



**Faculty of Electrical
Engineering**

WARSAW UNIVERSITY OF TECHNOLOGY
www.ee.pw.edu.pl

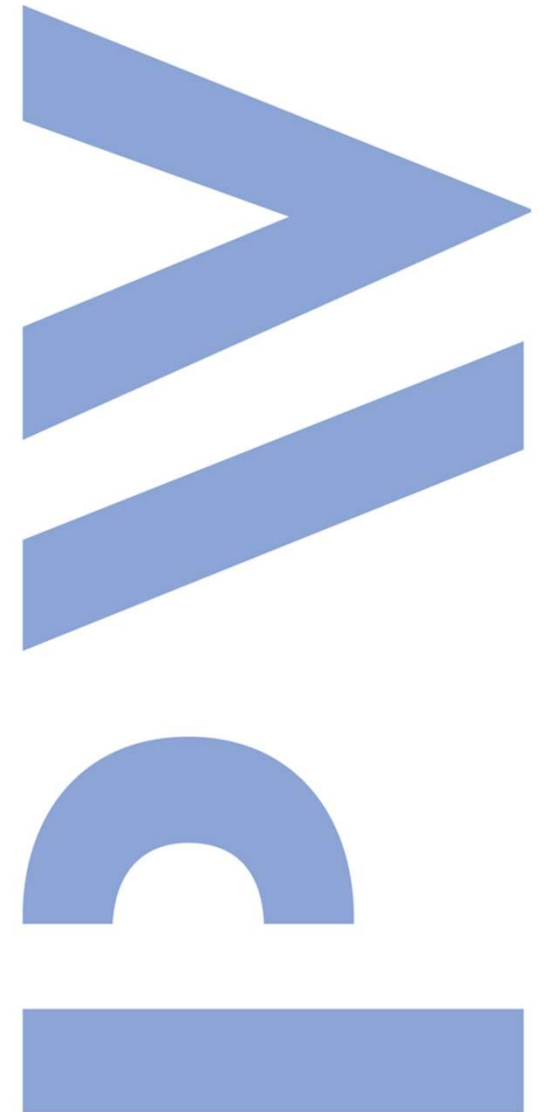


Control engineer – a professional hobbyist



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Faculty of Electrical Engineering
Institute of Control and Industrial Electronics
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This presentation was made by a human :)



Become an engineer!

Tesla CEO Elon Musk: „In the United States especially, there’s an over allocation of talent in finance and law. Basically, **too many smart people go into finance and law.**”



Source:

<https://finbold.com/elon-musk-says-tesla-stock-is-overvalued-but-worth-more-in-five-years/>

<https://www.youtube.com/watch?v=RcYjXbSjBN8> [Joe Rogan Experience #1470 - Elon Musk]

Dear Engineer!

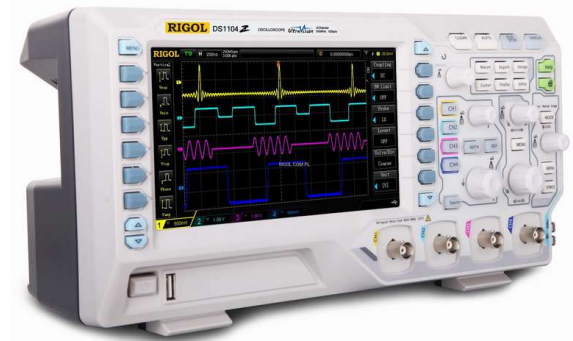
What equipment do you have at home?

- A multimeter?
- A soldering iron? An adjustable one?
- A logic analyzer?
- A laboratory power supply?
- A microcontroller evaluation board (uC eval kit)?
- An oscilloscope?

Let's set up an electronics lab!

