

The logo for Expert Sleepers, featuring three stylized 'z' characters stacked vertically on the left side of the text.

Expert Sleepers

FH-1 'faderHost' USB MIDI Host Firmware v2.0 User Manual

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Introduction

Congratulations on your purchase of an Expert Sleepers FH-1. Please read this user manual before operating your new module.

Installation



House the FH-1 in a Eurorack case of your choosing. The power connector is [Doepfer standard](#). If using the power cable supplied with the FH-1, the red edge of the cable is nearest the bottom of the PCB, and carries -12V. ("-12V" is marked on the PCB itself next to this end of the connector.) Be sure to connect the other end of the power cable correctly, again so -12V corresponds to the red stripe on the cable.

Inputs, Outputs and Controls



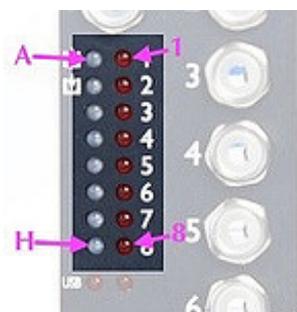
On the left side, from top to bottom, the FH-1 has

- Two input sockets (marked X & Y).
- 16 LEDs (8 pairs of blue/red), which display mode-specific information, for example, the current sequencer step.
- 2 red LEDs, which display USB status.
 - The left LED indicates whether a USB device is connected and active.
 - The right LED flashes whenever a MIDI message is received.
- A rotary encoder.
- A USB socket (type A).

On the right side, the FH-1 has

- Eight output sockets (marked 1-8).

The sockets are illuminated to reflect the voltage at the socket. Red indicates a positive voltage; blue indicates a negative voltage.



Below we will refer to the 16 LEDs by name as follows: the left column (blue), from top to bottom, are LEDs A-H; the right column (red) are LEDs 1-8.

Jumpers



There are 8 jumpers on the FH-1's top PCB, and 1 on the bottom PCB.

The 8 on the top PCB set the voltage range for each output. The options are:

- $\pm 5V$ - jumper in lower position (factory default setting)
- 0-10V - jumper in upper position
- 0-5V - jumper not fitted

The jumper on the lower PCB selects the power source for the attached USB device. The options are:

- use the FH-1's regulator to take power from the 12V bus - jumper in lower position (factory default setting)
- take power from the 5V bus - jumper in upper position

Needless to say, to make use of the second option your Eurorack PSU needs to be one that supplies 5V in addition to the usual $\pm 12V$.

Expansion

The 10 pin header labelled GT2 provides expansion in conjunction with the [FHX-1 Output Expander](#). Connect the cable provided with the FHX-1 to this header, oriented the same way as it is on the FHX-1.

Startup

When the module powers up it runs through some patterns on its LEDs, to a) give confidence that it's working correctly and b) display the firmware version.

There are actually two start-ups - first the bootloader (which allows firmware updates from a USB flash drive - see below), and then the main firmware.

The LED sequence is as follows:

- A, 1, B, 2, C, 3, etc.
- A + bootloader major version number as binary on 1-8 (1 is LSB)
- all off
- A + bootloader minor version number as binary on 1-8 (1 is LSB)
- H/8 flash alternately for 2 seconds while looking for a USB flash drive
- If no valid firmware is found, the bootloader stops here waiting for a USB drive to be inserted
- A to H, then 1 to 8
- A + firmware major version number as binary on 1-8 (1 is LSB)
- all off
- A + firmware minor version number as binary on 1-8 (1 is LSB)

Connecting and powering USB devices

Connect any class-compliant USB device to the FH-1's USB socket.

When a USB device is connected and successfully communicating with the FH-1, the left LED marked 'USB' lights. The right LED flickers to indicate activity.

The FH-1 will provide bus power to devices which require it. Remember though that this power load will be passed on to your Eurorack PSU.

The FH-1's own regulator will provide the USB specification's theoretical maximum of 500mA (FH-1 revision 1.1, from November 2015)¹. The regulator is about 83% efficient, which means that the current draw on the +12V rail is about half that drawn by the USB device. For example, if the USB device draws 100mA, the draw on the +12V rail would be about 50mA.

If you have insufficient power on your +12V rail, your options are

- If possible, provide power to the USB device directly (e.g. if it has a wall-wart input).
- Use the jumper to take power from the Eurorack 5V bus, if available (see above).

USB MIDI devices

The FH-1 supports class-compliant USB MIDI devices (indeed, these are its primary application).

USB HID (human interface device) peripherals

The FH-1 supports class-compliant USB HID peripherals (e.g. mice, trackballs, gamepads).

USB hubs

From firmware v2.0, the FH-1 supports USB hubs. A single USB hub is supported², with up to four ports.

When using a hub, the FH-1 supports up to four USB MIDI devices, and at most one USB HID peripheral.

Be careful when powering a hub and multiple devices from the FH-1, which is still limited to 500mA. If the total power required by the hub and the downstream devices exceeds this, then you will need to provide another means of powering all or some of the devices.

Note that just connecting a hub does not light the FH-1's 'USB' LED – it will only light when a supported device is plugged into the hub.

1 FH-1 revision 1.0 is able to supply about 300mA from its internal regulator, which is passed on 1:1 to the +12V rail (e.g. a USB device drawing 100mA will draw 100mA on the +12V rail via the regulator).

2 Note that some hubs in fact contain multiple, nested hubs internally. For a example, we have seen 7-port hubs that are in fact two 4-port hubs, with the input of one taken from the output of the other. In such cases, only one of the hubs is usable by the FH-1.

Principle of operation

The FH-1 receives MIDI CC and note on/off messages and generates outputs accordingly.

Each output of the FH-1 can operate in a number of modes e.g. direct CC control, sequencer output, LFO. Switching into one of these modes is achieved simply by sending a CC relating to that mode - for example, if an output is acting as a sequencer output, sending a MIDI CC corresponding to direct MIDI control will deactivate the sequencer on that output and start outputting the directly set value.

To put it another way, all the FH-1's various modes are simultaneously active. You don't need to explicitly switch from, say, MIDI/CV mode to LFO mode - you simply start using the mode you want (by sending the MIDI CCs for that mode), and the FH-1 enters that mode automatically.

