Open Source Desktop Tensile Testing Machine (EN-Version)

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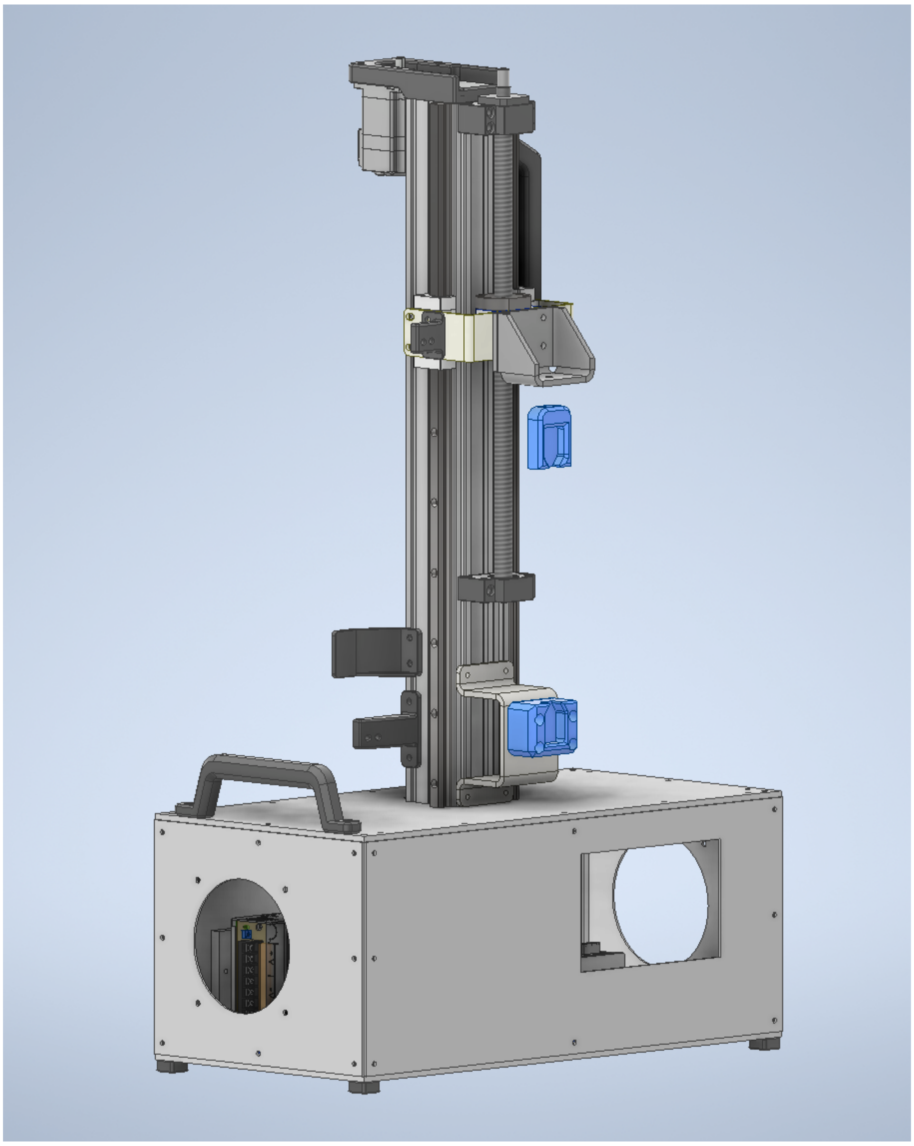

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1 Introduction

The tensile testing machine described here is a fully open-source device for determining the mechanical tensile strength of test specimens. At its core is a single-board computer (typically a Raspberry Pi), which, together with a load cell and an HX711 amplifier, performs precise force measurements. A bipolar stepper-motor module handles the defined positioning and feed control, enabling reproducible loading profiles.

