Flummi

Version h13, build #6, 2023-04-21, edit 2023-04-24

Flummi (= **Fl**ying G**um**) does not deliver audible signals. It is a CV generator and simulates a bouncing ball in real time. Seven different output voltages are available to control other modules as oscillators, filters and so on. Four main parameters are controllable either manually or by CV. Virtual ball is displayed on a small screen.

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1 Introduction

1.1 Physical Modeling

During last years enhancement in processing speed made computers more and more usable for “physical modeling”. That does not only mean weather prediction, but also the way of creating natural noises as there are a twittering bird, a crying violin, a breathing flute or a booming percussion membrane.

Most of these models use at least two important components: an oscillating element as sound source and a resonator to determine a typical sound character.

For physical modeling **Flummi** can only be seen as part of the oscillating element. It is only a part, because it cannot provide an audible signal itself. Therefore an extra VCA will be needed additionally.

In order to understand influence of parameter settings, it might be helpful having a look at some physical rules.

1.2 Physics Of a Bouncing Ball

You took a ball off from ground and now you’re holding it with your hand. While taking it off against earths gravity, you invested biochemical energy and gave it to the ball which now owns it as potential energy E_{pot}.

$$E_{pot} = m \cdot g \cdot h \qquad (1)$$

with:

W_{pot}	potential energy
m	mass
g	gravity
h	(“initial”) height

You can feel gravity force pulling the ball downwards. That is what we call the ball’s weight (Weight is proportional to mass). When you open your hand, this force pulls the ball downwards. Because gravity force is constantly near ground level, ball will be accelerated constantly. The lower the ball comes to ground the lower it’s potentially energy is. At same time it’s speed increases.

$$v = a \cdot t \qquad (2)$$

with: v final speed

a acceleration, here it is equal to gravity g

t time

Increasing speed results in increasing kinetic energy.

$$E_{kin} = ½ \cdot m \cdot v^2 \qquad (3)$$

with: E_{kin} kinetic energy

m mass

v speed

Finally ball gets contact with the ground. At this time ball's whole potential energy is transformed into kinetic energy. (Friction between ball and air molecules don't have important influence in this case and we will ignore it.) A basic rule in physics says: "Energy can never get lost. It can only be transformed into other kinds of energy."

This rule becomes very important now. Let us explain it with two possible extremes:

A: The ball consists of lead, the ground is sandy. Surely the ball will stop almost instantly while getting some inches into the sand. Where is the energy left? Friction between sand particles and ball transformed kinetic energy to thermal energy which was given to the environment.

B: The ball consists of super elastic rubber, the ground is smooth and hard. Kinetic energy will squeeze the ball to a flat piece. Compressed rubber gets spanned as a spring. Now kinetic energy has been changed to potential. There is nothing that holds the ball compressed. Within a very short moment the ball expands to it's round shape and accelerates. Then it jumps up until it reaches the height, we let it fall from.

In case A all energy was changed to thermal energy completely. We can say, there was a damping of 100 percent. In case B there wasn't any damping. Whole energy stayed mechanical. Damping was 0 percent.

It's almost done. There is still a special situation we have to look at.

At the beginning we hold the ball at height h. First we let the ball drop down (case A, see formula (1)). But we also could throw it upwards (case B) or downwards (case C).

Case B: The ball was thrown upwards. It will rise while gravity force tries to pull it down. Anytime ball's speed gets zero and ball starts falling down. Now this peak position is the new initial height h_{max}.

$$h_{max} = (v_0)^2 / (2 \cdot g) \qquad (4)$$

with:

	h_{max}	final height
	v_0	initial speed
	g	gravity

Case C: The ball was thrown downwards. Formula (2) has to be modified:

$$v = v_0 + a \cdot t \qquad (5)$$

with:

	v	final speed
	v_0	initial speed
	a	acceleration
	t	time

The ball needs less time to reach the ground. Because of it's initial speed, ball bounces the ground with a higher speed than it reached in formula (2). After impact with same damping ball will rise to a higher level than initial height was.

Now we know relation between various parameters and can threat module controls.

2 Module Controls

2.1 Input Section

On the input section you can preset all four main simulation parameters. Knobs can act on two ways:

- Without any cable connected to an input jack, related knob is used to preset parameter manually. You can left click and drag up or down to increase or decrease the value. You can also right click a knob and enter the value by typing it with the PC keyboard. Setable value range depends on parameter.

- When a cable is connected to the input jack, knob serves as attenuverter only. Setable range is any value from -200 to +200 percent. Input CV will be multiplied with attenuverter factor and then limited to be within range -5.0 to +5.0 volts.

Flummi module saves both manual preset and attenuverter preset knob states independently from each other.

Either a click on the ***kick*** button or a trigger pulse at the input jack starts/restarts a simulation process with preset parameters.

impulse is meant to be initial ball speed. Setable range is any value from -100.0 to +100.0 percent. (default: +100.0)

init. height is the initial height, the ball is dropped or thrown from. Setable range is any value from +1.0 to +100.0 percent. (default: +1.0) Changing ***init. height*** results in moving start platform to initial height, even when simulation is still running.

