Underwater Communication: From Dit to Dah

Jason Cardell

Department of Mechanical Engineering

(Undergraduate)

Brigham Young University

Provo, UT 84602

Email: jcardell@byu.net

Abstract

One major obstacle faced by underwater divers is how to communicate effectively, yet inexpensively, with individuals on the surface. Imagine yourself diving 50 feet under the water's surface when something goes wrong. Perhaps your oxygen is getting low or maybe your gear is lodged in a rock crevice. These are instances where an effective mode of communication can become your lifeline. There are currently many different communication devices on the market. Many of these are in the thousands of dollars range and require tethers in order to communicate effectively. These tethers are restrictive because they must connect directly to the diver. The purpose of this project was to explore inexpensive ways of communicating with underwater divers from the water's surface. It was required that this mode of communication be integrated onto a SeaPerch ROV (Remote Operated Vehicle) and be simple, yet effective in nature. The objective was achieved through the use of a Labview based GUI program developed specifically for this project (which is available for download).The following equipment was used in this project: an endoscope, one LED & resistor, an rs-232 to RJ45 cable, a junction box, and sealant. Morse code was used as the method of communication from the operator to the underwater diver. Although Morse code is a bit cumbersome due to the length of time to transmit a signal and experience required to interpret, it served as an effective method of communication because of its use universally and simplicity. The project design and implementation resulted in a clear communication method that enabled an ROV operator to input a string of text which was then translated into Morse code and relayed almost immediately to the underwater diver. A camera on the sea perch underwater enabled the ROV operator to then see the diver's reply via diver hand signals.

Introduction

Several of the challenges which arise in the implementation of underwater communication include the method of data transmission, overall expense and excessive noise that inhibits a clear signal being sent from the surface to a diver and vice versa.

Data transmission problems arise due to restrictions in underwater wireless technology. There are currently two main wireless transmission medians which are used, namely light and sound. Both methods have their advantages and disadvantages. Optical systems, which use lasers, have dramatic range limitations due to the diminishing effect of the laser caused by backscatter. Interference and noise often arise due to sound wave refraction and reflection (Ecosse, 2013). Refraction occurs as sound waves pass through different mediums, causing a prism effect. The surfaces which cause sound wave reflections include the water's surface, ocean floor, and large objects in the water. Sound wave reflections cause signal noise which is difficult to filter. (J H Goh & Al-Shamma'a, 2009) Although some technologies exist which utilize these methods, most underwater communication systems require a tether to be connected to the scuba diver's person. This is not only restricting, it is also a safety hazard because it can become tangled or it can limit the mobility of the diver. In addition, current ways of communicating underwater (rope signals, torch signals, etc.) may not be as clearly communicated due to noise, choppy seas, or low light. (Ecosse, 2013)

Prepackaged systems range between several hundred dollars to several thousand. Devices on the lower end of this range often have limiting pressure restrictions and ineffective resolutions. These restrictions make it very difficult to effectively communicate over such devices. The higher end products will quickly empty your wallet. As a result, there is a need to develop a cost effective means of communicating underwater that will enable the diver to remain mobile while being inexpensive enough for the everyday hobbyist.

A proposed solution to meet the criteria above, of providing a less expensive way for a diver to effectively communicate with the surface, would involve the use of a Morse code system relayed by voltage impulses to an LED that would then be visible to the diver. Diver's hand signals would be captured by a live video feed and relayed back to the surface. Both the camera and LED would be tethered to a small ROV which would keep the diver free of tethers on his person yet avoid noise which appears on wireless underwater systems. A system such as this may benefit an everyday or occasional diver by providing greater flexibility, communication, and safety. In addition, research in this area may have an impact on naval operations, ocean oil drilling operations, and other locations where underwater situations are common.

Goals

The purpose of this research was to create a communication system which would allow an inexperienced individual to effectively and inexpensively communicate with an underwater professional, using established methods of communication.

After investigating the need of immediate and cost effective communication, it was found that a simple system was needed that could be implemented using standard and generally accepted communication means such as described following.

