Expert Sleepers

FH-2 'factotum'

Firmware v1.13 User Manual

Table of Contents

Introduction

Congratulations on your purchase of an Expert Sleepers FH-2. Please read this user manual before operating your new module.

The key functions of the FH-2 are

- MIDI-to-CV conversion, or more generally, generating CVs in response to MIDI messages.
    - 'MIDI-to-CV conversion' is often used to mean simply generating CV/gate from MIDI notes. The FH-2's capabilities go way beyond that.
- Clocking.
    - Generating analogue clocks from MIDI clock, or generating MIDI clock from analogue clocks, or generating MIDI and/or analogue clocks from the module's own internal clock.

All this and more is spelled out in detail below.

Typical usages

With a MIDI keyboard
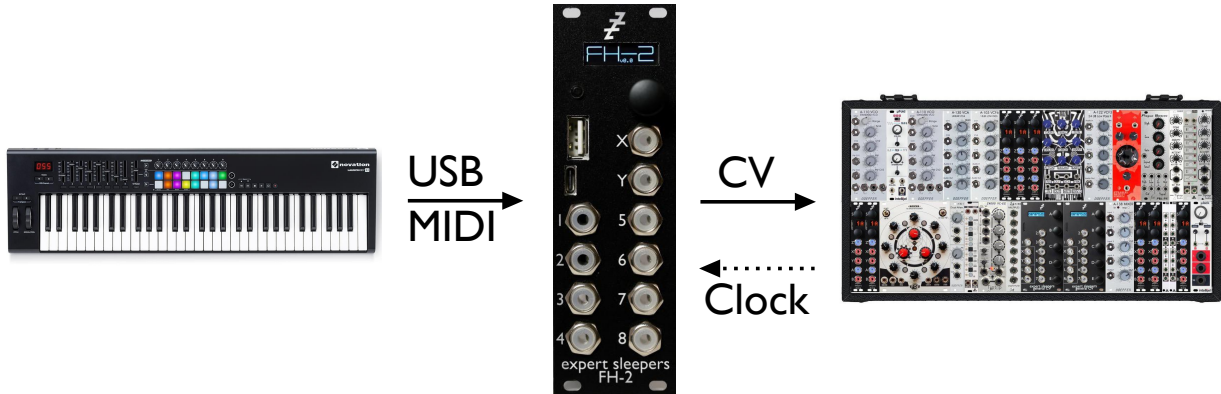
Up to 16 note polyphonic conversion, with optional pitch/gate/velocity etc. CVs per note. Also features arpeggiation, keyboard splits and more.

With an MPE controller
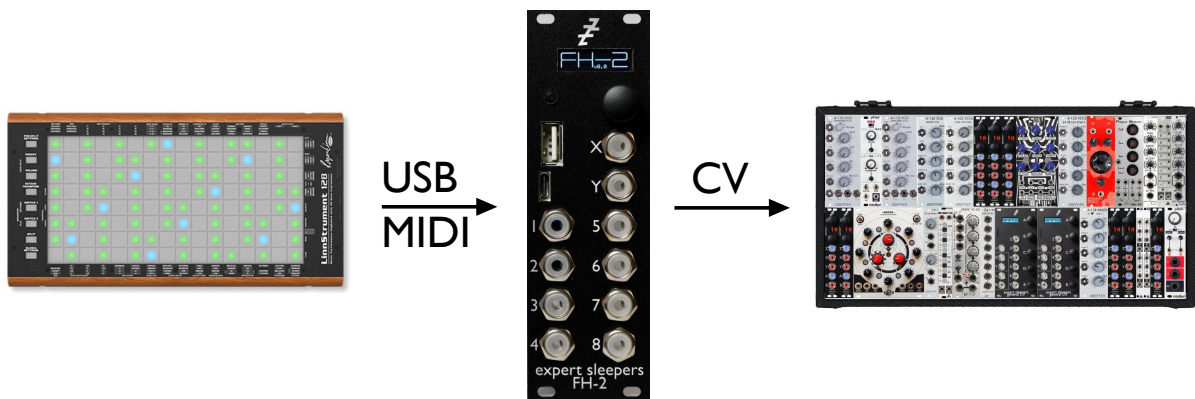
Up to 16 simultaneous touches converted with full position/pressure/glide etc. per touch.

With a MIDI controller
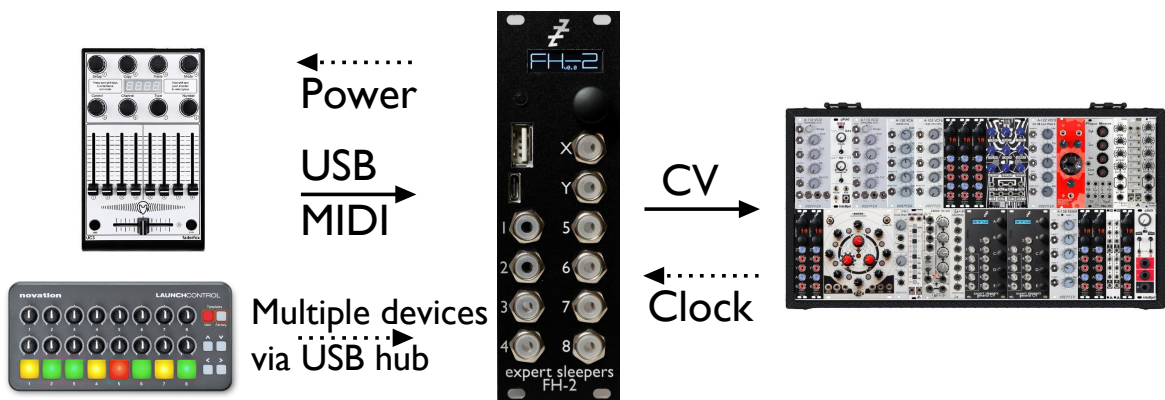
Up to 64 outputs. Direct control of CVs from faders, flexible and syncable LFOs, triggers from pads etc.

With a 'groovebox'

Clock

USB
MIDI

Clock

CV
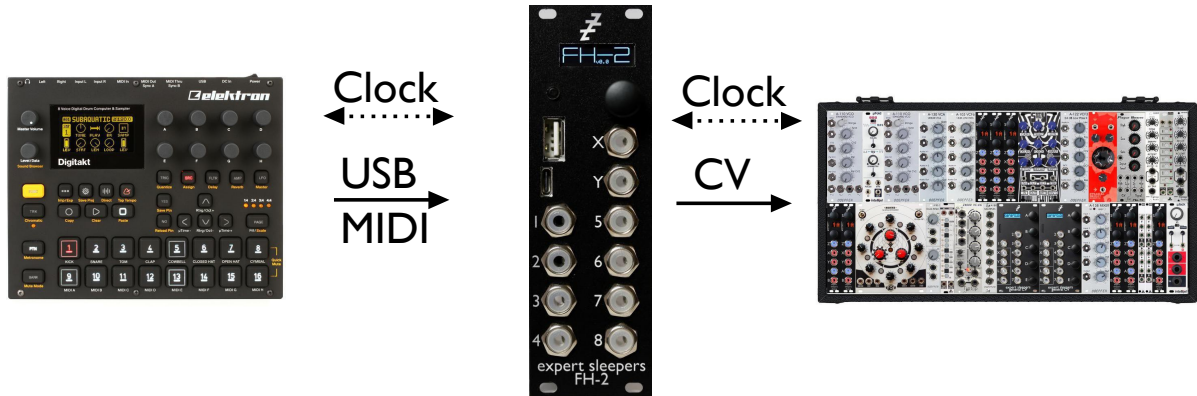
Multiple clock outs at different divisions, run/stop triggers etc. Groovebox, FH-2, or another module can be the clock master.

With a computer/tablet/phone

Clock

USB
MIDI

SysEx

Clock

CV
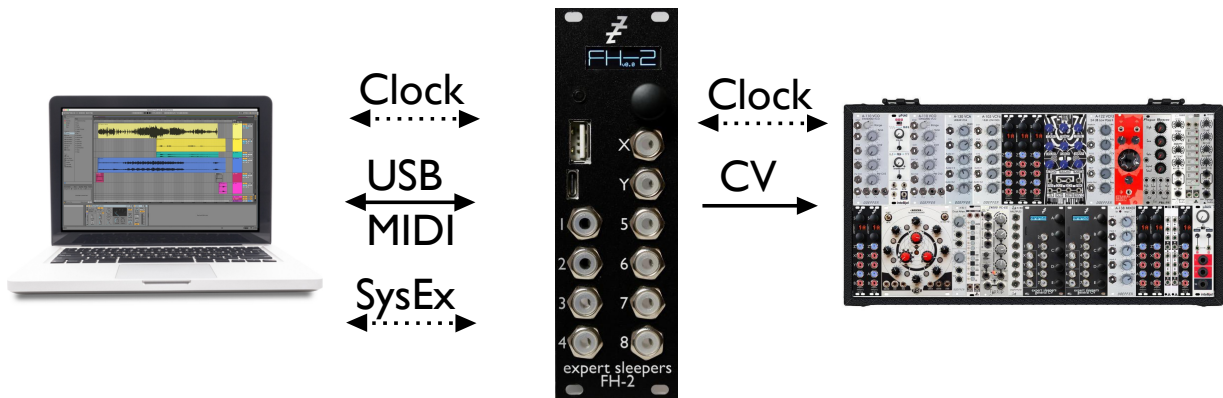
All of the above, plus SysEx for configuration of the FH-2.