While it is entirely possible to completely reconfigure the FH-1 itself (see below), the preferred approach is to configure your MIDI controller to send the right MIDI CCs to get the response from the FH-1 that you require.

The FH-1's primary modes are:

Direct control

The level of the output is directly set from the MIDI CC. Use of high resolution MIDI CCs allows access to the full 14 bit resolution of the FH-1's DACs.

LFOs

Each output can generate an LFO, which is added to the direct control level. The LFO has a speed control, an overall level multiplier, and a number of waveform levels (the various waveforms are added to create the overall LFO waveform). The LFOs can be synced to clock pulses on the FH-1's input.

Sequencers

The FH-1 has two, independent, 4 lane analogue-style sequencers. The sequencer steps can be set as direct levels, or in terms of musical notes.

Note On/Offs ("MIDI/CV conversion")

A number of modes of MIDI note to CV conversion are supported, from simple monophonic operation to 4 voice polyphonic. Trigger modes are also supported, which are more appropriate for controlling, say, drum sounds from controller pads.

Special purpose outputs

A number of special functions, mostly relating to clocking, can be configured for any output.

Tutorial

For a very readable overview of configuring the FH-1, please see [this tutorial](#) by Learning Modular.

MIDI message assignments

The full set of MIDI message assignments are shown in the following tables.

These default assignments can be completely customised via the configuration script.

The [html-based configuration tool](#) is also a handy reference for most of the default assignments.

MIDI CC assignments

The assignments are generally in groups of 8 sets of 8 CCs, numbered 0-7. The numbers refer to the expander (FHX-1) number, 'expander 0' being the FH-1 itself.

For example, for channel 3, CC 0-7, you will see “LFO speed 0”. These are the LFO speeds for the FH-1's own outputs, CC 0 corresponding to output 1, CC 1 corresponding to output 2, and so on up to CC 7 corresponding to output 8.

“Faders” means direct CC control of the output CV.

Channel	CC 0-7	CC 8-15	CC 16-23	CC 24-31
1	Faders 0	Faders 1	Faders 2	Faders 3
2	Faders 4	Faders 5	Faders 6	Faders 7
3	LFO speed 0	1	2	3
4	4	5	6	7
5	LFO multiplier 0	1	2	3
6	4	5	6	7
7				
8				
9				
10				
11				
12				
13				
14				
15	Sequencer A i 1-8	Sequencer A ii 1-8	Sequencer A iii 1-8	
16	Sequencer B i 1-8	Sequencer B ii 1-8	Sequencer B iii 1-8	

Channel	64-71	72-79	80-87	88-95
1	Smoothing 0	1	2	3
2	4	5	6	7
3	LFO clocked speed 0	1	2	3
4	4	5	6	7
5	LFO sin 0	1	2	3
6	4	5	6	7
7	LFO triangle 0	1	2	3
8	4	5	6	7
9	LFO saw 0	1	2	3
10	4	5	6	7
11	LFO random 0	1	2	3
12	4	5	6	7
13			Settings C	Settings D
14	Portamento 1-8	Portamento 9-16	Sustain 1-8	Sustain 9-16
15	Sequencer A gate 1-8	Sequencer A skip 1-8		Sequencer A params
16	Sequencer B gate 1-8	Sequencer B skip 1-8		Sequencer B params

Channel	96-103	104-111	112-119	120-127
1	Special purpose 0	1	2	3/calibration
2	4	5	6	7
3	LFO phase 0	1	2	3
4	4	5	6	7
5	LFO square 0	1	2	3
6	4	5	6	7
7	LFO PW 0	1	2	3
8	4	5	6	7
9				
10				
11	LFO noise 0	1	2	3
12	4	5	6	7
13	Menu E			
14	Arpeggiator			
15	Sequencer A i Quantized 1-8	Sequencer A iii Quantized 1-8		Sequencer A params 2
16	Sequencer B i Quantized 1-8	Sequencer B iii Quantized 1-8		Sequencer B params 2

Sequence parameters (channels 15-16, CCs 88-95 & 120-127)

89	scale
90	key
91	pre-scale transpose
92	post-scale transpose
93	glide i
94	glide ii
95	glide iii
120	gate length

MIDI Note on/off assignments

Outputs 1-8 are the FH-1 outputs; outputs 9-12 are the first four outputs of the first connected FHX-1 expander.

Channel	out 1	2	3	4	5	6	7	8	9	10	11	12
1	CV	gate										
2			CV	gate								
3					CV	gate						
4							CV	gate				
5	CV	gate	velocity									
6				velocity	CV	gate						
7							CV	gate	velocity			
8										velocity	CV	gate
9	CV	gate	velocity	after-touch								
10					CV	gate	velocity	after-touch				
11									CV	gate	velocity	aftertouch
12	notes 64-95 & velocity -> trigger/accent pairs											
13	notes 0-63 -> triggers 0-63, notes 64-127 -> gates 0-63, without velocity											
14	notes 0-63 -> triggers 0-63, notes 64-127 -> gates 0-63, with velocity											
15	CV (poly)	gate (poly)	CV (poly)	gate (poly)	velocity (poly)	velocity (poly)	after-touch	gate (para)				
16	CV (poly)	gate (poly)	CV (poly)	gate (poly)	CV (poly)	gate (poly)	CV (poly)	gate (poly)				

High resolution (14 bit) MIDI CCs

CC numbers 0-31 in the above charts support high resolution (14 bit) operation. In this case, each CC has a fine control (LSB) CC numbered 32 places higher. E.g. CC 4's fine control is CC 36. Normally this is handled transparently by MIDI devices that support 14 bit CCs, and you simply need to enable that mode on the hardware.

MIDI clock

The FH-1 supports receiving and sending MIDI clock.

Receiving MIDI clock

The FH-1 treats incoming MIDI clock as if clock pulses were applied to its input (X). That is, they clock the sequencers, and set the timebase for synced LFOs. The relationship between the rate of MIDI clocks and the rate of FH-1 clocks is controlled by a setting (see below). A MIDI start message is treated like a pulse on the reset input (Y).

Sending MIDI clock

If enabled (see settings, below), the FH-1 sends MIDI clock as long as clock pulses appear on its input (X). The relationship between the rate of MIDI clocks and the rate of FH-1 clocks is controlled by a setting (see below). When the FH-1 starts sending MIDI clock, it also sends a MIDI start message. If the FH-1 receives no clock pulses for two seconds, it sends a MIDI stop message and stops sending MIDI clock.

