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November 9, 2000

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Re: ENSC 340 Design Specification for the POSSESS

Dear Dr. Rawicz:

The attached document, *Design Specification for the POSSESS* (POrtable Safety and Sleep Enhancement SyStem), describes, in detail, the technical aspects of our product. The goal of the POSSESS is to awaken a user after he or she has completed an REM stage of sleep in a user-defined time window. Doing so will allow a user to consistently awaken refreshed and alert. The POSSESS satisfies a growing consumer need. As more people trade-off sleep for work, the market for POSSESS only grows larger.

Our design specifications include information concerning our analog signal acquisition front-end, the signal conditioning filters and amplifiers, and the microcontroller and algorithms used for signal processing. Details regarding our intuitive user interface are presented, as is information on the POSSESS' verification strategy. The aesthetics of the mechanical assembly and the electrodes of the POSSESS are also discussed.

QND Medical Devices is comprised of five talented and dedicated fourth-year engineering students: David Lee, Stephen Liu, Hiten Mistry, Roch Ripley, and Matt Ward. Should you have any comments, questions, or suggestions, please feel free to contact me at (604) 421-6126 or via the e-mail address listed above. Thank you for your time.

Regards,

Roch Ripley

Roch Ripley
President and CEO
QND Medical Devices

Enclosure: Design Specification for the POSSESS

QND Medical Devices

Design Specification for the
POSSESS
Portable Sleep and Safety Enhancement System

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ABSTRACT

The **PO**rtable **S**afety and **S**leep **E**nhancement **S**y**S**tem (POSSESS) deals with the current societal problem of people trading off sleep for productivity. Instead of sleeping an ideal eight hours per night, 33 % of all Americans sleep 6 ½ hours per night in order to get more work done. Instead of driving to work or spending time at the office alert and rested, millions of people do such tasks groggily and, in some cases, dangerously.

The POSSESS addresses this problem by using a total of four electrodes to monitor a sleeping person's brainwaves and eye movements. Prior to falling asleep, the user specifies a "time window" in which he or she would like to awaken. Electrodes are then attached to a user's head and data is acquired to determine if a person is in Rapid Eye Movement, or REM, sleep. If a user leaves REM sleep during the specified time window, he or she is immediately awakened. If the user does not experience or leave an REM stage by the end of the time window, he or she is awakened regardless.

Signal conditioning involves a series of active filters and amplifiers used to eliminate 60 Hz noise and magnify brainwave signals, which are generated by the human brain with magnitudes on the order of microvolts. The POSSESS then uses an Atmel AT90S8535 microcontroller to perform a Fast-Fourier Transform (FFT) on the input data to determine a user's sleep stage. Essentially, the microcontroller is the "brain" of our system. A 20 x 4 character alphanumeric liquid crystal display (LCD) serves as a visual interface to the user, and a simple speaker produces a tone that will awaken the user when necessary. Three push buttons control a "soft menu" structure, providing a way for the user to input data to the POSSESS in an intuitive and quick fashion.

The following document describes the parts, algorithms, schematics, and verification plan for the POSSESS.

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1 INTRODUCTION

No device is currently available to consumers that allow them to consistently awaken feeling alert and refreshed. Consequently, every day millions of people awaken feeling cranky and tired. In this dangerous state, many people proceed to drive their automobile to work. Increasingly often, “morning fatigue” is becoming a synonym for “morning fatality.”

QND Medical Devices’ solution to the fatigue problem is to awaken a person only when he or she will experience minimal grogginess: after an REM stage of sleep. In other words, we’re only going to wake a person up after they’ve had some dreams. By doing so, we will be awakening the user when his or her body temperature and metabolism are at their sleeping peak; thus, the transition from sleep to consciousness is made more easily than if a standard alarm clock were used.

The POSSESS interfaces with the user via an LCD screen that displays a soft menu which is controllable through push buttons. The number of buttons is kept to a minimum so as to ensure that the interface remains uncomplicated and intuitive. We will also attempt to design the POSSESS such that any electrodes we use need not be attached through hair and cause any type of inconvenience to the user. We want the POSSESS to be as minimally invasive as possible.

The purpose of this document is to describe the design specifications of the POSSESS. The names of critical components, descriptions of software algorithms, and some hardware descriptions are included. The audience for this work is composed of Dr. Andrew Rawicz, Mr. Steve Whitmore, Engineering Science 340 teaching assistants, QND Medical design engineers, and external third party design consultants.

2 SYSTEM OVERVIEW

The POSSESS is an alarm clock that awakens a sleeping person based on his/her brainwaves and eye movements. By performing signal processing on this data, the POSSESS determines which stage of sleep the user is experiencing. Figure 1 shows a detailed block diagram that gives an overview of how the POSSESS will acquire data, condition and process it, and generate an alarm tone.

