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FACULTY OF TRANSPORTATION ENGINEERING
Department of Automotive Engineering

CAPSTONE PROJECT: DESIGN A CALIBRATION EQUIPMENT FOR TOYOTA PRIUS 2006 STEERING TORQUE SENSOR

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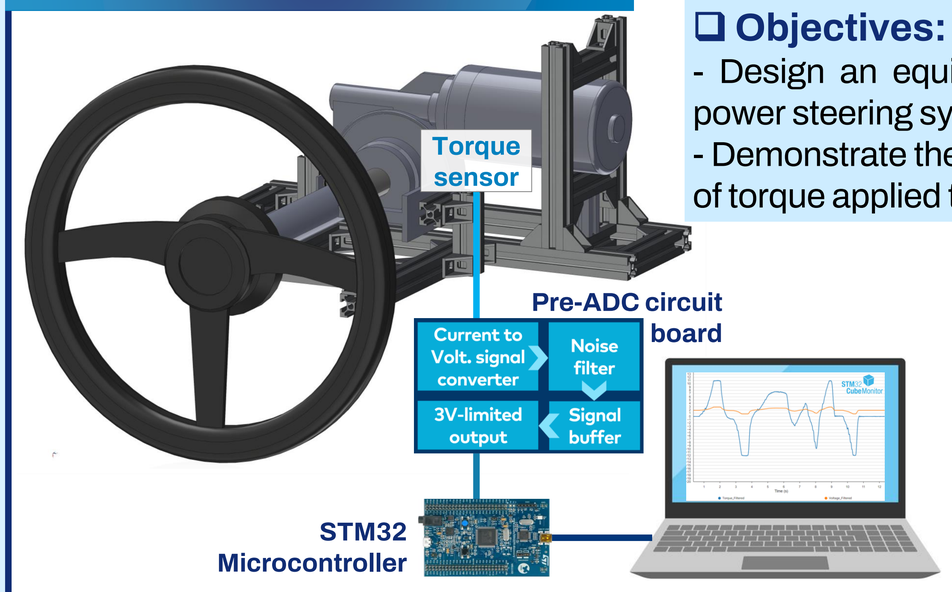
I. INTRODUCTION



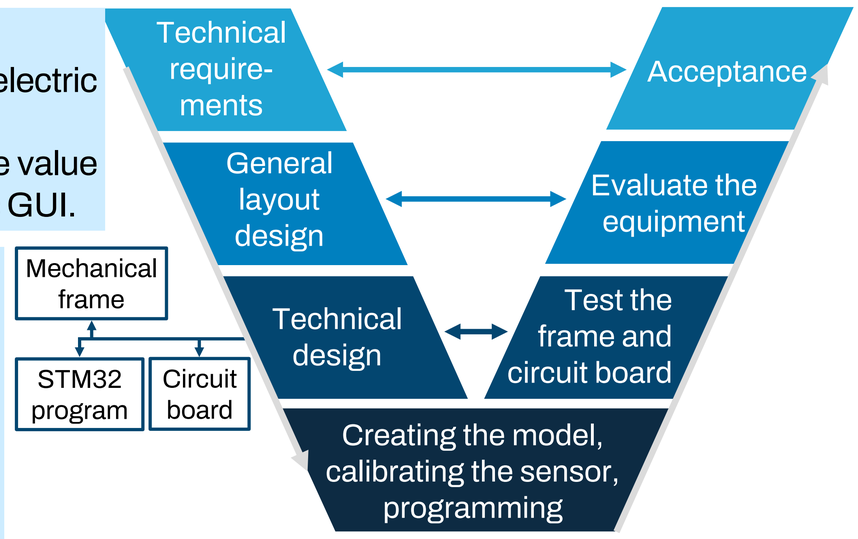
General layout of the calibration equipment for Toyota Prius 2006 steering torque sensor

❑ Objectives:

- Design an equipment to calibrate the torque sensor in the electric power steering system of Toyota Prius 2006.
- Demonstrate the correlation between the electrical signal and the value of torque applied to the sensor, then display the digital value in the GUI.

❑ Key problems:

- Design a mechanical frame for mounting the EPS assy.
- Design a circuit board to process the signal before inputting it to STM32 Microcontroller.
- Convert the sensor's electrical signal to digital signal using the ADC in STM32 and process the digital signal.

