EXPERIMENT MANUAL

GAMING ■ CODING ■ MAKING

CODE GAMER

with KosmoBits

THAMES & KOSMOS

620141-03090816

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100 10
1010
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››› IMPORTANT INFORMATION

Safety Information

WARNING! Only for use by children aged 10 years and older. Instructions for parents or other supervising adults are included and have to be observed. Keep the packaging and instructions as they contain important information.

WARNING! Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled.

Dear Parents and Supervising Adults,

This experiment kit will introduce your child to the exciting world of programming in a fun way.
Please be available to provide your child with help, advice, and support.

It is natural to have questions about safety. This kit meets U.S. and European safety standards. These standards impose obligations on the manufacturer, but also stipulate that adults should provide their children with advice and assistance during the experiments.

Tell your child to read all the relevant instructions and safety information, and to keep these materials on hand for reference. Be sure to stress the importance of following all the rules and information when performing the experiments.

We wish your child, and of course you as well, lots of fun and success with the experiments!

FCC Part 15 Statement

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications.
However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
• Reorient or relocate the receiving antenna.
• Increase the separation between the equipment and receiver.
• Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
• Consult the dealer or an experienced radio/TV technician for help.

Shielded cables must be used with this unit to ensure compliance with the Class B FCC limits.

FCC RF Exposure Statement

To comply with the FCC RF exposure compliance requirements, this device and its antenna must not be co-located or operating in conjunction with any other antenna or transmitter.

For body worn operation, this device has been tested and meets FCC RF exposure guidelines when used with an accessory that contains no metal and that positions the device a minimum of 5 mm from the body. Use of other accessories may not ensure compliance with FCC RF exposure guidelines.

IC Statement

RSS-Gen & RSS-247 statement:
• This device complies with Industry Canada licence-exempt RSS standard(s).
• Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.
• Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence.
• L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

RSS-102 Statement:
• This equipment complies with Industry Canada radiation exposure limits set forth for an uncontrolled environment.
• Cet équipement est conforme à l'exposition aux rayonnements Industry Canada limites établies pour un environnement non contrôlé.

Disposal of Electrical and Electronic Components
This product's electronic parts are reusable and, for the sake of protecting the environment, they should not be thrown into the regular household trash at the end of their lifespan. Instead, they must be delivered to a collection location for electronic waste, as indicated by the following symbol:
Please consult your local authorities for the appropriate disposal location.

Disposal of Battery
The battery does not belong in the household trash! In some states and countries, it is required by law to deliver batteries and rechargeable batteries to a local collection location or to a store. This will ensure that they will be disposed of in an environmentally responsible manner. Batteries containing hazardous substances are identified by this image or by chemical symbols (Cd = cadmium, Hg = mercury, Pb = lead).

Safety for Experiments with the Rechargeable Battery
››› A lithium polymer rechargeable battery is required for the experiments. Please use only the battery supplied with the kit!
››› The rechargeable battery is only to be charged under adult supervision.
››› Never perform experiments using household current! The wires are not to be inserted into socket-outlets. The high voltage can be extremely dangerous or fatal!
››› The battery is not to be short-circuited. It could overheat and explode!
››› Do not connect the battery's terminals to each other.
››› The battery is to be inserted with the correct polarity.
››› Avoid deforming the battery.
››› The battery is to be removed from the toy if it is defective.
››› Keep the kit out of the reach of small children.
››› When assembling the device and installing the battery, follow the instructions in this manual in order to avoid destruction of components.

Safe Handling of Electronic Components
››› Avoid contact with metallic objects and fluids of any kind!
››› After experimenting, pack all sensitive components in the bags provided for them and keep them together with the other parts in the experiment kit box.
››› If the KosmoBits hardware is not to be used for a long period of time, please disconnect the battery's connection wire from the interaction board.

The toy is only to be connected to Class II equipment bearing the following symbol:

Simplified EU Declaration of Conformity
Thames & Kosmos hereby declares that the KosmoBits radio communication unit model 620141 conforms to Directive 2014/53/EU.
The complete text of the EU conformity declaration is available at the following Internet address: http://thamesandkosmos.com/codegamer/declaration.pdf

Kosmos Quality and Safety

More than one hundred years of expertise in publishing science experiment kits stand behind every product that bears the Kosmos name. Kosmos experiment kits are designed by an experienced team of specialists and tested with the utmost care during development and production. With regard to product safety, these experiment kits follow European and US safety standards, as well as our own refined proprietary safety guidelines. By working closely with our manufacturing partners and safety testing labs, we are able to control all stages of production. While the majority of our products are made in Germany, all of our products, regardless of origin, follow the same rigid quality standards.

1st Edition 2016
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Manual photos: picsfive (all pushpins); askaja (all paper clips); Jaimie Duplass (all tape strips) (all © fotolia.com); 8vFanl (p. 61 bottom right); hopsalka (p. 61 top); krista (p. 2 bottom left, p. 21 bottom right); tepic (p. 20 bottom) (all © iStockphoto.com); Designua (p. 38 bottom) (© shutterstock.com); leejeongsoo (p. 35 bottom); theSOARnet (p. 38 top); Petr Kratochvil (p. 33 top) (all © pixabay.com); Johannes (p. 2 center right, p. 21 top right); Willi Heidelbach (p. 27) (all published under CC BY-SA 2.5, viewable under https://creativecommons.org/licenses/by-sa/2.5/deed.de); Philip Steffan (p. 60 all, © Make magazine); all screenshots of the Arduino program © Arduino; Andreas Resch, argfx, St. Ulrich am Waasen (front cover, p. 1 rendering gamepad, p. 1 and p. 32 SensorBots); Michael Flaig, proStudios, Stuttgart (p. 1 additional materials); Matthias Kaiser, Stuttgart (all other photos)

Packaging design concept, layout and typesetting: Michael Schlegel, komuniki, Würzburg
Packaging photos: Andreas Resch, argfx, St. Ulrich am Waasen (all renderings); Michael Flaig, pro-studios, Stuttgart (materials photo)

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Translation: David Gamon; Editing: Camille Duhamel and Ted McGuire; Additional Graphics and Layout: Dan Freitas

Distributed in North America by Thames & Kosmos, LLC. Providence, RI 02903
Phone: 800-587-2872; Web: www.thamesandkosmos.com

Distributed in United Kingdom by Thames & Kosmos UK, LP. Goudhurst, Kent TN17 2QZ
Phone: 01580 212000; Web: www.thamesandkosmos.co.uk

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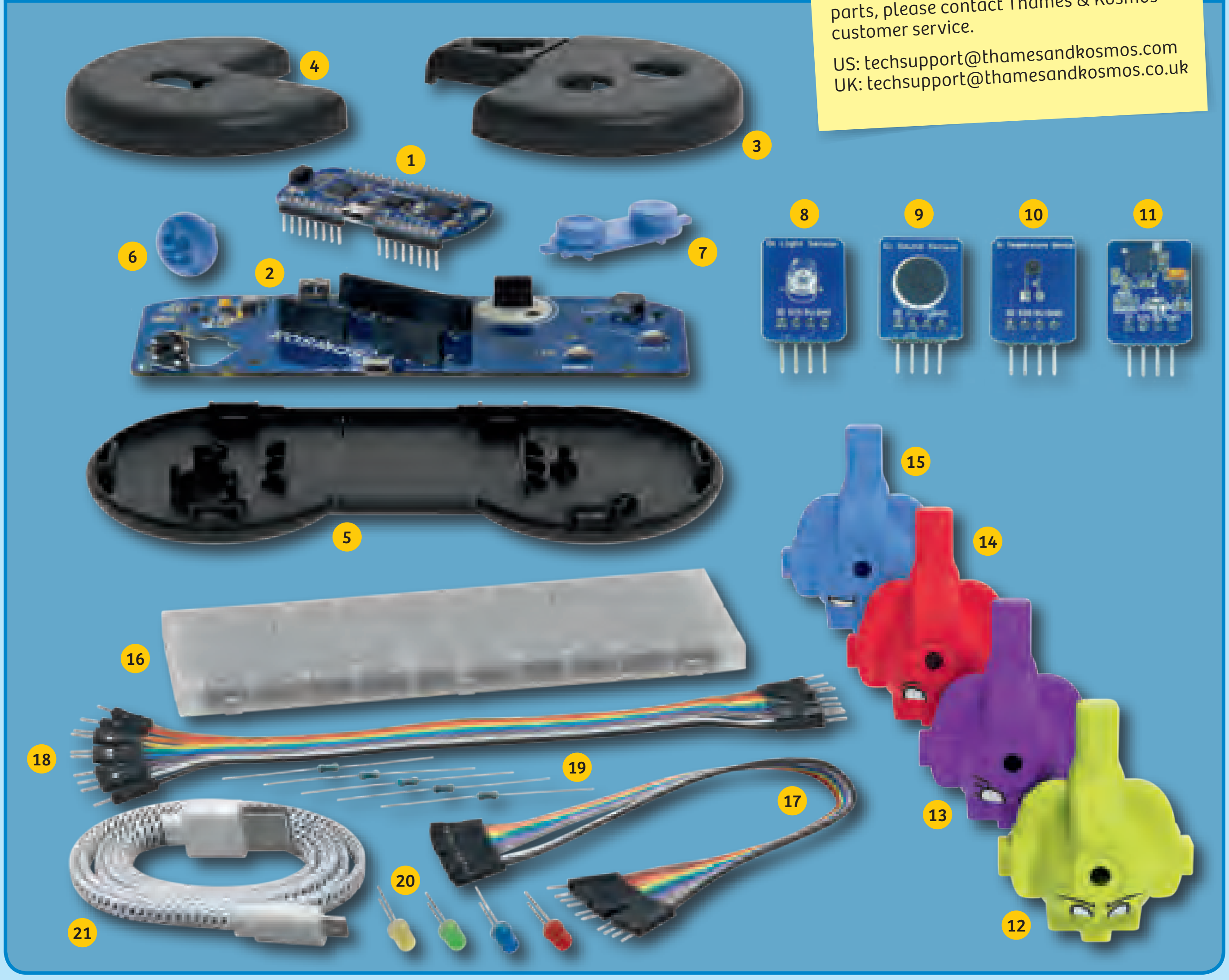
Printed in China / Imprimé en Chine

››› KIT CONTENTS

What's inside your experiment kit:

GOOD TO KNOW! If you are missing any parts, please contact Thames & Kosmos customer service.

US: techsupport@thamesandkosmos.com
UK: techsupport@thamesandkosmos.co.uk



Checklist: Find – Inspect – Check off

✔	No.	Description	Quantity	Item No.
❍	1	KosmoDuino	1	717 982
❍	2	Interaction board	1	717 981
❍	3	Gamepad housing, top right	1	718 006
❍	4	Gamepad housing, top left	1	718 007
❍	5	Gamepad housing, bottom	1	718 005
❍	6	Wheel with return spring	1	718 008 718 009
❍	7	Buttons with rubber feet	1	718 010 718 011
❍	8	Light sensor	1	717 985
❍	9	Sound sensor	1	717 986
❍	10	Temperature sensor	1	717 984
❍	11	Motion sensor	1	717 983
❍	12	Housing for sound sensor	1	718 000 718 004
❍	13	Housing for light sensor	1	717 999 718 003
❍	14	Housing for temperature sensor	1	717 997 718 001
❍	15	Housing for motion sensor	1	717 998 718 002
❍	16	Breadboard	1	717 996
❍	17	Jumper wires male-female	10	717 990
❍	18	Jumper wires male-male	10	717 989
❍	19	Resistors: 330 Ohm	5	717 991
❍	20	LEDs: yellow green blue red	1 each	717 994 717 993 717 995 717 992
❍	21	Cable: USB to Micro-USB	1	717 988
❍	22	Lithium polymer battery, 800 mAh (not shown)	1	717 987

You will also need:

Smartphone or tablet with Android (4.3 or later) or iOS (Version 7 or later). The device must support Bluetooth 4 or higher. PC with Internet access.

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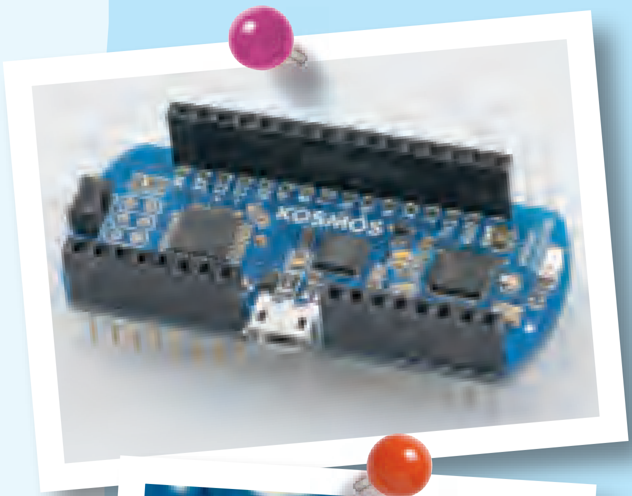
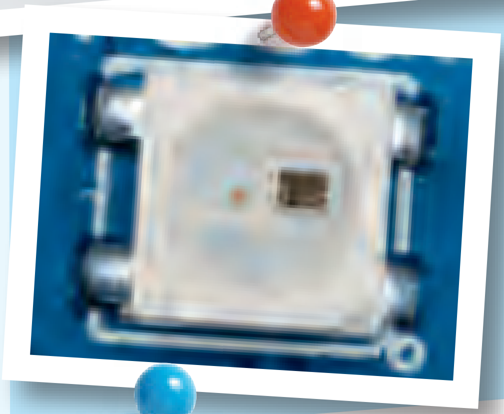
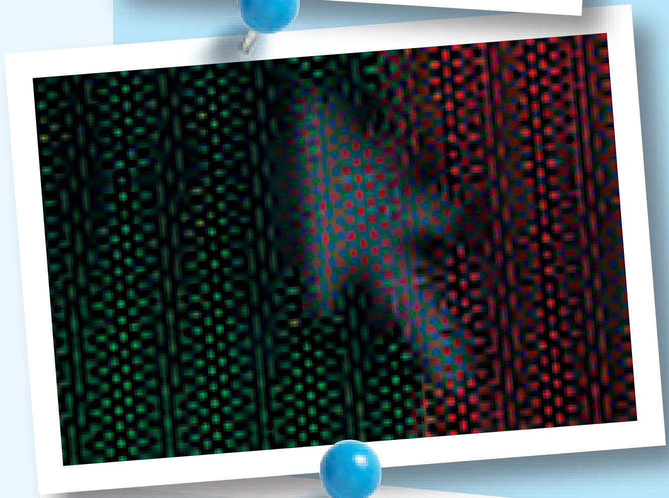
››› TABLE OF CONTENTS

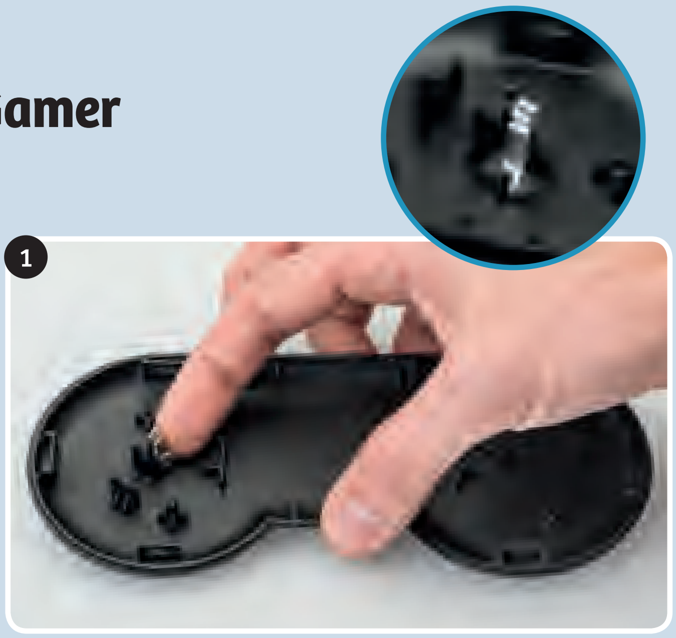




TIP!
You will find additional information on the "Check It Out" pages (21, 59-61) and "Knowledge Base" pages (24-25, 35, 41-42, and 58).

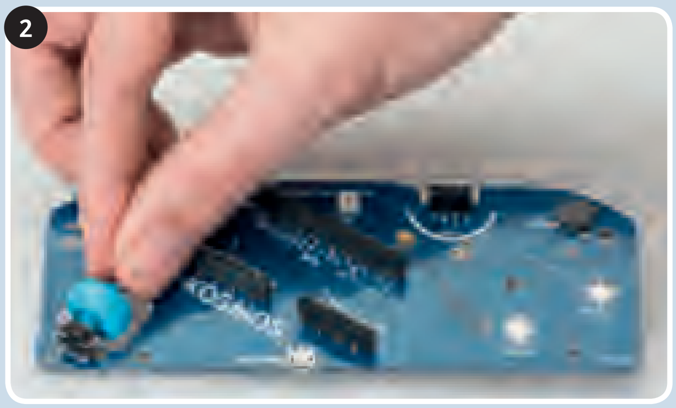
How to get started with CodeGamer

ASSEMBLING THE GAMEPAD

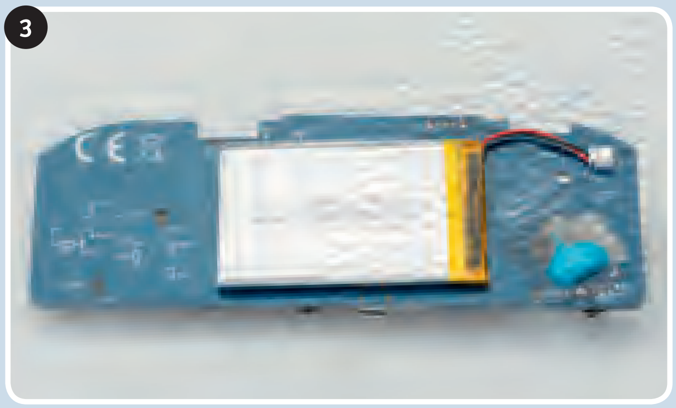
1. First of all, you will have to insert the little metal spring into its correct location in the left area of the bottom part of the housing. The spring will hold the wheel and ensure that it always returns to its original position.

1


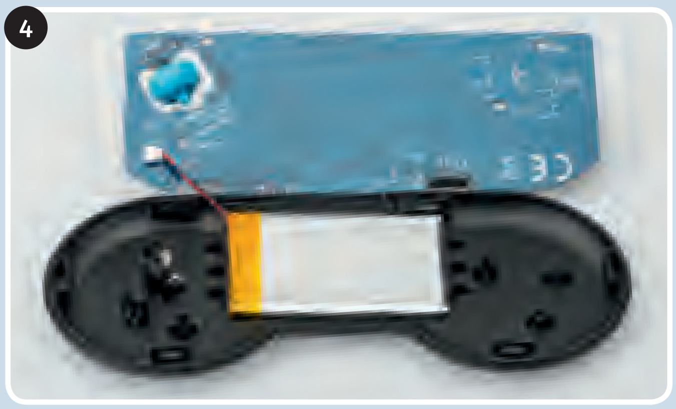
2. Next, you will have to insert the narrow axle of the wheel into the rotation encoder hole. The rotation encoder is attached to the interaction board and marked there.

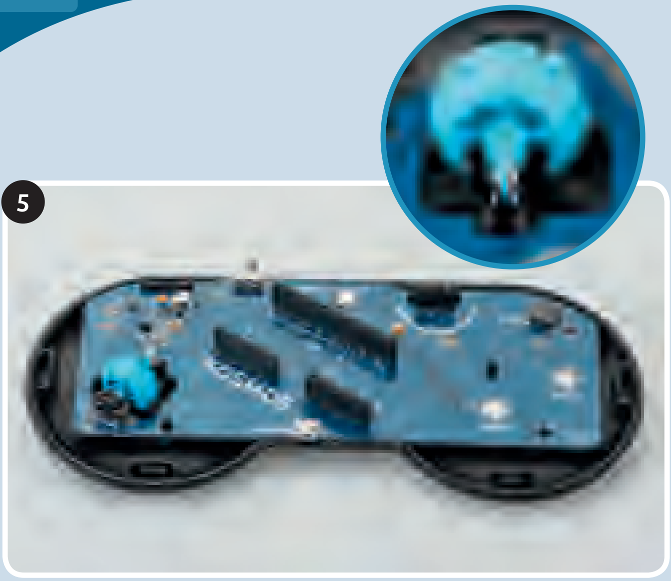
2


3. Connect the battery to the interaction board. The attachment is on the bottom side. The battery's plug is shaped in such a way that it can only be connected in the correct polarity direction. Do not force it!

