## **Pen Plotter Verification Report**

### **1. Test protocol doc# 01\_MERO\_VerP**

**Test Criteria to Verify:** Drawing accuracy and instruction interpretation via ESP32; modularity and open-source accessibility  
 **Test Procedure:**

* We uploaded the Nikolaus House G-code wirelessly to ESP32.
* We observed the plotted output for accuracy and refined the code to improve corner precision.
* We performed hardware module replacements and verified that the system could be reassembled within 10 minutes.

**Actual Result:** Code was successfully optimized; parts were replaced and reassembled efficiently.

### **2. Test protocol doc# 04\_MERO\_VerP**

**Test Criteria to Verify:** Dry-run feature validation  
 **Test Procedure:**

* We enabled the dry-run mode and executed a drawing without engaging the pen-lift mechanism.
* We confirmed that no pen contact occurred during the plotting.

**Actual Result:** Dry run completed accurately with no Z-axis movement.

### **3. Test protocol doc# 06\_MERO\_VerP**

**Test Criteria to Verify:** Mechanical strength of the base  
 **Test Procedure:**

* We applied a static 1 kg load on the center carriage and let it rest for one hour.
* We then used a vernier caliper to check for structural deformation.

**Actual Result:** Deformation stayed within acceptable tolerance (under 1 mm).

### **4. Test protocol doc# 07\_MERO\_VerP**

**Test Criteria to Verify:** User interface operability  
 **Test Procedure:**

* We asked two students from different backgrounds to operate the GUI interface.
* We gathered their feedback and improved the interface based on their suggestions.

**Actual Result:** Initial feedback was negative, but post-modification feedback was positive.

### **5. Test protocol doc# 08\_MERO\_VerP**

**Test Criteria to Verify:** Assembly and disassembly trial  
 **Test Procedure:**

* We completely disassembled and then reassembled the plotter using the provided toolkit.
* We recorded the time and noted any difficulties.

**Actual Result:** Full disassembly and reassembly completed in approximately 22 minutes.

### **6. Test protocol doc# 10\_MERO\_VerP**

**Test Criteria to Verify:** Feedback precision via encoders  
 **Test Procedure:**

* We moved the pen to known XY coordinates and measured the final position with a scale.
* We compared expected vs actual positions.

**Actual Result:** Accuracy varied from -2.5 mm to +3 mm; further refinement is in progress.

### **7. Test protocol doc# 11\_MERO\_VerP**

**Test Criteria to Verify:** Repeated drawing precision  
 **Test Procedure:**

* We ran the same drawing (Nikolaus House) 10 times.
* We overlaid the outputs and checked for drift or dimensional errors.

**Actual Result:** Precision degraded over cycles due to motor heating; accuracy fell to ±4 mm.

### **8. Test protocol doc# 15\_MERO\_VerP**

**Test Criteria to Verify:** Surface finish check  
 **Test Procedure:**

* We plotted long straight lines and checked for ink pooling, unevenness, or wobble.

**Actual Result:** Vertical accuracy remained within ±2 mm.

### **9. Test protocol doc# 16\_MERO\_VerP**

**Test Criteria to Verify:** Paper securement test  
 **Test Procedure:**

* We used magnetic clamps to secure the paper.
* We simulated vibrations to check if the paper stayed fixed.

**Actual Result:** Paper remained firmly in place, with deviation under 0.3 mm.

### **10. Test protocol doc# 18\_MERO\_VerP**

**Test Criteria to Verify:** Motion smoothness  
 **Test Procedure:**

* We performed diagonal and continuous motions.
* We examined the encoder's feedback and listened to mechanical noise.

**Actual Result:** Smoother motion achieved after design improvements.

### **11. Test protocol doc# 19\_MERO\_VerP**

**Test Criteria to Verify:** Pen grip check  
 **Test Procedure:**

* We tested pen mounting using glue and heat-insert nuts.
* We compared plotting accuracy in both setups.

**Actual Result:** Heat-insert nut showed 50–60% improvement in grip and precision.

### **12. Test protocol doc# 20\_MERO\_VerP**

**Test Criteria to Verify:** Pen size accommodation  
 **Test Procedure:**

* We inserted pens of various diameters (8 mm to 13 mm) and tested alignment.

**Actual Result:** All pens fit securely; modular design ensures good alignment.

### **13. Test protocol doc# 21\_MERO\_VerP**

**Test Criteria to Verify:** Command input validation  
 **Test Procedure:**

* We ran custom codes to check PWM signals, motor directions, and encoder readings.

**Actual Result:** All commands executed successfully.

### **14. Test protocol doc# 22\_MERO\_VerP**

**Test Criteria to Verify:** Pen lift functionality  
 **Test Procedure:**

* We toggled pen up/down commands via GUI.
* We measured the actuation time using a stopwatch.