As a clock generator

Clock

CV
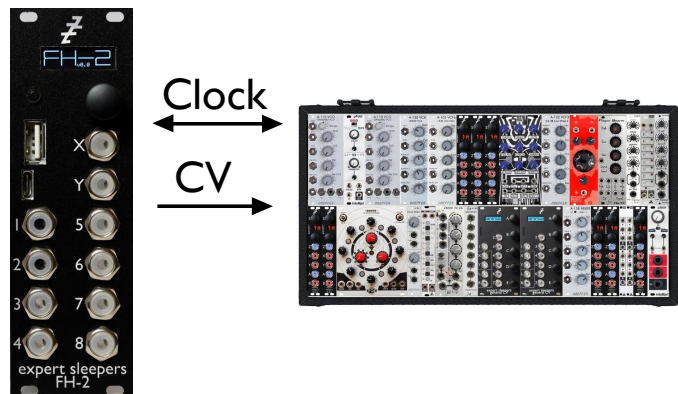
The FH-2 can operate as the clocking centre of your modular, also generating (syncable) LFOs, with no USB connection.

Installation

House the module in a Eurorack case of your choosing. The power connector is [Doepfer standard](1). If using the power cable supplied with the module, the red edge of the cable is furthest from the top edge 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.

Power requirements

The FH-2 draws 118mA on the +12V rail, and 48mA on the -12V rail.

It does not use the 5V rail, except for powering USB devices if so configured, as described below.

Understanding USB 'hosts' and 'devices'

In USB there is a clear distinction between 'hosts' and 'devices'. A 'device' has to connect to a 'host'. A 'host' can connect to one or more 'devices' (using a hub for multiple connections). A 'host' may power a 'device', or a 'device' may be self-powered.

In normal computing terms, the host is usually the PC, laptop, tablet etc. Devices are things like mice, keyboards, drives etc. and most USB MIDI hardware also falls into this category.

The FH-2 can operate both as a host and as a device (and can do both at the same time). The USB A socket (the upper, larger one) operates as a host – this is where you connect USB devices (including hubs). The USB C socket (the lower, smaller one) operates as a device – using this you can connect the FH-2 directly to a USB host such as a computer.

There is (currently) no difference in behaviour depending on whether the FH-2 receives its MIDI from the host or device port – both are handled in exactly the same way.

Connecting and powering USB devices

Connect any class-compliant USB MIDI or HID device to the FH-2's USB A socket.
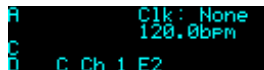
When a USB device is connected and successfully communicating with the FH-2, an 'A' appears in the USB indicator section at the left side of the display.

The FH-2 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-2's own regulator will provide the USB specification's theoretical maximum of 500mA. 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 include

- If possible, provide power to the USB device directly (e.g. if it has a wall-wart input).

- Use a powered hub.

- Use the jumper to take power from the Eurorack 5V bus, if available.

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1 http://www.doepfer.de/a100_man/a100t_e.htm

The jumper is labelled 'JP1' and is located close to the module's power connector. It has three pins, and its function is as follows:

- Jumper across pins 1 & 2: take USB power from the FH-2's own regulator

- Jumper across pins 2 & 3: take USB power from the Euroack 5V bus.

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.

USB hubs

A USB hub can be connected to the FH-2's USB A socket, and then multiple USB MIDI devices connected to the hub. The FH-2 supports up to four devices at once.

Connecting to a USB host

Connect any class-compliant USB MIDI host to the FH-2's USB C socket. Note that this does not require the host to have a USB C socket, or to support USB 3.0. For hosts without a USB C socket, use a 'Type A to type C' cable, specified for USB 2.0 or USB 3.0.

The FH-2 does not draw power from the USB C socket.
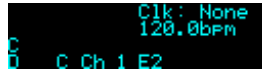
When a USB host is connected and successfully communicating with the FH-2, a 'C' appears in the USB indicator section at the left side of the display.

Connecting expansion modules

The 10 pin header labelled GT2 provides expansion in conjunction with the [FHX-8CV Expander](#)[2], the [FHX-8GT Gate Expander](#)[3], and the [FHX-1 Output Expander](#)[4]. Connect the 10-way cable provided with the FHX-8CV, FHX-8GT, or FHX-1 to this header, oriented the same way as it is on the expander.

An [FH-1](#) module may also be used as an expander, connected via a USB A to USB C cable to the FH-2's USB C socket. The FH-1 should be configured in its default state. On the FH-2, enable the FH-1 as an expander in the Settings. The FH-1 takes the place of the first FHX-8CV ('Show FHX-8CV Expander Output Configurator 1' in the config tool).

An FHX-8CV or FHX-1 output can be used for any purpose, just like the FH-2's own outputs. The FHX-8GT outputs can only be used for 'gate' type purposes e.g. gates, triggers, clocks, & Euclidean patterns.

Output numbering

Taking the expanders into account, there are a total of 128 possible outputs available – 64 CV outputs from the FH-2 and FHX-8CVs, and 64 gate outputs from the FHX-8GTs.

In the FH-2 UI, a single output number is often used, in which case outputs 1-8 are the FH-2's own outputs, outputs 9-64 are the FHX-8CV outputs, and outputs 65-128 are the FHX-8GT outputs.

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2   http://www.expert-sleepers.co.uk/fhx8cv.html
3   http://www.expert-sleepers.co.uk/fhx8gt.html
4   http://www.expert-sleepers.co.uk/fhx1.html

In the web UI, the FHX-8CV outputs are numbered '1/1' to '7/8' (outputs 1-8 on each of 7 possible FHX-8CVs), and the FHX-8GT outputs are numbered from '0/1' to '3/16' (outputs 1-16 on each of 4 possible FHX-8GTs).

Inputs and Outputs

The FH-2 has eight outputs, numbered 1-8, and two inputs, named X & Y.

The outputs are all equivalent, and any output can be assigned any function.

The digital-to-analogue conversion is at 14 bit resolution.

The voltage range of an output is adjustable, as set in the configuration (see below).

The function of the inputs is also set in the configuration. In some cases the inputs are digital inputs, responding to simple on/off signals, and in some cases the inputs are analogue, in which case the analogue-to-digital conversion is 12 bit. In both cases, the preferred input voltage range is 0-5V, but voltages outside of this range will not damage the module.

Controls

The FH-2 has two controls
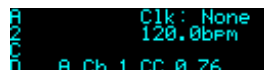
- a rotary encoder, which is also a push button, to the lower right of the display
- a push button, to the lower left of the display.

From here on these will be referred to as 'the encoder' and 'the left button'.

Display Modes

The FH-2's display is usually in one of a small number of modes.

Overview
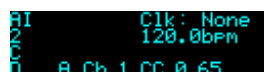
This is the FH-2's default display mode.

At the left of the screen are activity indicators for the possible MIDI connections:
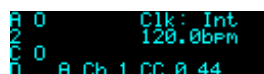
- 'A' indicates that a USB device is connected on the USB A port.
  - The number below 'A' shows the number of devices connected, if using a hub.
- 'C' indicates that a USB host is connected on the the USB C port.
- 'D' always appears, since there's no way of telling if a 5-pin DIN MIDI device is physically connected or not.

An 'I' next to the USB indicator shows that MIDI data is being received.

An 'O' next to the USB indicator shows that MIDI data is being sent.

The top right of the screen shows the current clock source. The possibilities are "None", "Int" (internal clock), "Ext" (external analogue clock), "USB A", "USB C", or "DIN".

A clock source in brackets (e.g. "(C)") indicates that MIDI clock messages are being received from that input, but that the clock is not started – either because a MIDI start message has not yet been received, or because the clock was stopped by a user action on the module, such as pressing the left button.

Below the clock source is the current tempo in BPM.

At the bottom of the screen the FH-2 shows the most recently received MIDI message, formatted as

source (A/C/D/I) / channel / message type (e.g. CC) / byte 1 (e.g. CC number) / byte 2 (e.g. value)

The sources are USB A, USB C, DIN, and Internal (from the CV/MIDI converters – see below).

In this display mode, pressing the encoder enters the menu system.

Turning the encoder and pressing the left button can have various functions, configured in the Settings.

Menu

```
                          Presets                  Edit preset
Presets                   Edit preset              Direct
```
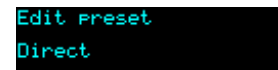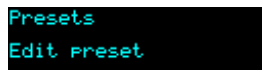
While in the menus, the encoder is used to select or modify items, and to descend to lower menu levels. The left button goes back up one menu level.

Holding the left button for more than half a second exits the menu entirely and returns to the overview screen.

Edit screens

Many menu pages which allow you to edit configuration or preset parameters share a common way of working, illustrated here with the Preset/Edit preset/LFOs page.

```
LFO Output 1          LFO Output 1          LFO Output 1
   Speed      0          Speed      0          Speed       0
```
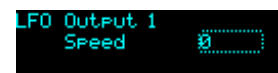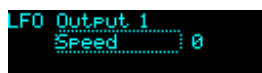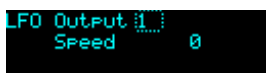
The rectangle is the 'cursor'. When the cursor is drawn using a dotted line, turning the encoder moves the cursor between items – in the images above, between the output number, the current item ('Speed') and the value.

Pressing the encoder changes the cursor to a continuous line:

```
LFO Output 1
   Speed      0
```
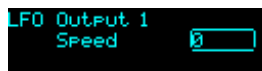
Now, turning the encoder changes the highlighted value, here the LFO Speed.

```
LFO Output 1
   Speed     21
```
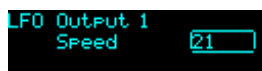
Pressing the encoder again returns the cursor to a dotted line.

```
LFO Output 1
   Speed     21
```
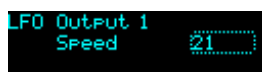
Pressing the left button at any time goes back up one menu level, as usual.

Note that all changes are immediate – you do not need to press the encoder to 'accept' the change.

Auto-blank

To extend the display lifetime, the module will automatically turn the display off after a period of inactivity (the duration of which can be changed in the Settings). Turning or pressing the encoder will turn it back on. Optionally (see the Settings) receiving MIDI will also turn it back on.

Key concepts

Signal flow

The basic signal flow in the FH-2 is

- CVs are generated
- LFOs and envelopes are added
- smoothing is applied.

Generators of CVs are: the MIDI/CV Converters, the Clocks, the Triggers, the Euclidean Patterns, or the Direct control. All of these can generate CVs destined for one or more outputs.