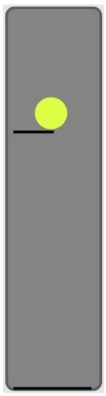
damping sets the “loss of energy”, when the ball hits the ground. Setable range is any value from 0.0 to +99.0 percent. (default: +10.0) Higher damping lets ball peak level decrease earlier. At 0.0 percent damping ball will never end bouncing.

gravity can be set from +1.0 to +100.0 percent. (default: +20.0) A lower value lets the ball jump higher.

A click on the button or a trigger pulse at the input jack stops a running simulation process instantly. When process was already finished, reset puts the ball to initial platform height.

2.2 Simulation Screen

This tall screen is visible, after module was loaded first time. It hows user the



platform line, which represents initial height, the ground line and the ball. At the beginning of the simulation the ball is placed on the platform. Finally it lays on the ground. When it's actual height is more than 100, ball can be invisible for a while. At a high bouncing frequency, the ball seems to not touch the ground or to move much more slowly that it actually does. That comes because graphic generation appears only 12.5 times per second. (in order to reduce CPU load)

Visualization area hides some extra controls too. To switch between both views, simply click on the **P.moon** logo on the module front bottom.

2.3 Final Conditions

Basically a bouncing ball would move for ever. It's peak height would become less and less, but never reach zero. Such a simulation would make no sense. So this bouncing ball simulation uses two methods as "emergency brake".

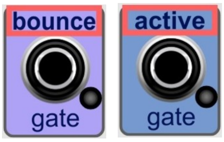
First: The code watches increasing bouncing frequency and stops processing, when this frequency gets too high.

Second: User can limit the maximal count of bounces, the ball should do. This ***final bounces*** number can be set from 1 to 998. When this value is set to 0, process will only be aborted, when ball frequency gets too high.

2.4 Output Section

Many users of *Voltage Modular*® prefer rather small modules. Following this wish, **Flummi** occupies only 1.4 inch width. This leads to a multiple purpose output layout. In other words, for every output jack one can chose of several signals. Output attenuverter knob states are stored separately for each output function. These knobs are visible only in extended view, when graphic area is invisible. To switch between views, click on **P.moon** logo.

2.4.1 Digital Signal Output



On top there is an output with two possible functions: ***bounce*** and ***active***. You can switch between both modes with a left click on the top label ***bounce*** or ***active.***

In ***bounce*** mode this output provides a 5 volt signal each time, when simulated ball touches the ground.

With knob value set to zero, trigger pulse is just one scan long = 1/48,000 second (at *Voltage* default sample rate 48,000 per second). This trigger mode is signalized by the label “trig” on a light violet background. Red LED will flash when a trigger pulse occurs.

Instead of a trigger pulse, you can also get a 5 volt gate signal with a length from 1 to 998 milliseconds. This gate mode is signalized by the label “gate” on a light violet background. Red LED will be lit as long as gate signal is on.

In active mode this output provides a 5 volt gate signal as long as simulation is running. This mode is signalized by the label “gate” on a light blue background.

2.4.2 Analog Signal Outputs

Simulation provides five analog CV signals:

- ***height*** actual ball height over ground
- ***speed*** actual ball speed, it is positive while ball is rising, negative while ball is falling
- ***peak*** maximal height, that the ball reached after last bounce
- ***period*** time interval between two bounces
- ***frequ*** frequency of bounces per second

Two output jacks are reserved for analog signals. For both jacks you can select one of the five signals. Because each signal can be sent to only one output, you have the choice to select two of five signals. If you will really need more than two analog signals at same time, feel free to use another instance of **Flummi** with identical setup parameters.

You can skip from one signal type to another available type by left clicking on the output label.

For ***peak*** and ***period*** output signals a smooth option can be activated.

Each output signal type has it’s own attenuverter. So if you move a signal type from one analog output jack to the other, it’s attenuverter value will move too.

Important note:

Extreme parameter settings can provide extreme analog output signal values. A +100.0 impulse at a minimal gravity of 0.1 can shoot the ball to the sky so that height signal can exceed +600 volts!

3 Signal Diagrams

Following signal diagrams should give you an overview on different signal types and how parameters can effect output signals.

