Guide to Programming with Turtle Art

Turtle Blocks expands upon what children can do with Logo and how it can be used as the underlying motivator for “improving” programming languages and programmable devices.

In this guide, we illustrate this point by both walking the reader through numerous examples, but also by discussing some of our favorite explorations of Turtle Blocks, including multi-media, the Internet (both as a forum for collaboration and data collection), and a broad collection of sensors.

Getting Started

Turtle Blocks Javascript is designed to run in a browser. Most of the development has been done in Chrome, but it should also work in Firefox. You can run it from a server maintained by Sugar Labs (http://turtle.sugarlabs.org), from the github repo (http://sugarlabs.github.io/turtleblocksjs), or by setting up a local server (https://github.com/sugarlabs/turtleblocksjs/blob/master/server.md).

You can also open it directly from `file://` with some browsers, e.g., FireFox.

Once you've launched it in your browser, start by clicking on (or dragging) blocks from the *Turtle* palette. Use multiple blocks to create drawings; as the turtle moves under your control, colorful lines are drawn.

You add blocks to your program by clicking on or dragging them from the palette to the main area. You can delete a block by dragging it back onto the palette. Click anywhere on a "stack" of blocks to start executing that stack or by clicking in the *Rabbit* (fast) or *Turtle* (slow) on the Main Toolbar. The *Snail* will step through your program, one block per click.

For more details on how to use Turtle Blocks JS, see Using Turtle Blocks JS (http://github.com/sugarlabs/turtleblocksjs/tree/master/documentation) for more details.

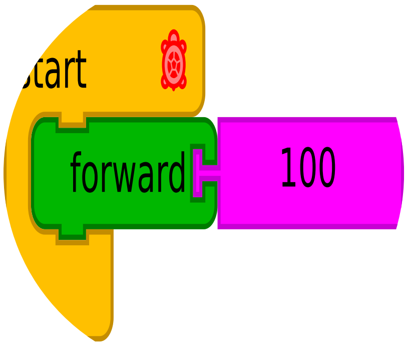
ABOUT THIS GUIDE

Many of the examples given in the guide have links to code you can run. Look for RUN LIVE links that will take you to http://turtle.sugarlabs.org (http://turtle.sugarlabs.org).

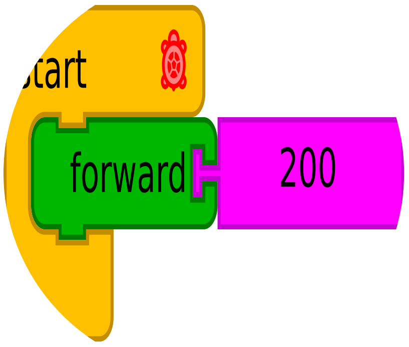
TO SQUARE

The traditional introduction to Logo has been to draw a square. Often times when running a workshop, I have the learners form a circle around one volunteer, the "turtle", and invite them to instruct the turtle to draw a square. (I coach the volunteer beforehand to take every command literally, as does our graphical turtle.) Eventually the group converges on "go forward some number of steps", "turn right (or left) 90 degrees", "go forward some number of steps", "turn right (or left) 90 degrees", "go forward some number of steps", "turn right (or left) 90 degrees", "go forward some number of steps". It is only on rare occasions that the group includes a final "turn right (or left) 90 degrees" in order to return the turtle to its original orientation. At this point I introduce the concept of "repeat" and then we start in with programming with Turtle Blocks.

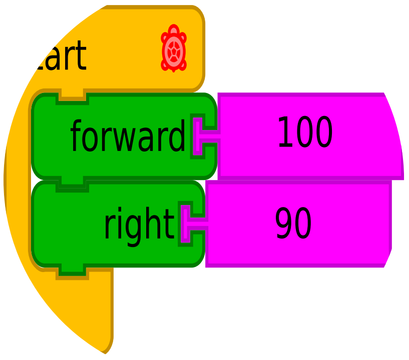
I. Turtle Basics



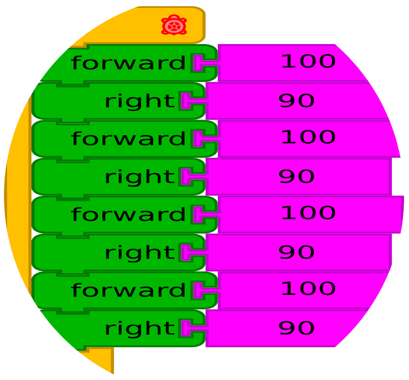
A single line of length 100 RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523359934621848&run=True)



Changing the line length to 200 RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360071975585&run=True)

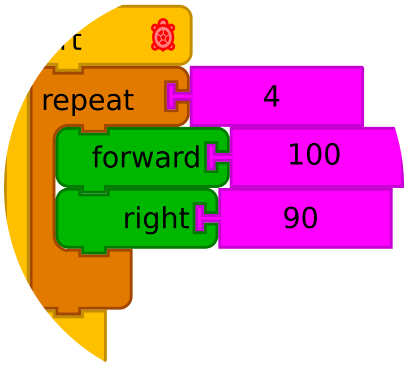


Adding a right turn of 90 degrees. Running this stack four times produces a square. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360268417654&run=True)



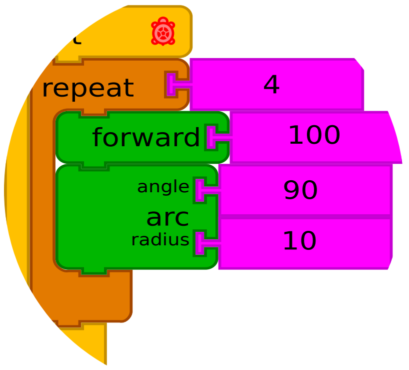
```
forward 100
right 90
forward 100
right 90
forward 100
right 90
forward 100
right 90
```

Forward, right, forward, right, ... RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360327901636&run=True)



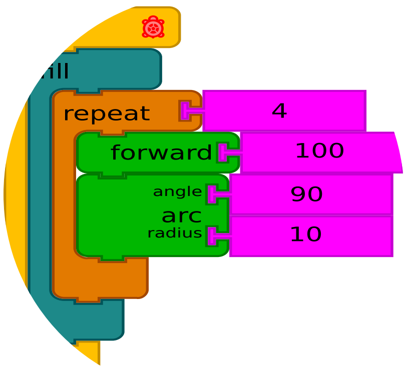
```
repeat 4
    forward 100
    right 90
```

Using the *Repeat* block from the *Flow* palette RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523294074349148&run=True)

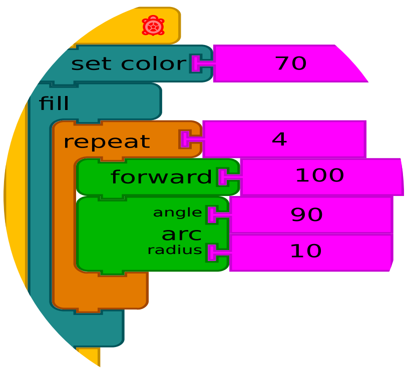


```
repeat 4
    forward 100
    arc angle 90
        radius 10
```

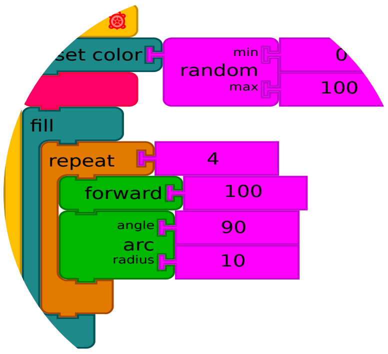
Using the *Arc* block to make rounded corners RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360547665676&run=True)



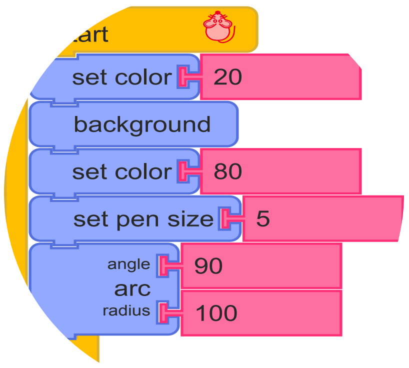
Using the *Fill* blocks from the Pen palette to make a solid square (what ever is drawn inside the *Fill* clamp will be filled upon exiting the clamp.) RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360674936456&run=True)



Changing the color to 70 (blue) using the *Set Color* block from the *Pen* palette RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360821674406&run=True)



Using the *Random* block from the *Numbers* palette to select a random color (0 to 100) RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523360917773878&run=True)



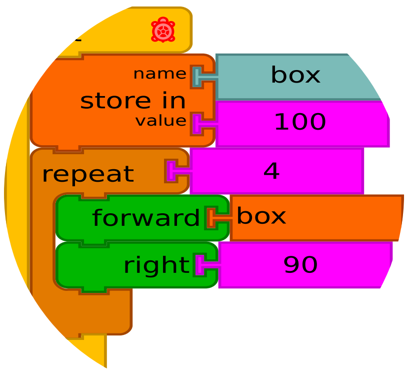
Use the *Background* block to set the background color to the current pen color. Note that if you do not subsequently change the pen color after you set the background, you will not be able to see what you are drawing as your "ink" will be the same color as your "paper". RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1581264197757866&run=True)

A SHOEBOX

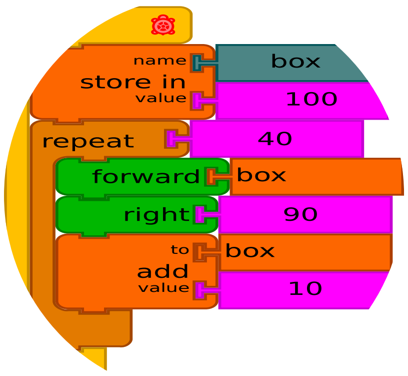
When explaining boxes in workshops, I often use a shoebox. I have someone write a number on a piece of paper and put it in the shoebox. I then ask repeatedly, "What is the number in the box?" Once it is clear that we can reference the number in the shoebox, I have someone put a different number in the shoebox. Again I ask, "What is the number in the box?" The power of the box is that you can refer to it multiple times from multiple places in your program.

II. Boxes

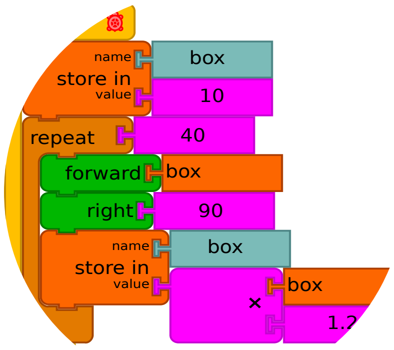
Boxes let you store an object, e.g., a number, and then refer to the object by using the name of the box. (Whenever you name a box, a new block is created on the Boxes palette that lets you access the content of the box.) This is used in a trivial way in the first example below: putting 100 in the box and then referencing the box from the Forward block. In the second example, we increase the value of the number stored in the box so each time the box is referenced by the Forward block, the value is larger.



Putting a value in a *Box* and then referring to the value in *Box* RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523361053378823&run=True)



We can change the value in a *Box* as the program runs. Here we add 10 to the value in the *Box* with each iteration. The result in this case is a spiral, since the turtle goes forward further with each step. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523361248940557&run=True)



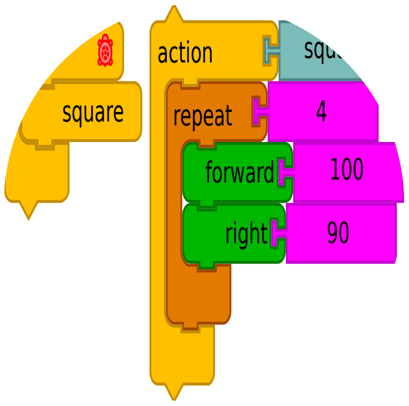
If we want to make a more complex change, we can store in the *Box* some computed value based on the current content of the *Box*. Here we multiply the content of the box by 1.2 and store the result in the *Box*. The result in this case is also a spiral, but one that grows geometrically instead of arithmetically.

In practice, the use of boxes is not unlike the use of keyword-value pairs in text-based programming languages. The keyword is the name of the *Box* and the value associated with the keyword is the value stored in the *Box*. You can have as many boxes as you'd like (until you run out of memory) and treat the boxes as if they were a dictionary. Note that the boxes are global, meaning all turtles and all action stacks share the same collection of boxes. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523368886737682&run=True)

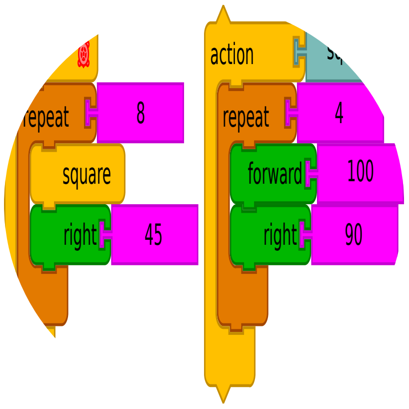
III. Action Stacks

With Turtle Blocks there is an opportunity for the learner to expand upon the language, taking the conversation in directions unanticipated by the Turtle Block developers.

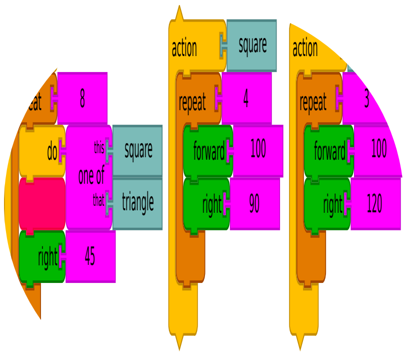
Action stacks let you extend the Turtle Blocks language by defining new blocks. For example, if you draw lots of squares, you may want a block to draw squares. In the examples below, we define an action that draws a square (repeat 4 forward 100 right 90), which in turn results in a new block on the *Actions* palette that we can use whenever we want to draw a square. Every new *Action* stack results in a new block.



Defining an action to create a new block, "*Square*" RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523369101107025&run=True)



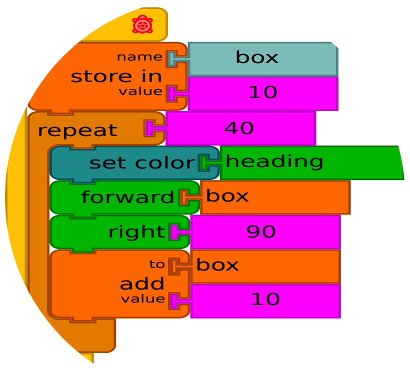
Using the "*Square*" block RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523369182696942&run=True)



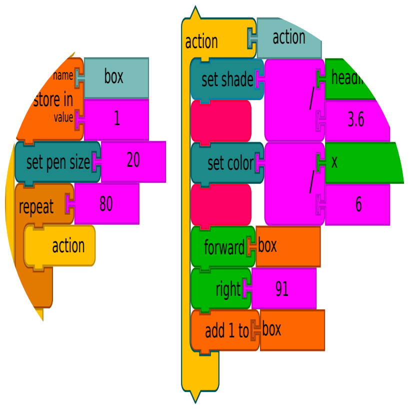
The *Do* block lets you specify an action by name. In this example, we choose "one of" two names, "*Square*" and "*Triangle*" to determine which action to take. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523369272178072&run=True)

IV. Parameters

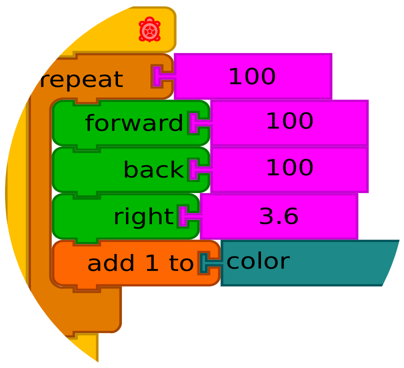
Parameter blocks hold a value that represents the state of some turtle attribute, e.g., the x or y position of the turtle, the heading of the turtle, the color of the pen, the size of the pen, etc. You can use parameter blocks interchangeably with number blocks. You can change their values with the *Add* block or with the corresponding set blocks.



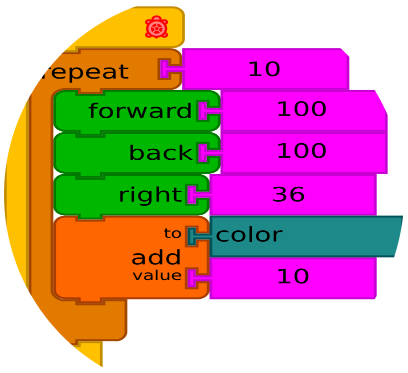
Using the *Heading* parameter, which changes each time the turtle changes direction, to change the color of a spiral RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523369515049913&run=True)



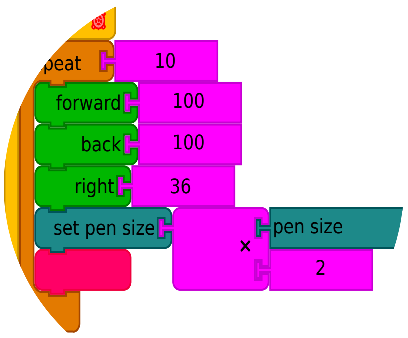
"Squiral" by Brian Silverman uses the *Heading* and *X* parameter blocks. RUN LIVE (https://walterbender.github.io/musicblocks/index.html?id=1523410445476847&run=True)



Often you want to just increment a parameter by 1. For this, use the *Add-1-to* block. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523369660208921&run=True)



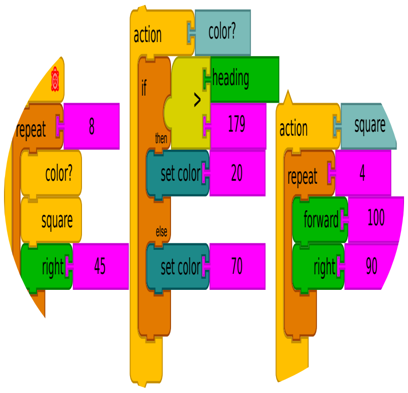
To increment (or decrement) a parameter by an arbitrary value, use the *Add-to* block. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523370184642548&run=True)



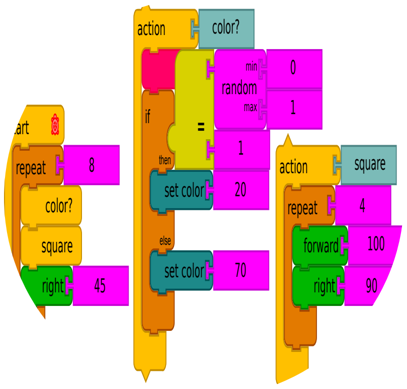
To make other changes to a parameter based on the current value, use the parameter's *Set* block. In this example, the pen size is doubled with each step in the iteration. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523370273985275&run=True)

V. Conditionals

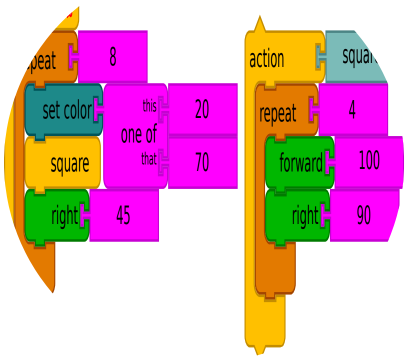
Conditionals are a powerful tool in computing. They let your program behave differently under differing circumstances. The basic idea is that if a condition is true, then take some action. Variants include if-then-else, while, until, and forever. Turtle Blocks provides logical constructs such as equal, greater than, less than, and, or, and not.



Using a conditional to select a color: Once the heading > 179, the color changes. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523370501577900&run=True)



Conditionals along with the *Random* block can be used to simulate a coin toss. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523370743897698&run=True)

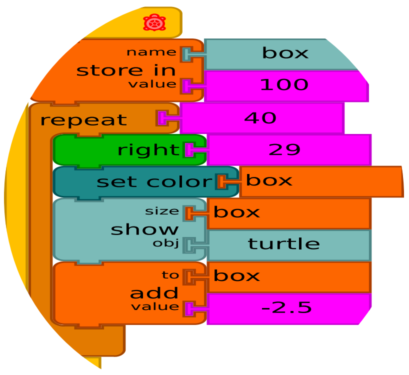


A coin toss is such a common operation that we added the *One-of* block as a convenience. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523370862902481&run=True)

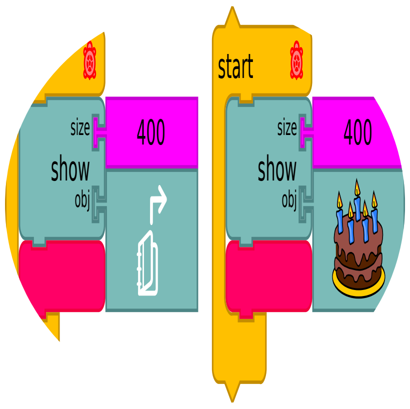
VI. Multimedia

Turtle Blocks provides rich-media tools that enable the incorporation of sound, typography, images, and video.

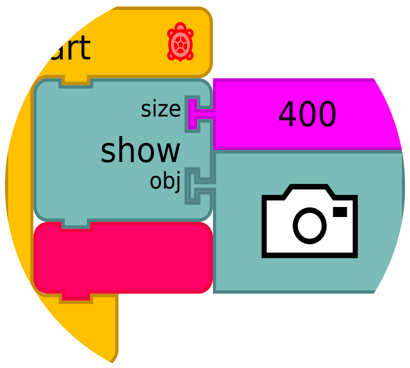
At the heart of the multimedia extensions is the *Show* block. It can be used to show text, image data from the web or the local file system, or a web camera. Other extensions include blocks for synthetic speech, tone generation, and video playback.



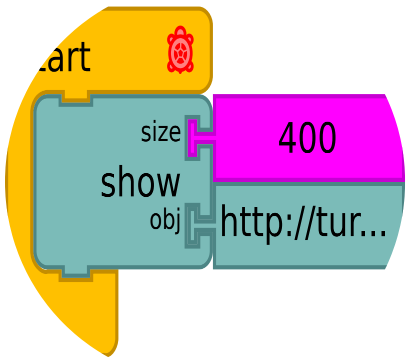
Using the *Show* block to display text; the orientation of the text matches the orientation of the turtle. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523370990567304&run=True)



You can also use the *Show* block to show images. Clicking on the Image block (left) will open a file browser. After selecting an image file (PNG, JPG, SVG, etc.) a thumbnail will appear on the *Image* block (right).



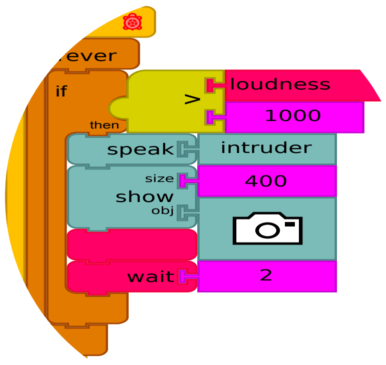
The *Show* block in combination with the *Camera* block will capture and display an image from a webcam. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523371139976408&run=True)



The *Show* block can also be used in conjunction with a URL that points to media. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523371406381048&run=True)

VII. Sensors

Seymour Papert's idea of learning through making is well supported in Turtle Blocks. According to Papert, "learning happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe". Research and development that supports and demonstrates the children's learning benefits as they interact with the physical world continues to grow. In similar ways, children can communicate with the physical world using a variety of sensors in Turtle Blocks. Sensor blocks include keyboard input, sound, time, camera, mouse location, color that the turtle sees. For example, children may want to build a burglar alarm and save photos of the thief to a file. Turtle Blocks also makes it possible to save and restore sensor data from a file. Children may use a “URL” block to import data from a web page.



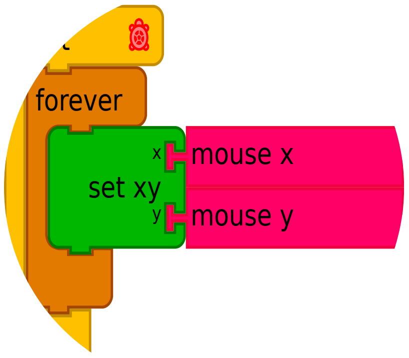
Using sensors. The *Loudness* block is used to determine if there is an intruder. A loud sound triggers the alarm action: the turtle shouts “intruder” and takes a picture of the intruder.

Teachers from the Sugar community have developed extensive collection of examples using Turtle Block sensors. Guzmán Trinidad, a physics teacher from Uruguay, wrote a book, *Physics of the XO*, which includes a wide variety of sensors and experiments. Tony Forster, an engineer from Australia, has also made remarkable contributions to the community by documenting examples using Turtle Blocks. In one example, Tony uses the series of switches to measure gravitational acceleration; a ball rolling down a ramp trips the switches in sequence. Examining the time between switch events can be used to determine the gravitational constant.

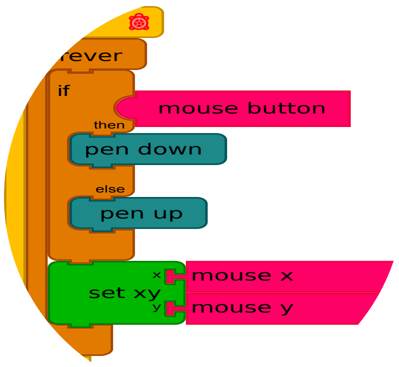
One of the typical challenges of using sensors is calibration. This is true as well in Turtle Blocks. The typical project life-cycle includes: (1) reading values; (2) plotting values as they change over time; (3) finding minimum and maximum values; and finally (4) incorporating the sensor block in a Turtle program.

