EMBER PROTOTYPES

Camera-Assisted XY Calibration (CXC)

User Manual

Background

The conventional standard for calibrating XY offsets on dual extruders, IDEX machines, and tool changers has been to print calibration line patterns and adjust the offset such that the lines match up.

However, many printers are only capable of calibrating with PLA, requiring filament switches. Furthermore, machines that are capable of calibrating other materials require waiting for the bed to heat to an acceptable temperature. This can take a significant amount of time for bed temps at 80C+.

The CXC eliminates the need for all of this by utilizing a camera and software to assist in quickly and easily calibrating the XY offsets with a higher degree of accuracy than existing standard methods*.

* The calibration accuracy is limited by your machine's minimum manual jog resolution. For example, if the minimum manual jog resolution on your printer is 0.1mm, the maximum error when aligning one nozzle to the software's crosshair will be up to +/-0.05mm. Since nozzles are aligned in pairs, the worst case maximum error is +/-0.1mm, however it is likely that your calibration accuracy will be better than this worst case scenario.

Requirements

The CXC was designed to be printer agnostic, however, to do so, your printer and setup must fulfill two requirements:

1. Ability to jog the gantry in steps of 0.1mm or less and read the position

2. Ability to override XY calibration values (or tune offsets in the slicer)

Hardware Overview

- USB camera module
- High brightness white LEDs
- Adjustable focus, short focal length lens
- Integrated magnet for adhering to spring steel build plates
- Reusable, washable adhesive stickers for non-steel build plates
- 4 x M3 mounting holes*
- 2m long USB cable**

Early versions may have holes for M2.5 or 2-28 thread rolling screws
*** Early versions may come with a short cable plus an additional USB extender*
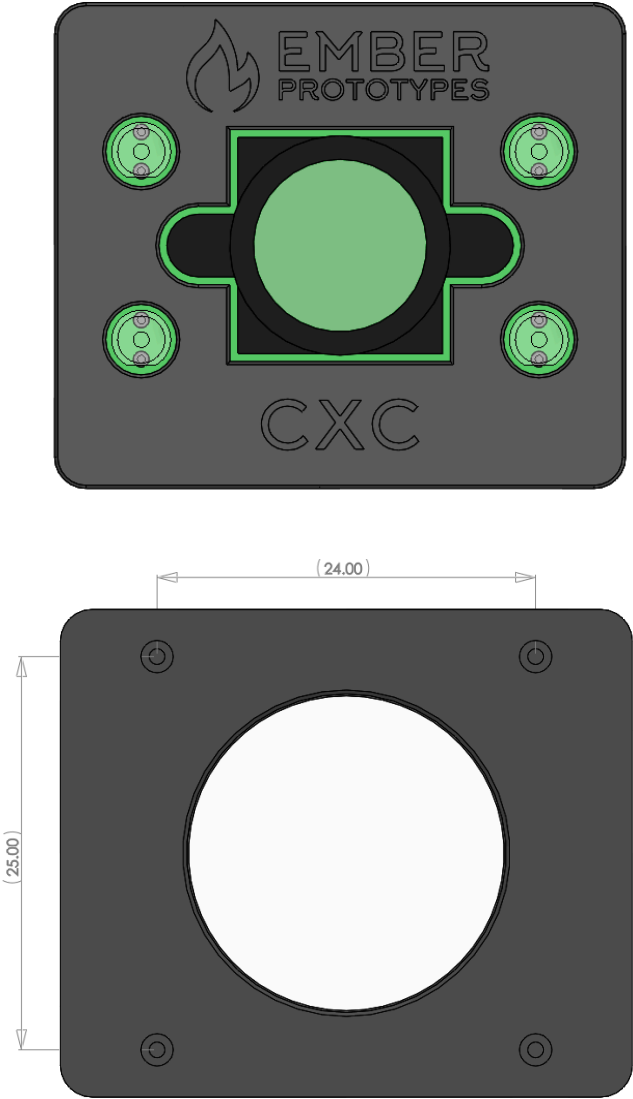
Software Overview