The LFOs and envelopes, if active, are always added to the CVs generated by one of the above.

Finally smoothing, if active, is applied to the sum of the LFOs/envelopes and generated CVs.

In this document, the term 'CV' (Control Voltage) is used interchangeably to mean either an actual voltage on one of the module outputs, or a digital signal within the module's processing that will eventually emerge as a control signal.

Clocking

All clocking in the FH-2 is in terms of 24ppqn (pulse-per-quarter-note) pulses. This is the rate used by MIDI clock messages, and also by the analogue DINsync standard. Thus if for example an LFO rate is given as '24' it means it will cycle at the speed of quarter notes; '12' means an eighth note etc.

When using the FH-2 to bridge between analogue and MIDI devices, in either direction, if possible choose 24ppqn clocks (i.e. a divider value of 1). Then the analogue and MIDI clocks are in one-to-one correspondence and there's no scope for error when generating the 'in between' pulses.

Understanding 'configurations' and 'presets'

The FH-2's state is divided into two separate concepts - 'configurations' and 'presets'.

The '**configuration**' defines what the module's inputs and outputs do (e.g. are they clocks, are they MIDI/CV converters), and how they're mapped to MIDI messages (e.g. MIDI CC assignments for controlling the LFOs).

The '**preset**' defines the module's state, in response to the incoming MIDI – for example, the directly-controlled outputs levels, the LFO rates etc.

To put it another way, the 'preset' is everything that is expected to change in real time – the 'configuration' defines how the preset will be controlled.

Presets and configurations can be separately saved to and recalled from flash memory. For example, you might have two configurations saved, one for when you want to use the FH-2 with a MIDI keyboard, which might define all 8 outputs as MIDI/CV converter outputs, and another for when you want to use the FH-2 with a MIDI controller, which might define all 8 outputs as being directly

controlled from knobs. When switching between these two use cases, you would simply recall the appropriate configuration. Similarly, you might save two presets, one applying smoothing to some outputs (for example, the aftertouch output from the MIDI/CV converters), and one setting up default levels and speeds for some LFOs.

Configurations menu

Configurations can be stored to flash memory. There are 30 configuration slots in flash.

In what follows, the 'current configuration' means the current module state, in RAM, not any of the flash configuration locations.

The Configurations menu is accessed at the top menu level; the submenu items are as follows.

Edit configuration

Allows you to edit the current configuration directly. See below for details of what makes up a configuration.

Note that you may find it more convenient to edit the configuration using the browser-based tool – see below.

Load configuration

The 'Load configuration' menu allows you to select one of the configuration slots, displaying its number and the name of the configuration stored in that slot. Pressing the encoder shows the message 'Are you sure?' - press the encoder again to load the configuration.

Save configuration
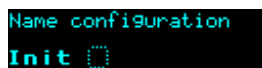
The 'Save configuration' menu allows you to select one of the configuration slots, displaying its number and the name of the configuration stored in that slot. Pressing the encoder shows the message 'Are you sure?' - press the encoder again to save the current configuration into the selected slot.

Reset configuration

This menu allows you to reset the current configuration to default values. It has no effect on the presets in flash memory.
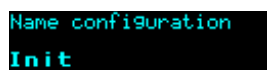
Name configuration

This allows you to edit the name of the current configuration. Typically you would do this before saving it to flash.
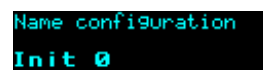
A dotted rectangle indicates the current cursor position. Turning the encoder moves the cursor. Pressing the encoder turns the rectangle into an underscore; turning the encoder now changes the character above the cursor.
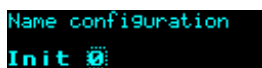
Pressing the encoder again returns to the dotted cursor.

Presets menu

Presets can be stored to flash memory. There are 30 preset slots in flash.

In what follows, the 'current preset' means the current module state, in RAM, not any of the flash preset locations.

The Presets menu is accessed at the top menu level; the submenu items are as follows.

Edit preset

Allows you to edit the current preset directly (rather than in response to MIDI). See below for details of what makes up a preset.

Load preset

The 'Load preset' menu allows you to select one of the preset slots, displaying its number and the name of the preset stored in that slot. Pressing the encoder shows the message 'Are you sure?' - press the encoder again to load the preset.

Save preset

The 'Save preset' menu allows you to select one of the preset slots, displaying its number and the name of the preset stored in that slot. Pressing the encoder shows the message 'Are you sure?' - press the encoder again to save the current preset into the selected slot.

Reset preset

This menu allows you to reset the current preset to default values. It has no effect on the presets in flash memory.

Name Preset

This allows you to edit the name of the current preset. Typically you would do this before saving it to flash.

Editing the preset name works in the same way as editing the configuration name, above.

Settings

The Settings menu provides access to some global settings which are not part of a configuration or a preset. These settings are stored and reapplied when the module powers up.

There are two sub-menus of general settings, as follows.

General page 1

Setting	Value range	Function
Contrast	0-255	Sets the display contrast/brightness.
Top-level encoder	0-2	Sets the function of turning the encoder when not in a menu. The options are "Off", "Tempo" and "Tempo (coarse)".
Top-level button	0-3	Sets the function of pressing the left button when not in a menu. The options are "Off", "Start/Stop", "Tap Tempo/Stop", and "Test FHX-8GT".
Startup preset	0-30	The preset number to load at startup, or '0' for none.
Startup configuration	0-30	The configuration number to load at startup, or '0' for none.
Enable MIDI clock out	0-2	Enable output of MIDI clock. The options are "Off", "On" (start and stop messages are sent) and "Clocks only" (no start and stop messages are sent).
Enable DIN MIDI out	0-1	Enable the 5-pin DIN MIDI output.
Clk stop=>LFOs stop	0-1	When set to 1, causes tempo-synced LFOs to stop when all internal and external clocks are stopped.
Display blank	1-30	The time in minutes after which the display will be turned off, if idle.
Use FH-1 as expander	0-1	Enables the use of an FH-1 as an expansion module.
Constrain rates	0-3	Constrains tempo-based rates (e.g. the arpeggiator rate) set from MIDI to multiples of the given division. The options are "Off", "32nd note", "16th note", and "8th note".
Display flip	0-1	Turns the display upside down.
USB reset time	1-100	Controls how long the FH-2 holds USB devices in reset before attempting to communicate with them. You should not normally need to adjust this unless advised by Expert Sleepers.

Setting	Value range	Function
Tuner pitch reference	400.0-500.0	The pitch used to define the note 'A' when using the tuner.
Menu wrap	0-1	When set to 1, menus wrap around when you scroll past the end or beginning.

General page 2

Setting	Value range	Function
Wake on MIDI	0-1	If set, the display will wake from sleep when the module receives any MIDI message.
Auto display switch	0-1	If set, the module will automatically switch to the relevant display mode when it receives MIDI CCs that affect the LFOs, arpeggiators, Euclidean patterns, or envelopes.
Button exits display	0-1	If set, pressing the left button while in the display modes for the LFOs, arpeggiators, Euclidean patterns, or envelopes will revert to the normal display mode. Otherwise, the left button has its function as set in the settings.
Config prog change ch	0-16	Sets a MIDI channel on which Program Change messages will change the current configuration, or '0' to disable this feature.
Local off DIN	0-1	If set, MIDI arriving on the DIN MIDI input is ignored (though it may still be forwarded).
Local off USB A	0-1	If set, MIDI arriving on the USB A port is ignored (though it may still be forwarded).
Local off USB C	0-1	If set, MIDI arriving on the USB C port is ignored (though it may still be forwarded).

Calibration

Basic

The settings contain basic scale and offset calibration for each output, which can be adjusted to get a precise 0V output for a nominally zero CV, and a proper 1V/octave slope. For more elaborate calibration, see also Calibrations, below.

The edit menu for the basic calibrations looks like this:


```
Output     1
Centre     8192
+3 octaves 13107
```

The top item lets you select the output you want to edit.

The centre item lets you set the 'centre' CV, which will be 0V if the output range is set to ±5V. It corresponds to MIDI note 60 (C4).

The lower item lets you set the '+3 octaves' CV, which should output 3V more than the centre CV,

or in terms of pitch, a note 3 octaves higher. It corresponds to MIDI note 96.

The output is set to the value you're editing as soon as you move the cursor over it.

Startup

You can choose for each output a calibration to be automatically loaded when the FH-2 starts up.

```
Output      1
Calibration 0  (None)
```

Choose '0' to not load a calibration for an output.

When choosing a calibration, the display will show "Match!" if the calibration selected is valid for the current output.

```
Output      1          Output      2
Calibration 5 Match!   Calibration 5
RS-95                  RS-95
```

In the examples above, calibration 5 was saved for output 1, so it shows as a match for output 1, but not output 2.

MIDI Forwarding

This Settings submenu allows you to set up 'forwarding' of MIDI messages between ports, in other words, routing of messages incoming on one port to the other ports.

```
MIDI Forwarding
from   DIN
to     USB A   On
```

On the middle line, select the MIDI source (DIN, USB A, or USB C). On the line below select the MIDI destination, and then enable or disable routing of MIDI messages from the source to the destination.

Each routing can be 'Off', 'On', or 'Clock'. The last lets through only clock and related messages (start/continue/stop).

History Inclusion

This Settings submenu allows you to control which MIDI messages are shown in the history displays (the single line in the Overview display, and the dedicated history display accessed from the Misc menu).

```
Include in history
Note On/Off   On
```

The following kinds of MIDI messages can be independently controlled: Note On/Off, CC, Pitch Bend, Real Time (e.g. clocks), and Aftertouch (channel pressure).

USB Device Name

Here you can set a custom string which will be appended to "FH-2" and used as the device name as seen from the computer. This may be useful if you have more than one FH-2 and want to be able to identify them more easily. You will need to reboot the FH-2 after changing this setting.

In macOS, you may also need to manually remove the device from the MIDI window of the Audio MIDI Setup utility, or macOS may continue to use the previous name.