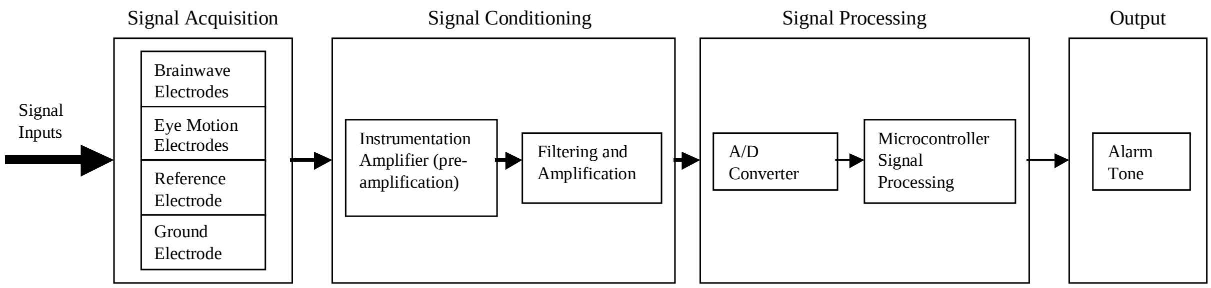

Figure 1: Detailed POSSESS Block Diagram

For normal operation, the user will use the soft menu to specify a time window in which he or she would like to awaken. Via four electrodes (two for brainwaves, one for eye movements, and one reference electrode), the POSSESS then acquires the required brainwaves and eye movements from the user. In the signal conditioning stage, the acquired signals are compared by an instrumentation amplifier and any common-mode signals (e.g.: 60 Hz noise) are rejected. The important differential signals are amplified. The amplified differential signal continues through multiple filtering and gain stages and is eventually amplified to the level required by the signal processing stage. The signal processing stage converts the analog signal it receives to a digital format for use in our Atmel AT90S8535 microcontroller. The custom software running on our microcontroller determines if a rapid-eye movement, or REM, stage of sleep terminates while the user is in his or her own defined time-window. If it is appropriate to do so, the user is awakened upon completion of the REM stage. If not, the user is awakened at the end of the time-window. For medical safety reasons, all components of the POSSESS run off power supplied by batteries.

3 SIGNAL ACQUISITION

Signal acquisition is the first stage of the POSSESS. Figure 2 highlights the Signal Acquisition stage of our signal chain.

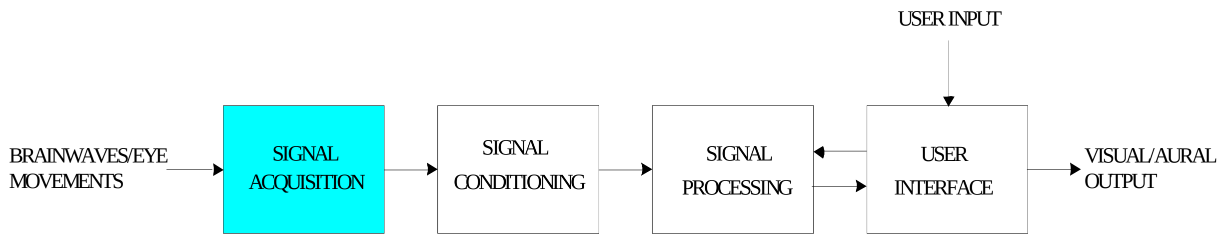

Figure 2: Context Diagram for the Signal Acquisition Stage

The POSSESS acquires input signals composed of brain waves of frequency less than 20 Hz and of amplitude ranging from tens to hundreds of microvolts. Such a range allows the POSSESS to determine when a user is, and isn't, in REM sleep. With this information, the remainder of the signal chain can determine when to awaken the user.

3.1 Electrode Placement

The POSSESS requires a total of four electrodes for proper operation: one electrode to act as a ground, one electrode to monitor eye movements, and two electrodes to monitor brainwaves. The ground electrode will be placed behind an ear while the electrode that monitors eye movements will be placed on a temple. A third electrode is placed 3 cm above the top of the notch located at the back of the head and is used as a reference. Ideally the fourth electrode, the signal electrode, would be placed on the top of the head; in practice, however, hair impedes the performance of this electrode. Thus, we will attempt to make the POSSESS work by capturing brainwaves with electrodes placed on the forehead. Should this not be sufficient, our already nearly bald CEO will sacrifice the remainder of his hair in order to allow electrodes to be placed on the top of the head. While we do not expect all POSSESS users to shave their heads, such action by the CEO allows POSSESS to be validated as a "proof of concept" device and defers the solution of the hair problem to future development.

3.2 Electrode Selection

In general, two types of electrodes are available on the market: disposable electrodes and reusable electrodes. The benefits and drawbacks of each will be discussed in following sections.

3.2.1 Disposable Electrodes

Disposable electrodes consist of a small adhesive gauze or foam pad upon which is mounted a small, metal, signal carrying contact. The diameter of the adhesive pad can vary from 6 mm to 12 mm, depending on manufacturer and model. Disposable electrodes should be replaced daily in normal product use. The main advantage of disposable electrodes is their low marginal cost. Over time, however, the cost of replacing electrodes daily becomes substantial. Disposable electrodes would be attached the POSSESS via wires that are designed to snap onto metal snaps on the back of each adhesive pad. This "snap" connection method allows for easy changing of electrodes. Unfortunately, disposable electrodes could give our product a "cheap" look, which might hurt product marketing.

In order to achieve a satisfactory signal-to-noise ratio, or SNR, disposable electrodes will have to be actively shielded. We have decided cover our electrode cables with a conductor that is driven to a certain non-zero potential driver to ensure maximum elimination of 60 Hz noise.

