

The MX2 is designed to be extremely simple to use, and to let you quickly input the most important parameters during a shoot. This document describes the means of interacting with the controller through the user interface, and how to use the main control screen.

## Buttons

There are five pushbuttons, four arranged in a cross-pattern, and one to the lower left. The four buttons together are [Left], [Right], [Up] and [Down] while the button to the lower left is the [Enter] button.

Enter:

- Brings up the main menu, or selects a menu item.
  - If item is another menu, that menu will be opened, otherwise the value selected will be shown for editing, or executed depending on the currently selected item.
- Saves the current value being edited
- Exits manual motor control

Up:

- Selects the menu item directly above
- Increases the value of the currently selected item
- Increases motor speed (manual motor control)

Down:

- Selects the menu item directly below
- Decreases the value of the currently selected item

- Decreases motor speed (manual motor control)

Left:

- Moves input selection left (main screen only)
- Moves current motor left (manual motor control)

Right:

- Moves input selection right (main screen only)
- Cancels value input (when changing the value of a selected item)
- Moves current motor right (manual motor control)

## Menus and Editing Values

When on the Main Screen, pressing the Enter button will draw the main menu. Pressing [Enter] on any menu item will either draw the sub-menu selected or, if the item selected is an input, it will be displayed for editing. When a value for editing is displayed, you may use [Up] and [Down] to alter the value. If you wish to save the value, simply press [Enter] again. To exit the editor without saving, press the [Right] button and the original value will be restored. The [Right] button also functions as the “back” button, allowing one to go back one level from any menu, or return to the Main Screen from the top-level menu.

For some values that you can edit, a limited selection of choices such as ‘Up/Down’, ‘On/Off’, ‘Left/Right’ may be displayed. Pressing either [Up] or [Down] in the edit screen will alternate between the available values. For some values, you may be allowed to enter more or less

than the value accepts — when saving in these cases the value will be set at its minimum or maximum, and will reflect this when next displayed.

To increase or decrease a number, you can simply hold [Up] or [Down] to continue to increase or decrease the value for as long as you hold it down. The longer the button is held, the faster it increases or decreases a value. In this manner, you may easily enter large numbers.

## Saving Input Values Permanently

When editing certain values (such as RPM for a motor axis, interval time, etc.) they are automatically saved to permanent memory for you. In this way, you will not have to make the same changes between re-start. The values which are saved permanently are indicated in their appropriate documentation. To wipe out permanent memory, and reset to default values, choose the 'Reset Mem' option in the Main Settings menu.

Please note that direction and speed of a given axis are designed to be changed regularly, and are not saved to permanent memory.

## The Main Screen

The Main Screen provides an overview of the current status and also allows for quick modification of key operating parameters. This screen has the following layout:

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**On 3s            [15]**

**R30.50% L0.00%**

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On the first line we have the current status (On or Off), the intervalometer timing (3s), and a count of shots fired since turned on ([15]). The second line displays the direction and speed for each motor, with motor 1 on the left, and motor 2 on the right.

Pressing [Right] will advance through the values that can be changed directly from the main screen: status, timing, direction and speed of each motor. When a particular value is displayed with a flashing cursor on it, you can change the value using [Up] and [Down].

**Notes:**

- You may change any value when the shoot is running — it will take effect immediately.
- Motor speed can be displayed in either percentage (%), inches-per-minute (i), or cm-per-minute (c) this is configurable in the Settings menu.
- Pressing [Left] will back up one setting on the screen
- Pressing [Enter] at any time when on the main screen will bring up the Main Menu, even if program is running

With the MX2 controller, you can either display and input speeds in percentages of maximum (relative) or inches per minute (absolute).

The speed display setting is global, and impacts all axes. You may not configure one for relative and one for absolute speed display.

If you modify the speed for a given axis while the program is running, it will immediately take effect.

## Displaying in Relative Speeds (Percentage)

When displaying in relative speeds, the main screen will show a floating-point number and the symbol '%' on the speed value for the given motor. You may modify this value to any value between 0 and 100% as allowed by the motion control mode you are in by highlighting it using the [Right] button on the main screen and then using [Up] and [Down] to change the value.

### To set the MX2 to display relative speeds:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Motor Disp.** and press [Enter]
4. [Up] or [Down] and choose **PCT**
5. [Enter] to save or [Right] to abort

## Displaying in Absolute Speeds (inches or cm)

When displaying in absolute speeds, the main screen will show a floating-point number and the symbol 'i' (or 'c' if in metric mode) next to the the speed value for the given motor. You may modify this value to any value as allowed by the motion control mode you are in by highlighting it using the [Right] button on the main screen and then using [Up] and [Down] to change the value.

### To set the MX2 to display absolute speeds:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Motor Disp.** and press [Enter]
4. [Up] or [Down] and choose **IPM**
5. [Enter] to save or [Right] to abort

## Displaying in Metric Values

The MX2 can shows absolute distances and speeds in centimeters. When you enable the *metric mode* parameter, all distance values stored in permanent memory are converted from inches to centimeters, and the display will show a ‘c’ on the main screen instead of ‘i’ for absolute speeds.

You should always re-start the MX2 after enabling the *metric mode* parameter.

### To set the MX2 to display metric values:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Metric Disp.** and press [Enter]
4. [Up] or [Down] and choose **On**
5. [Enter] to save or [Right] to abort
6. Power off the MX2 and power back on

The MX2 controller comes with the ability to control the LCD display to reduce power consumption or light pollution onto your shots at night. The standard LCD for the MX2 is a 16×2 character black on green LCD display. This LCD can easily be read during bright daylight without the backlight on and at night with very little backlight.

