สิ่งประดิษฐ์

Microcontroller based-photic stimulator controller

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A microcontroller is a programmable control device which is used in many imported medical equipments. Flash photic stimulation is a neurophyliologic technique used in routine electroencephalography to induce photo-sensitive epilepsy. Modern EEG acquisition machines usually have a photic stimulator controller installed to facilitate the work of the EEG technician. The equipment flashes a strobe light at an interval determined by a program. We designed a stand alone microcontroller based photic controller, calibrated its timing characteristics and tested it in a clinical EEG laboratory. The equipment design, calibration and clinical test results are presented.

Key words : *Photic stimulation, Microcontroller.*

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อุปกรณ์ทางการแพทย์หลาย ๆ ชนิดในปัจจุบันใช้ microcontroller เป็นส่วนประกอบ เพื่อควบคุมอุปกรณ์อื่น ๆ การกระตุ้นด้วยแสงไฟเป็นเทคนิคการตรวจทางประสาทสรีรวิทยาอย่างหนึ่ง ซึ่งใช้กระตุ้นอาการชักเนื่องจากแสงไฟระหว่างการตรวจคลื่นไฟฟ้าสมอง เครื่องตรวจคลื่นไฟฟ้าสมองยุคปัจจุบันมักมีเครื่องควบคุมการกระตุ้นด้วยแสงไฟติดตั้งอยู่ด้วย เพื่อช่วยในการทำงานของพนักงานตรวจคลื่นไฟฟ้าสมอง เครื่องมือนี้ฉายแสงไฟตามระยะเวลาที่ตั้งไว้ในโปรแกรม เราออกแบบเครื่องควบคุมการกระตุ้นด้วยแสงไฟชนิดที่ควบคุมด้วย microcontroller ทำการปรับฐานเวลาของเครื่องให้ถูกต้อง และทดลองใช้เครื่องมือดังกล่าวในห้องปฏิบัติการตรวจคลื่นไฟฟ้าสมอง บทความนี้จะรายงานถึงแนวคิดในการออกแบบ การปรับแต่งเครื่องมือ และตัวอย่างของการนำไปใช้ในห้องปฏิบัติการ

Medical instruments are becoming more sophisticated and easier to use but at the same time more expensive and harder to maintain, especially in developing countries. We designed and built our own photic stimulator controller for our EEG laboratory . Herein hope to point out that some medical equipments can be adequately designed and manufactured locally.

Materials and Methods

The literature on requirements , rationale and safety [1-3,6] precautions for flash photic stimulation reviewed. These were incorporated into the hardware and the software designs. The hardware and software are then tested and calibrated using a standard photic stimulator (Gross PS -33 Plus, Grass Instrument Company, Quincy, MA,USA) [4] and a standard digital EEG machine (Stellate Harmonie, Stellate Systems, Montreal, Quebec, Canada, using La Mont EEG amplifier, a La Mont Medical, Inc., Madison, WI, USA). [5] The machine is then tested without a patient for 100 sets of photic stimulations with random interruption looking for a malfunction. Its power supply was also connected and disconnected while the unit was connected to the photic stimulator to see whether this would set the photic stimulator off accidentally. It was then tested in out lab in an actual clinical setting.

Result

1. The Requirements

Photic stimulation is an activation procedure to detect photosensitivity. [1,3] It is performed by flashing a bright diffuse stroboscopic light approximately 30 cm in front of the patient eyes at a predetermined rate ranging from 1 to 25 FPS (flashes per second). [3] This is done by 1) "Step photic stimulation" where the flashes are repeated at one rate for about 10 seconds [3] followed by a pause, then repeated at another rate 2) changing the flashing rate continuously ("continuous sweep of rising or falling frequencies or both "). [1] The stimulation should be monitored by an additional recording channel. [2,3] Normal person may not have a demonstrable photic response or may have a photic drive consisting of a positive monophasic wave which occurs 50-150 milliseconds after each flash. These positive waves start to merge at flash rates over 3 FPS. [3] Childrenís driving response usually occurs at less than 10 FPS. After 10 years of age driving can be seen up to 15 to 20 FPS. [7] These responses end with the cessation of the stimulation. Many diseases may demonstrate abnormal photic stimulation responses. The most important one to recognize is photoparoxysmal or photo convulsive response. It consists of spikes or other epileptiform activities, shows no relationship with the stimulus frequency, often involves the entire head and may outlast the end of the stimulation. [3]

