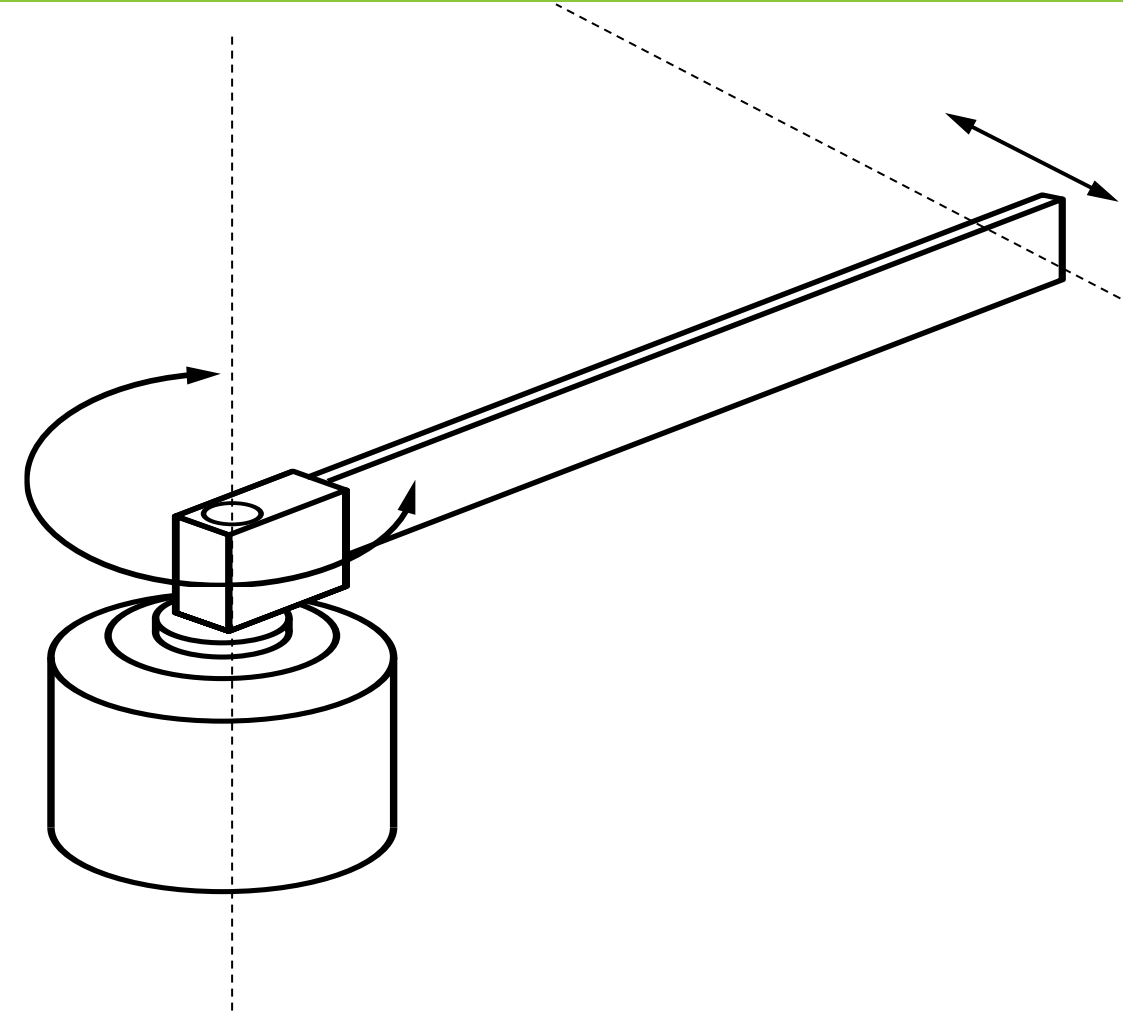
