Controlled pulse waveforms for TMS

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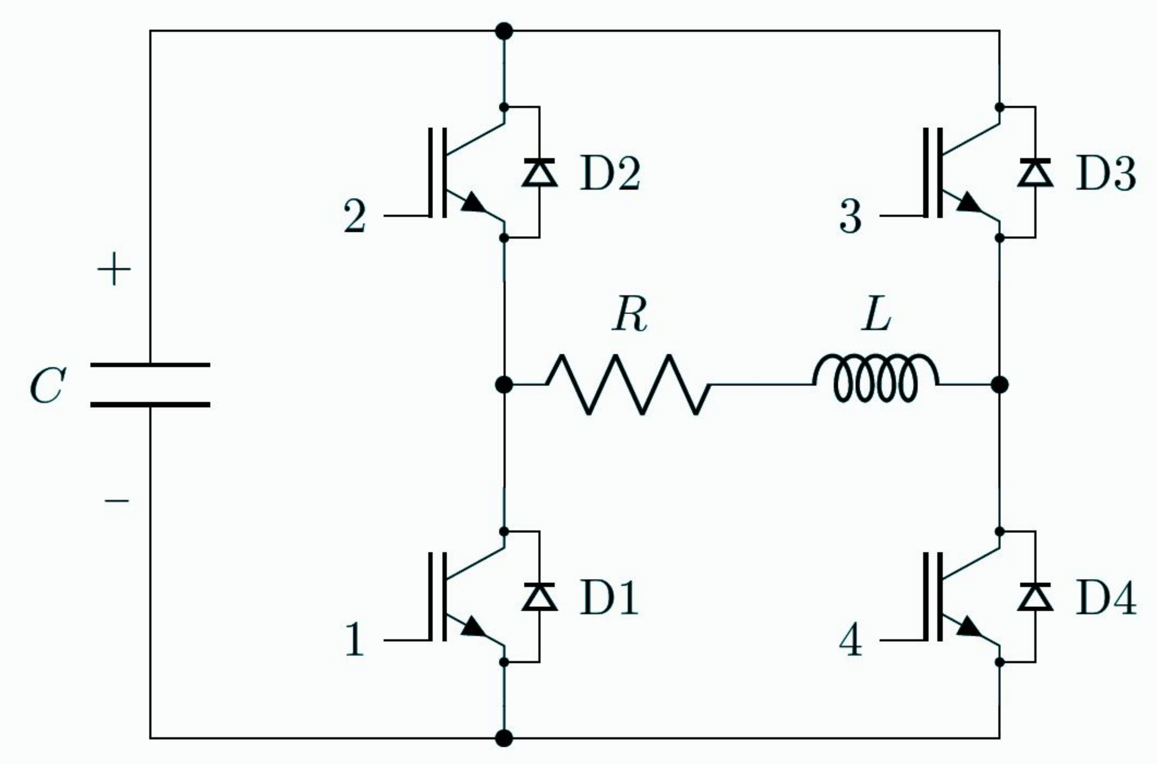
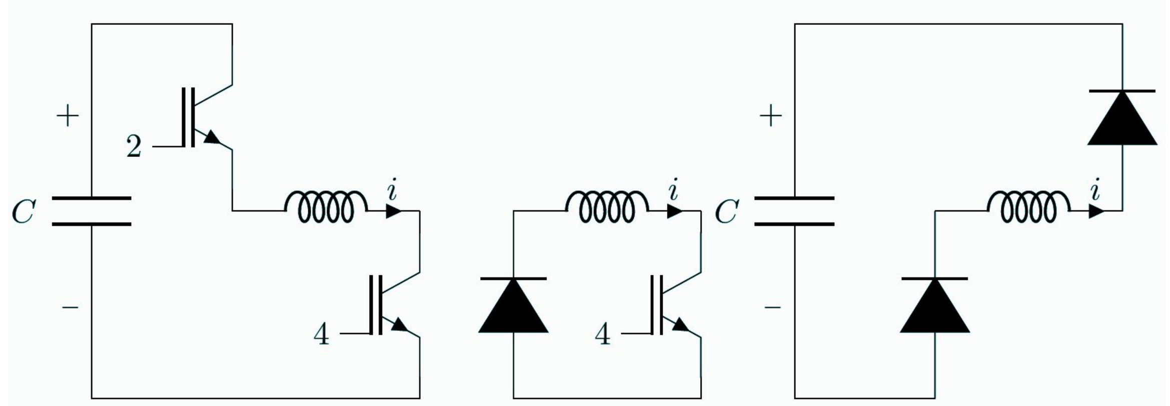
Multi-locus TMS (mTMS)

