The Theremin project

Project description and guidelines for teachers

Contents

PART A: Pedagogical Considerations

General approach/considerations

RoboScientists aims at engaging secondary school students in robotic artefact construction through interdisciplinary in nature projects. The set of the projects (that are going to be carried out) offer students opportunities to explore different aspects of the field of Science, Technology, Engineering Arts and Maths. Crafting/ handcrafting is a pivotal point in all the projects. Through the crafting process (highly interwoven in the robotic artefact construction) it is likely that the students will explore a number of engineering and design concepts, confront challenges and consider multiple solutions in order to achieve the results that they want.

About the Theremin project

The project aims to design and develop an electronic musical instrument controlled without physical contact by the performer. Sounds are produced by the movements of performer's hand around the instrument. The theremin is a great project because it is an uncommon instrument that is fun to watch and play. In addition to the aforementioned and besides the knowledge and skills to be developed when dealing with this project, it has some applications in many different products. For example, the Theremin project idea can be applied within a parking system, or in a walking stick for visually impaired people, etc. The Theremin project provides the opportunity for learning to be achieved through embodied practice.

When developing the designing and setting up the project, it is important to have in mind the presentations provided and discussions that took place during the training sessions. It is recommended to the educators that for a project to be delivered it is important to: employ the makeology approach, work in teams, encourage experimentation, involves crafting and coding, apply the Engineering design process is employed, encourage sharing, employ the STEAM approach, design and develop robotics models and artefacts, use various tool, equipment and materials, involve students as makers.

The 1st category: 21st century and transversal skills

The 21st century and transversal skills have been outlined and described in the literature by various researchers *(e.g. Bybee & Fuchs, 2006; Ananiadou & Claro, 2009; Trilling & Fadel, 2009; Mojika, 2010; Rotherham & Willingham, 2010; Griffin & Care, 2015)* and reports from ministries of education, policies and organizations *(UNESCO 2014, 2016).* These are the following: Communication, collaboration, critical thinking, problem solving, knowledge construction, creativity, innovation, self-directed learning, global citizenship and digital literacy. In the section below, definitions, descriptions and characteristics of the main 21st century and transversal skills are given.

Learn how to learn: It is a very important skill to learn how to acquire knowledge and skills on their own and manage to construct their own knowledge and meanings.

Investigation: Investigation can be defined quite simply as a systematic fact finding and reporting process. It is derived from the Latin word vestigere, to "track or trace," and encompasses a patient, step-by step inquiry. Investigation is finding facts; it is akin to research conducted in the academic arena. In addition, it is a multi-disciplined field of study. It encompasses law, the sciences, communications, and a host of other things. Finally it requires an inquisitive mind coupled with an attention to detail.

Exploration: Exploration-based learning is an active learning approach. Students' abilities are dynamically balanced with difficulty level in the system to provide exhilarating and fulfilling learning experiences. The visually and intellectually compelling storylines within the environment challenge each student to leverage their own curiosity and passion to solve complex problems using data and evidence, to form arguments and reach conclusions. This approach is positioned to deliver high levels of engagement and concentration while reducing stress and boredom for all students. Through these experiences, students build their levels of confidence and creativity, resulting in improved performance and sustained motivation to learn.

Reflection: Reflecting helps you to develop your skills and review their effectiveness, rather than just carry on doing things as you have always done them. It is about questioning, in a positive way, what you do and why you do it and then deciding whether there is a better, or more efficient, way of doing it in the future.

Problem Solving: Problem-solving skills help students determine the source of a problem and find an effective solution. Although problem-solving is often identified as its own separate skill, there are other related skills that contribute to this ability.

Critical Thinking: Critical thinking is not a matter of accumulating information. A person with a good memory and who knows a lot of facts is not necessarily good at critical thinking. A critical thinker is able to deduce consequences from what he knows, and he knows how to make use of information to solve problems, and to seek relevant sources of information to inform himself.

Digital literacy: Digital literacy refers to a particular set of competencies that allow you to function and participate fully in a digital world. Students, nowadays, are generally considered to be digital natives - able to use technology effectively and easily. They must be able to resolve conflicts, source material ethically and interact with the wider world in a responsible manner.

Creativity: Creativity simply means being able to come up with something new. Therefore, creative thinking is the ability to consider something – a conflict between employees, a data set, a group project – in a new way. The term is referring to the act of turning new and imaginative ideas into reality involves two processes: thinking, then producing. Finally, creativity is characterized by the ability to perceive the world in new ways, to find hidden patterns, to make connections between seemingly unrelated phenomena, and to generate solutions.

Innovation: Innovation skills refer to the talent of exploiting new ideas for the purpose of gaining social or economic value. Innovation skills are usually a combination of one's ability to think creatively, problem-solving ability, as well as functional and/or technical abilities. Fairly speaking, innovation skills are basically one's ability to apply a blend of knowledge, skills and attributes in a specific context.

Cooperation/ Collaboration: Cooperation is a division of labour between-group members. It occurs when a task is divided up into individually manageable subparts, which are subsequently constructed into a final outcome. Although this is conceptually different to collaboration, at a fine-grained level, all collaborative tasks have a degree of cooperation (Lai & Viering, 2012).

Communication: Communication is the art of transmitting information, thoughts and attitudes from one person to a different one's. It is the route of meaningful interaction among human beings. We learn basic communication skills by observing other people and modelling our behaviours based on what we see.

Building knowledge: Knowledge building provides an alternative that more directly addresses the need to educate people for a world in which knowledge creation and innovation are pervasive. Knowledge building may be defined as the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts. Knowledge building, thus, goes on throughout a knowledge society and is not limited to education.

The 2nd category: General Pedagogical Skills / Objectives

The second category of skills are the General pedagogical ones. These are the skills to be developed or in other words the general pedagogical objectives of the Curricula of various subject matters. They are mainly outlined within the Curricula of various subject matters and specifically from subject matters such as Mathematics, Science, Technology, Engineering, Social Sciences, Arts and Linguistics.

General skills

Information Management Skills: Students make various calculations and metrics, make estimates and use graphs, tables, charts, and more optical media, to manage the various information and solve the problems which are presented. Also, students communicate with different ideas, criteria, possible solutions and outcomes. This communication takes place through sketches, graphs and representations on paper and computer, making two-dimensional and three-dimensional models and prototypes through symbolic and verbal representations. At the same time, they recognize, organize, analyse, compile and evaluate data information and interpret different views and approaches.

Problem Solving Skills: The Design and Technology Study Program is particularly useful for developing problem solving skills. Ploblem solving is closely related to the development of critical, reflective and logical thinking mindset, the development of imagination and creativity, problem determination and analysis, the exploration, construction and control of products and constructions, the evaluation of processes and products.

Project Management Skills: Through cross-thematic activities proposed and implemented through teamwork, pupils can develop skills in targeting, managing time and the available resources, computation, risk-taking and dispute resolution.

Social and Interpersonal Skills: The proposed activities as well as the respective framework offer a rich and authentic communication environment between pupils and teachers, working in groups, respect and cooperation, etc.

Skill Category: Design

Middle School

1. Ask appropriate questions and through ideas of stature propose ideas for various constructions and procedures.

2. They discuss ready-made technology products, referring to their form, function and safety.

3. Analyse the factors that affect a problem, through the collection and utilization of various information.

4. Report and develop problem-solving ideas, taking into account security, ergonomics, aesthetics, economy, applying the design process.

5. Carry out research and evaluate sources and information about a particular product or process.

6. Evaluate products and processes based on criteria that have been set.

7. Apply the stages of the design process.

8. Recognize and use symbols in diagrams, circuits and drawings, in applications on paper and on PC.

High School

1. Investigate and evaluate industrial products and processes based on specifications.

2. Implement a manufacturing process according to the product they are going to manufacture.

3. Draw up an action plan and implement the planning process stages.

4. Evaluate products based on specifications and needs that have been put forward and propose modifications.

5. Report and document modifications and variations made during the design and construction phases and explain the necessity of these differentiations.