Example: Paint

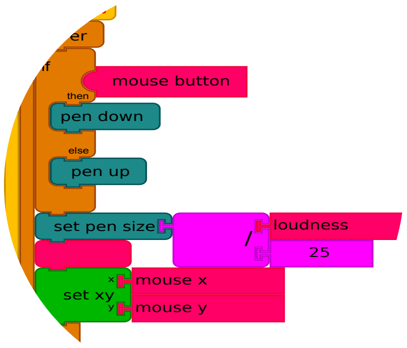
As described in the Sensors section, Turtle Blocks enables the programmer/artist to incorporate sensors into their work. Among the sensors available are the mouse button and mouse x and y position. These can be used to create a simple paint program, as illustrated below. Writing your own paint program is empowering: it demystifies a commonly used tool. At the same time, it places the burden of responsibility on the programmer: once we write it, it belongs to us, and we are responsible for making it cool. Some variations of paint are also shown below, including using microphone levels to vary the pen size as ambient sound-levels change. Once learners realize that they can make changes to the behavior of their paint program, they become deeply engaged. How will you modify paint?



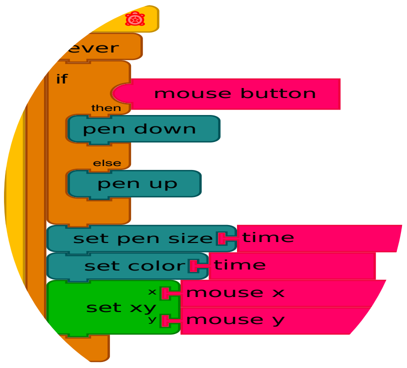
In its simplest form, paint is just a matter of moving the turtle to wherever the mouse is positioned. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523371509276932&run=True)



Adding a test for the mouse button lets us move the turtle without leaving a trail of ink. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523371673939089&run=True)

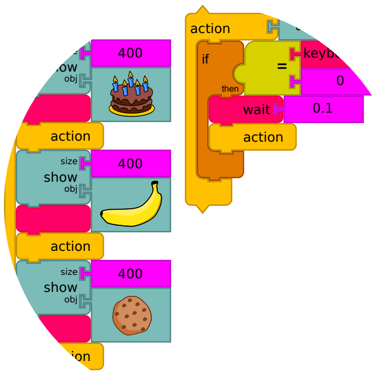


In this example, we change the pen size based on the volume of microphone input. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523371754657228&run=True)



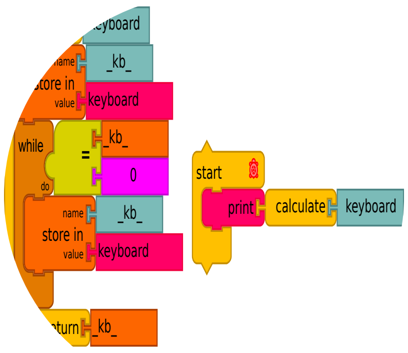
In another example, inspired by a student in a workshop in Colombia, we use time to change both the pen color and the pen size. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523371935195761&run=True)

Example: Slide Show

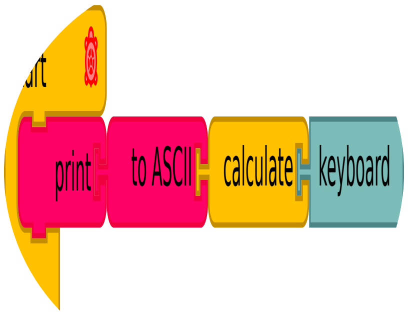


Why use Powerpoint when you can write Powerpoint? In this example, an Action stack is used to detect keyboard input: if the keyboard value is zero, then no key has been pressed, so we call the action again. If a key is pressed, the keyboard value is greater than zero, so we return from the action and show the next image.

Example: Keyboard

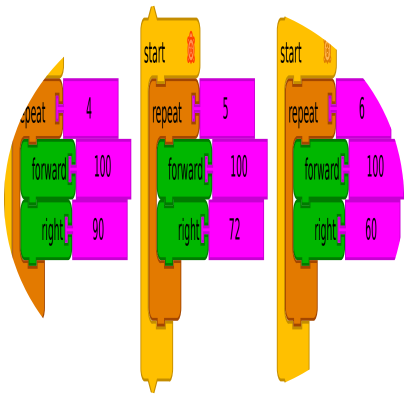


In order to grab keycodes from the keyboard, you need to use a *While* block. In the above example, we store the keyboard value in a box, test it, and if it is > 0, return the value. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523376704342158&run=True)

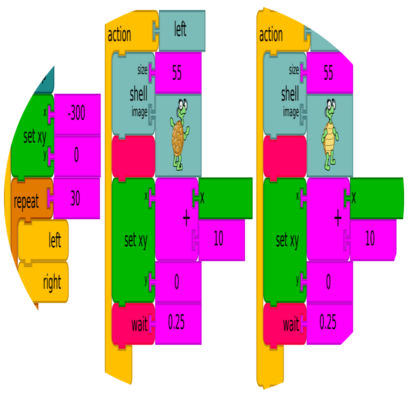


If you want to convert the keycode to a alphanumeric character, you need to use the *To ASCII* block. E.g., *toASCII(65) = A* RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523377042822413&run=True)

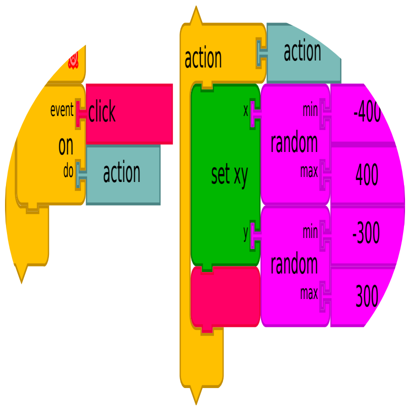
VIII. Turtles, Sprites, Buttons, and Events



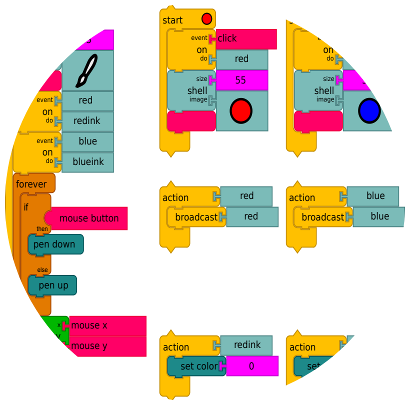
A separate turtle is created for each *Start* block. The turtles run their code in parallel with each other whenever the *Run* button is clicked. Each turtle maintains its own set of parameters for position, color, pen size, pen state, etc. In this example, three different turtles draw three different shapes. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523377203344616&run=True)



Custom graphics can be applied to the turtles, using the *Shell* block on the *Media* palette. Thus you can treat turtles as sprites that can be moved around the screen. In this example, the sprite changes back and forth between two states as it moves across the screen. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523377357693679&run=True)



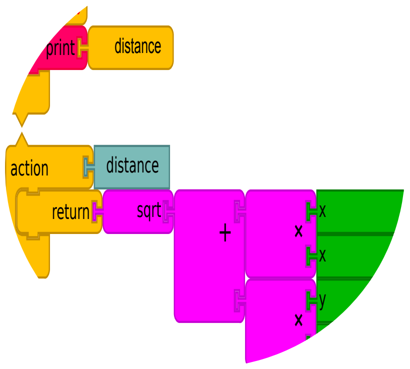
Turtles can be programmed to respond to a "click" event, so they can be used as buttons. In this example, each time the turtle is clicked, the action is run, which move the turtle to a random location on the screen. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523377513682595&run=True)



Events can be broadcast as well. In this example, another variant on Paint, turtle "buttons", which listen for "click" events, are used to broadcast change-color events. The turtle used as the paintbrush is listening for these events. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523378142359724&run=True)

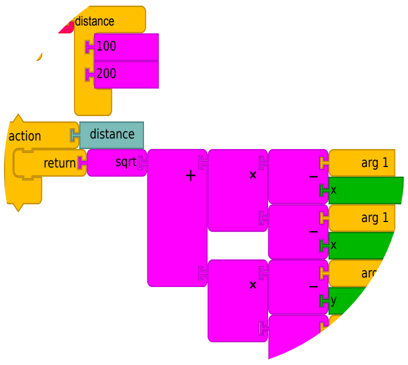
IX. Advanced Actions

Sometime you might want an action to not just run a stack of blocks but also to return a value. This is the role of the return block. If you put a return block into a stack, then the action stack becomes a calculate stack.



In this example, a *Calculate* stack is used to return the current distance of the turtle from the center of the screen. Renaming an action stack that has a *Return* block will cause the creation of a new block in the *Actions* palette that can be used to reference the return value: in this case, a *Distance* block is created. RUN LIVE

(https://turtle.sugarlabs.org/index.html?id=1523383380320451&run=True)

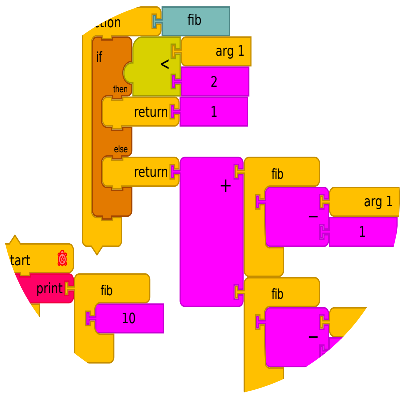


You can also pass arguments to an *Action* stack. In this example, we calculate the distance between the turtle and an arbitrary point on the screen by passing x and y coordinates in the *Calculate* block. You add additional arguments by dragging them into the "clamp".

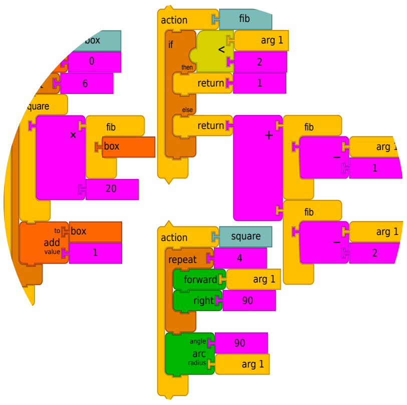
Note that args are local to *Action* stacks, but boxes are not. If you planned to use an action in a recursive function, you had best avoid boxes. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523382801625028&run=True)

Example: Fibonacci

Calculating the Fibonacci sequence is often done using a recursive method. In the example below, we pass an argument to the *Fib* action, which returns a value if the argument is < 2; otherwise it returns the sum of the result of calling the *Fib* action with argument - 1 and argument - 2.



Calculating Fibonacci RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523388667520324&run=True)

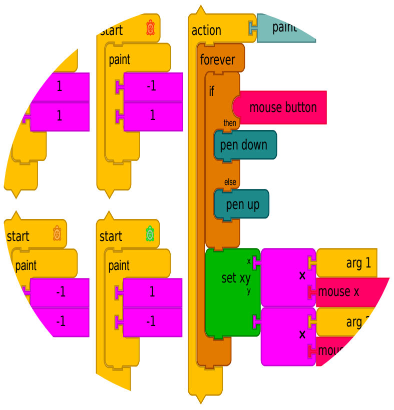


In the second example, we use a *Repeat* loop to generate the first six Fibonacci numbers and use them to draw a nautilus.

Draw a nautilus RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523388775236172&run=True)

Example: Reflection Paint

By combining multiple turtles and passing arguments to actions, we can have some more fun with paint. In the example below, the *Paint Action* uses *Arg 1* and *Arg 2* to reflect the mouse coordinates about the y and x axes. The result is that the painting is reflected into all four quadrants.

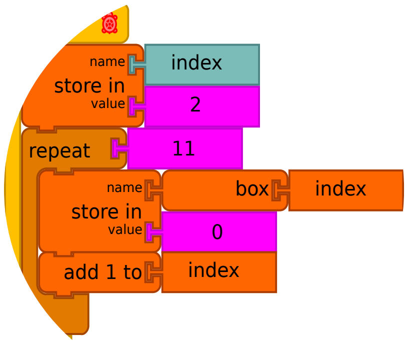


Reflection Paint RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523389168734406&run=True)

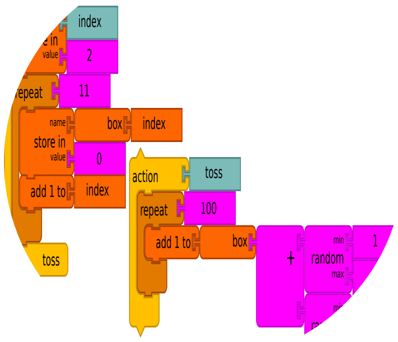
X. Advanced Boxes

Sometimes it is more convenient to compute the name of a *Box* than to specify it explicitly. (Note that the *Do* block affords a similar mechanism for computing the names of actions.)

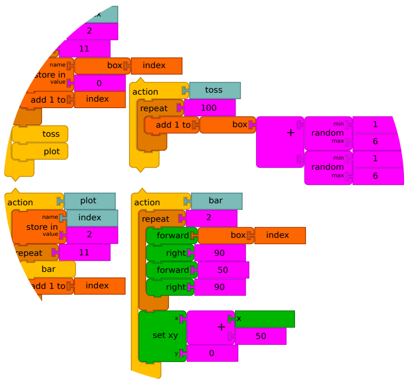
In the following examples, we use this to accumulate the results of toss a pair of dice 1600 times (example inspired by Tony Forster).



Rather than specifying a box to hold each possible result (2 through 12), we use a *Box* as a counter (index) and create a box with the name of the current value in the counter and store in that box a value of 0.



Next we add an *Action* to toss the dice 1600 times. To simulate tossing a pair of dice, we sum two random numbers between 1 and 6. We use the result as the name of the box we want to increment. So for example, if we throw a 7, we add one to the *Box* named 7. In this way we increment the value in the appropriate *Box*.



Finally, we plot the results. Again, we use a *Box* as a counter ("index") and call the *Plot Action* in a loop. In the *Bar Action*, we draw a rectangle of length value stored in the *Box* with the name of the current value of the index. E.g., when the value in the index *Box* equals 2, the turtle goes forward by the value in *Box 2*, which is the accumulated number of times that the dice toss resulted in a 2; when the value in the *Index Box* is 3, the turtle goes forward by the value in *Box 3*, which is the accumulated number of times that the dice toss resulted in a 3; etc. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523299313972510&run=True)

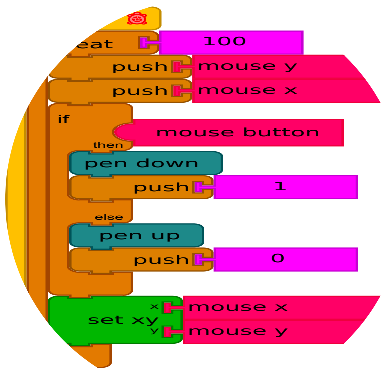
XI. The Heap

Sometimes you need a place to temporarily store data. One way to do it is with boxes (as mentioned at the end of the Boxes section of this guide, they can be used as a dictionary or individual keyword-value pairs). However, sometimes it is nice to simply use a heap.

A heap is a essential a pile. The first thing you put on the heap is on the bottom. The last thing you put on the heap is on the top. You put things onto the heap using the *Push* block. You take things off of the heap using the *Pop* block. In Turtle Blocks, the heap is first-in last-out (FILO), so you pop things off of the heap in the reverse order in which you put them onto the heap.

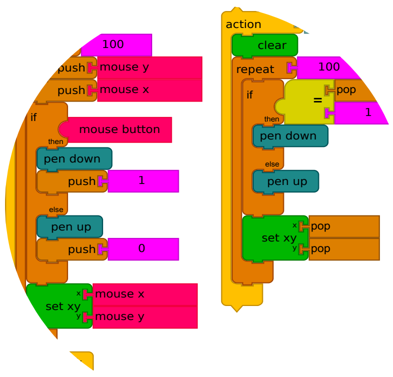
There is also an *Index* block that lets you refer to an item in the heap by an index. This essentially lets you treat the heap as an array. Some other useful blocks include a block to empty the heap, a block that returns the length of the heap, a block that saves the heap to a file, and a block that loads the heap from a file.

In the examples below we use the heap to store a drawing made with a paint program similar to the previous examples and then to playback the drawing by popping points off of the heap.



```
eat 100
  push mouse y
  push mouse x
  if mouse button
  then
    pen down
    push 1
  else
    pen up
    push 0
  set xy x mouse x
         y mouse y
```

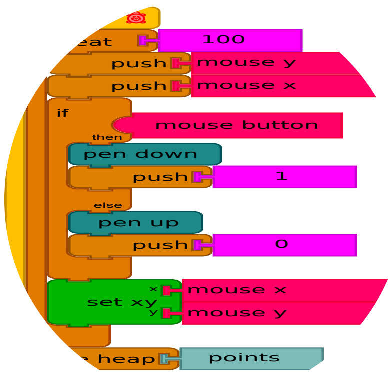
In the first example, we simply push the turtle position whenever we draw, along with the pen state. Note since we pop in the reverse order that we push, we push y, then x, then the mouse state.



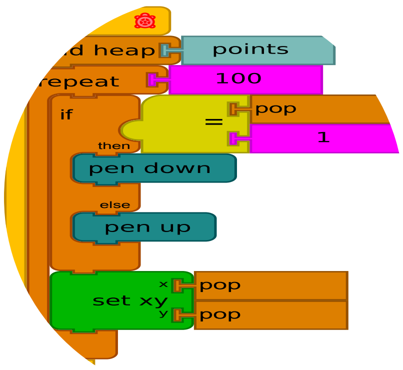
```
100
  push mouse y
  push mouse x
  if mouse button
  then
    pen down
    push 1
  else
    pen up
    push 0
  set xy x mouse x
         y mouse y

action
  clear
  repeat 100
    if pop = 1
    then
      pen down
    else
      pen up
    set xy x pop
           y pop
```

In the second example, we pop pen state, x, and y off of the heap and playback our drawing. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523389420306919&run=True)



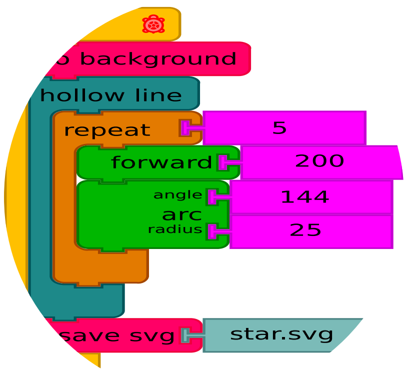
Use the *Save Heap* block to save the state of the heap to a file. In this example, we save our drawing to a file for playback later. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523390553182986&run=True)



Use the *Load Heap* block to load the heap from data saved in a file. In this example, we playback the drawing from data stored in a file. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523389601597904&run=True)

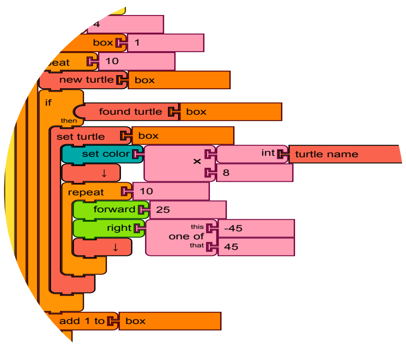
XII. Extras

The *Extras* palette is full of utilities that help you use your project's output in different ways.

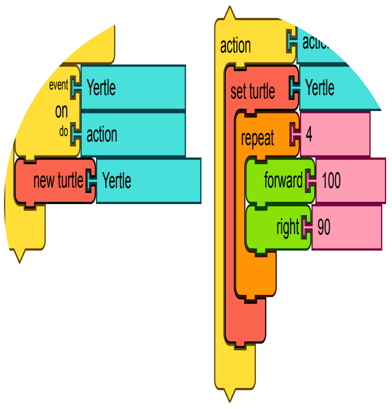


The *Save as SVG* block will save your drawing as simple vector graphics (SVG), a format compatible with HTML5 and many image manipulation programs, e.g., Inkscape. In the example above, we use it to save a design in a from that can be converted to STL, a common file format used by 3D printers. A few things to take note of: (1) the *No Background* block is used to suppress the inclusion of the background fill in the SVG output; (2) *Hollow lines* are used to make graphic have dimension; and (3) the *Save as SVG* block writes to the Downloads directory on your computer. (Josh Burker introduced me to Tinkercad, a website that can be used to convert SVG to STL.) RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523390883477748&run=True)

The *New Turtle* block is used to create new turtles on the fly. The *Set Turtle* block is used to run blocks by a selected turtle. In the example below, 10 turtles are created on the fly and each turtle is then set on a random walk across the screen. Note that the *Found Turtle* block is used to ensure that the each new turtle is *ready* before issuing commands. (Creating a turtle is not instantaneous and the *New Turtle* block does not block program flow waiting for the turtle to be created.) RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1525211505767290&run=True)

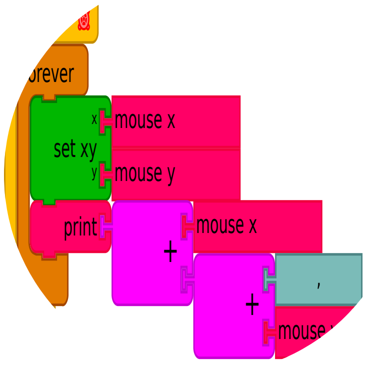


An alternative to using the *Found Turtle* block is to use the *Event* block. When a new turtle is created, an event with the name of the turtle is broadcast (See the example below).

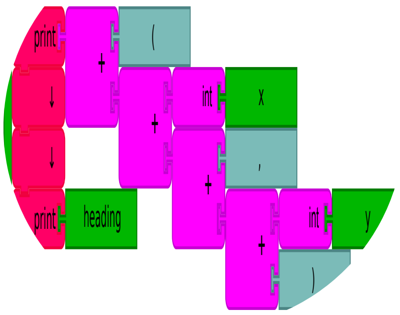


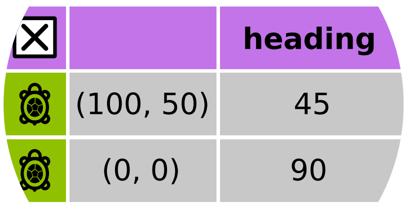
XIII. Debugging Aids

Probably the most oft-used debugging aid in any language is the print statement. In Turtle Blocks, it is also quite useful. You can use it to examine the value of parameters and variables (boxes) and to monitor progress through a program.



In this example, we use the addition operator to concatinate strings in a print statement. The mouse x + ", " + mouse y are printed in the inner loop. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523391206069261&run=True)





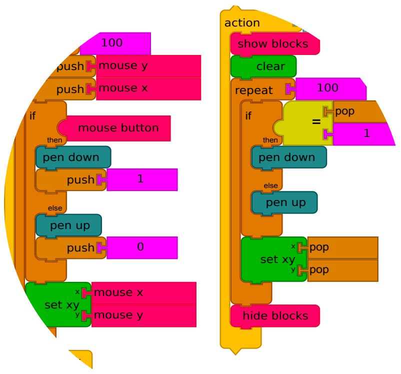
☒		heading
🐢	(100, 50)	45
🐢	(0, 0)	90

There is also a *Status* widget that can be programmed to show various paramters as per the figures above. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1528388082677564&run=True)

Parameter blocks, boxes, arithmetic and boolean operators, and many sensor blocks will print their current value as the program runs when running in "slow" or "step-by-step" mode, obviating the need to use the Print block in many situations.

The *Wait* block will pause program execution for some number (or fractions) of seconds.

The *Hide* and *Show* blocks can be used to set "break points". When a *Hide* block is encountered, the blocks are hidden and the program proceeds at full speed. When a *Show* block is encountered, the program proceeds at a slower pace an the block values are shown.



A *Show* block is used to slow down execution of the code in an *Action* stack in order to facilitate debugging. In this case, we slow down during playback in order to watch the values popped off the heap. RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523391034295213&run=True)

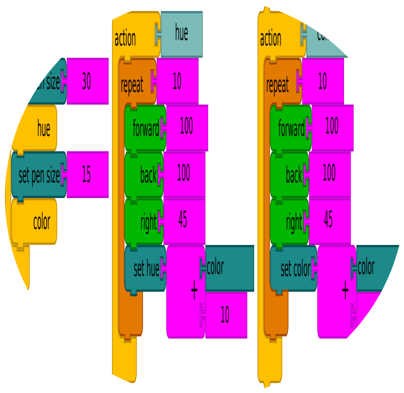
XIV. Advanced Color

The internal representation of color in Turtle Blocks is based on the Munsell color system (http://en.wikipedia.org/wiki/Munsell_color_system). It is a three-dimensional system: (1) hue (red, yellow, green, blue, and purple), (2) value (black to white), and (3) chroma (gray to vivid).

There are parameters for each color dimension and corresponding "setters". All three dimensions have been normalized to run from 0 to 100. For Hue, 0 maps to Munsell 0R. For Value, 0 maps to Munsell value 0 (black) and 100 maps to Munsell value 10 (white). For chroma, 0 maps to Munsell chroma 0 (gray) and 100 maps to Munsell chroma 26 (spectral color).

A note about Chroma: In the Munsell system, the maximum chroma of each hue varies with value. To simplify the model, if the chroma specified is greater than the maximum chroma available for a hue/value pair, the maximum chroma available is used.

The *Set Color* block maps the three dimensions of the Munsell color space into one dimension. It always returns the maximum value/chroma pair for a given hue, ensuring vivid colors. If you want to more subtle colors, be sure to use the *Set Hue* block rather than the *Set Color* block.



Color vs. hue example RUN LIVE (https://turtle.sugarlabs.org/index.html?id=1523391601724568&run=True)

To set the background color, use the *Background* block. It will set the background to the current hue/value/chroma triplet.

XV. Plugins

There are a growing number of extensions to Turtle Blocks in the from of plugins. See Plugins (http://github.com/sugarlabs/turtleblocksjs/tree/master/plugins) for more details.

Guide to Programming with Music Blocks

Music Blocks is a programming environment for children interested in music and graphics. It expands upon Turtle Blocks by adding a collection of features relating to pitch and rhythm.

The Turtle Blocks guide (https://github.com/sugarlabs/turtleblocksjs/blob/master/guide/README.md) is a good place to start learning about the basics. In this guide, we illustrate the musical features by walking the reader through numerous examples.

