

Love to Code: Volume 1

Microsoft MakeCode Edition

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Microsoft MakeCode Adaptation by Natalie Freed



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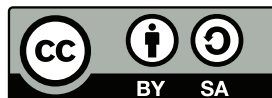
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Love to Code: Volume 1 Microsoft MakeCode Edition

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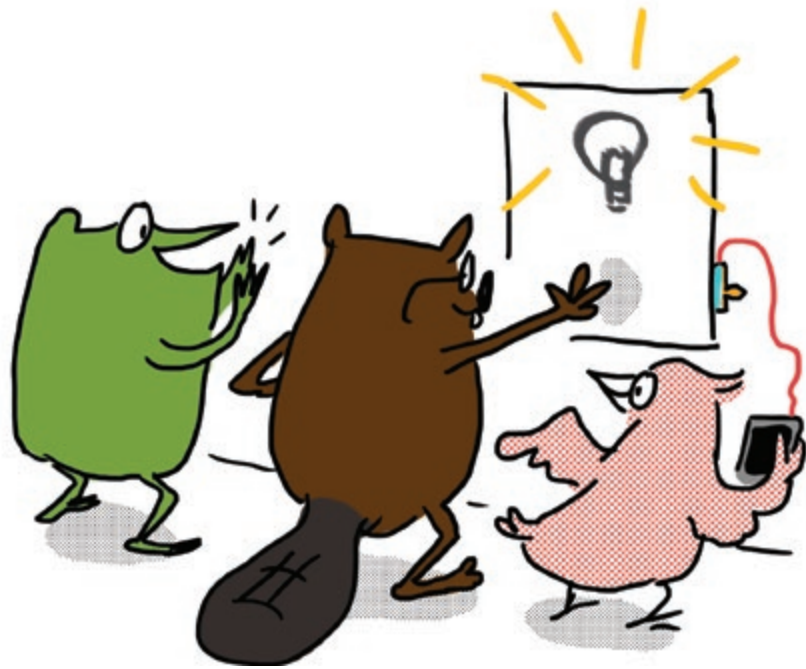


Prologue

Fern is a really creative frog.



Recently some of Fern's friends started to make drawings, paintings and costumes that would light up and were interactive...



"My friends are making drawings that **do** things!"

Fern wanted to make drawings that lit up too.



But everything was so complicated!

Her friend Sami, a seal, noticed that Fern was frustrated.

“Fern, do you want me to show you how to add lights to your drawings too?”

“Oh ... you don’t have to,” said Fern.

“But I can tell you want to do it. And look, you’ve already started!”

Sami barked cheerfully.

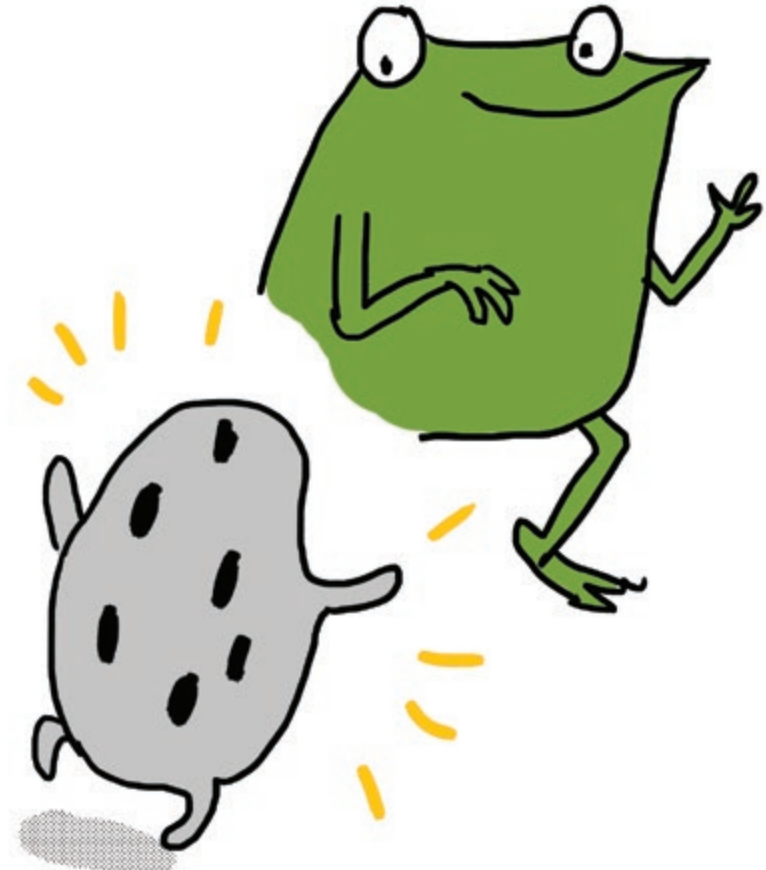


“Well, um,” Fern shuffled. “It’s just hard. There are just so many things to learn and sometimes it feels like I’ll never get there.”

Sami smiled. “Sometimes it’s hard. Learning any new thing can be challenging ... **but it can be fun too!** Let’s give it a try together!”



“I’ll be with you the whole time. What do you have to lose?”



Fern brightened at the thought and nodded with determination at Sami.

In this book, Fern gets help from not only Sami, but also from her whole gang of friends. Fern — and you — will learn how to add lights and sensors to drawings.

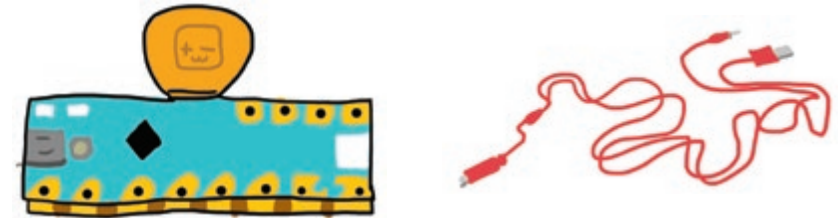
Fern promises that if you tag along and complete the activities in this book, your drawings will also be able to “do” something too!



The stuff in your Love to Code kit is what we'll use to make our drawings do something. Let's take a look at what's included in the kit!

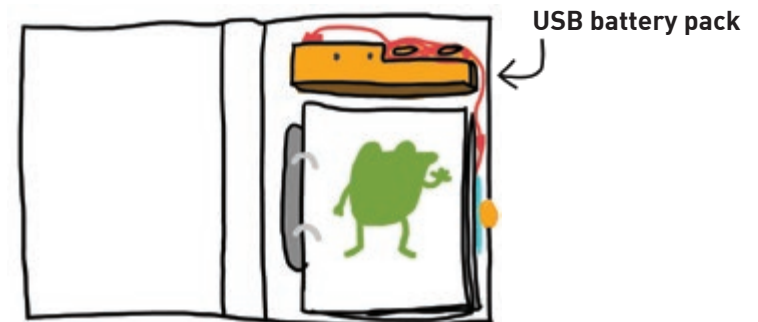
Chibi Chip and Cable

The Chibi Chip is the programmable brains behind our projects! It comes assembled with a clip so that we can quickly clip and unclip it to circuits. We use the special red cable to connect the Chibi Chip to our programming device — such as a tablet, phone or computer — and a USB power supply.



Chibi Book

The Chibi Book is a binder that comes with a built-in USB battery pack capable of powering a Chibi Chip. **Note:** you will need three AA batteries, which are not included in the kit.



To turn on the Chibi Book, slide the switch on the top of the battery pack to the left.



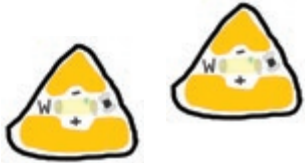
Power is available when the power light is green.

The batteries are low when the low battery light turns red.



LED stickers

These stickers are LED lights!
We'll use them to make our projects glow.



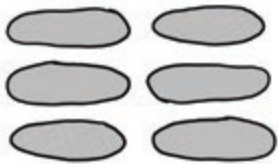
Copper tape

We use copper tape to connect the different parts of our circuit.



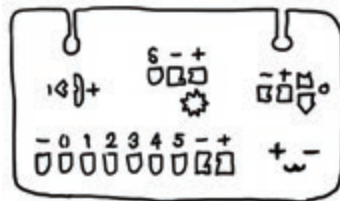
Fabric tape patches

These conductive fabric patches help us fix broken circuit connections.

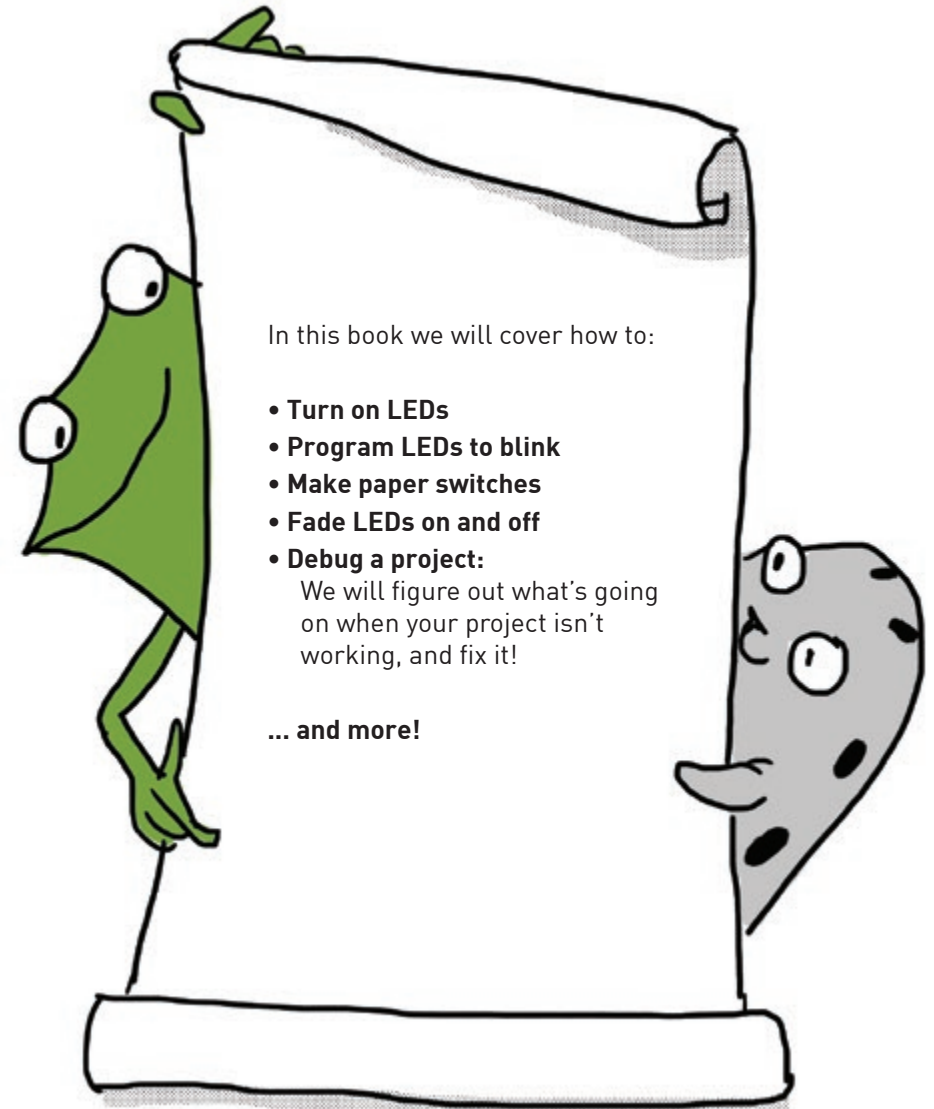


Circuit sticker stencil

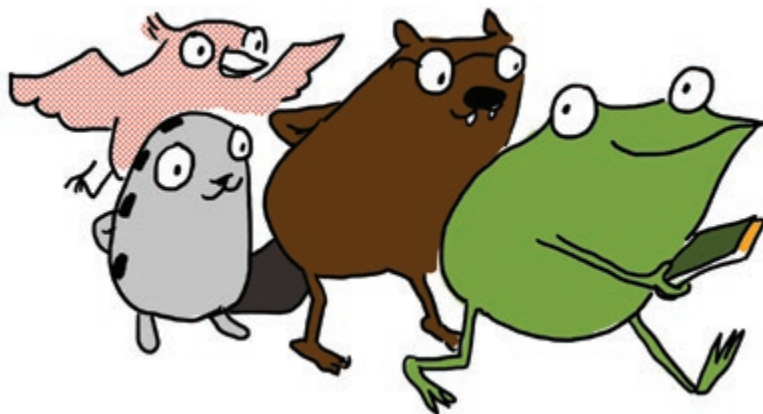
Use this stencil to help you sketch your own circuit designs!



We'll explain how to use all of this stuff in the chapters to come!



You can do the chapters in this book on your own, but they are also a lot of fun to do with a friend!



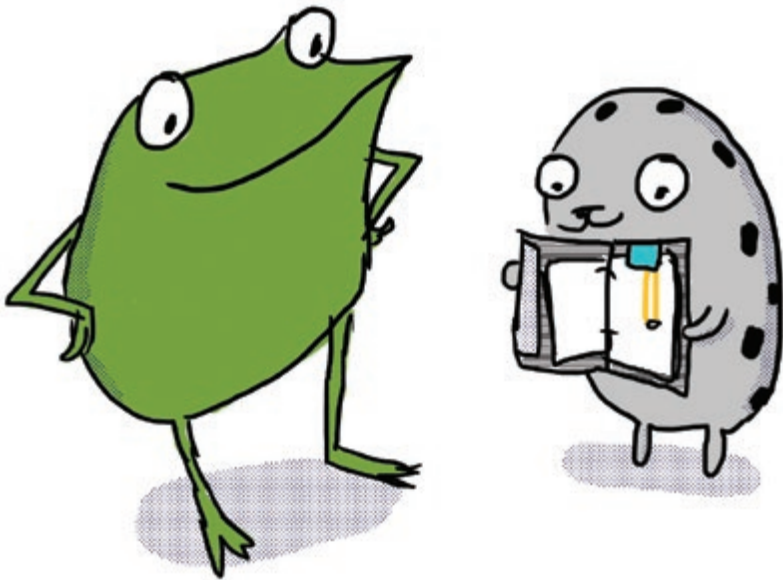
If you need help or get stuck, check out our web tutorials at:
chibitronics.com/lovetocode

Or send a detailed description of your problem to
help@chibitronics.com. We'll do our best to respond but please be patient, we're a small team of makers, artists, and dreamers — just like you!



Ready? Let's go!

Chapter 1: Light Up an LED!



“Let’s start with the basics,” said Sami the seal to Fern the frog.
“We can turn on a light by connecting it to a Chibi Chip!”

TURN ON A LIGHT!

In this activity we will power up our Chibi Chip and use it to light up an LED sticker!

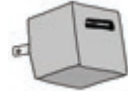
We will need:



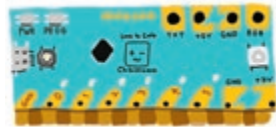
Chibi Light LED sticker



copper tape



USB power
(Chibi Book, laptop or wall plug)



Chibi Chip



USB cable

1. Stick copper tape over each of these gray lines.



2. Stick an LED sticker over the triangle footprint.



3. Plug the Chibi Chip into a power source, so that the green PWR light comes on.



4. Align and clip the Chibi Chip to the page over this rectangle. Make sure the metal pads of the clip touch your circuit.



5. Bask in the soft white glow of the LED!

OH WAIT, THE LED ISN'T ON? TRY THESE DEBUGGING TIPS!



THIS IS D. BUG. HE HANGS AROUND AND HELPS OUT WHEN PROBLEMS SHOW UP!

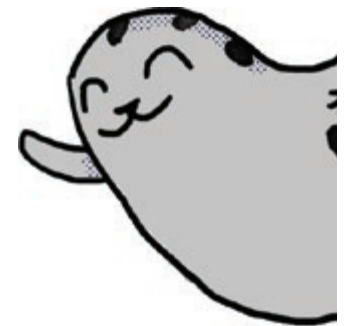
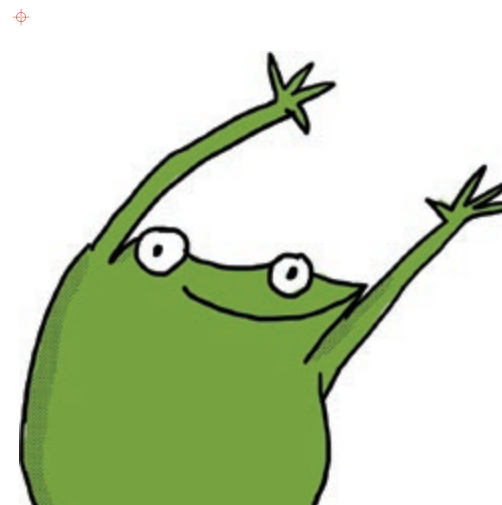


MAKE A STRONG CONNECTION! TRY PRESSING HARD ON THE METAL PADS OF THE LED.



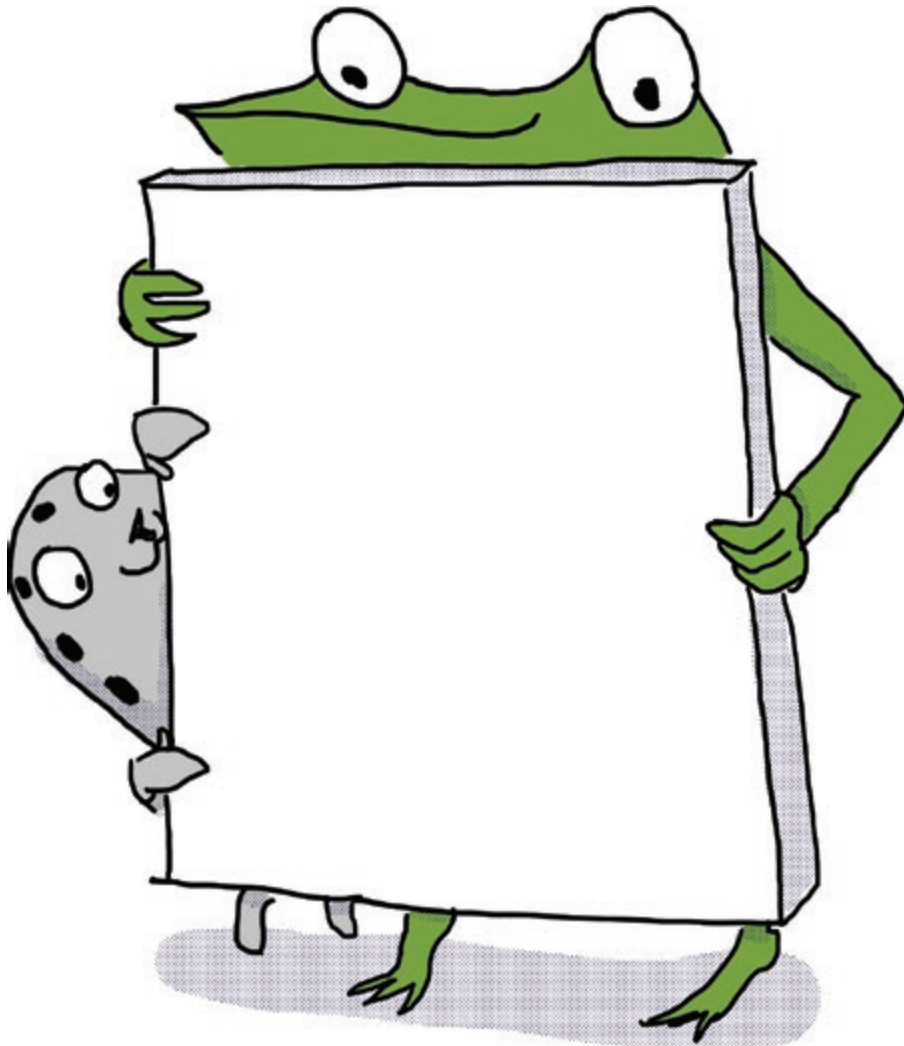
CHECK YOUR ALIGNMENT! MAKE SURE THE GOLDEN METALLIC STRIPES ON THE CHIBI CHIP ARE LINED UP AND MAKING SOLID CONTACT WITH THE COPPER TAPE.

STILL NOT LIGHTING UP? CHECK OUT THE DEBUGGING SECTION IN THE BACK OF THIS BOOK!



"You can see the LED's light through the paper!" exclaimed Sami. "Fern, let's draw something around the light."

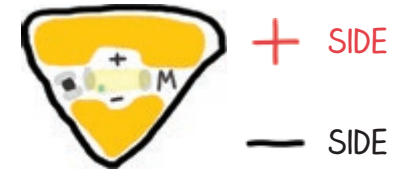
What should Fern draw?



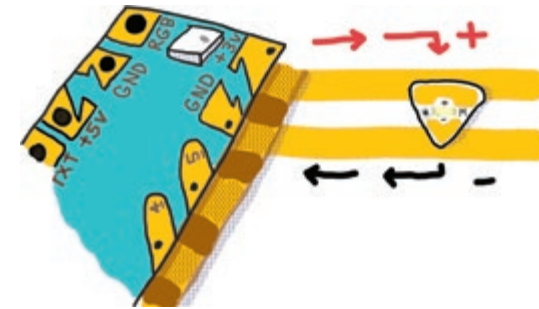
1-4

HOW DOES IT WORK?

LED stickers have two sides: the **positive (+)** side is the wider, rounder part of the triangle, and the **negative (-)** side is the pointy tip. LEDs turn on when the (+) side is connected to the +3V pin and the (-) side is connected to the GND pin of a Chibi Chip. Copper tape is used to connect the LED sticker to the pins of the Chibi Chip.



The Chibi Chip provides power, which is conducted through copper tape. A **conductor**, such as copper, is a material that allows electricity to flow easily and with little resistance. Conductors can be used to connect different parts of a **circuit**. Individual pieces of copper tape within a circuit are called **traces**.



Clipping on the Chibi Chip makes a complete circuit! This means that everything got connected in an unbroken loop that allows power to flow, turning on the LED light.

We can turn on more lights by connecting them in **parallel**, like in this picture to the right.



Light Up an LED!

1-5



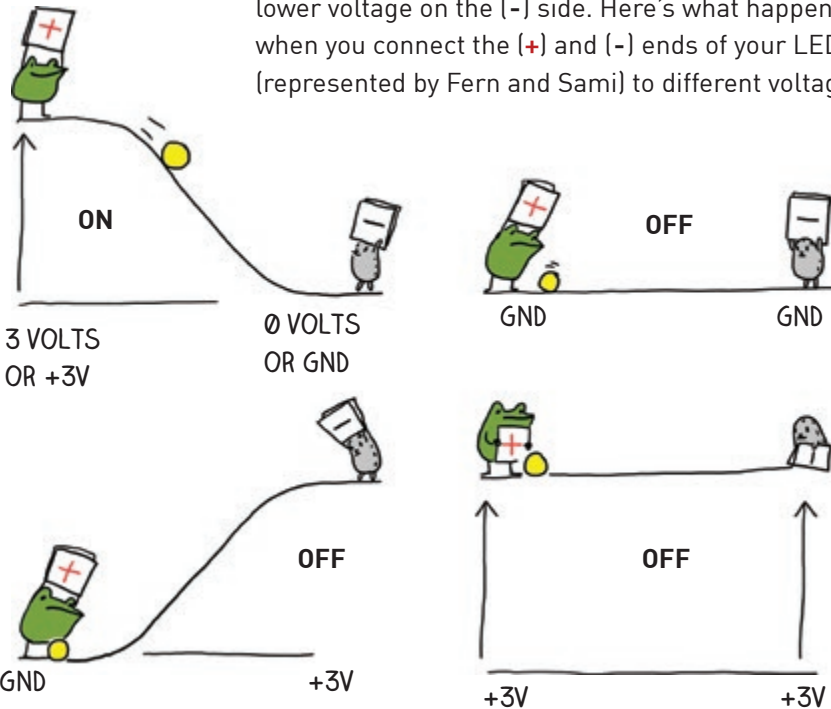
DOWN THE RABBIT HOLE: LED CIRCUITS

Electricity is a form of **energy** that flows to turn on your light. This flow of energy is called a **current**. Like a ball rolling down a hill, a current will only flow when there is a difference in height, from high to low.

In electronics, the difference in height is called a **voltage**. Voltage is a measurement of potential energy, just like the height of a ball on a hill.

