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Neural Signal – Action Potential Spike Count Transmision Through Embedded Wireless Mote

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Abstract

To enable a wireless neural recording system that benefit to finding the disease from the nerves system is remotely monitoring as prevention is better than cure. The neural recording system is counting the spike value from the defective nerve system of the patient that signal be transmit through the wireless network then the signal capture from the hospital and compare with past trials. So we detect the disease before it from the patient. The system consists of commercial-off-the-shelf wireless-enabled processor modules for communicating the neural signals, and a back-end database server and client application for achieving and browsing the neural signals. A neural-signal-acquisition application has been developed to enable the neural signals at a rate of 4000 12-bit samples per second, or detect and transmit spike heights and widths sampled at a rate of 16670 12-bit samples per second on a single channel. The motes acquire neural signals via a custom low-noise neural-signal amplifier with adjustable gain and high-pass corner frequency that has been designed, and fabricated in a 1.5- m CMOS process.

Keywords: Transmitter, neuroprosthetic, TelosB, Moteiv, TinyOS.

Introduction

Neuroscientists typically acquire neural signals from implanted depth electrodes interfaced with a recording apparatus via a bundle of fine wires. However, in Many cases it is preferable to acquire these signals when the test subjects are undeterred, freely behaving, and even interacting. Existing wireless neural-recording systems range from fully integrated analog transmitters, to analog transmitters with threshold- based spike detection to digital application – specific integrated circuits (ASICs), to microcontroller – based embedded systems, to commercial – off – the – shelf (COTS) PC–based systems. Fully integrated transmitters and ASICs benefit from being very small (several) and low-power (several mWs), thus enabling them to be implanted with the electrode and inductively powered. However, fully integrated approaches provide limited user-configurability while requiring considerable re-engineering for incorporating minor design or algorithmic changes. Microcontroller-based embedded systems are larger (several cm), and consume more power (tens of mWs), to the point where their lifetime is limited when using small batteries. However, these systems require less engineering to develop and to provide users with a higher degree of signal-processing flexibility. COTS PC-based systems are large and heavy (greater than 0.1 kg), while providing nearly the level of signal processing and communications that is available to a PC-class device. In the interest of increasing channel count and sampling rate while maintaining reasonable battery life, some groups have demonstrated solutions with some on-board signal-processing capability, such as threshold as demonstrated in and. Unfortunately, these threshold – based systems typically cannot differentiate spikes from artifacts, and require circuit redesign for modifying the detection algorithms. The limited adoption of existing wireless neural recording systems by the neuro scientific community may be an indicator that users could benefit from a greater degree of flexibility in terms of methods for spike detection. An attractive solution would leverage advances in an underlying, commercial architecture, in a manner similar to PCs, but without the upfront power penalty associated with the platform. Researchers have developed a wireless platform for small, low-power, and low-cost embedded sensors using COTS microcontrollers and transceivers. This effort led to the development of nesC, an extension to the C programming language designed to embody the structuring concepts and execution model of Tiny OS. Tiny OS is an event-driven operating system designed for sensor-network nodes that have limited memory and computational resources (e.g., 8 kB of program memory, 512 B of RAM). Tiny OS enables developers to access low-level hardware resources at the application level, thus resulting in a level of data-acquisition and communications flexibility that is unavailable to other existing mainstream wireless communications technologies.

This inherent flexibility enables Tiny OS developers to realize high-frequency real-time peer-to-peer communications systems (e.g., one node streaming neural signals captured at over 10 kHz to another node), as well as low-duty-cycle mesh networks.

Literature Survey

1. Active semiconductor neural probe.
2. MICA-2Based wireless neural interface.
3. Embedded electrophysiological recording.
4. G-Node integrated tool sharing to support neurophysiology.

Active semiconductor neural probe

In their paper [3], kyunghwan et al propose a systematic design guideline is presented for the noise performance of preamplifier for semiconductor neural probe which contains on-chip electronic circuitry. The overall signal-to-noise ratio (SNR) is calculated considering the spectral characteristics of the measured extra cellular action potential and the low-frequency noise spectrum of the CMOS device from typical fabrication processes. An analysis of the output SNR of a two-stage CMOS differential amplifier is given and the major factors which have significant effects on the SNR are determined. Metal microelectrodes are typically used for this purpose [3], [8], but they possess limitations, in that it is difficult to manufacture such electrodes with reproducible tip sizes and shapes.

