Trigger circuit design and system integration for simultaneous measurement of human EEG, motion, and gaze

Masayuki Fujiwara, Phan Hoang Huu Duc
Kyushu Institute of Technology, 2-4 Hibikino, Wakamatsu-ku, Kitakyushu, 808-0196, Japan
Email: m-fujiw@brain.kyutech.ac.jp, phan.duc-hoang516@mail.kyutech.jp

Laurent Bougrain, Patrick Hénaff
Université de Lorraine, CNRS, LORIA, F-54000 Nancy, France
Email: {laurent.bougrain, patrick.henaff}@loria.fr

Hiroaki Wagatsuma
Kyushu Institute of Technology, 2-4 Hibikino, Wakamatsu-ku, Kitakyushu, 808-0196, Japan
Email: waga@brain.kyutech.ac.jp

Abstract

Simultaneous measurement of EEG, motion, and gaze in humans has the potential to lead to the discovery of new scientific insights. In order to achieve these simultaneous measurements, it is necessary to manage triggers and time information between measurement devices, as well as to correct time offsets. However, the management of accurate triggers and time information requires the design of a dedicated circuit board and the integration of Transistor-Transistor Logic signal voltage information. In this study, we report on the building of a trigger circuit and an experimental system using it to solve these problems. We created a home-made trigger circuit board for voltage integration and combined it with a commercially available microcomputer to realize an integrated trigger circuit and measurement system.

Keywords: Trigger circuit design, Electroencephalography (EEG), Motion, Gaze

1. Introduction

Simultaneous recording of physiological and behavioral data in standard data formats and analysis of these data in combination may lead to new scientific discoveries. So, in recent years, multimodal measurement methods and data formats have been attracting attention. In response to this situation, data acquisition through the Lab Streaming Layer (LSL) [1], new standard data formats, such as Brain Imaging Data Structure (BIDS) [2], [3], Neuroscience Information eXchange [4] and Open metaData Markup Language [5] (NIX-odML) [6], have been proposed to integrate and handle multimodal data and meta information.

For these simultaneous recordings, an experimenter is faced with the necessity to manage the trigger and time information between measuring instruments and to compensate for time offsets. In fact, while there are paid software and hardware types of equipment that manage the trigger and time information, it is so challenging to handle between measuring instruments that do not support such information.

The simultaneous measurement of various types of information, such as movement and gaze, in conjunction with human electroencephalography (EEG), holds particular significance due to their intimate involvement with neural activities. As introduced by Iturrate et al. [7], in the case of humans, the information derived from the gaze is directed to the V1 area within a span of 60-90 ms, reaches the motor cortex in approximately 220 ms, and the expression of fingertip movements is processed with a latency roughly between 280-400 ms (it is noteworthy that the process is expedited in monkeys [8]). Measuring and analyzing brain activities during this process is beneficial to understanding human cognitive functions.

In the previous work, we have proposed a methodological design [9] to reveal human-robot interactions in the real world by managing Transistor-Transistor Logic (TTL) signals. This proposal provided a specific event analysis based on data from multiple instruments and contributed to a reproducible experimental scheme in which each element could be interchangeable in the future.

However, to achieve accurate trigger and time information to be managed, a dedicated and versatile circuit board and its system must be designed to integrate

