CHAPTER 19
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VIBRATING ALARM CLOCK

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INTRODUCTION

A Vibrating Alarm Clock for the people with hearing impairments (VACHI) was built using Freescale 68HC12 chip technologies. The main goal was to help people with hearing impairments to wake up in the morning. The base unit has a fully functional clock and alarm.

The requirements for this project included: 1) a fully functional alarm clock with buttons to set the clock display, alarm clock display, alarm on/off, and snooze; 2) no buzzers or radio components in the base unit; 3) the ability to send a wireless signal using a LINX Technologies RF module; 4) a wristband to receive a signal from the base unit when the alarm goes off to start vibrating the motor; and 5) an external microphone system to alert the user of any loud noises during sleep, such as an intruder or a fire alarm. The clock uses input from the microphone to send a signal to the wristband via the transmitter and receiver. The sensitivity of the microphone can be set by the user using an external potentiometer.

SUMMARY OF IMPACT

Any time an alarm goes off, a signal is sent to a wireless wristband, which causes a vibration to occur. The base unit has an internal microphone capable of picking up noise in the surrounding area. The microphone's sensitivity level can be adjusted by the user via a knob on the outside of the base unit's case. When an alarm sounds, lights in the base unit blink on and off, indicating an event has occurred.

TECHNICAL DESCRIPTION

BASE UNIT

The base unit consists of a 68HC12 microcontroller embedded in a Minidragon Development Board (Wytec, Inc.). The Minidragon regulates the clock's Liquid Crystal Display (LCD), pushbutton switches, alarm ON/OFF switch, clock functions, and alarm functions. If an alert is detected by the microphone the microcontroller will send a signal to the onboard LINX transmitter, which will in turn transmit a 418 MHz signal to the receiver in the wristband. If the preset alarm occurs, the microcontroller will again send a signal to the transmitter, which sends a 418 MHz signal to the receiver in the wristband. In both cases of alarm status, the bulb on the inside of the base unit will blink on and off for as long as a signal is being sent to the transmitter.

WRISTBAND

The wristband has three separate systems: a voltage source, a battery monitor circuit, and a motor vibration circuit. The voltage source consists of a CR2477 3 VDC 1000 mAH Lithium Ion battery. The battery monitor circuit is a Maxim 6435 battery supervisory circuit. This supervisory circuit monitors the 3 VDC supply for two threshold voltages as set by an external voltage divider network.

The motor vibration circuit consists of the LINX receiver, a Rx 418 LC planar antenna (which lies flat on the printed circuit board), a 2SK221100 N-channel MOSFET used as the motor driver, and a 3 VDC vibrating motor.

The packaging for the base unit is transparent blue Plexiglas so the components are visible. The bulb inside the base unit, when flashing, lights up the base unit with a blue glow. The wristband has a cloth case.