3.2.2 Reusable Electrodes

Reusable electrodes are made of "fine silver" (99.99% pure silver) and are often 6 mm in diameter. No gauze or foam pad is used. Instead of replacing the electrodes daily, the chloride layer on the electrodes must be regenerated. Daily dipping of the electrodes in a chloride bleach solution sufficiently revitalizes the electrodes. Reusable electrodes theoretically provide better readings than disposable electrodes, but due to their relatively prohibitive cost we have not yet been able to confirm this first-hand. Reusable electrodes rely on a custom connection composed of a stranded copper wire interior and a silicon shell exterior to attach to the base unit. Another potential advantage of reusable electrodes is that they would give our product a more professional and finished look than disposable electrodes. The POSSESS' resultant marketability would thus be enhanced.

Reusable electrodes have less of a need to be actively shielded as they are less affected by 60 Hz interference. While this may seem like it provides an advantage, the fact that we have a working driver circuit already makes it somewhat of a moot point.

3.2.3 Final Electrode Choice

Should we receive funding from the Wighton Development Fund, we will use reusable electrodes as they give our product a more professional look, are cheaper in the long-term, and can potentially provide better data to the POSSESS. Due to the relatively high cost of reusable electrodes, however, we will use disposable electrodes until additional funding becomes available.

No matter which type of electrode is selected, the signal acquired from the electrodes will be AC coupled via a 0.1 μF capacitor. The type of adhesive used on both electrodes type will be able to keep the electrode on the head for a maximum of eight hours, as required by our Functional Specifications.

4 SIGNAL CONDITIONING

Once the input signal has been successfully acquired, it must then be conditioned to the approximate frequency and amplitude required by the signal processing stage. Figure 3 shows the context diagram of this stage.

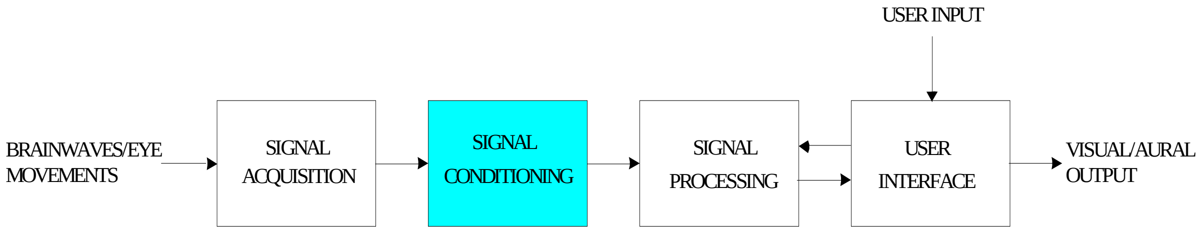

Figure 3: Context Diagram for the Signal Conditioning Stage

Figure 4 shows the functional block diagram of the signal conditioning stage.

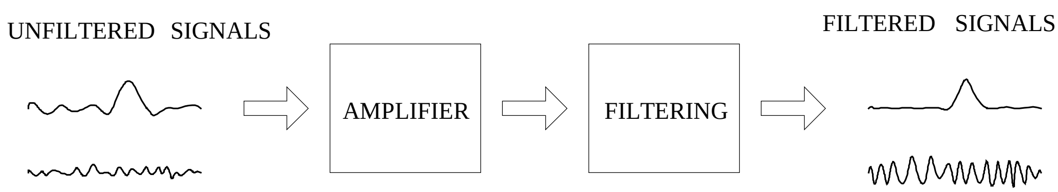

Figure 4: Functional Block Diagram of the Signal Conditioning Stage

4.1 INA128 Instrumentation Amplifier

First, an INA128 instrumentation amplifier takes the inputs from the signal and reference electrodes and amplifies the differential voltage.

The INA128 was selected due to its excellent power, bias current, noise, and supply voltage-requirement characteristics and its good offset voltage and common mode rejection ratio (CMRR) properties. These characteristics, along with its relatively low cost, offer a combination that is more attractive than any other instrumentation amplifier considered. Table 1 quantifies these characteristics.

Table 1: Characteristics of INA128 Instrumentation Amplifier

Parameter	*INA128*
Power Consumption	750 uA
CMRR	100 @ G=100
Supply Voltage	±2.25 V
Input Offset Voltage	50 uV
Input Bias Current	5 nA
Input Voltage Noise	10 nV / √Hz

The gain of the INA128 can be set from 1 to 1000 V/V using an external resistor network. A gain of about 100 V/V using a standard resistor size of 500 Ω is used. This level of gain was selected to ensure that the differential signal is adequately amplified before any filtering is performed, but that any unwanted noise is not significantly amplified.

4.2 Butterworth Filter

Next, the signal is filtered to eliminate frequencies that lie significantly outside the 2 to 20 Hz range of brain waves. A simple active filter with a tight bandwidth is used to accomplish this objective. Figure 5 shows the schematic of the filter, which is a second order Butterworth-type with a cut-off at 20-Hz.