Traditionally, the EEG technician will both manually control the photic stimulator and observe the patients clinical and EEG responses simultaneously. [1,3] The purpose of the activation is to demonstrate that there is an abnormal response to the flash photic stimulation but do not allow the patient to have a clinical seizure by stopping the stimulation as soon as the seizure activity appears. [3] There are many physiologic responses and artifacts that one has to recognize during the photic stimulation. Table 1 summarizes the common physiologic change and artifacts occurring during photic stimulation. The photic stimulator controller allows the technician to concentrate more on the patient, but it must provide a way to terminate the activation at any point during the stimulation.

Table 1. Physiological responses and artifacts that occurr during photic stimulation.

EEG Findings	Characteristics	EEG technician responses
Photomyogenic (Photomyoclonic) [1,3]	Brief muscle contractions 50-60 ms after each flash, mainly the eyelids, may spread to the head, neck and body. No EEG changes	Increase paper speed, Continue if eyelid only, stop if spreads.
Asymmetric photic response [3]	Asymmetry in amplitude, usually a normal variation	Continue
Photoparoxysmal [1,3]	Spikes or other epileptiform activity, may not stop at the end of the stimulation	Stop the stimulation immediately
Photoelectric [1]	Artifact due to photochemical reaction, occurs in the frontal electrode with high impedance, resuling in a spike-like transient	Cover the suspected electrode, fix the bad electrode.

2. The hardware & software

The photic controller hardware is based on PIC16C56 microcontroller (Microchip Technology Inc.) based BASIC STAMP (Parallax Inc.). The BASIC STAMP is a low cost single-board computer which can run BASIC language programs. [5] The unit is powered either by a nine volt battery or external power adapter. We connected pin 7 of the controller to the external control port of the GRASS PS-33 photic stimulator and used pin O to detect a push button. Pin 3 was connected to the EEG anplifier input via a adjustable resistance to provide a proper voltage for photic marking . Figure 1 shows the housing and wiring of the equipment. Figure 2 shows the wiring diagram. [5]

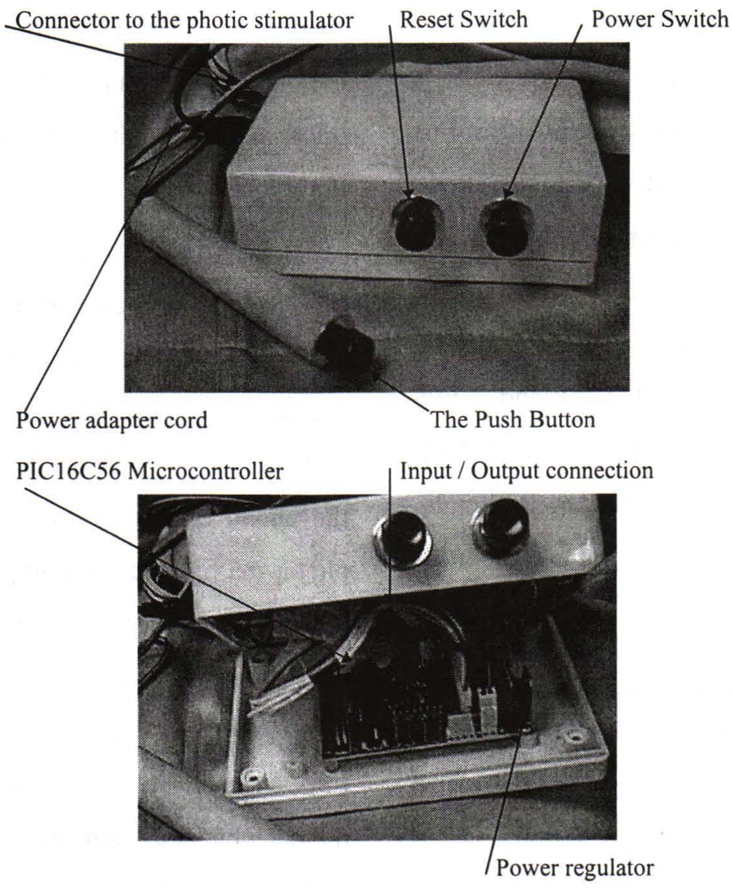


Figure 1. The housing and wiring of the equipment.