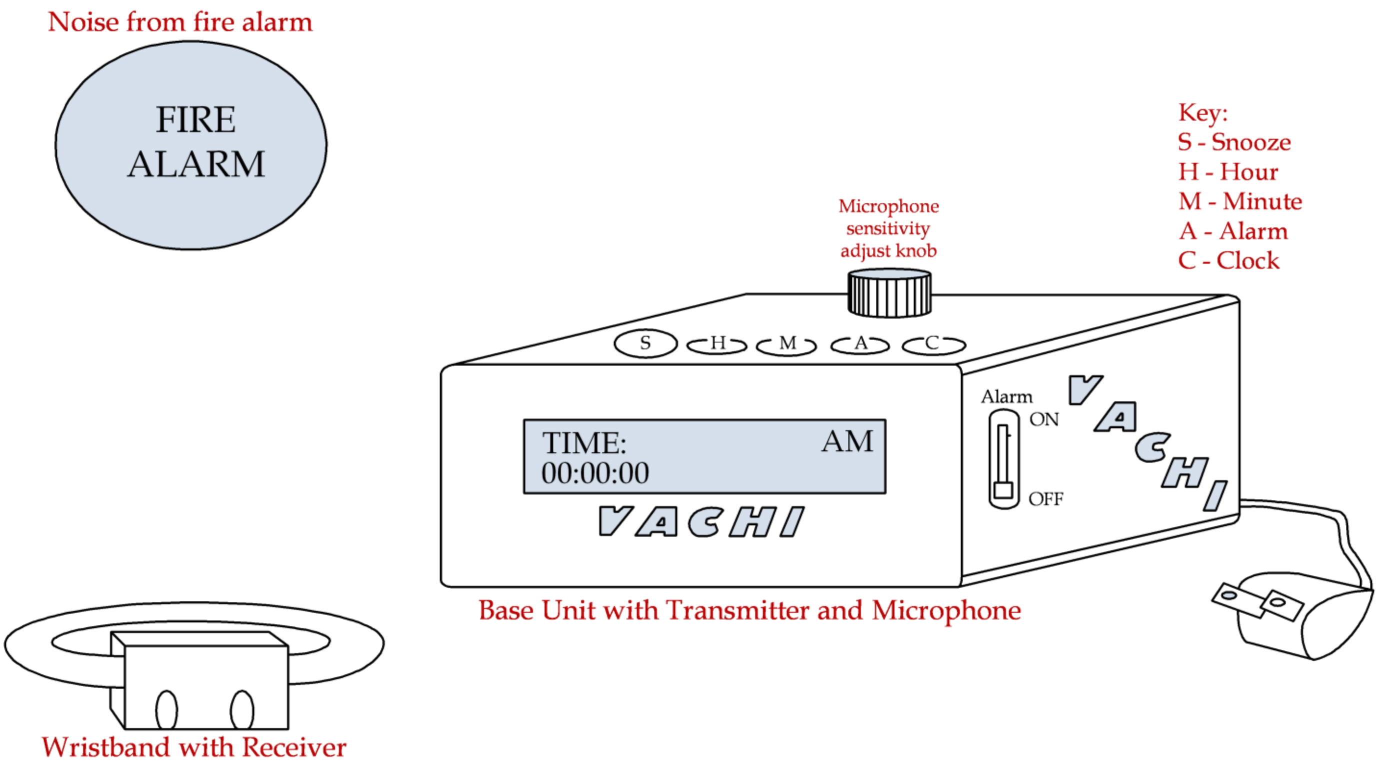

Fig. 19.1. An overall diagram of the project

INDOOR CHILD MONITORING SYSTEM

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INTRODUCTION

A teacher at an elementary school requested a device that could be worn or carried by a student with limited cognitive abilities so that he could be monitored remotely by a caregiver. The design of includes a radio frequency (RF) transmitter to be carried by the student. The transmitted signal is received by a set of RF receivers placed at strategic locations throughout the school. The receivers have a received signal strength indicator (RSSI) feature that enables measurement of signal strength via a central microcontroller. The microcontroller communicates with a Windows-based computer through a network cable. The computer runs software displaying a plot of the student's location on a floor map of the school.

SUMMARY OF IMPACT

This system is able to track an individual's movements. Due to time constraints, crucial testing for accuracy of measurements was not conducted.

TECHNICAL DESCRIPTION

This project has two primary components: hardware (transmitter and receivers) and software (Microsoft NET user interface). The microcontroller connects the two. Figure 19.2 shows a general outline of the project components connected together.

HARDWARE

Transmitter

The transmitter portion of this project consists of the following components: a prefabricated radio frequency (RF) transmitter, a binary counter, a crystal oscillator, a voltage regulator, an antenna, and a battery. The transmitter had to be small, compact, and easily mountable on a printed circuit board (PCB). It also had to have low-power RF output to prevent bodily harm and ensure compliance with Federal Communications Commission (FCC) standards. Cost was also a consideration.

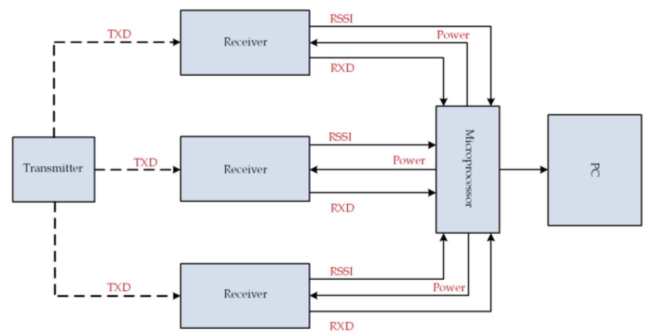

Fig. 19.2. System Overview.

The TX3A-914-64, a miniature ultra-high frequency (UHF) transmitter module designed by Radiometrix was mounted on a PCB. The TX3A operates at 914.5 megahertz (MHz). It has a 1 milli-watt (mW) RF output and conforms to the FCC regulation part 15.249. Figure 19.3 shows the transmitter and the 7-pin configuration. Pins 1-3 are designated for the RF transmission of data. Pin 2 is connected to a 50 ¼ wave-whip antenna, while pins 1 and 3 are connected to RF ground. Pin 4 is an enable pin used to put the transmitter in a low-power state while it is not being used. A switch that turns the unit off and on was not used in this design. Pin 4 is simply tied to the 5 V supply, so when the power is switched on, the transmitter is enabled. Pin 5 is the supply voltage and pin 6 is 0V, or ground. The transmitter operates at a regulated 5V from a common 9V alkaline battery. Pin 6 is tied to the ground terminal of the battery. Pin 7 of the transmitter accepts the data to be transmitted. This pin accepts digital data between 0 and the high voltage, which it clips to 2.5 volts. For this design, pin 7 was given a 15.6 kHz square wave generated by a 1.0 MHz crystal oscillator and a 14-stage binary counter was used as a frequency divider. The crystal oscillator generates a precise 1.0 MHz signal that is fed into the 14 stage binary counter. This binary counter acts as a frequency divider and is able to generate fractions of the input frequency by dividing it by a power of two, from 24 to 214.

The power for the transmitter comes from a common 9V alkaline battery. This 9V supply is regulated down to 5V by a voltage regulator in order to provide the transmitter circuit with a lower and more constant voltage.

Receiver

The receivers consist of the following components: a prefabricated RF receiver, a voltage regulator, an operational amplifier circuit, and an antenna.

The RX3 receiver is the receiving unit complementary to the TX3A transmitter. Designed with a surface acoustic wave (SAW) front end filter for good immunity to interference, this receiver module can receive transmissions in-building from a distance of roughly 30 meters or 120 meters line-of-sight. This receiver also has an RSSI with a 75 dBm range (power in decibels referenced to 1mW). This is crucial to the overall design as the RSSI signal enables plotting of the transmitter based on the relative strengths of the RSSI signals from the three receivers.

