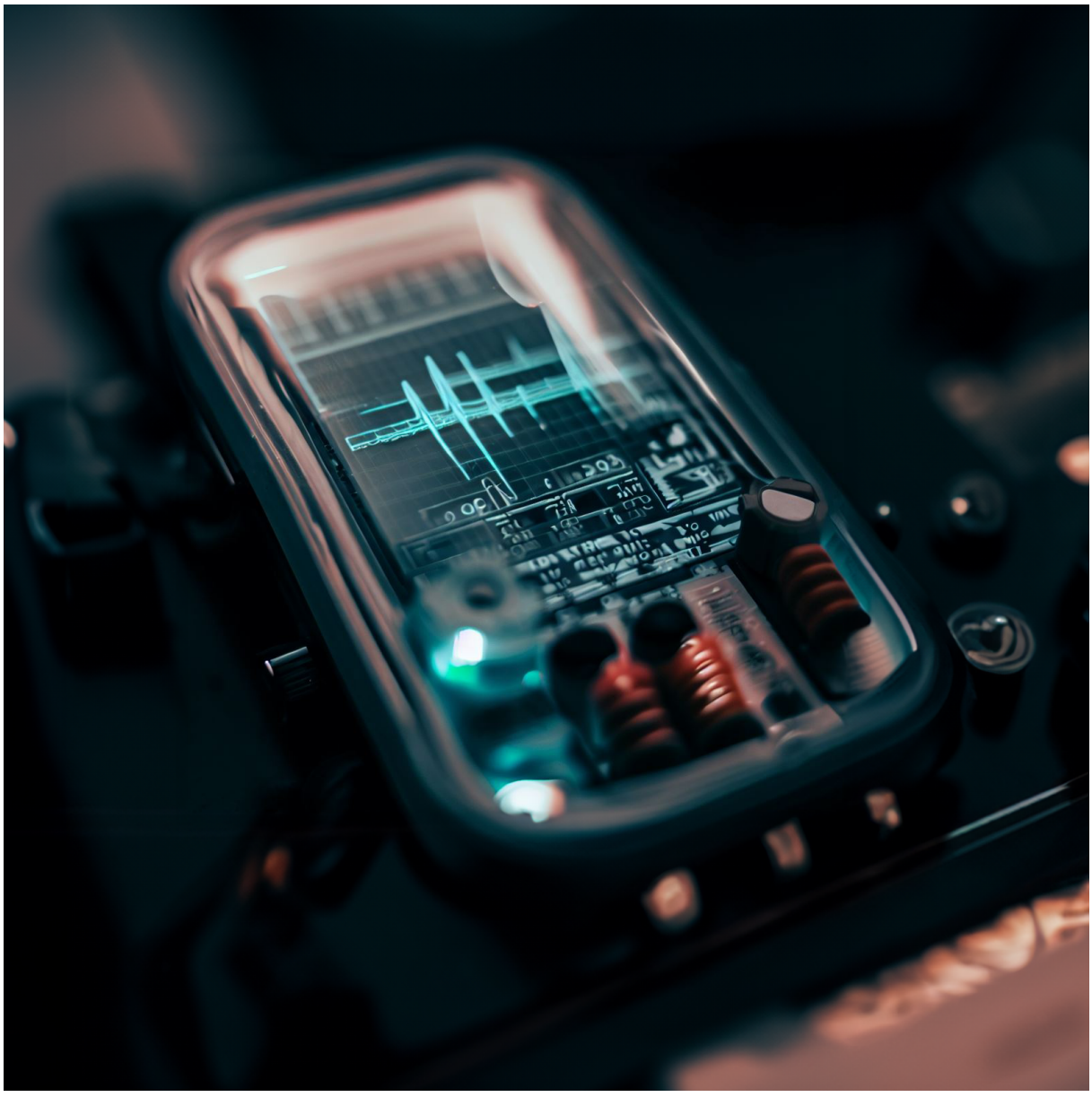
# HST Project S5

## CircuitVoyager Pre1



Submitted by:
**Joel Schaller**

Lecturer: Enrico Malacarne

22.09.2023

# Abstract

*Konzept (gestalterisch)*
*Methode*
*Wichtigste Ergebnisse*

# Contents

# 1 Introduction

The goal of this project is to develop a tiny extension Board for the STM32H747i-Disco Board, to allow it to act as a DMM. Additionally, a SW, that measures the DMM Values and displays them on the Touch Display. If there's more time I could extend the Project with Measurement Logging via a SD-Card or over USB to a Desktop application.
I want to learn how to implement high speed protocols such as Mipi DSI or QPSI. Later in the last year of my apprenticeship I'd like to develop a whole DMM on my own, but with a different approach as standard ones like these from Fluke. For example, I want to make the DMM rechargeable and modernize it a bit.
To realize this project I'm going to use the following tools: Altium Designer, STM32-CubeIDE, LaTeX, TouchGFX.
Also I won't make a diary, because it's easier for me to write my findings down sorted by theme rather than date. But to keep the chronological order of the stuff I've done, there's a Journal in Chapter: [4.1].

## 1.1 "Lastenheft"

This is a request from the imaginary customer, I'm making this project for:
I need a prototype for a DMM, that can measure voltage, current and continuity. The DMM should have a touchscreen that displays said values. The UI should be intuitive, so everyone who's ever used a DMM can use it to. Normal features as hold, minmax should be available and it would be great if you could fit in a power mode, where the DMM uses the voltage and current measurement to calculate the drawn power from the measured device. Because this project will only be used for the proof of concept, the DMM doesn't have to support mains voltage and we also won't need any safety circuits, AC measuring or negative voltages / currents. It's mainly about the SW. So you can also use DevBoards if there are any available.