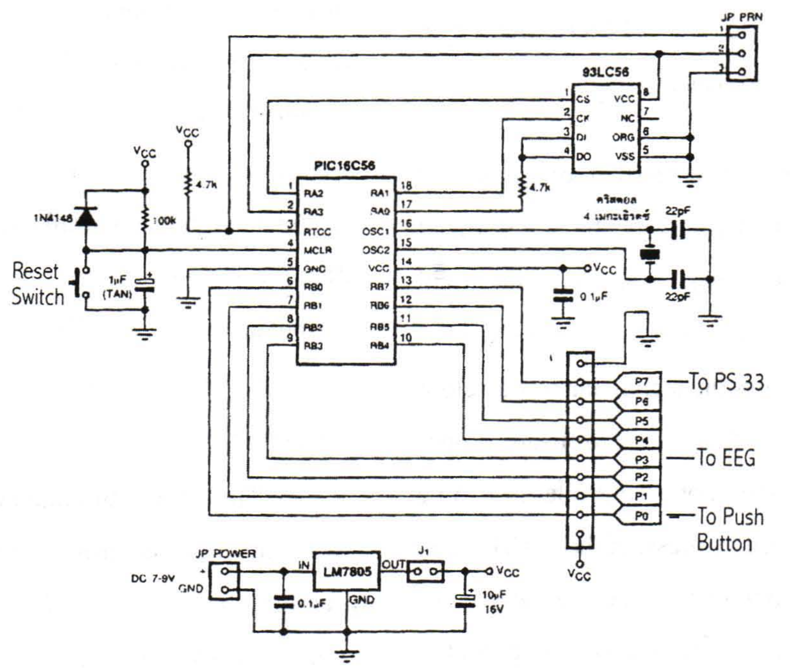


Figure 2. The wiring diagram.

The photic controller software is based on Parallax BASIC. This language allows us to accurately set the flash off at a predetermined rate by measuring the pause between each the flash. [5] This also allows used to calibrate the machine when additional programming was required for properly marking the EEG tracing. The program give a 10 second photic stimulations at 1, 5, 10, 15, 20, 12, 8 and 3 FPS followed by a sweep of frequency from 8 to 20 FPS. The program can be changed to any photic stimulation protocol. Figure 3 shows the sample loop that generates a flash at 12 FPS.

```
for B1 = 0 to 120
        pulsout 7.1
        pause 83
next
 pause 5000
```

Figure 3. A sample of Parallax BASIC loop to generate a flash at 12 FPS followed by a five second pause.