- A custom TMS system capable of driving multi-coil transducers [1]
- Multiple coils driven simultaneously to manipulate the induced electric field in the cortex





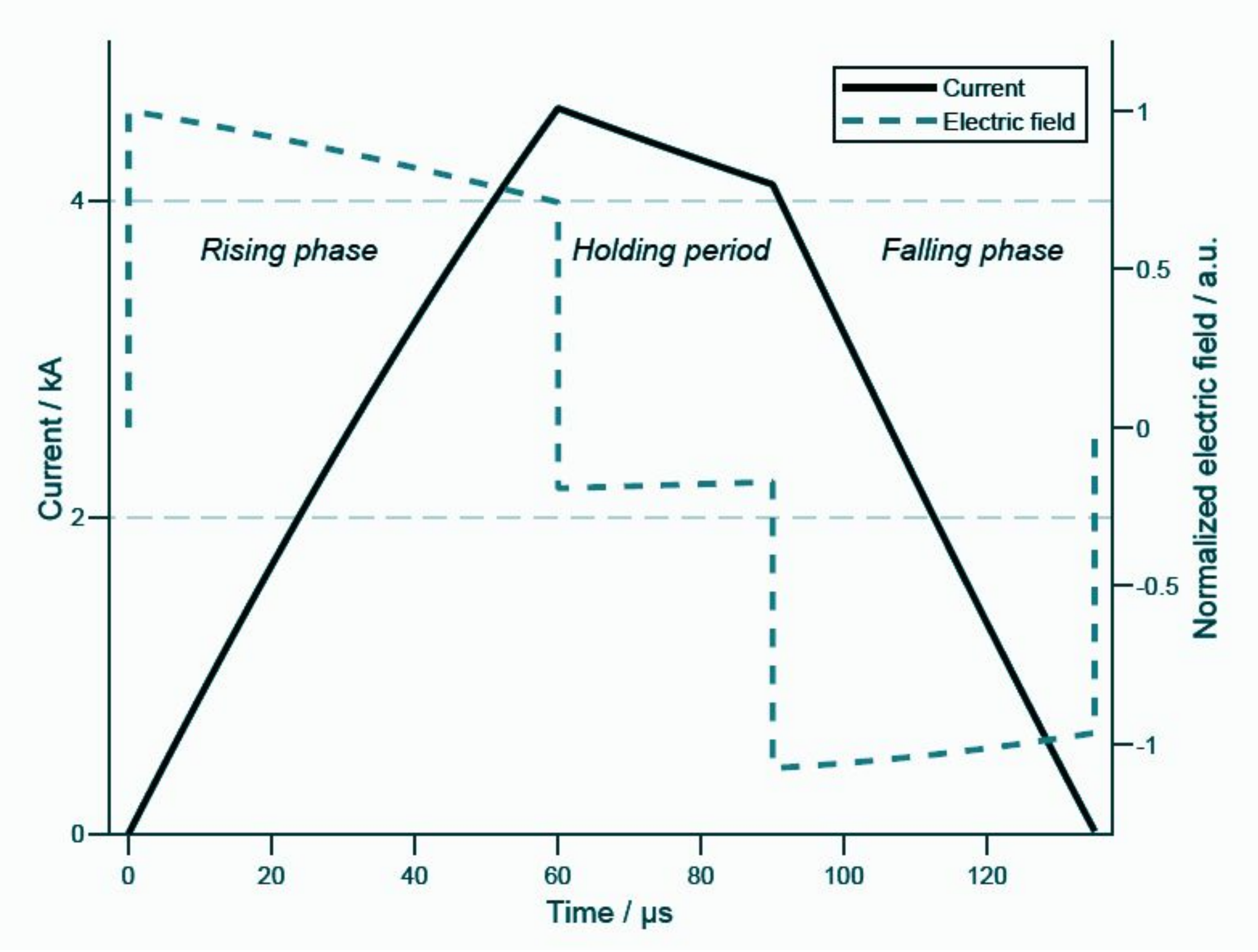


Fig 1: Left: an H-bridge and a capacitor, the power electronics for a TMS channel. Right: switching the transistors on or off controls the flow of current through the coil (top), and thus the induced electric field (bottom). L represents the TMS coil, C the pulse capacitor, and R the coil's winding resistance.

Modes

- The bridge circuit controls the flow of current through the coil