Reset Settings

This menu allows you to reset the settings to default values.

Miscellaneous

The top level menu item 'Misc' provides access to some miscellaneous functions that don't fit anywhere else.

Misc menu item	Function
Show firmware version	Displays the current firmware version.
Reboot	Causes the module to reboot.
Show MIDI history	Continuously shows the last four MIDI messages received.
Test inputs	Enters a mode which displays an oscilloscope-like view of the inputs, and shows the raw input ADC codes. Intended for factory use only.
Test outputs	Enters a mode which generates a continuous test signal on all eight of the module's outputs. Intended for factory use only.
Test FHX-8GT	Enters a mode which steps between the 16 outputs of an attached FHX-8GT expander. Intended for factory use only.
Test FHX-8CV	Enters a mode which generates a continuous test signal on all eight of an attached FHX-8CV expander's outputs. Intended for factory use only.

Resets

The 'Resets' menu allows you to reset certain aspects of the current preset to default values.

Reset LFOs

Resets all LFOs to defaults:

- Multiplier to maximum (16383).
- Waveform levels to zero, except saw, which is set to 64 (off).
- Pulse width to 64 (50%).
- Tempo Base to 24 and Tempo Mult to 1.
- Speed to zero, and the LFO rate is set as Hz.

Reset MIDI/CV

Resets all MIDI/CV converters to their initial state.

Configurations

A configuration consists of the following:

- the configuration name
- some global settings (trigger length, global transpose etc.)
- setup of the MIDI/CV converters
- setup of the MIDI CC assignments ('mappings')
- setup of the HID gamepad and keyboard assignments
- setup of the Clocks
- setup of the Triggers
- setup of the Euclidean Patterns
- for every output:
  - the voltage range setting
  - the output levels used if the output is a gate/trigger

Configurations can be edited directly via the menu system, or via SysEx. A browser-based tool is provided to edit configurations via SysEx, here[5].

Name

The configuration name is 16 characters long.

Globals

These are items that don't refer to a specific output or function.

Name	Value range	Description
Trigger length	1-100	Length of all triggers, in milliseconds.
Global transpose	-48 - 48	Applies a transposition to all MIDI/CV converters.
Legato velocity	0-1	When enabled, playing legato in monophonic MIDI/CV modes will use the note velocity only from the first note in a phrase.
Ext Clock Multiplier	1-96	Sets the multiplier relating the (incoming) external clock to the internal 24ppqn timebase.
Ext Clock Run Control	0-1	Sets the run control option (see below).
Euclidean Accent	0-127	Sets the scaling of non-accented pulses when accents are enable for Euclidean Patterns (see below).
Preset Program Change Ch	0-16	The MIDI channel on which to respond to Program Change messages by changing the current Preset, or '0' for Off.

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5   http://expert-sleepers.co.uk/webapps/fh2_config_tool.html

Name	Value range	Description
Soft takeover	0-1	Enables the 'soft takeover' feature. When enabled, an incoming MIDI CC will not control its target parameter until the CC has passed through the value matching the last loaded preset.

Example values for 'Ext Clock Multiplier' would be '24' for quarter note clocks, and '1' for 24ppqn clocks e.g. a DINsync clock.

The options for 'Run Control' are as follows:

- "None" (0) – the external clock is considered to start as soon as a clock pulse is received on the X input, and to stop when clock pulses stop arriving. The module waits up to 2 seconds after each clock pulse, and if another clock does not arrive in that time, the clock is considered to have stopped.

- "Run/Stop on Y" (1) – the Y input is used as a DINsync-style run/stop control. The clock runs while the signal is high, and stops when it is low.

Tap Tempo

Tap tempo can be controlled via the front panel button (if configured in the Settings) or via an incoming MIDI note or CC. This is set up in the configuration as follows:

Name	Value range	Description
Type	0-2	Sets how tap tempo is controlled via MIDI.
Channel	1-16	Sets the MIDI channel for the tap tempo control.
Note or CC	0-127	Sets the note or CC number for the tap tempo control.

The options for Type are "None", "Note", or "CC".

If the Type is Note, tap tempo happens when a Note On message is received matching the specified note number. If the Type is CC, tap tempo happens when a CC message is received matching the specified CC number, with a value of 64 or more.

Start/Stop

The internal clock can be started or stopped via an incoming MIDI note or CC, and also by a trigger or gate on the Y input. This is set up in the configuration as follows:

Name	Value range	Description
Type	0-4	Sets how the clock is controlled via MIDI or Y.
Channel	1-16	Sets the MIDI channel for the start/stop control.
Note or CC	0-127	Sets the note or CC number for the start/stop control.

The options for Type are "None", "Note Toggle", "CC Toggle", "Note Gate", "CC Gate", "Y Toggle", or "Y Gate".

'Note Toggle' starts or stops the clock when a Note On message is received. Similarly 'CC Toggle'

starts or stops the clock when a CC with a value of 64 or more is received. 'Y Toggle' starts or stops the clock when a trigger pulse is received.

'Note Gate' causes the clock to start on a Note On and stop on a Note Off. Similarly 'CC Gate' starts the clock on a CC of 64 or more and stops it on a CC of less than 64. 'Y Gate' starts the clock when the Y goes high and stops it when Y goes low.

Internal tempo CC

The tempo of the internal clock can be controlled via an incoming MIDI CC. The MDI channel and CC number can be freely chosen (via the configuration tool or the Mappings menu). You can also set the minimum and maximum tempos that will correspond to CC values 0-127.

Display mode/item CC

The module's display mode can be controlled via an incoming MIDI CC, and when displaying envelopes etc. the displayed item can also be controlled by MIDI CC. The recognised values for the display mode are as follows:

CC value	Display mode
0	Default
9	Euclidean patterns
10	Arpeggiator
11	LFO
12	Envelope

MIDI/CV converters

There are 16 MIDI/CV converters available, any number of which can be active in any given configuration. Each converter has the following properties:

Name	Value range	Description
Enable	0-1	Enable the converter
Channel	1-16	MIDI channel
Min Note	0-127	Lowest MIDI note (inclusive) to respond to
Max Note	0-127	Highest MIDI note (inclusive) to respond to
Type	0-2	Converter type: Monophonic, Polyphonic, or MPE
Polyphony	1-16	Number of voices. (Polyphonic or MPE types only.)
Bend range	0-64	Pitch bend depth, in semitones. See also 'Bend down' below.
Allocation	0-3	Voice allocation scheme: Round robin, Lowest voice, Unison, or Note range. See below. (Polyphonic or MPE types only.)

Name	Value range	Description
No stealing	0-1	If '1' prevent voice stealing - any keys pressed beyond the polyphony of the converter are ignored. Without this option, new notes replace any old ones being held. (Polyphonic or MPE types only.)
Gated After	0-1	If enabled, the aftertouch output is automatically set to zero when all keys are released.
Sustain	0-3	Controls whether MIDI CCs 64 & 66 are used in their normal role as sustain & sostenuto pedals. You can enable neither, either, or both.
Base output	1-64	The base output of the converter. (Outputs 9-64 are expander outputs.)
Base gate	0 or 65-128	The base gate output of the converter (using FHX-8GT expanders), or zero to use regular CV outputs for gates.
Stride	0-32	Sets the spacing between the per-voice sets of CVs. For example, if a polyphonic converter has just CV and gate per voice, and a base output of 1, then the voice outputs will be 1/2, 3/4, 5/6 etc. If however the stride is set to 3, then the outputs will be 1/2, 4/5, 7/8 etc. (Polyphonic or MPE types only.)
Last channel	2-16	The last MIDI channel to respond to, if the converter type is MPE.
Aftertouch	0-1	If enabled, the converter will have an aftertouch (aka channel pressure) output.
Para Gate	0-1	If enabled, the converter will have a paraphonic gate output, that is, a gate output that is high when one or more notes are held down.
CV out	0-1	If enabled, the converter will have a (pitch) CV output.
Gate out	0-1	If enabled, the converter will have a gate output.
VelGate out	0-1	If enabled, the converter will have a velocity gate output, that is, a gate output the level of which is scaled by the note on velocity.
Velocity out	0-1	If enabled, the converter will have a velocity output.
Rel Vel out	0-1	If enabled, the converter will have a release velocity output.
Trigger out	0-1	If enabled, the converter will have a trigger output.
Pressure out	0-1	If enabled, the converter will have a per-voice aftertouch output (using polyphonic aftertouch for Monophonic & Polyphonic converters, or per-voice channel pressure for MPE converters).
MPE Y CC	0-127	The MIDI CC number for the MPE 'y control', or 0 for off. (MPE type only.)
Envelope out	0-1	If enabled, the converter will have an envelope output.
Mono retrig	0-1	Controls when triggers and envelopes are fired for monophonic converters, specifically in the case when a note is triggered as the result of a key being released while another is held. When this option is on (1), such notes do not fire the trigger or envelope.

Name	Value range	Description
Intrpt gate	0-1	(Interrupt gate) If enabled, the gate will briefly go low when playing a new note legato, so an external envelope can be retriggered. (Note – a better solution is to use a gate and trigger output, and an envelope generator with both gate and trigger inputs, if available.)
Env zero st	0-1	(Envelope zero start) If enabled, envelopes start from zero at every note on. Otherwise, the attack portion ramps up from the current envelope value.
Bend down	-1-64	If '-1', the 'Bend range' as above is used for pitch bend in both directions. Otherwise, 'Bend range' is used for bending up, and 'Bend down' is used for bending down.

The assignment of functions to outputs is as follows: the first (lowest numbered) output used by the converter is specified by the 'Base output'. Then outputs are assigned in sequence in the order above, that is, CV/Gate/VelGate/Velocity/Rel Vel/Trigger/Pressure/MPE Y/Envelope, for any outputs that are enabled. For polyphonic converters, the outputs for each voice are assigned in this manner in turn. Finally, if enabled, the Aftertouch and Para Gate outputs are assigned.

