A MICROCONTOROLLER-BASED TELEMETRY SYSTEM FOR SYMPATHETIC NERVE ACTIVITY AND ECG MEASUREMENT

Eiich Harada
Department of Electronics, Hiroshima Institute of Technology, Hiroshima 731-51, Japan.

Yoshiharu Yonezawa
Department of Electronics, Hiroshima Institute of Technology, Hiroshima 731-51, Japan.

W. Morton Caldwell
Caldwell Biomedical Electronics, 510 Villa Ave. White Sulphur Springs, West Virginia 24986.

A. W. Hahne
Department of Veterinary Medicine and Surgery, University of Missouri-Columbia, Missouri 65211.

INTRODUCTION

It is well known that in awake animals the heart and blood vessels are influenced directly from higher central nervous system through autonomic neural controls, as well as reflexly from various receptors. Therefore, we required a small and long-term telemetry system for cardiovascular neural control research with conscious animal preparations. A number of radio and optical telemetry systems have been developed to record ECG, pressure and nerve signals [1-3]. However, radio telemetering in animal cages, especially metal enclosures, frequently encounters signal dropout problems. The main causes of dropout are multipath signal transmission and antenna directivity within the cage RF transmission environment. An infrared optical telemetry system was previously developed to solve the radio telemetry system problems, but its fairly high power consumption requires a large battery.

A new low power microcontroller-based telemetry system, employing an 8-bit microprocessor and a minimum parts count, was developed to fill the need for continuous recording of ECG and nerve signals. This report details the two channel, time multiplexed, digitally coded system, which is used in a metal animal cage for prevention of radio and 60 Hz interference. A high input impedance amplifier in the cage directly receives ECG and the nerve signal digital code generated by the microcontroller, which eliminates the inclusion of conventional RF transmitter and receiver stages.

