Remote Programmable Wake-Up Alarm Using Android OS

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REPORT SUMMARY

In this project, we are aiming to solve the issue of loud alarm clocks, which can cause problems for people who share rooms with others. To create a solution, we consider previous technology that could aid us, such as past alarm clocks and newer headsets. We also examine the issues of developing the solution, as well as component restrictions. Manufacturing the final product, health, and societal impact are prime concerns. A goal for the initial prototype is for it to be compact and wearable, thus we need to ensure that the user's health is not adversely affected. These issues and constraints determine our requirements for the final design proposal. Options for implementing the final product are also examined and compared on a basis of functionality and cost. The result is a simple two part system, which consists of a smartphone running Android OS that signals a hearing-aid style receiver to vibrate. The vibration from the receiver will be enough to wake the user whilst not waking any others. It is intended to work within the perimeters of a typical bedroom (about 20 meters maximum per wall), and be comfortable such that the user can sleep undisturbed. During the prototyping stage, the functions of the system will be tested: the software must send a signal out through the smartphone to the receiver, and the receiver must vibrate.

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Introduction

The impetus of this project stemmed from an issue that some people face in their everyday life: waking up to a loud alarm clock. At first this would seem to be a trivial issue, as some need such alarm clocks to wake up, but this is not always the case for people sharing bedrooms. Some people may use an alarm clock to wake up early in the morning, but get up before it goes off, fearing that they will wake those sleeping. Another example is sharing a room in a university dorm. Some college students could be heavy sleepers and need a loud alarm to be woken up. When roommates run on different schedules, early wake-up times can result in a situation where others are woken up earlier than needed or expected. These situations can be extended to roommates in apartments, couples sharing beds, and so on. Based upon personal experience, this issue is important enough that it should be solved.

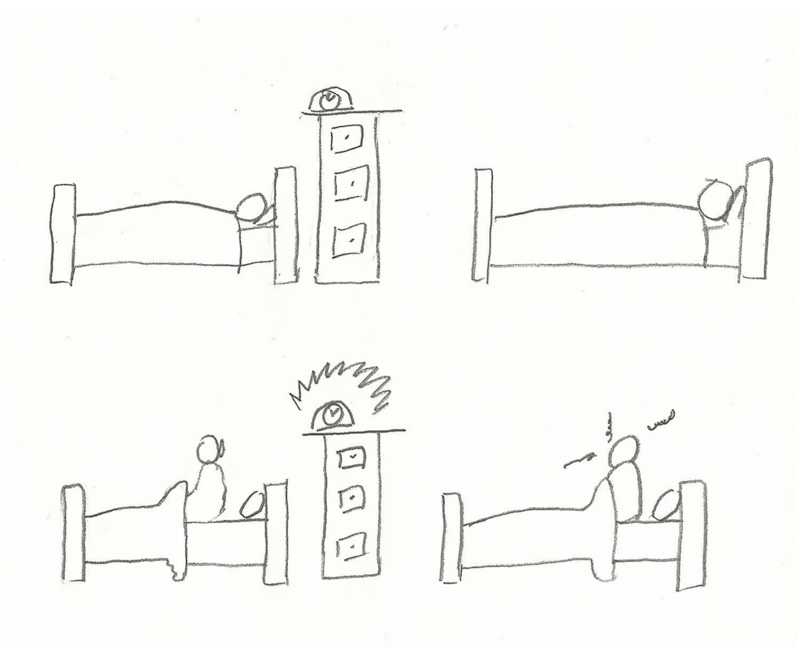

Figure 1: Artist's depiction of problem. Note the frustration in the other person .

To alleviate this problem, the goal of this project is to design a lightweight and portable receiver that will wake users in a quieter manner than before. The physical structure of the receiver is based off of hearing-aids, but will incorporate other materials and components to ensure comfort and feasibility of uninterrupted sleep. A separate signaling device – in the case of this project, a smartphone – will signal to the receiver using ubiquitous communication technologies available, while the system works within a typical-size bedroom. It will also have an interface that allows the user to see the time, be able to set the alarm, and view any other important information regarding the system process. Basically, the device takes an input, the alarm time, then outputs a signal to the receiver on the user's ear. The receiver will receive a signal from a remote device, activate, and then wake the user.

