Uses example of modifying toys to make them accessible for children with disabilities.

Overview

In this introduction to electronic engineering, you will learn some basic skills and then use them to modify an electronic toy to make it accessible for a child with a disability.

Modifying Toys

Electronics and embedded computer chips have added another dimension to the interactions that can occur between children and their toys. Smart toys are blurring the lines between play and learning by involving children in interactive activities. Sensors in the toys respond to touching, squeezing, sound, speech, movement, and in some cases, the toys even communicate among themselves. Thoughtfully designed toys can provide experiences that would otherwise be unavailable to many children. Children, who for whatever reason, cannot interact with these toys may find themselves at a disadvantage.

In this application note, we will show you how to modify smart toys to make them accessible to children with disabilities. Before we begin with the toys, however, it is important that we go over some basic concepts and look at the skills that you must have to successfully modify a toy. There are two essential things you must never forget – safety and reliability. You are not doing anyone a favor if you create something that is dangerous and may hurt them. For example, toys that run from one or two one-and-a-half volt penlight cells are generally completely safe to operate. The low voltages can't give the user an electric shock. In contrast, devices that run from the 110-volt household power always have the potential to electrocute people if it is handled improperly. We will discuss this in more detail when we talk about how to build switches. The other issue of reliability is to do with living up to expectations. Receiving a toy they can operate by themselves may be one of the highlights of a young disabled person's life. It is a terrible letdown for a child if the toy is erratic or breaks soon after they start using it. You are not doing them any favors if you give them something that doesn't live up to the promises.

Things you need to know before you get started

Electricity

This is a very brief and simplified explanation of electricity. Electricity and electronics depend on the flow of electrons from one place to another and the effect that these electrons have on nearby materials. Materials like metal, that allow electrons to flow easily, are call conductors. Materials like plastic, that prevent electrons from flowing, are called insulators. There is third type of material called semiconductors that can behave as either a conductor or an insulator. Semiconductors are used to make transistors, which are the main components in computer chips.

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For electrons to flow we need a conductor and we need an electrical force that is called voltage. Voltage can be provided by a battery or by an electrical generator. Batteries always push electrons in one direction and the flow of electrons is called Direct Current or DC. The voltage provided by a generator alternates between pushing electrons in one direction for a short time and then reversing the direction. In the U.S., the electrical supply system alternates sixty times a second. This creates a back-and-forth flow of electrons called “Alternating Current” or AC.

Batteries are generally used to power portable devices; generators are used to drive large loads such as lights, appliances and motors. Electronic power supplies change AC into DC for powering appliances like TVs and portable devices from the power distribution system.

Conductors have a property called “resistance” that opposes the flow of electricity. Voltage, current and resistance are directly related to each other by a simple formula called Ohms Law. Some conductors, such as copper, have very low resistance, and some conductors, such as tungsten, have a high resistance. The thickness of a conductor also controls the effective resistance.

Ohms Law is often written as: $I = V/R$. We use this relationship to calculate the amount of current that flows when we connect a voltage to a conductor.

Electronic components

Electronic components are the building blocks for making functioning electronic devices. Without going into the details of what they all do, the following list covers many of the components electronics engineers must understand very thoroughly to be able to design design working systems.

Wires and cables	Conductors that are used to connect components
Terminals	Metal contacts used to connect wires
Plugs and sockets	Connectors for linking groups of components together
Printed circuit boards	Insulating boards with conducting patterns that support and interconnect components.
Resistors	Devices that control the amount of current that flows.
Capacitors	Devices that store electrons as electric charge
Inductors	Devices that oppose the flow of alternating current by storing energy as a magnetic field.
Switches	Mechanical devices that make or break connections between components.