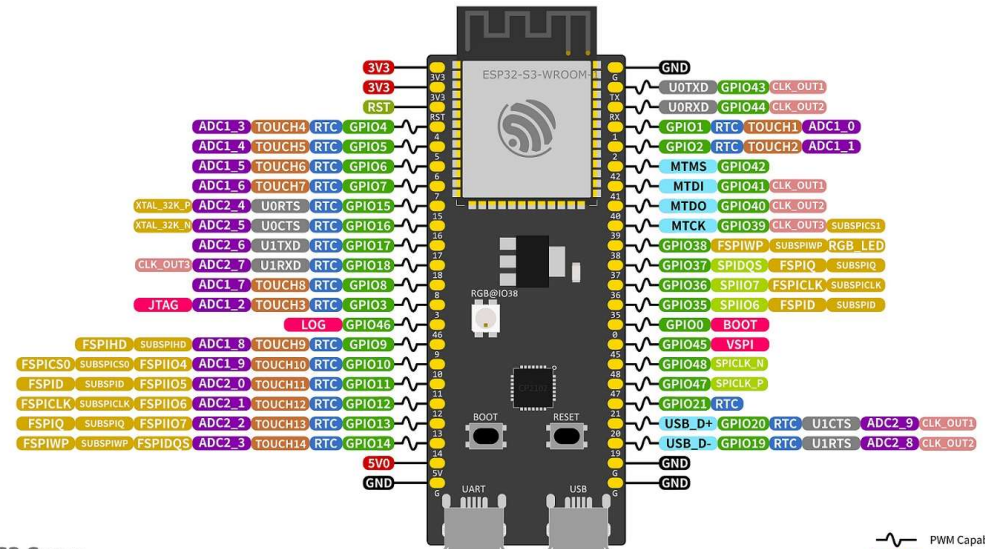
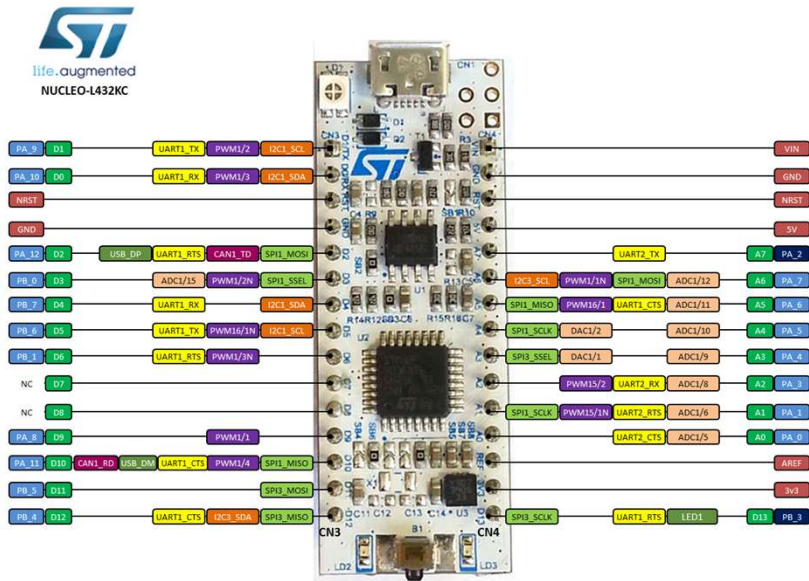
- logic analyzer (40 PLN for 8 CH 8 MS/s)
- multimeter (50 PLN)
- soldering station (130 PLN)
- power supply (340 PLN for 30V 10A)
- digital oscilloscope (1700 PLN brutto for 4 CH 50 MHz)

To put it into perspective: a popular gaming console will cost you around 2000 PLN.



Starring

ESP32-S3-DevKitC-1



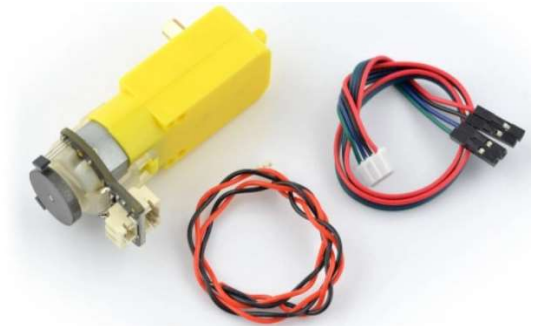
ESP32-S3 Specs

32-bit Xtensa® dual-core @240MHz
 Wi-Fi IEEE 802.11 b/g/n 2.4GHz + BLE 5 Mesh
 512 KB SRAM (16 KB SRAM in RTC)
 384 KB ROM
 45 GPIOs, 4x SPI, 3x UART, 2x I2C,
 14x Touch, 2x I2S, RMT, LED PWM, USB-OTG,
 TWAI®, 2x 12-bit ADC, 1x LCD interface, DVP

MISC Miscellaneous/SPI functions
 CLK_OUTx Clock Output

PWM Capable Pin
 GPIOx GPIO Input and Output
 JTAG/USB JTAG for Debugging and USB
 ADCx_CH Analog-to-Digital Converter
 TOUCHx Touch Sensor Input Channel
 OTHER Other Related Functions
 SERIAL Serial for Debug/Programming
 STRAP Strapping Pin Functions
 RTC RTC Power Domain (VDD3P3_RTC)
 GND Ground
 PWD Power Rails (3V3 and 5V)

Let's connect something to our uC!



- H-bridge converter (15 PLN, 15 V, 1.2 A per CH)
- DC machine with encoder (40 PLN)
- current transducer (10 PLN)
- CAN bus transceiver (20 PLN)
- OBD-II scanner (50 – 100 PLN)



Let's set up an electronics lab!

Development environments:

- Arduino IDE (<https://www.arduino.cc/en/software>)
- endless libraries and examples for e.g. ESP32 (see e.g. <https://github.com/explore>)
- PlatformIO (<https://platformio.org/>)
- STM32CubeIDE (<https://www.st.com/en/development-tools/stm32cubeide.html>)
- endless libraries and examples for STM32 (see e.g. <https://github.com/lamik/> and <https://github.com/explore>)
- Visual Studio Code if you don't like the editor provided by the Arduino IDE (<https://code.visualstudio.com/>)
- Android Studio (<https://developer.android.com/studio>)
- Visual Studio Community (<https://visualstudio.microsoft.com/>)

They are all free.