## Adjusting the BackLight Brightness

The backlight brightness can be dimmed by the MX2 firmware, but only when in *interleaved* motion mode. If you have turned on *continuous* motion mode, and run an axis below the defined *slow speed threshold*, the backlight dimmer will not work until the MX2 is re-started. When you have engaged in *continuous* motion at a speed under the *slow speed threshold*, the LCD will either be fully on or fully off depending on your LCD backlight settings.

You can set a value between 0 and 255 for the *backlight level*. If you enter a value larger than 255, it will automatically be limited to 255.

Like most values in the MX2 controller, the *backlight level* value is retained after power-off.

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Backlight** and press [Enter]
4. [Up] or [Down] to adjust the backlight level value
5. [Enter] to save or [Right] to abort

## Turning the LCD BackLight Off Automatically

You may wish to have the backlight on while entering values, but then to turn off automatically a few seconds later to reduce the power drain on your batteries. You can configure the MX2 to turn off the backlight after a number of seconds of inactivity by adjusting the *auto dim* parameter. The backlight will turn back on the next time a button is pressed.

Enter the *auto dim* parameter value in seconds of inactivity before the backlight turns off, set it to zero if you wish to disable automatic dimming of the LCD backlight.

Like most values in the MX2 controller, the *auto dim* value is retained after power-off.

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **AutoDim** and press [Enter]
4. [Up] or [Down] to adjust the auto dim value
5. [Enter] to save or [Right] to abort

## Disabling the Entire LCD Automatically

To save as much power as possible, the MX2 can completely disable the LCD, turning off the text in addition to the backlight. To enable this feature, enable the *blank lcd* parameter in addition to setting an *auto dim* time. When *blank lcd* is enabled, the LCD is turned off entirely after the number of seconds specified in the *auto dim* parameter value pass with no input via the buttons.

After the LCD has been blanked, the first button you press will simply re-enable the LCD to allow you to verify where you were on the screen before submitting a button press and taking an unknown action.

Like most values in the MX2 controller, the *blank lcd* value is retained after power-off.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Blank LCD** and press [Enter]
4. [Up] or [Down] to select **on** or **off**
5. [Enter] to save or [Right] to abort

The MX2 controller provides direct control of a camera through a cable connected to the remote release port of your camera. On most cameras, there are two primary functions provided: Control Shutter and Control Auto Focus. Here we'll describe how to set up the MX2 to handle different shooting requirements.

Remember that for the camera to be controlled by the MX2, the camera must be connected through its remote shutter port to the MX2 Camera port using an appropriate cable. For some cameras, it may be required to put the camera in Remote Control mode to recognize the signals from the remote shutter port.

All parameters indicated below are saved when the power is removed from the MX2, and only need to be modified when you want to change them.

## Setting the Exposure Interval

The *exposure interval* is the time between each exposure. This value is displayed on the Main Screen, and may be set in tenths of seconds (e.g. 0.2", 1.1", and so forth). It can be edited directly on the main screen, or through the Camera Menu.

Note that the *exposure interval* is the time between *triggering* each exposure, and not necessarily the time between completing one exposure and starting the next. The different camera delays you configure, for focus tapping, exposure delay, etc. will impact your actual *exposure interval* time, should they be longer than the interval when summed. In the case where your parameters have caused the interval time to be exceeded, the main screen will always display the *actual* interval time, and not the time you configured. It will not be possible to reduce the interval without first decreasing one of the other camera delays you have configured.

If you change the *exposure interval* while the program is running, it will take effect on the next exposure cycle.

Like most values in the MX2 controller, the *Exposure Interval* value is retained after power-off.

### **Setting the Exposure Interval via the Main Screen:**

1. [Right] or [Left] to select the displayed interval time
2. [Up] or [Down] to modify the value

### **Setting the Exposure Interval via the Camera Menu:**

1. [Enter] to enter the main menu
2. [Down] to select **Camera** and press [Enter]
3. [Down] to select **Interval** and press [Enter]
4. [Up] or [Down] to alter the value
5. [Enter] to save or [Right] to abort

## Controlling Exposure Time with the MX2

The MX2 controller is capable of doing bulb exposure control. The shutter line will be kept engaged for as long as the *exposure time* parameter is configured for. The exposure time is entered in milliseconds, and may be set for as low as your camera will recognize, or up to about 50 days. Remember that there are one thousand milliseconds in a second, so if you want a one second exposure, it would be entered as 1000.

Please note that different cameras have different *exposure time* requirements for bulb mode, both minimum and maximum time. If you need a controlled exposure for a shorter period of time than your camera will allow in bulb mode, you must use the camera to control the exposure in using its manual mode. You may need to experiment to discover the correct minimums and maximums for your particular camera.

### **Actions:**

1. Set camera to bulb (B) mode
2. [Enter] to enter the main menu
3. [Down] to select **Camera** and press [Enter]
4. [Down] to select **Exp. Time** and press [Enter]
5. [Up] or [Down] to alter the value

6. [Enter] to save or [Right] to abort
7. [Down] to select **Exp. Delay** and press [Enter]
8. [Up] or [Down] to set the value to **0**
9. [Enter] to save or [Right] to abort

## Controlling Exposure Time on the Camera

For most cases, you'll find it best to control the exposure on the camera, using manual, or some other mode to dial in the appropriate exposure time. Under certain conditions it will be important to tell the MX2 the actual exposure time you've dialed in on the camera, so that it does not attempt to trigger an exposure at the wrong time. The amount of time to wait after triggering an exposure is configured via the *exposure delay* value. This value is input in milliseconds, so one second would be entered as *1000*.

To disable any delay after triggering an exposure, set the *exposure delay* value to zero.

For *continuous motion* control, it is generally not necessary to set an exact *exposure delay* in the MX2 unless it exceeds your configured interval time. However, for *interleaved*, or shoot-move-shoot, motion control, it is essential to dial in the correct exposure time to prevent motor movement during the exposure. In many cases, it is advantageous to exceed the actual exposure time configured on the camera in the *exposure delay* parameter.