A communication system could be developed using Morse code and diver hand signals that would enable a diver to communicate with someone on the surface and vise versa. In order to increase the effectiveness of this communication system, a program would need to be developed which would translate a string of text into Morse code. The Morse code would then be transmitted to the diver through voltage impulses to an LED which would flash the Morse code dits and dahs. The LED would be mounted on the carriage of a SeaPerch ROV. The diver would then reply using hand signals which would be captured on a live video feed by an inexpensive waterproof endoscope. This camera would be fastened to the SeaPerch frame and then tethered to a laptop on the surface. This would enable the ROV operator to send Morse code messages to the diver and the diver to almost immediately reply using hand signals. The diver would need to know both Morse code and hand signals while the ROV operator would only need to know how to interpret the diver's hand signals.

Methods

In order to accomplish underwater to surface communication, a GUI (Graphical User Interface) program was created specifically for this project using National Instrument's Labview. This program is a key element in the life-line between the untrained ROV operator and an underwater professional. The major objective of this GUI is to provide an easy to use interface that requires no training or prior knowledge in order to operate. The technical interface section below provides a detailed description of the GUI. Essentially, the GUI enables an operator to enter a string of text which it then translates into Morse code impulses. It sends these impulses in the form of on/off voltage signals to the mounted LED where they are then emitted as light sequences for the diver to view.

This interface also includes a live webcam feed which enables an operator to have a set of eyes underwater. This will enable the operator above water to view the diver as he communicates using diver hand signals. An inexpensive endoscope is great for this application.

It is assumed that the Scuba diver is knowledgeable in Morse code as well as proficient in underwater safety hand signals. To accommodate this knowledge base, the GUI was designed to convert a simple string of text into dits and dahs (Morse code dots and dashes). The Speed at which the Morse code is pulsed has been made adjustable in order to tailor to the diver's skill level. This signal is transmitted to the SeaPerch via its cat5 control tether. Again, the ROV operator communicates with the diver using strings of text which are translated into Morse code and relayed using the GUI. The diver communicates with the ROV operator by the use of diver hand signals which are captured by a live video feed and relayed to the ROV operator.

A Morse code chart as well as a variety of hand signal charts (used by permission) have been compiled and inserted into the GUI for the convenience of the ROV operator. This reference material will give an ROV operator the ability to interpret the diver's hand signals.

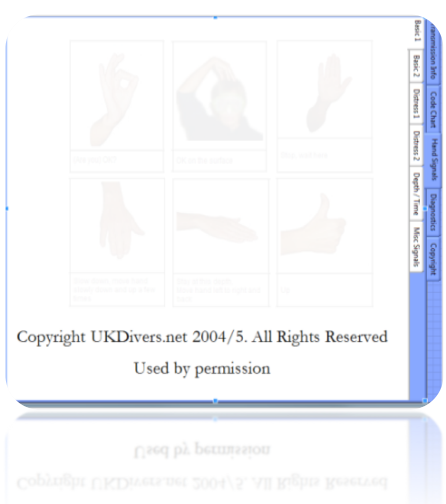


Figure 1: GUI screenshot of diver distress signals. Hand signal images taken from: (UKDivers.net, 2007), and used by permission.

The endoscope and led were submersed in water and tested to ensure adequate clarity and water protection. The camera and LED were submersed for over one hour and both continued to successfully transmit signals without any sign of water damage. It is estimated that, if sealed properly, this system would operate for extended periods of time without any hiccups.

Equipment

SeaPerch

The SeaPerch Program is funded by the Office of Naval Research (ONR) as part of the National Naval Responsibility for Naval Engineering. The supplies for the SeaPerch used in this project were partially donated by the ONR and are currently in the possession of Brigham Young University.

Endoscope

Although there are many endoscopes on the market, they are not all created equal. The camera purchased for this project came from Amazon.com and was affordable at $27.03. This price even includes shipping costs. Although retailers claim that these endoscopes are submersible, there waterproof rating is only IP66 – IP67. This means they are only rated for depths of 15 cm at best. To enhance the usable depth of our camera, liquid tape was added to both ends of the camera housing. This sealed the camera around both the cord and lens. Care was taken to not cover the camera's LEDs or the viewable area of the lens. If sealed properly, a simple endoscope becomes fully submersible for extended periods of time and for extended depths. Liquid tape can be purchased online or in many local hardware stores for less than $10.

Figure 2: Liquid Tape which was used to seal our endoscope and LED.