Online compilers and code sharing

Online compilers:

- OnlineGDB (<https://www.onlinegdb.com/>)
- Compiler Explorer (<https://godbolt.org/>)

Arduino simulator:

- Wokwi (<https://wokwi.com/>)

Git (version control system) repositories:

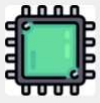
- GitHub (<https://github.com/>)
- GitLab (<https://about.gitlab.com/>)
- Bitbucket (<https://bitbucket.org/product/>)

and several more

They are all free.

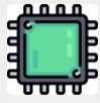


Control Engineering for Hobbyists on MS Teams



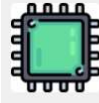
Control Engineering for Hobbyists ...

- Challenge 01 (Android sensors)
- Challenge 02 (H-bridge converter)
- Challenge 03 (Rubik's cube solver)
- Challenge 04 (Stepper motor)
- Challenge 05 (Incremental encoder)
- Challenge 06 (Line follower)
- Challenge 07 (Holonomic platforms)
- Challenge 08 (Swingbot)
- Challenge 09 (Self-balancing robot)
- Challenge 10 (CAN bus [Arduino])
- Challenge 11 (CAN bus [STM32])
- Challenge 12 (Self-balancing motorcycle)
- Challenge 13 (Persistence of vision)
- Challenge 14 (Word clock)
- Challenge 15 (Doomsday chat)
- Challenge 16 (Christmas aRGB LEDs [Arduino])
- Challenge 17 (LoRa networks)
- Challenge 18 (WS2812B [STM32])
- Challenge 19 (USB mouse and joystick [STM32])
- Challenge 20 (Thermal camera [Arduino])



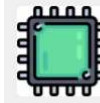
Control Engineering for Hobbyists ...

- Challenge 21 (Thermal camera [STM32])
- Challenge 22 (Spectrum analyser [STM32])
- Challenge 23 (IR remote [Arduino])
- Challenge 24 (IR remote [STM32])
- Challenge 25 (nRF24L01 [STM32])
- Challenge 26 (Easter eggbot)
- Challenge 27 (FDCAN protocol [STM32])
- Challenge 28 (Reaction wheel)
- Challenge 29 (Tensometric sensors, load cell)
- Challenge 30 (Drone)
- Challenge 31 (nRF905 [STM32])
- Challenge 32 (MPU6050, Kalman filter [STM32])
- Challenge 33 (XPT2046 touch screen)
- Challenge 34 (AI)
- Challenge 35 (Robot vision [Pixy2])
- Challenge 36 (Mass storage, USB, SDIO [STM32])
- Challenge 37 (Gesture sensor [STM32])
- Challenge 38 (I2C multiplexer [STM32])
- Challenge 39 (Multiple servos, PCA9685 [STM32])
- Challenge 40 (GPS receiver [STM32])



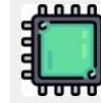
Control Engineering for Hobbyists ...

- Challenge 41 (1-Wire, DS18B20 temp. sensor)
- Challenge 42 (GSM, GPRS, SMS, SIM800L [STM32])
- Challenge 43 (FSMC TFT ILI9341)
- Challenge 44 (OV7670 camera sensor)
- Challenge 45 (The Game of Life)
- Challenge 46 (Useless machine)
- Challenge 47 (PCB design, KiCad)
- Challenge 48 (I2S microphone)
- Challenge 49 (OV2640 camera sensor)
- Challenge 50 (I2S WAV player)
- Challenge 51 (Weather station [STM32])
- Challenge 52 (Ethernet [STM32, ESP32])
- Challenge 53 (MP3 player [STM32])
- Challenge 54 (WAV recorder [STM32])
- Challenge 55 (Submarine)
- Challenge 56 (NTP)
- Challenge 57 (USB keyboard [STM32])
- Challenge 58 (Web server [ESP32])
- Challenge 59 (Ultrasonic sensors [STM32])
- Challenge 60 (ICM-20948 9DoF motion sensor)
- Challenge 61 (3D graphics)



Control Engineering for Hobbyists ...

- Challenge 62 (3D acoustic vector sensor)
- Challenge 63 (Optical tachometer)
- Challenge 64 (Menu)
- Challenge 65 (Smartwatch)
- Challenge 66 (Barometer, altimeter)
- Challenge 67 (FM tuner)
- Challenge 68 (External EEPROM and flash)
- Challenge 69 (TOF laser range sensor [CAN bus])
- Challenge 70 (ESP-NOW protocol)
- Challenge 71 (STM32CubeIDE vs. Arduino IDE)
- Challenge 72 (Fluid level meter)
- Challenge 73 (USB composite)
- Challenge 74 (MLX90614 pyrometer)
- Challenge 75 (GPS receiver and Kalman filter)
- Challenge 76 (ESP32 can CAN!)
- Challenge 77 (AM radio transmitter)
- Challenge 78 (Time lapse)
- Challenge 79 (Audio signal processing)
- Challenge 80 (Hysteresis control)
- Challenge 81 (Peltier effect cooling)



Control Engineering for Hobbyists ...