Additionally, you should configure the *exposure time* to its minimal value to prevent unnecessary delays. Each camera may have a different minimum *exposure time* required to honor the request to trip the shutter. For many cameras 100mS is a safe bet.

*Exposure time must always be greater than zero* to trigger the camera.

1. Set camera to manual (M) mode

2. Dial in the correct exposure on the camera
3. [Enter] to enter the main menu
4. [Down] to select **Camera** and press [Enter]
5. [Down] to select **Exp. Time** and press [Enter]
6. [Up] or [Down] to set the value to the minimum time for your camera
7. [Enter] to save or [Right] to abort
8. [Down] to select **Exp. Delay** and press [Enter]
9. [Up] or [Down] to set the value
10. [Enter] to save or [Right] to abort

## Limits the Number of Frames Taken

The MX2 can automatically stop running when a certain number of frames have been exposed. Simply set the *max shots* parameter for the camera.

Note that when ramping/feathering moves, setting the *max shots* parameter tells the MX2 when to start ramping down.

Like most values in the MX2 controller, the *Max Shots* value is retained after power-off.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Camera** and press [Enter]
3. [Down] to select **Max Shots** and press [Enter]
4. [Up] or [Down] to alter the value
5. [Enter] to save or [Right] to abort

# Auto-Focus, Waking the Camera from Sleep, and Shooting in Live View

For certain conditions, the focus control line can be used to control other aspects of the camera:

- Trip auto-focus before firing
- On long interval times, put the camera into auto-sleep mode and use the focus line to wake it up before firing
- For some live-view cameras, the camera may not respond to the first time the exposure is tripped unless the focus line is tripped first

The *focus tap* parameter allows you to define how long the focus line should be triggered before the exposure line is triggered. This time is input in milliseconds, and there will always be an additional 1/10th second (100mS) delay after disengaging the focus line before the exposure line will engage to prevent a bouncing effect being perceived by the camera.

It is important to set this value to the right amount required for your particular camera configuration. Some cameras focus slower than others, or require more time to wake up than others, and will require that the *focus tap* value be much higher. Experiment with your camera and shooting conditions to determine which works best for you.

To disable the focus tap functionality, set the time to zero (0) milliseconds.

Like most values in the MX2 controller, the *Focus Tap Time* value is retained after power-off.

## **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Camera** and press [Enter]

3. [Down] to select **Focus Tap** and press [Enter]
4. [Up] or [Down] to alter the value
5. [Enter] to save or [Right] to abort

## Cameras that Require Focus with Shutter (many Nikons)

The MX2 is capable of controlling cameras that require that the focus line be triggered along with the shutter line to trigger an exposure. Many Nikon cameras require this, and some Canon users also report that their cameras respond more reliably when the two lines are triggered together. The *shutter-focus* parameter allows you to control this behavior.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Camera** and press [Enter]
3. [Down] to select **Shutter+Focus** and press [Enter]
4. [Up] or [Down] to set the value to **on** or **off**
5. [Enter] to save or [Right] to abort

The two basic motion control modes for the MX2 controller are *Continuous Motion* and *Interleaved*. (Also known as *Shoot-Move-Shoot*.) In Continuous Motion mode, the motor moves irrespective of the camera being fired, and generally at a consistent speed. In Interleaved mode, the motor only moves between exposures. These two motion control modes can result in different aesthetics in your output video, and each are best geared to a specific type of shooting. The following table will help to summarize the best way to choose

between the two motion types based on the parameters of your shot, or the effect you wish to achieve:

Description	Continuous s	Interleaved	Notes
<i>Moderate Speed, Short Exposure</i>	X		Can add a small amount of motion blur, and is easier to set up
<i>Long Exposure</i>	X		If camera controls exposure, dial-in post exp. delay in MX2
<i>Very Slow Speeds</i>	X		Used Fixed SMS to achieve motion over hours or days
<i>Static Subjects, Medium Exposure</i>	X		Adds nice motion blur to otherwise static subjects

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<i>Static Subjects</i>	X	Set longest exposure time
<i>Sharp, Moving</i>		achievable
<i>Subjects Blurred</i>		
<i>Star Scenes</i>	X	If moving with stars, cont. can help prevent streaking, but will reduce foreground focus on very long exposures

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<i>Critical Focus,</i>	X	Prevent movement when
<i>Macro, or Long</i>		exposing

*Lens*

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Now, many photographers will use a particular mode more often than another, as a matter of taste or artistic intent. While the table above attempts to serve as a guide to when to choose between the modes, your workflow or shooting style may call for a specified mode that is in contradiction with the table. Every one is unique, and their style is their own — you should practice with each mode and understand which is right for you.

You may only choose one motion type at a time, it is not possible to run one axis in *continuous motion* and another in *interleaved*.

## Using Continuous Motion

The default behavior of the MX2 controller is to operate in *continuous motion* mode. For the highest end of the speed range, the control acts as a basic *Pulse Width Modulation* driver, varying the speed of the motor by changing the frequency at which voltage is applied to it. However, once the speed falls below the configured slow speed floor, a special “pulsing” mode kicks in. In *pulsing* mode, the motor is run at full speed for a brief period of time, usually on the order of milliseconds, and then shut down for a period of time. This causes the motor to operate at full torque at absolute minimum speeds. While the motor is only moving part of the time, the measured average speed over a period of time should largely approximate the inches per minute (or percentage of speed) specified.

In all *continuous motion* modes, you are able to choose from any one of 255 different speeds, from completely stopped to moving at full speed. As each change to the speed is a 1/255th speed change, speeds will appear to make larger jumps when being entered on the main screen than you might expect.

At the very slowest speeds, it is generally preferable to move to *interleaved* mode, because the added vibration of the long pulses on the motor.