The goal of the project is to provide an affordable, modular test rig that can be used and further developed by hobbyists as well as research laboratories. Control is provided via an intuitive touch GUI (using `ttkbootstrap` and `tkinter`), which visualizes all relevant parameters—test length, feed rate, force-drop threshold—in real time and automatically saves measurement data to CSV logs through programmable routines.

Thanks to the MIT open-source license, the entire source code is freely available on GitHub. The modular architecture and clear interfaces facilitate customization, extension, and integration of additional sensors or actuators. This makes the tensile tester a flexible platform for material testing, educational purposes, and DIY projects.

2 Bill of Materials – Electronics / Mechanics

ID	Bezeichnung	Shop / Firma	Menge
	Profile		
1	Aluprofil 20x20 I-Typ Nut5 200mm	Motedis	4
2	Aluprofil 20x20 I-Typ Nut5 210mm	Motedis	4
3	Aluprofil 20x20 I-Typ Nut5 460mm	Motedis	4
4	Aluprofil 20x60 I-Typ Nut5 600mm	Motedis	2
5	Winkel 20 I-Typ Nut 5	Motedis	30
6	Nutenstein I Typ 5 M4	Motedis	100
7	Nutenstein mit Steg I-Typ Nut 5 [M5]	Motedis	70
8	Energiekette 15x15 - 1m	Motedis	1
	Linearbewegung		
9	2Stück HGR20-600mm Führungsschiene mit 4Stück Hohe Präzision HGH20CA Linearlag	Amazon	1
10	SFU1605 Kugelumlaufspindel 450mm Gewindespindel Edelstahl Kugelumlaufspindel mi	Amazon	1
	Motor + Treiber		
11	1 x 1 Achsen Schrittmotor CNC Kit 3,0Nm(425oz.in) Nema 23 Schrittmotor und Treiber	Stepperonline	1
	Elektronik		
12	24V 5A 120W DC Schaltnetzteil AC 100V/240V auf DC-24V Netzteil	Amazon	1
13	YIMATEECO Staubfilter PC 120mm Lüfterabdeckungen für Computer-Kühlerlüfter	Amazon	1
14	LUCKFOX for Raspberry Pi Screen 7 inch HDMI Touchscreen for Raspberry Pi 5	Amazon	1
15	RPi GPIO Breakout-Erweiterungskarte + Flachbandkabel	Amazon	1
16	Raspberry Pi 5 4gb Ram	Berrybase	1
17	Raspberry Pi5 active Cooler	Berrybase	1
18	HX711 Wägezelle 24-Bit-A/D-Wandlerchip für elektronische Präzisionswaage	Amazon	1
19	DYMH 103 Mikro-Miniatur-Wägezelle Wägezelle Wägesensor Zugstangen-Druckspannun	Amazon	1
20	REV Standard, Feuchtraumsteckdose, Aufputz, grau	Amazon	1
21	3 Stück Kaltgeräte Einbau-Stecker 220-250V/ 10A	Amazon	1
	Blechteile		
22	Bodenplatte	Mon-Tec	
23	Deckplatte	Mon-Tec	
24	Festlagerblech	Mon-Tec	
25	Führungswinkel	Mon-Tec	2
26	Zugwinkel	Mon-Tec	
27	Seitenblech	Mon-Tec	2
28	Frontblech	Mon-Tec	
29	Rückblech	Mon-Tec	
	Schrauben		
30	M4x8 Inbus	Schraubenking	100
31	M4x10 Linsenflachkopf	Schraubenking	100
32	M5x12 Linsenflachkopf	Schraubenking	30
33	M5x16 Inbus	Schraubenking	20
34	Unterlegscheiben M4	Schraubenking	100
35	Unterlegscheiben M5	Schraubenking	10
36	M6 Mutter	Schraubenking	1

Figure 1: Bill of Materials

3 3D-Printed Parts

ID	3D-Druck Teile	Menge
1	Motorhalter Nema 23	1
2	Halterung Kabelschlepp fahrend	1
3	Halterung Kabelschlepp fix	1
4	Tragegriff	1
5	Tragegriff seite	1
6	Auflage Kabelschlepp	1
7	Fliegender Probenhalter (auch als Frästeil möglich)	1
8	Probenhalter fix (auch als Frästeil möglich)	1

Figure 2: List of 3D-Printed Parts

For part of the tensile tester, 3D-printed components were used (see list). In the original version, PCTG was employed. In general, the parts are designed for brass threaded inserts, which can be obtained from Rutex 3D.