- Windows [Software can be downloaded here](#)
- A cross-platform [web application can also be used at this link](#)
- Superimposed crosshair & circle help align the center of the nozzle
- The camera exposure can be adjusted with a slider
- The camera zoom can be adjusted with a slider
- The camera connection can be refreshed with the refresh button
- Flexible parameters to accommodate any printer type regardless of how the printer calculates and uses the offsets
- Detailed tool-tips on all parameters
- Automatic saving of parameters
- Settings for IDEX, dual extruders and tool changers
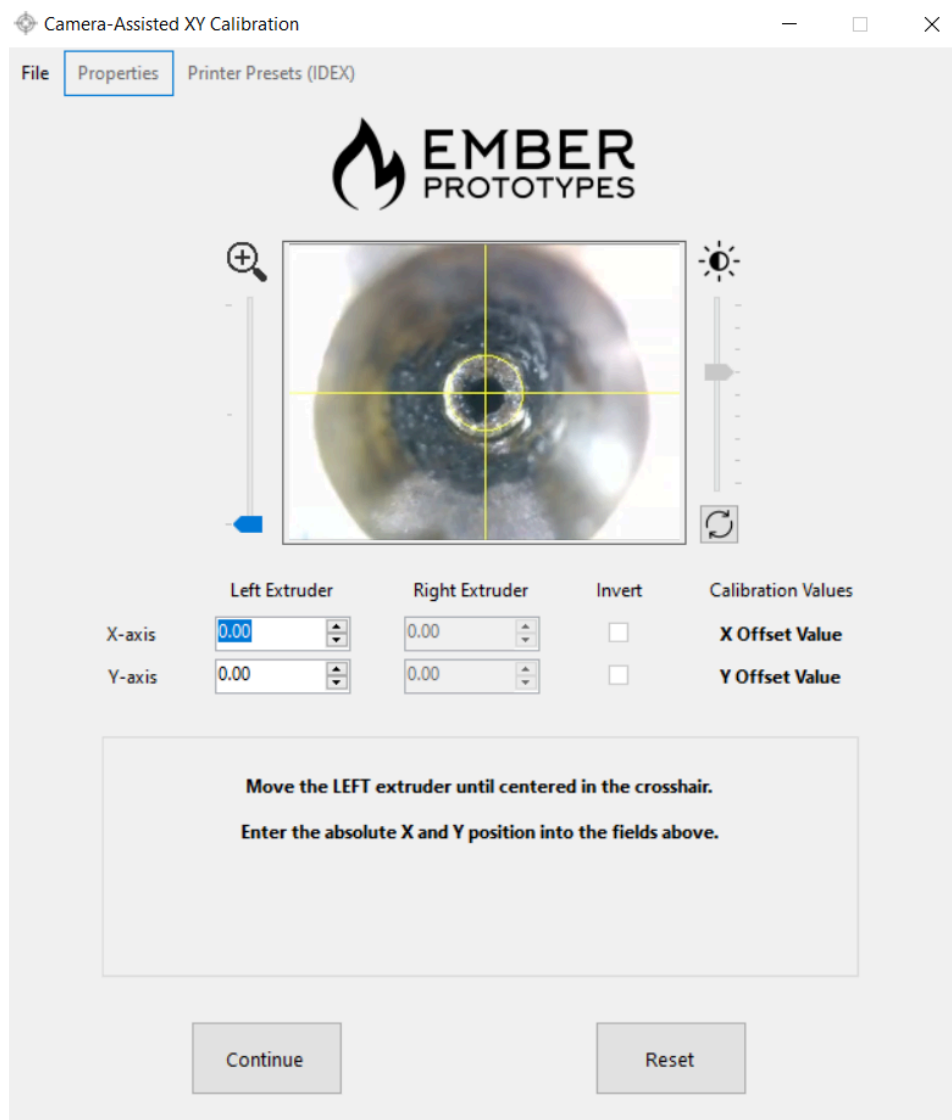
Quick Start - IDEX

1. Download and extract the software. Run "setup.exe" to install the software ([or use the web app here](#))

2. Connect the CXC to a laptop or PC USB port

3. Determine whether the magnet will work on your printer, or if you need to attach the reusable adhesive pad - if the latter, attach it over the magnet