To enable *Continuous Motion* mode:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Motor SI.Mod.** and press [Enter]
4. [Up] or [Down] and choose **pulse**

5. [Enter] to save or [Right] to abort

## Using Interleaved Motion

There are two types of *interleaved* motion control available on the MX2: *Calculated* and *Fixed*.

### Calculated Interleave Mode

In *calculated* mode, you input the distance moved in actual speed (inches or cm per minute), and the distance moved between each shot is determined based off of the *exposure interval* you input. For example, if you input 1 inch per minute as your speed, and your interval is set to 1 second, the axis would move 1/60th of an inch between each shot. This mode is used when you want to easily determine how fast you want to move from one point to another on the axis, and generally requires little forethought to set up a shot.

You may input values from 1/100th of an inch (or cm if in metric mode) to the maximum distance the motor can move in one minute.

To enable *Calculated Interleave* Mode:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Motor SI.Mod.** and press [Enter]
4. [Up] or [Down] and choose ***interleave***
5. [Enter] to save or [Right] to abort
6. [Right] to return to the main menu
7. [Down] to select **Axis x** and press [Enter]

8. [Down] to select **Fixed SMS** and press [Enter]
9. [Up] or [Down] and choose **Off**
10. [Enter] to save or [Right] to abort

## Fixed Interleave Mode

In *fixed* mode, you input the distance moved as *actual distance traveled* between each exposure. You may input values from 1/100th of an inch (or cm if in metric mode) to the maximum distance the motor can move in one minute. This mode is used when you want to accurately dial-in distances moved between exposures, or achieve very smooth ramp (feather) transitions. This is generally the preferred motion control method for extreme close-up shots and anything using a long telephoto lens to both prevent vibration during exposure and the accurately define motion from frame to frame.

To enable *Fixed Interleave* Mode:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Motor SI.Mod.** and press [Enter]
4. [Up] or [Down] and choose **interleave**
5. [Enter] to save or [Right] to abort
6. [Right] to return to the main menu
7. [Down] to select **Axis x** and press [Enter]
8. [Down] to select **Fixed SMS** and press [Enter]
9. [Up] or [Down] and choose **On**

10. [Enter] to save or [Right] to abort

Manual Motor Control can be used to position the cart on the rail between moves. Please note, however, that for very quick re-positioning of the cart, it is usually fastest to simply loosen one belt clip on the rail, pull the belt away from the pulley, and position the cart by hand.

## Using Manual Control

While on the *manual control* screen, you can use [Up] and [Down] to adjust the speed of the motor, up to its max speed, and by holding [Left] or [Right] down, the motor will move in the given direction at the specified speed until the button is released. To exit the *manual control* screen, press [Enter].

Note that in *manual control* mode, the available speeds at which the cart will move will range from about 80% to 100% of full speed, at lower speeds the cart may not move.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Manual** and press [Enter]
3. [Up] or [Down] to select the desired axis, and press [Enter]
4. [Up] or [Down] to set the desired speed
5. Hold [Right] or [Left] to move in the desired direction
6. [Enter] to exit the manual control screen
7. [Right] to return to the main menu

The MX2 controller can “feather” or ramp into and out of moves causing moves to start slowly and get faster within the video, providing a nice accelerating or decelerating effect. It does this by altering the distance moved between shots, or the speed moved, starting with no speed and ramping up to your desired speed over a configurable number of frames. Additionally, a lead-in or lead-out can be used to add a static period before or after a motor’s movements, adding to your ability to create the shot you want.

Ramp settings for a particular axis are saved between power-off cycles.

## Configuring Ramping

A ramp into or out of a movement is done by changing the speed or distance moved based on the number of frames that have been exposed. For example, I can set the *ramp value* for an axis to 24 frames, and at 24FPS output video it would take one second for the motion in the output video to come to full speed. This is achieved by starting the motor at no speed, and then increasing the speed just enough to match the desired output speed at the right interval to reach full speed at the desired frame as specified in the ramp value.

If you also configure the *max shots* parameter for the camera, the MX2 will automatically ramp down the motor to zero speed so that motion completes when the *max shots* count is reached. See [Configuring Camera Control](#).

Note that in *continuous motion* mode, you only have 255 speed increments available, this means that ramps into low speeds (1-10% of maximum speed) can be rough. To get

extremely smooth ramps, it's best to choose *fixed interleave* mode. See [Choosing Your Motion Mode](#) for more information.

To understand how ramping will affect your output video, take the following parameter values:

- Output video = 24 frames per second
- Max shots = 240 (10 seconds)
- Ramp rate = 24
- Axis speed = 1 inch per minute

The following will happen in the output video:

- For one second, the motion will accelerate to full speed
- For eight seconds, the motion will run at full speed (1 IPM)
- For one second, the motor will decelerate to no speed

This illustrates how ramping is achieved and the end result in your output video.

The *ramp value* for each axis is controlled independently.

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Ramp** and press [Enter]
4. [Up] or [Down] to input the number of frames to reach full speed
5. [Enter] to save or [Right] to abort without saving

6. [Right] to return to the main menu
7. [Right] to return to the main screen
8. [Right] as many times needed to select the desired axis speed
9. [Up] and [Down] to adjust the desired speed
10. [Left] to the On/Off control
11. [Up] to start the program running

Once the program starts running, the speed will set its self to zero for any axis with a ramp value configured. If you stop the program running before it reaches full speed, it will now see the current speed as the desired speed, and you will have to increase it back to your original value.

## Using a Lead-in or Lead-out

A *lead-in* defines a period of time, in frames from the beginning of the shoot, that the motor should not move. Conversely, a *lead-out* defines the period of time from the end of the shoot that the motor should not move. Each axis can have its own lead-in and lead-out times defined — however, to function, a *ramp value* must be set for that axis as well. Leads are executed through the ramping/feathering function of the controller, by simply preventing it from starting a ramp before a certain number of frames have passed (in the case of a lead-in), or reducing the overall number of frames counted before ramping all the way down to zero (in the case of a lead-out).

