Wave

Continuous High-Speed Video Camera

User Guide

Rev3 | 2021-02-11 | Camera FW v1.0.x | Wave Player SW v1.0.x
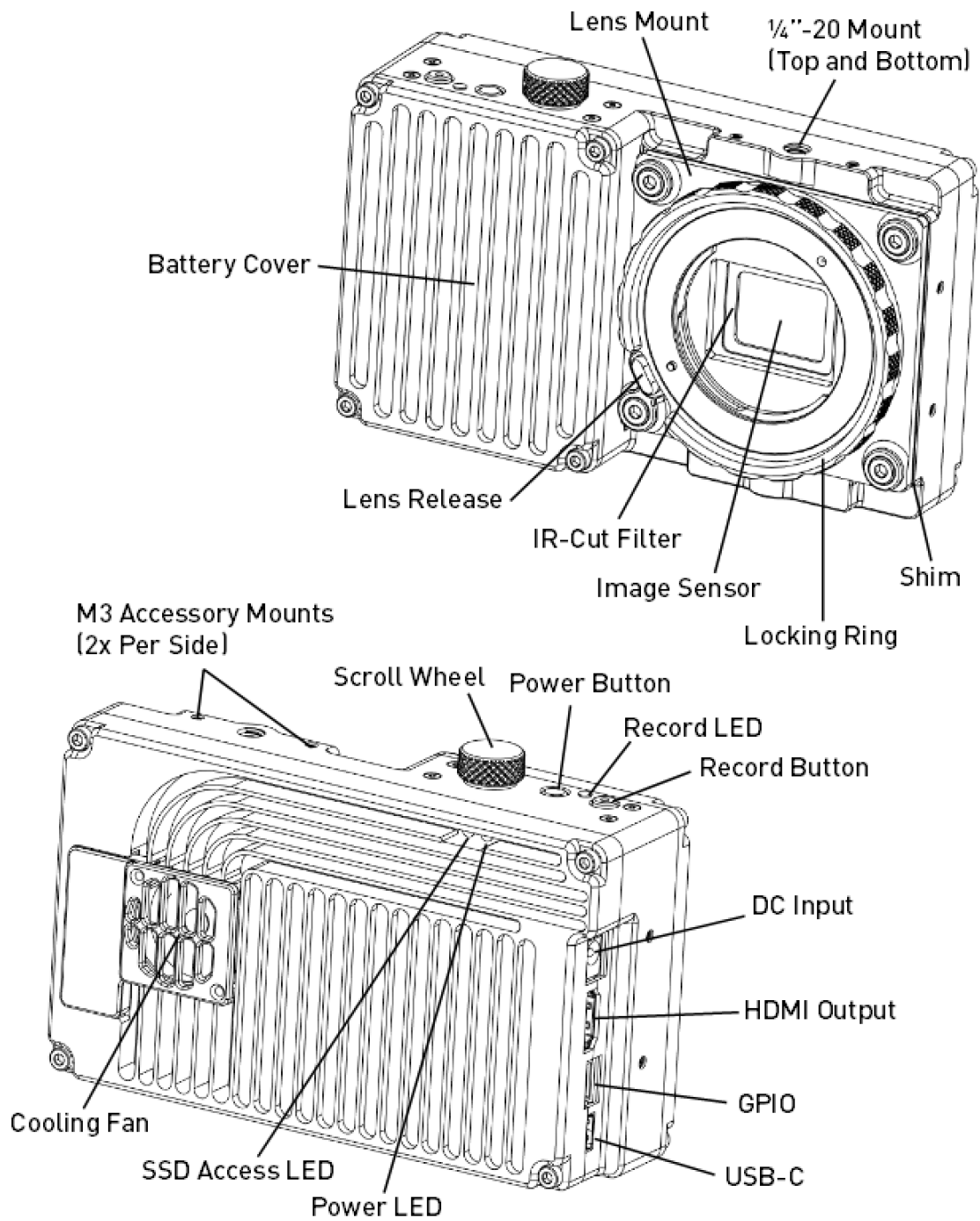
Figure 1: Wave Camera Components

1 Quick Start

1.1 Install Wave Player

1. Download the latest Wave Player software from the following URL:
   https://freefly.gitbook.io/freefly-public/products/wave-camera/downloads
2. Unzip the **WavePlayer_[version]** folder.
3. Run **WavePlayerSetup.msi** and follow the instructions. If Microsoft Defender initially prevents setup.exe from running, click **More info -> Run anyway**.
4. Run **WavePlayer.exe** from the installed location and confirm that a suitable graphics adapter is indicated in the Title Bar, for example:

1.2 Capture Test Clip

1. Connect an HDMI monitor to the HDMI Output.
2. Power on the camera (Power Button single press) and wait for a preview image.
3. Use the Scroll Wheel to navigate the camera menu and adjust settings:
   a. Scroll to select a setting.
   b. Click to display that setting's options.
   c. Scroll to select an option.
   d. Click to apply the selected option and return.
4. Adjust settings, exposure, and focus as-desired for the test clip.
5. Note the clip number in the bottom-left corner.
6. Record the clip by pressing the Record Button to start and stop recording.

1.3 View and Export Test Clip

1. Connect the USB-C port to the PC with Wave Player installed.
2. In Wave Player, click **Open Clip** and navigate to the camera's drive.
3. Select the folder corresponding to the clip number recorded.
4. Navigate within the clip using the Timeline Slider or keyboard shortcuts:
   a. Spacebar: Play/Pause
   b. Left/Right: Step Frame-by-Frame
   c. I/O: Set In and Out Marks for Export
5. Apply image adjustments as-desired using the Image Sliders.
6. Select one or more export formats (Cineform, PNG, JPEG).
7. Click **Export** and select an export location and file name.
8. Wait for the clip export to progress from the In Mark to the Out Mark, or end the export at the current frame by clicking Pause or pressing Spacebar.