3


4. Now place the battery in the lower housing of the interaction board. Insert it so that it is securely mounted and does not jiggle.

4
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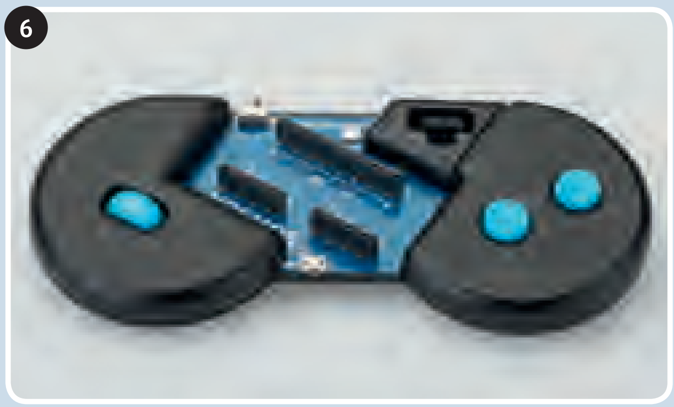
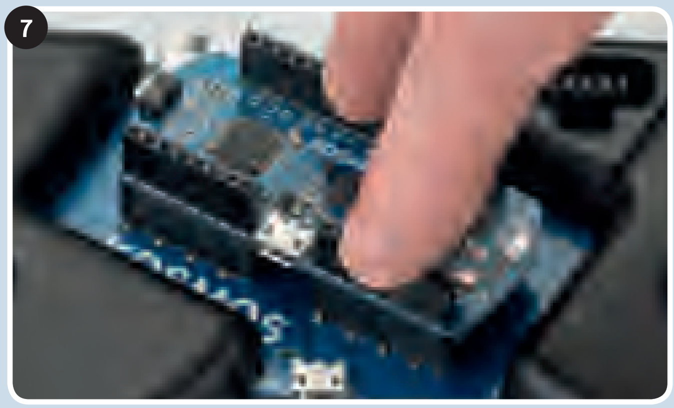
5. Now you can insert the interaction board into the housing. Be sure that the wheel is mounted correctly in the spring (see image in circle).

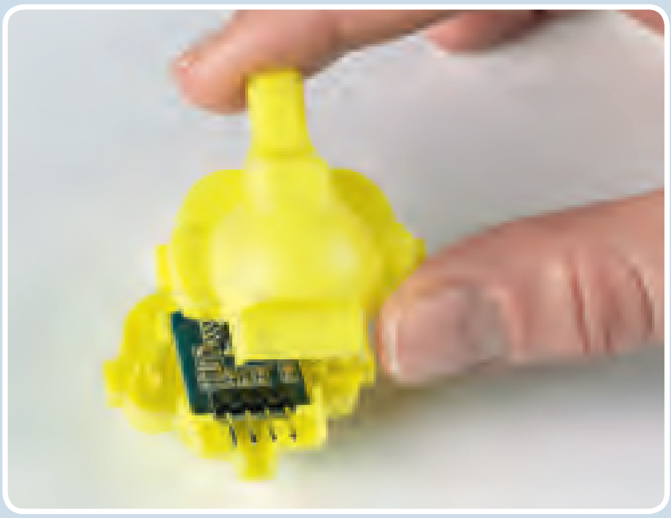

6

6. Attach the gray rubber feet onto the bottom of each button. To do this, simply insert the thinner side of the rubber foot into the recess on the bottom of the button.

Then, insert the button plate into the right upper gamepad housing. Be sure that the buttons are positioned correctly. You know that everything is correctly placed when you feel an explicit trigger point when the buttons are pushed. Then, attach the left upper housing.


7

7. Your gamepad is now completed except for its “control center,” the KosmoDuino. You can simply attach this to the interaction board. Make sure that all the pins fit and do not bend when you attach it. Press the KosmoDuino far enough in that its “feet” (the metal pins) are no longer visible.



ASSEMBLING THE SENSORBOTS

1. Take one of the sensors and look for the housing with the matching color (see page 1, “Kit Contents”). Insert the sensor front side forward into the half of the housing with the eyes printed on it. The sensors’ “feet” (the metal pins) are always closer to the back side.
2. Now all you have to do is attach the rear of the housing to the front part. To do that, just press the two parts firmly together.

SYSTEM REQUIREMENTS:
KosmoBits supports devices with Android 4.3 and iOS 7 operating systems or later. The device has to support Bluetooth 4 or higher.

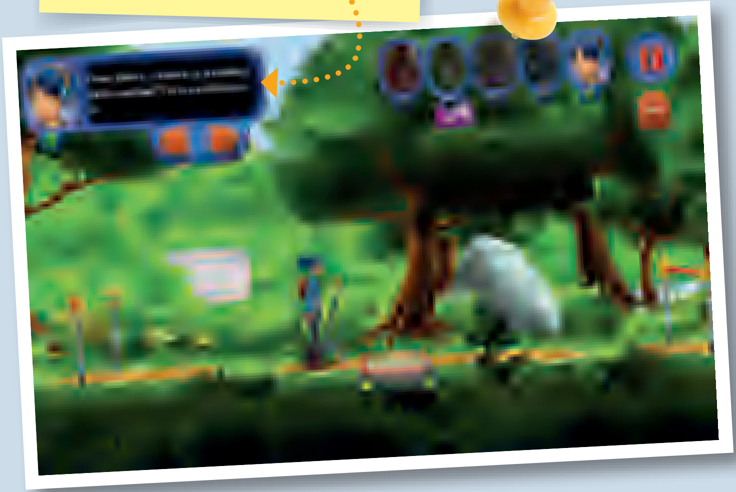
THE APP

To ease your entry into the world of programming, we have developed an app to help you start building experience in this area.

The core of the app is a video game in which you have to solve little programming puzzles. But don't be afraid — they aren't hard, and you will definitely be able to figure them out. The key to solving the puzzles lies with the **code monsters** that you will find at every level. **Collect them all,** because you will need them at the **computer terminals.** The computer terminals contain incomplete code. To fill in the blanks, you will need to **drag the correct code monster into the matching blank spaces.** To learn more about the monsters, just **tap once or twice on them in your inventory** — and they will tell you which blank space in the code they will complete.

Use your gamepad to control the characters in the game. To do this, you must have **Bluetooth** activated on your tablet or smartphone. Start the app and switch on the gamepad by sliding the switch at the upper edge to the "ON" position. The connection will then be made automatically in a few seconds. Once the connection is active, the **control elements** (arrows and A and B buttons) will disappear from the screen and you can control the app with just the gamepad. If you switch off your gamepad, the control elements will reappear. But the game is not nearly as much fun without the gamepad!

Important! Take the time to read the information, tips, and hints presented in the communication console here.



◄▲ *Various CodeGamer App screenshots*

!

HOW TO DOWNLOAD THE FREE APP:

To install your app, you will need access to Google Play or the Apple App Store. Ask your parents or adult supervisor for help installing the app.

If your device runs on Android, open Google Play. Open the App Store with an iPhone or iPad. Just enter the search term CodeGamer and install the app.

Download on the App Store

GET IT ON Google Play

You will need your **four sensorbots** to play the game. They are very handy for helping to **clear obstacles** out of your way in the game. You can simply insert them into your gamepad (see picture). As soon as you have inserted a sensorbot, your game character will turn into one of the four bots. Each one has its own special abilities. If you have inserted the blue "Newton" bot, for example, you will have to shake your gamepad vigorously back and forth to activate its abilities. We will let you find out on your own how to activate the special abilities of the other sensorbots.

Play the game once through and take a look at the other contents of the app in the main menu. You will find a lot there about your experiment kit and the topic of programming.

We hope you have a lot of fun experimenting with code!

The World of the Microcontroller

Welcome to the world of the microcontroller! It looks astonishingly similar to your own world. Or more precisely: It looks exactly like your own! All around you, there are countless microcontrollers going about their work unnoticed. There's hardly any electronic device that works without a microcontroller — an electrical toothbrush, the remote control for your TV, the controller for your video gaming system, a digital thermometer, a talking doll, a barking toy dog, the washing machine, the smoke detector, the toaster, and so on ...

▲ *KosmoBits controller*

BUT WHAT IS A *MICROCONTROLLER?*

A **microcontroller** is a small ("micro") computer. But it is also fundamentally different from the computers that you normally deal with: It has no keyboard, no mouse, and no screen.

Instead, it has a lot of little feet, known as **pins.** A pin is something like a connection between the microcontroller and the outside world. Some of the pins have specified functions. Most, however, are so-called **GPIO pins.** That's an abbreviation for **G**eneral **P**urpose **I**nput/**O**utput. These GPIO pins can be used for both inputs and outputs. And that's just what you need here.

1. INPUT:

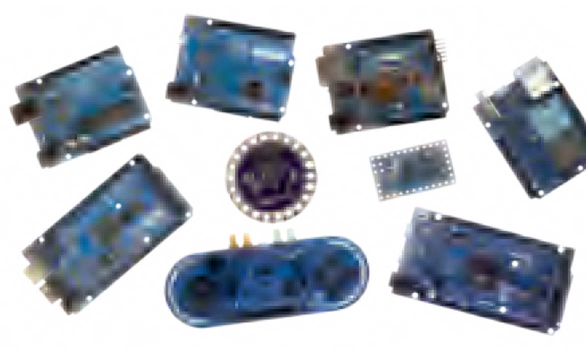
You can connect an input pin to a sensor, for example. This will monitor the outside world and send information about the surroundings, temperature, or brightness to the processor via fluctuating levels of electrical voltage. In your gamepad, an input pin is also activated when you press a button.

2. OUTPUT:

Depending on how it is programmed, the processor can also respond to this information. For that, you will need output pins to establish the connection to LEDs or the sound module, which will then react to the level of the transmitted electrical voltage by emitting various sounds or colors.

Things really get exciting when you use several pins at the same time. That way, the microcontroller can react to the sensors all on its own — for example, by sounding an alarm when it gets too hot.

The thing your microcontroller has in common with a normal computer is the main processor that serves as the brain of any computer. That's the little black square at the top left of your microcontroller. In the middle, there is a small processor. This is what is responsible for the communication between the microcontroller and the PC. At the right is the Bluetooth chip, which enables wireless connections with other devices.



WHAT DOES ARDUINO MEAN, ANYWAY?

In this instruction manual, you will come across the word "Arduino" a lot. That is the name for a widely-used microcontroller platform on which the KosmoDuino was based.

For a long time, microcontroller programming was only for specialists. In 2005, the founders of the Arduino project took it upon themselves to make the programming and use of simple microcontrollers as easy as possible. That way, art students and hobbyists who had never before had any experience with programming would be able to use microcontrollers in their work.

Since then, a large ***community*** *has formed around the Arduino platform and lots of interesting projects have developed out of it. You can copy a lot of them with your KosmoDuino, which is compatible with an Arduino Uno board.*

You can learn more about the Arduino project at www.arduino.cc.

Important! You must download and install the Arduino application from:
https://www.arduino.cc/en/main/software

and you must download and install the Kosmobits libraries and programs from:
http://thamesandkosmos.com/codegamer/kosmobits_archive.zip

THE KOSMOBITS CONTROLLER

With your **KosmoBits controller**, you are holding your very own microcontroller in your hands. We named it **KosmoDuino** because it is based on the Arduino microcontroller. (KosmoBits is the name of the electronic system in this kit.) You can do a lot with the KosmoDuino, but first you have to learn how to **program** it. This manual will explain how.

Preparation

To program your KosmoDuino, you will need an ordinary PC or laptop with the Arduino software installed on it. The software is also called a programming environment, since it includes a lot of tools that you will need for programming.

INSTALLATION OF THE ARDUINO SOFTWARE

Download the Arduino software from **https://www.arduino.cc/en/main/software.** On that page, you will find various versions for the current operating systems. For Windows operating systems, select “Windows Installer.”

Download the Arduino Software

▲ *Download page on www.arduino.cc*

On the next page, you will be asked for a contribution. The Arduino project, which promotes the development of the Arduino software, is largely financed by these kinds of donations. You can also download the software for free without making a donation by clicking on “Just Download.”

After downloading, execute the downloaded file. Since the Arduino software is constantly being revised, there are always new versions. At the time that this manual was printed, 1.6.6 was the current version, and the file was called *arduino-1.6.6-windows.exe*. However, **we recommend working with version 1.6.5,** since this is the version that was extensively tested by us. You will find older versions on the “PREVIOUS RELEASES” page. After starting the installer, follow the instructions to complete the installation.

INSTALLATION OF THE KOSMOBITS LIBRARIES AND SAMPLES

In a **software library,** you will find lots of useful and reusable functions that will make programming easier for. The ones we developed are called the **KosmoBits libraries.** They also contain a lot of sample programs that you will find in this manual. **You must install these libraries.**

The KosmoBits libraries can be downloaded by entering **http://thamesandkosmos.com/codegamer/kosmobits_archive.zip** link into your web browser. The file is called **kosmobits_archive.zip**. This is a zip file that you will have to unzip and move into the Arduino libraries folder.

Windows:
1. Open the explorer.
2. Go to the downloads folder.
3. Double-click the *kosmobits_archive.zip* file to open it.
4. Select all the files and folders in the *libraries* folder by simultaneously pressing the “Ctrl” and “A” keys.
5. Then press “Ctrl” and “C” to copy the selected files.
6. Go to the *Documents* → *Arduino* → *libraries* folder.
7. Now simultaneously press the “Ctrl” and “V” keys to paste the files and folders into the *libraries* folder.

Mac:
1. Unzip the *kosmobits_archive.zip* file.
2. Drag the contents of the *libraries* folder into the *Documents* → *Arduino* → *libraries* folder.

On either platform, you can alternatively try installing the libraries through the Arduino application itself:
1. In the Arduino application, go to the *Sketch* menu and choose *Include Library* → *Add .ZIP Library...*
2. Navigate to the *kosmobits_archive.zip* file and click *Choose/Open.*

Okay! Now you can begin programming. You will just need to open the Arduino application to get started.

PROGRAM CODE EXPLAINED:

This is where the explanation for the program code is written. Portions taken from the code are always highlighted in `orange`.

```
Here is where the program code is written
// Comments on the code are always in gray.
// This text is not a functional part of the
// code. It provides explanation and clarity.
```

Your first program: Blink!

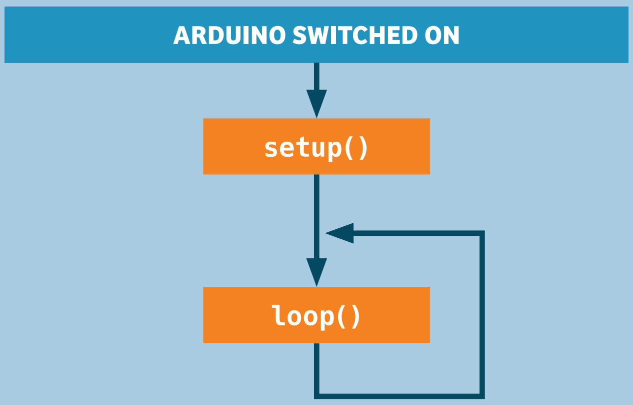
To write your first program, launch the Arduino environment on your computer. A window will open into which you can enter your program code. A few lines have already been entered for you:

```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

That is the basic skeleton for every Arduino program:

1. Your KosmoDuino starts by processing all instructions in the `setup()` **function**, i.e., all functions written in the curly brackets following `setup()`.
2. Then, the `loop()` function is invoked. That means that your microcontroller executes all instructions written in the curly brackets following `loop()`. Once the final instruction has been processed, your controller once again invokes the `loop()` function. In other words, the instructions in `loop()` are invoked over and over in an endless loop. That is why it's called a **loop function.**

You can visualize this idea a little more clearly in a **flow diagram.** The program always proceeds in the direction of the arrows: from switching on, to `setup()`, to `loop()` and then back to `loop()` again and again.



▲ *Flow diagram*

You could upload this program right away to your KosmoDuino if you wanted. But since there are no instructions in either `setup()` or `loop()`, the program wouldn't do anything.

So why not give your KosmoDuino something to do? Try changing the program code like this:

```
int ledPin = 13;

void setup() {
  pinMode(ledPin, OUTPUT);
}

void loop() {
  digitalWrite(ledPin, HIGH);
  delay(500);
  digitalWrite(ledPin, LOW);
  delay(500);
}
```

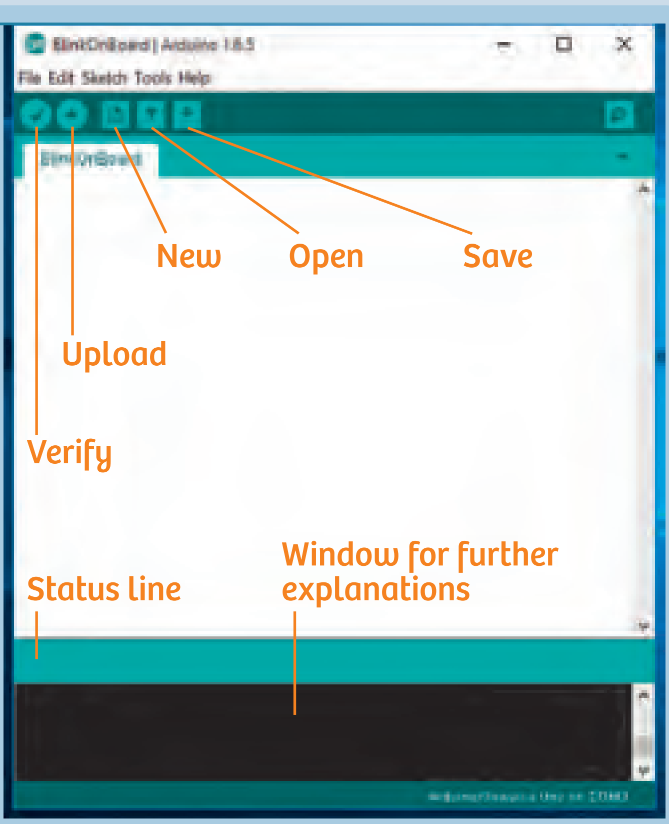
In the field of Arduino programming, the term "sketch" is often used to refer to a program. In this instruction manual, both terms will be used.

Don't let yourself be intimidated by all the strange terms and brackets! We will go through the program step by step. You will soon see that it isn't hard to understand at all! But before we can see what the program does, we have to upload it to the KosmoDuino. Follow the instructions below to learn how to do this.

UPLOADING A PROGRAM TO KOSMODUINO

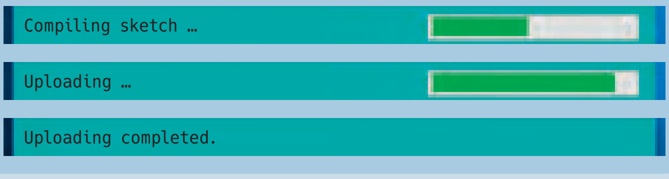
To upload a sketch to your KosmoDuino, proceed as follows:

1. Connect the KosmoDuino to your computer with the USB cable. You will not need the interaction board.
2. Save your program code if necessary. To do that, click on the "save" symbol in the Arduino environment.
3. Make sure that the correct board is selected: Tools → Board → "Arduino/Genuino Uno."
4. Make sure that you have selected the correct port: Tools → Port → e.g., "COM3" (Arduino/Genuino Uno).
5. Now click on the "upload" symbol in the Arduino environment.


BlinkOnBoard | Arduino 1.8.5
File Edit Sketch Tools Help
New
Open
Save
Upload
Verify
Status line
Window for further explanations

If you did everything correctly, the following messages should appear in sequence in the status line:

1. Compiling sketch ...
2. Uploading ...
3. Uploading completed.

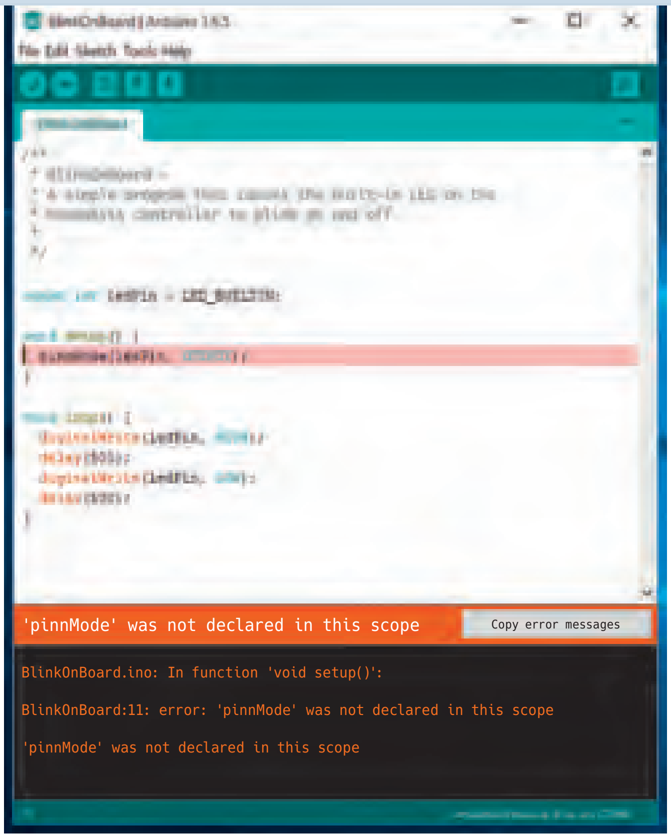


```
Compiling sketch …
Uploading …
Uploading completed.
```

*You can only ever upload one program at a time to your KosmoDuino. If you want to play the KosmoBits game with your gamepad, you will have to install the **KosmoBits_App.ino** file. This file comes pre-installed on your KosmoDuino when your kit is shipped.*

ERROR MESSAGE?

If you see an error message, take a careful look at the program text you entered. Is it possible that you wrote something incorrectly? The place where an error leads to problems in the program text is marked in red in the Arduino environment (see illustration). In any case, you should try looking for the actual error first. Even just tiny typos will lead to error messages! If you cannot find an error, then take a look at the yellow box below. There, under the "Opening the sample programs" heading, you will find an explanation of how you can use the example programs described in this manual without having to type them into the computer from scratch.



