Microprocessor Based Control of Electromechanical Devices by Using Electromyogram: A “Cricket Car” Model

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***Abstract*—The Cricket Car is a remote control car that uses electromyographic (EMG) signals to drive the car. Electrodes are inserted into the legs of the common field cricket and the myoelectric signal, also known as a motor action signal, is amplified. This amplified signal is then acquired by the PIC16F88 processor. Using threshold detection and conditional logic algorithms, the PIC processor sends command signals to the circuit of a remote control car. Features such as object/collision detection, cricket stimulus, and additional signal processing algorithms have been studied and developed. The project has been incorporated into a neuroengineering course. Continuation of this project by undergraduate and graduate students will serve as the impetus for further improvements.**

I. Introduction

The applications of biological signal-processing range from neurological disorders to cognitive based prosthetic devices. Common to all applications is acquiring the signal itself. Often, the type of electrodes used, the design of the pre-amp, the filtering, and the algorithm used to process the digitized signal have a combined synergy that can either enhance or degrade the overall process. To address this problem, the biomedical engineering lab at the University of Rhode Island has developed a microprocessor based circuit which acquires and processes electromyographic signals (EMG) from the hind legs of the common field cricket and uses those signals to drive a remote control car. While this particular application is somewhat lighthearted in nature, the underlying methodologies have much more serious implications, as the object of the processed signal could just as easily be a motorized wheel chair for a cerebral palsy patient instead of a remote control car. This project investigated several of the many segments of this acquisition system, including the biocompatibility of electrodes, the acquisition of the biological signal, and the processing of those signals. It has served as an effective project to attract the interest of students and to engage them in neuroengineering research.

II. Methods

A. The Interface

Figure 1 shows a prototype of the cricket (A), a cricket and an IC socket for the interface (B), and a typical EMG recording from the hind leg (C). Crickets belong to the Phylum Arthropoda, Class Insecta, and Order Orthoptera. They have a single giant nerve which runs through the center of the femur (Figure 2). It is this nerve that is responsible for the EMG signals used to drive the car. Using stainless steel insect pins as electrodes, the cricket is attached to the circuit in much the same way an IC would be - by using a socket. Two electrodes, one in each hind leg, are used to acquire the signals while one electrode placed in the abdomen is used as a reference. This allows for the use of a two channel preamp which is used to differentiate left and right movements. The proximity of the cricket to the circuit serves two purposes. First, the signal from the leg is susceptible to ambient noise unless the leads are either shielded or extremely close to the amplifier. Second, the cricket needs to be positioned on the car so that it will have a visual reference to its surrounding. This second benefit may sound somewhat superfluous but if the cricket is to have any behavioral input, it is necessary that the cricket have the same field of view that it would ordinarily have in its standard environment.

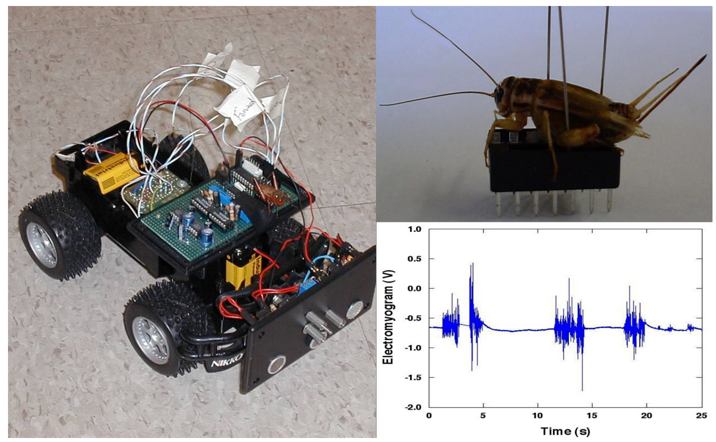

Fig. 1. (a) A prototype cricket car at left, (b) a cricket interface with an IC socket at top right, and (c) an EMG recording from the hind leg at bottom right.