2 Specifications

2.1 Key Specifications

Specification	Condition	Value
Image Sensor		
Format	-	S35
Aspect Ratio	-	4:3
Pixel Size	-	5.5μm x 5.5μm
Native Resolution	-	4096 x 3072
Active Area	-	22.53mm x 16.90mm
Shutter Type	-	Global Electronic
Native ISO	-	250
Lens Mount		
Standard Lens Mount	-	E-mount Compatible
Removable	-	Yes
Positive Locking	-	Yes
Electronic	-	No
Recording		
Media	-	Internal SSD
Media Size	-	1TB or 2TB
Format	-	Compressed RGB
Native Bit Depth	-	10-bit
Compression Ratio	Typical	5:1 to 6:1
Resolutions / Frame Rates	-	See Table 1.
Bit Rate	Maximum	1.00GB/s (8.00Gb/s)
	4096 x 2176, 422fps, 5.5:1	0.89GB/s (6.84Gb/s)
	2048 x 1088, 1461fps, 5.5:1	0.74GB/s (5.92Gb/s)
Continuous Capture Time	4096 x 2176, 422fps, 1TB	19min
	4096 x 2176, 422fps, 2TB	39min
	2048 x 1088, 1461fps, 1TB	23min
	2048 x 1088, 1461fps, 2TB	45min
	Others	Limited only by Media Size
Power		
Battery	-	Internal 11.1V, 2200mAh
Run Time	Standby	90min
	Recording (Max Rate)	60min
Charge Time	Powered Off	90min
DC Input Voltage	Operation	12V – 26V
	Charging to 100%	14V – 26V
Power Consumption	Standby	15W
	Recording (Max Rate)	19W
	Charging (Max)	24W

Interface		
DC Input	-	Barrel Jack 5.5mm OD x 2.1mm ID
HDMI Output	-	HDMI A (Full Size) 1080p30
GPIO	-	6-Pin JST GH Optically Isolated Start/Stop/Sync UART (3.3V or 5.0V) API[1]
USB	-	Type C (Reversible) USB 3.2 Gen1x1 SuperSpeed 5Gb/s
Wireless	-	WiFi 802.11b/g/n[2] Bluetooth v4.2[2]
Wave Player Software		
Operating System	-	Windows 10
Export Formats	-	Cineform (.MOV) PNG Sequence JPEG Sequence
Other Features		
Firmware Update	-	via USB-C
Upgradeable Storage	-	Yes
LCD	-	No
Audio Recording	-	No
Autofocus	-	No
Physical		
Dimensions	w/ E-mount	150mm x 97mm x 47mm
Weight	w/ E-mount	716g
Mounting Points	¼-20	2: 1x Top, 1x Bottom
	M3	8: 2x per Side
Environmental		
Operating Temperature	-	0ºC to 40ºC
Ingress Protection	-	IP52
Maximum Acceleration	-	TBC

[1]Hardware capability, API details TBD.

[2]Hardware capability, no software support or mobile app available as of this release.

2.2 Maximum Frame Rates

The maximum frame rate depends on image resolution as set by the Width and Height settings. Table 1 lists the maximum frame rate by aspect ratio for both Width options. Continuous recording is possible at all frame rates from 1fps up to the maximum in increments of 1fps. A set of standard frame rates is available in the menu under the rame Rate setting. For more details, see Section 4: Camera Settings Menu.

*Table 1: Maximum frame rates by aspect ratio for **4096** (4K and **2048** (2K) width options.*

Aspect Ratio	Width: 4096 (4K)		Width: 2048 (2K)	
	Height	Max FPS	Height	Max FPS
4:3	3072	300	1536	1049
16:9	2304	398	1152	1384
17:9	**2176**	**422**	**1088**	**1461**
2:1	2048	448	1024	1548
2.13:1	1920	477	960	1646
2.29:1	1792	511	896	1758
2.46:1	1664	549	832	1885
2.67:1	1536	594	768	2032
2.91:1	1408	647	704	2204
3.2:1	1280	711	640	2408
3.56:1	1152	788	576	2653
3.76:1	1088	833	544	2796
4:1	1024	884	512	2955
4.27:1	960	941	480	3132
4.57:1	896	1006	448	3333
4.92:1	832	1081	416	3561
5.33:1	768	1168	384	3822
5.82:1	704	1270	352	4125
6.4:1	640	1392	320	4480
7.11:1	576	1540	288	4901
8:1	512	1722	256	5411
9.14:1	448	1954	224	6038
10.67:1	384	2257	192	6830
12.8:1	320	2673	160	7861
16:1	256	3275	128	9259

The **2048** (2K) width option uses subsampling, which preserves the crop factor of the Image Sensor but does not increase its light sensitivity. For more information, see Section 4.2: Width.

3 Camera Operation Basics

3.1 Power and Charging

The camera is powered by an internal 11.1V, 2.2Ah lithium ion battery, which provides about 90min of standby time or 60min of continuous recording. For continuous operation beyond this, the included power supply can be connected to the DC Input. This supply provides enough power to both charge the battery and run the camera. When powered off, fully charging from 0% to 100% takes about 90min. When powered on, the charging time depends on simultaneous camera usage.

The DC Input can also be used to supply power from another source, such as an external battery or gimbal power supply. Table 2 lists the requirements for a power supply connected to the DC Input. An external V-Lock battery connected to the DC input is the preferred method for mobile operation with battery swapping. The internal battery is not meant for swapping, but can be accessed by removing the Battery Cover if needed.

WARNING	The voltage applied at the DC Input must not exceed 26V.