3.1 Digital Signals

3.1.1 Active Gate

Active gate signal is on as long as simulation is running. *(Diagram 1)*

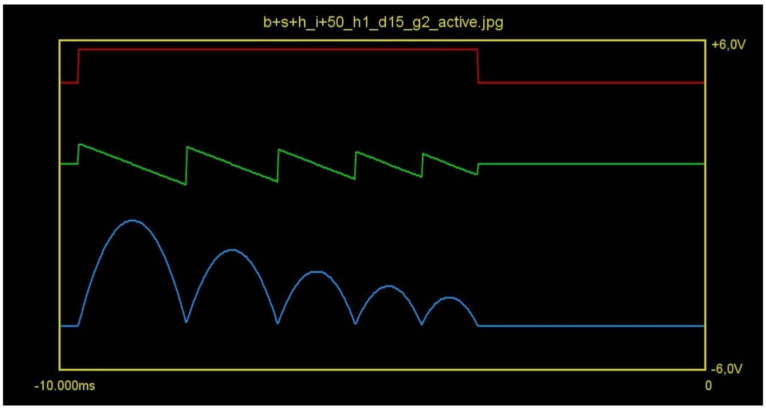


Diagram 1

Initial parameter:
final bounces 5

red: active gate
green: speed
blue: height

3.1.2 Bounce Trig

Every time the ball touches ground, a trigger pulse occurs. *(Diagram 2)*

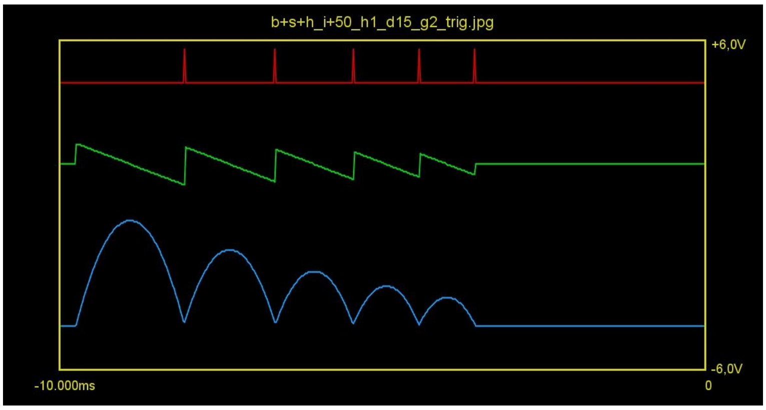


Diagram 2

Initial parameter:
final bounces 5

red: bounce trig
green: speed
blue: height

3.1.3 Bounce Gate

Every time the ball touches ground, a gate signal with preset length is sent to the digital output. *(Diagram 3)*

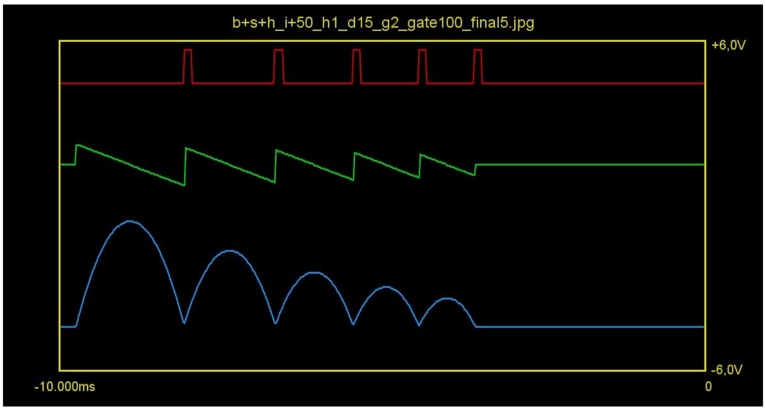


Diagram 3

Initial parameter:

final bounces	5
gate length	100 msec

red:	bounce gate
green:	speed
blue:	height

When gate time is longer than period, some gate pulses get lost. *(Diagram 4)*

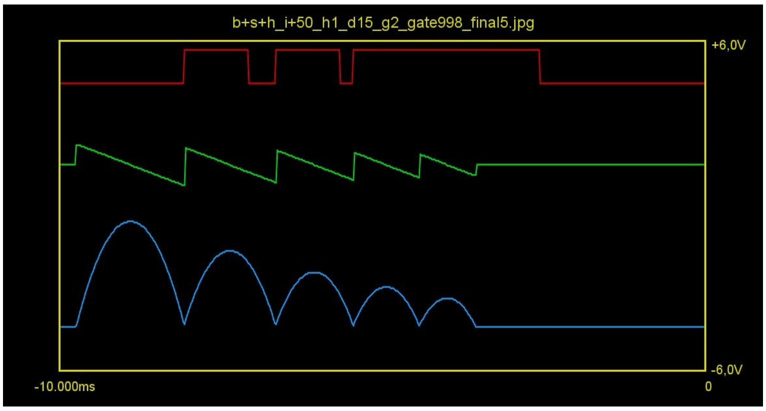


Diagram 4

Initial parameter:

final bounces	5
gate length	998 msec

red:	bounce gate
green:	speed
blue:	height

3.2 Analog Signals

3.2.1 Height

For first two simulations initial height is on minimal level 1. *(Diagrams 5, 6)*