The electrodes used for the signal pickup are standard stainless steel insect pins (Fig. 1B). One issue that has been observed as a result of using this pin is a discoloration of the pin entrance sites on the crickets legs and abdomen. In [1-4], a copper or silver wire was used and no discoloration was noted but our choice of pins helps also in the restraint of the cricket. While the pin remains intact, it is obvious that there is some interaction between the steel and the tissue. It is hoped that the switch to surgical grade steel pins will resolve any

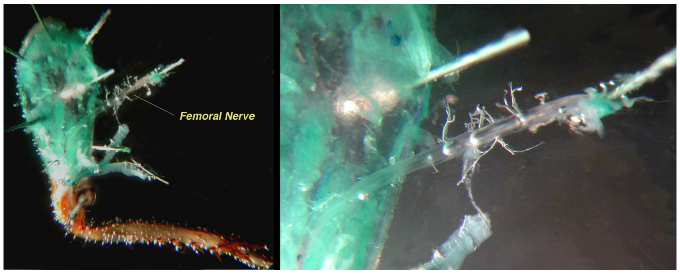

Fig. 2. The hind leg of the cricket with exoskeleton removed and stained with methylene blue (Left); The giant nerve through the center of the femur (Right).

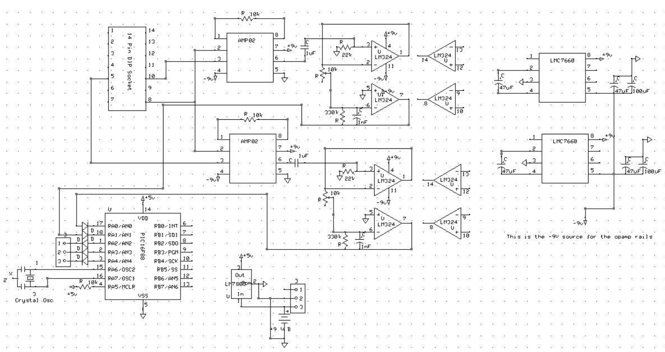

Fig. 3. Schematic diagram of the cricket car EMG acquisition circuit.

issues that may arise as a result of this interaction. This is a precautionary action as no significant adverse effects have been observed besides the discoloration. There may be issues related to the long term usability of any one cricket as the area most likely will suffer some signal degradation.

B. The Circuit

Measuring signals on the order of 0.1mA or less requires careful attention to details that ordinarily may be overlooked when measuring stronger signals. As with many signal acquisition situations, signal to noise ratio (SNR) is the main consideration. The difficulty here is that the signal is of such low power that even small amounts of noise keeps the ratio low. Long, small wires, such as those used as electrode leads, make excellent antennas and as such pick up 60Hz electrical noise. To address this issue, the circuit was designed in such a way as to keep the signal wires short, limiting the noise contamination.

The circuit (Figure 3) is a standard two channel preamp using Analog Devices AMP02 instrumentation amplifiers followed by National Semiconductor LM324 opamps. High pass filters are used to eliminate DC components and low pass filters are used for noise reduction. Similar to [1,2], a bandwidth of 300-3000Hz was chosen for the filters. The circuit is powered by a single 9V battery. In order to generate the -9V for the negative rails of the opamps, a charge pump is needed. This pump is built using National Semiconductor LMC7660 Switched Capacitor Voltage Inverter ICs. Two LM324 Quad opamp ICs are used for this circuit, however only 4 of the available 8 opamps are utilized- two from each opamp. This leaves four opamps for future use as either increased gain or active filters. Each of the two channels operates independently of the other. This is a useful feature in that any difficulties that arise in the operation of the circuit can quickly be isolated and segmented, making debugging a much less tedious exercise.

C. Collision Detection

As an input to the PIC processor, the object/collision detection circuit has override abilities in case the car comes close to another object or obstacle. Using an ultrasonic transmitter and receiver, collisions are avoided by measuring the return wave from the obstacle, i.e. echo location. Beam angle for these devices is measured at 60and as such one transmitter is incapable of providing front-end collision detection. The decision was made to include two transmitters, one on each front corner of the car. This will provide effective overlap in the center of the front-end as well as providing sufficient protection to the corners. The frequency, 40 KHz, is controlled by a network of resistors and capacitors with National Semiconductors LM555 timer while the transmitter is driven by the Texas Instruments CD4049UB inverting hex buffers. Each buffer is capable of delivering 10mA of current. Two buffers are used in parallel to supply 20mA of uninterrupted current, more than enough to drive the transmitter.

III. Discussion

A remote control car that is driven by a cricket has been proposed. Further research is being performed into the stimulation of the cricket to increase activity, behavioral examination to prolonged car use in an environment, and human EMG acquisition for electromechanical device control. In addition to further graduate research, the project should serve as a model to build undergraduate courses in biomedical engineering. Using a commercially available RC car, students will be required to demonstrate an ability to 1) understand basic electrophysiological processes as well as insect anatomy 2) understand, construct and improve signal amplifiers and filters and 3) formulate an algorithm in the C++ programming language capable of detecting, differentiating and interpreting different myoelectric signals.

Acknowledgments

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