Internal clock

The FH-1 supports an internal clock, to drive its sequencers and tempo-synced LFOs.

Clock functions are accessed via menu E. Menu E may also be invoked via MIDI CCs (by default, MIDI channel 13 CCs 96-103).

Item	Function	CC number
1	Start/stop internal clock	96
2	Start/stop internal clock with tap tempo	97

BPM-based clock

A simple BPM-based clock is configured with settings for tempo, PPQN and multiplier. It is started and stopped via menu E, item 1. It can also be controlled via MIDI channel 14, CC 120; a value of 64 or more starts the clock; 63 or less stops the clock.

Tempo sets the base tempo of the clock.

PPQN sets the number of pulses that are generated per quarter note. At the default setting of 1, 1 pulse is generated per quarter note, so e.g. at 120bpm, 4 pulses are generated every 2 seconds. A pulse corresponds to one step of the internal sequencers, exactly as if a pulse had arrived on the X input.

Multiplier multiplies the length of a pulse. E.g. at 120 bpm, with a ppqn of 1, setting multiplier to 4 will generate a pulse every 2 seconds (once per whole note).

Essentially, raising ppqn makes the clocks more frequent; raising the multiplier makes them less frequent.

Tap tempo

You can also start the clock with a tap tempo function, via menu E, item 2.

The PPQN and multiplier settings as above still apply, but the tempo is defined by the tap tempo. Tap out 4 quarter notes by pressing the encoder. The press to accept the menu function is the first tap; then press 4 more times. On the 5th tap, the clock will start.

Note that whatever the settings for ppqn and multiplier, you're still tapping out quarter notes.

LFOs

Each output has an LFO, which is added to the 'direct control' value. The LFO's controls are as follows.

- The speed can be set in one of two ways:
 - Direct speed control (14 bit). (CCs 0-31 on channels 3 & 4.) Sets the LFO speed, from 0.1Hz to 10Hz. A logarithmic scaling of the MIDI CC is used, to allow finer control over the slower end of the range.
 - As a multiple of the input clock rate. (CCs 64-95 on channels 3 & 4.) The clocks arriving at FH-1 input X are multiplied or divided according to the CC value. If the CC is 64, the LFO rate is the same as the clock rate. If the CC is greater than 64, then the LFO rate is multiplied by the CC value minus 63 (so 65 means double rate, 66 means triple rate etc.). If the CC is less than 64, then the LFO rate is divided by 65 minus the CC value (so 63 means half rate, 62 means one third rate etc.).
- Six waveform amounts. The waveforms are added together to make the final LFO waveform. The 6 basic shapes are Sine, Square, Triangle, Saw, Random and Noise.
 - The Saw wave is set to zero at MIDI CC value 64. Values greater than 64 give a rising sawtooth shape; values less than 64 give a falling shape.
 - All other shapes are zero at MIDI CC value 0 and maximum at CC value 127.
- A pulsewidth control for the square waveform.
- A multiplier (14 bit). This scales the overall waveform that is the result of combining the 6 basic shapes. It defaults to maximum, so to apply an LFO it is only necessary to set one of the basic shapes to a non-zero level.
- A phase control.

Sequencers

The FH-1 has two internal sequencers, inspired by classic analogue step sequencers. They use outputs 1-4 (Sequencer A) and 5-8 (Sequencer B). In each case, the first three outputs are 'CV' outputs, while the fourth output is a trigger/gate.

The sequencers are advanced by applying a clock pulse to the X input. A high level on the Y input will reset the sequencers to step 1. The current step is displayed on the LEDs - A-H (blue) display Sequencer A's position, while 1-8 (red) display Sequencer B's position.

A sequencer output becomes active when a CC to set one of its steps is received. Therefore, it is possible to use a subset of the sequencer's outputs while using other outputs for e.g. LFOs, simply by not sending CCs to set steps on the inactive sequencer outputs.

The sequencer steps can be set in one of two ways - either as direct (14 bit) CC values (CC numbers 0-23), or as quantized note values (CC numbers 96-111).

The per-step gate/trigger is set by CC numbers 64-71. The CC value should be one of the following:

- 0 - off. No gate/trigger on this step.
- 64 - tie. The gate output is high for the duration of the step.
- 127 - on. A trigger is generated on this step.
- 2 - next. The gate behaviour steps through the 3 options off/on/tie. This is useful when you have a push button mapped to send this CC value, to cycle through the step behaviours with repeated button pushes.

The per-step skip/reset behaviour is set by CC numbers 72-79. The CC value should be one of the following:

- 0 - off. The step plays normally.
- 64 - skip. The step is skipped.
- 127 - reset. When the sequence advances to this step it resets to step 1.
- 2 - next. The skip/reset behaviour steps through the 3 options off/skip/reset. This is useful when you have a push button mapped to send this CC value, to cycle through the step behaviours with repeated button pushes.

Musical scales can be imposed on the sequencer steps. If a scale is selected via the appropriate CC, the output notes of the sequencer are constrained to be notes from the selected scale. The available scales are:

CC value	Scale
0	No scale
1	Major scale
2	Minor scale (flattened 3rd)
3	Natural minor scale (flattened 3rd, 6th & 7th)
4	Harmonic minor scale (flattened 3rd & 6th)
5	Major triad
6	Minor triad
7	Root +5th
8	Major triad +6th
9	Minor triad +6th
10	Major triad +7th
11	Minor triad +7th
12	Root +5th +6th
13	Root +5th +7th
14	Pentatonic major
15	Pentatonic minor

There is a MIDI CC to select the key for the scale. A CC value of 0 sets the root note to be C, a value of 2 sets the root to be D etc.

There are also two transposition CCs, "pre-scale" transpose and "post-scale" transpose. "Post-scale" transpose simply transposes the output sequence, so if e.g. you are hearing a sequence in C major and you transpose it by 2, you will hear the same sequence shifted up into D major. "Pre-scale" transpose shifts the notes before they are forced into the selected scale, so it effectively moves the notes around within the key. So for example, if your sequence is C/E/G and the scale is C major triad, pre-scale transposing by 4 semitones will give you E/G/C.

