

Short Communication

A Microcomputer System for the Measurement of Avian Heart Rate

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A system is described for measuring changes in avian heart rate in response to auditory stimuli using an Apple II microcomputer. Heart beat signals and auditory stimuli are filtered and then recorded on a stereo cassette tape. These recorded signals are subsequently processed by computer interface hardware. The physiological signal passes through a simple feature detection circuit designed to discriminate between heart beats and physiological 'noise', while the auditory signal is shaped and passed through a Schmitt trigger and one-shot. Software programs then count heart beats for specified periods, and specially label counts obtained during auditory stimulus periods for later analysis.

Avian heart rate Microcomputer Hardware

Introduction

Recent studies of heart rate have used either tachograph output (3) or minicomputers (1). The former, although possessing the advantage of simplicity, produces data that require laborious analysis, whereas the latter necessitates a substantial investment in equipment. The recent availability of microcomputers and associated peripheral devices has made possible the development of an inexpensive alternative method for measuring heart rate that is comparable in speed and flexibility with earlier methods using minicomputers. We describe the design and characteristics of a microcomputer system, and provide some preliminary data.

Methods

Testing Procedures

Our subjects were 10-day-old Mallard ducklings *Anas platyrhynchos* that had been reared in the laboratory. The birds were partially shaved and given a topical application of xylocaine anesthetic (40 mg per ml). Two stainless steel 'C' suture needles were then implanted, one just anterior to the wings and the other in the tail. For testing, ducklings were placed in a dark, sound-deadened box with an externally grounded aluminium floor; small alligator clips

were attached to the electrodes with wires leading into an overhead mercury commutator.

Testing involved a series of trials, each consisting of a 12.5 s prestimulus period, a 10 s stimulus period and a 12.5 s poststimulus period. Auditory stimuli included a variety of species-typical calls, consisting of a series of brief (125 ms) repetitive notes, and pulses of pure tones.

Heart beat signals were amplified with a Grass model P511 preamplifier, passed through a Krohn-Hite model 314 variable filter set at a high pass of 20Hz and a low pass of 150Hz, and recorded on one channel of a stereo cassette tape using a Sony TC-FX33 tape deck. The auditory stimuli that were played to the test duckling were recorded on the other channel of the cassette tape. These taped signals were subsequently fed into an interface card mounted in peripheral slot 2 of an Apple II microcomputer. During playback, both signals were passed through a Realistic SA-10 amplifier, which enabled us to adjust the amplitude of the EKG to accommodate the small amount of inter-bird variability obtained with the implanting technique and testing conditions. This procedure was more convenient than altering the interface Schmitt trigger thresholds, which were set to typical values (see below).

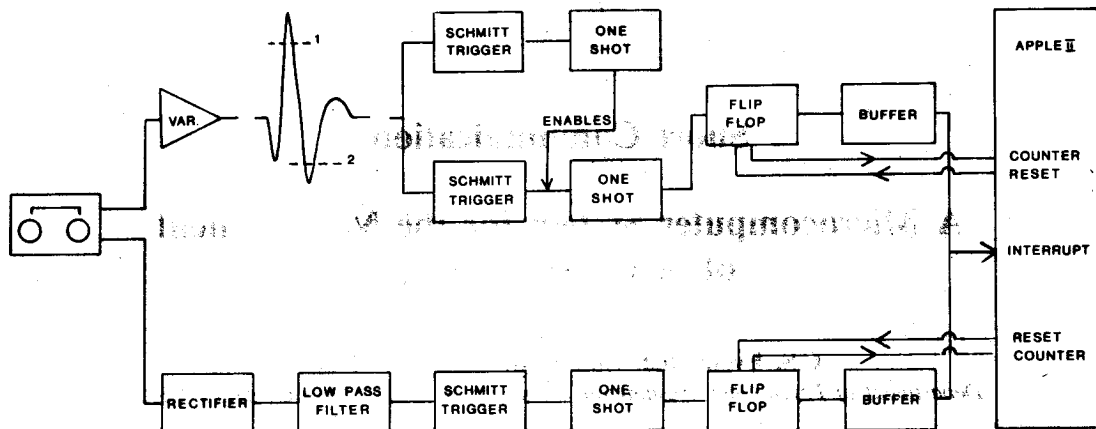


Figure 1. Schematic illustration of recording and computer interface hardware.