## 1.2 Mindmap

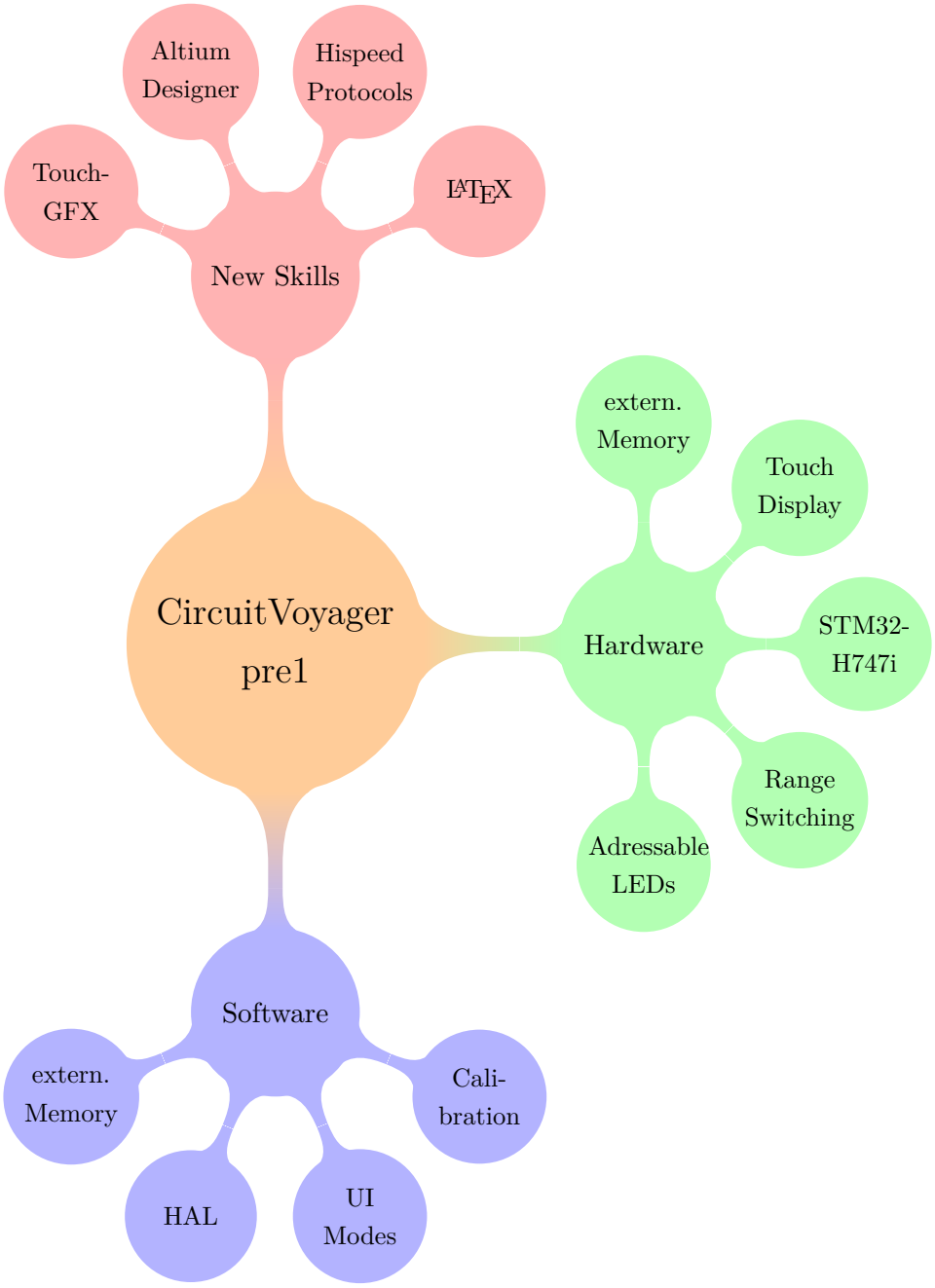



Figure 1.1: Project Mindmap

# 2 Main Body

## 2.1 "Pflichtenheft"

### Cost

I've already bought two DevBoards one of them stays at TBZ and the other is at home. One of these boards was paid by Mr. Malacarne. Further expenses from the PCB will be paid by me and shouldn't exceed about 50 CHF, as the HW isn't that complicated.

### Time

The most time of the project I will work at home because it's a rather big project to execute in one semester. I will also have much time in the fall holidays to work on it. The project will approximately take 100h to complete. Also the more detailed timeplan is in chapter: [4.3]

### Tools

To realize this project I will mainly use, the SW STM32CubeIDE with HAL and Altium Designer. The documentation is written in LaTeX in VSCode. And I'm planning to order the PCB on JLCPCB and I will populate and reflow the PCB at ETHZ, where I'm also allowed to use the measurement equipment for the HW tests.