Advantages

- Semiconductor Microelectrodes simultaneous recording of signals.
- Perform amplification and Multiplication.

Disadvantage

- Poor Noise Characteristics.

MICA2-Based wireless neural interface

Existing approaches used to develop by Shahin et al [5] compact low-power multi-channel wireless neural recording systems range from creating custom integrated circuits to assembling commercial-off-the-shelf (COTS) PC-based components. COTS-PC-technology yields high performance at the expense of large system size and increased power consumption. To achieve a balance between implementing an ultra-compact custom-fabricated neural transceiver and assembling COTS-PC-technology, an overlay of a neural interface upon the TinyOS-based MICA2 platform is described [2]. This data rate can be divided for recording on up to 6 channels, with a resolution of 8 bits per sample at a peak sampling rate of 1.2 kHz per channel.

Existing approaches to develop a wireless EEG measurement tool have ranged from designing a custom microfabricated recording and telemetry system [11], [9].

Advantages

- Greater degree design flexibility.
- Ability to optimize subsystem.
- Minimize power consumption, noise.
- Increasing signal – noise Ratio.

Disadvantages

- Neural Interface uses mainstream PC – cots technology.
- Bulky and Power intensive.
- Not designed for truly compact low – power applications.
- Fabrication N-Well Process.

Embedded electrophysiological recording

Jack et al [6] describes a fully-integrated, differential, dual-channel, gain-adjustable and bandwidth-adjustable neural preamplifier circuit. This chip has been designed to enable commercial-off-the-shelf (COTS) embedded-networked sensors (ENS) to acquire electrophysiological signals from mobile test subjects, while allowing for the user to remotely adjust amplifier gain and high-pass filtering characteristics for dynamically switching between local field potential and spike acquisition. A novel method for realizing a wireless neural recording system is the over lay of biological recording system upon in embedded wireless sensing and communication platform [5], [12]. Fabrication in a standard dual-poly dual-metal 1.5-µm process. Simulated input-referred noise is 4.4 µVrms between 0.5 and 5000 Hz.

Disadvantage

- Inability of user to select between different signals of interest.
- Amount of noise being coupled into the system via the wires.

G-Node integrated tool sharing to support neurophysiology

The global scale of neuroinformatics offers unprecedented opportunities for scientific collaborations between and among experimental and theoretical neuroscientists.to fully harvest these possibilities, a set of coordinated activities is required that will improve three key ingredients of neuroscientific research: data access, data storage, and analysis, together with supporting activities for teaching and training. Focusing on the development of tools aiming at neurophysiological dat, Andreas et al [8] newly established German Neuoinformatics Node (G-Node) [10] aims at addressing these aspects as part of the International Neuroinformatics Coordination Facility (INCF).

2.4.1 Disadvantages

- Date access problem.
- Impossible to share data with colleagues. Data storage

Current System

Introduction

The doctor finding a disease is an abnormal condition affecting the body of an organism. It is often constructed to be a medical condition associated with specific symptoms and signs. It may be caused by external factors, such as infectious disease or it may be caused by internal dysfunctions, such as autoimmune diseases. Ecologically, disease is defined as maladjustment of a body with environment. In humans, “disease” is often used more broadly to refer to any condition that causes pain, dysfunction, distress, social problems, and/or death to the person afflicted, or similar problems for those in contact with the person. In this broader sense, it sometimes includes injuries, disabilities, disorders, syndromes, infections, solvated symptoms, deviant behaviors, and atypical variations of structure and function, while in other contexts and for other purposes these may be considered distinguishable categories. A diseased body is quite often not only because of some dysfunction of a particular organ but can also be because of a state of mind of the affected person who is not at ease with a particular state of its body.