Table 2: DC Input Supply Requirements

Requirement	Value
Voltage (Operation)	12V – 26V
Voltage (Full Charge)	14V – 26V
Power (Recommended Supply Capability)	30W (12V, 2.50A) (18V, 1.67A) (24V, 1.25A)

To power on the camera, press the Power Button once. To power off the camera, press and hold the Power Button for three seconds. The Power LED indicates the power and charging state as shown in Table 3.

Table 3: Power and charging states indicated by the Power LED.

Power LED	Camera Power State
● Off	Powered Off, Charging Complete
● Orange	Powered Off, Charging in Progress
● Yellow	Powered On, Charging in Progress
● Green	Powered On, Charging Complete

3.2 Lens Mount

The camera has a positive-locking E-mount-compatible Lens Mount. There is no electrical connection between the lens and the passive mount, so **electronic lenses with focus-by-wire are not supported**. Two configurations are currently supported:

The Lens Mount can be detached by removing the four M4 screws. Behind it is an IR-Cut Filter assembly that can also be detached for cleaning or for IR photography. A set of shims (0.5mm, 0.8mm, 0.9mm, 1.0mm, and 1.1mm) are included for fine-tuning the back focal distance (see Section 3.2.2: Back Focus Adjustment). The 1.0mm shim is installed as-shipped from the factory and should provide adequate back focus with most lenses.

Caution	**When removing the lens mount and IR-Cut Filter assembly, be careful not to touch the IR-Cut Filter glass or Image Sensor cover glass.**

The Lens Mount supports for manual E-mount lenses. There is no electrical connection between the lens and the passive mount, so **electronic lenses with focus-by-wire are not supported**. E-mount has one of the shortest flange focal distances of any S35-size lens mount, allowing it to be readily adapted to other mounts. For a list of recommended lenses and adapters, visit the following URL:

https://freefly.gitbook.io/freefly-public/products/wave-camera/lens-recommendations

3.2.1 Locking Ring Operation

The Lens Mount features a Locking Ring that secures the lens firmly to the camera body, instead of relying on leaf springs. To attach an E-mount lens:

1. Align the lens marking with the dimple in the flange and insert the lens.
2. Rotate the lens clockwise (as seen from in front of the camera) until the Lens Release clicks into place.
3. Rotate the Locking Ring clockwise until it tightens on the lens. **Do not overtighten.** Use about the force it takes to turn a doorknob.

To remove the lens:

1. Rotate the Locking Ring counterclockwise as far as it will go.
2. Press down the Lens Release.
3. Carefully rotate the lens counterclockwise until it can be removed.

3.2.2 Back Focus Adjustment

A set of shims (0.5mm, 0.8mm, 0.9mm, 1.0mm, and 1.1mm) are included for fine-tuning the back focal distance. The 1.0mm shim is installed as-shipped from the factory and should provide adequate back focus with most lenses, but adjustments can be made in cases where back focus is especially critical, for example:

- Maintaining parfocal condition on a parfocal zoom lens.
- Matching up perfectly to lens markings.
- Achieving infinity focus exactly at a lens marking or hard stop.

To adjust the back focus, first set a focus target a fixed distance from the camera's focal plane, which is in line with the M3 Accessory Mounts on the left side. The distance should match one of the distances marked on the lens. Adjust the lens until the target is in focus, then follow the action indicated in Figure 2.
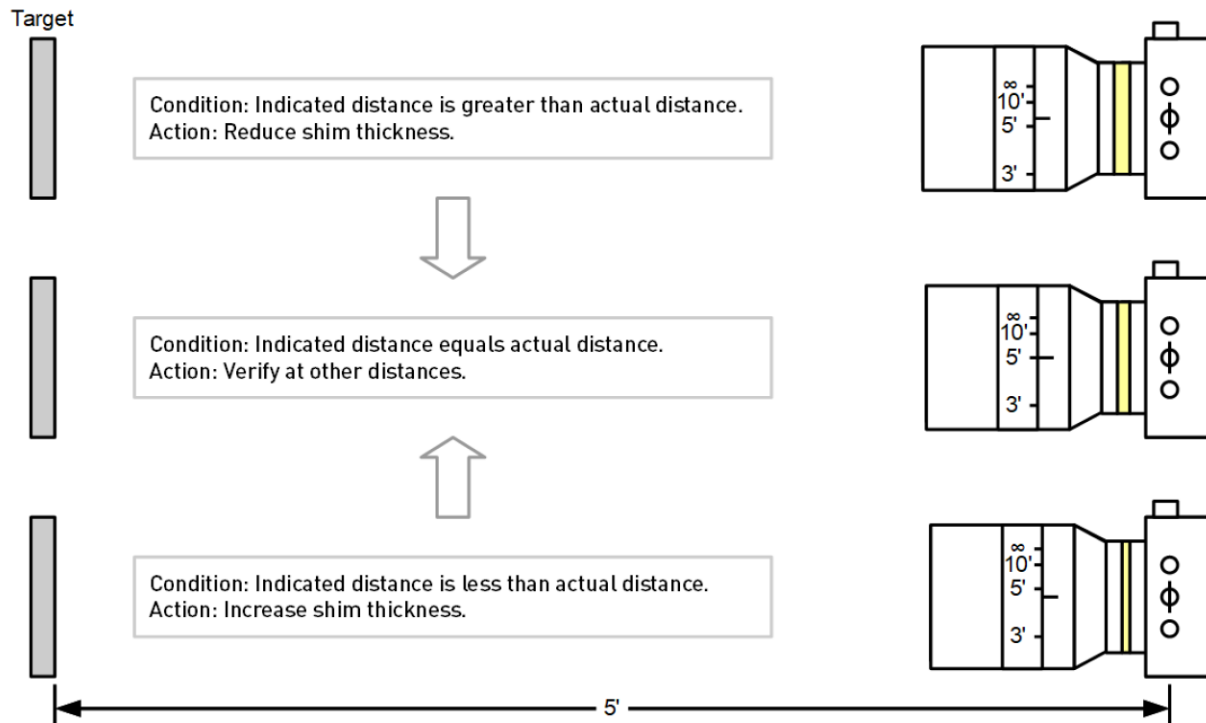

Figure 2: Back focus adjustment procedure.

