Reverse engineering of the Nissan Leaf isolated 400V voltage sensor

1. Introduction

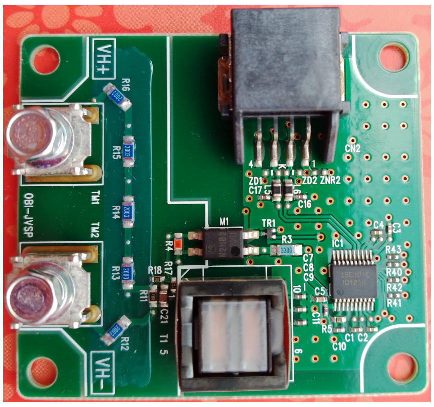
The goal of this document is to present the reverse engineering of a 400V voltage sensor from a 2012 Nissan Leaf.

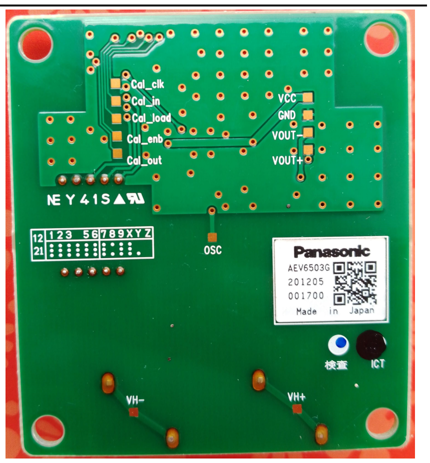
In this analysis, you will find the schematic, the electrical/mechanical measurements, and some simulations to understand the main concept.

The part number of this component is **Panasonic AEV6503G**, 201205 may refer to the production date, May 2012.

I bought this voltage sensor on the website leboncoin.fr. I purchased both the DC/DC converter and the voltage sensor for around 50 euros.

This analysis is for educational purposes only. My main goal is to provide a reverse engineering study of a voltage sensor that can be found in real cars. This analysis can help students and researchers better understand power electronics through a real-life example.





2. Schematics

I created the schematic based on visual observations, electrical measurements, and other methods. I cannot guarantee that the schematic is 100% accurate, but I believe it provides a good starting point for understanding this voltage sensor.

Below is the main schematic of this sensor.

You can find the full PDF schematic here.

You can download the KiCad schematic using this link.

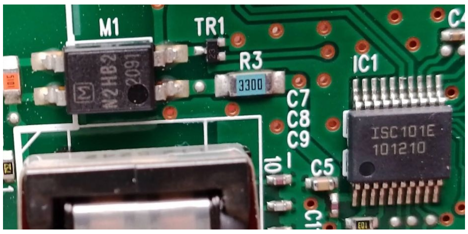
The sensor is composed of:

The voltage is measured by a resistor divider using resistors R11, R12, R13, R13, R15, and R16. The input resistance of this sensor is around 1 MΩ.

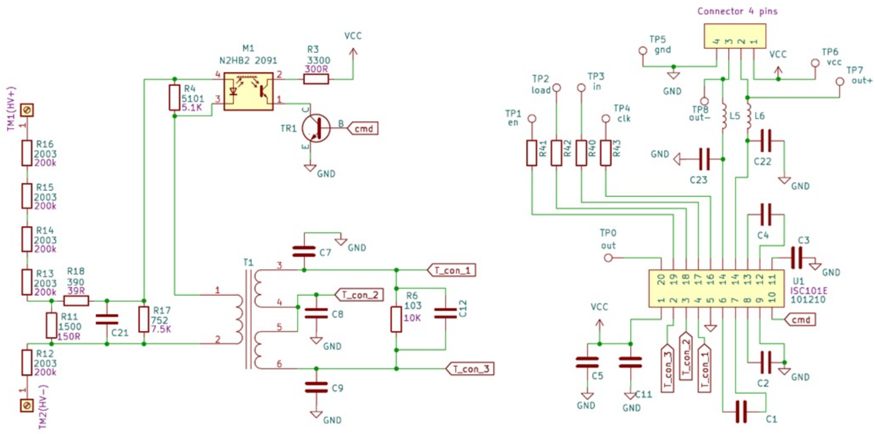
The DC voltage is converted to AC voltage using the optocoupler M1 and the transistor TR1. The transformer T1 is used to isolate the primary side from the secondary side.