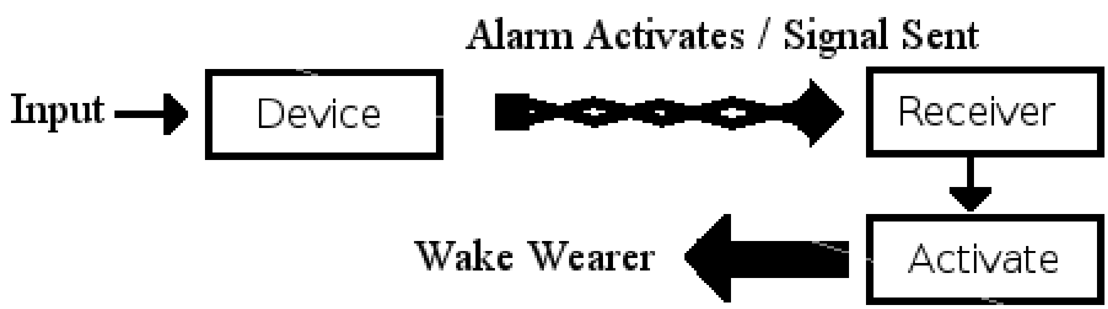

Figure 2: Basic and simple diagram of problem solution

This report is divided into several sections, ranging from Background to the Preliminary Design, that intend to clarify and further define the design of this project. The first section, the Background, will introduce the inventions and devices related to the problem and goal of this project, while also detailing the major issues concerning implementation, especially ethical issues and similar solutions currently in development. This will be followed by the Design Requirements, laying out the specifications and criteria for the project solution, including functions. Design Alternatives considers the possible options for implementing the project functions, supported by research conducted to examine various constraints. All of the requirements, reasoning and research will culminate in the Preliminary Proposed Design, the overall intended design of the project that will be followed in the prototyping stage.

Background

The earliest concept of alarm clocks probably stemmed from old large clocks, either in houses or on the public square, that would ring bells or make other noises to indicate a new hour in the day. This eventually evolved into smaller, personal clocks, where users could manually set the alarm time by moving the hands to indicate time. Alarm clocks in the present day are mostly digital, but this technology still relies on a physical clock within the device, as well as an alarm where the user has little control over the sound volume. Common digital alarm clocks have at most one or two buzzer settings, compared to white noise machines which have many more settings. An inherent problem with cheaper digital clocks is that after extensive use while being powered on, they begin to slowly gain time. One example is a digital clock used by the project author, after about 2-3 months the clock has gained about 4 minutes. This issue is easy to fix by resetting the clock, but these alarm clocks should be quiet and consistent. Utilizing smartphones could be the most precise measurement of time, and thus behave as our clock for the project.

Since the advent of cellphones and the Bluetooth standard [1], various “hands-free” devices have been developed and released on the market, functioning as mobile headsets without the wires. Bluetooth also extends into data distribution, when pushing data from one device onto another. This project involves a wireless receiver using both of these Bluetooth features, although other alternatives are explored, such as RFID. Initial inspiration for the project concept also came from hearing-aid design, which has existed for several decades. The conceptual aspects of both the on-ear hearing-aid and remote hands-free headset combine to form top-level design of the wireless receiver.

Devices similar to the design of this project are currently limited in number, though approximately a year or so before the writing of this report, Kyungmi Moon in South Korea designed something similar currently in development, the “Earlarm”[2]. The intended product is a three-sectional system, where one sets the alarm on a separate device with their smartphone, which then sends a signal to a pair of ear-plugs that will wake user. While similar in design to this project, the focus is more on encapsulating the activation process within just the receiver and smartphone, without functioning as an earplug like the “Earlarm”.

There are three major issues that will need to be addressed when determining the constraints and designing the project: manufacturing, health concerns, and the social impact. One of the goals of this project is compactness, but this may not be readily available during the design and prototyping process. Prototyping with regular and familiar circuit components would definitely ease the process, these components are not small. We also cannot just modify hearing-aids and current wireless headsets since they are rigid structures and would be considered product tampering. However, we can be confident that this project will come to fruition in the future using those products as a conceptual foundation. During the prototyping stage we want to ensure that the concept works, and once we confirm that it does, we can then focus on reducing the overall size.