The Music Blocks basic documentation (../documentation/README.md) is also a good resource.

And there is a short Guide to Debugging (../Debugging.md) to help you with your programming.

This guide details the many musical features of the language.

TABLE OF CONTENTS

Many of the examples given in the guide have links to code you can run. Look for `RUN LIVE` links.

1. Getting Started

Back to Table of Contents | Next Section (2. Making Sounds)

Music Blocks is designed to run in a browser. Most of the development has been done in Chrome, but it should also work in Firefox, Opera, and some versions of Safari. You can run it from musicblocks.sugarlabs.org (https://musicblocks.sugarlabs.org), from github io (https://musicblocks.sugarlabs.org), or by downloading a copy of the code and running a local copy directly from the file system of your computer. (Note that when running locally, you may have to use a local server to expose all of the features.)

This guide details the music-specific features of Music Blocks. You may also be interested in the Turtle Blocks Guide (http://github.com/sugarlabs/turtleblocksjs/tree/master/guide), which reviews many programming features common to both projects.

For more details on how to use Music Blocks, see Using Music Blocks (http://github.com/sugarlabs/musicblocks/tree/master/documentation). For more details on how to use Turtle Blocks, see Using Turtle Blocks JS (http://github.com/sugarlabs/turtleblocksjs/tree/master/documentation).

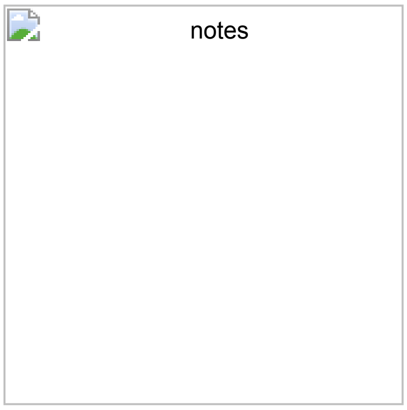
2. Making Sounds

Previous Section (1. Getting Started) | Back to Table of Contents | Next Section (3. Programming with Music)

Music Blocks incorporates many common elements of music, such as pitch, rhythm, volume, and, to some degree, timbre and texture.

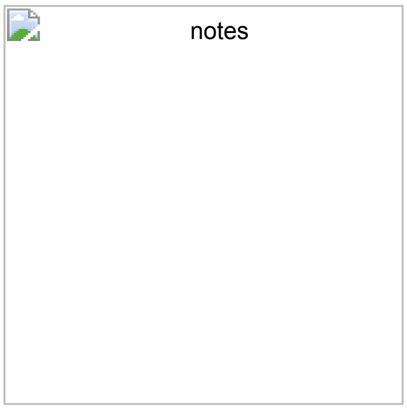
2.1 Note Value Blocks

At the heart of Music Blocks is the *Note value* block. The *Note value* block is a container for a *Pitch* block that specifies the duration (note value) of the pitch.



At the top of the example above, a single (detached) *Note value* block is shown. The `1/8` is value of the note, which is, in this case, an eighth note.

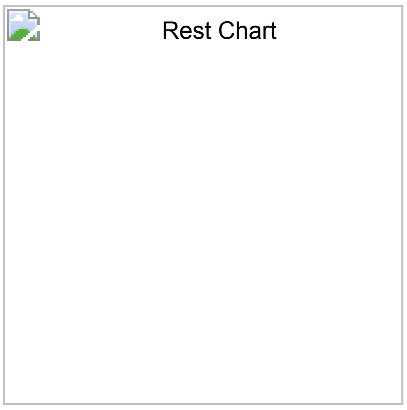
At the bottom, two notes that are played consecutively are shown. They are both `1/8` notes, making the duration of the entire sequence `1/4`.



In this example, different note values are shown. From top to bottom, they are: `1/4` for an quarter note, `1/16` for a sixteenth note, and `1/2` for a half note.

Note that any mathematical operations can be used as input to the *Note value*.

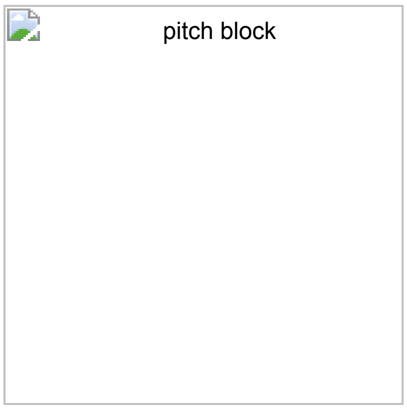
As a convenience, a pie menu is used for selecting common note values.



Please refer to the above picture for a visual representation of note values.

2.2 Pitch Blocks

As we have seen, *Pitch* blocks are used inside the *Note value* blocks. The *Pitch* block specifies the pitch name and pitch octave of a note that in combination determines the frequency (and therefore pitch) at which the note is played.



There are many systems you can use to specify a *pitch* block's name and octave. Some examples are shown above.

The top *Pitch* block is specified using a *Solfege* block (`Sol` in `Octave 4`), which contains the notes `Do Re Me Fa Sol La Ti .`

The pitch of the next block is specified using a *Pitch-name* block (`G` in `Octave 4`), which contains the notes `C D E F G A B`.

The next block is specified using a *Scale-degree* block (the `5th note` in the scale, 'G', also in 'Octave 4'), `C == 1, D == 2, ....` The *Scale-Degree* block has numbers like the *Number* block, but also has an accidental so that the user may play pitches outside a given key.

The next blocks is specified using a *Nth Modal Pitch* block. This block takes a number argument and turns it into the "nth pitch of a given scale" with an index of 0 (i.e. C for C major is 0). Therefore in order to get `G`, we input the number 4. The octave argument will force the octave up or down; otherwise the user may just keep going up or down in either direction to go through scalar pitches of any mode.

The next block is specified using a *Pitch-number* block (the `7th semi-tone` above `C` in `Octave 4` is `G`). The offset for the pitch number can be modified using the *Set-pitch-number-offset* block.

The pitch of the next block is specified using the *Hertz* block in conjunction with a *Number* block (`392` Hertz is `G` in `Octave 4`), which corresponds to the frequency of the sound made.

The octave is specified using a number block and is restricted to whole numbers. In the case where the pitch name is specified by frequency, the octave is ignored.The octave argument can also be specified using a *Text* block with values *current*, *previous*, *next* which does as 0, -1, 1 respectively.

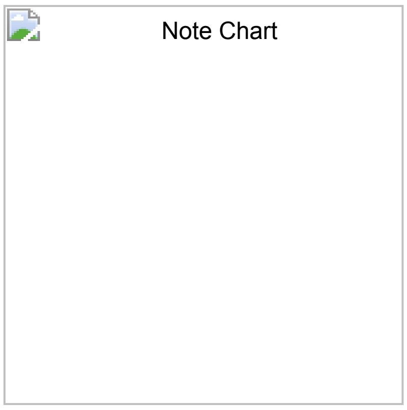
The octave of the next block is specified using a *current* text block (`Sol` in `Octave 4`).

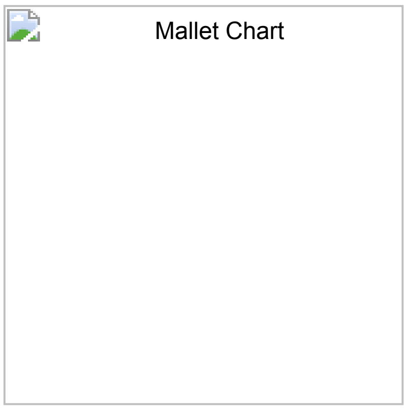
The octave of the next block is specified using a *previous* text block (`G` in `Octave 3`).

The octave of the last block is specified using a *next* text block (`G` in `Octave 5`).

Note that the pitch name can also be specified using a *Text* block.

As a convenience, a pie menu is used for selecting pitch, accidental, and octave.



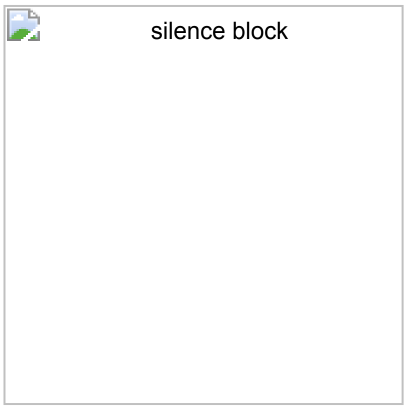


Please refer to the above charts for a visual representation of where notes are located on a keyboard or staff.

2.3 Multiple Pitches

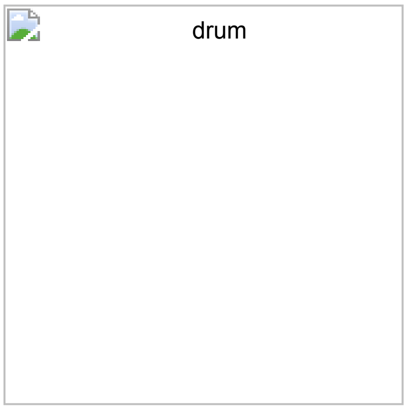
Multiple, simultaneous pitches can be specified by adding multiple *Pitch* blocks into a single *Note value* block, like the above example.

2.4 Rests

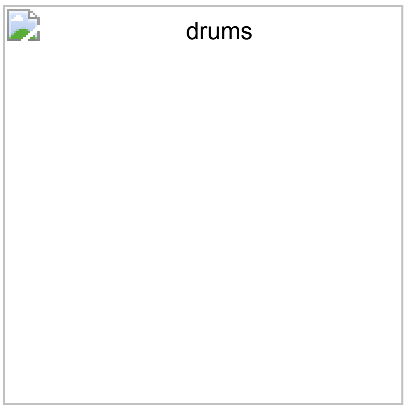


A rest of the specified note value duration can be constructed using a *Silence* block in place of a *Pitch* block.

2.5 Drums



Anywhere a *Pitch* block can be used—e.g., inside of the matrix or a *Note value* block—a *Drum Sample* block can also be used instead. Currently there about two dozen different samples from which to choose. The default drum is a kick drum.



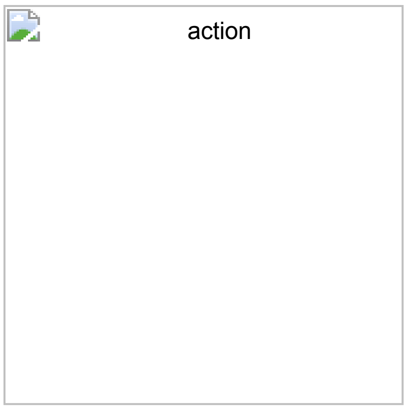
Just as in the multi-pitch example above, you can use multiple *Drum* blocks within a single *Note value* blocks, and combine them with *Pitch* blocks as well.

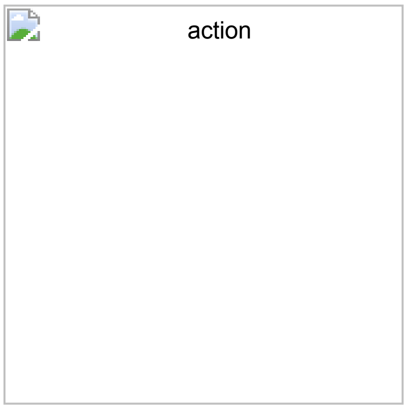
3. Programming with Music

Previous Section (2. Making Sounds) | Back to Table of Contents | Next Section (4. Widgets)

This section of the guide discusses how to use chunks of notes to program music. Note that you can program with chunks you create by hand or use *The Phrase Maker* widget to help you get started.

3.1 Actions



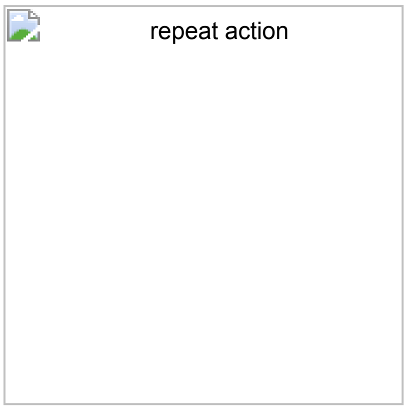


Every time you create a new *Action* stack, Music Blocks creates a new block specific to, and linked with, that stack. (The new block is found at the top of the *Block* palette, found on the left edge of the screen.) Clicking on and running this block is the same as clicking on your stack. By default, the new blocks are named `chunk`, `chunk1`, `chunk2`... but you can rename them by editing the labels on the *Action* blocks.

An *Action* block contains a sequence of actions that will only be executed when the block is referred to by something else, such as a start block. This is useful in orchestrating more complex programs of music.

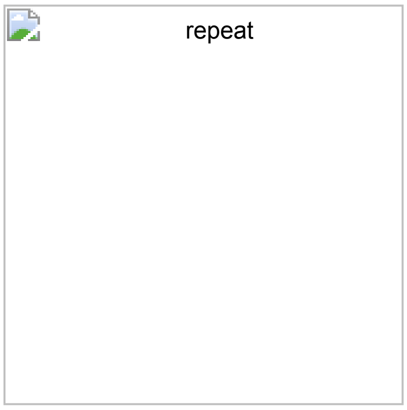
A *Start* Block is a *Action* that will automatically be executed once the start button is pressed. This is where most of your programs will begin at. There are many ways to *Run* a program: you can click on the *Run* button at the upper-left corner of the screen to run the music at a fast speed; a long press on the *Run* button will run it slower (useful for debugging); and the *Step* button can be used to step through the program one block per button press. (An extra-long press of the *Run* button will play back the music slowly. A long press of the *Step* button will step through the program note by note.)

In the example above, the *Action* block named "chunk" is inside of a *Start* block, which means that when any of the start buttons is pressed, the code inside the *Start* block (the *Action* block) will be executed. You can add more chunks after this one inside the *Start* block to execute them sequentially.



You can repeat actions either by using multiple *Action* blocks or using a *Repeat* block.

You can also mix and match actions. Here we play the *Action* block with name `chunk0`, followed by `chunk1` twice, and then `chunk0` again.



A few more chunks and we can make a song. (Can you read the block notation well enough to guess the outcome? Are you familiar with the song we created?)

3.2 Pitch Transformations

There are many ways to transform pitch, rhythm, and other sonic qualities.

3.2.1 Step Pitch Block

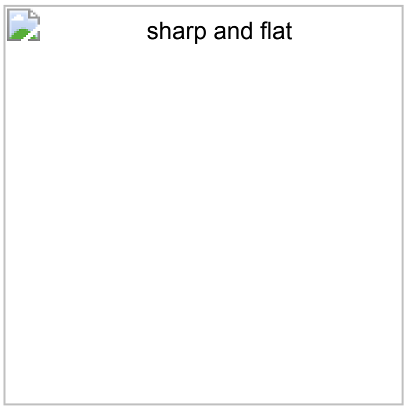
The *Step Pitch* block will move up or down notes in a scale from the last played note. In the example above, *Step Pitch* blocks are used inside of *Repeat* blocks to repeat the code `7` times, playing up and down a scale.

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523032034365533&run=True)

Another way to move up and down notes in a scale is to use the *Scalar Step Up* and *Scalar Step Down* blocks. These blocks calculate the number of half-steps to the next note in the current mode. (You can read more about Musical Modes below.) Note that the *Mouse Pitch Number* block returns the pitch number of the most recent note played.

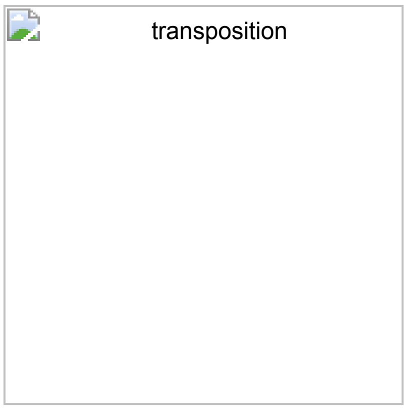
In this example, we are using the *Mode length* block, which returns the number of scalar steps in the current mode (7 for Major and Minor modes).

3.2.2 Sharps And Flats



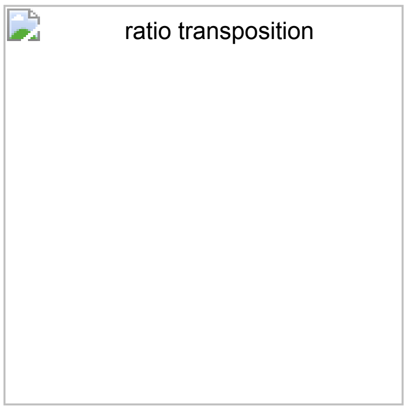
The *Accidental* block can be wrapped around *Pitch* blocks, *Note value* blocks, or chunks of notes inside of *Action* blocks. A sharp will raise the pitch by one half step. A flat will lower by one half step. In the example, on the left, just the *Pitch* block `Mi` is lowered by one half step; on the right, both *Pitch* blocks are raised by one half step. (You can also use a double-sharp or double-flat accidental.)

3.2.3 Adjusting Transposition



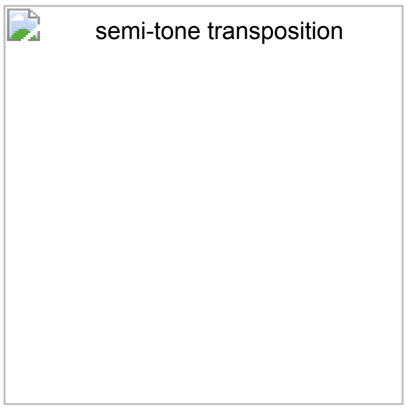
There are multiple ways to transpose a pitch: by semi-tone or scalar steps or by a ratio. The *Semi-tone-transposition* block (above left) can be used to make larger shifts in pitch in half-step units. A positive number shifts the pitch up and a negative number shifts the pitch down. The input must be a whole number. To shift up an entire octave, transpose by `12` half-steps. `-12` will shift down an entire octave.

The *Scalar-transposition* block (above right) shifts a pitch based on the current key and mode. For example, in `C Major`, a scalar transposition of `1` would transpose `C` to `D` (even though it is a transposition of `2` half steps). To transpose `E` to `F` is `1` scalar step (or `1` half step). To shift an entire octave, scalar transpose by the mode length up or down. (In major scales, the mode length is `7`.)



The *Transpose-by-ratio* block shifts a pitch based on a ratio. For example, a ratio of 2:1 would shift a pitch by an octave; a ratio of 3:2 would shift a pitch by a fifth.

As a convenience, a number of standard scalar transpositions are provided: *Unison*, *Second*, *Third*, ..., *Seventh*, *Down third*, and *Down sixth*, as well as a transposition for *Octave*.



In the example above, we take the song we programmed previously and raise it by one octave.

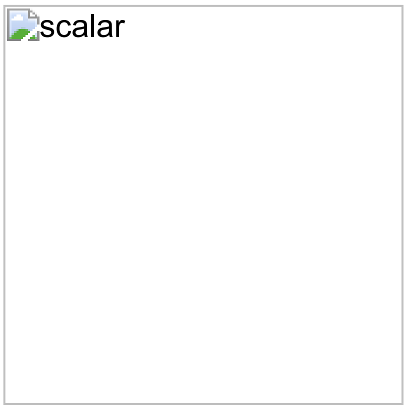
The *Register* block provides an easy way to modify the register (octave) of the notes that follow it. In the example above it is first used to bump the `Mi 4` note up by one octave and then to bump the `Sol 4` note down by one octave.

3.2.4 Summary of Pitch Movements

Representation	Pitch Movement	Properties
Scalar Step	scalar	0=no change

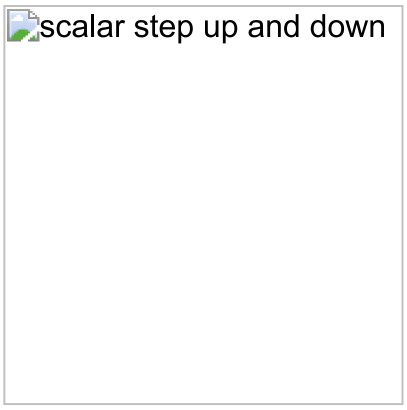
Representation	Pitch Movement	Properties
		1=next scalar pitch in current key and mode
		-1=previous scalar pitch in current key and mode
		If the argument to scalar step is positive, it moves up the scale; if it is negative, it moves down the scale.

Music Blocks Code for Scalar Step



The example above demonstrates traveling up and down the major scale by moving an octave up from the starting note, do, one note at a time and then back down the same way.

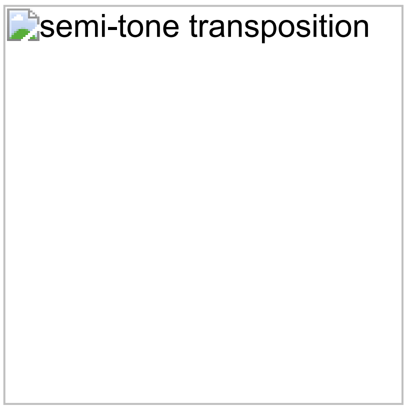
Standard Notation with Scalar Step



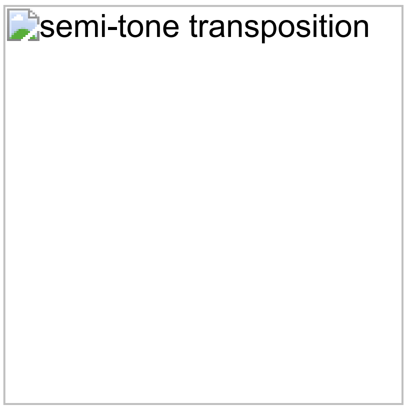
Representation	Pitch Movement	Properties
Transposition	Semi-tone	Creates shifts in pitch by half-steps
		If the argument to transpose is positive, it will shift upwards in pitch; if it is negative, there will be a downwards shift.
		There are 12 half-steps shifts per octave.
		An argument of -12 will shift down one octave.
		An argument of zero will not change the pitch.

Music Blocks Code with Scalar Transpose

Music Blocks Code with Scalar Transpose



Standard Notation for Scalar Transpose



Representation	Pitch Movement	Properties
Transposition	Scalar	Shifts the pitch based on the current key and mode Each number represents a scalar step. Scalar transposition can transform your original key to a new key by counting the notes between the keys. For example: Transposing C-D-E-F by 4 (fifth) will give us G-A-B-C To transpose an octave: shift by the mode length (7 in major scales) up or down.

3.2.5 Set Key

The *Set key* block is used to change both the mode and key of the current scale. (The current scale is used to define the mapping of Solfege [when set Movable Do = True] to notes and also the number of half steps take by the the *Scalar step* block.) For example, by setting the key to C Major, the scale is defined by starting at C (or Do) and applying the pattern of half steps defined by a Major mode. In this case, the pattern of steps skips past all of the sharps and flats. (On a piano, C Major is just the white keys).

When using the *Set key* block, the mode argument is used to define the pattern of half steps and the key argument is used to define the starting position of the pattern. For example, when mode = "major" and key = "C", the pattern of half steps is 2 2 1 2 2 2 1 and the first note in the scale from which the pattern is applied is "C".

Set Key Example

Set Key Example

Using the example above, one can modify the arguments to *Set key* in order to move up and down one octave in a scale. The example shows G Major scale, which has an F#, but it could be used for any combination of key and mode.

Standard Notation for Set Key Example

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1662103714150464&run=True)

Various examples for Major modes are shown in the following table.

Key	Mode	Mode Pattern in Half Steps	Pitch Pattern
C	Major	2 2 1 2 2 2 1	C, D, E, F, G, A, B, C
G	Major	2 2 1 2 2 2 1	G, A, B, C, D, E, F#, G
D	Major	2 2 1 2 2 2 1	D, E, F#, G, A, B, C#, D
F	Major	2 2 1 2 2 2 1	F, G, A, B♭, C, D, E, F
B♭	Major	2 2 1 2 2 2 1	B♭, C, D, E♭, F, G, A, B♭

The next table is the same sets of various keys (starting pitches), but the mode is set to "Dorian" instead of Major.

Key	Mode	Mode Pattern in Half Steps	Pitch Pattern
C	Dorian	2 1 2 2 2 1 2	C, D, E♭, F, G, A, B♭, C
G	Dorian	2 1 2 2 2 1 2	G, A, B♭, C, D, E, F, G
D	Dorian	2 1 2 2 2 1 2	D, E, F, G, A, B, C, D
F	Dorian	2 1 2 2 2 1 2	F, G, A♭, B♭, C, D, E♭, F
B♭	Dorian	2 1 2 2 2 1 2	B♭, C, D♭, E♭, F, G, A♭, B♭

This last table is the same set of keys as the above two tables, but the mode is set to "Phrygian".

Key	Mode	Mode Pattern in Half Steps	Pitch Pattern
C	Phrygian	1 2 2 2 1 2 2	C, D♭, E♭, F, G, A♭, B♭, C
G	Phrygian	1 2 2 2 1 2 2	G, A♭, B♭, C, D, E♭, F, G
D	Phrygian	1 2 2 2 1 2 2	D, E♭, F, G, A, B♭, C, D
F	Phrygian	1 2 2 2 1 2 2	F, G♭, A♭, B♭, C, D♭, E♭, F
B♭	Phrygian	1 2 2 2 1 2 2	B♭, C♭, D♭, E♭, F, G♭, A♭, B♭

Notice how in all the examples, the sets with the same mode results in the same "Mode Pattern of Half Steps", but the resultant "Pitch Pattern" is different. Also, notice how G Dorian and F Major have the same set of pitches in "Pitch Pattern" (they both have B♭ and no other sharps or flats). C Dorian, D Phrygian, and B♭ Major all have the same set of pitches as well (all three have B♭ and E♭).

If these lists were expanded further, there would be many more such examples. These are because these modes (Major, Dorian, and Phrygian) all have essentially the same modal pattern; the starting point is just shifted slightly for each: Dorian could be thought of starting from the second scale degree of Major and Phrygian from the third, for example. Not all modes have this relationship to Major. The ones that do are: Ionian (Major), Dorian, Phrygian, Lydian, Myxolydian, Aeolian (Minor), and Locrian.

