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November 6th, 2000

Dr. Andrew Rawicz
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Re: ENSC 340 Wireless Child Tether Design Specifications

Dear Dr. Rawicz,

The following document, *Wireless Child Tether Design Specifications*, describes the requirements for our wireless child tether. The goal of this project is to alert parents if their child wanders outside a predetermined area and to then provide means for tracking the child.

This document describes the implementation of the functions we described in our functional specification document. We describe the circuits and software that will make up the wireless child tether.

Second Sight Systems (SSS) consists of four talented and motivated third-year engineering students – Ian Foulds, Shaun Louie, Desmond Lee, and Andy Somody. If you have any questions concerning this project, please contact me by email at ifoulds@sfu.ca or by phone at 926-6921.

Sincerely,

Ian Foulds
President and CEO
Second Sight Systems

Enclosure: Wireless Child Tether Design Specifications



Wireless Child Tether

Design Specifications

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Submitted On: November 6th, 2000



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Executive Summary

The Second Sight wireless child tether acts as a child's tireless guardian. It consists of two complementary transceiver units – one for the parent, the other for the child. If the child wanders farther than a predetermined distance from the parent, an alarm on the parent's unit is activated. The parent can then use their unit to determine the direction of the missing child. Alternatively, the parent can remotely activate a distress alarm on the child's unit.

While child-monitoring systems are nothing new, the Second Sight wireless child tether has several key advantages over previous design solutions. There is no physical connection between the parent and child, which allows both parties freedom of movement. Additionally, our wireless child tether gives information about the child's direction, a feature missing from currently available design solutions.

The wireless child tether is a radio frequency system consisting of two devices operating in the 900 MHz range. We will be implementing the 900 MHz link with a Linx Technologies HP-900 evaluation board. The parent will carry one device, and the child will carry the other device. The parent will track the child in the event that the child ventures beyond a user defined signal-strength threshold. The parent will then be able to activate an audible alarm on the child unit. Descriptions of the implementation of all these features are given in this document. We also give descriptions of our provisions for safety and reliability. A test plan to help us determine the success of this project is also given.



Introduction

Children don't always understand the need to stay close to their guardians and tend to wander. At Second Sight Systems, our goal is to develop technology that helps guardians protect their children. Physical child tethers have been in existence for quite some time now but they have the disadvantage of being unwieldy and awkward. The physical tether is forever getting tangled around objects and even other people. It becomes a nuisance in large crowds, which ironically is where it is needed most. Fortunately, we at Second Sight have devised an elegant alternative – the wireless child tether.

The wireless child tether will allow both parent and child the freedom of movement but will help the parent to keep their child from wandering. An alarm is activated on the parent's unit when the signal strength of the child's transmitter is below a user-defined threshold at the parent's location. The parent's unit can then be used either to determine the direction in which their child has wandered, or set off an alarm on the child's unit.

In this document we begin with system overview block diagrams. We go on to describe the antenna layout and transmitter and receiver modules. We then describe the software and the selection of our microprocessor. Basic layouts for our enclosures are also given. We provide a test plan for verification of our product's features and functionality. Finally, we provide a bill of materials.

1. System Overview

Figure 1 and Figure 2 are block diagrams that describe the parent and child units.