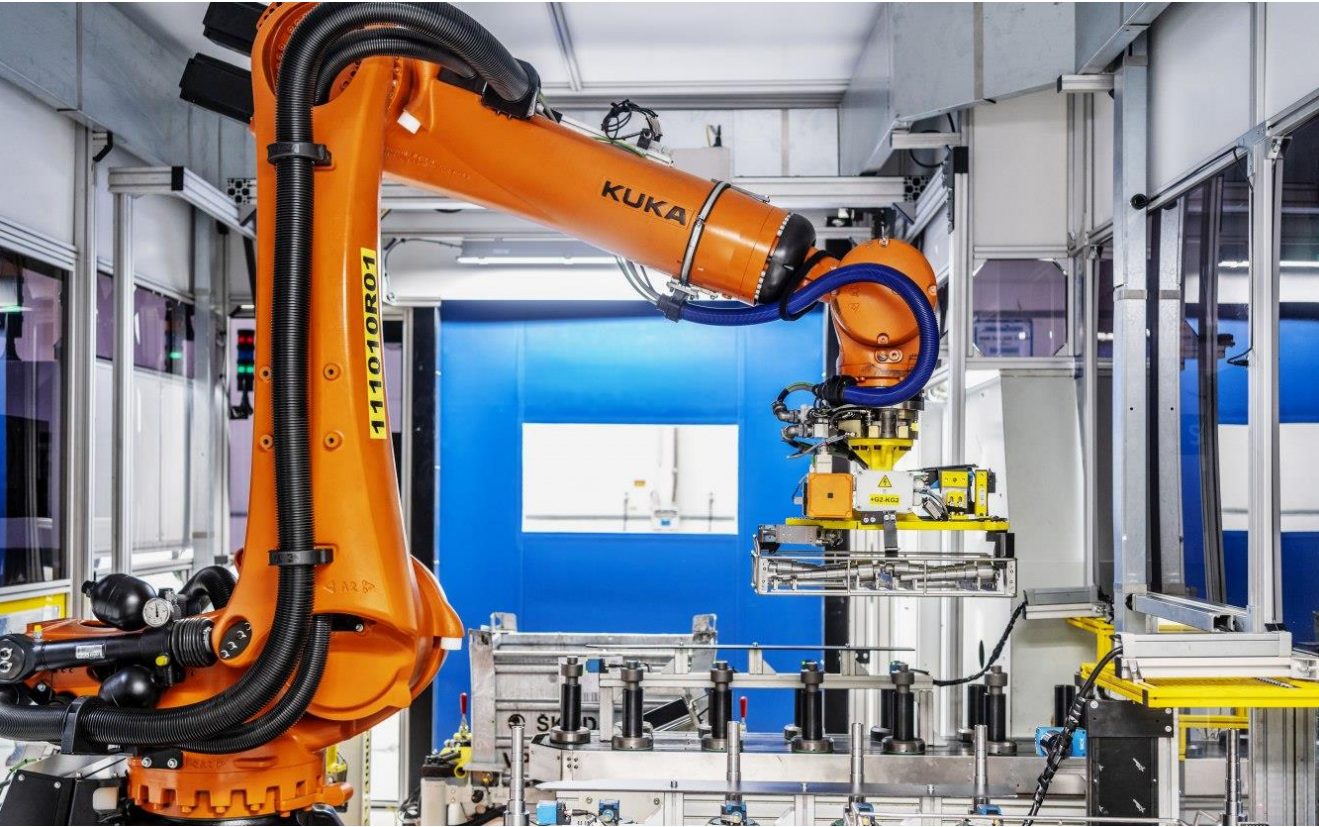