Set Key & Scalar Step

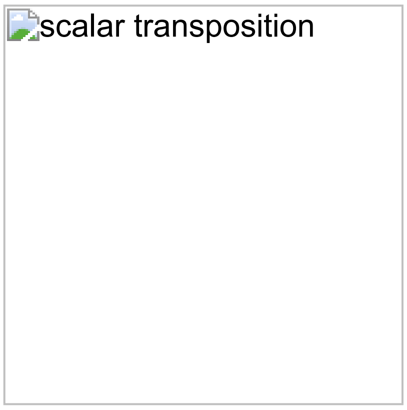
The *Set key* block is used to select a subset of notes in the given temperament. (By default, Music Blocks uses equal temperament of 12 equal divisions of the octave. The key and mode determine which of these notes will be used.)

Set Key & Movable Do

The *Set Key* block will change the key and mode of the mapping between solfege, e.g., `Do`, `Re`, `Mi`, to note names, e.g., `F#`, `G#`, `A#`, when in F# Major. It only impacts the mapping of solfege when the *movable Do* block is set to True.

You can find the *Set key* block on the *Intervals* palette.

Music Blocks for Set Key and Movable Do



Standard Notation for Set Key and Movable Do

Standard Notation for Set Key and Movable Do

scalar transposition

Representation	Pitch Movement	Properties
Scale Degree	Scalar	The key block sets the key and mode. The scale degree blocks indicate which position the pitch is taking in the scale relative to the tonic which is "scale degree 1".

Music Blocks Code with Scale Degrees 1-5

scale degree

Standard Notation for Scale Degrees 1-5

scale degree

Representation	Pitch Movement	Properties
Movable “Do”	Advanced transposition by mode	Movable Do in combination with the Scale/Mode blocks will transpose sections of music in a nuanced way. The Set-key block allows you to change both the mode and key of how solfege is mapped to the notes. For example, in C major - Do is C, Re is D, Mi is E, etc.

Representation	Pitch Movement	Properties
		In F major - Do is F, Re is G, Mi is A

Music Blocks Code with Set Key and Movable Do

Standard Notation Code for Set Key and Movable Do

Representation	Pitch Movement	Properties
Movable “Do”	Advanced transposition by mode	You also have the option of changing the mode to Minor, Major, Chromatic, and many other exotic modes like hirajoshi, as shown in the example below.

Music Blocks for Set Key and Scalar Step

Standard Notation with Set Key and Scalar Step

Standard Notation with Set Key and Scalar Step

movable do

3.2.6 Fixed and Movable Pitch Systems

Music Blocks allows users to express and explore musical ideas in a variety of different systems. The main systems of expression are fixed and movable.

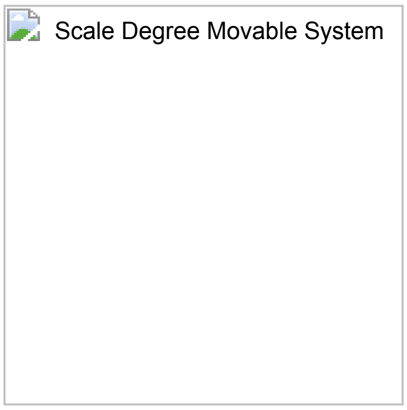
Fixed and Movable Systems

Fixed pitch systems represent pitches in an absolute way. Pitches in a fixed system do not change, regardless of a tonal context (such as key or mode). Movable systems, on the other hand, represent pitches in a relative way based on their tonal context.

An example of a fixed system is Alphabet Notation. Pitches are expressed as `A`, `B`, `C`, `D`, `E`, `F`, and `G`. Regardless of whether the key is C major or G minor, the pitch of `G` is the same. In Alphabet Notation, pitches are the same ("fixed") regardless of the context.

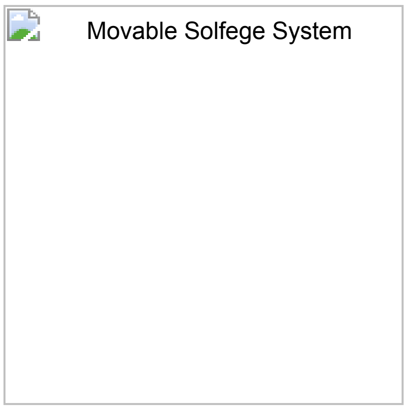
Alphabet Fixed System

An example of a movable system is Scale Degree. Pitches are expressed as `1`, `2`, `3`, `4`, `5`, `6`, and `7`. For C major, these pitches are `C`, `D`, `E`, `F`, `G`, `A`, and `B`. For G (natural) minor, these pitches are `G`, `A`, `B♭`, `C`, `D`, `E♭`, and `F`. For D dorian, these pitches are `D`, `E`, `F`, `G`, `A`, `B`, and `C`. In all three examples, the pitches are determined by the tonal context.



Solfege is an example of a system that can be either fixed or movable; it can either be a fixed system (Fixed Solfege) or a movable system (Movable Solfege).

Fixed Solfege works like the alphabet system; `La` is `A`, `Ti` is `B`, `Do` is `C`, etc. Context does not affect the sounding pitch. Movable Solfege works like the Scale Degree system; for any major, `Do` is 1st scale degree, `Re` is 2nd, `Mi` is 3rd, `Fa` is 4th, etc. Hence, in Movable Solfege in the key of G (natural) minor, `Do` is `G`, `Re` is `A`, et al.



Music Blocks users can create and preview code in both Fixed Solfege and Movable Solfege. Teachers and learners may use either system (or both) to express their musical ideas as well as deepen their understanding of music.

Using Tonal Context with Movable Systems

For movable systems an important point of context is its key and mode. For "C Major", the key is "C" and the mode is "Major" (also called Ionian). Key and mode are important as they define the tonal framework, i.e., which pitches are "in" and which are "out". It also defines the function of the pitches within the framework. This is why for scale degrees `1`, `2`, `3`, `4`, and `5`, the expected result for C major is `C`, `D`, `E`, `F`, and `G` (skipping any sharps/flats), while those same scale degrees for D major are `D`, `E`, `F#`, `G`, and `A`. The set of pitches that make up C major have no sharps or flats, so they are skipped. D major has two sharps, `F#` and `C#`. The `F#` is the 3rd scale degree for D major.

Scale Degree with *Set Key* is a very powerful tool for expression. It is also very common in music pedagogy. However, because the number values 1-7 are hard wired into this system, it is a tool that works best to express seven-pitch tonal frameworks (e.g. major, minor, and other common seven pitch scales). For musical ideas where a more purely mathematical form of expression is required, Music Blocks offers the user the *nth Modal Pitch* block.

nth Modal Pitch is similar to *Scale Degree* in that it is a movable system that uses numbers to express pitches. However, unlike *Scale Degree*, *nth Modal Pitch* starts at `0`, allows for negative numbers, and is not restricted to a seven-pitch tonal framework. `0` is the first pitch of the mode, `1` is the next pitch, `2` is the pitch above that, etc. `-1` is the pitch before the first pitch of the mode. This tool is especially helpful for expressing a musical idea that requires computation as you can run computations directly on the number value. It is also helpful if you are, for example, creating music in a whole tone (six note) pitch space. In the case of *Set Key* set to "whole tone", `6` would be the octave above.

Pitch Number, MIDI, and Set Pitch Number Offset

Pitch Number is similar to *nth Modal Pitch* in that it is a zero-based, mathematical system to express pitches. However, unlike *nth Modal Pitch*, *Pitch Number* disregards any tonal framework. It is also chromatic by default, meaning that its pitch space includes the sharp/flat pitches (black keys on piano) as well as the natural pitches (white keys on piano). By default, middle C (C_4) is `0`. The C major scale in the 4th octave is `0`, `2`, `4`, `5`, `7`, `9`, and `11`. `12` is the C an octave above middle C (C_5). This system is useful mathematically, but because it disregards key, it is difficult to control when creating music. That being said, fretted instruments such as ukulele and guitar use this system to express pitch, so it is a good system for expressing how these instruments work.

MIDI also uses a similar system to *Pitch Number* to express pitches, but the 0 is offset from Music Blocks' default. In order to change the sounding pitch of `0` for *Pitch Number*, use *set pitch number offset*. This makes *Pitch Number* blocks behave as a relative system as it transposes the pitches up or down accordingly (but has no effect on key).

Two Subsystems for Movable

For Movable Do, there exists yet two more systems. One system, which we call `Movable=Do`, allows the user to express solfege syllables in relation to the Major mode. Therefore, if a user were to specify A minor, then La would be A, the first scale degree in A Minor. The other system, which we call `Movable=La` allows the user to express solfege in relation to the particular mode specified. Therefore, if a user were to specify A Minor, then Do would be A. *Scale Degree* works like `Movable=La` by default such that `1` is always the first pitch of a given mode.

Because some users may want to explicitly spell out all of the pitches regardless of the chosen key, we allow them to use Scale Degree with the *Movable Do* block (remember, Scale Degree works like Movable=La by default). Please see this code (https://rawgithub.com/sugarlabs/musicblocks/master/examples/2-spelling-systems-for-Scale-Degree.html) as an example.

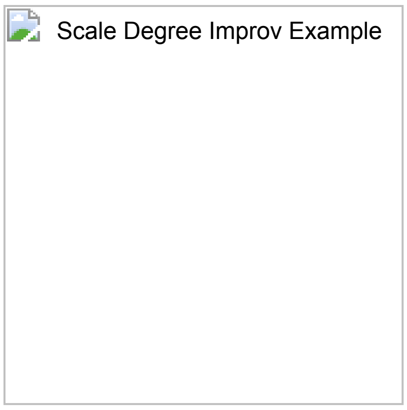
The following chart describes the behavior of different blocks depending on whether or not a *Movable Do* block is present.

Block(s)	Fixed or Movable? (Do or La?)	Set Key Transformation?
Alphabet Pitch	Fixed	No effect.
Solfege	Fixed by default	No effect.
Solfege and Movable=Do	Specified via "movable" block set to Do	Yes.
Solfege and Movable=La	Specified via "movable" block set to La	Yes. Works like Scale Degree.

Block(s)	Fixed or Movable? (Do or La?)	Set Key Transformation?
n^th modal pitch	Movable	Yes. Good for modes of any length.
Scale Degree	Movable	Yes. Most useful for 7 note systems. Works just like Movable=La for Solfege by default.
Scale Degree and Movable=Do	Movable	Yes. When preceded by Movable=Do, the user can be explicit in their spelling.
Scalar Step	Movable	Yes. Navigates up/down within *nth modal pitch* space.
Scalar Interval	Movable	Yes. Adds above/under within *nth modal pitch* space.
Scalar Inversion	Movable	Yes. Inversion around a specified axis within *nth modal pitch* space.
Pitch Number	Movable	No effect. Pitches can be transformed via Set Pitch Number Offset.

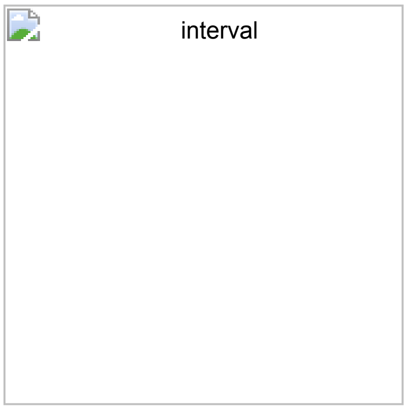
Illustrative example:

The following example demonstrates how the Scale Degree functionality combines math and musical modifiers. When combining numbers and accidentals, it recreates the same functionality as the *Scale Degree* block.



Scale Degree Improv (https://musicblocks.sugarlabs.org/index.html?id=1675577999425474&run=True)

3.2.7 Intervals



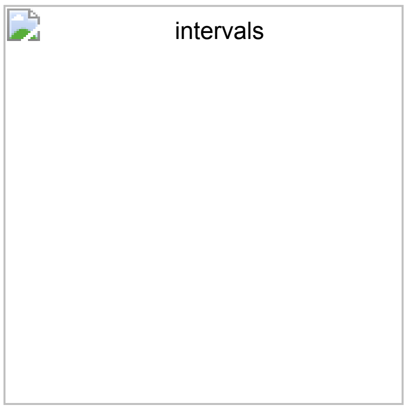
The *Scalar interval* block calculates a relative interval based on the current mode, skipping all notes outside of the mode. For example, a *fifth*, and adds the additional pitches to a note's playback. In the figure, we add `La` to `Re` and `Ti` to `Mi`.

As a convenience, a number of standard scalar intervals are provided on the *Intervals* palette: *Unison*, *Second*, *Third*, ..., *Seventh*, *Down third*, and *Down sixth*.

The *Scalar interval measure* block can be used to measure the number of scalar steps between two pitched.

3.2.7.1 Absolute Intervals

Absolute (or semi-tone) intervals are based on half-steps.



The *Augmented* block calculates an absolute interval (in half-steps), e.g., an augmented fifth, and adds the additional pitches to a note. Similarly, the *Minor* block calculates an absolute interval, e.g., a minor third. Other absolute intervals include *Perfect*, *Diminished*, and *Major*.

In the augmented fifth example above, a chord of `D5` and `A5` are played, followed by a chord of `E5` and `C5`. In the minor third example, which includes a shift of one octave, first a chord of `D5` and `F5` is played, followed by chord of `E5` and `G6`.

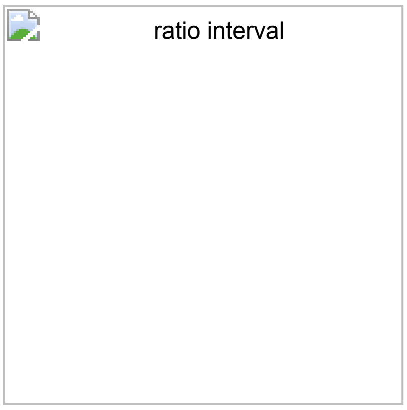
As a convenience, a number of standard absolute intervals are provided on the *Intervals* palette: *Major 2*, *Minor 3*, *Perfect 4*, *Augmented 6*, *Diminished 8*, et al.

The *Doubly* block can be used to create a double augmentation or double diminishment.

The *Semi-tone interval measure* block can be used to measure the number of half-steps between two pitches.

3.2.7.2 Ratio Intervals

Another way to think about intervals is in terms of ratios. For example, a ratio of 2:1 would be an octave shift up; 1:2 would be an octave shift down; 3/2 would be a fifth.

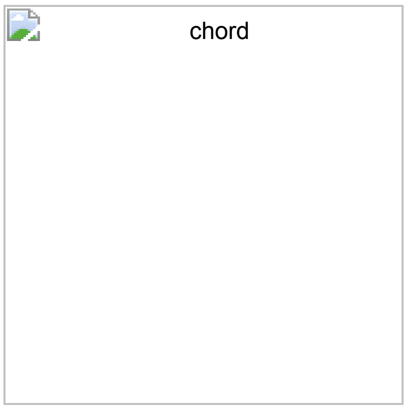


The *Ratio Interval* block lets you generate an interval based on a ratio.

3.2.8 Chords

A chord is a group of notes that are played together (often used for harmony in music). There are triads (three notes), tetrachords (four notes), and even five-, six-, and seven-note chords.

The *Chord* block builds a chord from a base note.



We support many basic chords:

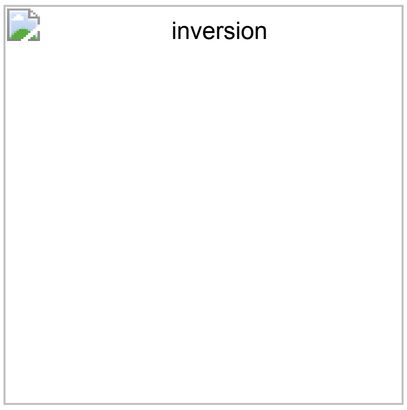
chord	intervals	example
major	1 4 7	C major C - E - G
minor	1 3 7	C minor C - E♭ - G
dominant 7	1 4 7 10	C7 C - E - G - B♭
minor 7	1 3 7 10	Cmin7 C - E♭ - G - B♭
major 7	1 4 7 11	Cmaj7 C - E - G - B

The *Arpeggio* block also builds a chord from a base note, but rather than playing all of the pitches at once, each pitch is played in sequence.

In the example above, since the Major chord intervals are 1 4 7, the notes played are do, mi, sol, sol, ti, mi.

3.2.9 Inversion

The *Invert* block will rotate a series of notes around a target note. There are three different modes of the *Invert* block: *even*, *odd*, and *scalar*. In *even* and *odd* modes, the rotation is based on half-steps. In *even* and *scalar* mode, the point of rotation is the given note. In *odd* mode, the point of rotation is shifted up by a `1/4` step, enabling rotation around a point between two notes. In "scalar" mode, the scalar interval is preserved around the point of rotation.



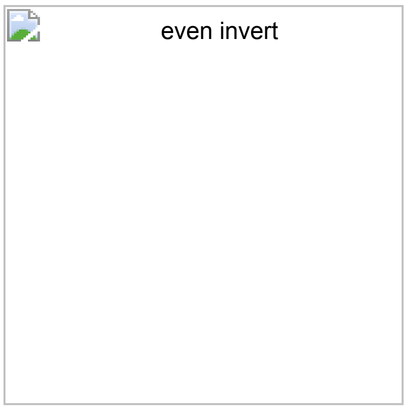
NOTE: The initial `C5` pitch (as a half note) remains unchanged (in all of the examples) as it is outside of the invert block.

The above example code has an *even* inversion for two notes `F5` and `D5` around the reference pitch of `C5`. We would expect the following results:

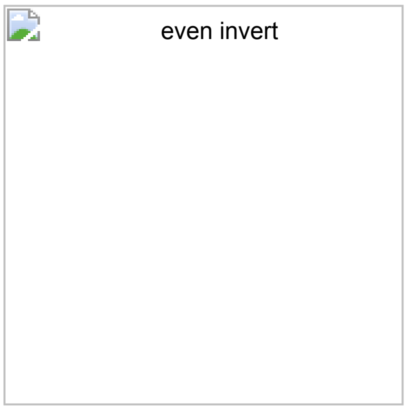
Even inversion

Starting pitch	Distance from `C5`	Inverse distance from `C5`	Ending pitch
`F5`	5 half steps *above*	5 half steps *below*	`G4`
`D5`	2 half steps *above*	2 half steps *below*	`B♭4`

This operation can also be visualized on a pitch clock. The arrows on the following diagram point from the starting pitch, around the axis of the reference pitch, to its destination ending pitch.



In standard notation the result of this *even* inversion operation is depicted in the second measure of the following example. The first measure is the original reference.

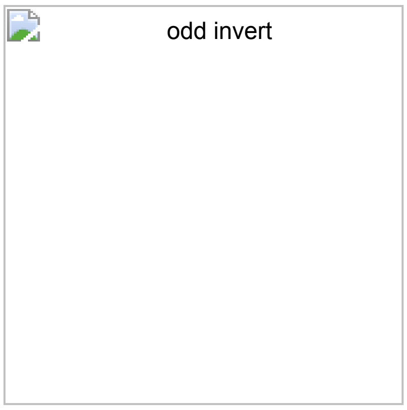


Underneath the *even* inversion in the example code is an *odd* inversion for the same two notes of `F5` and `D5` around the same reference pitch of `C5`. We would expect the following results:

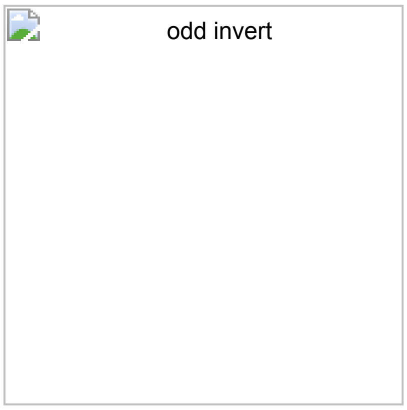
Odd inversion

Starting pitch	Distance from midway-point between `C5` and `C♯5`	Inverse distance from midway-point between `C5` and `C♯5`	Ending pitch
`F5`	4.5 half steps *above*	4.5 half steps *below*	`A♭4`
`D5`	1.5 half steps *below*	1.5 half steps *above*	`B4`

This operation can be visualized on a pitch clock similar to *even* inversion except offset in-between `C5` and `C♯5` (i.e. quarter step *above* `C5`).



In standard notation the result of this *odd* inversion operation is depicted in second measure of the following example. The first measure is the original reference. NOTE: The `C5` pitch remains unchanged as it is not operated upon in the example block code (above). If it were contained in the operation it would be changed to `C♯5` (i.e. `C5` is 0.5 half steps *below* the axis of rotation, so the result of an inversion around `C5` and `odd` would be 0.5 half steps *above* the axis of rotation).

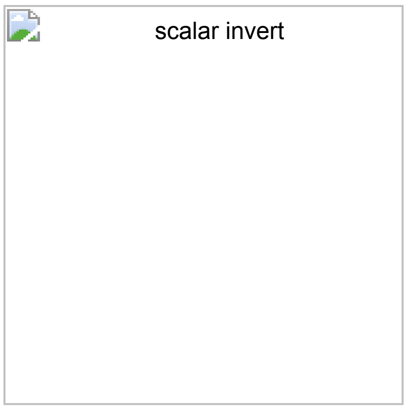


Scalar inversion

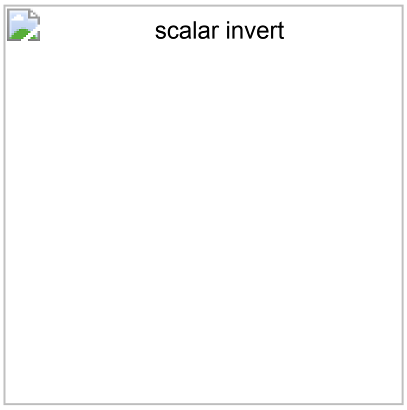
Underneath the *even* and *odd* inversion blocks in the example code is an inversion block set to *scalar*. We would expect the following results:

Starting pitch	Scalar distance from `c5` (in steps)	Inverse scalar distance from `c5` (in steps)	Ending pitch
`F5`	3 above (C5 --> D5 --> E5 --> F5)	3 below (C5 --> B4 --> A4 --> G4)	`G4`
`D5`	1 above (C5 --> D5)	1 below (C5 --> B4)	`B4`

This operation can be visualized on a pitch clock similar to *odd* and *even* except that all non-scalar pitches (i.e. pitches outside the chosen key) are skipped. NOTE: The scalar pitches are shown in bold in the following pitch clock diagram.



In standard notation the result of *scalar* inversion operation is depicted in the second measure of the following example. The first measure is the original reference.

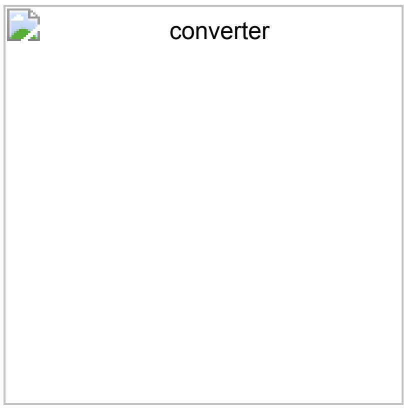


In the *invert (even)* example above, notes are inverted around `C5`. In the *invert (odd)* example, notes are inverted around a point midway between `C5` and `C♯5`. In the *invert (scalar)* example, notes are inverted around `C5`, by scalar steps rather than half-steps.

3.2.10 Converters

Converters are used to transform one form of inputs into other, more usable form of outputs. This section of the guide will talk about the various conversion options Music Blocks has to offer.

Generalized shape of a converter is:



where the right argument is converted accordingly, and output is received on the left side.

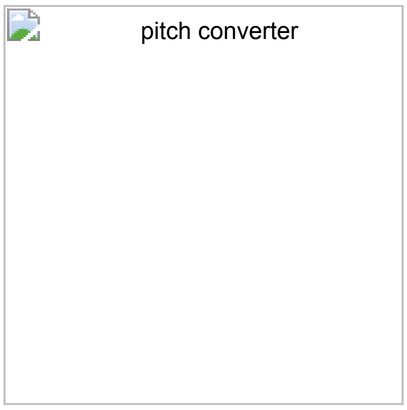
Note: Before an introduction of the different types of converters, a little introduction on Y staff in Music Blocks. Staff is a set of horizontal lines and spaces and different positions along Y axis represents different notes. [C, D, E, F, G, A, B]

3.2.9.1 Y to Pitch

This converter takes input in the form of a number that represents Staff Y position in pixels, and processes the value such that it can be used with certain pitch blocks (pitch number, nth modal pitch, pitch) to produce notes corresponding to given Staff Y position as an argument.

Additionally, the block can be plugged into a print block to view the converted note value.

3.2.9.2 Pitch converter



Pitch converter offers a range of options through a pie-menu based interface and it can potentially convert or extract info out of the current playing pitch using the current pitch block as an input. It can also take custom input in form or solfege, hertz, pitch number etc.

All these options are provided in the form of a pie-menu which can be accessed simply by clicking on the converter.

Below explained is the utility of every conversion option:

0. Alphabet:

Prints the alphabet data of the note being played e.g A, B, C, D, E, F, G, including accidentals.

1. Alphabet class:

Prints the alphabet data of the note being played e.g A, B, C, D, E, F, G. It doesn't print any info regarding accidentals.

2. Solfege Syllable:

Similar to Alphabet class, returns the data in form of solfege e.g do, re, mi. It too, gives no info regarding accidentals.

3. Pitch class:

Returns a number between 0 to 11, corresponding to the note played, where C is 0 and B is 11. Each increase in the number signifies an increase by one semitone.

4. Scalar class:

Returns a number between 1-7 corresponding to the scale degree of the note being played, with reference to the chosen mode. Provides no info regarding accidentals.