If 'Base gate' is specified, then Gate and Trigger outputs will be removed from the above assignments and instead assigned to FHX-8GT expander outputs, starting at the given output, and following the same sequence (Gate/Trigger per voice, then the Para Gate).

Converter types: Monophonic, Polyphonic & MPE

The type of the converter is fundamental to how it generates output CVs from incoming MIDI notes.

- *Monophonic* converters generate a single voice's set of CVs – one pitch, gate etc. A monophonic converter receives on one MIDI channel only. Incoming MIDI notes replace the current note.

- *Polyphonic* converters generate CVs for a number of voices, controlled by the converter's polyphony setting. Each voice has the same set of CVs; there are also two CVs that apply globally (the paraphonic gate and aftertouch CVs). A polyphonic converter receives on one MIDI channel only. Incoming MIDI notes are assigned to the voices according to the Voice Allocation and Prevent Stealing settings.

- *MPE* converters are much like polyphonic converters, but also make use of MIDI Polyphonic Expression or MPE[6]. An MPE converter receives on a number of MIDI channels. The Channel setting is taken as the MPE 'global' channel, so the voice channels will begin one channel up from that. The last channel to receive on is set by the Last Channel setting. So for example if Channel is 2 and Last Channel is 14, the converter will receive MIDI notes on channels 3 to 14.
  MPE converters may have per-channel aftertouch and 'Y dimension' CVs. The y dimension CV is enabled by choosing its CC number; 0 means off. Typically MPE controllers default to CC #74 for the y dimension.

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6   https://www.midi.org/articles/midi-polyphonic-expression-mpe
    https://www.midi.org/specifications/item/the-midi-1-0-specification (at bottom of page)

Voice allocation schemes

Polyphonic and MPE converters use the Voice allocation setting to control how new MIDI notes are assigned to the available voices. The options are:

Round robin	Each voice is used in turn. For example, in a 4 voice polyphonic converter, pressing the same note repeatedly will use voice 1, then 2, then 3, then 4, then 1 etc.
Lowest voice	The lowest numbered available voice is used. For example, in a 4 voice polyphonic converter, pressing the same note repeatedly will always use voice 1. Only when a note is held on voice 1 and another note played will voice 2 be used. If the note on voice 1 is then released while voice 2 is held, the next note will use voice 1 again.
Unison	All voices are always used. For example, in a 4 voice polyphonic converter, playing one note will play that note on all 4 voices. Playing 2 notes will play those notes on 2 voices each.
Unison 2	As 'Unison', but with different behaviour when notes stop. In 'Unison' mode, if you hold one note, add another, and then release one, all voices will revert to the one remaining note. In 'Unison 2' mode, if you do the same, both notes will still sound until you hold a new note. 'Unison 2' mode is particularly useful when playing a polyphonic VCO which doesn't have separate per-voice outputs, when you want to play a sequence of chords.
Note range	The voice is allocated strictly by its note number. This is a somewhat experimental option that was added for a specific customer requirement. The complete MIDI note range (0-127) is divided equally amongst the voices. For example, a 4 voice polyphonic converter will assign 32 notes per voice. A note numbered 0-31 will always use voice 1; a note numbered 32-63 will always use voice 2, and so on.

All Notes Off

Unless specifically mapped to control something else, MIDI CC numbers 120 and 123 are used by the MIDI/CV converters as All Notes Off messages.

Mappings

The mappings section defines how the FH-2 will respond to MIDI controllers, typically MIDI CCs (continuous controllers).

A configuration can have a maximum of 384 mappings. Each mapping has

- – a source MIDI channel

- – a source MIDI message type (currently only CC is implemented)

- – a target.

The target of a mapping can be one of

- – a per-output preset item: the direct level, or one of the LFO parameters.

- a per-MIDI/CV converter item: the arpeggiator parameters, or portamento.

- a per-Euclidean pattern item.

Many items that can be controlled by mappings have a range of 0-127 anyway, so the MIDI CC value is simply used directly. In other cases the MIDI CC range of 0-127 is scaled to map onto the range of the controlled parameter.

14 bit MIDI CCs

Some of the FH-2 parameters use a 14 bit representation for higher accuracy: specifically, the Direct levels, the LFO Speed and the LFO Multiplier.

A convention exists for sending 14 bit values via MIDI CCs, using two CCs (of 7 bits each).[7] The high 7 bits are sent on a CC in the range 0-31, and the low 7 bits are sent on the CC numbered 32 higher (which is therefore in the range 32-63). The low 7 bits are sent first.

The FH-2 configures this automatically, if

- one of the three 14 bit quantities is mapped to CC in the range 0-31, and

- the corresponding low bits CC is not mapped to anything else.

For example, say the direct level on output 5 is mapped to CC 4 on MIDI channel 1 (as it is in the default configuration). Then CC 36 (36 being 4 + 32) on MIDI channel 1 is automatically mapped as the low 7 bits, unless that CC has been explicitly mapped to control something else.

Note that this doesn't mean you *have* to control these quantities with 14 bit controllers. Sending a single CC to control the mapped value will control it perfectly well, just at a coarser resolution.

Voltage range

Each output of the FH-2 can be switched between voltage ranges of 0-10V, ±5V, 0-1V[8], 0-5V, and 0-8V.

The outputs of an FHX-8CV expander have the same options.

The FHX-1 expander outputs can be switched between 0-10V and ±5V, but for the FHX-1 this is done via a physical jumper on the module, rather than being software-configurable.

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7   Hardware controllers supporting this convention include the Faderfox UC3.
8   The 0-1V setting is provided primarily for compatibility with certain video synthesis modules.

Clocks

There are 32 clock generators available. These parameters define the clock:

Name	Value range	Description
Clock Type	0-8	The type of clock output: one of None, Clock, Run/Stop, Stop/Run, Start/Cont, Stop, All Trig, Start, or Start/Stop. See below.
Clock Base	1-96	The rate of the clock, in terms of 24ppqn pulses. Some convenient values include: 24 quarter notes 12 eighth notes 8 eighth note triplets 6 sixteenth notes
Multiplier	1-127	Multiplies the 'clock base' to give the actual clock rate. So for example if 'clock base' is 12 (1/8th notes) and 'multiplier' is 3, the clock will run at a rate of 3/8th notes.
Length	0-127	The length of the clock pulse in milliseconds. The special value '0' means that the clock is not a pulse, but a 50% duty cycle square wave.
Output	1-128	The clock output. (Outputs 9-128 are expander outputs.)
Shift	0-127	The amount by which to advance the clock, in terms of 24ppqn pulses. For example a half note clock advanced by a quarter note will fall on the off beats (2 & 4 of a 4/4 pattern).

The available Clock Types are as follows:

Value	Name	Description
0	None	No output.
1	Clock	A clock output, using the other parameters to determine its speed etc.
2	Run/Stop	Outputs a high gate level when the transport is running, low otherwise.
3	Stop/Run	Outputs a low gate level when the transport is running, high otherwise.
4	Start/Cont	Outputs a trigger pulse when the transport starts or continues[9].
5	Stop	Outputs a trigger pulse when the transport stops.
6	All Trig	Outputs a trigger pulse when the transport starts, continues, or stops.
7	Start	Outputs a trigger pulse when the transport starts, but not when it continues.
8	Start/Stop	Outputs a trigger pulse when the transport starts and stops but not when it continues.

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9   In the sense of a MIDI clock Start or Continue message. The internal and external clocks only start and stop.

Triggers

There are 64 trigger generators available, which take an incoming MIDI note and generate a trigger or gate signal in response. These parameters define the trigger generator:

Name	Value range	Description
Trig Type	0-6	The type of trigger output: one of None, Trigger, Gate, Vel Trig, Vel Gate, Acc Trig, Acc Gate
Channel	1-16	The MIDI channel.
Note	1-127	The MIDI note number.
Output	1-128	The trigger output. (Outputs 9-128 are expander outputs.)

The type of the trigger can be 'Trigger', a pulse (set by the configuration's global trigger length), or 'Gate', which stays high as long as the MIDI note is held.

'Vel Trig' and 'Vel Gate' use the MIDI note's velocity to set the output trigger level.

'Acc Trig' and 'Acc Gate' generate both the base trigger/gate and an additional accent trigger/gate, on the next output up (e.g. if the trigger output is set to 7, the accent will be on 8). The accent fires when the MIDI note velocity is 96 or more.

Euclidean Patterns

Most of the Euclidean Pattern setup is in the preset – see below. The configuration only defines the outputs that each pattern generator uses. The 'Output' outputs a trigger whenever a 'pulse' occurs in the pattern; the 'Off Output' outputs a trigger on steps where a 'pulse' does not occur.

Gate levels

Two values define the low and high output values to be used if the output in question is used as a gate, clock, trigger etc. These are given in terms of DAC codes for maximum control. The DACs are 14 bit, so the range of possible values is 0 to 16383. Note that the actual output voltage also depends on the output voltage range setting for the output (in the configuration for the FH-2 or FHX-8CV, or depending on the jumper setting for an FHX-1). Some example settings are:

Level setting	Output range	Resulting voltage
0	0-10V	0V
8192	0-10V	5V
16383	0-10V	10V
0	±5V	-5V
8192	±5V	0V
16383	±5V	5V

HID Gamepad

This section of the configuration defines the FH-2's response to a connected HID gamepad. Any class-compliant USB gamepad should work. The FH-2's default configuration is set up to give a useful response from a Sony DualShock 4.

There are 32 mapping 'slots' available, each of which maps a 'usage' to an FH-2 output. A usage in

USB HID terminology is a button press or joystick axis etc.

If a gamepad button is mapped, the button pressed/released status is simply mapped to the selected output, using the gate levels set in the configuration (see above).

