

# Macroduino – User Guide

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## Overview

*Macroduino* is an [Arduino Uno](#)-based system that lets you plan and execute precise focus stacks. Focus stacks are particularly useful in macro photography when it's difficult to get the entire subject in focus in a single frame.

The series of individual frames can be stitched together with software, e.g. [Photoshop](#) or [Helicon Focus](#), to produce an image that would otherwise be impossible to achieve.

Using the standard hardware recommendations, the linear resolution is approximately **1/200TH OF A MILLIMETER!**

## Core Concept

*Macroduino* relies on the fact that the [Depth of Field](#) for any combination of focus distance, lens focal length, etc., can be calculated using mathematical formulae.

There are a number of online calculators, e.g. <http://www.dofmaster.com/dofjs.html>, that let you enter a few parameters to find the near limit, far limit, etc. for your given circumstances.

*Macroduino* uses the same formulae to calculate the optimum number of frames needed to produce the desired stack, taking into account a sufficient amount of overlap between each frame that will enable the stitching software to produce a cohesive image.

While *Macroduino* does not strive to replace the artistic qualities of macrophotography, its goal is to eliminate the repetitive process of take a picture, move the camera, take a picture, move the camera...

## Disclaimers

*Macroduino* uses a stepper motor which has no internal mechanical connection. This means that if the motor encounters enough resistance, such as too much weight or reaching the end of the macro slide's travel limit, it will continue to try to execute the required movement.

While this won't have an immediate, detrimental affect on the motor, over time, it can be damaged.

Therefore....

**IT IS ALWAYS IMPORTANT TO ENSURE THAT THERE IS ENOUGH PHYSICAL TRAVEL FOR THE SLED TO EXECUTE THE STACK.**

*Macroduino* does not control the settings of your camera and/or lighting, it only executes the shutter release.

Therefore....

**IT IS ALWAYS IMPORTANT TO ENSURE THAT YOUR CAMERA AND/OR LIGHTING ARE SET CORRECTLY BEFORE EXECUTING THE STACK.**

## Navigation Basics

*Macroduino* uses an [Adafruit LCD Shield](#) to handle the display and navigation functions.

Table 1 - Navigation Summary

Button	Navigation Mode	Edit Mode
<b>Left</b>	Moves to the Parent of the current menu item	Integers – Subtracts 1 Booleans – Switches flag Lists – Selects previous
<b>Right</b>	Moves to the submenu for the current item	Integers – Adds 1 Booleans – Switches flag Lists – Selects next
<b>Up</b>	Moves to the previous option	Integers – Adds 10 Booleans – Switches flag Lists – Selects previous
<b>Down</b>	Moves to the next option	Integers – Subtracts 10 Booleans – Switches flag Lists – Selects next
<b>Select</b>	Switches to Edit Mode or executes the function	Stores the parameter value in memory and switches to Navigation Mode

The directional buttons – Left, Right, Up and Down – are used to navigate through the menu structure and to edit parameter values. Their functions are outlined in Table 1.

When you are displaying one of the parameter values, use the Select button to toggle *Edit Mode* on and off. When you first enter *Edit Mode* on the current parameter, you have to click Select twice. This is a quirk of the navigation system.

An asterisk (\*) will appear when you are in *Edit Mode*. Changes are saved immediately, but click Select again to leave *Edit Mode*.

All of your custom settings are stored permanently on the Arduino board and are only overwritten if you reset to the system defaults or there is a firmware update.

## Navigation Example

To change the Focal Length setting, starting from the main Welcome screen:

```
-----
|Macroduino      |
|Get stacking!   |
|-----|
> Press RIGHT
-----
|Macroduino      |
|Expert Mode     |
|-----|
> Press DOWN
-----
|Macroduino      |
|Normal Mode     |
|-----|
> Press RIGHT
-----
|Normal Mode     |
|Stack           |
|-----|
> Press DOWN
-----
|Normal Mode     |
|Camera/Lens     |
|-----|
> Press RIGHT
-----
|Camera/Lens     |
|Focal Length    |
|-----|
> Press RIGHT
-----
|Focal Length    |
|105             |
|-----|
> Press SELECT (twice) to enter Edit Mode
-----
|Focal Length    |
|105*            |
|-----|
> Press UP/DOWN/LEFT/RIGHT to change the value
> Press SELECT to leave Edit Mode
```