5. Scale Degree:

Intuitively, returns the scale degree of the note being played with reference to the chosen mode. It can also be thought of as Scalar class with accidentals.

6. N^th Degree:

Zero-based index of the degree of note being played in the chosen mode.

7. Pitch in Hertz:

Returns the value in hertz of the pitch of the note being currently played.

8. Pitch Number:

Value of the pitch of the note currently being played. It is different from Pitch class in the way that it can go below 0 and above 11 depending upon the octave.

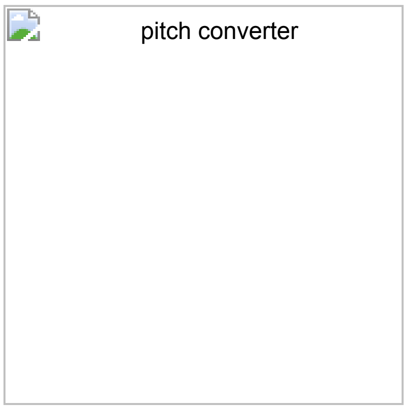
9. Staff Y:

Returns the Y staff position of the note being played according to staff dimensions. It takes into account only the alphabet class, no accidental info is processed.

3.2.9.3 Number to Octave

This converter takes a numeric value which denotes pitch number and returns the octave corresponding to that pitch number.

3.2.9.4 Number to Pitch



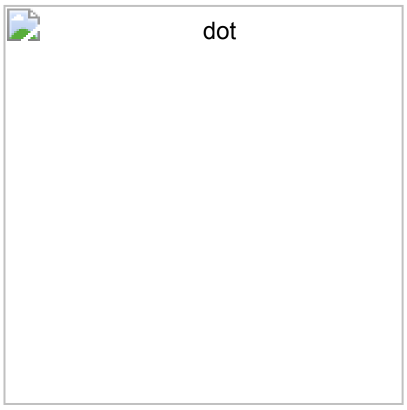
This converter takes a numeric value which denotes pitch number and returns the pitch name corresponding to that pitch number. No octave is inferred.

Converter Name	Description
alphabet	Converts pitch to letter (as defined above). G maps to G. G♯ maps to G#.
alphabet class	Converts pitch to letter (as defined above). G maps to G. G♯ also maps to G.
solfege syllable	Converts pitch to solfege (as defined above). G maps to sol.
solfege class	Converts pitch to solfege class (as defined above). G maps to sol. G♯ maps to sol.
pitch class	Converts pitch to pitch class (as defined above). G maps to 7.
scalar class	Converts pitch to scalar class (as defined above). G maps to 5.
scale degree	Converts pitch to scale degree (as defined above). G maps to 5.
nth degree	Converts pitch to nth degree (as defined above). G maps to 4.
staff y	Maps the current pitch to a y value that corresponds to a position on the staff. G4 maps to 50.
pitch number	Converts pitch to pitch number (as defined above). G maps to 7.
pitch in hertz	Converts pitch to hertz. G4 maps to 392Hz.

Converter Name	Description
pitch to color	Converts pitch to a color value (0-100). C maps to 0, G maps to 58.3, etc.
pitch to shade	Coverts the octave value of the current pitch to a shade. Octave 4 maps to 50.

3.3 Note Value Transformations

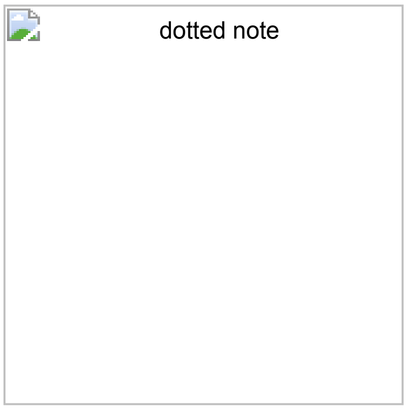
3.3.1 Dotted Notes



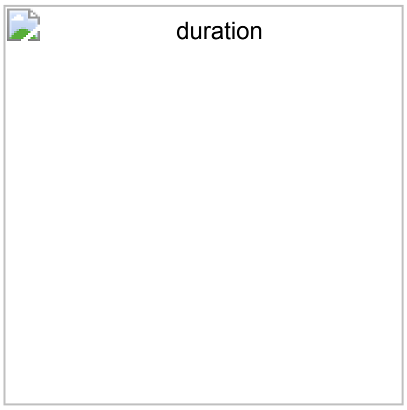
You can "dot" notes using the *Dot* block. A dotted note extends the rhythmic duration of a note by 50%. E.g., a dotted quarter note will play for `3/8 (i.e. 1/4 + 1/8)` of a beat. A dotted eighth note will play for `3/16 (i.e. 1/8 + 1/16)` of a beat. A double dot extends the duration by `75% (i.e. 50% + [50% of 50%])`. For example, a double-dotted quarter note will play for `7/16 (i.e. 1/4 + 1/8 + 1/16)` of a beat (which is the same as `4/16 + 2/16 + 1/16 = 7/16`).

The dot block is useful as an expression of musical rhythm--it is convenient and helps to organize musical ideas (e.g. many melodies use dots as the basis of their rhythmic motifs), however you can achieve the same rhythmic result as dot by putting the calculation directly into note value as well. For example, indicating `3/8` instead of `1/4` will result in a dotted quarter note.

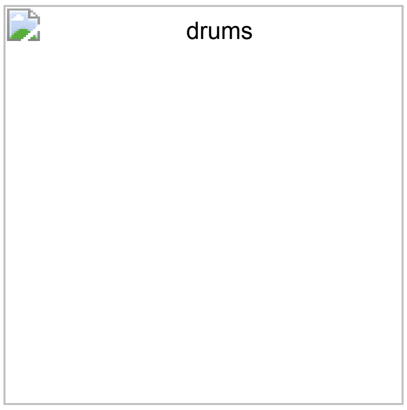
The chart below shows two common examples, dotted quarter and dotted eighth, and how to achieve them with either the dot block or by direct calculation into a note's note value.



3.3.2 Speeding Up and Slowing Down Notes via Mathematical Operations



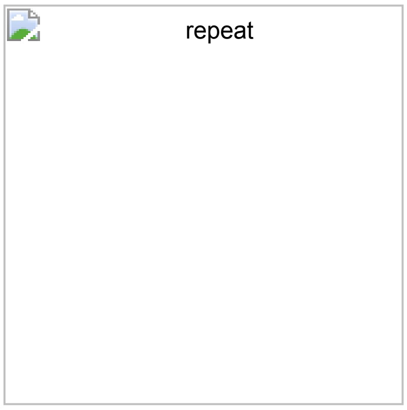
You can also multiply (or divide) the note value, which will change the duration of the notes by changing their note values. Multiplying the note value of an `1/8` note by `1/2` is the equivalent of playing a `1/16` note (i.e. `1/2 * 1/8 = 1/16`). Multiplying the note value of an `1/8` note by `2/1` (which has the effect of dividing by `1/2`) will result in the equivalent of a `1/4` note.



In the above example, the sequence of drum note values is decreased over time, at each repetition.

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523106271018484&run=True)

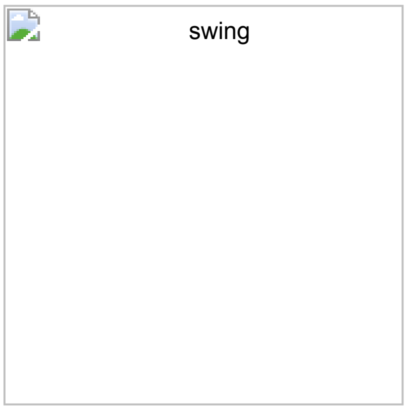
3.3.3 Repeating Notes



There are several ways to repeat notes. The *Repeat* block will play a sequence of notes multiple times; the *Duplicate* block will repeat each note in a sequence.

In the example, on the left, the result would be `Sol, Re, Sol, Sol, Re, Sol, Sol, Re, Sol, Sol, Re, Sol`; on the right the result would be `Sol, Sol, Sol, Sol, Re, Re, Re, Re, Sol, Sol, Sol, Sol`.

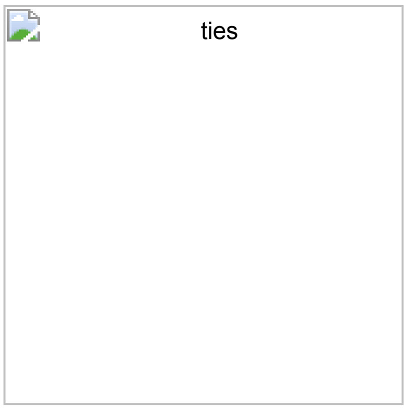
3.3.4 Swinging Notes and Tied Notes



The *Swing* block works on pairs of notes (specified by note value), adding some duration (specified by swing value) to the first note and taking the same amount from the second note. Notes that do not match note value are unchanged.

In the example, `re5` would be played as a `1/6` note and `mi5` would be played as a `1/12` note (`1/8 + 1/24 === 1/6` and `1/8 - 1/24 === 1/12`). Observe that the total duration of the pair of notes is unchanged.

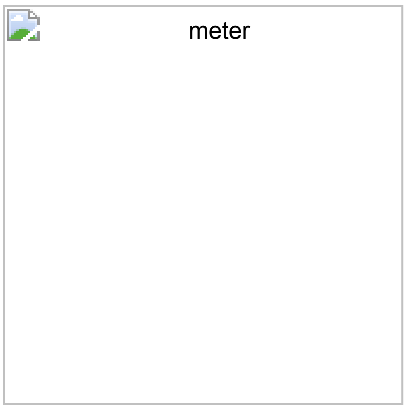
Tie also works on pairs of notes, combining them into one note. (The notes must be identical in pitch, but can vary in rhythm.)



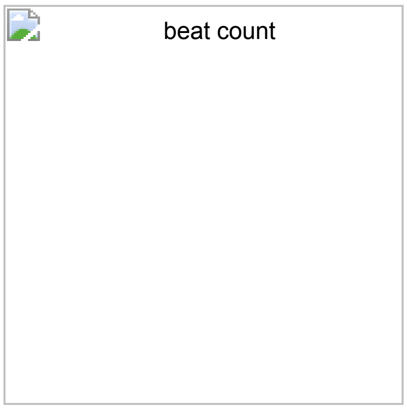
3.3.5 Beat

The beat of the music is determined by the *Meter* block (by default, it is set to 4:4).

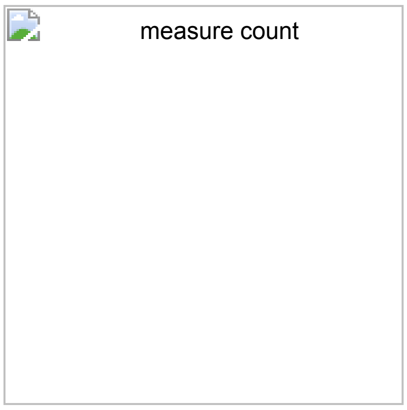
The *Pickup* block can be used to accommodate any notes that come in before the beat.



The Beat count block is the number of the current beat, eg 1, 2, 3, or 4. In the figure, it is used to take an action on the first beat of each measure.



The Measure count block returns the current measure.



Specifying beat is useful in that you can have the character of a note vary depending upon the beat. In the example below, the volume of notes on Beat `1` and Beat `3` are increased, while the volume of off beats is decreased.

The *On-Beat-Do* and *Off-Beat-Do* blocks let you specify actions to take on specific beats. (Note that the action is run before any blocks inside the note block associated with the beat are run.)

More examples can be found in the Graphics section below.

3.3.6 Staccato and Slur

The *Staccato* block shortens the length of the actual note—making them tighter bursts—while maintaining the specified rhythmic value of the notes.

The *Slur* block lengthens the sustain of notes—running longer than the noted duration and blending it into the next note—while maintaining the specified rhythmic value of the notes.

3.3.7 Backwards

The *Backward* block will play the contained notes in reverse order (retrograde). In the example above, the notes in `chunk` are played as `Sol`, `Ti`, `La`, `Sol`, i.e., from the bottom to the top of the stack.

An example from Bach is provided. In the example, there are two voices, one which plays the composition forward and one that plays the same composition backward. RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1522885752309944&run=True)

Note that all of the blocks inside a *Backward* block are reverse, so use this feature with caution if you include logic intermixed with notes.

3.4 Other Transformations

3.4.1 Set Volume and Crescendo

The *Set master volume* block will change the master volume. The default is `50`; the range is `0` (silence) to `100` (full volume).

The *Set synth volume* block will change the volume of a particular synth, e.g., `violin`, `snare drum`, etc. The default volume is `50`; the range is `0` (silence) to `100` (full volume). In the example, the *synth name* block is used to select the current synth.

As a convenience, a number of standard volume blocks are provided: from loudest to quietest, there is *fff*, *ff f*, *mf*, *mp*, *p*, *pp*, and *ppp*. In musical terms "f" means "forte" or loud, "p" means "piano" or soft, and "m" means "mezzo" or middle.

The *Set Relative Volume* block modifies the clamped note's volume according to the input value of the block in an added (or subtracted when negative) percentage with respect to the original volume. For example, `100` would mean doubling the current volume.

The *Crescendo* block will increase (or decrease) the volume of the contained notes by a specified amount for every note played. For example, if you have 3 notes in sequence contained in a *Crescendo* block with a value of `5`, the final note will be at 15% more than the original value for volume.

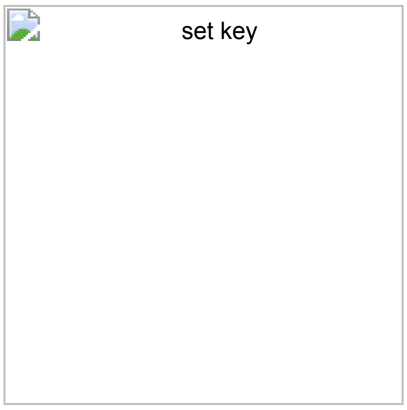
NOTE: The *Crescendo* block does not alter the volume of a note as it is being played. Music Blocks does not yet have this functionality.

3.4.2 Setting Instrument

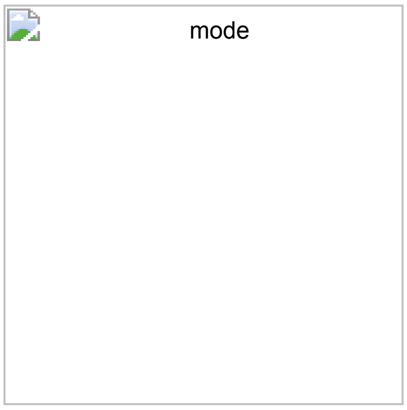
The default instrument is an electronic synthesizer, so by default, that is the instrument used when playing notes. You can override this default for a group of notes by using the *Set Instrument* block. It will select an instrument for the synthesizer for any contained blocks, e.g., violin.

You can also override the default using the *Set default instrument* block. In the example above, the default instrument is set to piano, so any note that is not inside of a *Set instrument* block will be played using the piano synthesizer. The first note in this example is piano; the second note is guitar; and the third is piano.

3.4.3 Setting Key and Mode

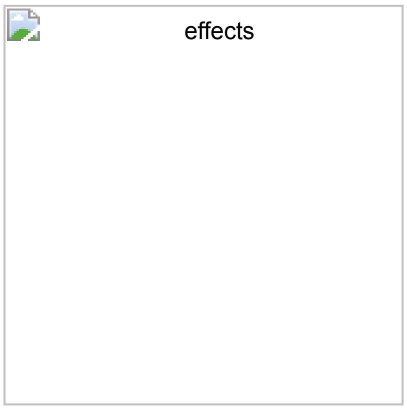


The *Set Key* block will change the key and mode of the mapping between solfege, e.g., `Do`, `Re`, `Mi`, to note names, e.g., `C`, `D`, `E`, when in C Major. Modes include Major and Minor, Chromatic, and a number of more exotic modes, such as Bebop, Geez, Maqam, etc. This block allows users to access "movable Do" within Music Blocks, where the mapping of solfege to particular pitch changes depending on the user's specified tonality.



The *Define mode* block can be used to define a custom mode by defining the number and size of the steps within an octave. You can use your custom mode with the *Set key* block.

3.4.4 Vibrato, Tremelo, et al.

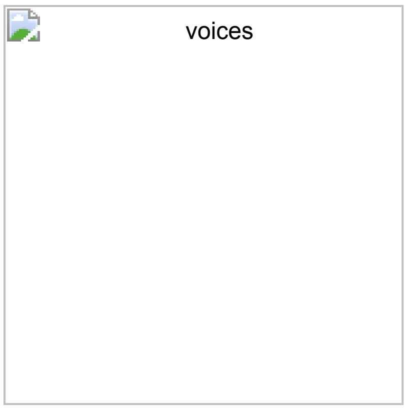


The *Vibrato* Block adds a rapid variation in pitch to any contained notes. The intensity of the variation ranges from `1` to `100` (cents), e.g. plus or minus up to one half step. The rate argument determines the rate of the variation.

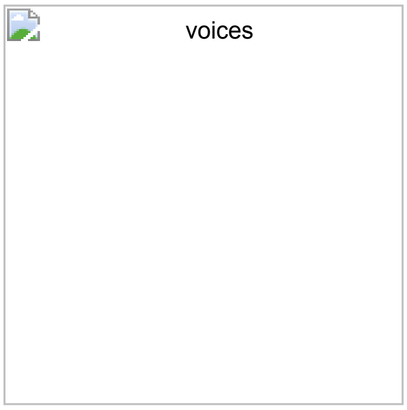
The other effects blocks also modulate pitch over time. Give them a try.

3.5 Voices

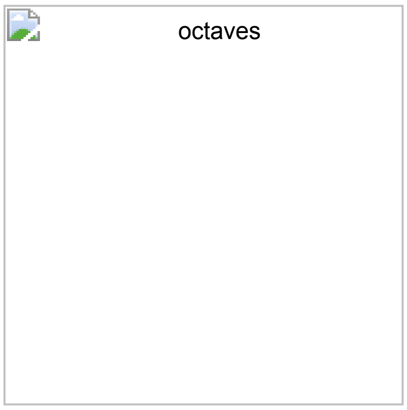
Each *Start* block runs as a separate voice in Music Blocks. (When you click on the Run button, all of the *Start* blocks are run concurrently.)



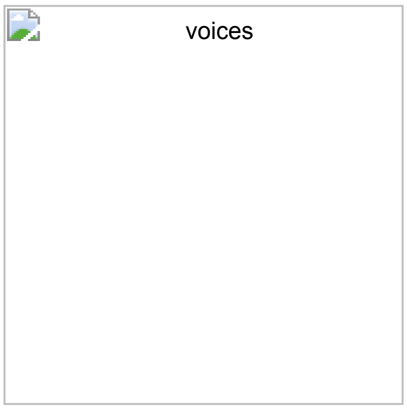
If we put our song into an action...



...we can run it from multiple *Start* blocks.

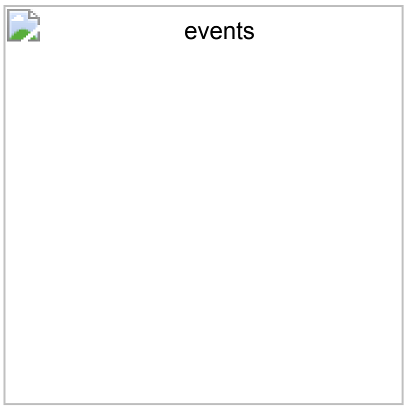


It gets more interesting if we shift up and down octaves.

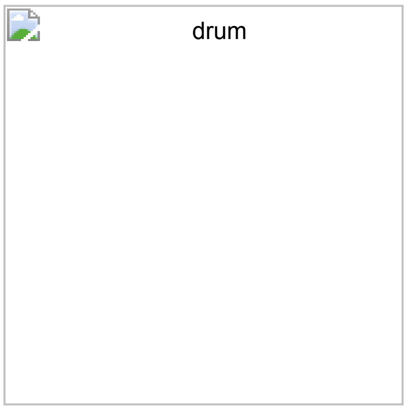


And even more interesting if we bring the various voices offset in time.

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523026536194324&run=True)

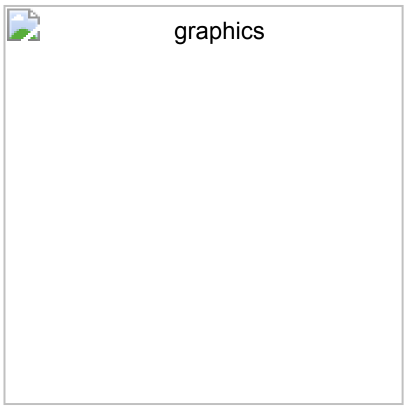


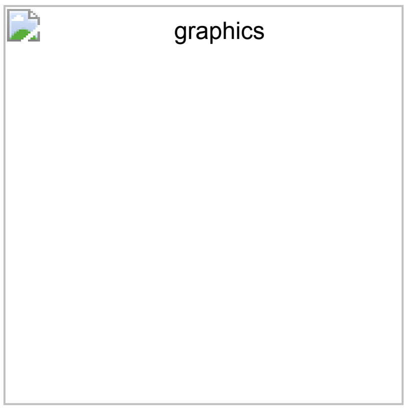
An alternative to use a preprogrammed delay is to use the *Broadcast* block to bring in multiple voices. In the example above, after each section of the song is played, a new event is broadcasted, bringing in a new voice. Note the use of the *Mouse Sync* block. This ensures that the multiple voices are synced to the same master clock.



A special *Start drum* version of the *Start* block is available for laying down a drum track. Any *Pitch* blocks encountered while starting from a drum will be played as `C2` with the default drum sample. In the example above, all of the notes in `chunk` will be played with a kick drum.

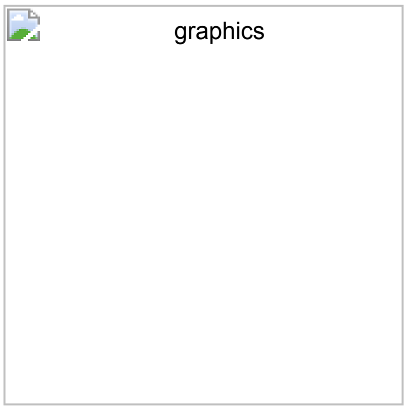
3.6 Adding graphics





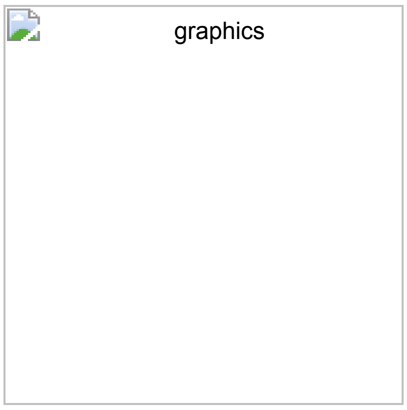
Turtle graphics can be combined with the music blocks. By placing graphics blocks, e.g., *Forward* and *Right*, inside of *Note value* blocks, the graphics stay in sync with the music. In this example, the turtle moves forward each time a quarter note is played. It turns right during the eighth note. The pitch is decreased by one half step, the pen size decreases, and the pen color increases at each step in the inner repeat loop.

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523494709674021&run=True)

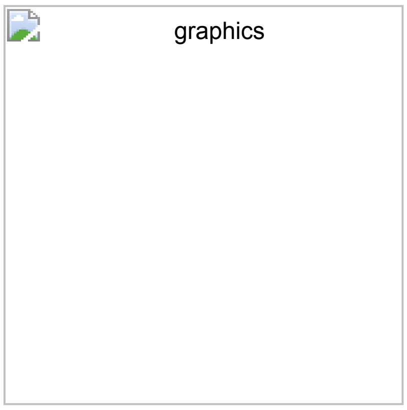


Another example of graphics synchronized to the music by placing the graphics commands inside of *Note value* blocks

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523106271018484&run=True)



Another approach to graphics is to use modulate them based on the beat. In the example above, we call the same graphics action for each note, but the parameters associated with the action, such as pen width, are dependent upon which beat we are on. On Beat 1, the pen size is set to `50` and the volume to `75`. On Beat `3`, the pen size is set to `25` and the volume to `50`. On off beats, the pen size is set to `5` and the volumne to `5`. The resultant graphic is shown below.

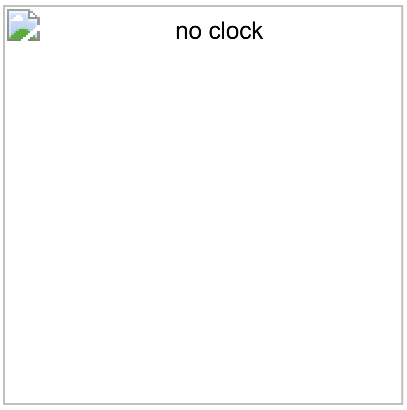


The *On-Every-Note-Do* block lets you specify an action to take whenever a note is played. In the example above, the note value is used to determine the portion of an arc to draw, i.e., a 1/4 note draws a 1/4 circle, a 1/2 note draw 1/2 circle, and a whole note draws a full circle.

The *On-Every-Note-Do* block is found in the Crab Canon project on the Planet to "plot the music". The mouse moves up and down based on the change in pich between notes and to the right in proportion to the note value.

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1522885323588493)

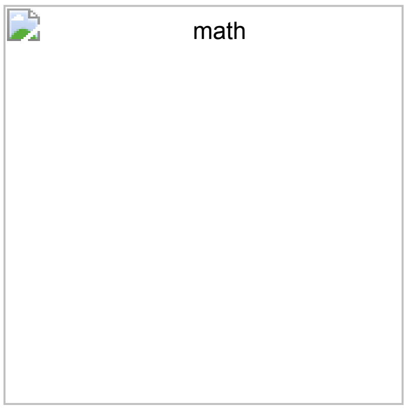
Music Blocks has an internal "conductor" maintaining the beat. When the Run button is clicked, the program begins and an internal master (or "conductor") clock starts up. All of the music tries to stay synced to that clock.