The RX3 pins are shown in Fig. 19.4. The receiver is a 9-pin device, in contrast to its 7-pin transmitter counterpart. The two additional pins on the receiver are a pin for the RSSI output and an analog RF output pin. The RF output pin is not used in this design. Pins 1-3 of the receiver are for the RF input. Pin 1 is the RF input and is connected to a 50 ¼ wave whip antenna. Pins 2 and 3 are connected to the RF ground plane. Pin 4 is an enable pin, used to put the receiver in a low power standby mode. This is not necessary in this design. Pin 5 is the RSSI signal output. The RSSI gives a DC voltage in the range of 0.0-1.0 volts. In this design, this value is used to calculate the distance from the receiver to the transmitter. Pin 6 is the 0V pin, or ground for the voltage supply. Pin 7 is for the supply voltage, which in this design is a regulated 5V. Pin 8 is an analog frequency output that is not used in this design. Pin 9 is the output of the received digital data. For this design, pin 9 receives a 15.6 kHz square wave, used by the microprocessor to affirm that the signal received is the intended one.

The receiver circuit also contains an operational amplifier circuit used to amplify the RSSI signal from a range of 0.2-1.0V to (ideally) 0.66-3.3V. This allows use of a larger range of the analog to digital (A-D) converter, allowing for values between 0 and 3.3V.

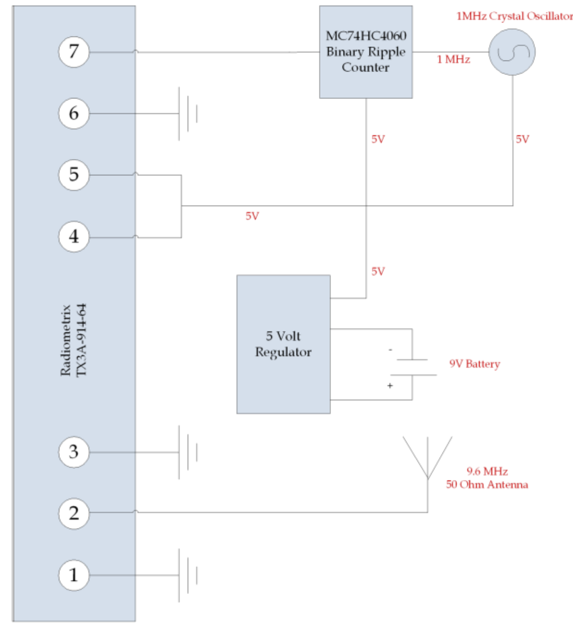

Fig. 19.3. Transmitter Schematic.

Power for the receiver units is supplied along category 5 (CAT5) cables that connect the receivers to the central microprocessor. Power is supplied by the power port on the microprocessor evaluation board. A measured 9.20V is supplied by the evaluation board's power port and delivered to the receivers through a CAT5 cable where it is regulated down to 5V for use by the RX3. See Fig. 19.4 for a diagram of the receivers.

Microprocessor

The microprocessor is the M9S12NE64. This is an HC12 variant with an Ethernet 10/100 megabit-per-second (Mbps) transceiver. The M9S12NE64 was purchased on the EVB9S12NE64 evaluation board from Freescale. This allowed easy connection of the receiver CAT5 cables into the evaluation board's breadboard to be read by the A-D converter.

The microprocessor takes in the RSSI signals from each of the 3 receivers, packages them in a UDP packet, and broadcasts the UDP packet onto a network. The RSSI signals are run into the A-D converter to digitize the analog signal. Once these signals are digitized, they are packaged by the microprocessor into the UDP packet. This packet is broadcast onto a network as a bit stream where it is retrieved by a PC for further processing.

SOFTWARE

The Microsoft NET programming environment is user friendly and provides a number of pre-programmed features that facilitate the process of designing a Windows application. First, when the program is started, it immediately starts sampling the network for data. When data are received, they are decoded and the values are stored. Then the program checks to see if 1000 samples have been taken since either the beginning or the most recent average, and if so, it averages these last 1000 samples. It then calculates a new point to draw a line to, indicating the child's current position and most recent movement. It draws the required lines on the map of the school, and then returns to sampling the network.

UDP is the protocol for broadcasting the RSSI information onto the network cable. An alternative to broadcasting the packet onto the network cable would have been to hard-code an IP (internet protocol) address into the microcontroller. This idea was quickly discarded, though, because it would have required the user to reconfigure the computer's IP address every time he or she used the program. Then he or she would have had to reconfigure the IP address again to close the program and use the internet. UDP is faster than other protocols and provides the flexibility of broadcasting quickly in case many samples must be averaged in a short period of time. Also, since there will be no other computers or devices on the network formed by the crossover cable linking the microcontroller with the computer, there is no danger of the broadcast bringing down critical office network applications.