3.3 Workflow

The Wave can record high-speed video continuously at any available frame rate, limited only by the size of the internal SSD. As such, there is no trigger or buffer setup required. The capture workflow is just like an ordinary video camera: press the Record Button once to start recording a clip and again to stop recording.

3.3.1 HDMI Preview and Menu Overlay

An HDMI monitor capable of receiving a 1080p30 input is required to view a preview image and interact with the camera menus. On-camera monitors typically also provide useful tools such as histograms and focus assist. The ¼-20 Mount on top of the camera is intended for monitor mounts. For a list of recommended on-camera monitors and monitor mounts, visit the following URL:

3.3.2 User Interface

The primary user input to the camera is the Scroll Wheel. This multi-purpose input can be used to enter and exit menus (by clicking) and adjust settings (by scrolling). The typical workflow for adjusting camera settings is as follows:

1. If it's not already visible, click the Scroll Wheel to display the settings menu.
2. Scroll to select a setting.
3. Click to display that setting's options.
4. Scroll to select an option.
5. Click to apply the selected option and return to the settings menu.
6. To hide the settings menu, scroll to and click the **X** in the top-left corner.

See Section 4: Camera Settings Menu for a detailed description of each setting and its options. Some settings have additional levels of user input that are described in more detail there.

The first setting, Mode, can be used to launch the on-camera playback interface, which is described in detail in Section 5: Playback Interface.

3.3.3 Viewing, Offloading, and Exporting Clips

Wave clips are recorded internally in a native file format optimized for speed, but they can't (yet) be opened directly by other editing tools. Wave Player is the PC software used to view native Wave clips, trim them, apply basic image adjustments, and export them to other formats. See Section 6: Wave Player Software for details.

Clips are organized by folders on the camera's drive, with the folder name corresponding to the clip number (e.g. D:\c0003 for clip 3). Within a clip folder, there are files containing clip metadata and clip frames. A specification for the Wave native file formats will be published separately at a later date.

Wave Player can open clips either directly from the camera's drive or from a local copy. To make a local copy of a clip, copy the entire clip folder from the camera's drive. Use Copy rather than Cut to move clip folders from the camera's drive to local storage. Additionally, clips should not be deleted directly, as it leaves the file system fragmented, which limits SSD write performance. Instead, use the on-camera Format setting to erase the internal SSD cleanly when all clips are backed-up or no longer needed.

Caution	Do not delete clips from the camera's internal drive, as it leaves the file system fragmented and limits SSD write performance. Use the on-camera Format setting to erase the internal SSD cleanly.

3.4 Firmware Update

The latest camera firmware can be downloaded from the following URL:

https://freefly.gitbook.io/freefly-public/products/wave-camera/downloads

The camera firmware can be updated over USB using the following procedure:

1. Hold down the Scroll Wheel while pressing the Power Button to power on the camera in Firmware Update mode. Continue to hold down the Scroll Wheel until the Record LED flashes slowly.
2. Plug in the USB cable. The camera will appear as a USB drive. **This drive is separate from the one where clips are stored, so your footage won't be visible but is safe and not affected by the firmware update.**
3. Drag the new firmware file (WAVE.BIN) into the fw folder.
4. Click the Scroll Wheel. The Record LED will begin to flash quickly as the firmware is updated.
5. Wait for the camera to automatically restart with the new firmware. This should take at most 30 seconds.
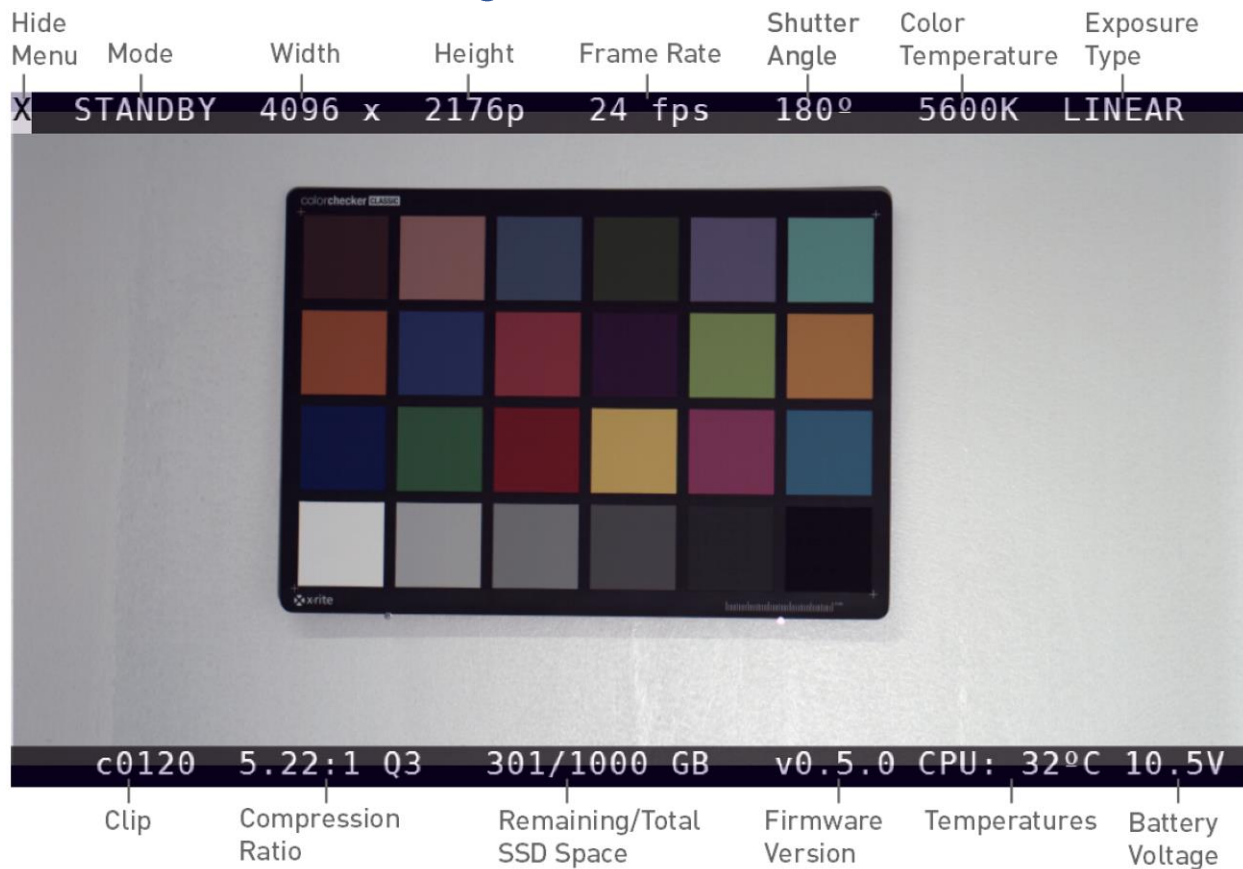
4 Camera Settings Menu