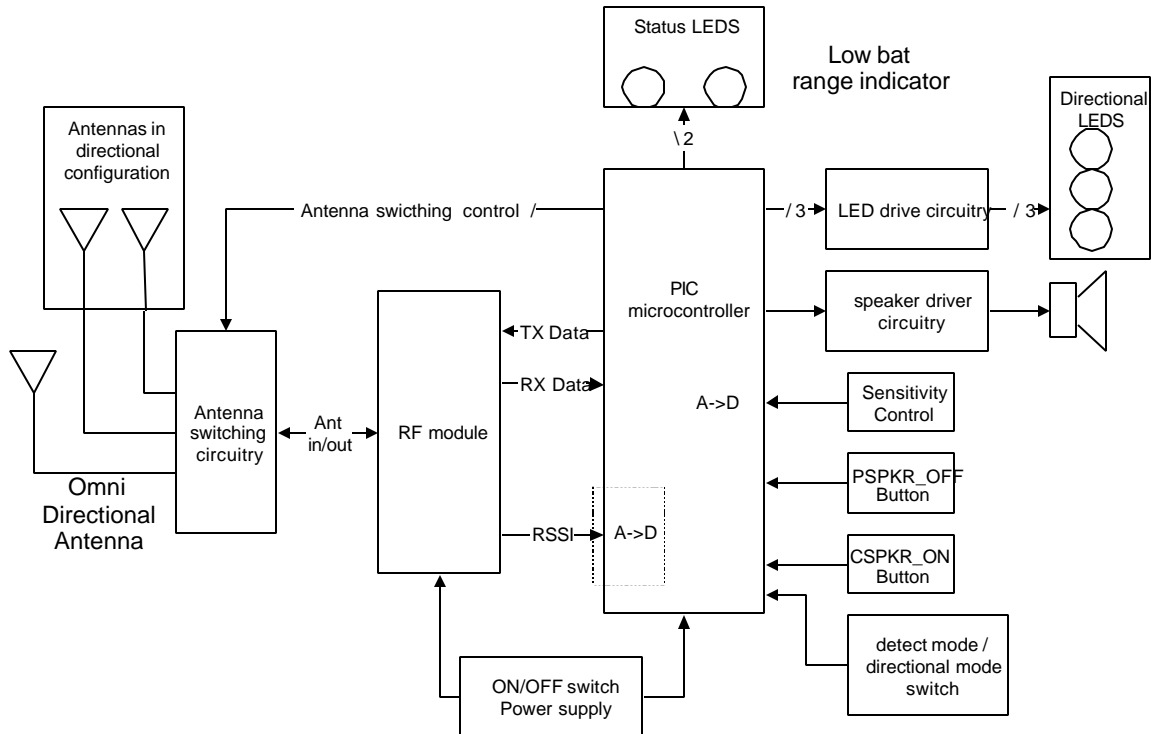


Figure 1: Parent unit system overview

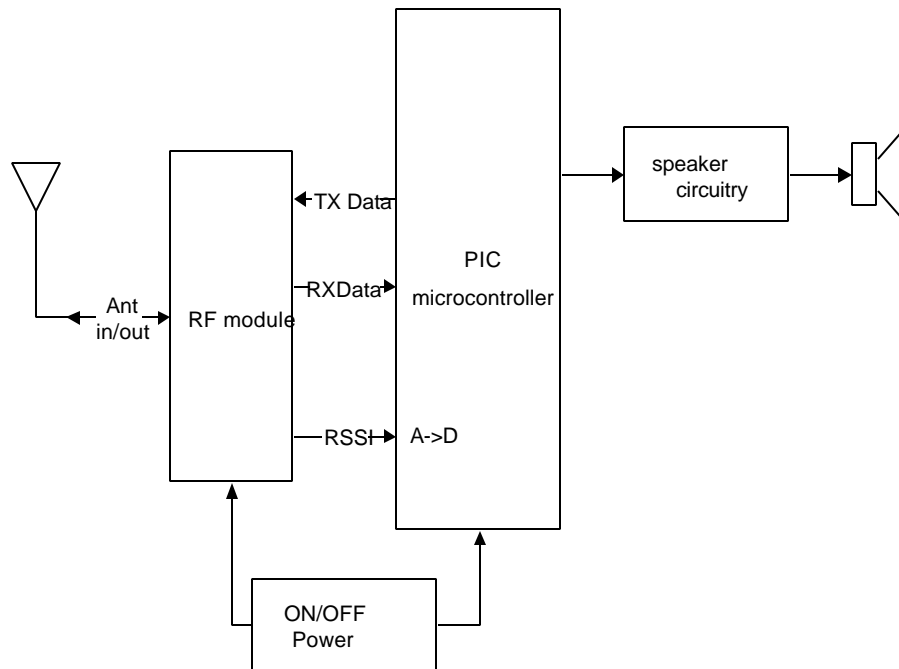


Figure 2: Child unit system overview

1.1. Signal Acquisition

1.1.1. Parent Unit

The parent unit will have two methods of receiving incoming signals from the child unit. As illustrated in Figure 1, the signal can be received through the omni directional antenna as well as the antennas in the direction detection configuration.

The detect/directional mode switch will tell the microcontroller which antennas to acquire a signal from. A control line from the controller to the antenna switching circuitry will select which antenna is connected to the ANT IN/OUT pin of the RF module.

The switching circuitry will be a 3-1 MUX style switch using 2 control lines. Currently a relay type device by dB Products is being evaluated. It allows for switching between 2 devices. Using 2 of these will allow for switching between the 3 antennas.

1.1.1.1. Detection mode

In detection mode operation the microcontroller will only be looking at the omni-directional antenna for input. Signals will be transmitted to the child through the omni-directional antenna.

1.1.1.2. Directional mode

In directional mode the controller will be switching through each of the antennas as input. The omni directional antenna will be a standard monopole antenna. It will be used to provide a RSSI value for LED indication of the child's signal level. If the child is out of the preset range the LED will be lit.

The directional antenna configuration will be used to determine the direction that the RF signal is coming from. The configuration will consist of 2 regular monopole antennas in a V placement. The antennas will be shielded on all sides except one, which will be the direction that the user is testing for a signal. The configuration is illustrated in Figure 3.