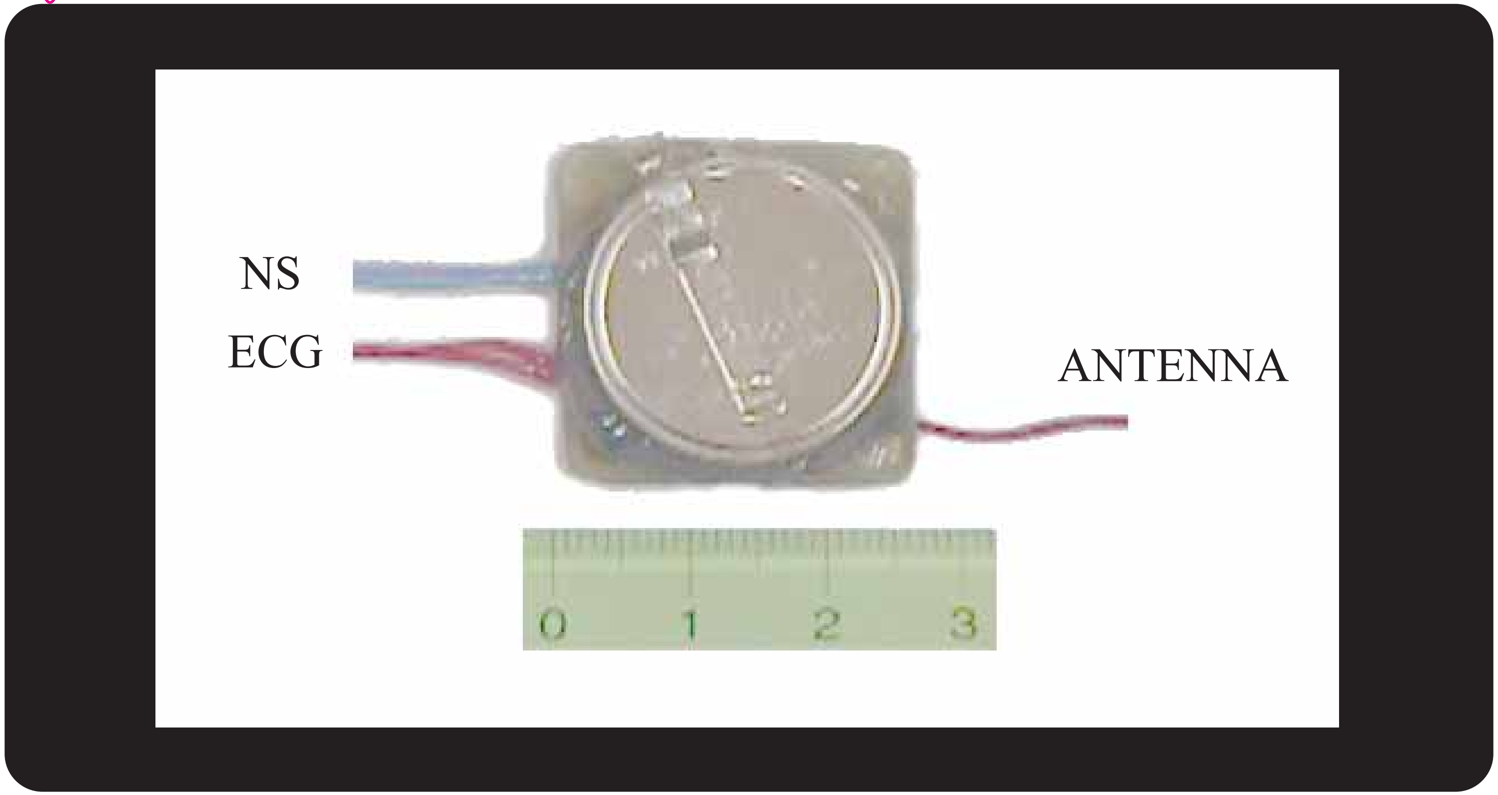

Fig.3 A new low power microcontroller-based telemetry system. The circuit is constructed on two 25×25 mm printed circuit boards and encapsulated in epoxy, yielding a total volume of 6.25 cc. The weight is 15g.

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SYSTEM DESCRIPTION

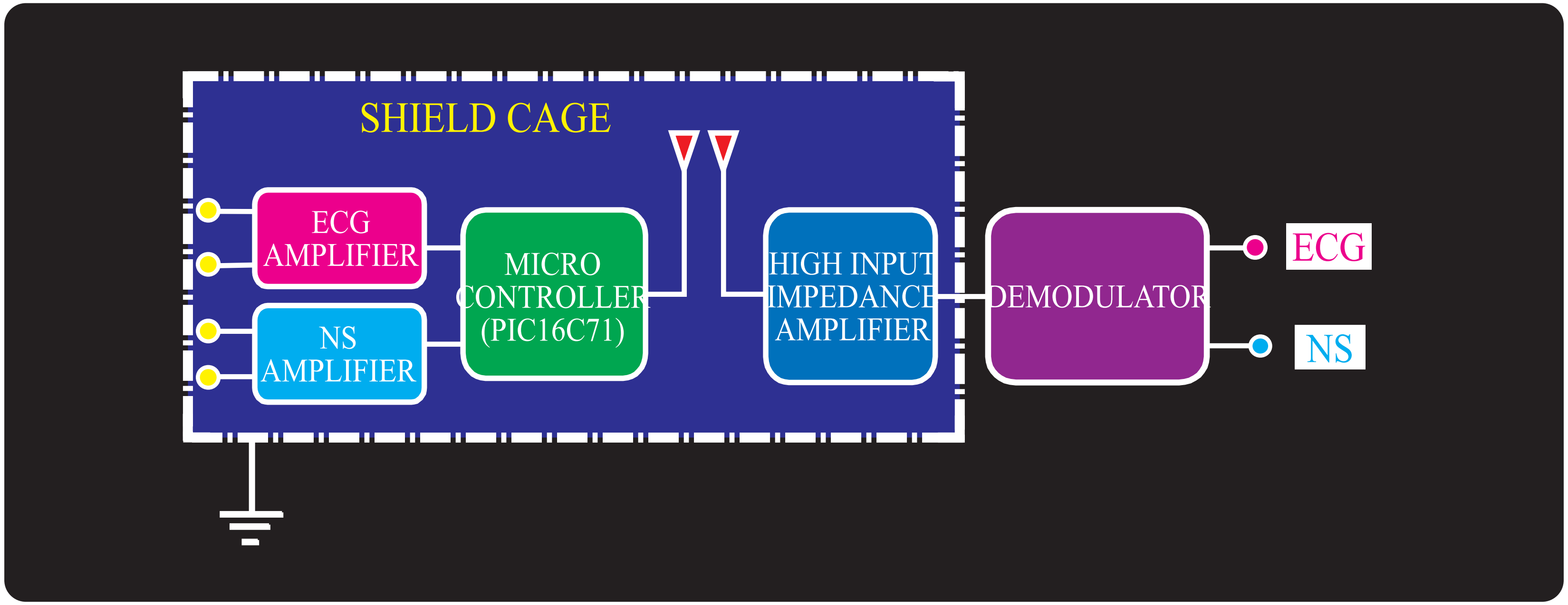

Fig.1 The overall telemetry system block diagram. The telemetry system is used in shielded animal cage to prevent radio and 60Hz interference. The animal-carried transmitter consists of ECG and nerve signal amplifiers, and an 8-bit microcontroller. Analog signals from implantable ECG and nerve electrodes are converted to an 8-bit serial digital format by individual A/D converters in the microcontroller. The converted serial binary code is applied directly to an antenna wire. The receiver is a high input impedance amplifier. A demodulator, which converts the received code to the original analog ECG and nerve signals, is comprised of a microcontroller and a D/A converter.