Another issue is safety regarding the use of the receiver. Since this will be a device that the user puts on their body and has close contact with the ear, health is a big concern. Using both wireless transmission standards and circuitry leads to concern over electrical shock and radiation from signals. Any problems that could affect the user’s ear, such as blocking the ear canal or physical damage, will be a factor in determining whether the receiver needs to be in the ear or outside the ear, and the powering of the device. We also want the receiver to be small, so it must be low-powered.

This project may have a social impact if it can be manufactured *en masse* and has a market release, but the impact would not be large. A small benefit to the use of the project would be that end users would have easier times waking up, and maybe not affect others' sleep. One detrimental aspect is that the final product might not work for those who need loud noises to wake them up, but this could be field tested during the prototyping process.

In terms of ethical issues, the intent of this project is to replace a tool with a better tool, replacing alarm clocks, only to wake people. When thinking of a problem to solve, another goal was to ensure that the final product would benefit as many lives as possible, and could have other applications beyond the scope of this project. Since it will use Bluetooth or other wireless standards on smartphone, the receiver may not be an entirely secure device and would pose an issue if hacked.

All of these major issues will be further addressed when we discuss the constraints of the project in the Design Requirements section. Overall, the main idea behind the project arose from old alarm clocks, the noise and time-keeping problems with current ones, and combining the technology with hearing-aids and wireless headsets. There may be problems with manufacturing the device, as well as health concerns and a possible social impact; but we will discuss these further in the next section.

DESIGN REQUIREMENTS

The project's behavior initially was split amongst the signaling device and the receiver as seen in Table 1, but as the design process continued the behavior of communication became a separate entity while some desired behaviors were no longer a goal. Some implementation choices were also considered when determining the final design criteria.

Table 1: Defined Behaviors and Constraints

Part	Behavior	Constraints To Consider
Signal Device	Signaling	Signal Standards, Availability

	Time Tracking	Designing a separate time system, Cost
	Power	Need to design power source, Cost
	Settings	Physical design of device, Circuit design
Receiver	Receiving	Linking with signal device, Health concerns
	Vibration	Circuit design, Power
	Power	Sourcing power, Cost
	Recharge-ability*	Cost, Effectiveness, Longevity
	Power Indication*	Circuit design, physical design
	Physical Design	Health concerns, Power, Recharge-ability*

The intended behavior of the system is spread out into two parts, a signaling device that can transmit signals and the receiver that receives these signals. Although both parts have some shared behavioral aspects, the receiver was initially planned to be a rechargeable device that stays on or in the ear while you sleep, while the alarm would be set with the signaling device. When the alarm goes off, a signal would be sent from the signal device to the ear attachment. Originally, one desired feature was to have the entire receiver itself vibrate, but other ways to use vibration were examined and decided upon later. The alarm should shut off automatically to preserve power and ease useability. Recharge-ability, another beneficial feature, would have depended on the power requirements for the ear device, with the power dependent on the signaling method. As the focus of this project shifted to ensuring the concept was feasible, recharge-ability was demoted to being a periphery feature and might not be implemented in the prototype.

Potential end users or customers for this system are people who share bedrooms that wish to have their wake-up routine not wake others. End-users in this kind of situation are most likely to be those who share apartments, sleep in the same bed, or college roommates. Other potential users could be those who simply would prefer a quieter, less abrupt way to wake. The end result needs to ensure that only those who use the device will wake up.

Earlier in the design process, there were a few design approaches examined and some choices researched in order to determine some of the design criteria. Their advantages and disadvantages were compared to choose final criteria, resulting in some design approaches and several choices to be discarded. These are all presented in Table 2, comparing between all possible approaches considered for each behavior. Choices at this stage were then further researched upon as options along with newly considered ones, the process detailed in the Design Alternatives section.