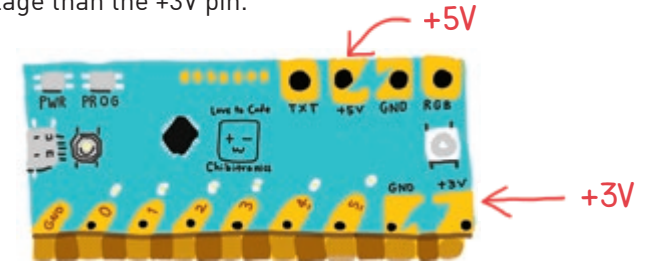


For an LED to turn on, current must flow through the LED from a higher voltage on the (+) side to a lower voltage on the (-) side. Here's what happens when you connect the (+) and (-) ends of your LED (represented by Fern and Sami) to different voltages:

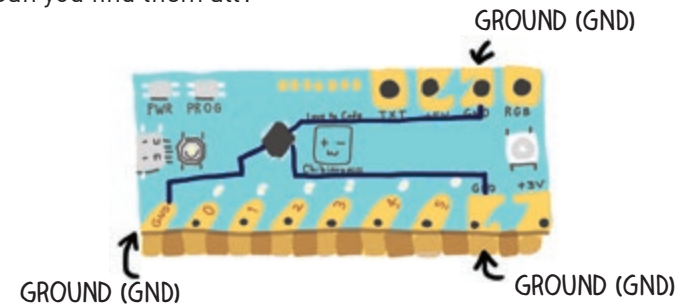


1-6

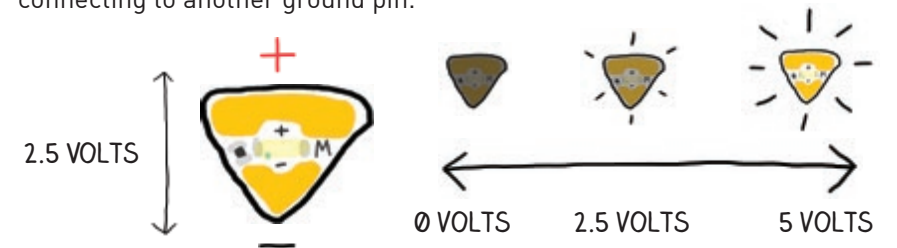
The +3V pin on your Chibi Chip sits at a height of 3 volts. There is another pin on the opposite side labeled +5V. This means it is at 5 volts. This pin provides even more voltage than the +3V pin.



0 volts is called **ground**, and we've labeled the pins with GND. This is where we connect the (-) side of our LED. There are actually three ground pins on a Chip. Can you find them all?

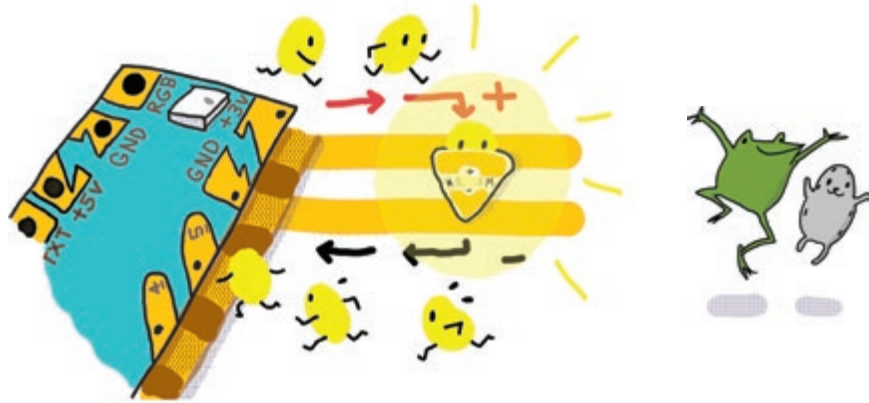


Even though they look like three separate pins, they are actually connected together by copper traces inside the Chibi Chip. This means that they are all at the same voltage (0 volts) so connecting to one ground pin is the same as connecting to another ground pin.



A typical LED sticker needs at least 2.5V to shine brightly, so when you connect it between the +3V pin and GND, there's more than enough voltage to turn the light on. The higher the voltage applied across an LED sticker, the brighter it will shine — up to a point. Be careful, if you give a single LED sticker too much voltage (more than 6V) it can burn out!

To summarize: when we connected the (+) side of the LED sticker to 3 volts and the (-) side to GND (or 0 volts), we provided enough voltage in the right direction for the LED to turn on!

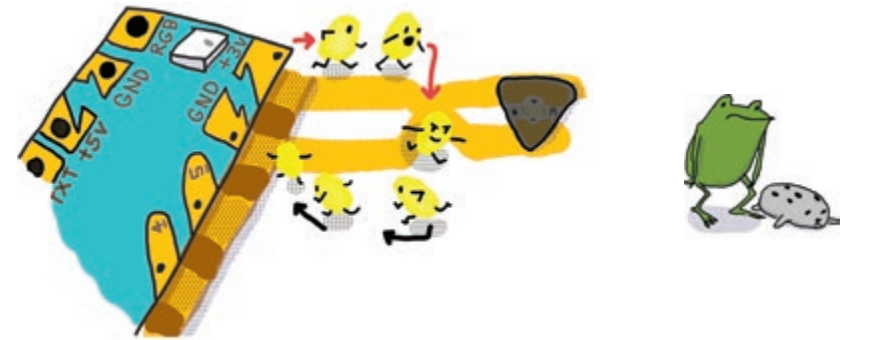


Don't worry if you accidentally connect the LED backwards. Nothing bad will happen, it will just not turn on.

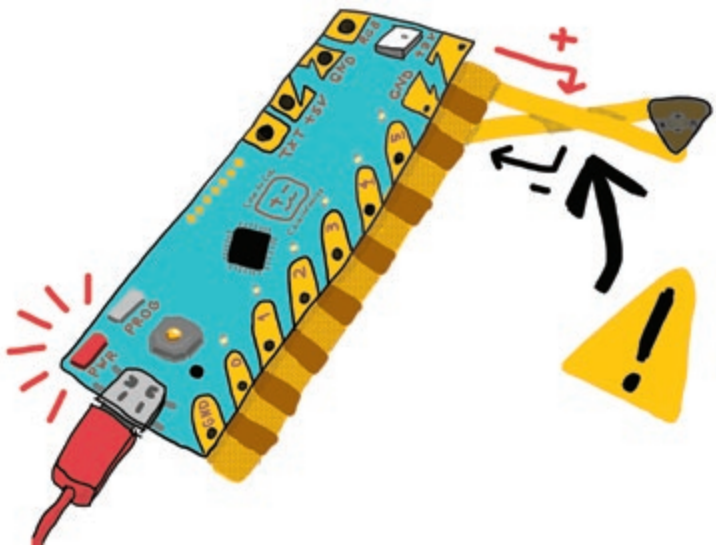
BE CAREFUL NOT TO CONNECT THE +3V PIN TO GND DIRECTLY BY CROSSING TRACES: THIS CREATES A SHORT CIRCUIT!



Electrons are lazy and will take any shortcut instead of going through your LED to turn it on, which is why this is called a "short" circuit.



In fact, short circuits are so appealing for electrons, they will stop flowing through the Chibi Chip and instead rush to flow through the short circuit. If there is a short circuit between power and ground, the Chibi Chip will stop working and it will drain a lot of power.



If this happens to a Chibi Chip, the Chip will shine a red warning light until the short circuit is disconnected.

If too much power flows through the short circuit during this burst, the circuit will get very warm, and the circuit might become permanently damaged if it gets too hot. So if you notice a short circuit, make sure to disconnect the Chibi Chip right away!



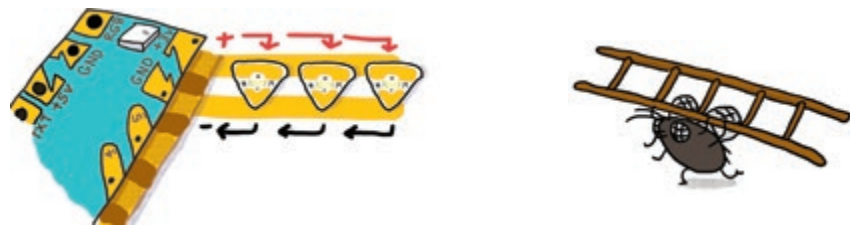


HOW CAN WE TURN ON A BUNCH OF LIGHTS?

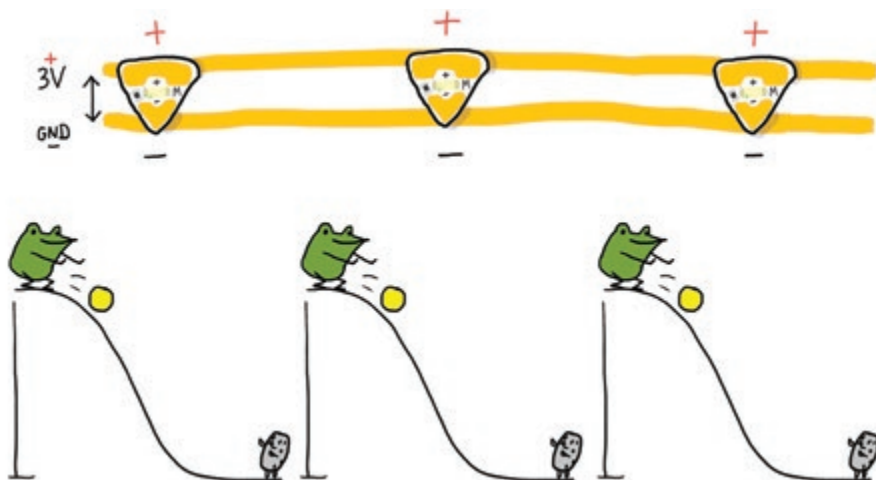
Here are a couple of ideas:

Parallel Circuits

Parallel circuits are where each LED shares a trace between +3V and GND. To connect LEDs in parallel, stick the LEDs next to each other between a (+) and a (-) track, like rungs on a ladder. You can turn the circuit on page 1-2 into a parallel circuit by just adding LEDs!



As the illustration above shows, all of the (+)'s go to the +3V pin, and all of the (-)'s connect to ground. This way the power source provides enough voltage ("height") for each LED. Since each LED needs at least 2.5V, connecting them in parallel to the +3V pin will turn all the LEDs on.



Series Circuits

Series circuits are where LEDs are connected back to back, like beads in a chain. The (+) of one LED goes to the (-) point of the next.



Since the LEDs are in a line, the required voltage also adds up so we'll need a higher voltage power source. For example, since each LED sticker requires 2.5V to shine brightly, to turn on 3 LEDs in series we will want a 7.5V power supply. They may still glow with less voltage, but not as bright.



If you want to try out a series circuit, connect 3 LED stickers in series like this:



First, make a circuit with copper tape going the GND pin. Leave gaps for LEDs and stick LEDs so that they all point toward GND.

Then, clip a wire such as an alligator clip to the +5V pad of the Chibi Chip and connect the other end to the (+) side of different stickers in the series chain.

You'll see that the more LEDs there are between the +5V and GND, the dimmer the lights are, until they don't turn on at all!

LET'S PLAY!

It's now time to design your own scene! Before we get started, here are some tips and tricks on how to use copper tape.

To turn copper tape around corners, try this folding trick:



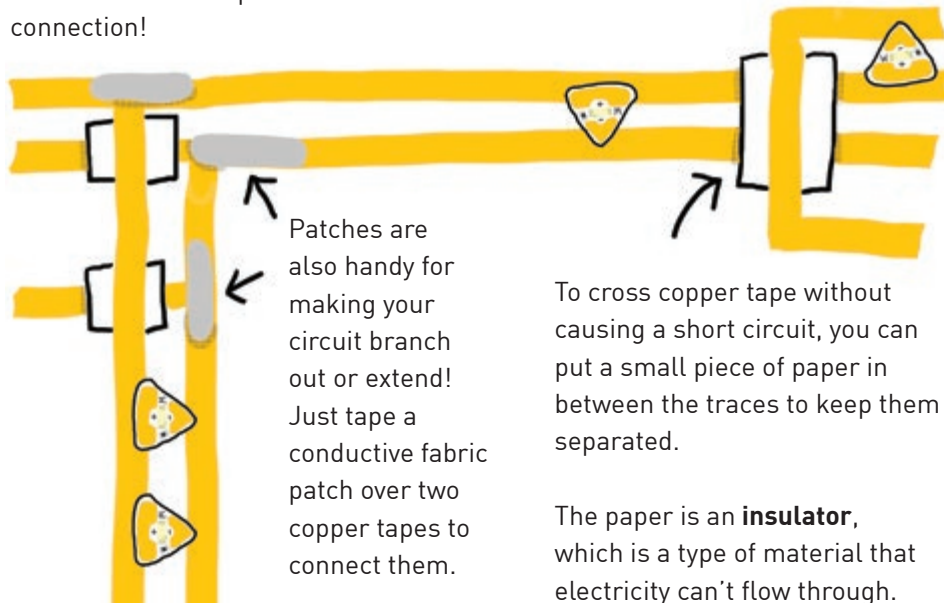
First, fold the tape back, so the sticky side faces up.

Then, flip and turn the tape.

Finally, flatten the corner.

Conductive fabric patches are like bandages for circuits. Accidentally torn copper tape can be rejoined by just sticking a conductive fabric patch over the broken connection!

If an LED is flickering, the connection can be improved by sticking a fabric patch over the LED and copper tape!



Patches are also handy for making your circuit branch out or extend! Just tape a conductive fabric patch over two copper tapes to connect them.

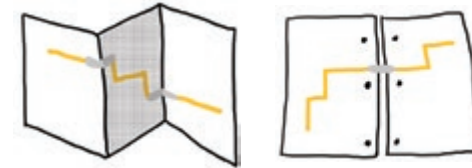
To cross copper tape without causing a short circuit, you can put a small piece of paper in between the traces to keep them separated.

The paper is an **insulator**, which is a type of material that electricity can't flow through.



COPPER TAPE WILL EVENTUALLY CRACK IF CREASED OR FOLDED TOO MANY TIMES!

Use conductive fabric patches to connect across creases or multiple sheets of paper! Unlike copper tape, fabric patches can be folded over and over again.



LED STICKERS WON'T WORK AS WELL IF THE UNDERLYING COPPER TAPE IS DIRTY OR WRINKLED!



Hands should be free of oil and dirt before crafting with copper tape. Also, before applying LED stickers, wrinkled copper tape can be smoothed out by rubbing over it with the barrel of a pen or pencil!

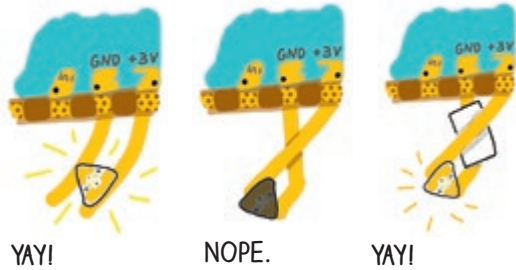


Look on the facing page! It's a magical flower pot! What's growing? What's glowing?

Draw your own creature on page 1-15 and then design a circuit on page 1-17 to light it up!



REMEMBER TO WATCH
OUT FOR SHORT
CIRCUITS!



Design your own circuit on this page!



Start your circuit here, so you can clip on a Chibi Chip after you're finished!



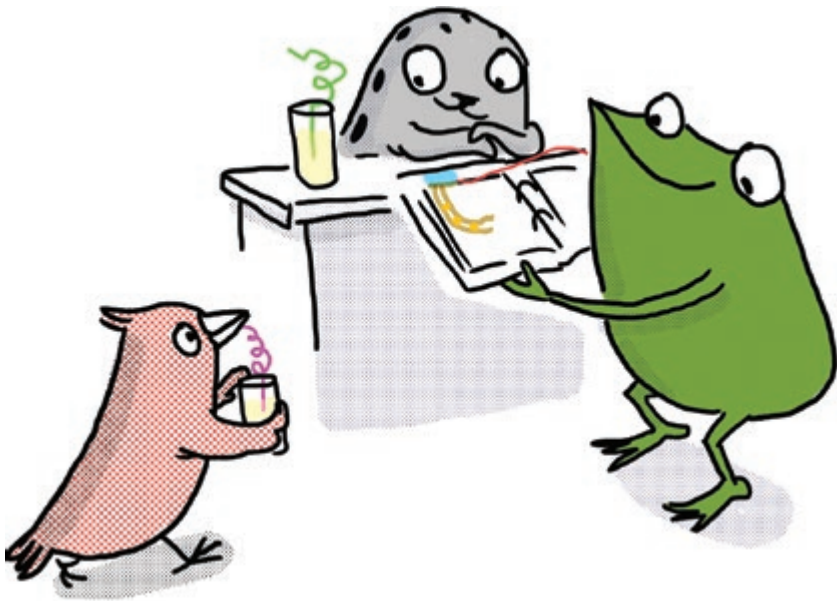


“Yay! This feels like magic!” Fern exclaimed.

Fern’s friend Carmen the bird walked past and admired the new creation. “Adding light to your art really does make it look magical,” she chirped.

Carmen, a clever programmer, thinks for a moment and asks, “Hey, do you want me to show you both how to make those lights blink?”

Chapter 2: Code a Blink!



“Wow, if those lights could blink, then my drawings would really come alive!” said Fern enthusiastically. “Can I really do that?”

“We can control lights by writing programs, through a process called coding,” said Carmen the bird. “Let’s get started!”

LET'S GET CODING!

We're going to upload a program to the Chibi Chip to make a light blink! We'll start by writing a program, which is a list of instructions for the Chibi Chip to follow. The program will then be translated into a "song" and played to the Chibi Chip through its cable. When the Chibi Chip hears the song, it will decode it back into instructions for turning the LED light on and off.



We will need:



Chibi Chip, mounted in a Clip



Programming and power cable



USB power (Chibi Book, laptop or wall plug)



Internet connection

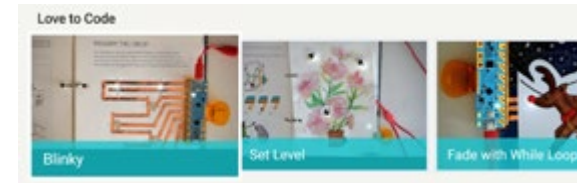


A device with a web browser (phone, computer, or tablet): this is the programming device

1. Make sure we have an Internet connection. Open a web browser and go to: <https://makecode.chibitronics.com/>

This brings us to the Microsoft MakeCode block programming editor. This is where we can write code to send to the Chibi Chip.

2. Begin by opening **Love to Code** → **Blinky**

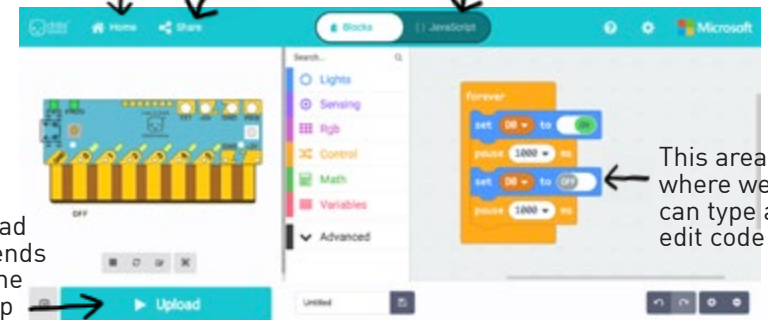


The Microsoft MakeCode editor has a basic layout like this:

Home includes examples to help us get started. We can also load programs that we've saved here.

Use this button to share projects with others!

This slider lets us switch back and forth between block-based and text-based code.



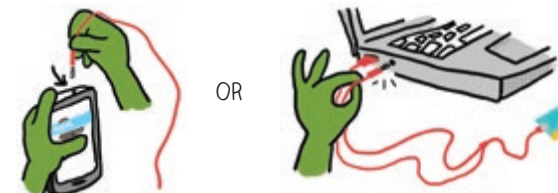
The Upload button sends code to the Chibi Chip

This area is where we can type and edit code!

3. Plug the small end of the programming and power cable into the Chibi Chip. Then plug the big end into a USB power supply, such as a computer, wall power or the Chibi Book's built-in battery pack.



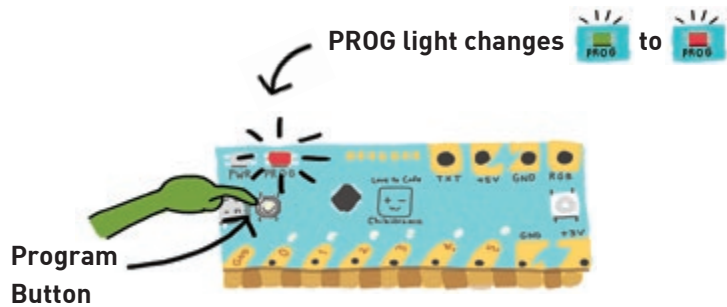
4. Plug the audio end of the programming and power cable into the audio jack of your programming device.



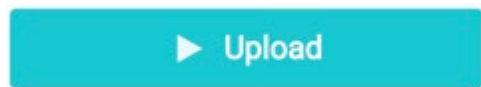
4. Turn the volume up to the max on the programming device and make sure it's not muted. Since code is uploaded to the Chibi Chip through the audio cable, we need to turn the volume up to 100% so the Chibi Chip can hear the code loud and clear!



5. Press and hold the program button on the Chibi Chip until the PROG light stays red. This lets the Chibi Chip know to listen for new code. Let go of the button after the light turns red.



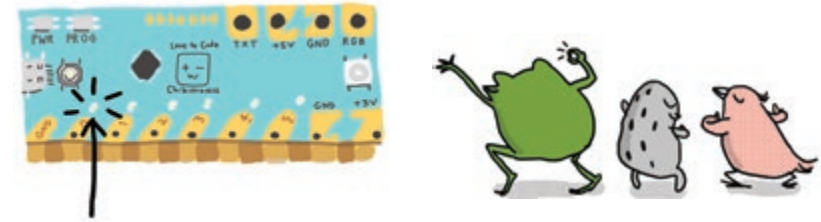
6. Click **Upload** on the screen to upload the code and program the Chibi Chip.



A sound waveform should appear at the bottom of the page. Its presence means the code is currently being played to the Chibi Chip. If this bar does not appear, try refreshing the page and uploading again.



7. When the sound bar is done flashing, the red PROG light should turn back to green. This means the code is done uploading. If everything worked, the LED over pin 0 should now be blinking!



The uploaded code is saved to the Chibi Chip, and it will automatically reload itself and run whenever the Chibi Chip is powered on. This means once the Chibi Chip has been programmed, it no longer needs to be connected to a programming device.

HOW DID IT GO? DID THE LIGHT BLINK? IF NOT, TRY CHECKING THE FOLLOWING:



DID THE UPLOAD SOUND WAVEFORM ANIMATION APPEAR? IF NOT, TRY REFRESHING THE PAGE AND CLICKING UPLOAD AGAIN.



DID THE PROG LIGHT TURN STEADY RED BEFORE PROGRAMMING? IF NOT PRESS AND HOLD THE PROG BUTTON UNTIL IT TURNS RED AND TRY UPLOADING AGAIN.



CHECK OUT THE DEBUGGING SECTION AT THE BACK OF THIS BOOK FOR MORE TIPS!



The original code that came with the Chibi Chip can be restored by uploading the example at:

Home → Examples → Light Cascade

DECODE THE CODE

How does the Chibi Chip blink the LED? It's actually following a set of instructions generated from our code! Let's take a look:

```
forever
  set D0 to ON
  pause 1000 ms
  set D0 to OFF
  pause 1000 ms
```

In this program, four instruction blocks are enclosed inside a "forever" loop.

This means "repeat these four instructions over and over."

The four instruction blocks sets the LED on, waits for a second (1000 ms), sets it off, and then waits for a second. Repeating these instructions makes the LED blink.

The program runs like a train on a track. When the Chibi Chip is powered on, it starts out on the track, following the instructions in your program one after the other. A "forever" block makes the track loop-shaped, so the train will come back around and around, repeating the sequence of instructions within the forever block.

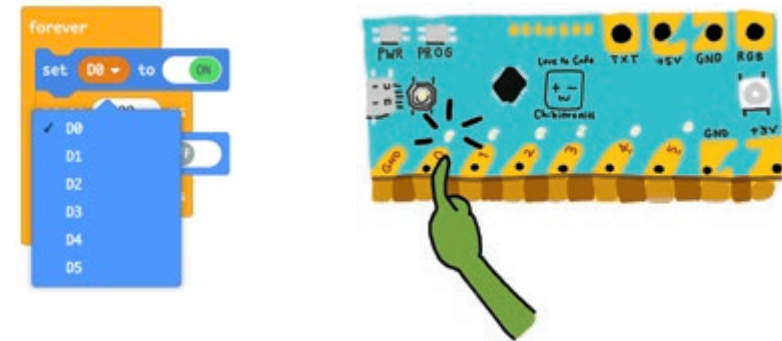


Inside the forever loop we have three different instructions: set on, set off, and pause. These three instructions allow us to blink a light by turning it on, waiting for a bit, then turning it off and waiting for a bit.

Set ON turns on a numbered pad on the Chibi Chip, turning on the light that is connected to it. These pads are referred to as "pins" on the chip. Set OFF turns off the numbered pin, turning the light off.



The set ON/OFF blocks have a drop-down menu with numbers D0 through D5. These select which pin will be turned on or off - in other words, which light we are controlling! Feel free to experiment with this now, and we'll also look at controlling multiple pins in more detail in a later section.