- Challenge 107 (DIY oscilloscope)
- Challenge 108 (Servo drive, half-duplex UART)
- Challenge 109 (Quick Charge 3.0)
- Challenge 110 (USB Power Delivery)
- Challenge 111 (FPGA)
- Challenge 112 (Inductive heating)
- Challenge 113 (Capacitive touch sensing)
- Challenge 114 (PS3 controller)
- Challenge 115 (Bootloader)
- Challenge 116 (Buck-boost converter)
- Challenge 117 (Tesla coil)
- Challenge 118 (Metal detector)
- Challenge 119 (CANopen [STM32])
- Challenge 120 (Air quality)
- Challenge 121 (Ucap vs. coin cell [BRTC])
- Challenge 122 (CAN TP)
- Challenge 123 (Airplane)
- Challenge 124 (OpenCV)
- Challenge 125 (BLE HMI on MCU [Arduino])
- Challenge 126 (BLE terminal [STM32])

Join us now! No strings attached!
Please send me a message via MS
Teams chat to become a member.

All set and done! But where to start?

“It takes half your life before you discover life is a do-it-yourself project.” Napoleon Hill

<https://medium.com/@nancy.e.huang/life-is-a-do-it-yourself-project-d131c4b82340>

- Just pick a DIY project that you would like to brag about and do it, and then brag about it!
- Be inspired by other DIY projects. Check them out e.g. on YT, Instructables, Arduino Project Hub, How 2 Electronics, Circuit Digest, Hackaday – these are just examples as this community is enormous, and that's good for us! Some of my favorite YT creators regarding STM32/ESP32 DIY projects are: Phil's Lab, Controllers Tech, DroneBot Workshop, and Andreas Spiess.
- „It is the time you have wasted for your rose that makes your rose so important.” – Antoine de Saint-Exupéry, The Little Prince. So maybe start from building a clock ;)



Learning resources

Tutorials, examples and libraries provided by the DIY industry. Some of my favorite ones are:

- <https://www.adafruit.com/>
- <https://www.waveshare.com/>
- <https://www.sparkfun.com/>
- <https://www.dfrobot.com/>
- <https://www.freenove.com/>
- <https://www.elegoo.com/>
- <https://www.upesy.com/>

Some DIY stores and training providers offer their own knowledge bases for free. Some of my favorite ones are unfortunately available only in Polish (fortunately, the C/C++ code itself is a universal language):

- <https://forbot.pl/blog/kursy>
- <https://msalamon.pl/>
- <https://ucgosu.pl/>
- <https://intertechacademy.pl/>

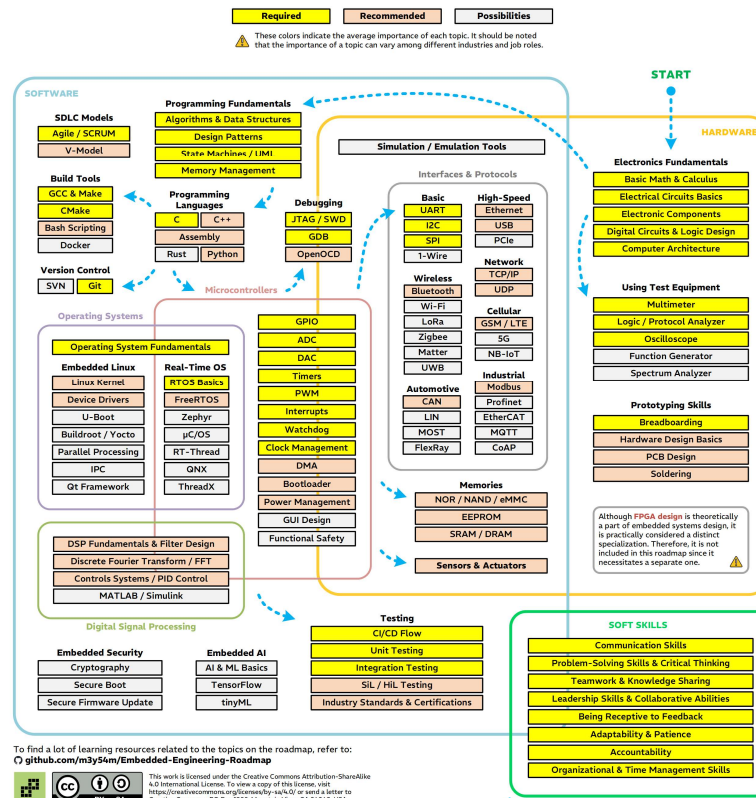
And last but not least – the communities around chip manufacturers itself, for example:

- <https://community.st.com/s/>



Embedded Systems Engineering Roadmap

EMBEDDED SYSTEMS ENGINEERING ROADMAP



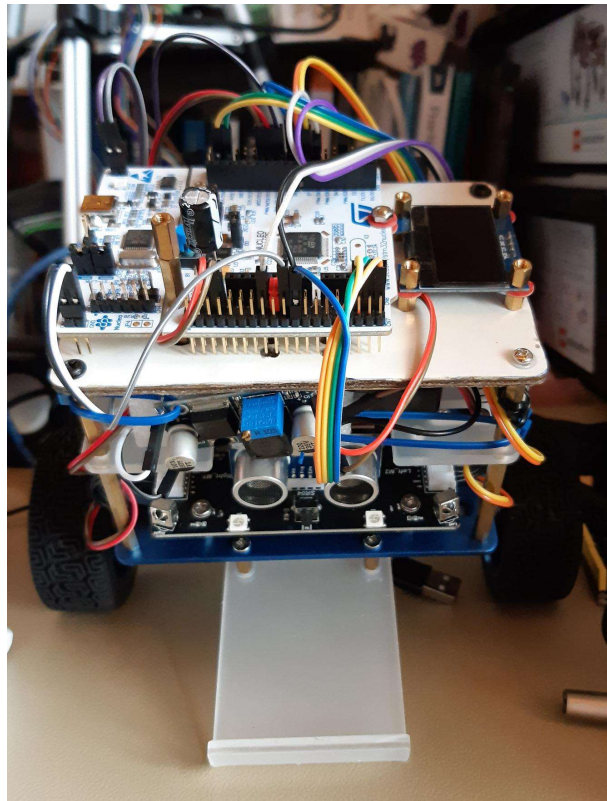
To find a lot of learning resources related to the topics on the roadmap, refer to:
github.com/m3y54m/Embedded-Engineering-Roadmap

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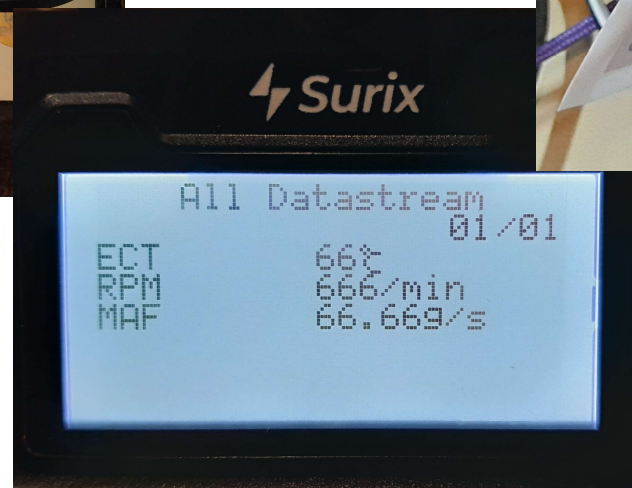
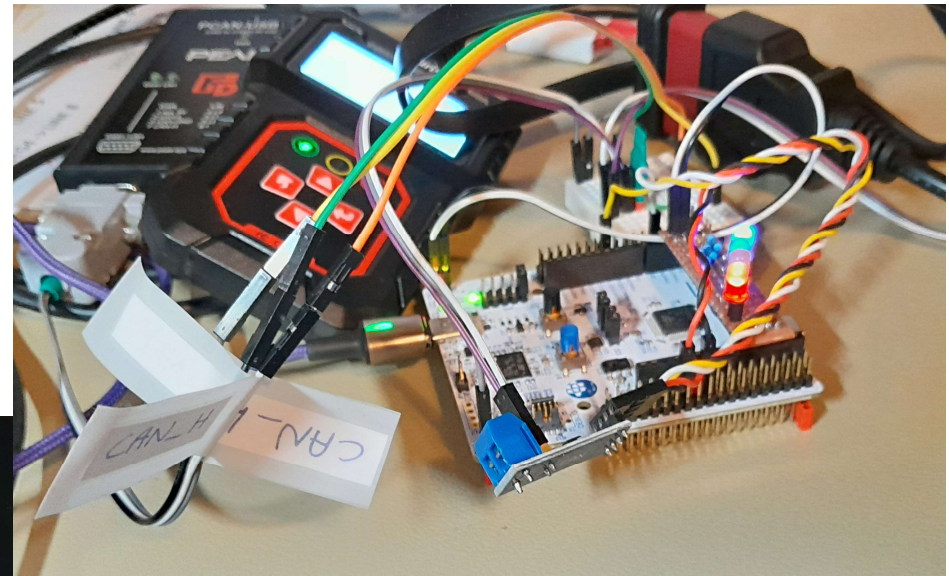
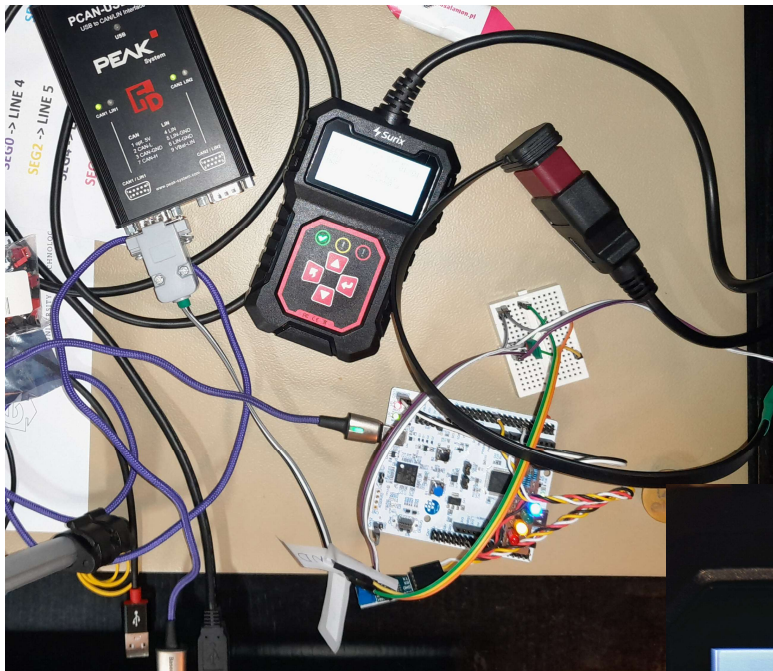
Creator & Maintainer: **Meysam Parvizi**
 Last update: 2023-09-11
 Revision: v1.1.0