Computer Interface Hardware

The computer input interface was constructed to provide the necessary signal processing for both the amplified heart beat and auditory signals output by the tape recorder (Figure 1). The heart beat signal is fed into two Schmitt triggers, the thresholds for which are set to correspond to the usual size of the R and S waves of the EKG (1 and 2 in Figure 1). The output from the first Schmitt trigger causes a one-shot to go high for 20 ms. The output from the second Schmitt trigger also goes into a one-shot; however, this second one-shot cannot go high unless the first one-shot is still high. Since the time for which the first one-shot is high closely corresponds to the maximum observed separation of the R and S waves of a duckling QRS complex, this 'And' gate design serves as a simple feature detection circuit for discriminating between heart beats and physiological noise, for example, muscle artifact, which rarely exceeds both the R and S waves in amplitude with the filter settings employed (Figure 2). The second one-shot remains high for 100 ms, during which triggering of the first one-shot has no effect. This 'refractory' period is less than the minimum period for heart beats in ducklings of this age (about 110 ms) and thus does not affect the counting of heart beats. It does serve, however, as a further mechanism for ensuring that physiological noise does not trigger the system. Output from the second one-shot causes a flip-flop to latch high; this in turn sends the common interrupt request buffer low, interrupting the execution of the main basic program (see below).

The auditory stimulus signal is passed through an

active rectifier (Figure 1) that amplifies the positive portion of the waveform. The resultant signal is then fed into a three pole low pass filter (set at 1 kHz) that creates an envelope of the waveform. The envelope is then fed into a Schmitt trigger, the output from which passes into a one-shot, which in turn causes a flip-flop to latch high. This causes a main program interrupt in the same way as the EKG processing hardware.

Computer Software

Interrupts caused by either channel in the interface hardware are dealt with by a handling routine in machine language. The routine determines which channel has caused the interrupt, increments the appropriate counter and resets the signal processing components. Since a rapid response to the start of the auditory stimulus is important, the handling routine gives priority to interrupts caused by auditory stimulus signals.

The main program was written in 'Applesoft', a floating point basic language, and then compiled for rapid execution with the 'Tasc' compiler (Microsoft, Inc.). This program is principally a timing loop that compares initial and current clock readings (from a Mountain Hardware clock in slot 6) until a specified sampling period is reached. The heart beat counter is then read and its contents stored in an array table that is continuously displayed on a video screen. Printout of the table contents may be obtained at any time by the experimenter by means of an external switch. The auditory signal counter is polled to determine whether an auditory stimulus is occurring. A number greater than zero in this counter serves as a 'flag' and causes the software