The pause block tells the Chibi Chip to wait and not do anything. The number inside the number box tells it how long to wait in milliseconds. In our blink code, pause 1000 means wait 1000 milliseconds, or 1 second.

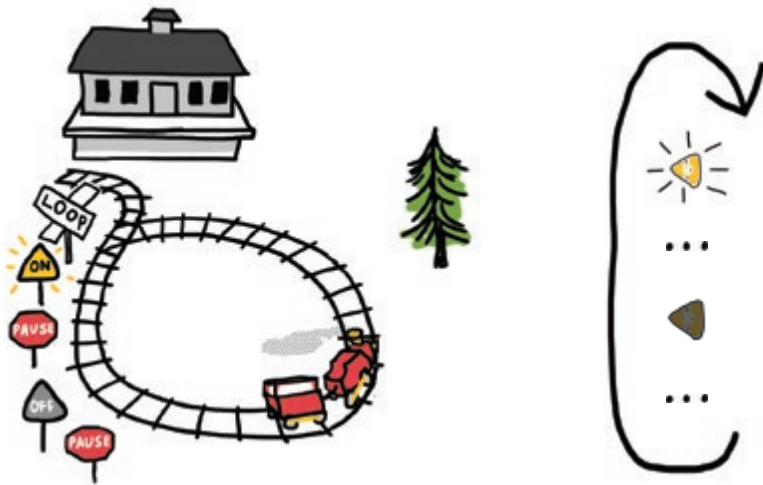


Take note!
There are 1000
milliseconds in
1 second.

The Chibi Chip goes so quickly from one instruction to the next that if we don't tell it to pause, everything blurs together! The smaller the delay, the faster things will go.

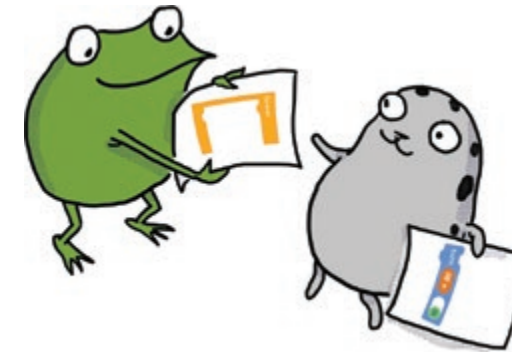
After going through all four steps one-by-one, the Chibi Clip will go back to step 1 and repeat. This is what makes your LED light blink!

Looking at the entire program again, this is what's happening:



CODING WITH BLOCKS

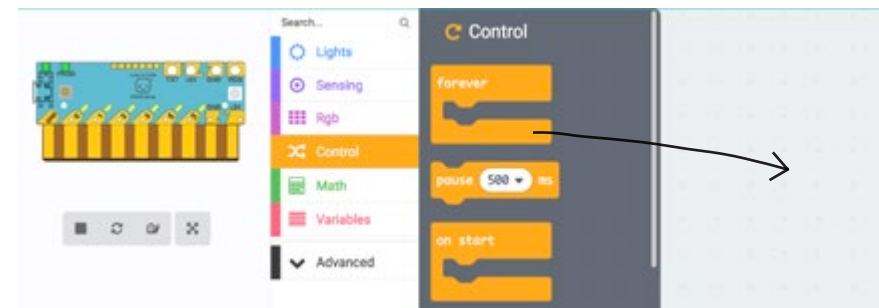
For this program, we started with a built-in example that already contains the code we need. What if we wanted to write a program from scratch? Or modify the code? Let's try building the Blinky example, so we can learn how to use the editor!



Start with an empty project, by clicking on the "Home" icon, and then selecting the red "New Project" button.



If there isn't already a yellow "forever" block in the programming area, click on the Control section in the middle of the editor. Click and drag a yellow forever block into the programming area. Release the mouse to place it.



Click on the Lights section. Drag a set ON block into the forever block, and then release it. It should snap into place.

MAKE SURE THE LIGHT BLOCK SNAPS INTO THE FOREVER CONTROL BLOCK, OR ELSE THE CODE WON'T BE RUN!

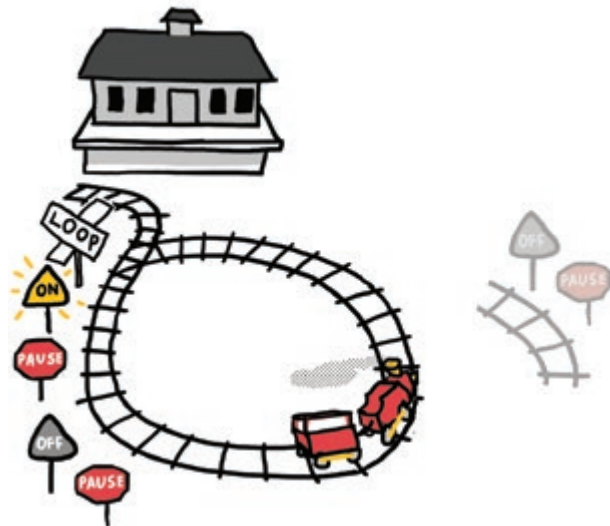
IF THE LIGHT BLOCK ISN'T SNAPPED IN PLACE, IT WILL APPEAR GRAYED-OUT TO SHOW THAT IT'S NOT ACTIVE.



YAY!

NOPE.

It's okay to keep grayed-out blocks in the programming area. They are helpful for when you want to switch different blocks quickly or add new code. They are like train tracks that aren't connected to the main track, so the train won't run on them, but they are quickly available for building new paths.



Click on the Control section again. Drag a pause block into the forever block, below the set ON block you just placed. The forever block will automatically grow in size to accept the new block, and a thin yellow highlight will appear on the edge of the block that the new block will snap to.

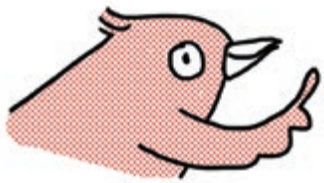


Click inside the rounded number box in the pause block to edit it. Use your keyboard to change the number to 1000. You can also choose "1 second" from the drop-down menu for the same result.

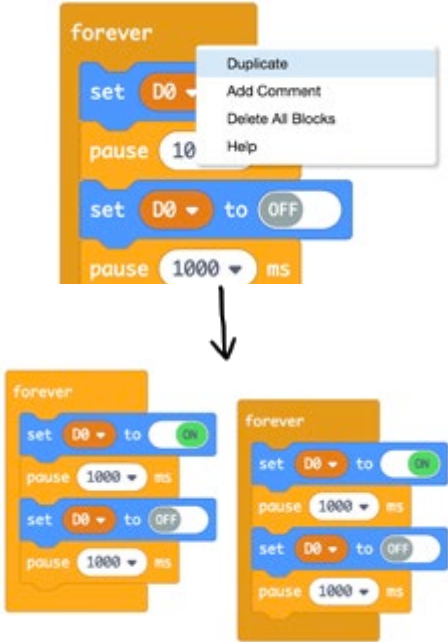
Your program will need a second, identical pause block. You can drag it from the control blocks menu and change the number again, or you can duplicate the existing pause block.

To duplicate, right-click on the pause block. You should see a menu appear. Choose "duplicate" and a second copy of your pause block will appear.

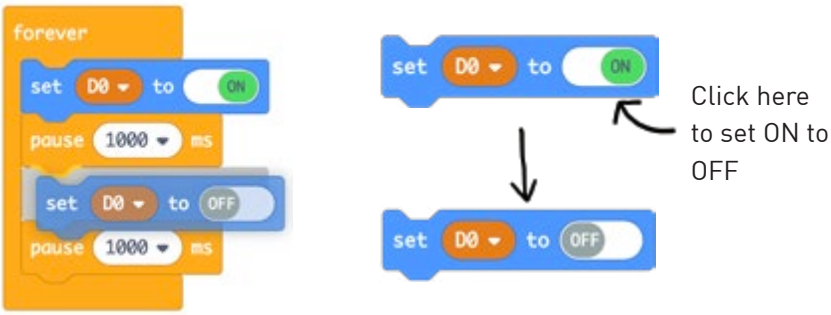




Tip: to duplicate a stack of blocks rather than just one, duplicate the control block surrounding them, such as the forever loop.



To finish the program, add another set ON block, then use the toggle to change it to OFF. Notice that you can drag a block between two existing blocks and it will snap into place.

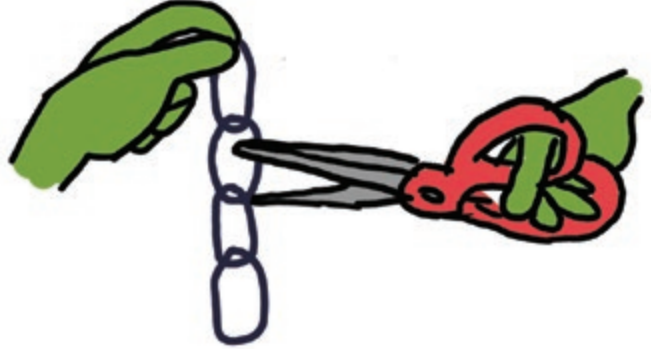


Deleting blocks

If you want to get rid of a block or a stack of blocks, drag them towards the left side of the screen where the block categories are. A trash can icon will appear. Release the blocks over the can to delete them.

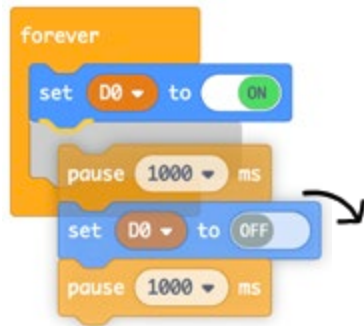


Removing blocks in the middle of other blocks takes a few steps, because the instructions stick together. It's a bit like removing one link from the middle of a chain: first, the chain has to be broken at the link that we want to discard. Then, the part of the chain that we want to keep has to be broken off from the unwanted link, and stuck back onto the active chain. Finally, the removed link is thrown into the trash.

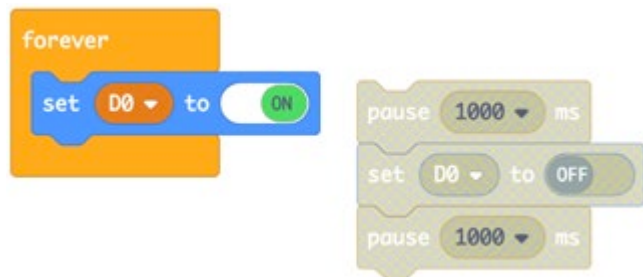


For example, suppose we want to remove the first “pause” block from the blink example, but nothing else.

Start by grabbing the pause block that we want to remove, and drag it to the side. All blocks beneath the pause block will come along, just like links in a chain.



Put the chain of removed blocks down somewhere in the programming area. Their grayed-out color means the removed chain of blocks won't run, since they are not inside one of the special control blocks.

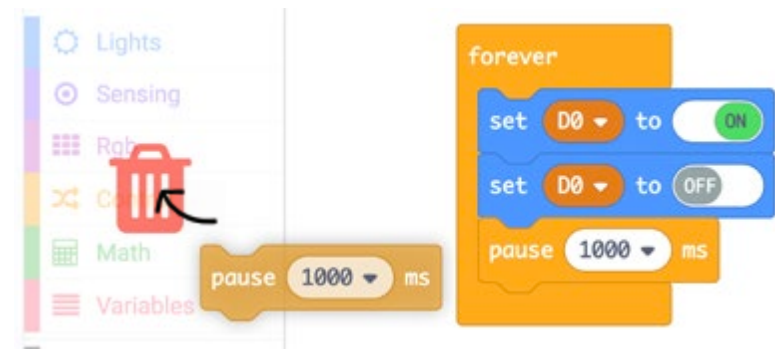


Then, grab the block in the grayed-out chain that is beneath the pause block that we're removing. The blocks beneath it will follow. Drag that chain of blocks back into your program.

Remember, the outer yellow control block (in this case a forever loop) will automatically grow to accept all the blocks in the chain.



If you don't plan on using the removed block anymore, throw it away by dragging it toward the left side of the screen.



PLAY WITH THE CODE

Now let's try playing with the code! Start by changing the pause times:

```
forever
  set D0 to ON
  pause 1000 ms
  set D0 to OFF
  pause 1000 ms
```

Upload this new code to the Chibi Chip using the procedure starting at step 5 on page 2-4 and see what happens.



REMEMBER TO PRESS THE PROG BUTTON ON YOUR CHIBI CHIP BEFORE CLICKING THE UPLOAD BUTTON, SO IT KNOWS TO LISTEN FOR CODE!

The light over pin 0 should now be flashing faster! Try some other numbers for the pause between on and off statements. Can you make it blink super slow?



We can also create more complex patterns by adding more on and off blocks too. For example, try this:

```
forever
  set D0 to ON
  pause 1000 ms
  set D0 to OFF
  pause 500 ms
  set D0 to ON
  pause 500 ms
  set D0 to OFF
  pause 500 ms
  set D0 to ON
  pause 500 ms
  set D0 to OFF
  pause 1000 ms
```

This makes a long-short-short blink pattern. Try making your own rhythms! How about a heartbeat?

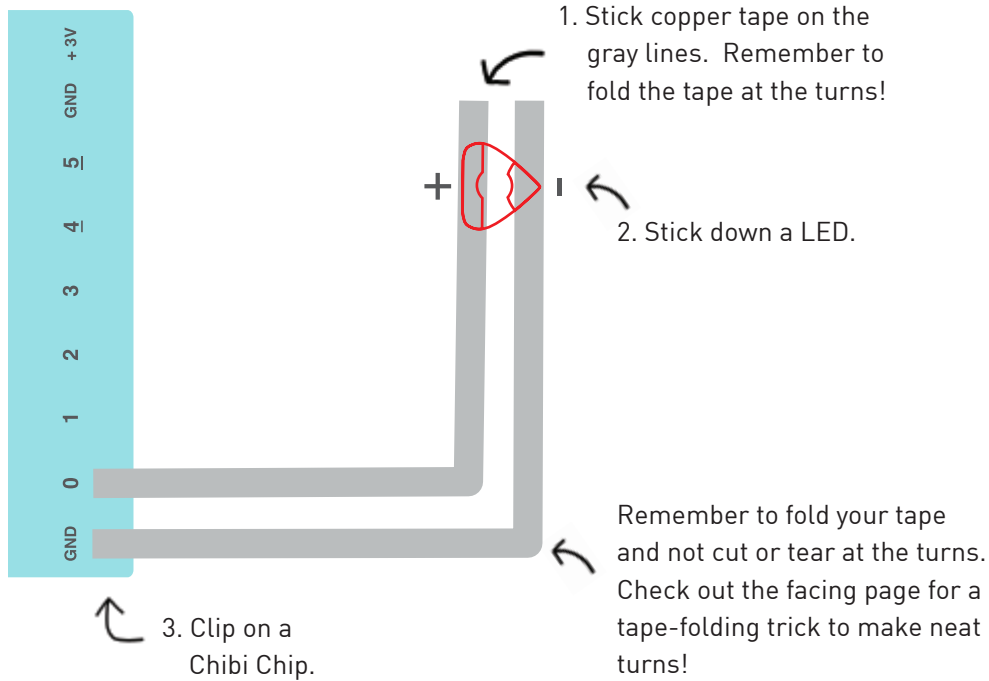


IF YOU DON'T SEE THE BLINK PATTERN YOU EXPECT, DOUBLE CHECK THAT YOU ARE ALTERNATING BETWEEN SET ON AND SET OFF.

OTHERWISE, THE LIGHT WILL JUST APPEAR TO STAY ON OR OFF LONGER THAN YOU INTENDED!

PROGRAM THIS CIRCUIT

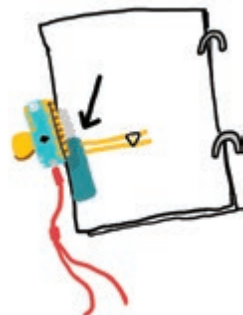
We can use a program to control a circuit of our own design. Try it with this template!



See how when you connect the LED circuit to pin 0, the LED also blinks just like the indicator light on the Chibi Chip? That's because the pin sends power to both the light on the Chip as well as to any LEDs in a circuit connected to that pin.



Try clipping GND and pin 0 to the "Turn on a Light" circuit on page 1-2, and see that blink too!



DRAW HERE!



To turn copper tape around corners without tearing, try this folding trick:



1. Fold the tape back, so the sticky side faces up.

2. Flip and turn the tape.

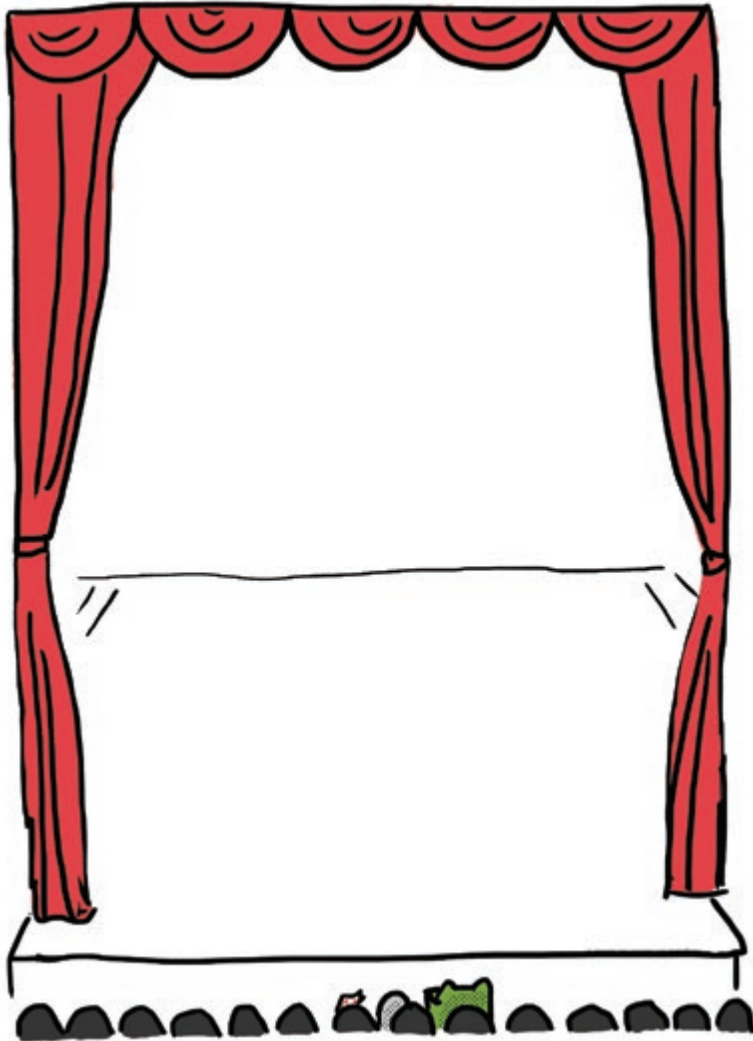
3. Flatten the corner!

If the tape tears, don't worry! Fix it with a conductive fabric patch!

REMEMBER TO SAVE YOUR CODE AS YOU GO!



Draw something on page 2-19 to see the shadow of your drawing appear when the light blinks on!

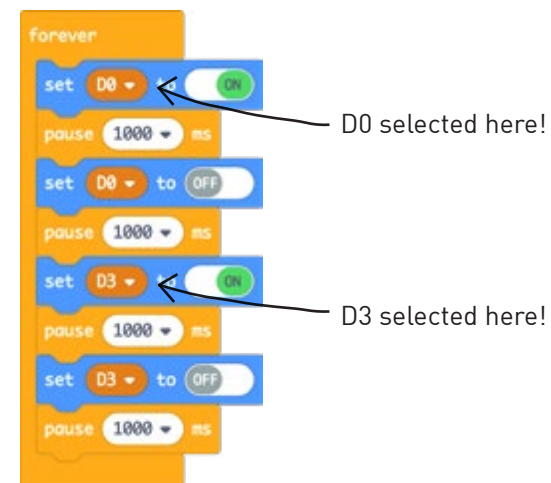


PLAY WITH THE CODE

Ready to add more pins to your program? First, remember that you can use the drop-down menu on the set ON/OFF blocks to select a different pin to turn on and off. Try it out! Can you modify your program so that it blinks the light on pin 2, instead of pin 0?



How about controlling more than one pin at a time? To do this, add more set on and set off instructions to your code. Then, change the pin number on the second set of on/off instructions to control a new pin.



Upload this new code and you will see both pin 0 and pin 3 blinking on and off!

To make the lights blink together, try this code:

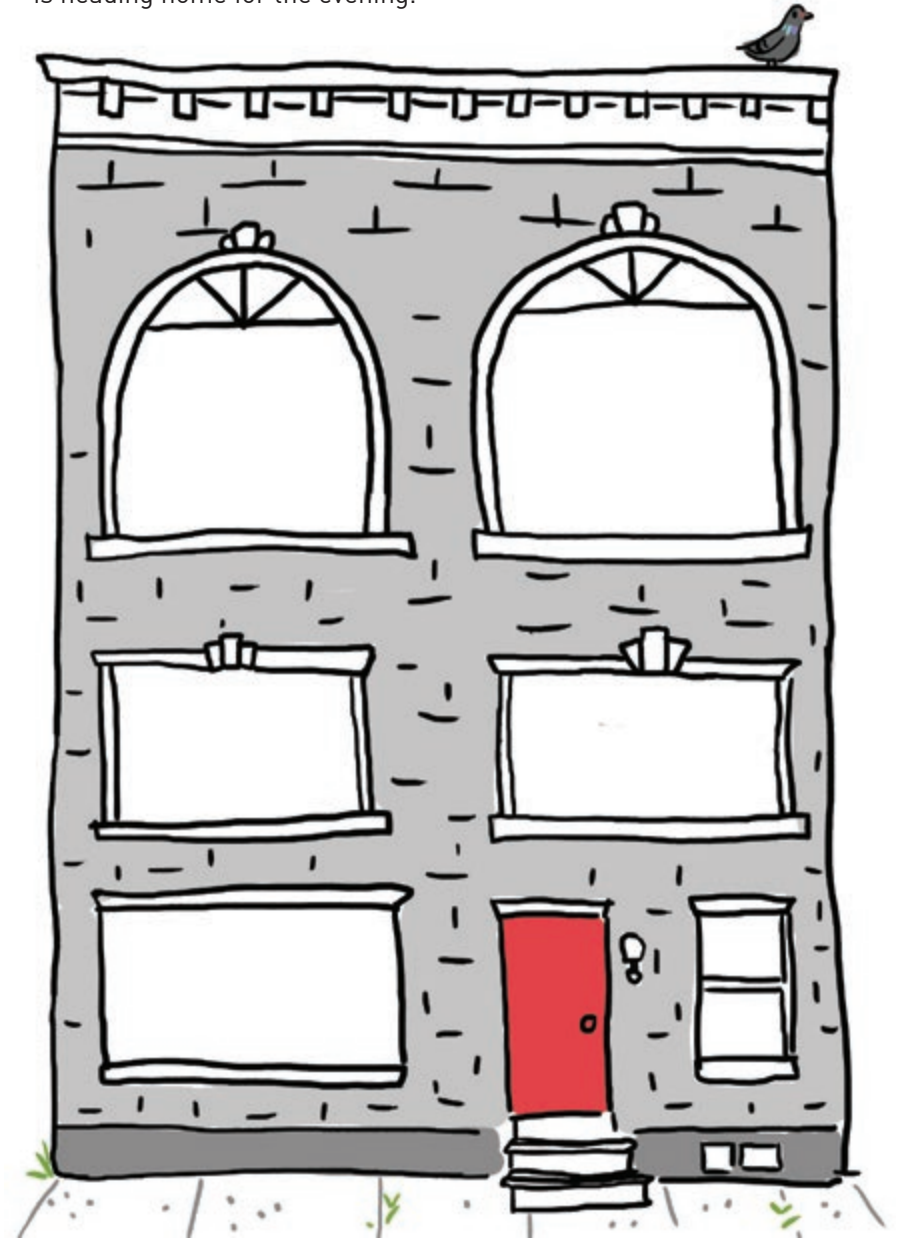
```
forever
  set D0 to ON
  set D3 to ON
  pause 1000 ms
  set D0 to OFF
  set D3 to OFF
  pause 1000 ms
```

Even though pin 3 and pin 0 are controlled with statements on different lines, the Chibi Chip goes from one step to the next so fast that they seem to happen at the same time!

There is another way to control multiple pins at the same time: we can use multiple forever loops. We'll learn more about this in chapter 4.



It's starting to get dark in Fern, Sami, and Carmen's town, so everyone is heading home for the evening.

