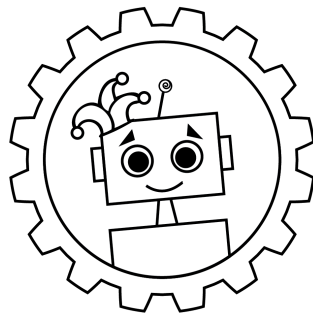


# Embedded Electronics for Theatre

Ben Peoples



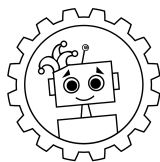
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# Chapter 1

## Introduction

Embedded technology - easily-programmable miniature electronics - has endless applications in the theatre industry. Recent innovations have made this technology more accessible than ever. The only thing standing between the theatre world and the world of embedded electronics is the need for a basic understanding of the technology and its potential uses. That's where this book comes in.

### 1.1 What is Embedded Electronics?

Embedded electronics is the use of tiny computers, called microcontrollers, to operate electronic elements. Among many other things, they can control the behavior of lights and motors, read data from sensors and react accordingly, and create communication links between electronic devices. Essentially, microcontrollers allow us to manipulate electronics in ways that would be difficult, cumbersome, or sometimes impossible with an ordinary computer.

### 1.2 How is this Useful in Theatre?

There are endless applications for embedded electronics in the theatre, and no two productions will use them in exactly the same way. Here are a few examples of potential applications, some of which you'll find instructions on building later in the book:

### 1.3. How do I Use this Book?

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- Create a spaceship control console with blinking LEDs for a production of *Forbidden Planet*. Using the methods you'll find in this book, the LEDs could simply blink in a random pattern, or they could react to button pushes, sliders, proximity of actors, or even noise around them. They could also be programmed into light cues and controlled through a wireless DMX link.
- Build a spinning windmill for *The Wizard of Oz*. The windmill could be easily cue-able through DMX, and could speed up during the storm and slow down again when it's over.
- Attach a practical elevator dial to a moving piece of scenery. The dial could be operated from offstage via a simple wired knob, or it could be controlled wirelessly via DMX.
- Have a ghost pop out from behind a wall in a haunted house. Use a proximity sensor to detect when people approach, programming the ghost to jump out at them automatically when they're close, then reset after a certain period of time.

## 1.3 How do I Use this Book?

*Embedded Electronics for Theatre* is a boot camp approach to learning the basics of electronics, geared specifically towards the information that is useful in the theatre. We'll start with the fundamentals of electricity, then work our way through the parts, pieces and tools you'll need to start building electronic devices. We'll touch on some very basic programming concepts, and then we'll show you how to build and program a variety of gadgets that have practical theatrical applications.

The book covers a lot of material, but it doesn't delve more deeply than what you need to know to actually build electronic devices that work. We also cover a good bit of math, since there are critical formulas and mathematical functions you'll need to understand to build electronic circuits. However, we will only go into the math when we need to. Understanding why the math works is far less important here than simply knowing how to plug some values into a formula.

If you get stuck in a section, just skip to the next one. Many topics are introduced in one place, explained in more detail later, and then finally implemented in the last few chapters. Everything will become clearer as you get further into the book. If you already have an understanding of the basic fundamentals of electronics and circuit

building, you may want to go directly to the later chapters that deal specifically with creating devices for theatre, referring back to earlier chapters if you need a refresher on a particular topic.

### 1.3. How do I Use this Book?

---

# Chapter 2

## How to Read This Book

Throughout this book, we'll be using quite a bit of math and referring frequently to circuit diagrams. Before delving into any of that, we've included quick refreshers on the necessary math and the basics of reading circuit diagrams. If you're comfortable with these topics already, just skip to the next chapter and jump right in!

### 2.1 Using the Glossary

Throughout the book, when a new term is introduced, it will show up slightly differently, like so: **resistor**. You'll find the definition of these terms in the Glossary, starting on page 233.

### 2.2 Math Refresher

While most of you reading this will have taken high-school Algebra, it may help to have a short refresher course. Here are the basics of what you need to know:

### 2.2.1 Arithmetic

We hope you are comfortable with the concepts of addition(+), subtraction(-), multiplication( $\times$  or  $\cdot$ ), and division ( $/$  or  $\div$ ). Here are some examples in case you're rusty:

$$\begin{aligned}13 + 7 &= 20 \\18 - 4 &= 14 \\3 \times 5 &= 15 \\42/6 &= 7\end{aligned}\tag{2.1}$$

When multiplying the same number times itself multiple times, exponents are used as shorthand. For example,  $2^3$  means the number 2 should be multiplied by itself three times:  $2^3 = 2 \cdot 2 \cdot 2 = 8$

Parenthesis ( ) are operators that group parts of the equation together. For instance, to subtract 4 from 18 and then multiply the result by 4, it can be expressed with parentheses:  $(18 - 4) \times 4 = 14 \times 4 = 56$

### 2.2.2 Order of Operations

When there are multiple operators in an equation, it's important to know what order to use them in. The order from first to last is: Parenthesis, Exponents, Multiplication and/or Division (left to right), and then Addition and/or Subtraction (left to right). A good mnemonic device for this is PEMDAS: Please Excuse My Dear Aunt Sally.