If a continuous quantity from the gamepad is mapped (e.g. a joystick axis), you can set a scale and offset that translates the USB HID value to the output DAC value. The values set in the configuration are multiplied by 4 to give the final 14 bit DAC code. For example, in the default configuration, axis Y is mapped with scale -16 and offset 4096. The USB HID value is 8 bit i.e. has the range 0-255, so these values cover the full DAC range:

4*(4096-16*0)=16384   4*(4096-16*255)=64

HID Keyboard

This section of the configuration defines the FH-2's response to a connected HID keyboard (i.e. a generic USB computer keyboard, not a musical keyboard). The FH-2's default configuration maps the keyboard keys 1-8 to the FH-2's eight outputs.

There are 32 mapping 'slots' available, each of which maps a key to an FH-2 output.

There are two types of mapping available: 'Press/Release' and 'Press only'. 'Press/Release' mappings change the output on key press and key release, and as such might be useful as triggers, gates etc. 'Press only' mappings only change the output on key press; this could be used to choose from a number of different CV values for an output, depending on which key was last pressed.

The output values for each key press and release can be set in the configuration. These are DAC codes – see the description of the gate levels, above.

LFO Resets

The FH-2 can be configured to reset/retrigger its LFOs in response to MIDI. This resets the phase of the LFO to zero, and begins a fade up from zero if the LFO fade time has been set. The various reset options are as follows:

Type	Available settings	Description
CC	MIDI channel and CC number	The LFO is reset when the chosen CC is sent with a value of 64 or more.
Note	MIDI channel and note number	The LFO is reset when a matching note on message is received.
Any note	MIDI/CV converter number	The LFO is reset when any note on message is received by the chosen MIDI/CV converter.
Paraphonic	MIDI/CV converter number	The LFO is reset when the chosen MIDI/CV converter's paraphonic gate goes high i.e. when a note is pressed when no notes are already held.
Poly voice	MIDI/CV converter number	The LFO is reset when a polyphonic voice is triggered that uses the LFO's output.

Most other LFO functions are part of the Preset and are described below.

CV/MIDI

The X & Y inputs can be used to generate MIDI from incoming CVs. Each input can be configured

independently. Note that when an input is enabled for CV/MIDI conversion it is no longer available for other duties; specifically, use as clock inputs is disabled.

The resulting MIDI can be sent out via any or all of the available MIDI ports (USB A, USB C, and DIN), and also used internally by the FH-2 as if the MIDI had arrived from elsewhere. It is therefore possible to use the CV inputs to control aspects of the FH-2's behaviour usually controlled via MIDI.

The types of CV/MIDI conversion available are as follows:

Type	Available settings	Description
CC	MIDI channel and CC number; 0V and 5V levels	The incoming CV is converted to a MIDI CC message. The 0V and 5V levels set the CC value that will be output for inputs of 0V and 5V respectively.
Trigger	MIDI channel and note number	The incoming CV will generate note on/off messages, when the CV rises above 1V and falls below 0.5V respectively.
Note	MIDI channel and note number; 0V and 5V levels	The incoming CV is converted to a MIDI note stream. The other input is used as a gate to control the note on/off timing. (So if CV/MIDI X is set to 'Note', input Y is also used, as the gate.) The 0V and 5V levels specify the input codes that correspond to 0V and 5V in the real world. Good starting values are 0 & 4096[10], but you may like to tweak these to calibrate the inputs. (See also 'Test inputs', above.) The specified note number is the base note, corresponding to a 0V input.
Prog chng	MIDI channel; 0V and 5V levels	The incoming CV is converted to a MIDI Program Change message. The 0V and 5V levels set the program value that will be output for inputs of 0V and 5V respectively.
Aftertouch	MIDI channel; 0V and 5V levels	The incoming CV is converted to a MIDI Aftertouch (aka Channel Pressure) message. The 0V and 5V levels set the aftertouch value that will be output for inputs of 0V and 5V respectively.

Using the Configuration Tool

A GUI tool is provided to edit configurations via SysEx. Please find the version appropriate to your FH-2 firmware version on the firmware download page[11].

A standalone version is provided for macOS and Windows, as well as a platform-independent browser-based version. This last uses the Web MIDI API, which at the time of writing will work only in browsers based on Google's Chromium (which includes Chrome).

All is well if the tool shows Web MIDI status: OK

If it shows Web MIDI status: No MIDI support in your browser then you need to use a different browser.

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10 The input ADCs are 12 bit.
11 https://expert-sleepers.co.uk/fh2firmware.html

The tool needs a MIDI connection to the FH-2. It is most convenient to connect the FH-2 directly to the computer running the tool via its USB C port, but it will work just as well connected indirectly via its USB A port or 5-pin DIN connection.

At the top of the tool are these controls:
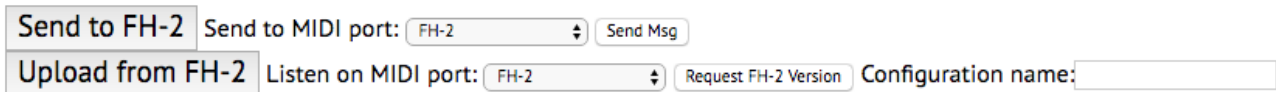
The Send to/Listen on MIDI port menus should say "FH-2" if the FH-2 is connected directly, or whichever MIDI device leads to the FH-2 if it is connected indirectly.

The Send Msg button tests the send connection – it sends a SysEx message to the FH-2 which displays a friendly greeting on the FH-2's screen.

The Request FH-2 Version button sends and receives short SysEx messages to report the FH-2's firmware version. It is useful to quickly test the connection. It will look something like this, in the tool's status boxes:
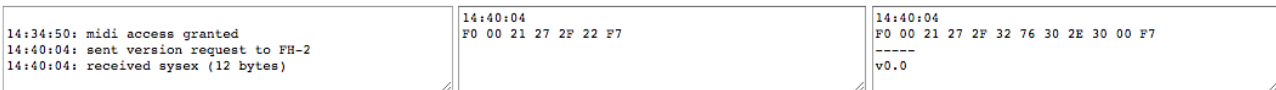
The left box is a log of messages reported by the tool. The centre box shows the last SysEx message sent by the tool. The right box shows the last SysEx message received by the tool, and in the case of the Message SysEx message, the actual message as plain text ("v0.0" in the example above).

The large buttons are the ones you'll use most - "Send to FH-2" and "Upload from FH-2".

"Send to FH-2" sends the tool's current configuration to the FH-2.

"Upload from FH-2" fetches the FH-2's current configuration and updates the tool UI to reflect it.

The final box in the top area is Configuration name, which allows you to edit the name of the configuration.

Next down are check boxes for showing and hiding various parts of the tool:
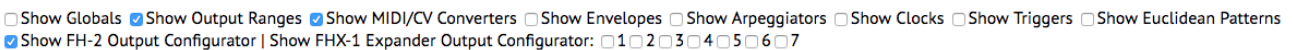
Each section of the tool UI should be fairly self-explanatory, referring to the relevant part of the configuration documentation, above.

Mappings are set by UI elements like so:

The left drop-down is the MIDI channel; the right drop-down is the CC number. If either is "--", the mapping is not defined.

Remember that the tool is editing the FH-2's current configuration, much as if you were editing it with the FH-2's menus. It does not save and recall configurations to/from flash memory. Remember to save your configuration, using the FH-2's menus, if you want to keep it.

You can also save configurations as SysEx files, using something like SysEx Librarian by Snoize[12]. If you set the librarian to listen for a SysEx file while pressing "Upload from FH-2" in the configuration tool, the librarian will capture the SysEx upload, which can then be saved to disk.

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12 https://www.snoize.com/SysExLibrarian/

Simply replaying the SysEx back into the FH-2 will reapply the configuration. This provides a convenient means to share configurations with other users.

Presets

A preset consists of the following:

- the preset name
- the internal clock tempo
- for every output:
  - the direct output levels
  - the LFO state
  - the smoothing amount
- for every MIDI/CV converter:
  - the arpeggiator state
  - the portamento rate
  - the transpose setting
  - the choice of Scala scale and keyboard mapping
- the Euclidean pattern generator states

In general most of these can be controlled via MIDI CCs, as defined in the Mappings.

Name

The preset name is 16 characters long.

Internal clock tempo

This is the tempo of the internal clock, set directly or via tap-tempo.

Direct output levels

'Direct' outputs levels is our term for when a MIDI controller directly controls an output e.g. the controller goes from 0-127 and the output goes from 0-10V.

The direct level is a 14 bit quantity – see above. When edited from the menu, a 'coarse' value is shown as well as the actual value. This makes it easier to make large changes.
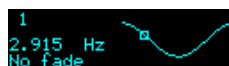

LFOs

Each output has an LFO, defined by the parameters below. The LFOs are added to any other CV being generated at a particular output. In the absence of a MIDI/CV converter, clock etc. this means the LFO waveforms are centred around the 'direct level' of the output. So, if the voltage range of an output is ±5V, to get an LFO centred on 0V, you would need to set the direct level to 8192 (mid-range) as well as set the LFO amplitudes. Note you needn't map a MIDI controller to set the direct level – you can just edit it via the menus, and if convenient save that as a preset.

The speed of each LFO can be set to a value in Hz, or it can be locked to the current tempo. Which is used depends on the last setting made; setting the 'Speed' switches the LFO into its Hz-based

mode, whereas setting the 'Tempo Base' or 'Tempo Mult' switches the LFO into its tempo-synced mode.

Name	Description
Speed	Sets the LFO speed, from 0.1Hz to 10Hz. A logarithmic scaling of the value is used, to allow finer control over the slower end of the range. A 14 bit quantity.
Tempo Base	The rate of the LFO, in terms of 24ppqn pulses.
Tempo Mult	Multiplies the 'Tempo Base' to give the actual LFO rate. So for example if 'Tempo Base' is 12 (1/8th notes) and 'multiplier' is 3, the LFO will run at a rate of 3/8th notes.
Multiplier	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 14 bit quantity.
Sine	The level of a sine wave's contribution to the LFO shape.
Square	The level of a square wave's contribution to the LFO shape.
PW	Pulse width control for the square waveform.
Triangle	The level of a triangle wave's contribution to the LFO shape.
Saw	The level of a saw wave's contribution to the LFO shape. The saw wave is set to zero at value 64. Values greater than 64 give a rising sawtooth shape; values less than 64 give a falling shape.
Random	The level of a random signal's contribution to the LFO shape.
Noise	The level of a noise signal's contribution to the LFO shape.
Phase	The phase of the LFO waveform.
Fade	The time over which the LFO will fade up from zero when retriggered.