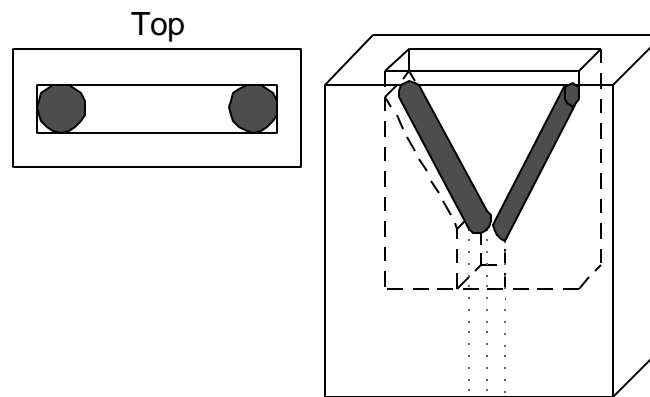


Figure 3: Directional antenna configuration

Depending on the direction of the signal, the signal strength detected at each antenna will be different. The controller will analyze the signal strength obtained from each antenna to decide the signal direction. The directional LEDs will light up to indicate which direction the signal is coming from. Figure 4 illustrates the directional situations that we will be looking for.

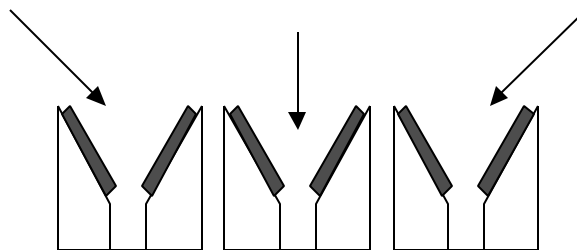


Figure 4: Signal direction determination

If the signal is coming straight ahead then the signal strength of each antenna should be similar.

1.1.2. Child Unit

The child unit TX signal will produce a bit stream which it will then transmit through the omni-directional antenna. The child unit will also receive data through the same antenna.

1.2. Signal Amplification / Filtering / Demodulation

The signals going into the RF modules from the antennas will consist of desired modulated data, noise and any other broadcasted signal detected by the antenna. The front end signal processing is performed by the LINX RF modules.

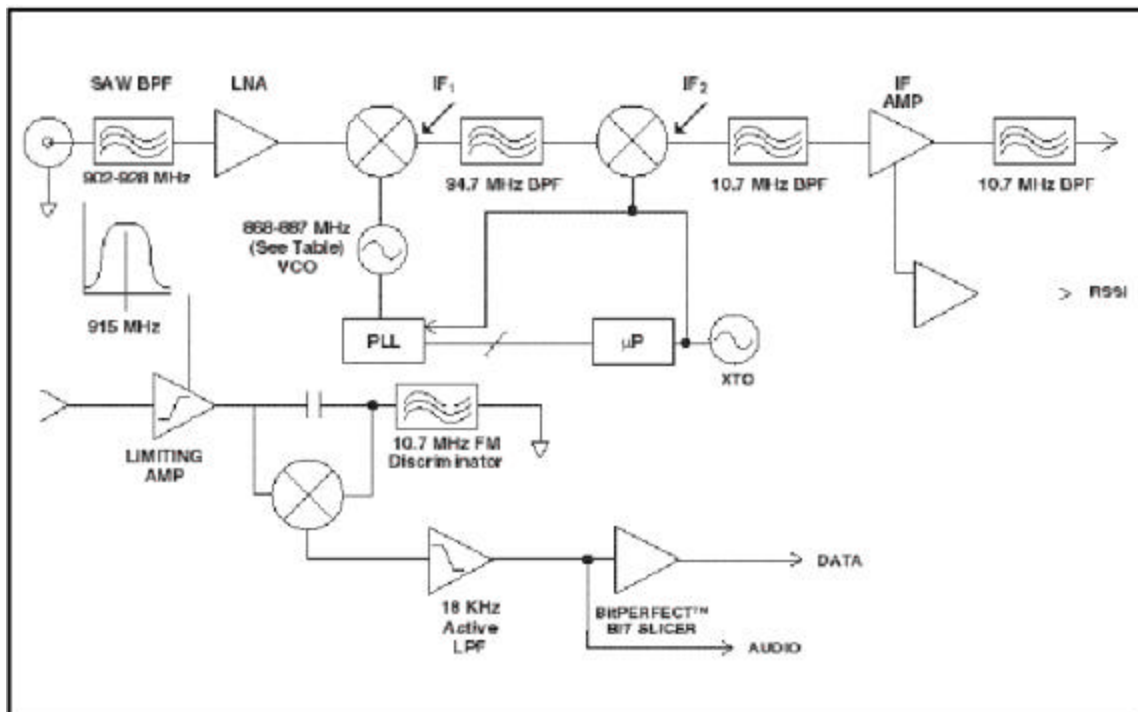


Figure 5: RX chain block diagram

The incoming modulated signal is filtered through a SAW band pass filter to eliminate anything that is not the desired signal. The filtered signal is amplified by a low noise amplifier (LNA) and brought down through 2 different intermediate frequencies before being filtered again and sent for demodulation. The demodulation is done by the Gilbert multiplier directly following the limiting amplifier in Figure 5. The output of the multiplier will be a signal resembling the original signal, modulated and transmitted by the transmitting source. For further details refer to the LINX receiver evaluation reference manual.