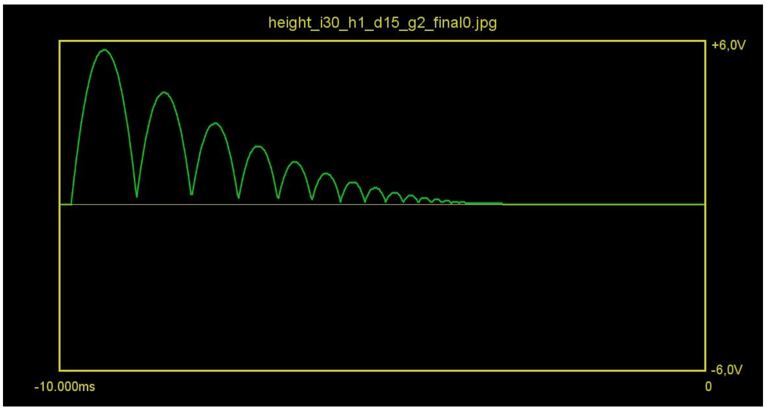


Diagram 5

Initial parameters:

impulse	30
height	1
damping	15
gravity	2
final bounces	0

Ball was thrown upwards.

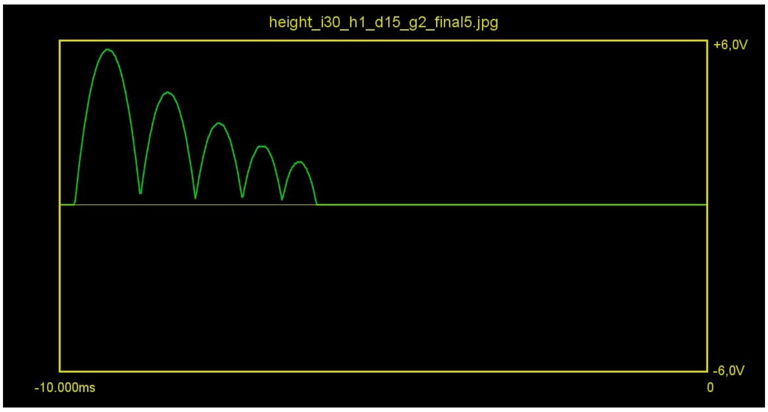


Diagram 6

Initial parameters:

impulse	30
height	1
damping	15
gravity	2
final bounces	5

Ball was thrown upwards.

Now start platform is lifted up. Initial impulse gets modified. *(Diagrams 7, 8, 9)*

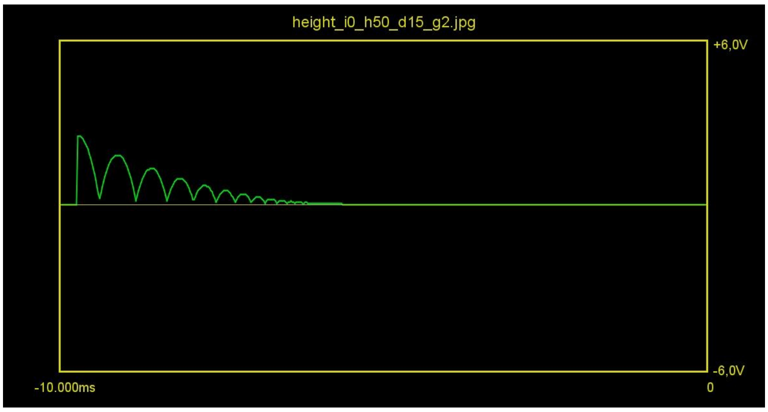


Diagram 7

Initial parameters:

impulse	0
height	50
damping	15
gravity	2
final bounces	0

Ball dropped down.

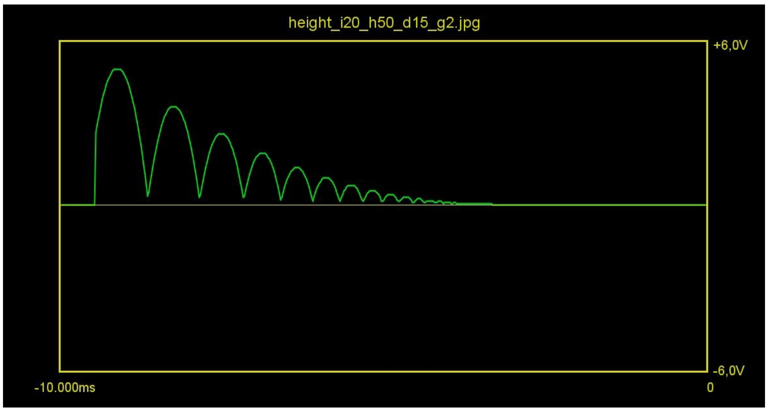


Diagram 8

Initial parameters:

impulse	+20
height	50
damping	15
gravity	2
final bounces	0

Ball was thrown upwards.