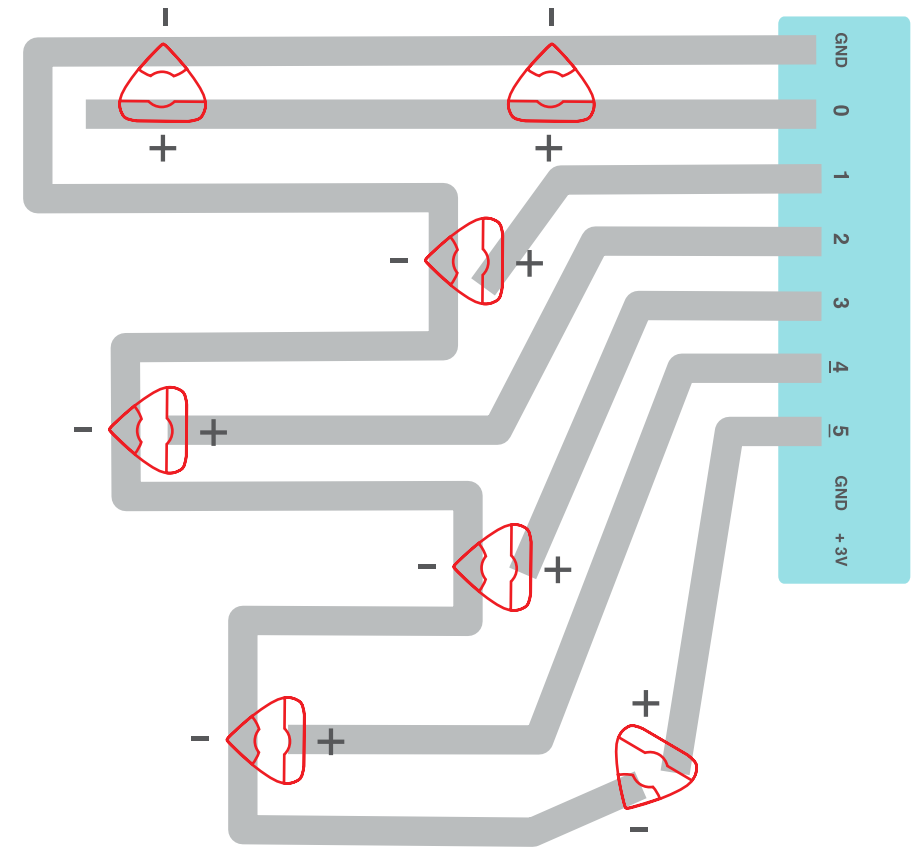


Draw what everyone in the apartment building is doing when they come home. Their shadows will show up in the windows when the LED stickers on the facing page turn on!



PROGRAM THIS CIRCUIT

Just like before, we can clip the Chibi Chip to a circuit and control the lights using a program. Here's a circuit where all of the pins are connected to LEDs, and the LEDs are placed in spots that will light up the windows on the page 2-23. Now we're ready to play with all the pins!

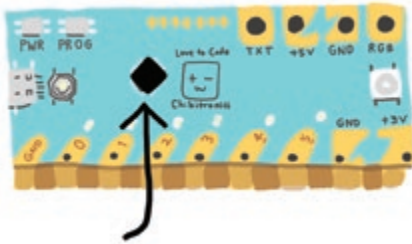


Can you get all 6 of the pins to blink in a pattern? If you get stuck while coding, check out [Love to Code → Six Pin Blink](#) to help you get started!



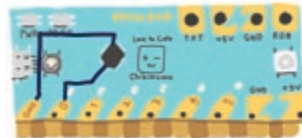
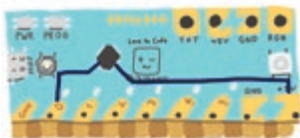
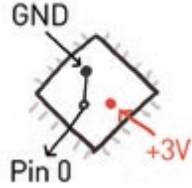
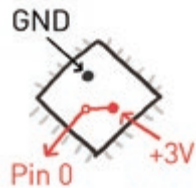
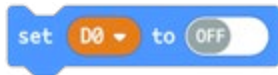
DOWN THE RABBIT HOLE: MICROCONTROLLERS

So how does a program actually make lights blink? There's a little black diamond on the Chibi Chip called a **microcontroller**: this is a tiny computer.

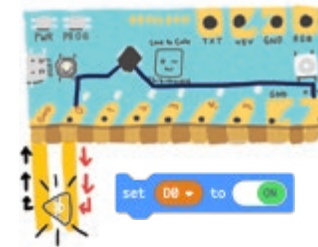


The microcontroller runs instructions coded by your program. Some of these instructions change how the pins behave.

Unlike the +3V and GND pads, which are permanently wired to +3V and GND, all the numbered pins can be programmed by statements in our code to connect to +3V, GND, or neither. All of this happens inside the tiny microcontroller!



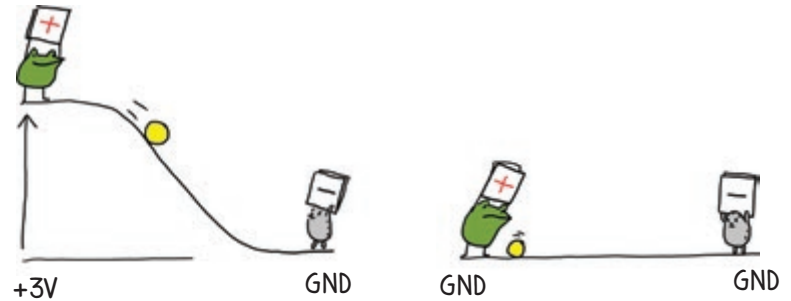
When we connect an LED to the Chibi Chip, we connect the (-) side to GND, and the (+) side to a pin (in this example, pin 0). Our code can configure the (+) side of the sticker to be either +3V or GND by using statements that set pin D0 on or off.



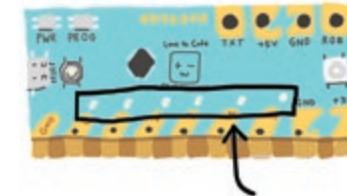
When pin 0 is **ON**, it's connected to +3V by the microcontroller. The LED turns on because the (+) end is connected to +3V through pin 0, and there is a voltage difference, allowing current to flow.



When pin 0 is **OFF**, it's connected to GND by the microcontroller. The LED turns off because both the (+) and (-) ends are connected to GND, and there is no voltage difference.



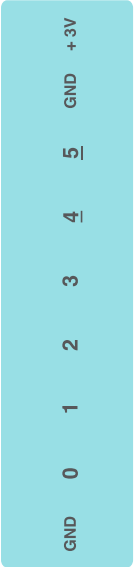
There's an indicator light built into the Chibi Chip for each numbered pin.



These indicator lights let us know what a program is doing without having to first build a circuit. They're really handy for testing programs and debugging circuits.

LET'S PLAY!

Now it's your turn to design your own circuit and light up the night sky (turn to page **2-30** for a preview).

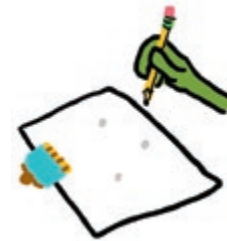


Above is a Chibi Clip template to help you get started. Use as many pins, and whatever circuit shape you like! If you're not sure how to start, take a look back at the circuit on page **2-25** for inspiration.

Remember: LEDs that are connected to the same pin will come on at the same time. Since the Chibi Chip has 6 programmable pins, you can control up to 6 separate groups of lights with one Chibi Chip!



One method for designing a circuit is to:



1. Draw dots where you want the lights to go.



2. Lay copper tape going from GND to each of these dots.



3. Tape copper traces from the programmable pins to the dots, and add your LED stickers!



Edith the beaver overheard her three friends enjoying the light show and looked out her window.

“How am I missing out on this party?” cried Edith, and she quickly rushed out to join the fun.

Chapter 3:

Add a Switch!



“I love building things! I can build switches out of paper and copper tape,” Edith the beaver quipped. “If we add a switch to our circuit, then we can interact with the lights!” Thwacking her tail enthusiastically, as if smacking a giant switch, Edith continued, “When someone presses the switch, we can make something happen, like blinking the lights.” “Amazing!” exclaimed Fern. “Show us how!”

PROGRAM A SWITCH

In this activity we'll add interactivity to our projects by using a switch to turn on a light. We can create different types of switches out of paper and use our switch to trigger light patterns.

We will need:



Chibi Chip



cable



USB Power



Internet connection



copper tape



Chibi Light LED Sticker



Web browser (phone, computer, or tablet): this is your **programming device**



scissors

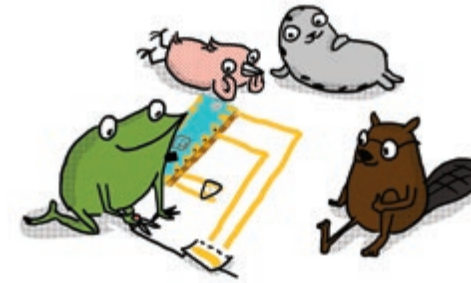
1. Turn the page and make the switch circuit template on page 3-4.
2. Upload the **Basic Switch** example code to the Chibi Chip. Go to **Love to Code → Basic Switch**

```

when D5 is pressed
  set D0 to ON

when D0 is released
  set D0 to OFF
  
```

3. The flap at the bottom of page 3-4 is the switch. Press it and see the LEDs on pin 0 and pin 5 turn on.



SWITCH NOT WORKING? FIRST, CHECK IF THE CODE WAS UPLOADED TO THE CHIP:



DID THE PROG LIGHT TURN STEADY RED BEFORE PROGRAMMING? IF NOT, PRESS AND HOLD THE PROG BUTTON UNTIL IT TURNS RED AND TRY UPLOADING AGAIN.



MAKE SURE THE VOLUME IS ALL THE WAY UP.



DID THE UPLOAD SOUND WAVEFORM ANIMATION APPEAR? IF NOT, TRY REFRESHING THE PAGE AND CLICKING UPLOAD AGAIN.

IF THE CODE LOOKS GOOD, LET'S TRY CHECKING OUR CIRCUIT:



CHECK YOUR ALIGNMENT. MAKE SURE THE GOLDEN METALLIC STRIPES ON THE CHIBI CHIP ARE LINED UP AND MAKING SOLID CONTACT WITH THE COPPER TAPE.



IS THE LED OVER PIN 0 TURNING ON, BUT NOT THE LED IN YOUR CIRCUIT? PRESS HARD ON THE LED STICKER'S METAL PADS FOR A STRONGER CONNECTION.

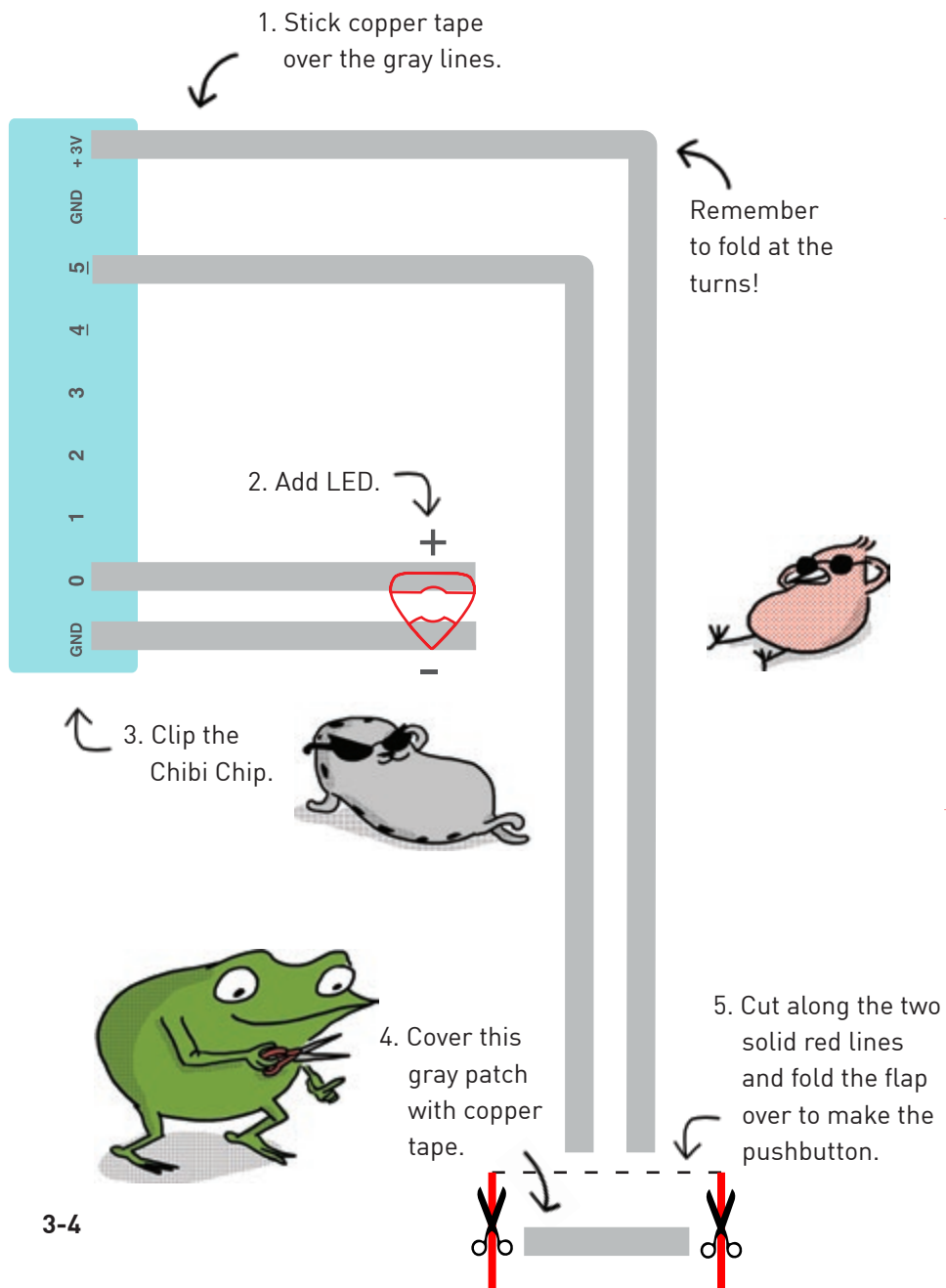


CHECK FOR TEARS. PATCH TEARS WITH CONDUCTIVE FABRIC TAPE.



STILL NOT WORKING? CHECK OUT THE DEBUGGING SECTION IN THE BACK OF THIS BOOK.

PUSHBUTTON SWITCH TEMPLATE



3-4

Almost done!

Add a Switch!

3-5

What happens when you press on Edith's tail?

DECODE THE CODE

Let's take a look at how the switch example program works. Here's our code:

```
when D5 is pressed  
  set D0 to ON
```

When the chip senses that the switch pin (5) has changed from off to on (switch pressed), the code inside this block will set the output LED to on.

```
when D0 is released  
  set D0 to OFF
```

When the chip senses a change from on to off (switch released), the code inside this block will set the output LED to off.



"Don't worry, I'll explain this," said Edith.

The C-shaped "when" block is a special block in the Sensing category. It listens to a pin and runs code whenever the Chibi Chip detects (senses!) a certain change in the circuit.

```
when D0 is pressed  
  ✓ pressed  
  released  
  changed  
  HIGH  
  LOW
```

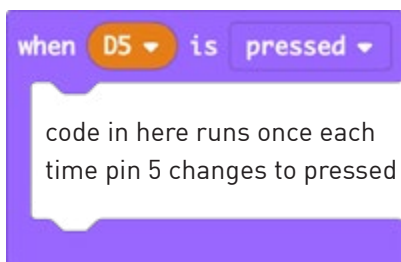
You can choose the type of change it is listening for in the dropdown menu. For instance, "pressed" (when switch is pressed), "released" (when you let go of the switch), or just "changed" (either a press or a release just happened).





You can also choose which pin the block listens to. Because our circuit has a switch connected to pin 5, here we chose D5 from the dropdown.

Here is how our code responds to a press and release of the switch:



pin 5 connected to +3V
pressed



pin 5 not connected to anything
released

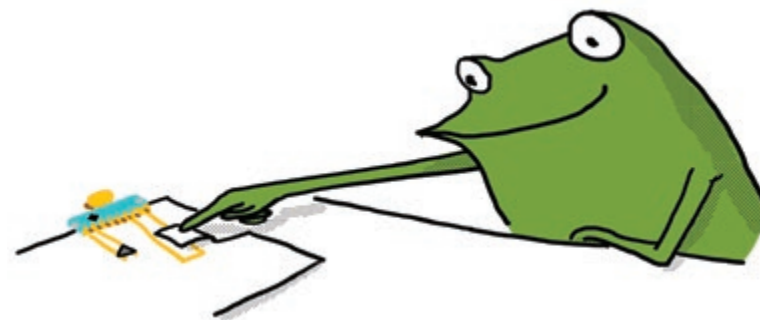
This useful block is **event-driven**: that means it runs code when some external event happens. It's more efficient than code that checks over and over for a change. It's like knowing that your friend will ring the doorbell when they arrive at your home. With the doorbell, you don't have to keep getting up to check if someone is at the door. You know the sound will interrupt you, so you can do something else fun while you wait. Like program your Chibi Chip!

In our program, the code inside the "when pressed" block sets pin D1 on, and the code inside the "when released" block sets it off. This gives us a light that is on when the pushbutton is pressed, and off when it is not pressed. What if we wanted the opposite to happen?

We can modify the original code by swapping which instruction block is inside "when pressed," and which is inside "when released." A simple way to do this is simply to slide ON to OFF, and OFF to ON. Here's the result:



Upload this new code to a Chibi Chip and clip it to the example switch circuit on page 3-4. Notice that pin 0 is on now, and when we press the button, pin 0 turns off!



We can make the pushbutton activate any light sequence by putting the code for the sequence inside a “when pressed” block.

For example, try uploading this blink sequence to see what happens!




Notice that the sequence ends by setting LED 0 off. We don't need a “when released” block in this program, because the code runs once every time the button is pressed and ends by turning off until the next press.

Voilà! We've made a trigger button! Now every time we press the button, it triggers the blink animation inside the “when pressed” block. Try programming your own patterns for the trigger button!



Hooray! Now we know a few cool ways to make our circuit respond to button presses. Here's one more: what if we wanted to be able to toggle an LED on or off every time we press the button? In other words, make it stay on if we press the button once, and turn off if we press the button again, like a flashlight.

Here's a program for you to try out. Upload it to your Chibi Chip and give it a try on your circuit on page 3-4. Now pressing the button toggles the light on or off, even after you release the button!



This code runs once when the Chibi Chip starts up. **light** keeps track of whether our light is on (1) or off (0). At the start, we set it to off.

Whenever the button on pin 5 is pressed, check whether the light is currently set to on (1) or off (0). If it is on, set it to off. If it is off, set it to on!

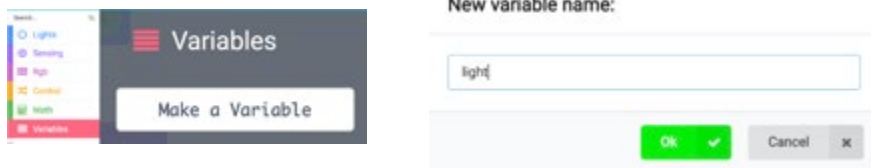
Once we've updated the light value, save the change to pin 0.

There are a few new things going on here! Let's go through it a little at a time.

One new technique we need for this program is a way to keep track of information over time. Every time we press the button, our program needs to know whether the light was set to on or off the previous time. That way, it can tell whether to change it to on, or change it to off.

A **variable** is a text name that can store a value, such as a number, over time. In this program, we created a variable and named it **light**. We use the **light** variable to store a number representing whether the LED is on or off: 0 for off, 1, for on.

We named our variable **light** because its purpose is to tell us whether the light is on or not, but we can give variables any name we want. Ideally, we give it a name that helps us remember what it does!



Once we have created our variable, we give it an initial value. This sets a starting point for our program; in this case, making the LED start in an off state. To do this, we use the "on start" block, which runs once when our Chibi Chip is powered on, but doesn't run repeatedly like the forever block.

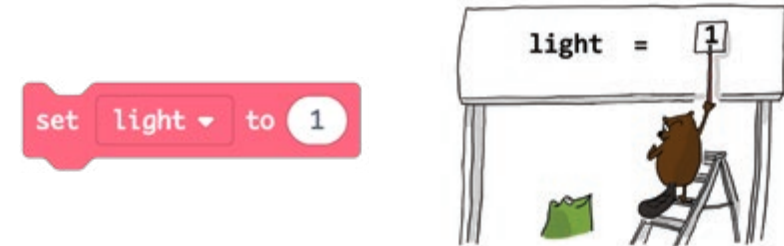


This code will run once, setting the initial value of the **light** variable.

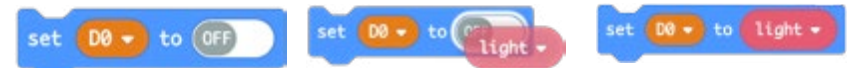


Now as long as we don't change **light** from 0, every time we use **light** in the code, it is the same as writing the number 0.

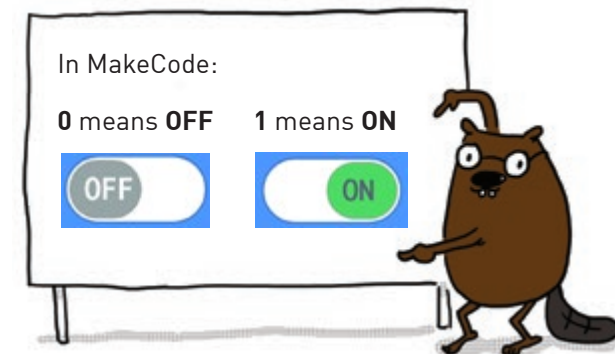
One cool thing about variables is that we can update the stored number. We do this by setting it to another value with the set variable block. For example, here's how we change the value stored inside **light** to 1 instead of 0:



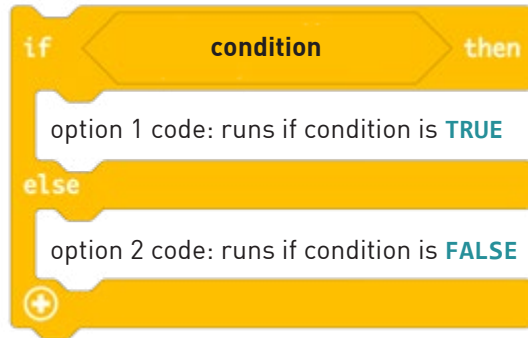
Once we know how to create and update a variable, we can use it to control another block. To do this, we drag and drop the name of the variable from the Variables section into one of the controls for the other block. Our toggle program replaces the default ON/OFF slider with the **light** variable, so now the variable controls whether the slider is on or off.



This block will now set the LED on pin 0 based on the number stored in the **light** variable. If **light** is set to 0, the LED will be turned OFF. If **light** is set to 1, the LED will be turned ON.

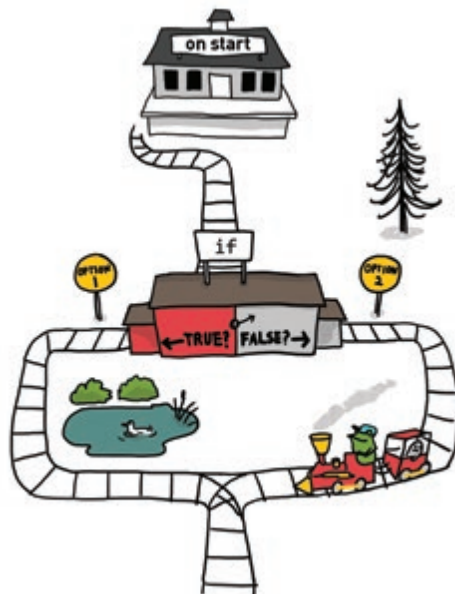


Now how do we make our light alternate between off and on? We change it based on its previous value using an **if statement**. Here is the general structure of the if statement:

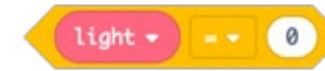


An if statement allows us to change the behavior of the program based on the answer to a question. This question is called a **condition**.

If the condition is **TRUE**, then the option 1 code runs. If the condition is not true, or **FALSE**, then the option 2 code runs. It's like train tracks that split into two paths, and which path the train takes depends on whether the condition is true or false.



In our code we ask "is it true that light is 0?" using this condition statement:



Condition statements are written as comparisons. The = equal sign asks, "Are the left and right sides are equal?"

We use this comparison in an if statement to test whether we need to change the light value to ON (if previously OFF) or to OFF (if it was ON).

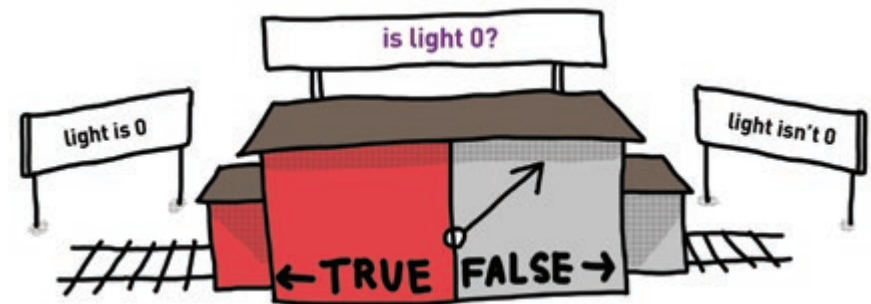


Condition statement: is **light** equal to 0?