Drawbacks in existing system

In clinical practice doctors personally assess patients in order to diagnose, treat, and prevent disease using clinical judgment. The doctor-patient relationship typically begins an interaction with an examination of the patient's medical history and medical record, followed a medical interview and a physical examination. Basic diagnostic medical devices (e.g. stethoscope, tongue depressor) are typically used. After examination for signs and interviewing for symptoms, the doctor may order medical tests (e.g. blood tests), take a biopsy, or prescribe pharmaceutical drugs or other therapies. Differential diagnosis methods help to rule out conditions based on the information provided. During the encounter, properly informing the patient of all relevant facts is an important part of the relationship and the development of trust. The medical encounter is then documented in the medical record.

Proposed System

Architecture

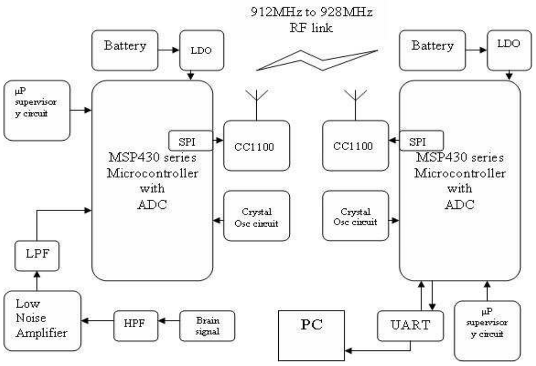

Figure 4.1. proposed architecture

Description

Our modular neural-recording system shown in Fig. 4.1 that benefit from advances in embedded microcontroller technologies and enable the user to implement custom filtering algorithms without re-implementing the entire application. Hardware and software has been designed to enable motes to acquire, process (in a programmable and modular fashion), and transmit neural signals. Specifically, we have developed 1) a neural-signal amplifier chip that can be interfaced directly to a microcontroller ADC for the selective acquisition of spikes and field potentials, 2) an application based upon a dynamically tunable signal-acquisition, filtering, and transmission framework [11] for spike detection, and 3) a back-end system architecture for receiving, archiving, hosting, and browsing the neural signals

Neuron Electric Potentials

Action Potential

1. short-lasting event in which the electrical membrane potential of a cell rapidly rises and falls, following a stereotyped trajectory
2. Caused by special types of voltage gated-ion channels embedded in a cell's plasma membrane
3. triggered when enough depolarization accumulates to bring the membrane potential up to threshold.

Stages of Action potential

1. Rising phase
2. Strong depolarization (increase in Vm) causes the voltage-sensitive sodium channels to open; the increasing permeability to sodium drives Vm closer to the sodium equilibrium voltage ENa≈ +55 mV. The increasing voltage in turn causes even more sodium channels to open, which pushes Vm still further towards ENa. This positive feedback continues until the sodium channels are fully open and Vm is close to ENa. The sharp rise in Vm and sodium permeability correspond to the rising phase of the action potential
3. Peak and Falling Phase

4. When membrane potential reaches the sodium equilibrium potential ENa≈ +55 mV, Sodium channel closes down and open potassium channel for its ion flow. This makes the membrane potential now falling towards potassium ion equilibrium voltage of -75mV, thus re-polarizing the membrane and producing the "falling phase" of the action potential
5. Refractory period
6. Even after a sufficient number of sodium channels have transitioned back to their resting state, it frequently happens that a fraction of potassium channels remains open, making it difficult for the membrane potential to depolarize, and thereby giving rise to the relative refractory period

Low-noise Instrumentation Amplifier for Neural Signal Sensing

The instrumentation amplifier design for implantable biomedical devices and systems with a 140-dB CMRR (common-mode rejection ratio). The proposed IA is composed of 3 stages, including a pre amplifier, a 2nd-order BPF (band-pass filter), and a DC-level shifter and output buffer stage. A low-noise gm-C amplifier is used in the pre-amplifier stage so as to reduce the coupled thermal noise which might overwhelm the weak neural signals. The BPF is designed based on an OTA (operational transconductance amplifier) with dual current switches aiming at the low power as well as low noise demands. A source follower is employed to carry out the DC-level shifter and the output buffer, which provides an output signal adequate to drive the following stage, which is usually an ADC (analog to digital converter). Detailed analysis of the proposed circuitry is derived to solidify the proposed architecture. The proposed design is implemented using TSMC 0.35 m 2P4M CMOS process. The results of post-layout simulations verify the performance of our design. The CMRR is better than 140 dB, and, most important of all, the input noise (RMS) is merely 23.28 dB at all PVT (process, supply voltage, temperature) corners.