An Early Hardware Prototype of a Miniature Low-Cost Flexible Link Experiment

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Motivation: What is a flexible link device?



Motivation: Commercial Flexible Link Devices



Quanser Rotary Flexible Link



Motivation: Improvised Flexible Link Devices



Tahir et al. (2017)



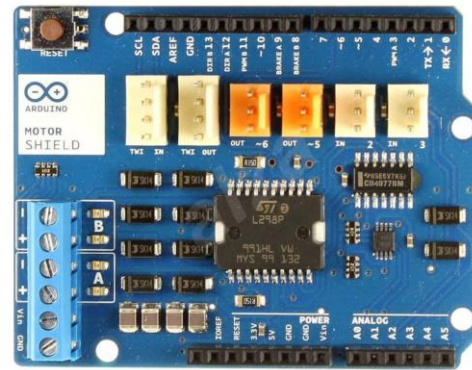
Motivation: Arduino, a universal platform to build on

- Cheap
- Open-source
- Easy to buy
- Standardized
- Free integrated development environment (IDE)
- Great community and abundance of learning materials
- Easy hardware expansion through so-called Shields



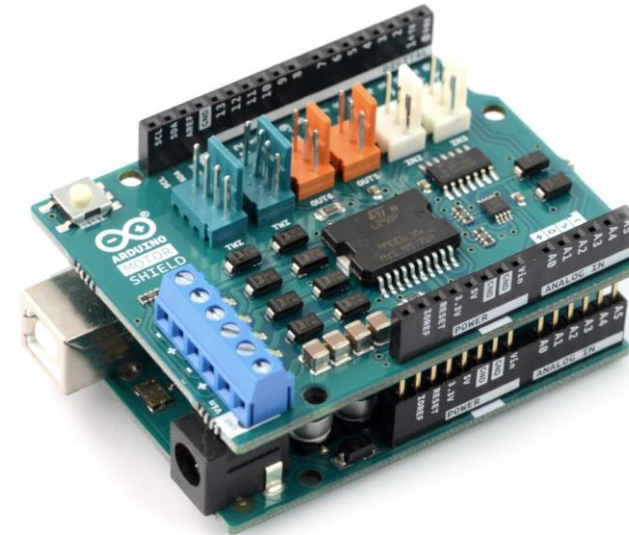
Arduino

+



Shield (Motor control)