### Technical Details

| value | min. | typ. | max. | unit | description |
|---|---|---|---|---|---|
| supply voltage | | 5 | | V | over USB |
| curent to measure | 0 | | 1 | A | |
| voltage to measure | 0 | | 10 | V | |

Table 2.1: Technical Details

## 2.2 Extension PCB

### 2.2.1 STMod+

Interface from DevBoard to Extension PCB.

- 5V Supply
- SPI
- $I_2C$
- ADC
- Interrupt
- PWM
- GPIOs

I will use the STMOD#14 connection that was intended to use as PWM, as a second ADC input. To measure current and voltage at the same time to later show the power cosumption of the DUT.

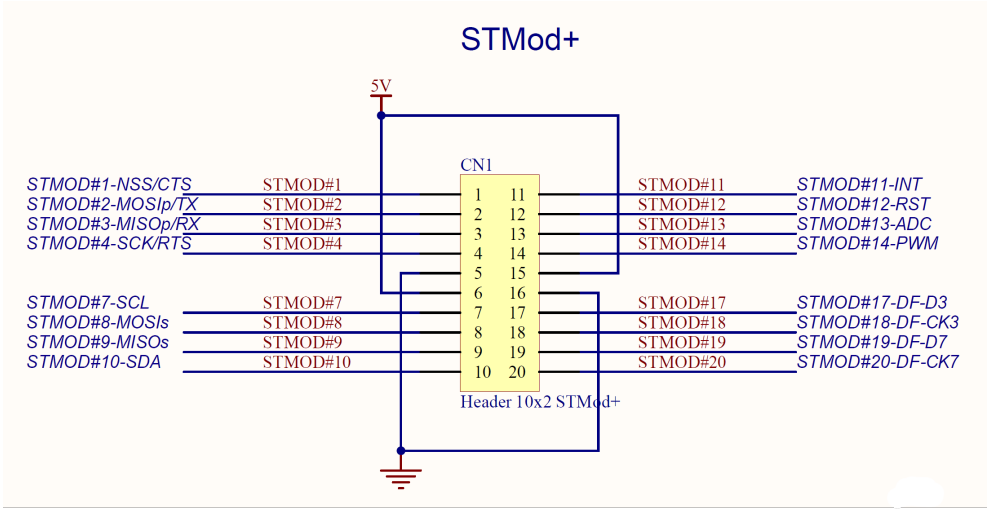



Figure 2.1: STMod+ Interface

### 2.2.2 Hardware concept

After some thoughts I came up with the following HW concept.