## Menu Structure

- Welcome
  - [Expert Mode](#)
    - [Frames](#)
    - [Steps](#)
    - [Run](#)
  - [Normal Mode](#)
    - [Stack](#)
      - [Total Dist](#)
      - [Focus Dist](#)
      - [Frame Overlap](#)
      - [Safety Frames](#)
      - [Frame Pause](#)
      - [Depth of Frame](#)
      - [Steps per Frame](#)
      - [Total Frames](#)
    - [Camera/Lens](#)
      - [Focal Length](#)
      - [F Number Index](#)
      - [F Number Scale](#)
      - [Circ of Conf](#)
      - [Focus Pause](#)
      - [Shutter Pause](#)
      - [F Number Value](#)
      - [Hyperfocal Dist](#)
      - [Near Focus Dist](#)
      - [Far Focus Dist](#)
      - [Depth of Field](#)
    - [Run](#)
  - [System](#)
    - [Motor](#)
      - [Revs per Min](#)
      - [Steps per Rev](#)
    - [Rail](#)
      - [Dist per Rev](#)
      - [Settle Pause](#)
      - [Dist per Step](#)
    - [Use Backlight](#)
    - [Use Speaker \(not used\)](#)
    - [Reset](#)

## Normal Mode

Use *Normal Mode* when you don't want to have to do a lot of complex calculations and just want to provide a few simple inputs.

Macroduino
Normal Mode

## Stack

Normal Mode
Stack

## Total Distance

The total depth of the stack you want to photograph. The macro rail travel distance physically limits this. Please note the [Disclaimer](#).

Table 2 – Total Distance

<b>Value type</b>	Integer
<b>Units</b>	Millimeters (mm)
<b>Min value</b>	1
<b>Max value</b>	88
<b>Default</b>	50

Stack
Total Dist

Total Dist
50

Total Dist
50*

## Focus Distance

This is how far away the focus point is. For Nikon cameras, this is measured from the focal plane, i.e. the sensor, however you should verify this for your particular gear.

Table 3 – Focus Distance

<b>Value type</b>	Integer
<b>Units</b>	Millimeters (mm)
<b>Min value</b>	1
<b>Max value</b>	65535
<b>Default</b>	315

Stack	
Focus Dist	
Focus Dist	
315	
Focus Dist	
315*	

### Frame Overlap

This allows you to specify how much of each frame is duplicated between successive frames. Doing this allows the stitching software to align the individual frames together to produce the composite image.

Table 4 – Frame Overlap

<b>Value type</b>	Integer
<b>Units</b>	%
<b>Min value</b>	1
<b>Max value</b>	99
<b>Default</b>	25

Stack	
Frame Overlap	
Frame Overlap	
25	
Frame Overlap	
25*	

## Safety Frames

This allows you to specify a number of frames to be added to the beginning and end of your Total Distance, to allow for human error in measurements, etc.

### Table 5 – Safety Frames

<b>Value type</b>	Integer
<b>Units</b>	Each
<b>Min value</b>	0
<b>Max value</b>	9
<b>Default</b>	5

Stack
Safety Frames

  

Safety Frames
5

  

Safety Frames
5*

## Frame Pause

This allows you to specify an interval of time for the camera to pause between each frame.

### Table 6 – Frame Pause

<b>Value type</b>	Integer
<b>Units</b>	Milliseconds (ms)
<b>Min value</b>	1
<b>Max value</b>	999
<b>Default</b>	250

Stack
Frame Pause

  

Frame Pause
250

  

Frame Pause
250*



### Depth of Frame

This calculated value shows the effective distance being captured with each frame, taking into account all of the other parameters.

Stack
Depth of Frame
-----
Depth of Frame
=6.1104354858
-----

### Steps per Frame

This calculated value shows the number of steps that are required to move the camera for each frame, taking into account all of the other parameters.

Stack
Steps per Frame
-----
Steps per Frame
=1152
-----

### Total Frames

This calculated value shows the total number of frames that will be taken to cover the necessary distance.

Stack
Total Frames
-----
Total Frames
=18
-----

### Camera/Lens

Normal Mode
Camera/Lens
-----

## Focal Length

This is the focal length of your lens. Use the actual focus length, not the effective length after adjusting for a crop factor.