An **infill of 50%** is recommended for these parts!

If the sample holders are also 3D-printed, **PCTG** or **ASA** is advised. A minimum of **5 wall loops** and at least **70% infill** are recommended.
A STEP file for the sample holders (for milling) is also available. In general, a milled aluminum or steel part is preferable to a 3D-printed plastic one.

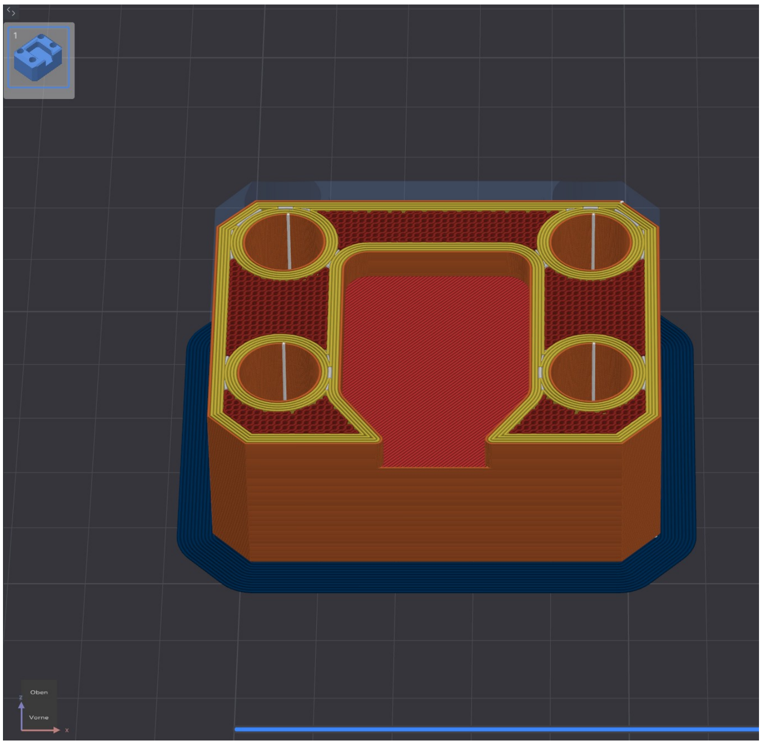

Figure 3: Fixed Sample Holder as 3D Print

4 Mechanics – Notes and Assembly

The sheet-metal parts to be ordered are designed for laser cutting and subsequent bending. Structural steel (S235 / S355) is specified. If tensile forces exceed 2kN, a more robust design in stronger steel—or even a machined part—should be used.

Pulleys and the timing belt are not included in the bill of materials. Order these to match the chosen motor and ball screw. For up to 2kN, a 6mm GT2 belt with fiberglass reinforcement is sufficient; above that, a wider belt system is recommended.

Mechanical assembly should follow the “Assembly” step. The 3D-printed parts include alignment aids for both the linear rails and the ball screw. It is critical that the linear guides and ball screw are precisely parallel—small misalignments can significantly increase motor load and lead to lost steps. Use a dial indicator for accurate alignment.

5 Electrical – Notes and Assembly

Warning: When working on the electrical assembly, please observe all general safety guidelines for handling mains voltage. Mains voltage (230V) can cause serious injury or equipment damage if handled incorrectly!

The base plate is intended for self-tapping screws, so all electronics can be mounted this way. Ensure the base plate is grounded via the power supply—failure to do so may damage the electronics over time.