LED

The LED used for this project was a standard 5mm red. A 1.5 kΩ resistor was placed in series with the LED to ensure only 6.5 mA of current was drawn from the serial port being used. This current level is substantial because many serial ports can't handle outputs any higher than 15–20mA per pin. The brightness of the LED was found to be adequate even in well-lit conditions. Although a smaller resistor could be used, to account for the variability in Serial port voltages and current tolerance levels from one manufacturer to another, a 1.5 kΩ resistor is recommended.

RS-232 to RJ45 Cable

A male serial RS-232 to male RJ45 Ethernet cable was used to connect a computer to the SeaPerch tether. This cable can be purchased online and ranges between five and twenty dollars. In order to make this setup plug and play compatible, a junction box was created which contains three female RJ45 Ethernet jacks. The RS-232 serial cable needs to have a male RJ45 connector on one end to make it compatible with the junction box.

Care was taken when wiring the junction box to ensure either the RTS or DTR and ground pins of the RS-232 cable were connected to the correct Ethernet wires on the SeaPerch control tether. Connecting the incorrect wires can potentially short out and damage the serial port or ROV controller used.

Junction Box

The junction box simply splices the LED signal wires (positive and negative) into the brown and brown/white wires on the ROV's Ethernet tether. This was necessary to make the system "plug and play" so that anybody could plug their SeaPerch into this system without having to cut and splice wires. The brown & brown/white wires are not used in the standard SeaPerch controls, which make them perfect for our application. The three Ethernet jacks which are mounted on the junction box interface with the SeaPerch controller, the SeaPerch tether, and the RS-232 to Ethernet cable coming from a computer. The Construction Section contains a detailed description on how to build this junction box, as well as a photo.

Technical Interface

The bulk of the project efforts, an estimated 70 percent of the work, came from the construction of the GUI. Built using National Instrument's Labview, the GUI was designed to be easy to use and seamless for the end-user. As an example, in order to transmit a Morse code sequence, all the end-user need do is enter a string of text and then hit the "transmit" button.

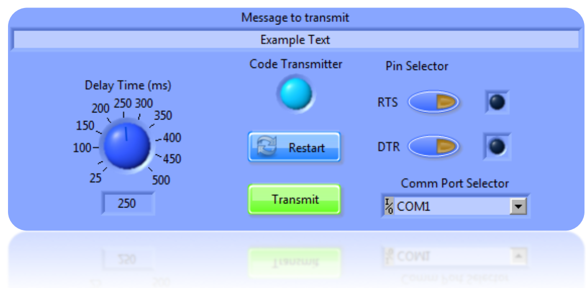


Figure 3: Morse code control interface found on GUI

Once this text is entered, the program will then convert the string of text into a series of ones and zeros. This string of ones and zeros is in turn converted to voltage impulses which can be viewed using an LED as dits and dahs according to the Morse code language. The delay time can also be controlled via a control knob on the GUI.

In addition to converting the text to Morse code, toggles have been included which control when and where the signal is to go (RTS or DTR pin). Once the "transmit" button is pressed and a pin selected, the Labview program will automatically begin transmitting the message by means of the RS232 cable to the SeaPerch below. A loop was built into the program such that it will continuously send the message to the SeaPerch. The user can toggle the output on and off via the GUI pin selector.

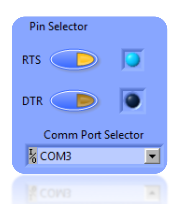


Figure 4: GUI serial port controls. The RTS pin on comm port 3 is toggled on and transmitting.

The GUI also displays a video feed screen that is connected to the endoscope camera beneath the surface. This allows the operator to view the diver's environment and to view the diver below the surface. It's through this camera that the diver can communicate with the ROV operator. The camera direction can be controlled by moving the SeaPerch about. This grants the SeaPerch operator the ability to follow the diver and frees up the diver's hands.

The video feed is continuously displayed on the GUI at a frame rate between 9 and 12 frames per second. The coding was developed specifically for this project by the research student. The Labview program and the executable built can be found on his website at http://www.et.byu.edu/~jcardell/. In order to use the executable, Labview run-time environment and IMAQ dx drivers must first be installed. These are available for download on National Instrument's website. For images of the code used, see Appendix A.