Table 2: Approaches for Signaling Device, Advantages and Disadvantages

Behavior	Design Approach	Choices	Advantages	Disadvantages
Signaling To Alarm Device	Smartphone App	RFID / Other	Direct from phone	Range, Standards
		Phone Signal	Use phone's signal directly	Unsure about protocols, Legality?
	Custom-Made	Design Transmitter	System specifically for receiver	Learn how to build it, complex circuit, standards
Time Tracking	Smartphone App	Phone's Clock	Atomic/Satellite	Access to clock difficult?
		Alarm Clock App	Existing software	Differing OS, Redundant
	Custom-Made	Physical System	-	Learn how to build accurate clocks, power issue
Power	Smartphone App	Phone Power	No separate power	Relies on phone
	Custom-Made	Built-in	Own power supply	Need to construct separate source, time consuming
Settings	Smartphone App	-	Construct software to maintain settings, easy to add new features	Need to function properly
	Custom-Made	-	Simple button based interface	Very limited and fixed design, choices will affect outer shell

Overall	Smartphone App	-	Smartphones nearly ubiquitous	Need to learn programming for OS, beholden to phone power, range, security
	Custom-Made	-	Separate controllable, portable device	Construction, Maintenance, Precision

For the signaling device, two approaches were explored for implementing behavior, as laid out and compared in Table 2. These were to either create a smartphone application, using the smartphone as the power and transmitter, or design and construct a custom-made receiver that would keep track of time.

For communication, there were two choices considered on the smartphone: utilizing RFID or other wireless capabilities; or using the phone signal, such as the GSM/CSMA bands. Instead using the smartphone hardware, a custom-built transmitter would select certain band frequencies, and could work specifically with a custom-built receiver. Considering the overall advantages and disadvantages, the RFID/Wireless system is the simplest, most cost-effective and easiest choice to implement out of the two, but it could have range issues and require understanding of specific transmission protocols. Time tracking would also constrain the overall design. With a smartphone, we can use the phone's own clock, which is synchronized to satellites and other atomic clocks. This is the most precise method of keeping track of time, compared to a custom-made clock system that requires understanding construction of digital clocks, which could be prone to error. Power for transmission could simply come from the smartphone itself, while a separate system would require a transformer to draw power from electrical outlets. All the settings could also be controlled by software on a smartphone, thus giving the ability to add more features easily. Putting the settings on the separate, possibly molded transmission device would be affected by the circuit design, as well as limiting addition of future features.

Overall, smartphones have become ubiquitous at the time of this project's development, but creating a software application would require some programming on smartphone operating systems and features would be restricted to the phone's specifications. For a custom-made transmitter, a separate device could be built that would then have its own specific capabilities and features, but designing all the specifications and ensuring precision would also be required – a strenuous process.

Table 3: Approaches for Receiver, Constraint Comparison

Behavior	Design Style	Implementation	Constraints
Receiving Signal	Hearing-Aid	Placed on bottom	Size of receiver, Health hazards
	Mesh Earplug	Receiver on end of plug, like a chip	Health hazards
Vibration	Hearing-Aid	Vibrator piece in ear	Comfort, Health
	Mesh Earplug	Whole plug vibrates	Design, Comfort, Health
Power	Hearing-Aid	Button Batteries	Battery types, Cost
	Mesh Earplug	Button Batteries	Battery types, Design, Cost
Recharge-ability (Replacement)*	Hearing-Aid	Compartment	Inserting and removing batteries
	Mesh Earplug	Compartment	Same as above, more problematic
Power Indicator*	Hearing-Aid	LED Light	Design, Manufacturing
	Mesh Earplug	LED Light	Design, Comfort, Manufacturing
Physical Design	Hearing-Aid	Around Ear	Health, Comfort
	Mesh Earplug	In-Ear Mesh	Health, Comfort, Functionality

Two design styles were considered for the receiver: a hearing-aid based design and a mesh earplug. Aside from circuit housing and the location of vibration, most of the implementation choices were the same: power limited to button batteries and indication being relegated to small LED lights. Since the receiver will be an ear device, a lot of decision-making was influence by health, design, and comfort.

Cost was primarily affected by power constraints. On Amazon (an online market that can sell products from many third-party suppliers) in the spring of 2015, a set of 60 single-use batteries for hearing-aids were about $15-25, while the lifespan was less than a week. On the other hand, rechargeables were much more expensive, where a two-pack of typical rechargeable hearing-aid size batteries were priced the same as the 60-pack for single-use. The one advantage with the rechargeables was that the lifespan on average is about a year, the average charge cycle typically 12-18 hours, depending on size. These types of batteries require a charger, maybe one using magnetism similar to recharging stations for hearing-aid batteries.