When the user interface program is started, the program creates a new thread (process) ,which runs in the background (independent of everything else the program is doing) and continually monitors the network cable for broadcasts. When this thread detects a UDP packet, it generates an interrupt "event." The main program thread recognizes this event as important and stops what it is doing to handle the event. Each time the event is generated, the main program decodes the UDP packet into a stream of bits and then into a series of integers representing the RSSI readings taken from the receivers by the microcontroller. After the main thread has the RSSI values, it runs them through an algorithm that selects the two strongest signals and calculates the position of the tracked individual based on the relative signal strengths of the two

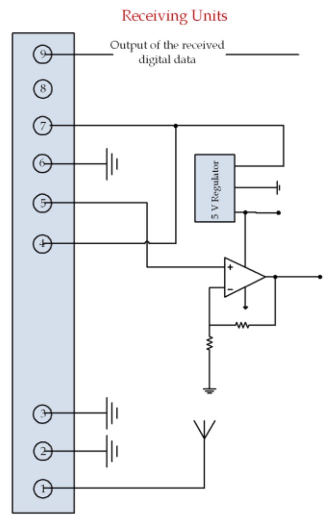

Fig. 19.4. Receiving Unit Schematic..

strongest receivers. A potential drawback to this approach is the possibility of a receiver generating a stronger RSSI reading than one of the receivers to which the individual is actually closer. This is unlikely because line-of-sight signals are stronger than signals that must travel through walls or other solid objects. If the signal strengths of the second- and third-strongest receivers are close to the same value, then the program assumes the individual is close to the location of the receiver for which the RSSI is strongest. It holds that position for a short length of time until one of the receivers begins generating a stronger signal strength reading.

On the main window, there is a picture box with a map of the floor plan of the building. When the program calculates the position of the individual being tracked, it draws a colored line connecting the current location of the signal to the previous location. Map position is specified in terms of the number of pixels from the left edge (x-coordinate) and from the top edge (y-coordinate).

The microcontroller, which uses the C programming language, was programmed to read the RSSI values on the analog-to-digital converter and broadcast them. The microcontroller reads analog values between 0 and 3.3V and converts them to one-byte integer values. This posed a small problem because NET expects four-byte integer values. This was solved by zero-padding the integer values so that the UDP broadcast contains one-byte values represented by four-byte integers.

ULTRASONIC CANE FOR PEOPLE WITH VISUAL IMPAIRMENTS

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INTRODUCTION

An ultrasonic cane was designed to enhance mobility of people with visual impairments. An ultrasonic transducer produces an audible or vibratory signal to alert the user about any large obstacles in his or her path up to 12 feet away. Design requirements were that the device be mobile and use rechargeable batteries.

SUMMARY OF IMPACT

The device is a functional, portable, ultrasonic proximity sensor. It cannot detect small objects or slight changes in surfaces; thus, it would not suffice as a single way-finding aid. As a supplemental device it could speed the user's locomotion by providing a general location of large objects, or holes (such as doorways) 12 feet in advance. It is portable and powered by two standard 9 V DC batteries.

A problem during the testing phase was echoing. The unit was working as planned, but every few seconds it would receive a false positive. The false positive could be confusing to a user and cause him to stop moving for fear of a large object in his path. At this point, the unit would guide a user down the hallway, but once the user was within 30 feet of a bend or junction in the hallway, the echo was bad enough to be hazardous to the user. Using the gating feature of the sensor should eliminate this problem.

Vibrations with only one vibrating motor and audible tones produced by the speaker are also not effective enough for user feedback. Suggestions for a second prototype would be to try and use a Braille display of some sort to "talk" to the user; 18 cell, 8-dot displays are available.

TECHNICAL DESCRIPTION

This project has four primary components: the ultrasonic sensor, the user interface portion, the power section, and the microcontroller. The sensor sends and receives the ultrasonic signal and determines how far away an object is. The feedback portion includes the vibrating motor, the speaker and all the hardware required to make it work. The power section supplies power to all of the active pieces in the design, including the sensor and microcontroller. The microcontroller incorporates all the pieces and gets them to function as a single unit.

TRANSDUCER

The ultrasonic transducer selected was the Senscomp-Mini A because of its versatility. It compensates for temperature internally and also provides a 0-5 VDC output for minimum and maximum distances. Also, the minimum and maximum distances can be changed, making it easy to adjust the distance if needed. One drawback to this model is the current draw during the transmit stage. The unit requires 2A during the 0.5 ms transmit stage. To help compensate for this, a 470 F capacitor is connected in parallel with the transducer and two 9 VDC batteries (connected in parallel with each other for the supply). A 100 ohm resistor is placed between the transducer outputs and the microcontroller input to protect the transducer on microcontroller startup.

USER INTERFACE

Feedback is provided through vibration and an audible signal. The vibration is created by a cell phone vibrating motor supplied by Sanyo. The motor is rated for 1.3 VDC and 160 mA. The PWM from the microcontroller powers the motor. The duty cycle ranges from 60% to 80%. As the duty cycle increases, the inductive nature of the motor averages the voltage coming in and the speed of the motor increases, increasing the vibration as the duty cycle increases. For an object more than 10 feet away, the motor only pulses once; for those between 5 and 10 feet, the motor will pulse twice and three times for objects closer than 5 feet. The current from the PWM pin is not sufficient to drive the motor, so a transistor in the common-emitter configuration is used as a motor interface.

The audio portion of the feedback is provided through a headphone jack. A pulse of noise that is perceived as a click or beep is sent to the user. The audio feedback ranges from 1 to 5 clicks. The vibration pulses in synch with the speaker for an increased impact on the user. No extra circuitry is needed for the speaker; it runs directly from the PWM.