In summary, the device can be used as follows:

1. Operator inputs a string of text into the GUI's textbox and presses "Transmit"
2. The GUI translates the text string into Morse code and sends it to the SeaPerch via tethered Ethernet cable
3. An LED on the SeaPerch flashes the message according to the dits (long light intervals) and dahs (short light intervals) of the message
4. The diver reads and comprehends this message
5. The diver then communicates back via hand signal which is captured using the mounted endoscope.
6. The video is transmitted via USB cable and displayed to the operator on the GUI screen

Construction of Device

To recreate the construction of the device, first obtain the items found in the bill of materials (Appendix B) as well as the following:

1. SeaPerch device
2. Labview program posted online at: http://www.et.byu.edu/~jcardell/
3. NI-Labview Runtime Software (ni.com)
4. IMAQ dx drivers (ni.com)
5. Mounting devices (Cable Ties)
6. Laptop that can display the Labview program

The Labview program can be uploaded onto any laptop. Installation instructions are included in the program file which will be posted online. LED must be connected to the end of the SeaPerch control Ethernet tether. The brown and brown/white wires can be used and the 1.5kΩ resistor must be connected in series with the LED. The LED connection should then be sealed using heat shrink tubing and liquid tape. It should then be fastened to the front of the SeaPerch frame. The endoscope should first be sealed using Liquid Tape and then mounted at least six inches away from the LED. The endoscope has built in lamps which provide light for the camera. These could hinder the diver's ability to see Morse code transmissions if the two are mounted too close together.

The Junction box components were purchased at home depot for about $10. They included a junction box, a 3 port Ethernet plate, and three Ethernet jacks. The Controller and ROV Ethernet jacks were wired together excluding the brown /brown white wires. The serial cable port was then wired to the brown / brown white wires on the ROV jack. Care was taken to ensure that the DTC or RTS and ground wires were used in this connection. Below is a picture of the junction box.

Figure 5: Junction box which junctions the RS232 / Ethernet adapter cable, ROV controller, and ROV tether.

Results

The GUI was successful in translating a string of text into Morse code which was then relayed to a submersed LED. This system was tested for multiple hours with no lag or hiccups. There was also no measureable delay time between the GUI and LED.

Two major concerns arose due to using a Morse code / LED based communication system. The first is the requirement that the diver must know Morse code. Until 1999 Morse code was used as the "distress call of the high seas" (Ohler, 1999). Since '99 it has become an almost forgotten art and a dying language. The second major concern is the time required to broadcast Morse code as well as the undivided attention required in order to interpret it. As an example, the message "is everything ok?" turns into ". . . . . - . . - . - . - - - . . . . . . - . - - . - - - - . -" and takes around 15 seconds to transmit. This time estimate uses 100ms as your Morse code time delay, which transmits at a reasonable pace. These 15 seconds could mean the difference between life and death to a distressed diver.

Due to this mode of communication being an unrealistic expectation for all modern divers and due to the time required to transmit, further research could be done to investigate a more effective mode. One possible solution is to have a mounted LED display which displays the text entered.

The camera feed set up on the SeaPerch allows the diver to communicate back to the ROV operator via hand signals. Diver hand signal communication is currently used by many divers and is a reasonable, effective mode of communication. One major limitation encountered during this research project was the effective range of the endoscope used. The endoscope's most effective range, as discovered through experimentation, was between 1.5 and 5.5 inches. Outside of this range the video begins to blur and the endoscope has trouble focusing. This presents obvious problems when trying to capture hand signals from a moving diver. Through further investigation, outside the realm of this project, a more adequate camera could potentially be found which would give a more effective range. Due to time and funding limitations further camera options were not explored.

The GUI was able to capture video at a frame rate of 9 to 12 frames per second. This frame rate will vary depending on the endoscope and computer used. Although this frame rate caused the video feed to be slightly choppy in appearance, it was able to discernibly capture diver hand signals. This rate was somewhat impressive concerning the bargain price at which the endoscope was purchased for. Another limitation to the current system is that the diver must be tethered back up to the boat in order for the Morse code and video feeds to communicate between diver and surface. Although not included in this project, the use of SONAR or underwater RADAR may be used to alleviate the need for a physical connection and enable the system to communicate wirelessly. In World War I, ships communicated by means of Morse code and similar voice/amplitude modulation systems. (II, 1968 and 2009)

In summary, the GUI was able to successfully transmit the messages to the SeaPerch device below the surface instantaneously. The GUI was also able to successfully capture diver hand signals at a reasonable rate. Although our proposed system is adequate, several improvements could be made to the system to improve its effectiveness and decrease its limitations.