Table 7 - Focal Length

<b>Value type</b>	Integer
<b>Units</b>	Millimeters (mm)
<b>Min value</b>	1
<b>Max value</b>	999
<b>Default</b>	105

```
-----  
| Camera/Lens |  
| Focal Length |  
-----
```

```
-----  
| Focal Length |  
| 105          |  
-----
```

```
-----  
| Focal Length |  
| 105*         |  
-----
```

## F Number Index

This is the aperture setting, using common notation. The values available to select depend on the F Number Scale selected.

Table 8 - F Number Index

<b>Value type</b>	List
<b>Units</b>	Selection
<b>Values</b>	Varies
<b>Default</b>	f/22

```
-----  
| Camera/Lens |  
| F Number Index |  
-----
```

```
-----  
| F Number Index |  
| f/22           |  
-----
```

```
-----  
| F Number Index |  
| f/22*          |  
-----
```

## F Number Scale

This lets you change the scale for the F Number Index parameter. You can choose to show the values in Whole, Half or Third steps

Table 9 – F Number Scale

<b>Value type</b>	List
<b>Units</b>	Selection
<b>Values</b>	Whole   Half   Third
<b>Default</b>	Third

Camera/Lens	
F Number Scale	
F Number Scale	
Third	
F Number Scale	
Third*	

## Circle of Confusion

The [circle of confusion](#) is the smallest part of an image that is acceptably sharp. This will vary by manufacture, sensor, etc. Table 11 contains a sample of common values, but please check your camera's documentation to verify the actual value.

Table 10 – Circle of Confusion

<b>Value type</b>	Integer
<b>Units</b>	Micrometers (um)
<b>Min value</b>	0
<b>Max value</b>	9999
<b>Default</b>	30

Camera/Lens	
Circ of Conf	
Circ of Conf	
30	
Circ of Conf	
30*	

Table 11 - Common Circle of Confusion Values

Manufacturer/Format	Reported Value	Value to Enter
<b>Nikon FX (D810, D610, etc)</b>	0.03mm	30
<b>Nikon DX (D7200, D5200, etc)</b>	0.02mm	20
<b>Canon 5D, 1D</b>	0.03mm	30
<b>Canon 7D, 60D, 70D</b>	0.019mm	19

### Focus Pause

This allows you to specify an interval of time for the camera's auto-focus/metering, i.e. a "half press", to be engaged before firing the shot. Nikons require the auto-focus/metering to be engaged for a short period of time before releasing the shutter, even if you are not using it to provide any information for the shot.

Table 12 - Focus Pause

<b>Value type</b>	Integer
<b>Units</b>	Milliseconds (ms)
<b>Min value</b>	1
<b>Max value</b>	999
<b>Default</b>	300

Camera/Lens	
Focus Pause	
Focus Pause	
300	
Focus Pause	
300*	

### Shutter Pause

This is the amount of time the shutter released, i.e. a "full press", is engaged.

Table 13 - Shutter Pause

<b>Value type</b>	Integer
<b>Units</b>	Milliseconds (ms)
<b>Min value</b>	1
<b>Max value</b>	999
<b>Default</b>	100

Camera/Lens
Shutter Pause
Shutter Pause
100
Shutter Pause
100*

### **F Number Value**

Although aperture settings are generally displayed in numbers like f/1.4, f/8, f/12, and f/22, the actual **F-number** values are based on the geometric sequence of the powers of the square root of 2 and are far from nice, round values. Table 15 shows the actual values (to 6 significant digits) for the Whole Stop scale compared to the notional values.

