Double Pulse Testing (remote) practical

For course "Advanced Power Electronics" EE4515 at Delft University of Technology

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Version: 00, Concept, date: December 2020
Version: 01, Updated PCB and schematics to latest version, date: August 2023

1. Introduction

For course EE4515 a Double Pulse Tester (DPT) has been developed, built and tested. The students will be introduced to a simplified half-bridge DPT configuration. In general DPT has many benefits, however the most valuable one is that future Power Electronic engineers (the students of this course) are able to test their future developed power electronics under worst-case conditions. Mainly to reduce the risk of later unforeseen problems. More details on DPT can be found in [1].

Fig. 1a shows the proposed topology, where Q1 and Q2 are the Devices Under Test (DUTs) and Fig. 1b the typical waveforms. Due to Covid-19, the developed set-up should be capable to be used onsite as well as online variant. The operating principle is as follows: With the variable pulse length of t1 the turn-off current is1 can be set at different levels. After turn-off of Q2 the inductive current (iL1) freewheels through the anti-parallel diode of Q1. When Q2 turns on again (pulse t2) the recovery of Q1 can be investigated.
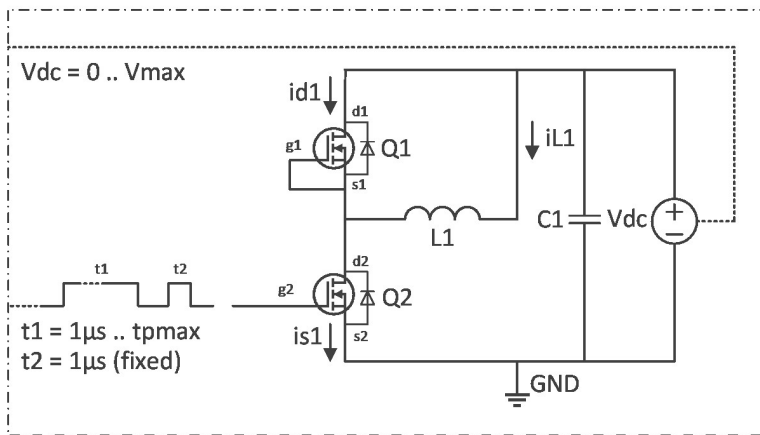

Fig.1a: Proposed DPT topology and schematic for remote variant   Fig. 1b: Typical DPT waveforms and zoom-in

During the onsite practical, the student has the ability to put different types of Mosfets or diodes (Si, SiC, GaN) in the sockets of Q1 and Q2 and investigate the commutation phenomena. The voltage Vdc and the pulse duration t1 can be set manually to get a certain current level. For the online variant these settings can be done remotely and there are more parallel set-ups with different semiconductor configurations. Typical waveforms depicted in Fig. 1b are gate voltage of Q2 (yellow); drain voltage of Q2 (green); source current Q2 (purple) and inductor current of L1 (blue). In the zoom-in window (bottom of Fig. 1b) the switching behavior of the individual pulses can be investigated in detail.

2. Specifications

The practical is build-up with the following equipment:

- Desktop PC with webcam, Matlab/Simulink and XWirepuller software from Yokogawa [2]

- SM400 AR from Delta Electronics (LAN option for remote control via Simulink)

- DLM3000 series oscilloscope from Yokogawa (including LAN remote interface)

- Current monitor 411 from Pearson (or on-board shunt resistor)

- TU-Delft interface boards with TMS320 Launchpad's from TI (for remote control & for SPT or DPT pulse generation).
    - Detailed electrical specifications of the pulses
        - SPT, single pulse mode:
            - t1 adjustable from 1µs ... tpmax (= 20µs max.)
            - Single pulse, or with repetition rate of 1Hz)
        - DPT, double pulse mode:
            - t1 adjustable from 1µs ... tpmax (= 20µs max.), and
            - t2 = 1µs (fixed)
            - Two pulses or with repetition rate of 1Hz

- Power supply (Vdc): adjustable 50..400V

- DUTs (Q1, Q2): N-type mosfets, which are compatible with TO220 and TO247 housing types. Or several types of diodes (for Q1) in different "anode"/"cathode" configurations, such as C3D04060, BYV29, C3D20060D, DSEI60, IDW30, will also fit in this design.