Skill Category: Communication

Middle School

1. Describe verbatim and / or design the design process for ideas to be implemented.

2. Use lines, shapes, and simple design methods to present their ideas.

3. Recognize and use symbols that recognize within diagrams, circuits and patterns.

4. Communicate using sketches and 3D drawings and spelling projections.

5. Communicate using recognized symbols.

High School

1. Enhance their designs by adding information through detailed three-dimensional drawings and magnifications.

2. They present ideas and ways of construction through three-dimensional drawings and spelling projections.

Skill Category: Construction

Middle School

1. Collect and categorize materials from simple constructions.

2. Prepare simple constructions with various materials, using different skills and manufacturing methods.

3. Cut, bind and shape materials to use in simple constructions.

4. Mark, cut and assemble with precision various materials.

5. Safely use a range of tools and machines to manufacture products made up of more than one kind of materials.

High School

1. Use manufacturing techniques, materials, tools and machinery in a way that appears to be familiar with manufacturing processes, taking into account safety during manufacture and quality assurance of the final product.

2. Propose and apply alternatives to implement their ideas.

Additionally, exploratory skills are promoted through the Curricula (Programs of Study) of Secondary Education. The exploratory skills are summarized below:

- Writing hypotheses that can be checked.
- Designing and conducting research, determining which variables will change, what will remain stable and what will be measured.
- Selecting appropriate tools, technological equipment and suitable materials for a construction.
- Presenting and interpreting the results using a range of representations and dynamic images, simulations and models.
- Communicating results and explaining structures to classmates and other audiences / users, using appropriate vocabulary.
- Evaluating ready-made technology products and suggesting improvements.
- Presenting a design and explaining the use of the finished product.

The 3rd category: The Learning Objectives

The third category includes the Learning Objectives to be achieved within various subject matters, or in other words across various disciplines. The Theremin project aims to achieve learning objectives from the disciplines/subject matters of Music, History, Language and Literature, Maths, Physics and ICT :

- **Mathematics:** angles, degrees, geometry
- **Music:** electronic musical instrument, various musical instruments, description, characteristics, emotions, uses
- **History:** facts, the story of the development of the theremin idea, important dates and names, inventors, the era it represents, its uses, why is needed
- **Language and Literature:** brainstorm, discuss and answer various questions regarding the theremin project and the idea it represents, develop reports, present, i.e. the use of the theremin project now and then
- **Maths:** variables, analogue reading transformation
- **Physics:** electrical circuit making, understanding what a motor is and how it works, controlling motion, antenna, control, pitch, volume
- **ICT:** operating principles, performance techniques, programming, connecting physical and digital world through the use and synchronization of multiple sensors

The process

The process to be followed from the students is the Engineering Design Process as presented in the following two diagrams.

Diagram 1: The Engineering Design Process

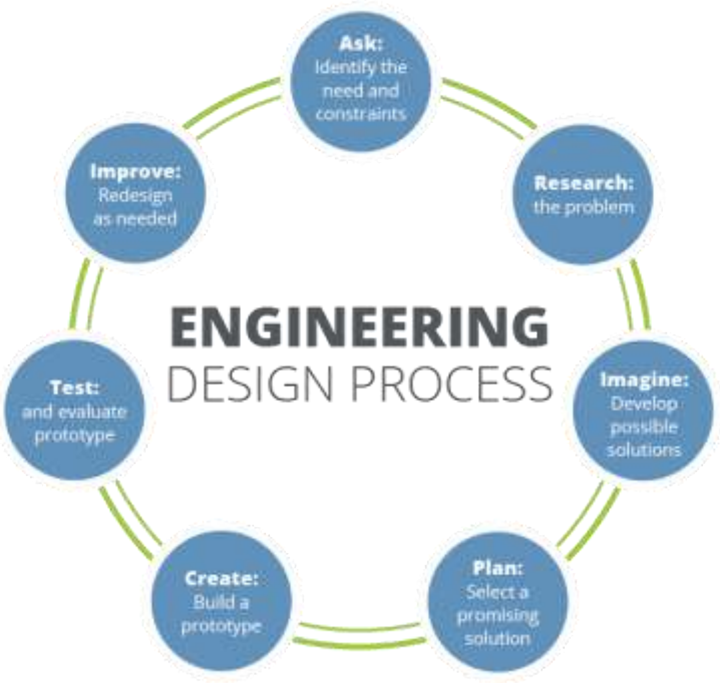


Diagram 2: The Engineering Design Process

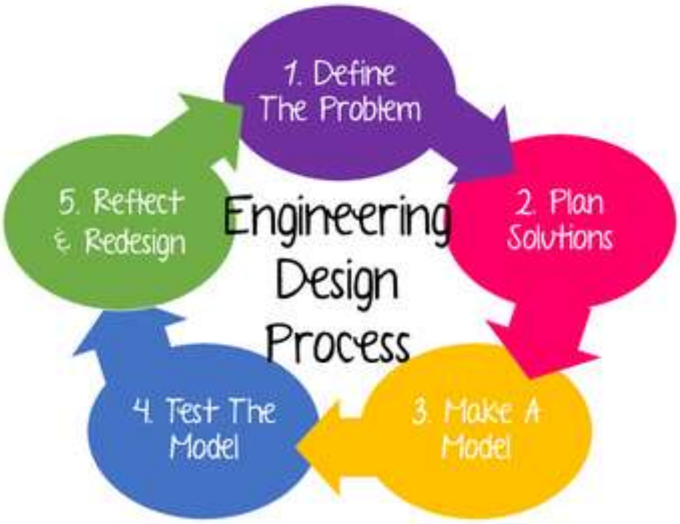
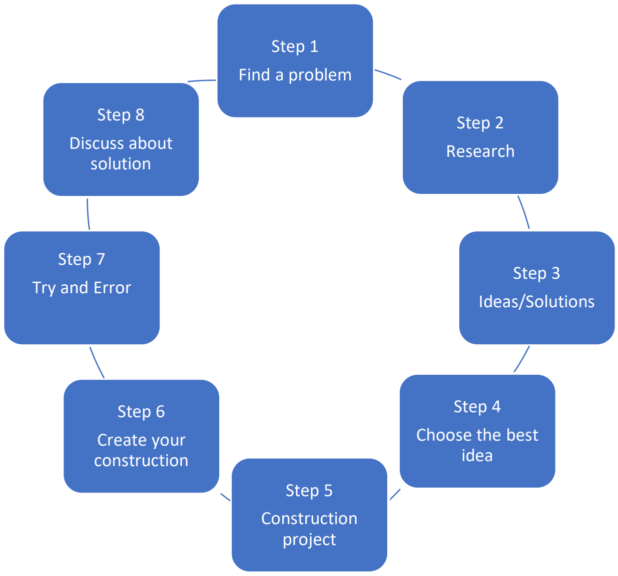


Diagram3: The Design process according the Design and Technology Curriculum (Cyprus Ministry of Education and Culture)



PART B: Practice

Level1: Creating a one-hand operated Theremin

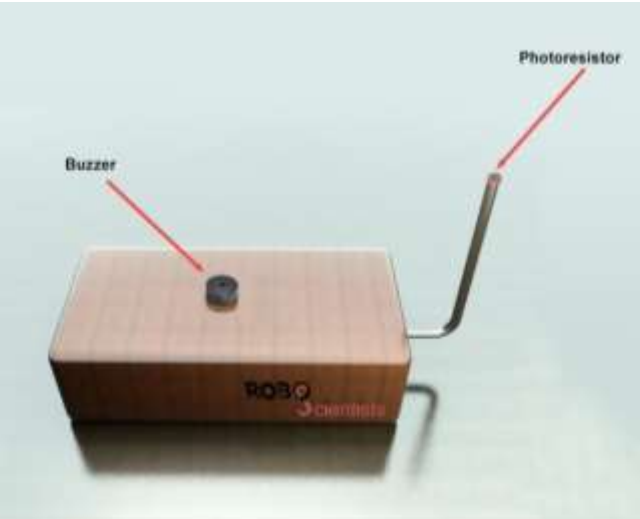


Figure 1: Implementing a Piezo buzzer and a Photoresistor for creating a one-hand operated Theremin

The main goal of this level is the creation of a one-hand operated Theremin through the implementation a photoresistor that controls the produced pitch provided by a Piezo buzzer (*Figure 1*).

The way of operating such kind/type of Theremin, is illustrated in *Figure 2*. In details, when the performer is moving his/her hand away from the photoresistor sensor, high pitched sounds are produces, but when the hand of the performer is getting closer to the photoresistor, low-pitched sounds are produced.