Figure 3: Camera settings menu.

This section covers the settings available in the on-camera menu in detail. The settings menu is displayed across the top bar of the HDMI preview image. To make the menu visible, click the Scroll Wheel. To hide it, scroll to and click the **X** in the top-left corner.

4.1 Mode

This setting is used to switch between capture and playback modes. It will display **STANDBY** when the camera is ready for capture and **REC** during capture. To switch to playback, click the Mode setting, scroll to and click **PLAYBACK**. This will launch the playback interface, which is detailed in Section 5: Playback Interface. The Mode setting will return to **STANDBY** when the playback interface is closed.

4.2 Width

This setting is the width in pixels of the captured image. The two options are **4096** (4K) and **2048** (2K). **4096** (4K) is the native width of the sensor and uses all available pixels. **2048** (2K) uses subsampling to generate a 2K image from the full width of the sensor, as in Figure 4, so the crop factor and angle of view don't change. This allows higher frame

rates, but with reduced image quality. The native ISO is the same in both width options, so proportionally more light is required for higher frame rates of the **2048** (2K) width.
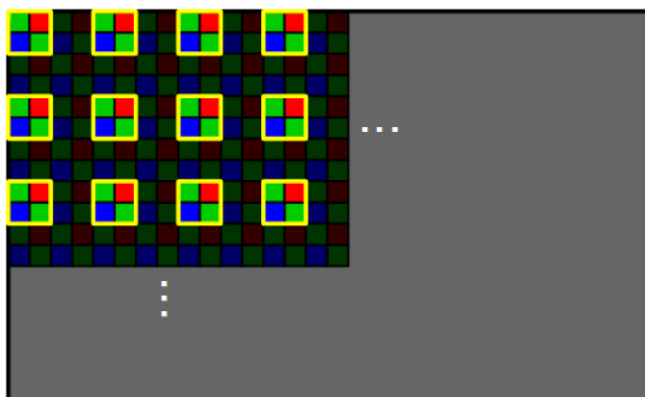

*Figure 4: Subsampling pattern in the **2048** (2K) width option.*

The available options for the Height and Frame Rate settings both depend on the Width option selected.

4.3 Height

This setting is the height in pixels of the captured image. The available options range from 128px to 3/4 of the Width setting (4:3 aspect ratio). Decreasing the Height increases the maximum frame rate. The closest Width and Height combinations that fully cover some common resolutions are shown in Table 4.

Table 4: Closest Width and Height settings that fully cover some common resolutions.

Deliverable Resolution	Width	Height	Max FPS
DCI 4K (4096 x 2160)	4096	2176	422
UHD 4K (3840 x 2160)	4096	2176	422
1080p HD (1920 x 1080)	2048	1088	1461
720p HD (1280 x 720)	2048	768	2032

4.4 Frame Rate

This setting is the number of frames per second (FPS) captured. The options listed include a set of standard frame rates (select multiples of 24fps, 25fps, and 30fps) from 24fps up to 9120fps. The available options are dependent on the Width and Height settings, limited by the maximum frame rate defined in Table 1.

A special option, **USER**, allows for entering any frame rate from 1fps up to the maximum in increments of 1fps. One application for this is for closely synchronizing to a vibrating or rotating object to measure its frequency or visualize its periodic movement (like a stroboscope). To enter a user frame rate:

1. Click the Frame Rate setting.
2. Scroll to and click **USER**.

3. Scroll left or right to adjust the user frame rate.
4. Click to apply the user frame rate.

A special option, **MAX**, applies the maximum frame rate for the current Width and Height settings, as defined in Table 1. This is usually slightly higher than the maximum standard frame rate option listed.