MICROCONTROLLER

The microcontroller chosen for this project is from the Atmel AVR line, specifically the ATmega8. This controller is an 8-bit, 16 MHz processor. It is equipped with a 16 bit timer/counter and three PWM channels, two of which are used to generate the user interfacing signals. The controller also has a 6-channel, 10-bit ADC used for the input from the sensor and to monitor the supply voltage. The Unified Modeling Language (UML) activity diagram for the control algorithm is provided in Fig. 19.5.

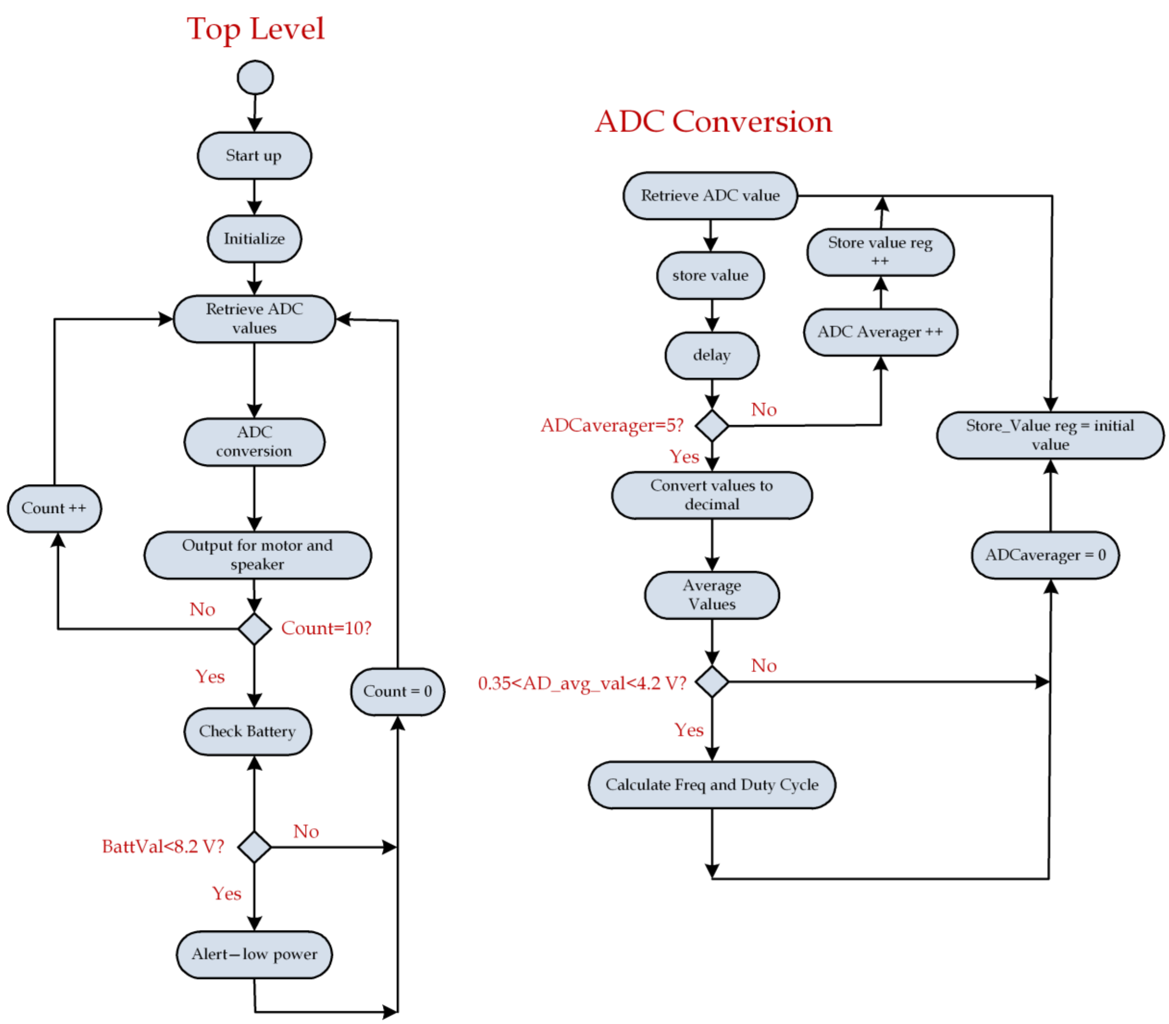

Fig. 19.5. Unified Modeling Language (UML) Activity Diagram for the Control Algorithm

EMERGENCY SIREN DETECTOR

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INTRODUCTION

An emergency siren detector was designed to be placed inside the vehicle of a motorist with a hearing impairment to provide a visual aid when an emergency vehicle sounding a siren is near.

SUMMARY OF IMPACT

The siren detector takes an emergency siren as input and creates a visual signal corresponding to the proximity of the emergency vehicle. The detector is constructed with various analog components such as a microphone, band-pass filter, and RMS-to-DC converter, Atmel microcontroller, and an LED display. The microphone takes in a wide range of frequencies and sends the signal to the band-pass filter, which eliminates unwanted frequencies. The RMS-to-DC converter outputs a steady voltage based on the rms value of the input signal. The microcontroller then illuminate up to eight LEDs based on the steady DC voltage.