As with ramping/feathering, a lead-out is only used if the *max shots* parameter has been set, and therefor the controller can determine when to start reducing speed.

To help clarify this function, we'll use the same parameters from the ramping example, and add a lead-in and lead-out:

take the following parameter values:

- Output video = 24 frames per second
- Max shots = 240 (10 seconds)
- Ramp rate = 24
- Lead-in = 24
- Lead-out = 24
- Axis speed = 1 inch per minute

The following will happen in the output video:

- For one second, no movement will occur
- For one second, the motion will accelerate to full speed
- For seconds seconds, the motion will run at full speed (1 IPM)
- For one second, the motor will decelerate to no speed
- For one second, no movement will occur

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Lead-in** or **Lead-out** and press [Enter]
4. [Up] or [Down] to input the number of frames to lead in or out with

5. [Enter] to save or [Right] to abort without saving

The MX2 controller comes pre-calibrated for a load of approximately 1.5kg (~ 3.5 lbs). This is the weight of a medium sized dSLR, zoom lens, and small ball head.

Calibrating is not essential to make use of the MX2 with the Stage Zero Dolly for timelapse use, however it can greatly increase the accuracy of specific distances you dial in when entering values in inches per minute. As the Stage Zero dolly's motor does not have feedback to the controller, the controller can only tell the motor to move at certain speeds and at certain times. Calibrating the controller allows you to adjust the controller for variations in how the motor behaves under different loads and at different speeds.

Calibration of the motor is saved when the MX2 is powered off, so you only need to re-calibrate when your payload (camera/lens/head/etc.) changes in weight significantly. If you swap out motors or pulleys, it is important to perform a calibration as well, after adjusting the motor parameters to match your new combination.

*Please note that it is impossible for the MX2 to make all speeds accurate at all times. The calibration routine will allow you to dial-in one or two specific speeds more accurately than others, but as a low-cost system, perfect accuracy is not achievable.*

## Adjusting the Angle of the Dolly

When operating the dolly at an angle, and using Inches Per Minute (IPM) speed input, you will want to inform the controller of the nearest angle of the track so that it can adjust based on the calibration for that angle. You may set the angle of the dolly (or any other linear axis) in

the Axis Configuration menu for the given axis. Three angle values are possible: 0, 45, and 90. The 0degree angle corresponds to the dolly being largely in parallel to the ground, 45 degrees corresponds to the track being at a 45-degree angle to the ground, and 90 degrees to being perpendicular to the ground. You should pick the angle closest to the one you are at, and when in doubt, err on the side of setting the angle higher.

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Angle** and press [Enter]
4. [Up] or [Down] and choose between 0, 45, and 90
5. [Enter] to save or [Right] to abort

## Using Automatic Calibration

Automatic calibration mode adjusts the assumptions the controller makes about the motor's performance. By moving at different speeds, in different modes, and in different directions the controller expects the cart to have moved a certain distance. During automatic calibration, you will measure the distance the cart has moved at each stage, and in doing so the controller will automatically adjust its expectations of the motor's performance at critical speeds.

You may calibrate the controller for each of the specified angles: 0, 45, and 90 degrees. Each angle must be calibrated separately, but each time you calibrate, the calibration will be saved

and you will not have to repeat it unless your payload substantially changes, or you change out the motor or main drive pulley.

To use automatic calibration, first move the dolly to the middle of the track, either through manual motor control or by loosening the belt and moving it by hand and then make sure that the belt is tightened fully before beginning. Now, place a ruler flat on the track in a position where neither the angle mounts nor the stabilizer bar will hit it, and line the edge of the ruler up with one of the edges of the cart. The cart will be moving to the right at first, so let the ruler stick out in that direction. For 45 degree and higher angles, it is worthwhile to tape down the ruler.

After selecting the angle you want to calibrate for and pressing [Enter], the cart will first move quickly to the right, and ask you to enter how far it went in hundredths of an inch. (Don't worry, just getting it close enough in tenths is good enough for most uses.) Enter the value using the up and down arrow keys and press enter to move to the next step. The cart will then move to the left and repeat the process, before going into two pulsing mode speed tests. The entire process should take around 3-4 minutes.

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Calibrate** and press [Enter]
4. [Up] or [Down] and choose between 0, 45, and 90 degree calibration modes
5. [Enter] to start the calibration process, or [Right] to exit without calibrating

6. After the move is completed, use [Up] and [Down] to input the distance moved in inches
7. Press [Enter] to save the value you input and repeat five more times
8. After all calibration steps have been completed, use [Right] to exit the calibration screen

**Notes:**

- After a new calibration, you will need to adjust the *Calibration Constant Value*, which is documented below to finely tune in the calibration
- If you are using your own motor/gear chain with the MX2, and the calibration does not appear to move at all, adjust the low and high speed targets as indicated below

## Adjusting Calibration

The MX2's calibration routine attempts to determine how much to adjust the on time of the motor based on its performance at default values. However, most motors behave non-linearly when adjusting their speed by changing the on time. This means that simply adjusting the on/off time alone is not enough to accurately dial in a speed that was off from the expected target. Usually, it results in the motor going much slower than expected for low speeds, as the non-linearity of the motor's behavior increases at the lowest speeds.

To compensate for this, a *calibration constant* was introduced in the 0.83 version of the MX2 firmware. This allows you to configure how much of the calibration change is actually applied during run time calculations. Generally speaking, if the motor still runs too slow after

calibration, the constant should be reduced, and if it runs too fast the constant should be increased.