Camera/Lens
F Number Value
F Number Value
=22.6274166107

**Table 14 - Actual F Numbers**

F Number - Notional	F Number - Actual
<b>f/1</b>	1.000000
<b>f/1.4</b>	1.414214
<b>f/2</b>	2.000000
<b>f/2.8</b>	2.828427
<b>f/4</b>	4.000000
<b>f/5.6</b>	5.656854
<b>f/8</b>	8.000000
<b>f/11</b>	11.313708
<b>f/16</b>	16.000000
<b>f/22</b>	22.627417
<b>f/32</b>	32.000000
<b>f/45</b>	45.254834
<b>f/64</b>	64.000000

### *Hyperfocal Distance*

This displays the calculated [hyperfocal distance](#), one of the requirements to calculate Depth of Field.

```
-----  
| Camera/Lens |  
| Hyperfocal Dist |  
-----  
  
-----  
| Hyperfocal Dist |  
| =16346.358398437 |  
-----
```

### *Near Focus Distance*

This displays the calculated distance to the closest point of acceptable sharpness.

```
-----  
| Camera/Lens |  
| Near Focus Dist |  
-----  
  
-----  
| Near Focus Dist |  
| =310.9790344238 |  
-----
```

### *Far Focus Distance*

This displays the calculated distance to the farthest point of acceptable sharpness.

```
-----  
| Camera/Lens |  
| Far Focus Dist |  
-----  
  
-----  
| Far Focus Dist |  
| =319.1262817382 |  
-----
```

### *Depth of Field*

This displays the calculated distance between the nearest and farthest points of acceptable sharpness.

```
-----  
| Camera/Lens |  
| Depth of Field |  
-----  
  
-----  
| Depth of Field |  
| =8.1472473144 |  
-----
```

### *Run (Normal Mode)*

Execute the stack defined in *Normal Mode*.

Normal Mode
Run

Starting in
3..2..1..

Adding safety
frames

Continuing in
3..2..1..

Frame
1 of 18

## Expert Mode

*Expert Mode* is best used for a couple of scenarios:

1. You are comfortable enough with your equipment to bypass the lengthier process of *Normal Mode*.
2. You are using equipment that might not fit the pre-defined workflow built into *Normal Mode*. For example, using [stacked lenses](#) to achieve extreme magnification.

In any case, some experimentation may be required to achieve the desired results.

```
-----  
|Macroduino|  
|Expert Mode|  
-----
```

## Frames

The number of frames to be taken.

Table 15 - Frames

<b>Value type</b>	Integer
<b>Units</b>	Each
<b>Min value</b>	1
<b>Max value</b>	999
<b>Default</b>	10

```
-----  
|Expert Mode|  
|Frames|  
-----
```

```
-----  
|Frames|  
|10|  
-----
```

```
-----  
|Frames|  
|10*|  
-----
```

## Steps

The number of steps per frame. For the default hardware, this will yield a shift of 1.06mm per frame



Table 16 – Steps

<b>Value type</b>	Integer
<b>Units</b>	Each
<b>Min value</b>	1
<b>Max value</b>	9999
<b>Default</b>	200

```
-----
| Expert Mode |
| Steps       |
|-----|
```

```
-----
| Steps       |
| 200        |
|-----|
```

```
-----
| Steps       |
| 200*       |
|-----|
```

### **Run (Expert Mode)**

Execute the stack defined in *Expert Mode*.

```
-----
| Expert Mode |
| Run        |
|-----|
```

```
-----
| Starting in |
| 3..2..1..   |
|-----|
```

```
-----
| Frame      |
| 1 of 18    |
|-----|
```

## System Settings

The parameters in this section will hardly ever be changed, except if you change hardware, e.g. use a different motor.

Macroduino
System

## Motor

System
Motor

## Revolutions per Minute

The speed at which the stepper motor operates.

Table 17 – Revs per Min

<b>Value type</b>	Integer
<b>Units</b>	Each
<b>Min value</b>	1
<b>Max value</b>	120
<b>Default</b>	120

Motor
Rev per Min

Rev per Min
120

Rev per Min
120*

## Steps per Revolution

This is a constant and comes from the specification of the motor. It will typically be 200 or 400, but with gearing options, this could be very high.

Table 18 – Steps per Rev

<b>Value type</b>	Integer
-------------------	---------

<b>Units</b>	Each
<b>Min value</b>	1
<b>Max value</b>	65535
<b>Default</b>	200

```

-----
| Motor                |
| Steps per Rev       |
|                     |
-----

```

```

-----
| Steps per Rev       |
| 200                 |
|                     |
-----

```

```

-----
| Steps per Rev       |
| 200*                |
|                     |
-----

```

## Rail

```

-----
| System              |
| Rail                |
|                     |
-----

```

## Distance per Revolution

This is a constant and comes from the specification of the macro rail. For the [Hejnar Photo MS5\\_8](#), it is 1.06mm (1060um) per revolution. Again, gearing options could lead to wide ranges of values.