Neural Signal Recording

Recent work in field of neuro prosthetics has demonstrated that by observing the simultaneous activity of many neurons in specific regions of the brain, it is possible to produce control signals that allow animals or humans to drive cursors or prosthetic limbs directly through thoughts. As neuroprosthetic devices transition from experimental to clinical use, there is a need for fully-implantable amplification and telemetry electronics in close proximity to the recording sites. To address these needs, we developed a prototype integrated circuit for wireless neural recording from a 100-channel microelectrode array. The design of both the system-level architecture and the individual circuits were driven by severe power constraints for small implantable devices; chronically heating tissue by only a few degrees Celsius leads to cell death. Due to the high data rate produced by 100 neural signals, the system must perform data reduction as well. We use a combination of a low-power ADC and an array of “spike detectors” to reduce the transmitted data rate while preserving critical information. The complete system receives power and commands (at 6.5 kb/s) wirelessly over a 2.64-MHz inductive link and transmits neural data back at a data rate of 330 kb/s using a fully-integrated 433-MHz FSK transmitter. The 4.7 X 5.9 mm2 chip was fabricated in a 0.5- m 3M2P CMOS process and consumes 13.5 mW of power. While cross-chip interference limits performance in single-chip operation, a two-chip system was used to record neural signals from a Utah Electrode Array in cat cortex and transmit the digitized signals wirelessly to a receiver.

Boosting

Boosting is a general method for improving the accuracy of any given learning algorithm. This short overview paper introduces the boosting algorithm Ada Boost, and explains the underlying theory of boosting, including an explanation of why boosting often does not suffer from over fitting as well as boosting’s relationship to support-vector machines.

Low – pass filter

A low-pass filter is a filter that passes low frequency signals but attenuates (reduces the amplitude of signals) with frequencies higher than the cutoff frequency. The actual amount of attenuation for each frequency varies from filter to filter. It is sometimes called a high-cut filter, or treble cut filter when used in audio applications. A low-pass filter is the opposite of a high-pass filter, and a band-pass filter is a combination of a low-pass and a high-pass.

Low-pass filters exist in many different forms, including electronic circuits (such as a hiss filter used in audio), digital filters for smoothing sets of data, acoustic barriers, blurring of images, and so on. The moving average operation used in fields such as finance is a particular kind of low-pass filter, and can be analyzed with the same signal processing techniques as are used for other low-pass filters.

TinyOS

TinyOS is a free and open source component-based operating system and platform targeting wireless sensor networks (WSNs). Tiny OS is an embedded operating system written in the nesC programming language as a set of cooperating tasks and processes. It is intended to be incorporated into smart dust. Tiny OS started as collaboration between the University of California, Berkeley in co-operation with Intel Research and Crossbow Technology, and has since grown to be an international consortium.

Advantages of proposed system

In the next few years, medical technology innovations will fundamentally transform the health care delivery system, providing new solutions with medical devices that will challenge existing paradigms and revolutionize the way treatments are administered.

Hardware Description

The type of mote used in this work is the TelosB mote produced by Crossbow Technology Inc. (San Jose, CA) and Moteiv (El Cerrito, CA). Data is processed by a microprocessor (MSP430, Texas Instruments, Dallas, TX). The TI MSP430 has 8 analog input channels that are time-multiplexed onto a single analog-to-digital converter (ADC). Data transmission is handled by a ZigBee-compliant (IEEE 802.15.4) 2.4-GHz transceiver (CC2420, Chipcon, Oslo, Norway). An antenna embedded on the printed-circuit board is used for wireless communication.

The mote is interfaced with neural tissue via a custom monolithic low-noise neural-signal amplifier with adjustable gain and bandwidth.