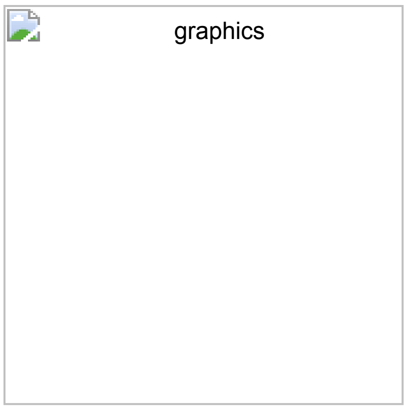
For example, if you have multiple voices (mice), they all share the same conductor in order to keep on the same beat. If a voice (mouse) is falling behind, Music Blocks tries to catch up on the next note by truncating it. If it is an 1/8 note behind and the next note is a 1/2 note, then only an 3/8 note would be played, so as to catch up. That is a somewhat extreme example—usually the timing errors are only very very small differences.

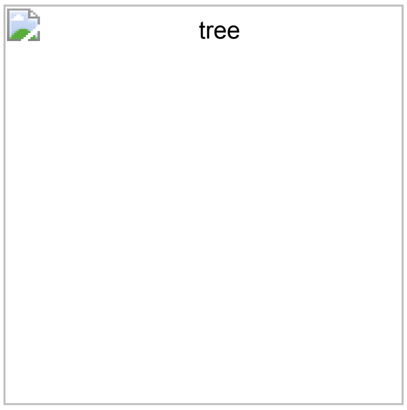
But in some situations, the timing errors can be very large. This is when the *No-clock* block is used.

A typical problem is when the music is not played continuously. Imagine an interactive game where a hero is battling a monster. Our hero plays theme music whenever the monster is defeated. But that might occur at any time, hence it is not going to be in sync with the conductor. The offset could be tens of seconds. This would mean that all of the notes in the theme music might be consumed by trying to catch up with the conductor. The *No-clock* block essentially says, do your own thing and don't worry about the conductor.

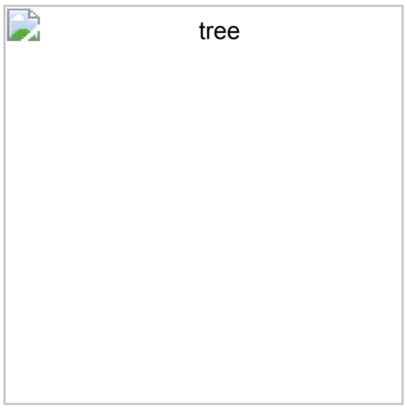


In this example, because the computation and graphics are more complex, a *No-clock* block is used to decouple the graphics from the master clock. The "No-clock* block prioritizes the sequence of actions over the specified rhythm.





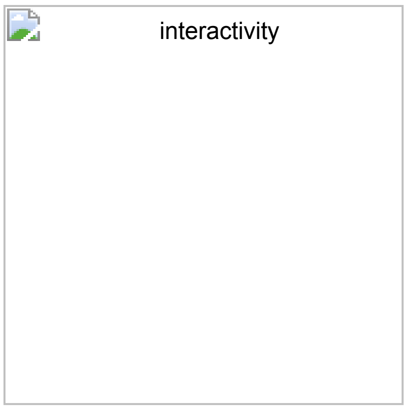
Another example of embedding graphics into notes: in case, a recursive tree drawing, where the pitch goes up as the branches ascend.



RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523029986215035&run=True)

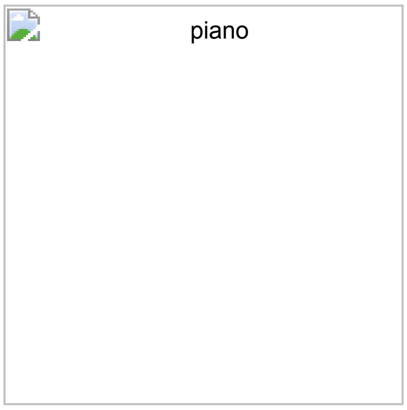
3.7 Interactions

There are many ways to interactive with Music Blocks, including tracking the mouse position to impact some aspect of the music.



For example, we can launch the phrases (chunks) interactively. We use the mouse position to generate a suffix: `0`, `1`, `2`, or `3`, depending on the quadrant. When the mouse is in the lower-left quadrant, `chunk0` is played; lower-right quadrant, `chunk1`; upper-left quadrant, `chunk2`; and upper-right quadrant, `chunk3`.

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523028011868930&run=True)



In the example above, a simple two-key piano is created by associating *click* events on two different turtles with individual notes. Can you make an 8-key piano?

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523107390715125&run=True)

You can also add a bit of randomness to your music. In the top example above, the *One-of* block is used to randomly assign either `Do` or `Re` each time the *Note value* block is played. In the bottom example above, the *One-of* block is used to randomly select between `chunk1` and `chunk2`.

Musical Paint has been a popular activity dating back to programs such as Dan Franzblau's *Vidsizer* (1979) or Morwaread Farbood's *Hyperscore* (2002). Music Blocks can be used to create musical paint as well. In the somewhat ambitious example below, we go a step further than the typical paint program in that you can not only paint music (a la Vidsizer) and playback your painting as a composition (a la Hyperscore), but also generate *Note* blocks from your composition.

The program works by first creating an array from the heap that corresponds to a 20x12 grid of notes on the screen: 20 columns, representing time from left to right; and 12 rows, corresponding to scalar pitch values, which increase in value from the bottom to the top.

The *record* action repeatedly calls the *paint* action until the *playback* button is clicked.

The *paint* action tracks the mouse (*Set XY* to *cursor x* and *cursor y*) and, if the mouse button is pressed, marks an entry in the array corresponding to that note, plays the note, and leaves behind a "drop of paint".

The *playback* action is invoked by clicking on the *play* mouse, which sets *recording* to `0`, thus breaking out of the paint "while loop". Playback scans each column in the array from left to right for pitches to play and generates a chord of pitches for each column.

Once the *playback* action is complete, the *save* action is invoked. Again each column in the array is scanned, but this time, instead of playing notes, the *Make Block* block is called in order to generate a stack of notes that correspond to the composition. This stack can be copied and pasted into another composition.

While a bit fanciful, this example, which can be run by clicking on the link below, takes musical paint in a novel direction.

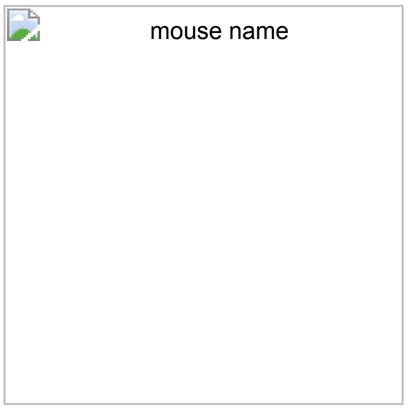
RUN LIVE (https://walterbender.github.io/musicblocks/index.html?id=1523896294964170&run=True&run=True)

3.8 Ensemble

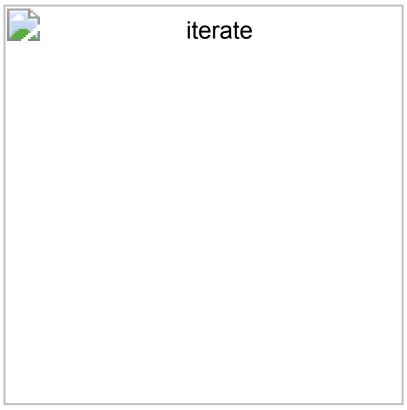
Much of music involves multiple instruments (voices or "mice" in Music Blocks) playing together. There are a number of special blocks that can be used to coordinate the actions of an ensemble of mice.

This section will guide about different ensemble blocks, which communicate the status of mice by name, including notes played, current pen color, pitch number, etc.

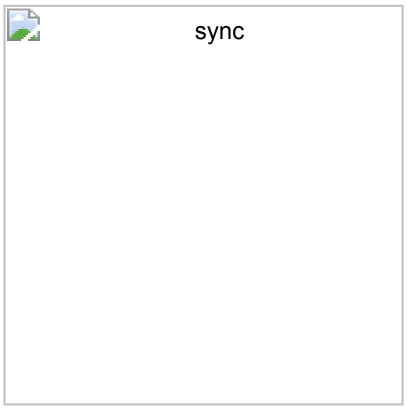
To use the ensemble blocks, you must assign a name to each mouse, as we will reference each mouse by its name.



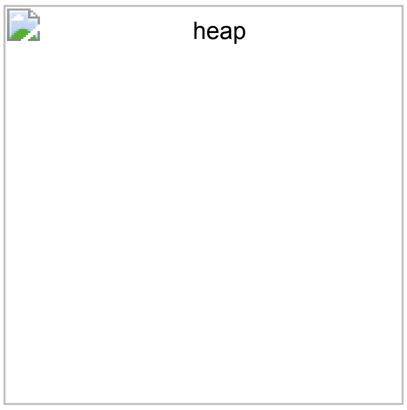
Use the *Mouse count* block in combination with the *Nth mouse name* block to iterate through all of the mice.



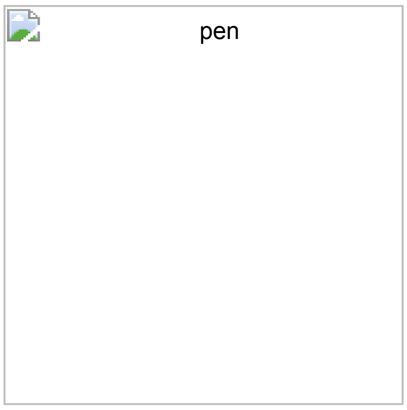
The *Mouse sync* block aligns the beat count between mice.



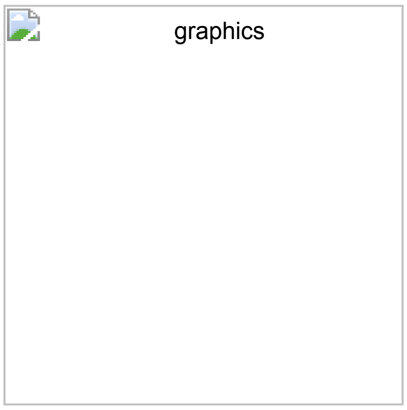
The *Mouse index heap* block returns a value in the heap at a specified location for a specified mouse.



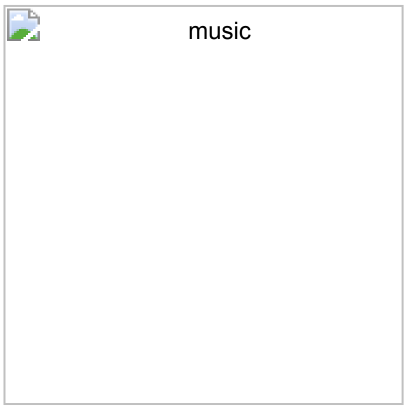
You can use the dictionary entries to data between mice. The *Get value* block lets you specify a mouse name and the value you want to access. For example, you can access a mouse's pen attributes, such as color, shade, and grey values.



You can also access the mouse's graphics attributes, such as x, y, and heading. You can also set attributes of a mouse using the *Set value* block. In the example, a mouse's heading is set to 90.



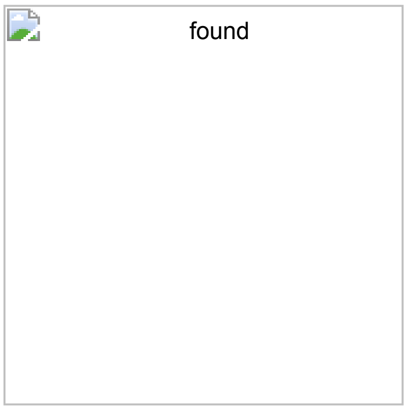
Some music status is also available through the dictionary. You can access a mouse's "current pitch", "pitch number", "note value", the number of "notes played".



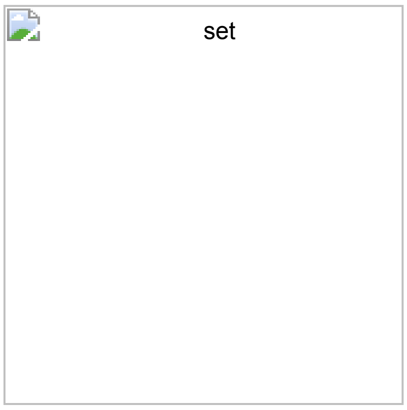
The dictionary can be used to share other things too. Just set a *key/value* pair with one mouse and access it from another.

Other Ensemble blocks include:

The *Found mouse* block will return true if the specified mouse can be found.



The *Set mouse* block sends a stack of blocks to be run by the specified mouse.



4. Widgets

Previous Section (3. Programming with Music) | Back to Table of Contents | Next Section (5. Beyond Music Blocks)

This section of the guide will talk about the various Widgets that can be used within Music Blocks to enhance your experience.

Every widget has a menu with at least two buttons.

You can hide the widget by clicking on the *Close* button.

You can move the widget by dragging its containing the window.

4.1 Status

The *Status widget* is a tool for inspecting the status of Music Blocks as it is running. By default, the key, BPM, and volume are displayed. Also, each note is displayed as it is played. There is one row per voice in the status table.

Additional *Print* blocks can be added to the *Status* widget to display additional music factors, e.g., duplicate, transposition, skip, staccato and slur, and graphics factors, e.g., x, y, heading, color, shade, grey, and pensize.

You can do additional programming within the status block. In the example above, `whole notes played` is multiplied by `4` (to calculate quarter notes played) before being displayed.

4.2 Generating Chunks of Notes

Using the Phrase Maker, it is possible to generate chunks of notes at a much faster speed.

4.2.1 The Phrase Maker

Music Blocks provides a widget, the *Phrase maker*, as a scaffold for getting started.

Once you've launched Music Blocks in your browser, start by clicking on the *Phrase maker* stack that appears in the middle of the screen. (For the moment, ignore the *Start* block.) You'll see a grid organized vertically by pitch and horizontally by rhythm.

The matrix in the figure above has three *Pitch* blocks and one *Rhythm* block, which is used to create a 3 x 3 grid of pitch and time.

Note that the default matrix has five *Pitch* blocks, one *Drum* block, and two *Mouse* (movement) blocks. Hence, you will see eight rows, one for each pitch, drum, and mouse (movement). (A ninth row at the bottom is used for specifying the rhythms associated with each note.) Also by default, there are two *Rhythm* blocks, which specifies six quarter `(1/4)` notes followed by one half `(1/2)` note.

By clicking on individual cells in the grid, you should hear individual notes (or chords if you click on more than one cell in a column). In the figure, three quarter notes are selected (black cells). First `Re 4`, followed by `Mi 4`, followed by `Sol 4`.

If you click on the *Play* button (found in the top row of the grid), you will hear a sequence of notes played (from left to right): `Re 4`, `Mi 4`, `Sol 4`.

Once you have a group of notes (a "chunk") that you like, click on the *Save* button (just to the right of the *Play* button). This will create a stack of blocks that can used to play these same notes programmatically. (More on that below.)

You can rearrange the selected notes in the grid and save other chunks as well.

The *Sort* button will reorder the pitches in the matrix from highest to lowest and eliminate any duplicate *Pitch* blocks.

There is also an Erase button that will clear the grid.

Don't worry. You can reopen the matrix at anytime (it will remember its previous state) and since you can define as many chunks as you want, feel free to experiment.

Tip: You can put a chunk inside a *Phrase maker* block to generate the matrix to corresponds to that chunk.

The chunk created when you click on the matrix is a stack of blocks. The blocks are nested: an *Action* block contains three *Note value* blocks, each of which contains a *Pitch* block. The *Action* block has a name automatically generated by the matrix, in this case, chunk. (You can rename the action by clicking on the name.). Each note has a duration (in this case 4, which represents a quarter note). Try putting different numbers in and see (hear) what happens. Each note block also has a pitch block (if it were a chord, there would be multiple *Pitch* blocks nested inside the Note block's clamp). Each pitch block has a pitch name (`Re`, `Mi`, and `Sol`), and a pitch octave; in this example, the octave is 4 for each pitch. (Try changing the pitch names and the pitch octaves.)

To play the chuck, simply click on the action block (on the word action). You should hear the notes play, ordered from top to bottom.

4.2.2 The Rhythm Block

Rhythm blocks are used to generate rhythm patterns in the *Phrase maker* block. The top argument to the *Rhythm* block is the number of notes. The bottom argument is the duration of the note. In the top example above, three columns for quarter notes would be generated in the matrix. In the middle example, one column for an eighth note would be generated. In the bottom example, seven columns for 16th notes would be generated.

You can use as many *Rhythm* blocks as you'd like inside the *Phrase maker* block. In the above example, two *Rhythm* blocks are used, resulting in three quarter notes and six eighth notes.

4.2.3 Creating Tuplets

Tuplets are a collection of notes that get scaled to a specific duration. Using tuplets makes it easy to create groups of notes that are not based on a power of 2.

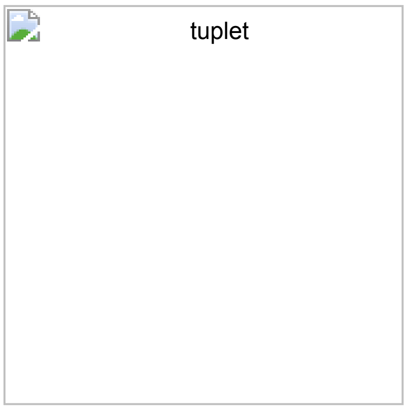
In the example above, three quarter notes—defined in the *Simple Tuplet* block—are played in the time of a single quarter note. The result is three twelfth notes. (This form, which is quite common in music, is called a *triplet*. Other common tuplets include a *quintuplet* and a *septuplet*.)

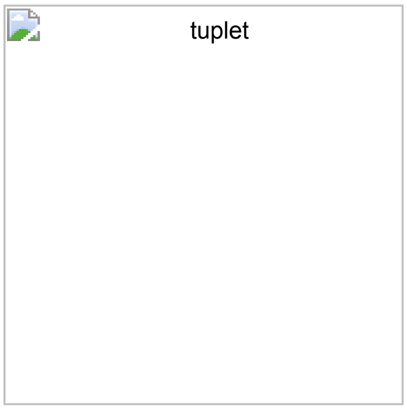
In the example above, the three quarter notes are defined in the *Rhythm* block embedded in the *Tuplet* block. As with the *Simple Tuplet* example, they are played in the time of a single quarter note. The result is three twelfth notes. This more complex form allows for intermixing multiple rhythms within single tuplet.

In the example above, the two *Rhythm* blocks are embedded in the *Tuplet* block, resulting in a more complex rhythm.

Note: You can mix and match *Rhythm* blocks and *Tuplet* blocks when defining your matrix.

4.2.4 What is a Tuplet?





4.2.5 Using Individual Notes

You can also use individual notes when defining the grid. These blocks will expand into *Rhythm* blocks with the corresponding values.

4.2.6 Using a Scale of Pitches

You can use the *Scalar step* block to generate a scale of pitches in the matrix. In the example above, the pitches comprising the G major scale in the 4th octave are added to the grid. Note that in order to put the highest note on top, the first pitch is the `Sol` in `Octave 5`. From there, we use `-1` as the argument to the *Scalar step* block inside the *Repeat*, working our way down to `Sol` in `Octave 4`. Another detail to note is the use of the *Mode length* block.

4.3 Generating Rhythms

The *Rhythm Maker* block is used to launch a widget similar to the *Phrase maker* block. The widget can be used to generate rhythmic patterns.

The argument to the *Rhythm Maker* block specifies the duration that will be subdivided to generate a rhythmic pattern. By default, it is 1 / 1, e.g., a whole note.

The *Set Drum* blocks contained in the clamp of the *Rhythm Maker* block indicates the number of rhythms to be defined simultaneously. By default, two rhythm "rulers" are defined. The embedded *Rhythm* blocks define the initial subdivision of each rhythm ruler.

When the *Rhythm Maker* block is clicked, the *Rhythm Maker* widget is opened. It contains a row for each rhythm ruler. An input in the top row of the widget is used to specify how many subdivisions will be created within a cell when it is clicked. By default, 2 subdivisions are created.

As shown in the above figure, the top rhythm ruler has been divided into two half-notes and the bottom rhythm ruler has been divided into three third-notes. Clicking on the *Play* button to the left of each row will playback the rhythm using a drum for each beat. The *Play-all* button on the upper-left of the widget will play back all rhythms simultaneously.

The rhythm can be further subdivided by clicking in individual cells. In the example above, two quarter-notes have been created by clicking on one of the half-notes.

By dragging across multiple cells, they become tied. In the example above, two third-notes have been tied into one two-thirds-note.

The *Save stack* button will export rhythm stacks.

These stacks of rhythms can be used to define rhythmic patterns used with the *Phrase maker* block.

The *Save drum machine* button will export *Start* stacks that will play the rhythms as drum machines.

Another feature of the *Rhythm Maker* widget is the ability to tap out a rhythm. By clicking on the *Tap* button and then clicking on a cell inside one of the rhythm rulers, you will be prompted (by four tones) to begin tapping the mouse button to divide the cell into sub-cells. Once the fourth tone has sounded, a progress bar will run from left to right across the screen. Each click of the mouse will define another beat within the cell. If you don't like your rhythm, use the *Undo* button and try again.

4.4 Musical Modes

Musical modes are used to specify the relationship between intervals (or steps) in a scale. Since Western music is based on 12 half-steps per octave, modes specify how many half steps there are between each note in a scale.

By default, Music Blocks uses the *Major* mode, which, in the Key of C, maps to the white keys on a piano. The intervals in the *Major* mode are `2, 2, 1, 2, 2, 2, 1`. Many other common modes are built into Music Blocks, including, of course, *Minor* mode, which uses `2, 1, 2, 2, 1, 2, 2` as its intervals.

Note that not every mode uses 7 intervals per octave. For example, the *Chromatic* mode uses 11 intervals: `1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1`. The *Japanese* mode uses only 5 intervals: `1, 4, 2, 3, 2],`. What is important is that the sum of the intervals in an octave is 12 half-steps.

The *Mode length* block will return the number of intervals (scalar steps) in the current mode.

The *Mode* widget lets you explore modes and generate custom modes. You invoke the widget with the *Custom mode* block. The mode specified in the *Set key* block will be the default mode when the widget launches.

In the above example, the widget has been launched with *Major* mode (the default). Note that the notes included in the mode are indicated by the protruding sectors with 'X's, which are arrayed in a circular pattern of twelve half-steps to complete the octave.

Since the intervals in the *Major* mode are `2, 2, 1, 2, 2, 2, 1`, the notes are `0`, `2`, `4`, `5`, `7`, `9`,`11`, and `12` (one octave above `0`).

The widget controls run along the toolbar at the top. From left to right are:

Play all, which will play a scale using the current mode;

Save, which will save the current mode as the *Custom* mode and save a stack of *Pitch* blocks that can be used with the *Phrase Maker* block;

Rotate counter-clockwise, which will rotate the mode counter-clockwise (See the example below);

Rotate clockwise, which will rotate the mode clockwise (See the example below);

Invert, which will invert the mode (See the example below);

Undo, which will restore the mode to the previous version; and

Close, which will close the widget.

You can also click on individual notes to activate or deactivate them.

Note that the mode inside the *Custom mode* block is updated whenever the mode is changed inside the widget.

In the above example, the *Major* mode has been rotated counter-clockwise, transforming it into *Dorian*.

In the above example, the *Major* mode has been rotated clockwise, transforming it into *Locrian*.

In the above example, the *Major* mode has been inverted, transforming it into *Phrygian*.

Note: The build-in modes in Music Blocks can be found in musicutils.js (https://github.com/sugarlabs/musicblocks/blob/master/js/musicutils.js#L68).

The *Save* button exports a stack of blocks representing the mode that can be used inside the *Phrase maker* block.

4.5 Meters

The *Meter Widget* block is used to explore strong and weak beats. Launch the widget with the meter you want to explore. (In the example, the meter is 4 beats per measure, where each beat is one quarter note.)

Inside the widget, you can click on a sector to indicate a strong beat. (Clicking on the *X* will revert the beat to a weak beat.) In the figure, the first and third beats are strong.

The *Play* button will play the beat, using a snare drum for strong beats and a kick drum for weak beats.

The *Save* button will export *On strong beat do* blocks for each strong beat.

4.6 The Pitch-Drum Matrix

The *Set Drum* block is used to map the enclosed pitches into drum sounds. Drum sounds are played in a monopitch using the specified drum sample. In the example above, a `kick drum` will be substituted for each occurrence of a `Re 4`.

As an experience for creating mapping with the *Set Drum* block, we provide the *Drum-Pitch* Matrix. You use it to map between pitches and drums. The output is a stack of *Set Dum* blocks.

4.7 Exploring Musical Proportions

The *Pitch Staircase* block is used to launch a widget similar to the *Phrase maker*, which can be used to generate different pitches using a given pitch and musical proportion.

The *Pitch* blocks contained in the clamp of the *Pitch Staircase* block define the pitches to be initialized simultaneously. By default, one pitch is defined and it have default note "la" and octave "3".

When *Pitch Staircase* block is clicked, the *Pitch Staircase* widget is initialized. The widget contains row for every *Pitch* block contained in the clamp of the *Pitch Staircase* block. The input fields in the top row of the widget specify the musical proportions used to create new pitches in the staircase. The inputs correspond to the numerator and denominator in the proportion respectively. By default the proportion is 3:2.

Clicking on the *Play* button to the left of each row will playback the notes associated with that step in the stairs. The *Play-all* button on the upper-left of the widget will play back all the pitch steps simultaneously. A second *Play-all* button to the right of the stair plays in increasing order of frequency first, then in decreasing order of frequency as well, completing a scale.