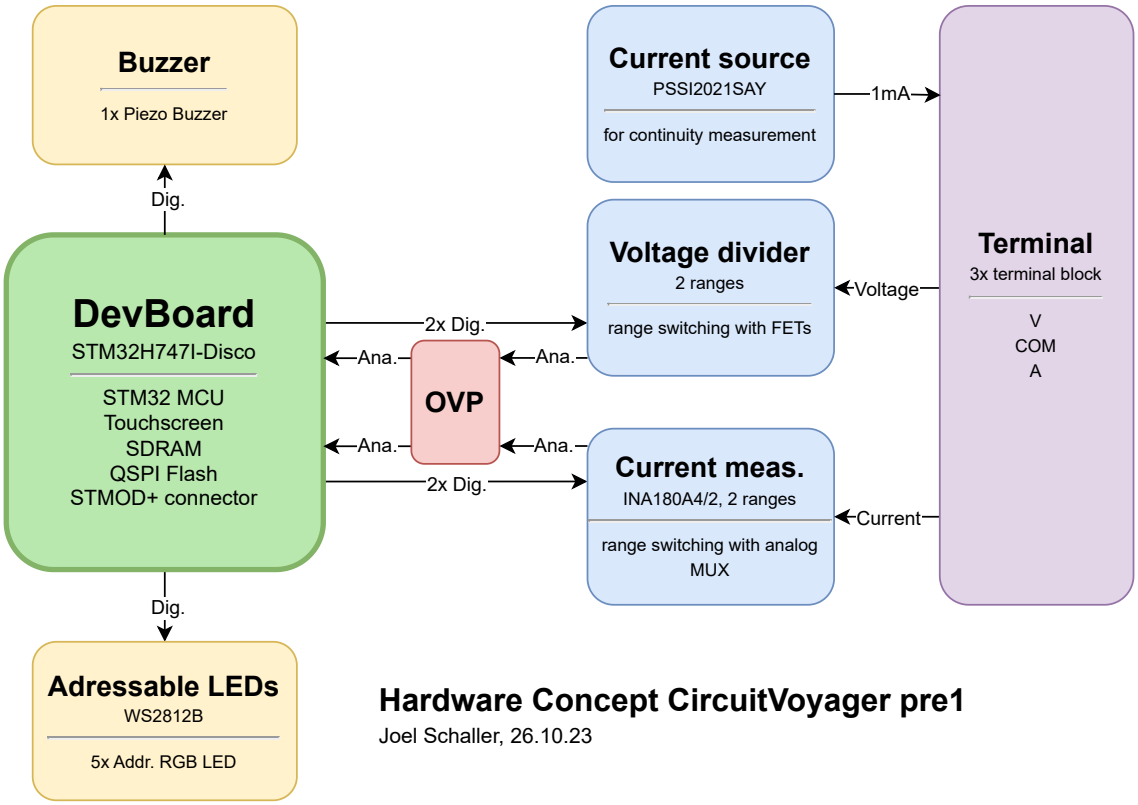



Figure 2.2: Extension PCB HW concept

#### Voltage measurement

To measure voltage, the DUT should be connected to the terminals V and COM. COM is connected internally to device GND. The V terminal is connected to the Voltage divider block. This block divides the input voltage down, so the ADC in the MCU doesn't overshoot. There are 2 ranges to measure voltage, which can be chosen by setting 2 digital output, that go from the MCU to the voltage divider. There's also an OVP, to protect the MCU from voltages higher than 3.3V. [1]

#### Current measurement

To measure current, the DUT should be connected to the terminals A and COM. COM is connected internally to device GND. The A terminal is connected to current measurement block. This block measures the current, by letting the current flow through one of two shunt resistors. The DMM can choose which resistor and

therefore range should be selected with the 2 digital Output that are connected from the MCU to the current measurement block. The voltage over the selected shunt is then amplified, by a current amplifier IC and then measured by the MCUs ADC. There's also an OVP, to protect the MCU from voltages higher than 3.3V. [1]

#### Continuity measurement

To measure continuity, both the voltage divider and the current source is used. The continuity between the V and COM pins is measured. For this a constant current produced by the current source is flowing out of the V terminal. Simultaneously the voltage across those terminals is measured and the resistance / continuity can be evaluated. If continuity is detected, either the buzzer beeps or the LEDs blink. [1]

### 2.2.3 Schematic

The schematic took me a bit longer than usual, because it's my first whole HW project in Altium before I used KiCAD and Altium is a lot more features and in my opinion is harder to learn. The schematic is in the Appendix [CHAPTER!!!! :)].