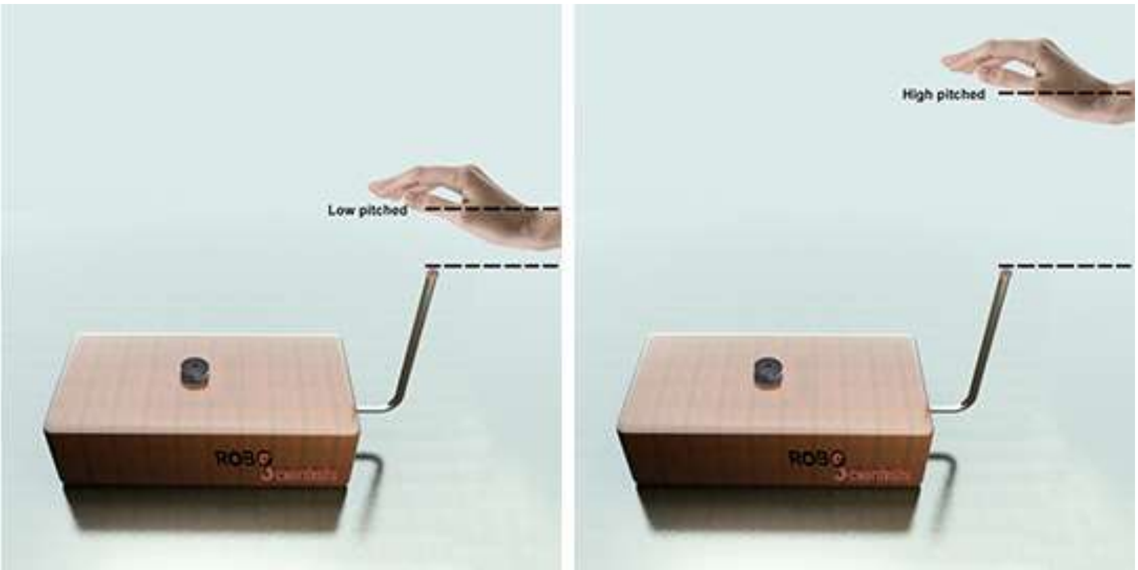
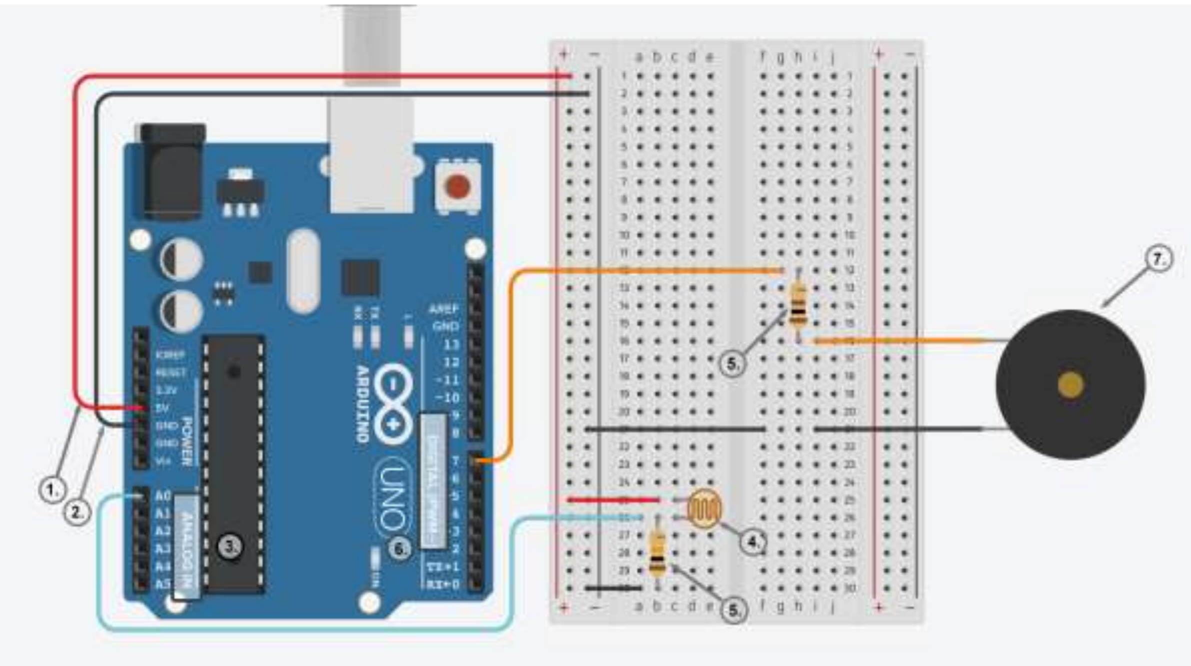


Figure 2: When the hand is moving closer to the photoresistor, low-pitched sounds are produced by the Piezo buzzer (left), while when the hand is moving away from the photoresistor, high-pitched sounds are produced (right).

Creating the circuit

For the circuit of this level, students will need – apart from the breadboard and some jumpers - a photoresistor and a 10 KΩ resistor, as well as a Piezo Buzzer and a 100-ohm resistor. The following diagram indicates how the aforementioned components should be connected to the Arduino.



- Use 5V (**1**) and Ground/ GND (**2**) pins to respectively provide 5V power and ground to your breadboard
- Connect one of photoresistor's (**4**) legs to power (5V), and the other to one of the analog pins (**3**) (pin A0 in the example), as well as to ground through the 10KΩ resistor (**5**).
- Use one of the digital pins (**6**) (pin 7 in the example) to connect the Piezo Buzzer (**7**) through the resistor (**5**).
- *Keep in mind that there is no polarity to photoresistors. Therefore, you can change the circuit (meaning connect one of photoresistor's leg to power through the 10KΩ resistor and the other to ground) and still have a functional sensor. However, the values that you get will differ and thus, you need to do the necessary adjustments and/or changes to your code later on.*

Questions that can be raised/discussed:

- Why the resistors are needed?
- What does the Piezo buzzer do?
- Why are we using digital instead of analog pins to connect the Piezo buzzer?
- Why are we using analog instead of digital pins to connect the photoresistor?

Towards a block-based programming solution

At this level, the students should be encouraged to breath some life into their construction by composing the relevant script.

The blocks that appear below will be needed: The gold blocks are from the Control palette. The turquoise blocks are from the Arduino palette and achieve the communication with the Arduino board, the fuchsia color block in order to play sounds and the purple block for the position info of our hand.

A script in Snap4Arduino (and in most of the block-based programming environments) is assembled by dragging blocks from a palette into the scripting area in the middle part of the window in Snap4Arduino. Blocks snap together when you drag a block so that its indentation is near the tab of the one above it. Below you can see the blocks that will be used to compose the final solution.

This is a *hat* block that indicates that the script should be carried out when the green flag will be clicked.

This is a *C*-block. The slot inside the *C* shape is a special kind of input slot that accepts a *script* as the input. Any script placed in there will be carried out forever in a circle.

This block comes from the Variables palette and sets the value of the variable '***pitch***' to the current analog reading retrieved from the photoresistor (controlled with your hand). You can create variables "by hand" that aren't limited to being used within a single block. At the top of the Variables palette, click the "Make a variable" button:

This block plays the buzzer tone that corresponds to the current value of the variable ***pitch***. The tone block works with two arguments: the pin number that you will use in Arduino (in our case pin 7) and the frequency that takes values approx. from 200 to 800 (given that is closely related to the readings from the photoresistor)

Solution in Snap4Arduino

In repeat, the buzzer reproduces the tone that corresponds to the current value of the variable pitch. The value that the variable ***pitch*** takes is closely related to the movement of our hand across the photoresistor. In general, the higher the number of the variable ***pitch***, the higher the pitch that is created.

Questions to be raised in the class:

- Can you find the relation between the value of the 'variable pitch' and the pitch that is created from the buzzer?