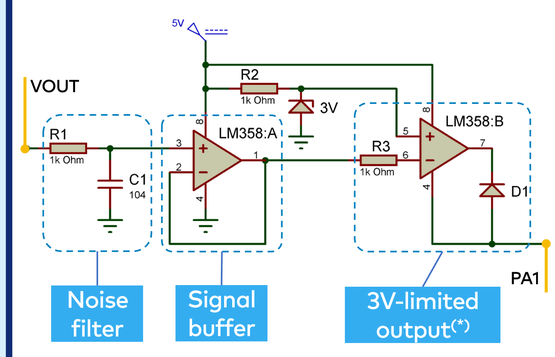


V-model of the project

❑ Technical requirements:

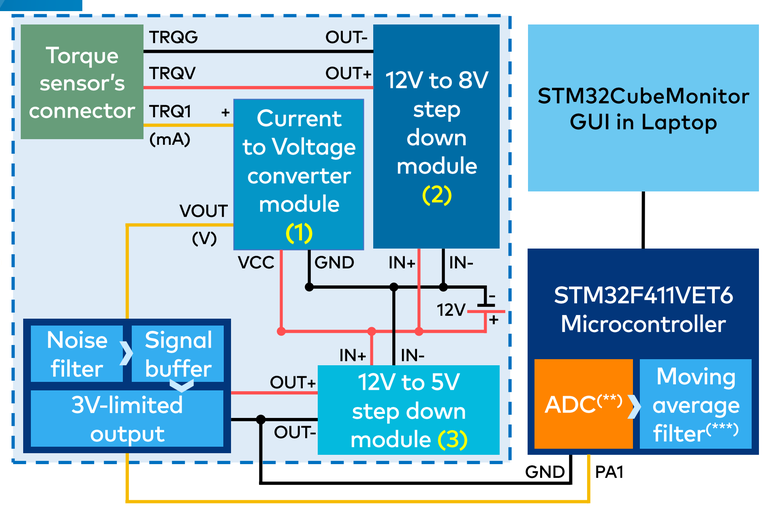
- Fast response of processed signal (<1ms); - Accuracy of estimated torque ≈ 90%.

II. CIRCUIT DESIGN

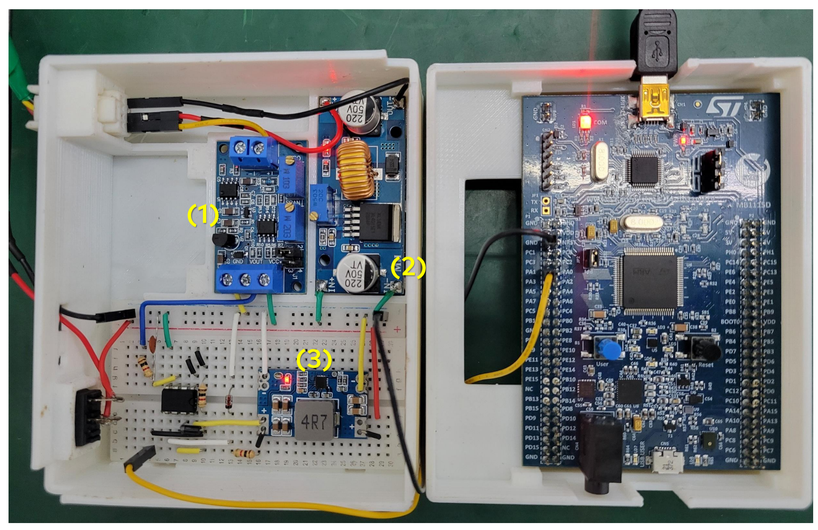


Voltage-signal processing circuit

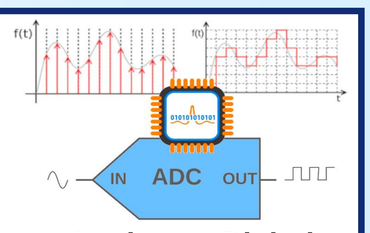
***3V-limited output:** this is to prevent the signal from exceeding 3V when go to PA1 for protecting the STM32.