- Mosfet driver (Q2): UCC37322 (8p PDIP for easy replacement in case of failure during onsite practicals)

- Load inductor (L1): ETD54 core and bobbin 110µH (or 200µH) (< 20A)

- Gate resistor (Rg) on studs easy adjustable by the students

- Gate bead (Lg), optional

See for more details the schematic depicted in appendix A.

3. Prototype and latest version

In the beginning of 2021 the first lab prototype was launched, which is based on the described specifications above. This set-up and the "student interface screen" is shown in Fig. 2a and Fig. 2b respectively. This set-up can be used onsite as well as remotely. The student has the ability to store his/her measurements as a screen dump as well as to download numerical CSV data for further analyses later.
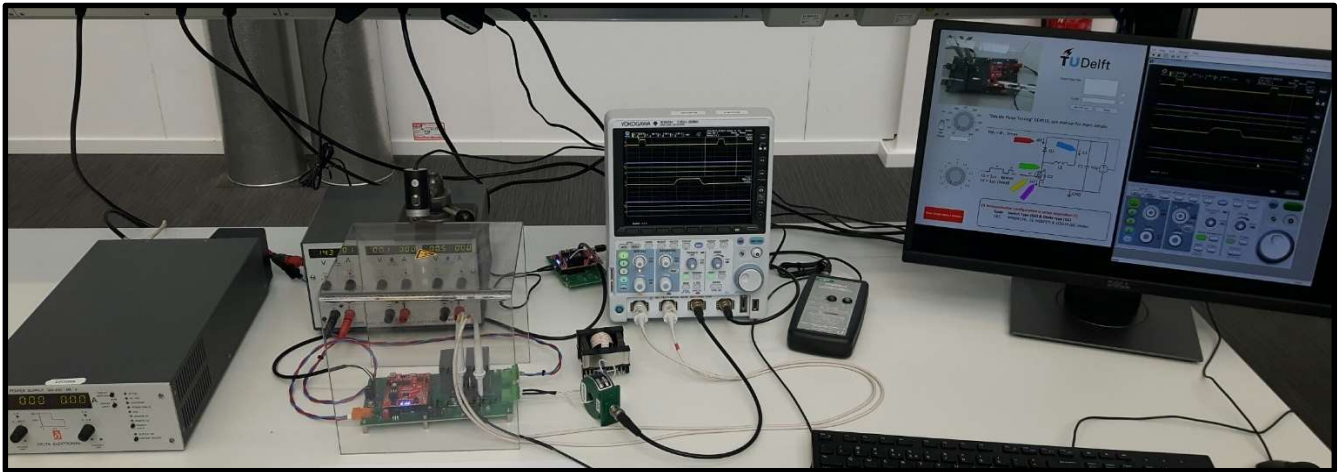
Fig 2a: Complete DPT practical set-up for onsite as well as online. With from left to right: power supply for Vdc, aux. power supply, DPT board with webcam, inductor, Pearson coil, control TMS, Oscilloscope, Rogowski coil and PC.
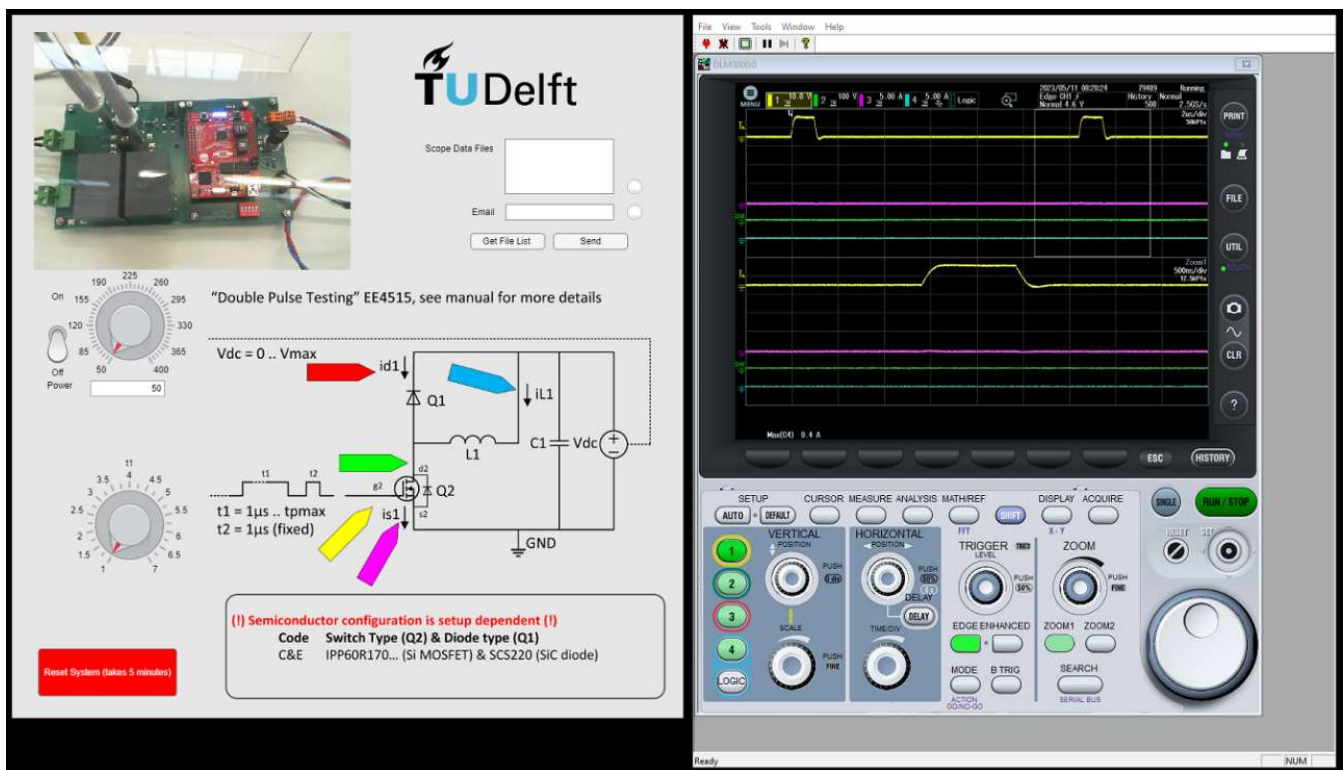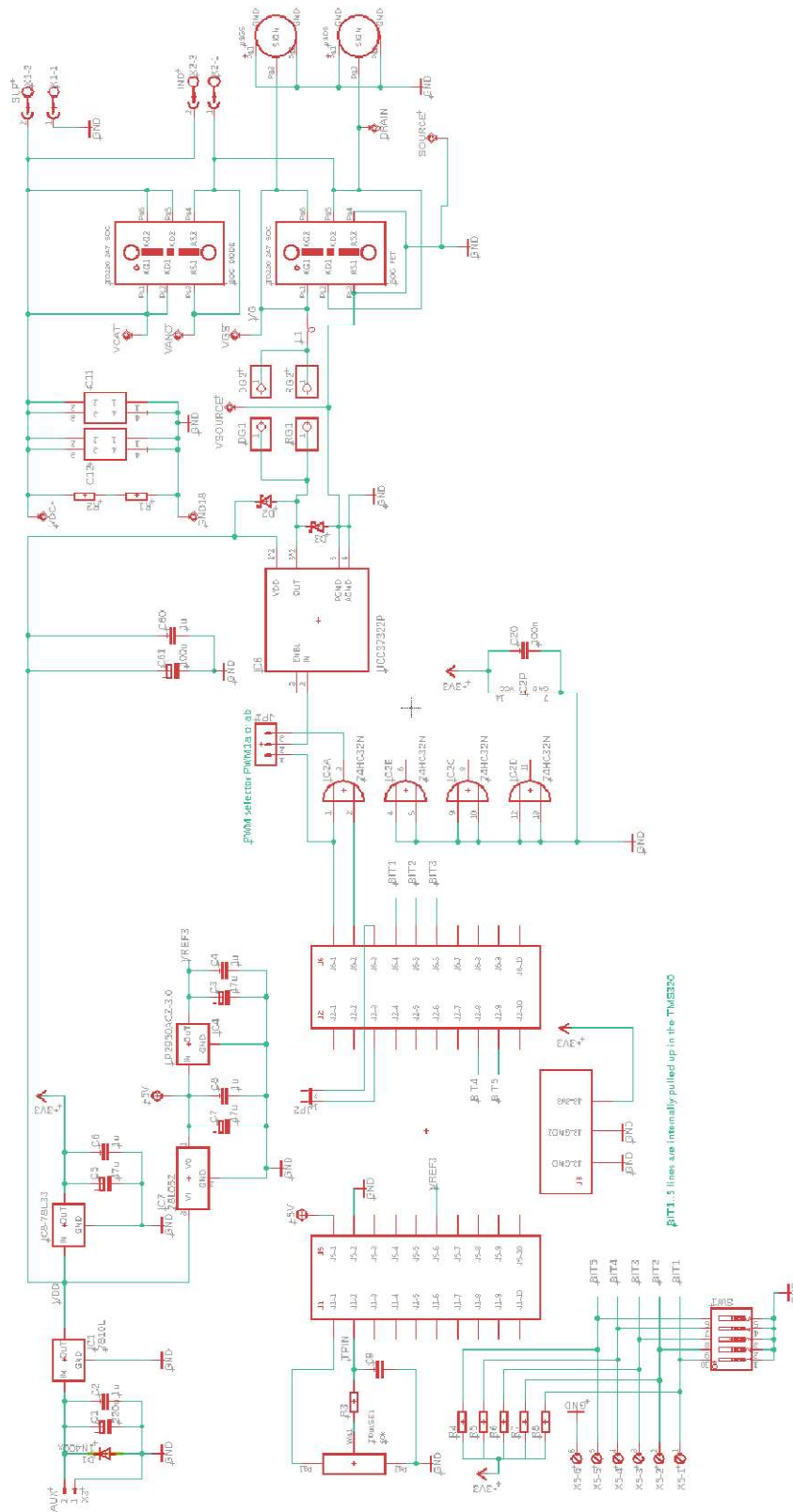