On the transmit side, a predetermined bit stream will be generated in the microprocessor and sent through the TX data input on the RF module. The

signal will be modulated, up-converted to the carrier frequency, amplified and finally filtered before being radiated from the antenna. A block diagram of the TX chain is shown in Figure 6 below.

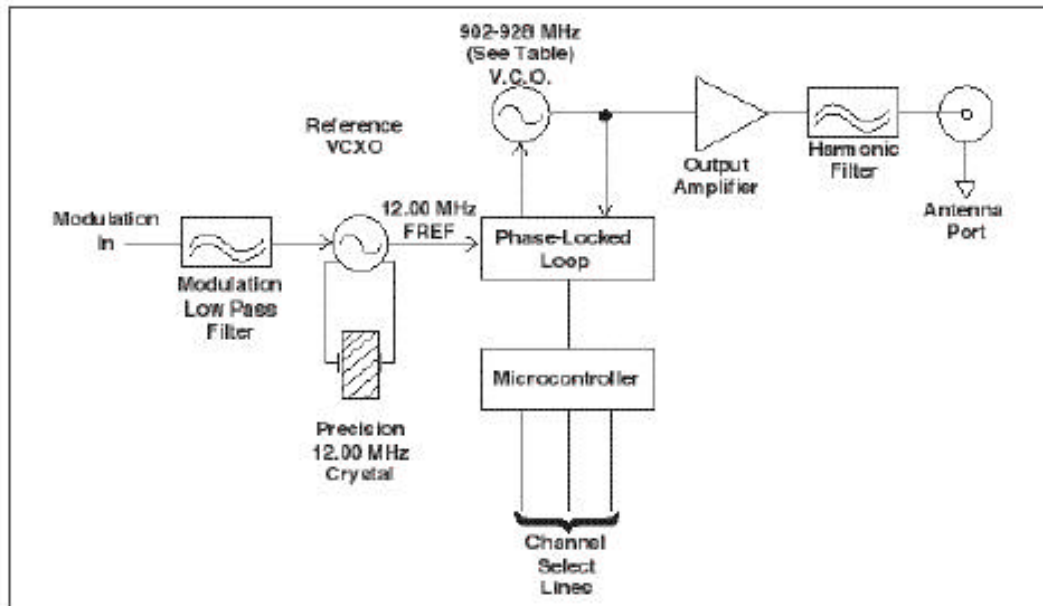


Figure 6: TX chain block diagram

1.3. Data Processing

The Data Processing units on the child and parent units perform complimentary functions. These functions are described in detail below.

1.3.1. Parent Unit

On power-up, the parent unit poles the mode switch and switches a physical switch to the appropriate antenna. It then enters one of two loops based on which antenna has been selected.

If the omni-directional antenna has been selected, the parent unit first reads the value of the sensitivity knob to determine the threshold RSSI level that the user has chosen. The parent unit then continues to check the received data until it sees the correct signal. If the predefined signal is not received within the given time period or if the RSSI of the signal is below the threshold, the visual and audio alarms on the parent unit are turned on. Otherwise, a confirmation signal is sent to the child unit.

The audio alarm on the parent's device can be deactivated by pressing the PSPKR_OFF (parent audio alarm off) button. In addition, the audio alarm on the child's device can be activated at the parent's discretion by pressing the CSPKR_ON (child's audio alarm on) button. Both of these buttons can be seen in



Figure 1. All of these alarms are automatically deactivated once the child is again safely within range.

Once directional mode has been selected, the parent's unit toggles between each directional antenna and compares their RSSI levels. If the RSSI of one antenna is 3dB stronger than that of the other, the corresponding LED on the directional interface is turned on. Otherwise, the middle LED is turned on.

A summary of these operations is shown in Figure 7 below.

