FACULTY OF ELECTRICAL ENGINEERING CTU IN PRAGUE

Driving and processing signals from LVDT sensor using NUCLEO-G474RE

Semestral work for courses B3B38LPE1 and B3B38SME1

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Summary

- Drive and process signals from LVDT sensor using STM32 Nucleo board
  - Typically a dedicated LVDT signal conditioner is used, such as AD598, AD698, TI PGA970...
- NUCLEO-G474RE is a low-cost development board with STM32G434RE microcontroller
  - 32-bit ARM Cortex-M4 core
  - up to 170MHz CPU clock
  - 5 **12-bit ADCs** 4 Msps, 3 **external DAC** channels
  - 2 8-channel **DMA controllers**, CORDIC trigonometric accelerator
- Output measured data as CSV through UART
- Show current values on OLED display

1. What is an LVDT sensor?

$$x_{\text{core}} = k\frac{A_1 - A_2}{A_1 + A_2} \qquad (1)$$

- where A_1 and A_2 are the amplitudes of secondary coils signals for the driving signal frequency
- $k\,[\mathrm{mm}]$ is the length-coefficient of the LVDT sensor
- holds true within the linear range (ours $\approx \pm 1.5\ \mathrm{cm}$)

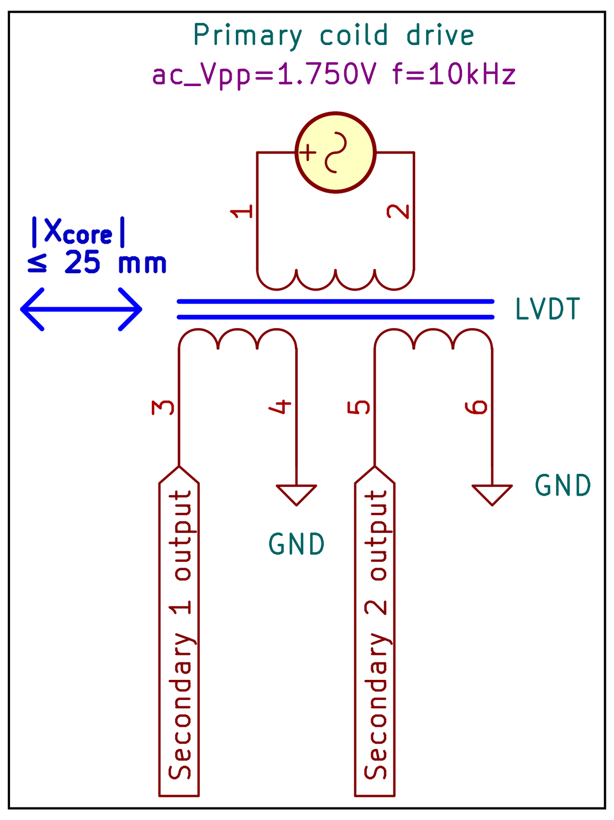

Fig. 1: LVDT sensor

2. Block schema

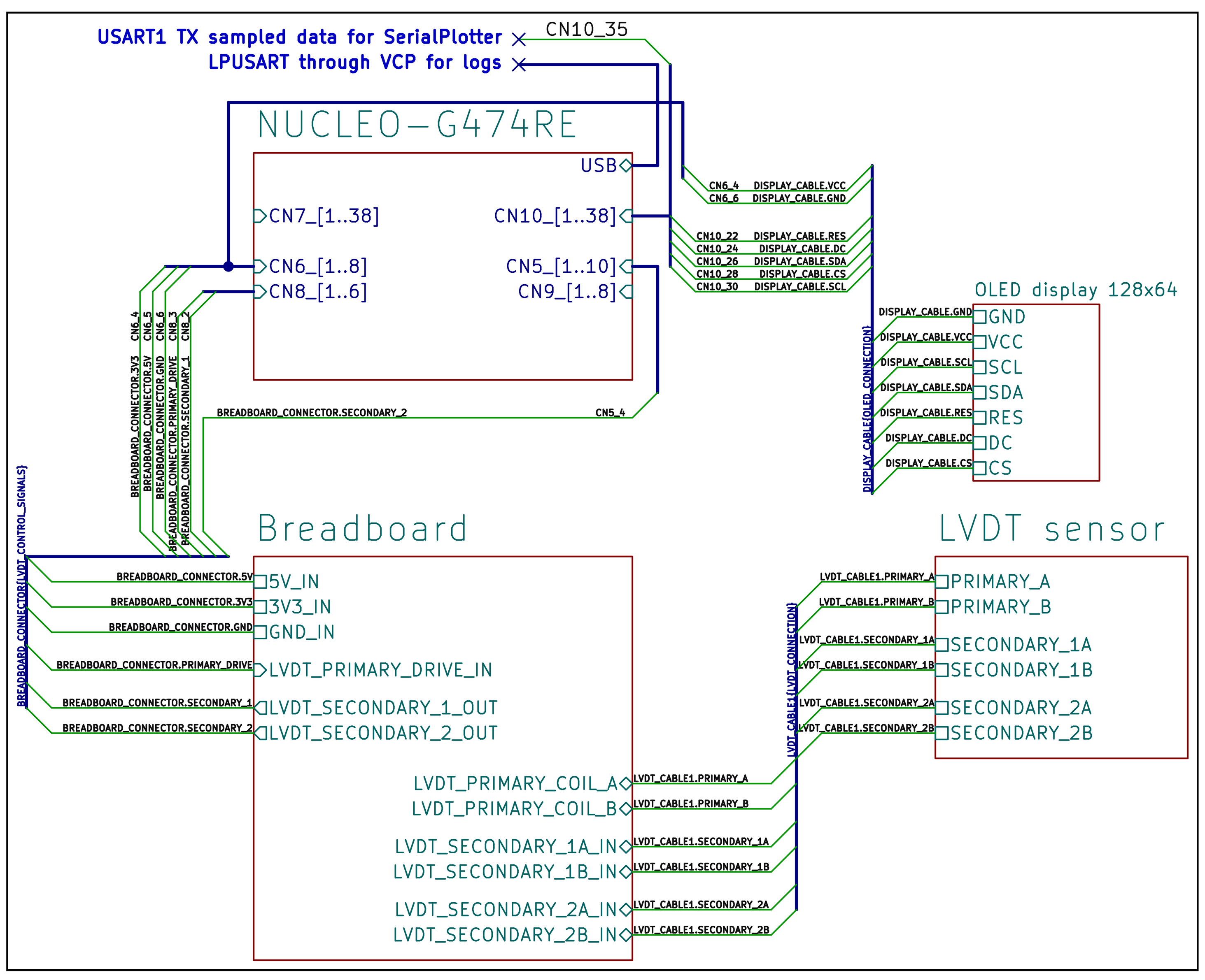

Fig. 2: Block schema of the NUCLEO-G474RE LVDT sensor driver

3. Driving the primary coil - $10\ \mathrm{kHz}$ sine wave

- Sine table programmed into FLASH
- TIM6 generates interrupts at $10\,\mathrm{kHz} \cdot N_{\text{samples}} = 1\,\mathrm{MHz}$
- DMA1 ch3 transfers data from FLASH to DAC1 ch1
- DC voltage removed by blocking capacitor C3
- LM4889 amplifier with $A = 1$ ensures low output impedance and power independence from MCU