If the FH-2's display is in its default mode when a CC is received that affects an LFO, the display switches to show the state of that LFO:

The LFO number is top left; below that is the LFO speed (in Hz or tempo-based units) and fade time (in seconds, or 'No fade' if the fade is zero). The right side of the display shows the LFO shape as a graph. The current LFO position is highlighted with a small square.

Smoothing

Each output has a 'smoothing' amount. 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-2: direct 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 pitch CV.

Arpeggiator

Each MIDI/CV converter of the FH-2 has its own arpeggiator.

The arpeggiator is controlled partly by items in the preset (which can be mapped to MIDI CCs as usual), and partly by CC 'commands', which have no corresponding item in the preset, but which should be considered live, performance controls, in much the same way that triggering MIDI notes drives the arpeggiator without changing the preset as such.

For Polyphonic and MPE converters, each new note in the arpeggio triggers a new voice, using a Round Robin allocation pattern.

The preset item controls are as follows:

Name	Description
Arp Mode	Mode - see below
Arp Range	Range - the number of octaves to repeat the arpeggiation pattern over. When mapped, CC values 0-127 map to 1-3 octaves.
Arp Gate Len	Gate length - the gate on time as a fraction of the clock rate. 64 is a 50% gate length. 0 is a special value and means a fixed length trigger pulse, unrelated to the clock rate.
Arp Latch	Latch on/off - see below
Arp Rate	The rate of the arpeggiator, in terms of 24ppqn clocks. The special value '0' means that the arpeggiator advances every time the FH-2 receives an external clock pulse. (This is useful in order to create irregular arpeggiation rhythms.)
Arp Reset	Sets a number of quarter notes after which the arpeggiator will automatically reset to step 1. This function is disabled if the reset value is set to zero.

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.

The 'command' controls are as follows:

Name	Description
Add	While the CC is 64 or more, incoming MIDI notes will be added to the arpeggiation pattern. This is most useful when the Mode is 'As Played' and Latch is on. It allows you to have repeated notes in the pattern.
Remove	While the CC is 64 or more, incoming MIDI notes will be removed from the pattern (if the note in question is actually in the pattern already). If the same note appears multiple times, the last occurrence will be removed.
Rest	When the CC transitions from below 64 to 64 or more, a rest is added to or removed from the arpeggiation pattern, according to whether Add or Remove is currently active.

Truncate	Scales the total length of the arpeggiation pattern according to the CC value, from 1 step at CC value 0, to the full length at CC value 127.
Transpose	While the CC is 64 or more, incoming MIDI notes will transpose the current pattern, by the amount of the difference between the incoming note and the root note of the pattern. The root note is by default the lowest note of the pattern, but see 'Set root' below.
Transpose in key	Like Transpose, but rather than a straight chromatic transposition, the pattern is transposed within the key defined by the root note. For example, if the pattern is C-E-G (root note C) and D is played, 'Transpose' will produce D-F♯-A, whereas 'Transpose in key' will produce D-F-A.
Set root	While the CC is 64 or more, an incoming MIDI note overrides the root note, so that subsequent transposition is based on the overridden note. For example, if the pattern is E-G-C, the default root note will be E, but you could use the 'Set root' command to let the arpeggiator know the key is C.

For the commands such as 'Add' which take effect while the CC is 64 or more, it is up to you and how you program your MIDI controller whether you want the control to be momentary (i.e. taking effect only while you're holding down a button, like a shift key) or latching (i.e. taking effect until you turn it off, like a caps lock key).

If the FH-2's display is in its default mode when a CC is received that affects an arpeggiator, the display switches to show the state of that arpeggiator:
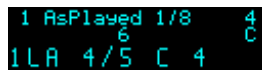
The top line, from left to right, shows: arpeggiator number; mode; rate; reset interval (if on).

The bottom line shows: range; 'L' if latched; the active command (Transpose, transpose in Key, Set root note, Add, Remove); the current step/highest step; the current note.

If truncate is active, the untruncated highest step is shown above the highest step ('6' in the image above, above '5').

On the right side, below the reset interval, is the current root note.

Portamento

Monophonic MIDI/CV converters use the portamento setting. This sets a glide time between notes played legato ("fingered portamento").

Transpose

Each MIDI/CV converter has a transpose setting, which transposes its notes up or down in semitones.

Euclidean Patterns

These generate rhythmic patterns of output pulses known as Euclidean patterns. For a detailed description of these patterns and how they are commonly found in music around the world see e.g. here[13] or here[14].

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13 https://en.wikipedia.org/wiki/Euclidean_rhythm
14 http://www.hisschemoller.com/blog/2011/euclidean-rhythms/

A pattern is described by the total number of steps and the number of pulses (i.e. the number steps on which a pulse is output). There is also the 'rotation' of the pattern. At zero rotation, the first step in the pattern will always be a pulse, and the remaining pulses distributed according to the algorithm. The rotation setting moves the first pulse by a number of steps i.e. moves the down beat.

Each Euclidean generator also has an Accent Rate. If enabled, this superimposes a regular accent on the pattern (so for example you could have a pattern in 16th notes with an accent on every quarter note). In terms of the output, the unaccented pulses are scaled down by a percentage set in the configuration globals (see above).

The controls are as follows:

Name	Description
Pulses	See above. A value of '0' effectively turns the generator off.
Steps	See above. The maximum number of steps is 32.
Rotation	See above.
Rate	The rate of the pattern, in terms of 24ppqn clocks. The special value '0' means that the pattern advances every time the FH-2 receives an external clock pulse. (This is useful in order to create irregular rhythms.)
Gate Length	Gate length - the gate on time as a fraction of the clock rate. 64 is a 50% gate length. 0 is a special value and means a fixed length trigger pulse, unrelated to the clock rate.
Accent Rate	The accent rate, in terms of 24ppqn clocks, or zero for off (no accents).
Reset	Sets a number of quarter notes after which the pattern will automatically reset to step 1. This function is disabled if the reset value is set to zero.

If the FH-2's display is in its default mode when a CC is received that affects a Euclidean pattern generator, the display switches to show the state of that generator:
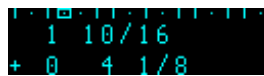
The display shows the Euclidean pattern number, the pulses/steps, the rotation, the current step, and the rate. Across the top is a graphical representation of the pattern and the current step.

Envelopes

Each MIDI/CV converter of the FH-2 has a per-voice envelope generator, of the traditional ADSR variety. The controls are as follows:

Name	Description
Attack	The envelope's attack time.
Decay	The envelope's decay time.
Sustain	The envelope's sustain level.
Release	The envelope's release time.
Range	Defines the time range for the Attack, Decay, and Release controls. The options are 200ms, 500ms, 1s, 2s, 5s, 10s, 20s, and 50s.
Depth	The envelope's depth i.e. amplitude. A value of 64 means zero depth; values greater than 64 mean a positive depth; values below 64 mean a negative depth.
Vel Depth	The amount by which the note on velocity affects the envelope's depth. At 64, the velocity has no effect on the envelope. For values above 64, the envelope's depth is increasingly affected by velocity. For values below 64, the envelope's depth is inversely related to the velocity i.e. higher velocity gives a smaller envelope.

Note that the envelope's depth setting is bipolar. For negative-going envelopes, you will probably want to set the direct output level to give the envelope a non-zero starting point.

If the FH-2's display is in its default mode when a CC is received that affects an envelope, the display switches to show the envelope shape (approximately – the FH-2's envelopes are not linear):

The display shows the MIDI/CV converter number top left.

Scala/MIDI Tuning Standard

The FH-2's MIDI/CV converters can use microtonal scales defined by the Scala file formats[15], or by the MIDI Tuning Standard (MTS)[16]. The MTS support is explicitly compatible with MTS-ESP by OddSound[17].

Each converter can independently be assigned a scale file (.scl) and a keyboard mapping file (.kbm), or be assigned to use MTS. Note that the current MTS scale is global for the whole FH-2.

The .scl and .kbm files are stored in the FH-2's flash memory. The are 32 slots for each kind of file. The files are installed via MIDI SysEx. A web-based tool to support installing the files from a computer to the FH-2 is provided here[18].

If an active MIDI/CV converter has a Scala tuning enabled, the frequency of the current note in Hz is displayed, or 'Unmapped key' if the last key pressed is not defined in the keyboard mapping.

'Scala Error' may also be displayed, if for example the .scl and .kbm files do not match (say if the .kbm refers to a 7-tone scale but the .scl only defines a 5-tone scale).

If the converter has MTS enabled, the retuned MIDI pitch value is displayed instead.

If using MTS via MTSMIDIClient, choose the 'MTS SYSEX' option:
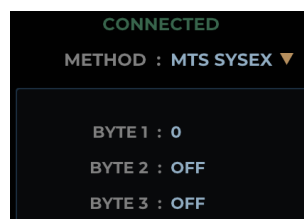
Calibrations

In addition to the basic calibration offered in the settings, above, the FH-2 can also perform an automatic calibration process much like that in the Expert Sleepers Silent Way software[19]. This is accessed via the top-level menu item Calibrations.

Calibrations can be saved to and loaded from flash memory. There are 70 calibration slots in flash.

15 http://huygens-fokker.org/scala/scl_format.html
16 https://en.wikipedia.org/wiki/MIDI_tuning_standard
17 http://www.oddsound.com/
18 http://expert-sleepers.co.uk/webapps/fh2_scala_tool.html
19 http://expert-sleepers.co.uk/silentway.html

A calibration is strongly linked to a particular module output, since as well as depending on the VCO being calibrated, it also depends on the fine electrical details of the module's circuitry which differ slightly from output to output. For this reason, a calibration performed on one output cannot be used on another output.