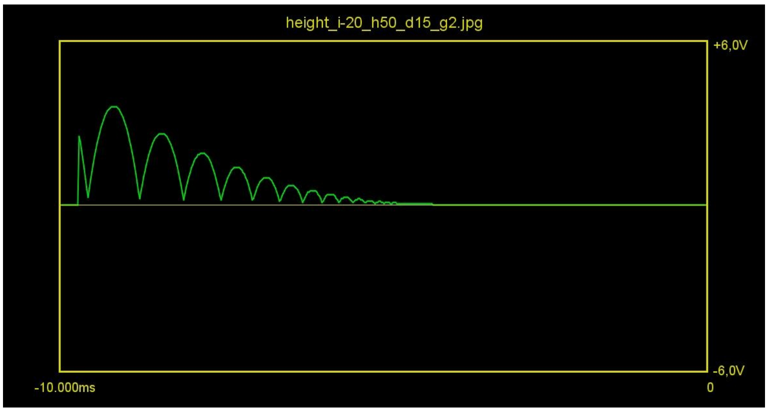


Diagram 9

Initial parameters:

impulse	-20
height	50
damping	15
gravity	2
final bounces	0

Ball was thrown downwards.

3.2.2 Peak

Peak signal (red) is the amplitude (maximal height) of ball's motion (height: green).

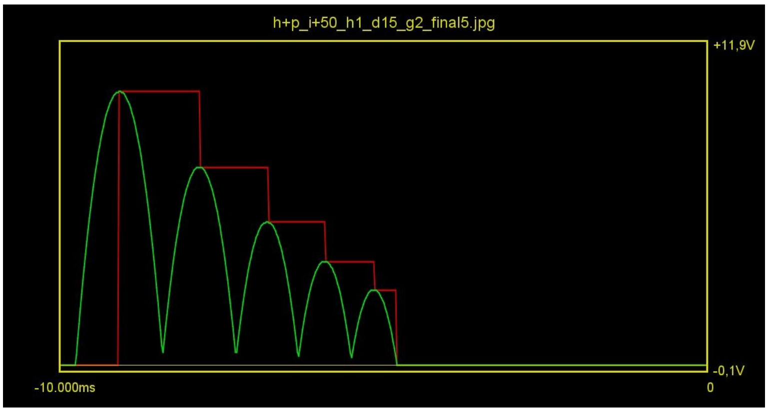


Diagram 10

Initial parameters:

impulse	+50
height	1
damping	15
gravity	2
final bounces	5

Ball was thrown upwards.

Now we activate smooth function for peak signal (red). Please note that smoothing can start only after second peak value is known.

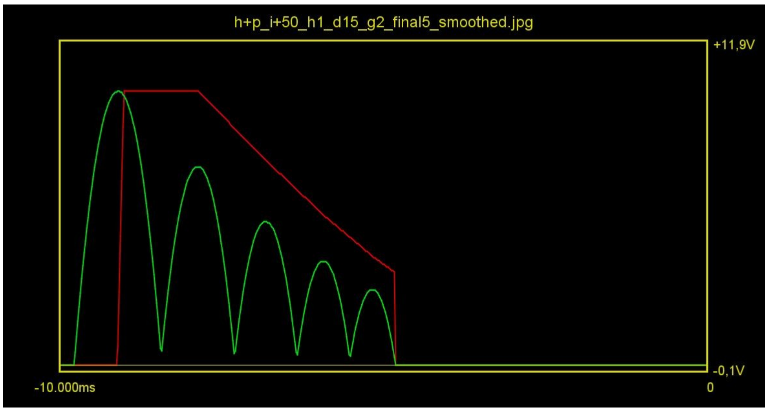


Diagram 11

Initial parameters:

impulse	+50
height	1
damping	15
gravity	2
final bounces	5

Ball was thrown upwards.

In diagram 11 red peak curve looked rather straight. Now diagram 12 shows (green) smoothed peak curve without final bounces limit.

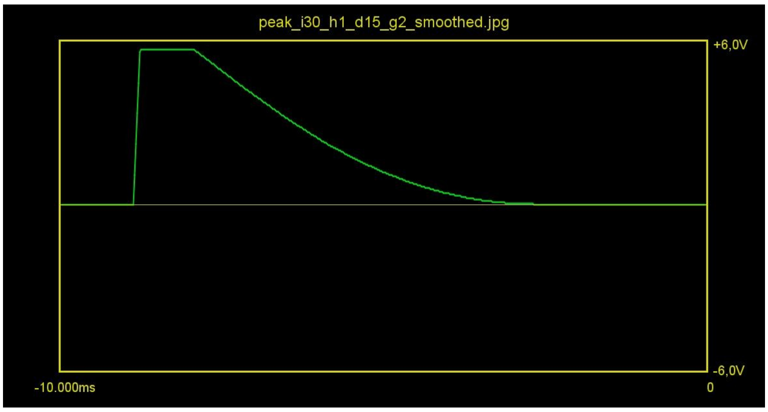


Diagram 12

Initial parameters:

impulse	+50
height	1
damping	15
gravity	2
final bounces	0

Ball was thrown upwards.

3.2.3 Speed

Speed is the only output signal that can become negative. As long as ball moves upwards, it's speed is positive. When ball is falling down, speed is negative.

Diagram 13 shows speed of the ball, when it is thrown upwards from ground.

