WIRELESS PANCAKE SWITCH CIRCUITS FOR ACCESSIBLE PLAY TECHNOLOGY

Chloe Chen, Sabrina Sanchez

Shu-Chien Gene-Lay Department of Bioengineering, University of California San Diego
La Jolla, CA, U.S.A

***Abstract* - Engaging in play is a fundamental aspect of human development, encompassing both physical and mental growth. However, it is crucial to acknowledge that children with disabilities, such as cerebral palsy and autism, often encounter significant challenges when it comes to interacting with conventional mainstream toys. Their limited range of motion can pose significant barriers to their engagement with these toys. Often, the buttons and controls on such toys are either too small, inconveniently located, or demand a level of flexibility that is more difficult for these children to achieve. Addressing the growing demand for adaptable toys and the existing deficit in the market, various organizations have emerged with a mission to provide a resource for families through toy lending libraries and modify toys to be external-switch-activated. Typically, these modifications involve altering the internal circuitry of toys to enable them to be activated by an external switch, making them more accessible to children with disabilities. This project sets the basis for the circuitry required to create a low cost wireless pancake button using RF technology and a 555 bistable timer.**

I. Introduction

Play is a significant and essential aspect of a child's cognitive and physical development. It allows them to develop skills such as negotiation, problem-solving, fine motor skills, sharing, decision-making, and the ability to collaborate with others[1]. However, children with disabilities related to fine or gross motor skills, such as cerebral palsy, experience restricted movement due to disturbances in the developing brain and are not able to use off-the-shelf toys[2]. Due to this restriction, they are not able to develop the social and physical skills sufficiently. To address this need, organizations have started the field of toy adaptation, in which toys are modified so that they can be activated through alternate switches more appropriately suited for the user. Examples of organizations involved in this field include HuskyADAPT, the Toy Adaptation Program, and the Adaptive Toy Project[3]. During community education workshops hosted by these programs, students are able to learn about the process of toy adaptation, as well as the importance of adaptable toys[3].

While the current method of toy adaptation is effective, the process is very invasive to the toy circuit, as it involves altering the circuitry of the toy[3]. Moreover, there is a very limited supply of switches and switch-adapted toys on the market, being sold for approximately 400% of the price of the original non-adapted toys[4]. Hence, though there are toy lending libraries offering free adapted toys and switches for families in need, they have to heavily rely on donations to keep up with the demand. These issues cause a supposedly accessible technology to be in reality inaccessible to families and children that need it most. Our team aims to address these issues by creating a cost-effective and non-invasive method of adapting toys, with an emphasis on remote activation, and working with the Toy and Software Lending Library of the United Cerebral Palsy of San Diego County (UCPSD) and student organizations at UC San Diego to increase the knowledge surrounding toy adaptation through toy adaptation workshops.

II. Circuit Design

Copper Plate

The main goal of this circuit was to create a non-invasive way to control a toy's circuit. In the project's prototypes of the pancake switch, a copper plate is inserted into the battery pack of the toy, allowing the current of the toy to be directed out of the original circuitry of the toy to be externally manipulated (Figure 1).

Figure 1. Copper plate in the toy's battery pack

This allows the circuit of the toy to be in series with the switch. The use of the copper plate grants more accessibility for adaptable toys because it can be used on the off the shelf toys. Therefore, the circuit design should make use of this copper plate for achieving the goal of making the process non-invasive.

RF Transmitter and Receiver

In order to create the most cost effective and reproducible circuit possible, pre-made RF transmitter and receiver modules were utilized as a part of this circuit. The transmitter sends out a one-time signal of 434 MHz when activated through a current. The transmitter and receiver require a power source of 6 volts.

With the help of these materials, a wireless switch circuit was designed (Figure 2).

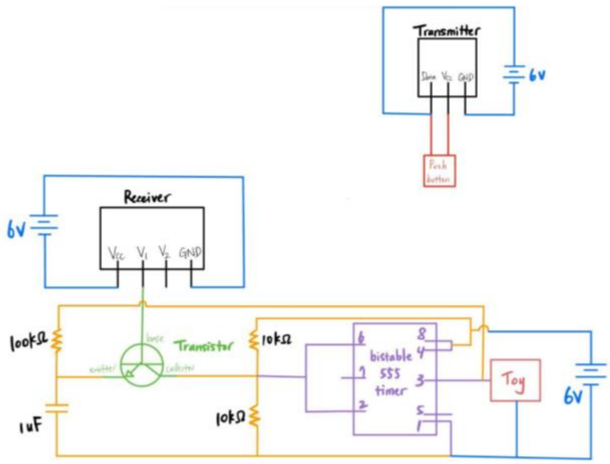

Figure 2. Circuit diagram of the wireless switch circuit.

Circuit Components

The table below (Table 1) lists the components of the circuit described in Figure 2.

Table 1. Component values and descriptions.