```
/**
 * BlinkOnBoard -
 * A simple program that causes the built-in LED on the
 * KosmoBits controller to blink on and off
 *
 */

const int ledPin = LED_BUILTIN;

void setup() {
  pinnMode(ledPin, OUTPUT);
}

void loop() {
  digitalWrite(ledPin, HIGH);
  delay(500);
  digitalWrite(ledPin, LOW);
  delay(500);
}
```

```
'pinnMode' was not declared in this scope

BlinkOnBoard.ino: In function 'void setup()':

BlinkOnBoard:11: error: 'pinnMode' was not declared in this scope

'pinnMode' was not declared in this scope
```

Typo: "pinnMode" instead of "pinMode!" The location of the error is highlighted in red. ▶

Did everything work? Great! If so, you will now see a little green LED — the "onboard LED" — blinking on and off on the KosmoDuino.

Opening the sample programs

All sample programs can be opened directly, so you can bypass typing them in by hand. You will find them in the Arduino environment in this menu:

File ➔ Examples ➔ KosmoBits

EXPLANATION

Now it's time to really understand the program. Let's take a closer look at it.

The first line reads: `int ledPin = 13;`

In the Arduino programming language, instructions must be closed with a semicolon (";").

This defines a variable with the name `ledPin`. Variables are important components of any program. You can save any value you like in a variable — numbers, letters, or entire words. Each variable has a name. The name allows you to invoke the saved value whenever you like.

If you want to save a value in a variable, use the equals sign ("="). The variable goes on the left side of the equals sign, while the value goes on the right. For example, `int ledPin = 13` means that the value 13 is saved in the variable `ledPin`. The way you say it is: "The value 13 is assigned to the variable `ledPin`."

Wherever you want to use the number 13 in your program, you can now write "ledPin" instead of "13."

BUT WHAT DOES `int` MEAN?

In the Arduino programming language, a variable cannot take just any value you like. The values must be of a certain **type** that has to be determined. In this case, the type is `int`. That means that the variable can take a so-called integer value.
For your KosmoDuino, those values are the whole numbers from -32768 to 32767.

```
void setup() {
  pinMode(ledPin, OUTPUT);
}
```

Here, a **function** is defined. The function is called `setup()`. When a function is invoked in the program code, all the instructions contained in it are carried out step by step. Those are all the instructions written between the curly brackets. So you can think of a function as a small sub-program.

The function `setup()`, by the way, is a special function. It is always the first thing that is automatically invoked whenever you start your KosmoDuino.

But what does the `setup()` function actually do? It invokes another function: `pinMode()`. This is the function that allows you to specify the operating mode in which a pin is going to work. In this case, the `ledPin` (pin number 13) is to work as `OUTPUT`, or the output pin.

An output pin works like a switch that you turn on or off as determined by the program. You will learn about the other possible operating modes in later projects.

If the instructions in `setup()` have been processed by your KosmoDuino, the next thing to be invoked is the `loop()` function. Let's take a look at what this function contains:

```
void loop() {
  digitalWrite(ledPin, HIGH);
  delay(500);
  digitalWrite(ledPin, LOW);
  delay(500);
}
```

!

FUNCTIONS

Functions allow you to divide up your programs into smaller blocks. That can help you keep a clear overview, and it promotes order in the program. Also, you can pack frequently used sequences of instructions into a single function. Instead of repeating the same text in the program code every time, you can simply invoke the corresponding function.

Just as with the definition of a variable, to define a function you have to start with an example. In this case, let's take `void`.
*This is the so-called **return type**. A function, in other words, can end by returning a value to the program that invoked it. In this case, the return type is* `void`*, meaning "empty." In other words, this function returns no value at all! An example of a value that might be returned is the temperature measured by a sensor.*

Important: Always give your functions a name that conveys what the function does. That will help you understand the program when you're reading it.

What happens when `loop()` is invoked? The first instruction in `loop()` is:

`digitalWrite(ledPin, HIGH);`

You can use `digitalWrite()` to control whether voltage is applied to an output pin or not. When issuing this request, there are two things that you will have to communicate to the `digitalWrite()` function:

1. Which pin is intended?
2. Should the voltage at the pin be switch on (`HIGH`) or off (`LOW`)?

In this case, voltage is switched on at pin number 13 (`ledPin`), and the LED lights up!
If you want to switch on another pin, let's say pin number 9, you would write `digitalWrite(9, HIGH);`.

The next instruction is:

`delay(500);`.

You can use the `delay()` instruction to delay the program sequence for a specific period of time — in other words, to make it wait. The amount of time is determined by the number that you assign with the request, in this case `500`. The time is indicated in milliseconds (thousandths of a second). 500 milliseconds is half a second. So the program waits and does nothing for half a second.

Then we have the instruction
`digitalWrite(ledPin, LOW);`.
You can probably understand this one without any help. Right — the LED is switched off again!

Then the KosmoDuino waits another half a second:
`delay(500);`.

And then?

Then it starts all over again from the beginning! `loop()` is a special function in the Arduino programming. It repeats endlessly! All commands in `loop()` are carried out over and over in an endless loop. This is known as the **main loop**. This makes `loop()` the most important function in any KosmoBits program. It controls what the KosmoDuino actually does, while `setup()` handles the required preliminary steps.

You have already seen what happens when the main loop is repeated: The LED is switched on and off, over and over, in regular intervals of half a second. In other words — the LED blinks.

TYPES *A few common type specifiers and their meanings*

TYPE	MEANING	VALUES
`int`	Whole numbers or HIGH / LOW (on/off)	-32,768 to 32,767
`long`	Whole numbers, large	-2,147,483,648 to 2,147,483,647
`float`	Floating decimal numbers: numbers with a decimal point	e.g., 1.5; 3.141; 2.678
`double`	Like `float` but with twice the precision	e.g., 3.141964; 21.45873
`char`	Individual letters	e.g., `a`; `A`; `c`; `C`
`const`	Unchangeable value	Can take any values

Warning! Not suitable for children under 8 years. There is a risk of hot surfaces of components on the PCB (printed circuit board) when different polarities are incorrectly short-circuited or the capacitor is subject to fault conditions.

Off switch

In your first "blink" sketch, you learned how to use a program to make an LED blink on your KosmoDuino. To do that, you used a pin on your controller as an output pin to make the LED switch on and off.

But you can also use a pin as an input pin. In this case, the pin is not turning voltage on or off. Instead, the program can tell you whether or not an electrical voltage is supplied to the pin.

You can then use that to turn the LED on and off with a simple switch.

YOU WILL NEED

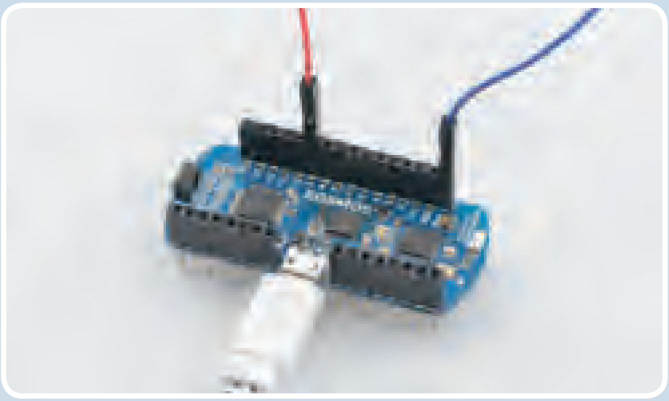
› **KosmoDuino**
› **2 male-male jumper wires (see explanation on p. 16)**

THE PLAN

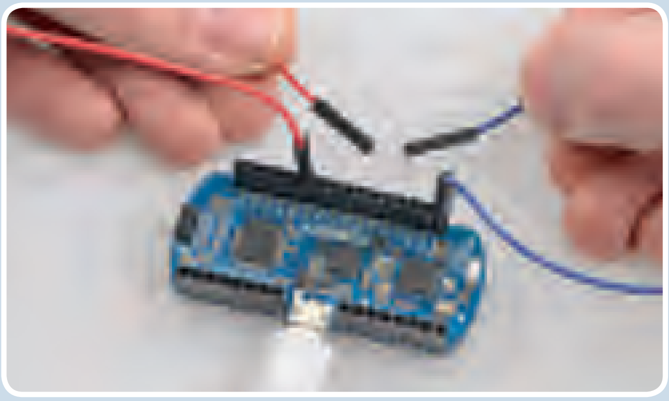
```
int ledPin = 13;
int switchPin = 9;
int switchValue = HIGH;

void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(switchPin, INPUT_PULLUP);
}

void loop() {
  switchValue = digitalRead(switchPin);
  digitalWrite(ledPin, switchValue);

  delay(50);
}
```

PREPARATION

Attach one jumper wire to pin 9 and the other to one of the GND pins. GND stands for ground or grounding. These pins have no actual function beyond conveying current.



Upload the sketch to your KosmoDuino as described on page 10. After uploading, the LED will light up. If you then bring the two free jumper wire contacts together and make them touch, the LED will stop shining.



THE PROGRAM

So what does the program do?

You will first have to define three variables:

- `ledPin` for the pin to which the LED is connected.
- `switchPin` should be assigned the value 9, because you will be connecting your "switch" to pin 9.
- `switchValue` will start by getting the value `HIGH`. Later on, you will "read out" pin 9 and save the readout value in `switchValue`.

```
int ledPin = 13;
int switchPin = 9;
int switchValue = HIGH;
```

PROJECT 3

Warning! Not suitable for children under 8 years. There is a risk of hot surfaces of components on the PCB (printed circuit board) when different polarities are incorrectly short-circuited or the capacitor is subject to fault conditions.

This is almost the same as in your first program. The `ledPin` is operated as an output pin (`OUTPUT`). Pin 9 (`switchPin`), on the other hand, is operated as an input pin. So in the `pinMode()` instruction for `switchPin`, instead of the value `OUTPUT`, you will use `INPUT_PULLUP`.

```
void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(switchPin, INPUT_PULLUP);
}
```

First, use `digitalRead(switchPin)` to read out the current state of pin 9. If the pin is electrically connected to a “GND” pin, it yields the value `LOW`. That means that there is no voltage supplied. Otherwise, it yields the value `HIGH`. Save this value in the `switchValue`.
Then, write this value into the LED pin. So if pin 9 is connected to the GND pin, it switches off the LED. Otherwise, the LED will be switched on.

Finally, `delay(50)` will make you wait briefly before the entire sequence repeats.

```
void loop() {
  switchValue = digitalRead(switchPin);
  digitalWrite(ledPin, switchValue);

  delay(50);
}
```

On switch

YOU WILL NEED

› **KosmoDuino**
› **2 male-male jumper wires**

PREPARATION

Connect one jumper wire to pin 9, and the other to one of the GND pins.

Upload the sketch to your KosmoDuino as described on page 10. This time, after uploading, the LED will remain dark. It only lights up when you touch the two free jumper wire contacts together.

THE PLAN

In the previous project, you learned how to switch off an LED with the help of a simple switch. But what do you do if you want it to work in reverse — in other words, to have the LED only come on if the contact is closed? Just change the program!

THE PROGRAM

```
int ledPin = 13;
int switchPin = 9;
int switchValue = HIGH;

void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(switchPin, INPUT_PULLUP);
}

void loop() {
  switchValue = digitalRead(switchPin);

  if(switchValue == LOW) {
    digitalWrite(ledPin, HIGH);
  } else {
    digitalWrite(ledPin, LOW);
  }
  delay(50);
}
```

EXPLANATION

Let's just take a look at the `loop()` function, because that's the only place where anything was changed relative to the "off switch" program.

Just as with the "off switch," you start by reading out the `switchPin` and saving the current value, i.e., `HIGH` or `LOW` in the `switchValue` variable.

But you do not want to write the read value into the LED pin — just the opposite: When `switchValue` has the value of `LOW`, you want to switch on the LED (`digitalWrite(ledPin, HIGH)`); otherwise, you want to switch off the LED (`digitalWrite(ledPin, LOW)`).

In the program text, you express that with `if(...){...} else{...}`. Note the "if" and "else." You guessed it — this lets you use the program to respond to different conditions.

The condition to which you are responding here is `switchValue == LOW`. You can understand that as a question: "Is the switch value equal to LOW?" You can evaluate the answer to that with the `if()` instruction: If the `switchValue` is equal to `LOW` (`if(switchValue == LOW)`), the program code in the first pair of curly brackets is carried out: `digitalWrite(ledPin, HIGH)`. The LED is switched on.

Otherwise (`else`) the part in the second pair of curly brackets is carried out: `digitalWrite(ledPin, LOW)`. The LED is switched off.

Finally, `delay(50)` will make you wait briefly before the entire sequence repeats.

```
void loop() {
  switchValue = digitalRead(switchPin);

  if(switchValue == LOW) {
    digitalWrite(ledPin, HIGH);
  } else {
    digitalWrite(ledPin, LOW);
  }

  delay(50);
}
```

JUMPER WIRES

Jumper wires serve as an easy way to connect electronic components to each other. In this experiment kit, you will find two different types: ***male-male*** *and* ***male-female****. They really are called that! "Male-male" means that there is a wire on both ends. While "male-female," on the other hand, there is a wire on one end and a socket on the other. Jumper wires are sometimes also called patch cables.*

The Interaction Board

OK, we admit it. Making a little LED light up is not very exciting. Still, it helped to give you a quick introduction to programming your KosmoDuino.

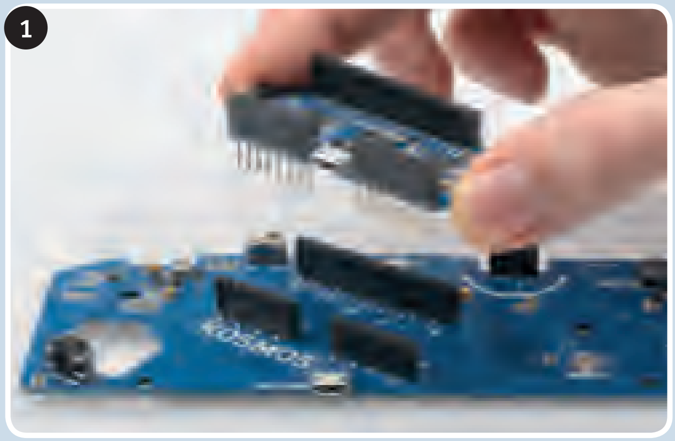
To help you learn how to do more exciting things with your microcontroller as quickly as possible, we have developed the interaction board. You may have gotten to know it a little already while playing the CodeGamer video game. It has several very practical components that will come in handy for lots of projects:

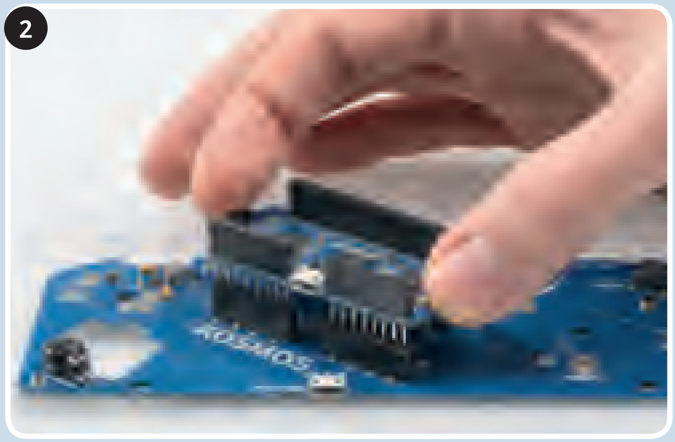
- Two buttons ("button 1" and "button 2")
- A multicolored LED ("NeoPixel")
- A rotating wheel ("rotary encoder")
- A speaker ("buzzer")

And most important:

- A socket for connecting the KosmoBits sensors (temperature, motion, brightness, loudness)
- A battery so that you can also use your KosmoDuino when it isn't attached to a computer.

To work with the interaction board, you will first have to insert your KosmoDuino into the board's pin socket (see illustration).

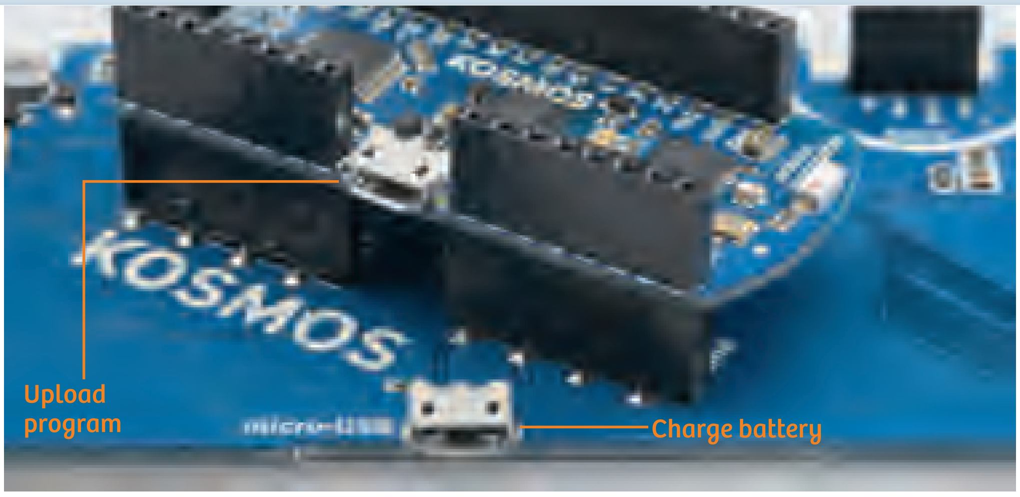

1


2

Then you'll be ready to start! In the following projects, you will start by exploring the interaction board's capabilities, and then move on to the more complex projects.

NOTE!

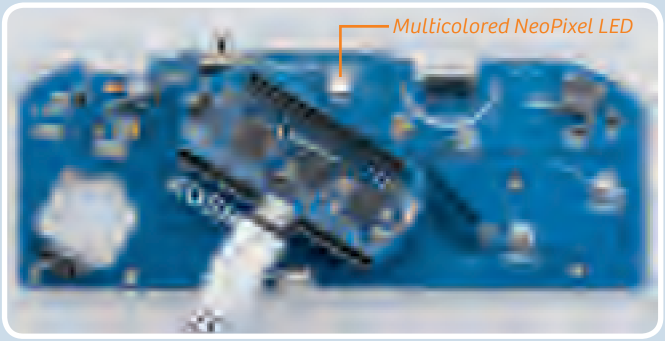
To upload a program to the microcontroller, you will insert the USB cable into the USB port on the KosmoDuino. The USB terminal on the interaction board is only for charging the battery.



Colored light

YOU WILL NEED

› **KosmoDuino in the interaction board**



THE PLAN

On the interaction board, you will find a multicolored LED called a NeoPixel. It's a kind of LED that lets you decide what color and brightness level you want it to have. This little project will show you how it works, and how to get your NeoPixel to shine in all sort of colors

THE PROGRAM

Here's something new to you. The `#include` instruction will let you include code from other programs in your program. In this case, you will be including content from the "Adafruit_NeoPixel.h" and "KosmoBits_Pixel.h" files.

You will always have to insert these two lines at the beginning of your program when you want to use the NeoPixel!