<https://github.com/m3y54m/Embedded-Engineering-Roadmap>

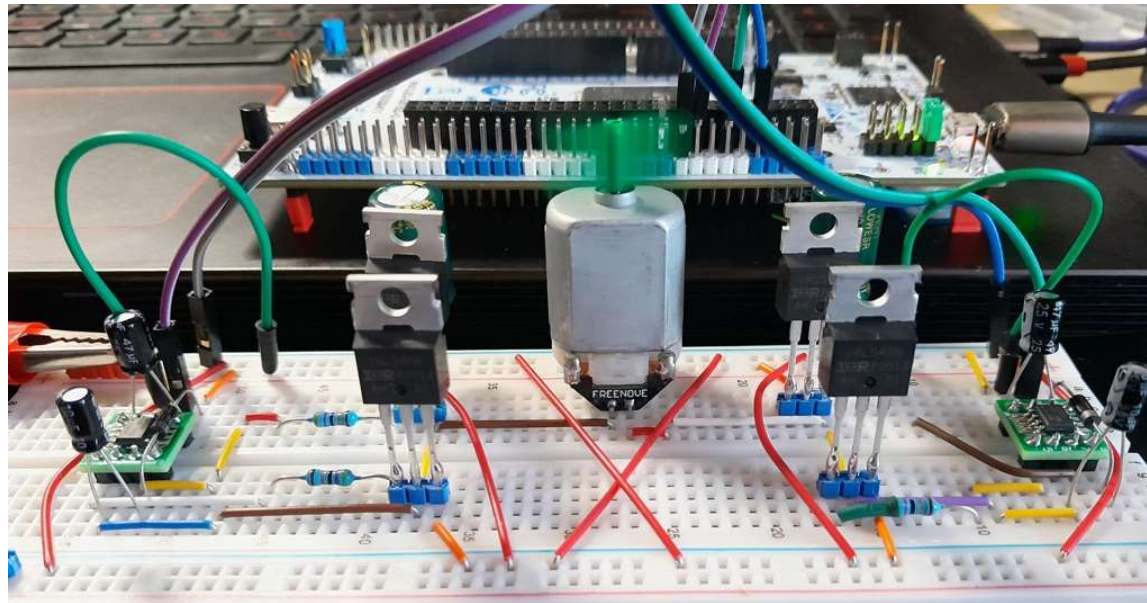
Let's build something!



Let's build something!



Let's build something!



Let's build something!

ST Motor Pilot V1.2.4 - profiler
GUI Configuration Help

Board Connection: UART, COM72, Speed: 1843200, Disconnect, Polling, ST MCDK 6.2.0

Graph & Record

Application Registers Logs

Board connected

B-G431B-ESC1
STM32G431CBUX

B-G431B-ESC1
Bus voltage: 8 - 28 Vdc
max rated current: 40 Apk

Start profile
Save

Electrical model
Rs 0.1 Ω Ls 0.01 mH
Vbus 10.88 V
Imax 12.75 Apk
Ke 0.44 Vrms/KRPM

Mechanical model
Friction 4.46 $\mu\text{N}\cdot\text{m}\cdot\text{s}$
Inertia 0.71 $\mu\text{N}\cdot\text{m}\cdot\text{s}^2$
Max speed 11928 RPM