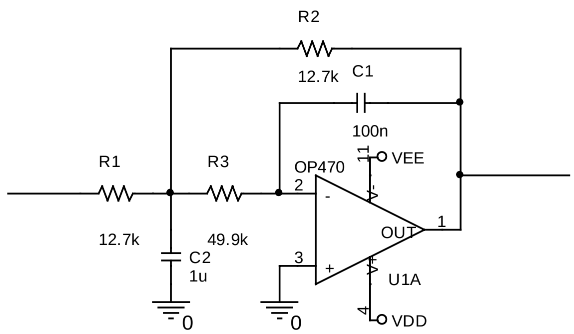

Figure 5: Schematic of a Second-Order Butterworth Filter

The small bandwidth requirement is achieved with this filter while providing the smoothest frequency response in the pass band. In addition, the filter is of third-order, generated simply by cascading a second-order filter with a simple RC filter. The values of the components used in the filter were obtained by using a computer program designed to be applicable only to filter design. Hence, no output plots were immediately available.

4.3 Voltage Amplifier

To generate a signal on the order of volts, as required by the signal processing stage, a voltage amplifier is used at the output of the signal conditioning. Although the INA128 provides a modest amplification of about 100 V/V, the original brain wave signals are on the order of tens of microvolts and the filter stages slightly attenuate the signal. As a result, a non-inverting amplifier is used to amplify the signal by an additional factor of approximately 100 V/V.

5 SIGNAL PROCESSING

The signal-processing unit is the brain of the entire system because decisions as to sleep stage and system action are made here. Figure 6 shows the context diagram of this stage.

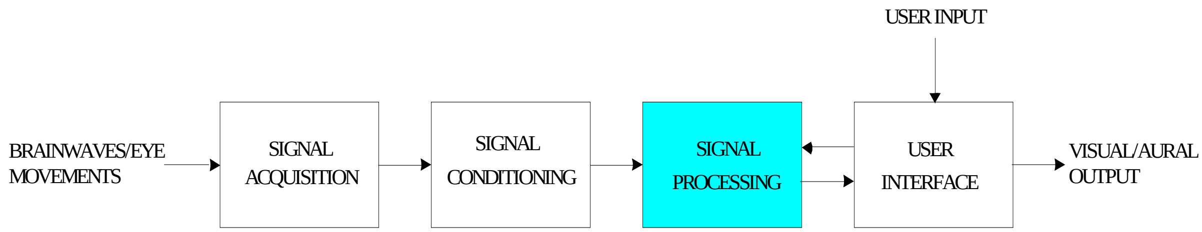

Figure 6: Context Diagram of the Signal Processing Stage

After the brain wave signals have been acquired and conditioned, the signal-processing unit analyzes them and determines whether or not to wake up the user. We apply the method of digital signal processing (DSP), where analog input signals are digitized to increase efficiency, accuracy, and practicality.

5.1 The Algorithm

The signal-processing unit has two major tasks: signal analysis and output generation, both of which are performed continuously. The flow chart in Figure 7 illustrates the process.

Main Program Flowchart (assuming all user input dealt with via appropriate interrupts):