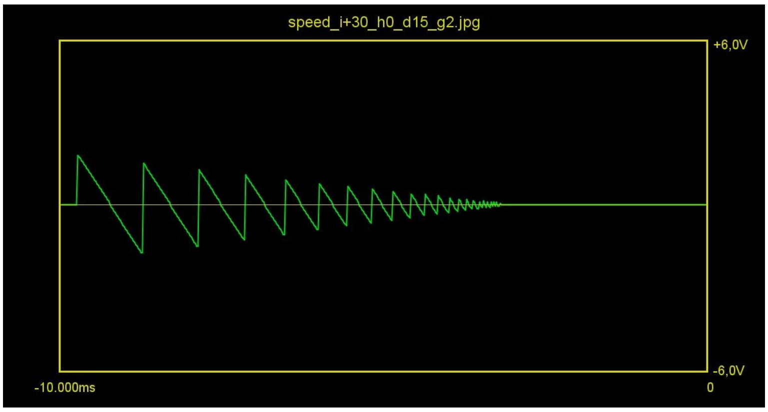


Diagram 13

Initial parameters:

impulse	+30
height	1
damping	15
gravity	2
final bounces	0

Ball was thrown upwards.

In diagram 14 simulation parameters are identical, but final bounces value stops simulation at fifth impact. Red curve (height) demonstrates relationship of both physical properties.

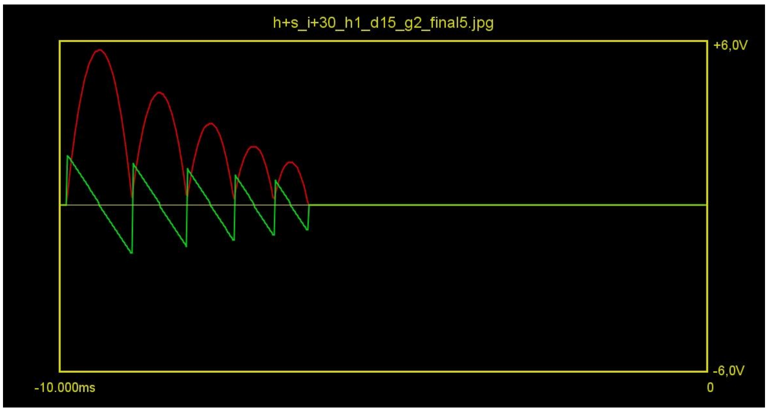


Diagram 14

Initial parameters:

impulse	+30
height	1
damping	15
gravity	2
final bounces	5

Ball was thrown upwards.

Next we lift up start platform again. For diagrams 15, 16 and 17 only initial impulse gets modified.

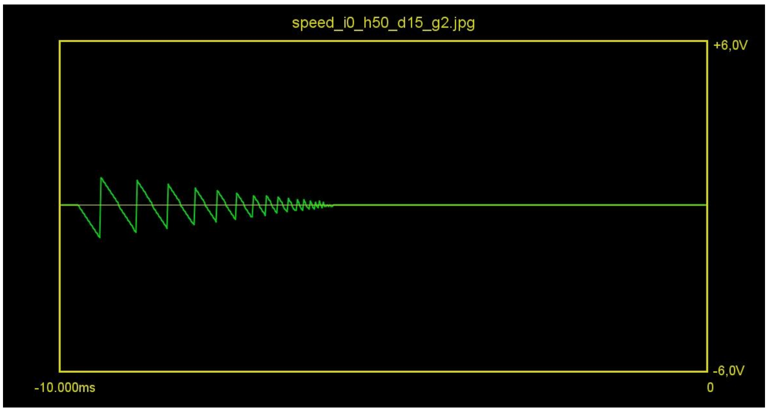


Diagram 15

Initial parameters:

impulse	0
height	50
damping	15
gravity	2
final bounces	0

Ball dropped down.

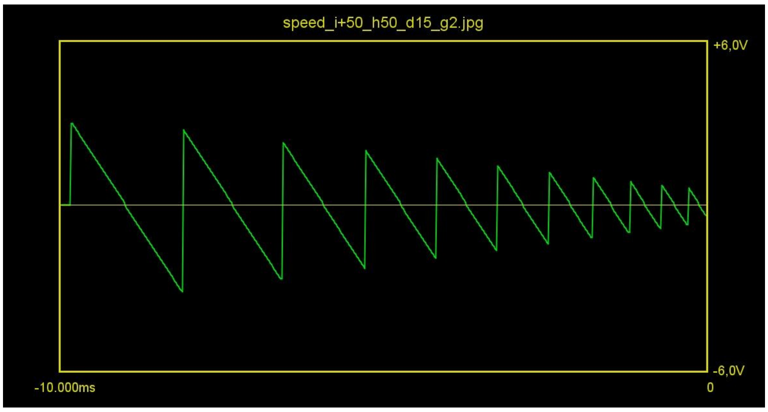


Diagram 16

Initial parameters:

impulse	+50
height	50
damping	15
gravity	2
final bounces	0

Ball was thrown upwards.