The workflow for finely tuning in a particular speed is as follows:

1. Set either the low or high speed target to the desired speed (see below)
2. Run the auto calibration
3. Set *max shots* to 60
4. Set *interval* to 1, disable all focus and post-exposure delays
5. Set the desired axis to the desired angle
6. Set the desired axis to the desired continuous speed on the main screen
7. Turn the program on, and measure actual distance traveled
8. Adjust calibration constant
9. Repeat 7-8 until the speed is tightly dialed-in

#### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Cal. Constant** and press [Enter]
4. [Up] or [Down] and adjust the value as desired
5. [Enter] to save the value, or [Right] to exit without saving

## Setting the Calibration Targets

When you want to dial-in one or two speeds to be your most accurate, you should choose the speeds you use most. To adjust the speeds used in calibration, you will need to adjust the low and *high calibration targets* to the speeds you desire.

These values are set in the *Main Settings* menu.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Cal. Spd. Low** or **Cal Spd. Hi** and press [Enter]
4. [Up] or [Down] and choose the target speed
5. [Enter] to save the new value
6. Repeat calibration process as indicated above

Like most values in the MX2 controller, the *Calibration Speed Targets* are retained after power-off.

### **Important Notes:**

- The Low speed target *must* be lower than the High speed target
- You must re-calibrate after changing the targets

## Adjusting for Very Heavy Weights or Weak Motors

If you're using the Stage Zero with a large camera/motion control payload, or are using the MX2 with a DIY rig with a smaller motor, you may need to adjust the minimum pulse time to give the motor enough time to get the cart moving at the lowest speeds. A larger minimum pulse time can make movements at low speeds rougher, so you generally want to keep it as low as possible, while still being able to start moving the cart forward at the lowest speed.

Like most values in the MX2 controller, the Minimum Pulse value is retained after power-off.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Min Pulse** and press [Enter]
4. [Up] and [Down] to adjust the minimum pulse time
5. [Enter] to save or [Right] to exit without saving

Stop-Motion and Timelapse have slightly a different workflow, namely in that in timelapse you want your exposures to continue uninterrupted, on your set interval, for a period of time. Whereas, in stop-motion filming, you want to control when each exposure occurs so that you may make set adjustments or take other actions between exposures. The MX2 supports both of these workflows easily.

## Enabling Manual Triggering of Exposure and Motion

In stop-motion, we want to take one exposure and make one move at-will, and have plenty of time to do what we need to do between exposures. To achieve this, we'll cause the MX2 to abort its program after a single shot, and we'll use [\*Fixed Interleave motion control\*](#) to establish our exact distance moved between shots. If we set the *maximum shot count* to 1 for the camera, when the MX2 is told to turn motion on, it will expose one frame make its required move and stop until it is turned on again.

### **Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Camera** and press [Enter]
3. [Down] to select **Max Shots** and press [Enter]
4. [Up] or [Down] and input a value of **1**
5. [Enter] to save or [Right] to abort
6. [Right] to return to the main menu
7. [Right] to return to the home screen

You should also be in the [\*Fixed Interleave\*](#) motion mode before beginning. On the main screen, input the desired distance to be moved between each shot, and then use [Left] to bring the cursor back to the *On/Off* value. Pressing [Up] will cause the MX2 to start running, fire a single shot, move, and then stop running. To fire the next frame, simply press [Up] again, and so forth.

If need be, you may also fashion a remote switch, connected to port *Ext 1*, and use this as a remote trigger to start the next exposure cycle. For more information see [Using Remote Inputs](#).

Most of the motor parameters in the MX2 will never need to be modified if you are using the Stage Zero dolly in the stock configuration. These parameters are largely designed to adjust distance values listed on the main screen when you input movement in inches per minute.

The MX2 controller displays inches per minute for linear axes by relating the maximum RPM of the motor to the distance traveled by the final drive gear. If you're using a pulley or gear as a final output drive (such as for a belt-driven system like the Stage Zero, or a rack-and-pinion driven system), the distance traveled is generally the pitch circumference of the gear. As these values effect the displayed distances for movements, you should only adjust them when changing something in the drivetrain. For calibrating different performance under different loads, you should [calibrate the axis](#) instead.

## Setting Motor RPM

This setting allows you to input the Revolutions Per Minute of the motor you are controlling. This aids in determining the max speed of the motor. If you have multiple gear transitions after the motor its self, make sure to account for them in the RPM. For example, if you have a 2:1 transition from the motor output shaft to your drive gear, you would reduce RPM by one half.

Do not use this setting to adjust performance of the motor under load! [Calibrate the axis](#) instead.

Like most settings, the value is stored when powering off, and only needs to be changed when you change motors.

**Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **RPM** and press [Enter]
4. [Up] or [Down] to input the correct RPM for your motor
5. [Enter] to save or [Right] to abort without saving

## Setting Output Drive Distance

To allow you to enter speeds and distances in actual distance, versus percentages, the MX2 must be aware of the actual distance moved per revolution of the motor. For most linear axes, the actual distance traveled will be based on the pitch circumference of the final output gear — for example: the pitch circumference of a drive pulley or the pitch circumference of a pinion on a rack-and-pinion drive.

Like most settings, the value is stored when powering off, and only needs to be changed when you change motors.

**Actions:**

1. [Enter] to enter the main menu
2. [Down] to select **Axis x** and press [Enter]
3. [Down] to select **Dist. per Rev.** and press [Enter]
4. [Up] or [Down] to input the correct pitch circumference (in inches) for your output gear
5. [Enter] to save or [Right] to abort without saving

Sometimes it happens to the best of us: we get a little carried away and then we have no idea what setting we messed up, or how, and we just want to get everything back to where we started. The MX2 saves most of the values you enter into permanent memory, reducing the amount of data entry you have to do for subsequent shoots, and letting you store calibration and so forth. There is a factory reset option which resets this permanent memory to its default state so that you can wipe all changes clean.

Resetting the permanent memory requires a restart of the MX2 controller, and it may take longer than normal to restart the first time after resetting the memory.

