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

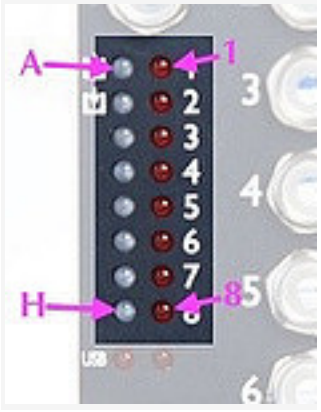
On the left side, from top to bottom, the FH-1 has

- 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:

- ±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 ±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 seqeuence 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 a USB device

Connect any class-compliant USB MIDI 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 MIDI message 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 theorectical maximum of 500mA (FH-1 revision 1.1, from November 2015)*. 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).

*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).

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.

The 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-stye 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.

MIDI message assignments

The full set of MIDI message assignments are shown in these charts:

CC assignment chart

Note on/off assignment chart

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

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).

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.

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 tranpose 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 betwen notes played legato ("fingered portamento").

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.

Settings

The FH-1 has a number of settings which are stored in flash memory and are not controlled via MIDI. 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).

Menu C - Settings

The available settings are:

Setting	Function	Default	Range	Note
1	Pitch bend depth	2	0-48	Sets the pitch bend depth in semitones for all "MIDI/CV" modes.
2	Legato velocity	1	0-1	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	Sets the preset to load at startup (or zero to start with defaults).

4	Global transpose	0	-48 - 48	Sets the transposition in semitones for all MIDI/CV converters.
5	Disable device-specific behaviour	0	0-1	When set, prevents the FH-1 from entering a device-specific mode when the device is attached.

Menu D - Clock Settings

The available settings are:

Setting	Function	Default	Range	Note
1	MIDI clock divisor	12	1-96	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	Enables output of MIDI clock (generated from incoming clock pulses).
3	Stop LFOs when clock stopped	0	0-1	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	Sets the tempo for the internal clock.
5	Internal clock PPQN	1	1-48	Sets the number of pulses per quarter note for the internal clock.
6	Internal clock multiplier	1	1-64	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.

Calbration 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 ±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.
-