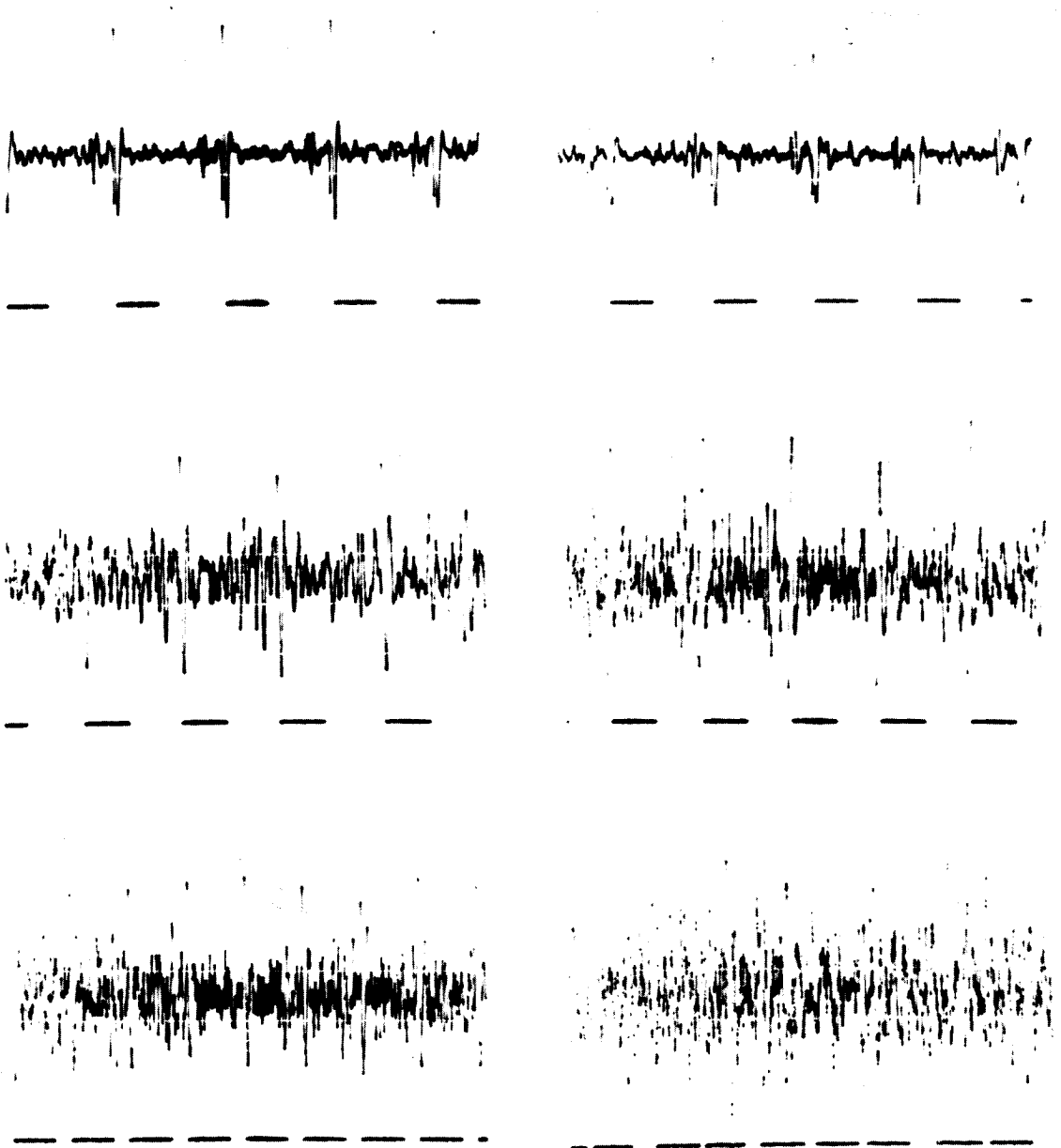


Figure 2. Photographs of 10 s oscilloscope traces. Top channel, input physiological signal; bottom channel, dashes are periods during which the second one-shot is high.