The *Save stack* button will export pitch stacks. For example, in the above configuration, the output from pressing the *Save stack* button is shown below:

These stacks can be used with the *Phrase maker* block to define the rows in the matrix.

4.8 Generating Arbitrary Pitches

The *Pitch Slider* block is used to launch a widget that is used to generate arbitrary pitches. It differs from the *Pitch Staircase* widget in that it is used to create frequencies that vary continuously within the range of a specified octave.

Each *Sine* block contained within the clamp of the *Pitch Slider* block defines the initial pitch for an octave.

When the *Pitch Slider* block is clicked, the *Pitch Slider* widget is initialized. The widget will have one column for each *Sine* block in the clamp. Every column has a slider that can be used to move up or down in frequency, continuously or in intervals of 1/12th of the starting frequency. The mouse is used to move the frequency up and down continuously. Buttons are used for intervals. Arrow keys can also be used to move up and down, or between columns.

Clicking in a column will extract the corresponding *Note* blocks, for example:

4.9 Changing Tempo

The *Tempo* block is used to launch a widget that enables the user to visualize Tempo, defined in beats per minute (BPM). When the *Tempo* block is clicked, the *Tempo* widget is initialized.

The *Master Beats per Minute* block contained in the clamp of the *Tempo* block sets the initial tempo used by the widget. This determines the speed at which the ball in the widget moves back and forth. If BPM is `60`, then it will take one second for the ball to move across the widget. A round-trip would take two seconds.

The top row of the widget holds the *Play/pause* button, the *Speed up* and *Slow down* buttons, and an input field for updating the Tempo.

You can also update the tempo by clicking twice in spaced succession in the widget: the new beats per minute (BPM) is determined as the time between the two clicks. For example, if there is `1/2` second between clicks, the new BPM will be set as `120`.

4.10 Custom Timbres

While Music Blocks comes with many built-in instruments, it is also possible to create custom timbres with unique sound qualities.

The *Timbre* block can be used to launch the *Timbre* widget, which lets you add synthesizers, oscillators, effects, and filters to create a custom timbre, which can be used in your Music Blocks programs.

The name of the custom timbre is defined by the argument passed to the block (by default, `custom`). This name is passed to the *Set timbre* block in order to use your custom timbre.

The *Timbre* widget has a number of different panels, each of which is used to set the parameters of the components that define your custom timbre.

- The *Play* button, which lets you test the sound quality of your custom timbre. By default, it will play `Sol`, `Mi`, `Sol` using the combination of filters you define.

You can also put notes in the *Timbre* block to use for testing your sound. In the example above, a scale will be used for the test.

- The *Save* button, which will save your custom timbre for use in your program.

- The *Synth* button, which lets you choose between an AM synth, a PM synth, or a Duo synth.

- The *Oscillator* button, which lets you choose between a sine wave, square wave, triangle wave, or sawtooth wave. You can also change the number of partials.

- The *Envelope* button, which lets you change the shape of the sound envelope, with controls for attack, decay, sustain, and release.

- The *Effects* button, which lets you add effects to your custom timbre: tremelo, vibrato, chorus, phaser, and distortion. When an effect is selected, additional controls will appear in the widget.

- The *Filter* button, which lets you choose between a number of different filter types.

- The *Add filter* button, which lets you add addition filters to your custom timbre.

- The *Undo* button.

As you add synthesizers, effects, and filters with the widget, blocks corresponding to your choices are added to the *Timbre* block. This lets you reopen the widget to fine-tune your custom timbre.

4.11 The Music Keyboard

The Music Keyboard is used to generate notes by pressing keys of a virtual keyboard.

When there are no *Pitch* blocks inside the widget clamp, a keyboard with all keys between C4 and G5 is created.

When there are *Pitch* blocks inside the widget clamp, a keyboard with only those pitches is created.

Click on the keys to hear sounds. Click on the Play button to playback all of the notes played. Click on the Save button to output code (a series of *Note* blocks). The Clear button is used to delete all keys pressed previously in order to start new.

The MIDI input allows for a using a MIDI device to generate notes.

The metronome feature will generate a beat to enable candence.

4.12 Changing Temperament

Tempering is the process of altering the size of an interval by making it narrower or wider than pure. It is also possible to change and create different tuning systems.

The *Temperament* block is used to launch a widget that enables the user to visualize and edit notes within an octave.

You can select a temperament system from the pie menu which is passed as an argument to the block. This name is passed to the *Set temperament* block in order to play the notes in selected temperament system. *Starting Pitch* is the argument of pitch block inside temperament block. In the above example, starting pitch is `C4`.

In the above example, selected temperament is *Just Intonation*. Notes within an octave can be viewed in the form of circle. These circles represent *pitch numbers*. Note that the pitches that are closer together in selected temperament system are visually closer and pitches that are farther apart looks farther.

The information regarding any note can be viewed by clicking on the respective circle. In the above example, circle (pitch number) `2` is `D4`. The frequency of note can be changed through edit button (left hand side corner of note information popup).

Information regarding notes can also be viewed in the form of a *table* as shown in the above example. The table will show all the information about pitches that lie within an octave. This information includes *pitch number*, *interval*, *ratio*, *note*, *frequency* and *mode*.

The frequency of any note is calculated by `Starting Pitch Frequency` x `Ratio`.

The widget controls are as follows:

The *Clear* button at the bottom of the widget will clear all pitches except for a single `0` from which the user may add pitches.

The *Play all* button will play through all the pitches in an octave and then it will play backwards down the pitches.

The *Save* button will save custom temperament for use in your program. It will create a *set temperament* block. This block will tune the notes attached to it according to the selected temperament.

The *Table* button is used to toggle between circular and tabular representation of notes.

The *Add* button is used to edit notes through different tools:

widget

widget

The `Equal` edit tool is used to make *equal divisions* between two pitch numbers. In the above example, two equal divisions are made between pitch numbers `0` and `1` and the resultant number of notes within an octave are changed from 12 to 13.

widget

widget

The `Ratio` tool is used to add notes of specified ratios in such a way that the resultant pitches wrap inside a single octave. Recursion represents the number of times notes ratio calculation is repeated. In the above example, 2 notes are added in pitch space and the resultant number of notes within an octave are changed from 12 to 14. Frequency of first pitch is (Starting Pitch Frequency) * (16/13) and second pitch is (Starting Pitch Frequency) * $(16/13)^2$.

The `Arbitrary` edit tool is used to add a note in an arbitrary position. In this panel, whenever the user hovers over the outer circle, a frequency-slider window pops up, allowing the user to add a note according to a chosen frequency. In the above example, a new note will be added somewhere between pitch numbers `2` and `3` by adjusting the frequency slider.

The `Octave Space` tool is used to edit the octave ratio. The standard octave space is 2:1. In the above example, octave space will be changed to 3:1 after clicking on `Done`.

The *Drag* button will drag the widget.

The *Close* button will close the widget.

4.13 The Oscilloscope

Music Blocks has an Oscilloscope Widget to visualize the music as it plays.

A separate wave will be displayed for each mouse.

4.14 The Sampler

You can import sound samples (.WAV files) and use them with the *Set Instrument" block. The *Sampler* widget lets you set the center pitch of your sample so that it can be tuned.

You can then use the *Sample* block as you would any input to the *Set Instrument* block.

4.15 Arpeggio

You can design custom sequences to use with the *Arpeggio* block using the *Arpeggio* widget. The widget lets you "paint" intervals that are then saved to a "custom" chord, which can be used with the *Arpeggio* block.

The numeric argument to the widget block, `12` in the figure above, designates the number of columns. The widget always provides a range of half-steps (one octave in the default a 12-step equal-temperament tuning). (If you are in a temperament with more notes per ocatve, the grid will expand.) The rows that represent notes in the current mode are highlighted.

The horizonal axis is time and the verical axis is half-step offsets from the base note.

The sequence in the pattern above is `do mi sol do do mi do sol mi do do sol`.

5. Beyond Music Blocks

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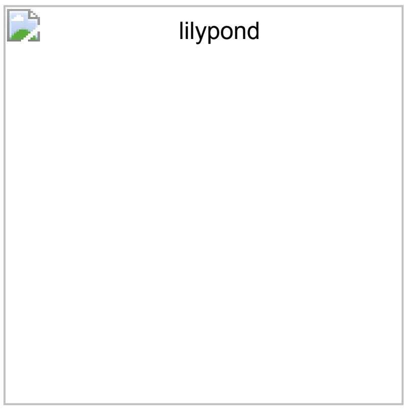
Music Blocks is a waypoint, not a destination. One of the goals is to point the learner towards other powerful tools.

5.1 Lilypond

One such tool is Lilypond (http://lilypond.org), a music engraving program.



The *Save as Lilypond* option from the Save menu will transcribe your composition (Only available in Advanced Mode).

Note that if you use a *Print* block inside of a note, Lilypond will create a "markup" or annotation for that note. It is a simple way to add lyrics to your score.

lilypond

```
\version "2.18.2"

mouse = {
c'8 c'8 c'8 c'8 c'4 c'4 g'8 g'8 g'8 g'8 g'4 g'4 a'8 a'8 a'8 a'8 a'4
a'4 g'8 g'8 g'8 g'8 g'4 g'4 f'8 f'8 f'8 f'8 f'4 f'4 e'8 e'8 e'8 e'8
e'4 e'4 d'8 d'8 d'8 d'8 d'4 d'4 c'8 c'8 c'8 c'8 c'4 c'4
}

\score {
<<
\new Staff = "treble" {
\clef "treble"
\set Staff.instrumentName = #"mouse" \mouse
}
>>
\layout { }
}
```

sheet music

RUN LIVE (https://musicblocks.sugarlabs.org/index.html?id=1523043053377623&run=True)

5.2 Other Exports

In addition to Lilypond, there are several other export formats supported, including ABC, MusicXML, WAV, SVG, and PNG.

ABC notation is a shorthand form of musical notation. In basic form it uses the letters A through G, letter notation, to represent the given notes, with other elements used to place added value on these – sharp, flat, the length of the note, key, ornamentation (See https://en.wikipedia.org/wiki/ABC_notation (https://en.wikipedia.org/wiki/ABC_notation)).

MusicXML is an XML-based file format for representing Western musical notation. The format is open, fully documented, and can be freely used under the W3C Community Final Specification Agreement (See https://en.wikipedia.org/wiki/MusicXML (https://en.wikipedia.org/wiki/MusicXML)).

WAV (Waveform Audio File Format) is an audio file format standard, developed by IBM and Microsoft, for storing an audio bitstream on PCs (See https://en.wikipedia.org/wiki/WAV (https://en.wikipedia.org/wiki/WAV)).

PNG (Portable Network Graphics) is a raster-graphics file format that supports lossless data compression (See https://en.wikipedia.org/wiki/Portable_Network_Graphics (https://en.wikipedia.org/wiki/Portable_Network_Graphics)). You can save your artwork as PNG.

SVG (Scalable Vector Graphics) is an Extensible Markup Language (XML)-based vector image format for two-dimensional graphics with support for interactivity and animation (See https://en.wikipedia.org/wiki/Scalable_Vector_Graphics (https://en.wikipedia.org/wiki/Scalable_Vector_Graphics)). You can also save your artwork as SVG.

Note that artwork saved as PNG or SVG can subsequently be imported into Music Blocks to be used with either the *Show* or *Avatar* blocks.

Help artwork

Note for translators: The artwork used by the help widget (and used in this README file) can be created by typing *Alt-H* into Music Blocks. Artwork for each block will be generated and saved by the browser.

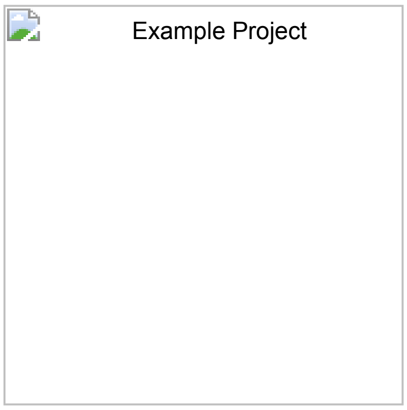
5.3 The JavaScript Editor

There are practical limits to the size and complexity of Music Blocks programs. At some point we expect Music Blocks programmers to move on to text-based programming languages. To facilitate this transition, there is a JavaScript widget that will convert your Music Blocks program into JavaScript.

The JavaScript code is written and viewed on the **JavaScript Editor** widget which can be opened by pressing on the "*Toggle JavaScript Editor*" (<>) button in the auxilliary menu.

Example code

For the block stacks (and mouse art generated after running),



the following code is generated:

```
let action = async mouse => {
    await mouse.playNote(1 / 4, async () => {
        await mouse.playPitch("do", 4);
        console.log(mouse.NOTEVALUE);
        return mouse.ENDFLOW;
    });
    let box1 = 0;
    let box2 = 360 / mouse.MODELENGTH;
    for (let i0 = 0; i0 < mouse.MODELENGTH * 2; i0++) {
        await mouse.playNote(1 / 4, async () => {
            if (box1 < mouse.MODELENGTH) {
                await mouse.stepPitch(1);
                await mouse.turnRight(box2);
            } else {
                await mouse.stepPitch(-1);
                await mouse.turnLeft(box2);
            }
            await mouse.goForward(100);
            return mouse.ENDFLOW;
        });
        box1 = box1 + 1;
    }
    return mouse.ENDFLOW;
};
new Mouse(async mouse => {
    await mouse.clear();
    await mouse.setInstrument("guitar", async () => {
        await mouse.setColor(50);
        await action(mouse);
        return mouse.ENDFLOW;
    });
    return mouse.ENDMOUSE;
});
MusicBlocks.run();
```

Here's the complete API (../js/js-export/samples/sample.js) of methods, getters, setters.

6. Appendix

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6.1 Beginner Palettes

Looking for a block? The tables below (one for beginner mode and one for advanced mode) list the blocks by the palette where they are found.

Beginner mode

Music		**Programming**		**Graphics**	
Palette	*Blocks*	*Palette*	*Blocks*	*Palette*	*Blocks*
Rhythm	note	**Flow**	repeat	**Graphics**	forward
	note value drum		forever		back
	silence		if then		left
	tie		if then else		right
	note value		backward		set xy
Meter	meter	**Action**	action		set heading
	beats per second		start		arc
	master beats per second		broadcast		scroll xy
	on every note do		on event do		x
	notes played		do		y
	beat count	**Boxes**	store in box1		heading
Pitch	pitch		box1	**Pen**	set color
	pitch G4		store in box2		set shade
	scalar step (+/-)		box2		set pen size
	pitch number		store in		pen down
	hertz		box		pen up
	fourth		add		fill
	fifth		add 1 to		background
	pitch in hertz	**Number**	number		color
	pitch number		random	**Media**	print
	scalar change in pitch		one of this or that		text
	change in pitch		+		show
Interval	set key		-		avatar
	mode length		x		height
	movable do		/		width
	third	**Boolean**	=		bottom (screen)
	sixth		<		top (screen)
	chord I		>		left (screen)
	chord IV				right (screen)
	chord V			**Sensors**	mouse button
	set temperament				cursor x
Tone	set instrument				cursor y
	vibrato				click

Music		**Programming**		**Graphics**	
	chorus				loudness
	tremolo			**Ensemble**	set name
Ornament	staccato				mouse name
	slur				
	neighbor (+/-)				
Volume	crescendo				
	decrescendo				
	set master volume				
	set synth volume				
	set drum volume				
Drum	drum				
	sound effect				
	set drum				
Widget	status				
	phrase maker				
	C major scale				
	G major scale				
	rhythm maker				
	music keyboard				
	pitch slider				
	tempo				
	custom mode				
	rhythm				
	simple tuplet				

6.2 Advanced Palettes

Music		**Programming**		**Graphics**	
Palette	*Blocks*	*Palette*	*Blocks*	*Palette*	*Blocks*
Rhythm	note value sol4	**Flow**	repeat	**Graphics**	forward
	note value G4		forever		back
	note value +1		if then		left
	note value 5 4		if then else		right
	note value 7		while		set xy
	note value 392 hertz		until		set heading
	dot		wait for		arc
	multiplicity note value		stop		bezier
	skipnotes		switch		control point 1
	swings		case		control point 2
	milliseconds		default		clear
Meter	pickup		duplicate		scroll xy

Music		**Programming**		**Graphics**	
	on strong beat		backward		wrap
	on weak beat do	**Action**	action		x
	no clock		start		y
	whole notes played		start drum		heading
	note counter		broadcast	**Pen**	set color
	measure count		on event do		set grey
	beat factor		do		set shade
	current meter		arg1		set hue
Pitch	scale degree		arg		set translucency
	sharp flat		calculate		set pen size
	accidental		do		pen down
	unison		calculate		pen up
	second		do		fill
	third		action		hollow line
	sixth		calculate		background
	seventh		return to URL		set font
	down third		return		pen size
	down sixth	**Boxes**	store in box1		color
	octave		box1		shade
	semi-tone transpose		store in box2		grey
	register		box2		black
	invert		store in		white
	sol		store in box		red
	G		box		orange
	sargam		box		yellow
	accidental		add		green
	number of octave		add 1 to		blue
	number of pitch	**Number**	number		purple
	set pitch number offset		random	**Media**	text
	MIDI		one of this or that		show
Intervals	set key		+		avatar
	current key		-		note to frequency
	current mode		-		hertz
	mode length		x		stop media
	movable Do		/		open file
	define mode		abs		height
	scalar interval (+/-)		sqrt		width
	semi tone interval (+/-)		^		bottom (screen)
	major 3		mod		top (screen)

Music		**Programming**		**Graphics**	
	scalar interval measure		int		left (screen)
	semi-tone interval measure	**Boolean**	true		right (screen)
	interval name		=	**Sensors**	keyboard
	doubly		<		to ASCII
	set temperament		>		mouse bottom
Tone	set instrument		or		cursor x
	voice name		and		cursor y
	audio sample		not		time
	vibrato	**Heap**	push		pixel color
	chorus		pop		red
	phaser		set heap		green
	tremolo		index heap		blue
	distortion		reverse heap		click
	harmonic		empty heap		loudness
	weighted partials		heap empty?	**Ensemble**	set name
	partial		heap length		mouse name
	FM synth		show heap		new mouse
	AM synth	**Dictionary**	get value		found mouse
	duo synth		set value		mouse sync
Ornament	staccato		get value by name		mouse note value
	slur		set value by name		mouse pitch number
	neighbor (+/-)		dictionary		mouse notes played
	neighbor (+/-)	**Extras**	print		mouse x
Volume	crescendo		comment		mouse y
	decrescendo		wait		set mouse
	set relative volume		open project		mouse heading
	set master volume		hide blocks		mouse color
	set synth volume		show blocks		start mouse
	set drum volume		no background		stop mouse
	fff	**Program**	set heap		mouse index heap
	ff		load heap		
	f		save heap		
	mf		set dictionary		
	mp		load dictionary		

Music		Programming		Graphics
	p		save heap to App	
	pp		load heap from App	
	ppp		open palette	
	master volume		open project	
Drum	drum		make block	
	sound effect		connect blocks	
	set drum		run blocks	
	map pitch to drum		move block	
	snare drum		delete block	
	kick drum			
	floor tom			
	cup drum			
	darbuka drum			
	hi hat			
	triangle drum			
	finger cymbals			
	ride bell			
	cow bell			
	crash			
	slap			
	clap			
	clang			
	chime			
	bubbles			
	bottle			
	dog			
	cricket			
	cat			
	duck			
	noise			
	effect			
	drum			
	noisename			
	tom tom			
Widget	status			
	phrase maker			
	C major scale			
	G major scale			
	rhythm maker			
	pitch staircase			
	music keyboard			

Music	Programming	Graphics
chromatic keyboard		
pitch slider		
pitch-drum maker		
audio sampler		
tempo		
meter		
timbre		
temperament		
rhythm		
simple tuplet		
triplet		
quintuplet		
septuplet		
tuplet		
whole note		
half note		
quarter note		
eighth note		
1/16 note		
1/32 note		
1/64 note		
custom mode		

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Using Music Blocks

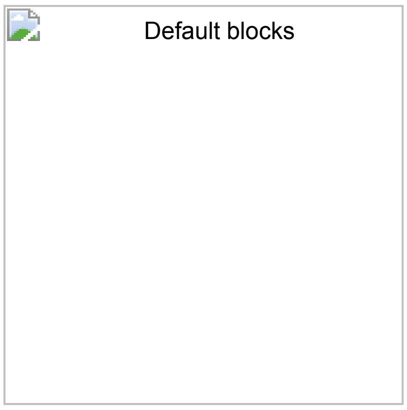
Music Blocks is a fork of Turtle Blocks (href=%22https://turtle.sugarlabs.org). It has extensions for exploring music: pitch and rhythm.

Music Blocks is designed to run in a browser. Most of the development has been done in Chrome.

Browser	Comments
Chrome	Supported
Safari	Supported
Firefox	Supported
Opera	Supported
IE	Not supported
Edge	Recent versions supported

You can run it from https://musicblocks.sugarlabs.org (https://musicblocks.sugarlabs.org).

Getting Started



When you first launch Music Blocks in your browser, you'll see a stack of blocks representing the notes: `Sol 4`, `Mi 4`and `Sol 4`. The first two notes are `1/4` note; third note is `1/2` note.

Try clicking on the *Start* block or click on the *Play* button. You should hear the notes play in succession: `Sol Mi Sol`.

To write your own programs, drag blocks from their respective palettes on the left side of the screen. Use multiple blocks in stack(s) to create music and drawings; as the mouse moves under your control, colorful lines are drawn and music of your creation is played.

Note that blocks either snap together vertically or horizontally. Vertical connections indicate program (and temporal) flow. Code is executed from the top to bottom of a stack of blocks. Horizontal connections are used for parameters and arguments, e.g., the name of a pitch, the duration of a note, the numerator and denominator of a division. From the shape of the block, it should be apparent whether they connect vertically or horizontally.

Some blocks, referred to as "clamp" blocks have an interior—child—flow. This might be code that is run *if* a condition is true, or, more common, the code that is run over the duration of a note.

For the most part, any combination of blocks will run (although there is no guarantee that they will produce music). Illegal combinations of blocks will be flag by a warning on the screen as the program runs.

You can delete a block by dragging it back into the trash area that appear at the bottom of the screen.

To maximize screen real estate, Music Blocks overlays the program elements (stacks of blocks) on top of the canvas. These blocks can be hidden at any time while running the program.

Toolbars

There are five toolbars:

(1) The *Main* toolbar across the top of the screen. There you will find the *Play* button, the *Stop* button, the *New Project* button, buttons for loading and saving projects, the *Planet* button, where you can access community projects, the *hamburger* button, which opens the secondary toolbar, and the *help* button.

(2) On the *Secondary* toolbar you will find the buttons *Run slowly*, *Run step by step*, *Display Statistics*, *beginner/advanced mode*, etc. and also the button for selecting language.

(3) The *Palette* toolbar is on the left side of the screen. New blocks are dragged from the palette.

(4) On the upper right of the canvas is a small toolbar for showing grids, clearing the screen, and toggling the display size.

(5) On the lower right of the canvas is a small toolbar where you will find the *Home* button, buttons for show/hide blocks, expand/collapse blocks and decrease/increase block size.

These toolbars are described in detail in the Turtle Blocks documentation pages (https://github.com/sugarlabs/turtleblocksjs/tree/master/documentation).

An additional "contextual" menu appears whenever you *right click* on a block.

Many blocks also incorporate "pie menus" for changing block parameters.

Context Menu

Context menus are an important part of user interfaces that provide users with quick access to a set of actions relevant to the context in which they are working.The right-click context menu in Music Blocks provides several options for working with blocks and the workspace. To access the right-click context menu, simply right-click anywhere in the workspace.

The Block context menu:

This context menu appears when you right-click on a block in the workspace. It provides options such as "Duplicate," "Delete," "Help," and "Copy to Palette." The "Duplicate" option creates a copy of the selected block, while the "Delete" option removes the selected block from the workspace. The "Help" option opens a help dialog for the selected block, and the "Copy to Palette" option adds the selected block to the user's custom block palette.

Right-click context menu

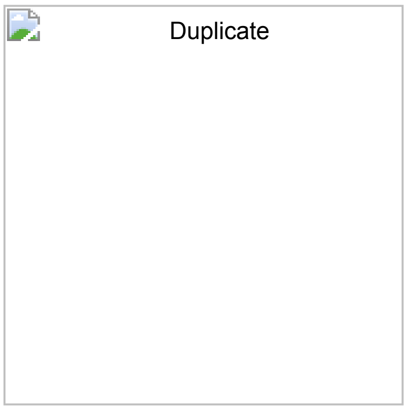
Extract

The "Extract" option in Music Blocks allows you to separate a nested block into its individual components or sub-blocks. This can be useful if you want to modify or reuse specific parts of a block without affecting the rest of the block.

Extract the selected block

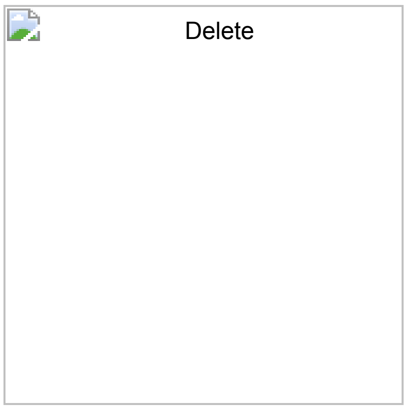
Duplicate

This option creates a duplicate of the selected block and places it next to the original block.



Delete

This option removes the selected block from your program



Help

This option shows a help screen with information about the selected block. You can use this option to learn more about the block's functionality and how to use it in your projects.

By using the right-click context menu in Music Blocks, you can quickly perform common tasks and manipulate blocks on the workspace. This can help you to work more efficiently and effectively in your projects.

Keyboard shortcuts

There are several keyboard shortcuts:

PgUp and *PgDn* will scroll the screen vertically. This is useful for creating long stacks of blocks.