# 3 Conclusion

## 3.1 HW development

I've learned much in this project part. Mainly this was Altium Designer, as this was my first complete project I've realised in Altium Designer. This also leaded to some not nicely solved solution. All components for example haver their own properities and this leads to a unreadable BOM.
But in the end I've also noticed, that the dataflow (that usually should go from left to right) goes in the wrong direction. This had already started in the HW-Chart and therefore also ended up in the schematic.
I've also used Draw.io one of the first times and by now it looks very promising. It's much easier and more straight forward than MS Visio. Everthing just works as intended.
*Gesamtschau, Arbeitsergebnis, Gesamturteil, evtl. Ausblick, was ich lernen konnte*

# 4 Appendix

## 4.1 Journal

| Date | Location | Duration | Activity |
|---|---|---|---|
| 01.09.2023 | TBZ | 1.5h | Selected and bought DevBoard |
| 08.09.2023 | TBZ | 2h | Tested DevBoard with demos |
| 08.09.2023 | TBZ | 0.5h | Noted first ideas for DMM |
| 15.09.2023 | TBZ | 1.5h | Written and signed Project Agreement [4.2] |
| 21.09.2023 | Home | 3h | Created documentation template |
| 22.09.2023 | TBZ | 2h | Started writing Journal [4.1] |
| 24.09.2023 | Home | 1.5h | Made GANTT chart [4.3] |
| 27.09.2023 | Home | 2h | Written detailed planning and introduction |
| 29.09.2023 | TBZ | 1.5h | Added mindmap, Lasten-, Pflichtenheft |
| 06.10.2023 | TBZ | 1h | Started with block diagram (extension PCB) |
| 20.10.2023 | ETH | 0.5h | Started Altium Project, Schematic template |
| 23.10.2023 | ETH | 3h | HW Concept / documentation |
| 23.10.2023 | ETH | 3h | Start schematic / documentation |
| 25.10.2023 | Home | 2h | Schematic: Current Src, Volt div |
| 26.10.2023 | ETH | 1.5h | Schematic: Current meas, ERC |
| 26.10.2023 | Home | 1h | Schematic: Cleanup, Comments, DS Saves |
| 26.10.2023 | Home | 1h | Documentation & prepared Interview 1 |

Table 4.1: Project Journal

## 4.2 Project Agreement

Information TBZ/EE / **2337.00** HST
jschaller
*HST: BüP* *Sem:* **5** 1_Project_Agreement.docx
TBZ Technische Berufsschule Zürich Abteilung Elektro/Elektronik

### 1 Projektvereinbarung

**Verfasser/innen:** Joel Schaller **Klasse:** BEN21
**Titel:** CircuitVoyager pre1

1. **Thema** (Hintergrund, Überblick, gegenwärtiger Wissensstand)

Develop a tiny extension Board for the STM32H747i-Disco Board, to allow it to act as a DMM. Additionally, a software, that measures the DMM Values and displays them on the Touch Display. If there's more time I could extend the Project with Measurement Logging via a SD-Card or over USB to a Desktop application.

2. **Eigene Fragestellung / Untersuchungsgegenstand**

2.1 Eigene Fragestellung (Leitfrage)
How to implement the following functions / protocols? (QSPI Flash, SDRAM, TouchGFX, Mipi DSI) and if the time is sufficient: (FAT with SDcards, Bootloaders)
2.2 Hypothese (Vermutung über das Ergebnis)
I want to learn, working with High Speed MCUs and implement such protocols.
2.3 Methoden und Vorgehen (mindestens 2 Methoden müssen angewendet werden)
HW-Dev (Altium), SW-Dev (STM32Cube with HAL), Documentation in LaTeX
2.4 Hilfsmittel
Internet, literature
2.5 Kontaktpersonen, Informationsstellen, Institutionen
Teachers, Instructor at ETH, Dad

3. **Persönlicher Bezug / Motivation**
In the next 2 Years I want to develop my own DMM, because I think there's much to improve with standard DMMs as Fluke. For Example: Touch Display, Rechargeable Battery…

4. **Bewertungsform**
This Project will only be done by me. Time: about 28 lesson and unknown time at home.
Project delivery on: 12.01.2023

5. **Besprechungstermine mit Lehrperson** (vorgeschrieben sind zwei Besprechungen)
Termin 1: 27.10.2023
Termin 2: 01.12.2023

Datum: 15.09.23 Die Lernenden: .....

