Untethered Patient Monitoring

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This paper describes the development of an untethered patient monitoring system. The system acquires three basic biomedical signals from the patient plus a distress call button signal. The three basic signals are electrocardiogram (EKG), phonocardiograms (PCG) and temperature. The signals are transmitted by a RF carrier, received and read into a personal computer through a parallel port interface. Commercially available software can then be used for data display and analysis.

Introduction

Telemetry is a process of making a measurement at a distance from the source.[1] The first physiological telemetry system was developed by the U.S. Army Signal Corps in 1921.[2] The system transmitted heart sounds from ships that had no physicians onboard to medical facilities on land. It was not until 1949 that additional work was done in the field of remote physiological monitoring when a FM radio link was used to transmit electroencephalograms (EEGs) of humans. Breaksell and Parker realized the possibilities of observing electrophysical data remotely and constructed the first modern working system.[3]

Since 1949, there have been many physiological radio telemetry systems developed. These range from large, complex, multi-channel, multi-patient monitoring systems for hospital use[4] to battery powered, multi-channel portable units for such uses as exercise physiology[5] to small single channel implantable systems for biological experimentation.[6] Advances made in miniaturizing integrated circuits have made possible systems that require less space and power, yet have greater capabilities.

Many biotelemetry systems used today have traditional display units much like those found in wire based biomedical instruments. However, with the continuing advancements in personal computers, PC-based systems for the acquisition and analysis of biomedical signals are becoming practical at the individual physician level. The physician can, in his office, have a small but very powerful and fairly inexpensive personal computer comparable to expensive systems, which until recently, could only be found in research facilities. Signal processing is easily computed with the use of software packages such as MATLAB and its accompanying Signal Processing TOOLBOX. This program allows for the study and modification of individual functions' algorithms, which makes it ideal for a development system. Labview is another program available for PC-based signal analysis. Labview gives the biotelemetry system designer an easy to use, graphical interface for displaying data. With Labview's digital filters and signal capturing abilities, it is another software package that is perfect for displaying biomedical signals on a personal computer.

The objective of this project is to develop a simple Untethered Patient Monitoring system that can be readily interfaced to a PC for easy in data acquisition and analysis.

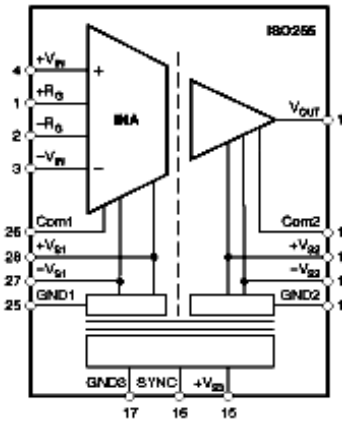
Signal Acquisition

Many different signals can be obtained from the patient and sent to a nearby monitoring computer using a telemetry system. Signals that provide diagnostic and health monitoring information with minimal interference with the patient signals include electrocardiograms (EKG), phonocardiograms (PCG), temperature, and patient activated distress signals. Collecting each of these signals requires a different approach. Noise plays an important consideration in collecting the signals, and much attention is placed on the electronic design to eliminate as much noise as possible.

The EKG signals are obtained using electrodes placed directly on the patient's skin. Usually three or more leads are required to get a significant measurement from the body. The PCG signals are collected using a microphone, which transforms the acoustical energy into electrical signals. The relative temperature of the patient can be obtained by using a direct skin probe or an optical ear probe. Some of the voltages acquired from the body are in the millivolt range and require the use of a differential amplifier to amplify the voltages and reject as much noise as possible. The distress signal is not a biomedical signal but an added feature that can alert a monitoring computer and a nurse of a condition that needs immediate attention. It also allows the computer to record any information about the patient preceding the distress for later evaluation by the physician.

Amplification and isolation

The amplification and isolation of the signals on the patient are very important. Not only is safety an issue, but also the elimination of common mode voltage and other unwanted signals. A new precision, powered, three-port isolated instrumentation amplifier, the Burr-Brown ISO255, has recently become available. Burr-Brown specifically designed the ISO255 for biomedical instrumentation, as well as other high precision test equipment, analytical measurements, and industrial process control. The chip is all housed in one 28-Pin plastic DIP. The only external component needed is a resistor, which determined the amount of gain desired. The isolation of the ISO255 separates the patient from the output and the power supply. It has a breakdown voltage of 1500 Vrms continuous and 2500 Vrms for one minute. The ISO255 has a CMRR of 90 dB that ensures adequate rejection of the common mode signals. Another nice feature of the amplifier is that the chip contains two isolated voltage outputs, so other circuits may also be isolated from the body.



Multiplexing/demultiplexing

Because the system still needs to be small and comfortable for the patient to wear, the signals to be transmitted and received need to be combined before transmission. Time division multiplexing is used to get the multiple signals down to one. "Time division multiplexing is a method of transmitting several messages on the same circuit by interleaving them in time."[11] There are two very important concerns involved with this type of data compression, sampling frequency and frame synchronization. If the sampling frequency is too slow, important data can be missed or lost. Because signals are being collected from the body for study, it is very important that no data is missed. The general rule followed in this case is that the sampling frequency needs to be at least twice that of the highest signal being sent into the multiplexer. As an example, if the highest frequency is 60Hz and if there are four signals to be multiplexed, the sampling frequency should be, at minimum, the number of channels (4) multiplied by twice the highest frequency (60Hz), which equals 480Hz.