Component	**Description**
R1	10 KΩ
R2	10 KΩ
R3	100 KΩ
C1	1 µF
555 Timer	NE555P Texas Instruments
Button	Momentary Latching button
RF Transmitter	Transmits signals at 434 MHz
RF Receiver	Receives signals at 434 MHz
Transistor	NPN 2N222

The RF transmitter, RF receiver and 555 timer all have 6 V power supplies.

Bistable 555 Timer

Within the circuit diagram is a bistable 555 timer, which alternates between two stable states. In the circuit designed above, the click of the push button changes the state. So, one click will turn the toy on and another click will turn the toy off. The output is triggered on when pin 2 (trigger) senses a voltage less than ⅓ of the supply voltage. The output is triggered off when pin 6 (threshold) senses a voltage more than ⅔ the supply voltage.

Since the push button sends a one- time signal as does the transmitter and receiver, the bistable 555 timer was crucial to the design, as it keeps the activation of the toy contingent to separate pushes of the button, instead of the toy promptly turning off after the receiving of the one-time RF signal.

Circuit Walk Through

When the circuit is first powered on, the voltage between pin 2 and pin 6 is equal. This is because the two resistors flanking pin 2 and 6 are equal, and that is why we chose those values. Once the button is pressed, a single signal is sent by the transmitter to the receiver. This signal is then sent to the transistor, which only allows current to flow through the toy's circuit if the RF receiver is activated. The capacitor then starts getting charged by drawing in current through the first 10 kiloohm resistor. A smaller value was chosen for the capacitor so the time it was able to charge was faster. This causes the voltage at pin 2 to go below ⅓ of the supply voltage and turn on the LED or toy.While the toy or LED is on, the capacitor is charged. So, once the button is pressed again, the capacitor's charge brings the voltage at pin 6 above ⅔ of the supply voltage and turns off the output.

III. Circuit Testing

The circuit above (Figure 2) was tested on a breadboard as a proof of concept (Figure 3).

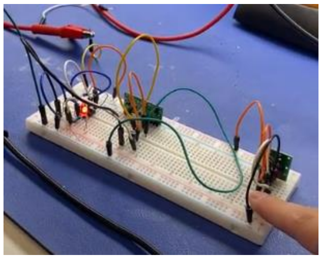

Figure 3. Circuit prototype of the wireless switch circuit with an LED instead of a toy.

The circuit prototype built in Figure 3 worked as desired, and would click on and off whenever the button was pressed.

The main difference between the circuit drawn (Figure 2) and the circuit prototype (Figure 3) is the inclusion of an LED instead of a toy. The reason that an LED was used as a proof of concept rather than a toy will be discussed in the limitations section.

IV. Design Advantages

In comparison to previous switch adaptable toys and buttons, this design allows for a non-invasive adaptation of off the shelf, battery-powered toys. This means that the user is not required to enter the circuit of the toy to switch and adapt the toy. This brings three main advantages: low cost, high reproducibility, and wide applicability.

V. Design Limitations and Future Changes

One of the limitations this circuit has, and was alluded to in the above section, was that it supplies voltage to the LED. Therefore, in order for this to work in a toy, the right amount of voltage, specific to the toy, must be supplied. This makes it less accessible to the user, as the amount of voltage output from the 555 timer must be adjusted for the individual toy.

In addition, because the toy has its own power source, the copper plate battery interrupter idea described previously needed a slight modification to navigate around the nature of the toy. If the user would like to use this circuit with the aforementioned copper plate battery interrupter, another transistor needs to be put after the output of the 555 timer so that the output of the 555 timer acts as a switch rather than a voltage source, which could be limiting based on the model of the 555 timer, and hence be interfering with the activation of the toy.

VI. Discussion and Biomedical Applications

In California alone, around 280,000 children are battling with major disabilities that limit their mobility ranges[5,6]. As of 2018, there are 73 registered toy lending libraries in California. However, most of them face the same issue as our partner at UCPSD, which is the extremely high cost of adaptive switches and toys, making their functioning highly dependent on donations[7].

As seen in Table 2, the predicted cost is $4.31 for the wireless pancake button. This project, in comparison to the current adaptive switches on the market, has significantly reduced the cost of the switch, making it more accessible for families and non-profits. The production of the switches in this project is not-for-profit, as the goal is to provide adaptive switches and accessible play technology to the children in need at low cost, through the collaboration with UCPSD and other organizations of similar goals.

Table 2: Total cost per wired/wireless switch.

Item	**Cost ($)**	**Amount needed: Wireless**
PLA	1.61	69.5g
Latch button	0.22	1
Spring	0.05	1
Copper plate	0.07	9.5x17mm
RF transmitter/ receiver	2.20	1
2N2222 NPN Transistor	0.04	1
Total ($)		**4.31**

Moreover, as we delve deeper into the realm of RF remote control and activation, we can translate the technology to various biomedical applications. Medical devices that are of limited accessibility to persons with disabilities due to the same usual design of intricate activation buttons could be improved on using the wireless pancake switch and hence be accessible to wider ranges of audiences. While achieving the set goal of adapting toys and enhancing accessibility for children with disabilities, the team also hopes for this project to serve as a momentum starter for accessible technology in more than just application to toys.

VII. References

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