Keep the 230V and 24V circuits as separate as possible. If the mains lines are routed too close to sensor or control cables, interference or errors may occur, compromising measurement accuracy.

The Raspberry Pi 5—and all other Raspberry Pi models—provides 3.3V on its GPIO pins. When ordering the motor driver, verify that its PUL/EN/DIR inputs tolerate a 3.3V high-level signal. The StepperOnline driver listed has been tested and works; alternatively, a TMC2209 on a breakout board may be used.

Important: Use an HX711 board rated for an 80Hz sampling rate!

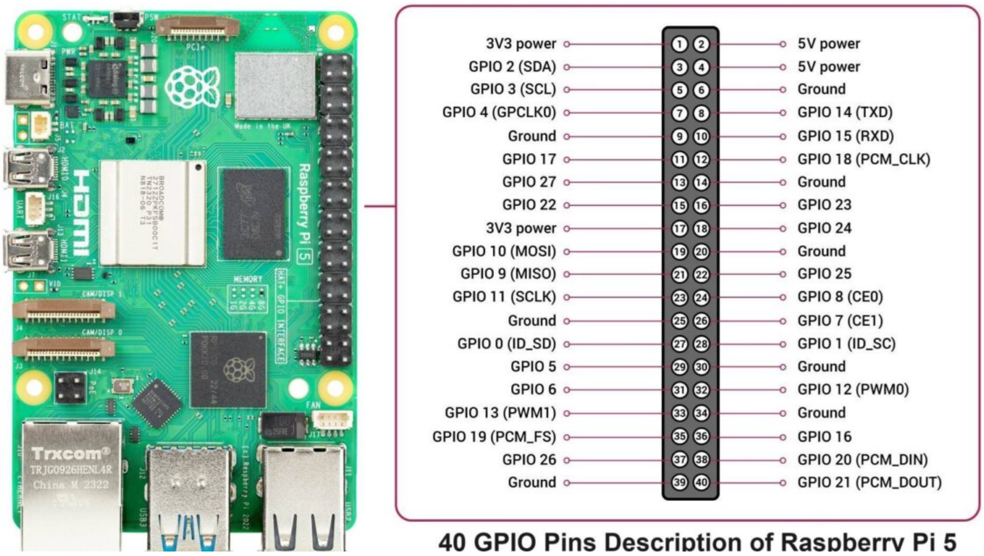

Figure 4: GPIO Pinout for Raspberry Pi 5

Pin Assignment (as programmed):

- `GPIO 05`: DT (HX711)
- `GPIO 06`: SCK (HX711)
- `GPIO 18`: STEP/PUL signal (motor driver)
- `GPIO 19`: DIR signal (motor driver)
- `GPIO 26`: EN signal (motor driver)