If yes, do this: change **light** to 1

Otherwise, do this: change **light** to 0

Set LED on or off based on the new **light** variable value



CODE CLEANUP

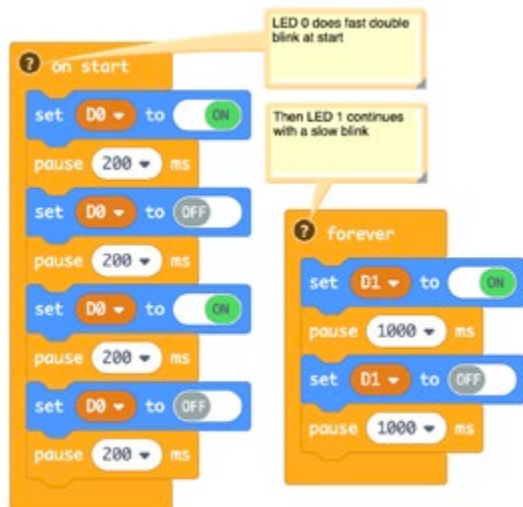
At this point our code is getting more complex. We can use **comments** and **variables** to help keep it readable and easy to debug!



Comments are human-readable text that explain what the code does without affecting how the code runs. Like labels or sticky notes, their purpose is to make the code much easier for us and our friends to read! You can add comments to any instruction block by right-clicking on it, then choosing Add Comment from the menu. Once a comment is attached to the block, click on the ? to view and edit it. You can drag your comment “sticky notes” to anywhere you like to make them easy to see.



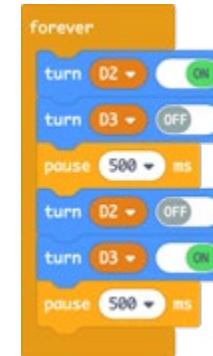
Check out this program with comments below. The comments help give you an idea of what the code is doing.



Another useful tool for making code readable is **variables**. As we've seen, variables can store information such as a number. This also means they can replace numbers in your code with more informative text names. This can make your code easier to understand and more efficient to modify.

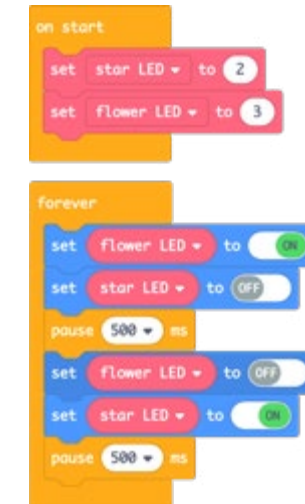
Before:

What is connected to pins 2 and 3? Nobody knows!



After:

When the LED pins are named as variables, everyone knows what the pins are for!



Using variables as labels also lets us quickly change a value in multiple places with a single edit. For example, it lets us change many pin numbers at once by editing just one number, instead of having to find and change every block that uses that pin number.



PAPERCRAFT SWITCHES

Now that we've cleaned up our code, it's time to get messy with craft materials! In the next several pages, we'll go through step-by-step instructions on how to build a few types of papercraft switches. But before we dig in, here is a brief introduction to the ideas we'll cover.



Paper Clip Switch Holder

Use a paper clip to hold down a switch that's been built at the edge of a page. The switch will stay on even when it's not being pressed! The switch circuit we built on page 3-4 is perfect for use with a paper clip.

Press-the-Flap Switch

Use a flap of paper with copper tape on it to close a circuit anywhere. This way, we can make switches anywhere on the page, not just on the edge or corner of the paper! To make sure the switch doesn't accidentally press itself and turn on, insert a bit of paper or foam tape as a spacer between the flap and the circuit. We can also use fun shapes for the flap, like some of the ones below!



Wind-Sensing Switch

Make a flap switch that has a thin stem, like a leaf shape, to make a wind-sensing switch! This shape will catch the wind, like a sail, and the stem makes it flexible enough to press down and close the circuit when blown on.



Pop-Up Switches

Circuits and switches don't have to be flat! We can put copper tape at the end of a long strip of paper, and curl or fold it so that it zigzags and pops off the page. These flexible switches can stretch to close different circuits or they can be clipped in place.



Pocket Character Switch

This switch comes in two parts: a character and a pocket. The character is a loose piece of paper that has copper tape pasted on a flap that's been rolled around to the back side. To hold the character, we place a pocket over the switch gap in our circuit.



Front

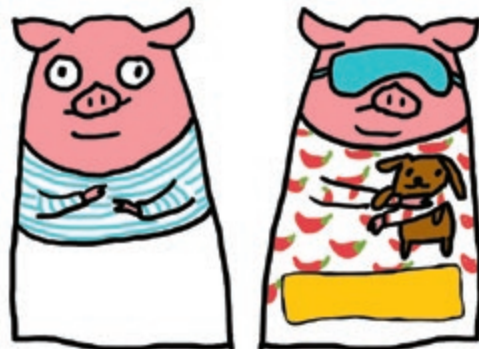


Back

When the character is placed inside the pocket, the copper tape on the character closes the switch gap and completes the circuit!



A character can work as an ON/OFF switch too! Just flip the character over so that the copper tape faces away from the circuit. That way, the switch is off even when the character is in the pocket!



SWITCH CRAFT GALLERY

The next few pages are a gallery of switches for us to craft! The artworks in this gallery are all incomplete and need our help to come to life. Once we're done, you can refer back to these pages for inspiration in your own projects!



All of the circuits use the **Basic Switch** example code so make sure that's loaded onto the Chibi Chip before starting. Then, complete the circuit template in each frame and follow the craft directions for the cutouts.

You'll need:



Chibi Chip



cable



copper tape



scissors



USB Power

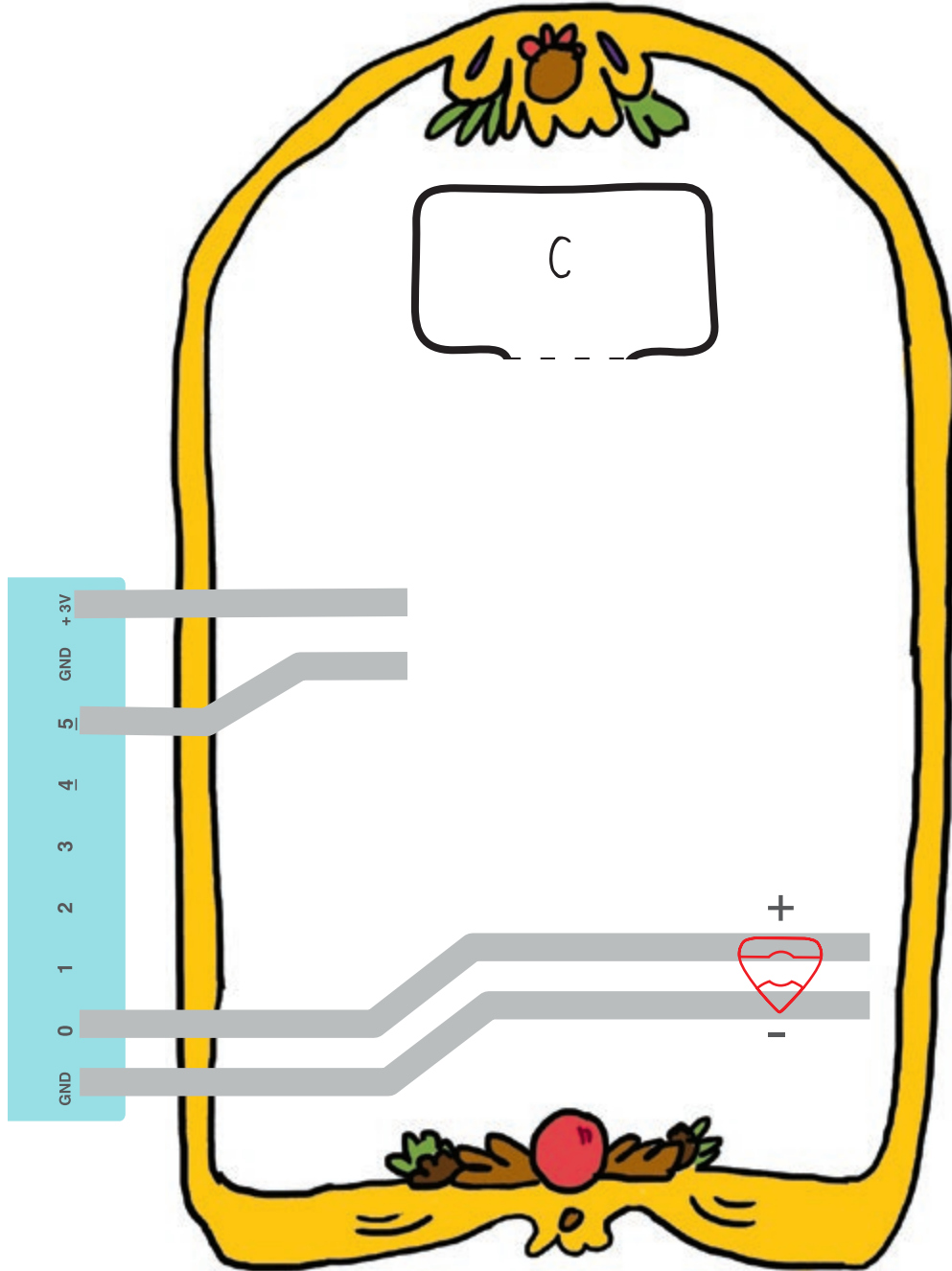


Chibi Light LED stickers



non-conductive tape

What glows when the pointer reaches the switch? Craft the switch by following the instructions on page 3-23!



POP-UP SWITCH

Make a Pop-Up Switch



1. Cut out the pointer, using the red outline on the back side of this page.



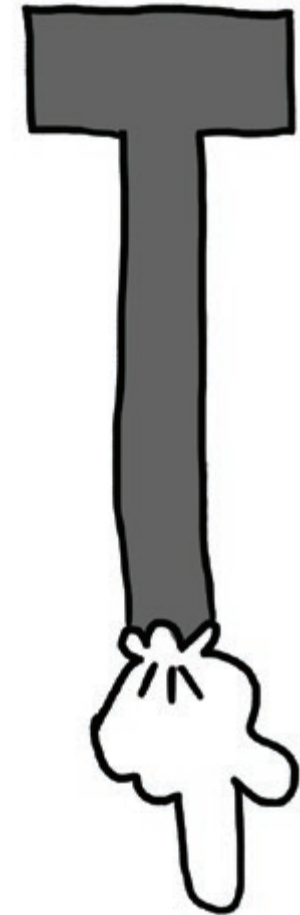
2. Add copper tape over the gray line.

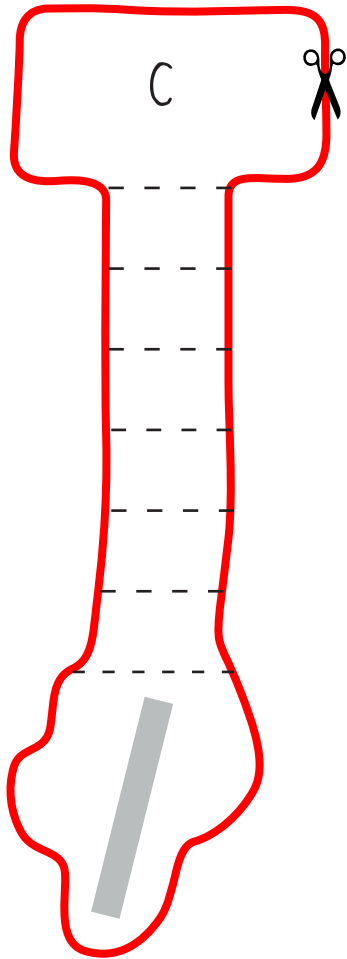


3. Fold along the dotted lines so that the pointer becomes a zig zag.



4. Tape the flap marked C over the footprint marked C on page 3-22.





Here's what the finished pop-up switch looks like! Stretch the pointer finger so reaches the switch contacts, and then press to activate the switch. When we let go, the pointer springs back up!

Make a Press-the-Flap Switch



1. Cut out the boot, using the red outline on the back side of this page.



2. Add copper tape over the gray line.

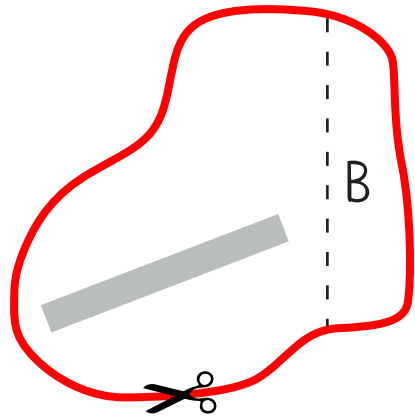


3. Fold along the dotted line.



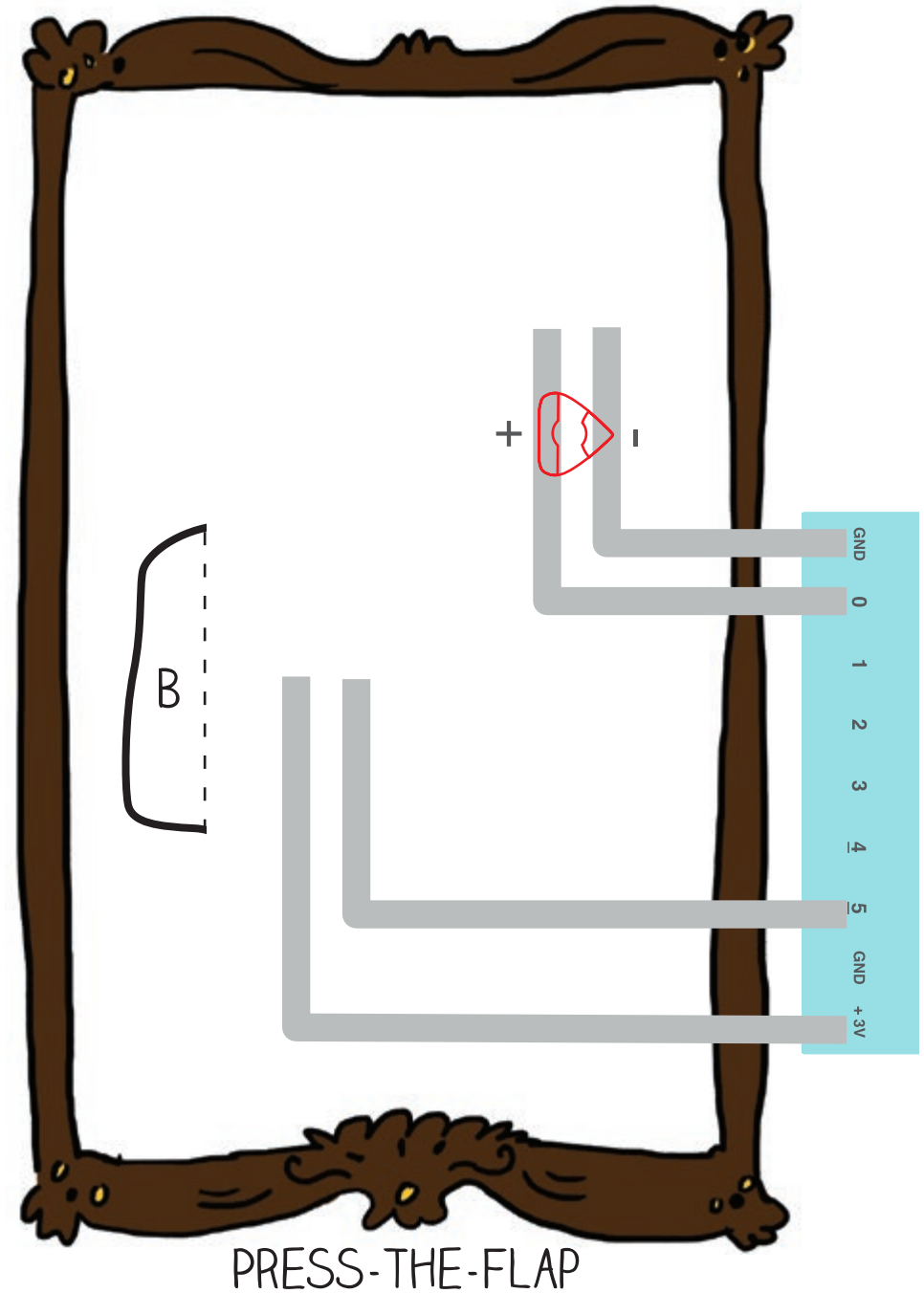
4. Tape the flap marked B over the footprint marked B on page 3-27.





Here's what the finished press-the-flap switch looks like! Press the boot to close the switch.

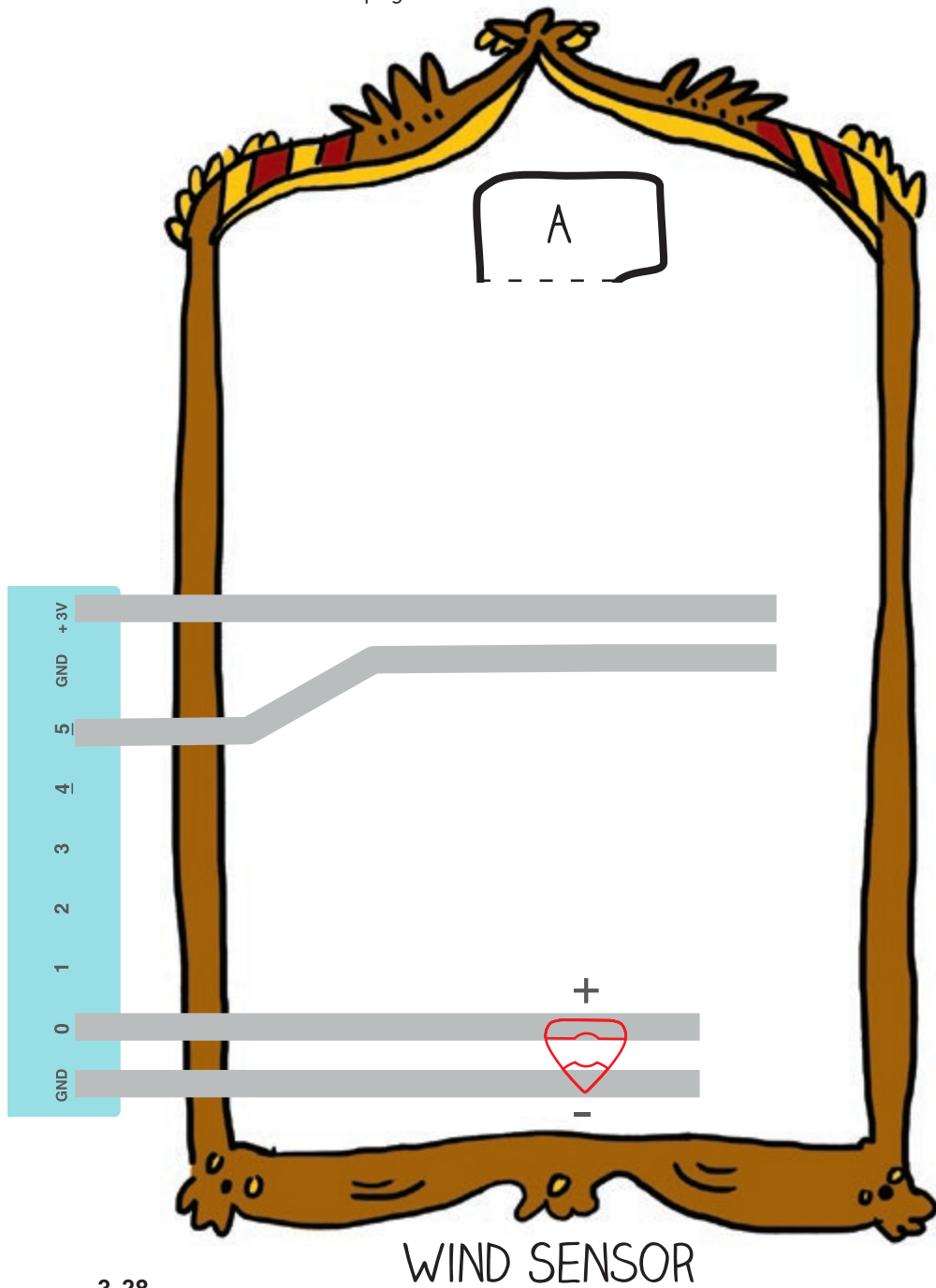
What glows when we press on the boot? Make it below!



PRESS-THE-FLAP



What glows when we blow on the flower? Craft the flower by following the instructions on page 3-29!



Make a Wind Sensor



1. Cut out the flower, using the red outline on the back side of this page.



2. Add copper tape over the overlapping gray lines on the back side of the flower.

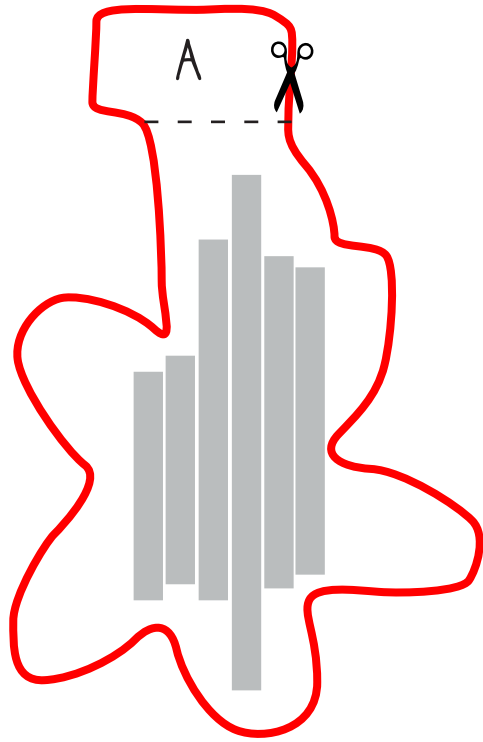


3. Fold along the dotted line.



4. Tape the flap marked A over the footprint marked A on page 3-28.





Here's what the finished wind sensor looks like! Blow on the flower to activate the switch. Try adjusting the position of the flower slightly to improve the contact between the copper tape on the flower and the paper. You can also press on the flower to operate the switch as well!



Make a Pocket Character Switch



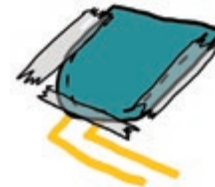
1. Cut out the cat and the pocket, using the red outline on the back side of this page.



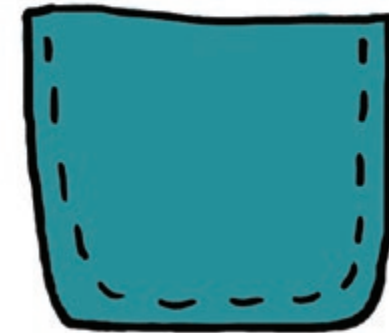
2. Roll up the paper along the dotted lines at the bottom of the cat cutout. This makes the paper thicker so it presses more securely against the switch, making a stronger connection.

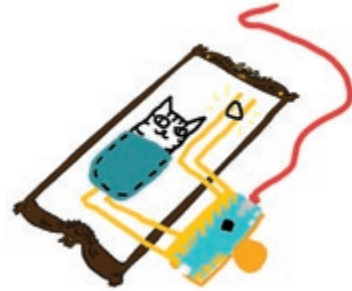
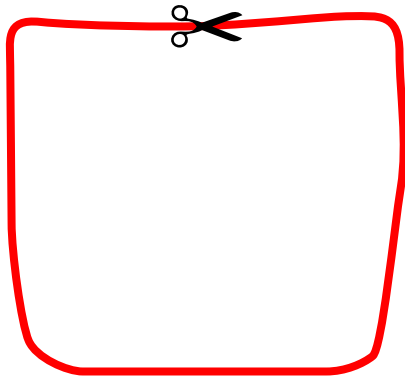
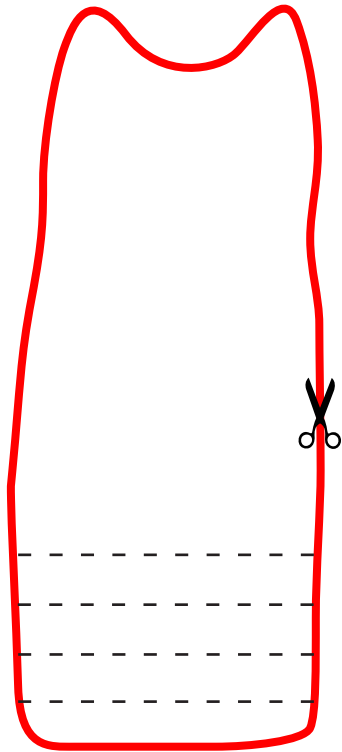


3. Add copper tape to the gray line, then build the circuit on page 3-33.



4. Tape the pocket over the footprint marked D, by taping the left, right and bottom sides. *Be sure to leave the top open.* Now the pocket is ready to hold the cat!

