# Design Specification for an Ultrasonic Wayfinder

## Specification

System Description

The design specification describes an implementation of an ultrasonic-range-finding device which utilizes haptic feedbacks to alert its user about obstacles in his path. This device is a wearable spatial recognition device for sight impaired individuals. At its core, is a combination of several transmitting and receiving circuits capable of emitting short pulses of ultrasonic-frequency waves through the transmitters while able to pick up the echoed pulses with the receiver. The time delay between the emission of the initial pulse and the receipt of the echo gives the system the necessary data to determine how far away the obstacle(s) is from the sensor, which can be conveyed to the user by vibrating a small motor at the intensity proportional to the distance. This gives the user a sense of spatial recognition in almost all kind of environments. This project is purposed as a proof-of-concept for a product that can be used by sight-impaired individuals to detect obstructions.

Specification of External Environment

The system is designed to operate in any dry environment. But its main purpose is to help the user navigate spaces with obstacles in their paths. Since the system utilizes ultrasonic echolocation to provide the user the ability to navigate close spaces, it works best when the ultrasonic waveforms are not be interrupted by other potential interferences in the general vicinity. Therefore, the amount of such way finding devices that can operate within the same area is limited. This is not a major concern in designing the system since it’s fairly rare for multiple people who require the assistance of such a system to be in the same space at once.

The device is powered by a 9V battery; therefore, it does not depend on an immobile power system. However, in order to ensure an uninterrupted working condition, the user is advised to carry a backup battery.

System Input and Output Specification

Inputs

The system supports the following basic inputs from the user:

* + - * Power on [User controlled] – On condition for the system
        + 9 V - Voltage threshold + or – 0.5 V
      * Power off [User controlled] – Off condition for the system
        + 0 V - + or – 0.01 V
      * Intensity HIGH [User controlled]– Specifies a higher intensity vibration proportional to the distance from the obstacles.
        + PWM Output 0-75% duty cycle + or – 0.02%
      * Intensity LOW [User controlled]– Specifies a lower intensity vibration proportional to the distance from the obstacles.
        + PWM Output 0-100% duty cycle + or – 0.02%

The internal system input, which does not rely on user specification:

* Echoed Signal [Internal system] – The input needed to determine the distance from the obstacles

Outputs

The system main outputs are the haptic feedback provided to the user:

* Vibration left – Left motor vibration to indicate obstacle on the left side.
  + PWM output duty cycle + or - 0.02%
* Vibration right – Right motor vibration to indicate obstacle on the right side.
  + PWM output duty cycle + or - 0.02%
* Vibration hand – Hand-attached motor vibration to indicate obstacle in the direction pointed to by the user
  + PWM output duty cycle + or - 0.02%
* Sound notification – A voice notification is provided to the user via a headphone output to indicate low battery condition, and obstacles left or right of the user
  + PWM output duty cycle + or - 0.02%

The internal system output, which does not rely on user specification:

* Transmitted Signal [Internal system] – The output from the system to echolocate the closest obstacles

User Interface

The user has control of three mechanical buttons:

* + - On button – Allows the user to turn the system on
    - Off button – Allows the user to turn the system off
    - Toggle intensity – Changes between HIGH and LOW intensity level

All outputs of the system will be in the form of haptic feedback or audio responses:

* Vibration left
* Vibration right
* Vibration hand
* Battery low indication (audio)

The system is not designed to include a display. But for general testing and debugging purposes, a terminal communication will be set up to monitor the system’s initial performance. The terminal displays the following information:

|  |
| --- |
| On/Off State: ON Intensity: LOW Distance: 1 meter PWM duty: 50% IR sensor: There is a person in front of you |

System Functional Specification

The ultrasonic wayfinder is intended to allow the user the ability to navigate close spaces without the dependency on the heavier equipment such as the traditional white cane. The system also gives the user a sense of spatial awareness that the traditional cane was not able to. The control of the system is relatively simple as the only task the user is required to do is equipping the necessary items, then turn on the system. The user also has the ability to choose between two vibration intensities to match his preference.

The output of the system includes haptic feedbacks to the three motors; the conditions and intensities of these feedbacks correspond to the environment in which the system is used. For example, if there exists an obstacle such as a wall about 35 degree and 1 foot away from the user, the left motor would vibrate at full intensity while the right motor stays idle. Correspondingly, if the obstacle were straight ahead and 1 foot away, both motors would vibrate at near-full intensity.

The hand-mounted motor vibrates whenever the user points their hand-mounted sensor at a nearby object. This hand-mounted device represents the traditional cane, but it is less wieldy and offers the user more spatial awareness due to the ability to be pointed anywhere. While the two main head-mounted sensors are more like seeing eyes, giving the user the ability to recognize obstacles ~60 degrees in front.