TECHNICAL DESCRIPTION

The emergency siren detector works in three stages. The first stage is when a sinusoidal signal is received by the microphone and passed to the band-pass filter to determine if the sinusoidal signal is of the valid frequency range, 1140 to 1650 Hertz. An emergency siren may be defined as a wail, yelp, or high-low signal. The wail is between 1140-1675 Hertz. The yelp has a frequency range of 780 to 1680 hertz. The high-low signal has a frequency range of 800 to 1650 Hertz.

The second stage entails passing the sinusoidal waveform through the band-pass filter and conversion of the signal to a constant DC voltage using an RMS-to-DC converter. If the sinusoidal signal that passes through the band-pass filter has a peak-to-peak value of 10 V RMS, then the RMS-to-DC converter outputs a value of 7.07 VDC.

The third stage consists of an Atmel ATmega8 microcontroller that takes the converted output voltage of the RMS-to-DC converter as an input. The ATmega8 was chosen because of the large number of available input/output pins, the on-chip RC crystal oscillator, and the 10-bit resolution of the analog-to-digital converter (ADC). The ADC on the ATmega8 performs a conversion on the input voltage and excites a bank of eight LEDs based on the output magnitude of the ADC. The block diagram in Fig. 19.6 illustrates the three stages of the emergency siren detector.

The system power for the emergency siren detector comes through a cigarette lighter of the user's vehicle. Using the cigarette lighter allows the device to receive a constant voltage while the vehicle is in operation. The cigarette lighter has an output voltage of +12 VDC, which does not suffice as a voltage for the overall device because some parts on the device require both positive and negative voltages. Therefore, a Mean Well DC/DC converter DCW03 was selected to allow the system to receive both positive and negative voltages. The DC/DC converter is capable of accepting input voltages in the range of 9 VDC to 18 VDC and supplying the system with an output voltage of +/- 12 VDC and a maximum current of 125 mA.

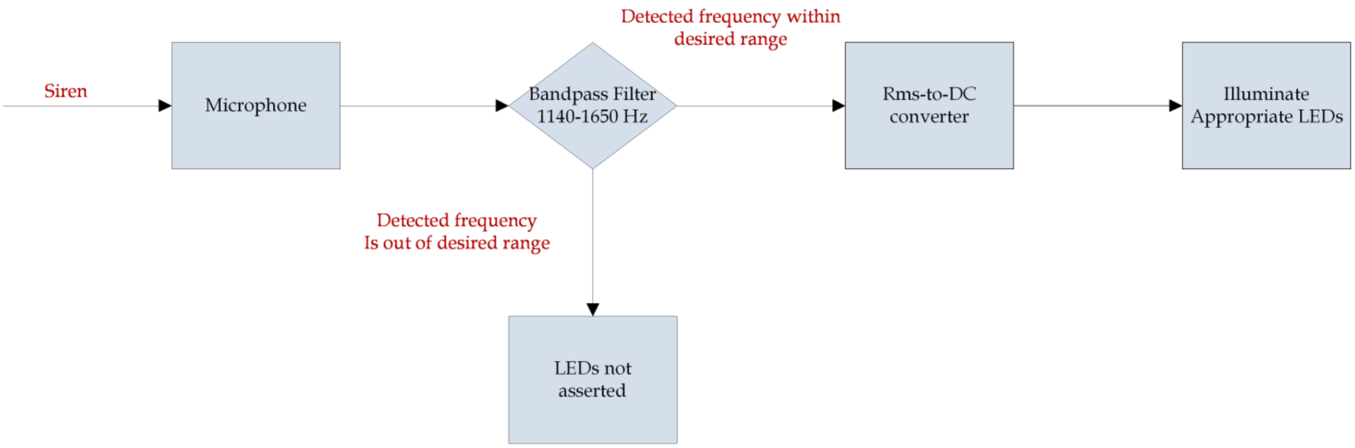

Fig. 19.6. Three Stages of the Emergency Siren Detector.

RUN ANYWEAR FITNESS PERFORMANCE SYSTEM

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INTRODUCTION

The Run AnyWear device was designed to promote physical fitness. The device was intended to provide heart rate, speed, distance traveled, and time elapsed. This can give a better indication of the effectiveness of the fitness program. It allows the user to make sure he or she is keeping his or her heart rate within the target range. This project may be expanded to store the user's exercise data and transfer them to a software program capable of providing statistics to help keep track of progress.

SUMMARY OF IMPACT

The Run AnyWear helps the user monitor his or her functioning during exercise. The main goal was to create an affordable fitness monitoring device appropriate for a wide variety of users. Unlike current machine-specific fitness systems, the Run AnyWear is not dependent upon custom workout equipment, shoes, or other expensive items. The user may use the device in any environment (indoors or outdoors). Due to time constraints, the speed and distance traveled functions were never completed.

The device is user-friendly and easy to read. This makes it more suitable for use by those who may have cognitive disabilities or visual impairments. For example, the display of the device is a four-digit seven-segment display, which has a much brighter contrast than can be provided through other displays.