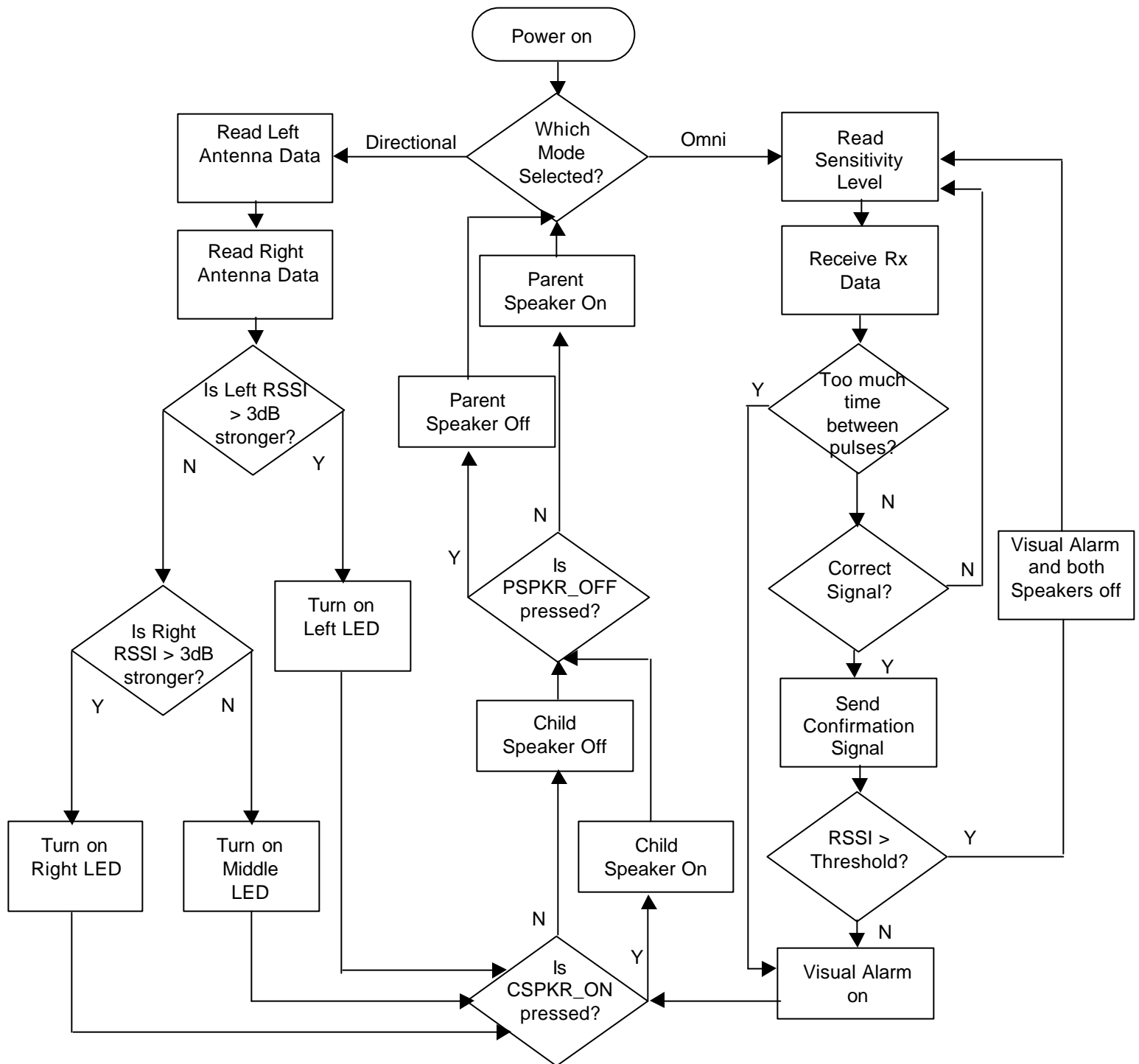


Figure 7: Flowchart for Parent Data Processing Unit

1.3.2. Child Unit

The child unit produces the predetermined data pulse at constant intervals and sends this pulse to its transmitter. It switches into receive mode between pulses so that it may respond to any commands the parent is sending. The child's transmitter is also put into sleep mode between pulses to conserve battery power.

If the child unit does not receive the confirmation signal from the parent, this indicates that the communication link between the two units has been dropped, so the child's audio alarm is activated. Likewise, if the parent triggers the CSPRK_ON command, the child's audio alarm should also be turned on. A summary of these operations is shown in Figure 8 below.