The transistor TR1 control and the voltage conditioning are done with the IC ISC101E. I did not find any public datasheet for this component.

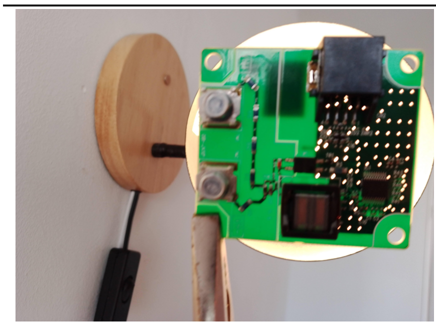
Below is an image that shows the reference of the IC and the optocoupler:

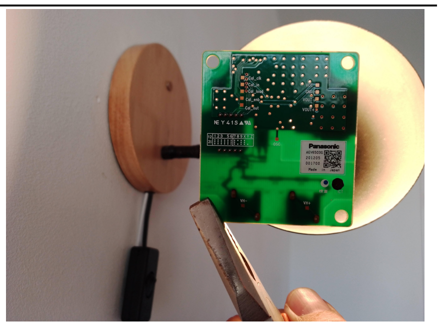


The output voltage is a differential voltage between pins 2 and 3 in the 4-pin connector.



Below are the PCB images taken with backlighting, revealing more internal details:

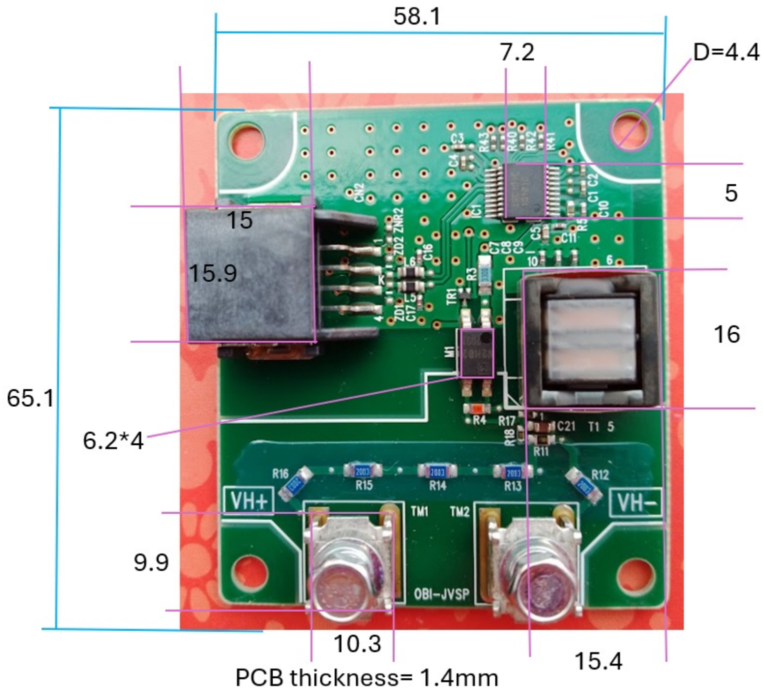




3. Measurements

3.1 Mechanical measurements

Below are some approximate measurements; all measurements are in mm.