TECHNICAL DESCRIPTION

The USB microcontroller, the main component of this project, analyzes all of the data from the accelerometer and pulse plethysmograph. It has several different functions. These functions include timing, data conversion, and displaying different statistics that are provided to the user. All of the subsystems are controlled through these functions in the microcontroller. Each data type is displayed for fifteen seconds at a time. The overall system flow is shown in the UML diagram in Fig. 19.8.

Fig. 19.7. The Run AnyWear

C programming was used because it is a high-level language and is easier to read and understand than assembly programming. AVR Studio4 was used to complete the microcontroller code because it has a built-in GCC compiler. This program was available at no cost on the Atmel website. It allowed completion of every step of the programming process, including writing the code, building the project, compiling, and programming the microcontroller chip. The microcontroller used was the ATmega8535, which is a 40-pin dual inline package (DIP) microcontroller produced by Atmel. The completed subsystems of the Run AnyWear are the timer, the heart rate, and the display.

The timer function was set up through a series of if-else loops. These loops control when the variables seconds, ten seconds, minutes, and ten minutes are incremented. Each digit must be illuminated separately so that the value sent to PORTB, which was used to select the appropriate digit, is cycled.

The value of the least significant digit is sent first so PORTB is originally set for that particular digit. This is followed by a 5 ms delay and PORTB being set to activate the second digit. This again is followed by another 5 ms delay, and then the third digit is displayed. This continues until a complete cycle is made, illuminating each digit in turn. A second elapses between each instant that the timer function is called. Another series of if-else statements is within the loop. These statements control which value is sent to PORTC, which in turn controls the illumination of individual segments to form the appropriate number.

For the heart rate subsystem, three separate functions are implemented in the microcontroller. These include an interrupt service routine for when a rising edge is detected on the input capture pin, a heart rate function that calculates the heart rate based on the value of timer1 at the time of a capture event, and a function that displays the heart rate. The heart rate display function is similar to the timer function. The only difference is that the variables that are examined are ones, tens, hundreds, and thousands instead of seconds, ten seconds, minutes, and ten minutes. However, before these comparisons can be made, a few calculations are completed to determine the values of these variables. Once the calculations are completed, a loop is entered, cycling through each digit and displaying the appropriate value. This code operates based on the register settings that are made in the initialize ports function. The heart rate subsystem also requires an interface between the pulse plethysmograph and the microcontroller. The initial testing of the sensor resulted in a waveform that varied between 5mV and 15mV. This waveform is dependent upon the person, the location of the sensor, whether or not the person is holding still, and the lighting conditions in the room.

The first step in creating the interface was to eliminate the DC component of the signal. Because the waveform had such a small magnitude, a gain of 100 was implemented. Both the original and amplified signals were centered around 0V, so the next step in the signal conditioning process involved using an op amp again to rectify the signal. The input capture function on the ATmega8535 senses rising or falling edges of a signal. Therefore, the last step required in the signal conditioning process was to adjust the rectified signal so that it became a square waveform. The effect of this conditioning

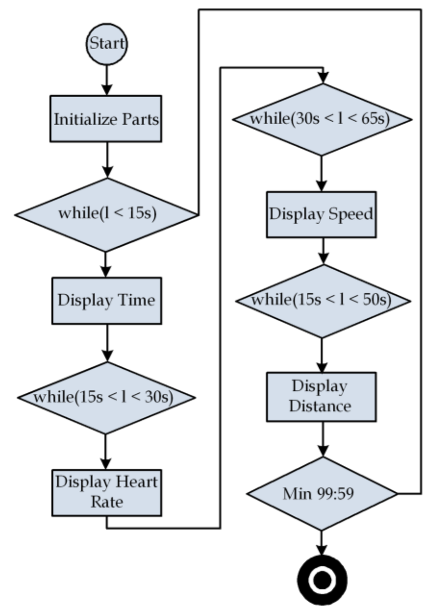

Fig. 19.8. UML Diagram of System Flow.

gave a pulse that could be adjusted to any range between 0V to 5V by tuning the potentiometer. After the voltage waveform is transformed to a square waveform between zero and five volts, it is sent to the microcontroller's input capture pin. This pin is suitable for edge detection. For this project, the microcontroller was set to capture on a rising edge. Every time a rising edge is detected, the timer1 is started. The counter continues incrementing until the next rising edge occurs. From this, the time per pulse is calculated based on the system clock speed and prescaler settings.

The user can view all statistics of a workout by simply observing the seven-segment display. The display chosen for this application has four digits, with a decimal point following each one. It also has a colon in the middle of the four digits so that it is suitable for displaying time. This colon is linked to the other decimal point of the second most significant digit on the display's pin configuration. There is a separate display loop for both the timer and the heart rate functions. The timer's display is integrated into the timer function because the loop is actually responsible for keeping track of time by making each value display for one second before entering the if-else statements again. In the case of the heart rate, a separate function is used to display the value.

The overall cost of this project was $209.

SMOKE ALARM FOR PEOPLE WITH HEARING IMPAIRMENT

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INTRODUCTION

A smoke alarm was designed for use by people with hearing disabilities who cannot hear standard alarms. The device uses RF transmission to send a signal from an active alarm to a receiver unit placed at the user's discretion. At the receiver unit two bright xenon tube strobe lights are used to notify the user of a triggered alarm.