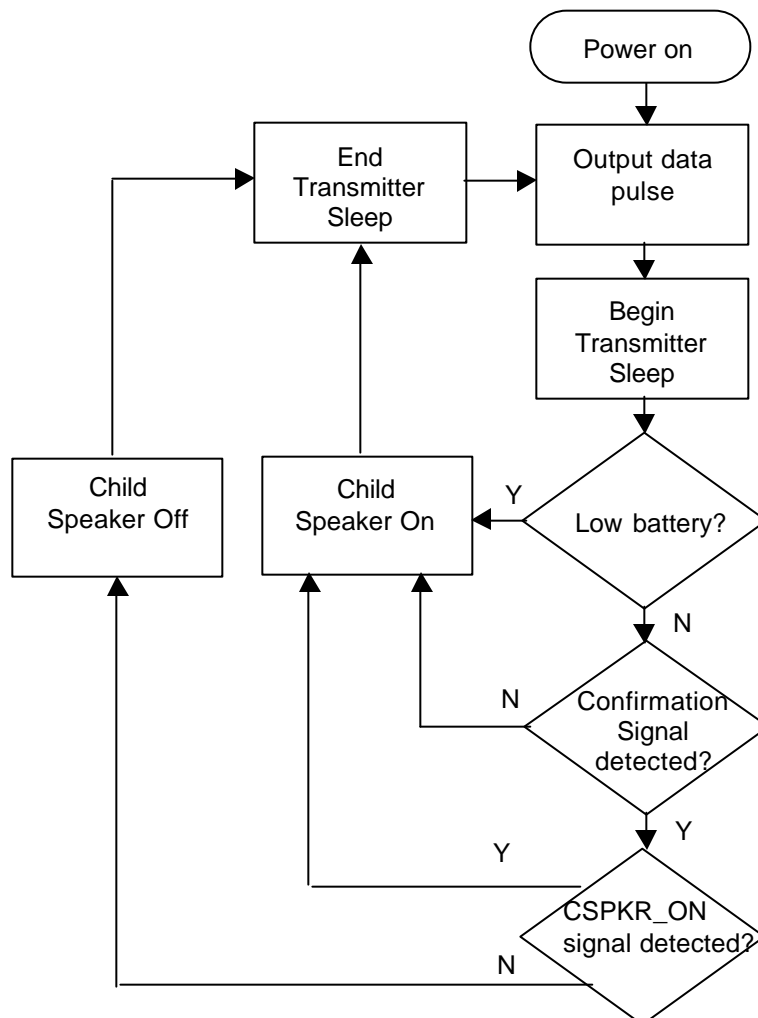


Figure 8: Flowchart for the Child Data Processing Unit

1.3.3. Microcontroller Selection

In choosing our microcontroller, we wanted to ensure that it could perform all of our required functions without being too expensive or difficult to interface with. We also decided to use the same microcontroller on both the child and parent unit. This has allowed us to become familiar with a single architecture and to use a common core of code for both units.

We chose to use the Microchip PIC16F873/20sp microcontroller for a few key reasons. It has 22 I/O pins, which is 8 more than the 14 pins required on the parent unit. These additional pins provide us with a substantial amount of headroom in case we want to add functionality or change the existing implementation slightly. For example, instead of cyclically switching between the two directional antennas and using a single RSSI input, we could have two RSSI inputs and have each being continuously polled. Although switching between the two antennas has inherent advantages (such as eliminating any impedance matching problems), we may decide that constantly polling both antennas is easier to implement. Having the additional I/O pins gives us that flexibility.

We did not want to choose a device with too many additional pins, since this would increase the device complexity and cost. Microchip offers other PIC microcontrollers with slight differences from the PIC16F873/20sp, such as the PIC16F877 and PIC16F874 lines. However, both of these alternatives have 33 I/O pins, a parallel slave port, and other advanced functionality that we do not need.

The PIC16F873/20sp microcontroller also has an Analog-to-Digital Converter with 5 inputs, which is more than the 2 A/D inputs we need for our current basic implementation. However, this again gives us implementation flexibility.

The PIC16F873/20sp can operate on an input voltage of 4.0V to 7.5V, which enables it to be powered off of the same batteries that are used to power the other active components, such as the transmitter/receiver and the speaker. However, our current regulator can only source up to 35 mA of current, so we may need an additional one in order to power the pic and the transmitter/receiver off the same battery source.

Our chosen microcontroller also possesses two external interrupts. This allows us to connect the PSPKR_OFF and CSPKR_ON buttons directly to these interrupts. If additional interrupts are required, we can perform these in software after reading the inputs through the general-purpose I/O ports.

The PIC16F873/20sp has a sleep mode feature that we can use to reduce power consumption on the child's unit between transmissions. This sleep operation can be synchronized to the on-board watchdog timer, which uses a dedicated RC oscillator to ensure that it still counts while the rest of the device is powered down. Thus, all of the components needed to implement a sleep feature are included in this microcontroller.

A schematic for the PIC16F873/20sp is shown in Figure 9 below.