The primary health concern regarding the receiver is where the parts of the device would be placed. Putting the vibrator inside the ear, similar to the in-ear portion of a hearing aid, could cause wax buildup in the ear and lead to ear infections. Instead, placing the vibrator on the outside would vibrate the skull. This method also works as the human skull can pick up vibrations that then travel to the eardrum. Utilizing this physiological feature allows the user to leave their ear canal open, avoiding infections and having to frequently clean the device.

Now that all the constraints are determined and we are leaning towards certain design approaches, project behavior can be rearranged into functions. All of the functions of the project can be grouped into three main sections: the transmitter, the communication, and the receiver. The transmitter, implemented through a smartphone, will contain the software application and keep track of time, functioning as the alarm settings. Communication will be either through a one-directional or bi-directional system, where either the smartphone sends signals to the receiver, or both devices communicate back and forth. The receiver has the most functions: receiving signal, power control (such as a sleep mode), enable (turning the device on and off), and vibration. The standard for receiving the signal will be the same as the communication, while power and enabling are needed to activate the vibration. Overall, this decomposition of functions needs to work in tandem with our final design criteria.

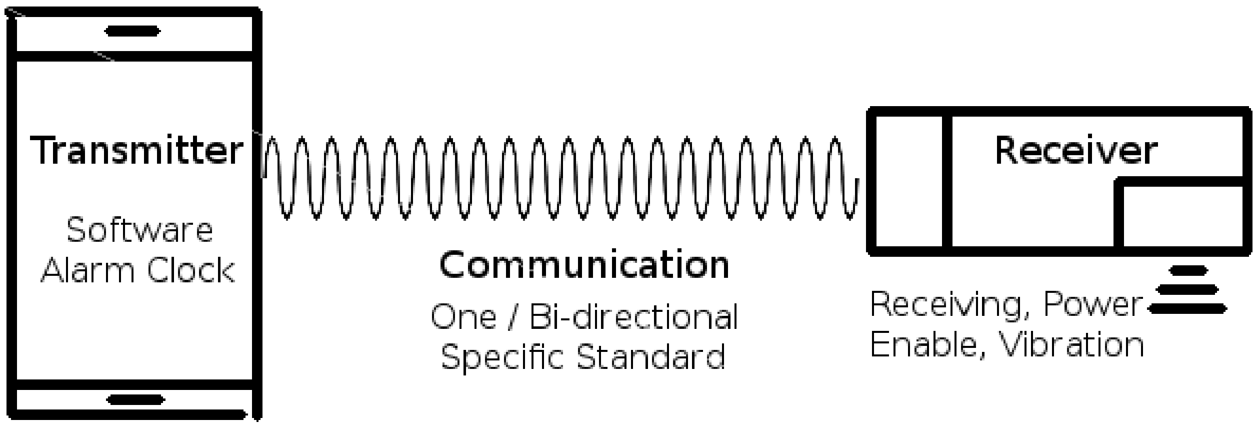

Figure 3: Graphic overview of functional decomposition of project. The smartphone behaves as the transmitter, sending the signal. Receiver gets signal, activates, and vibrates accordingly.

For the final design requirements, the signal device will be any smartphone model, while the software will be programmed for either iOS or Andriod operating systems (the two major ones). Utilization of wireless capabilities can simplify the process for designing the receiver. The receiver's build will be based on hearing-aids, but not exactly due to health concerns. Instead of having an in-ear portion of the device, the receiver will go around the ear, with a battery hatch at one end. The exact location of the vibrator is still unknown, but it will be part of the receiver. Lastly, recharge-ability and power indication are periphery features and no longer part of the main goals of the prototyping stage. Together with these goals and constraints, our primary requirements are: this device works in a 20x20 meter size room; is quiet enough to avoid waking non-users; is loud enough in vibration to wake the user, and is wireless.

Table 4: Final Decisions on Design Requirements

System Section	Decision
Transmitter	Smartphone: design an application for either iOS and Andriod devices, while using into the built-in communication technology. Will be much easier to make.
Communication	One/Bi-directional signals shared between the transmitter and receiver.

