Voltage Phase Angle Measurement System
based on Raspberry Pi Single Board Computers

Masterproject 22.03.2023
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Technology
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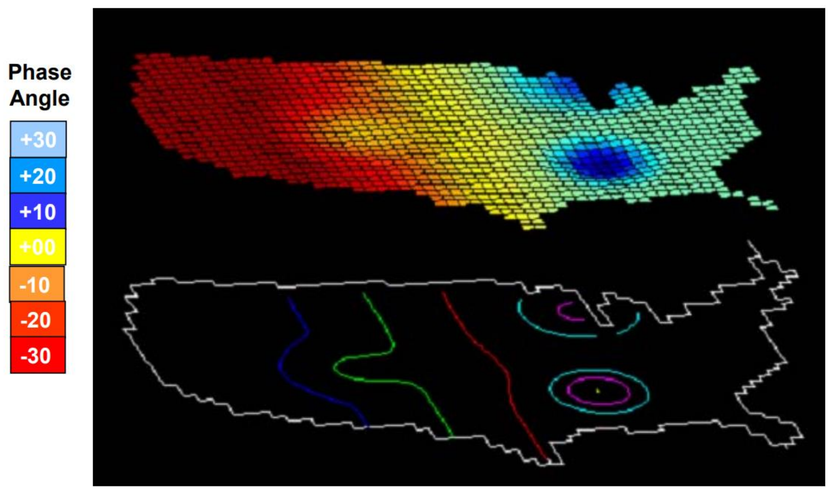
Abstract – The voltage angle between two nodes in a distribution grid can be used as an indicator for local power surplus, shortage and to estimate the grid topology. Raspberry Pi computers are used two compare the 50 Hz voltage signal to calculate the phase shift. A hardware-near C program takes time measurements via a hardware interrupt routine in relation to a fixed 1 Hz signal that is received from a GPS satellite. The results get sent to a cloud and can be evaluated from an external computer without interrupting the measurement. This project proves the feasibility of the system and analyses the accuracy of the time measurements under laboratory conditions.