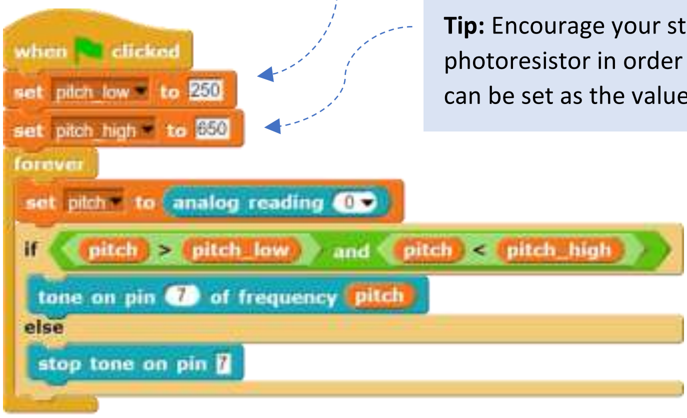
Solution in Arduino IDE

```
/*Pseudo Theremin with Photoresistor and buzzer Part 1*/

int buzzerPin = 7;
int photoresistorPin = 0;

void setup()
{
}


void loop()
{
  int pitch = analogRead(photoresistorPin);
  tone(buzzerPin, pitch);
}
```

Towards a more optimal block- based programming solution (optional)

Tip: Encourage your students to move their hand across the photoresistor in order to identify the lower analog reading, which can be set as the value of the ***pitch_low*** variable.

Tip: Encourage your students to move their hand across the photoresistor in order to identify the higher analog reading, which can be set as the value of the ***pitch_high*** variable.



pitch_low and ***pitch_high*** set the range of values out of which no tone will be played. In other words, knowing the lower value and the higher value, we can check whether the current analog reading from the photoresistor (stored into the variable ***pitch***) falls into our range. If it does, then the buzzer tone that corresponds to the current value of the variable ***pitch*** is played. If it does not, then nothing is played.

Tip: Ensure that your students have understood that the value of the ***pitch_low*** and ***pitch_high*** may not be necessarily 250 and 650; the values are related to the conditions in the room where the experimentation takes place.

Towards a more optimal programming solution in Arduino IDE (optional)

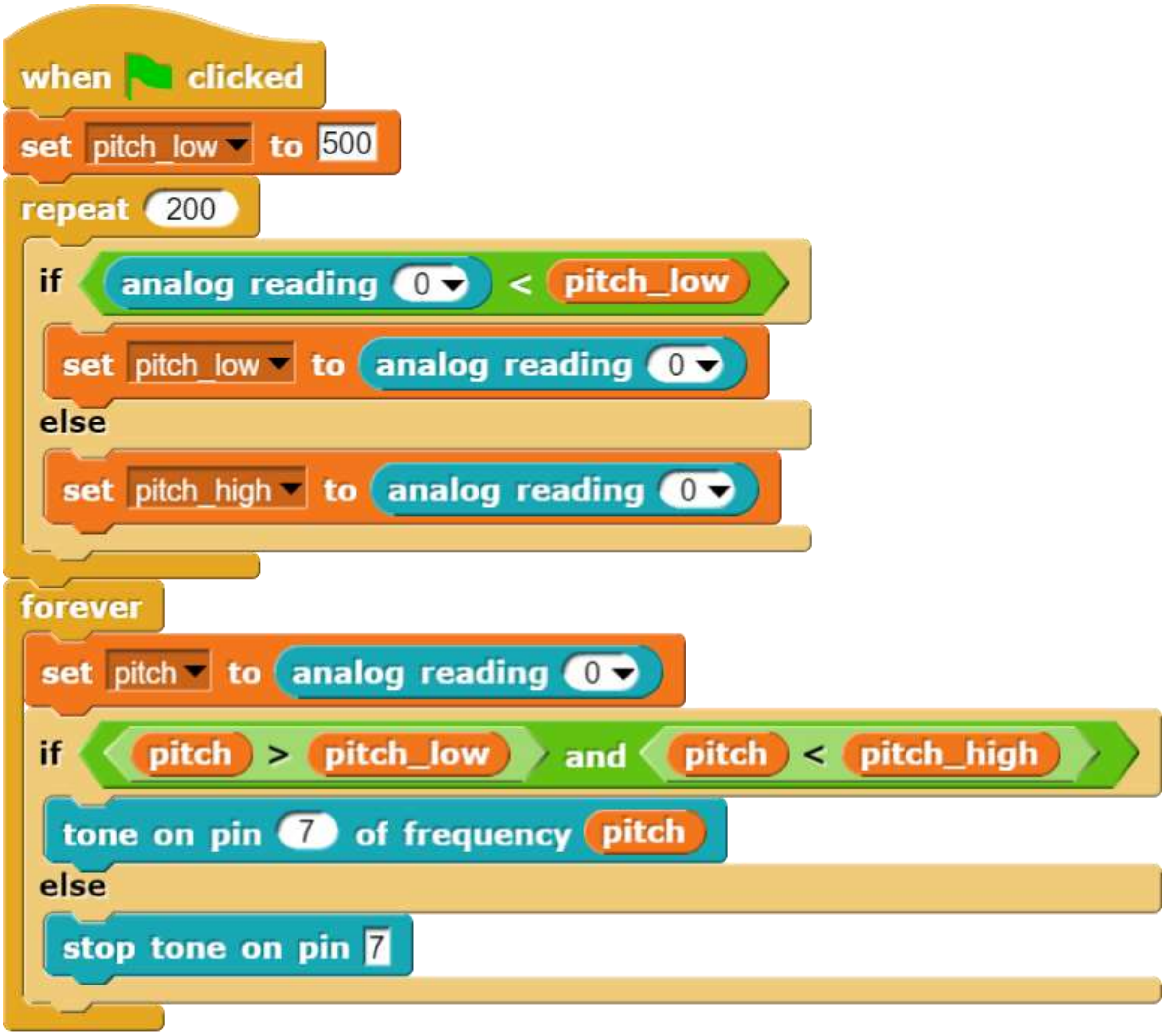
```
/*Pseudo Theremin with Photoresistor and buzzer Part 2*/

int buzzerPin = 7;
int photoresistorPin = 0;
int pitch_low;
int pitch_high;
int i;

void setup()
{
  for (i=0;i<200;i++)

  {
    int pitch = analogRead(photoresistorPin);
    if (pitch<pitch_low)
    {
      pitch_low=pitch;
    }
    else
    {
      pitch_high=pitch;
    }
   }
}



void loop()
{
  int pitch = analogRead(photoresistorPin);
  if (pitch>pitch_low and pitch<pitch_high)
  {
    tone(buzzerPin, pitch);
  }
  else
  {
    noTone(buzzerPin);
  }
}
```

Given the analog reading from the photoresistor the variables ***pitch_low*** and ***pitch_high*** receive several values. After 200 repetitions (it could be more or less)…the 2 variables will get a final value. In this way, the theremin is adjusted to the conditions in the current room.

Questions for further experimentation:

- Can you implement the same functionality of the “self-adjustable Theremin” in Snap4Arduino? *Check the solution in page 16.*

Implementing the self-adjustable Theremin in Snap4Arduino (optional)



Level 2: Creating a two-hand operated Theremin that reproduces sound through the PC

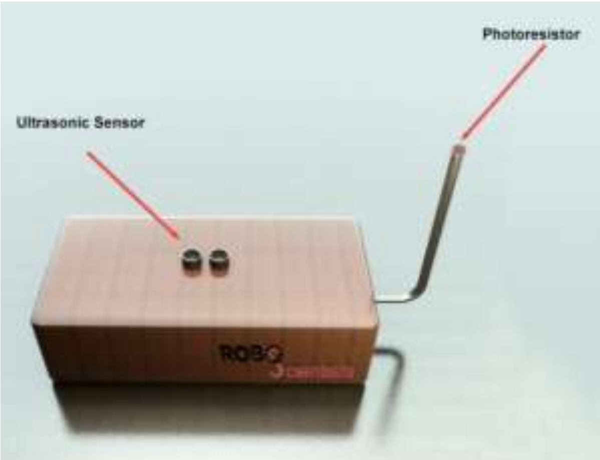


Figure 3: Implementing an Ultrasonic sensor and a Photoresistor for creating a two-hand operated Theremin

The main goal of this level is the creation of a two-hand operated Theremin through the implementation of an Ultrasonic sensor that controls the produced pitch provided by a PC, as well as through the implementation of a Photoresistor that controls the produced beat (*Figure 3*).

The way of operating such kind/type of Theremin, is illustrated in *Figure 4*. In details, when the performer is moving his/her left hand away from the Ultrasonic sensor, low pitched sounds are produces, but when the hand of the performer is getting closer to the sensor, high-pitched sounds are produced. Simultaneously, when s/he is moving his/her right hand away from the photoresistor, the produced beat is longer, but when his/her hand is getting closer to the photoresistor, the produce beat is shorter.