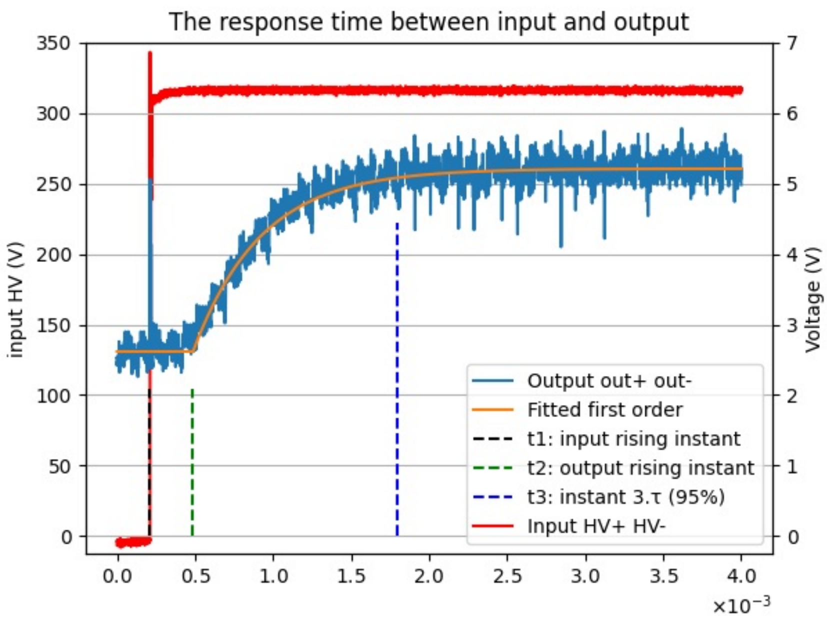
3.2 Electrical measurements

3.2.1 Materials employed for measurements

Equipment	Model
Oscilloscope	Tektronix TDS 3034-B
Isolated voltage sensor	YOKOGAWA 700924
Multimeter	TENMA 72-7780

3.2.2 Response time

The curve below presents the response time of this voltage sensor:



delta t1-t2 (dead time) = 0.275 ms delta t2-t3 (3·τ of the filter) = 1.31 ms delta t1-t3 (Total response time for 95%) = 1.58 ms

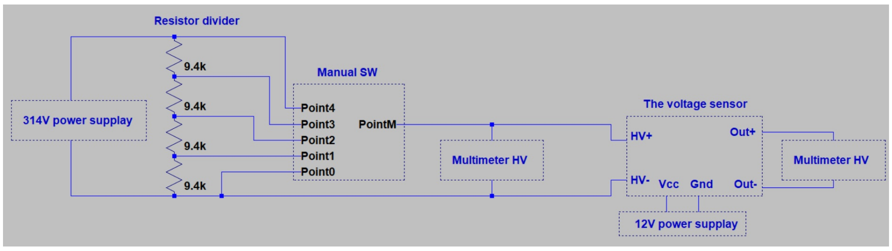
You can download the raw CSV data using this link.

3.2.3 Input-output characterization

Below is the characterization of the input/output DC voltage.

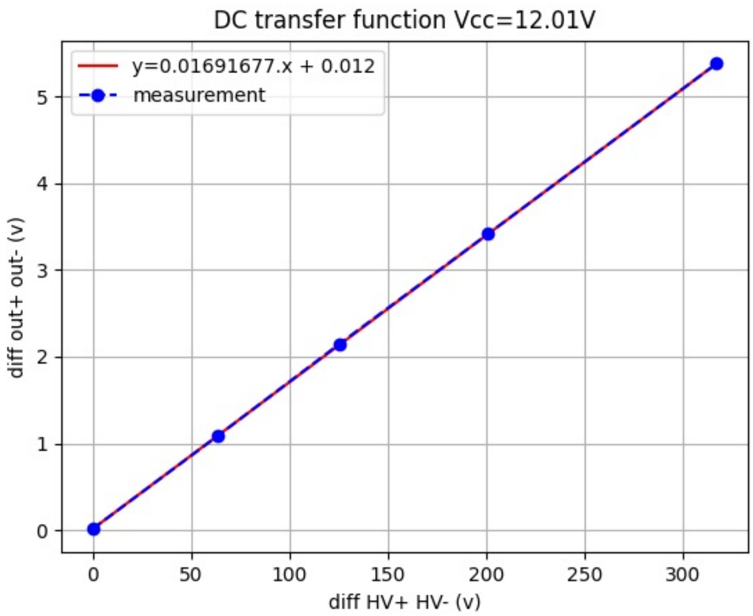
The battery voltage VCC is around 12.01 V.