If no scale is being applied, both transpose controls simply shift the notes up and down chromatically.

The transpose CCs are centred around value 64, meaning zero transposition. Values above 64 transpose up; values below 64 transpose down.

Each sequencer lane has a glide control. This sets the time for notes to change smoothly after a step which is a tie.

Each sequencer has a gate length control, which sets the length of the gate pulse as a fraction of the full step length (and therefore is dependent on tempo, clock division etc.). At a setting of zero (the default), the gate length is a fixed length pulse, and not dependent on the step length.

Smoothing

Each output has a 'smoothing' setting (by default, MIDI channels 1/2, CCs 64-95). When enabled, a low pass filter is applied to the output to smooth sudden changes into an exponential response. Zero means off; other values apply progressively more smoothing, up to a time constant of about 1 second.

Smoothing applies to every function of the FH-1: direct CC control, LFOs, sequencers, etc. You may find it particularly useful to smooth out e.g. aftertouch response in a MIDI/CV converter, but it can also be applied creatively, for example to make new LFO shapes, or to introduce glide on a sequencer pitch CV.

Note On/Offs ("MIDI/CV conversion")

The FH-1 responds to MIDI note on/off messages in a variety of ways, depending on the MIDI channel on which they arrive. These are:

- Monophonic CV/gate pairs. MIDI channels 1-4 output CV/gate pairs on outputs 1/2, 3/4, 5/6 & 7/8 respectively.
- Monophonic CV/gates with velocity. MIDI channels 5-8 output these signals on triples of outputs from 1-12 (outputs above 8 refer to outputs on the first connected FHX-1 expander). Refer to the chart for details.
- Monophonic CV/gates with velocity and aftertouch. MIDI channels 9-11 output these signals on sets of four outputs from 1-12 (outputs above 8 refer to outputs on the first connected FHX-1 expander). Refer to the chart for details.
- Duophonic CV/gate with velocity, aftertouch (channel pressure) and paraphonic gate. MIDI channel 15.
- Polyphonic (4 voices) CV/gate pairs. MIDI channel 16.
- Trigger/accent pairs. MIDI channel 12. MIDI notes 64-95 generate triggers on odd numbered outputs 1-63, with accents appearing on the adjacent even numbered output 2-64 if the note's velocity is 96 or above.

- Triggers (no velocity). MIDI channel 13, notes 0-63.
- Gates (no velocity). MIDI channel 13, notes 64-127.
- Triggers (with velocity). MIDI channel 14, notes 0-63.
- Gates (with velocity). MIDI channel 14, notes 64-127.

Monophonic MIDI/CV converters have a portamento setting (by default MIDI channel 14 CCs 64-79). This sets a glide time between notes played legato ("fingered portamento").

The FH-1's MIDI/CV converters are highly configurable - see below. As well as simple tasks such as moving the outputs around, this is how you can access extra features not in the base configuration e.g. release velocity and trigger outputs.

Gated Aftertouch

If enabled, the aftertouch output can automatically be set to zero when all keys are released. This is primarily provided for use with the [ROLI](#) controllers, so that aftertouch can be used directly for e.g. VCA control.

Voice Allocation

Polyphonic MIDI/CV converters can be configured for various different voice allocation schemes. The options are:

- **Round robin** (the default). Each voice is used in turn.
- **Lowest voice**. The lowest-numbered available voice is used for each new note. This means that if you start from no notes, the first note played will always be voice one, the second note voice two etc., so you can reliably for example hold a drone on voice one and play over it on a second voice.
- **Unison**. All voices are always used, duplicating notes if less notes are played than there are voices. This is very much like for example the Korg MonoPoly's "Unison/Share" mode.

Sustain

Monophonic and polyphonic MIDI/CV support the usual sustain mechanism. However the CC message that traditionally controls this (CC 64) is by default used for other purposes. Sustain on the FH-1's converters is controlled on MIDI channel 14, CCs 80-95. If desired this can be reconfigured to the usual CC 64 on the converter's own channel.

Arpeggiator

The FH-1 has a powerful arpeggiator. When enabled, it applies to the first MIDI/CV converter, which by default is the one on MIDI channel 1. This can be reconfigured as desired.

The arpeggiator is controlled by CCs 96-103 on MIDI channel 14.

The arpeggiator can be clocked by any of the FH-1's clock sources - the X input, MIDI clock, or the internal clock.

The controls are as follows:

CC number	Function
96	Mode - see below
97	Range - the number of octaves to repeat the arpeggiation pattern over. CC values 0-127 map to 1-3 octaves.
98	Gate length - the gate on time as a fraction of the clock rate. 64 (the default) is a 50% gate length. 0 is a special value and means a fixed length trigger pulse, unrelated to the clock rate.
99	Latch on/off - see below

The available modes are:

CC value	Mode	Description
0 - 18	Off	The arpeggiator is disabled.
19 - 36	Up	Notes are used in order from lowest to highest.
37 - 54	Down	Notes are used in order from highest to lowest.
55 - 73	Alt	Alternately up & down (e.g. 4 notes held gives you a 6 note pattern).
74 - 91	Alt2	Alternately up & down, repeating the highest and lowest notes (e.g. 4 notes held gives you an 8 note pattern).
92 - 109	Random	The notes held play in a random order.
110 - 127	As Played	The notes are repeated in the order in which they were played.

If 'latch' is enabled, notes are held until all keys are released and a new note played. This makes it particularly easy to play a chord, have it repeat and arpeggiate, play another chord, and so on.

Special purpose outputs

Any output can be configured with a number of special functions. This is by default on MIDI channels 1 & 2, CCs 96-127. The functions are as follows.

CC value	Function
0	No special purpose
1	Run/stop signal. Goes high when the internal clock or external MIDI clock is running.
2	Run/stop signal, inverted. Goes low when the internal clock or external MIDI clock is running.
3	Trigger on clock start (internal clock or external MIDI clock).
4	Trigger on clock stop (internal clock or external MIDI clock).
5	Trigger on clock start & stop (internal clock or external MIDI clock).

The encoder & menu system

Pressing the encoder enters the FH-1's menu system, which is indicated by the LEDs blinking. If the encoder is not turned or pressed for a few seconds, menu mode is exited and the FH-1 resumes normal operation.