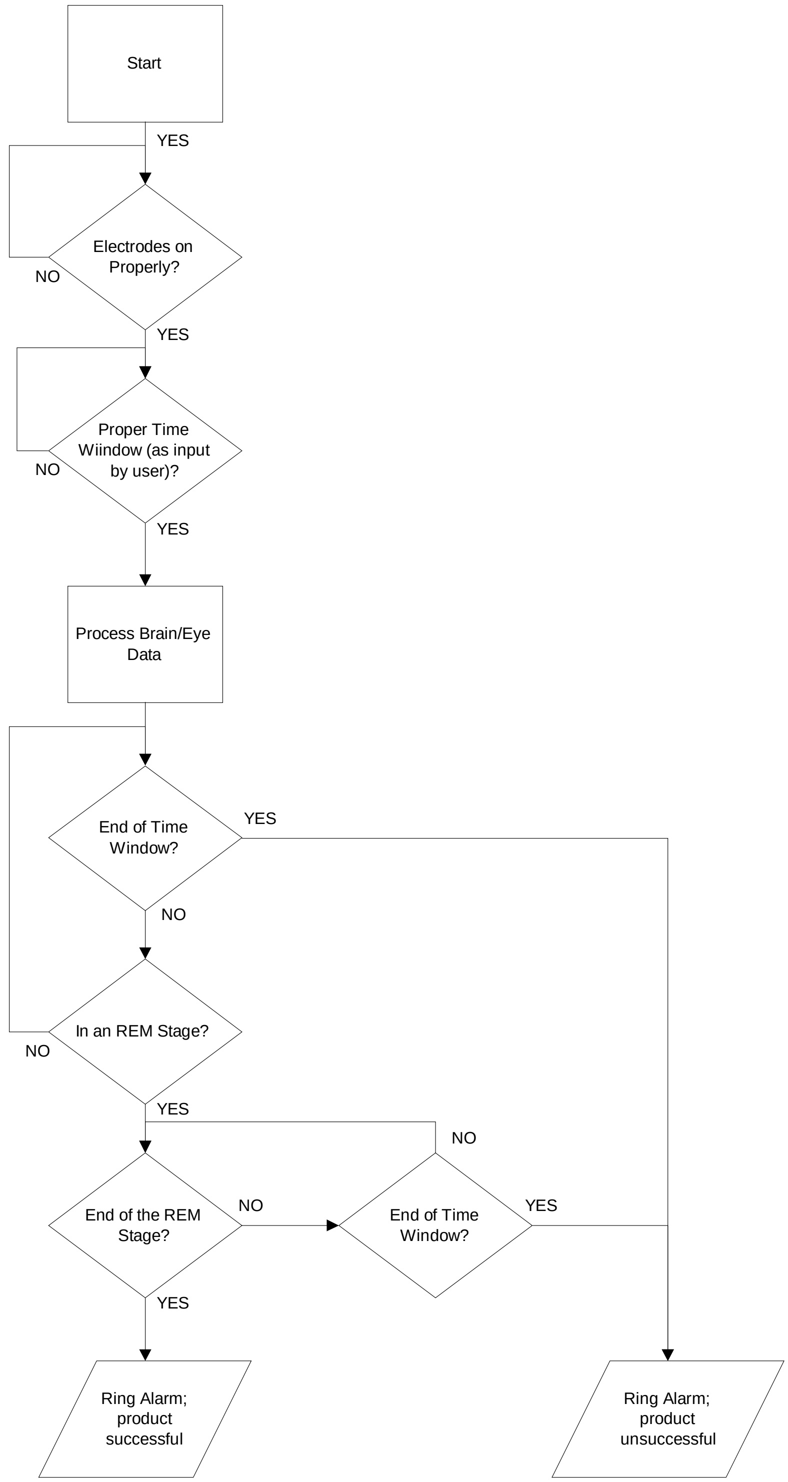

Figure 7: Process Flowchart of Signal Analysis and Output Generation

Our method of determining whether or not a user is in an REM stage of sleep was outlined in our Functional Specifications. Before a stage of sleep is confirmed as either REM or non-REM, we will have to analyze data from at least three consecutive sleep epochs. A sleep epoch is defined as a thirty-second period in which we will sample data once. If, in three consecutive sleep epochs, we record signals indicative of that person being in REM sleep, we will conclude that he or she is indeed in REM sleep. Once a person is confirmed to be in REM sleep, we will then have to record three sleep epochs in which non-REM data is sampled before we conclude that the user has left REM sleep. Figure 8 outlines this process.

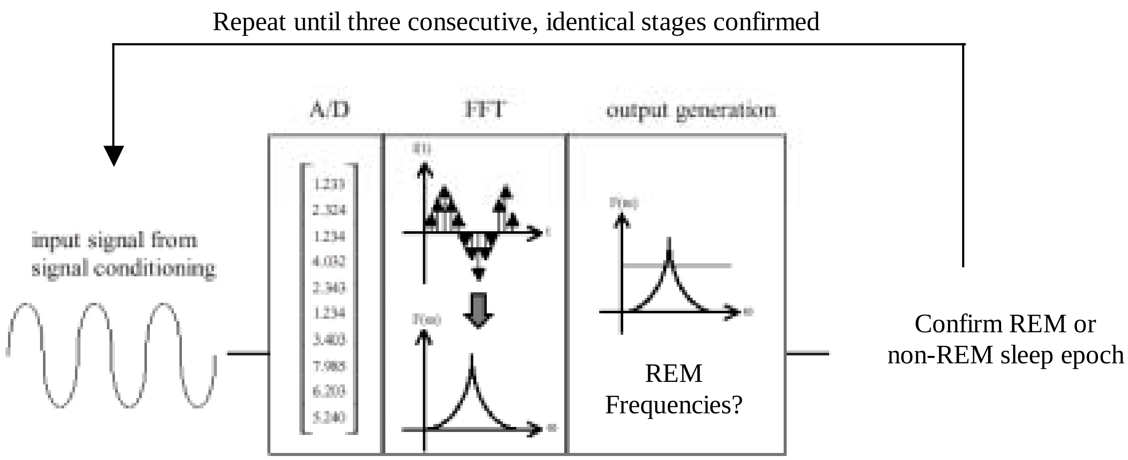

Figure 8: Overview of Sleep Stage Confirmation Algorithm

In order to analyze the inputs for frequency content indicative of different sleep stages, the digitized sequence is transformed from time domain to frequency domain by applying the radix-2 Fast Fourier Transform (FFT) algorithm.

5.2 Fast Fourier Transform

Fast Fourier Transform is an important tool employed in many DSP applications. Basically, information is converted from the time domain to the frequency domain. While there are different methods to implement a FFT, the radix-2 method is often applied because it reduces the number of instruction cycles. FFT analysis results in the division of the power spectrum into a set of frequency “bins”. However, this method has difficulties in partitioning frequency components lying on bin borders. Increasing reliability of the FFT analysis involves division of the power spectrum into two different sets of frequency bins and then comparing them for statistical purposes. An example of such a method would be a case where the first set of bins starts at DC and continues to higher frequencies, allotting one bin for every 5 Hz of the frequency spectrum. The second set, for example, could start at 2.5 Hz and continue in 5Hz divisions. Using both sets of bins allows improved analysis for frequency components that fall on the border between two bins in each of the sets. If a frequency component may fall on a bin partitioning frequency in the first set, that frequency would fall deterministically in a bin in the second set. For instance, a frequency at the 15 Hz point (where the 10 to 15 Hz bin meets the 15 to 20 Hz bin), falls in the middle of the 12.5 to 17.5 Hz bin in the second set.