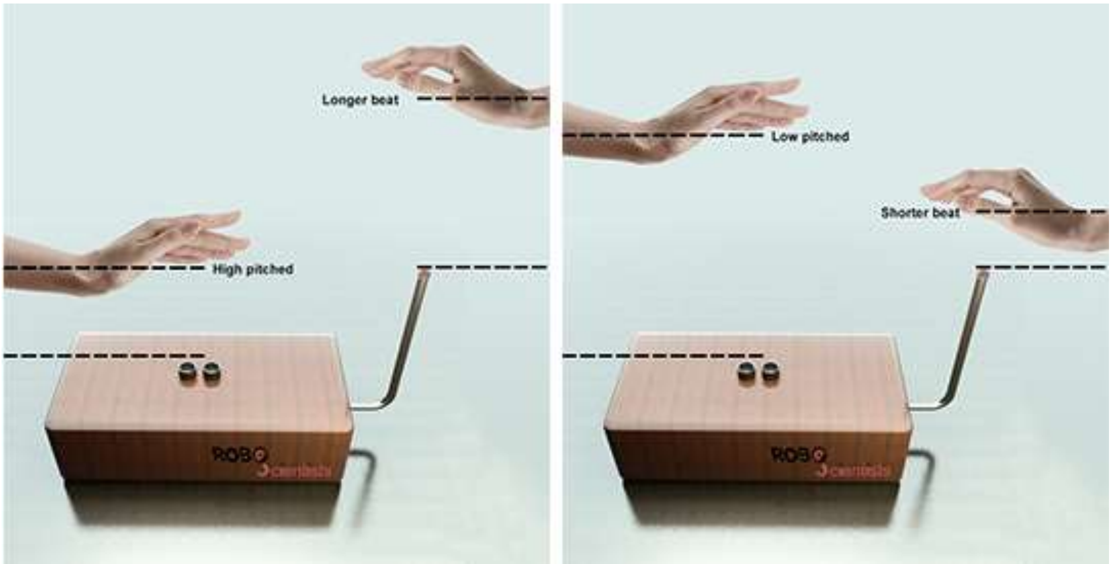
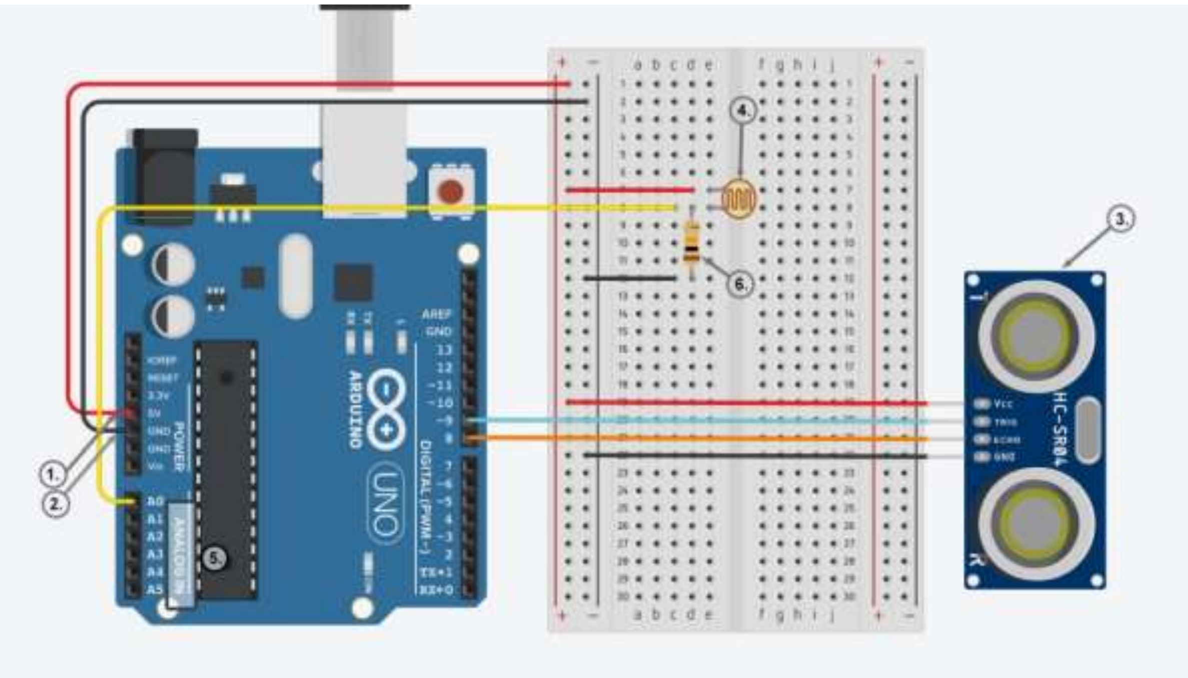


Figure 4: When the left hand is moving closer to the Ultrasonic Sensor and the right hand away from the photoresistor, high-pitched sounds of longer beat are produced by the PC (left), while when the right hand is moving away from the Ultrasonic Sensor and the right hand closer to the photoresistor, low-pitched sounds of shorter beat are produced (right).

Creating the circuit

For the circuit of this level, students will need – apart from the breadboard and some jumpers - a photoresistor and a 10 KΩ resistor, as well an Ultrasonic sensor (HC-SR04). The following diagram indicates how the aforementioned components should be connected to the Arduino.



- Use 5V (**1**) and Ground/ GND (**2**) pins to respectively provide 5V power and ground to your breadboard
- Connect one of the photoresistor's (**4**) legs to power (5V), and the other to one of the analog pins (**5**) (pin A0 in the example), as well as to ground through the 10KΩ resistor (**6**).
- Ultrasonic sensor (**3**) has four legs. Connect Vcc leg to 5V power, GND leg to ground, while Trigger and Echo legs to digital pins 9 and 8 respectively.

Questions that can be raised/discussed:

- Why a resistor is needed?
- What does the Ultrasonic sensor do?
- Why the Ultrasonic sensor does not need a resistor?
- Why are we using digital instead of analog pins to connect the Ultrasonic Sensor?
- Why are we using analog instead of digital pins to connect the photoresistor?

Towards a block-based programming solution

At this level, the students should be encouraged to breath some life into their construction by composing the relevant script that will allow them to create a two-hand operated Theremin.

The blocks that appear below will be needed: The gold blocks are from the Control palette. The turquoise blocks are from the Arduino palette and achieve the communication with the Arduino board and the fuchsia color blocks are used to play sounds and comes from the Sound palette.

A script in Snap4Arduino (and in most of the block-based programming environments) is assembled by dragging blocks from a palette into the scripting area in the middle part of the window in Snap4Arduino. Blocks snap together when you drag a block so that its indentation is near the tab of the one above it. Below you can see the blocks that will be used to compose the final solution.

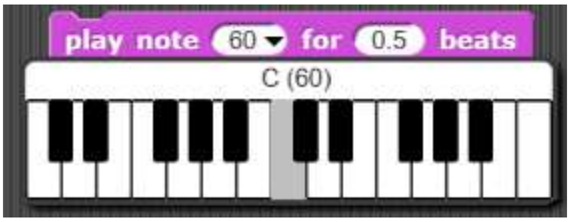
This is a *hat* block that indicates that the script should be carried out when the green flag will be clicked.

This is a *C*-block. The slot inside the *C* shape is a special kind of input slot that accepts a *script* as the input. Any script placed in there will be carried out forever in a circle.

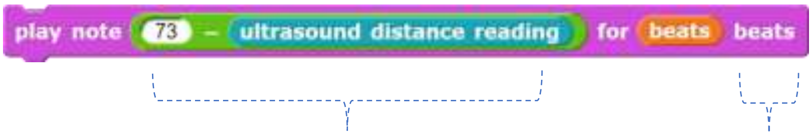
The if-else block runs its if-input script if (and only if) the expression in its hexagonal input reports true.

If it reports false the else-input is executed.

This block comes from the Variables palette and sets the variable '***beats***' to a specific value. This value can be inserted manually or can be linked to the analog readings of specific sensors (i.e. a photoresistor). You can create variables "by hand" that aren't limited to being used within a single block. At the top of the Variables palette, click the "Make a variable" button:



The Play Note () for () Beats block is a music block and a stack block. The block will play the specified note with a set MIDI instrument for the specified amount of beats. The notes are notated with numbers, unlike sheet music. In example, the selected Note is notated with number 60. Even though the drop-down keyboard shows only two octaves of notes (48 to 72), a number can be put in manually to get any note. To change octaves, simply add or subtract 12.