4. Run the software

5. Select the "Generic" profile

6. Adjust the offset inversion parameters if necessary*

7. Hit "Start" and follow the instructions to complete calibration

8. Print the verification model to ensure nozzle alignment**

9. Enter your printer and parameters into [the shared parameter spreadsheet](#)***

* Not necessary for most printer types - see [Custom Profile & Printer](#) section for more details and [check here](#) to see a list of parameters on user tested printers

** Optional - [Printing the verification model](#) is only recommended for first time calibrations of your printer to ensure settings are correct

*** Optional - this spreadsheet will get filled out over time by our user base so we can share parameter settings to the community

Quick Start - DUAL

1. Download and extract the software. Run "setup.exe" to install the software ([or use the web app here](#))
2. Connect the CXC to a laptop or PC USB port
3. Determine whether the magnet will work on your printer, or if you need to attach the reusable adhesive pad - if the latter, attach it over the magnet
4. Run the software
5. Select the "Generic" profile
6. Adjust the offset inversion parameters if necessary*
7. Enter the physical Nozzle Distance if required on your printer*
8. Select the Left or Right origin parameters if necessary*
9. Hit "Start" and follow the instructions to complete calibration
10. Print the verification model to ensure nozzle alignment**
11. Enter your printer and parameters into [the shared parameter spreadsheet](#)***

Not necessary for most printer types - see [Custom Profile & Printer](#) section for more details and [check here](#) to see a list of parameters on user tested printers

** *Optional - [Printing the verification model](#) is only recommended for first time calibrations of your printer to ensure settings are correct*

*** *Optional - this spreadsheet will get filled out over time by our user base so we can share parameter settings to the community*

Quick Start - TOOL CHANGER

1. Download and extract the software. Run "setup.exe" to install the software ([or use the web app here](#))

2. Connect the CXC to a laptop or PC USB port

3. Determine whether the magnet will work on your printer, or if you need to attach the reusable adhesive pad - if the latter, attach it over the magnet

4. Run the software

5. Select the "Tool Changer" property*

6. Hit "Start" and follow the instructions to complete calibration**

7. Print the verification model to ensure nozzle alignment***

8. Enter your printer and parameters into [the shared parameter spreadsheet](#)****

The CXC has been tested to work with the E3D tool changers. If you have a different tool changer you may need to adjust other parameters - see [Custom Profile & Printer](#) section for more details and [check here](#) to see a list of parameters on user tested printers

** For the E3D system, T0 will correspond to the probe location, while T1-T4 correspond to the actual extruders*

*** Optional - [Printing the verification model](#) is only recommended for first time calibrations of your printer to ensure settings are correct*

**** Optional - this spreadsheet will get filled out over time by our user base so we can share parameter settings to the community*

[We've created a brief Quick Start document for E3D Tool Changers here.](#)

Permanent Mounting

- The CXC comes with **4 x M3 holes** for mounting. This enables more convenient calibration in systems that have additional space. These holes are **not threaded** but can be self tapped by simply screwing M3 bolts into the holes. Take care not to strip the threads created.
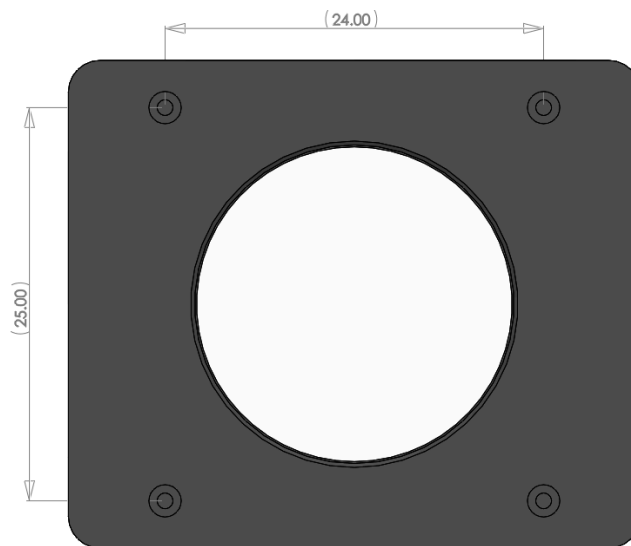
- Currently, as of **2024-03-29**, the CXC LEDs are always on when the device is plugged into a USB port - we are working on providing power control to the LEDs or enabling them only once the camera itself is connected to