In general, the menu system works like this:

- Press the encoder to enter menu mode.
- Turn the encoder to select the top level menu item (indicated on LEDs A-H), and press to select.
- Turn the encoder to select the second level menu item (indicated on LEDs 1-8), and press to

select.

- Press to confirm.

The top level menu items are:

Menu	Function	Submenu meaning
A	Load preset	Preset number
B	Save preset	Preset number
C	Settings	Select setting
D	Clock Settings	Select setting
E	Clock Functions	Select function
G	Miscellaneous functions	Select function
H	Resets	Select what to reset

Loading and saving Presets

A snapshot of the FH-1's current state can be stored as a preset. There are 8 preset slots.

Saving a preset

To store a preset into non-volatile memory:

- Press the encoder to enter menu mode. LED A starts flashing.
- Turn the encoder so that LED B is flashing.
- Press the encoder. LED 1 starts flashing.
- Turn the encoder to select the desired preset slot 1-8.
- Press the encoder. All the LEDs start flashing.
- Press the encoder again to confirm the save.

At any point, simply leave the encoder alone for a couple of seconds to abort the save process.

Loading a preset

To load a preset from non-volatile memory:

- Press the encoder to enter menu mode. LED A starts flashing.
- Press the encoder. LED 1 starts flashing.
- Turn the encoder to select the desired preset slot 1-8.
- Press the encoder. All the LEDs start flashing.
- Press the encoder again to confirm the load.

At any point, simply leave the encoder alone for a couple of seconds to abort the load process.

It is possible to configure the X & Y inputs to step through the presets in response to incoming trigger pulses - see setting C-6 below.

Settings

The FH-1 has a number of settings which are stored in flash memory and which are accessible from the front panel encoder. These are accessed via menus C & D. To change a setting:

- Press the encoder to enter menu mode.
- Select menu C or D and press the encoder.
- Select the setting to change and press the encoder.
- The setting's current value is shown on LEDs A-H as a binary number. Use the encoder to select the new value.
- Press the encoder to confirm and save the setting.

Settings may also be changed via MIDI CCs (by default, MIDI channel 13 CCs 80-95).

Settings are separate from the preset system; settings are not stored or loaded as part of a preset.

Menu C - Settings

The available settings are:

Setting	Function	Default	Range	CC number	Note
1	Pitch bend depth	2	0-48	80	Sets the pitch bend depth in semitones for all "MIDI/CV" modes.
2	Legato velocity	1	0-1	81	When enabled, playing legato in monophonic MIDI/CV modes (MIDI channels 5-11) will use the note velocity only from the first note in a phrase.
3	Startup preset	0	0-8	82	Sets the preset to load at startup (or zero to start with defaults).
4	Global transpose	0	-48 - 48	83	Sets the transposition in semitones for all MIDI/CV converters.
5	Disable device-specific behaviour	0	0-1	84	When set, prevents the FH-1 from entering a device-specific mode when the device is attached.
6	X/Y Input Mode	0	0-1	85	If 0 (the default), the X/Y inputs advance and reset the sequencers. If 1, the X/Y inputs advance through the presets.
7	Trigger length	50	1-100	86	The length, in milliseconds, of triggers generated by the FH-1. This includes those generated by the MIDI/CV converters, and the special purpose outputs.

Menu D - Clock Settings

The available settings are:

Setting	Function	Default	Range	CC number	Note
1	MIDI clock divisor	12	1-96	88	Sets the division of incoming MIDI clock. There are 24 MIDI clocks per quarter note. For example, the default value of 12 clocks the internal sequencer/LFOs on eighth notes. Also sets the multiplication of outgoing MIDI clock.
2	Enable MIDI clock out	0	0-1	89	Enables output of MIDI clock (generated from incoming clock pulses).
3	Stop LFOs when clock stopped	0	0-1	90	When set to 1, causes tempo-synced LFOs to stop when the internal clock and external MIDI clock are stopped.
4	Internal clock tempo	120	1-255	91	Sets the tempo for the internal clock. When controlled by MIDI CC, the available range is 60-187 BPM.
5	Internal clock PPQN	1	1-48	92	Sets the number of pulses per quarter note for the internal clock.
6	Internal clock multiplier	1	1-64	93	Sets the multiplier for the internal clock.

Calibration

A calibration process is available to fine tune the output of functions that produce pitch CVs e.g. the MIDI/CV converters, or the sequencers. It is stored with the settings i.e. it is global, not saved with each preset.

Calibration is accessed via menu G/1. In outline, the procedure is

- Enter calibration mode & select the output to be calibrated.
- Use MIDI CCs to set the desired output for MIDI note 60 (C4).
- Use MIDI CCs to set the desired output for MIDI note 96 (C7).

The outputs for other MIDI notes are then interpolated from the set values.

Calibration uses MIDI CCs 126 & 127 on MIDI channel 1. Two CCs are required because the FH-1's outputs are 14 bit; each CC sets 7 bits. CC 126 sets the high 7 bits (think of this as the coarse tune); CC 127 sets the low 7 bits (the fine tune). The suggested approach is to first set CC 127 to zero, and then use CC 126 to set the nearest possible value below the target value. Then raise CC 127 to get as close to the target as possible.

You can calibrate either with a voltmeter to directly measure the FH-1's output voltage, or using a connected VCO and tuner. If measuring voltages, the target voltages will depend on your jumper settings. With the default jumper setting, giving an output range of $\pm 5V$, the suggested voltages are 0V for C4 and 3V for C7. If you've selected an output range of 0-10V, then it would be more appropriate to tune C4 to 5V and C7 to 8V.

The full procedure in detail is as follows.

- Select menu G, submenu 1, and confirm.
- Now select the output to be calibrated. Here, LEDs A-H indicate the expander number (A, or 'expander 1', is the FH-1 itself). LEDs 1-8 indicate the output within the expander. The steps are the same as choosing a menu/submenu - first use the encoder to choose the expander, press the encoder, and then use the encoder to choose the output. During this process the LEDs will do a 'double-flash', to distinguish it from the menu selection process.
- After choosing the output 1-8, press the encoder again. The LEDs will now do a 'triple-flash', indicating that you should now use the CCs as above to tune the value for C4. During tuning, the menu time-out is much longer than usual, but it will still time out eventually if you do not move on to the next step.
- Once you have tuned C4, press the encoder. The LEDs will now flash quickly and continuously, indicating that you should tune for C7.
- When C7 is tuned, press the encoder to accept the calibration and store it in the settings.