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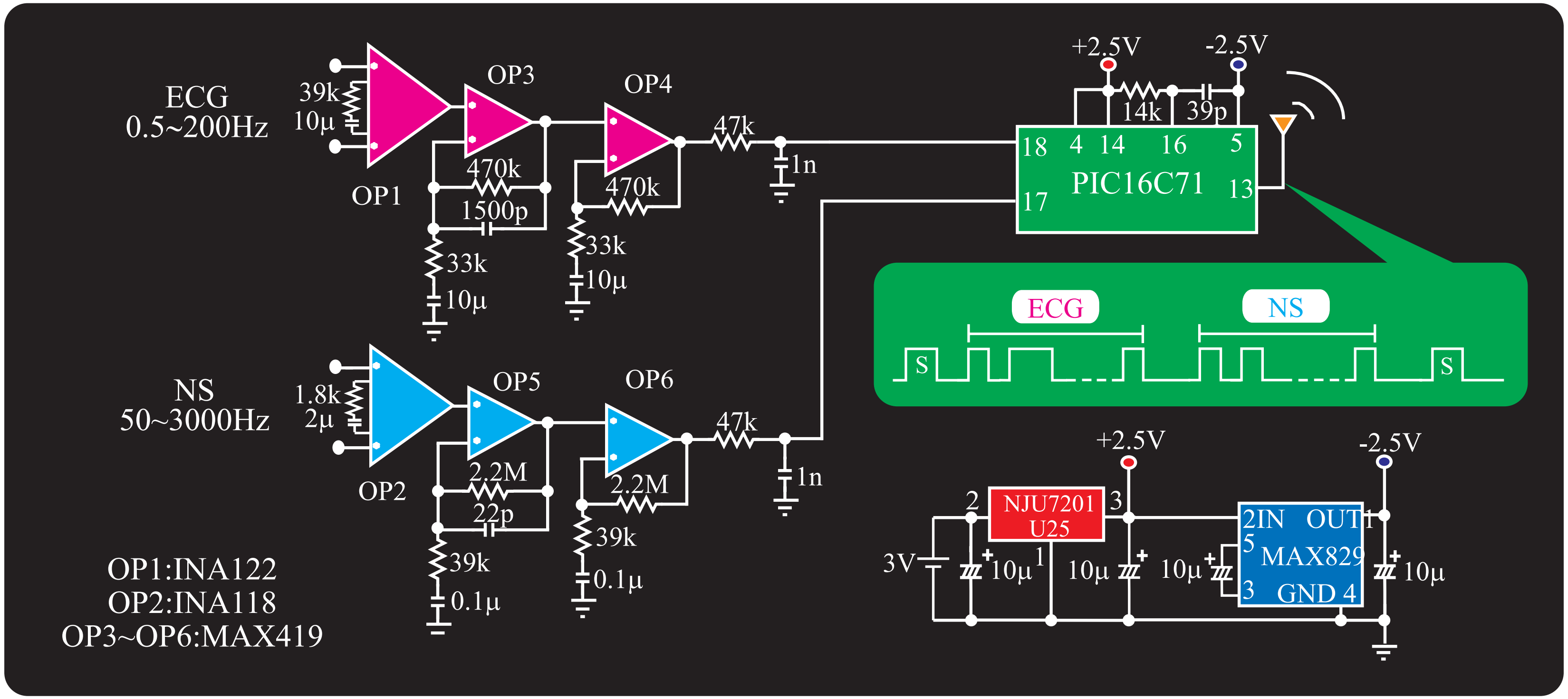

Fig.2 The detailed telemeter circuit diagram. The instrumentation amplifiers for ECG and nerve signal are designed with ultra low-power instrumentation amplifiers (INA118) and ultra low-power operational amplifiers (MAX419). The microcontroller (PIC16C71) is an 8-bit COMS RISC-like CPU with analog converters. The microcontroller converts the amplified ECG and nerve signals at a 6 kHz rate to an 8-bit digital code and then the microcontroller outputs a 24-bit serial digital data format. The power consumption is 6.2mW. The telemeter is powered by a small 3V lithium battery (CR3023), which provides 100 hours of continuous operation.