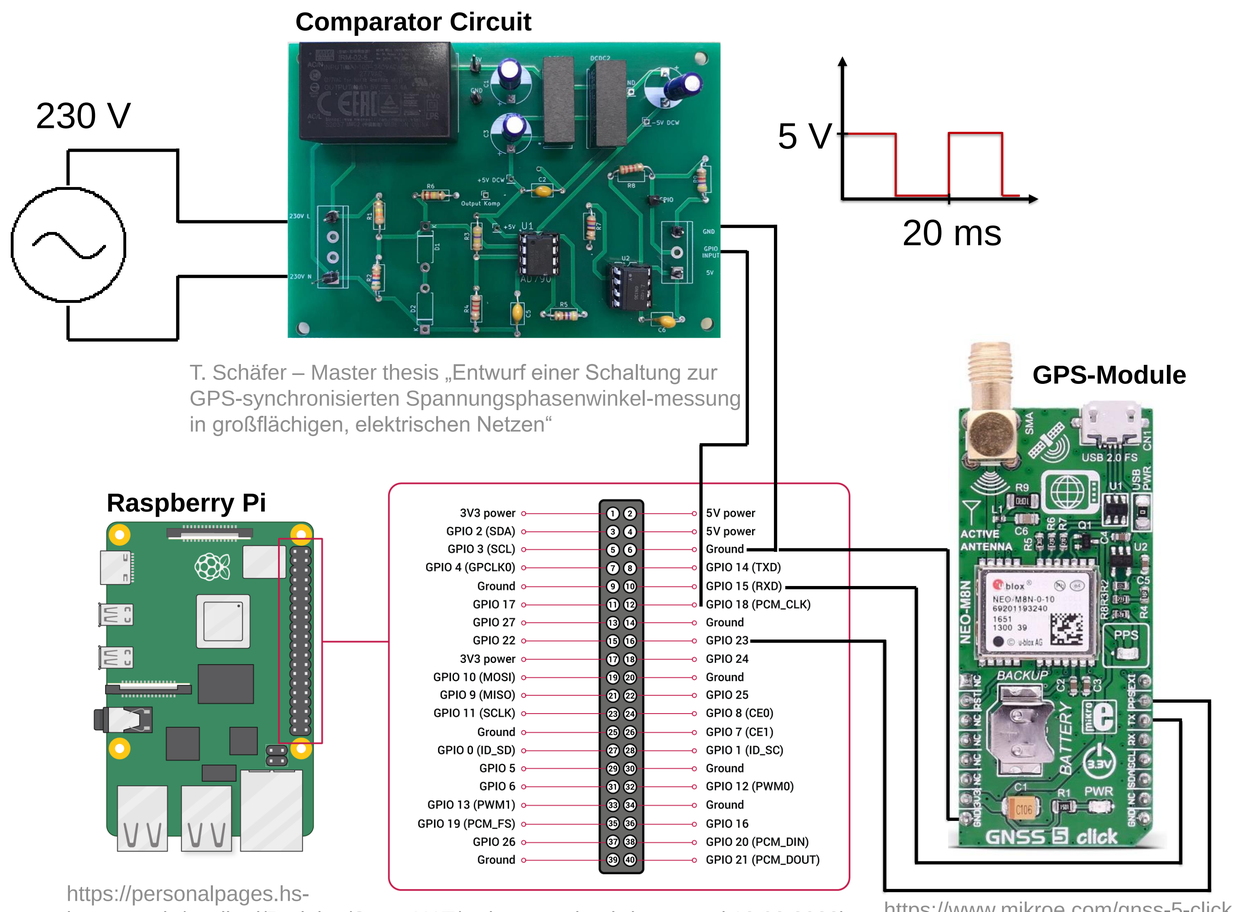
1. Motivation and Applications

- Shifts in voltage angle give information on power surplus and shortage
- Smart charging stations require information on network status
- Topology estimation in PROGRESSUS project
- Voltage phase angle accuracy of ± 0.3° needed



Mark Adamiak et al., “Synchrophasors: Definition, Measurement, and Application”, http://www.ece.cmu.edu/~electricityconference/2006/Adamiak_PremerIani_Kasztenny%20SynchroPhasors.pdf (accessed 15.03.2023)

2. Multiple Power Measurement Units (PMU)

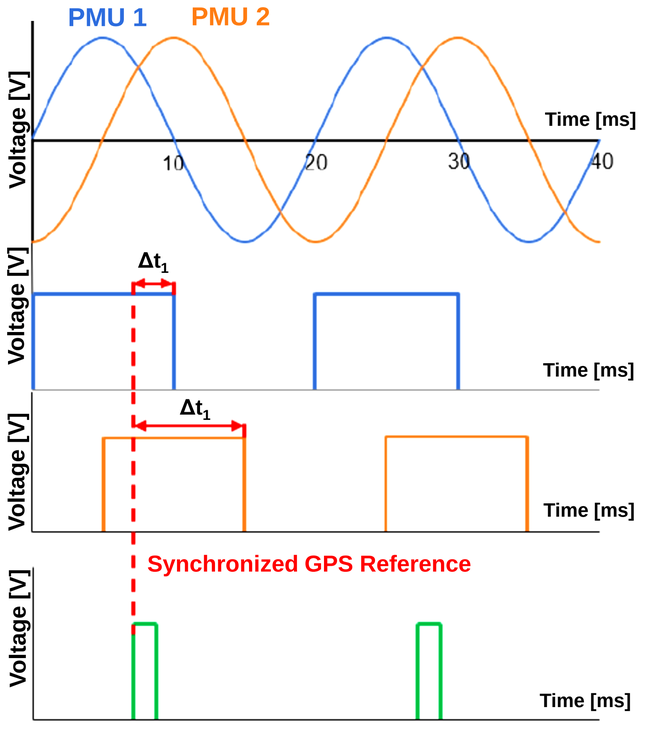


T. Schäfer – Master thesis „Entwurf einer Schaltung zur GPS-synchronisierten Spannungsphasenwinkel-messung in großflächigen, elektrischen Netzen“

https://personalpages.hs-kempten.de/~vollratj/Projekte/SenseHAT/web_report.html, (accessed 13.03.2023)

https://www.mikroe.com/gnss-5-click, (accessed 13.03.2023)

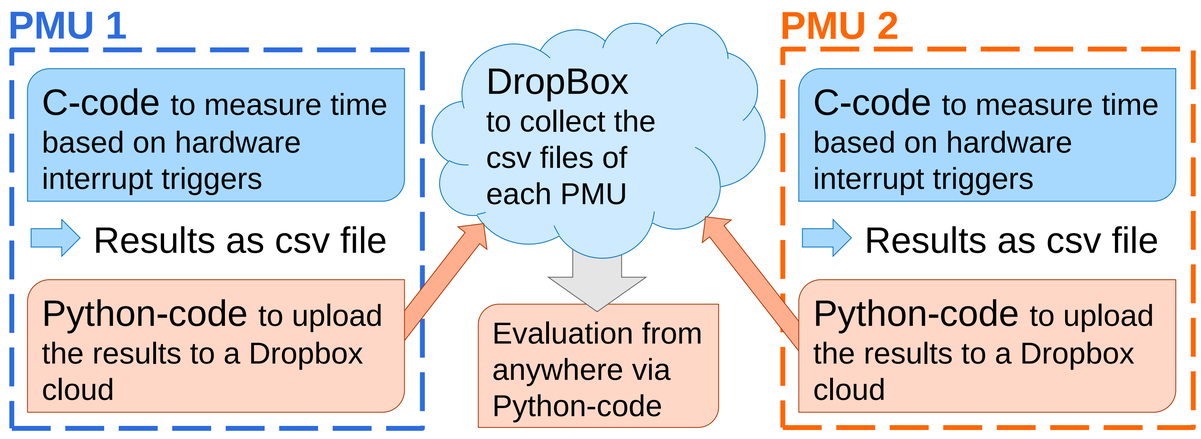
3. Comparison of Time Measurements



Based on E. Waffenschmidt – Introduction of master projects WiSe2021

- Wide Area Measurement System (WAMS)
- Two or more PMU on different nodes
- Transformation of 230 V sinus wave to 3,3 V square wave signal
- Zero-crossing detection
- Time synchronized by GPS satellite
- Time differences determine phase angle