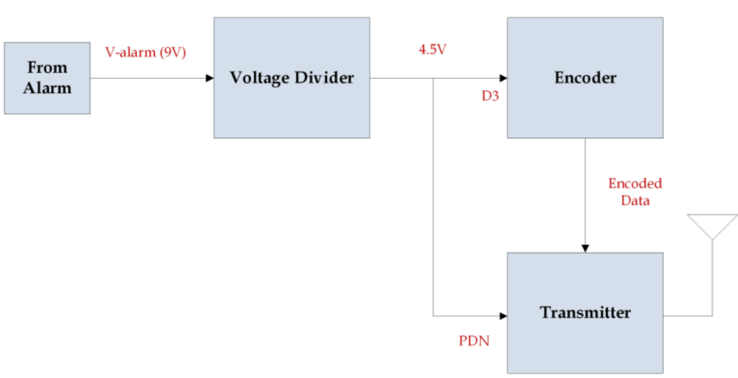
SUMMARY OF IMPACT

The device successfully notifies the user of a smoke or fire hazard. The coupled transmitter and receiver has a significant range to ensure signal reliability in an average sized home or office. Multiple receiver and transmitter units can be used on the same frequency to alert multiple users in a large building.

TECHNICAL DESCRIPTION

The alarm unit consists of a standard smoke alarm, a battery powered transmitter unit and a receiver unit. A signal from an active smoke alarm is used to activate an encoder. The data from the encoder is then sent to the transmitter where it is modulated and sent to the receiver. The transmitter section is battery operated and all components operate in the battery-saving low-current mode when an alarm is not present. The transmitter operation is shown in Fig. 19.9.

The receiver unit scans its programmed frequency for data sent by the transmitter. Once data are acquired they are sent to the decoder. Once the decoder verifies the data, it outputs a signal that acts as a control for two solid-state relays. After the relays are activated, the strobe lights are each connected to a 9V battery and proceed to flash. The receiver section's operation is shown in Fig. 19.10.



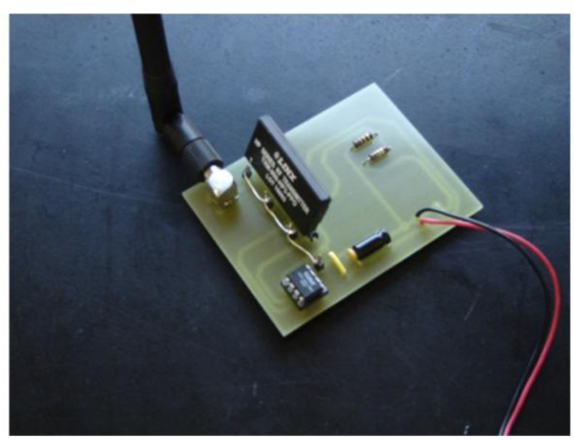


Fig. 19.9. Transmitter Operation Circuit and Photograph.

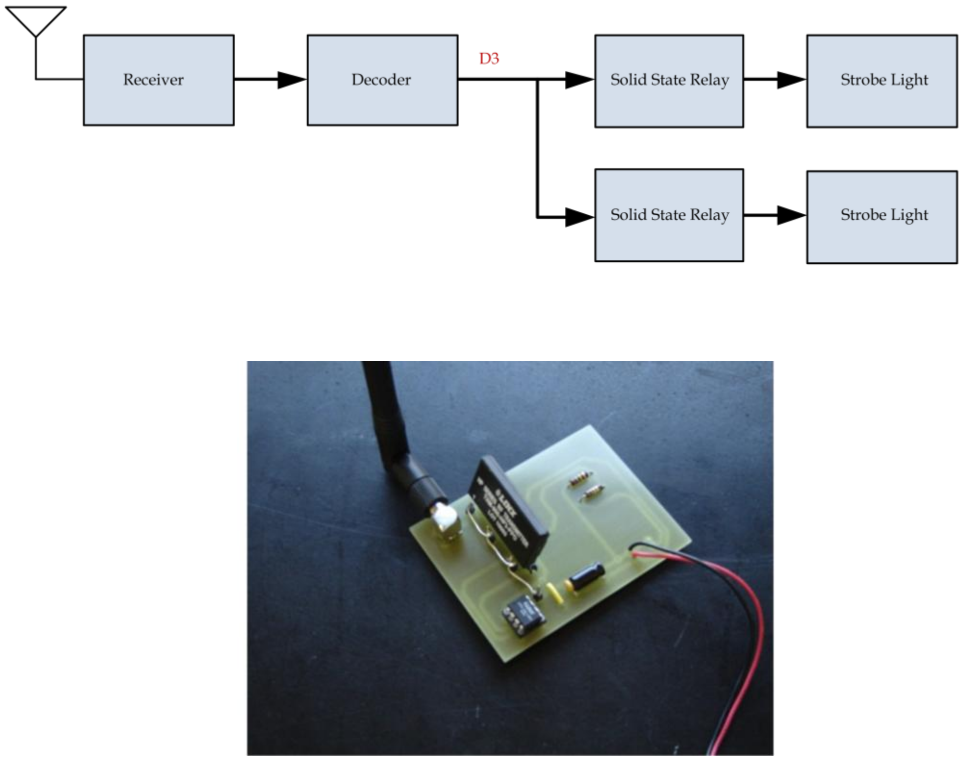


Fig. 19.10. Receiver Operation Circuit and Photograph.