4.5 Shutter Angle

This setting is the exposure time expressed as an angular fraction of the time between frames, as shown in Figure 5. At the default value of **180°**, the sensor accumulates light for half of the frame interval. At **360°**, the Image Sensor accumulates light for (nearly) the entire frame interval, resulting in twice as much light gathered but also twice as much motion blur. Conversely, at lower shutter angles, less light is gathered and there is less motion blur. The Wave Image Sensor uses a global electronic shutter, so all pixels are exposed at the same time.
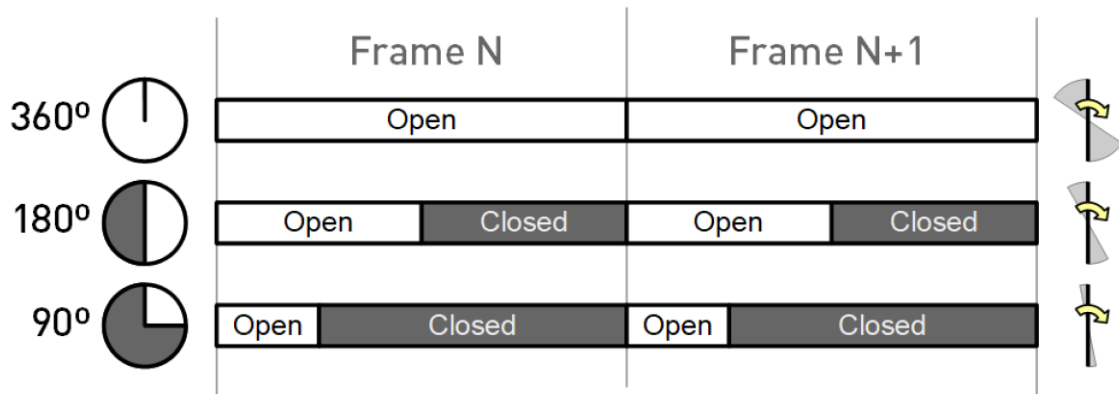

Figure 5: Shutter angle definition.

Table 5 lists the available shutter angle options and their equivalent value in stops above or below the default of **180°**. To convert between Shutter Angle and an exposure time in seconds, use the following equation:

$$(Exposure\ Time) = \left(\frac{Shutter\ Angle}{360°}\right)\left(\frac{1}{Frame\ Rate}\right)$$

*Table 5: Shutter angle options and their equivalent in stops relative to **180°**.*

Shutter Angle	Stops Relative to 180°
360°	+1
270°	+0.59
180°	**0**
135°	-0.42
90°	-1
63.6°	-1.5

45º	-2
31.8º	-2.5
22.5º	-3
15.9º	-3.5
11.3º	-4
7.96º	-4.5
5.63º	-5
3.98º	-5.5
2.81º	-6
1.99º	-6.5
1.41º	-7
0.99º	-7.5
0.70º	-8

4.6 Color Temperature

This setting adjusts the color temperature associated with the captured image. It is used by the HDMI preview to compensate for ambient lighting (white balance), and also embedded in the clip metadata so the Wave Player software can apply the same white balance by default. The setting does not affect the recorded image data, so the color temperature option can be changed later in the Wave Player software.

Color temperature options range from 2000K to 9600K, with higher values corresponding to cooler (bluer) ambient lighting conditions. The camera is calibrated at the 3200K (tungsten) and 5600K (daylight) color temperatures.

4.7 Exposure Type

This setting selects the type of exposure used by the Image Sensor and the output curve used by the HDMI preview and Wave Player software to display that exposure. The default setting is **Linear**, which records pixel data linearly proportional to light received on the pixels and uses a output curve (gamma) to lift shadows. Other options, such as multi-exposure HDR, may be added in future releases.

4.8 Date/Time Set

This setting is used to change the camera's internal date and time, used for time-stamping clip files.

4.9 Format

This setting triggers a format (clean erasure) of the internal SSD. This is the preferred method of erasing clips, as it restores the file system to ideal, unfragmented condition. To format the SSD, click the Format setting, scroll to and click **Confirm**.

Caution	Formatting the SSD will erase all clips permanently.

5 Playback Interface

Clip Info

X PLAYBACK   4096 x   2176p   24 fps 180.0º   5600K   LINEAR

X   c0119 PLAY   +1x   0/283   IOM CPU: 41ºC 10.4V

Exit   Clip   Play/Pause   Frame   Marks
Playback   (Adjust Speed)   (Step)

Figure 6: On-camera playback interface.

To switch to playback, click the Mode setting, scroll to and click **PLAYBACK**. This will launch the playback interface, shown in Figure 6. The Scroll Wheel cursor moves to the bottom bar playback menu and the most recently captured clip is opened for playback. The top bar is used to display Clip Info for the clip currently open. To exit playback and return to the Settings menu, click the **X** in the bottom-left corner.

5.1 Clip Selection

To select a different clip for playback, first highlight the Clip number and click the Scroll Wheel. This will display a list of available clips. While scrolling through the clips, the first frame will be displayed to help identify the clip. Find the desired clip and click the Scroll Wheel to load it. Depending on the size of the clip, it may take several seconds to fully load. Playback may be choppier while a clip is still loading.

5.2 Play/Pause

To start playback, highlight **PLAY** and click the Scroll Wheel. This will begin playing the clip at 1x speed. While the clip is playing, scroll left or right to change the playback speed. To pause playback, scroll to 0x speed. To reverse the playback direction, scroll left until the playback speed becomes negative. To stop playback, click the Scroll Wheel.

Playback speeds above 1x or below -1x are fast-seeking modes that require the HDMI preview to discard its frame buffer and start reading the clip data from scratch for every frame. As such, the preview will update at a lower frame rate even though the progress through the clip is faster (similar to fast-forwarding or rewinding a streaming video).

5.3 Frame-by-Frame Stepping

The current frame and total number of frames in the clip are displayed at the center of the playback menu. To step frame-by-frame through the clip, first highlight the current frame and click the Scroll Wheel. Then, scroll left or right to step backwards or forward through the clip. To exit frame-by-frame stepping, click the Scroll Wheel again.