```
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pixel.h>
```

Up to now, you have only learned about variables that act as containers for numerical values. The `pixel` variable that you are defining here is a little different: Instead of numbers, it serves as a container for an **object** of the KosmoBits_Pixel type. That sounds more confusing than it really is. It just means that objects can be more than simple values such as `int`.
More specifically, rather than just having one value, they can bring their own functions with them. These are also known as **methods**. Your `pixel`, for example, is an object that you can use to control the NeoPixel on your interaction board. For that purpose, it has a method by the name of `setColor()`, that you can use to adjust the color and brightness of the NeoPixel. Next, in the main loop, you will learn how this works.

```
KosmoBits_Pixel pixel;
```

To adjust the color and brightness of your NeoPixel, you will need four number values — one for the brightness and three for the primary colors red, green, and blue. These values will be saved in the corresponding variables `red`, `green`, `blue`, and `brightness`.

The various colors will be produced by mixing these three basic colors. You will be setting the corresponding number value to determine how strongly each of the colors in this mixture will be represented. You can use values from 0 to 255. 0 means that the corresponding color will not light up at all. With a value of 255, the color will shine with the highest possible brightness.

```
int red = 0;
int green = 0;
int blue = 0;
int brightness = 0;
```

In `setup()` there will be nothing for you to do this time, since the program that you will be linking with the `#include` instruction will already be handling it for you.

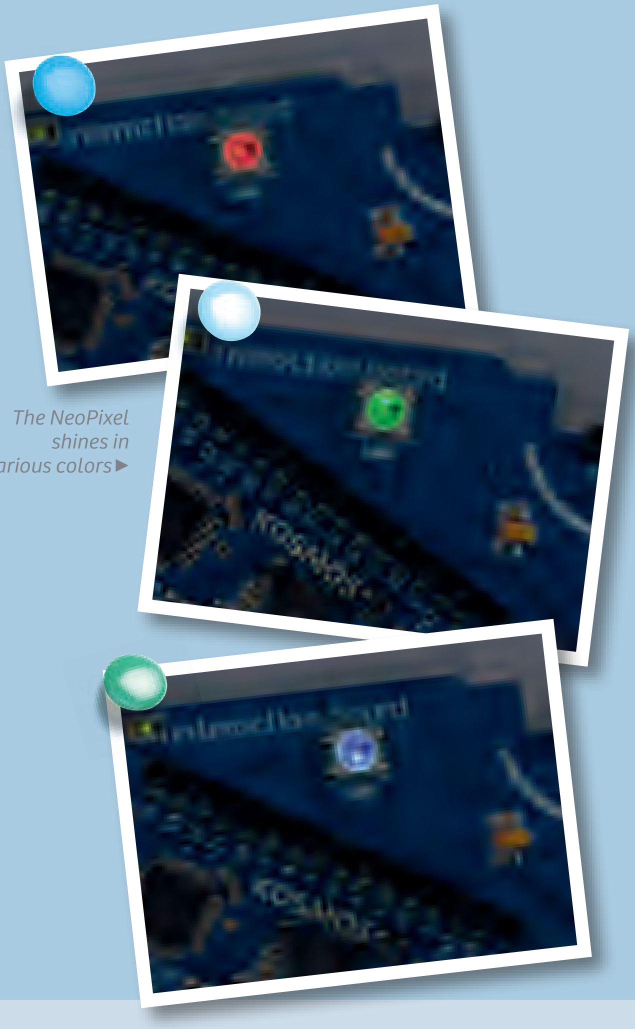
```
void setup() {
  // There is nothing to do here.
}
```

In the main loop, the first thing to do is set the brightness: `brightness = 50;`. The highest level of brightness is set with a value of 255; with 0, the NeoPixel remains dark.

Then the various colors are produced one after the other. To do that, you will be assigning the `red`, `green` and `blue` variables different values.

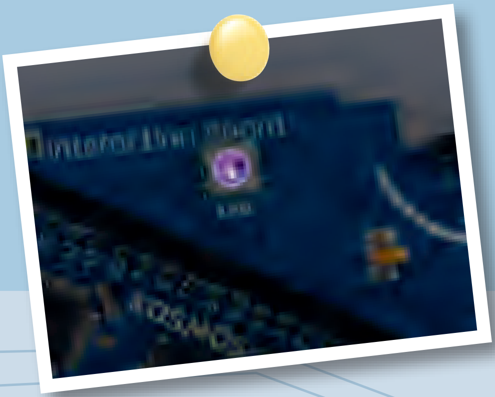
The line `pixel.setColor(red, green, blue, brightness);` is the decisive factor for each color. First of all, it tells the NeoPixel that it is supposed to display a new color! In these instructions, `setColor()` is a so-called method of the `pixel` object. To invoke a method of an object, the method's name is attached to the name of the object separated by a period.

With `delay(500);` you will make your KosmoDuino wait half a second before adjusting the net color.


The NeoPixel shines in various colors ▶

```
void loop() {
  // 50 is a good brightness value.
  // The highest brightness level is 255.
  // It can be a bit blinding though!
  brightness = 50;

  // red
  red = 255;
  green = 0;
  blue = 0;
  pixel.setColor(red, green, blue, brightness);
  delay(500);

  // green
  red = 0;
  green = 255;
  blue = 0;
  pixel.setColor(red, green, blue, brightness);
  delay(500);

  // blue
  red = 0;
  green = 0;
  blue = 255;
  pixel.setColor(red, green, blue, brightness);
  delay(500);

  // purple
  red = 255;
  green = 0;
  blue = 255;
  pixel.setColor(red, green, blue, brightness);
  delay(500);

  // turquoise
  red = 0;
  green = 255;
  blue = 255;
  pixel.setColor(red, green, blue, brightness);
  delay(500);

  // yellow
  red = 255;
  green = 255;
  blue = 0;
  pixel.setColor(red, green, blue, brightness);
  delay(500);
```

```
    // white
    red = 255;
    green = 255;
    blue  = 255;
    pixel.setColor(red, green, blue, brightness);
    delay(500);
}
```



!

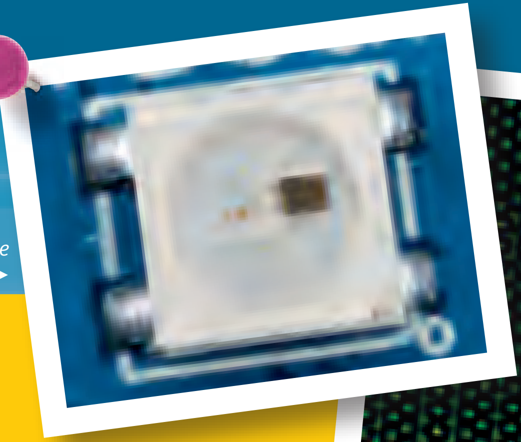
▲ *Another type of library*

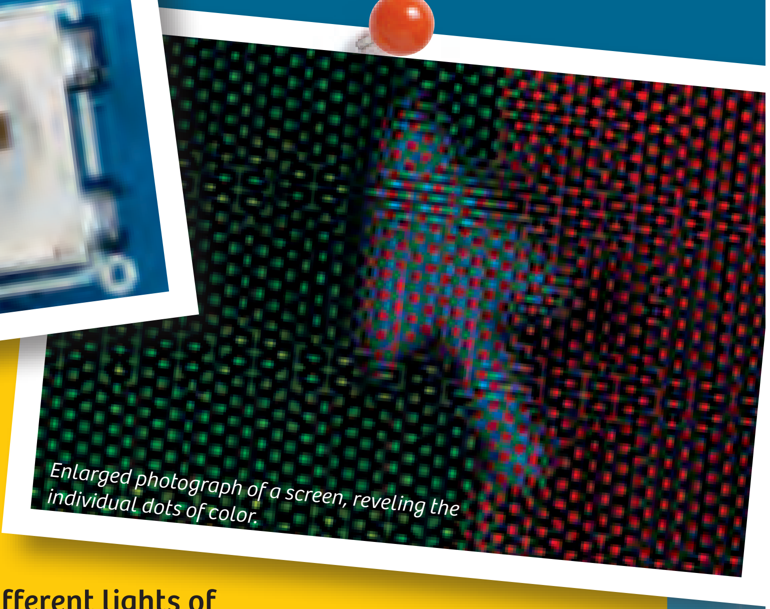
SOFTWARE LIBRARIES

*To avoid having to reinvent the wheel with every program, there are **software libraries**. These are not book collections. Instead, they contain reusable program functions and definitions. There are some libraries that provide mathematical functions, while there are others to make it easy to use certain types of hardware such as sensors or NeoPixels. To be able to use the tools that this kind of library can make available to you, you have to **include** the corresponding library in your own program.*
You do this with the help of the `#include` *instruction:* `#include <KosmoBits_Pixel.h>` *includes the KosmoBits_Pixel library, for example. Some libraries, however, use functions from other libraries. They have to be additionally included, such as in the KosmoBits_Pixel library. More specifically, in order to work they require the Adafruit_NeoPixel library, which is linked via* `#include <Adafruit_NeoPixel.h>`.

CHECK IT OUT

In this close-up, you can easily see the three individual LEDs of the NeoPixel. ►





Enlarged photograph of a screen, reveling the individual dots of color.

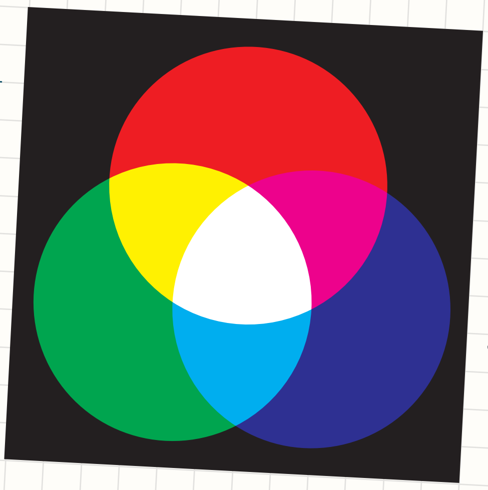
Additive Color Mixing

What you see as white light is actually a mixture of different lights of various colors. Which colors? Take a look at a rainbow and you will see them all. A rainbow is created when the sun's light is split up into its component colors by raindrops in the air.
This process can also work in reverse when you mix light of various colors together, resulting in a different color. Any color monitor or screen works by this principle — whether on your TV, your computer, your smartphone or your tablet. In all these devices, each individual picture element ("pixel") consists of three single-colored picture elements of red, green, and blue. Because they are packed so tightly together, you cannot perceive the individual dots from a normal distance. You can only see the individual dots of color if you get really close, or use a magnifying lens.
If you look carefully at the NeoPixel on the interaction board, you will be able to see three different regions (as long as it isn't shining). Each region can only produce one single color — red, green, or blue. With the help of the `setColor()` method, you can tell the NeoPixel how brightly you want each of the different regions to shine.

Experiment with mixing together other colors by varying the individual color values. The picture next to the table below will serve as a reference for anticipating which mixtures will produce which colors. Enter your findings into the following table:

▲ *You can see the component colors of sunlight in a rainbow.*

Color name	Red Value	Green Value	Blue Value
Red	255	0	0
Green	0	255	0
Blue	0	0	255



At the push of a button

In this project, you will learn how to use the buttons on the interaction board to make the NeoPixel light up in different colors.

YOU WILL NEED

› **KosmoDuino in the interaction board**

THE PLAN

▲ *Finger pushes right button — NeoPixel glows red*

▲ *Finger pushes left button — NeoPixel glows blue*

▲ *Two fingers push both buttons simultaneously — NeoPixel glows purple*

First, we want the NeoPixel to stay dark. If you press button 1, the NeoPixel will glow red, while if you press button 2 it will glow blue. If you press both at the same time, it glows purple.

THE PROGRAM

```
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pixel.h>
#include <KosmoBits_Pins.h>
```

You learned in the last project how to link to libraries and code from other files in a program. The new library here is `KosmoBits_Pins.h`. This defines names for the various KosmoDuino pins used by the interaction board. We will take a closer look at the KosmoBits libraries a little later on in this manual.

Here, you are defining two ***constants*** for the pins to which the two interaction board buttons are connected. These are abbreviated as `const`. This keyword communicates to the program that an object or a variable cannot be changed.

```
const int button1 = KOSMOBITS_BUTTON_1_PIN;
const int button2 = KOSMOBITS_BUTTON_2_PIN;
```

As in the previous program, you are saving the various color values and the brightness in corresponding variables that you define here.

```
int red = 0;
int green = 0;
int blue = 0;
const int brightness = 50;
```

To be able to control the NeoPixel on the interaction board, you once again need a KosmoBits_Pixel object. You are defining that here.

```
KosmoBits_Pixel pixel;
```

In `setup()`, you use `pinMode()` to set the operating mode for the button pins. Since the buttons are connected to the pins via a resistor, you will use the `INPUT` operating type.

```
void setup() {
  pinMode(button1, INPUT);
  pinMode(button2, INPUT);
}
```

In the first `if` instruction `digitalRead()` is used to read out the pin to which button 1 is connected. When the button is pressed, it yields the value `LOW`: The value `255`, i.e., the largest possible value, is assigned to `red`.
If the button is not pressed, `red` is set to `0`.

The entire sequence is repeated for button 2 in the second `if` instruction. The only difference is that the value for `blue` is given.

Finally,
`pixel.setColor(red, green, blue, brightness);`
sets the new color value for the NeoPixel.

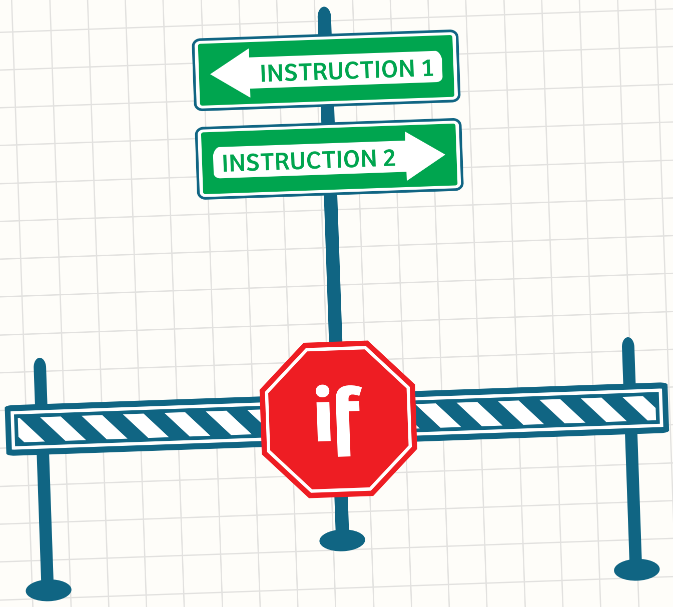
At the end of the main loop, you make the controller wait another 50 milliseconds.

```
void loop() {

  if (digitalRead(button1) == LOW) {
    red = 255;
  } else {
    red = 0;
  }

  if (digitalRead(button2) == LOW) {
    blue = 255;
  } else {
    blue = 0;
  }
  pixel.setColor(red, green, blue, brightness);

  delay(50);
}
```

WHAT ACTUALLY HAPPENS WHEN YOU UPLOAD SOMETHING?

*When you upload a program to your KosmoDuino, actually, a whole lot of things happen. The microcontroller does not really understand the program as you have written it. It simply doesn't speak the programming language. That's why the program first has to be translated into **machine language**. That is something handled by a so-called **compiler**.*

The programming language that you use, in other words, is just an intermediate language that is not only easy for you to understand and write, but most important of all, is one that the compiler can easily translate into machine language.



Only under one condition: The "if" instruction

You have already used the `if` instruction in the program code. Now it's time to take a closer look. By using the `if` instruction, you can require that portions of your program will be carried out only if a certain condition is fulfilled:

```
// Simple if instruction
if (Condition) {
  // The following is only carried out
  // if the condition is fulfilled.
  Instruction 1;
  Instruction 2;
  ...
}
```

ATTENTION!

A common and not always easy-to-find error in an `if` *statement is instead of the double equal sign to use a single equal sign. For example, instead of* `if (a == b)` *the incorrect statement would be* `if (a = b)`*.*
In the case of this `if` *statement the value of* `a` *is assigned the value* `b`*. If that value is greater than zero (*`true`*), the block of text in the curly brackets is executed.*

The parts of the program in the curly brackets will only be carried out if the condition is fulfilled. Otherwise, the entire block in the curly brackets will simply be skipped.

The condition must return a **truth value** either `true` or `false`. Usually, two numerical values are compared. In addition, there are relational operators that will probably be familiar to you from math class:

OPERATOR	MEANING	EXAMPLE	`true`
==	equal to	a == b	when a is equal to b
<	less than	a < b	when a is less than b
>	greater than	a > b	when a is greater than b
!=	unequal	a != b	when a is unequal to b
<=	less than or equal to	a <= b	when a is less than or equal to b
>=	greater than or equal to	a >= b	when a is greater than or equal to b

Truth values are also known as Boolean data types, abbreviated as `bool`*.*
These can only take the values true or false.

You can also extend an `if` instruction with an `else` statement. The `else` statement is carried out if and only if the condition is not fulfilled.

```
// if instruction with else statement
if (Condition) {
  // The following is only carried out
  // if the condition is fulfilled.
  Instruction 1;
  Instruction 22;
  ...
} else {
  // This block is carried out if
  // the condition is not fulfilled.
  Instruction 3;
  Instruction 4;
}
```

Finally, you can build in the additional block `else if` to check another condition if the first one is not fulfilled.

```
// if instruction with else block
if (Condition 1) {
  // The following is only carried out
  // if the condition is fulfilled.
  Instruction 1;
  Instruction 2;
  ...
} else if (Condition 2){
  // This block is carried out if
  // the condition is not fulfilled.
  Instruction 3;
  Instruction 4;
} else {
  // This block is carried out if
  // none of the previously checked
  // conditions are fulfilled.
  Instruction 5;
  ...
}
```

You can also omit the closing `else` statement. In addition, you can line up as many `else if` statements in a row as you like.

A blinking die

With this project, you will be turning your KosmoDuino into a simple die. At the push of a button, it will generate a random number from 1 to 6 and signal the result by blinking the NeoPixel.

YOU WILL NEED

› **KosmoDuino in the interaction board**

THE PLAN:

- If the controller is ready, the NeoPixel will glow blue.
- If you press button 1, the NeoPixel will begin to blink green in accordance with the die result, i.e., once if the rolled result was one, twice if it was two, etc.
- After a brief pause, the NeoPixel will return to blue. That means that it's ready to roll again.

THE PROGRAM

You start by including the familiar libraries and add a KosmoBits_Pixel to address the NeoPixel on the interaction board.

Then, you add a few constants to make the code legible.

```
#include <KosmoBits_Pins.h>
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pixel.h>

KosmoBits_Pixel pixel;

const int buttonPin = KOSMOBITS_BUTTON_1_PIN;
const int blinkDuration = 500; // Milliseconds
const int blinkPause = 250; // Milliseconds
const int brightness = 50;
```

In `setup()`, you prepare your controller for the upcoming tasks in the usual manner: Use `pinMode(buttonPin, INPUT)` to set the pin connected to button 1 as the input pin.

Later, you will be generating a random number. This will be handled by a random generator, which will need as random a value as possible to start with. To get that, read out pin 12 with `analogRead(12)`. Since nothing is connected there, any values that you get will be random. You will learn more about the `analogRead()` function a little later. Then `randomSeed(...)` delivers the read value to the random generator itself as a starting value.

Finally, `pixel.setColor(0, 0, 255, brightness);` makes the NeoPixel glow blue.

```
void setup() {
  pinMode(buttonPin, INPUT);
  randomSeed(analogRead(12)); // Starting value
  // for random generator
  pixel.setColor(0, 0, 255, brightness); // Blue
  // signals operational readiness
}
```

This is a shortened version of the notation that you learned in Project 4. The numbers in the brackets control the ***RGB value*** *(red/green/blue).*

In the main `loop()`, you read out the `buttonPin` with `digitalRead()`. When it is pushed, the result is `LOW`. With the help of the `if` instruction the `roll()` function is invoked, which calculates and outputs the result of the die roll. Otherwise, `loop()` does nothing.