=





AutomationShield

Control Systems Engineering Education

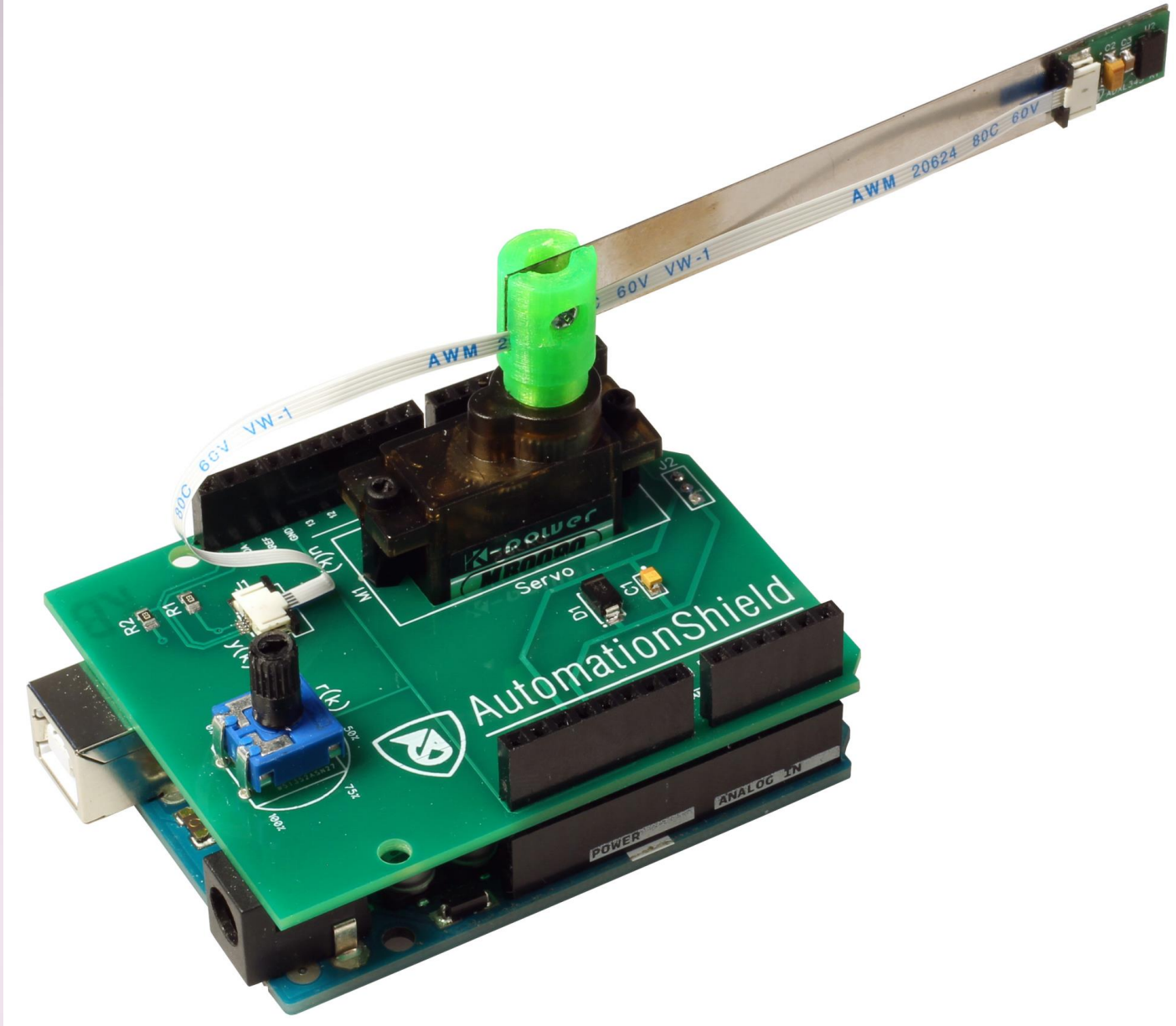
www.automationshield.org

Create novel tools for control engineering and mechatronics education, implementing a lab experiment on a single Arduino expansion Shield, essentially a tiny control / mechatronics laboratory in the palm of your hand that is