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Transistors	Solid state switches that control the flow of electrons.
Integrated Circuits (ICs)	Collections of transistors, conductors and other electronic components that are typically fabricated in Silicon.
Sensors	Devices such as microphones, temperature sensors, and accelerometers for sensing physical properties and generating an electronic representation.
Transducers	Devices such as loudspeakers and motors that transform electrical signals into physical properties such as sound, pressure, position, or movement.
Wireless Transmitters	Devices that use infrared or radio frequency signals to send information.
Wireless Receivers	Devices that detect infrared or radio frequency signals that convey information.
Wireless Transceivers	Devices that combine a transmitter and a receiver.
Microprocessors	Chips containing millions of transistors organized to perform computing operations
Memory Chips	Chips that store large amounts of information.

Electronic Circuits

An electronic circuit is a collection of electronic components wired together to perform one or more particular functions.

Circuit Diagrams

A circuit diagram is a graphical representation of an electronic circuit. Standardized symbols are used to designate the various components and their interconnections.

Skills

Electronic engineering involves many different intellectual and physical skills. Good engineers are not only required to be able to design circuits to perform required functions, they must also be able to build and test prototypes to show the circuit performs as intended. In some cases, they must also be able to design reliable and cost effective products.

Writing a Functional Design Specification	The functions of a circuit necessary to perform a required task are described in a text document called a specification

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Technical drawing	Initial circuits concepts are sketched out on paper.
CAD	Computer Aided Design software is used to do the detailed design of a circuit.
Computer simulation	Many different simulation and calculation tools are used to solve design equations, select components, and test the operation of a circuit using computer simulations of the real components.
Analog (AC) circuit design	The AC design of a circuit handles all of the analog signal requirements. Typical analog components include operational amplifier chips, resistors and capacitors.
DC Circuit design	The DC design sets up the correct operating conditions for all of the components in the circuit.
Digital Design	Digital logic is used in most circuits. Digital circuit design requires translation of mathematically described logic into the interconnection of appropriate logic chips.
Microprocessor programming	Embedded microprocessors are increasingly common in electronic circuits. Sometimes they are programmed in high-level languages such as C or Java but often they must be programmed in machine code or “assembly language” that is specific to a particular microprocessor.
Component selection	Different versions of the same functional component are required for different operating conditions such as high or low power handling, and high or low operating frequency.
Prototyping	There are many hidden interactions that must be checked by building a physical prototype that can be thoroughly tested under real operational conditions.
Testing	Many electrical, mechanical and thermal tests are required to show that a circuit will perform the required functions reliably for a long time.
Debugging	Any faults detected during testing must be analyzed to find the cause and the system must be redesigned to eliminate the faults.

3D design	As devices get smaller and smaller it is necessary to design layouts and packaging in 3 dimensions. Knowledge of plastics and molding is sometimes necessary.
PCB design	Layout of components on a Printed Circuit Board is critical for electrical and thermal stability and for fitting components into the available physical space.
Mechanical design	Properties of plastics and metals such as strength of materials, thermal properties and corrosion resistance are important along with knowledge of how to make cases that are small, strong and light and able to be assembled easily.
Assembling devices	There are many standards governing physical access and safety issues that have an impact on how devices are assembled. Users must not be able to touch any dangerous components under normal and some specified special situations.
Thermal design	Excessive heat is the biggest problem facing designers as more and more circuitry is packed into smaller devices.
Soldering	Solder is a conducting metal that is used to connect components to PCBs and to wires. The reliability of soldered connections is absolutely critical. One bad soldered joint can make a complete system fail.
Electrical Interference	All electronic devices must comply with very strict laws regarding how much electrical interference they can generate.
Writing clear documentation	Clearly written, complete, and easily understood documentation is absolutely critical for all electronic engineering projects.
Standards	Reading and understanding technical standards is a critical part of design because many organizations now require circuits to meet safety and performance standards set by government and industrial groups.
Patents	Many design concepts are covered by patents that can lead to legal problems of a designer infringes them.

Tools

Tools fall into several categories.