I used the simple setup below to make this test:



You can download the raw data using this link.

The output differential voltage is very linear, as you can see in the curve below:

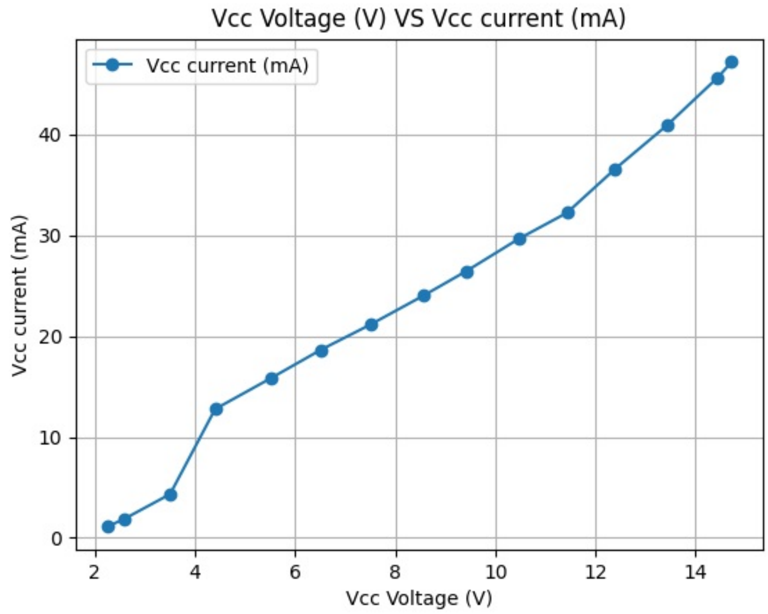


3.2.4 Power supply consumption

Below are the VCC voltage values and the corresponding current.

Vcc Voltage (V)	Vcc current (mA)
2.24	1.11
2.58	1.87
3.5	4.34
4.4	12.77
5.52	15.85
6.51	18.64
7.5	21.14
8.56	24.01
9.42	26.45
10.46	29.63
11.43	32.23
12.39	36.57
13.43	40.91
14.44	45.63
14.72	47.18

A graph summarizing the data is shown below:

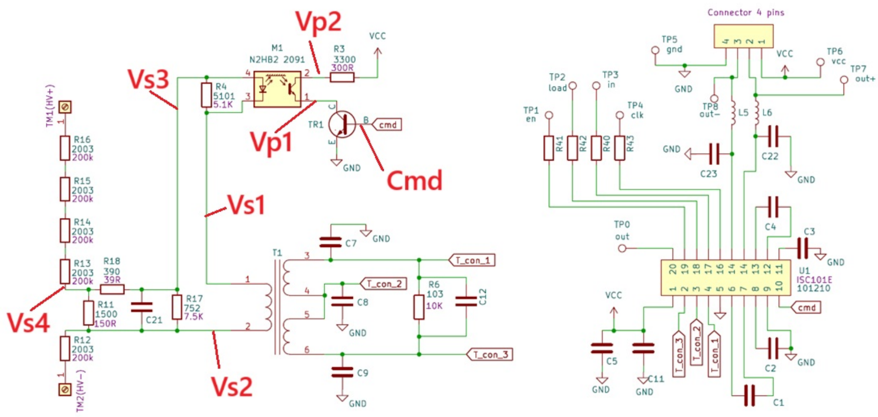


Below is the PWM status corresponding to the VCC value:
The UVP (under-voltage protection) threshold is around 2.3 V; the PWM is off below this value.