Table 19 – Distance per Revolution

<b>Value type</b>	Integer
<b>Units</b>	Micrometers (um)
<b>Min value</b>	1
<b>Max value</b>	65535
<b>Default</b>	1060

```

-----
| Rail                |
| Dist per Rev       |
|                     |
-----

```

```

-----
| Dist per Rev       |
| 1060               |
|                     |
-----

```

```

-----
| Dist per Rev       |
| 1060*              |
|                     |
-----

```

### Settle Pause

This allows you to specify an interval of time for the camera to come to rest after it has moved.

Table 20 – Settle Pause

<b>Value type</b>	Integer
<b>Units</b>	Milliseconds (ms)
<b>Min value</b>	1
<b>Max value</b>	999
<b>Default</b>	100

```
-----  
| Rail |  
| Settle Pause |  
-----  
  
| Settle Pause |  
| 100 |  
-----  
  
| Settle Pause |  
| 100* |  
-----
```

### Dist per Step

This is a calculation of distance the camera will move for each step of the motor. When using the [Hejnar Photo MS5\\_8](#) with a 200-step motor, this yields a resolution of 0.0053mm!

```
-----  
| Rail |  
| Dist per Step |  
-----  
  
| Dist per Step |  
| =0.0052999997 |  
-----
```

### Use Backlight

This toggles the LCD backlight feature on and off. During normal operation, the backlight will turn off after 15 seconds of inactivity. It will turn back on automatically as soon as the next button is pressed.

Table 21 – Use Backlight

<b>Value type</b>	Boolean
<b>Values</b>	YES   NO
<b>Default</b>	YES

System
Use Backlight
Use Backlight
YES
Use Backlight
YES*

## Use Speaker

This is a placeholder for a future feature to incorporate a small speaker to provide audible feedback.

Table 22 – Use Speaker

Value type	Boolean
Values	YES   NO
Default	YES

System
Use Speaker
Use Speaker
YES
Use Speaker
YES*

## Reset

This will reset your *Macroduino* to its default settings and overwrite all your saved configuration values. There is no confirmation.

**THIS WILL RESET YOUR MACRODUINO TO ITS DEFAULT SETTINGS AND OVERWRITE ALL YOUR SAVED CONFIGURATION VALUES. THERE IS NO CONFIRMATION.**

System
Reset

## Acknowledgements

While some of these did not end up in the final solution, all played one part or another in the inspiration, research and fulfillment of this project.

<http://www.davidhunt.ie/> - David Hunt has published several photography-related projects based on the Raspberry Pi. I didn't want to simply build copies his projects. Instead, I used them as examples of what could be done with microcomputers and photography and set out to do similar things on my own.

<http://photoduino.github.io/> - "Photoduino is the open source camera controller based on the Arduino platform which you can use to automatically take pictures with your DSLR camera." After following the build instructions and making my own Photoduino, I realized that the Arduino was a perfect platform for this project.

<https://www.arduino.cc/> - "Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects." It's setup/loop structure was the perfect basis for creating a "listening" user interface.

<http://www.adafruit.com/> - "Adafruit was founded in 2005 by MIT engineer, Limor "Ladyada" Fried. Her goal was to create the best place online for learning electronics and making the best designed products for makers of all ages and skill levels." Even though this was a DIY project, I had to decide what I could produce myself with sufficient quality and what I needed to purchase. Adafruit's [LCD Shield Kit](#) and [Motor Shield Kit](#) provided enough of a head start with the electronics hardware.

<https://github.com/0xPIT/menu> - Again, rather than reinventing the wheel of coding my own navigation, I opted to integrate an existing solution.

<http://www.hejnarphotostore.com/> - Design. Manufacture. Deliver. The final piece of the puzzle came while browsing Hejnar's web site. Having purchased rails from him in the past, I've been back to the site several times, just keeping up with what's available. Seeing their screw-adjusting macro rails, I knew there was no way I could build anything of comparable precision.

<http://www.dofmaster.com/dofjs.html> and [https://en.wikipedia.org/wiki/Depth\\_of\\_field](https://en.wikipedia.org/wiki/Depth_of_field) - Confirmation of the formulae needed.