Discussion and Conclusion

Take a moment to dive with me into an uncharted terrain. You're a trained diver who has a passion for the sea. As you explore a new exciting environment you stumble upon a beast of epic proportions. This hideous creature blocks the exit to your cave. You're pinned down and starting to panic! Using hand signals you sign for help. After a moment's pause your team on the surface relays a message back via Morse code. You're informed that this is a gentle giant which under no condition can or will harm you. You relax, enjoy the rest of your exhibition and thank your crew for a $58 investment well spent.

As discussed previously, one major obstacle faced by underwater divers is how to communicate effectively, yet inexpensively, with individuals on the surface. This research paper has explored the possibility of implementing a communication system at low cost which would enable direct and instantaneous communication between an underwater diver and a surface ROV operator.

The underwater communication system in this project, although simplistic in nature, appears to be effective, relatively inexpensive ($58), and easy to learn. It provides the means to allow communication between a diver and the surface above. A product such as this could be beneficial for current divers of all types including those in the tourism sector, the oil and gas industry, the underwater welding industry, and potentially in the naval services industry.

While able to transmit a clear message almost instantaneously and easily, the development of this device does have the limitations mentioned in the previous section. This project, however, has successfully explored new communication methods involving a SeaPerch ROV and an inexpensive set of hardware. It could serve as an effective launching pad for any individuals creative enough to explore new possibilities. With this research as a foundation, individuals or groups could potentially create a more effective mode of underwater communication. If nothing else, this project has shown that more effective methods of underwater communication exist and are waiting to be discovered.

References

Ecosse, B. I. (2013, April 10). *Diver Signals - Lecture 6*. Retrieved from http://users.ecosse.net/peebsac/peebsac_signals.htm

II, D. W. (1968 and 2009). Underwater Acoustic Communications. *Navel Engineers Journal*.

J H Goh, A. S., & Al-Shamma'a, A. I. (2009). Underwater wireless communication system. *Journal of Physics: Conference Series*.

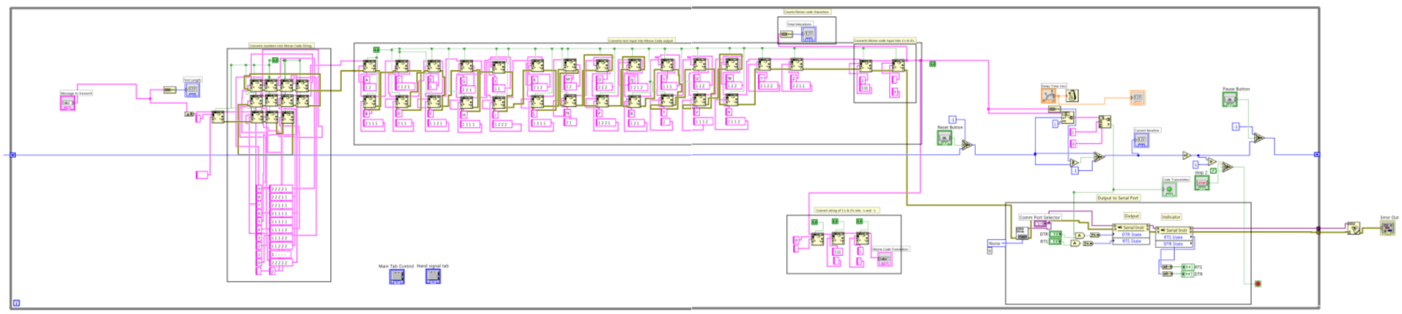
Oceanreef Group. (2010, October). Underwater Communication- Skills for a New Way of Diving. San Marcos, California, United States of America.

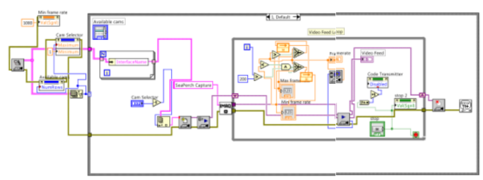
Ohler, S. (1999, February 2). Farewell to Morse Code- Saviour on the High Seas Ends Its 100-Year Reign. *The National Post*, p. A1 (Front Page).