Receiver	Hearing-aid style device: Around ear, with battery compartment. Vibrator location and position still unknown. Range no more than 20 meters.

DESIGN ALTERNATIVES

After determining the design specifications, options for implementing the design specifications were researched. Based on the functions, these options were then compared, just like Design Requirements, by their advantages and disadvantages, as well as their specifications and cost. Options were researched for four functions: communication, circuit power, vibration, and software. Only these were chosen because the other requirements were automatically met by selecting the smartphone as the transmitter.

Software and Communication would directly affect each other, so hardware and programming were considered when selecting options. For software, it was initially determined that either Android or iOS operating systems would be used. Applications could be easy to program for both systems using “PhoneGap”, a program that builds versions of applications for other operating systems, and thus the device would be ready for most of market. The only problem would be hardware compatibility issues. Though most Android-based smartphones and iPhones share similar hardware, their wireless capabilities would be limited by each other. Android OS has open-source coding, community support, and many APIs, especially for Bluetooth devices. Furthermore, everything can be programmed in Java, which the project author has past experience. The iPhone operating system, iOS, is already widespread due to high sales and a relatively huge customer base. Even with these benefits, both operating systems have their disadvantages. The project author would still need to learn how to program for either operating system. Android OS appears to be the better and cost-effective choice, as iOS built-in libraries are proprietary and Apple (the creators and maintainers of iOS) has strict application release policies.

For communications standards and technologies, we looked at four different options for implementation: Smartphone Hardware, Wi-Fi, RFID, and Bluetooth. Using the cellular signal of the phone was immediately rejected in the early stages of the decision process; although an interesting use of hardware, it is very specific to the smartphone models selected and probably would be illegal to tamper with. Wi-Fi could have been a good option because of its ubiquity throughout all communication devices, but since it is a rigid and complex IEEE standard with a lack of small-build, ready-to-use components on the market, this was not further explored. RFID and Bluetooth were both thoroughly researched as potential options, both with great benefits and difficulties. RFID could be used with readers that scan up to 25 meters, satisfying our range requirements, and the technology is already built in to some smartphones. Similarly, Bluetooth is available on practically all current smartphones, while it is easy to buy transceiver modules for circuits. But, the structural and compositional differences between these two options is significant. Bluetooth receivers vary depending on which components you buy and must adhere to certain "profiles", or specific device usage, of the standard. RFID comes in either a sizable two or three part system (scanners, transmitters and tags), is not as cheap as Bluetooth, and would be using the technology in a manner that deviates from its original purpose. Some smartphones come with NFC (Near Field Communications) technology that implements RFID, but this is not long-range and would require attaching an RFID scanner and transmitter on to the smartphone. In terms of cost, an entire custom-built RFID system could cost anywhere from $50-$100 upward (including all parts), while simple Bluetooth transceivers for circuits can cost $5-15 dollars at a minimum. Out of all of these options, Bluetooth appears to be the most cost-effective with readily available components and allows for a simpler communication system.

There are not many ways to power the receiver due to its small size, so the primary focus was to use button batteries. Since feasibility is also a priority for prototyping, other battery types were considered and researched in the process. Button batteries, specifically for hearing-aids, are manufactured into four main types: 10, 13, 312 and 675; all of them having similar voltages, but typically near 1.5 volts[3]. These types researched are all zinc air batteries that are disposable, once the pull tab is removed, they activate and only last about week depending on the hearing-aid[3]. The benefits with these batteries is hat they are small and compact, but they are low voltage and rechargeable ones are expensive. Another, slightly larger option investigated were coin cell batteries, mainly lithium and silver oxide-based ones. Coin cell batteries can vary depending on the type of manufacturer, but these typically carry a voltage of 3 volts with an amp-hour rating of 200-250mAh, bought in various sizes[4][5]. They are small and inexpensive, similar to button batteries, but they require specific holders, as would any of these batteries. One more type looked at were AA batteries, thought to be slim, common and cheap. Usually 1.2-1.6 volts depending on the material, though lithium-ion ones carry twice as much. Their current ratings are at least three times as much (>600mAh) as the coin cell batteries, but they are rather large for the project and would only be useful for the prototyping stage.