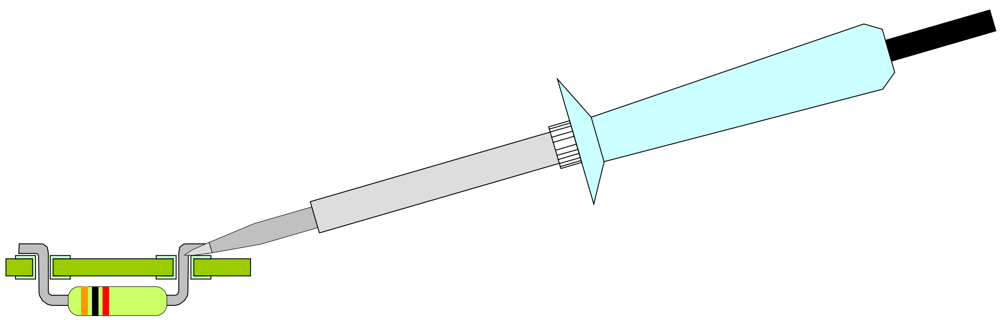
Design Tools	• Computer Aided Design for mechanical and physical design • Schematic design for designing circuits • PCB Design for laying out components and interconnections • Circuit simulators for testing options for implementing circuits
Assembly Tools	• Wire cutters for trimming wires and component leads • Long nosed pliers and tweezers for bending leads and inserting lthem into PCBs • Wire strippers for removing insulation from wires • Soldering iron and solder for joining components and PCBs • Solder sucker for removing solder from joints that are to be repaired • Magnifiers for checking component values and soldered joints • Drills for clearing mounting holes • Screw drivers and nut drivers • Dentist's mirror for seeing in confined spaces
Testing Tools	• Digital multimeter for measuring voltage, current, resistance, circuit continuity, and component values. • Power supplies for powering circuits and testing their performance at different supply voltages • Signal generators for inputting test signals • Oscilloscope for observing signals in an operating circuit • Digital thermometers for measuring temperatures. • Logic probes for injecting and observing digital signals • Logic analyzer for capturing and displaying multiple streams of digital data.

The foregoing summary briefly touches on many different topics. These represent the very minimum requirements for a competent engineer. Engineering is about taking care of the details. Scientists make discoveries about natural phenomena. Engineers work out how to use those discoveries to make products that benefit humankind. In doing so, it is often necessary to hide much of the internal detail from the end user.

It has been said that engineers are responsible for making things simple but this does not mean making them dumb. From the user's perspective, a product should be as simple as possible to set up and use. From the engineers perspective, the device should be as smart/complex as is necessary to make it simple for the user.

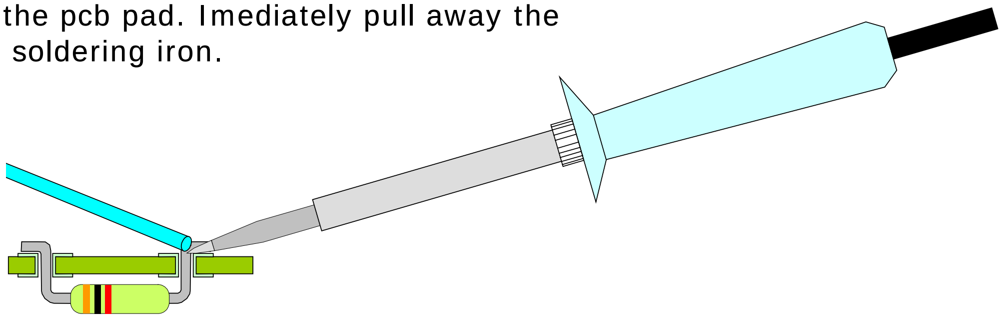
Soldering

Soldering is the most important skill you must master early on in order to make successful, reliable modifications. Correct soldering is a critical step in all electronic assembly. Soldering is automated in most manufacturing processes but it is still necessary for engineers to be able to assemble and repair components that are soldered together or to printed circuit boards.