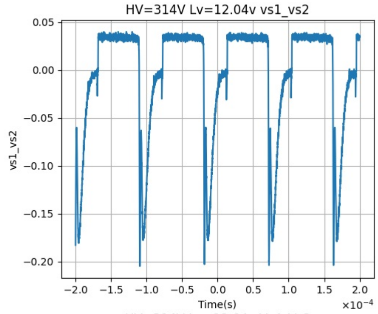
Vcc Voltage (V)	PWM active (cmd)
2.24	no
2.29	no
2.3	yes
2.32	yes
2.36	yes
2.39	yes
14.9	yes

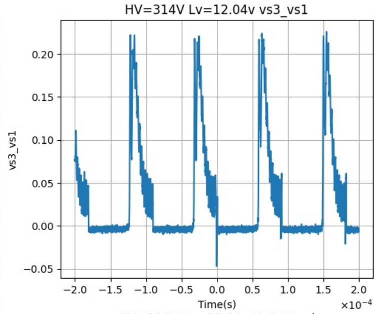
3.2.5 Other measurements

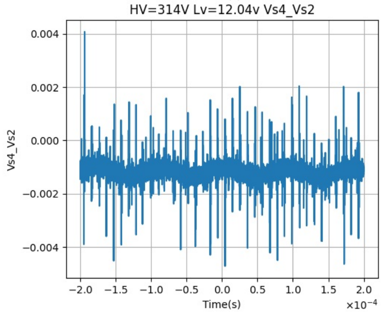
Below are the points used in the measurements:

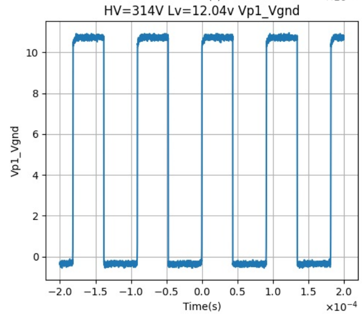


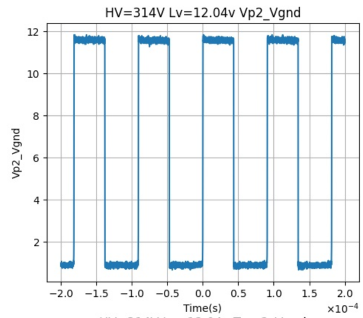
The oscilloscope measurements (without voltage probe):


HV=314V Lv=12.04v vs1_vs2
vs1_vs2
Time(s)


HV=314V Lv=12.04v vs3_vs1
vs3_vs1
Time(s)


HV=314V Lv=12.04v Vs4_Vs2
Vs4_Vs2
Time(s)


HV=314V Lv=12.04v Vp1_Vgnd
Vp1_Vgnd
Time(s)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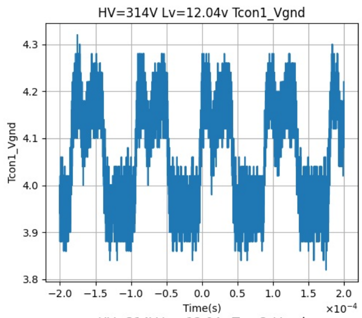
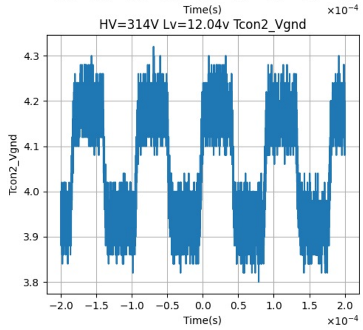
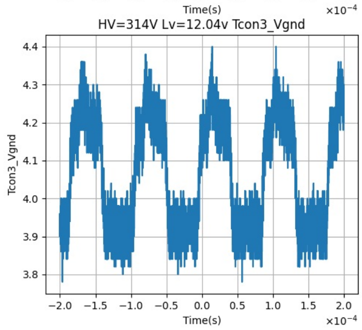
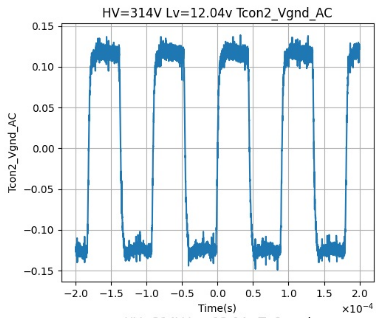
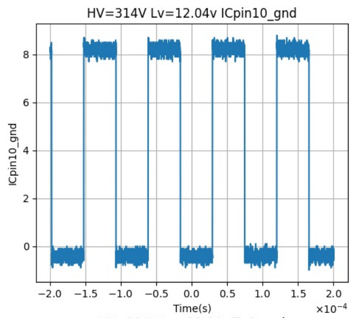
Vp2_Vgnd
Time(s)