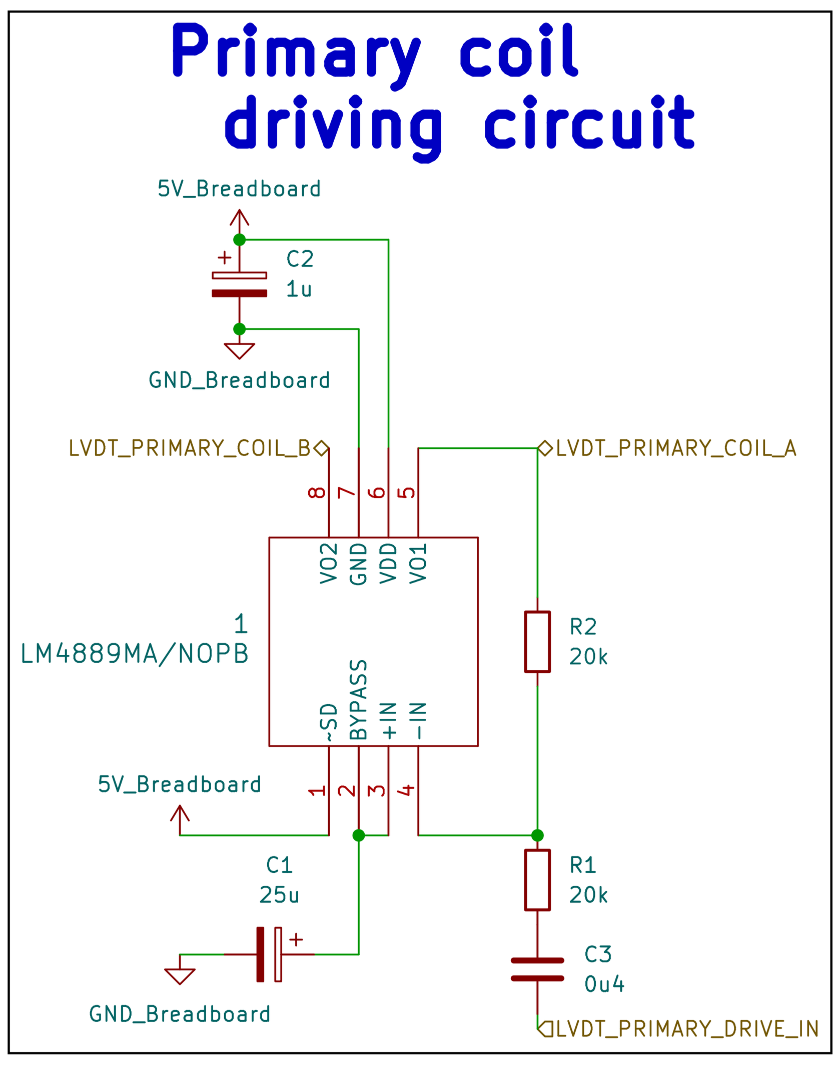

Fig. 3: Primary coil driving circuit

4. Measuring secondary coils - $120\ \mathrm{kSa/s}$

- connected trough blocking capacitors and voltage dividers
- TIM7 generates interrupts at $120\,\mathrm{kHz}$
- ADC1 & ADC2 in 12-bit Regular simultaneous mode sample both secondary coils at once
- DMA1 ch1 transfers data from ADC1 & ADC2 to $2\,\mathrm{kB}$ RAM buffer
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- after each halfbuffer transfer complete, interrupt handler transfers this halfbuffer into $1\,\mathrm{kB}$ processing buffer