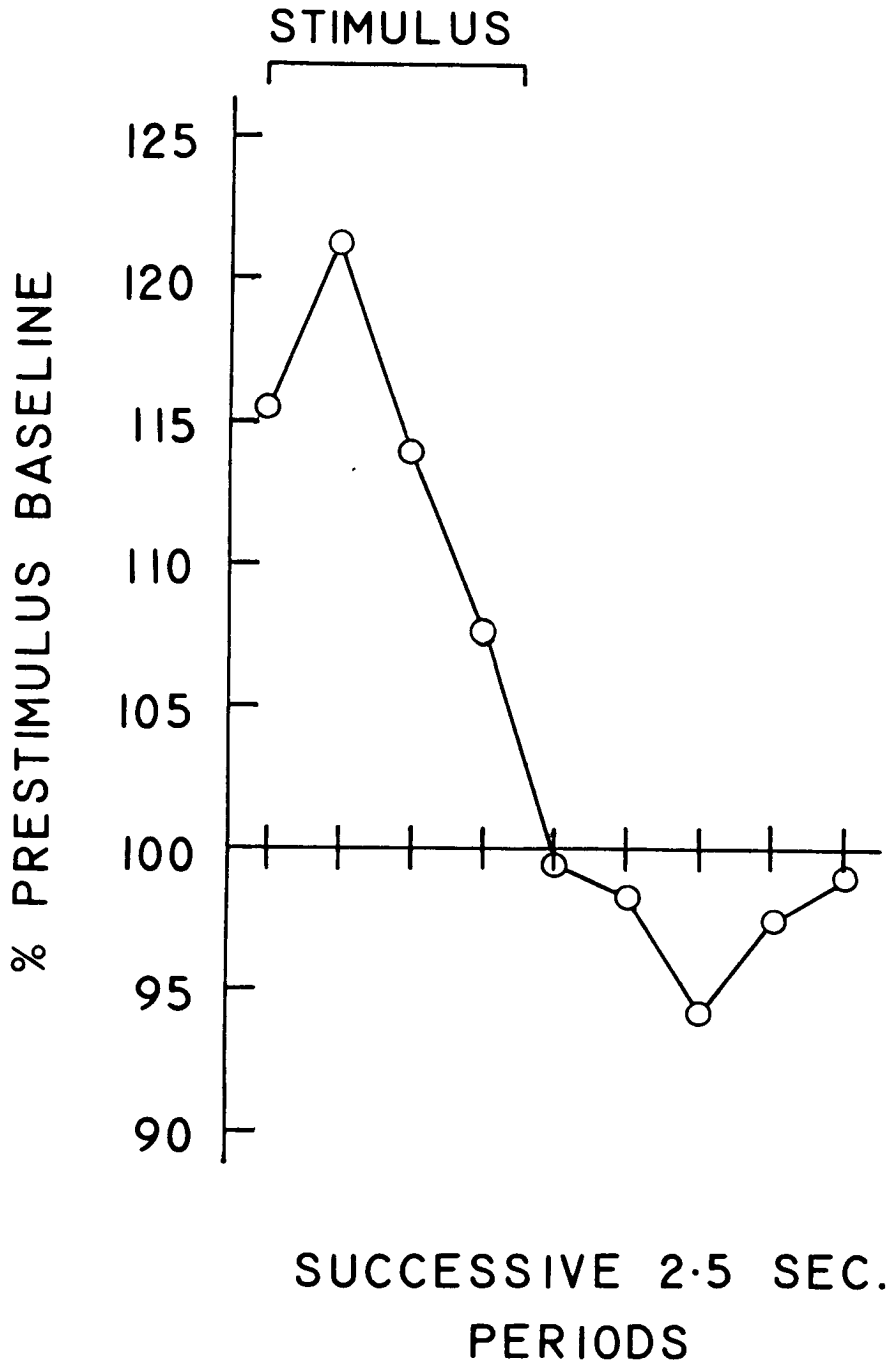


Figure 3. Mean heart rate as a percentage of pre-stimulus baseline, for seven ducklings presented with a 10 s conspecific distress call.

variable for elapsed time to be reset, thus synchronizing the start of a sampling period with the start of the auditory stimulus. Counts of heart beats obtained during sampling periods are specially marked so that they are obvious in the printout table.

Results

Figure 2 presents oscilloscope traces from the test sessions of six birds tested with this system. The top channel of each trace shows one second of the tape recorded physiological signal, and the bottom channel shows the firing of the second one-shot in response to the heart beats (see Computer Interface Hardware above). Note that the computer accurately counts heart beats in all cases, except for the input signal presented in the lower right corner.

Figure 3 presents some preliminary data on the changes in heart rate in response to conspecific distress calls for seven ducklings tested with this system. The overall biphasic pattern has frequently been reported in the cardiac response literature (2).

Discussion

Although the system described here is currently employed to examine heart rate changes in birds, it has a variety of other applications. Since adjustable potentiometers were used to control both Schmitt trigger

thresholds and one-shot durations, these components may accommodate a wide range of input waveforms. Phasic signals other than heart beats, such as plethysmograph output, may be counted, and events of particular importance 'marked' in the data table using the second channel. In addition, since the Apple II can easily handle more channels of interface hardware, the system could be developed to handle more than two input waveforms, and thus could provide a real alternative to multi-channel polygraph analysis.

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