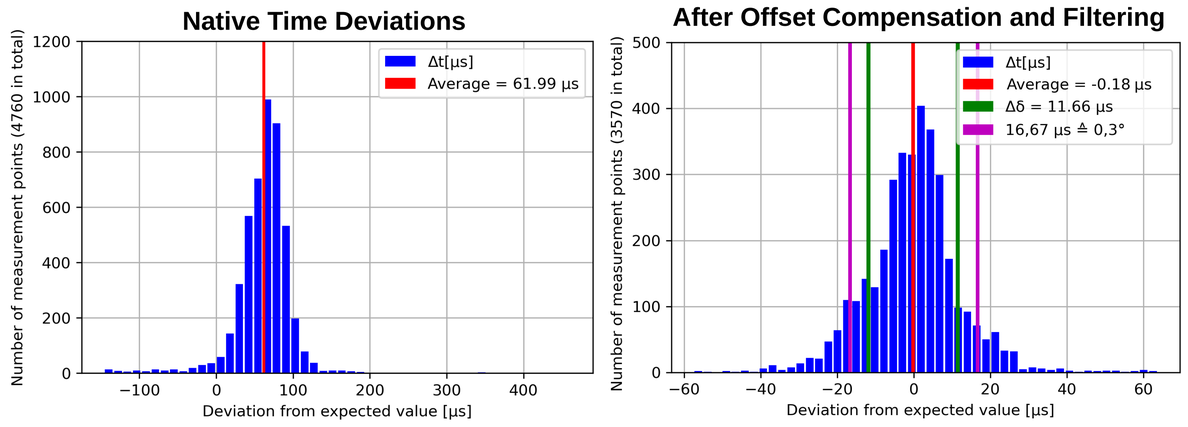
4. Code Structure



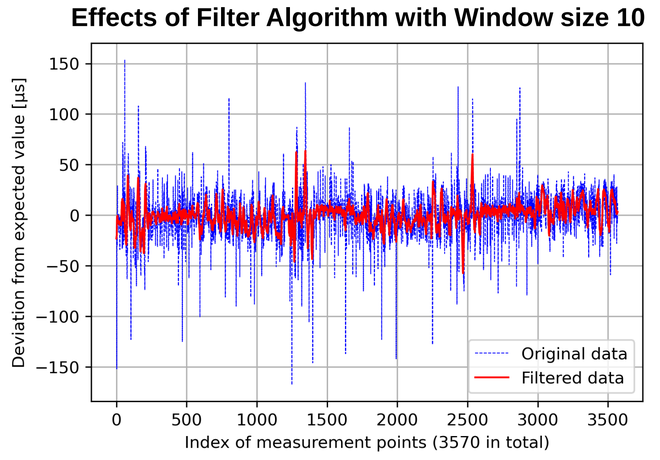
- C-code for time critical application
- Results of each device saved in csv format
- Collection of data in cloud storage
- Data from different nodes determines voltage phase angle

Scenario 1: Accuracy of Hardware Interrupts

- Precision of hardware interrupts tested on function generator
- No peripheral hardware, only Raspberry Pi

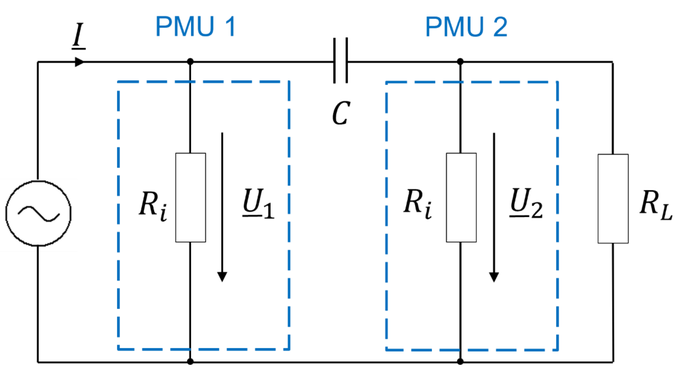


- Time delay between signal reception and code execution
- Constant offset can be compensated
- Results filtered to improve accuracy



Scenario 2: Voltage Phase Angle Measurement

- Simulation of simple power distribution grid
- Voltage phase angle between different impedances tested
- Feasibility of the system verified in Smart-Grid laboratory



5. Conclusions

- Raspberry Pi hardware interrupts work as measurement receiver
- Accuracy limited by lack of real time capabilities
- Multitasking makes time measurements less reliable
- Not reliable enough for topology estimation but regional power monitoring possible, accuracy of 1°

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