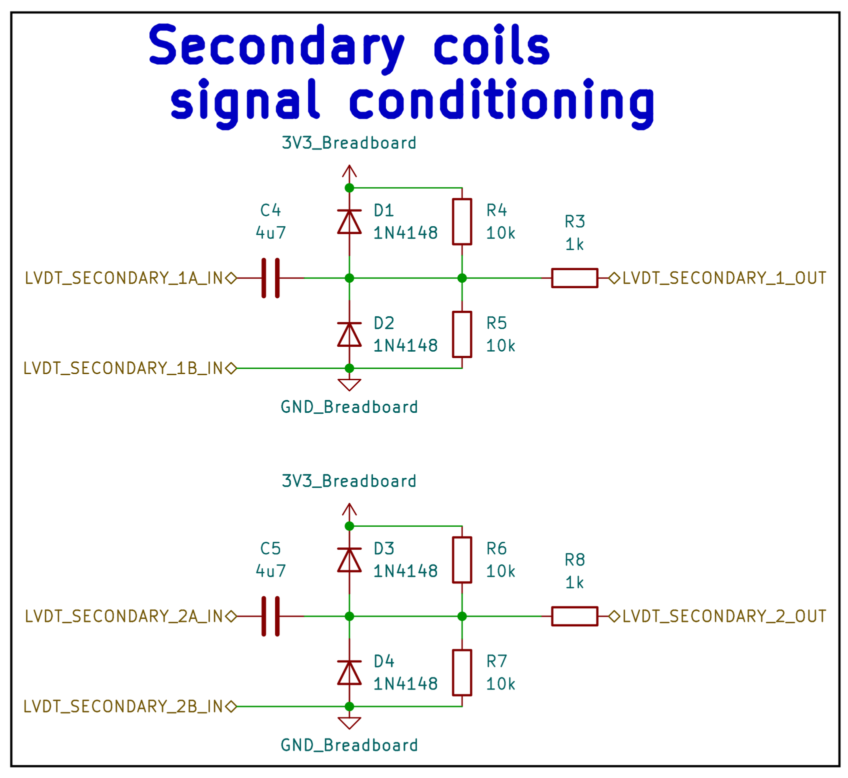

Fig. 4: Secondary coil measuring circuit

5. Signal processing - $\approx 110\ \mathrm{Hz}$ update

- Goertzel algorithm used to calculate the amplitude of secondary coils for the driving frequency
  - CORDIC trigonometric accelerator used to calculate the magnitude from the real and imaginary parts
- core position is calculated as per Equation 1

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6. Data presentation

- current values are shown on 128x64 OLED display
  - driving and sampling frequencies, calculated amplitudes, core position
  - core position visualized as horizontal slider
- calculated amplitudes and core position are sent through USART1

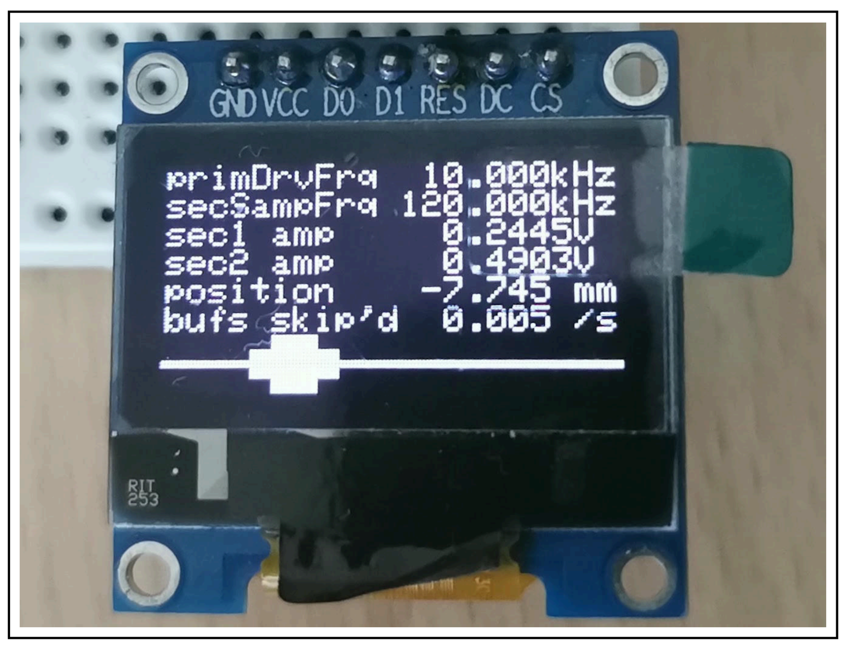

Fig. 5: OLED display with current values

7. Physical implementation

- small 23-by-12 breadboard hosts the circuitry
  - amplifier for driving the primary (Section 3)
  - voltage dividers and blocking capacitors for measuring secondaries (Section 4)
  - 128x64 OLED display (Section 6)
- connects to NUCLEO-G474RE through DuPont ribbons
  - 3w power, 1w primary drive, 2w secondary sense
  - 5w control signals for OLED display
- connects to the LVDT sensor itself through 6 wires leading to each coils' ends