Transmitting/receiving

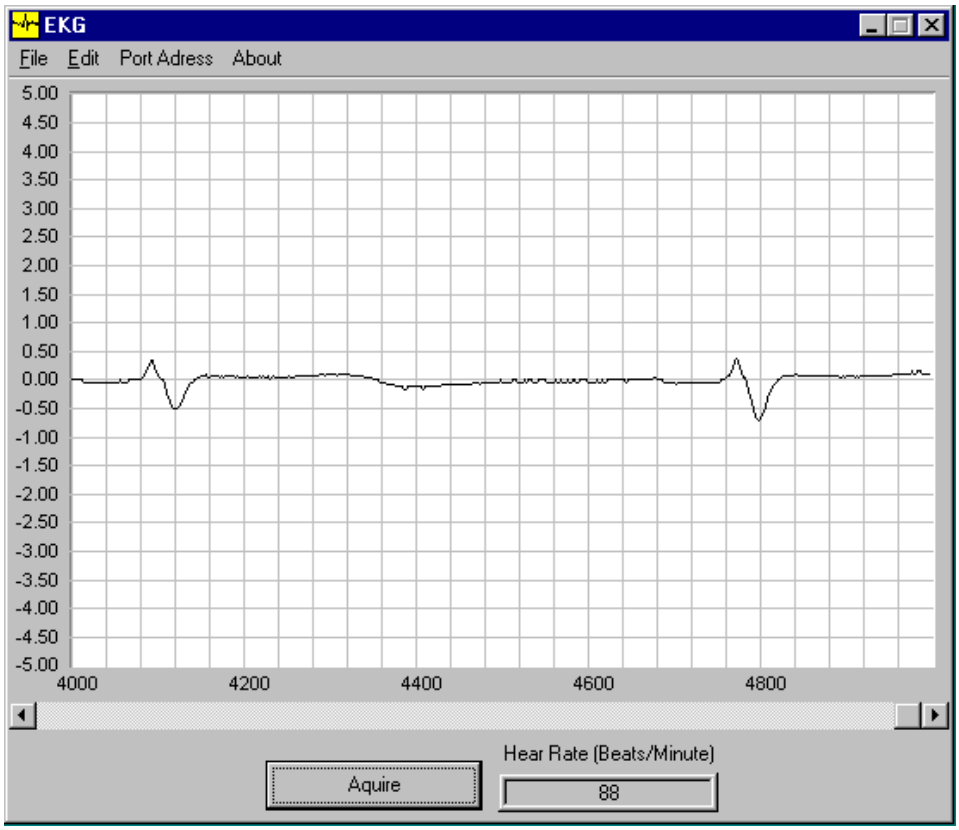
In the untethered transmission and reception of data signals, several methods can be used to transmit and obtain the needed data. In the world of biotelemetry, Radio Frequency is by far most commonly used. Within RF transmission there are several different modulation techniques that can be used. It is well known that frequency modulation has a much greater signal-to-noise ratio over other modulation schemes**.** Even more effective is the use of compound modulation systems such as FM-FM and FM-PCM (Pulse Code Modulation). FM-PCM modulation is the process of first converting the signal to a digital representation and then feeding it into a FM transmitter. By converting the signal to digital, errors introduced by nonlinear effects are greatly reduced. [15] There is a trade off between reduction in noise and increased complexity of the transmitter on the patient. The continually improve capabilities in integrated circuits have shifted this trade off to allow further reductions in noise by digitizing the signal before it is transmitted.

The FCC has recently recognized the importance of biomedical telemetry devices and allotted specific bandwidths within VHF and UHF frequencies for the use of only biomedical telemetry devices. Within VHF the allotted frequencies are 174-216 MHz with a field strength of 1500 microvolts/meter and 512-566 Mhz for UHF where the field strength can be up to 200 microvolts/meter. The FCC also limits the amount of power that can be used in this range at 5 mW. [17]

The receiver demodulates and demultiplexes the signals and must provide an interface to the computer. To simplify the interface, the parallel port on the computer is used. By using the parallel port, no additional plug-in cards are needed for the PC to receive information. This makes the system easily portable to any compatible computer systems, including laptop computers.

User interface

Once the data is available in the computer, a number of different commercial software packages can be used for display and analysis.



Conclusion

In the past ten years extended research has led to advanced capabilities of FM transmitters and receivers. The development of more complex, compact, and inexpensive integrated circuits has allowed for systems requiring less power and space. Smaller and lighter transmitters permit portable units to capture biomedical signals without overly restricting the patient's location. Personal computers have also become beneficial in this field as software for monitoring becomes less expensive. These incredible advancements may lead to new diagnostic procedures, improved health maintenance capabilities, and speedier recoveries, as systems become more common in other areas.

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