Resets

Menu H offers a number of reset functions.

Submenu number	Function
1	Reset the complete preset state - all the fader levels, all the LFOs, the sequencers etc.
2	Reset the sequencers to their default state
3	Reset the LFOs to their default state
4	Resets the internal MIDI/CV state to clear hanging notes etc.
6	Reboots the FH-1
7	Erases the configuration script
8	Resets all settings to their default values

Special support for certain devices

The FH-1 detects which USB MIDI device is connected, and for certain devices modifies its behaviour.

If the FH-1 is entering a device-specific mode, it flashes all 16 LEDs twice rapidly when the device is connected. There is a setting to disable all device-specific behaviour.

The devices with special support are:

- Novation Launch Control XL – the FH-1 sends MIDI back to the LCXL to drive its LEDs, on the assumption that the rows of knobs and buttons have been set up to control the FH-1's sequencers as in [this video](#).
- Novation Launchpad Mini & Launchpad Pro – the FH-1 enters a special mode which uses the Launchpad grid as a multi-lane trigger sequencer. The needs to be fleshed out and should be considered a work in progress at the moment.

USB HID (human interface device) peripherals

From firmware v2.0, the FH-1 supports direct control over its CV outputs from USB HID peripherals (e.g. a mouse or gamepad).

The exact mapping between the peripheral's controls and the FH-1's outputs can be specified in configuration scripts (see below) but a default mapping is provided which is intended to be as useful as possible without reconfiguring.

USB mouse

If the HID peripheral identifies itself as a mouse, then it controls the FH-1 as follows:

- Outputs 1 & 2 are controlled by the mouse X & Y movement.
- Output 3 is controlled by the mouse wheel (if present).
- Outputs 4-17 are controlled by the mouse buttons (i.e. up to 14 buttons are supported).

Other HID peripherals

If the device is not a mouse, a mapping is used which is designed to be most useful when applied to a Sony Dualshock 4, but which should apply fairly well to most gamepads. The controls are as follows:

- Outputs 1 & 2 are controlled by X & Y (the left stick).
- Outputs 3 & 4 are controlled by Z & Rz (the right stick).
- Outputs 5 & 6 are controlled by Rx & Ry (the L2 & R2 'triggers').
- Outputs 7 & 8 are controlled by buttons 5 & 6 (L1 & R1).
- Outputs 9-12 are controlled by the 'hat' aka d-pad.
- Outputs 13-16 are controlled by buttons 1-4 (the 'symbol' buttons).
- Outputs 17-24 are controlled by buttons 7-14.

Configuration scripts

The FH-1's response to MIDI can be customised via scripts, which are installed from a USB flash drive in the same manner as updating the firmware. They can also be installed via MIDI System Exclusive.

Note that this is not intended as the primary means of integrating the FH-1 with your setup. It is generally much easier to configure your MIDI controller to send the MIDI that the FH-1 expects, rather than reconfiguring the FH-1 to respond to the controller's default MIDI output.

The scripts serve three main purposes:

- To remap MIDI CCs.
- To configure the MIDI/CV converters.
- To configure the USB HID mapping.

CC remap is conceptually simple - for a given incoming MIDI channel and CC number, map that onto the FH-1's preprogrammed CC assignment. Configuration of the MIDI/CV converters is much

more flexible, allowing creation of MIDI/CV modes not supported in the standard FH-1 configuration.

The script stored in the FH-1 is invoked whenever a USB device is attached. If the script contains a RST (reset) command, this allows for resetting the FH-1 by detaching and reattaching the USB device. In combination with the DEV command, this allows for having the FH-1 change behaviour when one USB device is detached and a different one attached.

Tutorial

For a very readable overview of configuring the FH-1, please see [this tutorial](#) by Learning Modular.

Configuration tools

Some web-based tools are available to assist in creating scripts, and in transferring them to/from the FH-1. At present these are:

- [GUI-based script generation tool](#) - allows you to create and edit scripts entirely in a GUI, without actually typing anything.
- [SysEx-based script installation tool](#) - allows you to transfer scripts to/from the FH-1 over SysEx from the browser, and also to create a SysEx file from a script which can later be installed via another SysEx tool.
- [Script-to-Hex converter](#) - creates Hex files which can be used to install scripts via a USB flash drive.

Note that if you need/want to download local copies of these tools, you also need to download [this script file](#) on which they depend (just put it in the same local folder on your drive).

The script file

An FH-1 script is a simple text file. For example

```
FH-1 script v1
RC3
CC2:1:5
```

All scripts start with the line 'FH-1 script v1'. Subsequent lines are commands which are executed in order, and which are described below.

The script should end in a blank line - the last command should always have a carriage return after it.

Whitespace

(From firmware v1.4) All whitespace (i.e. spaces & tabs) in scripts is ignored. You can freely insert whitespace to aid readability. Note though that the total size of a script is limited, so for very long scripts you may need to watch how compact your script is.

Remapping CCs

Remapping CCs is done via two commands, 'RC' and 'CC'.

'RC' simply sets the incoming MIDI channel for subsequent 'CC' commands. RC is followed by the MIDI channel number 1-16. In the example above, 'RC3' indicates MIDI channel 3.

'CC' sets up the remap. The syntax is

```
CC<CC number or range>:<destination MIDI channel>:<destination CC range start>
```

so in the example above 'CC2:1:5' means remap CC 2 (on MIDI channel 3, as set up by the RC command) to CC 5 on MIDI channel 1.

The CC number can be a single number or a range. Ranges are specified with a dash e.g.

```
CC2-4:1:5
```

means remap CCs 2 to 4 (inclusive) to CCs 5 to 7.

A more extensive example is [here](#). This results in the CC assignments shown [here](#).

Note that to remap the 14 bit CCs (0-31), two CC commands are required, to map the high and low CCs in pairs.