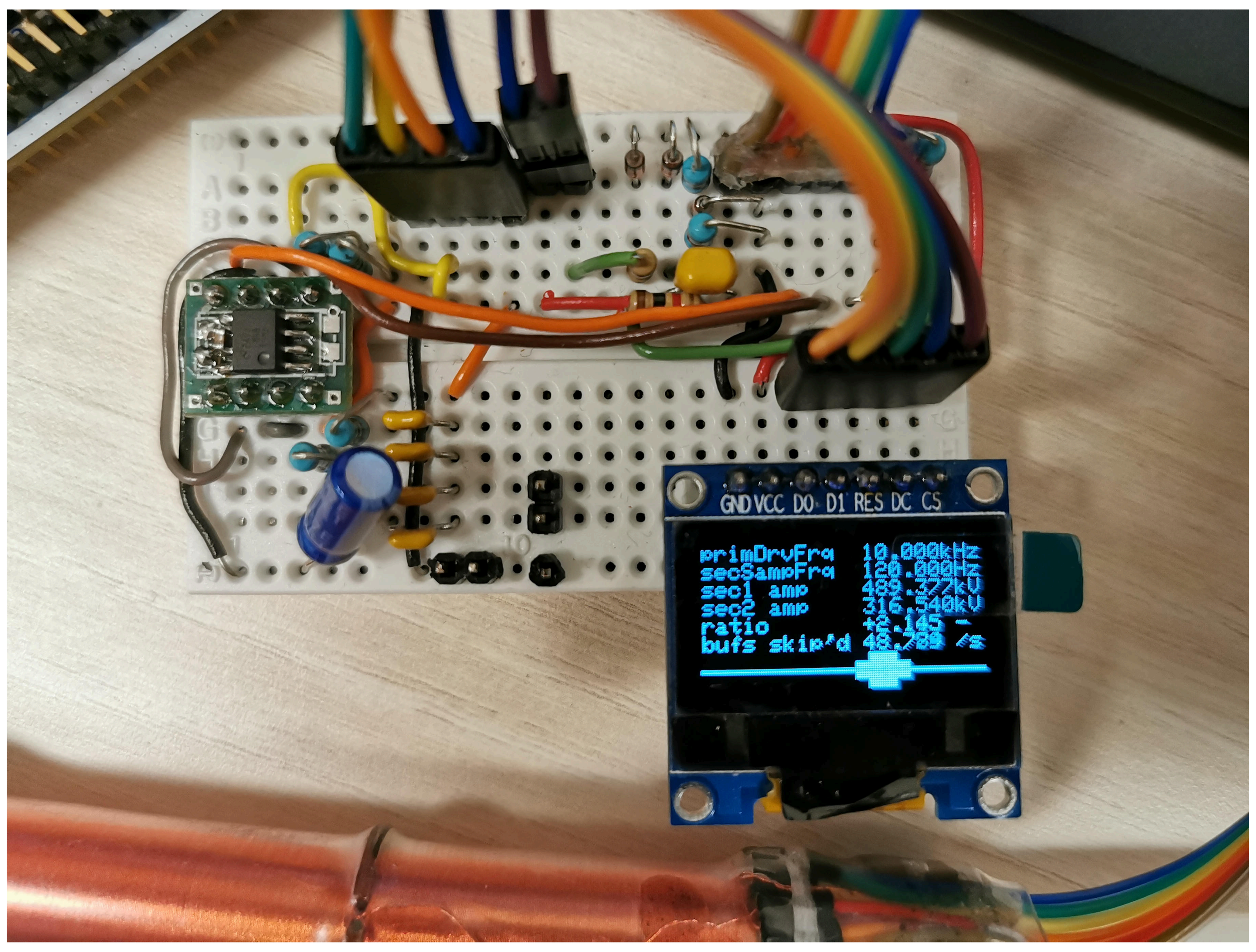

Fig. 6: Breadboard featuring circuits from Fig. 3, Fig. 4 and the OLED display

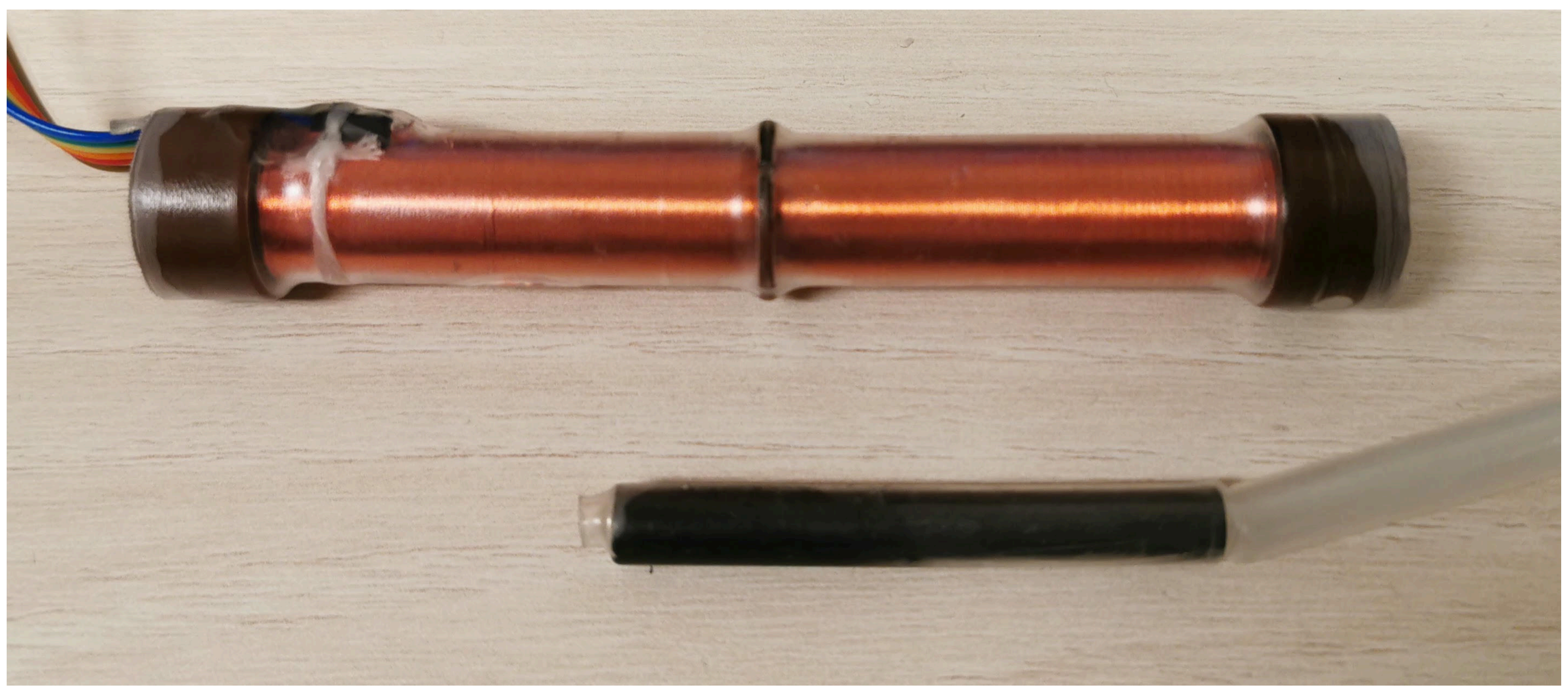

Fig. 7: LVDT sensor made by doc. Petrucha

8. Step response

- transfer characteristic of the used LVDT sensor was measured in Fig. 8
  - x axis is the core position as measured by vernier callipers, left y axis is the amplitude of the secondary coils, right y axis is the calculated core position divided by k
- k was calculated from the slope of the linear part of the transfer characteristic
  - $k = 2.319\ \mathrm{mm}$ for our sensor
- length of the linear range is $\approx 2 \cdot 1.5\ \mathrm{cm} = 3\ \mathrm{cm}$