- The next page will describe suggested workarounds for controlling power to the CXC in order to prolong LED lifetime (*inks provided are affiliate links to products on Amazon*)

⚠️⚠️ ***We do not recommend leaving the CXC powered on at all times*** ⚠️⚠️

⚠️⚠️ ***This will cause LED degradation and reduce brightness over time*** ⚠️⚠️

- [Use a USB extender with power switch rated for data transfer](#)

Purchased Mar 2024	Overall Pick ⌄
Cable Matters 2 Pack USB On Off Switch 3 ft Support Data and Power, Short USB Extension Cable with On Off Switch (USB Power Switch) 4.4 ★★★★⯪ ⌄ 269 ratings $18⁹⁹ ($9.50/count)	Onvian USB Power Switch, 2-Pack USB On/Off Switch Cable Supply Data and Power, USB Switch Cable Male to Female Cable for PC, TV, Ca... 4.7 ★★★★⯪ ⌄ 222 ratings 100+ bought in past month $9⁹⁸ ($4.99/Count)

- [Usb a USB hub with individual power switches rated for data transfer](#)

Purchased Mar 2024	
SABRENT 4-Port USB 2.0 Data Hub with Individual LED lit Power Switches [Charging NOT Supported] for Mac & PC (HB-UMLS) 4.5 ★★★★⯪ ⌄ 122,189 ratings 200+ bought in past month $10⁹⁹ List: $19.99	SABRENT 4-Port USB 3.0 Hub with Individual LED Power Switches - Slim, Portable Design - 2 Ft Cable - Fast Data Transfer - Compatible with Ma... 4.6 ★★★★⯪ ⌄ 178,703 ratings 3K+ bought in past month $15⁹⁹ List: $19.99

- Programmatically control power using a tool called **uhubctl** and an approved, compatible USB hub. See the Github page for more info.

Purchased Mar 2024

Inateck USB Hub with 4 USB A Ports, USB 3.2 Gen 2 Speed, 1.6 ft Cable, HB2025A

4.5 ★★★★⯪ ⌄ 3,540 ratings
200+ bought in past month

$16⁹⁹ List: $21.99

Delivery **Mon**
Ships to Canada

This is an approved hub which works

Automated Calibration

Users wishing to attempt automation with machine vision can read the following links. Note that optical automation is not fool proof and requires additional setup time and effort. Therefore, we still suggest the camera-assisted manual method as the primary means for calibration.

- [TAMV Jubilee Wiki](#)
  - Contains information regarding setting up TAMV on Duet along with useful troubleshooting hints and guides

- [kTAMV for Klipper](#)
  - Contains information for setting up TAMV on Klipper

- [Visual Assisted Offset Calibration](#)
  - Similar to TAMV, all in Mainsail
  - Used on the RatRig machines

- The most common reasons for TAMV not working have to do with camera focus and nozzle height/distance to the camera lens. If you are having trouble with circle detection, play around with focus and nozzle distance to the CXC.

- We will be releasing Klipper plug-ins for camera-assisted manual calibration as well as guides and tutorials for setting up kTAMV soon

Custom Profile & Printer

For printers that do not work with the generic profiles, there are some important parameters in the software to explain. [For a spreadsheet of user tested and contributed printer parameters - see here](). If you need to modify parameters for your printer, we encourage you to comment in the spreadsheet, or reach out to us at [info@emberprototypes.com]() so we can keep track of this for our user base.