Configuring MIDI/CV converters

By way of an example, here is the default script which is run at startup to configure the base functionality described in the user manual. Any user script is run after this one, and can redefine or disable the default converters.

```
FH-1 script v1
MCV1:1:0-127:C0G1
MCV2:2:0-127:C2G3
MCV3:3:0-127:C4G5
MCV4:4:0-127:C6G7
MCV5:5:0-127:C0G1V2
MCV6:6:0-127:C4G5V3
MCV7:7:0-127:C6G7V8
MCV8:8:0-127:C10G11V9
MCV9:9:0-127:C0G1V2A3
MCV10:10:0-127:C4G5V6A7
MCV11:11:0-127:C8G9V10A11
MCV12:12:64-95:-TA
MCV13:13:0-127:-GN
MCV14:14:0-127:-GV
MCV15:15:0-127:PA6G7:C0G1V4:C2G3V5
MCV16:16:0-127:P:C0G1:C2G3:C4G5:C6G7
```

As you can see, there is one command, 'MCV'. The syntax is

```
MCV<converter number>:<MIDI channel>:<note range>:<converter details>
```

or

```
MCV<converter number>:
```

The 'converter number' identifies the converter. There are 16 converters available, so this number can be in the range 1-16.

If the second form of the command is used (nothing following the converter number), the converter is disabled. E.g. 'MCV1:' by itself disables MIDI/CV converter number 1.

'MIDI channel' is in the range 1-16.

The 'note range' is the range of MIDI note numbers to which this converter will respond. '0-127' responds to all notes on the channel.

The 'converter details' section of the command takes a number of forms, as follows.

Special case converters

Converter details starting with '-' are special cases, and are not configurable except to select them on a particular channel.

- -TA : triggers with accents
- -GN : gates/triggers without velocity
- -GV : gates/triggers with velocity

Monophonic converters

Monophonic converters have up to 4 outputs, which can be any combination of CV (C), gate (G), velocity (V), release velocity (R), trigger (T) and aftertouch (A). The details string is a list of the required outputs, each followed by the FH-1 output number. So e.g. 'C0G1' means CV on output 0 and gate on output 1.

The output numbers range from 0 to 63. 0 to 7 are the FH-1's own outputs; 8-15 are the outputs on expander 1, and so on.

In addition an 'I' (capital letter I) can be included in the details string, which causes the gate to be inverted.

If aftertouch is specified with a lower case 'a' (rather than the usual 'A'), this enables the Gated Aftertouch feature.

Polyphonic converters

If the converter details start with a 'P', this indicates a polyphonic converter.

The 'P' can optionally be followed by an 'A/output' (for aftertouch) and/or a 'G/output' (for paraphonic gate i.e. a gate that is high when at least one of the voice gates is high). An example is in the script above for MCV15.

'P' can additionally be followed by 'S/option' to set the voice allocation scheme. For example

```
MCV16:16:0-127:PS1:C0G1:C2G3:C4G5:C6G7
```

is the same as default MIDI/CV converter 16 but with voice allocation scheme 1. The available schemes are:

- 0 : round robin (default)
- 1 : lowest voice
- 2 : unison

An 'L' after the 'P' disables voice stealing on the converter - any keys pressed beyond the polyphony of the converter are ignored. By default, without this option, new notes replace any old ones being held.

Next comes a section for each voice, in the same format as the monophonic converters. Each voice can have CV (C), gate (G), velocity (V), release velocity (R) and trigger (T). Note that each voice does not need to have the same selection of outputs.

The polyphony of the converter is defined implicitly by the number of voices specified. The

maximum polyphony is 16.

Raw MIDI

A script may contain raw MIDI messages, which are processed by the FH-1 exactly as if they'd arrived on its USB port. This provides an alternative setup method to storing presets.

MIDI is specified with the 'HEX' command, which is simply followed by a list of bytes in hexadecimal format. Whitespace between bytes is not required, but aids readability. You may also freely use commas to separate bytes. Upper or lower case letters may be used.

For example, to set the level of the FH-1's first output to halfway the command would be:

```
HEXb00040
```

which breaks down as CC change on channel 1, CC number 0, value 64. As another example, to set up a sine LFO on output 1 you could use

```
HEX b4 40 7f, b2 00 40, b0 00 40
```

You can use as many HEX commands as you like.

Reset

The 'RST' command anywhere in a script resets the FH-1's state (exactly equivalent to resetting via menu H/1).

Note-to-CC remaps

The FH-1 has the ability to map incoming note on/off's to CC messages. This is useful for example if your MIDI controller has pads which can only transmit notes, but you want them to control something for which the FH-1 uses CCs.

The syntax is

```
NC<type>:<note MIDI channel>:<note number>:<CC MIDI channel>:<CC number>:<off value>:<on value>
```

For example

```
NCC1:48:2:6:0:127
```

maps note 48 on MIDI channel 1 to control CC 6 on MIDI channel 2, with values of 0 (note off) and 127 (note on).

The available types are

- **C** (i.e. NCC) - the note on/off state controls the CC directly. Note on will set the CC to the on value; note off will set the CC to the off value.
- **T** (i.e. NCT) - note on toggles the CC value between the off and on values. Note offs are ignored.

Device-specific scripts

The 'DEV' command allows for scripts whose behaviour depends on the attached USB device. When the script encounters a DEV command, the device name in the command is compared with that of the currently connected device. If the two don't match, the following script commands are ignored, until the next DEV command.

Consider this example:

```
FH-1 script v1
RC9
CC74:1:4
DEV:nanoKEY2
RST
DEV:Launch Control XL
HEX b4 64 40 b2 44 3d b0 04 60
HEX b4 65 40 b2 45 3f b0 05 60
```

The remapping of channel 9 CC 74 always applies. If a nanoKEY2 is connected, then the RST command runs. If a Launch Control XL is connected, then the two HEX commands run.

Note that the device name in the DEV command is the one place where whitespace matters. E.g. a Launch Control XL will not match "DEV:LaunchControlXL" (no spaces) or "DEV:Launch Control XL" (double space).