The system comprises of several major blocks as given in the following high level block diagram

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| Figure 1. High level diagram |
|  |

**Input Subsystem** – The input subsystem includes the ultrasonic receivers and the PIR sensor. These two apparatus collect the data required for the operation of the wayfinder. They route the input signals to the appropriate portion of the control subsystem, which is the main PIC microcontroller.

**Output Subsystem** – The output subsystem is the driver for the audio feedback, vibrator plates, and the ultrasonic transmitter. This portion of the system maintains the logic necessary to convey the necessary data to the user.

**Time Base** – The time base is implemented as external 20MHz crystal oscillator, input to the main system through a one-wire connection. The crystal oscillator operates on a standard 5V input, similar to the main system. The time base provides the frequencies that are used to define the measurement windows for events such as the transmission rate of the transmitter, the measurement timing of the receiver as well as the idle time of the PIR sensor. The PWM module, which drives the vibrators also operate based on the main system clock.

Frequency

* 20 MHz + or – 10 Mhz

Period

* 5e-8 seconds + or – 0.01e-8

Events

Ultrasonic Transmission

* + - Frequency – 17 Hz + or – 1 Hz
    - Period – 60 ms

Ultrasonic Reception

* + - Frequency – 17 Hz + or – 1 Hz
    - Period – 60 ms

**Logic Subsystem** – The logic portion provides the main logic and control flow to the rest of the system.

When the system transmits an ultrasonic pulse, the main logic system starts a timer, which indicates the start time of the ranging period. Once the echoed pulse has been receive, the logic subsystem stops the counter, giving the system the necessary data to calculate how far away the wave has travelled before coming back to the device.

After measuring the distance, the logic subsystem determines the appropriate outputs. These output controls are fed into the output subsystem, completing one cycle of the control and logic task.

**Power Supply Subsystem** – The system will be powered by a 9 V battery. All three subsystems above operate on a 5 V input, which means it is essential for the supply subsystem to regulate the input voltage from the battery.

At power on, there shall be a negative going reset signal. The signal will remain in the low state indefinitely until an off signal is issued by the user.

Operating Specifications

The system will be expected operate in a standard commercial environment. In the cases of harsh weather such as rain, snow, or other extremities, the system is not expected to operate due to the nature of it being an electronic device. A weatherproof prototype may be developed in the future if the product performs exceedingly well in the initial development phase.

Temperature range

* 20 – 80°C

Humidity

* 20 – 60% non condensing

Pressure

* 1 atmosphere

Power

* 9 VDC + or – 0.5V

The system is design to meet the following specification

1 month

* Frequency – 20 MHz
* Period – 5e-8 seconds
* Events – Transmit, Receive, Calculation, Output

Since the system is a prototype, the expectation for durability is not strict. The subsequent refinements and updates shall create a more robust and efficient system which is able to operate after a longer period of time.

Reliability and Safety Specification

Because this system might ultimately be used by a person with disability, safety is one of the main design concerns. The following standards are followed during the design and implementation of the system:

* ANSI/ISA S82.02.02:1996 – Safety standard for electrical and electronic testing
* ECMA-287 – Standard of electronic equipment
* EN 50065-1:1991 – Signaling on low-voltage

During the current phase of the design, MTBF can’t be precisely estimated. The operation is expected to be working as intended for 1 month per demo purposes.

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| --- | --- | --- | --- | --- |
| **Bills of Material** |  |  |  |  |
| **Item** | **Quanitity** | **Price** | **Shipping** | **Item Total Price** |
| PIC18F25K22 | 3 | $6.84 | $0.00 | $20.52 |
| Breadboard | 1 | $26.00 | $0.00 | $26.00 |
| MAX232 | 1 | $0.60 | $0.00 | $0.60 |
| 20MHz Crystal Oscillator | 2 | $2.40 | $0.00 | $4.80 |
| SRAM CY7C128A | 2 | $4.00 | $0.00 | $8.00 |
| Jumper wire 75 pcs | 1 | $5.09 | $0.00 | $5.09 |
| IR Sensors | 1 | $0.98 | $0.00 | $0.98 |
| Vibration motor | 2 | $1.95 | $10.00 | $13.90 |
| Ultrasonic distance sensor | 3 | $14.98 | $0.00 | $44.94 |
| Headphones | 1 | $9.99 | $0.00 | $9.99 |
| Push button | 3 | $0.49 | $0.00 | $1.47 |
| 9 volt battery | 1 | $3.50 | $0.00 | $3.50 |
| Total Cost |  |  |  | $140.00 |

Figure . Bill of materials



Figure 4. Functional Decomposition



Figure 5. Schedule