IDEX Settings	Non-IDEX (Dual) Settings
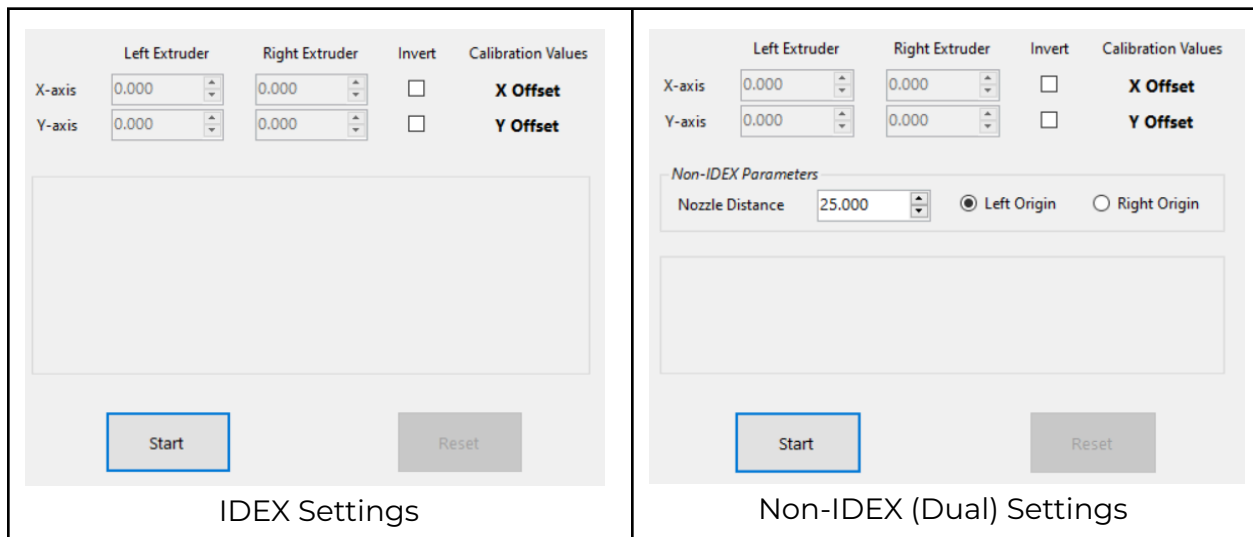
To understand the additional non-IDEX parameters observe the picture below (from the Snapmaker Artisan). The "Default Offset" refers to our physical "Nozzle Distance". This is the theoretical X offset between the nozzles. In many dual extrusion printers, the X Offset you enter into the machine follows a similar equation to the one below. In these instances the "Nozzle Distance" in our CXC software can be left at zero.

X Offset = Default Offset + △ (N × 0.08)

Y Offset = △ (N × 0.08)
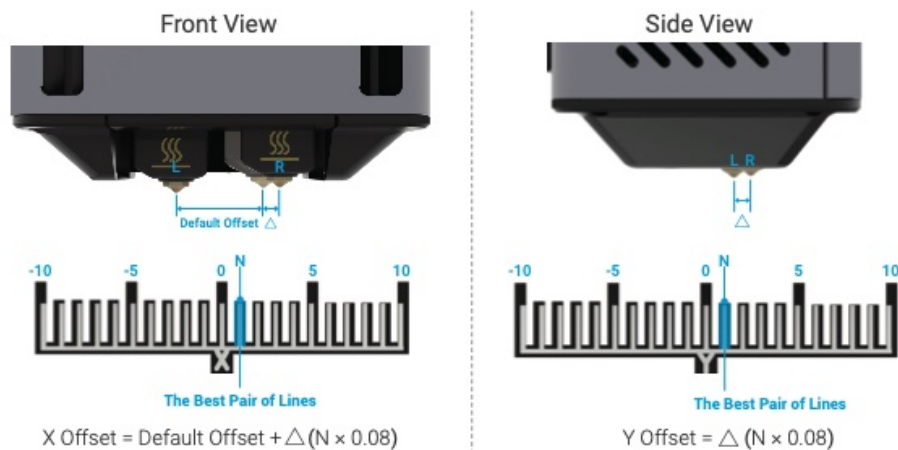
However, some printers remove the "Default Offset" or the "Nozzle Distance" from the offset before being entered into the printer settings. In these cases, the X Offset follows the formula below. For these printers, we need to know the "Default Offset" or the "Nozzle Distance" ahead of time so the CXC software can calculate the correct number to enter into the printer settings.

$$X \text{ Offset} = \triangle(N \times 0.08)$$

A detailed explanation of each parameter is documented in the table below. These descriptions are also present in the software as hoverable tool-tips.