Profiling % 100

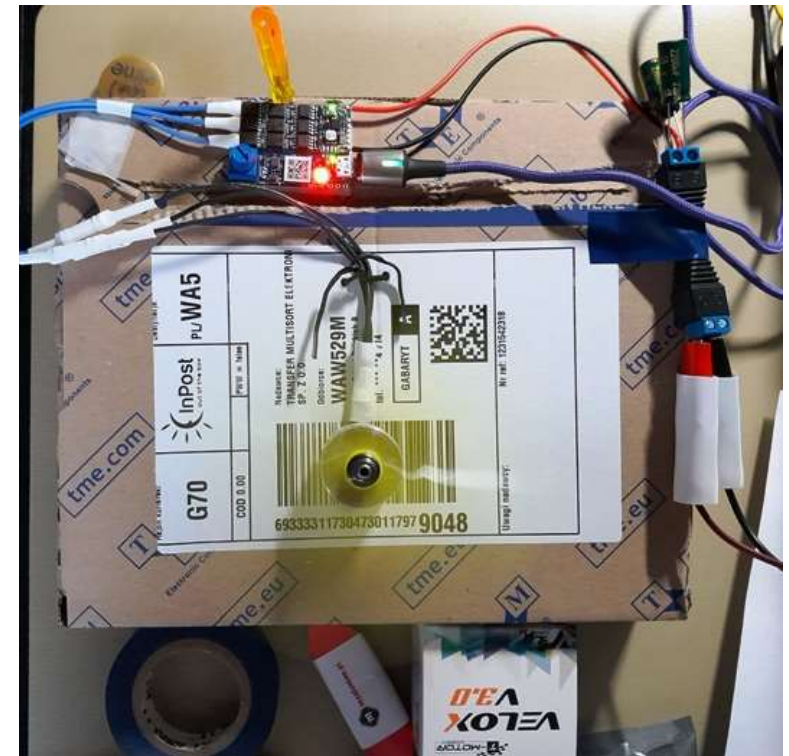
Pole pairs: 7
Max speed: 15000 RPM
Max current: 32.0 Apk
Under Voltage threshold: 6 < 11 < 15
Over Voltage threshold: 15
Magnetic: SPM... IPM...

Errors

- FOC Duration
- Over Voltage
- Under Voltage
- Over Heat
- Start Up Failure
- Speed Feedback
- Over Current
- Software Error
- Driver protection