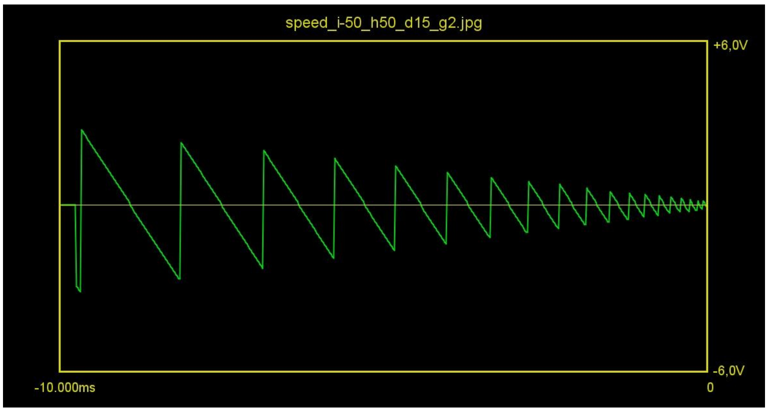


Diagram 17

Initial parameters:

impulse	-50
height	50
damping	15
gravity	2
final bounces	0

Ball was thrown downwards.

3.2.4 Period

Period is meant to be the time interval between two bounces. That explains that first period value is available only after ball touched ground second time. In order to provide the period signal earlier, a predicted value is sent to output before second bounce. This value is calculated as time interval between start and first impact. Diagram 18 can visualize this fact. Red curve is the ball's actual height.

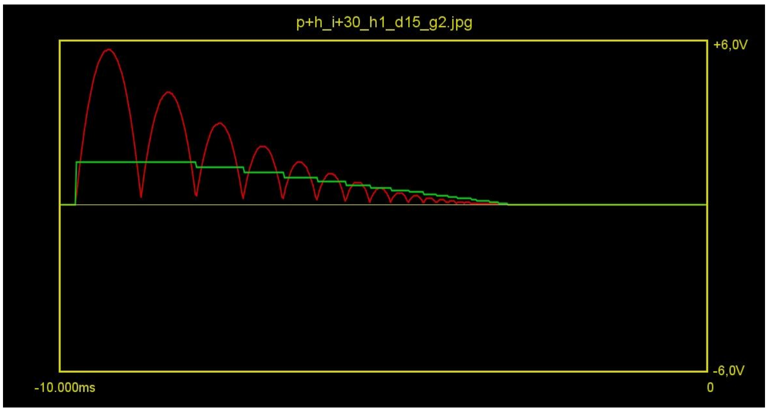


Diagram 18

Initial parameters:

impulse	+30
height	1
damping	15
gravity	2
final bounces	0

Ball was thrown upwards.

For next simulation we let the ball drop down from 50 percent level. Time interval from start to first impact is exactly half of regular value would be.

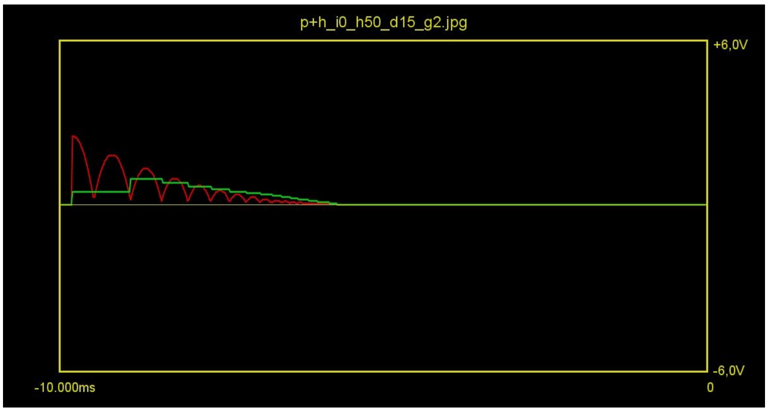


Diagram 19

Initial parameters:

impulse	0
height	50
damping	15
gravity	2
final bounces	0

Ball dropped down.

Now the balls gets initial impulse upwards and then downwards.
(Diagrams 20, 21)

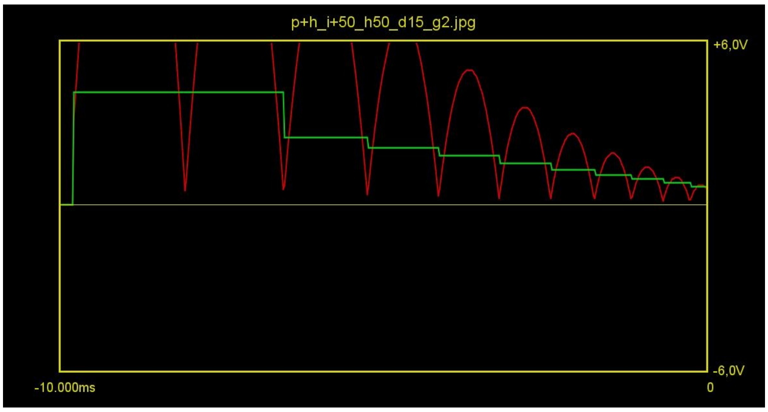


Diagram 20

Initial parameters:

impulse	+50
height	50
damping	15
gravity	2
final bounces	0

Ball dropped down.