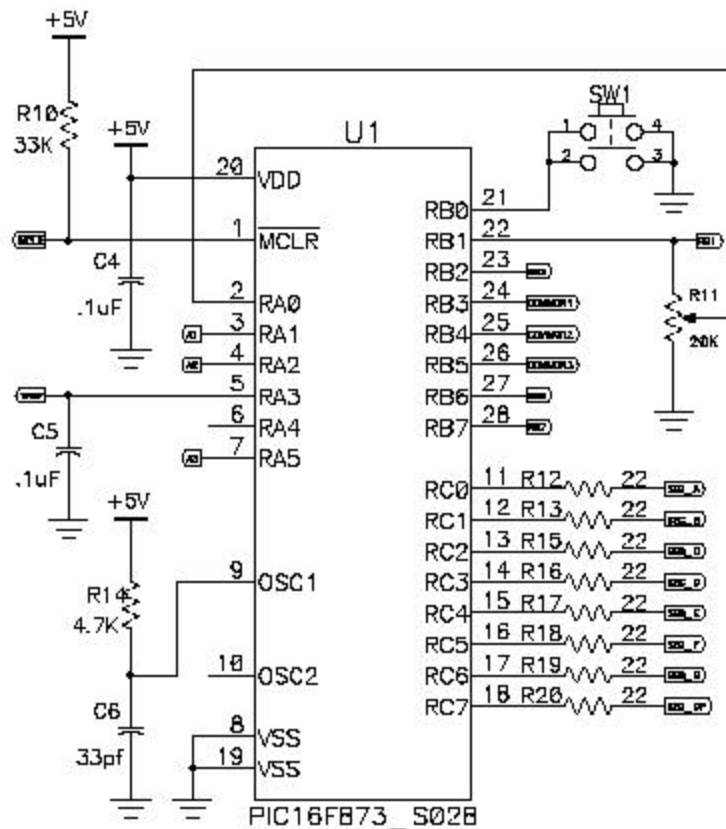


Figure 9: Schematic for PIC16F873/20sp

1.4. Alarm Stimulus

The buzzer we are using is a *Panasonic Piezoelectric Ceramic Buzzer* and is driven by the circuit shown in Figure 10. It requires a voltage of 3-20VDC, and will produce a tone of about 3 kHz at 100dB@12VDC. The loudness of the buzzer is determined by the voltage level that is driving it; higher voltages produce a louder tone. Note: PB in Figure 10 is the Piezoelectric Buzzer.

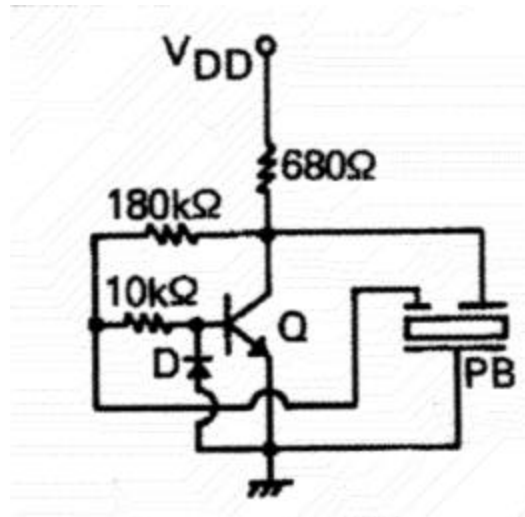


Figure 10: Buzzer Driver Circuit

Alarm Stimulus - at least 3 volts to drive the buzzer. The buzzer may need 10 volts to be effective at giving an audible alarm. The current requirement for the buzzer is 15mA @ 12VDC.

2. Electrical Specifications

The following table describes the electrical specifications for the wireless child tether's major components.

Device	Min	Typical	Max
Transmitter/Receiver			
Input Voltage (V)	2.7	10.0	16.0
Supply Current (mA)	-	15.0	17.0
Sleep Current (uA)	-	-	50
Power Consumption (W)	-	0.820	1.3
Microcontroller			
Input Voltage (V)	-0.3	-	7.5
Supply Current (mA)	-	1.6	4
Sleep Current (uA)	-	-	15
Current sunk by any I/O pin (mA)	-	-	25



Power Consumption (W)	-	1	-
Antennas			
Power Consumption (W)	-	0.5	0.5
Buzzer			
Input Voltage (V)	3.0	10.0	20.0
Supply Current (mA)	-	15.0	30.0

3. Enclosure

3.1. Parent Unit

A visual representation of the parent unit is shown in Figure 11.

The parent unit is turned on/off by the switch at the bottom right of the unit.

The three direction finding LED's are located at the top. When the switch is activated for direction finding mode (below the 3 LEDs), the left LED will light up to tell the parent to turn left, the right LED will light up to tell the parent to turn right, and the middle LED will light up to tell the parent to move straight ahead. These are rough directional indicators based on the relative RSSI values of the left and right antennas. If the centre LED lights up, that indicates that the child is within a cone of approximately 30° in front of the parent.

The alarm is to the right of the direction mode switch (blue slots in casing), and can be turned off by the yellow button located directly to its left.

A panic button (green) is located to the left of the direction mode switch, which activates the alarm on the child unit. This panic button corresponds to the CSPKR_ON button in Figure 1.

The sensitivity adjustment knob (black cylinder) will have either a brake or predefined 'stops' so that the sensitivity is not accidentally bumped and changed.

The low-power LED is located at the bottom left, and will change color from green to red when the power level goes to minimum levels.



Figure 11: Parent Unit

3.2. Child Unit

The child unit will be activated by connecting the two ends of wristband together. To make sure that it cannot be taken off by an unauthorized person the wristband can be locked by the parent.

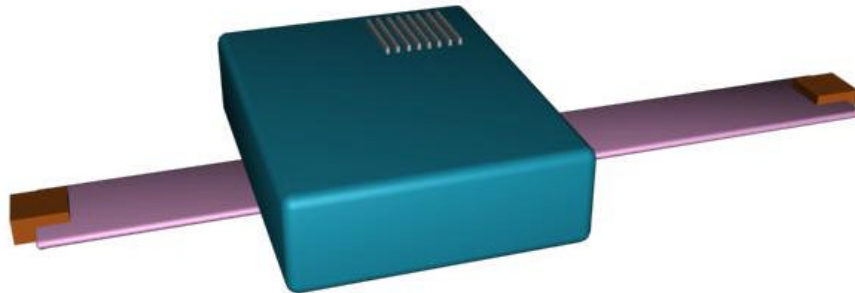


Figure 12: Child Unit



4. Failure Warnings

As well as transmitting intermittent signals to the parent unit, the child unit will also poll for incoming transmissions from the parent unit. If there are no signals from the parent unit during a specified period of time the alarm on the child unit will sound. The child unit will continue to try and send signals to the parent unit. The child alarm can be turned off either by unlocking and disconnecting the strap, or sending a command from the parent unit.