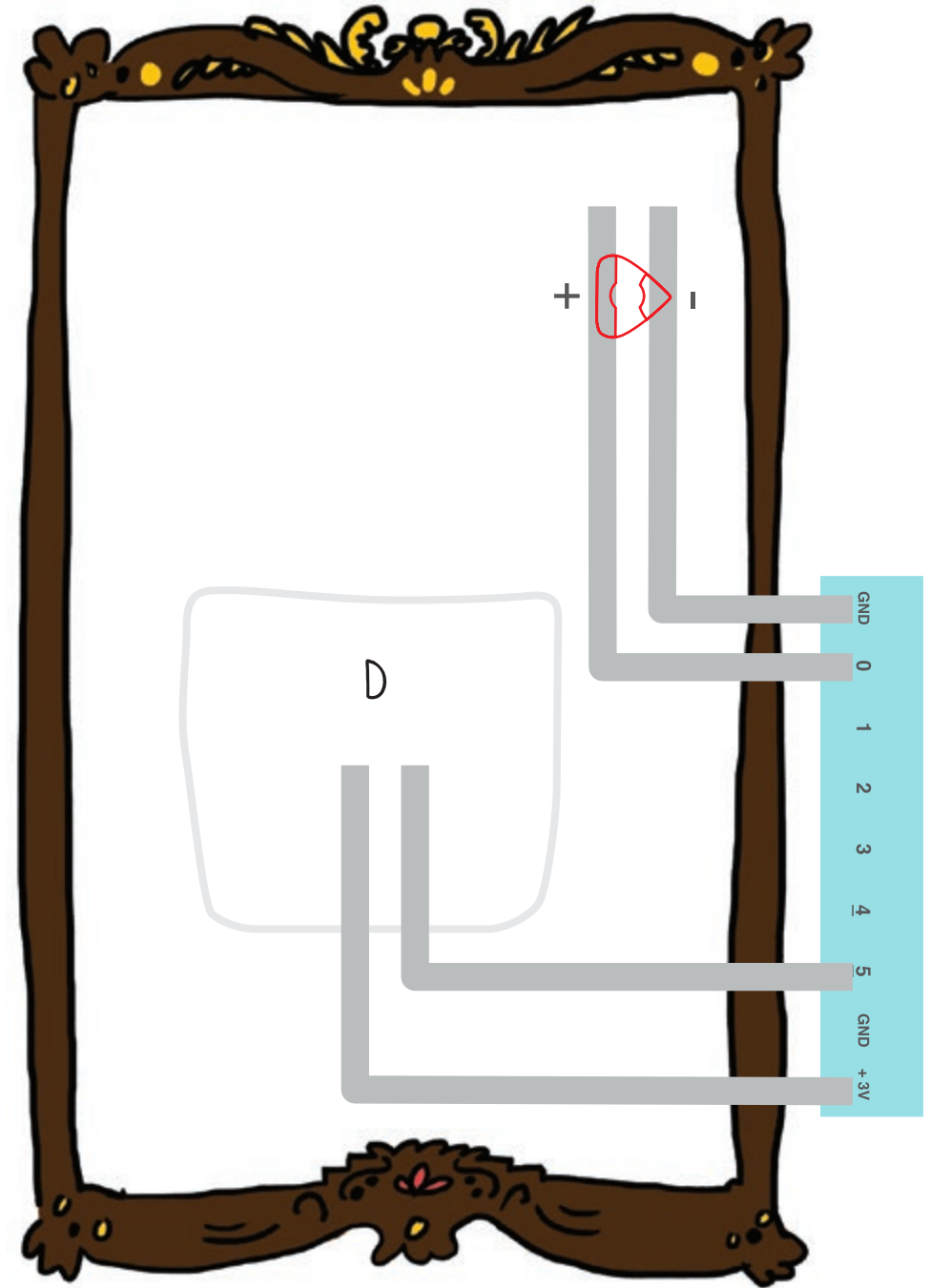




Here's what the finished pocket character switch looks like. When we put the cat in the pocket, it will close the circuit, turning the switch on. Make sure to push the cat all the way into the pocket for a secure connection.

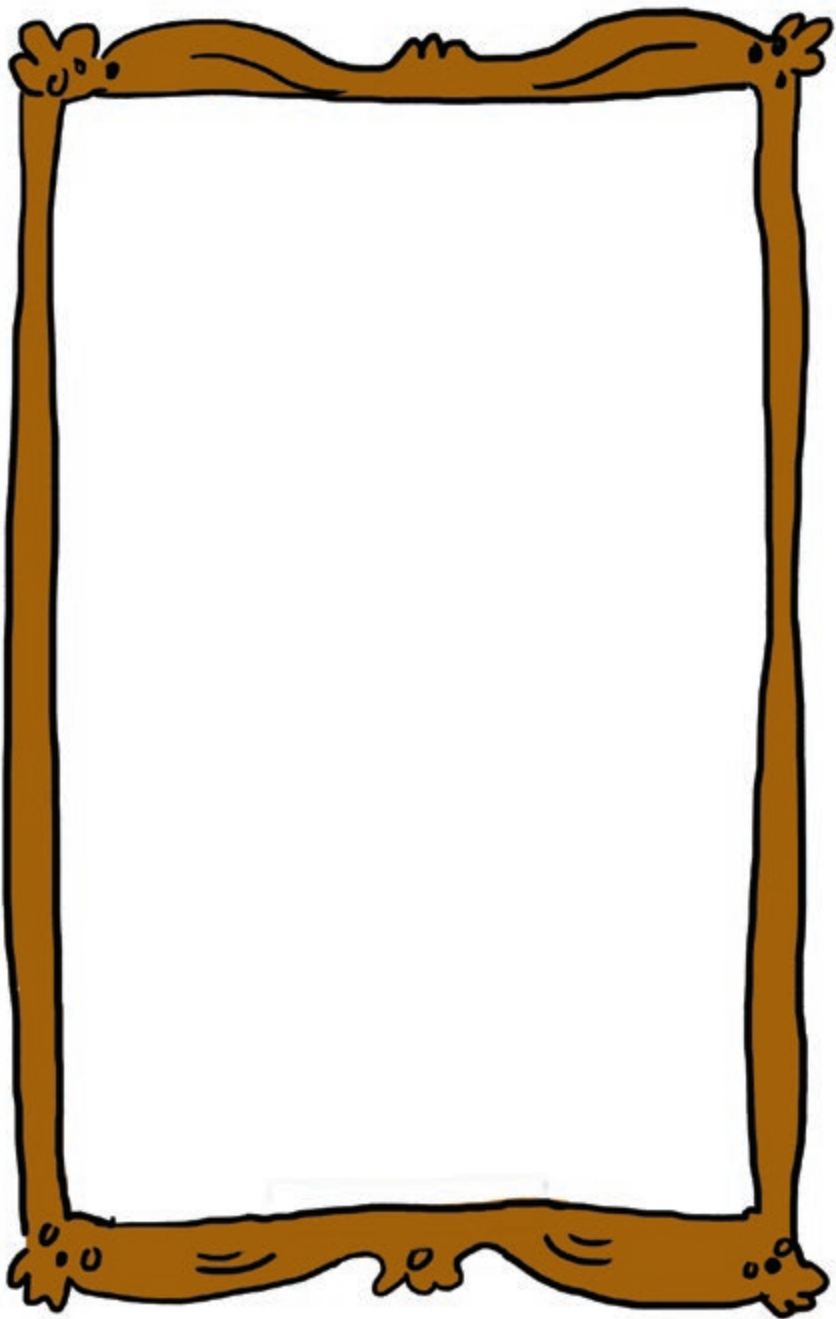


We can turn off the switch by pulling the cat out of the pocket, or by flipping the cat around so that the copper tape doesn't touch the circuit.



POCKET CHARACTER SWITCH

GND 0 1 2 3 4 5 GND +3V



YOUR SWITCH!

DESIGN YOUR OWN SWITCH!

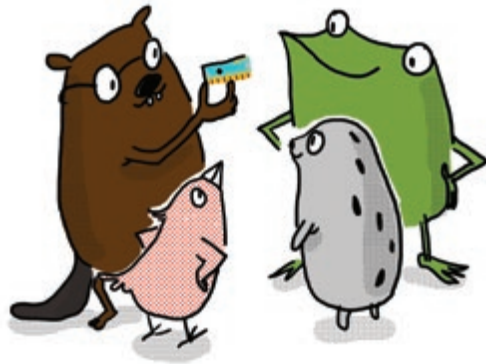
Well done! Now that we've crafted a bunch of switches, try drawing your own switch from scratch. Remember: it's all about making and breaking connections in the circuit!



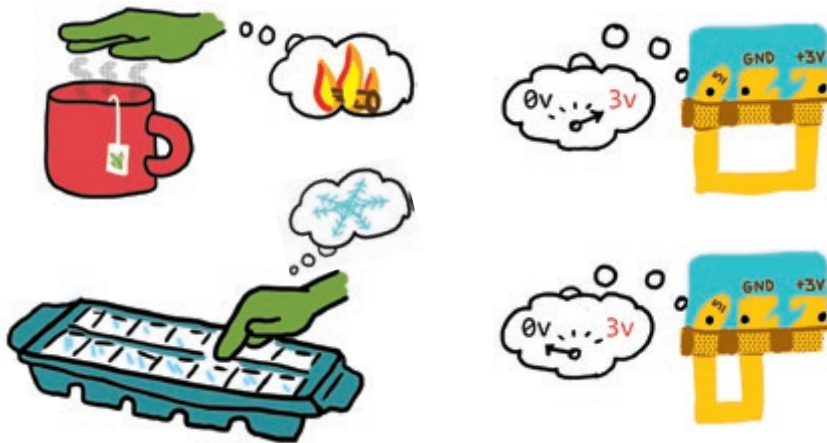


DOWN THE RABBIT HOLE: INPUT - PROCESS - OUTPUT

So we've played a bunch with switches now, and even designed our own! But how does the Chibi Chip actually know when to turn things on and off with the switch?



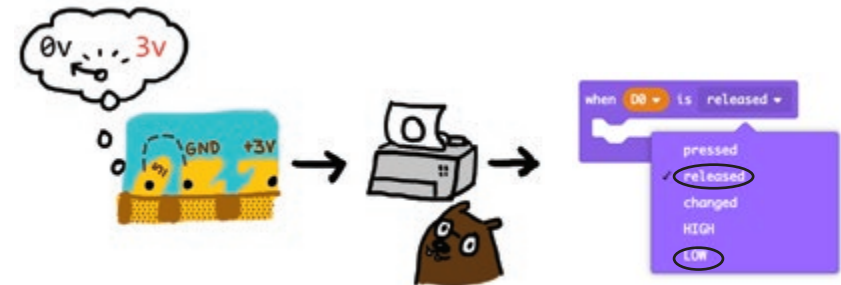
It works by taking in information from the world through an **input pin**. This is called "input" because information goes "in" to the board. What information, you ask? Voltage!



Just as we take in information about hot or cold through our fingers, a Chibi Chip takes in information about voltage through its pins.

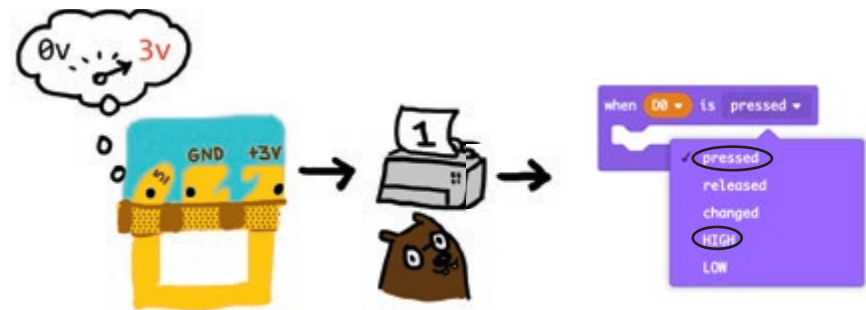
When nothing is connected to the input pin, a special circuit inside the Chibi Chip gently "rests" the pin at a value of 0 volts, so it reads **0**. The indicator light above the input pin matches this reading and is thus off when nothing is touching the pin.

When you include a "when released" block in your code (or a "when LOW," which works the same way), your chip will wait for that pin to change to 0V. When it does, the chip will trigger the code inside.

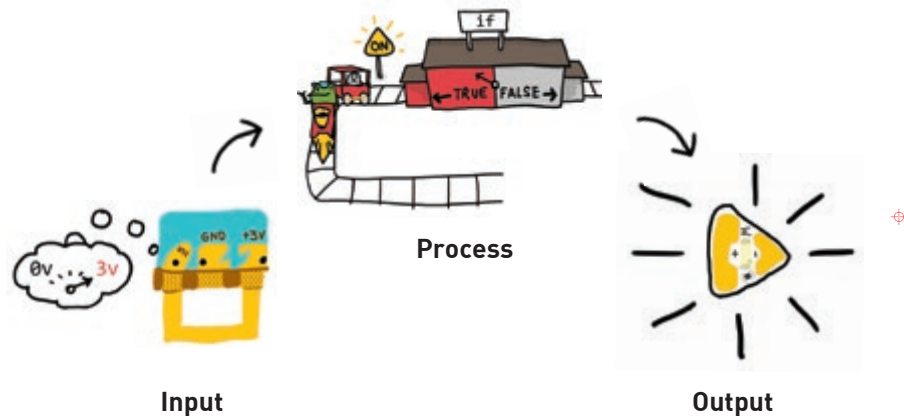


When we connect the input pin to +3V by pressing the switch, the pin can sense that the voltage has gone up. The voltage on the pin becomes 3V, so it reads **1**, and the indicator light turns on.

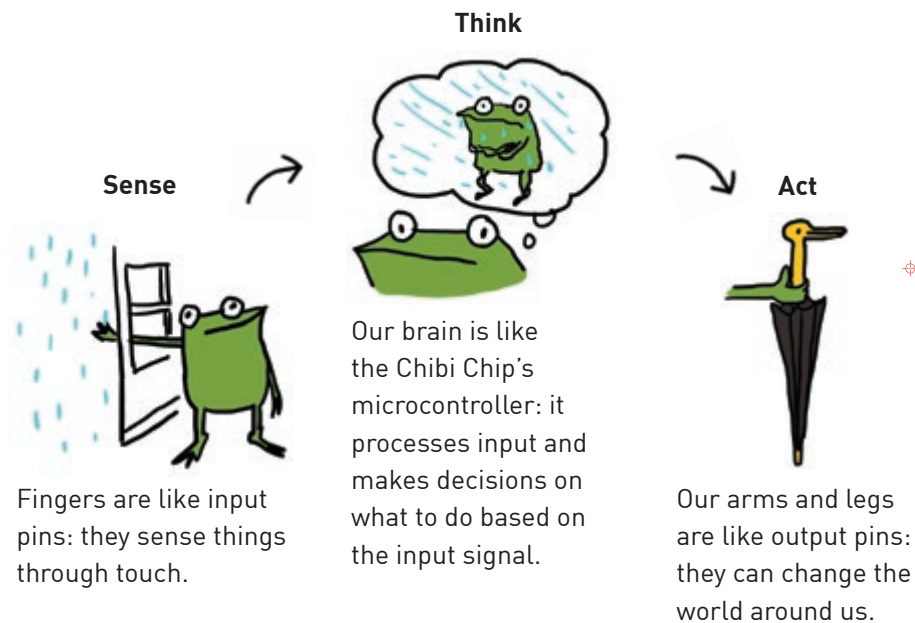
A "when pressed" or a "when HIGH" block will trigger in this case, when the voltage changes to 3V.



The code in the microcontroller processes the information from reading the input voltage to trigger the correct code to run. When the voltage is changed to 0 or +3V, the “when pressed” or “when released” block activates and runs code which sets the LED on or off.



It's a bit like how our hands work with our brain to sense the world around us and to do stuff in response:



“What else can we do with these lights?” asked Fern. Everyone sat down and thought for a moment. “Instead of going directly from off to on, could we make them transition gradually?” Carmen asked.

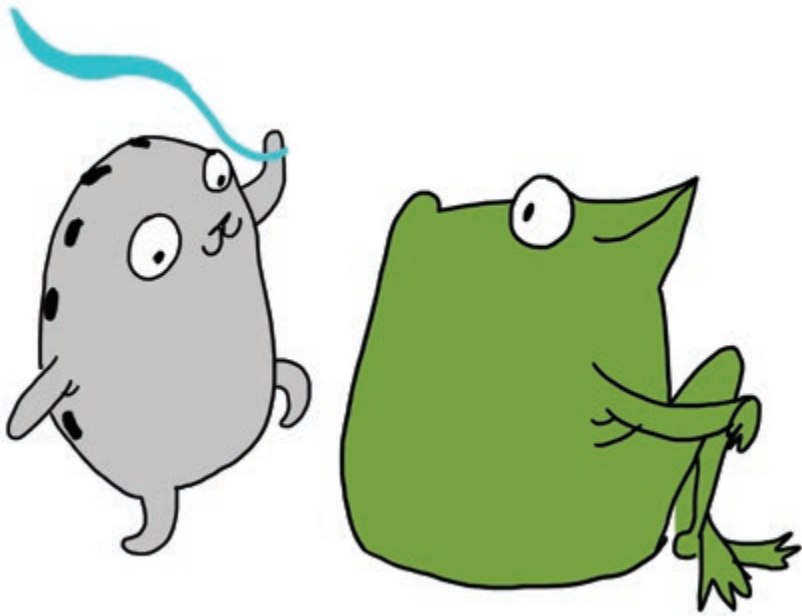


“You mean like fading them in and out?” said Edith. “Yeah!” exclaimed Fern. “That would make a really pretty effect that can go with all kinds of scenes.” “I feel like we could figure out how to do that!” Sami said. “Shall we try?”



Chapter 4:

Fade in and Out!



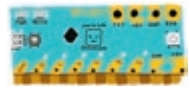
“We’ve figured out how to turn the lights on and off, but how can we make them fade slowly?” asked Fern the frog.

“I think I can explain!” said Sami the seal as she danced around the room. “And while we’re figuring it out, we can make dance costumes. We can have a parade later, and if we decorate our costumes with twinkling lights we will look even more fabulous!”

SET BRIGHTNESS LEVELS

Rather than turning LEDs fully on or fully off, we can also dim them to intermediate brightness levels! This lets us make fun new lighting effects, such as fading our lights in and out smoothly, or creating a twinkling effect!

You will need:



Chibi Chip, mounted in a Clip



Programming and power cable



A device with a web browser (phone, computer, or tablet): this is the programming device



Internet connection



USB Power

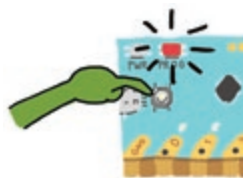
Upload the **Set Level** example code to the Chibi Chip. Go to **Love to Code** → **Set Level**. When the code is done uploading, the light on pin 0 will turn on and off by stepping through different brightness levels!



UPLOAD NOT WORKING? TRY THESE DEBUGGING TIPS. IF THESE DON'T HELP, CHECK OUT THE DEBUGGING SECTION IN THE BACK OF THE BOOK!



MAKE SURE THE VOLUME IS ALL THE WAY UP.



DID THE PROG LIGHT TURN STEADY RED BEFORE PROGRAMMING? IF NOT, PRESS AND HOLD THE PROG BUTTON UNTIL IT TURNS RED AND TRY UPLOADING AGAIN.

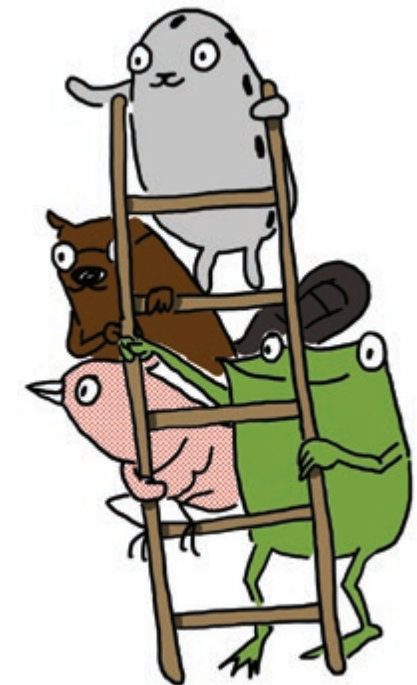


DID THE UPLOAD SOUND WAVEFORM ANIMATION APPEAR? IF NOT, TRY REFRESHING THE PAGE AND CLICKING UPLOAD AGAIN.

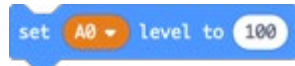
DECODE THE CODE

Let's take a look at the **Set Level** example code to see what's going on with our LED!

```
forever
  set A0 level to 0
  pause 500 ms
  set A0 level to 25
  pause 500 ms
  set A0 level to 50
  pause 500 ms
  set A0 level to 75
  pause 500 ms
  set A0 level to 100
  pause 500 ms
  set A0 level to 75
  pause 500 ms
  set A0 level to 50
  pause 500 ms
  set A0 level to 25
  pause 500 ms
  set A0 level to 0
  pause 500 ms
```

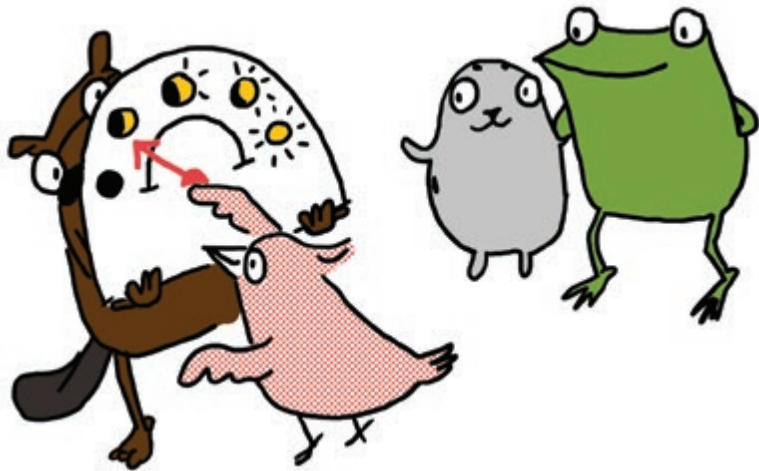


The set block sets the brightness level of a pin. It's like using a dimmer instead of an on/off switch to turn on a lamp. Instead of all the way on or all the way off, it allows us to set brightness levels that are in-between. Here's how it works:

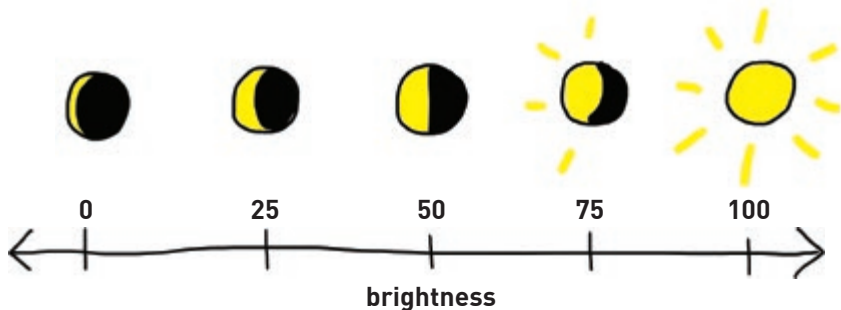


This tells the Chibi Chip which pin we are setting.

This is the brightness level we want. It can be any whole number, from 0 for all the way off, to 100 for all the way on.



In our example code, we first used this block to set pin 0 to 0% brightness. We then set pin 0 to varying brightness levels, anywhere from 0 for all the way off to 100 for full brightness, in increments of 25.



PLAY WITH CODE

Play with our example code by setting pin 0 to different brightness levels to create your own patterns.



After programming a new pattern, clip the Chibi Chip to a previous circuit, like the one on page 2-25, and see how it changes the scene!



That's the great thing about programming. Even with the same circuit and the same scene, we can tell different stories just by changing the code!

DECODE THE CODE

Rather than suddenly switching between brightness levels, how do we get the lights to transition even more smoothly? We want our brightness changes to glide up and down like a ramp, instead of stepping up and down like a staircase.

Right now, the brightness increments are big, at 25% per step. Perhaps things would smooth out if we could make the increments smaller?



The smallest brightness increment is 1. So to fade more smoothly from off (0) to full brightness (100), we could set the level to 0, then set it to 1, then to 2, then to 3.... and so on, one tiny change at a time until we get to level 100.

But that would take so much code, and take forever to write!



Luckily, there is a neat code structure called a loop to save us! To try out a looping style known as the while loop, go to the code editor and load the example found at **Love to Code → Fade with While Loop**.