```
void loop() {
  if (digitalRead(buttonPin) == LOW) {
    roll();
 }
}
```

PROJECT 6

Here's where you define your own function by the name of `roll()`. It will calculate and then output a random number in the range of 1 to 6. Let's go through it step by step:

First (1), you turn off the NeoPixel light and wait briefly. You know the corresponding commands by now.

Now we come to the actual roll. Since your KosmoDuino cannot literally roll dice, you have to get the result by some other means: You query a **random number generator**.

You do that with `random(1, 7)` (2). That lets you ask the random generator for a randomly selected number. The first parameter, 1 in this case, indicates that the smallest possible number is to be 1. The second parameter, 7 in this case, means that the randomly selected number should be less than 7.

Important: The second parameter must always be 1 greater than the largest possible number to be produced by the random generator. That may be a little confusing, but it's just how it is. The random number produced in this way is saved in the `number` variable.

Now the random number is to be output by blinking (3). For that, you make use of a so-called `for` loop. You will learn all about the composition of the `for` loop on the following pages. For now, the only important thing to know is that the code in the curly brackets is carried out exactly the indicated `number` of times. If `number` has the value of 1, it will be 1 time. If `number` has the value of 2, then 2 times, and so on.

What's happening inside the curly brackets? Exactly — The NeoPixel lights up in green for the length of time indicated by `blinkDuration` and then switches off for the length of time indicated by `blinkPause`. In brief: The NeoPixel blinks green a single time. But since the `for` loop is executed `number` times, the NeoPixel blinks `number` times altogether. So the result of the roll is output by blinking.

Finally (4), after another short pause (`delay(blinkDuration)`) the NeoPixel returns to blue to signal that you can roll again.

Since `roll()` is only invoked from the main loop `loop()` in your program, it then returns to the main loop. So the next thing that happens is another check in `loop()` to see whether the button is pressed or not.

```
void roll() {
  // (1)
  // Light off at first, to show that it is
  // ready to respond to the push of the button.
  pixel.setColor(0, 0, 0, 0); // Light off
  delay(500);

  // (2) Generate random number
  int number = random(1, 7);

  // (3) Blink number times
  for (int i = 0; i < number; ++i) {
    pixel.setColor(0, 255, 0, brightness);
  // Green
    delay(blinkDuration);
    pixel.setColor(0, 0, 0, 0); // Light off
    delay(blinkPause);
  }

  // (4) Signal conclusion of rolling.
  delay(blinkDuration); // Pause at end
  // somewhat longer
  pixel.setColor(0, 0, 255, brightness); // Blue
  // signals state of readiness
}
```

Have fun rolling!

You will find more information about the `for` loop on pages 30 and 31.

The serial monitor

YOU WILL NEED

› **KosmoDuino**
› **Computer**
› **USB cable**

THE PLAN

With the help of the serial monitor, you can send yourself a brief message from your KosmoDuino and have it appear on your computer screen.

To be able to use the serial monitor, proceed as follows:

THE PROGRAM

Insert the line `Serial.begin(115200);` in `setup()`.

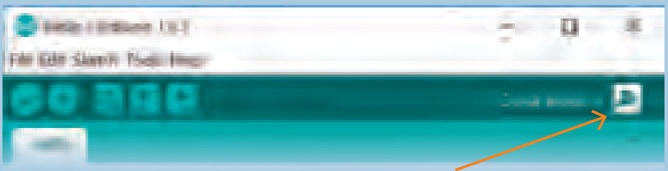
Whenever you want to output something to the serial monitor, you can do that by using the commands `Serial.print()` and `Serial.println()`. The difference between the two versions is that `Serial.println()` inserts an extra line break. The next output, in other words, starts on a new line.

Let's take a look with the help of a little example:

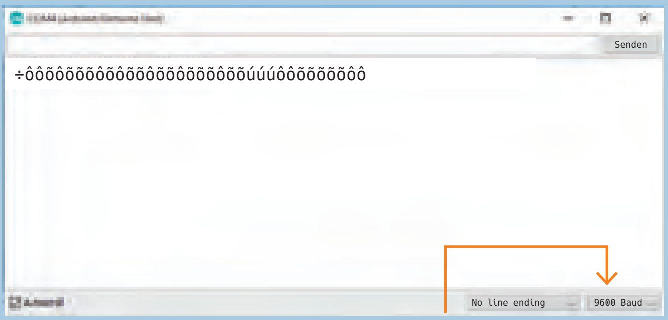
```
void setup() {
  Serial.begin(115200);
}

void loop() {
  Serial.print("Hello!");
  delay(500);
}
```

Upload the program to your KosmoDuino. Nothing will seem to happen. Now click on the magnifying glass symbol at the top right of the Arduino environment. A new window will open for the serial monitor.

At first, you will probably just see some funny symbols. You can fix that in a jiffy by setting the transmission rate correctly. At the bottom right in the serial monitor, you will find a drop-down list with a "115200 baud" option. Select that, and you should see one "Hello!" after another appear in the window.



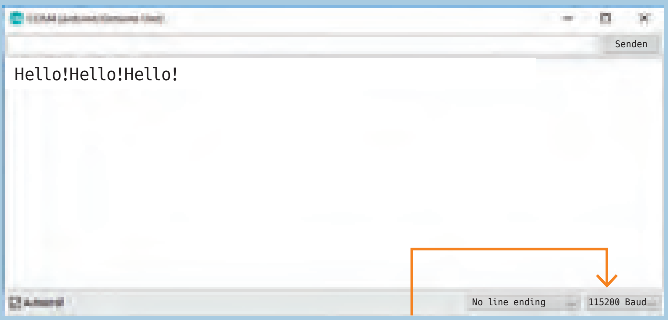
▲ *A click on the magnifying glass at the upper right will launch the serial monitor.*



```
÷ôôôôõõôôôõõõôôôõõõôôôôõõúúôôôôõõõõõô
```

9600 Baud

▲ *If the wrong baud rate is set (9600 baud in this case), you will only see a jumble of symbols.*



```
Hello!Hello!Hello!
```

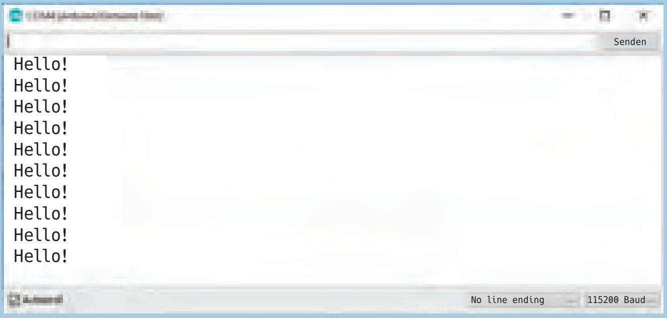
115200 Baud

▲ *Once the right transmission rate is set, you can receive "messages" from the KosmoDuino.*

Now close the serial monitor. In the main loop, replace the request `Serial.print("Hello!");` with `Serial.println("Hello!");`:

```
void loop() {
  Serial.println("Hello!");
  delay(500);
}
```

Load the changed program to the controller and restart the serial monitor. Each “Hello!” now gets its own line.



```
Hello!
Hello!
Hello!
Hello!
Hello!
Hello!
Hello!
Hello!
Hello!
Hello!
```

▲ *Unlike with **Serial.print()** you always get a new line with the **Serial.println()** output..*

`Serial.println()` doesn’t just let you output previously determined messages, though. It can also output newly determined measurement readings. You will learn about that in the project “Thermometer,” on page 33.

NOTE!

If you try to load a program to your KosmoDuino while the serial monitor is open, you may sometimes get an error message. If that happens, close the serial monitor and try uploading the program again.

The for loop

When parts of a program are repeatedly carried out, you call that a loop. You already learned about one import kind of loop — the main loop, `loop()`. Your KosmoDuino uses that to handle the most important tasks in your program. It reads out input pins, processes the measurement data, and then responds — over and over again from the beginning.

You may often prefer, however, not to get caught in an endless loop, and you might rather have just a certain number of repetitions. For that, you can use a `for` loop. You will usually be using it in the following manner as a so-called **counting loop:**

```
for (int i = 0; i < 20; ++i) {
  Instruction 1;
  Instruction 2;
  ...
}
```

What does that mean? The loop is introduced by the word `for`. The instructions that are carried out repeatedly are in the block inside the curly brackets. This block with the instructions to be repeated is often called the **loop body.** For the loop to know how often to repeat these instructions, the `for` loop needs some more information — which you can find inside the parentheses. Let's take a closer look:

`int i = 0;`:
This is known as the initialization of the loop. Before the loop is run through the first time, you apply the **counter variable** `i` and give it the value of 0. You can give the counter variable any name and starting value you like. As long as the counter variable has no special meaning, you usually use the letters `i`, `j`, and `k` as names. As a rule, you generally start with the starting value of 0.

`i < 20;`:
This is the test condition: **Before each pass** through the loop, this condition is checked. If the condition is met, the loop is passed through, meaning that the entire program code inside the curly brackets is carried out.
If the condition is not met, the loop is abandoned: The program code in the curly brackets is not carried again. Instead, the program continues with the next instruction following the loop.

`++i`:
First of all, this is an abbreviation for `i = i + 1`. The value of the counter variable `i` in other words, is increased by 1. But when? **After each pass through the loop!**

As long as the value of the counter variable `i` is not changed, the following is what happens:

Before the first pass, `i` has the value 0. That is less than 20. So the test condition is met, and the loop is passed through. After the instructions in the loop body have been carried out, the value of the counter variable is raised by 1. The value of `i` is now 1. The condition is still met, the loop body is carried out, `i` is raised by 1 again and so on and so forth. If `i` finally has the value of 19, the loop body is carried out one more time and `i` is then increased to the value of 20. The test condition is then no longer met, and the loop is abandoned.

How often has the loop body now been carried out? It has been carried out for the following values of the counter variable `i`: 0, 1, 2, 3, ..., 19. The numbers 1 to 19 yield 19 passes, and one more pass is added for the value 0. So there are 20 passes in all!

The counter variable, by the way, is not just there to count. You can use its current value at any time in the loop body. If, for example, you want to output all numbers from 1 to 42 on the serial monitor, you can do as follows:

```
// Outputs the numbers 1, 2, 3,..., 42:
for (int i = 1 ; i <= 42; ++i) {
  Serial.println(i); // Outputs the current
  // value from i
}
```

THE FOR LOOP

Here, the loop starts with the starting value of 1. This time, instead of testing whether `i` is less than 42, it tests whether `i` is less than or equal to 42. That means that the loop is also passed through one more time for the value of 42. But it also works in the opposite direction:

```
// Outputs the numbers 42, 41, 40, ..., 1:
for (int i = 42; i >= 1; --i) {
  Serial.println(i);
}
```

The loop starts with the value of 42. It keeps running through as long as `i` has a value that is greater or equal to 1. The `--i` means that `i` is reduced by 1 after each pass through the loop. In other words, it counts backwards.

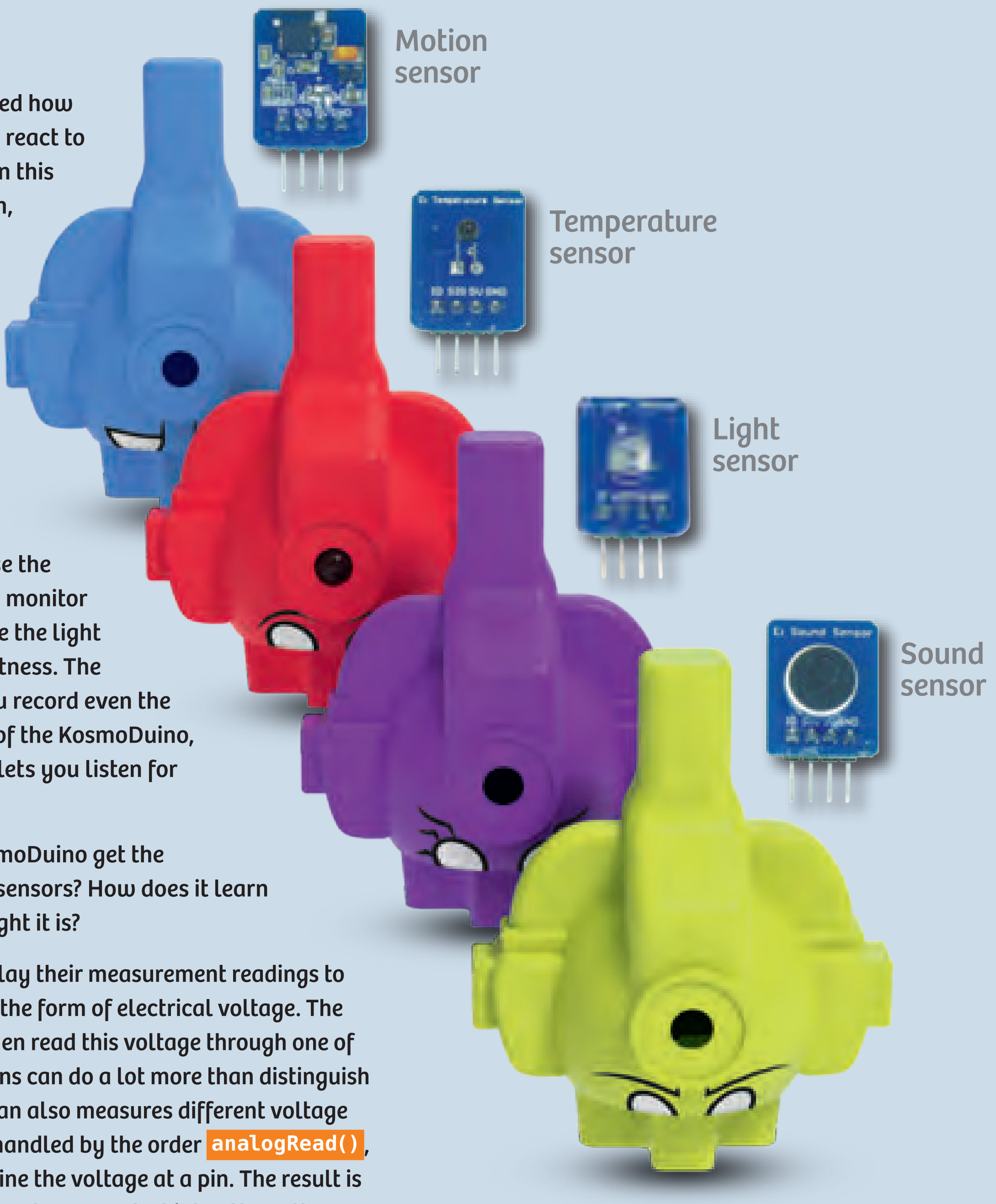
You can actually use any instructions you like in place of `++i` or `--i`. For example, you can just use even numbers:

```
// Outputs the numbers 2, 4, 6, ..., 42:
  for (int i = 2; i <= 42; i = i + 2) {
  Serial.println(i);
}
```

Here, the loop starts with 2 and `i = i + 2` raises the counter variable by 2 after each pass through the loop.

Sensors

So far, you have learned how your KosmoDuino can react to the push of a button. In this experiment kit, though, you will also find a lot of sensors that can be used to help your microcontroller respond to its environment. These are the KosmoBits modules!



Your controller can use the temperature sensor to monitor the temperature, while the light sensor monitors brightness. The motion sensor lets you record even the slightest movements of the KosmoDuino, and the sound sensor lets you listen for noises.

But how does the KosmoDuino get the information from the sensors? How does it learn how warm or how bright it is?

Simple: The sensors relay their measurement readings to the microcontroller in the form of electrical voltage. The microcontroller can then read this voltage through one of the pins. A lot of the pins can do a lot more than distinguish "on" from "off." They can also measures different voltage levels. That's what is handled by the order `analogRead()`, which lets you determine the voltage at a pin. The result is a numerical value from 0 to 1023. The higher the voltage arriving at a pin, the greater the numerical value. 0 indicates no voltage at all, while 1023 indicates 5 volts.

Of course, you will also have to tell `analogRead()` which pin to read. In general, it will be the `KOSMOBITS_SENSOR_PIN`, which is defined in the `KosmoBits_Pins.h` file. So you should always link this file with `#include <KosmoBits_Pins.h>` if you want to access the KosmoBits sensor modules.

You have already learned about the serial monitor. It's an important tool for working with the sensors. See the next projects to find out why.

PROJECT 8

Thermometer

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Temperature sensor**

PREPARATION

Mount the temperature sensor on the interaction board.

THE PLAN

In this project, you will be turning your KosmoDuino into a thermometer for measuring the temperature with the help of the temperature sensor. The temperature is output via the serial monitor.

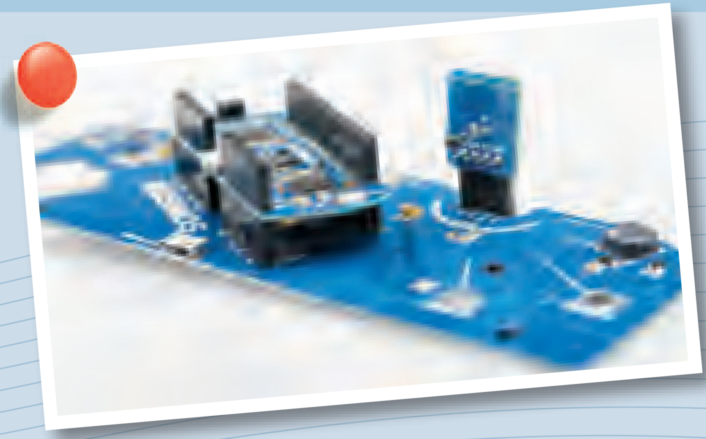
THE PROGRAM

Now, write the following code and upload it to the controller:

The program is easy to explain. The `analogRead()` portion ensures that the voltage is repeatedly read at the `sensorPin`. The measurement reading is then output through the serial monitor. **You will be using this program whenever you want to learn about a new sensor.**

So open the serial monitor and take a look at the measurement readings. Place your finger on the black dot sticking up out of the sensor housing. You should see the measurement readings change. It won't yet look like a temperature reading, though. You still have to convert the measurement readings into temperatures. The KosmoBits library can help you with that. It includes a function for that very task, called `thermistor_measurement_in_celsius()`. To use this function, you will first have to link the `KosmoBits_Thermistor.h` file.

```
#include <KosmoBits_Pins.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;

void setup() {
  pinMode(sensorPin, INPUT);
  Serial.begin(115200);
}

void loop() {
  int value = analogRead(sensorPin);

  Serial.print("measurementReading: ");
  Serial.println(value);
  delay(1000);
}
```



◄ *Board with temperature sensor*

SO CHANGE YOUR PROGRAM LIKE THIS:

Close the serial monitor, upload the program, and reopen the serial monitor. You will see that the current temperature is now being output at regular intervals.

```
#include <KosmoBits_Pins.h>
#include <KosmoBits_Thermistor.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;

void setup() {
  pinMode(sensorPin, INPUT);

  Serial.begin(115200); // Enable output via
// serial monitor.
}

void loop() {
  int measurement = analogRead(sensorPin);
  float celsius = thermistor_measurement_in_
celsius(measurement); // Convert
// measurement into degrees Celsius.
  Serial.print(celsius); // Celsius value
// is output.
  Serial.println(" degrees Celsius"); // Output
// of"Degrees Celsius" and line break.

  delay(1000);
}
```

CALCULATING IN THE PROGRAM:

You have already learned a little about numbers and variables that can incorporate numbers. They aren't much use, however, if you can't use them to calculate. After all, you will normally be using your KosmoDuino to read a numerical value from a sensor and then using that to control something else. To do that, you have to be able to calculate another numerical value from the measurement.

In the Arduino programming language, all the basic calculation types are available to you for this. For adding and subtracting, you use the typical "+" and "-" symbols. For multiplication, use a star ("*"). For division, use a simple forward slash ("/").

```
// Addition (plus)
int x; // x is a whole number.
x = 1 + 4; // x has the value 5.

// Subtraction (minus)
x = 5 - 3; // x has the value 2.

// Multiplication (times)
x = 3 * 4; // x has the value 12.

// Division (divided by)
x = 12 / 6; // x has the value 2.