This diagram shows a component mounted on a printed circuit board about to be soldered. The tip of the soldering iron is correctly placed to heat the lead and the printed circuit just prior to applying the solder.

Solder is applied briefly at the three-way junction made up by the component lead, the Printed circuit board and the tip of the soldering iron. As soon as the solder melts, it should flow smoothly around the component lead and over the pcb pad. Imediately pull away the solder and the soldering iron.



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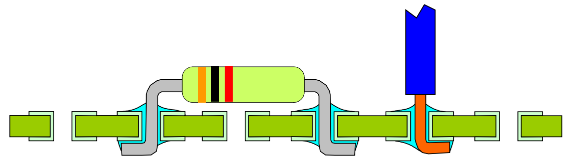
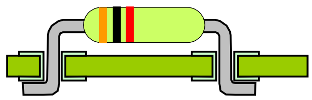
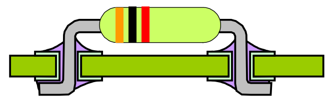
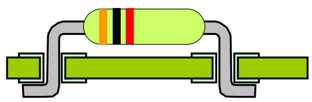
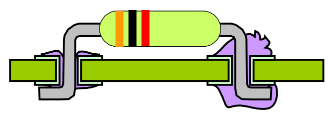
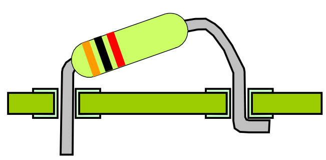
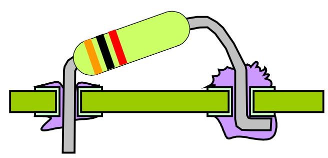
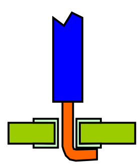
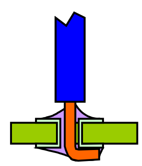
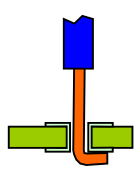
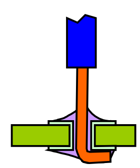
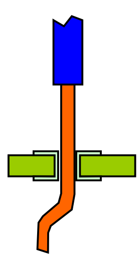
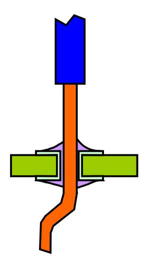
This diagram shows well formed solder joints with just the right amount of solder.



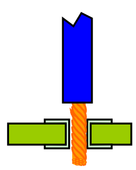
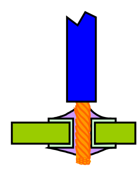
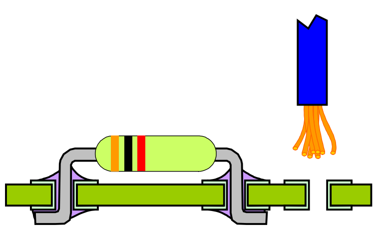
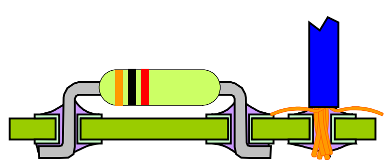
Examples of good and bad solder joints

Example	Component ready for soldering	Component after soldering	Comments
GOOD! **Properly soldered joints**			**Solder fills spaces without bumps and hollows**
BAD! **Too much solder**			**Big blob of solder that wasn't heated properly**
BAD! **Component not mounted properly**			**Bad mounting and bad soldering**
GOOD! **Wire has correct amount of insulation stripped off**			**Wire is properly soldered without exposed metal**
BAD! **Bare wire is exposed**			**Exposed wire is weakened and can cause short circuits**
REALLY BAD! **Wire is exposed on both sides of the board or terminal**			**Dangling exposed metal causes short circuits**

Stranded wires

Wires have either a single strand of thicker metal, usually copper, or a bunch of finer wires. The diameter of the strands and the number of strands in the wires or cable determine how well it conducts electricity and how well it stands up to being bent or stretched. The fatter the wire, the better it conducts and the more strands it has, the better it bends and flexes. The single strand wire is used for fixed wiring that is not going to be moved about after it is installed. Stranded wires are more flexible and must be used for wires that connect devices that are to be moved about.

