How We Teach

Singing greeting card beeper as a finger pulse sensor

Gregor Belušič and Gregor Zupančič

Department of Biology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

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Belušič G, Zupančič G. Singing greeting card beeper as a finger pulse sensor. Adv Physiol Educ 34: 90–92, 2010; doi:10.1152/advan.00015.2010.—We constructed a robust and low-priced finger pulse sensor from a singing greeting card beeper. The beeper outputs the plethysmographic signal, which is indistinguishable from that of commercial grade sensors. The sensor can be used in school for a number of experiments in human cardiovascular physiology.

Materials and methods

The human cardiovascular system offers numerous attractive experiments in human physiology at all levels of education. Time-resolved cardiovascular parameters can be relatively easily obtained by measuring the heart rate (HR) via ECG or finger pulse (FP) and the blood pressure (BP) with a sphygmomanometer. Computer-aided data acquisition nevertheless requires the proper galvanic separation of measurement instrumentation and the use of sensors that are not always available to the teachers. During a training course in human physiology for Slovene secondary school teachers, we realized that virtually all of them had access to instruments for computer-aided recordings such as LabPro or LabQuest by Vernier Software and Technology (5), usually shared with physics and chemistry teachers. Yet only a few of them had an ECG or other suitable sensors, so that they were very limited in their ability to record the parameters related to cardiovascular system functions. However, every Vernier instrument is, by default, equipped with a voltage probe, which allows the connection of appropriate voltage sources in the range of ±10 V with clips. We assumed that a suitable signal for such a system could be provided from a FP sensor. We constructed a low-cost sensor with a robust signal, proposed a few experiments for its application, and presented the sensor with the experiments to the teachers. The teachers positively accepted the proposal, learned how to construct the sensor themselves, and how to make recordings with it. The whole system is currently being implemented as part of the biology course in Slovene secondary schools.

Materials and methods

We assumed that a plethysmographic signal from fingers can be detected with a contact microphone firmly attached to a finger. A contact microphone, as such, is not necessarily required since any loudspeaker can, in principle, serve as a microphone. Several gadgets and toys contain such cheap loudspeakers. Our source was several different “singing” greeting cards, costing between 1 and 5 euros each, bought at the local post office (music modules for greeting cards manufactured by Tianyu Electronics, Shenzhen, China). The cheapest cards contained conveniently sized (25 mm diameter) piezoelectric beepers, whereas the more expensive “polyphonic” cards came with somewhat larger (40 mm diameter) electromagnetic speakers. We tried both types and found that the polyphonic speakers produced outputs that required a substantial amplification before analog-to-digital conversion and were, therefore, not the best suited for school use. In addition, they also delivered a poor signal, most likely due to displacement and immobilization of the coil in the finger-attached position, and were thus inferior to the piezoelectric beepers that we used in all the experiments described. These rigid piezoelectric speakers are especially well suited as contact microphones since they output relatively high voltages upon deformation and hence do not require any amplification, making them especially suited for school work. A quick online survey indicated that the beepers can be found within greeting cards worldwide. If not sold locally, greeting cards can be bought from internet retailers and shipped to practically all countries. Piezoelectric beepers alone are also available in different sizes and housings from online hobby electronic shops.

The beepers’ wires were detached from the electronic circuit, and the beepers were removed from the greeting cards. The beepers are housed in a plastic shell on one side, forming an acoustic cavity. The opposite side of the beeper can serve as the surface of a contact microphone. In some greeting cards, the beepers had a piece of soft plastic, 2–4 mm thick, attached to this side to dampen the very annoying sound produced when the speaker was in direct contact with the paper of the greeting card. Although it is not absolutely necessary, we found that this plastic actually also improves the recordings by concentrating the pressure on a smaller area of the finger. A beeper was secured with Leucoplast adhesive tape to a finger so that the exposed metal side with the soldered wires was in contact with the skin. To stabilize the signal, we constructed a simple passive resistor-capacitor (RC) high-pass filter with a 1-μF capacitor and 100-kΩ resistor soldered to a stripboard, yielding a 1.6-Hz cutoff frequency. This alternating current filter is not absolutely necessary since the beeper itself acted as a high-pass filter with a 0.3-s time constant. It was, however, useful to reject any direct current offsets and drifts, which often appeared in this low-cost device. The filter was soldered to the speaker terminals. The terminals were connected with the voltage probe clips to the LabQuest interface (Vernier) or with crocodile clips to a Powerlab 4/25T (ADInstruments). The sensor constructed from the beeper, wires, and a high-pass filter is shown in Fig. 1.