// Follow order of operations
x = 4 * 3 + 2; // x has the value 14.
```

By the way, you can also use the previous value of a variable to calculate something new with it:

```
int x = 4;
x = x + 2; // x has the value 6.
x = 2 * x; // x has the value 12.
```

There is even an abbreviation for the frequently used calculation step `i = i + 1;`:

```
int i = 0;
i++; // means x = x + 1.
++i; // also means x = x + 1.
```

PROJECT 9

Finger disco

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Motion sensor**

PREPARATION

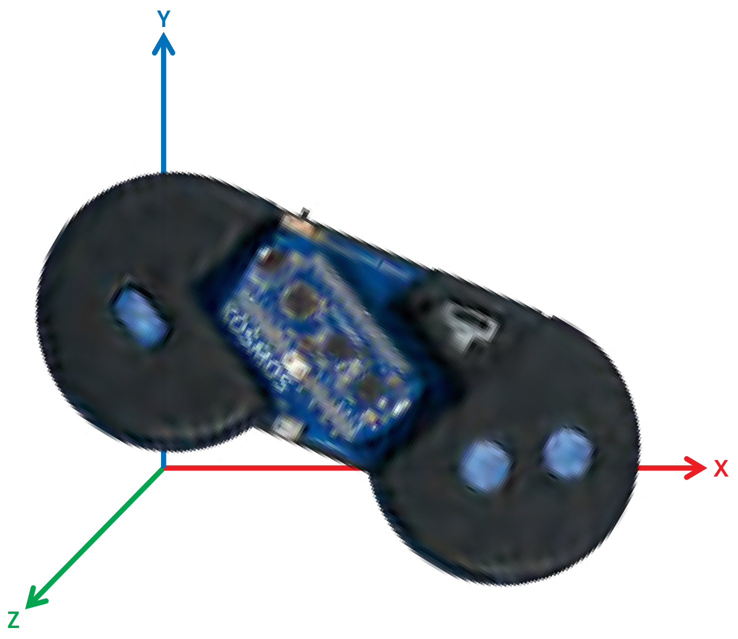
With the motion sensor, your KosmoDuino will be able to record even the tiniest movements. To develop the proper feel for it, start by inserting the motion sensor into the interaction board. Then upload the “ReadSensor” sketch to your KosmoDuino.

You will now be able to observe the motion sensor’s readings in the serial monitor. As long as you do not move the controller, the reading will just fluctuate slightly around an average value.

Now try moving the controller in different directions and rotating and tipping it. You will see how there are movement and rotation directions that cause the reading to change sharply. In other directions the reading may hardly change at all.

Now try drumming gently, and then somewhat more strongly with your fingers on the interaction board housing.

▲ *Fingers drum on the board and the NeoPixel blinks.*



In fact, the sensor merely measures the sensor’s acceleration along the so-called z-axis, or the “forward-and-backward axis.” That’s why the reading changes when you move the controller away from you or back towards you. Up-and-down movements, on the other hand, will not change the reading.

Even though the shaking caused by your fingers is very slight, it is registered by the sensor. If you place the controller on a table, you can even trigger the sensor by just drumming on the table.

We can make use of this to turn your KosmoDuino into a finger-drumming disco lighting device. To do that, use the following program:

THE PLAN

Bright lights dancing in rhythm to your fingers. With this project, you will be able to turn your KosmoDuino into a **Finger Disco**.

THE PROGRAM

Start by linking to the required libraries via the `#include` instructions, defining the `sensorPin` to be able to read the sensor readings, and defining the `pixel` in order to be able to control the NeoPixel.

To be able to recognize deviations from a resting state, you still have to define the `restingValue` variable. The resting average will be saved there.

```
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pins.h>
#include <KosmoBits_Pixel.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;
KosmoBits_Pixel pixel;

int restingValue = 0;
```

To determine the resting value, calculate the average of 20 readings. The number of readings will be saved in the N constant, so it can easily be changed. The average is stored in the `average` variable.

You know all about the `for` loop now. It will be passed through N times, or 20 times in this case.

With each pass through the loop, another measurement reading will be added to the current `average`. There is a pause of 10 milliseconds before each subsequent reading

When the loop is abandoned, the sum of the 20 measurement readings is saved in the `average` variable. To calculate the average from that, the total must be divided by the number of readings. That happens in the `average = average / N;` line.

Finally, `return average;` returns the calculated average.

```
int determineRestingValue() {
  const int N = 20; // measurement numbers
  float average = 0;
  for (int i = 0; i < 20; ++i) {
    average = average + analogRead(sensorPin);
    delay(10);
  }
  average = average / N;
  return average;
}
```

It's simple: `pinMode(sensorPin, INPUT);` sets the `sensorPin` as the input pin. Finally, the resting value is calculated and stored in the `restingValue` variable.

```
void setup() {
  pinMode(sensorPin, INPUT);
  restingValue = determineRestingValue();
}
```

In the main loop, a current sensor value is first read and saved in `value`. Now it's time to determine the deviation from the average and save it in the `difference` variable. The deviation always has to be positive. Since you don't know if the current sensor reading is greater than or less than `restingValue`, the `if` instruction will be used to decide between two cases: If `value` is greater than `restingValue`, `difference` is calculated as `value - restingValue`; otherwise, it is calculated as `restingValue - value`.

Now, `pixel.setColor()` is used to set the NeoPixel color independently of the `difference` value: The greater the difference, the higher the red portion, and the lower the green portion.

```
void loop() {
  int value = analogRead(sensorPin);
  int difference;
  if (value > restingValue) {
    difference = value - restingValue;
  } else {
    difference = restingValue - value;
  }

  pixel.setColor(2 * difference, 100 - 2 *
  difference, 0, difference); // RGB value and
  // brightness.
  delay(10);
}
```

Do you have your own ideas about how the NeoPixel color should react to the deviation from the resting value? Try it! You're sure to come up with all sorts of interesting variations.

PROJECT 10

Cheep!

You can also use the interaction board to produce sounds. This little project will show you how it works.

YOU WILL NEED

› **KosmoDuino in the interaction board**

THE PLAN

So far, the KosmoDuino just beeps at regular intervals. Don't worry — you will learn how to turn it into a siren or even a musical instrument.

THE PROGRAM

Start by including the `KosmoBits_Pins.h` file and defining the `buzzerPin` constant in order to address the pin to which the "buzzer" (the miniature speaker) is connected.

```
#include <KosmoBits_Pins.h>

const int buzzerPin = KOSMOBITS_BUZZER_PIN;
```

This time, you won't have to do anything in `setup()`.

```
void setup() {
  // Nothing to do.
}
```

The composition of the `loop()` will probably look familiar to you. It matches the "Blink" program, which was the very first program that you uploaded to your KosmoDuino. But this time, instead of making an LED blink, you will be making sounds. These two commands will help:

```
void loop() {
  tone(buzzerPin, 440);
  delay(500);
  noTone(buzzerPin);
  delay(500);
}
```

`tone(buzzerPin, 440);` produces a tone with a frequency of 440 Hz. This is the standard pitch of A. The tone stays on until you switch it off again with `noTone(buzzerPin);` To switch the tone on and off again at regular intervals, use `delay(500);` to attach a half-second pause to each of these commands.

PROJECT 11

Random sounds!

You just learned in the “Cheep!” project how to make your KosmoDuino start beeping. But it can get a little boring listening to the same tone over and over. Here’s where you learn how to get random sounds out of your controller.

YOU WILL NEED

› **KosmoDuino in the interaction board**

THE PLAN

The random generator will determine the pitch of the tones as well as their duration.

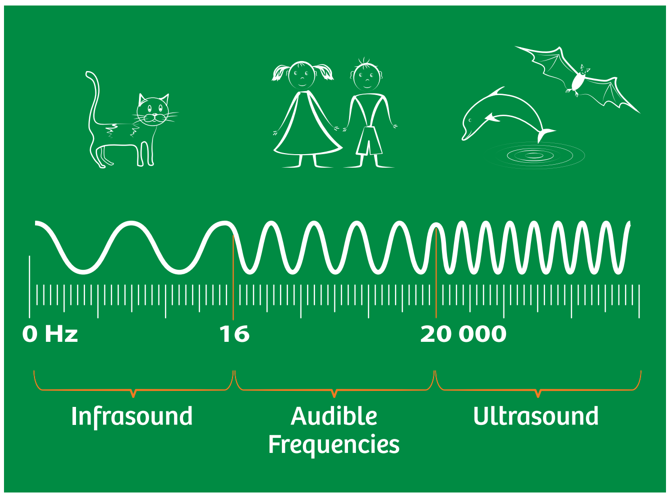
THE PROGRAM

The program is pretty simple. In `setup()`, you give the random generator a starting value just as you did in the die-rolling project.

Then, in the main loop, `int freq = random(110,1000);` randomly determines the frequency (`freq`) of the next tone, and then its duration in the same manner.

Finally, the tone is output with `tone(buzzerPin,freq);`. At the end, `delay(dauer);` ensures that the tone is played for the duration indicated by `duration`.

```
#include <KosmoBits_Pins.h>

const int buzzerPin = KOSMOBITS_BUZZER_PIN;

void setup() {
  randomSeed(analogRead(12));
}

void loop() {
  int freq = random(110, 1000);
  int duration = random(10, 150);
  tone(buzzerPin, freq);
  delay(duration);
}
```



SOUND

When the air pushing against our ear drums vibrates back and forth, we perceive it as sound. The faster the air vibrates, the higher the sound. Physicists measure that as “vibrations per second,” or frequency. The unit of frequency is known as a Hertz, abbreviated Hz. One Hertz means that the air completes one full oscillation (vibration back and forth) per second. The higher the frequency of a sound, the higher the pitch of the sound we hear. Humans can perceive sounds with frequencies between 16 and 20,000 Hertz. A lot of animals, on the other hand, are able to perceive sounds in the infrasonic and ultrasonic range.

Siren

Now it's time to bring some order to the acoustic chaos. This project will let you make your KosmoDuino howl like a siren.

YOU WILL NEED

› **KosmoDuino in the interaction board**

THE PLAN

With every pass through the main loop, a new sound will be output. Each time, the pitch will be raised a little. Once a certain frequency, or sound pitch, is attained, the pitch drops back to its starting value and the whole thing starts over from the beginning.

THE PROGRAM

Here's where you specify the frequency range within which the sound pitch is to move. `FREQ_MIN` corresponds to the deepest sound of the siren, and `FREQ_MAX` the highest. You can also experiment with these parameters by changing the values, and find a siren noise to suit your taste.

`DELAY` determines how long any given sound will be held.

The variable `freq` finally, saves the current frequency. The siren starts at `FREQ_MIN`.

```
#include <KosmoBits_Pins.h>

const int buzzerPin = KOSMOBITS_BUZZER_PIN;
const int FREQ_MIN = 440;
const int FREQ_MAX = 660;
const int DELAY = 4;

int freq = FREQ_MIN; // Frequency of the sound
// that is output.
```

This time, you won't have to do anything in `setup()`.

```
void setup() {
  // Nothing to do here.
}
```

The main loop starts by outputting a sound with the frequency `freq` (1). After a pause of length `DELAY`, the frequency `freq` is raised by 1 with `++freq;`. The `if` instruction then checks whether the maximum frequency has been exceeded. If so, the frequency `freq` is returned to the starting value `FREQ_MIN`.

```
void loop() {
  tone(buzzerPin, freq); // (1)
  delay(DELAY);
  ++freq; // Short for: freq = freq + 1;
  if (freq > FREQ_MAX) {
    freq = FREQ_MIN;
  }
}
```

In the next project, you will be producing an entire musical scale. But first you will have to learn about an important programming tool: Arrays.

KNOWLEDGE BASE

Arrays

If you want to save a lot of values of the same type, for example the last 100 values, it can be pretty time-consuming and confusing to have to enter all that in. You would have to apply a separate variable for each individual value, as follows:

```
int value 1;
int value 2;
int value 3;
...etc...
int value 100;
```

It's a lot simpler to use what's called an **array**.

In an array, you can store many values at one time. To make it possible to access the individual variables in the array, they are all consecutively numbered. So you can think of an array as a kind of table in which the individual values are entered into numbered columns. The numbering of the columns, however, starts with 0 rather than 1:

INDEX	0	1	2	3	...	n
VALUES	Value 0	Value 1	Value 2	Value 3	...	Value n

An array is sometimes called a ***Field*** *or* ***Data Field****. However the term* ***Array*** *is the much more common name.*

In general, an array is created as follows:

```
type arrayName[length];
```

The type specifies which type of data can be saved in the array (int, float, etc.). The number of values that can be stored in an array is known as its **length**.

So, for example, to create an array that can take 10 integer values, you proceed as follows:

```
int myArray[10]; // An array that can
// take 10 int values
```

You can also assign values to an array by specifying the individual values in curly brackets:

```
int myArray[4] = {0, 4, 2, 3};
```

In that case, you don't necessarily have to indicate how many values there are. You can also write:

```
int myArray[] = {0, 4, 2, 3};
```

KNOWLEDGE BASE

You will often want all individual values to be set to zero. You can do that quickly by writing as follows:

```
int myArray[10] = {}; // Array of
// length 10 with all the values
// set to 0.
```

To access the individual values of an array, you indicate the value in square brackets for the index that you want to access. So if you think of the array as a table, the index corresponds to the column number.

```
int myArray[100] = {}; // Array of
// length 100 with all values set to 0.
myArray[2] = 42; // The value at index
// position 2 is now 42.

int x = myArray[2]; // x contains the
// value saved at index position 2
// in myArray, in this case it is 42.
```

You may often want to calculate a new value from all the individual ones, for example the sum of all individual values. Since you can now address the individual values via their index, you can easily do this with a `for` loop:

```
// values is an array of length 100.

int sum = 0;
for (int index = 0; index < 100;
++index) {
  sum = sum + values[index];
}
```

With the first pass through the loop, the value `values[0]` is added to `sum`. Then, `index` is raised by 1, and the next value is added. This is repeated until the last value (`values[99]`) has been added.

In the next project, you will use an array to play a musical scale.

NOTE!

Since the index for the first value is 0 rather than 1, the highest possible index for an array of length N is not N, but rather N-1. With an array of length 100, in other words, the highest possible index would be 99. If you use a higher index, it will result in an error in the program sequence. It's impossible to predict what would happen then. So be careful only to use valid values for the index.

PROJECT 13

Musical scale

YOU WILL NEED

› **KosmoDuino in the interaction board**

THE PLAN

Your KosmoDuino will play a musical scale.

THE PROGRAM

First you include the `KosmoBits_Pins.h` file and define the `buzzerPin` and `freqRoot` constants. Finally, you apply the `scale[]` array, in which the frequency relationships of the notes of a major-key scale will be placed. To determine the frequency of a note, you will have to multiply the corresponding value by the frequency of the root chord.

```
#include <KosmoBits_Pins.h>

const int buzzerPin = KOSMOBITS_BUZZER_PIN;
const int freqRoot = 220; // This is the
// note A (one octave deeper than the standard
// pitch A from project 10).

float scale[] = {1.f, 9.f/8, 5.f/4, 4.f/3, 3.f/2,
5.f/3, 15.f/8, 2.f};
```

This time, everything is happening in `setup()`. In the `for` loop, the variable `i` is counted up from 0 to 7. For each value of `i` then, the `i`-th note of the scale is output with `tone(buzzerPin, scale[i] * freqRoot);`. As described above, the frequency of the root chord `freqRoot` is multiplied by the corresponding frequency relationship `scale[i]` to determine the right frequency.

After a pause, the `for` loop is passed through again until the highest note of the scale is reached. Then it's quiet: `noTone(buzzerPin);`.

```
void setup() {
  for (int i = 0; i < 8; ++i) {
    tone(buzzerPin, scale[i] * freqRoot);
    delay(500);
  }
  noTone(buzzerPin);
}
```

This time, nothing is done in the main loop. The scale is just played through a single time, in other words. To make the scale play again, you can press the reset button on the KosmoDuino. That will reset the code and carry it out again from the beginning.

```
void loop() {
  // Nothing is done here.
}
```

Sensor organ

Now that you have learned how to play musical scales, it's time to program an actual musical instrument.

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Motion sensor**

THE PLAN

You will produce musical notes at the push of a button. The pitch of the note can be changed by moving the interaction board. With a little practice, you can play an actual melody this way.

THE PROGRAM

First, you will define a few constants for sensor pin, buzzer pin, and button pin. Then, as you did in the last project, you will apply an array for the scale as well as a constant for the root chord.

With the `measurementMin` and `measurementMax` constants, you will be regulating how far the controller has to be tipped in order to play the highest or the lowest note. You can adjust these values to suit your own preferences later on. You will be using the `scaling` constant later on to determine the pitch from a measurement reading, dividing practically the entire measurement range into 9 portions.

The motion sensor is quite sensitive, so the readings will fluctuate a little. To keep the pitch from wavering too much, you won't be taking the last reading to measure the pitch. Instead, you will be calculating the average of 10 readings. The last 10 measurement readings will be saved in the `values[]` array for this purpose. All values in it will first be set to 0 by `int values[N] = {};`.

With the `index` variable, the array will be run through, starting with 0 as usual.

```
#include <KosmoBits_Pins.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;
const int buzzerPin = KOSMOBITS_BUZZER_PIN;
const int buttonPin = KOSMOBITS_BUTTON_2_PIN;

const float scale[] = {1.f, 9.f/8, 5.f/4, 4.f/3,
3.f/2, 5.f/3, 15.f/8, 2.f};
const int freqRoot = 220; // This is the
// note A.

const int measurementMin = 300;
const int measurementMax = 400;
const int scaling = (measurementMax -
measurementMin) / 9;

const int N = 10; // Number of values that
// are averaged.
int values[N] = {}; // Here is where the last
// 10 values are stored.
int index = 0;
```

This is where each of the pin modes is set.

```
void setup() {
  pinMode(sensorPin, INPUT);
  pinMode(buttonPin, INPUT);
}
```

You will start by taking a new measurement reading and saving it in the `values` array at the `index` position. To ensure that the next measurement reading is saved at the subsequent position, `++index;` raises the `index` by 1. If the value of `N` is reached, the `if` instruction sets `index`

```
void loop() {
  // Reads a new value from the sensor and
  // saves it in values[].
  values[index] = analogRead(sensorPin);
```

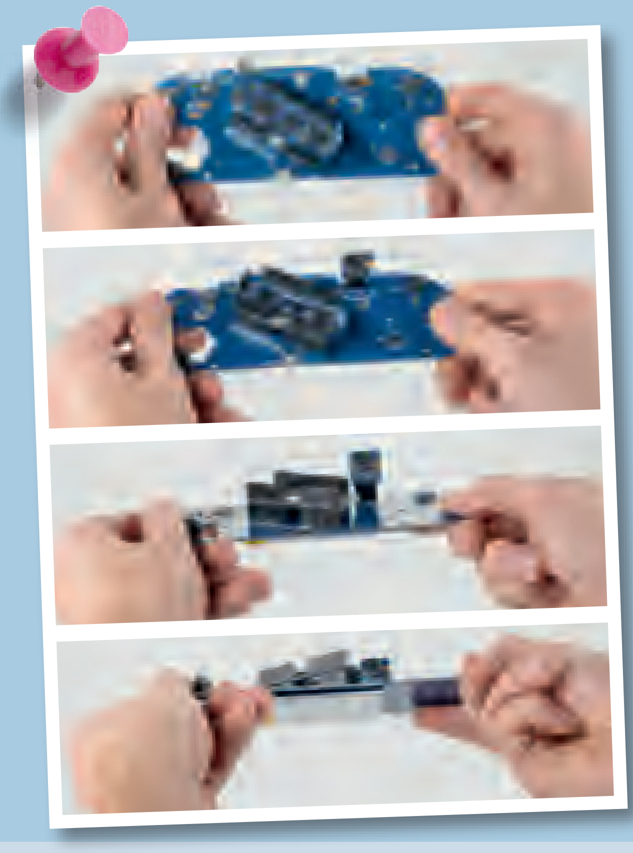
back to 0. The array is filled from the beginning again.

Then it's a matter of determining the average of the last 10 measurements. To do that, the `average` variable is first set to 0. In the `for` loop, then, all the values saved in the `value[]` array are added to `average`. To calculate the average from that, the result has to be divided by the number of values: `average = average / N;`.

With `int noteIndex = (average - measurementMin) / scaling;`, you will be determining the "note index": Which note in the scale sequence should be played?

It might happen that `noteIndex` has an invalid value — in other words, that it is less than 0 or greater than 7. That's why you will be correcting it with the `if-else` instruction in case of doubt.

Finally, the last `if` query checks whether the button is pushed. If so, the corresponding note is output. If not, no note is output.