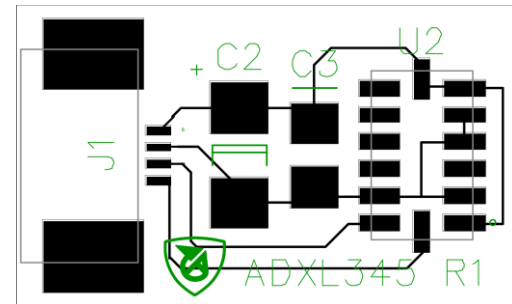
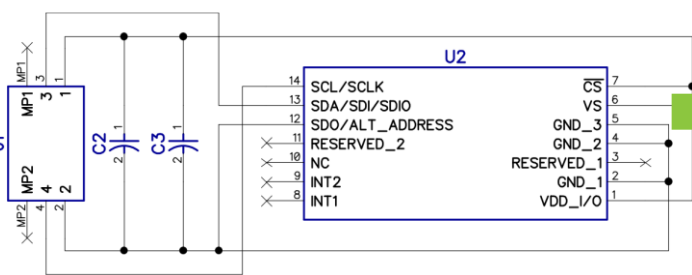
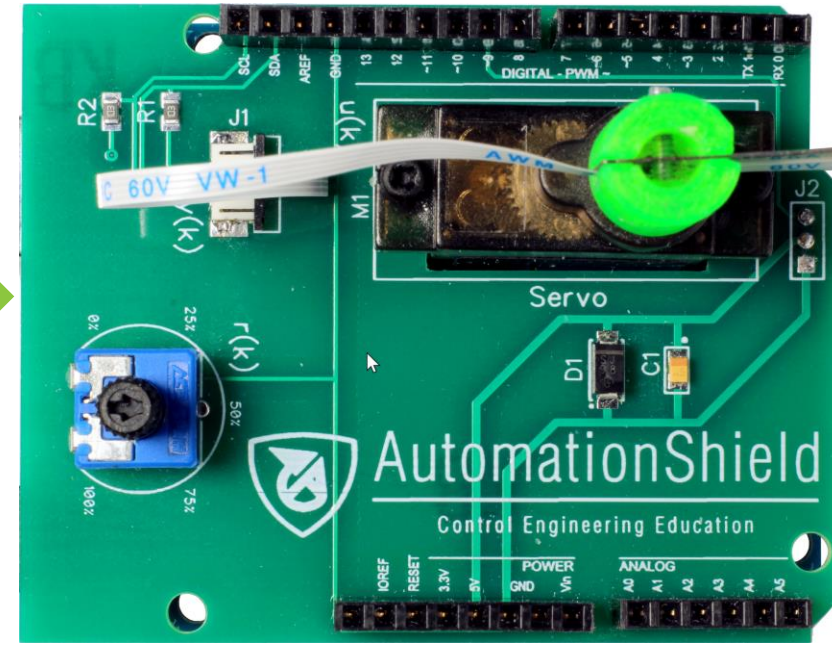
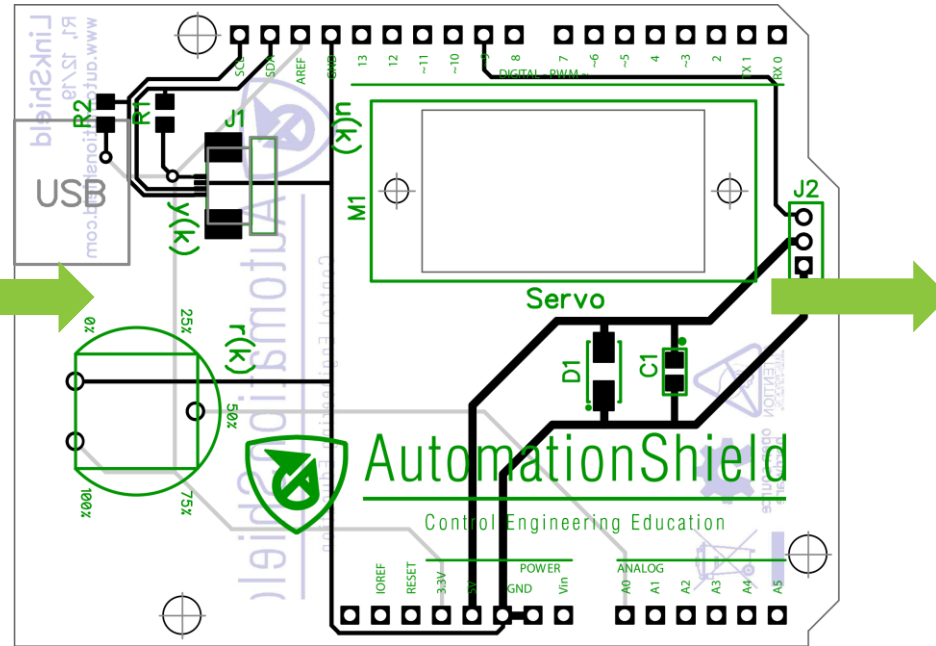
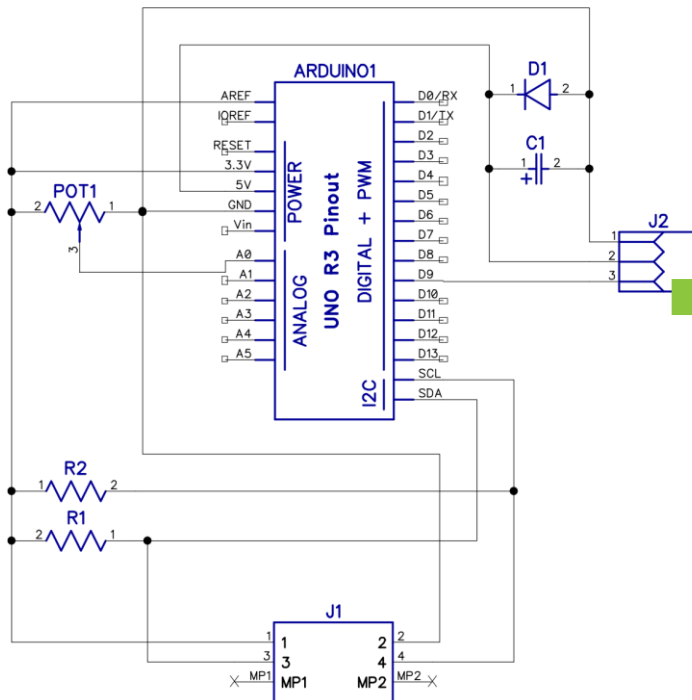
- Cheap
- Open-source
- Possible to build at home even by beginners (DIY)
- Standardized
- Free software library compatible to the Arduino IDE