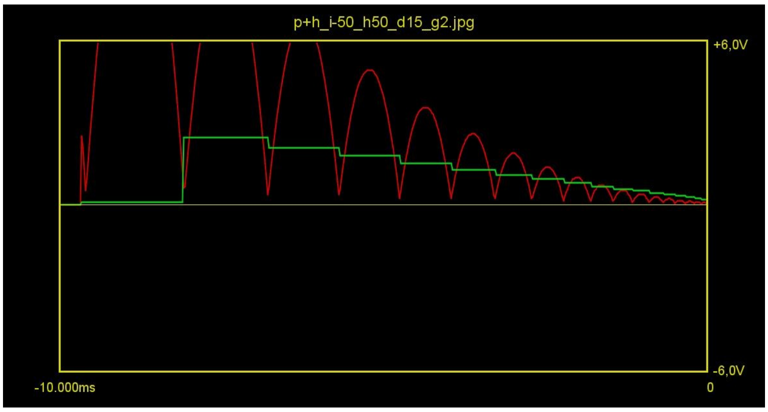


Diagram 21

Initial parameters:

impulse	0
height	-50
damping	15
gravity	2
final bounces	0

Ball dropped down.

For diagram 22 same parameters are used as for diagram 20, but now period signal is smoothed. As explained above, period value before second bounce is predicted. So it is clear that yellow drawn part of smoothed signal needs a further prediction of period value number two, which is measured even at third bounce.

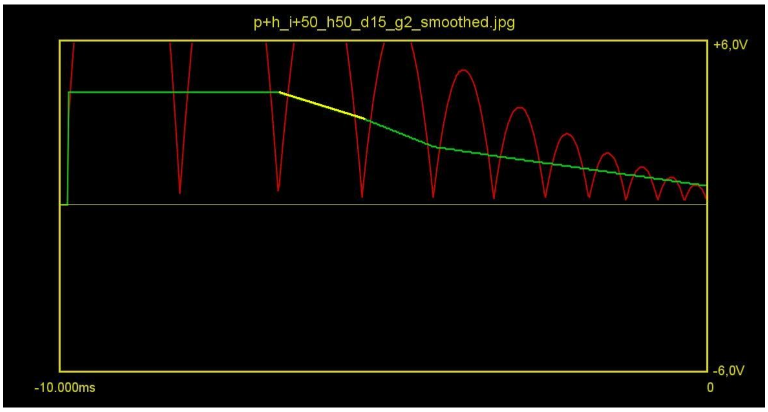


Diagram 22

Initial parameters:

impulse	+50
height	50
damping	15
gravity	2
final bounces	0

Ball dropped down.

3.2.5 Frequency

Mathematical definition of frequency is just reciprocal period. In **Flummi** period gets shorter the lower the peak level and the higher gravity is. At low damping values it can take more than a minute until frequency increases clearly.

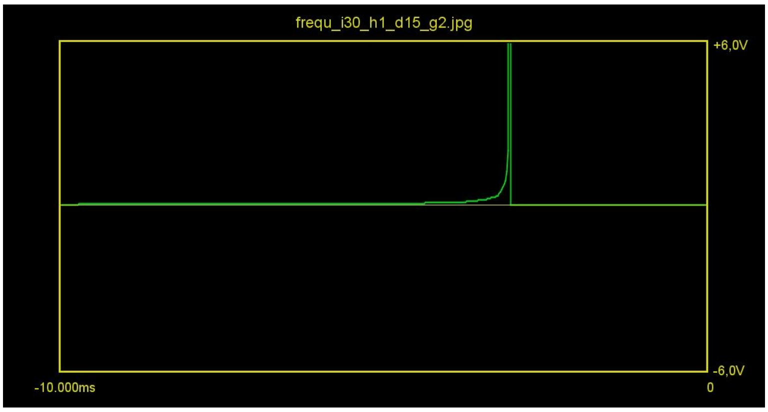


Diagram 23

Initial parameters:

impulse	+30
height	1
damping	15
gravity	2
final bounces	0

Ball is thrown upwards from ground.

4 Example Presets

Flummi - Alarm.voltagepreset

Flummi - Birdy 1.voltagepreset

Flummi - Birdy 2.voltagepreset

Flummi - Dancing Disc.voltagepreset

Flummi - Flipper 1.voltagepreset

Flummi - Flipper 2.voltagepreset

Flummi - Flipper 3.voltagepreset

Flummi - Flummi.voltagepreset

Flummi - Froggy.voltagepreset

Flummi - Ploink.voltagepreset

Flummi - Seagull.voltagepreset

You can find further information on **P.moon** modules on P.moon’s home page:

https://p-moon-modules.de/modules.htm