Once we've loaded this code into the Chibi Chip, the LED over pin 0 should be gently fading in and out. Here's our new code:

```
forever
  while brightness < 100
  do
    set A0 level to brightness
    pause 10 ms
    change brightness by 1

  while brightness > 0
  do
    set A0 level to brightness
    pause 10 ms
    change brightness by -1
```

We created a variable called brightness to store our current brightness level.

To fade in the LED:

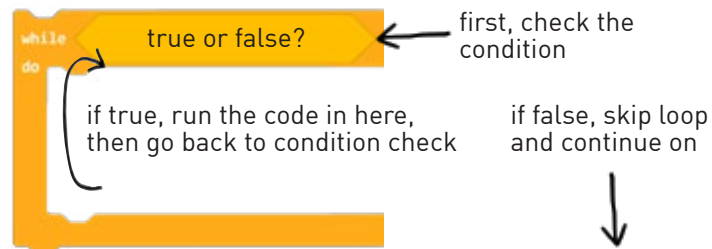
Set the LED to the current brightness, increase the brightness level by 1 and then repeat this loop until the brightness is 100, or fully on.

To fade out the LED:

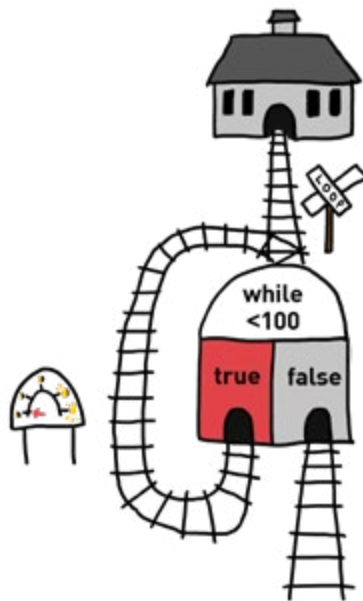
Set the LED to the current brightness, decrease the brightness level by 1 and then repeat this loop until the brightness is 0, or fully off.

Whew! It would've taken us about 400 set and pause blocks to write this program without while loops. Using loops, it is much more compact!

The while loop lets us repeatedly run a snippet of code without having to write it over and over. Any code inside the while loop runs only if the condition is true:



First the program checks if the condition is true. If so, it will run the code inside the while loop. When it's done running the inner code, it goes back to the top and checks again to see if the condition is still true. If so, it goes back and runs the while loop code again. This loop repeats until the condition is no longer found to be true.



To make sure we don't get stuck forever inside the while loop, we must update our current condition somewhere in the while loop's inner code so that at some point in time, the condition statement will no longer hold true. If we forget to do this, the Chibi Chip will get stuck inside the while loop. This is called an **infinite loop**!

So to gradually fade our light from off to on, we set the brightness using a while loop like this:

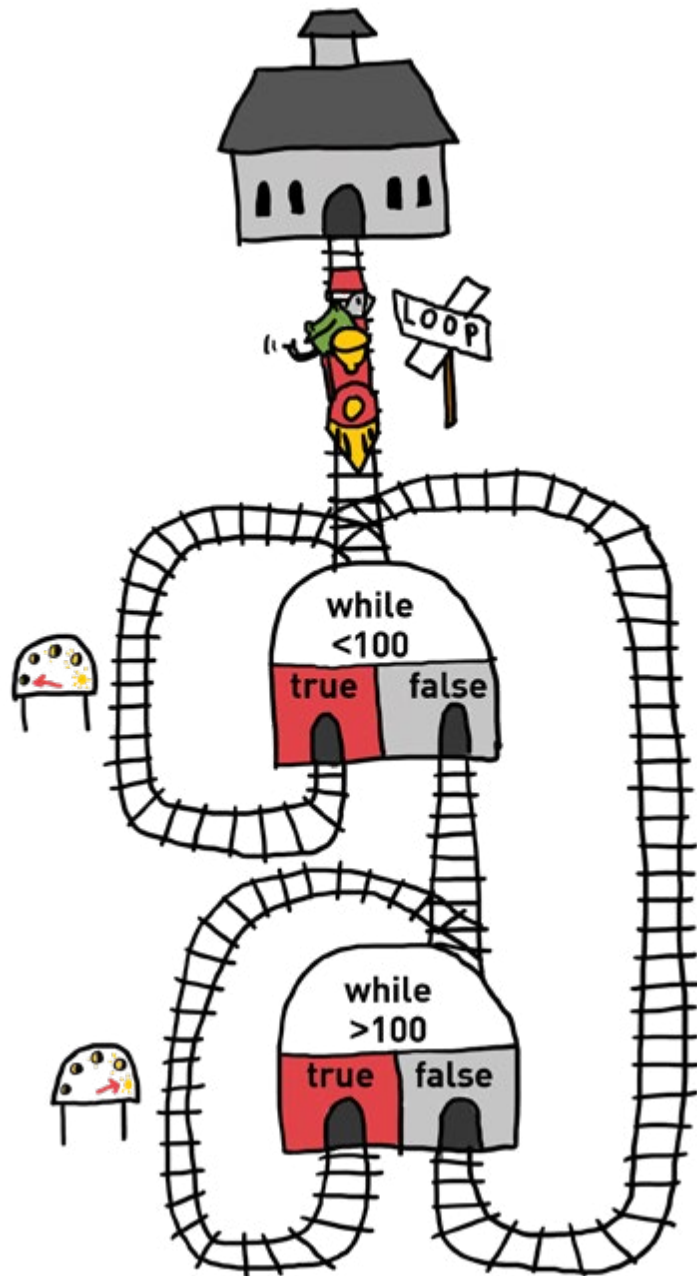
1. When this loop first runs, the value of the brightness variable is 0
2. Check if the current value of the variable is less than 100. If so, run the code inside this loop!
3. Set the LED pin to our current variable's value and wait 10 milliseconds before continuing, otherwise the brightness changes too fast for us to see!
4. Increase the variable by 1 so that the next time the loop runs, it will be just a little brighter.
5. Our code now goes back to the start of the loop and checks if the variable is still less than 100.

This keeps going until our brightness variable reaches 100. At this point, the condition "is brightness less than 100?" no longer holds true. The while loop will end, and our program will move on to the second while loop. Fading to dark works the same way, except now we are counting down. The brightness level starts at 100 and decreases by 1 each time the loop repeats until the brightness variable becomes 0 again!

Note that as always, the name of the variable is up to you. It doesn't have to be called 'brightness' for the same logic to work. A meaningful name just makes the code easier to read and share!



Putting it all together, here's what a map of our example code looks like for fading in and fading out using two back-to-back while loops!



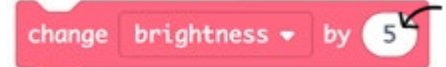
PLAY WITH CODE

Try playing around with the while loop code to create your own fading light effects!

Can you make the lights fade faster? Now how about slower? Just like with the **Blink** example code, we can change the pause time to make the fade effect go faster or slower.

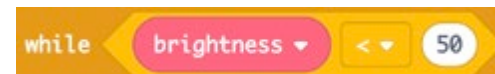


We can also try changing the brightness increment. For example, changing the increment to:



will make the LED fade faster. However, if the increment becomes too big, the fade goes from a smooth ramp back to choppy steps!

The light doesn't have to fade all the way on or off! We can fade to medium brightnesses by changing the condition statement in the while loop. For example, a loop like this will fade the light until it is only halfway on:



Try it out! Can you make a candle-like flickering effect?



DECODE THE CODE

Now that we have one pin doing fun fade effects, how do we get multiple pins to fade in different patterns? The easiest way is through **multithreading!** Multithreading means running multiple pieces of code at the same time. Each running bit of code is called a **thread**.



Try loading **Love to Code** → **Basic Multithreading** onto a Chibi Chip to see multithreading in action! We'll see each of the six indicator lights above the pins flashing different effects. Here's the code:

```

on start
  set brightness4 to 0
  set brightness5 to 100
  
```

← The "on start" code runs once at the start of the program, before any of the threads run. Here it allows us to set a starting value for the variables we will use to fade some of the LEDs.

```

Thread 0: Blink pin 0
  forever
    set D0 to ON
    pause 300 ms
    set D0 to OFF
    pause 300 ms
  
```



The code is longer, because we've crammed six programs into one, so it keeps going:

```

Thread 1: Blink pin 1
  forever
    set D1 to ON
    pause 500 ms
    set D1 to OFF
    pause 500 ms
  
```

```

Thread 2: Blink pin 2
  forever
    set D2 to ON
    pause 800 ms
    set D2 to OFF
    pause 800 ms
  
```

```

Thread 3: Blink pin 3
  forever
    set D3 to ON
    pause 1000 ms
    set D3 to OFF
    pause 1000 ms
  
```

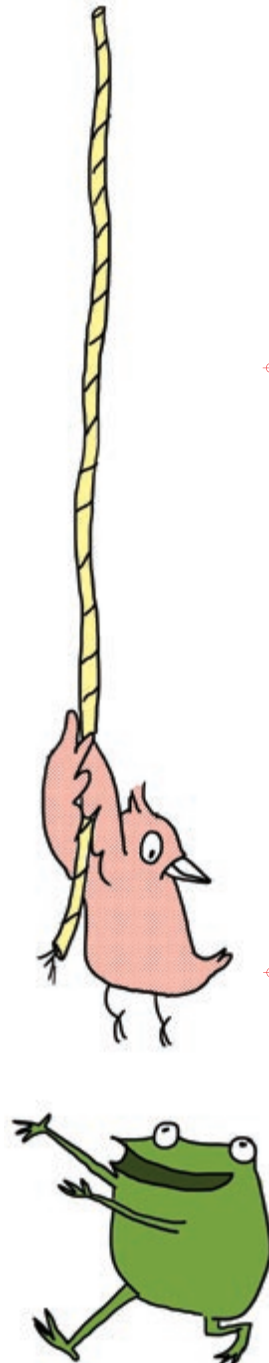


Thread 4:
Fade pin 4

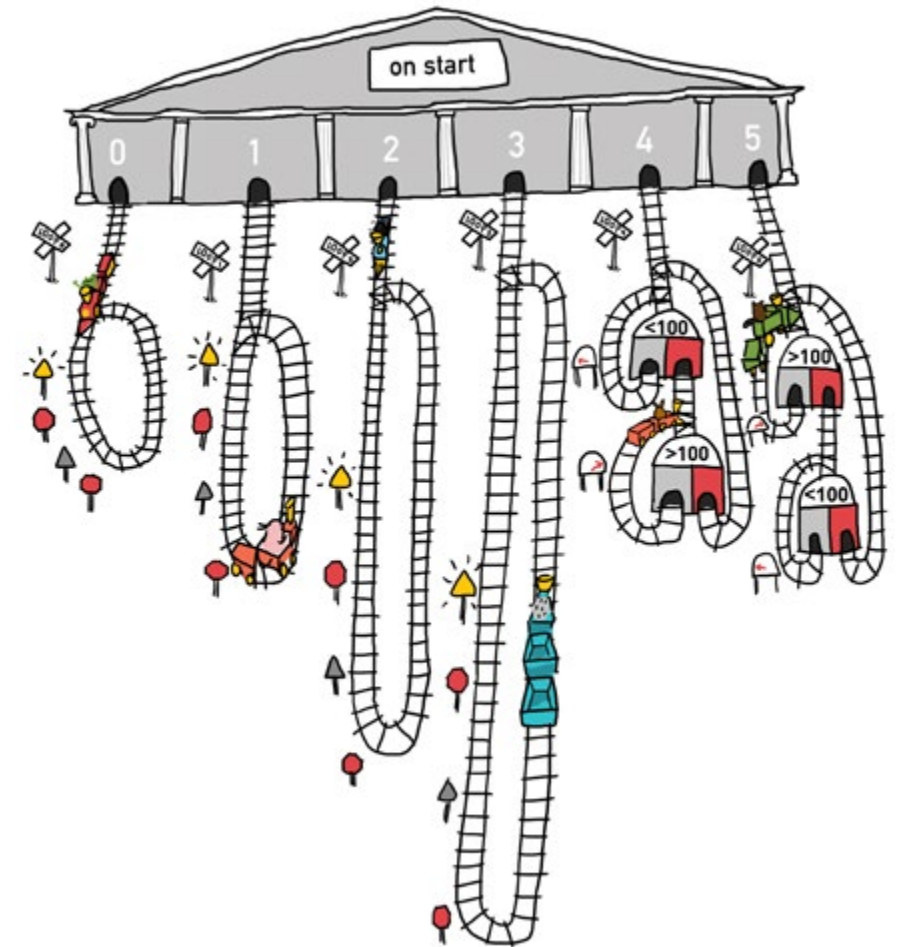
```
forever
  while brightness4 < 100
  do
    set A4 level to brightness4
    pause 10 ms
    change brightness4 by 1
  while brightness4 > 0
  do
    set A4 level to brightness4
    pause 10 ms
    change brightness4 by -1
```

Thread 5:
Fade pin 5

```
forever
  while brightness5 > 0
  do
    set A5 level to brightness5
    pause 10 ms
    change brightness5 by -1
  while brightness5 < 100
  do
    set A5 level to brightness5
    pause 10 ms
    change brightness5 by 1
```



Whew, that's all the code! Six forever blocks each controlling a different pin so they can each have their very own blink or fade sequence. It's like having six trains running at the same time on six different tracks!



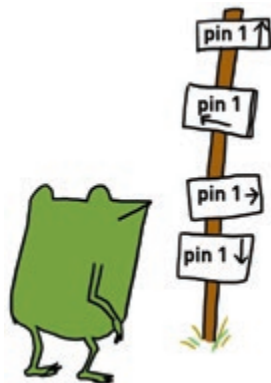
Just as real trains could collide if we put them on the same track at the same time, a Chibi Chip could get confused if two threads fight over a common resource. For example, if two forever loops both try to control pin 0, the result would be a confusing mix of commands from both loops. This kind of collision is called a **race condition**. In order to keep things **thread-safe**, which means preventing collisions, we just have to make sure that different threads don't ever try to control the same pin.



Likewise, we should also make sure the names of variables are different between threads, so the Chibi Chip doesn't get confused. It's like having two people with the same name share a mailbox — they'd have no way of knowing which message was meant for which recipient!

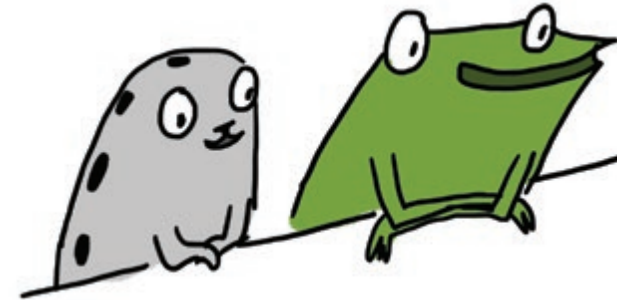
That's why we named the two variables keeping track of brightness to match the pin numbers being used in that thread ("brightness4" and brightness5"). We could name variables whatever we wanted, but naming them something different for each thread keeps things simple to understand and thread-safe.

Multithreading is easy, as long as we're careful to keep each thread's resources separate!



PLAY WITH CODE

Ready to play with some multithreading? Let's go! Try changing the blink and fade patterns inside each thread.



```

forever
  set D1 to ON
  pause 500 ms
  set D1 to OFF
  pause 500 ms
  
```

For example, you can change the pause times to adjust the rhythm of each light's blink sequence.

You can also add more set ON/OFF and pause instructions to make a more complex rhythm!

If you want to control more than one pin in one thread, that's okay. Just make sure you're not trying to control the same pin in another thread too, or else there might be a collision!



MAKE A SCENE

You've learned so much! Now use your coding chops to help Fern and friends design some light-up outfits for the parade.



GND +3V
5
4
3
2
1
0
GND

You can make a scene bigger by using conductive fabric patches to connect between two pages. Try it now!

First, remove pages **4-19** through **4-22** from the binder. Craft your circuits on this page, **4-18**, and on page **4-23**, using conductive fabric patches to bridge between the pages.

Once finished, lay page **4-20** over page **4-18**, and page **4-21** over page **4-23**. The lights will shine through the parade!





MAKE A SCENE - CONTINUED

Continue your circuit here! Use conductive fabric patches to extend the circuit from page **4-18** on to this page, and then lay the middle pages on top to complete the scene.





DOWN THE RABBIT HOLE: PULSE WIDTH MODULATION

So how does a Chibi Chip fade lights in and out? It may seem like the Chip is changing the voltage going to the LED to make it brighter or dimmer, as previously explained in Chapter 1, but it's actually turning the light on and off very quickly in a process called **pulse width modulation (PWM)**.

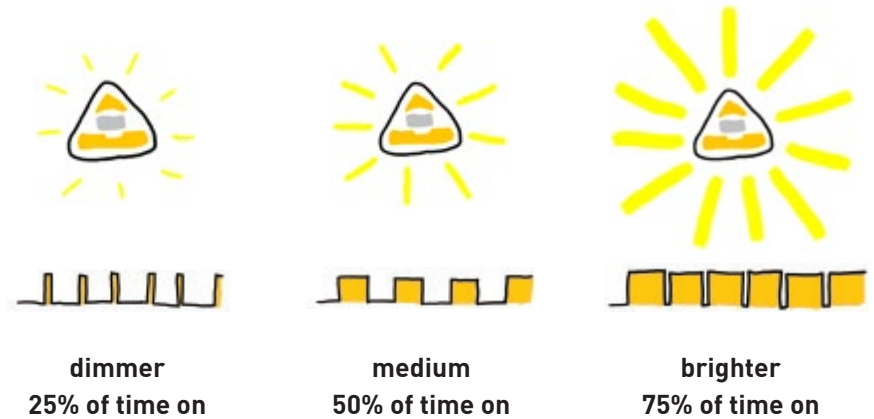


The Chibi Chip can only turn a pin fully on or fully off, so it cannot dim a LED by creating different voltages. Instead, to make the light look like it's partially on, the Chibi Chip blinks the light very quickly, around 400 times a second: so fast that we can't even notice it turning on and off!

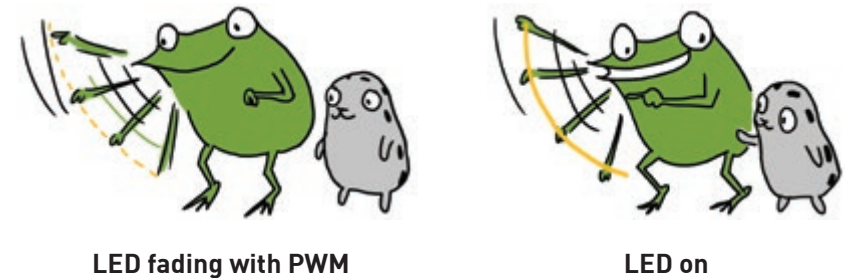


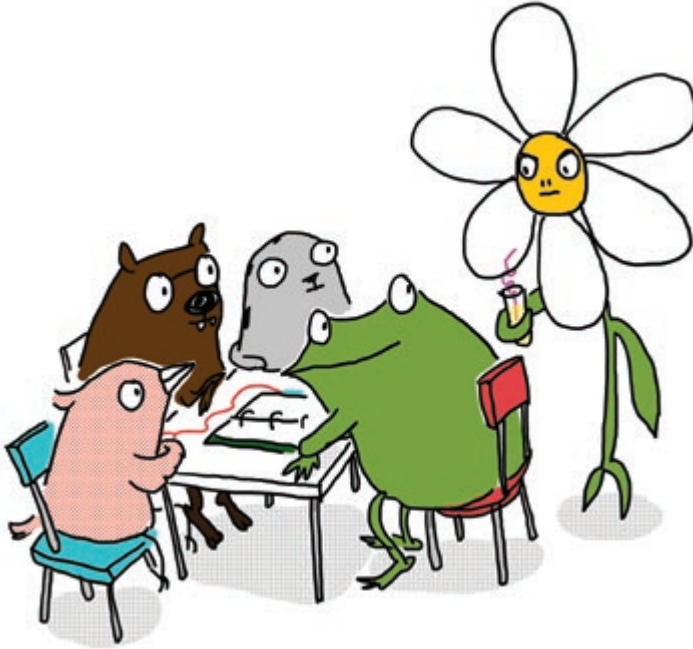
Instead, our eyes blur the rapid blinking so it seems like the LED is shining at a constant, but dimmer, light level.

Each blink is called a **pulse**. How dark the light fades depends on how much of the time the light spends in the on state versus the off state. This ratio is called the **duty cycle**, and it is expressed in terms of a percentage. So, when we use a set level block, the brightness input is actually specifying the duty cycle of the PWM.



There's a trick you can try to see the blinking for yourself. First, use a set level block to set a LED to a value less than 100. Then, wave it very quickly in front of your eyes. Instead of seeing a continuous streak of light, you will see a "dotted line" of light. This is the light turning on and off very rapidly! Next, fix the light to on by programming it using set ON, and try waving it around again. This time, you'll see a continuous, solid streak!





“This is really cool!” exclaimed Fern.

“It’s not **that** cool,” muttered a smug, sarcastic voice. It was George the flower. “There are way cooler switches you can make using a light sensor. Haven’t you heard of one before?”

Carmen and Edith both rolled their eyes. “This guy,” whispered Sami.

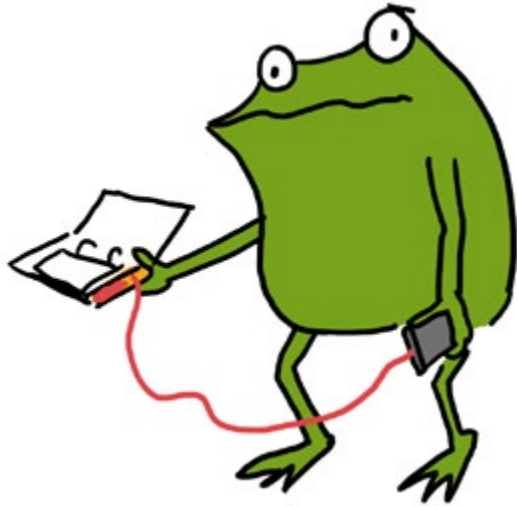
Fern thought for a minute. Maybe George could teach her something new she didn’t already know. “Hey George,” she said, “can you show us?”

George heaved a sigh. “I guess. If you can keep up.”

“I’m pretty sure we can,” said Fern with a smile.

You’re amazing! You’ve finished Love to Code Volume 1. For new adventures with Fern and friends, like how to use a light sensor, check out chibitronics.com/lovetocode.

Debugging



Stuff isn't working? No matter! That's what debugging is for! **Debugging** means looking closely at our project, finding the problems — also known as **bugs** — and then fixing them so that our project works as expected.



WELCOME TO MY WORLD!
DON'T WORRY WHEN THINGS
DON'T WORK THE FIRST TIME.
FIGURING OUT WHAT WENT
WRONG IS HOW DISCOVERIES
ARE MADE!

BREAKING IT DOWN

When a project doesn't work, it can seem overwhelming. The problem could be anywhere!



That's why we break it down into smaller parts and look at them one by one. Then it's not so scary anymore! It's just like how we take small bites when we eat, rather than swallowing the whole meal all at once!



Here are some of the smaller pieces we can break our Love to Code project into:

Power:

Is the Chibi Chip getting enough electricity to turn on and run our circuit?



Circuit:

Is everything in our circuit connected properly?



Upload:

Are we able to send code from our programming device to the Chibi Chip?



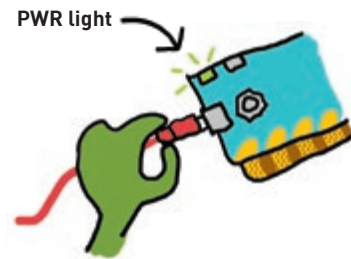
Code:

Are there errors in our code? Does our code actually say what we mean?

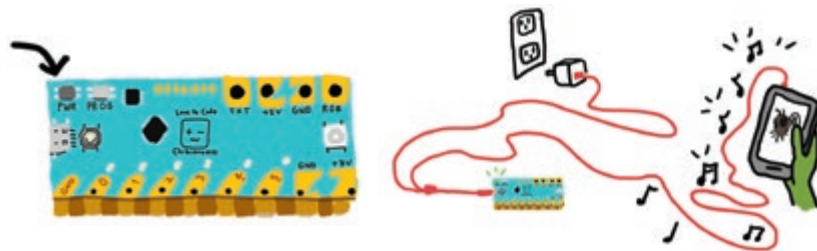


POWER

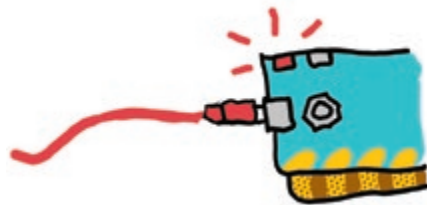
Let's start by checking the power! If everything is working properly, the power (PWR) light on the Chibi Chip will be green to show that it has enough power.