Invert X-Axis	Inverts the calculated X offset.
	Some printers may want their entered offset to represent the actual, physical offset and will compensate the difference in firmware. Other printers may want the entered offset to represent the distance the machine needs to compensate for on all travels.
	For example, if the right extruder is +0.1mm relative to the left, some printers may expect an entered offset of +0.1mm and will subtract 0.1mm from all X moves. For other systems, the entered offset may need to be -0.1mm, indicating that X moves for the right extruder need to be compensated by this amount.
	This is off by default.
Invert Y-Axis	Inverts the calculated Y offset.
	Some printers may want their entered offset to represent the actual, physical offset and will compensate the difference in firmware. Other printers may want the entered offset to represent the distance the machine needs to compensate for on all travels.
	For example, if the right extruder is

	+0.1mm relative to the left, some printers may expect an entered offset of +0.1mm and will subtract 0.1mm from all Y moves. For other systems, the entered offset may need to be -0.1mm, indicating that Y moves for the right extruder need to be compensated by this amount. This is off by default.
Nozzle Distance	Used in the offset calculations for dual extruder machines, this is ignored for IDEX printers. This value is commonly found in the slicer, user manual, or through technical support. Some machines require removing the nozzle distance from the entered offset. For example, if the right nozzle is +0.2mm relative to the left and has a 25mm nozzle distance, some printers may expect +0.2mm as the entered offset, while others require entering +25.2mm which includes the nozzle distance. For the latter scenario, leave the "Physical Offset" value at 0.
Left Origin	Select this if your machine's origin is on the left side (ie. moving left is a negative value while moving right is a positive value). This does not necessarily correspond with the physical home location of the extruders and is driven by the machine coordinates. This is used to determine whether the nozzle distance should be subtracted or added during the offset calculations.

	Left Origin is typically the default on most machines.
Right Origin	Select this if your machine's origin is on the right side (ie. moving left is a positive value while moving right is a negative value). This does not necessarily correspond with the physical home location of the extruders and is driven by the machine coordinates. This is used to determine whether the nozzle distance should be subtracted or added during the offset calculations. Left Origin is typically the default on most machines.

Verification

There are many ways to verify XY offset calibrations. We prefer to print a calibration cube rather than line patterns, as the latter are fragile and not 100% representative of a real multi-material or multi-color print.

- [Calibration Cube - Left Extruder](#)
- [Calibration Cube - Right Extruder](#)

If you do want to run a line pattern, we have a custom line pattern that you can use to run your verification. You are also welcome to use your own, or run the built-in calibration routine if your printer has one. We suggest printing ours with 125% flow, at a slow speed like 20mm/s.

- [Line Pattern - Left Extruder](#)
- [Line Pattern - Right Extruder](#)

Both of these files are only necessary for the first time you are calibrating and getting familiar with the process. You may need to re-run these if you have to change parameters like offset inversion.

Troubleshooting

Issue	Resolution
Offset values do not match real life observations from verification prints	Below are some common reasons why your offset values may be incorrect. You did not clear existing XY offset values from your printer and the machine is using these values to compensate for moves performed during calibration. You did not home the gantry after clearing existing XY offsets and the machine is using the previous offsets. Your CXC moved during calibration. Instead of moving the right extruder directly to the absolute location of the left extruder, you incrementally stepped the extruder over. This can stackup error and should be avoided. Your machine is expecting inverted offset values. See the explanation in the [Custom Profile & Printer](#) section. You may not have the correct nozzle distance or origin type specified. See the explanation in the [Custom Profile & Printer](#) section.

Re-running calibration is giving different offset values.	If calibration is done correctly, you should be able to obtain the same XY offset values repeatably.

You have existing XY offset values or you the values are different from what they were the last time you calibrated.

You did not home the gantry after modifying offsets, but you did home the gantry after modifying offsets the following time.

Your CXC moved during calibration.

Order of operations is critical during calibration - homing must always occur after changing of XY offset calibration values. |
| Software is not installing | The software setup downloads and installs published files from our Github page. This is required for auto update to function. Therefore when you run "setup.exe" it requires an internet connection. If you need to install the software on an offline computer run the ".application" file instead. Once your machine is online again it will be able to auto update. If your machine is always offline, auto updates will not work and you will need to update the software manually upon software releases. |

For further troubleshooting or questions not answered in this document, contact us at **info@emberprototypes.com**