You should always reset the permanent memory after doing any firmware upgrade. Retaining memory after an upgrade can result in some values that cannot be modified.

## Resetting Stored Memory to Defaults

To reset the permanent memory on the MX2, you will need to first enable the *factory reset* parameter, and then restart the MX2.

### Actions:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Reset Mem** and press [Enter]
4. [Up] or [Down] and choose **on**
5. [Enter] to save the value
6. Power-cycle the MX2 (may start slower than normal the first time after a memory reset)

The MX2 can be controlled remotely, much like it controls the camera, by using *Ext 1* inputs.

On the left side of the MX2 controller there are two 2.5mm TRS plugs labeled *Ext 0* and *Ext 1*. Each of these plugs breaks out into two I/O lines and one ground line, which is essential for establishing communication between two electronic components.

The *Ext 0* inputs connect directly to the Arduino microcontroller's hardware serial pins (Digital 1 is the tip connector, Digital 0 is the ring connector), and are reserved for special uses or serial communication. The *Ext 1* inputs, however, are general purpose inputs for use in controlling the MX2 and interacting with the environment.

To craft your own connection to a switch, or some other device, you will normally either buy a cable with a 2.5mm TRS connector on one end and bare leads on the other, or buy a 2.5mm TRS to 2.5mm TRS cable and cut one end off. Either way, make sure you accurately identify which wire matches which conductor — this is a simple task that can be accomplished simply by using a multi-meter in “continuity” mode. This mode tells you whether or not two test points are electrically connected, in many electronic multi-meters there is an audible “beep” when

the two points are connected. Simply test every wire in the cable against each conductor and label each wire as you go.

## The Basics of MX2 Inputs and Outputs

Before we go any further, let's describe how the MX2 inputs work. As we described earlier, there are two I/O lines and one GND line per input connector, this means there is no 5V signal! In fact, when an input is engaged in the MX2 firmware, it is immediately "pulled high" at 20K of resistance. This means that the MX2 will read a 5V signal off that input as long as the input is left unconnected. Thus, to trigger the input, you will need to connect the GND signal to the input you wish to trigger. This allows you to wire switches and other passive devices easily without needing a power source.

Only *Ext 1* inputs are available for triggering actions on the MX2.

As the internal pull-up resistors are 20K Ohms, you must not exceed 19K of resistance in your cabling, otherwise the signal will not be recognized. Limit yourself to under 20' of 20gg wiring.

All *Ext 1* inputs are automatically de-bounced for you, so you can use analog switches without having to build complicated de-bouncing circuitry.

**Under no circumstances should you ever send a positive signal (+V) down any Ext I/O line! Doing so may permanently damage your MX2!**

As for outputs, each input port may instead be converted to outputs, to trigger external devices like relays, lights, etc. As with inputs, the behavior of triggering an output is to connect the given output to the common GND signal.

## Actions Available Based On Inputs

Each individual input has the following actions which can be associated with it:

- Stop
- Start
- Toggle
- Remote Intervalometer

## Actions Available for Outputs

- Trigger before shot
- Trigger after shot
- Trigger before and after shot

The trigger times are shared between both outputs if they are configured to trigger at the same time.

## Dynamic Perception Multi-Function Switch Blocks

The [Multi-Function Switch Blocks](#) provide a quick and easy way to interact with the inputs on the MX2. They can be used either as limit switches, or as remote toggles. For information about how to configure the MX2 to work with the switch blocks in a particular role, see the sections below.

### Creating Limit Switches

For limit switches, the best type to use are momentary micro switches with a lever, either SPST (normally open), or SPDT (choose between normally open and normally closed). These switches are easily sourced cheaply, and work very well as limit switches. It is important to use the correct kind of switch for the correct application: the "lever-style" limit switches that have an arm are designed to be placed in a fixed position and the moving object should trip them by moving into them; if you want to place your switches on your cart - use a plunger-style switch instead.

To wire up your limit switch, connect the GND lead from your cable (the Sleeve of the TRS connector) to the Normally Open connector on the switch, and connect either the Ring (Input 1 in the MX2 firmware) or the Tip (Input 2 in the MX2 firmware) to the signal connector.

Leave the normally closed contact unconnected! Now, when the switch is depressed, the input will be connected to the GND signal, and the MX2 will recognize it.

When using limit switches on your cart, you should generally have one on each side of the cart, to stop it from moving too far in either direction. You can use the same input for both switches to save yourself an input on the MX2, just splice in some extra wires. The best place to locate your switches are on the cart its self, either glued or fastened to the edges such that the belt clamps trip the switches. By placing them on the cart, you will reduce the amount of wiring you need to use.

Remember that the Ring is Input 1 in the MX2 firmware and the Tip is Input 2 in the MX2 firmware.

**NOTE: The limit switch function will only work when the program is ‘on’, do NOT rely on limit switches in *manual motor control*! The input toggles do not apply to *manual motor control* and you must prevent over-running the belt clips by releasing the direction button before you hit them.**

**To configure the firmware to recognize your input as a limit switch:**

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Input x** and press [Enter]
4. [Up] or [Down] to set the value to **Stop**

5. [Enter] to save or [Right] to abort

## Creating Your Own Remote Toggle Switch

You can create your own toggle switch to start and stop the program from running when you press a remote button. Just like with limit switches above, we'll use a TRS cable to connect a momentary switch to the MX2. For this purpose, it is better to use an SPST Momentary Pushbutton (normally open) which are very easy to source and inexpensive. Connect one of the leads to one of the input conductors and the other to GND. Once you have configured the firmware correctly, every time you press the switch, the program will start if it is stopped, or stop if it is started.

Some wired remotes for cameras that have a 2.5mm TRS connector may work fine with the MX2, as long as they are not powered (no battery). You may have to experiment to see which input is triggered when using it.