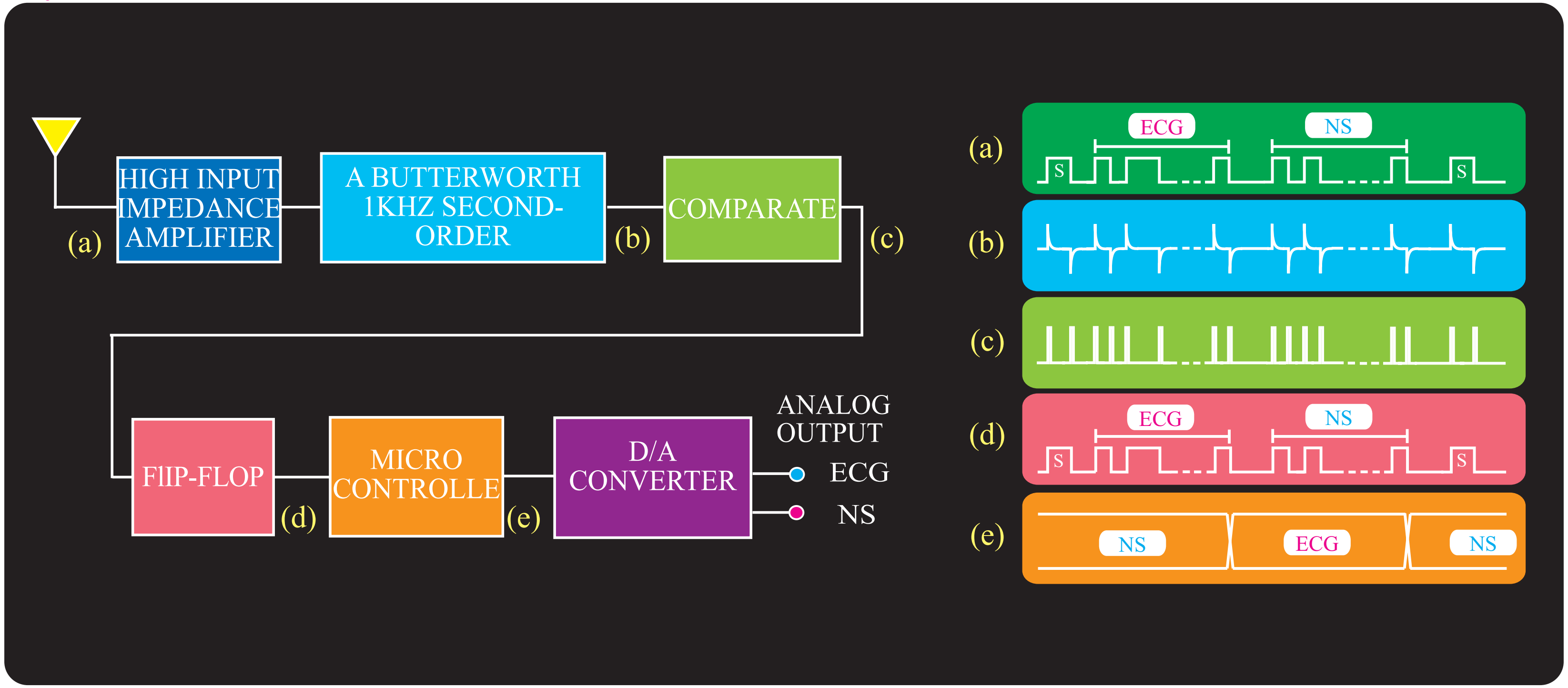

Fig.4 The receiver and demodulator circuit diagram. The transmitted code train is received by a high input impedance amplifier placed in the cage. However, it is impossible for the shielded cage to completely protect serial binary code from external radio signals and 60 Hz power line noise. Therefore, the amplified code contains external noises. A Butterworth 1 KHz second-order high pass filter eliminates the power line noise and simultaneously detects the rising and falling edges of the amplified code train. The amplified code train is converted to parallel code by the demodulator circuitry. The parallel codes are then converted to analog ECG and nerve signals by two D/A converters, respectively.