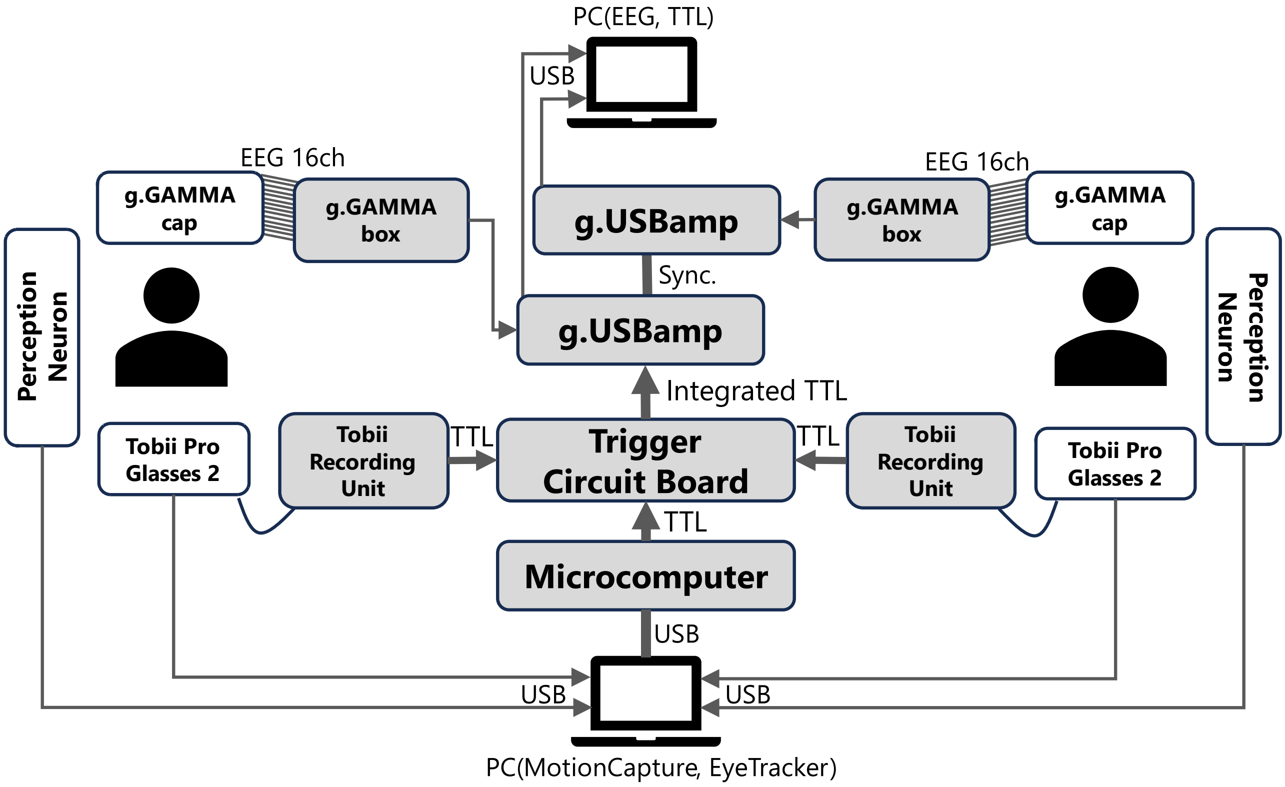


Fig. 1 Recording System Integration for human EEG, motion, and gaze data synchronization.

the voltage information of the TTL signal.

Therefore, this study reports on the fabrication of a trigger circuit and an experimental system using it to solve the problems mentioned above. We built a trigger circuit board for voltage integration and combined it with a commercially available microcontroller to integrate the trigger circuit and the measurement system.

2. Proposed Trigger circuit design and system integration s

2.1. *Recording System Integration*

The integrated measurement system of our recording instruments is shown in Fig. 1. The system uses a home-made trigger circuit and a microcomputer for integrated management of the voltage and time information output from each measurement instrument with and without trigger output function. The following is a description of the actual measurement instruments that were used:

- g.tec USBamp and g.tec GAMMAbox for EEG recording;
- Perception Neuron 2.0 for Motion Capturing;
- Tobii Pro Glasses 2 for Eye Tracking.

