Interfacing with Microcomputers in
the Physiology Laboratory

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My memory goes back to the time when spring-powered kymographs with recording paper smoked over a sooty flame were state-of-the-art in many undergraduate laboratories. Next came kymographs driven by electric motors which were considered quite an advance at the time. Electronic equipment with greatly increased efficiency, accuracy and versatility has largely replaced kymographs. I still have fond (?) memories of the kymograph. Every now and then I have students attempt to record some physiological event with the kymograph so that they more fully appreciate today’s equipment.

Multichannel chart recorders such as the Physiograph enable students to simultaneously record several physiological events. These events can then be analyzed and correlated; for example, recording the atrial and ventricular contractions of the pulsating turtle heart along with its electrical activity (EKG) on three channels. In our labs, both the Physiograph and Thornton recording equipment are used with good success by students. In this report, I make no attempt to describe the whole array of such equipment, but only some representative types with which I am familiar.

By the 1980’s, programs for physiological simulations utilizing microcomputers became available. "Physiological Simulations" (1980) is one that I have used successfully in the lab with the Apple computer, was developed by James E. Randall of Indiana University. Another recently developed simulation program we now use is on the "Mechanical Properties of Active Muscle" by Richard A. Meiss, also of Indiana University, and is available from QUEUE of Bridgeport, Ct. This program utilizes the IBM PC computer. Both simulation programs allow students to set up experimental conditions and observe the results on the screen. This stimulates the interest of many students.

Another development of the 1980’s that we now use in the lab is the Physiogrip by Inteliool of Wheaton, Illinois. This consists of a specially designed displacement transducer connected to an Apple computer along with software that enables display, recording and rapid analysis of human muscle contractions by stimulating the flexor digitorum superficialis muscle through the surface of the forearm.

Another system now available utilizing existing electronic equipment and microcomputers is the Sensor-Processor Interface (SPI) system by Thornton Associates, Inc., of Waltham, Massachusetts. Apple and IBM PC computers can be used with this system. The following are some examples of the use of the SPI system that are suitable for a biology or introductory physiology laboratory. Thornton electronics were interfaced with an Apple IIc computer, color monitor and an Imagewriter printer. The SPI unit does not occupy much space, as it measures only 9.25" x 8.5" x 2.5". The VOLT1 program, supplied with the system, plots voltage against time, with time on the X axis. The X and Y axis parameters can be set by the user, the settings depending on the event being recorded.

Figure 1 is a copy of a segment of an electrocardiogram made with a Type 400 Bio-Amplifier/Supply and a Type 410 Isolated
Preamplifier. The time between the data points was 0.02 second. The SPI memory configuration allows 8000 data points to be collected. When the sampling rate is set, the time per screen and the total time will be displayed. In this recording with sample points every 0.02 second, the total time is 160 seconds with the time per screen being 2.14 seconds. The data points are displayed as they are collected. At the end of the time period (160 sec. in this case), several options are presented. LOG will present the data in tabular form on the screen and on the printer. FILE will store the data to disk.

![Image: EKG and Volume Pulse](image)

**Figure 1.** Electrocardiogram with data points connected. P, QRS and T added.

**Figure 2.** Fingertip volume pulse. Data points not connected. Note dicrotic notch following each volume peak.

One can also scan each screen from the beginning or select any point during the total time period and begin scanning at that point. If something particularly interesting happens at a certain time, say at 60 seconds during the recording, one can begin scanning at about 58 seconds and save the time of scanning all the preceding screens. A hardcopy of any screen can be obtained by pressing P. One can RESTART the program with the X and Y parameters remaining as set. RESTART, however, will erase the current data so a decision must be made before doing this whether or not to save the data.

Figure 1 shows a 2.14 second segment of the EKG beginning at 2.0 seconds. An option of whether or not to connect the data points is available by simply pressing C when scanning the screens. Whether or not to do this depends on the nature of the data. By viewing it both ways, or making copies both ways, one can decide which way appears best on paper. In Figure 1, the data points are connected. Two complete cardiac cycles are shown, with the P, QRS, and T components labeled by me.

Figure 2 shows a screen of the recording of the volume pulse in the fingertip of a 22 year-old subject using a Type 428 Photoplethysmograph. The time between data points is 0.04 second with a total recording time of 320 seconds. In this copy, the data points are not connected. A prominent dicrotic notch is visible, caused by the elastic recoil of the large arteries after ventricular systole.