Introducing the LinkShield – an early prototype



LinkShield: Open-Source Hardware (see www.automationshield.org)



LinkShield: A truly low-cost hardware

Name	Part no., value	Desc.	Mark	Pcs.	Price	Total
Servo	digital, high-speed metal gear micro-servo (e.g. Savox SH-0257MG)	M1	(d)	1	16.76	16.76
Accelerometer	Analog Devices ADXL345	U2	(v)	1	0.89	0.89
Connector	0.5 mm pitch, 4-lead FFC/FPC (e.g. 52745-0497)	J1, J2	(h)	2	0.30	0.59
Potentiometer	10 k Ω , 250 mW (e.g. ACP CA14NV12,5-10KA2020)	POT1	(i)	1	0.10	0.10
Resistor	0805, 10 k Ω (e.g. ROYAL OHM 0805S8J0103T5E)	R1, R2	(g)	2	0.01	0.02
Capacitor	0805, tantalum, 4.7 μ F (e.g. AVX TAJP475K016RNJV)	C1	(f)	1	0.15	0.15
Capacitor	1206, tantalum, 10 μ F (e.g. T491A106M016AT)	C2	(u)	1	0.22	0.22
Capacitor	0805, ceramic, 100 nF (e.g. C0805C104M5RACTU)	C3	(t)	1	0.01	0.01
Diode	DO214AC (e.g. Vishay BYG20J, 1.5 A, 600 V)	D1	(e)	1	0.17	0.17
Cable	0.5 mm pitch, 4-lead FFC	-	(r)	1	0.12	0.12
PCB (shield)	2 layer, FR4, 1.6 mm thick, green mask	-	(a)	1	0.45	0.45
PCB (breakout)	1 layer, FR4, 0.6 mm thick (or less), green mask	-	(s)	1	0.45	0.45
Screw	M2 \times 8, steel	-	(o)	1	0.02	0.02
Nut	M2, steel	-	(p)	1	0.01	0.01
Spacer	hexagonal; polyamide; M2; 10 mm	-	(k)	2	0.15	0.30
Screw	M2 \times 5, Phillips, polyamide	-	(l)	2	0.13	0.25
Nut	M2, polyamide	-	(m)	2	0.06	0.12
Shaft	Potentiometer shaft, (e.g. ACP CA9MA9005)	-	(j)	1	0.10	0.10
Header	6 \times 1, female, 2.54 mm pitch	-	(c)	1	0.06	0.06
Header	8 \times 1, female, 2.54 mm pitch	-	(c)	2	0.09	0.18
Header	10 \times 1, female, 2.54 mm pitch	-	(c)	1	0.09	0.09
Hub	1.1 g green PETG filament, 21 m to print, 0.07 kWh electricity	-	(n)	1	0.04	0.04
Magnets	ϕ 9 \times 2 mm, N50, \sim 13 N (e.g. Omo Magnets N50D00960020)	-	-	3	0.12	0.36
Beam	85 \times 10 \times 0.3 mm, ϕ 2 mm hole 5 mm from edge, AISI 301 (S30100)	-	(q)	1	0.40	0.40

Total: 21.85€



Simplified application programming interface (API) in C/C++ included within the **AutomationShield library** for the free Arduino IDE:

- Initialize hardware

```
LinkShield.begin();
```

- Calibrate gravity offset/bias

```
LinkShield.calibration();
```

- Reading acceleration at end to y

```
y = LinkShield.sensorRead();
```

- Send a certain angle u to servo motor

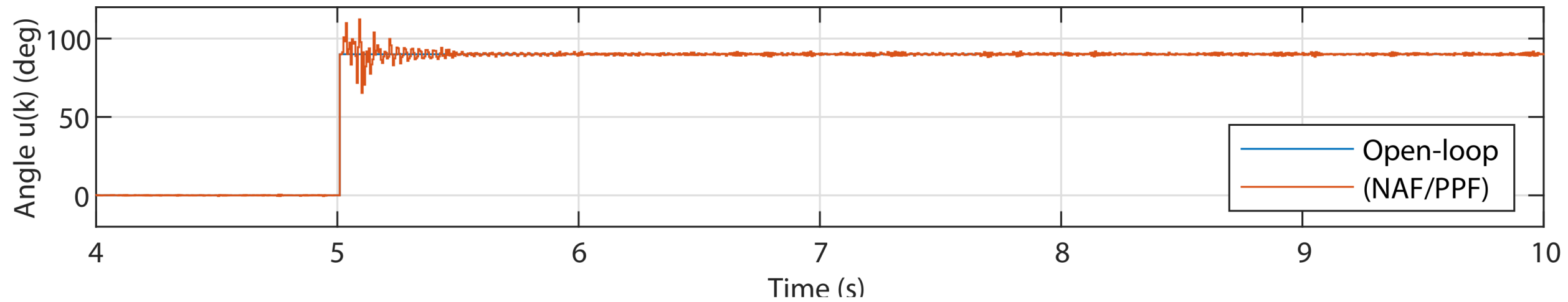
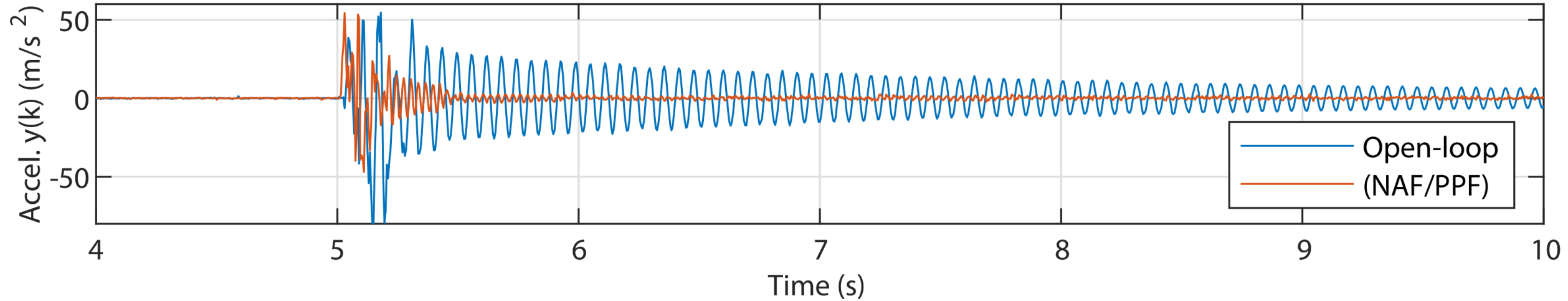
```
LinkShield.actuatorWrite(u);
```

- Read external reference r

```
r = LinkShield.referenceRead();
```



Typical classroom examples, e.g.: PPF control (Arduino IDE)



Conclusions and Further work

This paper introduced the LinkShield

- **A flexible link device for teaching mechatronics and control**
- **Completely open-source, low cost and well documented**
- **With an API for Arduino, including examples**

Work shall continue on the LinkShield, namely on

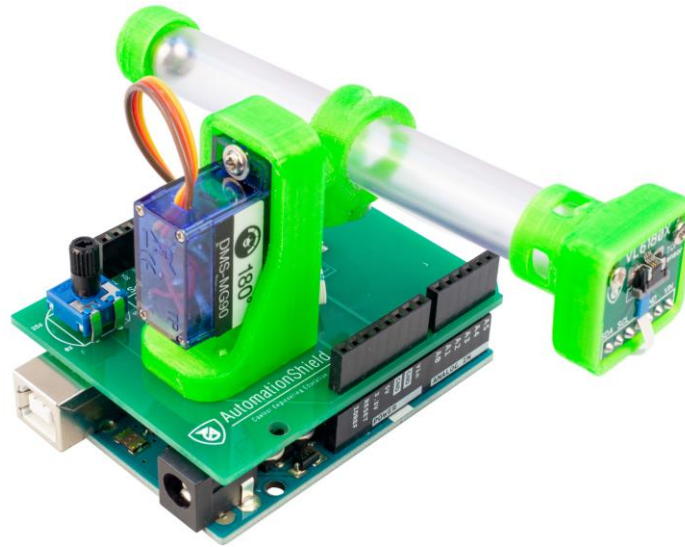
- **Better hardware** e.g. adding an IMU, servo position signal
- **More API**, e.g. for MATLAB, Simulink, Python
- **Modeling** and system identification
- **More control examples**, e.g. LQ, MPC, etc.