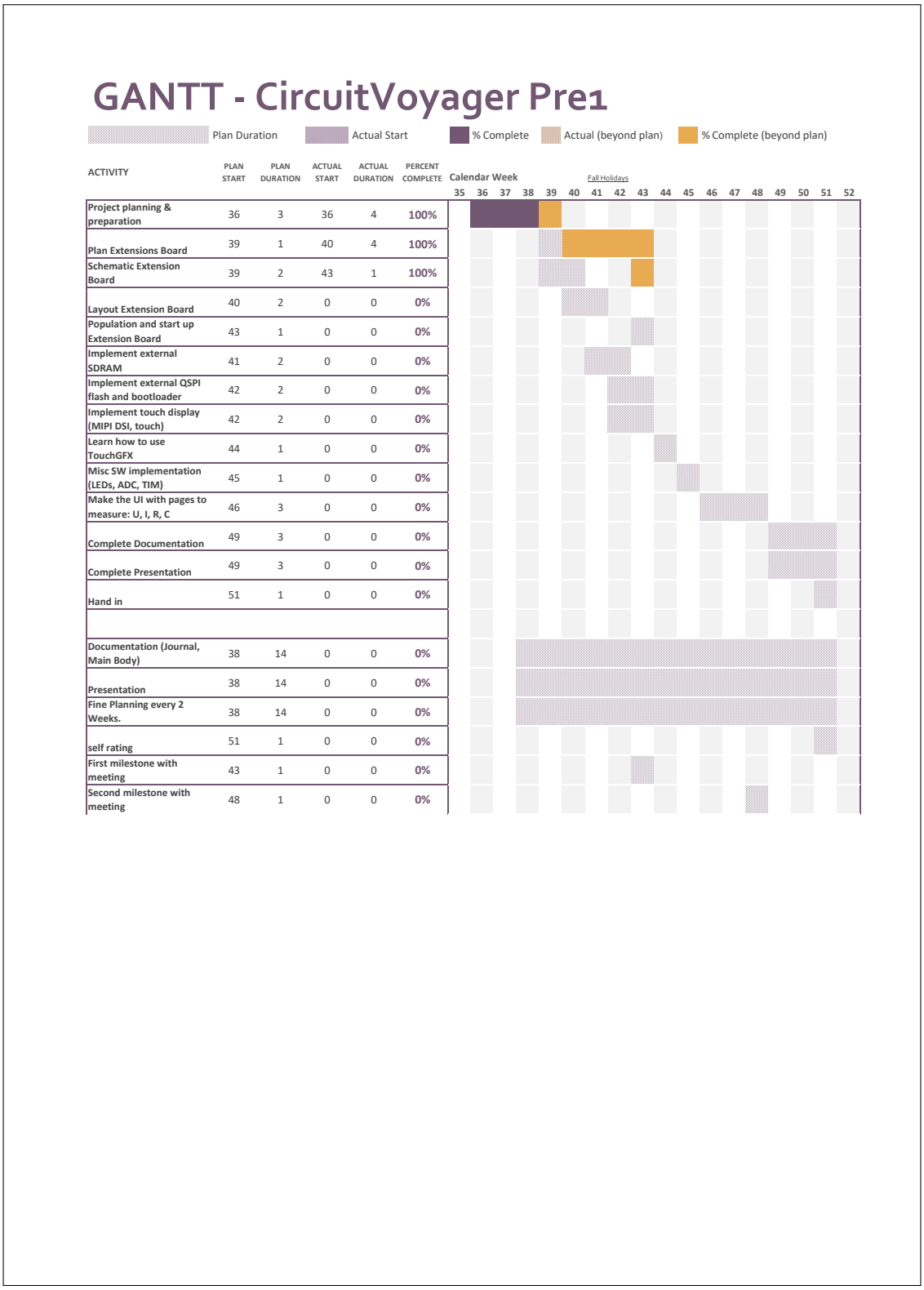
Datum: 15.9.23 Die Lehrperson: .....