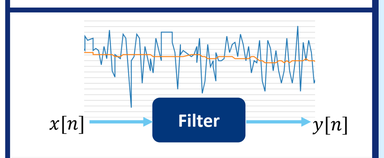
Wiring diagram of Pre-ADC circuit



Corresponding circuit board and wiring



***Analog-to-Digital converter*

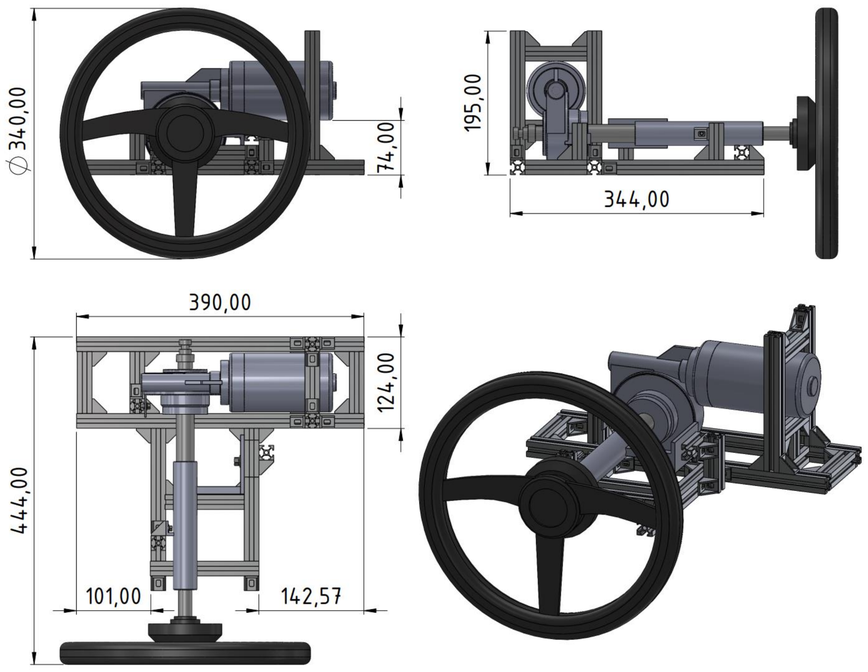


3-point: $y[n] = \frac{x[n] + x[n-1] + x[n-2]}{3}$

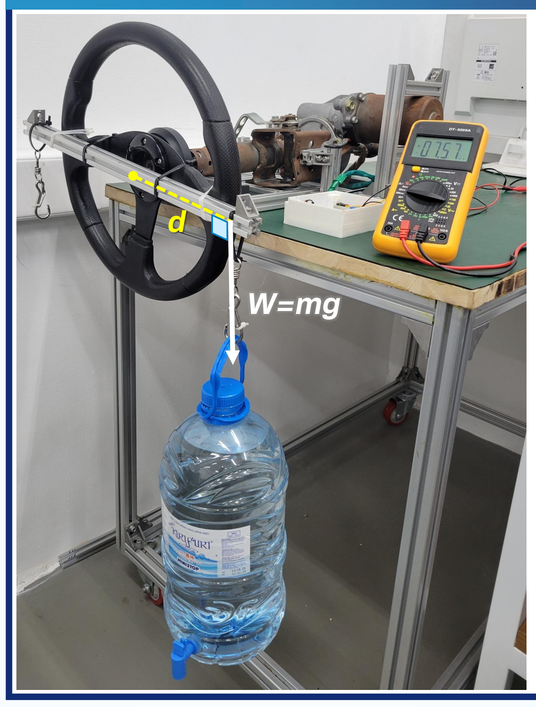
M-point: $y[n] = \frac{1}{M}\sum_{m=0}^{M-1} x[n-m]$

****Moving average filter*

III. MECHANICAL FRAME DESIGN



IV. CALIBRATION PROCESS



Equivalent torque:

$$T_{eq} = mgd$$

In which,

$g = 9.80665\ (ms^{-2})$

$d = 0.2\ (m)$

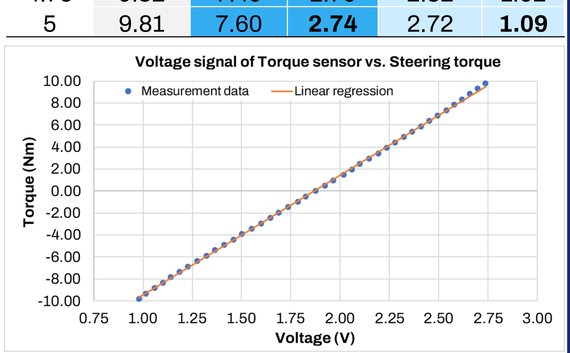
m is the mass of the water bottle (kg) that can be adjusted.