5.3 Timing

Due to the limited memory size of the processor, it is desirable to use the smallest number of data points that produce an optimal frequency spectrum while maximizing efficiency. A radix-2 FFT restricts the sequence size to a power of two, and a minimum of 128 Hz (just above the Nyquist frequency of 120 Hz) is needed to avoid aliasing with the noise at 60 Hz. A sampling rate of 128 Hz was chosen because it provides adequate resolution. 128 sampling points sampled at a rate of 128 samples per second results in a 1-second sampling duration.

5.4 Microcontroller Selection

To accomplish the signal processing, an appropriate microcontroller had to be selected. Table 2 shows some of the microcontrollers we considered, together with their more relevant parameters.

Table 2: Evaluated Microcontrollers and Their Most Important Features

Controller Name:	**AT90S8535 (Atmel AVR)**	**PIC16F876 (Microchip PIC)**	**68HC811E2 (Motorola HC11)**	**68HC911B32 (Motorola CPU12)**
Max Clock Rate (MHz)	8	20	2	8
RAM (Bytes)	512	368	256	1024
EEPROM (Bytes)	512	0	2048	768
Flash ROM (kBytes)	8	14	0	32
# of Pins	40	28	48	80
Availability	Borrowed eval board, Good	Good	Good	Good
Package Type	fat DIP	skinny DIP	fat DIP	quad flat pack (QFP)
Programmability	4 pins, in-circuit programmable	need special programmer	External EPROM bootloader	external EPROM bootloader
Support (official and non-official)	Good	Excellent	Average	Average
Comms Facilities	UART, SPI	USART	SPI, SCI	SPI, SCI
A to D Conversion	8 channels, 10 bits	5 channels, 10 bits	8 channels, 8 bits	8 channels, 10 bits
8x8 Unsigned Multiply Time	4 us	3 us	5 us	0.375 us

In the end, we chose the Atmel AT90S8535, a microcontroller from the Atmel's 8-bit Flash AVR family, because of its low cost, its reasonably fast multiply time, and its in-circuit programming abilities. The good analog-to-digital converting capabilities of the 8535 are also useful for our application. Also of note is the special real-time clock section of the AVR 8535. The clock-based nature of our project dictates heavy usage of the real-time clock feature. The Atmel AVR 8535 will be able to perform the complex mathematical manipulations required for our algorithm within a reasonable time frame. Even though it has a small amount of RAM, the 512 bytes will be sufficient to store sampled pre-processed data.

6 USER INTERFACE

The signal processing stage will take inputs from the user interface stage to determine alarm settings. The following context diagram illustrates how the user interface stage interacts with the signal processing stage.

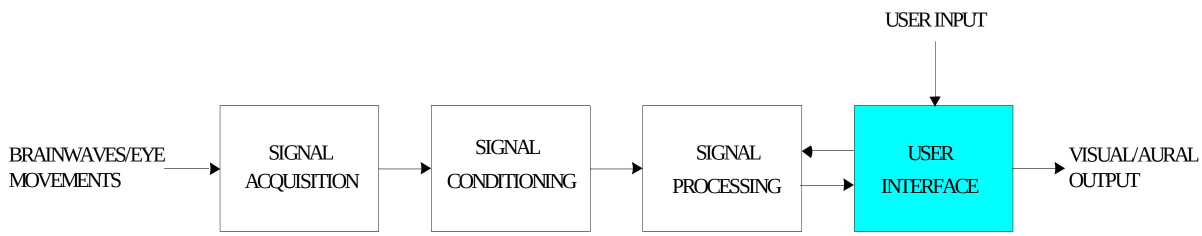

Figure 9: Context Diagram of the User Interface Stage

The final mechanical construction will be similar to that shown Figure 10. Notice that the user interface section of the unit consists of an alphanumeric LCD display that conveys system information to the user. Three push buttons are present on the device. Their functions change with different user selections, in effect creating what is known as a “soft menu”.

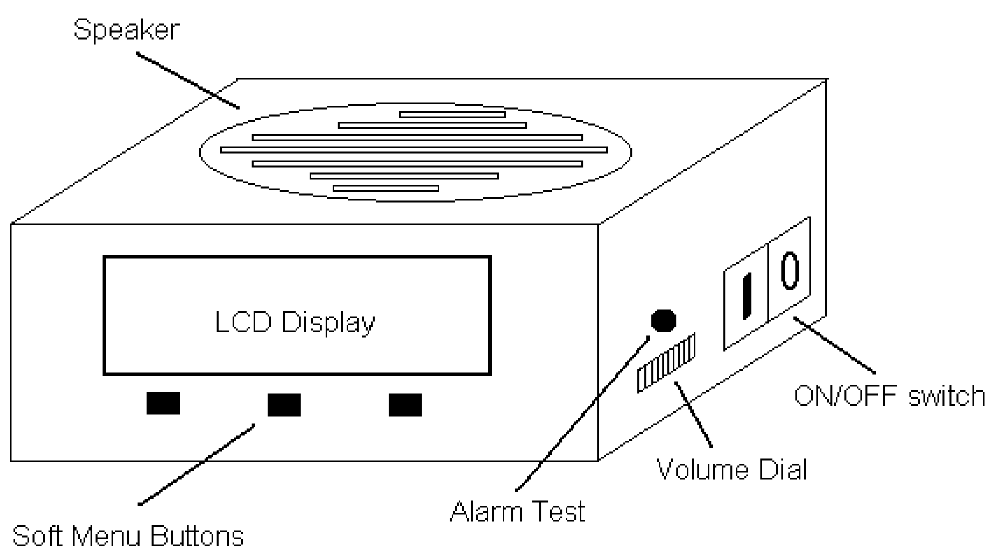

Figure 10: Mechanical Construction of the Unit

The bottom line of the LCD Display will show an icon above each button, indicating its operation in the soft menu structure. The allocation of the buttons is shown in Table 3.