Stranded wire requires more care when making connections because the strands tend to spread out. Stray ends can cause shorts to other parts of the circuit. You must always twist the strands tightly together to prevent them from spreading when you are working with them.

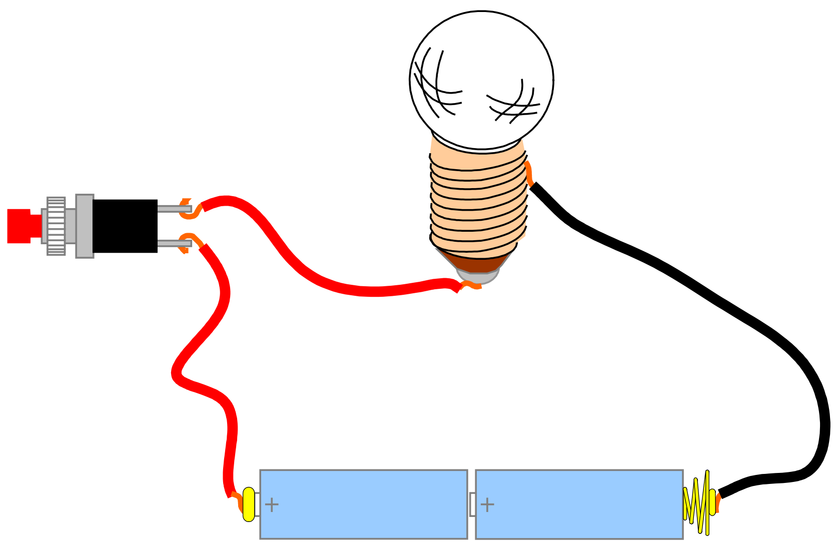
Stranded wire with some insulation stripped off			
Strands firmly twisted together			
GOOD! Strands twisted together to prevent stray ends			**No stray strands and correct amount of solder**
REALLY BAD! Strands not twisted together			**Stray strands cause short circuits to**

Practice Exercise

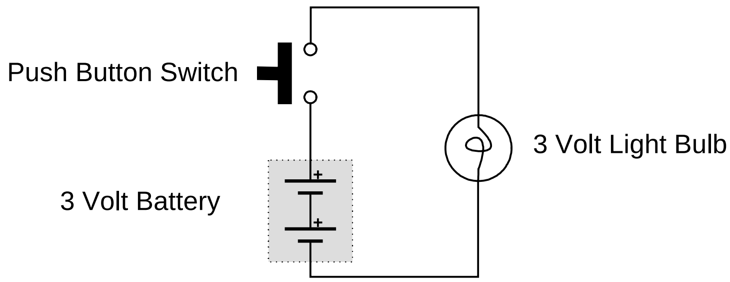
We have designed a simple exercise to help you understand some of the things discussed in the foregoing summary. You will assemble an electrical circuit consisting of a battery, switch and light. When you have completed this you will think about how this circuit could be extended to include an external switch that could be used by a disabled person. Then you will look at how you could add another output device such as a motor or beeper. When you have completed the exercise, you will be ready to tackle an electronic toy.

Step-by-step Instructions:

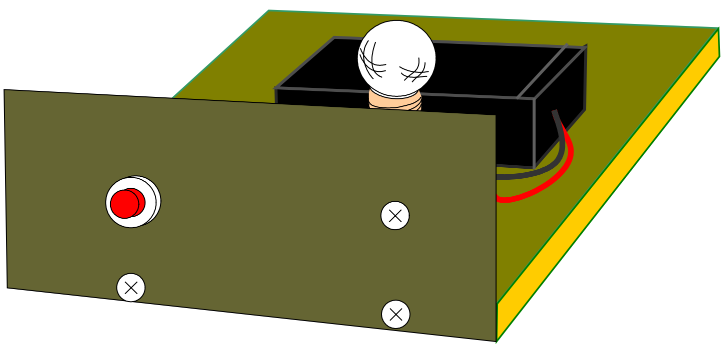
1. Components for Practice Exercise
    a. Mounting board
    b. Battery holder
    c. Two AA 1.5 volt batteries
    d. Push button switch
    e. Lamp holder
    f. 3 volt penlight bulb
2. Functional Connections