RESULTS

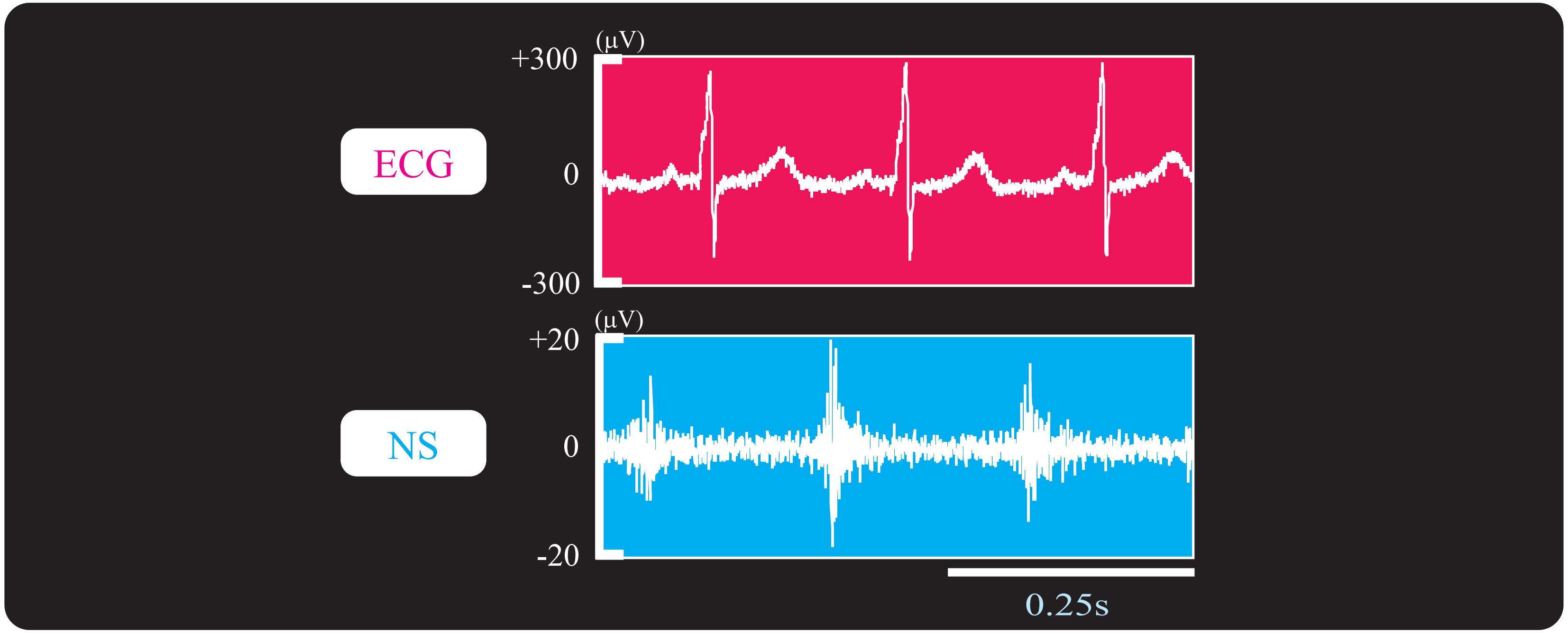

Fig.5 The ECG and renal nerve activity (NS) waveforms recorded from a chronically instrumented cat. Under sodium pentobarbital anesthesia, a bundle of nerve fibers from the left renal nerve was separated from the renal plexus located near the renal artery and vein and the recording electrode was attached to the nerve bundle. For recording ECG, a pair of wires (Ag, OD = 0.5 mm) was implanted in both sides of the chest wall. The electrode lead cables are soldered directly to the telemeter. The telemeter package was placed on the back. The recorded renal nerve discharge patterns are regular and show a grouped activity synchronous with the cardiac cycle.

CONCLUSION

The telemetry system employing the low power 8-bit microcontroller has been developed for chronic unanesthetized small animal studies. The system is used in the shielded animal cage to reduce interference from external radio signals and 60 Hz power line noise. Analog signals from implantable ECG and nerve electrodes are converted to the 8-bit serial digital format, and then the code is applied directly to the antenna wire. The code is received the high input impedance amplifier in the cage. Therefore, the system does not need to employ a separate transmitter, such as in FM or infrared optical telemeters. The telemeter is powered by a small 3 V lithium battery, which provides 100 hours of continuous operation. The circuit is constructed on two 25 × 25 mm printed circuit boards and encapsulated in epoxy, yielding a total volume of 6.25 cc. The weight is 15g.

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