- Electric (E) field intensity proportional to the slope of the current, and thus the capacitor voltage
- *Conventional* pulse: a trapezoid whose field mimics that of a classic monophasic pulse [2]

However

- Any capacitor voltage will result in a fixed-intensity E-field
- The voltage needs to be adjusted if one wants to change the E-field intensity (e.g., manipulating the field patterns induced by a multi-coil transducer)
- Especially reducing the voltage is very slow, limiting the rate at which successive pulses can be given

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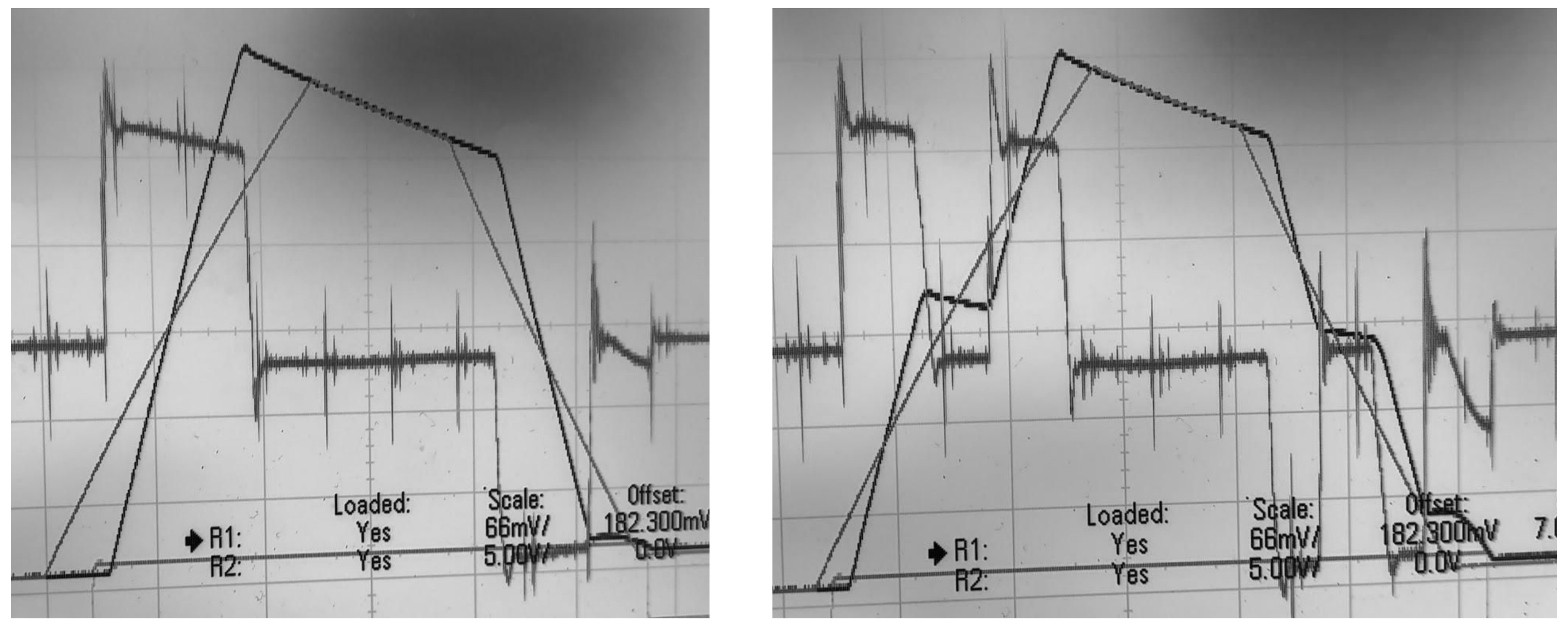
Approximating lower-voltage pulses