Low power for either device is a power level close to the minimum operating voltage of transmitter/receiver device or micro controller. A low power indicator will be located on the parent unit, which will warn the user that the batteries for either the child or parent unit are getting low. A two color LED is useful for this operation; a green light indicating batteries in good condition, and a red light indicating low batteries.

5. Testing

The test plan laid out in this section has been created so that we can have a more logical, step-by-step approach to the testing of our wireless child tether. We have tried to build this test plan so as to progress from the lower level concerns to the higher level ones.

5.1. Visual Inspection

The first step into testing phase is to do a visual inspection of the prototype. All components should be checked and confirmed that they are in the right position and orientation. All solder joints should be clean and there should be no solder bridges between adjacent pins or components.

5.2. Power to Ground Shorts

A digital multi-meter (DMM) will be used to check the resistance between power and ground; if this resistance is less than expected, a search for possible power to ground shorts will be done.

5.3. Power Supply Voltage

A DMM will be used to check the voltages at the pins of the LM7805 voltage regulator. Pin 1 should have a voltage between 9 and 5 volts. Pin 2 should be ground. And pin 3 should be 5 volts. If pin 3 does not show 5 volts then the circuit is likely drawing more current than the voltage regulator can supply and a second voltage regulator should be added. The voltage at pin 3 should be checked when the board is transmitting data, as this will be the situation in which the most current is drawn from the voltage regulator.



5.4. Data Transmission

Transmit data can be observed on pins 1, 3 and 5 of jumper 9 on the evaluation board. Receive data can be observed on pins 1, 3 and 5 of jumper 4 on the evaluation board. A test pattern should be transmitted from one evaluation board to the other and be observed on the receiving board with no errors. The board that was transmitting should then become the receiver and the board that was receiving should become the transmitter and the test pattern should be run again to make sure that we have established an error-free bi-directional link.

5.5. Software Testing

Using the flow chart given in section 3.1, the software will be taken through all of its various states to make sure that it transitions from state to state as expected. The first round of software testing should be undertaken in the hardware emulator supplied by the microprocessor supplier. In this way, the first round of software testing can begin while the hardware testing is in progress.

5.6. Buzzer

Applying a logic-high to the buzzer circuit input should sound the buzzer. If the buzzer does not sound the circuit should be trouble shot to determine the cause of failure. The conditions that cause the buzzer to go off should also be checked. The software should be set in all states that cause the buzzer sound to be sure that the software is outputting correctly.

5.7. Sensitivity/Range Testing

The sensitivity control on the parent unit should be adjusted to determine the range at which the buzzer goes off. The maximum and minimum allowable ranges are found. If the minimum allowable range is greater than 10 feet, the transmission power on the child unit needs to be attenuated.

5.8. Child Alarm

The child unit's alarm should be tested in two ways. First, the child unit should be moved far enough away from the parent unit as to make the signal strength received by the child unit lower than the preset threshold. This should cause the alarm on the child's unit to sound. Secondly, the panic button (This panic button corresponding to the CSPKR_ON button in Figure 1) on the parent's unit should be pressed which should cause the child's unit to sound. If either of these situations don't cause the alarm to sound, the cause should be found and fixed.

5.9. Field Testing

Once we have determined that the prototype is functioning as expected in the lab environment, it should be tested in environments representative of those that a



parent might wish to use the wireless child tether in. For example, the degradation of the RSSI over multiple reflections is an issue we need to quantify, so testing our wireless tether in an environment with many reflective walls and corners is a must. We also want to ensure that the material the walls are composed from does not drastically affect performance, so we will need to test the tether in a variety of building types. If the prototype does not function as expected in these environments we should determine the cause of the unexpected behavior and fix it if it is a design bug or come up with a “work around” if it is a design flaw.

References

Linx Technologies, Inc. www.linxtechnologies.com

Microchip Technology. www.microchip.com

DigiKey Corporation. www.digikey.com

Appendix

A. Bill of Materials

Part	Digi-Key part no.	Quantity
Transmitter/Receiver	N/A (direct from Linx)	2
Microcontroller	PIC16F873/20sp-ND	2
Antennas	ANT-916-CW-QW	6
Push button	501pb-nd	2
Buzzer	P9915-nd	2
Transistor	Ztx451	2
Diode	1n4148dict-nd	2
Red diff. LED	67-1102-nd	3
Red/grn diff LED	67-1124-nd	1
Potentiometer 1k	D4aa13-nd	1
Slide switch	Sw101-nd	2
Enclosure (Parent)	Hm112-nd	1
Enclosure (Child)	hm104-nd	1



B. Schematics

The following is a list of pending schematics:

- a) Switch and button circuitry.
- b) Antenna switching circuit.