The last portion of the system is the vibration, of which only two options were explored: mechanical actuators and piezobuzzers. Mechanical motors were initially sought after, since they create motion and vibration in a compact shell, but ones of decent quality turned out to be expensive and initially not suitable to the project by design. This leaves the piezeobuzzers, which create a buzzing noise that changes in volume depending on the voltage. These buzzers come from various manufacturers and can be bought cheaply on online marketplaces (like Amazon), or in mass orders through direct sources (like American Piezo [6]). They also are constructed with leads or pins for attaching to a circuit. To generate the buzzing noise, these buzzers use a square wave that causes a metal disk inside to expand and contract, and thus a wave generator is the only crucial requirement.

Overall, out of the four main functions of which options were explored, possibilities were compared and whittled down to one for prototyping: Android OS for the software; Bluetooth for signaling; coin cell batteries for power; and using piezobuzzers for vibration. Some of the reasoning behind these decisions is further detailed in the next section.

PRELIMINARY DESIGN

The main design proposal is divided in several portions, similar to the functions from the Design Requirements/Alternatives sections earlier in the report, the first and important being the software that will interface with the user. Since the transmitter will be part of a smartphone, one out of several operating systems was selected as a base for the application. Android OS was chosen due to some of its major advantages: open sourcing which allows ease of programming, community support, and available packages. Programs for the operating system are all written in an extended version of Java, which will be easier for the project author to adapt. The operating system also comes with several Bluetooth APIs (programming interfaces), that will aid with the communication aspect of the project. Since Android comes with an Alarms package, a base program used to set alarms for any smartphone, most of the software will use this package as a base with some modifications, such as interaction with one of the Bluetooth APIs and periphery settings for the receiver.

All communication will be carried out through the Bluetooth wireless standard, due to its versatility and wide availability on smartphones. When searching for transceiver modules, Bluetooth modules were easy to find, their low cost further swaying the decision. The transceiver that will be used for prototyping is an Arduino-based wireless Bluetooth transceiver. Called the JY-MCU, it is an HC-06 transceiver and is hard-wired to link with other Bluetooth devices. HC-06 type modules are always set to “slave mode” and therefore cannot be programmed to communicate with other devices on their own. Since this transceiver is designed to work with Arduino micro-processing boards, we will use a test circuit to determine its logical behavior. Constructing a simple LED switch circuit, we can connect an Android smartphone to an Arduino UNO board, sending out a "1" or "0" through BlueTerm, a Bluetooth emulation software for the operating system[7]. While the circuit is running, the sending and receiving wires will be connected to the LogicPort, a logic analyzer manufactured by Intronix[8]. This analyzer will allow us to examine the signals being transferred from the transceiver to the circuit board. As of the writing of this report, the testing phase is still not complete and currently no applicable results. Once testing is complete, we can design a logic circuit where the transceiver can send signals to the piezobuzzer without the need of the Arduino board. The total cost of this portion of the receiver could be less than $10 to manufacture. To ensure that the initial prototype works, efforts will be placed more on one-directional communication rather than bi-directional.

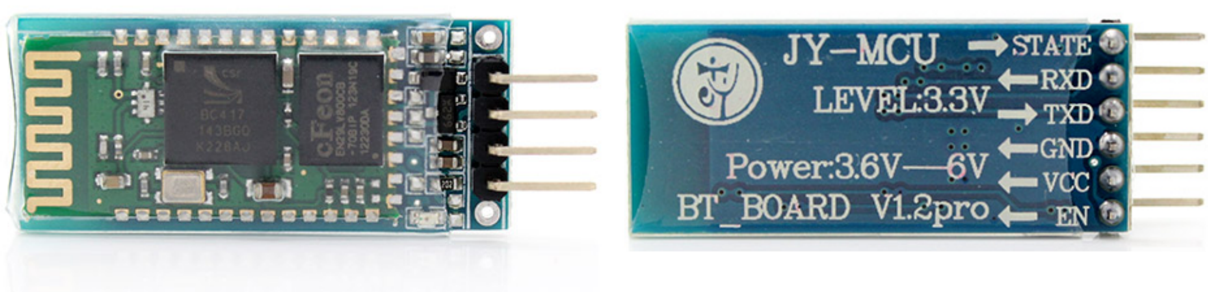

Figure 4: JY-MCU HC-06 Bluetooth transceiver to be used in the project. RXD and TXD are the receiving and sending pins, GND and VCC for power.