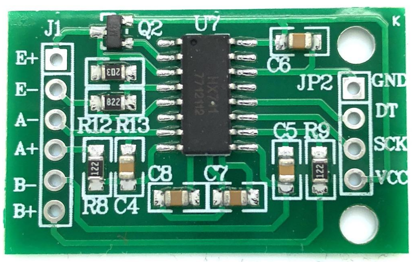

Figure 5: HX711 Load-Cell Amplifier Board

5.1 Circuit Diagram

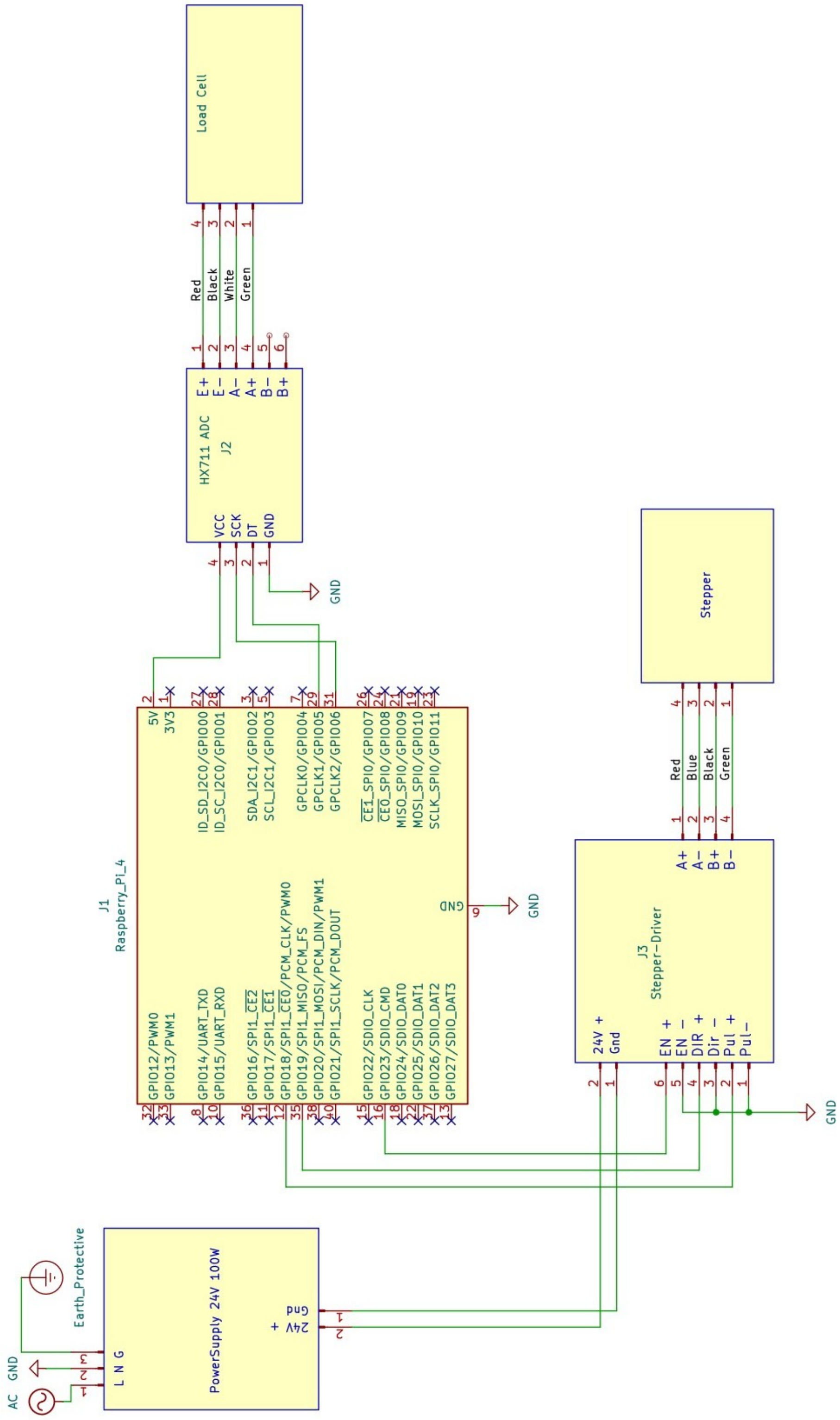

Figure 6: Circuit Diagram

6 Software Overview

6.1 Component Overview

- Programming Language: Python 3
- Libraries:
  - `gpiozero` (install via pip)
  - `ttkbootstrap` + `tkinter` (install via pip)
  - Module `HX711.py` (included in repository)
- Scripts:
  - `HX711.py`: Load-cell reading and calibration
  - `ZP_Final2.py`: Main GUI and logic

7 Installation

7.1 Clone the Repository

```
https://github.com/Edtison/
    desktop_tensile_testing_machine_eddi
```

Listing 1: Clone the Repository

7.2 Install Dependencies

```
pip install gpiozero ttkbootstrap tk
```

Listing 2: Install Python Packages

8 Configuration & Calibration

1. Open `HX711.py` and run `main()` to determine the *reference_unit* value. Weigh two known masses and adjust the value so that the displayed force is correct.
2. In `ZP_Final2.py`, adjust the `force` variable accordingly.