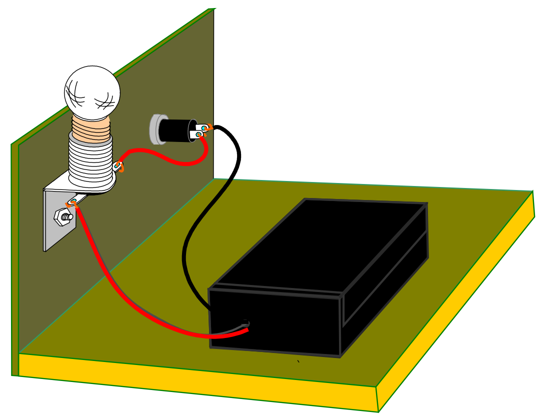


3. Circuit diagram



4. Assembly Instructions





a. Mount the switch onto the front panel
b. Mount the lamp holder onto the front panel
c. Use a strip of double sided sticky tape to hold the battery compartment onto the base board
d. Trim the red wire coming from the battery holder so that it comfortably reaches the lamp holder. The part you cut off must reach from the lamp holder to the switch.
e. Use the wirestrippers to remove ¼" of insulation from the ends of both red wires. Twist the exposed ends of wire to make the strands stay tightly bunched.
f. Pass the ends of the red and black wires through the holes in the terminals on the lamp holder and switch and wrap the ends around the terminals as shown in the above diagram.
g. Solder each joint being careful heat the metal parts and melt the solder properly without melting the insulation on the wire.

5. Testing

   a. Visually check your circuit before inserting the battery
   b. Insert the two AA batteries, making sure they are correctly polarized
   c. Use a voltmeter to check the voltage between the black wire and each of the red wires. When the switch is open and when it is closed.
   d. Screw in the flashlight bulb
   e. Press the switch – the lamp should light up.

6. Adding an external switch
   a. Discuss within your group how to do this and report your plans to your mentor
   b. If there is time, wire up an additional switch
7. Adding a motor
   a. Discuss within your group how to do this and report your plans to your mentor
   b. If there is time, wire a motor into your circuit
8. Adding a beeper
   a. Discuss within your group how to do this and report your plans to your mentor
   b. If there is time, wire a beeper into your circuit

Modifying a toy

The toys you will modify in this exercise are similar to the simple circuit you have just constructed. As noted in the following section, not all toys are this simple, however, and it is becoming increasingly complicated to modify toys to make them accessible.

Challenges

There are many different types of smart toy

- Some toys have a single on-off switch – you turn it on and it does something, you turn it off and it stops doing it. These toys are easily modified with a small device called a power interrupter that slips in between two of the batteries in the battery holder.
- Most electronic toys that are now available have an on-off switch that merely turns the toy on or off. To make the toy actually do something, it is necessary to touch one or more switches, or activate sensors, that are embedded in different parts of the toy. It is much more difficult to modify these toys to make them accessible for children with disabilities. The switches that trigger actions must be located and the wires that connect them to the control electronics must be exposed so that

external switches can be connected in parallel with the existing switches. It is necessary for the person who designs the modifications to understand how the circuits operate because incorrectly connected switches can easily destroy the electronics in a toy.

Toys are made to be kid-proof

- Kid-proof toys are difficult/impossible to dismantle without causing damage. Anything you do to get at the internal wires and components must be reversible.
- The toy must be kid-proof when you have completed the modification. For example, there must not be any sharp or dangerous components accessible to the child and there mustn't be anything that the child could pull off and swallow.