Fig. 2b: Student screen for remote (online) DPT practical. Left: Schematic, webcam view, power on/off, Vdc and t1 adjustment. Right: DLM oscilloscope

The design is further developed after student feedback and new insights. The latest variant, which is deployed in 2023, has; coaxial probe connections (no ground lead needed), coaxial current probe design (optional instead of Rogowski coil) and a lower inductive DC-bus design. The latest design changes are shown in Appendix A. Appendix B shows the typical investigated semi-conductor types in this course.

4. References

[1]: David Levett, Ziqing Zheng and Tim Frank, Infineon Technologies, Double Pulse Testing: The How, What and Why, Bodo´s Power Systems® April 2020 www.bodospower.com

[2]: Yokogawa XWirepuller application, https://tmi.yokogawa.com/solutions/products/oscilloscopes/oscilloscopes-application-software/xwirepuller/

Figure A1: Schematic of the Double Pulse Tester for onsite and online practical variant

Parameters at a glance:

- The single pulse (t1) and double pulse (t1+t2), where t1 is adjustable from 1…20us and t2 fixed at 1us, are generated via the TMS320 PWM1a and PWM1b channels and combined via jumper JP1.
  - Single Pulse Tester (SPT 1-2) or Double Pulse Tester (DPT 2-3)
- Pulse t1 is adjustable via:
  - On board potentiometer for on-site practical or
  - Five bits digital input for on-line practical control (data lines have pull-up resistor via TMS320, SW1 can be used for commissioning or test purposes of the on-line variant)
- Vdc max. is 400V (now limited by supply 400V; capacitor C10, 450V max.; plugs X1 and X2, 630V max.)
- The pulse(s) can triggered by onboard TMS320 button GPIO12 (onsite variant) or every 1 sec. automatically (jumper JP2)
- Studs DG and RG are for student adjustable gate resistor/diode combinations to adjust the switching speed.
- Special (quick change) sockets for most TO220 and TO243 transistor/diode types
- Onboard probe connection hooks (and coaxial) for gate, drain, source, cathode and anode measurement
- Easy through hole PCB design for easy maintenance in case of failure during practical's (e.g. gate driver change)
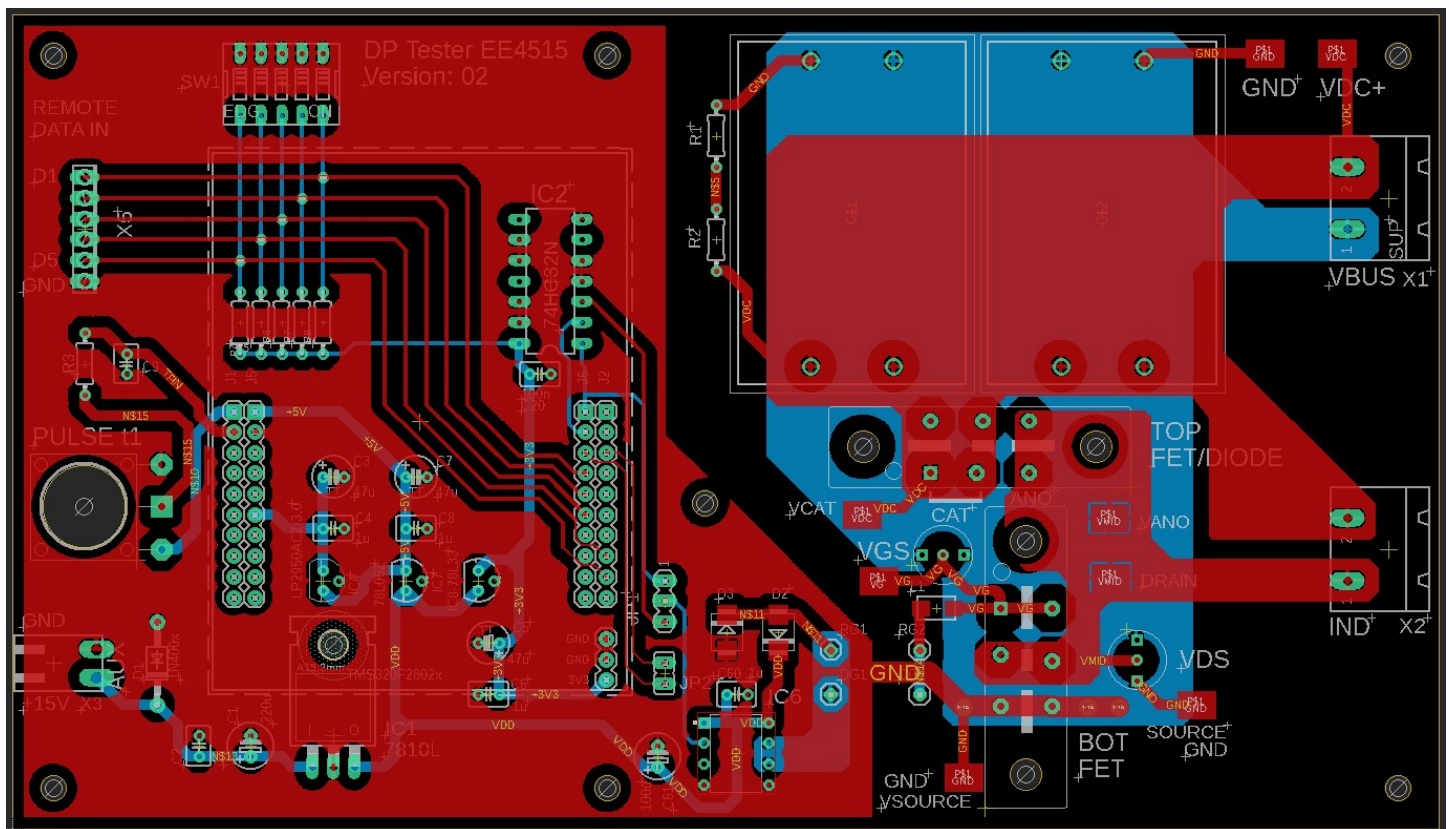- Single auxiliary 15V supply that creates the needed 10V (gate drive), 5V (logic), 3V3 (μC) and 3V (AD-ref).