5.4 Marks

While in playback, an In Mark and an Out Mark can be set to highlight a section of a clip. These marks are used by Wave Player to limit export of the clip to the marked section. The In Mark and Out Mark can be moved in Wave Player as well if needed. By default, the In Mark and Out Mark are on the first and last frames of the clip, respectively. General purpose marks can also be placed to indicate frames of interest.

Marks can be attached to individual frames by scrolling to and clicking the **I** (In Mark), **O** (Out Mark), or **M** (General Purpose Mark) mark letter. Once the frame is marked, the corresponding mark letter will be underlined. Clicking a mark letter again will clear the mark. (If it's an In Mark or Out Mark, it will be reset to the first or last frame, respectively.)

6 Wave Player Software

Figure 7: Wave Player software user interface.

Wave clips are recorded internally in a native file format optimized for speed, but they can't (yet) be opened directly by other editing tools. Wave Player is the PC software used to view native Wave clips, trim them, apply basic image adjustments, and export them to other formats.

Clips are organized by folders on the camera's drive, with the folder name corresponding to the clip number (e.g. D:\c0003 for clip 3). Within a clip folder, there are files containing clip metadata and clip frames. A specification for the Wave native file formats will be published separately at a later date.

Wave Player can open clips either directly from the camera's drive or from a local copy. To make a local copy of a clip, copy the entire clip folder from the camera's drive. Use Copy rather than Cut to move clip folders from the camera's drive to local storage. Additionally, clips should not be deleted directly, as it leaves the file system fragmented, which limits SSD write performance. Instead, use the on-camera Format setting to erase the internal SSD cleanly when all clips are backed-up or no longer needed.

Caution	Do not delete clips from the camera's internal drive, as it leaves the file system fragmented and limits SSD write performance. Use the on-camera Format setting to erase the internal SSD cleanly.

6.1 System Requirements

Table 6 lists the minimum and recommended PC system specifications for running Wave Player. Performance, in particular export frame rate, will improve significantly with system components meeting or exceeding the recommended specifications.

Table 6: Wave Player PC System Specifications

System Component	Minimum	Recommended
Operating System	Windows 10	Windows 10
CPU Cores	4	8
Memory	8GB	32GB
Graphics	2GB VRAM	Discrete, 8GB VRAM
DirectX Support	DX12	DX12
Display	2560 x 1440	4K
USB	USB 3.x (SS)	USB 3.x (SS)

The disk space required by Wave Player itself is small, so a minimum or recommended local drive size is not specified. However, exporting large video files typically requires a large (1TB or greater) and fast (NVMe SSD preferred) local storage drive. **Exporting back onto the camera's internal drive is not currently supported.**

6.2 Installation

The latest Wave Player can be downloaded from the following URL:

https://freefly.gitbook.io/freefly-public/products/wave-camera/downloads

After downloading the installer, run **setup.exe** and follow the instructions. If Microsoft Defender initially blocks the installer from running, click **More info -> Run anyway**. If prompted, download and install the latest Visual C++ runtime package as well.

After installation, navigate to the folder where Wave Player was installed (typically C:\Program Files\Wave Player) and run **WavePlayer.exe**. Wave Player will select the available graphics adapter with the most video memory, typically a dedicated graphics card. Confirm an appropriate graphics adapter is indicated in the title bar.

6.3 Opening and Viewing Clips

6.3.1 Opening a Clip

First, click Open Clip and navigate to the folder containing the desired clip. To open a clip on the camera's drive, make sure the camera is powered on and connected via USB-C. Depending on the size of the clip, it may take several seconds for the clip to load.

Once the clip finishes loading, a preview will be shown in the Image Preview area and the clip file name, resolution, frame rate, and exposure mode will be shown in the Clip Info

area. If an In Mark was set in on-camera playback, this will be displayed on the Timeline Slider and the clip will open on the marked frame. If an Out Mark was set in on-camera playback, this will also be displayed on the Timeline Slider.

6.3.2 Timeline Navigation
The current location in the clip is indicated by the Timeline Slider, as well as the Frame Counter in the bottom right corner. There are several ways to navigate within the clip:

- Click and drag the Timeline Slider.
- Use the Play/Pause, Step Left, and Step Right buttons.
- Use the keyboard:
    - Spacebar: Toggle Play/Pause
    - Left Arrow: Step Left
    - Right Arrow: Step Right

6.4 Image Adjustments
A limited set of image adjustments are available via the Image Sliders. These can be used for basic tonal and color corrections, but aren't meant to replace the full suite of color correction tools available in downstream editing software.

Where applicable, the default values of these adjustments are populated from clip metadata when a clip is opened. For example, if a clip was recorded with a Color Temperature setting of 4000K, this will be the value set on the Color Temp. Image Slider by default when the clip is opened. This can be changed as desired since the Color Temperature setting has no effect on the actual recorded data.

6.4.1 Black Level
This adjusts the level of the darkest part of the frame and sets a baseline for the other tonal corrections. If there is a black reference in the frame, this can be used to match its expected level. Otherwise, it can be set by eye to preference.

6.4.2 Color Temp.
This adjusts the color temperature associated with the captured image, to compensate for ambient lighting (white balance). Color temperature options range from 2000K to 9600K, with higher values corresponding to cooler (bluer) ambient lighting conditions. The camera is calibrated at the 3200K (tungsten) and 5600K (daylight) color temperatures.

Increasing the Color Temp. will associate the image with a cooler (bluer) ambient lighting condition, adding more red into the output to compensate. Decreasing the Color Temp. will have the opposite effect.

6.4.3 Tint

This adjusts the relative amount of green in the output image. Color temperature mostly affects red and blue, so Tint is used as separate adjustment for green. Increasing the Tint will add more green. Decreasing the Tint will remove green, leaving more magenta.