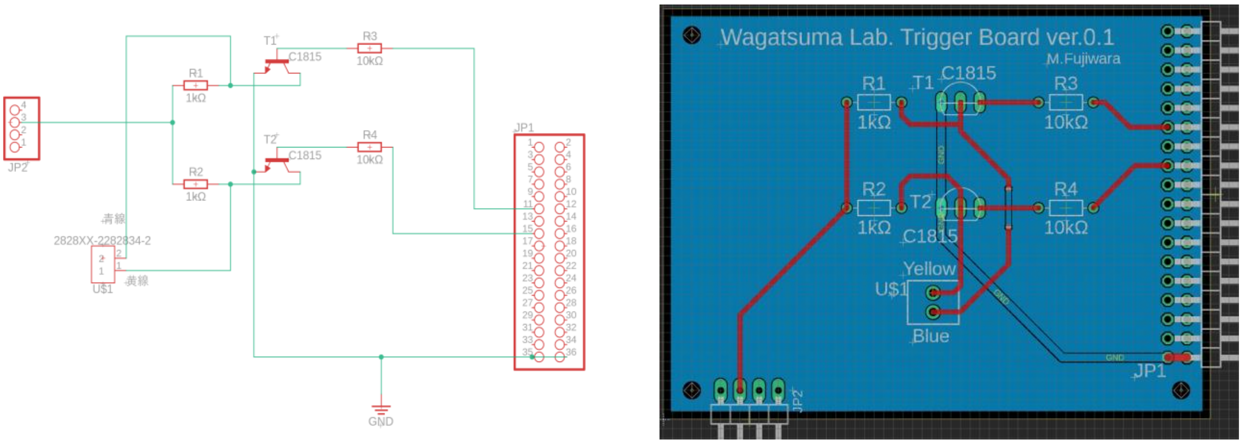
Perception Neuron 2.0 does not have a trigger output function. Nevertheless, the trigger and time information can be obtained by combining a trigger circuit and a microcomputer, as described in the next section. Note that the timing of the first output of the trigger signal depends on detecting the pressing of the Axis Neuron's recording button using software for the perception neuron with a global hook function on Windows.

2.2. *Home-made Trigger Circuit and Microcomputer*

Fig. 2 shows the fabrication and design of the trigger circuit board. We used Autodesk Fusion 360 [10] to unify circuit design (Fig. 2a) and board design (Fig. 2b). The designed circuit was fabricated to be integrated with the microcomputer (Fig. 3). Moreover, this circuit has two input ports (blue and yellow cables), but multiple input ports can be managed by increasing the number of level-shift circuits. For measurement instruments that do not have a trigger output, a timer function in the microcomputer is used to output a square wave (e.g., 5.00 [V]) with accuracy in the order of microseconds. The trigger and synchronization are managed by adding/subtracting the above-mentioned multiple trigger inputs to/from this voltage. If other measurement equipment has a trigger output, it can be integrated after checking the output voltage.

2.3. *Testing Equipment information*

We observed the trigger signals using a digital oscilloscope to test the integrated trigger circuit board and its recording system. Actually, we connected multiple measurement instruments to the input ports of the trigger circuit to capture the changes in the trigger



a. Schematic circuit diagram b. Circuit board diagram

Fig. 2 Fabrication and Design of Trigger Circuit Board

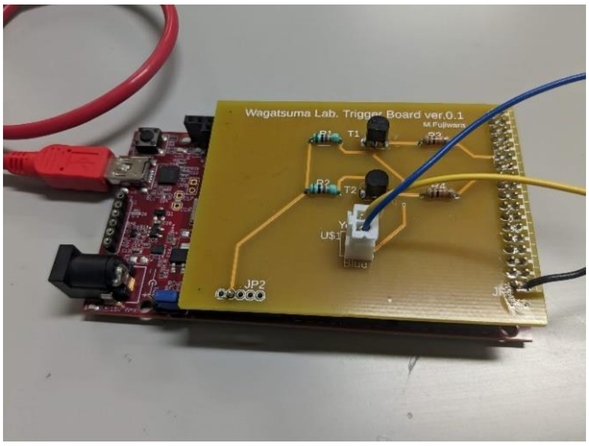
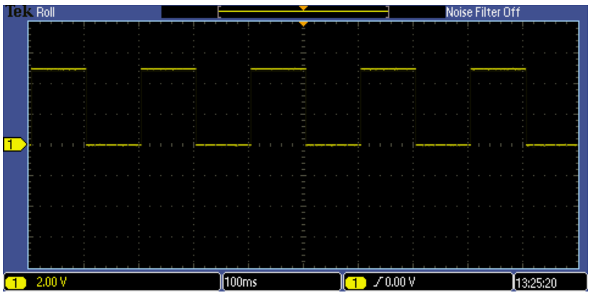
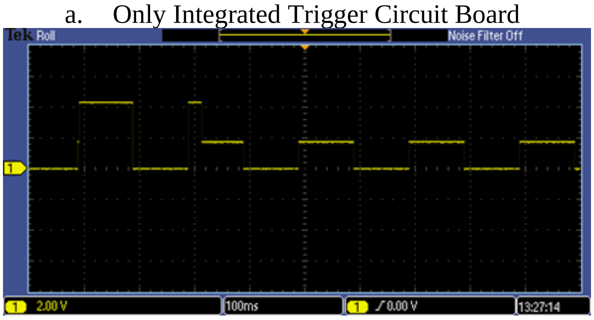