Identifying a note from 48 to 72

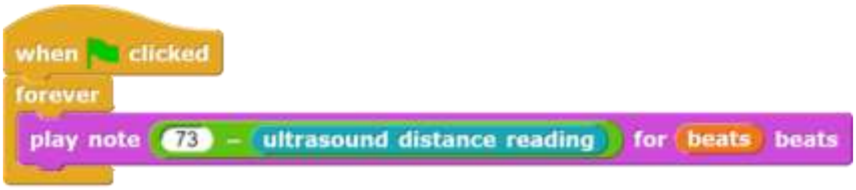
Rhythmic unit /Basic time unit in music

Explanation: As our hand approaches the ultrasound sensor (we get low values), we get high tones. For this reason, we use the subtraction operator. We subtract from the highest tone (72+1) the current ultrasound distance reading. In this way we get values from 48 (low-pitched) to 72 (high pitched) that corresponds to specific notes (see also the piano above). The “duration” of each note is defined by the value of the variable ***beats***.

Solution in Snap4Arduino

The solution brings together 3 scripts:

Script for controlling the ultrasonic sensor and reproducing a specific note (1st hand)

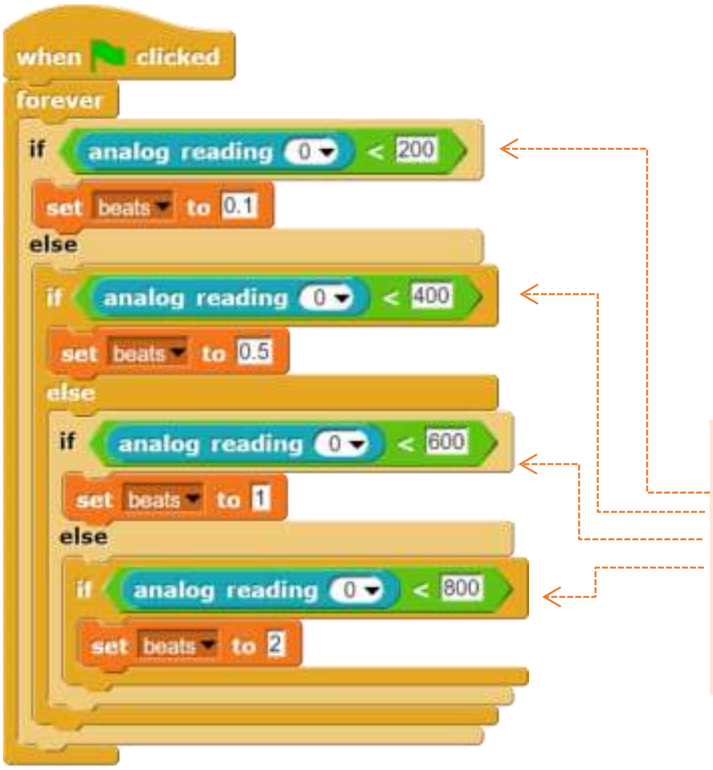


Script 1

Script for observing the value that corresponds to a specific note (optional use of this script)

Script 2

Script for controlling the photoresistor and setting the beats (2nd hand)



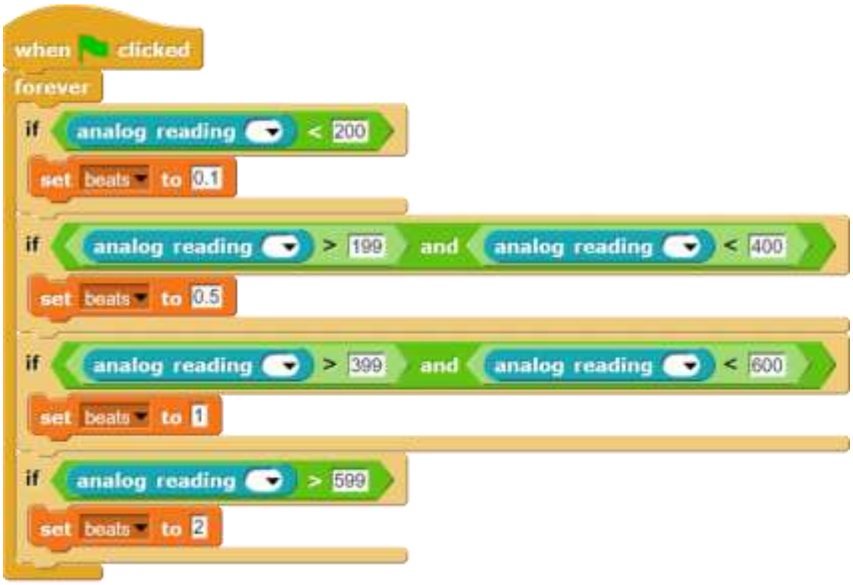
In this script the value of the variable ***beats*** changes according to the "analog reading" input value. The performer can adjust the duration of a note by moving the hand up or down.

Tip: While introducing the project in the class encourage the students to observe the analog readings retrieved by the photoresistor. The levels that have been set can change. The same applies to the value of the beats. Encourage free experimentation.

Script 3

Alternative script for controlling the photoresistor and setting the beats

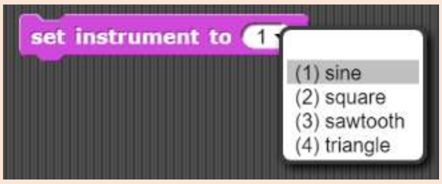
The script below has the same functionality with the script above (see script 3).



Script 4 (Alternative solution for script 3)

Questions/ Additional experimentations

- *Encourage your students to experiment with the available musical instruments by using the following block:*



Where should this block be placed?

- *Set different values to the variable beats. Which value works better?*

Level 3: Creating a two-hand operated Theremin that reproduces sound (created or imported by the students) through the PC

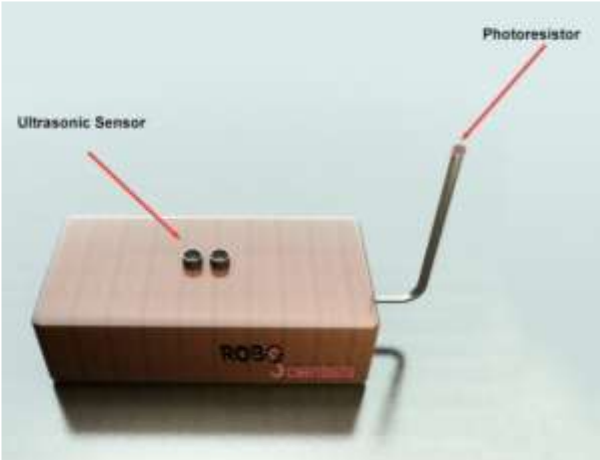


Figure 4: Implementing an Ultrasonic sensor and a Photoresistor for creating a two-hand operated Theremin

The main goal of this level is the creation of a two-hand operated Theremin through the implementation of an Ultrasonic sensor that controls the sounds that have been imported/composed by you, as well as through the implementation of a Photoresistor that controls the produced beat (*Figure 5*).

The way of operating such kind/type of Theremin, is illustrated in *Figure 6*. In details, when the performer is moving his/her left hand away from the Ultrasonic sensor, low pitched sounds are produced, but when the hand of the performer is getting closer to the sensor, high-pitched sounds are produced. Simultaneously, when s/he is moving his/her right hand away from the photoresistor, the produced beat is longer, but when his/her hand is getting closer to the photoresistor, the produce beat is shorter.