The novel amplifier is capable of many things. Specifically, it can reject the dc offset that occurs at the tissue electrode interface,

1. amplify the neural-signal potential from
2. the order of to volts for acquiring the signal with the best possible fidelity given the 12-bit resolution provided by the microcontroller ADC,
3. dc-reference the neural signal (which oscillates above and below the animal ground) to half the battery supply voltage, to operate from the single supply used by the mote to avoid requiring additional batteries that add mass and volume to the system,
4. provide the current necessary to drive an off-chip load (i.e., the microcontroller ADC),
5. provide adjustable high-pass-filtering and gain so that LFP or spikes can be acquired selectively,
6. have low input-referred noise to acquire the neural signals with satisfactory signal-to-noise ratio, and be monolithic to enable its integration with a recording head stage, as well as the opportunity to integrate it onto the same silicon as that of a future-generation single-chip mote.

Hardware Units

The Texas Instruments MSP430 shown in figure 5.1 the family of ultra low power microcontrollers consist of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low power modes is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that attribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6μs.

The MSP430x11x series is an ultra low-power mixed signal microcontroller with a built in 16-bit timer and fourteen I/O pins. Typical applications include sensor systems that capture analog signals, convert them to digital values, and then process the data and display them or transmit them to a host system. Stand alone RF sensor front-end is another area of application.

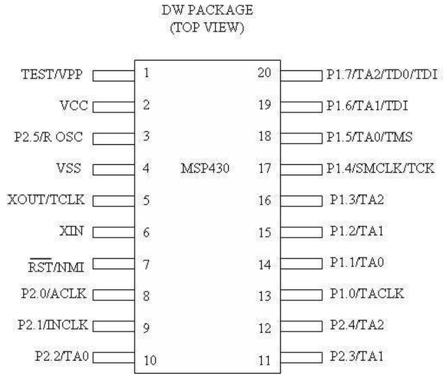

Figure 5.1 MSP430 pin diagram

CC1100 Single Chip Low Cost Low Power RF-Transceiver

The CC1100 is a low cost true single chip UHF transceiver designed for very low power wireless applications. The circuit is mainly intended for the ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency bands at 315, 433, 868 and 915MHz, but can easily be programmed for operation at other frequencies in the 300- 348MHz, 400-464MHz and 800-928MHz bands.

The RF transceiver is integrated with a highly configurable base band modem. The modem supports various modulation formats and has a configurable data rate up to 500kbps. Performance can be increased by enabling a Forward Error Correction option, which is integrated in the modem. CC1100 provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication and wake on radio. The main operating parameters and the 64- byte transmit/receive FIFOs of CC1100 can be controlled via an SPI interface. In a typical system, the CC1100 will be used together with a microcontroller and a few additional passive components. CC1100 is based on Chip con's SmartRF®04 technology in 0.18μm CMOS.

Key Features

1. Small size (QLP 4x4mm package, 20 pins)
2. True single chip UHF RF transceiver
3. Frequency bands: 300-348MHz, 400- 464MHz and 800-928MHz
4. High sensitivity (–110dBm at 1.2kbps, 1% packet error rate)
5. Programmable data rate up to 500kbps
6. Low current consumption (15.6mA in RX, 2.4kbps, 433MHz)
7. Programmable output power up to
8. +10dBm for all supported frequencies
9. Excellent receiver selectivity and blocking performance Very few external components: Totally on chip frequency synthesizer, no external filters or RF switch needed
10. Programmable base band modem
11. Ideal for multi-channel operation
12. Configurable packet handling hardware
13. Suitable for frequency hopping systems due to a fast settling frequency synthesizer
14. Optional Forward Error Correction with interleaving
15. Separate 64-byte RX and TX data FIFOs
16. Efficient SPI interface: All registers can be programmed with one “burst” transfer

Conclusion

Various methods have been developed for embedded neural recording systems. In our project the method of neural recording system counting the spike value from the defective nerve system of the patient that signal transmit through embedded wireless sensor mote. With the help of mote, we can easily detect the disease before it from the patient.

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