Fig.3 Integrated Trigger Circuit Board



a. Only Integrated Trigger Circuit Board



b. Combined with Other Measuring Instruments

Fig.4 Recorded Trigger Signals

signal. The settings used for observation were an amplitude of 2.00 [V]/scale and a period of 100 ms/scale.

3. Results and Discussion

We measured the trigger signal from the integrated trigger circuit board (Fig. 4). Fig. 4a shows the case in which only the trigger circuit was used, and a square wave (5.00 [V]) was measured. Fig. 4b shows a simultaneous measurement, including trigger signals from other measurement devices and the timing of multiple trigger inputs. These recorded trigger signals showed the management we expected.

As a limitation, if the measurement start time of the measurement device depends on the recording software, the accuracy of the trigger may be affected by the system clock of the Operating System (OS), leaving room for further study. Currently, in this case, a dedicated application is developed and used to output the trigger from the Universal Serial Bus port to detect the measurement start time, which may cause an accuracy problem.

4. Conclusion

We designed a custom trigger circuit board to measure EEG, motion, and eye movement simultaneously. This trigger circuit board and its system integrate the voltage information of multiple TTL signals, allowing for accurate triggering and time synchronization between different measurement instruments. It also may suggest a potential way to provide data from measurement instruments that do not have trigger output functions with respect to existing measurement methods for integrating multimodal data.

Future work is to investigate the accuracy of triggering at system time, etc., when relying on measurement software., i.e., the management of time information between the OS and the trigger circuit.

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Authors Introduction

Dr. Masayuki Fujiwara

He graduated from Fukuoka Institute of Technology (FIT) in 2015. He then went on to earned his Master and Ph.D (Knowledge Science) degrees from Japan Advanced Institute of Science and Technology (JAIST) in 2017 and 2023. Until 2020, he was a Research Fellow of the Japan Society for the Promotion of Science (JSPS) (DC1) and is now a researcher at Kyushu Institute of Technology (Kyutech). His research focuses on the EEG studies and neural modeling of (non-)symbolic communication from the perspective of cognitive neurodynamics.

Mr. Phan Hoang Huu Duc

He received Bachelor degree in Biomedical Engineering, from Department of Biomedical Engineering, Faculty of Applied Science, Ho Chi Minh City University of Technology (HCMUT) in 2021. He is currently studying Neuroscience in Kyushu Institute of Technology from 2022.

Dr. Laurent Bougrain

He earned his MSc in artificial intelligence from université Paris 6, his BS in psychology from université Nancy 2 and his Ph.D in Computer Science from Université de Nancy 1 in 2000. He is leading the Neurosys/Neurorhythms team since 2015 at LORIA. His research focuses on brain-computer interfaces, motor systems, machine learning, feature extraction and selection, post-stroke rehabilitation, artificial intelligence, and monitoring of general anesthesia. He is currently an Associate Professor of Computer Science at the University of Lorraine.

Dr. Patrick Hénaff

He earned his M.Sc and Ph.D in Robotics from Université Pierre et Marie Curie in 1989 and 1994. He worked as a lecturer at the University of Cergy-Pontoise and a researcher at LISV (Systems Engineering Laboratory at the University of Versailles) and the University of Cergy-Pontoise. Since 2013, he has been a Professor at the Ecole des Mines de Nancy, University of Lorraine, and worked in the LORIA laboratory. He led the Complex Systems, AI, and Robotics department at LORIA from 2015 to 2022, and the Computer Science department at Mines Nancy from 2018 to 2023.

Dr. Hiroaki Wagatsuma

He received his M.S., and Ph.D. degrees from Tokyo Denki University, Japan, in 1997 and 2005, respectively. In 2009, he joined Kyushu Institute of Technology, where he is currently an Associate Professor of the Department of Human Intelligence Systems. His research interests include non-linear dynamics and robotics. He is a member of the IEEE society.