Results

The volume changes due to the pulsed blood flow in the finger resulted in a large voltage signal coming from the beepers’ terminals. The beepers were able of delivering up to 0.7 V peak to peak. We found that all the beepers suffered from large and drifting offset potentials (up to 2 V). We corrected the offset potentials and stabilized the signal by inserting a simple passive RC high-pass filter (cutoff frequency = 1.6 Hz) between the beeper and terminal wires (see Materials and Methods). The filter distorted the signal slightly by picking a few millivolts of the 50-Hz mains noise, but this did not substantially degrade the quality of
the recording (Fig. 2, middle; signal = minimum 160 mV peak to peak, mains noise = maximum 5 mV peak to peak).

An example of a FP recording is shown in Fig. 2. Two sensors were attached to the two forefingers of a subject performing a Valsalva maneuver: a commercial-grade sensor (MLT 1010, ADInstruments) to the left forefinger (Fig. 2, top) and the beeper to the right forefinger (Fig. 2, middle). The plethysmographic signal from the beeper was virtually indistinguishable from the signal coming from the commercial-grade sensor. Both signals performed equally well in sensing and recording the main characteristics of the FP: multiple peaks due to elasticity of the arterial system and the signal size proportional to systolic BP. In both cases, this allowed for automatic peak detection and online calculation of HR (Fig. 2, bottom).

DISCUSSION

FP sensors allow teachers to perform a number of measurements and experiments in the classroom. The following are some examples:

1. The multiple peaks of the FP can be used to illustrate the Windkessel effect, BP wave reflection, and their relation to age, atherosclerosis, and hypertension (1, 3).

2. The FP signal can be used to demonstrate the measurement of systolic BP. FP can be obstructed with a sphygmomanometric cuff inflated to a pressure above the systolic BP, so that the sensor can partially substitute a stethoscope, and the obstruction of the FP can be observed on the screen.

3. The contribution of hydrostatic pressure to BP can be demonstrated by repeating systolic BP measurements with the hand elevated or lowered.

4. The amplitude of the FP follows systolic BP and the state of peripheral vasodilatation, both of which are related to stress, cold, etc. FP amplitude, the size of the secondary peak, and the interval between the primary and secondary peak can serve as a rough indicator of the changes in systolic BP.

5. The automatic (and, if possible, online) detection of HR from the FP allows one to monitor the effects of exercise on the cardiovascular system, to observe respiratory arrhyth-

![Fig. 1. A: finger pulse (FP) sensor assembled from the beeper and passive resistor-capacitor (RC) high-pass filter. The beeper side contacting the finger is shown oriented upward. A piece of soft rubbery plastic, which originally connected the beeper to the greeting card, was intentionally left on the beeper surface to improve the contact between the finger and sensor. The RC filter’s resistor and capacitor terminals are exposed to facilitate the connection of the clips. Inset: scheme of the sensor. The speaker icon represents the beeper. B: the beeper sticked to Leucoplast tape and the forefinger. The tape is glued to the plastic housing. C: the beeper secured to the proximal portion of the last segment of the forefinger.](image)

![Fig. 2. FP of a subject performing the Valsalva maneuver. The vertical lines at 4 and 40 s indicate the time of the beginning and end of the maneuver; abdominal pressure was further increased at 30 s. Top: FP detected with the commercial-grade sensor (MLT 1010, ADInstruments). Middle: FP detected with the sensor constructed from the beeper and RC filter. Bottom: heart rate [HR; in beats/min (bpm)] calculated from the middle. Insets at the top and middle show a magnified portion of the FP signal from the three heart beats preceding the maneuver. Changes in blood pressure are compensated through the changes in HR via the baroreceptor reflex.](image)
mia, and to perform more complex experiments, such as the diving response or Valsalva maneuver (2, 4).

GRANTS

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DISCLOSURES

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