*DMM = Digital Multimeter*
*TouchGFX = Graphical Designer for Embedded Touch Displays*

BEN21 Seite 1 (1) 1_Project_Agreement.docx

Figure 4.1: Project Agreement

## 4.3 GANTT Chart




| ACTIVITY | PLAN START | PLAN DURATION | ACTUAL START | ACTUAL DURATION | PERCENT COMPLETE |
|---|---|---|---|---|---|
| Project planning & preparation | 36 | 3 | 36 | 4 | 100% |
| Plan Extensions Board | 39 | 1 | 40 | 4 | 100% |
| Schematic Extension Board | 39 | 2 | 43 | 1 | 100% |
| Layout Extension Board | 40 | 2 | 0 | 0 | 0% |
| Population and start up Extension Board | 43 | 1 | 0 | 0 | 0% |
| Implement external SDRAM | 41 | 2 | 0 | 0 | 0% |
| Implement external QSPI flash and bootloader | 42 | 2 | 0 | 0 | 0% |
| Implement touch display (MIPI DSI, touch) | 42 | 2 | 0 | 0 | 0% |
| Learn how to use TouchGFX | 44 | 1 | 0 | 0 | 0% |
| Misc SW implementation (LEDs, ADC, TIM) | 45 | 1 | 0 | 0 | 0% |
| Make the UI with pages to measure: U, I, R, C | 46 | 3 | 0 | 0 | 0% |
| Complete Documentation | 49 | 3 | 0 | 0 | 0% |
| Complete Presentation | 49 | 3 | 0 | 0 | 0% |
| Hand in | 51 | 1 | 0 | 0 | 0% |
| | | | | | |
| Documentation (Journal, Main Body) | 38 | 14 | 0 | 0 | 0% |
| Presentation | 38 | 14 | 0 | 0 | 0% |
| Fine Planning every 2 Weeks. | 38 | 14 | 0 | 0 | 0% |
| self rating | 51 | 1 | 0 | 0 | 0% |
| First milestone with meeting | 43 | 1 | 0 | 0 | 0% |
| Second milestone with meeting | 48 | 1 | 0 | 0 | 0% |

Figure 4.2: GANTT Chart

## 4.4 Weekly plans

### 4.4.1 KW39 & 40

- Write introduction
- Planning: Cost, Tools, When, Why
- Create project diagram (learning process)
- ”Lastenheft”
- ”Pflichtenheft”
- Make a HW-Digram for the Extension PCB.
- Make the schematic of the Extension PCB.
  - Part to measure voltage.
  - Part to measure current.
  - Part to measure continuity.
  - Addressable LEDs.
- Start with the Layout of the Extension PCB.
- Reflection of the start of the project.

### 4.4.2 KW41 & 42

Fall holidays. I planned to invest much time in the holidays, but it turned out that my plans changed, and I was busy.

### 4.4.3 KW43 & 44

Mainly catching up.

- Make a HW-Digram for the Extension PCB.
- Make the schematic of the Extension PCB.
  - Part to measure voltage.
  - Part to measure current.
  - Part to measure continuity.

  - Addressable LEDs.

- Make the whole Layout of the Extension PCB.
- Order the Extension PCB and the components.
- Reflection of the start of the project.

and maybe if the time is sufficient I could start with implementing the SDRAM and QSPI Flash.