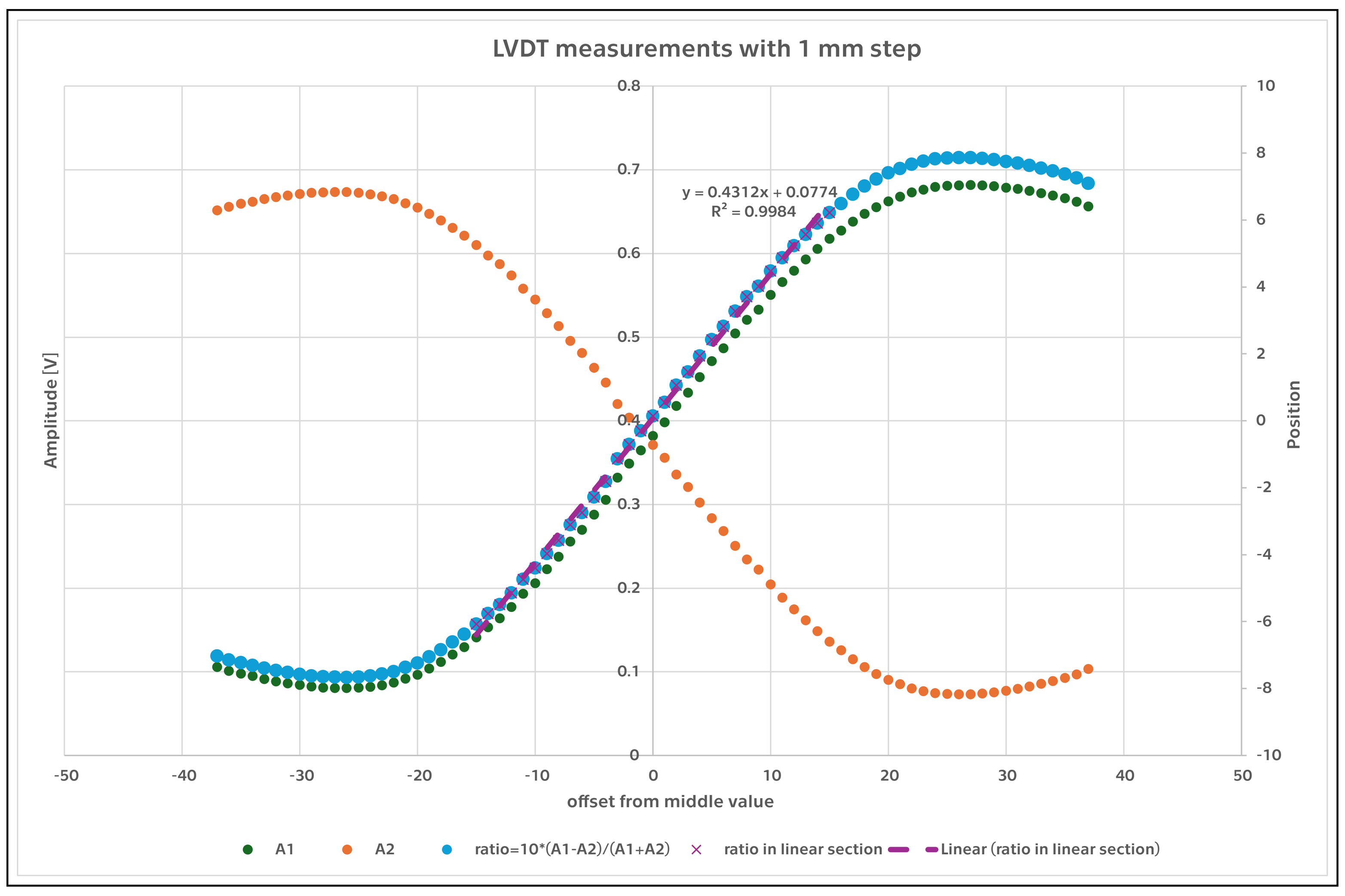

Fig. 8: Measured data - step response of the LVDT sensor

9. Parameters overview

Parameter	Value
Driving signal frequency	$10\,\mathrm{kHz}$
DAC Frequency	$1\,000\,\mathrm{MHz}$
DAC Resolution	$12\,\mathrm{b}$
DAC Sample transfer method	DMA
ADC Sampling frequency	$120\,\mathrm{kSa/s}$
ADC Resolution	$12\,\mathrm{b}$
ADC Sample transfer method	1 DMA for both ADCs
ADC Buffer length	$2\,\mathrm{kSa}$
Calculation buffer length	$1\,\mathrm{kSa}$
Calculation buffers sampled / second	$\approx 117.19\,\mathrm{Hz}$
Calculations performed / second	$> 100\,\mathrm{Hz}$

10. Conclusion

Both the physical circuitry and the firmware were successfully implemented. Thorugh the use of DMA and CORDIC, satisfying performance was achieved.

The NUCLEO-G474RE board is more than capable to be used instead of dedicated LVDT signal conditioners, while allowing any other custom processing to take place, or even handle other sensors.