The 'FORCE' command allows you to instruct the FH-1 to always assume a certain device is connected. This is useful for example if you want to use device specific behaviours but your FH-1 is connected indirectly to the device (e.g. through an [iConnectivity](#) interface). The usage is e.g.

```
FORCE:Launch Control XL
```

USB HID configuration

Just as with the MIDI/CV converters, the FH-1 runs a script at startup to configure itself with the default controller mapping. That script is:

```
HID:0:X:256:0
HID:1:Y:-256:65536
HID:2:Z:256:0
HID:3:RZ:-256:65536
HID:4:RX:128:32768
HID:5:RY:128:32768
HID:6:B5-6
HID:8:HU
HID:9:HD
HID:10:HL
HID:11:HR
HID:12:B1-4
HID:16:B7-14
USAGE:2
HID:2:W:1024:0
HID:3:B1-14
```

There are two commands relating to HID mapping: HID and USAGE.

USAGE is the counterpart to DEV (see above). Commands after it only apply if the HID usage of the device matches that given in the script. The command 'USAGE:2' matches mice. See for example [this page](#) for a list of possible usage values.

The basic syntax of the HID command is

```
HID:<output>:<usage>
```

where 'output' is the FH-1 output number from 0-63, and 'usage' is one of the possible values:

X, Y, Z, RX, RY, RZ, W, H, HU, HD, HL, HR, B

X, Y, Z, RX, RY, & RZ are usually the joysticks on a gamepad, or the axes of mouse movement. If these are specified, they must be followed by two numbers for the scale and offset that takes the USB report values and turns it into a 16 bit value for the FH-1's output. E.g.

```
HID:4:RX:128:32768
```

says that the RX input is scaled by 128 and offset by 32768.

Note that if the X, Y, Z etc. inputs are specified by the device as being relative (as is usual for a mouse) then the offset is not used, and the scale multiplies the movement amount reported by the device.

W is the 'wheel' usage. It also is followed by scale and offset values.

B is one of the buttons. 'B' is followed by the button number (starting with B1), or a range of buttons (e.g. 'B1-4'). If a range is specified the buttons in the range are mapped to the corresponding range of outputs starting at the specified output.

By default buttons output the lowest value when off and the highest value when pressed (leading to -5V and +5V with the default FH-1 jumper settings). The B command can optionally be provided with two extra numbers giving the off and on values e.g.

```
HID:3:B1:65535:32768
```

says the button outputs 65535 (the maximum, +5V with default jumpers) when not pressed and 32768 (midrange, or 0V with default jumpers) when pressed.

H is the 'hat', more commonly known as the directional pad. 'H' by itself uses the raw value, which is given as a rotation, as if the pad were another joystick. If the script uses 'HU', 'HD', 'HL' or 'HR', these are treated as presses of the individual d-pad buttons. In this case you can optionally specify off and on values, as for 'B'.

Installing scripts

There are two methods for installing scripts:

Installation from USB flash drive

The process for installing scripts is exactly the same as that for updating the firmware, that is, the script is converted to a file called 'image.hex', which is put on a USB flash drive and written to the FH-1's flash by the bootloader.

A web-based tool for converting scripts to Hex is [here](#).

Alternatively, a Python script for converting the FH-1 script to a Hex file is [here](#). Note that this depends on the [intelhex](#) package, which you will need to install first. The usage is

```
python script2hex.py <your script file.txt>
```

Installation via SysEx

Scripts may also be installed via MIDI System Exclusive. See the SysEx section below, and also the tools above.

Debugging

If there is a problem parsing the script, the FH-1 will flash LEDs C & D alternately for a short while at startup.

MIDI System Exclusive (SysEx)

The FH-1 supports a variety of features via MIDI System Exclusive messages. These mainly relate to configuration functions, rather than real-time operation.

SysEx Header

All SysEx messages are prefixed with a manufacturer's ID, which is a unique series of hex bytes assigned by the MIDI Manufacturers Association. The Expert Sleepers ID is 00H 21H 27H, so all SysEx messages relating to Expert Sleepers hardware will begin

```
F0 00 21 27
```

Messages for the FH-1 follow this with 1FH:

```
F0 00 21 27 1F
```

and then with a byte to identify the specific type of message e.g.

```
F0 00 21 27 1F 10
```

Received SysEx messages

01H - Set CC Remap

```
F0 00 21 27 1F 01 <from channel> <from CC> <to channel> <to CC> F7
```

From/to channel are 0-based MIDI channels (0-15). From/to CC are 0-based MIDI CC (0-127). For example

```
F0 00 21 27 1F 01 00 01 00 02 F7
```

says remap MIDI channel 1 CC 1 (by convention, the mod wheel) to channel 1 CC 2 (which is the FH-1 CC for direct control of output 3).

Remaps set via this message are volatile - they are not saved into flash memory.

10H - Install script

```
F0 00 21 27 1F 10 00 00 <NULL terminated ASCII string> F7
```

This message installs the included text as a configuration script, exactly as if it had been installed from a USB stick. Note that there is no need to encode the script into hex, as is the case when using USB.

21H - Request script dump

```
F0 00 21 27 1F 21 F7
```

This causes the FH-1 to respond with a SysEx message containing the currently installed configuration script. The response message is in exactly the format of the '10H - Install script' message above, so that it can be recorded into and played back from a SysEx librarian tool (for example, [this](#)).

Sent SysEx messages

10H - Install script

See above. This message is transmitted in response to a '21H - Request script dump' message, or when the 'Dump script via SysEx' menu item is used (menu G/2).

The script returned is that installed in the FH-1's flash (via USB or SysEx). It does not reflect any interactive changes from e.g. the '01H - Set CC Remap' message.

Firmware Updates

The FH-1's firmware can be updated from a USB flash drive. The process is as follows:

- Download the firmware from the Expert Sleepers website.
- Unzip the download.
- Copy the file 'image.hex' from the unzipped download to the root folder of a USB flash drive.
- Turn off the FH-1 and insert the USB flash drive.
- Turn on the FH-1. It will go through its startup sequence as above. At the stage where LEDs H/8 flash alternately, if the FH-1 finds a USB flash drive with a file named 'image.hex' on it, it will proceed to the next step.
- LEDs A-H will flash alternately with LEDs 1-8. This indicates the FH-1 is waiting for your confirmation before proceeding. At this point, spinning the encoder will cancel the upgrade process and the FH-1 will continue to boot its current firmware. To continue with the firmware update, press and hold the encoder for one second.
- When the update starts, LED B will light and LEDs 1-8 will flash to indicate progress. Do not remove the flash drive or turn off the power during the update.
- When the update is complete, the FH-1's usual boot process will resume.