Table 3: Main Menu Buttons

Button 1	Set Time
Button 2	Set Alarm Window
Button 3	Alarm ON/OFF

Once pushed, the system will enter a sub-menu in which the user can choose their desired settings. For example, if the user pushes the Set Time button, the system will enter the Set Time sub-menu. Once inside the sub-menu, Button 1 will be used to accept changes, Button 2 will be used to change hours, and Button 3 will be used to change minutes. The icons will be updated to indicate the operation of each button in the sub-menu. The Set Time sub-menu functions are summarized in the following table.

Table 4: Set Time Sub-Menu

Button1	OK
Button2	Change Hours
Button3	Change Minutes

The Set Alarm Window sub-menu is similar to that of the Set Time sub-menu, except that two specific times will be required. The user will first enter the beginning time of the window, press OK, enter the end time of the window, and press OK again to exit. Table 5 shows the button layout in this sub-menu.

Table 5: Set Alarm Window Sub-Menu

Button1	OK
Button2	Change Hours
Button3	Change Minutes

The Alarm ON/OFF button will be used to both turn the alarm on and off, and disable the waking tone should it be activated. Its sub-menu functions are shown in Table 6.

Table 6: Alarm ON/OFF Sub-Menu

Button1	OK
Button2	Alarm ON
Button3	Alarm OFF

The Volume Dial and Power ON/OFF switches have obvious functions. Their operation will be independent of the microprocessor. The Alarm Test button is used to manually generate a tone for the user to audibly assess the volume level.

6.1 Display Selection

Many factors were considered in selecting an appropriate display. Some of these factors were not adequately discussed in the Functional Specification, and will hence be discussed at this time. The display will:

- ⇒ Display textual and numeric information
- ⇒ Have enough display area to show required data
- ⇒ Possess some type of back-lighting, so it can be viewed in a dark room
- ⇒ Have good contrast and brightness characteristics
- ⇒ Be a able to create custom characters and small graphics
- ⇒ Be inexpensive
- ⇒ Consume small amounts of power
- ⇒ Be reliable

These requirements eliminated the possibility of using an LED display, as it is unable to show textual data. Graphics LCD displays were also unacceptable, due to their high cost and difficulty of implementation. Vacuum Fluorescent displays are expensive and unproven, as they are a relatively new display technology.

In the end, we decided on a 20 x 4-character backlit LCD display. A display of this type meets all of our above requirements. Most backlit LCD displays are similar in many respects. The majority of LCD displays use the industry standard display controller – the Hitachi HD44780. It has a track record of reliability and is known to have good usability.

The specific display we chose was the ACM2004D from AZ Displays. This selection was based on pricing and availability. A picture of this display is shown as Figure 11.

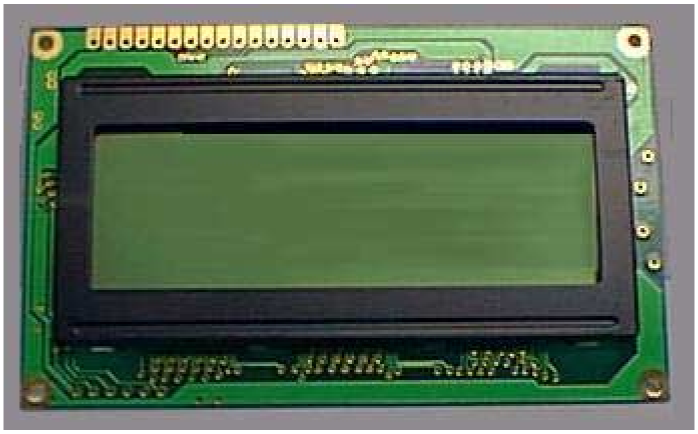

Figure 11: Picture of Hitachi HD44780 LCD Display

6.2 Display Allocation

The display to be used has a 4 line by 20-character resolution. A sample screen shot of the display appears as Figure 12.

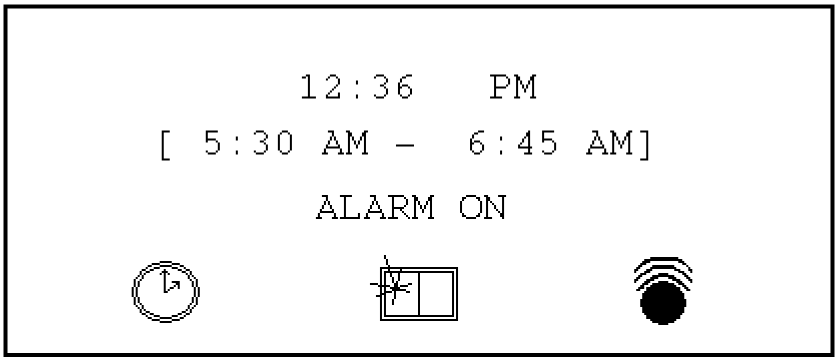

Figure 12: Possible Display Screen Shot

Table 7 shows the functions of each display line, as seen in Figure 12.