6.4.4 Contrast

This adjusts the overall contrast of the output image. Increasing the Contrast stretches out the image's tonal curve, making shadows darker and highlights brighter. Decreasing the Contrast has the opposite effect. Shadow and Highlight contrast can be fine-tuned further with the corresponding Image Sliders.

6.4.5 Saturation

This adjust the color saturation of the output image. Increasing the Saturation pushes colors further away from gray, making them more vibrant. Decreasing the Saturation has the opposite effect.

6.4.6 Shadows

This fine-tunes the contrast of the lower third the tone curve. Increasing the Shadows slider pulls up details in dark areas of the image, but will also amplify noise. Decreasing the Shadows slider suppressed detail in dark areas of the image, and can be used to reduce noise.

6.4.7 Highlights

This fine-tunes the contrast of the upper third of the tone curve. Increasing the Highlights slider brightens highlights. Decreasing the Highlights slider has the opposite effect.

6.4.8 Gamma

This adjusts how much the tone curve is lifted from the baseline linear exposure. As the shadows are amplified, so is the Image Sensor's inherent noise. This setting can be adjusted along with the Shadows slider to achieve the best balance of shadow detail to noise for a given scene.

6.4.9 Row Filter (Beta)

This is an experimental row noise reduction filter that can be used on dark scenes to reduce temporal row noise when pulling up shadows with the Shadows and Gamma sliders. Its effectiveness will be scene-dependent.

6.5 Exporting Clips

Clips, or sections of clips, can be exported from Wave Player in a number of different output formats for archiving, editing, or as a final deliverable. The In Mark and Out Mark set the start and end frames for export, respectively. They can be set by clicking and dragging the markers, or using the keyboard shortcuts "I" and "O", respectively.

After making any desired image adjustments and marking a section for export, select an export format and click Export. Then, select an output location for the clip and enter a file name. The clip export will begin from the In Mark and progress to the Out Mark. However, the export can be ended early by pressing Spacebar or clicking Pause. In this case, the portion of the clip already exported will still be available at the output location.

The following subsections go into more detail on the available output formats.

6.5.1 CineForm

CineForm is a high-quality, computationally-efficient wavelet compression codec that is good for both archiving and editing. It encodes output YUV data, so image adjustments made in Wave Player are "baked in" to the CineForm output. Nevertheless, it retains much of the image information and can handle further post-processing. Bit rates and file sizes are comparable to the camera's internal recording format.

6.5.2 PNG Sequence

This outputs individual frames as a sequence of PNG images, which use lossless compression and 8-bit color.

6.5.3 JPEG Sequence

This outputs individual frames as a sequence of JPEG images, which use lossy compression and 8-bit color. Quality 100 is used to minimize compression loss, at the expense of file size, but JPEG frames will still typically be smaller than PNG frames.

7 GPIO Connector

The GPIO connector provides two general-purpose inputs (GPI) and two general-purpose outputs (GPO). Figure 8 shows the pinout of this connector and the color coding of the Mōvi Pro Wave Remote Control Cable (Freefly P/N 910-00661).
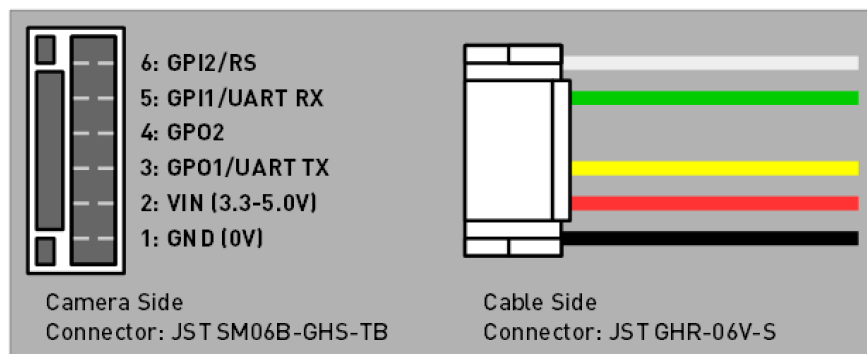

Figure 8: GPIO Connector Pinout and Color Coding

7.1 Custom Remote Start/Stop

A custom remote start/stop cable can be created by following the wiring diagram in Figure 9. The GPIO are optically isolated, so the host must supply a voltage (3.3V or 5V is okay) to power its side of the optocoupler. The current drawn will be <20mA.
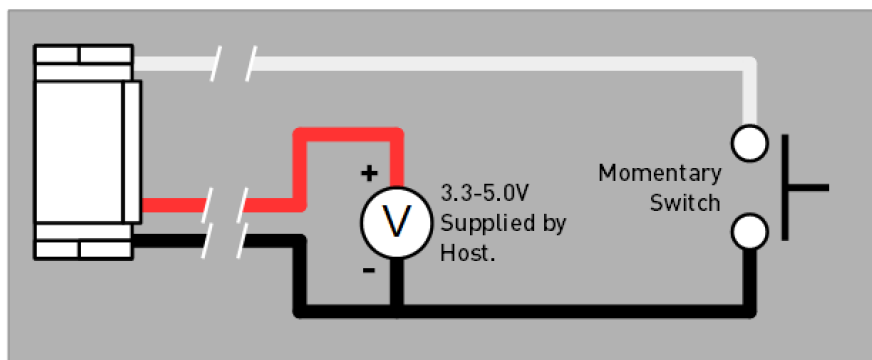

Figure 9: Wiring of a custom remote start/stop cable.

The momentary switch connects the GPI2/RS pin to GND (0V). Each single press will toggle the recording state on or off, just like the dedicated Record Button. For wireless remote start/stop, a relay- or transistor-based RC switch can also be used.