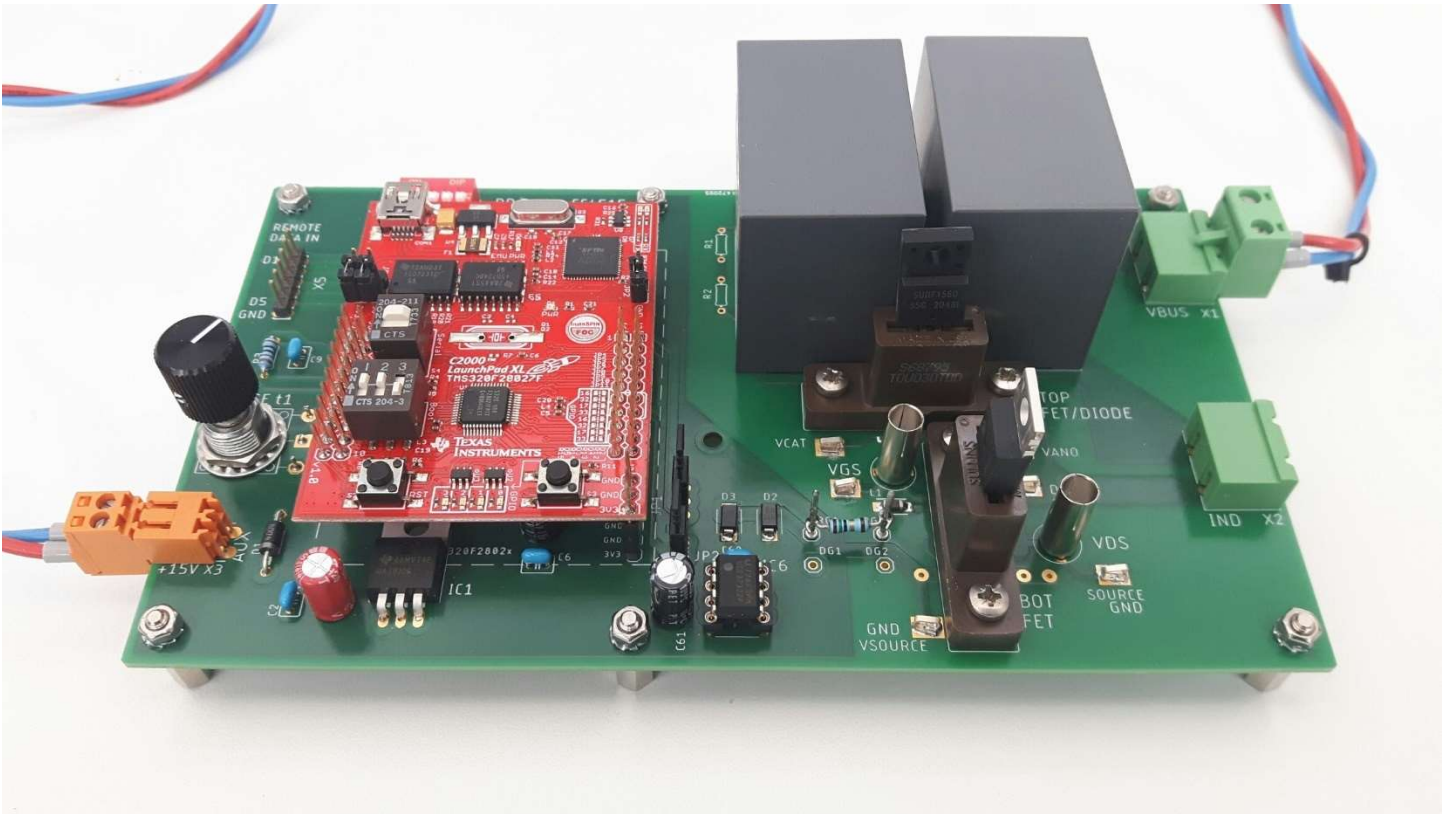
Figure A2: PCB layout used in 2023

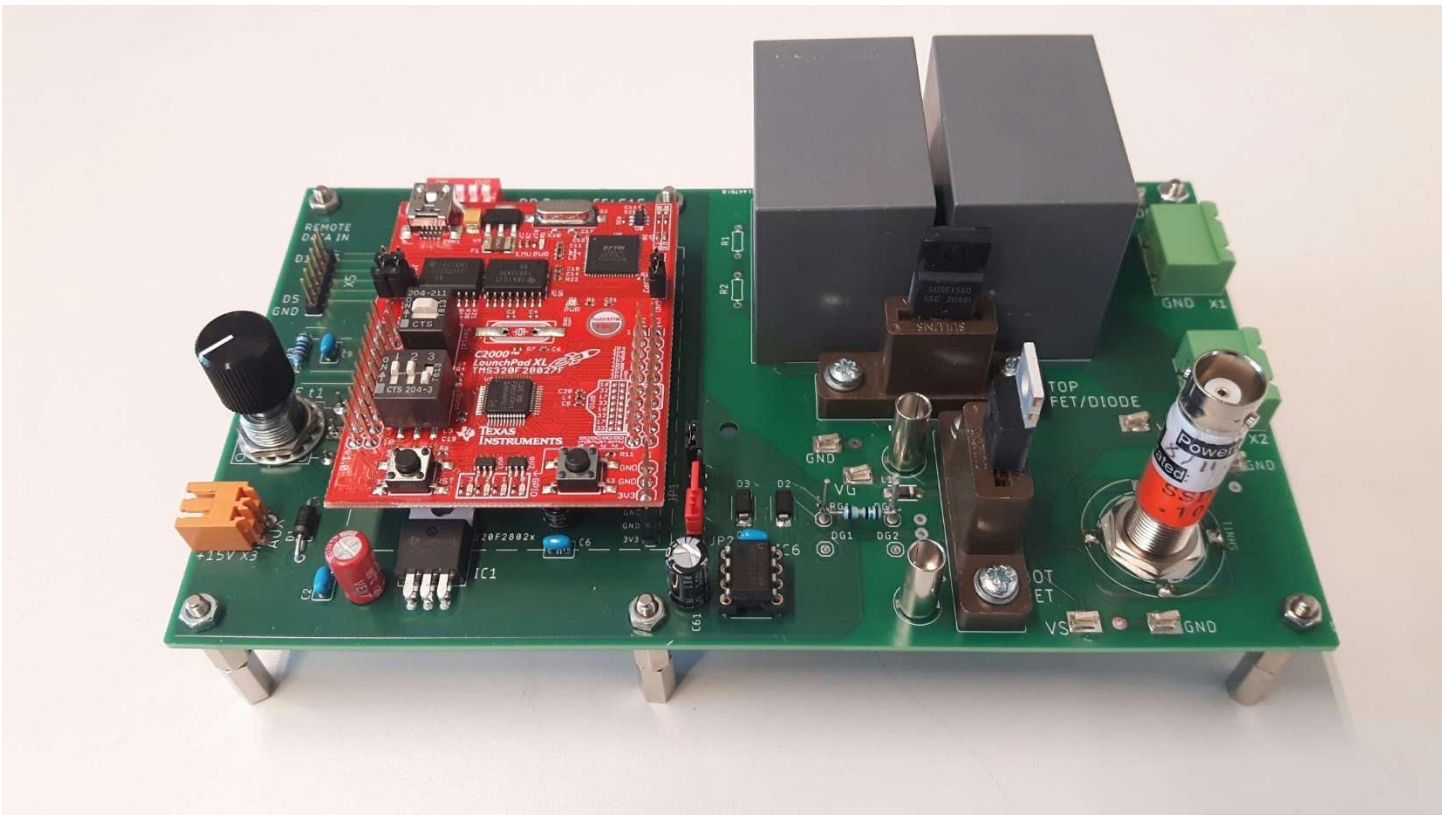*Figure A3: Latest assembled PCB used in 2023*

Figure A4: Assembled PCB with optional low inductive current shunt

Appendix B: Semiconductors for EE4515

Table B1 shows the used Mosfets for the DP testing and a few typical parameters. For a Vdc of 300V, 350V and 400V the needed pulse durations of t1 have been defined per semiconductor situation (i.e. A, B, C and D).

Table B1: Mosfets and diodes for DPT. Also parameters for Vdc and pulse lengths for a L=200µH are added.

					Vdc max	[V]	300	350	400
INPUT					L	[H]	2,00E-04	2,00E-04	2,00E-04
CALCULATION					didt	[A/us]	1,5	1,75	2
							↓	↓	↓
Comp.	Mosfet Type	Tech.	Vds/ak	Rdson	Housing	Imax DPT [A]	t1 max [us]	t1 max [us]	t1 max [us]
A	TPH3206PSB	GaN	650V	150mohm	TO-220	10	6,7	5,7	5,0
B	TPH3212PS	GaN	650V	72mohm	TO-220	20	13,3	11,4	10,0
C	IPP60R170CFD7XKSA1	Si	650V	170mohm	TO-220	10	6,7	5,7	5,0
D	IPP60R070CFD7XKSA1	Si	650V	70mohm	TO-220	20	13,3	11,4	10,0
	Diodes								
E	SCS220AM	Sic	650V	NA	TO-220	20A	NA	NA	NA
F	SURF1560	Si	600V	NA	TO-220	20A	NA	NA	NA

Table B2 shows which set-up runs in which week of Q4. It also shows which semiconductor situation/combination is used when.

Table B2: Practical per week

Wk (X vs. Y Comparison)	Components Set-up 1	Components Set-up2
4.1 (Si Mosfet C vs. Si Mosfet D)	C & E	*D & E*
4.2 (GaN Mosfet A vs. GaN Mosfet B)	A & E	**B & E**
4.3 (Si Mosfet D vs. GaN Mosfet B)	*D & E*	**B & E**
4.4 (Si diode F vs. SiC diode E)	B & F	**B & E**