***Linear** correlation between signal voltage (V) and applied torque on the steering wheel (Nm):*

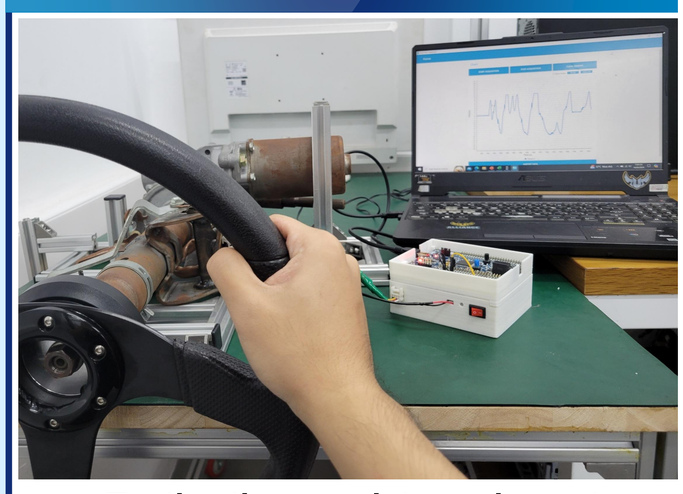
$$T = 10.9225U - 20.3983$$

Measurement table data

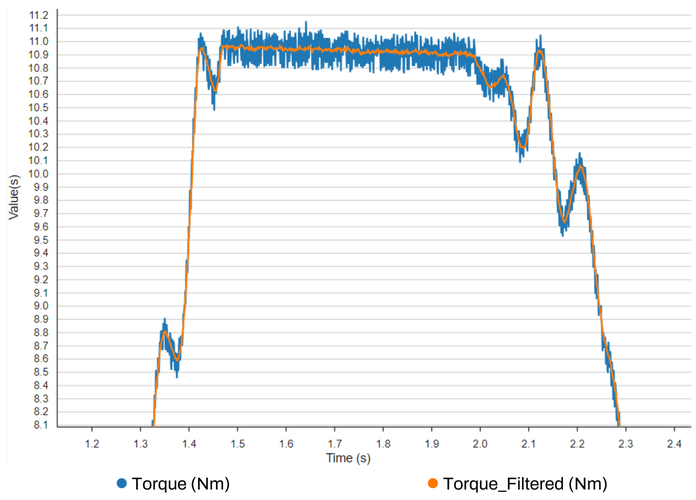
Weight (kg)	Torque (Nm)	Right side (CW) I (mA)	Right side (CW) U (V)	Left side (CCW) I (mA)	Left side (CCW) U (V)
0	0.00	5.21	1.88	5.21	1.88
0.25	0.49	5.34	1.92	5.07	1.83
0.5	0.98	5.46	1.97	4.96	1.79
...	...	...	...	...	...
4.5	8.83	7.38	2.66	2.94	1.06
4.75	9.32	7.49	2.70	2.82	1.02
5	9.81	7.60	**2.74**	2.72	**1.09**



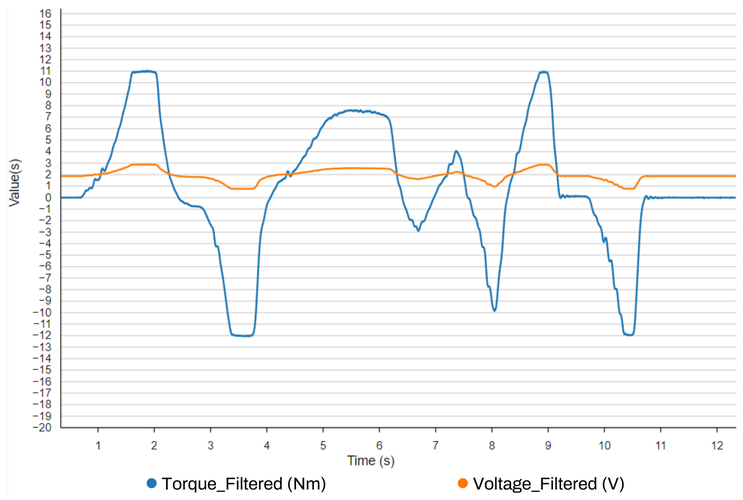
V. RESULTS



Testing the complete equipment



Response of moving average filter



Displaying the values in real-time with 10kHz sampling frequency.

Evaluation table data

Applied torque	Displayed torque	Relative error
-3.43	-3.43	0.07%
2.06	2.07	0.51%
9.81	9.38	4.53%
-7.94	-7.9	0.55%
-4.81	-4.78	0.53%
-7.06	-7.07	0.13%
-0.69	-0.62	9.68%
7.06	6.89	2.42%

Note: A negative sign indicates applied torque in the CCW direction.

VI. CONCLUSION AND FUTURE WORK

- ❑ The results of the project meet the proposed technical and content requirements.
- ❑ Design a EPS controller using STM32 microcontroller.

VII. ACKNOWLEDGMENT

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