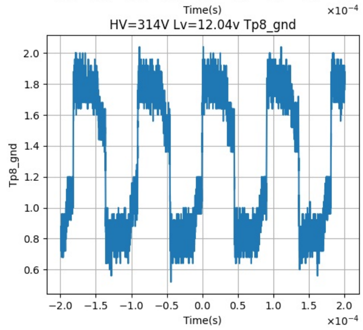

HV=314V Lv=12.04v Tcon1_Vgnd
Tcon1_Vgnd
Time(s)

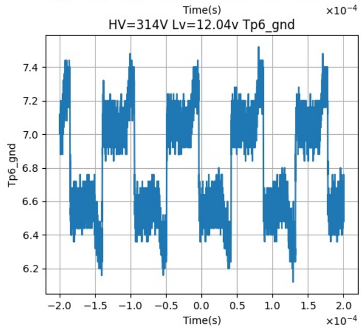

HV=314V Lv=12.04v Tcon2_Vgnd
Tcon2_Vgnd
Time(s)

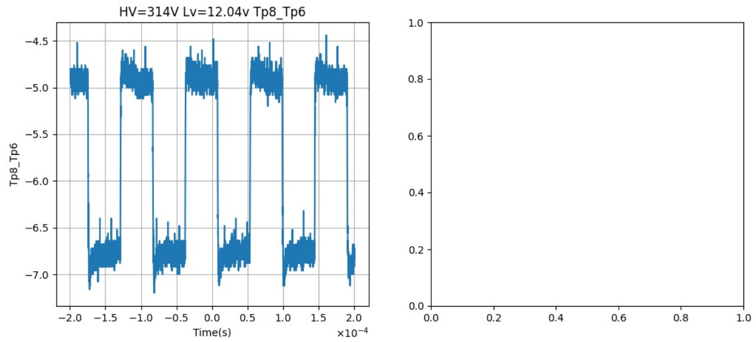

HV=314V Lv=12.04v Tcon3_Vgnd
Tcon3_Vgnd
Time(s)


HV=314V Lv=12.04v Tcon2_Vgnd_AC
Tcon2_Vgnd_AC
Time(s)


HV=314V Lv=12.04v ICpin10_gnd
ICpin10_gnd
Time(s)


HV=314V Lv=12.04v Tp8_gnd
Tp8_gnd
Time(s)


HV=314V Lv=12.04v Tp6_gnd
Tp6_gnd
Time(s)