### To configure the firmware to recognize your input as a toggle switch:

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Input x** and press [Enter]
4. [Up] or [Down] to set the value to **Toggle**
5. [Enter] to save or [Right] to abort

The MX2 controller is capable of controlling a low-cost motorized telescope head, in addition to its two axes of DC motor control. This functionality can be used to quickly and easily add

pan and tilt control to your MoCo project at a very low cost. The following telescope mounts are supported:

- Acuter Merlin
- Merlin SynScan AZ GoTo
- Orion Teletrack
- Skywatcher Multifunction
- Celestron Skywatcher ('Backpacker')

You'll notice that the only difference between these mounts is the name brand and the hand-controller on it. You do not need to buy the GoTo models, as the extra cost will be unrealized (the MX2 replaces the hand-controller when used with the MX2 or the Stage Zero). Please note that these are the only officially supported telescope mounts. Other models produced by Synta or the other name brands they market under *may work* but have not been tested, and even if they do support the same protocol, they may have wildly different wiring requirements that may make them incompatible. From here on out, we will refer to these heads collectively as *Merlin*.

## How The Merlin Integration Works

The MX2 controller is capable of pretending to be the hand-controller shipped with the telescope head. It is used in place of the original hand controller. A special connector cable is made (instructions below), and is used to connect the *EXT 0* port on the MX2 to the *HC* port on the Merlin. Once the telescope functions have been enabled in the MX2 firmware, you will now have a new manual control option labeled 'Scope', and a second home screen will be

available allowing you to specify the movement speeds or distances for the pan and tilt axes during program execution.

The MX2 communicates with the Merlin via a specially constructed cable, and uses a textual serial protocol to transmit and receive information from the Merlin mount.

Much of the integration work is based on the great work done by [Gustav Evertsson](#) on his [Gigapixel Photo Rig](#) and the [Papywizard](#) group where they have been working with the Merlin heads for some time. The MX2 firmware requires a modified version of Gustav's MerlinMount library that enables greater control of the head.

## Limitations

It goes without saying, there are always some limitations, and the Merlin control has a few:

- Ramping/feathering is not supported for the Merlin axes
- You cannot upload firmware with the Merlin cable connected to the MX2
- You must have the Merlin powered on and connected before attempting to use any Merlin-related features, or the MX2 will lockup and require a power cycle before responding
- You are limited to 1/10th of a degree speed/motion inputs for the Merlin head
- The Merlin head does not support *Calculated Interleave* mode, only *Fixed Interleave* and *Continuous motion modes* are supported.
- You cannot perform any other Serial communications with the MX2 via the USB port when the Merlin cable is connected
- You cannot use the camera port on the Merlin

- The Merlin requires its own 12V power supply
  - You can, however, use a Y-adapter for the 2.1mm power cable provided for the MX2
  - You can also run the Merlin off of AA batteries

## Running on USB Power Alone

If you wish to only control the Merlin and your camera with the MX2, and not control other DC motors via the motor ports, you may power the MX2 off of five volts via the USB cable. The Merlin will still need its own power supply, either via AA batteries or a 12V DC feed to the Merlin's power input port.

## Enabling Scope Control

To be able to control the Merlin via the MX2, you must enable the scope control in the firmware. This setting is found under the global settings menu.

### **To enable *Scope Control*:**

1. [Enter] to enter the main menu
2. [Down] to select **Settings** and press [Enter]
3. [Down] to select **Scope** and press [Enter]
4. [Up] or [Down] and choose **On**
5. [Enter] to save or [Right] to abort

## Manually Positioning the Merlin

Once you have enabled scope control, you will now have a new option available in the *manual control* screen labeled *scope*. This option enables you to control both axes of the Merlin from a single screen.

Inside the *scope* manual control screen, use [*left*] to cause the pan (yaw) axis to start moving left, and [*right*] to cause the pan axis to start moving right. Pressing either button again will cause the motion to stop. [*up*] and [*down*] cause the tilt (pitch) axis to move either up or down, again, pressing either a second time will stop movement.

Press [*enter*] to exit this screen and return to the main manual control screen.

*You can configure the speeds at which the pan and tilt axes move in the scope manual control screen by accessing the Main Menu->Scope menu, and configuring the desired manual speed, from 0.1 deg/minute, to 1,440 deg/minute.*

### **Actions:**

1. [*Enter*] to enter the main menu
2. [*Down*] to select **Manual** and press [*Enter*]
3. [*Down*] to select **Scope**, and press [*Enter*]
4. [*Up*], [*Down*], [*Left*], and [*Right*] to position the Merlin
5. [*Enter*] to exit the manual control screen
6. [*Right*] to return to the main menu

## Configuring the Merlin for Use During a Shot

Once you have enabled *scope control* in the MX2 firmware, you will now have an additional home screen available. To access the additional home screen, simply press [Up] on the home screen with no items selected, it will switch to a new screen that looks like the following:

=====

Off Scope

R0.0 U0.0

=====

This is the scope control screen. Like the normal home screen, you can use [Right] and [Left] to select an item to edit, the On/Off control works just as with the normal home screen, starting or stopping the current shot program. The pan axis is displayed first, and then the tilt axis, these values can be modified just like the normal axis controls on the normal home screen. You can select R for right or L for left for pan, or U for up and D for down for the tilt axis.

Distance values are input in tenths of degrees from 0.1 to 360. When in *continuous motion* mode these values indicate how many degrees to move per minute, whereas in *interleaved* mode, these values indicate how many degrees to move between each shot. Scope motion control always inherits from the global motion control mode with one caveat: when in

*interleaved* mode, the Merlin will only operate in Fixed SMS, even no other axis is set to fixed SMS. Additionally, ramping is not supported for the Merlin head at this time.

To exit the scope control screen, simply press [Up] again with no values currently selected for editing. You may switch back and forth between these home screens while the program is executing without issue.