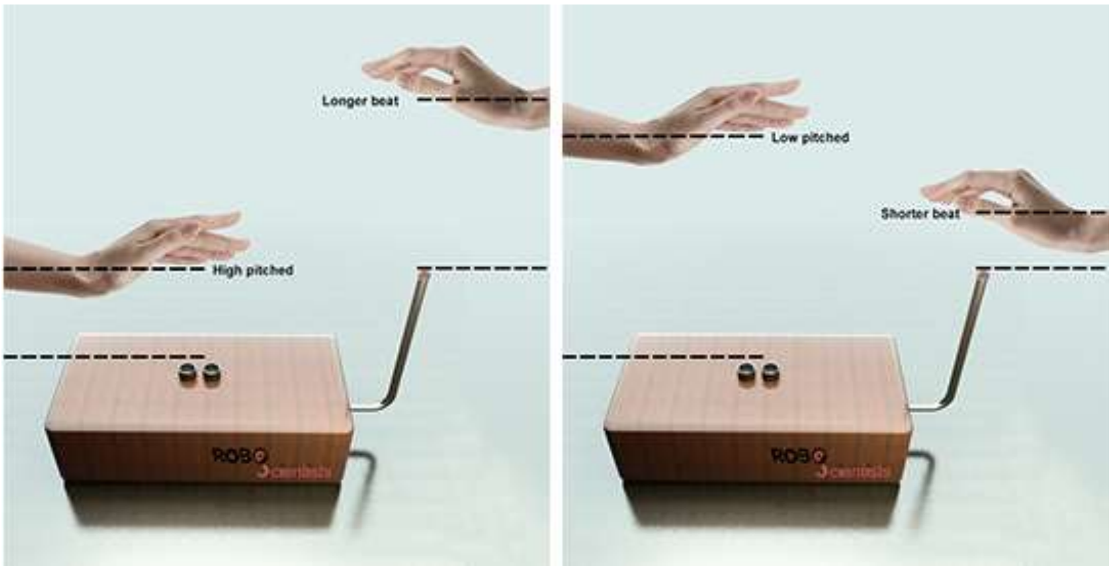
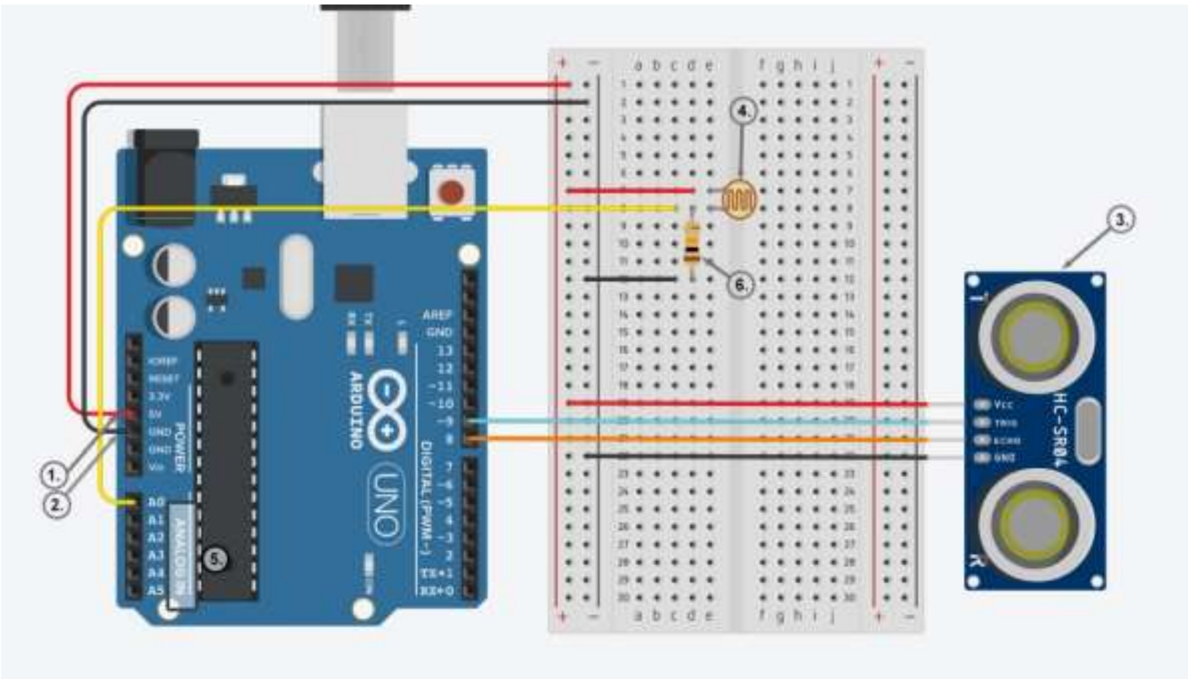


Figure 6: When the left hand is moving closer to the Ultrasonic Sensor and the right hand away from the photoresistor, high-pitched sounds of longer beat are produced by the PC (left), while when the right hand is moving away from the Ultrasonic Sensor and the right hand closer to the photoresistor, low-pitched sounds of shorter beat are produced (right).

Creating the circuit

The circuit of this level is the same as in level 2. The students will need – apart from the breadboard and some jumpers - a photoresistor and a 10 KΩ resistor, as well an Ultrasonic sensor (HC-SR04). The following diagram indicates how the aforementioned components should be connected to the Arduino.



- Use 5V (**1**) and Ground/ GND (**2**) pins to respectively provide 5V power and ground to your breadboard
- Connect one of the photoresistor's (**4**) legs to power (5V), and the other to one of the analog pins (**5**) (pin A0 in the example), as well as to ground through the 10KΩ resistor (**6**).
- Ultrasonic sensor (**3**) has four legs. Connect Vcc leg to 5V power, GND leg to ground, while Trigger and Echo legs to digital pins 9 and 8 respectively.

Towards a block-based programming solution

At this level, the students should be encouraged to breath some life into their construction by composing the relevant script that will allow them to create a two-hand operated Theremin. Sounds composed by the students or ready-made sounds can be imported in the Sound zone of Snap4Arduino. In this way, the Theremin can play sounds that are in line with students' preferences.

The blocks that appear below will be needed: The gold blocks are from the Control palette. The turquoise blocks are from the Arduino palette and achieve the communication with the Arduino board, the fuchsia color block in order to play sounds and the purple block for the position info of our hand.

A script in Snap4Arduino (and in most of the block-based programming environments) is assembled by dragging blocks from a palette into the scripting area in the middle part of the window in Snap4Arduino. Blocks snap together when you drag a block so that its indentation is near the tab of the one above it. Below you can see the blocks that will be used to compose the final solution.

This is a *hat* block that indicates that the script should be carried out when the green flag will be clicked.

This is a *C*-block. The slot inside the *C* shape is a special kind of input slot that accepts a *script* as the input. Any script placed in there will be carried out forever in a circle.

The if-else block runs its if-input script if (and only if) the expression in its hexagonal input reports true.

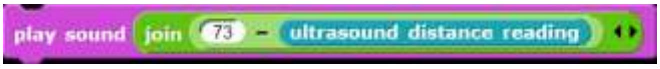
If it reports false the else-input is executed.

This block comes from the Variables palette and sets the variable '***beats***' to a specific value. This value can be inserted manually or can be linked to the analog readings of specific sensors (i.e. a photoresistor). You can create variables "by hand" that aren't limited to being used within a single block. At the top of the Variables palette, click the "Make a variable" button:

The Play Sound () block is a music block. The sounds are notated with numbers, unlike sheet music. In example, the selected sound is notated with number 60. Operations between sounds is possible.

The Rest for () Beats block is a music block and a stack block. The block pauses its script for the specified amount of beats, which can be a fraction.

The Join block is an Operators block and a Reporter block. It concatenates, or "links" the two values together and reports the result. It also takes as argument(s) "text" (string) or "Number" datatype(s) and returns "text".



Explanation: As our hand approaches the ultrasound sensor (we get low values), we get high tones. For this reason, we use the subtraction operator. We subtract from the highest tone (72+1) the current ultrasound distance reading. In this way we get values from 48 (low-pitched) to 72 (high pitched) that corresponds to specific sounds that have been manually imported. The Join block ensures that the result of the operation is in a text datatype, thereby compatible with what the *play sound block* can receive as input.

Importing sounds in Snap4Arduino

You can import sounds in 2 ways: either by selecting "import" from the dropdown menu (see *Figure 7*) and choosing the file that you would like to add or by simply dragging and dropping each file in the Sounds zone (see *Figure 8*).