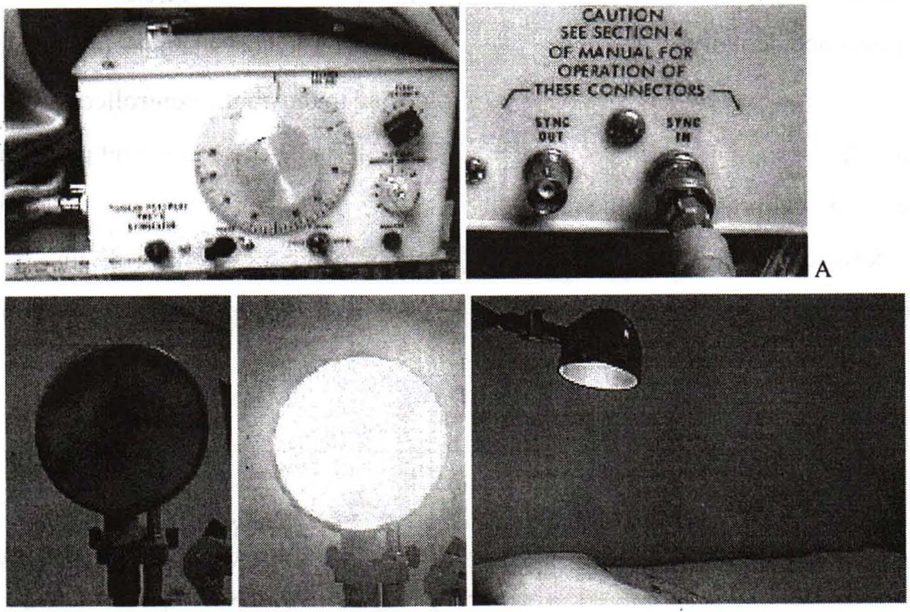
The program is written so that after power on or a reset the machine will always be in a dormant state with no photic flashing. [5] At this point it will wait for a hand-held push button activation to start stimulation . This allows the technician to stay close to the patient and the EEG machine to ensure proper stimulation. To run the photic controller has to be reset manually followed by pressing the push button. This prevents the program from accidentally commencing. At any point, the technician can press the reset button to abort the stimulation. [5] The power on -off switch is provided to save energy and to shut off the unit in case the program fails to abort with the reset button . At the end of the stimulation cycle, the microcontroller will be put into a sleep stage which draws only 20 μA. [5]

3. Timing Calibration & Initial Testing

The photic stimulator controller was connected to the lamp and the EEG machine as shown in figure 4. [4,5] The width of the pulse output of the photic controller was adjusted until the EEG photic markings consistently showed a mark with each flash. [5,6] The time delay between each loop was then calculated to incorporate the time required to give a proper photic marking . The program was then finished and ready to run . Figure 5 shows the photic marker obtained from the program . This timing schedule and light intensity are identical to our routine photic stimulation protocol.

The photic stimulator controller was then put through 100 test runs with random resets at various stages of the stimulation. The equipment started properly 99 % of the time. The only occasion it failed was because of a power failure due to the power adapter coming loose from the wall outlet. It started properly after the power adapter was reconnected and the equipment was reset. The equipment stopped immediately 100 % of the time when the reset switch was pressed.

The photic stimulator controller power cord was them removed from the wall outlet while the program was running and then reconnected. The equipment always entered the dormant state when the power supply was reconnected and the reset switch was pressed. Occasionally a single flash went off at



A

B

Figure 4. a) The connection between the photic stimulator controller to the Grass PS-33 Plus photic stimulator
b) The photic lamp, as viewed from the patientís view and from a side view as normally set up.