**Actual Result:** Actuation completed within 500 ms.

### **15. Test protocol doc# 23\_MERO\_VerP**

**Test Criteria to Verify:** Connectivity testing  
 **Test Procedure:**

* We connected to the web interface via both PC and mobile.
* We sent multiple commands and measured response time.

**Actual Result:** Reliable connectivity; response delay under 7 seconds.

### **16. Test protocol doc# 24\_MERO\_VerP**

**Test Criteria to Verify:** XY travel consistency  
 **Test Procedure:**

* We sent precise travel commands and measured actual pen movement.
* We adjusted belt tension as needed.

**Actual Result:** Movement was accurate within 2 mm deviation.

### **17. Test protocol doc# 25\_MERO\_VerP**

**Test Criteria to Verify:** Position tracking accuracy  
 **Test Procedure:**

* We compared encoder feedback to expected values after known movements.

**Actual Result:** Tracking showed >10% error; improvements are ongoing.

### **18. Test protocol doc# 26\_MERO\_VerP**

**Test Criteria to Verify:** PID loop performance  
 **Test Procedure:**

* We applied the load during motion and observed speed correction via PID control.

**Actual Result:** Current PID tuning is not sufficient; further work is needed.

### **19. Test protocol doc# 27\_MERO\_VerP**

**Test Criteria to Verify:** Pressure consistency  
 **Test Procedure:**

* We adjusted servo angles and tested pen pressure on paper with various pens.

**Actual Result:** Consistent pressure achieved after calibration.

### **20. Test protocol doc# 28\_MERO\_VerP**

**Test Criteria to Verify:** Homing routine  
 **Test Procedure:**

* We sent over-range coordinates to trigger limit switches.
* We activated the emergency stop and observed homing response.

**Actual Result:** Homing executed correctly within 10 seconds.

### **21. Test protocol doc# 30\_MERO\_VerP**

**Test Criteria to Verify:** Safe limit enforcement  
 **Test Procedure:**

* We attempted out-of-bounds moves to check limit switch response.

**Actual Result:** Limit switches triggered correctly and prevented damage.

### **22. Test protocol doc# 32\_MERO\_VerP**

**Test Criteria to Verify:** Modular upgrade feasibility  
 **Test Procedure:**

* We removed and replaced key modules (motor, pen holder, etc.)
* Measured time for hardware swaps.

**Actual Result:** Upgrades performed in under 10 minutes.

### **23. Test protocol doc# 33\_MERO\_VerP**

**Test Criteria to Verify:** Open-source tool compatibility  
 **Test Procedure:**

* We generated G-code in Inkscape and uploaded it via the Arduino IDE.

**Actual Result:** Successfully integrated with open-source platforms.

### **24. Test protocol doc# 34\_MERO\_VerP**

**Test Criteria to Verify:** Expandability  
 **Test Procedure:**

* We extended the working area by adjusting firmware limits.
* Paper held using magnetic clamps instead of rails.

**Actual Result:** System adaptable to larger surfaces.

### **25. Test protocol doc# 35\_MERO\_VerP**

**Test Criteria to Verify:** BOM cost review  
 **Test Procedure:**

* We calculated all material and shipping costs.
* We noted the operating voltage used.

**Actual Result:** Operating at 9V; costs reviewed and documented.

### **26. Test protocol doc# 36\_MERO\_VerP**

**Test Criteria to Verify:** Electrical safety  
 **Test Procedure:**

* We checked terminal voltages with a multimeter.
* We visually inspected insulation and wiring.

**Actual Result:** All checks passed; no safety issues found.

### **27. Test protocol doc# 37\_MERO\_VerP**

**Test Criteria to Verify:** Enclosure safety  
 **Test Procedure:**

* We reviewed the component enclosure for airflow and capacity.

**Actual Result:** Enclosure meets safety and organization standards.

### **28. Test protocol doc# 38\_MERO\_VerP**

**Test Criteria to Verify:** Emergency stop function  
 **Test Procedure:**

* We pressed the E-stop during active plotting.
* We observed system halt and recovery.

**Actual Result:** E-stop triggered system halt and safe homing.

### **29. Test protocol doc# 40\_MERO\_VerP**

**Test Criteria to Verify:** Weight verification  
 **Test Procedure:**

* We weighed the entire assembled unit.

**Actual Result:** Total weight is under 3.5 kg.

### **30. Test protocol doc# 41\_MERO\_VerP**

**Test Criteria to Verify:** Disassembly and portability  
 **Test Procedure:**

* We disassembled the system and packed it for transportation.
* Noted any tools needed.

**Actual Result:** Mostly tool-free; center mount requires bolts.

### **31. Test protocol doc# 43\_MERO\_VerP**

**Test Criteria to Verify:** Open-source licensing compliance  
 **Test Procedure:**

* We reviewed all code used and ensured it complied with open-source licenses.

**Actual Result:** All software and tools used are open-source compliant.