For instance:  $1 + 2 \times 3$  is equivalent to  $1 + (2 \times 3)$  NOT  $(1 + 2) \times 3$

### 2.2.3 Variable Substitution

When an exact value isn't known, a letter, like  $x$ , can be used in place of the number. The  $x$  is referred to as a **variable** and lets us use the value in an equation without knowing the exact number.

Variables behave just like numbers, so we can do things like  $3 \cdot 4x = 12x$ . A number that is directly before a variable is its **coefficient** and should be multiplied by the variable, so  $4x$  means the same thing as  $4 \cdot x$ .

Variables can also have subscripts, like this:  $V_f$  or  $R_2$ . This is just a way of "tagging" different variables to distinguish them from one another. One common use of subscripts

in this book is to differentiate the input value of something from the output value. For example, if  $V$  is the variable for voltage,  $V_i$  would be the input voltage and  $V_o$  would be the output voltage.

## 2.3 Circuit Diagrams

A **circuit** is a collection of wires and components that perform some function. Circuits are so named because the wires and components generally make a loop (or circuit) allowing electricity to flow. A circuit is said to be *closed* when electricity can flow all the way around the loop. A circuit is said to be *open* when there is a gap in the circuit that prevents the electricity from flowing all the way around.

A circuit diagram is a simplified drawing that lets us communicate what's important about the way a circuit is constructed, without having to draw the components in too much detail. Electrical components are drawn with wires connecting them. Where wires cross, they can either be *connected* or *not connected*.

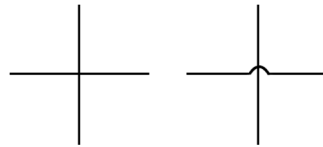


Figure 2.1: Wire Crossing: Not Connected

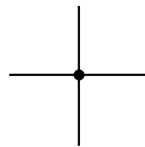


Figure 2.2: Wire Crossing: Connected

As you can see, if we draw wires that cross or intersect each other but do not connect, we'll show them without a dot at the intersection, or with a little jump showing that one crosses over the other. If the wires do connect, there will be a dot at the intersection.

## 2.3. Circuit Diagrams

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The following are electrical symbols for commonly found components. We'll go into detail about what these components are and how they're used later; for now, use this as a general key to follow and refer back to.

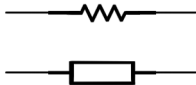
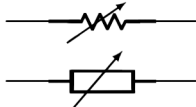
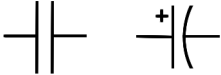

<p>Two different, but equivalent, symbols for a <b>resistor</b>. (See 5.1.)</p>	
<p>Two different, but equivalent, symbols for a <b>variable resistor</b>. (See 5.8.)</p>	
<p>A <b>capacitor</b> that does not care which way it is plugged in is <b>unpolarized</b> (left). A capacitor that reacts differently based on its orientation is <b>polarized</b> (right). (See 5.2.)</p>	
<p>An <b>inductor</b>. (See 5.4.)</p>	

Table 2.1: Circuit Diagram Symbols



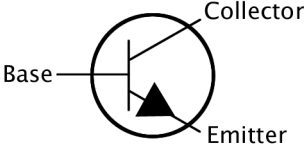
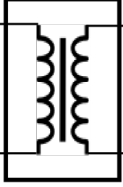
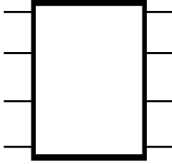
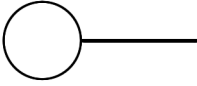
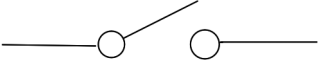
A Transistor (See 6.2)	
A transformer. See 5.4.4.	
An integrated circuit (IC). (See 6.5.)	
An inlet/test point. Used on diagrams to indicate a connection point.	
A switch. See Chapter 7.	

Table 2.2: Circuit Diagram Symbols

## 2.3. Circuit Diagrams

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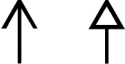

<p>A <b>battery</b> or <b>DC (direct current)</b> voltage source. Polarity indicated by + and -. (See 3.1.)</p>	
<p>An <b>AC (alternating current)</b> voltage source. (See 3.1.)</p>	
<p><b>V+ Supply:</b> indicates connection to the V+ supply. (See 3.1.)</p>	
<p><b>Ground:</b> indicates connection to the 0V reference. (See 3.1.)</p>	

Table 2.3: Circuit Diagram Symbols

Additional notes next to each component on a diagram will provide specific information about it, such as capacity, rating, etc.

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