- Channels driven with maximum voltage, cycling between the bridge modes in microsecond scale
- Instantaneous E-field intensity is high but the effective intensity lower, as the field is applied only periodically
- Lower-intensity fields can be approximated by controlling the pulse waveform
- Calculating the necessary switching times is fast compared to discharging the pulse capacitor
- Neurons won't know the difference, as the charge leakage is a slow process



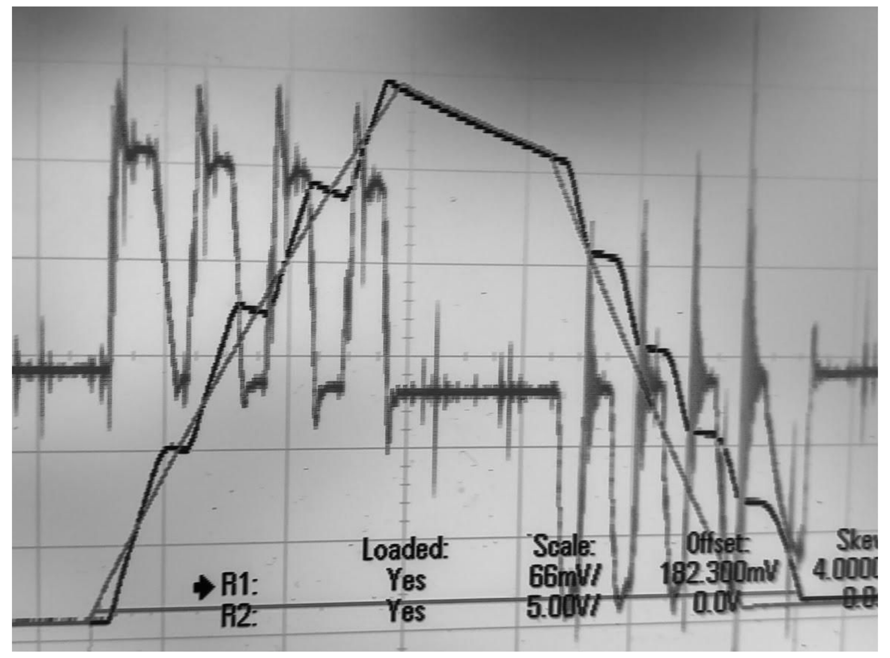


Fig 2: 1-, 2-, and 4-step approximations of a *conventional* pulse.