## 4.5 Extension PCB Schematics

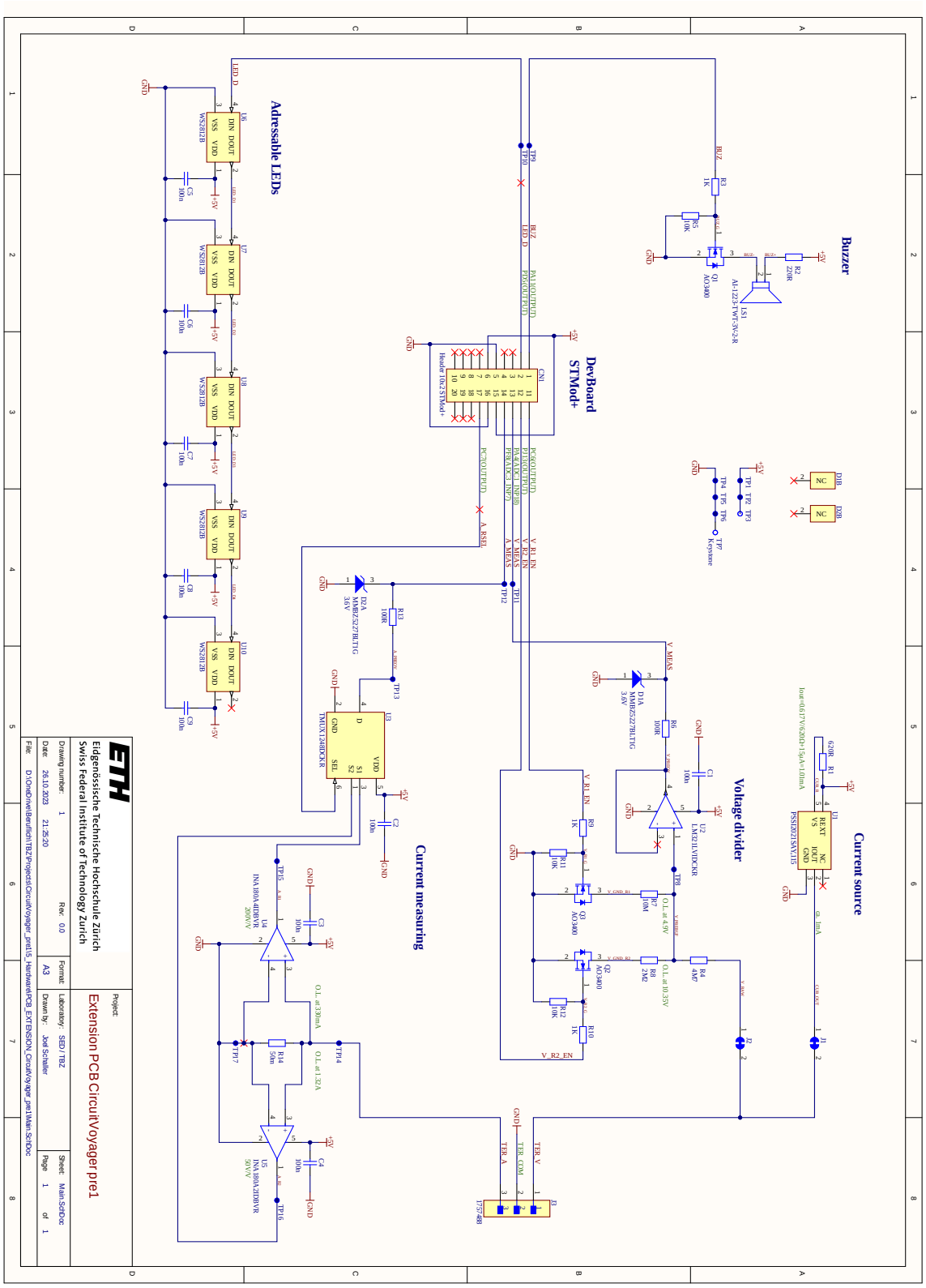



Figure 4.3: Extension PCB Schematics

# 5 Credits

# Bibliography

[1] ElectroNoobs, "Arduino 5 in 1 multimeter v2.0." Available at `http://electronoobs.com/eng_arduino_tut112.php` (2019/11/29).

# List of Figures

# List of Tables

# Listings

# Acronyms

**CircuitVoyager** The Name of the DMM I'm developing.

**DevBoard** main microcontroller developement board. (STM32H747I-Disco)

**DMM** digital multimeter

**HW** Hardware

**SW** Software

**QPSI** Quad SPI

**SPI** Serial Peripheral Interface (low level protocol)

**SDRAM** Synchronous Dynamic Random Access Memory (external RAM)

**TouchGFX** Graphical UI designer for STM32 MCUs

**UI** User Interface

**MCU** Micro Controlling Unit

**Mipi DSI** Digital Serial Interface (Display Protocol)

**FAT** File Allocation System (Low Level Filesystem)

**HAL** Hardware Abstraction Layer (STM32 Abstraction Library)

**ETHZ** Eidgenössische Technische Hochschule

**TBZ** Technische Berufsschule Zürich

**ADC** Analog Digital Converter

**TIM** Timer (Hardware Block in STM32)

**PCB** Printed Circuit Board

**DUT** Device under test

**OVP** Over voltage protection