```
  // Raise the index by 1, so the next
  // value can be saved at the next location
  // in the values[] field.
  ++index;

  // If index == N, the field is
  // fully described.
  // index is then set to 0, so that
  // the oldest value
  // is overwritten in the next pass.
  if (index == N) {
      index = 0;
  }

  // Now the average of the last N
  // measurement readings is calculated.
  int average = 0; // Start with the value 0

  // Total the measurement values.
  for (int i = 0; i < N; ++i) {
    average = average + values[i];
  }
  // Divide the total by the number of values.
  average = average / N;

  int noteIndex = (average - measurementMin) /
  scaling;

  // noteIndex must not be less than 0 or
  // greater than 7:
  if (noteIndex < 0) {
    noteIndex = 0;
  } else if (noteIndex > 7) {
    noteIndex = 7;
  }

  // Output note
  if (digitalRead(buttonPin) == LOW) {
    tone(buzzerPin, scale[noteIndex] * freqRoot);
    delay(10);
  } else {
    noTone(buzzerPin);
    delay(1);
  }
}
```

Admittedly, this was a little more involved.
But the results make it all worthwhile!

The serial plotter

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Sound sensor**

THE PLAN

The sound sensor is basically a small microphone that you can read via the sensor pin. To understand how it works, the best thing is to use another cool tool from the Arduino environment — the **serial plotter**.

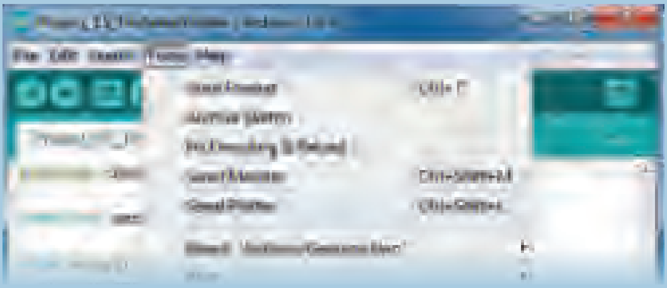
THE PROGRAM

Plug the sound sensor into the interaction board and then upload the following little program to your KosmoDuino:

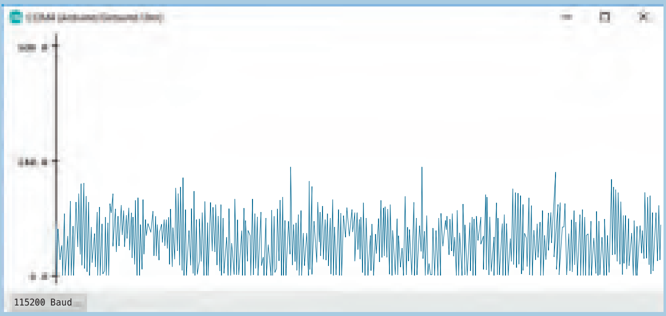
There isn't a whole lot that the code does. With each pass of the main loop, a new value is read by the sensor pin and output by `Serial.println()`.

```
#include <KosmoBits_Pins.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;

void setup() {
  pinMode(sensorPin, INPUT);
  Serial.begin(115200);
}

void loop() {
  Serial.println(analogRead(sensorPin));
}
```

Now start the **Serial Plotter** from the "Tools" menu. (If you do not see the Serial Plotter in the Tools menu, you may need to update your Arduino software to a newer version.)



A new window will open with some crazy-looking things happening.



Now try to make various sounds, such as whistling or singing. You will see how the image changes in the serial plotter.

The scale along the left edge makes it easy to read the magnitude of the values delivered by the sensor. In the example shown here, you can see that 0 is the lowest value. That should be obvious — after all `analogRead()` wouldn't be able to deliver anything smaller. The largest measured reading is about 250. But if you clap your hands, the readings may rise to 800.

You will be able to make excellent use of this in your next project.

PROJECT 16

Clap switch

Wouldn't it be cool if your KosmoDuino could respond to clapping? You can easily program it to do that with the help of your sound sensor.

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Sound sensor**

THE PLAN

If you clap once, it turns on the NeoPixel on the interaction board. If you clap again, it turns off.

THE PROGRAM

The usual files are linked and the `sensorPin` constant is defined for the sensor pin. The `threshold` constant controls the sensitivity of your clap switch. If the value set there is exceeded by the measurement reading, the switch toggles over — either from "on" to "off" or vice-versa. In the `on` variable, you will be storing the current state of the NeoPixel. If it is on, the variable is assigned the value `true`, otherwise it is assigned the value `false`. At the beginning of the program, the NeoPixel is off: `bool on = false;`.

```
#include <KosmoBits_Pins.h>
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pixel.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;
const int threshold = 500;

KosmoBits_Pixel pixel;

bool on = false;
```

In `setup()`, the pin mode of the sensor pin is set and the NeoPixel is switched off.

```
void setup() {
  pinMode(sensorPin, INPUT);
  pixel.setColor(0, 0, 0, 0);
}
```

In the main loop, the sound sensor is continuously read. If the measured value is greater than the value set in `threshold`, the `toggle()` function is invoked and there is a brief pause.

```
void loop() {
  int sensorValue = analogRead(sensorPin);
  Serial.println(sensorValue);
  if (sensorValue > threshold) {
    toggle();
    delay(200);
  }
}
```

Here, you will write your own `void toggle()` function. This queries whether the NeoPixel is currently on. If so, the NeoPixel is switched off and `on` is assigned the value `false`.
Otherwise ("else"), the NeoPixel is switched on and `on` is assigned the value `true`.

In brief: `toggle()` does exactly what its name suggests. It switches back and forth between "on" and "off."

```
void toggle() {
  if (on) {
    pixel.setColor(0, 0, 0, 0);
    on = false;
  } else {
    pixel.setColor(255, 0, 0, 30);
    on = true;
  }
}
```

Drawer monitor

Have you ever had the suspicion that your brother or sister might be secretly looking through your things when you're not home? With this drawer monitor, you will be able to catch them! And the best thing about it is that the perpetrator won't even know that the drawer is under surveillance. There is no alarm, and nothing to indicate to the culprit that his deed has been noticed. It is only when you ask the KosmoDuino that you will know whether someone has been peeking around!

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Light sensor**

THE PLAN

It's dark inside a closed drawer, and bright in an open one. So you can use a light sensor to tell whether your drawer has been opened or not.

You will be programming your KosmoDuino to do the following:

1. After it is switched on, it will wait for a push on button 1 to be armed.

2. Once the drawer monitor is armed, it will wait for the drawer to be closed. That's when it will start guarding the drawer.

3. If the drawer is opened again, there are two possibilities for what will happen then:

   a) If the drawer is closed again, it will count as "drawer was opened."

   b) If you push button 2, the NeoPixel will show you how often it was opened.

PREPARATION: MEASURING SENSOR VALUES

To know whether the drawer has been opened or not, you will be using the light sensor. It measures the brightness of the light that falls on it. As long as your KosmoDuino is in the darkness, the reading that it takes will be low. If the drawer is opened, though, the measurement will rise. Unfortunately, it is rarely completely dark in any closed drawer. What level of brightness signals that the drawer has been opened? Try to find out! Start by inserting your light sensor into the interaction board. Now you have to find out how bright it is in daylight. Do that by reading the sensor and outputting the reading through the serial monitor. As usual, you will do it with the **ReadSensor** sketch on page 33.

Note down the readings output by the sketch when you:

- *set the light sensor out under daylight,*
- *set the light sensor out at dusk,*
- *cover the sensor completely with your hand,*
- *shine a flashlight on the sensor.*

LIGHT	READING
Daylight	
Dusk	
Shaded	
Flashlight	

You will need these readings later on when you think about when the drawer should count as closed.

THE MATRIX

In this project, we will be using the NeoPixel and both buttons. So we will link to the required libraries here.

```
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pins.h>
#include <KosmoBits_Pixel.h>
```

We are defining three constants for reading the sensor and the buttons, as well as the three variables `button1`, `button2`, and `sensorValue`, which will store the current measurement readings.

```
const int sensorPin = KOSMOBITS_SENSOR_PIN;
const int button1Pin = KOSMOBITS_BUTTON_1_PIN;
const int button2Pin = KOSMOBITS_BUTTON_2_PIN;

int button1 = HIGH;
int button2 = HIGH;
int sensorValue = 0;
```

To make sure the program code remains clear, it helps to think of the program as a machine that can be operated in various operating modes. Different things happen in the main loop depending on the mode.

For that purpose, we are using `enum Mode` to define a so-called enumeration type: a variable of the `Mode` type can only take the values written between the curly brackets — `IDLE`, `COUNTDOWN`, etc.
Next, we define the `mode` variable in which the current operating mode is stored. We begin in `IDLE` mode.

```
enum Mode {IDLE, COUNTDOWN, WAIT_UNTIL_DARK,
CLOSED, OPEN};

Mode mode = IDLE;
```

The `DARK_VALUE` constant specifies the lowest light sensor reading at which the drawer should start to count as open. A lot of drawers will let in a little light even when they are closed. **So adjust the value to what makes sense for yours**. The readings that you took in your preliminary work should help!

The `counter` variable stores the number of times the drawer is opened. Finally, `pixel` gives us access to the NeoPixel.

```
const int DARK_VALUE = 100;
unsigned long counter = 0;
KosmoBits_Pixel pixel;
```

When the surveillance is over, we will want to return to the starting state — as if we had just turned on the KosmoDuino. For that, we are introducing the `reset()` function. The NeoPixel is switched off, `mode` is set to `IDLE` and `counter` back to `0`. As a check, “Reset!” is output via the serial interface.

```
void reset() {
  pixel.setColor(0, 0, 0, 0); // Pixel off
  mode = IDLE;
  counter = 0;
  Serial.println("Reset!");
}
```

In `setup()` as usual, we determine the operating modes of the pins being used and initialize the output through the serial interface. Then, `reset()` is invoked to return the drawer monitor to its starting state.

```
void setup() {
  pinMode(sensorPin, INPUT);
  pinMode(button1Pin, INPUT);
  pinMode(button2Pin, INPUT);
  Serial.begin(115200);
  reset();
}
```

In the main loop, depending on operating mode, different loop functions may be invoked. The `switch(mode)` instruction handles that, introducing a case differentiation. For each case, or possible `mode` value, a different function is invoked:

- *If* `mode` *has the value* `IDLE`, `loopIdle()` *is invoked.*
- *If* `mode` *has the value* `COUNTDOWN`, `loopCountdown()` *is invoked, etc.*

The `break;` instruction is important here for breaking off the treatment of a case and ending the case differentiation. Without the `break;` instruction, the code for the next case would also be carried out.

```
void loop() {
  switch(mode) {
  case IDLE:
    loopIdle();
    break;
  case COUNTDOWN:
    loopCountdown();
    break;
  case WAIT_UNTIL_DARK:
    loopUntilDark();
    break;
  case CLOSED:
    loopClosed();
    break;
  case OPEN:
    loopOpen();
    break;
  }
}
```

That ends the basic skeleton of our program. Now we will just have to think about what exactly we want the drawer monitor to do in its various operating modes.

◄ Board with light sensor

IN IDLE

When in its idle state, the drawer monitor is waiting for button 1 to be pushed before it starts monitoring. What's responsible for that is the `loopIdle()` function, which is invoked by the main loop in `IDLE` mode.

By now you probably have a pretty good understanding of the code. The `pressed` variable remembers whether the button was pressed. If button 1 is pressed, the `while()` loop is run through: The NeoPixel glows green, and the `pressed` variable is set to the `true` value. When button 1 is released, the `while()` loop is abandoned. Finally, the `if()` instruction tests whether the button was pressed. If so, the mode is set to `COUNTDOWN`. Otherwise, `loopIdle()` is quit and the main loop is invoked again. It in turn invokes `loopIdle()` again, since the mode hasn't changed.

```
void loopIdle() {
  Serial.println("Idle");
  bool pressed = false;
  while(digitalRead(button1Pin) == LOW) {
    // Button 1 was pressed.
    // Wait for it to be released again.
    pixel.setColor(0, 255, 0, 25);
    pressed = true;
    delay(50);
  }
  if (pressed) {
    mode = COUNTDOWN;
  }
}
```

COUNTDOWN

Here, too, you will be familiar with most of the code. First, the `COUNTDOWN_NUMBER` determines how many seconds the countdown should last: 5 seconds, in this case. The NeoPixel is turned off and after 500 milliseconds the actual countdown is started in the `for()` loop: 5 times "on — wait — off." Then, the NeoPixel is set to "red" for one second (1000 milliseconds). Finally, the mode is set to `WAIT_UNTIL_DARK` and `loopCountdown()` is quit.

```
void loopCountdown() {
  const int COUNTDOWN_NUMBER = 5;
  Serial.println("Countdown");
  pixel.setColor(0, 0, 0, 0); // Pixel OFF
  delay(500);
  // The actual countdown: Like Blink.
  for (int i = 0; i < COUNTDOWN_NUMBER; ++i) {
    pixel.setColor(0, 255, 0, 25); // Green
    delay(500);
    pixel.setColor(0, 0, 0, 0); // Pixel off
    delay(500);
  }
  pixel.setColor(255, 0, 0, 25); // Red
  delay(1000);
  pixel.setColor(0, 0, 0, 0); // Pixel off
  mode = WAIT_UNTIL_DARK;
}
```

WAIT_UNTIL_DARK

This is easy: It keeps running through the `while` loop as long as it's dark. Measurements are taken every 10 milliseconds. When the `while()` loop is abandoned, the mode is set to `CLOSED` and `loopUntilDark()` is quit.

```
void loopUntilDark() {
  Serial.println("Wait until dark");
  while (analogRead(sensorPin) > DARK_VALUE) {
    delay(10);
  }
  mode = CLOSED;
  delay(1000);
}
```

MONITORING (CLOSED)

The actual monitoring of the drawer happens in `CLOSED` mode, i.e. in `loopClosed()`. First, the current level of brightness is measured. If it's dark, it waits one second (1000 milliseconds). `loopClosed()` is then invoked once again from the main loop.

If it's bright, another reading is performed in 0.5 seconds. If it's still bright, it counts as "drawer is open." The mode is set to `OPEN`: In the next pass through the loop, then, `loopOPEN()` is invoked.

```
void loopClosed() {
  Serial.println("In the dark");
  sensorValue = analogRead(sensorPin);
  if (sensorValue < DARK_VALUE) {  // It is
  // still dark.
    delay(1000); // Wait 1 second, loop() invokes
    // this function again.
  } else {
    // It is bright! Check again
    // after 0.5 seconds.
    delay(500);
    if (analogRead(sensorPin) >= DARK_VALUE) {
      // It is bright: drawer opened!
      mode = OPEN;
    }
  }
}
```

INTRUDERS? (OPEN)

If the drawer has been opened, the drawer monitor still has to find out if it's due to an intruder. Maybe, after all, you opened it yourself. That task is handled by `loopOpen()`. This function is invoked from the main loop whenever `mode` has the value `OPEN`. We start by checking button 2: If it is pressed, the monitoring result is output by invoking the `output()` function.

If button 2 is not pressed, the brightness is checked in the `else if` part. If it is now dark, the drawer was closed again. `counter` is then raised by the value of 1 with `++counter`.

If button 2 is not pressed and the drawer has not been closed again, the function is abandoned and invoked once again by the main loop.

```
void loopOpen() {
  Serial.println("Opened");
  delay(50);
  button2 = digitalRead(button2Pin);
  sensorValue = analogRead(sensorPin);

  if (button2 == LOW) {
    output();
  } else if (sensorValue < DARK_VALUE) {
    // Drawer closed again.
    ++counter;
    mode = CLOSED;
  }
}
```

OUTPUT

The `output()` function is what takes care of the monitoring result output. First, the exact result is output via the serial interface. For a quick check without having a computer connected, though, the result is also output via the NeoPixel. If the drawer has been opened and then closed again (i.e., `counter > 0`), the NeoPixel glows red for 2 seconds. Otherwise, it glows green. Then the monitor is returned to its starting state with `reset()`.

```
void output() {
  Serial.print("The drawer was opened ");
  Serial.print(counter);
  Serial.print(" times!\n");
  if (counter > 0) {
    pixel.setColor(255, 0, 0, 25);
  } else {
    pixel.setColor(0, 255, 0, 25);
  }
  delay(2000);
  reset();
}
```

PROJECT 18

Warning! Not suitable for children under 8 years. There is a risk of hot surfaces of components on the PCB (printed circuit board) when different polarities are incorrectly short-circuited or the capacitor is subject to fault conditions.

Looking inside the fridge

How can you actually know if the light inside the fridge really does go out when you close the refrigerator door? You can't exactly check just by looking. You would have to open the door, and then the light would just turn on again. With your KosmoDuino, though, it's no problem at all!

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **Light sensor**
› **4 Male-female jumper wires**

PREPARATION

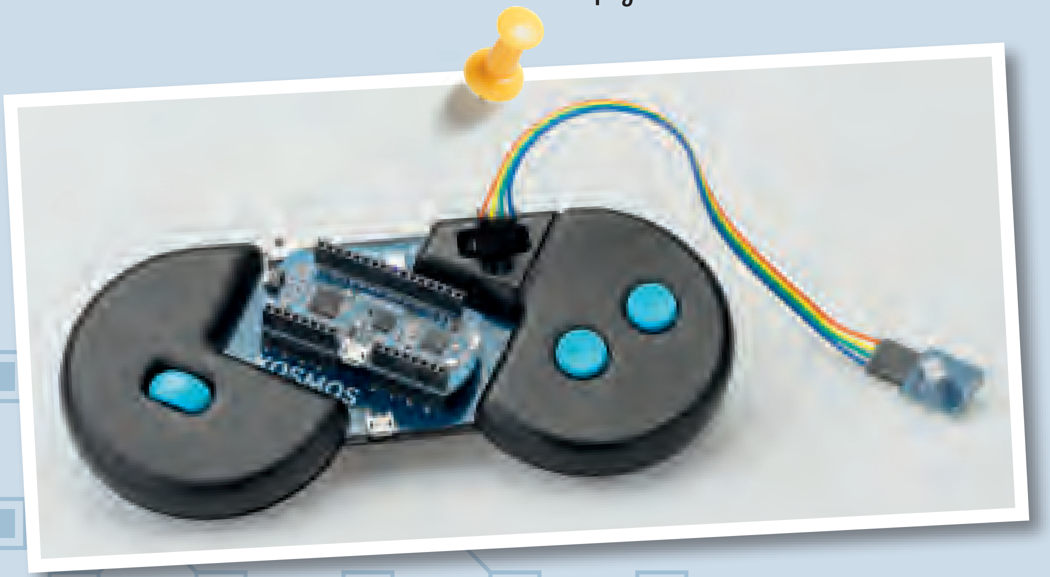
Remove one strand of 4 wires from the strand of male-female jumper wires. Insert the plug ends into the socket that you otherwise stick the KosmoBits sensor module into.

Then, insert the light sensor into the socket ends of the wires. Make sure that each of the light sensor pins is connected via the jumper wire to exactly the right socket into which it would normally be inserted. In other words, the wires must not be allowed to cross.

THE PLAN

You will be using the light sensor to measure the brightness inside the fridge, and you will have the NeoPixel light up on the interaction board in accordance with the measured level of brightness.
But how can you have a display outside the fridge for the brightness on the inside? Easy: You will use extension wires to hook up the sensor! Then, you will be using the wires to keep the sensor inside the fridge while KosmoDuino and its interaction board remain on the outside.

The wires are so thin that you will still be able to close the refrigerator door!



THE PROGRAM

You can probably understand the program without any help. In brief: In `setup()` you set the sensor pin mode and switch off the NeoPixel. In the main loop, you use the light sensor to measure the brightness and store the reading in the `brightness` variable. Since the brightness value must not be greater than 255 with `pixel.setColor()`, limit the `brightness` value to 255 with the help of the `if` instruction.

Now you just need to place the sensor in the fridge and close the door. And what's the answer? Does the light go out?