Auto-calibrate

Connect the FH-2's output which you want to calibrate to the VCO's pitch input. Connect a signal from the VCO to the FH-2's X input. Ideally this would be a simple waveform such as a triangle or sine wave. Select the output to be calibrated, highlight 'GO!' and press the encoder.

The FH-2's output will step through a number of voltages, starting low and working up (remember this will be affected by the output range setting in the configuration). If you're monitoring the output of the VCO (for example by taking another output and listening to it), you should hear it step through a rising set of pitches. As the calibration runs, the FH-2 will draw a graph, which ideally will end up looking something like this:

This shows pitch (horizontally) versus voltage (vertically). The steepness of the curve indicates the V/octave response of the VCO; the image above shows 1V/octave (the usual standard). For comparison, an approximately 1.5V/octave response looks like this:

Note that the pitch range is less, since less octaves fit into the FH-2's output range.

At the left and right edges of the graph, any uncalibrated areas are filled in with copies of the nearest calibrated areas, shifted by octaves.

When calibration is complete, the message "Accept?" appears. Press the encoder to accept the calibration and start using it on the chosen output. Press the left button to abandon the calibration and keep the pre-existing data.

Note that the X input is by default used as the module's external clock input, and may generate MIDI clock. If you connect a VCO to it when not in the Auto-calibrate mode, you are likely to generate extreme amounts of MIDI data. The X input's clock function is disabled when you enter the Auto-calibrate menu (where you see the 'GO!' text) – it is then safe to connect the VCO. Disconnect the VCO before responding to the 'Accept?' prompt.

Tuner

The FH-2 also offers a tuner function, accessed via the Calibrations menu.

Connect the source to be tuned to the FH-2's X input. The FH-2 displays the detected pitch as a note number and a frequency in Hz. The bar at the bottom of the screen shows how far off the displayed pitch the note is – it is sharp if the bar is to the right, or flat if the bar is to the left.

Load calibration

This menu lets you browse calibrations previously stored in flash and recall them.

The calibration slot number and its name is shown; turn the encoder to select different calibrations. The name shows "<Empty>" if no calibration is stored in the slot. If the slot is not empty, the display also shows "For output" followed by the output number that the calibration is for.

Press the encoder to load the calibration onto its designated output.

Save calibration

This menu lets you save a calibration to flash memory. This is a two step process: first, choose the output for which you want to save the calibration; then, choose the calibration slot into which you want to save. When choosing the slot, the name of any calibration already stored there is shown, or "<Empty>" if the slot is not used.

Reset calibration

This allows you to reset the calibration for an output back to the simple one defined in the settings, as described above. Note that this has no affect on any calibrations stored in flash.

Name calibration

This allows you to edit the name of the calibration you are about to save.

Editing the calibration name works in the same way as editing the configuration name, above.

View calibration

This function shows the calibration graph for an output.

The output number is displayed top left. Simply turn the encoder to select a different output.

5-pin DIN MIDI I/O

The FH-2 has an expansion header on the PCB which can be used to add a pair of traditional 5-pin DIN MIDI ports to the module (one input/one output). This is compatible with the Expert Sleepers MIDI breakout[20].

Connections

The MIDI ports are exposed on a 4-pin expansion header (labelled GT3) on the lower PCB. All of the necessary electronics are on the PCB; all that needs to be added is the actual sockets.

The header pin-out is as follows (pin 1 is closest to the 'GT3' text):

Pin	Function
1	OUT pin 4
2	OUT pin 5
3	IN pin 5
4	IN pin 4

Pin numbers refer to the 5-pin DIN socket as in the MIDI standard[21].

The header is a standard 0.1" pitch header compatible with e.g. typical IDC cable sockets.

When using the Expert Sleepers MIDI breakout, pin 1 of the breakout's header (GT1) corresponds to pin 1 of the FH-2's header (GT3). Orient the ribbon cable to match up these pins.

MIDI "Low-Voltage Signaling"

When MIDI was first conceived, standard logic circuits ran at 5V, and the initial hardware reference designs worked on this assumption. However, there is nothing in the MIDI standard that actually requires a specific voltage, since it operates as a current loop via an opto-isolator.

Nowadays it is much more common for logic to run at 3.3V or lower. The MIDI Manufacturers Association has now released a reference hardware design based on 3.3V, which they call the "Low-Voltage Signaling" standard, and it is this that the FH-2 uses.

The FH-2 is therefore fully compatible with any device that adheres strictly to the MIDI specification, but may not be with devices that play fast and loose with the spec and assume 5V.

Download the full MIDI electrical specification here[22].

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20 http://expert-sleepers.co.uk/dm4midibreakout.html
21 https://www.midi.org/specifications/item/midi-din-electrical-specification
22 https://www.midi.org/specifications/item/midi-din-electrical-specification

MIDI System Exclusive (SysEx)

The FH-2 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-2 follow this with 2FH:

```
F0 00 21 27 2F
```

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

```
F0 00 21 27 2F 10
```

Received SysEx messages

01H – Take screenshot

```
F0 00 21 27 2F 01 F7
```

This causes the FH-2 to respond with a SysEx message containing a capture of its screen.

Note that there is a web-based tool to capture FH-2 screenshots [here][23].

02H – Display message

```
F0 00 21 27 2F 02 <NULL terminated ASCII string> F7
```

Displays the enclosed string on the FH-2's screen.

03H – Set FHX-8GT outputs

```
F0 00 21 27 2F 03 <exp> <n0> <n1> <n2> <n3> F7
```

Sets the outputs of the FHX-8GT at index <exp>. <n0>-<n3> are four nybbles which each set four outputs of the FHX-8GT and its attached ESX-8GT.

10H – Install configuration

```
F0 00 21 27 2F 10 00 00 <configuration data> F7
```

Installs the enclosed data as the FH-2's currently active configuration.

11H – Install .scl

```
F0 00 21 27 2F 11 <slot number> <.scl file text> F7
```

Installs the enclosed data to a Scala scale file slot.

---

23 http://expert-sleepers.co.uk/webapps/fh2_screenshot_tool.html

12H – Install .kbm

```
F0 00 21 27 2F 12 <slot number> <.kbm file text> F7
```

Installs the enclosed data to a Scala keyboard mapping slot.

21H – Request configuration dump

```
F0 00 21 27 2F 21 F7
```

This causes the FH-2 to respond with a SysEx message containing the currently active configuration. The response message is in exactly the format of the '10H - Install configuration' message above, so that it can be recorded into and played back from a SysEx librarian tool (for example, this[24]).

22H – Request version string

```
F0 00 21 27 2F 22 F7
```

This causes the FH-2 to respond with a SysEx message containing the module's version string as text, using the '32H – Message' format, below.

Sent SysEx messages

10H – Install configuration

See above. This message is transmitted in response to a '21H - Request configuration dump' message, or when the 'Dump configuration via SysEx' menu item is used.

32H – Message

```
F0 00 21 27 2F 32 <NULL terminated ASCII string> F7
```

This message is transmitted in response to a '22H - Request version string' message.

33H – Screenshot

```
F0 00 21 27 2F 33 00 00 <screenshot data> F7
```

This message is transmitted in response to a '01H – Take screenshot' message.

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24 https://www.snoize.com/SysExLibrarian/

Command Shell

> This feature should be considered a prototype. It is by no means complete or fully functional. It is included at this point to gauge interest and invite feedback.
>
> Note – this feature is currently disabled.

When a HID keyboard is connected to the FH-2, it is possible to open a command shell and type commands in the programming language [Lua](https://www.lua.org)[25].

The shell is opened and closed by pressing the Escape key. Type a line of Lua and press Return to execute it.

Current limitations include:

- Each command is executed in a completely fresh instance of Lua. There is no persistent state, or storage of function definitions etc.

- There is very little interaction with the FH-2 hardware.

- There is no provision for running code in the background, or in response to MIDI or CV events etc.

All of these things are possible; they may be implemented if anyone thinks it's worthwhile.

Built-in functions

The following functions are defined as extensions to the base Lua language.

firmware()

Inputs: none

Returns: none

Prints the version of the installed firmware.

dac(output, value)

Inputs: output number (1-64), DAC code (0-16383)

Returns: none

Sets the FH-2 or expander output DAC directly to the given value.

---

25 https://www.lua.org

Firmware Updates

The FH-2's firmware can be updated using a USB flash drive, which must be formatted as 'FAT' (variously referred to as 'MS-DOS FAT', 'FAT16', 'FAT32'). 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 the USB flash drive.

- Insert the drive into the FH-2's USB A socket.

  - **You are advised to observe basic ESD (electrostatic discharge) precautions** - see for example [here](#)[26]. Don't be wearing a nylon sweater in an air conditioned room.

- Restart the FH-2 with the encoder knob pressed. (You can do this by power cycling it, or by rebooting from the Misc menu.) It will go through the first stage of its startup sequence, showing the bootloader version number.

- Keep the knob pressed until the message "Press left button to begin flashing..." is shown.

  - If at this point the FH-2 shows the message "Could not find the file 'image.hex' on the drive", no firmware file could be found on the drive. Remove the drive and check its contents and formatting.

  - If the FH-2 stalls on the message "Attempting to mount drive..." the drive is not formatted correctly.

- Press the left button to begin the flashing process. (If you change your mind and don't want to proceed, simply turn the power off.)

- When the flashing process starts, the display updates to indicate progress. Do not remove the drive or turn off the power during the update.

- When the flashing process is complete, the FH-2 will show the message "Success" if successful, or "Error:" plus an error code if there was a problem.

- Press the left button to reboot the FH-2 and resume normal operation.

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26 http://www.computerhope.com/esd.htm

Acknowledgments

'FH-2' logo and boot-up animation by Jason Evans.

The FH-2 uses [Lua](27), the copyright notice of which is reproduced below.

27 https://www.lua.org/