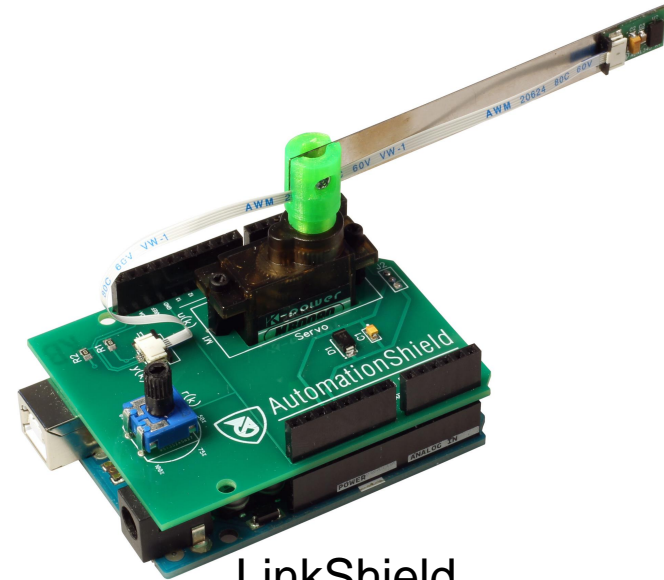
Range of shields within our initiative – visit www.automationshield.org



MagnetoShield



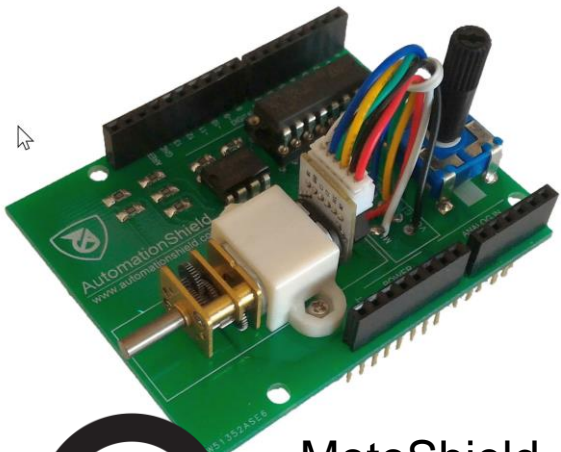
BOBShield



LinkShield



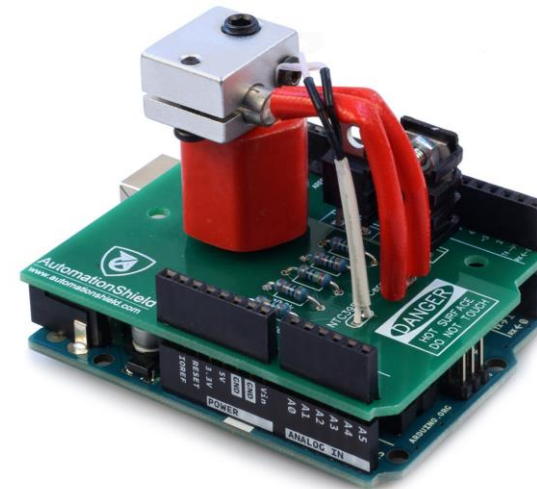
FloatShield



MotoShield



OptoShield



HeatShield



Thank you for your attention!

Visit www.automationshield.org for more details

and please feel free to contact me any time via:

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e-mail: gergely.takacs@stuba.sk

 researchgate.net/profile/Gergely_Takacs

 linkedin.com/in/gergelytakacs