```
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pixel.h>
#include <KosmoBits_Pins.h>

const int sensorPin = KOSMOBITS_SENSOR_PIN;
KosmoBits_Pixel pixel;

void setup() {
  pinMode(sensorPin, INPUT);
  pixel.setColor(255, 255, 255, 0);
}

void loop() {
  int brightness = analogRead(sensorPin);
  if (brightness > 255) {
    brightness = 255;
  }
  pixel.setColor(255, 255, 255, brightness);
  delay(10);
}
```

▲ *Jumper wire in fridge*

PROJECT 19

Warning! Not suitable for children under 8 years. There is a risk of hot surfaces of components on the PCB (printed circuit board) when different polarities are incorrectly short-circuited or the capacitor is subject to fault conditions.

Ghostly eyes

How would you like to turn your jack-o'-lantern into something even spookier this Halloween? With your KosmoDuino, you will be able to give it ghostly eyes.

YOU WILL NEED

› **KosmoDuino in the interaction board**
› **2 Resistors**
› **Green LED**
› **Red LED**
› **3 Male-male jumper wires**
› **4 Male-female jumper wires**
› **Breadboard**

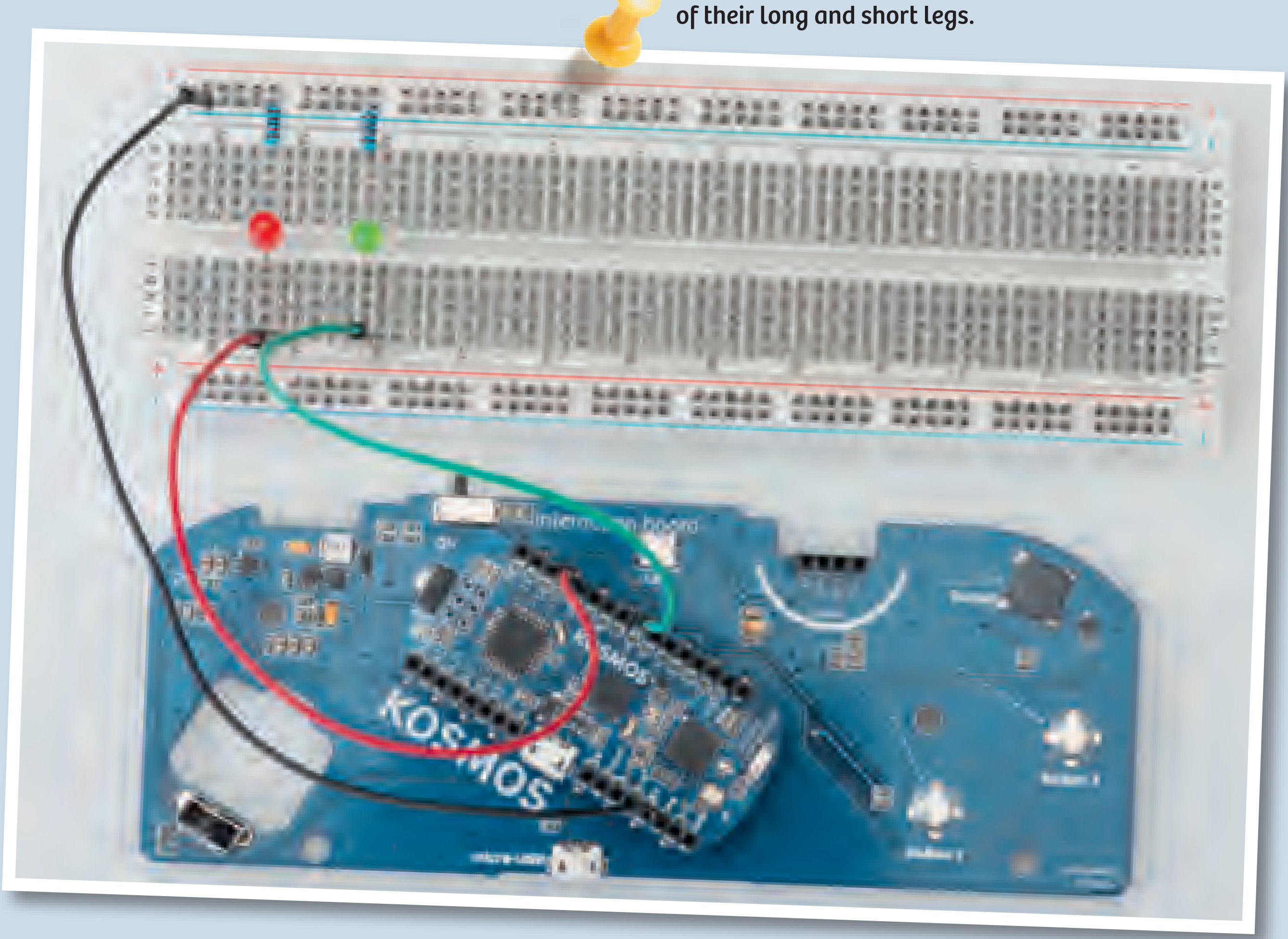
THE PLAN

Make your jack-o'-lantern's eyes blink colorfully. On top of that, you can have it make a gruesome hissing noise at irregular intervals.

PREPARATION

This time, you will need more than just the interaction board, because you will have to build a small electronic circuit. Assemble it out of the parts listed on the left, following the illustration.

Be careful to get the polarity of the LEDs correct! They only work in one direction. Pay attention to the orientation of their long and short legs.



IN THIS EXAMPLE, THE ASSEMBLY GOES AS FOLLOWS:

• One jumper wire connects one GND pin with the (–) strip of the breadboard.
• One jumper wire connects pin 11 of the KosmoDuino with hole j 57 of the breadboard.
• One jumper wire connects pin 6 of the KosmoDuino with hole j 51 of the breadboard.
• The resistors connect the (–) strip and hole a 57 along with the (–) strip and hole a 51.
• The long leg of the red LED is inserted in hole f 57, the short one in e 57. Place the short leg of the green LED in hole f 51 and the long leg in hole e 57.
• To guide the LEDs from the breadboard to the jack-o'-lantern's eyes, use the 4 male-female jumper wires to connect the correspondingly positioned LEDs with the breadboard.

THE PROGRAM

The program is extremely simple. First, the constants are defined for the pins you are using. In `setup()`, we will give a starting value to the random generator.

In the main loop, the brightness of each LED is first set to a random value, `random(0, 256)`, with `analogWrite()`. That will produce the flickering of the ghostly eyes.

To produce the hissing noise, you will use `random(0, 1000)` in the `if` statement to create another random number — this time between 0 (smallest possible value) and 999 (greatest possible value).
If the random number is greater than 900, write 3000 random values into the `buzzerPin` with `analogWrite(buzzerPin, random(0, 256));` in the adjacent `for` loop. That will produce the hissing sound in the speaker.

The random numbers to be produced with the help of the `random()` function are evenly distributed. That means that every possible number will occur just as often as any other over a long period of time. The hissing will only be output, however, when the random number is greater than 900. That happens about one tenth of the time. If you want the hissing to happen less often, just choose a number larger than 900.

Now you can install these ghostly flickering eyes in a jack-o'-lantern or a homemade ghost.

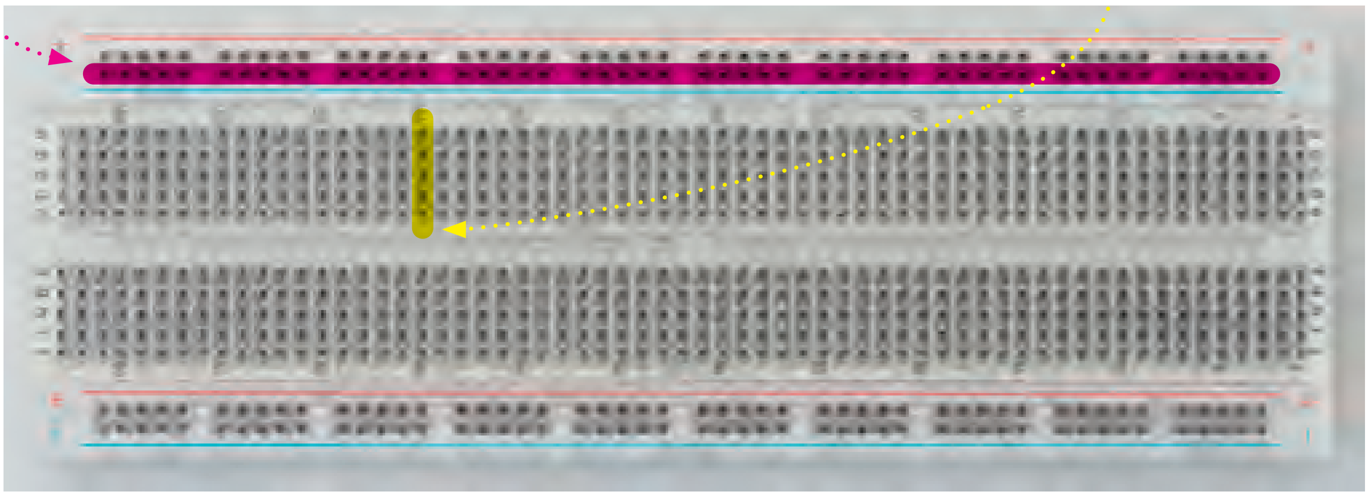
The ghostly eyes can be combined with lots of other excellent ideas. How about a siren than howls when you shine a flashlight on the jack-o'-lantern? You have already learned how to do that. No doubt, you will also have a lot of other great ideas of your own!

```
#include <KosmoBits_Pins.h>

const int buzzerPin = KOSMOBITS_BUZZER_PIN;
const int redPin = 11;
const int greenPin = 6;

void setup() {
  randomSeed(analogRead(3));
  pinMode(redPin, OUTPUT);
  pinMode(greenPin, OUTPUT);
}


void loop() {
  // Blinking
  analogWrite(redPin, random(0, 256));
  analogWrite(greenPin, random(0, 256));
  delay(200);

  // Hissing
  if (random(0, 1000) > 900) {
    for (int i = 0; i < 3000; ++i) {
      analogWrite(buzzerPin, random(0, 256));
    }
  }
}
```

▲ Ghostly eyes

BREADBOARD

The breadboard gives you an easy way to assemble electronic circuits. The outer red- and blue-marked rows are electrically connected to each other. This is where you usually connect the power supply. To do that, you connect one of the microcontroller pins marked with “GND” (for “ground”) with a (-) hole and one “5V” pin with a (+) hole in the breadboard. The vertical columns (a to e and f to j) are also electrically connected to each other — although only up to the “ditch” in the middle of the board. You can see all these details in the illustration.



Where does it go from here?

You have now acquired a solid foundation in Arduino programming. You can and should build on it. The CodeGamer kit and the KosmoBits system give you a good start, because in addition to the actual microcontroller you already have a breadboard, some LEDs, jumper wires and, of course, sensors. With the help of the battery, you will even be able to operate the entire setup independently of a computer and without any extra parts. The battery has a pretty high capacity. You will notice that by the fact that it rarely needs to be recharged. In short: You are well equipped!

You will find a lot of other project ideas on the Internet. Every once in a while, you will probably need an extra electronic component for one of those projects. You already have the rest though. Most important, you have even learned how to program by writing real code!

Now let your imagination run wild!

Indented

You may have wondered why a lot of the lines found in the programming text are indented, or moved a little to the right compared to the others. The reason for it is simple: It makes the programming text easier to read.

Let's take a simple example:

```
if (digitalRead(button1) == LOW) {
  red = 255;
} else {
  red = 0;
}
```

It could be written as follows:

```
if (digitalRead(button1) == LOW) {
red = 255;
} else {
red = 0;
}
```

Or — even worse — as follows:

```
if (digitalRead(button1) == LOW) {red = 255;} else
{red = 0;}
```

All these versions mean the same thing, it's just the formatting that changes. And yet, in the first example you can see the structure of the program at a glance. It is easier to read the code.

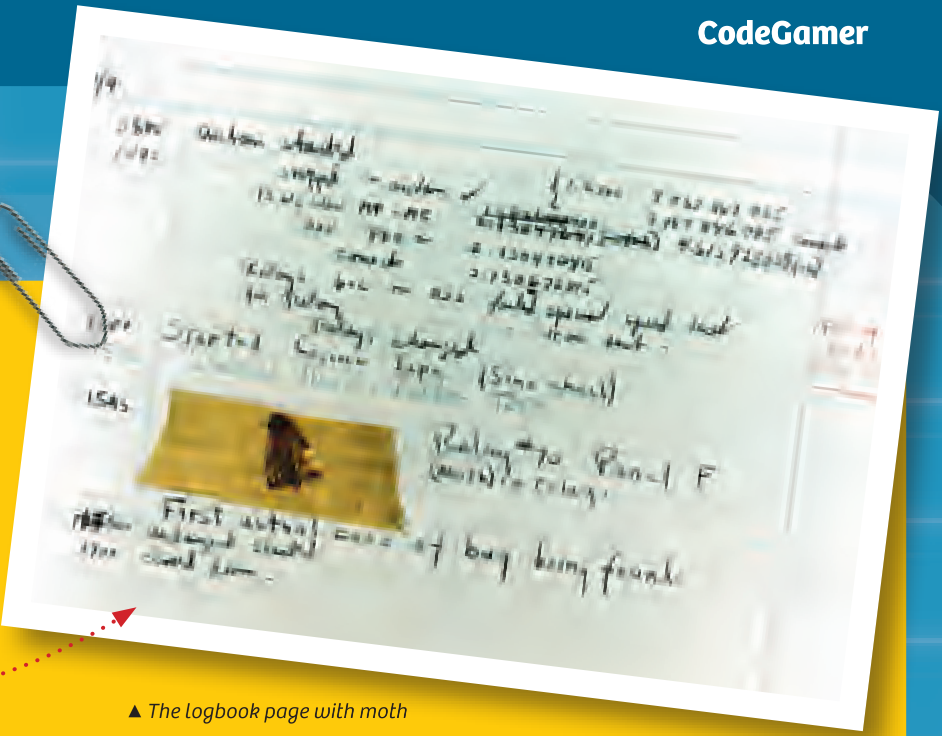
That is why it makes sense to indent the program code whenever it begins a new block. Also, as a rule, each individual instruction should get its own line.

The Arduino environment will help you with this, and usually moves new blocks to the right all by itself. If you ever want to indent portions of text by hand, though, use the tab key rather than the space key.

◄ *Automatic formatting*

CHECK IT OUT

What is a bug, anyway?


9/9

0800 Arctan started
1000 [illegible]

[illegible]

Started Cosine Tape (Sine check)

1545 Relay #70 Panel F (moth) in relay.

First actual case of bug being found.

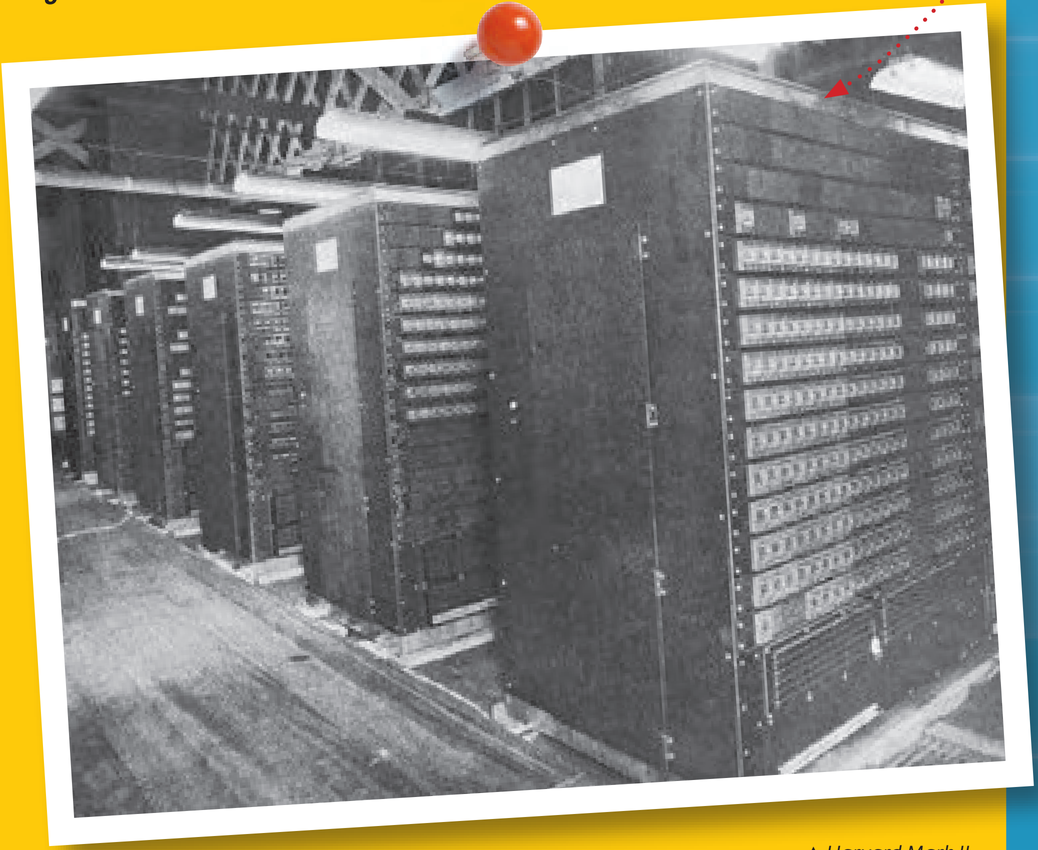
[illegible]

▲ *The logbook page with moth*

When a program doesn't do what it's supposed to do, the error is called a **bug.** You can just call it an error, but the term bug is used much more often. There's an amazing story behind this term!

Earlier computers, such as the *Harvard Mark II,* completed in 1947, did not yet have any microprocessors. Instead, they performed calculations with the help of **electromechanical relays.** A relay basically consists of an electromagnet and a magnetically activated switch. If the electromagnet is turned on, it activates the switch. If the magnet is turned on again, it moves the switch back to the "off" setting. The important thing is that this kind of relay involves the actual movement of something, namely the switch.

On September 9, 1947, the technicians responsible for the Mark II were looking for the source of an error. They found it: There was a moth that had wedged itself into a relay! The first bug in a computer program, in other words, literally was an insect. The moth, meanwhile, was dutifully taped into the Mark II logbook.



▲ *Harvard Mark II*

CHECK IT OUT

Arduino and the Maker

At a Maker Faire ▶

▲ Workshop at a Maker Faire

Have you ever dreamed of being an inventor? Of thinking up new machines and gadgets and turning them into reality? More and more people are moving beyond merely dreaming, and deciding to actually do it. They are **makers**!

Makers used to be called tinkerers or hobbyists. But those words aren't quite right anymore. While most tinkerers used to like to keep themselves busy all alone in their own workshops, makers also like to come out into the open and share their projects.

So a lot of **hackerspaces** or **makerspaces** have been created in cities around the world. These are like a cross between a meeting place and a community workshop. They are places where the makers can compare notes, present their latest ideas, give each other advice, and have access to shared parts and tools.

There are also more and more *Maker Faires* popping up around the world, which allow makers to present themselves to a larger public. They also typically offer an array of workshops for experienced makers to add to their knowledge and for beginners to take their first steps.

In the makers' projects, microcontrollers such as the one from Arduino often play an important role. They are what makes it possible to create complex gadgets without first having to develop expensive specialized electronics.

Maker project ▶

◀ A 3D printer at work

3D Printers

What good will the best electronics and the greatest software do you if you can't find an appropriate housing for your project? This is where a recent maker solution comes in: 3D printers.

These are devices that are capable of printing out three-dimensional (3D) objects rather than just two-dimensional (2D) images on paper. It may sound like science fiction, but it's very simple in principle. You typically start with a plastic material rolled up like thread on a spool. This filament is then heated to the melting point in a nozzle. In molten form, the plastic is computer-guided to a certain location and then squirted out. The plastic then cools and hardens. Drop by drop, layer by layer, even complicated and intricate structures can be built in this way.

Devices capable of doing this kind of thing have existed for a while, but it is only in the last few years that they have become affordable for hobbyists.

By the way: The first test versions of the KosmoBits controller were created in this way too!

▲ Filament for a 3D Printer

◀ Various 3D-printed prototypes from the CodeGamer development stages

Common Error Messages

`error: expected ';' before ')'`

Here, a semicolon was expected before the closing parenthesis, but it was not found.

EXAMPLE:

```
In function 'int average2()':
DoubleClap:86: error: expected ';' before
')' token
  for (int i = 0; i < N, ++i) {
                             ^
exit status 1
expected ';' before ')' token
```

SOLUTION:

The comma has to be replaced with a semicolon after `i < N`.

`error: '...' was not declared in this scope`

A name used in the program is not familiar to the computer. This is often an indication of a simple typo.

EXAMPLE:

```
error: 'pinnMode' was not declared in this
scope

  pinnMode(A1, INPUT);
```

SOLUTION:

Correct typo: It is actually called `pinMode`.

`error: '...' does not name a type`

A type used in the program is not familiar to the compiler. In most cases, this either involves a typo or you forgot to include the corresponding file.

EXAMPLE:

```
error: 'KosmoBits_Pixel' does not name a
type
  KosmoBits_Pixel pixel;
```

SOLUTION:

Include “KosmoBit_Pixel.h”:

```
#include <Adafruit_NeoPixel.h>
#include <KosmoBits_Pixel.h>
```

```
avrdude: ser_open(): can't open device "\\.\COM4": Access is denied.
```

You presumably forgot to close the serial monitor before trying to upload the program.

SOLUTION:

Close the serial monitor and re-upload the program.

```
avrdude: ser_open(): can't open device "\\.\COM4": The system cannot
find the file specified.
```

1. You forgot to connect the KosmoDuino to the computer. You might also have inserted the USB cable into the interaction board's charge socket by mistake.

SOLUTION:
Use the USB cable to connect your computer to the KosmoDuino via the USB port.

2. The wrong port has been set. Check *Tools* → *Port* and change the port if necessary.

SOLUTION:
Select a different port.

```
Low memory available, stability problems may occur.
```

```
Not enough memory.
```

Your program is using almost all the microcontroller's RAM or is even too large for it. You may have applied a large array.

EXAMPLE:

```
int array[1000] = {}; // That is too large!
```

SOLUTION:

Change your program by using a smaller array.

NOTES