You can use the arrow keys to move blocks and the *Delete* key to remove an individual block from a stack.

Enter is the equivalent of clicking the *Run* button.

Alt-C is copy and *Alt-V* is paste. Be sure that the cursor is highlighting the block(s) you want to copy.

You can directly type notes using *d* for `Do`, *r* for `Re`, *m* for `Mi`, *f* for `Fa`, *s* for `Sol`, *l* for `La`, and *t* for `Ti`.

Block Palettes

The block palettes are displayed on the left side of the screen. These palettes contain the blocks used to create programs.

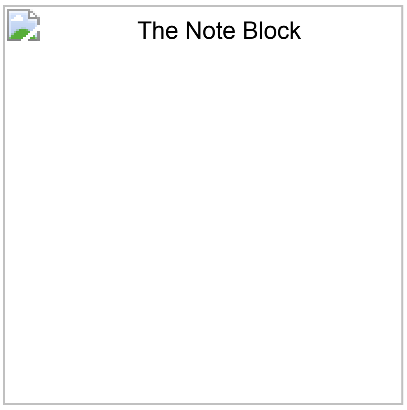
Looking for a block? Find it in the Palette Tables (https://github.com/sugarlabs/musicblocks/blob/master/guide/README.md#APPENDIX_1).

See the Turtle Blocks Programming Guide (http://github.com/sugarlabs/turtleblocksjs/tree/master/guide/README.md) for general details on how to use the blocks.

See the Music Blocks Programming Guide (http://github.com/sugarlabs/musicblocks/tree/master/guide/README.md) for details specific to music: *Rhythm*, *Meter*, *Pitch*, *Intervals*, *Tone*, *Ornament*, *Volume*, *Drum*, and *Widget*.

All of the other palettes are described in the Turtle Blocks documentation pages (http://github.com/sugarlabs/turtleblocksjs/tree/master/documentation).

Defining a note



At the heart of Music Blocks is the concept of a note. A note, defined by the *Note value* block defines a length of time and a set of actions to occur in that time. Typically the action is to play a pitch, or series of pitches (e.g., a chord). Whatever blocks are placed inside the "clamp" of a *Note value* block are played over the duration of the note.

The duration of a note is determined by its note value. By default, we use musical notation, referring to whole notes (`1`), half notes (`1/2`), quarter notes (`1/4`), etc., but you can use any number as the note duration. (There are some practical limitations, which you can discover through experimentation.) The relative length of a quarter note is half as long as a half note. By default, Music Blocks will play 90 quarter notes per second, so each quarter note is `2/3` seconds (`666` microseconds) in duration.

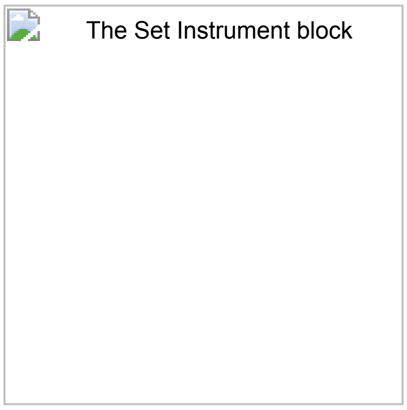
The *Pitch* block (found on the Pitch Palette) is used to specify the pitch of a note. By default, we use traditional western Solfege, i.e., `Do`, `Re`, `Mi`, `Fa`, `Sol`, `La`, `Ti`, where `Do` is mapped to `C`, `Re` is mapped to `D`, etc. (when the key and mode are `C Major`). You can also specify pitch by using a note name, e.g., `F#`. An octave specification is also required (as an argument for our pitch block) and changes integers for every cycle of `C` (i.e. `C4` is higher than B3). When used with the *Pitch-time Matrix* block, a row is created for each *Pitch* block.

In addition to specifying the note name, you must also specify an octave. The frequency of a note doubles as the octave increases. `A2` is `110 Hertz`; `A3` is `220 Hertz`; `A4` is `440 Hertz`; etc.

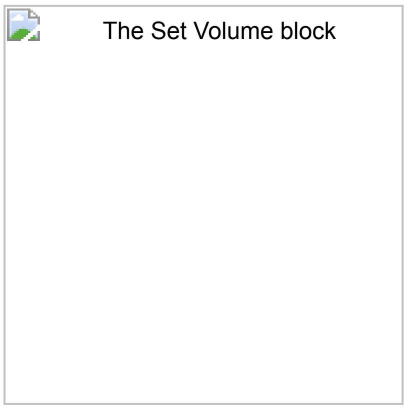
Two special blocks can be used with a *Pitch* block to specify the name of the pitch: the *Solfege* block and the *Pitch-Name* block. The *Solfege* block uses selectors to scroll through `Do`, `Re`, `Mi`, `Fa`, `Sol`, `La`, and `Ti`. A second selector is used for sharps and flats: `##`, `#`, `and`. The *Pitch-Name* block is similar in that it lets you scroll through `C`, `D`, `E`, `F`, `G`, `A`, `B`. It also uses a second selector for sharps and flats.

As noted, and described in more detail in the Music Blocks Programming Guide (http://github.com/sugarlabs/musicblocks/tree/master/guide/README.md), you can put as many *Pitch* blocks inside a note as you'd like. They will play together as a chord. You can also insert graphics blocks inside a note in order to create sound-sync animations.

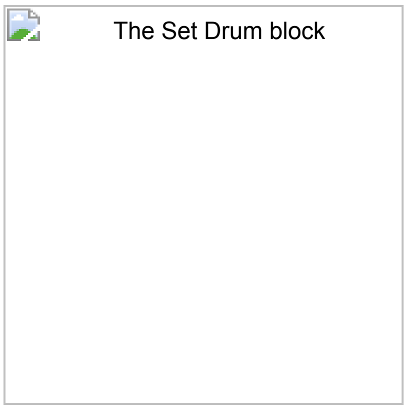
A quick tour of selected blocks



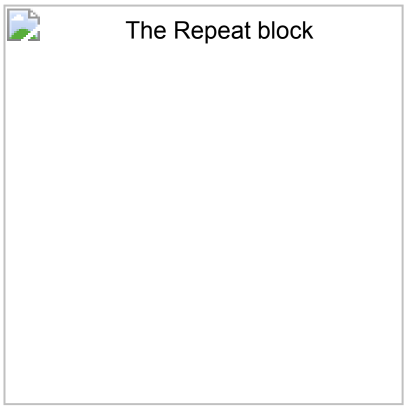
The *Set instrument* block, found on the *Tone* palette, lets you choose a timbre for a note. In the above example, a guitar model is used to make any notes contained within the block's clamp will sound as if they are being played on a guitar.



The *Set synth volume* block, found on the *Volume* palette, lets you change the volume, which ranges from `0` (silent) to `100` (full volume), of any notes contained with the block's clamp.



The *Set drum* block, which is used inside of the clamp of a *Note value* block is used to add drum sounds to a note. It is found on the *Drum* palette.



The *Repeat* block, found on the *Flow* palette, is used to create loops. Whatever stack of blocks are placed inside its clamp will be repeated. It can be used to repeat individual notes, or entire phrases of music.

The Duplicate block

The *Duplicate* block, found on the *Rhythms* palette, is used to repeat any contained notes. Similar to using a *Repeat* block, but rather than repeating a sequence of notes multiple times, each note is repeated in turn, e.g. duplicate x2 of `4 4 8` would result in `4 4 4 4 8 8`, where as repeat x2 of `4 4 8` would result in `4 4 8 4 4 8`.

The *Start* block, found on the *Action* palette, is tied to the *Run* button. Anything inside of the clamp of the *Start* button will be run when the button is pressed.

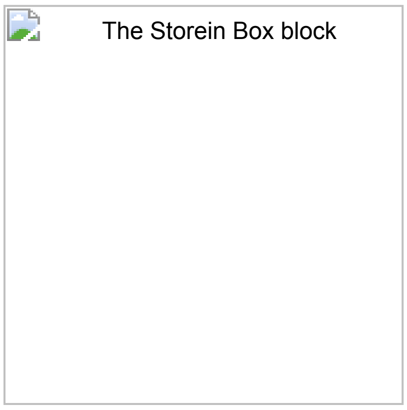
The Start block

Note that you can have multiple mice and that each mouse is equivalent to a "voice" in music. It can play notes of various pitches in sequence, and can even play multiple notes of the same "note value", but no one mouse can do counterpoint by itself—just like one mouse cannot draw two lines at the same time. If you want counterpoint, pull out an additional *Start* block, which will create a new mouse that can now perform a new voice.

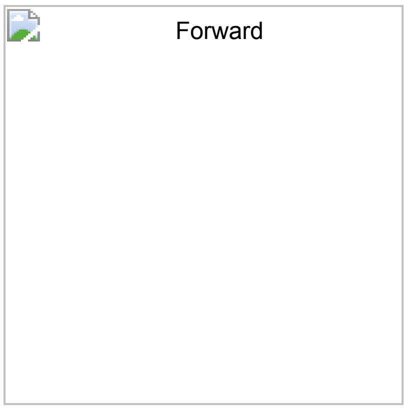
The Action block

The *Action* block, also found on the *Action* palette, is used to create a collection of blocks that can be run as a group. Whenever you create an *Action* block, a new block corresponding to that action is added to the palette. The name given to the action is the name associated with the new block. (It is common practice to use *Action* blocks to define short phrases of music that can be repeated and modified.)

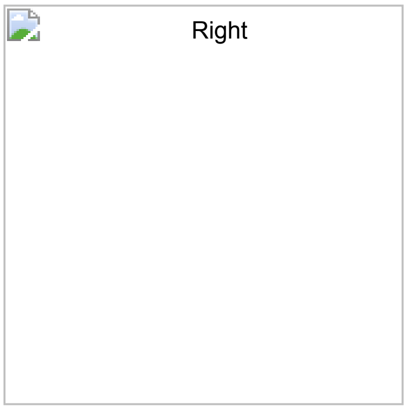
Actions are a powerful organizational element for your program and can be used in many powerful ways, e.g., an action can be associated with an event, such as an on beat or off beat or mouse click. See Music Blocks Programming Guide (http://github.com/sugarlabs/musicblocks/tree/master/guide/README.md), for further details and examples.



The *Store in* block, found on the *Boxes* palette, is used to store a value. That value can be retrieved using the *Box* block. The value can be modified using the *Add one* block. These blocks are the typical way in which variables are stored and retrieved in Music Blocks.



The *Forward* block, found on the *Mouse* palette, is used to draw straight lines. (Note that if this block is used inside of a *Note value* block—the line will be drawn as the note plays; otherwise the line is drawn "instantly".)



The *Right* block, found on the *Mouse* palette, is used to rotate the mouse heading. (Note that if this block is used inside of a *Note value* block—the heading will change as the note plays; otherwise the heading is changed "instantly".)

Pen Up

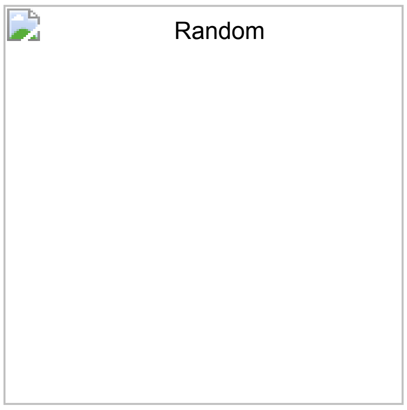
The *Pen up* and *Pen down* blocks, found on the *Pen* palette, determine whether or not the mouse draws as it moves.

Set Shade

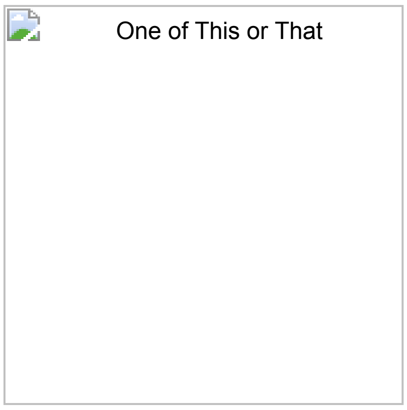
The *Set shade* block, also found on the *Pen* palette, is used to set the lightness or darkness of the "ink" used in the mouse pen. `set shade 0` is black. `set shade 100` is white.

Set Color

The *Set color* block, also found on the *Pen* palette, is used to set the color of the "ink" used in the mouse pen. `set color 0` is red. `set color 70` is blue.

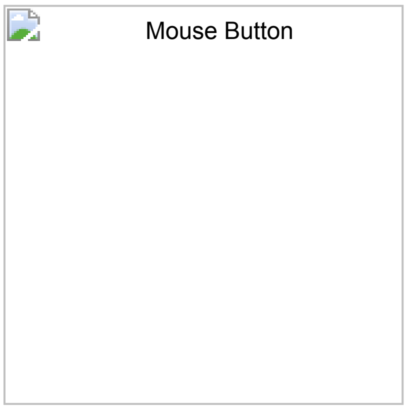


The *Random* block, found on the *Numbers* palette, is used to generate a random number, because sometimes being unpredictable is nice.

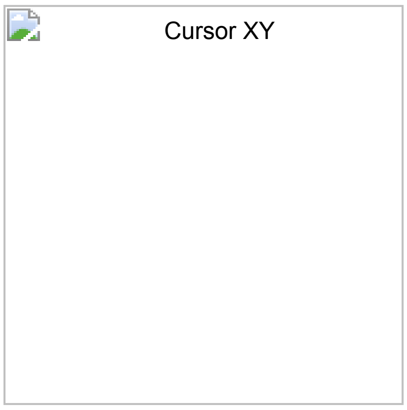


The *One of* block, also found on the *Numbers* palette, is used to generate a binary choice, one of "this" or "that", because sometimes being unpredictable is nice.

The *Show* block, found on the *Media* palette, is used to display text and images.

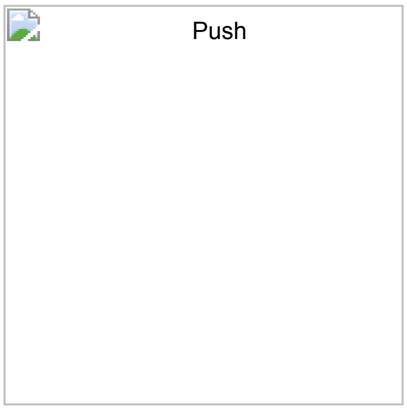


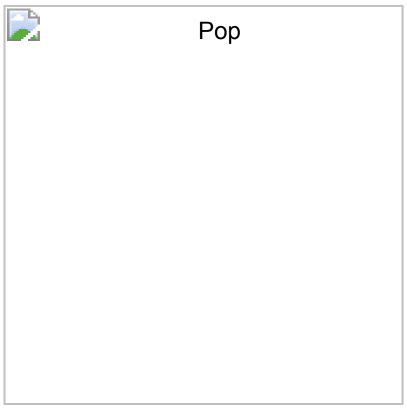
The *Mouse button* block, found on the *Sensors* palette, returns true if the mouse button is clicked. The mouse button block can be used to create some interactivity in your program.



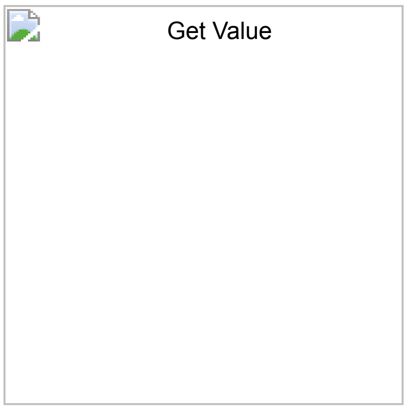
The *Cursor x* and *Cursor y* blocks, also found on the *Sensors* palette, return the X and Y coordinates of the cursor. These blocks can also be used to create interactive programs.

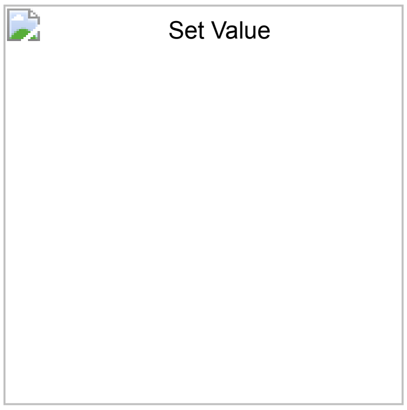
Prompting the user for input is done with the *Input* block. This block will display a messgae with a prompt and open an input form at the current position of the mouse. Program execution is paused until the user types into the form and types RETURN (or Enter). The contents of the input form are then transferred to *Input-value* block.



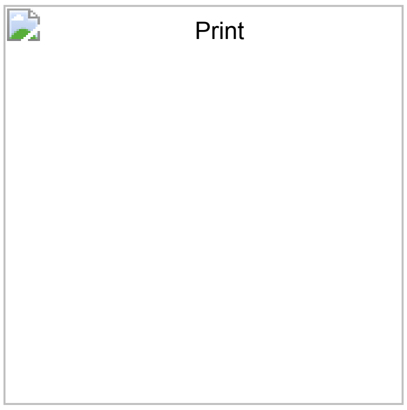


The *Push* and *Pop* blocks, found on the *Heap* palette, are used to store and retrieve values on/from a first-in, last-out (FILO) program heap. There is a separate heap maintained for each *Start* block.





The *Get value* and *Set value* blocks are found on the *Dictionary* palette. They are used to get and set values in a dictionary object. You can have as many key/value pairs as you'd like in the dictionary and you can have as many dictionaries as you'd like as well. There is also a built-in dictionary associated with each *Start* block that has key/value pairs for parameters such as x, y, heading, color, shade, grey, pen size, notes played, current pitch, pitch number, and note value.

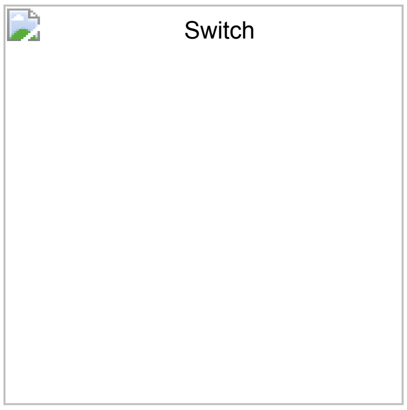


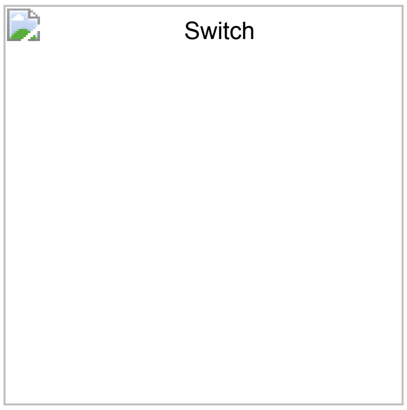
The *Print* block, found on the *Extras* palette, is used to print messages during program execution. It is very useful as a debugging tool and also as a means of adding lyrics to your music—think karaoke.

Flow Palette

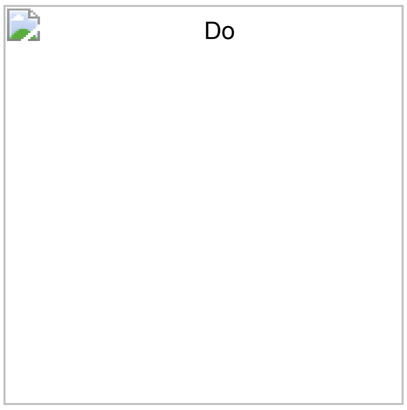
The Flow palette is described in more detail in the Turtle Blocks documentation. Here we review a few ways to approach taking different actions on different beats.

The *Switch* block will take the action defined in the *Case* that matches the argument passed to the *Switch* block. In the figure below, it will take a different action based on the beat value: "on case 1 run action1", "on case 2, run action2", ..., "on case 4 run action4". You can also define a default action.





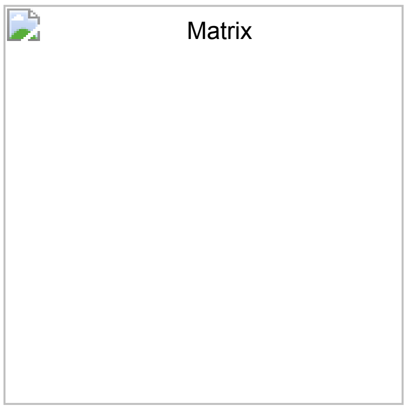
Another way to do the same thing is with the *Do* block found on the Action palette. In the figure below, we add the beat count to "action" to create a series of strings: "action1", "action2", ..., "action4". We then "do" that action.



Widget Palette

Music Blocks has various Widgets that can be used within Music Blocks to enhance your experience. The *Pitch-time matrix* is described here.

Many of the blocks on this palette are used to create a matrix of "pitch" and "note value". The matrix is a convenient and intuitive way for generating short musical gestures, which can be regenerated as a "chunk of notes" that can be played back programmatically. Musicians may find it helpful to think of the pitches within the pitch-time matrix as being akin to a bellset in which notes may be added and removed as desired. The "note value" representation acts as a "rhythmic tablature" that should be readable by both those familiar with the concepts of rhythm in music and those unfamiliar (but familiar with math).



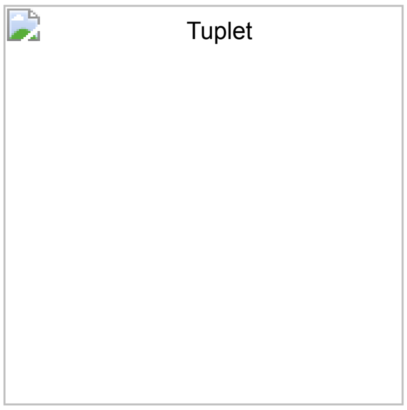
Pitch-time Matrix blocks clamp is used to define the matrix: A row in the matrix is created for each *Pitch* block and columns are created for individual notes, which are created by using *Rhythm* blocks, individual note blocks, or the *Tuplet* block.

The *Rhythm* block is used to specify a series of notes of the same duration (e.g., three quarter notes or seven eighth notes). The number of notes is the top argument; the bottom argument is the the note duration, e.g., `1/1` for a whole note, `1/2` for a half note, `1/4` for a quarter note, etc. (Recall that in traditional Western notation all note values are (1) in powers of two, and are (2) in relation to the "whole note", which is in turn (3) defined by tempo, or beats—usually quarter notes—per minute) Each note is represented by a column in the matrix.

Special ratios of the whole note can be created very easily with the *Rhythm* block by choosing an integer other than the traditional "powers of two" that standard Western music notation affords us. For example, putting a `1/5` into the argument for "note value" will create a note value equal to "one fifth the durational length of a whole note". This gives the user endless rhythmic possibilities.

As a convenience, blocks for the most common note values are also provided (whole note through 64th note). They are automatically converted into the corresponding *Rhythm* blocks, which can be used to create columns in the matrix.

If you would like multiple note values in a row, simply use the *Repeat* block clamp or *Duplicate* block clamp.



The *Tuplet* block is how we create rhythms that do not fit into a simple "power of two" rhythmic space. A tuplet, mathematically, is a collection of notes that are scaled to map into a specified duration. For example, if you would like to script/perform three unique notes into the duration of a single quarter note you would use the tuplet block. The *Tuplet* block is able to calculate how many notes you have inserted into the clamp and will generate the tuplet accordingly (e.g. if you put three notes in, it will generate a "triplet". We have designed the tuplet block to allow for any input of note value, so the triplet can be three quarter notes, three eighth notes, etc. This design choice allows for maximum flexibility) You can mix and match *Rhythm* and individual *Note* blocks within a *Tuplet* block to generate complex rhythms (e.g. two quarter notes plus an eighth note is possible within the tuplet). Each note is represented by a column in the matrix.

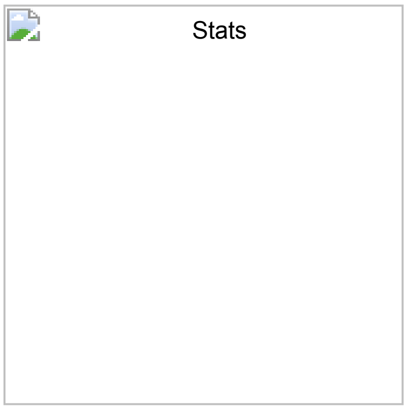
Note: Each time you open the matrix, it tries to reconstruct the notes marked from the previous matrix. If you modify the *Pitch* and *Rhythm* blocks in the *Pitch-time Matrix* clamp, Music Blocks will try to make a corresponding change in the matrix.

Note: You can construct a matrix from a chuck of blocks by including the chunk in the clamp of the *Pitch-time Marix* block.

More details about all of the widgets are available in the Music Blocks Programming Guide (http://github.com/sugarlabs/musicblocks/tree/master/guide/README.md).

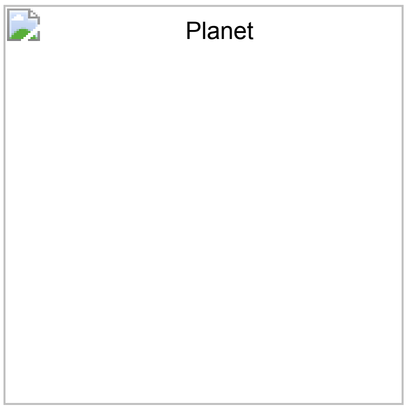
Stats

Project statistics are available from a button the the secondary toolbar in advanced mode.



Planet View

Music Blocks also provides a Planet view to find and share projects. It has options to load project from file locally and make new projects from scratch.



There are LOCAL and GLOBAL options to choose from. LOCAL lists the projects saved on your local machine. GLOBAL lets you explore projects shared by the community. You can filter these projects by tags such as Art, Math, Interactive, Design, Game, etc.

Projects are shown with a thumbnail image and a title. To get more details, click on thumbnail image. A short description is provided.

You can open a project in Music Blocks directly from the Planet or you can download.