The SPI system has two analog inputs and one or both can be used at the same time. In Figures 1 and 2, only one channel is used, but in Figure 3, both channels were used to show the relationship between the volume pulse and the electrocardiogram. The time between samples is the same as in Figure 1 (0.02 sec.). The EKG is not as clearly defined as in Figure 1 because the voltage parameters for a volume pulse are not the same as for an EKG. Only one set of voltage parameters can be used for both channels. Nevertheless, P, QRS, and T can be identified and the time delay between QRS (ventricular excitation) and the peak of the volume pulse in the fingertip can be easily seen. The prominent dicrotic notch seen in Figure 2 is
Figure 3. Relationship of volume, pulse and EKG. Data points connected. P, QRS and T have been added.

considerably diminished in Figure 3 because the volume pulse and EKG in this recording are of a 64 year-old individual. The diminished dicrotic notch is very likely the result of the aging process with the large arteries being less elastic than those of a 22 year-old individual.

Figure 4. Frog gastrocnemius muscle. Data points not connected. Arrow indicates point of stimulus followed by latent period.

The form curve of a single isotonic twitch of the frog gastrocnemius muscle is shown in Figure 4. The twitch was produced by a single pulse from a stimulator of six milliseconds duration and four volts in amplitude. The time between data points is 0.005 second with the time per screen at 0.55 second. A type 424 Displacement Transducer and a Type 450 Stimulator were used. The displacement transducer was connected to Channel 1 and the event output of the stimulator was connected to Channel 2. In this way, the stimulator served as a signal marker for the stimulus to the muscle. This is shown as the upper line in the screen. As the stimulator button is pressed, the line drops to the base line of the muscle lever. This allows the latent period of the muscle twitch to be measured, which in this case is 0.021 second. The time of the complete twitch at room temperature, including the latent period, is about 0.155 second. The form curve of the muscle twitch is comparable to any which can be produced on an oscilloscope screen and by utilizing the computer-driven printer which makes it a simple matter to obtain a copy of the twitch.

Figure 5. Superimposed twitches of two frog gastrocnemius muscles. Data points connected on isometric twitch.

Figure 5 shows an isotonic twitch and an isometric twitch of the right and left gastrocnemius muscle of a frog. The isotonic twitch was produced by connecting one muscle to a Type 424 Displacement Transducer and the isometric twitch was produced by connecting the other muscle to a Type 422 Force Transducer. The muscles were simultaneously stimulated with a Type 450 Stimulator. The time between data points is 0.005 second (same as in Fig. 4). The two twitches can easily be distinguished on the monitor screen because they appear in two colors, orange and blue. In Figure 5, the data points of the isometric twitch are connected (by hand) to distinguish it in the absence of color.

The characteristics of the two contractions can be compared by examining the
superimposed tracings. In Figure 5, the isometric twitch is the upper line beginning on the left side of the screen. The most noticeable differences are the shorter latent period and peak tension produced in the isometric twitch before the isometric twitch reaches maximum contraction. In the isometric twitch, the force transducer responds immediately to an increase in tension resulting from stimulation, whereas in the isotonic twitch, enough tension must be produced to overcome the inertia of the muscle lever and attached weight before there is any movement.

Figures 6 and 7 show the effect of fatigue on the frog gastrocnemius muscle. Both muscles of a frog were connected to Type 424 displacement transducers producing isotonic twitches. The conditions for both muscles were the same except one muscle had performed more work than the other before the twitches were recorded. On the screen, the two muscle contractions appeared as orange and blue. To distinguish them in these copies, the data points on the fatigued muscle are not connected.

In Figure 6, one muscle lifted a ten-gram weight 40 times more than the other. Some evidence for fatigue is visible in the longer relaxation period in the twitch. In Figure 7, the same muscle lifted the ten-gram weight 100 times more than the other. The effect of fatigue is more pronounced as shown by the slight delay in responding to the stimulus, not contracting to the same degree as the other muscle, and the considerably longer relaxation period.

Microcomputers are now an integral part of the physiology laboratory, whether they are used for physiological simulations, with special transducers or interfaced with components of other recording equipment.

![Image](image_url)

Figure 6. Isotonic twitches of two frog gastrocnemius muscles. Data points not connected on twitch showing fatigue.

In these examples of interfacing with microcomputers, Thornton equipment was used, but other analog sensors and transducers can also be used. Real-time data acquisition and analysis is simplified and enhanced. The Thornton SPI system adds another dimension to the laboratory and allows greater use of your existing electronic equipment and microcomputers. The extent of this depends on the ingenuity of the user.

Reference