1. Is the PWR light off? If so, it means the Chibi Chip is off because it isn't getting enough power! Try plugging the Chibi Chip into a power supply that you've recently used to charge a phone, like a USB wall plug or computer's USB port. Phones take a lot of power to charge, so if the USB port can charge a phone, it can power a Chibi Chip!



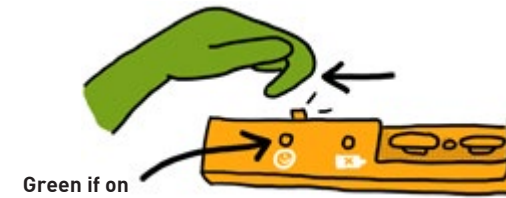
2. Is the PWR light red instead of green? That typically means we have a short circuit connecting +3V and GND directly to each other, draining power from the Chibi Chip! If you're powering the Chibi Chip from a computer, an error message may also pop up on your screen about too much power or current being drawn.



If this happens, unplug the Chibi Chip from the power source, find the connection causing the short circuit, and remove it. To learn more about short circuits, go to page **1-8**.

If you're using a Chibi Book for power, it's worth checking to see if the battery pack is working properly. Is the battery pack's green power light on? If not, here are a few things to check:

3a. Is the battery pack switched on? Make sure the switch at the top of the battery pack is flipped to the left, and that the green light is on.



3b. Are the batteries inserted properly? There should be three AA batteries placed in the battery pack like this with the + side (nub side) facing left:



3c. Is the red "low battery" light on or flashing? Is the green light flashing on and off? This usually means the batteries are running really low. The Chibi Book is trying to find the power to run your circuit, but exhausting itself and shutting down, only to try again after a short rest. Try placing fresh batteries into the Chibi Book's battery pack. The Chibi Book works best with alkaline or NiMH rechargeable batteries!



ONCE WE KNOW POWER IS GETTING TO THE CHIBI CHIP, WE CAN CHECK THE REST OF OUR CIRCUIT FOR OTHER PROBLEMS!



CIRCUIT

Is the Chibi Chip powered on, but the LEDs are still not turning on as expected? There might be a bug in the connections of our circuit! Maybe the circuit is incomplete because we forgot to make a connection, or the connection is faulty. Or maybe something is connected that should not be, causing a short circuit.



LET'S TAKE A LOOK AT SOME COMMON CIRCUIT BUGS!

1. Are your Chibi Light LEDs installed in the correct direction? Make sure that the pointy (-) end of every LED is connected to GND, and the wide (+) side of every LED is connected to a numbered pin or +3V. Otherwise, the LED is installed backwards, and it won't turn on.



YAY!



NOPE.

2. Are any LEDs causing a short circuit? Make sure that the shiny metal pads of your LEDs are touching only one strip of copper tape. If one pad of an LED is touching two different copper wires, then there is a short circuit and your light will not turn on. In the example below on the right, the wide (+) side is accidentally touching both GND and +3V, causing a short circuit!



YAY!



NOPE.

D-6

3. Is there enough overlap between the pads of your LED and the copper tape? There needs to be plenty of overlap between the metal pad of your LED and the copper tape for there to be a strong electrical connection. If the overlapping area is too small, then power can not flow to the LED.



YAY!



NOPE.

4. Are all the LEDs stuck down firmly? The conductive adhesive used on circuit stickers require a good press to make a solid connection. So, try pressing down on the metal pads of your LEDs to make the connection stronger. If an LED turns on when pressed, and off after letting go, that means there's a weak connection between the copper tape and the LED's metal pads.



If you have more than one LED connected in parallel, and only some of them are on, the most likely issue is a weak connection on the LEDs that aren't turning on. You can fix these weak connections by taping conductive fabric patches between the LED's metal pads and the underlying copper tape.



YAY!



NOPE.

5. If you've tried everything and an LED is still not turning on, try switching it out for a new LED. LEDs can break if they are creased, or if they are exposed to water, dirt, or grease.

CIRCUIT (CONT'D)

6. Is the Chibi Chip aligned properly with the circuit? Make sure the shiny metal pads on your Chibi Chip line up with and touch the copper tape of your circuit.



7. Is the copper tape really bumpy or wrinkly? If so, sometimes bumps and wrinkles can prevent solid connections to your LEDs or Chibi Chip. If this is the case, try smoothing out the tape by rolling over it with the flat side of a pen or pencil.



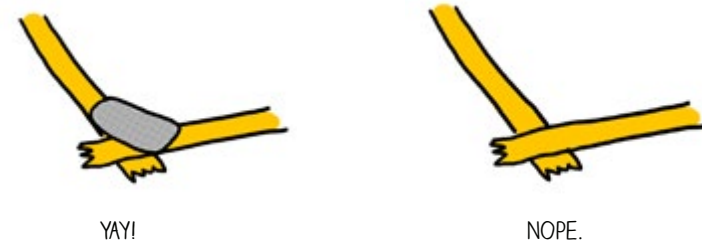
8. Is the copper tape or LED sticker not sticky anymore? Make sure your hands are clean and dry before working with the copper tape and stickers. If the stickers or tape get dirty, they may lose their tack, causing weak connections in the circuit. If this happens, try patching weak connections with conductive fabric patches.



9. Is there a tear in the copper tape? If so, the tear breaks the circuit's connection. Fix tears and restore the connection by taping over both sides of a tear with a single conductive fabric patch.



10. Is your circuit connected at turns and corners? Copper tape often tears at turns, and it is not enough to stick two pieces of copper tape on top of each other. When making a corner using two pieces of copper tape, reinforce the connection using a conductive fabric patch after sticking down the second piece of copper tape.



Make reliable turns with a single piece of copper tape and save on conductive fabric patches using this origami trick:



1. Fold tape back, so the sticky side faces up.



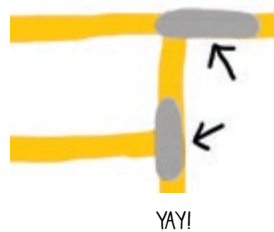
2. Flip and turn the tape at the same time.



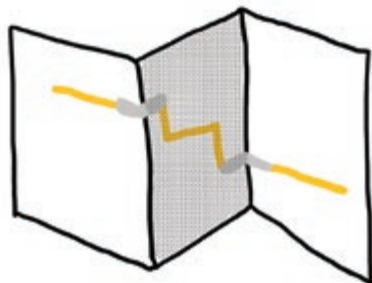
3. Flatten the corner, and you're done!

CIRCUIT (CONT'D)

11. Are there branches in your circuit, or do you need to extend your copper tape with another piece? Make sure to use a conductive fabric patch to connect multiple pieces of copper tape. Just sticking two pieces of copper tape on top of each other will not create a strong or reliable electrical connection. Even if the circuit seems to work at first, over time the connection will break down.



12. Do you have a moving hinge in your circuit? Make sure to reinforce it with a conductive fabric patch. Tears are especially common at places where the copper tape gets folded repeatedly. Copper tape will crack when folded too many times.



FABRIC PATCHES WON'T DEVELOP CRACKS EVEN WITH REPEATED FOLDING, SO THEY'RE GREAT FOR REINFORCING MOVING OR BENDING PARTS OF A CIRCUIT!

13. Is a switch not responding when pressed? If so, make sure that the copper tape on the switch actually lines up with the gap in the circuit. If it's not aligned, the copper tape won't close the circuit when the switch is pressed, and the switch will not work.



Make the copper tape patch large and the circuit gap small. This makes it easier for your switch to close the circuit. This is especially important for more advanced switches, such as the wind sensing switch (page 3-28), where the switch isn't actually pressed by hand.

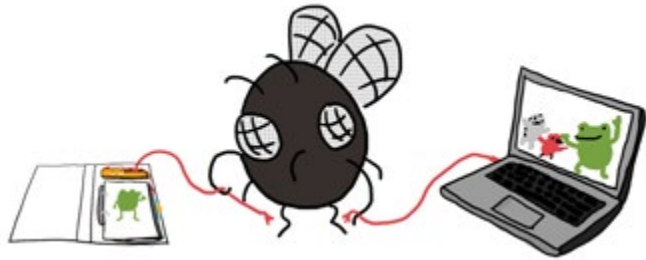


14. Is the switch sometimes working and sometimes not when pressed? That means the switch connection is unreliable. Check that the copper tape is smooth and clean on both halves of the switch. Then, try ways to increase the pressure between the pieces of copper tape in your switch.

For example, in the pocket character switch (page 3-31), if you use a thicker paper, this will make the switch stiffer and more springy. This applies more pressure to the connection, helping to make your switch more reliable.

UPLOAD

Even if the circuit is done, the Chibi Chip needs to be programmed correctly for our project to work. Sometimes there are problems when we try to send code from our programming device to the Chibi Chip. Here's how to check if this is an issue!



We test the upload process by trying to upload the Blink example program. Save any code you've written and open up the blink example code by selecting **Examples** → **Blinky**. We start with this known code because it's easy to tell if it's working properly. If the upload is successful, we will see pin 0 blink!



If the basic blink didn't upload, let's check out some possible reasons why:

1. Is the volume turned up all the way up? Is the sound accidentally muted? Make sure to unmute your sound and turn the volume all the way up so that the Chibi Chip can hear the code. One of the most common upload problems is that the audio is simply too quiet!



2. Is the code being converted into sound? Click the "Upload" button. Within a few seconds, this orange "sound banner" should appear at the bottom of the screen:



If the sound banner does not appear, the code is not being translated into sound. If this happens, try refreshing the browser. Then, re-open the blink example code, and click "Upload" again.



3. Can your browser play web audio? Try unplugging the audio cable from your programming device for a moment, turning the volume up to its maximum level, and clicking upload. When the sound banner appears, you should hear a staticky sound. This staticky sound is the code that the Chibi Chip is listening for.



If you can't hear the code playing, try testing to see if your browser is compatible with the Love to Code system. To run the test, visit ltc.chibitronics.com/test and click on the "Test Audio" button. If you hear a short tune play, that means your browser is compatible. If not, try switching to an up-to-date version of Chrome, Firefox or Edge.



Welcome to the Chibitronics browser compatibility test!
Tap the "Test Audio" button above.

UPLOAD (CONT'D)

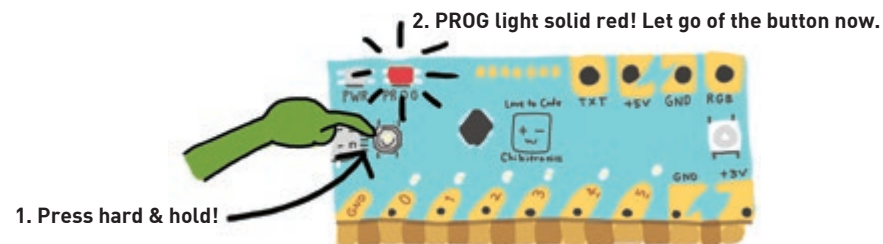
4. Is the audio being distorted? Some laptops automatically apply audio “enhancements” (such as Dolby Audio or bass boost). These enhancements will distort sound in a way that the Chibi Chip may not be able to understand. If you have a Windows computer, particularly those made by Lenovo, try following these instructions to disable pre-loaded audio distortions:



5. Do you hear a static sound while programming the Chibi Chip? That means your audio cable isn’t plugged all the way in. Make sure to push the audio cable all the way into your programming device, so that the Chibi Chip is hearing the code, and not you!



6. Is the Chibi Chip in program mode? Before clicking upload, make sure to press and hold the programming (PROG) button on the Chibi Chip until the PROG LED blinks and stays red. Otherwise the Chibi Chip won’t know to listen for new code.



7. Is the Chibi Chip hearing the audio code? During upload, the red PROG light on the Chibi Chip should blink to show that it hears the code. If the PROG light stays solid red, even though the sound should be playing, it means the audio is not making it to your Chibi Chip. If this is the case, try turning up the volume on your device and check that sounds are playing (**Step 3**).



8. Does the PROG light turn green? If so, that means the upload is successful. If your project still isn’t behaving as expected, try checking the circuit or the code!



If the PROG light just blinks red, but never turns green that means your Chibi Chip heard some of the sounds, but was not able to hear the entire program. Check again that your volume is turned all the way up (**Step 1**), and check for hidden add-ons or plug-ins that could be distorting the audio (**Step 4**). Furthermore, if another kind of device works, this means there is likely some kind of distortion in your programming device’s audio path.



8. Still stumped? Send us a note at help@chibitronics.com and we’ll try our best to debug with you!



CODE

Sometimes there will be errors in our code that makes our circuits do something other than what we intended. If so, we have to debug our code!

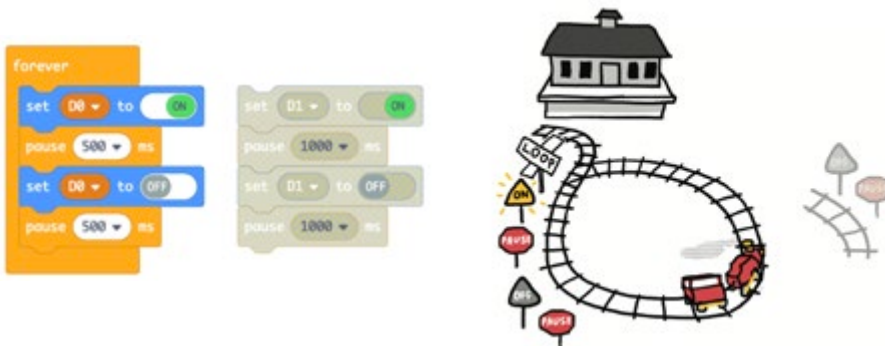


DEBUGGING CODE CAN OFTEN BE A LONG AND FRUSTRATING PROCESS, BUT REST ASSURED, IT'S REALLY SATISFYING WHEN YOU FINALLY FIGURE OUT WHAT'S WRONG AND GET YOUR PROJECTS WORKING!

The MakeCode block programming editor helps us out by preventing punctuation errors and many other "syntax" errors. However, we can still run into issues where some of our code won't be able to run as written.

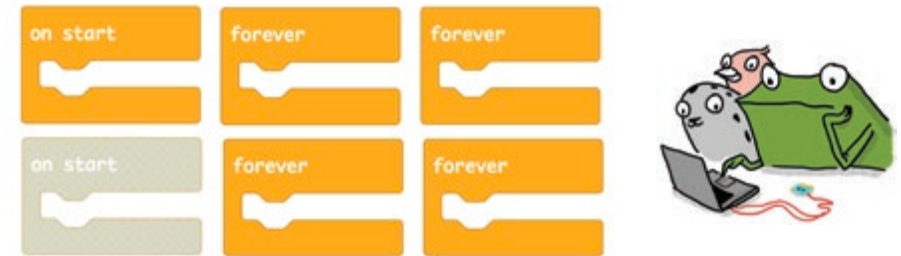
Is some of your code grayed-out?

If some of your code is grayed out, it indicates that this code won't run. One example that you've seen before is when you have code that is not snapped inside an enclosing block (such as a "forever," "on start," or "when pressed"). Without an enclosing block, these blocks are like train tracks that aren't connected to the main track. The train won't run on them!

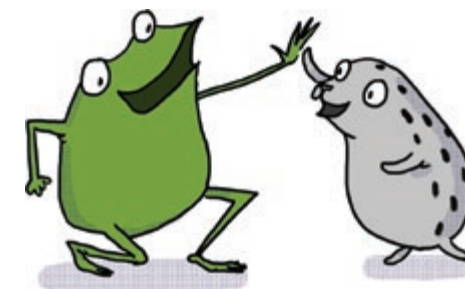


Of course, it's fine to keep grayed-out blocks in the programming area if you don't want that part of the code to run; for instance if you want to test something out without that code.

Another situation in which you might see grayed-out code is if you try to use more than one "on start" block. You can use as many forever blocks as you like, but only one "on start." Otherwise, your program wouldn't know which one to start with!



One more place you might see grayed-out code is if you have more than one of the same "when _" event block for the same pin. Double-check if you meant to include a "when pressed" and a "when released," or use a different pin number for each.



CODE (CONT'D)

Code uploaded properly, but not behaving as intended? That means the code is running, but it is not instructing the circuit to do what you had in mind. This type of error is called a **logic error**.



Logic errors can be challenging to spot and fix because we have to figure out our error based on the unexpected behavior of our circuit.



Some logic errors can be quick to spot. Here are a few examples of common logic errors:

1. Are there enough delays? If there are not enough delays in your program, or if the delays are not long enough, the logic might be running as intended, but the effects are happening too quickly for us to see.



2. Do the pins in the code match the pins in the circuit? It's easy to forget which pin was used when crafting a circuit. For example, when adding a switch, make sure to update the pin number in the example code to match the pin number you've wired the switch to!



CODE (CONT'D)

Most logic errors are hard to spot. But don't worry: finding bugs and fixing them is all part of learning to code! Here are some tips for finding the trickier bugs:



1. Pretend to be the Chibi Chip, and trace through the code line by line.

Tracing through a program slowly can help catch many bugs. For example: "set light on", "pause 1 second", "set light off", "loop ends, repeat", "set light on" - Aha, I was missing a pause after the "light off!", so the light turned off and on so quickly I couldn't see it!



2. Test one change at a time. If you make several changes at once, you may not know which change actually fixes the problem. Also, sometimes changes can introduce new bugs, so even if one change fixed the bug, the other change could have broken it again!



3. Reduce your code to the simplest possible version to isolate a bug.

Just as we broke our Love to Code projects into power, circuit, upload and code portions to simplify debugging, we can break a program down into smaller pieces of code so it's easier to work with.



For example, if you have a program that is blinking five lights, but one of those lights is not working, save your program into a new file or drag away some of the code so that it is grayed-out. Then simplify the code so that it controls only the single light that's having problems.



Once you figure out what's going on with the simple code for one light, you can refer to your original version and apply the fixes, testing each change as you go.



CODE (CONT'D)

A useful tool for finding and fixing bugs is to add a little extra code in your program that helps monitor the Chibi Chip's progress in running your code. For example, we could insert a bit of code that sets a LED on and off at a specific point in a program.



If the LED blinks, that means the Chibi Chip is able to run up to that part of the code. Likewise, if the LED doesn't blink, it means that the code leading up to the blink isn't being run. This way, we can use the blinking LED as an indicator for tracing through our code. If possible, try to use an LED that you aren't already using in your project! Below is a starting point for a blinkometer that you might find handy:

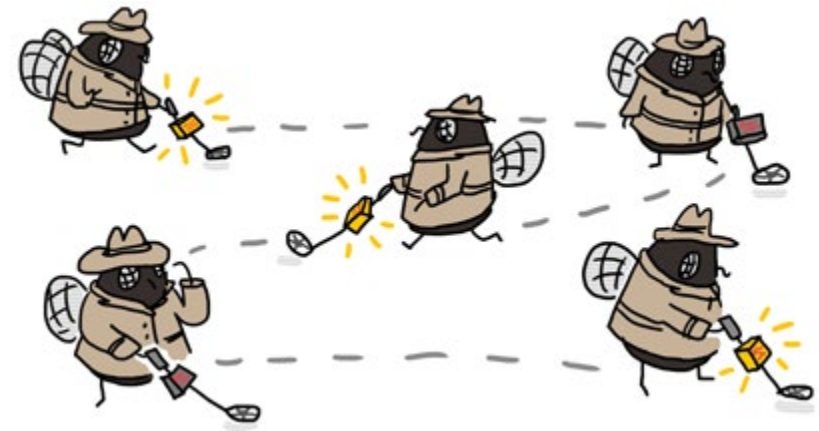
Insert this code snippet into your full program. It will blink pin 4 when it reaches that part of the code.



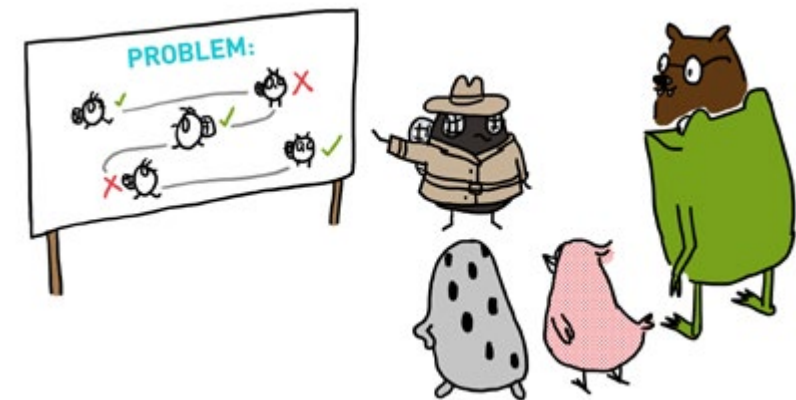
```
set D4 to ON
pause 500 ms
set D4 to OFF
pause 500 ms
```

The whole process looks like this:

- 1) Start from the very beginning and insert the LED blink code to establish that uploading is working, and that the blink code works.
- 2) Move the blink code a few lines down and upload the code again.
- 3) If the blink code didn't trigger, look before that point for clues on why it didn't get there.
- 4) If the blink code did trigger, move the blink code a little further down in the program and upload again.
- 5) Repeat steps 2-4 until you've found all your bugs!



Finally, debugging a program is not something you have to do alone. **Try explaining the problem you are having out loud to someone else.** Often you will catch the issues even before you finish explaining. If not, the other person may be able to offer suggestions or ask helpful questions. This technique is effective even if the other person hasn't coded before! In fact, some programmers use a technique called "rubber duck debugging" where they first try explaining their problems to a rubber duck.



Instead of simply saying "my code is not working" or "my code is broken!", break your story down into specific intentions and observations: "this is what I expected my code to do, but it's doing this instead." This helps clarify what you're trying to debug, and will also make it easier for someone else to help you.

CODE (CONT'D)



Debugging is an important programming skill! Don't worry if it takes you a while to solve a problem, you are building useful skills in the process, while growing to understand coding better!

...AND BEYOND

The debugging suggestions we shared in this chapter are only some of the most common tips meant to help you get started with the debugging process. For more debugging resources, check out our website at chibitronics.com/lovetocode.



Don't worry if it's frustrating at first. Debugging is a skill that takes some patience but you get better at it as you debug more projects. It can also be fun to create (and debug) with a friend. Fresh eyes can catch things that we don't see ourselves, so reach out and ask others for help too!

HAVE MORE QUESTIONS?
DROP US A NOTE AT
HELP@CHIBITRONICS.COM



Conclusion

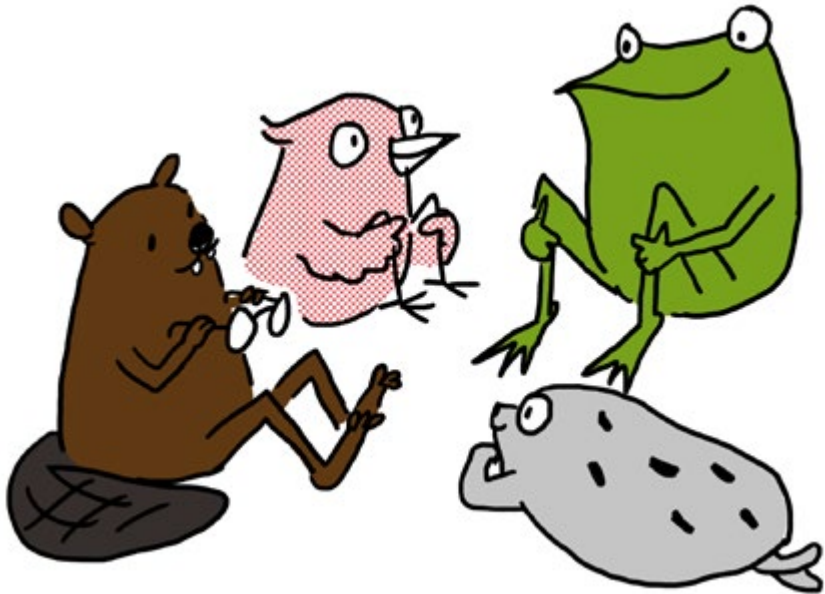
“We’ve made so much stuff!” said Fern.

“You’re the one who did it all,” said Edith.

“We just helped,” said Carmen.

“Even though you thought you couldn’t,” whispered Sami.

Fern smiled.



Together we've learned how to:



Turn on an LED light using our Chibi Chip

Add multiple LEDs to a project and make them all blink



Control our lights with various kinds of crafted switches

Fade lights in and out gradually, and make fun patterns with the LEDs using multithreading



Debug and fix our projects when something doesn't work!

"This is just the tip of the iceberg," said Sami. "We can do so much more!"



Ready for more? Here's a preview of other adventures waiting for you to take with Fern and friends:



Control circuits using a light sensor! Learn how to make projects that can respond to light and dark.

Make projects even more vivid and interactive using special LEDs that can be programmed to any color of the rainbow!



Check out: chibitronics.com/lovetocode for new chapters, new stickers, and more!

Join the party! Go to chibitronics.com/projects to see community projects and to share your own!



Happy making and see you again soon!

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