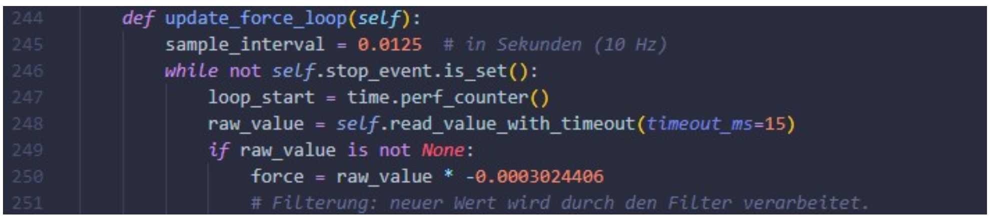

Figure 7: Reference Value for Force in ZP Final2

9 Usage

9.1 Starting the Application

```
python ZP_Final2.py
```

Listing 3: Start the GUI

Run either from a terminal or via Thonny.

9.2 Operation

- **Tare**: Zero the scale.
- **Feed & Test Length**: Adjust with the buttons.
- **Prozess Starten**: Begin the measurement run.
- **Pos. Nullsetzen**: Sets the current position to 0.
- **Zurück zu 0 Position**: Moves the crosshead back to 0mm.
- Log files are saved in `logs/`.
- Log base defines the filename prefix before the index.

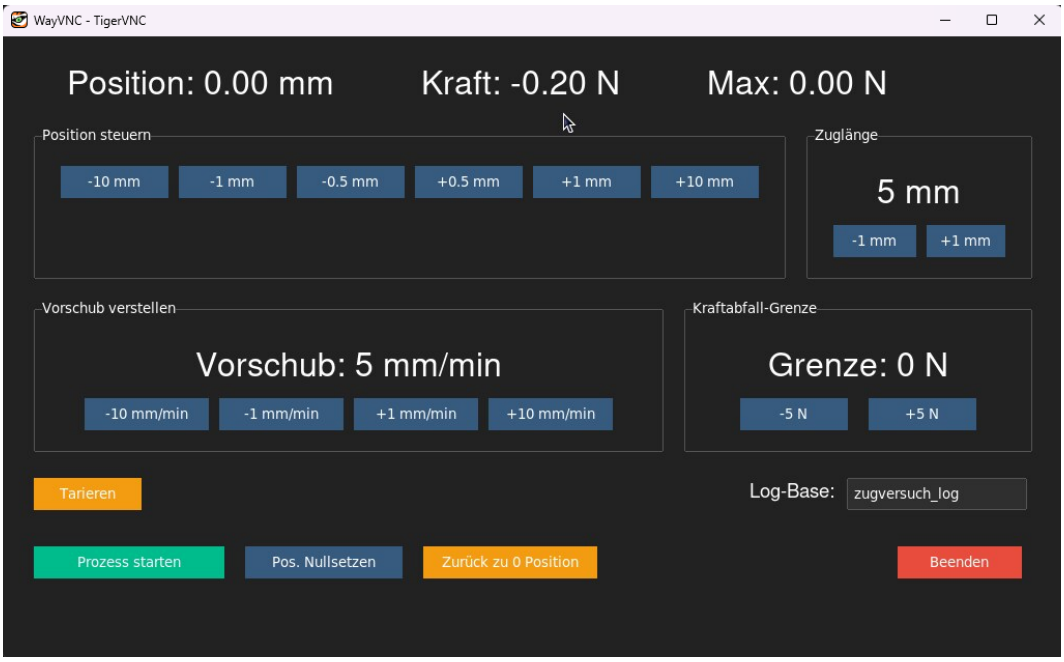

Figure 8: GUI of ZP Final2

10 License

This project is licensed under the MIT License. See `LICENSE`.