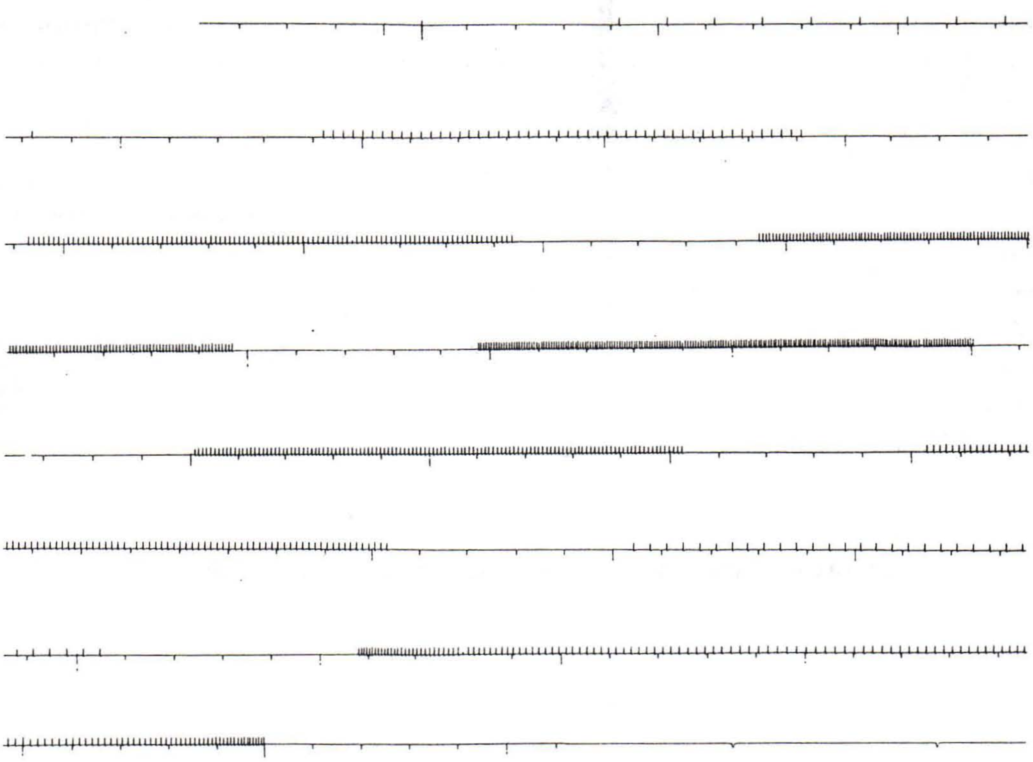


Figure 5. A continuous photic marker obtained from the calibrated program. Each thick line represents a one second time lapse, with twenty seconds per line. each flash is marked as a single deflection. The program gives 10 seconds of photic stimulation at 1,5,10,15,20,12,8 and 3 FPS followed by a sweep of frequency from 8 to 20 FPS.

the time of power reconnection. The stimulator never started activation runs accidentally.

4. Clinical Testing

After the timing calibration and the reliability testing were performed, the photic stimulator controller was then tested in our lab during routine EEG sessions from March 1-13, 1998. The lamp was always turned off when the power supply was reconnected to the photic controller. A total of 12 patients were tested. The equipment performed correctly on all 12 occasions with 3 of the 12 patients having photic driving response . Figure 6 shows the EEG tracing of a patient with photic driving.