Ack Faults

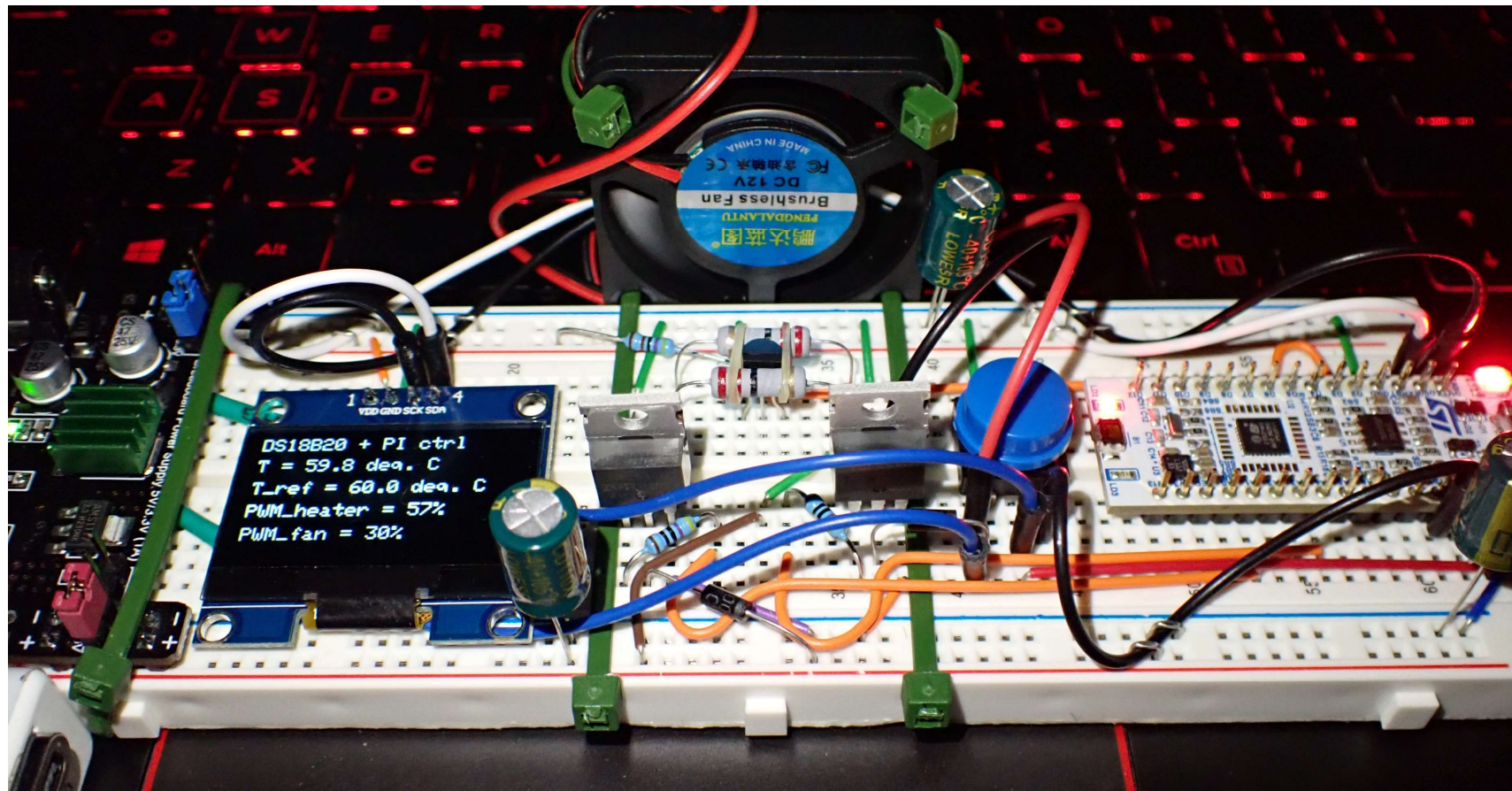
CPU= 1.8%



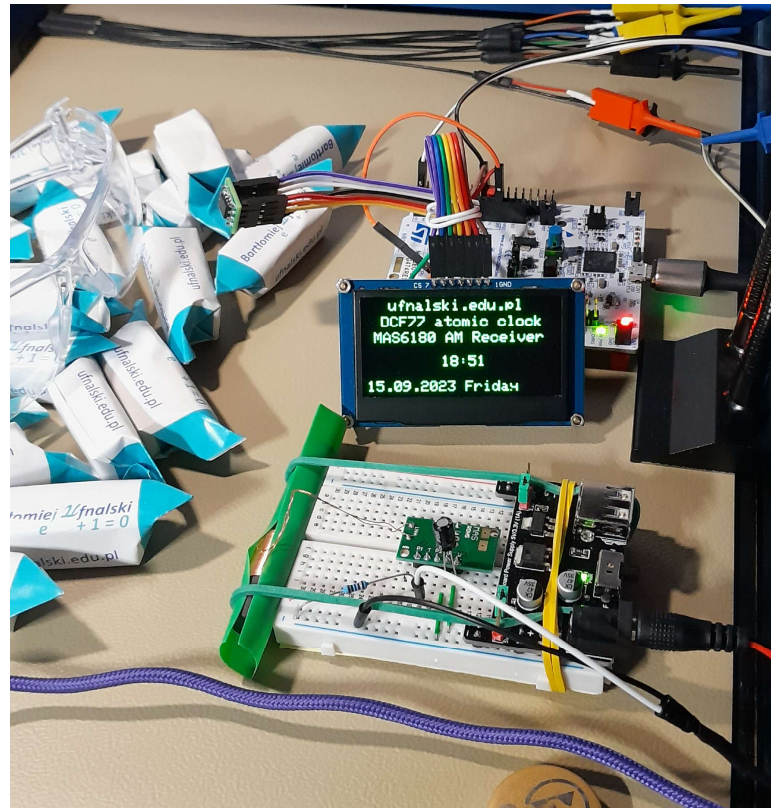
Education gemification

http://ufnalski.edu.pl/stm32_projects/dshot_esc_protocol/dshot_stanowisko_dydaktyczne_preprototyp.mp4

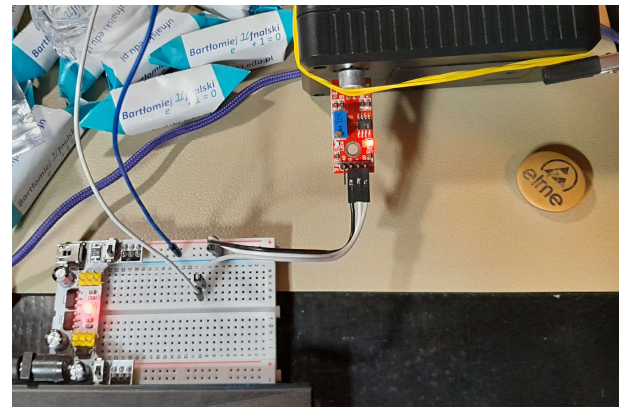
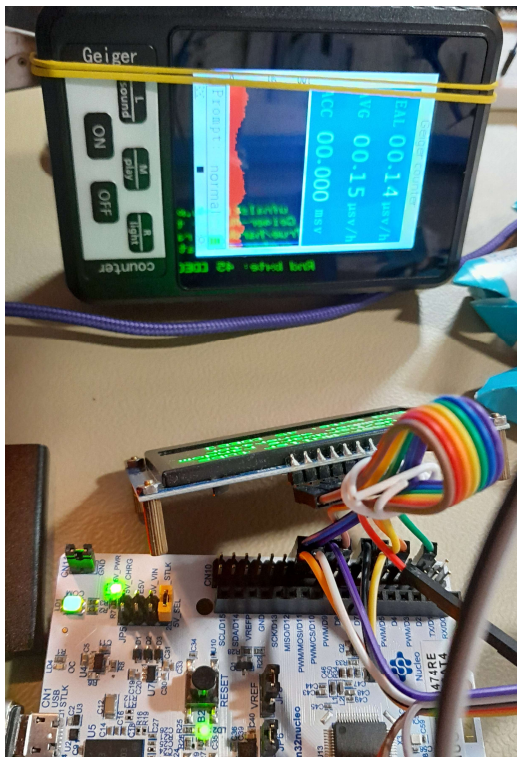
Let's build something!



Let's build something!



Let's build something!





Thank you for your kind attention!



WARNING

Control engineering – try this at home!