write((int)shoulderAngle);
  elbowServo.write((int)elbowAngle);
  clawServo.write((int)clawAngle);

  // Setup digital internal pullup resistors for joystick click toggles
  pinMode(LeftJoySW, INPUT_PULLUP);
```

```
  pinMode(RightJoySW, INPUT_PULLUP);

  Serial.begin(9600); // Initialize diagnostics pipeline trace
}

void loop() {
  // Read Analog Raw values from Joysticks (range 0 - 1023, Center is ~512)
  int valLeftX  = analogRead(LeftJoyX);
  int valLeftY  = analogRead(LeftJoyY);
  int valRightX = analogRead(RightJoyX);
  int valRightY = analogRead(RightJoyY);

  // --- AXIS 1: BASE ROTATION SERVO CONTROL (LEFT JOYSTICK X) ---
  if (abs(valLeftX - 512) > joystickDeadzone) {
    baseAngle += (valLeftX - 512) * speedFactor / 512.0;
  }
  // --- AXIS 2: SHOULDER PIVOT SERVO CONTROL (LEFT JOYSTICK Y) ---
  if (abs(valLeftY - 512) > joystickDeadzone) {
    shoulderAngle += (valLeftY - 512) * speedFactor / 512.0;
  }
  // --- AXIS 3: ELBOW PIVOT SERVO CONTROL (RIGHT JOYSTICK X) ---
  if (abs(valRightX - 512) > joystickDeadzone) {
    elbowAngle += (valRightX - 512) * speedFactor / 512.0;
  }
  // --- AXIS 4: CLAW GRIPPER SERVO CONTROL (RIGHT JOYSTICK Y) ---
  if (abs(valRightY - 512) > joystickDeadzone) {
    clawAngle += (valRightY - 512) * speedFactor / 512.0;
  }

  // --- HARDWARE SAFETY ANGLE LIMIT CONSTRAINTS ---
  // Limits prevent joints from rotating into structural acrylic crash zones
  baseAngle     = constrain(baseAngle, 0.0, 180.0);
  shoulderAngle = constrain(shoulderAngle, 35.0, 155.0); // Safe pivot threshold
  elbowAngle    = constrain(elbowAngle, 40.0, 160.0);    // Safe extension arc
  clawAngle     = constrain(clawAngle, 10.0, 110.0);     // 10=Fully Closed,
110=Open Max

  // Command physical positions to the servos
  baseServo.write((int)baseAngle);
  shoulderServo.write((int)shoulderAngle);
  elbowServo.write((int)elbowAngle);
  clawServo.write((int)clawAngle);

  delay(15); // Smooth timing control loop cycle delay
}
```

8. Troubleshooting & FAQ (Frequently Asked Questions)

Q1: The servos are twitching violently, vibrating loudly, or resetting constantly when trying to move.

Cause & Solution: This is a textbook symptoms of a low power brown-out. It means you are attempting to power the arm's four servo motors directly from your computer USB port or a weak phone charging cube. Servos pulling load require high immediate current bursts. Always disconnect the USB cable and plug the 5V 2A external wall transformer supply into the DC barrel head terminal on the shield to supply stable power.

Q2: One of the joints moves a little bit then completely binds up, and the servo becomes warm.

Cause & Solution: The joint mechanism's structural M3 pivot screws are fastened down too tight. Acrylic arms work via smooth moving hinges. Loosen the connecting bolt on that active joint by a quarter turn until the acrylic parts slide freely with minimum friction.

Q3: A joystick controls the wrong servo axis entirely (e.g., left moves the claw instead of base).

Cause & Solution: Your signal DuPont cords are mismatched on the expansion ports. Refer back to the wiring spreadsheet matrix in Section 4.2. Verify that the signal wire of the claw motor is seated securely on pin D12, and the base motor wire is on pin D9. Alternatively, you can change the Servo object pin map numbers directly in the setup routine of your Arduino sketch code.

Q4: The arm movements are reversed (e.g., pushing forward makes it move backwards).

Cause & Solution: You can fix this easily inside the sketch source code. In the loop logic, simply change the addition operator code signs. For instance, modify 'baseAngle += ...' to 'baseAngle -= ...' to immediately invert the response direction of that control vector.