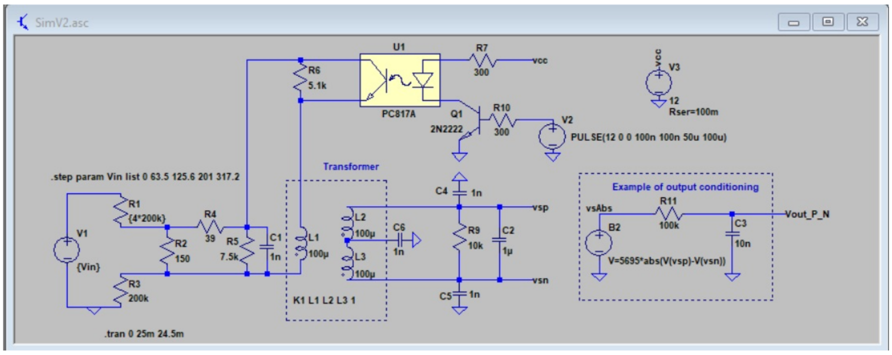
4. Understanding Simulations

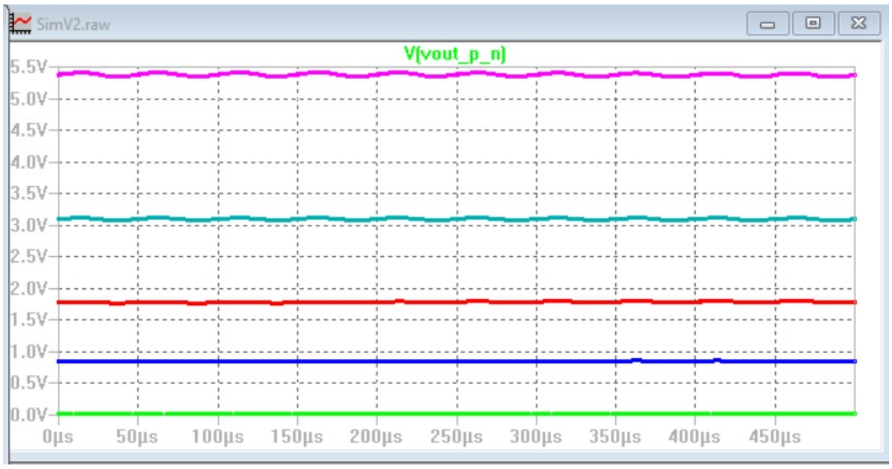
Our goal is to build **simple simulations** to illustrate key concepts, not to achieve precise accuracy.

4.1 DC Response

The LTspice simulation below demonstrates the concept of this isolated voltage sensor:

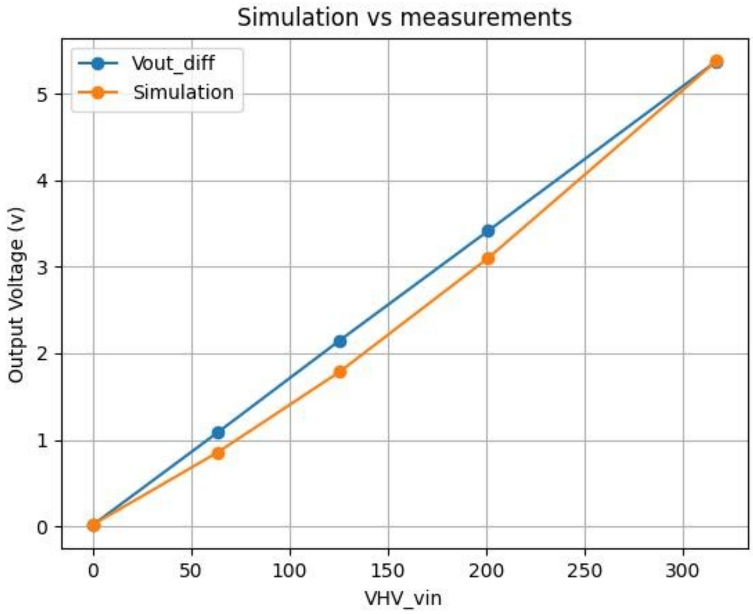
- Download the LTspice file here .





4.1.1 Results Comparison

The chart below compares the average output of each step (from the simulation) with the measured values:



Download the CSV data here .