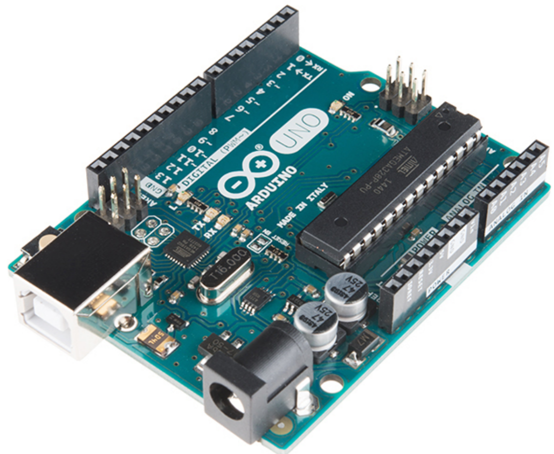

Figure 5: Arduino UNO R3, to be used in the testing phase

Since the Bluetooth transceiver requires 3.6 to 6 volts to operate, the circuit will be powered by two 3-volt coin batteries, particularly the CR2032. These batteries will be wired to the circuit using a holder with leading wires and will be able to power the transceiver, the logic circuit and piezobuzzers. The piezobuzzers that will be used in the circuit can handle anywhere from 3 volts to 24 volts, thus the current power for the prototype is sufficient and the low voltage will create noise that is quiet enough. The buzzer will also be connected to a switch that will enable power, either activated manually or by the logical circuit.

Table 5: Main Parts for Prototyping Stage

Part Name	Function	Reasoning
Sony Xperia Z3	Smartphone / Transmitter	Project author's personal smartphone, Android-based
JY-MCU HC-06 Bluetooth Transceiver for Arduino	Receiver / Communication	Popular transceiver for connecting Android devices
Arduino UNO R3 Microcontroller	Logic / Testing	Used only for the testing phase to determine logic and behavior of transceiver
CR2032 Coin Cell Silver Oxide Battery	Power	Two will provide sufficient voltage to circuit
Generic Piezobuzzers (3-24V)	Vibration	Simple buzzers for the

		prototyping stage, can handle wide range of volages

With all the parts together, the receiver will consist of a Bluetooth transceiver, a logical circuit designed to activate the buzzer, all of which will be powered by two coin cell batteries. The logical circuit still needs to be designed and will be done so in the final term for the project. For transmission, an application will be designed utilizing the customs Alarms package with one of the Bluetooth APIs. Users will be able to set the alarm through this application, and once the alarm goes off, the smartphone will send a signal to the receiver. Assuming the software is given out for free with the product, the total cost of the transmitter and receiver should be limited to the receiver, about $10-$20.

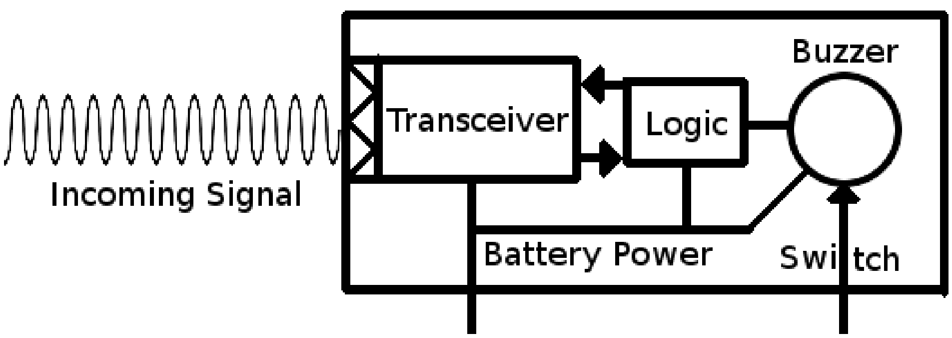

Figure 6: Illustration of basic receiver design: signal is received, the transceiver communicates with the logic circuit, activating the buzzer. All three powered by battery.

References

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[6] – Specs and Information page for American Piezo Company buzzers: https://www.americanpiezo.com/standard-products/buzzers.html
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[8] – Intronix Company Website: http://www.pctestinstruments.com/