Donated toys may be broken in some way when you receive them

- Before looking at how to make a toy accessible, it is essential that you test all of its normal functions. If there are faults, you must determine whether the faults can be fixed. In some cases, there may be enough other interesting functions that it is not necessary to fix the fault.
- If the faults are not fixable, it is often worthwhile to cannibalize the toy to get parts for fixing other toys. It is also very instructive to pull a toy apart completely to increase your understanding of how it works. This will give you ideas about how to make other toys more accessible.

Planning your work

It is essential that you plan your modification on paper before doing anything to the toy.

- Sketch out the toy showing how the various actions are triggered and how they are actually performed.
- Identify all switches and their particular function.
- Decide which actions you want make accessible to a disabled user.
- Figure out what modifications will be necessary to make the toy accessible
- Decide whether it is practical to make the necessary modifications.
- Decide whether you want to go any further. An inaccessible toy that still functions is more useful than one that no longer does anything due to an unsuccessful modification.
- If you decide to go ahead with the modification, draw out exactly what needs to be done showing all existing wires and components to which you plan to make connections and all additional wires, connectors and switches. Show the colors of all wires that you will connect to or add.
- Sketch the physical locations of the parts you plan on adding.

- Select the components that you will use to make the modification. Make sure the components will fit into the desired location when the toy is reassembled.
- Double-check all of the details before making any physical changes to the toy.
- Remove the batteries from the toy while you work on it in case an accidental short burns up part of the circuit.
- Make your modifications incrementally. For example, insert the connection for one switch and test its operation before going on to the next switch. It is often very difficult to find faults when you make several changes at the same time.
- If you make changes to the circuit, as you find and fix faults, modify your drawings to show the changes.

Testing your work

It is very easy to make wiring mistakes that, in most situations, make a circuit behave differently to what you intended. Modern electronic circuits are easily damaged by connecting the power supply backwards (getting positive and negative wires reversed), applying voltages that are too high, or accidentally connecting together parts of a circuit that were not meant to be connected.

Testing begins before you apply any power to a circuit. Using a close visual inspection and a multimeter to make continuity checks and resistance measurements, you should determine that all wires are connected to the correct components. Do not apply power to the circuit until you are sure the circuit is correctly wired.

When you insert the batteries and apply power, be ready to turn the system off and/or remove the batteries if anything gets hot, emits a puff of smoke, you smell something burning. Identify and fix the fault before applying the power again.

Where to get the parts

Pulling old electronic devices apart is a good source for some of the larger parts such as switches and connectors but modern assembly processes make it very difficult to retrieve many of the electronic components from printed circuit boards.

In addition to careful design and good workmanship, by far the best way to make reliable modifications to toys is to select and use good quality components. While it is possible to make a simple switch out of bits and pieces of metal, plastic and foil, this approach is a recipe for disappointment. ALWAYS USE REAL SWITCHES MOUNTED IN APPROPRIATE BOXES OR CASINGS. The wire and connectors you use to connect the switch to the toy must also be carefully chosen. Wires must be very flexible and it is best that you find a cable of the correct length in a catalog rather than trying to make your own.

RadioShack shops are widely distributed through shopping centers and provide a good source of reasonably priced components.

If you really get into electronics, the best sources of electronic components are on the Internet. The two best sources for selecting components and having them shipped to you are Mouser and Digikey. They stock all electronic components and will ship any quantity. You can easily find them on the web by entering their name into Google.

Safety

We will complete this document with another reference to safety. Switches designed to control battery toys must not be used to control 110V lamps or appliances. Even switches that are designed to handle 110 volts, such as the in-line switches found on some lamps, are not appropriate for placing near a person's face or in a bed, where they could get wet from drool, vomit or urine. If it is necessary to control a 110V lamp or appliance, you must use a device such as a relay board that is designed to control 110V circuits or an X10 module and controller. You can learn about X10 devices on the X10 website or on the SmartHome website.

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