UKDivers.net. (2007, October 16). *Underwater Signals*. Retrieved from UKDivers.net: http://ukdivers.net/comms/signals.htm

Appendix A: Labview Code

For more information regarding the Labview coding visit: [http://www.et.byu.edu/~jcardell/.](http://www.et.byu.edu/~jcardell/)





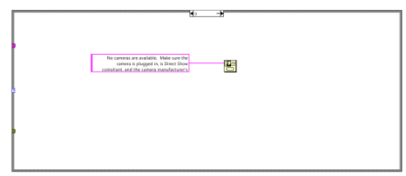


Figure 6: This code was created by Jason Cardell for the sole purpose of investigating underwater communication methods which can be integrated onto the SeaPerch ROV.

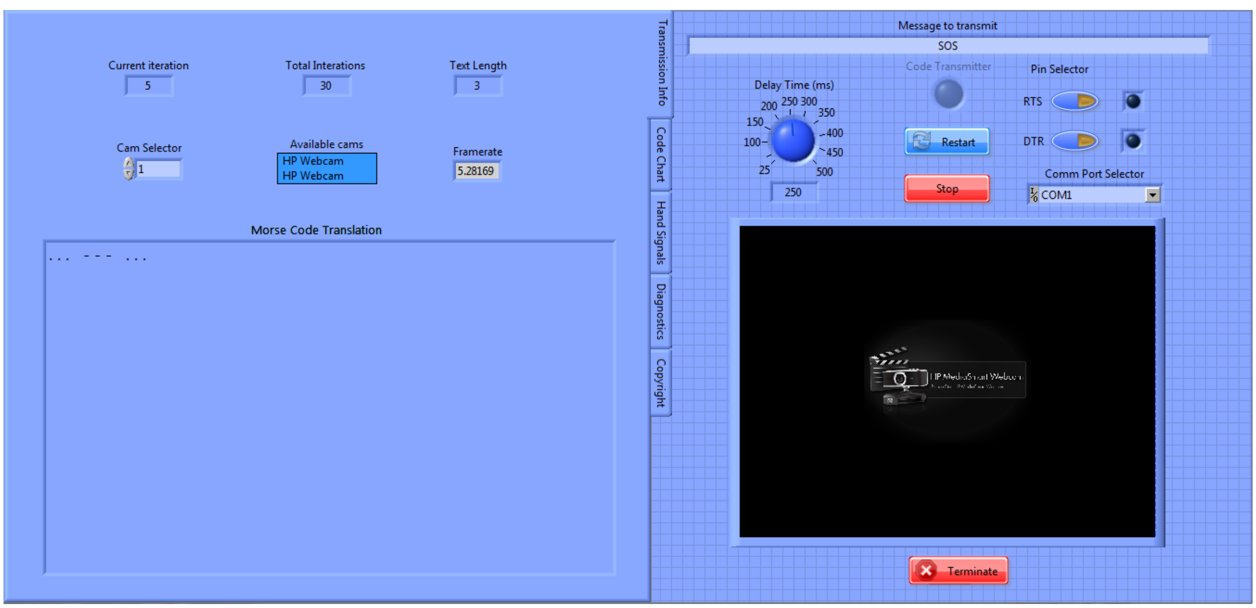


Figure 7: Complete GUI front panel. When the program is downloaded and used, this is the interface the user will see.

Appendix B: Bill of Materials

Table 1: Bill of materials (includes all non-virtual components used in this project)

Qty	Object	Object Description	Distributor	Part Number	Price
1	Endoscope	Endoscope inspection camera	Amazon.com	B006MNWHTQ	$27.03
1	RS232 Cable	RS232 to RJ45 adapter cable	Amazon.com	B004F72A9I	$5.94
1	Liquid Tape	Liquid Tape / Plastic Dip	Amazon.com	B00176FG0A	$8.61
1	Heat Shrink	Shrink wrap tubing	Harbor Freight tools	96024	$1.59
1	Junction Box	Rectangle electrical box	Home Depot	SB350S	$3.59
1	Ethernet Plate	Triple RJ45 electrical box plate	Home Depot	N/A	$1.80
3	Ethernet Jacks	Rj45 Ethernet wall jack	Home Depot	5015-WH	$6.84
1	LED	5mm Orange Super-bright LED	Radio Shack	55050621	$1.14
1	Resistor	1.5 kΩ Resistor (5 pack)	Radio Shack	271-1120	$1.49

Total Cost:	$58.03