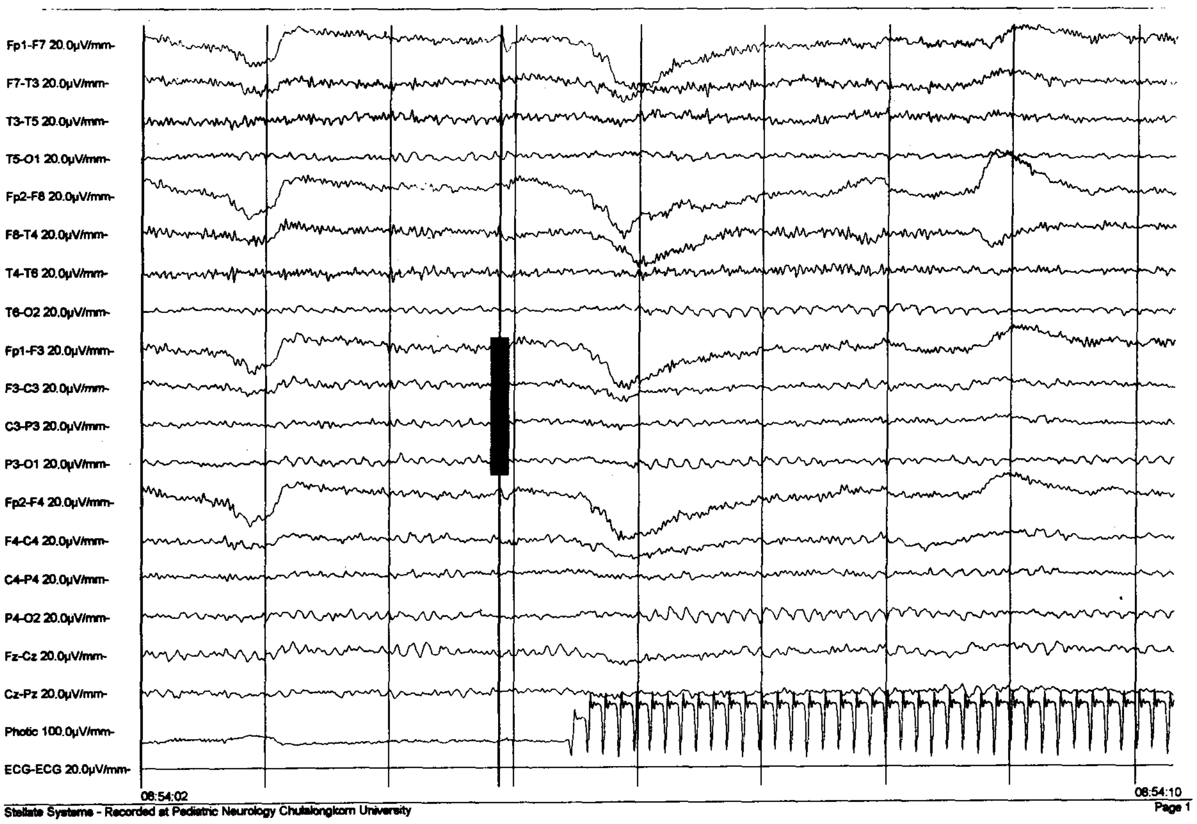


Figure 6. Shows the EEG tracing of patient with photic driving.

Discussion

The microcontroller has its origin in the 1970's. Rapid advances in micro-electronic has mode the equipment less expensive and more capable. The main advantage of the microcontroller when compared to traditional control circuits is in its programmability. [9] For the PIC16C56, once it is reprogrammed, its operating characteristics will change and remain constant even when the power supply is turned off. [5] Traditional control circuits need rewiring or changing of components to achieve the same results. We used the PIC16C56 microcontroller when we first developed the program as it would always power on in a dormant state and we could calibrate the flash rate. The PIC16C56 was reprogrammed with new instructions, tested and reprogrammed until the desired photic stimulation protocol was achieved. Both the hardware and software development took about 20 work hours.

Calibration and testing is an important phase in equipment development because it allow the developers to learn more about the equipment before clinical testing occurs. For example, we did not expect the single flash when the power supply was interrupted and then reconnected. This was most likely due to a power surge that occurs when the power supply is reconnected and not due to a program failure. The Grass PS-33 Plus photic stimulator external input port requires only 10 μS of 5V input to set the strobe off. [4] This suggests a precaution of turning the power of the lamp off when the power supply of the microcontroller is reconnected. The microcontroller never ran the program accidentally during a power failure reconnection test, and it always aborted when the reset switch was pressed. The latter is very important when the patient develops photoconvulsive responses.

The programmable photic stimulator controller can be either a stand-alone, such as a Nihon-Koden EEG machine [8] or under computer control, such as a Stellate HPS-95 photic stimulator controller. [7] We decided to develop a stand - alone photic stimulator controller first because it is simpler, can be used in many EEG laboratories in Thailand which still use analog EEG machines and do not have microcomputers available in the laboratory. The microcontroller can communicate with the computer via either its serial or parallel port. [5] This is appropriate for laboratories with digital EEG equipments. The main advantage of the direct computer control is the ease of reprogramming. The end-user can change the protocol on the screen without having to download and test the microcontroller firmware each time, as in our present equipment. [7]

One weak point for this project is its dependence on the Grass photic stimulator and its lamp. The author lacks the electric engineering expertise for a strobe light controller. We actually tested the strobe circuits available in the Thai electronic marker and found their maximum flashing rates too slow to be useful as a photic stimulator. We also could not ensure the safety of the lamp which has to be placed in close proximity to the patient's eye. If this obstacle could be solved, photic stimulator controller can be widely employed in routine EEG and researches in electrophysiology.

In conclusion, we present the development of a stand-alone, microcontroller based photic stimulator controller from the stand point of clinical and safety requirements, hardware and software development, calibration, testing and the actual clinical use. We hope that this article will stimulate interest for medical equipment development in Thailand which will lead to appropriately priced and easy to maintain locally designed and manufactured medical equipments.

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