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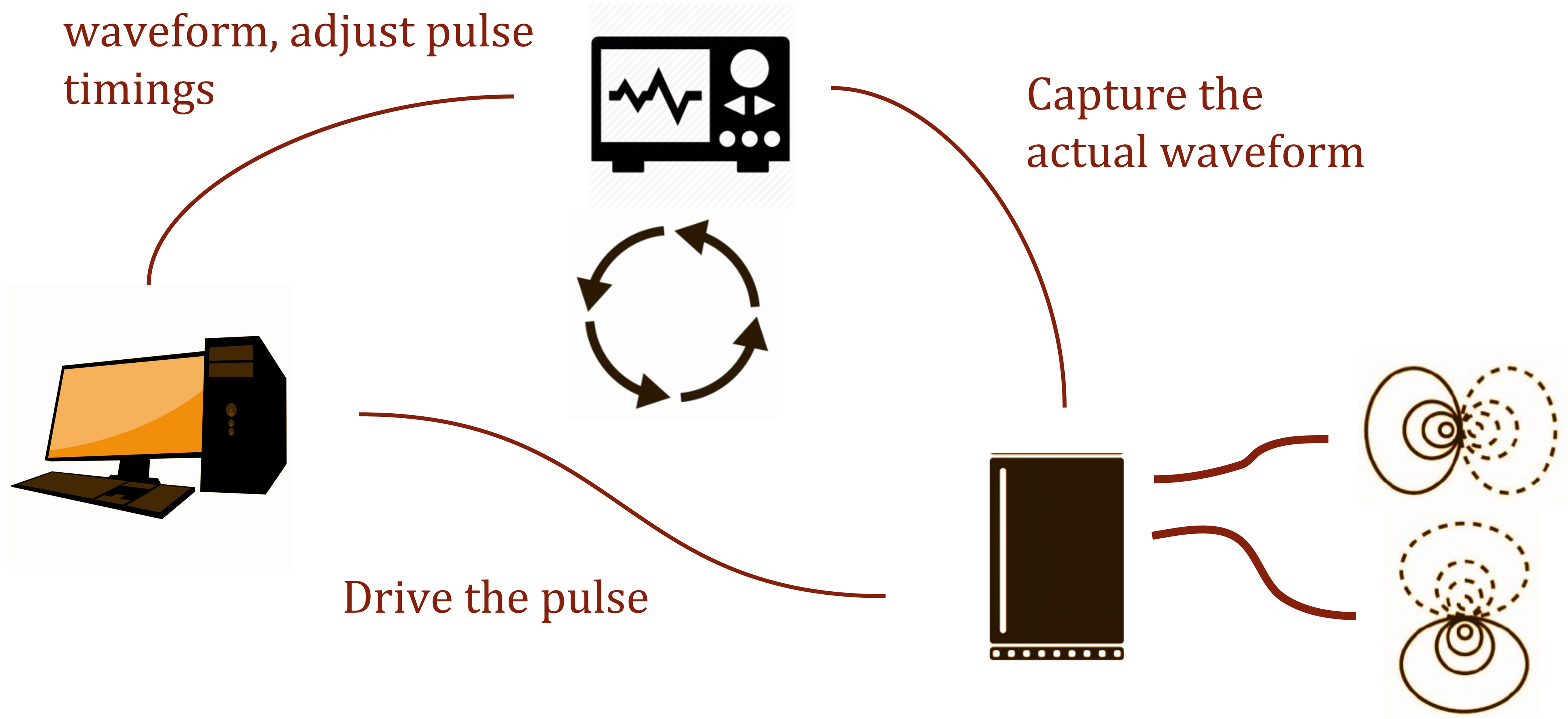
Automated calibration

- Observed waveforms quite distorted compared to calculations due to system non-idealities
- An automated calibration system planned to adjust the pulse timings accordingly



Conclusions

- Initial tests indicate that the stepped approximations result in similar brain activation as conventional pulses
- Allows for faster subsequent pulses
- A beneficial side effect is the reduced heat generation, as the capacitors do not need to be discharged

Clip art: Shmector, YA-Webdesign. [1] Koponen et al., Multi-locus transcranial magnetic stimulation—theory and implementation, Brain Stimul, 2018. [2] Koponen et al., Noninvasive extraction of microsecond-scale dynamics from human motor cortex, Human Brain Mapp, 2018.