Table 7: Line Allocation for the Display

Line 1	Current Time
Line 2	Alarm Window
Line 3	Alarm Status
Line 4	Icon Display

7 ENCLOSURE

A metal enclosure will be required for shielding our processing unit from all electro-magnetic interference. A thin layer should suffice for shielding purposes while keeping the weight at a minimum. This metal enclosure should be of an aesthetically pleasing form resembling digital alarm clocks currently on the market. Safety will also be taken into consideration, so that all corners of our enclosure will be rounded. Rubber feet will isolate the metal case from the surface on which it sits. The selection of a metal material provides rigid support and will allow the POSSESS to withstand certain shocks. We will defer the implementation of our 75-G shock requirement to further prototypes.

8 TEST PLAN

8.1 Signal Acquisition

The signal acquisition stage will be tested using the following procedure.

1. Use a function generator to apply test sine wave inputs to the electrode disk. Use input amplitudes less than or equal to 10 mV. Sweep the frequency of the input from 10 to 20 Hz. Display this input signal using an oscilloscope.
2. Display the output signal at the other end of the electrode on the oscilloscope. If the input and output sinusoids are nearly identical, the electrode is working properly. All electrodes should be tested.

8.2 Signal Conditioning

The signal condition stage will be tested using the following procedure.

1. Use a function generator to apply a 10 mV, 10 Hz sine wave across the inputs of the signal conditioning unit.
2. Measure the amplitude of the output signal using an oscilloscope and ensure that adequate gain is achieved, and that distortion is minimal.
3. Repeat above steps while sweeping through the frequency range of interest, 15 Hz to 50 Hz in 5 Hz steps. Judge performance based on required signal amplitude of 5 V peak-to-peak and amount of noise and distortion in the signal.

8.3 Signal Processing

The signal processing stage will be tested for its algorithm and for the ability to work with an analog signal input in real-time using the following procedure.

1. Modify detection software such that it may trigger an output LED on reaching the REM sleep stage at any time. This is achieved by removing the constraint that the software will only search for the sleep stages during certain time periods and by placing the system in "Alarm On" mode.
2. Place digitized data of a sample signal resembling a REM sleep stage in unused microcontroller Flash ROM.
3. Run software such that it takes data from the sample data memory and not the input port.
4. If test is successful the LED will turn on.
5. Repeat steps 2 to 4 for a non-REM sleep signal. LED should stay off. If executed successfully, revert software modifications such that sample data is from Analog to Digital converter and go to next step.
6. Input a small signal resembling non-REM sleep stage brainwaves to the Analog to Digital converter on the microcontroller.
7. LED should remain off. If the system falsely detects a REM stage it has already failed.
8. Input a signal resembling REM sleep stage brainwaves to the Analog to Digital converter on the microcontroller.
9. LED should turn to indicate successful execution of test.

8.4 User Interface

The user interface component of the system will be tested in the following manner.

1. Modify software to update the display on button presses such that an expectable pattern of display changes will be cycled with each button press.
2. If all display characters appear as expected in the correct positions, the display can be verified to work correctly.
3. If each button press only cycles through one display change every time, then the user inputs are verified to work.
4. Check the internal memory variables to verify that they are updated by the user input through the user interface.

8.5 Overall System

The signal processing stage will be tested using the following procedure.

1. Modify detection software such that it may trigger an output audio tone on finding a REM sleep stage at any time. This is achieved by removing the constraint that the software will only search for the sleep stages during certain time periods and by placing the system in "Alarm On" mode.
2. Input a small signal resembling non-REM sleep stage brainwaves to the electrodes. Signal should have amplitude less than 10 mV.
3. No outputs should be generated. If the system falsely detects a REM stage it has already failed.
4. Input a small signal resembling REM sleep stage brainwaves to the electrodes. Signal should have amplitude less than 20mV peak to peak.
5. An audio tone should sound to indicate successful execution of test.

If time is available to do so, the function generator used in this step will be replaced with a PC sound card that has been programmed to output analog voltages derived from real digitized brain wave data.

9 CONCLUSION

This document has outlined, in detail, the approach taken by the engineers of QND Medical Devices in building the POSSESS. At the time of writing, we believe that the outlined procedures and methodologies are best suited to satisfy the requirements outlined in the Functional Specifications. We reserve the right to deviate from the procedures outlined in this document should we find a better way to satisfy the requirements of our Functional Specifications and thus also better satisfy the needs of the consumer.

We are confident that we will be able to produce a working prototype of the POSSESS by the end of December 2000 and that, with further work, this prototype could become marketable. No device exists on the market that performs the same functions as the POSSESS, and we believe that should we ever develop a consumer version of the POSSESS that it would be welcomed by the marketplace.

The eventual completion of the POSSESS could potentially prevent thousands of fatalities per year. Additionally, the POSSESS could contribute to the happiness and well being of countless others. Although not as dramatic as a reduction in fatalities, an improvement in overall happiness would be a great benefit to society.

10 REFERENCES

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