Figure 7

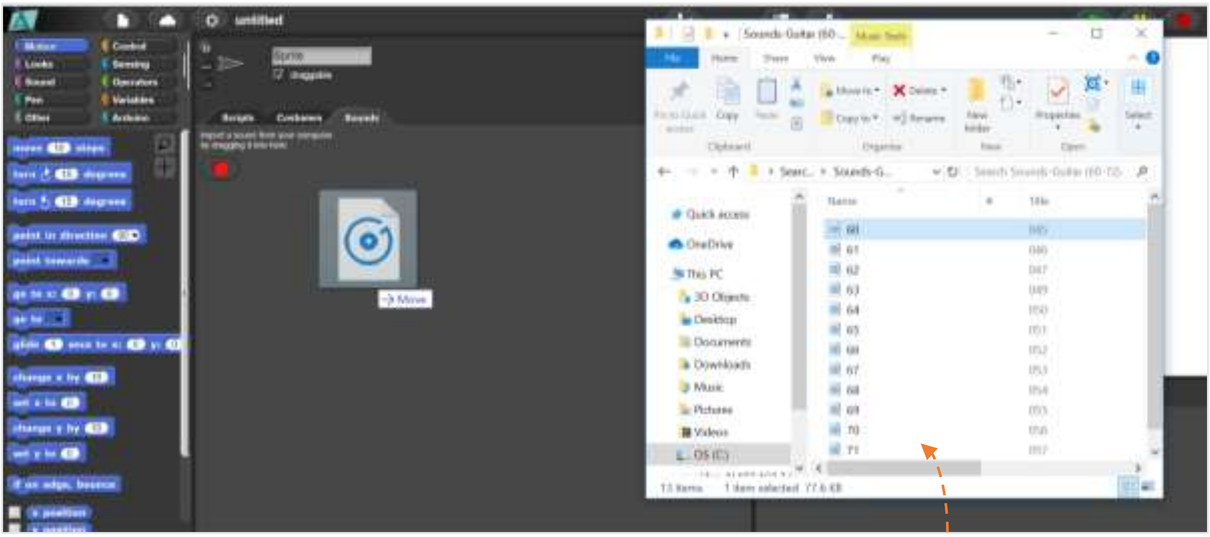


Figure 8

The imported sounds can be wav or mp3 files and should be named as appear above (60- 72) for the needs of Level 3.

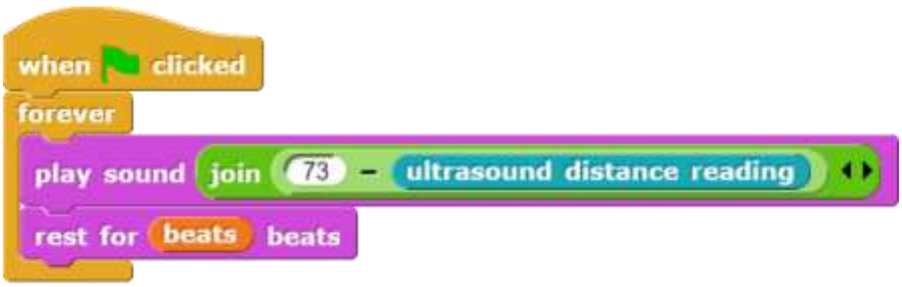
You can download sound samples from here: https://www.philharmonia.co.uk/explore/sound_samples

You can download a ready- made list from here: http://www.roboscientists.eu/wp-content/uploads/2019/09/Sounds-Guitar.zip

Solution in Snap4Arduino (it brings together 3 scripts)

The solution brings together 3 scripts:

Script for controlling the ultrasound sensor and reproducing sounds

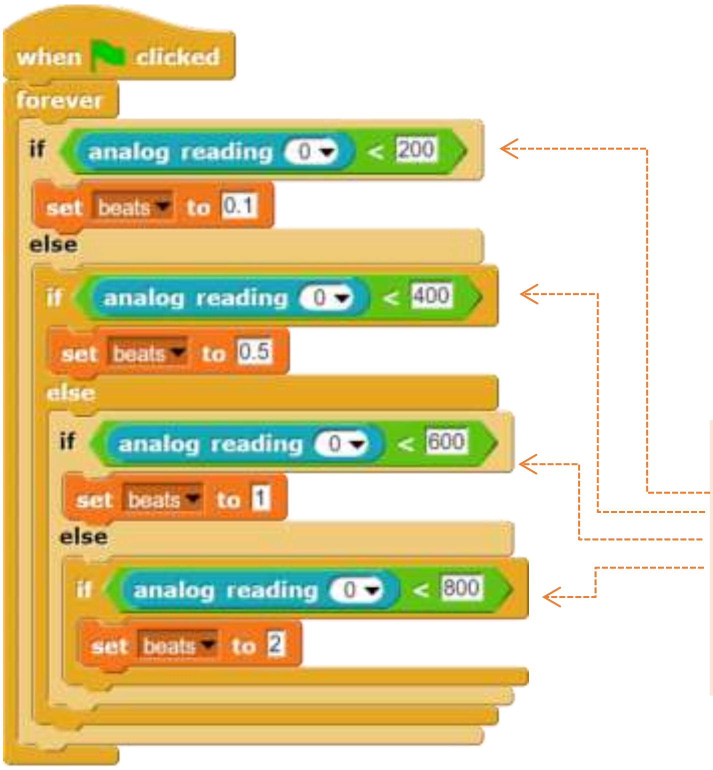


Script 1

Script for observing the value that corresponds to a specific sound (optional use of this script).

Script 5

Script for controlling the photoresistor and setting the beats (same as in level 2)



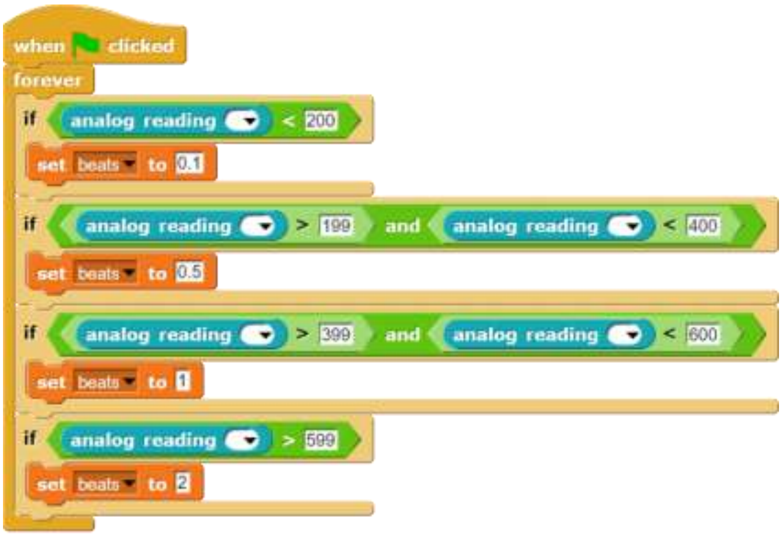
Script 3

In this script the value of the variable ***beats*** changes according to the "analog reading" input value. The performer can adjust the duration of a note by moving the hand up or down.

Tip: While introducing the project in the class encourage the students to observe the analog readings retrieved by the photoresistor. The levels that have been set can change. The same applies to the value of the beats. Encourage free experimentation.

Alternative script for controlling the photoresistor and setting the beats (same as in level 2)

The script below has the same functionality with the script above (see script 3).



Script 6 Alternative solution for script 3

Questions/ Additional experimentations

- *Encourage your students to experiment with several sounds.*
- *What will be the problem if they do not name their music files in the way it is suggested above (60-70)?*
- *Encourage your students to set different values to the variable beats. Which value works better?*
- *Can your students provide the definitions of "beats" after experimenting with several values for the variable beats?*

Terminology

Beat : The beat is often defined as the rhythm listeners would tap their toes to when listening to a piece of music. In popular use, beat can refer to a variety of related concepts, including pulse, tempo, meter, specific rhythms, and groove (Wikipedia).

Pitch **:** a perceptual property of sound which defines the degree of highness or lowness of a tone

Rhythm**:** Rhythm in music is characterized by a repeating sequence of stressed and unstressed beats (often called "strong" and "weak") and divided into bars organized by time signature and tempo indications (Wikipedia).

Useful links:
https://www.khanacademy.org/humanities/music/music-basics2/notes-rhythm/a/glossary-of-musical-terms
https://en.wikipedia.org/wiki/Beat_(music)

Additional technical tips

For more technical details and information about the selected technologies and tools please see O1 (technical tutorial: http://www.roboscientists.eu/outputs/output-1/)

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ROBOSCIENTISTS PROJECT

Motivating secondary school students towards STEM careers through robotic artefact making

Erasmus+ KA2 2018-1PL01-KA201-051129

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Declaration

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